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Research Article

The Development of an Enhanced Obstacle Detection System with Alarm Based on the Internet-of-Things

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A B S T R A C T

An enhanced obstacle detection system with a intelligent YJD1602A Liquid Crystal Display (LCD) based on the Internet-of-Things (IoT) with electronic alarm system which incorporated a 25-Watt audio amplifier have been proposed development, constructed and tested as detailed in this paper. The obstacle detection is accomplished using HC-SR04 ultrasonic sensor while the IoT technologies are achieved through an Arduino Mega 2560 development platform. The performance of the proposed enhanced obstacle detection system have been verified as it has been able to measure and display the distances of objects (obstacles) with range from 0 to 4 meters with simultaneous triggering of the electronic alarm system when an object is detected while the alarm is off when no object is detected. The proposed EOD system can be adapted and deployed for obstacle detection and avoidance system design for robotics and mechatronics applications.

Keywords: Arduino Mega2560, audio power amplifier, electronic alarm system, embedded system, enhanced obstacle detection (EOD), Internet-of-Things (IoT)

Introduction

Ultrasonic sensors are designed for non-contact of measurement of distance and they are made of transmitter and receiver or transreceiver which is capable of transmitting and receiving ultrasonic sound. The essence is to measure the time of fly of ultrasonic wave from sensor to the target. The term "ultrasonic" applied to sound refers to anything above the frequencies of audible sound, and nominally includes anything over 20,000 Hz. Ultrasonic transmitter transmit at a frequency above 20kHz in and at a speed of 344m/s and the receiver receives the reflected sound from the target. The distance between the object and the transmitter is simply calculated by considering the time it takes for the ultrasonic wave to travel from the transmitter and received back by the receiver.

Ultrasonic sensors are characterize by a low-cost and by the possibility of been used in environments and situations where it is not possible to use more complex sensors as cameras systems and laser systems [1, 2]. While, ultrasonic sensors are widely used in obstacle avoidance system; they are capable of performing distance measurement on transparent, shiny and dark surface object. This ability allows ultrasonic to detect materials ranging from clear glass bottle to black rubber tyre. It can also work in tough environmental conditions such as noisy, dusty or dark areas. However, they do not function well with small targets against large backgrounds.

Different authors have analyzed the behaviour of sonar sensors based on the time of flight evaluation for estimating the distance of the nearest objects.[3] In order to assist the visually impaired and blind pedestrian who need help of guidance, Nawerand co-worker[4] made use of ultrasonic sensor to detect obstacles. The method employed allows the microcontroller to obtain information from the ultrasonic waves and then it alerts the blind pedestrian through voice messages.[4]

Ultrasonic sensors have also been used in the robotic field, both in industrial applications and autonomous vehicle applications. In industrial applications, genetic algorithms such as neural networks are used in identifying objects found on conveyer belts, their orientation, and other features.[5] Brudka and Pacut outlined a system which uses an array of 40 ultrasonic sensors in order to achieve high enough resolution. By using certain algorithms, inexpensive ultrasonic sensors can be used in controlled industrial applications.[4]

In 2015, Saraswathiand co-workers[6] developed an obstacle detecting robot using Arduino and sensor. The robot was made using IR sensor, wheel encoder and it was controlled by an Arduino microcontroller.[6] The IR sensor was attached to the front portion of the robot which senses the obstacles and navigates its pathway to choose an obstacle free path. The data collected from the sensor is compared by the microcontroller to decide the movement of the robot wheel.

The desired objective of this research is to develop an obstacle detecting system to detect an obstacle within a stipulated range and then give an alarm sound for notification. This paper attempts to: 1). develop an obstacle detecting system that is capable of measuring the distance between objects and the ultrasonic sensor; 2). develop an alarm system for alerting the user. The system comprises of HC-SR04 ultrasonic sensor, an Arduino mega 2560 microcontroller, resistors, jumper wires, LEDs and buzzer. The ultrasonic sensor comprises of the transmitter and the receiver together. The transmitter sends the ultrasound wave to the surrounding. The ultrasonic receiver receives the reflected wave when the wave transmitted it's a target. The Arduino mega 2560 microcontroller processes all information received from the ultrasonic sensor and based on the input gives out the desired out. The LEDs are used as indicator to show if the target is within the stipulated range or not. The resistors are connected in series to the LEDs to limit the current in LED to a safe value.

The paper is organized as follows. Background knowledge together with an overview of the study and the historical overview of ultrasonic sensors as well as State-of-the-Art in Ultrasonic Technology Developments and Applications are presented in Section 2. The architecture of the proposed enhanced obstacle detection system in the context of the HC- SR04 ultrasonic sensor and the Arduino Mega 2560 are detailed in Section 3. The development, implementation and deployment of the enhanced obstacle detection is discussed in Section 4 together with the design of an alarm system incorporating an audio power amplifier. Section 5 concludes the paper with some highlights on future directions as part of recommendations on the way forward.

Table 1.The enhanced obstacle detection system nomenclatures and parameter definitions

Parameters	Definition	Parameters	Definition
LED	Light emitting diode	AC	Alternating current
UART	Universal Asynchronous Receiver-Transmitter	DC	Direct current
USB	Universal Serial Bus	GND	Ground
ICSP	In-Circuit Serial Programming	SCK	Serial clock
SPI	Serial Peripheral Interface	SS	Slave select
V	Volts	MISO	Master-In Slave-Out
IOREF	In/Out reference	MOSI	Master-Out Slave-In
mA	Milliamperes	PWM	Pulse-width modulator
µs	Microsecond	SDA	Data line
cm	Centimeter	SCL	Clock line
m	Meters	TWI	Two wire interface
TX	Digital pin 1 (Transmit)	RX	Digital pin 0 (Receive)
IDE	Integrated development environment	PCB	Printed circuit board
IR	Infrared	SRAM	Static random access memory
EEPROM	Electrically Erasable Programmable Read-Only Memory	TTL	Transistor-transistor logic
OS	Operating system	DTR	Data terminal ready
IC	Integrated circuit		

Background Knowledge

Overview of the Research

This work presents the development of an obstacle detection system capable of detecting an object within a stipulated range irrespective of the weather condition of the surroundings using a HC-SR04 ultrasonic sensor. An amplifying circuit is been designed to amplify the output signal when it comes across an obstacle within a stipulated range. The desired objective is for the proposed obstacle detection system to trigger an alarm system which will produce an audio signal when it comes across an object within the range of 0–4 metres. The Arduino Mega 2560 microcontroller has been used as the brain of the device system due to its low-cost, reliability and availability. This research work is expected to: 1). Measure the distance between objects; 2). Alert its users when it comes across an object within the range of 0–4 metres; and 3). The design system can be used for developing a security alarm system. Ultrasonic sensors have been used in wide variety of applications and still sonar systems are under research to produce more near to nature sensors. The following sub- sections highlights the work done in the field of sonar sensing.

