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Ultrasonic Distance Measurement Using PIC 16F877A and HC-SR04 Sensor

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Abstract

The aim of this project is to design and implement an inexpensive and effective device which can measure distance using ultrasonic sound. The system's cost is reduced with the use of the PIC16F877A micro-controller, and it is made non-contact through the use of the HC-SR04 ultrasonic transducer module. The non-contact distance measurement system is used in a wide range of applications, including industrial work, robotic movement control, thread or wire break detection, determining air flight distance, sea level detection, vehicle detection for car wash and automotive assembly and more. This paper focuses on the usage of a distance measurement system that may be automated and utilized for a variety of tasks. In a word, this paper presents a better technique for measuring distances in real-world situations. The hardware of the proposed ultrasonic distance measurement system is implemented and tested in breadboard and Printed Circuit Board (PCB).

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Chapter 1

Introduction

These days, length measurement is utilized in all aspects of life to promote fair business practices and the creation of new, improved goods and procedures that raise our level of living. There are several methods for measuring distance without making touch. One method makes use of a laser, and the other makes use of ultrasonic waves. "Ultrasound" is the term used to describe noises that are louder than the range of frequencies that fall inside human range of hearing, which is between 300 Hz and 14000 Hz. Ultrasound waves travel in a straight path because of their high frequency. Due to the tremendous energy of ultrasound, which can readily reflect from hard things in front of it, it may travel across great distances. These features of Ultrasonography can be applied to measuring distance. It is impossible to employ traditional distance measurement techniques in this situation if the distance is continually changing during the measurement. Because distances are continually changing, such as when detecting movement direction, determining distances for robotic and automobile applications, using infrared communication, and object identification investigations, distance determination using ultrasound sources is common.[**b1**].

