Method Article

Design, Implementation, Testing, and Evaluation of an Arduino-Based Mosquito Repellent System

ABSTRACT

Aims: The primary objective of this research driveis to design,develop, and evaluate anArduino-based mosquito repellent system.

Study design: Arduino microcontroller board is used, and an assembly language program is developed to repel mosquitoes from the surroundings. This system uses piezoelectric disks, LED lights, LCD monitor along withthe Arduino board. This system can produce ultrasonic sound to protect humans and the environment from mosquitoes and helps to provide an effective and sustainable solution for mosquito control, particularly in the areas where traditional methods are not suitable.

Place and Duration of Study: The research effort was steered by the authors in a group under the supervisor of a faculty member as a part of the coursecapstone project work of the Bachelor Science and Engineering degree in Computer Science and Engineering at American International University Bangladesh (AIUB), Dhaka, Bangladesh. The authors performed their research tasks at AIUB from May 2023 to January 2024.

Methodology: The innovative mosquito repellent system uses an ArduinoMega 2560 microcontroller to generate a cutting-edge solution to tackle the problem of mosquito infestations. The system can produce an electric signal that can emit mechanical ultrasound signals to be harnessed using a series-connected eight piezo-electric discs.In this way, it avoids the use of any harmful chemicals or pesticides to repel mosquitoes and hence the system is environmentally friendly. To power up the system, it uses four Li-ion rechargeable batteries charged by using solar energy from the home solar system. Besides, the system has one red and one green LED to indicate the status of the repellent system.This work underscores the importance of developing sustainable solutions for mosquito control.

Results: The generated ultrasonic signal is observed on the oscilloscope screen and its' value is exhibited on the LCD screen to evaluate the system performance. Besides, the system parameter and cost comparisonshow that this schemesuggests a worthwhile and sustainable result for making a mosquito-free environment.

Conclusion: The development of a mosquito repellent system using ultrasonic sound waves based on an Arduino microcontroller offers a sustainable and effective alternative to traditional methods of mosquito control. The power-up system can contributesignificantly to the progress of renewable energy use. Since the system is chemical and health hazard-free, it is environment-friendly and makes human life more comfortable. The system is portableand cost-effective, making it suitable for use in various settings.

Keywords: Mosquito Repellent System, Ultrasonic Frequency, Renewable Energy,Arduino Microcontroller, Piezo-Electric Disc.

1. INTRODUCTION

Mosquitoes spread diseases, like malaria,chikungunya fever, dengue, West Nile, yellow fever, Zika, etc. that have caused the deaths of countless people around the world [1]. Only mosquitoesruinlives of the people and other animals than any other organism on earth. According to the US Centers for Disease Control and Prevention,at least 619,000 people died from malaria in 2021 in the world [2]. A recent extensive literature survey revealed that from a total of 3578 species of mosquitoes, only 2.5 % of the total, i.e., 88species are vectors for 78 various types of diseases affected by the people around the world [3].Besides, 243 more mosquito species (6.8% of the total)were recognized as probable vectors of these diseases [3]. However, according to the World Health Organization (WHO), 700 million human beings contract a mosquito-borne disease and hence vector-borne diseases have caused above 17% of total infectious diseases accumulating more than 700,000 deaths per year [4]. Therefore, it is understood that mosquitoes pose a significant threat to public health due to their ability to carry and transmit dangerous diseases and as such it is required to develop a robust method of controlling or repelling mosquitoes from human body. Conventional methods of mosquito control, including the use of insecticides, have limitations ranging from environmental pollution to health risks and the development of resistance in mosquito populations [5]. Thus, there is an urgent need to explore alternative approaches that are efficient, eco-friendly, and cost-effective [6].

The microcontroller-based systems are found portable, cost-effective, and efficient for various -applications like motor control, bio-medical devices, cleaning systems, tracking, control and protection systems, etc. [7-14]. Microcontroller-based ultrasonic sound signal was employed in many types of systems including distance measurement applications [12, 15]. The ultrasonic sound can be produced using Arduino microcontroller and can be applied to repel mosquitoes with the recent studies indication of frequencies in the range of 18-48 kHz [16-18]. Therefore, this work proposes the development of a mosquito repellent system using Arduino, a widely used microcontroller platform capable of controlling electronic devices. The system aims to address the shortcomings of traditional mosquito control methods by employing basic technical and mechanical equipment that is safe for both humans and the environment.The primary objective is to offer an efficient and sustainable mosquito control solution, particularly in areas where traditional methods have proven ineffective or unsuitable. By utilizing Arduino's flexibility and programmability, the system can be tailored to specific requirements and environmental conditions, enhancing its efficacy.Through the realization of this innovative mosquito repellent system, thiswork aims to reduce mosquito-borne diseases, especially in developing countries where these diseases impose a significant burden on public health. Moreover, by focusing on environmental friendliness and cost-effectiveness, the proposed solution seeks to provide a viable alternative to conventional methods, thereby fostering long-term sustainability.The outcomes of this work have the potential to revolutionize mosquito control strategies, facilitating a safer and healthier environment for communities affected by mosquito-borne diseases. This mosquito repellent system maycreate substantial impacts on public health and lifesaving by offering a favorable avenue for mitigating the global threat due to mosquito-borne illnesses.

