A NEW PROCEDURE FOR HIGH FREQUENCY ELECTRONIC BALLAST DESIGN

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APRIL 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drives)"

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree Of Bachelor In Electrical Engineering (Power Electronic and Drives)

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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Date : 5 MEI 2008

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ABSTRACT

Electronic lamp ballast is widely spread over the world because of its high efficiency electronic control over the fluorescent lamp and make it the best choice to save the energy absorbed by the lighting system. The high frequency electronic ballast is an AC/ AC power converter. It converts line frequency power from the utility to a high frequency AC power in order to drive the lamp. The high frequency electronic ballast design consists of five parts. There are filter, AC/ DC rectifier, ballast controller, DC/ AC half bridge inverter and final output stage to power the lamp. This design is able to drive a 36W fluorescent lamp from a 180-255Vac input line with frequency 50-60Hz.

ABSTRAK

Lampu elektronik ballast mendapat sambutan yang hangat di seluruh dunia kerana ia mempunyai kecekapan yang tinggi dengan menggunakan kaedah kawalan elektronik terhadap lampu berpendafluor. Ini menjadikannya sebagai satu pilihan terbaik untuk menjimatkan tenaga dalam sistem pencahayaan. Elektronik ballast berfrekuensi tinggi merupakan satu AC/DC penukar kuasa. Ia dapat menukarkan frekuensi rendah daripada sumber tenaga kepada frekuensi yang tinggi untuk menyalakan lampu. Elektronik ballast berfrekuensi tinggi terdiri daripada lima bahagian iaitu, *filter*, *rectifier*, pengawal ballast, dan *half bridge inverter* untuk menyalakan lampu. Rekaan ini mampu menyalakan lampu berpendafluor 36W daripada sumber tenaga 180-225Vac dengan frekuensi 50-60Hz.

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LIST OF ABBREVATION

AC - Alternating Current
DC - Direct Current
HPS - High Pressure Sodium
LPS - Low Pressure Sodium
THD - Total Harmonic Distortion
PCB - Printed Circuit Board
EM - Electromagnetic
DIAC - Diode for Alternating Current
MOSFET - Metal–Oxide–Semiconductor Field-Effect Transistor
IC Integrated Circuit
SIP System In Package
CFL Compact Fluorescent Lamp
ZVS Zero Voltage Switching

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CHAPTER 1

INTRODUCTION

Light is defined as visually evaluated radiant energy, which stimulates man's eyes and enables him to see. Man has always sought to counter the influence of the darkness by creating artificial light. The discovery of electric power and the possibility of transmitting it in a simple manner facilitated the development of modern lamps. Today there are nearly 6,000 different lamps being manufactured, most of which can be divided into six categories: incandescent, fluorescent, mercury vapor, metal halide, high-pressure sodium (HPS) and low-pressure sodium (LPS). Except for incandescent lamps, all of these light sources can be termed as gas discharge lamps.

