October 29, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
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RE: ENSC 305W and ENSC 440W Capstone Design Specification for the Robison Detector

Dear Dr. Rawicz,

Please find the attached document for the design specification of the Robison Detector. The objective of this product is to alert drivers of a nearby emergency vehicle's siren so they can safely yield on the road. The device can be installed within vehicles and will interpret a siren, and then send a signal to the driver.

The following document details the design choices made and their justifications. Vantek has made these choices in accordance with the functional specifications while keeping user safety and performance in mind. Relevant scientific concepts, details of the Robison Detector's hardware and programming, and a test plan will be included in the design specification. This document will be used by the Vantek team for reference purposes.

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,

Shayan Ebrahimi

Shayan Ebrahimi
Chief Executive Officer
Vantek

Enclosed: A Design Specification for the Robison Detector

Design Specification for the Robison Detector

Shayan Ebrahimi, **Chief Executive Officer**
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Revision 1.4

Abstract

Vantek's Robison Detector is an innovative solution to a common problem. Emergency responders struggle with making other vehicles yield on the road. Often times other drivers simply do not notice an emergency vehicle's siren and so they don't yield properly or in time. A car equipped with the Robison Detector will safely alert the driver of a nearby emergency. This document covers the design decisions made for the Robison Detector and justifies Vantek's approach to the problem. Some theory of sound waves and electromagnetism apply to this project and so they will also be discussed. In addition to the design aspects of the device, many scenarios are taken into account during the building of the Robison Detector, especially during the testing plan. This document is intended for the Vantek team and for those who are qualified and given permission to view the detailed workings of the Robison Detector.

Contents

List of Figures & Equations

Glossary

EMV	Emergency vehicle (police car, ambulance, fire truck, etc.)
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
IVI	In-Vehicle Infotainment, an embedded system for cars that provides entertainment
FFT	Fast Fourier Transform, a method for analyzing analogue signals digitally
Black box	A device/system which is explained simply by its inputs and outputs and not its detailed internal workings
SNR	Signal to noise ratio, a higher value means less noise in the signal and thus a higher quality signal
MIPS	Million instructions per second, a measure of a processor's speed
USB	Universal Serial Bus, a standard connection platform for computing devices
OS	Operating System, software that interfaces between hardware and the user for ease of functionality
Tizen	An OS for the IVI system
SDK	Software Development Kit, software for developing hardware or other devices
IDE	Integrated Development Environment, a program that includes a compiler for software developing
UI	User Interface, a graphical interface that operates a program easily

1. Introduction

Many drivers on the road face numerous distractions while operating a vehicle. In addition to paying attention to the road some drivers will listen to loud music, talk on their cellular devices, or simply not be receptive to the events around them. This is unsafe behaviour as it puts all road users at risk, in particular EMVs. For instance, an EMV with its siren enabled must quickly reach its destination; however an unvigilant driver will not yield to the EMV, thus hindering the EMVs mobility on the road. This is a situation that occurs all too often and is especially frustrating for emergency workers [1].

Our solution to this problem is the Robison Detector. This device can be installed within motor vehicles and will automatically alert the driver when a nearby EMV's siren is enabled. In addition to an alert to the driver, the device will also lower the car stereo's volume if it is too loud, thus allowing the user to hear the siren. Also, depending on the model of the Robison Detector, it will give an alert via the vehicle's IVI system. Ultimately the device will improve road safety and reduce emergency response times by safely alerting the driver.

1.1. Scope

This document is created to specify the design specifications which are intended for the Robison Detector. This will include choices made for the project and the justification for these decisions. Some scientific theories will also be included for background purposes and for further clarification. A specific testing plan will also be included, and will eventually be used in preparation for demonstrations. Unless otherwise stated, all the designs and concepts contained in this document apply to the initial prototype.

1.2. Intended Audience

This document is meant for all the members of Vantek. It gives a thorough explanation of the Robison Detector's design and can be used for reference purposes. The test plan section of this document will also be used during prototyping. Any senior advisors may also view the document if permission is granted by the Vantek team.

2. General System Overview

2.1. Basic Design

The basic steps of how the Robison Detector works can be seen in Figure 1 below.

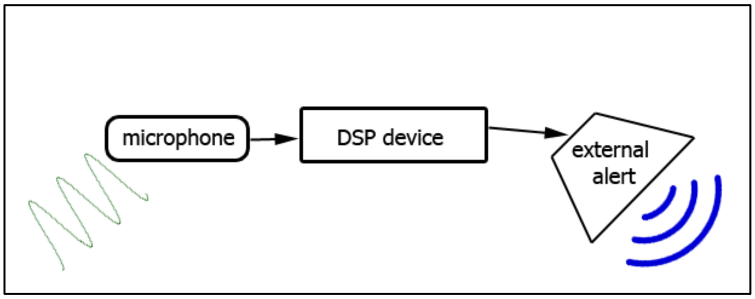

Figure 1 - The basic design of the Robison Detector, a black box approach

From Figure 1 it can been seen that the microphone receives the audio signal (EMV siren), the DSP will interpret it or in other words determine if it is indeed an actual emergency siren, and a signal will be sent to enable an external alert. This alert can be a simple LED for the prototype, and for future implementations the device can send a signal via the vehicle's IVI system.