Historical Overview of Ultrasonic Technology

The history of ultrasonic starts with Lazzaro Spallanzani (1729–1799), an Italian physiologist and priest who designed a set of experiments to explain how bats were able to fly at night.[7] By studying the bat's ability to see and hear, Spallanzani noted that if a bat was blinded, it was still able to fly confidently through space; however, when a bat was made deaf, even in one ear, it could not fly safely in the experimental environment. On the basis of these findings, Spallanzani hypothesized that bats relied on sound, not their vision, to navigate.[7]

Piezoelectricity (from the Greek word piezen, meaning to press or squeeze) was first discovered by brothers Jacques (1856–1941) and Pierre (1859–1906) Curie. They demonstrated that crystals of tourmaline, quartz, topaz, cane sugar, or Rochelle salt can generate electricity under pressure and that when a voltage is applied to these crystalline materials, pressure waves can be generated. The capacity of these crystals to both generate and receive pressure waves in the range of megahertz frequencies allowed the development of modern-day transducer technology.[8]

One of the first applications for ultrasonic was sonar (an acronym for sound navigation and ranging). It was employed on a large scale by the United States Navy during World War II to detect enemy submarines. Sonar operates by bouncing a series metal of high frequency, concentrated sound wave beams off a target and then recording the echo. Because the speed of sound in water is known, it is an easy matter to calculate the distance of the target. Prior to World War II researchers were inspired by sonar to develop analogous techniques for medical diagnosis. For example, the use of ultrasonic waves in detecting metal objects was discussed beginning in 1929.

Research into ultrasonic and - flaw detection in Japan was considerably curtailed when World war II broke out in 1941, at which time the Americans and the Germans were both diligently researching into ultrasonic and the development of the Radar. The study into Radar techniques in Japan was also in the disadvantage. As the war ended in 1945, research into high-power electronics was prohibited in Japan for some time (up till 1948, when developments of non-military electronics resumed).

Japanese enterprises took on the research from the U.S. and England and soon developed its own flaw detectors in non- destructive testing.[3–5] In about 1949, four Japanese companies started to manufacture their own flaw detectors. These were: the Mitsubishi Electric Corporation, the Japan Radio Company (later became the Aloka Company), the Shimadsu Manufacturing Company and the Tokyo Ultrasonic Industrial Company. Only Mitsubishi continued to expand in the field of non-destructive testing and the other companies moved on to other areas and in particular diagnostic medical ultrasound applications. The Japanese Society for Non-Destructive Inspection officially recognized the year 1952 as the first year non-destructive testing was implemented in Japan.

The use of Ultrasonic in the field of medicine had nonetheless started initially with its applications in therapy rather than diagnosis, utilizing its heating and disruptive effects on animal tissues.[7-10] The destructive ability of high intensity ultrasound had been recognized in the 1920s from the time of Langévin when he noted destruction of school of fishes in the sea and pain induced in the hand when placed in a water tank insonated with high intensity ultrasound; and from the seminal work in the late 1920s from Robert Wood and the legendary Alfred Loomis in New York.[8-11]

In the 1950s researchers in the United States and Europe became increasingly aware of the progress that had been made in Japan, and they began work on additional medical applications. The first ultrasonic instruments displayed their results with blips on an oscilloscope screen. That was followed by the use of two dimensional, gray scale imaging. High resolution, colour, computer-enhanced images are now common, Ultrasonic technology is now employed in a wide range of applications in research, industry and medicine.[7-15]

State-of-the-Art in Ultrasonic Technology Developments and Applications

Ultrasonic sensors are commonly used in mobile robotics for obstacle avoidance and detection. The concept of ultrasonic sensor is to produce high frequency sound wave in cone shape by transducer and receive back after the reflected off the target. Sensor will calculate the time between sending and receiving echo to determine the accurate distance from the object or target. It can estimate with a precision of less than 1 cm and up to 4m in distance measurement. Ultrasonic sensors are capable of performing distance measurement on transparent, shiny and dark surface object. This ability allows ultrasonic sensors to detect material ranging from clear glass bottle to black rubber tyre. It can also works in tough environment such as noisy, dusty or dark area.

Kuc and Siegel presented a method for discriminating planes, corners and edges using sonar data gathered at two positions.[9] Two significant follow-ups are the work of [3, 10] which differentiates planes and corners with multiple transducers at a single position. Followed by [11] which considered differentiates planes and corners with one transducer at two positions.

In [12], a real time world model based on data from onboard ultrasonic transducers is constructed and statistical methods are used to transform the digital map into a topographical map; a path planner based on the Virtual Force Field method is employed.

Spedicato co-workers [3] used a system of one ultrasonic transmitter with two receivers to determine the normal of the detected surface. A vector map is used to reconstruct the environment. A similar approach, where form is considered rather than localization is presented in.[14]

Fuzzy logic had used to solve the fundamental processes of perception and navigation.[15] The robot collects data from its sensors, builds local maps and integrates them into the global maps so far reconstructed, using fuzzy logic operators.[15] The inputs to the map-building phase are the range

measurements from the ultrasonic sensors. Its Outputs are two updated fuzzy maps. Both convey information about the risk of collision at each point in the environment.

Ultrasonic sensors have been found to be useful in automotive applications in determining occupant position and occupant velocity during a crash. When combined with the vehicle's crash sensors, ultrasonic sensors add to the airbag control methodology.[16]

The medical industry uses ultrasonic sensors to create two- dimensional images of the human body. Speed of sound, attenuation, and impedance depend on the body tissue the sound wave is passing through. By using these attributes a 2D image of the human body can be created.[17]

Ultrasonic sensors are very useful in the marine industry to map the sea floor and to detect man-made objects such as mines. Multiple sensors are used to recreate a three-dimensional scene. By adjusting the output frequency and amplitude, ultrasonic sensors can be used for long-range, two- dimensional object detection.

By creating an array of sensors in a circle around the vehicle, the overlap of cones allows for an increase in resolution on an autonomous vehicle.[19] The sensor array can then create a 360 degree view of the world around vehicle and the vehicle can make guidance decisions in real time.

Lee and co-worker[20] showed the use of multiple ultrasonic sensors employing the different beam-width sensors used simultaneously for mobile robot navigation purposes. The small beam-width sensor is good in resolution but for wider angular region the more number of sensors are required. The use of wide beam-width sensors results in less number of sensors while covering the detection area. However, it results in poor resolution which is solved by fusing (stacking) the different beam width sensors to get better resolution and also larger covering area making navigation powerful in complex environment.

Using a single camera Jeongdae and Yontage developed a mobile robot which avoided obstacles on its pathway. The objects were detected by Block Based Motion Estimation (BBME). In the method, an image is firstly divided into small blocks and then the motion of each block is searched by comparing two consecutive images. The method was verified by the indoor navigation experiment of a robot.[21]

Another interesting work is shown in[22] employing ultrasonic sensor in measuring distance. The device system comprises of an ultrasonic transmitter circuit and a receiver circuit. A microcontroller AT89C205 was used which serves as the brain of the device system. The device was used to measure a distance of 2.5m.

In tank level monitoring, Viswanathand co-workers[23] monitored the liquid content in a tank using ultrasonic sensor. The sensors was placed in a specified direction in the tank, calculating the level of liquid by time of flight of the ultrasonic wave and correlating with respect to the dimension of the tank to get more accurate values.

Recently, Vivekanadanand co-workers[24] designed a mobile robot with ultrasonic sensor for obstacle detection and avoidance, a flame sensor to detect fire and an Arduino board for processing. A fire extinguisher was attached to the robotic arm of the robot. When the flame sensor detects fire, the robot moves towards the direction of the fire avoiding obstacles on its pathway. The fire extinguisher along with actuators is used to extinguish the fire which is been detected. A wireless monitoring system with camera is used to display the present scenario.

The Proposed Research Methodology

The block diagram of the proposed enhanced obstacle detection (EOD) system with an electronic system based on the IoT technology is shown in Figure 1.

