AN ELECTRONIC SWITCH SENSOR WITH A POINT-TO-POINT INTRUSIVE MONITORING SYSTEM

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ABSTRACT

Sophistications in theft and other criminal damages necessitates for the symbiotic blending of technology with security needs. In this research, electronic switches in the form of sensors were used to implement a point-to point intrusive monitoring system for the detection of an unauthorized access to commercial and residential buildings. The system is a simple and reliable security system and uses switch sensor technology to revolutionize the standards of living. The system is also simple, adaptable and cost-effective. It is designed in six major units which include; the power supply, the input/sensor micro-switches, the monitoring and indicator, the timing, the tone generation and output units. To ensure steady power supply in the circuit, the power unit constitutes both the mains and DC supplies. The alarm unit are being activated by the normally closed sensor micro-switches unit which is connected in an electronic/door mat at both the entrance and exit of buildings. In order to facilitate easy location of the intruder, the exact point of intrusion is being determined by the monitoring and indicator unit which constitutes the quad R/S flip-flop IC and LED's. The timing/tone generation unit is built on the 555 timer IC, in the Astable mode, which output keeps changing as far as there is a breakage of the sensors. The output of the system is mainly the LEDs and buzzer, which gives electrical light and audio signal to notify the owner of an intruder in the building. Major design issues considered include; efficiency, portability, cost-effectiveness, durability, compatibility as well as the availability of required materials. This system works on the principle of the micro-switch sensor and dependent on the condition that an intruder entered through the door and stepped in any one of the switches under the mat. Verification and validation of the system indicate compliances to design specification hence the output requirements were met.

KEYWORDS

Security system, Automation, Electronic Switch, Sensors, Room Light, Electronic Circuit Design.

1. INTRODUCTION

Theft and criminal damage is a threat and cost to home and business. Hence, the need to protect our homes, offices and business environment. Improvement in technology by man has shown that knowledge and experience can be harmonized and refined to assist man to observe, perceive, communicate, remember, calculate, reason, and protect himself.

Electronics, electrical, mechanical and/or chemical materials can be designed to serve or function as detectors of intruder to our homes. Among these, Electronic intruder detection systems were found to be the best that can provide cost-effective protection and act as a deterrent to intruders while alerting household, staff and/or police depending on the design. Electronic systems can function in two states. They are either analog or digital [1-3].

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Analog and digital systems can be differentiated by their output representations; while the signal output is behaving linearly with the input in analog systems, and can be represented by a pointer on a scale, digital systems represent their output in discrete levels either as up or down, ‘1’ or ‘0’ and on or off and their output can display numeric or alphabetically [3-5]. The digital state of electronics is preferred and widely in use today.

Even with insurance cover, the real cost of a break-in can be detrimental and should not be ignored. Disruption may lead to lost of lives in homes, delays and inefficiencies in business activities or even lost customers. The major components of an electronic intruder alarm system include detection, control and signaling devices. Every part of this equipment will be developed to fulfill a specific task within the system. These components are strategically placed in the building to be protected, with an assurance of constant, reliable and disturbance-free functioning. Alarm or intruder detectors come in many forms depending on the purpose it is meant for and has been in existence for some time. The most common security sensors indicate the opening of a door or window or detect motion via passive infrared (PIR). Some alarm systems are meant for single mission, while others handle fire, intrusion, and safety alarms simultaneously. Sophistication ranges from small, self-contained noisemakers, to complicated, multi-zoned systems with color-coded computer monitor outputs. Many of these concepts also apply to portable alarms for protecting cars, trucks or other vehicles and their contents.

Two options are much prevalent in the choice of an alarm system. These include, (1) An audible alarm sounds at the premises or home it is protecting only. This requires someone to immediately contact and report the incident to the police too. (2) A Monitored alarm sounds at the premises then a signal is sent to an alarm receiving center through a phone line or mobile network [4-7]. The alarm receiving center (ARC) is usually law enforcement agencies e.g. police.

