AN IMPLEMENTATION OF AN ULTRASONIC DEVICE FOR THE VISUALLY IMPAIRED

By

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AN IMPLEMENTATION OF AN ULTRASONIC DEVICE FOR THE VISUALLY IMPAIRED

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Chapter 1

Introduction

Ultrasonic is defined as any bands above audible band (20 kHz) and up to MHz range. One unique characteristic about the ultrasonic waves is that its speed is approximately about 10^5 to 10^6 slower than the speed of electromagnetic waves in air, depending on the temperature and the medium density it is traveling and because of this, it is widely used in many fields, such as medical, engineering, and military. Another unique characteristic of ultrasonic waves is that it can penetrate opaque materials that other waves cannot. This makes it a very valuable asset to measure distance and thickness of an object in an inexpensive and a reliable way. Ultrasonic waves can be generated naturally and electronically. Some animals like bats emit ultrasonic waves to pinpoint their current position relative to an object in front of them, this phenomenon has been studied for many years by scientists. Humans can generate and transmit ultrasonic waves by using transducers. By having a better concept of ultrasonic waves, we are one step closer in understanding the mystery of nature and maybe improving our quality of life.

1.1 Thesis Problem

The purpose of this thesis is to design an ultrasonic device that will allow a blind person to detect an object far out from his/her reach. The device should be made as reliable, small, light, and cheap as possible. The final design of the device should also be easy to use and convenient for the blind person to wear.

1.2 Thesis Outline

This thesis is divided into 4 chapters. The second chapter will cover the background of ultrasonic. The third chapter will describe the research in this thesis in hardware and software, along with the experimental result. The last chapter will conclude everything discussed on this thesis.

Chapter 2

Background

2.1 Brief History of Ultrasonic

The history of ultrasonic can be traced back before the nineteenth century. The Savant wheel (1830), and Galton whistle (1876) were two of the oldest high frequency ultrasonic sources. The Savant wheel could generate up to 24 kHz of ultrasonic wave, while the Galton whistle basic frequency range was from 3 to 30 kHz. In World War II, ultrasonic was being used as sonar through water to detect enemies' ships and submarines. After World War II, ultrasonic was became a popular topic in research. Some researches employed using ultrasonic wave in detecting metal objects and flaws in solid material, as well as medical diagnostics.

2.2 Theory of Ultrasonic

At first we need to review some basic equations for sound waves. Ultrasonic wave's velocity differs at different mediums and temperatures therefore, a more detailed discussion is needed on each mediums, so as to have a better understanding of ultrasonic waves.

2.2.1 Review of basic sound waves

Assuming that the sound wave we have is sinusoidal. A sinusoidal signal will have a frequency (f) and a period (T). The relationship between them and other variables such as angular velocity and wavelength are as follows:

$$f = \frac{1}{T}$$

$$\omega = 2\pi f$$

$$\lambda = \frac{c}{f}$$

where: f = frequency [Hz]

T = period [second]

ω = angular frequency [radian/second]

λ = wavelength [meter]

c = velocity of wave propagation [meter/second]

2.2.2 Propagation of ultrasound in various mediums

The velocity of ultrasonic wave is different from one medium to another, and it changes significantly in liquids, solids and gases.

2.2.2.1 Liquids

The velocity of ultrasonic waves in liquids depends on the temperature of the liquids. Here is an equation that relates ultrasonic wave velocity with liquids temperature:

$$c = c_{initial} + \gamma\theta$$

And it can also be calculated from the following equation:

$$c = \sqrt{\frac{1}{\beta_{ad}\rho}}$$

Where β_{ad} is:

$$\beta_{ad} = \frac{\beta_{is}}{\chi}$$

where: c = ultrasonic waves velocity at final temperature [meter/second]

$c_{initial}$ = ultrasonic waves velocity at initial temperature [meter/second]

θ = temperature difference of the liquids between the final and initial temperature [$^\circ Celcius$]

γ = absolute temperature coefficient [meter / (second * $^\circ Kelvin$)]

χ = Poisson's constant

ρ = liquid density [kg/m^3]

β_{ad} = adiabatic coefficients of compressibility

β_{is} = isothermal coefficients of compressibility

For liquids other than water, the velocity of ultrasonic waves decreases with increasing temperature. For water, however, the velocity increases with temperature up to 74 °C and then decreases.

2.2.2.2 Solids

The velocity of ultrasonic waves in solids depends on the density of the solids. Here is an equation that relates ultrasonic wave's velocity with solids density:

$$c_T = \sqrt{\frac{G_s}{\rho}}$$

$$G_s = \frac{E_p}{2(1+\mu)}$$

where: c_T = ultrasonic waves velocity [meter/second]

G_s = modulus of transverse elasticity [Pa]

ρ = solid density [kg/m^3]

E_p = Young's modulus [Pa]

μ = Poisson's ratio

2.2.2.3 Gasses

The velocity of ultrasonic waves in gasses depends on the gas density and temperatures (for small variations). Here is an equation that relates ultrasonic wave's velocity with gasses density and temperatures:

$$c = \sqrt{\chi \frac{P_a}{\rho}}$$

$$c = c_0 + \gamma.(\theta - \theta_0)$$

where: c = ultrasonic waves velocity [meter/second]

c_0 = ultrasonic waves velocity in gas at 0 $°C$ [meter/second]

P_a = atmospheric pressure [Pa]

χ = Poisson's constant

ρ = gas density [kg/m^3]

γ = Absolute temperature coefficient [m s^{-1} K^{-1}]

θ = absolute temperature [K]

θ_0 = Temperature at 0^0 C

A special case for gasses is air. Air has a propagation velocity of 331m/s and the temperature coefficient of 0.61 [m s^{-1} K^{-1}].

2.2.3 Ultrasonic Reflection and Transmission

Ultrasonic reflection and transmission happen when ultrasonic waves move from one medium to another medium with different wave resistance. Acoustic pressure, p, is created during the transition of ultrasonic wave through a medium. The acoustic pressure is a function of acoustic impedance and acoustic velocity. The real value of acoustic impedance is usually referred to as wave resistance. If both of the medium has the same wave resistance, then there will be no reflection, only transmission. This is illustrated in Fig. 2.1.

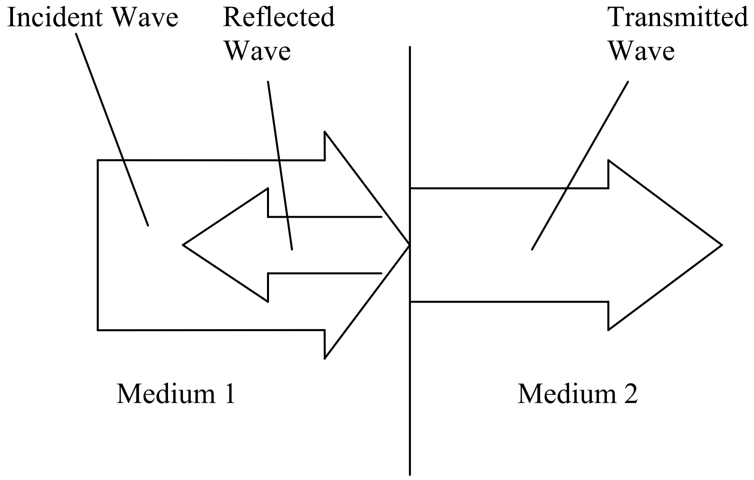


Figure 2.1 Ultrasonic wave incidence to 2 different mediums

Assume the wave resistance and wave intensity of medium 1 and 2 to be Z1 and I1, and Z2 and I2. Ro, the reflection coefficient can be found by using the following equation:

$$Ro = \frac{I3}{I1} = \left(\frac{Z2 - Z1}{Z2 + Z1} \right)^2$$

$$I3 = I1 - I2$$

$$Z = \rho\ c$$

$$D = \frac{I2}{I1}$$

where: Ro = reflection coefficient

Z1 = wave resistance of medium 1

I1 = wave intensity of medium 1

Z2 = wave resistance of medium 2

I2 = wave intensity of medium 2

I3 = the difference of wave intensity in medium 1 and 2

D = transmission coefficient

2.2.4 Ultrasonic Refraction

Refraction occurs when ultrasonic waves travel from one medium to another medium at oblique angle. Fig. 2.2 illustrates this.

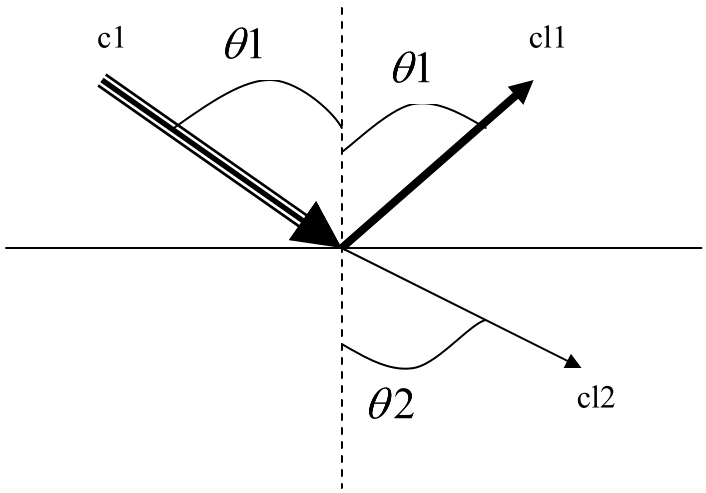


Figure 2.2 Ultrasonic waves transmission and refraction in 2 different mediums with longitudinal velocities

Snell's Law of refractions says that:

$$\frac{\sin\theta 1}{cl1} = \frac{\sin\theta 2}{cl2}$$

where: cl1 = longitudinal velocity of ultrasonic wave in medium 1

cl2 = longitudinal velocity of ultrasonic wave in medium 2

$\theta 1$ = the reflected angle of longitudinal velocity of ultrasonic wave in medium 1

$\theta 2$ = the transmitted angle of longitudinal velocity of ultrasonic wave in medium 2

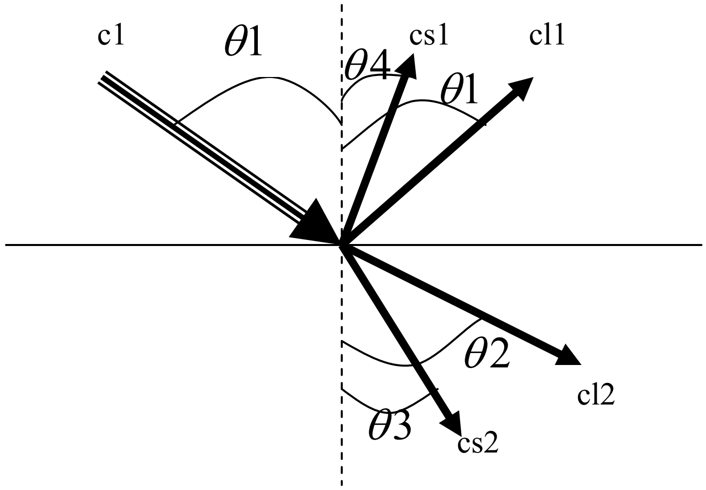


Figure 2.3 Ultrasonic waves reflection and refraction in 2 different mediums with longitudinal and shear velocities

Snell's Law also holds for shear waves. Fig. 2.3 illustrates this.

$$\frac{\sin\theta 1}{cl1} = \frac{\sin\theta 2}{cl2} = \frac{\sin\theta 3}{cs2} = \frac{\sin\theta 4}{cs1}$$

where: cs1 = shear velocity of ultrasonic wave in medium 1

cs2 = shear velocity of ultrasonic wave in medium 2

$\theta 3$ = the transmitted angle of shear velocity of ultrasonic wave in medium 2

$\theta 4$ = the reflected angle of shear velocity of ultrasonic wave in medium 1

Rayleigh found an equation to describe the intensities of the reflected and the transmitted waves.

$$I_{reflected} = I\left(\frac{\sqrt{1-\sin^2\theta 1} - \frac{\rho 1}{\rho 2}\sqrt{\frac{c1^2}{c2^2} - \sin^2\theta 1}}{\sqrt{1-\sin^2\theta 1} + \frac{\rho 1}{\rho 2}\sqrt{\frac{c1^2}{c2^2} - \sin^2\theta 1}}\right)^2$$

$$I_{transmitted} = I\left(\frac{4\frac{\rho 1}{\rho 2}\sqrt{\frac{c1}{c2} - \sin^2\theta 1}}{\sqrt{1-\sin^2\theta 1} + \frac{\rho 1}{\rho 2}\sqrt{\frac{c1^2}{c2^2} - \sin^2\theta 1}}\right)$$

where: c1 = sound propagation velocities in medium 1

c2 = sound propagation velocities in medium 2

$\rho 1$ = the density of medium 1 [kg/m^3]

$\rho 2$ = the density of medium 2 [kg/m^3]

2.3 Ultrasonic Applications

2.3.1 Social

One of the popular topics in using ultrasonic wave in social field is to create Electronic Travel Aids (ETA) gadgets for disabled people, especially the blinds. Previous research in this area ranges from a simple walking cane which has a simple ultrasonic transmitter and receiver, to a mobile walking cane that has a more complex circuit to measure distance. The principle of these kinds of gadgets is not hard to understand. An ultrasonic transmitter is needed to emit ultrasonic waves using a simple sinusoidal or rectangular wave generator. Once the ultrasonic waves hit an object, they will scatter. The job of the receiver is to detect the incoming scattered waves and measure their amplitudes. The larger the amplitude received means that there is a higher probability an object exists in front of the person in a short range. Lower amplitude, on the other hand, means that there is an object in a far range. Fig. 3.1 illustrates this.

