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Arduino based Distance Measurement Sensor using Ultrasonic Sensor

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Abstract: ***The project we designed is used to develop a distance measurement system using ultrasonic waves and interfaced with Arduino UNO. We know that the human audible range is from 20hz to 20khz. We can use these frequency range waves through ultrasonic sensor HC-SR04.***
The main advantages of this sensor are when this sensor is interfaced with Arduino which is a control system and a sensing system, a proper calculation of the distance measurement can be done by using different types of new techniques. As huge amounts are spent on hundreds of inflexible circuit boards, the Arduino board will allow the business to bring many more unique devices. These distance measurement systems are mostly used as range meters and as proximity detectors in the different types of industries. The hardware part of the ultrasonic sensor is interfaced with the Arduino Uno board. This type of measuring distance is an efficient way to measure even small distances accurately. The distance of an object from the sensor is measured by using an ultrasonic sensor. After knowing the speed of the sound wave the distance of an object can be calculated.
Keywords: Arduino UNO, Motion, Ultrasonic sensor, LCD

I. INTRODUCTION

The ultrasonic sensor is a cheap sensor that can measure from 2cm to 400cm with non-contact measurement functionality with a ranging accuracy that can reach up to 3mm. This sensor uses the sonar waves for the echolocation just like bats to measure the distances. This project is an introduction to the use of an ultrasonic sensor and interfacing Arduino Uno with this sensor and LCD Since it is often not straightforward not initiative to wire and code.

There are many different ways to measure distance without contact. One of those ways is to an Ultrasonic sensor which uses ultrasonic waves at the frequency 40 kHz to calculate distance. Ultrasonic sensor transducers measure the amount of time taken for a pulse of a sound wave to travel from the sensor to a particular surface/object and return as the reflected echo. This circuit calculates the distance based on the speed of sound waves at a 25°C ambient temperature and shows it on a Liquid-crystal display(LCD). Using these we can measure the distance up to 4 meters accurately. Linear measurement is a major problem that a lot of applications in the industrial sector and consumer market segment have to contend with. Ultrasonic technology is one of the solutions used by the industries as it is cheaper and accurate.

Because an optimized balance between cost and features must for almost all the target applications. The ultrasonic distance measurement device (UDM) is mainly used in applications where a non-contact measurer is required. A Distance meter is used to measure the distance between the two objects. The Ultrasonic Distance Meter (UDM) working principle is based upon the ultrasonic waves. Since the human ear audible perception ranges from 20 Hz to 20 kHz, it does not affect or is insensitive to ultrasonic waves. Therefore the ultrasound waves can be used for applications in industries or vehicles without hindering human activities. Here, the distance is calculated by using the pulse-echo and phase measurement method.

The signal or sound wave is transmitted by an ultrasonic transducer, reflected by an obstacle/object, and received by another transducer where the signal is detected. The time delay of the transmitted and the received signal is proportional to the distance between the system and the obstacle/object. The speed of the sound wave depends upon the medium through which it has to travel. In general, the speed of sound is directly proportional (the square root of the ratio) to the stiffness of the medium and its density.

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II. LITERATURE SURVEY

The Ultrasonic Sensor sends a high-frequency sound wave and calculates how long does it take for the echo of the sound wave to reflect the senor. The Ultrasonic sensor has 2 openings on its front side. One opening transmits ultrasonic waves (like a tiny speaker) whereas the other opening receives them(like a tiny microphone).

The speed of the soundwave is approximately equal to 341 meters or 1100 feet per second in air. The ultrasonic sensor takes this value along with the time difference between the transmitted wave and the received wave of the sound pulse to determine the distance to an object. The distance is calculated by using the following mathematical equation:

Distance = Time x Speed of Sound wave / 2

The human audible range can be converted to measure the distance precisely manner. There are many different ways to measure distance without any contact. One of those ways is to use ultrasonic soundwaves with a frequency of 40 kHz for distance measurement. The Ultrasonic transducers measure the amount of time taken for a soundwave to travel to a particular object and return as the reflected echo. This device calculates the distance based on the speed of the soundwave at 25°C ambient temperature and shows it on an LCD. With the help of this device, we can even measure distance up to 4 meters.

