VEHICLE ACTIVE SUSPENSION SYSTEM

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Special dedication to my beloved father and mom, my entire sibling and my kind hearted supervisor Mr. Amat Amir bin Basari, also to all my dearest friends.

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ABSTRACT

The project aim was to establish a mathematical model for active suspension system and controlled by a PID controller. The objective is to improve car comfort and stability. A classic car used a passive suspension and the performance is too low where the body isolation cannot be control when facing road disturbance. This project will focus on improving a car suspension system using proportional-integral-derivative (PID) controller. Therefore to achieve that objective, the passive suspension system must be replaced with the active suspension system. The desired settings of PID controller obtain using the simulink/Matlab.

ABSTRAK

Projek ini bertujuan menerbitkan model matematik untuk system gantungan aktif dan di kawal oleh pengawal ”proportional-integral-derivative” (PID). Ini bertujuan meningkatkan keselesaan dan stabiliti kereta. Kereta lama menggunakan gantungan pasif dan prestasinya sangat lemah dimana ayunan badan kereta tidak dapat dikawal apabila menghadapi gangguan dari jalan. Projek ini akan menumpukan pada meningkatkan sistem gantugan dengan sistem gantungan aktif menggunakan pengawal ”proportional-integral-derivative” (PID). Kerana itu, sistem gantungan pasif harus digantikan dengan sistem gantungan aktif. Ketetapan yang diperlukan oleh pengawal PID diperoleh menggunakan simulasi simulink/Matlab.

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PID	-	Proportional Integrate Derivative

CHAPTER 1

INTRODUCTION

1.1 Project Introduction

Nowadays, vehicle is so importance in our life. It is needed for moving from one place to another. Companies that produce cars struggle to improve their product quality and performance. One of the important performance characteristic that have to be considered in making a car is a good suspension system. Suspension system will determine the comfortness and handling performance of a car. This characteristics deal with body movement. An ideal suspension system should isolate the body from road disturbances and inertial disturbances associated with cornering and braking or acceleration.

A classic car widely used a passive suspension system for passengers but the suspension spring and damper only control the motion of the car body and wheel by limiting the suspension velocity according to the rate determined by the designer. To overcome the problem, active suspension systems have been proposed.

Active suspension system respond to changes in the road because of the controller ability to supply energy to produce relative motion between the body and wheel. Active suspension system include sensors to measure suspension variables. An active suspension system has actuators that supply additional forces to the system. These additional forces are determined by a feedback control data from sensors attached to the vehicle.

There are various control strategies such as optimal state feedback, backsteeping method, fuzzy logic control, sliding mode control and many more but for this research, the PID controller is chosen.

1.2 Problem Statement

There are several types of vehicle suspension system, passive suspension system and semi-active suspension system also known as active suspension systems. Combination of traditional spring and damper is referred to a passive suspension system and this type of suspension is leaking of performance. Therefore, this project is to achieve better ride comfort and controllability of vehicles that pursued by automotive industries by considering the use of active suspensions system.

1.3 Objective Project

The objectives of this project is to develop a system that can be control by PID controller and capable to achieve the desired level of performance. Analysis will concentrate on the isolation of the car body from the road disturbance, pitch and roll that happen while abrupt the maneuvers and also the wheels bouncing when the vehicle strike an abrupt bump. A detail study of the model and the classification of the road roughness are presented together with a certain method for comparing the results.

1.4 Project Scope

Throughout this project, there are several guidelines and specification that must be followed to make sure the project is within the scope.

1. The scope of this project is to develop an Active Suspension System with PID Controller based on a quarter car model.
2. To start this project, fist of all the concept of a passive suspension system have to be studied and understand the characteristic and the limit of the system.
3. The next step is to study the concept of semi-active and active suspension system. Therefore the different of the two systems can be discovered.
4. Then the mathematical model of an active suspension system will be derive to get the desired result.
5. Next is to study and derive a mathematical model of PID controller for an active suspension system using quarter car model.
6. All simulations is performed using Matlab/Simulink

1.5 Methodology

1. Project Planning
    a. Consult with supervisor, En. Amat Amir bin Basari to get the exact information about the project.
    b. Prepare Gantt chart for guidelines and progress report.
    c. Search for information about this project and past research related to suspension system.
    d. Derive mathematical equation for passive suspension system before applying in the SIMULINK.

CHAPTER 2

LITERATURE REVIEW

2.0 Control System

A control system is an arrangement of physical components connected or related in such a manner as to command, direct, or regulate itself or another system. Control system has two important terms, which is define as input and output. The input is the stimulus, excitation or command applied to a control system, usually from an external energy source in order to produce a specified response from the control system. The output is the actual response obtained from a control system. It may or may not be equal to specified response implied by the input.

