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Reducing Noise in Emergency Triage Care Units through SIRENO

An Interactive Qualifying Project

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Bachelor of Science

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ABSTRACT

The objective of this IQP project is to study the effects of noise in and around an ambulance van and to understand their significance in order to help eliminate their causes. The project's primary focus became the elimination of the use of the siren, since this was found to be the major cause of noise related health effects on paramedic workers as well as drivers and residents exposed to siren noise. The solution to this problem, entitled SIRENO, is an overall system to be implemented into major cities across the United States. SIRENO will consist of two parts; a transmitter and receiver pair and a traffic light tracking system. The traffic light tracking system will use existing technology called Opticom GPS to manipulate traffic lights and ensure quicker response times for EMS. The SIRENO transmitter will be installed in the EMS vans and will send a radio frequency signal within a certain radius to SIRENO receivers that will be installed in commercial vehicles, alerting them of the approaching EMS. The implementation of SIRENO will thus reduce response times and effectively eliminate the need for a siren and its dangerously high noise levels.

TABLE OF CONTENTS

List of Figures

Acknowledgements

The project team would like to thank everyone that aided in the development of SIRENO, especially the Deputy Superintendent of Boston EMS and the UMass Chief of EMS for attending the presentations and providing useful feedback as well as new directions to take the project in. The Worcester Police Department was also very helpful in outlining the 911 emergency response teams' duties and how the overall structure of the system works. The team would like to especially thank Professor Fofana for his time and dedication. Professor Fofana's passion and enthusiasm were critical in developing SIRENO.

CHAPTER 1: PROJECT OBJECTIVES AND LAYOUT

Introduction

The noise and vibrations in emergency triage care units has been globally analyzed and much has already been done in attempt to reduce their effects in ambulances. Studies have shown that paramedics are losing their hearing at a much higher rate than people of their own age of different professions. It is imperative for the EMT's to maintain their hearing because sounds such as breathing and beeping from the monitors attached to the patients all need to be constantly observed. The health of EMT's is just as important as the patients' health. Without capable and efficient EMT's the chance of the patients surviving is drastically decreased. Reducing noise caused by ambulances is a project that is intended to completely eliminate any sources of noise that may affect the health of paramedics, patients or any surrounding persons.

This project will conduct a detailed analysis on the definition of noise and the main sources of noise as well as specifying the source that has the largest impact on the paramedics' health and ability to operate efficiently. Through research, this source has been found to be the siren. As such the purpose of this study is to fully understand the consequences of the use of sirens, so that a solution can be made to relieve the stresses caused by them. The main objectives are

- To explore the level of noise transferred to the cabin of the ambulance by the siren

- Determine what long-term affects the siren has on the emergency medical technicians
- Provide possible solutions to reduce noise caused by the siren or possibly eliminate the need of a siren on ambulances.

This project will be conducted over the entirety of a year and each term will have specific goals assigned to it. During the start of A-term, the team will outline each member's responsibilities and roles, set up specific meeting times as a group and with Professor Fofana and design a plan for the IQP for the whole year. The remainder of the term will be dedicated to postulating the problem at hand and begin researching the history of ambulances and siren development. All of B-term will be committed to finishing the background research. Other topics that will be covered include the definition of sound and noise, sources of noise in an ambulance and different forms of communication that can be used to replace the use of the siren in an ambulance. At the end of B-term, the writing of the report will also begin and this will be completed by the end of C-term. D-term will comprise of finishing the written report and preparing for the final presentation. The organization of this report reflects the order of completion of this project. Chapter 2 will be comprised entirely of background research on all relevant topics. Chapter 3 will introduce the product created by the team, entitled SIRENO and how it has been developed. It will also include details on the implementation of SIRENO into the public as well as possible improvements for the future. Finally the report will be concluded in chapter 4, with an evaluation and analysis of SIRENO.

CHAPTER 2: RELEVANT EMS BACKGROUNG RESEARCH

2.1 Introduction

This chapter of the report will show research done in each of the key aspects of our project. We will thoroughly investigate sound and vibrations as well as the history of the Emergency Medical Services, the use of sirens and airplane communication system. This research will be the foundation and the reference used for the basis of Chapter 3.

2.1.1 Timeline on integration of Ambulance and EMT in the US

Below is the time line table on the integration of the Ambulance and EMT in the United States of America [5]:

Year	Ambulance Development
1816	Stethoscope was invented.
1863	Sphygmomanometers were invented.
1865	America's first ambulance service was established by the U.S. Military
1869	America's first city ambulance service was instituted in New York City by Bellevue Hospital.
1870	The first documented case of Aero-medical transportation. Here the Prussian siege of Paris used hot air balloons to transport wounded soldiers
1881	Red Cross was founded.
1898	The Sphygmomanometer was redesigned to be more accurate in blood pressure readings.
1899	Michael Reese Hospital in Chicago began to operate an automobile

	ambulance that was capable of speeds up to 16 mph.
1905	Nikolai Korotkoff, a Russian surgeon developed the method of using Stethoscope to listen to blood movement through arteries.
1916	Military started using the Model T as an ambulance in World War One.
1928	Julian Stanley Wise organized the first rescue squad called Roanoke Life Saving Crew.
1940	Leading to World War II, hospitals provided ambulance service in many large cities around the United States. “With the severe manpower shortages imposed by the war effort, it became difficult for many hospitals to maintain their ambulance operations. City governments in many cases turned ambulance service over to the police or fire department. No laws requiring minimal training for ambulance personnel and no training
1947	Claude Beck and James Rand designed and built the first Defibrillator.
1951	Helicopters began to be used for medical evacuations during the Korean War
1956	Dr. Élan & Dr. Safar developed mouth-to-mouth resuscitation
1956	Paul Zola developed a more powerful defibrillator
1959	Researchers at John's Hopkins Hospital in Baltimore, MD developed the first portable defibrillator as well as a perfected CPR.
1960	Los Angeles County Fire Chief Keith Klinger proudly announced that every engine, ladder and rescue company in is department was to be equipped with a resuscitator. This department is believed to have been the

	first large department to adopt uniformly medical emergency responsibility.
1966	"Dr. Partridge in Belfast, Ireland, started to deliver pre-hospital coronary care using ambulances. His research showed that his program significantly improved patient survivability in out-of-hospital cardiac events.
1968	St. Vincent's Hospital in New York City started this nation's first mobile coronary care unit; the program first used physicians, then paramedics. The American Telephone and Telegraph starts to reserve the digits 9-1-1 for emergency use. In Virginia, The Virginia Ambulance Law is passed and establishes the state's authority to regulate ambulances, verify first aid training, and issues permits.
1969	The Miami, Florida Fire Department started the nation's first paramedic program under Dr. Eugene Nagel. The very first out-of-hospital defibrillation occurred shortly thereafter (the patient survived and left the hospital neurologically intact). In Seattle, Dr. Leonard Cobb at Harbor View Medical Center teams up with the Seattle Fire Department and creates Medic I. Medic I is a Winnebago, called "Mobic Pig" by the firefighters manning it, based at the hospital and is dispatched only on cardiac related calls.
1970	The Charlottesville-Albemarle Rescue Squad in Charlottesville, VA starts

	the nation's first volunteer paramedic program under Dr. Richard Crompton. One of their first patients was President Lyndon Johnson, who suffered a heart attack while visiting his son-in-law Chuck Robb at UVA.
1972	The Department of Transportation and Department of Defense team up to form a helicopter evacuation service. In Seattle, Medic II is instituted. Medic II is a program to train 100,000 citizens in CPR. Harbor View Medical Center starts up the nation's most intensive training program for paramedics. The course is 5,000 hours long, compared to 3,600 hours a medical student endures to become a doctor.
1973	St. Anthony's Hospital in Denver starts the nation's first civilian aero-medical transport service. (The program was called "Flight for Life"). The EMS Systems Act (public law 93-144) is passed by Congress, which funds 300 regional EMS systems. The Star of Life is published by the DOT. The EMS Systems Act (public law 93-144) is passed by congress, which funds 300 regional EMS Systems
1975	The American Medical Association recognizes emergency medicine as a specialty. The University of Pittsburgh & Nancy Caroline MD, is awarded a contract to develop the first nationwide paramedic training course. The National Association of EMT's is formed.
1981	In Salt Lake City, Jeff Lawson, MD, comes out with an emergency

	medical dispatcher program and priority dispatching.
1990	The Trauma Care System Planning & Development Act is passed by Congress. Fire Department organizations join together in a resolution to expand into EMS
1993	It is proposed that EMT-P's assume an expanded role in primary care of non-emergent patients by learning expanded skills

2.1.2 Background of an ambulance

The first ambulance was designed in 1792 by Dominique Larrey. This was a simple design of a roofed carriage attached to two horses. Its primary purpose was to transport injured soldiers during battle [1].

Figure 1: First Ambulance invented in 1792 [1]

This idea has been worked on by many men since then and the design has significantly improved with time. The first gasoline power ambulance was the Palliser

Ambulance invented by Major Palliser of the Canadian Army. It was designed for military us so it was heavily armored [4]. In the United State of America, the first motor ambulance was developed in Chicago. It had a weight of 1600 pounds and had speed up to 16 miles per hour [2].

Figure 2: First motor ambulance developed in Chicago [2]

In 1909, the James Cunningham, So and Company of Rochester based in New York manufactured an ambulance that had electric lights and two seats for ambulance attendant (EMTs) [4]. It had pneumatic tires that made the rides smoother than before, hence better comfort for the patient. This ambulance was designed with a 32 horsepower four cylinder internal combustion engine and a side mounted gong to alert carriages and pedestrians about is approach [4].

During the World Wars Two era, the ambulance was greatly improved. Ambulances were based at hospitals and a communication system to get the ambulance to patients was put in place. Both telegraph and telephones had been inverted during the wars and were used by civilians to call the police who in return would dispatch the ambulance to the patient's location.

Figure 3: Motorized ambulance (year 1909) [4]

2.1.3 History of the Siren

The first siren was invented by John Robison of Scotland in the 1790s but it was nothing like the modern sirens. Robison's siren was initially designed as a musical instrument [3]. The design was later modified by Charles Cagniard to produce sound loud enough to be heard under water. This siren was "powered by difference in air pressure, it worked by allowing air blast through small holes that discontinuously produced siren sounds" [3].

Figure 4: Pneumatic Siren [3].

Sirens were first used as warning devices in the early 20th century. They were installed in factories, trains, and lighthouse for signaling people about approaching trains, ships or for emergency evacuation of factories. Late in the 20th century sirens were incorporated into emergency vehicles to alert other vehicles, bikers, and pedestrians.

Today, sirens play a vital role in the police, fire, and other emergency responses. They provide an audible warning of oncoming emergency vehicles, which may be traveling at high velocity, and send a clear message to nearby traffic and pedestrians to pull over and allow these public safety workers to pass safely. While many pneumatic or mechanical sirens are still in use today, more and more modern police cars, fire trucks, and ambulance services use electronic sirens to alert the public to their presence and approach. Advanced circuit-based technology allows the frequency and volume of the siren to be controlled precisely and often allow the emergency vehicle personnel to decide on which tone pattern will be most effective in a particular situation.

Caution should be used with certain siren devices, since they can produce sound loud enough to temporarily deafen those nearby if not properly modulated. This is especially true of concealed or partially recessed sirens, which often create a great deal of sound inside the cabin of the emergency vehicle and can cause hearing problems for first responders who receive prolonged exposure to siren noise. Properly shielded and positioned sirens produce much less noise inside the passenger compartment and provide better advance warning to the public as well. The staff at Extreme Tactical Dynamics can advise your agency on the correct positioning and most appropriate and useful sirens for your specific needs [21].

Figure 5: Early Siren Design for Ambulance [21]

2.2 Emergency Medical Services

This section presents the history of how Emergency Medical Services (EMS) were created and improved over the years, and the everyday job of Emergency Medical Services, beginning with the lowest level of EMS to the highest level of EMS. The Scope of Practice goes into detail about the different EMS levels and what procedures each EMT is legally allowed to perform.

2.2.1 History of EMS

The formal progression of an organized civilian EMS system began in the 1960s and continues to evolve as we further define and enhance our structure, oversight, and organization. At first, no standards existed to define practice and there was no clear description of scopes of practice in EMS. The development of what we know as modern day Emergency Medical Services started in the 1950's by the American College of Surgeons. They developed the first training program for ambulance attendants, which greatly influenced the need to address "Health, Medical Care and Transportation of the

Injured" [6] in order to reduce traffic fatalities.

The next steps were taken in 1966, where The National Academy of Science published an article titled Accidental Death and Disability: The Neglected Diseased of Modern Society. It is precise to state that it's "the EMS white paper that started it all". In this article, they brought to attention the magnitude of traffic-related deaths in U.S. and described the insufficiencies in pre-hospital care. The article included three major aspects: the first one was calling for ambulance standards. Second were state-level policies and regulations. The third aspect was recommendations to adopt methods for providing consistent ambulance services at the local level. This quickly led to the Highway Safety Act of 1966, which required each State to adopt highway safety programs to comply with Federal standards. Not long after, in 1970 the Nation Registry of EMTs (NREMT) held their first board meeting with the goal to provide uniform standards for credentialing ambulance attendants. From this meeting they created a mission statement to abide by:

> "*To serve as the National EMS Certification organization by providing a valid, uniform process to assess the knowledge and skills required for competent practice by EMS professionals throughout their careers and by maintaining a registry of certification status*" [7].

