Microcontroller based smart street light control system

A Thesis submitted in partial fulfilment of the requirements for the award of degree of

Master of Engineering
in
Electronic Instrumentation and Control

Submitted By

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July 2014

DECLARATION

I hereby certify that the work is being presented in this thesis work entitled "**Microcontroller based smart street light control system**" in partial fulfilment of award of degree of Master of Engineering in Electronics Instrumentation & Control submitted in Electrical & Instrumentation Engineering Department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Dr. M D Singh**, Assistant Professor, Department Of Electrical & Instrumentation Engineering, Thapar University, Patiala, Punjab.

Date: 15 july 2014

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I certify that the above statement made by the student is correct to the best of my knowledge and belief.

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Dheeraj sharma

TU, PATIALA

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LIST OF ABBREVIATIONS

ADC	➢ Analog to Digital Converter
ALU	➢ Arithmetic and logical unit
AT	➢ Atmel
CLK	➢ Clock
CPU	➢ Central Processing Unit
EPROM	➢ Erasable and programmable read only memory
EEPROM	➢ Electrically erasable programmable read only Memory
GND	➢ Ground
I/O	➢ Input/ Output
IC	➢ Integrated circuit
LCD	➢ Liquid Crystal Display
LDR	➢ Light dependent resistor
LED	➢ Light emitting diode
MCU	➢ Microcontroller unit
MHZ	➢ Megahertz
PCB	➢ Printed Circuit Board
PWM	➢ Pulse width modulation
RAM	➢ Random access memory
ROM	➢ Read only memory
RTC	➢ Real time clock
SLC	➢ Street light control
WSN	➢ Wireless sensor network
XTAL	➢ Crystal

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ABSTRACT

The work in this Thesis is directed towards the automation of ‘High Brightness LED’ based street light systems in India.

Presently street lights in India are manually controlled or controlled by hardware timers in some cities. However they have the disadvantage of wastage of electrical power due to improper switching of lights during day/night times and undisciplined changeovers of time settings required for hardware timer based lights.

The LDR based systems could be an alternative to these systems for automatic switching but they have poor reliability due to factors like dust, moisture e.t.c. and not popularly installed.

In this thesis a sensor-less, robust and energy efficient street light control system which requires minimum maintenance and is simple in architecture has been designed. Time based switching to decide intensity of street light has been used. The statistical data of daily sunrise and sunset has been taken from reliable resources for Chandigarh (India).

The system uses Microcontroller, Real time clock and External memory chip. The control logic has been tested in Proteus software for proper functionality. Calculations have been done taking into care the characteristics of 36W LED street lamp (Voltage vs. power consumption characteristics).Total Power saving of 365 days of year 2014 has been found out.

Chapter 1: Introduction

The inspiration for this Thesis was obtained from the shortage of power in an ever increasing power demand scenario in India. Relevant questions such as, “What can be done in order to reduce the deficit of power?” “Is setting up of more power plants the only solution for the problem?” “Do DSM and other power management techniques provide lasting results?” “Or is it sensible and feasible to set up an autonomous system that can manage its own power consumptions?” cropped up.

Though there are several power management techniques such as smart grid technology, home automation technology, that are in place to reduce wastage of power, it was intriguing to find out that there is no such system in place for street lights which are switched on for almost 12hrs or more daily. Though there is an automatic switching facility to switch on the street lights at dusk and switch off at dawn by implementation of hardware timers , it is more of a convenience than an effort to reduce power wastage. Though this reduces the power consumption, it is not optimal and reliable. Hence, the idea of Smart Street Lights technology became concrete. Smart Street Lights can be designed in several ways.

The design methodology adopted in this thesis is to reduce power of the system, to optimize it based on cost and to make it sensor-less for maximum reliability.

Energy consumed by the existing system of lighting is high and is most inefficient which can be seen by the 2 points explained below:

1. The present system has a timer for switching on/off of the lights at dawn/dusk which is not that convenient as it may get dark quickly in winter which is

drawback of the timer system. Time settings have to be changed periodically by a technician manually.

2. LDR based systems provide low reliability and require more maintenance.

Supply uncertainty and price volatility of the fossil fuels and dependence of energy on their supply, as well as the growing social concern about the negative effects of global warming related to pollutant emissions and greenhouse gases, among other reasons, have led in recent years to develop policies to promote and encourage the rationale use of the energy and energy saving. It is convenient to have a cost effective system that avoids maintenance staff, with reliable information and allows robust control over the lighting at all times. This can be achieved by designing an efficient, robust and low power component LED Street light control system as done in this Thesis.LED street lights have some advantages over Sodium vapor Lamps as shown below:

Table 1.1 Characteristics of LED lamps vs. Sodium vapor lamps

Parameter	**LED Array**	**Sodium Vapor lamp**
Power	36W	150W
Life	50000 Hrs	5000 Hrs
Intensity Control	Possible	Not possible

Point to be noted is for the same intensity o/p the power required by LED array is 5 times less.

Chapter 2: Basic street light control systems

This chapter describes the introduction to Smart Street Light Control systems and literature survey.

2.1 Introduction to Smart Street Light Control Systems

The work related to design of energy efficient street lighting system mainly focuses on using sensor based technology. The work can be classified broadly into two categories, to sense the demand by detecting the traffic in the vicinity or to detect ambient natural light.

The sensor based systems hence developed decide the state of the street light based on the data received from the sensors.

The major issue regarding the use of sensor based systems is their poor reliability. Thus, such systems are not robust. To improve the system reliability one may go for wireless sensor networks but cost of infrastructure and maintenance in that case would be high. To develop a cost effective and robust energy efficient system which requires minimum maintenance, a time based approach can be utilized by studying astronomical clocks depending upon geographical area.

2.2 A basic Street Light control system using LDR as sensor to detect ambient natural light[12].

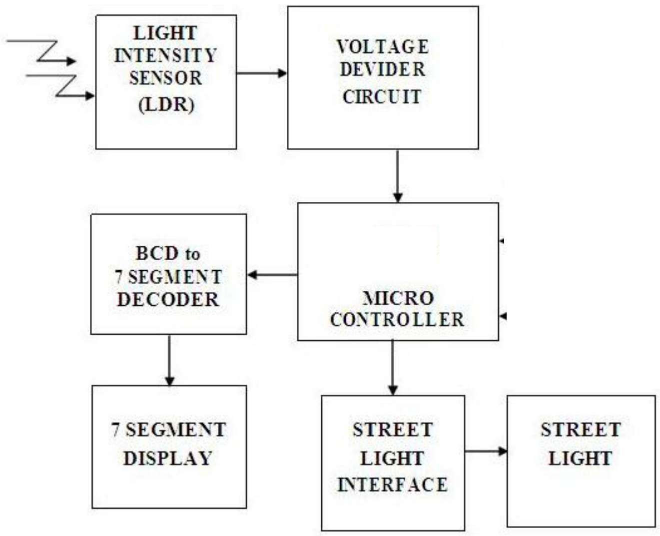


FIGURE 2.1 Basic SLC system using LDR

A microcontroller senses the ambient light intensity to control the switching of the street light. Conventionally ON-OFF control action is implemented Some emerging Controllers are providing Gradient control of Intensity of Street light depending upon the ambient natural light intensity.