An ultrasonic sensor interfaced with an Arduino Mega2560 embedded system development board initiates the

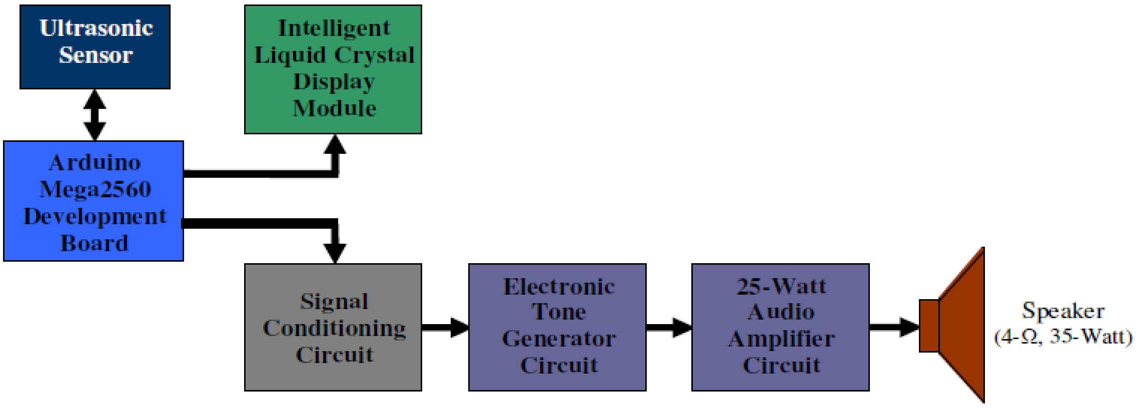


Figure 1.The block Diagram of the Proposed Enhanced Obstacle Detection System with Alarm Based on the Internet-of-Things (IoT)

obstacle detection process. The communication between the ultrasonic sensor is bidirectional so that real-time measurements can be updated once available and the corresponding measurement is displayed on an intelligent liquid crystal display also interfaced with the Arduino Mega2560 embedded system development board.

In the proposed EOD design, when an object is detected within the range of 0 to 4 meter, an electronic alarm system is triggered on while in the absence of any object outside this range the alarm system is turned off. As shown in Figure 1, the electronic alarm system consist of the signal conditioning circuit and an electronic tone generator circuit as well as an output 25-Watt audio amplifier circuit which drives a 4-Ω 35- Watt speaker.

Architecture of The Proposed Enhanced Obstacle Detection System

Architecture of the HC-SR04Ultrasonic Sensor

Ultrasonic Sensor

An ultrasonic sensor is a device that is capable of measuring the distance to an object by using sound waves as depicted in Figure 2(a) and (b). It measures by sending a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object.[25]

Working Principle

Ultrasonic transducers convert ultrasound waves to electrical signals and vice versa. These devices work on a principle similar to that used by transducers in radar and sonar systems, which evaluate the attributes of the target object by processing the echo signals from radio or sound waves, respectively.[25] Ultrasonic sensors consist of two parts: transmitter and receiver, which create a transducer that converts ultrasound waves into electrical signals (AC) or vice versa. The transceiver vibrates and creates an ultrasonic wave that is transmitted and travels until it hits an object and is reflected back to the receiver. The interval between the signal being sent and received is typically referred to as time-of-flight (ToF) and depends on the distance the ultrasonic wave travels until it is reflected as illustrated in Figure 2(a). The basic equation: time is equal to distance divided by speed, can be used to measure fluid level, fluid identification/concentration and distance. The object range is proportional to the echo travel time (to and from the object) as the velocity of sound (c) is known to be 344 meters per second (m/s) in the air at standard temperature and pressure as shown in Figure 2(b). The range (r) to the object/target is calculated by the following equation.

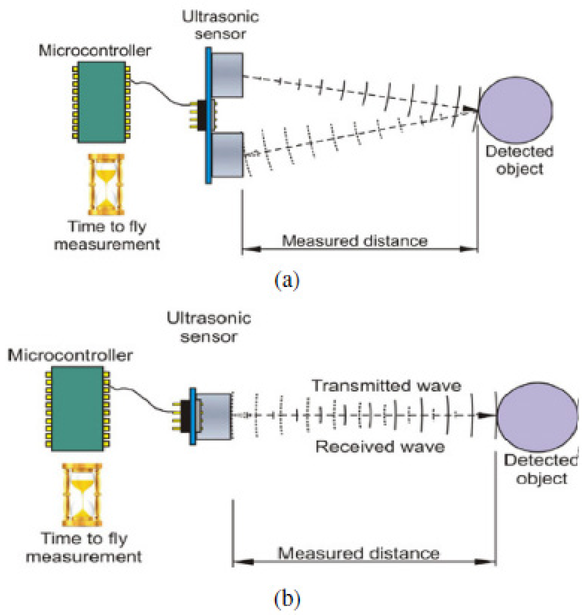


Figure 2.The basic working principle of the ultrasonic sensor: (a)top view and (b) side view

$$r = \frac{ct}{2} \quad (1)$$

where r is equal to multiplication of speed of sound c and time taken t by the pulse to and from the target. The division by 2 converts the total distance travelled by the pulse to half the distance, which is the range to the object. The factors that limit the range in the air are beam losses due to spreading and acoustic absorption. It means that the expected range is not achieved because air is an open medium and some of the beam is absorbed and diverted to different angles than to the target alone.

When used for sensing functions, the ultrasonic method has unique advantages over conventional sensors: 1). Discrete distances to moving objects can be detected and measured; 2). Less affected by target materials and surfaces, and not affected by colour; 3).Solid-state units have virtually unlimited, maintenance free life. Can detect small objects over long operating distances [25]; 4). Resistance to external disturbances such as vibration, infrared radiation, ambient noise, and EMI radiation; 5). Excellent long term stability; 6). Low power consumption and low cost realization Directional sensitivity; 7). High structural resolution due to large bandwidth; 8). Remote measurement, low interference with objects to be detected, sensitivity to virtually all kinds of

Figure 3.The HC-SR04 Ultrasonic Sensors

objects; and 9). Imperviousness to wetness, contamination or wear.

The HC-SR04 Ultrasonic Sensor: Components and Devices

Common electronic components and devices used in the obstacle detection system are briefly discussed in the following. Ultrasonic sensors are very popular for range detection. This sensing technique is a SONAR technique which can also be seen in some animals like dolphins and bats. In the proposed EOD design, the HC-SR04 ultrasonic sensor shown in Figure 3 has been adopted.[25] This sensor offers very high accuracy for range detection. Also the stability of the readings is found to be high. They are capable of finding hard as well as soft materials.

The HC-SR04 module is a four pin sensor. Two pins ensure the power supply whereas one pins is for transmission and one for echo reception. It works on a 5 V voltage supply. The ultrasonic sensor of Figure 3 have both transmitter and receiver on the same chip as illustrated in Figure 2 described in Section III(A)(1) and (2). When given a high pulse to the transmit pin of the sensor, it triggers a chirp signal, which get reflected back from the object and received by the echo pin.

Typically, the HC-SR04 ultrasonic sensor has the following specifications: 1). It works on a power supply of 5V DC; 2). Frequency of operation is 40 kHz; 3). Typical Quiescent current is less than 2 mA; 4). Typical operating current is 15 mA; 5). Range is from 2cm to 400 cm; 6). The typical measuring angle is 300 where it can deviate depending upon the surface; 7). Maximum effectual angle is 150; and 8). It generates a trigger pulse of 10 µS.