There are also the choices of either hard wired or wire free systems. Comparison between the two indicates that the *Hardwired* is more reliable and cheaper but takes longer to install. Most commercial alarms are wired. Wire free is easy to install but are more expensive than a wired system and are mostly used in homes or small business premises.

Alarm intrusion detectors can also be classified as Point detectors and Area detectors. While point detectors indicate an intrusion at a specific point, area detectors indicate an intruder's presence within the protected area. Point detector types include mechanical or magnetic contacts on doors and windows, photocell or microwave beams across pathways, pressure-sensitive mats, fiber-optic bend or stress sensors, proximity switches that detect humans and vibration sensors among others. Area detectors use such technologies like the infrared (heat) detectors ultrasonic transducers, and microwave transducers, sometimes in combination within one sensor. In general, area detectors detect a sudden change in an environment being protected and trigger at some predetermined threshold. Often because of improper aiming or other adjustments, they are much more prone to false alarms than Point detectors. But interested readers can see [8-11] for theory of other components and methods adopted for this work.

2. System Design Methodology, Analysis, and Calculations

This section will discuss the design procedure and the analysis of the components used for this work and generally deals with the design of the individual stages of the electronic security alarm System, which consist of the following units:

I. The power supply unit
II. Input/sensor micro-switches
III. Monitoring and indicator unit

IV. Timing unit
V. Tone generator unit
VI. Output unit

2.1. Design Methodology

The design of this work and principle of operation was demonstrated using the prototype of a building. In the design, four (4) entrances were selected to be monitored and protected by the alarm. An integrated circuit (I.C) that has four (4) set and reset pins was employed for the purpose of demonstrating the principle of operation of the intruder alarm system. Micro switches were used as detectors. The Micro-switches detectors were connected in electronic mats placed at the doorsteps of each of the four entrances to be protected and finally connected to the system. The monitoring and indicator unit serves as an output of the system. Each LED is labeled to correspond to a switching point and indicates which switch is tripped ON. These micro switches and infrared sensors can either be connected to door entrances or windows. Below (Fig. 1), is the complete block diagram of the system.

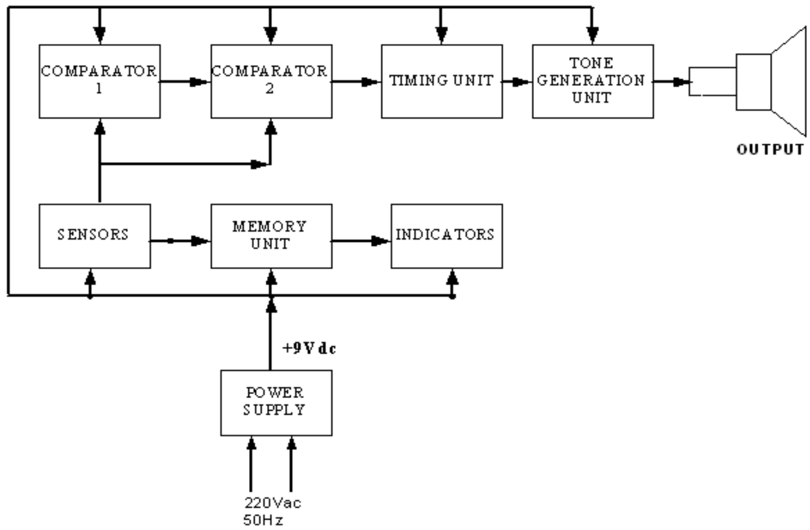

Fig. 1:Schematic block diagram of electronic alarm system

The electronic circuit was powered by a 12 volt direct current from a full wave rectified voltage. To ensure stability of power supply of the equipment, a 12volt battery backup was designed into it and connected in parallel to serve as an alternative power source. With this a 24 hour protection is guaranteed.

