# PWM PIC16F877A DIMMING ELECTRONIC BALLAST FOR HPS LAMP

NATRA BINTI ISMAIL

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*Dedicated to my beloved father & mother*

*Ismail Bin Abdullah & Hamidah Binti Samat*

*Siblings:*

*Nazera*

*Nadia*

*Nabila*

*Nazree*

*Abdul Samat*

*Nekmaa*

*And*

*My Entire friend in MEP programme*

*For their encouragement*

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# ABSTRACT

Universiti Teknologi Malaysia (UTM) is a second highest on energy consumption in Johor Baharu. One of the factors influenced the consumption of energy in UTM is street lighting energy usage which consumes about 1,238.24 MWh per year of the total energy consumption in UTM. This is approximately 2.08% of the total of energy consumption in UTM. Currently, the conventional street lighting installed in the UTM consists of 956 units of 150W and 277 units of 250W High Pressure Sodium (HPS) lamp. This type of street lighting usually integrated with magnetic ballast where it is cheap and robust. However, the operation hours cannot be controlled by using this ballast, meaning the operating hours for the street lighting are 12 hours per day, hence consuming more energy. Thus, to overcome the problem on high energy consumption and operating cost, this thesis proposes to use a Pulse Width Modulation (PWM) PIC16F877a dimming electronic ballast to replace the existing system. The aim is to develop the PWM dimming electronic ballast for the street lighting system with more energy saving and environmental friendly. An experiment on the developed electronic ballast controller was performed on one unit of a 150W HPS lamp and the result was projected for 956 units for 150W HPS lamp in UTM. Results show that this new ballast system able to save energy up to 31.79% with a payback period of 1 year and 7 months. Analysis also indicates the reduction of Carbon Dioxide ($CO_2$) emission of 173397.79 kg per year.

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# ABSTRAK

Universiti Teknologi Malaysia (UTM) merupakan pengguna kedua tertinggi dalam penggunaan tenaga di Johor Baharu. Faktor yang mempengaruhi penggunaan tenaga di UTM ialah lampu jalan dimana jumlah penggunaan tenaga adalah 1,238.24 MWh bagi setiap tahun. Ia merupakan 2.08% daripada jumlah keseluruhan penggunaan tenaga di UTM. Sebanyak, 956 unit untuk 150W dan 277 unit untuk lampu 250W bagi lampu HPS. Balast magnetik yang digunakan untuk lampu jalan.konvensyional kerana ianya boleh diperolehi dengan harga yang murah. Bagaimanapun, waktu operasi tidak dapat dikawal menggunakan balast tersebut, bermaksud ia akan beroperasi selama 12 jam setiap hari dan akan menggunakan lebih banyak tenaga. Maka, untuk mengatasi masalah yang berkait dengan penggunaan tenaga yang tinggi dan kos operasi, tesis ini akan mencadangkan untuk menggunakan pemodulatan lebar denyut (PWM) PIC16F877a balast elektronik menggantikan system lampu jalan yang sedia ada. Tujuannya adalah membangunkan PWM pemalapan balast elektronik untuk sistem lampu jalan yang dapat mnghasilkan penjimatan tenaga dan mesra alam. Ujian dilakukan ke atas satu unit lampu 150W HPS dan keputusan telah diunjukan untuk 956 unit lampu HPS. Keputusan menunjukkan bahawa sistem balast elektronik ini mampu memberi penjimatan tenaga sebanyak 31.79% dengan tempoh bayar selama 1 tahun 7 bulan. Analisis juga dmenunjukkan pengurangan pelepasan karbon dioksida (CO2) kepada 173397.79 kg setiap tahun.

