INTEGRATED ENERGY MANAGEMENT USING COMPUTERIZED CONTROL SYSTEM

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfilment of the Requirements
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

The objective of this project is to create an "Integrated Energy Management by Using Central Controlling System". Considering the energy costs increasing day by day and competitive challenge among companies in efficiency rises, implementing smart energy management solutions in offices in order to compensate for the energy losses is necessary. By paying more attention to energy consumption of an office building , one can easily realize how much energy is wasted where it could be saved only by clicking on a tab in the Central Controlling Unit Program in the office. There are so many stand-alone energy efficiency devices, but in order for them to fully function in a building environment, an integrated system implemented via computer system is inevitable. This Project focuses on creating an integrated computerized system that can develop a load management profile and control the output equipments such as lights and air conditions, accordingly. A user friendly program enables the user to adjust the desired preferences of choice which both satisfies the comfort ability of the user and saves energy. This report discusses the methodology and analysis that is required to develop such a system.

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LIST OF ABBREVIATIONS

CCS -Computerized Control System

CLTD -Cooling Load Temperature Differential

GUI -Graphical user Interface

PIC -Peripheral Interface Controller

VAV -Variable air volume

CHAPTER 1

INTRODUCTION

"Energy management is the practice of using energy more efficiently by eliminating energy wastage in an organization's operations." [1]. A successful energy management program will not only save costs for an organization but reduces the negative impacts of consumption on environment. Energy management does not necessarily mean cutting down power usage but it is using equipments efficiently and effectively.

1.1 Background of study

Malaysia lies entirely in the equatorial region causing the ambient temperature to remain uniformly high over the country throughout the year. Average ambient temperature in peninsula Malaysia varies from 26.0 to 32.0 °C. Most location have a relative humidity of 80 to 88% rising nearly to 90% in the highland areas, and never fall below 60% [2]. On the other hand statistics show that total annual sales of air conditioner units in Malaysia in the period of July 2002 to June 2003 were nearly 200,000 units . Furthermore only in year 1999, more than 1.2 million air conditioners were exported, where more than half was within the Asian region [3]. Malaysia is a very hot and humid country and unlike non-equatorial countries does not have significant season changes. Therefore, industries, governmental and private offices and businesses and residences practically use cooling devices, such as air conditions and fans, all year long. A normal room air conditioner package uses an average of 2500 watts. Comparing to a fan or a light bulb that uses 100 watts, air conditioners consume a notably high rate of power everyday which is about 2500 watts.

In the meantime architectures and lighting designers have been striving to reach an impossible goal which is to come up with a lighting system which maximizes energy saving, meets ergonomic standards and yet earns an interesting financial return. Although this has been noted as an impossible goal, but the idea of the modern office provides an opportunity to optimize the office lightning solutions [4].

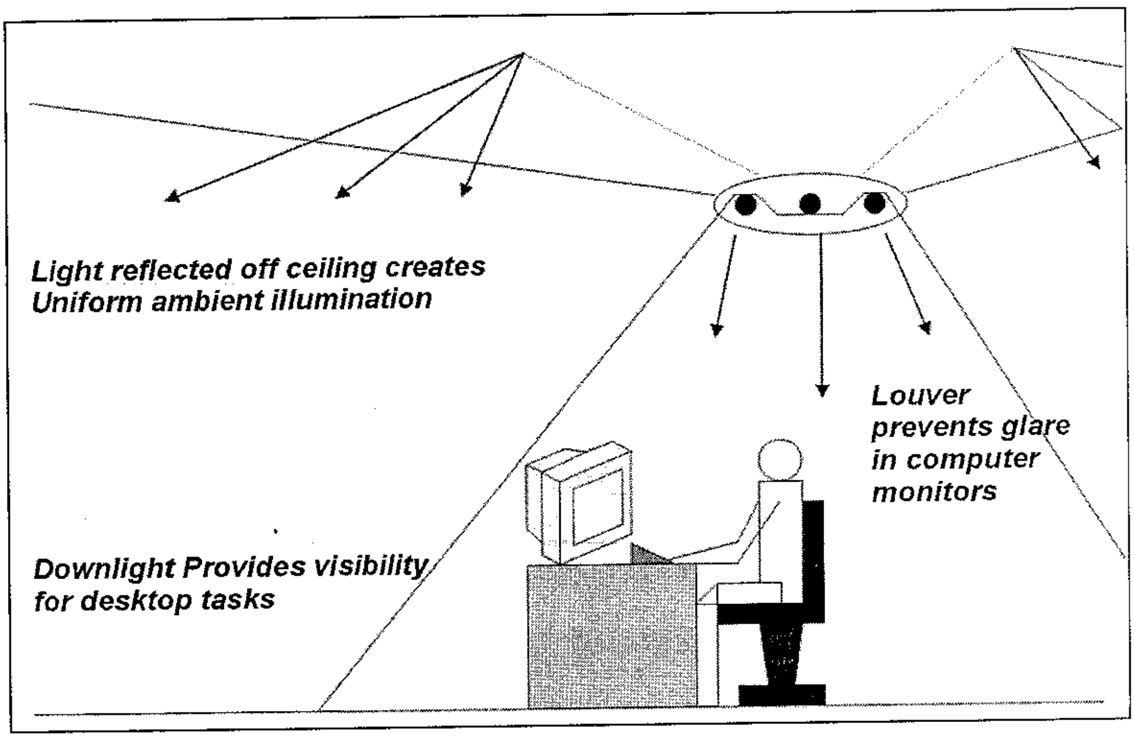


Figure 1.1 Workspace-specific direct-indirect lighting system provide both task lighting (down-lighting) and ambient lighting (up-lighting) [4].

As shown in Figure 1.1, a suspended luminaire over each workspace can provide the needed task and ambient lighting. Down-lighting component can provide the appropriate light for reading and writing surfaces while up-lighting component provides the comfortable and uniform ambient lighting as it reflects off the ceiling and brightens the walls and ceiling [4]. Combining information technology with integrated controls, office lightning fixtures can be controlled individually or as a whole building system through internet or intranet and even short messaging system (SMS) via mobile phones. Individual workers can adjust the light level of their offices or work areas using software that sends messages to specifically addressed lights to turn them on or off or even adjust the density of luminance. Energy managers can enable, re-configure and even schedule the control settings for specific occupancy sensors all from a personal computer.

Businesses, industries and government organizations have been under tremendous economic and environmental pressure in the past few years with the instable oil prices that increases day by day. Being economically competitive in the global marketplace and meeting increasing environmental standards to reduce air and water pollution have been the major driving factors in most of recent operational costs and investment decisions for all organizations. Energy management has been an important tool to help organizations meet these critical objectives for their short term survival and long-term success.

1.2 Problem Statement

The cost of energy is rising and there is a growing need for efficient energy management system. There are so many stand-alone energy efficiency devices, but in order for them to fully function in building environment, an integrated system implemented via computer system is inevitable.

Electricity prices haven't risen in Malaysia since 1997 and government-controlled Tenaga has repeatedly warned it will not be able to keep up debt repayments and its MYR4 billion annual capital expenditure if prices remain unchanged. In early March, the government asked Tenaga to resubmit a power price change proposal. Analysts said the move showed the government had rejected Tenaga's earlier plan for a 10 percent price increase [5]. Tenaga increased rates an average 12 percent from first of June 2006 to cover rising fuel costs. The increase came three months after Malaysia raised interest rates and gasoline and diesel prices. Fuel price gains drew public outcries and street protests by opposition groups in March [6]. It seems like the story will not end here and the increase in power tariffs in future due to middle east crisis is inevitable.

Due to inefficient usage of electricity organizations and companies that do not have an effective energy management programs, a high amount of energy is wasted everyday. Technologies introduced are stand-alone energy saving devices but the fact is there is no integrated system to link up all these devices as a whole unit. Current practices of energy management mainly focus in minimizing the energy consumption of a single device. A computerized system that minimizes the wastage of energy by synchronizing all devices in a single sector of an office has not been discussed as a solution for energy management.

1.3 Objectives and Scope of Study

The main objectives of the project are:

- To enhance an energy management system that reduces the wastage of energy using load analysis.
- To design an integrated energy management control system fully controlled by computer which operates, controls and manages all or most of the electrical devices in an office. The targeted devices for this project are:

    1. Lighting
    2. Air-conditioning system and windows.
    3. Motors of the elevators

The scope of the study is an office located in Malaysia. The office is equipped with facilities such as air-conditioner, fan and lights. The size is assumed 15 square meters.

CHAPTER 2

LITERATURE REVIEW AND THEORY

Energy management and optimization program includes the ability to forecast electricity, steam and fuel consumption. It maximizes cost efficiency by load scheduling and optimizing electricity generation and manages electricity purchase and sales. An efficient program can monitor and control peak loads, energy balance and efficiency and support decision making with simulation and analysis. Together, these advanced tools support the energy business from both operational and economic perspectives, helping industries increase efficiencies and cut costs. Following is the description of the current practices of energy management.

2.1 Residential sector

Residential sectors are private residences such as family houses, apartments , hostels. Energy consumption in this section varies due to regional climate differences. Statistics shows that about half of the energy used in the U.S. homes is used for heating and cooling purposes. Since the energy crisis during the 1970s the efficiency of the air conditioners and heaters have been increased. [7]

The 1987 National Appliance Energy Conservation Act authorized the Department of Energy to set minimum efficiency standards for space conditioning equipment and other appliances each year, based on what is "technologically feasible and economically justified". Beyond these minimum standards, the Environmental Protection Agency awards the Energy Star designation to appliances that exceed industry efficiency averages by an EPA-specified percentage.[7]

Despite technological improvements through the years lifestyle changes caused higher demands and standards of living which eventually caused higher demands on heating and cooling resources. The single stay household culture grew and as a result energy wastage has increased.

2.2 Commercial sector

Shops, stores, offices (private or government sectors), restaurants, schools and workplaces fall under category of commercial sector. Final consumers of energy are in fact the same as residential sectors with a difference in proportion. The biggest consumption area in this sector is again heating and cooling systems and represents only 30% of the energy use. Second place is lighting, at 25%, plays a more major role in commercial energy consumption rather than in residential. [8]

According to a number of case studies, more efficient lighting and elimination of over-illumination can reduce lighting energy by approximately fifty percent in many commercial buildings. A thoughtful design can increase energy efficiency in commercial buildings.

Commercial buildings often use centralized control and coordination of energy as a part of their professional management. For instance, using fluorescent lighting which is about four times as efficient as incandescent has become standard for most commercial buildings, although it may produce health effects [9]. As most buildings have consistent hours of operation, programmed thermostats and lighting controls are common. However, surveys show that many companies believe that having a computer controlled building automation system guarantees energy efficiency. As an example one large company in Northern California boasted that it was confident of its state of the art system had optimized space heating. A more careful analysis by Lumina Technologies showed the system had been given programming instructions to maintain constant 24 hour temperatures in the entire building complex. This instruction caused the injection of nighttime heat into vacant buildings when the daytime summer temperatures would often exceed 90 °F. This mis-programming cost the company over $130,000 per year (Lumina Technologies, 1997). Many corporations and governments also require the Energy Star rating for any new equipment purchased for their building

Solar heat loading through standard window designs leads to high demand for air conditioning in summer months and especially in equatorial regions such as Malaysia. Some modern technologies like Dakin Building in Brisbane, California, has designed a building to attain a certain angle so that it allows maximum reflection of solar heat; this design also assisted in reducing interior over-illumination to enhance worker efficiency and comfort [10].

2.2 Modern Technologies in Saving Energy

2.2.1 Building automation

"Building automation is a programmed, computerized, "intelligent" network of electronic devices that monitor and control the mechanical and lighting systems in a building. The intent is to create an intelligent building and reduce energy and maintenance costs." [11]

This system uses a controller which comes in a wide range of sizes and capabilities to control devices that are common in buildings. These systems usually use complex programming and are centralized and can be operated from a control room to monitor the whole target areas which are usually vast regions. An example of building automation topology is shown in figure 2.1.

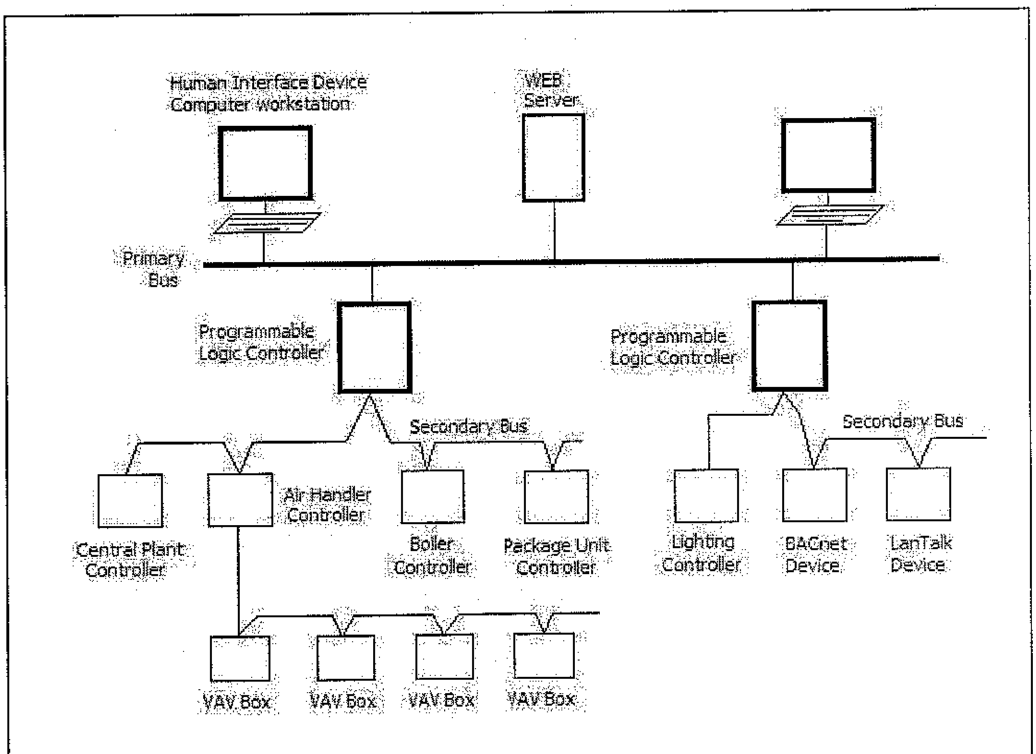


Figure 2.1 .An example of building automation topology [11]

2.2.2 Variable Volume Air-Handling Units

One of the most efficient solutions in current energy management control systems is "Variable air volume (VAV) Air-Handling Unit,". VAVs supply pressurized air to VAV boxes, usually one box per room or area. A VAV air handler can change the pressure to the VAV boxes by changing the speed of a fan with a variable frequency drive . The amount of air is determined by the needs of the spaces served by the VAV boxes .Each VAV box supply air to a small space, like an office and has a damper that is opened or closed based on how much heating or cooling is required in its space. The more boxes are open, the more air is required, and a greater amount of air is supplied by the VAV air-handling unit [12].

