# AUTOMATIC BARRIER SYSTEM

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

_______________________

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TRONOH, PERAK

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ADIBAH SALLEH

# ABSTRACT

The automatic barrier system is widely used in many applications such as parking lots, commercial premises and apartment block access. The problem arises in some situations where some traffic congestion happens at the gate and some minor accidents also occurred, which results in losses to the persons involved. One of the factors that cause the problems is because the attitude of the users who do not obey the instructions of the route stated by the authority. Pertaining to this, Automatic Barrier System is constructed with the objective to design and construct an automatic barrier system, which uses the inductive sensor. The system can be used to control the flow of vehicles at the entrance/exit of an area. The usage of inductive sensor can reduce the dependency on the human handling in controlling the barrier. The system is designed such that the vehicles will only be allowed to enter or exit the area by using the designate gate only. The implementation of this project covers the theories and applications of electronics devices to control DC motor as well as mechanical concepts on the barrier design.

## ACKNOWLEDGEMENT

I wish to remain indebted to a number of individuals who had been of invaluable assistance in the course of realising this Final Year Project. My gratitude goes to my supervisor, Dr. Nazir Ahmed Arain for his valuable suggestions, guidance and help without which this project would have not been realised. His personal warmth, sympathetic considerations for humanity and gentle but firm attitude toward me will remain in my memories forever.

With gratitude, I acknowledge Miss Hawa Md Tahir and all other technicians, for their personal concern and cooperation to me throughout my project period in this university since July 2003 until to date. I also wish to register my thanks to my friends, whose help and support had greatly helped me to adapt and successfully complete the BEng course of study in time. To my family, all the encouragement and continue support given will remain in my memories forever.

Last, but not least, is my indebtedness to my BEng Session 1999-2004 lecturers, the department administrative staff and management of Universiti Teknologi PETRONAS for their patience and kindness without which far less would have achieved.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Objectives of Automatic Barrier System

- To design and construct an automatic barrier system which uses the inductive sensor that can be used to control the flow of vehicles at the entrance/exit of an area.

## 1.2 Background of Study

The automatic barrier system is used for parking lots, toll gates, goods yards, railway crossings, commercial premises, apartment block access and other applications.

Factories and universities also use the system. These premises are categorized as 'busy' as there is large number of vehicles going in and out everyday. The premises usually have two gates, one for the vehicle going "IN" and the other for going "OUT". Unfortunately, there are situations where some traffic congestion happens at the gate. Some minor accidents also occurred that can cause losses to the person involved.

## 1.3 Problem Statement

One of the factors that cause the problems to occur is because the users do not obey the instructions of the route stated by the authority. The premises usually have two gates, one for the vehicle going “IN” and the other for going “OUT”. When the users use wrong entrance or exit, congestion will occur. The direction should be followed by all users to avoid such situation, thus ensuring smooth traffic flow at the gate.

The problems can be overcome by designing one barrier system, which will allow the vehicles to enter or exit the area by using the designate gate only (refer Figure 1.1). The barrier will make sure that the “IN” gate is only been used for incoming vehicles and the “OUT” gate is used for outgoing vehicles as the sensor will only sense the vehicles from one direction. This will ensure smooth traffic flow, as the vehicles will only move in one direction at one side of the gate. Concurrently, percentage of minor accidents to occur can also be reduced.

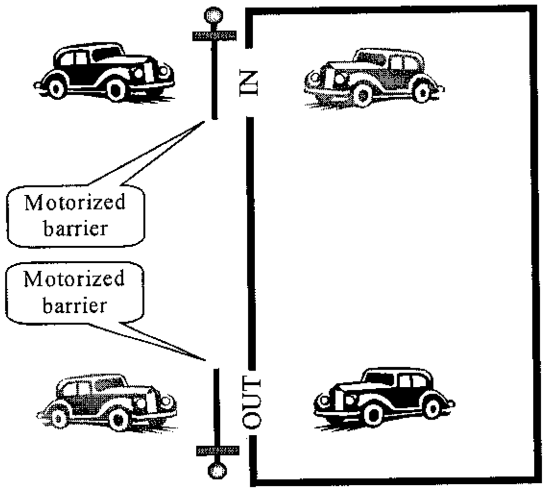


*Figure 1.1 : General concept of barrier system*

Figure 1.1 shows the general concept of barrier system. Two motor operated barriers used to control the vehicles. The barrier at the “IN” gate lifts up only for the vehicles, which come from the outside, and the barrier at the “OUT” gate lifts up only for the outgoing vehicles.

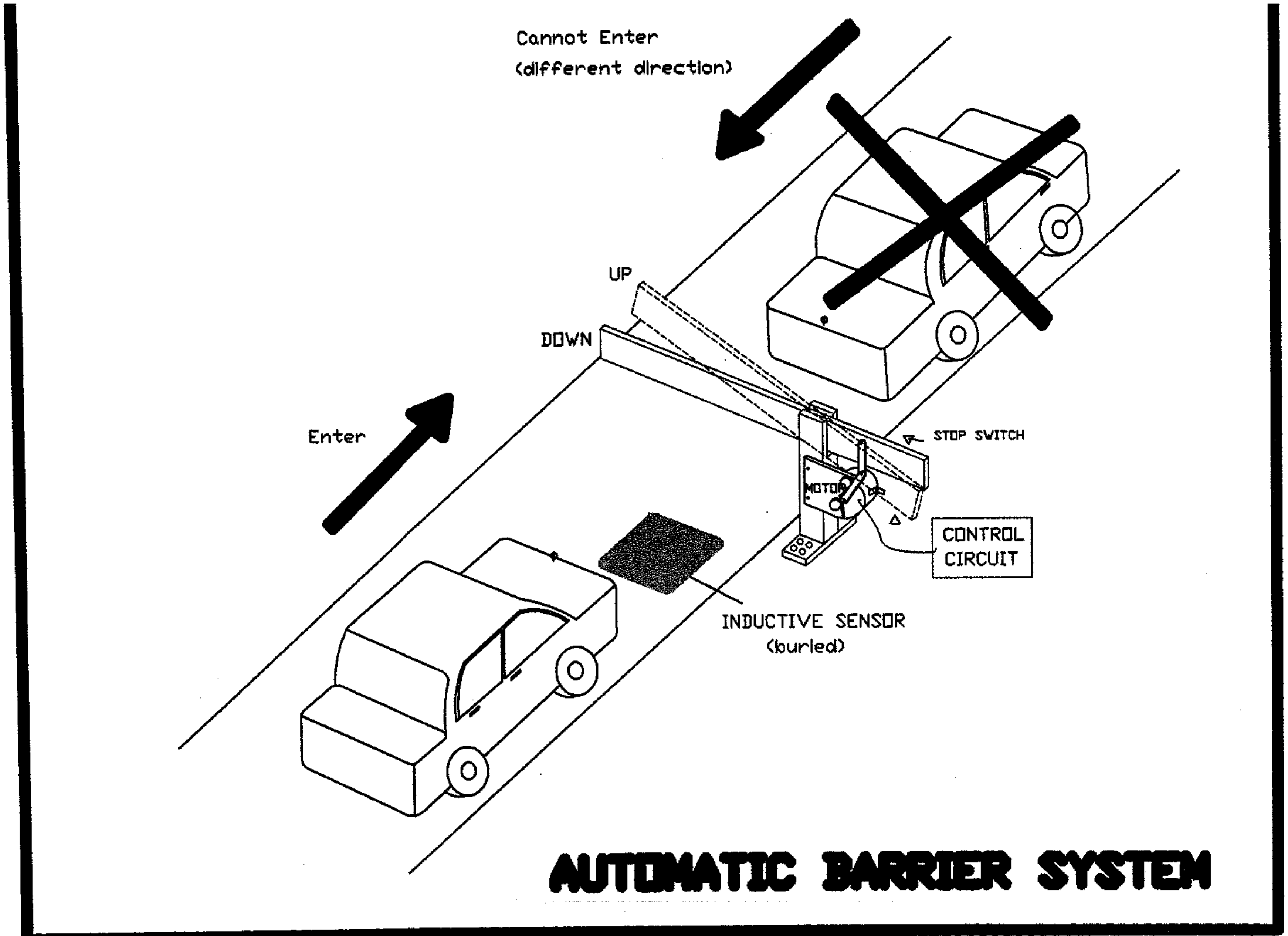


*Figure 1.2 : Block diagram of Automatic Barrier System*

As required by the project, two inductive sensors are used, and buried in the road, one inside the "OUT" gate, and other outside the "IN" gate. Basically, those sensors will only respond to the vehicles, which are going in at the entrance gate, and to the vehicles that are going out at the exit gate. The output signal of the sensor is input signal for the motor, which lifts-up the barrier, when a vehicle comes over the sensor. As shown in Figure 1.2, the crossed vehicles or the one from different direction cannot be sensed by the system, and therefore, the barriers remain down for these vehicles. By applying the concepts and usage of inductive sensors, it will not only focus on controlling the traffic but also it will benefit in economical savings compared to hiring a person to manually handle the barrier or other alternatives.

## 1.4 Scope of Study

Basically the study of this project covers several aspects of designing and applying the system based on relevant concepts in electrical and electronics engineering such as relays, transistors and DC motor as well as some basic concept of mechanical system. A good understanding will be needed in the DC motor control concept and power supply circuits. The project will also use the simulation software such as Electronics Workbench (EWB) in order to simulate the internal functions in the circuit of the system.

The objective of the project is to produce a barrier system that will use the inductive sensor. Thus, as per required, the project will be focused on designing the system but not the inductive sensor. For the purpose of the project, in the prototype, the sensor will be replaced with the switch to give input to the system.

The first semester is allocated for design and simulation of the system. In the second semester, the hardware and prototype development are done. Overall, the scope of study covers the theories and applications of electronics devices to control DC motor as well as mechanical concepts on the barrier design.

# CHAPTER 2
# LITERATURE REVIEW AND THEORY

## 2.1 Theory

The Automatic Barrier System is a barrier system that controls the flow of vehicles entering or exiting specific area by setting one gate for entry and one for exit.

With the normal gate system and without specific entrance and exit gate, the flow of vehicles entering and exiting the area will be disorganized. This can result in a bad traffic system and might cause minor accidents to occur. This can lead to the worst traffic condition at the gate especially during the peak hour when the number of vehicles passing the gate is maximum.

With the implementation of the Automatic Barrier System, the flow of vehicles will be controlled, as the vehicles need to use the designate gate to enter or exit the area.

## 2.2 Full-Wave Bridge Rectifier

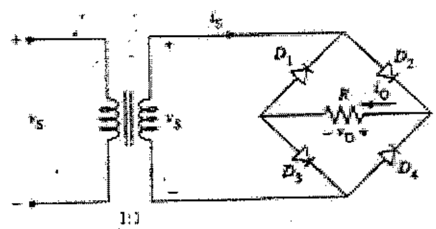


*Figure 2.1 : A full-wave bridge rectifier circui [2]*

Full-wave rectification can be obtained by using a bridge rectifier (refer to Figure 2.1). This full-wave bridge rectifier uses four diodes. During the positive half cycle of the source voltage (refer to Figure 2.2), diodes $D_2$ and $D_3$ are forward biased and can therefore be replaced by a closed switch. The load current flow during this period is through $D_2$ and the load R and then through $D_3$ and back to the source. This causes a positive drop across R.

