SMART LIGHTING SYSTEMS:
MODULAR INTELLIGENT CONTROL SYSTEM

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Electrical & Electronic Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"MODULAR INTELLIGENT CONTROL SYSTSEM"** was prepared by **Liu Chee Wei** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of (Hons.) Electrical & Electronic Engineering at Universiti Tunku Abdul Rahman.

Approved by,

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Specially dedicated to
my beloved family

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Throughout the whole process of the final year project, I had gained a lot of knowledge and experience. Unlike the ordinary course subject, final year project are able to train us in independently and practically on handling a project. This is a very valuable and precious experience where it cannot be obtain in ordinary studies or books and it would be a good training for the undergraduate student before entering their career life. Hence, I would like to thanks University Tunku Abdul Rahman (UTAR) for offering this unit (UEEA 4913 – Project) in my Engineering course.

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MODULAR INTELLIGENT CONTROL SYSTEM (MICS)

ABSTRACT

The goal of this project is to design a smart lighting system with the aim of energy saving and autonomous operation. Problem arises when a large group of lighting in a building are hardly to control which causes energy wastage. Current smart lighting technologies that exist in the market reviewed and the product features, advantages had learnt for implementing in this smart lighting system design project. For the kick-start of designing Modular Intelligent Control System (MICS), different sensors and lighting control technology are studied. The summarization of all the input/output of sensors and lighting control technology given an outcome that sensors output are mostly either in analogue or digital, while the input for control lighting are mostly in pulses or pulse width modulation (PWM). The development of MICS is to integrate each of the sensors and lighting control system into different modules. Each of the modules connected to one management console that acts as the main processor of the whole systems. Furthermore, the modular design approaches applied to MICS design, thus, any additional sensors or lighting module can be easily add to the whole system - scalability feature. MICS divide into two modules: Input module and Light module. Input module receives the sensor signal while light module controls the lighting system. Between the communications of MICS with the management console, there is data protocol that is predefined. MICS are capable to become the lighting solution on most of the buildings. The MICS are compatibility with the current commercial technologies such as Schneider Electric commercial product. Part of the work has been used for the competition held by Schneider Electric and won the first runner up with the prototype works.

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LIST OF SYMBOLS / ABBREVIATIONS

MICS	Modular Intelligent Control System
IHAS	Intelligent Home Automation System
TRIAC	Triode for Alternating Current
LDR	Light Dependent Resistor
ROI	Return of Investment
DALI	Digital Addressable Lighting Interface
PWM	Pulse Width Modulation
AC	Alternating Current
DC	Direct Current
RC	Resistor Capacitor
SCR	Silicon Controlled Rectifiers
IC	Integrated Circuit
HVAC	Heating Ventilation and Air Conditioning

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CHAPTER 1

INTRODUCTION

This chapter cover the background of this project entitled Modular Intelligent Control System (MICS) for smart lighting system, the aim of this project, project motivation, project objectives, project overall organization, task responsibilities for the author, justification, involvement in the project, project scope, project planning, project deliverables, and overview of the thesis outline.

1.1 Modular Intelligent Control System Background (MICS)

Recently Green issue has been raised as a hot topic, especially in Engineering Field, where most of the researcher and engineer are involving themselves in finding a solution to reduce the energy usage at the same time increasing their product efficiency. One of the methods is the smart system, where it is commonly applied to residential, commercial and industrial area. Smart systems have been assisting in the past and now it is still being improves and implemented in every sector.

Smart system is an autonomous operations where detects the environment changes through sensors and acts to correct the offset cause by the environment. Moreover, the systems continually perform from time to time to reach the optimal result that pre-defined in the system.

Control system is integration of a number of devices to incorporate functions of sensing, actuation and control. This system is capable of describing and analysing a situation and takes the decision based on the actions that are pre-defined. As showing in the figure 1.1, it is one of the close loop control system where is commonly used to control a process with the assist of the feedback from the sensors.

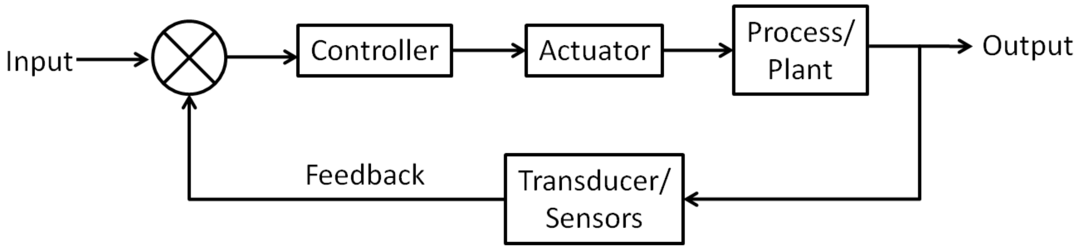


Figure 1.1: Close loop control system (Sources: www.industrial-electricity.com)

Peoples are told to turn OFF the lights when are not in use – one of the best way to save energy. These days, many buildings integrated with automated lighting where people do not even have to toggle the switch to save energy. With the aid of automated lighting, the lights are turn ON if there is person in the room and turn OFF when there is none - close loop control system. For a smart lighting system, a number of sensors are incorporate together to control the lights effectively, which fulfil the "smart" criteria. As example, some of the smart lighting systems are add-on with the extra feature where it will control the lights luminance correspond to the ambient lights. This method is uncommon in most of the buildings today and thus there is a big opportunity to save more energy with the smart lighting system.

Modular Intelligence Control System (MICS) is design in such a way that the system able to integrate with the most different types of sensors to control the lights effectively. In addition, with the modular design approach, MICS is easy to expand and thus this makes the whole system scalability. Furthermore, MICS is a robust system where it perform well not only under ordinary conditions but also under unusual conditions (e.g. power interruption).

1.2 Project Motivation

As energy saving becomes the hot topic nowadays, one of the issue always been discussed – the energy saving could be achieved through the lighting as it is one of the most power consumption electrical devices. Although one unit of the lighting is low (about 36W), due to their large number and the long duration of their working period, it becomes one of the energy saving target.

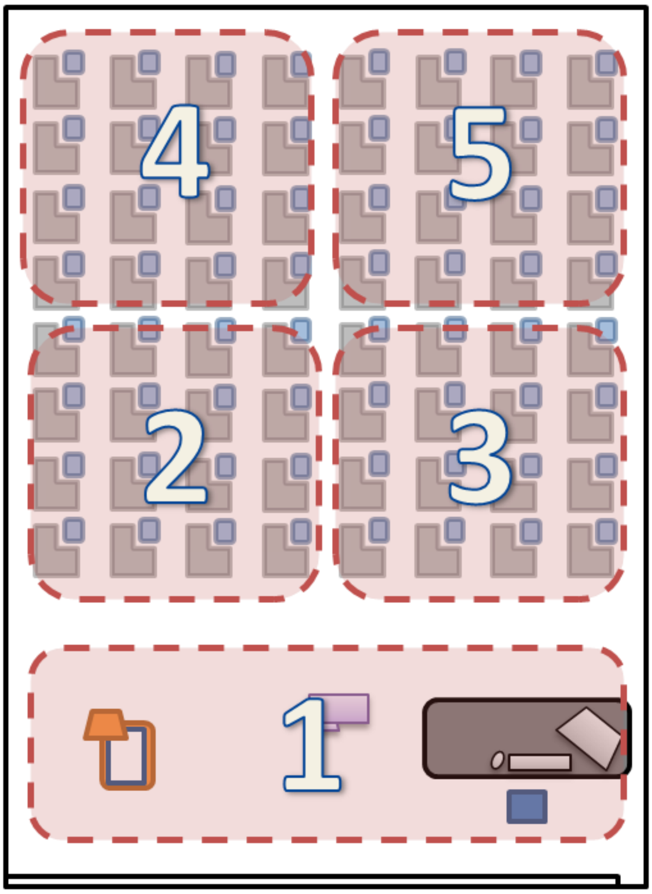


Figure 1.2: Illustrated lecture hall

An example in a lecture hall can use as an illustrated problem, where the illustrated diagram is show figure 1.2. Zone 1 is the groups of lighting for the lecture area while the other zones (zone 2 to zone 4) are the groups of lighting for the student area.

Some of the possible problems that always occur in the lecture hall can be:

Case 1: Whenever the lecture hall is unoccupied, the lightings in the lecture hall will still be turning ON.

Case 2: When a small group number of student occupies the class, (e.g. only zone 2 and zone 3 occupied by student) all the lights in zone 1 to zone 4 will still be turning ON.

Case 3: Lecturers are having hard time whenever they switch their teaching mode (e.g. white board to projector screen). This is because different teaching mode needs different lighting environment.

Donald Graham (2009) had studied that lighting can represent up to 55% of an education facility use. With the improved lighting efficiency and controllability, it can yield energy savings up to 40% and some of the latest new products are able to achieve energy savings up to 60%. From the research and study, it shows an important message that lighting could become one of the energy saving target. Furthermore, with the smart lighting system, a great energy and cost saving could achieve.

As mentioned earlier, smart system is an autonomous operation. It becomes one of the important trends in building's technology. Hence, this project not only just aiming for energy saving, but also in advancing the technology of smart home system. From the research and studies done, smart home systems equipment that currently present in residential and commercial market is costly (e.g. C-Bus Clipsal, DALI). Thus, an idea comes where the design of the MICS need to be cost effective and yet effective performance. The target of the MICS is to become the choice of affordable smart lighting solution with the motto: Every house light can now be SMART.

1.3 Aims and Objectives

The aim for this project is to design a smart lighting system which targets the energy saving and autonomous operation on economical affordable for residential and commercial.

Objectives of this project are to:

- Build an energy saving smart lighting system with integrated sensors and controllers.
- Design a smart lighting system with modular approach design, which makes the system scalability and expandability.
- Design a smart lighting system which compatibility and scalability with other commercial product and automation system, which might include more than lighting systems.

1.4 Project Overall Organization

This MICS project is handling together parallel with Intelligent Home Automation System (IHAS) - Mak Kwan Wuey (2011). With the combination of these two systems, it shows the complete smart lighting system. They can be working separately but it works best when both of the system integrated together where MCIS becomes the management console in the whole system. The role of the IHAS is to perform algorithms of the controlling lights and their intensity correspond to the sensor signal, and at the same time give the control access to the user to control the lights system with the designed user interface (UI). The communication between MICS and IHAS are through serial communication. Please refer to Intelligent Home Automation System (IHAS) (Mak Kwan Wuey, 2011) for further understanding.

The MICS are builds in different modules, with the modules categorized into two types - input module and light module. The complete basic diagram of the MICS is show in figure 1.3.

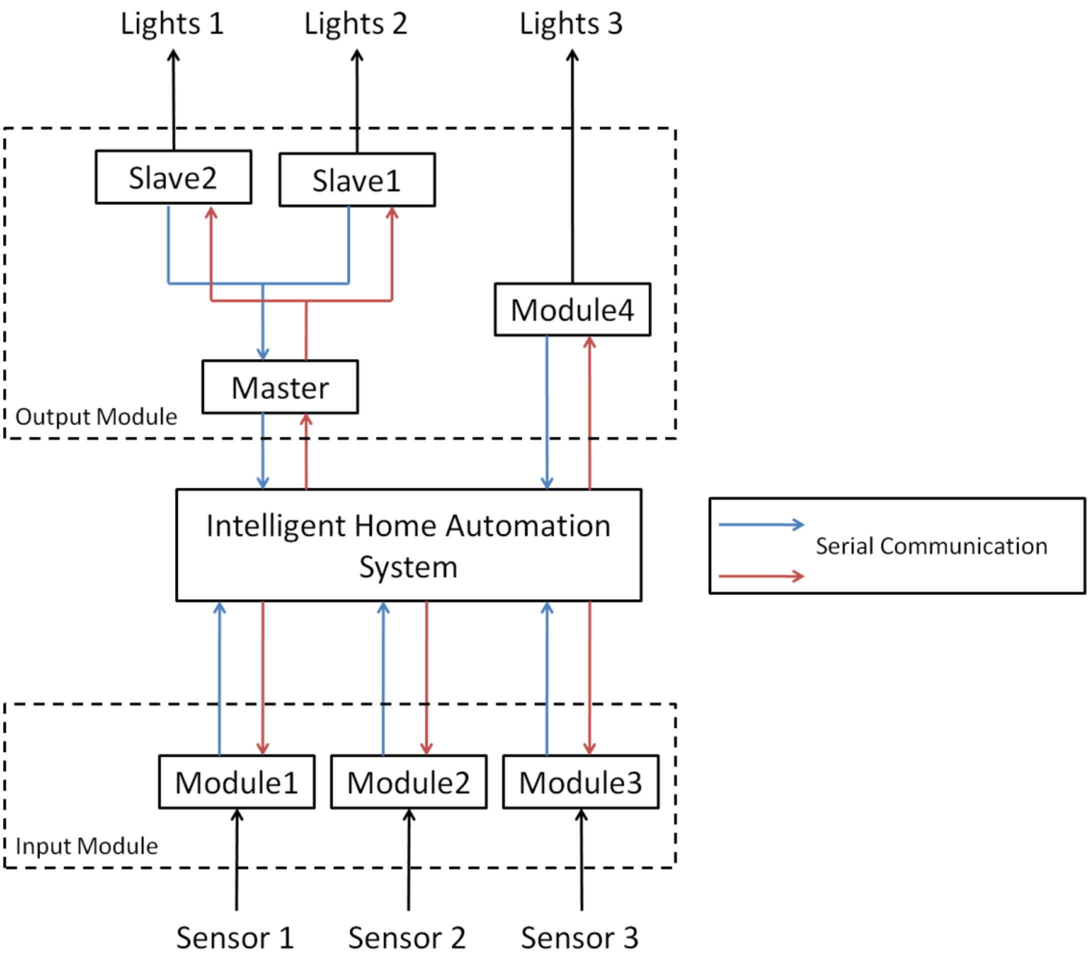


Figure 1.3: Basic block diagram of MICS

The input module receive the sensor signal and send the signal to IHAS where the light module receive the command signal from the IHAS and control the lights based on the command received. The light module also can divide into master-salve module or single module. Detail about the MICS will discuss later.

1.5 Methodology

The first stage of this projects starts from literature review, studied on current smart lighting technology, and learnt about how does the lighting system and sensors integrates. The product features and advantages gained from the outcome of the studies and noted down for implementing on this project. The sources of the information are from website, journal, books etc.

Next different lighting control system and related sensors are researched and the summarization on the input/output is made for the ease of designing MICS. The choice of the sensors based on the product in the market that easy to obtain. The operation of each sensors and lighting control system is build and tested.

The design of the MICS is proceed with decision of the choices of microcontroller based of the feature and function the MICS need. The prototype of MICS is build and tested.

Lastly, the projects proceed with the integration of both MICS and IHAS. After the successful of integration of both system, the progress is proceed on implement the hardware on different module to shows that the compatibility of the system with current product technology such as Schneider Electric energy efficiency product.

1.6 Thesis Outline

This thesis will start with discussion about the current smart lighting technology that available in the market, and the design of other University student on lighting system.

In the next chapter, the outcomes of the research of different type of lighting control system and sensor technologies will be discuss with a summarization of input/output for lighting control system and sensor for the ease of referring when designing MICS.

The next chapter will explain the MICS design in detail and the feature of MICS such as compatibility with current product technology that available in the market.

Finally, the last chapter will have a brief summary on the outcome of the design of MICS with the feature, advantages and future implementation direction of MICS.