2. LITERATURE REVIEW

The article in reference [19] discussed the design and implementation of a mosquito repellent system using Arduino and solar energy. The authors highlight the importance of finding alternative and sustainable methods for mosquito control, especially in developing countries. The article represents, the study aims to develop a solar-powered smart mosquito repellent system using ultrasonic sound waves controlled by an Arduino microcontroller.The

system is cost-effective and environmentally friendly compared to traditional methods of mosquito control using insecticides.The system has potential for use in remote areas where traditional mosquito control methods are not available or feasible and emphasizes the importance of using sustainable and environmentally friendly methods for mosquito control to prevent the spread of mosquito-borne diseases.

The research paperof reference [20] presents the design and realization of an integrated mosquito repellent system that uses ultrasound and frequency. The authors highlight the restrictions of conventional mosquito control techniques and the demand for more effective and sustainable way outs. The article aims to develop a portable and affordable integrated mosquito repellent system that uses ultrasound and frequency controlled by an Arduino microcontroller.The system was found effective in repelling mosquitoes and is more cost-effective and environmentally friendly than traditional methods of mosquito control using insecticides.The system has potential for use in outdoor settings, such as camping or outdoor events and emphasizes the importance of developing sustainable and effective methods for mosquito control to prevent the spread of mosquito-borne diseases.

The research article in [21]reports the design and implementation of a smart ultrasonic repeller system for repelling insects and pets in farms and inventories. The authors highlight the importance of finding efficient and eco-friendly solutions for pest control in agriculture, and the need for smarter systems that can be remotely controlled and monitored. The article provides a detailed description of the hardware components of the system, including an ultrasonic sensor, a microcontroller, and a wireless communication module.The study aims to develop a smart ultrasonic insect and pets repeller that can be used in farms and inventories to repel insects and pests without the use of harmful chemicals or insecticides.The system is effective in repelling insects and pets and is more environmentally friendly and cost-effective than traditional methods of insect and pest control. The system has potential for use in various settings, such as farms, warehouses, and inventories, where insect and pest control are necessary, and emphasizes the importance of developing sustainable and effective methods for insect and pest control to prevent the spread of diseases and reduce the negative impact on the environment.

3. WORKING METHODOLOGY

The proposed mosquito repellent system uses Arduino, a cutting-edge solution to tackle the problem of mosquito infestations. By harnessing the power of technology, this work uses the Arduino Mega 2560 microcontroller and a set of eight piezoelectric disks to emit ultrasonic sound waves, that is sound waves with frequency over 20 kHz [15] to repel mosquitoes without using any harmful chemicals or pesticides. As a result, the proposed system is environmentally friendly, using solar energy and rechargeable batteries. The system is equipped with a red and a green LED to indicate the status of the repellent system. This work showcases the potential of using technology to address real-world issues and underscores the importance of developing sustainable solutions for mosquito control.

The block and schematic diagrams of the proposed system areprovided in Figs. 1-2. In the block diagram of the system of Fig. 1, all components and their connections are shown along with the direction of signal flow from and to the Arduino Mega 2560 microcontroller.

In the schematic diagram of the system of Fig. 2, all components and their connections are shown according to their implementation in real-time hardware parts. According to this schematic diagram, the Arduino Mega2560 sends signals to the piezoelectric disks to emit ultrasonic sound waves.The ultrasonic sound waves disrupt the nervous system of mosquitoes and repel them.The status of the system is indicated by the red and green

LEDs.The system is powered by a rechargeable battery pack of around 10 V DC, making the system portable.The system provides a sustainable and effective alternative to traditional mosquito control methods. The purposes of utilizing several elements are clarified in the next few sub-sections.

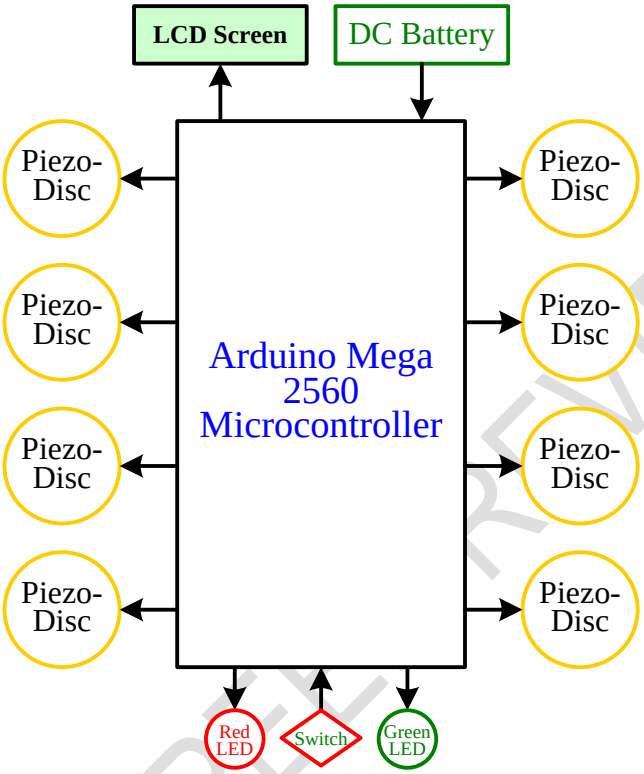

Fig. 1.Block diagram of the proposed mosquito repellent system.

