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Design and Construction of Electronic Pest Repellent for Use in Homes and Farmland

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Abstract- ***An electronic based pest repellent is presented as an alternative to pesticides commonly in used in farmlands and homes. It is made up of power supply unit (PSU), Peripheral Interface Controller (PIC), switches for mode selection, LCD display, power amplifier and speaker. The system was designed at the Computer Engineering Laboratory of the Abubakar Tafawa Balewa University. The device generates repelling signals in the range of 30 and 50 kHz within the ultrasonic frequency. A digital oscilloscope was used to test the ultrasonic signals within the above range for ten experimental trials for different type of pests. The results of the trial showed that the pest repelling ranges were highly precise to designed specification. The outcomes of this study are comparable to those obtained from the commercial ultrasound. It has also established that the simulation and experimental results were consistent within a measuring uncertainty of ±5% at an affordable cost of one-fifth rate lower than the propoxur insecticide.***

Indexed Terms- ***Peripheral Interface Controller, Pest Repellent and ultrasonic signal***

I. INTRODUCTION

Insects, ants, rats and mice are among pests commonly found in homes and on farmlands. Pest constitute serious irritant nuisance that disturb humans and plants They are often controlled using chemical insect pesticides such DDT (Dichloro-diphenyl-trichloroethane, an organochlorine, originally developed as an insecticide, rodenticides such as sulfaquinoxaline and Difethialone rat pesticides. These chemicals act by poisoning their targets but they are ultimately becoming infamous for their environmental impacts. 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 (Shagunet al., 2009). 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.

A study established the fact that birds do not respond to ultra sound (Beason, 2004). 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).

A study confirmed that ultrasonic sound devices do have both a repellent effect as well as a reduction in mating and reproduction of various insects (Ibrahim et al., 2013). However, when both results were cross 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.

A study at Genesis Laboratories could not confirm the effectiveness of electronic repellent devices for deterrence to certain pests in controlled environments (Shagunet al., 2009). In this work, cockroaches initially found to respond to electronic pest control devices by moving about a bit more than usual, but were not overly eager to escape from the sound waves. Also, rodents adjusted to the ultrasound (or any new sound) and eventually ignored it. Although, researchers use the increased cockroach activity as a good measure of the apathy of insects to the ultra sound signals yet tests of commercial ultrasonic devices have indicated that rodents may be repelled from the immediate area of the ultrasound device for a few minutes or to a day. 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.

This paper presents the design and testing of Electronic pest repellent aimed at developing a device that is capable of emitting ultrasonic energy of various frequencies in the range of up to 80 kHz. These frequencies do affect the auditory senses of pests such as mosquitoes, rodents, avian and nocturnal insects by making them uncomfortable in their abode. However these frequencies do not affect the hearing ability of humans.

A medical veterinary taxonomy on arthropod-borne disease established mosquitoes as the vector with the most dangerous diseases which causative agents ranged from viruses, protozoans and filarial carrying many harmful diseases like Malaria, Dengue Fever, Chikungunya, Lyme disease etc Mullen (2009) and a greater risk established in Europe by Lonc et al. (2011). 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). Researchers such as Rani et al. (2013) and Shukla et al. (2018) have proposed alternative repellence methods using herbal products. Therefore, such an alternative to the chemical mosquito repellents would be preferred. This work could offer a replacement to the expensive methods and serve as an alternative way of repelling pests.

In a patented research, a fluorescent lamp was used at night near bushes which attracted many insects in the dark and thereafter ultrasonic pest repelling device was activated (Sasaki, 2017). The frequency produced caused the insects moved on and repelled entirely. Brower et al. (1999) tested the axiom whether insects respond to frequency from 2 to 100 kHz and adjudged to detect sounds from long distances (10 m or more) with the aid of tympanic organs or eardrums.

Aktar et al. (2009) emphasized that agriculture would provide a good platform to eliminate poverty and unemployment in developing nations. If the challenges hampering the smooth implementation of the electronic pest control device are overcome, it would reduce farmland pests, encourages farmers to produce more food, increases farmers income, makes agriculture attractive profession and thereby enhancing food sufficiency.

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. Devender (2012) reported an electronic circuit for pests 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). 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.