The circuit was connected and the program was sent to the Arduino ATmega328 microcontroller chip to run the circuit. The ultrasonic sensor was able to send the ultrasonic sound waves to the approaching object. By adding a buzzer and potentiometer we can produce alarm sound for distances that are greater than 0cm and less than 150cm. The results were accurate for the distances that are greater than or equal to 150cm and for the distance of 0cm no sound is produced by the buzzer.

The variation of distances as the object comes closer to the ultrasonic sensor can be displayed using an LCD. When the set-up is fed with power, values were recorded by seeing in the LCD screen which indicates that the connection was correct. A Potentiometer can control the intensity of the screen of which the same was approved. This tool can be made chosen for many applications such as in automatic cars or in cars fitting to aid when reversing. We can observe this in many cars like vertigo and it could tell the level of water in storage tanks or wells etc. In simple words, we can use this as a water level indicator. This can also be introduced with the GSM for proper usage of remote monitoring. This one can also be used in the tunnels like trains or vehicles to indicate if there are any complications.

III. BLOCK DIGRAM

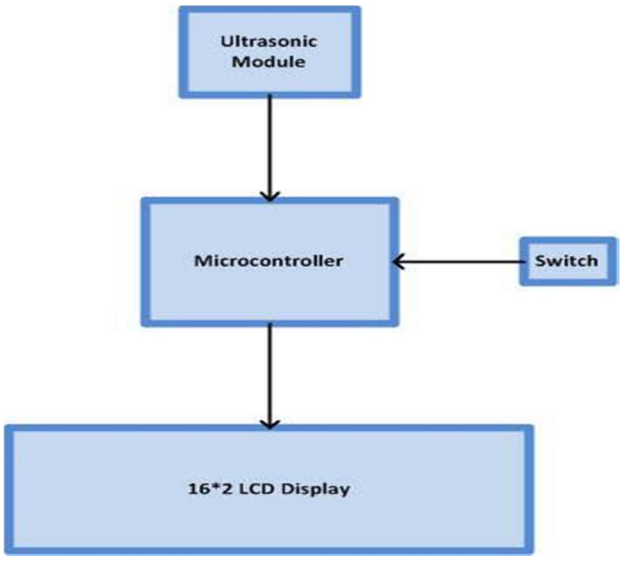

Figure 3.1. Block diagram

A. Components Required

1) HC-SR04 Ultrasonic Sensor Module
2) Arduino UNO
3) 16×2 LCD
4) Jumper Cables and Connecting Wires

a) Ultrasonic Sensor

Figure 3.2. Ultrasonic sensor

Plausibly, the most common type of distance measuring sensor is the Ultrasonic sensor. It measures the distance between the objects by emitting high-frequency ultrasonic waves. The sensor used here is HC-SR04, which is a non-contact Ultrasonic measurement device. This sensor is capable of measuring the distance within the range of 2cm – 400cm accurately.

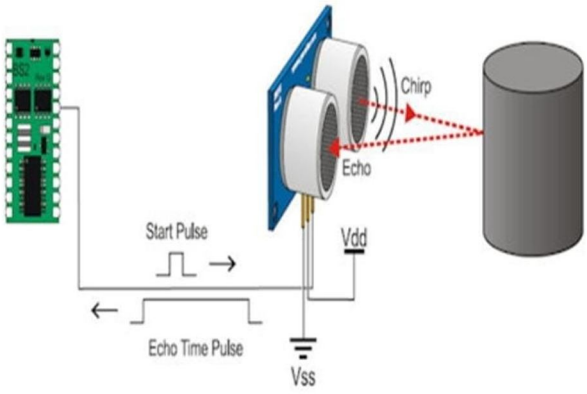

Figure 3.3. Reflection of ultrasound wave

This sensor consists of 2 parts, they are Ultrasonic transmitter and an ultrasonic receiver. The working principle is quite simple. Firstly, this ultrasonic sensor emits high frequency(40khz) sound waves towards the targeted object for 10µs. When the targeted object picks up the sound wave waves, they are then bounced off and reflected towards the ultrasonic sensor. The time it took for the sound wave to return to the sensor is used for calculating the distance between.

