DESIGN AND CONSTRUCTION OF AUTOMATIC DOOR CONTROLLER

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2000/9771EE

A Thesis submitted to the Department of Electrical and Computer Engineering, Federal University of Technology, Minna.

OCTOBER 2006

Dedication

This project is dedicated to my parents, Mr and Mrs. Joseph Aboi for their love, prayers encouragement and support.

Declaration

I, Aboi Florence Nyeni, 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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Acknowledgement

My profound gratitude goes to God Almighty for giving me life and grace to see this day. I also wish to express my thanks to my parents for their financial support, my siblings Susan, Deanna, Godwin and Anne for their encouragement, my project supervisor Dr E.N. Onwuka for her constant scrutiny, constructive criticism and advise, my cousin, Rhoda and friends Mercy, Hyelni, Gellal, Nani and Veronica for helping out in various ways. I also acknowledge my course and group mates for their numerous suggestions and criticisms.

Abstract

The automatic door control is a form of automation that opens a door when there is approaching traffic and closes the door three seconds after the last person has passed through the door. It works on the principle of infrared (IR) as a sensor for approaching traffic, where an IR beam is projected from an IR transmitter to an IR sensor across the door. A prototype was built with a modified personal computer (PC) CD ROM drive serving as the door. The CD ROM drive door opened when the IR beam was broken and closed three seconds after the IR beam has been restored. The device is easy to install, brings convenience in operating frequently used doors like library doors, hospitals restaurants and eateries, hotels, airports, bus stations e.t.c.

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CHAPTER ONE

INTRODUCTION

Engineering is all about making life easier through the application of science for the design and construction of machines and structures [2]. In a world where ease and comfort are some of man`s basic desires, man`s search for a method of perfection brought about what is now known as automation [3]. It is the ability of a machine to perform a self oriented function thereby saving time, human energy dissipation and increasing the accuracy of production specification. The word automatic is an attachment to several machines and equipments in this present generation [9].

Science and technology has rapidly advanced in the last few years, making it possible for man to get work done with ease and at a faster rate especially since recent development in solid state electronics is rapidly revolutionizing the field of control technology. Control techniques are now compact and very flexible and enabling modern machines and equipments to be self-oriented and perform predefined operations via the use of sensors, logical control units and transducers. These control techniques are being used in an ever widening variety of electronic products like the automatic electric kettle.

Woodword J. (1965) pointed out that the kind of technology employed by an organization would determine the structure of the organization [4]. Hickson D. et al (1969) viewed the automation of equipment as a factor of work- flow integration, which is a determinant of organizational effectiveness [4].

A door is a floor-length opening in a wall (doorway), often equipped with a hinged or sliding panel to ensure or deny access to a door. By design, a door may slide or rotate but here the design is limited to a one-way slide door. This project is about a form of automation that enables a one-way slide door to open when approached and close a few seconds after opening.

1.1 Methodology

The coordination of the door is digitally achieved through the application of Infra-Red (IR) transmitter/receiver units and related logical control units. An IR beam is projected from an IR transmitter on one side of a doorway and is incident on an IR receiver on the opposite side of the doorway. The receiving unit serves as an energy transformation unit that converts the IR energy into a corresponding electrical signal, which is amplified and fed into a logical control. This unit is designed to digitally recognize the states of the IR beam i.e. whether the beam is broken (logical 0) or if the beam is intact (logical 1). Two of such IR transmitter/receiver units are incorporated in the circuit design with each pair located on each side of the door such as to allow entrance and exit through the door.

The states of the IR beam (1/0) define the appropriate control for the door; when the door is approached, the IR beam on that side of the door is broken thereby activating the circuit that opens the door for a few seconds before closing it. An electromechanical unit whose major device is a bi-directional D.C. electric motor is incorporated in the design for the door's motion control.

1.2 Objectives

The automatic one-way slide door control provides an easy and luxurious manner of controlling a door. Boasting the greatest user friendliness and safety features. It also lends itself to volume traffic and simplicity of operation [1]. Demerits of this design are:

1. When the IR sensor is subjected to high-level light illumination of wavelength between 750nm and 1 mm, the system may malfunction.
2. The door could respond to a false input such as a piece of flying paper.

Due to cost and complication, this project is limited to a simple un-scaled plastic prototype and can be used almost everywhere in retail outlets, airports, hospitals, offices, factories, public buildings, rail and bus stations, leisure centers, hotels, residential homes, doctors surgeries etc wherever simple, efficient access is required.

CHAPTER TWO

THEORETICAL BACKGROUND

2.1.0 Literature Review

A door is a relatively solid surface, opaque or wholly or partly glazed that closes an entrance to a building or room [8, 14]. Doors are nearly universal in shape and are found in houses, buildings, vehicles, cupboards, cages, etc. The purpose of a door is to permit entry or exit, for ventilation, preventing passage of air; reducing air drafts and creating an enclosed space that can be heated or cooled more effectively (revolving doors are especially efficient for this purpose), privacy and noise reduction, for aesthetics (e.g. cupboard doors cutting off view of the contents) [5, 8, 14,]

Automatic doors are powered open and closed using electro-mechanical set-up. There are three methods by which an automatic door is activated.

- A sensor detects approaching traffic and activates a corresponding circuit to open or close the door.
- A switch is operated manually, perhaps after security checks. This can be a push button switch or a swipe card.
- The user pushes, or pulls the door, once the door detects the applied force, it completes the open or close cycle. These are also known as power-assisted doors.[5,8]

2.1.1 Sensor Review.

Sensors for automatic doors are generally:

- Pressure sensor. This is mostly a floor mat (mat actuator) which activates the open or close circuit of the door when of someone stands on it.
- Infra-red sensor. This is made up of an infrared transmitter (LED) which shines invisible light onto an infrared sensor. When someone or something blocks the beam, the door opens and closes when the beam is restored.
- Motion sensor which uses low-power microwave radar.
- Radio wave sensor which can be triggered by something that someone carries, or is installed inside a vehicle. These are popular for garage doors.[5,8, 17]

In order to activate sensors, automatic doors are generally fitted with safety sensors whose purpose is to prevent the door opening or slows its speed if an object is detected in its path whilst opening and to prevent the door closing or reactivate it if an object is detected in its path whilst closing.

