ELECTRONIC THROTTLE CONTROL

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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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.

Nurahmet Tonniyev Bezirgenovich

ABSTRACT

Electronic Throttle Control(ETC) is becoming an important part of automotive industry. ETC or "Drive-by-Wire" system, if applied properly, can result in an efficient control of throttle body. Position of the throttle body was the main focus of the project. For this purpose RC servo motor for positional control was used. The system was analyzed and a mathematical equation was derived. To improve the system dynamics PID(Proportional Integral Derivative) control method was applied using Matlab Simulink. Initially, the system was simulated and some overshoot was detected which then was reduced using PID control. From the results, it was observed that the integral par of the PID control does not or have very little effect to the system, therefore the system was tuned using PD(Proportional Derivate). In conclusion, a mathematical equation of the system was derived, simulated and improved using PID successfully.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

DC	Direct Current
PIC	Programmable Interface Chip
RC	Radio Control
LED	Light Emitting Diode
ETC	Electronic Throttle Control
PID	Proportional Integral Derivative

CHAPTER 1
INTRODUCTION

Electronic Throttle Control will essentially be more important in the near future as there is a great need for efficient use of energy.

For the first semester, attempts were made to accomplish a real time control of a throttle body using a stepper motor. It was inefficient, because the stepper motor was not proper for position control and was not suitable for a closed-loop system.

1.1 Background of Study

The Electronic Throttle Control has been around for about 20 years. It is also called "Drive-by-Wire" system. The idea here is to reduce the reliance on mechanical parts and make the system more efficient. Since its first introduction, "Drive-by-Wire" system has been used in many new technologies. For example the famous British military Harrier plane uses a complex system of "Fly-by-Wire". Future of this technological advance seems bright in automotive industry. Nowadays, most high-end cars use the system to enhance drivers' experience, save energy by adjusting the pedal to the throttle position dynamically. Some even go as far as saying that in the future it is possible to see cars controlled by a joystick.

The idea of the project is to control a DC motor. So, it is essential to learn about the motor. The DC motors are the first mechanical devices to convert electrical energy to mechanical power. Its origin can be traced to machines made and tested by Nicholas Tesla. A motor design is based on the placement of conductors in a magnetic field. A winding has many conductors, and the contribution of each individual turn adds to the intensity of the interaction. The force developed from a winding is dependent on the current passing through the winding and the magnetic field strength. More current yields more force.

In setting up a system, one has to make a decision for the system to be open loop or closed loop. A stepper drive is a perfect example of an open loop system. One pulse from the control to the motor will move the motor one increment. If for some reason the stepper does not move, the control is unaware of the problem and cannot make any corrections. This can be dangerous in some cases, especially when controlling a carburetor. If a signal is returned to provide information that motion has occurred, then the system is a closed loop. The return signal (feedback signal) provides the means to monitor the process for correctness. If for example a shaft cannot rotate from angle A to angle B, the feedback will inform the control of an error and control can alert or correct the error automatically. For high accuracy and precision, the closed loop system is better. Its weaknesses are complexity and price.

1.2 Problem Statement

The main problem in this project is to control the throttle. To control the throttle body one needs a servomechanism. The function, or task, of a servo can be described as follows. A command signal which is issued from the user's interface panel comes into the servo's positioning controller. The positioning controller is the device which stores information about various jobs or tasks. It should be programmed to activate the motor/load. The main problem is interfacing the system to a monitor/PC to examine the mechanism.

1.3 Objectives and Scope of the Study

The main objective of this project is to build a functional Electronic Throttle Control system and study control elements in the process. After the project is carried out, we will have revisited/learned a broad scope of engineering subjects from electronics to programming.

CHAPTER 2
LITERATURE REVIEW

The servomechanisms caught a lot of attention when USA and USSR started the "Space race". The engineers needed more accurate and more controllable system for space exploration. Since then it has been improving steadily. With the implementation of electricity and modern control systems, attempts were made to make a better control of the throttle body.

2.1 Theory

There are a lot of techniques for studying the behavior of a DC motor, PID control, Velocity Feedback Control, State Feedback Control and so on. These techniques are used to make a stable and robust system, but before controlling a system one must understand in mathematical terms how the system behaves without control. PID control method was used for the project because it is easier and more familiar technique to implement.

2.1.1 Open Loop Control of System

As can be observed from Figure 1, first there is an input transducer, then the transfer function block, the process is the movement of throttle body. Figure 1 is the block diagram for open loop control. The input of the system is a digital signal, the signal then enters the controller, the system is controlled by using PIC18F452. The disturbance can be of any nature, there is no real disturbance in for the process because the motor is very precise. The main problem with the open loop system is its inability to detect error, while in a closed loop control the output signal is fed back into the input to eliminate any error that may occur.

2.1.2 Closed Loop Control of System

The closed loop system is much more feasible for a servo system. It is much more stable than open loop system because of the feedback or error signal is fed back into the controller for correction. Figure 2 shows the block diagram of a closed loop system. The closed loop system is more advantageous because its feedback signal corrects any error that may occur.

