ENSC 305W/440W Grading Rubric for Functional Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the functionality of the proposed product without excessive design content (i.e., outlines the “what” rather than the “how”).	**/10%**
Technical Correctness	Ideas presented represent valid functional specifications that must be considered for a marketed product. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text).	**/15%**
Process Details	Complete analysis of problem. Justification for chosen functionalities. Sources of ideas referenced. Specification distinguishes between functions for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Comprehensively details current constraints.	**/20%**
Engineering Standards	Outlines specific engineering standards that apply to the device or system and lists them in the references.	**/10%**
Sustainability/Safety	Issues related to sustainability issues and safety of the device are carefully analyzed. This analysis must cover the “cradle-to-cradle” cycle for the current version of the device and should outline major considerations for a device at the production stage.	**/10%**
Conclusion/References	Summarizes functionality. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format Issues	Includes letter of transmittal, title page, executive summary, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	8.2 Responsibilities of an Engineer: 8.5 Integration of Standards: 9.2 Sustainability:	

September 28, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, B.C.
V5A 1S6

RE: ENSC 305W and ENSC 440W Capstone Functional Specification for the Robison Detector

Dear Dr. Rawicz,

Please find the enclosed document for the functional specification of the Robison Detector. This is a device that can be installed into cars and will receive EMV sirens. Once the siren is interpreted, it will safely alert the driver so they can yield to the surrounding EMV.

The functional specification document details what the device will be capable of in terms of features. These features will be categorized according to system requirements, hardware requirements, and software requirements. A priority will also be assigned to these features for reference purposes. The functional specification will also include relevant engineering standards and issues relating to sustainability and safety. This document will be used by the entire Vantek team during development and for future reference if necessary.

Vantek was founded by six inventive and motivated senior engineering students: Shayan Ebrahimi, Kartick Verma, Raj Wardhan, Siheng (Shane) Wu, Siavash Seyfollahi, and Gurinder Singh.

If you have any questions or comments, please do not hesitate to reach me at 604.817.7588 or shayane@sfu.ca

Sincerely,

ShayanEbrahimi

Shayan Ebrahimi
Chief Executive Officer
Vantek

Enclosed: A Functional Specification for the Robison Detector

Functional Specification for the Robison Detector

Shayan Ebrahimi, **Chief Executive Officer**
Siavash Seyfollahi, **Chief Operating Officer**
Raj Wardhan, **Chief Financial Officer**
Gurinder Singh, **Chief Technology Officer**
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Primary Contact: Shayan Ebrahimi, shayane@sfu.ca
Submitted to: Dr. Andrew Rawicz (ENSC 440)
Steve Whitmore (ENSC 305)
School of Engineering Science
Simon Fraser University
Issue Date: October 15, 2014
Revision 1.2

Executive Summary

In 1987, 102 ambulance collisions were reported during a three and a half year period in Tennessee [1]. More recently 1,412 Emergency Vehicle collisions occurred over four years in the state of New York [1]. Most of these collisions were the consequence of miscommunication between road users failing to yield properly to nearby EMVs. This could be a case of the driver not noticing the EMV or they were distracted in their vehicle which made them miss it. Hence, there should be some kind of prior communication between EMVs and the road users to avoid a situation like this. Or better yet, an alert that notifies the driver in the vehicle.

Hence, the objective of the Robison Detector is to ensure the safety of road users in the case of an EMV sharing the road. Furthermore, we are implementing our product in such a way that it will seamlessly integrate into road vehicles and the only thing visible to the driver will be an alert in the case of an EMV needing the nearby road. The device will consist of a MCU and DSP that will interpret a signal from the microphone and then send an external alert if necessary.

For reference, the requirements have been laid out in this document. They've been separated into sections, with special attention given to the hardware and software parts because of their crucial role in the project. These requirements include features, limitations, and performance specifications.

Also, for efficient advancement of the product, development stages will be categorized into two categories. The first stage will include basic testing of the three fundamental components of the detector: the microphone, the microcontroller, and the external alert. The final testing stage will include regression testing and testing for any additional external alerts that have been added. Topics of sustainability, safety, and constraints will also be discussed in this document.