Micro switches connected to the four (4) doormats and/or windows are in a normally open condition. When they are stepped on, it closes sending a signal to the circuit thus triggering the alarm. Each micro switch is connected to the memory module and the LED indicators connected to the memory unit.When an intruder steps on the mat thus opening the micro switch, pulses are generated. These pulses generated are responsible for the activation of the tone generator connected in an astable mode on a timing unit. The tone generator and timing unit were both built on an integrated circuit called 555 timer but the timing unit was connected in a monostable mode.

2.2. The Power Supply Unit

In this sub-section, we describe and explain the design of the power supply unit. For the circuit we would require a 7812-voltage regulator as shown in the Fig. 2 below, which gives the required output of +12V. The voltage regulator regulates input voltages above its required output voltage. If the input voltage is below its required output voltage, it would be passed out without being regulated. To achieve this, the following steps were undergone.

- Stepping down the A C supply with a transformer
- Full wave rectification
- Removal of ripple from the rectified waveform
- Voltage regulation to desired value
- Power display LED

The power unit involves the transformer-bridge rectifier circuit. A 24V transformer is used to provide power to 7812 regulators, which produce, regulated 12V.

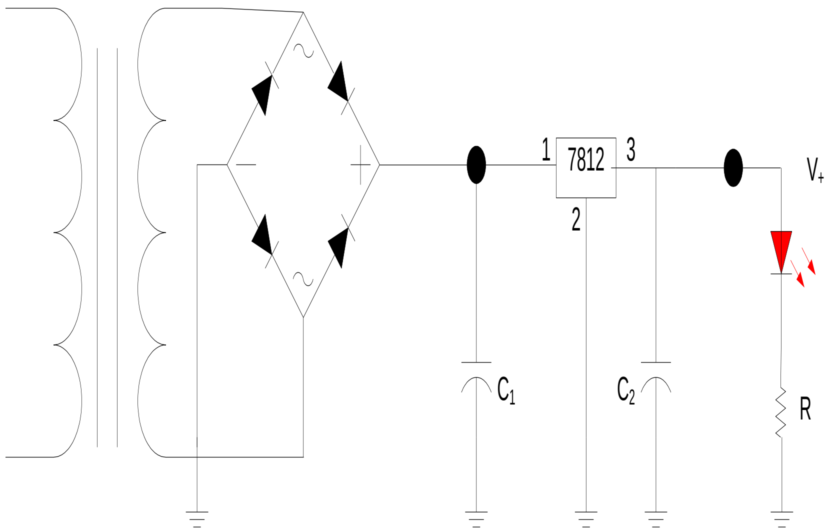

Fig. 2: The power supply unit

The common bridge rectifier, comprising four rectifying diodes, is used for converting the 24V AC power supply into corresponding roughly 24V DC voltage. The involved ripple at the output of the bridge rectifier is filtered through *a* 2200µF, 35V capacitor. The voltage rating of the capacitor is about twice the expected output voltage of the rectifier, to protect the device from the effect of the high voltage supply.A power switch was used to open and close the complete circuit when required. The 7812-voltage regulator is connected in parallel across the rectified voltage output. The devices are aimed for the stability of the complete circuit. The 12V power supply from the 7812 is connected to the main circuit.

2.2.1. Analysis of the Power Supply Unit

If the input to the 7812 is greater than the required output by saying, a factor of 4, the voltage regulator IC will start getting hot and will then eventually be damaged. As such an input of approximately 16V (i.e 12+4) is required. Recall that diode drops 0.6V and there are 4 rectifying diodes constituting a full wave bridge, we will then have a voltage drop of 0.6 x 4 = 2.4V

Considering a peak voltage of 16+2.4=18.4V peak.

Also considering an r.m.s voltage = $\frac{18.4}{\sqrt{2}} = \frac{18.4}{1.4} = 13.143V$

Therefore a transformer of a preferred value of 15V was employed. i.e. 220V/15V transformer.

Assuming a ripple voltage of 15%

$$dv = \frac{15}{100} \times 18.4V = 2.76$$

and $$dt = \frac{1}{2f} = \frac{1}{100} = 0.01$$

$$C_1 = \frac{1 \times 0.01}{2.76} = 3.623 \times 10^{-3}F$$

$$C_1 = 3300\mu F$$

A preferred value of 3300µF was however employed.