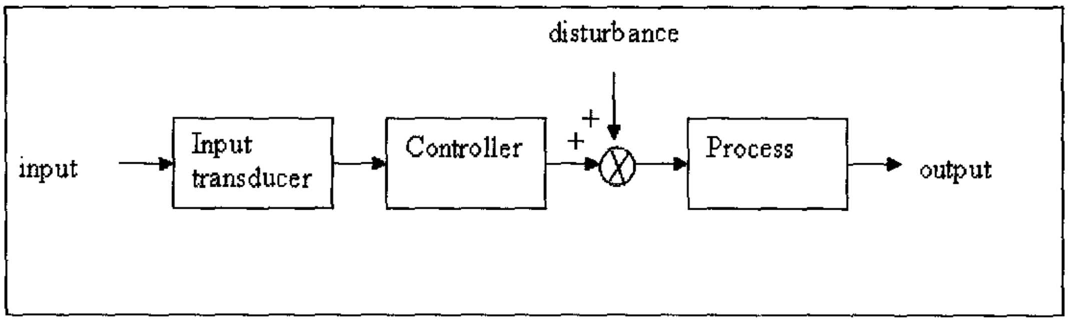

Figure 1 Open Loop Control

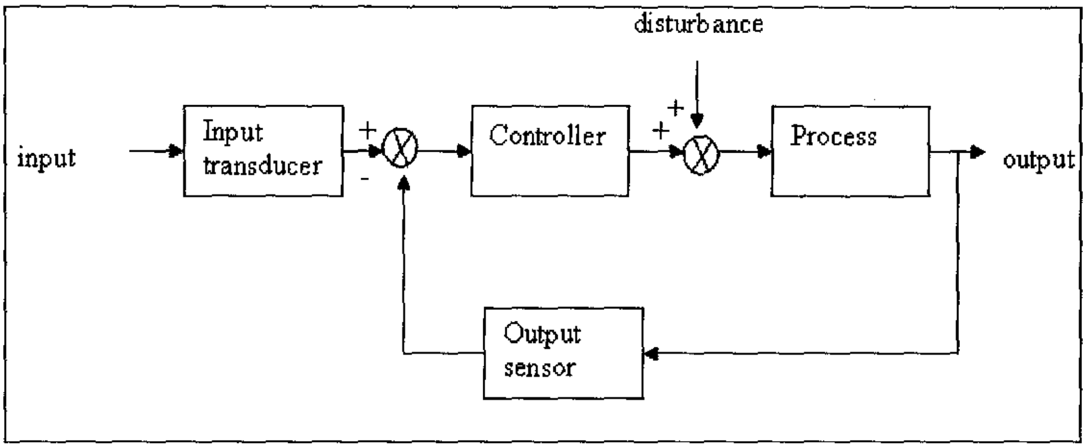

Figure 2 Closed Loop Control

2.2 PID Control

The PID control makes a system stable with almost zero offset. It is a simple, single equation, but it can provide good control performance for many different processes including servomechanism. The general PID formula is as follows,

$$G_c(s) = MV(S)/E(S) = K_c\,(1 + 1/T_I S + T_d S)$$

where G_c, control gain, MV, manipulated variable, E(s), controlled variable, K_c, controller gain, T_I, integral time constant, T_d, derivative time constant.

2.2.1 Proportional Control

The proportional mode, K_c, provides a rapid adjustment of the manipulated variable, does not provide zero offset although it reduces the error, speeds the dynamic response, and can cause instability. The proportional control does not return zero offset for most models.

2.2.2 Integral Control

The integral mode, T_I, provides zero offset; adjusts the manipulated variable in a slower manner than the proportional mode, gives a poor dynamic performance, can cause instability. Too much integral time constant, Ti, makes a system much slower than needed.

2.2.3 Derivative Control

The derivative mode, T_d, does not influence the final steady-state value of error, but provides rapid correction based on the rate of change of the controlled variable, can cause undesirable results. A general Laplace domain PID controller scheme is shown below in Figure 5. Mainly, the derivative control compensates for the lag created by integral control.

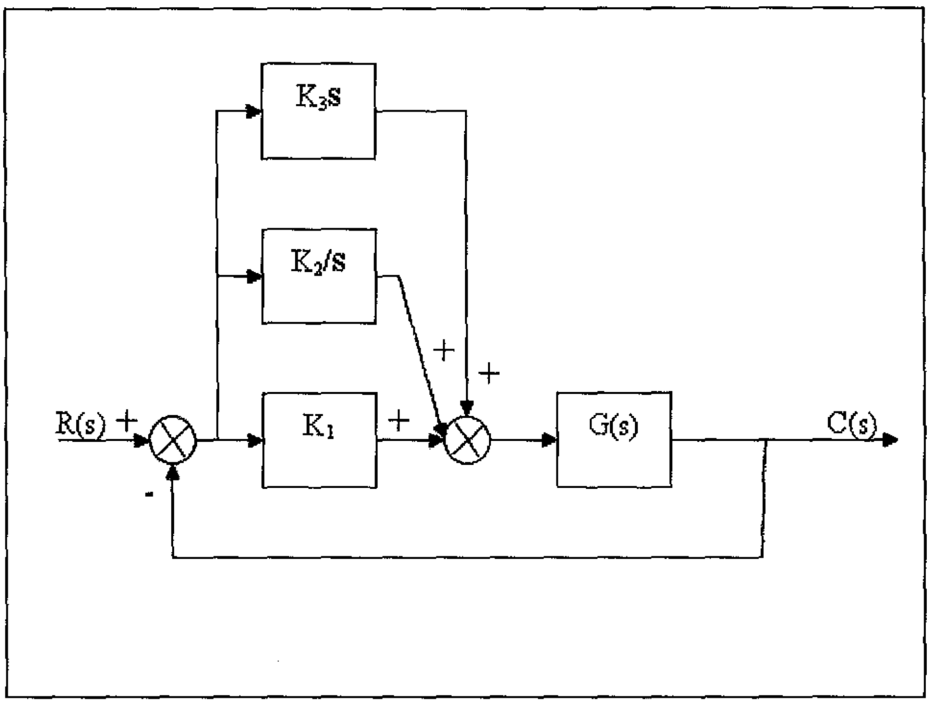

Figure 3 PID controller

CHAPTER 3
METHODOLOGY

The tasks are carried out from easy to hard. First, the research was conducted to find the most feasible way of controlling the DC motor. Then the hardware part is implemented. Although there has been some confusion about what motor to use, it was decided to use an RC Servo Motor which is suitable for a closed loop control as well as positional control. The process flow of tasks is shown in Figure 4.

