

DESIGN AND IMPLEMENTATION OF AN ELECTRONIC MOSQUITO REPELLENT

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Abstract

The control of mosquitoes is an issue of utmost importance in the present day as a result of rising number of mosquito borne illnesses which have resulted in the use of various types of pesticides, herbicides and other mosquito's repellent agents that are toxic and a risk to human health. This risk has necessitated the design of an Electronic Mosquito Repellent, EMR as a means of controlling the menace of mosquitoes that is very effective, cheap, eco-friendly and produces no risk to human health. Electronic Mosquito Repellent is an electronic device that has the capability of generating high frequency sound waves of high pitch at an Ultrasonic frequency range, not audible to human ear but to insects and pests. The constructed EMR generates ultrasonic sound waves at a frequency range of 20 – 38 kHz that travels at an angle 45° from the source to cover a wide radius. Due to the intense auditory stress of these ultrasonic sound waves on the mosquitoes, they are rendered inactive or forced away from the vicinity of the device. The device is designed on 555 Timer IC and can be used indoors or outdoors by the general public to combat the menace of mosquitoes.

Keywords – 555 Timer, A stable multivibrator, Buzzer, Electronic mosquito repellent, Ultrasonic frequency, Ultrasonic sound

1.0 Introduction

Malaria affects more than 250 million people and causes more than a million deaths annually [22]. One important preventive strategy against this and other mosquito-borne diseases is control, which aims to reduce human-mosquito contact. Different control measures are used routinely against mosquitoes and their larvae, including chemical (e.g. insecticides), biological (e.g. carnivorous fish, carnivorous flowers or pathogenic fungi), environmental (e.g. land filling or draining of drainage), and personal protection (e.g. mosquito repellents formulated as pills, coils, ointments, lotions, sprays and insecticide treated and untreated bed nets). Electronic mosquito repellents (EMRs) are marketed in response to a huge demand from the public for convenient, safe, and effective anti-mosquito products [18].

Malaria is a major health problem that particularly affects people living in Sub-Saharan Africa and other tropical parts of the world. It often causes considerable morbidity and mortality especially in children under five. It is transmitted by mosquito bites from infected female mosquitoes. Severally strategies and approaches are available for preventing mosquito bites and malaria infection, including repellents and these approaches will be considered by those living in affected areas and by travelers to areas where there is high risks of infection. There was no evidence in the field studies to support their promotion or use. Future randomized controlled trails are not proposed as there was no suggestion in the field of studies that EMRs show any promise as a preventive measure against malaria [12].

An electronic insect repellent is a safer alternative compared to toxic insect repellent. These are electronic

devices that have either electromagnetic or ultra sound waves to repel mosquitoes and roaches. The effectiveness of these devices has not been clearly established but the numerous studies foe experiments have shown that these electrical devices are indeed effective in repelling or eliminating pests. Some examples of electronic insects repellents are plug in electronic repellents, ultrasonic transmitters and the electromagnetic lamps. These electronic pest control devices are very affordable [10], [16].

Human, animal or anything can produce sound. This sound is created by the insect during their movement or anything. Insect can be defined as any of numerous small invertebrate (without a backbone) animals (as centipedes or spiders) that are more or less obviously segmented. Insects can be a nuisance to human and, under certain conditions, can be a hazard to health and lives of people. There are many approaches to controlling insects' populations, including chemical pesticide control, insect-repelling plants and insect's traps. Electronic pest control devices also provide a convenient means for controlling insects in or near your home [4].

However, research has shown that male mosquitoes are actually the ones attracted by the female flight sound and females normally have a very weak sensitivity for sound compared with the males. Another reason is that mosquitoes avoid the ultrasonic cries of bats, although both explanations may be conceivable, there is no published scientific information to support either idea. Different brands of EMRs have been examined for their efficacy under laboratory conditions, none of which showed any effects for the devices tested [1], [3].