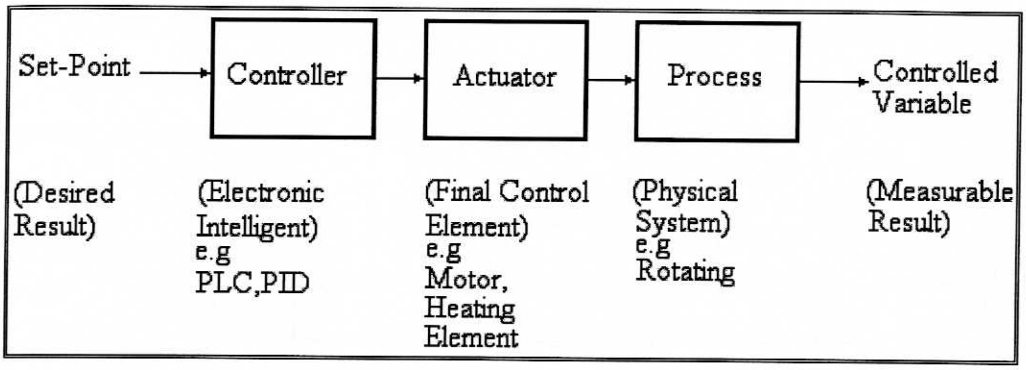

Figure 2.0:- A Block Diagram of general Control System

2.0.1 Open-Loop and Closed-Loop Control Systems

Control systems are classified into two general categories, open-loop and closed-loop systems. An open-loop system is one which the control action is independent of the output. A closed-loop control system is one in which the control action is somehow dependent on the output.

Open-Loop System is a control system that does not use feedback. The controller sends a measured signal to the actuator, which specifies the desired action. This type of system is not self-correcting. If some external disturbance changes the load on machine or process being performed, some degree of physical effort of human operator is required to make necessary modifications. The system manually controlled by the human.

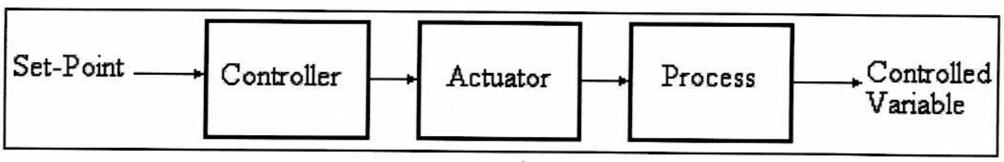

Figure 2.0.1 a: Open Loop System

To avoid the problems of the open-loop controller, the feedback was added. A closed-loop controller uses feedback to control outputs of a dynamical system. Process input has an effect on the process outputs, which is measured with sensors and processed by the controller; the result (the control signal) is used as input to the process, closing the loop. Since the controller knows what the system is actually doing, it can make any adjustments necessary to keep the output where it belongs.

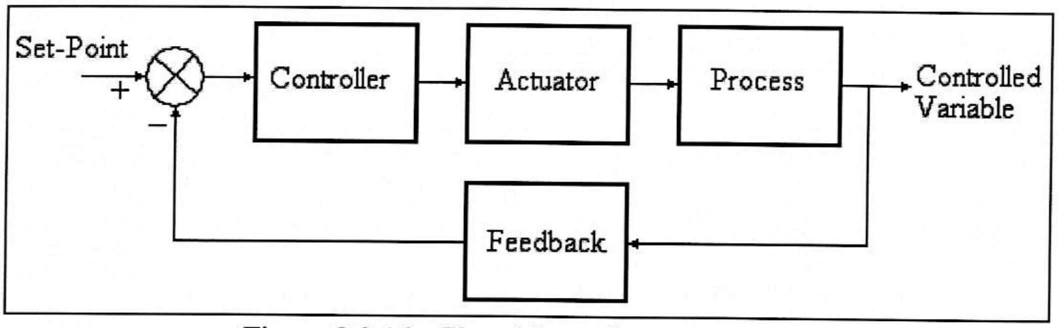

Figure 2.0.1 b: Closed Loop System

Closed-loop controllers have the following advantages over open-loop controllers:

- disturbance rejection (such as unmeasured friction in a motor)
- guaranteed performance even with model uncertainties, when the model structure does not match perfectly the real process and the model parameters are not exact
- unstable processes can be stabilized
- reduced sensitivity to parameter variations
- improved reference tracking performance

2.1 PID Controllers

A proportional-integral-derivative controller (PID controller) is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set-point by calculating and then outputting a corrective action that can adjust the process accordingly.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values. The Proportional value determines the reaction to the current error, the Integral determines the reaction based on the sum of recent errors and the Derivative determines the reaction to the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element.