Chapter 2

Working and Design of Circuit

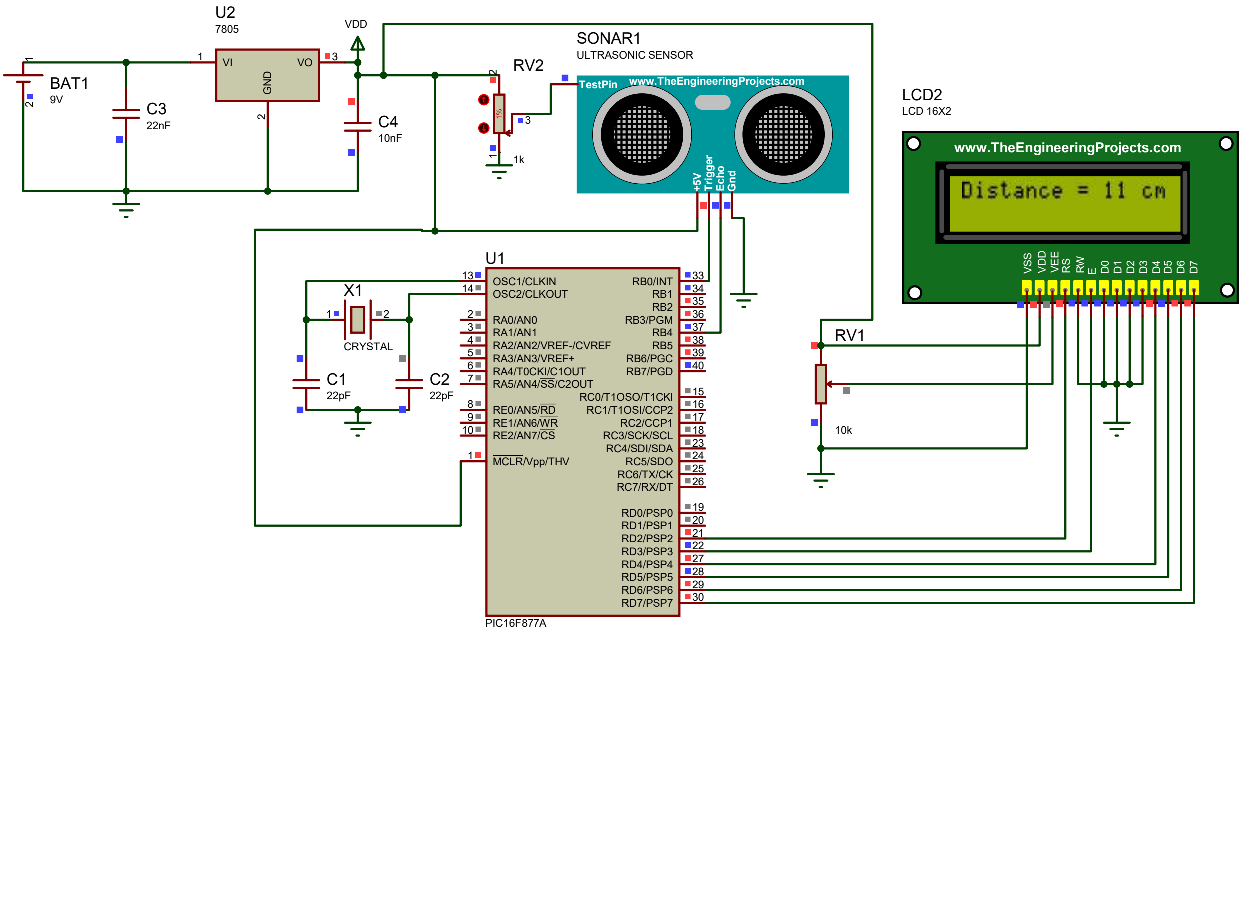

Figure 2.1: Circuit Diagram (Software Aided Design)

The designed system mainly consists of a 40-pin micro-controller unit (PIC16F877A), a 4- pin sonar sensor (HC-SR04), an LCD display, a 8 MHz crystal oscillator to provide clock frequency, two 22 pf capacitors etc. The ultrasonic sensor initiates an ultrasonic burst of 8 pulses at 40 kHz when the micro-controller sends a 10 s pulse to the trig pin of the sensor.When an ultrasonic burst is transmitted, the echo pin goes high, and when the sensor receives the echo, it goes low.The duration that the echo pin remains high is utilized to calculate the distance.Simple math is used to convert the analog data of the time it took for the sound wave to reach the sensor into distance. The computed result is displayed on the LCD module and gives the distance in centimeters. Only once the echo has faded away can the next triggering pulse be sent, and this time period is called cycle period.The cycle period for HC-SR04 must not be below 400 µs.

2.1 Flowchart

The entire working principle can be very briefly understood via a flow chart.

