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

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Table of Contents

1.0 Executive Summary

Demands on lower education have never been greater. Federal requirements and increased access has put a strain on elementary schools as well as their staff. Curriculum are standardized, and is therefore specifically planned throughout the academic year. Deviations increase pressure on school to perform as required. This project aims to address one factors that leads to such deviations in classes with special needs children, specifically children with Autism Spectrum Disorder (ASD) or Emotional Behavior Disorder (EBD). This factor is known as off-task behavior. It is any behavior that does not directly relate to academia.

One obstacle of educators/caregivers is that special needs children often have issues transitioning between activities in a school day. 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 several wearable sensors 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. Admittedly, it takes time to accomplish, but autistic children need a cooldown to reset any sensory overloads.

The idea is to use sensors 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 sensors will alert the teacher when they sense certain markers and the teacher may be able to intervene even before the child knows what is going on. Attached to the sensors, 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 sensors, timer and electronic device will be controlled with the Atmeg328P microcontroller using the Arduino IDE and programming language.

This paper identifies all the steps made during the design process. This includes the requirements mentioned as well as their specifications, all research to meet these requirements specifications, all design constraints applicable to our group, and all related standards to the final device. It also discusses the hardware and software designs, initial parts testing and the prototype testing plan for each subsystem.

2.0 Project Description

2.1 Project Motivation

Students with Autism Spectrum Disorder (ASD) or Emotional Behavior Disorders (EBD) face more problems than just keeping up with the curriculum. We will refer to this as on-task behavior. Frustrations arise that result in off-task behaviors which negatively affect the learning process for themselves and others. Let us be clear that we are speaking of “meltdowns” as the result of too much stimulation. This is not referring to tantrums which are the result of a child behaving in a certain way to achieve a specific goal. Simply put, meltdowns are not controlled by the child while tantrums are.

One example that commonly leads to such meltdowns is the difficulty that comes with transitioning from one event or activity to another. For example, going from Math to Reading, or from Centers to lunch, or even dismissal. This may be due to a greater need for predictability [1], challenges in understanding what activity will be coming next [2], or difficulty when a pattern of behavior is disrupted [3]. Of course, other frustrations can occur during any activity/lesson whereby the student becomes upset. The result is the same. Class time interrupted as the teacher must now spend time dealing with the student directly, and unrelated to curriculum.

2.2 Goals and Objectives

This project attempts to reduce off-task behavior through prevention, anticipation and mitigation. Three methods are being considered to achieve this. The first method uses a system comprised of two devices. One is a set of sensors worn by the student that will detect anxiety, or the onset of a behavioral problem. The second device is interactive and will try to diffuse the problem. It shall be a touch-screen which represents a tablet-like device that may be used in schools.

The system will *prevent* off-task behavior by providing the student with a visual indication of how much time remains on a specific activity/lesson. The idea is to help the student transition because they can prepare for it. This “timer” will be on the sensor like a watch face. As discussed in section 3.2.6, the chosen timer will be made of a circumference of light-emitting diodes (LEDs) that extinguish as the timer counts down. This timer shall be programmed by the caregiver via the touchscreen to reflect the day’s schedule. It shall be programmable in case the schedule differs between days.

This leads to two methods in which the LEDs can extinguish. The two methods are referred to as period-based and time-based. In the period-based method, all the LEDs are lit at the beginning of the period, or block of curriculum that is separated by transitions. The LEDs then extinguish at a rate proportional to the length of the period. The method is qualitative; the amount of lit LEDs do not refer to a specific time remaining, but rather how much relative to the whole remains. In this method, blocks of different lengths would have all the LEDs lit at the start and all extinguish by the end.

The time-based method is purely quantitative. The LEDs extinguish at a constant rate proportional to time. As such the entire circumference would be associated with the longest block, while shorter blocks would be represented by an incomplete circle of LEDs. In this method a two-hour block may be represented by the entire circumference of LEDs being lit. By the end of the two-hour block all have extinguished. A one-hour block, on the other hand, would be represented by half the LEDs being lit at the start of the clock and then extinguishing at the same rate as the timer for the two-hour block. The difference between the two methods is illustrated in Figure 2.1 below.

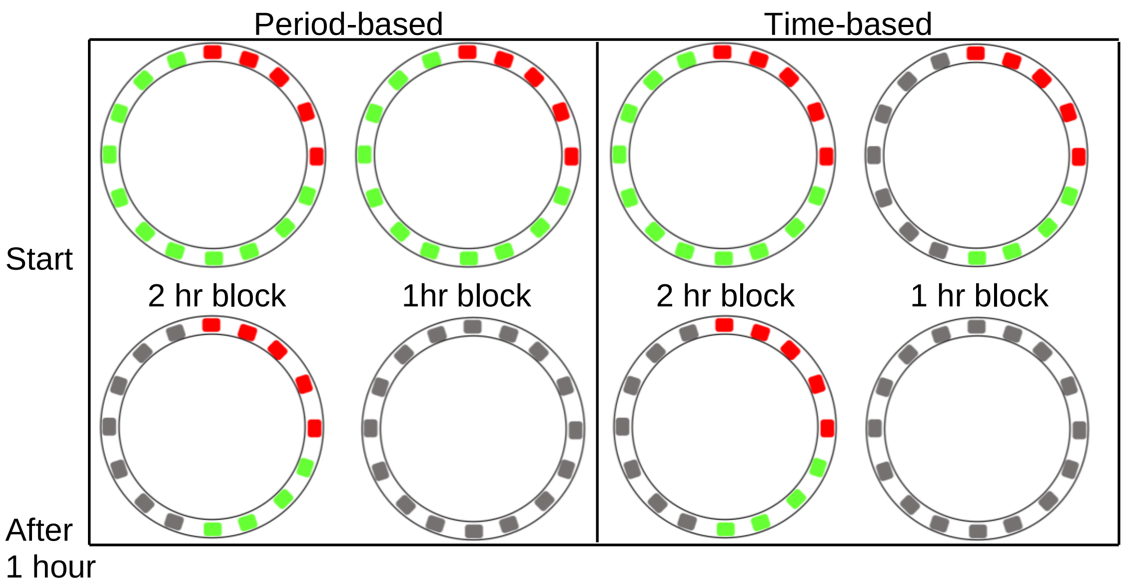


Figure 2.1: Period-based vs. Time-based timers

The question becomes which is better for a special needs student? A timer that shows a reference of remaining time and extinguishes at a rate comparable to that time, or a timer that shows specific amount of time represented as lit LEDs and extinguishes at a constant rate regardless of the length of the block. We are still researching the best method

The system will *anticipate* conditions of off-task behavior by being programmed to the student's schedule (indicating transition events) and by responding to physical markers such as heart rate, temperature, movement, or sweat. These physiological markers will be used to indicate the onset of a potential behavioral issue.

The system will *mitigate* off-task behavior through methods corresponding to the cause. When a problem is imminent the system will direct the student's attention away from the cause to the interactive device. The purpose of this is two-fold. If the student is experiencing a behavior issue that does not require immediate attention and is not related to transitioning, then the system can calm the student down (i.e. de-escalate). This is analogous to “taking five”. If, however, it is related to transitioning, then it will distract the student from the activity from which they are transitioning to some activity on the interactive device. This will then keep their attention until the activity is completed, thus providing a sense of closure, and allowing the student to successfully transition to the next activity/lesson.

This system is not intended to complement their academic lessons. Rather, it provides a kind of automatic response that identifies and handles the problem in a manner that would be quicker than direct intervention by a teacher or guardian. Any interference from the “timer” or touch screen activity would be justified since less time is taken away from the academic day than if the teacher had to completely interrupt the lesson to get the student back on track. The downside of this method is that it is possible for the activity to be either distracting when not needed, or it may exacerbate the problem.

That leads us to the second approach. In this method, there is still a sensor with a timer that will prevent and anticipate off-task behavior, respectively. However, there is no device for the child to interact with. When an issue is anticipated, the caregiver (parent, teacher, paraprofessional, etc.) will receive a notification, and it will be up to them to mitigate the issue. This method is not autonomous; caregiver intervention will be required. The advantage still holds that by monitoring physiological markers associated with the autonomic response, the caregiver will be alerted before the student knows there is about to be a problem.

The final method incorporates the two previous methods. Its aim is to negate the disadvantage of the first method. The caregiver shall also have control of the device, and can remove it if it begins to be a distraction or makes a bigger problem. For the remainder of this paper, we shall assume that this is the method to be used. This may change as the scope of the project changes.

2.3 Requirements Specifications

The main goal of this project is to reduce the amount of class time that is not being used for curriculum. For the system to be unobtrusive, then, it must meet certain criteria. One of which would be portable; the monitor itself must be small and light enough to not be an added burden. These dimensions were chosen based on existing wearable devices that are tailored to special needs persons, even those who have sensory problems that make wearing devices a possible burden. The touchscreen should be small and light enough that its mere presence does not negatively affect the class. Modern classrooms incorporate interactive devices such as computers and iPads as part of the curriculum, so this should not pose as much of a problem. The supplemental device’s dimensions are similar to popular hand-held devices.

As this is primarily conveyed by a special needs student, it must also be durable and water resistant. These requirements are obvious for any child during normal school activities. Rubber polymer is up to such a task, and it is popular for even wearable devices that are worn by athletes.

It must also be easy to use; teachers/parents/guardians will need to program the “timer” feature such that is corresponds to the daily schedule. This will need to be done initially, and then any time the day’s schedule is altered. Schedules may differ from day to day, school to school, or even change within a school day. This must be as simple as possible using preset prompts with basic “Enter” or “Next” inputs. In addition, the interactive feature of the system is used by a special needs student; simplicity is inherent. If it is too complicated, it can actually act as an aggressor and defeat its purpose entirely.

The devices work together to provide the desired outputs: the student is calmed and/or the teacher is notified. They must then be able to communicate with each other. To satisfy the requirements that it be unobtrusive, then, they should communicate wirelessly.

While the system could possibly work in any condition where transitions or other frustrations are possibly present, it is intended mainly for those during scheduled class time. The system must then last throughout an entire school day, at least. External powering of the system goes against that goal of minimally interfering in the normal school day class schedule. The system should then be able to be used for at least an entire school day without needing to be powered externally. This can be achieve through a combination of a powerful battery with recharging capabilities and low power consumption. The latter can be done by using parts that do not draw more power than the battery can handle in a day.

The key to anticipation is accurately monitoring those physiological markers that indicate a problem is about to occur, not just that a problem currently exists. Thankfully, these need not be quantitative, merely qualitative. For example, the caregiver does not need to know the child’s skin temperature. They, in fact should they know if they are not a medical professional. They just need to know that there was a rapid change in temperature which indicates a possible problem is about to occur. The accuracy of the sensors is not as critical as it would be if specific values were needed. However, the sensors still need to accurate enough to provide accurate alerts.

Finally, this should not be so expensive to make that a group of two cannot complete it, or that a normal consumer cannot purchase it. End users will only pay what they consider is fair value. Producers should then minimize the cost of development to achieve that fair value, along with a profit if possible.

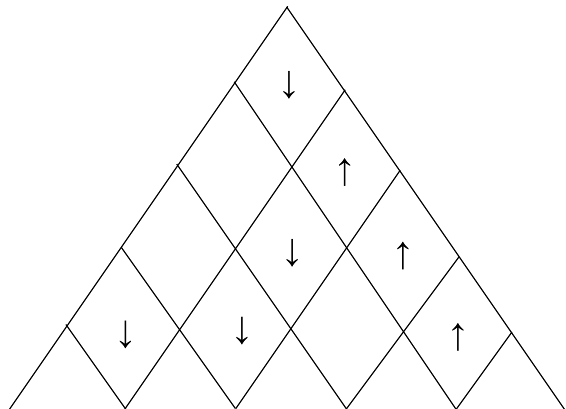
The engineering requirements for the project are listed in Table 2.1 below along with their associated marketing requirements discussed above and their justifications.

Marketing Requirements	Engineering Requirements	Justification
1, 2, 4	1. Dimensions of both components. (a) Wearable sensors on rubber strap: 2” × 2” × 0.75”, less than 8 oz. (b) Touch screen: 8” × 4” × 1”, less than 3 lbs.	These are comparable to current GPS locator devices worn on a wrist strap, and handheld devices. Rubber is proven durable and water resistant.
5	2. Batteries for both components should be able to operate for 12 hours at average power consumption of less than 50 watts.	This ensures that the system can be used for at least an entire school day without having to recharge at a power consumption that is comparable to current devices (iPad, Kindle).
6	3. Sensors’ accuracies should all be within ±20%.	This takes into account the accuracies of the sensors with changes to ambient conditions.
3	4. System use will follow three (3) prompts from the touchscreen: “ENTER”, “NEXT”, and number input.	Programming the timer and interactive features should be simple for all users.
7	5. Production cost should be less than $500.	This is comparable to current monitors (GPS, anxiety sensors).
Marketing Requirements 1. Portability (small, light-weight) 2. Durable/Water resistant 3. Easy to use 4. Wireless 5. Low power consumption 6. Accurate sensors 7. Low cost		

Table 2.1: Requirements Specifications

2.4 House of Quality Analysis

Figure 2.2 below correlates the effects of the marketing requirements to the engineering requirements. The positive “+” and negative “-” symbols next to each requirement refer to its polarity; increasing or decreasing that requirement increases the desirability of the system. The up and down arrows indicate if the requirements correlate as positive (↑), strongly positive (↑↑), negative (↑), or strongly negative (↑↑).



		Dimensions	Battery Life	Accuracy	Ease of Use	Cost
		-	+	+	+	-
Portability	+	↓	↓		↑	↑↑
Ease of Use	+		↓		↑↑	↑↑
Durability	+					↑↑
Wireless	+				↑	↑↑
Power consumption	-	↑	↓↓			↑↑
Accuracy	+			↑↑		↑↑
Cost	-	↓	↑↑	↑↑	↑↑	↑↑
Targets for Engineering Requirements		2 × 2 × ¾ in., < 8 oz. 8 × 4 × 1 in., < 3lbs	≥ 12 hours @ < 50 watts	±20%.	Three (3) entry prompts	< $500

Figure 2.2: House of Quality

3.0 Research Related to Project Definition

3.1 Existing Similar Projects and Products

3.1.1 Bio-Feedback Wristwatch Device for EH Children

This Senior Design project was from 2000. The only information found online was from a PowerPoint presentation posted on SlideServe. It was done by Nezha Chafik (EE), Raymond Findlater (CpE), Andrew Jarvis (CpE) and Luc Nicolet (EE) under the sponsorship of Dr. Rebecca Hines. It was designed for emotionally handicapped children between the ages of 6-10 years old [4]. It monitored motion and skin temperature to anticipate violent behavioral patterns. A game system then attempted to redirect those patterns through distraction.

The skin temperature was monitored using a thermally sensitive resistor (thermistor) because of its large change in resistance vs. temperature, fast response time, small size and high stability and accuracy. The output of the thermistor was connected to a TL082 op-amp and then to a TLC 549 eight-bit analog-to-digital converter. The motion sensor circuit was made up of an electret condenser microphone, a binary counter, a timer and an AND gate. The movement of the microphone affects its diaphragm like sound waves would. This converted to a pulse that represent the movement. The outputs of the temperature and motion sensors goes to a PIC16F876 microcontroller, and date can be stored on a 24LC16B EEPROM for data retention. The outputs on the microcontroller can activate the game and/or an audible alarm. It cost $380.50 according to their budget. The figure below is from Dr. Wei's Spring 2017 Senior Design I introduction lecture.

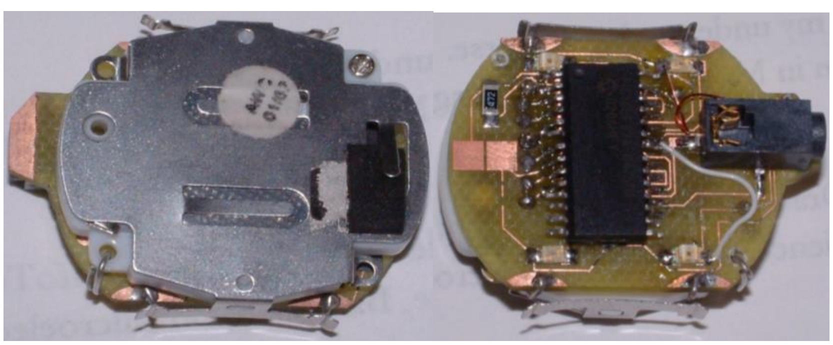


Figure 3.1: Bio-Feedback Wristwatch Device for EH Children

3.1.2 Home Healthcare Assistant

This is a Senior Design project from 2015 by Nicholas Cinti, Alexander Diaz-Rivera, Jonathan Stagnaro and Syed Zishan Zaidi. The Home Healthcare Assistant is a device that monitors patients' vitals from home and sends the data securely and wirelessly to a healthcare professional. This way, it can be possible to make quicker diagnoses than an emergency room visit would. The goal is to reduce inpatient overheard experienced in hospitals. It uses four sensors along with an LCD touchscreen which allows the patient to respond to a questionnaire about their current health, similar to a routine doctor's visit.

Patient temperature is taken orally using a shielded semiconductor integrated circuit (IC) temperature detector. The output voltage is a function of input voltage, device temperature (corresponding to patient's temperature), and the characteristics of the transistor. Its output will then be sent to a comparator that indicates if the patient has a fever or is suffering from hypothermia. Blood oxygen levels and heart rate are monitored by a pulse oximeter. It uses two light-emitting diodes (LEDs), one in the visible red spectrum and the other in the infrared spectrum. The light is shines through the patient's finger. On the other side of the finger is a light detector sensor which absorbs whatever light reaches it and converts it to a voltage. This output corresponds to how much light is not absorbed by the blood in the finger. This will change as the heart pumps blood causing the volume of the blood in the finger to change. Using two LEDs at different wavelengths along with the appropriate calculations allows determining the oxygen level in the blood, while the changes in absorbed light determines the heart rate. Blood pressure was monitored through the Microlife BP3MY1-1P blood pressure monitor. Finally, the patient's weight is measured using the Taylor 7519 weight scale circuit attached to a Wii balance board.

3.1.3 Empatica E4 Wristband

This product, known as a wearable physiological sensor device, was released in 2015, and is the culmination of work and research done by MIT professor and wearables pioneer, Dr. Rosalind Picard. It is a wearable wireless device designed for "comfortable, continuous, real-time data acquisition in daily life" [5]. It comes with an adjustable wristband, a USB dock and a USB cable for charging, and it contains four sensors. These are illustrated in Figure 3.2.

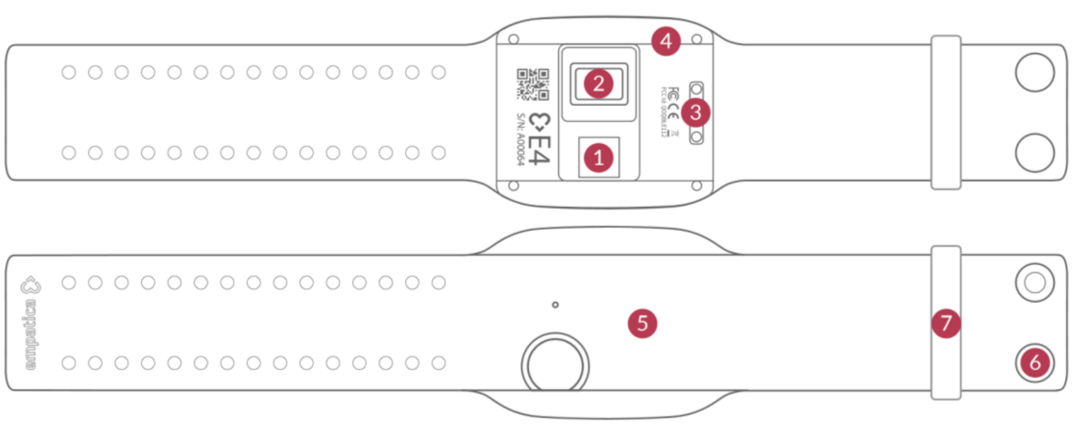


Figure 3.2: Empatica E4 Wristband. Reprinted with permission from Empatica.

(1) An infrared thermopile measures skin temperature. (2) A photo-plethysmography (PPG) sensor monitors blood volume pulse in order to derive heart rate and heart rate variablilty. (3) Silver plated USB terminals. (4) Polycarbonate and 30% glass fiber bottom cover. (5) Termoplastic polyurethane top cover. (6) Stainless steel electrodes for the electrodermal activity (EDA) sensor which monitors the sympathetic nervous system arousal to derive features related to stress, engagement and excitement.(7) Termoplastic polyurethane loop band. Finally, within the wrist piece is an accelerometer which captures motion on all three axes.

All the sensors are linked to different software applications which allows viewing real-time data on a mobile device using Bluetooth using Empatica Realtime, or to store the data usng Empatica Connect for later viewing via the Empatica Manager. It is intended for use by either healthy individuals or patients under a physician's care for the continuous, non-invasive monitoring of blood volume pulse, peripheral heart rate, electrodermal activity, surface body temperature and physical activity. When used under a healthcare professional, it can monitor physiological data to be used to monitor basic vital signs which may provide diagnostics that prompt further monitoring. For example, an expert can analyze the data to see what parameters may alert the onset of a seizure. This product is available to purchase for $1690.00.

3.1.4 Reveal

Reveal is a wearable device from Awake Labs, Inc. It is scheduled to be released in May 2017. As such, there is not much available information regarding it. A picture of the current version is shown in Figure 3.3 below.

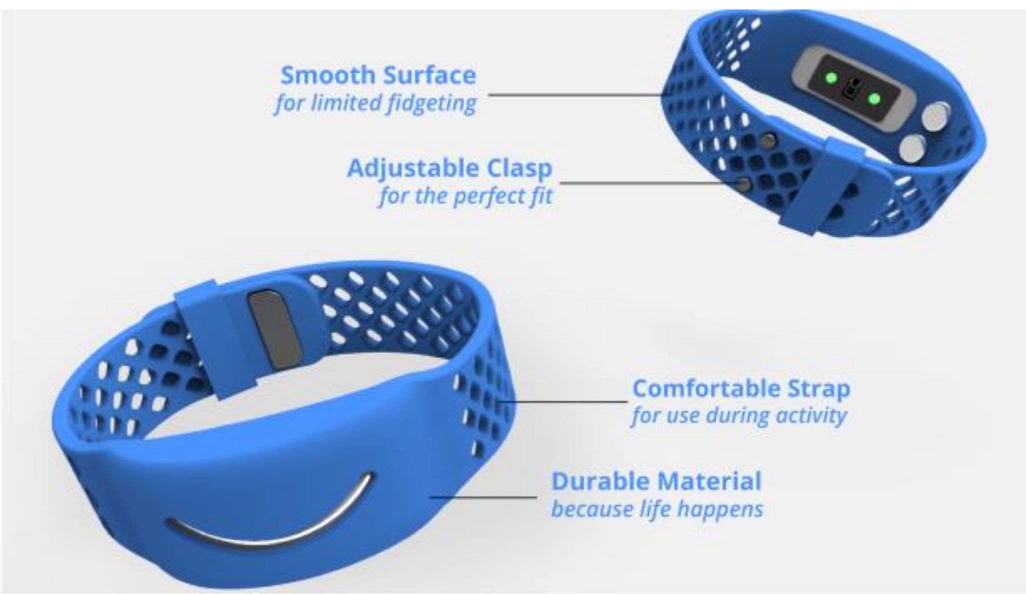


Figure 3.3: Reveal wearable device. Reprinted with permission from Indiegogo..

It is not known at this time how much it will cost. What is known is that it, too, measures and tracks anxiety in real time [6]. It is designed to worn by children with autism under the care of a parent, guardian, or caregiver to help understand behavior, provide insight into care, and notify them of an oncoming meltdown.

It can also be used as a tool for self-regulation. It functions similarly to the Empatica E4 wristband. Three sensors work in conjunction with an algorithm to provide notification when anxiety levels start to rise. I connects to mobile devices using Bluetooth. The sensors measure and track the three leading physiological indicators of changes in anxiety: heart rate, electrodermal activity and temperature. An image of the proposed prototype is below.

It should be noted that both the Empatica E4 wristband and the Reveal wearable device work to monitor and track physiological parameters. These can be used to learn to calm oneself, track exercise effectiveness and review the data later to determine possible triggers in the autonomic response. The difference between these and our project is that we want to track this physiological data to achieve a response that provides immediate help.

3.2 Relevant Technologies

3.2.1 Sensors

3.2.1.1 Electrodermal Activity Sensors: Electrodermal Activity (EDA) is also known as Galvanic Skin Response (GSR) or Skin Conductance (SC). It is due to the autonomic activation of sweat glands in the skin due to some emotional arousal [7]. It can be measured quite simply. A small voltage (typically 0.5 VDC) is applied to one stage of an amplifier and to the skin via two electrodes usually placed on two fingers or the palm. The skin electrodes are connected to the other stage of the amplifier in series to ground. The output of the amplifier is thus proportional to resistance of the skin. This voltage output can then be sent to an analog to digital converter, and then to a microprocessor to translate the data. Skin conductance is measured in micro-Siemens (µS) or micro-Mho (µM). Skin resistance depends on more than just emotional state. It can vary from 25 kOhms to 2 MOhms. This corresponds to a skin conductance of 0.5 µS to 40 µS.

The amplitude of the GSR signal contains a skin conductance level (SCL) and a skin conductance response (SCR). The former responds slowly to external stimuli on the order of tens of seconds to minutes. It acts as a kind of baseline value. The latter responds quickly to stimuli at between about one to five seconds. This rapid response reveals itself as peaks in the GSR amplitude. These peaks have characteristics that are important to the analysis of the data. As such, they also have an impact on the design of the sensor hardware and software. Figure 3.4 is a basic curve of the peak. Refer to it for the following explanation.

There are four basic characteristics of the GSR: (1) Latency, (2) Peak Amplitude, (3) Rise Time, and (4) Recovery Time. Latency refers to the time between when there is some external stimulus to when the body starts to respond (i.e. when the GSR value changes noticeably from the baseline). The peak amplitude is difference between GSR baseline and the peak value. Rise time is the time it takes to reach the peak amplitude as measured from when the body starts to respond. Recovery time is time it takes GSR to go from the peak amplitude to the baseline value.

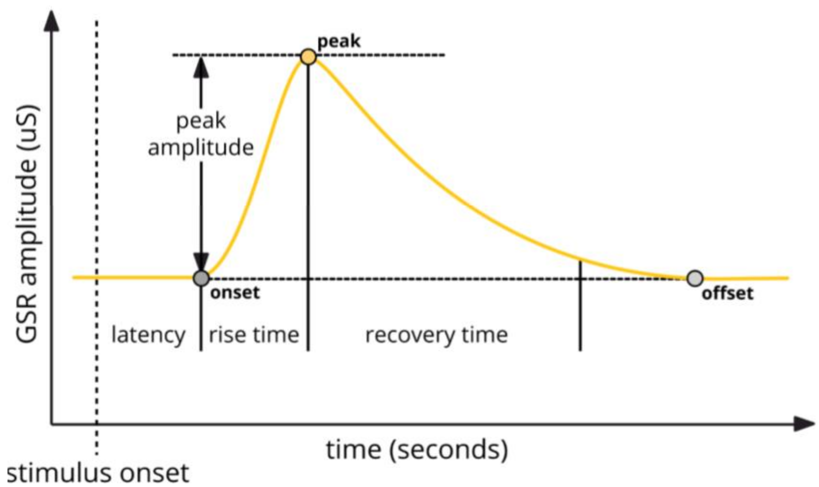


Figure 3.4: GSR Response. Reprinted with permission from iMotions.

This is important because the basic structure of the skin conductance technology follows GSR characteristics. They all require a small DC voltage supply. A difference amplifier is needed to calculate the skin resistance from the output voltage. Since the slower SCL can be ignored for the faster SCR, a high-pass filter is needed to remove the SCL effects and create a baseline GSR. In addition, a low-pass filter may be subsequently needed to filter out noise. The sampling rate of GSR can also be quite low given that the response is long compared to microprocessor events. A sampling frequency of 10 Hz is enough to capture the GSR with no loss in signal quality.