2.2.3 Passive house (Passivhaus)

Passive house is a standard for energy , figure 2.2, used in low energy buildings which require little amount of energy for space heating. A similar standard, MINERGIE-P®, is used in Switzerland [13]. The first Passivhaus buildings were built in Darmstadt, Germany, in 1990, and occupied the following year. In September 1996 the Passivhaus-Institut was founded in Darmstadt to promote and control the standard. Since then more than 6,000 Passivhaus buildings have been constructed in Europe, most of them in Germany and Austria, with others in various countries world-wide. The first Passivhaus in North America was built in Urbana, Illinois in 2002.

The Passivhaus standard requires that the building is within the following limits [14]:

- The building must not use more than (≤) 15 kWh/m²a (4,755 Btu/ft²/yr) in heating energy.
- The specific heat load for the heating source at design temperature must be less than 10 W/m² (3.17 Btu/ft²).
- With the building pressurised to 50Pa by a blower door, the building must not leak more air than 0.6 times the house volume per hour ($n50 \leq 0.6/h$).
- Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/(m²a) (38,039 Btu/ft²/yr)

These standards are much higher than the standards currently used to construct houses and require effort to be globalized and being used everywhere.

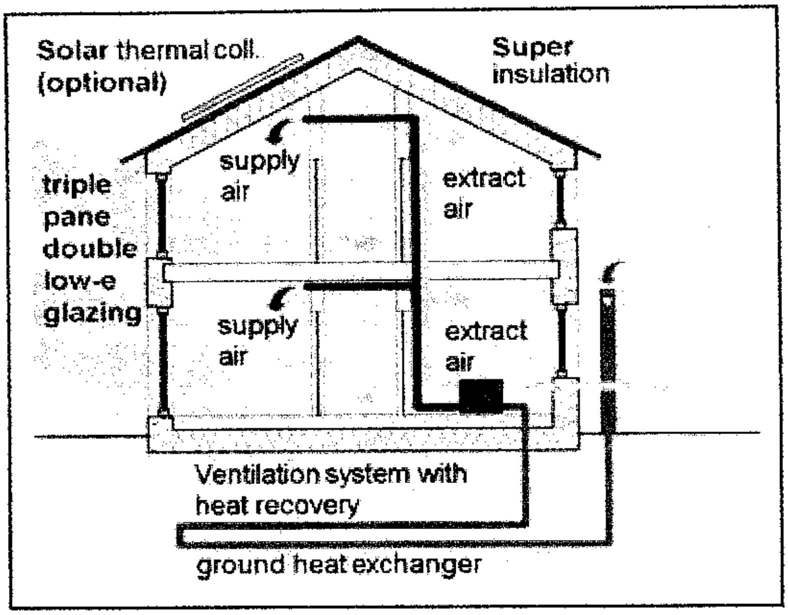


Figure 2.2 Passive house

2.3 Principles of Air Conditioner

The basic principle of air conditioner is that it uses the evaporation of a liquid to absorb heat. Evaporation of water absorbs heat resulting in reducing the temperature of the surface. If water is replaced with any liquid that has a lower boiling temperature, alcohol for instance, the efficiency of the system can be improved. The liquid, or refrigerant, used in an air conditioner evaporates in an extremely low temperature; therefore it can produce much cooler surface as water does. There are five basic parts to air conditioning systems namely the compressor, the heat exchanging pipes – serpentine or coiled set of pipes outside the unit, expansion valve, and heat exchanging pipes – serpentine or coiled set of pipes inside the unit and refrigerant – liquid that evaporates to create cold temperatures. In conventional air conditioner, the compressor compresses the refrigerant gas. This raises the pressure of the refrigerant and temperature; the condenser coils outside the air-conditioned allow the refrigerant to dissipate the heat of pressurization. As it cools, the refrigerant condenses into liquid form and flows through the expansion valve, Figure 2.3.

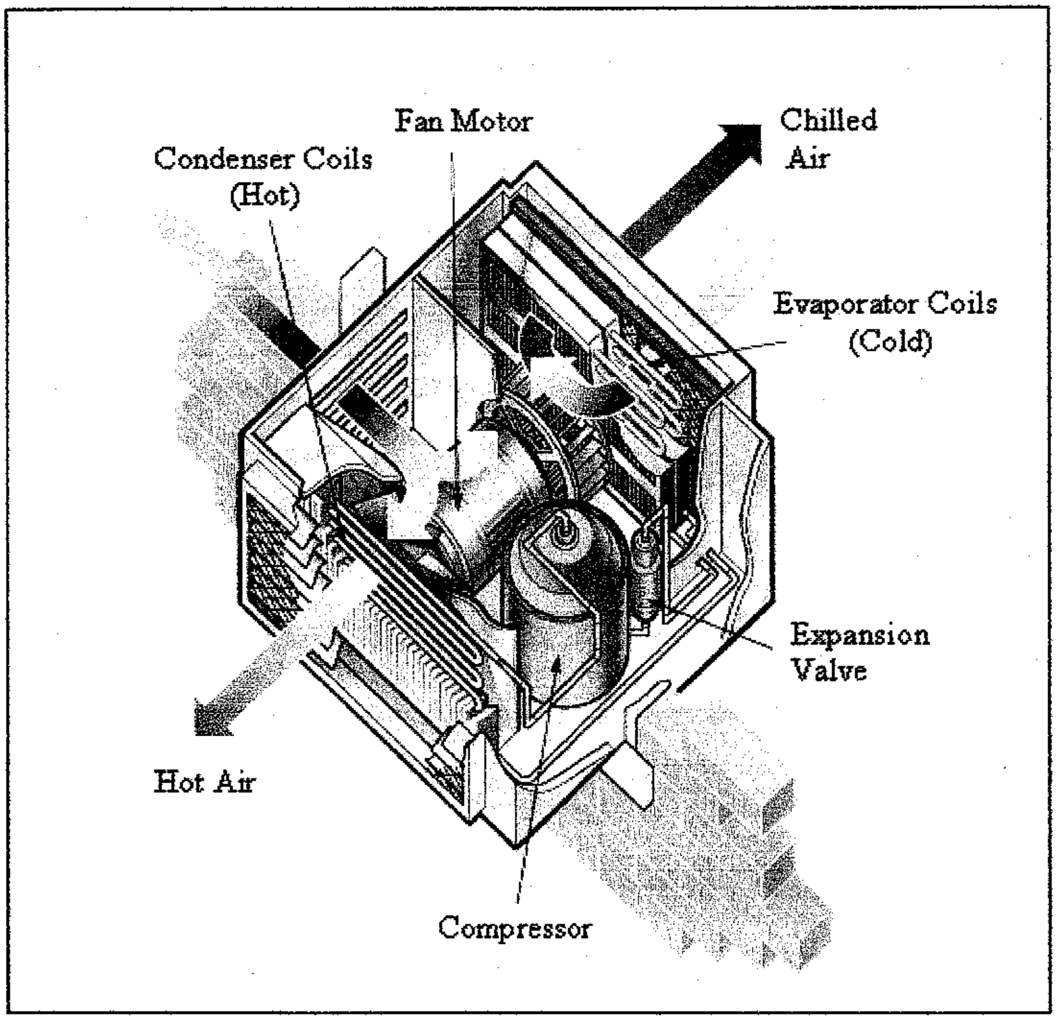


Figure 2.3 Basic mechanism of air conditioner [15]

The liquid refrigerant is then allowed to move from a high pressure zone to a low pressure zone, so it expands and evaporates and absorbs heat. The coils inside the air conditioner allow the refrigerant to absorb heat, making the air conditioner cold inside. A fan motor blows out the chilled air to cool down the temperature of the surroundings.

The cycle then repeats causing the room with the air conditioner to lose heat and produce a desirable temperature. A conventional air conditioner is a high power consuming device. A unit of air conditioning system consumes about one third of the total electricity usage in residential or office sector [16].

2.4 Block cooling

Heavy concrete floor blocks have the ability to quickly store heat, and, when necessary, to provide cooling (or heating) energy to the room. As soon as the room becomes too hot, heat is rejected to the block , whereas if it is too cool, heat is withdrawn .Buildings with this type of system provide the user with a high level of comfort and very low operating costs, are simple operate, and do not require expensive installations or control equipment. Displacement ventilation added to cooled slabs has the additional advantage of providing excellent indoor air quality at low energy consumption rates. In the system shown in Figure 2.4, air is introduced to the room at the floor level at a temperature slightly under room temperature. Being cooler and denser than the air in the room, the supply air spreads out to form a pool of fresh air along the floor. Rising convection currents (plumes) are formed around any heat sources present in the room, transporting air upwards from the pool towards the ceiling [17].

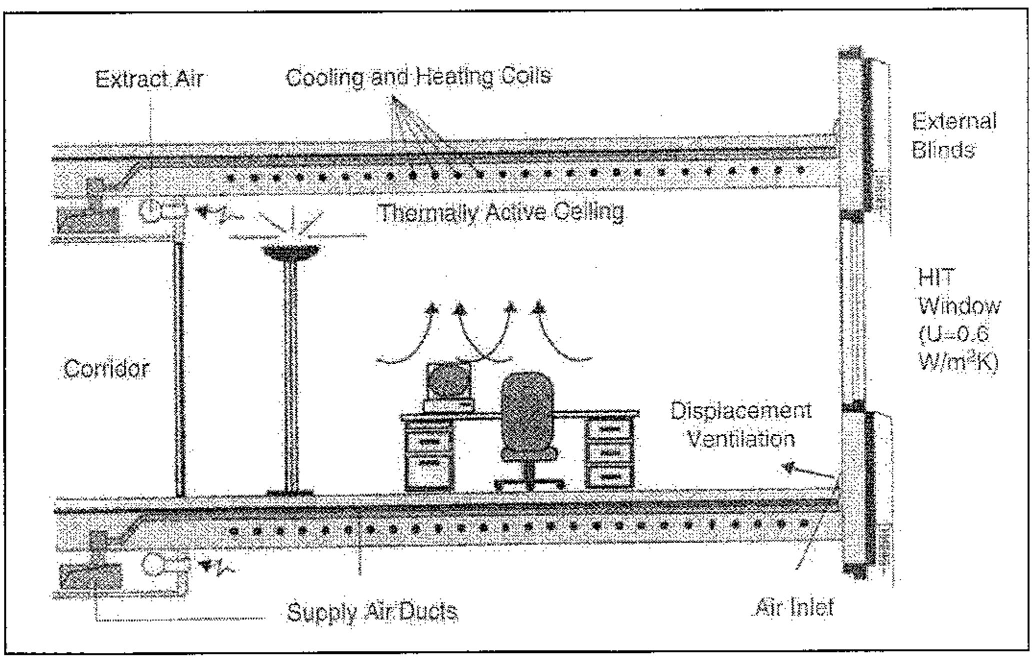


Figure 2.4 Schematic section building

2.5 Maximizing Cost efficiency by proper load analysis

Companies strive to optimize energy both from operational and financial perspectives. Energy needs are fulfilled by the most economical combination of the company's own production resources, and electricity and fuel purchased through bilateral agreements and the open market. Service and transfer costs can be taken into account in the optimization.

Effective energy management involves understanding energy needs and meeting those needs at the lowest possible cost in a way that suits each individual customer. Through effective energy management, companies increase profits, reduce costs and create more value. An effective energy management system, provides lowest energy cost, avoids waste of energy by managing occupied space and makes efficient use of staff through centralized control and integrating information from different sources. Use of intelligent computer-based processing enables the automation of all basic building systems. The individual systems are networked for effective management and control. The value of intelligent building systems improves dramatically as more systems are integrated.

CHAPTER 3

METHODOLOGY

By implementing a comprehensive energy management plan by utilizing a computerized control system in organizations, industries, offices and even residences, a huge amount of energy losses can be compensated. After all well organized plan can save unbelievable amount of energy in a long term period.

In order to achieve the objective of the project a circuit is designed for the controlling module as well as integrated controlling software. The controlling module communicates through serial port with computer. The system consists of output units (fan, air-conditioner, lights) and input units (sensors).The computerized control system processes data collected by the input units and compares it with the data obtained given by the user and then creates a profile for the system to act upon. User can input the desired preferences into the program. The program is a user friendly interface which is operable on all versions of Microsoft Windows. The system diagram can be illustrated as in Figure 3.1.

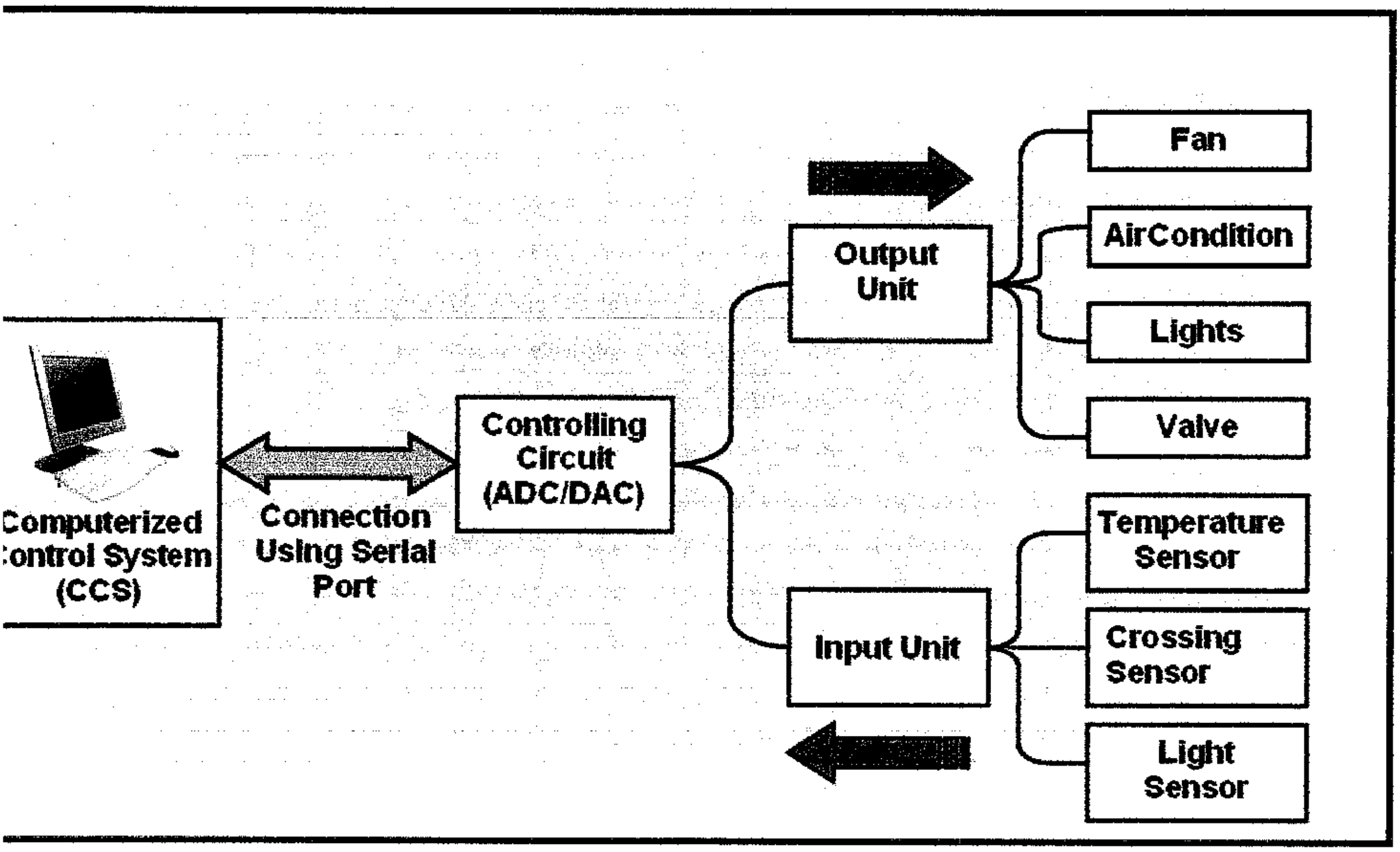


Figure 3.1 Diagram of the System and functions.

