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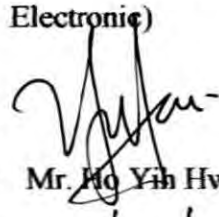
Signature : 

Name of Supervisor : Mr. Ho Yih Hwa

Date : 07/04/2005

ELECTROMAGNETIC LEVITATION DEMONSTRATOR

RUSMEYATI BINTI NORDIN

This Report Is Submitted In Partial Fulfillment Of Requirements For The Bachelor Degree of Electronic Engineering (Industrial Electronic)

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer
Kolej Universiti Teknikal Kebangsaan Malaysia

March 2005

"I hereby declare that this thesis is the result of my own effort except as clearly stated in the sources of reference"

Signature : Rusmeyati

Writer : Rusmeyati binti Nordin

Date : 1 APRIL 2005

First and foremost, I would like to express my deepest gratitude to my supervisor Mr. Ho Yih Hwa for his supervision and invaluable guidance throughout this work.

I am most grateful to my lovely parents for being understanding and supportive in whatever decision I made.

A special thanks to En. Mohd Razi bin Yaacob for his supported and En. Aini for his kindly assistance in providing all the necessary equipment in this project.

ABSTRACT

Electromagnetic Levitation System had become a fast develop technologies providing environmentally benefit solutions for industry and transportation. This project is develop a Electromagnetic Levitation Demonstrator consist of two photo-detector and one lifting coil. It is demonstrated how an electromagnetic can floating / pulls a steel ball upward until it interrupts a light beam that falls on the photo-detector and how the coil effect to electromagnetic levitation demonstrator but this system can only reach out a few short centimeter and anything further might as well be infinity. This device need a design and construct the circuit such as the coil driver and the different amplifier circuit, Infrared emitter and Photo-detector circuit, the reference voltage and phase lead network circuit and need to design the lifting coil.

ABSTRAK

Sistem Pengapungan Elektromagnetik menjadi satu tecknologi yang berkembang pesat dan menyediakan pelbagai faedah penyelesaian untuk industri dan pengangkutan. Projek ini menunjukkan Sistem Pengapungan Elektromagnetik yang terdiri daripada dua pengesan cahaya dan satu gegelung pengangkat. Ia menunjukkan bagaimana elektomagnetik tersebut boleh mengapungkan / menarik bebola logam naik ke atas hingga biasan sinar cahaya terhadap pengesan cahaya yang akan menjatuhkannya dan bagaimana gegelung pengangkat akan memberi kesan kepada penunjuk Sistem Pengapungan Elektomagnetic ini. Sistem ini hanya boleh digunakan untuk jarak yang pendek iaitu dalam beberapa sentimeter dan sebarang tambahan jarak seterusnya akan menjadi ifiniti. Projek ini memerlukan rekaan dan susunan litar seperti litar pemacu gelung, litar penguat pembezaan, litar pemancara inframerah, litar pengesan cahaya, litar untuk voltan rujukan, litar penunjuk fasa dan memerlukan rekaan bagi gegelung pengangkat.

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CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

This thesis report on the design of the controller for keeping a steel ball suspended in the air. In the ideal, the magnetic force produced by current from an electromagnetic will counteract the weight of the steel ball. Nevertheless, the fixed electromagnetic force is very sensitive, and there is noise that creates acceleration force on the steel ball, causing the ball to move into the unbalance region. The main function of this controller is to maintain the balance between the magnetic force and the ball's weight. According to the analytical method, the mathematical models of this magnetic levitation system were established with the goal of designing the control system. System linearization and phase lead composition were employed to design the controller of this unstable nonlinear system. The algorithm proposed in this thesis provides a robust closed-loop magnetic levitation system which can stabilize the system over a large range of variations of the suspended mass. The design methods of this system are presented on this thesis and the hardware is implemented for the scientific demonstration. Presented in this thesis is about the magnetic levitation demonstrator which used two photo-

detector as a signal and reference, and a lifting coil to produce magnetic field current to pull a steel ball floating in the air.

1.2 PROJECT OBJECTIVE

The project objective is to demonstrated the concept of electromagnetic levitation system by using two photo-detector and lifting coil and to produces the low cost of electromagnetic levitation demonstrator. This electromagnetic levitation system is selected and was build by follow their specification. The specification are to build a magnetic coil which can produce an electromagnetic force carries with 2A of current, and to definitely with less current the steel ball will move downward and when the high current the steel ball will move upward.