3.2.1.2 Temperature Sensors: Skin temperature is also affected by the body's autonomic response. Stress causes peripheral vasoconstriction (narrowing of the blood vessels resulting from contraction of the muscular wall of the vessels), causing a rapid, short-term drop in skin temperature. There are several technologies in use for remote, on-contact temperature measurement. They are thermocouples (TC), resistance temperature detectors (RTDs), thermistors, infrared thermopiles (IR) and semiconductor (IC) temperature sensors. Table 3.1 below summarizes the comparisons between the different temperature sensors.

Criteria	TC	RTD	Thermistor	IR	IC
Range	-267°C to +2316°C	-240°C to 700°C	-100°C to 500°C	-100°C to 500°C	-55°C to 150°C
Accuracy	Depends on cold junction compensation	Meets reqs	Depends on calibration	Depends on calibration	Meets reqs
Linearity	Better	Better	Least	Better	Best
Sensitivity	Least	Less	Best	Less	Better
Simplicity	Complex	Complex	Simpler	Simple to Complex	Simplest
Power	High	High	Low	Medium	Lowest
Cost	$$	$$$	$-$$$	$$	$

Table 3.1: Comparison on temperature sensors. Reprinted with permission from Texas Instruments.

Thermocouples are made up of two dissimilar metals connected at one end and open at the other [8]. Heat at the connected end produces a small voltage at the open end that can be read with a voltmeter and converted to temperature. Thermocouples are self-powered, simple in design, rugged, cheap and have a wide temperature range. This range makes them less accurate with respect to the small temperature deviations. They are also least stable and least sensitive.

RTDs, as the name suggests, use the relationship between temperature and resistance known as the temperature coefficient of resistance – how much resistance changes with a change in temperature. A constant current is applied to the wire, the voltage drop is measured, and the resistance across it is determined using Ohm's law. The temperature is then extrapolated from the measured resistance via a relatively linear relationship. These are more sensitive and accurate than TCs at low temperatures, but require an external current source and are more expensive.

Thermistors are actual resistors whose resistance vary with temperature [9]. They are made from semiconductor material and exhibit a non-linear resistance to temperature relationship. This makes for a large resistance change for a given change in temperature; thermistors are thus the most sensitive temperature sensor. Thermistors, like RTDs, require and external current source.

IR temperature sensors are based on the Seebeck effect, Plank's law of blackbody radiation and Stefan-Boltzmann law of radiative heat transfer [10]. The thermopile IR sensor has several thermocouples connected in series with their hot junctions attached to a thin IR absorber. The absorber and the object whose temperature is to be measured exchange IR radiation which changes the temperature of the absorber. The voltage at the cold ends is measured, and the object's temperature is derived from this. These are slightly more complicated than the other sensors. Their main advantage is that they are non-contact sensors.

IC temperature sensors function based on the temperature coefficient of a base-emitter junction forward voltage drop in a bipolar junction transistor (BJT) [11]. Unlike the previous sensors, these have an exactly linear voltage (or current) to temperature relationship. As indicated, they can come in either voltage, current, or even digital output. They are also cheap and small, but need an external power supply.

3.2.1.3 Heart Rate Monitor: Autonomic arousal of the sympathetic nervous system causes the heart rate to increase. Almost synonymous with monitoring the human heart rate is the electrocardiogram (EKG) which has been around for several decades. Simply put, the electrocardiogram records the electrical impulses that stimulate the heart to contract, or "beat" [12]. This electrical signal can be picked up through electrodes placed on the skin. This done by twelve located on the torso around the heart.

The beating of the heart may be caused by electrical impulses, but it causes blood to circulate throughout the body, including the surface of the skin. An indirect method for determining heart rate is photoplethysmography (PPG). This method is an optical technique that detects volumetric changes in blood in peripheral circulation [13]. It exposes the skin to near-infrared light from high-intensity green LEDs which gets absorbed by skin, bones and blood. This light is more strongly absorbed by blood, though. Photodetectors detect the change in intensity of the reflected light, and this change corresponds to heart rate. A basic PPG device is made up of an infrared-LED, a photo-transistor and an amplifier to boost the output. Filters may also need to be implemented to isolate the pulse rate.

3.2.1.4 Motion Sensor: Stress can also make special needs children move in erratic ways. An example common to children with ASD is hand flapping. An accelerometer is an electromechanical device that measures the acceleration (change in motion) of the object it is attached to. They can use either capacitive plates or a piezoelectric material such as a crystal. In the former, acceleration causes changes in capacitance between plates in the device that are translated to a voltage. In the latter, acceleration causes stresses on a crystal which creates a voltage. These voltages are then interpreted by the accelerometer as motion, usually through an amplifier and some software [14].

3.2.2 Power Supply

3.2.2.1 Batteries: Having a great power supply is essential for any project that requires any electrical output. For every component in our project to perform at its peak performance and last the duration needed for a day's use, having the proper external power supply is crucial to keep up with the demands of all the components. We need to explore all options for maintaining this power and to do that we look at a power sources such as batteries which are small and can last for the duration of a day. In the upcoming sections we talk about a few batteries and weigh their pros and cons and then justify which will benefit our project the most.

Our wearable device for special needs children obviously needs to be able to run on battery power and not plugged in constantly. Looking ahead at various battery types and their specifications is crucial since we have certain criteria needs for our specific project. Every battery is different with each having its own strength and weakness and we need to look into what makes each battery unique. After we have got enough information on a few different batteries we will then compare them in a table and chose one to fit our project needs. Our decision will be based on price, performance, weight, recharge-ability, charging time, and battery life.

Lithium Ion (Li-Ion) Batteries: This battery is made of a very light material known as lithium. The common devices that use such a battery are known to most people since they are in our cell phones. They actually hold their charge for relatively 8 hours in those devices, so this type of battery should last a very long time in our device. We will have to weigh the pros and cons in the Table 3.2 below to help us decide on if this battery would be helpful for our use.

Pros	Cons
Maintenance is very low and does not require a partial-recharge.	When left in cold places it can cause premature aging because of the chemical makeup.
Does not need an extended first charge and can be left on the charger even if the battery is fully-charged.	Because of the genetic makeup. the battery may need to be replaced every 6 months, which leads to its high cost initially and going forward.
For its size and weight it has a very high energy density.	Because of the size it is fragile, therefore there needs to be other circuits in your device to help maintain safe current and voltage levels.
Small in size and extremely light. Fits great into tight space constraints.	Extreme temperature changes can fluctuate the battery ideal life.
For its size it has an incredible low self-discharge.	This battery requires careful consideration when it comes to being charged.

Table 3.2: Pros and Cons of Li-Ion batteries. Reprinted with permission from Cadex Electronics, Inc.

Nickel-Metal Hydride (NiMH) Batteries: These batteries, unlike others, don't have toxic chemicals in their make-up. Therefore, they are considered environmentally safe. Also they tend to have an extremely high energy density and capacity compared to the competition. One of the shortcomings of these batteries is that they tend to struggle with large numbers of charging and discharging, so their lifecycle may seem shorter than other batteries. Also if they are left on the charger too long meaning more than a few days they lose their efficiency. Let's look at the Table 3.3 below to do a pros and cons list to see if this battery could be a potential candidate for our project needs.

Pros	Cons
Since these are designed to be non-toxic they are much safer to use than the competition.	These batteries are known to be more expensive than others due to their design and make-up.
There are a variety of shapes and sizes which are small and thin and can conform to most electronic devices such as our detection device.	Because of the design, the charging process for them is a bit more complex. Therefore, they need to be charged at or near 100% causing them to be hot to the touch.
These have very high capacity and energy potential compared to other batteries, as much as 50%.	The life cycle is not the strong point of these batteries because after a few hundred charges their life cycle diminishes greatly.
These are considered great for the environment meaning recyclable.	Over-charging a full battery is known as trickle charging and this type of battery suffers when being trickle charged.

Table 3.3: Pros and Cons of NiMH Batteries. Reprinted with permission from Cadex Electronics, Inc.

Nickel Cadmium (NiCd) Batteries: This battery, unlike those previously mentioned, does prefer to be recharged frequently because there are effects to the pole cells which can be deteriorated by crystals if it stays charged over a long time frame without having to be discharged. This sounds like a potential suitor for our project but again we need to weigh the pros and cons of this battery so we will look at the Table 3.4 below to see if this battery will fit our needs.

Alkaline (Alk) Batteries: These batteries are the cheapest of the four options and are readily and easily available. Also these batteries have the ability to store a very large amount of capacity and at their price is considered a good bang for the buck. Unlike the previously mentioned batteries these are not easily found as rechargeable and the ones that you can find are not as efficient in devices that are known to be high-draining. Also these batteries compared to the others have what is known to be a linear-voltage drop, which means as they get used the voltage on them drops as the battery is being drained which could affect the device that these are being used in. The price and availability is what makes these so tempting to look at so in the Table 3.5 shown below we will list the pros and cons to help us decided if these are right for our project.

Pros	Cons
These batteries have an incredibly long shelf life no matter the state of their charge. Also they have an incredible 1000 cycle life.	The cells can have a build-up of crystals on them in they are not charged frequently.
When being charged these batteries exhibit very little heat and they do not have specific temperature ranges at which they need to be charged at.	Unlike NiMH batteries these contain toxic metals therefore are deemed bad for the environment
These batteries are very cost effective and they are easy to find. Their shape is mostly cylindrical which means they fit into small spaces.	These batteries have an issue with discharging, therefore if they are stored for an extended period of time they will need to be recharged.

Table 3.4: Pros and Cons of NiCd Batteries. Reprinted with permission from Cadex Electronics, Inc.

Pros	Cons
These batteries are readily available meaning you could go to the store and get one same day.	These batteries have low load currents which means they are not ideal in high load devices that are power hungry.
The cost of these are much cheaper than the other batteries mentioned above.	Finding rechargeable alkaline batteries is tough and they too are not good in high-drain devices.
These batteries are also leak-proof when fully-charged and they are very environmentally friendly.	You may have to replace the battery often which can be an inconvenience for people who forget to check the power or don't have the time.

Table 3.5: Pros and Cons of Alk Batteries. Reprinted with permission from Cadex Electronics, Inc.

Having looked at four different types of batteries and weighing each on their strengths and weaknesses which were compiled from compliments of BatteryUniversity.com. We will now compare these four batteries in detail comparing price, specs, and what characteristics each has and can bring to the table. Listed in Table 3.6 below will help us ultimately decide on which battery to choose to help power our device for the best price and to keep it safe and running all day[15].

3.2.2.2 Battery Chargers: We know that a battery will not last forever and therefore it need to either be replaced or recharged. Now that we have gone through and fully discussed the batteries we be interested in using it is time to take a look at the different types of charging methods out there and base or choice on the battery we chose. These batteries have different chemical make-ups and we need to look at a variety of chargers to find the best one that suits the batteries and our needs. We researched a few charging methods below and which will help aide us in making our decision.

Parameter	Li-Ion	NiMH	NiCd	Alk
Internal Resistance in mΩ	150 to 250 7.2V	200 to 300 6V	100 to 200 6V	200 to 2000 6V
Fast Charge Time	2 to 4 hours	2 to 4 hours	1 hour	2 to 3 hours
Self-Discharging in a Month at Room Temperature	10%	30%	20%	0.3%
Overcharging Tolerance	Very Low	Low	Moderate	Moderate
Cycle Life (to 80%)	500 to 1000	300 to 500	1500	50 (To 50%)
Cell Voltage	3.6V	1.25V	1.25V	1.5V
Operating Temp.	-20 to 60 ℃	-20 to 60 ℃	-40 to 60 ℃	0 to 65 ℃
Maintenance Req.	Not Req.	60 to 90 days	30 to 60 days	Not Req.
Cost	$100 (7.2V)	$60 (7.2V)	$50 (7.2V)	$5 (9V)

Table 3.6: Comparing the details of the four rechargeable batteries. Reprinted with permission from Cadex Electronics, Inc.

USB Charging: A USB charger seems like a practical and obvious choice as they are common charging methods for our phones batteries and our project will feature a battery of similar or smaller size. In this day and age even the most non-tech savvy person knows how to plug in a USB charger to charge their device and most new cars even come standard with a few USB ports so people can charge their devices. When not connected to an AC outlet this charging method is known as slow-charging but the benefit is that it does not require a lot of power to do so.

Smart/Wireless Charging: This method of charging is the newest and most expensive way to charge a device but it is also the most convenient in terms of being wireless and also the fact that they can display a time remaining until the charge is complete which can be a way of deterring overcharging a device where the battery loses it efficiency if overcharged. This charger favors the NiMH brand so we will have to keep that battery and this charger in mind so if there is room in the budget we will consider it.

Basic/Simple Charging: This method of charging is relatively cheap and very simple for the common person. To charge a device it uses a step-down transformer which uses the AC voltage from a standard power outlet and modifies it to support a DC voltage which in turn charges the battery. One of the shortcomings of these charging methods is that they are slow and have been known to take nearly a full day to charge which in turn means that they get hot and therefore uses more energy and could affect the battery that is charging to have life cycle issues if the incorrect battery is used. One of the batteries that could be used here is the Li-Ion battery so we will have to take that battery into consideration when thinking about this charging method [16].

3.2.3 Wireless Communication

In our project we will require the use of wireless communication which will link the phone of the teacher up to the device the student wears. The teacher will be able to link up their phone with the students device so that they may get alerts of when the student may be feeling pressured from being able to complete a task and move on. Also we know that there will be multiple students and only one teacher so we will need multiple communication links. Additionally, we know that a classroom size is large but the teacher is generally never more than 10 feet away from their students, so that gives us a good idea on the range we will need to be sufficient for these communication links. Now that we know we need a device that will communicate well within a certain area, we also have to keep in mind of picking a wireless device with cost and power consumption in mind and also the size because we do not want it to be too cumbersome for anybody involved. Based on the information above and the limitations we set for this project we have selected to consider a few on the following wireless technologies for our project. The products that were looked at include: Wi-Fi, ZigBee, Bluetooth, and Bluetooth Low Energy (BLE).

3.2.3.1 Wi-Fi (802.11): Wi-Fi (802.11) is a part of the IEEE family and is a wireless network technology that allows computers and other devices to be connected to each other in a local area network (LAN) and to the internet without the hassle of wires or cables. The benefit of having a Wi-Fi network is that it offers enormous power for communicating between multiple devices in a given radius. The radius for someone on a Wi-Fi network is about 60 plus feet which is beneficial for large areas. The further a person gets from the signal the weaker the transmission becomes and the more power the device will use to keep that signal. Also if the Wi-Fi signal is left on it can tax a device even if not in use and will drain the battery at a much faster pace than other wireless devices. The power and range of Wi-Fi, along with is hunger for power on the battery life may be more than we need for our project [17].

3.2.3.2 ZigBee (802.15.4): ZigBee (802.15.4) is also part of the IEEE family and is known for its high-level communication protocols. This wireless technology is used mainly for personal area networks (PAN) and unlike Wi-Fi, this is meant for implementing low-power projects that also have low-bandwidth needs. Since this has low power consumption there are limitations to the distance such as 30 feet which is half of what Wi-Fi is. This wireless communication is great for extended battery life because of the low power consumption and also features the ability to secure the network that the devices are connected to using 128 bit encryption. This device may be what we need for our project because of the power consumption, security, and battery life. In Figure 3.5 below shows how many use ZigBee can be networked with [18].

Figure 3.5: ZigBee Wireless Communication. Permission pending.

3.2.3.3 Bluetooth (802.15.1): In Figure 3.6 below shows the multi-use of ways Bluetooth can connect multiple devices on the same secure network [19].

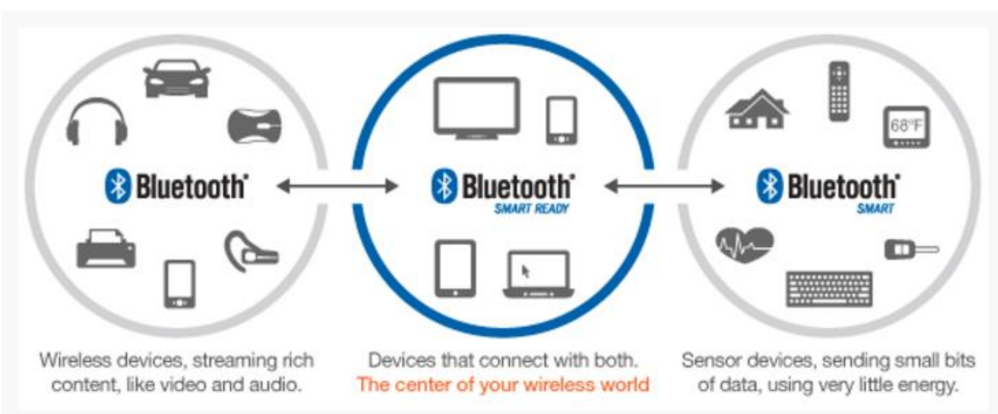


Figure 3.6: Bluetooth Connectivity. Permission pending.

Bluetooth (802.15.1) was standardized by IEEE but is now managed by the Bluetooth Special Interest Group (SIG). This technology is a wireless technology which is best suited for exchanging data over short distances. Bluetooth operates in the 2.4 GHz range just like Wi-Fi and ZigBee and uses what is known as frequency-hopping which is part of the radio technology. Bluetooth is known as a packet-based protocol which uses a master-slave structure. Having such a structure allows one master and up to seven slaves in a setup. On the master-slave setup all the devices being used use the master's clock which keeps all devices in sync. Bluetooth is best suited for applications needing low power and short range and thanks to the radio communication style there is no need for a direct line of sight when using this technology. This wireless technology seems very fitting for our project based on the ease of use and low power consumption and since we have multiple sensors and you can use up to seven slave's, then that will leave us plenty of head room.

3.2.3.4 Bluetooth Low Energy (BLE): Bluetooth Low Energy (BLE) is also known as Bluetooth Smart and is part of the Bluetooth family which still operates in the 2.4 GHz range and is a PAN, similar to the original Bluetooth but has been improved to help lower the power consumption as well as the cost while still maintaining very similar range when it comes to communication. One of the main benefits over the original Bluetooth is its improved efficiency for battery life, meaning it could operate for many months even up to a whole year depending on use. Other than the improved power consumption there is not much difference between BLE and Classic BT therefore we are unsure if the power consumption outweighs non-BLE standard BT such as supporting up to 7 slaves. In the Figure 3.6 above BLE also see benefits for our project because of the sensor devices that will be used [20].

Comparing all the specifications of the Wireless Communications:
In this area we have made a comparison table of the four potential wireless devices which might be best suited for our project. Here we will look at some of the characteristics of each device and then decide on which is right for us. In the below Table 3.7 we will compare many aspects such as power consumption, data rate, cost, the ease of setup and a few more important determining factors.

Parameter	Wi-Fi	ZigBee	Bluetooth	BT BLE
Data Rate	1 to 866 Mbit/s	20 to 250 kbit/s	1 to 3 Mbit/s	125 kbit/s to 2 Mbit/s
Distance	10ft to 330ft	32ft to 328ft	330ft	330ft
Security	128 to 256-bit	128-bit	56 to 128-bit	128-bit
Latency	6 ms to 35 ms	10 ms	100 ms	6 ms
Power Consumption	1 to 6 Watts	0.03 Watts	1 Watt	0.01 to 0.5 Watts
Peak Current Consumption	40ma	32.5mA	30mA	15mA
Bandwidth	20 to 160 MHz	2 MHz	25 Mbit/s	25 Mbit/s
Frequency	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Cost	$45	$35	$20	$20
Ease of Setup	Complex	Complex	Simple	Simple

Table 3.7: Comparison of Important Characteristics of Wireless Communications

3.2.4 User Interface

3.2.4.1 Displays: We live in a time where technology is advancing and when it comes to displays the options are abundant. As a group we had to decide what were a few important factors to determine the right display for our project and how to go about on choosing what fit our needs and budget.

- The cost needs to be low: as a two man group we are short on funding, so picking the correct component at the lowest cost is ideal, but still meets our requirements.
- Having a low power consumption: we are targeting low power consumption because the device is wearable thus keeping the heat down and making sure the device last all day.
- Small in size: the device is wearable and needs to be comfortable and non-intrusive so the user is not distracted and helps keep comfortability in mind.
- High-Resolution with Color: the end user needs to be able to clearly see any information on screen such as their heart-rate and temperature. Also a timer will be displayed and they need to be able to accurately see the time remaining.

Having this criteria above helps let us know which displays to look out for and which will best fit our project needs. In the upcoming selection of screens we discuss the technology that drives them and their strengths and weaknesses which will aide us to help make a decision on which to pick.

LCD (Liquid Crystal Display): These displays use a technique by using the crystals to block certain light where each pixel which is made from a layer of molecules, which gets wedged between two pieces of glass and two polarized filters with electrodes. To create the image on an LCD a voltage is applied which allows control over which light gets blocked or which is allowed to pass. Also by orienting the glass and filter panels helps determine how the light can pass through the crystals. A disadvantage to LCD displays is that they require an external light source to display the picture. One of the big advantages of an LCD screen is that it has a low energy consumption but still retains a high-resolution color display plus it has been around long enough to keep the cost low [21].

TFT (Thin-Film-Transistor) Display: These displays are actually apart of the LCD family that use transistor technology and use a technique that is called active matrix display. By using transistors it helps aide in a matrix style setup because each RGB sub-color pixel will have a transistor to accompany it which actually keeps the sub-color pixel at the required intensity until the next frame. An active matrix is done by using rows and columns, which is useful in larger displays by reducing the number of connections. A disadvantage to TFT is that during the manufacturing process if there are any faulty transistors you will get dead pixels on the screen. An advantage to using TFT is the fact that it is still part of the LCD family which helps keep the cost low [22].

LED (Light-Emitting Diode) Display: These displays actually are also part of the LCD family but use LED's to light up the screen vs an external light source. These panels use an array of LED's to represent the pixels and each block in the array uses the standard RGB with a white LED compacted together which actually simulate the pixel. By using LED's as a light source the screen is actually brighter and much easier to see in direct sun light compared to traditional LCD screens. The disadvantage to LED screens is the up-front cost, since the technology is relatively new. The advantage to LED screens is their natural brightness and their long life since LED's tend to produce less heat [23].

3.2.4.2 Touchscreen Displays: Living in the 21st century we have become accustomed to having the luxury of displays that we cannot just look at but interact with too. Ever since 2007 and the first iPhone, touch screen displays have become the new standard way of living. We have the technology in not just our phones but now computers, watches, car stereos, even our appliances and mirrors are becoming touch screen capable. Obviously the benefits are vast when it comes to this technology one being that there is no more use for mechanical buttons which means the less parts there are the less failures that can happen. Also now that there are less parts means there is less of a risk for unwanted foreign material seeping through the small crevices where buttons once occupied plus the screen itself crates the best seal. Size is another luxury that we are able to scale back on without mechanical buttons. With a smaller size come the potential of lighter weight which means better more efficient design of being water proof and ease of storage, also the device can be much more discreet without buttons. One other great feature of a touch only display is more screen space which means visibility increases as well as multi-touch use. While the touch screen trend is rising the cost are dropping because there are more vendors available to make them and competition keeps the cost low and the features rich.

Resistive touch screens: These touch screen have several layers, a flexible plastic and a glass which are both electrically resistive layers. Generally the front surface, which can be plastic, is the first layer is meant to be scratch-resistant with a coating of a conductive material known as ITO printed on its underside. There is a gap in between the firsts and second layer, which also has ITO in it, and thus an electrical resistance is created between the layers. When pressing down on the outer layers either by using your finger or a stylus, both of these layers of ITO meet and this is what causes the measure of the resistance of both layers, which then gives the most accurate point of impact. The advantage of these types of screens can be low cost, a high resistance to dust and water, can be recognized by more than just your finger. Some of the disadvantages to this type of screen is that you need to use more pressure, there is no multi-touch feature, and the contrast ratio is not the best.

Capacitive touch screens: These touch screens also have a similar design to them compared to the resistive ones because the also have two spaced layers of glass that use ITO. These use the human body as an electrical charge conductor because when a finger touches the glass of the capacitive surface, it changes the local electrostatic field. These systems continuously monitor the movement of each tiny capacitor. Since these screens do not use pressure for detection like the resistive ones, they can easily detect the lightest of touches and since the cover screen is not as bendable they are stronger and more resistive to scratches. Some disadvantages to this screen setup is that if the person is wearing gloves their gestures won’t be recognized by the screen. Also the glass is more prone to breaking if dropped and the glass can be more expensive to replace then plastic. Some advantages these screens exhibit are the fact that they use thicker glass which result in better clarity on screen and they much more sensitive to touch meaning you won’t need a stylus. Also they have multi-touch functions so the user can zoom in or type much faster. Below in Figure 3.7 is an example of a resistive and capacitive touchscreen [24].

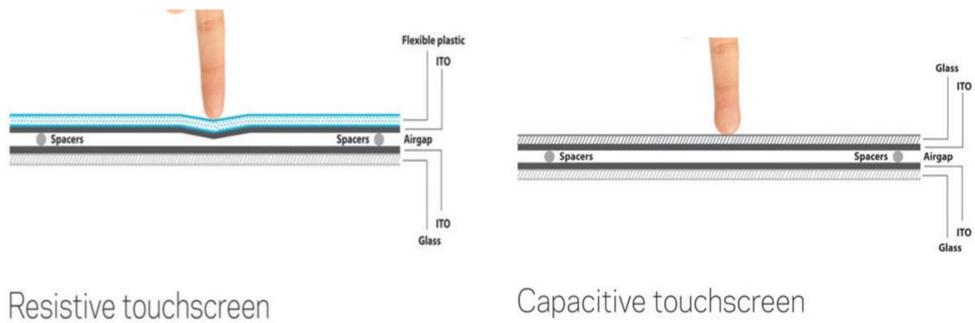


Figure 3.7 Resistive and Capacitive Touch screens. Permission pending.

3.2.5 Timers

For our project we are going to use a timer, and that timer must be visible to the child. The timer will be there to help the child deal with their need for completion in a manner so that they complete their need without getting to far off topic. This timer need to be light weight and visible to the child using it, the timer may be wearable or sit on the desk, but it has to be specific to the child needing it at that time. In the section ahead we will look into the different types of timers that are out there and look at a few of the implementations on how to make a timer if necessary.

Types of Timers: The two types of timers we will talk about are mechanical and electronic timers. The mechanical timers would be the one that would be sitting on the desk with a turn dial that you have to manually turn. These timers are commonly found in just about any store and are easily heard with an audible ding when the time is expired. As for the electronic timer that one can be on the desk too, but it can also be made wearable due to the use of small components and can come in a variety of colors while choosing to be audile or not. This type of timer can be bought at most local stores or can be made to fit like on a watch. We will take about these two types of timers and make our decision based on ease of use, simplicity, cost, and non-distracting.

Mechanical Timers: The first type of timer that we might be able to use is called a mechanical timer. These timers are the type that get set manually by turning a dial to the desired time interval and when the timer is up an audible noise can be heard. The way these timers work is when the user turns the dial, you are storing energy in the mainspring which in turn allows the mechanism to run. These timers function by using the energy in the mainspring to trigger a balance wheel and it rotates back and forth. When the wheel is released it slowly moves the gear train inside by such a small amount which in turn causes the dial to rotate backwards until it makes its way back to zero, then an audible bell will ring which indicates the time is up. This method would be the one that would sit on the desk in front of the student, which is a simple setup and cost effective but not very technical or subtle.

Electronic Timers: These types of timers have special electronics in them and are much more accurate than the mechanical timers. The makeup of these timers comes from having digital displays and digital electronics. These timers are implemented using simple integrated computer chip and can be made using software. There are no mechanical parts involved and therefore can be made in different shapes and sizes. Since these can be programmed, the user can make the clock have any color, so it's easy to read and the use of noise on these timers is optional. Also to make it less distracting to other students, it can be made to flash or turn off which will indicate time is over. This type of timer is much more desirable because it can be made for custom sizing, the parts are relatively cheap, and it is more technical for our project [32].