2.0 Review of Related Work

"The world's most dangerous animal is the mosquito," according to a BBC World Service health program as they carry of many harmful diseases like Malaria, Dengue Fever,

Chikungunya, Lyme disease etc. Chemical repellent is used generally to repel mosquito which has a remarkable safety profile, but they are toxic against the skin & nervous system and also causes rashes, swelling, and eye irritation. It causes brain swelling in children, anaphylactic shock, and low blood pressure [8]. Also, it has discovered that Chemicals brings about the genetic mutation of the internal make up of these pests such as mosquitoes that they produce off spring that are immune to these chemicals that were used on their earlier generation [10]. There have been several focused on designing an ultrasonic pest repellent system which can be a very useful device to counter the various problems due to ants, insects, pests, rodents, etc. Due to the compactness, low cost and pollution free source unlike the other chemical repellents the device can be highly effective [16].

The electronic ultrasonic repellent device of [13] was designed to repel many types of insects other than mosquitoes. On activation of the device, it was discovered that some of the insect moved away at certain constant frequency but other species of insect didn't move as repelling frequency was found different for different species of arthropods. Author [4] also talks about a circuit of an electronic pest repellent. It is effective over a diameter around 16 meters. Wide varieties of electric mosquito repellent that are still not in practice so much are available in market. 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. Some of these devices are costly in operation as well. This Electronic Mosquito Repellent only uses generated ultrasonic waves rather than chemical fumes or harmful toxic smoke. This circuit generates ultrasonic wave as an output in the range of 20 - 38 kHz that travels at an angle 45° from the source to cover a wide radius. Ultrasonic wave is not audible to us and hence is harmless to human beings. The oscillator unit is built using 555 timer astable multivibrator which is responsible for driving a piezo buzzer that converts the ultrasonic frequency to sound wave at high pitch as the desired output. This EMR has power efficiency of 9-volts DC and it is portable, cheap and designed based on simple and elegant circuit.

