

PROPOSAL FOR TEAM 9

Tom Aprik
Natalie Hannon
Jeremy Konz
Don Vanderlaan

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1 Executive Summary

In order to increase automobile safety and driver awareness, an “alerting system” will be designed and built. Its primary function will be to notify the driver of a proximal emergency vehicle. The proposed “alerting system” will have three main tasks: detect an emergency siren audio signal, turn down the volume of the stereo and display an indicator symbol on the dashboard. The proposed solution will be cost-effective and noninvasive to implement in the automobile.

2 Introduction

In order to increase automobile safety, a driver must have ample time to react to an emergency vehicle. In fact, “U.S. Fire Administration (USFA) is working with the Society of Automotive Engineers (SAE) on [the Emergency Vehicle Safety Initiative] to study the effect and effective mitigation of the disorientation of motorists caused by emergency warning lights, including the effects on normal, impaired and drowsy drivers.”¹ The proposed “alerting system” will further this initiative by increasing emergency vehicle siren effectiveness. “Year after year approximately 25 percent of firefighters killed in the line of duty are responding or returning from incidents, with the majority of the fatalities from vehicle crashes.”¹ A measure of success for the proposed “alerting system” would be a reduction in the number of emergency personnel fatalities.

3 Background

The proposed “alerting system” has similarities to technology already in use, known as traffic signal preemption.² This technology gives emergency vehicles the right-of-way through intersections by changing traffic lights.² Traffic signal preemption relies on infrared signals

from emergency vehicles to communicate with receivers mounted on traffic lights. However, infrared signals are problematic because detection requires line-of-sight between sender and receiver.

The proposed “alerting system” is different from traffic signal preemption in several ways. First, the “alerting system” is to be designed for citizen use, not government use, so it must be affordable and not add significant cost to the automobile. Second, instead of controlling traffic lights, the “alerting system” will control functions inside the automobile to help the driver react to the emergency situation. Third, there will not be directional dependence - the “alerting system” will function regardless of the direction of travel of either the emergency vehicle or automobile itself.

4 Objectives

The “alerting system” will increase automobile safety and driver awareness by detecting and notifying the driver of a proximal emergency vehicle. The system will continuously monitor the acoustic environment external to the vehicle with a microphone. The detection of a siren signal will automatically result in a reduction of volume of the stereo and display an indicator symbol on the dashboard. This will notify the driver of the situation and limit the number of distractions inside the car, providing the driver with more time to react to the situation.

5 Proposed Design

5.1 Software Overview

Software for the “alerting system” will consist of a main “listening” function, matched filter function, and several interrupt service routines (ISRs). The computationally-intensive matched filter function dictated the choice of the microcontroller, as described in Section 5.2. The software will be coded in C and compiled to run on the microcontroller.

Matlab will be used for development of the matched filter function. Advantages to using Matlab include coding ease and visualization of the output. Sample siren and sample noise audio files will be used as inputs to the matched filter function. For development, white noise will be used to represent background noise. Once the algorithm is successfully developed in white noise it will be tested using more complicated samples of background noise. The sample siren and sample noise audio files will be kept separate in order to maintain control over individual signal properties. The algorithm is discussed in Section 5.3.

5.2 Hardware Overview

In order to have sufficient processing power to perform the matched filtering algorithm, a microcontroller/DSP combination module will be required for the “alerting system”. The dsPIC30F3014 by Microchip has all the capability of a standard microcontroller while containing performance enhancements specifically for digital signal processing. The microcontroller/DSP combo will be central to the “alerting system”, receiving microphone audio inputs and sending stereo and indicator outputs.

Taken from the 12-bit analog-to-digital (A/D) port of the microcontroller, the external acoustic environment will be sampled at 5kHz. After each sample is taken from the A/D port it will be stored on an external 1MB EEPROM. The EEPROM will be connected to the microcontroller with its SPI connection which operates at a speed of 20Mbps. The output

ports of the dsPIC will be wired to the stereo relay and LED indicator.

