DESIGN AND CONSTRUCTION OF A REFRIGERATOR DOOR ALARM DEVICE

BY

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DEDICATION

This Thesis is dedicated to Almighty God for His abundant grace and favour over my life since the day I was conceived till date. And to my lovely and caring parent; Mr. Clement Dele Adeosun and Mrs. Taiwo Olubunmi Adeosun.

DECLARATION

I, ADEOSUN OJO SAMSON declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the federal university of technology, minna.

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ABSTRACT

This Thesis documents the research, design and construction of a refrigerator door alarm device with the aims of keeping the refrigerator contents cool always, prevent unnecessary exhausting of the compressor and reducing the electric power bill since the refrigerator tends to work more if the door is left open. Modules method was used in the design and construction. Each module was tested and confirmed to work perfectly. The device is powered with 220V AC and there is provision for backup in case there is power failure.

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CHAPTER ONE

1.1 INTRODUCTION

Normally we just push the refrigerator door closed, hoping that the door gasket magnet will hold it. Often the door does not stay closed tightly in many households either due to the weakening of the mechanical components(screws and nuts) that is supposed to hold it tight, or sometimes the refrigerator maybe too filled up thereby disallowing the refrigerator door to take its proper position. Carrying out multi activities at a time most especially in the kitchen or in the shop may make one to forget totally to close the refrigerator door. Most children in the house do not generally bother to keep the refrigerator door properly closed. [1]

If the refrigerator door is not properly closed, the cooling will be lost, the refrigerator tends to work more, thus increasing the power bill and exhausting the compressor thereby making it liable to mechanical fault. These will definitely have negative effects on the family economy. The effects are not only affecting the people that can afford the refrigerator of their own but also to low income earning families, the students, the labourers, and even some of the office users that will not be able to buy the cold contents(pure water, soft drinks, sobo, kunnu, juice, lolly e.t.c.) that are satisfactory.

This project is aimed at finding solution to the above mentioned problems by designing and developing a device that gives an alarm whenever the refrigerator door either not being properly closed or left opened for over 20 secs by reminding the user with an alarm. The alarm will continue to sound as long as the refrigerator door is opened, telling you to do your job fast and close the refrigerator door. It also serves as a security guard against unauthorized person intending to open the refrigerator unaware.

The project is an idea that was recently conceived to be a very useful one in our environment as it affects virtually everybody and has advantage over the existing one that cannot be recharged but depends totally on the replaceable battery (e.g. Tiger product). It is a purely locally made device that is affordable, moveable and durable.

1.2 SCOPE OF PROJECT

The scope of this project entails the design and construction of a device that gives an alarm when the refrigerator door is left open for over 20sec. This was achieved by using a modular approach. The power unit was made up of both 230V AC and rechargeable battery for backup in case of electric power failure. The timing part that was made up of 555 timers IC and other passive components enables the device to follow a specific timing pattern that the user desired. Logic unit enables the output signal of the IC to be inverted to suit the aim of the project. The part carrying the name ''alarm'' is the buzzer that serves as the basic component for the output module.

1.3 SPECIFIC AIM

The specific aim of this project is to design and construct a device that will give an alarm if the door of the refrigerator is left open for over 20 seconds.

1.4 AIMS

1. To continuously keep the refrigerator contents cool.
2. To reduce the electric power bill since the refrigerator tends to work more if the door is left open.
3. To prevent unnecessarily exhausting of the Compressor.

1.5 OBJECTIVES

1. Determine the average time lapse between opening a refrigerator, taking something or putting something and closing it, then build a system that will ensure that the refrigerator is closed after this period.
2. Determine the common causes of refrigerator faults

1.6 METHODOLGY

In achieving this device, the literature review of the device was first done(majorly through internet service) to know the basic background and the level of improvements that can be added

In designing it, a modular method was employed. Each module was independently designed, constructed and tested. Upon testing, the modules were found working as expected.The casing was designed to accommodate the alarm circuit, power supply circuit and provisions for buzzer, the switch cable and the power cable. The device was also tested again after the casing.

CHAPTER TWO

2.1 HISTORICAL BACKGROUND/ LITERATURE REVIEW

Electronic control systems have been in existence for years now and have been affecting virtually all the areas of human endeavors. One of these electronic control systems is refrigerator door alarm.

The first refrigerator door alarm was designed in 1999. Unfortunately that circuit stopped operating when the battery voltage falls below about 2.6-2.7volts. This was due to the 4060 CMOS IC used. In some cases, devices made by some manufacturers fail to operate even at nominal 3v supply voltage. [2]

A simple remedy to this shortcoming could be the substitution of the original IC specified with a 74HC4060 chip. This should allow circuit operation down to 2V but, unfortunately, this IC is not easily available.

For this reasons, an equivalent circuit using about the same parts was developed by Italian inventor flario dellepiane, in order to allow safe operation even when the battery voltage falls down to about 1.3V. [3] The challenges that the circuit designed by this great Italian inventor faced were:

1. How the sensor device (Photoresistor) will be used in a type of refrigerator that their light is always ON whether it is closed or opened (fridge use in restaurant, beer parlour…)

2. How we can power the device with a rechargeable source as to avoid unnecessary changing of the Battery when its life-span reach

2.1.1 OTHER CONTROL SYSTEMS THAT ARE EMPLOYED IN FRIDGE ARE:

1. THERMOSTAT CONTROL SYSTEM: It is designed to keep the interior temperature constant via internal and external sensors and independent of any external temperature fluctuations. The multisensory control regulates temperature precisely under all conditions for optimal food storage and preservation. Food remains fresh and aromatic for a longer period. The interior temperature is also kept at its optimal consistently.

2. HUMIDITY CONTROL SYSTEM: It allows adjustment of both temperature and humidity levels thus maximising the shelf-life of meat, fruit and vegetables. For example, low humidity is suitable for meat and fish while high humidity is ideal for keeping fruit and vegetables.

3. AIRFRESH FILTER: The Airfresh filter reduces odours of smell-intensive food (garlic, fish, durians, locust beans e.t.c) significantly and it also reduces the cross contamination of odours in the interior. It is a lifelong protection. Hence, the hassle of replacement is gone.

4. INVERTER COMPRESSOR: It assumes maximum energy efficiently and practically silent operation. The innovative variable speed compressor reacts to the needs of each compartment according to the load (refrigerator contents) conditions. The total energy consumption of the compressor variable adapts to the ambient temperature and load conditions controlled by several sensors.

5. LIGHT SYSTEM: It provides excellent illumination to the interior of the refrigerator. The clever positioning of the lightning in the side walls ensures that no storage space is lost. Some light systems are activated (ON) upon the opening of the refrigerator door while some are continuously ON depending on the usage.[4]

2.1.2 OTHER ELECTRONIC CONTROL SYSTEMS THAT ARE USED FOR VARIOUS PURPOSES ARE:

1. Intruder Alarm System: For security purposes.
2. Metal Detector: Applicable in Banks.
3. Glass Break Detector: For internal perimeter building protection.
4. Fire Detector: Protect from the risk of fire in its area of application.
5. Access Control and Bypass Codes: For Authorization.[5]

2.2 THEORETICAL BACKGROUND

The basic theory that the design and construction of this device depends on is TIMING through a component known as "555 TIMER IC"

The 555 timer IC is an integrated circuit (chip) implementing a variety of timer and multivibrator applications. The IC was designed by Hans R. Camenzind in 1970 and brought to market in 1971 by Signetics (later acquired by Philips) [6] . The original name was the SE555 (metal can)/ NE555(plastic DIP) and the part was described as " The IC Time Machine" It has been claimed that the 555 gets its name from the three 5kohms resistors used in typically early implementations, but Hans Canmenzind has stated that the number was arbitrary. As of 2003, it is estimated that 1 billion units are manufactured every year.

Depending on the manufacturer, the standard 555 package includes over 20 transistors, 2 diodes and 15 resistors on a silicon chip installed in an 8-pin mini dual-in-line package (DIP-8). Variants available include the 556(a 14-pin DIP combining two 555s on one chip), and the 558(a 16-pin DIP combining four slightly modified 555s with DIS&THR connected internally, and TRI falling edge sensitive instead of level sensitive).