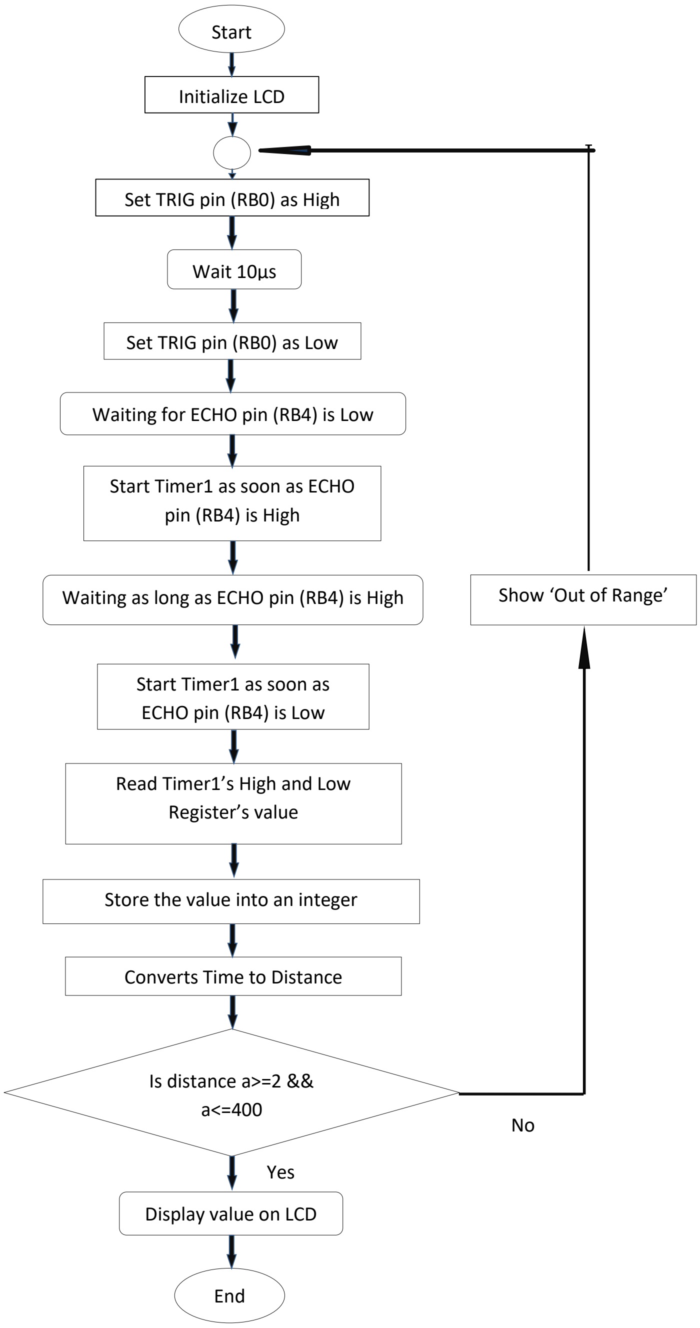

Figure 2.2: Flowchart of the project architecture

2.2 Description of Components

1. PIC 16F877A

   The PIC16F877A ,a 40-pin device, is one of the popular micro-controllers used in complex applications. The device offers 8192 x 14 flash program memory, 368 bytes of RAM, 256 bytes of non-volatile EEPROM memory, 33 I/O pins, 14 ADC pins and two comparator circuits, USTART, and external interrupt facilities.

Figure 2.3: PIC 16F877A

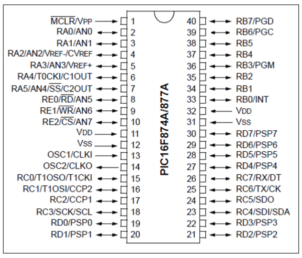

Figure 2.4: The pin configuration of the PIC16F887A micro-controller

2. HC-SR04 Ultrasonic Sensor

   Distance Sensor does non-contact distance measuring. With a 3mm accuracy, it can measure a range of distances from 2 cm to 400 cm. This module has an ultrasonic receiver, an ultrasonic transmitter, and a control circuit. On the HC-SR04, there are only four pins: VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground). To connect this module to a micro-controller, TRIG and ECHO pins can be used. The input and output pins are TTL (0 to 5V).

Figure 2.5: HC-SR04 Ultrasonic Sensor

3. 8MHz crystal

   8MHz crystal oscillator is an electronic device which is used to generate a constant frequency signal. It absorbs pressure and movement energy and then transforms it into an electrical frequency. It generates periodic signals.

Figure 2.6: 8MHz crystal

4. The 16 x 2 Lines LCD Module

   A liquid crystal display (LCD) is a type of electronic display that may show text, numbers, and measuring information. Alphanumeric text displays and numeric displays are the two basic categories of LCD displays. The LCD 16x2 has 16 Columns and 2 Rows, allowing it to display a total of 32 characters (16 x 2=32), each of which is made up of 5x8 Pixel Dots. Therefore, 32 x 40 or 1280 pixels can be used to calculate the total number of pixels in this LCD.

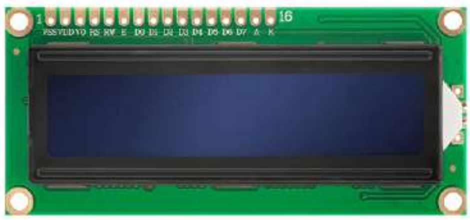

Figure 2.7: 16 x 2 Lines LCD Module

5. Power Supply

The operating voltage of the PIC16F887A micro-controller is between 4.2 volts to 5.5 volts to make it works. The ultrasonic sensor and other devices use the same amount of power. To supply power to the micro-controller, a 9 Volts dc non-rechargeable battery has been used for this project and it is further converted to 5 Volts using a voltage regulator.

Figure 2.8: Power Supply

6. The 7805 Voltage Regulator

The output voltage is kept constant using a voltage regulator integrated circuit (IC). The voltage regulator IC 7805 is actually a component of the voltage regulator ICs in the 78xx series, where the xx stands for the value of the fixed output voltage that the specific IC offers. A fixed linear voltage regulator, that is. It is a +5V DC controlled power supply for the 7805 IC.

Figure 2.9: The 7805 Voltage Regulator

7. Potentiometer 10 kΩ

Potentiometers are used to change the electrical parameters of a system. 10k Potentiometer with a rotating knob,is commonly called as a rotary potentiometer or just POT in short.In this project we use this potentiometer to change the contrast of the LCD.