Process flow of the project is as below:

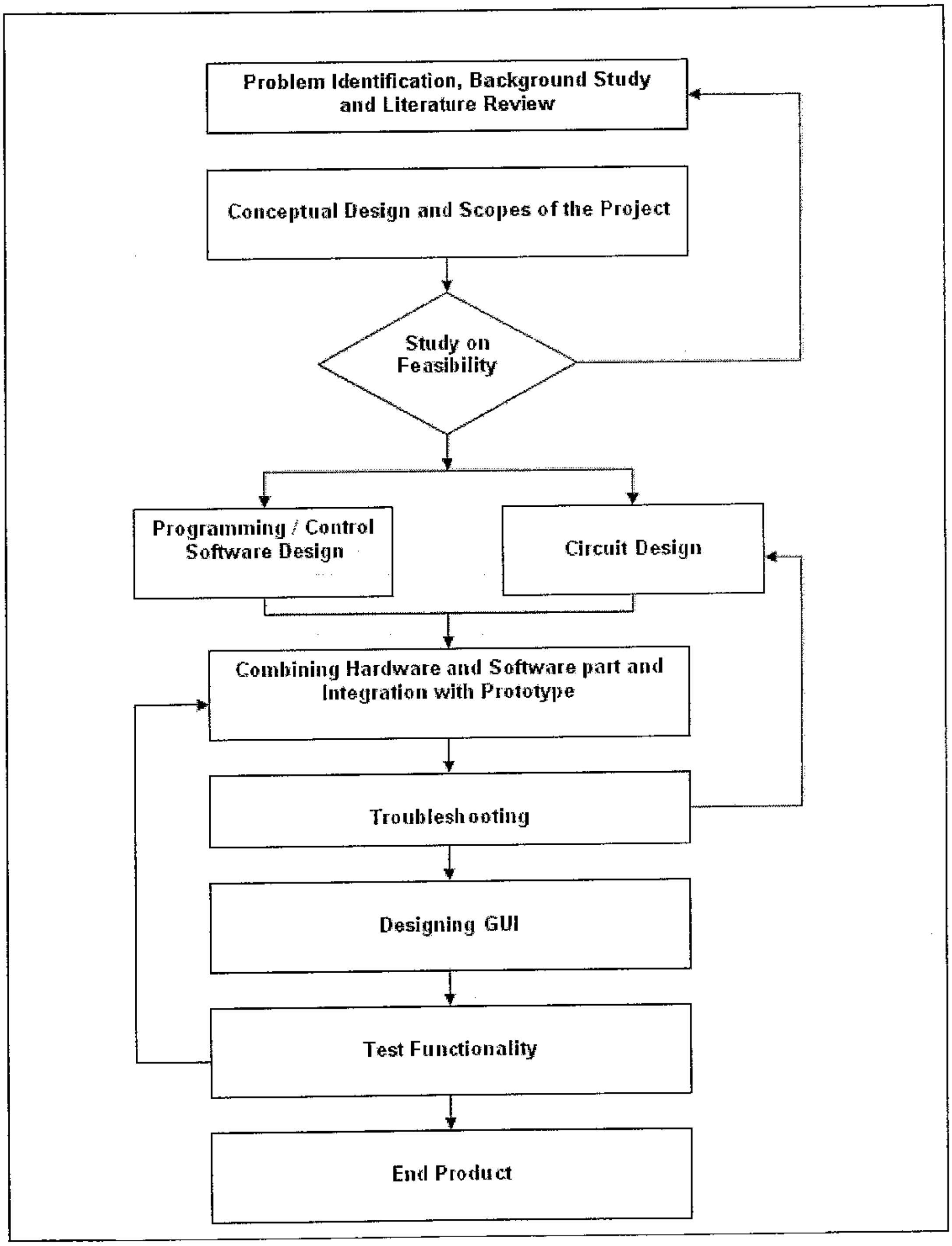


Figure 3.2 Process flow

3.1 System Analysis

The whole system can be categorized in three major units:

- Computerized Control System
- Controlling circuit
- Inputs and outputs

3.1.1 Computerized Control System (CCS)

This unit can simply be any personal computer that operates with Windows operating system. CCS receives the data collected by the input system, sensors, analyzes them and responds to the output units accordingly. CCS uses Visual Basic based software, Figure 3.3, to control the units via controlling circuit.

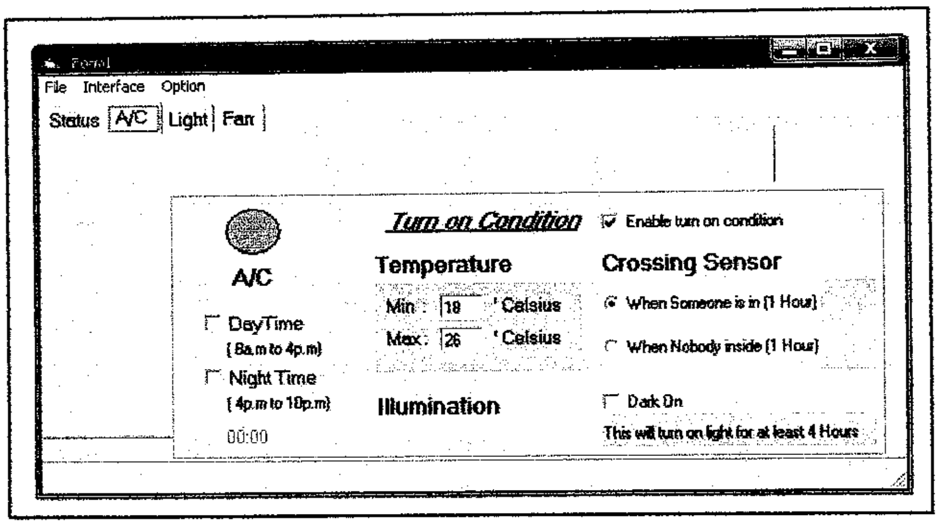


Figure 3.3. Inteface

3.1.2 Controlling Circuit

Controlling circuit uses ADC/DAC concept to establish a connection between CCS unit and input/output unit. The connection between this unit and CCS is done by a cable using serial port. Controlling circuit is supplied by an independent power supply.

3.1.3 Input/Output

This unit itself comprises two units, Input and output. Input unit collects the data from the environment and sends data to controlling circuit to be converted for analysis in CCS unit. Input unit includes sensors which are discussed in detail in 3.6.1, namely light, temperature and occupancy sensors. The output unit are the controlled systems in the office such as fan, air conditioning, lights.

3.2 Utility Functions

3.2.1 Lighting

Lighting needs to vary with each property and the goal is to furnish the occupants with the lighting required to complete specific visual tasks effectively and productively. This system introduces new solutions for lightning. Features of the lighting system include:

- Allows individuals to adjust their lighting through computer.
- Automatically turn on and off lights by computer schedule.
- Turn devices on and off through computer.
- Manage energy consumption by monitoring room occupancy and adjusting lighting to suit the occupants' requirement.

3.2.2 Ventilation and Air Conditioning

For ventilation, air-conditioning and indoor air quality the system features are:

- Permit individual occupants to adjust workspace temperatures (within prescribed limits)
- Monitor temperature, and adjust according to a usage profile and office size
- Adjust indoor air quality based on room occupancy and building standards
- Combine usage of fan and air-conditioning system so that both can be operated independently or co-dependently in order to obtain desired temperature and save energy.

The system offered ensures utmost efficiency and lower operating cost. The total energy consumption can be monitored using the system to minimize the operating costs.

3.3 Mathematical Concept

3.3.1 Cooling Load

The air inside the office receives heat from number of sources. If the temperature and humidity of the air are to be maintained at a comfortable level, this heat must be removed. The amount of heat that must be removed is called cooling load. The cooling load must be determined because it is the basis for the selection of the roper size air conditioning equipment and distribution system. It is also a main factor in analyzing the energy consumption and conservation [18].

The cooling load is not always equal to the amount of heat received at a given time. The difference is a result of heat storage and time lag effects of the total amount if heat entering the building at any instant, only a portion of it heats the room air immediately; the other part which is the radiation heats the building mass (roof ,walls ,floors and furnishing).This is known as the heat storage effect. Only at a later time does the stored heat portion contribute to heating the room air. The room cooling load is the rate at which heat must be removed from the air to maintain it at design temperature and humidity [18].

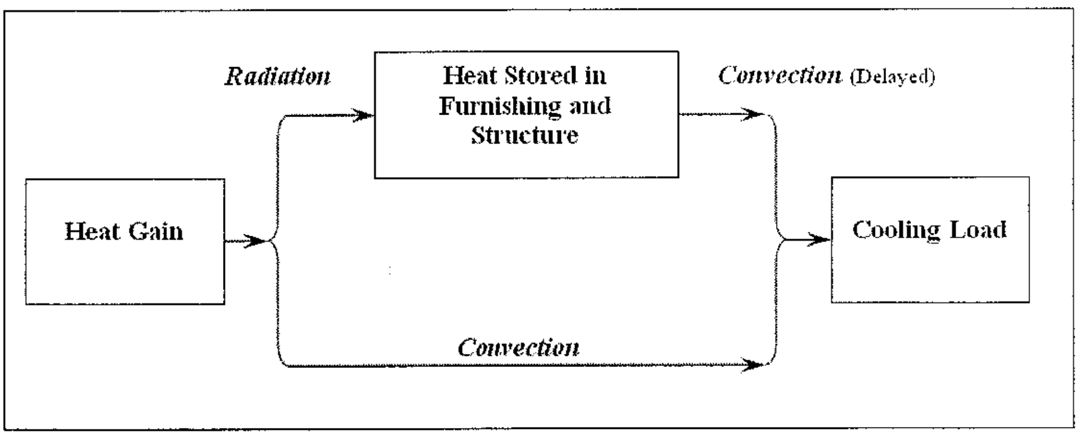


Figure 3.4 Heat Flow diagram showing building heat gain, heat storage and cooling load.

3.3.2 Commercial Cooling Load calculation Procedures

In order to design a system that can control the energy consumption of an in bound area the first step is to have an exact analysis of the amount of energy consumed during a day. Therefore following steps should be considered in calculating cooling load of any structure:

1. Indoor and outdoor design conditions should be selected from Table 1.
2. Architectural plans should be used in order to measure dimensions of all surfaces through which there will be external heat gains, for each room.
3. Areas of all surfaces should be calculated
4. Heat transfer coefficient U-values should be calculated for each element from appropriate tables.
5. Time of the day and month of the peak load for each room should be determined by calculating external heat gains at times they are expected to be maximum.
6. Internal heat gain from the people, lights, and equipment should be added to external heat gain.
7. Time of building peak load should be found by a proper process.
8. Cooling coil and refrigeration load should be found by adding the ventilation load from Table 2.

3.4 Cooling Load Calculations

3.4.1 Conduction through Exterior Structure

The cooling loads caused by conduction heat gains through the exterior roof, walls , and glass are each found by following equation :

$$Q_E = U \times A \times CLTD_c \tag{3.1}$$

where

Q_E = cooling load from roof, wall, or glass, BTU/hr

U= overall heat transfer coefficient for the roof, wall , or glass , BTU/hr-ft^2-F

A= area of roof, wall, or glass, ft^2

$CLTD_c$= corrected cooling load temperature difference, F

The cooling load temperature difference (CLTD) is not the actual temperature difference between the outdoor and indoor air. CLTD should be modified as:

$$CLTD_c = CLTD - (t_a - t_R) \tag{3.2}$$

where

$CLTD_c$= corrected value of CLTD, F

CLTD = corrected cooling load temperature difference, F

t_R = room temperature, F

t_a = average outside temperature on a design day

CLTD values can be obtained from Table 3.

3.4.2 Solar Radiation through Glass

Radiant energy from the sun that passes through glass and becomes a heat gain to the room can be calculated as follow:

$$Q_R = SHGF \times A \times SC \times CLF \qquad (3.3)$$

where

Q_R = solar radiation cooling load from glass, BTU/hr

SHGF = maximum solar heat gain factor, BTU/hr-ft^2

A= area of glass, ft^2

CLF = cooling load from glass

SHGF can be obtained from Table 4.

3.4.3 Lightning

The equation for determining cooling load due to heat gain from lightning is

$$Q_L = 3.4 \times W \times BF \times CLF \qquad (3.4)$$

where

Q_L = cooling load from lightning BTU/hr

W = lightning capacity, watts

BF = ballast factor ($\cong 1.0$)

CLF = cooling load factor for lightning ($\cong 1.0$)

3.4.4 People

The heat gain from people is composed of two parts, sensible heat and the latent heat resulting from perspiration. The equations for cooling loads from sensible and latent heat gain from people are

$$Q_s = q_s \times n \times CLF \qquad (3.5)$$

$$Q_l = q_l \times n \qquad (3.6)$$

where

Q_s ,Q_l = sensible and latent heat gains (loads)

q_s, q_l = sensible and latent heat gains per person

n = number of people

CLF = cooling load factor for people.

Table 5. has mentioned values for some typical activities.

Total cooling load ,Q_{Total} , can be calculated as follow

$$Q_{Total} = Q_E + Q_R + Q_L + (Q_s + Q_l) + Q_a \qquad (3.7)$$

where

Q_E = cooling load from roof, wall, or glass, BTU/hr

Q_R = solar radiation cooling load from glass, BTU/hr

Q_L = cooling load from lightning BTU/hr

Q_s ,Q_l = sensible and latent heat gains (loads)

Q_a =cooling load for appliances is equivalent to their total watts.[18]

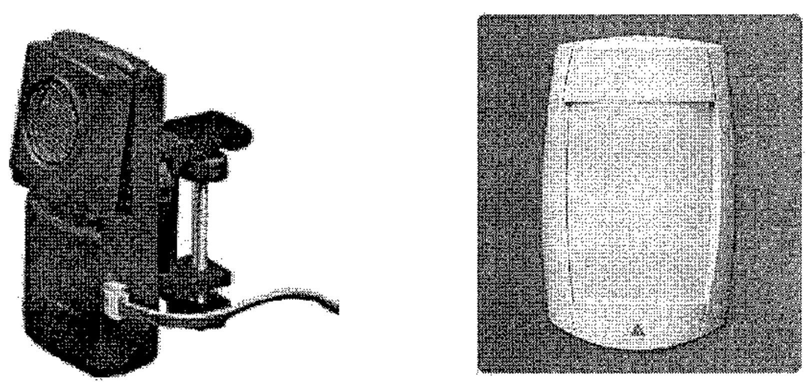
3.6 Requirements

All anticipated hardware and software are listed as follow:

3.6.1 Hardware Requirements:

- Temperature Sensor: Temperature sensing elements are a critical part of any building control system .Various temperature sensors are available in the market. ScienceWorkshop®750 was used to collect data from temperature sensor Type K which is available in Physics Lab, Building 19.