Ultra-low power versions of the 555 are also available, such as the 7555 and TLC555. The 7555 requires slightly differently wiring using fewer external components and less power.[7]

THE PINOUT DIAGRAM OF 555 TIMER IC

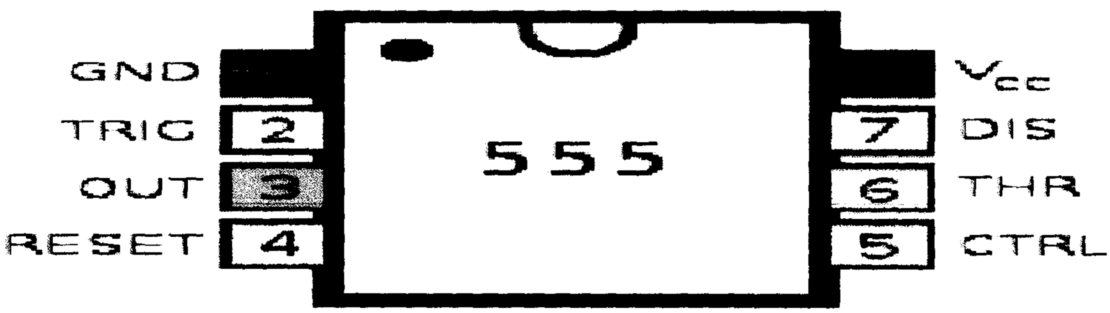

Fig 2.1: 555 TIMER IC showing its pins numbers and corresponding names

PIN	NAME	PURPOSE
1	GND	Ground, low level (0 V)
2	TRIG	OUT rises, and interval starts, when this input falls below 1/3 V_{CC}.
3	OUT	This output is driven to $+V_{CC}$ or GND.
4	RESET	A timing interval may be interrupted by driving this

			input to GND.
5	CTRL	(by	"Control" access to the internal voltage divider default, 2/3 V_{CC}).
6	THR	greater	The interval ends when the voltage at THR is than at CTRL.
7	DIS	capacitor	Open collector output; may discharge a between intervals.
8	$V+$, V_{CC}	and 15 V	Positive supply voltage is usually between 3

2.2.1 THE THREE OPERATING MODES OF 555 TIMER IC

1. MONOSTABLE MODE: In this mode, the 555 functions as a "one- shot". Applications include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) etc.

MONOSTABLE MODE CONFIGURATION

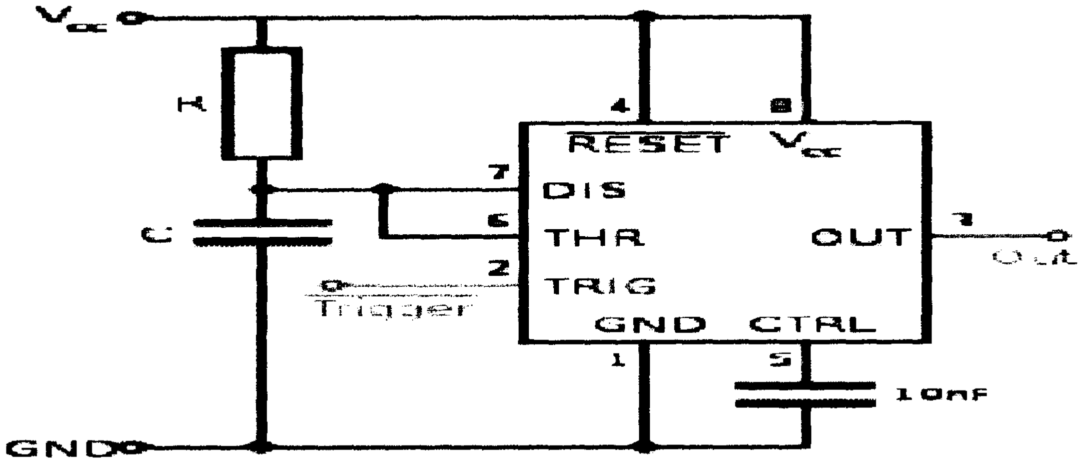

Fig 2.2: monostable mode configuration

In the Monostable mode, the 555 timer acts as a "one-shot" pulse generator. The pulse begins when the 555 timer receives a signal at the trigger input that falls below one- third of the voltage supply. The width of the pulse is determined by the time constant of a RC network, which consists of a capacitor(C) and a resistor(R). The pulse ends when the change on the C equals 2/3 of the supply voltage. The pulse width can be lengthened or shortened to the need of the specific application by adjusting the values of R and C.

The pulse width of time T, which is the time it takes to charge C to 2/3 of the supply voltage, is given by:

$$T = RC \ln(3) = 1.1\ RC$$

Where T is in seconds, R is in ohms and C is in farads.

2. BISTABLE MODE: In Bistable mode, the 555 timer acts as a basic flip-flop. The trigger and reset inputs (pins 2 and 4 respectively) are held high via pull-up resistors while the threshold input (pin 6) is simply grounded. Thus configured, pulling the trigger momentarily to ground acts as a "set" and transitions the output pin (pin 3) to Vcc(high state). Pulling the reset input to ground acts as a "reset" and transitions the output pin to ground (low state). No capacitors are required in a bistable configuration. Pin 8(Vcc) is, of course, tied to Vcc while pin 1(Gnd) is grounded. Pins 5 and 7 (control and discharge) are left floating.

3. ASTABLE MODE: In Astable mode, the 555 timer puts a continuous stream of rectangular pulses having a specific frequency.

ASTABLE MODE CONFIGURATION

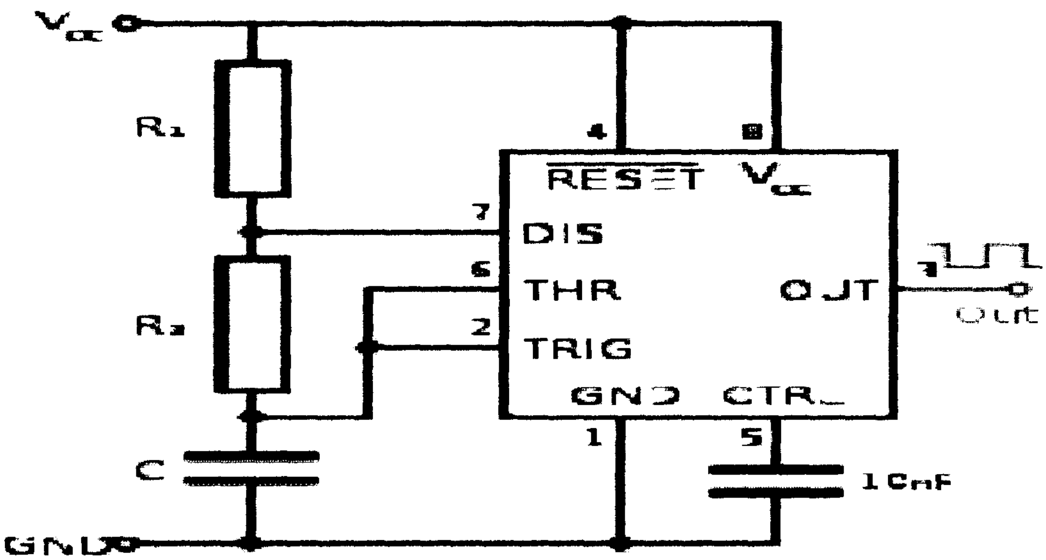

Fig 2.3: Bistable mode configuration

The resistor R1 is connected between Vcc and the discharge pin (pin7) and another resistor R2 connected between the discharge pin (pin7), and the trigger pin (pin2) and the threshold pin(pin6) that share a common node. Hence, the capacitor is charged through R1 and R2, and discharged only through R2, since pin7 has low impedance to ground during output low intervals of the cycle, therefore discharging the capacitor.[8]

In the astable mode, the frequency of the pulse stream depends on the values of the R1,R2 and C.

$$F = \frac{1}{Ln(2).\ C.\ (R1+2R2)}$$

The high time from each pulse is given by

$$high = Ln(2).(R1+R2).C$$

and the low time from each pulse is given by

$$low = Ln(2).\ R2.\ C$$

where RI and R2 are the values of the resistors in ohms and C is the value of the capacitor in farads.

2.2.2 SPECIFICATIONS

These specifications are applied to NE555. Other 555 timers can have better specifications depending on the grade (military, medical, etc)

Supply voltage (Vcc)	4.5 to 15v
Supply current (Vcc = +5v)	3 to 6mA
Supply current (Vcc = +15v)	10 to 15mA
Output current (maximum)	200mA
Power dissipation	600mW