Chip to handle the timer:: The 555 timer IC is a chip that can be used in many different applications for timers. This chip can provide time delays, as an oscillator and as a flip-flop element. This chip includes 25 transistors, 2 diodes, and 15 resistors and a single silicon chip. The 555 timer gets its name from having three 5kΩ resistors which is the 15 total in the silicon chip. There are many variations of the standard 555 timer which can range to help cause less power supply noise such as the 7555 variant and it also does not require a control capacitor like the original did. This timer has three operating modes known as Bi-stable; which lets the timer operate as a flip-flop, Mono-stable; which lets the timer operate as a one-shot pulse generator, and Astable; which operates as an electronic oscillator [26].

On-Delay Timers: By using this type of timer, the timer begins when the voltage is applied. The contacts close when the timer has expired and will stay closed until the voltage is removed from the coil. If the voltage is removed before time-out occurs, then the time delay gets reset [27].

Off-Delay Timers: By using this type of timer, if voltage is applied nothing will actually happen. Instead closing the input switch causes the contacts to transfer. By opening the control input then the timing will begin and with that the contacts will remain closed. If there is a timeout that occurs then the contacts will transfer. If the control input is closed prior to time-out then it will be reset [27].

Pulse Timers: This type of timer is used to produce a fixed duration output from some initiating input. It includes two independent edge detector channels with the ability to generate two independent outgoing signals. One of the benefits to this timer is the fact that it can eliminate the need for many common relays and timing devices [28].

3.3 Strategic Components and Part Selection

3.3.1 Sensors

The sensors for this project are comprised of either simple microelectronic devices (operational amplifiers for the EDA sensors and all circuits, thermistors and IC temperature sensors, and LEDs and photodiodes for heart rate monitor), or specialized devices whose construction are not the intent of this project (electrodes for the EDA sensors, a thermopile IR temperature sensor, and an accelerometer).

The EDA sensor is basically made up of two electrodes attached to an amplifier with resistor values to achieve the desired gain. Within the circuit will likely be filters made from more op-amps, resistors and capacitors. The other sensor circuits may also require amplifiers to boost the analog signal. Electrodes can be made from almost any conductors; two washes attached to a wire would suffice. However, sensitivity might cause future problems. For that reason we chose to purchase re-usable electrodes. Relatively cheap versions that did not need to meet the rigorous requirements of medical equipment came from PLUX wireless biosignals S.A. A 10 pack of re-usable electrodes at $14.00 were purchased.

There are plenty of amplifiers to choose from. The desirable characteristics specialized to this project are cheap, easily obtained, low-power and compact. Precision is not as important because the sensors will be used to determine a change in parameters rather than their exact values. As such, general-use, low-power, quad-operational amplifiers were researched.

Linear Technology has a JFET type input operational amplifier, LT1055/LT10556 [29]. JFET types have a very high input impedance which is excellent for sensors. Its applications include use with photodiodes. This one specifically offers precision specifications and high speed performance. These are not as important to our design. It comes on a single chip which makes for a larger circuit. It is also dual supply making the circuit more complicated.

Texas Instruments' LMx24-N series of low-power, quad op-amps offer such features. It is made up of four independent, high-gain, internally frequency compensated operational amplifiers [30]. It allows for a low voltage (3V to 32 V) single power supply versus a dual supply. This makes it compatible for battery operation, it makes the power supply of the entire unit simpler, and it makes it compatible for low-voltage digital systems. Finally, having four integrated op-amps makes the entire circuit smaller, and different sensors can share amplifiers.

Microchip Technology's MCP6001/2/4 series are low-power op-amps, specifically designed for general-purpose applications [31]. Such applications also include portable equipment, photodiode amplifiers, and battery-powered systems. All of these are attractive to our project. In addition, they are available in quad packages and their supply voltage is only 1.8V to 6.0V. It is for these reasons that the MCP6004 op-amp was chosen.

Two of the temperature sensors stood out as candidates for this project. The IC type and the thermopile IR type. The IC temperature sensors are extremely simple, requiring only a transistor. This is ideal for size considerations. All that is needed is to measure the base-emitter voltage drop. This voltage can then be used to determine its temperature through the linear relationship between the two. Note that this is the temperature of the transistor. To reflect the skin temperature, the transistor must be in equilibrium with the skin. This would require contact and time to equilibrate. Unfortunately, the response of skin temperature to stimulus is rapid and of a small magnitude. The time required for the transistor to equilibrate offsets its compact design.

The thermopile IR sensor, on the other hand, is primarily a non-contact measurement device. There is no need for the device to equilibrate with the skin. The temperature is calculated from the output voltage. Although this is not a strictly linear relationship it is still possible to determine the temperature, or, more importantly, the change in temperature. It is for these reasons that the thermopile IR temperature sensor was chosen. It is not the intent of this project to build a thermopile sensor. Rather a thermopile was chosen and the circuit was built to support it.

While many products already include the circuit, a thermopile was found from Amphenol Advanced Sensors that would support the creation of a skin temperature sensor that is both small and sensitive to rapid changes in temperature. It is the ZTP-101T Thermopile Sensor. It features a small-size sensor package, ambient temperature-sensor for compensation, high sensitivity, fast response time, and low cost [32].

The heart rate monitor can also be implement using basic microelectronics: a near-infrared LED, a photodiode and an amplifier/filter circuit. The operational amplifier discussed previously will suffice for the circuit. As for the LED/photodiode pair, there are many to choose from. Unfortunately, compact ones are usually part of a circuit that would be difficult to integrate. Stand-alone LED/photodiodes are generally larger, but will be acceptable for the prototype. In the end, 940 nm infrared emitter and receiver diode pairs manufactured by XLX were used because they were cheap and easy to obtain.

The selection of the accelerometer followed that of the LED/photodiode pairs. There are many circuits in which an accelerometer is included. The acquisition of a simple accelerometer to be integrated in our design was a little more difficult as we are not an electronics company willing to purchase them in bulks of thousands. The accelerometer obtained from Freescale was their 3-axis, 12-bit, digital accelerometer, MMA8652FC. It features a small, low-power design [33].

3.3.2 Power Supply

We will be looking at a few different batteries to power our project and what we will be looking for is small in size, cost, and voltage. We would like to compare at least 3 different types of Li-Po batteries and discuss the benefits of each. The first type of battery we are looking at is the Li-Po battery from Adafruit which cost $10 and has 1200mAh with 3.7V these have circuitry protection in them to keep the battery voltage from going either too high or too low. This battery weighs 23g and the dimensions for this battery are 34mm*62mm*5mm in size so this is a relatively small battery and it is rechargeable. The other Li-Po battery we were looking at was the 2500mAh 3.7V battery also from Adafruit. The cost of this battery is a little more expensive at $15 and is a little larger in weight coming in at 52 grams and is also larger in size at 51mm*65mm*8mm which might be too large for our design, also this battery is rechargeable. The last battery we looked at was the lowest costing of the three batteries at $10a piece, this battery was also from Adafruit and it was also a Li-Po battery with 3.7V which is the same as the other two but this battery has the lowest milli-ampere hours at 150mAh of the three. Since it has the lowest mAh it is no surprise that the weight which is 4.65g and size 19.75mm*26.02mm*3.8mm makes this the smallest battery of the three which helps it fit into a small package which our project will need. We know we want to use a Li-Po battery because of their power for their size and if left on the charger then it will not drain the battery, but we until further testing and finding out our exact mAh needs, we can’t say for sure at this time which battery is best.

Parameter	Li-Po Batteries 3.7V Options		
Cost	$10	$10	$15
Weight	4.65 grams	23 grams	52 grams
mAh	150mAh	1200mAh	2500mAh

Table 3.8: Lithium Ion Battery Polymer Options

3.3.3 Wireless Communication

Based on our previous discussion in part 3.2 we chose Bluetooth as our wireless communication device for our project based on cost, area needed, and ease of implementation. We will be looking at a few different Bluetooth modules to determine which is best for our projects needs such as power output, cost, and weight. The first BT module we looked at was the Feather nRF52 BF LE which is a low energy BT module this part is from Adafruit and it cost $25 which is a about right for a module of this area. The power output was 4dBm which is pretty low and the voltage ranges from 1.7V to 3.3V which is well within the means for our project. The weight and size of the module are both relatively small, this module weighs only 5.7 grams and the dimensions are 51mm*23mm*8mm, which is great for a small project like ours. The second BT module we looked at was the Feather 32u4 BF LE module which is also a low energy module from Adafruit and it cost a little more than the first one at $30. This module has a 3.3V regulator with a 500mA peak current output which means it is on the high end of our but would still work. Also this module is just as light as the first module weighing only 5.7 grams and has the same dimensions of 51mm*23mm*8mm so there is no difference in size or weight. The other option was to look for a master and slave combination because of how many sensors we have and we found the HC-06 which is the salve and the HC-05 which is the master. These modules were not on Adafruit but rather we found them on Amazon for $8 a piece which is the cheapest of the three options. The range these are great for is good for 10m which should be plenty in a classroom setup. These modules weigh a little bit more than the other two modules weighing in at 8.5g but it is nothing major. As for the dimensions these come in at 27.94mm*15.24mm*2.54mm which is smaller dimension wise than the other two modules. These modules operate at 3.3V LDO input voltage which is the same as the other two modules. Based on these findings we chose to go with the HC-05 and HC-06 in master and slave combination because of the sensors that we have and based on the price since everything else was nearly identical.

3.3.4 User Interface

We will be looking at a few different touch screens to see what screen fits our needs such as size, budget, capacitive vs resistive, resolution, and ease of use. We will look and compare at least three different touchscreens and weigh their pros and cons. The first one we looked at was the Uno R3 2.8” TFT touch screen. The cost for this unit is relatively cheap being under $16 and it is small in size which helps keep it discrete. The ease of use of this should be relatively easy for students with small hands and is a resistive touchscreen. Another screen we looked at was the larger 3.5” TFT which also would work with the Arduino board that we are using but the cost is nearly $40 so that is one of the downfalls. Other than the price the size is nice and large, giving the student with larger fingers more space, also this touchscreen is resistive too. The last screen we look at was another 2.8” TFT touch screen that is also used for Arduino but rather than resistive this one is capacitive which is good for not needing a stylus and it supports multi-touch. Since the size is small it will be discrete and will fit better into the hands of the students using it. The cost on this unit is high though the price is $45 for this screen which is more than the resistive 2.8” and even more than the larger 3.5”. Looking that the Table 3.9 below we will weigh the pros and cons and then decide.

Parameter	2.8” TFT	3.5” TFT	2.8” TFT
Cost	$16	$40	$45
Dimensions	78*53mm	97*56mm	78*53mm
Style	Resistive	Resistive	Capacitive
Ease of Use	Easy for those with small hands and includes a stylus	Bigger screen size makes it easy to use for those with larger hands also comes with a stylus	Does not come with a stylus but is great for those with small hands
Resolution	320*240	480*320	240*320

Table 3.9: Pro and Cons of Touchscreen.

3.3.5 Microcontroller

The design of this project is straight forward enough that it does not require a complicated microprocessor. The sensors provide four different inputs in order to get up to four outputs; either the digitized values of each parameter or simply the activation of the user interface to calm the student, and alert a guardian. The microcontrollers needed should both meet the goals of the project while not overburdening ourselves. With that in mind, only two microcontrollers were considered: Texas Instruments’ MSP430G2553 and Atmel’s ATmega328P.

The main reasons for these two choices were popularity and familiarity. These two are by far the more popular microcontrollers available. The MSP430G2553 has an entire semester dedicated to its use. The ATmega328P is popular in Arduino which is very attractive to beginners. They are comparable in many aspects. Important to us are cost, availability and ease of use. Other features are speed, power draw, I/O capacity. Speed is not that critical. Even a relatively slow microcontroller is probably fast enough for our applications. The MSP460G2553 runs at up to 16 MHz [34] while the ATmega328P runs at 20 MHz processing speeds [35]. Either of these should be adequate. The MSP430G2553 has several low power modes to extend battery life, while having an input voltage of 3.6V. The ATmega328P can run at 5V which is compatible with the rest of the design, simplifying the power supply circuit. The MSP430G2553 has 16 I/O pins while the ATmega328P has 20. Again, either one should be sufficient for our goals.

Disregarding shipping costs, they both are between $1 per chip in bulk quantities and $3 when purchased individually. Both are available on-line. They both have plenty of supporting material online. The popularity for each is a result of something different between them. The MSP430G2553 is popular among more serious users of embedded systems with more in-depth projects. The ATmega328P is popular among those whose designs are not complicated. The final contributing feature is ease of use. A big hurdle for this project will be programming as neither of us are computer engineering students. We shall rely heavily on simpler programming and product community support, of which there is plenty with the ATmega328P. It is for these reasons that it was chosen over the MSP430G2553.

3.3.6 Timer

As stated before in section 3.2 we will be using an electronic timer in conjunction with a 555 IC timer to implement the timer for our program. We will be looking at a few different types of timers here to see which one best fits the needs of our project. For our project we are basing our purchase on cost, size, battery used, and simplicity. We would like to compare at least 3 different types of timers and see the benefits each three has to offer before we decide on which to use. The first timer we looked at was an 8x8 ultra-bright matrix display which was on Adafruit and can be used with the Atmega 328p chip on the Arduino so implementation would be easy. The cost of the timer was $29 which is not the cheapest option. This device uses LED’s to light up the display and it uses a coin battery and can last for over a year on this battery so the power consumption is very low. The second timer we looked at was a DIY timer with a PCB on the back and an acrylic cover on the front so you can see the digital display mounted to the PCB. This design is slightly more expensive than the first coming in at $30. This timer has a 60mm in diameter and weighs only 43 grams. This timer uses a lot of power even though it uses LED lighting and the battery that is required to power this device is a CR2032 battery which would not power our whole project. In addition, if we used this timer, then it would add more weight than necessary. The third timer we looked at was known as RGB LED development board and it was purchased from a website called Banggood and the cost was pretty low considering per item at roughly $4 each but the shipping is where the cost can rise. The weight of this comes in at 3.03 grams and the size of the timer is 6.8cm on the outside and 5.5cm on the inside which makes this the smallest and lightest of the three timers. This timer uses 16 LED’s to display the time in an extinguishing style and to power the whole thing you need 5V. Looking at the Table 3.10 below we have a comparison of the three different timers.

Parameter	8x8 UBMD	DIY Timer	16 RGB LED
Cost	$29	$30	$4
Size	40 grams	43 grams	3.03 grams
Battery Used	Coin Battery	CR2032	Li-Po

Table 3.10: Variation of 3 Different Types of Timers

Based on the research of these three timers we chose to go with the GRB LED timer because of the cost, battery use, and how light-weight the material was.

3.4 Possible Architectures and Related Diagrams

A possible overall design for this project is provided in the block diagram of Figure 3.8.

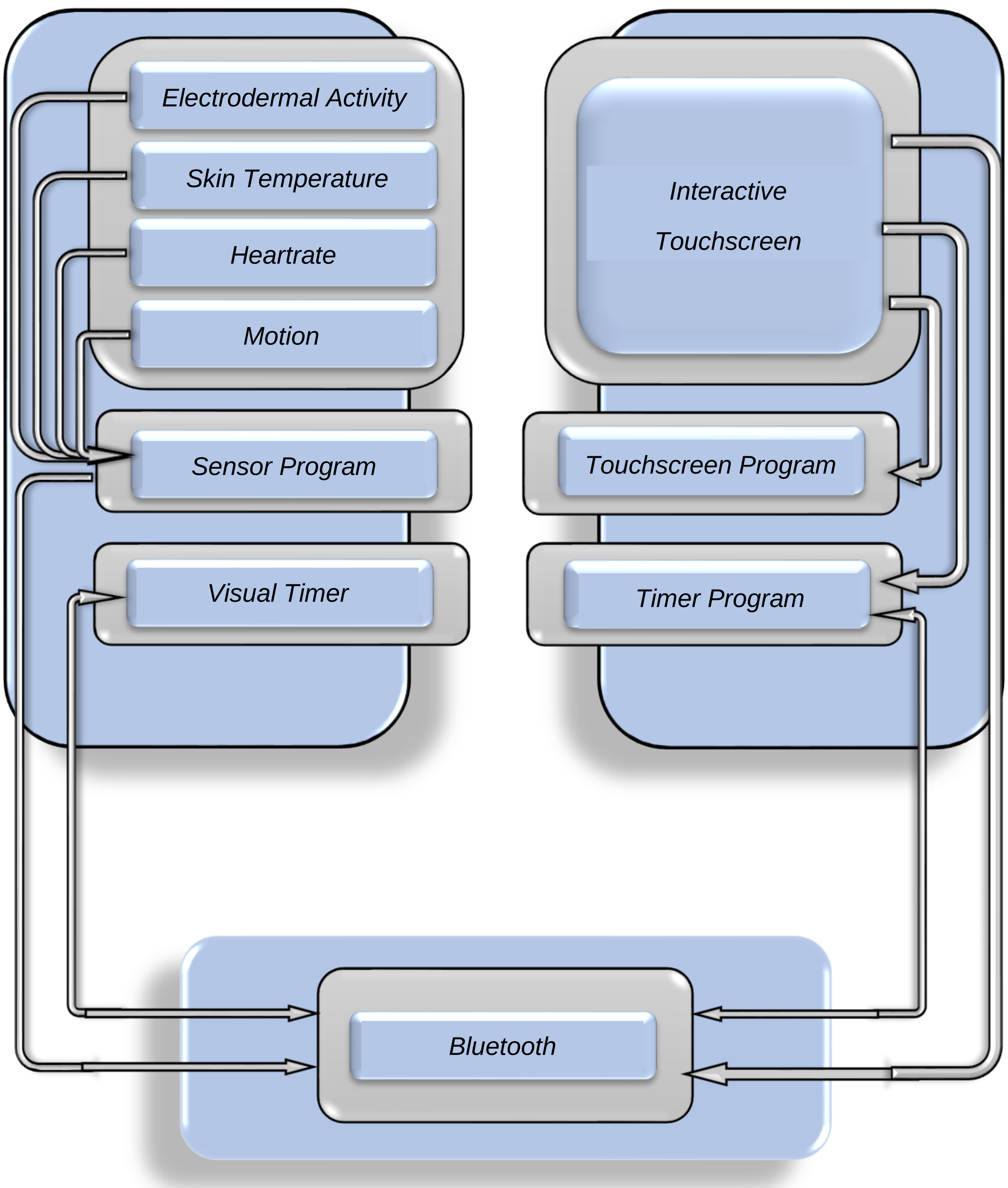


Figure 3.8 Possible project architecture

3.5 Parts Selection Summary

Table 3.11 below summarizes the parts that were finally chosen. Some were bought directly from the manufacturer while others from a third-party seller. This was done to expedite the acquisition of the required part(s), or to avoid having to buy in bulk.

	Part Name	Manufacturer/Seller	Part Number	Cost
1	Electrodes (10 pk)	PLUX	EL-DRY-REUSABLE-5-10	$14.00
2	MCP6004 Op-Amp (10 pk)	Microchip Technology	MCP6004-E/P	$6.71
3	Thermopile (5 pk)	Amphenol Advanced Sensors	ZTP-101T	$22.00
4	LEDs/photodiodes (50 pairs)	XLX	B01MFCFLA7	$11.99
5	Accelerometer (10 pk)	Freescale	MMA8652FC	$14.76
6	Microcontroller (3 pk)	Atmel	ATmega328P	$13.45
7	Touchscreen	Amazon	LYSB00UAA2XIC	$15.99
8	Bluetooth Master (2 pk)	DSD TECH	B01G9KSAF6	$7.99
9	Bluetooth Slave (2 pk)	DSD TECH	B01FCQZ8VW	$7.99
10	Timer (3 pk)	Banggood	976036	$10.56
	Battery	Pending		
			Total	$125.44

Table 3.11: Parts Selection Summary

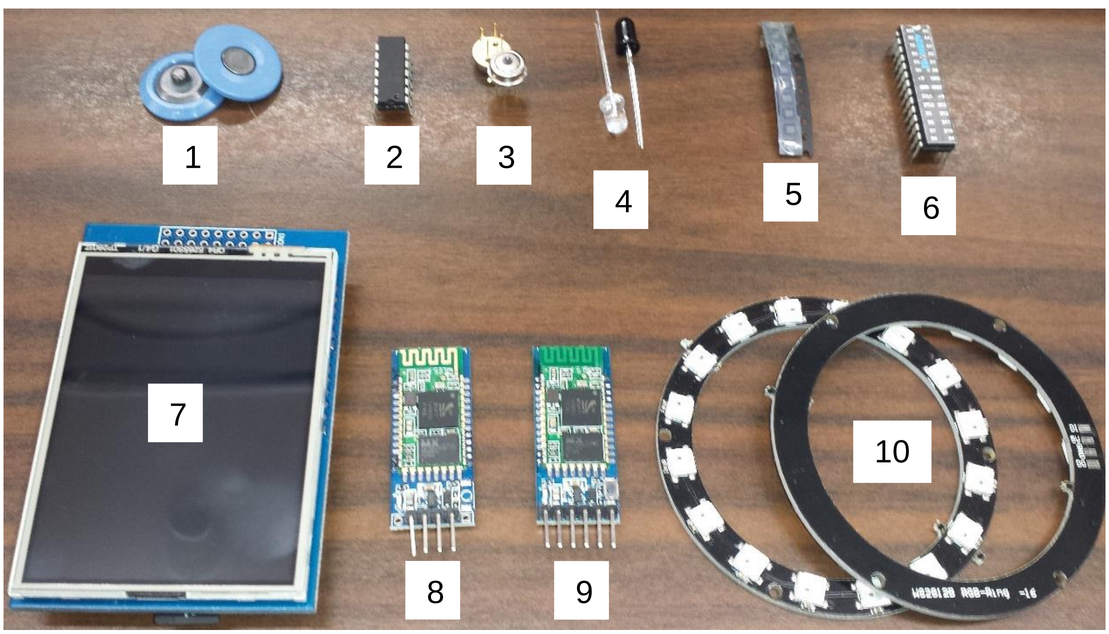


Figure 3.9: Parts

4.0 Related Standards and Realistic Design Constraints

4.1 Standards

In everyone's life we all live by a code of standards to help determine what is important to us. The definition of what a standard is, it's a set of characteristic or qualities that describes the features of a product, process, or service. IEEE has a code of ethics in which they hold their standards to, to construct and define the electrical and computer science community. For our project, all the electronic equipment that we are using should meet all the requirements of IEEE standards, which should help reduce any and all risks. A big priority for IEEE members is to accept the responsibility of the decision making process which effects the public's health, safety, and well-being. As up and coming engineers ourselves, we look to follow IEEE standards and will apply it to our project.

4.1.1 Relevant Standards

Words like quality and dependability can be generally associated with what we have come to know when we think of standards. For example, when a person goes to buy a new car and spend their hard earned dollars, they expect a standard that the car will last a certain mileage without much headache. Now cars can be hand built like certain exotics or machine built like most cars are, but still humans have some work in there too. No matter who or what built that vehicle it is expected to start and work for a duration of time without extra money needing to keep it going and this is a standard from the industry to keep the customer happy and safe. In our project we have a wearable device that has sensors to monitor the child and that device must work properly and not fail when it is needed. To make sure our project functions we must look at some of the standards below and follow that criteria.

- ANSI C84.1
  - Electric Power Systems and Equipment – Voltage Ratings (60 Hertz).
- Electronic Code of Federal Regulations Title 47 - Telecommunication
  - Part 15 - Radio Frequency Devices.
- Bluetooth 4.0
  - Bluetooth Standard that includes Bluetooth Low Energy protocol.
- IEC 61188-5-1 PCB Assemblies – Design and Use
  - Provides information on land pattern geometries used for the surface attachment of electronic components.
- IEC 61191-1 Printed Board Assemblies Part 1 General Specifications
  - Requirements for soldered electrical and electronic assemblies using surface mount and related assembly technologies.
- BSR/IEEE 2700-201x Standard for Sensor Performance Parameter Definitions

- This document provides a common framework for sensor performance specification terminology, units, conditions and limits. The specific sensors discussed in this document are Accelerometer, Magnetometer, Gyro-meter/Gyroscope, Barometer/Pressure Sensors, Hygrometer/Humidity Sensors, Temperature Sensors, Ambient Light Sensors, and Proximity Sensors.

- BS IEC 60287-3-2:2012 Electric cables
  - Calculation of the current rating. Sections on operating conditions. Economic optimization of power cable size (British Standard).
- ISO 10014:2006 Quality management
  - Guidelines for realizing financial and economic benefits.
- IEC 60086-1 Ed. 11.0 b: 2011 Primary batteries - Part 1: General
  - IEC 60086-1:2011 is intended to standardize primary batteries with respect to dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety and environmental aspects. The object of IEC 60086-1 is to benefit primary battery users, device designers and battery manufacturers by ensuring that batteries from different manufacturers are interchangeable according to standard form, fit and function.
- IEC 60086-4 Ed. 4.0 b: 2014 Safety of Lithium Batteries
  - IEC 60086-4:2014 specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.
- IEC 60747-14-1 Ed. 1.0 Semiconductor Devices - Part 14-1
  - Semiconductor sensors - General and classification.
- ISO 20282-1:2006 Ease of operation of everyday products
  - Provides requirements and recommendations for the design of easy-to-operate everyday products, where ease of operation addresses a subset of the concept of usability concerned with the user interface by taking account of the relevant user characteristics and the context of use.
- ISO/IEC 18021:2002 User Interfaces
  - User interfaces for mobile tools for management of database communications in a client-server model.
- IEC 61340-5-3 Ed. 2.0 b: 2015 Protection of electronic devices from electrostatic phenomena
  - Defines the ESD protective packaging properties needed to protect electrostatic discharge sensitive devices (ESDS) through all phases of production, rework/maintenance, transport and storage. Test methods are referenced to evaluate packaging and packaging materials for these product and material properties. Performance limits are provided. This standard does not address protection from electromagnetic interference (EMI), electromagnetic pulsing (EMP) or protection of volatile materials.
- BSR/IPC 2615-200x Printed Board Dimensions and Tolerances
  - Covers the dimensions and tolerances of electronic packaging as it relates to printed boards and the assembly of printed boards. The concepts

defined in this standard are derived from American National Standard for the dimensions and tolerances, ANSI/ASME Y14.5-1994 (R1999).

4.1.2 Design Impact of Relevant Standards

For our project, most of the standards listed above apply to most of the components we will use. As for the electrical side of our project standards such as IEC 61340-5-3 which is for the protection of electronic devices from ESD is associated with IEC 60287-3-2 which is for the electric cables and calculating the current rating and is also related to ANSI C84.1 which deals with electric power systems and equipment. These standards are all helpful to guide us along the way to make sure our device does is up to the job on the electrical side and does not get overheated or destroyed through miscalculations or outside factors. Since our device will have multiple sensors detecting the child's temperature, heart rate, and skin conductance we will adhere to the following standards such as BSR/IEEE 2700-201x which is for the performance of different sensors which also correlates with IEC 60747-14-1 which is for Semiconductor devices and sensors and by following these standards will help us make sure we get the proper devices necessary to monitor the specific areas properly. The Electronic Code of Federal Regulations Title 47 is for communication and is used with radio frequency also the Bluetooth Standard that includes Bluetooth Low Energy protocol. These two standards work well with teaching us how to communicate between multiple devices within our project such as linking the device the student will wear to the teachers phone to be able to receive feedback from the students wearable device with all the sensors. As for making the circuit board that attaches all of the components we will use the standards most helpful for that will be IEC 61188-5-1 PCB Assemblies which is for designing the layout of the board and where to place all of the electronic components also IEC 61191-1 Printed Board Assemblies Part 1 General Specifications which will teach us how and where to solder the electrical components and the last one being BSR/IPC 2615-200x Printed Board Dimensions and Tolerances which helps us figure out the dimensions and tolerances of electronic packaging as it relates to our specific PCB. When it comes to powering the device and making sure it works all day long we have to look at the battery standards and the ones we came across were IEC 60086-1 which is used to standardize primary batteries with respect to dimensions, performance, markings and testing from various manufactures, also IEC 60086-4 which is for the safety of Lithium Ion batteries which makes sure they are usable and safe which is helpful for our project because we will use batteries to supply power to the device and the battery that we will use is a lithium ion battery. The next area that comes into play for our project is about the ease of use and the interface on which is used by the student. For this area we looked at two standards, the first being ISO 20282-1 which talks about the ease of use of the product it provides requirements and recommendations for the design of easy-to- operate everyday products. The second requirement is ISO/IEC 18021 which is for the user interface of the product. Both of these standards are useful in making sure the product is clear and easy to use. The last standard for our project is non-other than the quality standard ISO

10014 which is helpful for realizing financial and economic benefits and for our project quality is very important because of the cost of making the product affordable and making sure the product is reliable and fits the needs of the students.

