DEVELOPMENT OF DIMMABLE ELECTRONIC BALLAST FOR FLUORESCENT LAMP

NG ENG BENG

MAY 2009

"I hereby declare that I have read through this report entitle "DEVELOPMENT OF DIMMABLE ELECTRONIC BALLAST FOR FLUORESCENT LAMP" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

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A report submitted in partial fulfillment of requirements for the degree of Bachelor in Electrical Engineering (Power Electronic and Drive)

Faculty of Electrical Engineering
UNIVERSITY TEKNIKAL MALAYSIA MELAKA

MAY 2009

I declare that this report entitle "DEVELOPMENT OF DIMMABLE ELECTRONIC BALLAST FOR FLUORESCENT LAMP" is the result of my own research except as cited as references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	NG ENG BENG
Date	:	12 MAY 2009

To my beloved mother and father

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ABSTRACT

The project titled as "Development of Dimmable Electronic Ballast for Fluorescent Lamp". Nowadays 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. To develop an electronic ballast with the expectation dimmable feature, it can be achieved by applying the fixed frequency oscillation while to vary voltage duty cycle.

Based on the dimming control requirement from the title, I had design the circuit by implement IC SG 3526 function as oscillator that the voltage duty cycle can varying in order to drive the circuit in dimming control. In fact 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. Regarding to this the circuit design for the electronic ballast include a AC/DC rectifier, DC/AC half-bridge inverter, optocouplers, DC power supply and oscillator.

ABSTRAK

Projek adalah berjudul sebagai "Pembangunan Pengelaman Balast Elektronik Untuk Lampu Kalimantang". Pada masa kini, balast lampu elektronik adalah dengan meluasnya dibawa ke dunia kerana kecekapan tingginya kawalan elektronik atas lampu kalimantang dan merupakan pilihan terbaik untuk menjimatkan tenaga terserap sistem lampu. Bagi membangunkan satu balast elektronik dengan jangkaan kemalapan ciri, ia boleh dicapai menjelang menggunakan kekerapan tetap ayunan manakala untuk mengubah voltan kitar tugas.

Berdasarkan pengelaman mengawal keperluan daripada gelaran, saya telah mereka litar dengan melaksanakan IC SG 3526 fungsi sebagai pengayun bahawa voltan itu kitar tugas boleh berbeza-beza dengan tujuan memandu litar dalam pengelaman kawalan. Sebenarnya frekuensi tinggi balast elektronik adalah satu kuasa AC/AC penukar. Ia tukar frekuensi garis kuasa daripada utiliti untuk satu frekuensi tinggi kuasa AC dengan tujuan memandu lampu. Mengenai untuk ini rekabentuk litar untuk balast elektronik termasuk satu penerus AC / DC, DC/AC penyongsang, optocouplers, bekalan kuasa DC dan pengayun.

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AC - Alternating Current

DC - Direct Current

HPS - High Pressure Sodium

LPS - Low Pressure Sodium

THD - Total Harmonic Distortion

PAR - Parabolic Aluminized Reflector

EM - Electromagnetic

nm - Nanometer

MOSFET - Metal–Oxide–Semiconductor Field-Effect Transistor

UV - Ultraviolet

IR - Infrared

EMI - Electromagnetic Interference

LED - Light Emitting Diode

RMS - Root Mean Square

PFC - Power Factor Correction

CTR - Current Transfer Ratio

Amps - Amperes

IC - Integrated circuit

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CHAPTER 1

INTRODUCTION

1.1 Light

Light, or visible light, is electromagnetic radiation of a wavelength that is visible to the human eye (about 400–700 nm), or up to 380–750 nm. In the broader field of physics, light is often used to refer to electromagnetic radiation of all wavelengths, whether visible or not.

Light can exhibit properties of both waves and particles (photons). This property is referred to as wave-particle duality. The study of light, known as optics, is an important research area in modern physics.

Three primary properties of light are:

- Intensity
- Frequency of wavelength and;
- Polarization

1.1.1 Intensity

In doing lighting efficiency work, we need to measure light intensity. We also need to know how to express light intensity for selecting lamps and for laying out the overall lighting configuration. Unfortunately, lighting terminology tends to be confusing and somewhat inconsistent. There are terms that the lighting trade uses to communicate about light intensity, and it points out which of these terms are important to know.

"Lumen" is the unit of total light output from a light source. If a lamp or fixture were surrounded by a transparent bubble, the total rate of light flow through the bubble is measured in lumens. Lumens indicate a rate of energy flow. Thus, it is a power unit, like the watt or horsepower. Lumens used to order most types of lamps, to compare lamp outputs, and to calculate lamp energy efficiencies (which are expressed as lumens per watt). Note that lumen output is not related to the light distribution pattern of the lamp. A large fraction of a lamp's lumen output may be useless if it goes in the wrong directions.