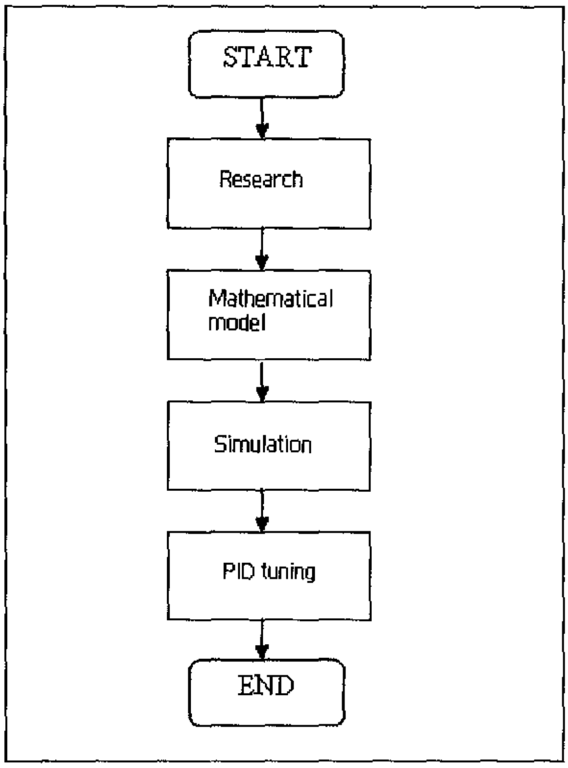

Figure 4 Process Flow Diagram

The components are not obtained from store because it is not available at the store so it must be bought from outside the University. The components needed are a breadboard, LEDs, RC Servo Motor, a 18F452 PIC, a carburetor, a potentiometer.

3.1 RC Servo Motor

The RC Servo Motor is the most suitable for the project because it can be manipulated to control the position of a throttle body, it is compact, high torque and cheaper, also it is designed for closed loop systems. One particular model, SX-01 will be used for the construction of the servo system. The RC Servo Motor is shown below in Figure 3. The motor below is suitable for the positional control because of its price, size and robust positioning of the throttle.

Figure 5 RC Servo Motor

Below are the specifications for the above motor taken from a website:

- Speed : 180^0 in 1.5s
- Torque (Kg-cm): 3.4Kg.cm/6V
- Size (mm): 39.0x20x36mm
- Weight (g): 45g
- Designed for "closed feedback".
- Able to control the position of the motor

3.2 Programming of the PIC

For the first round of tests, the PIC will be used to control the Servo Motor position using digital inputs. Attempts were made to control it in real time using a potentiometer. The basic flowchart for the preliminary program is shown in Figure 4, and the C code is in Appendix 1. As can be observed from the figure below, the programming has two positions home(reference) and set position. Whenever the system is turned on the motor turns to home position, then it can be set to a preprogrammed position using a switch.

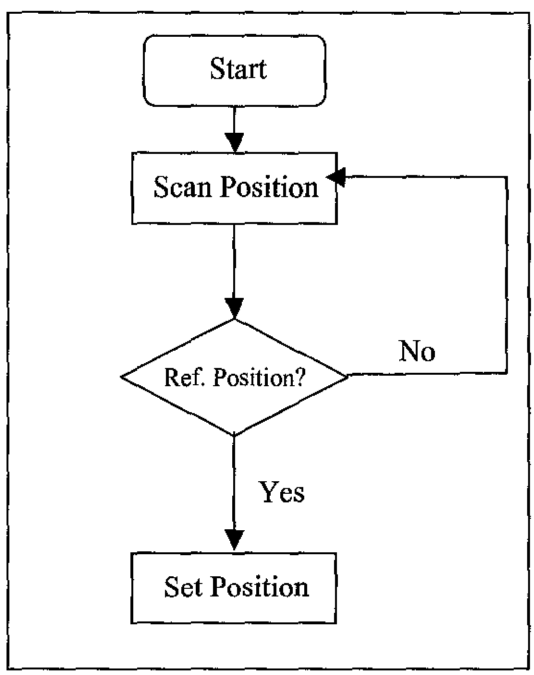

Figure 6 Flowchart

3.3 Circuitry

The circuitry of the motor is basic and straightforward. A switch will be used to control the movement of the motor, PIC for the memory and a 5V-6V power supply. The figures 5 and 6 show the circuit diagram and the circuit picture respectively.