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| | | |
|---|---|---|
| $L$ | - | Inductor |
| $C$ | - | Capacitor |
| $VS$ | - | Voltage supply |
| $\omega$ | - | Switching frequency |
| $\omega o$ | - | Resonance frequency |
| $Cs$ | - | Shunt capacitor |
| $Cr$ | - | Parallel capacitor |
| $I$ | - | Current |
| $t$ | - | Time |
| $f$ | - | Frequency |
| $D$ | - | Duty cycle |
| $Ton$ | - | Time ON |
| $Toff$ | - | Time OFF |
| $R$ | - | Resistance |
| $CF$ | - | Passive power factor |
| $Vgs$ | - | Voltage gate source |
| $Vcp$ | - | Ignition peak voltage |
| $Q$ | - | Quality factor |
| $Vs$ | - | Voltage supply |
| $Resr$ | - | Series equivalent resistance |
| $m$ | - | Modulation index |

# LIST OF ABBREAVIATIONS

| | | |
|---|---|---|
| *AC* | - | Alternating current |
| *ANSI* | - | American National Standard Institute |
| *CF* | - | Passive power factor |
| *CF* | - | Crest factor |
| $CO_2$ | - | Carbon dioxide |
| *CRI* | - | Colour rendering index |
| *DC* | - | Direct current |
| *EMI* | - | Electromagnetic interference |
| *GDP* | - | Gross domestic product |
| *GHG* | - | Greenhouse gases |
| *HID* | - | High-intensity discharge |
| *HPS* | - | High Pressure Sodium |
| *IEA* | - | International Energy Agency |
| *IEC* | - | International Electrotechnical Commission |
| *LCC* | - | Series-parallel inductor capacitor-capacitor |
| *LCL* | - | Series inductor capacitor |
| *LED* | - | Light emitting diode |
| *LPS* | - | Low pressure sodium |
| *MOSFET* | - | Metal-oxide-semiconductor field-effect transistor |
| *P* | - | Power |
| *PF* | - | Power factor |
| *PFC* | - | Power factor corrector |
| *PWM* | - | Pulse width modulation |

# CHAPTER 1

# INTRODUCTION

## 1.0 Background

Nowadays, the world had to deal with the problems of the most critical issues which are associated with rising energy prices. This problem is due to the limitation and depleting of fossil fuel. Another reason influenced the rising energy price is increasing of global warming, greenhouse gases (GHG), and health problem [23]. This problem can be overcome by reduction of carbon dioxide ($CO_2$) [23]. As information, the productions of carbon dioxide are caused by the burning of fossil fuel to produce electricity. The higher the rate of combustion of fossil fuel to produce electricity, it will cause the higher the carbon dioxide emissions into the air. Apart from that, the population growth in this country also resulted energy consumption growing.

For South Asia, the very largest energy consumer in ASEAN with the massive scope for growth is Indonesia followed by Thailand. Thailand is a country that dependent on the energy imports due to the limited energy resources in this country. The aim of this country is to diversity the electricity generation [1]. Then, Malaysia is the third-largest energy consumer in ASEAN with relatively high per

-capita (ktoe) consumption. Based on the statistical from the Suruhanjaya Tenaga, the electricity consumption in Malaysia was increased due to the high growth rate of population [2]. Figure 1.1 shows the energy consumption for 2009, 2010, 2011 and 2012 in Malaysia. This figure stated that the electricity consumption increased from 96,302 GWh to 116,353 GWh [2]. In addition, one of the factors that lead to increased electricity consumption is increasing in the development of industries such as factory. This statement can be proven as shown in Figure 1.2.

