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Dual Mode Multi Sensor Burglary Detection and Shut-Out/Security Call System

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Abstract

Break-ins for robberies have become a common occurrence in Nigeria such that it is hardly considered news any longer when it happens except where loss of lives is involved. Though, there are emergency police numbers, these are hardly used under sudden attacks hoodlums who take unkindly to anybody calling security agents. This paper presents the design and implementation of a dual mode anti-burglary security system that shuts window-access points into a house under attack and alerts security centre (or precoded number) in case of an attempt to break into the house. The HC-SR04 ultrasonic proximity sensor was used for intrusion detection while glass break sensors were used for window glass break detection. The control unit was built using PIC16F877A microcontroller to which the sensors and the alarm and motor-drive circuits were interfaced. The bidirectional motor-drive circuit is for locking protected access points with bullet-proof or metal sheets when break-in attempt is detected and opening them when the threat has been contained. The alarm circuit is to alert the neighbourhood of a security breach while a GSM module alerts security centre of an on-going break-in attack or attempted intrusion. Also an alternate RF remote control was provided for locking the protected area in case of intrusion if the sensors failed. The test of the system showed that between 0.01 and 0.88 meters, the ultrasonic motion detector was able to detect intrusion while the glass break sensor also detected intrusion when the glass for the access point to which it was used was broken or smashed. The manually operated RF transmitter of the remote operated up to 29.8 meter range. The system worked within the specified ranges and alerted precoded numbers when security breach was detected by the sensors.

Keywords: Burglary, Alarm, Microcontroller, Sensors, Dual-mode, Metal sheet, Bulletproof

1. Introduction

As the standard of living improves, people focus more on the home safety and warehouse safety (Zhijie *et al*, 2011). Home break-ins for robberies are a common denominator in many cities across Nigeria. This has been a growing phenomenon precipitated by high inflation, high cost of living, high unemployment, low volume of cash in the hands of the low income and the middle classes. Break-ins for robberies in Nigeria mostly take place at night and are done with the intention of meeting the home owners for the purpose of robbing them of cash and other possessions like handsets and jewelleries. These incidences are so common and are hardly considered news any longer except where loss of life is involved.

Over the years, various measures have been adopted to provide security for the home. One of such measures is the use of security lighting systems for proper illumination of the area surrounding the home. From a field survey done at Ado-Ekiti, 66.1% of persons interviewed said they scarcely had light (Olajide and Kolawole, *2013*). This is the situation with most cities in Nigeria. This makes the use of security light ineffective due to the irregularities of power supply and the expensive nature of alternative power sources. Besides, availability of light does not even prevent break-in attacks.

Vigilante/security agents are a good antidote to break-in robberies/crimes. But vigilantes are often not allowed to carry weapons making them vulnerable and helpless against usually armed (sometimes, heavily armed) burglars/robbers.

Other measures involve installing security gadgets that detect break-ins and provide notifications to the house owners. One such method uses gate magnetic switch to guard against house break- in. In case of an attempted break-in, the microcontroller control unit causes a camera to take photos and send MMS through GSM module (Huiping *et al*, 2010) to the householder (Zhijie *et al*, 2011).

Another approach uses a smartphone which is designed to be used as mobile for communication purpose and also to provide home security against intrusion in the absence of the home owner. A GSM modem is attached with microcontroller which would send SMS to the device holder as well as emergency services providers like police (Alka, 2012).

This work designed a system that can detect any intruder trying to gain access to a building through the window or some other protected access point, and automatically shuts the intruder out and then place call to the coded number(s). It also provides a manual intrusion detection mode in case the intrusion detection sensors fail for some reason.

2.0 Design Methodology of the security system

Figure 1 is the block diagram of the security system. The security system is made up automatic detection system a proximity sensor which operates only at night. Thus it is provided with a delay circuit which ensures that the proximity sensor will become operational at a time of night when false detections are minimized. The proximity detector unit detects an approaching intruder at an odd hour of the night while the glass break detector unit detects attempted break-in through the window which involves breaking or smashing window glasses. The motor drive unit, with the bullet-proof sheet, are used to shut the protected point of access with a bullet-proof or bullet/iron/fire resistant metal sheet to prevent access into the house. The control unit accepts the sensors outputs as inputs and generates control signals to drive the motor drive unit and cause the GSM module to communicate with the security centre. The manual detection involves an RF remote control that can be used to trigger the shutting of the access point and to make contact with security centre.