The Sensor used is LDR (Light dependent resistor).The LDR forms a part of the voltage divider circuitry. Thus a voltage proportional to the intensity of Light sensed is generated across the LDR.

The voltage is fed to the microcontroller at a Analog interface, which can be properly scaled with the help of mathematical calculations inside the microcontroller.

The Scaled value is then compared with some suitable reference value to generate the output for Street light.

In Gradient type control actions, the intensity of the Street Light is made inversely proportional to the sensed ambient natural light intensity by the help of suitable logic inside the Microcontroller.

The downside with the system is that the LDRs provide poor reliability and such systems also encounter maintenance related issues.

2.3 A basic Street light control system that senses the demand by detecting the traffic in the vicinity [13]

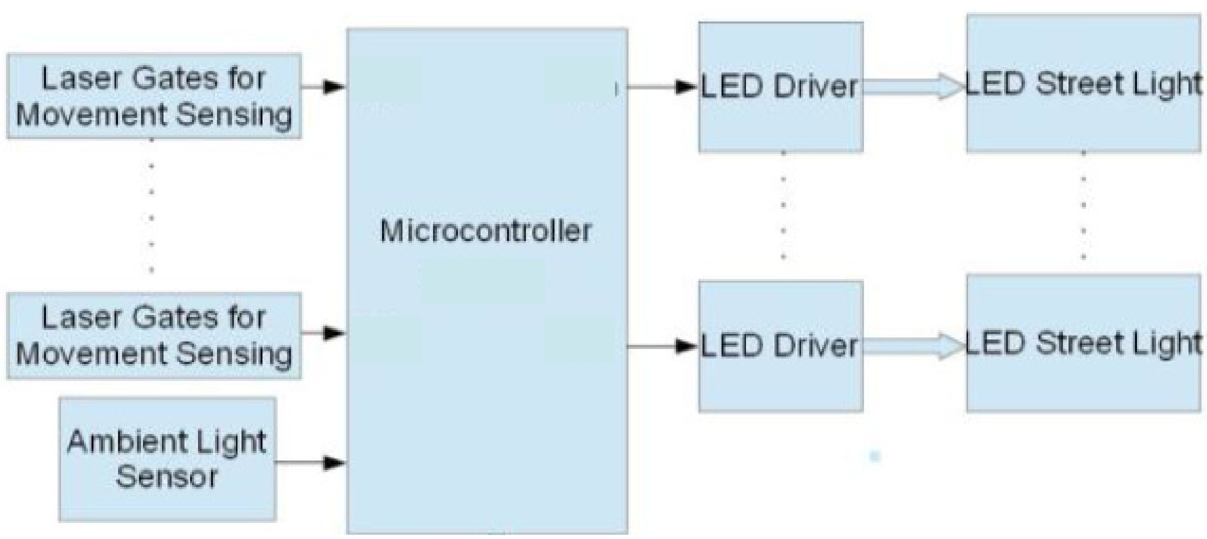


FIGURE 2.2 Basic SLC system that senses traffic in vicinity

In such systems LED street lights are switched on whenever the ambient light intensity falls below a threshold. And have an RTC which monitors the time and sends a signal to the lights for dimming, if the time is 11.30pm. The use of LASER gates for the detection of movement on the road between the 11.30pm and 5am is employed and makes Particular Street lights go to full intensity to show light to the travelers. This not only reduces the power consumption and also lights the path for the late night travelers.

A system is employed to detect the movement on the road in the middle of the night (from 11.30 pm to 5am say). For this Laser gates placed at a height of 2ft off the ground, and at each lamp post are used.

The block diagram mainly consists of a sensor block, control block and the lighting block.

SENSOR BLOCK:

1. The first sensor is the Ambient Light intensity sensor.
2. The second sensor is an array of Laser Gates to detect movement on the road.

CONTROL BLOCK:

The control block consists of microcontroller which interprets the inputs from the sensor and sends out control signals to the LED driver in the Lighting Block.

LIGHITING BLOCK:

Lighting block consists of an array of LEDs for lighting, and an LED driver for Dimming and full intensity control of the LEDs.

Thus the downside with such systems is that they need a major setup of infrastructure to sense the vehicular movement at night and since a sensor based approach is used, these systems encounter reliability issues.