Operating temperature 0 to 70°C

2.3 BLOCK DIAGRAM OF FRIDGE DOOR ALARM

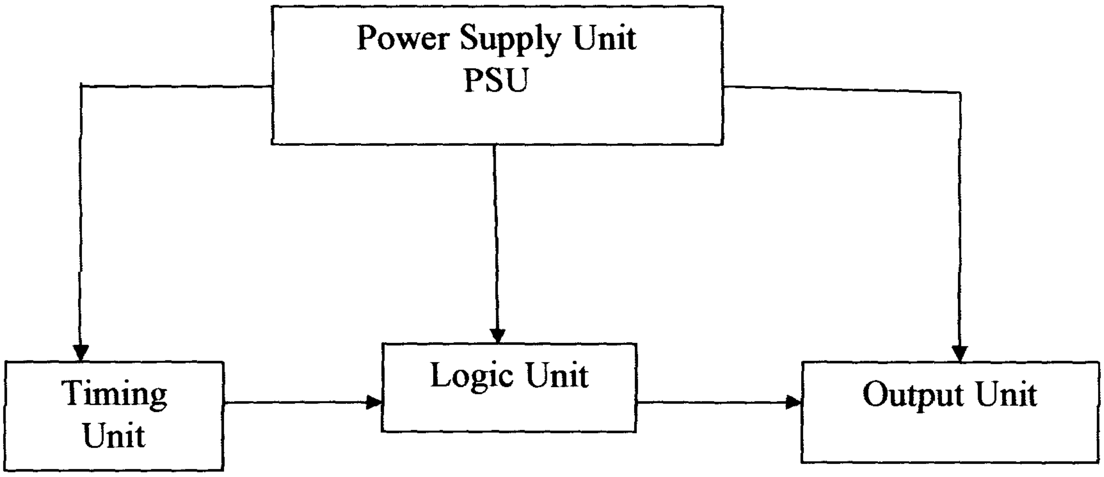

Fig 2.4: Block diagram of refrigerator door alarm

1. POWER SUPPLY UNIT: Is made up of both the AC and DC Supply. When there is electric power supply, the device depends on the AC and at same time charging the Rechargeable Battery of 9V. But, once the AC supply fails (due to power failure from PHCN) the device will immediately switch to the 9V rechargeable battery with the help of a 9V Relay.
2. TIMING UNIT: This unit is made up of two 555 TIMER ICs. One of the ICs is responsible for the delay time and the other is responsible for the beeper repetition rate of the alarm.
3. LOGIC UNIT: It contains basically 7404 NOT GATE IC, and voltage regulator of 7805 to power the IC. The 7404 IC is responsible for the inversion of the output signal of the 555 TIMER IC.
4. OUTPUT UNIT: It contains 6V Buzzer that gives the expected output inform of an alarm.

CHAPTER THREE

3.1 DESIGN AND IMPLEMENTATION

The design and construction of a refrigerator door alarm device is based on the modules that are represented in the block diagram shown in Figure 3.1 below:

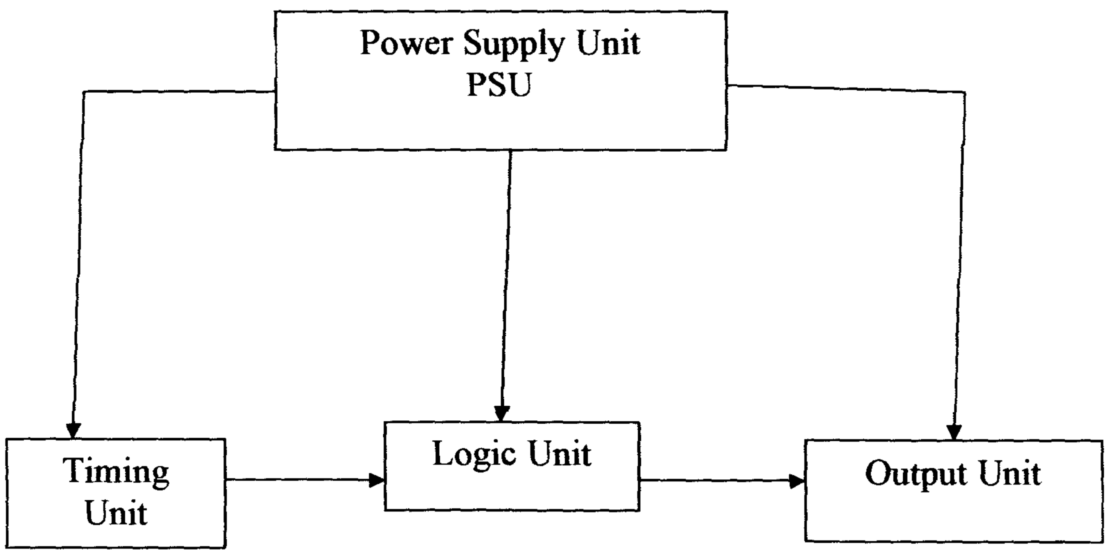

Fig 3.1: Block diagram of a refrigerator door alarm device

The Refrigerator door alarm comprises of the following units:

1. Power Supply Unit
2. Timing Unit
3. Logic Unit
4. Output Unit

3.2 POWER SUPPLY UNIT

There are two ways of powering the device, namely:

1. Through the 240V AC Supply and
2. Through the 9V Rechargeable Battery

The power supply unit comprises of the following stages:

1. Stepping down of the 240V AC Supply to 12V AC Supply by a Transformer
2. Rectification of the 12V AC by a full wave rectifier
3. Smoothening/Filtering of ripples by a capacitor
4. Regulation by a fixed voltage regulator
5. Charging of the 9V Rechargeable Battery
6. Relay Circuit that switches from either Electric Power Supply or the 9V Rechargeable Battery

The Power Supply Unit can be represented in form of block diagram below:

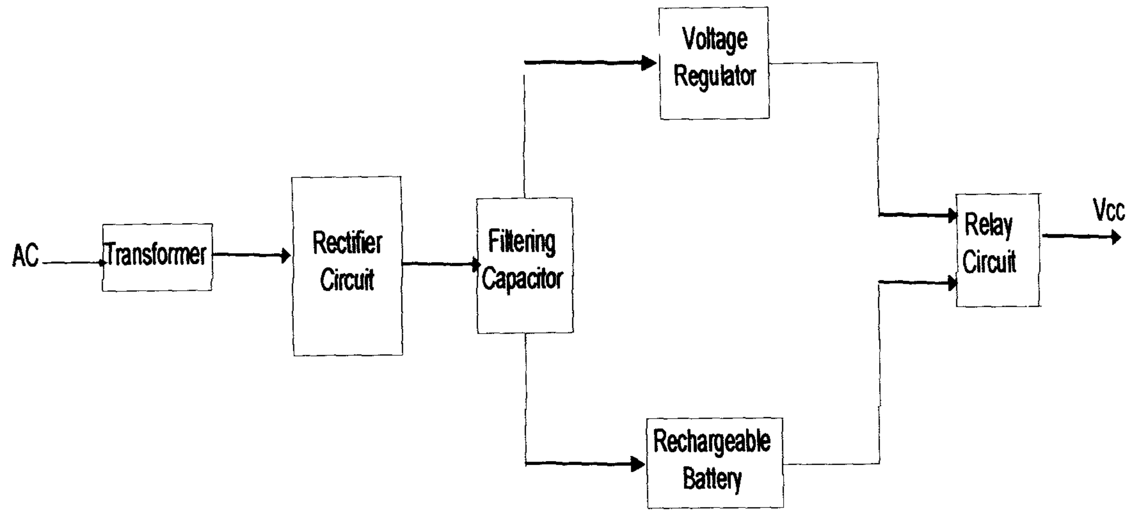

Fig 3.2: Block diagram of the power supply unit

3.2.1. TRANSFORMER: A 240V to 12V AC step down Transformer was used to reduce the 240V AC to a value that the whole circuit can withstand.

3.2.2. RECTIFIER CIRCUIT; The rectifier circuit was made up of four rectifier diodes (IN4001) connected in such a way that two of these diodes conduct in alternate half cycle of the supply voltage as shown below:[9]

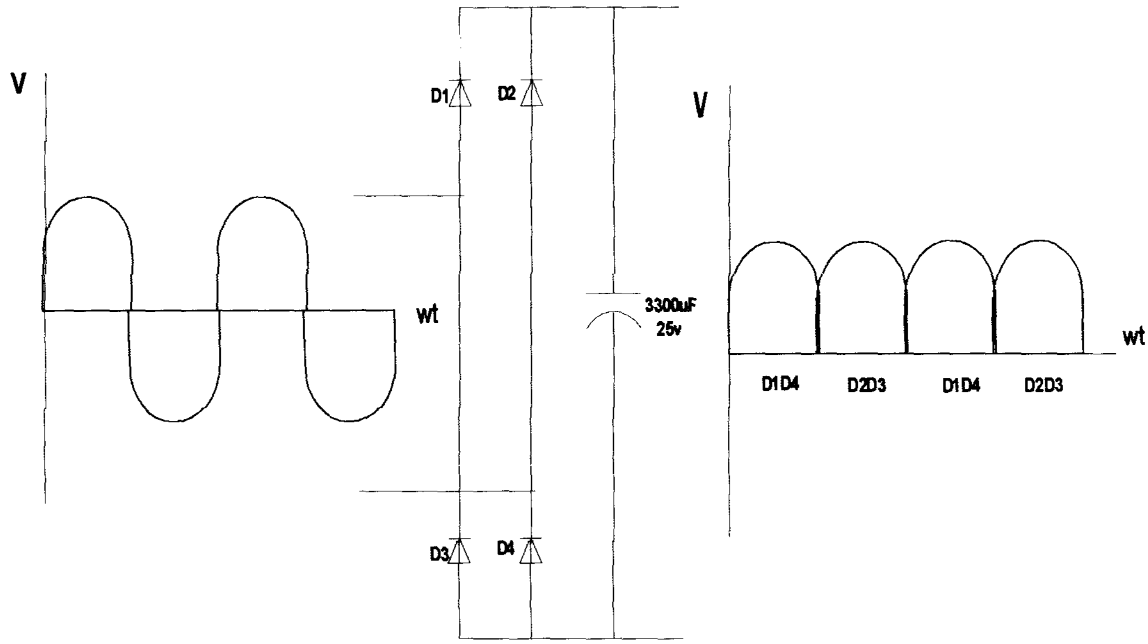

Fig 3.3: Circuit diagram of the Rectifier Section

3.2.3. FILTERING CAPACITOR: A filtering Capacitor was used to filter the AC ripples that could present at the output of the rectifier circuit. The standard rating of filtering capacitor is 2200uF or above with voltage rating of 25V.[10]

3.2.4. VOLTAGE REGULATOR: The 7809_ 9V fixed voltage regulator is an integrated circuit regulator that is capable of taking input voltage in the range of 7-35V and produces a fixed 9V output. Hence, it regulates the output voltage (12V) to 9V which is required by the device to operate.[11]

3.2.5. RECHARGEABLE BATTERY: 9V Rechargeable Battery was used to supply the circuit when ever there is interruption in Electric Power Supply. The Battery is charged when ever there is Electric Power Supply. A Zener diode of 9v breakdown voltage was connected across the Battery to prevent overcharging.[12]

3.2.6. RELAY: 9V Relay was used to switch either from Electric Power Supply to Rechargeable Battery when there is electric power failure or from Rechargeable Battery to Electric Power Supply when the electric power is restored.