CHAPTER 2

LITERATURE REVIEW

In general, this chapter cover the literature review from different sources related to the smart lighting system – invention of other's project, technology and current industrial product. Observation and findings about their advantages and recommendation from the studies discuss in this chapter too.

2.1 Smart Street Lamp Monitoring System

2.1.1 Overview

A group of student (Prakash, Shankar, Guha, Alam, 2010) from institute Sir M. Visvesvaraya Technology had invented smart street lamp monitoring system using Xbee wireless module. Their aim is to monitor the health of street lamps and forward monitored result to the control station.

Figure 2.1 shows the simplified block diagram of the complete smart street lamp monitoring system. Inside the lamp module, it consists of light dependent resistors (LDR) module, microcontroller module and transmission module. The lamp module will communicate with the control centre through wireless using Xbee.

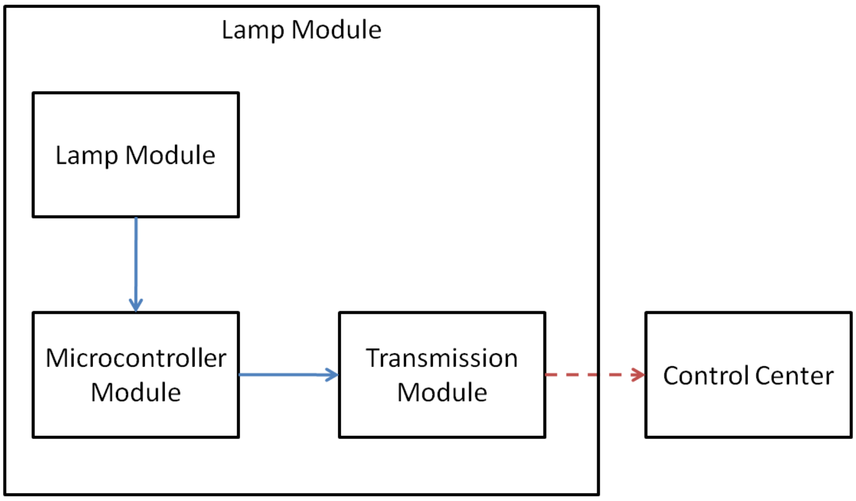


Figure 2.1: Simplified block diagram of smart street lamp monitoring system

In the LDR module, it consists of two LDR. One of the LDR is install on top of the street lamp for the checking the day/night status condition. Another LDR is place under the street lamp to monitor and checking the lamp health status. The results of the LDRs send to microcontroller, where the microcontroller will process the data and send the data to the transmission module. In the transmission module, there is wireless Xbee that transmit the data through wireless to the control centre. In the control centre, it will monitors each of the street lamp status, as well as controlling the operation of the street lamps.

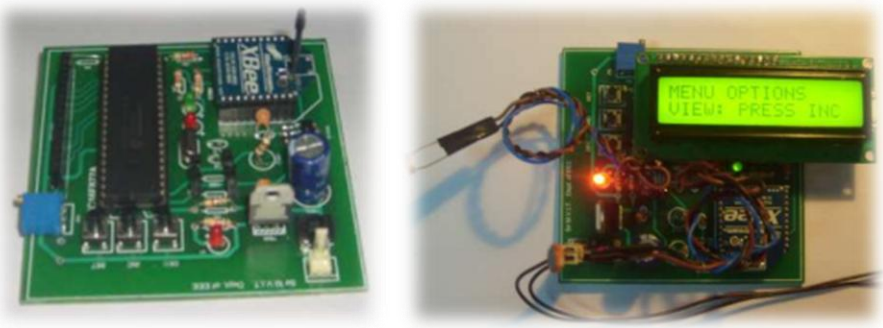


Figure 2.2: Smart Street Lamp monitoring System (source: www.slideshare.net)

2.1.2 Findings and Recommendation

This system resolves the faulty street lamps issue, where people are rarely taking the initiative to report faulty street lamps in their locality. With this device, it able to track whenever there is faulty lamps and sends the data to the control centre. Thus, technician will be able to acknowledge the faulty street lamps at the first moment and head for the repair.

Another benefit of this system is the cost saving in terms of wiring. The Xbee module will allow the streets lamps communicate to the control system via wireless. With the wiring method, the high cost of the construction and material makes the system uneconomical; moreover, the reliability of the system will reduce too.

Although this system monitors the health of the street lamp status, it did not have other smart feature whereby controlling the street lamps by automatically turning ON or OFF the lamps. If this feature is apply to this system, this allow another great energy saving. In addition, any faulty lamp will be automatically turning OFF which avoid more energy wastage causes by the faulty lamps.

With the application of the lamp illumination control on the system, the lamps are able to turn ON the lights with low illumination when the surrounding condition needs the low light illumination of the lamps (e.g. rainy or cloudy day).

There are no data of the return of investment (ROI) of this system, but it may believe that the ROI will be in less than 8 years. One of the main weaknesses of this system is the device are placed at outdoor, thus, precaution steps need to be taken whereby the case of the devices must be designed carefully. It must be sealed or isolated probably to avoid the environmental that could affect the lifespan of the devices.

2.2 Digital Addressable Lighting Interface (DALI)

2.2.1 Overview

DALI is technical standard that control lighting in buildings for a network based system. One of the DALI controllers from ABB-bus KNX® is shows in figure 2.3. DALI standard specified in the IEC 60929 - standard for fluorescent lamp ballast, encompass the communications protocol and electrical interface for lighting control networks. (Digital Addressable Lighting Interface from Wikipedia, 2010). Further detail on IEC 60929 standard is show in figure 2.4 below.

Figure 2.3: ABB-bus KNX® DALI Light Controller (taken from ABB-bus KNX®)

IEC 60929 is an international standard created by the International Electro-technical Commission and covers electronic ballasts used in AC supplies with voltages up to 1000 V and with operating frequencies at 50 Hz or 60 Hz. The actual operating frequency may deviate from the specified supply frequency – (Digital Addressable Lighting Interface, 2010)

Figure 2.4: IEC 60929 standard

From the studies of Li, Wu and Zhog (2008), DALI allow electronic ballast, dimmers, light sensor, transformers relay, controllers to be mixed and matched into a single control system. Thus, this will form a network that each of the devices is likely to be "talk" to each other in the network. The controller in the DALI network is able to control each light by means of a bi-directional data exchange, thus this allows the control of the device status message (e.g. lamp fault). DALI protocol permits devices to individually address or simultaneously address multiple devices.

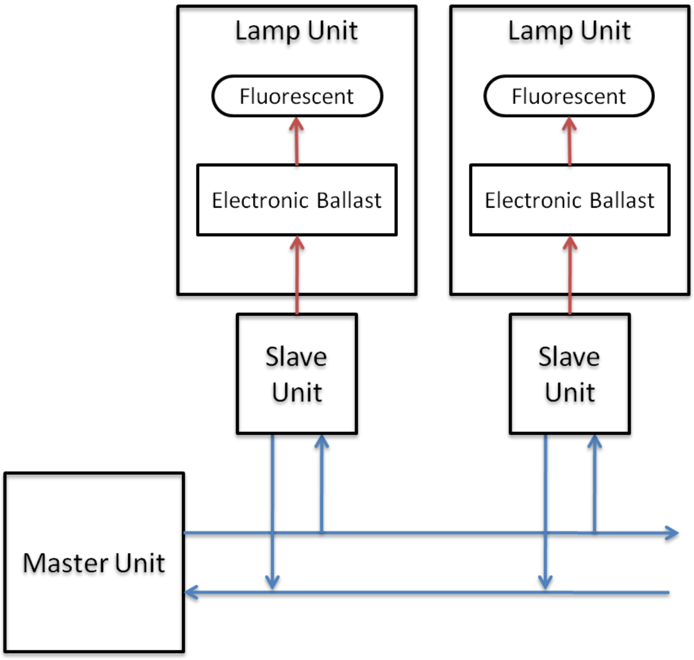


Figure 2.5: DALI Master Slave Module

Figure 2.4 shows the block diagram of DALI module, where it consists of master and slave unit. Every DALI master can control a numbers of slaves, and gives each of the slaves an individual physical address. For dimmable ballast, it can be subordinate to any one group of the slave. Other devices may also apply with the DALI module such as sensors.

2.2.2 Findings and Recommendations

DALI has its advantages if it used to control a group of lights. Rather than each light with a controller, DALI able to become the master module of all the lights whereby it gives each of the slaves an individual unique address. Thus, the master module becomes the main controller whereby the master module controls the operation of the status of the lights. In addition, DALI master module is able to receive signal from the other communication (e.g. RS232) and control each slaves with the pre-set program or the command from the other communication. Furthermore, DALI are a two-way communications, whereby it able to receive signal from a particular slave, this will become handy when dealing with the faulty lights where the slaves are able to send the faulty lamp signal to the master. Not to forget mention that DALI are also able to install with sensors such as LDR. Hence, it is an applicable method into the project for controlling the large group of fluorescent lamp with the electronic ballast.

CHAPTER 3

Lighting Control & Sensor Technologies

This chapter cover the technology of lighting control and sensors used in Modular Intelligent Control System (MICS). It will starts with discuss the method for lighting control for different types of lights. Next, this chapter will discuss the appropriate sensor in assisting the smart lighting systems.

3.1 Introduction

The studies of the method of lighting control and the sensors integrated in smart lighting technology will helps in further understanding of the design and working principle of MICS.

3.2 Light Dimmer

Light dimmer had been assisted in the past few decades on improving their efficiency. Voltage is the basic factor in controlling the lights intensity. The earlier voltage control methods achieve using power resistor and adjustable transformers. Basic principle of this voltage control method is the power distribution through the resistance, which in result of low power efficiency. The other problems are bulky, expensive and hardly to control in remote location.

Since 1960, power electronics had improved effectively where thyristors and TRICS introduced in the market. By using this component in controlling the lighting intensity (or control voltage), the energy efficiency is well improved. At the same time, it is small and inexpensive and it makes the light dimming are easily controllable from remote location. This type of electronics light dimmers becomes available after 1970 and nowadays it is still widely used in many locations. (Engdahl, 1997-2000)

3.2.1 Incandescent Bulb Dimmer

Incandescent bulb is the source electric light works by incandescence (general term for heat driven light emission). It has the lowest efficiency or the highest power consumption among the lights, which the power are mostly wasted in the bulb heating. By controlling the intensity of the incandescent bulb (using power switching method - TRIAC), it will greatly improve its power efficiency hence achieve power saving.

3.2.1.1 Triode for Alternating Current (TRIAC)

TRIAC (or bidirectional triode thyristor) is a bidirectional switch for AC circuits that control the percentage of the current flow through the TRIAC to the load. It is an electronic component approximately equivalent to two silicon-controlled rectifiers (SRC). TRIAC is commonly used in many applications such as lights dimmers, speed control etc. Although variable resistor is one of the solutions to control the AC current to a load, the heat dissipated on the resistor is high and thus, it is not advisable for energy saving usage. TRIAC controls the current flow by applying trigger pulse at a controllable point in an AC cycle. (Kuphaldt, 2009)

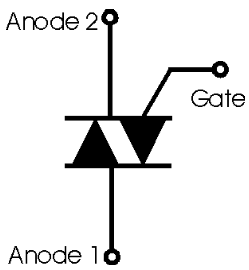


Figure 3.1: TRIAC symbol

Figure 3.1 shows the circuit symbol for the TRIAC. Unlike thyristor, which is only able to conduct current in one direction, TRIAC is a bidirectional device. Hence, it is suitable to be use in AC source where the current are allow to flows through the two anode terminals. The gate terminals would trigger by either positive or negative voltage. Once it triggered, the devices continues to conduct until a current through the anode drops to below a certain threshold value - the holding current (or zero crossing point), such as at the end of the half cycle of AC mains power. Figure 3.2 below explain the working principle of TRIAC in diagram.

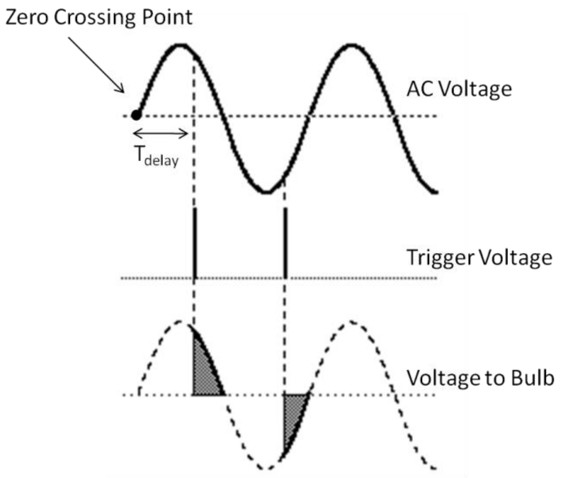


Figure 3.2: Triggering of TRIAC

Figure 3.2 gives a better explanation of TRIAC working principle. To control the incandescent light intensity, it depends the time (T_{delay}) between the gate trigger time and previous zero crossing point time. The shorter the period, the brighter the bulb is.

From the microchip website reference (Curtis, Dimming AC Incandescent Lamps , 2005), the TRIAC gate can be control through voltage pulse trigger that produced from microcontroller, which in return control the intensity of the incandescent bulb. At the same time microcontroller needs timing of zero crossing point thus it can produce appropriate delay time for gate voltage triggering. The complete circuit is show in figure 3.3.

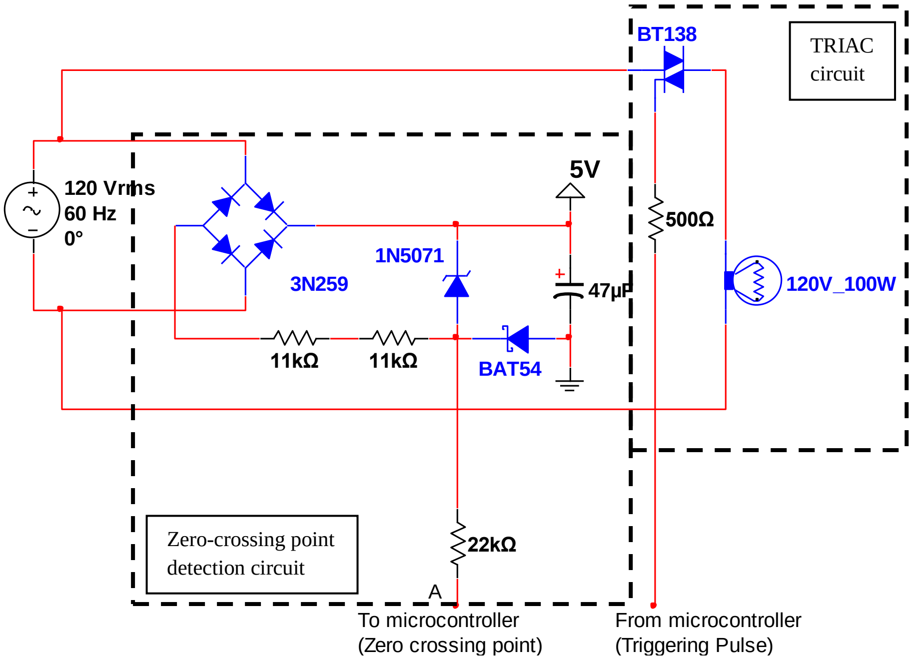


Figure 3.3: Bulb control circuit with TRIAC (Source: www.microchip.com)

The V_{AC} input voltage is reference to the US standard - $120V_{AC}$. From figure 3.3 shown, the circuit divide into two parts: incandescent bulb control with TRIAC and AC zero current signal detection circuit. For the TRIAC circuit, the gate of the TRIAC is triggering by a pulse supply from the microcontroller. As discuss above, the time for the zero crossing point is important as microcontroller needs to send the appropriate trigger pulse delay correspond to the zero crossing time. The zener diode, Schottky diode and capacitor come to play the role for detecting the zero crossing point of the AC voltage. The operating principle of this circuit is simple as: When the AC voltage is higher than 5V, the capacitor will charged and the point A connected to the microcontroller (shown in figure 3.3) will be high (5V). Once the AC voltage supply drop below 5V, the capacitor discharge and drop to 0V (ideal case). This causes the point A will be in low threshold (0V). With this information, the microcontroller will generate the appropriate delay time for TRIAC gate triggering once it detect low threshold on point A.

