Nome's Child Safety Seat with Car Integration and Android Application Support

EE/CpE Team: Matt Bivona, Michael Covitt, Jason Nagin, and Donnell Robinson.

IE/Business Team: Garielle Edelmann, Ching Fang Chang, Eliezer Lorenzo, Rewel Maldonado, and Jodi Sweatland

Dept. of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450, U.S.A.

***Abstract* — The objective of this project is to create a safety child car seat insert that allows the monitoring of the child's environment and provides awareness options to remind the vehicle operator not to leave their child in the vehicle. The insert device will communicate with a smartphone application via Bluetooth and provide multiple stages of attention grabbing techniques to the owner. In critical situations the device will assume control of the vehicles onboard features in an attempt to save the lives of the child. The group chose this project to demonstrate the advantage of having a multi-discipline senior design group.**

***Index Terms* — Alarm Systems, Bluetooth, Cellular Phones, Temperature Measurement, Vehicle Safety, Weight Measurement.**

I. Introduction

Frequently in the news are stories where children and infants being accidentally left in vehicles. Severe environmental conditions, including heat, humidity and cold often have a fatal effect on these children. Engineering can help solve this issue with a better designed car seat and better automobile and human interactions. Our goal is to create a child seat that will implement an array of sensors and a control board to ensure that these safety features keep the infant safe. This device will function in situations such as extreme heat and extreme cold where the parent or guardian will be notified and the car be controlled to ensure the child remains safe.

The motivation behind this product is to apply all of our combined engineering knowledge gained from our time here at the University of Central Florida to create a safer environment for children. Our team is the first attempt at creating a working real world project using a mixed majors group of students. The team consists of four industrial engineers, two computer engineers, two electrical engineers, and one business major. Each member of this team has a unique specialty which will be heavily utilized in order to accomplish the full design.

Our goal is to create a base product that is both affordable and reliable to the customer. If this prototype is taken to a manufacturing scale then the device will easily allow additional features to be added to the design. The product will be designed to have many purchasable, but not required, features so the consumer will be able to mix and match their own safety device that specifically applies to their unique situation. Our team chose this approach because our target audiences of new families are not the same in regards to age, income, number of parents or guardians, and even technological knowledge.

Throughout this project these people have been great assets in the fields in which they are professionals in. The Boeing Company's interest in our project has awarded us with additional funding that will be used for research and development. Dr. Calabrese's also provided financial assistance as well as his knowledge in industrial engineering provided us with ways to make our project organized and efficient. Mr. Civitello's medical knowledge assisted us in determining safety parameters where the device is needed the most. Mrs. Hesse's access to our targeted audience provided critical marketing feedback and targeted audience information. Dr. Renk helped us determine the psychological causes and the types of responses our device shall administer to get the full attention from the parent or guardian. With these resources we designed and developed a working prototype of the safety insert system.

II. Statistics and Research

Engineers are natural problem solves, but in order to create a solution they much first fully understand the problem at hand. This section is the sum of all the research our team members have obtained and with it we plan on making the best product we possibly can to ensure the safety of these children.

A. Heatstroke Statistics

The main deaths of children being left inside of hot vehicles are caused by heatstroke. Figure 1 shows the statistics of the cause of vehicular child death over the past 15 years. Before 1998, the main threat was the airbags. The team assumed that 1998 was when automobile industries began to add in air bag safety features, which greatly decrease its killer effect on children. On the other hand, the number of causes for heatstroke has been going up and down since 1994. Three to four times a month a set of loving parents in the United States are horrified to realize that they have forgotten their child in its car seat.

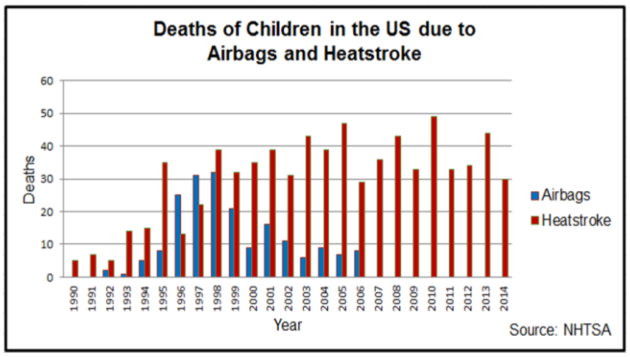

Fig. 1. Vehicular Child Death Statistics. Data obtained from the NHTSA [1].