A compensating capacitor C_2 was used To reduce the ripple left in the system and a 4065µF was employed.

2.2.2. Power Indicator

A power indicator circuit comprising of a resistor and Light Emitting Diode (LED) shows the presence of power in the circuit.

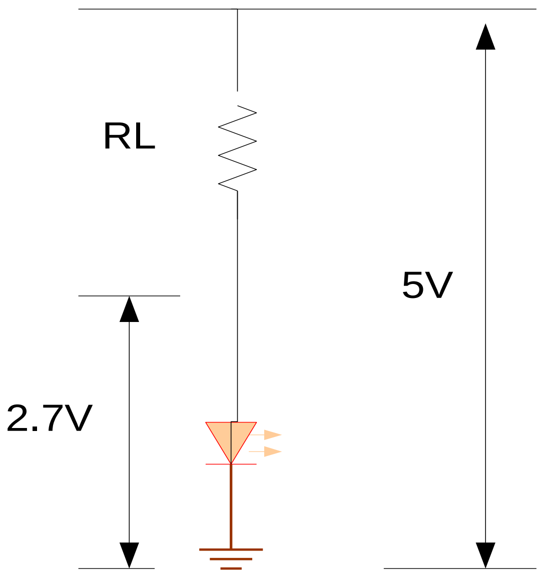

Fig. 3: The Power Indicator Circuit

A voltage of around 2.7V is expected across the diode with a current of roughly 2mA.

$$R_L = \frac{5 - 2.7}{2 \times 10^{-3}} = 1150\,\Omega \; = 1.15\text{k}\Omega$$

A resistor of 1kΩ is used instead for more practical importance and availability. It was also chosen to limit the power of the light emitting diode, LED. The power dissipated by the resistor is given by $P = V^2/R$. - $I2^2$/I000-0.I44W

2.3. Micro-Switches Input/Sensor Unit

The Intrusion sensor detectors used in this project are micro-switches in normally close-mode. The switches are connected in an electronic mat which could be used as a door mat at the entrance and exit to buildings or the switches could also be fixed to the windows in a normally close-mode. Any pressure of the heel or sole of a shoe as it steps on the mat or an attempt at opening the window causes the switches to open hence, triggering the alarm system.

2.4. Monitoring and Indicator Unit

The monitoring and indicator unit is used in determining the exact point of intrusion hence, facilitating easy location of the intruder. The Unit is built on a 4044 (Quad R/S Flip-flop) IC. This package contains 4 independent Set/Reset flip-flops sharing a common output Tristate enable control. On any one flip-flop Set and Reset should normally be a high. If Set (S) is made low, as when the input switch is triggered, the Q output goes and stays high. If Reset (R) is made low; the Q output goes and stays low, hence clearing the memory. If both S and R go low, the output goes low. This is a normally disallowed state and the last input to go high determines the final state of the flip-flop.

The outputs Qs are seen via LEDs. Each LED is connected to a separate output pin, while the Set pins are triggered via the input switches separately so that the point of intrusion that is, the switch triggered can be determined by the LED indicator that comes on. The circuit diagram below (Fig. 4), shows the connection of the monitoring and indicator unit.