Architecture of the Arduino Mega 2560 Development Board

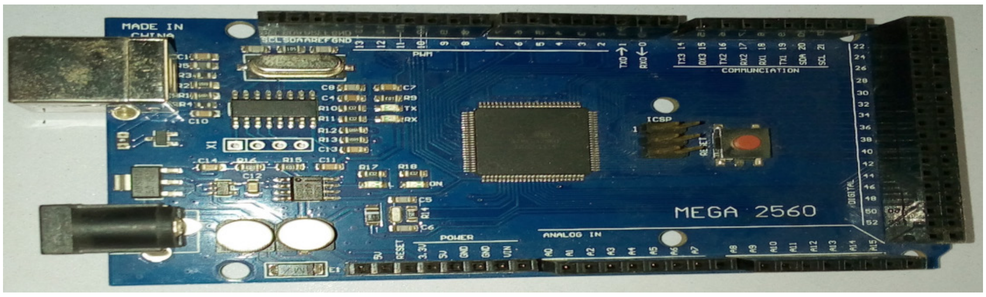
The Arduino Mega 2560 embedded systems development board shown in Figure 4 [26] is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started [26]. The Mega is compatible with most shields designed for the Arduino Duemilanove or Decimals. The ATmega2560 on the Mega 2560 comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware Programmer. It communicates using the original STK500 protocol (reference, C header files).

Power

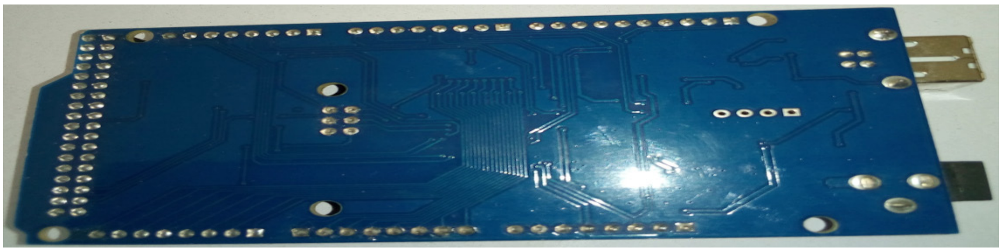
The Mega 2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery [26]. The adapter can be connected by plugging a 2.1 mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.[26]

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The power pins are defined as follows:

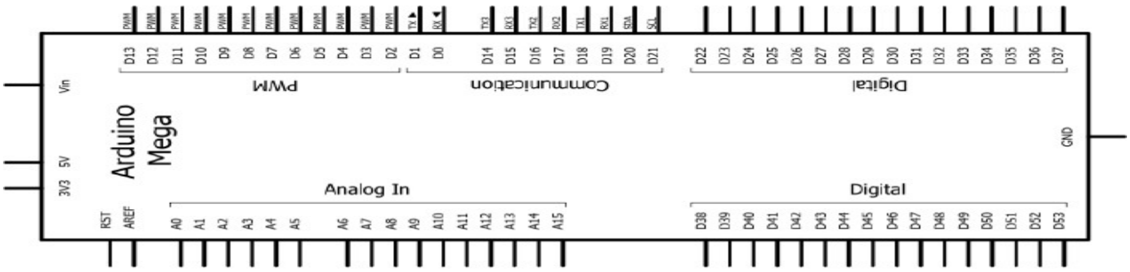
Vin: The input voltage to the board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via



(a)



(b)



(c)

Figure 4.Arduino Mega 2560 embedded development board: (a) top view, (b) bottom view and (c) pin description.

the power jack, access it through this pin.[26]

- 5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator and can damage the board [26]. We do not advise this approach.
- 3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND: Ground pins.
- IOREF. This pin on the board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

Memory

The ATMega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).[26]

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pin Mode(), digital Write(), and digital Read() functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20 – 50 kΩ. A maximum of 40 mA is the value that must not be exceeded to avoid permanent damage to the microcontroller. (Please see Figure A.1 and Table A.1 in the Appendix for more detailed input and output pin descriptions) In addition, some pins have specialized functions and these include: Serial: 0 (RX) and 1 (TX); Serial 1:19 (RX) and 18 (TX); Serial 2:17 (RX) and 16 (TX); Serial 3:15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega16U2 USB-to-TTL.

Serial Chip

External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt3) and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low level, a rising or falling edge, or a change in level. These pins are defined as follows:

PWM: 2 to 13 and 44 to 46. Provide 8-bit PWM output with the analog Write() function.

- SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Arduino/Genuino Uno and the old Duemilanove and Diecimila Arduino boards [26].
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- TWI: 20 (SDA) and 21 (SCL). Support TWI communication using the Wire library. Note that these pins are not in the same location as the TWI pins on the old Duemilanove or Diecimila Arduino boards.

The Mega 2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function. There are a couple of other pins on the board, namely: 1). AREF. Reference voltage for the analog inputs. Used with analogReference(); and 2). Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega 2560 board has a number of facilities for communicating with a computer, another board, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication.[26]

Arduino IDE

The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2/ ATmega16U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Mega 2560's digital pins. The Mega 2560 also supports TWI and SPI communication. The Arduino Software (IDE) includes a Wire library to simplify use of the TWI bus. For SPI communication, use the SPI library.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega 2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega 2560 is designed to be compatible with most shields designed for the Uno and the older Diecimila or Duemilanove Arduino boards. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Furthermore, the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega 2560 and Duemilanove/ Diecimila boards.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Mega 2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino Software (IDE) uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This

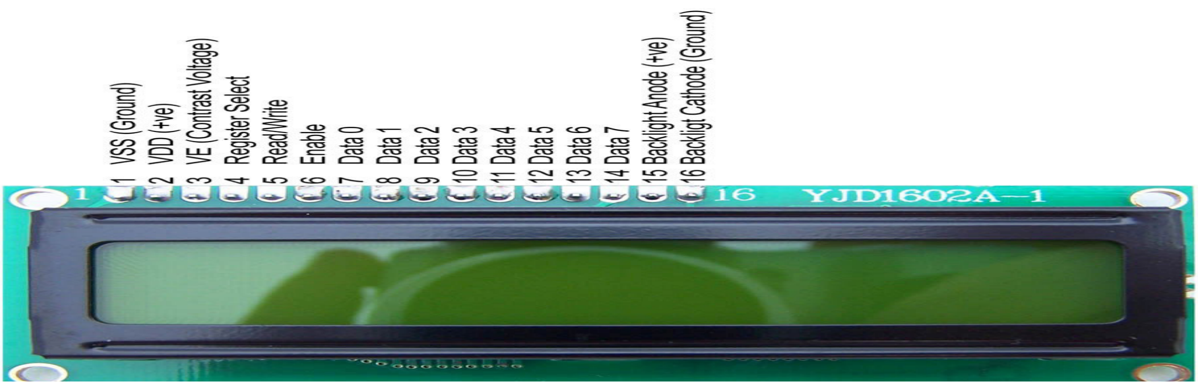


Figure 5.The physical picture and pin definition of the YJD1602A-1 16-by-2 LCD display module

