VIBRATION-FREE POSITIONING OF FLEXIBLE SYSTEMS USING FILTERING TECHNIQUE

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This report is submitted in partial fulfillment of requirements for the award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

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To my beloved family

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ABSTRACT

Filtering technique is one of the simple techniques to reduce the residual vibration in positioning lightly damped systems. It is use to shape the input function by using Bang-bang input. This technique will be applied to the gantry crane system where it is one of the examples for positioning lightly damped systems. Positioning a crane swinging load, at the bottom end of a cable, by moving a gantry trolley at the top, involve resolving the apparently conflicting of demands of exact load positioning and active swing damping. By contrast, when using filtering technique, assuming an idealized cable, stops the load dead, exactly at the target in a finite time for all. In the other word this method is used to position the trolley and to reduce the sway angle of the load. The simulation has been done to the fourth order system to study the application of the technique to the system by using Matlab. The performance of this method has been compared with other input shaping technique. By using the proposed method, satisfactory in the reduction vibration during positioning the trolley of a crane and reduction of sway angle of payload has been achieved.

ABSTRAK

Penurasan teknik adalah salah satu teknik yang mudah untuk mengurangkan saki baki getaran didalam menetapkan sistem teredam. Ianya digunakn untuk untuk membentuk satu fungsi masukan dimana fungsi masukan ini adalah '*Bang-Bang*'. Teknik ini akan di aplikasikan pada kren Gantri dimana kren Gantri ini adalah salah satu contoh aplikasi yang digunakn untuk sistem teredam. Menggerakkan kren Gantri beban yang berayun, iaitu pada kedudukan bawah, pengakhiran kabel, dengan mengerakkan troli Gantri pada kedudukan atas kren, melibatkan masalah untuk mendapatkan kedudukan sebenar beban dan untuk mengurangkan ayunan yang disebakan beban tersebut. Disebaliknya, dengan menggunakn teknik penurasan ini, dan mengandaikan kabel yang ideal, teknik ini boleh memberhentikan beban secara tiba- tiba ataupun tidak dengan memberi keputusan keadaan yang lebih baik daripada sistem yang tidak menggunakan teknik ini. Dalam maksud yang lain, teknik ini digunakan untuk menetapkan kedudukan troli dan juga sudut ayunan yang disebabkan oleh beban. Sistem order keempat digunakan dalam simulasi untuk mengetahui kesan sistem ini. Apabila selesai menjalankan projek ini, perlaksanaan teknik ini dibandingkan dengan teknik yang lain iaitu teknik *Input Shaping*. Dengan menggunakan teknik ini, getaran ketika pergerakan troli dan sudut ayunan dapat dikurangkan.

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LIST OF SYMBOLS

M	-	Trolley mass
m	-	Payload mass
l	-	Length of hoisting rope
F_x	-	Input force
g	-	Gravitational acceleration = $9.81ms^{-2}$
G	-	Centre point
S	-	Point of suspension
x	-	Trolley position
$\dot{x}$	-	Velocity
$\ddot{x}$	-	Acceleration
θ	-	Sway angle
$\dot{\theta}$	-	Angular velocity
$\ddot{\theta}$	-	Angular acceleration

CHAPTER I

INTRODUCTION

1.1 Project Introduction

The fundamental motions of a gantry crane consist of travelling, load hoisting and load lowering. The significant characteristic of a gantry crane is that all motions are performed simultaneously at relatively high speed. Crane travel and transverse motions, especially when starting or stopping, induce undesirable swinging of the suspended load. This swinging could cause the suspension rope to leave it groove which could lead to over wrapping and possibly serious damage. Therefore, a crane should seek a satisfactory control method to suppress the load swing during transport.

Various attempts in controlling gantry cranes system based on open loop system were proposed. For this project, it will use filtering technique to control the gantry crane. Filtering technique is used to shape the input function, in this case, the input function is Bang-Bang input. This method is used to reduce the residual vibration in positioning lightly damped systems. The filter that will be used is Low Pass Filter (LPF). This technique will filter all the response that has vibration and will remains only the desired output response. This technique will be applied to the fourth order system and the performance of this technique will be compared with other input shaping technique

1.2 Project Objectives

The objective of this project is to design the model gantry crane with vibration free positioning using filtering technique and to shape the input function that is Bang-Band input to achieve the desired result. This technique is introduced to gantry crane to reduce the residual vibration in positioning lightly damped system.