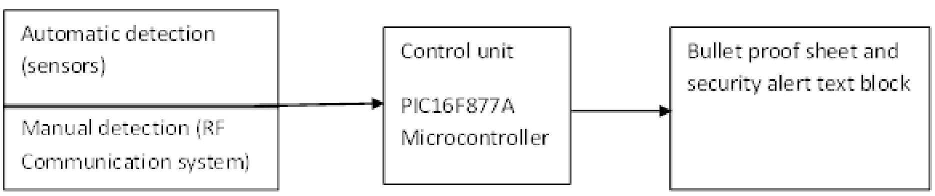


Fig.1: Block diagram of the security system

2.1 Design of power supply units

The system is supplied from a 12V and 5V dual dc output source whose input is 220V ac. Besides powering some parts of the system requiring 12Vdc supply, the 12V is used to charge a 12V rechargeable battery that serves as alternate power source in times of power outage. Fig. 2 shows the circuit diagram of the power supply unit.

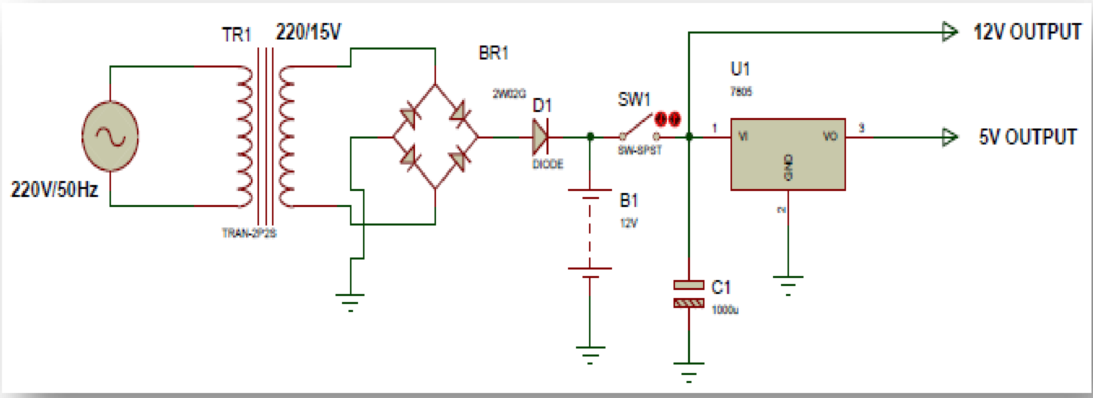


Fig. 2: Power supply unit circuit diagram circuit.

2.2 Design of the night/day sensor unit

The night and day sensor unit detects when it is night or day. It does this by sampling the ambient light intensity with a light dependent resistor. Shown in Fig. 3 is the night/day sensor unit circuit diagram.

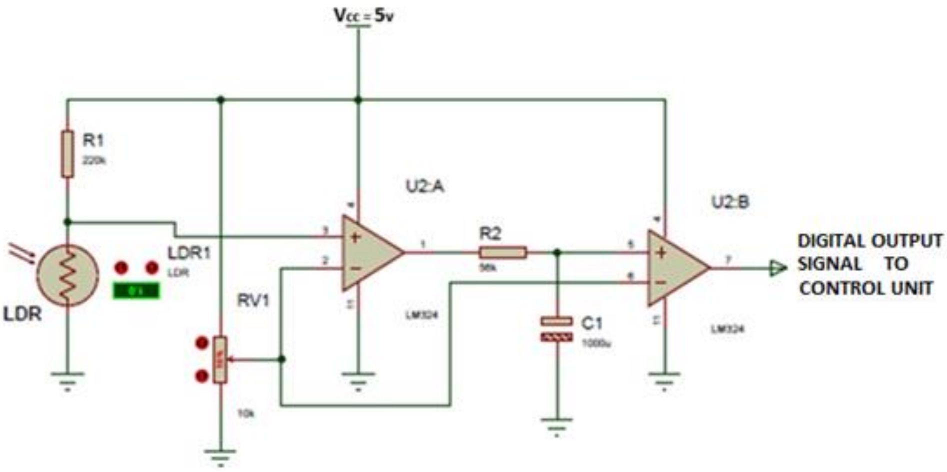


Fig. 3: Night/day sensor circuit diagram.