3.0 Methodology

3.1 Block Diagram

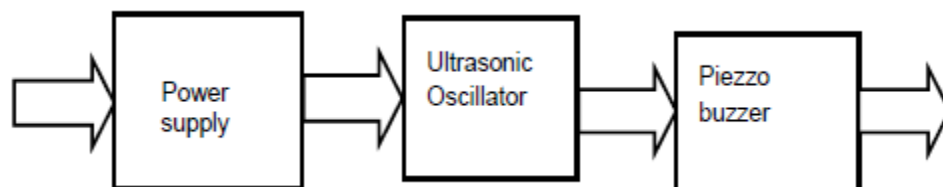


Figure 1: The block diagram of an Electronic Mosquito Repellent

3.2 Design of Electronic Mosquito Repellent Circuit

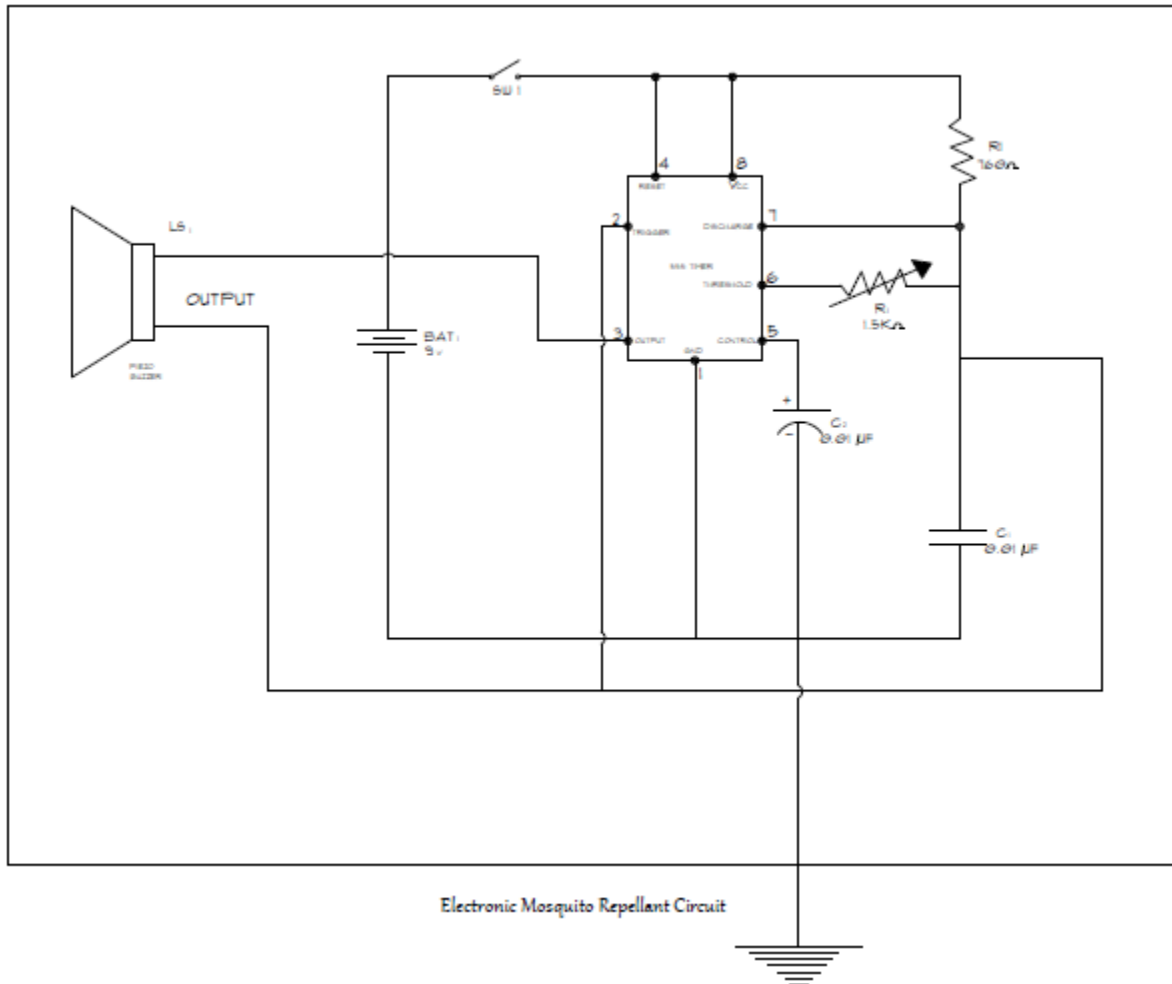


Figure 2: Electronic Mosquito Repellent Circuit Diagram

3.2.1 Design Equations and Computed Values

The components used are: 555 timer, an electrolyte capacitor C_1 of $0.01\mu\text{F}$, a ceramic capacitor C_2 of $0.01\mu\text{F}$, a resistor R_1 of 760Ω , a variable resistor R_2 of $1.5\text{k}\Omega$, piezo buzzer, a SPST switch and a 9 V battery. The design of this circuit is based on the principle of using a buzzer to produce sound at an ultrasonic frequency. An oscillator circuit which is made up of a 555 timer astable multivibrator circuit is responsible for driving the buzzer. Designing the circuit of EMR involves designing the circuit of an astable multivibrator circuit. A multivibrator is an electronic circuit producing a pulsed output signal. Generally multivibrators are classified based on the nature of stability of output. A multivibrator with no stable state is known as an astable multivibrator and is used as an oscillator. Astable multivibrator is also called as Free Running Multivibrator. It has no stable states and continuously switches between the two states without

application of any external trigger. The IC 555 can be made to work as an astable multivibrator with the addition of three external components which are two resistors, R_1 and R_2 and a capacitor, C . Generally, the frequency of the output signal produced by a 555 astable multivibrator is given by:

$$f = \frac{1.44}{C(R_1 + 2R_2)}$$

Where;

R_1 = the resistor between pin 7 and V_{cc} ,

R_2 = the resistor between pin 7 and pin 6,

Let;

$$f = 38 \text{ kHz}$$

$C_1 = 0.01\mu\text{F}$ (i.e. capacitor between pin 6 and ground),

Duty cycle, $D = 60\%$ (It is not possible to 555 timer to produce with 50% duty cycle)

Hence the resistors R_1 and R_2 can be expressed respectively as;

$$R_1 = \frac{1.44(2D-1)}{f C_1}$$

And

$$R_2 = \frac{1.44(1-D)}{f C_1}$$

Substituting the values of C_1 , f and D ;

$$R_1 = \frac{1.44(2(0.6)-1)}{38000 \times 0.00000001} = 758 \Omega \text{ (0.758k}\Omega\text{)}$$

$$R_2 = \frac{1.44(1-0.6)}{38000 \times 0.00000001} = 0.01516 \times 10^3 = 1.52\text{k}\Omega$$

Thus 760Ω can be used for R_1 and $1.5\text{k}\Omega$ for R_2 . Here a potentiometer of $1.5\text{k}\Omega$ is used.