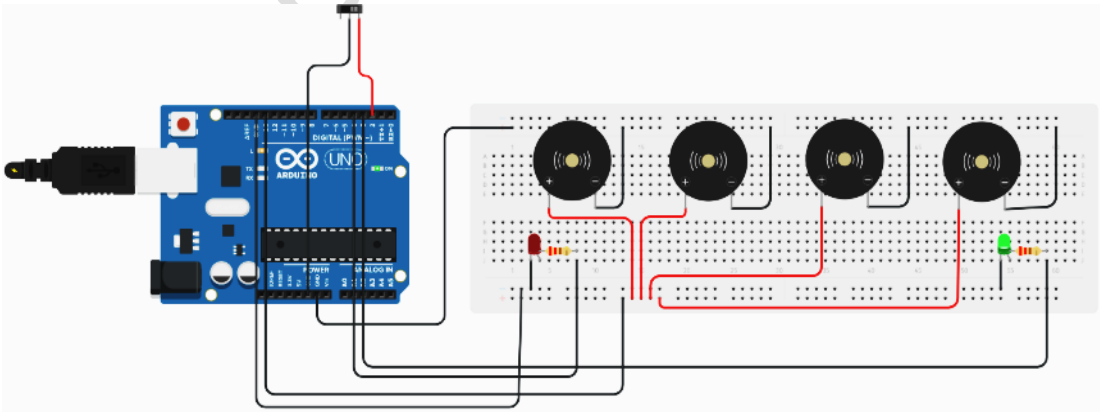

Fig.2.Schematic diagram of the proposed mosquito repellent system.

3.1 Piezoelectric Disks

Piezoelectric disks are electronic components that can convert mechanical energy into electrical energy and vice versa. When pressure or vibration is applied to the disk, it

produces an electric charge that can be used in various applications, such as sensors, speakers, and alternatively, if any electrical signal is applied to these discs, then they produce mechanical vibrations for which ultrasonic mechanical oscillatory signals are produced and applied in our desired mosquito repellent systems.

3.2 Arduino Mega2560

The Arduino Mega2560 microcontroller is aimportant component of the project as it provides the required processing power and control to drive the ultrasonic piezoelectric disks and LEDs. Its high memory and input/output capabilities make it an ideal choice for controlling complex systems, such as the mosquito repellent system.

3.3Li-Ion Rechargeable Battery

Lithium-ion (Li-ion) rechargeable battery is used in this work because it is very eco-friendly,possesses veryenergy density and lower rates of self-discharge. During the discharging and recharging cycles, it undergoes movement of charged particles through cathodes and anodes to create current flow. Therefore, it can be reusedseveral times. So, it provides a cost-efficient long-term solution. Besides, itis a lightweight and safe device for its users [23-24].

3.4LED Light

In this work, the LED lights are used as indicators to understand and to know whether the system is working, and the frequencies are being generated or not.

3.5LCD Device and Driver

The LCD display is widely used to present vital information, including sensor readings, system status, messages, and menu options. It provides a simple and cost-effective way to visually present data to the user [30]. In this work, we used an LCD having the capacity of displaying 16 characters in 2 lines.To connectthe LCD screen tothe microcontroller, we used anInter-Integrated Circuit (I2C) LCD driver module, which communicates via I2C protocol. This module requires no complex connections or setup, thus saving time [31].

After studying all the necessary components, we connected8 piezoelectric disks to the Arduino Mega2560 microcontroller through its 8 different ports. After that, we connected a red and a green LED through two 220 Ω resistors to the microcontroller's two other digital output ports. Resistors are connected to the LEDs in series to limit the current flow into the LEDs. After that, we connected a 2-pin on/off rocker switch button to turn on/off the system. The whole system is powered by a rechargeable battery pack. After hardware setup, we wrote, debugged, and uploaded the program into the Arduino board through its COMx port. Finally, the system is tested to evaluate its functionality.

4. SIMULATION MODEL

Figure 2denotes the simulation model of the proposed system designed using the Porteous simulator. Arduino Mega2560 is used as a microcontroller. To detect dust and time, two LDR sensors are connected to the input terminals. An LCD display is connected to theoutput terminals through an I2C LCD driver to show the output status.

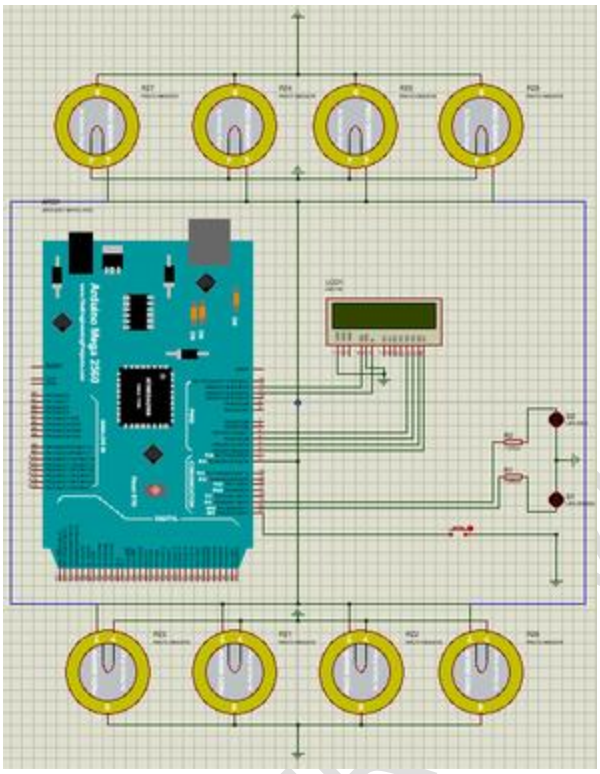

Fig.3.Simulation model of an automated mosquito repellent system using ultrasound generation through 8 piezoelectric discs.