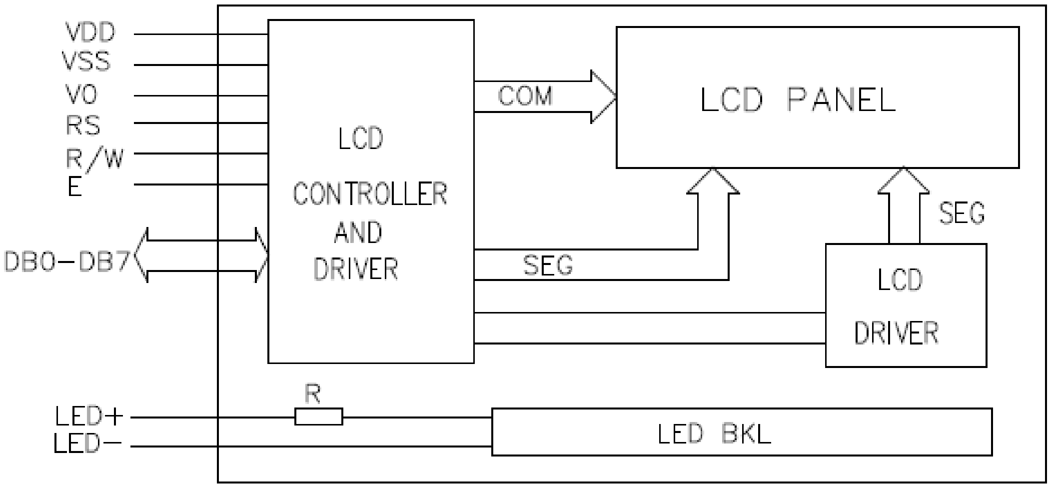


Figure 6.The block diagram of the internal architecture of the ADM1602K-NSW-FBS/3.3V LCD module

Table 2.Absolute maximum ratings for normal operation of the ADM1602K-NSW-FBS/3.3V liquid crystal display (LCD) module

S. No.	Item	Symbol	Standard			Unit
			Minimum	Typical	Maximum	
1.	Power voltage	VDD - DSS	0	-	7	V
2.	Input voltage	VIN	VSS	-	VDD	
3.	Operating temperature	VOP	0	-	+50	°C
4.	Storage temperature range	VST	-10	-	+60	

Table 3.Interface pin description for the ADM1602K-NSW-FBS/3.3V liquid crystal display (LCD) module

S. No.	Pin Number	Symbol	External Connection	Function Symbol
1.	1	VSS	Power supply	Signal ground for LCM
2.	2	VDD		Power supply for logic for LCM
3.	3	V_0		Contrast adjust
4.	4	RS	MPU	Register select signal
5.	5	R/W	MPU	Read/write select signal
6.	6	E	MPU	Operation (data read/write) enable signal
7.	7 – 10	DB0 ~ DB3	MPU	Four low-order bidirectional three-state data bus lines used for data transfer between the MPU and the LCM. These four are not used during 4-bit operation
8.	11 – 14	DB4 ~ DB7	MPU	Four high-order bidirectional three-state data bus lines used for data transfer between the MPU
9.	15	LED+	LED BKL power supply	Power supply for BKL
10.	16	LED–		Power supply for BKL

means that the bootloader can have a shorter timeout, as the lowering of DTR can be well coordinated with the start of the upload.

This setup has other implications. When the Mega 2560 board is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the ATMega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of

data sent to the board after a connection is opened. The Mega 2560 board contains a trace that can be cut to disable the auto- reset. The pads on either side of the trace can be soldered together to re-enable it. It's labelled "RESET-EN"

YJD1602A-1 16-by-2 LCD Display Module

Liquid Crystal Display (LCD) screen is an electronic display module and find a wide range of applications. The 16x2 LCD display is a very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multisegment light emitting diodes (LEDs). The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special& even custom characters (unlike in seven segments), animations and so on.

The 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc [27]. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

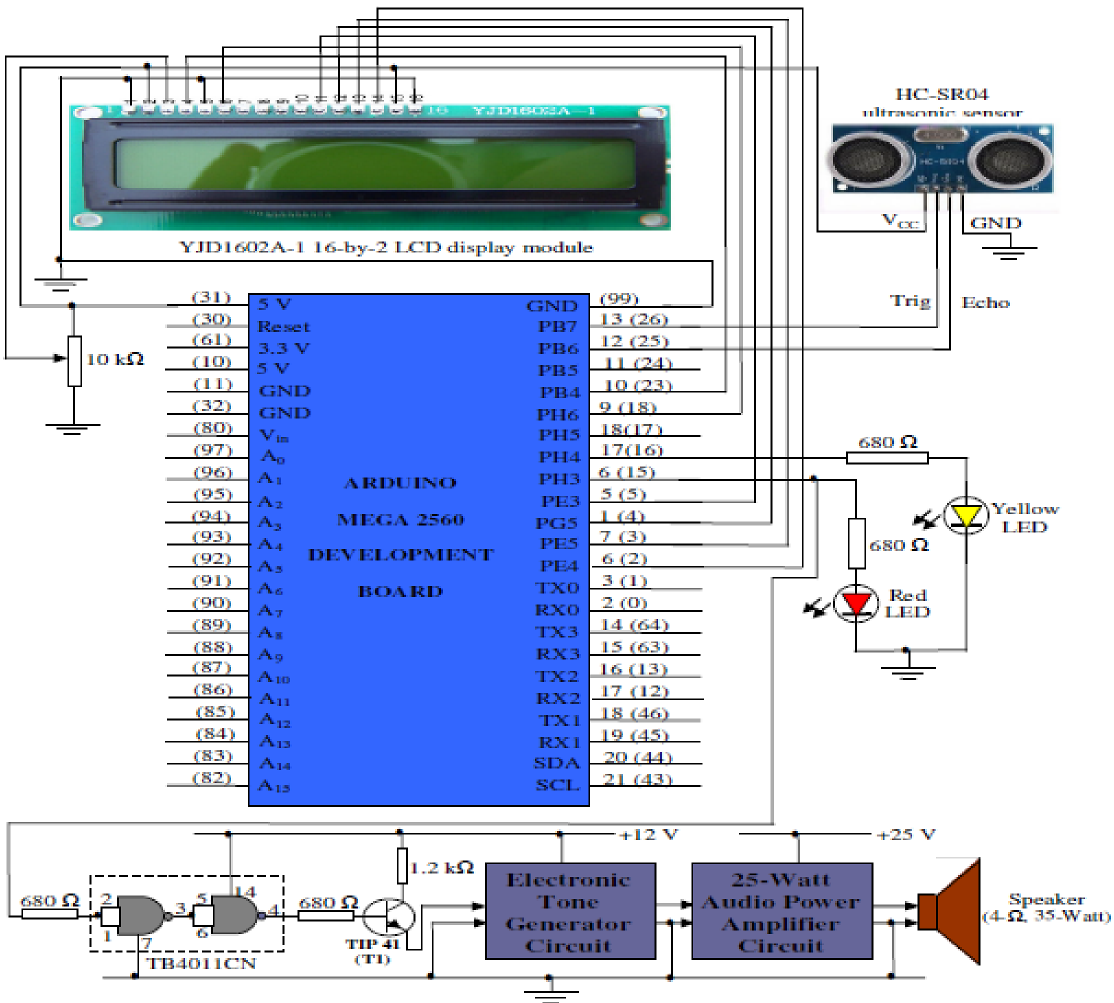


Figure 7.The block diagram implementation of the proposed enhanced obstacle detection system incorporating an electronic alarm integrating a 25-Watt audio amplifier based on IoT technology with a signal conditioning circuit