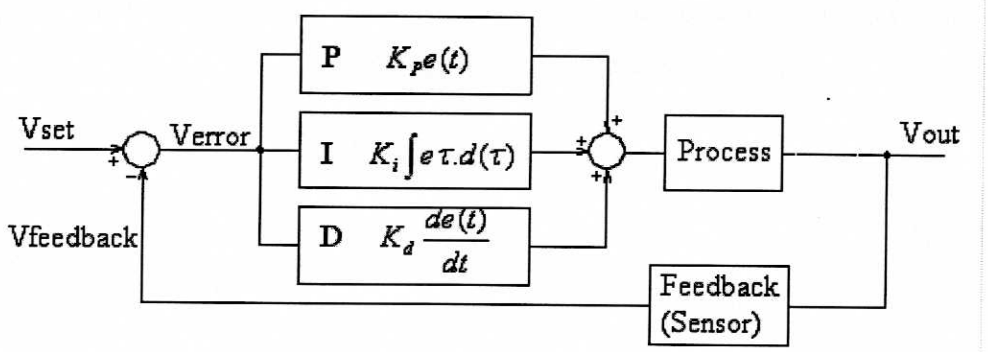

Figure 2.1:- The PID Controllers Block Diagram

By "tuning" the three constants in the PID controller algorithm the PID can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set-point and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system.

Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise, and the absence of an integral value prevents the system from reaching its target value due to the control action.

The table below summarizes the PID terms and their effect on a control system.

Term	***Math Function***	***Effect on Control System***
P Proportional	KP x Verror	Typically the main drive in a control loop, KP reduces a large part of the overall error.
I Integral	KI x ∫ Verror dt	Reduces the final error in a system. Summing even a small error over time produces a drive signal large enough to move the system toward a smaller error.
D Derivative	KD x dVerror / dt	Counteracts the KP and KI terms when the output changes quickly. This helps reduce overshoot and ringing. It has no effect on final error.

Table 2.1: PID Controller Effect

2.1.1 Proportional Controller

The proportional term makes a change to the output that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain. The proportional term is given by:

$$P_{out} = K_p e(t)$$

Where

- P_{out}: Proportional output
- K_p: Proportional Gain, a tuning parameter
- e: Error = $SP - PV$
- t: Time or instantaneous time (the present)

