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Design and construction of a burglary alarm system for vehicles in Nigeria

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ABSTRACT

Alarm system is made up of sections to detect, determine and deter criminal activities or other threatening situations. An alarm system can detect an event such as an intrusion, fire, gas leaks, or environmental changes. Therefore, this study presents a prototype for a vehicular burglary alarm system. The system integrates a Passive Infrared (PIR) sensor and a piezoelectric sensor, functioning collaboratively to detect unauthorized intrusions. The design incorporates a 555 timer IC configured in the monostable mode, interfaced with both a buzzer and an LED to promptly alert vehicle owners upon intrusion. The entire system operates on a 9-Volt DC power source. The operational principle is straightforward: upon detection of intrusion by either the PIR or piezoelectric sensor, the trigger pin of the 555 timer IC is activated, initiating the activation of the buzzer and illumination of the LED. The system was tested and found to be working to specifications and predictions. Based on the results of this study certain recommendations were provided for further studies: such as an amplifier be incorporated into the system in order to boost the signal powering the siren, more sensors should be installed at different locations in the vehicle to detect a myriad of intrusions and improving the system by interfacing the alarm system with a microcomputer to boost the effectiveness of the entire system.

***Keywords*:** DC power source, buzzer, vehicles, alarm system, passive infrared sensor, piezoelectric sensor, intrusion, Nigeria

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1. INTRODUCTION

Globally, most vehicle owners desire an effective, reliable and a cost effective product to protect their vehicles. Recent studies reported an annual record of 7.5 million cases of stolen vehicles globally (Interpol, 2018). This is a pointer to the fact that existing alarm systems are either inefficient or unaffordable to majority of car owners.

The global issue related to a constant increase in the rate of car theft needs to be urgently addressed by both develop and developing countries. For the first half of the 20th century, few vehicle thefts were recorded and vehicle security devices were rare. Then thefts started rising in the 1960s and steering locks were introduced as a result. These checked rather than halted rising crime, leading to a ‘second wave’ of security devices in the 1980s and 1990s including central locking, car alarms and electronic immobilisers (Morgan et al. 2016).

Nigeria has recorded a conspicuous surge in the incidence of automotive theft, with malefactors and vandals adeptly infiltrating vehicles to abscond with valuables or, in more severe instances, purloin the vehicles themselves. This escalating predicament has engendered a pressing exigency for the development of sophisticated systems geared towards the identification and thwarting of unauthorized access to parked vehicles in Nigeria. Recently due to increasing in technology, scientific researchers are presenting new era of discoveries, the need for security is also increasing in all areas. Vehicle usage has become a basic necessity for individuals for transportation, therefore proper protection against theft is very important. (Kiruthiga et al. 2015).

According to Ehikhamenle, (2016) defined an intrusion as any kind of unauthorised or unapproved activity in a network or a system. Zhang, 2006 also defined intrusion as any set of actions that attempt to compromise the integrity, confidentiality or availability of a resource. Intrusion detection is typically one part of an overall protection system that is installed around a system or device and it is not a stand-alone measure (Ngad, 2008). An intruder detection system (IDS) is needed to help identify, assess and report an intrusion. These intrusions could be physical or in some cases may occur as cyber-attacks. Cyber-attacks on vehicles usually include a series of operations, such as sniffing and fuzzing of CAN bus and reverse engineering the firmware of ECU (Wu et al. 2017). Intrusion prevention methodologies typically constitute the primary layer of defence against unauthorized access. These techniques encompass a spectrum of measures, including the deactivation of the vehicle's ignition system, activation of audible alarm systems, and initiation of communication with the vehicle owner, among other proactive measures. A buzzer alarm has a loud noise or signal for alerting or informing people of a danger or a problem (Zungeru, 2012).

An alarm system constitutes a security apparatus designed to emit auditory signals for the purpose of alerting individuals to specific dangers or activating attention through warning sounds. Specifically, a burglar alarm system represents a network of interconnected electronic devices operating in tandem with a central control panel, collectively engineered to safeguard against theft and potential unauthorized entries. The historical evolution of alarm systems traces back to antiquity, with early human societies employing rudimentary methods such as hand claps, vocal alerts, drum beats, and gong strikes to communicate and forewarn of impending dangers.

