Developmental Features and Implementation Challenges of Electronic Pest Control Devices in Developing Countries.

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Abstract—This work presents the makeup and striking advances recorded in all spheres of electronic pest control. Challenges hampering the smooth implementation of the gains of electronic pest control devices especially in developing countries were highlighted. It was recommended that more work be done in this field by researchers and governments of developing nations in order to domesticate the gains of this technology.

Keyword: Amplifier, habituation, oscillator, pests, ultrasonic transducer.

1 INTRODUCTION

In In an earlier work, electronic pest control devices were considered in the light of their necessity, controversies and the design considerations to technically fortify them in order to increase their long-term effectiveness by delaying habituation were proffered [1]. Electronic pest control devices refer to several types of electrically powered devices designed to repel pests. Such devices are either known as electronic pest repellents, electronic pest chasers, electronic pest deterrent or electronic pesticides; but generally they are known as electronic pest control devices. The device is a contribution of electronics to pest control. Introduction of the device is fallout of the environmental pollution problem which remains the major drawback associated with the most popular pest control method: The conventional (chemical) pest control method [2]. The aftermaths of this contamination on target and non target organisms of the ecosystem include resistance to chemicals [3], chemical and biological degradation [4], accumulation along food chain [5], effect on fish [6], birds [7] and finally possible toxicity to man. The short and long term effects to the person using the pesticide and to the public that consumes the food grown using such pesticides include mutation, cancers, abnormal birth to mention just a few [8]. Records of death and diseases due to pesticide poisoning stands at about 1 million per year [9]. Non-chemical pest control methods have been advocated as the best way to reduce pesticide contamination in our environment [2]. Electronic pest control is one of the pesticides-free alternatives to raising food. Although, an emerging technology, its merits over others include the fact that they are cheap, eco-system friendly, environmentally friendly and have no known risk to human [10]. This work focuses on the ultrasonic type of electronic pest control devices. The device is designed and constructed to emit ultrasound which is sound of frequency above 20 kHz [11]. Above this value of frequency, sound is inaudible to the human ear, but when targeted at pests, it makes them uncomfortable within the area of coverage thereby repelling them away from the area without affecting the environment and non target organisms including man. Like other emerging technology, ultrasonic pest control devices are not free of controversies [12], [13] and [14]. Thus, they are still under intense research. Nevertheless, some users attest that the devices have made a considerable impact on their pest problems and can be rated as being effective [15].

2 Features of Electronic Pest Control Devices

The characteristic features of an electronic pest control device comprise principally of the oscillator, amplifier and the ultrasonic transducer.

2.1 Oscillator

A source of ultrasound of desired frequency is a foremost requirement for an electronic pest control device. This requirement is found in an electronic oscillator. The function of an electronic oscillator is to repetitively generate electrical signal of a specific frequency [16]. In this case, 20 kHz and above. The frequency of oscillation depends on the constants of the device [17]. Oscillatory circuits suitable for electronic pest control abound. A simple oscillatory circuit consists of a capacitor, C_1 and inductance coil, L_1 in parallel as shown in Figure 1.

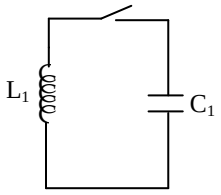

Figure 1: L-C Oscillatory Circuit

The system in Figure 1 can produce electronic oscillation of frequency determined by the values of L_1 and C_1. The frequency of oscillation of the circuit is given by,

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}} \quad (1)$$

Another simple oscillatory circuit comprises of a resistor, R_1 and

capacitor, C_2 as shown in Figure 2.