3.2.1.2 Summary

In short, incandescent dimmer with TRIAC are one of the energy saving solution. With the circuit shown in figure 3.3, the microcontroller able to detect the AC zero current signal and supply a trigger voltage to the TRIAC gate with appropriate delay. Thus, to control the intensity of the bulb, the delay for the gate triggering can be control: the longer the delay, the lower the intensity of the bulb.

3.2.2 Fluorescent Light Dimmer

Fluorescent light is the most commonly used lighting in buildings. Ballast is use as voltage regulator for the fluorescent light. There are two types of ballast, which namely as magnetic ballast and electronic ballast.

3.2.2.1 Ballast

Magnetic ballast (or reactive ballast) is the simplest and commonly used in regulate voltage for fluorescent lights by using magnetic core. Magnetic ballast is used rather than resistors are due to the power lost in resistance and lost in magnetic core is significant. The magnetic ballast still did have some disadvantages, which the main problem is the magnetic ballast is not dimmable ballast. In addition, the inductance load of the magnetic core causes poor power factor (consume more reactive power) which leads lower power efficiency. To turn ON the fluorescent lamps, a high in rush current is need initially during light ignition (the reason of light flickering during turn ON). Thus, frequently turn ON and OFF the lights will leads to more power loss and reduce the lifetime of the magnetic ballast.

With the improvements of the power electronics introduces electronic ballast. Electronics ballast increases the power efficiency at the same time reduce the operating cost. The basic operation of electronics ballast is converts the 60Hz AC voltage to high frequency AC voltage (20k to 40k Hz). With high operating frequency improves the power efficiency to 15% to 20% (Eley, 1993). Nevertheless, electronics ballast is small in size and quicker operation while eliminating the flickering. With the controllable electronics ballast, the intensity of a fluorescent lights can be adjust. Circuit in figure 3.4 are one of the examples of controllable electronic ballast circuit.

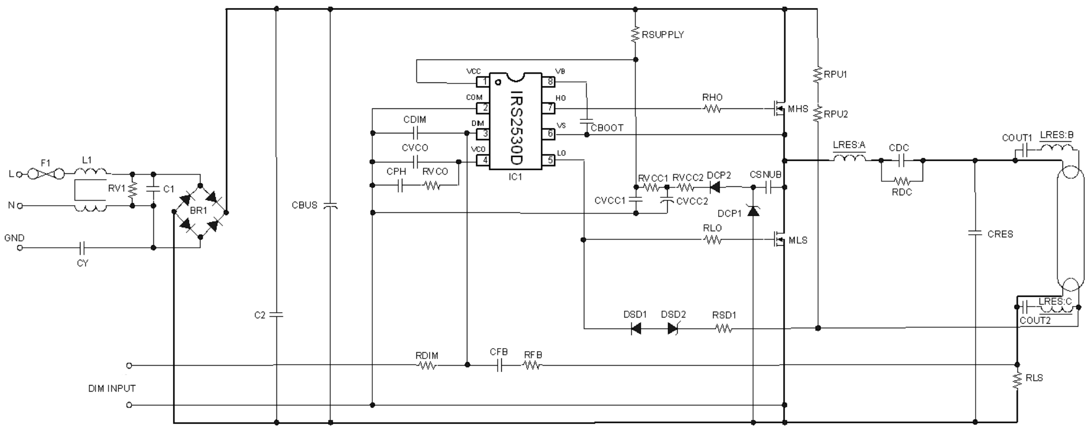


Figure 3.4: Controllable electronic ballast circuit (Source: International Rectifier)

DC dim input voltage reference is the control factor of adjusting the intensity of fluorescent lights. In this circuit example given, the range of the dim input is from 0V to 5V. On the other hand, the dim input can be control through Pulse Width Modulation (PWM) where different duty cycles of PWM give the result of different analogue voltage level - average voltage level of PWM.

3.2.2.2 Summary

An overview of dimming electronic ballast has been presented. Electronics ballast are commonly used in most of the building with the aim of achieve energy saving. However, with the remotely controlled electronics ballast, another great milestone of energy saving can achieve.

3.2.3 Light Emitting Diode

LED is the current lighting technology that improves significantly. Although the light output of an individual LED is small compare to incandescent and fluorescent lights, multiples LED will gives better light output. Note that LED has high efficiency, thus it is one of the best choices in smart lighting system.

PWM is one of the control factors in controlling the LED light intensity. With the ordinary small LED, their intensity are not high enough to be use as lighting system in a building, thus, a high power LED is introduce, which the LED consumes 1 Watt power in return produce a high intensity of brightness (e.g. 300mA, 3.3V - Luxeon LED) . Figure 3.5 shows an example diagram of high watt LED.

Figure 3.5: High power LED

Multiple of high power LED(e.g. 10 high power LED) are capable of producing a high intensity level that able to lights up a room by just consuming 10 watts power. In addition, these high watt LED's are believes having longer lifespan compare to fluorescent and incandescent bulb. One of the main disadvantages of this type of LED is expensive, thus it is still unable to be widely used in residential and commercial building.

To circuit in figure 3.5 shows the circuit connection to control a high power LED, the PWM generated (e.g. from microcontroller) are usually having low current which is not enough power to light up the LED, thus fast switching speed transistor (2N2222) is need to assist in the dimming control.

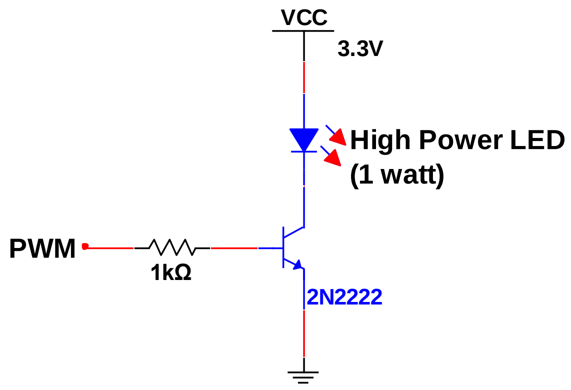


Figure 3.6: Circuit connection to control a high power LED

3.2.3.1 Summary

High power LED has advantages in high power efficiency, low and simple operating cost and small in size. The control factor of the high-power LED dimming circuit is PWM with the assists of transistor.

3.3 Sensors

Sensor is an important device in assisting the operation of a smart lighting system. Their functions such as detecting the present of human, ambient lights etc are important in triggering the lights and controlling the intensity. A number of sensors has been considering during MICS design, which will be available in the following section.

3.3.1 Human Sensor

Human sensors use in detecting the present of the human. The idea of human sensors in assist of MICS is whenever there is present of occupancy, the lights will trigger and turn ON. Once the sensors unable to detect the present of human, the lights will be turning OFF. Passive infrared sensors (PIR) are widely used in detecting present of human by detecting the motion. PIR are also names as motion sensors. A diagram of PIR sensors is show in diagram below in figure 3.7.

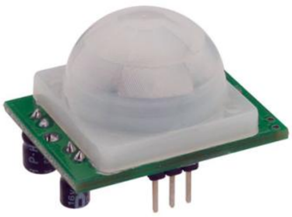


Figure 3.7: PIR motion sensor

This PIR sensors signals produce are only high (motion detected) and low (no motion detected). With this signal feed into the controller, the controller will able to notice the present of the human and thus takes appropriate action on the lights.

To be precise, the PIR sensors are only detects motion, rather than occupancy. If the occupancy is stand still, the motion sense that there is no occupancy detects and thus it send the wrong signals. Another problem arises where PIR trigger whenever there is motion (non-human) such as animal, insect pass by.

An occupancy sensor introduce where it improves the function of PIR sensors. Occupancy sensors are much more accurate in term of detecting the present of human by detects the human body infrared level. Thus, any non-human motion will not trigger this occupancy sensors, also, if the human is stand still the occupancy sensors will still able to detects the present of humans. Diagram below shows one of the human occupancy sensors from CLIPSAL.

Figure 3.8: C-Bus Multi sensors (Source: C-Bus CLIPSAL)

With some modifications apply into the PIR sensor by align two or more PIR sensors together. With the method, PIR sensors can detect the human motion with directional detection.

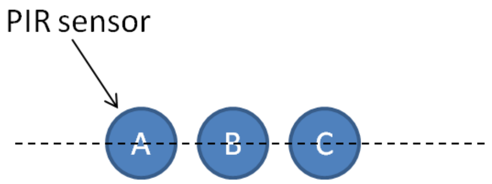


Figure 3.9: 3 PIR sensors align (Directional Detection)

As shown in figure above, when a motion is move from right to left, the sequence triggering will be (C → B → A) and vice versa. The directional detection function can be use for knowing the occupancy is move from which direction. The apply condition is very narrow: it must install in a narrow path. As example:

- Beside a door to detect occupancy is either head in the room or vice versa
- Corridor
- Staircase
- Switch

3.3.2 Ambient Light Sensors

Ambient light sensor is the most essential item in smart lighting system, where it tells the current ambient lights to the controller. There are many types of light sensors where one of them is LDR (light dependent resistors). LDR is suitable in determine the light or dark situation, where it have high resistance in dark, when there is lights, the resistance LDR will falls. The graph ambient light versus LDR resistance is show in the figure graph below.

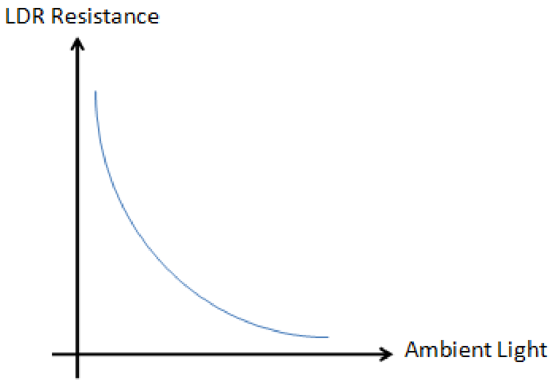


Figure 3.10: Graph characteristic of LDR

The disadvantage of the LDR is unstable, and its resistance can be affect by the heat cause by the lights. Thus, it is not suitable and eliminated in MICS design. Another ambient light sensors is introduced - phototransistor. Phototransistor is design specifically to overcome the LDR problem. It has stable feedback of ambient light intensity and its high resistance to the environmental temperature. The phototransistor (NPN bipolar type) based region is expose base. Where light strikes on the base will replace what the ordinary voltage applied to it: Higher light luminance will produce higher current thus allow more current to pass through common to emitter. (Seale, 2003)

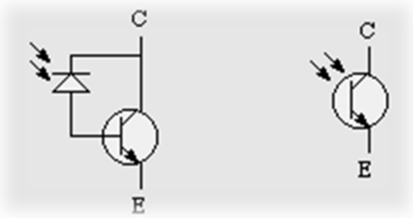


Figure 3.11: Circuit diagram of phototransistor (Source: Enecyclobeamia)

There is some of the phototransistor may have base lead that allow the bias of phototransistor lights response.

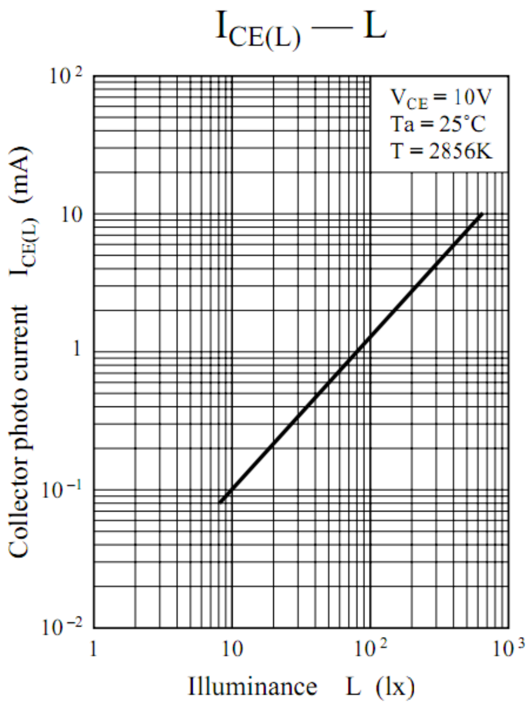


Figure 3.12: Characteristic graph of phototransistor (Source: Panasonic datasheet)

From the characteristic graph of phototransistor, it shows that phototransistors are far more stable and suitable then LDR for MICS design. The data signal that phototransistor produced will be in DC analogue voltage that the controllers need to have Analogue Digital Converter (ADC) to receive the feedback ambient light that given by the phototransistor.

Another challenge is the ambient light reader that the ambient light sensor must be accurate to feedback the ambient light level. This will be a great achievement if the controller able to did this and the MICS user will easily know the ambient light level and control the light level to their desired value.

3.3.3 Seat Occupancy Sensors

The idea of the seat occupancy sensor is by putting a switch underneath user chair to detect the present of human on that particular chair and thus, trigger the lights above the corresponding chair. It is suitable to use in restaurant, which the waiter can determine which seat is occupy on which table. In addition, the sensor used for seat occupancy is just a push ON release OFF switch, thus it is one of the cost effective sensors. The signal feed into the controller is easy to interpret by controller (either digital High or Low).

3.4 Conclusion

This summarization for the input/output for the light and sensors is important for the referring of MICS design, as shows in table 3.1.

Table 3.1: Summarization of input/output for lights and sensors

Lights	Incandescent bulb	Voltage pulse from controller; AC zero current signal to the controller
	Fluorescent	PWM from controller
	LED	PWM from controller
Sensor	PIR	1-bit digital signal to controller, 2 bits if 2 PIR is used
	Ambient Light	DC analogue voltage level to the controller
	Seat occupancy	Digital signal to controller

CHAPTER 4

MODULAR INTELLGIENT CONTROL SYSTEM

This chapter explain in detail about the design of Modular Intelligent Control System (MICS): the hardware design, communication type use, communication protocol and features of MICS.

4.1 Introduction

As shown in figure 1.3, MICS divides into two types of module: input module and light module. Each module has a controller to process the input/output signal. In addition, controller will communicate with the management console (e.g. Intelligent Home Automation System, IHAS) through serial communication. Input Module receive the input from the sensor (Digital or Analogue Signal) while Light Module produce the output signal to control the lighting (via PWM or Pulse). The controller suggested to use in this MICS design is 8-bit microcontroller - PIC18F family.

4.2 Input Module

As discussed in the conclusion of Chapter 3, sensors output signal are mainly either in the form of digital or analogue output. Thus, input modules are capable to receive both analogue and digital signal.