From the circuit diagram, U2A and U2B are analog voltage comparators. A reference voltage of 2.5V is set with potentiometer RV1 at the non-inverting input of U2A and U2B respectively. The voltage at the inverting of U2A is set by the voltage divider network of resistor R_1 and LDR1. At day time, the resistance of LDR1 drops to a value that makes the voltage output of the voltage divider less than 2.5V(Vref at the non-inverting input of U2A). The output of comparator U2A switches to zero volts (i.e. 0V) and Capacitor C_1 discharges through resistor R_2. Capacitor C_1 and Resistor R_2 form a delay network which prevents the circuit from responding to false signal from the light sensor due to noise from the environment. When the voltage at non-inverting input of comparator U2A discharges below the 2.5V (Vref), the output of U2B which is used as signal input to the control unit switches to 0V(i.e. logic 0). The control unit senses this as day and then deactivates the ultrasonic sensor.

From Fig.4, Vref is obtained using voltage divider rule.

$$V_{ref} = 5 * \frac{LDR}{R_1 + LDR} \quad (1)$$

$$But\ V_{ref} = 2.5V$$

$$R_1 + LDR = 2.5\ LDR$$

$$Choosing\ R_1 = 220\ K,$$

$$LDR = \frac{220\ K}{1.5} = 146667\Omega$$

Therefore, an LDR with a maximum dark resistance of 2MΩ was used.

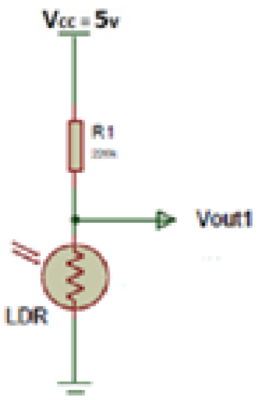


Fig. 4: Voltage divider network circuit diagram.

From Fig. 5, T which is the delay period of the delay network (seconds) in given by (2): (Apeh *et al*, 2010)

$$T = 0.693 * R2 * C1 \quad (2)$$

Choosing $C1 = 0.01\mu f$ and for a 290ms delay,

$$R_2 = \frac{T}{0.693\ C_1} = \frac{290 \times 10^{-3}}{0.693 \times 10^{-8}} = 41.8K$$

$$Therefore,\ R2\ is\ chosen\ to\ be = 56k$$

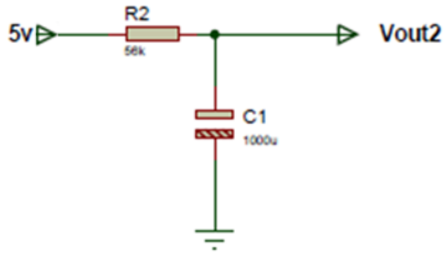


Fig. 5: Delay network circuit diagram

2.3 Proximity detector unit

The proximity detector circuit is implemented with the HC-SR04 ultrasonic sensor module. It consists of an ultrasonic transmitter and receiver. When a person approaches the access point (windows), signal being transmitted is reflected back to the receiver in form of echo. The level of echo received is proportional to the distance between the person and the access point. Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The module includes ultrasonic transmitters, receiver and control circuit. Shown in Fig.6 is the ultrasonic proximity detector circuit.

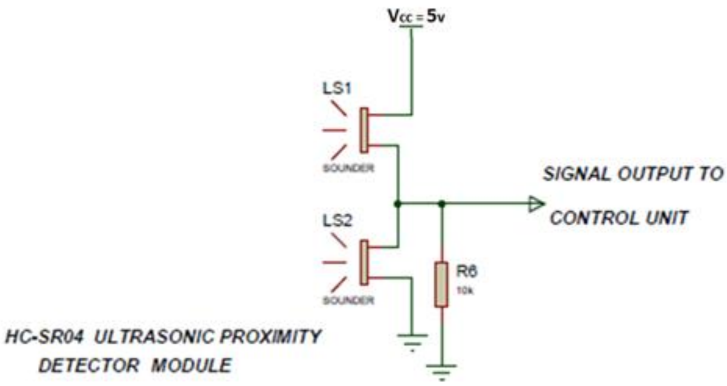


Fig. 6: The ultrasonic proximity detector circuit

The basic working principle is that using IO trigger for at least 10µs high level signal, the Module automatically sends eight 40 kHz tones and detects whether there is a pulsed echo signal. If the signal echoes back, time of high output IO duration is the time from sending ultrasonic to receiving the echo signal. Thus, test distance is obtained using equation (3): (Luciano *et al*, 2011).

$$Test\ distance = \frac{High\ level\ time \times Velocity\ of\ sound}{2} \quad (3)$$

Thus, $Test\ distance = \frac{Pulse\ duration \times 340(\frac{m}{s})}{2}$

Thus, for 4m distance detection,

$Pulse\ duration = \frac{2 \times Test\ distance}{340} = \frac{2 \times 4}{340}s = 23.5\ ms$

2.4 The motor drive unit

The motor drive unit controls the direction of rotation of the DC motor which opens and closes the metal sheet. The motor drive unit receives signal from the control unit and carries out the appropriate action. Fig.7 is the motor drive unit circuit diagram.