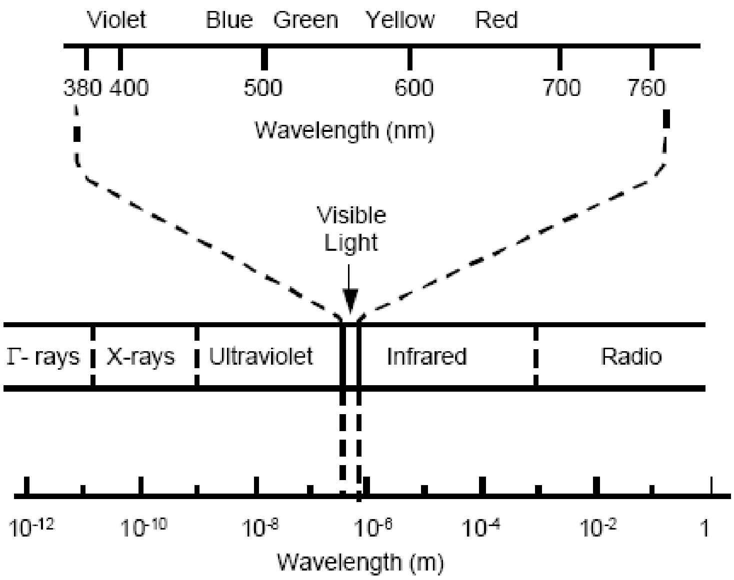

Figure 1.1: Electromagnetic spectrum

The major characteristics to be considered when choosing a lamp are its luminous efficacy, life, lumen depreciation and color rendering. Luminous efficacy is the measure of the lamp's ability to convert input electric power, in watts, into output luminous flux, in lumens, and is measured in lumens per watt (lm/w). The luminous flux of a light source is the electromagnetic radiation within the visible part of the electromagnetic spectrum multiplied by the sensitivity of man's eyes to that part of the light from the source. The visible portion of the spectrum covers the wavelength range from approximately 380 nm to 780 nm as shown in Figure 1.1. The life of a lamp is the number of hours it takes for approximately 50% of a large group of lamps of the same kind to fail. Failure means that the lamp will no longer light or that light output has dropped to a specific percentage value. Lumen depreciation during life is a characteristic of all lamps. This is a process of lamp aging, an important consideration in lighting design. Finally, there is the matter of color rendering. The lamp types do not provide the same nominal "white." Their difference in spectral distribution can produce two effects within a lighted space. Some of the colors of objects within that space can appear unnatural or faded – reds can appear brown, violets nearly black, etc. Second, the entire space may "feel" warm or cool. For example, a mercury lamp, lacking in reds and oranges, makes a space seem cool, whereas an incandescent lamp, with deficiencies in the blue and violets, makes a space feels warm.

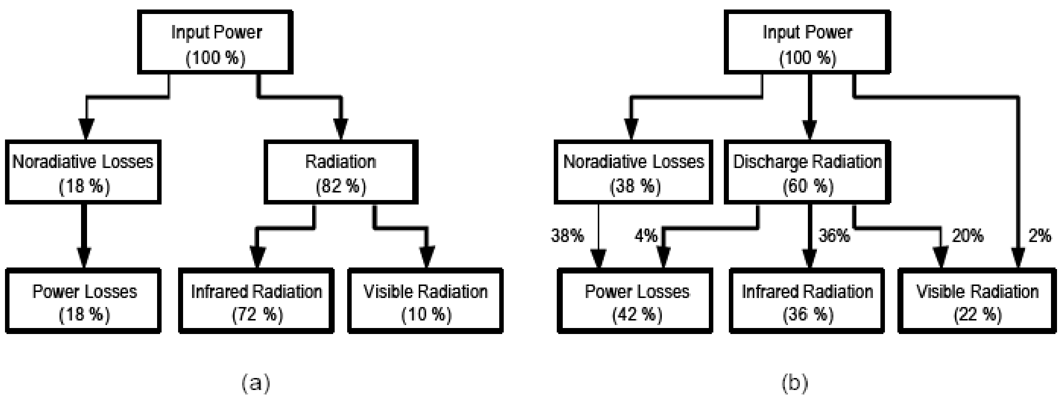

Figure 1.2: (a) Energy distribution of an incandescent lamp (b) Energy distribution of a fluorescent lamp

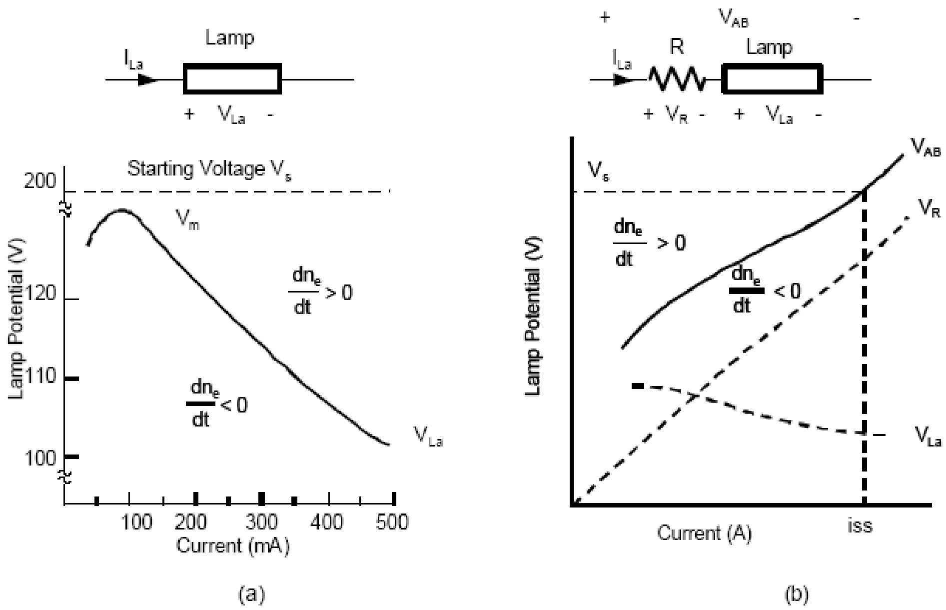

Figure 1.3: (a) Discharge potential drop versus current (b) The effect of series resistance in stabilizing lamp current