1.3 SCOPE PROJECT

This project built to studies and construct the emitter circuit, reference detector circuit, photodetector circuit, different amplifier circuit, design the lifting coil, design the signal detector circuit, design the non inverting amplifier circuit and design the phase lead network circuit to demonstrate a steel ball float in the air.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discuss about how the steel ball can float in the air by using the lifting coil and two photodetector which produce the magnetic force into this device. The magnetic levitation demonstrator is the simple structure an is based on electromagnetic science by *Samuel Earnshaw Theorem*. In his theorem expressed the perversity of inanimate of magnetic objects.

> *When we hold two permanent magnets close together, you see that one of them will jump strongly toward from the other. It explains this frustrating behavior will always prevent you from suspending one permanent magnet above or below another, no matter how one arranges the two magnets. However, an active control circuit can get around this problem by rapidly adjusting the magnet's strength.*
>
> *1842, Samuel Earnshaw*

The basic principles is to used a current to manipulate electromagnetic power which can counteract the weight of the steel ball and keep it suspended in the air.

2.1.1 BACKGROUND OF MAGNETIC LEVITATION DEMONSTRATOR

This magnetic levitation demonstrator is a technological advances in areas offer the possibility of generating high electromagnetic fields with high efficiency. The magnetic levitation was build to give the advance mode of surface high speed transportation whereby a vehicles gliding above a guide way is suspended, guided and propelled by magnetic force, which without the magnetic levitation the speed will be slow, take a long time and high cost but with magnetic levitation, the speed become fast and the time is less for example the Maglev trans-rapid. Maglev is the short form for magnetic levitation which means the train will float at the guide way using the basic principles of magnet to replace the old steel wheel and train tracks. Maglev trains float on a cushion of air, eliminating friction. This lack of friction and the trains aerodynamic design allow the trains to reach unprecedented ground transportation speed of more that 310mph. Besides that the magnetic levitation is a good technologies that can reduce the pollution such as reduce air and highway congestion, air pollution and petroleum used.

2.1.2 ELECTROMAGNETIC LEVITATION

The electromagnetic system keeps a steel ball suspended in the air by countering the balls weight with electromagnetic force which can be expressed as the dynamic following formula in an upward direction according to Newton's law.

$$F = mg \tag{2.1}$$

where **m** is the weight of the ball, **g** as a gravitational constant and **F** is the force produce from electromagnetic coil. The magnetic field generated by current and calculated from Ampere's Law or Biot-Savart Law are characterized by magnetic field B and the unit is in Tesla. When the generated field pass through the magnetic materials which contribute internal magnetic field, ambiguities can arise a part of the field from external current and the materials. The magnetic field strength had defined as another magnetic field quantity designated as H, and the relation ship is:

$$H = B / \mu_0 \tag{2.2}$$

and if the value of unambiguous designated the driving magnetic influence from extend current in a material, independent of the material magnetic response. The relationship of B can be written in the equivalent form:

$$B = \mu_0 (H + M) \tag{2.3}$$

H and M will have the same units, amperes'/meter. The relationship in eq. (2.3) holds for all material whether they are linear or not. For linear materials, M in (A/m) depends linearity on H such that:

$$M = Xm\ H \tag{2.4}$$

where Xm is a dimensionless quantity (ratio of M to H) called magnetic susceptibility of the medium. It is more or less a measure of how susceptible or sensitive the material is to a magnetic field. Substituting eq. (2.4) into eq. (2.3) yields:

$$B = \mu_0 (1 + Xm)\ H = \mu H \tag{2.5}$$

or

$$B = \mu_0\ \mu_r\ H \tag{2.6}$$

$$B = \mu_0 H \qquad \text{where } \mu_r = 1$$

The quantity $\mu = \mu_0\ \mu_r$ is called the permeability of the material and is measured in henry's/meter; the henry is the unit of inductance and will be defined a little later. The dimensionless quantity μ_r is the ratio of the permeability of a given material to that of free space and is known as a relative permeability of the material and μ_0 being the magnetic free space permeability $\mu_0 = 4\pi \times 10^{-7}$. The magnetic force will produce the electromagnetic flux for the magnetic circuit. The magnetic force produce flux with *l* which called as flux path.

$$H = I\,N / l \tag{2.7}$$

for a circular path : $l = 2 \pi r$

$$H = I N / 2 \pi r \qquad (2.8)$$

Force on magnetic material is the practical interest to determined the force that a magnetic field exert on a piece of magnetic material in the field. This is useful in electromechanical system such as electromagnetic levitation system. An electromagnet made from iron of constant relative permeability as shown in Figure 2.1. The coil has N turn and carries a current I. with ignored the fringing, the magnetic field in the air gap is the same as that in iron ($B_{1n} = B_{2n}$).