2.2. Basic Functionality

Vantek's previous efforts included a system that had a MCU and a DSP. However, because of unforeseen API limitations, a new DSP device had to be used and the MCU is no longer needed.

The flowchart in Figure 2 below shows how the device functions in more detail.

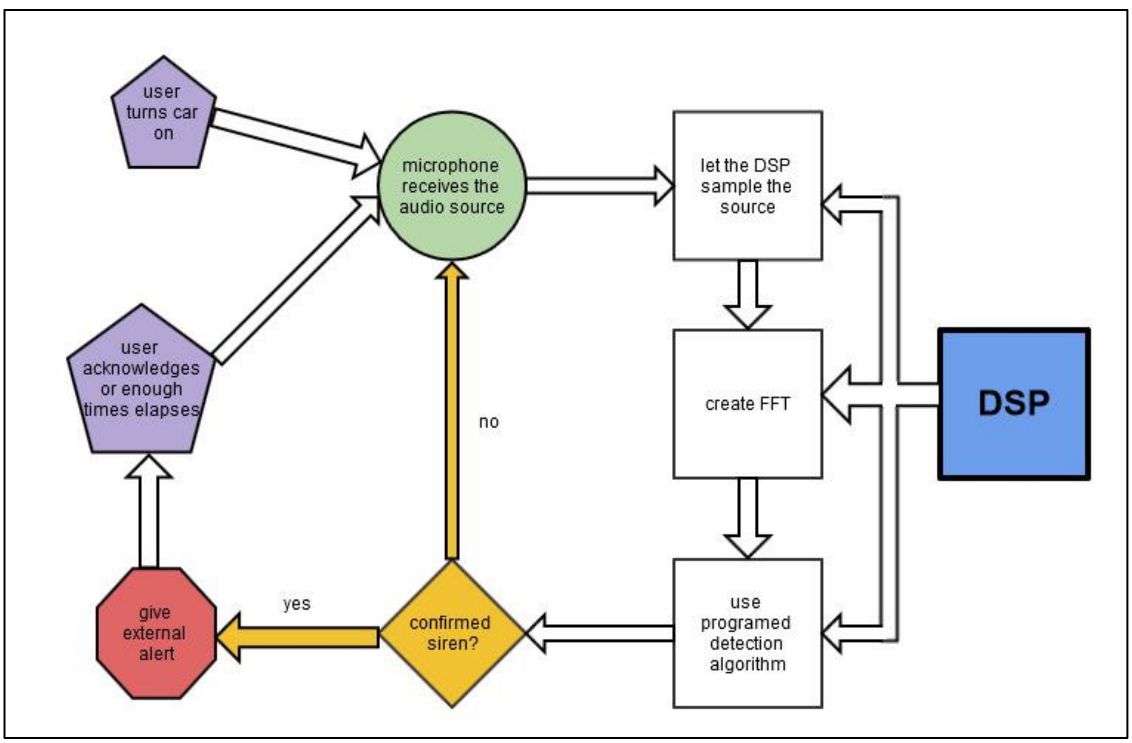

Figure 2 - A flowchart of the Robison Detector's functionality

In Figure 2 the objects in purple relate to actions by the user, objects in green are related to the external environment, objects in red are the device's output, objects in yellow relate to decisions, and finally objects in blue are linked to the hardware. The flowchart begins when the car is turned on and the device starts to read in audio sources. The DSP device does the interpreting, and finally an alert may or may not be sent. If it is not, then the cycle is repeated. When the car is not turned off, the Robison Detector is as well.

The model shown in Figure 1 represents the most basic solution to the siren problem. It was chosen because of its simplicity and logical behaviour, therefore its implementation will be relatively simple. The functionality shown in Figure 2 covers the basic scenarios of how an audio signal can be received and how the user will interact with the device. This approach was chosen because of its rationality and because it functions adequately in almost all situations.

3. Hardware Design Specifications

3.1. Microphone

3.1.1. Background Information

Sound propagates in waves and travels through a medium, such as air. Its speed, c, is governed by the following equation:

$$c = \sqrt{\frac{K}{\rho}}$$

Equation 1 - Speed of sound

where K is the coefficient of stiffness and ρ is the density of the medium. It can be seen that as ρ increases, so does the speed of sound. These waves can be read and converted to digital signals using the proper hardware and software. This is essentially how a microphone works. One of the devices connected to our DSP will be a microphone and it will perform this way. Figure 3 below shows how a typical microphone can read in an audio signal.

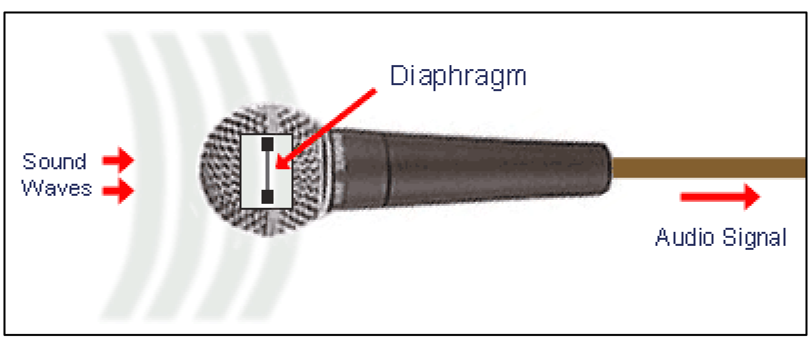

Figure 3 - A basic microphone reading in sound waves [2]

From Figure 3 it can be seen that the sound waves enter the diaphragm, which is a thin piece of metal that vibrates when it is struck by the sound waves. When this vibrating motion occurs, it causes other components in the microphone to be activated, which then convert the signal to an electrical one. Figure 4 shows this process in more detail.