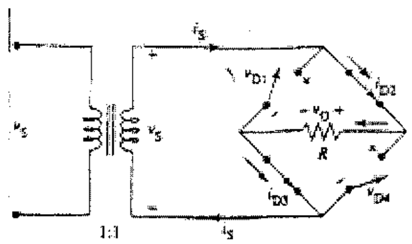

*Figure 2.2 : Bridge rectifier during positive half-cycle [2]*

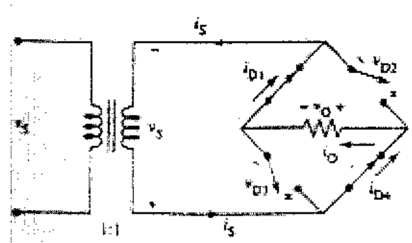

*Figure 2.3 : Bridge rectifier during negative half-cycle [2]*

Figure 2.3 shows the full-wave bridge circuit during the negative half-cycle of the source voltage. Now diodes D1 and D4 are forward biased and can therefore be replaced by closed switches. The load current path is now through $D_4$, through R and then through $D_1$ to the source. The current path through R is in the same direction as before, so there is a positive drop across R during both half cycles. Thus the full-wave bridge rectifier causes the load current to flow during both half-cycles. Figure 2.4 shows the appropriate waveform [2].

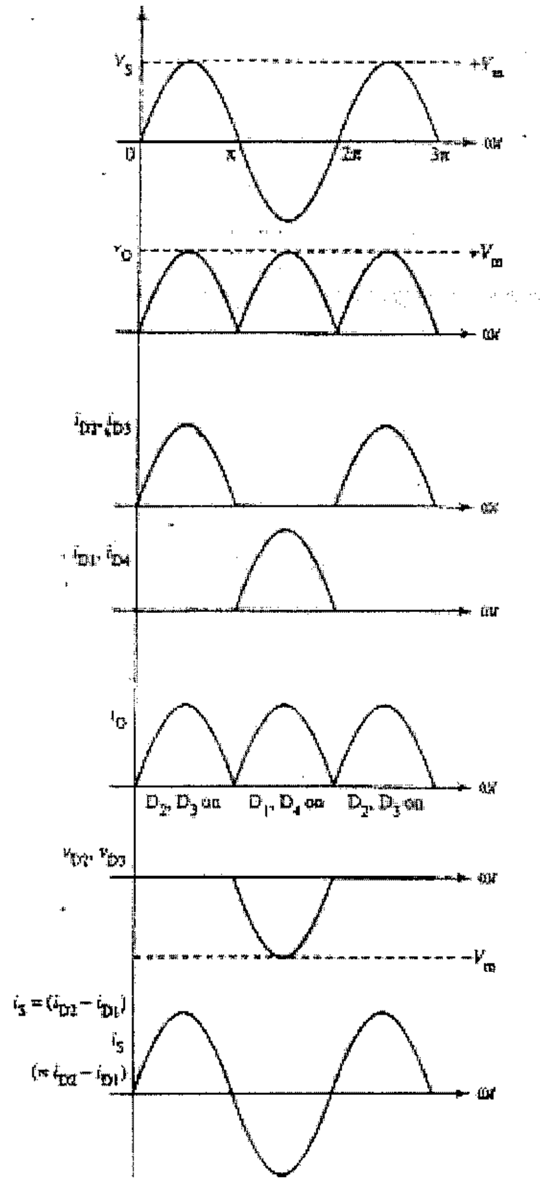


*Figure 2.4 : Bridge rectifier waveforms[2]*

## 2.3 DC Motor Drive using a dc-to-dc Switching Converter

There are a few methods that can be used to control the direction of the DC motor. One of those is by reversing the armature. In this method, the direction of current flowing across the motor is reversed, causing the motor to rotate in reverse direction.

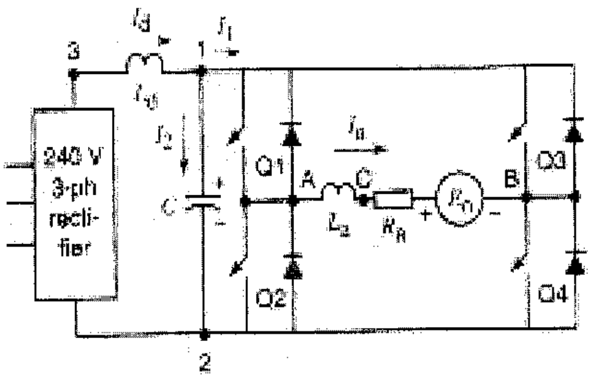


*Figure 2.5 : DC motor controlled by a 4-quadrant dc-o-dc converter[1]*

Figure 2.5 shows a DC motor circuit controlled by a 4-quadrant dc-to-dc converter. This circuit shows that the 3-phase source is converted to dc by means of a 6 pulse uncontrolled rectifier. The converter is composed of IGBT switches Q1, Q2, Q3, Q4 and their associated diodes. Its output terminal A and B are connected to the armature of a DC motor. In this circuit, Q1 and Q4 operate simultaneously, followed by Q2 and Q3, which also open and close simultaneously.

When Q1 and Q4 are conducting, the armature current follows the path shown in Figure 2.5. The motor will then rotate in one direction. When Q2 and Q3 are then operating, the direction of the armature current is reversed i.e. flowing in the opposite direction of the one during Q1 and Q operation. This causes the motor to rotate in reversed direction [1].

## 2.4 Latching Circuit

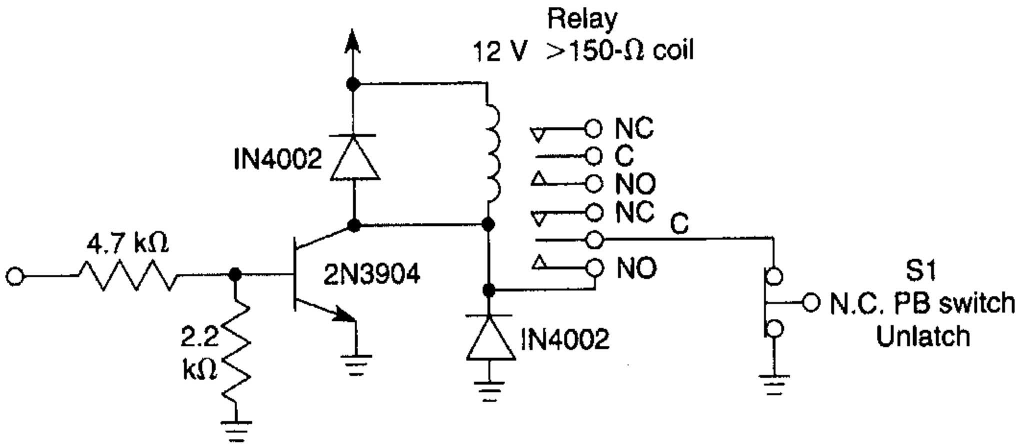


*Figure 2.6 : Latching Circuit [10]*

Part list:

R1 = 4.7 kΩ

R2 = 2.2 kΩ

Q1 = 2N3904

D1, D2 = 1N4002

Relay = 12 V

S1 = Momentary break (normally closed)

Figure 2.6 shows a latching circuit. The latching circuit is used to ensure that the system would trigger and not stop until the reset button is pushed. An input of 4V or greater will drive the circuit. When the relay pulls in, one pair of contacts is used to latch the relay closed. It will remain closed until S1 is pressed and momentarily disrupts power to the latch [10].

# CHAPTER 3
# METHODOLOGY

## 3.1 Methodology

In implementing the project, the procedures as in Figure 3.1 will be followed as a guideline. In the initial stage, research and data gathering will be done to get the overview of the project and obtaining the information related. This procedure will be done throughout the project period. The research will cover the theories and concepts involved, components required, datasheets on every part and system related to barrier system. All circuits related are evaluated and the suitable concepts are implemented on the project. Parts needed for the project are transformer 240 V/ 12 V, transistor, resistor (various values), capacitor, relay 12 V, diode, reset button, switches, breadboard and Printed Circuit Board (PCB).

The layout of the barrier system will need to be designed. This will involve the mechanical system that can be applied in controlling the barrier up and down. The most suitable concept obtained will be applied and built. The DC motor is considered the heart of the system. Selection of the motor will need to be carefully done to assure its quality and reliability so that it can comply with the system requirement. The design of electronic circuitry involved both power supply circuit and switching circuit.

The mechanical system, DC motor and the electronic circuitry will be tested concurrently. Any problems will be evaluated and overcame. At the final stage, the prototype of the barrier system will be constructed. The prototype will be tested to check whether it fulfill the system requirement or not.