T_C = Charging time or Time at which the output is high

$$= 0.693 C_1 (R_1 + R_2) = 0.693 \times 0.01 \times 10^{-6} (760 + 1500) = 15.66 \times 10^{-6} = 15.66 \mu s$$

T_D = Discharging time or Time at which the output is low

$$= 0.693 R_2 C_1 = 0.693 \times 1500 \times 0.01 \times 10^{-6} = 10.395 \times 10^{-6} = 10.395 \mu F$$

Therefore, the time period of one complete cycle is;

$$T = T_C + T_D = 15.66 + 10.39 = 26.05 \mu F$$

Frequency of charging when the output is high;

$$f_c = \frac{1}{T_c} = \frac{1}{15.66 \times 10^{-6}} = 63.86 \text{ kHz}$$

Frequency of discharging when the output is low;

$$f_d = \frac{1}{T_d} = \frac{1}{10.39 \times 10^{-6}} = 96.25 \text{ kHz}$$

$$\% \text{ Duty cycle at } f_c = \frac{T_c}{T} = \frac{15.66}{26.05} \times 100\% = 60.12\%$$

$$\% \text{ Duty cycle at } f_d = \frac{T_d}{T} = \frac{10.39}{26.05} \times 100\% = 39.88\%$$

3.2.2 The 555 Timer Circuit Connections (The Oscillator Unit)

The 555 Timer IC is the most common type of Astable multivibrator. It is basically an 8 pin IC [18] and it consists of consists of 23 transistors, 2 diodes and 16 resistors [15]. The 555 Timer IC has the following pin connections. Pin 1- is the ground and it is directly connected to the negative terminal of the battery. Pin 2 - Trigger pin. It is an active low pin. The timer is triggered when signal at this pin is less than one third of voltage supply. For astable operation, this pin is connected directly to pin number 6. Pin 3 - It is the output pin. Pin 4 - It is the reset and an active low pin. It is usually connected to the positive rail of the battery. Pin 5 - It is the control pin which is seldom used. For the purpose of safety, this pin is connected through ground to a $0.01 \mu F$ ceramic capacitor to avoid any noise problem. Pin 6 - It is the threshold pin. The timer output is back to its stable state when voltage at this pin is greater than or equal to two-thirds of supply voltage. For astable operation, this pin is shorted to pin 2 and connected to pin 7 using a resistor for stable operation. Pin 7 - It is the discharge pin and provides the discharge path for the capacitor.

