

Development and preliminary testing of an electronic pest repeller with automatic frequency variation

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ABSTRACT: *This study presents the development and preliminary performance evaluation of an improved electronic pest repeller with automatic frequency variation. The study is aimed at developing a device that is capable of emitting ultrasonic energy of varied frequencies. These frequencies do affect the auditory senses of pests such as rodents, avian and nocturnal insects by making them uncomfortable in their abode. However these frequencies do not affect the hearing ability of man. An Astable Multi-vibrator (AMV), timer NE555 was used to generate the required ultrasonic frequency and automatically varied in five steps by a pulse generating IC (CA3130) and a counter (CD4017). A D-type flip-flop IC (CD4013) was used to obtain a symmetrical output signal which was amplified in push-pull mode by 2-NPN Transistors (BD-139) and 2-PNP transistors (BD140). Five variable resistors (each 100KΩ) were used to control the different frequencies selection. Two transducers (tweeters) were employed to produce an efficient sound generated. The unit was tested with three groups of white foot mice (*Peromyscus leucopus*) and a female house mouse *Mus musculus* which all responded positively from a distance of up to fifteen (15) meters from the source. The average designed efficiency was found to be 86.5%. The device can be utilized by both small and large scale farmers for the purpose of repelling pests. The performance of the device could be greatly improved with little modifications, for instance, using microcontrollers and ultrasonic sensors to transmit the ultrasonic sound in a special band of frequency.*

Keywords—*Development, electronic, pest, frequency, repeller, sound*

I. INTRODUCTION

Electronic pest control 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.

Numerous electronic pest control devices are readily available throughout the world. Hardware stores and garden centers usually stock some sort of electronic device advertised to repel a variety of pests and one can also find them on the internet. Although these devices have been around for at least 20 years, they have only recently become popular and widely advertised, probably due to their environmentally friendly claims. There is a wide range of opinion about these devices. Some people claim that they work for them, while others claim they are not effective at all [1]. Several methods have been used and are still being used for the control of pest; many of them have been proved ineffective in one way or the other.

The commonest method of pest control is the use of pesticides (chemicals). Pesticides are substances or a mixture of substances used for destroying, preventing, repelling or mitigating pests. Pesticides are commonly used in and around homes because they are easy to apply, fast-acting, and effective against a wide variety of pests. There are instances where the use of pesticides in rodents control may be effective, but there is no registration which specifically refers to the use of pesticide against pests control which does not constitute a potential hazard to man and his environment. Chemical method of pest control has been found to be very effective but quite expensive to maintain. Also, these chemicals are highly poisonous and harsh both to humans and pests alike as a result of their ability to pollute the air. Air pollution is thought to be one of the most important risk factors for respiratory diseases, particularly for bronchial asthma and chronic obstructive pulmonary disease (COPD). However, a direct causal relationship is not easy to prove because air pollutants do not occur as individual entities but in combination. In addition, the concentration and duration of exposure to air pollutants required for inducing an adverse pulmonary effect have not yet been determined [2]. Moreover, it adversely affects the environment that it brings about the genetic mutation of the internal make up of these pests that they produce offspring that are immune to these chemicals that were used on their predecessor. [3]. This, coupled with society's growing concern about environmental risks, makes alternative methods of pest control increasingly attractive.

An ecofriendly alternative to chemical pesticides is biopesticides, which encompasses a broad array of microbial pesticides, biochemicals derived from micro-organisms and other natural sources, and processes involving the genetic incorporation of DNA into agricultural commodities that confer protection against pest damage. Biopesticides fall into three major classes. The potential benefits to agriculture and public health programmes through the use of biopesticides are considerable. The interest in biopesticides is based on the disadvantages associated with chemical pesticides. The total world production of biopesticides is over 3,000 tons/yr, which is increasing at a rapid rate. The market share of biopesticides is only 2.5% of the total pesticide market. The stress on organic farming and on residue free commodities would certainly warrant increased adoption of biopesticides by the farmers. Biopesticides being target pest specific are presumed to be relatively safe to non-target organism including humans [4]. However, correct identification of the pest is the first step in control, coupled with information on pest biology, ecology, and behavior. This renders this method rather cumbersome because, its adoption by farmers needs education for maximizing gains.

The mechanical method of controlling pest involves generating sounds mechanically to scare pests away. It also involves setting of traps, the use of guns and other mechanical means to kill pests. Any pest can be controlled by sound. Fireworks, acetylene exploders, balls horns and other noise makers have been utilized in birds' control [3]. Each has some applications but there is always one problem or the other which limits the situation to which it is applicable. Specialized equipment is needed to produce the required sound under different field conditions.