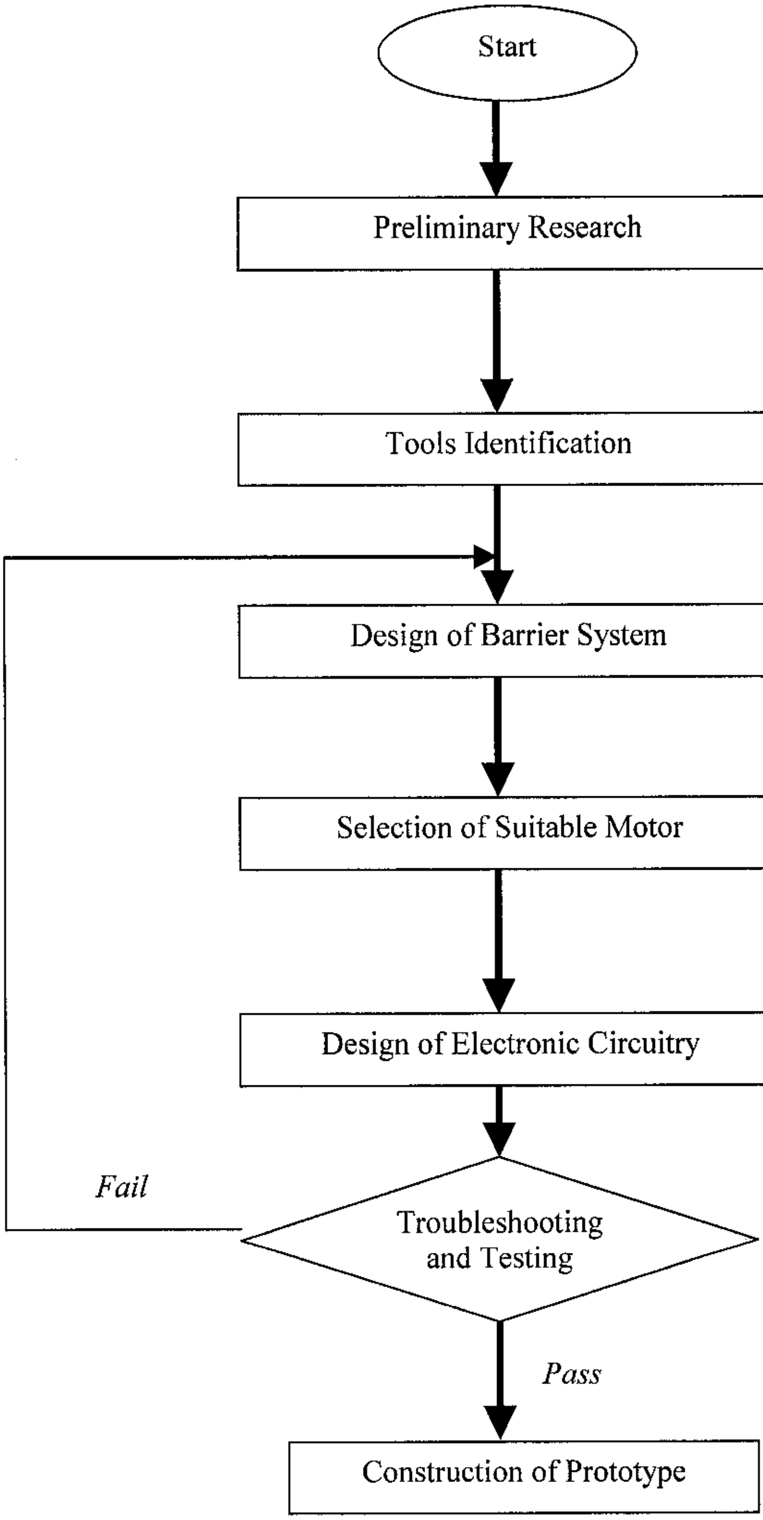


*Figure 3.1 : Project Flow Chart*

## 3.2 Project Work

Under this section, a brief discussion will be presented on the works and procedure that have been done.

### 3.2.1 Research and Data Gathering

This is the most important and crucial part in executing the project. Research was done continuously since the first week and will be continued throughout the project period. Basically, a thorough research has been done on suitable mechanical concept for the barrier design, the electronic circuit required to control the system, the barrier system requirements, reliability and components availability and cost.. The research and data gathering was done via the reference books and the internet (please refer to the references section).

(a) Barrier System Requirements

The first step is to define precisely the requirement of a barrier system. The system should able to interface the inductive sensor and this can be done by the electronics circuitry. A suitable mechanical system needs to be designed to allow it to be driven by the electronic circuitry.

(b) Basic Barrier Concept and Circuit

Research on this matter was thoroughly done from the internet and electronic books. The information on the latching circuit [10], switching circuit [11], power supply circuit, DC motor as well as suitable mechanical concept are obtained. Before applying them, this information is modified to assure the results fulfill the system requirement.
The circuit designed is simulated using the Electronics Workbench (EWB) software. This is to prove that the circuit works fine and is reliable before constructing the prototype of the system.

### 3.2.2 Prototype

After designing and simulating the system in the EWB, the circuit is then constructed on the breadboard for testing. The condition required for testing the circuit is at normal room temperature and preferably in the lab because a multimeter will be required for troubleshooting, as errors will occur during this stage. The mechanical system is also constructed as designed. The electronic circuitry is then interfaced with the mechanical system and the barrier system is then tested for it workability and reliability. A proper prototype is then prepared where the electronic circuitry is then constructed on the bare board and the mechanical system is properly built.

# CHAPTER 4
# RESULTS AND DISCUSSION

Basically, the automatic barrier system is a combination of two main sub-system i.e. mechanical systems and electronics system (the circuitry). As can be seen, the barrier will be attached to the motor that will control its movement. This motor will be controlled by the electronic circuit. The circuitry is designed to control the motor and interface it with the input from the inductive sensor.

## 4.1 Barrier Design and Construction

Two main components are involved in this section, which are the motor and the mechanical design for the layout.

### 4.1.1 Motor

The car wiper motor is one of the motors that can be used for the barrier design. The motor will functions as the source, which will control the movement of the barrier. The motor will rotate in both directions i.e. clockwise and anti-clockwise, and this will result in lifting the barrier up or down.

The motor used in the system is the car wiper motor that uses 12V DC as the power source. The motor will rotate in both directions. When activated, the motor will rotate and this causes the barrier arm to be lifted up or down.

### 4.1.2 Mechanical System

As stated, the barrier arm will be controlled by the movement of the motor (refer Figure 4.4 for system layout). Two aluminum plats are attached, to the motor (refer Figure 4.1). The plat is then attached to one end of the barrier arm. (refer Figure 4.2 and Figure 4.3). When the motor is driven to rotate in clockwise direction, the plat will pull one side of the barrier arm down, thus lifting the other end up (refer Figure 4.5). One spring is attached at the end of the barrier arm to give more force in pulling up the barrier arm as well as for safety precaution. When the motor is driven to rotate in anti-clockwise direction, the plat will push the barrier arm up, thus pulling down its other end (refer Figure 4.6). In this position, the whole system is said to be in home position. The level of the barrier arm being lifted up or pulled down is controlled by putting two corks, which will hold the motor from rotating further. The corks can withstand the force by the motor since the motor is running in lower speed, which actually give lower torque.