Advancement in science and technology ushered in an improvement in alarm systems. This saw to the introduction of electronic alarm systems in the late eighteenth century (British international studies Association, 2015). These electronic alarm systems operated without any human effort. It is equipped with a myriad of sensors for intrusion detection and an alarm system for alerting property owners of any intrusion.

The study seeks to address the issue of car theft and the shortcomings of existing alarm systems Nigeria. One of the very obvious shortcomings of existing alarm system is the problem of giving off false alarms. This alarm system is constructed to provide security to vehicles alongside other properties and ensure alarms are only activated when an unauthorised person tries to gain access to parked vehicles. This is achieved through the use of sensors that are easy to acquire, a 555 timer IC and a simple buzzer alongside other circuit components. These few components ensured a cost effective and efficient alarm system that would provide security and ensure alarm whenever there is an intrusion is constructed.

The aim of this study is the construction of a burglar alarm system for vehicles with the objectives which includes;

i) To construct a vehicle (car) alarm system capable of alerting car owners of an intrusion or an attempted intrusion.
ii) Ensure the security of vehicles by deterring persons intending to burgle a vehicle and warning vehicle owners of any unauthorised access to their parked vehicles.
iii) To have the psychological satisfaction of having your parked vehicle secure.

2. LITERATURE REVIEW

Eze et al. (2018) worked on the design and development of an advanced anti-theft car security system employing Radio-Frequency Identification (RFID) technology. The research aimed was to engineer a robust and user-friendly security solution that enables individuals to effectively safeguard their vehicles and belongings within them. Their study successfully harnessed the capabilities of Arduino Uno, a widely utilized open-source electronics platform, and seamlessly integrated it with RFID technology to create a cost-effective yet highly efficient anti-theft security system.. The system they devised empowers users with the ability to lock and secure their vehicles, along with the valuables contained within, employing RFID tags for seamless identification and authentication processes. This not only enhances the overall security posture but also introduces a layer of convenience for users in managing access to their vehicles.

As reported in the analysis conducted by Hodgison et al. (2016), the Vancouver region of Canada experienced a cumulative total of 33,496 reported car theft incidents during the temporal span from 2003 to 2013. Their empirical findings elucidate a discernible decrement in the incidence of car thefts, registering a decline from 3,300 cases in 2003 to 1,000 cases in 2013. Brown, 2015 in his recent study based on interviews with offenders asked their views on why crime had declined. The most popular response from offenders was to attribute the crime drop to improvements in security system used in vehicles.

Sayyad et al. (2017) carried out an innovative and advanced car security system designed and implementation. The study employed a multifaceted approach, integrating cutting-edge technologies such as Arduino, GPRS, GSM, and an RFID fingerprint scanner into their security system. Their findings provided system boasted, a CNG gas leak detection mechanism, enhancing the safety aspect of the vehicle. The result also signifies a substantial leap in the domain of automotive security systems.

The amalgamation of sophisticated technologies and the incorporation of diverse sensors not only enhance the security posture of vehicles but also contribute to the evolving landscape of smart and connected transportation systems.

Noman et al. (2018) have devised an Anti-Theft vehicle security system aimed at addressing security concerns associated with unauthorized access to vehicles. The intricately designed system incorporates a PIC16F876A microcontroller, along with components such as a fingerprint scanner, RFID technology, GPS-GSM modules, and a tilt sensor. Operationally, the vehicle is initiated through a multi-factor authentication process involving RFID, fingerprint, or password verification. In the event of an unauthorized attempt to open the vehicle's door, the system prompts for the correct RFID, password, or fingerprint input. The integration of a tilt sensor serves to detect any instances of window or door breakage, as well as the movement of the vehicle. In such scenarios, an alert message containing the car's location is transmitted to the owner's mobile device via the GPS-GSM module. Additionally, the system triggers an audible alarm to further deter unauthorized access. Beyond alerting the owner, the security system takes preventative measures by deactivating the connection to the car's fuel injector, preventing any unauthorized attempts to start the vehicle. This multifaceted approach not only enhances the chances of recovering the car but also acts as a robust deterrent against theft. The technical sophistication of this Anti-Theft security system positions it as a comprehensive and effective solution to mitigate the vulnerabilities associated with vehicle security.