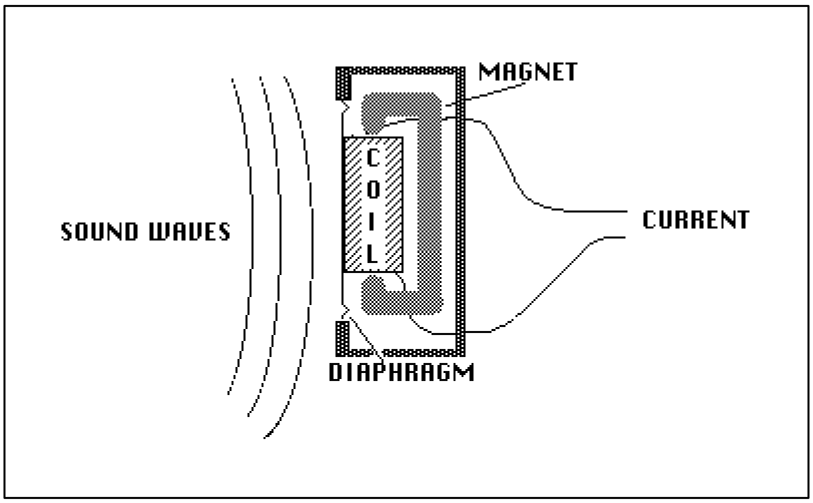

Figure 4 - A detailed look inside a microphone [3]

As seen from above, when the diaphragm moves, the coil moves in the magnetic field thus producing a current by means of electromagnetic induction.

Once the sound wave is converted to a digital signal, it can be interpreted by computers in numerous ways. Or it can also be checked to see if it matches a particular signal, such as in our case where we need to know when an audio signal is an EMV siren. This method of reading in the audio signal was chosen because microphones are relatively cheap and they are easy to setup and configure with many other hardware devices. Also, microphones vary greatly in size and our requirements are limited to small components only, which is feasible with microphones.

3.1.2. Microphone Specifications

For the testing of the Robison Detector, ear-bud microphones are being used. They are small enough so they can be tested during integration with a vehicle and they are cheap enough that they can be easily replaced. Also their performance is stable for testing purposes. Figure 5 below shows these kinds of microphones that can be used.

Figure 5 - Ear-bud microphones [4]

However, for the final prototype a higher quality microphone will be ordered that will receive sounds in greater detail and from a greater distance. In particular, an omnidirectional microphone will be needed since the EMV siren could come in from any angle with respect to the driver's vehicle. The Audio-Technica U841A is a good candidate; its picture is shown below in Figure 6.

Figure 6 - The Audio-Technica U841A microphone [5]

The U841A meets all of the requirements for the final prototype of the Robison Detector:

1) Its size and weight are small enough to be installed within a vehicle
2) The frequencies it receives, 20 to 20,000 Hz, are well within the siren range [5]
3) It has a relatively high SNR ratio of 73 dB [5]
4) The microphone type is omnidirectional, ideal for sounds coming in all directions
5) It is compatible with our DSP unit
6) 1.5V are required to power the microphone, which is within our limit [5]

The SNR ratio can be described by the following equation:

$$SNR = \frac{P_{signal}}{P_{noise}}$$

Equation 2 – SNR ratio

So it can be seen that the higher the power of the signal (P_{signal}), then the higher the SNR ratio. Therefore a high quality microphone will have a high SNR ratio because it can retrieve a strong signal while minimizing noise. The Robison Detector's microphone is connected to the DSP device via a line-in jack and from the DSP its signal is processed.

3.2. DSP

3.2.1. Background Information

Once the microphone receives the external sound and converts it to a digital signal, there needs to be a device which can interpret the signal and determine if it is indeed an EMV siren. It needs to be configurable in a few ways so that it can recognize a particular pattern of sound, which in our case is a siren. The processing power also needs to be quick enough so that it can send a signal to the external alert in time for the driver to yield. In addition to the above, it needs to be physically small enough so that it can be integrated into a motor vehicle. A DSP is ideal in this situation.

3.2.2. DSP Specifications

As mentioned earlier, a new DSP was chosen because of unpredictable coding limitations. The new chip is the eZdspC5535 and Figure 7 below shows its components.