Figure 2.10: Potentiometer 10 kΩ

8. 22pF Capacitors

22pF capacitor is used with crystals for loading purposes. 22pF capacitors connected along with the crystal will stabilize the oscillations generated by the crystal.

Figure 2.11: 22pF Capacitors

2.3 Mathematical Formula

The formula used for distance calculation is as follows: $D = vt/2$

Determining the time delay between the sending and the receiving signals and considering the velocity of sound wave,the distance is calculated in centimeters.

$DISTANCE = SPEED * TIME$

Let d be the distance between HC-SR04 Ultrasonic Sensor and Target

Total distance traveled by the ultrasonic burst : 2d (forward and backward)

Speed of Sound in Air : 340 m/s = 34000 cm/s

$Thus, d = (34000 * T)/2, whereT = (TMR1H : TMR1L)/(1000000)$

$$Therefore, d = (TMR1H : TMR1L)/58.82cm$$

TMR1H:TMR1L = $TMR1L|(TMR1H << 8)$

2.3.1 Program code

Listing 2.1: A MicroC code for the distance measurement using PIC 16F877A and HC-SR04 Sensor label

```
// LCD module connections
sbit LCD_RS at RD2_bit;
sbit LCD_EN at RD3_bit;
sbit LCD_D4 at RD4_bit;
sbit LCD_D5 at RD5_bit;
sbit LCD_D6 at RD6_bit;
sbit LCD_D7 at RD7_bit;

sbit LCD_RS_Direction at TRISD2_bit;
sbit LCD_EN_Direction at TRISD3_bit;
sbit LCD_D4_Direction at TRISD4_bit;
sbit LCD_D5_Direction at TRISD5_bit;
sbit LCD_D6_Direction at TRISD6_bit;
sbit LCD_D7_Direction at TRISD7_bit;
// End LCD module connections

void main()
{
  int a;
  char txt[7];
  Lcd_Init();
  Lcd_Cmd(_LCD_CLEAR);          // Clear display
  Lcd_Cmd(_LCD_CURSOR_OFF);     // Cursor off
```

```
  TRISB = 0b00010000;            //RB4 as Input PIN (ECHO)

  Lcd_Cmd(_LCD_CLEAR);

  T1CON = 0x10;                  //Initialize Timer Module

  while(1)
  {
    TMR1H = 0;                   //Sets the Initial Value of Timer
    TMR1L = 0;                   //Sets the Initial Value of Timer

    PORTB.F0 = 1;                //TRIGGER HIGH
    Delay_us(10);                //10uS Delay
    PORTB.F0 = 0;                //TRIGGER LOW

    while(!PORTB.F4);            //Waiting for Echo
    T1CON.F0 = 1;                //Timer Starts
    while(PORTB.F4);             //Waiting for Echo goes LOW
    T1CON.F0 = 0;                //Timer Stops

    a = (TMR1L | (TMR1H<<8));    //Reads Timer Value
    a = a/58.82;                 //Converts Time to Distance
    a = a + 1;                   //Distance Calibration
    if(a>=2 && a<=400)           //Check whether the result is valid or not
    {
      IntToStr(a,txt);
      Ltrim(txt);
      Lcd_Cmd(_LCD_CLEAR);
      Lcd_Out(1,1,"Distance = ");
      Lcd_Out(1,12,txt);
      Lcd_Out(1,15,"cm");
    }
    else
    {
      Lcd_Cmd(_LCD_CLEAR);
      Lcd_Out(1,1,"Out of Range");
    }
    Delay_ms(400);
  }
}
```

