Tribhuvan University

Institute of Engineering

Central Campus

Pulchowk Lalitpur,Nepal.

A

Report on

Major Project

(Real Time Location System(RTLS) based

License Trial Automation System)

Submitted To:

Department of Electronics and Computer Engineering

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PREFACE

Nepal Government has introduced a new trial system for providing license to drivers. Traffic authorities present at the trial venue decide on the basis of inspection whether the driver is qualified to acquire a driving license or not.

Use of technology in the field of road traffic management has long prevalence in Nepal, specially though the use of automatic traffic lights placed at almost every chowks of the cities with busy traffic. Use of breathalyzers to control the drink-drive cases in Nepal has had a great positive impact reducing significantly the road accidents. This has eased the task of policeman as well as increased human safety.

Also the use of radar gun to measure the vehicle speed on road has assisted the police greatly instantly capturing a overspeed vehicle thereby preventing a potential accident.

Use of technology has clearly have a positive impact in the traffic management area. One area that still lacks proper use of technology is traffic license acquiring process by riders and drivers. So far in Nepal the rider is let drive on the specially designed track to decide whether he is capable enough to drive safely in the busy road. Human invigilator inspects the whole process.But human eye inspection is not reliable enough to decide, with great accuracy the prevalent license trial system.

Articles in newspapers suggest that the increased road accidents are directly related to the drivers driving their vehicle without acquiring license or those acquiring fraud license without passing the trial examination.

Though the new trial system improves the standard of examination and tests the drivers properly, rumors of people acquiring fraud driving license do not cease to exist. Thus the idea is to build a system where a computer rather than human eye decides the validity of a trial, thus eliminating the chances of fraud license.

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Abstract

For the fulfillment of course requirement for Electronics Engineering student are required to do a project with considerable level of difficulty applying the theoretical knowledge acquired during the whole tenure of undergraduate studies. This is final report of the project. We have chosen to do a project in Real Time Location System (RTLS), based license trial automation system to improve the existing trial system in Nepal. We have first proposed this system to be applied for the trial automation for two-Wheeler motorbikes. In first phase, ultrasonic sensors are used to find the distance of the vehicle form at least three predefined locations, then use trilateration to find the exact space co-ordinate referring to our local coordinate system. We have used ultrasonic sensors to find the distance of the object from three predefined locations. The next phase is to apply the positioning system to automate the trial system. There is a provision of graphical visualization of the process in an Graphical User Interface (GUI) application.

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1. INTRODUCTION

The need to locate people and objects as soon as possible has always been an important part of any organization or industry. With use of wireless technology, we are trying to remotely locate objects within a predefined time frame. Global Positioning System (GPS) is obviously the most widely used outdoor location sensing technology, but there are several drawbacks which make GPS impossible to be used as an indoor positioning system with high precision. Due to line-of-sight demand between the satellites and the receiver, and specialized hardware requirement, it has poor indoor coverage and insufficient accuracy[**?**].

We typically use small low-power transceiver attached to assets as well as sets of readers that map the location of these assets. Systems that map a location relative to a fixed set of coordinates are more accurately called RTLS. Wireless RTLS tags are attached to objects or worn by people, and in most RTLS, fixed reference points receive wireless signals from tags to determine their location. RTLS is one of the latest solutions for tracking objects in real time with high precision. RTLS has many advantages and can be combined with different technologies depending in which it is being applied. This is the type of system that we are looking to build first and implement it to automate the driving license trial system.

1.1   Objectives

The major objectives behind trying to build this system is to replace traditional human inspection based method of giving license to the drivers in the license trial.

1. To apply the knowledge gained in engineering tenure in an useful project.

2. To learn the implementation of Real Time Location System.

3. To automate the license trial system.

4. To eliminate the errors in current trial system.

1.2 Statement of Problem

Using real time location system, we aim to automate the license trial system. The real time path followed by the vehicle is tracked using the RTLS. The track followed by the vehicle should be within some limit in the real trial system. In this project, we put ultrasonic transmitters on the vehicle subjected to trial and we also place three ultrasonic receivers in three predefined location, which receive the ultrasonic signal transmitted by the transmitter in the vehicle. The time taken by the signal to travel from transmitter to receiver along the air can be used to find the distance between the transmitter and receiver. From this distance, the position of the vehicle can be identified. And by using the information of the path followed by the vehicle using RTLS, it can be judged whether the path followed by the vehicle was within the trial track. The major goal of this project is to actually judge whether the vehicle followed the correct path.

1.3 Motivation

Statistics reveal the death of great number of people and loss of huge property due to the increasing road accidents. Studies have attributed the major cause of road accidents to drivers in charge of safety of passengers. Even the licensed drivers have been found guilty of major road accidents if not people who are not authorized to drive.

In a regular basis lots of people are dead without having to do any error of their own but just because the unlucky vehicle they happened to be was driven by unskilled drivers.

It has already been shown that the driving license trial system has a flaw, human error of inspection may lead to granting of driving license to non-skilled drivers. Something has to be instantly done to address such severe condition.

We, the engineering students, have come up with certain ideas to eliminate the situation. What we could do from our perspective is to contribute with a automatic system to replace the license trial system.

2.   PROPOSED SYSTEM BLOCK DIAGRAM

As explained in the preceding section, the two parts of the system, RTLS ans its implementation can be explained through the Figure **??**.
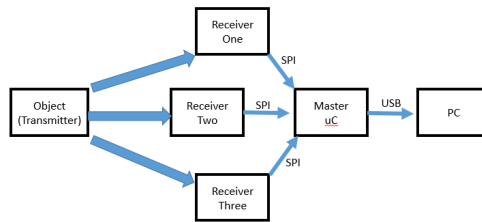

Figure 1: System Block Diagram

The object to be tracked is equipped with a transceiver that can independently communicate with the three stations around it in the field of it. The distance can be measured with procedure possibly time of flight. The distance obtained is then fed to the control unit from each of the three stations. Then the data is sent to the computer for analysis using a microcontroller. The computer analyses the data, stores them and then gives out the necessary signal to the user through the use of any of the signaling method - light or sound or any convenient method.

3. LITERATURE REVIEW

GPS has been successful in outdoor-locating solutions, however, it cannot quite repeat this success indoors. Since GPS signal is unable to pass through solid structures, it is impossible to be used indoors, underground and under the water. Enter the Local Positioning System (LPS), a technology that provides location information within a small coverage region. RTLS is a special type of LPS which is used to track and identify the location of an object in real time, usually within a building or other contained area.

RTLS consists of specialized receivers or readers kept at a known position which receive wireless signals from small Identity (ID) batch or tag or node, attached to, or embedded in the object to be tracked. Wireless technologies include Wifi, Radio Frequency Identitification (RFID), Infrared, Bluetooth, ultrasonic systems. These different technologies possess their own feature and are suitable for different applications. There is no all-purpose solution when it comes out to the selection of wireless technology. Tags and the fixed reference points can be transmitters, receivers or both.

By positioning the readers or receivers at fixed know location in a given environment, the real-time location of the tags or object-to-be-tracked is determined by analyzing the different aspects of the communication between tags and readers. Most widely used techniques for these calculations are, Distance/Angle calculation, Position computation and localization. Again, the choice of method depends on the need of application. Wireless signals from a tag is received by multiple readers. Different aspect of this communication can be used to calculate the distance of the tag from different readers. Now the position of the tag is estimated using one or more locating algorithms like trilateration, multilateration, or triangulation. Finally the calculated position of the tag is displayed on a map (2D or 3D).

RTLS has been used to effectively track assets, equipment, people and animal within a predefined area. Wireless tags can be attached to the object and their location can be viewed in a map. This information is used in many applications in different fields like in inventory and asset tracking,health care, security, animal tracking, vehicle tracking.

3.1 Wireless Technologies

3.1.1 Infrared (IR) Based Systems

The most prominent advantage of IR is its wide availability since many devices are equipped with IR sources, such as mobile phones, Television (TV), printer, and so forth. In addition, since the whole infrastructure is very simple, it does not need costly installation and maintenance. However, due to its requirement of line-of-sight and its inability to penetrate opaque obstacles, it can not be applied to some kinds of indoor scenarios in which the environment is pretty complex. Besides, it is also subject to interference of other sources of IR devices.

3.1.2 Radio Frequency (RF) Based Systems

RF Based Systems Systems designed based on RF can cover larger distance since it uses electromagnetic transmission, which is able to penetrate opaque objects such as people and walls. Besides, a RF system can uniquely identify people or objects tracked in the system. Based on this technology, RTLS, Wireless Local Area Network (WLAN), Bluetooth, wireless sensor networks, Ultra Wide Band (UWB) are created. In addition, RF based technologies are further divided into narrow band based technologies (RFID, Bluetooth and WLAN) and wide band based technologies UWB.

RFID is technology used for identifying an object using radio waves and tags. RFID is normally used indoors. RFID usually uses Low Frequency, High Frequency and Ultra High Frequency. RFID tags can be placed at the object whose position is to be located and then by using low, high or ultra high frequency signals, a communication between the receivers and the tag is established.

