# Development of Energy Efficiency Controller using PIC 16F877A

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*Abstract*— **The word 'forgot' is seems to be a nature habit to human. The main purpose of this project is to develop energy efficiency controller to control electrical energy used by user efficiently. Sometimes, people do not aware to switch off the equipments such as light and air-conditioner before they leave their room. The concept of this project is to switch off the air-conditioner and lights when there are no users in the room and switch on the device automatically when a person enter the room. The system interface is using the peripheral interface controller (PIC) 16F877A for the sensor automation concept of the system. From the data collection, there are several assumptions been made such as calculation of current usage for air-conditioner at a classroom. The initial result of the energy efficiency controlled showed it can improve the efficiency of the energy.**

***Keywords-PIC 16F877, energy efficiency.***

## I. INTRODUCTION

Energy use is crucial to human survival and development. Improvements in lifestyle have historically been associated with increase in energy consumption and the access to appropriate energy service has always been seemed as a necessary precondition for development [1]. Efficient energy use, sometimes simply called energy efficiency. It is mean by using less energy to provide the same level of energy service [2]. Energy efficiency is important for the power consumption of any building. Energy efficiency is increasingly becoming more important due to the increasing in cost of electrical energy [3]. Nowadays, many product of air-conditioner were designed in the market. It shows that demand to the air-conditioner is increase due to the improvements in lifestyle and become more important as living standards rise. Survey by The Center for Environment, Technology & Development, Malaysia (CETDEM), shows that air-conditioner became second largest consumer of electricity in a typical Malaysian terraced house as shown in Figure 1 [4]. Besides, from the report of "Energy Efficiency: Designing Low Energy Building Using Energy10" by Ar. Chan Seong Aun. It shows that the factors affecting energy use in buildings can be categorized into two groupings as shows in the Table I [4].

However, users lack of awareness about the energy efficiency opportunities. Sometimes users do not aware to switch off the equipment such as air-conditioner and lights before they leave their room. This will increase the cost of TNB's bill and waste the energy use. The main purpose of this project is to control the equipments such as air-conditioner and lights, ON and OFF automatically. This system will need more focus on peripheral interface controller (PIC) 16F877A. Software development must be synchronizing with the main objective of this project. This project is a device of an automation systems designed to control the room that use electrical energy efficiently, to reduce energy cost for the users and to promote efficient utilization of energy.

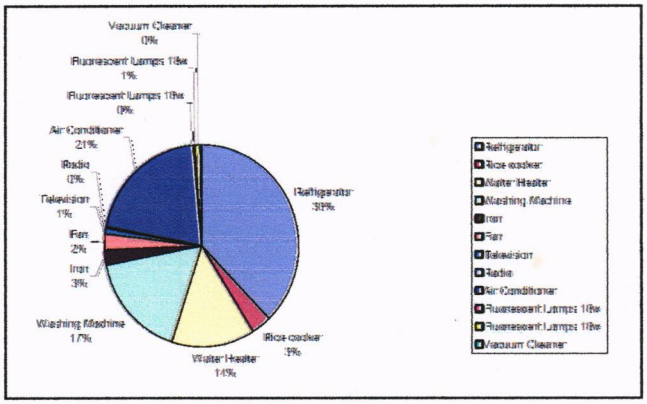


Figure 1. Malaysian home energy use estimation

TABLE I. FACTOR OF ENERGY USE IN BUILDING

| | |
|---|---|
| End-use | i. Air-conditioning<br>ii. Lighting<br>iii. Power and proses |
| Factors | i. Occupancy and management<br>ii. Environmental standards<br>iii. Climate<br>iv. Building design and construction<br>v. Mechanical and electrical equipment |

Therefore, in this project, assumptions has made to identify and to compare two data of power usage of an air-conditioner

type fan coil unit (FCU) and 2x36Watt reflector fluorescent lamp in term of running hours per day and the cost that have been saved between with and without the controller.