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. It is an Ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment. The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides [5]. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

An electronic device can utilize sonic or ultrasonic sound waves, ultraviolet or UV rays, visual scare characteristics or other means to discourage, scare or repel pests. The most popular of these are the ultrasonic pest repellers. Ultrasonic pest repellers have been extensively promoted for the control of rodent problems, primarily within buildings. While generally developed for use against rats and mice, some types of ultrasonic devices are promoted as repelling squirrels, chipmunks (*Eutamias* spp.), bats (Order Chiroptera), skunks, deer and/or coyotes. The high-frequency sounds produced by such devices are inaudible to most adult humans, although it is well established that most rodent species can hear and communicate with such sounds [6].

These devices have suffered quantum of 'setbacks' as most research results turn down the claims by their manufacturers about their effectiveness in pest control. For instance, 'while rodents may temporarily avoid areas "covered" with high-frequency sounds, they habituate to them and will feed or nest alongside the operating devices' [6]. 'Ultrasonic devices, as demonstrated by many tests, will not drive established rodents out of buildings or areas' [7]. 'High-frequency sound is ineffective on the European rabbit (*Oryctolagus cuniculus*)' [8]. However, some research works gave credence to the effectiveness of ultrasonic devices in pest control. For instance, the laboratory evaluation of the efficacy of the Pest-A-Cator/Riddex system to Exclude Mice; revealed that the behavior of wild house mice changed in conjunction with the introduction of the device and signal into their immediate environment; and concluded that if the same responses occurred in home and office settings, ultrasonic devices should have application as part of integrated rodent management program [9]. An extensive study on "ultrasound and Arthropod Pest Control" carried out at Kansas State University confirmed that ultrasonic sound devices do have both a repellent effect as well as a reduction in mating and reproduction of various insects. However, the results were mixed and ultrasonic sound had little or no effect on some pests. Ultrasonic devices were highly effective on crickets while the same devices had little repellent effect on cockroaches. The conclusion based on the mixed results, revealed that electronic pest devices may not have a promising future if existing devices are not improved through scientific and market research. 'Combination treatments should be explored: Light + ultrasound; ultrasonic barriers; ultrasound and attractants (push-pull strategy)' [10]. There is also the need to explore frequency ranges and pulse durations that give the best response. The effectiveness of ultrasonic devices can be increased by continuously varying the frequency of oscillation [3].

The objective of this study is to develop an electronic device for pests control that generates multiple frequencies of oscillation and at the same time covers a broad range of pests. TABLE I gives the frequency hearing range of selected animals.

Table I: Frequency Hearing Range for Selected Animals

Animals	frequency range (Hz)
Pig	45-45,000
Ferret	16-44,000
Raccoon	100-40,000
Risso's dolphin	8,000-100,000
Jamaican fruit bat	2,800-131,000
Rabbit	360-42,000
Human	31-17,000
Guinea pig	54-50,000
Rat	500-64,000
Mouse	2,300-85,000
G gerbil	100-60,000
Manatee	400-46,000
<i>Birds</i>	
Pigeon	?-5,800
Chicken	125-2,000
Canary	250-8,000
Cockatiel	250-8,000
Parakeet	200-8,500
Penguin	100-15,000
Owl	200-12,000
<i>Insects</i>	
Noctuid moth	1,000-240,000
Grasshopper	100-50,000

Source: (www.Hypertextbook.com, retrieved 23-08-2010) [11]

II. MATERIALS AND METHODS

The Components used are as follows: 1-9volts transformer, 1-9v battery, four diode rectifiers (IN4001), 1- μ f capacitor, 3-100k Ω , 2-4.7k Ω , 2-1k Ω , 1-18k Ω (fixed resistors), 5-100k Ω (Variable resistors), 1-470k Ω (variable resistor), 1-1 μ F/25v, 1-330pf, 1-10 μ F (capacitors) 4-ICs (CA3130, CD4017, NE555, CD4013), 2-NPN transistors ($T_1=T_2=$ BD139) 3-PNP transistors ($T_3 =T_4=$ BD140) 2-power switches, 4-iezoelectric tweeters (transducers) 2-LED. 1-vero board, 1 – casing made of mild steel metal sheet of gauge 16. The device comprises the power unit, the pulse generator unit, the oscillating unit and the amplifier unit. The most important units are the oscillating unit. Fig. I, fig. II and fig III show the schematic diagram of the pulse generator and counter unit, the oscillating unit and the output waveform of the Astable Multivibrator respectively.