Zainun et al. (2020) conducted a pioneering effort in designing an innovative Anti-theft System tailored for automotive security. The intricacies of the system design reflect a meticulous consideration of multiple factors aimed at enhancing its efficacy. Specifically, the system was engineered to address key security concerns, including the detection of sound frequencies generated when a burglar attempts to break the vehicle's mirrors and monitoring the motion of the intruder within the vehicle. To achieve their findings objectives, the system's design incorporated a microphone and bandpass filter, enabling the detection of the specific sound frequency associated with vehicle glass breakage. Additionally, the motion of a burglar within the vehicle was meticulously monitored through the integration of a Passive Infrared (PIR) sensor within the system. The use of an Arduino Nano served as a central component for programming the input signals from these sensors to orchestrate various outputs, such as activating a buzzer capable of emitting a loud noise. The system also initiate a phone call to the user whenever triggered, be it by the breaking of the vehicle's glass or the detection of motion within. This proactive communication feature significantly contributes to the system's effectiveness, providing real-time notifications to the user and facilitating prompt response measures

Jacob et al. (2017) developed a technologically advanced car surveillance security system. The central components of their system include a mini central processing unit (CPU), a motion-detecting sensor, a camera module, and a buzzer. The security network is designed to enable wireless monitoring and control of the vehicle. The mini CPU, specifically the Raspberry Pi, serves as the common platform for interfacing all embedded peripherals concurrently. This configuration facilitates seamless communication and coordination, allowing for efficient management of the vehicle through mobile phones at a minimal cost. The system operates by utilizing Putty software, which detects motion, triggers the buzzer, captures images through the camera module, and subsequently emails them to the owner. The research underscores the advantages of the Internet of Things (IoT) and demonstrates its application in realizing a smart car security system. The integration of Raspberry Pi, camera modules, and sensors exemplifies how IoT technologies can enhance vehicle security through sophisticated monitoring and communication capabilities.

Khadarbasha and Yogeshwaran (2020) carried out a research study where a Vehicle Anti-Theft Detection and Protection system was meticulously designed with an additional feature of Air Quality IoT Notification. The research focused on developing a compact, cost-effective, and efficient system, employing Raspberry Pi as the central processing unit. The system integrates various sensors, including Passive Infra-Red (PIR) motion sensor, pressure sensor, gas sensor, Global Positioning System (GPS), Pi camera, buzzer, and Liquid Crystal Display (LCD), within an embedded Linux environment. Operationally, the device is configured to function in two distinct modes: User mode and Theft mode. In the event of an intrusion, the system activates an alarm and transmits coordinates to the user's designated email address. This design is particularly effective in scenarios such as bike theft, where the vehicle can be displaced without initiating the engine or deactivating physical locks. The system enables effortless vehicle tracking and precise positioning on google maps.

3. MATERIALS AND METHODOLOGY

3. 1. Selection of tools and components

A lot of tools and components were employed in the course of the design and construction of this project. The tools used are the basic electrical tools used in most electronic works. Some of which include: Soldering iron, Multimeter, Screw drivers, Pliers.

The study employed the usage of a Piezoelectric sensor (Figure 1), which is a type of sensor that converts mechanical vibration into electrical signals. Fuel atomizer, keyless door entry, seat belt buzzers air bag sensor, air flow sensor, audible alarms, knock sensors, tire pressure sensors are one of the major employers of Piezoelectric material applications(Kulkarni et al., 2018). The use of the Piezoelectric sensor would to a large extent lower the rate of false alarms. In practical cases, this sensor is to be inconspicuously installed on a vehicles glass in order to detect vibrations caused by bangs or shattering of glasses.

Another sensor employed was the passive infrared (PIR) sensor, which is a type of sensor that detects human motion within its calibrated area of coverage. PIR which means Passive Infrared Sensor is a sensor that is used to sense motion within a range. It is also known as PID which stands for Passive Infrared Detector. Any motion of an object having a temperature above absolute zero is detected by PIR sensor (Mouri et al., 2015). This sensor is to be installed within the car in order to avoid false triggering and also to detect intruders in cases where the piezoelectric has been successfully breached. Both sensors used in this study are interfaced with a 555 timer IC in monostable mode which picks signals from any of the two sensors before activating the buzzer in case of an intrusion. In monostable mode, a pulse of pre-defined length is produced when a trigger button is pressed. The output pin stays low until the button is pressed and once pressed it remains high for a period of time decided by the value of resistor (R_1) and Capacitor (C_1) shown in the circuit (Figure 2). The whole of the setup (Figure 2) is powered by a 9volts battery inconspicuously hidden in the car. This secondary power source (9 Volts battery) is used in order to avoid situations whereby alarm systems could be disarmed by disconnecting the vehicle's main battery. The pin description and components used in this study are summarized in Table 1 and 2 respectively.

