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Design and Implementation of a Micro-Controller Based Mosquito Repellent System

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ABSTRACT

Mosquito-borne diseases pose a significant threat to public health worldwide. This study presents the design and development of a mosquito repellent system that utilizes ultrasonic frequency and UV light to repel and eliminate mosquitoes and machine learning algorithms. The system consists of a microcontroller, UV light source, ultrasonic frequency generator, and a DC fan. The microcontroller coordinates the operation of the system, activating the UV light to attract mosquitoes, followed by the ultrasonic frequency to repel them, and finally the DC fan to eliminate the trapped mosquitoes. The system was tested in various environments, and the results showed a significant reduction in mosquito populations. This study demonstrates the effectiveness of the designed system in repelling and eliminating mosquitoes, providing a potential solution for mosquito-borne disease control.

Keywords: Mosquito, Repellent, Micro-controller, Sensors, Ultrasonic

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INTRODUCTION

Mosquito-borne diseases such as chikungunya, malaria, dengue fever, yellow fever, West Nile virus, and Zika virus (Reiter, 2001) continue to pose a significant threat to public health worldwide. According to the World Health Organization (WHO), this has resulted to the death of over one million deaths annually. Traditional methods of mosquito control, such as insecticides and mosquito nets, have proven to be ineffective in many cases. To kill mosquitoes and prevent their spread, there are several approaches such as killer spray, oils, coils, machines perfumes, etc. For the most efficient outcomes without involving any side effects, the best solution is to build an Electronic mosquito repellent by using basic electronic components. Alternative environment friendly methods have been developed using electronic devices (Tiwari and Ansari, 2016). Electronic Pest Control (EPC) is the name given to the use of any of the several types of electrically powered devices designed to repel or eliminate pests, usually rodents or insects. The operation of EPC could be based upon ultrasonic and electromagnetic principles. Ultrasonic devices operate by emitting short wavelength, high frequency sound waves, at high pitch greater than 20,000 Hz but inaudible to the human ear. More specifically, it deters insects with ultrasonic frequency in the range of 30 kHz to 50 kHz. It wards off other pests by emitting this pulse ultrasonic signal creating a piercing sound and aggressive environment for them but however safe for humans and household animals (Shukla *et al*., 2018). In order to increase the effectiveness of the device, the frequency of ultrasonic oscillator can be varied between certain limits depending on the types of pests. An Electronic Mosquito Repellent repels mosquitoes by using a small speaker or piezoelectric disk to generate ultrasound. The frequency of these sound waves is in the order of 20 kHz to 100 kHz. These sound waves cannot be heard by humans; however they can be heard by some animals, usually those that are small.

In recent years, machine learning and Internet of Things (IoT) technologies have emerged as promising solutions for various applications, including mosquito control (Vasconcelo *et al*, 2021). Machine learning algorithms can be trained to detect the presence of mosquitoes based on sensor data, such as ultrasonic and infrared signals. IoT technologies can be used to integrate sensors, actuators, and communication devices to create a smart mosquito repellent system.

This project work is to design and implement a micro-controller based mosquito repellent system using machine learning algorithms. The system will use ultrasonic and infrared sensors to detect the presence of mosquitoes and activate a repellent device to deter them. It also uses ultraviolet UV) light source to attract mosquito, then using a fan to spin them off. The system will be trained using machine learning algorithms to improve its accuracy and effectiveness. The proposed system has the potential to provide a reliable and efficient solution for mosquito control, and could be used in various settings, including homes, hospitals, and public spaces.

REVIEW OF WORK DONE ON MOSQUITO REPELLENT SYSTEMS

Kole *et al*. (1999) developed an electronic circuit design as useful means of repelling pests that could be better than chemical pesticides. Such design will better adapt to the environment of developing countries. Shukla *et al*. (2018) presented a compact, affordable, and eco-friendly ultrasonic pest repellent system. The device uses a microcontroller unit (MCU) to generate a 1 V peak-to-peak square wave, amplified by an LM380 audio power amplifier to produce ultrasonic frequencies around 80 kHz. A user-friendly 4x4 keypad and 16-pin LCD display allow for multiple operational modes. The system effectively repels pests like ants, insects, and rodents, offering a sustainable alternative to chemical pesticides. Simulations, experiments, and life-cycle cost analysis demonstrate its efficacy and sustainability.

Ibrahim *et al*., (2013) confirmed that ultrasonic sound devices do have both a repellent effect as well as a reduction in mating and reproduction of various insects. However, when both results were correlated, ultrasonic sound had little or no effect on some pests. Various ultrasonic devices were highly effective on crickets, while the same devices had little or no repellent effect on cockroaches. The study also emphasized that there was no effect on ants or spiders in any of the tests.