Figure 2 displays the average heatstroke distribution in America. Most heating up occurs in first 10-15 minutes. On average, temperature increases at rate of 3.4 degrees (F) per 5 minutes. Temperatures can increase in the range from 9 degrees (F) high up to 19 degrees in the first 10 minutes. Most common heat-caused health effects on children are Dehydration, development of faintness, headaches, extreme fatigue, and shortness of breath. As you can see the most deaths caused by heatstroke occur in the warmest states such as California, Texas, and Florida. We find ourselves beneficial to be conducting our research in Florida because we can get critical data and information from surveying potential customers in the second highest rated state.

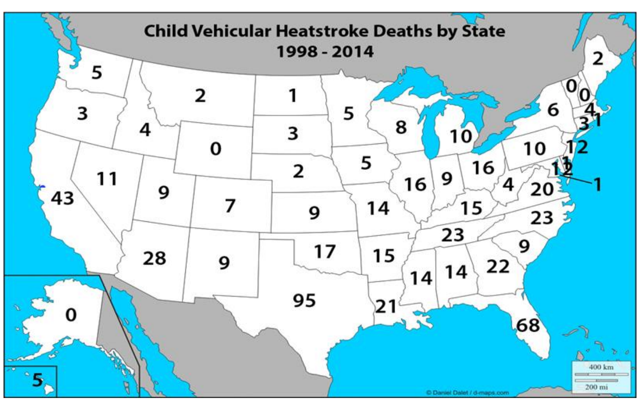

Fig. 2. Heatstroke Distributions (1998-2014) Reprinted with permission from ggweather.com [2].

B. Psychology

The average American is under a tremendous amount of stress. According to Medical News 77% of parents are stressed about money. Add to that the sleep deprivation that parents of newborns and small children experience and you have could have a lethal combination. Dr. David Diamond [3] of the University of South Florida continues to research a phenomenon he calls, “Forgotten Baby Syndrome”. This syndrome is a, “Failure of prospective memory, which refers to the planning and execution of an action in the future.” In other words, it is indeed possible for people of all ages, incomes, education levels, and genders, to forget their babies in their cars and just go off to the office.

C. Bluetooth

Bluetooth is a wireless standard for exchanging data over short distances. It operates at between 2400 and 2483.5 MHz. Bluetooth provides benefits over other 2.4 GHz technologies due to the implementation of adaptive frequency hopping. This provides it the ability to detect other devices that are using the spectrum and change the frequency to an unused one to avoid any noise. Bluetooth has 79 frequencies that are 1Mhz apart. Bluetooth has a range that is mandated by the specification but there is not a limit on the upward side, and the range can be extended based upon the use case that is needed.

III. Related Standards

A. Bluetooth

The standard for Bluetooth is 802.15.1-2002 IEEE Standard for Telecommunications and Information Exchange between Systems which is a standard that allows for the wireless connection between short ranges. Bluetooth uses RF based connectivity for portable personal devices which will allow for the car seat to talk with the phone. This standard will include medium access control (MAC) which includes, logical link control and adaptation protocol (L2CAP), link manager protocol (LMP), Baseband, physical layer (PHY), logical link control (LLC), protocol implementation conformance statement (PICS), and specification and description language (SDL).

B. JTAG

The standard for JTAG is IEEE Standard 1149.1 (JTAG) which allows for the CPU to use the test access port (TAP) which are four pins TMS, TCK, TDI, and TDO to communicate with the CPU. This allows for the pins to act as regular 1/0s and JTAG pins. The TAP controller uses 16 states which receives two control inputs TMS and TCK which generate control and clock signals for the other test logic. It also includes an instruction register which consists of five IR cells what have shift-register stage and a latch stage. This allows for the data to be shifted up toward the TDO.

C. Java

We have chosen to follow the Java coding standards from IEEE. The software quality must reflect functionality, reliability, usability, efficiency, maintainability, and portability. File structure for our source code will be used to place all our files under a single location that is easy to access and efficient for the entire group. Our architectural structure will follow a modular flow to represent a monolithic flow. Variables will be uniquely defined and only used for a single instance and then not repeated. When a function was no longer used it was removed completely so there are no ghost functions residing in the final installation of code. A change long has been recorded to keep track of the development of the project.