3. FLOW CHART

The flow chart of an automated mosquito repellent system using ultrasound generation through 8 piezoelectric discs is shown in Fig. 3. According to this flow chart, the assembly language program written for this system starts with turning on the power of the system. After that, some variables are initialized. Thus, the LCD monitor displays a welcome message to indicate that the user can start the program. Now, if a button is pressed in the hardware part of the system, then it turns on the green color LED to indicate the system is ready to run. After that, the ultrasonic discs (in this work, we used 8 different discs) emit an ultrasonic signal of around 31 kHz. Then the value of ultrasonic sound is displayed on the same LCD monitor. If the switch is pressed, then it sends a signal to the microcontroller, either HIGH or LOW.

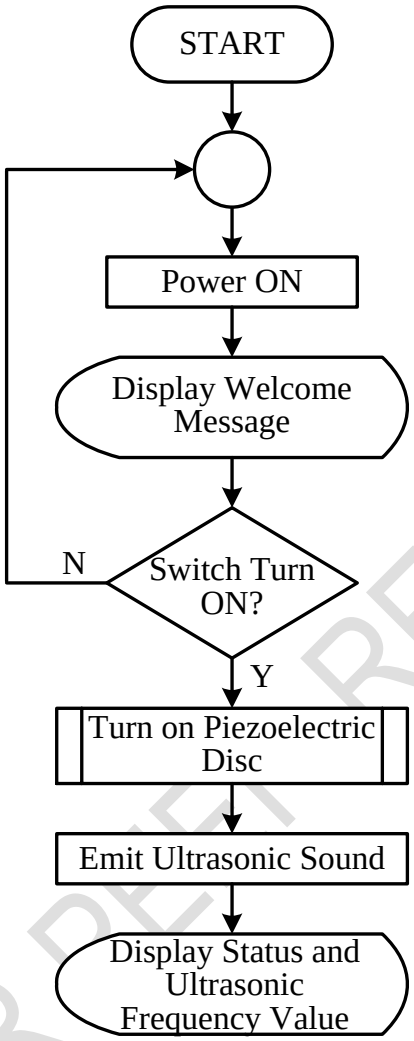

Fig.4.Flow chart of the assembly language program for the automatic mosquito repelling system.

3. RESULTS AND DISCUSSION

Figures 4-5 show the simulation results of mosquito repellent system. When the system is turned on, but the switch (just above the bottom layer's 4 discs) is not pressed then only the red LED (upper LED at the right) is turned on and the LCD screen (just below the upper layer's 4 discs) shows a welcome message. When the system is turned on and the switch is pressed green LED (lower LED at the right) is turned on and the LCD screen shows the emitting ultrasound frequency of 31 kHz. Here, 8 piezoelectric discs are used to emit ultrasound frequency of 31 kHz by each disc. Discs are arranged in two rows, each row containing 4 discs to emit ultrasound wave to repel mosquitoes from all directions.