## II. METHODOLOGY

In this section, the methodology of the project development was described in the flowchart shown in Figure 2.

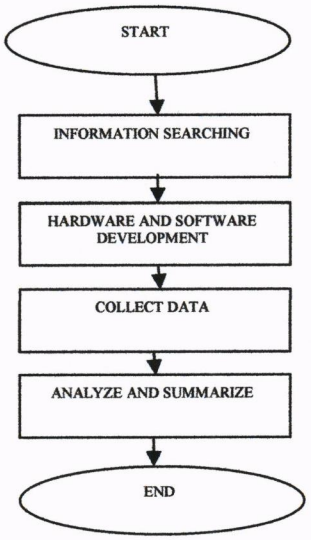


Figure 2. Flowchart of the project development

- Information searching is to retrieve the information of automation concept using IR sensor and controller PIC. In this project PIC 16F877A has been chooses as the main device for the controller function successfully.
- Hardware and software development is a part to design a controller which is synchronized with the main objective of this project.
- Data collection has been made using a digital clamp meter to get the running current reading of air-conditioner and lighting.
- The final step is to analyze the data by the comparison in power usage and energy cost saved with and without the control device.

The main operation of this project is based on sense person enter and exit the room. Once sensor A (entrance sensor) detect the first person pass through the door which is sensor A locate, it will switch on the air-conditioner and light automatically. Besides, the number of person who has entered the room will appear on the display. Switching activity will controlled by the relay as a switch for light and air-conditioner. So, when the last person exit the room and pass through the exit door, the sensor B (exit sensor) at the exit door will take responsibility to sent a signal to the PIC 16F877A and control the relay to switch off the air-conditioner and light automatically. Then the word 'Room empty' will appear on the display. Figure 3 show complete block diagram of hardware design.

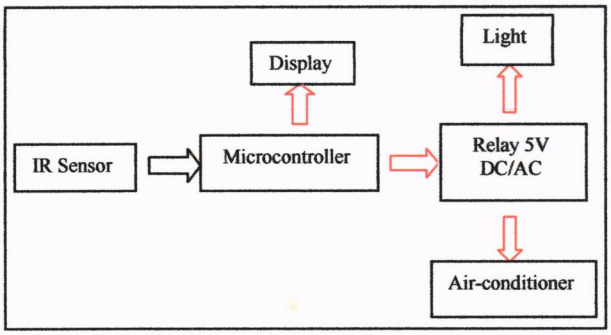


Figure 3. Block diagram of the project

### A. *Schematic Diagram and PCB Layout Design*

The Protel DXP 2004 has used in designing schematic diagram and PCB layout. The original schematic diagram had shown in Figure 4.

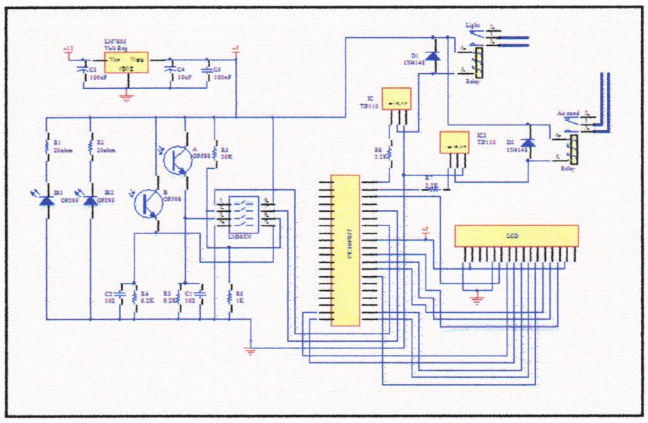

Figure 4. Schematic diagram

From the schematic diagram, PCB layout can be made easily with considers the connections to all pins from SK40C board [6]. The overall PCB layout was designed by considering pins for relays 5 volts, direct current input/alternate current output (5V DC/AC) connections as shown in Figure 5. The relays 5V DC/AC had been designed in separate PCB as shown in Figure 6.