IV. Hardware Design

A. PCB

We require a small compact PCB that will have the microcontroller and Bluetooth on it. Here we will have to implement a design on the board to allow us access to the programing pins of the microprocessor, supply power to the microprocessor, and transmit over Bluetooth with an antenna. Here we will also have to create the PCB so that the board fits behind the car seat in a location that will allow for the Bluetooth communication not to be blocked. We have to take into consideration all of the components of the system. Here we will have to make sure that everything can fit onto the PCB board and still be small enough to fit on the car seat. The hardware configuration will take into consideration the placement of the microcontroller so that all the requirements above can be met and so that there is ample room for the battery to be able to sit close to the PCB. To do this we will design a PCB using Eagle to customize the location of resistor networks and microcontroller placement allows for the PCB to be to correct size. Figure 3 displays the general design for our PCB Layout.

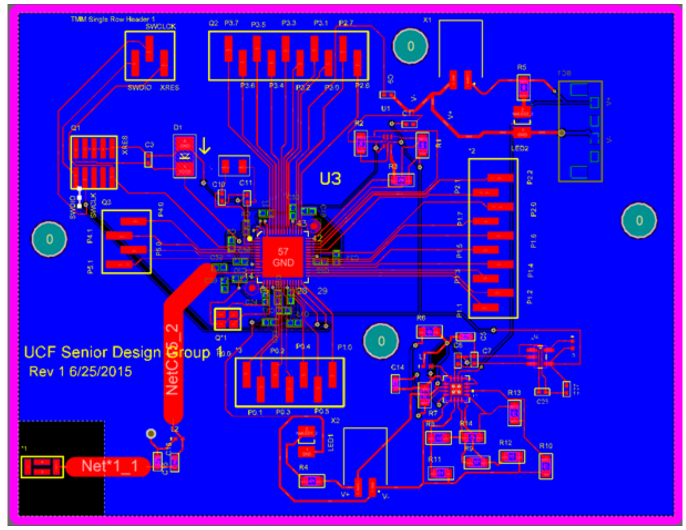

Fig. 3. General PCB Layout

B. Microcontroller

The Microcontroller that we are going to be using for this project is the PSOC4 BLE. The microcontroller is crucial for the system to work so we will have to implement the controller onto the board in such a way that the microcontroller can be the central unit in the system. This microcontroller allows us to implement the needed features on a small PCB. The reason that we chose to use the PSOC4 BLE is that it allowed us to use super low power allowing for the battery to last longer and for the solar panels to have less work when charging the battery. Another huge benefit of using the PSOC4 BLE is that it has a Bluetooth chip embedded, allowing for us to keep the PCB small. The PSOC4 BLE uses an Arm M0 processor which allows us to gain experience in using Arm devices. We will learn how to embed the chip onto a PCB board and how to program the Arm chip. This is a plus because experience in arm processers will be very useful in the workplace.

The standard clock rate in the internal main oscillator is 24-Mhz which can be changed between 3-MHz and 48-Mhz in increments of 1-MHz. This allows for a wide variety of options when we implement the reading of data. If we do not need to use the full clock speed we can save on power allowing for us to use less of the battery, which will make it easier for the solar panel to keep the battery charged. The analog clock leads the digital clock which will let us get data from the sensors before the digital clock cycle takes place. The PSOC 4 BLE can have its voltage input be supplied from a range of 1.9V to 5.5V and connecting this directly to the digital supply (VDDD), analog supply (VDDA), and radio supply (VDDR) pins. This device has internal LDOs which allow the device to regulate the supply voltage for the correct blocks. The PSOC 4 BLE also has separate regulators for the deep-sleep and hibernation modes which allow it to consume less power. The radio turns off at 1.9V but the device is able to continue working as low as 1.71 V without the RF enabled. In Table I we can see the different allowed values for each voltage supply points bypass capacitor. These are necessary to remove noise from the voltage line to the device.

Table I: Power Supply Bypass Capacitors

Power Supply	Bypass Capacitors
VDDD, VDDA, VDDR	0.1-μF ceramic at each pin plus bulk capacitor 1 μF to 10 μF.
VCCD	1-μF ceramic capacitor at the VCCD pin.
VREF	The internal bandgap may be bypassed with a 1-μF to 10μF capacitor.

C. Bluetooth

Since we chose the PSOC 4 BLE microcontroller we are able to use the embedded Bluetooth chip on this device this helps us to implement our design by reducing the amount of hardware on the PCB board and lets us easily use the Bluetooth stack that comes with chip. It is also good from a production standpoint as the manufacturer will only have to purchase one chip that has both devices on it allowing for the overall design to save on production cost.

