ANALYSIS OF THE SIGNALS GENERATED IN A DESIGNED AND CONSTRUCTED MULTI-TONE ULTRASONIC RODENT REPELLER.

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Abstract
A solar powered multi-tone ultrasonic rodent repeller was designed, constructed and characterized. The data generated during the simulation of the designed circuit using an oscilloscope of an Electronic Work Bench was investigated and analyzed. The plot of the data resulted to a rectangular pulses which confirms the use of 555 timer connected in astable multivibrator mode for generation of electrical signal, which is converted to ultrasound using a piezo crystal. The analysis of the pulses generated an ultrasonic frequency of 36 kHz which is used in repelling rodents. Also the Fourier analysis of the signal was computed and the intensity of the ultrasound was calculated, which infers that the intensity of the ultrasound is more on the rodents as it gets closer to the repeller. Therefore an ultrasonic frequency (which is frequency above 20 kHz) can be used to repel rodents.

Keyword: Ultrasound, Solar Cell, Astable Multivibrator and 555 Timer.

Introduction

An ultrasound is a sound (i.e. mechanical vibration phenomenon) having a frequency above the range of human hearing, 20 kHz, which requires a material medium for its propagation (Jacke, 1979; Rapacholi, 1981). Ultrasound consists of electronically generated sound wave with frequencies too high to be heard by human ear and repels rodents by subjecting them to intense auditory stress. It hunts their ear and makes them uncomfortable by causing temporal threshold shift in sound perception, alters blood sugar levels, electrolyte imbalance, fatigue, headache, nausea, tinnitus and finally fatigue.
(IPSC, 1982)

Physical characteristics of an ultrasound

Ultrasound consists of propagating disturbances in a medium, which causes particles of medium to vibrate. The vibratory motion of the particles characterizes ultrasound energy propagation. It is transmitted through a medium unlike electromagnetic radiations. The transmission through medium depends to great extent on the ultrasound frequency and the state of the medium either gas, liquid or solid.
In solid, compressional (longitudinal) waves and shear (transverse) waves exists but the ultrasound propagation in gaseous or liquid are mainly inform of longitudinal or compressional waves formed by alternate regions of compression and rarefraction of the particles of the medium, which vibrate in the direction of energy propagation (IPSC, 1982).

Experimental and Theoretical procedures

Integrated circuits, four 555timers were connected in astable multivibrator mode. An oscilloscope of Electronic Work Bench was used to simulate the designed circuit and the output voltages of the signal were collected against time.

The data collected were plotted as shown in fig 1 and the ultrasonic frequency computed thus:

From the graph and using the formula for calculating the frequency generated by 555 timer when connected astable multivibrator mode (Boylestad and Nashelky, 2002; Horowtiz and Hill, 1992; Theraja and Theraja, 1997; Leach and Malvino, 2003; Rozzani, 2004).

$$F = \frac{1.44}{R_1 + 2R_2}$$

F= frequency which the number of oscillations that is made in one second, measured in hertz, R_1 andR_2 are resistor that is connected across the 555 timer, measured in ohms

But

$$T = \frac{1}{F}$$

Where *T* is the time taken for one complete oscillation

$$T = 27.5$$

$$F = \frac{1}{27.5 \times 10^{-6}}$$

= 36 kHz

The Fourier approximation of the signal generated is shown in fig 2 and the mathematical representation of the pulse is given by

$$f(t) = \begin{cases} 173 & 0 \leq t < 13 \\ 0 & 13 \leq t < 25 \end{cases}$$

The Fourier series of a periodic function with arbitrary period T as above in the interval $o < t < T$ *is given by*

$$f(t) = \frac{a_0}{2} + a_1 \cos\frac{2\pi}{T}t + a_2 \cos 2\frac{2\pi}{T}t + ---+ a_n \cos n\frac{2\pi}{T}t$$
$$+ b_1 \sin\frac{2\pi}{T}t + b_2 \sin 2\frac{2\pi}{T}t + ---+ b_n \sin n\frac{2\pi}{T}t$$

$$a_n = \frac{2}{T}\int_0^T f(t)\cos n\frac{2\pi}{T}tdt \quad n = 1,2,3---$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin n\frac{2\pi}{T}tdt \quad n = 1,2,3---$$

$$a_o = \frac{2}{T}\int_0^T f(t)dt$$

$$T = \frac{2\pi}{\omega}$$

$$\Rightarrow \omega = \frac{2\pi}{T}$$

From the graph and computing for a_o, a_n, b_n

$$a_o = 179.92,$$

$$a_n = \frac{173}{n\pi}\left[\sin\left(\frac{26}{25}\right)n\pi\right]$$

$$b_n = \frac{173}{n\pi}\left[1-\cos\left(\frac{26}{25}\right)n\pi\right]$$

$$b_n = \frac{173}{n\pi}\left[1-\cos\left(\frac{26}{25}\right)n\pi\right] \quad n = 1, 2, 3,---$$

The calculated coefficients for n = 1, 2, 3, --- is shown in table 1.

Results and Discussion

Fig 1 and 2 depicts the plot of data gotten after the simulation of the circuits. The graphs resulted to rectangular pulses, which show that 555timer circuit when designed and connected in astable multivibrator mode and after construction can generate electrical signal which is converted to ultrasound using a piezo. This resulted ultrasound, otherwise known as ultrasonic repeller can be used as an alternative means of repelling and eradicating rodent. Ultrasound repels rodents by subjecting them to intense auditory stress.