All the team members at Vantek will contribute their skills, knowledge, and experience to develop the Robison Detector. The provided document will outline the functional specifications and other requirements. Demos for the prototypes of the device will take place during December. At the end of the final development stage a working product should be delivered no later than December 15th, 2014. The Robison Detector will comply with CSA and IEEE standards and serve its main purpose of improving road safety.

Contents

List of Figures & Tables

Glossary

EMV	Emergency vehicle (police car, ambulance, fire truck, etc.)
Embedded System	A computing device within a larger system that performs a dedicated task
MCU	A microcontroller unit that is fundamentally a computer and has basic inputs and outputs
DSP	Digital Signal Processor, a device that will read and process analogue (real-world) signals
LED	Light Emitting Diode, a simple circuit device that emits light
MATLAB	Software that can be used for math functions, testing algorithms, and performing simulations
"Cradle to cradle"	A design philosophy that maximizes the use of all resources and puts a strong emphasis on efficiency [2]
PCB	Printed Circuit Board, an electronics board that supports various components such as resistors, capacitors, etc.
IVI	In-Vehicle Infotainment, an embedded system for cars that provides entertainment
IEEE	Institute of Electrical and Electronics Engineers, a worldwide professional association that has established standards in the industry
FFT	Fast Fourier Transform, a method for analyzing analogue signals digitally
API	Application Programming Interface, specifies how to implement features of a system

1. Introduction

The Robison Detector is an embedded device within a motor vehicle that detects an emergency siren and safely alerts the driver so they can properly yield to the EMV. The alert will lower the car stereo's volume if it is too loud. Also, depending on the model it can give an alert via the In-Vehicle Infotainment (IVI) system and notify the driver with a voice prompt the location of the siren. This way, the driver can safely yield to the EMV.

1.1. Scope

This document is created to specify the functional requirements which must be met by the Robison Detector. A list of requirements will be given to provide a developmental reference for the project. In addition, their priorities will also be listed, with the highest priority aiming to make the first prototype and the lowest priority to perhaps make the final product. Comprehensive sections on the hardware and software will also be present. Issues related to sustainability, safety, and constraints will also be discussed. All of the requirements below will be referenced by the Vantek team.

1.2. Intended Audience

The intended audience for this document is the entire Vantek team. The Functional Specification will provide the design criteria needed for the project as well as some guidelines for development. Most importantly, the Vantek team will refer to this document throughout the project to make sure all the software and hardware requirements are being met. This document may also be useful for any further designs beyond the first prototype.

1.3. Classification Specification

The following convention will be used for the specifications throughout this document:

[XX-##-P] Functional requirement

Where **XX** is the category of requirements (hardware, software, etc.), **##** is the number within that category, and **P** is the priority of the requirement within that category. The priority ranges from highest to lowest, with **A** being the highest and **C** being the lowest. Requirements with priority **A** will be projected to make the first prototype. Priority **B** and **C** requirements will make the second prototype, however some may not at the team's discretion.

Vantek

2. System Overview

2.1. Basic Design of the Robison Detector

The fundamental design of the Robison Detector is shown in Figure 1 below where a microphone receives a siren audio signal, the microcontroller interprets it, and the external alert will remind the driver of a nearby EMV.