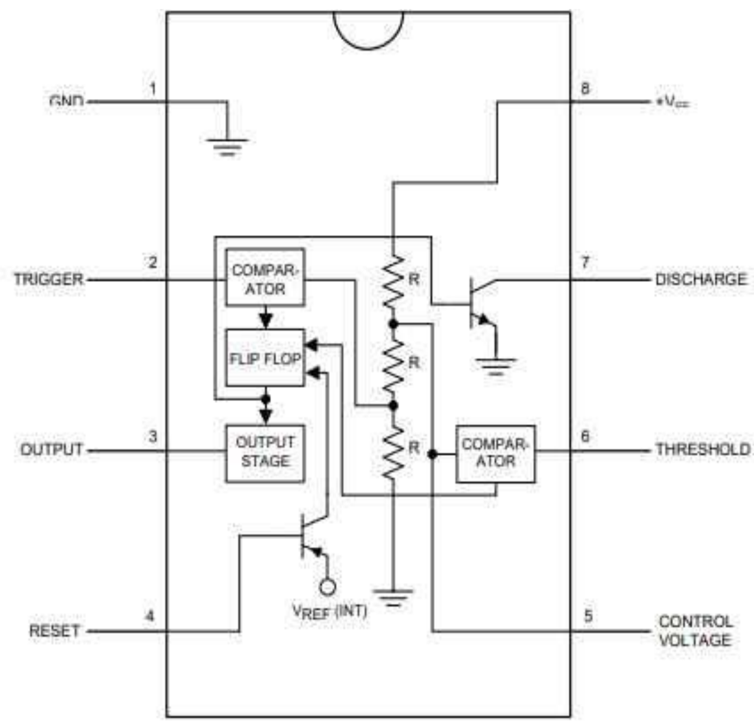

Fig. 1. Internal structure and the pin description of a 555 timer IC. (Texas Instruments, 2015, p. 3)