CIRCUIT DIAGRAM OF POWER SUPPLY UNIT

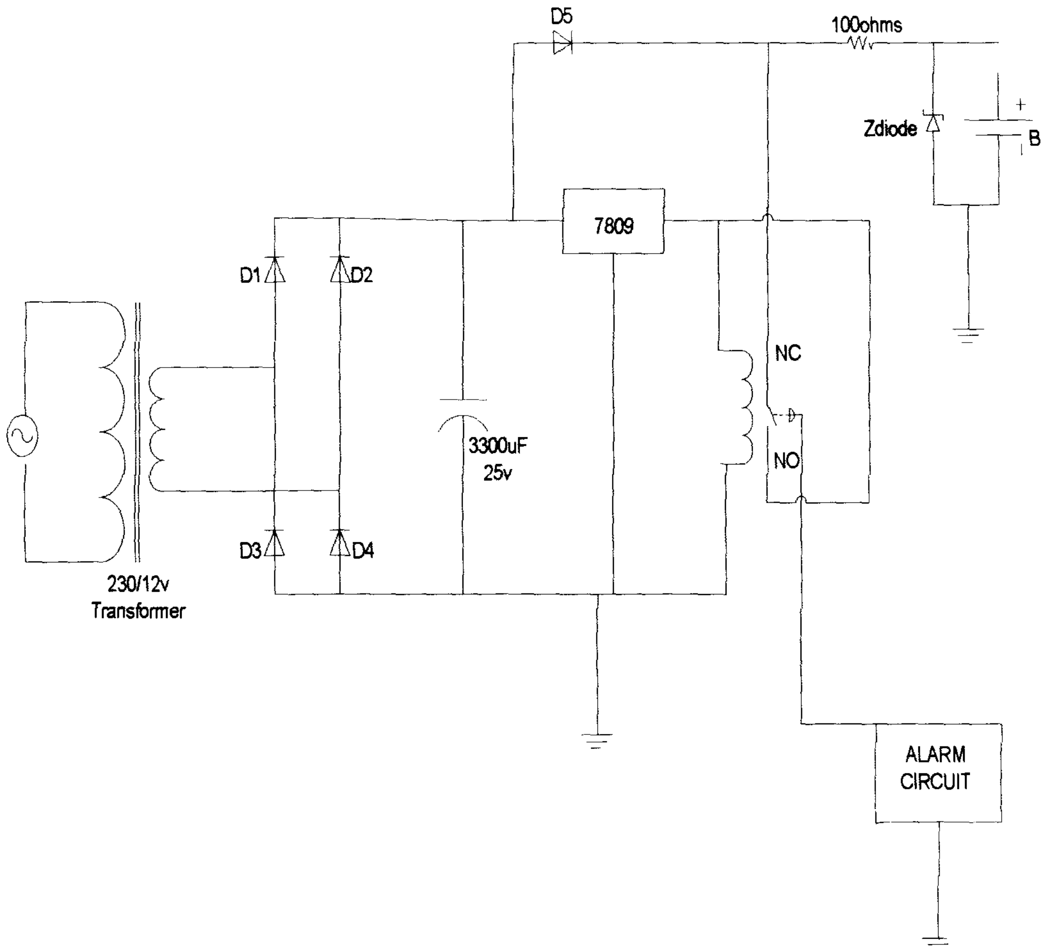

Fig 3.4: The circuit diagram of power supply unit

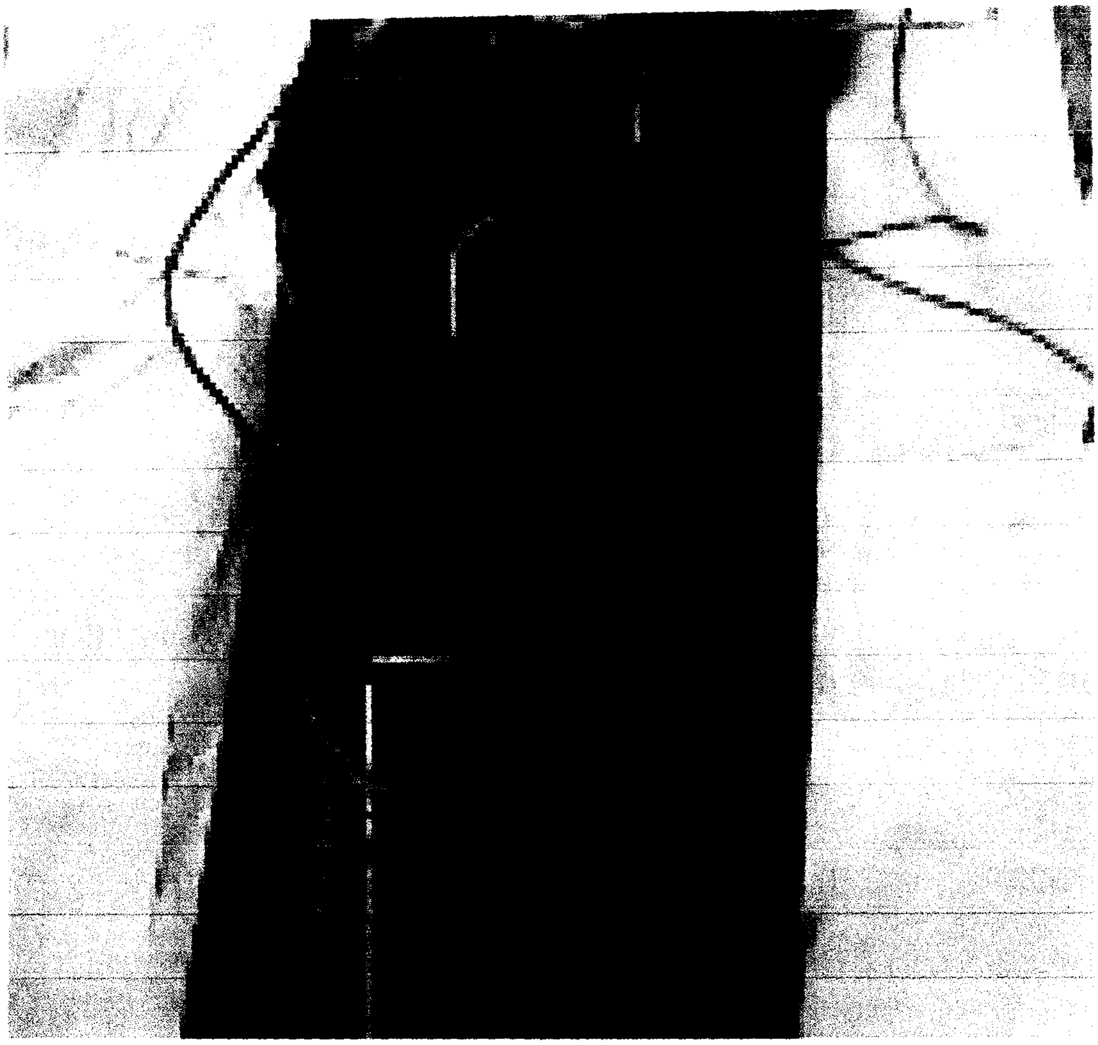

Fig 3.5 : Veroboard construction diagram of power supply unit.