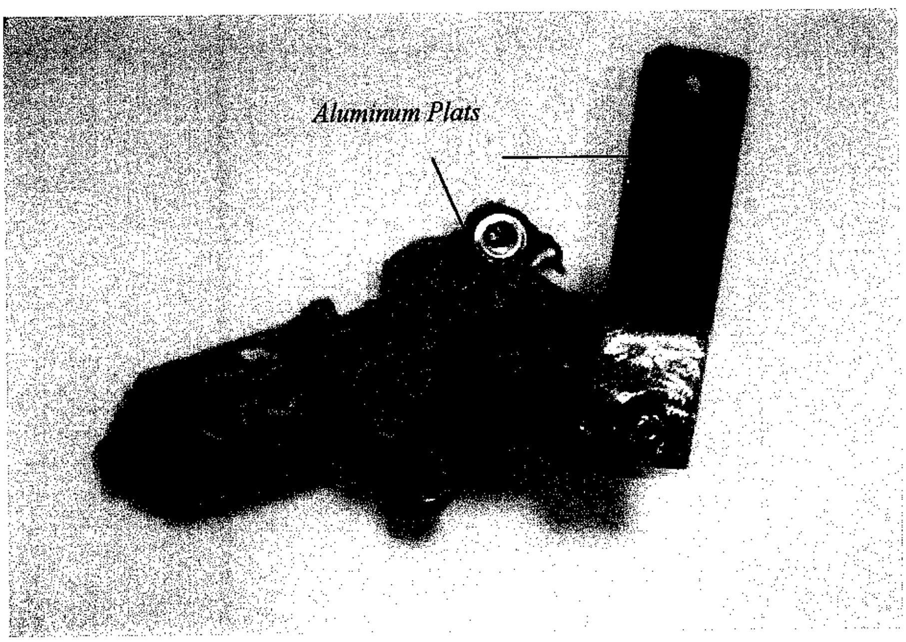


*Figure 4.1 : Motor with two aluminum plats attached*

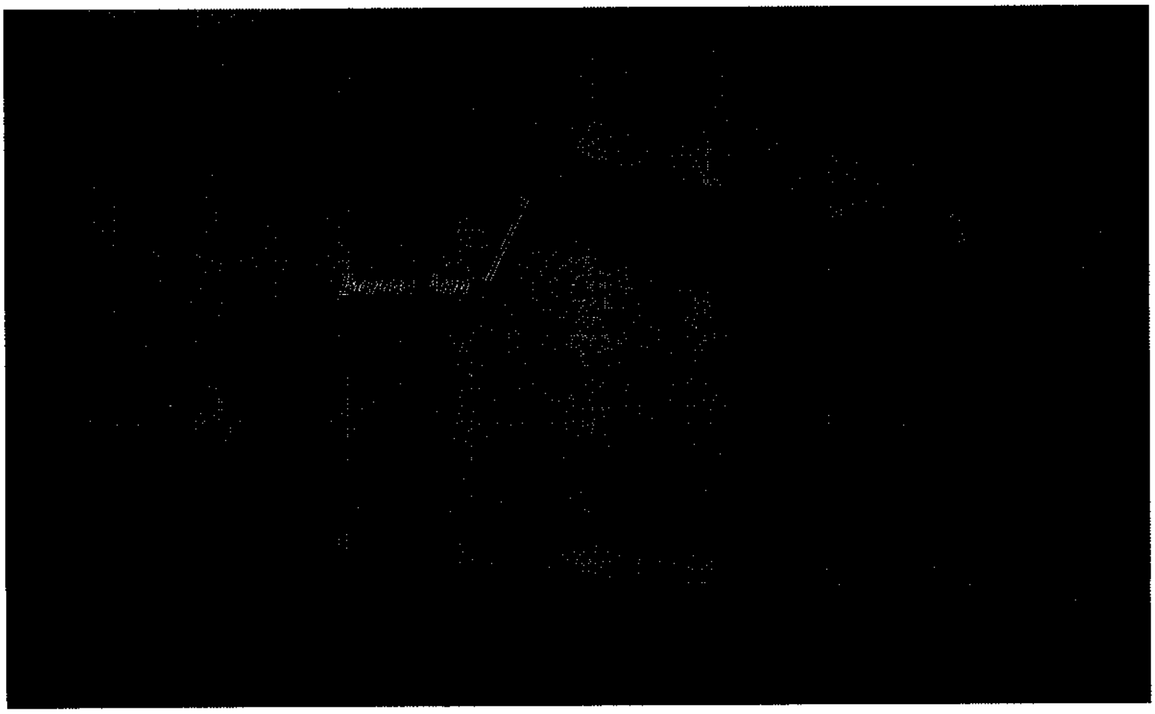

*Figure 4.2 : The model of the barrier arm*

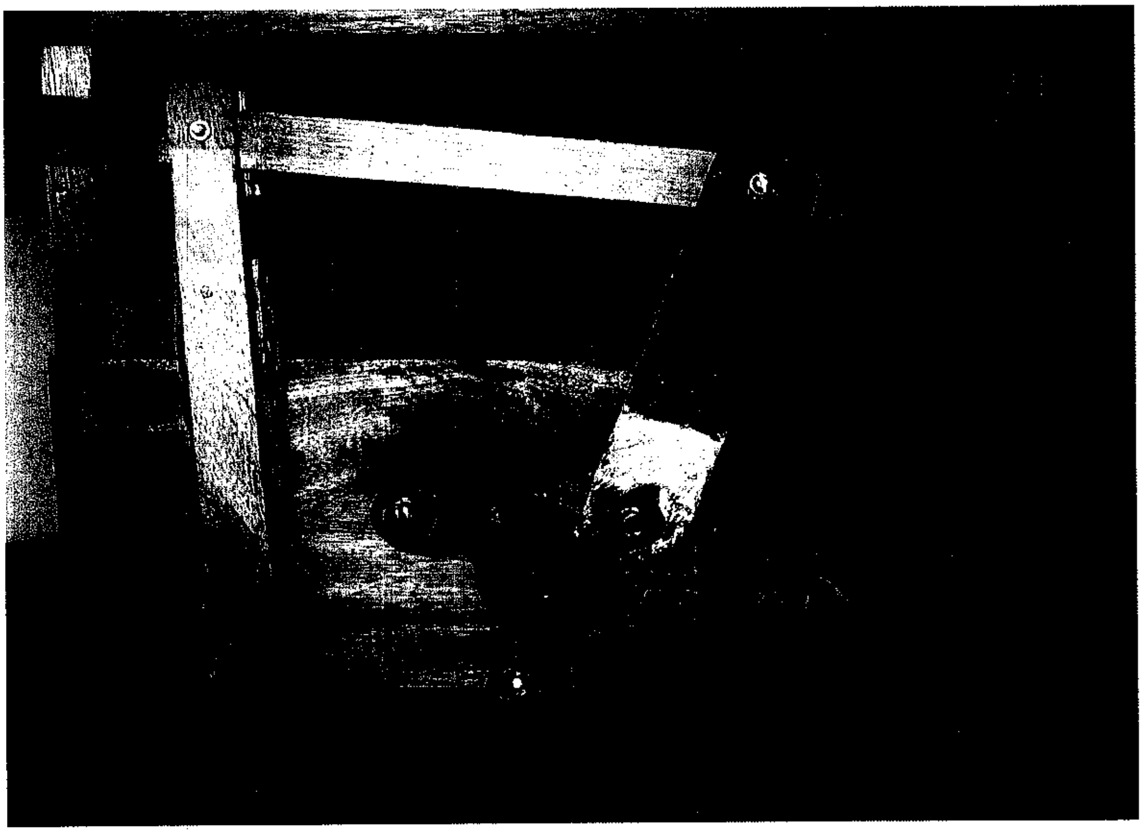

*Figure 4.3: The plat is attached to one side of the barrier arm.*

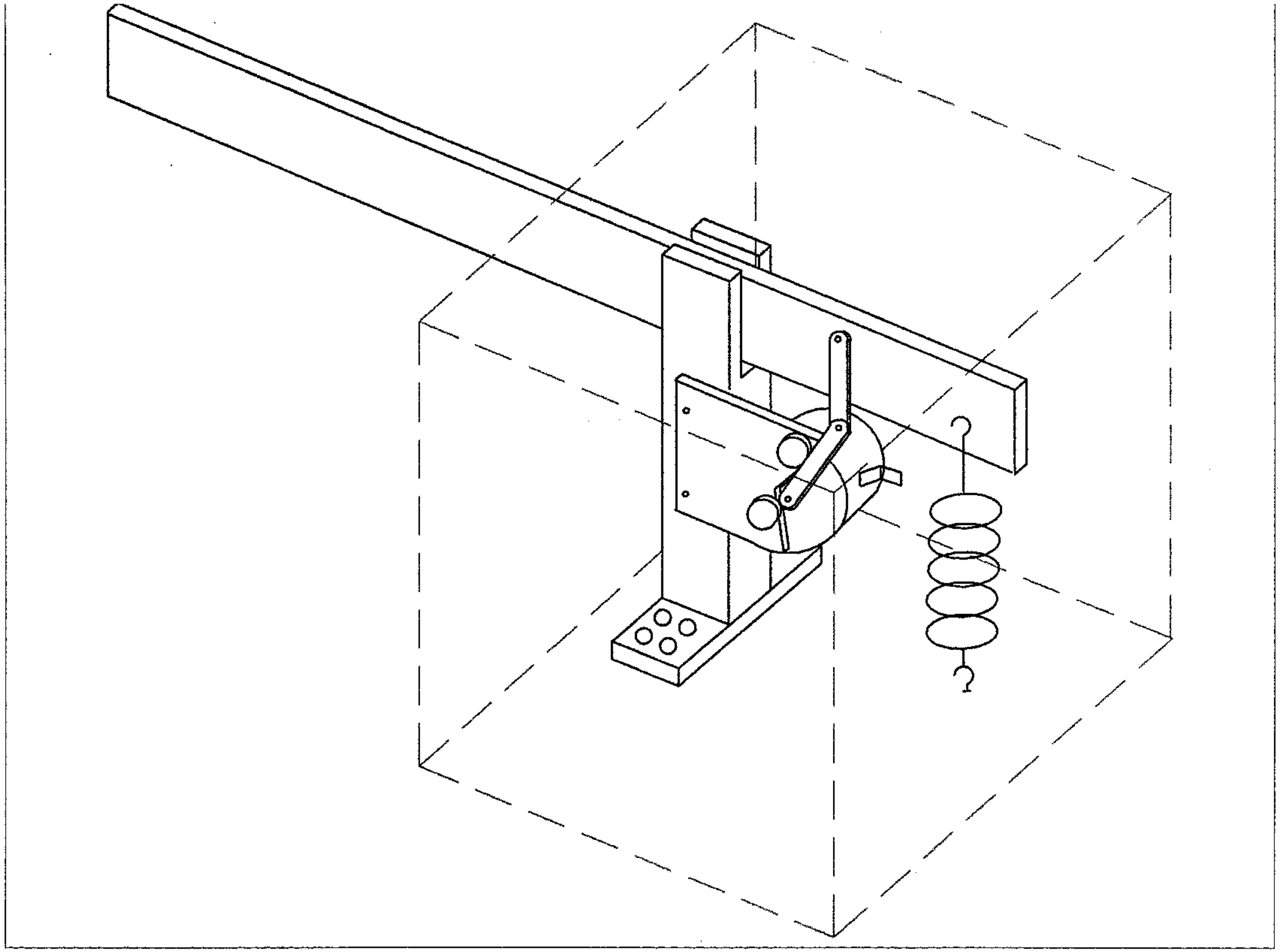

*Figure 4.4: Layout of barrier system*

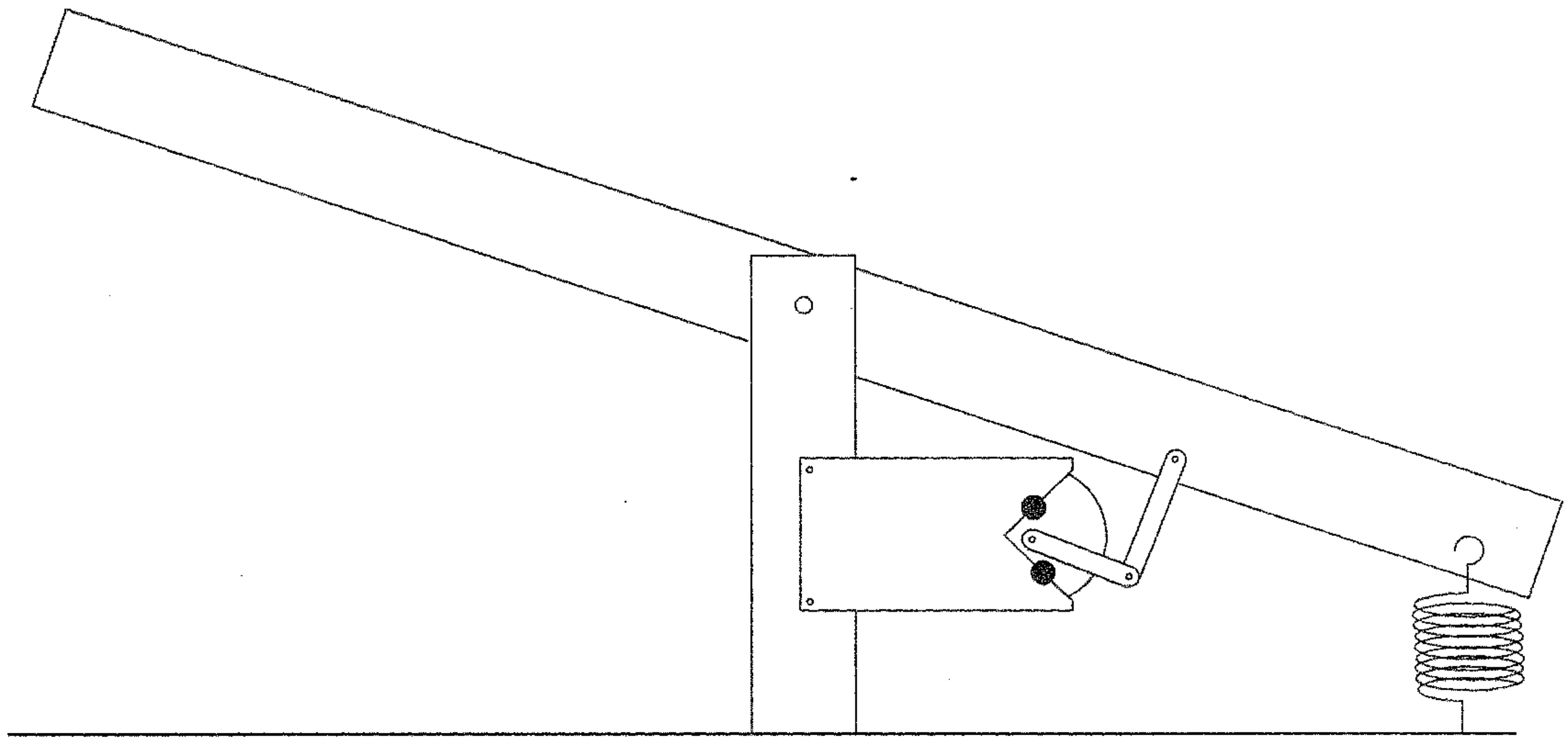

*Figure 4.5: Barrier being lifted up*

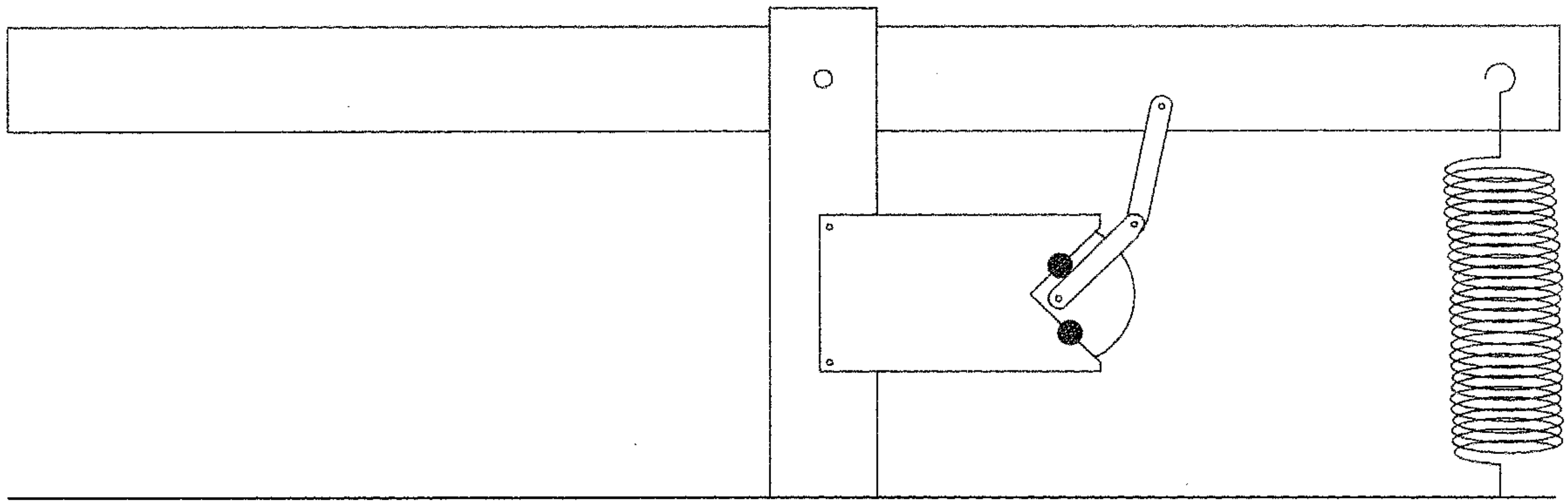

*Figure 4.6: Barrier being lifted down (home position)*

## 4.2 Electronic Circuit Design and Construction

There are two main electronic circuit used, which are the power supply circuit and the switching circuit. Figure 4.7 shows the block diagram of the electronic system used.