"Footcandles" and "lux" are units that indicate the density of light that falls on a surface. This is what light meters measure. The footcandle is an older unit based on English measurements. It is equal to one lumen per square foot. It is being replaced by lux, a metric unit equal to one lumen per square meter. One footcandle is 10.76 lux. The general term for lux or footcandles is "illuminance". Normally footcandles or lux is used to measure the adequacy of lighting on the task. Footcandles and lux relate only to the task area, not to the lighting equipment or to the geometry of the space. For energy conservation work in existing facilities, you need a light meter that measures illuminance in footcandles or lux. You will use it continually as you lay out lighting, select fixtures to be delamped, etc.

"Candlepower" is a measure of lighting concentration in a light beam. It is used primarily with lamps that focus, such as spotlights and PAR lamps. The official unit of candlepower is the "candela," which is equal to one lumen per steradian. (A steradian is a fraction of the surface area of a sphere that is equal to the square of the radius divided by the total surface area. This is approximately 8% of the total surface area.)

In general, "brightness" is an expression of the amount of light emitted from a surface per unit of area. "Brightness" is not an official term of the lighting trade, and lighting designers may become huffy when you use it. However, the concept is essential for understanding visual quality, especially in relation to contrast and glare. The closest official term is "luminance," which is expressed as candelas per square meter of light emitting surface. Luminance is defined in terms of the direction of light emission. The details get technical, and you probably will not need to deal with them. In brief, the brightness of an object usually depends on the direction from which you look at it. Luminance is the converse of illuminance. The former describes the intensity of light that is leaving a surface, whereas the latter describes the intensity of light that is falling on a surface. For light reflected from a surface, luminance equals illuminance multiplied by the percentage of reflectance. "Brightness" also is used to describe the subjective sensation of light intensity. This sensation largely depends on the overall layout of the scene surrounding the viewer. An uncomfortable level of brightness is described as "glare." [1]

1.1.2 Frequency or wavelength

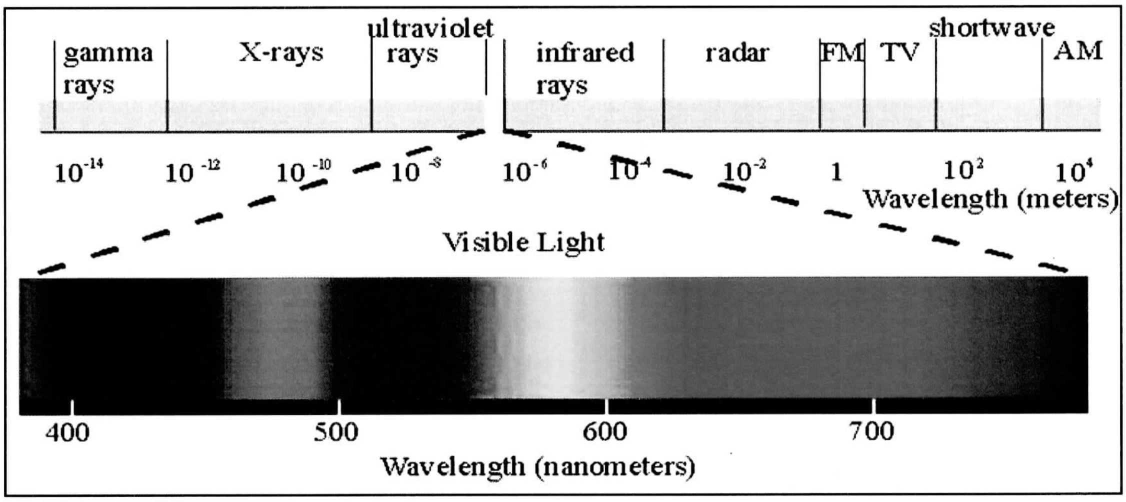

Figure 1.1: Electromagnetic spectrum

The form of electromagnetic radiation your eyes can detect is called ``visible" or ``optical". Astronomers have only recently (within the past few decades) been able to use the other forms of electromagnetic radiation or light. Every time technology has been developed to detect another form of light, a revolution in our understanding of the universe has occurred. The figure 1.1 shows all of the forms of electromagnetic radiation in order of increasing wavelength (given in nanometers (nm)) and decreasing energy.