Although gas discharge lamps have tremendous advantages over incandescent lamps, they require an auxiliary apparatus called a ballast to run with them because gas discharge lamps have negative incremental impedance. Figure 1.3(a) shows a typical curve of discharge potential drop versus current when a lamp is operated from a DC power source. The curve can also be regarded as the locus of points (*i,v*) for which the time rate of change of electron density, *dne/dt*, is zero. For points above and to the right, *dne/dt* is greater than zero (production exceeds loss), and electron density would increase with time. For points below and to the left, *dne/dt* is less than zero, and electron density would decrease with time. Obviously, the slope of the curve, defined as incremental impedance r ≡ *dv/di*, is negative. The negative increase impedance characteristic poses a circuit problem for operating lamps. In general, a starting voltage Vs that is higher than the steady-state operation voltage is needed to establish ionization in the gas. After the discharge begins, the operating point (*i,v*) of the discharge would lie somewhere on the line of the constant V =Vs, which is in the domain for which the ionization rate exceeds the loss rate, and thus electron density *ne* increases continuously with time. Consequently, the discharge current increases without any regulation, and eventually causes system failure.

As a result, gas discharge lamps cannot be directly connected to a voltage source. Certain impedance must be placed between the discharge lamp and the voltage source as a means to limit lamp current. For example, Figure 1.3(b) shows the effect of series resistance in stabilizing lamp current. The dotted lines V_{La} and V_R show the voltage potential across the discharge and resistor, respectively, and the solid line VAB shows the potential across the pair in series.

Upon application of a starting voltage to the lamp-resistor system and establishment of ionization, the operating point (*i*,*v*) is in the domain of positive *dne/dt*, increasing the lamp current until it reaches the point (*iss,Vs*). A further increase in current would move the operating point into the region of negative *dne/dt*, forcing the current back to *iss*. The resistor *R* helps to establish the stable operating point of the discharge lamp and acts as the ballast.

Obviously, the resistive ballast incurs large power loss and significantly reduces the system efficiency. Fortunately, most discharge lamps are operated in alternating-current (AC) circuits so that inductive or capacitive impedance can be used to provide current limitation. AC operation also balances the wearing of two electrodes and maintains a longer lamp life. The inductor ballast represents the conventional ballasting approaches, and is known as magnetic ballasts.[1]

Nowadays, a great amount of produced electrical energy in the world is consumed in the form of artificial illumination, and any improvement in the efficiency of illuminating systems is desirable. The use of fluorescent lamps reduce the consumption of electrical energy when compared to incandescent lamps, because the former present higher efficacy (lm/W). The performance of fluorescent lamps are improved when they are supplied by electronic ballasts instead of electromagnetic ones, due their features, such as high efficacy, low audible noise, longer lamp useful life, small size, light weight, and flicker absence. The drive circuit is easily employed with self-oscillating circuit to use in electronic ballasts. When it uses the self-oscillating gate drive circuit, it brings additional improvements, such as reliability, low cost, and little energy consumption. Beyond of features of high frequency operation; the main attractiveness is the simplest configuration, and zero voltage switching operation.

1.1 Problem statements

The design circuit for high frequency electronic ballast must perform three main functions:

1. Provide a start up voltage across the end electrodes of the lamp.
2. Construct a self-oscillating gate driver.
3. Maintain a constant current when lamp is operating in steady-state.
4. Assure that the circuit will remain stable.

1.2 Project objectives

These are the objectives of this project:

1. Study the characteristic of high frequency electronic ballast.
2. Design high frequency electronic ballast.
3. Develop the circuit of high frequency electronic ballast.
4. Comparison between electronic ballast with conventional ballast.