D. Temperature Sensor

The temperature sensor allows the Nome's baby car seat to have knowledge about how high or low the ambient temperature in the car is in order to activate preemptive measures such as activated the car and notifying the parent through the application to save the child's life. The information of knowing the ambient temperature is crucial because it will determine the activation of the subsystems of the project to save a child's life. The temperature sensor that has been chosen is built by Texas Instruments and the temperature sensor chosen reaches a temperature range of -40°C to +125°C and has a temperature accuracy of ±.5°C which is in are required specifications for this project. The TMP112 device is a digital temperature sensor ideal for NTC/PTC thermistor replacement where high accuracy is required. The device offers an accuracy of ±0.5°C

E. Load Sensor

The load sensor is the starting mechanism for the entire system to come out of a hibernation state. When the presence of any weight is felt in the car seat by the load sensor the load sensor will communicate with the micro controller to activate the system and link with the car as well as the application placed on the phone. For this project the load sensor needed to be flexible to fit the lining of the car seat as well as be shaped to the shape of the seat to cover as much area as possible for when a child is placed in the seat.

The Flexiforce 25lb load sensor made by Tekscan fit all of our requirements but has the only drawback of not having a large area sensor pad to cover the seat. This problem was promptly solved by ordering more of the sensors since they are relatively inexpensive. The Flexiforce sensor will be behind a washable cushion that is a part of the seat.

F. Battery

Figures The battery is also a key component in the power subsystem that is created for the project because it will be the main power source for the Nome's car seat during daylight hours and times of no sunlight. A lithium ion battery was chosen for this project because we wanted the capability of a rechargeable battery with a small loss in charge over time. The battery will not need a high capacity do to the low powered nature of the system.

The battery will provide the power for the entire system as well as be charged via a solar panel. Another complication that needed to be overcome was portability of the device so the choice of a lead acid battery was excluded since they are heavier than other forms of batteries. The size of the battery was also a factor since the battery must fit into the wedge housing of the car seat and must not overburden and add to the weight of the car seat. The OEM Samsung EB-L1F2HVU meets all specifications that were set by the group and is a 3.3V battery with a 1750mAh capacity. The battery will meet the requirements for use in the power system for the baby car seat.

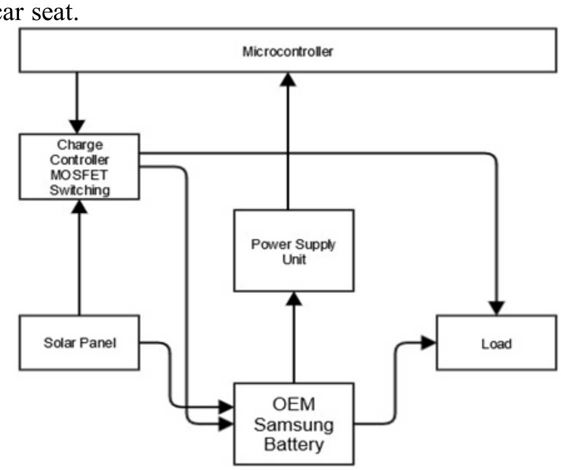

Fig. 4. Component Connections

The charge controller will be placed in the circuit along with the micro controller to prevent overcharging of the battery. The battery, solar panel and the charge controller system only have to accomplish the goal of preventing overcharging and to maintain the battery life to support the system and to make sure the system does not fail. The lithium ion battery is physically mounted inside the wedge housing with the hardware components and will be encased in a plastic resin mounting to protect it from water damage. It will be accessible if replacement has to occur for the battery and overall the area in which the battery is located is in a compact area. Figure 4 which is a drawing of the battery that displays its size.

G. Solar Panel

In this project the solar panel has become an important part of the project because it is charging the lithium ion 3.3V battery that is powering the micro-controller unit which is controlling all other subsystems in the project. The solar panel chosen was matched correctly with the battery that is used to power the system which is 3.3V and 1750 mAh in our project. The solar panel must be at least 1 Watt to be able to fully charge the battery in the time frame allocated of 12 hours.