3.3 TIMING UNIT: The basic component that formed the timing unit is 555 Timer IC that was connected in an Astable mode.

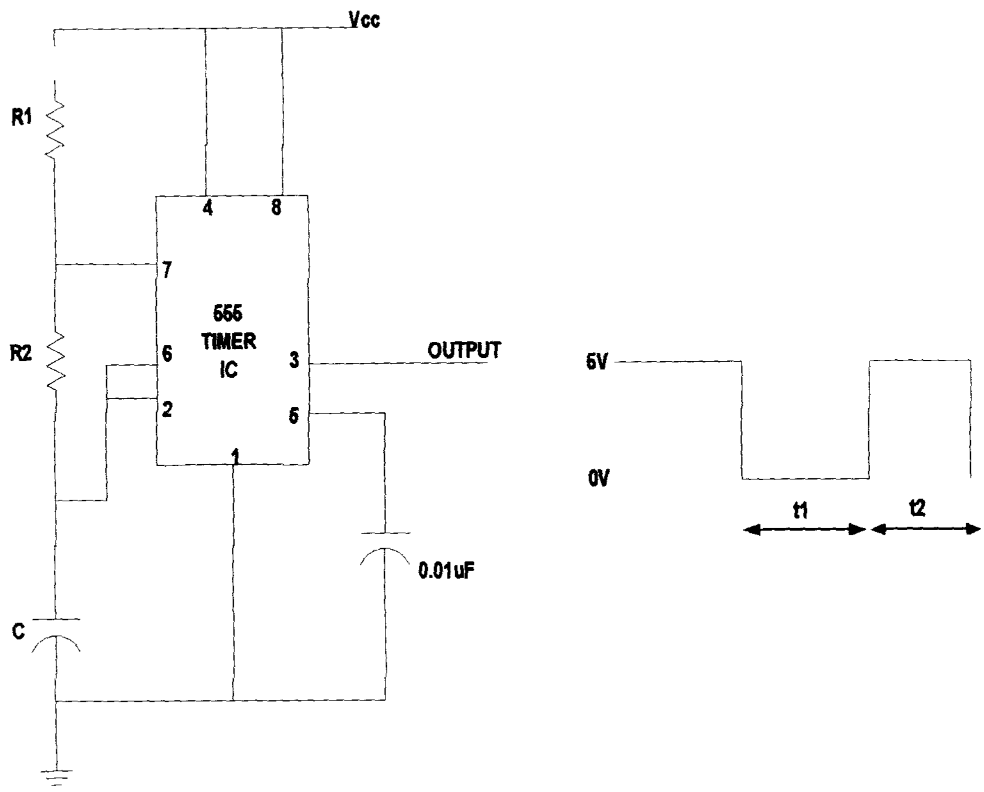

Fig: 3.6: Circuit diagram of the timing unit

$t_1 = 0.7 R_2 C$ and $t_2 = 0.7 (R_1 + R_2) C$

Since the alarm is expected to be activated after 20sec in which the fridge door has been opened. Hence,

$$t_2 = 0.7 (R_1 + R_2) C$$

The value of R_1 must be greater than 1Kohms and the value of C must be greater than 500pF . for the purpose of design. Hence,

For R1 = 10KΩ and C = 10μF

Therefore, $t_2 = 0.7 (R_1 + R_2) C$

$$20 = 0.7\,(10\times10^{3} + R_2)\,10\times10^{-6}$$

$$R2 = 2.85\times10^{6}$$

Hence, 2.2MΩ was used (readily available) for the construction

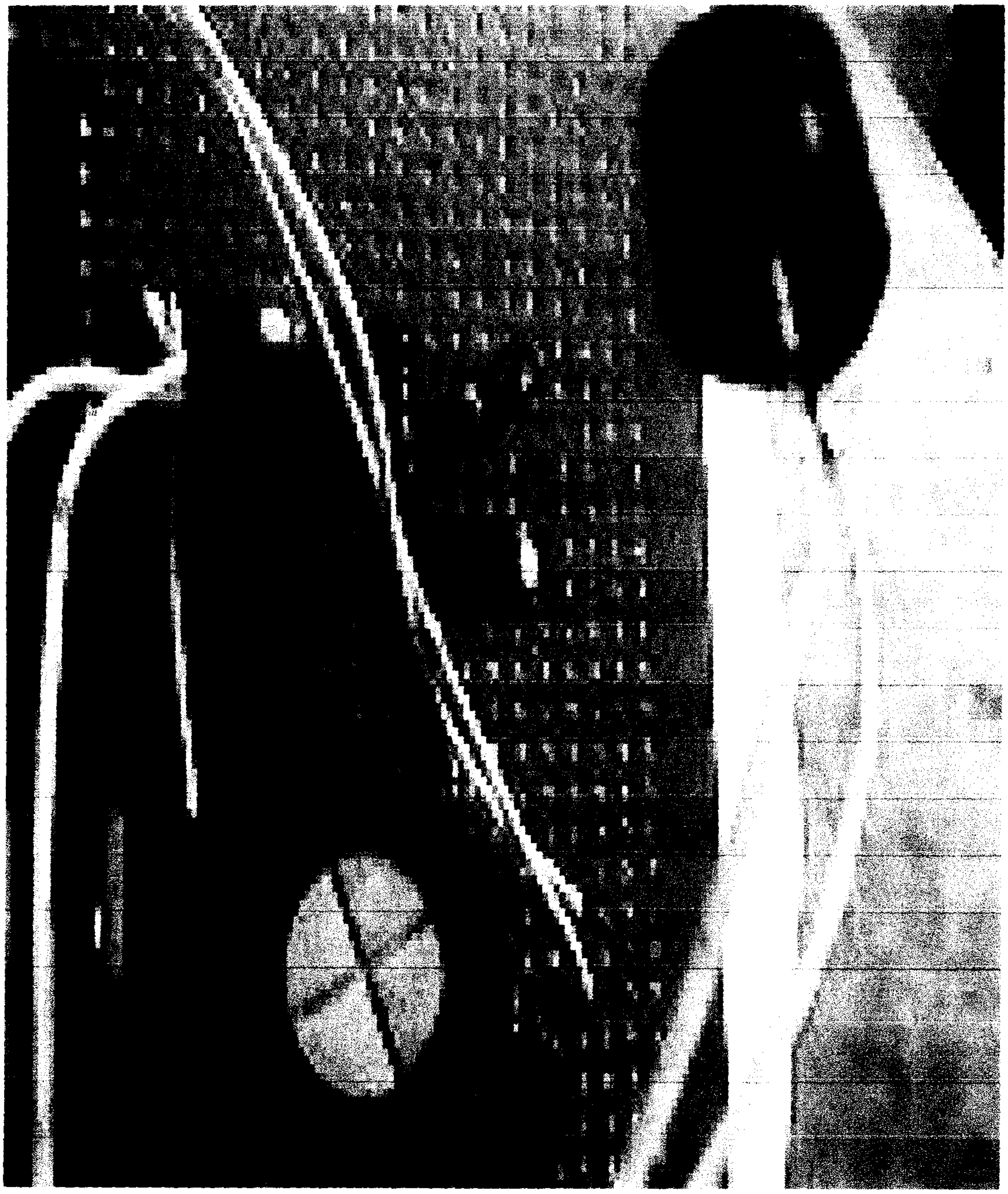

Fig 3.7: Veroboard construction diagram of timer unit

3.4. LOGIC UNIT: The logic unit contains basically 7404 IC as its major component. The IC has six NOT gates in it. The logic gate performs inversion (also called complementation) operation. It changes one logic level to the opposite logic level.i.e from HIGH to LOW level or from LOW to HIGH level. Hence, it inverts the output signal of 555 Timer IC to suit the our application.

3.5. OUTPUT UNIT: It contains 6v Buzzer that is activated by the output of the 7404 IC.

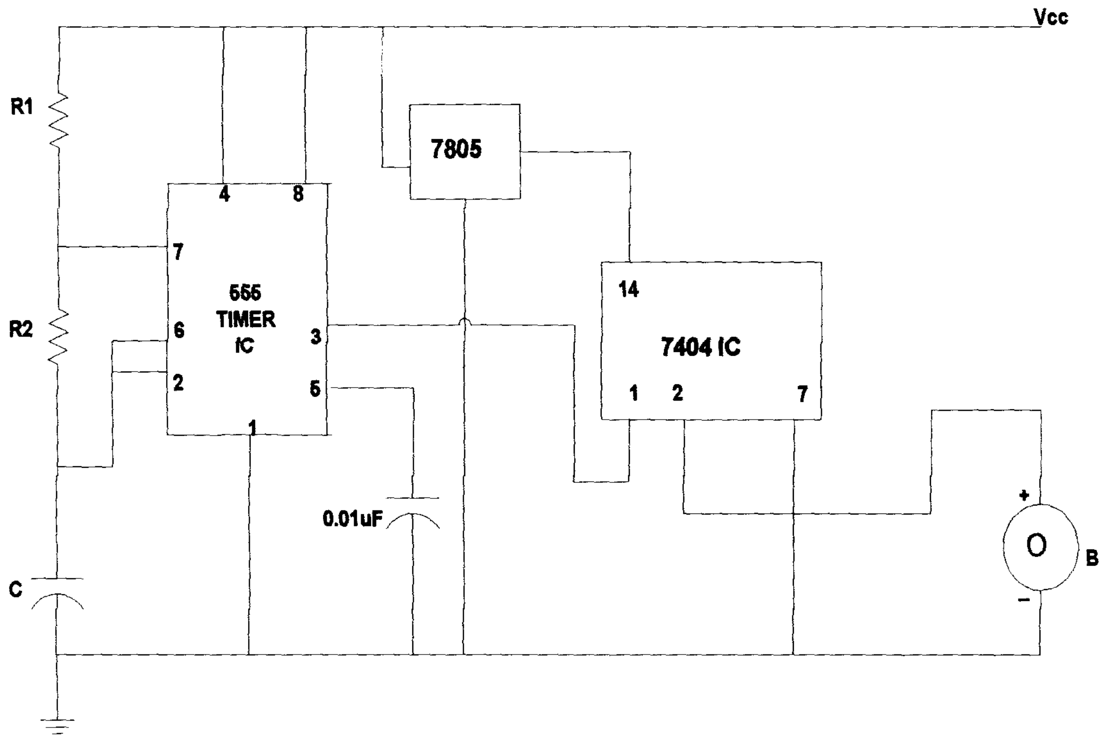

Fig3.8: Circuit showing how Timing Unit, Logic Unit and Output Unit were connected together.