### 4.2.1 Power Supply

Figure 4.8 shows the power supply circuit. A power supply circuit is used to control the voltage supply to the circuit. A center tab transformer is used to step down the source supply. Combination of capacitor-input filter with an integrated circuit (IC) voltage regulator is used. A voltage regulator prevents changes in the filter dc voltage due to variations in input voltage load. An integrated circuit voltage regulator is connected to the output of a filtered rectifier and maintains a constant output voltage (or current) despite changes in the input, the load current or the temperature. This device will take a variable input voltage (usually up to 20-30 Volts) and drop it down to a fixed output voltage. The capacitor-input filter reduces the input ripple to the regulator to an acceptable level. The combination of a large capacitor and an IC regulator is inexpensive and helps to produce an excellent small power supply [3].

In the power supply circuit, the fixed three terminal regulator used is 7812 series, which has a +12 V output. The voltage regulated will be supplied to the input of the switching circuit. Filtering is done by capacitor, C1 of 10000 μF. An output capacitor, C2 (1 μF) is placed in parallel to output to improve the transient response.

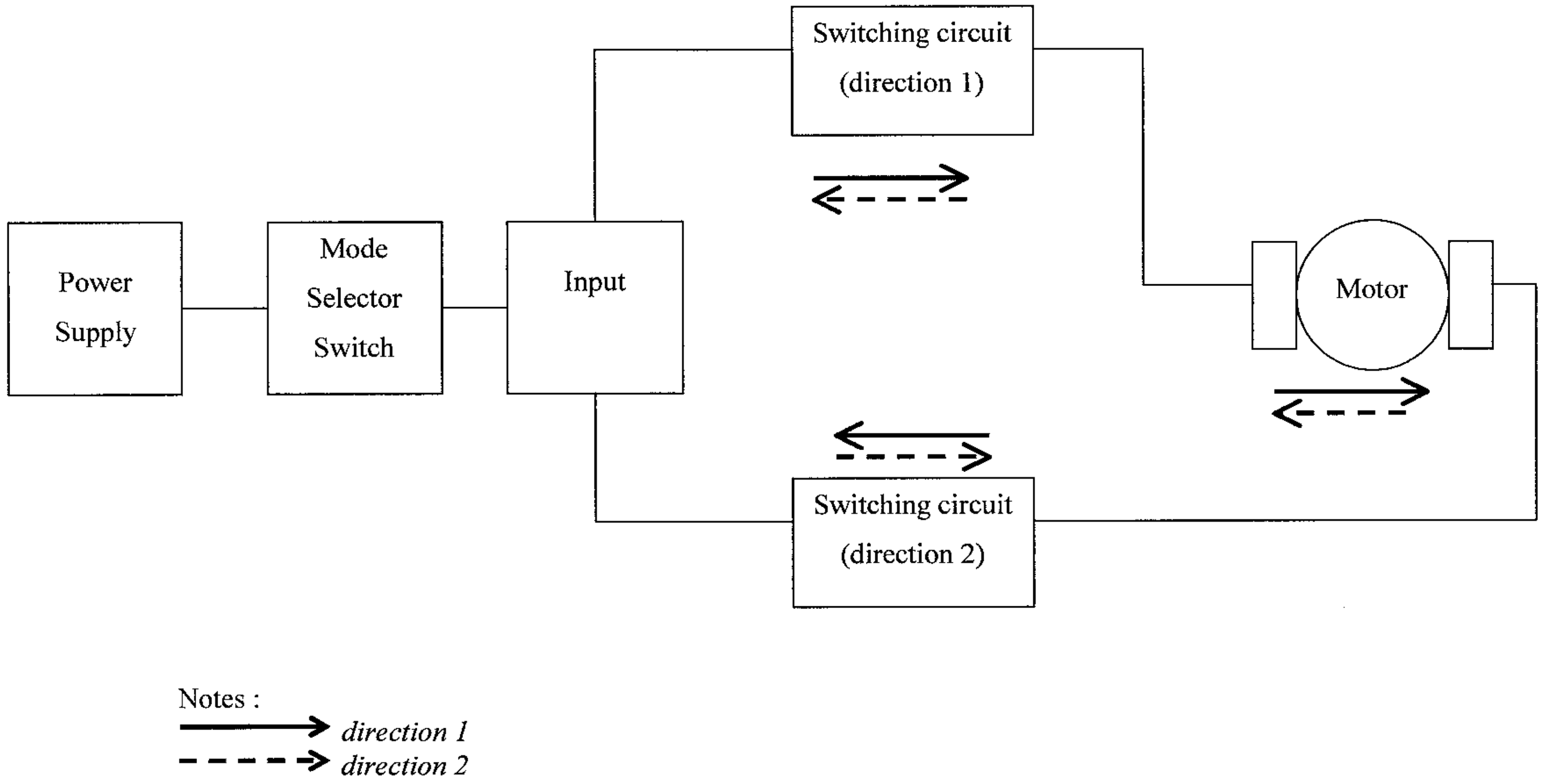


*Figure 4.7: Block diagram of electronic system*

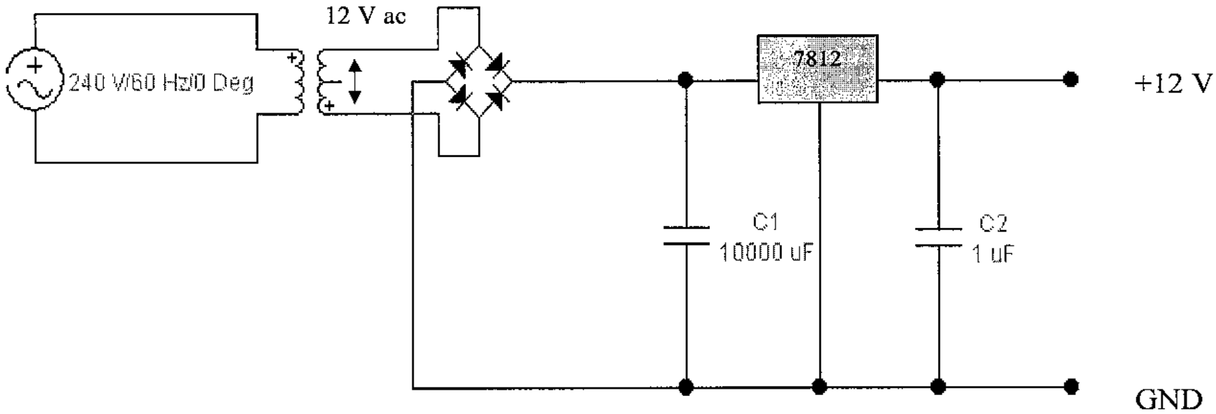


*Figure 4.8 : A +12 V Regulated Power Supply*

### 4.2.2 Switching Circuit

As shown in Figure 4.7, the electronic system consist of two switching circuit, which will be activated one at a time. When switching circuit 1 is activated, the current will flow in direction 1 (according to the fine line arrow) and the motor will rotate in direction 1. When switching circuit 2 is activated, the current will flow in direction 2 (according to the dashed line arrow) and the motor will rotate in direction 2. Figure 4.9 shows the DC motor switching circuit. The circuit controls the direction of the motor, but not the speed. In this circuit, the latching circuit [10] is combined with the switching circuit, which is controlled by the relay. Latching circuit is applied as to give signal and upon the signal, the circuit will continuously operate until reset switch is pressed. The relays control the forward, reverse and stop action. In DC motor application, the direction of the motor should not be straightly reversed because when running, a motor develops a back emf voltage which would add to current flow in the opposite direction. Pertaining to this, in this circuit, the stop switch should be pressed first before reversing the direction, either forward or backward. When the forward button is pressed, the motor will run continuously in one direction. The reverse button will cause the motor to rotate in opposite direction, or until the stop button is used.

This circuit is able to operate in two modes, manual and automatic. One mode selector switch is provided. Manual mode allows the user to manually give the input to the system. In automatic mode, the input is given by the inductive sensor. The input will trigger the circuit and the circuit operates automatically.

For safety purposes, the stop button can be controlled both automatically and manually. This will help in case of any switch failure. Other than this, one emergency switch is provided. In case of emergency, the switch can be pressed and the supply to the circuit will be cut. All operation will be disabled until the emergency switch is released.

*Circuit Operation:*

Assume the motor is not running, all relays are unenergized and emergency switch is released. The mode selector switch is pressed according to the mode required. When the Forward switch is activated (either in manual or automatic mode), a positive battery is applied via Relay RB1. The latching circuit operates (transistor on) and Relay RA1 will be activated. The relay activates Relay RA2 and RC1. The contacts apply power to the motor, which will now run continuously in one direction. If now the Reverse switch is activated, nothing will happen because the positive supply for the switch is fed via the contact of Relay RB1, which is not being operated. To stop the motor, the stop switch, S1 is activated, which will then turn off the transistor and cut the power to Relay RA1, Relay RA2 and Relay RC1. If the Reverse switch is now activated, a positive battery is applied via Relay RA1. The latching circuit operates (transistor on) and Relay RB1 will be activated. The relay activates Relay RB2 and RC2. The contacts apply power to the motor, which will now run continuously in one direction. To stop the motor, the stop switch, S2 is activated, which will then turn off the transistor and cut the power to Relay RB1, Relay RB2 and Relay RC2.