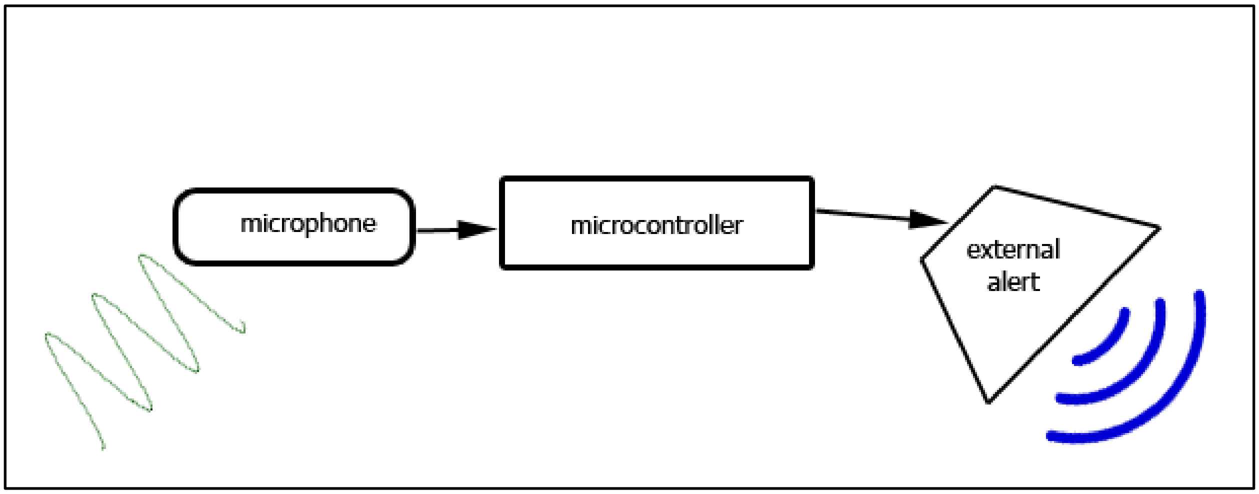

Figure 1 - The three basic components for the Robison Detector

The microcontroller, and any additional electronic components, perform the majority of the work for the Robison Detector. It is responsible for isolating the siren signal, confirming it is indeed a valid EMV siren, and sending a signal to the external alert. The entire unit will act as an embedded device within a motor vehicle, working in the background as the driver operates the vehicle. Eventually during the later stages of development, additional external alerts like Bluetooth can be added. Also, integration with the vehicle's IVI system will be included.

2.2. Prototype 1

Prototype 1 of the Robison Detector will consist of the microphone and microcontroller; however the external alert will be an LED that will flash to notify the driver of a surrounding EMV. Having the simple LED as the first prototype will simplify the building of the detector. But it will still be fully functional and capable of being incorporated into a motor vehicle.

2.3. Prototype 2

The second prototype of the Robison Detector will be the same as the first, but the external alert will also consist of a notification via Bluetooth (for those vehicles that have it) connected devices in the vehicle. For instance a Bluetooth-enabled smart-phone can be used in this case. It may also contain the feature of automatically lowering the stereo's volume if it is determined to be too loud. These additional features give the Robison Detector further functionality, especially for modern motor vehicles. Full integration with the IVI system will also be included in this prototype. This way, the alert will go through the IVI system, which may include an oral alert or a visual aid, depending on the system model.

3. Requirements

3.1. General Requirements

[GE-01-C] The final device does not require any setup from the end user
[GE-02-C] An option to turn off the Robison Detector from inside the IVI system
[GE-03-A] A motor vehicle such as a car or truck should already be purchased (one with an IVI system is preferable)

3.2. Physical Requirements

[PH-01-B] The device's inner components (microphone and electronics) should be hidden
[PH-02-A] The whole unit should be small enough to integrate into a car
[PH-03-A] The unit's weight must be small enough so that the car's total mass does not increase significantly
[PH-04-A] An external notification should be present to alert the driver
[PH-05-C] The device's exterior colour scheme should match that of its vehicle's

3.3. Electrical Requirements

[EL-01-A] A power supply that will sufficiently support the device should be present
[EL-02-A] The device should be enabled whenever the car is turned on
[EL-03-A] All circuits should be properly grounded
[EL-04-A] All electrical wires should be properly insulated
[EL-05-A] The voltage and current required by the device will about 9.0 V and 3.0 μA, respectively

3.4. Environmental Requirements

[EN-01-B] The device should be able to withstand conditions near a typical car engine
[EN-02-C] The device should still function in harsh climates, from -30°C to +40°C
[EN-03-B] The unit must be resilient to wind and thus should not be dislodged easily
[EN-04-B] To prevent short circuiting, the circuitry should be enclosed in an apparatus