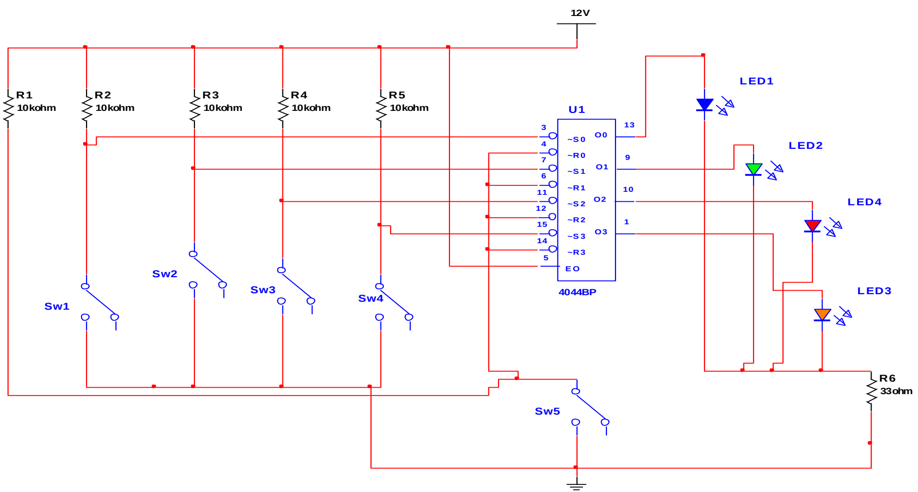

Fig. 4: circuit diagram of the monitoring and indicator unit

Sw1, 2, 3, and 4 serve as input switches with 10K pull-up resistors each, while Sw5 is the reset switch with all reset pins looped together. The LEDs act as output (indicators) when any corresponding switch is triggered.

2.5. The Tone Generator Unit

An Astable mode 555 timer IC is the "backbone" of the Tone Generator Unit; therefore it has no stable state as in the case of the monostable state, therefore the output is continually changing between 'low' and 'high'.

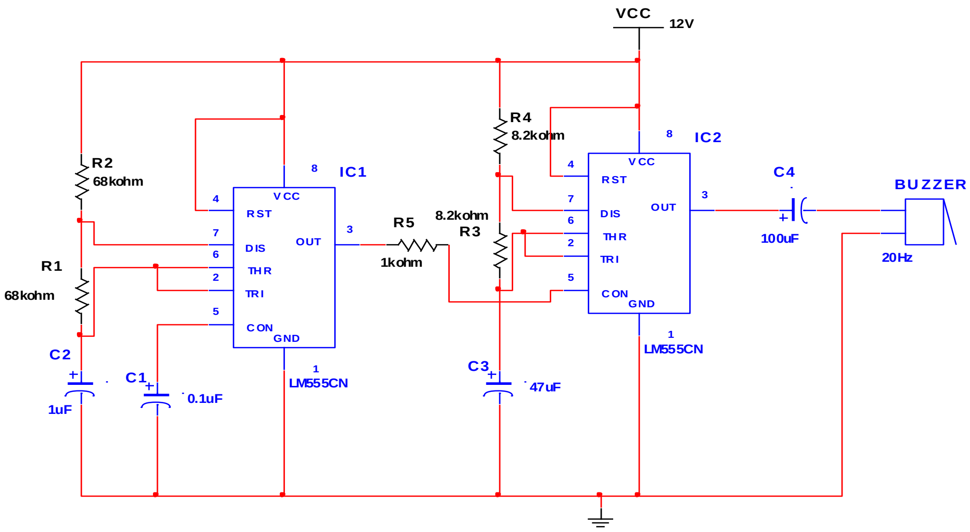

Fig. 5: circuit diagram of the tone generation unit

2.5.1. Astable Operation

The capacitor C_2 is charged by the current flowing through R_1 and R_2, with the output high (+Vs).). The output becomes low and the discharge pin (pin7) is connected to 0V when the capacitor voltage reaches 2/3 VS (threshold voltage). The threshold and trigger inputs monitor the capacitor voltage.

With current flowing through R2 in the discharge pin, the capacitor now begins to discharge. The output becomes high again when the voltage falls to 1/3Vs (trigger voltage) and the discharge pin is then disconnected, allowing the capacitor to start charging again. The cycle keeps repeating continuously unless the reset input is connected to 0V which forces the output low while, a reset is 0V.