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. In Jeon kyu, Chan-soo and Jong-kwon (2007) the electronic pest control device was established to be a contribution of electronics engineers to agriculture. This non chemical pest control method have been alternatively advocated as the best and efficient way to reduce pesticide contamination in our environment as it is also pesticides-free alternatives to raising food.

Shagun et al. (2009) focused their work on designing an ultrasonic pest repellent system which can be a very useful device to counter the various problems vectored from 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. They used an audio power amplifier that takes 1 V p-p square wave input generated from the microcontroller unit and gives an amplified signal to the speaker. The microcontroller unit can operate in various modes depending on user input. Similarly 4x4 keypad was used to give various input modes depending upon environment condition and availability of pest and different working conditions selected by the user. A standard 16 pin LCD display was used to view the choice entered by the user mode selected in which the circuit was working. LM 380 audio power amplifier was used to generate frequency range around 80 kHz. To transmit these sound waves a speaker of appropriate frequency range is used. Microcontroller generates sweep in sound frequencies and tested experimentally on ants, bugs, and small insects, and found successful in repelling them by generation of such ultrasonic frequency.

There is a need to give more attention to non-chemical methods of repelling pests for use in homes and farmlands and this is thrust of this paper. The rest of article describes the materials, methods as well as simulation and experimental results obtained in the research. It also justifies this method using life-cycle cost analysis (LCC) as against the chemical pesticides which is exhaustible.

II. MATERIALS AND METHODS

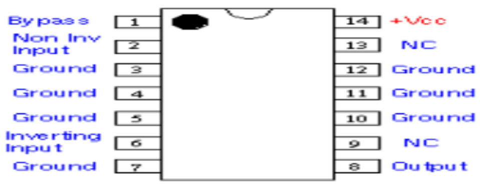
The design of electronic pest repellent involves a power supply, PIC microcontroller, Button for selection of different mode, LCD display, power amplifier and speaker.PIC16F887 is used for the frequency variation, with a voltage gain of up to 80 kHz. The power amplifier LM380 is used for amplification of the signal with a voltage gain of 34 dB .The output signal is obtained via the 8ohms speaker.

The circuit was initially constructed on strip board and tested. During the testing of the circuit, it was observed that the signal for a particular mode is not giving the required frequency range, later on this problem was rectified and the circuit performance remarkably improved.

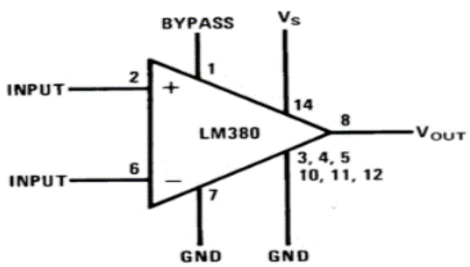
After soldering the circuit on Vero Board, it was then tested again and the final test aimed at characterizing the device was carried out in the Control Engineering Laboratory of the Abubakar Tafawa Balewa University, Bauchi which further affirmed the circuit functionality.

2.1.1 LM 380 Ultrasonic Transducer

LM 380 ultrasonic transducer is used as the amplifier of the circuit. This is a 2.5 W audio power amplifier. Its gain is internally fixed at 34 dB. The schematic diagram is shown in Figure 1.



(a)



(b)

Fig. 1. LM380 (a) Pin Diagram (b) Block Diagram

2.1.2 THE PIC16F887

The PIC 16F887 was employed in the research to generate the various frequency within the ultrasonic region that is aimed at repelling the pests. This pin configuration of the integrated circuit is shown in Figure 2.

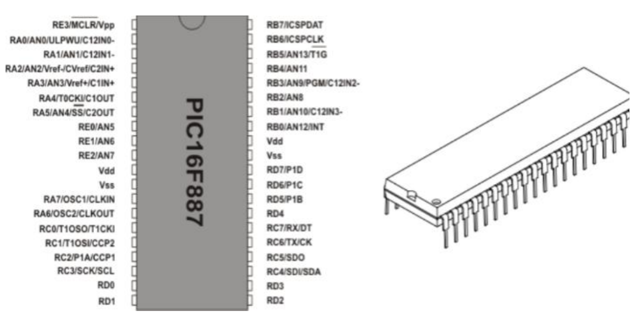


Fig 2. Pin diagram of PIC16F887

This microcontroller is used for the circuit because different modes of frequency variations are needed and this serves the purpose. This is also cheap and easily available as compared to some other microcontrollers.

