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Baby Smart Seat

ICOM 5047

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Abstract

This document proposes the creation of a tool to prevent accidents caused by parents who forget their children inside a vehicle. This tool is called Baby on Board Smart Seat and it is equipped with temperature and CO sensors to prevent children's deaths due to hyperthermia or CO intoxication. Furthermore, Baby Smart Seat will provide a 24/7 service, which consist of a control center that will monitor every Smart Seat and will notify authorities if the parent does not respond to the alarm on time. These functionalities will be done using two devices, one that goes in the car seat and the other is a key chain. The proposal will present information about the design elements that are needed for the implementation of the system including hardware and software specifications, milestones, budget plan, objectives, and so forth.

Table of Content

Executive Summary

Baby Smart Seat System is a product that aims to help parents avoid forgetting their children inside their vehicles. The system will also help to prevent cases of hyperthermia and carbon monoxide intoxication of children in vehicles.

The system consists of two main devices, one that is attached to the car seat of the child and one for the parent's key chain. The device in the car seat will detect when the child is placed on it and will start a communication with the key chain. This will allow the system to detect if the parent walks away from the car, while the child is still on board. Also, the car seat device provides monitoring of the temperature and carbon monoxide levels, and will alert the parent when these factors are not safe for the child. To reinforce the safety of the infant and provide necessary attention, every alert will be sent to a Control Center where an employee will be in charge of contacting parents or pertinent authorities.

At the end of the project there will be four prototypes including the parent's unit, car seat device, a workstation application for the Control Center and a web application. The control center application will receive any alarm activated in the system and will display the contact information of the parent including the location where the alarm was triggered. The web application will allow parents to enter and manage their contact information and product information to complete the registration of the device. In addition to the prototypes, planning report, design report, progress report and final product documentation will be provided.

The software and hardware design should be completed for the week of March 14th – 18th. The design includes schematics of circuitry, code flowcharts and a detailed product specification. The implementation of every individual module is expected to be delivered by the week of April 11th – 14th. The integration of the modules should be completed by the week of May 2nd – 6th and at this point the prototypes should be working as a whole to finally conclude the product (Appendix IV).

The total cost of the implementation of this project will be $55,743.84; this amount includes the cost of the components and the payroll for every team member (Table 4 of Budget section). With a suggested selling price of $75 and a monthly payment of $20 for the Control Center Support during a period of 4 years, the prototype investment and device manufacturing cost should be recovered after the sale of 320 units (Appendix V). Similar products in the market provide less functionality as standalone devices for a retailed price of around $150.

Introduction

Last year, in the United States, hyperthermia occupied the second place for infant deaths with 33%, followed by 18% of infants struck by vehicles [1]. The 54% of the parents in these cases had intentionally left the child in the car, underestimating the risk; whereas 46% had simply forgotten the child was with them while driving to work or coming back home [2]. Netherland, Iceland and Hungary have also reported fatal cases of hyperthermia as the result of children being left in cars. "The truth is that infants die of heat stroke for being left in a vehicle far more frequently than anyone might expect" [2]. Most of the victims of hyperthermia incidents in vehicles are between 0 – 4 years of age [3]. Heatstroke occurs when a person's temperature exceeds 104 degrees Fahrenheit and their thermoregulatory mechanism is overwhelmed [4]. A parked car on a warm day can quickly become a dangerous place for an infant. Children's thermoregulatory systems are not as efficient as an adult's and their body temperatures warm at a rate 3 to 5 times faster than an adult's [4]. Some days, it takes only 30 to 45 minutes to kill a little one left inside [5]. A car heats up quickly, even in the morning when the sun isn't yet properly heating up the air. Not even cracking a window will lower the temperature [4].

Cars are inappropriate places for children to be left without adult supervision [6]. There are systems already installed in people's vehicles to warn them that they have left the headlights on or the keys in the ignition. Children deserve at least that same protection. These tragic incidents are entirely preventable.

That's how Baby Smart Seat was born. The system consists of two principal modules; one for the car seat and one for the parent's key chain. The car seat device will by detecting if the child is seated in the car seat or not. If the child is seated it will automatically awake the system. Once the system is awake it will immediately start scanning the baby´s surroundings. This device will be able to read temperature and carbon monoxide level inside the car. A carbon dioxide sensor will not be included because no data was found to indicate any child's death due to carbon dioxide intoxication. In case that the parent left an established perimeter around the car, the key chain device will immediately activate an alarm that will indicate the parent that the child is still inside the vehicle. The alarm will keep ringing until the infant is removed. The key chain device will also activate an alarm if the temperature or the carbon monoxide levels are too dangerous for the infant. Another important feature about the Baby on Board Smart Seat is the 24/7 vigilance service. In case the parents are not able to reach the child in time, an employee in a control center will be informed and will be able to call the parents to notify them that their child is in danger. If the parent does not respond, the person at the control station should be able to notify the authorities and give them the location of the car using a GPS system.

Baby Smart Seat takes advantage of technology to bring a solution for this problem and help to save lives. It brings to the customer a tool that will help prevent them from making a mistake that may endthe life of an innocent child.

Problem Statement

A change in routine, a distraction or accidents are some of the main reasons of why parents forget their infants inside of a vehicle [4]. In 2010, hyperthermia constituted the second most common type of infant deaths preceded by back- over. The system will address this matter by alerting the parents when they leave the baby on board and walk away from the vehicle. Another concern is the temperature inside the vehicle. In this case the system will monitor the temperature around the baby and alert the parent when the temperature is not safe. In the same way, the system will monitor the level of carbon monoxide around the baby and alert the parent when the baby is exposed to high levels of this substance. Lastly, since every alert will be made from a small device attached to the key chain, and often the keys of the vehicle can be missing, the system will send every alert made to a control center where a personnel will be able to locate the vehicle via GPS and call the parent or pertinent authorities in case of an emergency.

Project Antecedents

Project Background

The Baby on Board device is an implementation that has been brought from the Microprocessor Interfacing Course (ICOM5217) of the fall semester of 2010. The previous implementation had two devices, one is at car seat and the other is a key chain. The system detects if the parents walk away from the car seat and determines if the temperature is dangerous for the infant. The improvements that will be implemented as part of the actual product will be:

- A reduction in the power consumption of the system.
- A reduction in the size of the key chain.
- A monitor to determine the battery status.
- A single power supply system.
- A more accurate temperature sensor.
- A carbon monoxide sensor.

For more information related to the project background, refer to the final report submitted as a requirement for the ICOM5217 course that can be found in Appendix VI.

Market Overview

Baby Smart Seat's potential customers are parents with kids in the ages from 0-4 years old. The interviewed clients were Angelica Torres and Wildalys Carrasquillo, and the interview details can be found in Appendix 1. There are similar products in the market like the NASA's child car seat safety device with a price of $30. This device only has the feature of detecting if the parent is far from the vehicle. Another similar product is the Halo baby seat safety system. It has an estimated retailed price of $149. The halo baby safety system contains the feature of detecting if the parent is far from the car; it also detects if the temperature is dangerous for the baby. Baby on Board smart seat has an estimated retailed price of $75 (Appendix V). Baby on Board as a standalone device will contain the features of detecting if the parent is far from the vehicle, detecting if the temperature and the carbon monoxide levels are dangerous for the infant. Neither the Halo baby seat safety system nor the NASA's child car seat safety seat contains the feature of determine if the carbon monoxide levels are dangerous. Additionally with a monthly payment of $20 Baby on Board will provide a 24/7 vigilance service. Compared to other systems Baby on Board smart seat provides better features than the products mentioned before and with a lower price than the Halo baby seat safety system.

Potential competition

***NASA's child car seat safety* device** [6] **– Price $30**

- Features
  - The NASA device, inspired by aircraft flight test technology, uses precision materials and electronics to sense when a child is seated in a car infant or booster seat after the driver has left the vehicle.
  - The Child Presence Sensor driver alarm, designed to hang on the driver's key ring, sounds ten warning beeps if the driver moves too far away from the vehicle. If the driver doesn't return within one minute, the alarm will beep continuously and cannot be turned off until it is reset by returning to the child safety seat.
  - The sensor detects weight once the child is placed in the seat, transmitting a unique code to the driver-alarm module via a radio-frequency link.
  - The system incorporates a long-life battery for reliability. If the battery is low, the system alerts the driver with an audible alarm.

The Halo baby seat Safety System [7] **– Price $149**

- Features
  - When the baby is placed in the car seat the system is activated.
  - If the driver exits the car without removing the baby from the car seat, an alarm sounds on the key pod.
  - This reminds the driver that the baby has been left in the car.
  - If the temperature in the car becomes dangerously hot or cold for baby, an alarm will again sound on the driver's key ring.
  - If the driver does not hear or respond to the alarm within a predetermined elapsed time a louder alarm, using a voice synthesizer, saying "Baby in Danger" will activate from the seat pad itself, hopefully alerting a passerby to the situation.

Competitive advantage of Baby Smart Seat system

- Baby Smart Seat system is aimed to prevent parents from forgetting their children inside a car.
- Baby Smart Seat system helps to establish a safety environment around the baby.
- Unlike other product Baby car safety system will provide a control center. This feature will enable the ability to track the position of the car seat in case that parent does not respond.
- Baby on Board system will provide a monitoring system. This feature provides the ability to inform the police the location of the car seat if the parent doesn't respond to the emergency call.

Economical analysis

The "US Market Review about baby durable" tells that the market stands to gain from conducive demographics, such as, older parents with higher discretionary spends, dual income households, and the increasing number of women in the workforce, and rising and uncompromising emphasis on child safety, health and wellness, as well as growing awareness on the correct approaches to parenting [8]

Another thing that the US Market Reviews tells is that the market is supposed to increase sales even though the birth rate is slow. Parents are willing to buy expensive, eco-friendly, high-end products for their infants, and toddlers [8]. Maybe this is because now more and more parents are deciding to create a family after they are financially stable.

Baby on Board offers some features that the other products don't. This feature is the 24/7 vigilance that provides additional security in case the alarm is not heard or something else happens that prevents the customer from remove the baby from the car.

Standards

The final system should comply with the following standards:

FCC Policy on Human Exposure to Radiofrequency Electromagnetic Fields

"The FCC is required by the National Environmental Policy Act of 1969, among other things, to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. Several organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields." [9]

US DoD Releases Updated Global Positioning System Standard

"The Department of Defense released a new GPS performance standard. The new performance standard codifies a change announced last year to discontinue DoD's ability to decrease GPS accuracy. DoD, as operator of the GPS, now provides civil users a horizontal positioning accuracy of 36 meters, compared to 100-meter accuracy in the previous edition of the standard, which was published in 1995. DoD also promises to notify the civil user community whenever serious or unforeseen problems could affect the new performance level. Future improvements to the system are projected to include new civil codes to correct for ionospheric distortion and to assure continuity of service." [10]

Consumer Product Safety Commission (CPSC) The Dangers of Electric Toys

"Electric toys and other electrically operated products intended for use by children can be extremely hazardous if improperly used, used without supervision, or not properly designed and/or constructed. The possible dangers are many: electric shock, burns, especially if the product has a heating element; and a wide variety of mechanical hazards common to toys in general, such as sharp edges and points and dangerous moving parts." [11]

Objectives

- Design and implement a device to be installed in a car seat to detect if an infant is seated on it and monitor if the temperature inside the vehicle is safe for the infant and if the level of carbon monoxide is acceptable.

- Design and implement a wireless device that trigger an alarm to notify parents when the infant is seated in the car seat and one of the following events has occurred:
  - The parents have left an established perimeter around the car seat.
  - The car seat device has detected that the temperature is not safe.
  - The level of carbon monoxide is not acceptable.

- Design and implement an application that provides to employees in a Control Center, information about the event that triggered the alarm and contact information of the owner of the car seat device.

- Design and implement a web application for the clients (parents, caregivers or tutors) so they can manage their contact information and register their "Baby Smart Seats".

Product Specifications

System overview and block diagram

Smart Car Seat is divided in three major modules as shown in Fig 1. A device in the backside of the car seat will provide sensors that monitor temperature and concentration of Carbon Monoxide inside the vehicle. The presence of the infant, will be determine using an array of force sensors strategically positioned on the car seat in order to avoid false detections. In addition, the parents will have a key chain that when they get far away from the car seat module or one of the sensor measures a condition out of the established parameter, this device should initiate an audible and a visual notification. Moreover, the car seat module should get the location of the vehicle using a GPS device, and send the coordinates and information about the conditions that triggered the alarm, to a Control Center using the GSM Network. The Control Center is in charge of managing alarms and providing necessary information to representatives, so they can contact the parents or pertinent authorities.

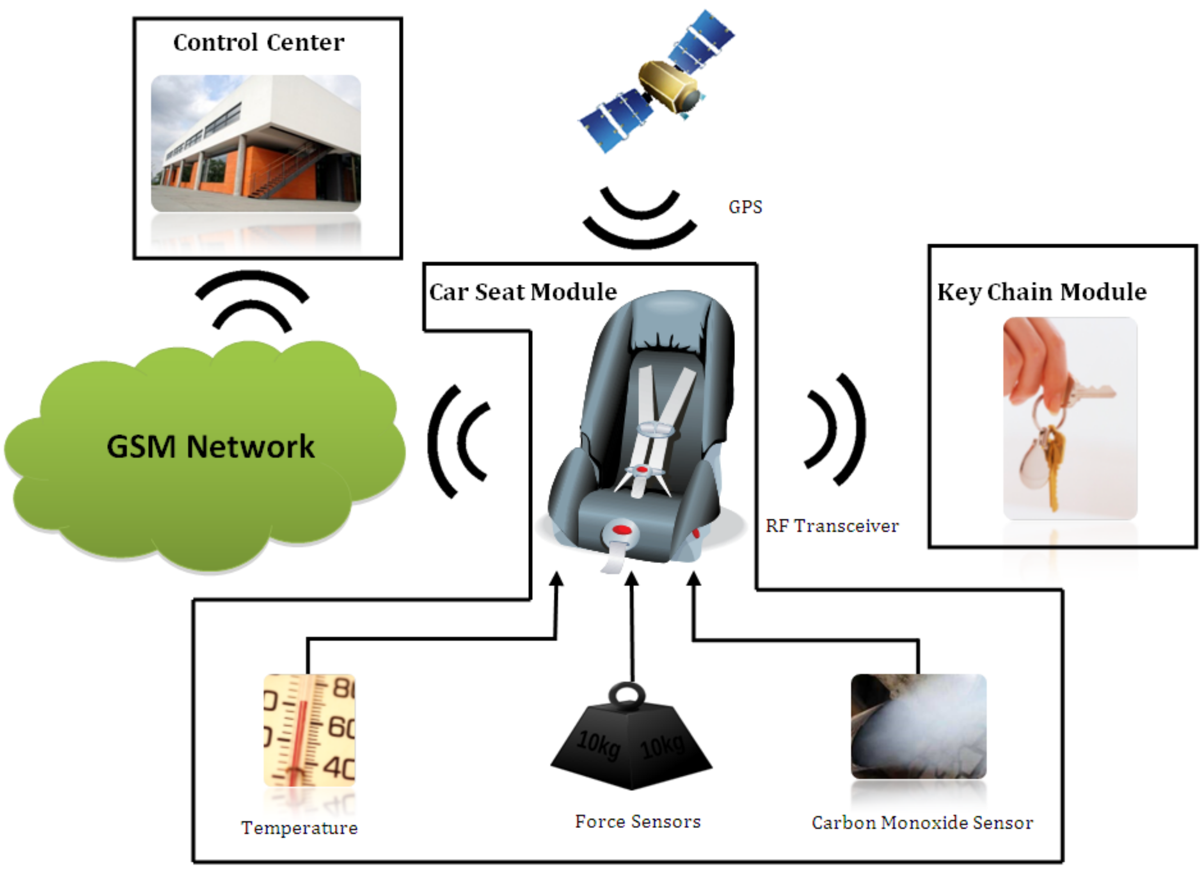

Fig 1– System Overview Diagram

Hardware Specifications

Key Chain Device Block Diagram

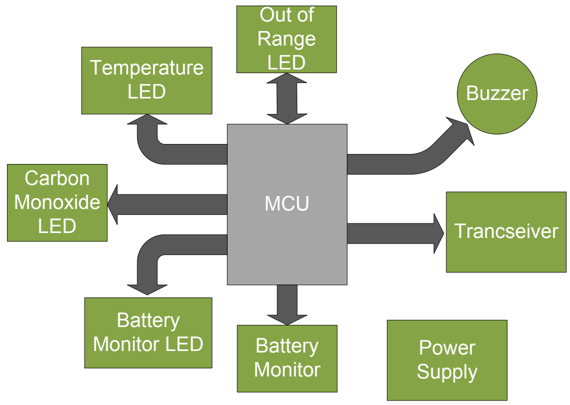

Fig 2 – Key Chain Block Diagram

Key Chain hardware components

- Buzzer - The buzzer will produce an alert sound in case an alarm is activated.
- Temperature, LED- This LED will blink in case a temperature alarm is activated.
- Carbon Monoxide, LED- This LED will blink in case the carbon monoxide alarm is activated.
- Battery Monitor, LED- This LED will blink in if the low battery alarm is activated.
- Out of Range, LED- This LED will blink if an alarm is activated because parent has left the establish perimeter.
- Transceiver- The transceiver will establish the communication between the key chain device and the car seat device.
- Power Supply - A battery will provide power to the key chain device.
- Microcontroller - In charge of controlling the key chain device.
- Battery Monitor - Read the level of charge of the battery.