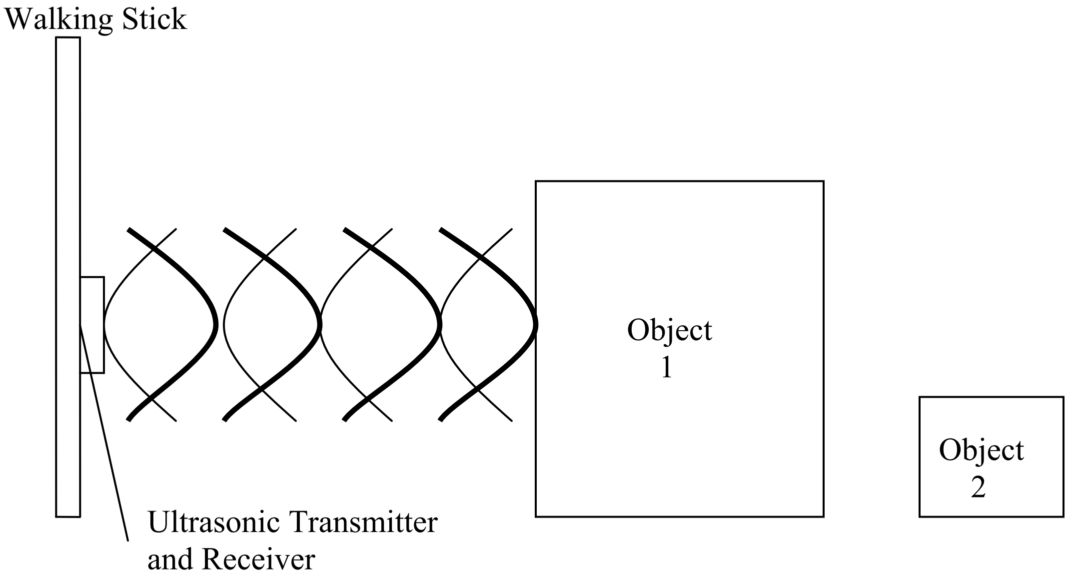


Figure 2.4 Transmitted ultrasonic waves and echo location

There are some problems corresponding to these types of devices:

1. Natural ultrasonic waves might interfere with the incoming reflected ultrasonic waves.
2. If there is more than one object in front of a person, the one that is closest to the person will deflect the emitted ultrasonic wave.
3. Small or soft objects might not reflect much of the emitted ultrasonic waves.

4. The emitted ultrasonic waves might interfere with animals near us like dogs.
5. Mobile walking cane as discussed in [21] and [22] has one important flaw, it only works on a flat terrain. That device cannot be used in real life situation, and it is expensive and requires some maintenance.

2.3.2 Medical

Since World War II, ultrasonic waves have been widely used in therapy, such as inspection of vivo samples, and cavitation damage, monitoring blood flow, vitro studies and most importantly, fetal imaging. The main idea of using ultrasonic waves in medical applications is to transmit ultrasonic waves to any part of human body that wished to be checked and receive the reflected ultrasonic wave. The energy in ultrasonic waves is attenuated during its transit thorough tissues, and the energy is lost by either absorption or scatter. Some of the energy that got absorbed locally might lead to heating and cause injure to patients. Another biological effect of ultrasonic is cavitation, which is the formation of gas or bubbles in a liquid by ultrasonic waves. There are two types of cavitation, stable and transient cavitation [27]. Both of them have the ability to injure patients. High intensity of ultrasonic may cause cell lysis, which is a disintegration or disruption of a cell. High intensity of ultrasonic wave may also change cellular ultrastructure, and might even affect DNA. The research to see how much ultrasonic might affect DNA, is still undergoing.

2.3.3 Military

Back in World War II, ultrasonic was used underwater to check the position of enemies' ships and submarines. On the other hand, it is also used for navigation. The idea behind this is similar to the one we use for the blinds. A submarine can generate high intensity ultrasonic waves, with longer length scale, to a specific place and then check the incoming scattered ultrasonic waves signal. There are some problems in using ultrasonic underwater. Temperature gradient, bubbles phenomena, and natural ultrasonic waves might affect the ultrasonic signals that are supposed to go back to the submarine. The smaller the bubbles size, the higher resonance frequency they can cause. Dolphin and whales communicate using ultrasound underwater. Their communication frequency can easily go from 7 kHz up to 150 kHz.

2.3.4 Oceanography

The use of ultrasonic in this area is similar to the one the military uses. Oceanography uses ultrasonic to check a steady target instead of using ultrasonic to check a moving target. Ultrasonic in this area is primarily used to check the depth of an ocean and maybe even try to find out what is at the bottom of the ocean. The use of the ultrasonic doesn't end there. It can also be used in finding sunken ships, lost treasures, oils and minerals.

Chapter 3

Device Design

The purpose of the design is to create an inexpensive and reliable device for a blind person as a guiding system. One way to accomplish this is to measure the duty cycle on an ultrasonic receiver. Low duty cycle means that an object is far away from the blind person, high duty cycle means that an object is near. The final device has two parts, ultrasonic transmitter and receiver. The transmitter will always send 40 KHz pulses back to back and the receiver will decode the incoming signal and warn the user whether an object is near or not by using a beeper or a buzzer.

3.1 Hardware

3.1.1 Transmitter

The hardware design started with selecting parts for the ultrasonic transmitter part. In this case an ultrasonic transmitter from Panasonic – ECG, Ultrasonic Type Q, was chosen due to its wide availability at www.digikey.com. The second part that needed to consider was the square wave generator to generate 40 kHz square waves. In this case timer LM 555 was also chosen due to its wide availability and use. From LM 555 datasheet, one can configure LM 555 to be in astable mode and output 40 kHz square wave signal by using the following formula:

$$f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2)C}$$

Choosing R1 to be 20.3 kΩ , R2 to be 15 kΩ, and C to be 680 pF will generate approximately 40 kHz signals based on the equation above. Fig. 3.1 is the schematic used for the ultrasonic transmitter part. Fig. 3.2 shows the output of the LM 555 using an oscilloscope.

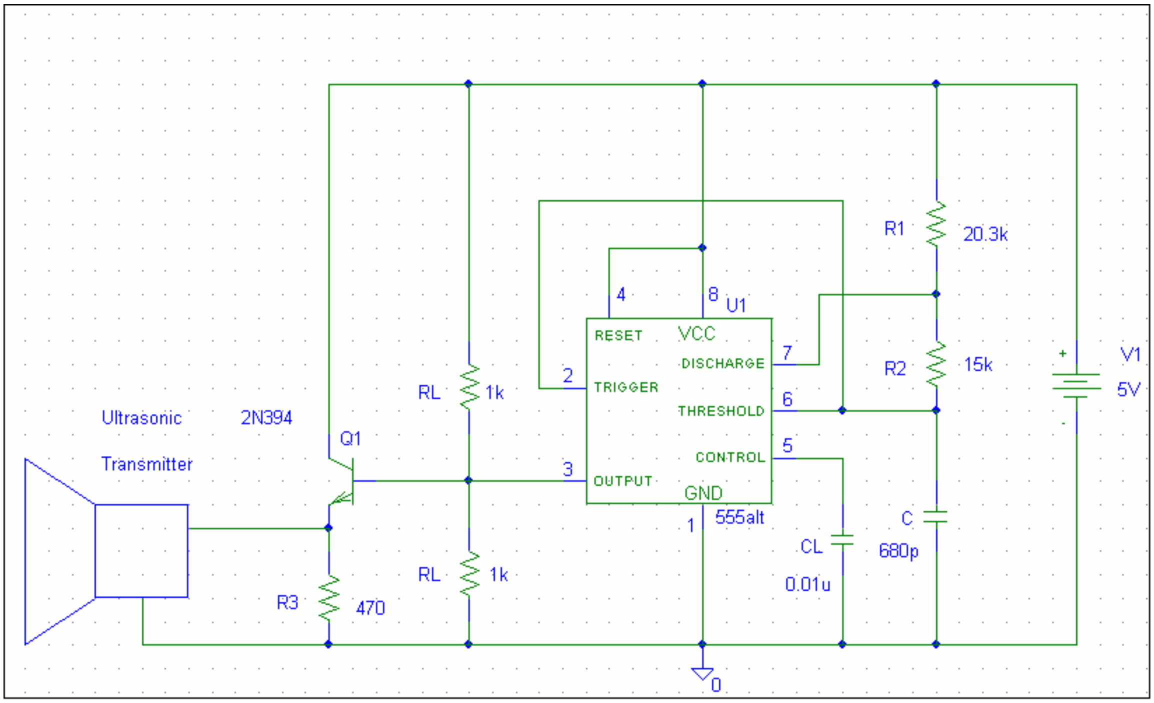


Figure 3.1 The schematic for ultrasonic transmitter

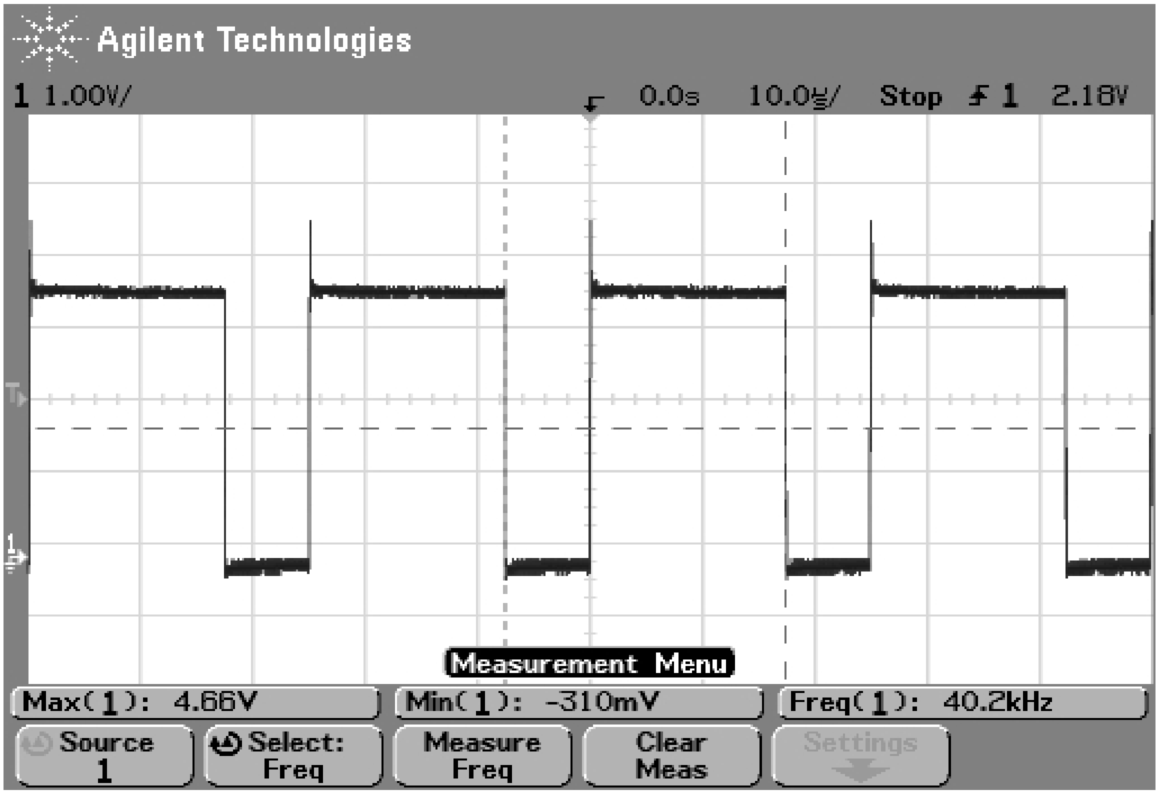


Figure 3.2 LM 555 output using an oscilloscope

3.1.2 Receiver

The hardware design for this part started with selecting an ultrasonic receiver. In this case an ultrasonic receiver from Panasonic – ECG, Ultrasonic Type Q, was chosen because we already used ultrasonic transmitter Type Q for the ultrasonic transmitter. An advantage of this receiver is that not only it does work as a receiver, it also works as a bandpass filter which filters out any signals below 40 kHz and above 40.5 kHz, based on the experiment done on the lab. The ways the receiver works are as follows:

1. Detect the reflected signals

   40 kHz signals are received by the ultrasonic receiver. The signals received by the ultrasonic receiver are weak therefore they need to be

amplified by the next stage.

2. Amplify the reflected signals

The signals are then amplified 10000 times using LF 412. LF 412 is a Dual JFET Operational Amplifier with a 3 MHz bandwidth. At this point

the amplified incoming signals should be of sinusoid form with a range from -5 to +5 Volts.