- Occupancy Sensor : Which saves energy by turning off lights in spaces that are unoccupied, When the senor detects motion, it activates a control device that turns ON a lighting system, If no motion is detected within a specified period , the lights are turned OFF until motion is sensed again. Occupancy sensors are produced in two primary types: Ultrasonic (US) and Passive Infrared (PIR). Dual-Technology Sensors (DT) sensors that have both ultrasonic and passive infrared detectors are also available. In this project infrared sensor is used.



(a) (b)

Figure 3.5 (a): Ultrasonic (US) Motion Detector. (b) Passive Infrared (PIR) Motion Detector Sensor.

- Serial port interface circuits: Input serial port interface circuit and output serial port interface circuit, which are used to connect to the computer via serial port so that the computer can process the information transmitted by the sensors.

- Controlling Circuit: As was mentioned before controlling circuit uses ADC/DAC concept to establish a connection between CCS unit and input/output unit. The circuit consists of five main sections as shown in figure 3.6.

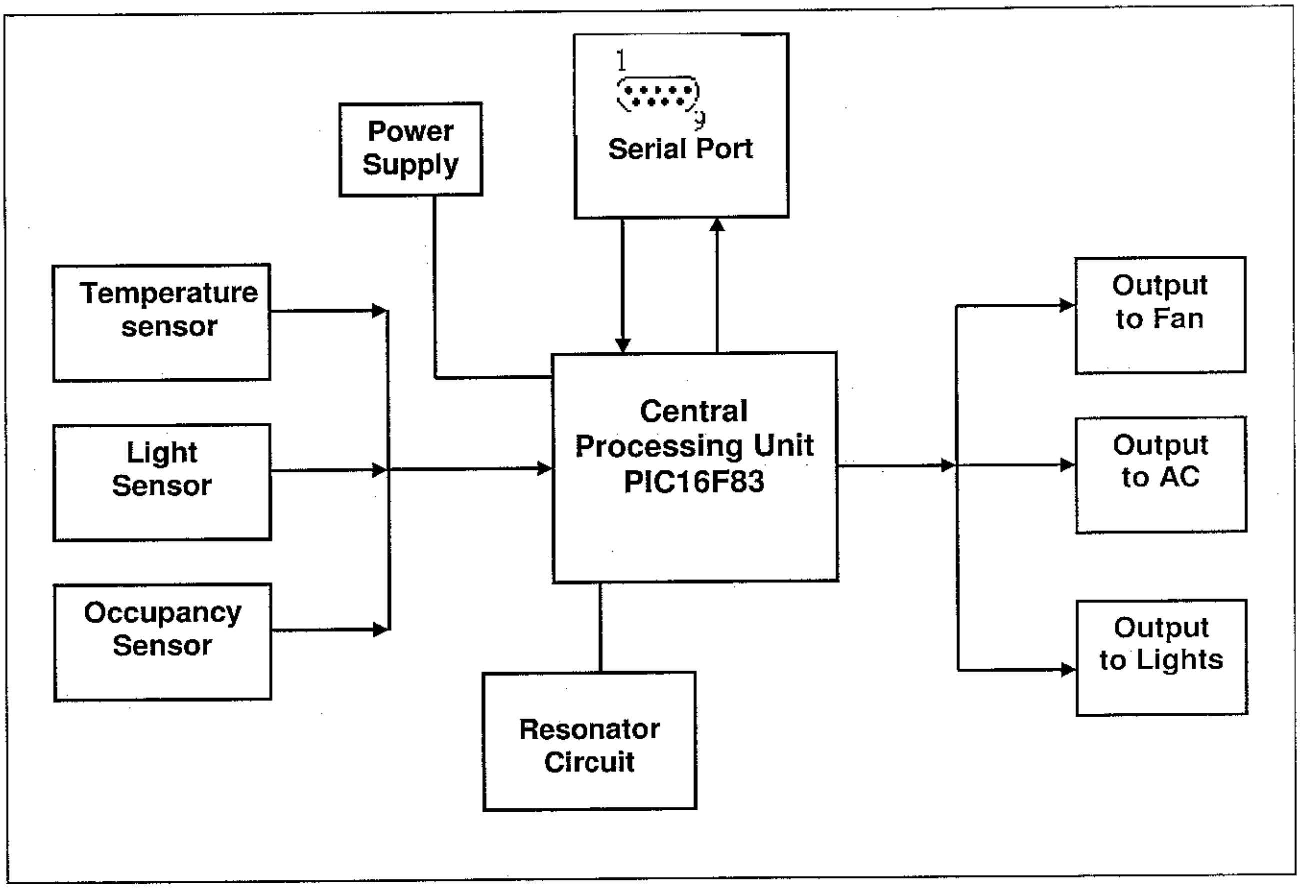


Figure 3.6 Block Diagram of the Controlling Circuit.

The main units are namely:

- Central Processing unit
- Serial port
- Sensors
- Outputs

Figure 3.7 shows the schematic of the designed controlling circuit and indicates utilized pins of the PIC16F873 which are connected to different sections of the circuit as described in figure 3.6.

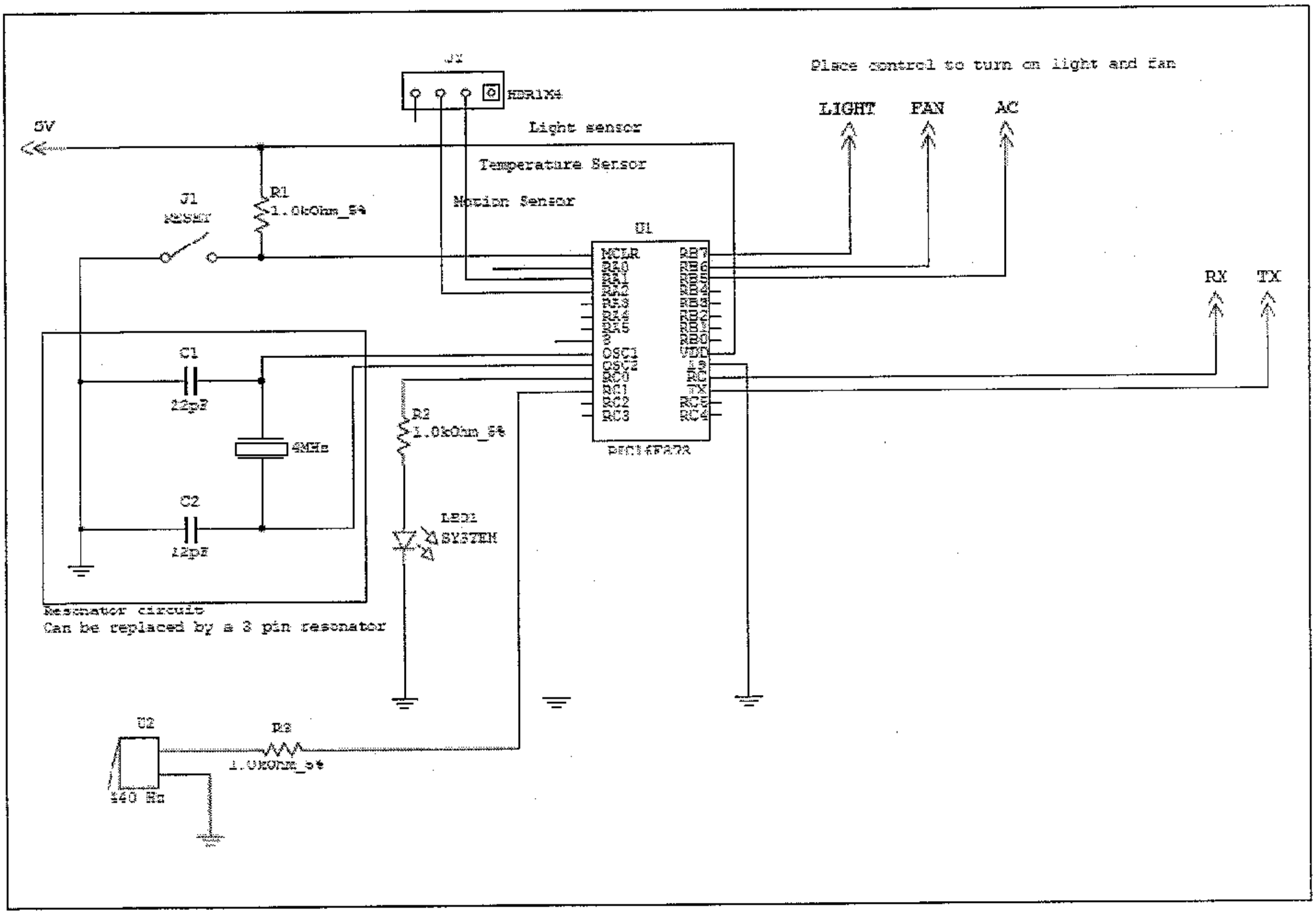


Figure 3.7 Schematics of the controlling circuit

3.6.2 Central Processing Unit

A microchip (PIC16873) was utilized to along with a program to control process input data from the sensors to run the outputs. The 16F873 was selected because of its high capacity of code size, about eight times the old models, much more RAM, much more I/O pins, a UART and A/D converter. In the meantime modifying the program on this microchip can be done easily. The range of commands for this IC allows controlling output devices, such as motors and lamps that are connected to the PIC microcontroller. Devices can be switched on or off in sequences using: timing, counting, repetition, and decisions based on signals from digital and analogue sensors that are connected to the PIC microcontroller.

Asynchronous communication concept was used in programming the microcontroller. While transmitting or receiving data from the IC the condition of "0" and "1" must be assigned in order for the receiving side to recognize it. In asynchronous communication a start bit to the head of the transferred data(8 bits or 9 bits) and it puts a stop bit at the end of the data which does the data recognition . The start bit is an L level and the stop bit is the signal of the H level. H level is the condition of not transferring data, when L condition begins the receiving side recognizes that the data transfer has begun. After that, according to the signalling speed, the transfer of the data is done. The transfer of the block ends when a stop bit (H level) is detected last. A signalling speed is controlled by the timer which is independent in the sender and the receiving side.

In the asynchronous mode communication, the RX port is used for receiving and the TX port, figure 3.7, is used for the transmission, so, it is possible to send and receive at the same time (Full duplex). These pins are shown in figure 3.8. The code for the program used can be found in APPENDIX C.

Some important pins (Figure 3.8) on 16F873 are:

- PIN 1 is ACTIVE LOW RESET
- PINS 2 through 7 are the ANALOG ports
- PINS 8 and 19 connect to GROUND and PIN 20 to 5V
- PIN 9 takes in the clock (20MHz) signal
- PINS 12 and 13 are the PWM pins
- PINS 21-28, 14-18 can be used as a digital port

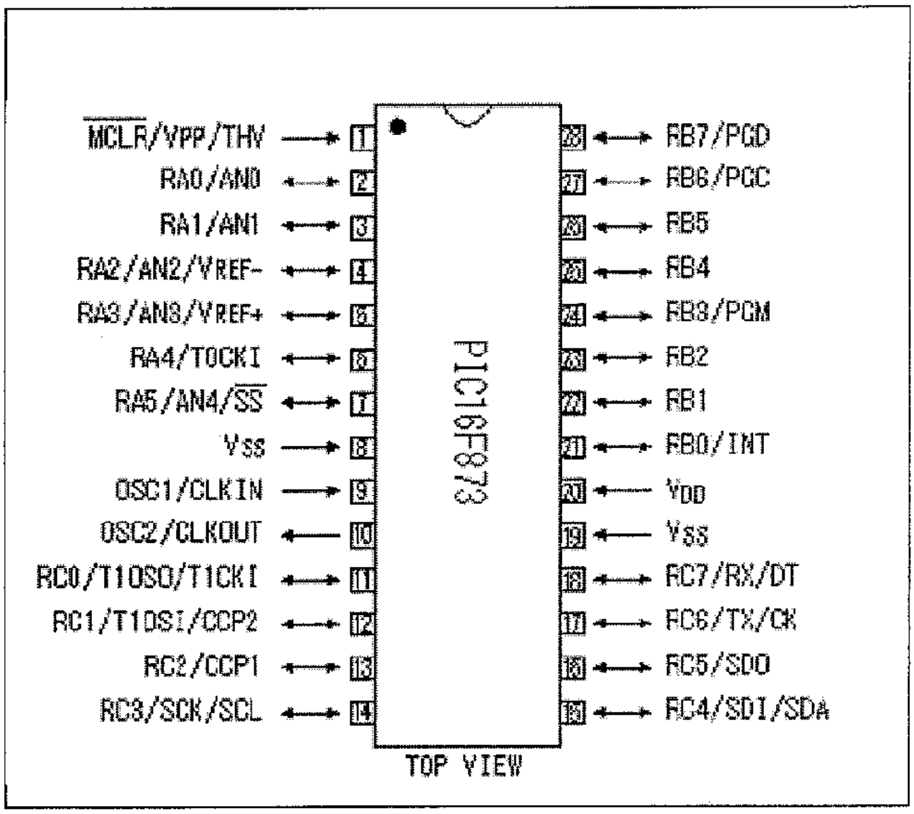
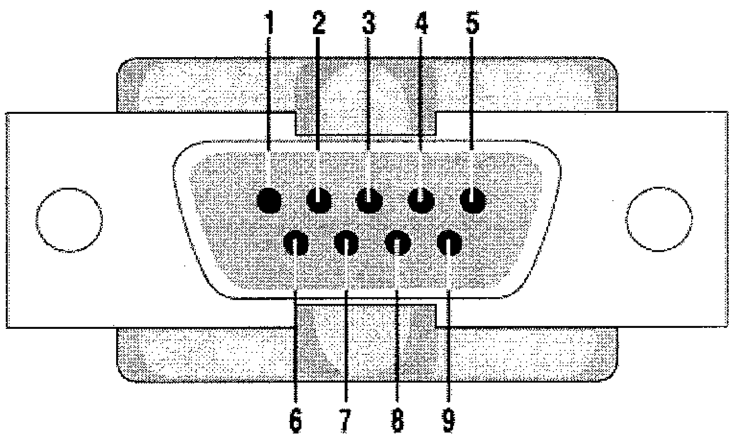


Figure 3.8 PIC 16f873 pin assignments

3.6.3 Serial Port

Serial port is the only means to transmit and receive from and to the computer and controlling circuit. There are several types of ports but DB-9 is the best option for this application. It is defined as a digital signaling interface between customers (DTE) equipment and carrier's equipment (DCE). And thus primarily used for telecom equipment. The main reason for DB-9 to be chosen is its availability on nearly all types of personal computers. In fact all computers come with 2 sets of DB-9 ports named COM1 and COM2. Using other means of communication requires adapters or simply adds up to the complexity of the system which increases the cost of final product and is unnecessary. Figure 3.9 shows pins assignment of serial port.



Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data terminology Ready	9	Ring Indicator
5	Signal Ground		

Figure 3.9 Pin assignments of the serial port

3.6.4 Sensors

There are three types of sensors used in this project:

- Temperature sensor: Detects the degree of temperature and sends signals as the temperature exceeds or become less than the desired interval. A figure 3.11 shows the schematic and an image of the sensor

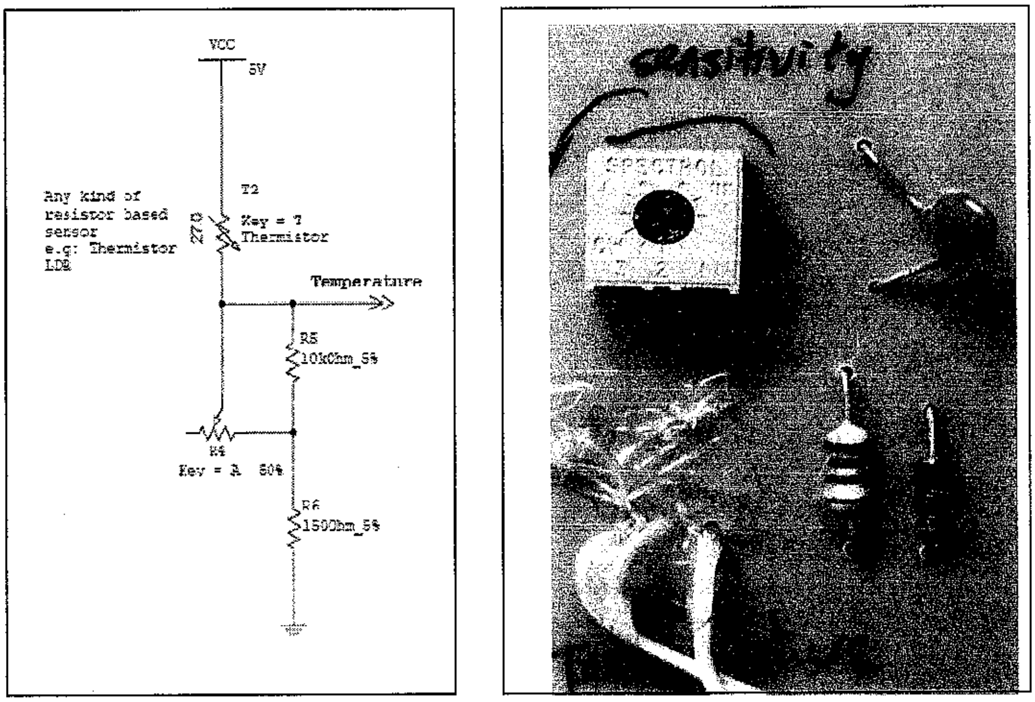


Figure 3.10 Schematic and image of the temperature sensor

- Light sensor: This sensor detects the degree of illumination of the room and transmits the signal to the controlling circuit. The main active device in the sensor is the light dependant resistor. Light dependant resistors operate the same way as variable resistors. The sensitivity of the sensor can be adjusted as it can be varied on a variable resistor. A figure 3.11 shows the schematic and an image of the sensor.

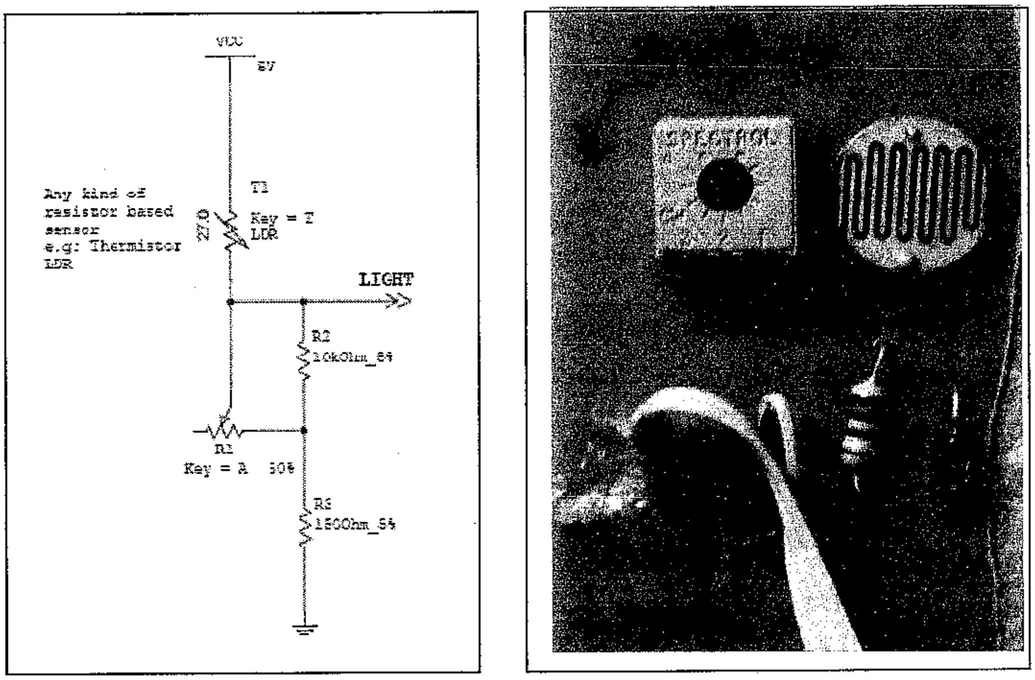


Figure 3.11 Schematic and image of the light sensor

- Occupancy sensor: The infrared sensor uses an infra red beam to monitor passage way of the office. When the beam is broken a relay is tripped which can trigger the circuit to send the signal to controlling circuit. The IR beam is very strong and can cover a distance of at least 5-7 meters. A 9v battery is required to power the circuit.

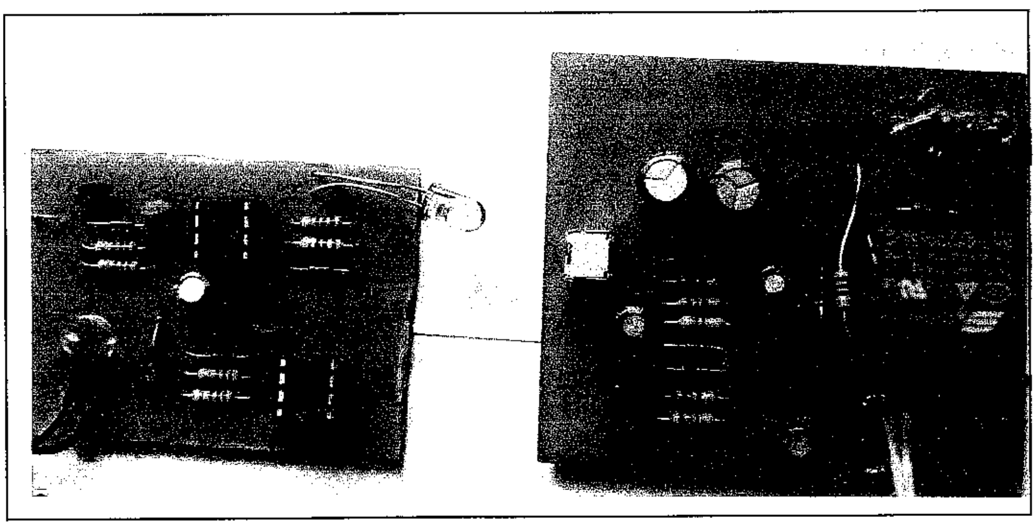


Figure 3.12 IR crossing Sensor

3.6.2 Software Requirements:

Soft wares required for this project are:

- Microsoft Visual Basic®
- Microchip MPLAB IDE V7.50
- BurnTecFP V1.5
- Data Studio®
- AutoCAD®
- Eagle®
- PSPICE 8.0

CHAPTER 4

RESULTS AND DISCUSSION

4.1 CLTD Calculations

As mentioned in chapter 3, the amount of the heat from convection, radiation and delayed convection that must be removed from a building is called the CLTD. In order to get the precise idea of how much energy shall be consumed in order to cool down the room below parameters were assumed for the hypothetical office of study:

Walls: 2" insulation + 4" common brick
Windows: Regular double glass with no inside shading, 1.5m by 2m
Roof: 4" lightweight concrete without suspended ceiling
Time: 12pm
Ambient temperature: 28° Celsius
Temperature of outside room: 32° Celsius
Occupants: One person, resting
Light: One 40W fluorescent lamp

In order to follow the formulas and tables mentioned in chapter 3 all Celsius units should be converted to Fahrenheit and all units in meters should be altered to feet. Calculations for roof, window and walls are mentioned in table1.

Table1. CLTD calculations of roof, wall and window

	Wall	**Roof**	**Window**
U-value (BTU)	0.111	0.213	30
CLTD	9	62	-
$CLTD_c$ (F)	$CLTD_c = CLTD - (t_a - t_R)$ $= 9 - (89.6 - 82.4)$ $= 1.8F$	$CLTD_c = CLTD - (t_a - t_R)$ $= 64 - (89.6 - 82.4)$ $= 56.8F$	-
Q (BTU/hr)	$Q_w = U \times A \times CLTD_c$ $= 0.111 \times (16.4042)(9.8425) \times 1.8$ $Q_w = 32.26 BTU / hr$	$Q_R = U \times A \times CLTD_c$ $= 0.213 \times (16.4042)(9.8425) \times 56.8$ $Q_R = 1953.398 BTU / hr$	$Q_G = A \times CLF$ $= (4.9213)(6.517)(30)$ $Q_G = 968.76 BTU / hr$

CLTD of occupancy and lights is :

$$Q_{occupancy} = 140 BTU / hr$$

$$Q_{Electrical} = 40 BTU / hr$$

Hence,

$$Q_{Total} = Q_R + Q_W + Q_G + Q_{Ocuupancy} + Q_{Electrical}$$

$$Q_{Total} = (1953.39 + 32.36 + 968.76 + 140 + 40) BTU / hr$$

$$Q_{Total} = 3134.41 BTU / hr = 918.64 \text{ Watts}$$

Thus, for the room to maintain its current temperature a CLTD of 918.64 Watts of power should be removed. Therefore an air-condition with the capability of 1.5hp is required for this office.

4.2 Radiation Calculations Using MATLAB

An experimental Matlab program, appendix C. has also been developed to calculate the rate of heat transfer in an enclosed area with diffused grey surfaces. Calculation of radiation in non-black enclosed areas is very complicated and difficult task. To make a simple radiation analysis simpler, it is common to assume the surfaces of an enclosure to be opaque, diffuse, and grey. That is the surfaces are non transparent, they are diffuse emitters and diffuse reflectors, and their radiation properties are independent of wavelength [9].

Yet with all this assumptions calculations for this task is not easy but Matlab has made it easier using matrices. By assuming walls to be 3 meters and 5 meters long , Figure 4.1 ,and view factors according to Table 7 ,program calculates for two parameters of radiosity (W/m^2) as well Net radiation heat transfer to or from a surface (W). The algebraic sum of radiation heat transfers equals zero so that the rate heat gained and removed would be equal.

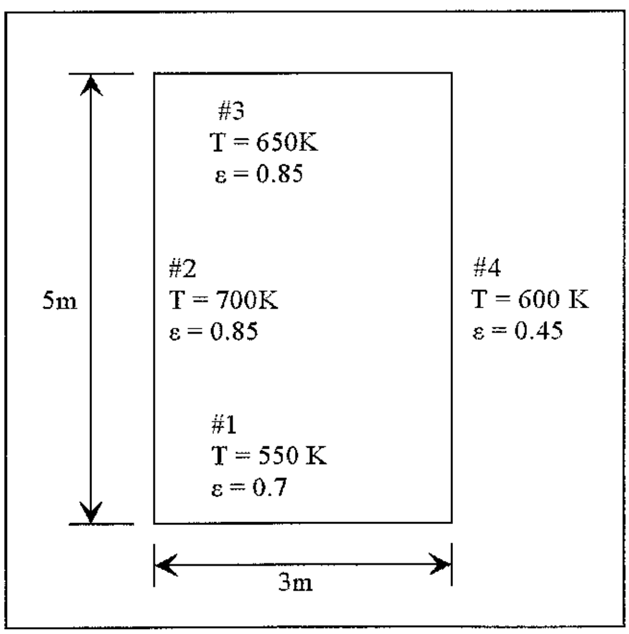


Figure 4.1 Specification of the assumed enclosed area for radiation surface

4.3 Prototype

4.3.1 Software

The prototype includes a software program to run with the serial port interface which shows the on and off status of the fan, air conditioner, and light in the "status tab". The interface includes 3 more tabs where the user can input the preference of the desired profile. The program has 2 modes for the time.

- Day time (8am to 4pm): Normal office hours when the system is used most. At this interval of time of it is not completely dark and the light system should not necessarily be used with all capacity. In order to use lights at full capacity during daytime according to need, an option was designed for the user called "Dark On". By choosing this option user can have the capabilities of the system at night time during daytime at least for four hours. The system will automatically recovers back to daytime mode after four hours so that for instance if the user forgot to turn off the dark on mode, system will not allow further energy wastage.
- Night time (4pm to 10pm): Some employees work overtime after office hours. Night time profile was designed for those staying in office after 4pm.at this interval of time lights are usually utilized in higher capacity unlike the air conditioner which only half of its capacity would be utilized due to temperature drop outside.

- Crossing sensor: This option allows user to turn off all three peripherals at the same time once exiting the office without touching the switches of the peripherals. Once user exits the office the crossing sensor detects the passage and automatically turns off the equipments. The system automatically turns back on once someone enters back in the office. User can define for the system if the office has multiple entries during a day so that entering an individual would not interfere with the system turning on and off.

All of the previous options are available for the rest of the peripherals so that user can choose the best usage profile.

- Temperature : Minimum and maximum desired temperature can be set by the user from personal computer so that the system will automatically turn on and off the air conditioner and fan in order to get the desired temperature.

Figure 4.2 shows a caption of the interface.