There are some *general properties of electromagnetic radiation:*

1. It can travel through empty space. Other types of waves need some sort of medium to move through: water waves need liquid water and sound waves need some gas, liquid, or solid material to be heard.
2. The speed of light is constant in space. All forms of light have the same speed of 299,800 kilometers/second in space (often abbreviated as *c*). From highest energy

to lowest energy the forms of light are Gamma rays, X-rays, Ultraviolet, Visible, Infrared, Radio. (Microwaves are high-energy radio waves.)

3. A wavelength of light is defined similarly to that of water waves---distance between crests or between troughs. Visible light (what your eye detects) has wavelengths 4000-8000 Ångstroms. 1 Ångstrom = 10^{-10} meter. Visible light is sometimes also measured in nanometers (``nm" in the figure 1.1): 1 nanometer = 10^{-9} meter = 10 Ångstroms, so in nanometers, the visible band is from 400 to 800 nanometers. Radio wavelengths are often measured in centimeters: 1 centimeter = 10^{-2} meter = 0.01 meter. The abbreviation used for wavelength is the Greek letter lambda:λ.

White light is made of different colours (wavelengths). When white light is passed through a prism or diffraction grating, it is spread out into all of its different colours. You see this happen every time you see a rainbow. Not all wavelengths of light from space make it to the surface. Only long-wave UV, Visible, parts of the IR and radio bands make it to surface.

Besides using wavelength to describe the form of light, you can also use the frequency--the number of crests of the wave that pass by a point every second. Frequency is measured in units of hertz (Hz): 1 hertz = 1 wave crest/second. For light there is a simple relation between the speed of light (c), wavelength (λ), and frequency (f):

$f = c/\lambda$.

Since the wavelength λ is in the bottom of the fraction, the frequency is inversely proportional to the wavelength. This means that light with a smaller wavelength has a *higher* (larger) frequency. Light with a longer wavelength has a *lower* (smaller) frequency. [2]

1.1.3 Polarization

An important property of optical waves is their polarization state. A vertically polarized wave is one for which the electric field lies only along the z-axis if the wave propagates along the y-axis (Figure 1.2). Similarly, a horizontally polarized wave is one in which the electric field lies only along the x-axis. Any polarization state propagating along the y-axis can be superposed into vertically and horizontally polarized waves with a specific relative phase. The amplitude of the two components is determined by projections of the polarization direction along the vertical or horizontal axes. For instance, light polarized at 45° to the x-z plane is equal in amplitude and phase for both vertically and horizontally polarized light (Figure 1.3).

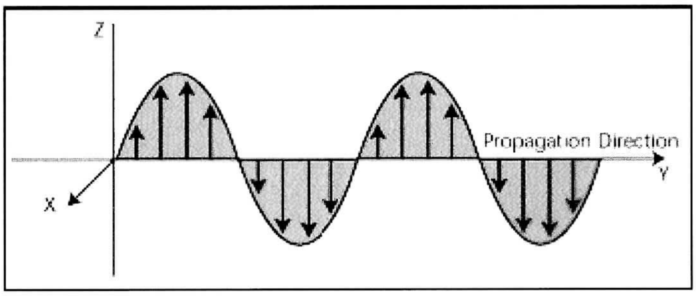

Figure 1.2: Linearly polarized light in the vertical direction

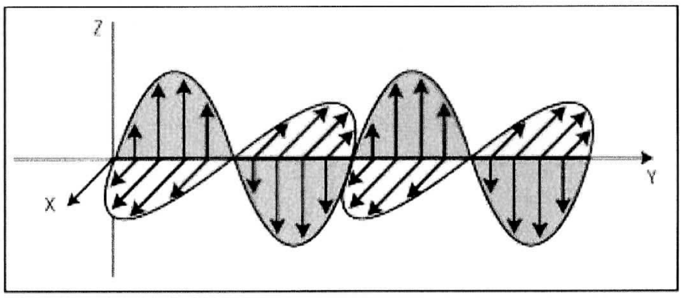

Figure 1.3: Linearly polarized light at 45 degrees.