Chapter 3

PCB layout

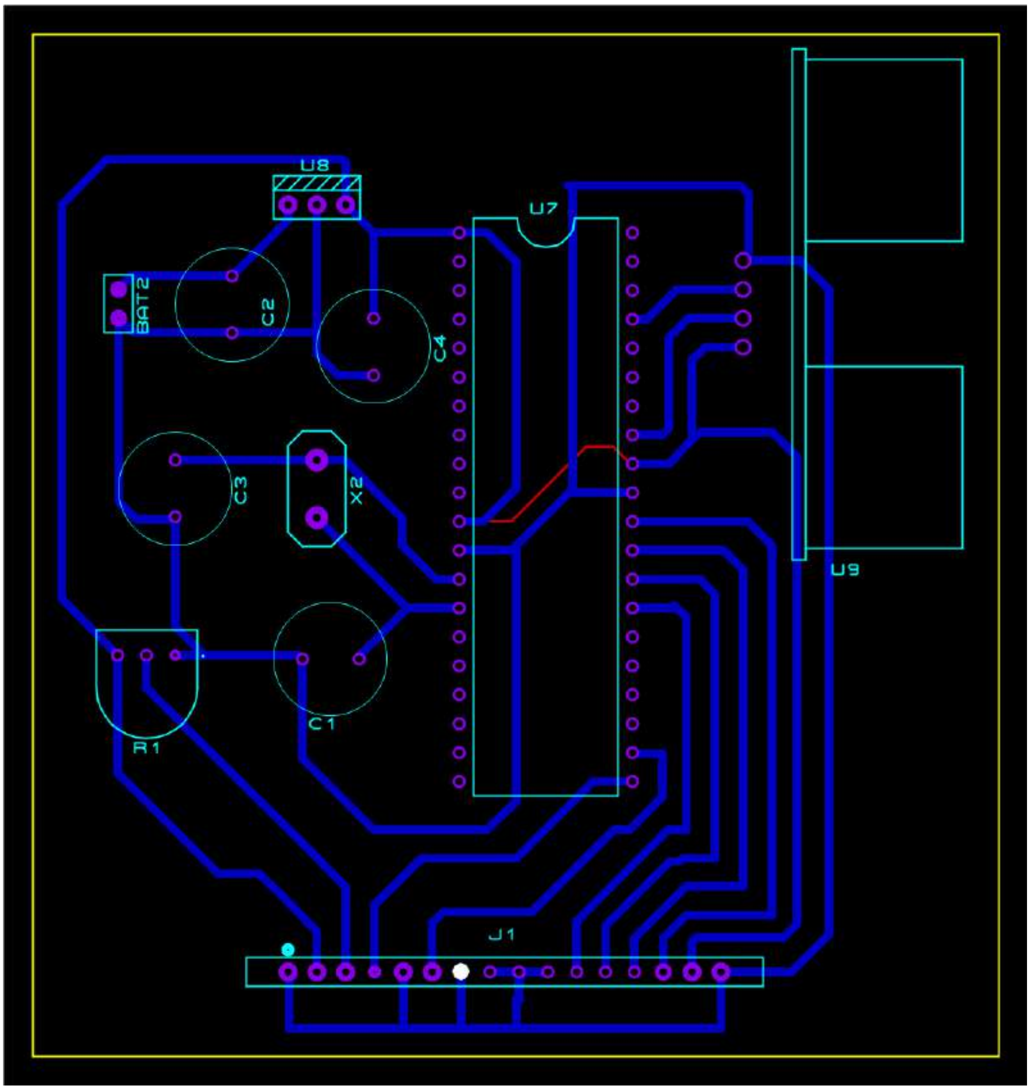

Figure 3.1: PCB Layout design(PROTEUS)

The pcb layout have been designed in Proteous software using one copper layer with traces routed on the other side.Instead of opting for automatic routing,the manual routing has been done based on the diagram with the traces thickness of 30th which has maintained the required clearance.