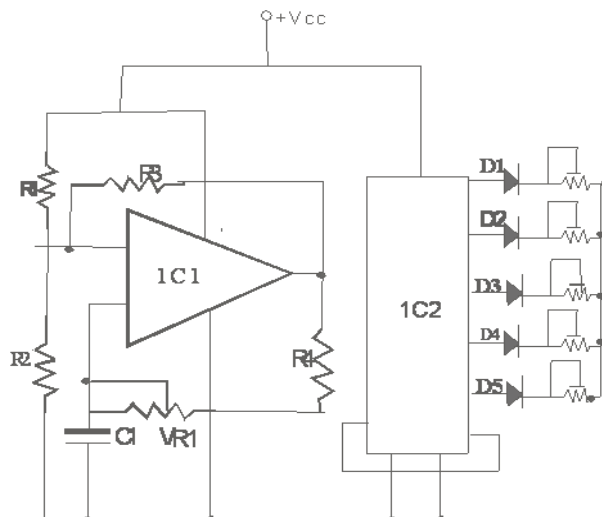


Figure1: schematic diagram of the pulse generator and counter unit

By using this module, frequency of emission of ultrasonic sound is continuously varied step by step automatically. Five stages of variation were used. For each clock pulse output from operating ICI CA3130 (which is wired here as a low frequency square wave oscillator), the logic 1 output of IC2 CD4017, which act as the counter, shifts from the output of D1 to the output of D5. Five presets are set for different values and connected to the input of the oscillating unit.

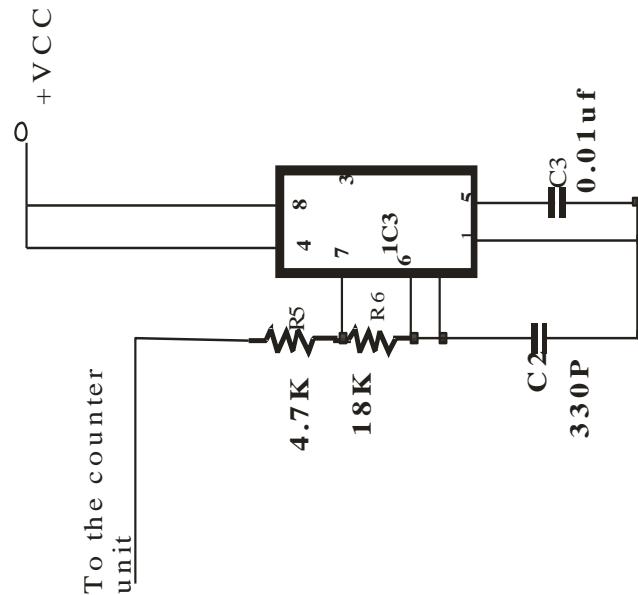


Figure2: schematic diagram of the oscillating unit

Pin 7 of IC3 (NE555) is electronically connected to the output of the counter unit. VR1 is used to change pulse clock rate. IC3 is wired as an astable multivibrator which oscillates at a frequency range of 30kHz-105kHz. Its output is not symmetrical. IC4 (see fig 2), a D-type flip-flop which delivers symmetrical 50kHz signals at its outputs.

2.1 Design equations and computed values

T_H = time high in (sec)

T_L = Time low in (sec)

T = Period

T_{max} = maximum period in (s)

T_{min} = minimum period in (s)

F = Frequency in Hz

$$T_H = 0.693 C_A (R_A + R_B) \quad [12] \quad 1$$

$$T_L = 0.693 C_A R_B \quad 2$$

However, R_A from the circuit above is

$R_{D1} + V_{R2} + R_5$ since these are in series

Where;

R_A = the input resistance of the oscillator

R_{D1} = diode resistance (IN4148) = 618Ω

V_{R2} = the maximum value of each of the variable resistors (100kΩ), $R_5 = 4.7kΩ$

$$R_{A(max)} = 0.618 + 100 + 4.7 = 105.318kΩ$$

$$R_B = 18kΩ, C_A = C_2 = 330 \times 10^{-12} = 330P$$

Therefore time low = $0.693 \times 330 \times 10^{-12} \times 18 \times 10^3 \mu s$

$$T_L = 4.12 \times 10^{-6} S = 4.12 \mu s$$

Time High is;

$$T_H = 0.693 \times 330 \times 10^{-12} \times (105.318 \times 10^3 + 18 \times 10^3)$$