3.5. Reliability and Durability Requirements

[RE-01-B] The device should be capable of being powered for extended periods of time, for instance however long a car may be driving
[RE-02-B] The unit should be compatible with a motor vehicle's power supply since that will eventually be its source of power
[RE-03-B] The device should withstand constant motion and sudden movement
[RE-04-B] The device's external notification should be noticeable at all times, day or night

3.6. Safety Requirements

[SA-01-A] The power given to the Robison Detector by the vehicle should not be leaked anywhere else
[SA-02-C] The device should have an off switch in case of an emergency
[SA-03-A] The device should not obstruct the drivers' vision
[SA-04-A] Any hazardous parts will be labelled as such
[SA-05-B] The device should be thoroughly tested to ensure it does not overheat
[SA-06-B] The unit's external notification should not startle the driver, but instead safely alert them of a surrounding EMV as shown in Figure 2

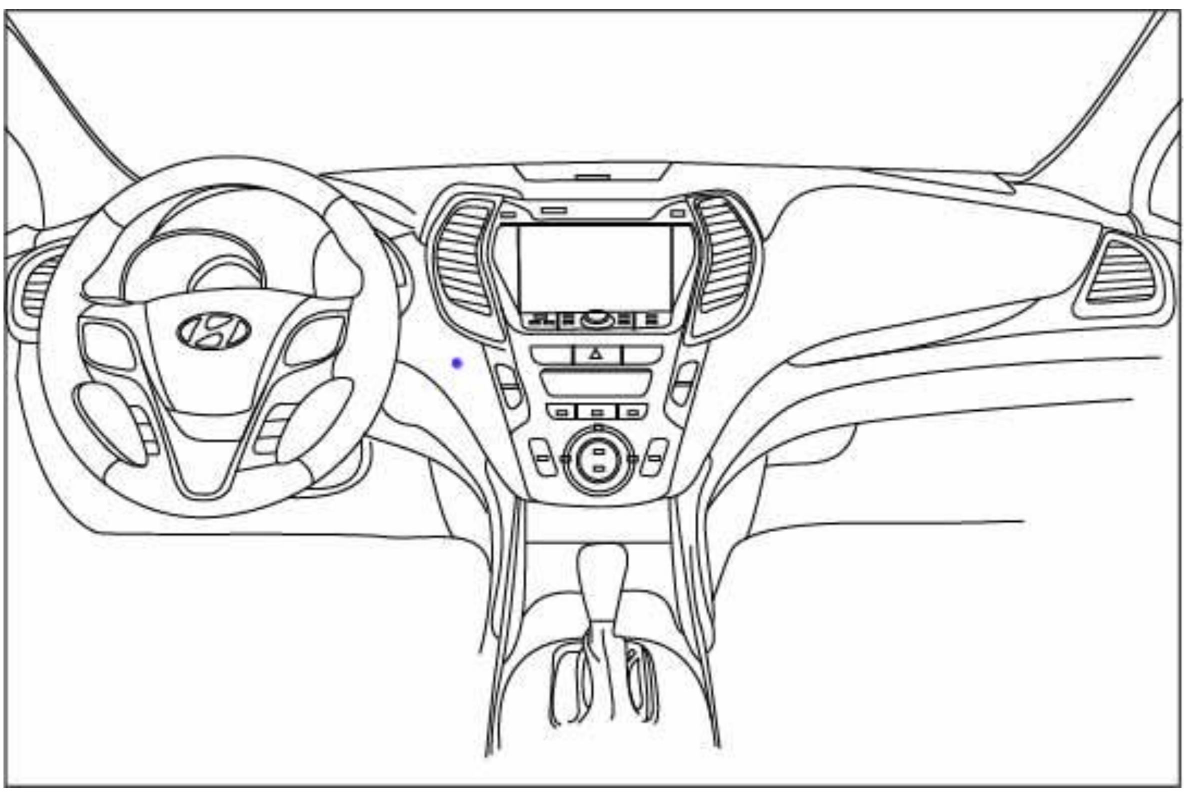

Figure 2 - A blue LED alert on a car's dashboard [3]