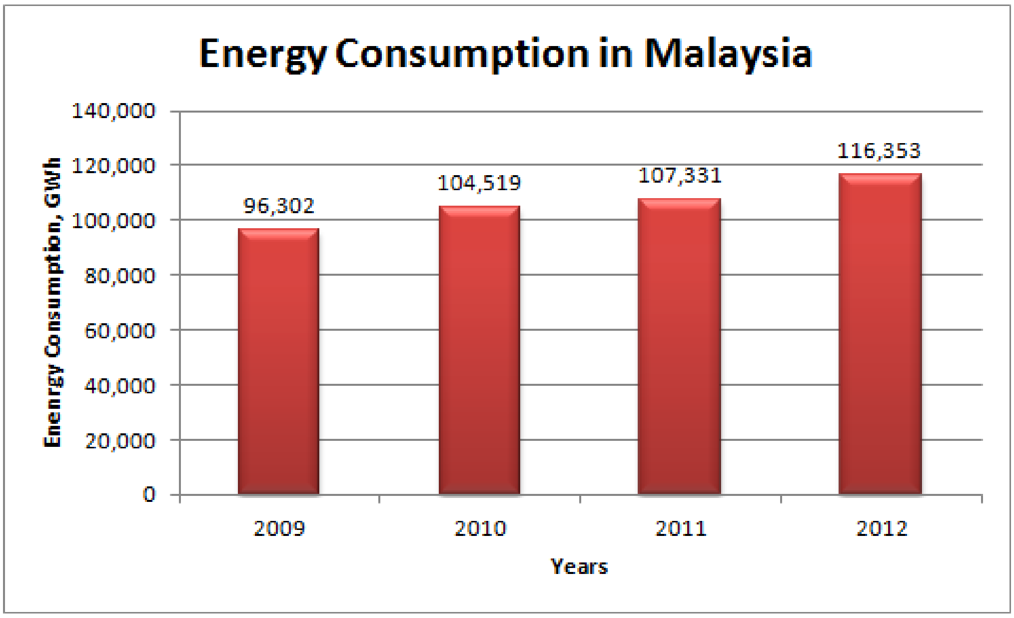


**Figure 1.1**: The Energy Consumption in Malaysia [1]

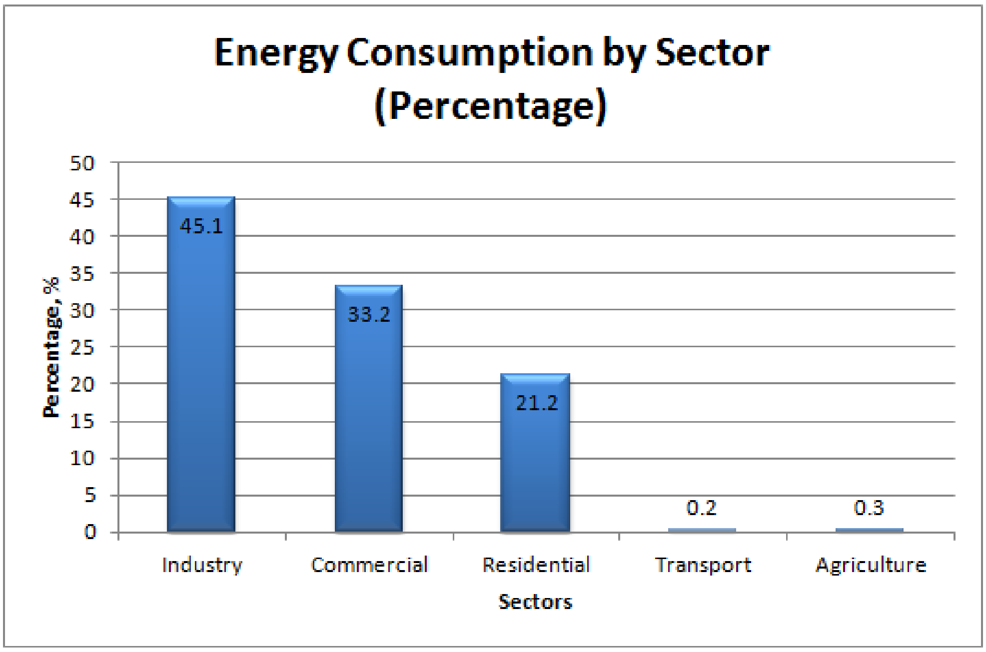


**Figure 1. 2**: Energy Consumption by Sector in Percentage [1,3]

In Malaysia, mixed generation had been used by the utility to fulfil the energy demand that consists of 53% natural gas, 26% coal, 12% hydro and the other 9% from the other form of fuels as shown in Figure 1.3. The electricity sub-sector in Malaysia is dominated by three integrated utilities such as Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB), and Sarawak Energy Berhad (SEB) and they are tabulated in Table 1.1 [4]. The main energy sources are used to generate the electricity in Peninsular Malaysia is natural gas and coal.