The functions of the microcontroller need in input module are analogue digital converter (ADC) and Universal Synchronous Asynchronous Receiver Transmitter (USART). ADC is to convert analogue input to corresponding digital number while USART is need for communication between controller and management console.

Summarization of I/Os and functions of a controller needs for an input module:

- Analogue Input (0 - 5V)
- Digital Input
- USART (1 pair of Receiver Transmitter)
- Analogue Digital Converter (ADC)

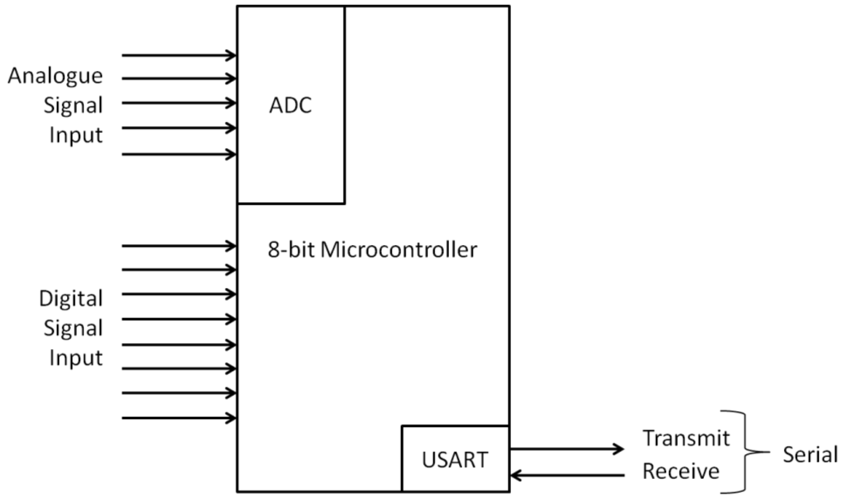
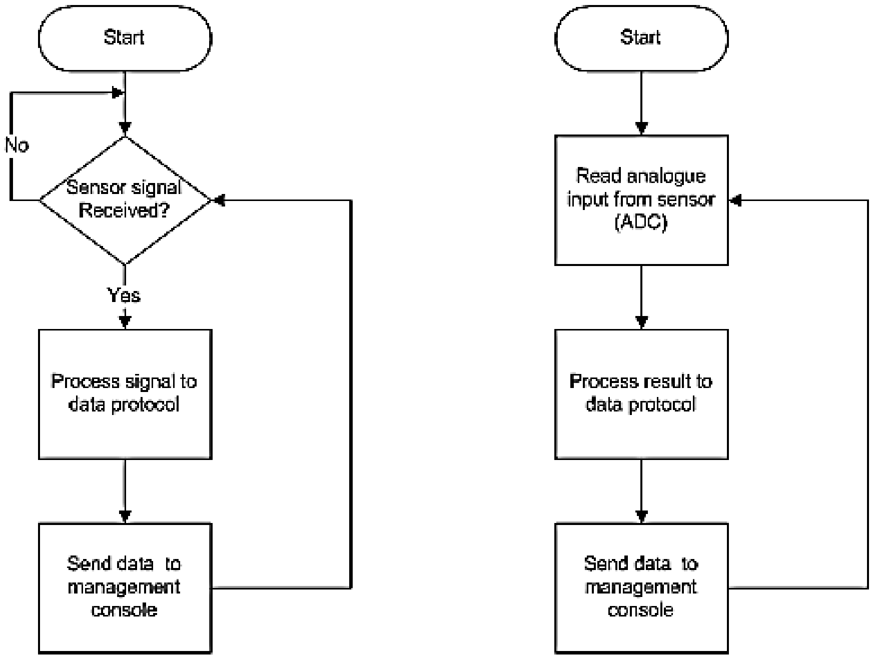


Figure 4.1: Input module

Figure 4.2 shown is the illustration diagram of an input module microcontroller. PIC18F2550 is suggested microcontroller where it has one USART, 10 ADC channel and 24 I/O pins.



(a) Digital Input (b) Analogue Input

Figure 4.2: Process flow of input module (a: Digital Input; b: Analogue Input)

The flow chart shown in figure 4.3 is the process flow of microcontroller for both digital and analogue input. The process of the microcontroller of an input module is simple: Obtain data from sensor, process signal to data protocol, and send the data protocol to management console. The data protocols contain the data of type of sensor, sensors zone and the sensors data.

Sensors that connected to this input module are not just limited on the few sensors as discussed previously. As long as the sensors output are in digital or analogue form, they can integrate to this input module too. This makes the input module expandable and scalable with most of the sensors technology.

4.3 Light Module

Light module works by controlling the lightings based on the data it received from management console. Each light module will assign a zone that belongs to a group of lights. Lights intensity can be control through PWM, voltage pulse or by just turning ON or OFF using digital output (with relay assist). Every single light module will integrate with an ambient light sensor for the detection of the total ambient lights on that particular zone. In addition, buttons connect to this module to allow the user having direct control on the lights. Microcontroller functions that need in light module are PWM generator, ADC and USART.

Summarization of I/Os and functions of a controller need for light module:

- PWM
- Digital input (buttons)
- Digital output
- Analogue input (0V - 5V)
- Analogue Digital Converter (ADC)
- USART (1 pair of transmitter and receiver)

Figure 4.4 shows the illustration diagram of a light module. The suggested microcontroller is PIC18F26J13 which it have 22 I/O pins, 10 ADC channel, 2 USART and 10-PWM peripherals.

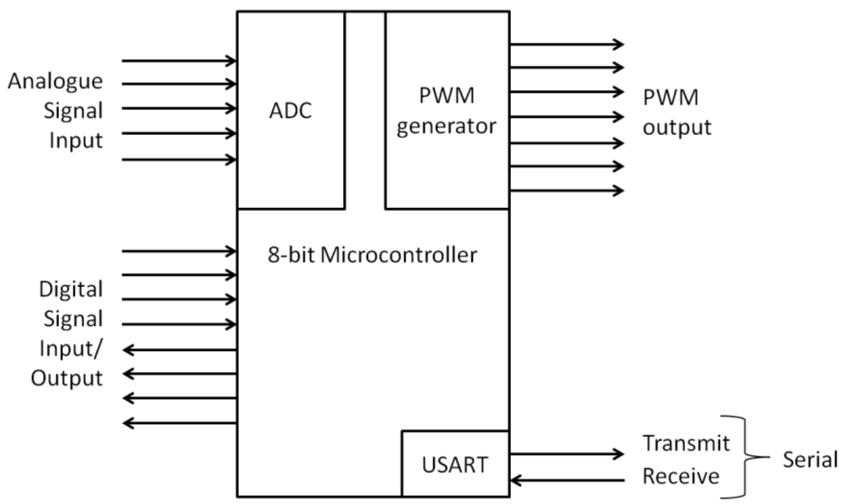


Figure 4.3: Light module

Light module will receive the two main data from the management console: ambient light data or light intensity data. The process flows of how microcontroller acts for different types of data are shows in figure 4.5.

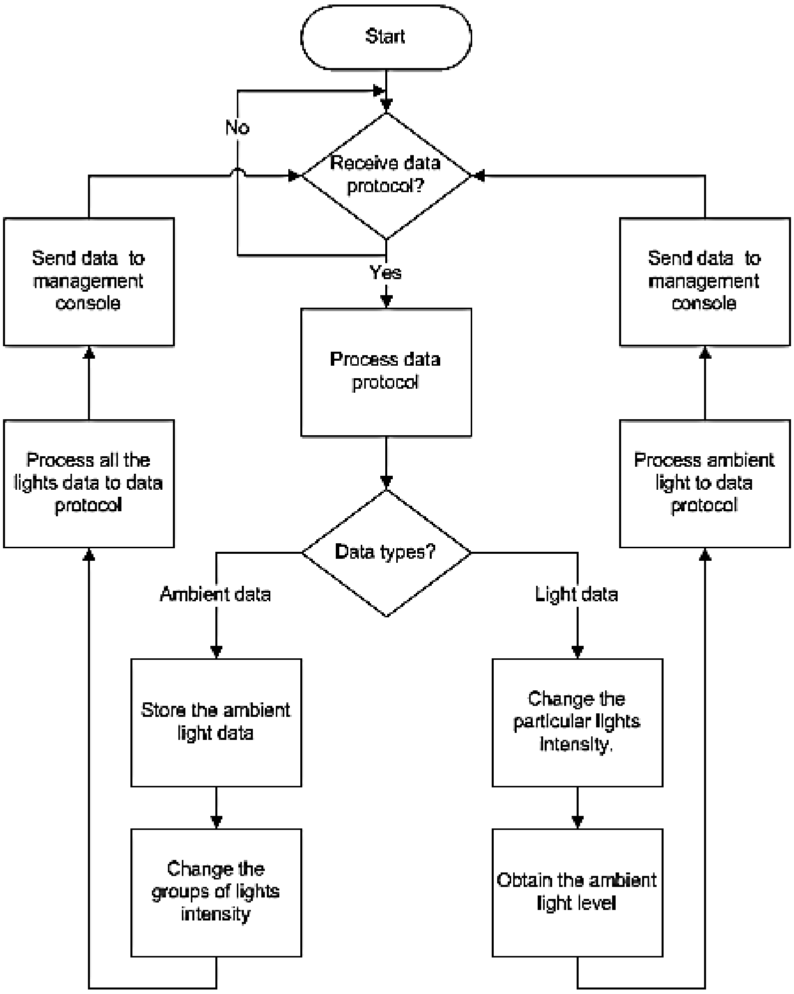


Figure 4.4: Process flow of light module controller

When the environmental ambient light changes in the particular zone, the output light module will performs to adjust the ambient light level to compensate the offset of the ambient light cause by the environment. The whole process flow is show in figure 4.6.

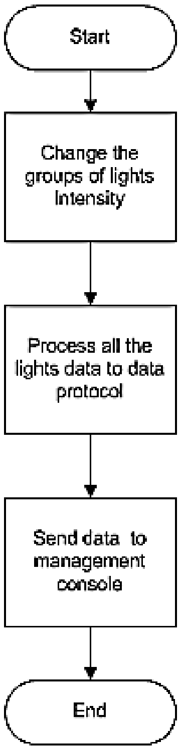


Figure 4.5: Process flow when environmental ambient light changes

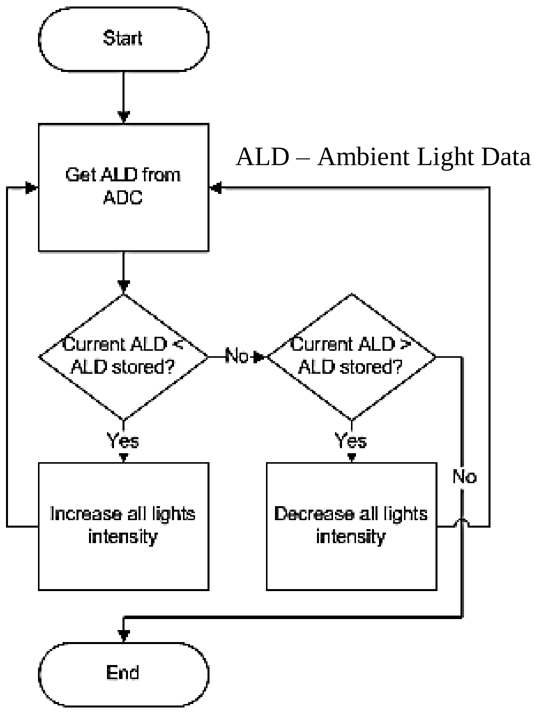


Figure 4.6: Process flow of changing groups of lights intensity

Figure 4.7 shows the process of changing the whole group of lights intensity when the ambient light data obtain from the sensor and the data stores in the microcontroller are different. The causes of the difference might be the new ambient light data that obtain from the management console or the changes of the environmental ambient light.

Recall back that the light module integrated with buttons to allow the user to direct control particular lights intensity. When the user press and release the button in less than one second, the lights will either turning ON or OFF. If the users press the button more than one second, the lights intensity will change until the button is release. The full process of button response is show in figure 4.8 below.

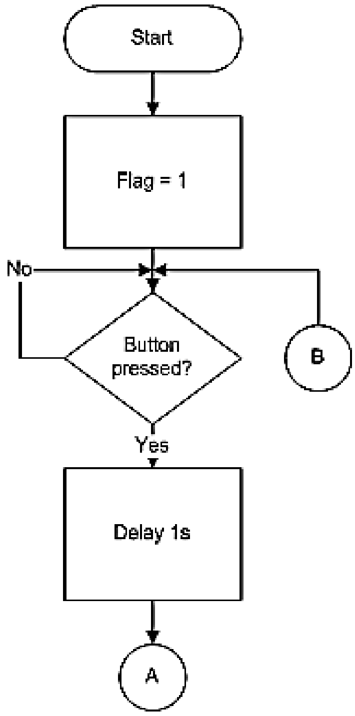


Figure 4.7: Process flow of button responses (Part 1)

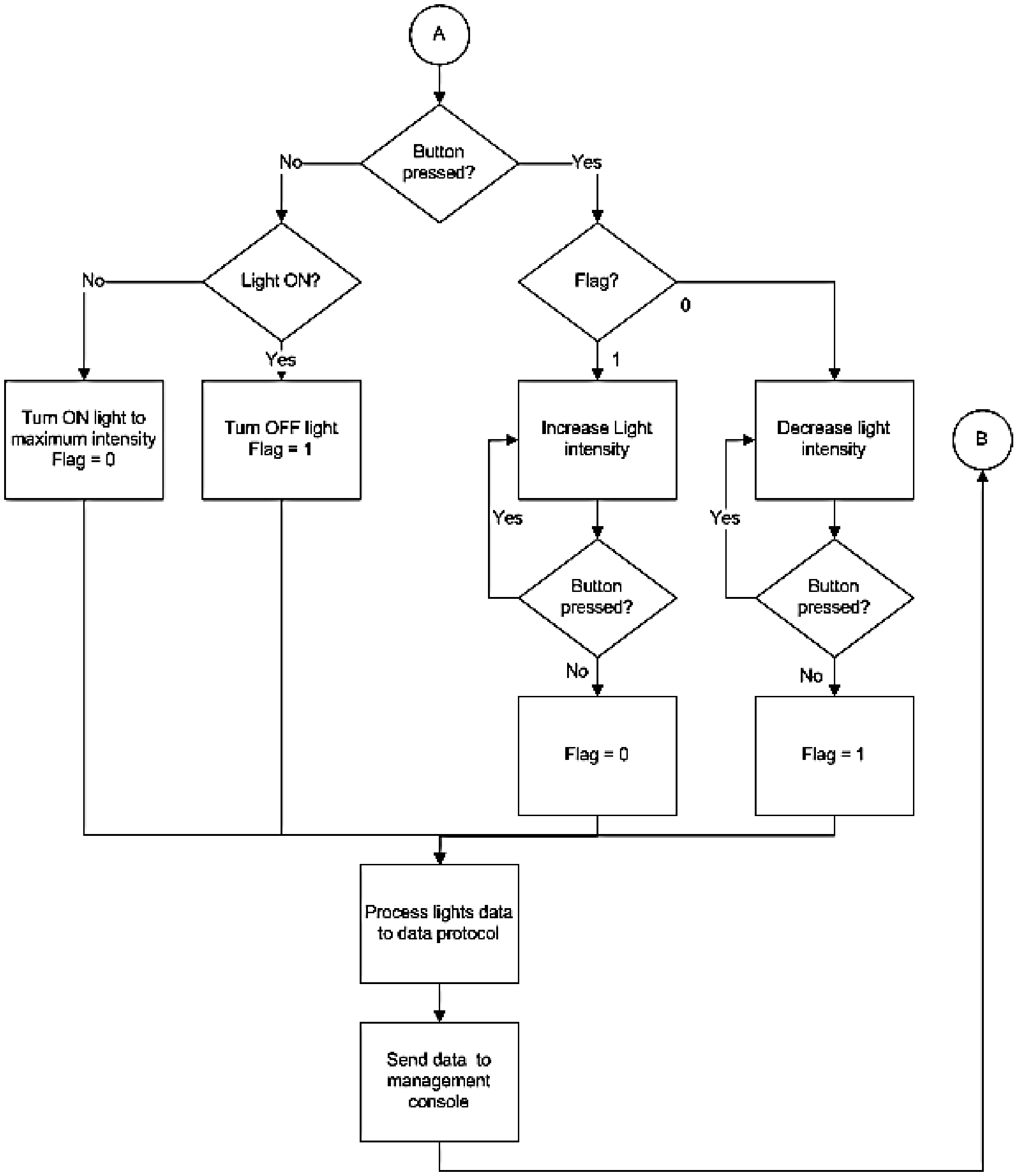


Figure 4.8: Process flow of button response (Part 2)

As shown in figure 1.3, there are two types of light module: stand-alone module and master-slave module. Stand-alone design allows the management console direct control the light module. For the master-slave design, a group of the light module (Slaves) will be control by one master module. This master module will become the middle communication between the light module and the management console.