1.3 Scope Of The Project

The scopes of work to complete this project includes:

a. Do some researches about a gantry crane system using filtering technique and get the datasheet for motor, sensor, PIC microcontroller that will be used in the gantry crane. After that, feasibility study and read up related technical knowledge.
b. Get some literature review about filtering technique that involve in this project like band pass filter and low pass filter. Also, find some journal about gantry technique to study the previous techniques that have done before
c. Find what is the Bang-bang input.
d. Learn how to derive the equation that involve in this project like fourth order system.
e. Learn more detail about Simulink in the MATLAB software
f. Get some example for filtering technique by using Simulink in Matlab then learn how it does relate to each block.
g. Apply filtering technique in the Matlab.
h. Design the gantry crane
i. Build the gantry crane.
j. Apply the technique to the gantry crane, testing and troubleshooting

1.4 Problem Statement

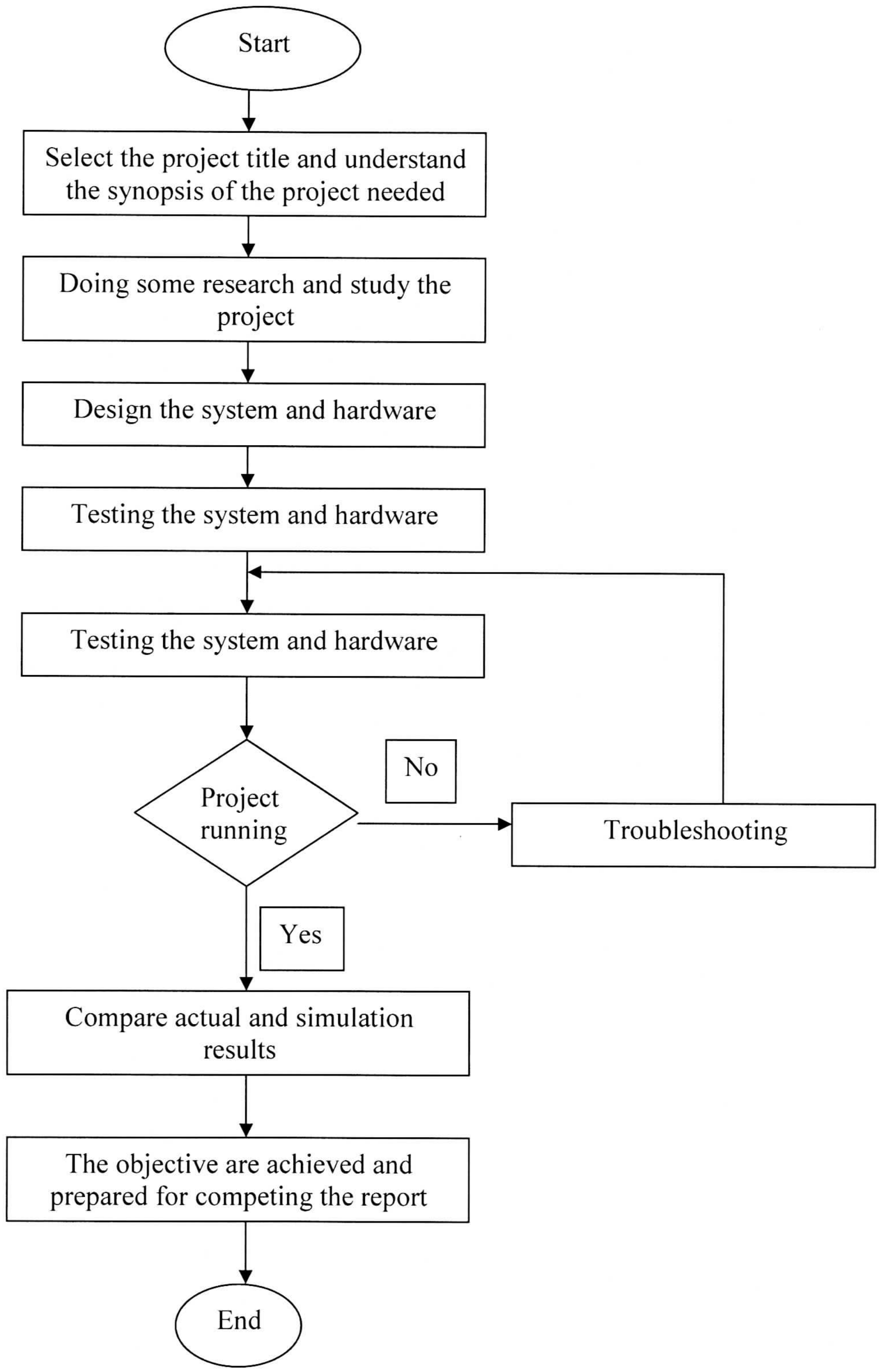
The use of gantry crane systems for transporting payload is very common in industrial application. However, moving the payload using the crane is not an easy task especially when strict specifications on the swing angle and on the transfer time need to be satisfied. The fundamental motions of a gantry crane consist of travelling, load hoisting and load lowering. When the gantry crane start or finished the operation, it will give the undesirable result where it is swinging and vibration to the suspended load.