Key Chain firmware

- When the device is turned ON, the microcontroller will enter in low power mode to save the battery life until it receives a message from the car seat device.
- If the key chain device receives a message indicating that the temperature is dangerous, an alarm will be activated.
- If the key chain device receives a message indicating that the carbon monoxide level is dangerous, an alarm will be activated.
- If the key chain device receives a message indicating that the battery level is low, an alarm will be activated.
- If the key chain device does not receives a message in certain time, alarm will be activated indicated that the parent is out of range.

Car Seat device Block Diagram

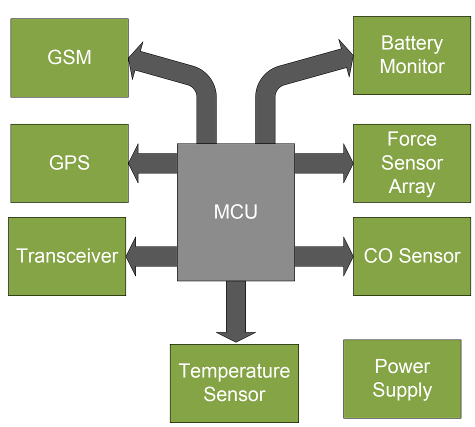

Fig 3- Car Seat Block Diagram

Car Seat Hardware components

- Force Sensor Array - This sensor has the task to detect the presence of the baby.
- Temperature Sensor - Determine the temperature around the baby.
- Carbon Oxide Sensor - Determine the levels of CO around the baby.
- Transceiver - The transceiver will create a safety perimeter around the baby. Also it will send constant information about the surrounding of the baby.
- Microcontroller - In charge of controlling the car seat device.
- GPS* - Is in charge of tracking the position of the car seat.
- GSM* - Will establish communication with the car seat device and the control station.
- Power Supply - A battery that will provide power to the car seat device.
- Battery monitor - Read the level of charge of the battery.

** Issues related to non signal use cases, will be discussed during design stage*

Car Seat Firmware

- When the device is turned ON, the microcontroller will enter in low power mode to save the battery life until a message is ready to be sent.
- The device should send data every 30 seconds to the key chain device.
- The device will determined if the infant remains on the car seat.
- The device will read the temperature level around the car seat and determine if it's dangerous for the infant.
- The device will read the carbon monoxide level around the car seat and determine if it's dangerous for the infant.
- After the data is ready the transceiver will transmit the pertinent data to the key chain device.
- If an alarm is activated the car seat device will send a notification to the control center.
- The device will turn off once the infant is removed from the car seat.

Hardware Considerations

Power Consumption

Baby on Board is a portable device, that means that it run with batteries. Not taking into account the power dissipation of our device could end in the death of a baby. For that the reason all components that will be chosen to be a part of the device should be low power. Previously Baby Smart Seat contained a uOLED display that showed an alarm message. This display will be removed from the key chain device, in order to reduce power consumption. The Baby on Board smart seat will use low power MCU's.

Low Cost

Baby on Board is a device that will be created to accessible for people from different economic levels, therefore one of our main concerns is the price. For this reason all components will be chosen taking the price into consideration. Also removing the display will decrease the price of the device significantly.

Software Specifications

Control Center

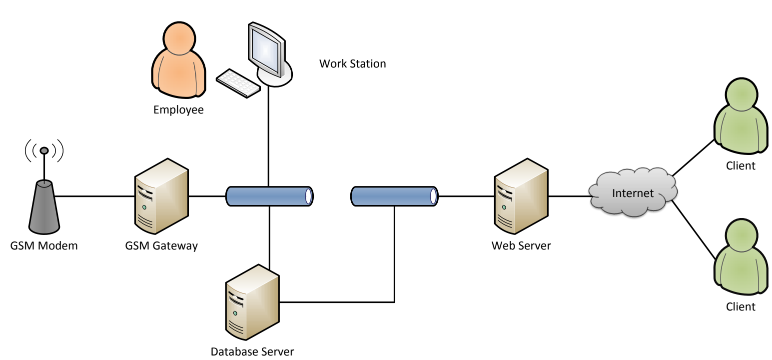

Fig 4- Software architecture: Control Center

As shown in figure 4**,** the Control Center consists of the following elements:

- GSM Modem - Receive Text Messages coming from the car Seat units
- GSM Gateway - Takes the information received from the text message and stores it in a Database.
- Work Stations Application - Provide a graphic user interface to employees that are in charge of monitoring the alarms. Provide visual and audible notifications when an alarm is received. Access clients profile to get contact information
- Database Server - Stores Clients profiles, registration of the car seat devices and information related to alarms received
- Web Server -Host the web application that is used by clients to introduce and maintain their contact information. Provide an interface to register the Car seat unit. Product Information and quick guides will be presented in this web site

Software Considerations

The Control Center must ensure that every alarm is processed with a respond time less than 10 minutes [4] in order to ensure that there's enough time for the authorities or the parent to attend the infant on time. User interface for employees must be simple and intuitive. Necessary information must be available with a minimum of latency. Client profile and Car seat device registration, cannot take too much time to be completed and the interface must be simple.

General Approach

Managerial Approach

Meetings and Work Hours

The team will have meetings three times a week and work hours every day, whenever possible. These meetings will be held Monday, Wednesday and Friday at 2:00 pm and will have duration of approximately 1 hour. After the meetings, the team will work from 6:00pm to 8:00pm. Also, the team will work Tuesdays and Thursdays from 5:00pm to 7:00pm, working a total of 2 hours a day weekly.

Team Management

The team will meet during scheduled meeting time on Mondays, every week, to report task progress, following an Agile Software development methodology [12]. During Wednesdays and Fridays meetings, changes to design or implementation, decisions and concerns, if any, will be discussed and voted on. These will keep the project manager up to date on task progress and changes on the project and they will help problem solving and addressing concerns among the team members.

Team Organization

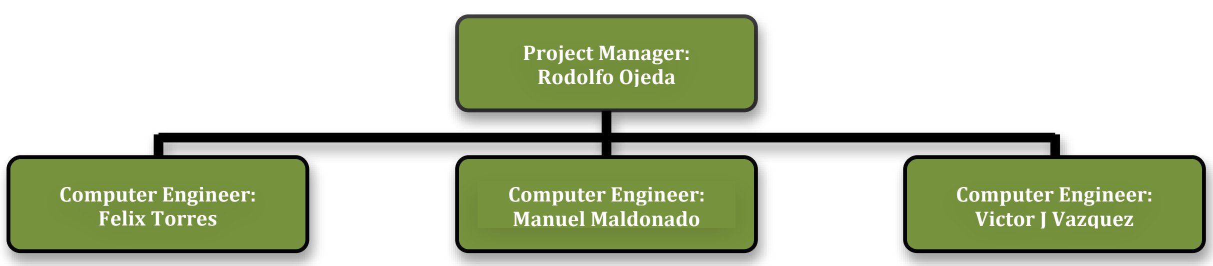

Fig 5 - Organization Breakdown

Biographies of team members

Refer to Appendix II.

Testing Restrictions/Scope

This testing Chart presents different test scenarios, steps and expected results of the Testing Phase, dividing it into three sections: Module Testing, Integration Testing and Unit Testing. The Module Testing section will be done right after each module is implemented and both the Integration and Unit Testing will be done after all modules have been implemented. Finally, a percentage is also stated to track progress of each section and the entire Testing Phase of the project.

Phase	Type	To be Tested	Test steps	Expected Result
Module Testing **30%**	Temp. Sensor **2%**	Sensor measures correct values of Temperature.	Measure known temperatures. Verify correct values.	Accurate measurement of known temperature.
	Carbon Monoxide Sensor **3%**	Sensor measures correct values of Carbon Monoxide.	Measure different Carbon Monoxide levels in a control environment and compare measurement with real values.	Carbon Monoxide levels measured should be accurate with the real levels of Carbon Monoxide present.
	Force Sensor **2%**	Force sensor activates when pressed.	Manually apply known amounts of force until sensor activates.	MCU will acknowledge the force sensor's signals. Value of amount of force needed is correct.
	RF Transceivers **2%**	RF Transceiver distance from Car Seat.	Walk away to known distances until Transceivers link is broken.	Distance Alarm should be triggered after link between transceivers is broken.
		RF is able to transmit and receive data.	Send known packages of data between transceivers.	Data is successfully sent and received on the other transceiver.
	Battery Monitor **4%**	Monitor measures correct battery level.	Compare measurements done using the installed Battery monitor and compare values with an external battery monitor to compare them.	Take measurements of different, known, battery levels and compare to real values.
	GPS **4%**	GPS gives correct coordinates.	Acquire different coordinates from the GPS and countercheck they are correct as per Google Maps.	Able to receive coordinates from GPS and compare with real ones as per Google maps.
	GSM Modem **5%**	GSM modem on car seat is able to send data and GSM modem on back en is able to receive data.	Manually trigger events to be sent to Control Center and verify if events are being sent from MCU to GSM and those same events are being received on the backend GSM modem.	Able to receive Data on the backend sent from the Car seat device.
	Database **1%**	Able to run queries and Web Application and Workstation application connect to it.	Query the database and receive the correct/expected information.	Database is properly configured and Web application and Workstation application are able to access it.
	Web Application **2%**	Connect and login to Web Application.	Web application and Workstation application are able to access the DB with the correct credentials.	Web application is accessible from the open internet. Users are able to create, retrieve and alter their profiles.
			Being able to create a profile, retrieve profile information and login and logout.	
	Workstation Application **3%**	Able to process events.	Generate manual events and document software output and responses of such event.	Workstation application receives events the dummy events and it is able to process them.

	Keychain Re-design **1%**	Keychain is operational as per designed.	Set custom values for Battery level, Carbon Monoxide, Temperature and distance to trigger the different alarms.	Keychain alarm, buzzer and LEDs work, when threshold values are reached for distance, Carbon Monoxide, Temperature and Battery level.
	Car Seat Re-design **1%**	Car seat is comfortable and easily manageable.	Manually stress chair for sturdiness, installed parts should not move.	Car seat is operational, parts are safely attached and design is sturdy and comfortable.
Integration Testing 50%	Carbon Monoxide Alarm **10%**	Alarm is triggered when CO levels are over safe threshold.	Seat a baby/child and verify the seat is comfortable for both child and parent. Verify Force Sensors are in place and don't move. On a controlled environment, inject a known level of CO that will go over the safe threshold.	CO Alarm will be triggered on the Key Chain if the car seat is activated.
	Temperature Alarm **5%**	Alarm is triggered when Temperature is over/under safe threshold.	Manually raise temperature over threshold.	Temperature Alarm will be triggered on the Key Chain if the car seat is activated.
	Parent Alarm **5%**	Alarm is triggered when parent with keychain is out of range of the car seat.	Manually lower temperature over threshold. Activate car seat and move keychain out of range.	Distance Alarm will be triggered on the Key Chain.
	Sending Events **10%**	After an event, it's information plus GPS information will be packaged and sent to Control Center to be stored on the DB.	Make a custom script that will kick off an event, and verify if the event was sent, received on the Control Center and stored on the DB.	Event information appears on the DB with the correct information packaged.
	Workstation Event Handling, **10%**	Workstation will receive events to be handled. Able to access/alter user data.	A pre-defined event will be saved on the DB for the Workstation to handle.	Workstation receives event and handles it according to flowcharts.
	Web application profiles **10%**	Clients will be able to create, update and delete profiles. These changes will be stored on the DB.	Create multiple dummy profiles, change values and store changes.	DB should reflect every change done.
Unit Testing 20%	Alarms handling **20%**	For CO, Temp and Parent distance alarms, an event will be triggered and sent to the Control Center for handling.	Client will create a profile. Different alarms will be triggered using the Integration testing section as guide, then, the specific event should be received on the workstation to be processed.	Each specific event should reach the workstation.

Table 1- Testing Restrictions

Design and Documentation standards

During the design and implementation phases of the project, a series of design and documentations standards will be followed. Unified Modeling Language (UML), Workflows and Flowcharts will be used to model Firmware and Software behavior and an Entity Relation model (ER diagram) will be used to represent database schema. For hardware schematics, the IEEE std. 315 for Graphic Symbols of Electronic components will be used. During the implementation phase, JavaDoc will be used for documenting Java code and Doxygen will be used for documenting C, php, html and any other script that may be needed.

Schedule

Work Breakdown Structure

Project stages where distributed throughout the schedule following the schema presented on the milestone section. The First stage starts with the requirement acquisition and proposal writing. With the proposal accepted, the team leaders will design the modules that were assigned to each of them. This milestone finishes with the first Oral Report where the system design is presented to clients. The implementation is divided in the same way of the design stage where the team leader provide most of the implementation of his assigned modules, but will have additional workforce provided by the supporting members specified for each module. The implementation process for every module consists of the interfacing of necessary component, programming, calibration if necessary and finalizing with testing and refining. This stage finishes with the second oral report, which requires that every module works properly as established in the testing plan. The next stage consists of the integration of modules into corresponding device (Key chain, Car Seat and Control Center) and complete testing and refining process for each one. An important part of the schedule will be dedicated to the integration of the Keychain device with the device on the car seat, and the integration of the Control Center with the device on the Car Seat. An overall test will be done to ensure that every device meets the requirements and work properly before the presentation of the third oral report. The project will finish with the deployment and client acceptance.

Tasks that were considered to be very time consuming and constitute important dependencies, where placed early in the design and implementation stages to take them out of the critical path, leaving minor risk tasks to be part of it. For this purpose we used the prioritization schema specified in the Resources Assigned section of the proposal. During the rest of the stages, since most of the tasks are performed serially, respective tasks are part of the critical path.

The details of the work assignment, timeline and critical path, are specified in Appendix IV.

Personnel

Personnel Skills

- **Has Knowledge (HK):** This person has the knowledge to complete assigned tasks. If needed, he can seek expert advice with the information provided bellow.
- **Training Needed (TN):** This person needs training to complete certain tasks. Training and expert contact information for consults are provided bellow.

Skills required for the project	Felix Torres	Manuel Maldonado	Rodolfo Ojeda	Victor J Vazquez
PIC family Microcontroller	**HK**	**TN**	**HK**	**TN**
GSM Modem Communication	**TN**		**TN**	**TN**
GPS system		**TN**		**TN**
SMS & SMPP Protocol	**TN**		**TN**	**TN**
Web Application development	**TN**	**TN**		
Database creation & Management	**HK**	**HK**	**HK**	
Java Development	**HK**	**HK**	**HK**	**HK**

Table 2 - Skills required for the project

Training Information:

- PIC family Microcontroller, *self-teaching*:
    - PIC specific Data Sheet & Family Guide
    - Web tutorials
    - **Consult experts**
        - *Manuel Jimenez (PhD)*
- GSM Modem Communication, *self-teaching*:
    - GSM model's data sheet & Guide.
- GPS system, self-teaching:
    - GPS model's datasheet & Guide.
- SMS & SMPP Protocol, *self-teaching*:
    - SMS & SMPP protocol specification sheets & Guides.
    - Web Tutorials.
- Web Application development, *self-teaching*:
    - Web tutorials.
    - ***Consult experts***
        - *Manuel Rodriguez*
- Database creation & Management, *self-teaching*:
    - Book: Database System Concepts. 5th Ed.
    - Web tutorials.
    - ***Consult experts***
        - *Manuel Rodriguez*
        - *Amir H. Chinaei*
- Java Development, *self-teaching*:
    - Book: Java Concepts. 5th Ed.
    - Web tutorials.
    - ***Consult experts***
        - *Prof. Pedro I. Rivera*

Project skills and Resources Assigned

- **Team Leader (TL):** The team leader is the person who will respond for the specific task and has the responsibility to inform the progress of such task to the Project Manager and other team members.
- **Supporting Member (SM):** The supporting member is the person who will work side by side with the team leader and is responsible for the task if the team leader cannot be present.

Knowledge required for the project	Felix Torres	Manuel Maldonado	Rodolfo Ojeda	Victor J Vazquez	Priority
Data Acquisition:					
• **Temperature sensor**	SM		**TL**		500
• **Force sensor**	SM		**TL**		500
• **CO sensor**	SM	SM	**TL**		700
• **Battery Monitor**	**TL**	SM			700
• **RF Transceiver**	**TL**	SM			700
• **GPS**		**TL**		SM	800
GSM Installation	SM			**TL**	**900, 800**
GSM Gateway			SM	**TL**	650
Database	**TL**	SM		SM	800
Web Application	SM	**TL**			700
Workstation Application	SM		**TL**	SM	700
Keychain Re-design	**TL**			SM	500
Car seat Re-design		SM	**TL**		800

Table 3 – Resources assignation

Resource Requirements

Technical Resources

The resources that will be provided by UPRM are listed below:

- Computers.
- Servers with Java Virtual Machines running.
- Web Server.
- Database software and staging.
- PIC Debugger tools.
- Software, such as, Eclipse, NetBeans, MPLAB, MS Office and MySQL Workbench.
- Soldering stations.
- Multi-meters.

The team will provide additional resources that UPRM cannot provide including hardware components specified in the *Budget, List of components* section.

Budget

Project Costs

Information related to payroll of professionals and project total costs are presented as follow:

Employees	Position	Annual Salary [13]	Annual Benefits*	Total Annual Compensation	Cost Hour	Hours dedicated to Project*	Payroll per Employee (Without Overhead)
Rodolfo Ojeda	Project Manager	$40,000.00	$16,657.22	$56,657.22	$27.16	300	$8,149.33
Victor J. Vazquez	Computer Eng	$35,000.00	$14,575.07	$49,575.07	$23.77	300	$7,130.66
Manuel Maldonado	Computer Eng	$35,000.00	$14,575.07	$49,575.07	$23.77	300	$7,130.66
Felix R. Torres	Computer Eng	$35,000.00	$14,575.07	$49,575.07	$23.77	300	$7,130.66

	Total
Hours dedicated to Project	1200
Cost	*$29,541.31*
Non-billable Direct hours	561
Billable direct hours	639
Overhead *	**87.79%**
Cost	*$25,935.33*
Project Payroll	**$55,476.64**
Project Cost including parts	**$55,743.84**

Table 4 – Project Cost

*For more information about *Annual Benefits*, *Hours dedicated to Project* and *Overhead Breakdown*, please refer to the Appendix III.