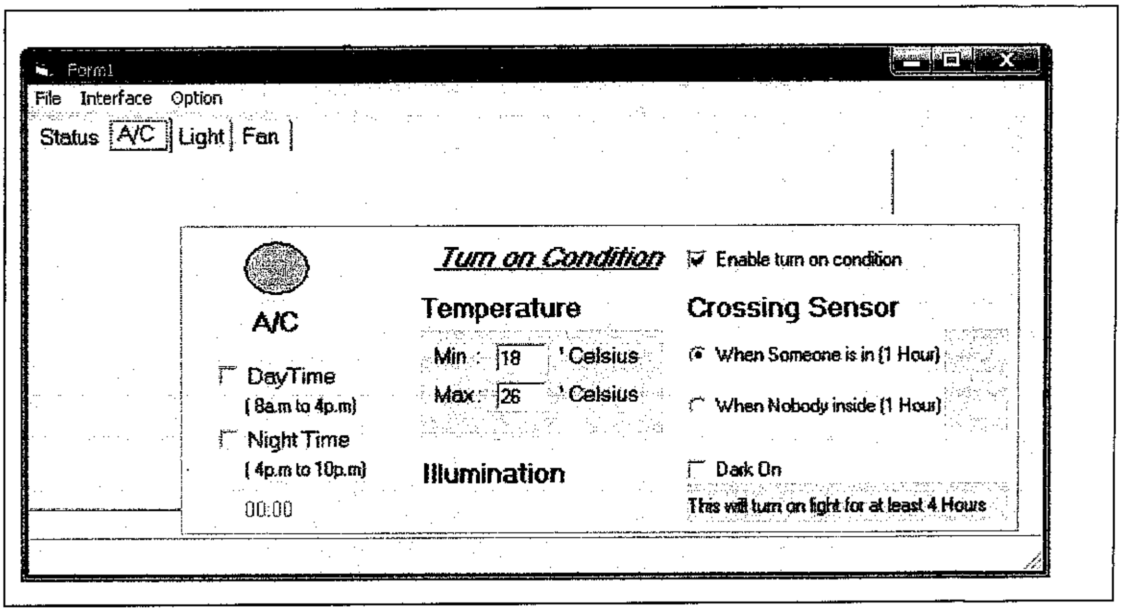


Figure 4.2: A caption of the interface

4.3.2 Hardware

The hardware as was introduced in chapter 3, can be seen in figure 4.3. and 4.4. The circuit has an onboard troubleshooting feature which makes it easy for normal people to realize if there is anything wrong with the system. LEDs on different locations on the circuit can show the status of each working device. LED 1 shows that the prototype is connected to the power supply and current is flowing through the circuit. Meanwhile LED2 shows the status of the serial port connected to the computer. Once the software

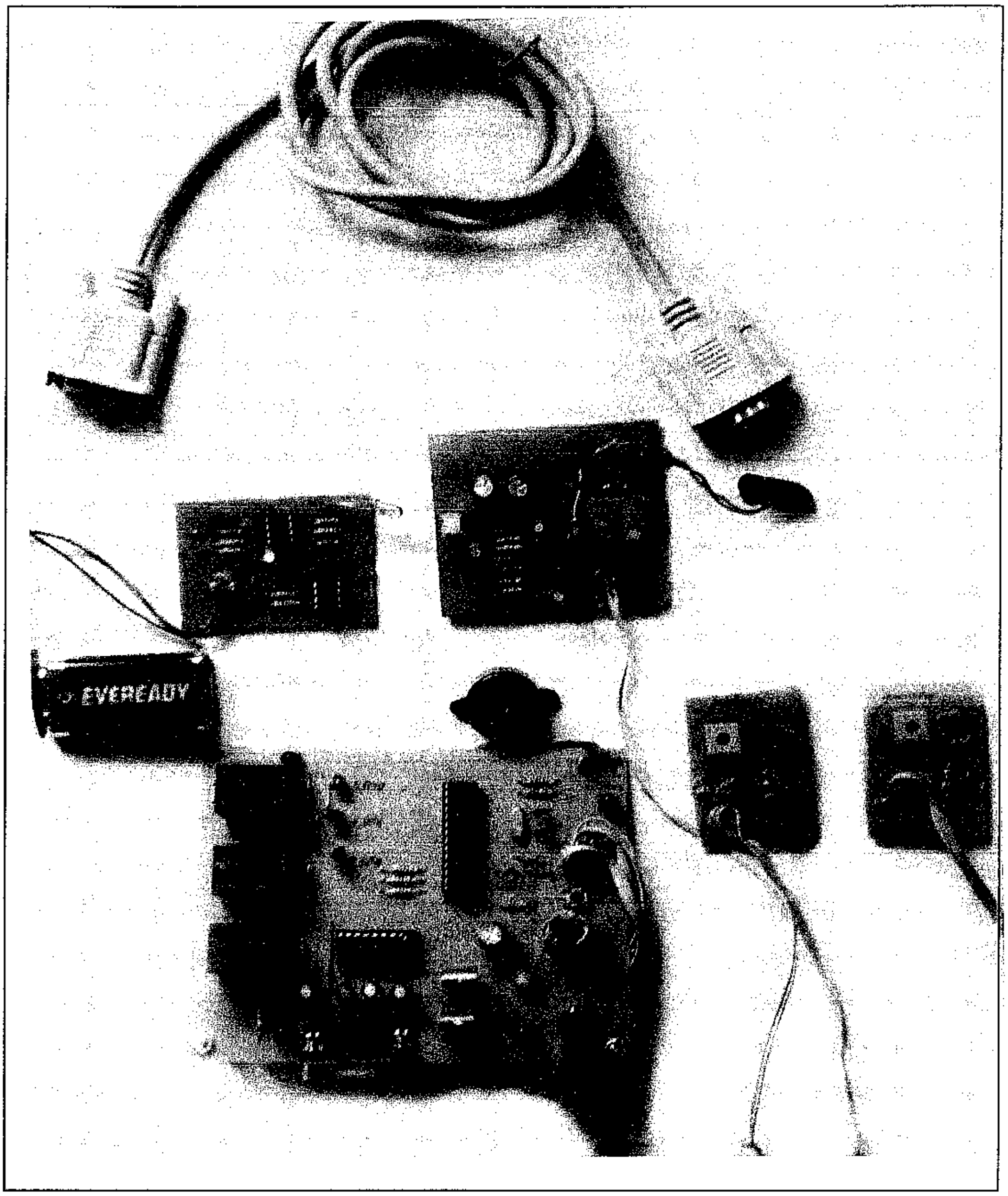


Figure 4.4 Controlling circuit along with sensors.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A great amount of energy can be saved if it is used wisely and properly, knowing each device should be operated when and how. Computerized Control System (CCS) has made it possible to save massive amount of energy wasted daily by simply controlling the office equipments through computer. This can bring satisfaction to both employees and organization as CCS makes device handling and energy conservation much easier which simply results in lower energy bills monthly. This project provides a challenging and interesting experience for all parties involved. The tasks, ranging from load analysis of an office, to evaluating the simulation results, to its actual implementation in the controlling module and interface has made this project to be one of a kind. The project carried two major stages. Developing software and producing software. Technical and theoretical knowledge was applied in completing this project. The main purpose of this project is to reduce the wastage of energy in an office in a certain period of time .The objectives are achieved and were successfully implemented on the prototype. A computerized control system which is simple yet technologically advanced was successfully designed with minimum costs and maximum efficiency. This system will hopefully satisfy the need of the user to control typical equipments of an office without disturbing the activities of the employee while working.

5.2 Recommendations

The heat gain from a building must be removed somehow to save the consumed energy in the office. One effective way is to prevent the radiated energy to enter the office area. This can be done using a number of aluminium pipes embedded in between outer layers of the walls which are exposed to sun. The cold water fed to the pipes is controlled by an automatic valve connected to the central computerized system which opens and closes the valve when necessary. The cold water passing through the pipes absorbs a great deal of heat radiated to the wall .The warm water will be stored in another storage tank beneath the building to be used for other purposes (Figure 5.1)

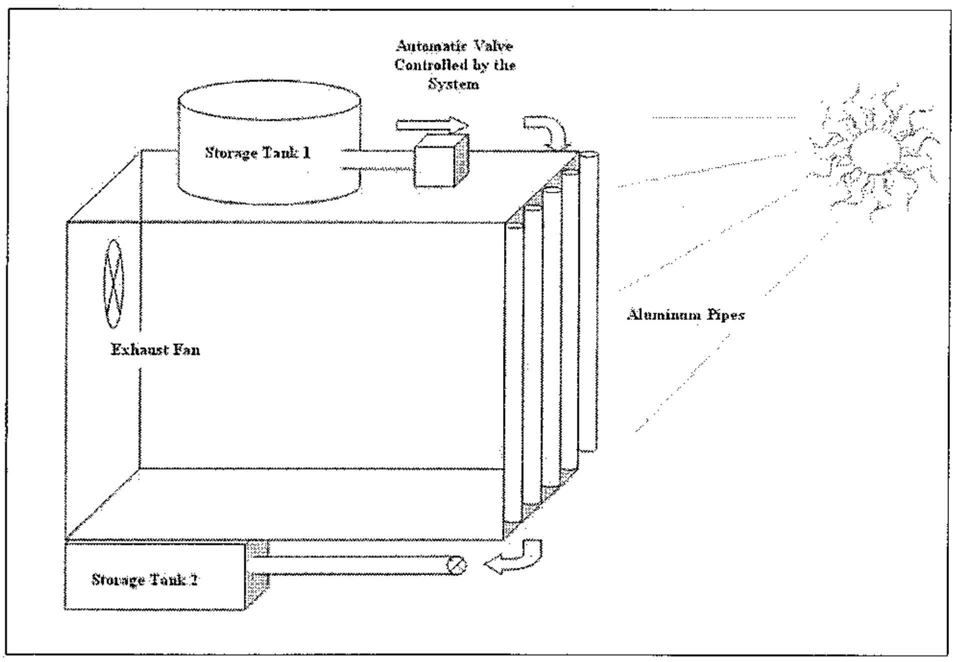


Figure 5.1 Layout of the system proposed to reduce the heat gain from radiation.

Some other future modification to the project can be mentioned as below:

- Adjust humidity, air flow speeds
- Make use of outside air if temperature outside is good enough to be utilized.
- Ability to access building services remotely through Internet and short text messaging services (SMS).

The system can be integrated with photovoltaic cells to save even more energy and to make use of large amount of solar power that Malaysia is so fortunate to receive throughout the year .

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APPENDICES

APPENDIX A

GANTT CHART

1) Gantt chart from semester 1

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of Project Topic	■	■													
	• Topic assigned to students															
2	Preliminary Research Work			■	■	■	■	■	■							
	• Background															
	• Objectives															
	• Literature reviews and theory															
3	Submission of Preliminary Report				●											
4	Project work						■	■	■	■	■					
	• Reference/Literature															
	• Collecting information about components availability															
5	Submission Progressive Report								●							
6	Continue with studies								■	■	■	■	■	■		
	• Visual Basic Programming															
	• Learning about Microcontroller															
	• Organizing all the researches to use in reports															
7	Submission of Draft Report												●			
8	Submission of interim report														●	
9	Oral Presentation															●

■ Process ● Suggested Milestone

2) Gantt Chart for semester 2

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	19
1	Project Work Continue	■	■	■												
	• Practical/Laboratory Work															
2	Submission of Progress Report 1				●											
3	Project Work Continue				■	■	■	■								
	• Practical/Laboratory Work															
4	Submission of Progress Report 2								●							
5	Project Work Continue								■	■	■	■				
	• Practical/Laboratory Work															
6	Submission of Dissertation Final Draft												●			
7	Submission of Final Report (Soft Cover)														●	
8	Oral Presentation															●
9	Submission of Final Report (Hard Cover)															●

■ Process ● Suggested Milestone

APPENDIX B
TABLES

Table 2. Outdoor heating and cooling design conditions (world location: singapore)

		Heating		Cooling				
Location	LAT	Degree Days	DB	DB	MWB	WB	MDB	DR
SAUDI ARABIA								
Riyadh	25N		41	111	64	69	96	25
SINGAPORE								
Singapore	1N		73	91	79	81	88	11
SOUTH AFRICA								
Johannesburg	26S		34	84	60	65	77	19
SPAIN								
Barcelona	41N		32	85	74	77	83	15
Madrid	41N		24	97	69	71	94	29
SWEDEN								
Stockholm	59N		-1	79	63	66	74	16
SWITZERLAND								
Geneva	46N		18	86	56	68	82	22
TAIWAN								
Taipei	25N		48	94	80	82	91	13
THAILAND								
Bangkok	14N		65	99	80	84	94	17
TURKEY								
Istanbul	41N		26	86	70	74	82	13
UNITED KINGDOM								
Birmingham	52N		21	78	64	65	75	17
London	51N		23	80	65	67	77	18
UKRAINE								
Kiev	50N		-2	83	67	69	79	17
URUGUAY								
Montevideo	35S		35	89	72	76	83	17
VENEZUELA								
Caracas	11N		70	92	84	86	90	13
VIETNAM								
Ho Chi Minh City (Saigon)	11N		68	95	77	81	90	15
YUGOSLAVIA								
Belgrade	45N		11	92	71	73	87	22
ZIMBABWE								
Harare	18S		45	86	62	68	76	21

Lat. = latitude
DB = dry bulb temperature, F
MWB = mean coincident wet bulb temperature, F
MDB = mean coincident dry bulb temperature, F
DR = mean daily range of DB temperature, F
Abridged with permission from the *1997 ASHRAE Handbook—Fundamentals*.

Table 3 Minimum mechanical ventilation requirements rates

Outdoor air shall be provided at a rate no less than the greater of either

A. 15 CFM per person, times the expected occupancy rate.

B. The applicable ventilation rate from the following list, times the conditioned floor area of the space.

Type of Use	CFM per Square Foot of Conditioned Floor Area
Auto repair workshops	1.50
Barber shops	0.40
Bars, cocktail lounges, and casinos	1.50
Beauty shops	0.40
Coin-operated dry cleaning	0.30
Commercial dry cleaning	0.45
Hotel guest rooms (less than 500 sq ft)	30 CFM/Guest Room
Hotel guest rooms (500 sq ft or greater)	0.15
Retail stores	0.20
Smoking lounges	1.50
All others	0.15

Abridged from *Energy Efficiency Standards*, California Energy Commission, 1999.

Table 4 Commercial cooling load calculations

Project ____________ Bldg/Room ____________
Location ____________ Engrs. ____________ Calc. by ____________ Chk. by ____________

		DB F	WB F	RH %	W gr/lb
Design Conditions	Outdoor				
	Room				

Daily Range ______ F Ave. ______ F
Day ______ Time ______
Lat. ______

Conduction	Dir.	Color	U	A, ft² Gross	A, ft² Net	CLTD, F Table	CLTD, F Corr.	SCL BTU/hr
Glass								
Wall (Group)								
Roof/ceiling								
Floor								
Partition								
Door								

Solar	Dir.	Sh.	SHGF	A	SC	CLF
Glass						

$RSHR = \frac{RSCL}{RTCL}$

$CFM_{sr} = \frac{RSCL}{1.1 \times (t_r - t_s)}$

LCL BTU/hr

Lights ______ W × 3.41 × ______ BF × ______ CLF
Lights ______ W × 3.41 × ______ BF × ______ CLF
People ______ SHG × ______ n × ______ CLF
______ LHG × ______ n
Equipment ______ ______
Equipment ______ ______
Infiltration 1.1 × ______ CFM × ______ TC
0.68 × ______ CFM × ______ gr/lb

Subtotal

SA duct gain ______
SA duct leakage ______
______
SA fan gain (draw through) ______

Room/Building Cooling Load

Total CL BTU/hr

SA fan gain (blow through) ______
Ventilation 1.1 × ______ CFM × ______ TC
0.68 × ______ CFM × ______ gr/lb
RA duct gain ______
RA fan gain ______

