

PROPOSAL FOR TEAM 9

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October 17th, 2008

Contents

1	Executive Summary	2
2	Introduction	2
3	Background	2
4	Objectives	2
5	Proposed Design	3
5.1	Software Overview	3
5.2	Hardware Overview	3
5.3	Algorithm	3
6	Design Considerations	6
7	Project Management	7
8	Budget	7

1 Executive Summary

Distracted driving is on the rise as new technology is brought into the automobile. This in turn increases accident potential on roadways. 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 “alerting system” will have three primary functions: detect an emergency siren audio signal, turn down the volume of the car stereo and display an indicator symbol on the dashboard. The proposed solution will be cost-effective and unobtrusive to the vehicle.

2 Introduction

In order to increase automobile safety, the 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 this effort 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 are killed in the line of duty are responding or returning from incidents, with the majority of the fatalities from vehicle crashes.”¹ This number can be reduced by implementing the “alerting system” in automobiles. ¹

3 Background

The “alerting system” has similarities to technology already in use, known as Traffic Signal Preemption. This technology gives emergency vehicles the right-of-way through intersections by changing traffic lights to reduce drive time. Traffic Signal Preemption relies on infrared signals from emergency vehicles to communicate with receivers mounted on traffic lights. Infrared signals are difficult to detect because the signal 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 a significant cost to the vehicle. Second, instead of controlling lights, our system will control functions inside the vehicle to help the driver react to the emergency situation. Third, there needs to be no positional reliance - the “alerting system” will function regardless of the direction of travel of the emergency vehicle.

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

¹<http://www.usfa.dhs.gov/fireservice/research/safety/vehicle.shtm>

audible noise external to the vehicle. The detection of a siren signal will automatically turn down the volume of the car stereo and display an indicator symbol on the dashboard. This will both notify the driver of the situation and limit the number of distractions inside the car, providing the driver with more time to react.

5 Proposed Design

5.1 Software Overview

Software for the siren detection algorithm will be developed in Matlab, mainly due to debugging ease and automatic memory capability. Matlab code is easy to edit, requires no compiling and allows us to easily visualize the signals we are working with. Testing in Matlab will initially be done with siren and street noise recordings so that all variants of the software will be tested with the same data. Using recordings also allows us to control every aspect of the signals, such as the relative strengths of the siren and street noise.

Once an acceptable algorithm is completed and tested satisfactorily in Matlab, we will code it in C/C++ and compile it to run on our microcontroller. At this point, we can then use the microcontroller's DAQ to test the algorithm on a real sirens and real noise.

5.2 Hardware Overview

Implementing this project will be accomplished using a microcontroller, a microphone, and some light emitting diodes. The microphone will be connected directly to the analog to digital port on the microcontroller. With this input, the algorithm of the microcontroller will then sample the A/D read at a rate between 5k-10k per second. Initially, testing of the algorithm's performance (described in following section) will be run on the PIC 18F4520. Should the PIC be unable to perform the convolution required to confirm a signal match, then an external digital signal processing chip will be added to the circuit. Should this be necessary, the DSP chip will communicate on board with the PIC via USART ports.

After processing is complete on the PIC, it will verify if this signal is really a siren. If the signal is a siren, then the output of the pic will display an indication via LED and also turn off the radio.

5.3 Algorithm

The siren detection algorithm will rely on matched filters to detect the siren among other audio-band signals. Using a matched filter has both advantages and disadvantages; however, in our case the advantages outweigh the disadvantages. Implementing a matched filter will require processing in the time domain, thus requiring computationally intensive convolution.

Current microprocessor technology thwarts this issue, as commercial digital signal processors are capable of real time convolution of audio-band signals, due to the low sampling rate requirements. Advantages of matched filters include ease of implementation and generally good detection rates so long as information is known about the signal attempting to be detected.

An initial matched filter algorithm has been tested in Matlab, with a sample siren signal and a recording of an audience at an event used as noise. The siren signal oscillates with frequency and the recording is multiple iterations long. This algorithm uses a single iteration of the siren as the matched filter and convolves it 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 - which we estimate will contain components not more than 2 KHz. The higher rate was used because we plan to test the algorithm's susceptibility to the Doppler effect.

In testing the algorithm, we set the relative ratio of the noise signal to the siren signal to 3.7. In reality, the siren should be much louder but this represents the worst case scenario. The siren sample, the microphone signal and the convolved output can be seen in Figure 1. The siren signal added to the noise signal was offset by 20,000 samples and from the figure there is no visible difference. The siren sample is only one fourth of the siren signal that was added to the noise signal. The remainder was not simply a repetition of the first iteration, but continued recording of the police 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 3 iterations of the actual siren signal.