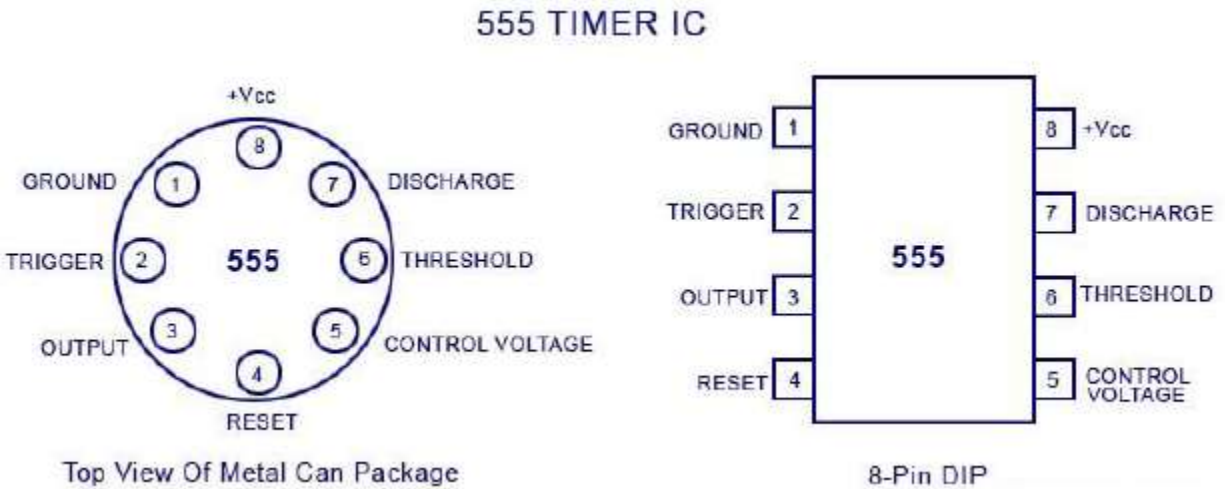


Figure 3: 555 Timer IC Pin Configurations.

Pin 2 and pin 7 of the 555 oscillator circuit are connected together thereby allowing the circuit to re-trigger itself on each and every cycle hence allowing it to operate as a free running oscillator. During each cycle, the capacitor C charges up during both timing resistors, R_1 and R_2 but discharges itself only through resistor, R_2 as the other side of R_2 is connected to discharge terminal, pin 7. Then the capacitor charges up to $\frac{2}{3}V_{CC}$ (the upper comparator limit when the output is high) which is determined by the expression of charge time or time when the output is high, $T_C = 0.693(R_1 + R_2)C$ combination and discharge itself down to $\frac{1}{3}V_{CC}$ (the lower comparator limit when the output is low) determined by the discharged time or time when the output is low, $T_D = 0.693CR_2$ combination [15], [18]. This results in an output waveform whose voltage level is approximately equal to $V_{CC} - 1.5V$ and whose output "ON" and "OFF" time periods are determined by capacitor and resistors combination [23]. The total period of oscillation is $T = 0.693(R_1 + 2R_2) C$ and frequency of oscillation $f = 1.44/C(R_1 + 2R_2)$

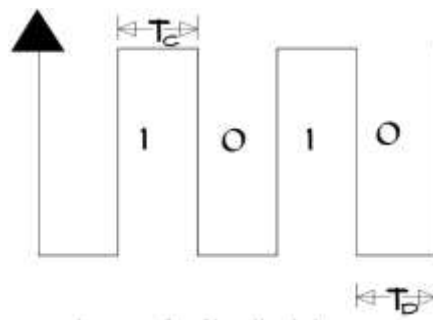


Figure 4: Output waveform of the 555 Timer in Astable Multivibrator Mode

3.2.3 Electronic Mosquito Repellent Circuit Operation

Once the switch of the circuit is closed, the 555 timer gets the power supply. As regards the inner circuit, the capacitor voltage will be zero at the initial stage; hence the voltage at the threshold and the trigger pin will be zero. As the capacitor charges through the resistors R_1 and R_2 , a point is reached where the voltage at threshold pin is less than the capacitor voltage. This causes a change in timer output to a high at $T_C = 0.693(R_1 + R_2)C$.