3.1.3 Ultrasound Based Systems

Ultrasonic systems can also be used in RTLS with a small coverage region. The systems based on ultrasound technology is relatively cheap and the precision is lower in comparison with IR based systems due to the reflect influence. Additionally, this kind of systems is always associated with RF or IR technology to fulfill the synchronization requirement. Ultrasonic systems use ultrasonic transmitter and receivers to triangulate the position of objects. This project also uses ultrasonic system. We have made use of ultrasonic transmitters and receivers which operate at 40kHz frequency to locate the path followed by the vehicle during the trial.

3.2 Existing Trial system

RTLS has been a growing field in the past few years. Extensive use of RTLS based system have shown improvement in respective area of use. As described earlier, RTLS has been in use from animal tracking to health care services. However, the complexity and cost of this system has to be taken into account before implementing this system.

RTLS systems have been build through different techniques. But, no such system is prevalent in Nepal regarding the license trial automation system. We expect this kind of license trial system to be the first of its kind in the country.

3.2.1 License Trial Track

Recently the government of Nepal has changed the license trial system changing the track of the trial. The new trial track looks the following. The drivers have to drive their vehicle within the permitted track following all the traffic rules and do as specified. For example they have to stop in the places written 'STOP' and do as instructed.
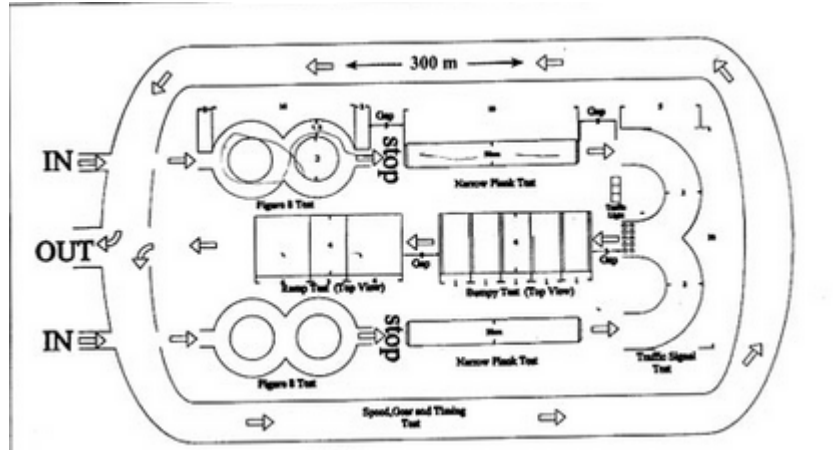
Figure 2: License Trial Track

4. METHODOLOGY

The first phase involved the task of locating any object with a transceiver attached to it. Ultrasonic transceivers have been used to first measure the distance of the asset to be located from three predefined coordinates we like. With the three distances in hand trilateration can be to find the coordinate of the asset.

The second phase is to apply this system to automate the license trial system prevalent in Nepal. We would attach a ultrasonic transceiver with the vehicle and let it go in the track. With the coordinate of the vehicle during the course of its trial, the vehicle velocity[1] and acceleration in real time can be calculated.

We would build a GUI to display the graphical model of the real time situation. We can further save the data acquired in the server and keep for future investigation. Each of these is explained below.

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[1]Calculating the derivative of the position coordinates with interpolation would give us the velocity

4.1 Measurement of Distance

There are various methods implemented for distance measurement electrically. Each of the methods can be implemented electrically using various component but regardless the components used, the technique remains the same. Some of the techniques are:

4.1.1 Time of Arrival (TOA)

With TOA, the distance between the transmitting node and the receiving node is deduced from the transmission time delay and the corresponding speed of signal as follows:

$$R = speed \times Time \tag{1}$$

where speed denotes the traveling speed of the signal, time the amount of time spent by the signal traveling from the transmitting to the receiving node, and R the distance between the transmitting node and the receiving node. Since speed can be regarded as a known constant, R can be computed by observing time.[?]

4.1.2 Time of Flight (TOF)

In time of flight method the time taken by signal to go from one node to the other is calculated and is used to calculate the distance. The distance can be known form the following relation.

$$R = \frac{t_{rt} \times speed}{2} \tag{2}$$

where t_{rt} is the round trip time of the signal travel.

4.2 Trilateration

Trilateration is the technique utilized to find the co-ordinate of any point with the distance of the point given from fixed known points.
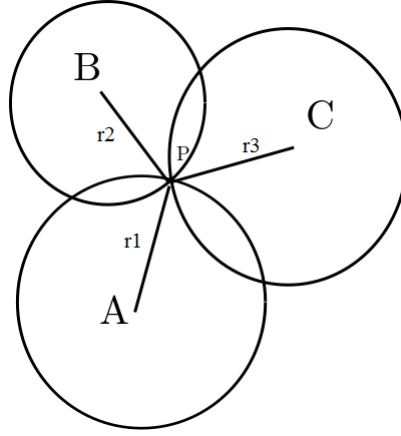
Figure 3: Trilateration

If in figure **??** the Point to be located is P and the distance of P from A, B and C is known respectively to be r_1, r_2, and r_3 to us.If we know the coordinate of the points $A(x_1, y_1, z_1)$, $B(x_2, y_2, z_2)$ and $C(x_3, y_3, z_3)$ then the coordinate (x, y, z) of the point P can be calculated from the set of equations:

In three dimensional geometry, when it is known that a point lies on the surfaces of three spheres, then the centers of the three spheres along with their radii provide sufficient information to narrow the possible locations down to no more than two(unless the centers lie on a straight line).

4.2.1   Derivation

The intersections of the surfaces of three spheres is found by formulating the equations for three sphere surfaces and then solving the three equations for three unknown x,y and z.

$$(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 = r_1{}^2 \tag{3}$$

$$(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 = r_2{}^2 \tag{4}$$

$$(x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 = r_3{}^2 \tag{5}$$

To simplify the calculations, the equations are formulated so that the centers of the spheres lie on $z = 0$ plane. Also the formulation is such that location of one of the

known points is origin and that of another known point is on the x-axis. Assuming this thing, we first calculate the location of the required unknown point and then the solution is transformed back to the original three dimensional Cartesian coordinate system.

Therefore, the coordinates of three known points are : $P_1(0, 0, 0)$, $P_2(d, 0, 0)$ and $P_3(i, j, 0)$. Now, equation **??**, equation **??** and equation **??** become :

$$x^2 + y^2 + z^2 = r_1{}^2 \tag{6}$$

$$(x - d)^2 + y^2 + z^2 = r_2{}^2 \tag{7}$$

$$(x - i)^2 + (y - j)^2 + z^2 = r_3{}^2 \tag{8}$$

Now, using r_1 and r_2 to eliminate y and z from equation and solving for x, we get

$$r_1{}^2 - r_2{}^2 = x^2 - (x - d)^2$$
$$x = \frac{r_1{}^2 - r_2{}^2 + d^2}{2d} \tag{9}$$

Assuming that the first two spheres intersect in more than one point, that is,

$$d - r_1 < r_2 < d + r1$$

Now, substituting the equation for x back into the equation for the first sphere produces the equation for a circle. The solution to the intersection of the first two spheres is:

$$y^2 + z^2 = r_1{}^2 - \frac{(r_1{}^2 - r_2{}^2 + d^2)^2}{4d^2}$$

Substituting the value of z^2 from equation **??**, we get,

$$y = \frac{r_1{}^2 - r_3{}^2 + i^2 + j^2}{2j} - \frac{i}{j}x \tag{10}$$

Now that the x and y coordinates of the solution points are determined, the formula can be rearranged for the first sphere to find the z-coordinate of the solution point. Therefore,

$$z = \pm\sqrt{r_1{}^2 - x^2 - y^2} \tag{11}$$

Now the solution to all three points x, y and z is found. Because z is expressed as the positive or negative square root, it is possible for there to be zero, one or two solutions to the problem.

This last part can be visualized as taking the circle found from intersecting the first and second sphere and intersecting that with the third sphere. If that circle falls entirely outside of the sphere, z is equal to the square root of a negative number, which implies no real solution exists. If that circle touches the sphere on exactly one point, z is equal to zero. If that circle touches the surface of the sphere at two points, then z is equal to plus or minus the square root of a positive number.

4.3 Final Computation

The Derivation section pointed out that the coordinate system in which the sphere centers are designated must be such that

1. All three centers are in the plane $z = 0$

2. The sphere center, P_1, is at the origin

3. The sphere center, P_2, is on the x-axis.

In general the problem will not be given in a form such that these requirements are met.

This problem can be overcome as described below where the points, P_1, P_2, and P_3 are treated as vectors from the origin where indicated. P_1, P_2, and P_3 are expressed in the original coordinate system.