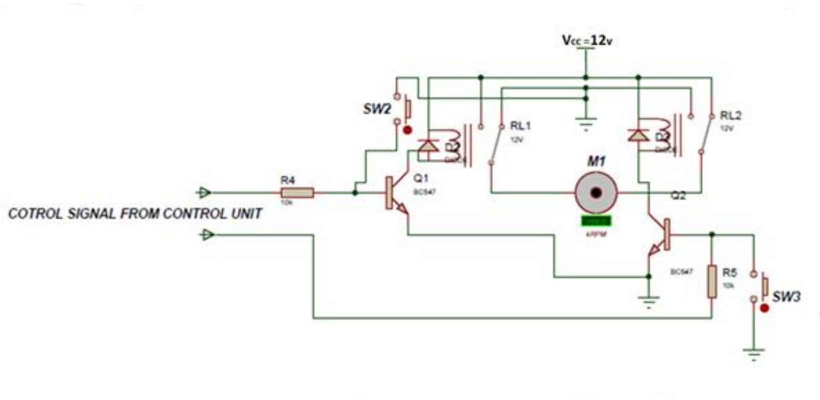


Fig.7: The motor drive circuit diagram.

The signal from Port C.0 and Port C.1 of the PIC16F877A microcontroller are applied to the bases of BJT transistors Q1 and Q2 respectively. Resistors R_4 and R_5 are current limiting resistors which are used to bias the base current of transistors Q1 and Q2. E.O.T1 (i.e. SW2) and E.O.T2 (i.e. SW3) are end of track switches placed at both ends of the track to stop the motor from rotating when the metal sheet gets to the end of the track.
At maximum rating of the BC547 (from datasheet), Ic = 100mA, h_{fe} = 700, V_{BE} max = 0.9) R_4=R_5 is determined according to equations (4) and (5) (Apeh, *et al*, 2010; Theraja and Theraja, 2002)

$$R_4 = \frac{V - V_{BE}}{I_B} \quad (4)$$

$$I_B = \frac{I_C}{h_{fe}} \quad (5)$$

$$I_B = \frac{I_C}{h_{fe}} = \frac{100 \times 10^{-3}}{700} = 1.42857 \times 10^{-4} A = 142.857 \ \mu A$$

For safe operation of the transistor, 4 times the operating current value for biasing. Thus,

$$R_4 = \frac{5 - 0.9}{4 \times 1.42857 \times 10^{-4}} = 0.7175 \times 10^4 \ \Omega = 7.2 \ K\Omega$$

10 KΩ was chosen.

2.5 The control unit

The control unit receives signals from the various sensors that make up the system and is interfaced with the motor drive unit, alarm unit and the SMS controller unit. The output from the control unit determines the closing of the access point's metal sheet, sending an SMS to the specified emergency number(s), and sounding the alarm. It also displays the status of the system on a 16x2 LCD screen. Fig.8 is the control unit circuit diagram.

From Figure 8, the control circuit is implemented with a PIC16F877A microcontroller. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the Synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). (Vipin *et al*, 2014). The PIC16F877A microcontroller has five I/O ports (i.e. port A, port B, port C, port D and port E).

Port A is configured as an input port and it is used to send sensor signals into the microcontroller. Port B is used to drive the 16x2 LCD, and is configured as an output port. Port C is configured as an output port and it is used to drive the buzzer alarm and the D.C motor control signal. Also, port D is used to implement USB communication with the GSM modem for sending SMS. The microcontroller unit is operated with 4MHz crystal oscillator. The LCD is operated in 4-bits mode.