The Emergency Medical Services Act of 1973 enacted by Congress as Title XII of the Public Health Services Act was able to give $300 million in funding for Emergency Medical services over 8 years [10]. This act allowed for EMS system planning and implementation, required states to focus on EMS personnel and training, and resulted in legislation and regulation of EMS personnel levels. Soon after the American Medical Association (AMA) recognized and accepted an EMT-Paramedic as an allied health occupation, in 1996, the EMS Agenda for the Future was published. This agreement was developed with funding from the National Highway Traffic Safety Administration and the Health Resources and Services Administration. The agenda was designed to guide the government and private organizations in EMS planning, development, and policy-making. It defined a new image of EMS education. The EMS education system proposed in the EMS Agenda for the Future is further articulated into the model shown in Figure below. This system was designed to develop an integrated system of EMS regulation, certification, and licensure**.**

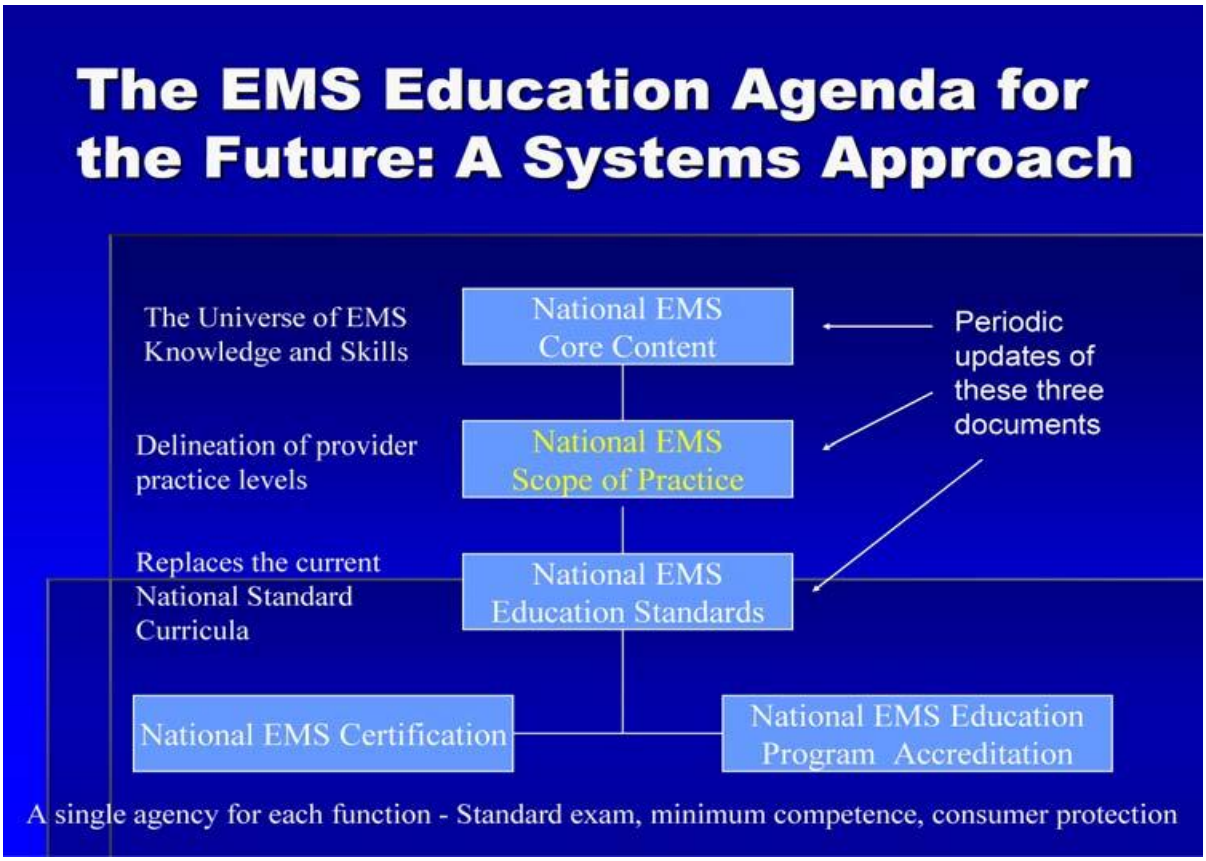

Figure 6: EMS Model System [10]

PEW Health Professions Commission Taskforce on Health Care Workforce Regulation published the article called Strengthening Consumer Protection: Priorities for Health Care Workforce Regulation. This article recommended National Policy Advisory Board to establish standards and model legislative language for uniform scope of practice authority for health professions [7]. It also put emphasis on states' responsibility to adopt a uniform scope of practice. In 2005 the National Highway Traffic Safety Administration (NHTSA) and the Health Resources and Services Administration published the National EMS Core Content. The article defined the domain and universal knowledge and skills of EMS personnel. Two years later the National EMS Scope of Practice was published by the NHTSA outlining national guidelines and regulation in obtaining a EMS license. The National EMS Scope of Practice created a mechanism to address the introduction of new technologies, research findings, and similar progression of EMS practice separately from education [8]. It is also a tool to promote national consistency and public understanding of EMS practice while at the same time recognizing the authority and responsibility of States to implement scopes of practice that reflect their individual needs and circumstances.

2.2.2 Scope of Practice

In order to analyze the affect that noise has on the EMT and patient in an ambulance, it is important to develop a complete understanding of the duties that an EMT performs. A better understanding of these duties will also make it easier to implement solutions to the problems caused by noise. Scope of Practice is an authorized term defined as the skills that a health care provider is licensed to perform [6]. Each health care profession has a scope of practice outlined by the state government, federal government, or the certified organization. This is based on the concept of education, certification, licensure, and credentialing. Essentially the scope of practice is a list of the skills that an EMT must perform in specific emergency situations. The figure below shows an image of the practice of scope circle and how all the concepts are related and crossover each other.

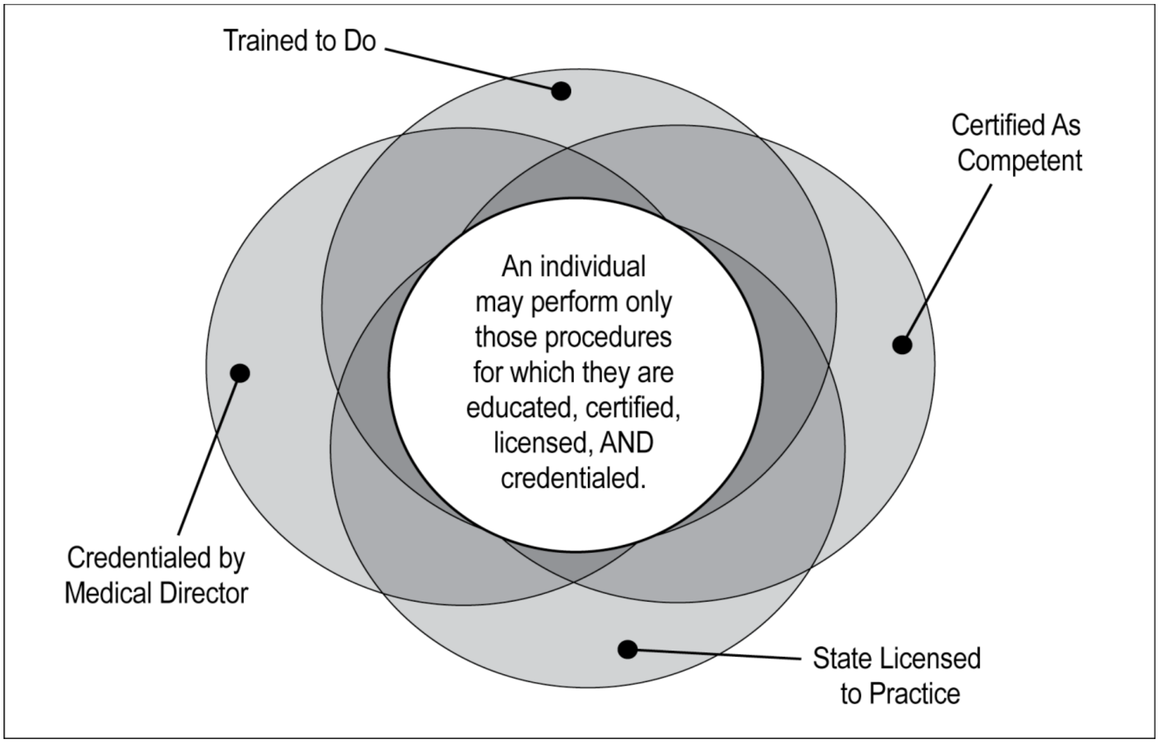

Figure 7: Requirements for procedural applications [6]

The Scope of Practice describes four levels of EMS personnel licensure: Emergency Medical Responder (EMR), Emergency Medical Technician (EMT), Advanced Emergency Medical Technician (AEMT), and Paramedic [8]. The Scope of Practice further defines practice, addresses prior educational preparation, and describes necessary skills at each level of licensure [9]. Each level represents it's own unique scope of practice.

Emergency Medical Responder is the lowest level in emergency medical services. The scope of practice of an EMR requires simple skills focused on basic lifesaving situation for critical patients. Typically, the Emergency Medical Responder renders on-scene emergency care while awaiting additional EMS response and may serve as part of the transporting crew, but not as the primary care giver. They must function with an EMT or higher-level personnel during the transportation of emergency patients. EMR's are limited to skills that are effective and can be performed safely in an out-of-hospital setting with medical oversight. After plenty experience as part of an EMS response system emergency medical responders can go on and upgrade to the level of assessment and care.

The Emergency Medical Technician's scope of practice includes basic skills focused on the management and transportation of critical patients. Also they are responsible for providing care to minimize secondary injury and comfort to the patient and their family while transporting them to an emergency care facility. An EMT's knowledge, skills, and abilities are acquired through formal education and training. They also must be able to perform all the skill and acts of an EMR [9]. The Emergency Medical Technician transports all emergency patients to an appropriate medical facility. They are not prepared to make decisions independently regarding the appropriate disposition of patients. A major difference between the Emergency Medical Responder and the Emergency Medical Technician is the knowledge and skills necessary to provide medical transportation to emergency patients.

The Advanced Emergency Medical Technician is the next level up from an EMT. Their scope of practice includes the knowledge and practice of advanced skills involving:

management and transportation of a patient and administering an IV to a patient. AEMT is a high level of out-of-hospital care. They must go through a formal education and training process while also having the knowledge of an EMR and EMT. The major difference between the Advanced Emergency Medical Technician and the Emergency Medical Technician is the ability to perform limited advanced skills and provide pharmacological interventions to emergency patients.

A Paramedic is the highest level of out-of-hospital care. The Paramedic's scope of practice includes basic and advanced skills focused on the management and transportation of patients. They are also responsible for invasive and pharmacological interventions to reduce the morbidity and mortality associated with acute out-of-hospital medical and harrowing emergencies. The Paramedic has knowledge, skills, and abilities developed by appropriate formal education and training. They also must have knowledge and skills associated with that of the EMR, EMT, and AEMT. The major difference between the Paramedic and the Advanced Emergency Medical Technician is the ability to perform a larger range of advanced skills.

The table below show the skill sets of the four levels of Emergency Medical Services as describes above.

Airway and Breathing Minimum Psychomotor Skill Set			
Emergency Medical Responder	**Emergency Medical Technician**	**Advanced Emergency Medical Technician**	**Paramedic**
• Oral airway • BVM • Sellick's Maneuver • Head-tilt chin lift • Jaw thrust • Modified chin lift • Obstruction manual • Oxygen therapy • Nasal cannula • Non-rebreathe face mask • Upper airway suction	• Humidifiers • Partial rebreathers • Venturi mask • Manually triggered ventilator • Automatic transport ventilator • Oral and nasal airway	• Esophageal – tracheal multi-lumen airways	• BiPAP/ CPAP • Needle chest decompression • Chest tube monitoring • Percutaneous Cricothyrotomy • $ETCO_2$/ Capnogragh • NG/OG tube • Nasal and oral endotracheal intubation • Airway obstruction removal by direct laryngoscopy • PEER

Pharmacological Intervention Minimum Psychomotor Skill Set			
Emergency Medical Responder	**Emergency Medical Technician**	**Advanced Emergency Medical Technician**	**Paramedic**
Tech of Med Administration • unit dose auto injectors for self or peer care	Assisted Medication Assisting a patient in administering own prescribed medication and auto injection Tech of Med Administration • Buccal • Oral Administrated Meds • Physician approved over the counter medications (Oral glucose, ASA for chest pain of suspected ischemic origin	Peipheral IV insertion IV fluid infusion Pediatric IO Tech of Med Administration • Aerosolized • Subcutaneous • Intramuscular • Nebulized • Sublingual • Intranasal • IV push of D50 and narcotic antagonist only Administered Meds • SL Nitroglycerine for chest pain of suspected ischemic origin • SQ of IM epinephrine for anaphylaxis • Glucagon and IV D50 for	Central line monitoring IO insertion Venous blood sampling Tech of Med Administration • Endotracheal • IV push and infusion • NG • Rectal • IO • Topical • Accessing implanted central IV port Administered Meds • Physician approved medications • Maintenance of blood administration • Thrombolytic initiation

		hypoglaycemia • Inhaled beta agonist for dyspnea and wheezing • Narcotic antagonist • Nitrous oxide for pain relief	
Emergency Trauma Care Minimum Psychomotor Skill Set			
Emergency Medical Responder	**Emergency Medical Technician**	**Advanced Emergency Medical Technician**	**Paramedic**
• Manual cervical stabilization • Manual extremity • Eye irrigation • Direct pressure • Hemorrhage control • Emergency moves for endangered patients	• Spinal immobilization • Seated spinal immobilization • Long board • Extremity splinting • Mechanical pt. restraint • Tourniquet • MAST/ PASG • Cervical collar • Rapid extrication		• Morgan Lens

2.3 Sound

Noise is defined as unwanted or disturbing sound. To properly understand noise, the concept of sound and its various properties need to be studied. The following sections focus on sound and its characteristics. Sound is defined as vibrations through a medium such as air, liquid or another gas, which can be heard when they reach an ear of a person or animal [20]. Sound can be explained in three ways, mechanically, longitudinally, and as pressure.

2.3.1Mechanically

This section describes sound in terms of its mechanical properties. A wave is considered to be particles that transport energy from one point to another. A good way to think of a wave is using Slinkys attached to blocks. This image can be seen below:

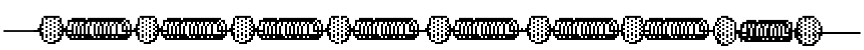

Figure 8: Slinky Model showing Wave properties [20]

When the first slinky is disturbed by movement of the first block, the next slinky will be disturbed causing the second block to react as well. The third slinky will react to the second Slinky's movement; this will happen all the way down the line until it reaches its final destination.