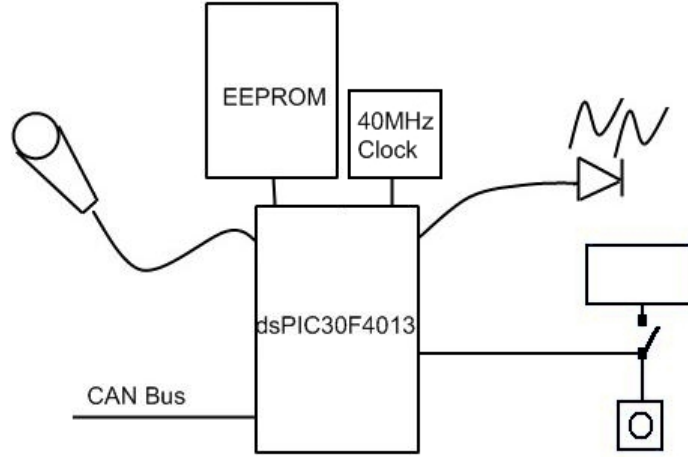


Figure 1: Hardware Schematic

5.3 Algorithm

The siren detection algorithm will use matched filtering to detect the siren from the external acoustic environment. A disadvantage to matched filtering is time-domain signal processing, requiring computationally intensive convolution for a large sample count. A second disadvantage to matched filtering is the requirement that information exist about the signal prior to detection. However, a major advantage to matched filtering is a high detection rate. In addition, the microcontroller outlined in Section 5.2 has the capability to handle the computationally intensive convolution. Therefore, the advantages of matched filtering outweigh the disadvantages in this application.

An initial matched filter algorithm has been tested in Matlab with a sample siren signal and sample noise signal. In this case, the sample noise signal is the applause of an audience. The pitch of the siren signal varies and cycles with time. The algorithm uses a single iteration of the siren as the matched filter and convolves it without time reversal with the microphone input. For testing purposes the microphone input was set as the noise signal summed with

an offset version of the full length siren signal. The sampling rate used in this test was 44.1 KHz, which is more than sufficient for the siren signal, assuming it does not contain frequencies higher than 2.5 KHz.

In testing the algorithm, the relative ratio of the noise signal to the siren signal was 3.7. In reality, the siren should be much louder. The siren sample, the microphone signal and the convolved output can be seen in Figure 2. The first repetition of the siren signal was added to the noise signal and offset by 454ms, as shown in Figure 2a. The remainder of the siren signal was not simply a repetition of the first iteration but a continued recording of the siren. As seen by the convolved output, the algorithm successfully detected all four iterations of the siren, even though the siren sample differed slightly from the other three iterations of the actual siren signal.

In practical deployment, emergency vehicles will be moving, so the algorithm must be immune to reasonable Doppler effects. This was tested by time compressing the siren signal by 10% and then adding it to the noise signal. The original siren sample was used in convolution and the respective plots are shown in Figure 3. Peaks in the convolved output are still present indicating successful detection. To make the peaks stand out even further, the audio sample will be cross-correlated with itself.