Table 4.Arduino Mega 2560 pin connections defined for the proposed design

S. No.	Pins on Arduino	Connections	Remarks
1.	26	Trigger pin of HC-SR04 sonar sensor	Trigger input of Sensor
2.	25	Echo pin of HC-SR04 sonar Sensor	Echo output of Sensor
3.	31	VCC terminal of HC-SR04 sonar sensor	5 V supply
4.	99	Ground terminal of HC-SR04 sonar sensor	Ground supply (GND)
5.	15	Positive of red LED.	Goes ON when it detects an obstacle within range of 0 to 4 m
6.	16	Positive of yellow LED	Goes ON when no obstacle is been detected between 0 to 4 m
7.	23	Register Select Pin of LCD	Selects Command Register when Low; and Data Register when High
8.	18	Enable Pin of LCD	Sends Data to Data Pins when a High to Low pulse is given
9.	5	Data 4 Pin of LCD	
10.	1	Data 5 Pin of LCD	
11.	7	Data 6 Pin of LCD	
12.	6	Data 7 Pin of LCD	

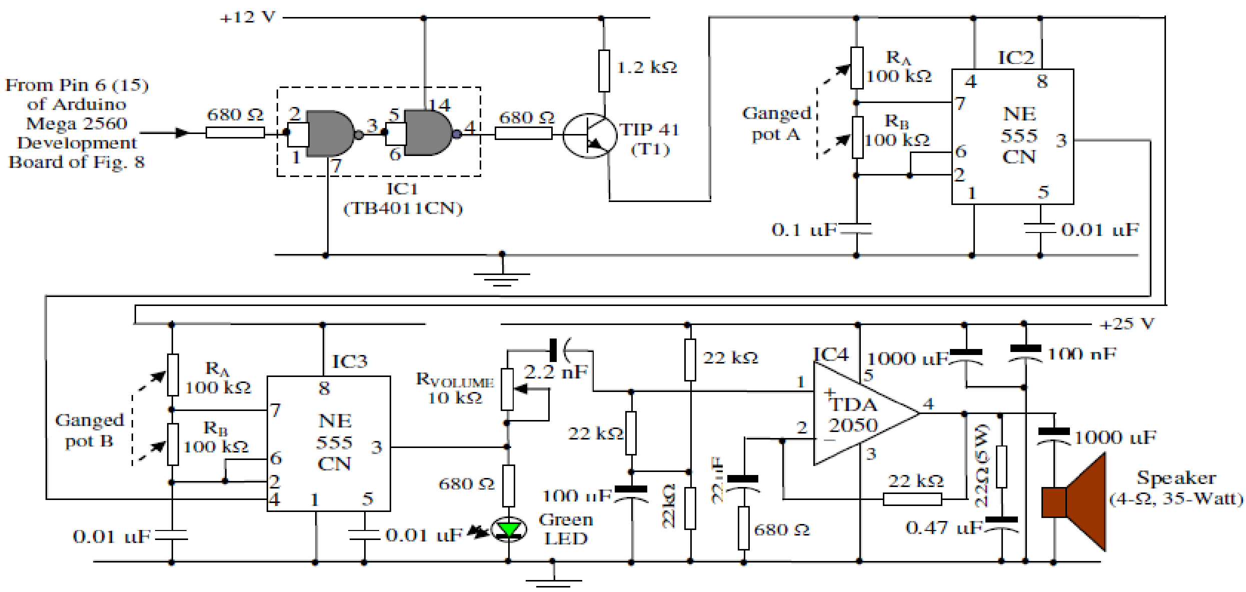


Figure 8.The complete circuit diagram of the enhanced obstacle detection system with the electronic alarm system with audio amplifier

The LCD used in this work is the YJD1602A-1 16-by-2 LCD display module shown in Figure 5 and Figure 6. The physical picture and pin description is shown in Figure 5 while the block diagram of the internal architecture is shown in Figure 6. The absolute maximum ratings for normal operation is shown in Table 2 while the pin description for interfacing the YJD1602A-1 16-by-2 LCD display module is given in Table 3.

Development, Implementation and Deployment of The Enhanced Obstacle Detection with An Alarm System

In the Section, the development, implementation and deployment of the proposed EOD based on IoT is presented. The developmental architecture of the proposed EOD is illustrated in Figure 7. The expanded block diagram shown in Figure 7 closely follows the proposed block diagram shown in Figure 1. An Arduino Mega 2560 interfaced to an HC-SR04 ultrasonic sensor and the YJD1602A 16-by-2 LCD display module together with an electronic alarm system. The LEDs are used to indicate if the ultrasonic receives a reflected wave when an object is within the stipulated range of 0–4 meters.

Male and female jumper wires are used for connections between the microcontroller and the ultrasonic sensor.

Development of the Enhanced Obstacle Detection System with the Alarm System

The block diagram of the proposed EOD system based on sensor, YJD1602A LCD module and the electronic alarm

Table 5.The Complete Program for The Implementation of the Proposed Enhanced Obstacle Detection (EOD) System

```
/*
HC-SR04 ultrasonic distance sensor]
VCC to arduino 5v GND to arduino GND
Echo to Arduino pin 13 Trig to Arduino pin 12
Red POS to Arduino pin 11
Green POS to Arduino pin 10
560 ohm resistor to both LED NEG and GRD power rail
*/
#include <LiquidCrystal.h>
LiquidCrystal lcd(10, 9, 5, 4, 3, 2); // Initializes the LCD Ports
#define trigPin 13
#define echoPin 12
#define led 7 // Triggers Yellow LED
#define alarm 6 // Triggers Red LED and the Electronic Alarm System

void setup() {
  Serial.begin (9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(led, OUTPUT);
  pinMode(alarm, OUTPUT);
}
void loop() {
  float duration, distance;
  digitalWrite(trigPin, LOW);  // Added this line
  delayMicroseconds(2); // Added this line
  digitalWrite(trigPin, HIGH);
//  delayMicroseconds(1000); - Removed this line
  delayMicroseconds(10); // Added this line
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;
  if (distance < 100) {  // This is where the LED On/Off happens
    digitalWrite(led,HIGH); // When the Red condition is met, the yellow LED should turn off
  digitalWrite(alarm,LOW);

  lcd.begin(16, 2);
  lcd.print("within range  ");
  lcd.setCursor(0,1);
  lcd.print("limit  ");
    delay(500);
}
  else {
    digitalWrite(led,LOW);
    digitalWrite(alarm,LOW);

    lcd.print(distance);
    lcd.print(" cm ");
    delay(2000);
  }
  if (distance >= 100 || distance <= 0){
    digitalWrite(led,LOW); // When the Red condition is met, the Green LED should turn off
  digitalWrite(alarm,HIGH);
  lcd.print(" obstacle alert ");
    delay(500);
  }
  else {
    digitalWrite(led,HIGH); // When the Red condition is met, the Green LED should turn off
  digitalWrite(alarm,LOW);
  lcd.print(distance);
    lcd.print(" cm");
    delay(500);
  }
delay(500);
  lcd.clear();
}
```