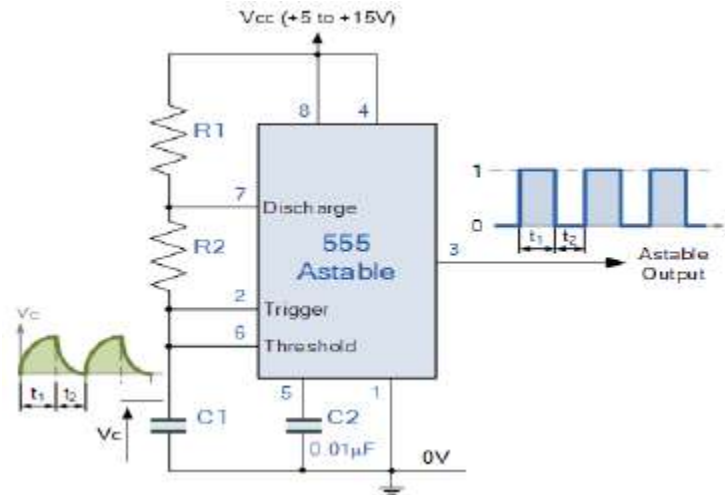


Figure 5: Astable Multivibrator

The capacitor now starts discharging through the resistor R_2 , which means the discharge continues so until the output voltage is back to the original state at $T_D = 0.693CR_2$. This process continuously switches back and forth at a rate depending on the RC network of the circuit [14]. Thus the output signal is an oscillating signal of frequency 38 kHz. The output from this astable multivibrator circuit drives a 38 kHz buzzer, producing ultrasound at regular intervals. The output frequency can also be varied between 20 - 38 kHz by varying the values of the potentiometer R_2 .

4.0 Result and Discussion

4.1 Outdoor Test

This test was conducted in known mosquito breeding ground in the presence of human bait with EMR device TURNED-OFF and observed for 12 minutes. The human bait felt many mosquitoes landing on different parts of his body. It was not possible to determine whether the landed mosquitoes were of the same species or not. The EMR device was TURNED-ON and observed for another round of 12 minutes. In the first 4 minutes 8 mosquitoes were observed to have landed on the human bait. The last 8 minutes

witnessed the landing of only 2 mosquitoes at an average of 1 mosquito for every 4 minutes. The landing rate of mosquitoes with and without EMR ON is different. This indicates the capability of the EMR device in repelling mosquitoes outdoor.

4.2 Indoor Test

The second test was conducted indoor in a closed class room with two human baits. The first human bait was positioned at the centre while the second human bait was positioned at one of the corners of the classroom respectively. The landings of mosquitoes on each of the human baits were observed. In the first 12 minutes with the EMR device TURNED-OFF, the human bait positioned at the middle of the classroom was observed to record the highest number of mosquito landings. The EMR device was placed between the two human baits and then TURNED-ON after the first 12 minutes. The human bait positioned at the centre of the classroom experienced more mosquito landings with most of the landings recorded from the side body of the human bait away from the EMR device. The second human bait positioned at the corner of the classroom experienced few numbers of mosquito landings in the first 4 minutes after which the landing rate drop drastically to zero.

5.0 Conclusion

The results of these tests provided clear evidence from field-based observations that this device had effect on mosquito landing rates. These observations examined the effectiveness of the electronic mosquito repellent on different locations (since the location and environmental conditions may affect the transmission of the Ultrasound). The frequencies of the sound emitted by the device was also adjusted (since mosquitoes may respond to a particular sound wavelength), and times of day (since day-biting and night-biting mosquitoes may behave differently to the sound emitted by the electronic mosquito repellent), and mosquito density (since this may affect electronic mosquito efficacy), but the differences were very subtle and unappreciable. These performance evaluations have revealed that the EMR has capability to repel mosquitoes. The EMR capability is based on 555 Timer which is responsible for the generation of ultrasonic frequency, convert analog voltage signal to digital frequency signal, and in astable multivibrator mode acts as an oscillator to generate clock pulse in a wide range of frequencies with enough output power to drive the IC. In order to control the frequency generated and also make the circuit functioned to generate variable frequencies, a preset resistor and variable resistor have to be included.

References

- [1] Andrade, C.F.S and Bueno, V.S., "Mosquito-Repelling Devices Using *Aedes Albopictus* (Skuce) (Diptera : Culicidae)," *Neotropical Entomology*, vol. 30, no. 3, September, 2001.