The main advantages of Ultrasonic Sensors are that it is not affected by object color and even it is transparency as it detects distance through sound waves. It even consumes low power and it is capable of multiple interface options for pairing with a microcontroller, etc. The disadvantages of Ultrasonic Sensors are the sensors which a limited detection range with low resolution and slow refresh rate.

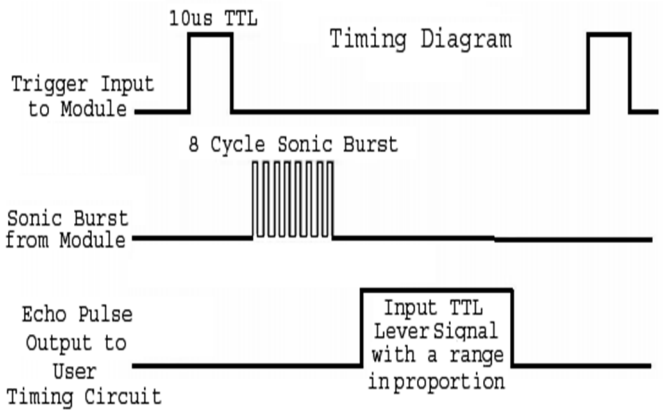

Figure 3.4. A Timing diagram of the sensor

b) Arduino Uno: The Arduino Uno ATmega328 is the most commonly used microcontroller board. It has 14 digital input/output pins (of which 6 pins can be used as PWM outputs) and 6 pins as analog inputs. It contains everything needed to support the microcontroller to function with high accuracy. To make it ON simply connect it to a computer with a USB cable or supply the power with an AC-DC adapter/battery. As technology had increased nowadays, the UNO board has become synonymous with Arduino. As the features in the Arduino-Uno result in more flexibility and more accuracy with less cost. There are 9 main components of the Arduino UNO board are as follows:

- USB connector
- Power port
- Microcontroller
- Analog input pins
- Digital pins
- Reset switch
- Crystal oscillator
- USB interface chip
- TX RX LED's

Figure 3.5 Pin diagram of Arduino-Uno AtMega328

c) 16×2 LCD Module: LCD screen (Liquid Crystal Display) is an electronic display module, which has a very wide range of applications. A 16x2 LCD is a basic module and is commonly used in most devices and circuits. These modules are preferred over seven segment and multi-segment LEDs. The reasons are- LCDs are economical (cheaper); easily programmable (configurable); has no limitation of displaying special & even custom characters (unlike in seven segments), animations, and many others that can be displayed. A 16x2 LCD is named so as it can display 16 characters n each line and there are 2 such more rows/lines in the display screen. LCD has two registers namely, the Command and Data. These modules are widely used at many places in embedded systems because they are quite cheaper and easy to interface with microcontroller chips. We may have seen this type of display in many devices like in calculators, multimeters, etc. The LCD module used here can display 16 characters in a row and it is having two rows. So, generally, as it has 16 columns and 2 rows. Each character that is displayed is made up of 5×8 pixels (pixel matrix). If you calculate total pixels on the LCD screen then it results in 5x8x16x2=1280 pixels, which is a large number of pixels. Now to display anything on the LCD, we need to specify the position of characters. So, it is really hard to do. So, to manage the proper working of it, an IC named HD44780 is used. IC fetches the data and commands from a microcontroller and then does some processing so that the desired output can be displayed on the LCD. IC makes the interfacing of LCD very easy. We may use this type of LCD in many of our projects to display the outcome through the sensor or from any module. Let us have a look at some of the technical specifications of a 16*2 LCD module.