In the real world, emergency vehicles will be moving, so the algorithm must be immune to reasonable Doppler effects. We tested this by time compressing the siren signal by 5% and then added it to the noise signal. The original siren sample was used in convolution, and the respective plots are shown in Figure 2. Peaks in the convolved output are still present indicating successful detection.

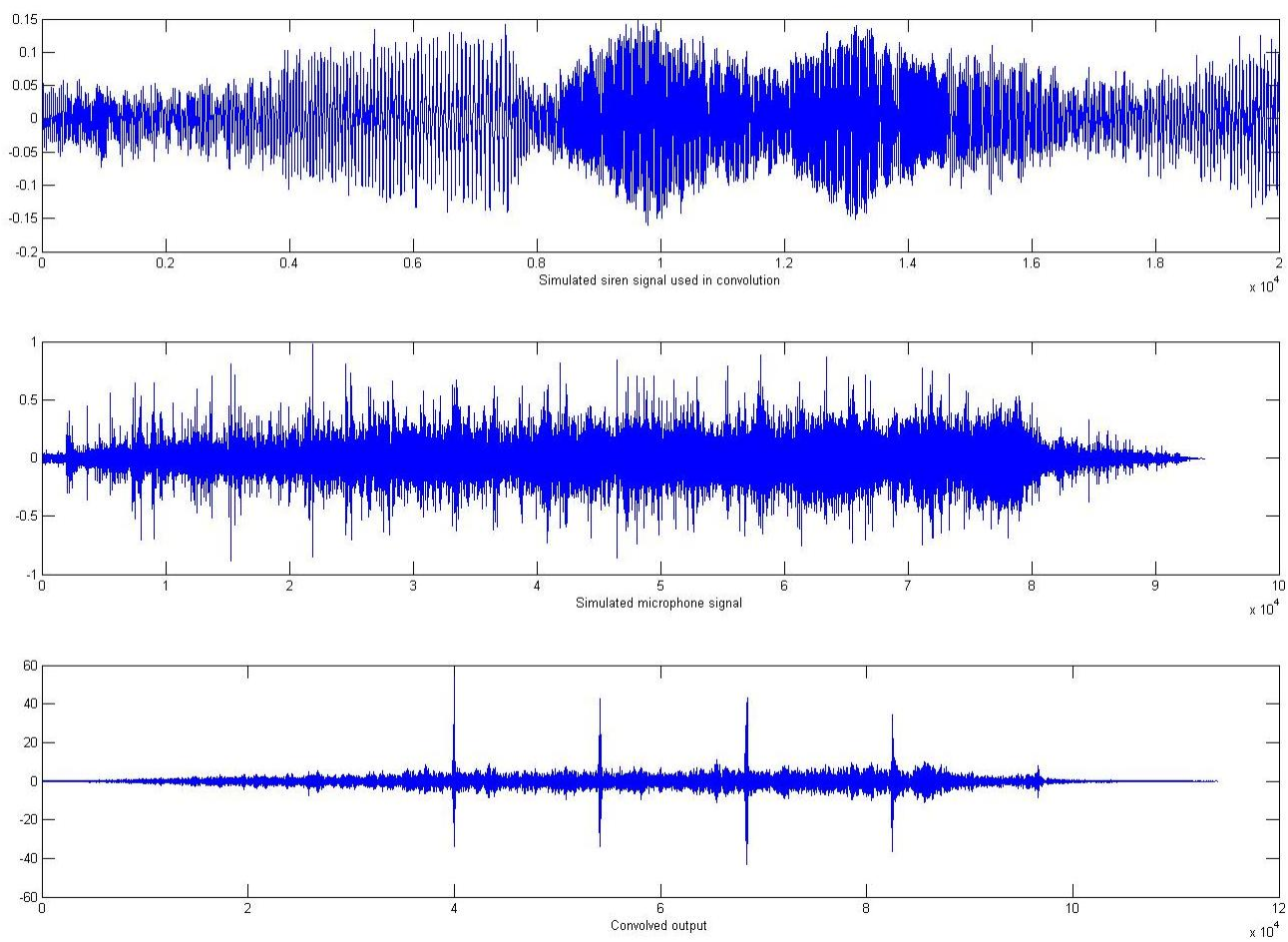


Figure 1: Siren Signal Processing

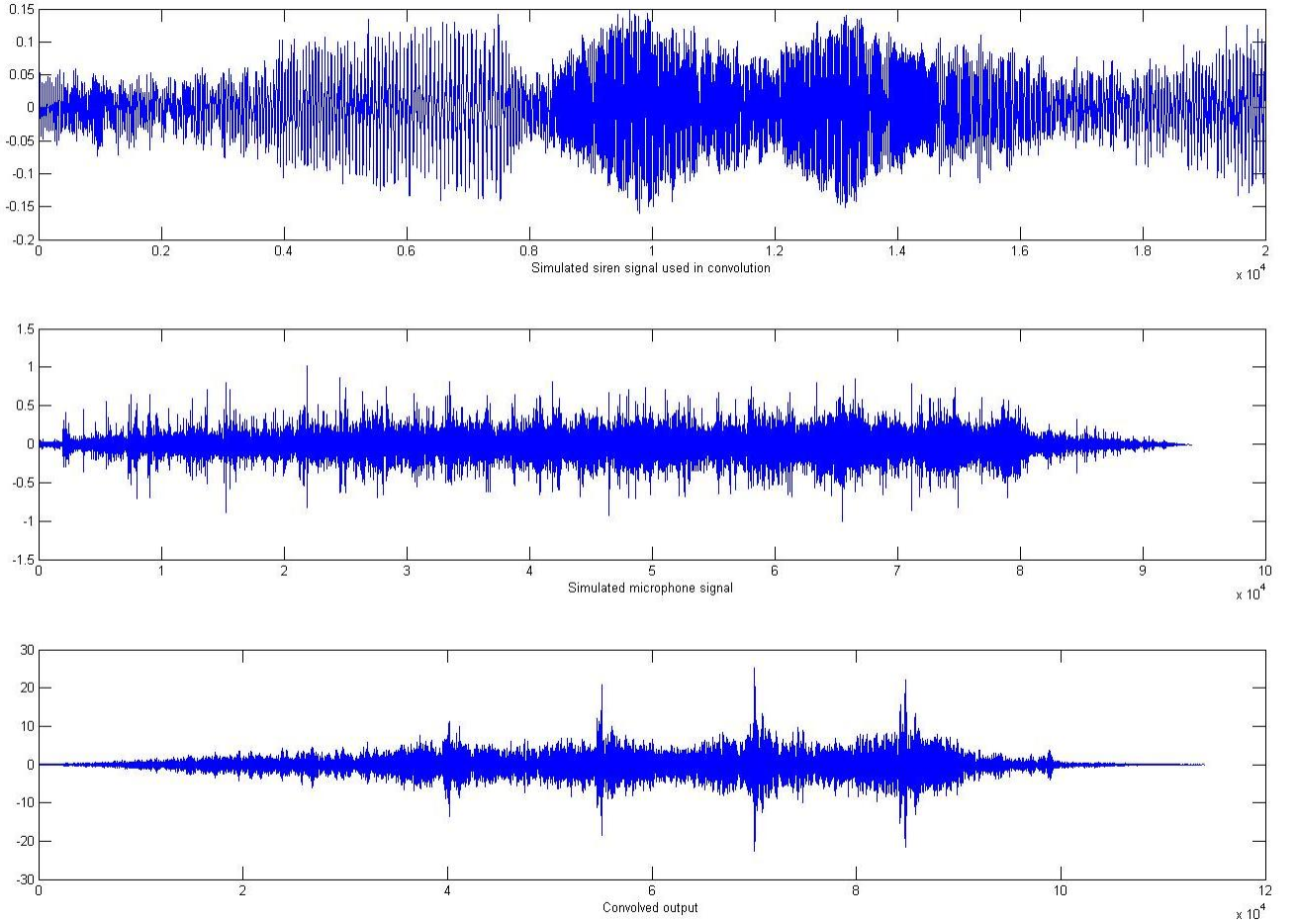


Figure 2: Siren Signal Processing with Doppler effect

6 Design Considerations

Mounting an acoustic sensor on the exterior of the vehicle introduces several variables to be considered in the design process. The acoustic sensor will be recording all external noise, including honking horns, trains, screeching tires, pedestrians, etc. It is crucial to be able to detect the emergency siren amidst all noise in order to construct a realistic prototype. With this, the “alerting system” must be tested for false-positives. 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 known emergency sirens will be constructed and stored

in the microprocessor.

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 to implement signal processing code
- Interface components to build prototype
- Test prototype for reliability
- Package prototype for automobile

8 Budget

The expenditures for the project will include:

- PIC microcontroller
- acoustic sensor
- protoboard
- indicator LEDs
- relay, to turn off radio