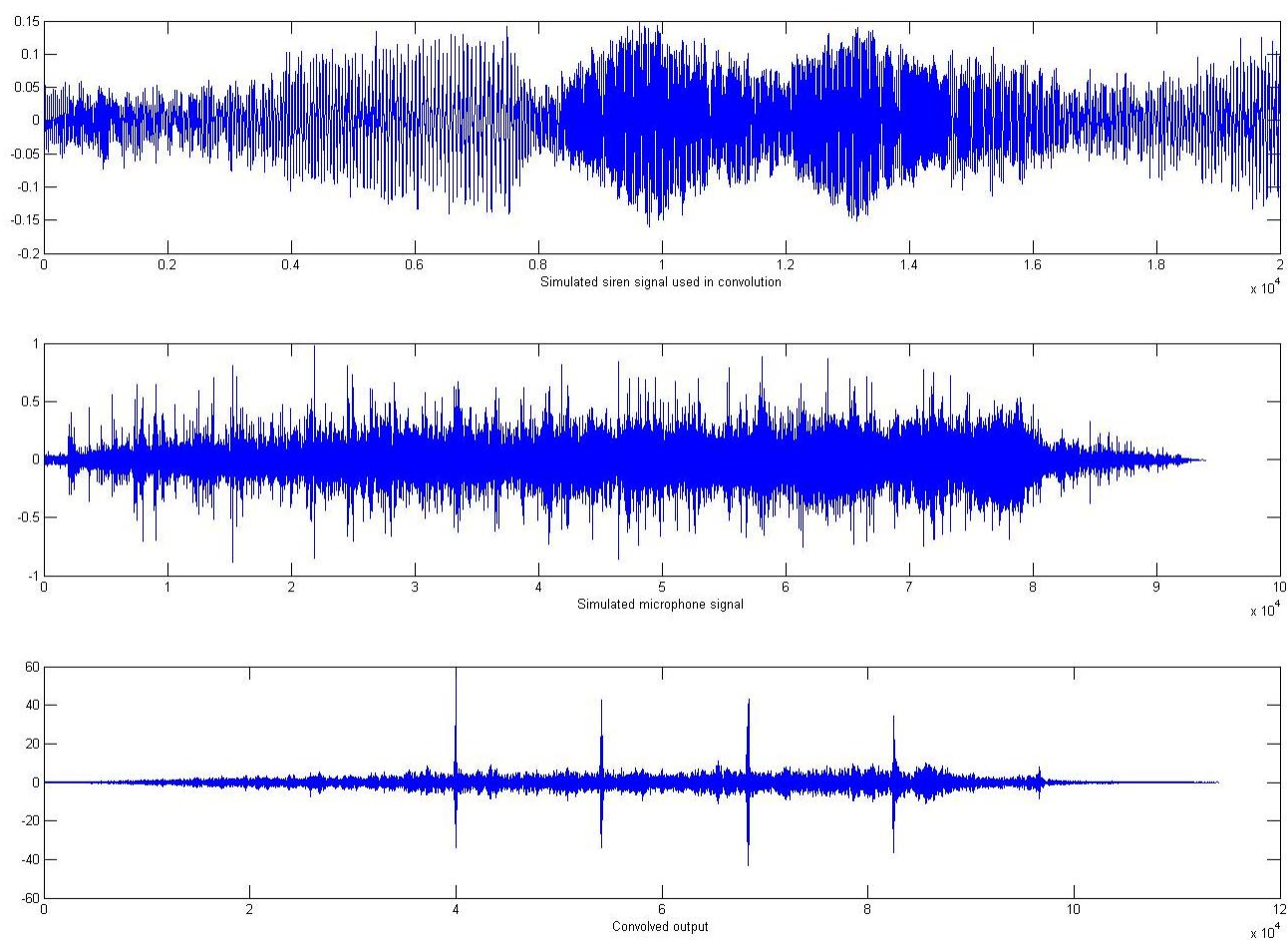


Figure 2: Siren signal processing

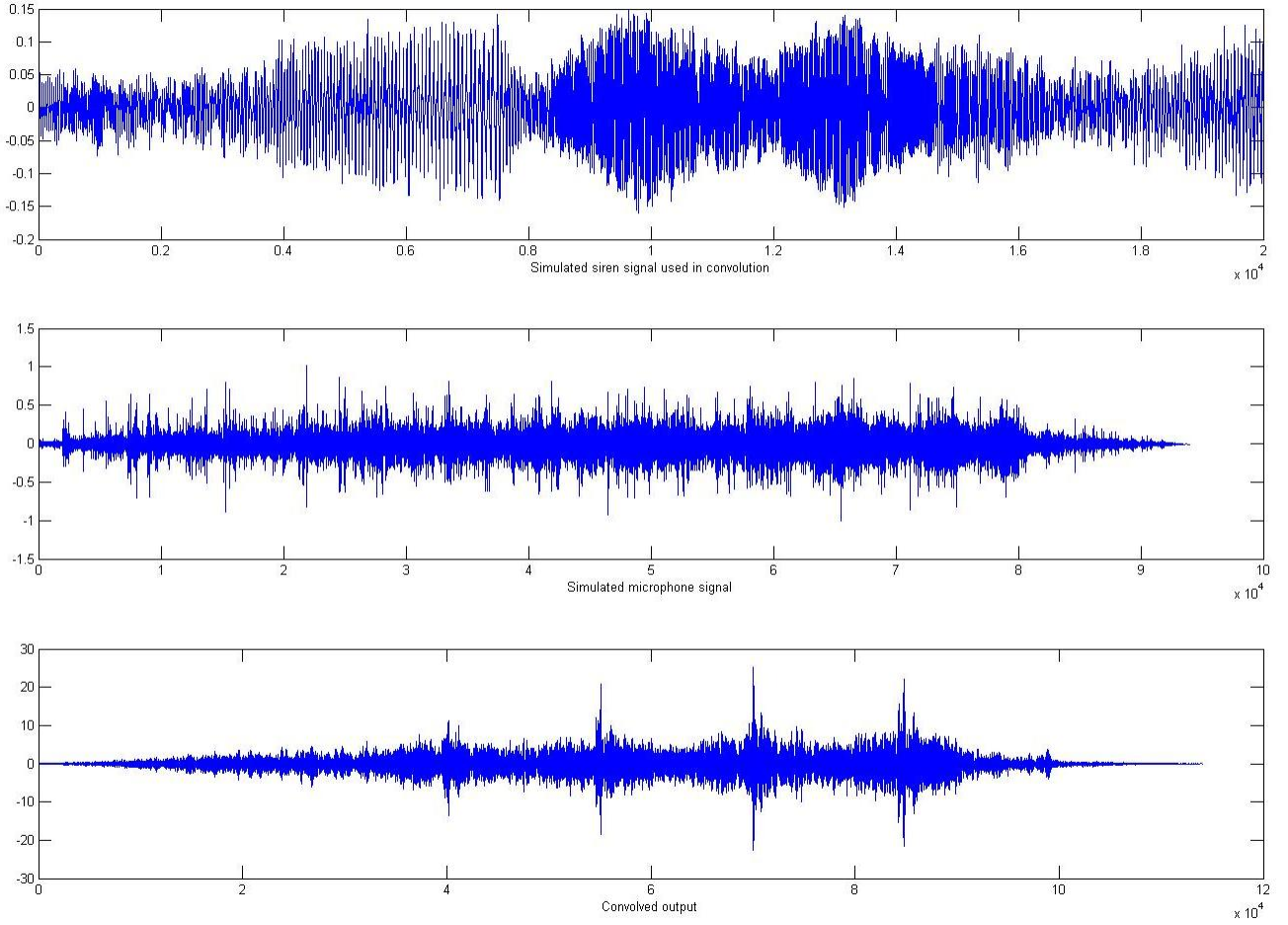


Figure 3: Siren signal processing with Doppler effect

6 Design Considerations

Mounting an acoustic sensor on the exterior of the vehicle introduces several factors to be considered in the design process. The acoustic sensor will be recording all external noise, including horns, trains, screeching tires, pedestrians, etc. It is crucial to be able to detect the emergency siren amidst all noise in order to develop a viable product. The “alerting system” must be tested under a variety of conditions, as specified in Section 7. Another concern is damage to the external acoustic sensor. It must be robust enough to withstand all external conditions the vehicle encounters, such as severe weather. An additional concern is being able to detect all emergency sirens. A database of common emergency sirens will be stored in the microprocessor for the matched filtering function.

7 Project Management

The tasks will be assigned to team members based on individual experience in each specific area. The main tasks are:

- Develop Matlab code for signal processing
- Program microcontroller
 - Main “listening” function
 - Matched filter function
 - ISR for the acknowledge button
 - ISR for the sample rate
 - Read/write external memory
- Interface components to build prototype

- Voltage regulator
- Microphone amplifier and biasing network
- Relay for stereo
- LED indicator display
- Test prototype for reliability
 - Test in various noise conditions