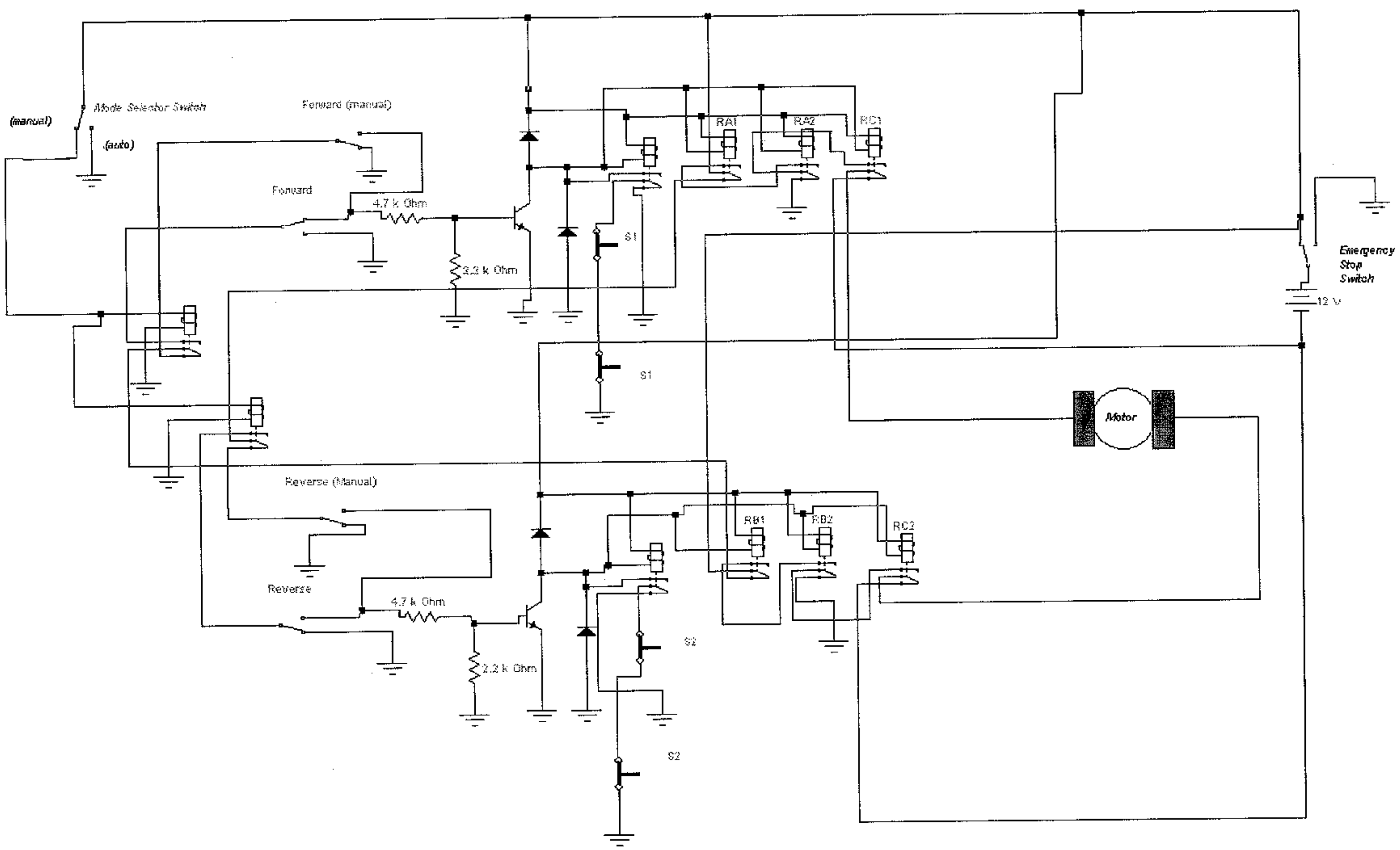


*Figure 4.9: Switching circuit*

**4.3 Interfacing the barrier system with the electronic circuitry**

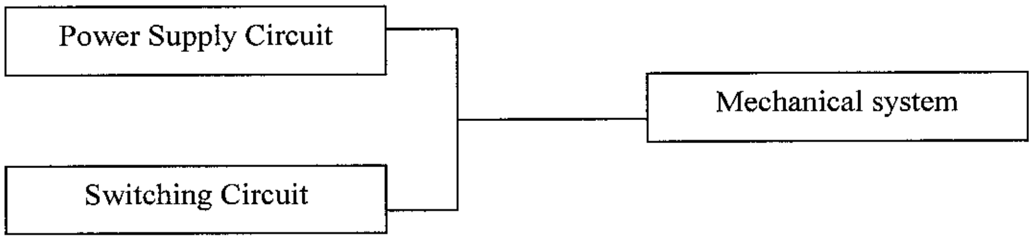


*Figure 4.10: Interfacing the sub-system*

Figure 4.10 shows the sub-system of the barrier system. In the electronic circuit, power supply will be used to give supply to the switching circuit. This will ensure all relay triggering can be done and the circuit functions accordingly. The electronic circuitry will then be interfaced with the barrier system by using it to control the operation of the motor.

Figure 4.11, 4.12, 4.13 and 4.14 show the barrier system. The electronic circuitry has been interfaced with the mechanical system. The barrier system operates as required.