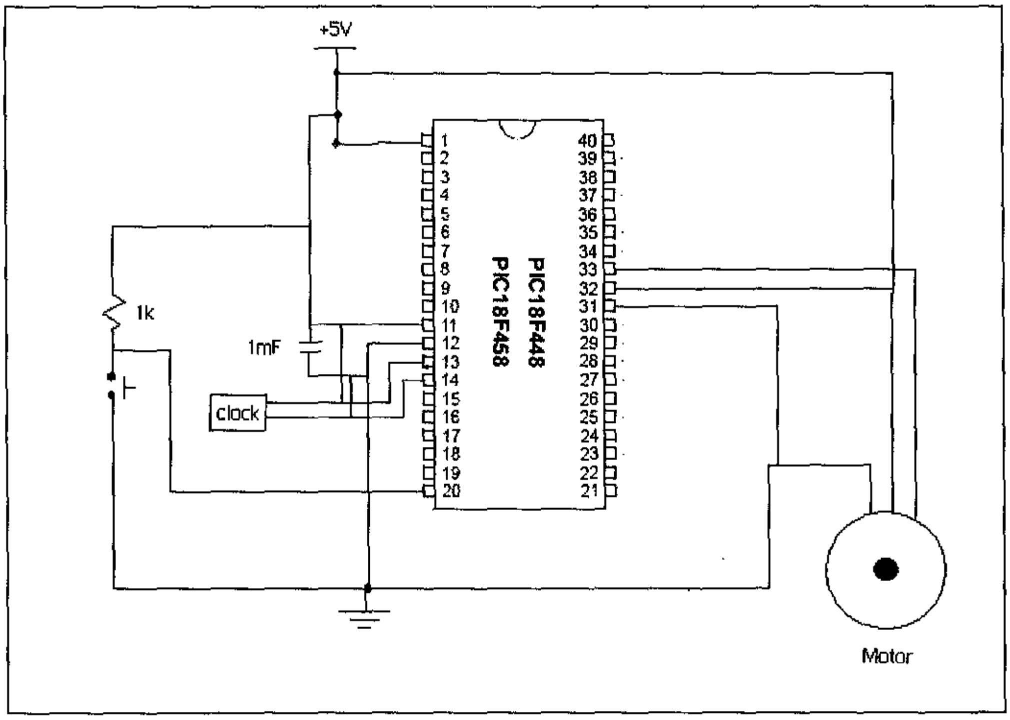

Figure 7 Circuit diagram

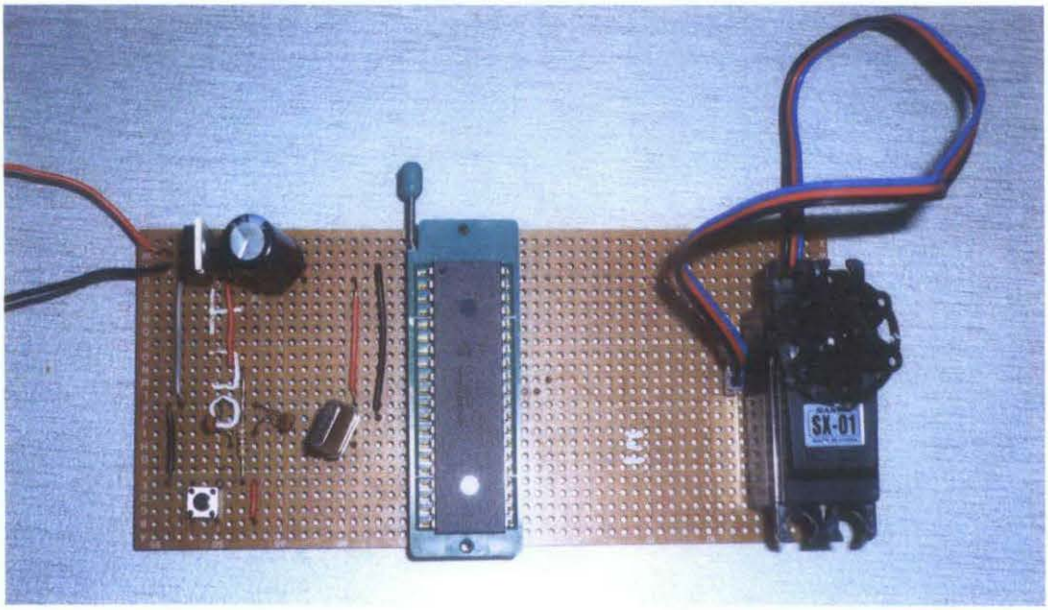

Figure 8 Circuit picture

CHAPTER 4
RESULTS AND DISCUSSION

RC Servo motor was used for the project because from the results of research it is obvious Pittman DC motor is not feasible for this project because of its very high speed, low torque and inability to give a positional feedback. Instead I am to use the RC Servo Motor as mentioned before. The selection of items has been finalised, the next step is PID control of the system.

4.1 System Transfer Function

There are two kinds of systems as mentioned above, which are open and closed loop systems. Simulations of open loop and closed loop systems were carried out. Both open and closed loop systems were simulated using Matlab Simulink. The system chosen is the closed loop because it stops at the set position while the open loop keeps increasing uncontrollably.
The transfer function of the system is as follows:
$T(s)=[K/s(\tau s+1)]=24.39/[s(0.061s+1)]$, calculations are shown in appendix 2.

4.1.1 Open Loop System Simulation

As can be observed from the figure 10, the overall system is not stable for the open loop, the output value keeps increasing uncontrollably. Thus, the open loop system is unstable because the controller is not fed information about the output position of the motor, it only receives the increase signal.