Chapter 4

Breadboard Implementation

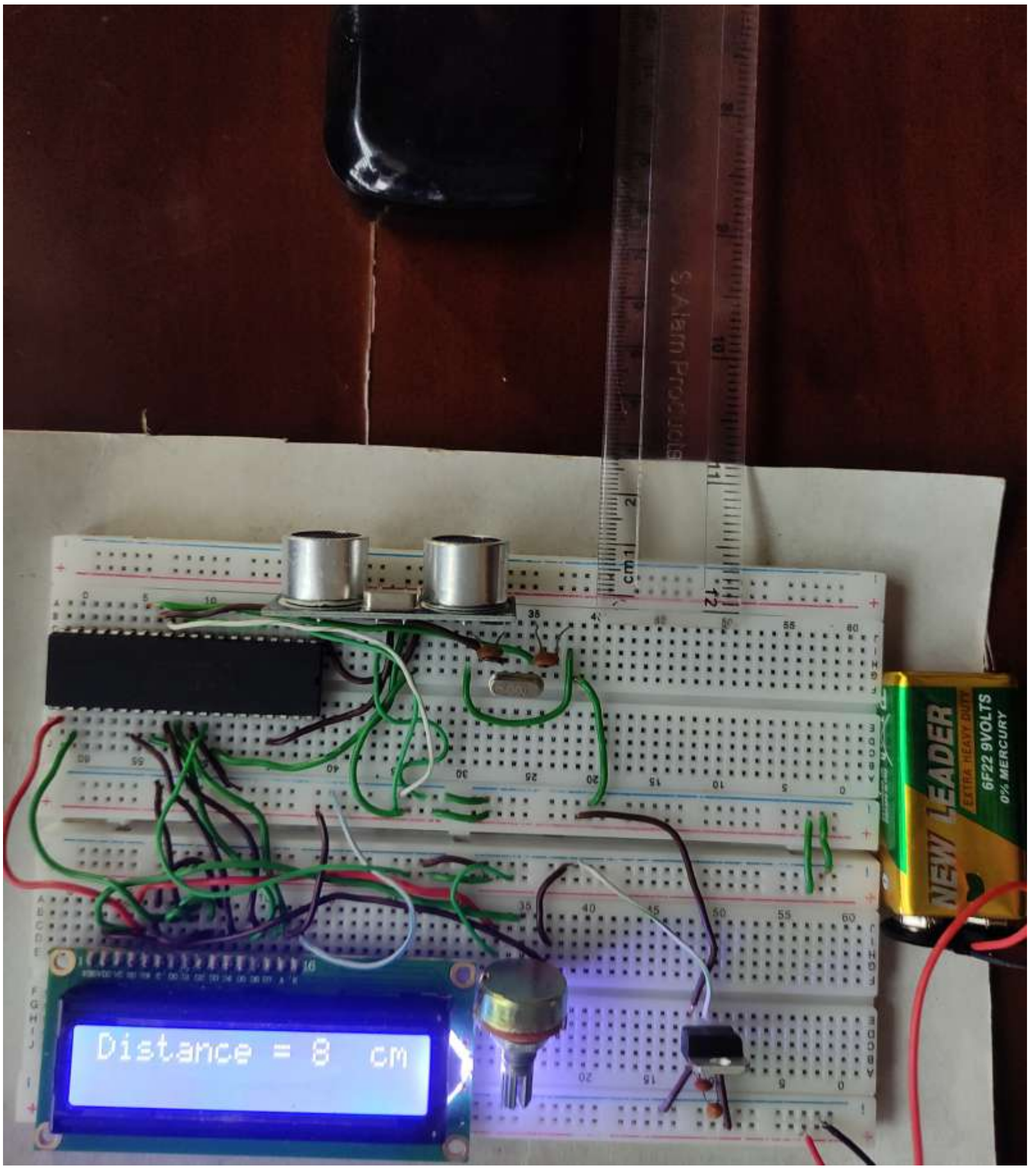

Figure 4.1: Breadboard Implementation of the Simulated Circuit

In the implementation of the breadboard,at first we connected a power supply to the micro-controller so that it can work. The PIC 16F877A need 4.2V to 5.5V to work. In our case we use 9V dc non-rechargeable battery which is further converted to 5V using a 7805 voltage regulator. Capacitors which are placed at the input and output terminals, between those pins and ground (GND)are used to filter out AC noise, suppress rapid voltage changes, and improve feedback loop characteristics. VDD(pin 11 and pin 32) and VSS(pin 12 and pin 31) of PIC Micro-controller is connected to +5V and GND respectively which will provide necessary power for its operation. The 8MHz crystal is connected to the OSC1 and OSC2 pins of the PIC to provide the clock signal. Two 22pF capacitors are connected in parallel with the crystal to load the crystal so that the circuit oscillates at the correct frequency. The micro-controller has several port for input and output. We have used port RB for connecting the sensor (HC-SR04) to the controller ,TRIGGER pin is connected to RB0 (pin 33) of PIC which is to be configured as an Output PIN and ECHO pin is connected to RB4 (pin 37) which is to be configured as an Input PIN. The port RD of the microcontroller is used to connect the LCD. The pin VDD is the power supply of LCD connected to the 5V , the pin VSS is connected to the ground, the pin VEE controls the contrast of the LCD ,which is connected to the output pin of the potentiometer to make precise contrast adjustments. Pin Rs is connected to the RD2(pin 21) which is used to separate the commands ,pin RW, pin D0 to D3 are shorted. The LCD pin D4,D5,D6,D7 are connected to the pin RD4(pin 27),RD5(pin 2),RD6(pin 29),RD7(pin 30) of the controller that send the result to the display. This is the overall breadboard connection for the project of ultrasonic distance measurement.