After looking through a couple of solar panels the group has found one that is flexible and gives a charge time to the battery of 6 hours. The solar panel must produce enough power to keep the battery from discharging below the 50% capacity because this will shorten the life of the battery. The solar panel is waterproof also by having epoxy on the back contacts which will help and account for spills of liquids. The dimensions of the solar panel are 3in by 5in and can fit safely between the arm and wedge housing on the car seat. The solar panel will be able to fully charge the lithium ion battery during the day and is a 3.3V and 1750 mAh battery.

The solar panel will be mounted to the side of the baby car seat using epoxy adhesives since it will hold up against extreme heat conditions and will protect and make the solar panel waterproof. The solar panel must have the back contacts covered in this epoxy to withstand rigorous conditions that might occur from the child or extraneous conditions such as rain. Solar panels are mounted in a similar way to withstand liquid problems. The main objective that must be achieved for the solar panel is to provide enough solar energy to trickle charge the battery so that the device can run in a continuous matter without having the battery drain and the system become inoperable. This requires that the solar panel to be large enough to fully charge the battery in the 12 hour period of sunlight time and the battery must have a large enough capacity to keep the device powered. This was ensured by the choices in battery and the fact that the system draws energy in the nano watt range.

V. Software Design

A. Microcontroller

The microcontroller is controllered by the triggers that are returned from our multiple sensors. The software block diagram for the microcontroller is shown in Figure 5 and represents the specific events which will trigger the states in sequence. This also displays the overall triggers in which the microcontroller will contact the application.

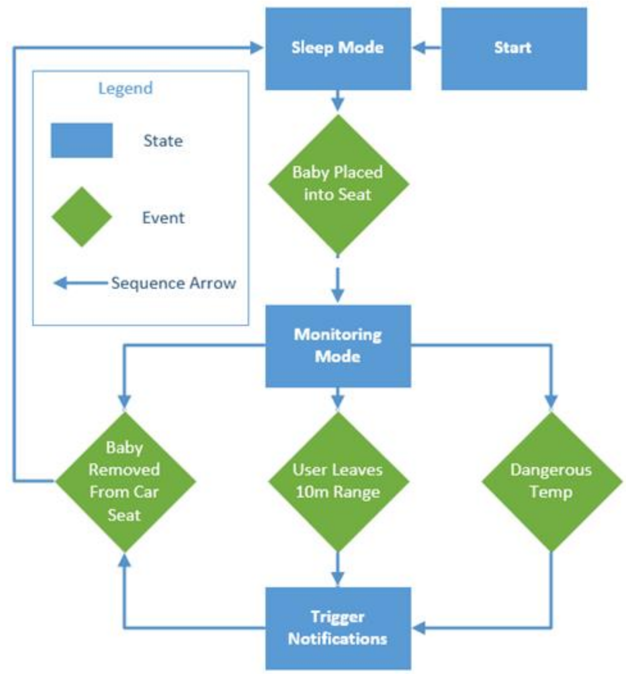

Fig. 5. Microcontroller Software Block Diagram

The device starts by initializing the sensors and verifying functionality, afterward the device enters the sleep state where it waits for the parent or guardian to place a child inside the car seat. When a child is placed inside the device enters the monitoring mode where it looks for three events. If the baby is removed from the car seat then the device returns to sleep mode. For instances where the temperature becomes dangerous or the application operator leaves the range of the device without taking their child then the device will start to trigger notifications and alarms to the application. For the notifications and alarms to cease the child must be removed from the car seat, then the device will return to sleep mode.

B. Android Application

This section is about the organization and design of the applications user interface. The software environment in which we will be developing the android application will be the free Android Studio version 1.1.0, which is the most up to date version. This software allows us to easily create an application with multiple tools available to us. When creating a new application you may select any version of android you wish and the software will notify you of the statistics of users you will be able satisfy. Our team has decided to use Version 4.0.3 which will cover about 90% of the android market allowing us to provide the maximum coverage with maximum efficiency. An example of the Android Application to be installed on the vehicle operator's phone is shown in Figure 6. This shows the loading screen as well as the main menu screen of the application.