The unit vector in the direction from P_1 to P_2 is:

$$\hat{e}_x = \frac{P_2 - P_1}{\|P_2 - P_1\|}$$

The signed magnitude of the x component, of the vector from P_1 to P_3 is:

$$i = \hat{e}_x \cdot (P_3 - P_1)$$

The unit vector in the y direction can be found as:

$$\hat{e}_y = \frac{P_3 - P_1 - i\,\hat{e}_x}{\|P_3 - P_1 - i\,\hat{e}_x\|}$$

The third basis unit vector is

$$\hat{e}_z = \hat{e}_x \times \hat{e}_y$$

Therefore,

The distance between the centers P_1 and P_2 is $d = \|P_2 - P_1\|$ and the signed magnitude of the y component, of the vector from P_1 to P_3 is:

$$j = \hat{e}_y \cdot (P_3 - P_1)$$

Using $i,\ d$ and j as computed above, the values for x, y and z can be solved as described in the Derivation section.Then,

$$\vec{p}_{1,2} = P_1 + x\,\hat{e}_x + y\,\hat{e}_y \pm z\,\hat{e}_z \tag{12}$$

Equation **??** gives the points in the original coordinate system, since, $\hat{e}_x,\ \hat{e}_y$ and $\hat{e}_z$, the basis unit vectors, are expressed in the original coordinate system.

4.4 Control/Notification

As soon as the vehicle stops at restricted locations in the track, or if it moves in the position to be stopped, an immediate notification will be given to the driver and s/he will be disqualified from further license processing as per the rules of Vehicle Management Department, Government of Nepal.

4.5   Graphical User Interface

With the real time data of location of the vehicle fed to the computer, we have made a visualization showing the location of vehicle in the track and the information of the situation(speed, etc). A computer program has been made for the visualization.

5. IMPLEMENTATION

The implementation of distance measurement has been done by using the method of time of flight. There are two stations each mounted with transmitter and receiver module respectively. The transmitter module contains a ultrasonic transmitter and receiver section contains a ultrasonic receiver and we measure the time of flight of the sound signal that originates from the transmitter station ending up at the receiver station.

5.1 Transmitter Section

The transmitter module is run with a PWM generated form a microcontroller. The overall block diagram of transmitter section is given in Figure. **??**
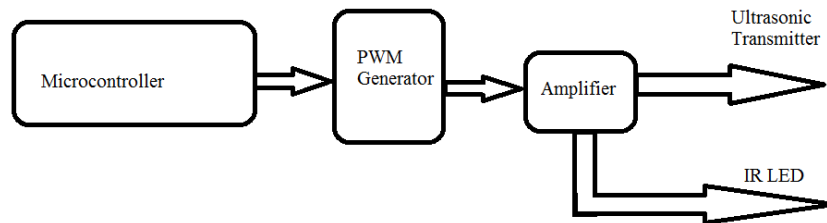
Figure 4: Transmitter Module Block Diagram

5.1.1 Synchronization

Synchronization is the most crucial part of the whole process of distance measurement. The receiver must exactly know when the transmitter is going to send the incoming signal in order to have the prior knowledge to start the time within it. It is not possible to know when exactly the transmitter will send the incoming signal but we can achieve somewhat close approximation by the use of light transmitter and receiver.

The speed of light is approximately $3 \times 10^8 m/s$. If we set up transmitter such that the transmitter station sends a pulse of light and sound at the same time, the light pulse reaches the receiver at no time compared to the sound pulse due to the massive difference of speed of each of these.

5.1.2 Calculation

If the distance between light transmitter and receiver is x, then the time taken by light to reach the receiver station is

$$t_l = \frac{x}{c} \tag{13}$$

Where t_l is the time taken by light to reach the receiver station. Similarly time taken by sound to reach the receiver station is given by the relation.

$$t_s = \frac{x}{v_s} \tag{14}$$

where v_s is the speed of sound.

Now as soon as the receiver station detects the light signal, we start the timer and stop the timer as soon as it detects the sound signal. The time recorded by the receiver station will thus be

$$\Delta t = x \left(\frac{1}{v_s} - \frac{1}{c} \right) \tag{15}$$

Since $c >> v_s$ $\Delta t \approx \frac{x}{v_s}$. The error committed in the process is

$$\epsilon = x \left(\frac{1}{v_s} - \frac{1}{c} \right) - \frac{x}{v_s} \tag{16}$$

Which gives us the error percentage of

$$
\begin{aligned}
Error\% &= \frac{\epsilon}{t_s} \times 100\% \\
&= \frac{v_s}{c} \times 100\% \\
&\approx 0.0001\%
\end{aligned}
$$
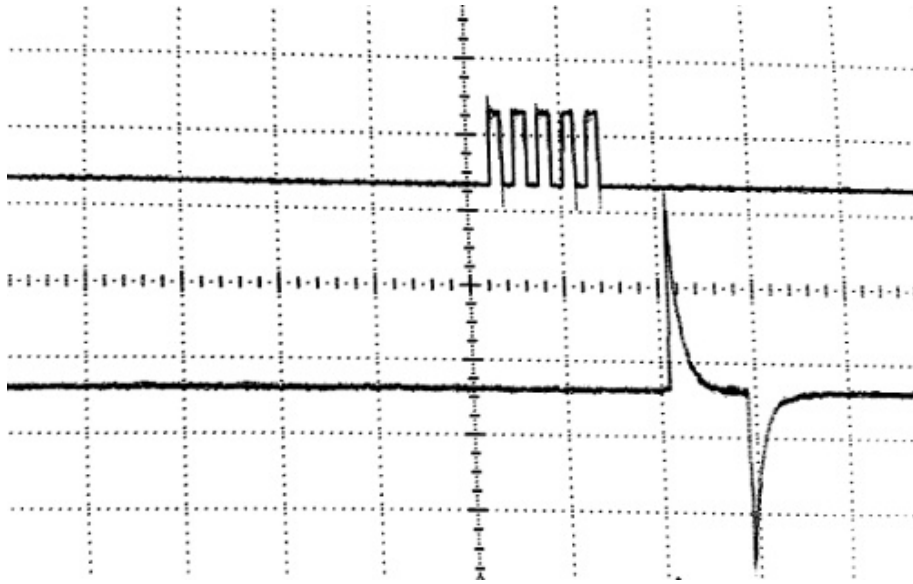
Figure 5: TSOP response to detected IR signal by IRLED

We thus place at the transmitter side a Infra-Red Light Emitting Diode (IRLED) and a ultrasonic signal transmitter. At the receiver we place ultrasonic receiver and a TSOP. The TSOP detects the light signal.

In Figure.?? the upper waveform is the signal fed to the IRLED transmitter and the lower waveform is the response of TSOP circuitry to the detected signal.

5.1.3 Ultrasound Transmission

The ultrasonic transmitter typically works at a frequency of $40kHz$. So we generate the required signal using a microcontroller. The microcontroller generates the required signal by pulling a particular pin at high and low at calculated intervals. Following piece of code is written in C for ATmega8 to generate 40kHz signal at a particular pin.

```
void DriveIRLED()
{
  int Peaks = 5;
  int i = 0;
  for(;i< Peaks*2; i++) {
    TOGGLE(PORTC,PC5);
    _delay_us(12);
  }
}
```

In Figure.?? the lower signal with regular spikes is the signal applied to Ultrasonic trans-
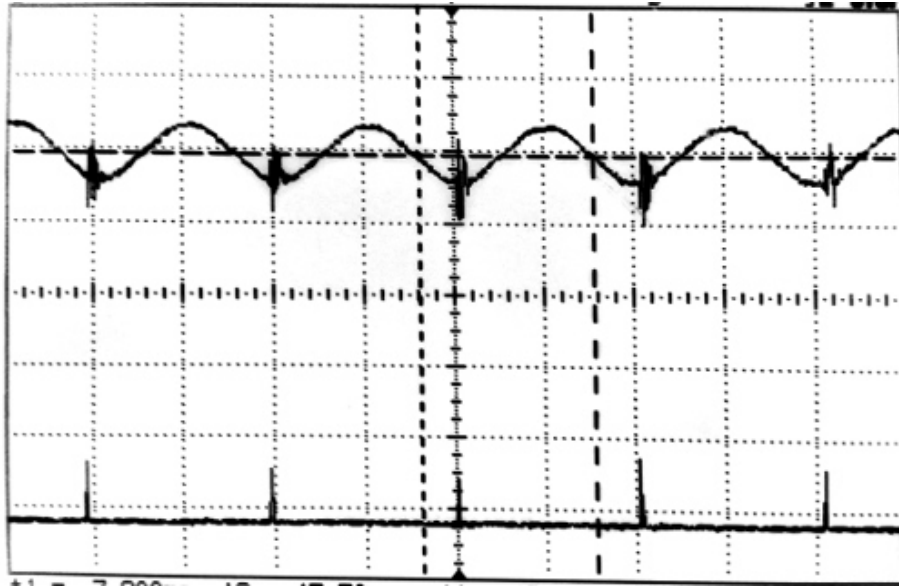
Figure 6: Signal Transmission and Reception by Ultrasonic pair
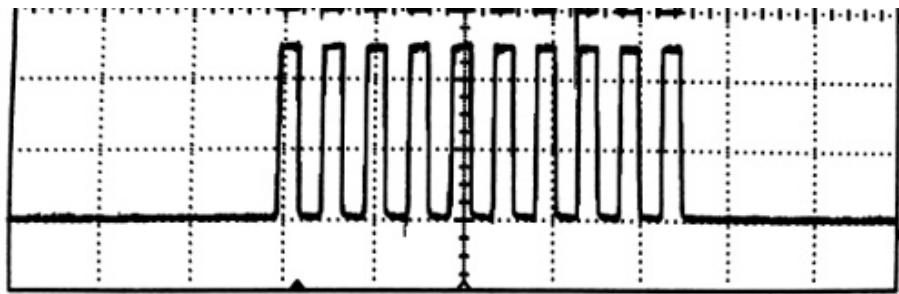
Figure 7: 40kHz Signal Burst applied at ultrasonic transmitter