2.4 A basic Street light control system based on wireless sensor networks[7]

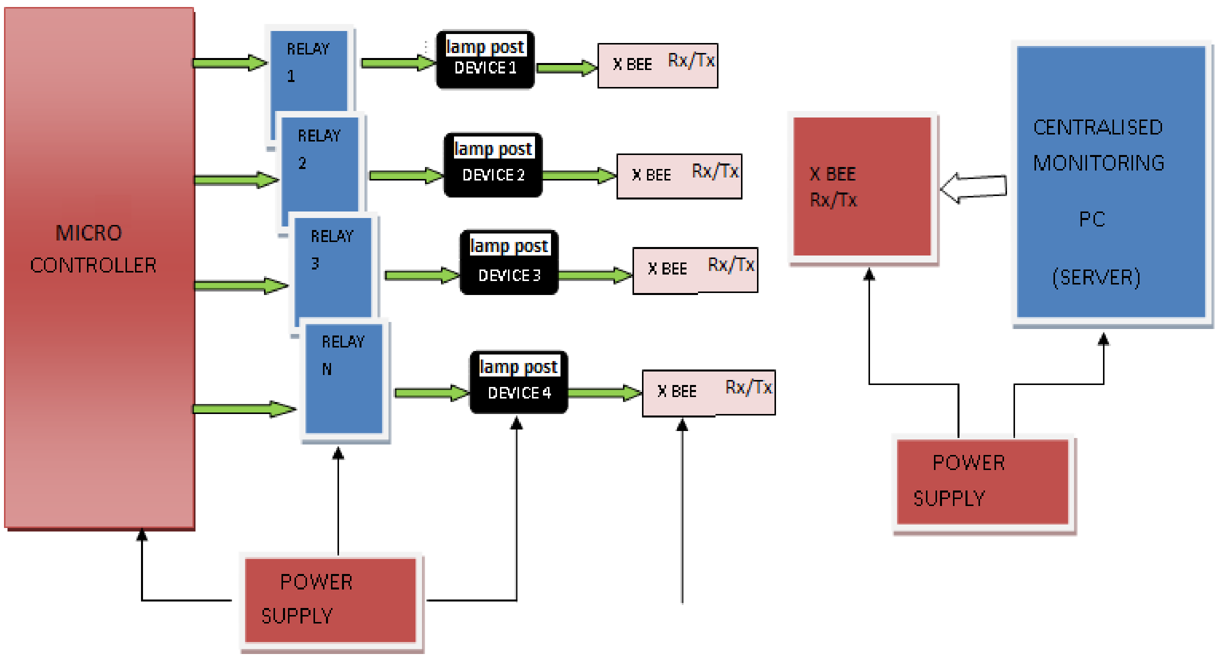


FIGURE 2.3 Basic SLC system based on WSN

The system consists of a group of measuring stations in the street (one station located in each lamppost) and a base station located nearby. The system is designed as a modular system, easily extendable. The measuring stations are used to observe street conditions as the intensity of daylight and, depending on the conditions they activate or off the lamps. Other factors influencing the activation are: climatic conditions, seasons, geographical location, and many possible alternative factors.

For these reasons every lamp is designed independent to decide about the activation of light. The base station conjointly checks if any lamp is correctly operating and sends the message using the wireless network to the operator who will act in case of malfunction.

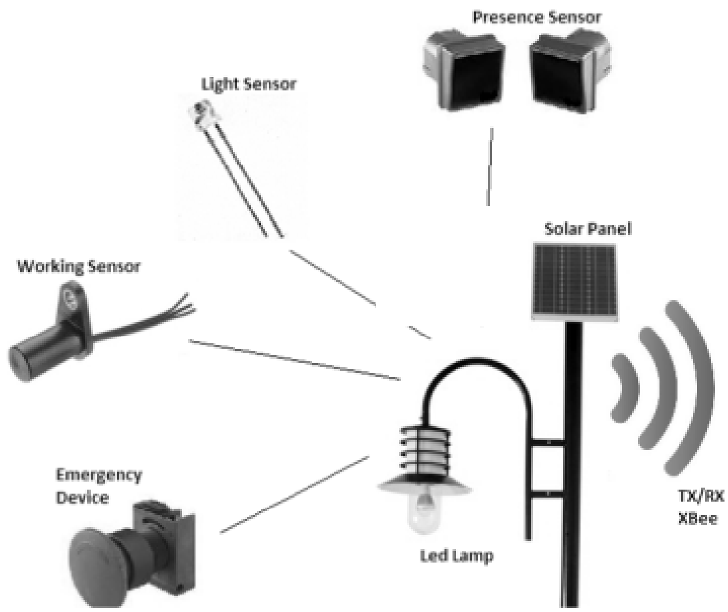


FIGURE 2.4 Scheme of a Lamppost with sensors

A. Measuring Stations

The measuring station located in every lamppost consists of many modules: the presence sensor, the sunshine sensor, the failure sensor and an emergency switch.

These devices work along and transfer the information to a microcontroller that processes the information and chooses the action. Every of those sensors has an assigned priority of transmission, for instance, the emergency switch takes precedence over the others.

B. Presence detector

The presence sensor has the task of identifying the passage of a vehicle or pedestrian causing the switching on of lamps. This feature permits to activate the lamps solely when necessary, avoiding waste of energy. The sensor ought to be placed at the optimal height, neither too low (e.g. to avoid any erroneous detection of small animals) nor too high (to avoid failure to detect e.g. children).

C. Light sensor

Light sensor measures the external light intensity to assure a minimum level of illumination of the road, as needed by regulations. The sensor should have high sensitivity within the visible spectrum, providing a photocurrent high enough for low-light luminance levels. The microcontroller drives the lamp so as to keep up the constant level of illumination. Clearly, this action isn't needed throughout daylight time, however is desired within the early morning and at dusk, when it is not necessary to operate the lamp at full power however merely to "support" the daylight. This mode permits to save electrical power.

D. Supervision module

This sensor improves fault management and system maintenance. A Hall sensor detects when the lamp is switched on. The system recognizes false positives, as detected parameters are compared with the stored information. This information is reported by the ZigBee network to the station management unit, within which the operator is informed regarding the placement of the broken-down lamp and may send a technician to exchange the lamp. Additional security can provide the temperature sensor to ascertain the optimal operation of the lamp and constantly monitor the temperature of the LEDs (which influences the lifespan of the LED lamps). The chosen sensor allows precise AC or DC current sensing, additionally permitting the on-line power consumption measurement.

E. Control unit

The sensors transfer the collected information to a controller that runs the software to manage the system. The operation is processed as follows:

After initial setting, the system is controlled by the light sensor that activates the microcontroller on condition that the daylight illumination is below a set threshold. During this case, the system reads the state of the emergency button, and activates the lamp. The same happens if the presence sensor detects a vehicle or pedestrian. Once the lamp has been switched on, the operating sensor starts the monitoring and, in case of fault detection, sends information to the management center. If no fault is detected, the microcontroller measures the current by the Hall sensor storing the values in memory. All the operation is regulated by a timing management that permits the system is set for the predetermined time. At the stop signal, the lamp is turned off and therefore the cycle restarts.

F. Management center

The management center is that the hub of the system, since it permits the visualization and control of the complete lighting system. The transmission system consists of ZigBee devices that receives data of the state of the lamps and sends it to a terminal. The processing unit consists of a terminal with a serial UART interface that receives data regarding the state of the lamps provided by a ZigBee device, connected to the UART interface. The terminal is needed for graphical presentation of results. Additionally, knowledge on lamps operation are received along with the lamp address, consequently all faults can be easily identified. The graphical interface permits to visualize the state of the system with the state of the lights and the power consumption of every lamp (Power Consumption Data button).The management can be extended so that other electrical systems, not solely lampposts are connected, and might send data regarding power consumptions to a central system for adjusting energy consumption to energy prices and for remote switching and management.

G. Wireless ZigBee Network

ZigBee is wireless communication technology primarily based on IEEE 802.15.4 norm for communication among multiple devices in a WPAN (Wireless Personal space Network). ZigBee is intended to be less complicated than other WPANs (such as Bluetooth) in terms of price and consumption of energy. The ZigBee Personal space Network consists of a minimum of one Coordinator, one (or more) Devices and, if necessary, of one (or more) Router. The bit rate of transmission depends on the frequency band. On 2.4 GHz band the typical bit rate is of 250 kb/s, 40 kb/s at 915 MHz and 20 kb/s at 868 MHz. The standard distance of a ZigBee transmission vary, depending on the atmospheric conditions and therefore the transmission power, ranges from tens to hundred meters since the transmission power is deliberately kept as low as necessary (in the order of few mW) to keep up very low energy consumption .