1.3 Project scopes

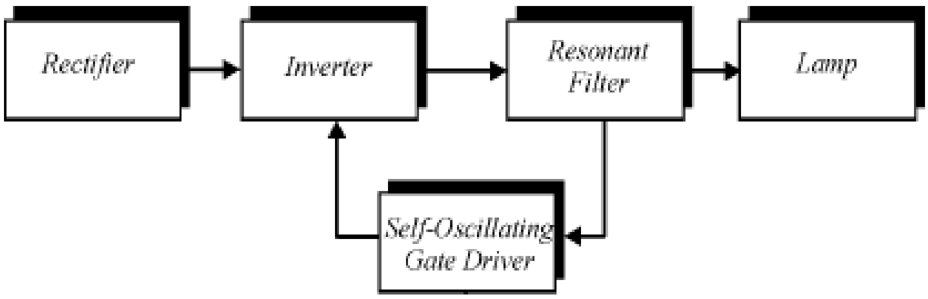

Figure 1.4: Scope of constructing electronic ballast

The scope of this project is to build electronic ballast according to the Figure 1.4. The electronic ballast consists of rectifier, inverter, self-oscillating gate drive, and resonant filter. A bridge rectifier makes use of four diodes in a bridge arrangement to achieve full-wave rectification. Bridge rectifier is used to convert AC power to DC power. A self-oscillating gate driver is used to switch on and off complimentary of transistors to produce a high frequency square wave of inverter output. Then, the square wave is gone through the low-pass filter to eliminate the undesired harmonic components. Finally, a comparison between electronic ballast and conventional ballast will be done by doing circuit analysis.

1.4 Thesis outline

In this project, I would like to design electronic ballast to drive a 36W fluorescent lamp. In this report, I will discuss it in detail in five sections. There are introduction, literature review, methodology, results and discussions, and conclusion.

In chapter one (introduction), I discussed about the major characteristics to be considered when choosing a lamp. There are more advantages of gas discharge lamps over incandescent lamps but they require a ballast to run with them because gas discharge lamps have negative incremental impedance. The problem statement, project objectives, scope and thesis outline are also included in this chapter.

In chapter two (literature review), a comparison between the conventional and electronic ballast is made. The comparison is made by discussing the operation of conventional ballast and the problems caused by conventional ballast. Then electronic alternatives are provided to encounter the problems. Later, each part of the electronic ballast is discussed in detail. The full bridge rectifier, half bridge inverter, and filter is discussed separately in their contribution to the functional of electronic ballast.

In chapter three (methodology), I discussed about the techniques and consideration that I applied during I carried out my PSM1 and PSM2. Fourier analysis is an important tool to consider the harmonic components in the square wave. In simulation part, OrCAD software is used to simulate the design circuit before I proceed to the hardware part. The Fluke meter is used to do the analysis of the circuit operation and comparison between magnetic ballast and electronic ballast. Besides that, the illuminator is used to measure the lighting level.

In chapter four (results and discussions), the results are obtained using the methodology discussed in previous chapter. The calculation using Fourier analysis is done to determine the required filter. Then, OrCAD simulation is done to the design circuit to ensure it functions probably. This is determined by looking at the graph obtained during simulation. Finally, I proceed to the hardware part. Here all the obtained results are gathered. Finally, analysis is done according to the results.

In chapter five (conclusion), a brief summary and recommendation of this project are provided. Besides that, I also include my personal experiences during the construction of electronic ballast. Finally, I have finished all the parts in my project planning according to the objectives and scopes.

1.5 Project planning

Table 1.1: Gantt chart

PERANCANGAN PROJEK *PROJECT PLANNING*													
Senaraikan aktiviti-aktiviti utama bagi projek yang dicadangkan. Nyatakan jangka masa yang diperlukan bagi setiap aktiviti. *List major activities involved in the proposed project. Indicate duration of each activity to the related month(s).*													
	2007							**2008**					
Aktiviti Projek *Project's Activities*	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**
Report project PSM 1 & 2		X	X	X	X	X	X	X	X	X			
Research on electronic ballast design		X	X	X									
Study and design circuit using OrCAD (software)			X	X	X	X	X	X	X	X			
Presentation PSM 1				X	X								
Build and troubleshoot the circuit (hardware)				X	X	X	X	X	X	X			
Analysis circuit by doing comparison between the electronic ballast and conventional ballast								X	X	X			
Writing thesis and presentation PSM 2								X	X	X			

The Gantt chart shows the project planning of the major activities in PSM 1 and PSM 2. In PSM 1, I have completed the research on electronic ballast design, study and design circuit using OrCAD, presentation, and build the circuit. In PSM2, I have completed the analysis of electronic ballast and magnetic ballast.