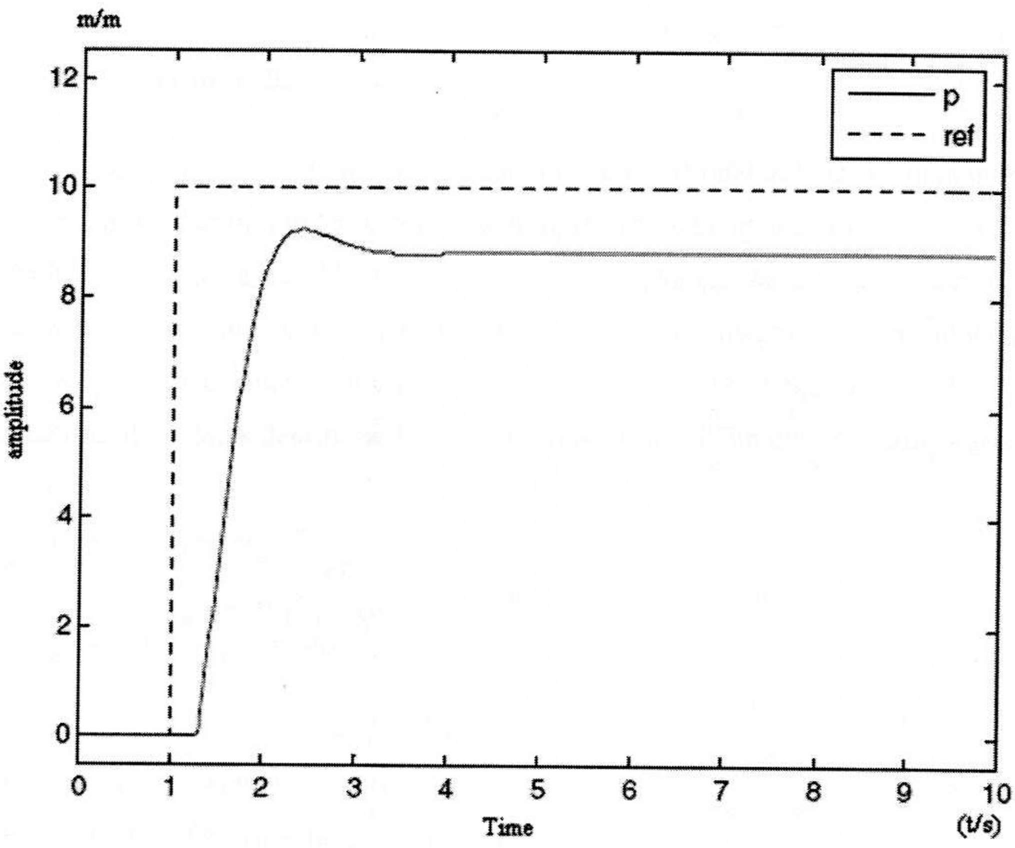

Figure 2.1.1:- The Step Response for P Controller

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable (See the section on Loop Tuning). In contrast, a small gain results in a small output response to a large input error, and a less responsive (or sensitive) controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances.

In the absence of disturbances pure proportional control will not settle at its target value, but will retain a steady state error that is a function of the proportional gain and the process gain. Despite the steady-state offset, both tuning theory and industrial practice indicate that it is the proportional term that should contribute the bulk of the output change.

2.1.2 Integral Controller

The contribution from the **integral term** is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error over time (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, K_i. The integral term is given by:

$$I_{\text{out}} = K_i \int_0^t e(\tau)\, d\tau$$

Where

- I_{out}: Integral output
- K_i: **Integral Gain**, a tuning parameter
- e: **Error** = $SP - PV$
- τ: **Time** in the past contributing to the integral response

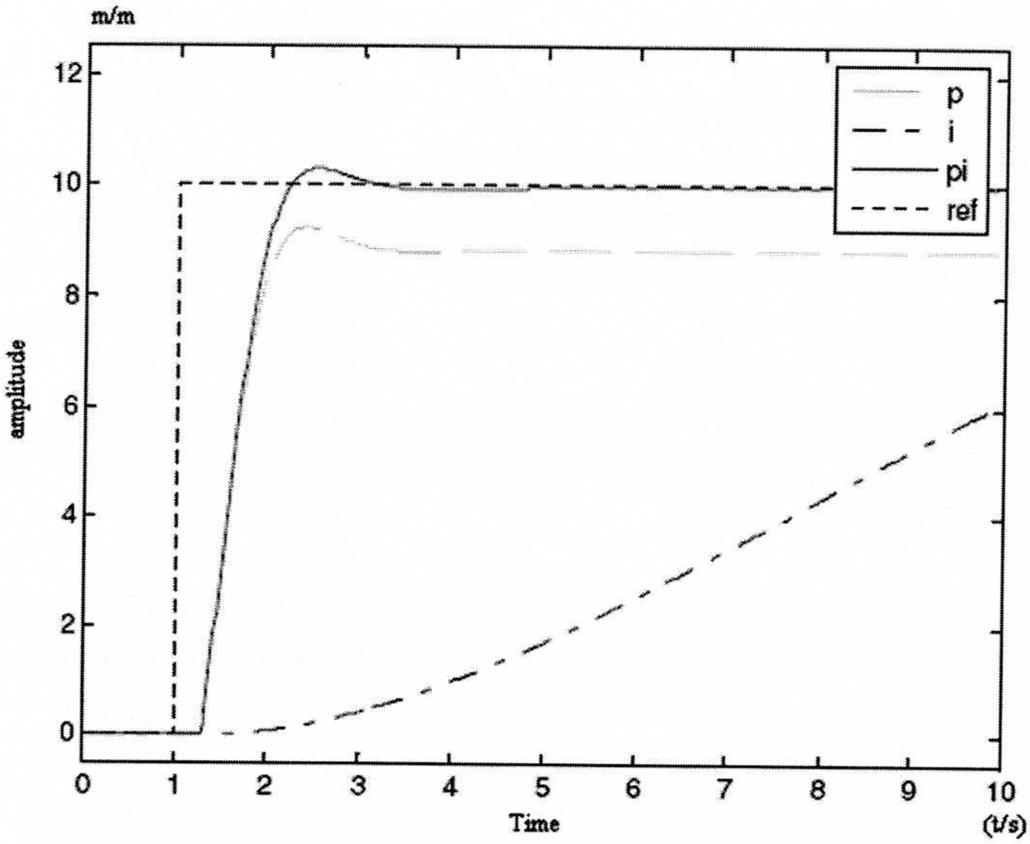

Figure 2.1.2:- The Step Response for P, I and PI Controller

The integral term (when added to the proportional term) accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a proportional only controller. However, since the integral term is responding to accumulated errors from the past, it can cause the present value to **overshoot** the setpoint value (cross over the setpoint and then create a deviation in the other direction). For further notes regarding integral gain tuning and controller stability, see the section on Loop Tuning.