2.2 Historical Background

2.2.1 History of Doors

The oldest door in England can be found in Westminster Abbey and dates from 1050. The earliest records of doors are those represented in the paintings of the Egyptian tombs, in which they are depicted as single or double doors, each in a single piece of wood. Heron of

Alexandria (B.C. 10 – 70) created the first automatic door. He was a Hellenized Egyptian engineer and geometer in Alexandria, Egypt. [5, 8]

2.2.2 History of Automation.

One of the first applications of automatic control was James Watt's use of the flyball governor in 1987 to keep the steam engine he invented running at constant speed. An earlier example was Edmund Lee's (England 1745) use of a small pilot windmill to keep a large windmill faced into the wind [10, 13]

2.2.3. History of Automatic Doors.

The first automatic sliding doors for use by people were invented in 1954 by Lew Hewitt and Dee Horto and were installed in 1960. It made use of a mat actuator. The idea came to them in the mid-1950's, when they saw that existing swing doors had difficulty operating in the high winds of Corpus Christi, Texas. [1, 8]. Upward sliding garage doors date from the 1920's; the first electric door openers (not automatic) were sold in 1926. The rolltop desk, which has a similar form, was around in the mid-eighteenth century. [1].

2.2.4. History of Infra-Red Radiation.

Sir William Herschel, an astronomer, discovered infrared in 1800[11, 12]. Infrared (IR) radiation is electromagnetic radiation of a wavelength longer than that of visible light, but shorter than that of microwave radiation. The name means "below red" (from the Latin *infra*, "below"), red being the color of visible light of longest wavelength. Infrared radiation spans three orders of magnitude and has wavelengths between approximately 750 nm and 1 mm [3, 6, 7, 11, 12]. The active element of the design is IR radiation. In electronics, the common producer of IR radiation is Light Emitting Diode (LED). [5, 6, 7, 11, 12]

In this project, an IR beam is projected across the entrance of a door, from an IR transmitter to an IR sensor. When someone crosses the invisible beam, the circuit is activated thereby opening the door. The door is closed when the beam is restored. The choice of infrared as a sensor was because of the following reasons;

1. It is very accurate.
2. It is cost effective.
3. Unlike the radio wave sensor, it does not interfere with other devices in adjoining rooms.[15]
4. It is readily available.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

The circuit design of the automatic door control was carried out in modules as shown below.

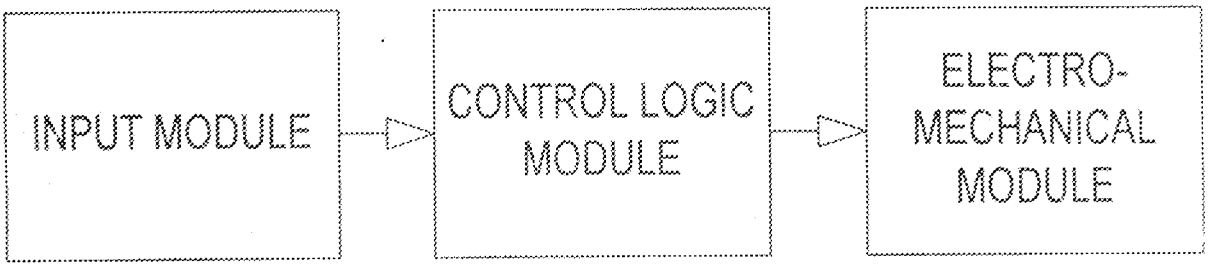


Fig 3.1 Block diagram of an automatic door control.

The above block diagram consists of the power module, the input sensor module, the control logic module, the load and the alarm unit.

3.1 The Power Module.

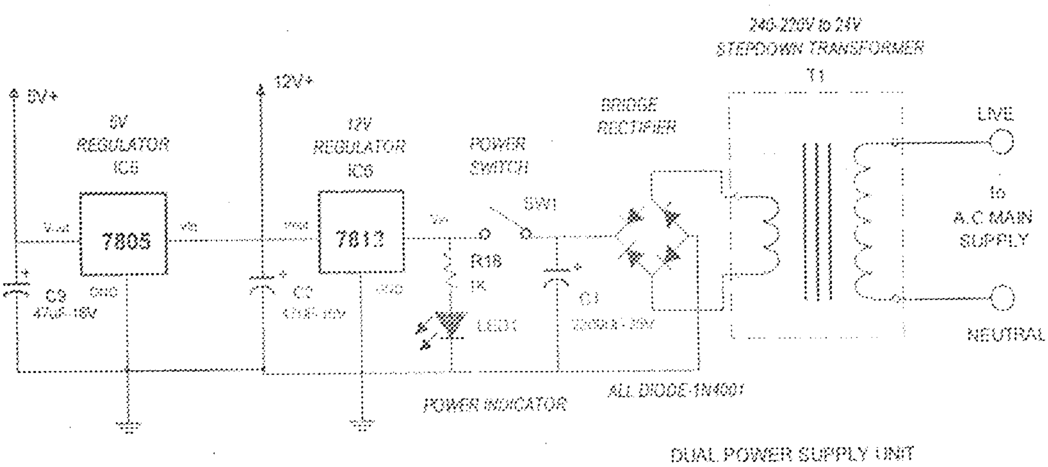


Fig 3.2 Circuit diagram of the power module.

The power supply module was designed to supply two regulated Direct Current (DC) voltages of 5volts and 12 volts. A 24 volts step-down Alternating Current (AC) transformer was used as the power input to the circuit, with its primary terminals connected to the AC mains supply from Power Holding Company of Nigeria, PHCN and its secondary terminals connected to a bridge rectifier circuit. The bridge rectifier circuit is made of four IN4001 diodes and converts the 24 volts AC from the transformer to 24 volts DC which is not always stable, hence the need for the filtering capacitor C_1 connected across the negative and positive terminals of the power supply. C_1 is used to reduce the AC ripple component in the DC supply thus making the DC power supply more stable. For 17% ripple voltage content V_R after filtering with a peak voltage V_p,

$V_R = (17/100) \times V_p$

but V_p = regulated supply + voltage drop across rectifier circuit.