Figure.3.6. LCD with pin description

- Related Post: 12V to 5V Converter Circuit
- Operating Voltage: 4.7V to 5.3V
- Current Consumption: 1mA without using backlight
- 2 lines with 16 characters in each line.
- Each character is made up of 5×8 pixel matrix.
- The display is Alphanumeric so it can display numbers as well as alphabets and special characters too.
- It comes in a Green/Blue backlight variant.
- Jumper wires and Connecting cables
- A jumper wire is an electrical wire that acts as a connector that passes electricity or current through it. It even has a group of wires in some cables.
- We can connect the ends of the jumper wires or connecting wires with a connector or pin. It is also known as jump, jumper wire, jumper cable, DuPont wire, or cable.
- Individual jumper wires are fitted by inserting their end connectors (pins) into the slots that are provided in the breadboards, microcontrollers, etc.

There are 3 types of jumper wires available in the market. They are male to male connectors, female to male or male to female connectors, female to female connectors.

- These jumper wires do not have any specific color, they are available in different colors.
- The main advantage of these jumper wires is this wire connects two points without soldering.
- Jumper wires are flexible and cheaper.
- There are different types of jump wires. Some of the common connectors are:
- Solid tips – are used to connect on or with a breadboard or female header connector.
- Crocodile clips – are used for all other applications, temporarily bridge sensors, buttons, and other elements of prototypes with components or equipment that have arbitrary connectors, wires, screw terminals, etc.
- Banana connectors – are commonly used to test the equipment for low frequencies of AC signals and DC.
- A Registered Jack(RJNN) – is commonly used for telephone and computer networking (RJ45) purposes.
- RCA connectors – are often used for audio, low-resolution composite video signals, or low-frequency applications requiring a shielded cable.
- RF connectors – are used to carry Radio Frequency(RF) signals between circuits, test equipment, and antennas.
- RF jumper cables- Jumper cables are smaller and flexible corrugated cable which is used to connect antennas and other components to network cabling. Jumpers are also used in the base stations to connect antennas and radio units. Usually, the most bendable jump cable's diameter is 1/2.

Circuit

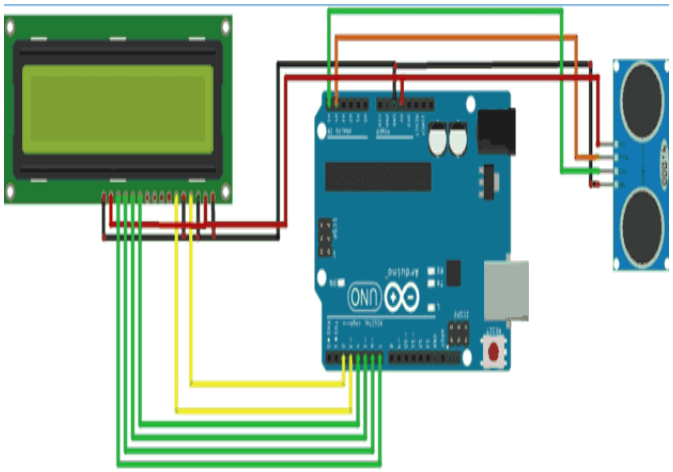

Figure.3.7 Circuit diagram

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IV. METHODOLOGY

A. Hardware Part

1) Working of Distance Measurement Circuit: After creating the code, dump it to Arduino and then you are all set. Now bring any of the object or your hand closer to the sensor. Check the distance on the LCD screen. Keep changing the distance of the object from the sensor and then you get a good, accurate distance. When we initialize the sensor by sending the high pulse for 10µs, the sensor sends eight 40kHz ultrasonic full cycles and if they get reflected by any object then they get reflected the receiver. Now, the time taken in traveling the ultrasonic signal from transmitter to obstacle and from the obstacle to a receiver is given by the sensor. So, this time is needed to calculate the distance between the sensor and the obstacle.