COMPLETE CIRCUIT DIAGRAM OF FRIDGE DOOR ALARM

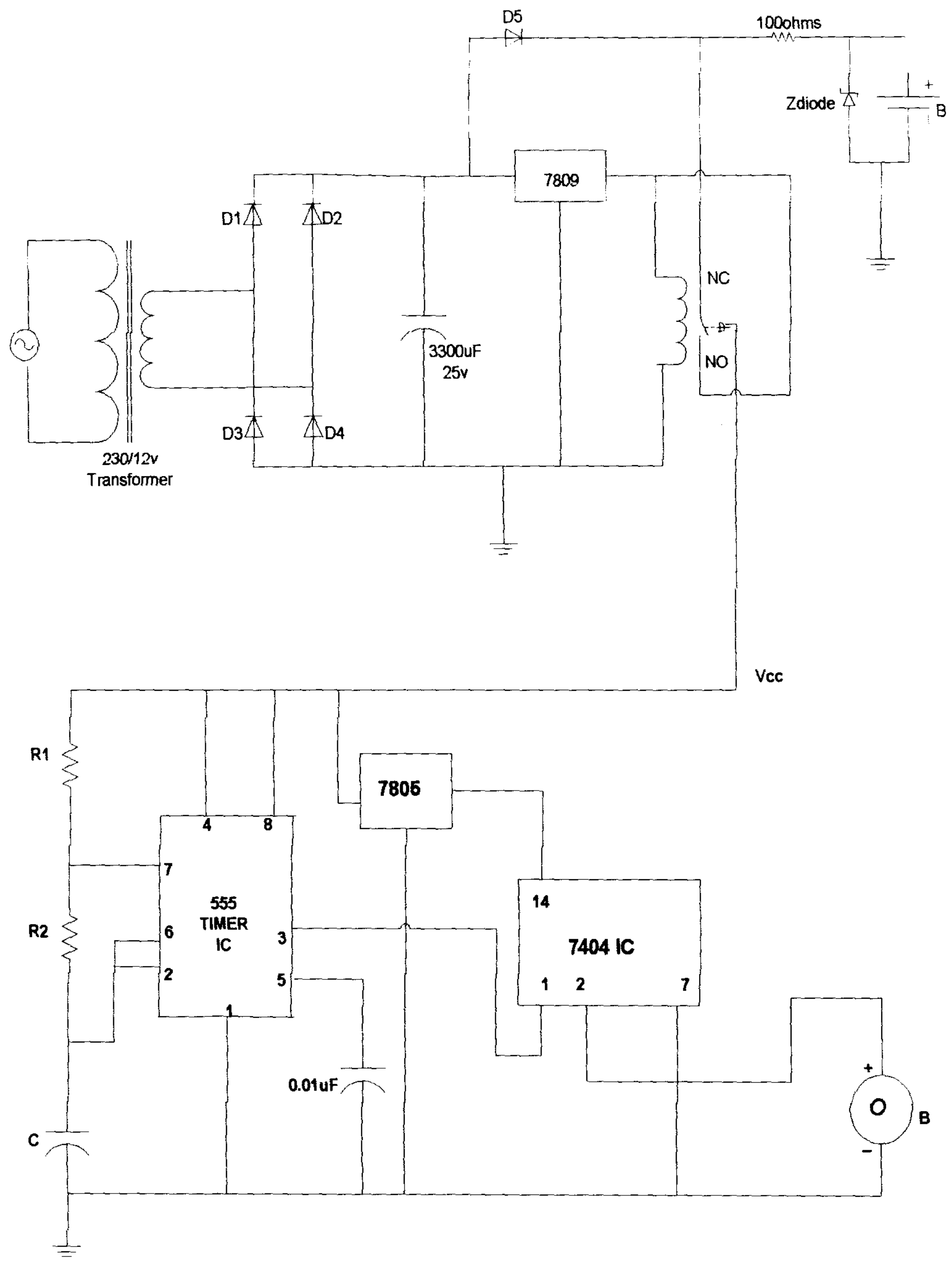

Fig 3.9: Complete circuit diagram of refrigerator door alarm

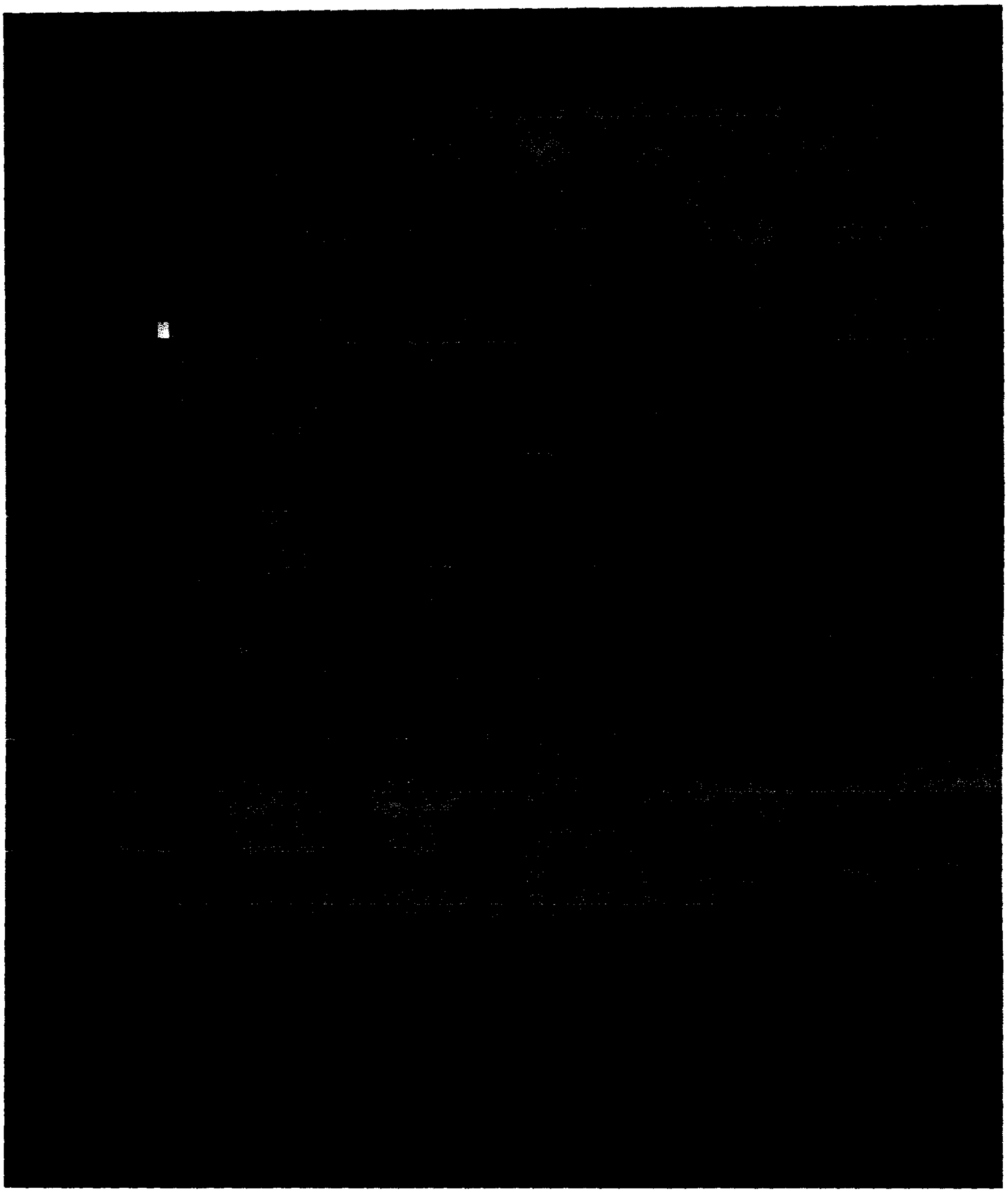

Fig 3.10: Breadboard construction of complete circuit diagram

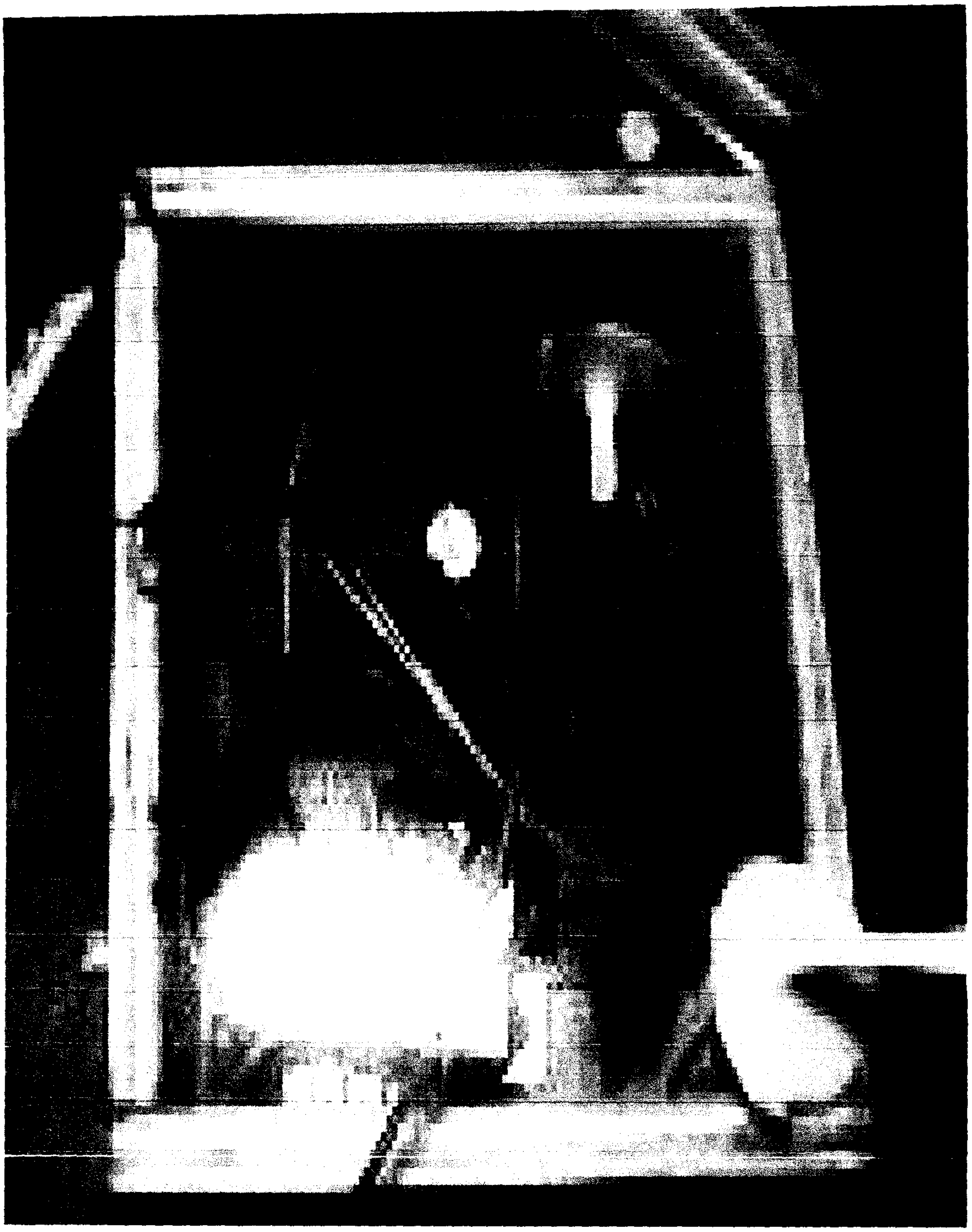

Fig 3.11: Veroboard construction of complete circuit diagram

3.6 CONSTRUCTION PRECAUTIONS

1. All soldered joints(points) were tested for continuity so as to avoid open circuit
2. All the excess leads were removed to avoid short circuit on the board
3. Polarity of the electrolytic capacitor was properly checked to be correctly positioned before soldering on the veroboard.
4. ICs were mounted on the IC sockets to avoid overheating them during soldering.
5. Excess heating of the components was avoided.

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1. TESTS: Series of tests were done on this device, starting from its conceptualized level to the final level where it was achieved. Such tests are: circuit simulation test, component test, bread boarding test etc.

4.1.1. Circuit Simulation Test: The circuit diagram of the device was tested on the computer using MULTISIM 10 software for the simulation. The required timing of the 555 TIMER IC was tested and confirmed using lower corresponding values of components in order for the software to respond to it. The alarm portion of the device was achieved using Buzzer as the testing component on the software. Also, the expected waveform of the output signal (voltage) of the 555 timer was also confirmed using oscilloscope on the software.