Chapter 5

PCB Implementation

Figure 5.1: Circuit Diagram(PCB Implementation)

To implement the PCB design,the final layout of the design was printed by a laser printer on the glossy paper.The PCB design was implemented by etching the copper traces and pads onto the PCB board. A PCB drilling machine was used to drill the drill holes in the PCB board. The components were then precisely positioned and soldered to the PCB board.

Chapter 6

Price Table

Table 6.1: Price list of components to implement the Project

Component	Quantity	Total Cost(BDT)
HCSR04(Ultrasonic Sensor)	1	90
PIC 16F877A(Microcontroller)	1	320
16x2 LCD	1	270
22pF capacitor	4	4
5V voltage converter	1	20
Crystal(8MHz)	1	15
Wires	2	15
Soldering Wires	1.	50
Microcontroller cage Base	1	15
9V Battery Battery	1	80
PCB board	1	40
Bread Board	1	130
Total Cost		1,049

Chapter 7

Future Improvement

Distance measurement with ultrasonic sensors has been highly devoted to engineering fields for a long time. It is being used to determine the level of water tanks, to find the distance of obstacles such as pedestrians, vehicles, etc. from vehicles, in self-driving robots or autonomously flying drones, as parking assistance systems in vehicles. However, it has been used in limited applications for its low sampling rates, low detection ranges, and vulnerability to environmental noise. For these limitations, this device gives us data of low accuracy.We almost got the perfect response for every observation with almost zero error. Although the error is negligible ,this should be compensated.

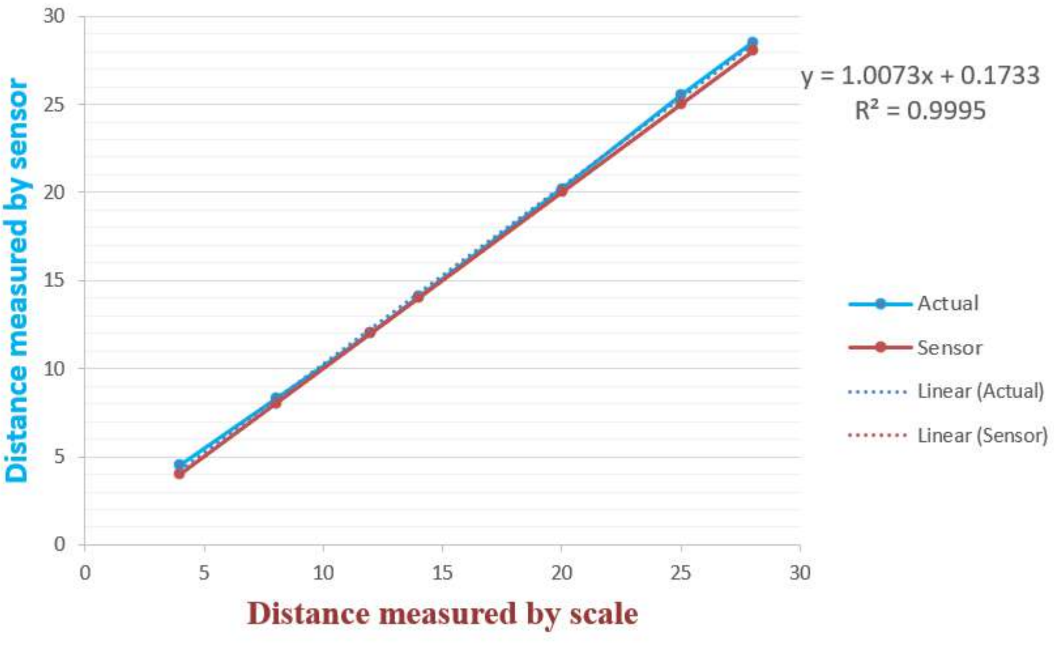

Figure 7.1: Comparison between label data and measured data in this project

In a competitive market environment, companies hunt to produce high-quality, low-cost products without increasing production costs. In this study, we have looked forward to some affordable solutions to increase the accuracy up to the millimeter level which are discussed below. Using temperature compensation, this device can be used over a wide temperature range. To improve the accuracy, other equipment and methods can be used, such as Fraunhofer IPMS which presents innovative solutions in ultrasonic measurement at Sensor.The micro-machined ultrasonic transducers (MUT) are developed by Fraunhofer IPMS which is based on micro-electro-mechanical systems (MEMS). It helps to minimize the size of components therefore devices are what all industrial and technical sectors are looking for. This miniaturized transducer benefits from reliable manufacturing processes and enables cost-effective, RoHS-compliant production in high volumes. Another approach for precise distance measurement is applying a Kalman filter to the measured data.