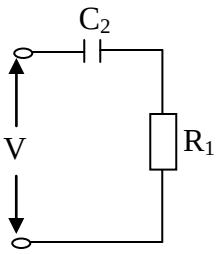

Figure 2: R-C Oscillatory Circuit

The system in Figure 2 produces electronic oscillation with frequency given by,

$$f = \frac{1}{2\pi R_1 C_2 \sqrt{6}} \quad (2)$$

A major limitation of LC and RC oscillators is that their frequency does not remain strictly constant. In order to maintain constant frequency, piezoelectric crystals such as quartz and tourmaline are used in place of LC or RC circuit. Oscillators of this type are called crystal oscillators. When a.c voltage is applied across them, they vibrate at the frequency of the applied voltage. However, if the frequency of the applied field is made equal to the natural frequency of the crystal, resonance takes place and crystal vibration reaches a maximum value. The natural frequency of a crystal is given by;

$$f = \frac{k}{t} \quad (3)$$

Where k is a constant that depends upon the cut and t is the thickness of the crystal. Frequencies between 25 kHz to 5 MHz have been obtained with crystals.

As the frequency increases further in the ultrasound region, it is natural that the electrical voltage supplied to the crystal must be obtained from a radio frequency oscillator and applied to the input of a transistor amplifier [18]. Any type of radio frequency oscillator such as Hartley or Colpitts may be employed. A typical crystal controlled oscillator is shown in Figure 3.

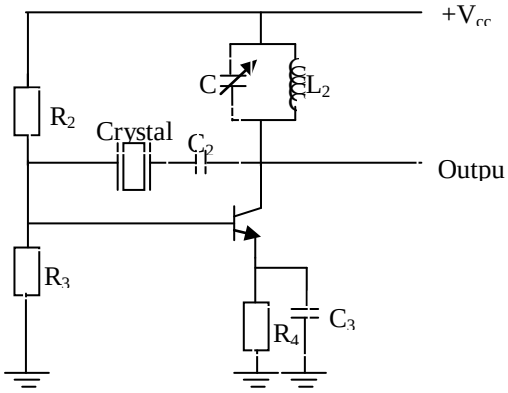

Figure 3: A Crystal controlled oscillator [16].

Recently, piezoelectric ceramics such as barium titanate and lead zirconate titanate were introduced due to their good piezoelectric properties, ease of manufacture, low voltage requirement and are usable up to about 300°C [19].

Intergrated circuits (IC) can be used to achieve oscillation. They have an overall advantage of effectively operating at designed frequency and portability. Some IC usually used as oscillators in electronic pest control devices are the 555 timer and CD4047. The 555 timer is more popular and is known for its versatility. It has three modes of connection namely: Monostable, Astable and Bistable which determines the nature of output and application. When connected in the astable mode, the 555 IC will operate as an oscillator [20].

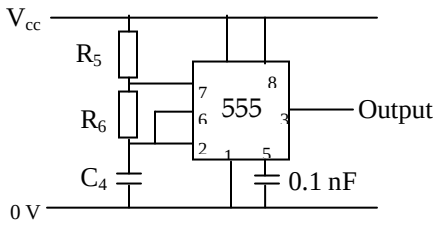

Figure 4: 555 IC in Astable mode

The frequency of operation of the oscillator is dependent upon the values of R_5, R_6, and C_4 referred to as the timing resistors and capacitor respectively. The design formula for the frequency f, of the pulses is:

$$f = \frac{1}{(0.693 \times C_4 \times (R_5 + 2R_6))} \quad (4)$$

Parameters can be adjusted to satisfy the rule: $(R_5+R_6) \leq 3.3\ M\Omega$. With $R_5 \geq 1k\Omega$ and $R_6 \geq 1k\Omega$ [20].

2.2 Amplifier

Ultrasound signals are by nature weak. A means of electronically increasing the power of the ultrasonic signal so generated by the oscillator is needed for a wider reach. An amplifier is a device that raises the strength of a weak signal without any alteration in its original shape [17]. Therefore, a power amplifier of desirable gain is connected to the output of the oscillator to boost the weak ultrasound to an appreciable level to effectively drive the succeeding stage. Absence of an amplifier or the presence of one of low power will result in small area of coverage. In some cases, just a few meters away from the stand might be secured while pests further away will be having a field day feasting on farm crops. To forestall this occurrence, transistors of high gain are choosen and incorporated into booster electronic designs. The gain A, of an amplifier refers to the number of times the output is magnified [18]. This can be in terms of voltage or power gain. Voltage gain (A_v) is the ratio of change in output voltage (ΔV_{out}) to the change in input voltage (ΔV_{in}) while the power gain (A_p) is the ratio of output signal power (P_{out}) to the input signal power (P_{in}) as expressed by equations 5 and 6 respectively:

$$A_v = \frac{\Delta V_{out}}{\Delta V_{in}} \quad (5)$$

$$A_p = \frac{P_{out}}{P_{in}} \quad (6)$$

High amplification parameters are usually implemented in designing electronic pest control devices. By this, the reach will increase and the magnitude of disturbance responsible for the scary effect is increased and further propagated to farther distances.