The Fourier coefficient of the analyzed signal and the nature of the signal are shown in Table 1 and fig 2. From the graph 3, it showed that the signal fades away with distances, meaning that the intensity of the signal is more experienced by the rodents as it gets closer to the device making it to be much irritated and demobilized.

The complete Fourier approximation of the generated pulse of 555 timer circuit in fig 1 is obtained as

$$f(t) = 86.5 + \sum_{n=1}^{100} \sin\left(\frac{26}{25}.n\pi\right).\cos\left(\frac{2n\pi}{25}.t\right) + \sum_{n=1}^{100} \frac{173}{n\pi}\left(1-\cos\frac{26}{25}.n\pi\right).\sin\left(\frac{2n\pi}{25}.t\right)$$

The intensity associated with this Fourier approximation is given by

$$I = \sqrt{(a_n{}^2 + b_n{}^2)}$$

$$= \sum_{n=1}^{\infty}\left[\frac{173}{n\pi}\sin\left(\frac{26}{25}n\pi\right)\right]^2 + \sum_{n=1}^{\infty}\left[\frac{173}{n\pi}\left(1-\cos\left(\frac{26}{25}n\pi\right)\right)\right]^2$$

Conclusion

A 555timer is an integrated circuit which when connected in astable multivibrator form can be used to generate rectangular signals and this signals can be converted to ultrasound which can repel rodents. The intensity of the ultrasound is more on the rodents when it gets closer to the repeller.

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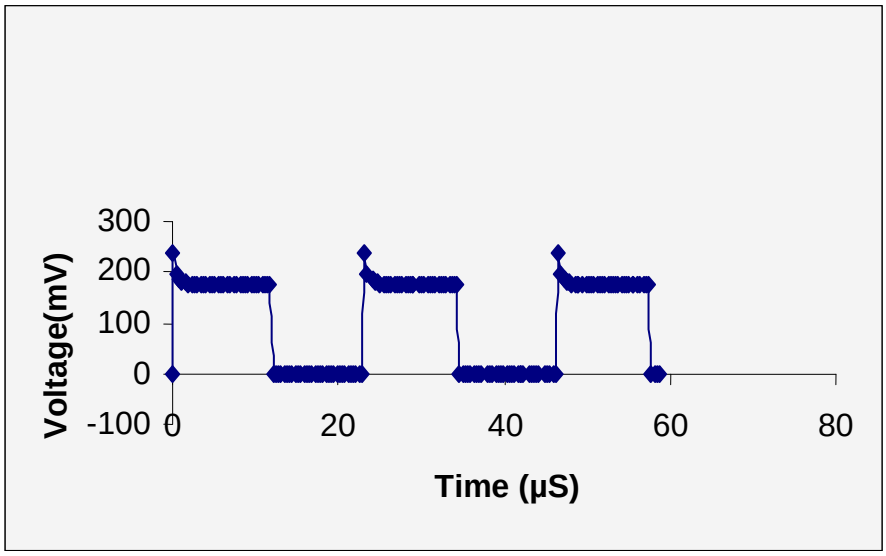

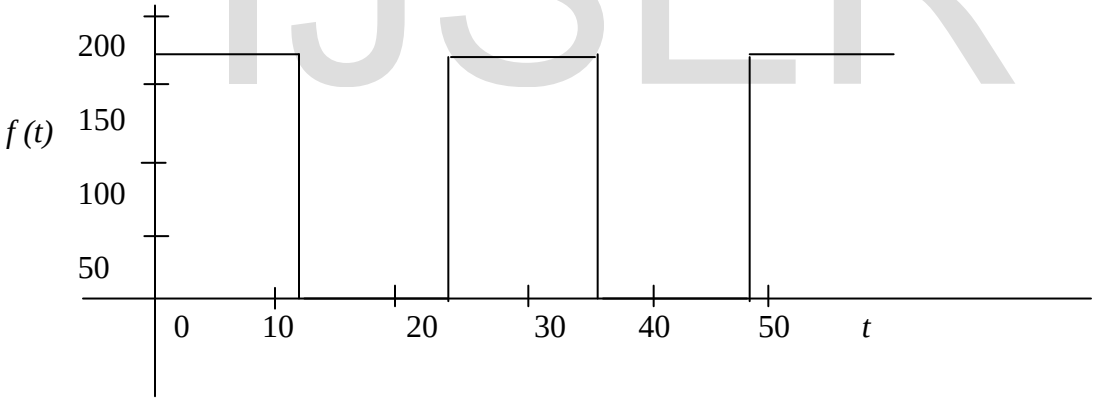

Fig 2: Graph of the Fourier approximation of 555timer circuit

Table 1: Fourier coefficients of the generated signal of 555 timer of circuit of fig 1

an	bn
-6.924	54.623
6.869	0.8722
-6.778	35.409
6.652	1.714
-6.491	19.907
6.299	2.503
-6.076	12.861
5.824	3.214
-5.545	8.702
5.244	7.185
-4.921	5.921
4.581	4.853
-4.226	4.525
3.859	4.692
-3.484	2.514

Fig 3: The graph of the Fourier coefficient of the generated signal is shown in fig 2