4.2 Realistic Design Constraints

When it comes to working on a project whether it be for school, work, or other people, there are always some sort of design constraints involved. Now these constraints are known to be somewhat limiting for the task at hand not by internal but rather external. A few of these outside factors can be but not limited to time, economic, political, social, health, ethical, safety, sustainability, and even manufacturability. In the discussions below we will talk about all of these constraints and how they will relate to our project.

4.2.1 Economical and Time Constraints

When talking about an economic constraint it can be known as a financial constraint towards a project. Which in turn could be related to the projects total cost or it could be a damper on the products overall sales in the given market. As for our project the economic constraint was more about coming up with the cost between two people and splitting it evenly. The talk about our budget and spending is later discussed in more detail in the Budget and Finance section which is towards the end of the paper. We had no funding by any company or organizations therefore it was on us to fund the entire project 100%. Luckily, our work is not a product but rather a project, therefore there is nothing to be sold making that part of the constraint non-existent. If we pretend that our project were more than just that and it was more of a product to be sold then an important aspect would be to get feedback from the device and have it stored onto an SD card or sent directly to the parents email address. Most parents with autistic children just want their kids to have as normal of a life as the next kid, and to help with that there needs to be data logs showing when the child is calm the most and when they show signs of stress. By having tangible data they could take it to a specialist and help find a way to counteract the stress levels and help the child feel more at ease often thus bring the stress of the child, parent and care takers down to more manageable levels throughout the day. Again this would be ideal if we had more man power and a bigger budget.

When talking about a time constraint it can be defined as the time frame that a project has until it needs to be finished and presented. As for our project we are given a time frame on two semesters to complete it. During the first semester we are in the planning phase, which means that we come up with an idea, research and buy the necessary parts, and write about what we have researched and how it all comes together. During the second semester we must have a prototype on a breadboard and then proceed to send it out to make it on a PCB board for final presentations. To go into further detail on how long each term is, we started in the spring which gives us a total of 16 weeks, then will pick up in the fall for another 16 weeks. During the hiatus in the summer will give us extra time to refine our project which not everyone gets the opportunity to do so. Having this extra time gives us leeway on perfecting the presentation and making sure our documentation, PCB design, and programming go extra smooth making the transition to fall much smoother.

4.2.2 Environmental, Social, and Political Constraints

When talking about an environmental constraint it can be known as what is surrounding your product that may accidentally harm the product or end user non-intentionally. As for our project we need to make sure that the design is sealed tight so no harm may come to the child using it or the device itself. Since our device is wearable we need to make sure it can withstand day to day use and the exposures it may endure. To ensure the safety of the user and the device, we need to construct a solid housing around all of the inner components which will help keep everything tucked away nicely and safely. Also we need to be considerate of the user washing their hands or getting caught in the rain or even sweating from activity or nervousness which may cause the device to short or even catch on fire. Having a great enclosure is vital to all parties involved which is why knowing about how the environment around will affect our device is crucial forethought.

When talking about a social constraint on a project it can be known that there are risks involved regarding how people might be afraid whether the device is safe and secure to talk about with others. Parents often want what is best for their child but also have fear in mind when talking about a product that is new and they are unaware of the risks vs rewards. A big fear is that with wireless technology someone may have the wrong intentions to access the information about their child and use it to harm the child, so the social aspect is a great concern amongst parents. Another social aspect is that the device may make their child look out of place or not inviting to other students which may make them feel out of place and not wanted. To avoid this from happening we need to look into ways of making the wearable device seem appropriate for the times. One other social constraint that the device may suffer from is that the parents may be afraid of the short or long term effects that wearing a device that monitors their child has on their health and we need to be aware of the backlash that may come from uninformed parents.

The last part we need to address is the political constraints that a project may suffer from due to new or existing laws or even the rights of the end user. When addressing political constraints for our project we need to be aware of the privacy of the end user and how this may affect their lives. Every person has their right to privacy and if the data that the device gets is leaked or hacked that will be a flaw in the system and we may have repercussions due to violations of privacy laws. To address the privacy concern we will have to use a security feature so that the connection is protected and the data will only be accessible to those with a code they have set up to retrieve such data. Ultimately it will be up to the end user to create a password that not only is difficult for others to gain access to but one that they can remember. Also the device needs to have warning and instruction labels included with each device to take care of the legal or political ramifications that a device may endure. We will need to cover ourselves to avoid confusion and to make sure we are not stepping over an individual's rights with this device.

4.2.3 Ethical, Health, and Safety Constraints

When talking about an ethical constraint that a project may have it can be known that there are right and wrong ways to go about doing the business and getting the job done. For our project we need to make sure that people know we are sincere and that our heart is in this to help make the family's lives easier. As mentioned above people have a right to know that the product they are buying is one that will be secure and accurate and that no harm will come to the child wearing the device. So, ethically speaking that is why the warning labels need to be attached to the device and instructions need to be clear so that there is no confusion on how to properly setup the device so the end user gets that extra peace of mind knowing their child's information is in their hands and not out there to be taken by someone with bad intentions.

When talking about a health constraint that a project may have it can be known that each device may have some risk involved but the risk needs to be kept to a minimum. For example, when a wireless communications device is trying to enter the market, it must for have numerous testing done before it is deemed safe enough for public use. As for our project the health risk involved is kept to a minimum thanks to the device being encased securely so there is no risk of electrocution to the end user. The only risk involved is that if someone puts the wearable device on too tightly or when playing outside during recess the device gets purposely or accidentally damaged during physical activity which may leave a bruise on the child's arm. To avoid these possible health concerns we will recommend that the child only wears the device when inside to avoid such probability, but it will be up to the parents on if they want their child using it all day.

When talking about the safety constraints that a project can have it is known that not every items is 100% safe from human error. For example, child toys are made to be bright and colorful, but they have to be large enough so the child can't swallow the toy and if swallowed the toys paint must be lead free and not made of harmful material. For our project the number one safety is always about the child that is wearing the device. To keep them safe we must make sure that the wearable material is flexible but tight enough not to fall off and that it is enclosed properly so that if the device gets wet by either washing their hands or rain gets on it, then the child is safe from being electrocuted. Keeping this product safe goes back to being ethical, political, and environmentally safe for all parties involved.

4.2.4 Manufacturability and Sustainability Constraints

When talking about the manufacturability constraints on a project it is known that sometimes parts don't always work like you had hoped they would or getting the parts in time does not pan out. As for our project we knew that ordering the parts from a variety of vendors was one of the ways to keep up with the deadlines that a semester has. We were told to order a minimum of three of everything so that if a part breaks we have backups and that this way we would have to wait for the time it takes from ordering the part to having it shipped from its location. After the parts have been ordered the process is to make sure each part works like it should individually then combine them to make sure they work coherently together. After making sure these items work on a breadboard we then need to make the PCB design of the board and make sure we get it out in time because of the turn-around-time can be up to one month so it is smart to have different vendors and multiple PCB's made. The manufacturing process can be lengthy even when precautions are taken into account therefore for our project needs to be well thought out and the parts need to be ordered promptly to avoid such constraints. Also we need to keep the cost down by making sure there are as few parts as possible so we minimize the manufacturability constraints.

When considering the sustainability constraints of any project one needs to consider that the product needs to last in harsh environments and that the parts last for an extended time prompting more people to have faith in your product. For our project we need to have faith in our work and know who we are catering to and what their needs and wants are. Our product needs to last a day's use which means the battery life needs to last which means the parts we choose must be efficient and have low power consumption. Also we need to do temperature testing making sure that our product works in many different places around the world ranging from cold to hot temperature climates even humid and dry environments need to be stress tested to make sure that no matter when the customer lives they have a product that they trust no matter where they take it. To help ensure that this product is sustainable it will be enclosed, waterproof, use low power, and have the proper battery to meet all the demands that are required.

5.0 Hardware and Software Design Details

5.1 Initial Design Architecture and Related Diagrams

The figures below give an idea of design of our project. Figure 5.1 represents the wearable sensor device with visual timer attached. Figure 5.2 represents both the interactive touchscreen for the child to use to calm down as well as the method for the caregiver to receive alerts and program the timer to fit the schedule.

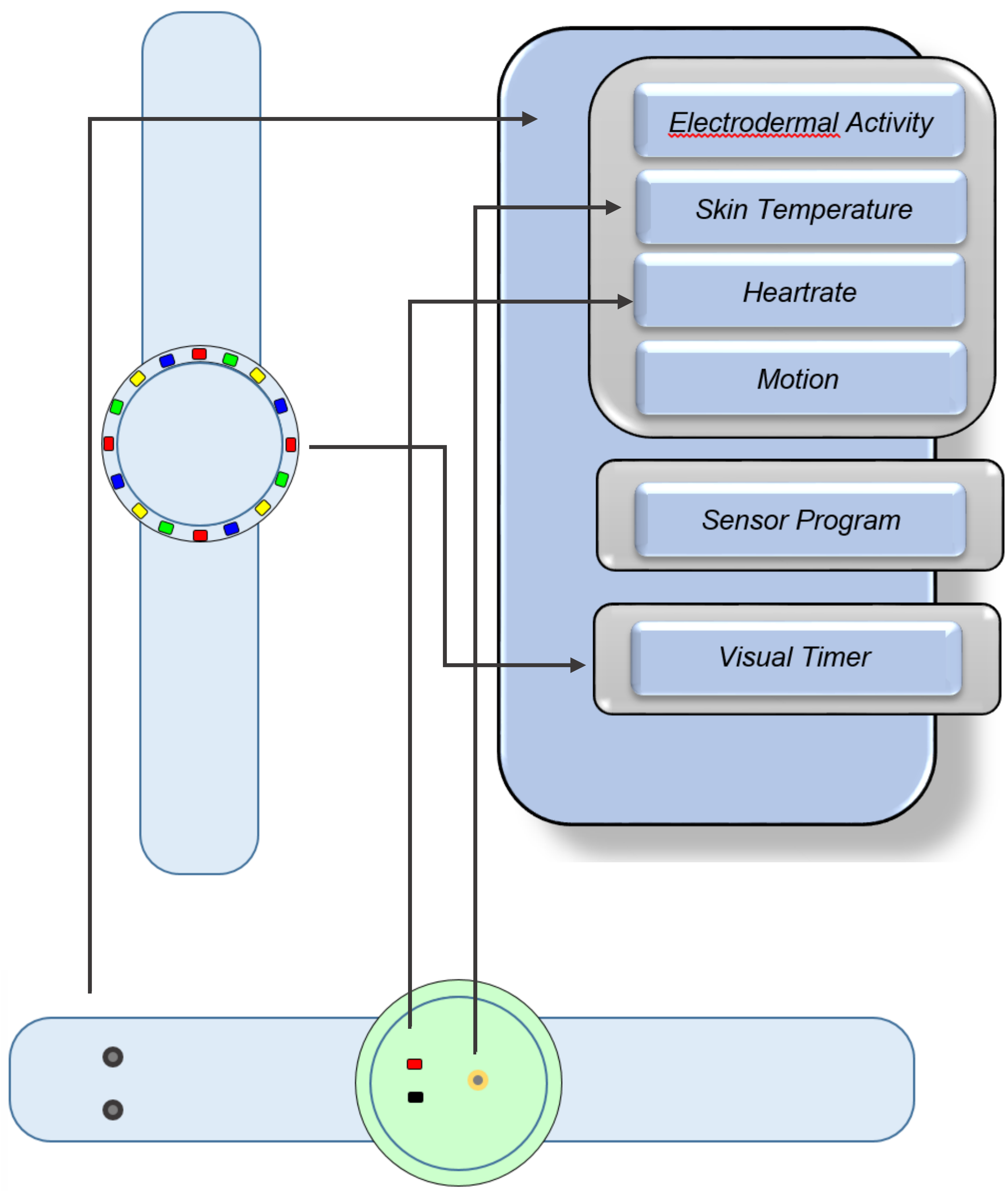


Figure 5.1: Wearable Sensor with Timer

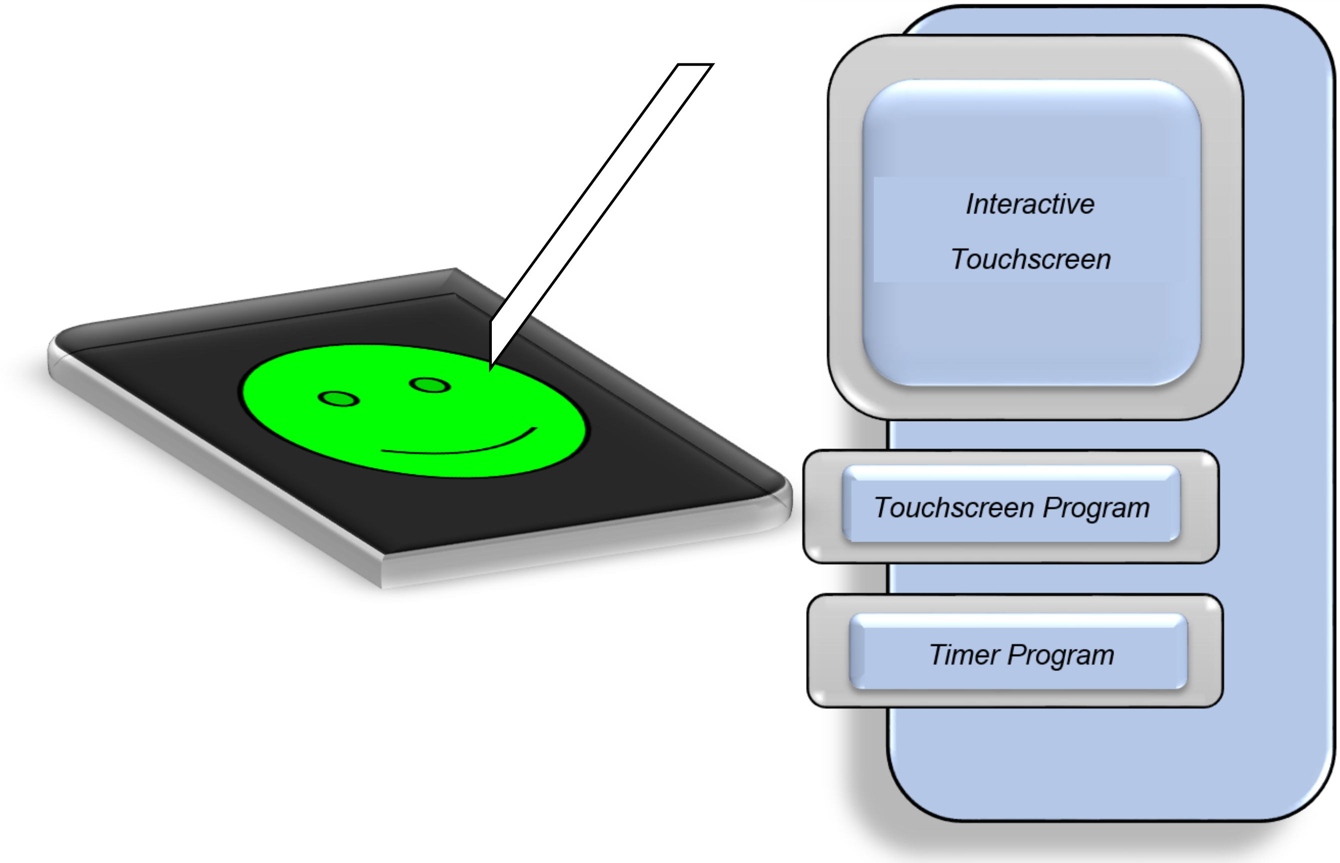


Figure 5.2: Interactive Touchscreen

5.2 Sensors, Breadboard Test, and Schematics

5.2.1 EDA Sensor

A basic circuit for measuring electrodermal activity is shown in Figure 5.3. In the circuit R_S represent skin resistance. This is realized through two electrodes located near each other on the wearable device's wristband. One electrode is connected to the inverting input of the op-amp, and the other connects to the circuit's ground. Also, R_G represents the gain resistance that provides amplification.

The idea is to use a non-inverting op-amp such that the output voltage is proportional to skin resistance (the inverse of conductance). The output of the circuit will go to an analog input of the microcontroller. An amplifier is necessary because the voltage applied is small compared to the required voltage for the microcontroller analog input. The input of the amplifier goes through a voltage divider. Our supply voltage will be the same as for the microcontroller and op-amps, 5V. The voltage divider drops the input voltage to 0.5V. This is necessary because skin conductance responds linearly at applied voltages of 0.5V.

The output for the circuit in Figure 5.3 is given by the following expression:

$$V_o = 0.5\left(1 + \frac{R_G}{R_S}\right)$$

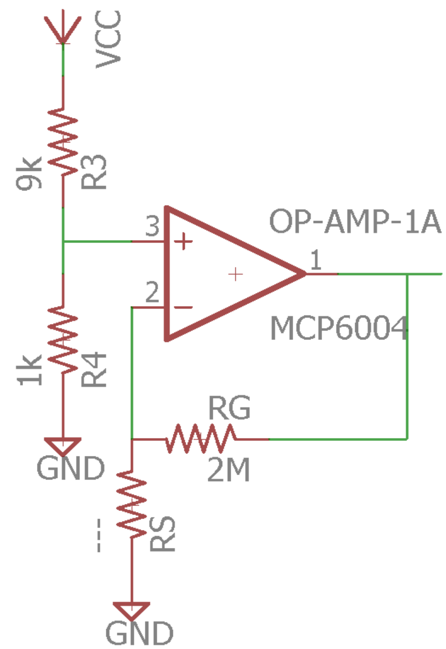


Figure 5.3: Basic EDA sensor

At a gain resistance, R_G, comparable to an average skin resistance of 2 MΩ this will result in approximately 1V output voltage. As we increase the gain resistance, the output voltage will increase correspondingly. We must be careful for several reasons. If the gain voltage is too low, then the microcontroller may not register it. However, if the gain is too high, then the output may exceed the maximum analog input pin voltage. In order for the sensor to provide a usable output during both instances of normal skin resistance and lowered resistance, it was determined to limit the gain resistances to between 2 MΩ and 5.6 MΩ.

Another concept to consider in the EDA sensor is the removal of the slower skin conductance level (SCL) and possible noise. As discussed earlier, this can be accomplished through the use of a high pass and a low pass filter, respectively. The high pass filter can remove the response due to the slower acting SCL that acts as a base line. The low pass filter will remove noise from nearby AC sources. This circuit is represented in Figure 5.4.

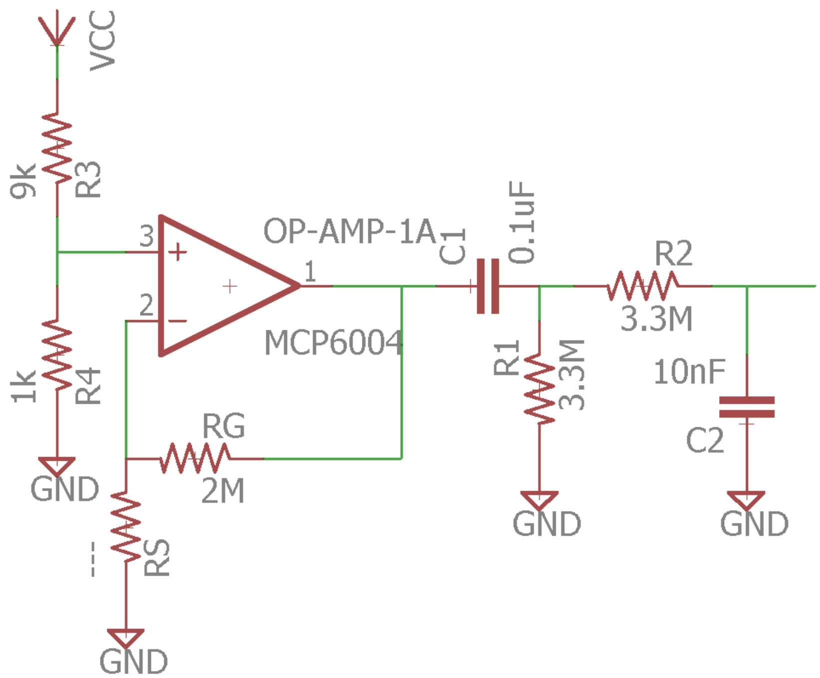


Figure 5.4: EDA sensor with filters

Both filters are after amplification to avoid affecting the input voltage to both the amplifier and the electrodes. The high pass filter is first with a cutoff frequency of 0.48 Hz followed by a low pass filter with a cutoff frequency of 4.8 Hz. These values were chosen to filter SCL and noise while permitting the response discussed in Section 3.2.1.1 as illustrated in Figure 3.4. The galvanic skin response is approximately 1 – 2 Hz.

The circuit was tested using the electrodes attached to the wrist. The output of the circuit was sent to the microcontroller. An algorithm converted the signal voltage to conductance is µS. Figure 5.5 shows the output. Several peaks are seen which corresponded to stimulus directed to the wearer. In addition, several resistors were placed between the electrodes and the measured values were with-in less than 5% of the resistors' values.

5.2.2 Skin Temperature

The ZPT-101T thermopile that was chosen is very simple. The circuit is shown in Figure 5.5. Most notable is that the thermopile does not require an external power source. The thermopile itself is made up of only four pins: thermopile, thermopile ground, thermistor and thermistor ground. The thermistor would be used to determine the temperature of an object using non-contact means via infrared radiation. This is because ambient temperature is required to determine object temperature. In our project, however, we do not want to know what the skin temperature is. We are only interested in knowing if it changes rapidly in a manner consistent with stressful stimuli. As such, we do not need the thermistor.

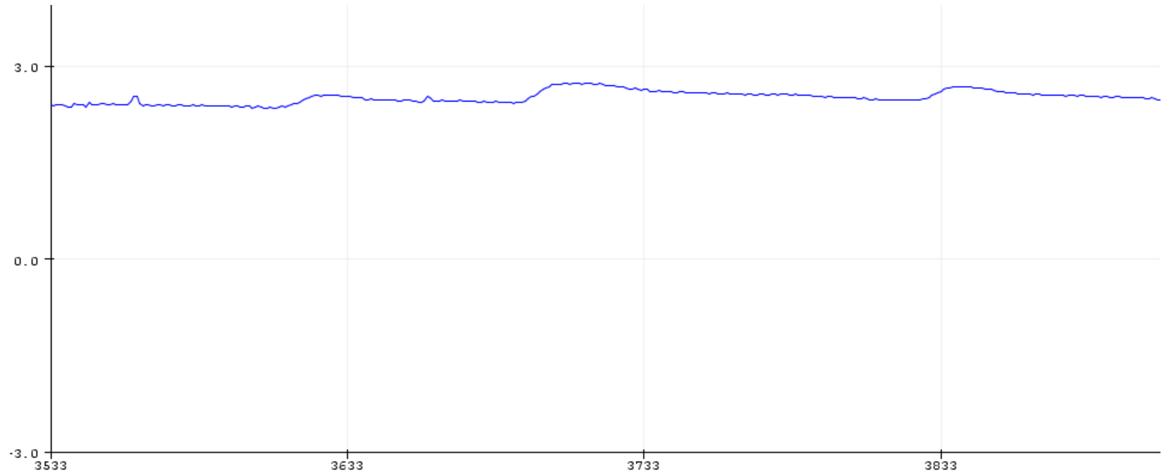


Figure 5.5: Skin conductance response

The output of the thermopile for normal skin temperature will only be about 0.3 mV. This is clearly not enough for the analog input pins of the microcontroller. An amplifier is again needed. Its gain must be of a magnitude of 10^4 to achieve a usable output voltage. The gain of the amplifier in Figure 5.6 is $1 + 10^4 \approx 10^4$.

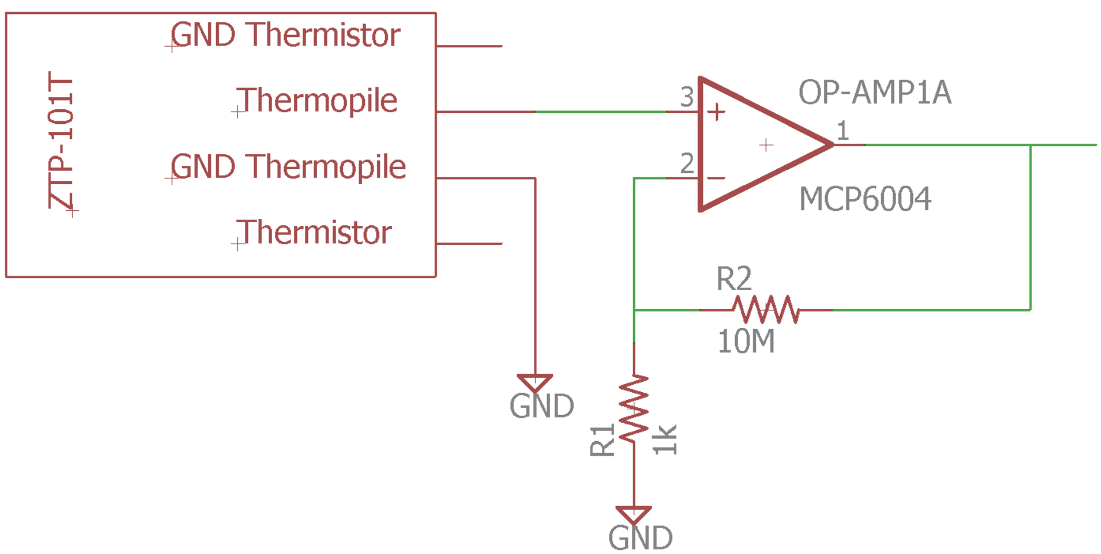


Figure 5.6: Skin temperature circuit

The circuit was created on the breadboard. The thermopile remained on the breadboard, as well. Its output was sent to the microcontroller along with an algorithm to see the output voltage. While recording the data, different objects were placed above the thermopile. These were a piece of ice, a finger, and the tip of a soldering iron. The sensor responded quickly to the addition or removal of an object whose temperature differed from ambient. This is shown in Figure 5.7 below.

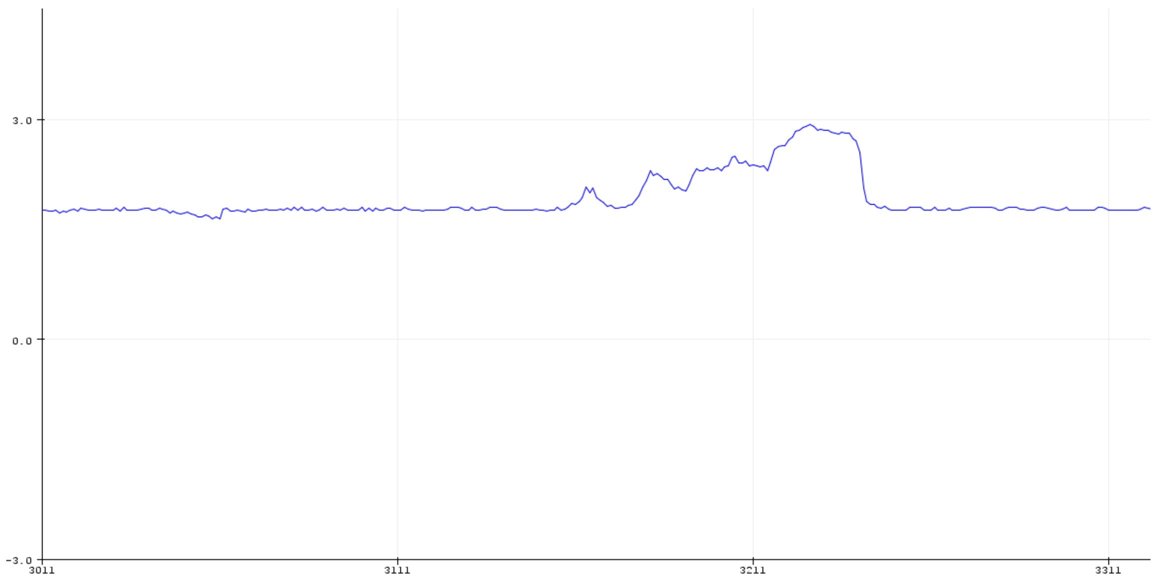


Figure 5.7: Thermopile response

5.2.3 Heartrate

The heartrate is determined through photoplethysmography (PPG) as discussed in section 3.2.1.3. This method is actually for determining blood volume. We are using it to indirectly determine heartrate because with each beat of the heart there is more blood volume in any part of the body. The idea is to expose the skin to infrared light and see how much of that light is absorbed/reflected. The light is absorbed by skin, bone and blood. The reflected light is exposed to a photodiode which converts it to current. By determining how this current changes we can derive heartrate.