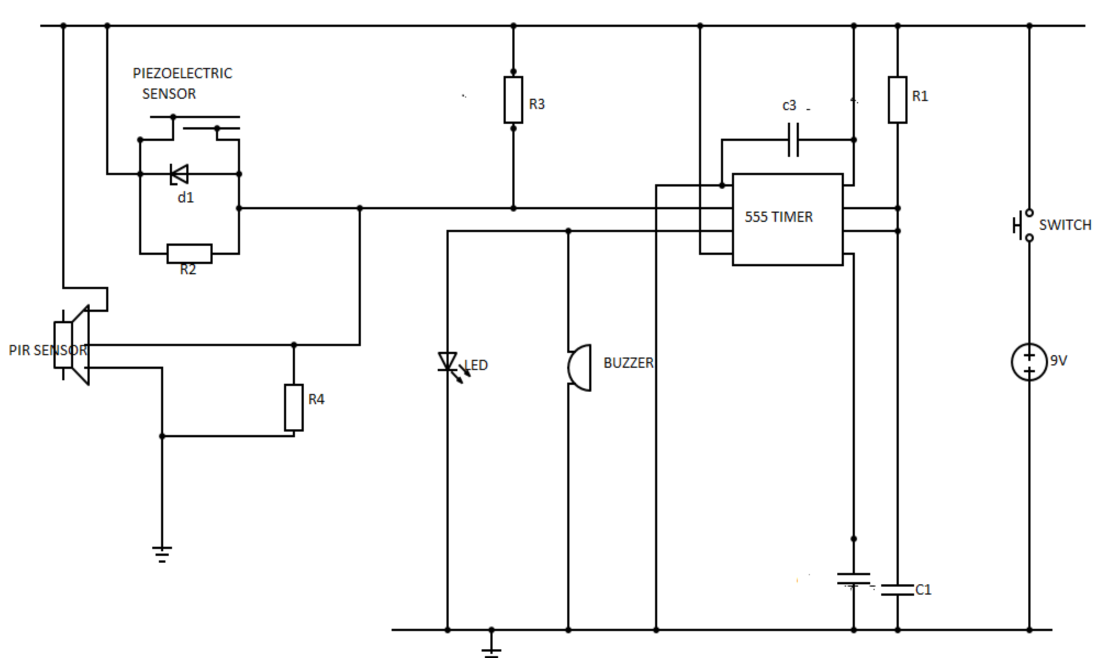

Fig. 2. Complete circuit diagram of the system

Table 1. Pin description

Pin number	Pin name	Description
1	Ground	Ground Reference Voltage V
2	Trigger	Responsible for transition of the flip-flop from set to reset. The output of the timer depends on the amplitude of the external trigger pulse applied to this pin
3	Output	This pin is normally connected to load as it is the only pin with output driven waveform
4	Reset	Negative pulse applied to this pin to disable or reset the timer. When not used for reset 4 I purposes, it should be connected to V_{CC} to avoid false triggering
5	Control	Controls the threshold and trigger levels. It determines the pulse width of the output 5 Voltage I waveform. An external voltage applied to this pin can also be used to modulate the output waveform
6	Threshold	Compares the voltage applied to the terminal with a reference voltage of 2/3 Vcc. The 6 I amplitude of voltage applied to this terminal is responsible for the set state of the flip-flop
7	Discharge	Open collector output which discharges a capacitor between intervals (in phase with output). 7 I It toggles the output from high to low when voltage reaches 2/3 of the supply voltage
8	Vcc	Supply Voltage (Typical = 5V, Maximum = 18V)

Table 2. Components list and specifications

SYMBOLS	COMPONENTS	RATING
C_1	Capacitor	100µF,25 volts
C2,C3	Capacitor	0.1µF
Buzzer	Buzzer	2.2watts, 8Ω
555 Timer	IC	555 timer
R_1	Resistor	100kΩ

R_2,R_3	Resistor	1MΏ
PIR	PIR sensor	5v0lts
Piezoelectric	Piezoelectric sensor	5 volts
D_1	Diode	IN4001
LED	Light emitting diode	NTE3010
DC source	Battery	9 Volts

3. 2. Concept of alarms and burglar alarm systems

All alarm systems work based on the same principle. They use a number of different sensors to detect a break-in into a property (vehicle). Depending on what the sensors are meant to detect, the alarm system would alert us of these dangers. The alerting mode could be in different forms, it could be by sounding a siren or buzzer, placing a call to a monitoring station or property owner, blinking of lights etc. Alarm systems come in different forms with the main distinguishing factor being the type of sensor employed in that alarm system. The sensor type used in a given alarm system depends on the factor we intend to protect our properties from.

The primary function of the alarm system is to warn property (vehicle) owners about a situation that is not normal (Engineering Equipment and Materials Users Association (2001). An alarm system is the collection of hardware and software that detects an alarm state, communicates the indication of that state to operators, and records changes in the alarm state Securing entry points is the basic principle of any burglar alarm system (Kaced et al. 2019). A burglar alarm system is a network of integrated electronic devices working together with a central control panel to protect against theft and other possible illegal entries. Basically, an alarm system is made up of sections to detect, determine and deter criminal activities or other threatening situations. An alarm system can detect an event such as an intrusion, fire, gas leaks, or environmental changes. The component of an alarm system that detects activities is called a sensor. Some of the common types of sensors used in alarm systems include motion sensors, shock sensors, smoke detectors etc. The sensors are interfaced with the control panel of the alarm system. The function of the control panel is to process signals it receives from the sensors and respond accordingly. Control panels could be in the form of microcontrollers, integrated circuits (IC) or other complex circuits made up of ICs, microcontrollers alongside other circuit components. The control panel is usually connected to an alarm panel which triggers an alarm by activating physical alarms such as: sirens, buzzers, strobe lights etc. These devices (alarms) are used to scare away intruders from a parked vehicle or protected property or alert us of a threatening situation.

3. 2. 1. Types of alarm systems

Alarm types are defined by the type of sensors employed in the alarm system. There are a number of ways in which sensing devices may be classified:

i) By their type of operation - analogue or digital.
ii) Whether the quantity is sensed directly or indirectly.
iii) By the medium by which they operate - optical, electrical etc.
iv) By their applications.

The choice of sensor is determined by the physical, environmental and control conditions. They include the following:

3. 2. 1. 1. Mechanical

One can choose any appropriate mechanical or electrical switch for the application. However, micro switches are commonly preferred due to their ability to operate with minimal force, unlike mechanical switches that typically require a certain amount of force.