2.1.3 LM 7805 Voltage Regulator

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, Hi Fi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents. In this work, we use series of IC as power input to the microcontroller according to the following voltage ranges: LM7805C 5V, LM7812C 12V and LM7815C 15V

2.1.4 PUSH BUTTON

These are micro-switches for selecting the different mode of the frequency.

2.2 Design of Power Supply

In this design, the required D.C voltage is about 12 V for the power amplifier and 5v for the microcontroller PIC.

2.3 Power Amplifier

Audio Power Amplifier: The audio power amplifier takes 1 V p-p square wave input generated from the microcontroller unit and gives an amplified signal to the speaker. The LM380 IC used is a 2.5 W audio amplifier. The output of the amplifier was measured using an ultrasonic receiver circuit during testing stages, and the gain was found to remain almost constant up to 80 KHz, a range conveniently suited to our needs.

2.4 Microcontroller Unit:

The microcontroller unit can operate in various modes depending on user input. In each mode the microcontroller generates a square wave signal at port C2 whose frequency varies continuously in a set range. This ensures that the sound output continuously changes.

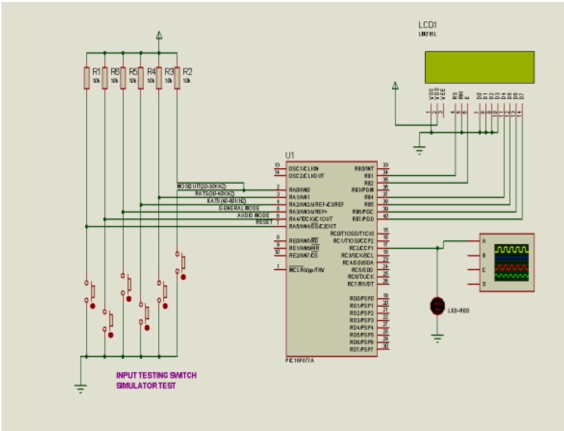


Figure 3. Circuit Diagram for PIC Simulation

2.5 LCD Display

We use a standard 16 pin LCD display to view the choice entered by the user and the current mode in which the circuit is working. The entire circuit diagram is shown in Figure 4.

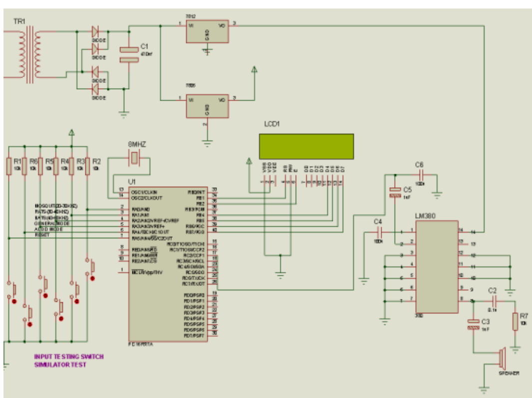


Fig. 4. Circuit diagram of electronic based pest repellent

2.6 Life Cycle Cost (LCC) Analysis

The Life Cycle Cost (LCC) Analysis is cast as in Eqn. (1).

LCC=Cost to buy+Cost to maintain+Running Cost+Replacement costs-Salvage value (1)

The cost of respective components used in the construction of the electronic pest repellent were added up to give the first term of the LCC equation while the cost to maintain and salvage values assumed to be negligible and the running cost of the electricity cost was applied as $0.085. In case of chemical pests repellent, Walker (2000) proposed prices for some selected Organochlorines with DDT having the lowest cost and Carbomates with Propoxur having highest cost. It was equally adopted that the applications of the chemical pesticides will be administered twice a year. Thus, for sake of cost-comparison of the electronics Pests Repellent and chemical insecticides the LCC was restricted to the one year time frame. Though, the life expectancy of the electronics components used in this work would be very conservative, the real lifetime is much longer than estimated.

III. RESULTS AND DISCUSSION

After designing the power supply section, PIC microcontroller section, LCD Display and push button, Power amplifier with speaker on bread board, the next step was the documentation of the performance of the device. Tables1, 2, 3 and 4 presented the values of components used.