The current from the photodiode is not useful with regards to the microcontroller input pins. The circuit uses a transimpedance amplifier to convert the photodiode current to a voltage. The high resistance of the feedback resistor acts as a gain and amplifies the current to make the output voltage high enough to be useful. The capacitor in parallel with the gain resistor acts as a low pass filter to reduce high-frequency noise. The average heartbeat of school age children can be anywhere between 60 – 120 beats. This equates to a frequency of 1 – 2 Hz. The low pass filter cutoff frequency is set to approximately 5 Hz.

The only problem with using the transimpedance amplifier is that its output is inverted with respect to its input. A reference voltage is applied at a high pass filter. The reference voltage is needed as a bias to make sure that the output of the circuit is positive so as to be useful for the analog pin of the microcontroller. The high pass filter is then needed to remove any low frequency affects from the DC bias on the signal. Its cutoff frequency is set to 0.56 Hz. This is followed by another amplifier to boost the signal.

The circuit is realized in Figure 5.8. This was tested on the breadboard with the LED and photodiode adjacent on another smaller breadboard. This allowed the user to place their finger over the two without disturbing the entire circuit. The output was jumped to one of the analog inputs of the microcontroller. The output (in volts) is shown in Figure 5.9. There is an observable pattern consistent with heartbeat. The interruptions can be attributed to light that was able to leak in during use.

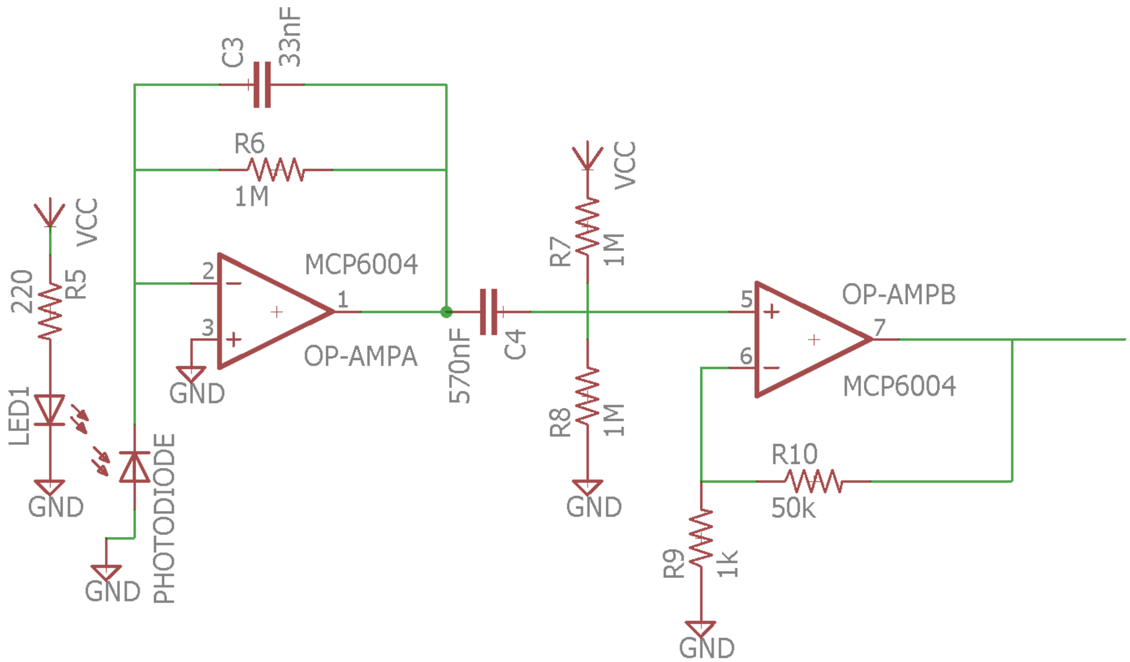
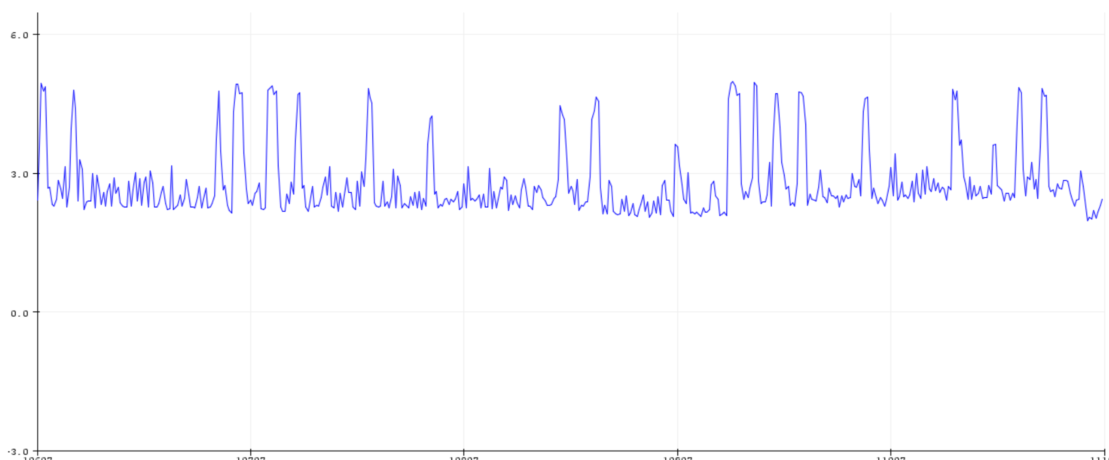


Figure 5.8: Heartrate sensor with biasing and amplification



Figre 5.9: Signal output from heartrate circuit

5.3 Power Supply

In our project there will be at least eight main components that are connected which will help to form our Detection and Prevention device. With all of these components we will power them with a single battery. It is now time to calculate how much power all of these components use and that will help us in choosing the right battery for the job. We will look at the datasheets for all seven components to give us the exact power measurements. After all the power has been calculated perfectly it is always a good idea to leave more head room in case there is energy loss that may have been overseen from the small components used.

5.3.1 Specifications for Powering the System

In the Table 5.1 below we calculated the total power that was required for our Detection and Prevention project. From the datasheets we were able to get all of the necessary voltages, currents, and power for each of the eight components that make up our project. After getting all this data we then calculated the power using the power equation.

Component	Voltage Range	Current Consumption	Power
Microcontroller	5V	200mA	1W
2.8" TFT	3.3V to 5V	200mA	1W
Timer	5V	20mA	100mW
Bluetooth (HC-06)	3.1V to 4.2V	30mA to 40mA	168mW
Motion Sensor	1.95V to 3.6V	6 µA to 165 µA	0.594mW
Heart Rate Sensor	5V	20mA	100mW
Temperature Sensor	5V	20mA	100mW
0.59EDA Sensor	5V	0.5mA	2.5mW
Total	N/A	501mA	2.472W

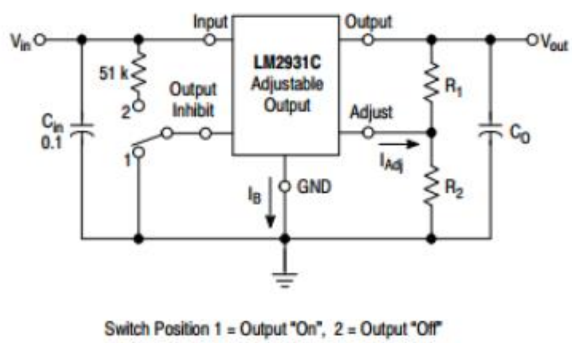
Table 5.1: Voltage, Current, and Power of All Major Components

5.3.2 Power Source

Now that we have talked about what it would take to power our project, it is time to talk about the specific battery that we feel would get the job done. In the research section we knew we wanted to use a Li-Po battery and we thought we could use a small battery such a 3.3V, but now we see that we need at least a 5V battery. After choosing the battery, we need it to last a day at school, therefore finding the right charger is crucial. If we know how long it takes for the battery to discharge under heavy and light use then this will aide us in picking the right battery. As we can see from the table above our max voltage that we need for our project is 5 volts. We can use one battery but it may need to be charged multiple times if used frequently. Size is also of concern. The 3.7 volt Li-Po batteries discussed in 3.3.2 do not have the required voltage, but the common 9 volt batteries are too large. For this reason, the 3.7 volt batteries were chosen with power boost modules to raise the voltage to 5 volts. The portable device uses a 3.7 volt, 2000mAh with a power boost shield that can be stacked with the touchscreen and PCB. The wearable device uses a 3.7 volt, 150mAh Li-Po battery with a power boost to raise voltage to the required 5 volts.

5.3.3 Voltage Regulator

Now that we have talked about powering our system it is time to figure out what voltage regulator should be used to divide the voltages for all of our components in our project. Looking back at Table 5.1 above we can see from the data gathered that we will need a voltage regulator with an output greater than or equal to 5 volts which seems to be the highest voltage for most of our components. The most popular regulators we are looking at are linear regulators. The regulator we are going with for now is the LM2931-5.0 which has a voltage output that ranges from 3V to 24V and it has an adjustable output voltage. Another advantage to this regulator is that it can act like a switching regulator being able to switch back and forth. This regulator is commonly used in consumer products that rely heavily on being battery powered. In the Figure 5.10 below is the voltage regulator showing how to calculate the output voltage and how it is similar to a switching regulator.



$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right) + I_{Adj} R_2 \qquad 22.5\,k \geq \frac{R_1 R_2}{R_1 + R_2}$$

Figure 5.10: The LM2931-5 Linear Voltage Regulator

5.4 Wireless Communication

After reviewing all of the types of wireless communication modules we could have chosen for our project, we went with a Bluetooth module. The specific Bluetooth module we chose for our project was the HC-05/-06, hereafter referred to as the HC-05. This module is great for Arduino projects and we can download an app to connect to the module which will be used to communicate with all of the devices in our project. We will use jumper wire to connect the Bluetooth module to the microcontroller on the breadboard which will then be able to communicate with all of our sensors and the timer.

Our decision to choose this specific Bluetooth module was based on the components we chose and what type of communication system would be best suited and easy to implement. For our project we do not require the device to be used over long distances because we are in a classroom setting where the teacher is normally within thirty feet of the student. By knowing the range we looked then at power consumption and Bluetooth was much less power hungry than the other wireless communication devices and is much simpler to implement. In the Table 5.2 listed below we have listed the specification for the HC-05 and how it will relate specifically to out project.

Parameter	Rating	How it Relates to Our Project
Range	10 meters	The range on this module is plenty because we are using this device in a classroom setting.
Rate of Data	2 Mbps	We are only transmitting warnings to from the teacher so this data rate is sufficient.
Frequency	2.4Ghz	This frequency is common for Bluetooth and will not interfere with other devices.
Operating Voltage	3.3V	Having low voltage means less power and we are promoting low power.
Communication	SPI	Our Microcontroller supports this type of communication as well as the other devices used.
Size	27mm X 13mm X 2mm	Small size means it will be easy to fit into a device that is wearable.
Cost	$5	The low cost helps ensure the project will stay competitive with other products.
Weight	3 grams	Light weight means the user will not be loaded down on their wrist.

Table 5.2: Bluetooth HC-05 Specifications and Relatability

5.4.1 Pinout of the HC-05

To connect our Bluetooth module to the breadboard we must first identify all of the pins on the module and where they connect to our microprocessor, which is the Atmega328p. In the Table 5.3 below we talk about the pins that are on the device, the names of each pin, and how a brief description of each pin. This information has been provided by from the datasheet and the user manual of the HC-05.

Pin Name	Pin Type	Pin Number	Description
TX	Transmit Data	1	This is used to send data to and from the device.
RX	Receive Data	2	This is used to receive data from the other devices.
Reset	Clear	11	This is used for resetting the device to clear out the pairing.
VCC	Power Supply	12	This is the voltage supply for the logic. The standard voltage is 3.3V, but can work at 3.0 to 6.0V.
GND	Ground	13	This is to ground the unit.
GND	Ground	22	This is to ground the device.
PI01	LED Indicator	24	This lets us know when the device is on, working, or needs to be pair.
PI03	Pairing	26	This is used for emptying information about pairing and look for new pairing.

Table 5.3: Pinout of the Bluetooth Module.

5.4.2 Connecting the HC-05 to the Atmega328p

To be able to connect the Bluetooth module to the Arduino we built on the breadboard we need to connect the four SPI to each other. In the Table 5.4 below we will give the pins for both the HC-05 and the MCU and the description on each.

Pin of HC-05	Description of HC-05	Pin of Atmega328p	Description of Atmega328p
13	Ground	22	Ground
1	TX	2	RX
2	RX	3	TX
12	VCC	20	VCC

Table 5.4**:** Connecting the Pins of the HC-05 to the MCU

Now that the mapping of the pins between our HC-05 and MCU have been figured out, it is time to visually show the schematic to see how they connect. To show this connection we chose to use Eagle, which is a CAD software to help implement a design. In Figure 5.11 below we have connected the two parts together.

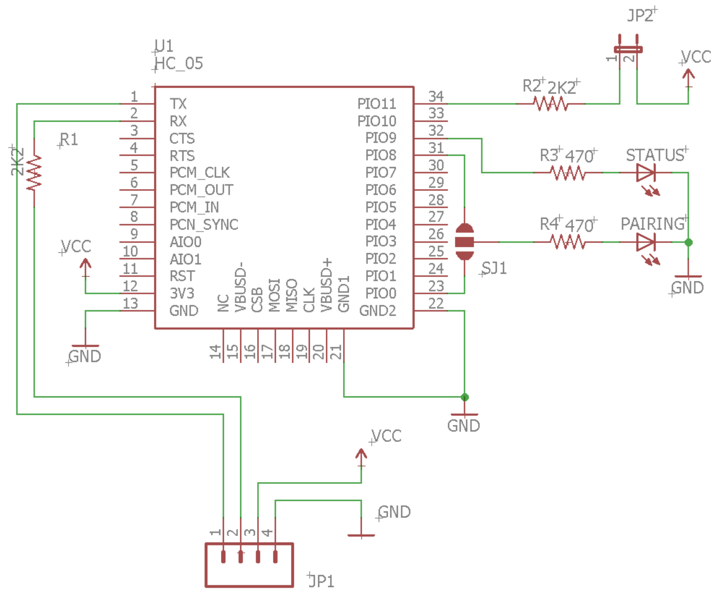


Figure 5.11: HC-05 Bluetooth Module Schematic

5.4.3 Breadboard Test For Bluetooth

As for the breadboard test we hooked up the Bluetooth module to the Atmega328p and connected three LED's and wrote a program using Arduino IDE. After getting the program to work we downloaded an app on our phones to connect to the Bluetooth module and cycled through the LED's to make sure it communicated properly. In Figure 5.12 below is the breadboard test to confirm we could cycle through the LED's.

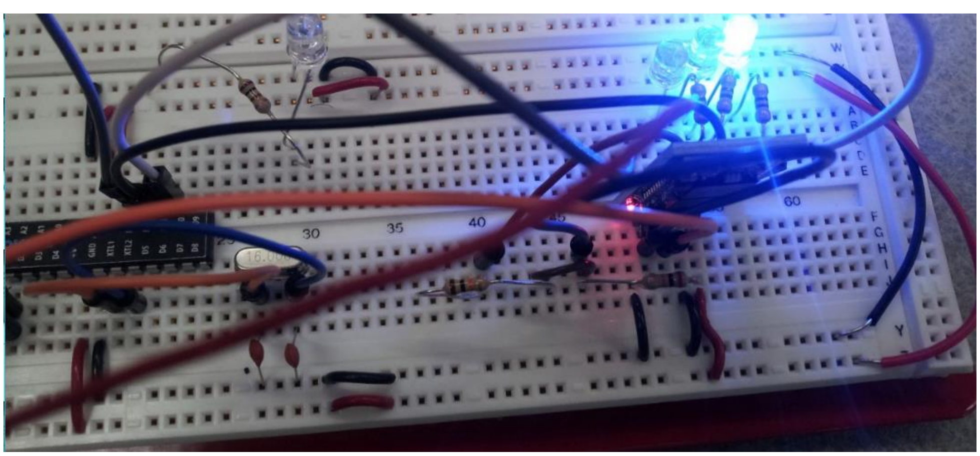


Figure 5.12: Bluetooth Connected to Atmega328p Using Arduino Software

5.5 User Interface

For our display we want the design to be simple to allow the student who is using it to be comfortable and find it easy and not difficult or frustrating. In this section we will talk about both the software and hardware and how and why we are choosing them for our project. In the Figure 5.13 below is the touchscreen display we chose to use for our project.

Figure 5.13: Elegoo Uno R3 2.8” TFT Touchscreen

5.5.1 Software

The software needs to be easy and friendly to use for the student, therefore we are going to make fun quick little games that won’t frustrate the user. The games will be simple such as tracing or simple scribbling. We know that an autistic student can get frustrated easy and will not care for math much so it is important to keep it simple and fun.

5.5.2 Graphical User Interface (GUI)

As for the GUI it needs to be very simple because the students who are using it are autistic and they can become frustrated very easy. If we have too many options on the main screen then they may not find it easy to use and become more frustrated and it will make it harder for them and the teacher. In the Figure 5.14 below we can see a simple game show up for the student to play which is simple with the name of the game they are playing. They can use a stylus or their finger, which ever they find easier. This is just one example of a simple game with a simple layout.

Figure 5.14: View of Simple Layout of GUI

5.5.3 Hardware

As for the hardware part of our system it will consist of two devices, one that is worn on the wrist to detect when a student becomes frustrated and will need to calm down and the other is the touchscreen, which is used to help them calm down. On the wrist there will be a few monitoring devices such as a temperature sensor, heart rate, motion sensor, and an EDA sensor, when those levels elevate past a certain range then the teacher will get a notification via Bluetooth to their phone and then the student is able to use the touchscreen to calm down if needed. As for the screen we are using it is a 2.8” TFT touchscreen with a stylus to the student can choose to use their hands or the provided stylus. We bought this touchscreen from Amazon and Elegoo is the ones who manufacture the touchscreen. In the Table 5.5 below are the description and type for the display used.

Description	Type
SKU	60280361205
Screen Type	Resistive
Connection Type	Pin Header
Interface Type	4 Wire
Power Supply	3.3V or 5V
Operating Temperature	-40℃ to + 85℃

Table 5.5: Display Description and Type

5.5.4 Dimensions of touchscreen

In the Table 5.6 below are the exact dimensions for this display which was provided by the distributor in the specifications page.

Description	Size
Weight	0.3 Ounces
Dimensions	78.22mm by 52.7mm
Viewing Area	57.6mm by 43.3mm
Screen Size	2.8”

Table 5.6: Display Dimensions

5.5.5 Resolution of the Display

In the Table 5.7 below are the specifications for the displays resolution which was provided by the distributor in the specifications page.

Description	Size
Type of Display	TFT LCD Color
Response Time (typical)	25 ms
Pixels	320 x 240
Colors	16-bit
Backlight Type	4 LED
Contrast Ratio	500:1

Table 5.7: Display Resolution

5.5.6 Hardware Interfacing With Module

Since the touchscreen will be the way to calm a student down, it is a vital communication link between the device on the students wrist, which is monitoring their vitals. Therefore, we took careful consideration in choosing this module. The touchscreen will be connected to our microcontroller using nearly every pin. As seen in Figure 5.15 below are the pins connecting the microcontroller to the touchscreen.

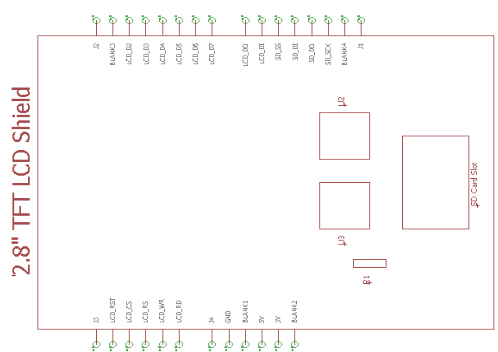


Figure 5.15: 2.8” Touchscreen Schematic

5.5.7 Breadboard Test for Touchscreen

As for the breadboard testing we hooked up the touchscreen module to the Atmega328p and connected and wrote a program using Arduino IDE. After getting the program to work we turned on the screen and checked to see if the touchscreen worked with the stylus and with our fingers. In Figure 5.16 below is the breadboard test to confirm that the screen powered on and worked properly.

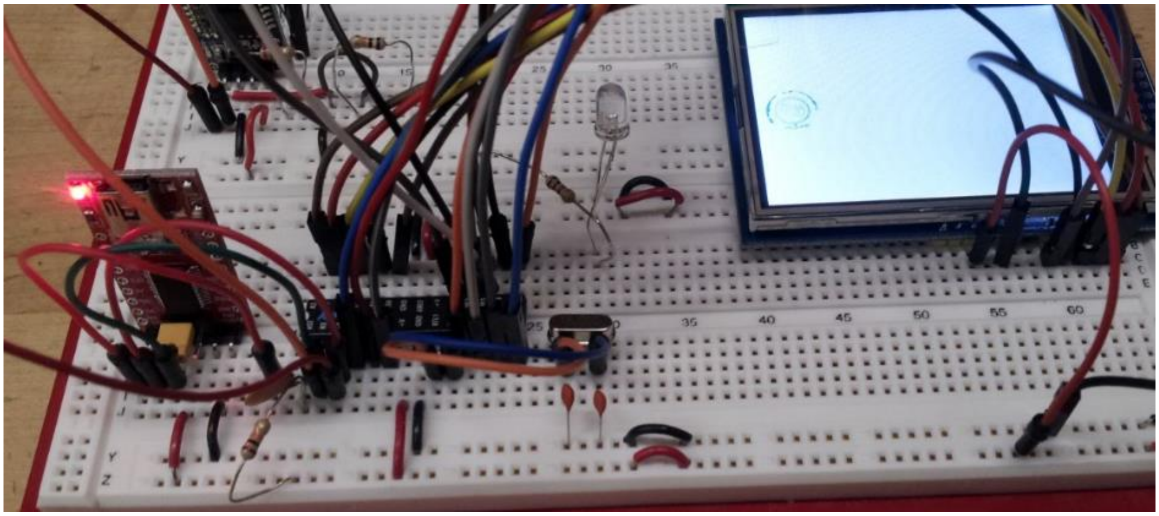


Figure 5.16: Breadboard Test for Touchscreen

5.6 Timer

Since our project is about helping autistic students transition from one subject to another subject while in class we want to implement a timer to help let them know when that transition period is coming up. There were many timers to choose from but we thought a visual representation of extinguishing LED's were a good compromise. This timer will be on their wrist like a watch and for each subject we want there to be a different color to help them get familiar with a schedule and what color means what subject they are on at the time. When the LED becomes fully extinguished that means the next subject is approaching and they will need to transition soon. To make this timer possible we are considering just using the timer that is built into the microcontroller. The timer will be controlled via Bluetooth from the teacher's phone and the teacher will reset the timer for each new subject throughout the day. In the Figure 5.17 below is an example of the timer on the student's wrist which shows the extinguishing LED's. The next figure which is Figure 5.18 beneath Figure 5.17 is the schematic from for the LED timer, notice there are two strips connected together in series, these strips make up the ring.

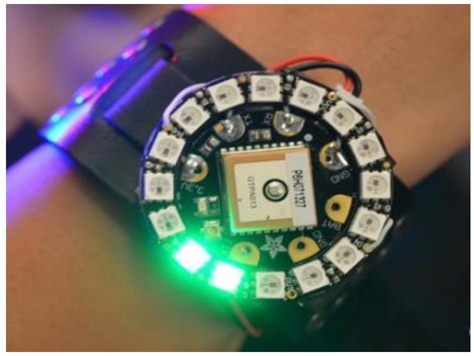


Figure 5.17: Extinguishing LED Timer

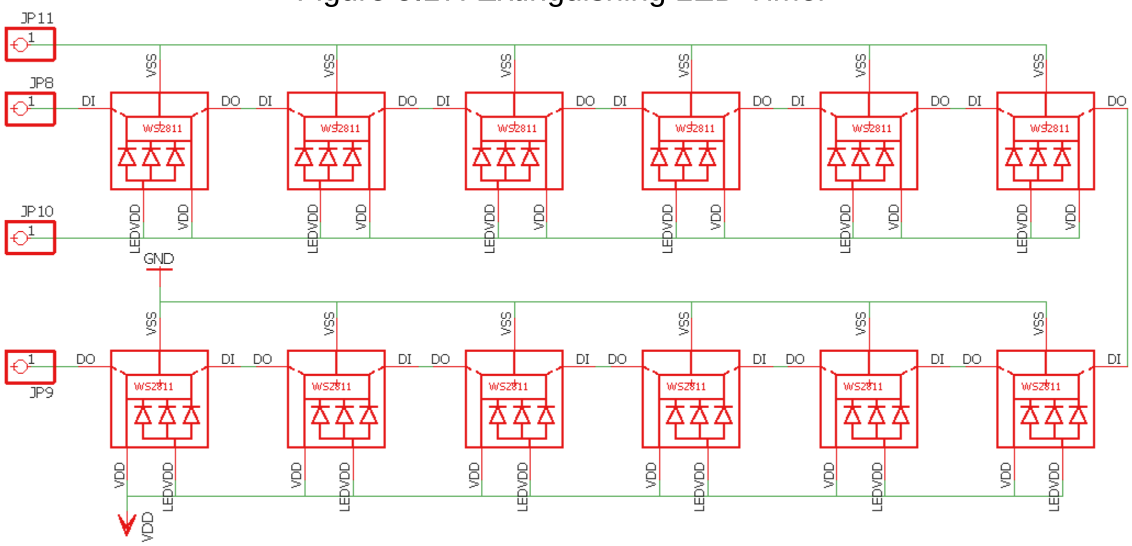


Figure 5.18**: Neopixel Ring Schematic Separated into 2 parallel strips**

5.7 Software Design

One of the requirements specification of this project is its ease of use. This puts an emphasis on the software. Minimal interaction with the caregiver and the student is an important concept for the project to meet its purpose. This means that the coding design has to accommodate three subsystems: (1) the sensors, (2) the timer (3) the touchscreen.

5.7.1 Sensors

The purpose of the sensor software design is to notify the caregiver when any sensor is triggered by the child's autonomic response. We repeat here that qualitative values are not desired because a teacher is not a health care professional and has no need to see any physiological data, and because no two children are the same; any quantitative values are subjective. For these reasons, the software will focus on qualitative changes is those physiological markers. Whenever a deviation from the steady-state value occurs, the microcontroller shall alert the caregiver through wireless notification, or signal the start of the touchscreen program, again, wirelessly.

The outputs of each sensor is a voltage sent serially to separate analog input pins of the microcontroller. These serial signal are all proportional to the monitored parameter (skin conductance, pulse, skin temperature and motion). This proportionality will be sufficient to identify an abrupt change resulting from activation of the autonomic response. There is one exception. The magnitude of the pulse is not useful to determine the heartrate. The frequency of the pulse indicates heartrate. The signal of each pulse must then be converted to a rate. This can be done by establishing a threshold voltage that any pulse signal (regardless of magnitude) will go above and then below. Basically, the program will determine the period between which the signal goes above this threshold and convert it to heartrate. Note that it does not determine the time difference between when the signal crosses the threshold. Only an entire period will indicate heartrate. So it must determine the time difference between when the signal goes from below to above the threshold twice, or when the signal goes from above or below the threshold twice. This will equate to heartrate.