Calculation

$$T_{ON} = 0.7 \times (R_1 + R_2) \times C_2 \quad (1)$$

And $T_{OFF} = 0.7 \times R_3 \times C_3$ (2)

Where, T = time period in seconds (s) = $T_{ON} + T_{OFF}$

With $R_1 = R_2 = 68K$, and C_2 = luF,

$T_{ON} = 0.7 \times (2 \times 68 \times 10^3) \times 10^{-6}$

$T_{ON} = 0.0952\, sec.$

With R3 = 8.2KΩ and C3 = 47uF

$T_{OFF} = 0.7 \times (8.2 \times 10^3) \times 47 \times 10^{-6}$

$T_{OFF} = 0.26978\, sec.$

$T_{OFF} \cong 0.27\, sec.$

Therefore, $T = 0.0952 + 0.27$

$T = 0.3652\, sec.$

$Since\ frequency, F = {}^{1}\!/_{T}$

$F = 1/0.3652$

$F = 2.74\, Hz.$

The tone generator unit is controlled by the timing unit via a transistor (BC 108), which acts as a switch to trigger the generator unit ON. Hence, once the timing period is elapsed the generated tone also ceases.

2.5.2. Monostable Operation

When the trigger input (555 pin 2) is less than 1/3 Vs the timing period is started. Therefore making the output high (+Vs) and the capacitor C1 begins to charge through resistor R1. Further trigger pulses are ignored once the time period has started.

When the voltage across C1 reaches 1/3 Vs, the time period is over and the output becomes low. The threshold input (555 pin 6) monitors the voltage across C1. At the same instant, discharge (555 pin 7) is connected to 0V, discharging the capacitor and ready for the next trigger.

2.6. Output Unit

The output of this system are LEDs and a buzzer. The output of the LEDs has been discussed earlier. Any light of the LEDs that shows tells us which of the entrance is being burgled.

The other output used to sound was a buzzer. The one used has the following specifications from data sheets:

Frequency = 15 Hz
Impedance = 300Ω
Voltage rating = 12V

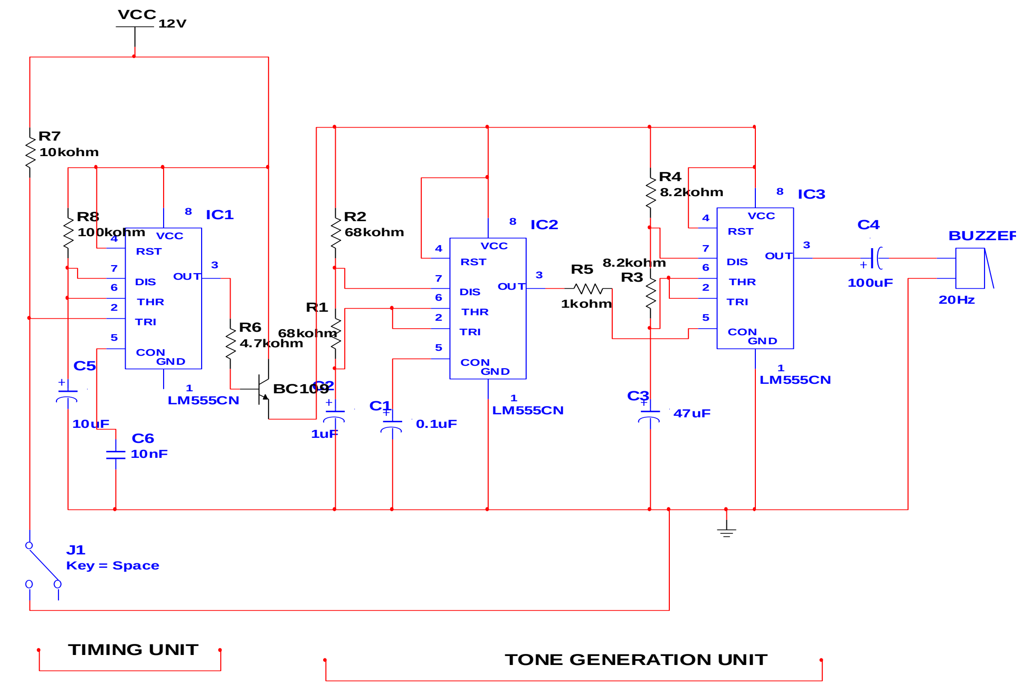

Fig. 6:Combination of the timing and tone generation unit

2.7. Principle of Operation

This system has four micro switches detectors that sense an intruder independently. The micro switches are either laid under the carpets, foot mats or window hinges. When an intruder steps on any of the switches in any of the four/all entrances or attempt to open the window, the switch closes and sends a signal through the circuitry that triggers the flip-flop.