$= 24V + 2.4V = 26.4V$

$V_R = (17/100) \times 26.4 = 4.488V$

$\approx 4.5V$

The 17% ripple is assumed to prevent charging up of the compensation capacitor.

Time between half cycle, $dt = ½ T = ½ \times (1/F)$

Where T is the period for one cycle and F is the PHCN frequency = 50Hz

$dt = ½ \times (1/50) = 1/100 = 0.01s.$

the current rating of the diode, I is 1A

$I = C\, dv/dt$

Where $dv = V_R$ and c is the capacitor size

$1 = C \times (4.5/0.01)$

$C = 0.01/4.5 = 2.222 \times 10^{-3} F = 2222\ \mu F.$

A 2200 µF was used because is the closest in size to the calculated value and readily available. The switch SW_1 controls connection or disconnection of the circuit to the rectified power source. The two voltage regulators 7812 and 7805 provide constant voltages of 12volts and 5 volts respectively. The Light Emitting Diode (LED) serves as a power indicator while the 1000 Ω resistor R_1 drops the voltage across the LED, thereby protecting it from over current since it operates at 2.8 V

3.2 The Input (Sensor) Module.

This module consists of two motion sensor units each comprising of an IR transmitter, an IR sensor and a signal amplifier. The signal amplifier circuit consists of three switching transistor circuits in the common emitter configuration as shown below.

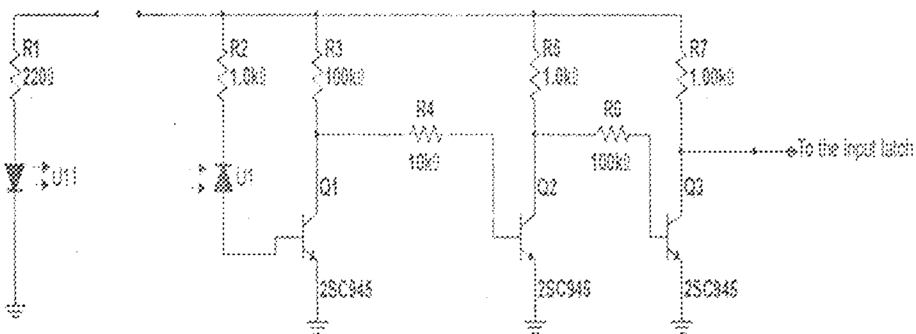


Fig 3.3 The input module circuit diagram

3.2.1 The IR Transmitter-Sensor Unit.

This is made up of an IR transmitting diode with effective range of one feet (1 ft) and a 220 Ω limiting resistor. The diode operates on a voltage of 2.7V and a current of 9mA, therefore the value of the resistor R_6 can thus be computed

$R_6 = (V_s - V_D) / I_D$

Where V_s is supply voltage and V_D is demanded voltage

$= (5 - 2.7) / (9 \times 10^{-3}) = 255.5\ \Omega\ R_6 \approx 256\ \Omega$

A 220 Ω resistor was used in the circuit instead of the 256 Ω because it is readily available.

3.2.2 The Amplifier Unit.

This unit consists of three 2SC945 NPN transistors in the common emitter configuration. The transistors have a current gain of approximately 100 each. Due to the high impedance characteristic of the infrared sensor, a 100kΩ resistor (R_3) is connected across the collector of Q_1 for compatibility with the base current. The current at the collector I_{c1} of Q_1 is;

$I_{c1} = V_{cc} / R_3$

$= 5 / (100 \times 10^3) = 0.05$ mA.

The base current I_{b1} is:

$I_{b1} = I_{c1} / h_{fe}$

Where h_{fe} (100) is the current gain of the transistor

$I_{b1} = (0.05 \times 10^3) / 100 = 0.0005$mA.

The value of the base is low but sufficient to turn on the transistor. A load of 1kΩ (R_5) is connected across the collector of Q_2 .The current at the collector I_{c2} of Q_2 is;

$I_{c2} = V_{cc}/ R_5$

$I_{c2} = 5/ 1000 = 0.5mA$

The base current I_{b2} is;

$I_{b2} = I_{c2} /h_{fe}$

$= (0.5 \times 10^{-3})/ 100 = 0.005mA$

A load of 1kΩ (R_7) is connected across the collector of Q_3.The current at the collector I_{c3} of Q_3 is;

$I_{c2} = V_{cc}/ R_7$

$= 5/1000 = 0.5mA$

The base current I_{b3} is;

$I_{b3} = I_{c3} /h_{fe}$

$= (0.5 \times 10^{-3})/ 100 = 0.005mA.$

The amplifier unit was designed to serve as a switch.

3.3 The Control Logic Module.

This module which was designed to control the switching and bi-directional operation of the motor (load) consists of two latches and two oscillators. The input latch is an SR flip-flop and stores the input signals from the IR unit. When someone crosses the infrared beam, a high logic level(1) is applied to the set input , making the Q output a high logic level and $\overline{Q}$ a low logic level as shown below.

Table 3.1 Truth table of an SR flip-flop

S	R	Q	$\overline{Q}$
1	0	1	0
0	1	0	1
1	1	1	1
0	0	Qx	$\overline{Qx}$

The OR gate sums the output of the input module and $\overline{Q}$ and applies the result to pin 12 of oscillator 1, while the Q output is connected to the base of an NPN transistor (2SD400).

The transistor switches on the relays whenever the base is applied with a high signal (5V), thereby opening the door by changing the polarity of the motor through the relays. Since the motor cannot function without the negative terminal of the power supply, the output control latch and oscillator 2 were incorporated to serve as negative feeders.