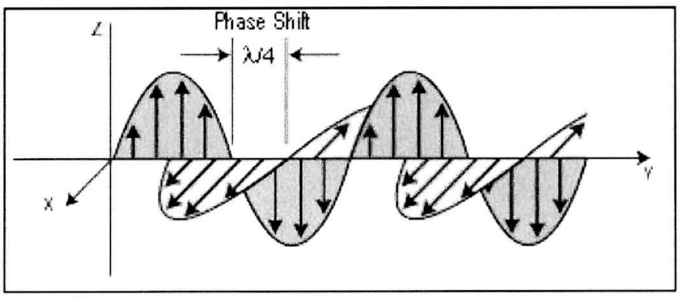

Figure 1.4: Circularly polarized light

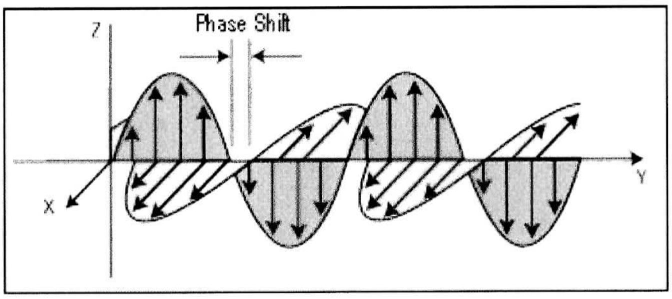

Figure 1.5: Elliptically polarized light

Circularly polarized light is created when one linear electric field component is phase shifted in relation to the orthogonal component by λ/4, as shown in Figure 1.4.

Elliptically polarized light represents an arbitrary phase shift between the two electric field components, as seen in Figure 1.5.

We produce linearly polarized light when we send unpolarized light through a polarizing medium whose axis is in line with the desired linear polarization. Passing this polarized light through a second polarizer allows only the components that are parallel to the polarizing axis to emerge while the orthogonal component is absorbed. If vertically polarized light is sent through a polarizer oriented at 45° the emerging light is reduced in amplitude by a factor of $1/\sqrt{2}$ and in intensity by 50% of the original intensity. If vertically polarized light is sent through a horizontally oriented polarizer no component of the original light is parallel to the polarization direction and no light emerges. [3]

1.2 Problem statements

The design of dimming control electronic ballast must perform with conditions as stated below:

1. Provide a start up voltage across the end electrodes of the lamp.
2. Maintain predefined current flow in the circuit during steady state operation of the lamp.
3. Dimmable feature is applied to provide the dimming control for the circuit.
4. Assure the fluorescent lamp remain stable which not to flickering.

1.3 Project objectives

Objectives of this project are:

1. Design the electronic ballast within dimming control.
2. Study the characteristic of fluorescent lamp.
3. The circuits provide dimmable feature to the ballast so that the lamp can dim between 100% to 10% luminosity.

1.4 Project scopes

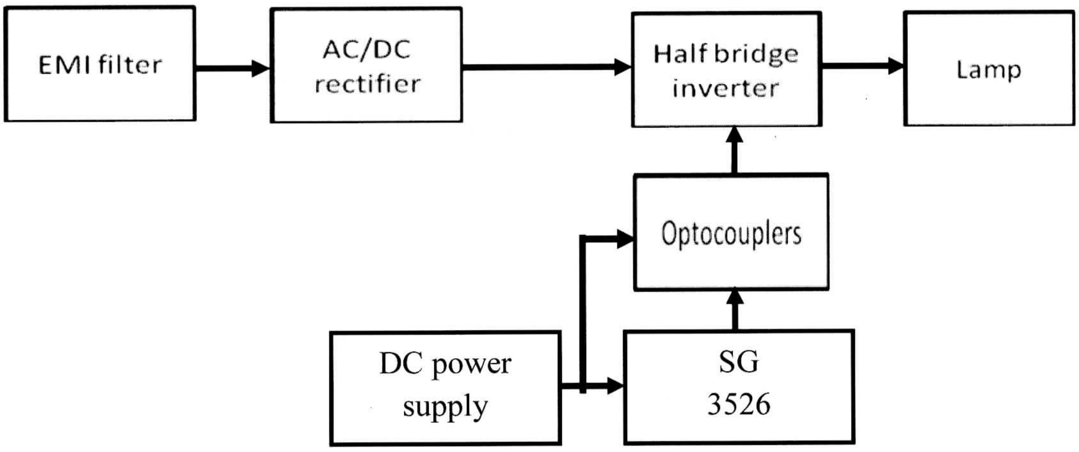

Figure 1.6: Scope of constructing electronic ballast.

The scope of this project is to build a dimmable electronic ballast according to Figure 1.6. The electronic ballast consists of AC/DC rectifier, DC power supply, half bridge inverter, optocouplers and IC SG 3526. In order to develop an electronic ballast with the expectation dimmable feature, it can be achieved by applying fixed frequency oscillation while to vary the voltage duty cycle. By implementing IC SG 3526 function as oscillator, we can vary the voltage duty cycle which to drive the circuit in dimming control. The load of the circuit is a fluorescent lamp with the power unit 10 watt. Finally the result can observed through light intensity produced by the fluorescent lamp. By doing this PSM title, it is to implement dimming control in electronic ballast which to drive the fluorescent lamp.