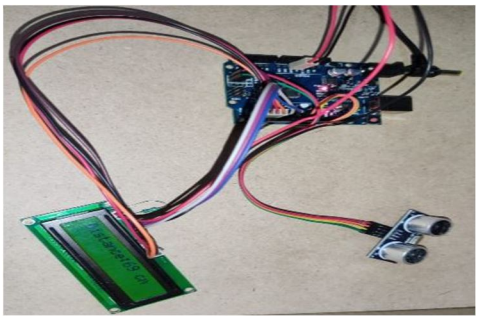

Figure.4.1 practical Hardware kit

V. METHODOLOGY

The method or the technique here we used is based on the Chiropteran also known as Bats. Instead of seeing these birds had evolved a special method to find food for them by using sound waves. While traveling they produce a hamming sound continuously that enables them to navigate. They can easily fly and find even in dark by using this method. It is also known as Echolocation. These birds produce echolocation by emitting high-frequency sound waves or pulses with the help of their mouth or nose. It transmits these waves and listens to the back waves or echoes simultaneously.

The echo signal or echo are the waves that had been traveled back after touching a surface or an object. These echoes help the bat to determine the shape and size of the object. With the help of these echoes, the bats can avoid the obstacles in their path.

Using this principle, a sensor had made and it is named as Ultrasonic senor. This sensor transmits high-frequency sound waves and waits for echoes. Utilizing this echo the distance of an object is determined.

VI. TEST AND EVALUATION

A. Software Part

Programming Arduino for Ultrasonic Sensor Distance Measurement. The coding part is easy for this project.

CODE

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(7,6, 5, 4, 3, 2);
#define trigPin 9
#define echoPin 10
void setup()
{
  Serial.begin(9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  lcd.begin(16,2);
lcd.setCursor(0,0);
lcd.print("DISTANCE MEASURE");
lcd.setCursor(0,1);
lcd.print("USING ULTRASONIC");
delay(2000);
lcd.clear();
```