The Q output of the input latch has to return to 0 for the close. Oscillator 1 makes it return to 0 by acting as a timer. It starts counting just after logic level 1 is absent from the S input and applies logic level 1 to the R terminal to return Q back to logic level 0, thus allowing a period of time to elapse before the door closes. The negative feeding to the relay stops the motor from functioning immediately the door is fully opened or closed. This is achieved as oscillator 2 acts as a timer

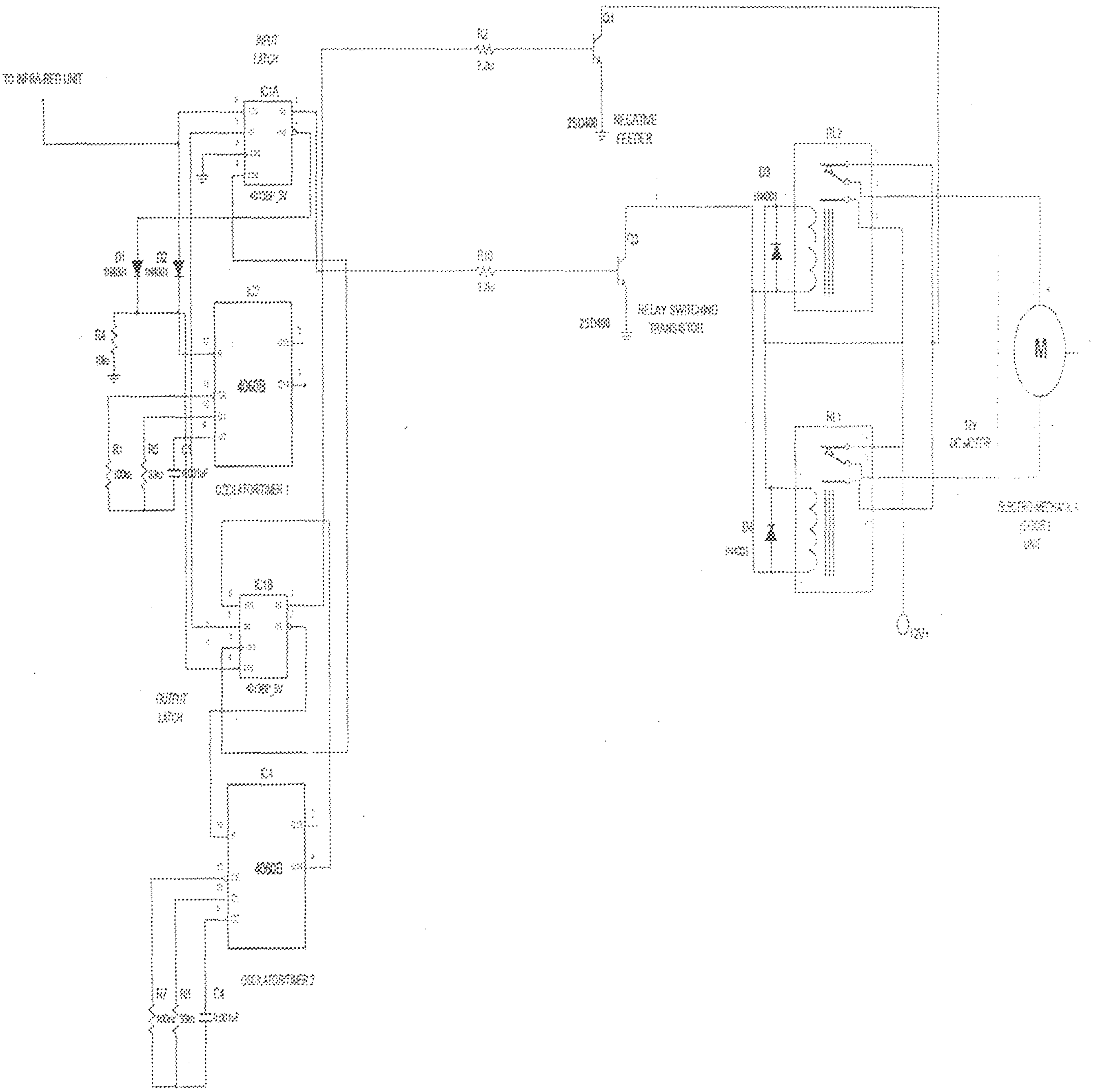


Fig 3.4 Circuit diagram of the control logic module and the electromechanical module.

The output control latch controls the transistor through its Q terminal which is at a high logic level 1 when the infrared beam has been disturbed.

3.3.1 The Oscillator and Latch Circuit. The main frequency fm of oscillator 1 which has a resistor –capacitor RC configuration of 33000 ohm and 0.001uF is;

$f_m = 1 / (2.3\ RC)$

$= 1/(2.3 \times (33\times10^3) \times (0.001\times10^{-6}))$

$= 13.2$ KHz

This signal is used for setting the input latch through pin 3 therefore the frequency of pin 3 is;

$f_{pin\ 3} = f_m/2^{14} = (13.2 \times 10^3) / (2^{14})$

0.81Hz

The time delay of pin 3, T_{pin3} before the input latch is reset is;

$T_{pin3} = 1/ f_{pin\ 3} = 1/0.81$

$= 1.23$ s.

The theoretical time delay is not very accurate due to the inaccuracy of the frequency formula and internal capacitance of the circuit and in practical situations, the time delay is larger, about 3.0seconds, therefore having a jitter of 1.77 seconds.

Oscillator 2 has the same main frequency and time delay as oscillator 1.

3.3.2 The Relay Switching Circuit. Each relay load (R_{L1} and R_{L2}) is 400 Ω therefore the resultant load on the transistor, R_R is:

$R_R = (1/R_{L1}) + (1/R_{L2})$

$= (1/400) + (1/400) = 200\ \Omega.$

The collector current $I_c = Vcc/ R_R$

$= 12/200 = 0.06\ A$

The general current gain of the transistor h_{fe} is 100

The base current $I_B = I_c / h_{fe}$

$= 0.06/100 = 0.06\ mA$

Assuming a high signal (5V) is applied at the base of the transistor,

$R_B = (Vs\text{-}Vce) / I_B$

Where Vs is the supply voltage = 5V

Vce is the voltage = 0.07V and

I_B is the base current = 0.06 mA

$R_B = (5\text{-}0.7)/ (0.06\times10^3) = 7.166\ \Omega$

R_B is lower than 7.166 Ω in practical cases because V_s is lower than 5V practically.