$$= 0.693 \times 330 \times 123.318 \times 10^{-9}$$

$$= 28.2 \times 10^{-6} S = 28.2 \mu s$$

$$T_{max} = T_L + T_H \quad 3$$

$$T_{max} = (4.12 + 28.2) \mu s = 32.32 \mu s$$

Minimum Frequency is

$$F_{\min} = \frac{1}{T_{\max}} \quad [13] \quad 4$$

$$F_{\min} = \frac{10^6}{32.32} = 30940.594$$

$$F_{\min} = 30.940\text{kHz}$$

$$\text{Duty circle at } F_{\min} = \frac{T_H}{T_{\max}} \quad 5$$

$$\text{Duty Circle at } F_{\min} = \left(\frac{28.2}{32.32}\right) \times 100\% = 87.3\%$$

$$R_{A(\min)} = 4.7 + 0.618 = 5.318$$

$$\text{Minimum time high} = 0.693 \times 330 \times 10^{-12} \times (5.318 \times 10^3 + 18 \times 10^3)$$

$$= 0.693 \times 330 \times 23.318 \times 10^{-12} \times 10^3$$

$$T_{H(\min)} = 5.33 \times 10^{-6} = 5.33\mu\text{S}$$

$$\text{Minimum time low} = 4.12\mu\text{S}$$

$$\text{Minimum period} = T_{L(\min)} + T_{H(\min)} \quad 6$$

$$T_{(\min)} = (5.33 + 4.12) \mu\text{S} = 9.45\mu\text{S}$$

$$\text{Maximum Frequency, } F_{\max} = \frac{1}{T_{(\min)}} \quad 7$$

$$F_{(\max)} = \frac{10^6}{9.45} = 105820.1058\text{Hz} = 105.8\text{kHz}$$

$$\text{Duty circle at } F_{\max}: D = \frac{T_{H(\min)}}{T_{(\min)}} \quad 8$$

$$D = \frac{5.33}{9.45} \times 100 = 56.4\%$$

The output wave form of the Astable Multi-Vibrator (AMV) is shown in fig.3

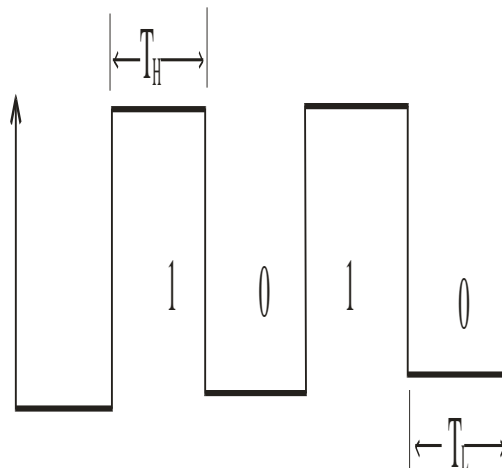


Figure3: the output waveform of the astable multi-vibrator

Fig.4 gives the complete circuit diagram of the electronic pests repeller

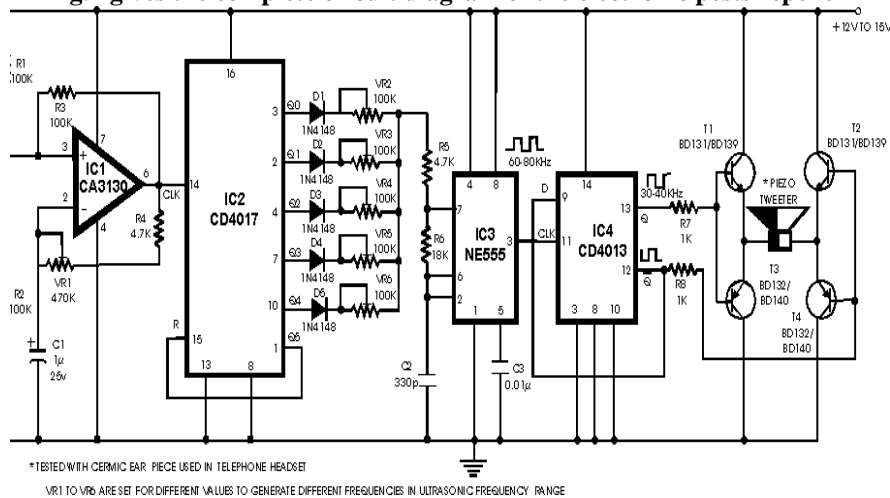


Figure 4 complete circuit diagram of the designed electronic pests repeller

The generated equation and computed values are summarized in TABLE II below

Table II: Generated Equations and Computed Values

Equations	Calculated values	Unit
$T_L=0.693C_A R_B$	4.21	μs
$T_H=0.693 CA(RA+R_B)$	28.2	μs
$T_{max} (\mu s)= T_L+ T_H$	32.32	μs
$F_{min}= 1/T_{max}$	30.94	kHz
Duty Cycle at $F_{min}= T_H/ T_{max}$	87.3	%
$R_{A(min)}=R_{D1}+R_5$	5.32	$k\Omega$
$T_H=0.693 CA(R_{A(min)}+R_B)$	5.33	μs
$T_{min} = T_L+ T_{H(min)}$	9.45	μs
$F_{max}= 1/T_{min}$	105.8	kHz
Duty Cycle at F_{max} %	56.4	%