2.3 Ultrasonic transducer

The ultrasonic signal generated by oscillators and energized by the amplifier are electrical in nature. A means of converting them into ultrasonic sound (ultrasound) is required. This conversion is achieved with an ultrasonic transducer. In general, a transducer is used as a means of converting non electrical signal into electrical (or vice versa) for ease of processing [21]. While an ultrasonic transducer is a device used to convert some type of energy into an ultrasonic vibration [22]. The ultrasonic transducer mostly used in electronic pest control devices is the Piezoelectric transducers. These also make use of piezoelectric crystals earlier discussed, and convert

the amplified ultrasonic electric signal applied to the crystal into mechanical vibrations (ultrasound) of equal frequency. In practice, piezoelectric tweeters operating over the desired frequency range are employed. The choice of a tweeter as best suited for this is due to its unique roles of not only converting the electrical signals to ultrasound, but also transmitting (or broadcasting) same at rated output levels to constitute disturbance to pests in their hideouts or on the field. Thus, scarring them out of the area of coverage.

In addition to the above basic features, some electronic pest control devices have other embellishments which enhance their performance. Some of the additional features include: sonic circuit and tripping circuit.

2.4 Sonic circuits

Some electronic pest control devices are furnished with circuits capable of producing sounds that are audible both to pests and to human ear. It is a replica of a traditional pest control method in which shouting and clapping of hands are used to scare pests [23]. In electronic pest control devices, these can be in the form of recorded predator cries and distress calls of a variety of targeted pests. These improve the overall effectiveness of the device over a long period of time as they are better fortified against habituation by pests.

2.5 Tripping circuits

Animals exhibit habituation to familiar stimulus [12]. Therefore, pests also show habituation to electronic pest control devices. This is because the device operates repeatedly over a long period. To curb or slow down the process of habituation, judicious use of the device was advocated [24]. Therefore, tripping circuits were introduced to shut the device at intervals and to come up when the pests are attempting to enter the protected area or farm. One way of achieving this is by use of sensors capable of identifying peak pest periods of the day, number of pests, direction of movement and other parameters of interest.

3.0 Developments

Electronic pest control devices have passed through several stages of growth. Although, an evolving technology, it has advanced appreciably. Some striking improvements are discussed below.

3.1 Analogue to Digital

Like other advanced devices, electronic pest control devices started with analogue components combining their individual typical functions to achieve a desired purpose. Components like resistors, capacitors, diodes and inductors were predominantly used in the oscillator design while simple transistors were used as amplifiers. With the advent of digital components like IC's, components like the 555 timer are now used as oscillators and operational amplifiers as the amplifier section. This has led to reduced size and more control. It is also common to have a combination of both analogue and digital components in some electronic pest control devices exploring the benefits of both types where necessary, as shown in Figure 5 [25].

3.2 Uni-directional to Multi-directional

Earlier designs of electronic pest control devices were uni-directional. That is, they transmit ultrasound in one direction of broadcast. Effect of such ultrasound can only be felt by pests along the line of travel while pests outside the line of sight are unaffected and continue feasting on crops. This occurence is due to the fact that ultrasound is uni-directional by nature [26], and this knowledge has influenced the emergence of electronic pest control devices that are multi-directional. Such devices are able to transmit ultrasound in more than one direction. Some designs replicates the oscillators, amplifiers and ultrasonic transducer in other directions while others maintain the design but only introduce four ultrasonic transducers position 90^o apart and summing up to 360^o broadcast and pest deterrent in all directions [27].