```
}
 void loop()
{
   long duration, distance;
  while(1)
 {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
    distance = (duration/2) / 29.1;
  Serial.println(distance);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Distance:");
  lcd.print(distance);
  lcd.print(" cm");
  delay(2000);
}
}
```

VII. WORKING

In the circuit, the connections of "trigger" and "echo" pins of the Ultrasonic sensor module are directly connected to pins 18(A4) and 19(A5) of Arduino-Uno respectively. A 16x2 LCD is connected to the Arduino-Uno for interfacing in a 4-bit mode. The control pins RS, RW, and En of LCD are directly connected to the Arduino-Uno pins 2, GND, and 3 respectively. And the data pins from D4-D7 of LCD are connected to pins 4, 5, 6, and 7 of Arduino-Uno. Firstly, we need to trigger the ultrasonic sensor module to transmit the signal by using Arduino-Uno and then wait for the signal to reflect and receive ECHO. Arduino reads the time taken for the signal between triggering and Received ECHO. We know that speed of the sound wave is around 340m/s. Hence we can calculate the distance by using the given formula:

Distance= (travel time/2) x speed of a sound wave

Now, let's move to the software path. Firstly, it has a header file which the pre-defined functions of the LCD. As we have two signals trigger and echo we need to define those and therefore declaration had been done. Here a specific number 9600 had been used to begin serial communication at the rate of 9600 bits/sec. As the trigger signal is transmitting signal and echo is receiving signal we declared them as input and output respectively. And then we declared a 16x2 LCD and cleared all the pre vales of that LCD. Using the time duration of echo the distance of the object is calculating with the formula and hence displayed in the LCD.

VIII. RESULT

Thus, performed and obtained the required output of distance between the sensor and the obstacle This study sought to first designed to achieve this, the components that include the Arduino Uno, LCD, and ultrasonic sensor were fixed to the connection as described in the circuit diagram chapter.

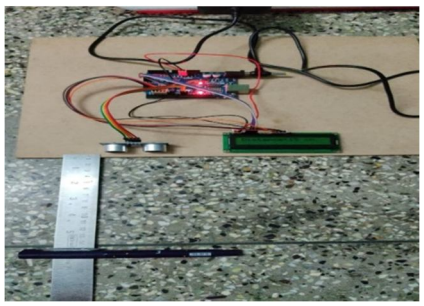

Figure.8.1 output-1 of LCD display

The LCD displaying the distance when the pen is placed as an object in front of Ultrasonic sensor

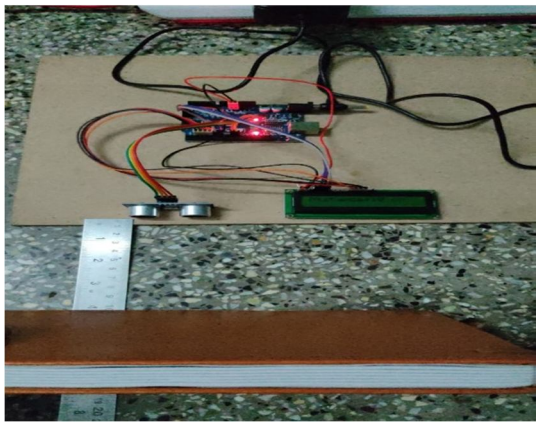

Figure.8.2 output-2 on LCD display

The LCD displaying the distance when the book is used as an object in front of Ultrasonic sensor

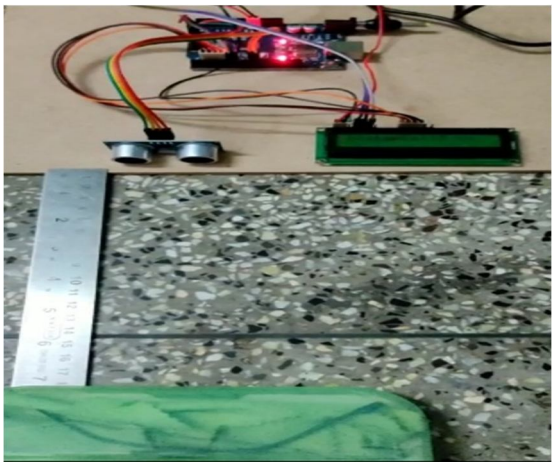

Figure 8.3 output-3 on LCD display

The LCD displaying the distance when the box is placed as an object in front of Ultrasonic sensor

IX. ANALYSIS

1) Not being affected by the color or transparency of any object placed. Ultrasonic sensors reflect the sound of objects, so the color or transparency doesn't have any effect on the sensor's reading.

2) Can be used in the dark environment also, Unlike proximity sensors using light or cameras, dark environments which don't have any effect on ultrasonic sensor's detection ability.