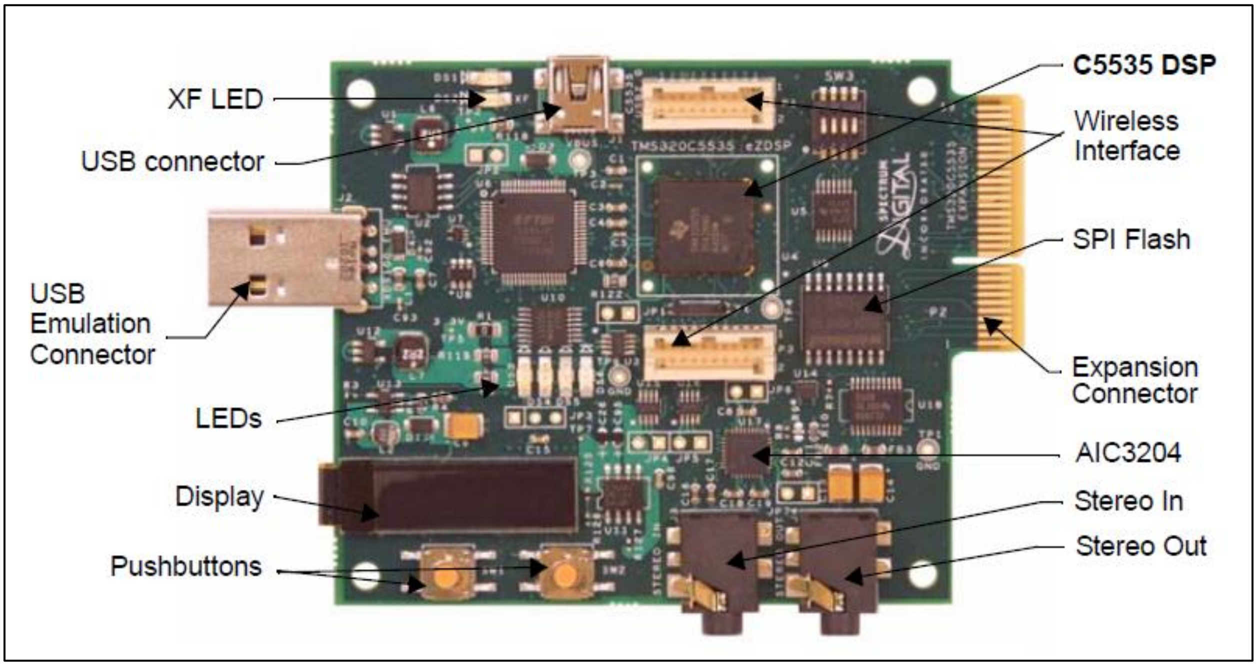

Figure 7 - The eZdspC5535 Development Kit [6]

In addition to the reasons mentioned above for selecting this device, here are some specifications for the eZdspC5535 which meet our requirements:

1) 320 KB of on-chip memory [6]
2) Mic-in audio jack
3) 16-bit processor with 240 MIPS [6]
4) USB 2.0 high speed
5) Hardware accelerated FFT computation [6]

The on-chip memory will be enough to hold the C code necessary for configuring the DSP and the 240 MIPS processor will be fast enough to analyze the signal and send an alert within a reasonable amount of time. The Mic-in jack will be necessary for connecting a microphone and the USB will likely be needed for connecting the DSP board to an IVI system or any other external alerts. The 5th requirement will be helpful in speeding up the FFT computations since the calculations will be done on hardware rather than in software, which will eventually result in a faster alert time.

From Figure 7 the stereo audio codec AIC3204 chip can also be seen. This component will be responsible for some of the audio recognition that will take place in the Robison Detector. It is connected directly on-chip with the C5535 DSP and its schematic can be seen below in Figure 8.