A sound wave is very similar to this example using Slinkys and blocks because there is a medium that the wave is traveling through. In the Slinkys Model, the slinky coils are the medium while for a sound wave the medium will most likely be the air. Next there is the source of the wave, like in the example above the movement of the first block is the source of the wave, for sound the original source could be something such as a stereo or someone's mouth when speaking. And lastly the wave is transported from the original source to another location, in the example the last block would be the final destination while for a sound wave the final destination would be someone's ear. [18]

An example of how a sound wave could be made mechanically is considering a tuning fork. When a tuning fork is struck the vibrations of the prongs create a disturbance in the molecules surrounding it, this disturbance continues to travel through the surrounding molecules and particles creating a sound wave that will be transported to the ear.

2.3.2 Longitudinally

The vibrations of the particles and molecules of sound waves traveling through the air can best described as longitudinal waves. A longitudinal wave is a wave where the motion of particles of the medium are traveling in parallel with the direction of the transportation of the energy from the wave as seen from the figure below. Figure 9 shows a slinky that has an energy moving left to right and the resulting wave is the coils moving left and right as well17].

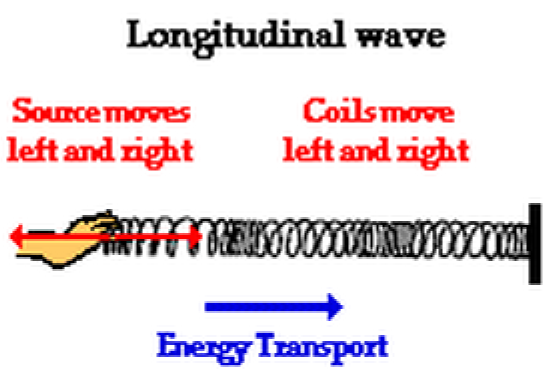

Figure 9: Image of Longitudinal Wave

A string can make longitudinal waves because as the string moves to the right it pushes on the surrounding molecules hence moving them in the same direction. As the string moves to the left it pulls the surrounding molecules to the left as well. This can be seen in the series of figures below.

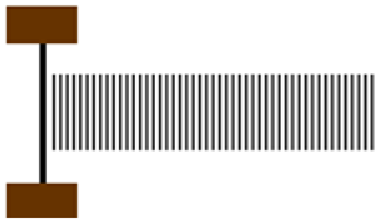

Figure 10: Static String

This figure shows the static string and the static molecules.

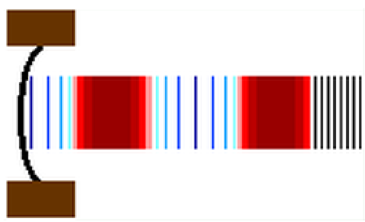

Figure 11: String Moving Left

This figure show the string moving to the left and pulling the molecules that should have been static molecules to the left and further apart from each other, as shown by the blue lines.

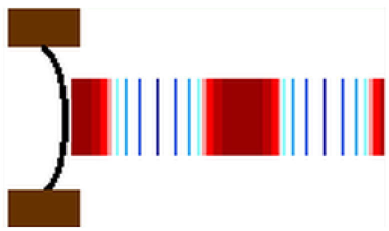

Figure 12: String Moving Right

This figure shows the string moving to the right and pushing the molecules that should have been static molecules to the right and closer together, as shown by the thick red blocks. The combinations of the leftward and rightward movements are going to cause a longitudinal wave to create movement to the right. These left and right vibrations cause the red compressions and the blue rarefactions in the air.

2.3.3 Pressure

The last way a sound wave can be described is as a pressure wave. This is created with high and low pressure areas as shown in the figure below. The figure demonstrates a tuning fork's reaction after being struck. The spots where the dots are really close together signify high pressure while where the dots are far away signify low pressure.

Figure 13: Tuning Fork sending off vibrations

A wave consists of two different parts; the rarefactions and compressions. Rarefactions are in the low pressure areas. Compressions are in the high pressure areas. These two parts can be seen below in the figure. The figure below and the one above both demonstrate the rarefaction and compressions in a wave.

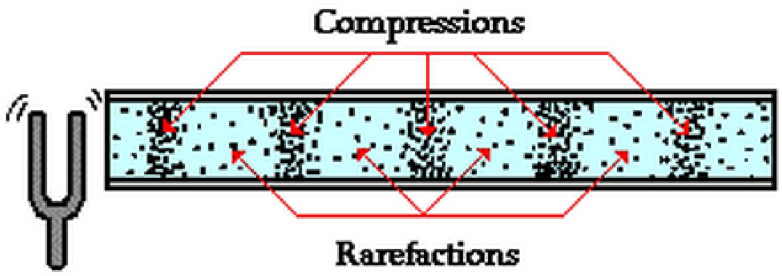

Figure 14: Tuning fork showing rarefactions and compressions [19]

A sound wave consists of repeating high and low pressure areas through a medium. Since they consist of a repeating pattern they can be described by a wavelength. A wavelength is just how long it takes a wave to do one complete signal. These wavelengths can be described by sinusoidal waves as shown below. A wavelength would be from one high peak to the next high peak. The rarefactions and compressions can be seen better and understood easier by the figure below as well and how they correspond into a sinusoid.

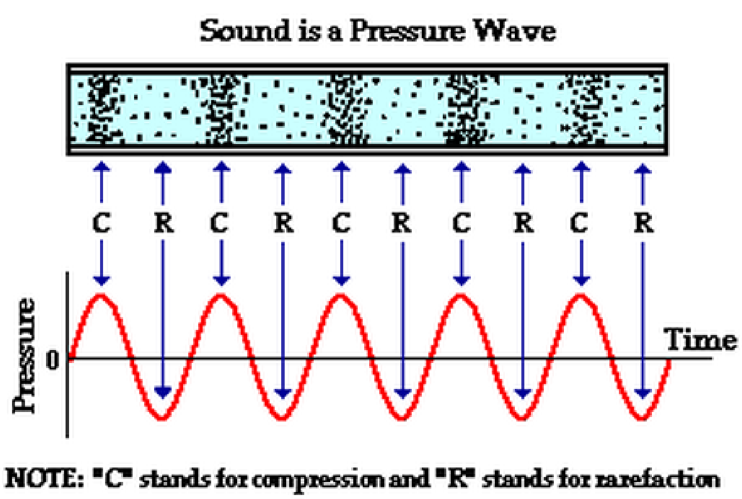

Figure 15: Correlating rarefactions and compressions into a sinusoidal wave [19]

These rarefactions and compression will then be received by some sort of detector such as a human ear. The detector acts the same way as the vibrating sting but instead of causing the wave, it is reacting to the wave. So in the rarefactions the “string” or eardrum will be pull out to the left and in the compressions the eardrum will be pushed right and then the brain will interpret this as sound. This reaction can be seen in the series of figures below [19].

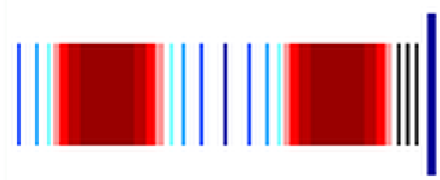

Figure 16: Static Detector

This figure shows the static molecules being taken in by the “string” or eardrum and how the eardrum is static.

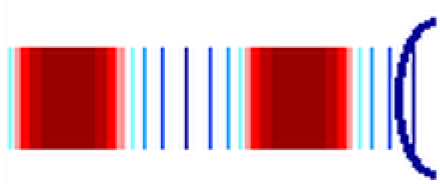

Figure 17: Detector during rarefaction

This figure shows the eardrum taking in the wave at the rarefaction. As the eardrum is introduced to the low pressure it reacts by getting pulled to the left.

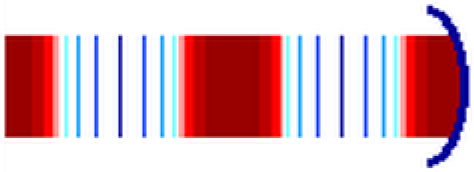

Figure 18: Detector during compression

This figure shows the eardrum taking the wave at compression. As the eardrum is introduced to the high pressure it reacts by pushing into the right.

2.3.4 Frequency and Pitch

As previously stated, when a string vibrates it causes the particles around to move to. The speed at which these particles move is known as frequency. Frequency can be measured by vibrations per second. The standard unit of measurement for frequency is hertz and can be symbolized as Hz. Each particle in the medium vibrates at the same frequency. Another way to think of frequency is considering the number of rarefactions or compressions that pass in a unit of time. A way to measure the frequency of a sound wave is to use the period. A period is the time it takes to reach one high pressure point to the next one in the wave, or the time between one low pressure point and the next one. The smaller the period the high the frequency will be, as shown in the figure below; this is because frequency is equal to one per unit time (1/T) [16].

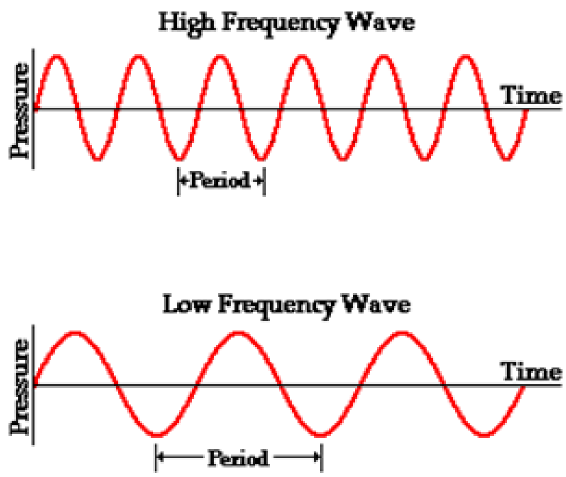

Figure 19: Waves of different frequencies [16]

In the above figure it is easy to see that higher frequency waves will have shorter periods than low frequency waves. Different frequencies cause different pitches. A pitch is referred to the sensation that is caused by a certain frequency. For a sound wave, the higher the frequency the higher the pitch and the lower the frequency the lower the pitch will be.

2.3.5 Intensity of sounds

Intensity is defined by the energy that is transported from the original source to the final destination. This is directly correlated to the amplitude of the wave. The greater the amplitude of the wave, the higher it's intensity. The intensity of a sound will decrease as the distance from the source increases. This can be proved by the equation:

$$\text{Intesnsity} = \frac{\text{Power}}{\text{Area}}$$

Since power will remain constant throughout the wave's life but the area will change, hence the intensity will decrease as the area increases. When a wave moves further away from its source the more area the sound wave needs to cover. This can be seen from the figure below.

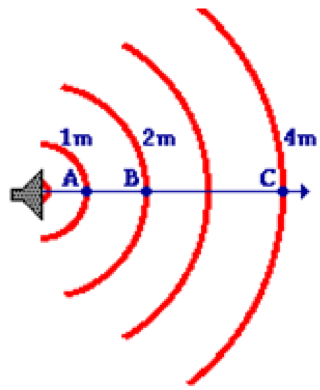

Figure 20: Intensity Level diagram

When the distance from the source is increased by a factor of two the intensity will be decreased by a factor of four because of the inversed square relationship from the area. So if the distance is increased by a factor four the intensity will decrease by a factor of 16. This relationship can be seen in the table below. [15]

Relationship between Distance and Intensity	
Distance (meters)	Intensity (units)
1	160
2	40
3	17.8
4	10

Below is a table showing different intensities of different sounds. Intensity is measure on the decibel scale which is a logarithmic scale. Something that is measured with an intensity of 10dB is 10 times louder than threshold of hearing which is assigned 0dB. Something that is 30dB is 1000 times louder than 0dB and every 10dB higher something is measured to be it is 10 times louder.

Different Intensities of Different Sound			
Source	Intensity (W/m^2)	Instensity Level (dB)	Number of Times Greater that TOH
Threshold of Hearing	1*10^-12	0	10^0
Rustling Leaves	1*10^-11	10	10^1
Whisper	1*10^-10	20	10^2
Normal Converation	1*10^-6	60	10^6
Busy Street Traffic	1*10^-5	70	10^7
Vaccum Cleaner	1*10^-4	80	10^8
Large Orchesta	6.8*10^-3	98	10^9.8
Walkman at Maximum Level	1*10^-2	100	10^10
Front Rows of Rock Concert	1*10^-1	110	10^11
Threshold of Pain	1*10^1	130	10^13
Military Jet Takeoff	1*10^2	140	10^14
Instant Perforation of Eardrum	1*10^4	160	10^16

2.4 Interference of Waves

An interference of waves occurs when two waves are passing through the same medium at the same time. These interferences can either be destructive of constructive. Destructive interference is caused when two waves 180 degrees out of phase and they will change the amplitude of the wave. Constructive interference is when they are in phase and they build on each other to make a wave with greater amplitude. This can be seen in the figure below.

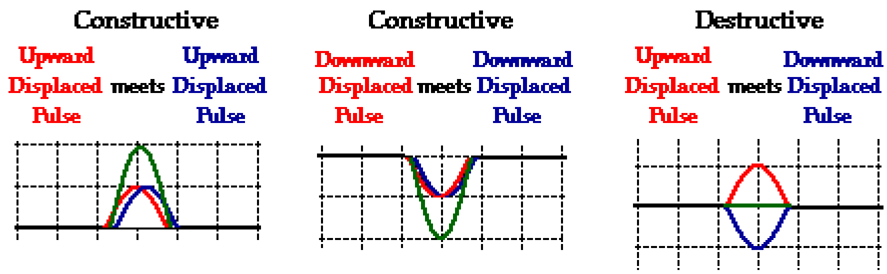

Figure 21: Interference of waves

On the left most part of the figure it shows two waves at their upper peaks that are interfering with each other. In this case since they are exactly in phase the amplitudes are just added together and since the waves are equal in amplitude the new amplitude is just doubled. The middle part of the figure is the same expect it is showing waves at their lower peak or rarefaction. The rightmost part of the figure shows two waves of the same amplitude interfering, but they are 180 degrees out of phase so the amplitudes added together equal zero, which will cancel the sound wave. [14]

Although some waves can be completely taken away with disruptive interference that is not always the case, if they are not exactly 180 degrees out of phase they can make completely different shaped waves as shown below. The rightmost part of the figure clearly shows what can happen with two waves that are different in amplitude, do not have the same frequency, and are not in phase.