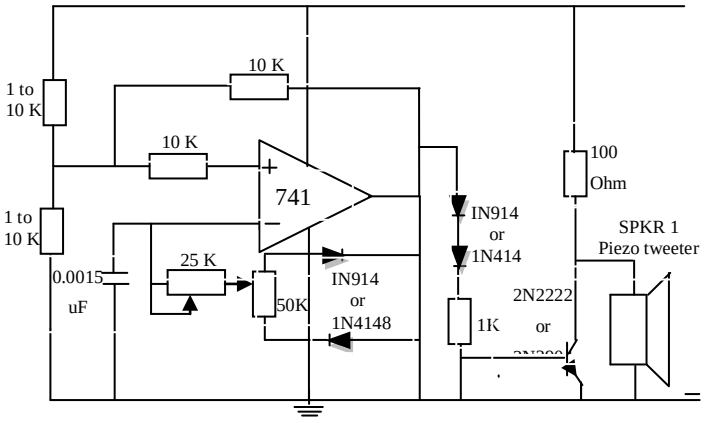

Figure 5: Ultrasound Generator [25]

3.3 Simple to complex Designs

Electronic pest control devices started as a simple device comprising the oscillator, a small transistor amplifier and a twitter as shown in Figure 6 [26].

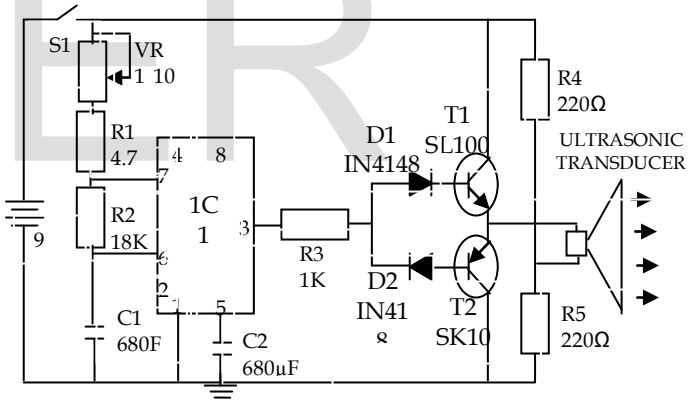

Figure 6: Ultrasonic Transmitter Circuit [26]

A look at recent circuit designs will reveal a complex assembly consisting a lot more than that of Figure 6. Additional circuits like tripping circuits, sonic circuit, preamplifier, frequency selection circuit for variable frequency type and other additional incorporations. All these will be further replicated in each of the four arms resulting in a multifaceted circuit too elaborate to be captured on a page. This makes recent designs more equip for effectively deterring pests around the vicinity of the device.

3.4 Fixed frequency to variable frequency

Electronic pest control devices emit ultrasound which corresponds to threshold sound hearing capacity of targeted pests. So are early versions of the device, their oscillators were designed to generate a constant frequency of interest to target specific pests [25] and [26]. Although with the advantage of handling specific pest effectively, it also has the disadvantage of easy susceptibility to habituation. Since all pests do not react to the same ultrasonic frequency [28] and [29],

designers nowadays use oscillators or IC's capable of generating variable frequencies [30]. These have the advantage of not only handling a variety of pests having threshold sound hearing capacity within the transmitted frequencies, but also introduces variability which is a way of delaying habituation [27].

3.5 Simple Amplifiers to Compound Amplifiers

Initial electronic pest control devices were propelled by simple low power amplifiers consisting of few transistors as shown in Figures 4 and 5. Their power output is low which reduces their effectiveness. Thus, they have a small area of coverage good enough for household's pest control. In recent times, the device has developed with a high-power built-in amplifier consisting of several stages of cascaded transistors. Such amplifiers are mostly preceded by a preamplifier circuit which boosts the strength of the weak ultrasound signal to an appreciable level before being fed into the input of the amplifier [31]. With this, the reach will not only increase, but the magnitude of disturbance responsible for the scary effect is further increased with enhanced effect on the pest. . such a device with amplifier advancement shown in Figure 7 is more suitable for outdoor conditions especially in farms.