They concluded, based on the mixed results, that more research is needed to improve these devices. Devender (2012) reported an electronic circuit for pest repulsion. It is effective over a diameter around 16 meters. These basically consist of a small hot plate or a chemical mat in order to produce smokes and fumes. These fumes not only affect the mosquitoes and other insects but also adversely to human beings. The work thereafter proposed a circuit working using ultrasonic waves rather than the chemical fumes or harmful toxic smoke. This circuit generated an output from 30 to50 kHz, which is not audible and harmless to human beings. The CD4017 decade counter having ten outputs as a variable frequency and each output goes high one after another. The oscillator was built using NE555 timer clocks this decade counter CD4017 which generates the frequency and gives the desired output. The presence of pests in any food handling premises is undesired and unacceptable (Hatfields, 2009). Brower *et al*., (1999) aimed to design a circuit using ultrasonic sensors that repelled insects using its frequency hearing range. The design was characterized with low cost, portability and high fidelity sound frequency detector. This device could widely be used depending on situation and places are tested to detect signal within the coverage area about 21mm to 37mm on a solid wall room. (Sasaki, *et al*, 2017). The frequency produced caused the insects moved on and repelled entirely. The risks posed by pests include the spread of disease by pathogens which are transferred from the gut or any other external surface of the pest. The objective of the electronic pest control should be to prevent these activities, as far as practicable, reducing the introduction of pests on this area and to minimize the conditions that may encourage their presence. Detrick and Forest used ultrasonic repellent and a driver control circuit as outdoor devices for electro cutting flying insects. Unfortunately, electronic pest control devices have not yet enjoyed wide popularity and publicity as public are still dependable on chemical methods.

Other tests have shown that the degree of repellence depends on the frequency, intensity and the pre-existing condition of the rodent infestation (Timm, 1994). The intensity of such sounds must be so great that damage to humans or domestic animals would also be much more likely. Fortunately, commercial ultrasonic pest control devices do not produce sounds of such intensity. (Beason, 2004) established the fact that birds do not respond to ultra sound. However, it is now apparent that insect-hunting bats can detect frequencies from 50,000 Hz to 100,000 Hz generated by grasshoppers and locusts and respond very well to ultrasound as high as 240,000 Hz produced by some insects such as moth and lacewings. Insects detect sound by special hairs or sensilla located on the antennae (mosquitoes) or genitalia (cockroaches), or by more complicated tympana organs (grasshoppers, locusts, moths and butterflies). However, chemical repellent are used generally to repel mosquito which has a remarkable safety profile, but they are toxic against the skin and nervous system and also causes rashes, swelling, and eye irritation. This has been reportedly causing brain swelling in children, anaphylactic shock, and low blood pressure (Eldridge, 2008).

Working principles of Ultrasound Repel Mosquitoes

Male mosquito is the natural enemy of female mosquito after breeding. Both male and female mosquitoes use plant juice as food. But female mosquito requires human blood protein for the maturation of their eggs. Male mosquitoes will not bite human beings. On the first day of emergence, the female mosquito will not bite but after mating with male it starts to bite human beings to get blood. Female mosquito will not allow males to mate again and they avoid the presence of males. Females detect the presence of males by sensing the Ultrasonic or Ultrasonic Sound (US) produced by the males. If an US generator is used, it will imitate male mosquito by producing 38 kHz US. This will repel Female mosquitoes. Furthermore, the ultrasonic waves will exert stress on the sensillae located on the antennae of female mosquitoes, prompting them to move away from the source of the ultrasound.

METHODOLOGY

The general block diagram of the design and implementation of a micro-controller based mosquito repellent system with the flow of signals can be seen in (Figure 1). The design comprises of both Hardware components and Software components.

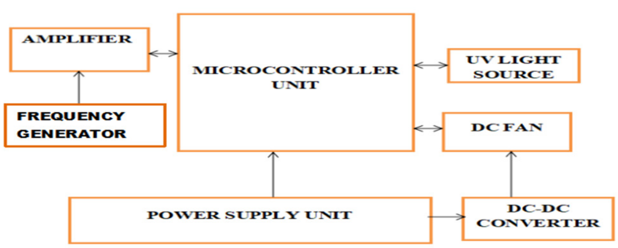

Figure 1: Block Diagram of the Developed Mosquito Repellent System

Hardware Components or Materials

The list of the hardware components and their corresponding values are shown in (Table 1).