 - Test for Doppler shift
- Package prototype for automobile
 - Layout circuit board
 - Box components

Don will primarily focus on developing the matched filter function in Matlab due to his experience with signal processing. He will also focus on the circuit design due to expressed interest in that area.

Jeremy will be responsible for determining what hardware to buy, including what micro-controller has the features required for the “alerting system”. He will also be part of the software team, coding the read/write functions of the EEPROM.

Natalie will be part of the software team, coding the main “listening” function and ISR for the acknowledge button. She will also assemble a test plan for the “alerting system” after preliminary software and hardware development is complete.

Tom will be part of the software team, coding the matched filter function and ISR for the sample rate. He will also be responsible for packaging the prototype for display and demonstration.

8 Budget

The expenditures for the project will include but are not limited to:

Item	Cost
dsPIC	\$8.85
Electret Microphone	\$1.01
External Memory	\$3.77
Relay	\$6.02
Directed Siren	\$28.11
Total	\$47.76

References

- [1] “Emergency Vehicle Safety” U.S. Fire Administration. 3 October 2007: Emmitsburg, MD. 15 Oct 2008.

<http://www.usfa.dhs.gov/fireservice/research/safety/vehicle.shtm>

- [2] “Traffic Signal Preemption for Emergency Vehicles” U.S. Department of Transportation. January 2006: Washington D.C. 20 Oct 2008

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