4.3.1 Stand-alone Design

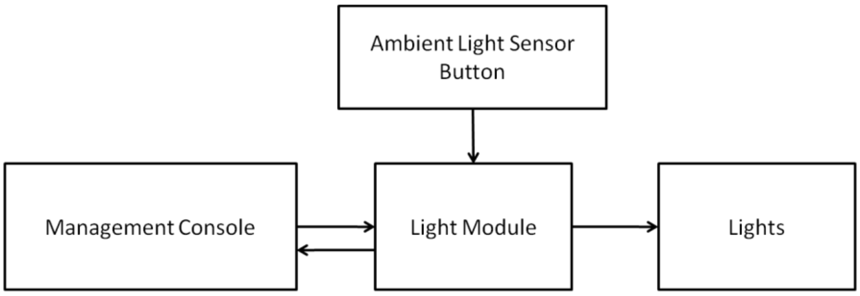


Figure 4.9: Stand-alone Design

In stand-alone design, management console have direct communication with the light module, as shown in figure 4.10 above. Although the speed of this design is fast, the cost on the management console will increase if more light module is used. The reason is each light module will occupy one serial port from the management console, thus, more light module will cause the management console needs more serial port to handle all of the light modules.

4.3.2 Master-slaves Design

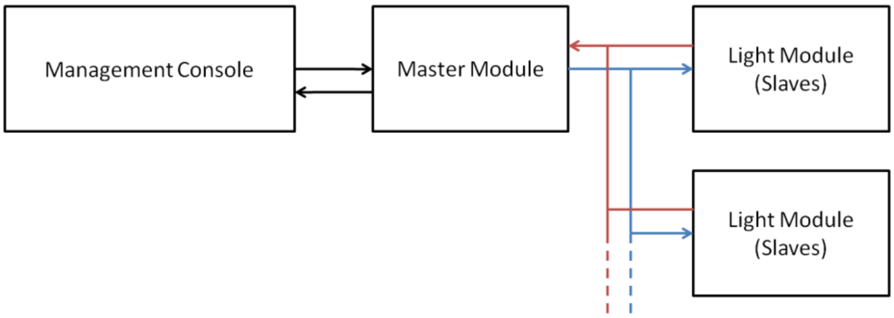
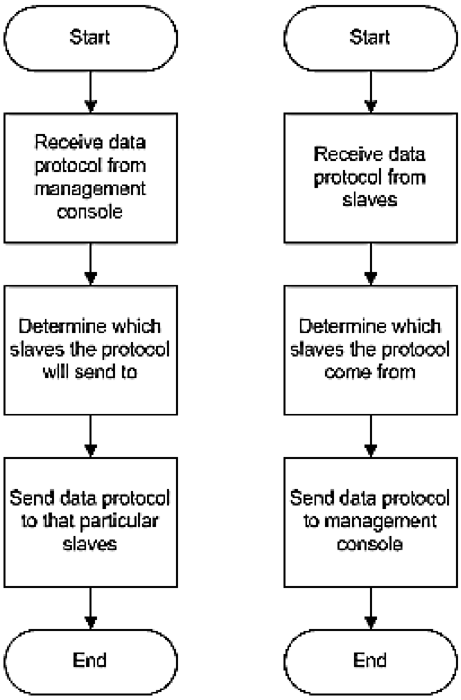


Figure 4.10: Master-slaves Design

Master-slaves designs are the solution of lacking serial ports in management console. This master will be the intermediate communication between management consoles and the light modules as shown in figure 4.11.

The only main function need in master module is two USART – one for management console and another for slaves communication. The suggested microcontroller for the master module is PIC18F23K22 which it has two USART.

The function of the master module is simple, where it receives the data protocol from the management console, determine which slaves or light module to be sending to, and send the corresponding data protocol to the particular light module. Master module also able to receive the data from the light modules and send it to the management console. Each of the light module will be having their own unique address so that the master module will able to determine which light module are belongs to which zone. Figure 4.12 below shows the process flow of the master module.



(a) (b)

Figure 4.11: Process flow of master module

(a: Send data to slave; b: Receive data from salve)

The drawback of master-slaves design is the process speed is slower than the stand-alone design. Furthermore, the light modules that connected to the master module are limited too as the more light modules connected to the master, the slower the speed and there might some data lost in between the communication. In addition, failure of master unit will causes all of the light modules fail to works. Using PIC microcontroller in master-slave design might result in data collision. When two slave modules send their data at the same time to the master module, data collision happen and it will causes data loss in between this communication.

4.4 Features of MICS

Some extra operations of MICS will discuss in this section. These operations make the system robust and capable to works well in abnormal condition and it is integrate on both input module and light module.

4.4.1 Polling

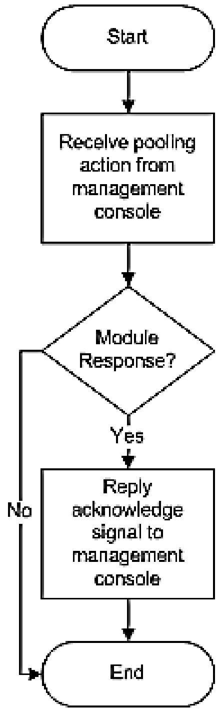


Figure 4.12: Pooling action

Polling is the status checking of the each module from the management console. The management console will always send a 'test' signal every 30 second to each module.

When the modules receive the 'test' signal, they will reply 'acknowledge' signal back to the management console. Thus, if any of the modules fails to replay 'acknowledge' signal, management console will determine that particular module failure and will inform the user through the UI of the management console. Figure 4.13 shows the polling action on MICS module.

4.4.2 Power-up Action

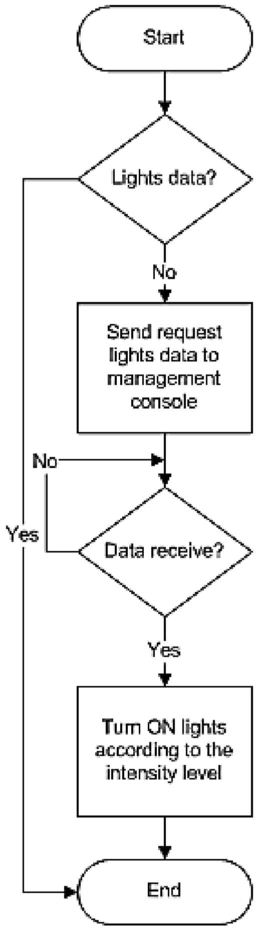


Figure 4.13: Power up action

The power up action is important for the module to works well for device power-up. Due to the controller are unable to store the data of the lights permanently, when there is power failure, the controller will lose the data as well. Thus, once the module recovers from the power failure, it will request the lights data from the management console. The process of the module for the power up action shows in figure 4.14.

4.5 Communication Protocol

A standard communication protocol between the management console and MICS modules is established. The protocol, as shows in figure 4.15, is set in the way that it is easy to understand yet scalable. Additional modules are easily to be adding up by following the standard protocol.

Device	Type	Zone	Number	Data	End

Figure 4.14: String of standard data protocol

Note that the data characters sent in ASCII code, where one ASCII character occupies one byte of data in the protocol.

Device	Type	Zone	Number	Data	End
3-bytes	2-bytes	2-bytes	2-bytes	3-bytes	1-bytes

Figure 4.15: Bytes occupied in data protocol

Figure 4.16 above shows the number of bytes of each data occupied in the data protocol. The explanation of each data in the data protocol:

- Device: Represent the data is either for sensor (SEN) or lighting (LIG).
- Type: Represent the type sensor or lights, or the action of microcontroller.
- Zone: Represent which zone the module is.
- Number: Represent the number of that device on that zone.
- Data: Contain the data or information.
- End: Represent the end of the string of prototype (symbol # is used).

Table 4.1: Example list of data protocol used

Device	Type	Zone		Number		Data	End
SEN	ST	Z	X	Ø	Ø	XXX	#
SEN	OS	Z	X	Ø	Ø	XXX	#
SEN	LS	Z	X	Ø	Ø	XXX	#
LIG	LD	Z	X	L	X	XXX	#
LIG	LL	Z	X	Ø	Ø	XXX	#
LIG	TS	Ø	Ø	Ø	Ø	ØØØ	#
LIG	AK	Ø	Ø	Ø	Ø	ØØØ	#

SEN = Sensor

LIG = Light

ST = Seat Sensor

OS = Occupancy Sensor

LS = Light Sensor

LD = LED

LL = Light Level (Ambient Light)

TS = Test Module

AK = Acknowledge Module

Ø will fill the space of the data if that particular data space not used.

X represent number range from 0 to 9.

Table 4.1 are some example of the list of data protocol used in MICS. Note that the length of the data protocol must be in 13-bytes. Thus, if there is some other data sections are not in use, 'Ø' will replace the data space.

There is also a standard communication protocol designed for master-slaves design for light module. Their communication protocol are different due to the first bytes of the protocol is used to represent the slaves address. The string of the data protocol use in master-slave module is show in figure 4.17 below.

Address	Type	Data	End
1-bytes	2-bytes	3-bytes	1-bytes

Figure 4.16: String of data protocol for master-slave design

The only address bytes of the data protocol are not in ASCII characters code, they are representing in hexadecimal code. Data "Type" in the data protocol can be represent the data type, action, or which lights the data protocol commanding to. There is some example list of data protocol used in master-slave design are shows in table 4.2.

Table 4.2: Example list of data protocol used in master-slave design

Address	**Type**	**Data**	**End**
0×01	LX	XXX	#
0×02	AM	XXX	#
0×03	TS	ØØØ	#
0×04	AK	ØØØ	#

L = Light
TS = Test Module
AM = Ambient Light
AK = Acknowledge Module
Ø will fill the space of the data if that particular data space not used.
X represent number range from 0 to 9.

Recall back that the functions of master module are intermediate communication between the management console and light module (slaves). From the difference of the data protocol in figure 4.16 and figure 4.17, this shows that the master module also performs as converter to convert the data protocol in figure 4.16, to data protocol in figure 4.17 and vice versa.

4.6 Compatibility of MICS

MICS are not only works well with designed application, but they are also compatibility with the current commercial product. One of the commercial products will take as example - Schneider Electric (Global Specialist in Energy Management).

The following figure 4.18 shows one of the designed energy saving solutions that apply in a University campus. By referring to the figure, features of this design solution are:

- The management consoles are able to control the lighting through XBee wireless communication and C-Bus Network.
- Management console is able to control the 3-phase motor through PLC, which can represent the 3-phase blower in central air-conditioning system, and 3-phase pump in chilling tower or heat extracting system.
- Few sensors (i.e. occupancy sensors, temperature sensors, seat occupancy and RFID) will assist the management console in monitoring the whole system.
- Power meter which able to keep track of the power usage of the whole system.

The whole designs are come from mainly two types of product devices, Clipsal C-Bus and Telemecanique. Clipsal C-Bus devices is mainly for controlling lightings through C-Bus networks, while Telemacanique devices are works for controlling the 3-phase motor and receiving RFID signal through the PLC. The local processing unit is the intermediate communication between the C-bus networks and Telemacanique.

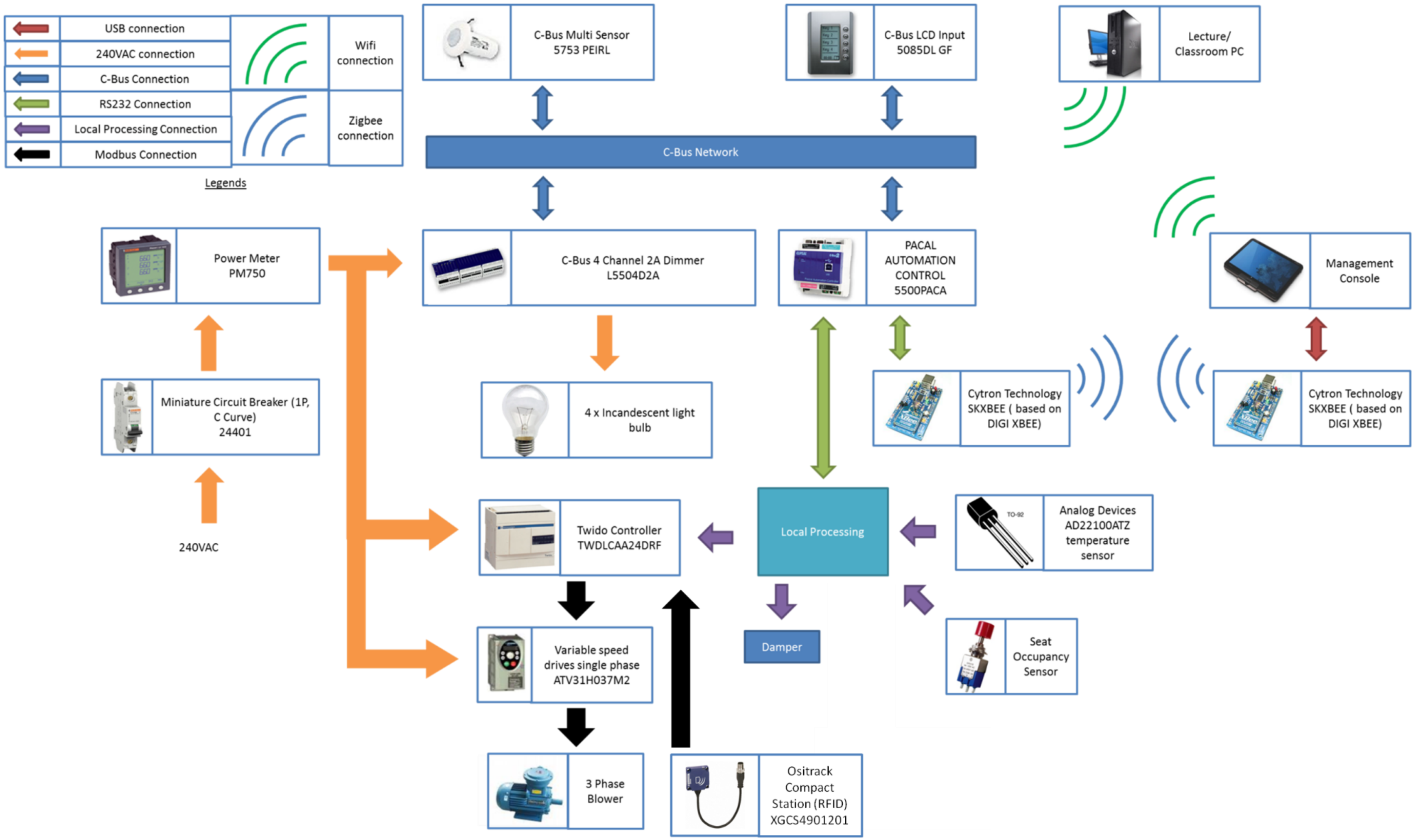


Figure 4.17: Design solution on Energy Saving on Campus

Local processing unit roles are to receive input from sensors and at the same time given digital output signal to the PLC and control the damper. At the same time, the local processing will communicate with the C-Bus PACAL through serial communication. MICS are able to works as the local processing unit on this designed energy solution systems.