3. 2. 1. 2. Pneumatic

Proximity sensors function by interrupting or altering airflow. An illustration of a contact-type sensor is the pneumatic proximity sensor. However, they are unsuitable for environments where lightweight components might be displaced by air currents.

3. 2. 1. 3. Optical

At their most basic level, optical proximity sensors function by interrupting a light beam directed onto a light-sensitive device, such as a photocell. These sensors fall under the category of non-contact sensors. It is crucial to consider the lighting conditions surrounding these sensors; for instance, optical sensors may experience impairment from flashes during arc welding processes, and the presence of airborne dust or smoke clouds can hinder light transmission..

3. 2. 1. 4. Electrical

Electrical proximity sensors can be categorized as either contact or non-contact devices. Basic contact sensors function by establishing an electrical circuit between the sensor and the component. On the other hand, non-contact electrical proximity sensors utilize electrical principles, relying on induction to detect metals or capacitance to detect non-metals.

3. 2. 1. 5. Range Sensing

Electrical proximity sensors can be categorized as either contact or non-contact devices. Basic contact sensors function by establishing an electrical circuit between the sensor and the component. On the other hand, non-contact electrical proximity sensors utilize electrical principles, relying on induction to detect metals or capacitance to detect non-metals.

3. 3. System design

The capacitor C_1 has to charge through resistance R_1. The larger the time constant R_1 C_1, the longer it takes for the capacitor voltage to reach $\frac{+2}{3}Vcc$. In other words, the R-C time constant controls the width of the output pulse. The time during which the timer output remains high is given as:

$$t = 1.1 \times R_1 \times C_1 \qquad 1$$

where R_1 is in ohms and C_1 is in farads. Equation 1 is derived as the voltage across the capacitor Vc at any instant during charging period is given as

$$V_c = V_{cc}\left(1 - \frac{e - t}{R_1 C_1}\right) \qquad 2$$

Substituting $V_c = \frac{2}{3}Vcc$ in equation 2, gives the time taken by the capacitor to charge from 0 to $\frac{+2}{3}Vcc$.

Therefore $\frac{+2}{3}Vcc\ V_{cc}\left(1 - \frac{e-t}{R_1 C_1}\right) \vee t - R_1 C_1 log_e 3 = 1.0986 R_1 C_1$ 3

The pulse width, $t = 1.0986 \times R_1 \times C_1$ can be expressed approximately as $t = 1.1 \times R_1 \times C_1$. The pulse width of the circuit may range from micro-seconds to many second.

The choice of the capacitor C_1 and resistor R_1 are dependent on the time the alarm circuit is required to stay ON after it has been triggered by either of the sensors. For the circuit, the time required is approximately ten minutes from equation 1.

Taking a resistance value of 100 kΩ

$$C_1 = \frac{t}{1.1 \times R_1} \qquad 4$$

$$C_1 = \frac{10}{1.1 \times 100000} = 90.9 \times 10^{-6} F$$

Therefore, the selected capacitance is 90.9×10^{-6} F; which is the capacitor value that is closest to 100 μF that was used.

3. 4. System analysis

The entire setup is powered by a 9 Volts dc source. When either of the sensors detects the condition it was intended to detect, the LED and the buzzer stays ON in duration set by the resistor value R_1 and the capacitor value C_1. Altering either of the two values would vary the length of time the LED and buzzer stays ON.

The capacitor C_3 is incorporated in order to pick up any current spikes that could damage the chip in the course of its operation. R_3 is called a pull up resistor .It connects the trigger pin of the IC to the power source so that it keeps the state of the trigger pin high until it is triggered by the sensors.

The piezoelectric sensor is biased using resistor R_1 and diode D_1 because the trigger pin of the IC only responds to negative trigger.

The biasing as shown in the circuit above ensures a negative signal is supplied to the trigger pin of the IC.

4. RESULT

The construction of the system in this study was carried out in three stages. The circuit was first tested using a bread board with each connected stage tested with a multimeter to ensure it is working perfectly before going to the next stage. This helps to detect mistakes and faults easily. The soldering of the component was done on a 10 cm by 20 cm Vero board. The second stage of the system construction is the casing of the soldered circuit. Casing refers to the outer covering that serves as a container or covering. For the purpose of this system, the material used for the casing was aluminium metal sheet. Proper dimensioning of the casing was marked out to give the desired shape based on the size of the constructed project work on Vero board. After fabricating the casing, finishing was done on it which involves smoothing with file to give aesthetic values to the system.