Fig. 3.3 illustrates this:

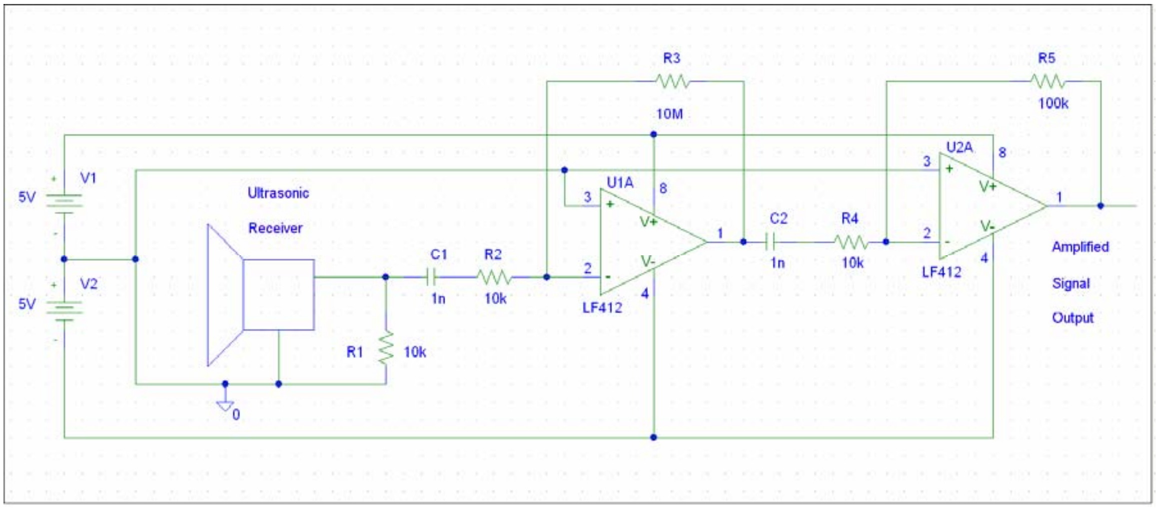


Figure 3.3 Two-Stage Amplifier

The first amplifier stage will amplify the signal 1000 times (60 dB). The second amplifier will amplify the amplified the signal from the first amplifier 10 times (20 dB). The total amplification will be 10000 times (80 dB).

3. Rectify the amplified signals

The amplified signals are then rectified by using super diode circuit to cut off any signals below 0 Volts. This will insure that there is no voltage drop across the diode which might affect the duty cycle. Fig. 3.4 illustrates this:

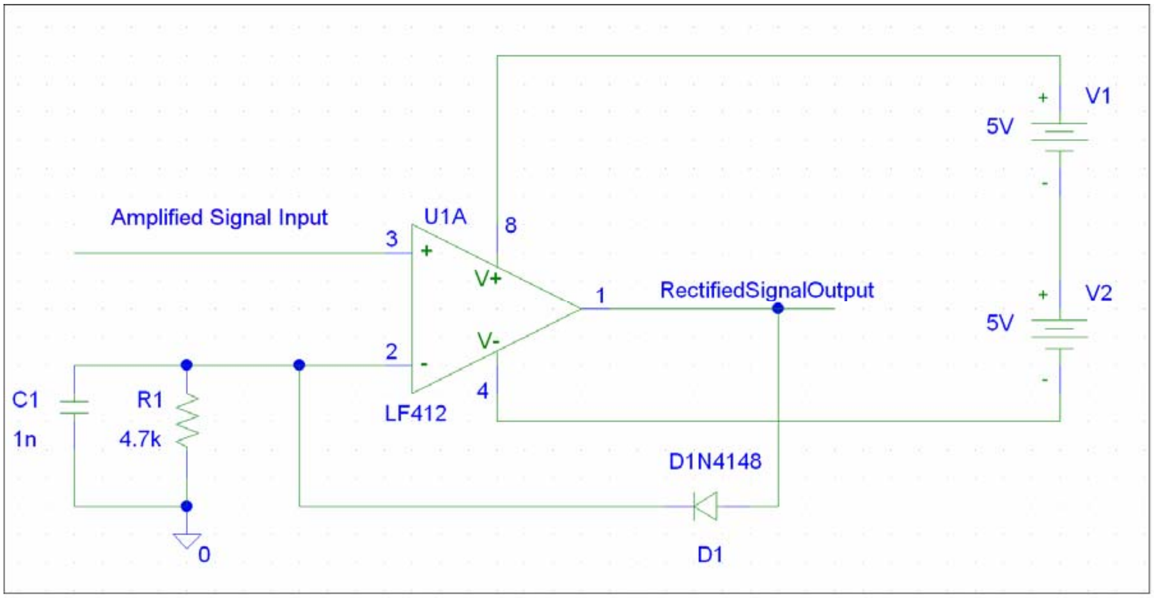


Figure 3.4 Rectifier circuit

4. Digitize the rectified signals

The rectified signals are then digitized using a voltage comparator, DV 339. Ultrasonic receiver will pick up noises and those noises will be amplified as well. At non-working mode the noise can go up as high as 200 mV. By setting the voltage reference to the inverting input of DV 339 as 250 mV, this will insure that the noises will not affect the rest of the circuits and duty cycle calculations at the end. Fig. 3.5 illustrates this:

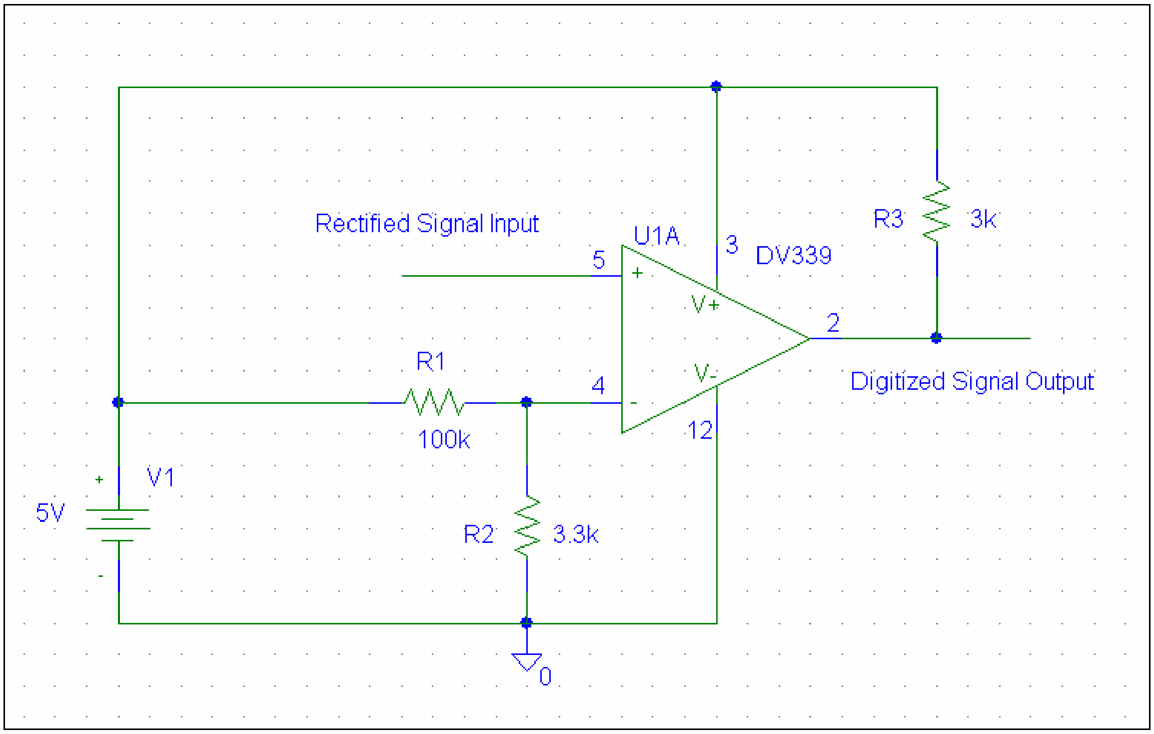


Figure 3.5 Digital Circuit

5. Use the digitized signals as a clock

The digitized signals are then used as a clock for a 8 bit D Flip Flop, 74LS273. The D Flip Flop constantly reads a value from CD4040, a 12 bit counter. This 12 bit counter uses a 10 MHz oscillator and an inverter chip 74HC04 to generate 10 MHz square wave signals ranging from 0 to 5 Volts. The 12 bit counter needs to be reset right after the D flip flop grabbed the value from the counter. This can be easily done by delaying the signal coming to the D flip flop clock using two inverters. The purpose of the counter is to map a 40 kHz signal to an eight bit value. The period of a 40 kHz signal is:

$$T = \frac{1}{f} = \frac{1}{40kHz} = 25\mu s$$

To map a 25 µs signal to an 8 bit value, each bit will have a period of:

$$T_{1bit} = \frac{25\mu s}{256} = 0.0977\mu s$$

The frequency needed to map a 25 µs signal to an 8 bit value:

$$f_{1bit} = \frac{1}{T_{1bit}} = \frac{1}{0.0977\mu s} = 10.235MHz$$

LM 555 can only generate up to 3 MHz signals. To solve this problem, a 10 MHz oscillator must be used with two capacitors and inverters. Fig. 3.6 will illustrate this:

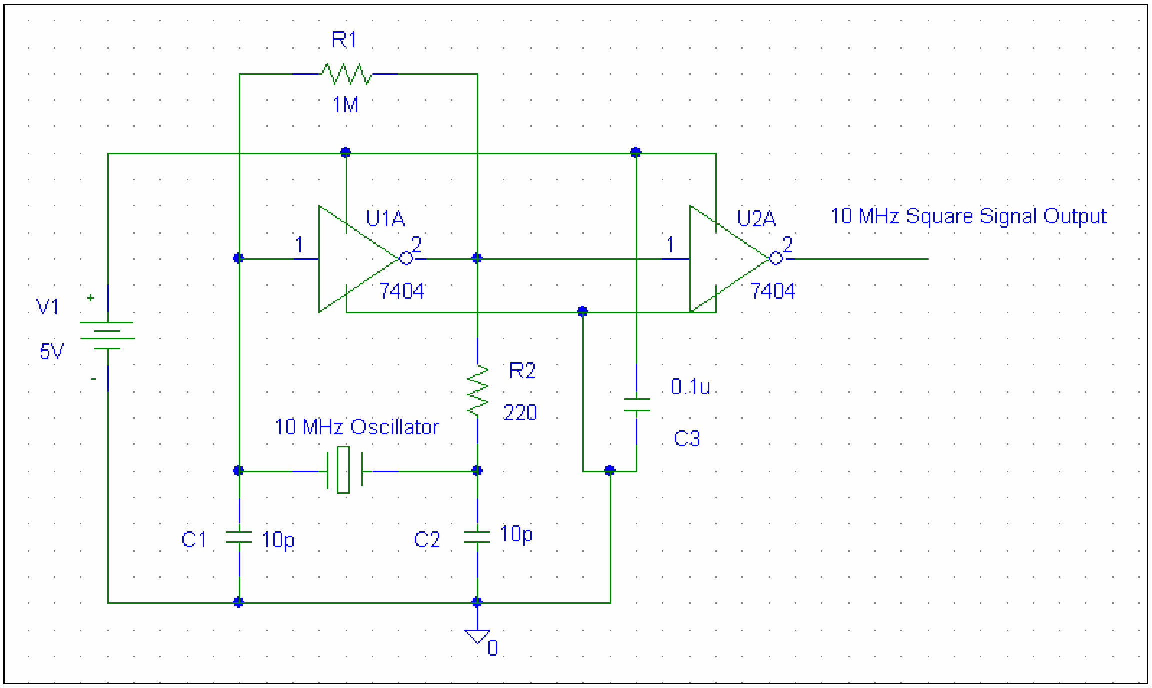


Figure 3.6 Oscillator

Fig. 3.7 shows the output of the oscillator using an oscilloscope:

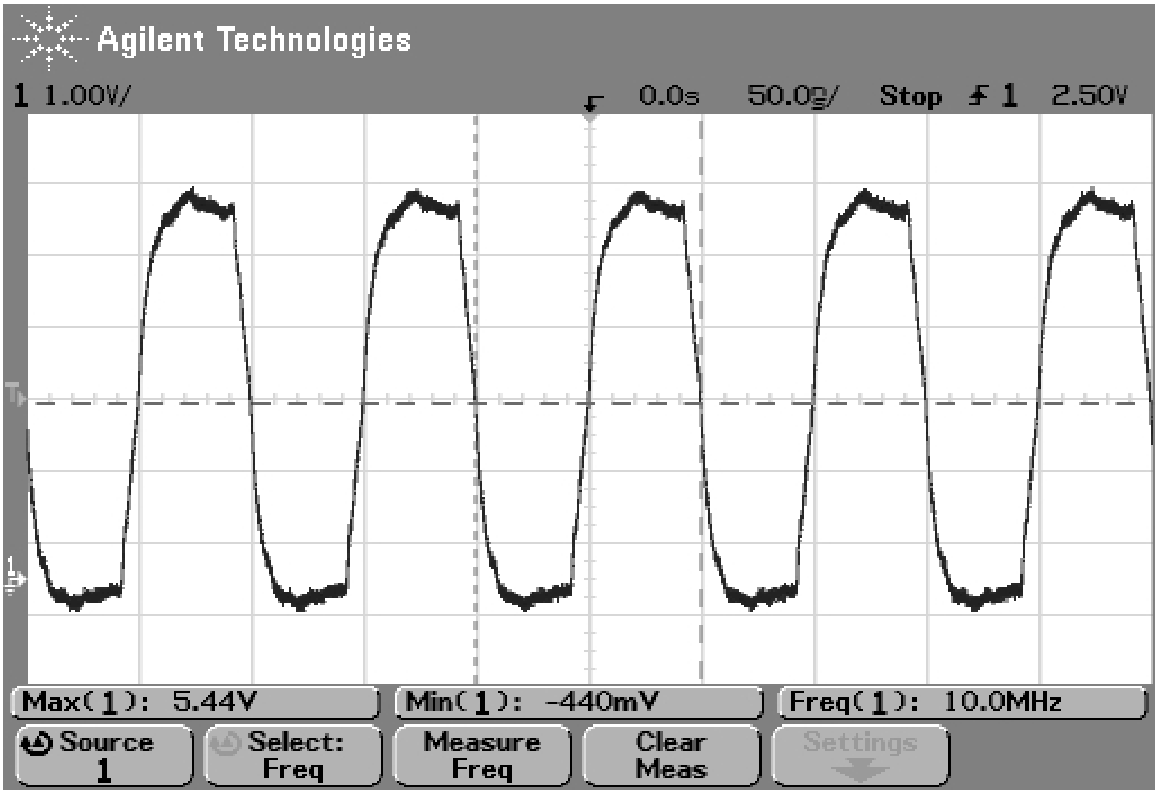


Figure 3.7 Oscillator's output

Using a 10 MHz oscillator, the maximum value we can have is:

Number of bits $= 25\mu s * 10MHz = 250$ bits

which can be represented by an eight bit value.