Data is transferred purpose by purpose, from one lamppost to another one where every lamppost has a distinctive address within the system. The chosen transmission distance between the lampposts assures that in case of failure of one lamp within the chain, the signal

will reach other operational lamppost while not breaking the chain. ZigBee wireless communication utilizes radio frequency modules. They operate within the ISM band at the frequency of 2.4 GHz. The receiver sensitivity is high and therefore the chance of receiving bad packets is low (about 1%). The modules ought to be provided by 3V DC supply, and then the power consumption is within the order of 50 mA. The module supports sleep mode where consumption is smaller than 10µA.

The only downside of Street light Control System based on Zigbee Wireless Sensor Networks is that the cost of infrastructure and maintenance is high.

Chapter3: Literature Review

Manuel Burgos Payán, Francisco Javier, Correa Moreno and Jesús Manuel Riquelme Santos [1] have described in detail about how the replacement of Sodium Vapor Lamps or High pressure mercury vapor lamps with LED lamps can save a lot of Electrical energy in existing Street Light lamps of Spain.
The paper contains detailed analysis of power consumption by different types of Lamps, features of these lamps and Energy saved by replacing each type of lamp.

Distribution of the various types of Lamps in Spain has been studied and estimation of Total energy cost savings by replacing them with LED Lamps has been projected.

The major areas of focus are Illumination technology and the benefits of using reflectors for directing the light beam at proper location.

Po Yen Chen, Yi Hua Liu, Yeu Torng Yau, Hung Chun Lee [2] have proposed an Ethernet-based communication interface to perform the Street Light lamp monitoring, management and light control. Ethernet-based communication interface makes centralized control possible; therefore allows a better and less expensive lighting scheme for municipalities.

The presented system consists of a LED lamp module, a digitally-controlled multi-phase driving system for LED lamp and an Ethernet-based communication interface. Block diagram is shown below:

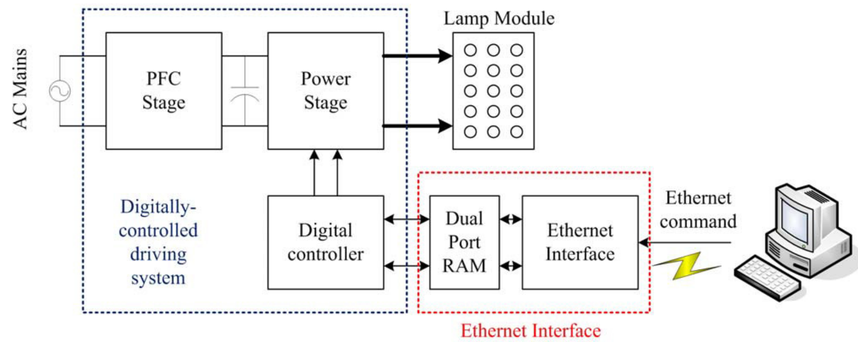


FIGURE 3.1 Block diagram of control system of [2]

Gustavo Denardin, Carlos Barriquello, Rafael Pinto, Marcelo Silva, Alexandre Campos and Ricardo N. do Prado [3] have put forward another Street light Control System. Their work aims to add communication capabilities to the systems already in use, through the integration of a ZigBee™ compatible transceiver to the photoelectric relay used to turn the HPS lamps on/off. That change will turn each device into a node of a large wireless network across the city.

The main idea is the integration of a ZigBee™ compatible transceiver to the relay used to turn the HPS lamps ON/OFF, turning each device into a node of a large wireless network across the city. The proposed system makes easier to read sensor measurements (current, voltage, power, illumination, etc.) and it can reduce total system power consumption and maintenance costs. Also it enables the system to be used in a variety of other public services. Block diagram of the system is shown below:

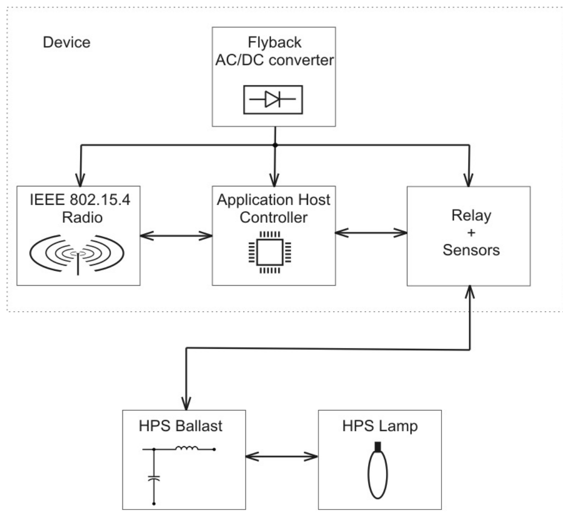


FIGURE 3.2 Block diagram of control system of [3]

Gustavo Denardin, Carlos Barriquello, Alexandre Campos, Rafael Pinto, Marco Dalla Costa and Ricardo do Prado [4] have designed a control network which enables disconnection of the street lighting system from the mains during peak load time, reducing its impact in the distributed power system automatically at overload conditions. In order to meet the system requirements, a wireless sensor network based on IEEE 802.15.4TM standard is employed. Its network layer is implemented using geographic routing strategy, which provides low overhead and high scalability features. Block diagram is shown below:

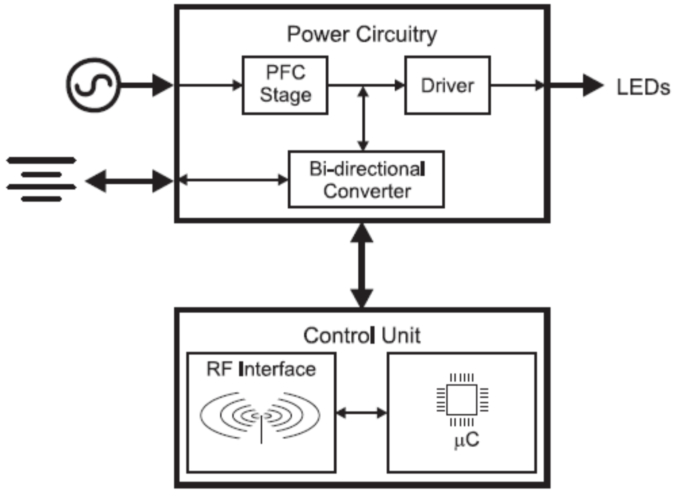


FIGURE 3.3 Block diagram of control system of [4]

Sunita Jadhav [5] presents a Smart Street Light system, a framework developed for a dynamic switching of street lamps based on pedestrians' locations and desired safety (or "fear") zones. In the developed system prototype, each pedestrian is localized via his/her smart phone, periodically sending location and configuration information to the SSL server.