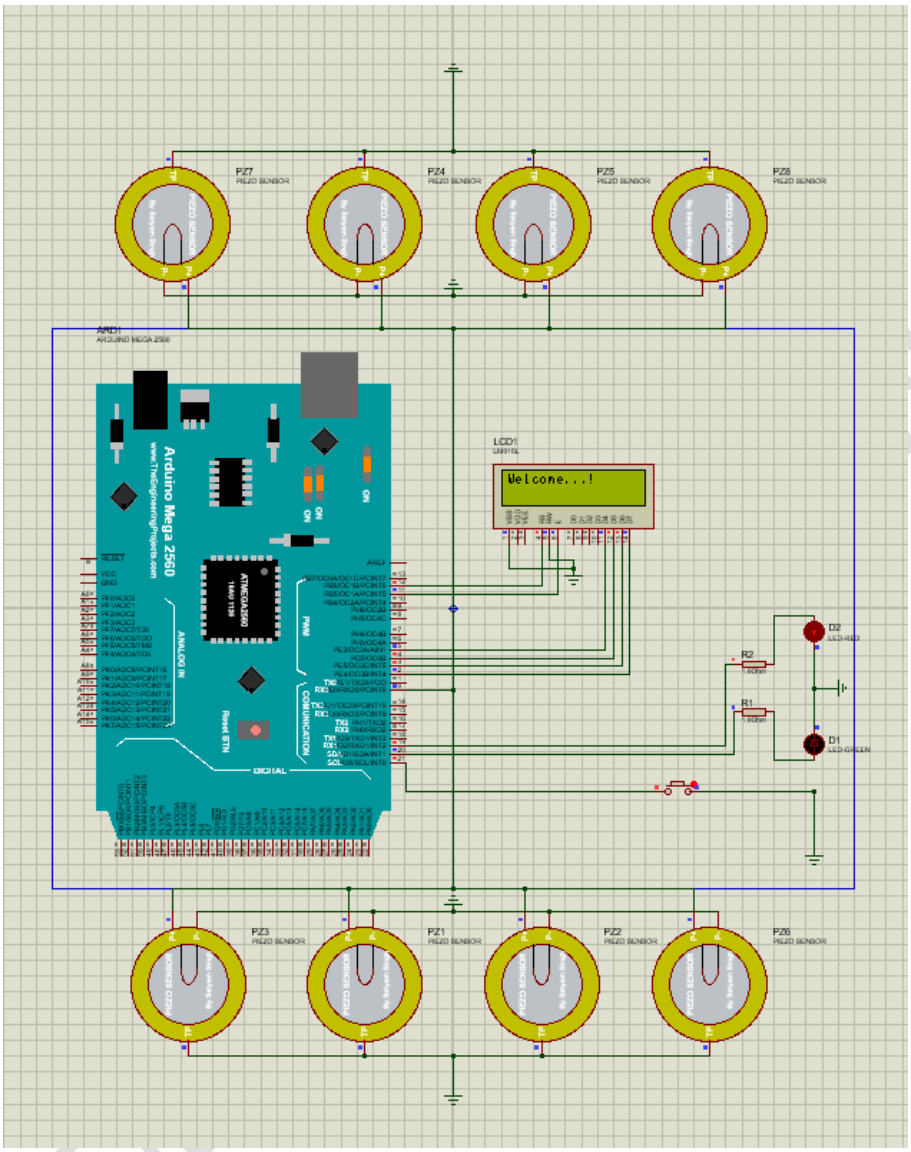

Fig.5.Simulation results of the system when the system is turned ON and the red LED is turned ON (upper LED at the right side).

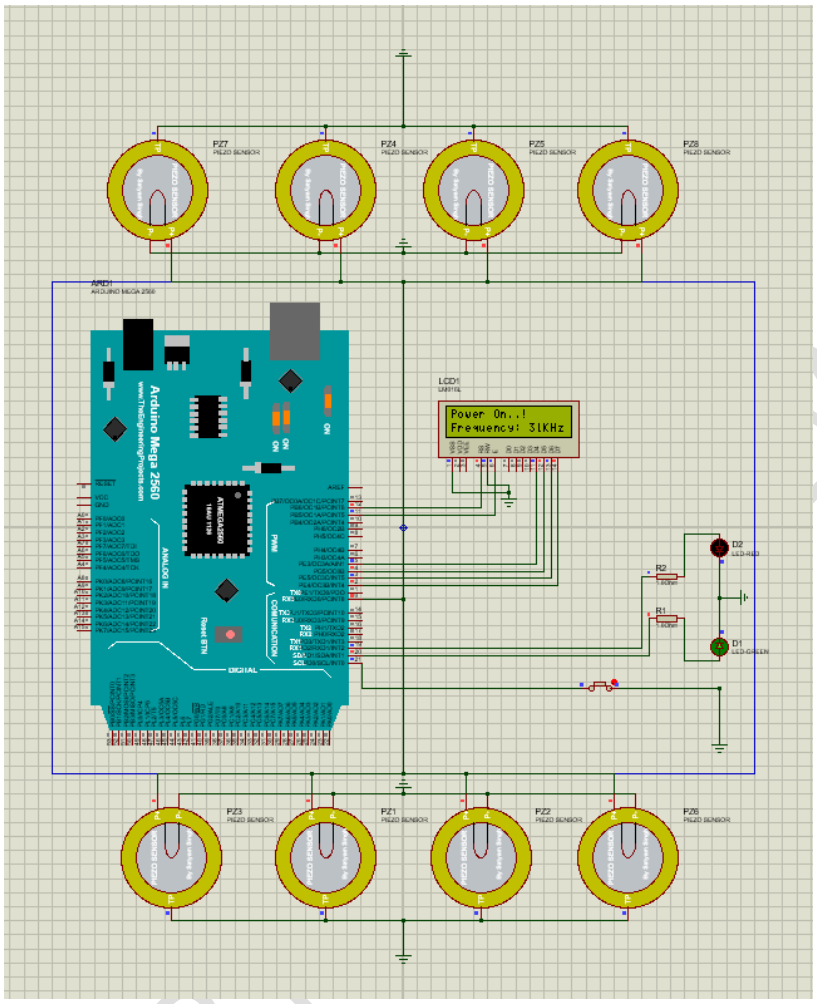

Fig.6.Simulation results of the system when ultrasound frequency 31 kHz is shown on the LCD screen and the green LED is turned ON (lower LED at the right side).

A few hardware implementation outputs are revealed in Figs. 6-10.Figure 6demonstratesthehardware implementation of the mosquito repellent system when the DC power is supplied to the system the red LED is turned ON and the LCD screen shows a welcome message. The outcome on the LCD screen's message is shown in Fig. 7. After that, the switch is turned ON and hence the red LED is turned ON and the LCD screen shows the ultrasound frequency of 31 kHz as shown in Figs. 8-9.