5.7.2 Timer

This will be the mostly interactive portion of the project. In order for the visual timer to warn of an upcoming transition change it must be programmed for that day. No two class schedules are the same, so the start and duration of each timer must be programmed by the teacher. It is possible that the day-to-day schedule is constant. In this case, the timer need only be programmed once. This will also allow reprogramming the timer should a day's events change in the middle.

Programming the timer by the teacher will be accomplished through preset prompts. The teacher will only have to select digits that correspond to the number of subject periods in the day, and how long each is. Completion of these prompts will start a program that will send serial data wirelessly to the visual timer. This will use the clock signal and programmed presets to first illuminate all LEDs, and then extinguish each at a rate corresponding to the clock (time based), at a rate corresponding to the length of the current subject (period based). After the day's schedule is completed, the program will remain dormant until the start of the next school day, where the same program will repeat. If there is a change to the schedule, then the program will stay dormant until activated by the teacher.

5.7.3 Touchscreen

The main purpose of the touchscreen is to provide a simple activity to allow the student to wind down. Its activation is through the wireless signal from the microcontroller that receives signals from the sensors. A simple paint program will be used initially for this purpose. It does not require any analytical demands that may exacerbate the anxiety of the child. Rather, the student can draw until calm.

After the paint program has been unused for a reasonable time (indicating the student has resumed school activities), then the paint program and touch screen go dormant.

5.8 Summary of Design

The breadboard design used to test the components and act as a template for the overall schematic is shown in Figure 5.19. The overall schematic of the project is shown in Figure 5.20. It is composed of two major sections. One contains the wearable device. This will include the sensors, the visual timer, the microcontroller, and the Bluetooth slave. The second section contains the touchscreen, another microcontroller, and the Bluetooth master. Other discrete components are included to meets the systems' function as described previously in this section. The Bill of Materials in shown in Figure 5.20.

The software design marries the hardware design to the ultimate goals of the design. The alert/touchscreen is wirelessly activated by changes in the signals from the sensors via the Bluetooth slave. The timer is controlled wirelessly by the Bluetooth master after being programmed by the teacher.

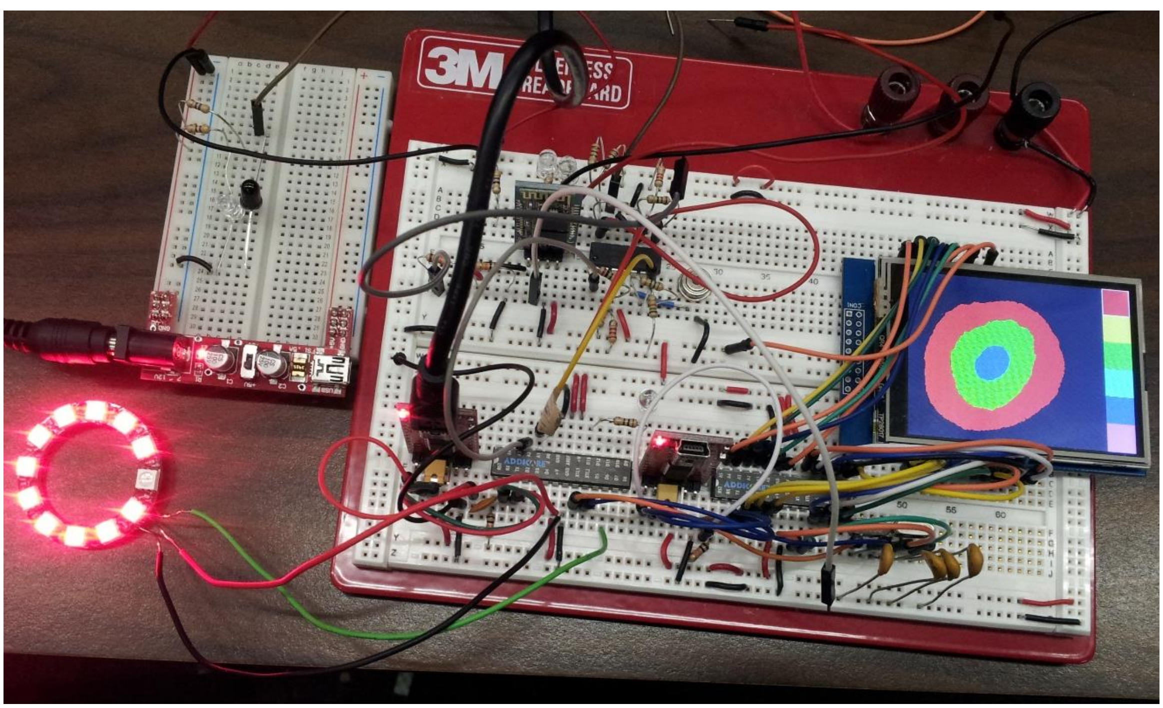


Figure 5.19: Breadboard test assembly

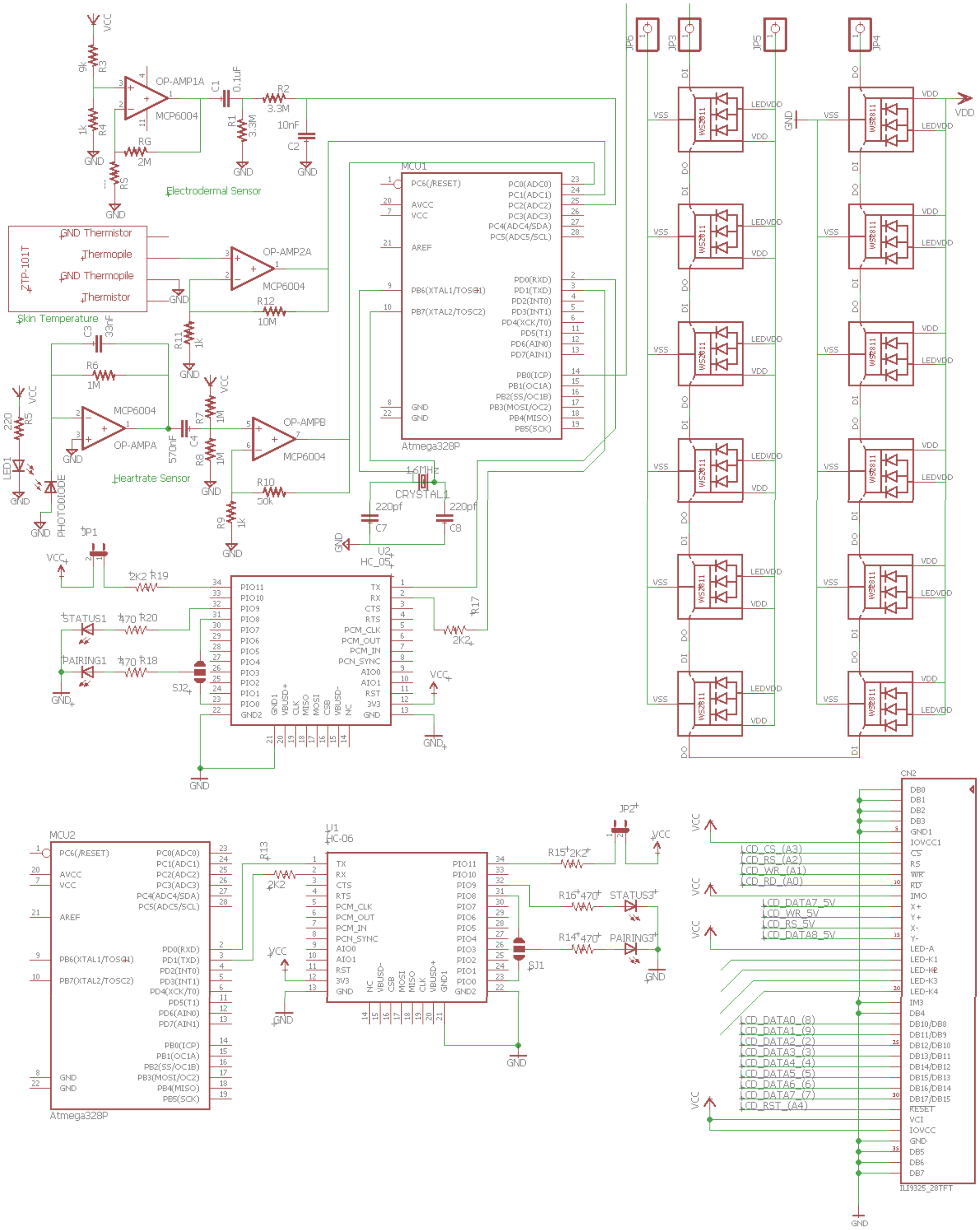


Figure 5.20: Overall schematic

	Part Name	Part Number	Cost Per Part	Number Used	Total Cost
1	Electrodes	EL-DRY-REUSABLE-5-10	$1.40	2	$2.80
2	MCP6004 Op-Amp	MCP6004-E/P	$0.67	1	$0.67
3	Thermopile (5 pk)	ZTP-101T	$4.40	1	$4.40
4	IR LED	B01MFCFLA7	$0.12	1	$0.12
5	Photodiode	B01MFCFLA7	$0.12	1	$0.12
6	Microcontroller	ATmega328P	$4.49	2	$8.98
7	Touchscreen	LYSB00UAA2XIC	$15.99	1	$15.99
8	Bluetooth Master	B01G9KSAF6	$4.00	1	$4.00
9	Bluetooth Slave	B01FCQZ8VW	$4.00	1	$4.00
10	Timer	976036	$3.52	1	$3.52
	Resistors/Capacitors	Various	Various	<50	Low
				Total	$44.60

Figure 5.20: Bill of Materials

6.0 Prototype Construction and Coding

The prototype that was implemented in Senior Design II was based on the hardware design discussed in Section 5, Figure 5.20. It was altered to achieve the best possible working design, and implemented on a printed circuit board (PCB). As such, the software design was altered to coincide with the hardware changes. Figure 6.1 shows the overall design.

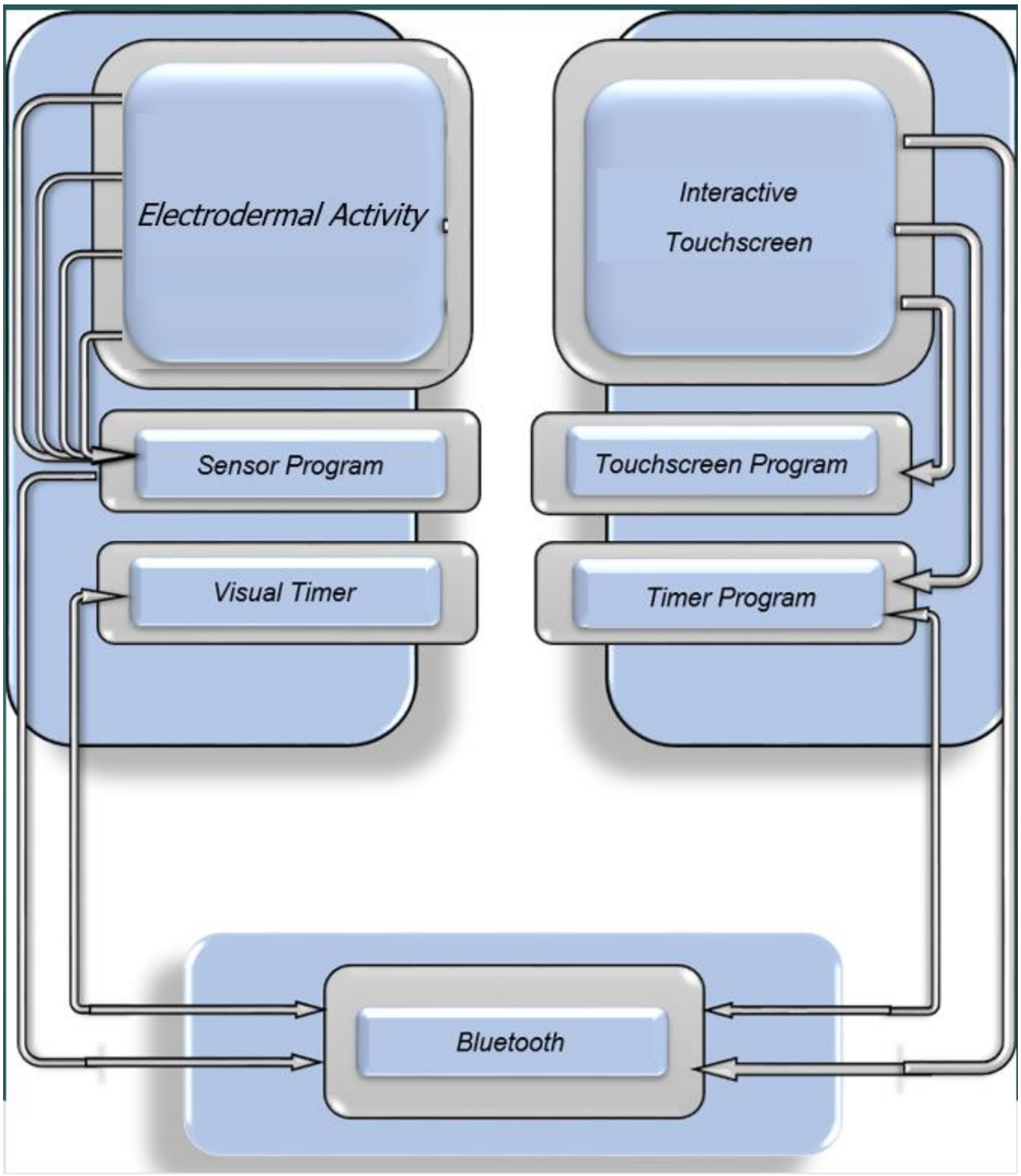


Figure 6.1: Final project architecture

6.1 Final Hardware Design

6.1.1 Wearable Design

Figure 6.2 shows the final design of the wearable device.

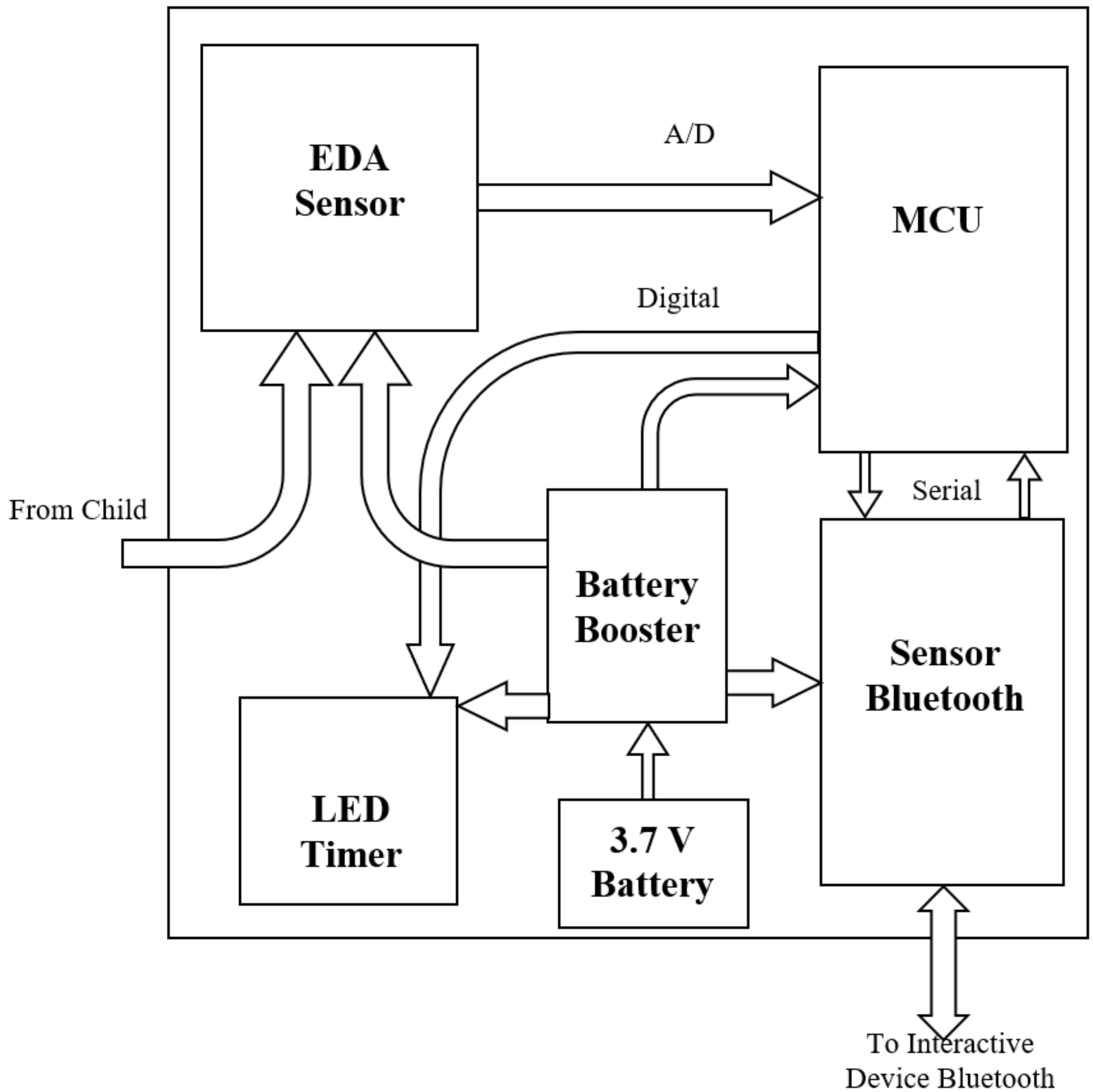


Figure 6.2: Sensor/Timer subsection

Our initial design incorporated four sensors on the wearable device. It became clear early on that the motion sensor (accelerometer) may not be a usable sensor for autistic children. This is because people (children and adults) with autism stim. The term “stimming” is short for self-stimulatory behavior [36]. It takes the form of rocking, flapping, pacing or flicking their fingers on a regular basis. It is almost always a symptom of autism.

The hardware filters for the EDA and skin temperature sensors were eliminated for space considerations. Software filters were implemented through a smoothing algorithm that averaged the inputs from these sensors. When it came to coding the sensors together, there was a concern with loss of precision regarding the heart rate monitor compared to the EDA and skin temperature sensors. The input of the heartrate sensor is a voltage signal comparable to the volume of blood in the part of the body on which the IR LED and photodiode rest. In order to glean a heartrate from this oscillating signal, the frequency at which the signal passes defined thresholds must be averaged, and these averaged values must be continuously compared to their previous ones to identify a change is heartrate. The concern is that with all these averages, there may be considerable loss of fidelity. For these reasons, the heartrate monitor was eliminated.

Further considerations for use by special needs students caused us to revisit the use of the timer. The original idea was to have the all possible timers programmed by the teacher at the beginning of the day, and then let run. Also, the different subjects may cause differing timers (Period-based vs. Time-based) as discussed in Section 2.2. The timer activation was changed to the teacher's discretion. When they decide, the timer will be activated by choosing such from the portable device. This will cause the timer to light all twelve LEDS red, and extinguish each at rate of one every 25 seconds so that all are extinguished after five minutes. This consistency is important for the psyche of special needs student.

6.1.2 Portable Device Design

Figure 6.3 shows the final design of the portable device. The portable device was designed to hold the touchscreen, batter boost shield, Bluetooth, and a LED visible to the teacher during normal class time. The touchscreen has two functions. The main function is to allow a student to calm down by playing a simple paint program in which they can choose different colors and doodle until they are calm. The other function is to display a prompt when it is touched (woken up). When it is touch from sleeping mode, then it shows two boxes, one labeled "Timer?" and the other labeled "Paint?". When the timer box is selected, the timer on the wearable device starts and the touchscreen goes back to sleep. The paint box is chosen to start the paint program whenever the teacher wants to give it to a student to calm them. In addition, there is a red LED on the PCB. When the wearable sensor indicates that there may be a problem, it will blink every second for up to 5 minutes, then go back to sleep. This can be interrupted by pressing the touchscreen which opens the prompt screen again.

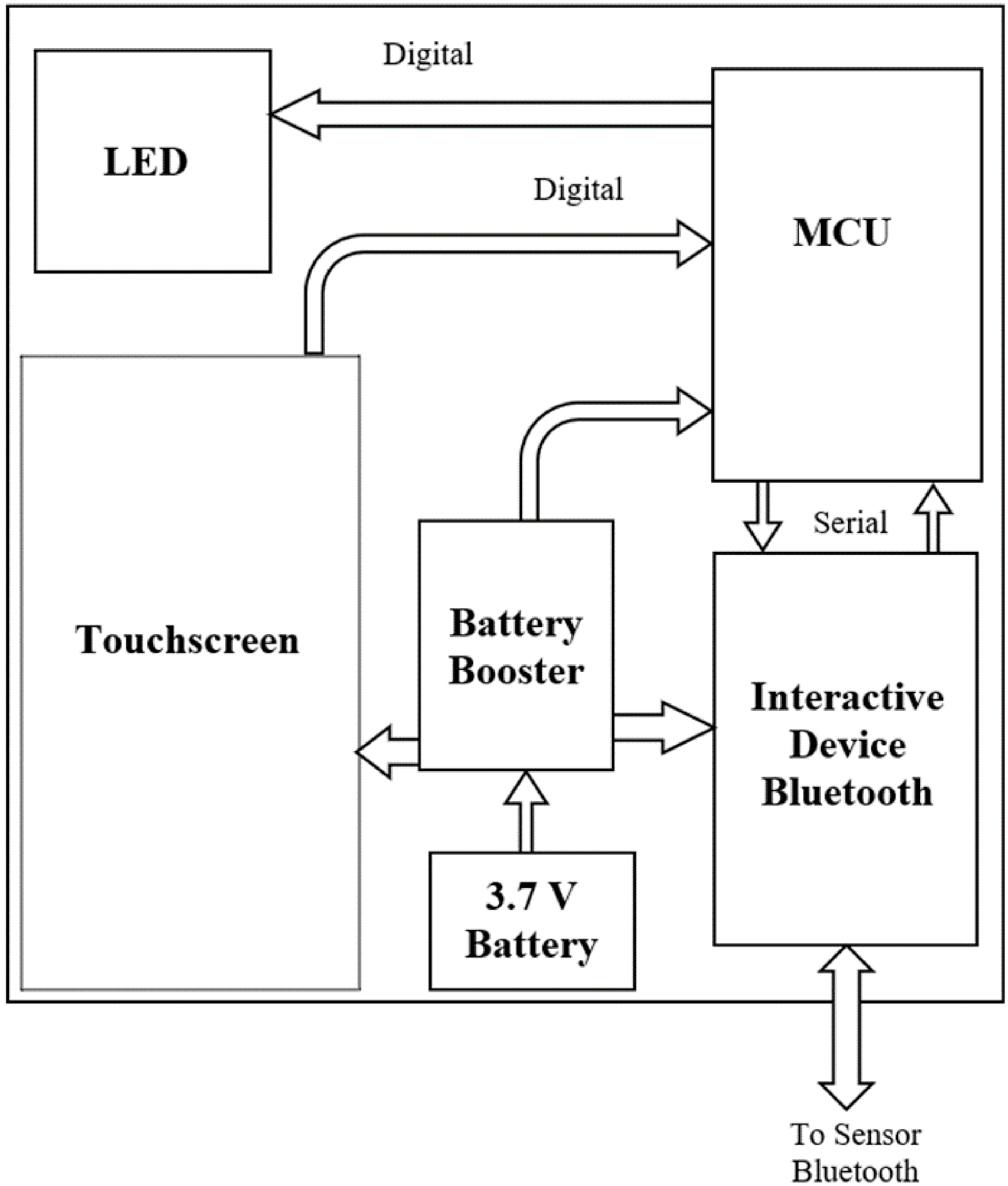


Figure 6.3: Portable device

6.2 PCB Design

6.2.1 Defining a PCB

A PCB is an electronic circuit board that has many traces which connect different areas together, allowing there to be power which carries a signal that circulates between two components. A PCB has many layers which consists of different materials that are overlaid on top of each other. Every layer is there for a reason and they are stacked in such a way to make the circuit board work. To be able to add various components, the PCB has holes drilled into it, which help give way for various components. Over the years PCB design has become more streamlined and there are an abundance of manufactures that make PCB's, therefore the pricing has come down over time, thus making it easier to design a PCB.

6.2.2 Designing our PCB

It is important for our project to make sure all of our components are tested properly before we decide on them because once the PCB process starts it is difficult to change and time consuming. Breadboard testing is smart to do ahead of time and there are many programs out there to help us check and make sure our components work. In the previous labs we have experience with building the circuits using software such as Multi-sim. Once we have definitive information that our components work on both the breadboard and on Multi-sim, then it will give us the confidence knowing we can proceed with making the PCB design.

Once we have verified that all of our testing is solid, then we may proceed to the PCB design area. For our project we will use a program called Eagle, which is free, so there will be no cost to us. Eagle has many libraries built in from the Adafruit library and many of our components have libraries from there so this should make the process easier, as we have no experience with Eagle yet. This software also allows to create our own schematics if we can't find an existing library for our components which will then make it seamless for our PCB design.

By using this eagle software we are able to make a schematic and the layout of the board and then save it to a file which we can send out to the manufacture of our choice who will then create our PCB. We need to make sure all of our designs in Eagle are perfect because once we send them out the manufacture will create the board we sent them, and if we make a mistake on any of the traces or the holes, then that will be our fault and not the manufactures. We may need to have many revisions and send out for multiple PCB's, so it will be crucial to keep the files organized and labeled properly.

Once we are satisfied with our design and have sent out the board it is important to inspect it when it comes back from the manufacture. These boards can take a long time to send out and come back especially if we decide to use vendor from overseas. Even though the manufactures are skilled and have been doing this for a long time, the board may get damaged in the shipping process, so we need to make sure it works because we may need to get a new board if it does not operate. When the PCB is finished and arrives we quickly have to analyze the board to make sure everything is on the right place. Once we have checked the board is properly working we will then proceed to place our components on to make sure they too work with the board and all the holes match up and can be soldered.

6.2.3 Finding the Right Vendor

We live in an era where there are many companies who manufacture PCB boards and with shipping to all over the world there are many to choose from. It is important for us to make sure we keep our cost down to help keep this product affordable. To keep the cost down we will make a list of a few companies that make PCB's and analyze how much each vendor charges and where they are located because part of the cost is also in the turn-around time. In the Table 6.4 below is a list of companies and their location and cost which will give us a variety of options to choose from and will give us the best option.

Manufacturer	Location	Cost	Turn Around Time
Advance Circuits	USA	$33 for students	1 week or less
Sunstone	USA	$6 per square inch	1 day to 3 weeks
OSH Park	USA	$5 per square inch	12 days
PCB Unlimited	USA	$1.65 per square inch	9 days or less
PCB way	China	$2 per square inch	10 Days or less
PCB Cart	China	$2 per square inch	8 days

Table 6.4: PCB Vendor Details

In the end, we chose to go with PCB Way. The designs in the figures below were converted to the required Gerber files that allowed for construction of the boards. Figure 6.5 is the final wearable schematic, Figure 6.6 is its PCB design, Figure 6.7 is the final portable device schematic and Figure 6.8 is its PCB design.