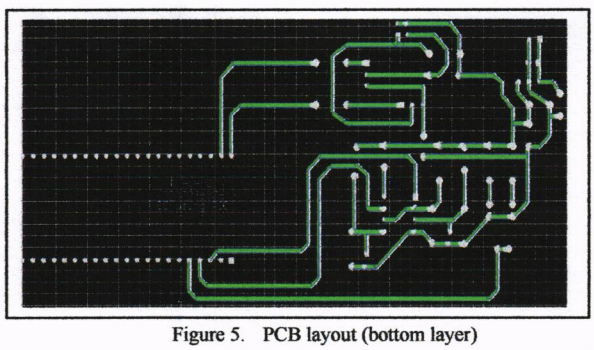

Figure 5. PCB layout (bottom layer)

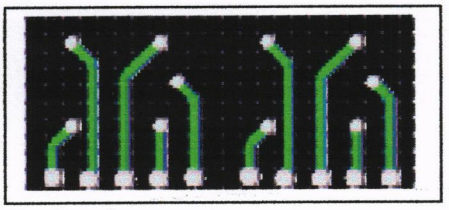

Figure 6. Relays 5V DC/AC layout (bottom layer)

### B. *Hardware Development*

Hardware development review including sensor, relays and microcontroller circuitry done to assure each part is well function before assembling the hardware. Figure 7 show the assemble of the sensor circuit.

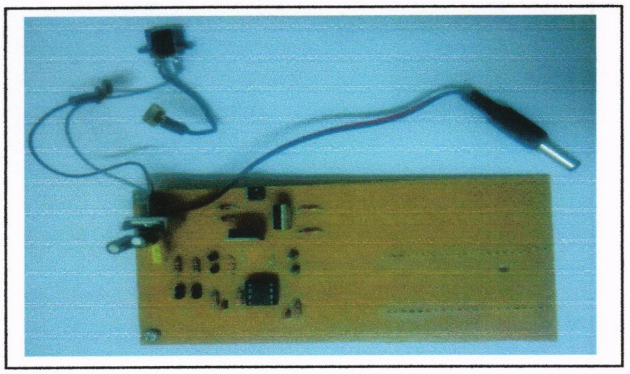

Figure 7. Assemble of the sensor circuit

Basically, a microcontroller is a device which integrates a number of the components of a microprocessor system onto a single microchip and optimised to interact. A microprocessor is normally optimised to co-ordinate the flow of information between separate memory and peripheral devices which are located outside itself but a microcontrollers processor and peripherals are built on the same silicon. Microcontrollers will also combine other devices such as timer module, serial I/O port and analog to digital converter (ADC) [9].

A microcontroller PIC 16F877A has been use to interface the system of the project. This chip has 40 pins, 5 ports and has 8K x 14words of FLASH program memory [7]. As the peripheral signals usually are substantially different from the ones that microcontroller can understand (zero and one), they have to be converted into a pattern which can be comprehended by a microcontroller. This task is performed by a block for analog to digital conversion or by an ADC [9]. The PIC16F877A has an ADC ports as shown in Figure 8 [7].

SK40C is another enhanced version of 40 pins PIC microcontroller unit (MCU) start up kit. It is designed to offer an easy to start board for PIC MCU user. However, all interface and program should be developed by user. This board comes with basic element for user to begin project development. It offer plug and use features as shown in Figure 9 [6].