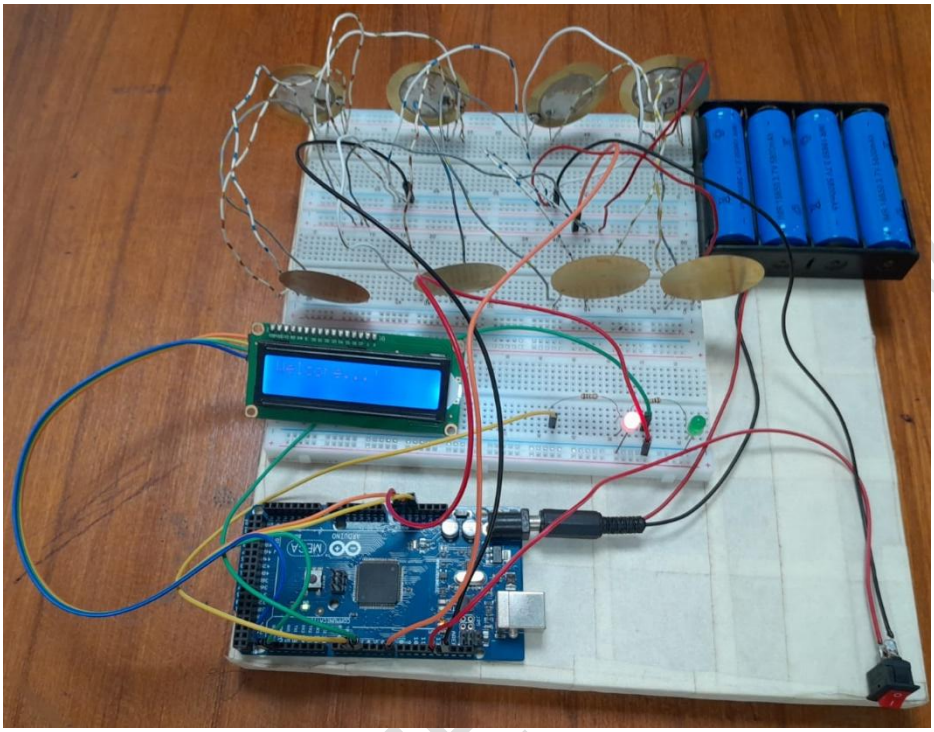

Fig.7.Hardware implementation of the system with power supplied from DC battery.

Fig.8.When the power is ON, the LCD screen is showing a Welcome message.

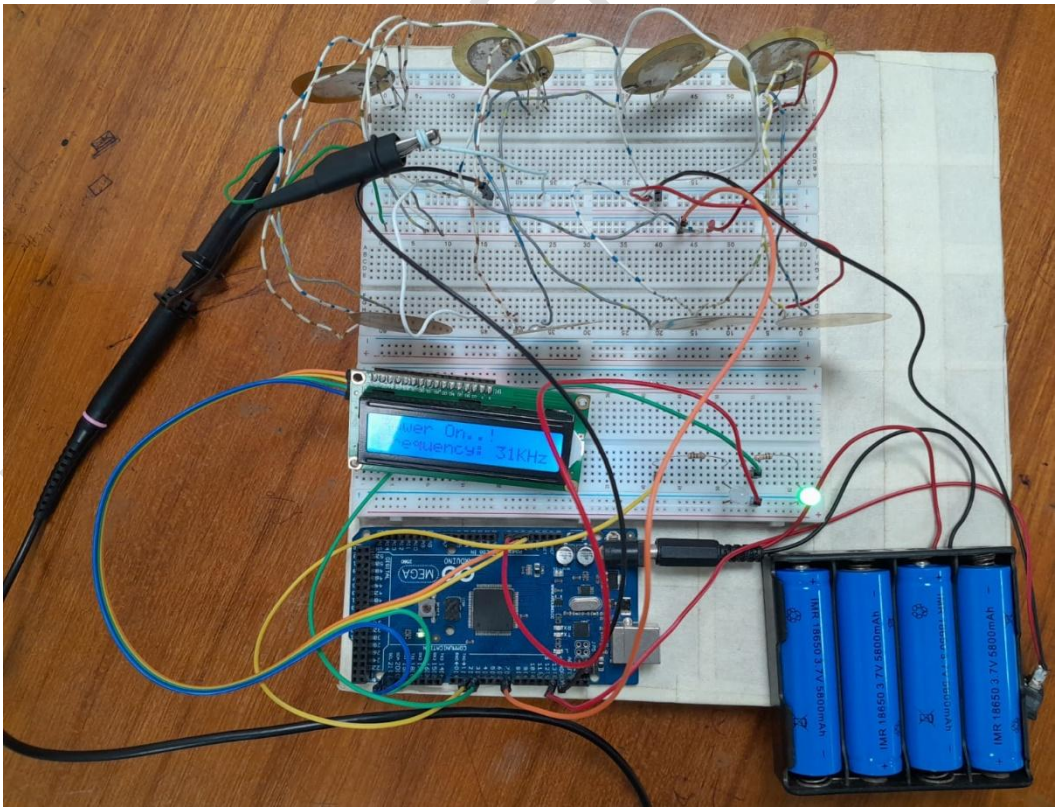

Fig. 9.Hardware implementation of the system when the switch is ON.