For street lamp control each and every lamppost is equipped with a ZigBee-based radio device, receiving control information from the SSL server via multi-hop routing.

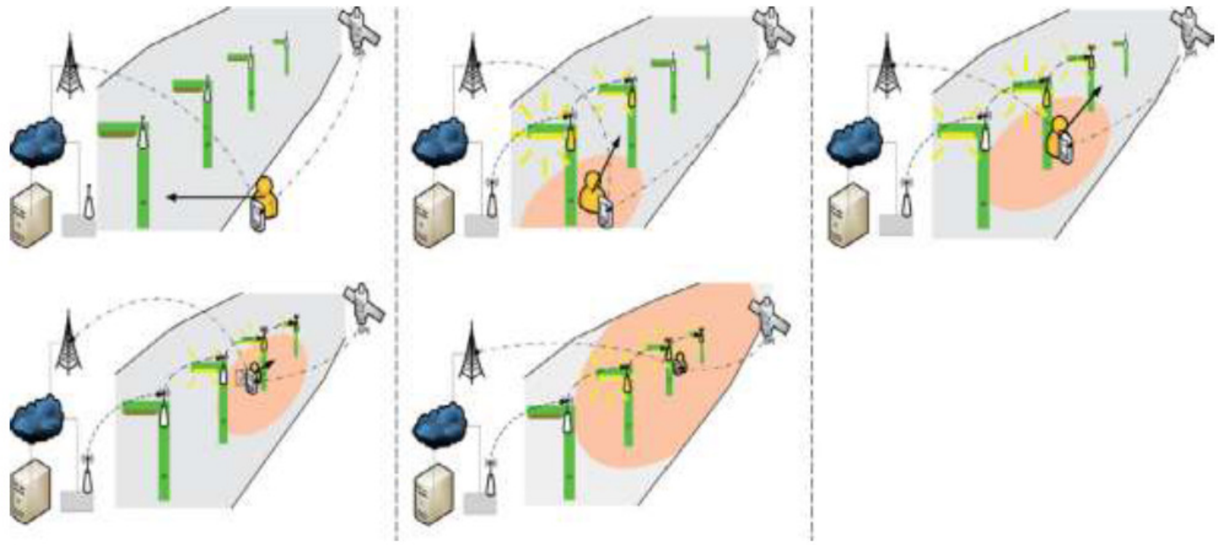


FIGURE 3.4 Behavior of user aware Street Lamps[6]

Alexandru Lavric, Valentin Popa, Codrin Males, Ilie Finis [7] have taken into account, two aspects: the selection of the adequate communication protocol, on the one hand, and the selection of the network topology that supports the architecture, on the other hand. Given these circumstances, the paper focuses on an assessment of the performance of the mesh and tree network topologies which, along with the ZigBee communication protocol, can be implemented in a street lighting control architecture. As a result of the simulations that have been conducted, the data reveals that the tree topology is much more efficient than the mesh topology.

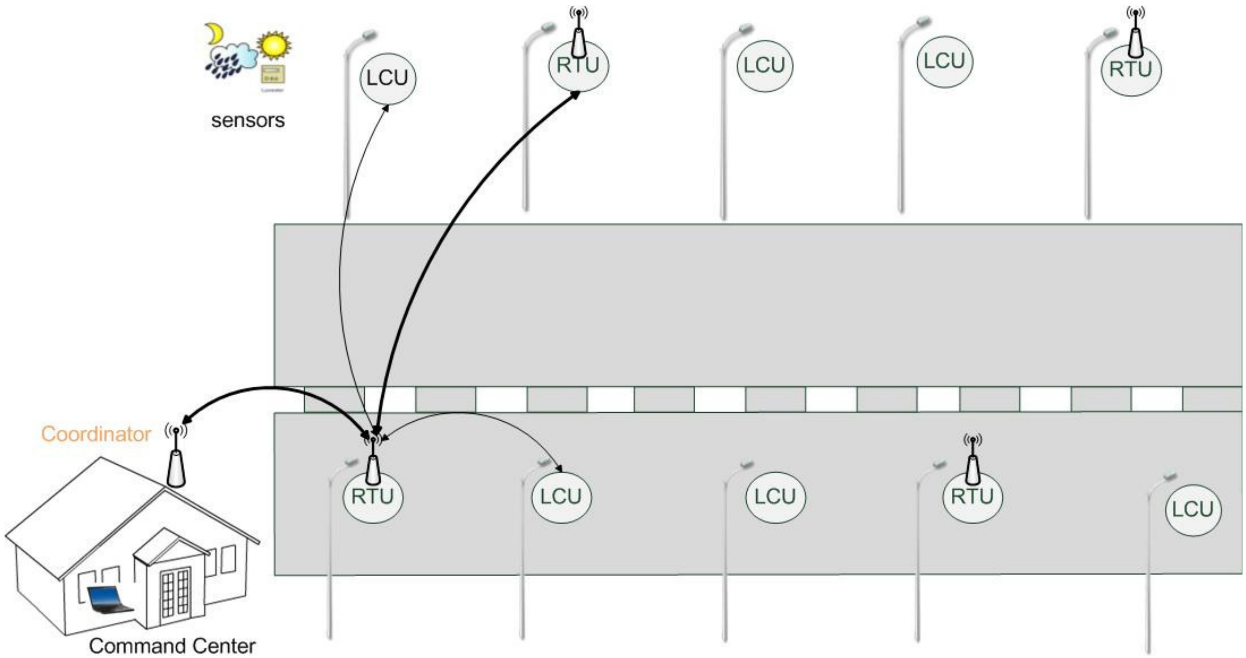


FIGURE 3.5 Tree topology used in [7]

When employing the tree network topology, the network load is divided among the coordinator and the local routers, thus reducing collisions and the number of lost packages. Therefore, the performance of the tree network topology far outbalances the benefits of a mesh topology. The number of hops performed in a mesh network is much higher than that of a tree topology. This particular characteristic may equate a lower power consumption than that required by tree network topologies if the nodes are battery-powered.

The tree topology performs highly better than mesh topologies when implementing a street lighting control system.