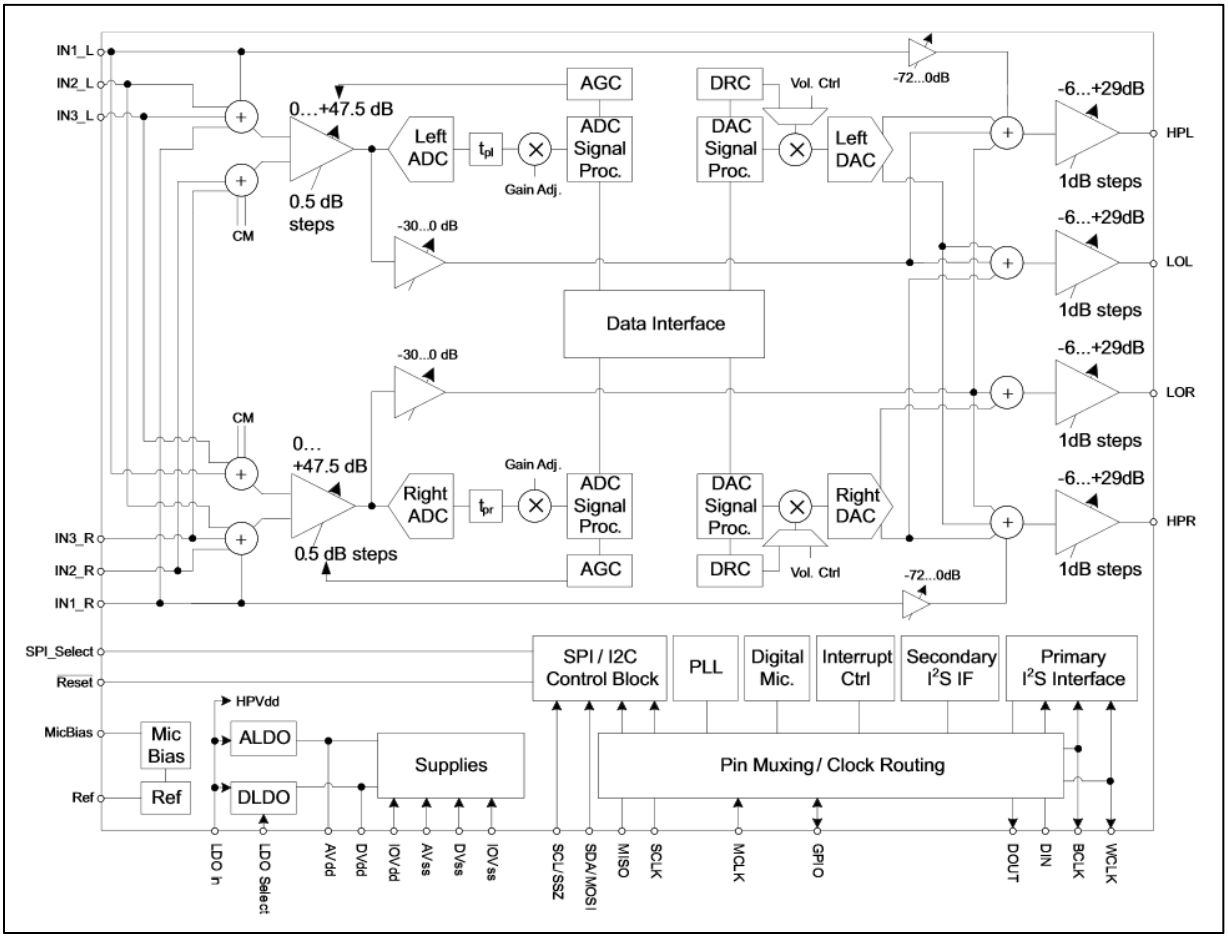

Figure 8 - TI AIC3204 stereo audio codec chip [7]

Since the AIC3204 is directly connected to the DSP on-chip, it can be configured through the DSP using C code. It is also responsible for the hardware accelerated FFT computations that will be programmed. Figure 9 below shows a flowchart of the DSP's functionality.

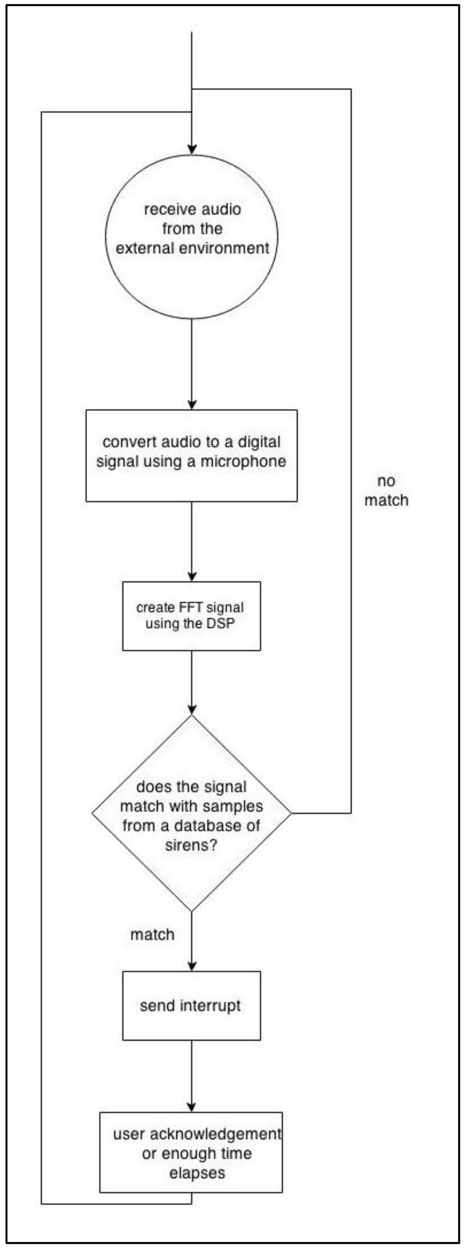

Figure 9 - A flowchart for the audio recognition algorithm

The above algorithm in Figure 9 is programmed using C code. The DSP receives audio from the environment in real-time, converts the signal to an FFT one, and compares it to a pre-populated database of sirens. If there is a match then an interrupt will be sent and an external alert is enabled. If there is no match, the algorithm begins receiving signals all over again.

3.3. External Alerts

3.3.1. Background Information

Once a siren is detected by the DSP, it needs to a send a signal for an alert. This alert will inform the driver in a safe way that an EMV is nearby and it will need the driver to yield. The Robison Detector will have different alerts, depending on the prototype and model of the device.

3.3.2. First Prototype Alerts

The following two alerts will likely be present in the prototype of the Robison Detector. The LED alert is the simpler of the two to implement since the other alert requires integration with a stereo system's controls. However with even one of these alerts in place, the Robison Detector is fully functional and capable of notifying the driver of an EMV siren.

3.3.2.1. LED Alert Specifications

The LED alert is the simplest of the alerts. It is installed on the car's dashboard as shown below in Figure 10.