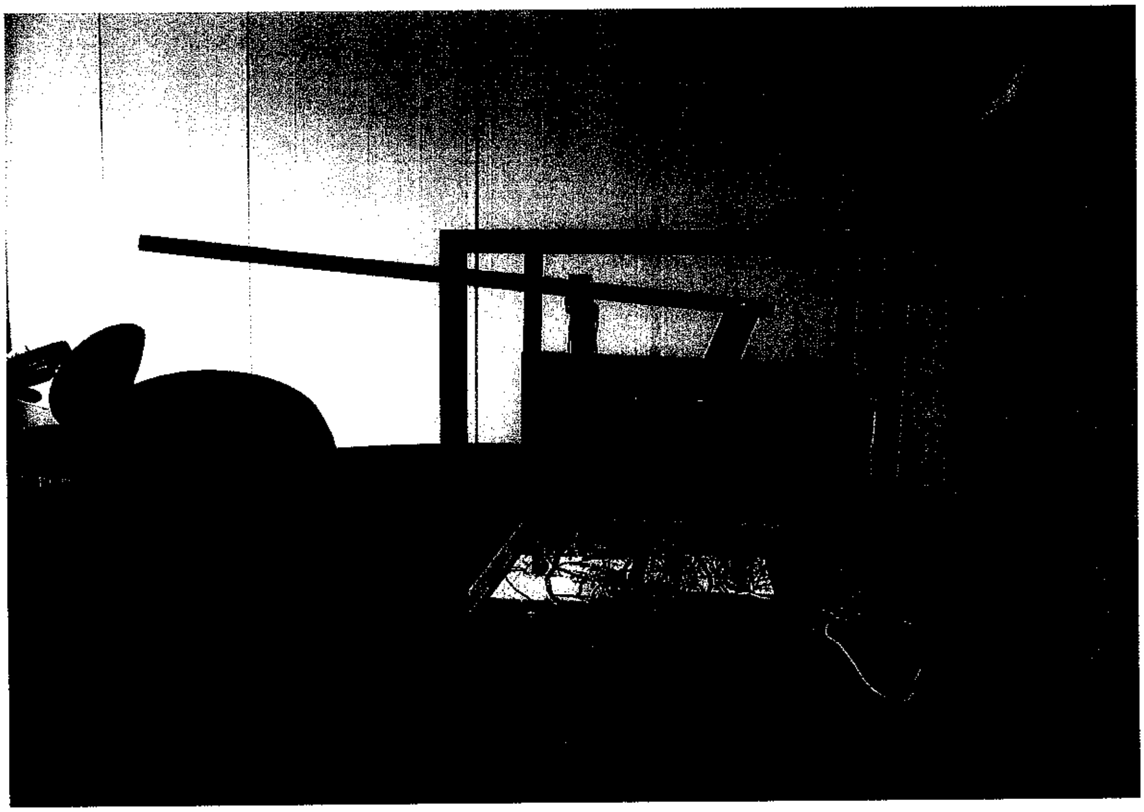

*Figure 4.11 : Overall layout of Automatic Barrier System*

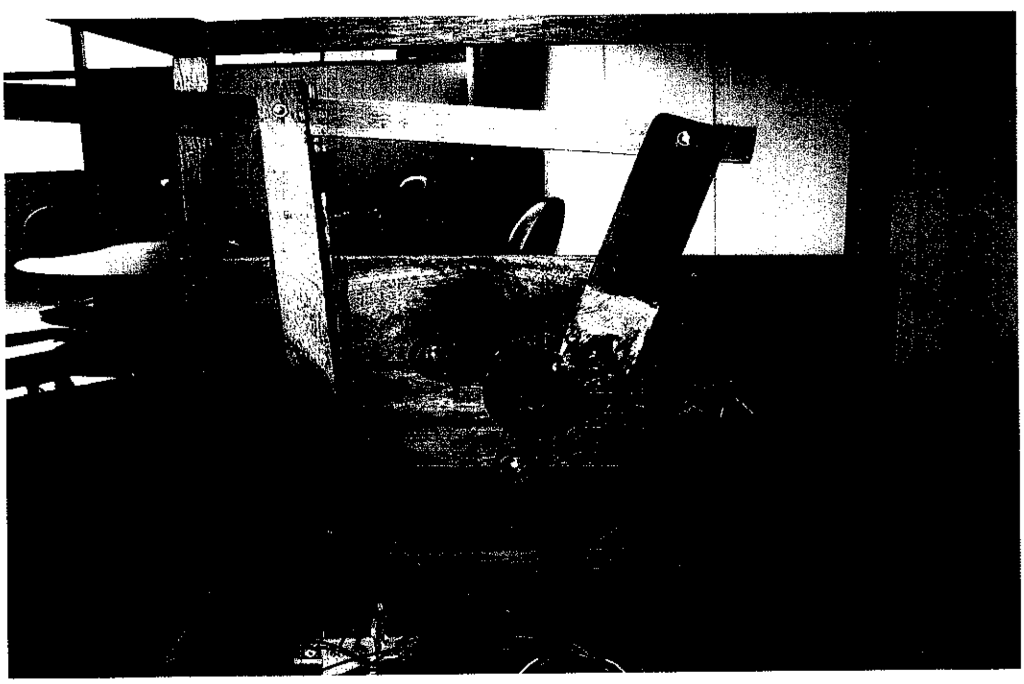

*Figure 4.12 : Motor attached to the barrier arm*

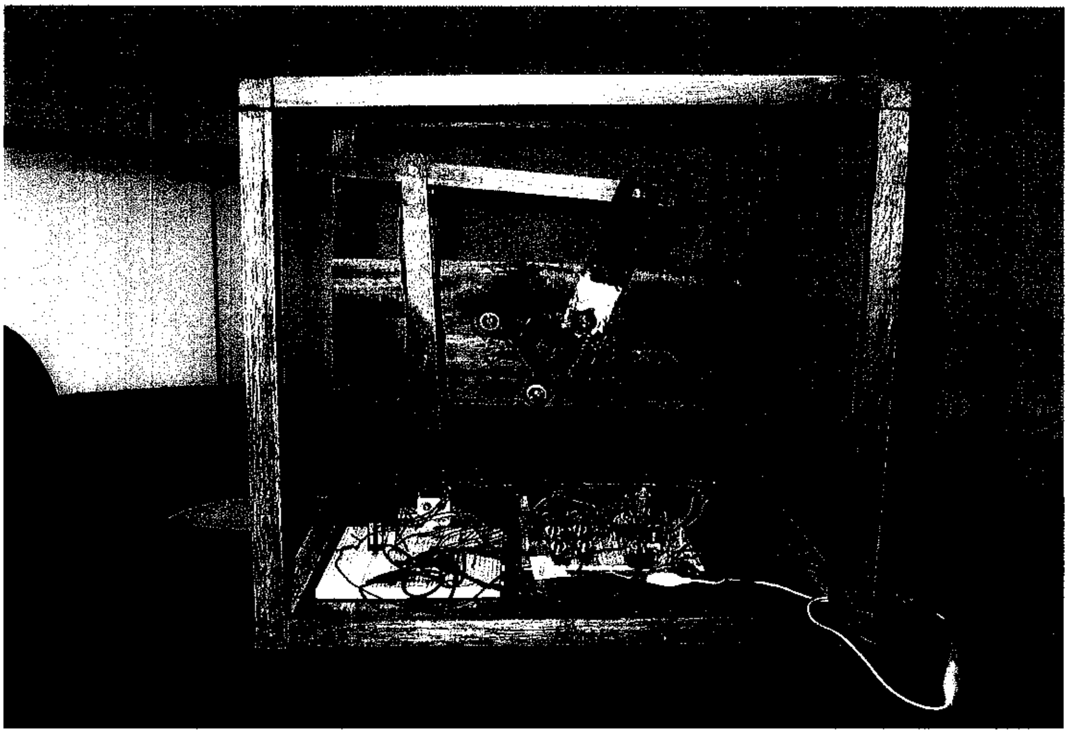

*Figure 4.13: Motor controlled by the electronic circuitry attached to the mechanical system*

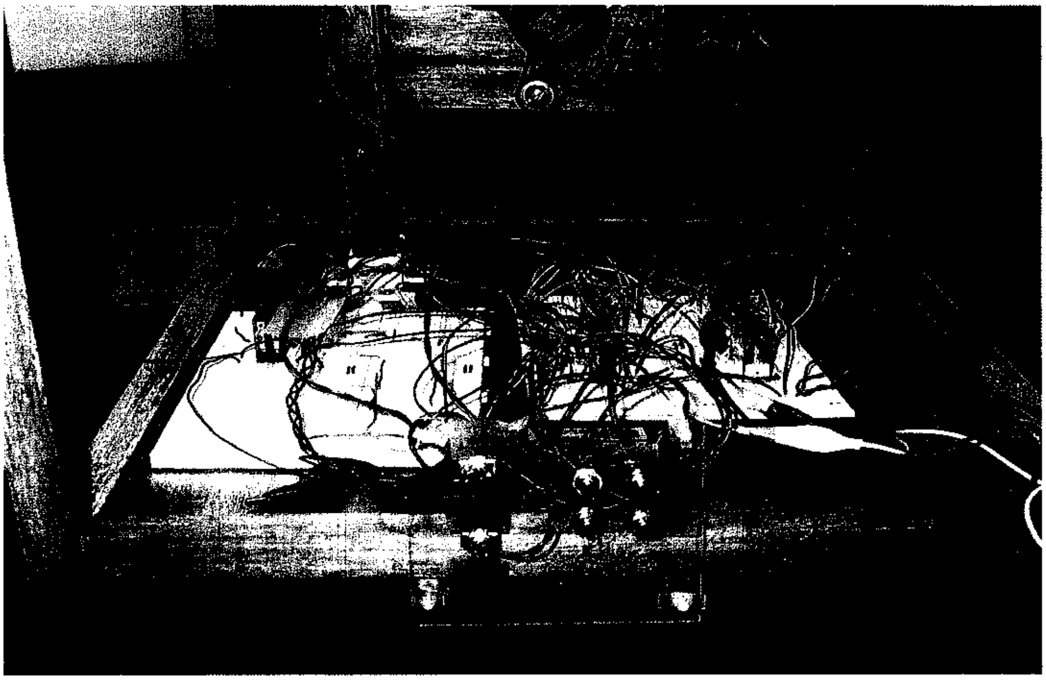

*Figure 4.14 : Electronic circuitry to control the barrier system*

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The Automatic Barrier System designed in this project uses the input from the inductive sensor as in the automatic mode. This is to reduce the dependency on the human handling in controlling the barrier system. The usage of the sensor proved that the design of the Automatic Barrier System fulfills the project requirement as to design and construct an automatic barrier system which uses the inductive sensor. As a conclusion, the objective of this project has successfully been achieved.

The Automatic Barrier System has been designed in such a way that the vehicles are allowed to enter or exit the area by using the designate gate only. This is assured by the sensors used, which will only respond to the vehicles that are going in at the entrance gate, and to the vehicles that are going out at the exit gate. This concept will make sure that the vehicles will only flow in one direction at one gate. From the concept, it is shown that the design of this Automatic Barrier System achieved the other objectives of the project, which is to control the flow of vehicles at the entrance/exit of an area. Once again, the requirement of the project has successfully been fulfilled.

## 5.2 Recommendation

There are several recommendations that can be applied to further improve the system in the future.

### 5.2.1 Replacing relay with logic gates

For system improvement, the relay can be replaced by logic gates such as flip flop as the usage of the gates is more reliable.

### 5.2.2 Use of more sensors

To increase the efficiency of the system, more sensors can be used such as weight sensor or infrared sensor, together with the inductive sensor. This can also improve the system accuracy as more factors are being considered before triggering the system.

### 5.2.3 System applicable for both direct source and battery source

The system can also be designed so that it can receive the supply from both direct power source or from 12 V battery. This can increase the system efficiency and reliability.

### 5.2.4 Advance interfacing component

Some advance components can be added into the system. Connections for ticket dispenser, photocells, loop detector, IC card, alarm lamp and remote controller can be designed and this will widen the usage of this Automatic Barrier System.

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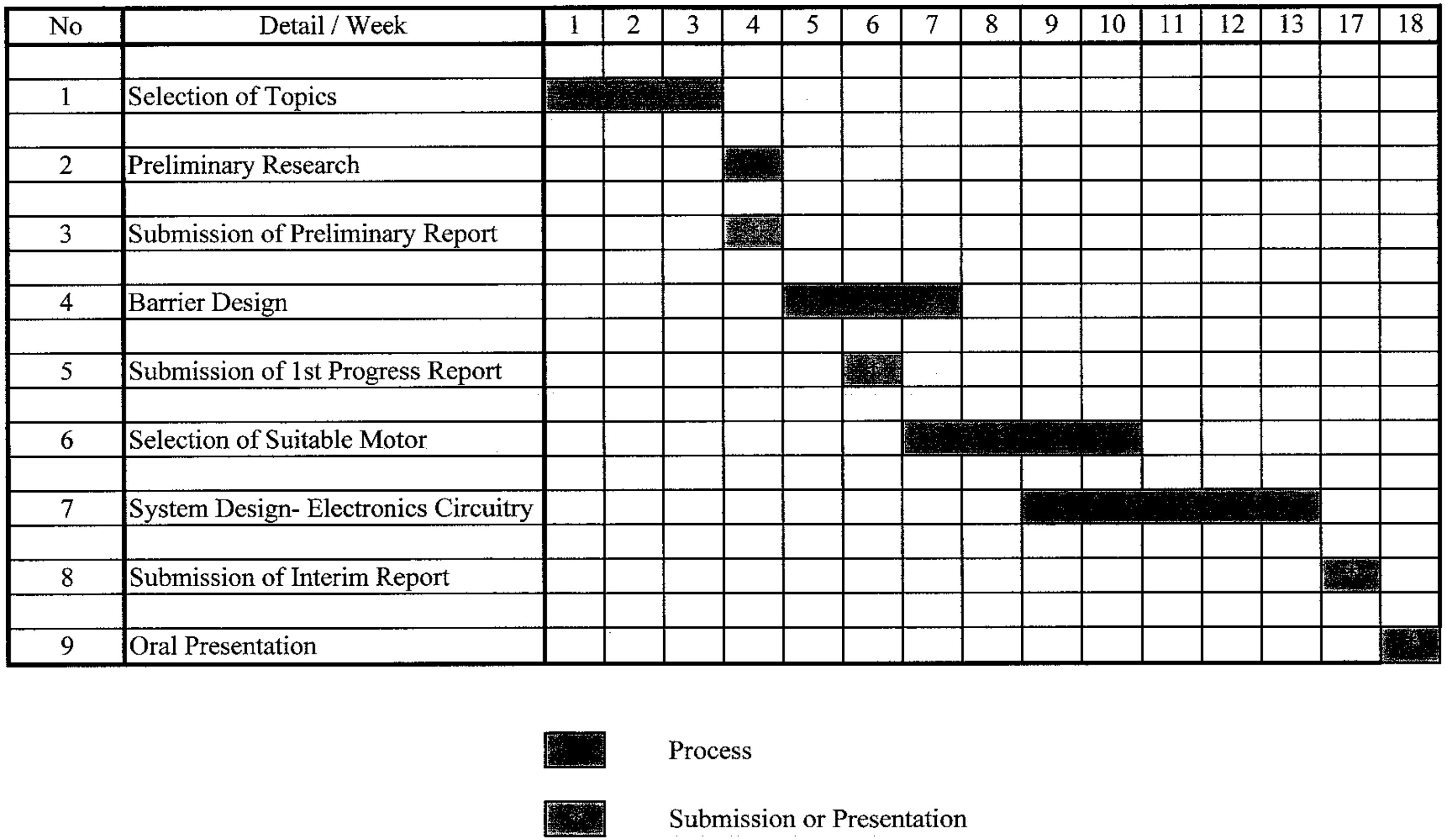
# APPENDICES