3) Low-cost option. Our sensors start at $29.85. They come calibrated and ready-made forms to use. We try to give a low-cost, high-quality product suited for required needs.

4) Not highly affected by dirt, dust, or high-moisture or humidity environment. Although our sensors work well in these environments at room temperature, they can still give incorrect readings in the presence of dirt or water, especially in extreme conditions.

This method has greater accuracy than other
Methods in measuring thickness and distance to a parallel surface.

a) Their high frequency, sensitivity, and penetrating power make it easy in detecting external or deep objects.

b) Ultrasonic sensors are very easy to use and not dangerous during operation to nearby objects, people or equipment, or the environment.

c) Our sensors can easily be interfaced with microcontrollers or any type of controller.

A. Limitations

1) Cannot work in a vacuum

2) Because ultrasonic sensors operate using sound, they are completely nonfunctional in a vacuum as there is no air for the sound to travel through.

3) Not designed for underwater use. These sensors have not been properly tested in all environments, for underwater applications with ultrasonic, there are many articles on Water Depth Sensing with Ultrasonic and Underwater Ranging for more information.

4) Sensing accuracy is affected by soft materials.

5) Objects covered in a very soft fabric absorb more sound waves making it hard for the sensor to see the target.

6) Sensing accuracy is affected by changes in temperature of 5-10 degrees or more.

7) Although this is true, we have a variety of temperature compensated sensors available that either calibrate upon start-up or before every range reading depending on the sensor model.

8) During this time is when the sensor will calibrate with any change in temperature, voltage, etc. This dramatically decreases this problem.

9) Have a limited detection range.

10) At the moment, our longest range sensors have a maximum range of 10 meters, and the cargo sensor detects up to 16.5m. While this is a disadvantage in certain applications, ultrasonic sensors have great mid-range capabilities and are still suited for many applications.

X. APPLICATIONS

A. Robotic sensing
B. Stacking height control
C. Loop control process
D. Liquid level control
E. Full detection purpose
F. Counting people/people detection
G. Presence detection of object or human
H. Detecting breaks in threads or wires
I. Box sorting
J. Contouring or profiling
K. Irregular parts detection
L. Tank level detection
M. Many applications in the production line
N. Vehicle Parking Distance Detection
O. Smart cars(Tesla uses ultrasonic sensors as part of its Autopilot or unmanned vehicle program)
P. Military applications.
Q. Parking assistance systems in vehicles with ultrasonic transmitter power as high.
R. Can be used as burglar alarm with selected choice
S. Software for homes and offices.
T. Used for measurement liquid level.
U. Used to find if there are any damages in threads or wires**.**

XI.FUTURESCOPE

A. New prototyping hardware, interfacing and capability with other electronics devices such as TV and smartphones.