- [2] Belton, P., "An Acoustic Evaluation of Electronic Mosquito Repellents," Reprinted from Mosquito News, vol. 41, no.4, pp. 751-755, December, 1981.
- [3] Cabrini, I. and Andrade C.F.S., "Evaluation of Seven Electronic Mosquito Repellers," *Entomologia Experimentalis Et Applicata*, vol. 121, no. 2, pp. 185 – 188, October 13, 2006.
- [4] Chapman, R.F., "The Insects Structure and Function," 3rd Edition, London: Hodder and Stoughton, 1982.
- [5] Curtis, C., "Insecticide – Treated Bed-Nets for Malaria," *Mosquito Control Association*, vol. 22, no. 3, pp. 501 – 506, 2006.
- [6] Devender Krishan, Ultrasonic Pest Repeller, "Electronics for you Magazine", March 2012.
- [7] Dileep Kumar Tiwari and Mamta Alam Ansari, "Electronic Pest Repellent: A Review," 2016 International Conference on Innovations in Information Embedded and Communication Systems (ICIIECS'16) pp. 435-439, March, 2016.
- [8] Enayati, A.A., Hemingway, J., Garner, P.A., "Electronic Mosquito Repellents for Preventing Mosquito Bites and Malaria Infection (Review)", The Cochrane Collaboration. Published by John Wiley & Sons Ltd., 2010.
- [9] Ezeonu, S. O., Amaefule, D. O. and Okonkwo, G. N., "Construction And Testing Of Ultrasonic Bird Repellent," *Journal of Natural Sciences Research*, vol.2, no.9, pp. 8-17, ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online), 2012.
- [10] Foster, W.A. and Lutes, K.I., "Tests of Ultrasonic Emissions on Mosquitoes Attraction to Hosts in Flight Chambers," *Journal of the American Mosquito Control Association*, 1(2), pp. 199-202, 1985.
- [11] Ft Detrick and Forest Glen Annex, Armed Forces Pest Management Board, Information Services Division, Office of the Deputy under Secretary of Defense.
- [12] Helson B. V., and Wright R. E., "Field Evaluation of Electronic Mosquito-Repellers in Ontario," *Proceedings of Entomological Society of Ontario*, vol.1108, pp.59-61, 1977.
- [13] Ibrahim A.G., Oyedun, O.D., Awojoyogbe, and Okeke O.B., "Electronic Pest Control Devices: A Review of their Necessity, Controversies and a submission of Design Considerations" S.S.N. Department of Physics, Federal University of Technology, Minna, Nigeria. *The International Journal of Engineering and Science (IJES)*, vol. 2, pp. 2319 – 1805, 2013.
- [14] Ikeri, H. I., Onyia, A. I., Chima, A.I., and Nwobodo, A.N ., "Construction and Empirical Study of Electronic Piezzo Buzzer Mosquito Repellent," *International Journal of Scientific & Engineering Research (IJSER)*, vol. 8, issue 11, pp. 1605-1610, ISSN 2229-5518, November, 2017. <http://www.ijser.org>
- [15] Introduction to 555 Timer IC, <http://todayscircuits.blogspot.com/2011/06/555-timer-complete-basic-guide.html#.s>
- [16] Jensen, T., Lamp R., Slamecka M.C. and Novak R.J., "Field Efficacy of Commercial Anti-Mosquito Products in Illinois," *Journal of American Mosquito Control Association*, vol.16, no. 2, pp. 148-152, 2000.

- [17] Kurma, R., Insect "Pest Control, Arnold Ltd., Great Britain," 15, 1999.
- [18] Kutz, F. W., "Evaluations of An Electronic Mosquito Repelling Device," Mosquito News, vol. 34, pp. 369-375, December 1, 1974.
- [19] Shagun Jhaver, Rahul Singh, Tejas Hiremani, "Electronic Pest Repellent", EE 318 Electronic Design Lab, Project Report, EE Dept., IIT Bombay, April 2009.
- [20] Simeon M. I., Mohammed A.S., Adebayo S. E., "Development and Preliminary Testing of An Electronic Pest Repeller with Automatic Frequency Variation, "International Journal of Engineering Science Invention(IJESI), vol. 2, issue 1, pp. 14-20, ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726, January, 2013.
www.ijesi.org
- [21] Suchandana R. S., Dhrubojyoti G., Koustuva K. M., "Mosquito Repellent Circuit," International Journal of Engineering and Technical Research (IJETR), vol. 4, Issue 2, ISSN: pp. 2321-0869 (Online), pp. 2454-4698 (P), February 2016.
- [22] W.H.O. 2005. "Global Partnership to Roll Back Malaria World Malaria Report," Geneva: *World Health Organization*; 2005.
- [23] Teja R., " Astable Multivibrator using 555 Timer Circuit, Duty Cycle, Applications,"
Apr. 7, 2021.