List of Components

The cost of the components needed in order to implement a prototype of the project, as well as the cost of the same product produced in bulk, is presented as follow [14] [15]:

	Quantity	Unit Price	Bulk Price	Total Unit Cost	Total Bulk Cost
Carbon Monoxide Sensor	1	$4.95	$3.96	$4.95	$3.96
Gas Sensor Breakout Board	1	$0.95	$0.76	$0.95	$0.76
Temperature Sensor	1	$5.95	$4.76	$5.95	$4.76
Force Sensitive Resistor - Small	3	$5.95	$4.76	$17.85	$14.28
GSM Module	1	$49.95	$39.96	$49.95	$39.96
Quad-band Wired Cellular Antenna SMA	1	$11.95	$9.56	$11.95	$9.56
SMD Connector	1	$2.95	$2.36	$2.95	$2.36
Interface Cable SMA to U.FL	1	$4.95	$3.96	$4.95	$3.96
GPS Micro-Mini with SMA Connector	1	$79.95	$63.96	$79.95	$63.96
Antenna GPS 3V Magnetic Mount SMA	1	$12.95	$10.36	$12.95	$10.36
Battery Holder	2	$1.95	$1.56	$3.90	$3.12
Voltage Regulator	2	$0.60	$0.40	$1.20	$0.80

Battery Monitor	2	$2.95	$2.49	$5.90	$4.98
Transceiver	2	$19.95	$15.96	$39.90	$31.92
LED	3	$0.35	$0.28	$1.05	$0.84
Tri-Color LED	1	$1.95	$1.56	$1.95	$1.56
Buzzer	1	$1.95	$1.56	$1.95	$1.56
Microcontroller	2	$3.00	$3.00	$6.00	$6.00

	Total	
Subtotal	$254.25	$204.70
Shipping	$54.00	$54.00
Parts cost	**$308.25**	$258.70

Table 5- Cost of Components

Assessment Methods

Progress Evaluation Plan

A percentage method is presented to track the status of each task. The project is divided in ***three*** phases: *Design*, *Implementation* and *Testing* and each phase will be completed to *100%* before the next phase starts, following a modified version of the 'Waterfall' development model. As stated before, progress on each task will be presented on *Monday* meetings for the Project Manager to collect on a task log for progress evaluation. The metrics used are the following:

Phase	Total Percentage	Module	Individual Task weight
Design Phase	**4%**	Temperature sensor	• Draw schematics. 2% • Code flowchart, 2%
	10%	Carbon Monoxide sensor	• Draw schematics, 5% • Code flowchart, 5%
	4%	Force sensor	• Draw schematics, 2% • Code flowchart, 2%
	12%	Battery Monitor	• Draw schematics, 8% • Code flowchart, 4%
	4%	RF Transceiver	• Draw schematics, 2% • Code flowchart, 2%
	12%	GPS	• Draw schematics, 6% • Code flowchart, 6%
	12%	GSM installation	• Draw schematics, 6% • Code flowchart, 6%
	4%	Database	• Entity Relationship Diagram, 2% • Relational Diagram, 2%
	13%	Web Application	• Web Application design diagram. 5% • PHP server-side flowcharts. 8%
	15%	Workstation Application	• GUI design. 5% • Software event handling Flowchart. 10%
	5%	Keychain Re-design	• New Keychain schematic. 2% • Software flowchart. 2% • New Keychain physical design. 1%
	5%	Car seat Re-design	• New car seat physical design schematic/design. 5%
	4%	Temperature sensor	Firmware, 2% • Read data and convert data, 1% • Analyze data, 1% Hardware, 2%

Implementation Phase			• Schematic implementation, 2%
	10%	Carbon Monoxide sensor	Firmware, 4% • Read and convert Data, 2%: • Analyze data, 2% Hardware, 6% • Schematic implementation, 6%
	4%	Force sensor	Firmware, 2% • Read Data, 1%: • Analyze data of force sensors should be triggered to make sure there is an infant present and start the system. 1% Hardware, 2% • Schematic implementation, 2%
	12%	Battery Monitor	Firmware, 5% • Read Data, 2%: • Convert Data, 2%: • Analyze Data, if battery value is lower than a 'safe' threshold, a warning will be sent to the keychain. 1% Hardware, 7% • Schematic implementation, 7%
	4%	RF Transceivers	Firmware, 2% • Transmit/Recieve Data, 1%: • Analyze data for knowing distance of parent from car seat. 1% Hardware, 2% • Schematic implementation, 2%
	12%	GPS	Firmware, 7% • Read data from the GPS sensors. This will be done only when events are sent to the Control Center. 4% • Analyze data, GPS data should be interpreted and stripped to only the necessary information to be sent to the Control Center. 3% Hardware, 5% • Schematic implementation, 5%
	12%	GSM installation	Firmware/Software, 7% • GSM/Backend communication (Software) 2%: • GSM/MCU communication. (Firmware) 2%: • Send Data, MCU should be able to send data to the GSM modem to be sent to the Control Center. (Firmware) 3% Hardware, 5% • Schematic implementation, 5%
	4%	Database	Software 4% • Database software installation. 1% • ER diagram implementation. 2% • Create Store Procedures. 1%
	13%	Web Application	Software 13% • Installing and setup of the web-server instance. 3% • Web Application implementation with html and php. 10%
	15%	Workstation Application	Software 15% • GUI creation. 3% • Database access. 3% • Event handling software implemented. 6% • GUI integration with event handling software. 3%
	5%	Keychain Re-design	Software 2% • Complete Flowchart implementation. 1% • RF Signal Acknowledge implementation. 1% Hardware 3% • 'Old' Keychain dismantlement. 1% • New schematic implementation. 1%

			• 'New' Keychain assembled. 1%
	5%	Car seat Re-design	Hardware 5% • Install the system to the car seat by following the design schematic. 5%
Testing Phase	Please refer to ***Table 1- Testing Restrictions*** for complete testing information.		

Table 6 - Progress Evaluation Plan

Risk Management

Risk Management Plan

No.	Risk	Probability	Impact	Priority	Mitigation
1.	Ece.uprm.edu network un-reliable for hosting Database and web server.	Low	High	1	• Utilize a personal laptop of one of the team members. • Install required software for hosting a database and an html and php web server. • Register a free hostname for the hosting computer. This is done to be able to refer to the computer by hostname. • Install a dynamic DNS daemon to maintain the hostname updated with the IP address of the computer.
2.	Components do not arrive on time.	Low	High	2	• Work on tasks that do not require the missing components. • Ask either professors or other students for spare components. • If necessary, buy component from another supplier with next day shipping.
3.	Damage or theft of components.	Low	High	2	• Whenever possible, have spares components. • Ask professors or other students for spare components. • Buy lost components and work on tasks that are independent of such components.
4.	Excess of work on other courses for one or more of the team members.	Low	High	2	• Use the weekly meetings to discuss progress of each member and determine if redistribution is required. • Redistribution workload to team members with less academic load.
5.	One or more team members abandon the project	Low	High	2	• Assign at least two people to be responsible for the same task. • Make rotations so everyone could have experience in every area • Maintain good communication with other team members • Redistribute tasks to the remaining team members
6.	Loss of information.	Low	High	2	• Use a repository to store and keep track of everyone's progress • Actualize the repository frequently
7.	Strikes or university closed down because of power or water lost, among other causes.	High	Low	2	• Work remotely, if possible. • Work on tasks that do not require lab equipment. • Try to contact advisors to get equipment loans and work from remote locations. • Update Gantt chart and reschedule to reflect the loss of workable days, if necessary.
8.	Sickness of one or more Team members.	Low	High	2	• Assign at least two people to be responsible for the same task. • Use a repository to store and keep track of everyone's progress. • Work remotely, if possible. • Redistribute tasks to compensate for the temporary loss

					of a team member.
9.	Family emergency or personal situation.	Low	High	2	• Assign at least two people to be responsible for the same task. • Use a repository to store and keep track of everyone's progress. • Work remotely, if possible. • Redistribute tasks to compensate for the temporary loss of a team member.
10.	Adverse weather conditions or catastrophes.	Low	High	2	• Work remotely, if possible. • Work on tasks that do not require lab equipment. • Try to contact advisors to get equipment loans and work from remote locations. • Update Gantt chart and reschedule to reflect the loss of workable days, if necessary.
11.	Unexpected travels of a team member.	Low	Low	3	• Assign at least two people to be responsible for the same task. • Use a repository to store and keep track of everyone's progress. • Work remotely, if possible. • Redistribute tasks to compensate for the temporary loss of a team member.

Table 7 – Risk Management Plan

Impact and other Issues

Impact of project

The Baby Smart Seat has a social impact because it provides a tool for the parents to rely for any occurrence that can threat or harm the baby's life while in a vehicle. Also give a more secure feeling to the parents when placing a baby on the car seat. The Control Center will provide employment opportunities when providing the assistance service. As for the environmental impact, the Baby Smart Seat is reusable in case the parents decide to have more children or they decide to pass it on to future parents, thus reducing waste.

Baby Smart Seat could be involved in legal problems if the baby's safety is at risk. A potential risk that could harm the baby is assembling problems; such as small pieces misplaced, unprotected cables, and so forth. This could be a problem in the prototype model, but it should not be found if the product is develop by a manufacturing company, since extensive system testing should be performed before going into mass production.

Commitments

Please refer to *Product Specifications* section.

Legal issues of project

Software licenses might be needed and will be noted during the design phase. To prevent licensing issues, open source software and solutions, will be chosen if reliable and support is available.

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Appendix

Appendix I

Clients Feedbacks

Name: Angelica M. Torres

Mother of: 1

Email: amtsantiago@gmail.com

As parents there are some moments when we admit that we need help. For those days when our heads are getting away from our responsibilities as parents, it is very satisfying to know that there is a mechanism to help us not forget our children. It is my personal thought that no one will like to forget a child in a car but no matter how careful a person could be, an accident could occur. Baby on board is a realistic alternative for parents who have very stressful days with work and besides that for parents who don't have the money to pay for a personal nanny for their children. It is our responsibility to take care of our children but if we could have the alternative to receive an extra help that is amazing. As a first child mom I was not used to be taking care of a child. It was my routine to sleep well and to go straight from home to my job, now that I have my baby my entire routine has changed and I must admit that in a few occasions my son has traveled with me all the way to my work office. Now that Baby on Board is an option my stress of forgetting my baby in a daily routine change has gone away because no matter what this artifact will advice the presence of my child inside the car.

Name: Wildalys Carrasquillo Lopez

Mother of: 2

Email: wylddalys@yahoo.com

For my first baby I had no car, so I had to travel using public transportation and in that time I hadn't many worries other than the baby. With my second daughter, 14 years later, I can say my life routine was totally different. Months before, a typical day consisted of take my eldest daughter to school, going to work, leave work and going to school again. After the birth, in addition to these tasks, I stared to visit the daycare in mornings and afternoons, assisting more frequently to medical appointments, to the food store and other places that I didn't frequent because I had been without babies in home during a long time.

At this time, in Puerto Rico, occurred an incident with family that left the baby unintentionally in the car while participating of religious activity as a result of a misunderstanding. Since this incident, I always have been very aware about this risk. For this reason my eldest daughter, usually comes on the backseat with the baby, but this practice doesn't ensure a complete protection against these situations. Usually I'm the person who carries my daughters, but sometimes my husband takes care of them and is an event that changes his normal routine. In these cases I usually call him many times to ensure that everything is fine. As seen, the wellness and safety of my daughters is the most important thing for me and I'm really worried about this problematic because we never know when things can go wrong. Misunderstanding, stress, change in routines and many other factors could provoke undesirable situations. For this reason I consider this project is very important, because it increase the protection of babies and makes us fill more relaxed because we won't be alone taking care of our children, and this is priceless. The key chain and the command center is an excellent idea, because in case of a situation, it provides a double check to ensure a response that would save the life of the baby. I really believe this product will help to decrease the statistics of deaths of children in vehicles by being left unattended. In terms of the price I considered it is affordable and I would be interested in the acquisition of this product.

Appendix II

Biographies of Teams Members

Félix R. Torres-Santiago was born August 8th1987 in Ponce, PR. Currently resided in Villalba and is a senior student of Computer Engineering academic program offered at the University of Puerto Rico Mayaguez Campus. His main area of interest is Software Development and Database Management Systems.

Manuel Maldonado was born September 16th 1987 in Ponce, PR. Resided in Villalba and attended the Eladio Rosa Romero elementary school. As a middle school student, he attended the Norma I. Torres public school until 8th grade. From 9th grade to 12th grade he attended and graduated from the "Centro de Oportunidades Educativas de Mayagüez" (C.R.O.E.M.) which is a specialized public school that focuses in math, engineering and sciences. Currently, Manuel is a senior student at the University of Puerto Rico, Mayagüez Campus (UPRM-RUM) where he is a bachelor of Computer Engineering.

Rodolfo Ojeda was born January 8th 1988 in San Juan, PR. Resided in Canovanas and attended the Pedro Gutierrez elementary school. Rodolfo Ojeda attended Georgina Baquero from 7th to 12th grade. Currently he is a senior student at the University of Puerto Rico at Mayaguez. He is studying Computer Engineering. After graduating, Rodolfo is planning to build his own company. Rodolfo is planning to obtain a master degree in marketing.

Victor J. Vazquez-Lopez is a senior student of the Computer Engineering academic program offered at the University of Puerto Rico at Mayaguez. Focusing in the area of Software Development, some of the courses he has taken are Databases Design, Networking, Software Engineering, Data Structures, Programing Languages and Computer Networks. In addition, he has made research in wireless mesh networks and worked for the industry doing an internship with The John Hopkins University – Applied Physics Laboratory and a COOP with Ely Lilly and Company. These experiences have provided additional knowledge in his area of expertise and important soft skills. As part of his extracurricular activities, he has been an active member of the IEEE, mentor student for the Electrical and Computer Engineering Department, and percussionist in the church to which he belongs.

Appendix III

Budget Additional information

Workable Hours

Contract Period	Net Number of Days	Holidays	Workable Days	Average project hours per Day	Expected Project Hours
January/27 - May/19	**81**	**6**	**75**	**4**	**300**

Salary Facts

Benefits percentage of Total Employee Compensation [16]	Weeks per month	Works Hours per Year (40 hours/ week based)
29.4%	**4.3**	**2085.7**

Benefits Breakdown [16]

Paid leave	**6.7%**
Supplemental pay	**2.8%**
Insurance	**8.0%**
Health	7.5%
Retirement and savings	**3.6%**
Defined Benefits	1.6%
Defined Contribution	2.0%
Legally required	***8.3%***
Total Benefits	**29.4%**

Overhead Hours Breakdown

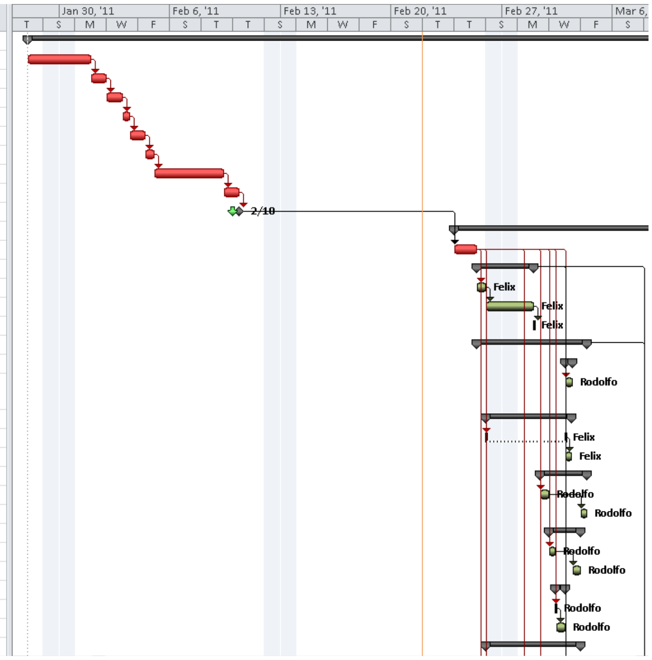
Hours spend	Weekly	During Contract Period	Team hours (4 Members)
Meetings	3	45	180
Writing Reports	4	60	240
Class Conferences		20	80
Workshops		4	16
Presentations		3	12
Oral Exams		3	12
Meetings with client		9	9
Parts acquisition		12	12
		Total	
	Non-billable Direct hours	**156**	**561**