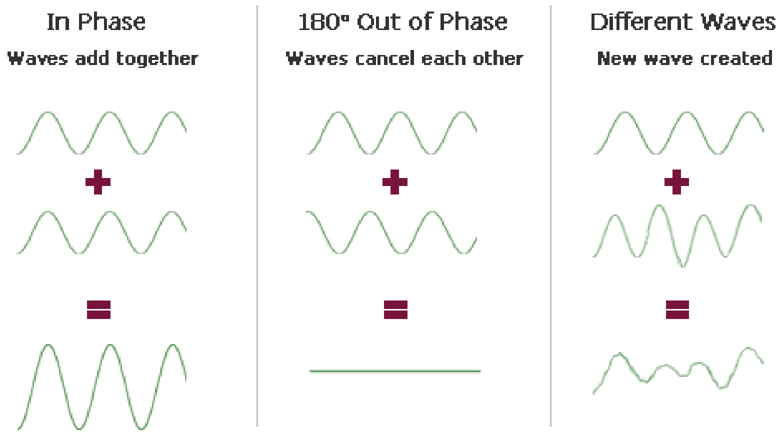

Figure 22: More interference of waves [12]

2.4.1 The Doppler Effect

The Doppler Effect is a phenomenon that can be observed when waves are moving with respect to something or someone. It can be described in a noticeable increase in the frequency when the source of waves is approaching the observer, and in return there is a noticeable decrease in frequency when the source is moving away from the observer. An example of when a Doppler effect can be observed is when an emergency vehicle approaches and then drives away from you. The observed change in frequency can be looked at in the figure below. [11]

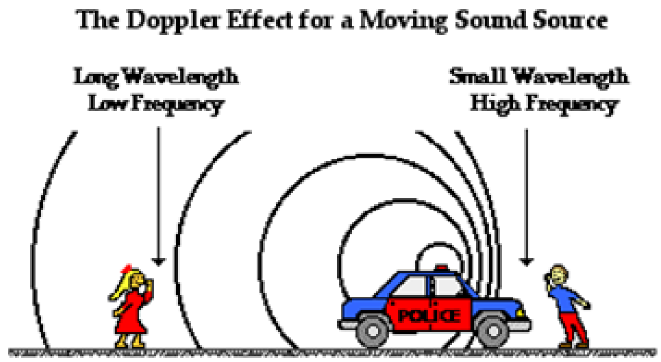

Figure 23: Doppler Effect

It is easily noticeable that the pitch of the siren gets higher as the ambulance approaches and the pitch starts fading after it passes and drives away. This happens because the source of a sound always emits the same frequency so for the same amount of time the same amount of waves must fit between the source and the observer. And if the observer is getting further away there is a greater distance at which the waves can be spread out, but when the source is getting closer to the observer the waves need to be compressed into a smaller distance. Because of this the observer will either perceive sound either at lower or higher rate resulting in a lower or higher pitch.

2.4.2 Human Ear

The ear consists of three main parts which include the outer ear, the middle ear, and the inner ear which can be seen in the figure below. The outer ear is meant to try and collect as much sound waves as possible and funnel them into the middle ear. The middle ear then transforms these waves into vibrations using the ligaments inside the ear. And the inner ear transforms the energy to waves through fluids which acts as nerve impulses that are sent to the brain and decoded into a sound. [13]

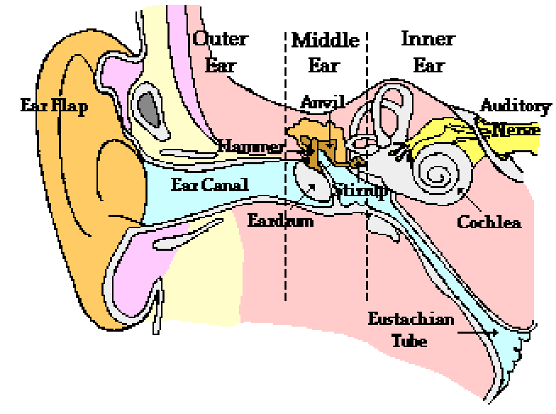

Figure 24: Human Ear [13]

2.5 Use of Lights and Sirens in EMS

To understand the need for sirens and its current usage, researching the history of sirens is not enough. The procedure for using sirens and lights in an EMS and its risks and dangers need to be learnt. In many cases, using lights and sirens have found to cause more damage than good and have in fact led to accidents. To provide guidance to the states' EMS medical directors and system managers, the National Association of EMS Physicians (NAEMSP) and the National Association of State EMS Directors (NAEMSD) endorse the following positions regarding the use of warning L&S in EMV response and patient transport.

2.5.1 Position Statements

1. *"Emergency medical services (EMS) medical directors should participate directly in the development of policies governing EMV response, patient transport, and the use of warning lights and siren"* [21].

Emergency medical vehicle response policy decisions involve many medical care and medical direction issues including patient outcome, quality improvement, patient and emergency medical provider safety, and risk management. Therefore, EMV response and patient transport decisions should be guided, reviewed, and approved by the EMS medical director.

2. *"The use of warning lights and siren during an emergency response to the scene and during patient transport should be based on standardized protocols that take into account situational and patient problem assessments"* [21].

Written protocols and guidelines should delineate when to use Lights and Sirens during scene response and patient transport. These protocols should be based on a reasonable identification of situations for which a reduction in response and transport times might improve patient outcome. The protocols should be developed in conjunction with local emergency response practices and statutes and should receive approval from the EMS director. Final protocols should be distributed to all dispatch and EMS entities. Warning lights and siren protocols should be enforced, and inappropriate use of L&S by EMS personnel will be limited.

3. *"EMS dispatch agencies should utilize an emergency medical dispatch priority reference system that has been developed in conjunction with and approved by the EMS medical director to determine which request for pre-hospital medical care requires the use of warning lights and siren"* [21].

Sound dispatch prioritization systems establish a patient's level of severity, which then allows the determination of the type of vehicle (s) that should respond and the urgency of that response. Emergency medical dispatch centers should institute the protocols and monitor adherence to them.

4. *"Except for suspected life-threatening, time-critical cases or cases involving multiple patients, L&S response by more than one EMV usually is unnecessary"* [21].

Guidelines for the multi-EMV L&S response should be outlined in emergency medical response policies and dispatch procedures.

5. *"The utilization of emergency warning L&S should be limited to emergency response and emergency transport situations only"* [21].

Alternative practices, such as returning to a station or quarters using L&S or using L&S for "staging" or moving to designated areas to stand-by for a response, should be discontinued. Exceptions to such a policy would include extraordinary circumstances such as a disaster, or situations in which patient outcome could be affected.

6. *"All agencies that operates EMVs or are responsible for emergency medical responders should institute and maintain emergency vehicle operation education programs for the EMV operators"* [21].

Initial and continuing education of EMS personnel should include instruction in safe and appropriate EMV driving techniques and should take place prior to initial EMV operation. Knowledge and demonstrated skill in EMV operation are prerequisites for all public-safety vehicle operators.

7. *"Emergency medical vehicle-related collisions occurring during an emergency response or transport should be evaluated by EMS system managers and medical directors"* [21].

Such evaluations should include an assessment of the dispatch process, as well as initial (at the beginning of the transport) and final patient conditions.

8. *"A national reporting system for EMV collisions should be established"* [21].

Data are needed regarding the prevalence, circumstances, and causes of EMV collisions, including related injuries and deaths, and "wake effect" collisions. Collection of the information should start at the state and local levels; the information collected should include uniform data elements for tabulation and nationwide comparison.

9. *"Scientific studies evaluating the effectiveness of warning L&S under specific situations should be conducted and validated"* [21].

These important research efforts should be supported by both public and private resources.

- *"Laws and statutes should take into account prudent safety practices by both EMS providers and the monitoring public"* [21].

The major emphasis and focus should remain on the exercise of prudent judgment and due regard by EMV operators. Laws and statutes also should emphasize the motoring public's responsibility to clear a lane or access way for EMVs.

11. *"National standards for safe EMV operation should be developed"* [21].

Such standards should mandate that EMV operators should approach intersections safely and have a clear view of all lanes of traffic before proceeding through. Standard also should set appropriate speed limits for emergency responses and transports in urban and rural settings, and for responses that occur under adverse road, traffic, and weather conditions.

In order to ensure that we "first do no harm," sound rationale and corresponding protocols and policies for the use of warning L&S in EMV response and patient transport should be developed and instituted in all EMS systems. All EMV operators should be trained adequately and regulated. The judicious use of warning L&S in the initial response and subsequent transport of patients likely will result in a more balanced system of appropriate care with minimization of iatrogenic injury and death.

2.5.2 Common Noise Levels

Noise is defined as unwanted or disturbing sound. High levels of noise can lead to serious health problems such as sleep disruption, high blood pressure, speech interference, heart disease and most commonly noise induced hearing loss (NIHL). Some of the sources of noise for EMS paramedics are street traffic such as the noise of engines, exhaust systems, horns, tires screeching and accelerating vehicles. However, the major sources of noise come from the EMS van itself including the horn, engine and most importantly, the siren. Figure 27 below shows a wide range of noises and their actual measurements in decibels

Decibels	**Description**	**Source of noise**
110 dB	Deafening	Close to a train
100 dB	Very Loud	Passing truck, home lawn mower, car horn @ 5 meters
90 dB	Very Loud	Decibels at or above 90 regularly cause ear damage. Truck without muffler
80 dB	Loud	Noisy office, electric shaver, alarm clock, police whistle
70 dB	Loud (Annoyingly loud to some people	Average radio, normal street noise,
60 dB	Moderate	Conversational speech
50 dB	Moderate	Normal office noise, quiet stream
45 dB	Moderate	To awaken a sleeping person

Figure 25: Common Noise Levels

2.5.3 Study on Hearing Loss

While researching the adverse effects of the noise of an ambulance siren, the following study was found on the Annals of Emergency Medicine. Ambulance cab noise levels during siren use, hearing levels of 56 ambulance paramedics, and hearing acuity changes of four ambulance paramedics during a 14-year period were examined to determine whether environmental noise levels are sufficient to produce hearing loss, to determine if hearing loss is indeed present in ambulance paramedics, and to determine if ambulance paramedics lose hearing acuity at rates faster than "normal" peers. Ambulance cab noise levels during siren use were intense (mean of 102.5 dBA in a common conditions), well above the Occupational Safety and Health Administration's suggested guidelines of 90 dBA. Hearing levels of paramedics were reduced much more than expected. In the lower and higher frequency ranges, the personnel showed hearing acuity approximately one standard deviation below the normal mean. This meant that mean hearing thresholds were depressed approximately 5 dB to 2 dB, depending on age and frequency. Ambulance paramedics over a 14-year term appeared to lose hearing acuity at a rate faster than 'normal' peers that is people of the same age who don't work as paramedics. [22]

2.6 Flight Communication

The study on hearing loss made our group realize that we needed to redirect the focus of our project and concentrate on eliminating the siren from use in an ambulance. As part of our ideas to construct a working prototype of this substitute, our group began researching different forms of communication to implement the most optimal design when it comes to constructing our prototype and use it to alert drivers of an incoming ambulance van without the need of a siren. One of the forms of communication we researched was flight communication. Flight communication has constantly progressed over the last century and the following research outlines the major changes.

The following excerpt is taken from an interview conducted with Captain Lim of Malaysian Airways;

"Technology has changed somewhat since the era of the Second World War. Nevertheless, High Frequency (HF), communication continues to be used but its quality has improved a lot. Notwithstanding the better performance, the clarity of HF communication suffers when used at night. Hence it can be a rather irritating form of communication when traffic becomes too congested during this unfavorable period. Today, many airliners on Oceanic flights use a new form of communication known as Future Air Navigation System (FANS) to keep in touch with the ground station. Once contact is established using Controller Pilot Data Link Communication (CPDLC), the pilot virtually stops transmitting position reports. The ground controller knows exactly where the plane is with regards to its position, speed, level, etc. When within range of any ground stations, the pilot is only required to monitor the station's Very High Frequency (VHF) communication or the HF when it gets out of range. To communicate with company dispatch, Aircraft Communications Addressing and Reporting System (ACARS) is being used in most modern airliners such as the Boeing 777). The ACARS makes use of satellite communications and send or receive messages like a telex machine. We can also use the satellite phones for urgent communication but still fall back on the HF as a backup [23]."

An important aspect of flight communications is the Aircraft Communications Addressing and Reporting System or ACARS. This is a digital data link system for transmission of short, relatively simple messages between aircraft and ground stations via radio or satellite. The protocol, which was designed by ARINC (Aeronautical Radio, Incorporated) to replace their VHF voice service and deployed in 1978, uses telex formats. SITA later augmented their worldwide ground data network by adding radio stations to provide ACARS service. Over the next 20 years, ACARS will be superseded by the Aeronautical Telecommunications Network (ATN) protocol for Air Traffic Control communications and by the Internet Protocol for airline communications.

Prior to the introduction of data link, all communication between the aircraft (i.e., the flight crew) and personnel on the ground was performed using voice communication. This communication used either VHF or HF voice radios, which was further augmented with SATCOM in the early 1990s. In many cases, the voice-relayed information involves dedicated radio operators and digital messages sent to an airline teletype system or its successor systems. The Engineering Department at Aeronautical Radio, Inc (ARINC), in an effort to reduce crew workload and improve data integrity, introduced the ACARS system in July 1978. The first day operations saw about 4000 transactions. A few experimental ACARS systems were introduced earlier but ACARS did not start to get any widespread use by the major airlines until the 1980s.

The original ARINC development team was headed by Crawford Lane and included Betty Peck, a programmer, and Ralf Emory, an engineer. The terrestrial central site, a pair of Honeywell Level 6 minicomputers, (AFEPS) software was developed by subcontractor, Eno Compton of ECOM, Inc.