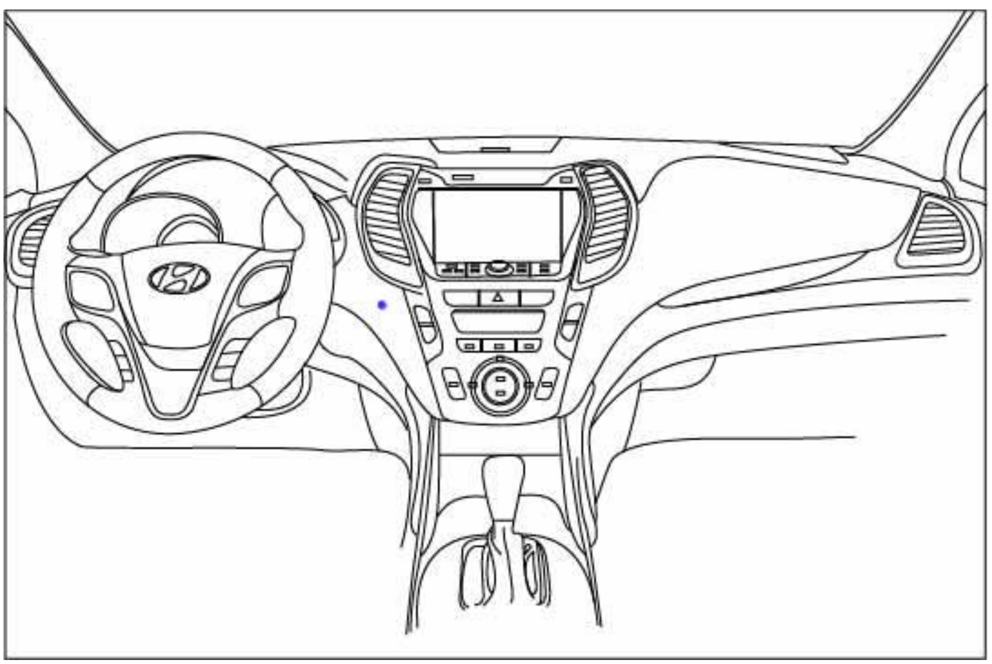

Figure 10 - The blue LED shown to the right of the driving wheel alerts the user [8]

The LED can be activated by the DSP's interrupt system and a simple circuit. The schematic is shown in Figure 11 below.

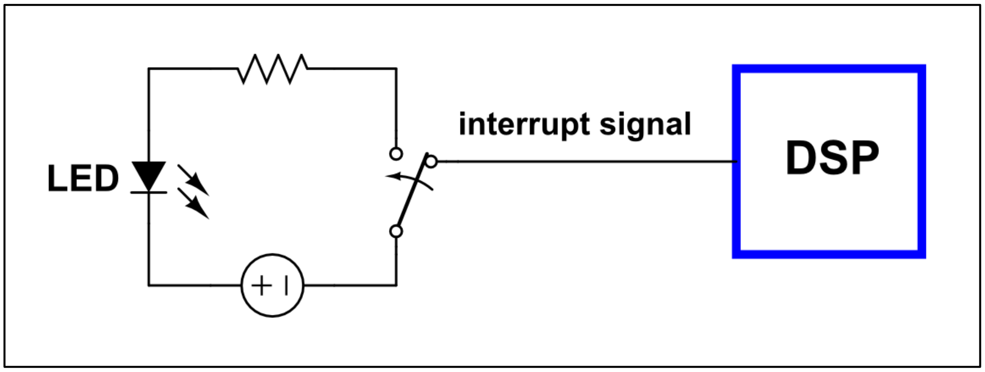

Figure 11 - The electrical circuit for the LED alert

The circuit on the left side of Figure 11 will complete once the DSP detects a siren and the LED will be lit. A DC voltage supply will be needed, but this can easily be attained from the car battery or an external source since an LED requires only a small voltage. Most LEDs require 1V to 2V to run, so if the DC supply is too large a voltage divider can be added to the circuit to supply the correct voltage to the LED. Otherwise, a resistor can also step down the voltage as shown in Figure 11.

The LED alert was chosen as part of the prototype because it is very simple to implement and it can easily test the functionality of the Robison Detector, in particular the algorithm described in Figure 9. Also, since a flashing LED is easily noticed, it works well as an alert to the driver.

3.3.2.2. Car Stereo Alert Specifications

The stereo alert works a little differently than the LED alert. Instead of directly alerting the diver of an EMV siren, this feature of the Robison Detector will lower the stereo's volume if it is determined to be too loud. This will require more testing than the other alerts because of the various models of car stereos. Some are third party devices that are installed outside the car dealership and some are built by the manufacturer themselves. Also, car stereos provide different kinds of access to their controls, depending on their make and model.

A threshold volume level should be determined as a reference point that is too loud. At this level, a nearby siren could easily be drowned out. An EMV's siren from around 10 feet is about 115 dB [9]. Anything close to or above that volume level would keep the driver from hearing the siren. So therefore a threshold of 115 dB is selected. Motorcycles and very loud music are also at this threshold level [10]. Now when the DSP detects an EMV siren and the stereo is outputting audio greater than 115 dB, a control signal will be sent to the stereo which will automatically lower the volume to a more reasonable level. This could be about 70 dB, which is just softer than a phone's dial tone [10]. The control signal will have to interface with the car stereo since it will have direct control over its volume. This will be simple in some situations where the stereo's manufacturer gives easy access to its controls, however this won't always be the case. But a car with an IVI system will have a more open platform and so access will be easier.

3.3.3. Second Prototype Alert

An alert for the second prototype of the Robison Detector is the IVI system alert, this connects the Robison Detector with a vehicle's IVI system and sends an alert through its Tizen OS. There are other alerts which may also be considered in the future, but for now the IVI alert is the intended target for the second prototype.