Appendix IV

Detailed Gantt chart

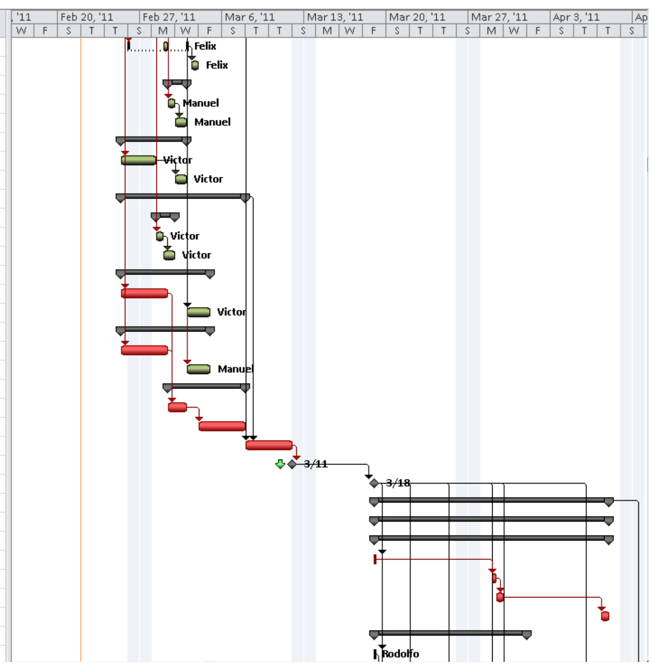
Gantt Chart

	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Baby Smart Seat Project**	**497 hrs**	**Fri 1/28/11**	**Tue 5/3/11**		
2	System Specification	16 hrs	Fri 1/28/11	Mon 1/31/11		
3	Definition of Needs	6 hrs	Tue 2/1/11	Tue 2/1/11	2	Felix,Manuel,Rodolfo,Victor
4	Concept Development	8 hrs	Tue 2/1/11	Wed 2/2/11	3	Rodolfo,Victor,Felix,Manuel
5	Analysis of alternatives	5 hrs	Wed 2/2/11	Thu 2/3/11	4	Rodolfo,Victor,Felix,Manuel
6	System requirements Assessment	8 hrs	Thu 2/3/11	Fri 2/4/11	5	Victor,Felix,Manuel,Rodolfo
7	Client Interview	3 hrs	Fri 2/4/11	Fri 2/4/11	6	Victor
8	Write Proposal	20 hrs	Fri 2/4/11	Wed 2/9/11	7	Victor,Felix,Manuel,Rodolfo
9	Review Proposal	8 hrs	Wed 2/9/11	Thu 2/10/11	8	Felix,Manuel,Rodolfo,Victor
10	Submit Proposal	0 hrs	Thu 2/10/11	Thu 2/10/11	9	
11	**System Design**	**132 hrs**	**Thu 2/24/11**	**Fri 3/18/11**		
12	System architecture	10 hrs	Thu 2/24/11	Fri 2/25/11	10	Manuel
13	**Re-Design Key Chain Module**	**12 hrs**	**Fri 2/25/11**	**Mon 2/28/11**		
14	New Keychain schematic	5 hrs	Fri 2/25/11	Fri 2/25/11	12	Felix
15	Code flowchart	5 hrs	Fri 2/25/11	Mon 2/28/11	14	Felix
16	New Keychain physical design	2 hrs	Mon 2/28/11	Mon 2/28/11	15	Felix
17	**Detail Design Car seat Module**	**40 hrs**	**Fri 2/25/11**	**Fri 3/4/11**		
18	**Re-Design Architecture**	**6 hrs**	**Wed 3/2/11**	**Thu 3/3/11**		
19	New car seat physical design schematic/design	6 hrs	Wed 3/2/11	Thu 3/3/11	12	Rodolfo
20	**Re-design Transceiver Module**	**27 hrs**	**Fri 2/25/11**	**Thu 3/3/11**		
21	Draw Schematics	2 hrs	Fri 2/25/11	Wed 3/2/11	12	Felix
22	Code Flowchart	2 hrs	Thu 3/3/11	Thu 3/3/11	21	Felix
23	**Design CO Sensor module**	**24 hrs**	**Tue 3/1/11**	**Fri 3/4/11**		
24	Draw Schematics	5 hrs	Tue 3/1/11	Tue 3/1/11	12	Rodolfo
25	Code Flowchart	5 hrs	Thu 3/3/11	Fri 3/4/11	24	Rodolfo
26	**Design Temperature Module**	**14 hrs**	**Tue 3/1/11**	**Thu 3/3/11**		
27	Draw Schematics	2 hrs	Tue 3/1/11	Wed 3/2/11	12	Rodolfo
28	Code Flowchart	2 hrs	Thu 3/3/11	Thu 3/3/11	27	Rodolfo
29	**Design Force Sensors Module**	**4 hrs**	**Wed 3/2/11**	**Wed 3/2/11**		
30	Draw Schematics	2 hrs	Wed 3/2/11	Wed 3/2/11	12	Rodolfo
31	Code Flowchart	2 hrs	Wed 3/2/11	Wed 3/2/11	30	Rodolfo
32	**Battery Monitor**	**33 hrs**	**Fri 2/25/11**	**Thu 3/3/11**		

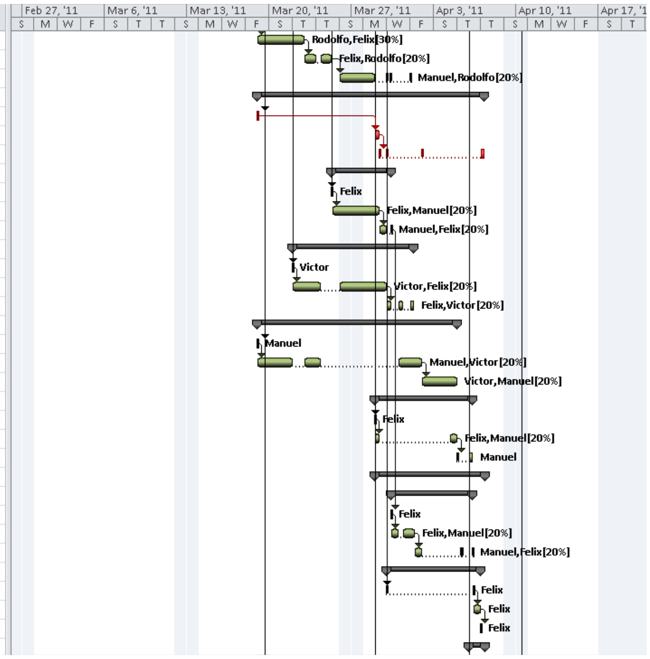


Gantt Chart

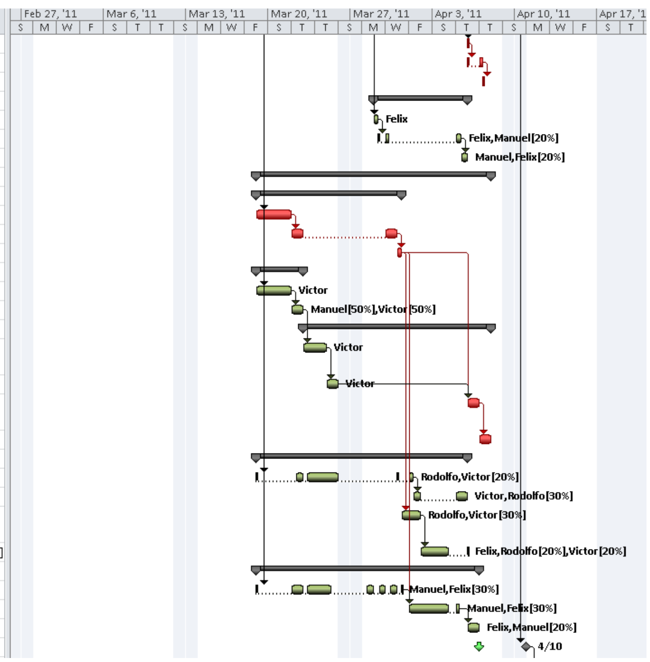
	Task Name	Duration	Start	Finish	Predecessors	Resource Names
33	Draw Schematics	6 hrs	Fri 2/25/11	Wed 3/2/11	12	Felix
34	Code Flowchart	6 hrs	Thu 3/3/11	Thu 3/3/11	33	Felix
35	**Design GPS Module**	**12 hrs**	**Tue 3/1/11**	**Wed 3/2/11**		
36	Draw Schematics	6 hrs	Tue 3/1/11	Tue 3/1/11	12	Manuel
37	Code Flowchart	6 hrs	Wed 3/2/11	Wed 3/2/11	36	Manuel
38	**Design GSM Module**	**28 hrs**	**Fri 2/25/11**	**Wed 3/2/11**		
39	Draw Schematics	8 hrs	Fri 2/25/11	Mon 2/28/11	12	Victor
40	Code Flowchart	8 hrs	Tue 3/1/11	Wed 3/2/11	39	Victor
41	**Design Control Center Application**	**50 hrs**	**Fri 2/25/11**	**Mon 3/7/11**		
42	**GSM Gateway**	**12 hrs**	**Mon 2/28/11**	**Tue 3/1/11**		
43	Design GSM Modem Manager	4 hrs	Mon 2/28/11	Mon 2/28/11	12	Victor
44	Design information management	8 hrs	Mon 2/28/11	Tue 3/1/11	43	Victor
45	**Workstation Application**	**44 hrs**	**Fri 2/25/11**	**Fri 3/4/11**		
46	Design Grafic User Interface	16 hrs	Fri 2/25/11	Tue 3/1/11	12	Rodolfo
47	Design Core Application	16 hrs	Wed 3/2/11	Fri 3/4/11	13	Victor
48	**Web Application**	**44 hrs**	**Fri 2/25/11**	**Fri 3/4/11**		
49	Design Grafic User Interface	16 hrs	Fri 2/25/11	Tue 3/1/11	12	Manuel
50	Design Server Side Application	16 hrs	Wed 3/2/11	Fri 3/4/11	12	Manuel
51	**Database**	**34 hrs**	**Tue 3/1/11**	**Mon 3/7/11**		
52	Entity Relationship Diagram	12 hrs	Tue 3/1/11	Wed 3/2/11	46,49	Felix
53	Relational Diagram	12 hrs	Fri 3/4/11	Mon 3/7/11	52	Felix
54	Review Design	32 hrs	Mon 3/7/11	Fri 3/11/11	41,17,13	Felix,Manuel,Rodolfo,Victor
55	Submit Design	0 hrs	Fri 3/11/11	Fri 3/11/11	54	
56	Design Acceptance - HP1	0 hrs	Fri 3/18/11	Fri 3/18/11	55	
57	**Implementation**	**114.83 hrs**	**Fri 3/18/11**	**Thu 4/7/11**		
58	**Implementation of car seat module**	**112 hrs**	**Fri 3/18/11**	**Thu 4/7/11**		
59	**Temperature Sensor**	**109 hrs**	**Fri 3/18/11**	**Thu 4/7/11**		
60	Schematic implementation	1 hr	Fri 3/18/11	Fri 3/18/11	56	Rodolfo
61	Firmware implementation	3 hrs	Mon 3/28/11	Tue 3/29/11	60	Rodolfo
62	Calibration	2 hrs	Tue 3/29/11	Tue 3/29/11	61	Rodolfo
63	Testing & Refining	3 hrs	Thu 4/7/11	Thu 4/7/11	62	Felix
64	**Carbon Monoxide Sensors**	**74.83 hrs**	**Fri 3/18/11**	**Thu 3/31/11**		
65	Schematic implementation	3 hrs	Fri 3/18/11	Fri 3/18/11	56	Rodolfo



	Task Name	Duration	Start	Finish	Predecessors	Resource Names
66	Firmware implementation	14 hrs	Fri 3/18/11	Tue 3/22/11	65	Rodolfo,Felix[30%]
67	Calibration	15 hrs	Tue 3/22/11	Fri 3/25/11	66	Felix,Rodolfo[20%]
68	Testing & Refining	14.83 hrs	Fri 3/25/11	Thu 3/31/11	67	Manuel,Rodolfo[20%]
69	**Force Sensors**	**106 hrs**	**Fri 3/18/11**	**Thu 4/7/11**		
70	Schematic implementation	1 hr	Fri 3/18/11	Fri 3/18/11	56	Rodolfo
71	Firmware implementation	3 hrs	Mon 3/28/11	Tue 3/29/11	70	Rodolfo
72	Testing & Refining	6 hrs	Tue 3/29/11	Thu 4/7/11	71	Felix,Rodolfo[20%]
73	**Transceiver Module**	**24.83 hrs**	**Fri 3/25/11**	**Wed 3/30/11**		
74	Schematic implementation	1 hr	Fri 3/25/11	Fri 3/25/11	56	Felix
75	Firmware implementation	13 hrs	Fri 3/25/11	Tue 3/29/11	74	Felix,Manuel[20%]
76	Testing & Refining	4.33 hrs	Tue 3/29/11	Wed 3/30/11	75	Manuel,Felix[20%]
77	**GSM Module**	**69 hrs**	**Mon 3/21/11**	**Fri 4/1/11**		
78	Schematic implementation	2 hrs	Mon 3/21/11	Mon 3/21/11	56	Victor
79	Firmware implementation	38 hrs	Mon 3/21/11	Tue 3/29/11	78	Victor,Felix[20%]
80	Testing & Refining	13.5 hrs	Tue 3/29/11	Fri 4/1/11	79	Felix,Victor[20%]
81	**GPS Module**	**92 hrs**	**Fri 3/18/11**	**Mon 4/4/11**		
82	Schematic implementation	2 hrs	Fri 3/18/11	Fri 3/18/11	56	Manuel
83	Firmware implementation	38 hrs	Fri 3/18/11	Fri 4/1/11	82	Manuel,Victor[20%]
84	Testing & Refining	10 hrs	Fri 4/1/11	Mon 4/4/11	83	Victor,Manuel[20%]
85	**Battery Monitor**	**51 hrs**	**Mon 3/28/11**	**Wed 4/6/11**		
86	Schematic implementation	2 hrs	Mon 3/28/11	Mon 3/28/11	56	Felix
87	Firmware implementation	8 hrs	Mon 3/28/11	Mon 4/4/11	86	Felix,Manuel[20%]
88	Testing & Refining	3 hrs	Mon 4/4/11	Wed 4/6/11	87	Manuel
89	**Implementation of key chain module**	**58.33 hrs**	**Mon 3/28/11**	**Thu 4/7/11**		
90	**Transceiver Module**	**39.33 hrs**	**Wed 3/30/11**	**Wed 4/6/11**		
91	Schematic implementation	1 hr	Wed 3/30/11	Wed 3/30/11	76	Felix
92	Firmware implementation	13.67 hrs	Wed 3/30/11	Fri 4/1/11	91	Felix,Manuel[20%]
93	Testing & Refining	8 hrs	Fri 4/1/11	Wed 4/6/11	92	Manuel,Felix[20%]
94	**Buzzer**	**47.33 hrs**	**Tue 3/29/11**	**Wed 4/6/11**		
95	Schematic implementation	1 hr	Tue 3/29/11	Wed 4/6/11	56	Felix
96	Firmware implementation	2 hrs	Wed 4/6/11	Wed 4/6/11	95	Felix
97	Testing & Refining	2 hrs	Wed 4/6/11	Wed 4/6/11	96	Felix
98	**LED Indicators**	**10.83 hrs**	**Tue 4/5/11**	**Thu 4/7/11**		

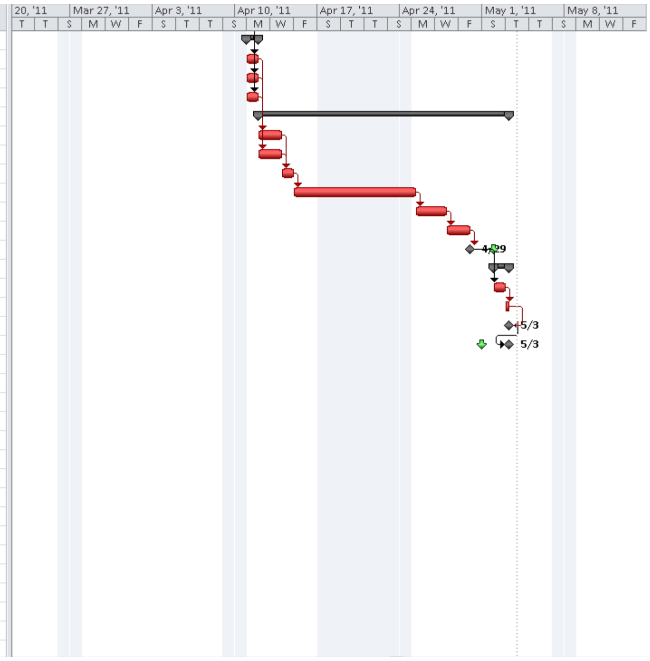


	Task Name	Duration	Start	Finish	Predecessors	Resource Names
99	Schematic implementation	1 hr	Tue 4/5/11	Tue 4/5/11	56	Victor
100	Firmware implementation	2 hrs	Tue 4/5/11	Thu 4/7/11	99	Victor
101	Testing & Refining	1 hr	Thu 4/7/11	Thu 4/7/11	100	Victor
102	**Battery Monitor**	**47 hrs**	**Mon 3/28/11**	**Tue 4/5/11**		
103	Schematic implementation	2 hrs	Mon 3/28/11	Tue 3/29/11	56	Felix
104	Firmware implementation	7.33 hrs	Tue 3/29/11	Tue 4/5/11	103	Felix,Manuel[20%]
105	Testing & Refining	3 hrs	Tue 4/5/11	Tue 4/5/11	104	Manuel,Felix[20%]
106	**Implementation of Control Center**	**114.83 hrs**	**Fri 3/18/11**	**Thu 4/7/11**		
107	**Database Implementation**	**70 hrs**	**Fri 3/18/11**	**Thu 3/31/11**		
108	Implement Tables	10 hrs	Fri 3/18/11	Mon 3/21/11	56	Felix
109	Creat Stored Procedures	12 hrs	Mon 3/21/11	Wed 3/30/11	108	Victor
110	Debug and Testing	6 hrs	Wed 3/30/11	Thu 3/31/11	109	Felix,Victo,Manuel
111	**GSM Modem**	**16 hrs**	**Fri 3/18/11**	**Tue 3/22/11**		
112	Configure Modem	8 hrs	Fri 3/18/11	Mon 3/21/11	56	Victor
113	Testing Modem	8 hrs	Mon 3/21/11	Tue 3/22/11	112	Manuel[50%],Victor[50%]
114	**GSM Gateway**	**98.83 hrs**	**Tue 3/22/11**	**Thu 4/7/11**		
115	Script to get data from GSM Modem	16 hrs	Tue 3/22/11	Thu 3/24/11	113	Victor
116	Test & Debug	8 hrs	Thu 3/24/11	Fri 3/25/11	115	Victor
117	Script to store alarms information in Database	8 hrs	Tue 4/5/11	Wed 4/6/11	116,110	Victor
118	Test & Debug	8 hrs	Wed 4/6/11	Thu 4/7/11	117	Rodolfo
119	**WorkStation Application**	**95.83 hrs**	**Fri 3/18/11**	**Tue 4/5/11**		
120	Implement Interface	35 hrs	Fri 3/18/11	Fri 4/1/11	56	Rodolfo,Victor[20%]
121	Test & Debug Interface	8 hrs	Fri 4/1/11	Tue 4/5/11	120	Victor,Rodolfo[30%]
122	Script to read and write data to Database	12 hrs	Thu 3/31/11	Fri 4/1/11	110	Rodolfo,Victor[30%]
123	Test & debug script	7.83 hrs	Fri 4/1/11	Tue 4/5/11	122	Felix,Rodolfo[20%],Victor[20%]
124	**Web Application**	**104.33 hrs**	**Fri 3/18/11**	**Wed 4/6/11**		
125	Implement Interfaces	35 hrs	Fri 3/18/11	Thu 3/31/11	56	Manuel,Felix[30%]
126	Implement Server side application	10.83 hrs	Thu 3/31/11	Tue 4/5/11	125,110	Manuel,Felix[30%]
127	Test & Debug	6 hrs	Tue 4/5/11	Wed 4/6/11	126	Felix,Manuel[20%]
128	Individual components tested - HP2	0 hrs	Sun 4/10/11	Sun 4/10/11	57	