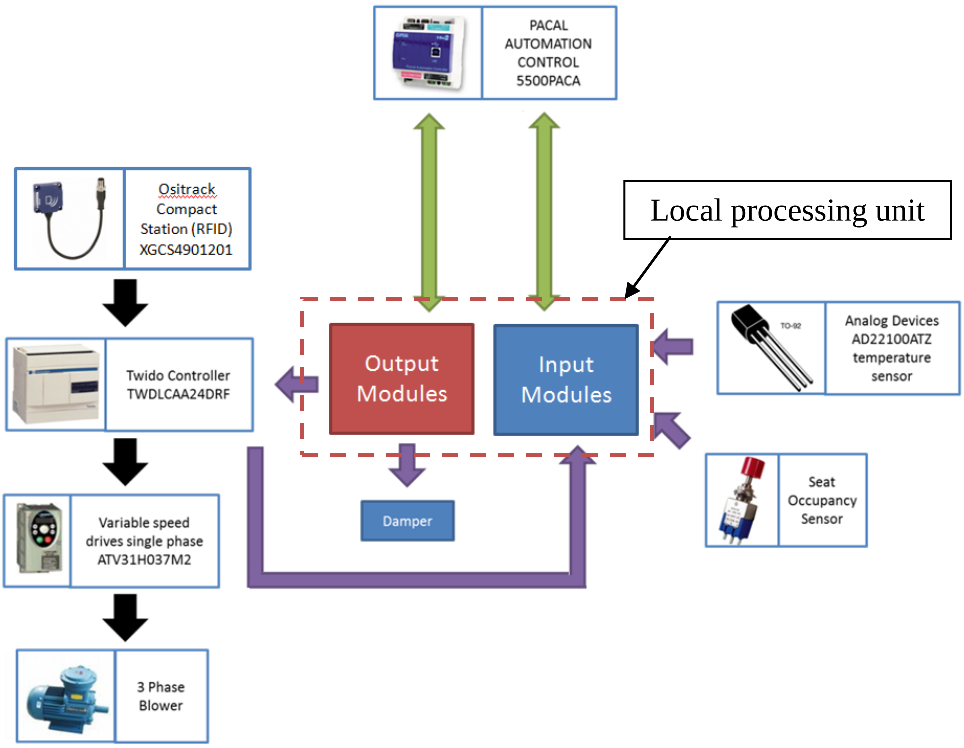


Figure 4.18: Integration with MICS design

The figure 4.19 above shows the integration of the design solution with the MICS design. The input and output module are the local processing unit. Instead of the IHAS, now the management console of the MICS design is Pacal C-Bus Automation Control. Note that name of output module is replacing the light module; this is because there are no lights to control in the output module in this design.

The input modules will receive the sensor signal (Temperature sensor - Analogue input; Seat Occupancy - Digital input) and address of the RFID from the PLC (8-bits address). All the data that input module receive is process and the data is send to the Pacal C-Bus. The Pacal C-Bus are able to send the data to the output module to control the damper (4-bits address, digital output) and the PLC (digital output). This compatibility shows that the MICS system not just only applicable on lighting systems, but also some other commercial system such as the example given – Schneider Electric energy saving design solution. MICS help this whole system with advantages of expandability, where in the future, if there is any other device (either input or output) to add up, the input/output module will ease the adding up process.

The more the input/output module, which increase the line of the serial communication, where it will causes a high investment budget on Pacal C-Bus (Each Pacal C-Bus have only 2 serial communication). The master-slave approach can apply in the design too.

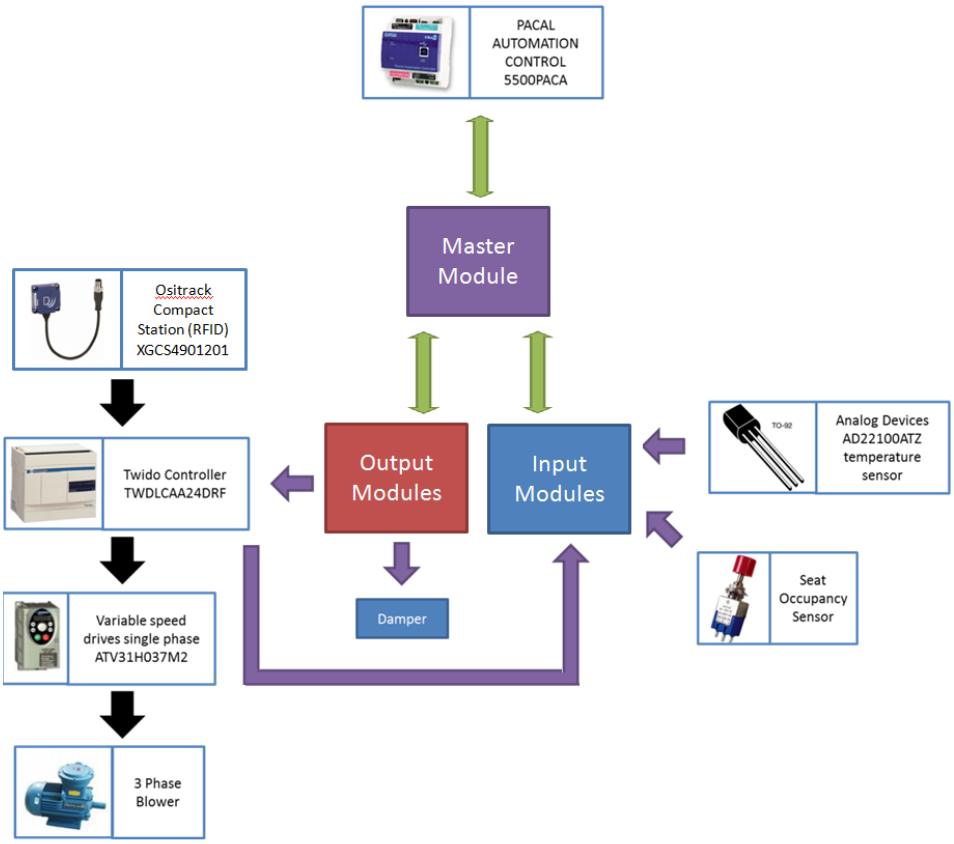


Figure 4.19: Integration with MICS design (with Master-Slave approach)

Although the master-slaves approach will reduce the investment budget on Pacal C-Bus, the more input light module will reduce the processing speed. In addition, any failure of the master module at the same time will cause the whole system fail to work.

4.7 Conclusion

The overview of MICS has been presented in this chapter. There are three types of modules, which is input module, light module and master modules. Different module using different controller depends on the functionality the module need. The summarization of the microcontroller use for different module is show in table 4.3 below.

Table 4.3: Summarize of microcontroller for different module

Input Module	USART Analogue Digital Converter	PIC18F2550
Light Module	Pulse Width Modulation Analogue Digital Converter USART	PIC18F26J13
Master Module	2 USART	PIC18F23K22

There are some action is implemented in MICS to ensure the system is robust, such as the polling and power up action. This allows the reliability of MICS and ensure the system are capable to works well in abnormal situation such as power failure.

Not only in controlling the lightings, MICS are compatibility with other system such as security system, air ventilation etc. An example of energy saving design solution on campus is given (Schneider Electric commercial product) that the capability of MICS works with the current commercial product that available in the market..

CHAPTER 5

IMPLEMENTATION & RESULTS

This chapter will cover the implementation of the MICS with the prototype for the proof of concept purposes.

5.1 Introduction

With the sensors, lighting control technology and MICS design discussed on the previous chapter, the implementation of the whole system on different case are available in this chapter. In addition, the prototypes are builds for the proof of concept purposes are attach together as well. The Intelligent Home Automation System (IHAS) will now be the management console for all the implementation.

5.2 Hygiene Switch

As discussed previously, aligned PIR sensors can be use as directional sensors. With some modification of the enclosure case, as shown in figure 5.1, the PIR sensors now can be act as a switch to turn ON or OFF the lights.

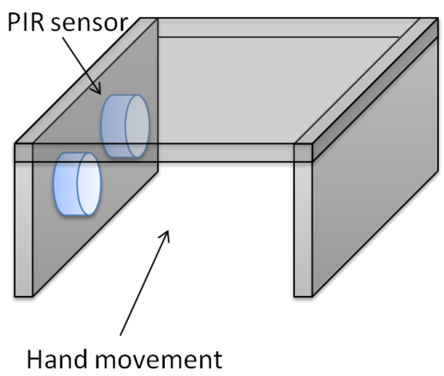


Figure 5.1: PIR sensor with directional sense

The hand movement's direction onto the enclosure can be either from left or from right. The hand movement direction can assign as an action: Left to Right - lights turn ON; Right to Left - lights turn OFF. The input module will receive the directional signal determine which action it is and send the data to IHAS. IHAS will then command the light module to either turn ON or turn OFF the lighting depending on the signal it received from the input module.

This type of the switch design advantages is hygiene, where the user can control the lightings without making any contact to the switch. Hence, it is suitable to use in places such as hospital, where the hygiene are important.

The prototype of this implementation design is simple, with the two PIR sensors align together in an enclosure and they are connected to the input module. The output module will control one fluorescent lights by just turning ON or OFF with the assist of relay. The circuit diagram is shows in figure 5.2 and figure 5.3 below.

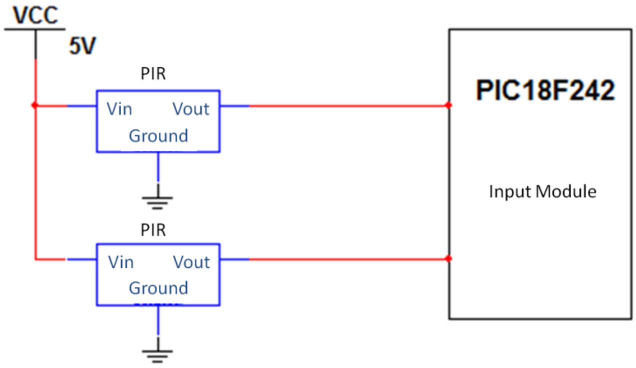


Figure 5.2: Hygiene switch circuit (with input module)

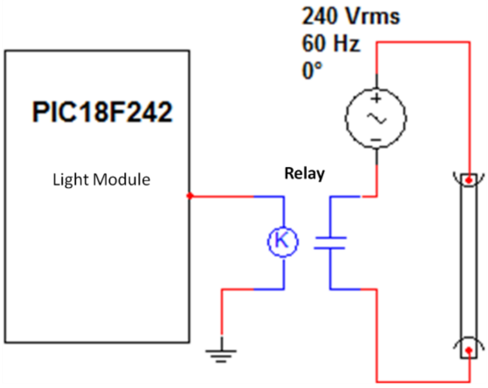


Figure 5.3: Fluorescent light control circuit (with light module)

5.3 Restaurant Lighting System

The assist of the seat occupancy sensors helps the lighting control in a restaurant. Illustrated of the situation diagram is show in figure 5.4. Note that each seat will install with the seat occupancy sensor.

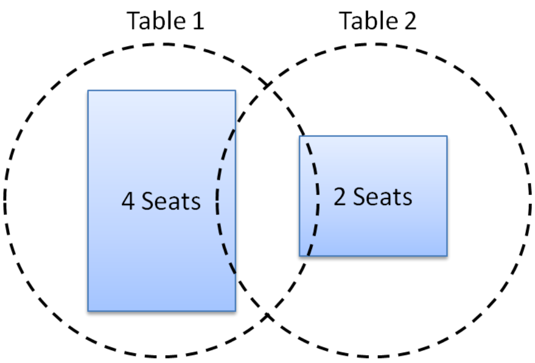


Figure 5.4: Illustrated situation

Algorithm of how seat occupancy works with the lighting system in a restaurant:

- When both of the table's seats are unoccupied, the lights on top of the both table will be in below 50% of its maximum intensity.
- When more than two people occupy table 1, the lights intensity will increase to maximum. Same as table 2 where the light intensity will increase into maximum when there is 1 or 2 seat occupied. At the same time when the lights increase maximum intensity, a signal will send to the control panel to acknowledge the waiter that particular table is occupied.
- When only one or two person occupies table 1, the lights will not increase to maximum intensity. Instead, a signal will send to the control panel to notice the waiter to serve the particular table 1 customer to table 2. This will helps in avoided some table that have more than four seats are occupy by only small number of people. Of course, the control panel allow the waiter manually control the lights.

The prototype that demos the illustration of the restaurant is build, as show in figure 5.5 and 5.6. High power LED is use as the light source. As mentioned, the seat occupancy sensors are an ordinary push ON release OFF switch.

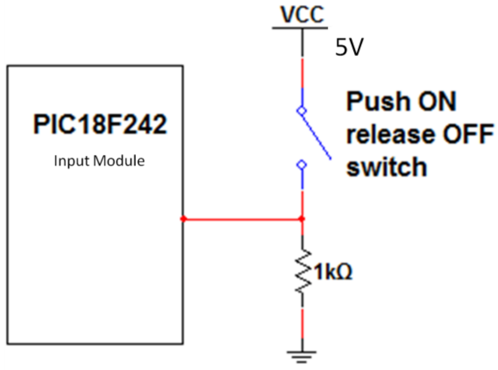


Figure 5.5: Push ON release OFF circuit on one of the seat (with input module)

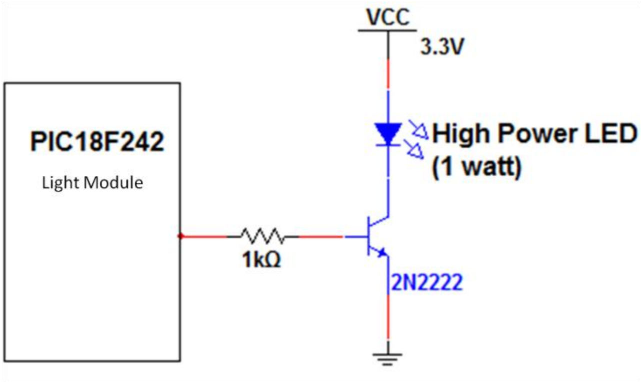


Figure 5.6: LED light circuit (with light module)

5.4 Light Module

The demo prototype of the light module on the responses of the lights intensity to the ambient light sensor and button switch is build in an enclosure, which shows in the figure 5.7.