6. Read values from the D flip flop

The function of first/master Peripheral Interface Controller (PIC) is to grab the values from the D flip flop three times then take the average of those values and pass it to the second PIC. At the same time the first PIC also clears the D Flip Flop right after the PIC read the value on the D Flip Flop.

7. Read values from the master PIC

The function of second PIC is to read the average value being passed from the first PIC and generate a signal from 1 to around 18 Hz depending on the value received. Fig. 3.8 and 3.9 illustrate this:

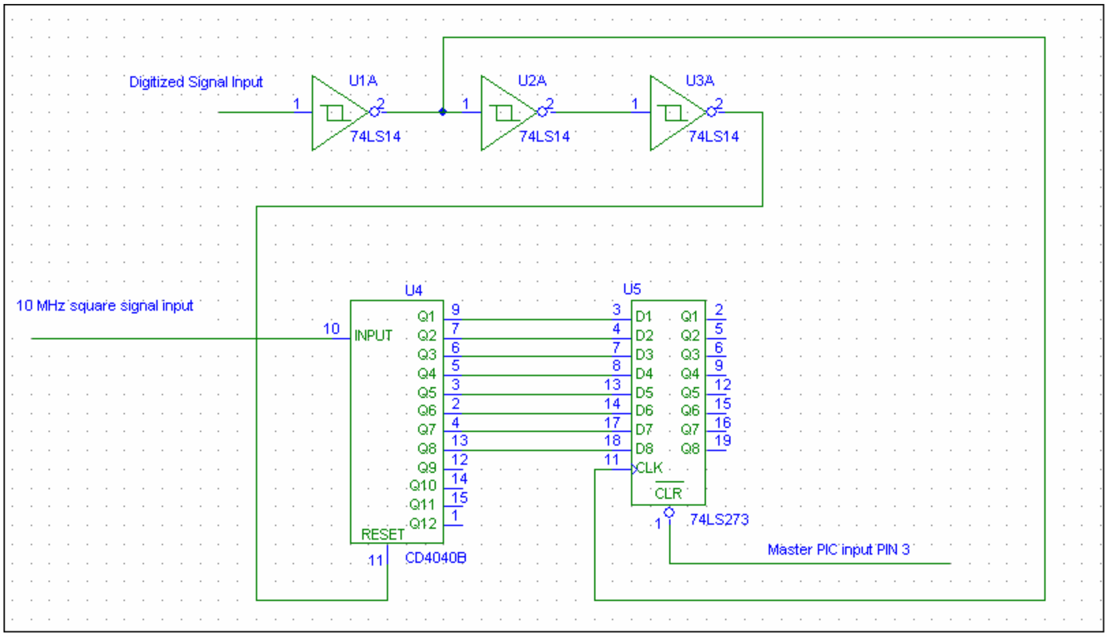


Figure 3.8 Counter and D Flip Flop

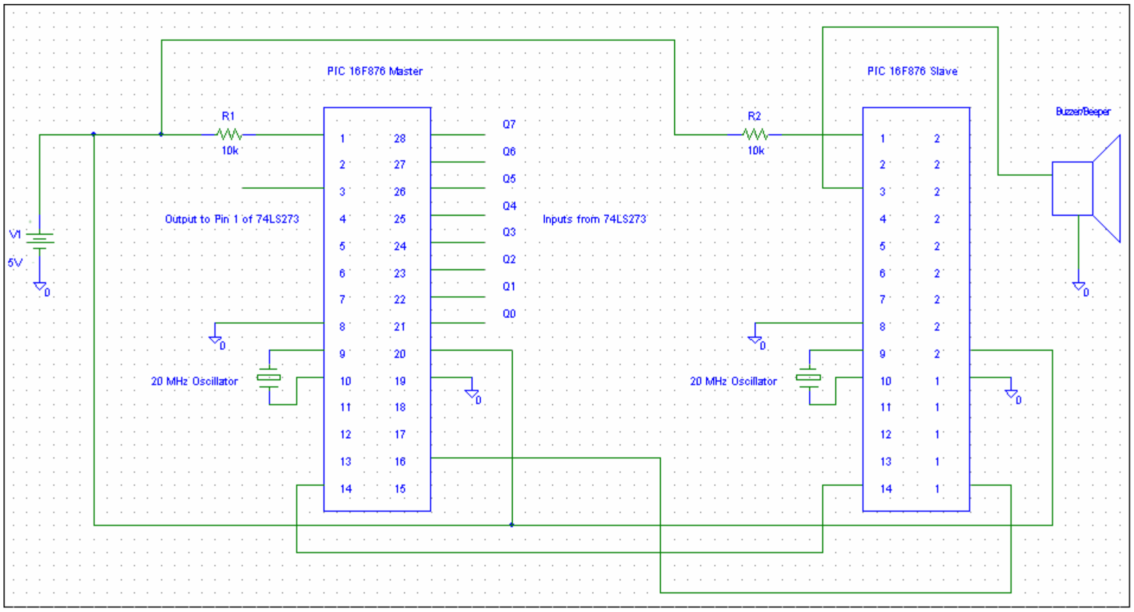


Figure 3.9 Master and slave PIC

3.2 Software

The programming language used to write the codes for the PICs is C. Two PICs are being used in this design, a master and a slave PIC.

3.2.1 Master PIC

Fig. 3.10 illustrates the flow diagram of the master PIC code.

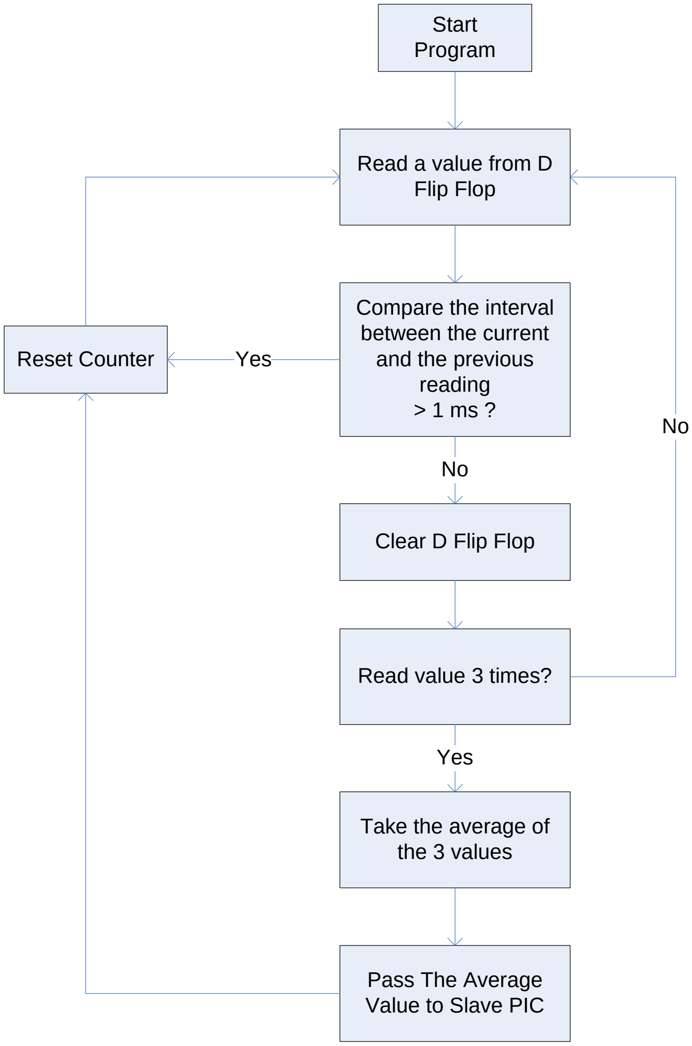


Figure 3.10 Master PIC flow diagram

The following is the code for the transmitter:

```
#if defined(__PCM__)

#include <16F876.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=20000000)

#use rs232(baud=4800,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)

#int_EXT


int8 loop;

int8 upper0;

int8 newdata;

int8 timeout;

int16 alldata;

int16 newdata16;


#INT_TIMER1

void wave_timer() {


if (timeout > 623) {

  timeout = timeout + 1;

  newdata = 0;

  newdata16 = 0;
```

```
  alldata = 0;

  timeout = 0;

  loop = 1;

  spi_write(newdata);

  SPI_READ();

}

}


void main(void)

{


  setup_spi(SPI_MASTER|SPI_L_TO_H|SPI_CLK_DIV_4);

  setup_timer_1(T1_DIV_BY_1);

  enable_interrupts(INT_TIMER1);

  enable_interrupts(GLOBAL);

  output_high(PIN_A1);

  timeout = 0;

  newdata = 0;

  alldata = 0;

  upper0 = 0;


  while(TRUE){
```

```
for (loop=1;loop<=3;loop++) {
  while (!input(PIN_A0));
  while (input(PIN_A0));
  while (!input(PIN_A0));
  while (input(PIN_A0));


  if (timeout <623) {
  newdata = input_b();
  output_low(PIN_A1);
  newdata16 = make16(upper0, newdata);
  alldata = alldata + newdata16;
  output_high(PIN_A1);
  timeout = 0;
  delay_us(10); }
  }
 newdata16 = alldata/3;
 newdata = make8(newdata16,0);
 spi_write(newdata);
 SPI_READ();
 newdata = 0;
 newdata16 = 0;
 alldata = 0;
 timeout = 0;
```

```
  }
}
```

Timer 1 is used for Master PIC. This 16 bit timer will increment every 1.6 μs by using a 20 MHz oscillator. An interrupt is needed to clear all values if there is a 1 ms gap between each signal. To do this we need to calculate how many times the timer needs to interrupt by using the following equation:

$$\text{Number of interrupts } = \frac{1ms}{1.6\mu s} = 625$$

3.2.2 Slave PIC

Fig. 3.11 illustrates the flow diagram of the slave PIC code.

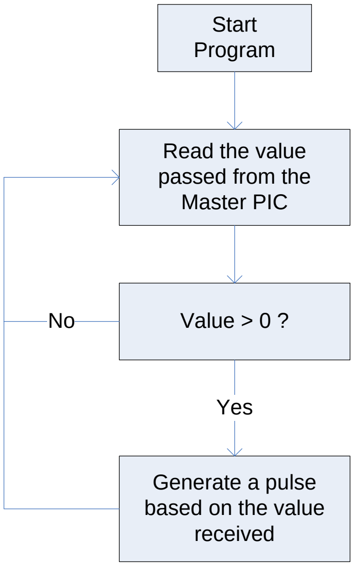


Figure 3.11 Slave PIC flow diagram

The following is the code for the transmitter:

```
#if defined(__PCM__)

#include <16F876.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=20000000)

#use rs232(baud=56000, xmit=PIN_C6, rcv=PIN_C7, stream=HOSTPC)

#int_EXT


int16 newfreq, value, reminder, pulse_width;

int8 totalperiod, periodhigh, periodlow;


void main(void)

{

  setup_spi(SPI_SLAVE|SPI_L_TO_H|SPI_CLK_DIV_4);

  pulse_width = 0;


  while(TRUE){


  if (spi_data_is_in()) {

    pulse_width = spi_read();


    if (pulse_width>0)     {
```

```
     newfreq = ((pulse_width*100) /3);
     value = 10000/newfreq;
     value = value*10;
     reminder = 10000%newfreq;
     reminder = (reminder*10)/newfreq;
     totalperiod = value + reminder;
     periodhigh = totalperiod/2;
     periodlow = totalperiod - periodhigh;
     output_high(PIN_A1);
     delay_ms(periodhigh);
     output_low(PIN_A1);
     delay_ms(periodlow);
                    }
                }
 }
}
```

The slave PIC only accepts the average value from the master PIC if and only if the value is greater than 0, which means that there is a signal coming to the master PIC. The next thing that the slave PIC does is to generate a square wave signal corresponding to the average value the slave PIC received from 1 Hz, which corresponds to an average value of 1 to 18 Hz which corresponds to an average value of 255. The easiest way to do this using a calculator is to divide 255 with 14 which will give us 18.2143, and since the PIC can only delay integer numbers, it will round 18.2857 to 18. The same thing will happen if the PIC happens to read 254, 254 divide by 14 will also yield 18 as the final answer. To solve this problem we need to have a reminder. The followings are the explanation on how the slave PIC does the calculation to generate a square wave pulse:

1. Multiply pulse_width (the average value sent by the master PIC) by 100 then divide the result by 14.

   newfreq = ((pulse_width*100) /14);

   Assuming pulse_width = 255, the value of newfreq will be 1821

2. Divide 10000 with newfreq to generate value

   value = 10000/newfreq;

   at this point the value of value will be 5

3. Multiply value by 10

   value = value*10;

   at this point the value of value will be 50

4. Find the reminder of 10000 divided by newfreq

   reminder = 10000%newfreq;

   at this point the value of the reminder will be 895

5. To find the decimal value of newfreq, we can use

   reminder = (reminder*10)/newfreq;

   at this point the value of the reminder will be 4

6. The total period of the output pulse will be

   totalperiod = value + reminder;

   which is equal to 50 + 4 = 54 ms (close to 18 Hz)

7. To generate the square wave pulse and make the duty cycle to be 50% or close to 50% we need to make sure that the period when the signal stays high and low are approximately equal. A simple solution to do this is by using the following equations:

   periodhigh = totalperiod/2;

   periodlow = totalperiod - periodhigh;

   at this point the value of periodhigh will be 27 ms and periodlow will be 27 ms. This is to prevent two values on pulse_width having the same periodhigh if we are to say that periodhigh = periodlow = totalperiod/2. For example: having totalperiod to be 52 and 53 will yield 26 for periodhigh, but they yield different values for period low.