mitter. Each spike (contracted in time) is a burst of square wave pulses shown in Figure.**??**. The interval of each burst is $2ms$. The upper signal in Figure.**??** is the response of Ultrasonic receiver to the obtained signal. There are clear spikes detected at exactly the interval sent by the transmitter.

Since the received signal is noisy and very low power, it requires to be amplified and filtered for the required frequency.

5.2 Receiver Section

The receiver section collects the signal transmitted by the transmitter module. The overall block diagram of the receiver module is given in Figure. **??**
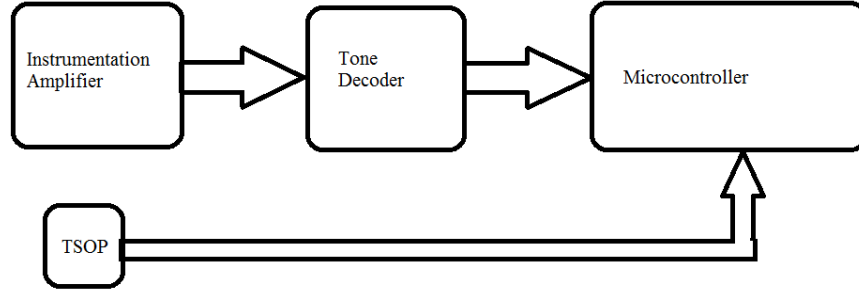
Figure 8: Receiver Module Block Diagram

5.2.1 Signal Amplification

The received sound signal is converted into electrical signal by ultrasonic receiver. Since the sound undergoes massive attenuation in air, the received signal is pretty low in voltage and needs to be amplified in order to use it for distance measurement.

An amplifier is an electronic device that increases the power of a signal. An operational amplifier ("op-amp") is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In the configuration as shown in **??**, an op-amp produces a output potential that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

The output voltage of this operational amplifier closed loop negative feedback is given by :-

$$V_{out} = -\frac{R_f}{Rg}V_{in} \tag{17}$$

Where,

R_f is feedback resistor
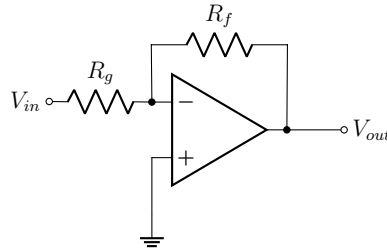
Figure 9: A negative feedback inverting Amplifier

R_g is input resistance.

V_{in} is input voltage,

V_{out} is output voltage.

The gain of the amplifier is controlled by two resistors, R_f and R_g. The gain is the ratio of the feedback resistor to the input resistor. However, the opamp we used,i.e. IL741 has a maximum practical gain of 2.5 dB only. Since the electrical signal produced by the ultrasonic receiver is pretty low in voltage, it needs to be amplified with amplifier having very high gain. This task of amplifying the received pretty low voltage signal is carried out by an instrumentation amplifier. The circuit diagram for instrumentation amplifier is as shown in **??**

5.2.2 Instrumentation Amplifier

The main disadvantages of the differential amplifier or single operational amplifier are its low input impedance and low common mode rejection ratio Common Mode Rejection Ratio (CMRR). Such kind of problems can be solved by using instrumentation amplifier. Instrumentation amplifier is a high precision amplifier with an adjustable gain having high CMRR and input impedance. It is a kind of differential amplifier with additional input buffers. It uses 3 operational amplifiers, the first two amplifier acts as the buffer which has very high input impedance and low output impedance and the latter one is used as a differential amplifier to amplify the signal applied to its input. The advantage of the input buffers stages makes it easy to match the impedance of the amplifier with the preceding stage. The inputs are applied to the first two operational

amplifiers. The difference in the applied signal is only amplified by the amplifier but it rejects the common signal applied to its inputs. So whatever the environment is, the noise signal gets rejected. Its output impedance is very low so that there is low signal attenuation to transfer the whole amplified signal to the required circuit. Instrumentation amplifier is used for the higher accuracy and the stability of the circuit.
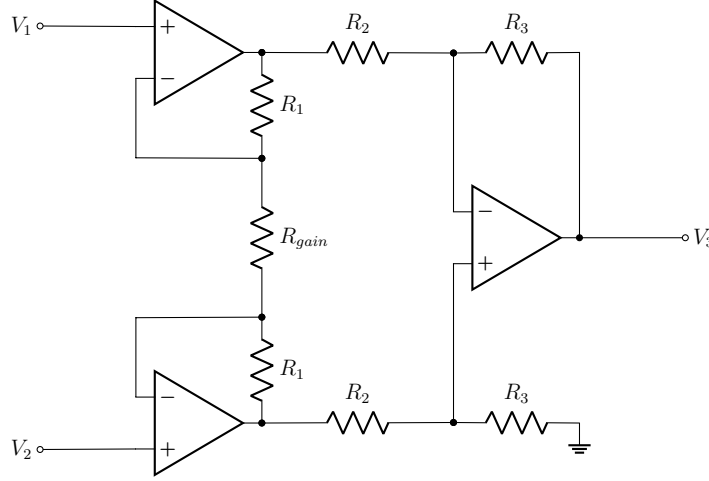

Figure 10: Instrumentation Amplifier

The gain of the instrumentation amplifier is given as:

$$\frac{V_{out}}{V_1 - V_2} = (1 + \frac{2R_1}{R_{gain}})\frac{R_3}{R_2} \tag{18}$$

where, V_1 and V_2 are the signals applied to the non-inverting inputs of operational amplifiers. The gain of the amplifier can be adjusted by changing the resistor value R_{gain}. We have used a potentiometer in place of the R_gain so that the value of the gain can be adjusted. For the simplification other resistor values are kept same.

Similarly, the CMRR of the instrumentation amplifier can be written in terms of CMRR of the single operational amplifier as:

$$CMRR_{ins-amp} = (1 + 2\frac{R_1}{R_gain})CMRR_{op-amp}$$

Hence the CMRR of the instrumentation amplifier is $(1+2\frac{R_1}{R_{gain}})$ times greater than that of a single operational amplifier.

Thus the low voltage signal received through the receiver of ultrasonic sensor is amplified using instrumentation amplifier circuit. The values of the component of this oper-

ational amplifier is calculated so that the required signal strength can be achieved. The amplified signal is now fed into the input of tone decoder circuit.

5.2.3 Signal Filtering

The transducer will pick up most sounds within a fairly wide range. Thus ultrasonic signal received by the receiver not just contain the 40kHz required signal. It also comprises of some other noise signals. To make sure the system only picks up the ultrasound signal that was transmitted, we need to lock the receiver onto a frequency of 40kHz.

For this, we have used IL567 Tone Decoder Integrated Circuit (IC). This tone decoder is a general purpose tone decoder which looks for a close match between the frequency of incoming signal and of its internal oscillator. The frequency of it's internal oscillator can be controlled by adjusting the values of capacitor and resistor between Pin 5 and Pin 6 of the IC. The frequency of internal oscillator is given by the expression :[?]

$$f = \frac{1}{1.1 * R * C} \tag{19}$$

where, R = Resistor placed between Pin 5 and Pin 6 C = capacitor placed at Pin 6
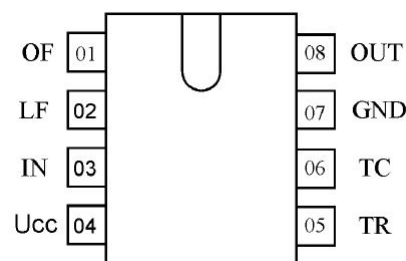
Figure 11: IL567 Pin Out

This IC sets it's output(Pin 8) to low when the frequency of incoming signal matches the frequency of internal oscillator. When there is incoming signal of other frequencies or there is no signal at all, the output(Pin 8) remains high. We used a capacitor of 0.01μ F. In order to lock the frequency of internal oscillator at 40kHz, we need a resistor of

Table 1: Pin Description of IL567 IC[?]