3.4 The Electromechanical Module

This unit is made up of a model of a one-way slide door with a bidirectional motor

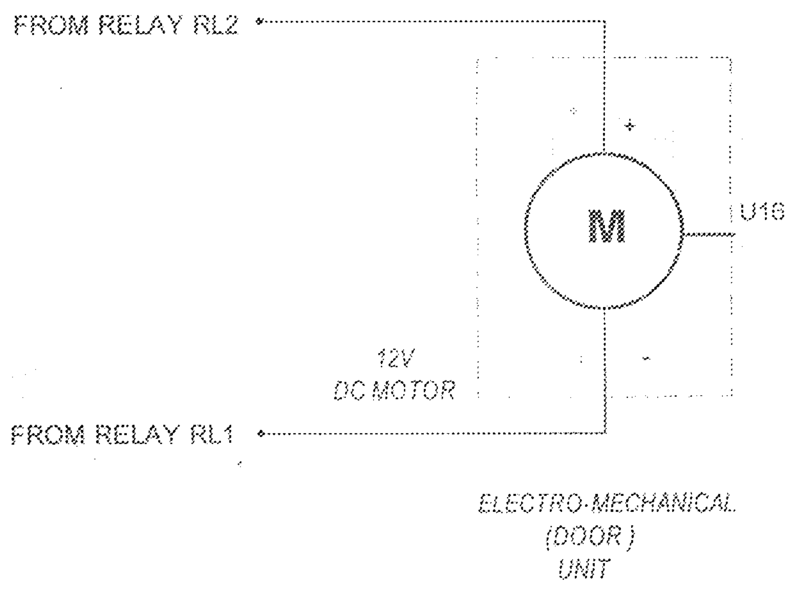
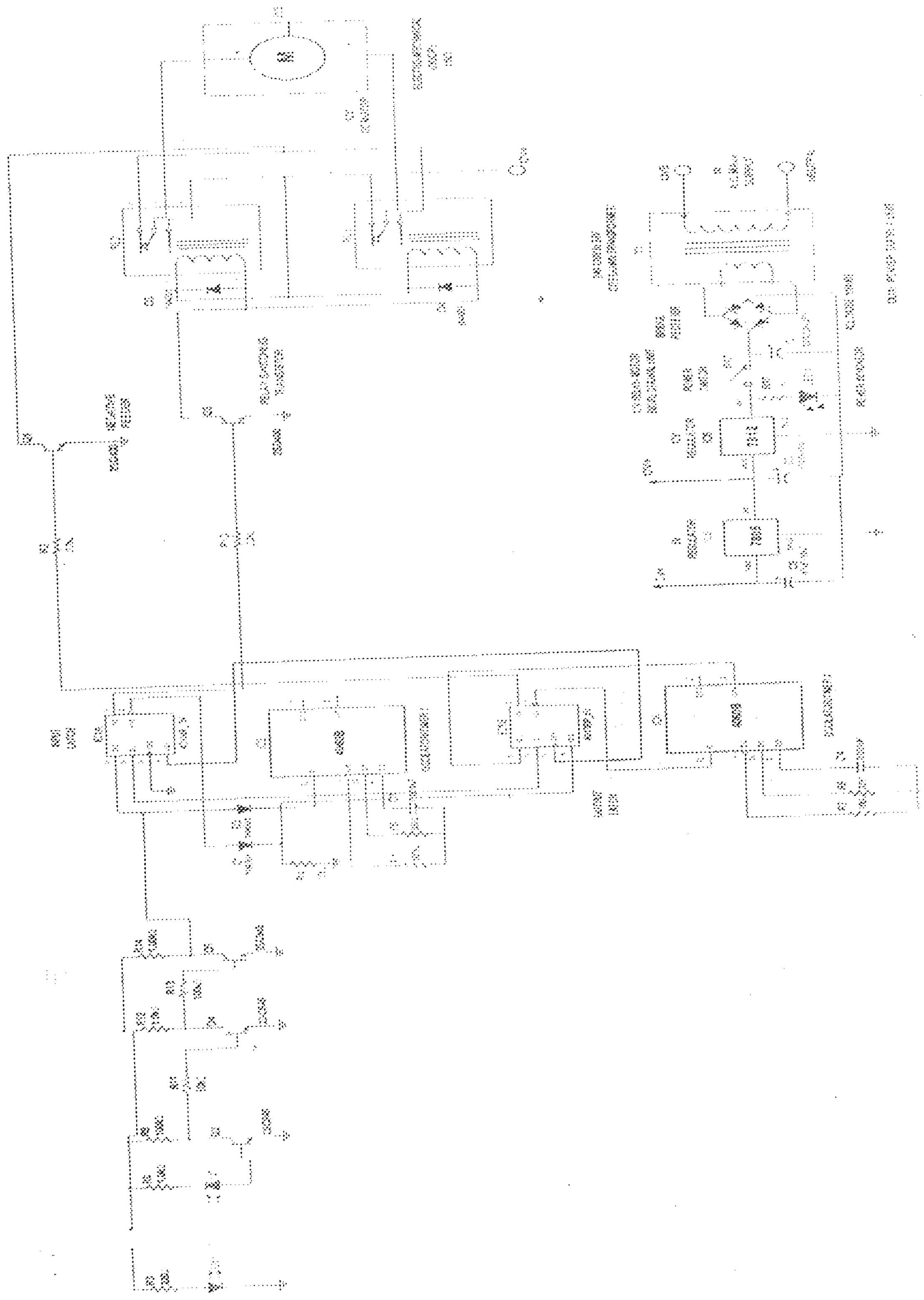


Fig 3.5 circuit diagram of the electromechanical module



3.5 Component Description.

The main components involved are two 4060B oscillators, a 4013B flip- flop, a 7805 regulator, a 7812 regulator, three 2SC945 NPN transistors and two 2SD400 NPN transistors. Others are two 12V relays, a bidirectional motor, eight IN4001 diodes, a power switch, a LED, a 24v step-down transformer, resistors and capacitors of various capacities.

The involved components were selected for reasonable performance and economy. Their rate of power consumption was also put into consideration and selected to be compatible.