In testing the designed and constructed system (Figure 3), four basic steps were taken.

Fig. 3. Testing the system

These steps are sequentially listed as:

Step 1: to ensure that all the components to be used are functionally operating, they were first tested with a digital multi meter and failed ones replaced before finally soldering them on the Vero board.

Step 2: to ensure that there was no breakage in the circuit path on the Vero board, immediately after soldering on Vero board, the circuit path was tested using the Digital Multi-meter. This was done to also ensure continuity of circuit on the Vero board.

Step 3: using Circuit Maker 6 (Student Edition), the circuit was simulated. The result obtained from the simulation closely corresponds to the desired result, with only some slight variations

Step 4: the period of time for the alarm sound (Time out period) was manually tested. This was achieved using Digital Stop Watch and the result obtained was found to be 10.60 seconds. The value obtained from the manual testing closely agrees with that obtained in the design specifications i.e. 10.00 seconds.

5. DISCUSSION

All the components was tested before they were finally soldered on the veroboard this is to avoid the painstaking effort it will take to de-solder faulty components at the end of the day. From the continuity test carried out on the veroboard to check the circuit path, it was discovered that the circuit was in a perfect working condition as continuity was ensured. Simulation of the circuit design was also done as mentioned earlier, with the sole objective of comparing the results obtained from design calculations to that obtained from simulation. The two results when compared closely correspond with only a very slight discrepancy in values.

As earlier stated, the project is presented in an aluminium casing. With the switch turned ON an LED indicator comes ON indicating current flow within the system. For the detection of vibration we hit the area on the casing around where the piezoelectric sensor is installed. This causes the buzzer to sound for about 10 seconds before going off. Furthermore, for the detection of motion, a hand is passed over the PIR sensor. This also causes the buzzer to give off sound.

6. CONCLUSIONS

This study presents a prototype of a burglary alarm system for vehicles which is equipped with a PIR sensor and a piezoelectric sensor for detecting intruders. The input stage; made up of the two sensors is interfaced with the output stage; made up of a buzzer and an LED using a 555 timer IC operated in the monostable mode The focus of the study is the design, construction and testing of a burglary alarm system for vehicles. The principle of operation of this burglar alarm is simple. When either of the installed sensors (PIR and piezoelectric) detects any intrusion, the alarm is triggered, the buzzer begins to give off sound; and the installed LEDs comes on. These actions thus alert the owner of the vehicle and security personnel of the presence of an intruder. The aim was to develop a cheap, affordable, reliable and efficient security system, which was successfully realized at the end of the design process. One factor that accounts for the cheapness of the product was the proper choice of components used.

The ones that were readily available were used, while a close substitute was found for those that were not readily available. The reliability of the entire alarm system was considered by the use of a dc power supply source which ensures that the alarm system would consume less power and caution the effect of power interruption. Thus, this guarantees constant supply of power to the main circuit. The system was tested and found to be working to specifications and predictions. Based on the results of this study, the following recommendations were made for further studies:

i) It is recommended that in practical case a siren be used in place of a buzzer.
ii) An amplifier be incorporated into the system in order to boost the signal powering the siren.
iii) More sensors should be installed at different locations in the vehicle to detect a myriad of intrusions.
iv) Improving the system by interfacing the alarm system with a microcomputer to boost the effectiveness of the entire system should be considered.

References

[1] British Security Industry Association (BISA) (2005). Strategy for intruder alarm systems. *Journal on Security System* 4(5), 1-3

[2] Ehimkhamenle, A. (2016). Design and development of a smart auto intruder system with GSM network. *International Journal of Innovation Research in Computer and Communication Cngineering,* 4(12), 20588-20597.C

[3] Interpol (2018). Car theft data. Retrieved July 15, 2018 from http://www.interpol.int/crime-areas/vehicle-crime/database-statistics

[4] Ngad, A., Mandala, S. & Abdullah, A. (2008) A survey on MANET intrusion detection. *International Journal for Computer Science and Security,* 2(1), 244-260

[5] Zhang, Y., Lee, w. & Huang, Y. (2003) Intrusion techniques for mobile wireless networks. *ACM/Kluwer Mobile Networks and Application* 5(8), 545-556

[6] Zungeru, A., Kolo, G. & Olumide, I. (2012). A simple reliable touch sensitive security system. *Journal of Innovative System Designs and Engineering* 7(4), 29-41

[7] Kiruthiga, N., Latha, L., & Thangasamy, S. (2015). Real Time Biometrics BasedVehicle Security System with GPS and GSM Technology. *ProcediaComputer Science*, 47, 471-479. https://doi.org/10.1016/j.procs.2015.03.231

[8] Morgan, N., Shaw, O., Feist, A., & Byron, C. (2016). Reducing criminal opportunity: Vehicle security and vehicle crime (Research Report No.87). Home Office.