Microcontroller Unit

This unit which comprises an Atmega328p chip (Arduino Uno) with on-board boot loader and other peripherals serves as an interface for all other electronic components used for the design of the system. Its voltage requirement for operation is between 1.8 V to 5.5 V.

Table 1: Hardware Components of the Mosquito Repellant System

Component	Typical Values
Microcontroller	ATMEGA328
Power Supply	5V (for microcontroller and peripherals)
GPIO Pins	Digital Pins 2-13 (for Arduino)
Sound Frequency	20 kHz
Amplifier Output Power	1 to 5 Watts
UV Light Wavelength, current rating	365 nm, ~350 mA
Photodiode Sensitivity	200-400 nm
ADC Resolution (ADS1115)	10-bit
Control Logic Threshold Voltage	0.5V (for decision making)
DC Fan	1 - 5 Watts, 1000 - 3000 RPM

Power Supply Unit

The power supply designed comprises of four main blocks as indicated in (Figure 2), which are: transformer, rectification, filteration, and the Voltage Regulation unit. The power supply unit (PSU) is designed to provide a stable and efficient power source for the microcontroller-based mosquito repellent system. The PSU consists of a step-down transformer, which reduces the mains voltage (230V AC) to a lower voltage (12V AC). The transformed voltage is then rectified using a bridge rectifier circuit, comprising four diodes, to convert the AC voltage to a pulsating DC voltage. A filtering stage, consisting of a capacitor (1000uF) and an inductor (10uH), is employed to smooth out the DC voltage and reduce ripple. Finally, a voltage regulator (LM7805) is used to regulate the DC voltage to a stable 5V, which is required by the microcontroller and other components. This design ensures a reliable and efficient power supply for the system, minimizing power losses and heat generation.

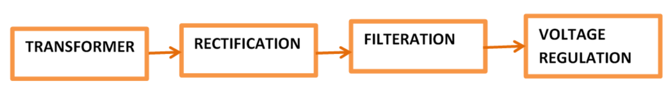

Figure 2: Block Diagram of Power Supply Unit

Analog to Digital Converter (ADS1115)

This is an analog to digital converter with a high resolution dedicated for the conversion of analog input signal. It has four input channels that can be configured for single ended, differential or comparator measurements. The value of a bit determined by the programmable gain amplifier (PGA) setting as is this setting establishes full scale. The ads1115 connection to arduino Uno shown in (Figure 3) has its pins (VDD, GND, SCL, SDA) connected to 5.0 V, GND, SCL (pin 4), SDA (pin5) of the arduino respectively. With this configuration, a higher resolution per bit is attained for sensor output calibration when compared with 5 mV per bit of arduino Uno on-board ADC. Therefore, the right code for this sensor can be obtained using; Reference voltage of ADC = 2.4 V =2400 mV,

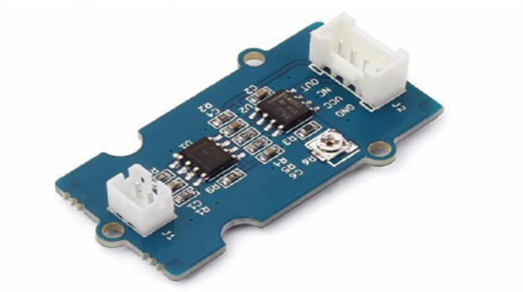

Figure 3: Grove piezo amplifier breakout board (Grove, 2018).

Microcontroller bit (12bit) = 2^{12} = 2^{12} -1= 4095
To change from the ADC value to Voltage in mV, $V_{out} = V_{out}\left(\frac{2400}{4095}\right)$.

Grove Operational Amplifier

The measured output signal from the 16-bit analog to digital converter (ADC) is fed into the Grove-piezo vibration amplifier. It has wide frequency ranges of 20 Hz to 20 kHz (suitable for mosquito deterrence) with adjustable sensitivity and high receptivity for strong impact as specified in the datasheet. This amplifier outputs a high logic when is detected. It is a breakout board which comprises an LM2904DR dual general-purpose operational amplifier for the piezo signal input amplification and an LM293D low power dual comparator for signal optimization. Figure 4 shows the pictorial view of the amplifier. For better efficiency class D amplifier with 1 Watt to 5 Watts output power and supply voltage of 5 - 12 V used.