3.5.1 The 4060B oscillator.

The 4060B is a Complementary Metal Oxide Semiconductor (CMOS) fourteen-stage oscillator IC designed to produce ten frequencies at once. The outputs of this IC are results of multiple division of a main frequency. The oscillator works on both resistor capacitor (RC) configuration and crystal configuration. [21]. The input to pin 12 of the IC has to be at low logic level (0) in order to enable the IC. Pins 9, 10 and 11 are required for oscillation. The value of the main output frequency is not predetermined by the manufacturer but depends on the value of the resistances and capacitance connected across its terminals. [21, 24, 26]

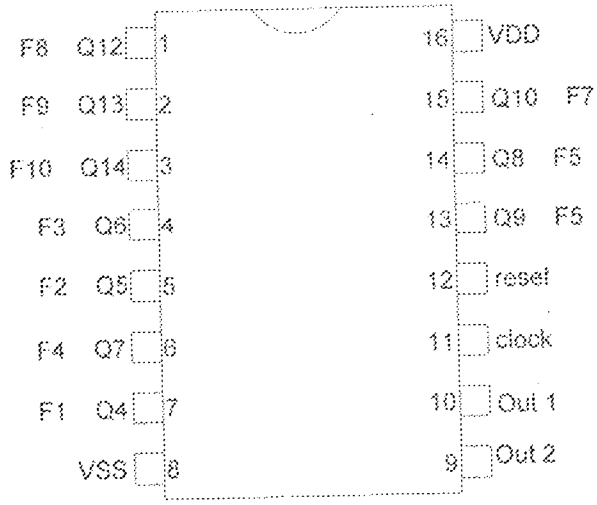


Fig 3.7 The pin configuration of the 4060B

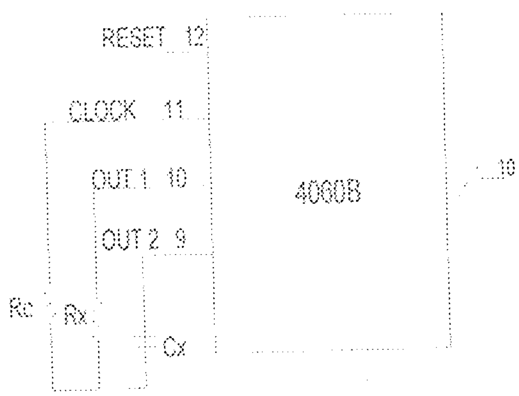


Fig 3.8 The normal RC configuration of 4060B oscillator

The main frequency $f_m = 1/(2.3R_X C_X)$

Where $2R_X \leq R_C \leq 10R_X$

The frequency of a particular output f_X is given by;

$F_X = f_M/2^x$

Where x is the Q value of a particular output or pin.

The 4060B is usually used for control, division, and timing functions and is attributed to stable outputs. Its multiple outputs make it more desirable to the 555 timer which has only one output frequency. [21]

3.5.2 The 4013B flip flop.

The 4013 B is a dual D-type CMOS flip-flop IC. It embodies two D-type flip-flops with each unit functioning independently. Though it is a D-type device, it is frequently used in the SET- RESET (SR) mode. The 4013B is active in the high (1) state. [16, 27, 30]

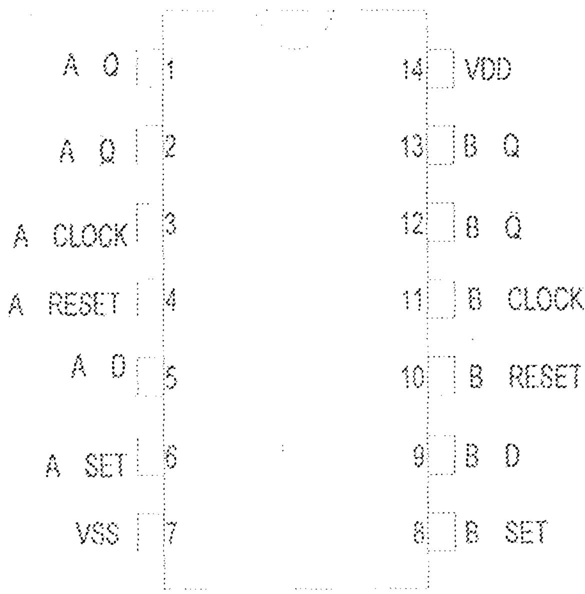


Fig 3.9 The pin assignment of 4013B

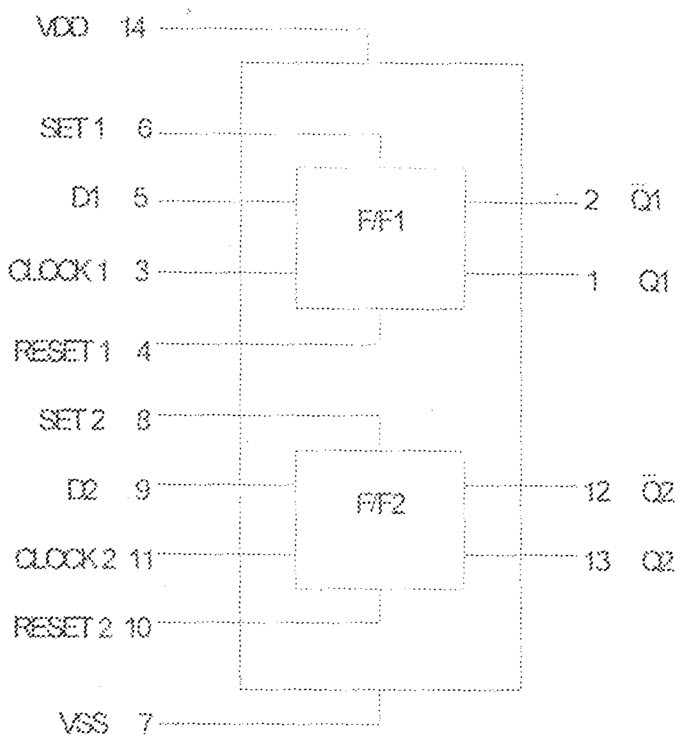


Fig 3.10 The internal circuitry of the 4013B

Table 3.1 Truth table of an SR flip-flop

S	R	Q	$\bar{Q}$
1	0	1	0
0	1	0	1
1	1	1	1
0	0	Qx	$\bar{Q}$x

3.5.3 The 7805 and 7812 voltage regulators.

These are voltage regulators of output 5 volts and 12 volts respectively. The two Ics have a current of 1A and a maximum voltage input of 35volts. Their pin configurations are as shown below.