Thus makes the efficiency of the crane work lower. Moreover, the gantry crane needs a skilful operator to control manually to stop the swing immediately at the right position. It is also makes crane work very dangerous when workers or other obstacle exist in the crane workspace. The failure of controlling crane might cause accident and may harm people and surrounding.

Furthermore, to unload, the operator has to wait the load to stop from swinging. The residual vibration at the end of a move is the most determination and extent of the residual vibration limits the performance of the system.

To overcome the problems filtering technique command is used. It is based on the use of filter to shape the input function (Bang-Bang input) that will filter all the respond that has vibration and will remains only the desired output response

1.5 Methodology



1.6 Thesis Outline

The thesis is stated in the six Chapters, Chapter I provides some background of the project, objective, scope of the project, problem statement and short review on the methodology. Literature review on some concern concept of filtering, technology and anything that helps in the study are presented in Chapter II. Chapter III involves the method and approach that used in the modeling nonlinear system on fourth order system. To be concern in Chapter IV is the result, analysis and discussion from the simulation. Hardware implementation was discussed in Chapter V. Last but not least, Chapter VI includes conclusion of the project with some suggestion for future work.

CHAPTER II

LITERATURE REVIEW

This chapter presents all the literature review and some research based on filtering technique and gantry crane. This literature review is required to study all the characteristics and requirements needed in this project. All the information that has been collected is very important to ensure this project reach the objective.

There are some parts that I have to study in this project such as filter, low pass filter, band pass filter, bang-bang input and Simulink in the Matlab

2.1 Filter

It is not necessary for electronic circuit designer to understand the theory of filters, but it is necessary to know how to use them. Filters can be passive by using only resistor, capacitor and inductor. Passive filter tend to be used when there is requirement to pass direct current. They are also used more in specialized application, such as in high frequency filters or where large dynamics range (low distortion, low noise and high power) is needed. Being passive they do not consume any power, which is an advantage in some low-power systems. Their main disadvantage is that inductors tend to be bulky, particularly when dc is being passed, because the diameter of the wire has to be large enough to keep its resistance low.

Active filters use operational amplifier (op-amp) combined with resistors and capacitor to avoid the use of inductors. Because there are gain and bandwidth limitations for all op-amps, the performance of the filter can be limited. Active filter designs used to be limited to about 100 kHz, but wide bandwidth op-amps (particularly current feedback types) are now allowing filter designs up to a few megahertz (Mhz). Unfortunately op-amps do add noise to the signal, and signal amplitude is limited by the output slew rate and power supplies. Harmonic distortion can also be introduced, particularly at the output stage.

Active filters are suited to design something that is not very demanding, where no rapid changes in amplitudes occur as the frequency of the signal is changed. Even in a non-demanding filter, signals within the filter circuit can be larger or lower when applied with voltage. Device within the filter must therefore be able to handle signals with large amplitudes at frequencies well beyond the passband required.

2.2 Low Pass Filter

Low pass filter, as the name implies, are design to pass low frequencies and to reject higher frequencies. Figure 2.1 shows the basic frequency response of a low pass filter

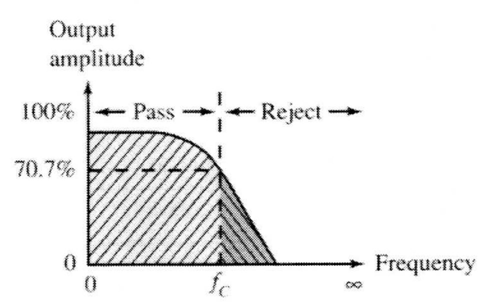


Figure 2.1 Basic frequency response of a low pass filter

There are several ways to obtain the frequency response that is shown in Figure 2.2. This figures show the fundamental requirement for low pas filter action. As shown in Figure 2.2(a), the low frequency signal must have a low series impedance and high shunt impedance. Figure 2.2(b) shows the condition that must exist in a high frequency signal, that is high series impedance and low shunt impedance.