3.7. Performance Requirements

[PE-01-A] During a siren notification, the device should lower the car stereo's volume if it is determined to be too loud.
[PE-02-B] The device should not interfere with the other features of a vehicle during operation
[PE-03-B] The unit should operate quickly enough so that the driver gets a notification in advance of an EMV approaching
[PE-04-B] The device should be able to isolate the siren sound from ambient noises in order to avoid false notifications
[PE-05-B] The device's microphone must be able to receive sound from at least 100 metres away
[PE-06-C] The device should recognize the location of the EMV and send (or not send) a notification based on the EMV's location, a situation like this is shown in Figure 3

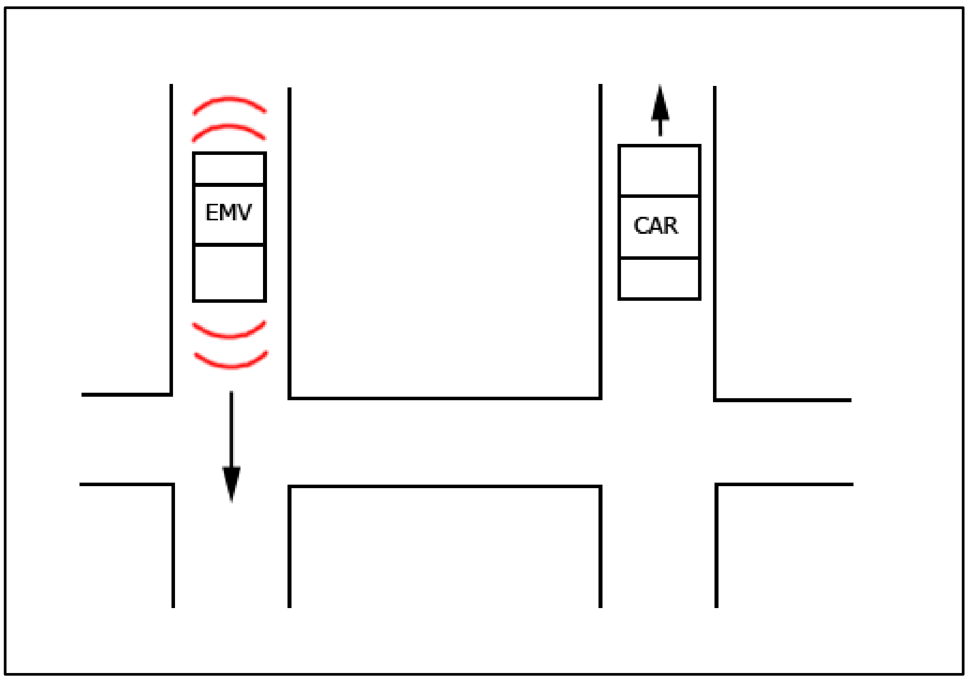

Figure 3 - The EMV has a siren, but its route is not interfering with the car's, so the Robison Detector should not send an alert in this situation

3.8. Usability Requirements

[US-01-B]The Robison Detector should function correctly without user interference

4. Hardware

4.1. Hardware Overview

The Robison Detector contains 3 components that come together to form the device. From Figure 1 it can be seen that the 3 components are the microphone-like device that receives the signal, an electronic circuit which interprets the signal, and an external alert which is enabled if the circuit determines the signal to be an EMV siren. The first prototype will contain a microphone, a circuit, and an LED for the alert. Further development may require changing some of these components for additional features. Also, further prototypes will be fully integrated into vehicles and will draw their power from the car battery.

Figure 4 below shows the basic layout of all the hardware components and a workflow with the arrows representing communication paths. The MCU that we have chosen is the TI MSP430. It has low voltage and current requirements, physically the board is small enough to fit inside a vehicle, it has ample processing power, enough features, and was well within the planned budget. The MCU controls most of the operations in the Robison Detector. Attached to the MSP430 is the C5535 BoosterPack which acts as a DSP, it is responsible for interpreting any received audio signals and sending any alerts (if required) to the external alert. The MCU controls the DSP and commands it to perform operations. In the prototype, the DSP will send a signal to the MCU when a siren has been positively identified and the MCU will send the signal to the external alert. This is the behaviour Figure 4 shows.