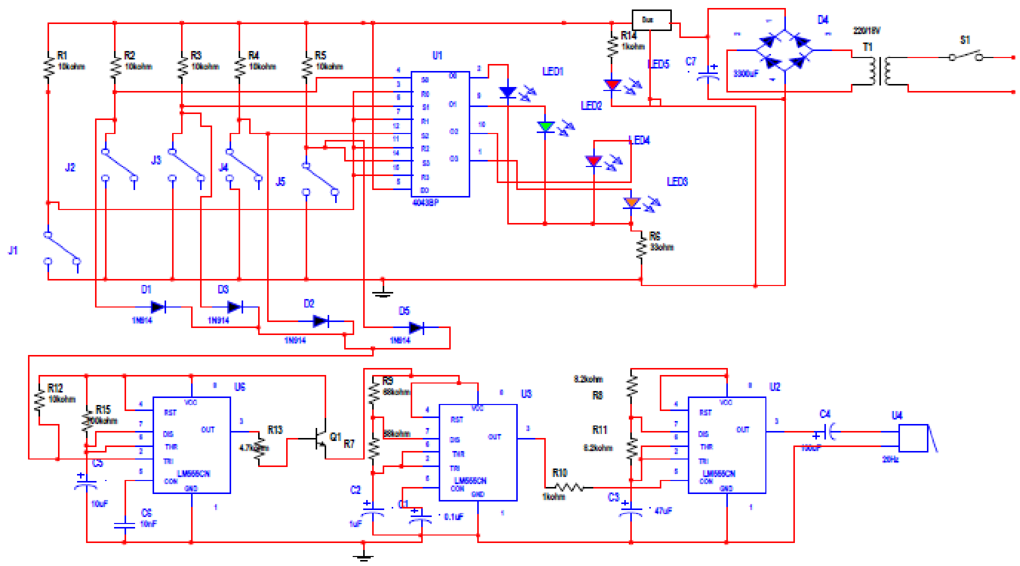

Fig. 7: Complete circuit diagram of the electronic switch sensor with a point-to-point intrusive monitoring system

3. SYSTEM CONSTRUCTION, TESTING AND DISCUSSIONS

3.1. Testing

It is one thing to develop and construct a system, but the beauty of it is for the construction to pass all tests and work to specification. The project was physically and functionally realized. After the paper design and analysis, the different stages of the circuit were constructed and tested to ensure error free system and was finally coupled together to meet the desired specifications. The process of testing and troubleshooting required the use of some of the equipment as:

Digital Multimeter: The digital Multimeter basically measures voltages, resistance, continuity, current, frequency, temperature and transistor. Measurement of parameters like, voltages, continuity, resistance values of the components and in some cases frequency measurement are required in the implementation of the design on the board. The digital Multimeter was used to check the various voltage drops at all stages in the project. It is almost the most useful tools for troubleshooting during construction and coupling.

Electronic Workbench: The design and simulation of this project were carried out first using a Computer Aided Software known as Electronic Workbench, with each block designed and tested, where upon getting the required output results, the test was carried out on a breadboard. The specified components were obtained and test was carried out stage by stage and it was found to be functional on the breadboard within the design specifications.

The entire components were then transferred onto a Vero board. Before soldering the components on the Vero board, the strip lines of the Vero board were cleaned with a methylated spirit in order to remove any form of conductor or dirt on it.