Although the term ACARS is often taken into context as the data link avionics line-replaceable unit installed on the aircraft, the term actually refers to a complete air and ground system. The original meaning was Arinc Communications Addressing and Reporting System. Later, the meaning was changed to Airline Communications, Addressing and Reporting System. On the aircraft, the ACARS system was made up of an avionics computer called an ACARS Management Unit (MU) and a Control Display Unit (CDU). The MU was designed to send and receive digital messages from the ground using existing VHF radios. On the ground, the ACARS system was made up of a network of radio transceivers, managed by a central site computer called AFEPS (Arinc Front End Processor System), which would receive (or transmit) the data link messages, as well as route them to various airlines on the network.

The initial ACARS systems were designed to ARINC Characteristic 597. This was later upgraded in the late 1980s by the publication of ARINC Characteristic 724. ARINC 724 is intended for aircrafts installed with avionics supporting digital data bus interfaces. ARINC 724 was updated to the current standard ARINC Characteristic 724B, which is the predominate standard for all digital aircraft. With the introduction of ARINC 724B, the ACARS MUs were also coupled with industry standard protocols for operation with flight management system MCDUs (ARINC 739), and printers (ARINC 740 and ARINC 744). The ACARS MU has been since expanded to server broader needs using a Communications Management Unit (CM) defined by ARINC Characteristic 758. Today new aircraft designs integrate CM functions in Integrated Modular Avionics

(IMA). ARINC Standards are prepared by the Airlines Electronic Engineering Committee (AEEC) [24].

2.6.1 OOOI Events

One of the initial applications for ACARS was to automatically detect and report changes to the major flight phases (**O**ut of the gate, **O**ff the ground, **O**n the ground, and **I**nto the gate); referred to in the industry, as OOOI. These OOOI events were determined by algorithms in the ACARS MUs that used aircraft sensors (such as doors, parking brake and strut switch sensors) as inputs. At the start of each flight phase, the ACARS MU would transmit a digital message to the ground containing the flight phase, the time at which it occurred, and other related information such as fuel on board or origin and destination. These messages were primarily used to automate the payroll functions within an airline, where flight crews were paid different rates depending on the flight phase [24].

2.6.2 Flight management system Interface

In addition to detecting events on the aircraft and sending messages automatically to the ground, initial systems were expanded to support new interfaces with other on-board avionics. During the late 1980s and early 1990s, a data link interface between the

ACARS MUs and Flight management systems (FMS) was introduced. This interface enabled flight plans and weather information to be sent from the ground to the ACARS MU, which would then be forwarded to the FMS. This feature gave the airline the capability to update FMSs while in flight, and allowed the flight crew to evaluate new weather conditions, or alternative flight plans [24].

2.6.3 Maintenance Data Download

It was the introduction in the early 1990s of the interface between the FDAMS / ACMS systems and the ACARS MU that resulted in data link gaining a wider acceptance by airlines. The FDAMS / ACMS systems which analyze engine, aircraft, and operational performance conditions, were now able to provide performance data to the airlines on the ground in real time using the ACARS network. This reduced the need for airline personnel to go to the aircraft to off-load the data from these systems. These systems were capable of identifying abnormal flight conditions and automatically sending real-time messages to an airline. Detailed engine reports could also be transmitted to the ground via ACARS. The airlines used these reports to automate engine trending activities. This capability enabled airlines to better monitor their engine performance and identify and plan repair and maintenance activities.

In addition to the FMS and FDAMS interfaces, the industry started to upgrade the on-board Maintenance Computers in the 1990s to support the transmission of maintenance related information real-time through ACARS. This enabled airline maintenance personnel to receive real-time data associated with maintenance faults on the aircraft. When coupled with the FDAMS data, airline maintenance personnel could now start planning repair and maintenance activities while the aircraft was still in flight [24].

2.7 Interactive Crew Interface

All of the processing described above is performed automatically by the ACARS MU and the associated other avionics systems, with no action performed by the flight crew. As part of the growth of the ACARS functionality, the ACARS MUs also interfaced directly with a control display unit (CDU), located in the cockpit. This CDU, often referred to as an MCDU or MIDU, provides the flight crew with the ability to send and receive messages similar to today's email. To facilitate this communication, the airlines in partnership with their ACARS vendor, would define MCDU screens that could be presented to the flight crew and enable them to perform specific functions. This feature provided the flight crew flexibility in the types of information requested from the ground, and the types of reports sent to the ground.

As an example, the flight crew could pull up an MCDU screen that allows them to send to the ground a request for various weather information. Upon entering in the desired locations for the weather information and the type of weather information desired, the ACARS would then transmit the message to the ground. In response to this request message, ground computers would send the requested weather information back to the ACARS MU, which would be displayed and/or printed.

Airlines began adding new messages to support new applications (Weather, Winds, Clearances, Connecting Flights, etc.) and ACARS systems became customized to support airline unique applications, and unique ground computer requirements. This results in each airline having their own unique ACARS application operating on their aircraft. Some airlines have more than 75 MCDU screens for their flight crews, where other airlines may have only a dozen different screens. In addition, since each airline's ground computers were different, the contents and formats of the messages sent by an ACARS MU were different for each airline.

In the wake of the crash of Air France Flight 447, there has been discussion about making the ACARS into an "online-black-box”. If such a system were in place, it would avoid the loss of data due to Black-box destruction and the inability to locate the black-box following loss of the aircraft. However the cost of this, due to the high bandwidth requirements, would be excessive. Also there have been very few incidents where the black boxes were not recoverable [24].

After completing research on flight communications, our group realized there are many aspects to the technology used in aircraft communications that can be applied to an EMS system. The word system here refers not just to the EMS vans but to the whole grid within the ambulance and 911 response teams. Flight towers are able to communicate with individual flights and maintain complete order so that flights can arrive and depart, with everything running smoothly and minimal accidents. This could be applied to EMS. Major stations could be established in large cities that control the overall EMS transport system and 911 response teams. With the right technology, these systems could help improve response times and ensure no accidents occur when ambulance vans are out on the roads. There are already electronic systems in place that would allow these stations to control traffic lights on the roads EMS vans are using. If each van is tracked and their paths are cleared of traffic, this would make a major difference in EMS. Also, with our technology, which will be explained in more detail in the following chapter, these stations would be able to alert nearby traffic through a transmitter on the EMS vans to clear the way. This would completely eliminate the need for a siren; the objective of our project.

CHAPTER 3: IDEA (SIRENO) DEVELOPMENT

3.1 Introduction

Chapter three contains the team's explanation of their major goals and ideas. Possible solutions to the problem will be assessed along with their pseudo results. Also this chapter will discuss the equipment and processes needed to complete the project.

3.2 Methodology

The main objective of this Interactive Qualifying Project was to investigate how the noises vibrations due to the siren affect the patient and Emergency Medical Technician in the moving ambulance. The noises causes by the siren have the potential to affect the quality and safety of patient care, but mainly the long-term health of the EMT. The team determined that the project would achieve the following goals:

1. Explore the level of noise transferred to the cabin of the ambulance caused by the siren.
2. Determine what long-term affect the siren has on the emergency medical technician
3. Provide solution recommendations to reduce noise caused by the siren or possibly eliminate the need of a siren on ambulances.

3.4 Sireno

The siren has become accustom to people all around the world as an indication of an emergency medical vehicle approaching. It is the only means of communication used by emergency medical vehicles but no much attention has been given to its effect on the environment. As discussed in the previous chapter, the intensity of the noise caused by the siren is very harmful. In this project an idea of getting rid of the siren on the ambulance will be explored. We want to create a communication system between the ambulance or other emergency vehicles and the passenger vehicles. An ideal communication system which does not involve the use of a siren instead uses means of signal transmission. In the ideal world the means of communication will involve a transmitter located on the control panel in the ambulance that would send a specific signal picked up by a receiver located in all surrounding passenger vehicles. This device is what we called Sireno. It will completely eliminate the need of a siren as an alerting device on ambulance.

3.5 Background Information

For the purpose of this project, the team needed to conduct background research in order to obtain both a broad understanding of the EMS profession and a focused understanding of the noises caused by the siren in an ambulance. First, the team started by researching the progression of ambulances and sirens overtime to see what have improved or changed over the years. Next, the team focused on gaining complete knowledge of the history of the EMT profession, as well as an EMT's scope of practice, or the skills they are trained to do. We felt it was vital to fully comprehend these subjects to have base knowledge for further research. We brought most of our attention to the actual sound produced by the siren. Specifically we were concerned with the pressure, along with the frequency and pitch of the siren noise level. It is very necessary to understand all aspects of the siren in order to further diagnosis the problem. The group spent time researching many case studies of hearing loss due to a siren over a certain amount of years. We utilized previous research done by other students to familiarize ourselves with ways to measure sound.

Furthermore, the team researched existing equipment used today that allows communication between two vehicles using Bluetooth, radio signal or infrared signal. In the real world, there already exists technology that allows communication to happen between two vehicles by using Bluetooth, radio signal or infrared signal, such communication systems include the Opticom GPS System and Snap Shot. The Opticom GPS is currently being used in many major cities all over the United States and Snap shot is used by the Progressive insurance company, Admiral Insurance, and other insurance companies in the Europe.

3.5.1 The Opticom GPS System

This is a communication system between the ambulance, fire apparatus, law enforcement vehicles and the traffic light. The Opticom GPS System consists of two main devices, an M3 Opticom emitter and Opticom receiver. The Opticom receiver consists of a GPS system that is used in the triangulation of a signal location that is being received.

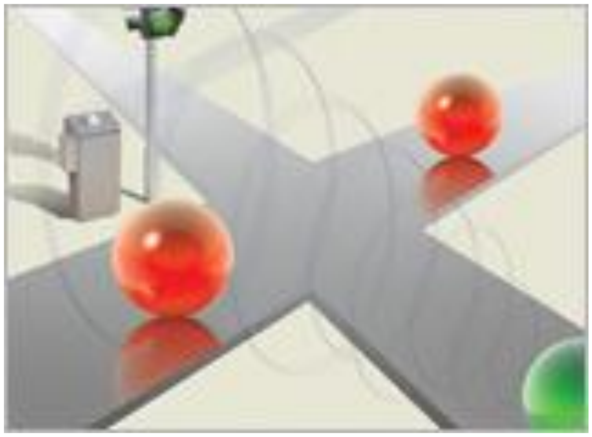

Figure 26: The Opticom System in practice [26]

The Opticom GPS system works in the following way: An Opticom emitter located on top of the ambulance (at the light bars) is switched on from the control panel inside the ambulance.

Figure 27: Opticom emitter on the light bar

The emitter then emits a discrete infrared signal to a detector located on top of the traffic light poles. The detector is wired to an Opticom receiver that triangulates the location of the signal/ ambulance. The receiver has an encoded signal transmission that enables it to shop traffic from other lanes, hence giving the emergency vehicles the right of way through an intersection. The M3 Opticom emitter consists of a self-contained power supply to sure that a signal is always emitted. The emitter's power consumption is also considerably low, "less than five amps peak current is drawn."[26] This makes the emitter more sufficient and reliable. The Opticom system has a transmission range up to 2500 feet [26.]

Below are the design specifications of the Opticom emitter.

<u>Specifications</u>	
Input Voltage	10 to 16 VDC
Current Used	Below 5 amps
<u>Dimensions</u>	
Width	5.8 inches/ 14.7 centimeters
Height	3.7 inches/ 9.4 centimeters
Depth	3.5 inches/ 8.9 centimeters

Figure 28: Design specification of the Opticom emitter

Figure 29: Opticom Receiver and detector on to traffic lights

Studies have been carried out to check the benefits of this Opticom system. The results showed that this technology:

- " Has improved safety by eliminating right-of-way conflicts at the intersection by using the first-come, first-serve authorization and vehicle descriptors enable streamlined coding activity
- Has facilitated safe, efficient movement through turns by turning signal recognition and relay leads preemption in the intended direction. Turning signal recognition clears right-of-way around corners for emergency vehicles.
- Has integrated easily with industry standard communications applications such providing GPS data output for other on-board devices. The Opticom technology interfaces with AVL for conditional priority hence enabling automated operation.

- Has provided precise activation and data reporting on ambulances' hence better estimate arrival of ambulance to health care centers.[27]

3.5.2 Snap Shot

Another device that was studied is the snap shot device. Snap shot is currently being used in the real by insurance companies for rating how good customers driver. In return the insurance companies award their customers for safe driving. This is the general purpose for snap shot, but for this project we focused on how collects and analysis data that is used rate drivers.

Figure 30: The snap shot device [28]

The snap shot device consists of an accelerometer, a receiver, an antenna, GPS, and a gyroscope as the main parts. The gyroscope is used to determine the angles between the vehicle's x-y-z -axis and the device's x-y-z-axis. The accelerometer measures the acceleration of the vehicle in the x, y and z-axis. The device is programmed to calculate the forces in the x-y-z-axis. The GPS is used to triangulate the location of the device. The device includes a sim-card that is used for data storage. The snap shot does not have a self-power supply; instead it is powered by the car battery. The device is programmed switch on at 12volts ±1volts.

The device had a three flashing LED light code, basically when snap shot is plugged into the vehicle, the LED flash in sequence, then the red LED stays solid indicating that it is receiving power. The blue LED flashes (searching for GPS signal), it stays solid if GPS signal is being received. The green flashes and stays solid if data is being collected.

Integrating the Opticom receiver technology in the Sireno receiver will enable the device to locate the position of emergency vehicle; hence every vehicle in the signal range will know the position of the ambulance. Getting the Sireno receiver to receive the signal as emitted by the 3M Opticom emitter will make the production/ development of Sireno cheaper. This is because the Opticom emitters are already installed in most emergency vehicles. Using the same signal will eliminate the need of designing a Sireno emitter.

3.6 Equipment

To make this product work a lot of different equipment were used not only to build it but to test it as well. The equipment we considered to test our idea is:

- A GW INSTEK GPS-3303 DC power supply, this would be used in place of the 12 volt batteries that would be used to supply both the transmitter and receiver. This can be used to supply a constant DC voltage of anywhere between 0 and 32 volts per channel. This DC power supply is change able on two of the channels but channel three is set to stay at a constant 5 volts. We would use channels one and two set to 12 volts to simulate the power supply coming in from the batteries of the cars or ambulances.