3.6 Battery Powered to Alternative Power Supply

Electronic pest control devices are battery operated. For the reason that they are able to cope with the energy requirement (being low energy consuming) and the advantage of portability, recent designs have begun to explore solar power alternative [27]. Considering the fact that the battery easily runs down with reduced performance of the device, solar panel can be used to charge a rechargeable battery for obtaining a linear performance. Although the solar panel will add to the size of the device, this is compensated for by a constant reservoir of energy and can easily be detached when necessary, especially when on transit. The idea of solar power is also to harness the solar energy potentials abundant in some developing countries of the world especially Africa [32].

4.0 Implementation challenges in Developing Countries

The noble idea behind electronic pest control devices is a welcome development to agriculture, homes and other reserved territories where pest activities are inimical. Globally, especially the developing nations, the benefits of this device are yet to fully harnessed. Developing countries generally have peculiar challenges which include inadequate power supply, poor educational system and technical knowhow, unemployment, poverty, corrupt government and neglect of agriculture, among others [33-34]. All these affect the perception, practices and profits of the populace. Thus, the deployment of electronic pest control devices in such countries of the world will definitely be marred by lots of peculiar implementation challenges as highlighted below.

4.1 Acceptance

Of all the pest control methods, electronic pest control devices are the most recent. As usual with new products, there is always the problem of acceptance. It is customary in most parts of the world, especially in developing countries, find it easier to continue an existing pest control method (even if ineffective) than to accept a new method with all its gains. Being an electronic device, the general skepticism and worry expressed by intending users of the device are that it looks too complicated to use, it may be difficult to fix in case it develops a fault, it may not really solve one's particular pest problems, it may not be safe to use and that it will be too expensive. However, all doubts about the device have already been taken care of. Electronic pest control devices are safe, simple, easy to use, easily maintained and not costly. The challenge of acceptance will become a thing of the past as more trial results will convince potential users to patronize them.

4.2 Power Supply

The major occupation of majority in developing nations is agriculture [35]. Therefore, the application of this technology in farms is most beneficial to inhabitants of these regions as it eliminates one of the threats to food sufficiency: pests. Unfortunately, most farm locations are away from urban centre's with less likelihood of public power supply. Electronic pest control devices for now are battery operated [25] and [26] with the risk of running down frequently. This affects the optimal performance of the device which is also prone to shut down at critical battery levels. The epileptic nature of public power supply in developing countries makes public power not to be the best alternatives even when they exits. The way out of this power challenge is the use of solar powered electronic pest control devices. Most of these countries especially Africa have high solar energy potentials [32] and so, the introduction of solar powered electronic pest control devices will surmount the power challenge by ensuring twenty four hours (day and night) pest chasing.

4.3 Controversy

Electronic pest control devices are one of the most criticised pest control methods in advanced world. The usual arguments by users are that it is ineffective [12], partially effective [13] or very effective [14]. This controversy has constituted a huge challenge to the implementation of the device in the developing world as it hampers acceptance. Rather than sit back and watch the controversy settled before accepting the technology, more proactive researchers from a developing nation have recognised habituation as one reason behind the controversy and that delay of habituation by the introduction of variability will contribute to resolving the controversy [27]. Design considerations and practices to technically fortify the device and aid in the delay of habituation were also proffered [1]. This step will lead to the emergence of electronic pest control devices that can be used with less controversy.

4.4 Sanctions

In the year 2003, electronic pest control devices have its worst blow when a category, the electromagnetic pest control devices was banned in the United States by the US Federal Trade Commission until the claims are backed by credible scientific proof [13]. This action was on the ground of ineffectiveness. Rather than addressing a specific type from a manufacturer of the device, a wrong message was perceived by intending users of other series of the device that they are equally ineffective. This saga in no small measure affected the implementation of electronic pest control devices around the world, particularly in developing nations.