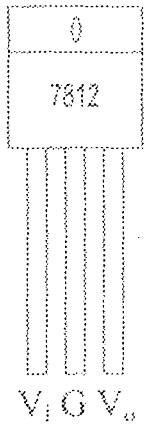


Fig 3.12 The pin layout of the 7812 voltage regulator

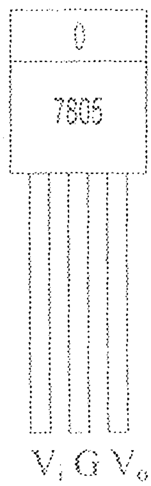


Fig 3.13 The pin layout of the 7805 voltage regulator

Where V_i is the input voltage terminal,

G is ground terminal and

V_o is the regulated output voltage terminal. [18, 19]

3.5.4 The 2SC945 NPN transistor.

The 2SC945 is an NPN bipolar transistor designed for use in the driver stage of Audio Frequency (AF) amplifier and low speed switching applications. It has a current gain h_{fe} of 170 at 30°c. Temperature affects the current gain of the device.

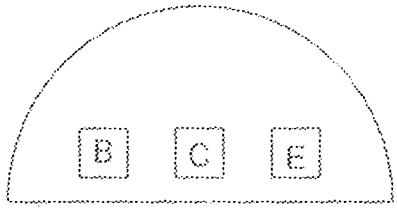


Fig 3.14 The pin layout of the 2SC945 transistor.

Where B is the base terminal,

C is the collector terminal and

E is the emitter terminal. [23, 25, 28]

3.5.5 The 2SD400 transistor.

The 2SD400 is a NPN epitaxial planar silicon transistor. It is a complement of the 2SB544, its PNP equivalent. it possesses a maximum collector to base voltage V_{cbo} and collector to emitter voltage V_{ceo} of 25V while it's emitter to base voltage V_{ebo} is 5V. The 2SD400 handles a maximum collector current I_c of 1A and can handle 2A when pulsed. It has a peak power output of 900mV at the effective operating temperature of 150° c ,therefore it is used for high current applications.

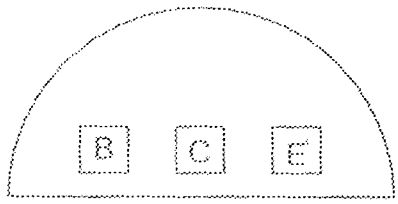


Fig 3.15 The pin layout of the 2SD400 transistor.

Where B is the base terminal,

C is the collector terminal and

E is the emitter terminal. [22, 29, 31]

CHAPTER FOUR

4.1 Tests, Results and Discussion

The circuit was made on a Vero board which was first scrapped with a razor blade. The operation encourages smooth and neat soldering of the components on the board. Usually, the surface of the board is covered with dirt which limits the 'metal-to-metal' soldering contact.

Construction on a bread board was avoided due to assurance that the circuit was going to function properly. This assurance was gotten with the use of the simulation software 'Multisim.' The connection on vero board was done with a moderately heated soldering iron to avoid heat destruction of the components. Numerous changes were made on the initial proposal to obtain effective result.

The first time the circuit was tested; it malfunctioned because the infrared sensor responded to external sources of light thereby giving a false input. Proper shielding of the IR sensor from external light sources with a dark material eradicated this problem.

To test the circuit a one-way slide door had to be used. Making one posed a problem so a modified CD ROM drive was used as a door. This is because it is readily available and cost effective.

The door opened each time someone approached it and closed three seconds after opening. It also remained open for as long as there was someone standing between any one of the IR pairs. The jitter which is 1.7 seconds is due to practical differences and error.

4.2 Casing

The casing is made up of a decorated wooden platform a plastic casing housing the circuit and a modified CD-ROM drive as the door. Two pairs of IR devices are mounted on plastic, on each side of the doorway.