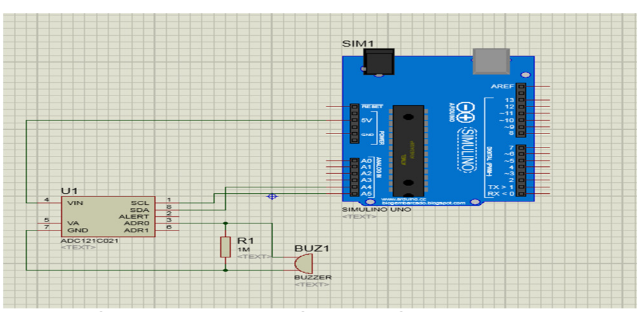

Figure 4: Connection of the ADS1115 ADC with Arduino Uno

UV Light Source as Mosquito Attractor

An attempt to develop a perfect mosquito killer that manipulates the mosquito sensors to lure and kill mosquitos using a smartly designed mosquito killer machine is essential. The machine makes use of high powered suction system with some blue light (UV light) to develop this system. A low intensity blue light in the center which glows at a very low intensity so as to be visible in the dark but not bright enough to drive away mosquitoes could be adopted. Below the UV light is a DC fan which is used to kill mosquitoes attracted by the UV light using electric current. Thus, the system attempts to find a way using smartly designed technology to lower the mosquito problem faced globally.

Photodiode Sensitivity (200-400 nm)

The photodiode is sensitive to ultraviolet (UV) and visible light in the range of 200-400 nanometers is suitable for detecting UV light emitted by mosquitoes, which is typically in the range of 300-400 nm enables it to detect the presence of mosquitoes.

Control Logic Threshold Voltage (0.5V)

The control logic threshold voltage is set at 0.5V, which means that when the photodiode's output voltage exceeds 0.5V, the control logic will trigger an action. This threshold voltage is used for decision-making, such as turning on the ultrasonic repellent or activating an alarm and it provides a clear distinction between the presence and absence of mosquitoes.

Loop Detection Frequency (1 second)

The loop detection frequency is set at 1 second, which means that the system checks for the presence of mosquitoes every second. This frequency provides a good balance between responsiveness and power consumption. A faster detection frequency might be desirable, but it could also lead to increased power consumption and false positives.

DC Fan Design

The DC fan design is a crucial component of the mosquito repellent system, responsible for dispersing the ultrasonic waves and airflow to repel mosquitoes.

Design Parameters:

- Fan Type: Centrifugal fan or axial fan with a DC motor
- Fan Size: 50-80 mm diameter, depending on the system's size and airflow requirements
- Fan Speed: Adjustable speed, typically between 1000-3000 RPM
- Airflow: 10-30 CFM (cubic feet per minute), depending on the fan size and speed
- Power Consumption: 1-5 watts, depending on the fan size and speed.

The DC fan was designed to operate quietly (<30 dBA), with minimal vibration, high durability (>10,000 hours), and optimal cost-effectiveness, balancing performance and affordability. It has a good electronic control features that include PWM (Pulse Width Modulation) for adjustable speed and reduced power consumption, a speed sensor for monitoring and adjustment, and protections against overheating and reverse polarity.

Working Principles of the Developed Mosquito Repellent System

The mosquito repellent system's circuit diagram, illustrated in (Figure 5), comprises a microcontroller, UV light source, ultrasound frequency source, DC fan, and power supply. The microcontroller serves as the central processing unit, coordinating the operation of all components by executing a pre-programmed algorithm that activates the UV light source to attract mosquitoes, followed by the DC fan to trap and eliminate them, while generating an ultrasonic frequency of 365 nm to repel mosquitoes. The system operates on an alternating current (AC) power source, converted to direct current (DC) using a rectifier circuit, and is filtered and regulated to provide a stable voltage supply to all components. The microcontroller's control and coordination enable the system to effectively repel and eliminate mosquitoes through a sequential operation of its components.

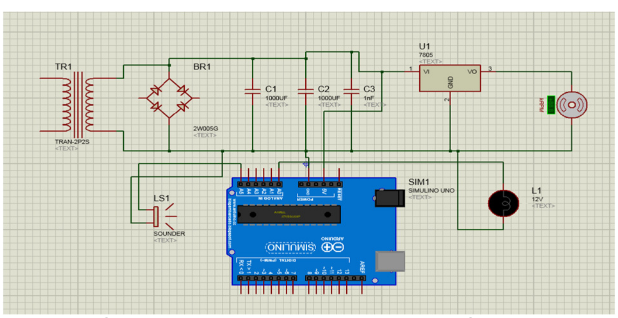

Figure 5: Circuit Diagram of Mosquito Repellent System

Software Components

The software components of the mosquito repellent system are designed using Python, a versatile and user-friendly programming language. The software is responsible for controlling the system's hardware components, processing sensor data, and implementing the repellent logic.