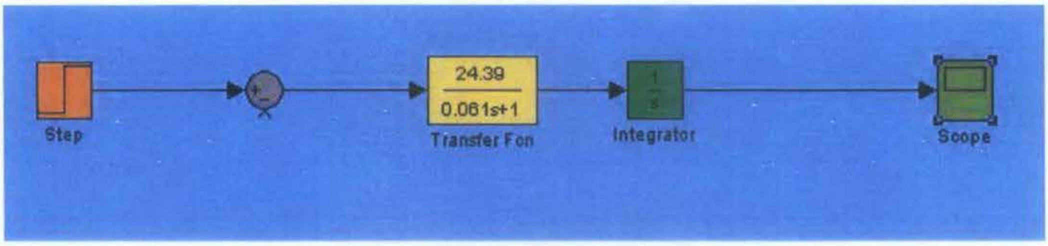

Figure 9 Open Loop System

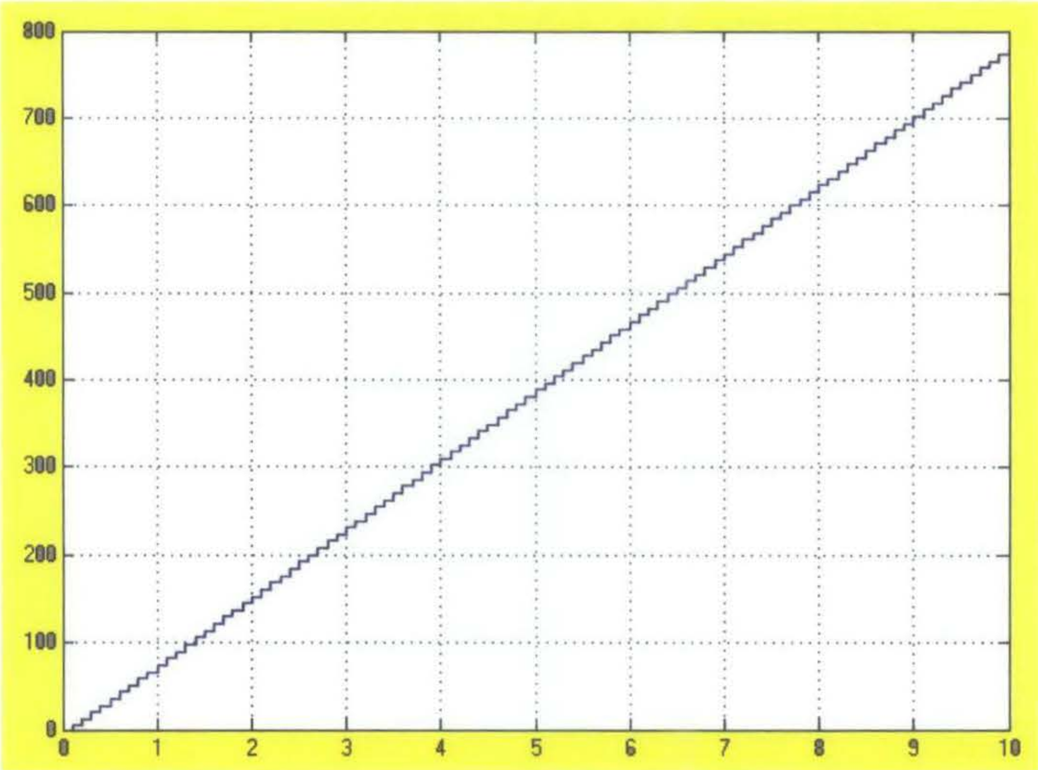

Figure 10 Open Loop System Graph

4.1.2 Closed Loop System

Closed loop systems are more advantageous than the open loop system mainly because of the feedback which corrects an error comparing it with a reference input. For positional control system, the closed loop is very much feasible. Block diagram and the output characteristics of the system are shown in figure 11 and figure 12 respectively. However, there are some initial overshoot and oscillation detected.