4. Tizen IVI

4.1. Background Information

Tizen IVI will be used for the communication between the DSP device and the IVI system, which contains the notification alert. The working principle is once the siren is detected an interrupt signal will be generated by the DSP and delivered to IVI system. A Tizen IVI application will be implemented to deliver the notification to the vehicle to inform the driver that it is necessary to pull over safely. The Robison Detector's application will only be shown and activated when a signal is received.

4.1.1. IVI

With the rapid development of the automobile and transportation industry, IVI has become an innovative in-vehicle computer application which provides the most real-time traffic information and entertainment services anywhere and anytime. This includes navigation, audio and video streaming, and network interconnection. IVI systems can be installed as an add-on or built-in by car manufacturers. The IVI interface requires a strong system core coupled with a versatile operating system in order to meet the needs of complex applications. That is one of the reasons that some of the basic hardware functions are now replaced by software such as audio with IVI. "In order to compete, the automotive industry must now keep pace with the innovation and scalability found in the consumer electronics industry," says senior analyst Stephanie Ethier [11]. "Along with a rich multimedia experience, today's drivers and passengers are also demanding constant connectivity in the car" [11]. The graphic below in Figure 12 shows some of these features.

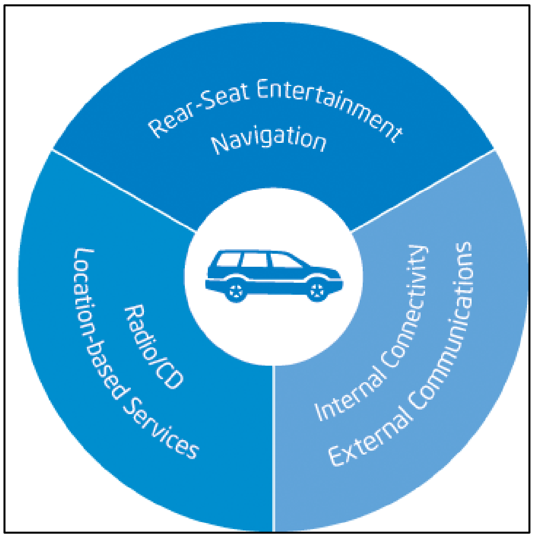

Figure 12 - A few of IVI's features [12]

4.1.2. Tizen Programming

Tizen IVI is a Linux based OS development platform for an automotive embedded computing system. It is developed in an open source environment which is also supported by various car manufacturers worldwide. The Tizen SDK allows developers to write applications using HTML5, Java, and other web technologies that run on supported devices. Applications that are based on numerous frameworks are able to run on the Tizen IVI. Therefore, it is an ideal platform for our objective of receiving an interrupt from the DSP and sending a notification to the vehicle. There are a few advantages to Tizen:

1) Tizen is a powerful and flexible open source software platform; it highlights the strong support for HTML5
2) Tizen can be customized for targeted OS vendors and original equipment manufacturers to achieve innovation
3) Tizen provides a set of complete development tools and defines the workflow which collaborates on the development of operating systems and applications

The above can be summarized in Figure 13 below.

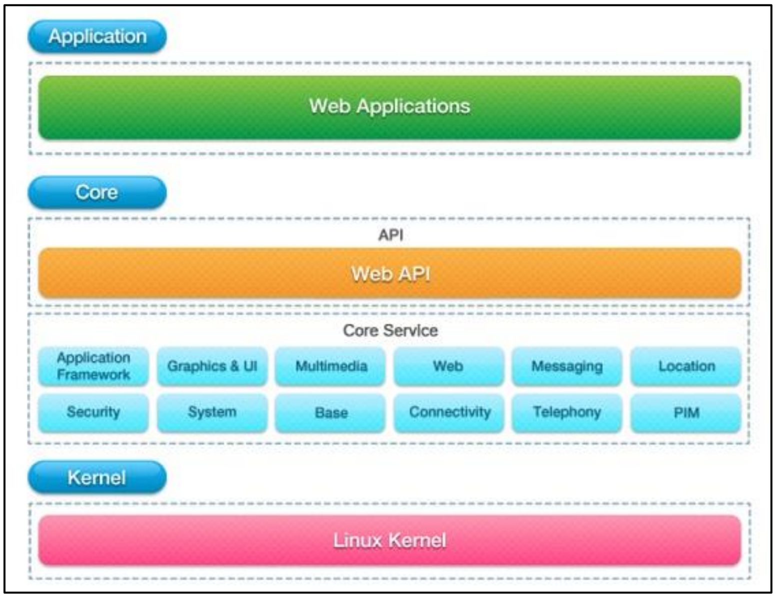

Figure 13 - An overview of the Tizen architecture

4.2. Tizen Web Application Development

Figure 14 below shows the process for Tizen's application development.