- A Tektronix TDS 2004B four channel oscilloscope would be used to see the output wave of the transmitter to make sure a steady waveform appears when the transmitter is activated, another channel would be looking at the input waveform that the receiver is getting when the transmitter is activated, this would be used to see the two waveforms next to each other to make sure that they are corresponding correctly.
- An Agilent 34405A 5 ½ digital multimeter would be used to probe certain parts of the circuits to make sure they have the correct voltage or current at the point. We want to check to make sure pins on the microcontrollers are at a digital one when they're supposed to be or at a digital zero when they are supposed to be.
- PICStart plus will be used to program the PIC microcontrollers, the pins of the microcontrollers will be inserted into corresponding sockets. The PICStart Plus has the capability of programming a 64 pin Integrated circuit
- MP Lab is the program that is used to program the PIC microcontrollers; this program uses the C programming language to program the specified pins of the PIC microcontrollers.

To build the actual circuits required to transmit and receive the signals the following equipment will need to be used:

- We will use three PIC16F88 microcontrollers. In our original design we had planned on using two because we would only need one for the transmitter in the ambulance and another one in the receiver inside the car. After realizing we wanted to integrate our system into the Opticom GPS because they were already being used to change light signals at intersections. So we added another transmitter on these and on street signs. These Microcontrollers will be programmed using MP Lab and PICStart Plus as stated above. The pins will be turned on high or low depending on the code. The Coding that will be used will do the picture below, this is the simplest way to explain the code:

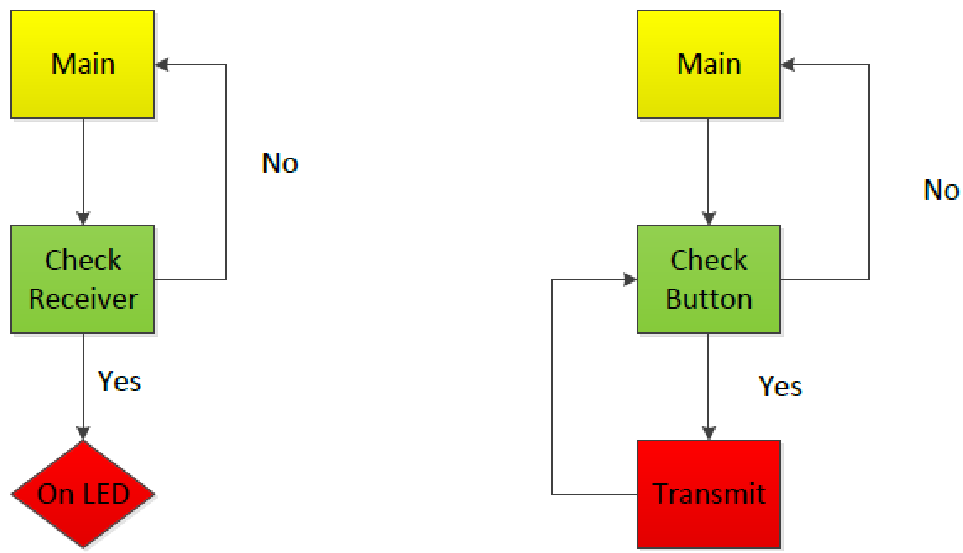

Figure 31: Sireno Transmitter Circuit Flow Chat

- We will use two TWS-BS-3 433MHz, with the same reasoning as stated in the above paragraph we were going to use only one at first but decided we needed two. This transmitter will be attached to the power supply, the microcontrollers and the antennas. The transmitter will be turned on when the pin on the microcontroller is turned high by the coding. The transmitter will send the signal to the receiver in the cars.
- We will use one RWS-371 at 433MHz. This will be used in the cars' devices so that when an ambulance is near and the transmitters are turned on the receiver will pick

up that signal. The pin that the receiver is attached to on the microcontroller will be turned high, this will alert the microcontroller to go into a different part of coding which will tell the pin that the LED's are attached to turn high, thus turning on the flashing "H" signal.

- 15-20 red LED's will be used in the device inside the car so that when the receiver picks up a signal the LED's can alert the driver, the LED's will be turned on when the pin that they are attached to is turn high due to a change of coding.
- Two 5V 1 Amp voltage regulators will be used to keep the power supply going to the transmitters at a solid 5 volts , this will ensure that the microcontroller and the transmitters will work properly and not get broken.
- Three 18 Pin IC Sockets will be used to mount the PIC microcontrollers into the soldering boards to make sure that the pins don't break
- Many various resistors will be used to create currents in the circuits to make them actually work. The microcontrollers actually require certain resistors in certain places to make it work correctly, also resistors will be used to create lowpass, highpass, or bandpass filters depending on the types of signals that are normally around the receivers. We want to be able to block out certain frequencies so that only our particular frequency that is created by the transmitter is received. This will get rid of noise and static that could possible cause the sensors inside the cars to go off.
- Many various capacitors will also be used in the circuits; they will be used because the microcontroller requires certain capacitors to make it work. Capacitors will also be used to create filters like the band pass low pass and high pass filters described above.

- Antennas will be used to make the signal stronger and clearer to block out interference. They will be used on the transmitters and receivers so that there is a lot lower of a chance that the signal is interfered with.
- Soldering boards will also be used to solder all the components together into one unit, and then these can be placed inside casings to make the look aesthetically pleasing.
- Cases will be used to protect the transmitter on the lights and street signs from the rain and weather. Other cases will be used on the transmitter in the ambulance and the receiver in cars to make them aesthetically pleasing and more functional.

All this equipment is extremely essential to make our system work correctly and to make it highly efficient, testing is very important and all the equipment needed will help us to fine tune our system. All the little parts such as the resistors capacitors, voltage dividers and LED's will allow us to construct this efficient system. The systems will be put together as shown below:

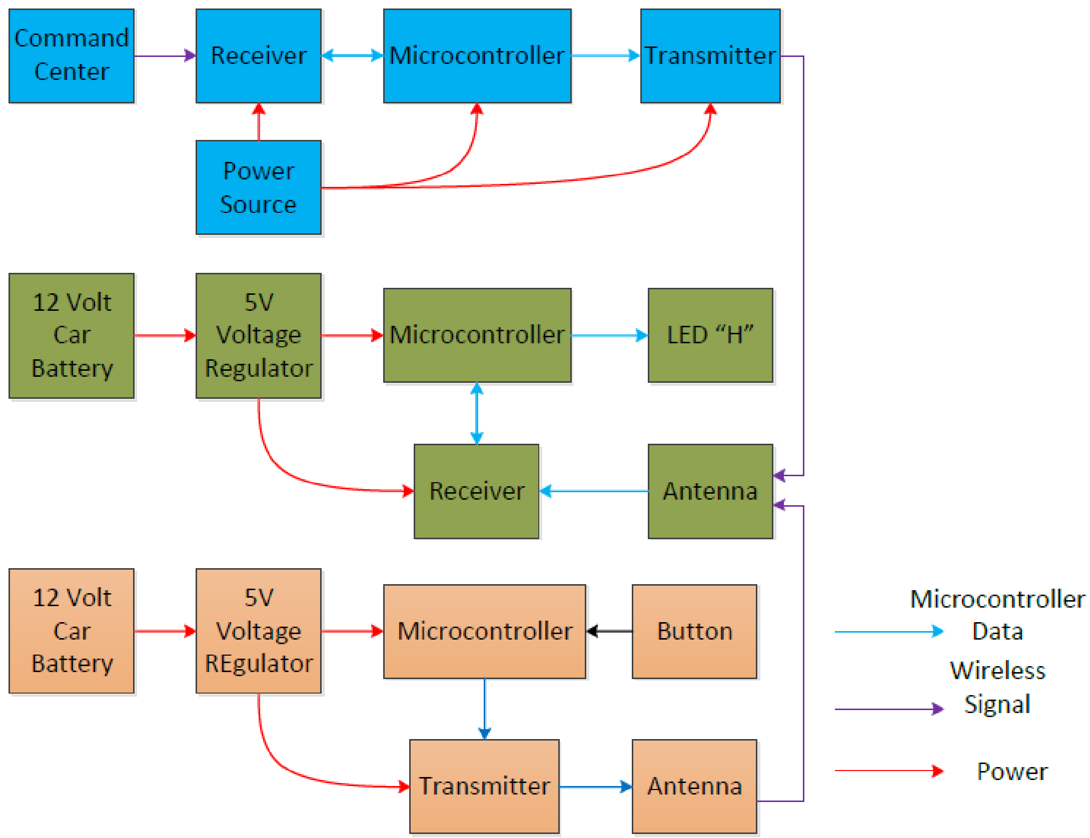

Figure 32: Sireno Receiver Circuit Flow Chat

3.7 Process

The completion of this project involved many steps. These steps varied from research and analysis to product compilation and testing. This section describes these steps in more detail.

The first step was determining the problem at hand. Initially, the project idea was remodeling emergency triage care units to reduce sound, vibrations and contaminants. This seemed to be a very significant contemporary issue. After researching about vibrations and sound, it was concluded that reducing sound levels in and around the ambulance was the most important and practical aspect of this topic within the given time frame. According to the research, the main sources of vibration in an EMS are car engines, potholes, roadwork and frost heaves. It was determined that attempting to reduce these causes would be extremely demanding due to budget restrictions, the weather in this region of the country and the short time period assigned for this project. As such, reducing the sources of noise was much more plausible.

Once it was decided that the reduction of sounds in and around an ambulance will be the primary focus of the project, the second step was to research the health related effects of noise in an ambulance and possible ways of reducing this noise. A study on hearing loss showed that the most significant adverse effects from noise on paramedic workers came from the siren. Hence, the IQP project was entitled 'SIRENO'. Research was then concentrated on how to eliminate the use of the siren. To replace the siren, technology would need to be used to alert nearby drivers and pedestrians of an EMS without using noise. There were many possible methods to use such as Bluetooth signals, FM transmitters, and GPS. These were all pretty viable but the one that seemed to be the best for this idea would be using FM transmitters and receivers. The reason that Bluetooth could not be implemented was because it would be extremely expensive. The use of Bluetooth with PIC Microcontroller being used in this project also requires more detailed programming knowledge that none of the group members of this project had. GPS presented the same problems as Bluetooth. Another problem when using GPS is that many people would feel uncomfortable with having a GPS locator installed into their car. To effectively replace the siren, the technology created would need to be installed into commercial vehicles as part of a mandatory car inspection and GPS would not be received favorably amongst the public.

The next step was to order and receive the parts required so that construction of the prototype could begin. After that the circuits were assembled and the code for the microcontrollers was written. After completing those two things the design was tested to see how it works. At the conclusion of this project, the product was still in testing but showed promising results.

3.8 Constraints

With a project like this there are a lot of factors that cause constraints on producing a system to work the way you want it to, such as accessibility to information or parts. The structure of this project also caused time and budget to become constraints.

One of the major constraints of this project was the lack of access to the actual Opticom GPS system. The information behind these systems such as the technology and equipment used is not open to the public. SIRENO consists of a transmitter and receiver as well as the Opticom GPS system. Since more detailed information was not available, only a basic integration of Opticom GPS into SIRENO was established. More technical information on how this would actually work is needed to completely integrate the two together.

The lack of programming knowledge was also a constraint in this project. Since the group consists of two mechanical engineers and two electrical and computer engineers, no one had a very detailed understanding of programming languages or the experience required to construct the transmitter and receiver prototype using more convenient forms of technology, such as Bluetooth.

Another constraint of this project was access to information. To improve the argument on eliminating the use of the siren, more articles on the adverse effects of the siren as well as news articles on siren related accidents would have been preferred. However, much of this information is sensitive and protected, with limited access to the public.

The final constraints of this project were time and budget restrictions. Due to the structure of this IQP taking place over the whole year rather than a single term, the time each member could dedicate each term to the project was limited. The continuation of the project from one term to another was also difficult since there was a definite loss in momentum. Ideally, more time for this project would have been preferred over a shorter period so that a more definite product could be established. One of the IQP requirements is to find an inexpensive solution to the given problem. Putting this requirement in consideration, the construction of SIRENO had to have a lower budget. A larger budget would mean better equipment, hence a more enhanced SIRENO system would be achieved.

3.9 Results

Once an idea is established and the corresponding product is constructed, it is important to analyze the results of the product at hand and its effectiveness in the real world. Essentially, the following questions should be addressed;

- How well does the product work?
- Does the product meet all its initial requirements?
- What are the faults of the product? Why?
- How could the product be improved?

Furthermore, a study into its effectiveness on the market and in practical use should be centered on;

- What are the advantages of your product?
- What are the disadvantages of your product?
- How would your product relatively compare on the market?
- How cost effective is your product?

These are some of the questions that are going to be addressed in this section of chapter.

In essence, our product can be broken down to a simple transmitter and receiver module. Once a signal is sent from the centralized station (e.g. Boston EMS), the transmitter on the ambulance van will be switched on. This will send out a signal to all nearby cars that are turned on and will be picked up by the individual receivers within the car that are part of our product. Since these receivers require a regulated voltage stemming from a car battery, only those cars that are turned on and pose an actual problem for an EMS van will receive this signal. Since the centralized station will be monitoring the motion of the EMS van, it will be in charge of controlling all nearby streetlights to provide quick and safe passage to the EMS. Through the use of Opticom GPS, it can turn the traffic lights of all rounds inbound on the EMS van's path red and ensure the van itself has consecutive green lights. This allows for the EMS to get through traffic with great efficiency and at a much quicker pace. It is also much safer than the current situation, where drivers are expected to give way to the EMS van and no preventative action is taken against incoming cars from nearby roads. If measured, the time difference between an EMS van travelling through a busy main street in its current predicament and the same van travelling with the help of Opticom GPS will be quite significant. The Opticom GPS system is already being used for EMS in major cities. Our product, Sireno, works in sync with Opticom. While monitoring the street traffic surrounding the EMS van, the centralized station can also trigger the transmitter in the EMS van. The transmitter only works within a certain radius and so will only alert cars within the vicinity of the EMS van. These cars will all have the receiver part of Sireno installed onto their dashboards. The signal sent from the transmitter in the EMS van will be picked up by the receiver and processed by the attached microcontroller. This microcontroller will in turn cause the 'H' sign on the display to flash red and trigger a voice command, alerting drivers to the presence of an incoming ambulance.