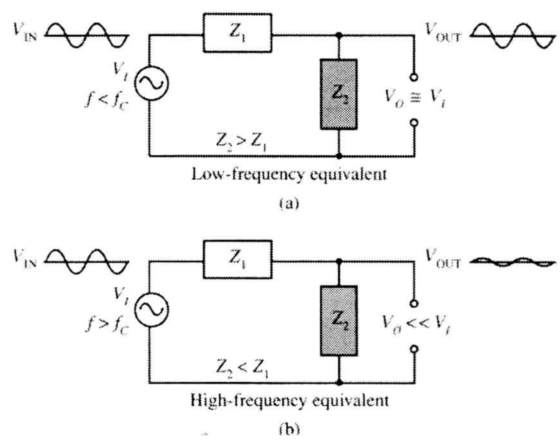


Figure 2.2 Fundamental requirement for low pas filter action

There are two common methods to achieve those requirements. By using RC and RL circuits.

2.2.1 RC Filter

Figure 2.3 shows a basic RC low-pass filter circuit. The range of input frequency is shown to be from zero dc to infinity. The output frequency range, by contrast, will only consist of those frequencies that are below the cutoff frequency.

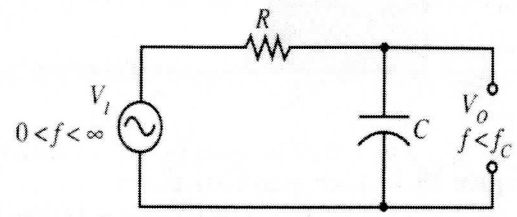


Figure 2.3 A basic RC low pass filter circuit

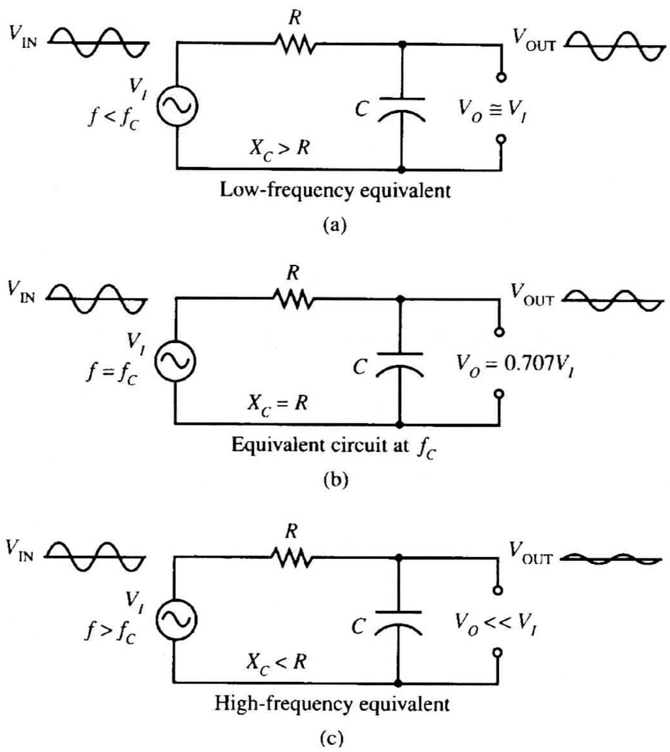


Figure 2.4 The equivalent circuits for an RC low pass filter at three key frequencies

Figure 2.4 shows the relative behavior of the RC low pass filter at three key frequencies, which is below the cutoff frequency, at the cutoff frequency and above the cutoff frequency. In figure 2.4 (a), the input frequency is below the cutoff frequency. Capacitive reactance is inversely proportional to frequency. So as frequency goes down, capacitive reactance goes up. The voltage divider action caused by a capacitive reactance that is greater than the series resistance results in an output voltage that is nearly the same as the input voltage. That is, the frequencies below the cutoff frequency