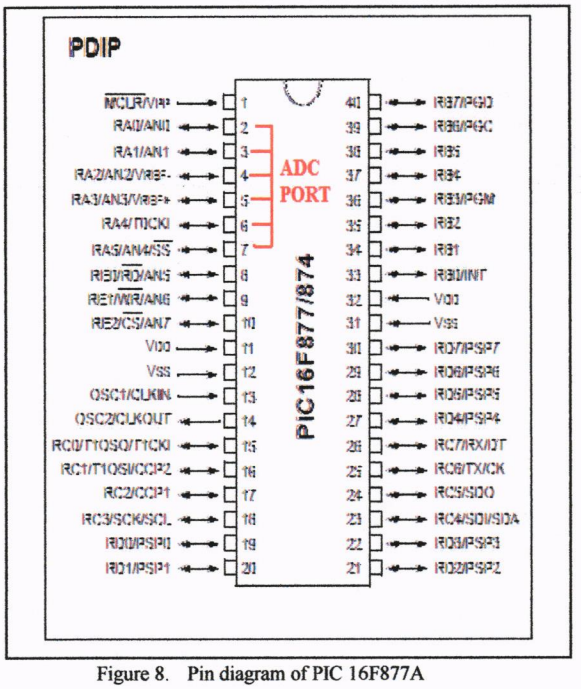


Figure 8. Pin diagram of PIC 16F877A

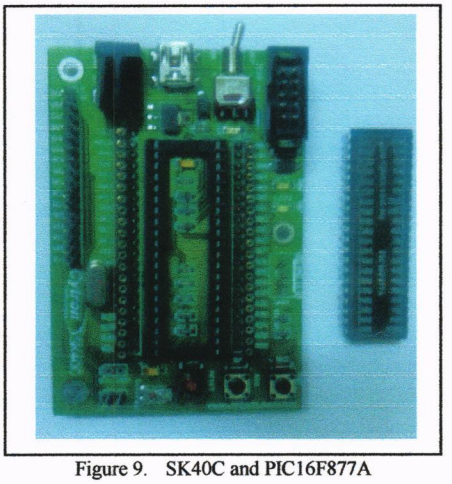

Figure 9. SK40C and PIC16F877A

### C. *Software Development*

Software development was beginning with the flowchart of the program. Experimental test was done by running the program using MIKROBASIC Pro software to make sure the programming synchronized with the main function of the project before burn the program into the PIC 16F877A. The program is described in flowchart as shown in Figure 10 on the next page.