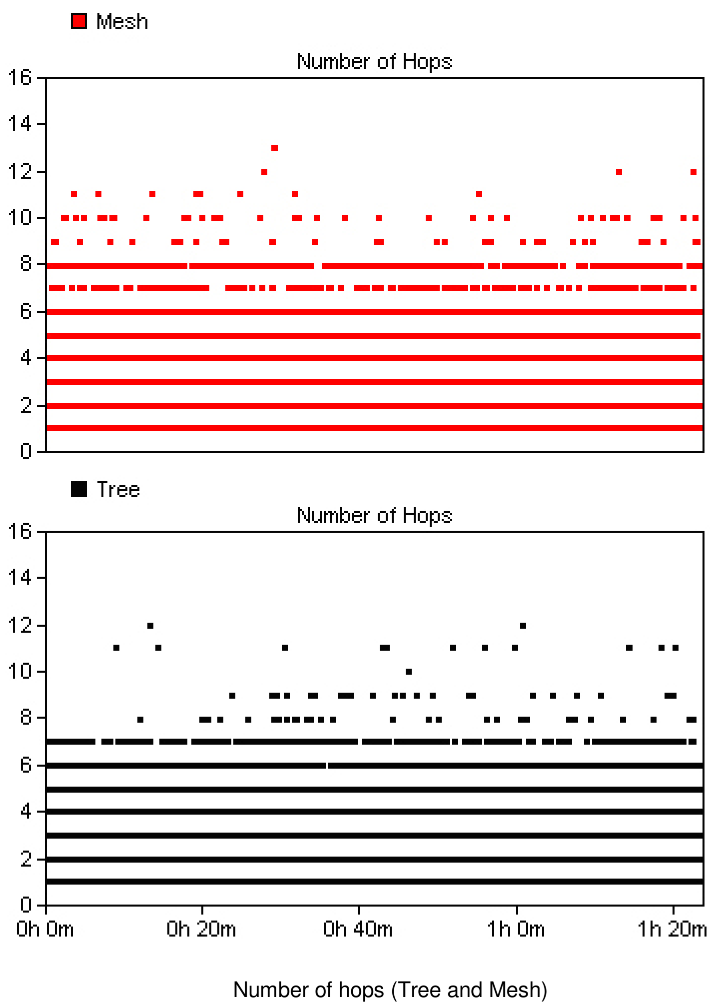


FIGURE 3.6 Hops in Tree and Mesh as analyzed in [7]

Fabio Leccese and Zbigniew Leonowicz [8] propose an innovative wireless street lighting system with optimized management and efficiency. Wireless communication uses ZigBee-based wireless devices which allow more efficient street lamp system management due to an advanced interface and control architecture. It uses many sensors to control and guarantee the optimal system parameters; the information is transferred point-by-point using ZigBee transmitters and receivers and is sent to a control terminal used to check the state of the street lamps and to take appropriate measures in case of failure. The system allows substantial energy savings with increased performance and maintainability.

View of the test system.

FIGURE 3.7 View of actual test system in [8]

Long, Liao, Zhou [9] have designed a high performance/cost LED module for general lighting, the 9LEDM has been designed and evaluated. An adaptive driver with two frequencies to enhance the life time and simplify the induction treatment has been proposed. Photometric, thermal and electrical factors have been considered together in order to obtain a complete street lighting system. Finally, experimental results based on the suggested methodology have been obtained from laboratory measurements and a demonstration project.

Reinhard Mullner and Andreas Riener [10] have presented the SSL system, a framework for fast, reliable, and power efficient street lamp switching based on pedestrians' location and personal desires of safety (increased or reduced illuminated area all around a passersby).In the developed prototype user location, detection as well as safety zone definition and announcement of other configuration information is accomplished using standard Smartphone capabilities. An application on the phone is periodically sending location and other information to the SSL server. For street lamp control, each and every lamppost is extended with a ZigBee-based radio device, receiving control information from the SSL server via multi-hop routing.

The authors have emphasized that the broad utilization of SSL can easily help to overcome the regulatory requirement for CO_2 emission reduction by switching off lampposts whenever not required.

Vijayakumar and Kartthik srinivas [11] have designed a system based on ZIGBEE wireless technology involving zigbee coordinator, zigbee end node interfaced with a microcontroller (ATMEGA16). The microcontroller is interfaced with a GSM modem to achieve long distance communication. The street lights can be monitored and controlled from a centralized area (DTMF) and also controlled remotely via cell phone by a suitable street light application. Brightness of lights is adjusted using dimming control circuit (IRS2530D) at the lamp post. The brightness of the street light can also be adjusted with respect to surrounding ambience using sensor (LDR) at the microcontroller side.

Layout architecture

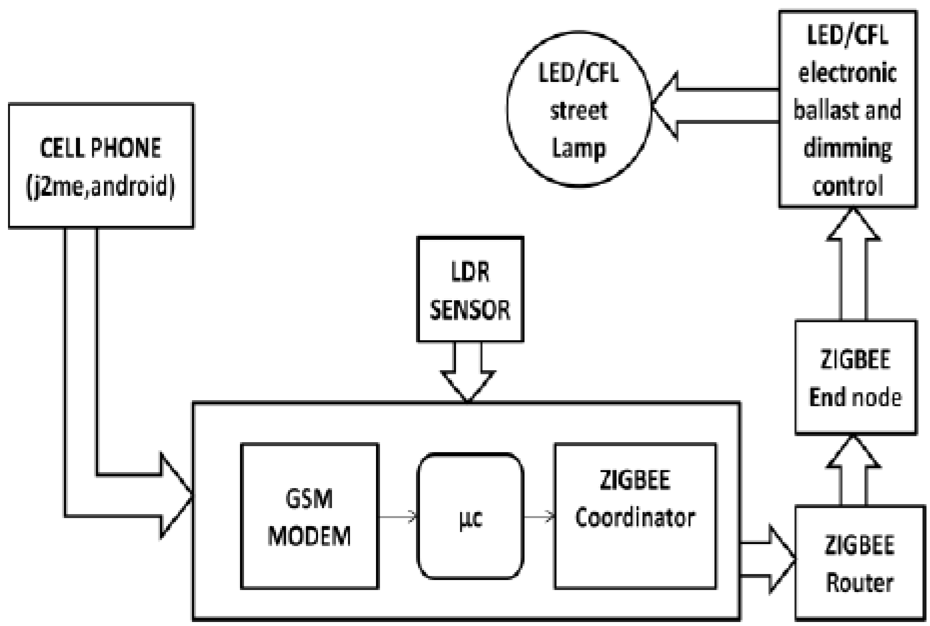


FIGURE 3.8 Block diagram of control system in [11]

The proposed system can be extended to other areas of lighting as well. The power consumption of the system is lowest among existing systems due to the use zigbee wireless network, so false activations as in the case of sensor based systems is ruled out.