Unfortunately the above calculations only work in theory. In real life the master PIC will take some time to execute each line. This will result in lower output frequency than we expected. One way to solve this is to change the divisor on step 1 from 14 to 3.

3.3 Result

The first test that was conducted to check whether the ultrasonic transmitter and receiver worked or not was to put them facing each other directly. Fig. 3.12 will illustrate this.

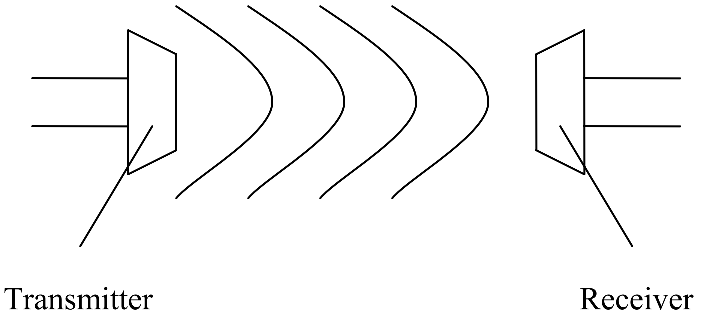
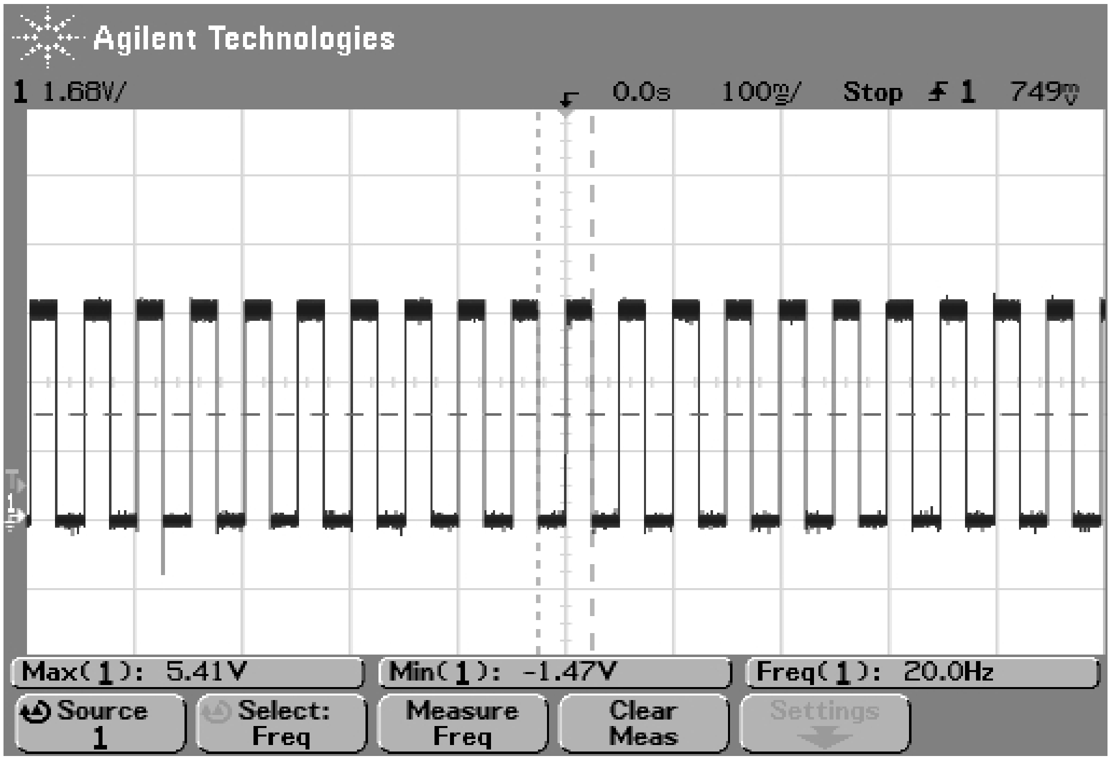


Figure 3.12 Ultrasonic transmitter and receiver facing each other

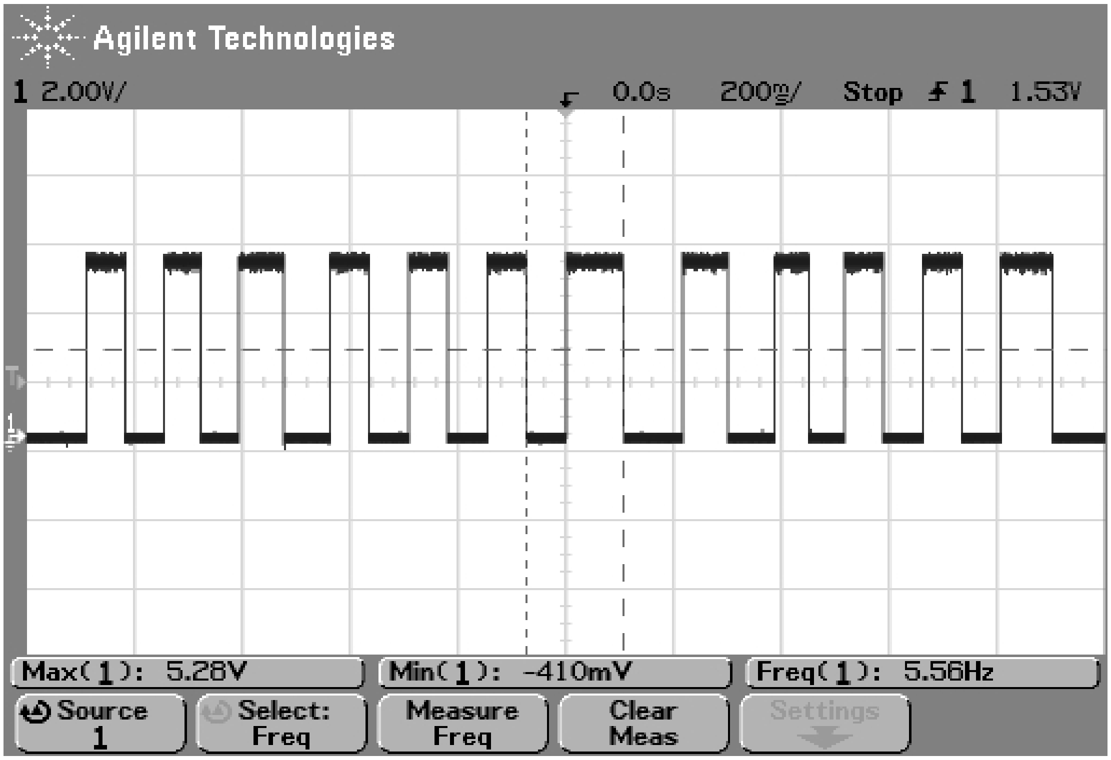
Fig. 3.13 and 3.14 show the output of the slave PIC when the transmitter and receiver were about 5 cm and 5 m apart inside a lab.



1 1.68V/ 0.0s 100µs/ Stop 1 749mV

Max(1): 5.41V
Min(1): -1.47V
Freq(1): 20.0Hz

Figure 3.13 Ultrasonic receiver output when it was 5 cm in front of transmitter



1 2.00V/ 0.0s 200µs/ Stop 1 1.53V

Max(1): 5.28V
Min(1): -410mV
Freq(1): 5.56Hz

Figure 3.14 Ultrasonic receiver output when it was 5 m in front of transmitter

One can conclude that the transmitter and receiver work just fine within 5 meter range and probably even more when they are facing each other. The test that was needed for the final design was to put the ultrasonic transmitter and receiver side by side and see whether the ultrasonic receiver can pick up the reflection signals or not. Fig. 3.15 illustrates this.

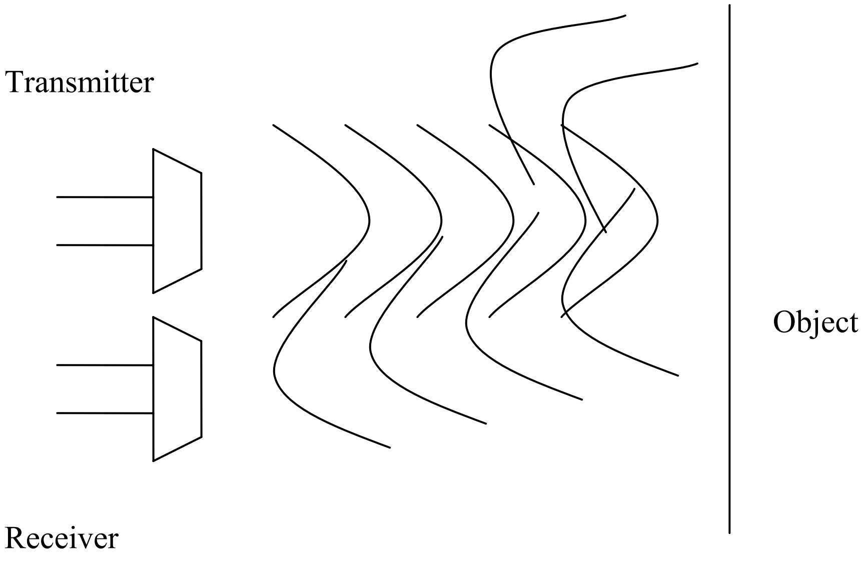


Figure 3.15 Ultrasonic transmitter and receiver are in parallel

The reason we need to have quite a distance between the ultrasonic transmitter and receiver is because we do not want the receiver to receive the signals. One way to solve this is to insert a metal between the ultrasonic transmitter and receiver. This was proven to be a problem because it is hard to find the right metal to isolate the ultrasonic transmitter and receiver, and cut the metal so that it will match the size of the ultrasonic transmitter and receiver. Another way to do it is to separate them far enough so that they will not interfere each other. This has proven to be the most cost effective method in solving the problem, and it also brings a whole new perspective on how the ultrasonic transmitter and receiver may be attached to a blind person. Fig. 3.16 shows the final design on how the transmitter and receiver may be attached to a human body.

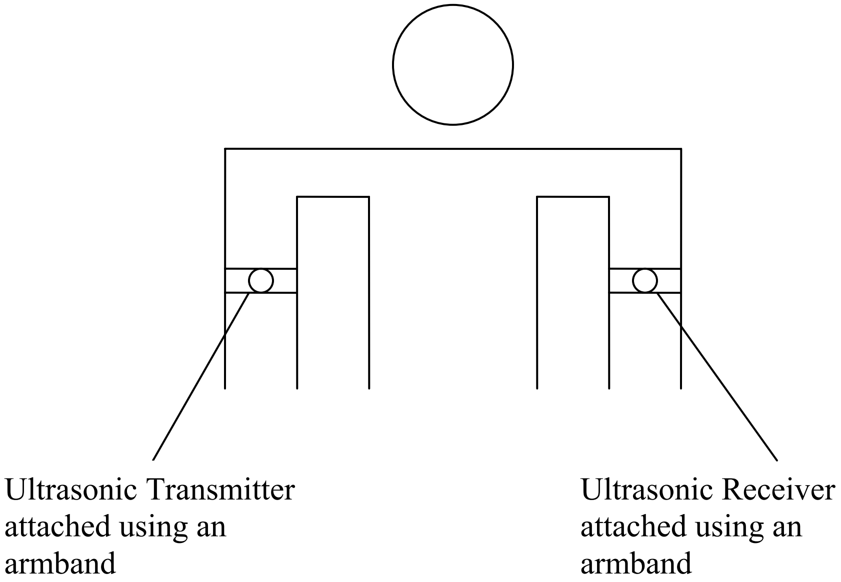


Figure 3.16 Ultrasonic device attached to human arms

The ultrasonic transmitter and receiver are facing front or away of us. This way the ultrasonic transmitter will not be able interfere the receiver directly.