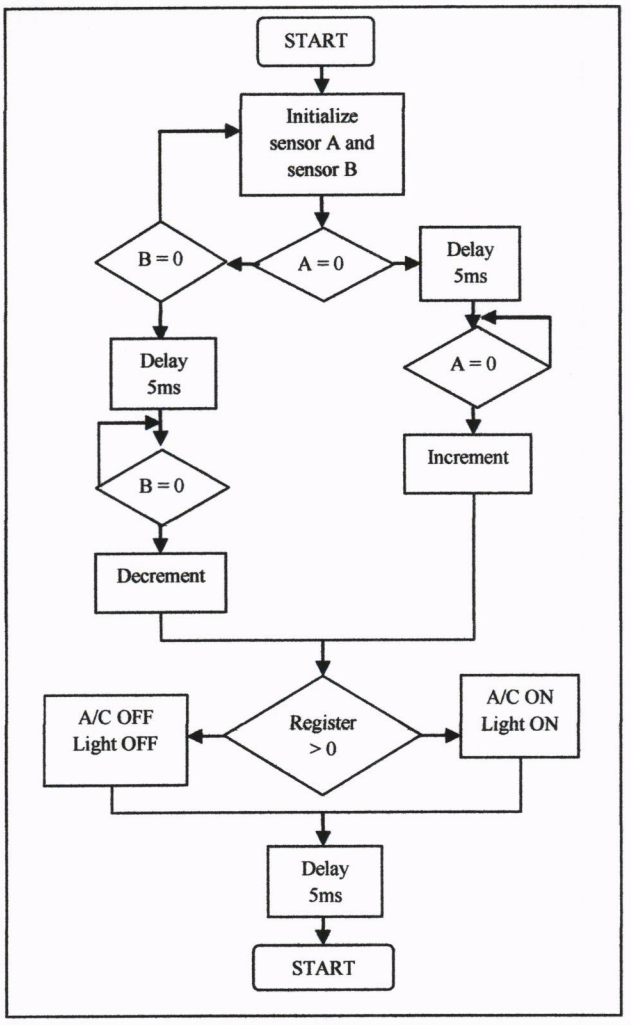


Figure 10. Flowchart of the PIC 16F877A program

*D. Data Collection*

In this part, the method of collecting data will be discussed. A digital clamp meter will be used to collect the data of current usage for air-conditioner type fan coil unit, FCU. The power usage (P) and the unit is in watt (W) for this type of air-conditioner will be analyzes by using the equation, as in

$$P = I \times V \quad (1)$$

and the power usage for lighting can be computed as

$$P = \text{number of fixture} \times \text{Watt/fixture} \quad (2)$$

From the total power usage for air-conditioner and lighting, the monthly hour usage (MHU) will be discuss by using the equation, as in

$$\text{MHU (hour/month)} = \text{(hour/day)} \times \text{(day/month)} \quad (3)$$

and the monthly usage (MU) for lighting and FCU air conditioner can be computed as

$$\text{MU (kWh/month)} = P \times \text{MHU} \quad (4)$$

After doing the comparison on MU between with and without project, total energy saved (TES) will be discussed using the equation, as in

$$\text{TES (kWh/month)} = \text{MU} - \tilde{\text{MU}} \quad (5)$$

while $\tilde{\text{MU}}$ is represent the MU with the project.

## III. RESULTS AND DISCUSSIONS

In this section, the result on testing circuit and data analysis will be discussed. The data on current usage for FCU air-conditioner has taken at classroom B4-A5-5, Science and Technology Building. The air-conditioner in this room is type FCU 4/5-12 (0.66hp) while lighting is type 2×36W fluorescent lamp which is 12 set.

*A. Testing Circuit*

In order to make sure the sensor circuit function successfully, the test was repeated 3 times and the result is summarized in Table II.

TABLE II. TEST RESULTS ON SENSOR CIRCUIT

| Component | Volt (V) | | |
|---|---|---|---|
| | *Test 1* | *Test 2* | *Test 3* |
| R1 | 3.26 | 2.68 | 3.24 |
| R2 | 3.11 | 3.10 | 3.21 |
| R3 | 0.97 | 1.17 | 1.25 |
| R4 | 1.10 | 1.07 | 1.33 |
| R5 | 4.79 | 4.80 | 4.79 |
| R6 | 0.16 | 0.15 | 0.15 |
| OP295a | 1.13 | 1.41 | 1.41 |
| OP295b | 1.10 | 1.42 | 1.40 |
| OP598a | 4.23 | 4.33 | 4.58 |
| OP598b | 4.06 | 4.29 | 4.55 |
| LM393, pin 1 | 1.07 | 1.12 | 1.40 |
| LM393, pin 7 | 1.06 | 1.10 | 1.41 |

Infrared emitting diodes (OP295), Infrared detector (OP598),

To make sure the distance of sensor sensitivity between a pair of OP295a and OP598a for sensor A and OP295b and OP598b for sensor B achieve the width of the door, the test was repeated 3 times by changing the resistor R3 and R4 with smaller value. The results have shown in a Table III.

TABLE III. DISTANCE BETWEEN A PAIR OF OP295 AND OP598

| Component | Distance (cm) | | |
|---|---|---|---|
| | *Test 1* | *Test 2* | *Test 3* |
| Sensor A | 3.0 | 10.0 | 20.0 |
| Sensor B | 2.85 | 9.0 | 18.5 |

### *B. Data on Lighting and FCU air-conditioner Power Usage*

In this part, the calculation has been done to get the current usage for lighting while digital clamp meter has been used to get the starting and running current of FCU air-conditioner at a minimum fan speed. The result has shown in Table IV below.