Pin Number	Symbol	Description
01	OF	FIlter output
02	LF	Loop Filter
03	IN	Frequency Input
04	U_{cc}	Supply Voltage
05	TR	Timing Resistor
06	TC	Timing Capacitor
07	GND	Common Pin(Ground)
08	OUT	Output

approximately 2.272 KΩ . Now since exactly this value resistor was not available, we used a potentiometer of 10K instead of this resistor.

5.2.4 Fixing The Frequency of Internal Oscillator

To make sure that the tone decoder recognizes 40kHz signal and sets it output to low only on the arrival of 40kHz signal, the frequency of it's internal oscillator needs to be fixed at 40kHz. Since we do not have exactly 2.272KΩ resistor available, we use a potentiometer to adjust the frequency of internal oscillator.

We fed a 40kHz sinusoidal signal to the input of the IL567 from function generator. Since the output of the IC is high when the frequency of incoming signal does not match the frequency of internal oscillator or also when there is no signal whatsoever, initially the output of this IC was high. Now the potentiometer was adjusted until the output of the IC was low. Thus, the frequency of internal oscillator of the IL567 was finalized to 40kHz.
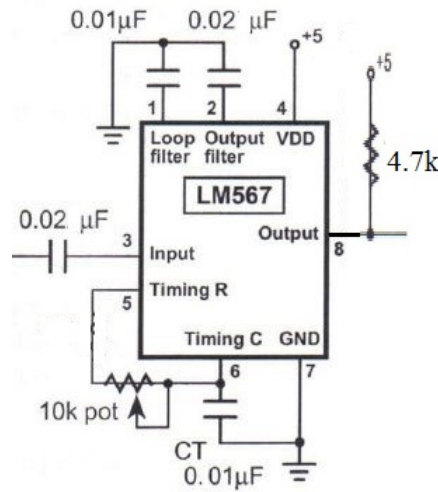
Figure 12: Circuit Diagram for Tone Decoding

5.2.5 Detection of Incoming Signal

The ultrasonic receiver receives the 40kHz signal transmitted from the transmitter. This signal is amplified using a two stage operational amplifier. The output of the amplifier circuit is fed as an input to the IL567. Now, as soon as the output of the IL567 goes low, we can know that the incoming signal is the transmitted signal with frequency of 40kHz. Thus, this can operate as a bandpass filter at 40kHz.

The output pin (Pin 8) on the LM567 Tone Decoder is connected to an input configured I/O pin on the microcontroller so that it is able to detect signals from the LM567 Tone Decoder. When the output pin (Pin 8) on the LM567 Tone Decoder is pulled low, the microcontroller knows that an ultrasonic signal has been received, and it stops running the counter and calculates the travel time of the signal.

5.3 Distance Calculation

Now equipped with all these stages we are finally able to calculate the distance between the transmitter and receiver station. Since we have the time recorded, we can use the time recorded using Equation.?? to calculate the original distance. Let the time recorded by

the receiver station be T_r. Then we can use this recorded time to calculate distance as

$$
\begin{aligned}
d &= T_r \times v_s \\
&= \Delta t \times v_s \\
&\approx \frac{x}{v_s} \times v_s \\
&= x
\end{aligned}
$$

Thus we can find the actual distance x by this process.

5.4   Data Collection

The distance measured by this process is collected in each of the three receiver station. The data collected in each of the three receiver station should be collected in one micro-controller to transmit to the computer. The overall block diagram of the data collection section is given in Figure. **??**
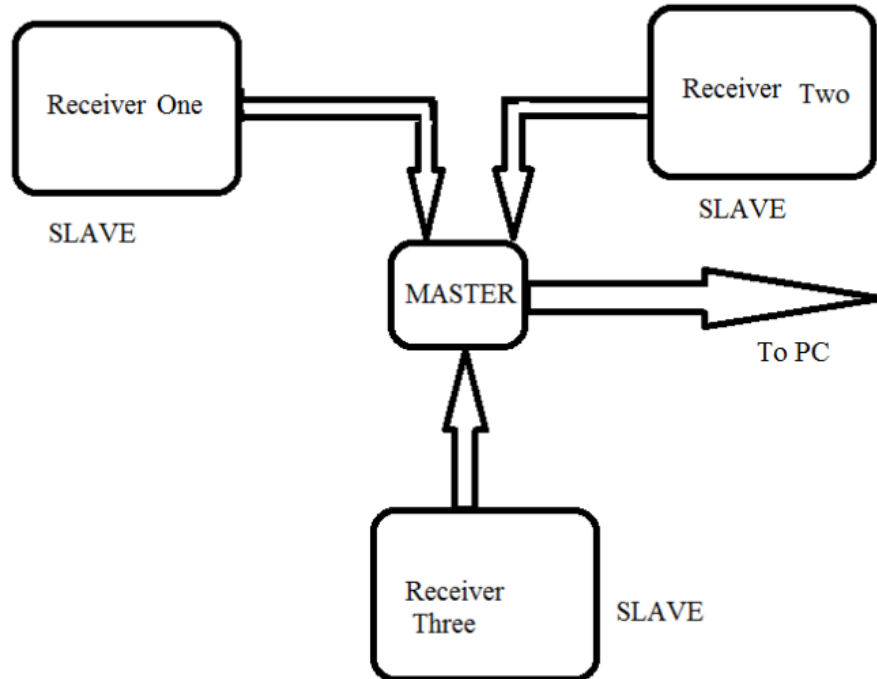
Figure 13: Data Collection Section Block Diagram

5.4.1 Communication Between Microcontrollers

The output of tone decoder is either a logic high or a logic low. Logic high means the receiver is not receiving the required signal and logic low means that receiver is receiving required transmitted $40kHz$ ultrasonic signal.

The output of the tone decoder is fed into one of the I/O pin of microcontroller AT-Mega8. Similarly, we have output of TSOP fed into another pin of the same microcontroller. The difference between time of arrival of the infrared signal, which is denoted by the output of TSOP and that of ultrasonic signal, which is denoted by the output of tone decoder is used for finding the distance between transmitter and receiver. All the calculations are performed within the microcontroller and thus the microcontroller contains the information of distance between transmitter and receiver.

In this way, all three microcontrollers residing on receiving modules comprise the information of distance between respective transmitters and receivers. All these distances are essential to determine the location of the transmitter using trilateration. As explained on the methodology section, when the distances between the transmitter and three predefined receivers are known, the location of a transmitter can be determined using trilateration.

This task of communicating between the microcontrollers is achieved by using Serial Peripheral Interface (SPI). SPI is one of the most used serial communication protocols.The SPI allows high-speed synchronous data transfer between the AVR and peripheral devices or between several AVR devices. The interconnection between two SPI devices always happens between a master device and a slave device. Compared to some peripheral devices like sensors which can only run in slave mode, the SPI of the AVR can be configured for both master and slave mode. The mode the AVR is running in is specified by the settings of the master bit (MSTR) in the SPI control register (SPCR). Special considerations about the SS pin have to be taken into account. This will be described later in the section "Multi Slave Systems - SS pin Functionality on page 3. The master is the active part in this system and has to provide the clock signal a serial data trans-

mission is based on. The slave is not capable of generating the clock signal and thus can not get active on its own. The slave just sends and receives data if the master generates the necessary clock signal. The master however generates the clock signal only while sending data. That means that the master has to send data to the slave to read data from the slave.

5.4.2 Data Transmission Between Master and Slave

The interaction between a master and a slave AVR is shown in Figure **??**. Two identical SPI units are displayed. The left unit is configured as master while the right unit is configured as slave. The MISO, MOSI and SCK lines are connected with the corresponding lines of the other part. The mode in which a part is running determines if they are input or output signal lines. Because a bit is shifted from the master to the slave and from the slave to the master simultaneously in one clock cycle both 8-bit shift registers can be considered as one 16-bit circular shift register. This means that after eight SCK clock pulses the data between master and slave will be exchanged.
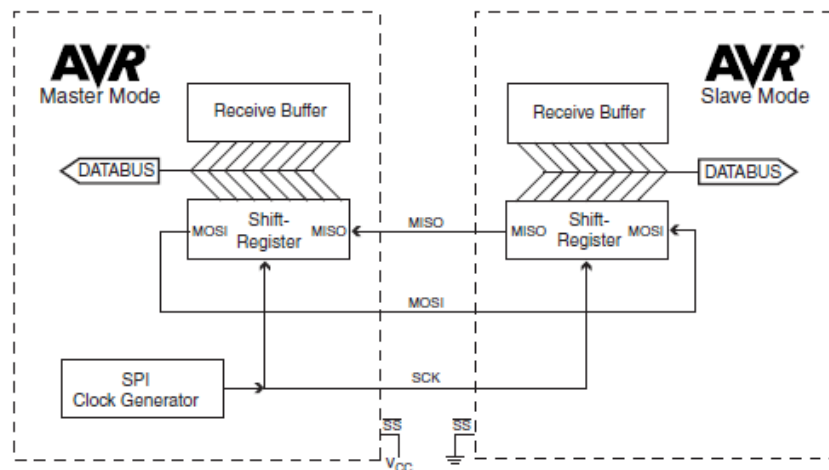
Figure 14: Interaction between a master and a slave

The system is single buffered in the transmit direction and double buffered in the receive direction. This influences the data handling in the following ways:

1. New bytes to be sent can not be written to the data register (SPDR) / shift register

before the entire shift cycle is completed.