4.5 Publicity

No matter how effective a new product is, it cannot initially sell itself above the publicity accorded to it. Electronic pest control devices have not enjoyed wide publicity. It is mostly restricted to promo pages on the internet and academic journals which does not command large viewership. The challenge of acceptance highlighted above would not have arisen if adequate publicity were carried out. Only such publicity is needed to erase the fears associated with

acceptance. Right publicity carried beyond the internet and direct to intended users in simple language can reassure potential users of the gains and raise their confidence to change from the familiar traditional pest control methods to a new one. Publicity also lays the foundation for availability as the device for now is only available upon order from the internet where its publicity is restricted to. This work is also aimed at targeting manufacturers, researchers and governments to publicize electronic pest control devices directly to farmers and making them available to intending users until a time when they can be bought over the shelve.

5.0 Conclusion

It has been advocated in many quarters that agriculture provides a good platform out of the poverty and unemployment quagmire of developing nations [35]. The electronic pest control device is a contribution of electronics to agriculture as it reduces loss to pests, encourages farmers to produce more food, increases farmers income, makes agriculture attractive to the unemployed and thereby enhancing food sufficiency. If the challenges hampering the smooth implementation of the device are surmounted, the future is bright for developing nations. With the interest of indigenous researchers of the developing world, it is clear that these implementation challenges shall be overcome in good time, especially if research and developments continue unabated. Governments of developing nations should put the right policies in place, such as funding research in this area, relevant public enlightenment, granting credit facilities to intending users, increasing productivity of small farms by deployment of agricultural extension workers to farmers to help in trial of this device, developing industrial policies to promote manufacturing among others will help in surmounting these implementation challenges. Also, bottlenecks on the path of the devices smooth implementation such as policy somersault, poor maintenance culture, use of inappropriate technology, promoting policies that encourage developing countries as dumping ground of outdated, inappropriate technologies and practices should be done away with. The focus of future research should therefore include:

- Development of electronic circuit design in line with design consideration proffered earlier [1]. Such design will better adapt to the environment of developing countries.
- Construction of the said device in line with stated circuit design to encourage user friendliness.
- Laboratory and field testing of the designed and constructed device for proper performance evaluation.

With all these in place, developing countries will fare better in reaping the dividend of electronic pest control devices now and in the future.

REFERENCES

[1] A.G. Ibrahim, O.D. Oyedum, O.D. Awojoyogbe, S.S.N. Okeke, Electronic Pest Control Devices: Their Necessity, Controversies and Design Considerations. The International Journal of Engineering And Science (IJES), 2(9), 2013, 26-30.

[2] M.W. Aktar, G. Sengupta and A. Chowdhury, Impact of Pesticides use in Agriculture: Their Benefit and Hazards. *Interdisciplinary Toxicology*. 2(1), 2009, 1–12.

[3] S.R. Palumbi, Humans as the World's Greatest Evolutionary Force, *Science* 293, 2001, 1786–1790.

[4] C. Savonen, Soil microorganisms object of new OSU service. Good Fruit Grower. 1997.

[5] S. Tanabe, F. Gondaira, A.N. Subramanian, A. Ramesh, D. Mohan, P. Kumaran, V.K, Venugopalan and R. Tatsukawa, Specific Pattern of Persistent Organochlorine Residues in Human Breast Milk from South India. *J Agric Food Chem*. 38, 1990, 899–903.

[6] T.M. Shafiei and H.H. Costa, The Susceptibility and Resistance of Fry and Fingerlings of Oreochromis mossambicus Peters to some pesticides commonly used in Sri Lanka. *J Appl Ichthyol*. 6, 1990, 73–80.

[7] R.A. Liroff, Balancing risks of DDT and Malaria in the global POPs treaty. *Pesticide Safety News*. 4, 2000, 3.

[8] A. Brouwer, M.P. Longnecker, L.S. Birnbaum, J. Cogliano, P. Kostyniak, J. Moore, S. Schantz and G. Winneke, Characterization of Potential Endocrine Related Health Effects at Lowdose Levels of Exposure to PCBs. *Environ Health Perspect*. 107, 1999. 639.

[9] Environews Forum, Killer Environment. *Environ Health Perspect*. 107, 1999, 62.

[10] J. Hangiandreou, Physics Tutorial for Residents: Topics in US: B-mode US: Basic Concepts and New Technology *Radiographics* 23 (4): 2003, 1019.

[11] R. Novelline. Squire's Fundamentals of Radiology (5th Ed.). Harvard University Press. 1997, 34–35.