Fig 4.1: captured waveform on the oscilloscope during simulation

4.1.2. Components Test: The resistors values were identified by interpreting their colour codes. The transformer was tested for continuity with the aid of digital multimeter. The value of the capacitor was read from inscription on it. All other components (e.g. relay, diode, buzzer etc.) were also tested to see that they were all in good condition before putting them in use.

4.1.3. Breadboarding Test: After implementing the circuit diagram by simulation and availability of components, the next practical test that was done is bread-boarding test. A

Breadboard is a temporary board for circuit testing with tiny sockets that allow for electronic components to be easily plugged or removed freely without damaging the component. The bread-board is meant for preconstruction testing of circuit and sub-circuit before the components are soldered on the Veroboard (where real construction starts)

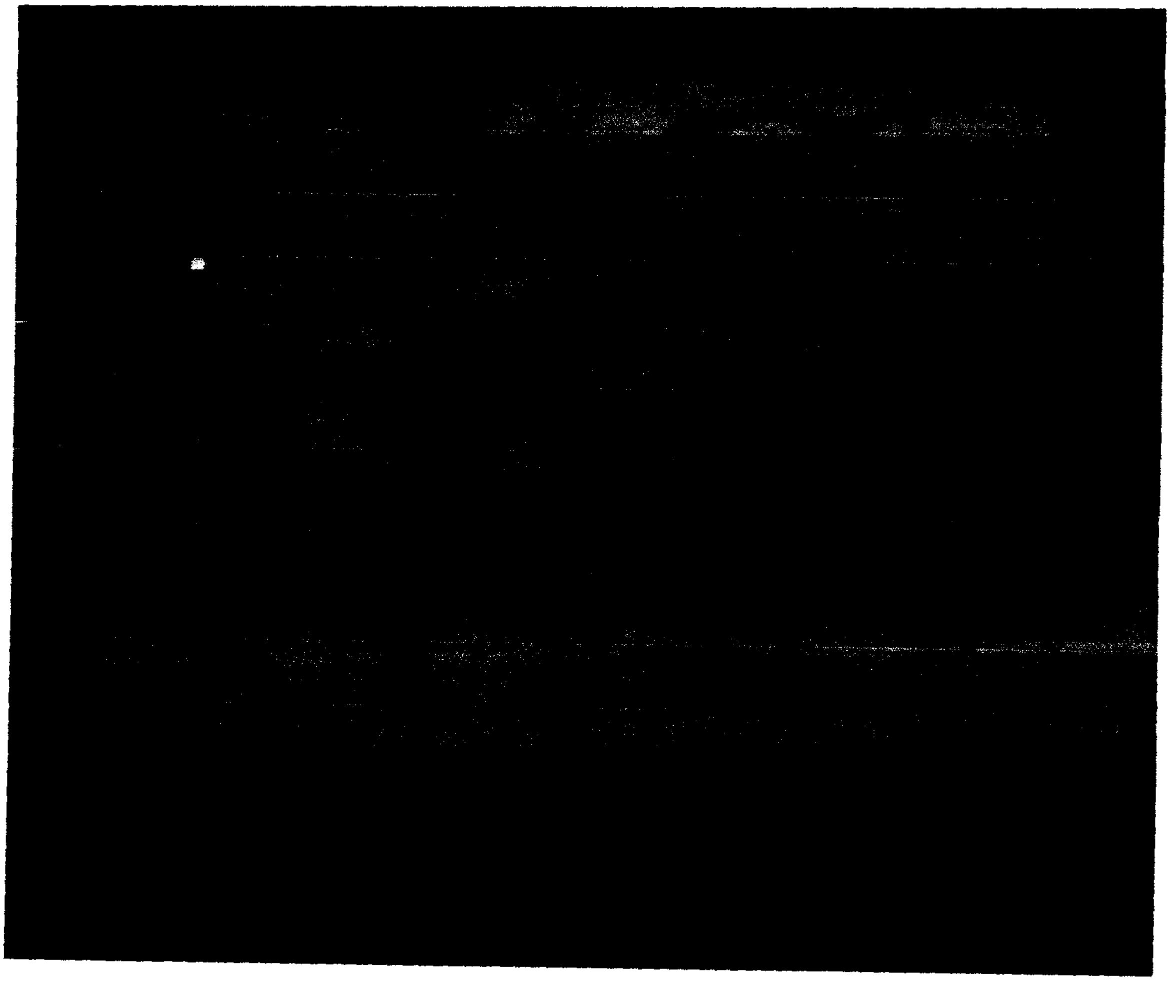

Fig 4.2: Breadboard circuit used to obtain the tabulated results

4.2. RESULTS

The following results were achieved on the breadboard where values of resistors R1 and R2 were varied and value of capacitor C was kept constant until the suited timing was achieved.