Cooling Coil Load

Pump gain ______

Refrigeration Load

Roof No.	Description of Construction	Weight, lb/ft²	U-value, BTU/h·ft²·°F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Hour of Maximum CLTD	Minimum CLTD	Maximum CLTD	Difference CLTD
				Solar Time																											
	With Suspended Ceiling																														
1	Steel sheet with 1-in. (or 2-in.) insulation	7 (8)	0.134 (0.092)	2	0	−2	−3	−4	−4	−1	9	23	37	50	62	71	77	78	74	67	56	42	28	18	12	8	5	15	−4	78	82
2	1-in. wood with 1-in. ins.	10	0.115	20	15	11	8	5	3	2	3	7	13	21	30	40	48	55	60	62	61	58	51	44	37	30	25	17	2	62	60
3	4-in. lightweight concrete	20	0.134	19	14	10	7	4	2	0	0	4	10	19	29	39	48	56	62	65	64	61	54	46	38	30	24	17	0	65	65
4	2-in. heavyweight concrete with 1-in. insulation	30	0.131	28	25	23	20	17	15	13	13	14	16	20	25	30	35	39	43	46	47	46	44	41	38	35	32	18	13	47	34
5	1-in. wood with 2-in. ins	10	0.083	25	20	16	13	10	7	5	5	7	12	18	25	33	41	48	53	57	57	56	52	46	40	34	29	16	5	57	52
6	6-in. lightweight concrete	26	0.109	32	28	23	19	16	13	10	8	7	8	11	16	22	29	36	42	48	52	54	54	54	47	42	37	20	7	54	47
7	2.5-in. wood with 1-in. insulation	13	0.096	34	31	29	26	23	21	19	16	15	15	16	18	21	25	30	34	38	41	43	44	44	42	40	37	21	15	44	29
8	8-in. lightweight concrete	33	0.093	39	36	33	31	29	26	23	20	18	15	14	14	13	17	20	25	29	34	38	42	43	46	44	42	22	14	46	32
9	4-in. heavyweight concrete with 1-in. (or 2-in.) ins.	53 (54)	0.128 (0.090)	30	29	27	26	24	22	21	20	20	21	22	24	27	29	32	34	36	38	38	38	37	36	34	33	19	20	38	18
10	2.5-in. wood with 2-in. ins	13	0.072	35	33	30	28	26	24	22	20	18	18	18	20	22	25	28	32	35	38	40	41	41	40	39	37	21	18	41	23
11	Roof terrace system	77	0.082	30	29	28	27	26	25	24	23	22	22	22	23	23	25	26	28	29	31	32	33	33	33	33	32	22	22	33	11
12	6-in. heavyweight concrete with 1-in. (or 2-in.) insulation	77 (77)	0.125 (0.088)	29	28	27	26	25	24	23	22	21	21	22	23	25	26	28	30	32	33	34	34	34	33	32	31	20	21	34	13
13	4-in. wood with 1-in. (or 2-in.) insulation	19 (20)	0.082 (0.064)	35	34	33	32	31	29	27	26	24	23	22	21	22	22	24	25	27	30	32	34	35	36	37	36	23	21	37	16

Table 4 Cooling load temperature differences (CLTD) for calculating cooling load from flat roofs

Table 5 Shading coefficients for glass without or with interior shading devices

Type of Glazing	Nominal Thickness, in (Each light)	Without Shading	With Interior Shading				
			Venetian Blinds		Roller Shades		
					Opaque		Translucent
			Medium	Light	Dark	Light	Light
Single glass							
Clear	¼	0.94	0.74	0.67	0.81	0.39	0.44
Heat absorbing	¼	0.69	0.57	0.53	0.45	0.30	0.36
Double glass							
Clear	¼	0.81	0.62	0.58	0.71	0.35	0.40
Heat absorbing	¼	0.55	0.39	0.36	0.40	0.22	0.30

Note: Venetian blinds are assumed set at a 45° position. Adapted with permission from the *1993 ASHRAE Handbook—Fundamentals*.

Table 6 Rates of heat gain from occupants of conditioned spaces

Degree of Activity		Total Heat Adults: Adult Male	Total Heat Adults: Adjusted M/F[a]	Sensible Heat, Btu/h	Latent Heat, Btu/h
[illegible] theater	Theater—matinee	390	330	225	105
[illegible] theater, night	Theater—night	390	350	245	105
[illegible] very light work	Offices, hotels, apartments	450	400	245	155
[illegible]ly active [illegible] work	Offices, hotels, apartments	475	450	250	200
[illegible], light work; [illegible]	Department store, retail store	550	450	250	200
[illegible], standing	Drug store, bank	550	500	250	250
[illegible] work	Restaurant[b]	490	550	275	275
[illegible] bench work	Factory	800	750	275	475
[illegible] dancing	Dance hall	900	850	305	545
[illegible] 3 mph; light [illegible] work	Factory	1000	1000	375	625
[illegible]	Bowling alley	1500	1450	580	870
[illegible] work	Factory	1500	1450	580	870
[illegible] machine [illegible] lifting	Factory	1600	1600	635	965
[illegible]	Gymnasium	2000	1800	710	1090

[illegible]
[illegible] values are based on 75°F room dry-bulb temperature. For 80°F room dry-bulb, the total heat remains the same, but the [illegible] heat values should be decreased by approximately 20%, and the latent heat values increased accordingly.
[illegible] heat gain is based on normal percentage of men, women, and children for the application listed, with the postulate that the [illegible] an adult female is 85% of that for an adult male, and that the gain from a child is 75% of that for an adult male.
[illegible] total heat gain for *Sedentary work, Restaurant*, includes 60 Btu/h for food per individual (30 Btu/h sensible and 30 Btu/h latent.)
[illegible] person per alley actually bowling, and all others as sitting (400 Btu/h) or standing or walking slowly (550 Btu/h).

[illegible] permission from the *1997 ASHRAE Handbook—Fundamentals.*

Table 7 Results Gained from Experimental Matlab Program.

Q (Kw)	-8.6279	8.0611	4.5259	-3.9591
T (K)	0	0	0	0
Q(kW/m^2)	-2.8760	1.6122	1.5086	-0.7918

APPENDIX C
PROGRAMMING CODES

1) PIC16F873 codes

```
; PicBasic Pro Compiler 2.43, (c) 1998, 2002 microEngineering Labs,
Inc. All Rights Reserved.
PM_USED                 EQU    0

      INCLUDE     "16F877.INC"


; Define statements.
#define           CODE_SIZE          8
#define           LOADER_USED        1
#define           OSC          4
#define           ADC_BITS                8
#define           ADC_CLOCK               3
#define           ADC_SAMPLEUS                  50

RAM_START               EQU    00020h
RAM_END                 EQU    001EFh
RAM_BANKS               EQU    00004h
BANK0_START             EQU    00020h
BANK0_END               EQU    0007Fh
BANK1_START             EQU    000A0h
BANK1_END               EQU    000EFh
BANK2_START             EQU    00110h
BANK2_END               EQU    0016Fh
BANK3_START             EQU    00190h
BANK3_END               EQU    001EFh
EEPROM_START            EQU    02100h
EEPROM_END              EQU    021FFh

R0                      EQU    RAM_START + 000h
R1                      EQU    RAM_START + 002h
R2                      EQU    RAM_START + 004h
R3                      EQU    RAM_START + 006h
```

```
R4                      EQU    RAM_START + 008h
R5                      EQU    RAM_START + 00Ah
R6                      EQU    RAM_START + 00Ch
R7                      EQU    RAM_START + 00Eh
R8                      EQU    RAM_START + 010h
FLAGS                   EQU    RAM_START + 012h
GOP                     EQU    RAM_START + 013h
RM1                     EQU    RAM_START + 014h
RM2                     EQU    RAM_START + 015h
RR1                     EQU    RAM_START + 016h
RR2                     EQU    RAM_START + 017h
_adval                  EQU    RAM_START + 018h
_heat                   EQU    RAM_START + 019h
_i                      EQU    RAM_START + 01Ah
_light                  EQU    RAM_START + 01Bh
_PIR                    EQU    RAM_START + 01Ch
_receive                EQU    RAM_START + 01Dh
_temp                   EQU    RAM_START + 01Eh
_PORTL                  EQU     PORTB
_PORTH                  EQU     PORTC
_TRISL                  EQU     TRISB
_TRISH                  EQU     TRISC
#define _IR                    _PORTA_2
#define _TX                    _PORTC_6
#define _RX                    _PORTC_7
#define _LED                   _PORTC_0
#define _BUZZ                  _PORTC_1
#define _RLY1                  _PORTB_7
#define _RLY2                  _PORTB_6
#define _RLY3                  _PORTB_5
#define _PORTA_2                PORTA, 002h
#define _PORTC_6                PORTC, 006h
#define _PORTC_7                PORTC, 007h
#define _PORTC_0                PORTC, 000h
#define _PORTC_1                PORTC, 001h
#define _PORTB_7                PORTB, 007h
#define _PORTB_6                PORTB, 006h
#define _PORTB_5                PORTB, 005h
```

```
INCLUDE         "AFSHIN1.MAC"
INCLUDE         "PBPPIC14.LIB"


LABEL?L         _INIT
MOVE?CB         004h, ADCON1
MOVE?CB         00Fh, TRISA
MOVE?CB         000h, TRISB
MOVE?CB         080h, TRISC
MOVE?CB         0FFh, PORTB
MOVE?CT         001h, _TX
MOVE?CT         001h, _LED
PAUSE?C         001F4h

LABEL?L         _RESET
MOVE?CT         001h, _BUZZ
PAUSE?C         001F4h
SEROUT2DPIN?T         _TX
SEROUT2MODE?C         _BaudRate
SEROUT2PACE?C         000h
SEROUT2?C       052h
SEROUT2?C       045h
SEROUT2?C       053h
SEROUT2?C       045h
SEROUT2?C       054h
SEROUT2?C       023h
MOVE?CT         000h, _LED
MOVE?CT         000h, _BUZZ
MOVE?CB         000h, PORTB
PAUSE?C         064h

LABEL?L         _MAIN
ADCIN?CB        000h, _adval
MOVE?BB         _adval, _heat
ADCIN?CB        001h, _adval
MOVE?BB         _adval, _light
CMPNE?TCL       _IR, 001h, L00001
```

```
MOVE?CB        031h, _PIR
GOTO?L         L00002
LABEL?L        L00001
MOVE?CB        030h, _PIR
LABEL?L        L00002
TOGGLE?T       _LED
SERPIN?T       _RX
SERMODE?C      _T9600
SERTIME?C      001F4h
SERIN?BL       _receive, _MAIN
CMPNE?BCL      _receive, 072h, L00003
GOTO?L         _RESET
LABEL?L        L00003
CMPNE?BCL      _receive, 073h, L00005
SEROUT2DPIN?T        _TX
SEROUT2MODE?C        _BaudRate
SEROUT2PACE?C        000h
SEROUT2?C      02Ah
SEROUT2?C      053h
SEROUT2?C      04Ch
SEROUT2COUNT?C       003h
SEROUT2NUM?B         _light
SEROUT2DEC?
PAUSE?C        032h
SEROUT2DPIN?T        _TX
SEROUT2MODE?C        _BaudRate
SEROUT2PACE?C        000h
SEROUT2?C      02Ah
SEROUT2?C      053h
SEROUT2?C      048h
SEROUT2COUNT?C       003h
SEROUT2NUM?B         _heat
SEROUT2DEC?
PAUSE?C        032h
CMPNE?BCL      _PIR, 031h, L00007
SEROUT2DPIN?T        _TX
SEROUT2MODE?C        _BaudRate
SEROUT2PACE?C        000h
```

```
SEROUT2?C     02Ah
SEROUT2?C     043h
SEROUT2?C     052h
SEROUT2?C     04Fh
SEROUT2?C     053h
SEROUT2?C     053h
GOTO?L        L00008
LABEL?L       L00007
SEROUT2DPIN?T       _TX
SEROUT2MODE?C       _BaudRate
SEROUT2PACE?C       000h
SEROUT2?C     02Ah
SEROUT2?C     042h
SEROUT2?C     04Ch
SEROUT2?C     04Fh
SEROUT2?C     043h
SEROUT2?C     04Bh
LABEL?L       L00008
PAUSE?C       032h
SHIFTR?BCB    PORTB, 005h, _temp
SEROUT2DPIN?T       _TX
SEROUT2MODE?C       _BaudRate
SEROUT2PACE?C       000h
SEROUT2?C     02Ah
SEROUT2?C     052h
SEROUT2?C     042h
SEROUT2COUNT?C      003h
SEROUT2NUM?B        _temp
SEROUT2BIN?
PAUSE?C       032h
LABEL?L       L00005
CMPNE?BCL     _receive, 062h, L00009
MOVE?CT       001h, _BUZZ
PAUSE?C       0C8h
MOVE?CT       000h, _BUZZ
SEROUT2DPIN?T       _TX
SEROUT2MODE?C       _BaudRate
SEROUT2PACE?C       000h
```

```
TOGGLE?T      _RLY3
LABEL?L       L00019
GOTO?L        _MAIN
END?

END
```

2) PC Interface Control

```
' PC interface control
'

   Include "modedefs.bas"

Define LOADER_USED 1
define OSC 4

' Define ADCIN parameters
Define ADC_BITS      8       ' Set number of bits in result
Define ADC_CLOCK     3       ' Set clock source (3=rc)
Define ADC_SAMPLEUS  50      ' Set sampling time in uS

' Define Allias
IR       var PORTA.2
TX       var PORTC.6
RX       var PORTC.7
LED      var PORTC.0
BUZZ     var PORTC.1
RLY1     var PORTB.7
RLY2     var PORTB.6
RLY3     var PORTB.5

' define Constant
BaudRate     CON     84  ' 9600 bps, True, 8N1

' define variable
adval        var     byte' adc input temperarily buffer
receive      VAR     byte' RS232 receive buffer
light        var     byte
heat         var     byte
PIR          var     byte ' crossing sensor detection
i            var     byte
temp         var     byte

INIT:
        ' initialize routine
        adcon1  = %00000100       ' AN0,AN1,AN3 as analogue, others as digital
        TRISA   = %00001111 ' all input
```

```
        TRISB    = 0          ' all output
        TRISC    = %10000000 ' all output except for RXD - RS232 communication
        PORTB    = $ff        ' Turn on all relay as testing
        TX       = 1          ' Initialize RS232 communication
        LED      = 1          ' Turn on system LED
        pause 500
RESET:
        BUZZ     = 1          ' Turn on buzzer
        pause 500             ' pause
        serout2 TX,baudrate,["RESET#"]  ' reset word in 6 byte
        LED      = 0
        BUZZ     = 0          ' Turn off
        PORTB    = 0          ' Turn off Relay
        pause 100             ' Routine
MAIN:
        adcin   0,adval                 ' read temperature
        ' temperature reading set to 75 initially
        ' for linear incremental
        ' to sensitivity set to bias of 50
        ' so, celcius degree = (value - 50)
        heat = adval
        adcin   1,adval                 ' read lumininary
        ' light sensing set at 200 in normal light condition
        ' if  light in dimm light room should be around 60 - 100
        ' the sensitivity can be adjust to two setting
        ' < 100 which is light need room
        '  < 30 which is dark room
        light = adval
        if  IR = 1 then
            PIR = "1"
        else
            PIR = "0"                    ' detect crossing
        endif

        ' Initiate status reply all the while
        ' serout2 TX,baudrate,["*",PORTB,Light,heat,pir,"#"]
        toggle LED                      ' Toggle led on off
        serin RX,T9600,500,Main,receive ' check for PC command

        if receive = "r" then
            ' reset circuit
            goto reset
```

```
    endif
    if receive = "s" then
        ' initiate status send
        serout2 TX,baudrate,["*SL",DEC3 light]
        pause 50
        serout2 TX,baudrate,["*SH",DEC3 heat]
        pause 50
        if pir = "1" then
            serout2 TX,baudrate,["*CROSS"]
            pause 400
        next i
        led = 0
        serout2 TX,baudrate,["@ERROR"]
        pause 100
    endif
    if receive = "1" then
        ' relay switch 1
        toggle rly1
    endif
    if receive = "2" then
        ' relay switch 2
        toggle rly2
    endif
    if receive = "3" then
        ' relay switch 3
        toggle rly3
    endif

    goto main


end
```