[12] B. Subramanyam, Ultrasound and Arthropod Pest Control: Hearing is Believing! (pdf). Kansas State University. 2001.

[13] US FTC, Analysis of Proposed Consent Order to Aid Public Comment In the Matter of Global Instruments Ltd., and Charles Patterson". Federal Trade Commission 2003.

[14] Victor Pest, Rodent Repellents http://www.victorpest.com/advice/all-about/victor-repellents/types-of- repellents. Retrieved 2009-10-22.

[15] R.J. Lawrence, http://www.selfgrowth.com/articles/electronic_pest_control_and_ultrasonic_pest_control_vs_traditional_chemical_pesticides.html.

[16] B. Theraja, Basic Electronics, Solid State. S. Chand Company Limited. 2005, pp 499.

[17] V.K. Mehta and R. Mehta, Principles of Electronics, S. Chad. 2010, 193, 366.

[18] S.S.N. Okeke, and E. Ezeonu, Techniques for the Generation of Ultrasound, a Review, Natural and Science Journals 5(1), 2003), pp 128-138.

[19] M. Berke, Introduction to Ultrasonic Testing, Agfa NDT, hurtu, Germany. 2002, pp 3

[20] V. Tony, LM555 AND LM556 TIMER CIRCUITS, DOCTRONICS WILLIAMS LAB, retieve from www.matni.com/Arabic/Elec.../NE555%20DETAILS/555.htm

[21] A. Sa, Principles of Electronic Instrumentation. Chapman and Hall Inc., New York. 1990. 83.

[22] "ultrasound." Encyclopædia Britannica. Ultimate Reference Suite. Chicago: Encyclopædia Britannica, 2013.

[23] E. O. Bright, E.B. Tologbonse, and S. Ogunyemi, Farmers' Perceptions and Management Practices of Weaver Bird Pests in Niger State, Nigeria. *Production Agriculture and Technology* 2009, 5(1), 1-13.

[24] H. Rankin, T. Abrams, R. Barry, S. Bhatnagar, D. Clayton, J. Colombo, and R. Thompson, Habituation Revisited: An Updated and Revised Description of the Behavioral Characteristics of Habituation. *Neurobiology of Learning and Memory* 92 (2): 2009, 135–138.

[25] J. Lundgren, Critter Ridder - Ultrasonic Sound Generator, www.ee.washington.edu/circuit_archive 1996. Retrieved 16, October 2013.
[26] P. Mariam, Electronic pest repellent. www.electronic-circuits-diagrams.com. Retrieved November, 2009.
[27] A.G. Ibrahim, O.D. Oyedun, O.B. Awojoyogbe. S.N.N. Okeke, Design, Construction and Characterisation of an Ultrasonic Device for the Control of Birds in Farms. A paper presented at the Nigerian Institute of Physics Conference held in March 2013 in Abuja, Nigeria.
[28] R.A. Adams, S.C. Pedersen, Ontogeny, Functional Ecology, and Evolution of Bats. Cambridge University Press. 2000, 139–140. ISBN 0521626323.
[29] T. Condon, Frequency Range of Dog Hearing. In Elert, Glenn. The Physics Factbook. http://hypertextbook.com/facts/2003/TimCondon.shtml. Retrieved 2008-10- 22.
[30] www.tronicszone.com
[31] S.S.N. Okeke, and E. Ezeonu, Design, Construction and Characterisation of Ultrasonic Rodent Repeller, Natural and Science Journals 8(1), 2003, pp 4536-4543.
[32] O.D. Oyedum, J.A. Ezenwora, K.C. Igwe, J.O. Eichie, A.S. Moses, Diurnal and Annual Cycle of Surface Refractivity and Related Parameters in Minna, Nigeria. Nigerian Journal of Space Research (NJSR), Vol 10, 2011,141-156.
[33] J. Sloman, Economics, 6th Edition. 2007, 100.
[34] B.L. Das, Challenges of Developing countries in the Near Future. Third world network, Malaysia. 2001, 14.
[35] C.G Ramesh, Debt Problems of Developing Countries. 2006, 93.