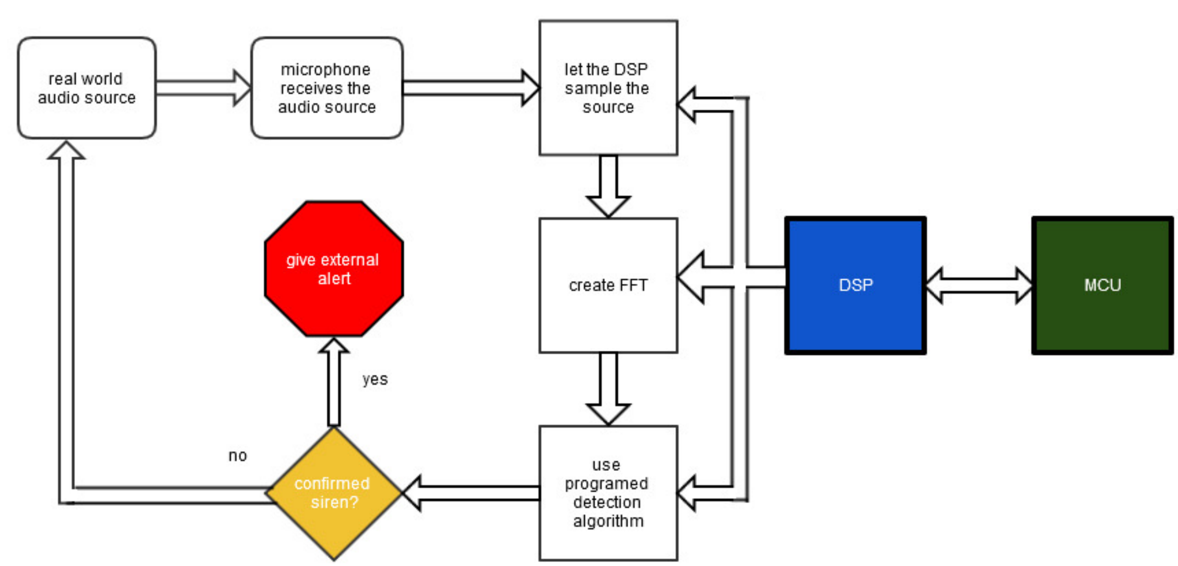

Figure 4 - A flowchart for the workflow of the device, including its hardware

4.2. Hardware Requirements

[HW-01-A] Must be able to process the siren signal quickly enough for an alert
[HW-02-B] Should be able to communicate with external environments such as Bluetooth or IVI
[HW-03-C] Device will eventually be designed on a custom PCB for mass manufacturing
[HW-04-A] Must be able to sample up to 1 kHz audio frequency for correct siren detection
[HW-05-A] Must have an input for a microphone-like device for receiving sound
[HW-06-A] A microphone-like device should be connected for recording sound
[HW-07-A] The MCU must be programmable to interface with a microphone and DSP
[HW-08-B] The MCU should have enough memory for all the required features to work
[HW-09-B] DSP must be able to perform FFT for digital processing of an analogue signal
[HW-10-B] Any additional electronic boards must be compatible with the TI MSP430 MCU
[HW-11-B] Should be able to interface with a car stereo in order to control its volume
[HW-12-B] The device should eventually be able to fully integrate into a vehicle

5. Software

5.1. Software Overview

The software will primarily be responsible for detecting the EMV siren. In particular the algorithm for the siren detection which will be implemented in software. Using the APIs of the MCU, the DSP functionality can be fully controlled. This includes receiving the audio signal, sampling it, applying the FFT to it, and then using the detection algorithm to determine if it is indeed an EMV siren. All of this is being programmed in C code. The code itself can be written on a standard computer, then the MCU can be connected to it, and the code can be uploaded. In addition to this, the code must also receive the audio and be able to prepare it for the detection algorithm.

All of the code will be written and uploaded to the MCU. However, additional boards may be added to the future prototypes, for example a Bluetooth or IVI board. In this case it would be ideal if it could be programmed through the MCU since we will be already be comfortable doing it from the DSP. However, it may need direct programming and the language may be different as well, it could be Java or even assembly.