Gantt Chart

	Task Name	Duration	Start	Finish	Predecessors	Resource Names
129	**Integration Testing & Refining**	**8 hrs**	**Mon 4/11/11**	**Mon 4/11/11**		
130	Testing car seat device	8 hrs	Mon 4/11/11	Mon 4/11/11	128	Rodolfo,Manuel[50%]
131	Testing key chain device	6 hrs	Mon 4/11/11	Mon 4/11/11	128	Felix
132	Testing Control Center overall process	8 hrs	Mon 4/11/11	Mon 4/11/11	128	Victor,Manuel[50%]
133	**System Integration**	**81 hrs**	**Tue 4/12/11**	**Tue 5/3/11**		
134	Integration of car sea & key chain	12 hrs	Tue 4/12/11	Wed 4/13/11	130,131	Felix,Rodolfo
135	Integration of car seat & control	12 hrs	Tue 4/12/11	Wed 4/13/11	132,130	Victor,Manuel
136	Full Integration	12 hrs	Wed 4/13/11	Thu 4/14/11	134,135	Felix,Manuel,Rodolfo,Victor
137	Test & refine	10 hrs	Fri 4/15/11	Mon 4/25/11	136	Felix,Manuel,Rodolfo,Victor
138	System Demo with real scenario	20 hrs	Mon 4/25/11	Wed 4/27/11	137	Felix,Manuel,Rodolfo,Victor
139	System Final Adjustments	18 hrs	Wed 4/27/11	Fri 4/29/11	138	Felix,Manuel,Rodolfo,Victor
140	Integration completed	0 hrs	Fri 4/29/11	Fri 4/29/11	139	
141	**Delivery**	**9 hrs**	**Mon 5/2/11**	**Tue 5/3/11**		
142	Deployment	6 hrs	Mon 5/2/11	Mon 5/2/11	140	Felix,Manuel,Rodolfo,Victor
143	Training	3 hrs	Mon 5/2/11	Tue 5/3/11	142	Felix,Manuel,Rodolfo,Victor
144	Client acceptance	0 hrs	Tue 5/3/11	Tue 5/3/11	143FF	
145	Project Finish	0 hrs	Tue 5/3/11	Tue 5/3/11	144	



Appendix V

Detailed Economical Analysis

The following scenario is presented to analyze the economical viability of the propose product:

Device Selling Price	Monthly Payment	Units Sold	Schedule	MARR*
$75.00	$20	1,000	4 Years	6%

Sales Revenues	Monthly Income	Devices Building Cost**	Prototype Development Cost	Total Initial Investment	Cash Flow
$75,000.00	$20,000.00	($224,700.00)	($55,784.89)	($280,484.89)	($205,484.89)
					$20,000.00
					$20,000.00
					.
					4 Years
					.
					.
					$20,000.00
					$20,000.00

IRR	10%
PV	$111,618.52

*This value is assumed in order to simplify the analysis

**This value includes parts cost and is assuming $20 of building Cost per device

Since the Internal rate of return is higher than the minimum attractive rate of return assumed, the investment is considered viable.

The Investment is recovered when 320 devices are sold.

Appendix VI

Final Report – Baby on Board

University of Puerto Rico
Mayagüez Campus
Department of Electrical and Computer Engineering

Baby On Board

"A Proposal Submitted as a partial requirement of the Microprocessor Interfacing course ICOM-5217"

Prepared for:
Professor Manuel A. Jiménez, Ph.D

Course: ICOM 5217, Section 096

By:
Felix Torres
Rodolfo Ojeda
December 17, 2010

Abstract

Every year infants and small children die because they have been left in vehicles. Baby on board was created to prevent that to happen. Baby on board is a safety device that alert parents that they have forgot their children inside the car. Also it will alert the father if the temperature is dangerous for the baby even if the father stills in the car. This system consists of a device that is placed in the car seat and the other device is a key chain. It is developed to be low power efficient and portable. The car seat device uses a weight sensor that detects if the baby is seated on the car seat. The temperature sensor is a LM 335 and Nordic RF transceivers to communicate. The key chain device contains a uOLED to displays the data, a buzzer and a LED to alert the parent. It uses a Nordic RF transceiver to communicate with the car seat device. The Baby on board was design using a PIC16LF722 by microchip.

Table of Contents **Page**

List of Illustrations Page

1. Introduction

Stressed, overloaded, exhausted, distracted or confused by a change in routine, working parents can completely forget that they've left their children unattended. Others may leave sleeping children in car seats while they exit their vehicles for what they believe will be a quick errand. Yet, left alone for only a few minutes, a small child can be abducted, set the vehicle in motion, or suffer a deadly heatstroke.

Last year there were 33 deaths in hot cars just in the United States. The truth is that babies die of heat stroke for being left in a car far more frequently than any of us would like to believe. A parked car on a warm day can quickly become the last place you will see your child alive. Some days, it takes only 30 to 45 minutes to kill a little one left inside. A car heats up quickly, that it’s the morning and the sun isn’t yet properly heating up the air does not delay matters much. Neither will cracking the window a bit.

Cars are inappropriate places for children to be left without adult supervision. There are systems already installed in our vehicles to warn us that we have left our headlights on or our keys in the ignition. Our beloved children deserve at least that same protection. These tragic incidents are entirely preventable. Now we describe how Baby on Board takes advantage of technology to bring a solution for this problem and help to save lives.

We knew that we have to develop something that prevents parents to forget their children inside the cars. We knew it has to be something portable and low portable, and capable of detect every time the parent walk away from the car. The system have to be something of everyday use not too heavy not too big, not too expensive. It has to be of simple use because we don’t want babies to die just because their parents don’t know how to use it. It has to detect a minimum difference in temperature because it can be the difference between the life and death of a child.

That’s the way Baby on board was born. The system consists of a car seat device and a key chain device. The car seat device will by detecting if the child is seated in the car seat or not. If the child is seated it will automatically awake the system. Once the system is awake it will read the temperature provided by the LM335 that is a precision temperature sensor. Then it will send all the information to the car seat device using a Nordic RF transceiver it will be resending the signal every ten seconds. If the car seat device is inside the range provided by the device it will then display the temperature in the uOLED. If the Nordic RF in the key change does not receive a signal in 10 seconds it will ring the alarm and it will keep ringing until the baby is finally removed from the car seat. Also if the temperature is dangerous for the baby (too hot or too cold) it will automatically ring the alarm until the baby is removed from the car seat or the temperature is safe. This device will be a relief for all those parents with a high potential of forgetting their child inside of the car.

The microcontroller selected for the implementation of our system is a PIC16LF722 provide by Microchip. His microcontroller provides us a low power option for our system.

2. Theory

When a baby is *intentionally* left in a car and dies from extreme heat or cold, we rightfully blame the parent. But when a baby is *accidentally* left in a vehicle and dies we still blame the parent. According to KidsInCars.org, 665 kids died left in vehicles between 2002 and 2006 in America, an average 133 kids every year.

We are outraged because we can't imagine anyone forgetting a child in a car, but psychologists can. It is the worst case of "out of sight, out of mind" possible. One expert who studies how people interact with technology thinks these car deaths started to skyrocket when laws began requiring babies to be placed in the back seats of vehicles.

What if we approached this issue like we do our homes? We can buy outlet covers, hallway gates and hundreds of other devices to protect babies from our lapses, from our periods of absent-minded parenting. What if we demanded the same safety measures for car seats? Your car beeps if the driver's seat belt isn't latched or if you forget to turn off your headlights. Our cars should alert us if we leave with a baby unattended. It is possible.

Calculation of temperature

The LM335 series are precision, easily-calibrated, integrated circuit temperature sensors. Operating as a 2-terminal zener, the LM135 has a breakdown voltage directly proportional to absolute temperature at +10 mV/°K. With less than 1Ω dynamic impedance the device operates over a current range of 400 μA to 5 mA with virtually no change in performance. When calibrated at 25°C the LM135 has typically less than 1°C error over a 100°C temperature range. Unlike other sensors the LM135 has a linear output.

Basically what the temperature sensor does is convert the temperature in to a voltage measure. This voltage output is connected to a pin at the MCU. This pin is an analog to digital converter. This ADC has a voltage reference connected to Vdd. This gives us a range from 0 Kelvin to 330 Kelvin. We are going to obtain a value that goes from 0 to 255. This is converted to a real temperature value with the next equation:

Temperature (K) = ADCvalue(Tempmax)/255

ADCvalue is the value given by the analog to digital converter.

Tempmax is the maximum temperature allowed by the Vdd.

Doing this we obtain the Kelvin temperature. Now the next step is turn that into Fahrenheit scale. To do this we use the equation utilize for the conversion of this two scales which is:

° F = 9/5(° K - 273) + 32

Figure 1: Formula used to change from Kelvin to Fahrenheit.

3. Hardware Design and Implementation

3.1 Block Diagram

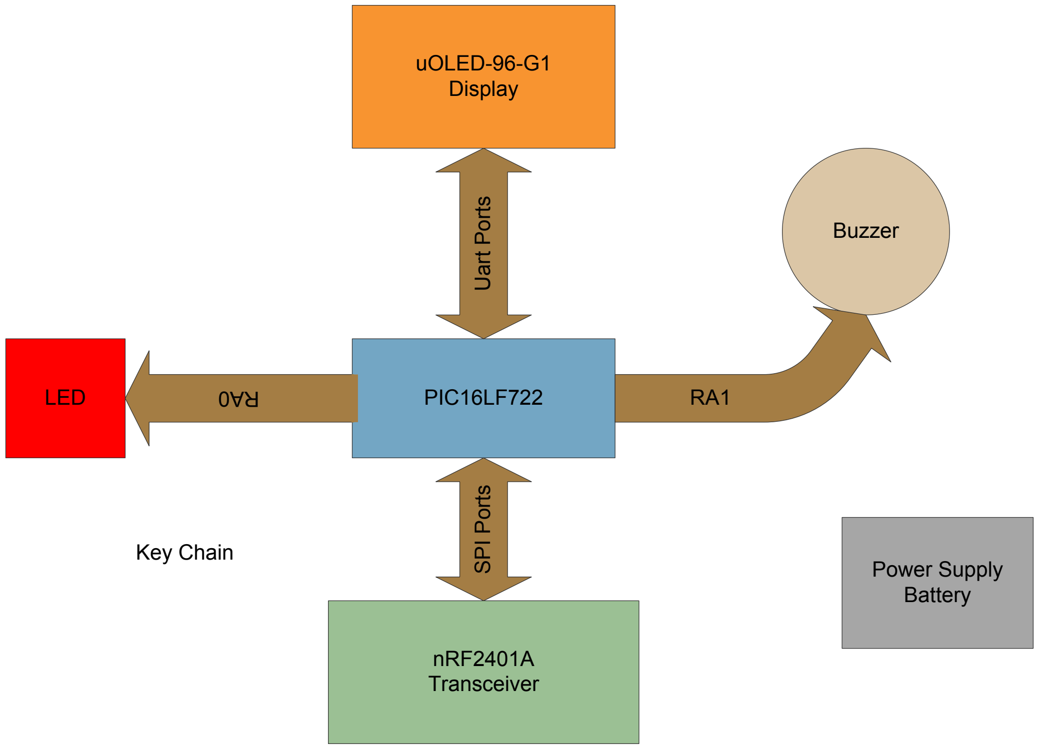


Figure 2: Key Chain Block diagram.

- uOLED-96-G1 display – The display used has a size of 0.96" so it is small enough to carry around. It will present information about temperature around the baby and also display the alert message.
- Buzzer – To produce an alert sound when baby is forgotten in the car.
- Pic16LF722 – In charge of receiving the data from the car seat device and displaying in the LCD. Also maintain knowledge if the transceiver is actually receiving data. It manages the display and triggers the LED and the Buzzer.
- nRF24L01+ 2.4GHz transceiver – To create the proximity sensor, it will act as a switch trigger when lost reception. It will create a communication with the car seat device.
- LED – It will flash when the device is activated.
- Power Supply – Will be using batteries to provide power to the system

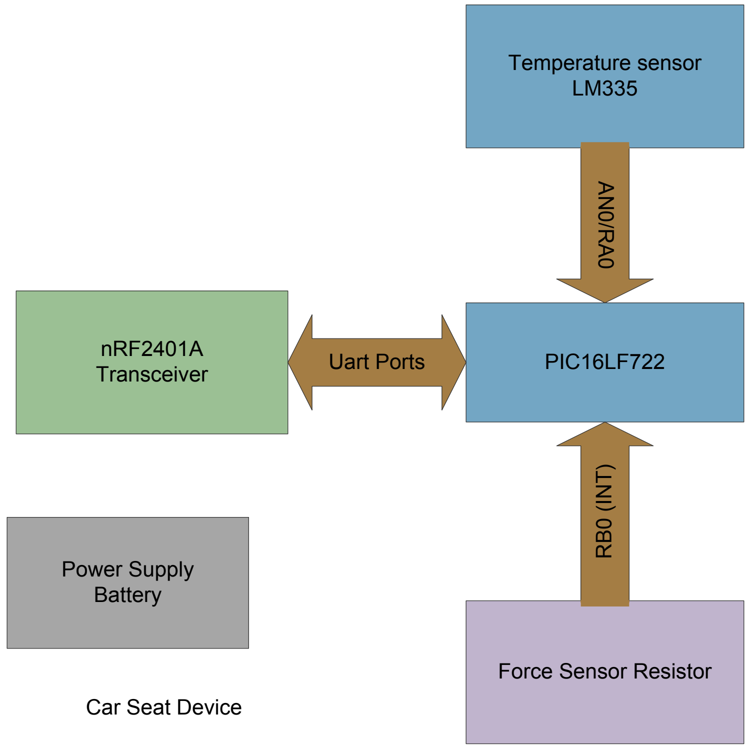


Figure 3: Car Seat Device Block diagram.

- nRF24L01+ 2.4GHz transceiver – It will create the perimeter around the baby. It will continuously be sending a signal. It will create a communication with the key chain.
- Pic16LF722 – In charge of collecting data from the temperature sensor and give an alert whenever the baby is in danger.
- Force sensor resistor – Responsible to detect whether there is a baby on board or not. Also is responsible to activate the whole circuit.
- LM335 Temperature sensor – Responsible of collecting the temperature around the baby and notify the microcontroller.
- Power Supply – Will be using batteries to provide power to the system.

3.2 Power Analysis

The power consumption of our system is calculated based on each of the operation modes of the device. The device has four operation modes which are device off, standby, device on alert off and device on alert on. Next you will find a power consumption analysis for each of those modes:

Car Seat Device

- **Device OFF**

All components are turned off.

Total Power = P PIC16LF722 + P uOLED + P nRF24L01 + P LM335+P LED+ P Buzzer

= 0 mW + 0 mW + 0 mW + 0 mW +0mW+0mW+0mW

Total Power = 0 mW

- **Standby**

When the device is turned on but the kid is no sited on the car seat it is in the standby mode. When the device transmits the data it goes back to the stand by for 10 seconds before retransmitting. This mode is only reachable if the device is On. During this mode everything except for the MCU and the LM335 is on..

Total Power = P PIC16LF722 + P nRF24L01 + P LM335

= 66nW + 22uW + 10 mW

Total Power = 10.022 mW

- **Device On alarm off**

The system is on and all the components are working.

Total Power = P PIC16LF722 + P nRF24L01 + P LM335

= 1 mW + 17.0 mW + 10 mW

Total Power = 28mW

- **Device On alarm On**

The system is on and all components are working.

Total Power = P PIC16LF722 + P nRF24L01 + P LM335

= 1 mW + 17.0 mW + 10 mW

Total Power = 28mW

The maximum power consumption of the device is when it is on. When it is on each one of the components are working. Then the maximum power consumption is 28mW

Power supply = 4 AA Duracell (1500mAh)

Runtime in standby mode.

Power consumption = 10.022mW
Approximate amperage = 1mA + 25uA+ 600u = 1.625mA
Time = 1500mah/1.625mA = 923horas

Runtime in Device ON alarm OFF mode.