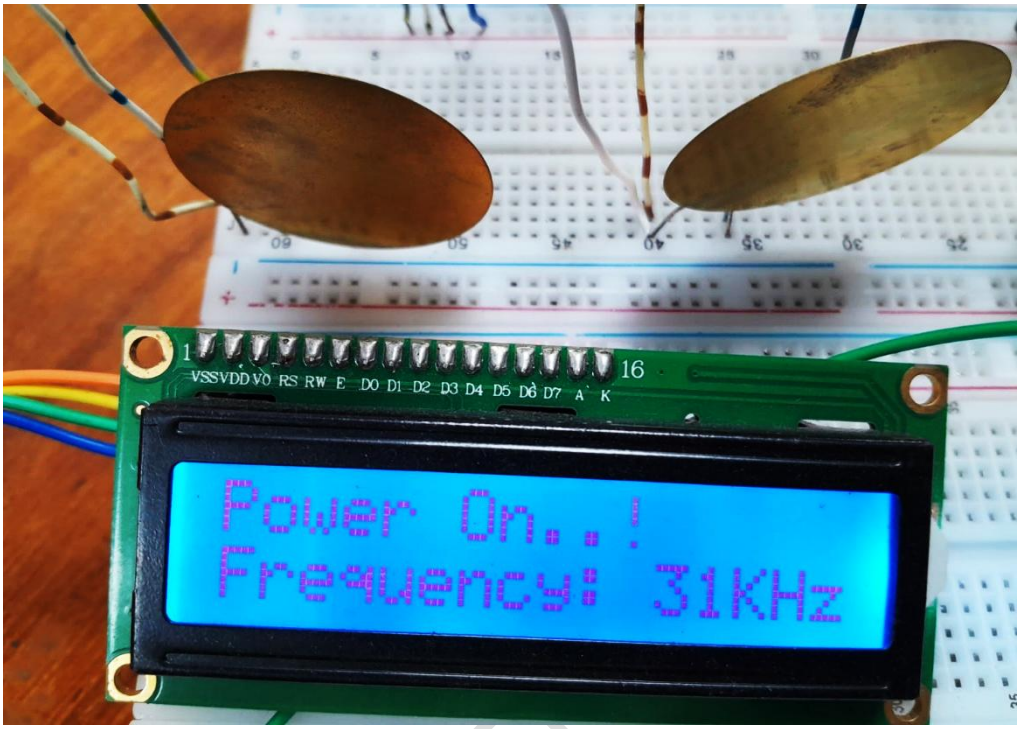

Fig. 10. When the switch is ON, the LCD screen is showing the ultrasonic frequency.

Figure 10 represents themeasurement of signal frequency by a digital storage oscilloscope in the laboratory. The disc's output frequency is obtained on the oscilloscope screen as 31.2 kHz. It is slightly higher than that obtained in Proteus simulation. The peak-to-peak ac output signal voltage measured by the digital storage oscilloscope is 3.8 V and its rms value is 2.62 V. The same value is measured by the DC multimeter and found as 2.63 V, which is almost the same as measured by the oscilloscope. Besides, the ac output rms current is 5.44 mA.

Besides, the DC supply voltage and supply current are measured by the digital multimeter as 10.8 V and 135 mA. So, the input DC power to the system is 10.8×135 = 1458 mW = 1.458 W. So, we can say that it is a very low-power system.

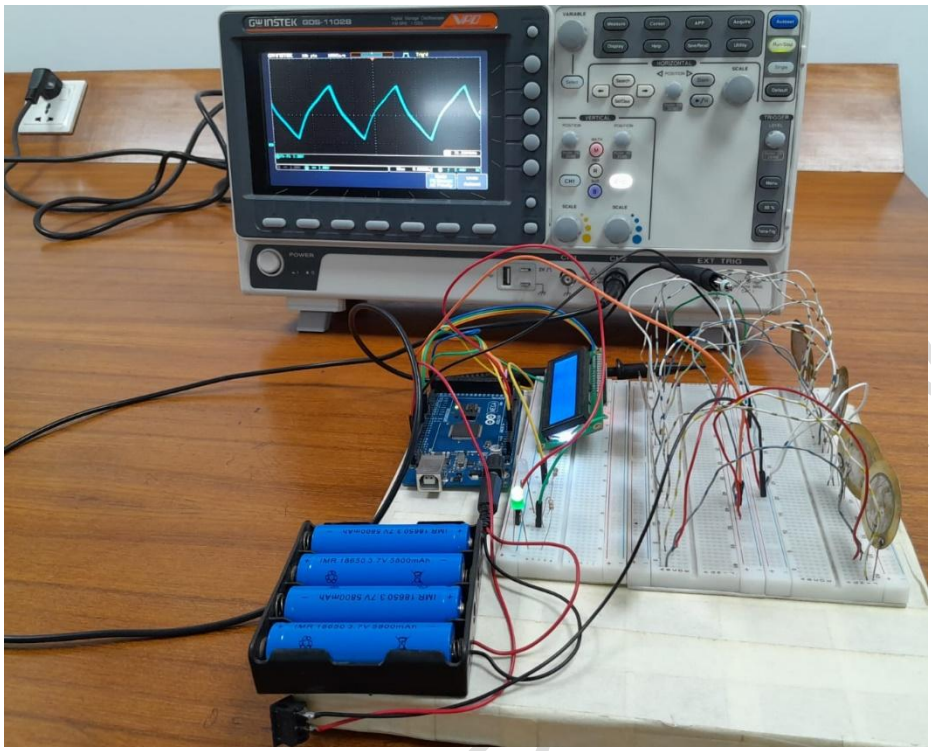

Fig.11.Measurement ofsignal frequencyusingthe digital storage oscilloscope.

Fig.12.Generated signal's frequency on the digital storage oscilloscope screen.

Table 1 shows the breakdown of prices of various components used in this work. The total cost required for this work is BDTK3524 (Bangladeshi Taka three thousand five hundred and twenty-four only), which may be approximately equal to US$32.07 (US Dollar thirty-two point zero seven). The proposed system is a very low-cost solution as noted from the cost analysis.

Table 1.Cost estimation ofa microcontroller-based mosquito repellent system.