Given parameters: $RA(max) = 105.82 k\Omega$, $CA= 330*10^{-12}Farads$, $RB = R6= 18k\Omega$

2.1 PERFORMANCE EVALUATION

The device was designed to generate a frequency range of 31-105kHz. Preliminary test was carried out using the digital multi-meter, to measure the actual frequencies (lower and upper frequencies) before amplification and the output impedance after amplification. The results from this test are presented in TABLE III

Table III: Output Frequencies and Impedance

Designed frequency range (kHz)	Actual frequency range (kHz)	Output impedance (Ω)
31-105	30-80	8

Base on the results above, the efficiency of the device in terms of frequency generation is calculated as

$$\text{Efficiency} = \frac{\text{actual value}}{\text{designed value}} \times 100 \tag{10}$$

$$\text{Efficiency based on minimum frequency} = \frac{30}{31} \times 100 = 96.8\%$$

$$\text{Efficiency based on maximum frequency} = \frac{80}{105} \times 100 = 76.2\%$$

$$\text{Average efficiency} = \frac{96.8+76.2}{2} = 86.5\%$$

2.3 Experimental procedure for Laboratory testing of the device on pests

The device was fully tested on three groups of white foot mice over a distance of five (5), ten (10), and fifteen (15) meters at the biological laboratory of the Federal University of Technology, Minna. The mice were housed in cages in order to confine their movement, to make food available and to make observation easy. The device was activated and the reaction of each of the groups was observed simultaneously.

Again, the repelling ability of the device was tested on a female house mouse with a two day old litter of three. It was activated at a distance of five (5) meters from the mouse and its litter for five (5) minutes after which it was deactivated.

III. RESULTS AND DISCUSSIONS

The actual (measured) minimum and maximum frequencies are respectively 30kHz and 80Khz against 31kHz and 105kHz, the designed frequencies. The average designed efficiency based on frequency generation is computed to be 86.5%. The output frequency test revealed that there is variation between the designed frequency and the actual frequencies. This is due to the variation between the actual values of components used and the theoretical values as presented in TABLE IV. The theoretical values of components were used for the designed calculation. Comparing efficiency based on minimum frequency with that based on maximum frequency as computed above, it can be deduced that the device is more efficient in generating lower frequencies in the selected frequency range than the higher frequencies. This implies therefore, that the device is more effective in repelling pest that respond to sounds of the lower frequencies range.

Each group of mice shows an abrupt response to the activation of the device. Group A and group B responded instantly whereas it took group C about thirty seconds to show the same kind of response. In each case, the mice abandoned their food, stampeding and jumping against the walls of the cage looking for ways of escape. In the case of the female house mouse, it was observed to display some kind of discomfort, uneasy and some abnormal behavior such as jumping and became frantic. The moment the device was deactivated, the

mouse jumped out of its abode, leaving its litter behind. This was accompanied by the death of the offspring after the second day since their mother never returned to feed them

Table IV: Results on components testing

Resistor	Theoretical resistances (kΩ)	Actual resistances(kΩ)	difference(kΩ)	*Tolerance %
R1	100	95.9	4.1	5
R2	100	95.6	4.4	5
R3	100	96.1	3.9	5
R4	4.7	4.7	-	2
R5(RA)	4.7	4.6	0.1	2
R6(RB)	18	17.6	0.4	5
R7	1	0.99	0.01	5
VR1	470	454	26	5
VR2	100	98.2	1.8	5

(Source: components testing with the multi-meter). *Tolerances are obtained as specified by manufacturers with colour coding.

IV. CONCLUSION

An extensive performance evaluation is required to determine the efficacy of the device on different pests. However, preliminary results obtained from the preliminary performance evaluation revealed that the device has the potential to eliminate rodents. If the same responses occurred for other pests, the device should be used in farms to repel pest and should have application as part of integrated rodent management program, which is in line with earlier findings. The performance of the device could be greatly improved with little modifications, for instance, using microcontrollers and ultrasonic sensors to transmit the sound in a special band of frequency. The device can be utilized by both small and large scale farmers for the purpose of repelling pests. However, for home use, the amplification is not necessary as the sound intensity may cause hearing impediment.

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