5.2. Software Requirements

[SW-01-A] C language should be able to read any real world audio signals
[SW-02-B] C language should be able to handle FFT audio signals
[SW-03-A] C language be able to support a detection algorithm for an EMV siren

[SW-04-B] The detection algorithm should be written efficiently to avoid any potential delays
[SW-05-A] The entire piece of code must be small enough to be uploaded to the MCU
[SW-06-C] The software should be programmed for compatibility with the car's IVI system

6. Constraints

One of the constraints on the project will be the memory size on the MSP430. Any piece of code that has to be written for the device should not be too big. Our MCU has 16 kB of flash and 512 MB of RAM [4]. So any software development would have to be done carefully so that the code does not grow too big. Also any algorithms would have to be checked for efficiency to ensure the code size stays at a minimum.

Another constraint that our group faces is that of funds and resources. We do not have extensive resources or unlimited funds for our project. So for instance, a spare vehicle is not available for the testing of integrating the Robison Detector. This will have to take place later on if the product becomes successful or receives any additional funding.

7. Standards and Safety

[SS-01-A] The device will conform to the "Automotive" standard under the CSA Group [5]
[SS-02-B] The device will conform to the "Software & Systems Engineering" standard under the IEEE [6]
[SS-03-C] The device will conform to the "Wired & Wireless" standard under the IEEE [6]
[SS-04-C] The device will conform to the "Lighting" standard under the CSA Group [5]

In addition to the above standards that will be met by the Robison Detector, there are a few issues of safety that must be considered during the design stage.

Firstly, the alert that the driver receives should not be distracting. But it also should not be easily missed. The alert should notify the driver promptly and not startle them, which could lead to a loss of concentration on the road. This would defeat the entire purpose of the Robison Detector's goal for enhanced road safety. For an LED alert, the light should not be too bright and it should not flash repeatedly either. Instead it should slowly light up to a moderate brightness and stay on until the driver acknowledges it. For an alert directly to a Bluetooth device, it should not be too loud and it should not be too soft either. The alert should quickly let the driver know of a surrounding EMV.

The second issue of safety is ensuring the microcontroller and any additional circuitry do not pose a hazard to the vehicle or its driver, especially during harsh climates. For example during hot summers the temperatures can become very high, especially those inside a vehicle. Sometimes these temperatures can reach beyond the suggested operating levels of some electronic parts. This could lead to a fire of it is hot enough or the device's failure. Similar risks exist for cold temperatures. Proper care will have to be taken in designing the installation location and the enclosure of the Robison Detector in order to avoid this potential hazard.

8. Sustainability

The current version of the device is very bare-boned. It is the TI launch-pad with an attached DSP board. These 2 boards meet the feature requirements for the project, so they were purchased specifically to function as the core hardware. For now the audio source (EMV siren) is being fed into the board digitally and the detection algorithm is being tested. Once the algorithm is finalised, a decision will be made on the microphone that will receive the real world siren. Also for testing purposes, the external alert is currently being detected through software. Once the project has progressed further, a proper alert such as an LED or via IVI will be implemented.

Prior to using any hardware, thorough research was completed to ensure the right components were selected. It would be poor planning to hastily order a part, only to find out that it wasn't going to meet one of our requirements. By doing the proper research, electronic waste can be minimized. Additionally, any parts that are no longer needed during development should not be thrown in the garbage. Instead they can be saved for future projects, donated to schools, or recycled at the local waste depot.

As of now, a prototype is being built and there has not been that much emphasis on sustainability. However a few issues have been brought up. If an LED is used for the external alert, one can be borrowed from the Engineering department or someone else instead of purchasing one. The TI launch-pad and DSP board can be used for testing in future prototypes of the Robison Detector. They can also serve as testing platforms for any new features or modifications that may be made to the device. The "cradle to cradle" philosophy is minimized during this stage of development.