Power consumption = 28mW
Aproxímate amperaje = 1mA + 12.6mA+ 10mA = 33.6mA
Time = 1500mah/1.625mA = 44horas

Runtime in Device ON alarm ON mode.

Power consumption = 28mW
Aproxímate amperaje = 1mA + 12.6mA+ 10mA = 33.6mA
Time = 1500mah/1.625mA = 44horas

Key Chain

• **Device OFF**

All components are turned off.

Total Power = P PIC16LF722 + P uOLED + P nRF24L01 +P LED+ P Buzzer
= 0 mW + 0 mW + 0 mW + 0 mW +0mW+0mW+0mW
Total Power = 0 mW

- **Standby**

  When the device is turned on but the kid is no sited on the car seat it is in the standby mode. When the device transmits the data it goes back to the stand by for 10 seconds before retransmitting. This mode is only reachable if the device is On. During this mode everything except for the MCU and the nRF24L01 is on.

  Total Power = P PIC16LF722 + P uOLED + P nRF24L01 +P LED+ P Buzzer
  = 66nW + 0mW + 17uW +0mW +0mW
  Total Power = 17.066 uW

- **Device On alarm off**

  The system is on but the alarm is not ringing. The buzzer and the LED are turned off

  Total Power = P PIC16LF722 + P uOLED + P nRF24L01 +P LED+ P Buzzer
  = 1 mW + 22.0 mW + 17 mW + 0 mW+0 mW
  Total Power = 40 mW

- **Device On alarm On**

  The system is on and the alarm is ringing. The buzzer and the LED are now on.

  Total Power = P PIC16LF722 + P uOLED + P nRF24L01 +P LED+ P Buzzer
  = 1 mW + 22.0 mW + 17 mW + 6 mW+3 mW
  Total Power = 47 mW

  For the key chain device we still are looking for a battery strong enough to feed our system.

3.3 Driver Analysis

The results of the driver analysis are here in details and we can see that all components are compatible. Since all our components are compatible there is no need to create an interface to connect them together.

MCU (DRIVER) VDD=3.3v	uOLED display (LOAD)VDD=5.0v
V_{OH}=2.6v > V_{IH}= 2.0v	I_{OH}= 3mA > Not Provided
V_{OL}= 0.6v < V_{IL}= 0.8v	I_{OL}=6mA > Not Provided

MCU (LOAD) VDD=3.3v	uOLED display (DRIVER)VDD=5.0v
V_{OH}=2.4v> V_{IH}= 1.625v	I_{OH}= 4mA >Not Provided
V_{OL}= -0.3v < V_{IL}= 0.15v	I_{OL}=3.4mA > 125nA

MCU(DRIVER)VDD=3.3v	nRF24L01 transceiver(LOAD)VDD=3.3v
V_{OH}=2.6v > V_{IH}= 2.2v	I_{OH}= 3mA > Not Provided
V_{OL}= -0.3v < V_{IL}= 0.3v	I_{OL}=6mA > Not Provided

MCU(LOAD)VDD=3.3v	nRF24L01 transceiver(DRIVER)VDD=3.3v
V_{OH}=2.2v> V_{IH}= 1.625v	I_{OH}= -0.5mA >Not Provided
V_{OL}= -0.3v < V_{IL}= 0.15v	I_{OL}=0.5mA > 125nA

3.4 Timing Analysis

The most important thing to know when using microcontrollers is the frequency at which the chip is running. Our microcontroller is running at 8MHz at which we consider is ok, since we don't have anything that is tightly constrained by time we don't worry too much and don't even bother to change it.

Now it is important for us to determine the baud rate at which the microcontroller will be communication through the uart Ports. This will be important when trying to establish communication with the display. Since our display has a command to auto synchronized the baud rate that is determine by the microcontroller there is no error when trying to communicate between them.

Now I will let you see some operational time from the components in our project.

- PIC16LF722 – MCU

    200ns per instruction

- uOLED-96-G1 – Display

    Operational delay: 500 ns

- nRF24L01+ – RF module transceiver

    TX ShockBurst: 195µs
    RX: 202µs

Note:

Most of the communication time in our project will be determined by software. All components will be used in serial connection therefore the communication is mainly control by software.

3.5 Memory Map

The data memory of the pic16lf722 is partitioned into multiple banks which contain the General Purpose Registers (GPRs) and the Special Function Registers (SFRs). Bits RP0 and RP1 are bank select bits.

RP1	RP0	
0	0	- Bank 0 selected
0	1	- Bank 1 selected
1	0	- Bank 2 selected
1	1	- Bank 3 selected

Each bank extends up to 7Fh (128 bytes).

Note: Refer to PIC16F72X/PIC16LF72X datasheet.

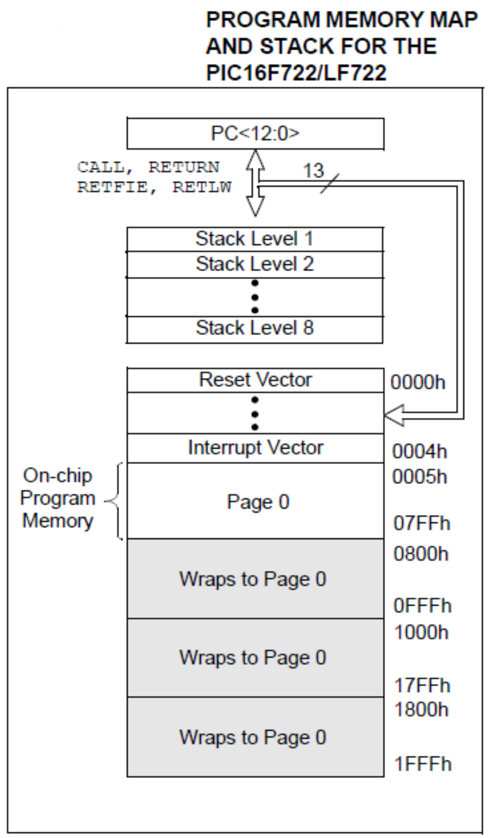


Figure 4: Memory Map PIC16LF722.

3.6 Hardware Schematics

Car Seat Device

The schematic of the car seat device show the last version of the hardware implementation of the car seat device. This schematic shows all the components utilize in the implementation of it. First we have a source of 6V that will be implemented with batteries; this power supply will be connected to a voltage regulator. This voltage regulator will regulate the voltage to a 3.3V. This 3.3 V will be provided to every component except for the temperature sensor. The MCU used to implement the device is a PIC16LF722, this MCU work with a voltage of 3.3V and provide us a low voltage system. This system is activated by a weigh sensor cal FSR that works as a switch that is connected to an interrupt port. Then we have our transceiver called nRF24L01 that is in charge of the communication between devices. Each one of these components was selected to because of the compatibility with the MCU.

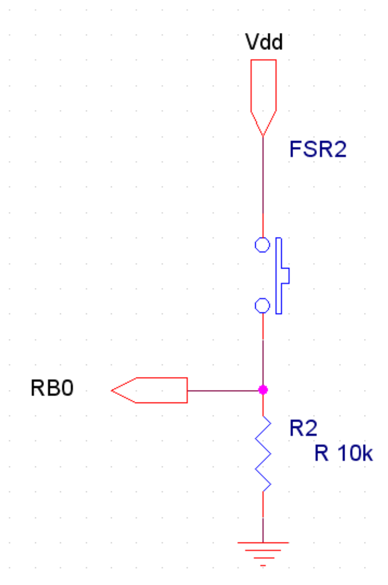


Figure 5: Schematic of the Force Sensitive Resistor

Force Sensitive Resistor (FSR)

The FSR is the device that is in charge to wake up the system. FSRs are sensors that allow you to detect physical pressure, squeezing and weight. FSR's are basically a resistor that changes its resistive value (in ohms Ω) depending on how much it's pressed. This sensor detects the presences of the baby activating an interrupt. This interrupt is the one that put the system to work. This FSR give us a range of 0 to 20 pounds.

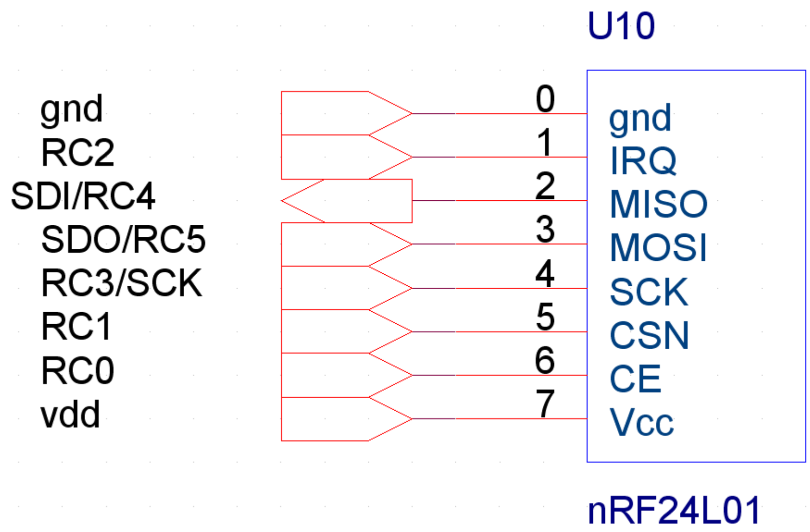


Figure 6: Schematic of the Transceiver.

nRF24L01+ Transceivers

The nRF24L01 is a unique wireless solution for compact, battery operated applications with stringent requirements on battery lifetime and cost. The transceiver operates in the license free worldwide 2.4GHz ISM band. These transceivers are interfaced using SPI ports which provide us another serial interface. This transceiver is in charge of send the data to the key chain device. Basically it is the most important component of our device. It sends for bytes of data, the first one is a byte with two main bits. The first one is the present bit which tell if the baby is seated or not, the second bit is the temperature bit that is set if the temperature is dangerous for the baby. The next three bytes are the temperature but separate by decimal position. First the most significant value (100), then follows the next most significant (10) and finally the least significant (1). Once the data is send it goes to a standby mode.

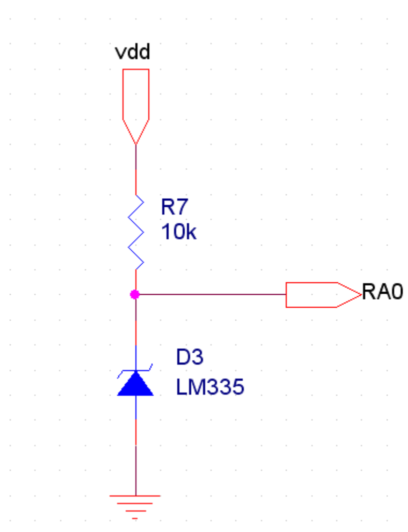


Figure 7: Schematic of the temperature sensor.

LM335 Precision temperature sensor

The LM135 series are precision, easily-calibrated, integrated circuit temperature sensors. Operating as a 2-terminal zener, the LM135 has a breakdown voltage directly proportional to absolute temperature at +10 mV/°K. With less than 1Ω dynamic impedance the device operates over a current range of 400 μA to 5 mA with virtually no change in performance. This sensor will be on charge of reading the temperature of the system. The analog to digital converter will be in charge of the interpretation of the voltage provided by the sensor. Then it will make the conversion of the analog voltage that represents the temperature to a digital representation.

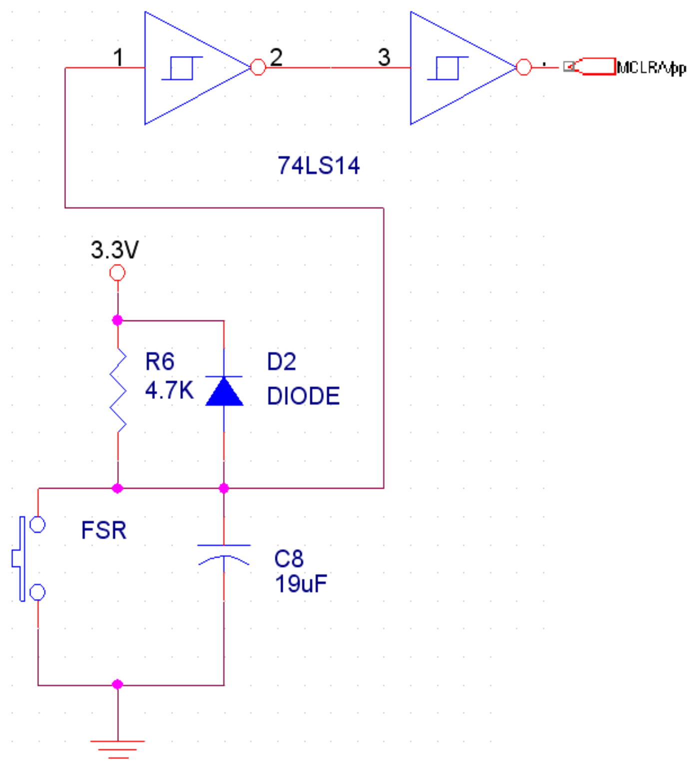


Figure 8: Schematic of the reset button.

The power on reset button

This button will provide the user the ability to restart the system. This will be useful in case of a malfunctioning of the system or another incident that makes the system to work wrong. Also when the batteries are put in the system it is recommended to restart the system to be sure that the system will work properly.

Voltage Regulator

The voltage regulator is in charge of reducing the voltage provided by our power supply. This component is needed because our power supply gives 6V which is too much for all our components that just work with a maximum voltage of 3.6V.

Key Chain

The schematic of the key chain device show the last version of the hardware implementation of this part of the system. This schematic shows all the components utilize in the implementation of it. This system contains a 6V power supply that provides voltage to every single component. This voltage source is connected to a voltage regulator that sets the voltage to 3.3V. This voltage is distributed through the entire system. The MCU that we use for this device is PIC16LF722. This MCU works with 3.3V and provide us a low voltage system. Connected to the MCU we have the uOLED which works with 3.3V and provide us the capability of display our data. Then we have the buzzer that works with a low voltage and small current. It also provides us a loud sound which is essential for our application. The next element is the LED that provides a bright light with just 3.3V of input. The last element of this system is the nRF24L01 that is in charge of the communication between systems. Each one of these components was selected to because of the compatibility with the MCU.

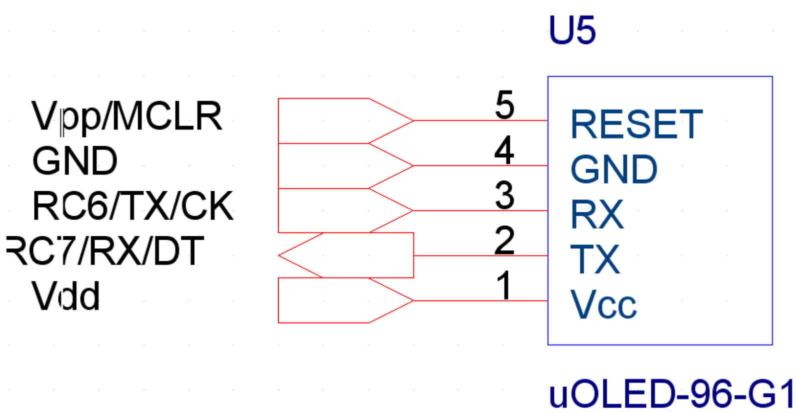


Figure 9: Schematic of the uOLED display.

uOLED-96-G1

The **uOLED-96-G1** is a compact and cost effective display module using the latest state of the art Passive Matrix OLED (PMOLED) technology with an embedded GOLDELOX-GFX2 graphics processor that delivers 'stand-alone' functionality to any project. This uOLED provide the capability of display the data to the user. It will display the temperature and in case the alarm is on it will display a danger message. This uOLED is interface using the uart ports that are used for serial communication.

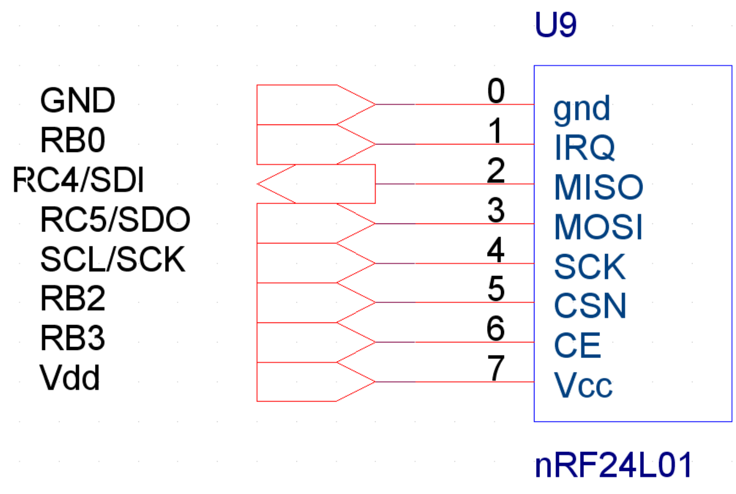


Figure 10: Schematic of the Transceiver.

nRF24L01 Transceivers

The nRF24L01 is a unique wireless solution for compact, battery operated applications with stringent requirements on battery lifetime and cost. The transceiver operates in the license free worldwide 2.4GHz ISM band. These transceivers are interfaced using SPI ports which provide us another serial interface. This transceiver is in charge of receiving the data that was send by the transceiver in the car seat device. Basically it is the most important component of our device. It receives four bytes of data; the first one is a byte with two main bits. The first one is the present bit which tell if the baby is seated or not, the second bit is the temperature bit that is set if the temperature is dangerous for the baby. The next three bytes are the temperature but separate by decimal position. First the most significant value (100), then follows the next most significant (10) and finally the least significant (1). Once the data is received it will keep checking the air for a new retransmission.