[9] Wu, W., Huang.Y., Kurachi, R., Zeng, G., Xie, G., Li, R., & LI, K.(2018). Sliding Window Optimized Information Entropy Analysis Method for Intrusion Detection on In-Vehicle Networks. *IEEE Access*, *6*, 45233-45245. https://doi.org/10.1109/ACCESS.2018.2865169

[10] Hodgison, T., Anderson, M. A., & Farrell, G. (2016). The decline and locational shift of automotive theft: A local level analysis. *Journal of Criminal Justice*, 44, 49-57 https://doi.org/10.1016/j.jcrimjus.2015.12.003

[11] Kulkarni, H., Zohaib, K., Khusru, A., & Aiyappa, K. S. (2018). Application of piezoelectric technology in automotive systems. *Materials Today: Proceedings*, 5(10), Part 1, 21299-21304. https://doi.org/10.1016/j.matpr.2018.06.532

[12] Mouri, S. P., Sakib, S. N., Ferdous, Z., & Taher, M. A. (2015). Automaticlighting and security system design using PIR motion sensor. *Journal of Institute of Information Technology, Jahangirnagar University*, 14(8), 1-5

[13] Eze, P. C., Achebe, P. N., Jeremiah, L., & Ageh, T. A. (2018). Anti-Theft System for Car Security using RFID. *International Journal of Science and Management Studies* 1(4), 2581-5946

[14] Sayyad, J., Taha, M., & Sankpal, A. (2017). Advanced Car Security System. *International Journal of Scientific Research in Network Security and Communication* 5(3), 165-169

[15] Noman, A. T., Hossain, S., Islam, S., Islam, M. E., Ahmed, N., & Chowdhury, M. A. M. (2018). Design and Implementation of Microcontroller Based Anti-Theft Vehicle Security System using GPS, GSM and RFID. In *2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT)* (97-101). Dhaka, Bangladesh. https://doi:10.1109/CEEICT.2018.8628051

[16] Zainun, F., Hwa, S. C. K., Mohd Halmy, N. A., How, C. C., & Mahyuddin, M. N. (2020). An Innovative Anti-theft System for Automotive. Intelligent Manufacturing and Mechatronics. Sympo SIMM 2019 (Lecture Notes inMechanical Engineering). Springer, Singapore. https://doi.org/10.1007/978-98113-9539-0_17

[17] Jacob, A. S., Chaurasiya, V., Sharda, V., & Dixit, S. (2017). Car surveillance security system. In 2017 International Conference of Electronics, Communication and Aerospace Technology (ICECA) (735-739). Coimbatore, India. https://doi:10.1109/ICECA.2017.8203640

[18] Khadarbasha, N., & Yogeshwaran, A. (2020). Vehicle Anti-Theft Detection and Protection with Air Quality IoT Notification. *Irish Interdisciplinary Journal of Science & Research* 4(4), 01-06. http://dx.doi.org/10.2139/ssrn.3814146

[19] Kaced, R., Kouadri, A., & Baiche, K. (2019). Designing alarm system using modified generalized delay-timer. *Journal of Loss Prevention in the Process Industries*, 61, 40-48. https://doi.org/10.1016/j.jlp.2019.04.010

[20] Narayana, S., Prasad, R. V., Rao, V. S., Prabhakar, T. V., Kowshik, S. S., & Iyer, M. S. (2015). PIR sensors: characterization and novel localization technique. In *Proceedings of the 14th International Conference on Information Processing in Sensor Networks*, 14,142–153. https://doi.org/10.1145/2737095.2742561

[21] Gautschi, G. (2002). Piezoelectric Sensors. In Piezoelectric Sensorics. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-04732-3_5

[22] Texas Instruments. (2015). LM555 Timer Data Sheet (Document No. SNAS548D). https://www.ti.com/lit/ds/snas548d/snas548d.pdf