TABLE IV. CURRENT USAGE FOR LIGHTING AND FCU AIR-CONDITIONER

| Equipment | Current usage (A) | |
|---|---|---|
| | *Starting current* | *Running current* |
| Lighting | 3.6 | 3.6 |
| FCU air-conditioner | 3.3 | 1.2 |

The comparison on running hour of the lighting and FCU air-conditioner has been made between with the controller and without the controller installation. This data has been taken from 8 am until 11pm everyday which is without the controller while with the controller, running hour for the light and FCU air-conditioner will synchronized with the time period of the classroom used for lecture which has been shown in Table V below.

TABLE V. RUNNING HOUR PER DAY

| Day | Running Hour | |
|---|---|---|
| | *Without the controller (hours)* | *With controller (hours)* |
| Monday | 15 | 6 |
| Tuesday | 15 | 4 |
| Wednesday | 15 | 2 |
| Thursday | 15 | 6 |
| Friday | 15 | 6 |
| Saturday | 15 | - |
| Sunday | 15 | - |
| Total hour per week | 105 | 24 |

Next, monthly electricity usage with the controller and without the controller will more clear shown in Table VI and Table VII below. Finally, the total energy save will be discussed by calculation on comparison between MU with controller and MU without controller. The results of total energy saved shown in Table VIII.

TABLE VI. MONTHLY ELECTRICITY USAGE WITHOUT THE CONTROLLER

| | Equipment | |
|---|---|---|
| | *Lighting* | *FCU air-conditioner* |
| Power (kW) | 0.864 | 0.288 |
| MHU (hour/month) | 2,715 | 2,715 |
| MU (kWh/month) | 2,345.76 | 781.92 |

TABLE VII. MONTHLY ELECTRICITY USAGE WITH THE CONTROLLER

| | Equipment | |
|---|---|---|
| | *Lighting* | *FCU air-conditioner* |
| Power (kW) | 0.864 | 0.288 |
| MHU (hour/month) | 624 | 624 |
| MU (kWh/month) | 539.136 | 179.712 |

TABLE VIII. TOTAL ENERGY SAVED

| Equipment | Energy Saved (kWh) |
|---|---|
| Lighting | 1,806.624 |
| FCU air-conditioner | 602.208 |
| Total Energy Saved (kWh) | 2,408.832 |

From Table VIII, it shows that this controller can reduce the electricity usage about 2,408.832 kilowatt hour (kWh). For lighting is 1,806.624 kWh while for FCU is 602.208 kWh. TNB's rate for 1 kilowatt hour of electricity usage is about RM0.288 [10]. The cost that will be saved by using this controller for TNB's bill has shown in Table IX below.

TABLE IX. TOTAL COST SAVED

| Equipment | Cost saved (RM) |
|---|---|
| Lighting | 520.31 |
| FCU air-conditioner | 173.44 |
| Total cost saved (RM) | 693.75 |

Based on the observation, this controller achieves the main objective with some improvement on the circuitry. Table IX shows the total cost saved is RM693.75 for a room size 27 feet × 29 feet × 8 feet. Cost saved using this controller for lighting estimation is RM520.31 while for the FCU air-conditioner estimation is RM173.44.

## IV. CONCLUSION

A controller which can improve the energy efficiency and reduce the cost has been developed using PIC16F877A. From the results obtained, it is shown that the microcontroller part works well with the sensors and the relay but there are some improvement must be done on the sensor unit. It is to make sure the sensor can function effectively with larger distance of sensitivity.

## V. FUTURE DEVELOPMENT

In order to increase the effectiveness of this automation system, a few suggestions are recommended include to improve this systems which is use suitable device to display date and time. Besides that, the temperature sensor can be added in this controller. The function of temperature sensor is to control the temperature of the air-conditioner vary with the number of person in the room.


## ACKNOWLEDGMENT

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