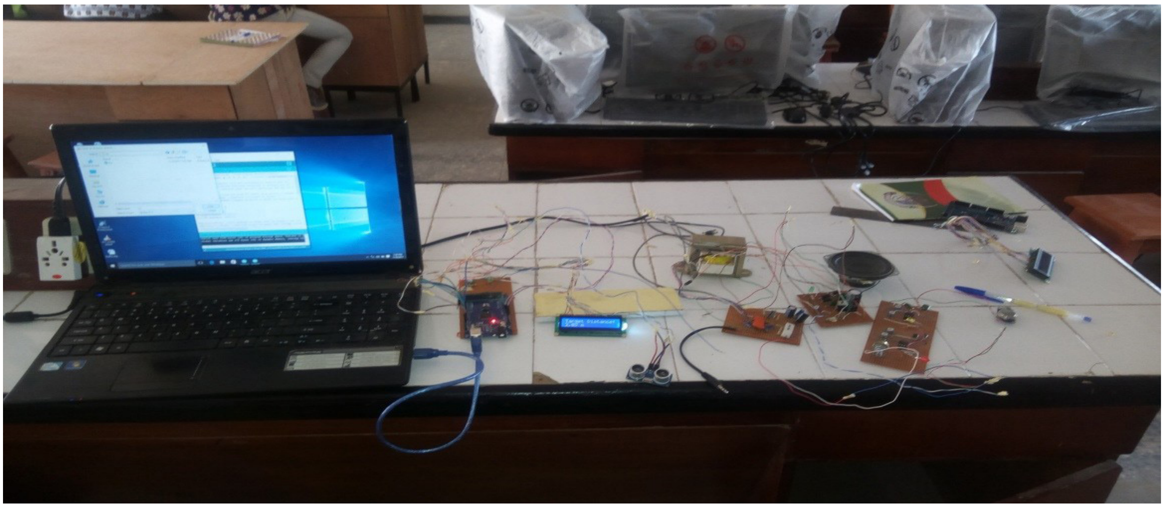


Figure 9.Photograph of the EOD System Experimental Setup and Performance Evaluation

system. The pin 26 and 25 of the Arduino Mega 2560 embedded development board are connected to the Trigger and Echo pin of the HC-SR04 respectively to receive signal. (Please refer to Figure A.1 and Table A.1 in the Appendix for more detailed input and output pin descriptions). When the up. When there are no obstacles detected within the range, the red LED lights up.

The Arduino Integrated Development Environment (IDE) is a cross-platform application written in Java and most of the Arduino programs are written in C or C++. It can runs in all operating systems like Windows, Mac OS, and Linux. It is designed to introduce programming skills to artists and other newcomers who are unfamiliar with software development or hardware programming. It includes a code editor with common developer software features like syntax highlighting, brace matching, and automatic indentation. It also provide functions that are capable of compiling and uploading programs to the Mega2560 development board via USB. It is a user-friendly interface for everyone from beginner to professional to learn or use.

The Electronic Alarm System

The complete circuit diagram for the proposed enhanced obstacle detection system together with the electronic alarm system is shown in Figure 8. The electronic alarm system is built around two NE555CN timer ICs and a TDA2050 audio amplifier IC. Following the discussions above, whenever an obstacle is detected, RED LED comes and the consequently the electronic alarm system is triggered simultaneously.

In order to protect the Arduino Mega 2560 output ports, the output pin 15 is used to bias transistor Q1 (TIP 41 NPN transistor) via 5.6 kΩ which delivers +12 V which serves as power supply voltages to the circuit of IC1. The circuit of IC1 is a NE555CN timer wired as an astable multivibrator. The output taken at pin 3 of IC1 is high for one half of a cycle for one second and goes low for the next half cycle.[27,28] When the output is low, IC2 is inhibited and the loud-speaker is off. During the next half cycle the output is high. Thus, the output of IC2 oscillates at 1 kHz and this oscillating signal was amplified by a 25 Watts audio power amplifier built around IC3, TDA2050,[28–31] and passed to the speaker situated on the far right bottom of Figure 7. When this electronic alarm is on, it however signifies that an intruder or obstacle have been encountered The sound level (i.e. the volume) of the audio amplifier is regulated by the 100 kΩ potentiometer (R_{VOL}).

Performance Evaluation of the Proposed EOD System

The performance evaluation of the proposed EOD system with a view to ascertain the functionality of the designed EOD system is investigated in this Sub-Section. Based on the fabrication and construction of the complete design shown in Figure 7 and Figure 5, the complete program listed in Table 5 was implemented. The experimental setup for the performance evaluation of the proposed EOD is shown in the photograph of Figure 9.

The electronic alarm system initially off with object outside the range of 4 m. However, the proposed EOD system has been able detect any object with the range of 0 to 4 meters with the simultaneous triggering of the electronic alarm system and displaying the corresponding object distance on the YJD1602A LCD.

Conclusion and Future Directions

The paper has presented a technique that can be used to design a circuit that is capable of detecting an obstacle within a range of 0–4 meters and alerting its users by triggering an electronic alarm system incorporating an audio power amplifier. The objective was met since the system works effectively for object detection at various distances up to a maximum of 4 m. When an obstacle is within a range of 0 to 4 m, the system triggers an alarm signal indicating an obstacle on its path or detected. When there are no obstacles detected, a yellow LED switched ON whereas when an obstacle is detected a red LED is switched ON and the alarm system is triggered while the yellow LED turns OFF.

This system can be of great help in both domestic and industrial settings to detect obstacles especially for visually impaired persons who requires guidance. The system can also be used to deter personnel from moving to a particular section since it gives an alarm signal when it comes across any obstacle within a range.

The cost of implementing this system is relatively low since the components used are relatively cheap and are easily available in the market. The single microcontroller can be used to interface several sensors with alarms located in different locations as long as more pins are freed for multiple inputs multiple outs.

The safety of personnel is a very crucial aspect in both domestic and industrial setting; hence the use of ultrasonic sensors is inevitable in addition to other more sophisticated security systems. This system should be placed in a cool and dry place in order to ensure a longer life span.

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Appendix A: Arduino ATMega2560 Microcontroller Pin Definition