2. Received bytes are written to the Receive Buffer immediately after the transmission is completed.

3. The Receive Buffer has to be read before the next transmission is completed or data will be lost.

4. Reading the SPDR will return the data of the Receive Buffer.

After a transfer is completed the SPI Interrupt Flag (SPIF) will be set in the SPI Status Register (SPSR). This will cause the corresponding interrupt to be executed if this interrupt and the global interrupts are enabled. Setting the SPI Interrupt Enable (SPIE) bit in the SPCR enables the interrupt of the SPI while setting the I bit in the SREG enables the global interrupts.

5.4.3 SPI Pins

The SPI consists of four different signal lines. These lines are the shift clock (SCK), the Master Out Slave In line (MOSI), the Master In Slave Out line (MISO) and the active low Slave Select 3 line (SS). When the SPI is enabled, the data direction of the MOSI, MISO, SCK and SS pins are overridden according to the table.

Table 2: SPI pin overrides

Pin	Direction Master Mode	Direction Slave Mode
MOSI	User Defined	Input
MISO	Input	User Defined
SCk	User Defined	Input
$\overline{SS}$	User Defined	Input

5.4.4 Multi-Slave System

The Slave Select $\overline{SS}$ pin plays a central role in the SPI configuration. Depending on the mode the part is running in and the configuration of this pin, it can be used to activate or deactivate the devices. The $\overline{SS}$ pin can be compared with a chip select pin which has some extra features. In master mode, the $\overline{SS}$ pin must be held high to ensure master SPI operation if this pin is configured as an input pin. A low level will switch the SPI into slave mode.

The ability to connect several devices to the same SPI-bus is based on the fact that only one master and only one slave is active at the same time. The multi-slave system is demonstrated by Figure **??**.
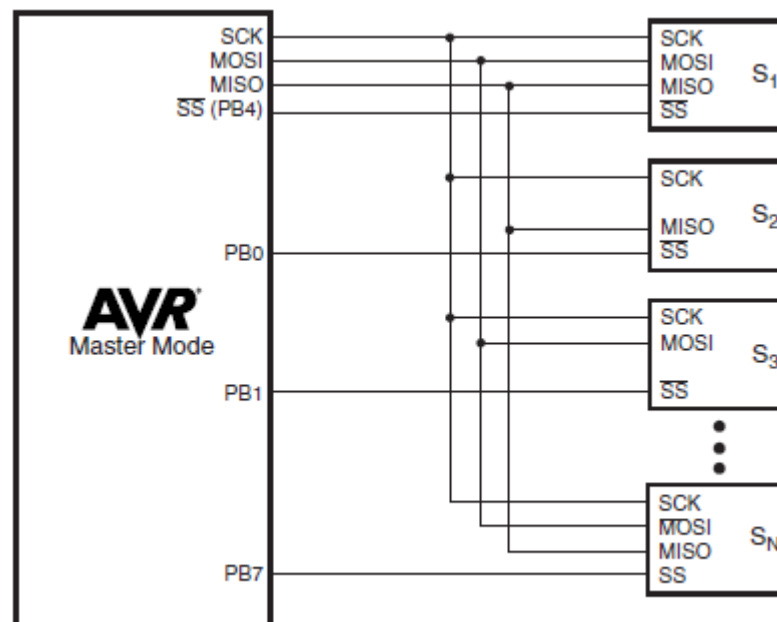
Figure 15: Multi-Slave System

Thus, the slave select pin of the slave whose data is to be transmitted to the master is held low at a time while the slave select pins of other slaves are held high. Thus, the master also knows from which slave it is receiving the data.

Thus, all three distances need to be fed into one another computational device for determining the location of the transmitter. Thus, all three microcontrollers send the information of distance into one another microcontroller, which feeds the data to PC via

Universal Serial Bus (USB) cable where the task of locating the transmitter is done.

5.5 Communication Between Microcontroller and PC

V-USB is a very useful software-only implementation of low-speed USB device for AVR microcontrollers. It adds USB functionality for almost any AVR, particularly for those without hardware USB functionality. The communication with PC has two distinct parts:

1. Firmware on Device

2. Host Driver Software on PC

5.5.1 Firmware

To make the interface to communicate with pc we have used VUSB library. This library helps to communicate data between PC and the microcontroller. The firmware does the necessary tasks required for preparation of putting the data in device buffer and send data to the PC following the USB protocol. These data is sent to the PC through USB cable.

5.5.2 Host Software

Once the data is received in the computer, the task remaining is to trace out the values on PC screen. For plotting this data into the screen as a function of time, we have prepared a graph plotting software ourselves, which plots the values received at the PC through USB port into the display of the PC making the waveform of the input signals visible.

Host software again makes use of lib USB library to make proper communication with the firmware on the device. A channel is formed between the host software and device through the USB connection.
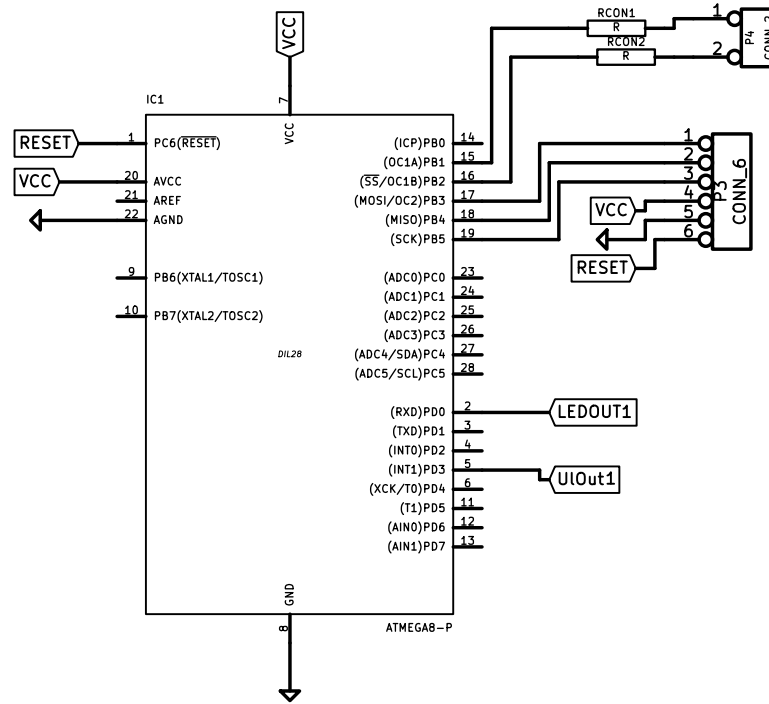
Figure 16: PWM Signal Generator

The software interfaces are made in C++ programming language and compiled for Linux Operating system. But the programs are made platform independent and can be easily compiled for other operating systems with just minor changes.

5.6 Circuit Realization

We have made the transmitter circuit which comprises of a Pulse Width Modulation (PWM)Generator to transmit $40kHz$ ultrasonic signal as well as a $38kHz$ IR signal.

The generated PWM signal is fed to the Ultrasonic Transmitter, but signal sinking causes the signal to die out in the ultrasonic transmitter. So we have used a transistor to decouple the circuit from the ultrasonic transmitter. Figure.?? shows the Ultrasonic transmitter attached to the output pin of PWM generator in Atmega8.

Also for synchronization process IRLED is also driven by the microcontroller. Figure.?? shows the IRLED attached to the PWM generator.
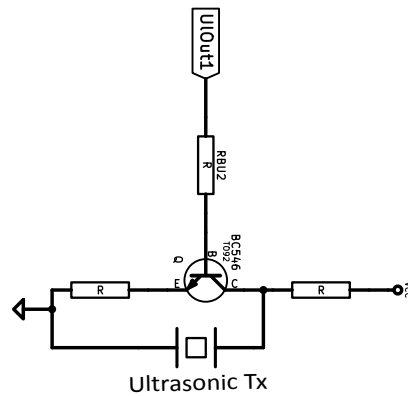
Figure 17: Ultrasonic transmitter driven by PWM
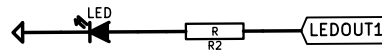
Figure 18: IRLED driven by PWM

Finally a Printed Circuit Board (PCB) is made for the transmitter which is shown in Figure.**??**.