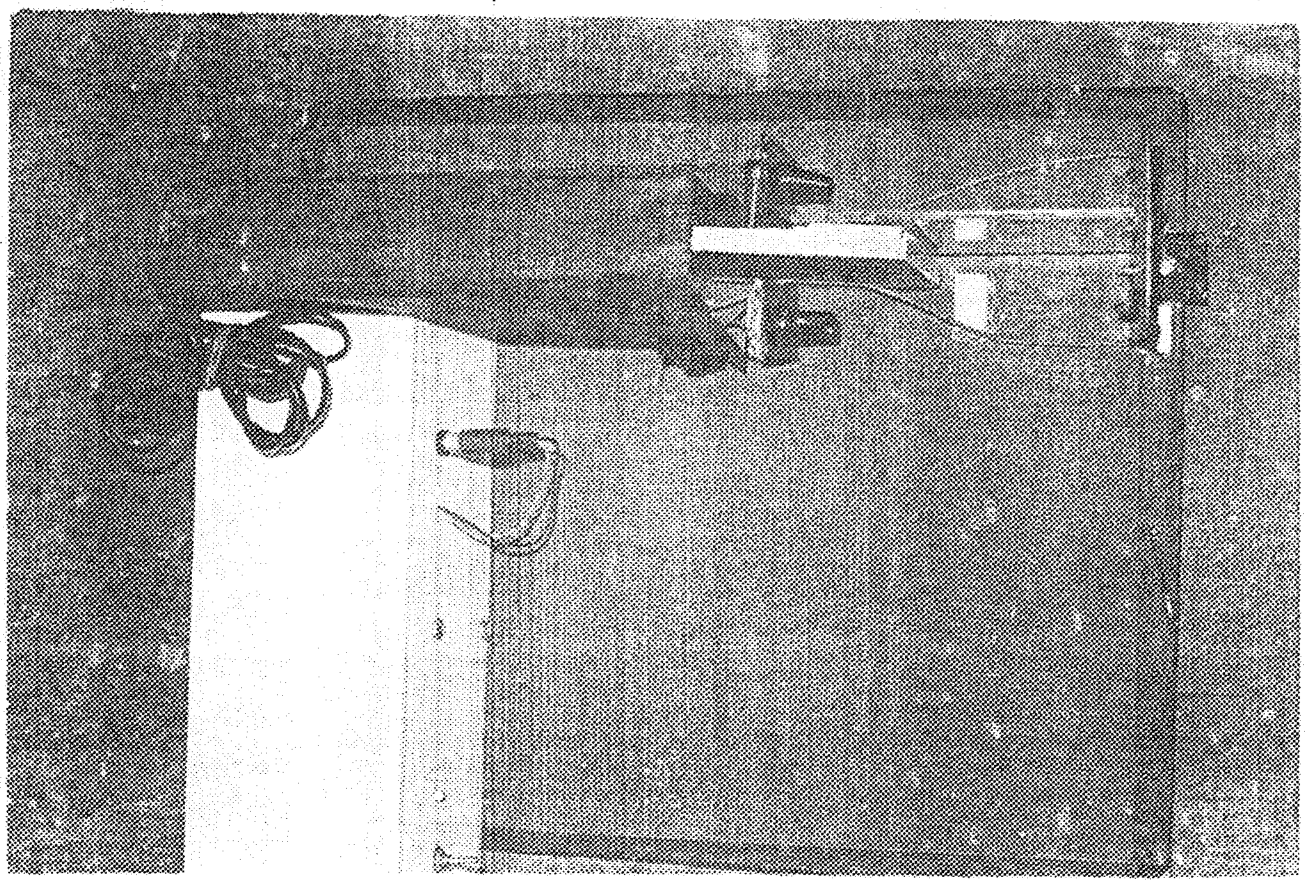


Fig 4.1 Aerial view of the prototype

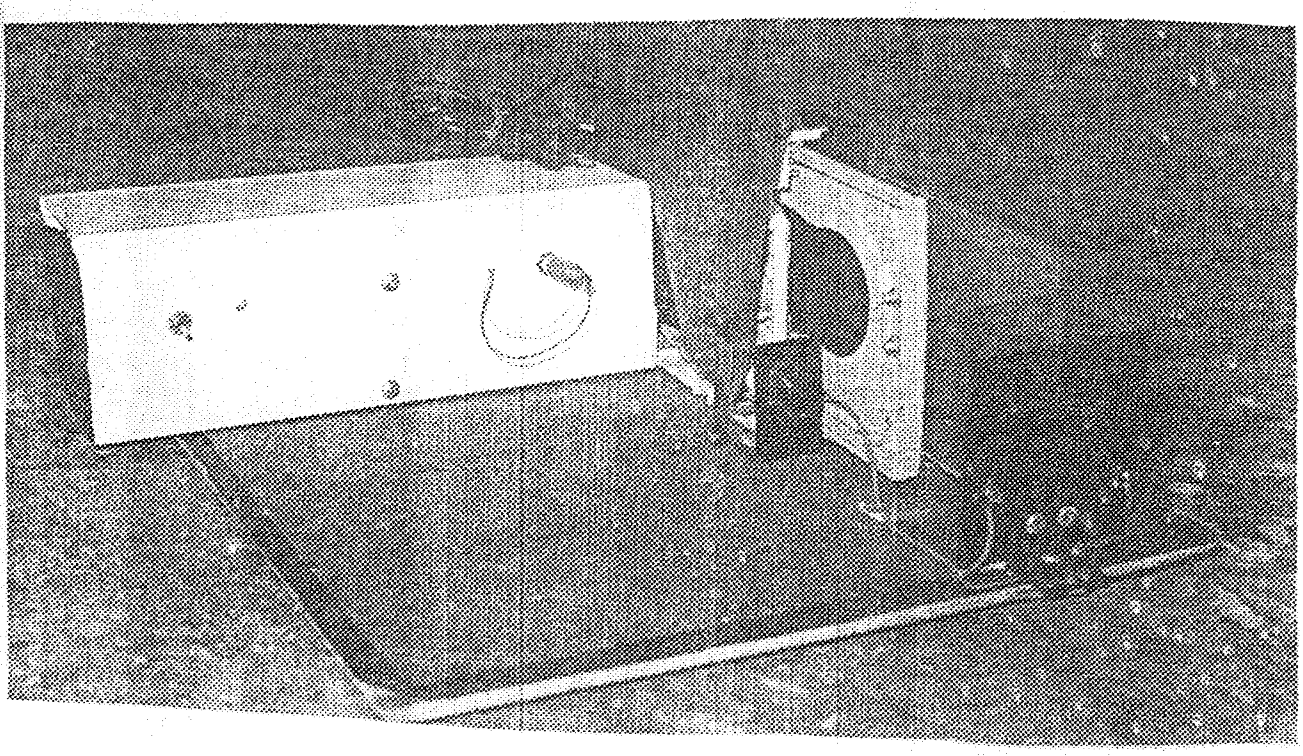


Fig 4.2 Perspective of the prototype

CHAPTER FIVE

CONCLUSION

The project provided a basic experience on electronic components and design. It demonstrated the importance of electronics in control applications.

The application of IR related control techniques in the circuit proofed successful. The involved door was able to be controlled in terms of opening and closing operation, through the breakage and restoration of any of the two IR lines.

The timing feature of the circuit performed to expectation. It allowed for good coordination of the door. Due to time delay, the door did not quickly respond to input conditions. There was delay in action for moderating the operation of the output electric motor which powers the door.

The project exposed me to more electronics and their applications. It is a demonstration of the acquired experience and knowledge within my stay in the university.

5.1 Recommendation

i. The involved ICs could be replaced by a compact microcontroller.

ii. The involved cross-type IR motion sensor could be replaced with relative-type which provides better performance in term of stability. Only two of such devise correspond to three of the early.

iii. A project like this better with computer interfacing which might involve multiple doors.

iv. The involved door system could be incorporated with security features.

v. The circuit could be modified for timing feature which automatically lock and unlock the door at preset time.

vi. A printed board could serve the place of the used Vero board simply for ease in construction.

vii. An uninterruptible power supply (UPS) is better for backing up the system when there is power outage.

5.2 Precautions

i. Each involved IC was protected with a socket. The socket prevents heat damage to the IC

ii. The circuit was never plucked before proper check of the power terminals for short circuit.

iii. Sensitive wires were firmly glued to the Vero board to prevent removal.

iv. Necessary information was possessed on each involved IC before incorporated into the design.

v. Voltage regulators were incorporated into the circuit to prevent effect of low and high voltage from the A.C mains.

vi. Each IR sensor was covered for protection from external light or IR sources which might lead to circuit malfunction.

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