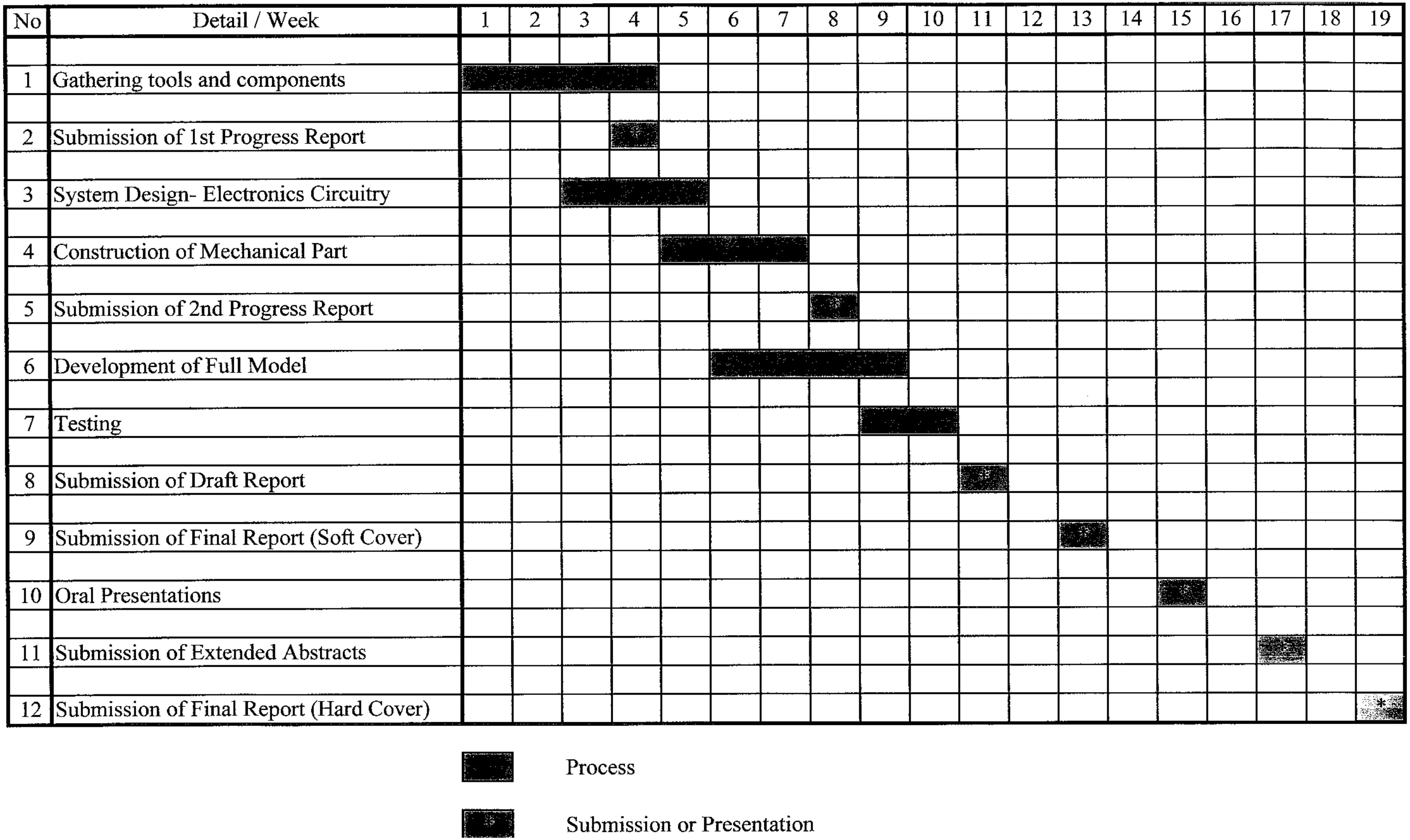
# APPENDIX A

# PROJECT GANTT CHART

**Appendix A-1 : Gantt Chart for the First Semester of Final Year Project ( July 2003)**



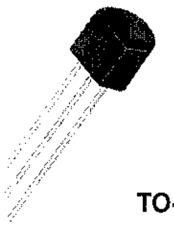
Appendix A-2 : Gantt Chart for the Second Semester of Final Year Project (January 2007)



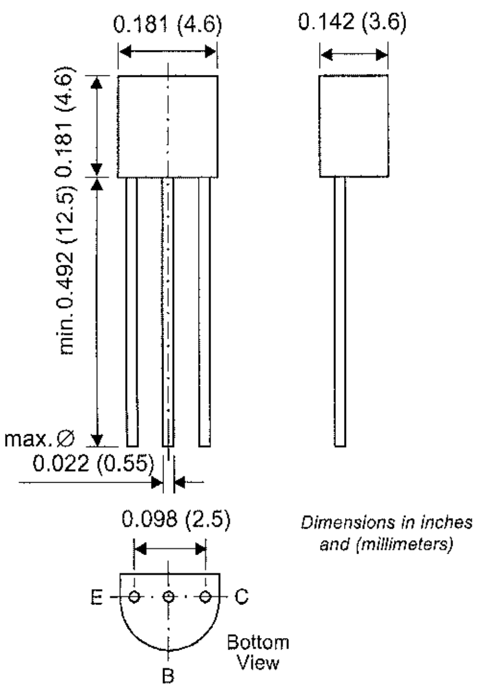
# APPENDIX B

# DATASHEET

# Small Signal Transistor (NPN)



**TO-226AA (TO-92)**




*Dimensions in inches and (millimeters)*

## Features

- NPN Silicon Epitaxial Planar Transistor for switching and amplifier applications.
- As complementary type, the PNP transistor 2N3906 is recommended.
- On special request, this transistor is also manufactured in the pin configuration TO-18.
- This transistor is also available in the SOT-23 case with the type designation MMBT3904.

## Mechanical Data

**Case:** TO-92 Plastic Package

**Weight:** approx. 0.18g

**Packaging Codes/Options:**

E6/Bulk – 5K per container, 20K/box

E7/4K per Ammo mag., 20K/box

## ximum Ratings & Thermal Characteristics

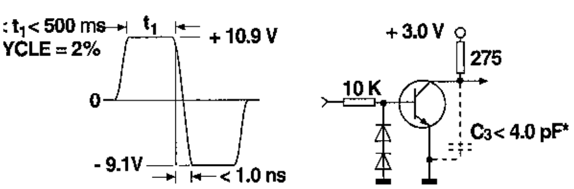
Ratings at 25°C ambient temperature unless otherwise specified.

| imeter | | Symbol | Value | Unit |
|---|---|---|---|---|
| ector-Emitter Voltage | | $V_{CEO}$ | 40 | V |
| ector-Base Voltage | | $V_{CBO}$ | 60 | V |
| ter-Base Voltage | | $V_{EBO}$ | 6.0 | V |
| ector Current | | $I_C$ | 200 | mA |
| er Dissipation | $T_A = 25°C$<br>$T_C = 25°C$ | $P_{tot}$ | 625<br>1.5 | mW<br>W |
| mal Resistance Junction to Ambient Air | | $R_{\Theta JA}$ | 250[1] | °C/W |
| tion Temperature | | $T_j$ | 150 | °C |
| age Temperature Range | | $T_S$ | –65 to +150 | °C |

lid provided that leads are kept at ambient temperature.

## trical Characteristics ($T_J$ = 25°C unless otherwise noted)

| ster | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| or-Base Breakdown Voltage | $V_{(BR)CBO}$ | $I_C$ = 10 µA, $I_E$ = 0 | 60 | — | — | V |
| or-Emitter Breakdown Voltage[1] | $V_{(BR)CEO}$ | $I_C$ = 1 mA, $I_B$ = 0 | 40 | — | — | V |
| -Base Breakdown Voltage | $V_{(BR)EBO}$ | $I_E$ = 10 µA, $I_C$ = 0 | 6 | — | — | V |
| or Saturation Voltage | $V_{CEsat}$ | $I_C$ = 10 mA, $I_B$ = 1 mA<br>$I_C$ = 50 mA, $I_B$ = 5 mA | —<br>— | —<br>— | 0.2<br>0.3 | V |
| aturation Voltage | $V_{BEsat}$ | $I_C$ = 10 mA, $I_B$ = 1 mA<br>$I_C$ = 50 mA, $I_B$ = 5 mA | —<br>— | —<br>— | 0.85<br>0.95 | V |
| or-Emitter Cutoff Current | $I_{CEV}$ | $V_{EB}$ = 3 V, $V_{CE}$ = 30 V | — | — | 50 | nA |
| -Base Cutoff Current | $I_{EBV}$ | $V_{EB}$ = 3 V, $V_{CE}$ = 30 V | — | — | 50 | nA |
| rent Gain | $h_{FE}$ | $V_{CE}$ = 1 V, $I_C$ = 0.1 mA<br>$V_{CE}$ = 1 V, $I_C$ = 1 mA<br>$V_{CE}$ = 1 V, $I_C$ = 10 mA<br>$V_{CE}$ = 1 V, $I_C$ = 50 mA<br>$V_{CE}$ = 1 V, $I_C$ = 100 mA | 40<br>70<br>100<br>60<br>30 | —<br>—<br>300<br>—<br>— | —<br>—<br>—<br>—<br>— | — |
| npedance | $h_{ie}$ | $V_{CE}$ = 10 V, $I_C$ = 1 mA<br>f = 1 kHz | 1 | — | 10 | kΩ |
| Feedback Ratio | $h_{re}$ | $V_{CE}$ = 10 V, $I_C$ = 1 mA<br>f = 1 kHz | $0.5 \cdot 10^{-4}$ | — | $8 \cdot 10^{-4}$ | — |
| andwidth Product | $f_T$ | $V_{CE}$ = 20 V, $I_C$ = 10 mA<br>f = 100 MHz | 300 | — | — | MHz |
| or-Base Capacitance | $C_{CBO}$ | $V_{CB}$ = 5 V, f = 100 kHz | — | — | 4 | pF |
| -Base Capacitance | $C_{EBO}$ | $V_{CB}$ = 0.5 V, f = 100 kHz | — | — | 8 | pF |
| Signal Current Gain | $h_{fe}$ | $V_{CE}$ = 10 V, $I_C$ = 1 mA,<br>f = 1 kHz | 100 | — | 400 | — |
| Admittance | $h_{oe}$ | $V_{CE}$ = 1 V, $I_C$ = 1 mA,<br>f = 1 kHz | 1 | — | 40 | µS |
| Figure | NF | $V_{CE}$ = 5 V, $I_C$ = 100 µA,<br>$R_G$ = 1 kΩ, f = 10...15000 kHz | — | — | 5 | dB |
| Time (see fig. 1) | $t_d$ | $I_{B1}$ = 1 mA, $I_C$ = 10 mA | — | — | 35 | ns |
| me (see fig. 1) | $t_r$ | $I_{B1}$ = 1 mA, $I_C$ = 10 mA | — | — | 35 | ns |
| e Time (see fig. 2) | $t_s$ | $-I_{B1}$ = $I_{B2}$ = 1 mA<br>$I_C$ = 10 mA | — | — | 200 | ns |
| ne (see fig. 2) | $t_f$ | $-I_{B1}$ = $I_{B2}$ = 1 mA<br>$I_C$ = 10 mA | — | — | 50 | ns |




Test circuit for delay and rise time
shunt capacitance of test jig and
ectors

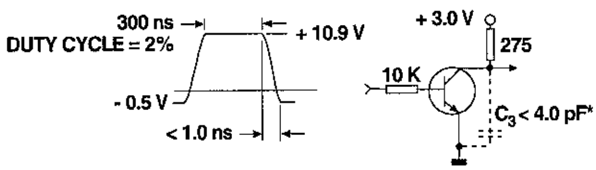



**Fig. 2:** Test circuit for storage and fall time
* total shunt capacitance of test jig and
connectors