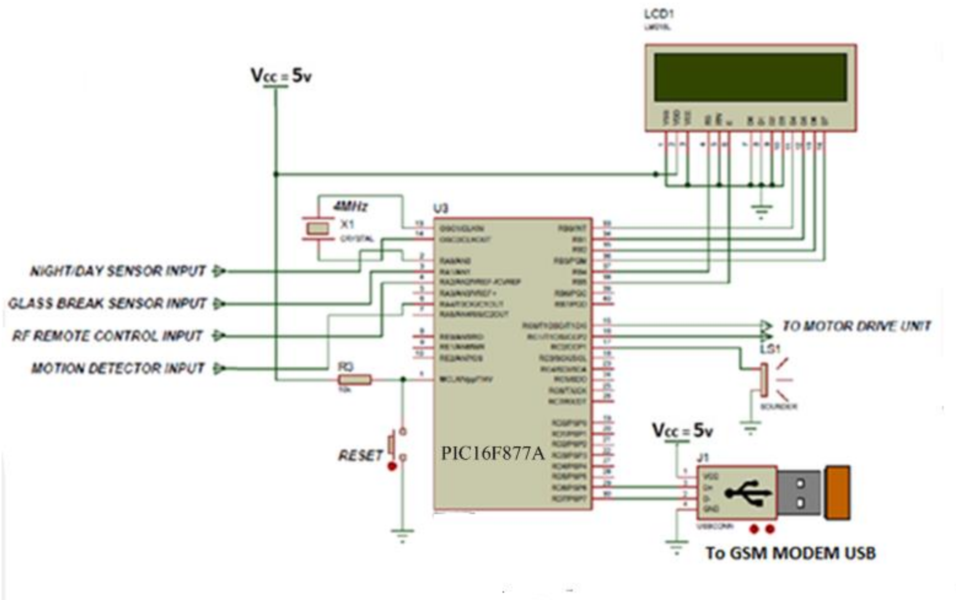


Fig. 8: The control unit circuit diagram

The microcontroller continuously scans port A to determine the bit status of port A. When sensor's output causes a change in port A bit status, the microcontroller then uses the appropriate subroutine in its programme to send control signal to other peripheral controlled units (i.e. the LCD, alarm, and motor drive unit).

Figure 9 shows the flowchart for the microcontroller program that performs the control functions.

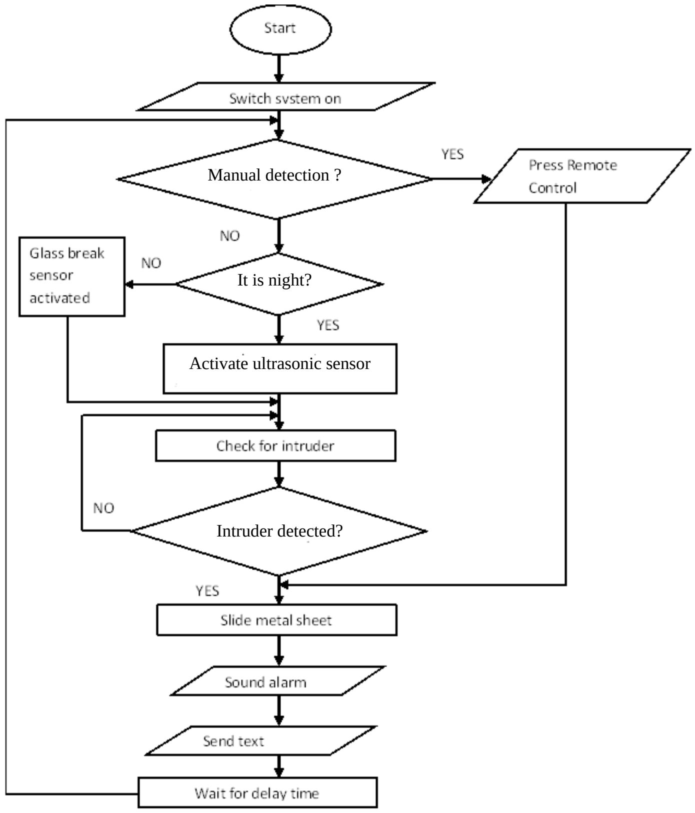


Fig. 9: Flowchart for the control unit

2.6 The radio frequency receiver/transmitter remote control unit

The RF remote control unit consists of an RF base transmitter/receiver single button remote control. It is used to control the opening and closing action of the access point metal sheet. The remote control receiver unit is interfaced with the microcontroller which decodes the information sent from the transmitter unit. The RF remote control unit is implemented with a RRF415D RF remote control module. Figure 10 is the functional circuit diagram of the RF remote control.