3) VB Interface Code

```
Const colorGreen = &HFF00&
Const colorRed = &HFF&
Const colorWhite = &HFFFFFF

Dim stage As Integer
Dim temp As Integer
Dim sensor As Boolean
Dim i As Integer
Dim morning_shift(3) As Boolean
Dim evening_shift(3) As Boolean
Dim dark_interval(3) As Boolean
Dim cross_interval(3) As Boolean
Dim relay(3) As Integer
Dim onhour(3) As Integer
Dim onrequest(3) As Boolean


Private Sub Form_Load()

    Call Init
    ' clear check box and setting
    Check1.Value = 0
    Check2.Value = 0
    txt_tmin1.Text = "18"
    txt_tmax1.Text = "26"
    Option1.Value = True            ' when somebody is inside
    Option2.Value = False
    Darkon1.Value = 0
    ' frame2
    Check5.Value = 0
    Check6.Value = 0
    txt_tmin2.Text = "18"
    txt_tmax2.Text = "26"
    Option3.Value = True            ' when somebody is inside
    Option4.Value = False
    Darkon2.Value = 0
    ' frame3
    Check9.Value = 0
    Check10.Value = 0
    txt_tmin3.Text = "18"
    txt_tmax3.Text = "26"
    Option5.Value = True            ' when somebody is inside
    Option6.Value = False
    Darkon3.Value = 0


    ' enable turn on condition
    For i = 0 To 2
        ' enable turn on condition
        TurnOn(i).Value = 1
    Next i
```

```
End Sub

Public Function Init()

    ' Rename RLY1 , 2, 3 to respective name

    mnu_RLY1.Caption = "Rename " & TabStrip1.Tabs.Item(2).Caption
    mnu_RLY2.Caption = "Rename " & TabStrip1.Tabs.Item(3).Caption
    mnu_RLY3.Caption = "Rename " & TabStrip1.Tabs.Item(4).Caption
    mnu_on1.Caption = "Toggle on/off " &
TabStrip1.Tabs.Item(2).Caption
    mnu_on2.Caption = "Toggle on/off " &
TabStrip1.Tabs.Item(3).Caption
    mnu_on3.Caption = "Toggle on/off " &
TabStrip1.Tabs.Item(4).Caption

    ' Status monitor wording
    lbl_rly(0).Caption = TabStrip1.Tabs.Item(2).Caption
    lbl_rly(1).Caption = TabStrip1.Tabs.Item(3).Caption
    lbl_rly(2).Caption = TabStrip1.Tabs.Item(4).Caption
    lbl_rly(3).Caption = lbl_rly(0).Caption
    lbl_rly(4).Caption = lbl_rly(1).Caption
    lbl_rly(5).Caption = lbl_rly(2).Caption
    ' Select status tab
    TabStrip1.Tabs.Item(1).Selected = True
    Frame1.Visible = True
    Frame2.Visible = False
    Frame3.Visible = False
    Frame4.Visible = False

    ' Menu visiblility
    mnu_help.Visible = False
    mnu_connect.Enabled = True
    mnu_disconnect.Enabled = False
    mnu_reset.Enabled = False
    mnu_option.Enabled = False

    TabStrip1.Enabled = False

    ' disable timer animation first
    tmr_ani.Enabled = False

    For i = 0 To 3
        morning_shift(i) = False
         evening_shift(i) = False
         dark_interval(3) = False
         cross_interval(3) = False
         onrequest(3) = False
    Next i

    Option1.Value = False
    Option2.Value = False
    Option3.Value = False
    Option4.Value = False
```

```
    Option5.Value = False
    Option6.Value = False

End Function

Private Sub Form_Unload(Cancel As Integer)

    If MSComm1.PortOpen = True Then

        ' reset hardware first
        MSComm1.Output = "r"
        DoEvents

        MSComm1.PortOpen = False
    End If

End Sub

Private Sub mnu_connect_Click()

  On Error GoTo porterror

        Dim Str_Temp As String

        If MSComm1.PortOpen = True Then MSComm1.PortOpen = False
        Str_Temp = InputBox("Please enter the communication port
number", "Hardware Search", 1)
        If Val(Str_Temp) <> 0 Then
            MSComm1.CommPort = Val(Str_Temp)
        Else
            tmr_stage.Interval = 6000    ' 6 second repeat
            Exit Sub     ' cancelled operation
        End If

        With MSComm1
            .InputMode = comInputModeText
            .Settings = "9600,n,8,1"
            .RThreshold = 6
            .InputLen = 6 ' 6 byte protocol
            .PortOpen = True
        End With

        ctext ("COM" & MSComm1.CommPort & " open...")
        mnu_connect.Enabled = False
        mnu_disconnect.Enabled = True
        mnu_reset.Enabled = True
        mnu_option.Enabled = True

        TabStrip1.Enabled = True
        tmr_stage.Enabled = True
        tmr_stage.Interval = 1000
        stage = 1

        Exit Sub


porterror:
```

```
        MsgBox "Unable to open port ! ", vbCritical, "COM" & Str_Temp
& ", Error -99"

End Sub

Private Sub mnu_debug_Click()

    If mnu_debug.Checked = False Then
        mnu_debug.Checked = True
        ' disable turn on condition
        For i = 0 To 2
            ' disable turn on condition
            TurnOn(i).Value = 0
        Next i
        ctext ("Debug Mode - " & "Disable all turn on condition")
    Else
        mnu_debug.Checked = False
        ' enable turn on condition
        For i = 0 To 2
            ' enable turn on condition
            TurnOn(i).Value = 1
        Next i
        ctext ("Re-enable all turn on condition")
    End If

End Sub

Private Sub mnu_disconnect_Click()

    MSComm1.PortOpen = False
    Form1.Caption = "... (Offline)"
    ctext ("Disconnect from hardware ...")
    tmr_stage.Enabled = False

    Call Init

End Sub

Private Sub mnu_exit_Click()

    Unload Me

End Sub

Private Sub mnu_on1_Click()

    MSComm1.Output = "1"

End Sub

Private Sub mnu_on2_Click()

 MSComm1.Output = "2"

End Sub

Private Sub mnu_on3_Click()
```

```
 MSComm1.Output = "3"

End Sub

Private Sub mnu_reset_Click()

 MSComm1.Output = "r"

End Sub

Private Sub mnu_rly1_Click()

    ' Rename
    Dim Str_Temp As String
    Str_Temp = InputBox(mnu_RLY1.Caption & " to" & vbNewLine,
"Rename", TabStrip1.Tabs.Item(2).Caption)
    If Str_Temp <> "" Then
        TabStrip1.Tabs.Item(2).Caption = Str_Temp
        mnu_RLY1.Caption = "Rename " & Str_Temp
        mnu_on1.Caption = "Toggle on/off " & Str_Temp
        lbl_rly(0).Caption = Str_Temp
    End If

End Sub

Private Sub mnu_rly2_Click()

 ' Rename
    Dim Str_Temp As String
    Str_Temp = InputBox(mnu_RLY2.Caption & " to" & vbNewLine,
"Rename", TabStrip1.Tabs.Item(3).Caption)
    If Str_Temp <> "" Then
        TabStrip1.Tabs.Item(3).Caption = Str_Temp
        mnu_RLY2.Caption = "Rename " & Str_Temp
        mnu_on2.Caption = "Toggle on/off " & Str_Temp
        lbl_rly(1).Caption = Str_Temp
    End If

End Sub

Private Sub mnu_RLY3_Click()

 ' Rename
    Dim Str_Temp As String
    Str_Temp = InputBox(mnu_RLY3.Caption & " to" & vbNewLine,
"Rename", TabStrip1.Tabs.Item(4).Caption)
    If Str_Temp <> "" Then
        TabStrip1.Tabs.Item(4).Caption = Str_Temp
        mnu_RLY3.Caption = "Rename " & Str_Temp
        mnu_on3.Caption = "Toggle on/off " & Str_Temp
        lbl_rly(2).Caption = Str_Temp
    End If

End Sub

Private Sub MSComm1_OnComm()
```

```
Dim buffer As String

' clear to unchange
For i = 0 To 3
    relay(i) = 0
Next i

buffer = MSComm1.Input

If buffer = "RESET#" Then
    ' reset start
    stage = 2
End If

If Mid(buffer, 1, 3) = "*SL" Then
    ' decode light density
    temp = Val(Mid(buffer, 4, 3))
    If temp > 180 Then
        Label5.Caption = "Bright"
    End If
    If temp < 180 And temp > 120 Then
        Label5.Caption = "DayLight"
    End If
    If temp < 120 And temp > 60 Then
        Label5.Caption = "WarmLight"
    End If
    If temp < 60 Then
        Label5.Caption = "Darkness"
    End If
End If

If Mid(buffer, 1, 3) = "*SH" Then
    ' decode heat and temperature
     temp = Val(Mid(buffer, 4, 3)) - 48
     Label4.Caption = temp & "' Celsius"
End If
If buffer = "*CROSS" Then
    '
    ImageS3.Picture = LoadPicture("C:\cross.jpg")
    sensor = False
    DoEvents

End If
If buffer = "*BLOCK" Then
    '
    ImageS3.Picture = LoadPicture("C:\block.jpg")
    sensor = True
    DoEvents

End If

If Mid(buffer, 1, 3) = "*RB" Then
    ' decode relay output
    If Mid(buffer, 4, 1) = "1" Then
        ShapeRLY(0).BackColor = colorGreen
```

```
        Else
            ShapeRLY(0).BackColor = colorRed
        End If
        If Mid(buffer, 5, 1) = "1" Then
            ShapeRLY(1).BackColor = colorGreen
        Else
            ShapeRLY(1).BackColor = colorRed
        End If
        If Mid(buffer, 6, 1) = "1" Then
            ShapeRLY(2).BackColor = colorGreen
        Else
            ShapeRLY(2).BackColor = colorRed
        End If
         ' call check condition
        Call Chk_Condition(Mid(buffer, 4, 1), Mid(buffer, 5, 1),
Mid(buffer, 6, 1), temp)

    End If


End Sub

Private Sub Option5_Click()

    Option5.Value = True
    Option6.Value = False


End Sub

Private Sub Option6_Click()

    Option6.Value = True
    Option5.Value = False


End Sub

Private Sub Option3_Click()

    Option3.Value = True
    Option4.Value = False


End Sub

Private Sub Option4_Click()

    Option4.Value = True
    Option3.Value = False



    End If
    If Frame3.Visible = True Then
```

```
        ' activate setting tab
        stage = 5

    End If
    If Frame4.Visible = True Then

        ' activate setting tab
        stage = 6

    End If


End Sub

Private Sub tmr_ani_Timer()

    If Shape1.BackColor = colorGreen Then

        Shape1.BackColor = colorWhite
    Else
        Shape1.BackColor = colorGreen
    End If

    ' clock
    lbl_clock1.Caption = Time$
    lbl_clock2.Caption = Time$
    lbl_clock3.Caption = Time$
    Label39.Caption = Time$
End Sub

Private Sub tmr_stage_Timer()

    Select Case (stage)

        Case 0
            ' havent connect to
            Call mnu_connect_Click
        Case 1
            ' need verify
            MSComm1.Output = "r"
            tmr_stage.Interval = 300
            ctext ("Searching for hardware")
        Case 2
            ' on line
            Form1.Caption = "PC interfaced Intelligence Unit " &
"V1.0"
            ' sound buzzer indicate system online
            MSComm1.Output = "b"
            ' enable status collection
            tmr_stage.Interval = 1000
            tmr_ani.Enabled = True
            ImageS3.Picture = LoadPicture("C:\cross.jpg")
            sensor = False                                ' no people
block
            stage = 3
        Case 3
            ' collect status every second
```

```
            If onrequest(0) = True Then
                onrequest(0) = False
                MSComm1.Output = "1"
                tmr_stage.Interval = 300
                Exit Sub
            End If
            If onrequest(1) = True Then
                onrequest(1) = False
                MSComm1.Output = "2"
                tmr_stage.Interval = 300
                Exit Sub
        End If

' ******************

        If relay(1) = 1 And RLY2 <> "1" Then
            ' toggle relay
            onrequest(1) = True
             Exit Function
        End If
        If relay(1) = 2 And RLY2 = "1" Then
            ' toggle relay
            onrequest(1) = True
             Exit Function
        End If


    End If

    If TurnOn(2).Value = 1 Then

' **********************
        If morning_shift(2) = True Then
            If Hour(Time) > 7 And Hour(Time) < 16 Then
                ' turn on relay if not on
                If RLY3 <> "1" Then
                    relay(2) = 1     ' on
                End If
            End If
        Else
            If Hour(Time) > 7 And Hour(Time) < 16 Then
                ' turn on relay if not on
                If RLY3 = "1" Then
                    relay(2) = 2     ' off
                End If
            End If
        End If
        If evening_shift(2) = True Then
            If Hour(Time) > 15 And Hour(Time) < 22 Then
                ' turn on relay if not on
                If RLY3 <> "1" Then
                    relay(2) = 1     ' on
                End If
            End If
        Else
            If Hour(Time) > 15 And Hour(Time) < 22 Then
                ' turn on relay if not on
```

```
              If RLY3 = "1" Then
                  relay(2) = 2      ' on
              End If
          End If

      End If
' **********************
      If temperature < Val(txt_tmin3.Text) Then
          ' less than turn on condition
          relay(2) = 2               ' turn off
      End If
      If temperature > Val(txt_tmax3.Text) Then
          ' more than turn on condition
          relay(2) = 2
      End If
 ' ********************
       onhour(2) = Hour(Time)

      If Option5.Value = True And sensor = True Then
          ' somebody inside
          onhour(2) = Hour(Time) + 1        ' 0 - 23, not valid for 23
to 0
      End If
      If Option6.Value = True And sensor = False Then
          ' nobody condition inside
          onhour(2) = Hour(Time) + 1
      End If

      If Darkon3.Value = 1 And Label5.Caption = "Darkness" Then
          onhour(2) = Hour(Time) + 4
      End If

      If onhour(2) > 23 And Hour(Time) < 4 Then
          onhour(2) = onhour(2) - 24
      End If
      If onhour(2) > Hour(Time) Then
          relay(2) = 1 'on
      End If

 ' ******************

      If relay(2) = 1 And RLY3 <> "1" Then
          ' toggle relay
          onrequest(2) = True
          Exit Function
      End If
      If relay(2) = 2 And RLY3 = "1" Then
          ' toggle relay
          onrequest(2) = True
           Exit Function
      End If


  End If
```

```
End Function
```

MATLAB CODE

```
sigma=5.6693e-8;N=4;
A=[3 5 3 5];epsilon=[0.7 0.3 0.85 0.45];
T=[550 700 650 600];
F=-[0 0.3615 0.277 0.3615;...
    0.2169 0 0.2169 0.5662;...
    0.277 0.3615 0 0.3615;...
    0.2169 0.5662 0.2169 0];
Q=[0 0 0 0];
c=[0 0 0 0];
b=sigma*epsilon./(1-epsilon).*(1-c).*T.^4+c.*Q./A;
d=(1-c).*1./(1-epsilon)+c;
for k=1:N
    F(k,k)=d(k)+F(k,k);
end
q0=F\b';
Q=A.*epsilon./(1-epsilon).*(1-c).*(sigma*T.^4-q0')
T=c.*((Q./A.*(1-epsilon)./epsilon + q0')/sigma).^(1/4)
q=Q./A
```