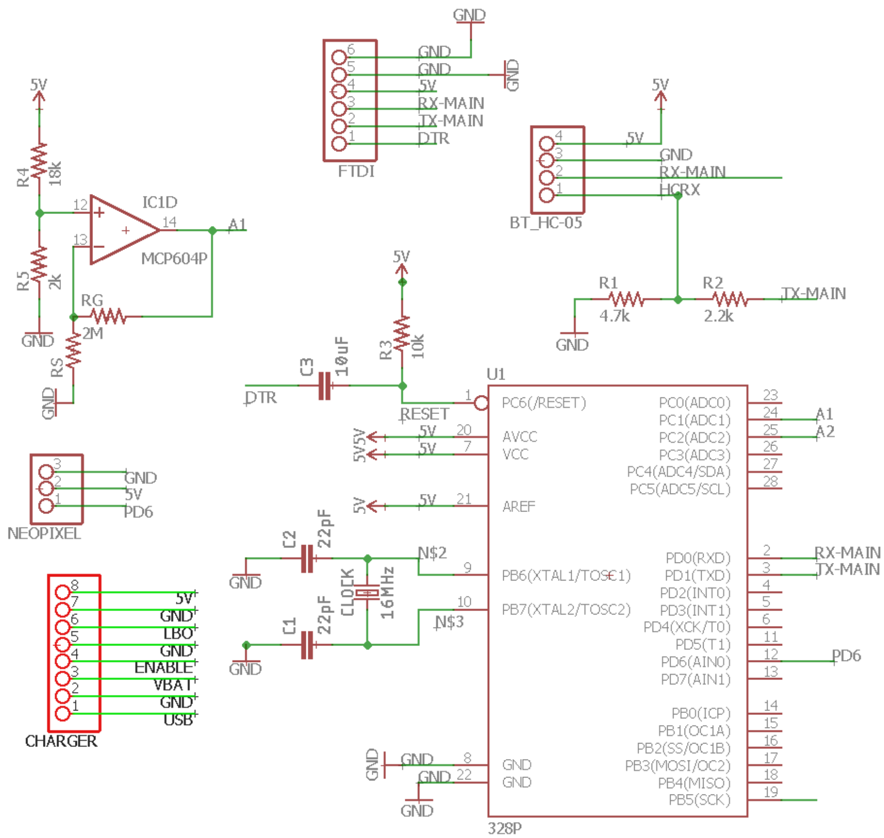


Figure 6.5: Wearable schematic

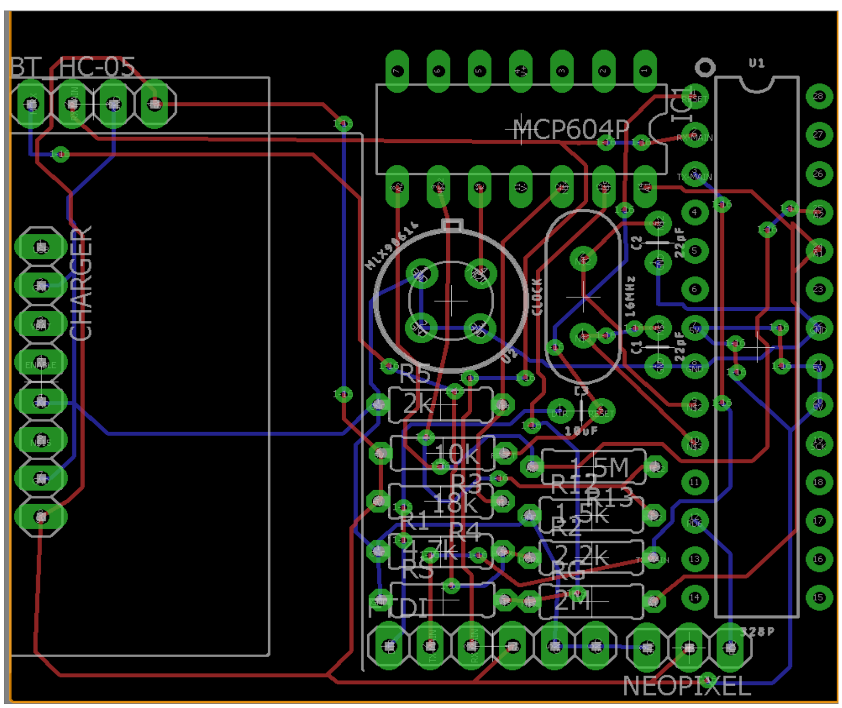


Figure 6.6: Wearable PCB

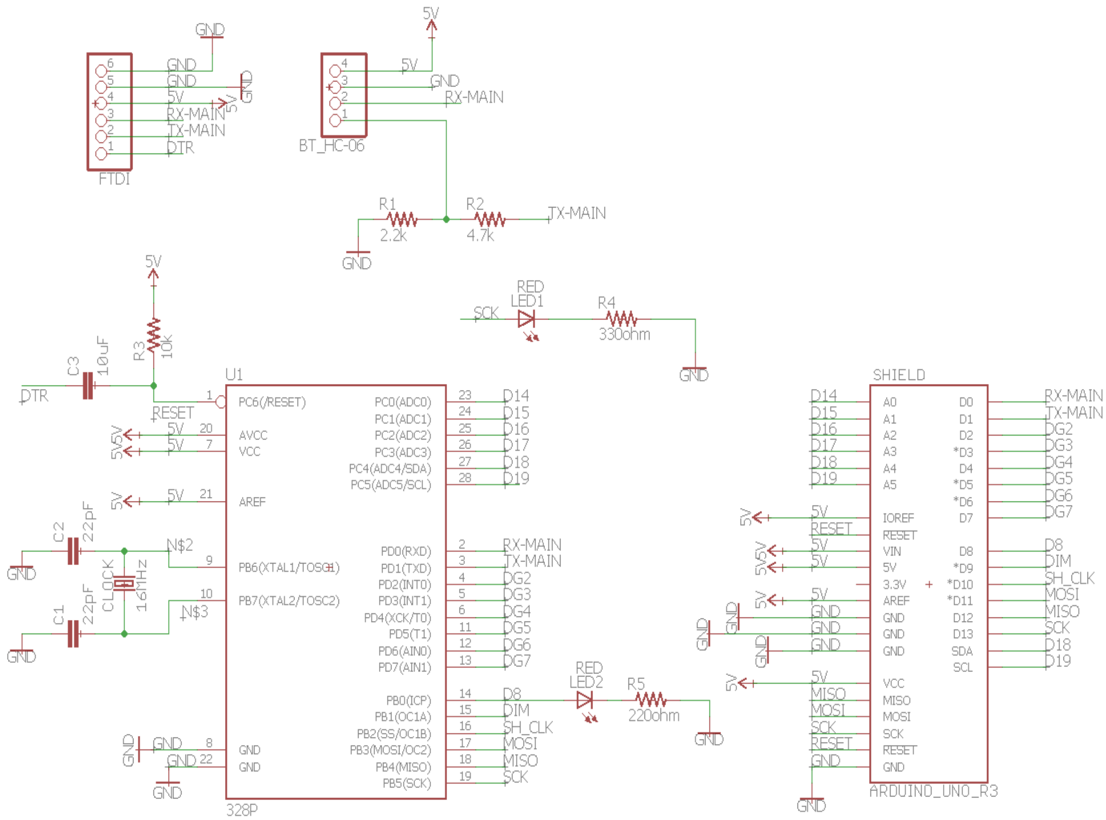


Figure 6.7: Portable device schematic

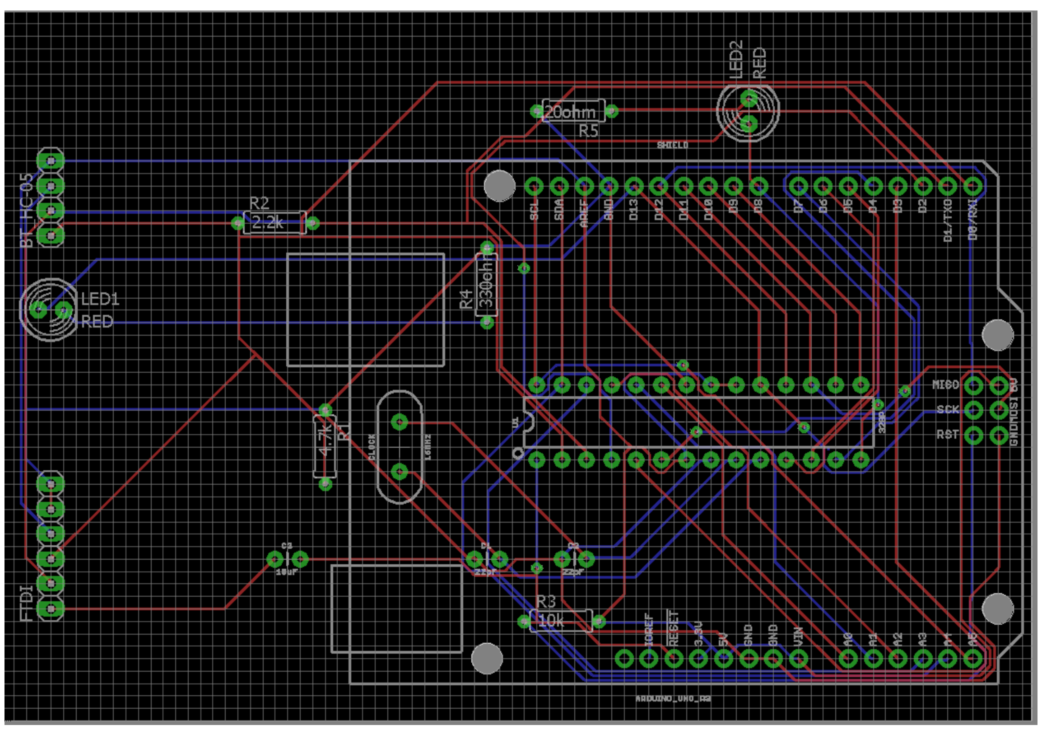


Figure 6.8: Portable device PCB

6.3 Final Software Design

Here is the coding plan to realize the software design as discussed in Section 5.

6.3.1 Wearable Device

The main code for the sensors is shown in Figure 6.9. During the program, it is continuously pooling for the signal from the portable device to start the timer on the wearable device. If the timer is being called for, then another program is run which lights all LEDs red, and then extinguishes them individually every 25 seconds so that all are extinguished after five minutes.

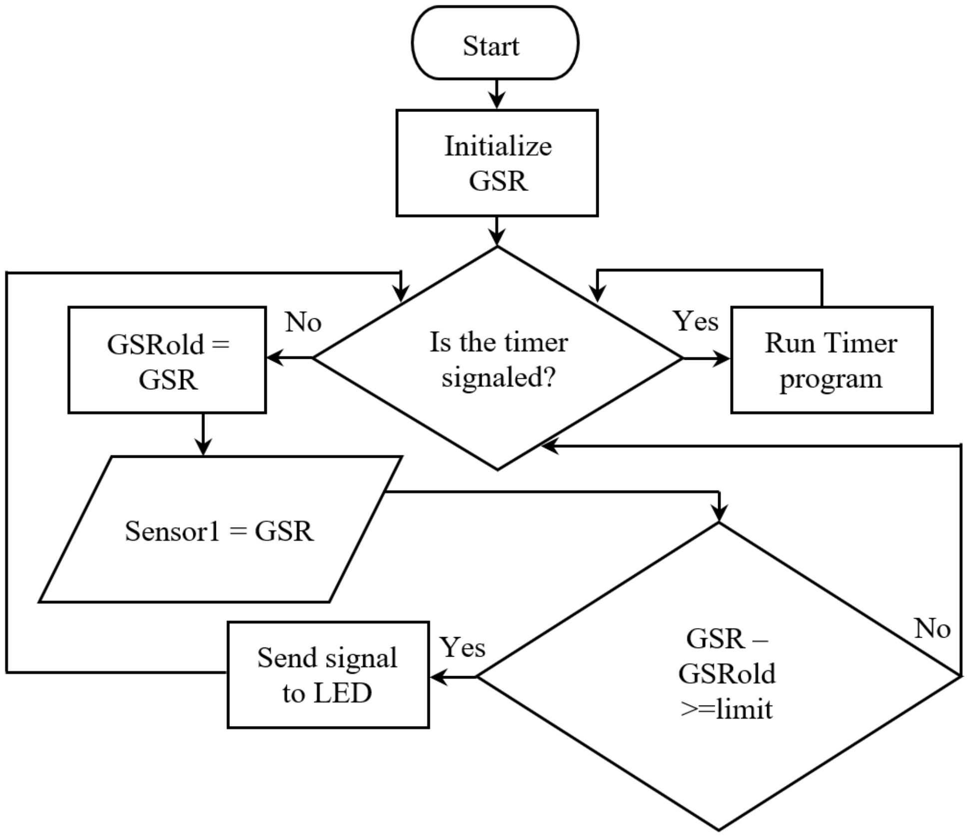


Figure 6.9: Wearable sensor program

The algorithm for the sensor basically smooths the signal with an average value. The data is being sent serially at 9600 baud rate. The rate at which this data changes is small compared to how long it takes the microcontroller to read the input. Therefore, averaging the input is acceptable with little loss in signal resolution. If the data deviates, or continues to deviate, from the running average, then the microcontroller alerts the caregiver via Bluetooth and starts the portable device program that blinks the LED. The main program loops continuously.

6.3.2 Portable Device

The portable device main code is illustrated in Figure 6.10. When the screen is woken, it prompts the user to start the timer on the wearable device or start the paint program on the portable device. In the sleep mode and in the prompt mode the code is also continuously pooling for the signal from the wearable sensor indicating that a student is having trouble. This activates a red LED visible to the teacher that blinks until it time's out or the teacher stops it by pressing the screen.

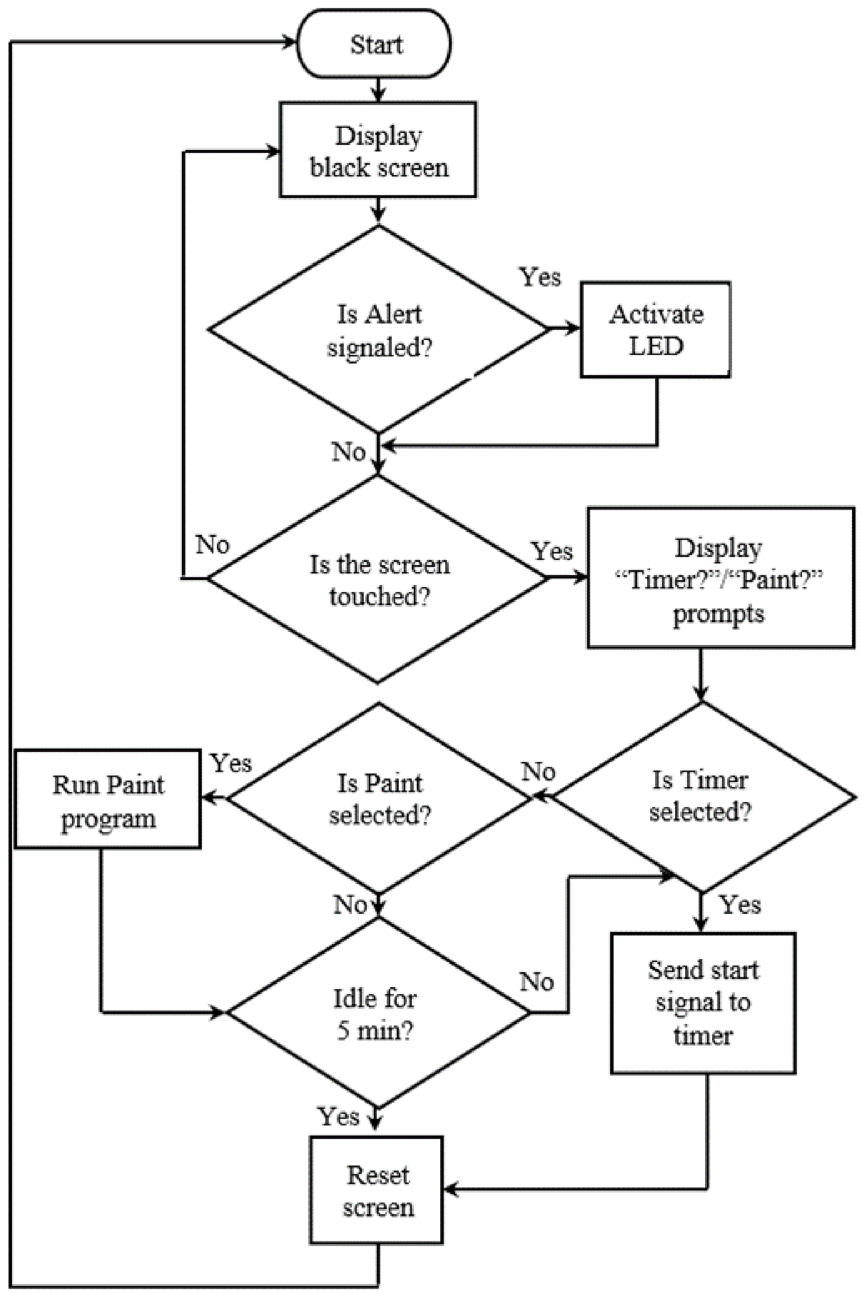


Figure 6.10: Portable device program

The paint program itself senses when there are changes in resistance on the surface. The surface it divided into seven segment. Six segments are located along the right y-axis. These represent six possible colors to use. Whenever there is a resistance change in one of these blocks, it selects that color to be used when there is a change in resistance in the last block. This remaining block is the paint area. When there is a resistance change within this area, the LCDs change to the color that was last selected. By default, it begins with the red color. The paint area is cleared by touching the far bottom. It will become dormant and go blank if there is no interaction for several minutes.

7.0 Prototype Testing Plan

Breadboard testing is completed. Next will be to build the prototype on the PCB.

7.1 Hardware Test Environment

To be able to test our product to its full potential, we need to make sure it goes through rigorous testing, so that we may analyze the results and make changes if necessary. We know the components we are using, and we know that each component has their own limitation thanks to the datasheets provided. We must make sure that each component works individually and together for this project to be successful. One of the environments we are looking into is how the components react to temperature. Most electronics have a threshold for how hot or cold a device may get before they do not work and knowing that this is going to be on a child's wrist means we need to make sure it does not overheat causing the reading to be off and sending false alerts.

7.2 Hardware Specific Testing

In this area we will go into detail testing of each component and finding out how each component responds in the area of efficiency. This process is crucial because it will allow us to see if the components we picked are the right ones for the job and if they are not, then it gives us time to make last minute adjustments. Also it will give us time to work out any kinks that the components may have with one another. By doing this testing on each component, we will save time by figuring it out now rather than hoping for the best and costing us time later on if we run into issues. Testing each component individually and then adding on to that is crucial for ensuring that we have the rights part for this project.

7.2.1 Sensor/Timer

The main purpose of the sensors is to read the wearer's autonomic response to stress. The ideal test would be to subject someone wearing it to stressful stimuli. This may be difficult at the least, setting aside any ethical considerations. Two possibilities exist. One is to simulate the autonomic response. This will not be completely accurate to the natural response, but will test the sensor. The EDA sensor could be tested by moving the sensor from dry skin to slightly damp skin. The second possibility is to subject the wearer to certain videos that are designed to elicit the autonomic response. The wearable device was worn and moved around to finesse the threshold at which it alerts the portable device. We did not want it too sensitive or under-sensitive. To test the rise in EDA, a small amount of water was applied very lightly to the skin. The sensor was then moved around on the dry skin without alarming, and then moved onto the wet skin. This did cause the portable device to alarm, thus successfully testing the wearable device.

7.2.2 Power Supply

With the rechargeable 3.7 Li-Po batteries fully charged, they were plenty to power both devices for hours. During idle periods, the largest current draw was from both active Bluetooth modules, but his was still only about 3 mA. The largest current drawn from the wearable device was when the LED timer was lit. The intensity was lowered so that the current draw was lowered from the 20 mA at full intensity to about 5 – 10 mA at lowest intensity (which was still plenty bright to see). Given that the timer is not on at all times, this showed that the battery was perfect for this application. The portable device followed a similar fashion. When idle the current draw was negligible given the capacity of the battery. If was only significant during the paint program. Considering the paint program is also not running continuously, and that the portable device can be charged while not in use, this battery was also justified.

7.2.3 Bluetooth Module

In our project we are communicating wirelessly with the device on the student's wrist and the portable device. The Bluetooth module is crucial for communicating with the sensor, microcontroller, and the display which will allow the students to transition. Also to make sure that distance is not a factor one of us went to the opposite end of the room and made sure our connection was still there and that we were able to send the information to control the LED timer and it worked perfectly simulating if a teacher was further away from a student in the classroom.

7.2.4 Touchscreen

In this project we are using a 2.8" TFT resistive touchscreen and it will be used as a way for the student to transition if they are having a difficult time. First we connected the touchscreen and applied the correct voltage and made sure the backlight came on. Once we verified that the screen worked, we then connected it to the microcontroller and downloaded a few programs to test the touchscreen functionality. Since the touchscreen is resistive it can be used with either a finger or a stylus, so once we got the paint program up and running we used both our fingers and the stylus to select the colors and proceeded to draw and noticed that the stylus was better because it was smaller and more accurate. The point of testing the touchscreen is because if we get frustrated, then the student using it may get frustrated too and we are trying to avoid that.

7.3 Software Test Environment

In any project it is important to make sure the software and the hardware are speaking with each other perfectly. If there is a hiccup between the two, then there will be issues and if you can't get them to communicate then it can make or break a project. In our group, we are two electrical engineers, who do not have the best programming experience, so for us it was crucial to find a microcontroller that was easy to program for and had many tutorials and libraries online to help aide us. Each component has been tested software-wise on a breadboard using Arduino to program them. Any further software testing will be done concurrent with the hardware testing, and therefore, in the same place. All programming will be written and uploaded using the Arduino IDE. This will also allow us to see the sensor outputs through the serial plotter.

7.4 Software Specific Testing

In this area we are going to discuss what we noticed with each of the components and how we were able to get them to communicate with the microcontroller. The software for most of the components we used was online already which made it easier, but there were a few tweaks needed to get them to work the way we needed them to. Doing these software tests helped us better understand, as electrical engineers with little programming experience we struggled with the coding part, but it was necessary to better understand how these devices communicate with one another.

7.4.1 Sensor/Timer

The software testing already completed verified that the program converted the signals from the sensor to a usable output. The remaining factor was to ensure that the change in output chosen to signal an alert was not too sensitive or not sensitive enough. Several trials were performed while wearing the device so that movement could check it was not overly sensitive. The sensor was also passed from dry to damp skin to check it was sensitive enough.

7.4.2 Bluetooth

To test the software of the Bluetooth module we needed to initially download an app on our phones called serial two terminal. After we got the app successfully installed we used the Arduino libraries that were out there connecting our specific module to the microcontroller. We then paired the two Bluetooth modules so that the wearable device Bluetooth acted as the master, and the other acted as the slave. We then tested that the timer worked within the room with the portable device with the timer was chosen on the portable device. The same was done for the portable device. When the sensor alerted a change in EDA, it was verified that the LED on the portable device blinked until it timed out or was stopped by the user.

7.4.3 Portable Device

To test the software of the touchscreen we connected it to the microcontroller and downloaded the software to use a simple paint program because we do not want the student getting frustrated and we want them to see something familiar. During testing we ran into a problem where the screen was flipped and we knew if it caused us frustration, then it would cause the student frustration too. We had to revise the code to make it not flipped and then we tested the paint program with both our finger and the supplied stylus. We also checked to make sure we could select the different colors easily and erase the image we just created. After getting the paint program fully tested, we modified the code to incorporate the prompt, sending the timer signal and receiving the sensor alert signal.

8.0 Project Operation

This section describes the correct operation of all functions of the project. It is broken into the wearable device operation and the portable device operation.

8.1 Wearable Device

The wearable device is worn on the user's wrist similar to a watch with the timer (face) on top of the wrist. Figure 8.1 illustrates this. On the straps are the EDA electrodes. While the wearable device and the portable device are on, they will be automatically paired if they are in the same room. Also, it will continuously monitor the EDA sensor outputs, and check for a signal from the portable device. When the wearable device is initially attached to the wearer, there may be a rapid change in sensed EDA. This may cause an alert to be sent to the portable device. If this occurs, then ignore the alert.

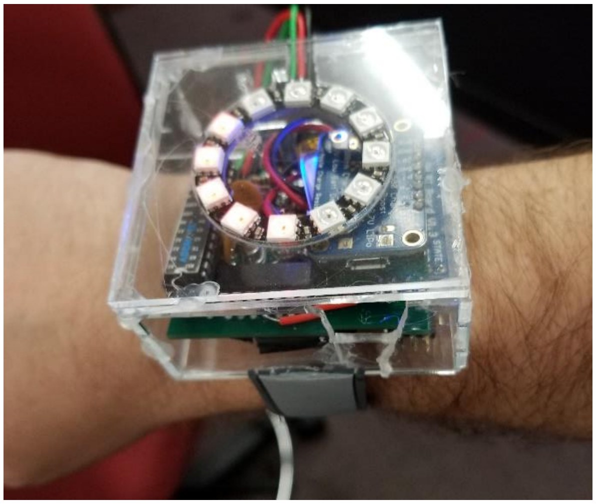


Figure 8.1: Wearable device

It may be continuously worn while the user is in the same class/room as the portable device. While it is worn, it will continuously monitor the EDA outputs and signal the portable device if there is a significant change in EDA indicating a potential issue. There is no reason for it to be worn while the devices are not paired. When is it not being used, it can be charged using a normal micro USB charger. Figure 8.2 show the device charging.

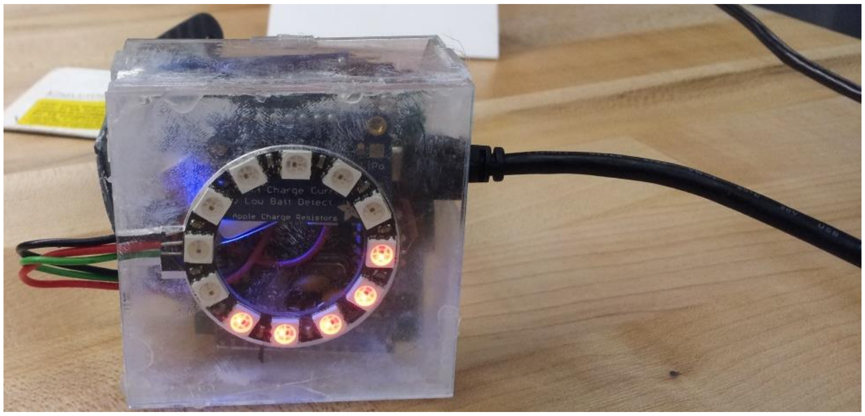


Figure 8.2: Charging wearable device

8.2 Portable Device

The portable device is turned on by a switch located on the power boost shield. It will automatically pair with the wearable device when both are on. This is shown on the portable device’s Bluetooth HC-06 module. Its red LED will stop blinking when it is paired. The screen will initially be blank after the device is powered. The device will begin to continuously monitor for the wearable signal. If it receives a signal during this “sleep” mode, then an LED on the side will blink for 5 minutes or until the screen is touched.

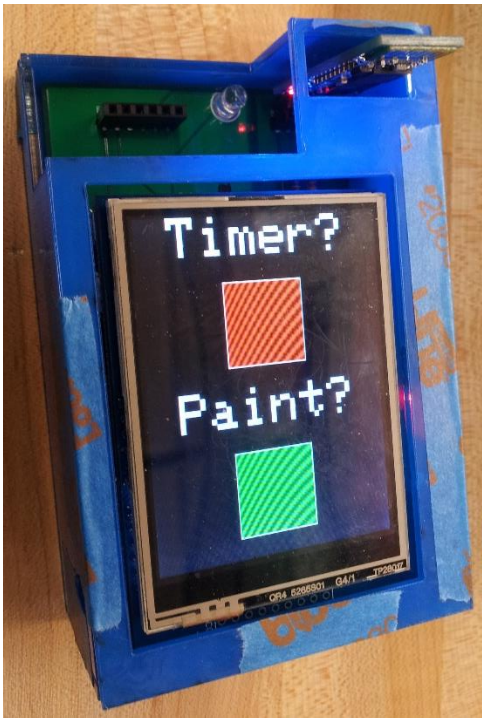


Figure 8.3: Prompt screen

When the touchscreen is first touched, it will show a prompt screen. The two choices are “Timer?” and “Paint?”, and there is a box beneath each. This is illustrated in Figure 8.3. When the box under “Timer?” is pressed, then the screen goes black and the timer on the wearable device begins. When the box under “Paint?” is pressed, then the paint program is started. If no choice is made, then the screen will go blank again until the screen is touched. During the time that the prompt is open, the device still waits for a signal from the wearable device.