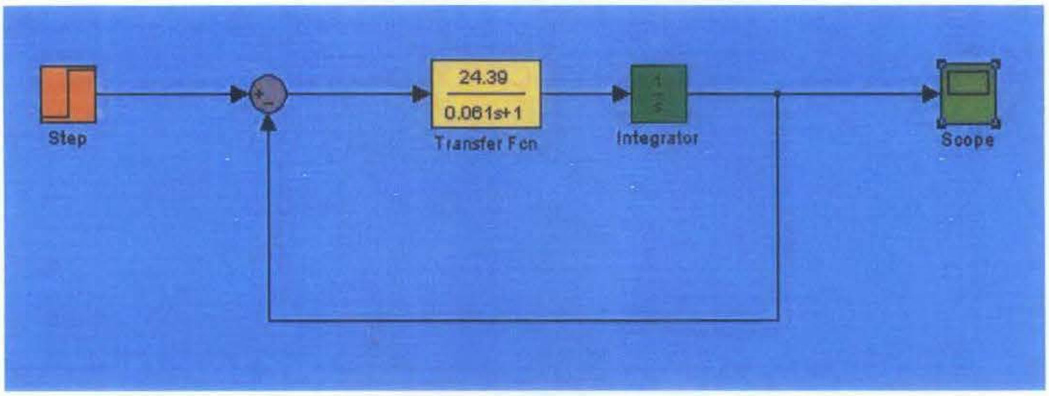

Figure 11 Closed Loop System

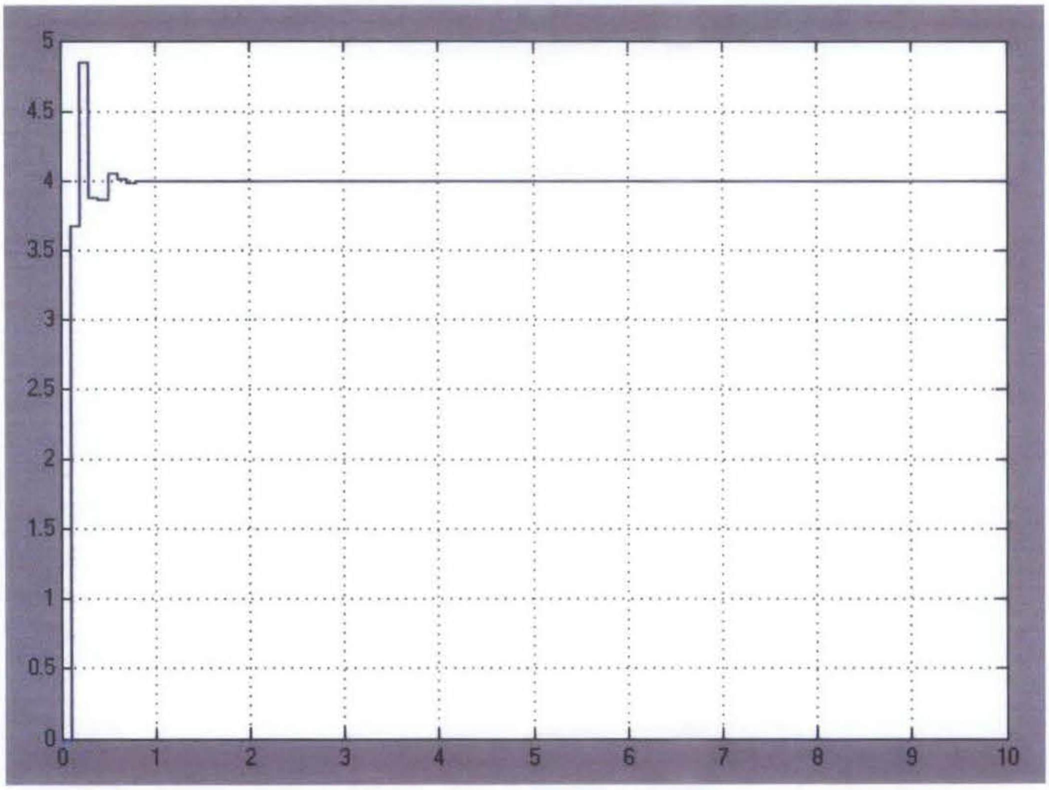

Figure 12 Closed Loop System Graph

4.2 Manual PID Tuning

Manual tuning method uses trial and error to optimize the system. First, for the proportional control set the T_I and T_D values to zero. Increase K_p until the output of the loop oscillates, then K_p should be left set to be approximately half of ¼ amplitude decay. Then increase the T_D until any offset is correct in sufficient time for the process. Too much T_D will cause instability. Finally, increase T_I, if desired until the loop is acceptably quick to reach its reference after a load disturbance. However, too much T_I causes excessive response and overshoot. In table 1 shown the effects of increasing parameters. The block diagram of the system is shown below in figure 13.

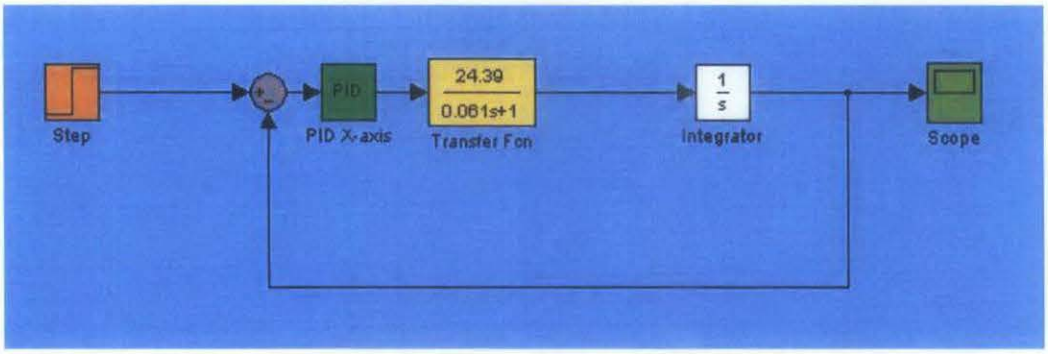

Figure 13 PID Control

Effects of increasing parameters				
Parameter	**Rise Time**	**Overshoot**	**Settling Time**	**S.S. Error**
K_p	Decrease	Increase	Small Change	Decrease
T_I	Decrease	Increase	Increase	Eliminate
T_D	Small Decrease	Decrease	Decrease	None

Table 1 Effects of Increasing Parameters

4.2.1 Proportional Control Simulation

A high proportional gain will result in a large change in the output and a very high proportional gain results in an unstable output. The proportional control does not settle at a steady state. The best K_p value is shown below in figure 14. It is the best Kp value because it eliminated the overshoot and most of the oscillation.

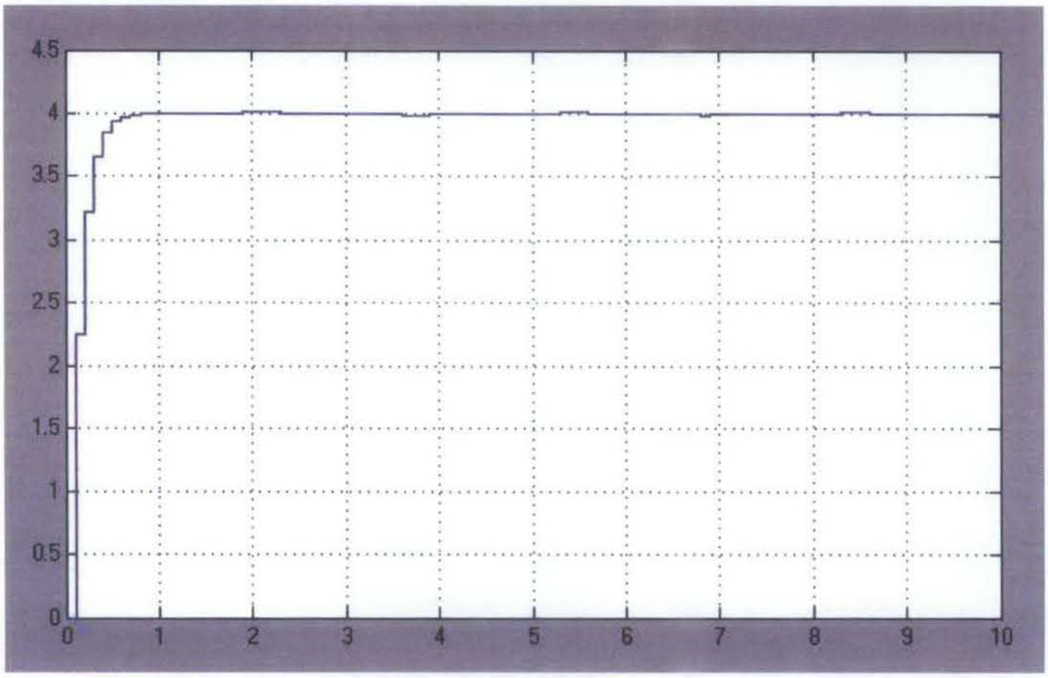

Figure 14 K_p=10

4.2.2 Proportional Integral Control Simulation

For the integral control, there is no change in the output of the system. In other words, it does not affect the output of the system. Normally, integral control helps reach the reference point, too much T_I causes the system to reach its steady-state slowly. In the figure 14 and figure 15 below, values of T_I=10 and T_I=0.1 were shown.