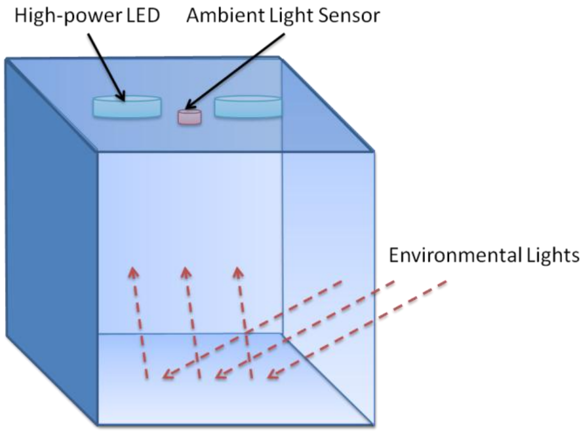


Figure 5.7: Illustrated hardware prototype

Note that the whole system design of the light module is show in this prototype. For the hygiene switch and restaurant lighting system prototype, there is no ambient light sensors and input button on the light module.

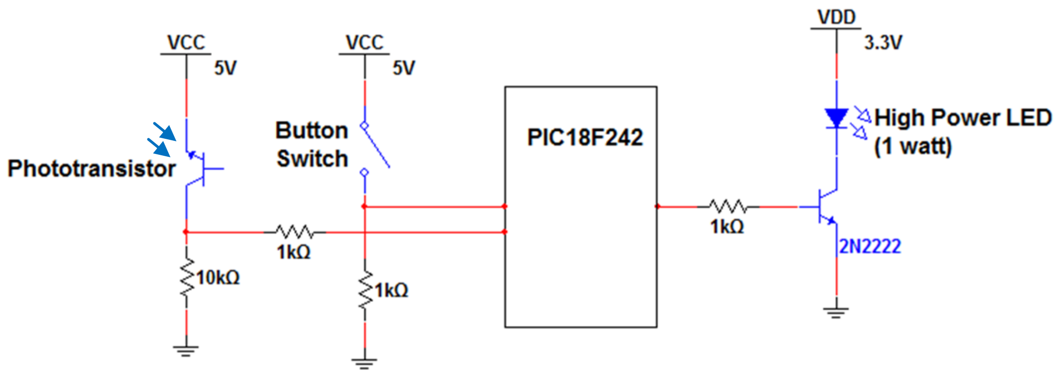


Figure 5.8: Schematic diagram of light module

Figure 5.8 shows the detail of the circuit design of a light module. For the operating algorithm of the light module, please refer to Chapter 4, section 4.3 - Light Module.

5.5 Solution for Illustrated Problem

Recap back the problem illustrated in Chapter 1, section 1.2 – Project Motivation, figure 1.2, if MICS designs are implement on the lecture hall, the problems are solve easily.

In the problem cases where when the lecture hall are occupied by a small group of student - only zone 2 and 3, lights in zone 4 and 5 will not be turning ON. Seat occupancy sensor or PIR motion sensors can be use to assist the detection of students on each zone. In addition, the seat occupancy sensors are able to detects when the lecture hall empty. With the help of the IHAS, the lecturers are able to choose the preset lighting through the UI to suites their teaching style.

5.6 Developed Prototype

The prototypes developed based on the implementation of MICS discussed for the proof of concept purposes. Figure 5.9 shows the prototypes are build in a bookshelf, which act as the enclosure. All of the modules are place on top of the bookshelf as shows in figure 5.10. Each of the modules is place on an electrical case, which shows in figure 5.11.

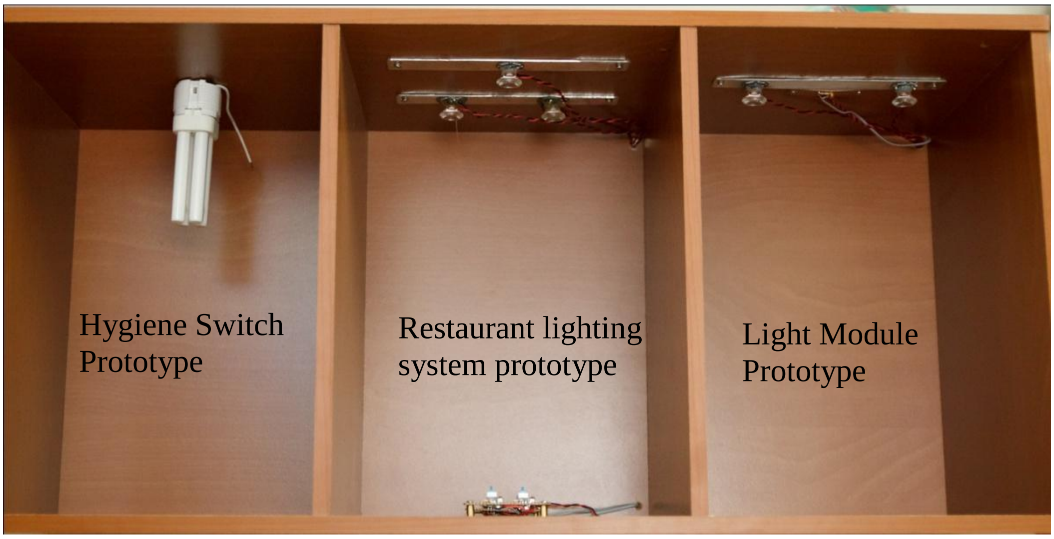


Figure 5.9: Prototype builds in a bookshelf

Figure 5.10: Arrangement of each module on top of the bookshelf

Figure 5.11: One of the modules in a case

5.7 Implementation on Commercial Product

This section discusses the implementation of the design with commercial product as discuss in Chapter 4, section 4.6 – Compatibility of MICS. The prototype of the design solution is different with the design solution shown in figure 4.18. This is because there are some important devices that are not included in the prototype design, which is C-Bus PACAL automation controller and Xbee. The prototype design is collaborated with Mak Kwan Wuey and Gan Yu Han. The modified prototype design solution is shows in figure 5.12.

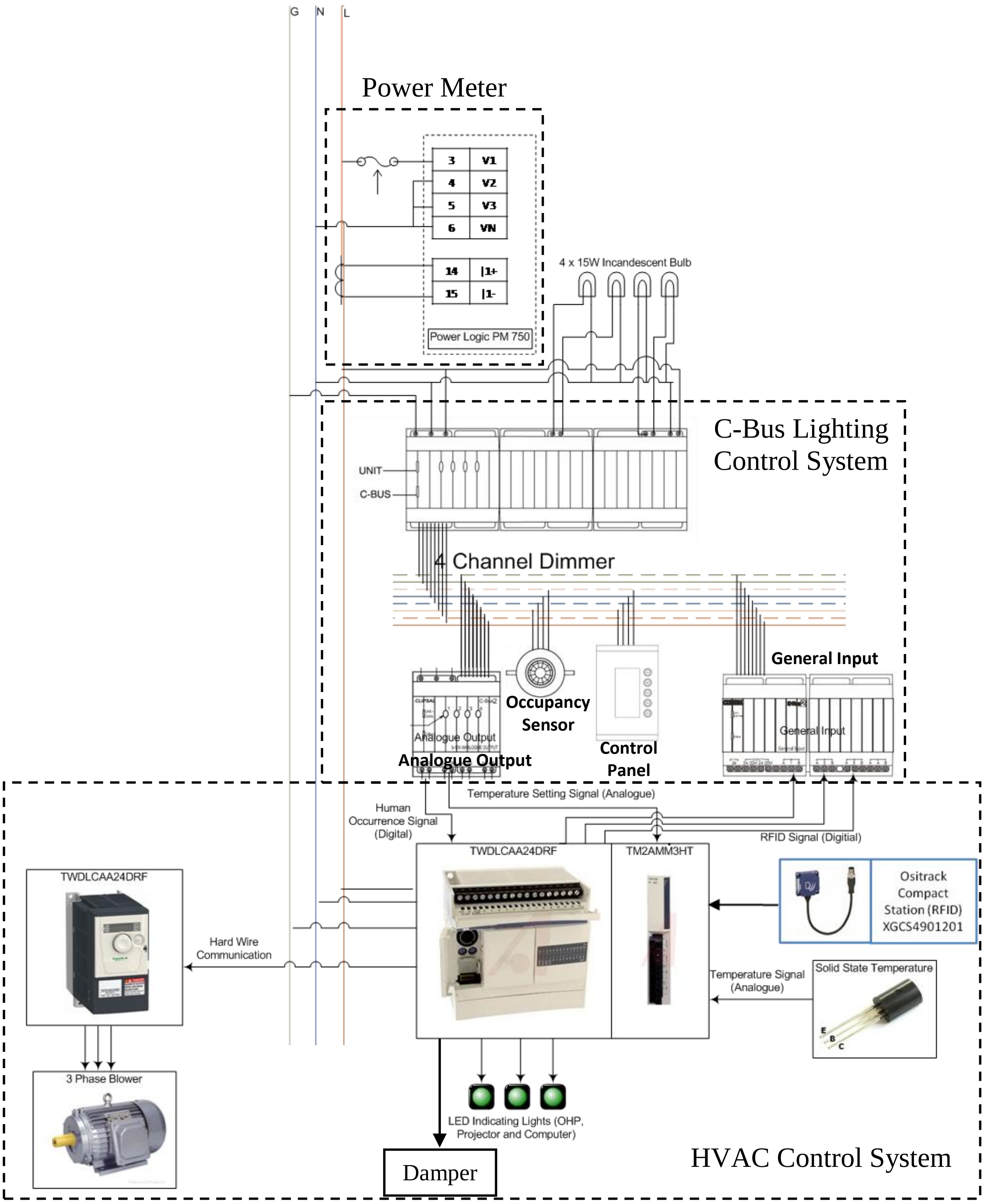


Figure 5.12: Prototype design solution

As shown in figure 5.12, the prototype module can consists of three parts: Power Meter, C-Bus Lighting Control and Heating, Ventilation and Air Conditioning (HVAC) Control System.

5.7.1 C-Bus Lighting Control System

The C-Bus Lighting Control section consists of 4-Channel Dimmer, C-Bus Analogue Output and General input, as well as the control panel and occupancy sensor. The main function of the analogue input and general output unit is the communication between the Programmable Logic Control (PLC) and C-Bus network. The occupancy sensor is use to detects the present of occupancy. This type of the occupancy sensor is integrate with ambient light sensor where it makes the occupancy sensor capable of detects the ambient light level. 4-Channel Dimmer is capable to control the intensity of the incandescent bulb and one 4-Channel Dimmer unit are able to drives four incandescent bulb. The control panel allow to user to direct control the lighting.

5.7.2 HVAC Control System

The HVAC control system consists of variable speed drive, PLC, RFID, damper and solid-state temperature sensor. PLC is the master on this HVAC control system. Note that this PLC integrates with analogue input module, which allows the PLC to receive analogue input.

PLC is the master of this control system, where it capable to receive RFID and temperature sensor signal, and control the Damper and variable speed drive (which in return the variable speed drive control the 3-phase motor). Furthermore, PLC is the main communication with the C-Bus analogue output and general input module. The PLC also consists of LED lights that represent electronic devices, which are OHP, Projector and Computer.

5.7.3 Power Meter

Power meter are install to monitor the power usage of this system. It is important in obtaining the data on how much does the power saving achieve on this system.

5.7.4 Prototype Design & Operating Principle

The designed solution prototype is target on the lecture hall where it is able to control both lighting and HVAC system. In addition, both systems are well integrated. Figure 5.13 shows the illustrated diagram of the lighting control prototype.

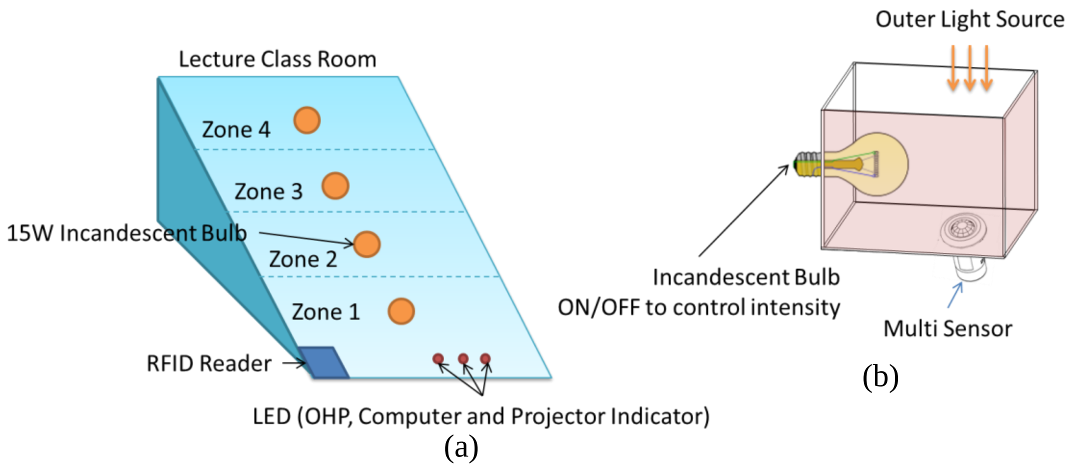


Figure 5.13: Lighting Control Prototype

(a): Lecture hall (b)Enclosure for multi sensor

On the surface of the illustrated lecture class room, there have four 15W incandescent lights where each light will be represent one zone of area in the lecture hall. On the zone one of the lecture hall area, there is three LED lights and one RFID reader. The three LED lights will represent the signal light of computer, projector and OHP. Turn ON any lights of this will represent the signal of the current usage of the respective equipment.

The multi sensor install on another enclosure, where the enclosure contain another incandescent bulb. This incandescent bulb will be controlling the ambient lights inside the enclosure by turning ON/OFF. The top of the enclosure is open for the purpose for the outer lights source for lighting up inside the enclosure. It also serves the purpose to detect the present of the human’s hand.

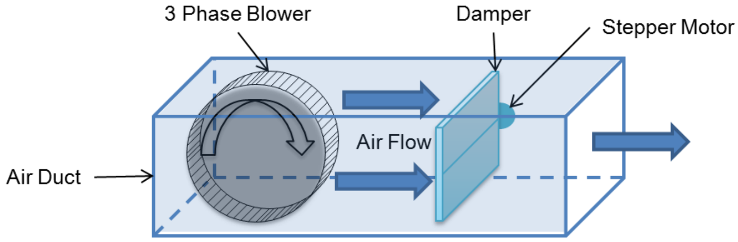


Figure 5.14: HVAC Prototype

Figure 5.14 shows the HVAC prototype that is use to show the blower in AHU and damper control in the HVAC system. The blower speed and the damper opening will be determined by the PLC, which the signal is from C-Bus network.

Whenever there is hand movement on the enclosure, the lights on the zone will turn ON. At the same time, the blower will operate and Damper will open to allow the airflow pass through the damper. The RFID reader will also able to trigger the lights in different luminance for different RFID access card. At the same time, the RFID will control which LED to be turn ON. This shows that the different RFID will have different teaching modes that are preset in the system.

When the incandescent bulb in the enclosure are turn ON, the multi sensor will sense the increase level of the ambient light, thus, all the incandescent bulb of the lecture hall will reduce their intensity. Note that through the control panel, every individual incandescent bulb can be control.

For the HVAC prototype, the temperature sensor controls the speed of the blower and angle of the damper. Once the temperature sensor sense the high temperature level of the environment, speed of the blower will increase and the damper will open to allow more air flow through the air duct.