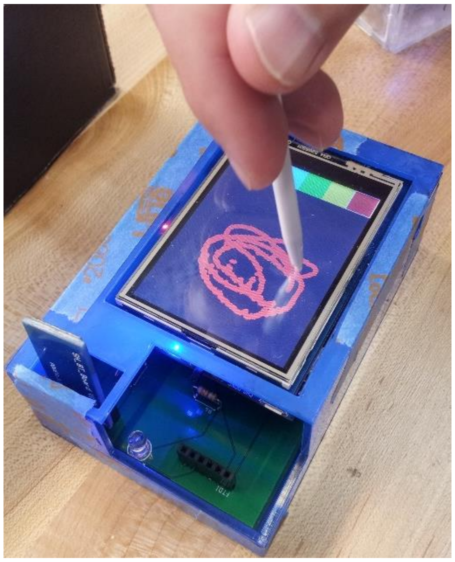


Figure 8.4: Paint program

While the portable device is running the paint program, the user can doodle in six different colors: red, yellow green, cyan, blue and magenta. This is indicated by the six colored boxes on the bottom of the screen. The default color is red. The red box will have a white rectangle around it indicating that it is the chosen color. When the remaining screen is touched, the doodle will be in red. When a different color is chosen, that color’s box will have a white rectangle around it, and the doodle will be in the selected color. Figure 8.4 is a photo of the paint program. To clear the screen, the user much touch the area under the colored boxes. If there is no activity for five minutes, then the program ends, the screen goes black, and the device returns to sleep mode.

9.0 Administrative Content

Two aspects allowed for a successful start to our project. The first was planning. Objectives were clearly set along with their deadlines. The next was early parts acquisition. This was done by ourselves using our own funds.

9.1 Milestones

Table 9.1 discusses the milestones that have been completed for Senior Design I and Senior Design II.

Milestone	Start	End
Senior Design I	01/09/2017	04/27/2017
Project Ideas	01/09/2017	01/13/2017
Divide and Conquer 1	01/13/2017	02/03/2017
Divide and Conquer 2	02/03/2017	02/10/2017
Research and Parts Selection	02/10/2017	03/31/2017
60 Page Draft Document	02/10/2017	03/31/2017
Breadboard Design and Testing	03/31/2017	04/27/2017
100 Page Draft Document	03/31/2017	04/14/2017
Final Document	04/14/2017	04/27/2017
Summer Break	04/27/2017	08/21/2017
Finalize Software	04/27/2017	11/28/2017
PCB Construction	04/27/2017	11/01/2017
Senior Design II	08/21/2017	12/02/2017
Build Prototype	08/21/2017	11/10/2017
Testing and Redesign	10/02/2017	11/20/2017
Finalize Prototype	10/21/2017	11/25/2017
Critical Design Review	09/22/2017	10/06/2017
Peer Review	11/30/2017	12/06/2017
Conference Paper	11/05/2017	11/17/2017
Final Documentation	11/21/2017	12/05/2017
Final Presentation	11/29/2017	11/29/2017

Table 9.1: Milestones

9.2 Budget and Finance Discussion

The budget was based on the parts selection of Table 3.11. It is modified in Table 9.2 below to include PCB and prototype testing requirements. The finances have been split between team members. There were no sponsors.

	Part Name	Manufacturer/Seller	Part Number	Cost
1	Electrodes (10 pk)	PLUX	EL-DRY-REUSABLE-5-10	$14.00
2	MCP6004 Op-Amp (10 pk)	Microchip Technology	MCP6004-E/P	$6.71
3	Microcontroller (3 pk)	Atmel	ATmega328P	$13.45
4	Touchscreen	Amazon	LYSB00UAA2XIC	$15.99
5	Bluetooth Master (2 pk)	DSD TECH	B01G9KSAF6	$7.99
6	Bluetooth Slave (2 pk)	DSD TECH	B01FCQZ8VW	$7.99
7	Timer (3 pk)	Banggood	976036	$10.56
8	Crystal Oscillator (10 pk)	Uxcell	HC-49S	$4.57
9	Serial Adapter (2 pk)	Gifkun	FT232RL	$9.88
10	Breadboard Power Supply Module (2 pk)	Wangdd22	B10	$8.99
11	PCB (2 Separate PCB's)	PCB Way	Custom PCB	$54
12	Battery and Charger (Port)	Adafruit	LP803860	$35
13	Battery and Charger (Wear)	Adafruit	LP402025	$25
			Total	$214.13

Table 8.2: Project Budget

10.0 Conclusion

Going into this class we both had our doubts and coming up with a bunch of ideas for a senior design project was not the difficult part, it was choosing an idea that we thought could really inspire and change the world. After all the great ideas we brainstormed together, we finally came up with one that would help detect when an autistic child in the classroom was having a hard time transitioning to another subject, so we chose to help others. For our design we wanted the device to be wearable and light weight so it would not be a distraction to the student but rather a method to help them and the teacher. We knew what we wanted to achieve and now we had to go off and explore the technologies that were out there and learn about how they could be used to create this idea we had. The technologies we learned about along the way were very helpful and insightful, we learned about Thin-Film-Technology (TFT) which will allow the student to calm down by using a program they are familiar with such as paint, Bluetooth modules which consist of a master and a slave and will help to communicate with all the components to the teachers phone, the microprocessor unit and how it can bring all of the components together to allow them to communicate with each other. Also we learned about all of the sensors such as a heart-rate, skin conductance, and an accelerometer with EDA ultimately being the one which will detect when the student is having a difficult time transitioning. The last component we learned about was the neo-pixel ring and its use as a timer.

Once the PCBs were developed and received, the remaining testing fell into place. It was during this testing that the code was finalized for just the EDA sensor rather than all the others.

We are very impressed with ourselves seeing this project start from just an idea to a working prototype. Also we agreed that we both learned how to manage our time between classes, family, work, and just life in general. This course was not a cakewalk or an easy A, but it is very rewarding to see your baby (project) start from something so small, but if nurtured right and cared for, it will grow into something you are proud to say you helped make that grow into what it is today. The final take away for us as a group was learning about communication and how important it is and how something so simple as an email or phone call would ease the tension or confusion we may have experienced. Well after going through a full year of learning how to work in a group and trusting our team members, we feel this was a great learning experience. It felt like we were creating something that we could actually use in the real world to help people who have autism.

Appendix A: References

[1] Flannery, K. & Horner, R. (1994). The relationship between predictability and problem behavior for students with severe disabilities. *Journal of Behavioral Education, 4*, 157-176.

[2] Mesibov, G., Shea, V., & Schopler, E. (2005). *The TEACHH® approach to autism spectrum disorders*. New York, NY: Plenum Publishers.

[3] Hume, Kara. (2008). Transition Time: Helping Individuals on the Autism Spectrum Move Successfully from One Activity to Another. The Reporter 13(2), 6-10.

[4] Chafik, Nezha. Findlater, Raymond. Jarvis, Andrew. Nicolet, Luc. "Bio-Feedback Wristwatch Device for EH Children", PowerPoint, http://www.slideserve.com/traci/bio-feedback-wristwatch-device-for-eh-children. Accessed on 28 February 2017.

[5] Empatica (2015). *E4 Wristband: User manual*. Retrieved from https://empatica.app.box.com/v/e4-user-manual.

[6] Awake Labs, "Reveal: Empowered Care for Autism", https://www.indiegogo.com/projects/reveal-empowered-care-for-autism. Accessed on 24 February 2017.

[7] iMotions A/S (2016). GSR Pocket Guide. Retrieved from https://imotions.com/guides on 24 February 2017.

[8] Grob, Bernard. *Basic Electronics*. New York. 6th Edition. McGraw-Hill,1989. Print.

[9] Siimpson, Colin. Principles of Electronics. New Jersey. Prentice Hall. 2000. Print.

[10] Karaki, Habib. Polyzoev, Vasco. "Demystifying Thermopile IR Temp Sensors." Sensor Mag, 27 February 2014, www.sensorsmag.com/sensors-mag/demystifying-thermopile-ir-temp-sensors-13157. Accessed 06 March 2017.

[11] Emmy Denton . Temperature Sensor Applications . Texas Instruments . March 17, 2015 . Learn How to Measure Body Temperature . Accurately and Cost Effectively

[12] Dubin, Dale, M.D. Rapid Interpretation of EKG's. Florida. Cover Publishing Company. 1970.

[13] Cheriyedath, Susha. “Photoplethysmography (PPG).” 18 July 2016. www.news-medical.net/health/Photoplethysmography-(PPG).aspx. Accessed 06 March 2017

[14] Goodrich, Ryan. “Accelerometers: What They Are and How They Work.” 01 October 2013. www.livescience.com/40102-accelerometers.html. Accessed 06 March 2017.

[15] Buchmann, Isidor. “Battery Types: How Do These Batteries Work.” 2017. http://batteryuniversity.com/learn/article/lithium_based_batteries. Accessed 02 March 2017.

[16] Buchmann, Isidor. “Battery Chargers: How Do Battery Chargers Work.” 2017. http://batteryuniversity.com/learn/article/all_about_chargers. Accessed 02 March 2017.

[17] Tutorials Point. “Wi-Fi: IEEE Standard.” 2017. https://www.tutorialspoint.com/wi-fi/wifi_ieee_standards.htm. Accessed 03 March 2017.

[18] Radio Electronics. “Zigbee: Technology Tutorial.” 2017. http://www.radio-electronics.com/info/wireless/zigbee/zigbee.php. Accessed 03 Mach 2017.

[19] Panasonic. “Wireless Connectivity: Bluetooth.” 2017. https://eu.industrial.panasonic.com/products/wireless-connectivity/bluetooth. Accessed 03 March 2017.

[20] Link Labs. “Bluetooth Vs. Bluetooth Low Energy: What’s The Difference?” 2017. https://www.link-labs.com/blog/bluetooth-vs-bluetooth-low-energy. Accessed 03 March 2017.

[21] Practical Home Theater Guide. “How It Works: LCD Display Technology.” 19 September 2013. http://www.practical-home-theater-guide.com/lcd-display.html. Accessed 05 March 2017.

[22] Rouse, Margaret. “Tech Target: Thin-Film Transistor.” 2017. http://whatis.techtarget.com/definition/thin-film-transistor-TFT. Accessed 05 March 2017.

[23] Future Electronics. “What is and LED Display?” 2017. http://www.futureelectronics.com/en/optoelectronics/led-displays.aspx. Accessed 05 March 2017.

[24] Tech Explainer. “Touchscreen: Resistive vs Capacitive.” 2017. https://techexplainer.wordpress.com/2012/04/02/resistive-vs-capacitive-touchscreen/. Accessed 05 March 2017

[25] "Timers." Wikipedia. Wikipedia Foundation, 30 March 2017. https://en.wikipedia.org/wiki/Timer. Accessed 12 March 2017.

[26] Electronics Tutorials. "Timers: 555." 2017. http://www.electronics-tutorials.ws/waveforms/555_timer.html. Accessed 12 March 2017.

[27] Bredhold, David. "The Basic of Time Delays: Application Requirements for Time Delay Relay." 01 August 2010. http://ecmweb.com/training/basics-time-delay-relays. Accessed 12 March 2017.

[28] Programming Timers. "Pulse Timers." 26 December 2003. Page 6. https://booksite.elsevier.com/9781856176217/appendices/02~Ch12.pdf. Accessed 12 March 2017.

[29] Linear Technology, "LT1055/LT1056 Precision, High Speed, JFET Input Operational Amplifiers," datasheet, August 2015.

[30] Texas Instruments, "LMx24-N, LM2902-N Low-Power, Quad-Operational Amplifiers," datasheet, March 2000 [Revised January 2015].

[31] Microchip, "MCP6001/1R/1U/2/4 1 MHz, Low-Power Op Amp," datasheet, June 2002 [Revised November 2009].

[32] Amphenol Advanced Sensors, "ZTP-101T Thermopile IR Sensor," datasheet, 2014.

[33] Freescale, "MMA8652FC, 3-Axis, 12-bit, Digital Accelerometer," datasheet, October 2012 [Revised October 2015].

[34] Texas Instruments, "MSP430G2x53 MSP430G2x13 Mixed Signal Microcontroller," datasheet, April 2011 [Revised May 2013].

[35] Atmel, "ATmega328/P," datasheet, June 2016 [Revised November 2016].

[36] Goldman S. et al. "Motor stereotypes in children with autism and other developmental disorders." Developmental Medicine & Child Neurology. Jan 2009; 51(1):30-8.

Appendix B: Copyright Permissions

[iMotions] Re: GSR Pocket Guide Diagram Permission

Isabella Leon (iMotions Support) <support@imotions.com>
02/28/2017
Jeffrey Thompson

##- Please type your reply above this line -##

Your request (10081) has been updated. To add additional comments, reply to this email.

Isabella Leon (iMotions)

Feb 28, 5:34 PM EST

Hi Jeff,

Thanks for reaching out!

Of course you can use the image as long as you reference us as the source or give credit to us in some way. Let me know if you need anything else.

Thanks,
Isabella

Jthompson1101

Feb 28, 5:30 PM EST

My name is Jeff Thompson. I am an electrical engineering student at the University of Central Florida. My senior design project involves using galvanic skin response (GSR). I respectfully request permission to include some diagrams from the GSR Pocket Guide to include in the research portion of my report. Specifically, the diagram of the basic raw GSR signal on page 25. This will be used as a reference only, and credit will be given to iMotions.com.

Also, a response email specifying permission would be appreciated as it must go in the report.

Thank you for your time.

This email is a service from iMotions. Delivered by Zendesk

Copyright Permission

BL

Bassuk, Larry <l-bassuk@ti.com>

|

Thu 3/2, 5:17 PM

Dear Jeff,

Thank you for your interest in Texas Instruments. We grant the permission you request in your email below.

On each copy, please provide the following credit:

Courtesy Texas Instruments

Regards,

Larry Bassuk

Senior Patent Counsel &

Copyright Counsel

Texas Instruments Incorporated

214-479-1152

JT

Jeffrey Thompson

Reply all |

Wed 3/1, 3:28 PM

...

Good afternoon. My name is Jeff Thompson. I am an electrical engineering student at University of Central Florida. My partner and I, Gary Shotts, are working on a senior design project involving wearable sensors.

We respectfully request permission to use the information from the table comparing temperature sensors on page 7 of Emmy Denton's "Learn How to Measure Body Temperature Accurately and Cost Effectively" located at http://www.ti.com/lit/ml/slyw051/slyw051.pdf.

The information will be used in the research portion of our report with proper credit given to Emmy Denton and Texas Instruments.

Thank you for your time.

Jeff Thompson

Mzia from Empatica (Empatica Help Center)

Mar 23, 08:58 CET

Hi Jeffrey,

Thank you for reaching out. I apologize for the delay in response. I'm glad to hear that you'll be featuring E4 wristband in your project! You'll find high-resolution images of the wristband here: https://empatica.app.box.com/v/e4-presskit

Should you have any follow-up questions, please don't hesitate to contact me. Thank you!

Kind regards,
Mzia
Empatica Team
www.empatica.com

Jeffrey Thompson

Mar 21, 13:10 CET

Good morning. My name is Jeff Thompson. I am an Electrical Engineering student at the University of Central Florida. My partner, Gary Shotts, and I are doing a Senior Design project involving a wearable sensor for special needs children. Part of our report is to reference similar products. I am requesting permission to include images of the E4 wristband in our discussion of it with credit attributed to Empatica.

Thank you for your time.

Jeff Thompson

Paul Fijal <paul@awakelabs.com>

Mon 3/27/2017 7:30 PM
To: Jeffrey Thompson <jthompson1101@Knights.ucf.edu>;

Cc: hello@AwakeLabs.com <hello@AwakeLabs.com>;

Hi Jeff,

Sorry for the delay in response. Thank you for checking with us! I don't have any issues with you and your partner using the image on our Indiegogo page for your report.

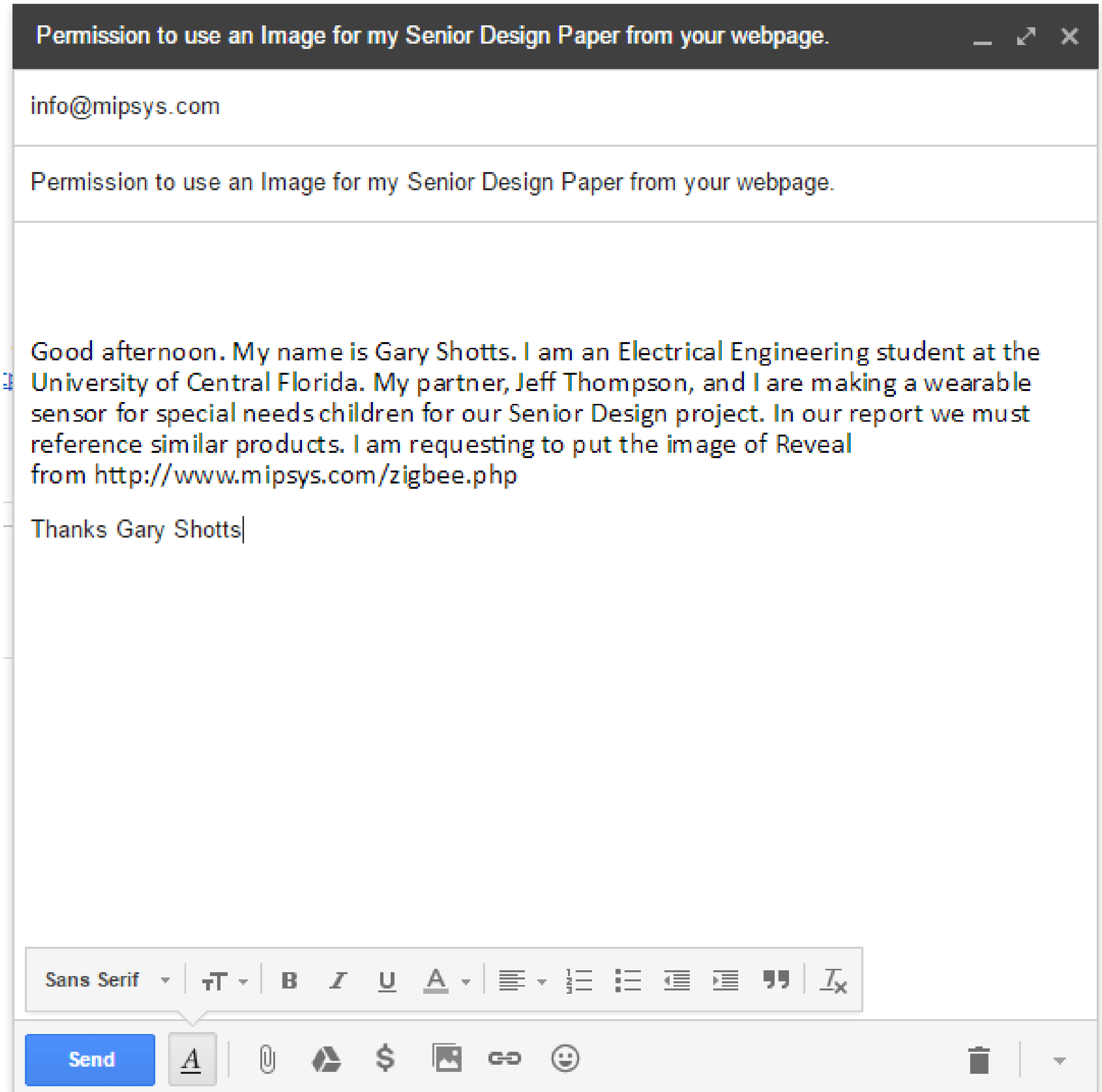
Best,
Paul

Paul Fijal
Product Dev | Awake Labs | awakelabs.com
skype | paulfijal
tel | 1 604 970 3482 [Canada]
linkedin

On Mar 21, 2017, at 8:11 AM, Jeff Thompson <jthompson1101@knights.ucf.edu> wrote:

Name: Jeff Thompson
Email: jthompson1101@knights.ucf.edu

Message: Good afternoon. My name is Jeff Thompson. I am an Electrical Engineering student at the University of Central Florida. My partner, Gary Shotts, and I are making a wearable sensor for special needs children for our Senior Design project. In our report we must reference similar products. I am requesting to put the image of Reveal from https://www.indiegogo.com/projects/reveal-empowered-care-for-autism--2#/ in our report with credit given to Awake Labs Inc. Thank you for your time. Jeff Thompson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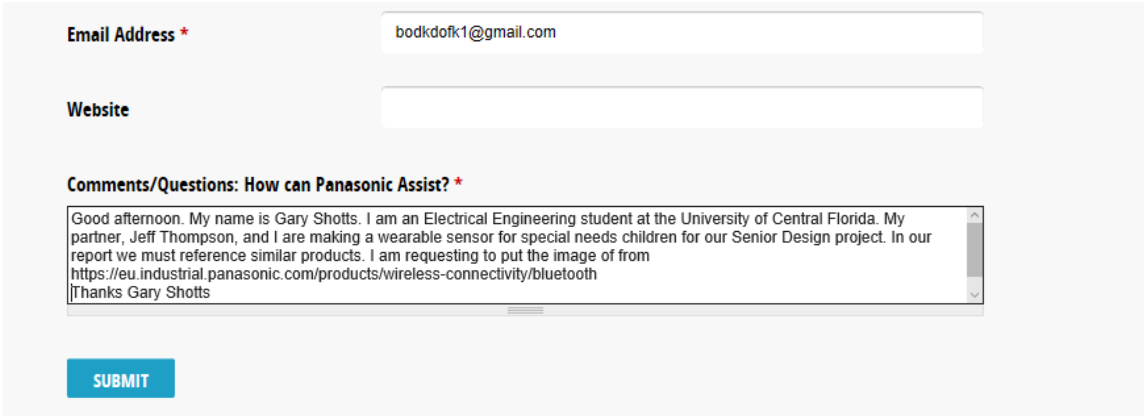
info@mipsys.com

Permission to use an Image for my Senior Design Paper from your webpage.

Good afternoon. My name is Gary Shotts. I am an Electrical Engineering student at the University of Central Florida. My partner, Jeff Thompson, and I are making a wearable sensor for special needs children for our Senior Design project. In our report we must reference similar products. I am requesting to put the image of Reveal from http://www.mipsys.com/zigbee.php

Thanks Gary Shotts



Email Address *

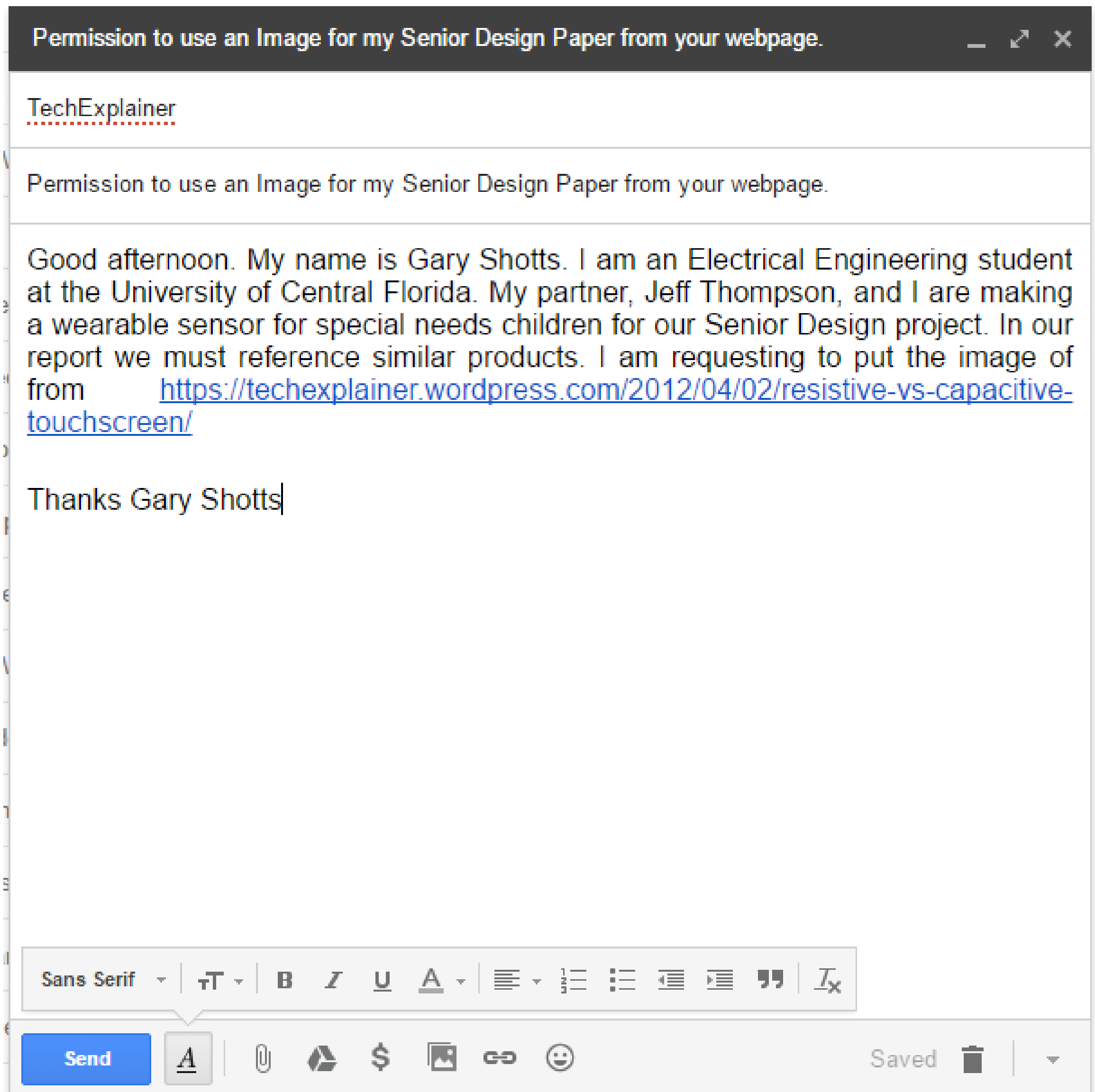
bodkdofk1@gmail.com

Website

Comments/Questions: How can Panasonic Assist? *

Good afternoon. My name is Gary Shotts. I am an Electrical Engineering student at the University of Central Florida. My partner, Jeff Thompson, and I are making a wearable sensor for special needs children for our Senior Design project. In our report we must reference similar products. I am requesting to put the image of from https://eu.industrial.panasonic.com/products/wireless-connectivity/bluetooth
Thanks Gary Shotts

SUBMIT



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TechExplainer

Permission to use an Image for my Senior Design Paper from your webpage.

Good afternoon. My name is Gary Shotts. I am an Electrical Engineering student at the University of Central Florida. My partner, Jeff Thompson, and I are making a wearable sensor for special needs children for our Senior Design project. In our report we must reference similar products. I am requesting to put the image of from https://techexplainer.wordpress.com/2012/04/02/resistive-vs-capacitive-touchscreen/

Thanks Gary Shotts

Sans Serif

Send

Saved

Permission to use a few of the tables relating to many batteries for my Senior Design P...

BatteryU@cadex.com

Permission to use a few of the tables relating to many batteries for my Senior Design Paper from yo

Good afternoon. My name is Gary Shotts. I am an Electrical Engineering student at the University of Central Florida. My partner, Jeff Thompson, and I are making a wearable sensor for special needs children for our Senior Design project. In our report we must reference similar products. I am requesting to put the image of from http://batteryuniversity.com/learn/article/lithium_based_batteries and http://batteryuniversity.com/learn/article/all_about_chargers

Thanks Gary Shotts

Sans Serif

Send

Saved

BatteryU
to me

Hi Gary,

Yes, you may use the material as requested. Please cite sources where appropriate.

Regards,

John Bradshaw - Marketing Communications Manager
Cadex Electronics Inc. | www.cadex.com
Vancouver | Minneapolis | Frankfurt
Tel: +1 604 231-7777 x319 | Toll Free: 1-800 565-5228

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>>> Gary Shotts <bodkdofk1@gmail.com> 3/30/2017 9:05 PM >>>

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