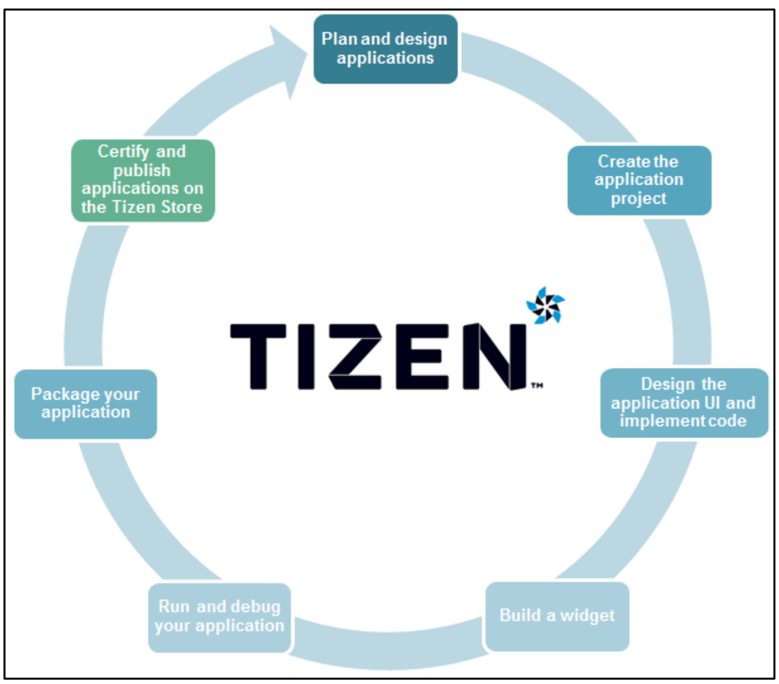

Figure 14 - Tizen's development cycle

4.2.1 Application Design Specification

The Robison Detector will eventually contain several features which are developed in Tizen IVI, including sending audio and visual notifications and also lowering the car stereo's volume.

4.2.2. Tizen Notification API

The notification API is used to deliver alerts to users even while other applications are running. Audio features can also be added to these notifications. The IVI's API comes with a fully featured IDE for development purposes. There are three types of notifications in Tizen:

1. SIMPLE: Displaying the notification right after posting and all statuses will be cleared when users close it.
2. ONGOING: Notifying users of the application's running status which cannot be deleted by users.
3. PROGRESS: Showing users the progress of specific tasks such as downloading, it cannot be deleted by users.

There are also 4 types of pushing notifications:

1. Notification Panel: A simple summary of recent activities.
2. Ticker: A notification line will show up in a certain area and only stay for some time.
3. Pop- up: A notification interface will be displayed, sometimes with different options for users to close or delete.
4. Badge: Not an immediate notification with only the number of unread activities on the badge icon.

The Robison Detector will be using Pop-up SIMPLE notification which poses the minimum distraction to the driver.

4.2.3. IVI User Interface

Tizen's IDE includes templates for Web UI that we can use to develop the user interface for the IVI system. The UI Builder from Tizen can be used to develop graphical user interfaces which are relatively straight forward to design. Elements can be dragged and dropped, or programmed by the UI Builder's programming model. Furthermore, the UI Builder can generate a UI layout code which can be included in the IVI application.

4.2.4. Simulations of Application

An application can be running in the Web Simulator, Emulator, or Target device.

4.2.4.1. Web Simulator

The Tizen Web Simulator is a tool for HTML5 Web application debugging which runs on Google Chrome, its preferences can also be modified.

4.2.4.2. Emulator

The Emulator Manager will be used to launch the emulator with a target environment that meets all the specifications that apply to the real device. The Tizen SDK Emulator is a virtual device that allows developers to test IVI applications before deploying to the target device.

4.2.4.3. Target Device

Running on a Target Device will test the applications in real-time. It will not be used for the Robison Detector's prototype.

We will be performing Tizen testing on the emulator for now as we don't have access to any Tizen devices or infotainment systems. Once all the testing is done on the emulator we will attempt to deploy the Tizen code on a real Tizen device or infotainment system.

5. Testing Plan

5.1. 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.

5.2. Unit Testing Plan (First Stage)

During the first development stage, the algorithm required to detect a surrounding EMV vehicle would detect the correct input signal excluding any ambient noises. Once a filtered input signal is detected, an interrupt will be sent to the infotainment system via serial bus or wirelessly.

Once unit testing on all components is carried out, we will start integrating while ensuring proper functionality. Then, once we ensure the proper functioning of the hardware components, we will be connecting the hardware to the Tizen infotainment system for further interrupt testing and alert message notification.

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 IVI (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.

5.3. Final Product Testing (Second Stage)

This will be our final testing stage which will be done by deploying the product in the car. These tests will include product overheating and hearing disability tests. One of the main objectives of this phase will be the testing of microphones in different noise levels and audio capturing power. Different test scenarios will be taken into consideration while performing these tests such as weather, noise level, and people sitting in the car.

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

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

6. Conclusion

The proposed design specification for all the parts of the Robison Detector are aimed at meeting the priority "A" requirements from the functional specification document. Each of the three parts which make up the Robison Detector is described in detail and their variations in different prototypes. Some of the design specifications are not completely finalized; therefore a few of them may not be met or will be altered for the first prototype. The fundamental design of the project however will not change. Despite this, Vantek's full effort will be put forth in meeting these requirements. The detailed test plan in this document will be utilized during the testing phase of the Robison Detector, as will other parts of this document.

7. References

[1] W. Vermaak. (2014, May 5). *Safe Driving when Hearing the Emergency Siren.* [Online]. Available: https://www.arrivealive.co.za/Safe-Driving-when-Hearing-the-Emergency-Siren. Date accessed: August 22, 2014.

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