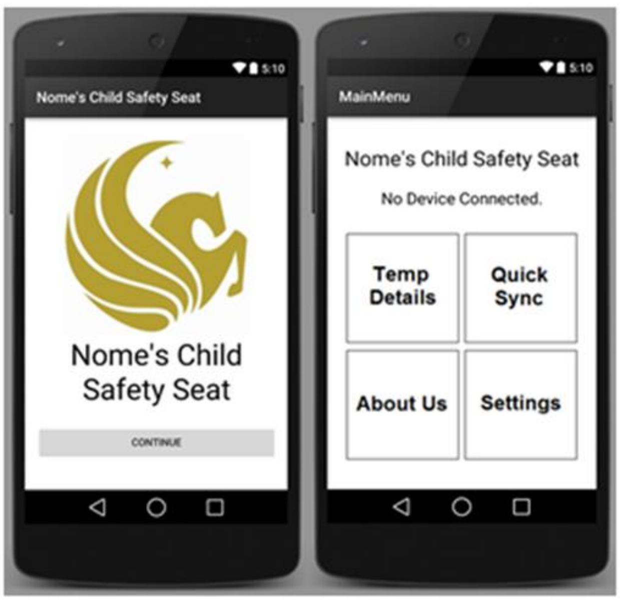

Fig. 6. Android Application Example

The application when first launch will need to be synchronized with the child car seat device. This can be done right from the main menu using the "Quick Sync" button. Other features available on the application include temperature details and custom alarm settings. The temperature menu will display the details the system is currently experiencing. The current temperature will be displayed in the center of the screen. Below this reading will be a small graphic showing the safe temperatures recommended for child safety as well as when the safety system will trigger. The "Settings" menu includes three buttons what will take the user to change their notification configuration, choose to add, remove, or modify current synchronized devices, and request assistance from the help menu. Also featured in the application is a help menu which is designed to include tips and troubleshooting techniques for any issues the user may experience.

VI. Prototype Assembly

A. Microcontroller

In order to prototype the microcontroller, a TIVA-C was used to test a basic outline of the code. This allowed us to test the states and ensure that all of our cases were handled properly. Once the code was decided, the microcontroller was ordered. The code can then be transferred with minimal effort due to the test board and the final processor both being an ARM processor. The eventual prototyping will include a development board for the correct processor where the code will be fully tested with proper sensors and then the a new microcontroller will be ordered that can be soldered to our PCB.

B. Housing

The environment in which the Nome's baby child seat will be operating is in a housing wedge. The wedge housing will be able to sustain the system in hot, dry climates or humid, cold climates and any other climates. The housing will make the system waterproof, and protect the system from surge shocks that could occur if the system was drop.

C. PCB

The PCB was originally tested using a solderless breadboard. This included connecting the test components to the board and running the program. Once the paths have all been determined and tested, a PCB will be printed. The PCB will be designed in EAGLE since most companies will accept a design that was made using that product. An additional step that may be used will be for us to use a toner transfer method to print our own PCB. The toner transfer method is a relatively simple method used for rapid prototyping.

The process begins by printing an inverted image of the traces. Then the printout is placed on a blank PCB and heat is applied so the toner transfers from the paper to the blank PCB. Once all of the traces have been applied, the blank is submerged in a chemical that will remove any copper that is not coated with toner. Once that process has completed the board will have the proper traces but with toner covering them. A second chemical will be used to remove the toner. Once that process has completed, the board will be ready for the holes to be drilled and used.

VII. Testing

The following section contains an overall look at the hardware testing plan, in order to ensure that the final prototype's hardware subsystems achieve all objectives and fits all specifications that have been designed. The Nome's Child Safety Seat Project will strive to thoroughly test its iterative prototyping phases that increasingly functional systems. A system will be generated from the knowledge of constructing the device and testing each subsystem of the device.

To ensure that the finished product will work the way it was intended to function product testing is used an essential tool. To develop a successful test plan for the power system, the overall objective of system must be considered. In this design the power system will provide energy to all of the other subsystems which include the micro-controller, load sensor, and the temperature sensor. In maintaining the battery the battery must not be overcharged or deep discharging the battery. The charge controller will operate to turn off the current from the solar panel once the battery has reached an optimal charge which is around 80% of its capacity to extend battery life. The battery, charge controller and solar panels will be connected together to test the power system for the car seat. When the battery has reached the optimal charge as explained the charge controller will shut off the charge coming from the solar panel to the battery.

To test the solar panel and to make sure that it is operating properly during normal operation in direct sunlight it must output a 6V during this time to effectively charge the battery in the power system. This factor is easily tested by setting the solar panel in direct sunlight outside and measuring the voltage of the solar panel which should be giving off 6V consistently if working properly. Since the power system will not be on constantly due to the built in nature of the system being sleep with no weight present to trigger the system there is no need for an extensive 24 hour period of testing the battery. In the need that this needs to occur the battery is left fully charged alone for a 24 hour period and when returned to the battery should still output 3.3 V with an error of no more than 5% due to discharge.