Chapter 8

Conclusion

We designed and implemented a microcontroller-based highly precise contactless distance measurement system that can calculate the distance of tracked objects. we developed the system with a 40 kHz ultrasonic transmitter-receiver pair which is triggered by a PIC microcontroller. The microcontroller assessed the time gap of the traveled ultrasonic signal between the transmitter to the object and then the object to the receiver. Later, the calculated value is displayed on the LCD screen in the cm scale. Through several tests, we found that the system gives us almost accurate values in various distances from 5 cm distance up to 4 meters which is quite satisfactory. However, we have ignored the effect of temperature and density of medium-like parameters during measurement. By the way, this system has limited application as it can be used for short-range detection. It is useful in working in multiple fields like water level measurement, guidance devices for visually impaired persons, obstacle avoidance robots, accident avoidance cars, etc.

Chapter 9

Plagiarism Declaration

With the exception of any statement to the contrary, all the material presented in this report is the result of my own efforts. In addition, no parts of this report are copied from other sources. I understand that any evidence of plagiarism and/or the use of unacknowledged third party materials will be dealt with as a serious matter.

References

[1] Y.Ege, H.Çıtak, M.Çoramık, M. Kabadayı, O.Kalender , "PIC Microcontroller Based Ultrasonic Distance Measurement," *'International Journal of Engineering and Technical Research (IJETR)'.* ISSN: 2321-0869 (O) 2454-4698 (P), Volume-3, Issue-9, 2015

[2] R.Titlee, M.H.Bhuyan, "Design, Implementation and Testing of Ultrasonic High Precision Contactless Distance Measurement System Using Microcontroller," *'SEU Journal of Science and Engineering'*, Vol. 10, No. 2 ,1999-1630,2016

[3] Y.Y.Swe, M.M.Soe , "Design and Construction of Distance Meter Based on PIC Microcontroller," *'Yadanabon University Research Journal'*, Vol.11, No. 1 , 2020

[4] E. A. V. Cabral and I. Valdez, "Airborne ultrasonic sensor node for distance measurement," *SENSORS, 2013 IEEE*, Baltimore, MD, USA, 2013, pp. 1-4, doi: 10.1109/ICSENS.2013.6688534.

[5] Y. Jang, S. Shin, J. W. Lee and S. Kim, "A Preliminary Study for Portable Walking Distance Measurement System Using Ultrasonic Sensors," *2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Lyon, France, 2007, pp. 5290-5293, doi: 10.1109/IEMBS.2007.4353535.

[6] L. Deng, "Study on Ultrasonic Ranging System Design," *2009 Fifth International Conference on Information Assurance and Security*, Xi'an, China, 2009, pp. 414-416, doi: 10.1109/IAS.2009.352.

[7] Electrical4U. (2020, October 27). Voltage Regulator 7805. *Electrical4U.* https://www.electrical4u.com/voltage-regulator-7805/

[8] George, L. (2021). Interfacing HC-SR04 Ultrasonic Sensor with PIC Microcontroller. *electroSome.* https://electrosome.com/hc-sr04-ultrasonic-sensor-pic/

[9] Utmel. (2021, September 8). PIC16F877A Microcontroller: Datasheet, Pinout and features. *Utmel All Rights Reserved.* https://www.utmel.com/components/pic16f877a-microcontroller-datasheet-pinout-and-features?id=522cat2/

[10] Admin. (2022). Why you should use an 8MHz crystal? *ChipSun Technology Co.,Ltd.* https://www.chinachipsun.com/8mhz-crystal/

[11] WatElectronics. (2021, October 12). LCD 16X2: PIN configuration, commands, interfacing its applications. *WatElectronics.com.*https://www.watelectronics.com/lcd-16x2/