**Table 1.1** Utilities of Electricity in Malaysia [4]

| Area | Utility |
|---|---|
| Peninsular Malaysia | Tenaga Nasional Berhad (TNB) |
| Sabah | Sabah Electricity SDN. BHD. (SESB) |
| Sarawak | Sarawak Energy Berhad (SEB) |

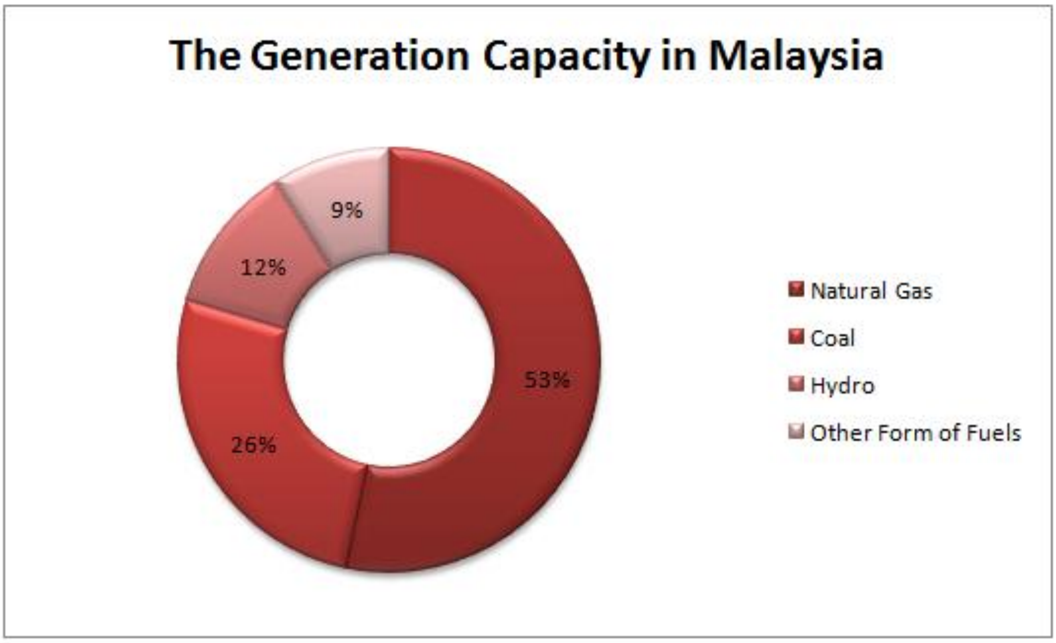


**Figure 1. 3**: The Generation Capacity in Malaysia [1]

Figure 1.3 shows the energy consumption used by sector in percentage. The sectors can be divided into industry, commercial, residential, transport and agriculture [2]. The main sector contributing in energy consumption is industry with 45.1%, followed by commercial 33% and 21.2% for residential. As can be seen in Figure 1.3, the lighting is included in residential sector that is third largest in energy consumption in Malaysia. The lighting system can be divided into two part that are indoor lighting and outdoor lighting. Indoor lighting is the lamp inside the building and usually accomplished using light fixture. While, the outdoor light is installed outside the building and refers to several types, one of them is street lighting.

Definition of street lighting is fixed lighting installation intended to provide good visibility to user of outdoor public traffic areas during the hours of darkness to support traffic safety, traffic low and public security [5]. Function of outdoor lighting is to avoid the accidents and for residential streets is promoting the safety and well being.

However, the installation of lighting can caused the higher energy consumption in our country. The approximate value of energy consumption used for lighting around 20% in Malaysia [6]. Therefore, many researches were conducted on how to reduce the usage of energy especially for street lighting.

## 1.1 Problem Statement

As mentioned above, the use of street lighting is one of the factors that contributed toward higher energy consumption to our country. Besides that, it also will be caused harmful to our environment. In order to reduce this two factor that influenced more in our economy, the new idea regarding it to be established.

So, many researchers had purposed techniques on how to reduce the energy consumption for street lighting. In the past the conventional electronic ballast is very popular to be integrated with the lamp. However, by using this conventional ballast, it will affect the environment due to emission of carbon dioxide into the atmosphere. Besides that, this conventional street lighting cannot be controlled in dimming the brightness of the lamp. Therefore, the street lighting will be operated throughout the night with full of power. It just used timer to turn ON and OFF the lamp and the timer operated at 7pm until 7am.

Awareness on the street lighting energy consumption is increasing with new ideas had been established to integrate an electronic ballast with dimming capabilities. The use of electronic ballast to be built in with the HPS lamp has the potential to reduce the energy consumption. Hence, the impact of this way, it will reduce the carbon dioxide emission to the atmosphere and reduces the effect of greenhouse.