Sl. No.	Items	Quantity	Unit Price (BDT)	Price (BDT)	Price (US$)*
1	Arduino Mega 2560	1	1995	1995	18.1545

2	Red LED	10	1	10	0.091
3	Green LED	10	1	10	0.091
4	Yellow LED	10	1	10	0.091
5	35 mm Piezoelectric Disk	8	50	400	3.64
6	18650 Li-ion Rechargeable Battery	4	95	380	3.458
7	18650 Battery Holder with Wire	1	100	100	0.91
8	DC Male Power Jack Connector	1	7	7	0.0637
9	Jumper Wires	25	6	150	1.365
10	1 mElectrical Wire - Black	1	20	20	0.182
11	1 mElectrical Wire - Red	1	20	20	0.182
12	Resistors 220 Ohm	20	1	20	0.182
13	On/Off Switch	1	12	12	0.1092
14	Bread Board	2	145	290	2.639
15	1A Li-ion Battery Charging Module Type - C	2	50	100	0.91
	Total Price in BDT and US$, respectively			**3524**	**32.0684**

** Costs are given based on prices of the components in Bangladesh in Bangladeshi Taka (BDTK). But it may vary depending on the country of purchase and dollar rate. In general, 1 US$ = 120 BDT.*

The total cost is compared with three other researchers' works and is shown in Table 2. This table shows that we have optimized our costs significantly.

Table 2. Cost comparison of a microcontroller-based mosquito repellent system.

Ref. No.	Name of the Paper	Approach	Total Cost
23	Design and construction of electronic pest repellent for use in homes and farmland	Pest Repellent using PIC16F887	$138.80
24	Solar energy driven autonomous smart ultrasonicmosquito repeller system	Solar Driven Ultra SonicRepellent System	$50.06
25	Waterproof, low-cost, long-battery-lifesound trap for surveillance of male Aedesaegypti for rear-and-release mosquitocontrol program	Various Low-Powered Microcontroller and Speaker	$64.86

The technical issues of the same methods are compared with this proposed system. These comparative features are shown in Table 3.

Table 3. Comparative features of various technical issues of a microcontroller-based mosquito repellent system.

Ref. No.	Method	Key Highlights	Pros	Cons

23	Integrated ultrasonic and frequency system	Ultrasonic transducers and frequencies controlled by Arduino Portable and compact design. Ultrasonic sensors and wireless modules Remote monitoring and control capabilities	Eco-friendly and no chemicals Portable for outdoor use Can be deployed at a scale in farms/warehouses. No harmful chemicals	Ultrasonic effectiveness varies Limited repellent range. Higher Cost Compared to other similar cheaper designs. Not tailored for household use. Effectiveness across insects varies
24	Solar-powered smart ultrasonic system	Uses solar energy to power ultrasonic transducers Microcontroller controls transducers to emit ultrasonic frequencies (38-44 kHz) Costs $50 in components.	Eco-friendly power source Ultrasonic frequencies specifically target mosquitoes Low power consumption (0.735W)	High initial cost for solar panels| Limited mosquito repellent range Complex design requiring expertise
25	Acoustic lure device	Low-cost, low-power, waterproof acoustic lure that mimics female mosquito wingbeats to attract and trap male Aedes aegypti mosquitoes in inexpensive gravid traps.	Provides a low-cost method for surveillance of male Aedes aegypti populations. Reduces costs compared to commercial traps like the BG-Sentinel. Lower power usage extends battery life.	Waterproofing could reduce sound emission and range. More variable catch rates compared to commercial traps in extended field trials. May be less effective for mosquito species that do not swarm using wingbeat frequencies. Limited field-testing data so effectiveness across regions is uncertain.
Proposed System	Arduino piezoelectric system	Piezoelectric discs emit ultrasonic waves Arduino controls discs and status LEDs	Very low cost at $32 Simple and customizable design Portable and rechargeable battery	Limited repellent range

Our observation from this comparative study is that the Arduino piezoelectric system stands out as the most cost-effective design at only US$32 (US Dollar thirty-two only) while using eco-friendly ultrasonic frequencies. Besides, it has a simple design focused solely on repellent functionality rather than complex multi-functional systems. This allows keeping costs low. Its simplicity and customizability also make it easy to tailor and deploy for household use. However, the limitation of this system is its moderate repellent range,but the

low cost makes it feasible to deploy multiple units for wider coverage.Solar-powered systems as proposed in [24] can provide renewable power but have very high initial costs. Their maintenance and durability are also unclear.

Besides setting up a solar power repellent system is also very complex and compromises its usability. Remote monitoring and control system proposed in [23] are useful features but add complexity and cost if not needed. Therefore, the Arduino piezoelectric system provides the most promising approach for a low-cost, eco-friendly, simple, customizable, and effective household mosquito repellent system for resource-limited settings.

4. CONCLUSION

In conclusion, the development of a mosquito repellent system using ultrasonic sound waves and an Arduino Mega 2560 microcontroller offers a sustainable and effective alternative to traditional methods of mosquito control. The system is portable, environmentally friendly, and cost-effective, making it suitable for use in various settings. While there are some limitations to the system, such as reduced effectiveness in range, overall, the project has demonstrated the potential for using technology to address important issues related to public health and the environment.For future endeavors, the mosquito repellent system could be further optimized in improving the range and signal strength of the ultrasonic sound waves to enhance the system's performance. Besides, the system may be developedwith a more user-friendly interface for controlling and monitoring the system and optimized for different kinds of mosquito species. We are exploring the potential for integrating other mosquito control methods, such as trapping or sterilization, into the system and expandingits use to other insect and pest control applications, such as in agriculture or household pests.The effectiveness of the system may changebased on the species of mosquitoes in the area, as some mosquitoes may be less affected by ultrasonic sound waves. However, this can be overcome by using additional methods in combination with the ultrasonic repellent system.

CONSENT

There is no consent required for this publication except for ours.

ETHICAL APPROVAL

There is no ethical approval requirement for this task.

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