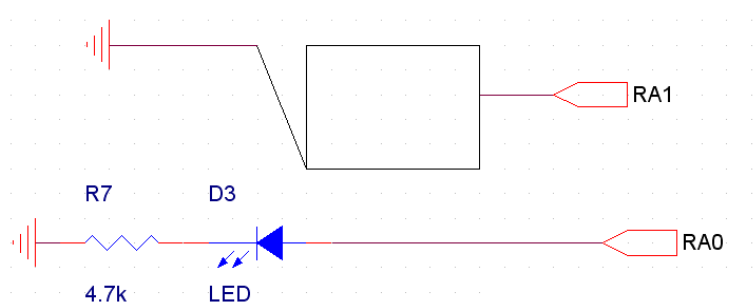


Figure 11: Schematic Buzzer and LED.

Buzzer and LED

These components were specially selected for our application because both work with a low voltage and low current. This makes the perfect because our MCU just provide 3.3V. Both components work as an alarm to alert the parent. The buzzer makes a sound strong enough to alert the parent and at the same time the LED is flashing.

Voltage Regulator

The voltage regulator is in charge of reducing the voltage provided by our power supply. This component is needed because our power supply gives 6V which is too much for all our components that just work with a maximum voltage of 3.6V.

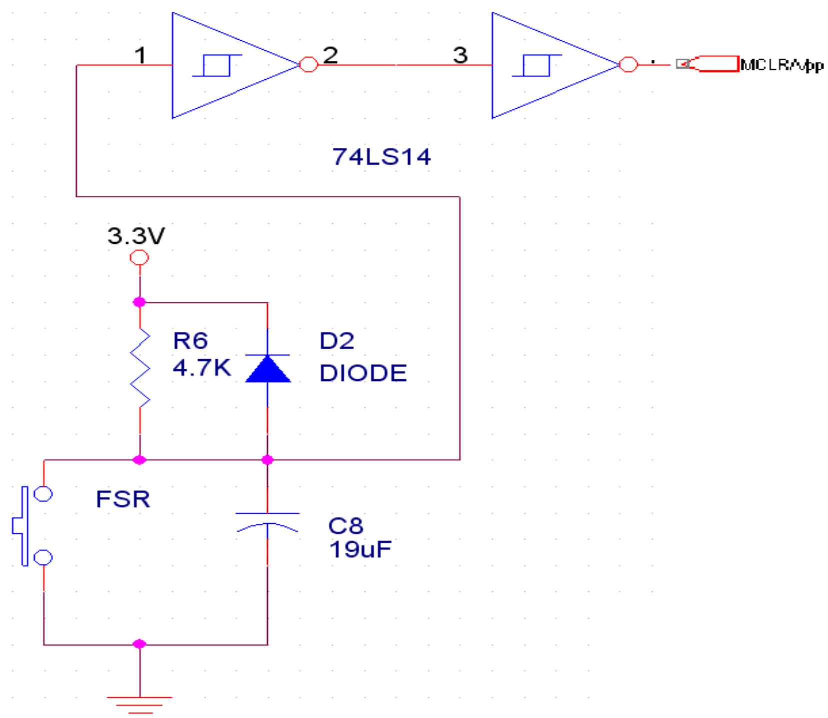


Figure 12: Schematic of the reset button.

The power on reset button

This button will provide the user the ability to restart the system. This will be useful in case of a malfunctioning of the system or another incident that makes the system to work wrong. Also when the batteries are put in the system it is recommended to restart the system to be sure that the system will work properly.

3.7 Trustworthiness and considerations

At the moment we start to design our system our main focus was the power efficiency. Baby on board is portable which means that it should consume the less amount of power possible. When we were looking for the elements of the system we always look for a low level consumption. This consideration could mean the life or dead of a baby. Now I will give a briefly description of the consideration on each element of the system.

Low Power considerations:

PIC16LF722

- Sleep Mode: 20 nA
- Watchdog Timer: 500 nA

nRF 24L01+

- 900nA in power down
- 22µA in standby-I
- On chip voltage regulator
- 1.9 to 3.6V supply range

Another design consideration was the size of the system. Our application contains a key chain so we had find elements that can fulfill our expectances and also can fit in the key chain little space. This is very important because we don't want a key chain of the size of a book and weighing 10 pounds. So we had to look carefully for some devices that were of low power consumption and also with a little size.

The key chain device had two main elements that had to be very efficient in space utilization and power efficiency. Those are the display and the transceiver. Fortunately we find the uOLED display and the nRF24L01+ each one of them fulfills both of the consideration. Unfortunately we were not able to find a buzzer that generates a sound loud enough to alert the parent but without sacrificing the size.

uOLED

- 0.96" diagonal size, 32.7 x 23 x 4.9mm.
  Active Display Area: 20mm x 14mm.

Our system is very trustable because every element operates very well with the respective voltage supplied to them. Also the speed of the system represents no problem because we are able to adapt each one of the devices to the speed of the MCU. The only problem with our system is that we don't have a voltage monitoring system and that is a huge problem at the time of trustworthiness because at any moment the battery can fail and maybe that can cost the life of a baby.

3.8 Hardware Termination Level

The system develop in the project has all the components needed to be a functional device. We have every single element integrated at with each other. The car seat device is doing every task that it is suppose to do. First the temperature sensor is reading the right temperature. The FSR detects if there is a minimum change in the weight and wake up the system. The communication is working properly. In the key chain the display is displaying the data that the car seat send, and the buzzer and let make their respective task in case is needed. There are some minimum improvements that we would like to add in the future to optimize the system.

We would like to implements few thing in our design, one of those things is a sensor that detects when the clip of the car seat is close. This will be useful at the time to differentiate if there's a baby on the seat or is just something that was put on it. Also we would like to add in a future is a battery monitoring system. This will help the user to verify if he has to change the battery. Those are additional features that we would like to add in a future but for now our prototype accomplish each of our goals.

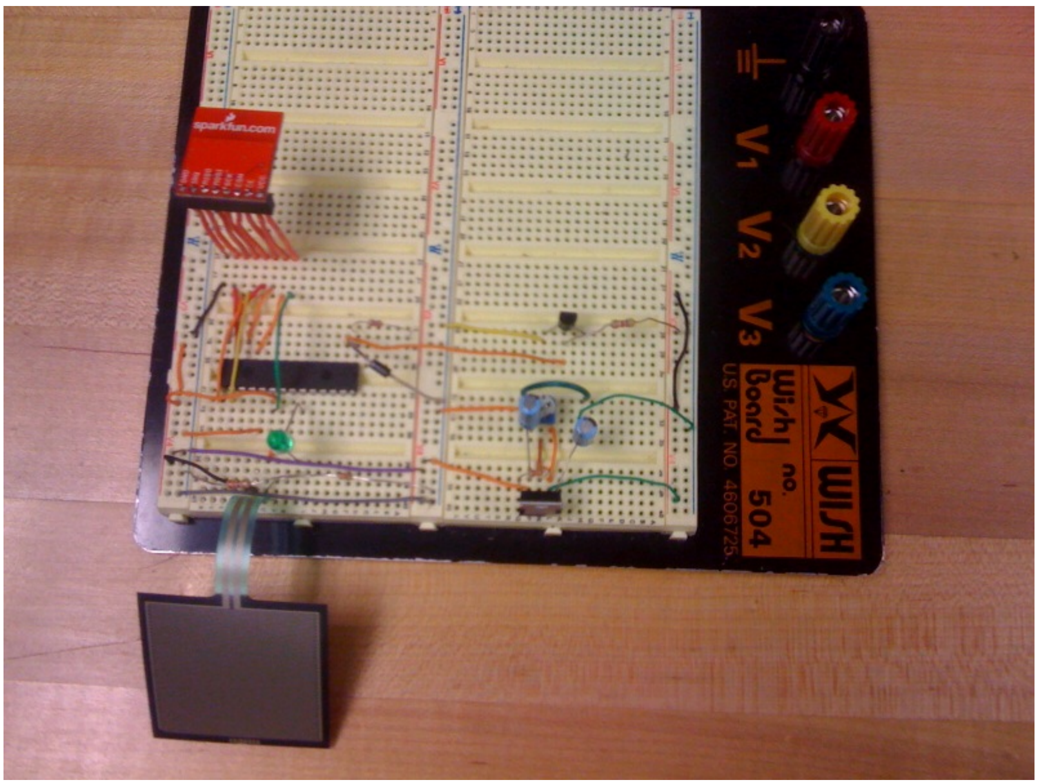


Figure 13: Car seat device circuit.

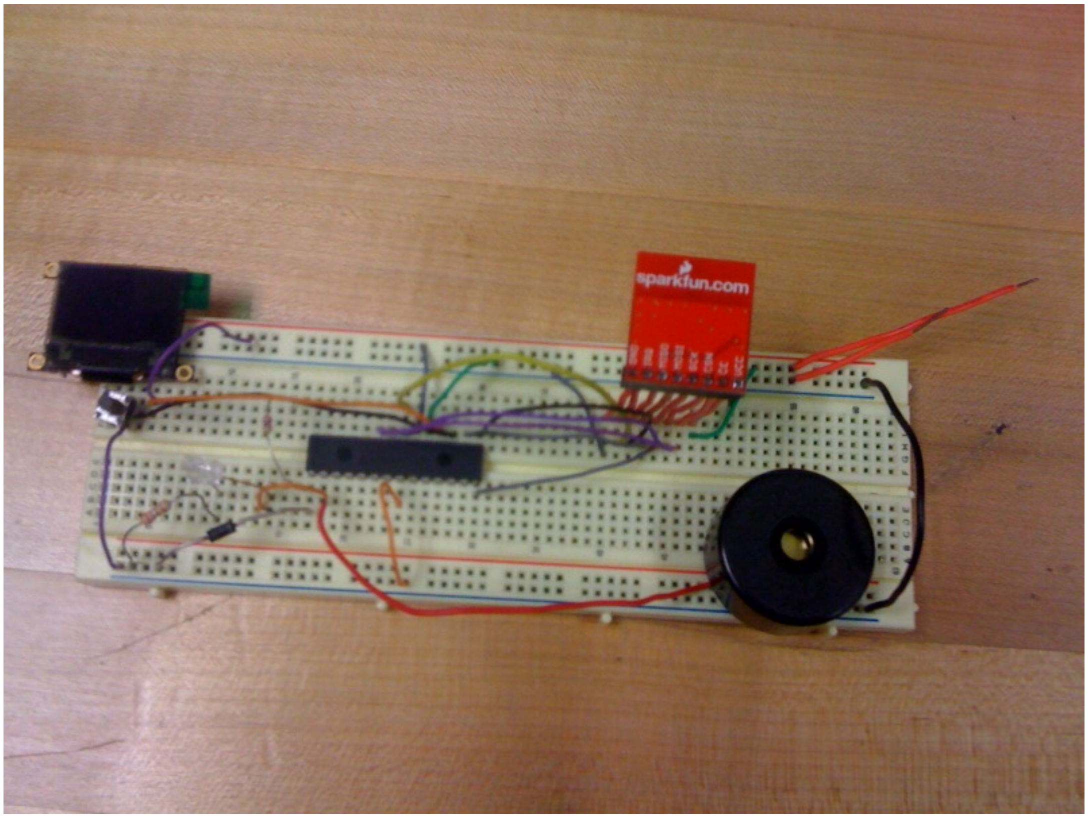


Figure 14: Key chain circuit.

3.9 Demo-backed chart

Hardware (Car seat)

Sensor weigh	Integrated
Temperature sensor	Integrated
RF transceiver	Integrated
Voltage Regulator	Integrated
Power Supply	Integrated

Hardware (Key chain)

uOLED-Display	Integrated
Buzzer	Integrated
LED	Integrated
RF transceiver	Integrated
Voltage Regulator	Integrated
Power Supply	Not Integrated

4. Software Design and Implementation

4.1 System Flow Charts

The following section explains the operating flow charts for the Baby On Board software.

Key Chain

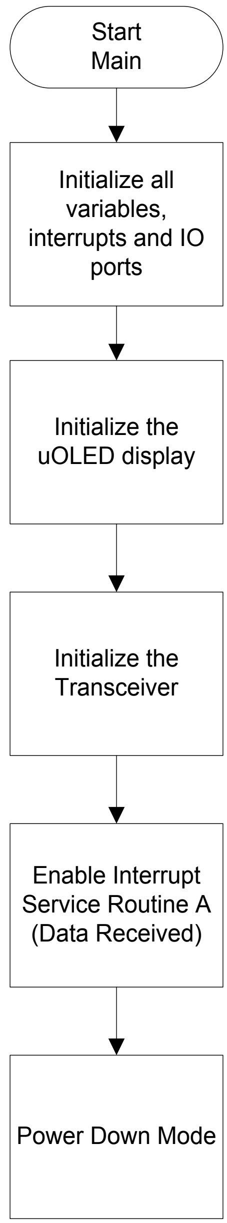


Figure 15: System Main Routine for Key Chain

Once the system is power up the microcontroller will initialize all variables to default values. It will set the IO ports to the corresponding status as inputs or outputs. Also it will enable the interrupts, uart ports, SPI ports and the timer0.

The transceiver will be initialized using the SPI ports and set into receiving mode. Whenever the transceiver receives a packet it will trigger the interrupt and the ISR A will be executed.

The next step is to initialize the display through the uart ports, sending the auto baud command. This will enable configure the baud rate for the display to be synchronize with the baud rate from the microcontroller.

Timer0 is initialized to control the time between every packet received. This allows us to determine when to trigger the alarm in the key chain. Every time a timer0 overflow interrupt occurred the ISR B will be executed.

Finally once all this initializing process in the main subroutine is done the microcontroller will enter power down mode to save life battery. Only the interrupts will wake the microcontroller from power down mode and as soon as they are finished it will enter power down mode again.

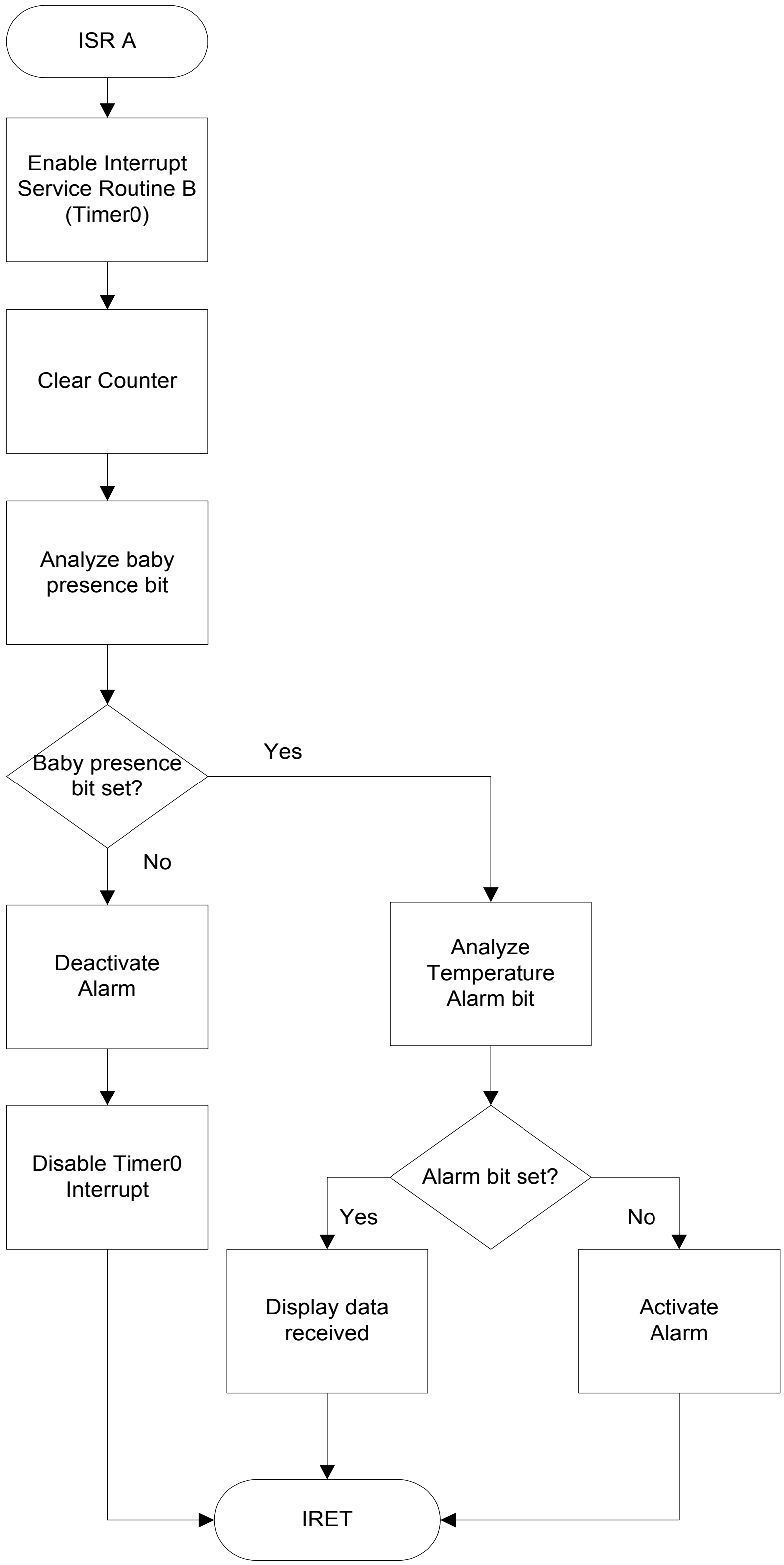


Figure 16: Interrupt subroutine A (Data Received).

The interrupt service subroutine A is trigger when any data is received by the transceiver. This subroutine purpose is to analyze the data receive and determine what to do base on that information.