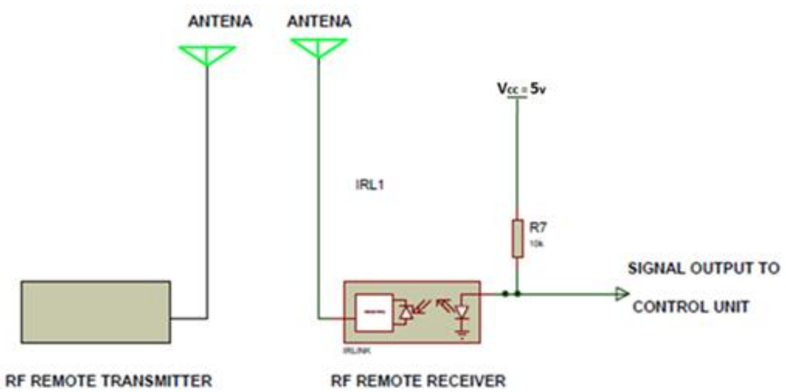


Fig. 10: The functional circuit diagram of the RF remote control

2.7 The glass break detector unit

The glass break detector unit, shown in Figure 11, detects whenever there is a glass break such as window glasses within the range of 9m. The sensor module sends an active high signal to the control unit whenever glass break is detected. The signal from the glass break sensor is connected to PORT A1 which is configured as an input port. When an active high signal is received at PORT A1, the control unit activates the closure of the sliding metal sheet, sounds the alarm and sends SMS to the specified Phone number(s).

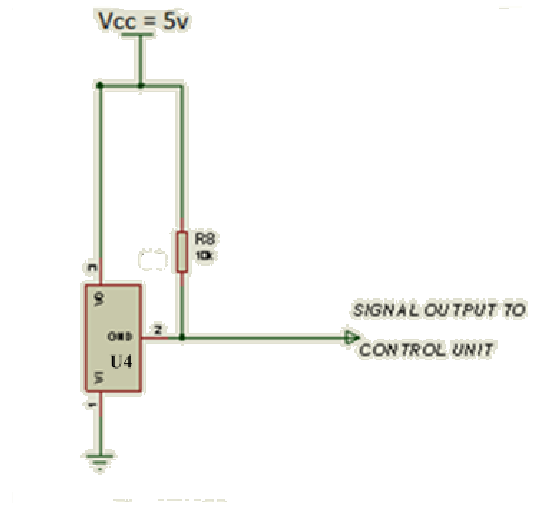


Fig. 11: Glass break sensor circuit diagram

2.9 Design of alarm unit

The alarm unit controls the alarm that is sounded once the metal sheet closes. The buzzer receives signal from the control unit upon activation of the closure of the metal sheet to sound an alarm. Figure12 is the alarm unit circuit diagram.

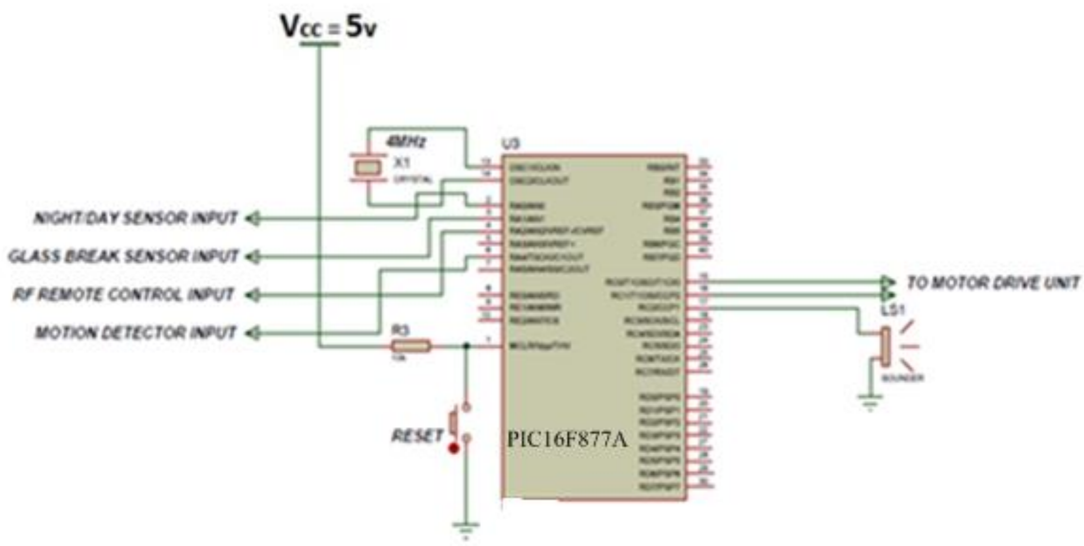


Fig. 12: The Alarm Circuit

Port C.2 is configured to be an output port. The signal from Port C.2 is applied to the Vcc of the buzzer. Upon activation of the closure of the metal sheet due to a high signal from any of the sensors, a high signal from port C.2 is applied to the Vcc of the Buzzer to sound the alarm.