Integrated Circuit bases were soldered on the Vero board instead of the ICs themselves directly to avoid over-heating them during soldering and for easy replacement when necessary. Great care was taken in handling CMOS ICs because any form of static discharge or heat during soldering could easily damage them.

Holes were then bore through the prototype base at the four entrances where the micro-switches were installed to protrude just for slight contact. The LEDs that serve as indicators were mounted at the center of the building where it will be conspicuous to all households.

3.2 Result Analysis

After simulation using computer software (Multisim Electronic Workbench) to test the operation of the project, the result below was obtained from the timing circuit. The below graph (Fig. 8), shows the simulated result gotten from the operation of the timing and tone generation unit, hence the result conformed to the stipulated output result. The test was then carried out with the specified components on the breadboard, and found to have worked satisfactorily according to the specifications of the design.

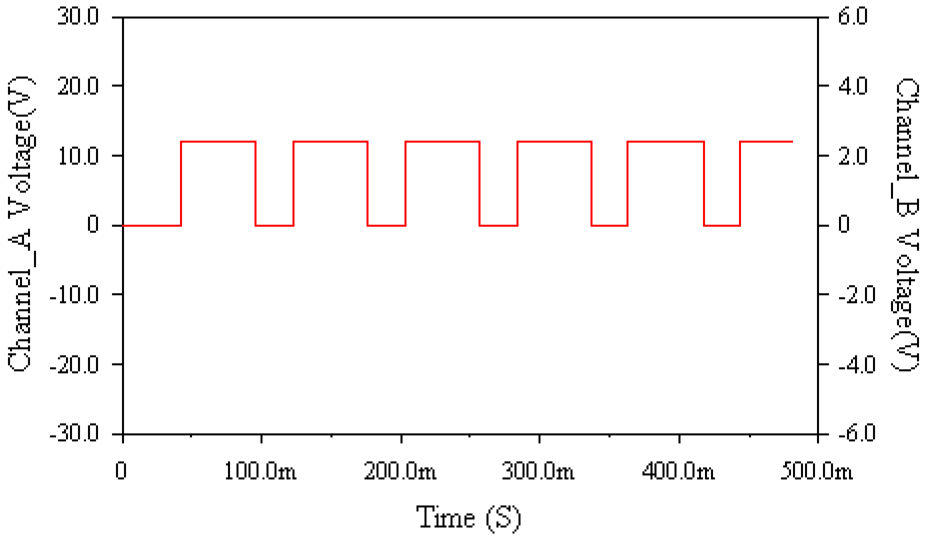

Fig. 8: Waveform generated

4. CONCLUSION

The aim and objective of the electronic security alarm system design were achieved, constructed and tested to work according to specifications.It is a known fact that even the highest fences, coupled with efficient security guards and dogs cannot make a home impenetrable. The use of this Electronics security alarm system whose operation is not based on sentiments is our best option today. At this time of insecure society this design work is the best for all homes and offices that needs to know when there is an intruder to unauthorized places.The micro switches used for this project as detectors are very sensitive and inconspicuous. Even when an intruder detects it and tries to disconnect it, the alarm will still be triggered because they were genuinely sensitive. Availability of components and their cost-effectiveness will go a long way in making this system stand the test of time. This system works on the principle of the micro-switch sensor and dependent on the condition that an intruder entered through the door and stepped in any one of the switches under the mat. All constructs were deliberate and carefully carried out with effective troubleshooting and maintenance criteria. The design of this security system involves; research in both analog and digital electronics. Research was done on timers and logic control circuits,as well as with relays and Opto-devices (e.g. Photodiodes, photo cells etc.). The implemented system was a typical prototype of the model.

There are areas that need improvements on this design such as if the purpose is not to scare away intruders but to catch them, then the alarm portion should be removed and be replaced with a special signal. This signal can be hidden bulbs or the signal can be wired to the security service unit. A hidden digital camera can also be incorporated into the system to take pictures of intruders without their knowledge at the point of intrusion.

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