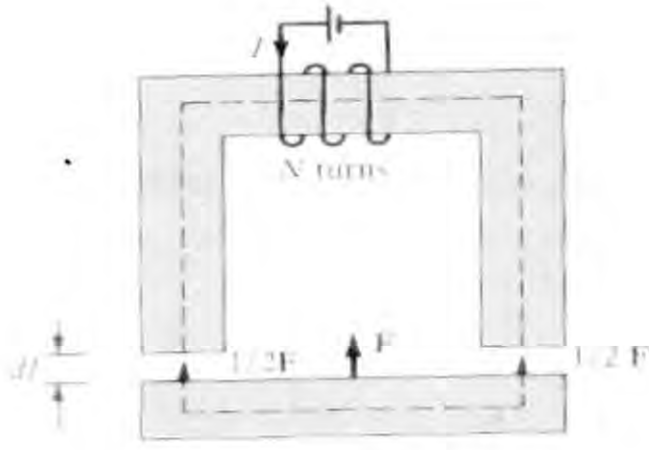

Figure 2.1: An Electromagnetic

To find the force between the two pieces of iron, the changed of total energy were calculated that would result of the two pieces of magnetic circuit separated by a differential displacement *dl*. The work required to effect the displacement is equal to the changed the stored energy in the air gap (assuming constant current) that is :

$$-F dl = d\mathrm{W}m = 2 [(1 / 2) (B^2 / \mu_0) S \, dl] \qquad (2.9)$$

where S is the cross-sectional area of a gap, the factor two accounts for the two air gaps. And the negative sign indicates that the force acts to reduce the air gaps (or that the force is attractive). Thus

$$F = -2 (B^2 S / 2 \mu_0) \quad (2.10)$$

The force is exerted on the lower piece and not and the current-carrying upper piece giving rise in to the field. The tractive force across a single gap can be obtained from eq.(2.10) as

$$F = - B^2 S / 2 \mu_0 \quad (2.11)$$

This equation can be used to calculated the forces in many types of devices including in electromagnetic levitation system. The tractive pressure in (N/m2) in a magnetic surface is

$$P = F / S = B^2 / 2 \mu_0 = 1 / 2 BH \quad (2.12)$$

Which is the same as the energy density Wm in the air gap

CHAPTER III

SYSTEM DESIGN

3.1 INTRODUCTION

This chapter explained about the overall process flow and construction to build the electromagnetic levitation demonstrator in Figure 3.1(a) from start until progress the final report, to design the circuit and to make sure the objectives of this project successfully done. Figure 3.1(b) show the flow process of electromagnetic levitation system functioned and their specifications, This system used the looping system as phase lead network to reduced the coil strength to allow the ball to go down but doesn't turn to the coil until the ball is past the reference spot. This system also used the transfer function and looping feedback system.