S/N	Capacitor C (μF)	Resistor R1 (KΩ)	Resistor R2 (MΩ)	Delay Time (Sec)
1.	10	1.0	1.0	7
2.	10	1.5	1.2	10
3.	10	2.0	1.5	13
4.	10	4.7	2.0	17
5.	10	10.0	2.2	20

Table 4.1: Results obtained

The 20sec delay was achieved for the first period due to the charging of the capacitor C. For the rest periods, the delay time and the active time alternate at the same time of 15sec which made the duty ratio almost 50%. This desired result was also achieved on veroboard after the construction.

4.3. OVER ALL TESTING OF THE DEVICE

The power cable was connected to the mains (230Vac) and the normally open switch was pressed and after 20sec, alarm was activated. The alarm continued at regular interval of 15sec. The power cable was removed from the supply to confirm whether the back up(rechargeable battery) was intact. Rechargeable battery powered the circuit after the power cable had been removed from the mains.

4.4 CASING

The casing of the entire circuit was done with wood for durability and rug- edibility compare to glass casing. Ability to withstand heat compare to plastic casing. There were provisions for Buzzer, switch and power cable, small holes for the ventilation of transformer. The casing is of dimension (12.2cm X 11.8cm X 6.3cm)

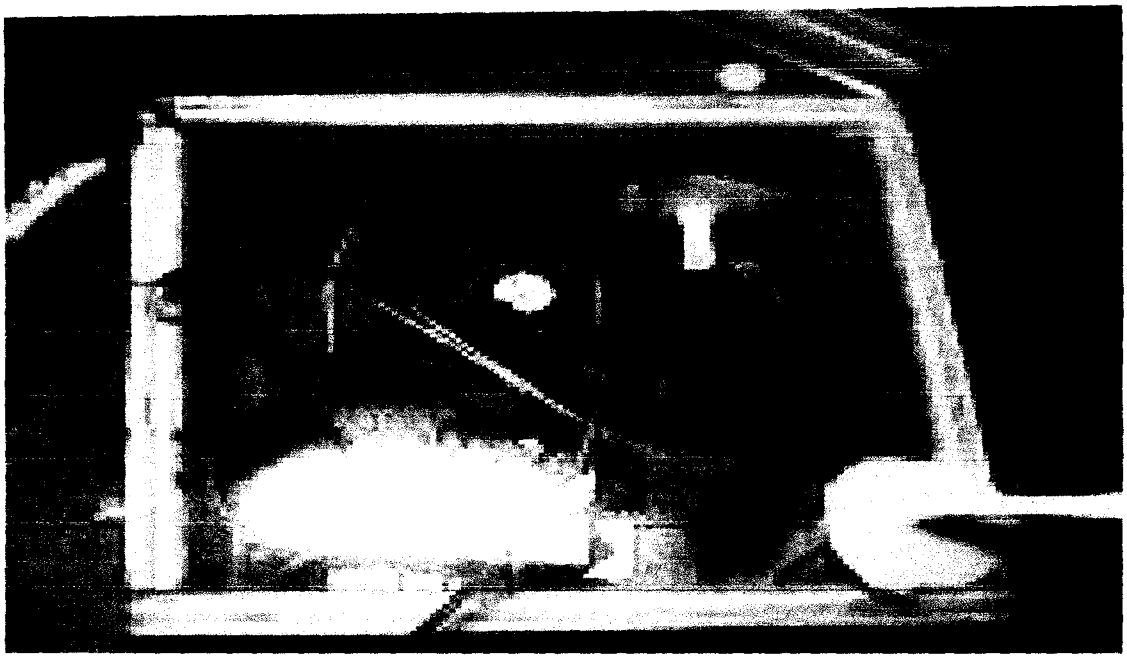

Fig 4.3: Process of positioning the complete circuit into its case

4.5. PROBLEMS ENCOUNTERED AND PREFERRED SOLUTIONS

i. The initial stage soldering was characterized by some mistakes, such as; overflow of molten lead, burning of finger with iron. But with time and together with the advice of the technologists, these difficulties were overcome.

ii. The challenge of positioning and connecting the device was faced and later overcame with advices from my colleagues.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The aim of this project work has to a large extent been achieved, which is a contribution to the field of engineering as it is applied to our immediate environment. The backup provided for the power supply makes it more reliable. It is a locally made device that is affordable, moveable and durable.

5.2. RECOMMENDATION

Although, the name of the project may be tagged "refrigerator door alarm device" but, the device itself can be used in any other places where contact or closeness is very paramount e.g. room door, residential gate, car door etc. All what is needed is to either increase or decrease the timing to suit the area of application.

The device can be improved on by using a microcontroller in such a way that it is voice that we be heard instead of an alarm.

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APPENDIXES

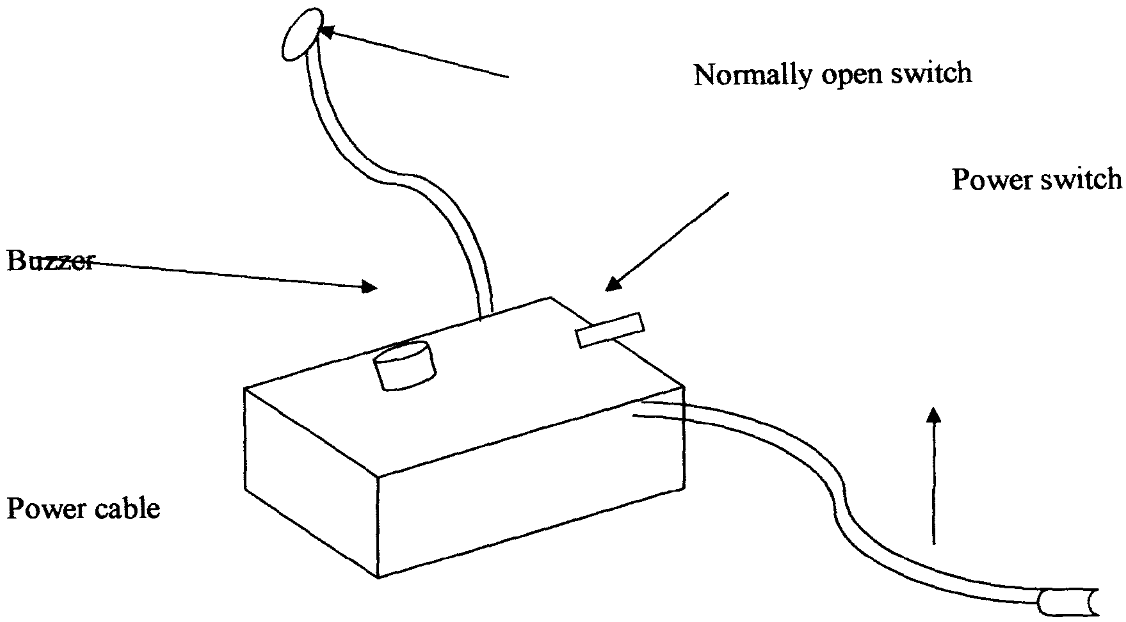
1. POSSIBLE FAULTS, CAUSES AND REMEDIES (TROUBLE SHOOTING)

Since no guaranty of 100% for an electronic component, there is tendency that there may be some faults. The following are the common trouble shooting guide:

S/N	TYPES OF FAULTS	POSSIBLE CAUSES	SOLUTIONS
1.	The device fails to work (i.e. alarm not working)	i. Power supply circuit fails ii. Switch fails to close iii. The Buzzer is faulty	i. Check if there is supply from the mains ii. Check if the relay is performing its function, if not, replace it with new one. iii. Remove the Buzzer and test it with 9Vdc whether it is working or not. If is not working, then replace it with new one.

2.	The alarm continues (Non stop)	555 TIMER ICs malfunction	Check and test the resistors and capacitor connected around the 555 TIMER IC whether they are still working. If not, replace them with new one.
3.	The device fails to Work after passiving an electrical burning odour.	Short circuit has occurred	Check the power supply unit of the device for short circuit fault.

2.USER MANUAL



The following steps should be strongly followed as a guide for the usage of this device;

1. Place the device at the back of the refrigerator where there would not be contact with water or falling of heavy object on it.
2. Pass the normally open switch cable through the underneath of the refrigerator and position the switch very close to the down entrance of the refrigerator as shown below;

3. Connect the power cable to the supply(230V AC)
4. Switch ON the device (located on the device)
5. Leave the refrigerator door open for over 20sec and wait for the respond(i.e. alarm should be activated)
6. Close the refrigerator door and listen instantly(i.e. alarm should stop)