The Reset Circuit comprises a push button connected from Pin 1 of the microcontroller to GND and a pull up resistor to Vcc. To use the reset function of the microcontroller, a logic condition which is 1 and 0 is created to the reset pin. A logic 1 mean the reset pin get 5V. If the reset pin logic is 1, then the program in the PIC will execute, but if the reset pin logic condition is 0 (which is 0V) then the PIC will not execute the program. To achieve this push button switch was used. When the switch is not pushed, current will flow through 10K resistor and MCLR Pin 1. As a result, MCLR Pin 1 receives 5V and PIC reads it as logic 1. But when the switch is pushed, current will flow through 10K resistor, the switch and directly to ground. There is no voltage received at MCLR Pin 1. This gives logic 0 at MCLR Pin 1 to reset the MCLR.

2.10 Complete schematic circuit diagram

Figure 13 shows the complete circuit diagram for the dual sensor security system

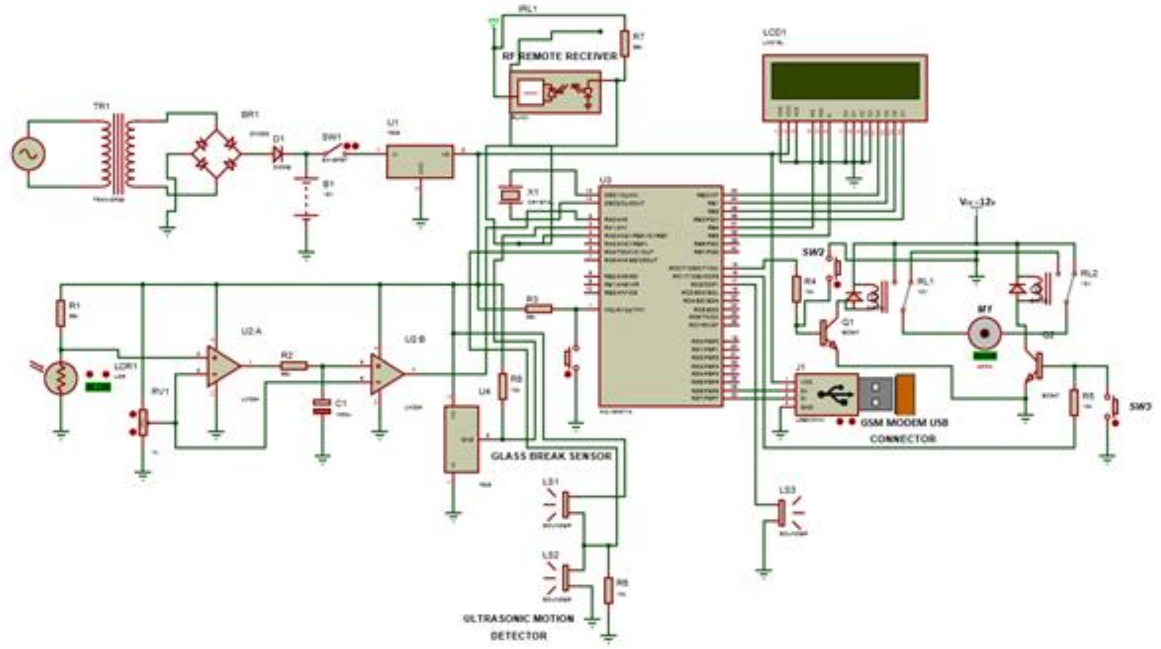


Fig. 13: The complete circuit diagram for the dual sensor security system

3.0. Tests

Tests were carried out by triggering the sensors and observing the behaviour of the device. The Ultrasonic Motion Detector was tested together with its operational range by starting from close to the sensor and gradually walking away from it and observing in each case if the sensor was triggered. This was done to determine operational characteristics including the minimum and maximum range of detection. The range measurement was done using a measuring tape.

Glass Break Sensor test was achieved by breaking the prototyped window glass to determine if the sensor would be triggered or not, Fig. 14.

The RF Module test was done using the single button RF remote control by deactivating the sensors so that manual detection could be tested using the RF remote control, Fig. 15. Also, to determine the minimum and maximum ranges of activation and the effect of physical obstruction of the RF signal on the operation of the unit, the remote control was used to manually trigger the device's response to intrusion at different locations from the device.