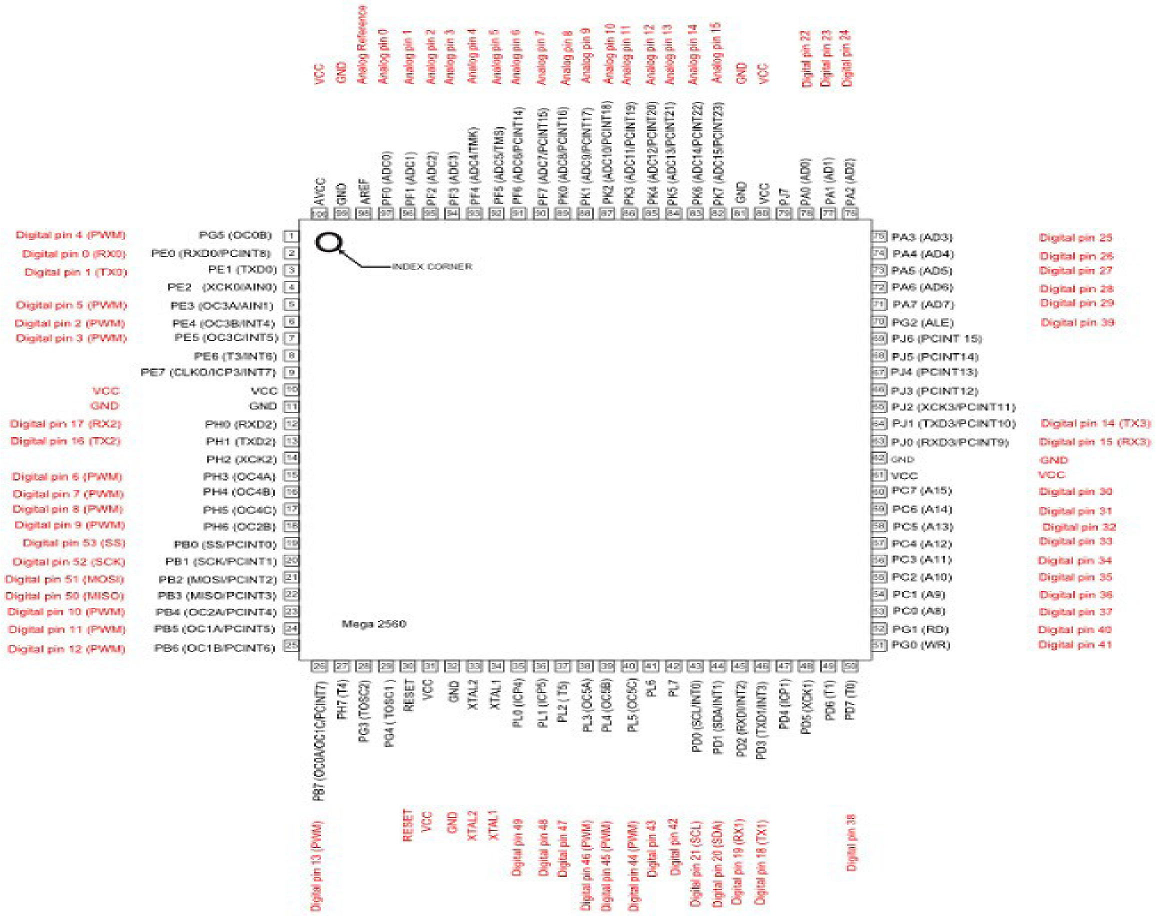

Figure A.1.Arduino ATMega2560 microcontroller Pin Definition

Table A.1.Arduino Mega 2560 PIN mapping table for the ATMega2560 integrated circuit of Fig. A.1

Pin Number	Pin Name	Mapped Pin Name	Pin Number	Pin Name	Mapped Pin Name
1	PG5 (OC0B)	Digital pin 4 (PWM)	51	PG0 (WR)	Digital pin 41
2	PE0 (RXD0/PCINT8)	Digital pin 0 (RX0)	52	PG1 (RD)	Digital pin 40
3	PE1 (TXD0)	Digital pin 1 (TX0)	53	PC0 (A8)	Digital pin 37
4	PE2 (XCK0/AIN0)		54	PC1 (A9)	Digital pin 36
5	PE3 (OC3A/AIN1)	Digital pin 5 (PWM)	55	PC2 (A10)	Digital pin 35
6	PE4 (OC3B/INT4)	Digital pin 2 (PWM)	56	PC3 (A11)	Digital pin 34
7	PE5 (OC3C/INT5)	Digital pin 3 (PWM)	57	PC4 (A12)	Digital pin 33
8	PE6 (T3/INT6)		58	PC5 (A13)	Digital pin 32
9	PE7 (CLKO/ICP3/ INT7)		59	PC6 (A14)	Digital pin 31
10	VCC	VCC	60	PC7 (A15)	Digital pin 30
11	GND	GND	61	VCC	VCC
12	PH0 (RXD2)	Digital pin 17 (RX2)	62	GND	GND
13	PH1(TXD2)	Digital pin 16 (TX2)	63	PJ0 (RXD3/ PCINT9)	Digital pin 15 (RX3)

14	PH2(XCK2)		64	PJ1 (RXD3/ PCINT9)	Digital pin 14 (TX3)
15	PH3(OC4A)	Digital pin 6 (PWM)	65	PJ2 (RXD3/ PCINT9)	
16	PH4(OC4B)	Digital pin 7 (PWM)	66	PJ3 (PCINT12)	
17	PH5(OC4C)	Digital pin 8 (PWM)	67	PJ4 (PCINT13)	
18	PH6(OC2B)	Digital pin 9 (PWM)	68	PJ5 (PCINT14)	
19	PB0 (SS/PCINT0)	Digital pin 53 (SS)	69	PJ6 (PCINT15)	
20	PB1(SCK/PCINT1)	Digital pin 52 (SCK)	70	PG2 (ALE)	Digital pin 39
21	PB2(MOSI/PCINT2)	Digital pin 51 (MOSI)	71	PA7 (AD7)	Digital pin 29
22	PB3(MISO/PCINT3)	Digital pin 50 (MISO)	72	PA6 (AD6)	Digital pin 28
23	PB4(OC2A/PCINT4)	Digital pin 10 (PWM)	73	PA5 (AD5)	Digital pin 27
24	PB5(OC1A/PCINT5)	Digital pin 11 (PWM)	74	PA4 (AD4)	Digital pin 26
25	PB6(OC1B/PCINT6)	Digital pin 12 (PWM)	75	PA3 (AD3)	Digital pin 25
26	PB7 (OC0A/OC1C/ PCINT7)	Digital pin 13 (PWM)	76	PA2 (AD2)	Digital pin 24
27	PH7 (T4)		77	PA1 (AD1)	Digital pin 23
28	PG3 (TOSC2)		78	PA0 (AD0)	Digital pin 22
29	PG4 (TOSC1)		79	PJ7	
30	RESET	RESET	80	VCC	VCC
31	VCC	VCC	81	GND	GND
32	GND	GND	82	PK7 (ADC15/ PCINT23)	Analog pin 15
33	XTAL2	XTAL2	83	PK6 (ADC14/ PCINT22)	Analog pin 14
34	XTAL1	XTAL1	84	PK5 (ADC13/ PCINT21)	Analog pin 13
35	PL0 (ICP4)	Digital pin 49	85	PK4 (ADC12/ PCINT20)	Analog pin 12
36	PL1(ICP5)	Digital pin 48	86	PK3 (ADC11/ PCINT19)	Analog pin 11
37	PL2(T5)	Digital pin 47	87	PK2 (ADC10/ PCINT18)	Analog pin 10
38	PL3(OC5A)	Digital pin 46 (PWM)	88	PK1 (ADC9/ PCINT17)	Analog pin 9
39	PL4(OC5B)	Digital pin 45 (PWM)	89	PK0 (ADC8/ PCINT16)	Analog pin 8
40	PL5(OC5C)	Digital pin 44 (PWM)	90	PF7(ADC7)	Analog pin 7
41	PL6	Digital pin 43	91	PF6 (ADC6)	Analog pin 6
42	PL7	Digital pin 42	92	PF5 (ADC5/ TMS)	Analog pin 5
43	PD0 (SCL/INT0)	Digital pin 21 (SCL)	93	PF4 (ADC4/ TMK)	Analog pin 4
44	PD1 (SDA/INT1)	Digital pin 20 (SDA)	94	PF3 (ADC3)	Analog pin 3
45	PD2 (RXD1/INT2)	Digital pin 19 (RX1)	95	PF2 (ADC2)	Analog pin 2

46	PD3 (TXD1/INT3)	Digital pin 18 (TX1)	96	PF1 (ADC1)	Analog pin 1
47	PD4 (ICP1)		97	PF0 (ADC0)	Analog pin 0
48	PD5 (XCK1)		98	AREF	Analog Reference
49	PD6 (T1)		99	GND	GND
50	PD7 (T0)	Digital pin 38	100	AVCC	AVCC