## 1.2 Project Objective

The main objective for this project is to develop a prototype of electronic ballast of street lighting microcontroller. This objective will be met through the three objectives:

- **i.** To design a PWM PIC16F877A Dimming Electronic Ballast System for 150W HPS lamp street lighting.
- **ii.** To implement the prototype of PWM PIC16F877A Dimming Electronic Ballast and 150W HPS lamp.
- **iii.** To analyse and validate the energy consumption on the developed electronic ballast controller to the conventional ballast.

## 1.3 Scope of Study

The scopes of study are very important to ensure this project is conducted according to the given time and successfully. There several scopes of works for this project:

- **i.** Design a PWM PIC16F877a Dimming Electronic Ballast System for 150W HPS lamp street lighting.
- **ii.** Develop a prototype of PWM PIC16F877a Dimming Electronic Ballast and 150W HPS lamp.
- **iii.** Cost comparison between conventional and proposed PWM Dimming Electronic Ballast in term of energy consumption and the reduction of CO2.

## 1.4 Project Methodology

The project methodology is as Figure 1.4. First step, an understanding on current electronic ballast is needed to be read. After that, the electronic ballast for 150W HPS lamp is designed by using Matlab Simulink. Then, the controller for the electronic ballast is designed by using Proteus and embedded the coding in the PIC16F877a by using MPLab. Lastly, the electronic ballast microcontroller is conducted in term of cost of energy and $CO_2$ emission. Hence, perfect of planning will be caused all the development process will run smoothly without any problem.

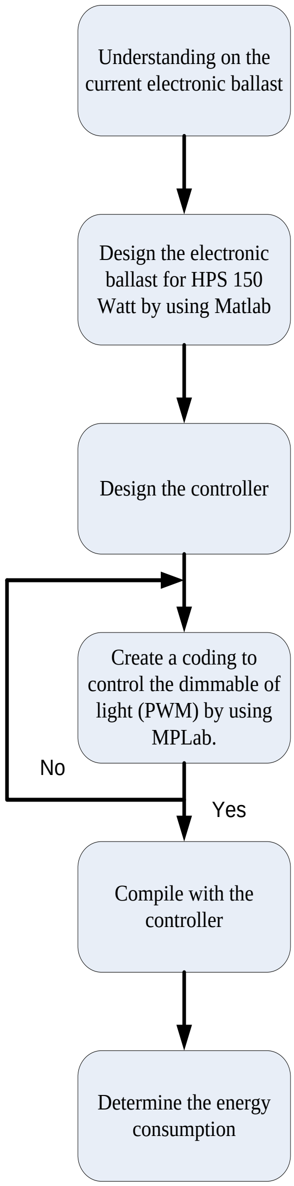


**Figure 1. 4**: Steps of Project Methodology

## 1.5 Thesis Outline

This thesis consists of four chapters. In the first chapter, it explains deeply about the objectives and scopes of the project. Besides that, in this chapter also describes about the flow charts and the process to achieve all the objectives in this project.

In chapter 2, the theory and background of this study is discussed. The theory have been discussed in this chapter includes the theory of magnetic ballast, electronic ballast and microcontroller used for electronic ballast especially for street lighting.

In the chapter 3, the discussion is more about the software and hardware will be used in this project. It includes the design and develops the prototype of electronic ballast for street lighting (150Watts). There are four parts in this circuit that including EMI Filter, Rectifier and Power Factor Correction (PFC), Inverter and Resonant load. All these parts are explained more details in this chapter. MATLAB Simulink needs to be used to do simulation on electronic ballast circuit.

The complete circuit is presented in chapter 4. In this chapter, the result of the electronic ballast in MATLAB Simulink was discussed in details. The parameters involved in this circuit analysis are voltage, current and output power of lamp. All these parameter were used for three different level of dimmable of lamp. To get a different level of brightness, the modulation index, m had been varied into 3 times, for 100%, 80% and 50%. The comparison between conventional ballast and electronic ballast were discussed in this chapter to know the suitable ballast used for reducing the energy consumption. An additional, the $CO_2$ emission was calculated for both ballast.

As a conclusion, by using PWM PIC16f877a dimming electronic ballast for HPS Lamp is the best solution to reduce the energy consumption for street lighting. Besides that, the $CO_2$ also were reduced when the energy consumption became lower. In order to produce the intelligent street lighting, the future recommendation was explained in the last chapter.

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