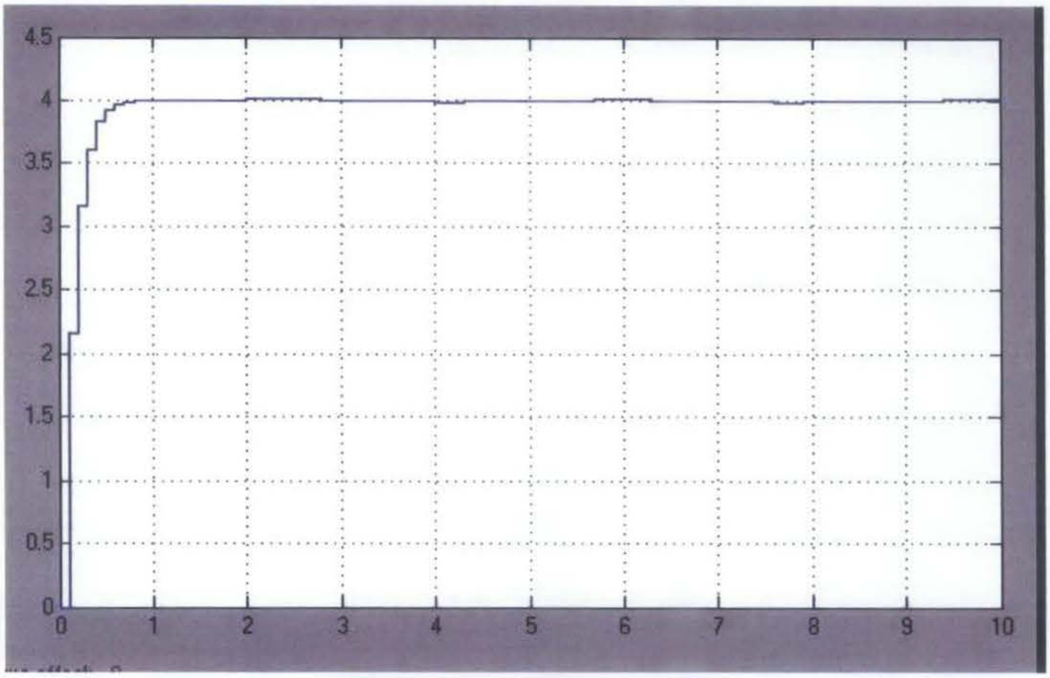

Figure 15 T_I=10

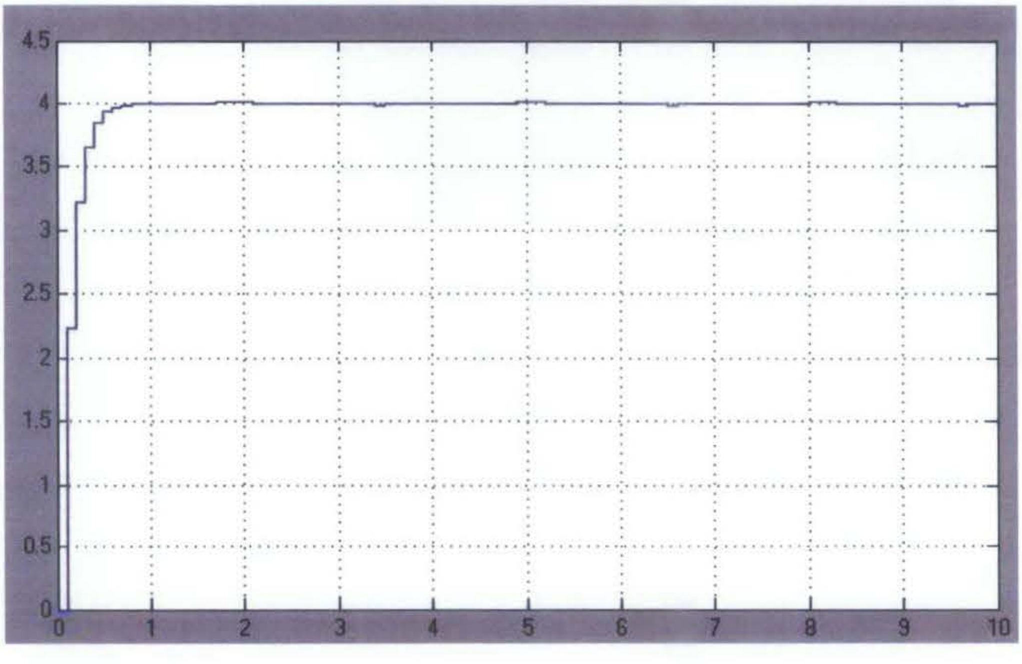

Figure 16 T_I=0.1

4.2.3 Proportional Derivative Control Simulation

The derivative control slows the rate of change of the controller output and this effect is most noticeable close to the controller setpoint. Thus, derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller-process stability. This means that the derivative control compensates for shortcomings of the integral component. As can be observed from the figure 17, when T_D=10, the time it reaches to steady-state is high, but when we reduce it, the time reduces too, which is good. The best value for T_D is 2. Because below that value the system becomes oscillatory. The output graph for T_D=2 is shown below in figure 18. In figure 17 it takes 2s to reach the steady state whereas in figure 18 it takes only 1s.