Our current version of Sireno is an initial prototype of what we expect the final product to be. It has been subject to various constraints, such as time and money and as a result, still needs various improvements before it can actually be put into use for the public. Firstly, the transmitter and receiver work together, however, the range of the transmitter is still not at the desired level. Whenever using a transmitter and receiver, it is important that they function at the same frequency and are meant to be paired together. This means the software code within the microcontroller allows for smooth communication between these parts and the overall effect of noise when sending and receiving the signal is reduced. Unfortunately due to budget constraints, the transmitter and receiver used for the prototype are not the best ones available. There are much more effective versions of these products available and will be the ones used when designing the final version of Sireno. The more effective versions have a much larger range of operation and further reduce the effect of noise when transmitting a signal. Both the transmitter and receiver, as part of their setup, require antennas. Some of the more advanced versions available have these antennas built in. However, for the purposes of the prototype, stripped wire was used. A stripped piece of wire can easily work as an antenna; however, a real antenna would be much more ideal. When using a stripped wire for an antenna, the transmission of the signal can be very sensitive and there can be a lot of interference, primarily a result of noise.

Other than the hardware of the prototype, such as the transmitter and receiver, there are certain software issues that could also be addressed when designing a more improved version of the product. The microcontroller being used is quite effective and has an ideal small size, so this is not a major issue in the product design. As for the software, the code being implemented is fine; however, a more succinct code would help run the loops in the microcontroller more efficiently which in turn would conserve the power of the product and extend its battery life. To improve on this, more time will need to be spent on writing the code and perhaps outside help can be sought from persons with more expertise in computer programming.

3.10 Analysis

Once the issues and possible improvements of a product are addressed, it is important to look at its functionality and usefulness in the market. In the case of Sireno, there is no actual market competition. Sireno is the first product of its kind and has the advantage of not having to compete with other products. Unfortunately this also has the disadvantage of customers being less inclined to purchase a product they've never purchased before or seen the need to. This is where Sireno, in its effectiveness and practicality, has to convince drivers into purchasing it. The advantages of Sireno are clearly evident. No longer will paramedics, drivers or nearby pedestrians and residents have to be subject to the loud shrill noise of ambulance sirens. With Sireno, as soon as an ambulance approaches, all nearby drivers are simply informed through a flashing red LED and voice command on their dashboard that an EMS van is passing through a certain street. This, in sync with Opticom, ensures safe and quick passage for EMS vans and that nearby cars and pedestrians are out of the way. There aren't any real disadvantages to Sireno. While some drivers may complain about having a device attached to their dashboard, in reality this should not be an issue. The receiver part of Sireno is very small and does not take up a significant amount of space on the dashboard, comparable to a small GPS device. Essentially the main disadvantage of Sireno would be its price. In its current stage, the production of the prototype would cost just under $100. This would not however be the price for customers. If Sireno became successful, mass production of the device itself would reduce the price considerably. For the most part, Sireno is a stable and functioning product that will not require much, if any, maintenance over time. This means customers can assured that even the final cost is a one-time fee only for a product that will not only help them not have to suffer the shrill noise of a siren but will also help EMS paramedics work more efficiently to provide medical attention to people. If Sireno is established as an effective product it can also become a mandatory requirement for all drivers within the country, thus ensuring everyone has it. Otherwise, the omission of the siren would be dangerous to drivers without Sireno.

3.10.1 Discussion

This chapter outlined our group's main ideas to implement SIRENO. The research from chapter two was used to finalize the type of transmitter and receiver to be used. Once this was decided, the rest of the electrical components to complete the system such as the microcontroller and its source code were chosen and the overall system was put together. As mentioned earlier, the transmitter and receiver electronic system will be part of a greater 911 emergency response grid. This will be implemented along with the Opticom System to track EMS vans working on the streets through GPS and ensure their paths are cleared of traffic and the street lights work in their favor, thus reducing response times and risk of accidents. The transmitter and receiver will be used to alert nearby drivers that an EMS van is approaching.

CHAPTER 4: CONCLUSION

The objective of our group's IQP began as a study on the effects of noise and vibrations within and around an ambulance van. Our vibration research resulted in concluding that the main sources of vibration in EMS van are roadwork, potholes, frost heaves, structure of the road material, and Engine. Vibrations cause a lot of discomfort to the patient, hinders the work of paramedics, and limit medical procedures that paramedics can perform during patient transports. Reducing vibration is important but after analyzing its main sources and effects, the issue of noise seemed to supersede that of vibrations and so noise and reducing its effects became the focus of our project.

For noise, the research was focused primarily on the definition of noise and how it can adversely affect a person's health. There were various issues and health problems found to be a direct result of overexposure to high levels of noise. This directly applied to paramedics working in ambulance vans, as well as other drivers and residents who are exposed to the siren of the EMS van. Research showed siren levels were recorded being as high as 102.5 decibels. The Occupational Safety and Hazard limit is 90 decibels. A noise level of 102.5 decibels is on par with the noise made by a passing truck or train. Some of the effects on one's health from high levels of noise include sleep disruption, high blood pressure, heart disease, and most commonly, noise induced hearing loss (NIHL).

One of the main articles found during research on noise was a study on the Annals of Emergency Medicine [22], taken over a fourteen year period on the hearing levels of paramedics compared to people of the same age of other professions. The study showed that the prolonged exposure to siren noise had serious effects on the paramedic workers.

Most of them presented with noise induced hearing loss and in almost every case the hearing thresholds of the paramedics was severely reduced compared to their ‘peers’. After finding this study, our group decided that as part of the objective of our IQP, our goal should be to work towards the elimination of the use of the siren in EMS vans and renamed our project SIRENO.

To eliminate the use of the siren, our group began by brainstorming various ideas and methods of alerting drivers of an incoming ambulance van without having to expose them to high levels of noise. Since two of the four members of our group are Electrical and Computer Engineering majors, the group used their background in signals and communication networks to implement a transmitter and receiver system to replace the use of sirens.

Before deciding on the exact type of transmitter and receiver to use, our group decided to conduct more research on the existing types of transmitter technology and its implementations. Research into flight communications showed how flight towers are able to communicate with incoming and outgoing flights using high frequency radio waves. These towers are able to ensure that flights can travel to and from the airports without collisions or excess traffic.

Our group decided to use the research into flight communications and apply it to an overall EMS and 911 response grid. These can be implemented into major cities across the US. The 911 response centers at these grids will handle all incoming emergency calls and once an EMS van is dispatched in response, its movements can be tracked using GPS. Using existing technology such as the Opticom System, these grids will be able to control all traffic lights the van comes across to ensure faster response times and reduce the chance of an accident. These grids will also be able to work in sync with transmitters placed in each EMS van. These transmitters will send radio frequency waves to receivers placed in drivers' cars to alert them through text and a voice activated message that an EMS van is approaching. These transmitters will have a certain radius so that only nearby drivers are alerted. The receivers can be installed into drivers' cars during a routine checkup, as part of a new regulation.

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Appendices

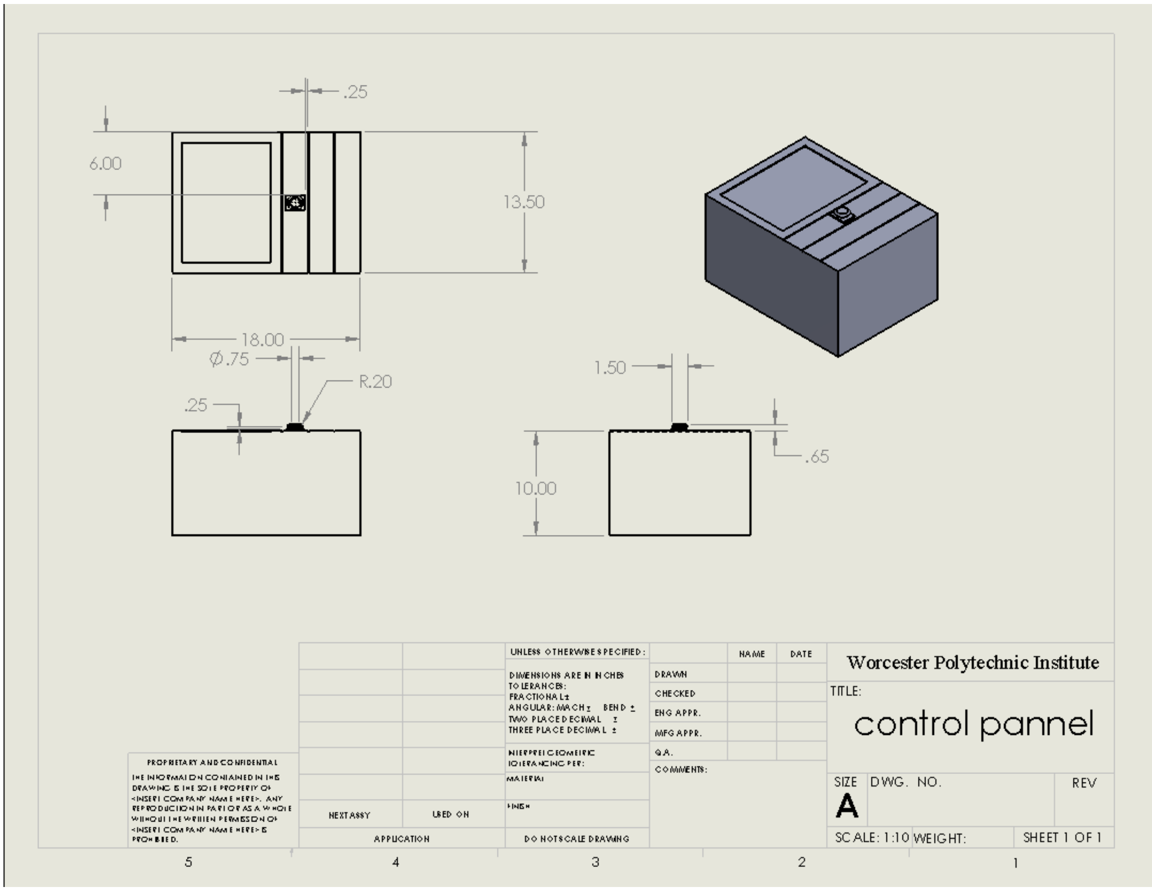

Figure 33: CAD drawing of the location of the transmitter button on the control panel

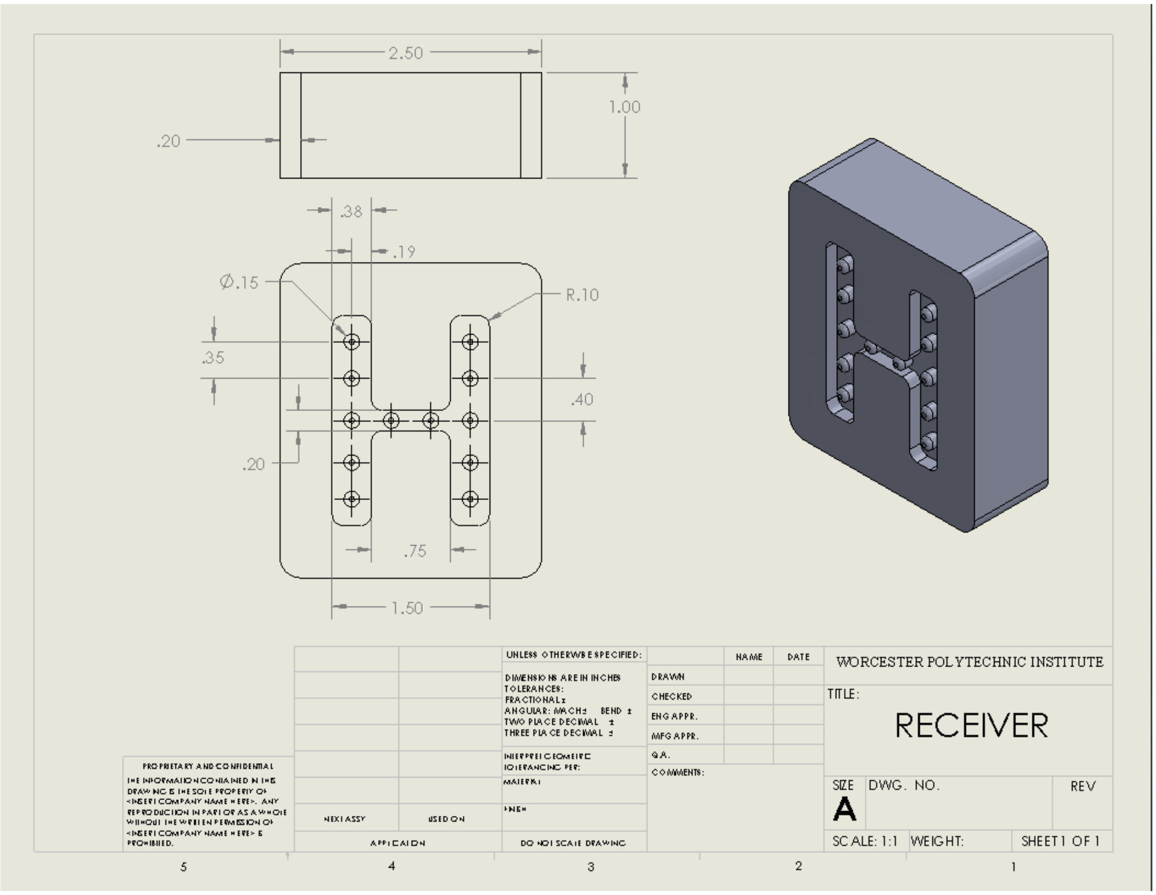

Figure 34: CAD drawing of the Sireno receiver

}

Transmitter Code

```
#include <htc.h>


///// Functions ///////

void transmit();

void interrupt ISR();

void init();

void stoptrans();


////// Global Variables /////

int myTimer=0;

int flag=0;


////// MAIN PROGRAM ///////

void main()

{

        init(); //Initialize the relevant registers


        while(RA1=0){

                if RA1= 0{

                fullTransmit();

}
```

```
}


}
void fullTransmit(){
void transmit(){
        RA0 = 1;
 }


void stoptrans(){
        RA0 = 0;
 }


///////////// Interrupt Service Routine ///////////
void interrupt ISR(){


        if(TMR0IE && TMR0IF){
                TMR0IF=0;
                myTimer++;
        }


        if (myTimer % 1 == 0)
                transmit();
```

```
        if (myTimer % 2 == 0)
                stoptrans();
}
}

/////////////// Initializing the System ////////////
void init(){
//Direction of ports
        TRISA = 0b00000000;
// Adjustment of ports
        RA0 = 0;
        RA1 = 0;
        RA2 = 0;
        RA3 = 0;
        RA4 = 0;
        RA5 = 0;
        RA6 = 0;
        RA7 = 0;

        ANSEL = 0;              //Set inputs to be digital I/O
        TMR0 = 0;//Clear the TMR0 register
/*Configure Timer0 as follows:
        - Use the internal instruction clock
```

```
        as the source to the module

        - Assign the Prescaler to the Watchdog

        Timer so that TMR0 increments at a 1:1

        ratio with the internal instruction clock*/

        OPTION_REG = 0B00000000;

        TMR0IE = 1;

        GIE = 1;

}
```