The following figures show the output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 15 cm, 30 cm, 45 cm, 60 cm, 75 cm, 90 cm, 120 cm, 150 cm, 180 cm, and 210 cm apart inside a lab in a sequence. Note that the distance between the ultrasonic transmitter and receiver were about 25 cm apart.

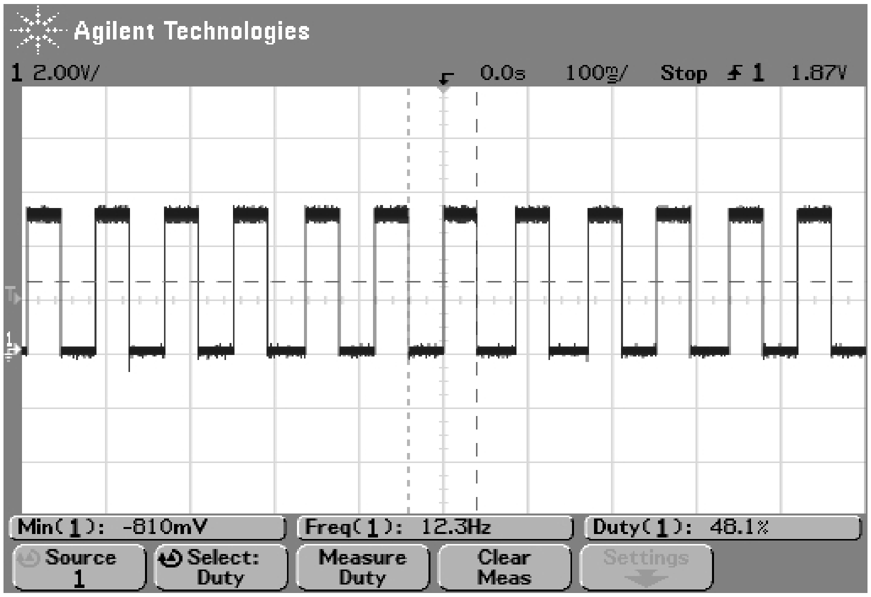


Figure 3.17 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 15 cm

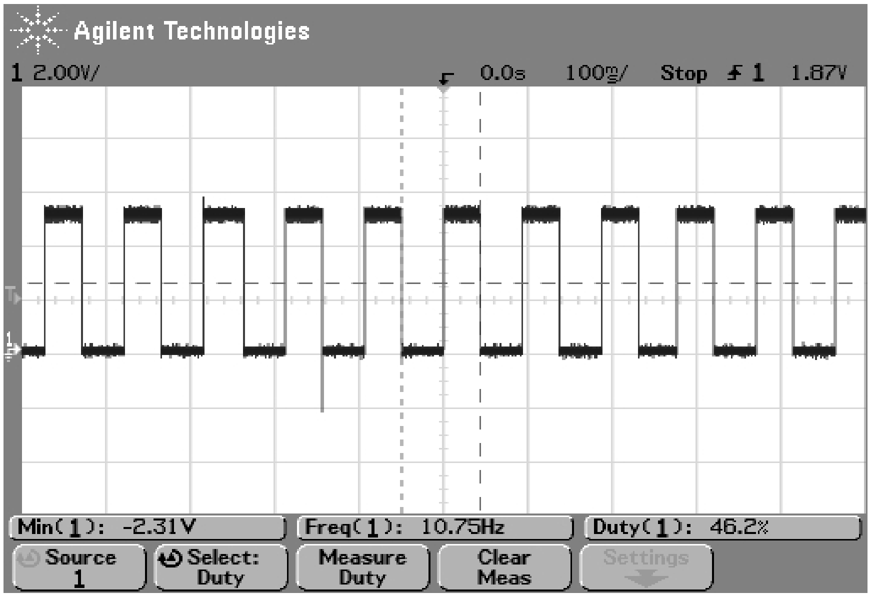
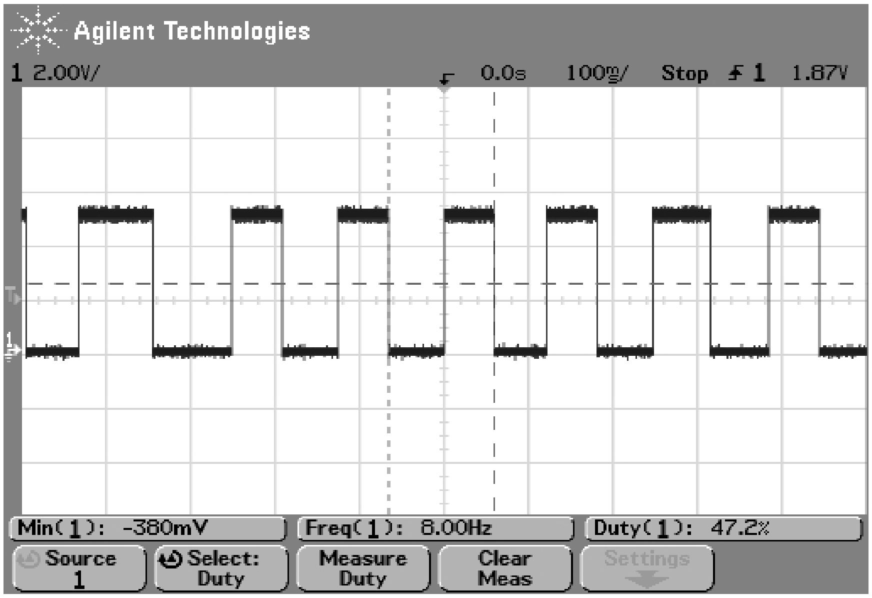


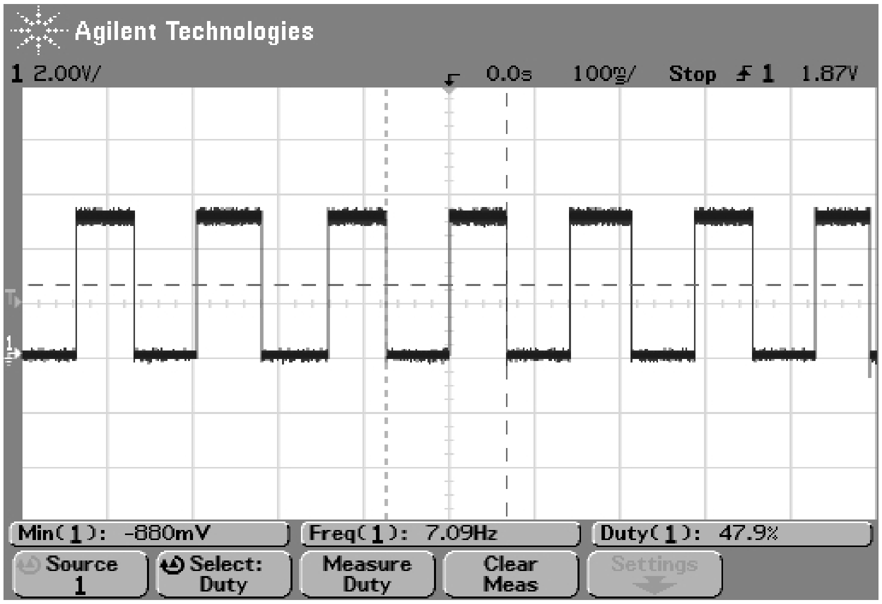
Figure 3.18 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 30 cm