Similarly, there are three receivers which receive the signals transmitted from transmitter section in all three directions. PCB for the receiver is shown in Figure.**??**

The receiver modules act as slave to transmit the distances to another microcontroller, which acts as a master. The implementation of master's module is as shown in Figure.**??**
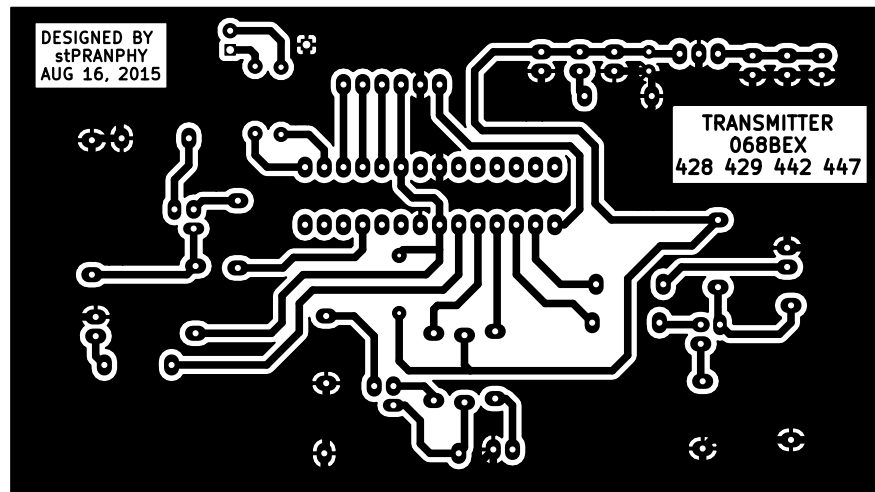
Figure 19: PCB of the transmitter section
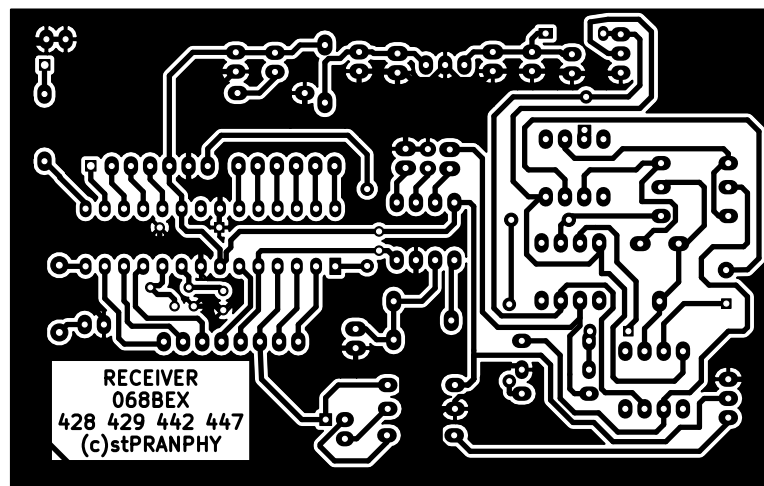
Figure 20: PCB of the Receiver Module
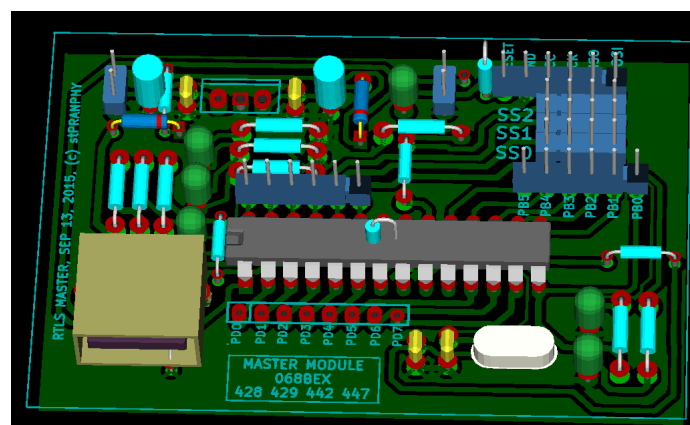
Figure 21: 3-D view of Master Module

6. COMPONENTS USED

6.1 Microcontroller ATMega8

Atmega8 is a high-performance, Low-power AVR, 8-bit Microcontroller with advanced Reduced Instruction Set Computer (RISC) architecture. We have used ATmega8 to generate PWM signals, to drive IRLED and Ultrasonic sensors.
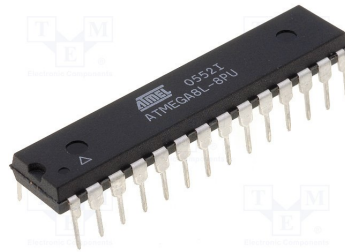
Figure 22: Microcontroller ATMega8

6.2 Operational Amplifier

UA741 operational amplifier is used in the system. UA741 is a general purpose operational amplifier and it can be used to amplify signal in the required range 40kHz. It is stable at this frequency range and has a stable response centered at this frequency.
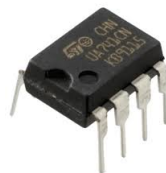
Figure 23: UA741 Operational Amplifier

6.3 Tone Decoder

IL567 Tone Decoder IC is used in the system. This tone decoder is a general purpose tone decoder which looks for a close match between the frequency of incoming signal and of its internal oscillator. The frequency of it's internal oscillator can be controlled by adjusting the values of external capacitor and resistor connected to the IC. To filter out unnecessary signals picked up at the ultrasonic receiver we have used this IL567 Tone Decoder.
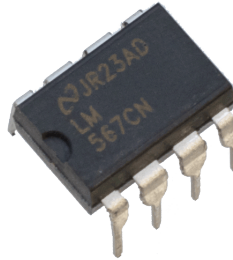

Figure 24: Tone Decoder IL567

6.4 TSOP and IRLED

For the synchronization purpose we have used a pair of IRLED and TSOP. IRLED is used to send handshake signal which the TSOP detects and uses to synchronize the ultrasonic signal.
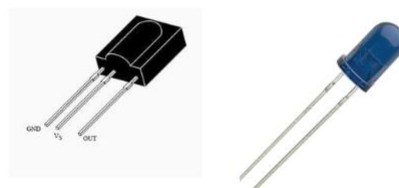

Figure 25: TSOP and IRLED

7. SOFTWARES AND TOOLS USED

7.1 KiCad

KiCad has been extensively used to design the PCB for the circuit. We have used KiCad with the following specification.

Version: (25-Oct-2014 BZR 4029)-stable

Build: wxWidgets 3.0.2 (debug,wchar_t,compiler with C++ ABI 1002,GCC 4.9.2,wx containers,compatible with 2.8)

Platform: Linux 3.19.0-22-generic x86_64, 64 bit, Little endian, wxGTK Boost version: 1.53.0

7.2 Proteus

Proteus is a simulation software for various designs. It is a handy tool to test programs and embedded electronics designs. It can be used to simulate programs for microcontroller as well as test various circuits before implementing them into hardware. We have used Proteas 7.8 for the most part.

7.3 Programmer

Avrdude has been used as a tool to communicate between program written in computer and the microcontroller on which the program is to be written. The programmer is made form ATMEGA8 microcontroller. We opted to get one already available in the market.

Figure 26: USBasp Programmer

7.4 AVR GCC compiler

AVR-GCC is a compiler that takes C language high level code and creates a binary source which can be uploaded into an AVR micro controller. Once code in 'C' is written for a particular project, AVR-GCC will turn C code into assembly language files.

Individual assembler files are then converted into object files. Object files are files of code that AVR chips could run. The linker AVR-ld will take all these assembler files, and cross-reference functions names to create one single object file. The linker will also take modules from the 'C' library and make them into a single object. Normally this linked object is in ELF format and furthermore AVR-objcopy is used to generate a HEX format file.

8. RESULTS

The entire project can be subdivided into three categories.

8.1   Transmitter

In the transmitter section, three ultrasonic transmitters and a microcontroller AtMega8 is used to transmit a $40kHz$ in three directions. Similarly, simultaneously, three IRLED transmits $38kHz$ infrared signal in respective direction.

8.2   Receiver

In the receiver section, there are three receivers located at three direction. Each receiver comprise of an ultrasonic receiver, a TSOP, a three op-amp instrumentation amplifier, tone decoder and a microcontroller. Ultrasonic receiver receives the $40kHz$ ultrasonic signal while the TSOP receives the $38kHz$ infrared signal.