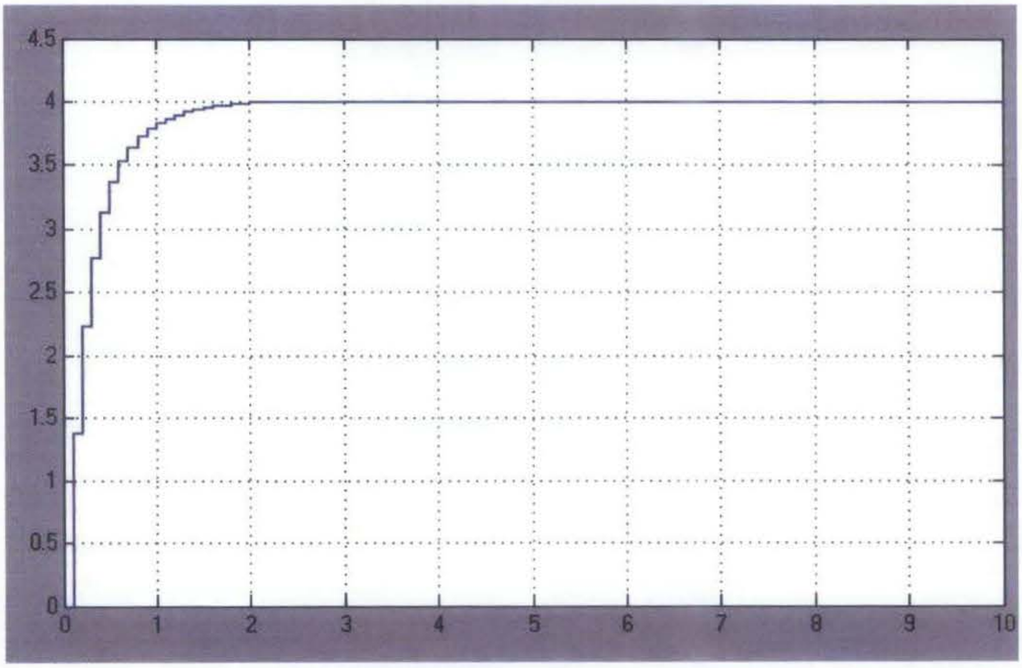

Figure 17 T_D=10

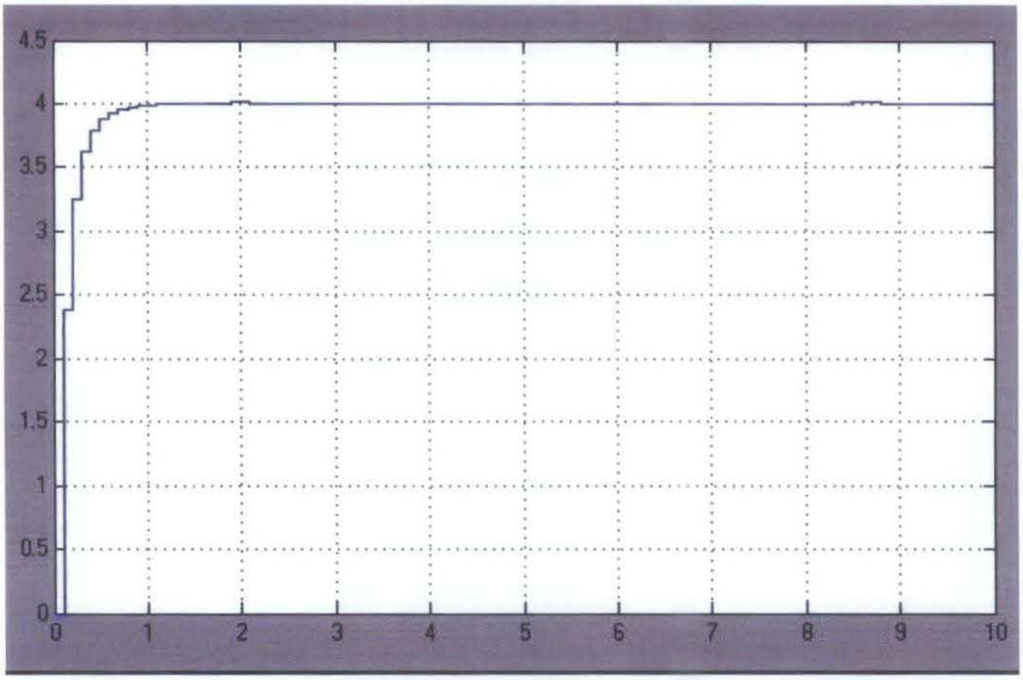

Figure 18 T_D=2

4.2.4 PID Control

In the end the best control option available is the Proportional-Derivative control since the integral control does not affect the system. This way the system output reaches the steady state in the most optimal time.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In the project carried out, a comprehensive system of Electronic Throttle Control was built using Matlab Simulink. A prototype using a servo motor was built and studied. Numerous simulations on the open loop, closed loop systems was carried out. PID control was done in order to increase the efficiency, robustness of the system. Potential benefits of the Electronic Throttle Control system was realized and learned.

In the course of this project, there were some difficulties in finding tools for building the prototype. There is no carburetor to meet the requirement of the project, and it lacks the proper electronic boards to interface it to a PC.

Overall, the project was successful and most objectives were carried out in a timely manner

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APPENDICES

APPENDIX A

C CODE

```
#include<18f458.h>
#fuses XT,NOPROTECT,NOLVP,NOBROWNOUT
#use delay(clock=4000000)
int main()
{
while(1)
{
if (input(PIN_D0==1))// to be altered using adc variable resistor
{
output_high(PIN_B0);
delay_us(1500); //SET POSITION
output_low(PIN_B0);
delay_ms(20);
}
else
{
output_high(PIN_B0);
delay_us(700);// HOME POSITION
output_low(PIN_B0);
delay_ms(20);
}}}
```

APPENDIX B
PARAMETER CALCULATIONS

$K=K_t/(bR_a+K_tK_e)$

Where K_t=0.05Nm/A, b=0.0001Nm/rad/s, J_m=0.00025Nm/rad/s^2, K_e=0.05V/rad/s

Thus, K=24.39

$\tau = (R_aJ_m)/(bR_a+K_tK_e)$, where b=0.0001Nm/rad/s^2, R_a=0.5Ω

τ =0.061