1 2.00V/ 0.0s 100ms/ Stop 1 1.87V

Min(1): -380mV Freq(1): 8.00Hz Duty(1): 47.2%

Figure 3.19 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 45 cm



1 2.00V/ 0.0s 100ms/ Stop 1 1.87V

Min(1): -880mV Freq(1): 7.09Hz Duty(1): 47.9%

Figure 3.20 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 60 cm

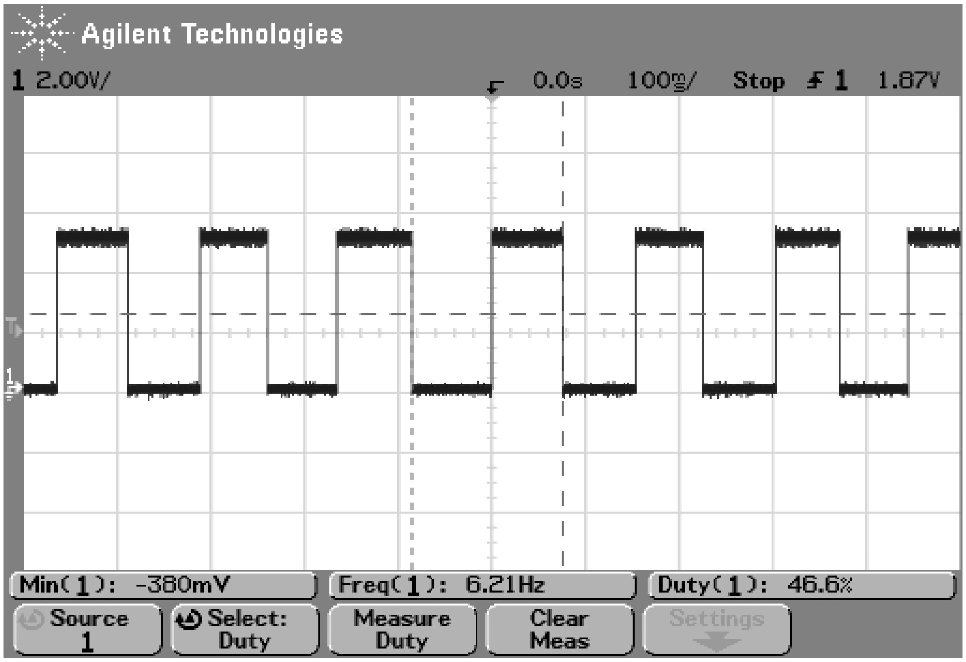


Figure 3.21 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 75 cm

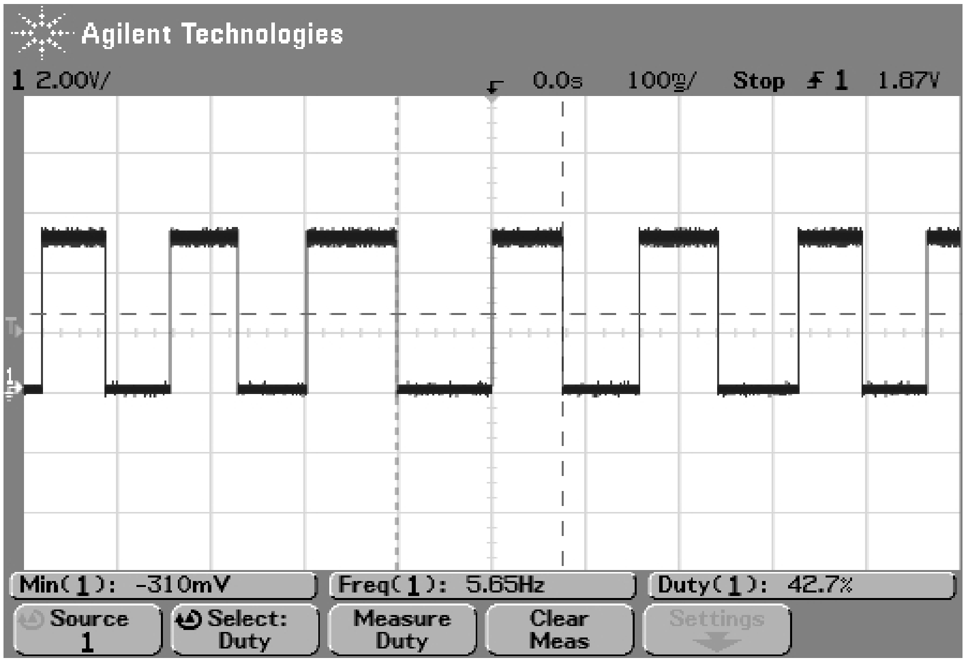


Figure 3.22 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 90 cm

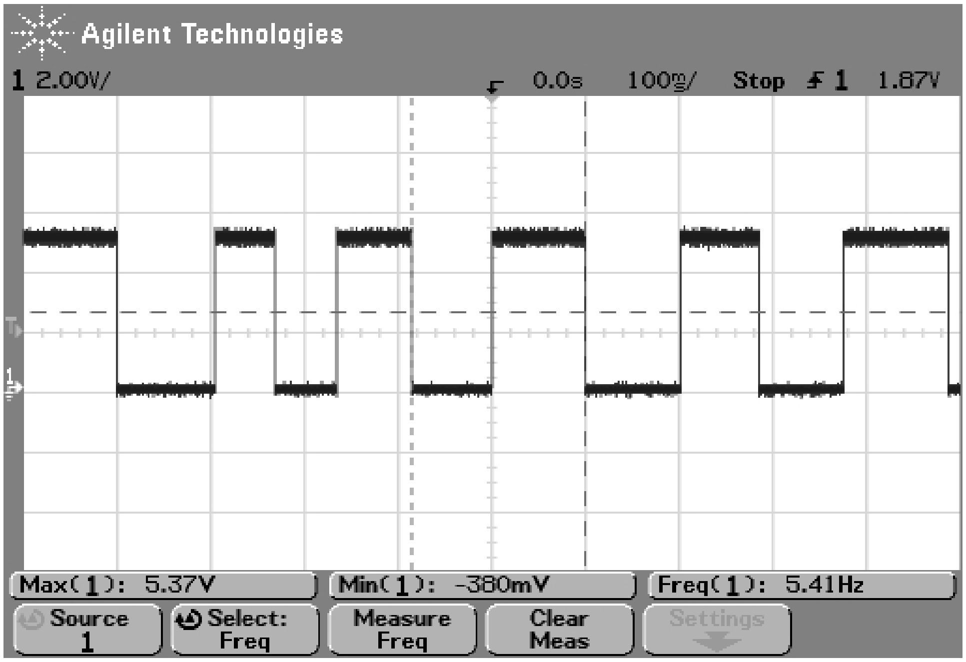


Figure 3.23 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 120 cm

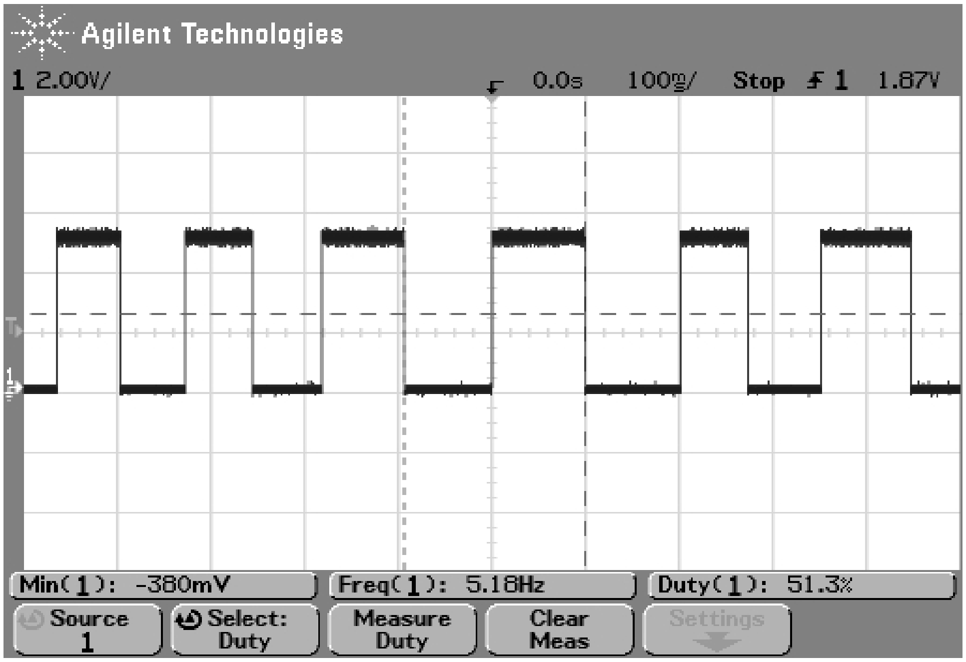


Figure 3.24 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 150 cm

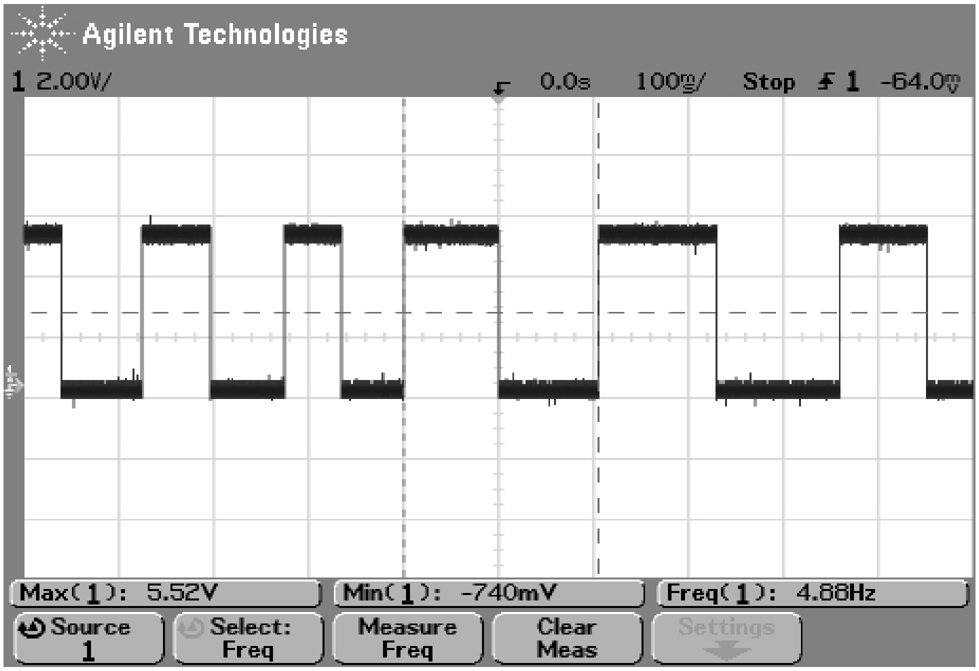


Figure 3.25 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 180 cm

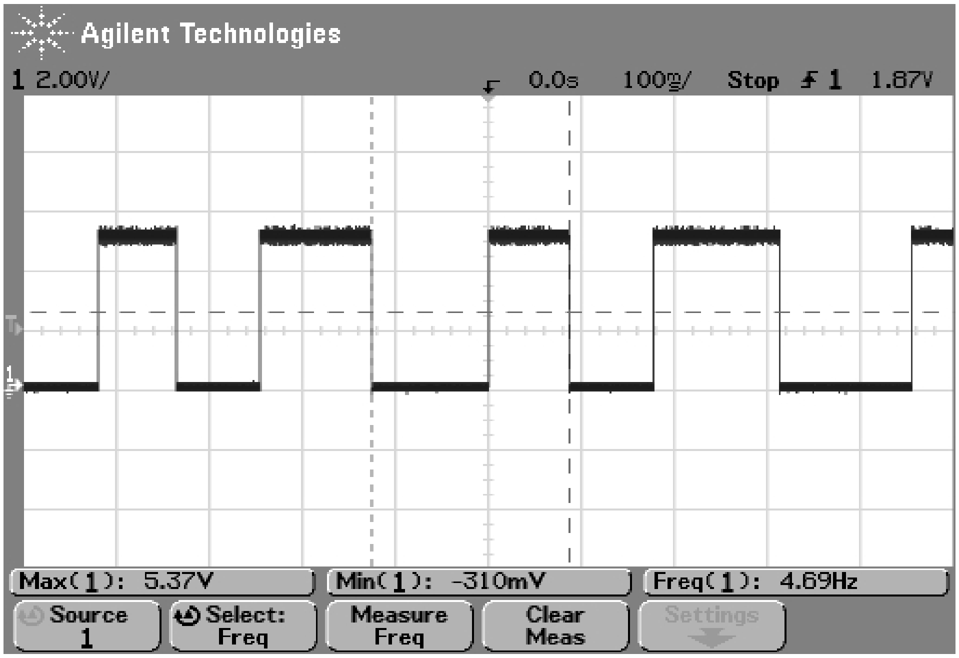


Figure 3.26 The Output of the slave PIC when the distance between the ultrasonic transmitter and receiver, and a wall were about 210 cm

Fig. 3.27 below shows the relationship between the distance of an object relative to the ultrasonic transmitter and receiver with the signals frequency generated by the PIC based on the measurements taken above.

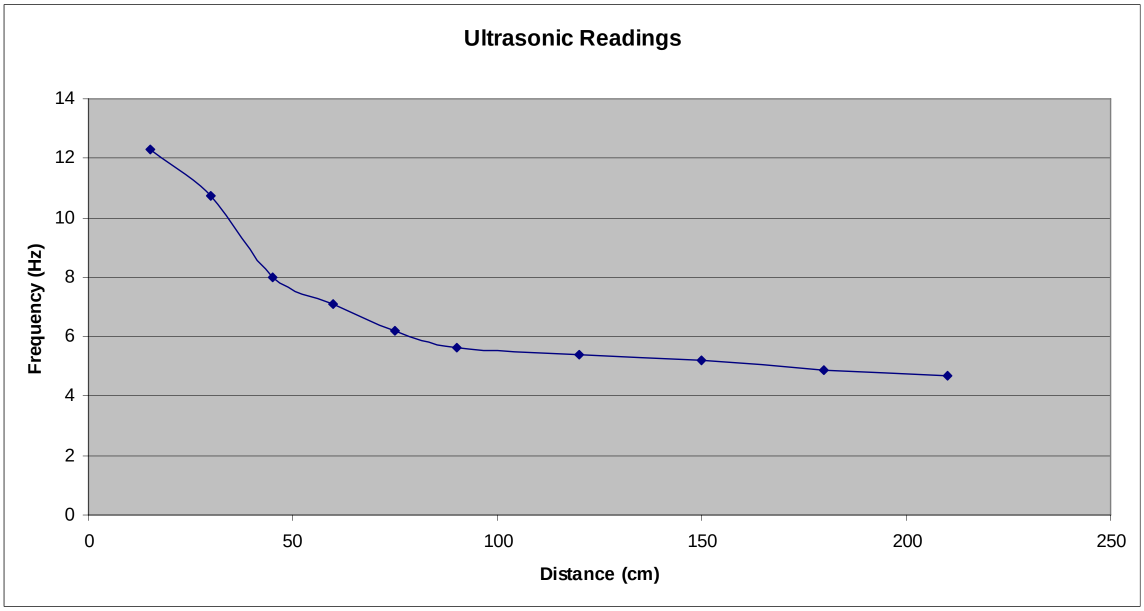


Figure 3.27 A graphical representative of the ultrasonic readings taken from a lab

The readings taken on the lab, which has metal desks and chairs, was not as reliable as any readings outside the lab. Any metal objects will reflect ultrasound, and too many metal objects will cause interferences. Ultrasonic readings is more reliable outside of the lab, on the open fields, where no metal objects will affect the readings severely. Using the same configurations above, where the ultrasonic transmitter and receiver are in parallel with 25 cm distance between them, the receiver can get signal up to 6 meters in front of it. One technical challenge that was faced was the use of a PIC to measure the duty cycle of the digitized signals. The 16F876 PIC can not be used for such application. The PIC has at least an 8 bit timer and a 16 bit timer. Timer 1, which is a 16 bit timer, will increment every 1.6 μs using a 20 MHz oscillator. Based on our calculations above, to map a 25 μs signal to an 8 bit value, each bit will have a period of:

$$T_{1bit} = \frac{25\mu s}{256} = 0.0977\mu s$$

Timer 0 which is an 8 bit timer, will even increment at a slower rate than Timer 1 using a 20 MHz oscillator. 1.6 μs is clearly greater than 0.0977 μs and because of this some additional circuits are needed such as a 20 MHz oscillator, inverters and a D Flip flop to map a 40 kHz signal to a 256 bit value.

Chapter 4

Conclusion

This thesis has discussed some fundamental ideas of ultrasonic, how ultrasonic waves propagate, measure their velocities in three different mediums, what causes ultrasonic waves to reflect and refract, and some real life examples where they can be used to help increasing our quality of life. The advantages of using this design are portable, relatively light, relatively easy to build and reliable in open field. This device can detect any objects up to 6 meters in range. This device always updates its readings in miliseconds, which is good in detecting fast motion objects such as cars and motorcycles. Most of the components used here are low power chips, hence increasing the life of the batteries used. The idea of putting the ultrasonic transmitter and receiver on someone's arms will allow that person to detect any objects directly in front of him and on the ground as well. This design is reliable in an open field area such as on a park or on a sidewalk. There are still a lot of applications out there that might find ultrasonic to be useful, it is up to engineers to design and improve those applications using their creativity.