Uday Kumar , Kaladhara Sarma [12] have designed a system which has an LDR and an RTC interfaced to the microcontroller. An LDR sense the light and the variation of its o/p resistance is given to the signal conditioning circuit. Where it is converted in to a Voltage signal and is given to the microcontroller through the ADC. There is a provision to modify/set the time using the key pad. Also one can set the time period during which the lights are to be turned On/Off. The Microcontroller has programmed in such a way that both the criteria are considered i.e. time & intensity and accordingly the street lights will be switched on/off.

Deepak Srivatsa, Preethi , Parinitha , Sumana [13] introduced a system in which the LED street lights are switched on whenever the ambient light intensity falls below a threshold. It has an RTC which monitors the time and sends a signal to the lights for dimming, if the time is 11.30pm. microcontroller with an internal RTC has been used. LASER gates have been used for the detection of movement on the road between the 11.30pm and 5am and make Particular Street lights go to full intensity to show light to the travelers. This not only reduces the power consumption and also lights the path for the late night travelers.

Ahmad Fahmi [14] has designed an electrical energy saver for public street lighting which he has named Timer & Dimmer, which can save energy consumption up to 35% of total operating hours. Moreover, the appliance can reduce energy consumption up to 40% when it is applied in good quality of distribution network and lamps. The Timer & Dimmer uses a microcontroller as the central setting for the rise time control efficiency in minutes and can be done more than two times period automatically.

According to the implementation, this device able to extend life time of lamps and electronic ballast up to twice compared with magnetic ballast, total harmonic distortion is low, and Power factor is about 0.9 to 0.99, electronic ballast life time attains 5 years.

Mukul Joshi, Rajashri Madri, Shruti Sonawane, Abhinav Gunjal [15] have designed a simple, robust and energy efficient street light control system which requires minimum maintenance. The principle used is sensing time for deciding the intensity of the street light. The astronomical clock depending on geographical area is studied to generate statistical data. The intensity is varied in five steps as per the variations in ambient natural light obtained from the statistical data. The system uses microcontroller, real time clock and MOSFET based driver circuit for controlling intensity of an LED array. Energy saving is 15.96 KWhr per street light per year in comparison with simple on-off
systems. The system is more reliable than sensor based systems and requires less maintenance as compared to wireless sensor networks.

Chapter 4: System Design and Development

For the design and development of the system, the methodology used involves the software and hardware implementation. The actual implementation of the system involves the following steps:

1.) **System Definition**: Broad definition of system hardware including microcontroller and its interface with display, memory, RTC etc.

2.) **Circuit Design**: Selection of 8051 microcontroller and other interfacing devices, as per system definition. Design of hardware circuit and its testing on laboratory kits with some simple microcontroller software routines.

3.) **PCB Design and Fabrication**: Generation of schematic diagrams and the production of circuit board layout data for the procurement of the circuit board.

4.) **Hardware Modifications**: Making any hardware changes found necessary after the initial hardware tests, to produce a revised circuit board schematic diagram and layout.

5.) **Software Design**: Developing algorithm for the system, allocating memory blocks as per functionality, coding and testing.

6.) **Integration and Final Testing**: Integrating the entire hardware and software modules and its final testing.

Thus the complete design is divided into two parts:

1.) Hardware Implementation.
2.) Software Implementation.

4.1 Hardware Implementation

It involves the details of the set of design specifications. The hardware design consists of, the selection of system components as per the requirement, the details of subsystems that are required for the complete implementation of the system and full hardware schematics for the PCB layout. Design of the circuit and its testing has been carried out. It involves the component selection, component description and hardware details of the system designed.

1.) Component selection and description.
2.) Hardware details of the system designed.

4.1.1 Component selection and description

Temperature measurement using microcontroller based data logger includes the following components:

1.) Microcontroller (AT89C51)
2.) Liquid Crystal Display (LM016L)
3.) External Memory (6264)
4.) Octal D-type Latch (74HCT573- with tristate outputs)
5.) Real Time Clock (DS1307)

1. Microcontroller chip

- Criteria for choosing a microcontroller

1.) The first and foremost criterion for choosing a microcontroller is that it must meet the task at hand efficiently and cost effectively [20]. In analyzing the needs of a microcontroller-based project, it is seen whether an 8-bit, 16-bit or 32-bit microcontroller can best handle the computing needs of the task most effectively. Among the other considerations in this category are:

(a) Speed – What is the highest speed that the microcontroller supports?

(b) Packaging – Does it come in 40-pin DIP (dual inline package) or a QFP (quad flat package), or some other packaging format? This is important in terms of space, assembling, and prototyping the end product.

(c) Power consumption – This is especially critical for battery-powered products.

(d) The number of I/O pins and the timer on the chip.

(f) How easy it is to upgrade to higher –performance or lower consumption versions.

(g) Cost per unit – this is important in terms of the final cost of the product in which a microcontroller is used.

2.) The second criterion in choosing a microcontroller is how easy it is to develop products around it. Key considerations include the availability of an assembler, debugger, a code –efficient compiler, technical support.

3.) The third criterion in choosing a microcontroller is its ready availability in needed quantities both now and in the future. Currently of the leading 8-bit microcontrollers, the 8051 family has the largest number of diversified suppliers. By supplier is meant a producer besides the originator of the microcontroller. In the case of the 8051, this has originated by Intel several companies also currently producing the 8051.

Thus the microcontroller AT89C51 satisfying this entire criterion is chosen for this work.

- AT89C51 Microcontroller

The 8051 family of microcontrollers is based on an architecture which is highly optimized for embedded control systems. It is used in a wide variety of applications from military equipment to automobiles to the keyboard. Second only to the Motorola 68HC11 in eight bit processors sales, the 8051 family of microcontrollers is available in a wide array of variations from manufacturers such as Intel, Philips, and Siemens. These manufacturers have added numerous features and peripherals to the 8051 such as I2C interfaces, analog to digital converters, watchdog timers, and pulse width modulated outputs. Variations of the 8051 with clock speeds up to 40MHz and voltage requirements down to 1.5 volts are available. This wide range of parts based on one core makes the 8051 family an excellent choice as the base architecture for a company's entire line of products since it can perform many functions and developers will only have to learn this one platform [22] .

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer, which provides a highly-flexible and cost-effective solution to many embedded control applications [22].