The Algorithm steps are:

1. Initialize the system
2. Generate a high-frequency sound wave (around 20 kHz) using the microcontroller's timer/counter module
3. Amplify the sound wave using the Grove-piezo vibration amplifier
4. Detect mosquitoes using the UV light and ADC
5. If mosquitoes are detected, turn on the UV light and generate the high-frequency sound wave
6. If no mosquitoes are detected, turn off the UV light and stop generating the high-frequency sound wave
7. Repeat steps 4-6 continuously

The flowchart of the Work

The flowchart is the representation of a real-time automated Mosquito Repellent System technique is shown in (Figure 6).

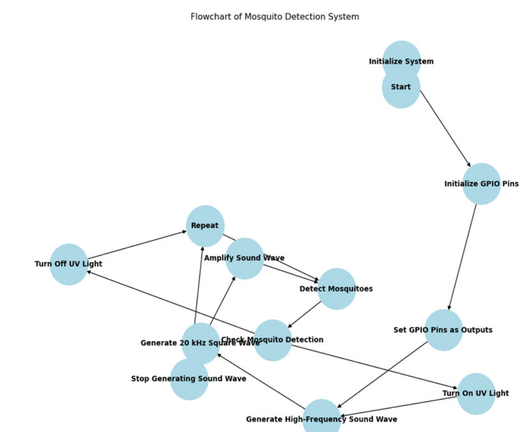

Figure 6: Flowchart of Mosquito Repellant System

The graph visually represents the flow of operations in the mosquito detection system. The breakdown of the components and what they signify are discuss briefly:
Each node in the graph corresponds to a specific step in the system:

Start: The initiation point for the process.

Initialize System: This step involves preparing the system for operation.

Initialize GPIO Pins: This indicates that the relevant General Purpose Input/Output pins are being set up.

Set GPIO Pins as Outputs: The pins are configured to send signals rather than receive them.

Generate High-Frequency Sound Wave: The system is tasked with producing sound waves at a high frequency to deter mosquitoes.

Generate 20 kHz Square Wave: A specific wave pattern is created to optimize effectiveness.

Amplify Sound Wave: The sound signal is amplified for greater impact.

Detect Mosquitoes: The system actively searches for the presence of mosquitoes.

Check Mosquito Detection: The system evaluates the detection results.

Turn on UV Light: If mosquitoes are detected, UV light is activated to attract them.

Stop Generating Sound Wave: If no mosquitoes are detected, the sound production stops.

Turn off UV Light: The UV light is turned off in the absence of mosquitoes to conserve energy.

Repeat: The process returns to the detection phase, ensuring constant monitoring.

Flow Analysis

Sequential Flow: Movement through the system is generally linear, highlighting a straightforward approach to monitoring and responding to mosquito presence.

Decision Points: The presence of decision points makes the system adaptable and responsive, altering actions based on real-time detections.

Efficiency Consideration: The design reflects efficiency in energy usage, as it activates and deactivates components based on whether mosquitoes are detected.

The directed graph successfully captures the operational flow of a mosquito detection system, providing insights into its structure and decision-making process. This visual representation aids in understanding how the system operates and can be useful for both design discussions and educational purposes.

SYSTEM TESTING RESULTS

Upon completion of the prototype assembly (Figures 7 and 8), a comprehensive testing regimen was conducted to validate the system's performance. The testing protocol included continuity testing, insulation testing, and physical inspection to ensure the integrity of the system's components and connections. Subsequent field testing was conducted by deploying the device in various environments, including halls, offices, and homes, for an extended period.


Figure 7: Pictorial view of Dc fan and UV light source of the Mosquito Repellant System.


Figure 8: Exterior View of the Developed Mosquito Repellant System.

The results showed a significant reduction in mosquito populations, with dead mosquitoes found in the vicinity of the device. The ultrasonic frequency range of 365 nm - 400 nm was found to be effective in repelling mosquitoes. Additionally, the UV light source successfully attracted mosquitoes, which were then exterminated by the DC fan. The overall performance evaluation demonstrated the effectiveness of the device in reducing mosquito populations.

CONCLUSION

The project demonstrates the potential of using technology in addressing public health and environmental issues. Future enhancements include optimizing the system's range and signal strength, developing a user-friendly interface, and adapting it to different mosquito species. Integrating other control methods, such as trapping or sterilization, and expanding its use to agriculture or household pests are also potential avenues for exploration.

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