Now the received ultrasonic signal is fed to the instrumentation amplifier. The outputs of instrumentation amplifier at different distances from the transmitter is shown in table **??**

A graph of signal strength vs. distance was plotted and the observed graph is shown in Figure **??**

The output obtained from the instrumentation amplifier was plotted against the input at instrumentation. The observed graph is shown in Figure.**??**

Table 3: Output of instrumentation amplifier at different distances

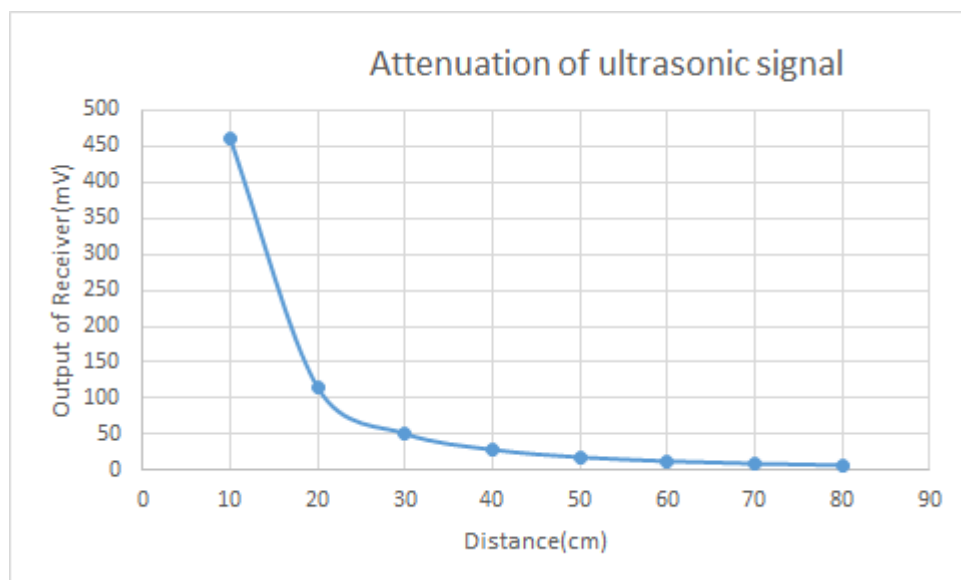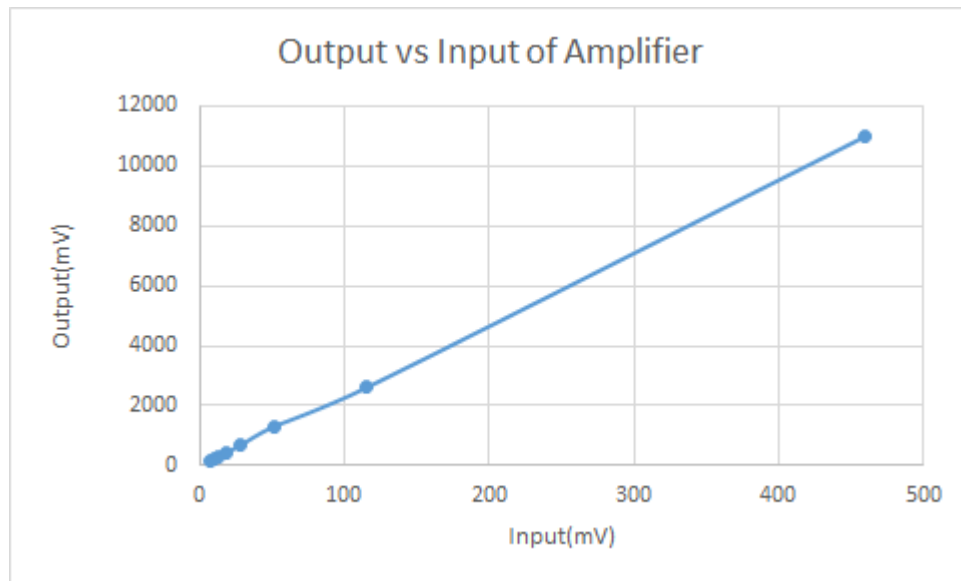| Distance(cm)	Input(mV)	Output(mV)
10	460	11100
20	115	2785
30	51	1238
40	28	690
50	18	440
60	13	305
70	9.5	227
80	7.2	170

Figure 27: Attenuation of signal

Figure 28: Output vs Input graph

8.3 Graphical User Interface

After sending the distance information between all the ultrasonic transmitters and re-
ceivers to PC via USB cable, the location of transmitter is determined using trilateration.
Now the location of the transmitter is displayed in a GUI. One instance of locating the
path of transmitter in PC is shown in Figure.??

Figure 29: Real Time View of Moving Transmitter

9.   FINAL VERSION OF CIRCUITS

9.1   Transmitter

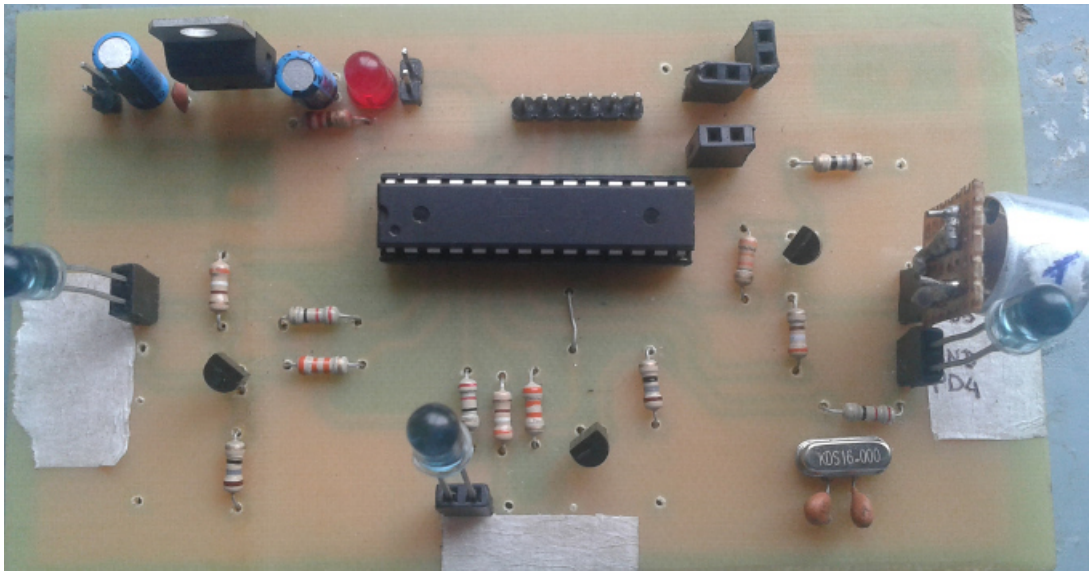The final version of the transmitter is shown in Figure **??**

Figure 30: Final version of transmitter

9.2   Instrumentation Amplifier

The implementation of instrumentation amplifier is shown in Figure **??**

9.3   Receiver

The final version of the receiver is shown in Figure **??**

Figure 31: Implementation of Instrumentation Amplifier

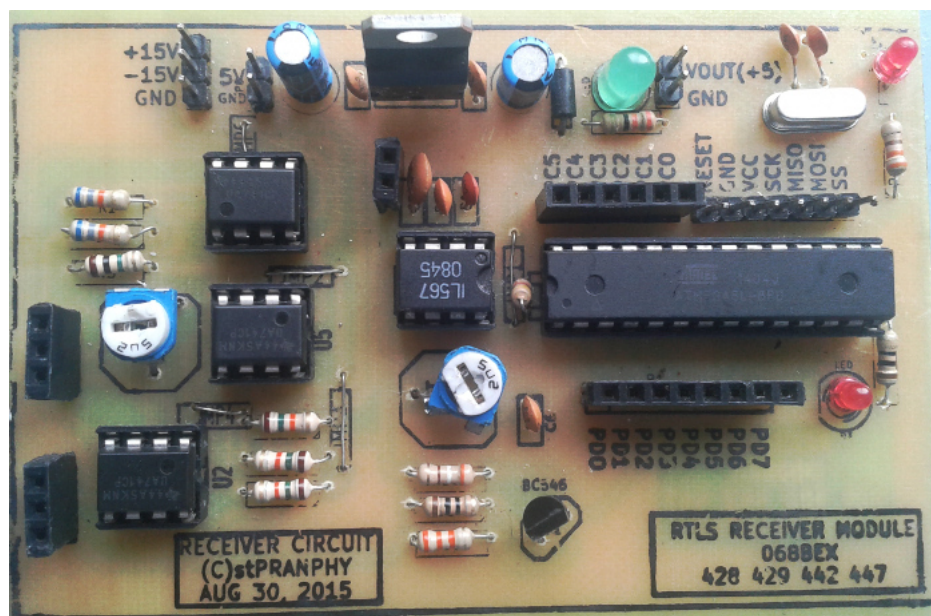
Figure 32: Final version of Receiver

10. APPLICATION

Studies have suggested that use of RTLS have significantly improved[?] the performance wherever it has been applied. With the recent government reports indicating increased road accidents even by the licensed drivers, it is high time we went for major overhauling in the license trial system. An RTLS based automation system would work perfect for the cause, eliminating human errors, bribery and other sneaky ways people use to get license.

11. CONCLUSION

Thus from this major project, we got an opportunity to explore different recent developments on Real Time Location System and different ways of implementing RTLS. We learnt properly, how ultrasonic systems can be used to achieve RTLS. This project also provided us an opportunity to utilize the knowledge acquired in the field of electronics during these four years of engineering studies.