5.7.5 Results and Outcome

Calculations of the saving targeted on the UTAR FES campus with the system implement are made. The lighting system could achieve 44% of savings while HVAC system could achieve savings of 66%. Although the installations of the devices are expensive, the Return of Investment of the whole system are prove to be less than 3.07 years. Refer to Appendix B for the detail calculation.

This system are brought to the competition organized by Schneider Electric with the title Green the World @ My Campus and have won the first runner up title as shows in figure 5.15.

Figure 5.15: Lighting and HVAC system prototype with the prize won

The system again are brought to the exhibition of IEEE student conference 2010 and again the system proves to be works well with the best exhibition award, as shows in figure 5.16.

Figure 5.16: Best Exhibition Award

From left: Mak Kwan Wuey, Liu Chee Wei, Gan Yu Han

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

This chapter covers the conclusion of the first phase of project done. In addition, the future improvement of this project will discuss in this chapter too.

6.1 Findings, Conclusion and Recommendations

The MICS are one of the cost effective lighting solution. The strong feature of the MICS is flexibility, expandability, robustness and compatibility.

The MICS makes the ease integration of lighting control and sensors into different types of modules that is input module and light module. Stand-alone design and master-slave design can be apply on the light module depends on different types of situation. Stand-alone design occupies more serial port of the management console. Master-slave design is the solution of reducing the needs of the serial port, but it have some drawbacks, which the speed of the performance will reduce, and data collision will happen when two slaves send the data to the master module at the same time.

Not just effective on controlling lightings, MICS works well in most of the abnormal condition. Polling for the detection of module failure and power up device action allow the smoothness of the operation of the whole system.

The implementations of MICS on different kind of illustrated problem had well proven that MICS are one of the effective lighting solutions with the prototype constructed for the purposes of proof of concept.

With the example shown in Schneider Electric energy saving solution design, the compatibility of the MICS with the other technology had well proven. MICS although able to compatible well with other current technologies, they are best when they integrate with IHAS.

MICS are not a perfect system, instead it consist some of the weakness. The controller needs to handle a multiple task such as receiving data protocol, polling, send data protocol etc that makes the slow performance of the system. In addition, there are chances of the data collision when master-slaves module is used.

6.2 Future Improvement

There are some lists of the future improvement on MICS design. These future improvements will helps MICS design to perform even better, efficient and effectively.

- Ambient light reader: Even with the stable phototransistor, the accurate values of the ambient light level are hardly achieve. Thus, if the MICS design is able to read or obtain the ambient light accurately, this will be an added advantage in controlling the lights intensity. In addition, it will help the IHAS accurately display the ambient light value on the UI for the user.
- Fast performance controller: The current controllers in the MICS design are slow. This is because the controller needs to handle a lot of operating (e.g. polling, power-up action, control lighting, process data protocol etc.). High-speed controllers are suggest on improving the performance of the controller. In addition, multitasking allow the controller to handle multiple task at the same time. For microcontroller, RTOS are suggesting to implement in the controller for the purposes of the multitasking.

- Integrate with other systems: As mention, the aim of MICS design are not just on controlling the lights, but also control the other systems. Thus, in future work development, more modules can be design to handle more system such as air-conditioning, security system etc. This allows the MICS to expend to perform well in most of the system.

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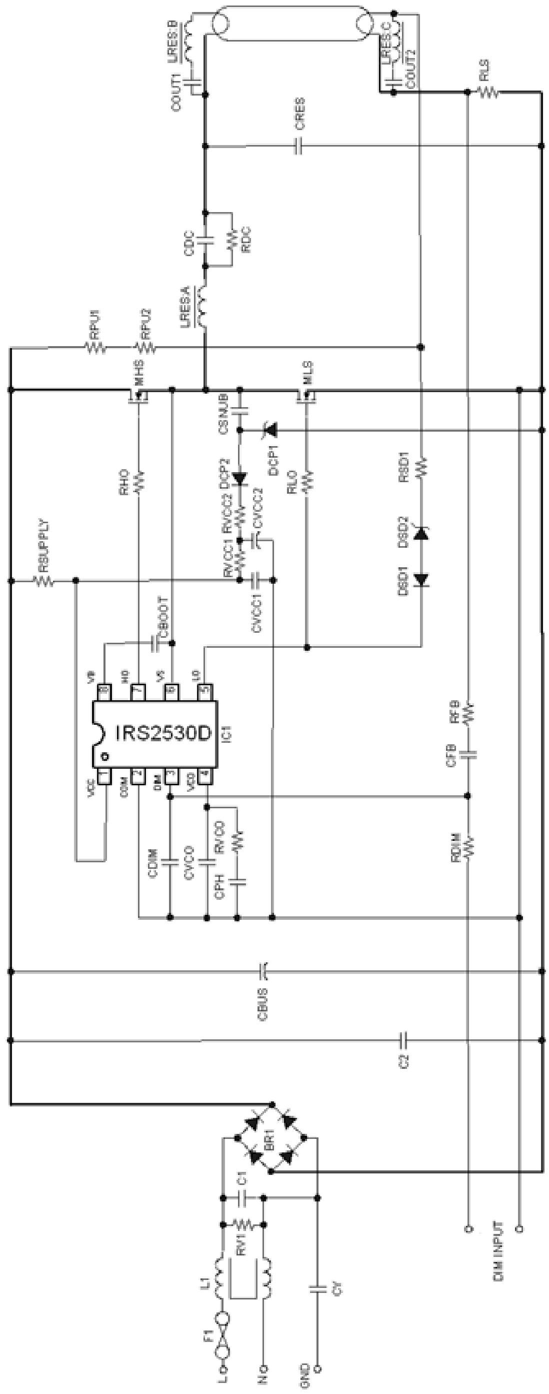
APPENDICES

APPENDIX A: Electronic Ballast Circuit



This is one of the circuit diagrams of electronic ballast, which is taken from the International Rectifier reference.

APPENDIX B: Detail Calculation of Saving Achieved

Cost and bill of material

	dimmer	sensor	RFID	power meter	infar red	key input	twido	twido analog	general input	analog cbus	altivar 21	
SA	5	5	0	1	0	5	5	5	0	0	10	
SB	8	8	0	1	0	8	2	2	0	0	2	
SC	8	6	0	1	0	1	1	0	0	0	1	
SD	6	6	0	1	6	6	0	0	0	0	0	
SE	13	13	0	1	13	13	0	0	0	0	0	
DK	12	24	6	1	0	6	8	8	6	6	2	
S	15	15	0	1	15	15	0	0	0	0	0	
	67	77	6	7	34	54	16	15	6	6	15	
price per unit (RM)	3450	1000	2430	3250	2015	1500	1500	1150	2400	1700	5000	
total (RM)	231150	77000	14580	22750	68510	81000	24000	17250	14400	10200	75000	635840
installation cost												3030
labour cost												50000
misc												1000
heat extractor build cost												100000
												789870

- Dimmer : Clipsal C-Bus 4 Channel Universal Dimmer L5504D2UP
- Sensor: Clipsal C-Bus Multi Sensor 5753 PEIRL
- Key input: Clipsal C-Bus LCD Input 5085DL GF
- Infrared red: Clipsal C-Bus IR transmitter unit C5034NIRTWE (for non-centralized air conditioner)
- Analog cbus: Clipsal C-Bus Analog output unit L5504AMP (for centralized air conditioner)
- Power meter: Schneider Electric Power Meter PM750
- Altivar 21: Schneider Electric Altivar ATV21HU55N4
- Twido: Schneider Electric Twido Controller TWDLCAA24DRF
- Twido analog: Schneider Electric Analog Module TM2AMM3HT
- General input: C-Bus General Input unit 5504GL

Baseline Data

From the UTAR electricity bill that we obtain, we able to obtain the power consumption average of UTAR in one month according to the Tariff C1:

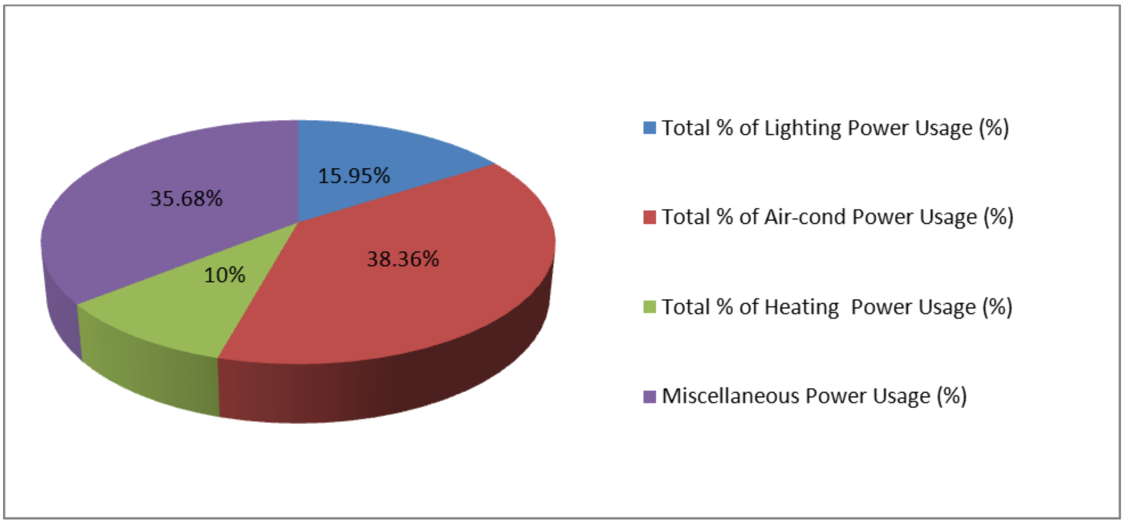
Tariff C1 – Medium Voltage General Commercial Tariff

- For each kW of maximum demand per month, tariff is RM 24.60 / kW
- For all units, tariff is RM0.296 / kWh
- Minimum monthly charge is RM 500.00

Total Energy Usage	**230862 kWh**
Maximum Demand	1009.27 kW
Cost / Month	RM 93 663.31

*Refer to UTAR's Electricity.xlsx for more detail

Also, we also obtain the UTAR floor plan which contains the number of lights in the UTAR. From the data we obtain and the survey made in UTAR for HVAC consumption, we able to obtain a rough data for our UTAR power consumption in Setapak campus.



Thus is will become the main aim for out saving achieve in our UTAR Setapak Campus.

Lighting Control System Savings

As mention previously, we manage to obtain the UTAR floor plans which contain the position of the lights in one floor. Thus, we made counting from there and obtain the number of lights for each block and each room and we manage to obtain the total number of lights and the total power consumption.

Also, we manage to obtain the ratio of the lights between class room and non-class room (such as office, canteen, and corridor).

Total lights consumption in one month = RM 10 880.00

Total power consumption for class room in one month = RM 4 912.44

Total power consumption for non-class room in one month = RM 5 967.97

Ratio of lights (classroom: non-class room) – 1:1.22

On the other hand, we manage to obtain the time table schedule of each class in one week for that particular semester. Hence, another data obtain which is the total power consumption in one class in one day.

As we gather all the data we obtain, we manage to calculate and obtain for some useful information with some assumption made:

Assumption:

SD201										
Time	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7
Monda y											

As shown in the table above, it was extract from one of the classes in Wednesday from the time table we obtain. There are 2 assumptions we made, that is:

- Before implementing the system into our class, we made the assumption that on early the morning, the lights of the class will be turn ON at 9a.m. then it would not be turn off until 7p.m. which the security will patrol around the class and turn OFF the lights on that particular class.
- After implement our system into the class, the lights will be automatically turn ON and OFF according to the occurrence of the people in the class which mean following the class time table schedule.

Note that the assumption and calculation made is just based on turning ON and OFF, without considering the dimming factor yet.

Thus, we calculate that if the system is implementing in each class, each class will obtain in average about 44% of saving by just controlling the lights automatically turning ON and OFF (without dimming factor).

Further calculation made based on the data and result we obtain (Calculation is just made on whole lecture and tutorial classes and without dimming factor):

Average % power saved per class= 44%

Total maximum power per week = 3 829 860 W

Total reduce power per week = 2 285 406 W

Maximum cost per week = RM 1133.64

Cost reduced per week = RM 676.48

Total savings per week = RM 457.16

Saving per month due to class time reduction = RM 1981.02 3

Total cost per month = RM 2931.42

Saving per month (with dimming) = RM 2931.42 x 23% (from research) = RM 688.88

Total saving per month = RM 3620.30

Total saving per month for non class room = RM 1402.47

Total annual savings per year = **RM 60,273.24**

Maximum demand calculation

Maximum demand per month = RM 25,000

Lights maximum demand = RM 3987.50

Savings for maximum demand per month due to dimming only= RM598.10

Total annual savings = RM 67,450.40

HVAC savings calculation

We have discussed that HVAC consumes UTAR FES campus 38.36% of electricity cost. We also knew that the AHU in UTAR FES campus is direct-on-line method. By using Schneider Electric ECO2 software, we could estimate how much savings on AHU blower alone.

ECO2 on AHU calculation

Parameters in using ECO2:

Market	Buildin gs								
Type of application	FAN								
Consumption at nominal flow	11.0 A								
Type of mechanical regulation	Outlet damper								
Motor (nominal values)									
Power	5.5 HP								
Power factor	0.79								
Efficiency	0.88								
Voltage	415 V								
CYCLIC TIME	3432 h								
100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
0 h	0 h	1029 h	686 h	514 h	343 h	343 h	171 h	171 h	171 h

The annual savings are reversed calculated based on the average bill from UTAR. We know that HVAC accounts for 38.36% of the total bill. The ratio between central air conditioner and split unit air conditioner are as below:

BLOCK	Power Consumption (kW)	Air cond types
SA	40.00	Central
SB	40.00	Central
SC	7.50	Split unit
SD	72.70	Split unit
SE	72.70	Split unit
SF	24.30	Split unit
DK	60.00	Central
S	70.00	Split unit
TOTAL SUM:	387.20	

Therefore, the ratio between central air conditioner and split unit air conditioner is 140kW:247.2kW which is then simplify to **1:1.76**.

The calculation for HVAC savings from average electricity bill:

Average monthly bill = RM 93000

Average Maximum Demand = RM 25000

Calculation for monthly savings without maximum demand

Average monthly bill without maximum demand = RM68000

HVAC accounts for 38.36% of average monthly bill, which is RM26084.80

*Central air conditioner : Split unit air conditioner ratio = 1:1.76

Therefore,

Central air conditioner monthly bill = RM9451

Split Unit air conditioner monthly bill = RM16633.8

Savings achieve for central air conditioning = 60% (from ECO2)

Savings achieve for split unit air conditioner = 44% (from class time savings, please refer to lighting calculation for more details)

Savings monthly for central air conditioner = RM5670.60

Savings monthly for split unit air conditioner = RM7318.80

Calculation for maximum demand savings

HVAC accounts for 38.36% of maximum demand cost, which is RM9590

Central air conditioner monthly bill = RM3474.64

Split Unit air conditioner monthly bill = RM6115.36

Savings achieve for central air conditioning = 44% (from ECO2)

Savings achieve for split unit air conditioner = 15% (from regulating temperature settings and class time savings)

Savings monthly for central air conditioner = RM1528.85

Savings monthly for split unit air conditioner = RM917.30

ANNUAL SAVINGS from total HVAC calculations = **RM185, 226.60**