Receiver Code

```
#include <htc.h>


///// Functions ///////

void interrupt ISR();

void init();

void timedelay();

void checkinfo();

void timedelay();


////// Global Variables /////

unsigned int myTimer=0;

int flag1=0;

int flag2=0;

int flag3=0;
```

```
unsigned int curr_time = 0, prev_time = 0;


////// MAIN PROGRAM ///////

void main()

{

	init(); //Initialize the relevant registers

	while(1){

		checkinfo();

	}

}


/////// Check to see if signal is received //////

void checkinfo(){

	prev_time = myTimer;


	if(RA1 == 1){

		flag1 = 0;

		flag2 = 0;

		flag3 = 0;

	}


	while(1){

		curr_time = myTimer;
```

```
		if ((curr_time - prev_time) == 100){
			if (RA1 == 0){
				flag1 = 1;
				if ((flag1 == 1) && (RA1 == 0)){
					flag2 = 1;
				if ((flag1 == 1) && (flag2 == 1) && (RA1 == 0)){
					flag3 = 1;
				break;
				}
				}
			}
			else{
				timedelay();
				break;
			}
		}
	}
}
void timedelay(){
	prev_time = myTimer;
	while(1){
		curr_time = myTimer;
```

```
            if((curr_time - prev_time) == 100){
                break;
            }
        }
}
///////////// Interrupt Service Routine ////////////
void interrupt ISR(){

        if(TMR0IE && TMR0IF){
            TMR0IF=0;
            myTimer++;
        }
        if (RA1 == 1){
            flag1 = 0;
            flag2 = 0;
            flag3 = 0;
        }
        if (flag1==1 && flag2==1 && flag3==1){
            RA0 = 1;
            while(1){}
        }
}
/////////////// Initializing the System ////////////
```

```
void init(){
//Direction of ports
	TRISA = 0b00000010;
// Adjustment of ports
	RA0 = 0;
	RA2 = 0;
	RA3 = 0;
	RA4 = 0;
	RA5 = 0;
	RA6 = 0;
	RA7 = 0;
	ANSEL = 0;		//Set inputs to be digital I/O
	TMR0 = 0;//Clear the TMR0 register
/*Configure Timer0 as follows:
	- Use the internal instruction clock
	as the source to the module
	- Assign the Prescaler to the Watchdog
	Timer so that TMR0 increments at a 1:1
	ratio with the internal instruction clock*/
	OPTION_REG = 0B00000000;
	TMR0IE = 1;
	GIE = 1;
}
```

Receiver

Electrical Characteristic

Characteristic	Sym	Min	Type	Max	Unit
Operating Radio Frequency	FC	433.420	433.920	434.420	MHz
Sensitivity	Pref.	-106	-108	-110	dBm
Channel Width		-500		+ 500	KHz
Noise Equivalent BW	NEB		5	4	
Baseboard Data Rate				3	KB/S
Receiver Turn On Time				3	ms

DC Characteristic

Symbol	Parameter	Condition	Min	Type	Max	Unit
Vcc	Operating Supply Voltage		4.9	5	5.1	
I Tot	Operating Supply Voltage			4.5		
V Data	Data Out	1 Data = +200uA (High)	Vcc -0.5	Vcc		V
		1 Data = -10uA (Low)			0.3	V

Figure 35: Sireno Receiver Specifications

Pin Assignment

Pin	Function
1	GND
2	Digital Output
3	Linear Out
4	VCC
5	VCC
6	GND
7	GND
8	ANT(About 13cm)

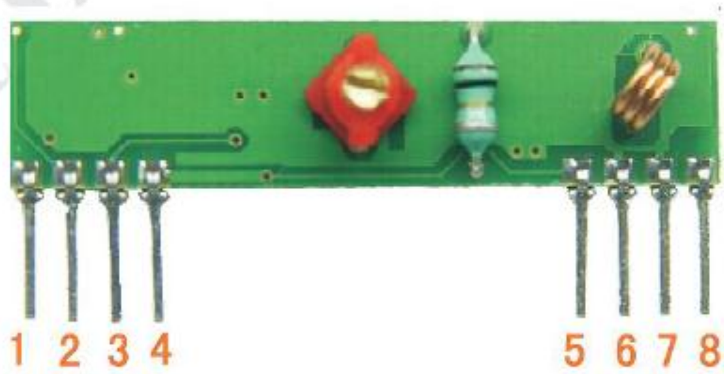

Figure 36: Pin Assignment 1

Transmitter

Absolute Maximum Rating

Rating	Value	Unit
Power Supply and All Input/ Output Pins	-0.3~+12.0	V
Non-Operating Case Temperature	-20~+85	℃
Soldering Temperature(10 seconds)	230	℃

Electrical Characteristic

Characteristic	Min	Type	Max	Unit
Operating Frequency (±250KHz)	433.67	433.92	434.17	MHz
Data Rate			8	Kbps
Current Consumption			8	mA
Output Power			32	mW
Operating Voltage	3		12	Vdc
Operating Ambient Temperature	-20		+85	℃

Pin Assignment

Pin	Function
1	GND
2	Data in
3	Vcc
4	ANT

Figure 37: Pin Assignment 2

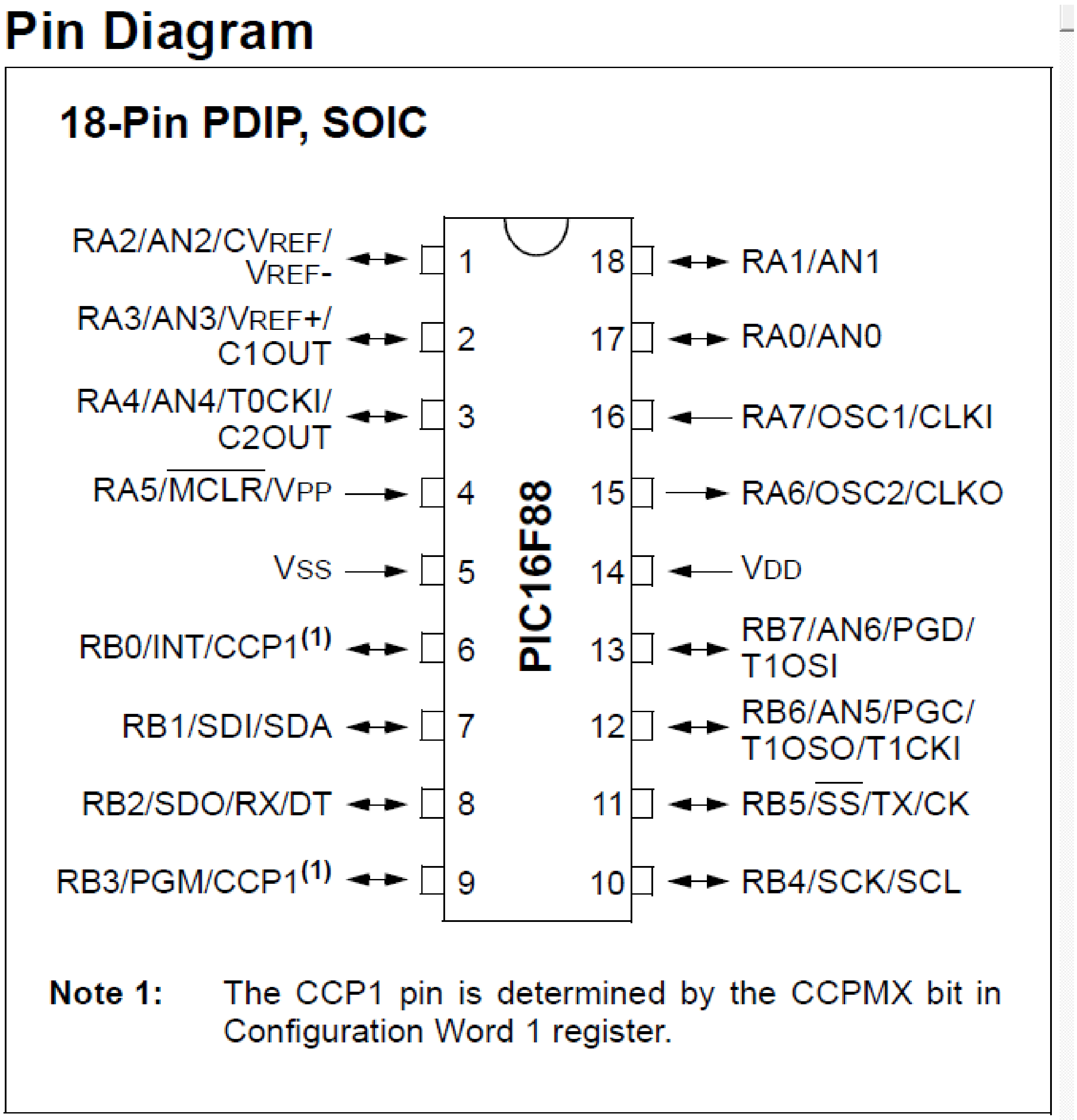

Figure 38: Microcontroller

18.2 DC Characteristics: Power-Down and Supply Current PIC16F87/88 (Industrial, Extended) PIC16LF87/88 (Industrial) (Continued)

PIC16LF87/88 (Industrial)		Standard Operating Conditions (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for industrial					
PIC16F87/88 (Industrial, Extended)		**Standard Operating Conditions (unless otherwise stated)** Operating temperature -40°C ≤ TA ≤ +85°C for industrial -40°C ≤ TA ≤ +125°C for extended					
Param No.	**Device**	**Typ**	**Max**	**Units**	**Conditions**		
	Supply Current (IDD)[2,3]						
	PIC16LF87/88	9	20	μA	-40°C	VDD = 2.0V	FOSC = 32 kHz (LP Oscillator)
		7	15	μA	+25°C		
		7	15	μA	+85°C		
	PIC16LF87/88	16	30	μA	-40°C	VDD = 3.0V	
		14	25	μA	+25°C		
		14	25	μA	+85°C		
	All devices	32	40	μA	-40°C	VDD = 5.0V	
		26	35	μA	+25°C		
		26	35	μA	+85°C		
	Extended Devices	35	53	μA	+125°C		

TABLE 5-1: PORTA FUNCTIONS

Name	Bit#	Buffer	Function
RA0/AN0	bit 0	TTL	Input/output or analog input.
RA1/AN1	bit 1	TTL	Input/output or analog input.
RA2/AN2/CVREF/VREF-[2]	bit 2	TTL	Input/output, analog input, VREF- or comparator VREF output.
RA3/AN3/VREF+[2]/C1OUT	bit 3	TTL	Input/output, analog input, VREF+ or comparator output.
RA4/AN4[2]/T0CKI/C2OUT	bit 4	ST	Input/output, analog input, TMR0 external input or comparator output.
RA5/MCLR/VPP	bit 5	ST	Input, Master Clear (Reset) or programming voltage input.
RA6/OSC2/CLKO	bit 6	ST	Input/output, connects to crystal or resonator, oscillator output or 1/4 the frequency of OSC1 and denotes the instruction cycle in RC mode.
RA7/OSC1/CLKI	bit 7	ST/CMOS[1]	Input/output, connects to crystal or resonator or oscillator input.

Legend: TTL = TTL input, ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

2: PIC16F88 only.

Figure 39: DC Characteristics

REGISTER 6-1: OPTION_REG: OPTION CONTROL REGISTER (ADDRESS 81h, 181h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0

bit 7   bit 0

bit 7 **$\overline{RBPU}$:** PORTB Pull-up Enable bit

bit 6 **INTEDG:** Interrupt Edge Select bit

bit 5 **T0CS**: TMR0 Clock Source Select bit
- 1 = Transition on T0CKI pin
- 0 = Internal instruction cycle clock (CLKO)

bit 4 **T0SE**: TMR0 Source Edge Select bit
- 1 = Increment on high-to-low transition on T0CKI pin
- 0 = Increment on low-to-high transition on T0CKI pin

bit 3 **PSA**: Prescaler Assignment bit
- 1 = Prescaler is assigned to the WDT
- 0 = Prescaler is assigned to the Timer0 module

bit 2-0 **PS<2:0>:** Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

Legend:

R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

> **Note:** To avoid an unintended device Reset, the instruction sequence shown in the *"PICmicro® Mid-Range MCU Family Reference Manual"* (DS33023) must be executed when changing the prescaler assignment from Timer0 to the WDT. This sequence must be followed even if the WDT is disabled.

TABLE 6-1: REGISTERS ASSOCIATED WITH TIMER0

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on POR, BOR	Value on all other Resets
01h,101h	TMR0	Timer0 Module Register								xxxx xxxx	uuuu uuuu
0Bh,8Bh, 10Bh,18Bh	INTCON	GIE	PEIE	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF	0000 000x	0000 000u
81h,181h	OPTION_REG	$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111

Legend: x = unknown, u = unchanged. Shaded cells are not used by Timer0.