B. To reduce the size of the equipment even more for different applications.
C. It is compatible with many programming languages and may see even more flexible programming types & development options
D. To increase the operating temperature range by using temperature compensation.
E. Military applications, Height measurement, Agriculture applications, protection can be other application.

It's an economic technology, can be used in other sectors as well, some of them are listed below:

1) Parking assistance systems in vehicles with ultrasonic transmitter power as high.
2) Can be used as burglar alarm with selected choice
3) Software for homes and offices.
4) Used for measurement liquid level.
5) Used to find if there are any damages in threads or wires**.**

XII. CONCLUSION

Ultrasonic distance measurement is a simple and convenient method rather than a routine one which is by using the measurement scales. This type of measurement is particularly applicable to inaccessible areas where common means cannot be used such as high temperature, pressure zones, etc. As ultrasonic sensors are non-contact distance measurers, these will have great future scope. The Ultrasonic Distance Meter's application area is most widely used in rescue operations, spy robot, are versatile and used in autonomous technology, mining. It has found as highly used in the light industry (Toy industry) agriculture, car parking systems, and other engineering practices.

Distance measurement using Arduino and ultrasonic sensor consists of a transmitter of ultrasonic module unit ultrasonic high-frequency waves are in the form of polices after the collision of waves with any object, these waves are detected by microphone and time taken by these waves from the transmitter and receiver is used to measure the distance from any of the object. We had used an ultrasonic sensor module of HC-SR04, because this ultrasonic module is initiated with a pulse of 10µs the distance from any object is calculated by the formula.

Distance =speed*time

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Dr. Varkuti Kumara Swamy, currently working as Associate Professor & Associate Head in Department of Electronics and Communication Engineering at Sreenidhi Institute of Science and Technology(SNIST).He completed his Ph. D in faculty of ECE, Jawaharlal Nehru Technological University, Hyderabad (JNTUH) during May 2020. His research topic is Adoption of Wave Dynamic Differential Logic against Differential Power Analysis Attack. He has 22 years and 6 months of academia teaching and Industrial experience in India and Libya, North Africa. He has total 25 international and national level paper publications. He taught courses like VLSI Technology and Design, VHDL modeling of Digital Systems, Modeling of Digital Systems with Verilog HDL, Low power VLSI Design, Algorithms for VLSI Design Automation and many others.

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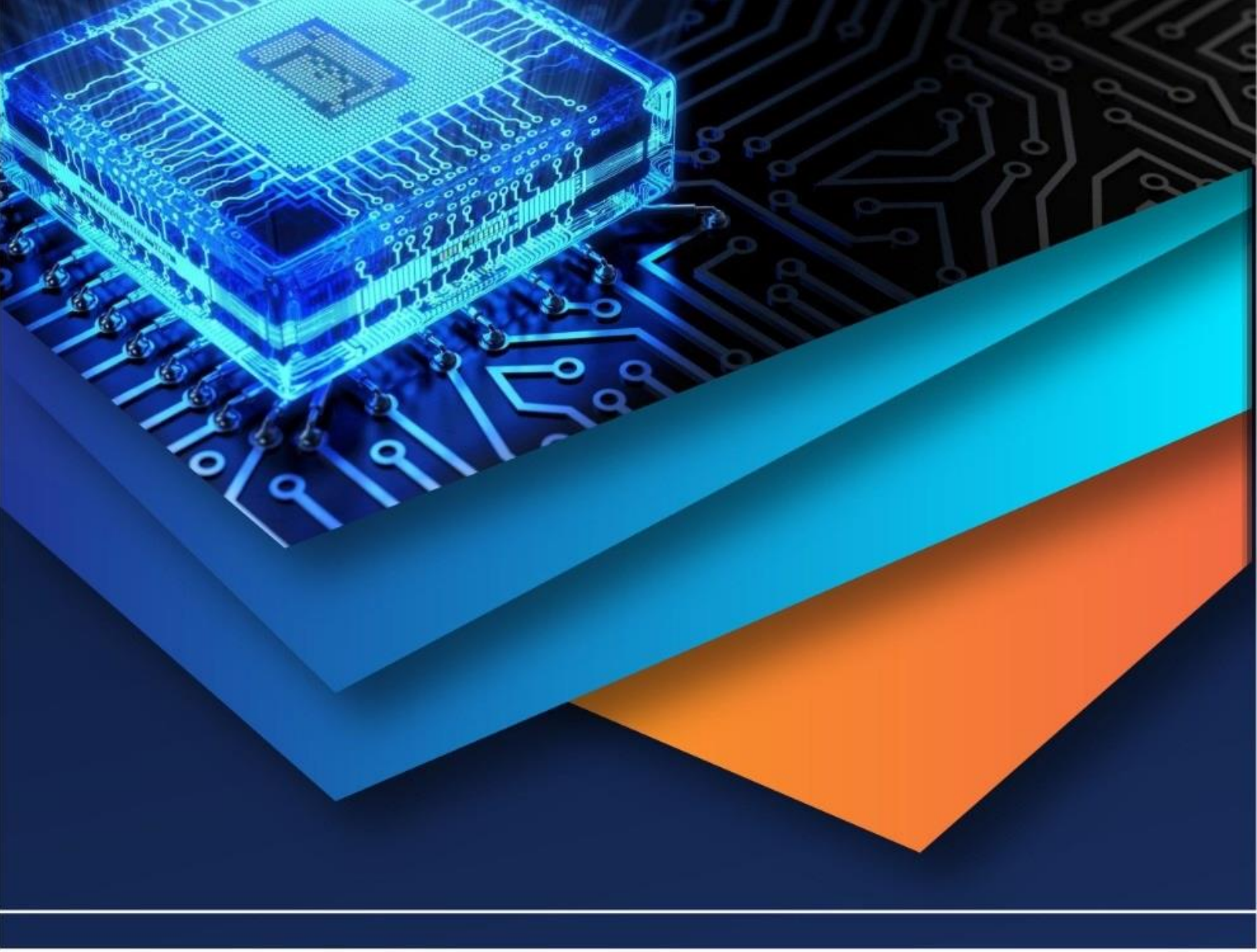

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