The cumulative cost of the components used in the construction was obtained by summing the sub-totals in Tables 1 to 4. Table 5 presents the LCC of the electronics Pest Repellent and two extreme price regimes of the commercial chemical insecticides of organochlorine and carbomates types. It was deduced that the LCC favoured the use of DDT to the proposed Electronics Pest Repellent at five times rate within year time horizon but could catch up with the DDT cost under the assumption of 5 years life expectancy. The comparison of the design with Propoxur insecticide was five times higher for just within the one year time horizon.

Tables 6 and 7 present the responses of the device for different types of pests: mosquito, bugs, rats, bats and cockcoaches. The audio frequency ranged between 20 and 60 kHz for ±5% uncertainty margin. Also, the comparison was made with simulation and commercial products and also found with the error margin of 5%.

Table 1. Integrated Circuits (ICs)

S/No	ICS	Qty	Present Value ($)
1	PIC 16F887	1	2.9128
2	LM380	10	1.390
3	LM7805C	10	1.2906

4	LM7812C	10	1.2906
		Sub-total	$3.9712

Table 2. Capacitors

S/No	Capacitors	Qty	Value	Present Value ($)
1	Electrolytic capacitor	2	470µF	0.30
2	Filter capacitor	1	0.1µF	0.15
3	Filter capacitor	1	0.47µ	0.15
			Sub-total	$0.6

Table 3. Resistors

S/No	Resistors	VALUE	Present Value ($)
1	R1	4.7k	0.79
		Sub-total	$0.79

Table 4. Accessories

S/No	Components	Qty	VALUE	Present Value ($)
1	LCD Display	1	16 pin	3.95
2	Speaker	1	8 ohms	2.99
3	Push button	6	No	1.83
4	Switch	1	No	2.53
			Sub-total	$11.3

Table 5: Cost-comparison of Electronics Pests Repellent and Chemical Insecticides

	Electronics Type	Chemical Type (Propoxur) Walker (2000)	Chemical Type (DDT) Walker (2000)
Rating	6 Watts	-	
Cost of Pests Repellent ($)	$16.6612	$37.20	$1.60
Application Time ~ 1 year	10,000 h	2 times	2 times
Pests	1	2 times -	2 times -
Repellent needed for same life		$37.20 X 2= $ 74.40	$1.60 X 2= $ 3.20
Energy Consumption	6 Watts x 10,000 h 60,000 Wh = 60 kWh	-	-
Price of electricity	$0.085	-	-
Cost of Electricity needed for 10,000 h	60 kWh x 0.085/kWh = $5.10	-	-
Total Cost (Life Cycle costs) to own and operate the bulbs for 10,000 h	$16.6612+ $5.10 $21.7612	$74.40+$37.20 $111.60	$1.60+$ 3.20 $4.80

Table 6.Comparison of Simulation and Experimental Results

Uncertainty ±5%	Selected Animals	Ultrasonic Frequency (Simulated)	Ultrasonic Frequency (Experimental)	Volt (peak-to-peak) Simulated	Volt (peak-to-peak) Experimental
Error ±5%	Mosquitoes,Bugs	20-30 kHz	21-29 kHz	5V	4.964 V
	Rats	30-40 kHz	31-39 kHZ	5V	4.964 V
	Bats,Cockroaches	40-60 kHz	41-59 kHZ	5V	4.964 V
	General mode	20-60 kHz	21 -59 kHZ	5V	4.964 V
	Audio mode	100 Hz-10 kHz	99Hz-9 kHz	5V	4.964 V

Table 7: The Prototype and Commercial Devices

Uncertainty ±5%	Ultrasonic Frequency (Commercial)	Ultrasonic Frequency (Prototype)
Error ±5%	Up to 130db	Up to 80KHZ

IV. CONCLUSION

This paper has presented the design of an electronic pest repellent. An audio power amplifier circuit was designed producing sound in the frequency range of up to 80 kHz. A speaker of appropriate frequency range is used to transmit these sound waves. This device is a viable alternative to pesticides commonly in used in farmlands and homes. The oscilloscope displays indicated that the generated signals were within the repelling frequency range of 30 and 50 kHz of the ultrasonic frequency. The ultrasonic signals tested for ten experimental trials for different ranges of pests were within the stated range. This has therefore established that the simulation and experimental results were consistent within a measuring uncertainty of ±5% at an affordable cost of one-fifth rate lower than the propoxur insecticide.

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