Once all the components are connected together the current and voltages of the battery and the solar panel can be connected and the charge controller can be tested if it is operating properly. When tested there should be a flow of current going into the battery verifying that the solar panel is charging the battery correctly.

VIII. Conclusion

The Nome's Child Safety Seat is an insert for a child's car seat that allows the monitoring of the child and provides awareness options to remind the vehicle operator not to leave their child in the vehicle. The insert device will communicate with a smartphone application via Bluetooth and provide multiple stages of attention grabbing techniques to the owner. In critical situations the device will assume control of the vehicles onboard features in an attempt to save the lives of the child.

Our team reached this design though multiple forms of research and data gathering from our future consumer market. The industrial engineers and business team developed statistics and marketing surveys to identify the need for such a safety device. Upon reviewing the statistics our team concluded that the main problem was not only saving the children but also that the parent or guardians were actually forgetting their children on a psychological level. Now that we clearly identified the problems we were facing we were able to identify and create a targeted performance platform for which to begin further design. After reviewing current safety systems on the market we developed features that would not only make our product stand out but that were better suit the targeted consumer audience.

With a clear design in mind we began comparing components looking for the specific part that this design required. Parts were chosen based on their functionality and reliability under the situations that they will be required to work in. Being a safety system we spent extra time making sure that the parts were indeed reliable because if the system fails to trigger it could mean losing a life. The device will alert the owner in three increasing stages of alerts. The first alert is via the smart phone application where will alert the parent or guardian via text, noise, and vibration to remind them to go back. The second stage of alert involves honking the car horns, and alarms to alert nearby people. The final stage is for emergency situations when the temperature reaches dangerously hot or cold for the infant and the system will turn on the vehicle and use the air conditioning to raise or lower the temperature inside the vehicle accordingly.

Acknowledgement

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References

[1] NHTSA Child Seat Research. (n.d.). Retrieved March 30, 2015, from http://www.nhtsa.gov/Research/Child+Seat+Research

[2] Null, 'State Totals', Ggweather.com, 2015. [Online]. Available: http://ggweather.com/heat/state_totals.jpg. [Accessed: 30- Apr- 2015].

[3] Diamond, D. (2014, July 12). Op-ed: Can parents really forget kids in cars? Retrieved from HLN: http://www.hlntv.com/article/2014/06/30/cooper-harris-child-dies-hot-car-why-parents-forget

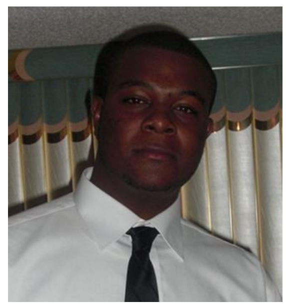
[4] Processors.wiki.ti.com, 'Texas Instruments Wiki', 2015. [Online]. Available: http://processors.wiki.ti.com/index.php/Main_Page. [Accessed: 30- Apr- 2015].

ENGINEER'S BIOGRAPHY

Matthew Bivona is currently a senior at the University of Central Florida and will be receiving his Bachelors of Science in Electrical Engineering in August of 2015. He is currently searching for a job dealing with consumer electronics. Matt plans to further his degree by attending college for his Masters in Business after 5 years of work experience. Then plans to manage engineers in the department.

Michael Covitt is currently a senior at the University of Central Florida and will be receiving his Bachelors of Science in Computer Engineering and a minor degree in Information Technology in August of 2015. He is currently searching for a job in his hometown where he can be close to family. He hopes to find a job working in the Florida Memorial Hospital in Ormond Beach alongside his fiancée. Michael has no plans to further his enducation in the engineering field however a degree is culinary is not out of the question.

Jason Nagin is currently a senior at the University of Central Florida and will be receiving his Bachelors of Science in Computer Engineering in August of 2015. When he graduates he plans to continue working at his job as a Computer Repair Technician at the College of Sciences. Jason is not planning on furthering his education or advancing his degree.



Donnell Robinson is currently a senior at the University of Central Florida and will be receiving his Bachelors of Science in Electrical Engineering in August of 2015. He has attended the University of Central Florida for four years and plans to work for Lockheed Martin in Texas at an aeronautical instrumentation lab. After completing one year he will go back to college to obtain a masters in Electrical Engineering. My primary interest lie in instrumentation of aircraft and power digital signal processing.