Once a functioning prototype is built, the product will be ready for production. It is now when sustainability and efficiency of design need to be strongly considered. If there are enough features and it is economically feasible, a customized PCB could be built and replace the TI launch-pad and DSP. In this case, the manufacturing house which produces the boards needs to be efficient in its production so that excessive waste is not created. If possible a manufacturing house that used recycled materials would be used. Adjustments may need to be made in the final design to see if the device's efficiency can be improved. This could include testing to see if less hardware can be used or if lowered voltages and currents can be met.

9. Testing Plan

9.1. System testing plan

In order to ensure efficient performance of the Robison detector unit testing will be conducted for the earlier stages of building. Once the device is completely built with a successful unit test, further testing will be conducted to ensure that the implemented features work correctly.

The testing will involve two stages. The first stage will test the highest priority requirements and the second will test the secondary priority requirement including any tertiary requirements that will be included. Any additional external alerts can be added as modules during the later stages of testing.

9.2. Unit Testing Plan (First Stage)

Microcontroller test

- To test the MCU, simple functions will be used to confirm they work correctly. This will also test the programming capabilities of the MCU. An example of a simple test like this would be turning an LED on and off through the MCU controls. Further testing will deal with configuring the DSP to correctly decode the audio signals received by the microphone and programming the MCU to send an interrupt once the correct comparison is made.

Filtration of detected audio signal from ambient noise test

- In order for an accurate detection of an EMV siren, testing will be conducted to ignore the different types of ambient noise. This will make sure false positives do not occur and the siren can be detected alongside other sounds, which closely simulates the real-world.

Alert message test

- Testing will be conducted to make sure that an alert is being sent out in the form of a LED (Prototype 1) or notification via Bluetooth (Prototype 2). This test will also incorporate user feedback to make sure they are notified of the alert.

Volume control test

- Testing will be done to ensure that the audio levels are being lowered if they are too high once the signal is detected and an interrupt has been sent. This will also ensure that the alert is not delivered if the Robison Detector is turned off from inside the vehicle.

Regression testing will also be conducted along with these set of tests if new modules are added to the product.

9.3. Final Product Testing (Second Stage)

Product overheat test

- The final product will be tested to ensure the safety of the end users. These set of tests will be conducted in various temperatures. For instance, in summers there is a possibility of the product overheating, leading to a device failure and a potential fire hazard.

Hearing disability test

- These tests will be conducted for people who wear hearing aids, making sure that the alert's sound level is appropriate for them.

Different cars test (optional to put in the final report)

- These tests are intended to ensure that the correct product functionality is independent of car model or type.

10. Conclusion

The functional specifications and requirements for Vantek's Robison Detector have been presented in this document that defines the current design for it. Some of the requirements are tentative, but most are in place and will be implemented during development. However, they may change during the course of testing for the device.

Vantek is a group of senior and motivated engineers that are dedicated to bring an effective yet simple solution for road safety, especially with EMVs. Early prototypes will have the basic functionality and an LED alert. The final product is expected to provide advanced IVI integration with vehicles and automated stereo control during an EMV siren. Bluetooth may also be added as an additional external alert.

Vantek will try its best to keep the product relatively inexpensive for road users and safe to use. The Robison detector is expected to be released in early December, 2014.

11. References

[1] J. Clawson. (1997, Dec. 3). *The wake effect. Emergency vehicle-related collisions.* Available: http://www.emergencydispatch.org/files/articles/wakeeffect1.htm. Date accessed: October 13, 2014.

[2] L. Lovins. (2008, May 8). *State of the World: Innovations for a Sustainable Economy.* [Online] Available: http://www.worldwatch.org/files/pdf/SOW08_chapter_3.pdf. Date accessed: October 15, 2014.

[3] GPS Tom. (2014). *Gps tom.* [Online] Available: http://imgarcade.com/1/car-dashboard-sketch/. Date accessed: October 15, 2014.

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[5] CSA. (2014). CSA Group Standards. [Online] Available: http://www.csagroup.org/ca/en/industries/automotive. Date accessed: October 13, 2014.

[6] IEEE. (2014). *IEEE Standards Association.* [Online] Available: http://standards.ieee.org/findstds/index.html. Date accessed: October 13, 2014.