The first time this interrupt is called it will enable the Timer0 interrupt. Then it will analyze the data received to set the presence bit and the alarm bit. Once this data is extracted the system will determine whether or not to continue or to activate the alarm. If it continues and the alarm is not trigger the system will used the remainder data to display the temperature detected around the car seat.

The presence bit is used to determine whether or not the baby is actually on board. If the data received has the presence bit clear the key chain is send into power down mode. Before sending the key chain into power down mode the timer0 interrupt will be disable to prevent the microcontroller to waste power when the baby is not place in the car seat.

The alarm bit is used to trigger the alarm when the temperature around the baby is not safe for him. This bit will be determined in the car seat device using a predetermined safe range of temperature, whenever the temperature is below or above this range the alarm bit will be set.

The counter is used to determine if the parent is near the car. Therefore since the key chain is receiving data this counter is clear every time it enters this subroutine.

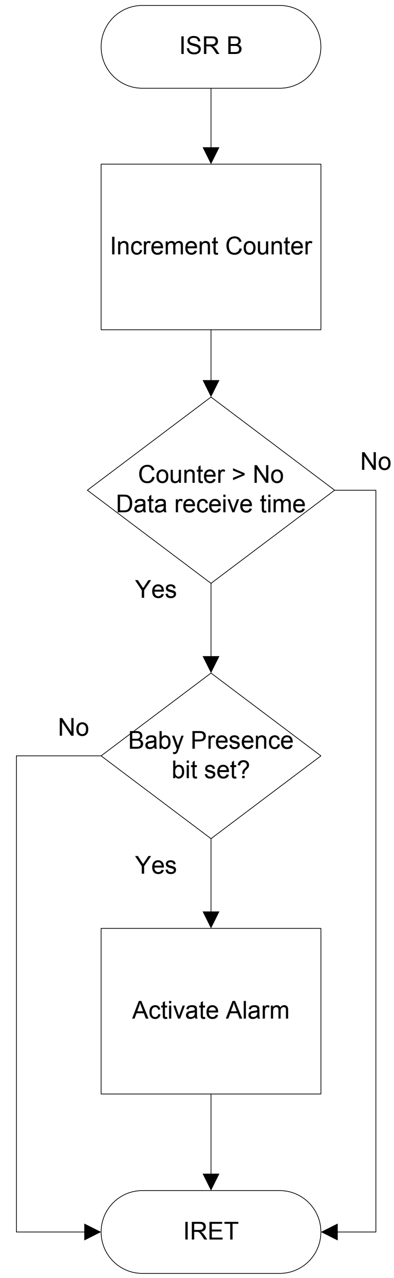


Figure 17: Interrupt subroutine B (Timer0).

The interrupt service subroutine B in the key chain is the timer0 interrupt. The main purpose of this interrupt is to allow a certain time to pass by before receiving more data, and to increment the counter that determine if the parent is near the baby.

Every time this subroutine is called the counter that a certain time has passed and the key chain haven't received any data will increment. In case that the counter over passed the expected time to received data the microcontroller examine the last value of the presence bit , if is set it will trigger the alarm meaning that the parent has left the perimeter. In this moment the baby has been forgotten in the car.

Car Seat Device

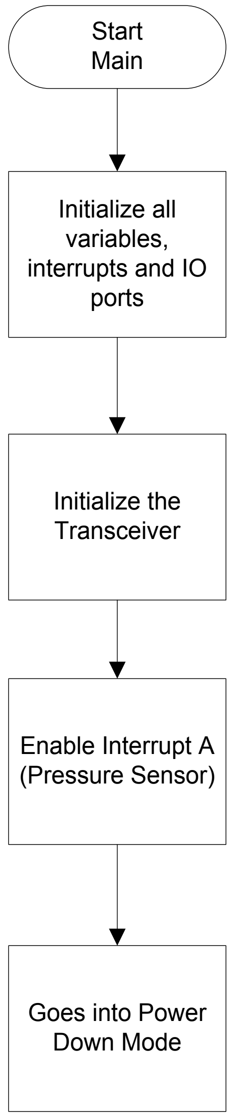


Figure 18: System Main Routine for Car Seat Device.

Once the car seat device is power up the microcontroller initialize all the variable, IO ports and interrupts. Also it will initialize the ADC converter used for the read of the temperature. The transceiver in this case will be initialized using the SPI ports and is configure to transmitter mode. Once the transceiver is configured it will enable the interrupt used to detect that a baby has been placed in the car seat.

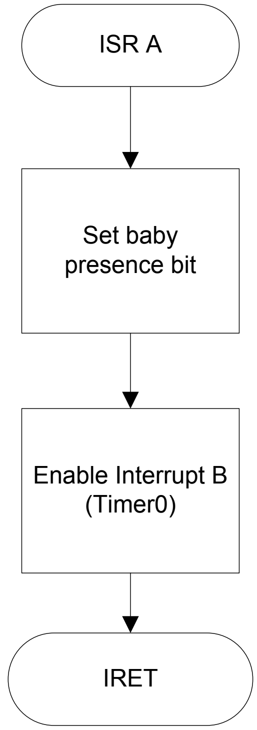


Figure 19: Interrupt service subroutine A (pressure sensor).

The interrupt service subroutine A is used to activated the circuit setting the presence bit and enabling the timer0 interrupt subroutine that read the temperature and send the data obtain.

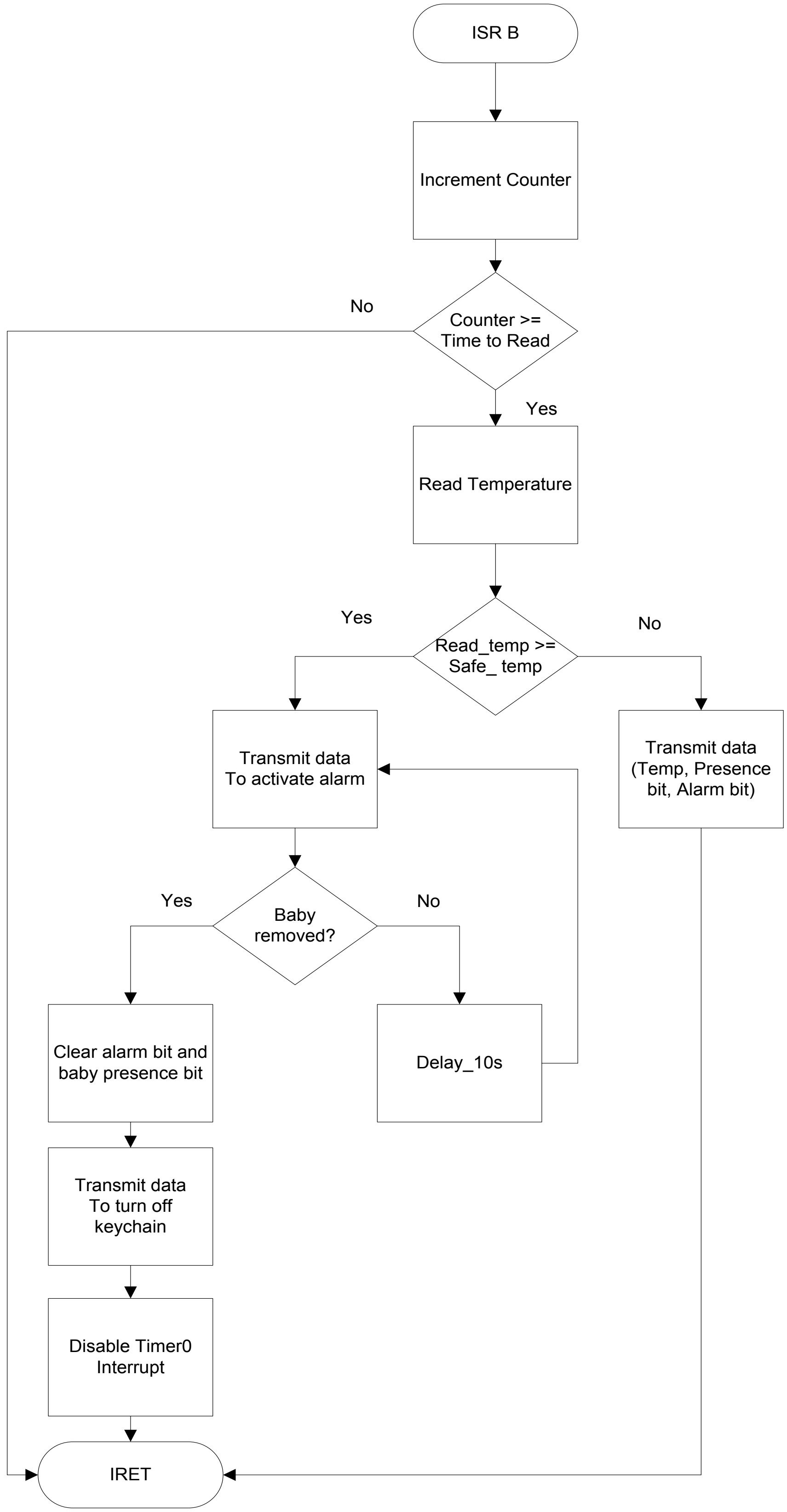


Figure 20: Interrupt service subroutine B (Timer0).

The interrupt service subroutine B is the timer0 interrupt. This interrupt is in charge of reading the data from the ADC converter obtain from the temperature sensor. This timer interrupt is a 1 second delay so in order to create a reading every 5 seconds the device use a counter when this counter reach the 5 seconds it read the temperature and will convert it into Fahrenheit scale since the temperature sensor give us the output in Kelvin scale.

Once the temperature has been read it determines whether or not the temperature is in range. If the temperature is safe the device send the data obtain if not it will send the data with the alarm bit set to let know the key chain that the alarm must be trigger. Then it will wait for the baby to be removed to then send a packet to disable the key chain alarm. When the baby is removed the timer0 interrupt is disabled to save battery power.

4.2 Efficiency and Trustworthiness

In the development of our project we had to be very careful since any error can mislead to a fail attempt to save a life of a forgotten baby on board. Since our project main goal is to save life we had to take several precautions in the software implementation.

Therefore a list is presented below of the optimizations and precautions taken to develop a reliable and efficient system.

- **Interrupt Handling**

Using interrupts to handle every event of our project save a lot of microcontroller cycles so we are able to put the device in power down mode and save energy. Also using a timer interrupt instead of creating delays increased the time the microcontroller is in power down mode resulting in more save in energy.

- **Data Packet Size**

Using small data packet size decreased the percent of losing a packet during transmission. Making more successfully transmissions the system is more reliable and trustworthiness. Basically using a packet of only 2 bytes increased the percentage of successfully transmission instead of using the 32 bytes that is capable of transmitting the nRF24L01+ module.

- **ADC Converter**

An ADC converter integrated in the microcontroller was used to make read the temperature sensor. Using this 8-bit converter make the temperature more precise to provide more accurate information about the condition around the baby.

4.3 Software Termination Level

Key Chain

The key chain device software includes all the main system functionalities. This includes functions to establish communication with the transceiver and with the display. In terms of the transceiver connected to the key chain the software is able to configure the device in receiver mode and retrieve any data receive by the transceiver. In terms of the display the software contains all the basics instructions to communicate with the device and send data to be display. Other software functions of the key chain are the ability to activate the buzzer and the led to create the sound and light of the alarm.

Car Seat Device

The car seat device also has all the main system functionalities. It also includes the functions to establish communication with the transceiver and with the temperature sensor and the pressure pad. In terms of the transceiver they are almost identical to the key chain but instead of receiving data, the device is configured in transmitter mode and the primary software function is to send data. Other significantly function is to read from the ADC converter the value obtain from the temperature sensor and transform the value into Fahrenheit scale.

4.4 Demo- backed chart

Software (Car seat)

Sensor activates the system	Integrated
Read Temperature Sensor using ADC	Integrated
RF transmit the data	Integrated
Convert the value of the ADC to ℉	Integrated
Sleep mode	Integrated

Software (Key chain)

UOLED displays the alert	Integrated
Buzzer rings	Integrated
Led turn on	Integrated
RF receive data	Integrated
Sleep mode	Integrated

4.5 User Guide

The Baby on Board system is pretty simple to use and it's create to be used with just by adding some battery.

First you will need to place the car seat device to the baby car seat. This is accomplished by placing the pad under the cushion cover of the car seat and placing the rest of the device on the side or in the back of the car seat. Using some simple Velcro the device can be hook to the car seat to prevent from moving around and not work properly.

Once the device is place on the car seat you will need to attach the key chain to your set of keys and then press the reset button on both devices.

There will be three different messages that can be displayed on the key chain. The first one and more common will be the message "Baby on board. Temperature = XXX F". This message will be display while the baby is placed on the car seat. It will only let you know that the baby is on board and the temperature around the baby.

If the parents walked away from the vehicle while the baby still on the car seat the message will be "Alert baby on board" and it will create a beeping sound to let you know that you have forgotten the baby.

In case that the temperature is not safe for the baby the message on screen will be "Danger Temperature Not Safe" and the beeping sound will be slower than the "Alert Baby on Board" beeping sound.

These are the only three messages than can be display and in the two messages that produce a beeping sound the parent will have to remove the baby from the car seat in order for the beeping sound to stop.

In case that the alarm does not go off after removing the baby from the car seat you can press reset button on each device, this will stop the alarm.

5. Part List

NAME	Price/unit	Total Price
(2)PIC16LF722 – MCU	$1.35	$2.70
(2) nRF24L01– RF transceiver	$20.00	$40.00
uOLED – 96-G1 – DISPLAY	$49.79	$49.79
LM335 – Temperature sensor	$1.95	$1.95
Force sensitive resistors (FSR)	$ 7.45	$7.45
Buzzer –	$3.95	$3.95
LED –	$1.95	$1.95
(4) SONY CR2450 Lithium Battery 3V, 600 mAh	$2.25	$9.00
(2) Lithium 2450 Battery Holder	$1.95	$3.90
Printed circuit board (PCB)	$4.00	$2.00
(2)LM317T- Voltage regulator	$2.79	$5.38
7805 – 5V regulator	$1.79	$1.79
(2)10k Micro potentiometer-	$1.79	$5.38
Key chain case	$5.00	$3.00
10K resistor	$0.45	$0.45
240 Ohms resistor	$0.45	$0.45
(2)4.7K Ohm resistor	$0.45	$0.90
1uF Capacitor	$0.45	$0.45
.1uF Capacitor	$0.45	$0.45
(9)4.7uF Capacitor	$0.45	$7.65
Total		$148.59

6. Conclusion

After all the design process and all the analysis related with the system, we were able to deliver a product that fulfill all the expectances that we have. We were able to create a device that accomplish all the establish goals and executes them very precisely. Our final product is everything we expected it to be. The system uses RF transceiver to establish a range between our two devices. The system also reads the temperature in Kelvin scale and internally our software has the responsibility to turn it to Fahrenheit scale because it is the scale that is commonly used, using simple algorithms. All this information is then send to de key chain device were the data will be display in the user interface in a very simple way. All this is done using a PIC16LF722 that provide us all the interfaces that we need it and also using low power.

Our main consideration choosing the hardware components were to achieve power efficiency, low cost and simple as possible. Our microcontroller provide us a low power architecture that works with 3.3V and almost each one of the elements were able to work with that amount of voltage. This helps us to save energy because the power consumption of all the system is pretty low. We tried to develop a low cost system but there's always a tradeoff between simplicity and cost. We tried to balance those things creating then a system with a relatively low cost and very simple for every user. Our user interface is pretty simple for any kind of user because it only consists of a uOLED display, a LED and a buzzer. This expands our market options for a wide range of customers.

There are some issues that need to be fix are few. But the most important is the accuracy of the device by reading the temperature. This happens because of the internal configuration of the microprocessor and the decimal point precision. All the calculations of the temperature are done internally and when the final result is displayed there is a small difference between the real temperature and the one displayed. Also the distance of the radius allowed can be decreased to decrease the time it will take to the parent to take out the baby.

We know that this device is not a luxury it is a necessity. Because of the need of our product we know that it can be integrated to a bigger system in which along with other elements will maximize the security of every child. We can turn our product into a service and not just a device.

7. Future Work

The baby on board system allowed us to implement a bigger application. The idea of Baby on board begins as a device to prevent parents to forget their children inside of cars. Then we realize that it can become a huge system to improve the safety of children. We realize that our product can become not just a device but also can be part of a service. This service that will incorporate a network that connects some of our devices and a group of people searching for any baby on danger.

When we finished our system we figured out that there is a lot more that can be implemented with it. We decide that we should expand it and make it even more efficient because there is nothing more important for a parent that his child. So then we analyzed and discuss how can we make it better? How we can take something that work properly and turn it to something great. Then we realize how many potential our idea has. Here is a structure idea of our future work:

The main idea is to turn our device in to a service. We want to create a security system that work similar to the security systems created for homes and buildings. We want to design a network that connects every single Baby on Board device in to a single system. This network will provide us the ability to track every one of those devices. The true question is how that is going to improve our system? I will give a detail explanation on how will it work.

As we explain later our system will consist in a network of Baby on boards. This network will be connected to a main system that will keep track of each one of them. If a parent forgets his child his device will start ringing and at the same time the person behind the main system will be notified that there is a problem with one of the devices. He will have the information of the person in charge of the device. That person will call the person in charge of the device. In case he answers he will be asked if everything is alright with the kid. In case the answer is no we will call the police to go and help him. If the person does not answer the phone the person behind the main system will call the police and tell them where the car is located that has the child inside. This will be possible because we are going to have a tracking system that will provide the location of the car seat device.

We think that this is going to be a revolutionary idea. This will improve every single device designed for the babies' security. We plan to implement this idea in a near future. This system will improve our system in a huge way and will decrease the probability of babies dying because of parent's forgiveness.

8. References

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[10] Force Sensitive Resistors

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