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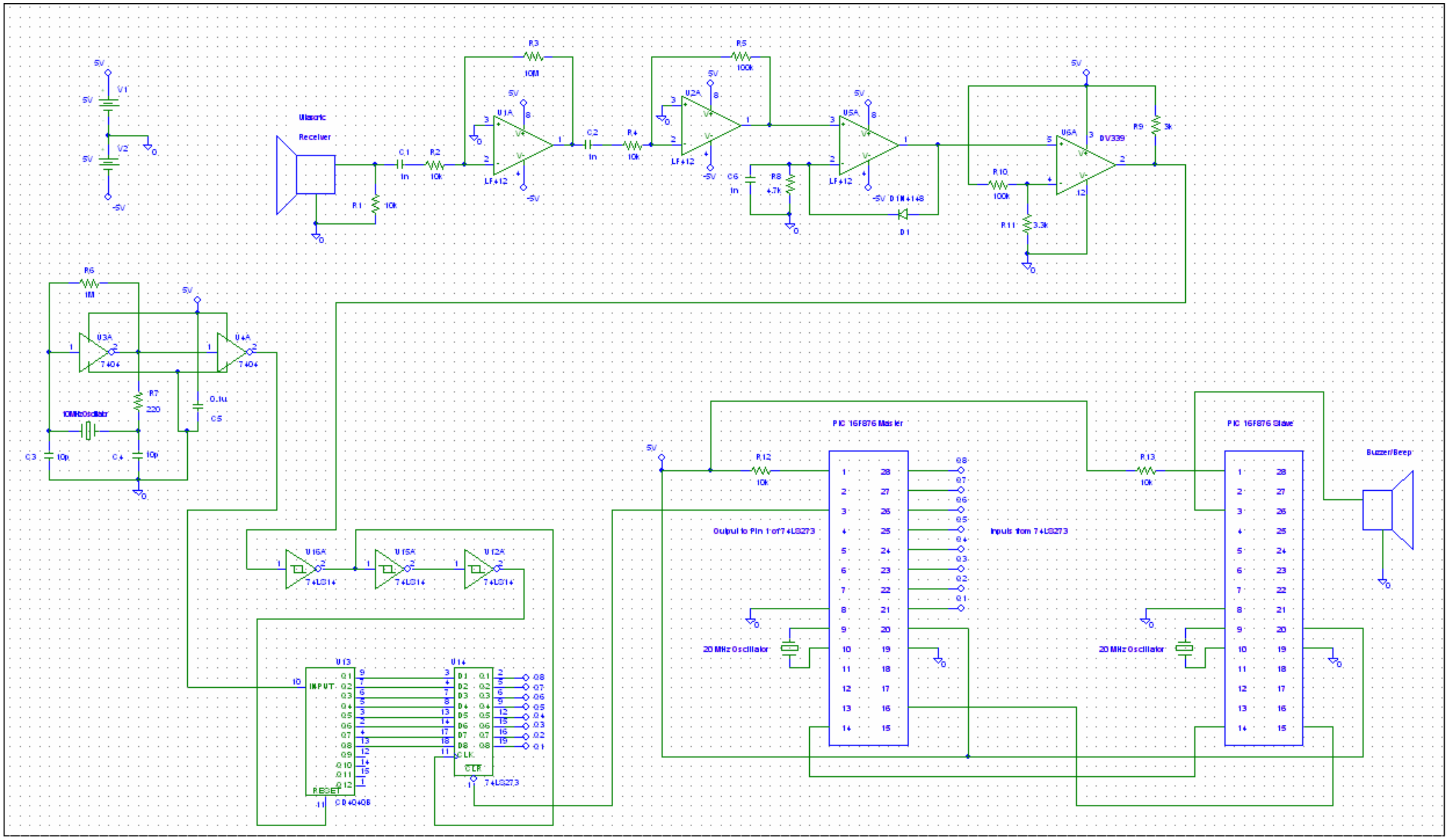
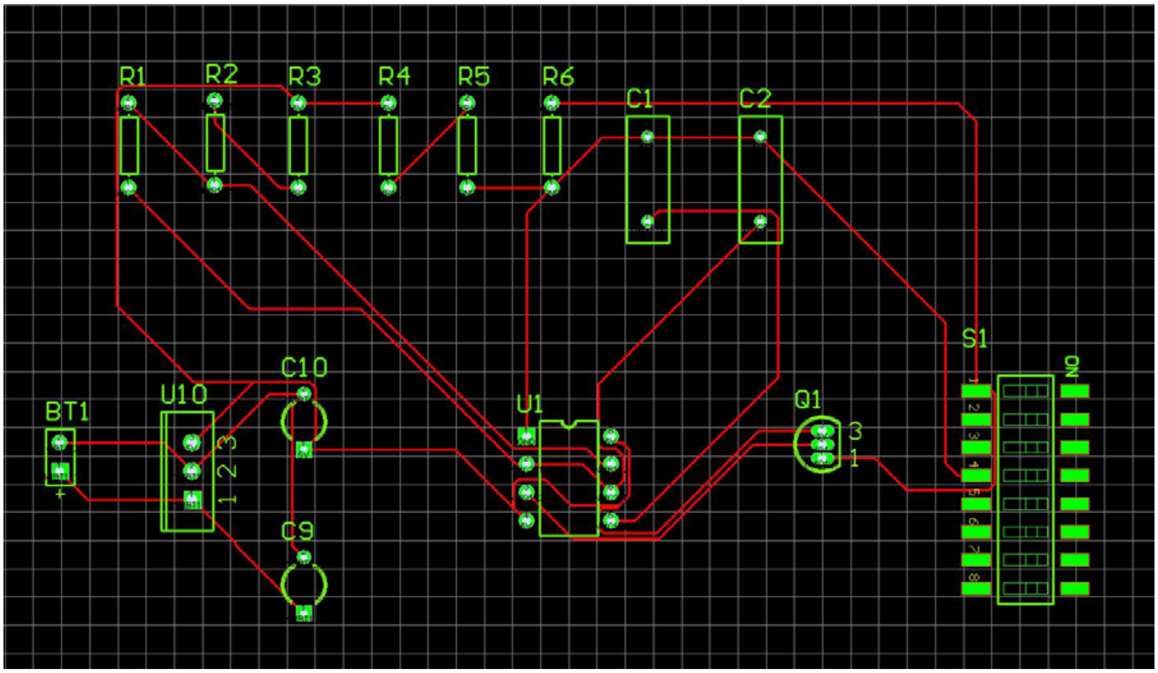
APPENDIX A

Ultrasonic Receiver full circuit


V1
V2
5V
-5V
Ultrasonic
Receiver
R1
10k
C1
1n
R2
10k
U1A
LF412
R3
10M
C2
1n
R4
10k
U2A
LF412
R5
100k
U5A
LF412
C6
1n
R8
4.7k
D1
D1N4148
U6A
DV339
R9
3k
R10
100k
R11
3.3k
R6
1M
U3A
7404
U4A
7404
R7
220
C5
0.1u
C3
10p
C4
10p
10MHz Oscillator
U16A
U15A
U12A
74LS14
U13
INPUT
RESET
CD4040B
U14
CLK
CLR
74LS273
PIC 16F876 Master
PIC 16F876 Slave
R12
10k
R13
10k
20 MHz Oscillator
Output to Pin 1 of 74LS273
Inputs from 74LS273
Buzzer/Beep

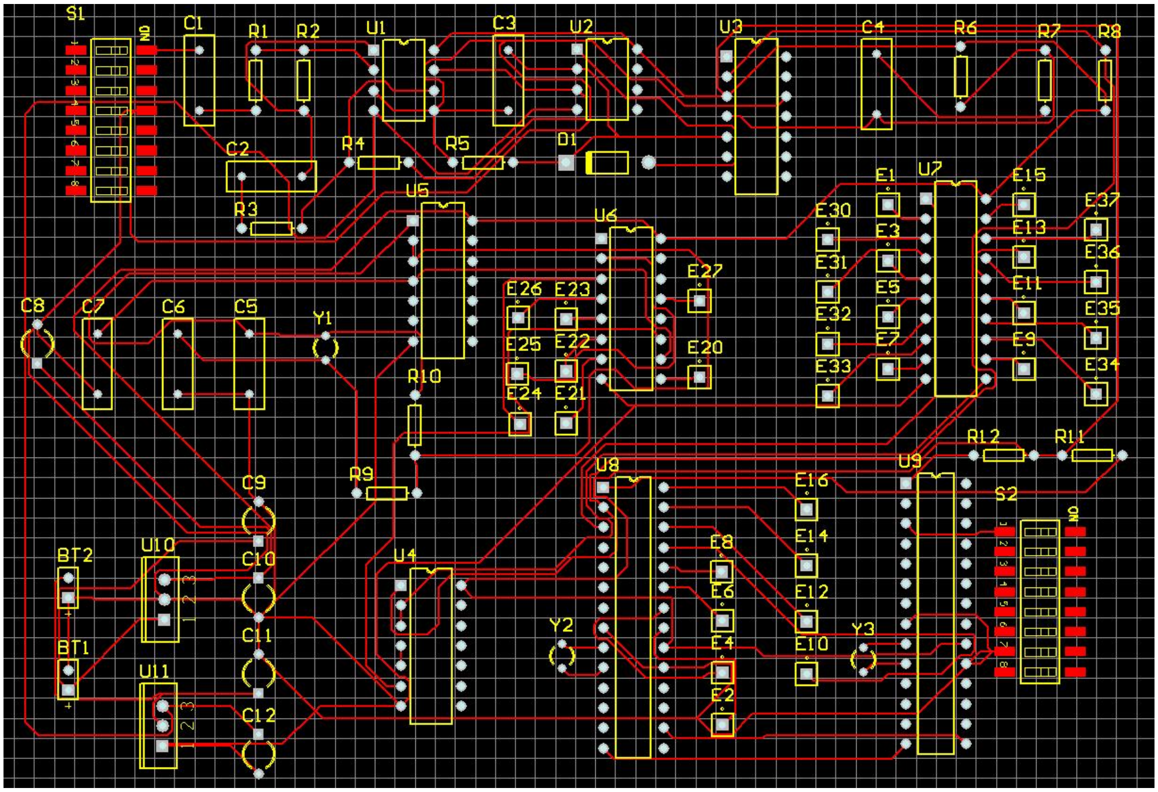
APPENDIX B

Ultrasonic Transmitter Printed Circuit Board Traces



This drawing is generated using Protel 2004.

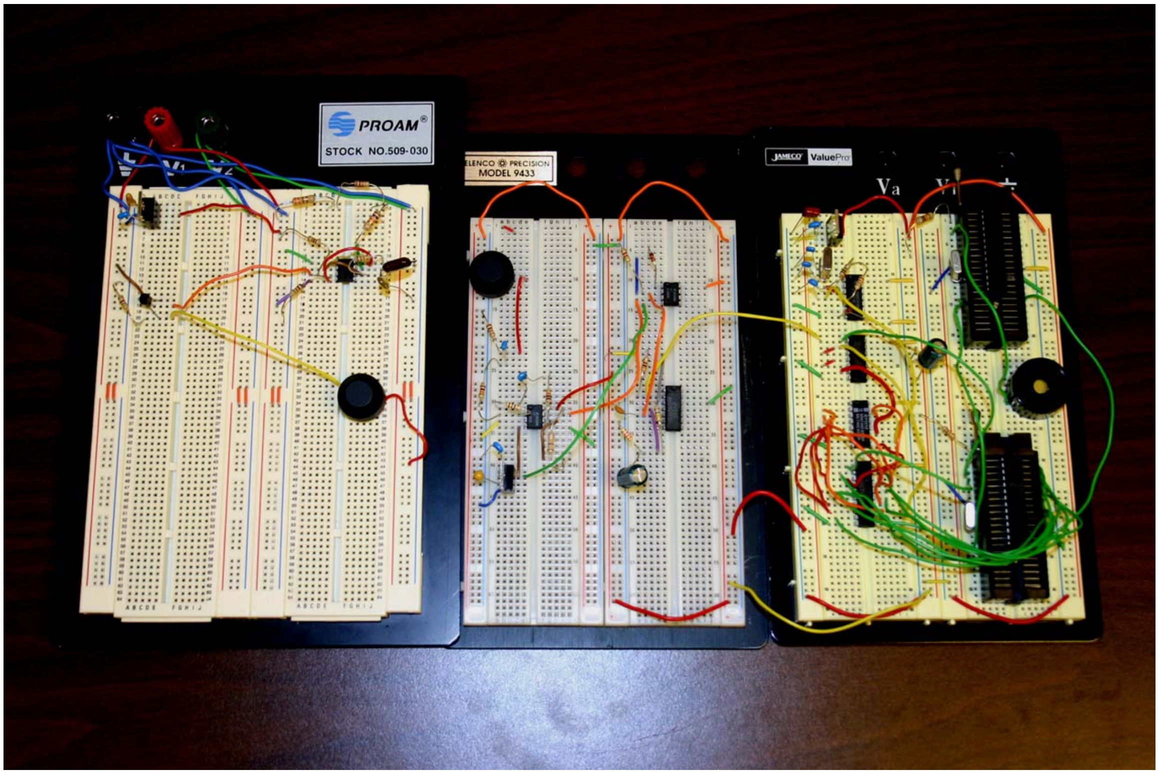
Ultrasonic Receiver Printed Circuit Board Traces



This drawing is generated using Protel 2004.

APPENDIX C

Breadboard photo



The left breadboard is used for the ultrasonic transmitter.

The middle and right breadboard are used for the ultrasonic receiver.

VITA

Julius J. Marpaung

Candidate for the Degree of

Master of Science

Thesis: AN IMPLEMENTATION OF AN ULTRASONIC DEVICE FOR THE VISUALLY IMPAIRED

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Name: Julius Marpaung Date of Degree: May, 2006
Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: AN IMPLEMENTATION OF AN ULTRASONIC DEVICE FOR THE VISUALLY IMPAIRED

Pages in Study: 54 Candidate for the Degree of Master of Science
Major field: Electrical and Computer Engineering

Scope and Method of Study: Ultrasonic is defined as any bands above audible band (20 kHz) and up to MHz range, and it is widely used in many fields, such as medical, engineering, and military. Another unique characteristic of ultrasonic waves is that it can penetrate opaque materials that other waves cannot. This makes it a very valuable asset to measure distance and thickness of an object in an inexpensive and reliable way.

This paper describes a simple and inexpensive but yet reliable ultrasonic device to help the visually impaired people to detect objects several meters away. There are a number of ways to design a device engaging ultrasonic principle. In our approach the detection is initially reflected as a change of duty cycle, and then it is converted into the variation of the frequency, and eventually the user is alerted by the sound from a buzzer. The transmitter sends a continuous 40 kHz signal without modulation. The reflected ultrasonic signal collected by the receiver is very weak, and thus it needs to be amplified and rectified. Two Peripheral Interface Controllers (PICs) are employed in this design.

Findings and Conclusions: A good feature about this device is that it can updates its readings very quickly, which is required in detecting fast moving objects, such as cars and motorcycles. Most of the components used here are low power chips, hence battery lifetime can be prolonged. The small volume and light weight make it possible to put the ultrasonic transmitter and receiver on someone's arms, which is a convenient way to detect objects on the way ahead.

Advisor's Approval: Dr. Yumin Zhang