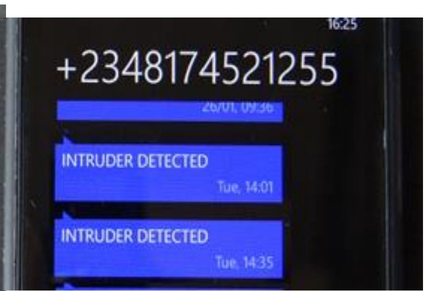
The GSM module alert system was tested by timing with stop watch, the time it took for the alert SMS to be delivered to the coded number. To achieve this, a coded number was used at the location of testing. Also, the time of close of the protective sheet used in the window model was determined with a stop watch.

Window model before detection

Ultrasonic sensor inactive
Glass break sensor active

Window glass broken

Intruder detected by glass break sensor



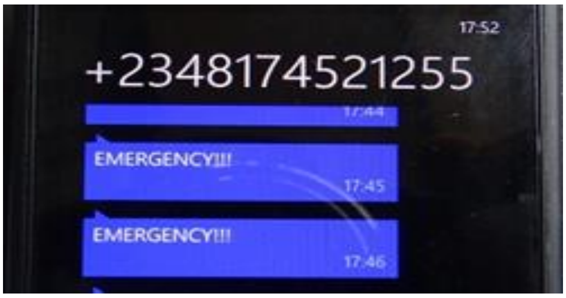
Intruder SMS alert sent and delivered to coded number

Fig. 14: Glass break sensor test

Window model before activation

Window model after activation (by breaking window glass)

Status display after manual trigger with remote control



SMS alert after operating remote control (SMS alert status of alerted number)

Fig. 15: Manual detection (remote control) and response status

3.1. Results

The results of the tests are presented in Table 1. The system component tested with the test method and then the test results were tabulated for clarity and to aid discussion on the results.

From the results obtained, it was observed that between 0.01 m and 0.88 m, the ultrasonic motion detector was able to detect intrusion.

Between 0.01 and 7.8 m toward the direction the glass break sensor was installed, the Glass break sensor was able to detect a glass break. However, it was observed that the glass break sensor was more sensitive at a maximum range of 6.4 meters

For the RF Module, between 0.0 and 29.8 m around the point the RF receiver was installed, the RF transmitter remained active. The Operation of the RF Module was not affected by any physical obstruction within the range of operation.

On the average, it took 1 min for the SMS to be delivered after the closure of the metal sheet and activation of the alarm. However, the duration for delivery of the SMS may vary due to GSM network challenges.

Table 1: Test results

S/N	Component Parts	Test Method	Test Result
1	Ultra Sonic Motion Detector	The ultrasonic motion detector was tested by walking into the operational range of the sensor.	Alert SMS "intruder detected" sent and delivered to coded number Metal sheet closed the access point
		Range of detection (physical measurement using measuring tape)	The Range of detection of the Ultra Sonic Motion Detector was between 0.01meters and 0.88meters.
2	Glass Break Sensor	Glass broken when sensor active.	Glass broken status displayed on device screen. Alert SMS "intruder detected" sent and delivered to coded number. Metal sheet closed the access point.
3	RF Module	Sensors deactivated and glass broken. Then, remote control operated.	"Emergency" displayed on device's screen. "Emergency" sent as SMS and delivered to the coded number
		Remote control operated at different ranges.	The range of Operation was between 0.0Meters to 29.8Meters.
		Effect of physical obstruction	No effect on the Operating range and efficiency of the RF Module
4	GSM Module	Time between device trigger and delivery of the SMS alert.	1 minute on average for the SMS to be delivered.

4.0 Conclusion

This study designed and developed a dual mode anti-burglary security system to aid the fight against this menace. It utilized HC-SR04 ultrasonic proximity detector as well as glass break sensors for burglary or break-in detection. The control circuit was implemented using a PIC16F877A microcontroller and motor-drive circuit for locking (and opening) protected points with bullet-proof (or metal sheets). A GSM module that alerts security centre of on-going break-in attack or attempted intrusion was added. An alternate RF remote control was provided for locking the protected area in case of attack if the detector and response units failed.

From the tests and results obtained, the ultrasonic motion detector was able to detect intrusion up to 0.88 m proximity with the sensor. The RF Module operates upto 29.8 m range while the GSM module delivered alert messages successfully and within acceptable time limits and the metal sheet closed in record time to protect access points on intrusion detection.

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