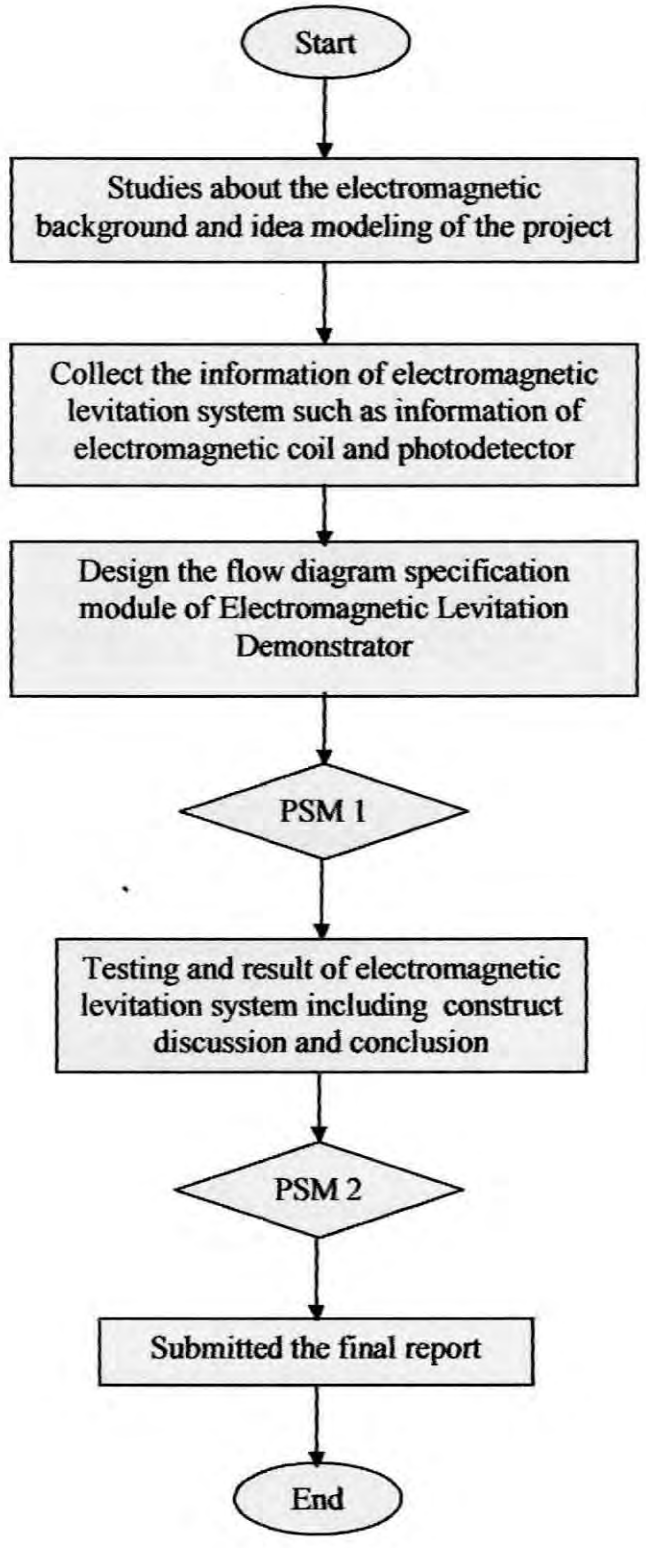

Figure 3.1(a) : Overall Process Flow

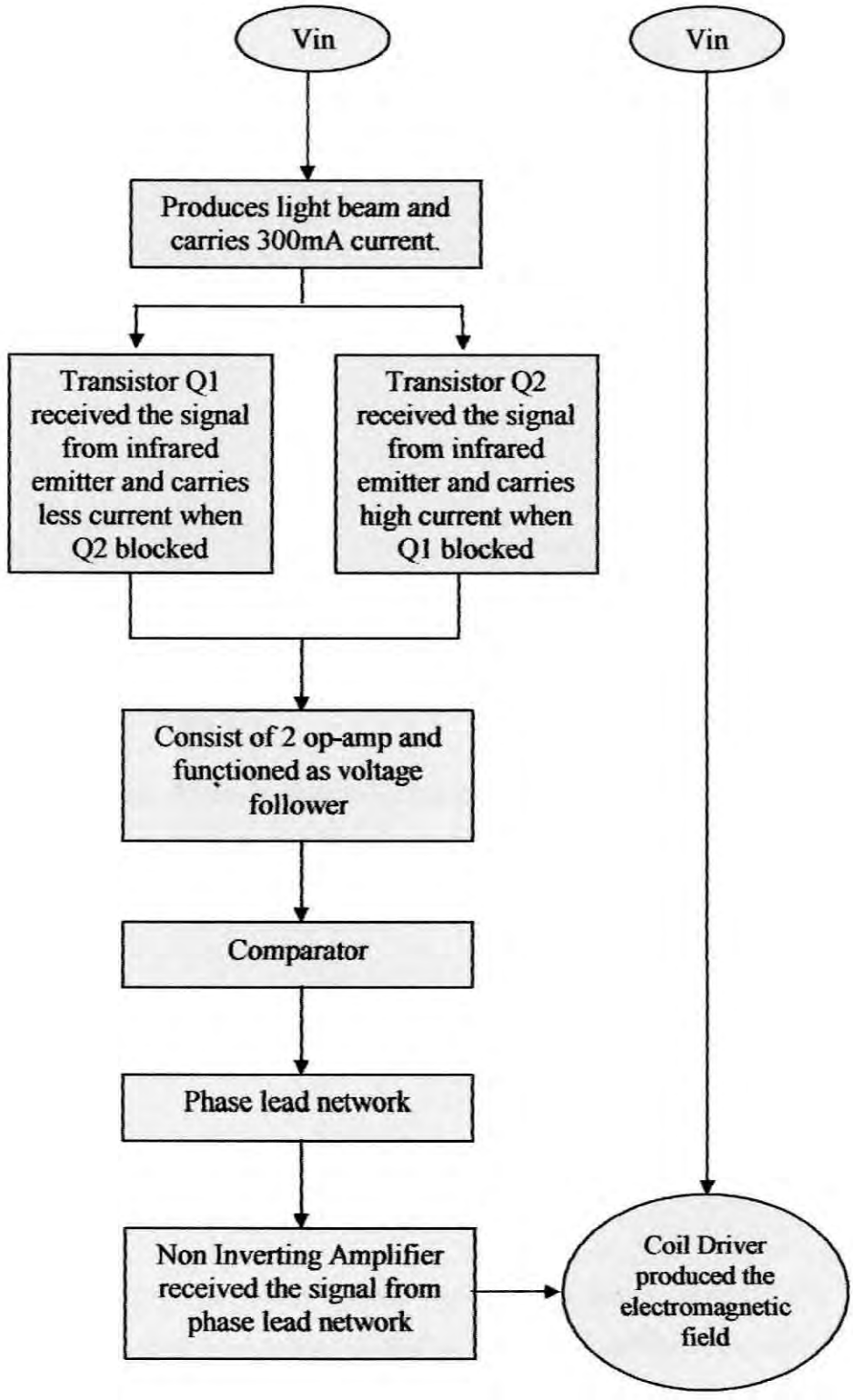

Figure 3.1(b) : Flow Process of Electromagnetic Levitation System

3.2 FLOW DIAGRAM OF ELECTROMAGNETIC LEVITATION SYSTEM

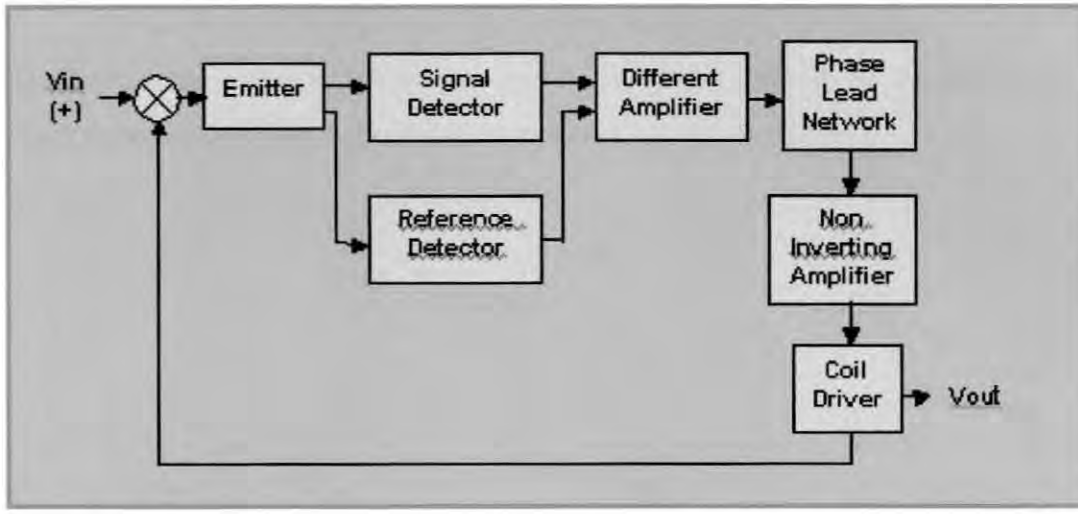

Figure 3.2: Flow Diagram of Electromagnetic Levitation With Looping Feedback System

The flow diagram shown in Figure 3.2 explained about the process sequence for electromagnetic levitation system which separated by eight stage start from input until output. Each stage explained are :

3.2.1 INPUT

The type of the input voltage that used is direct current (DC). This electromagnetic system used three input voltage for lifting coil and for integrated circuit