The basic architecture of AT89C51 consists of the following features:

1.) An eight bit ALU
2.) 32 discrete I/O pins (4groups of 8) which can be individually accessed
3.) Two 16 bit timer/counters
4.) Full duplex UART
5.) 6 interrupt sources with 2 priority levels
6.) 128 bytes of on board RAM
7.) Separate 64K byte address spaces for DATA and CODE memory

One 8051 processor cycle consists of twelve oscillator periods. Each of the twelve oscillator periods is used for a special function by the 8051 core. The time required for any 8051 instruction can be computed by dividing the clock frequency by 12, inverting that result and multiplying it by the number of processor cycles required by the instruction in question [23]. Therefore, if you have a system which is using an 11.059MHz clock, you can compute the number of instructions per second by dividing this value by 12. This gives an instruction frequency of 921583 instructions per second. Inverting this will provide the amount of time taken by each instruction cycle (1.085 microseconds).

2. Liquid Crystal Display.

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. It uses very small amounts of electric power, and is therefore suitable for use in battery powered electronic devices. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other [25]. More microcontroller devices are using 'smart LCD' displays to output visual information.

LCD displays designed around Hitachi's LCD HD44780 module (Part no. LM016L), are inexpensive, easy to use, and it is even possible to produce a readout using the 8x80 pixels of the display. Hitachi LCD displays have a standard ASCII set of characters plus Japanese, Greek and mathematical symbols. For an 8-bit data bus, the display requires a +5V supply plus 11 I/O lines. For a 4-bit data bus it only requires the supply lines plus seven extra lines. When the LCD display is not enabled, data lines are tri-state which means they are in a state of high impendence (as though they are disconnected) and this means they do not interfere with the operation of the microcontroller when the display is not being addressed.

In LCD we can put data at any location. For 16×2 LCD, the address locations are:

Cursor addresses for LCD

First line	80	81	82	83	84	85	86	through	8F
Second line	C0	C1	C2	C3	C4	C6	C7	through	CF

- Signals to the LCD

The LCD also requires 3 control lines from the microcontroller:

Enable (E)

This line allows access to the display through R/W and RS lines. When this line is low, the LCD is disabled and ignores signals from R/W and RS. When (E) line is high, the LCD checks the state of the two control lines and responds accordingly [25].

Read/Write (R/W)

This line determines the direction of data between the LCD and microcontroller. When it is low, data is written to the LCD. When it is high, data is read from the LCD.

Register select (RS)

With the help of this line, the LCD interprets the type of data on data lines. When it is low, an instruction is being written to the LCD. When it is high, a character is being written to the LCD.

Logic status on control lines:

E - 0 Access to LCD disabled
-1 Access to LCD enabled

R/W -0 Writing data to LCD
-1 Reading data from LCD

RS -0 Instruction
-1 Character

- Writing and reading the data from the LCD

Writing data to the LCD is done in several steps:

1.) Set R/W bit to low

2.) Set RS bit to logic 0 or 1 (instruction or character)

3.) Set data to data lines (if it is writing)

4.) Set E line to high

5.) Set E line to low

Read data from data lines (if it is reading)

1.) Set R/W bit to high

2.) Set RS bit to logic 0 or 1 (instruction or character)

3.) Set data to data lines (if it is writing)

4.) Set E line to high

5.) Set E line to low

3. External Memory.

The microcontroller AT89C51 that has been used in designing a Smart Street light Control System has internal memory of 8k.

In the design of the Street Light Control System, the need is to store Look up table data of daily sunrise and sunset based on the geographical location (nearly 20Kbytes data) in the memory that is why using the external memory is significant as it is not possible to write data in internal memory of microcontroller.

For this application 64 K RAM 6264 has been used which is accessed like a Static RAM for the read cycles without the need for external components [26].

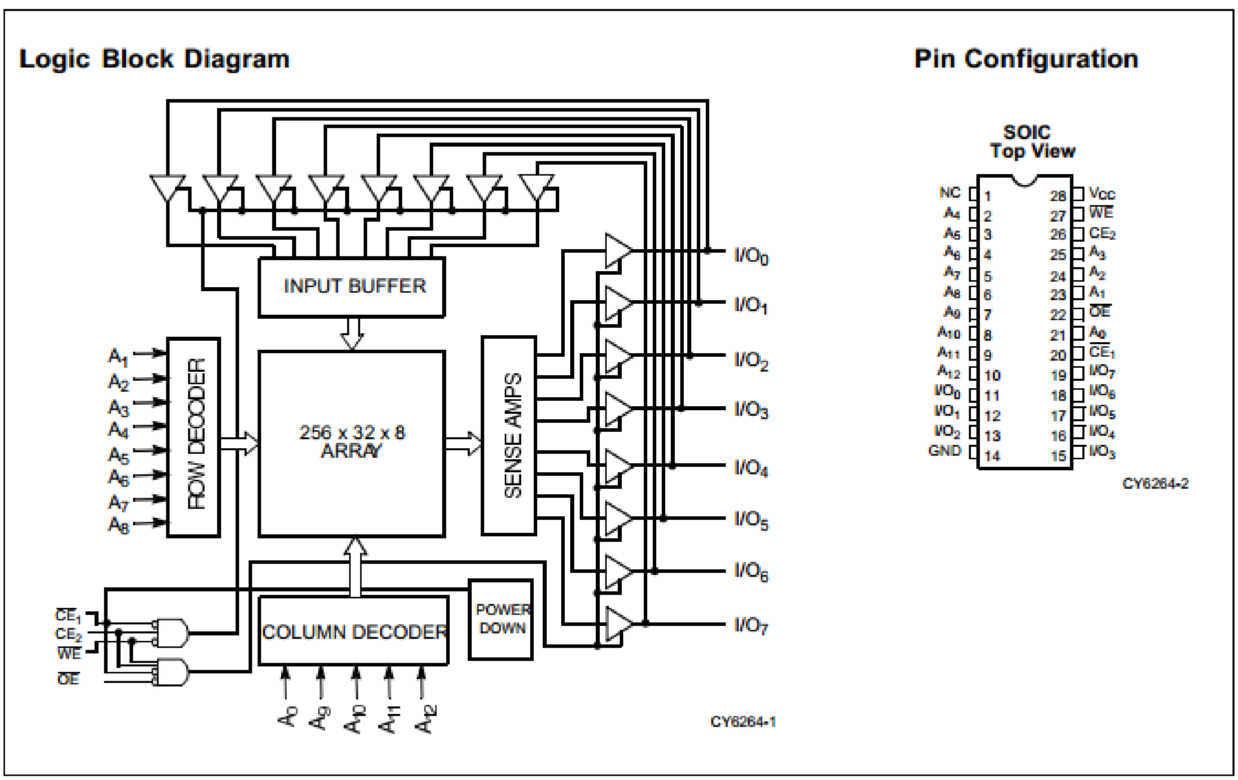


FIGURE 4.1 Logic block diagram of SRAM 6264

Features

• High speed -Fast access time: 85/100 ns (max)

• Low power-Standby: 10 μW (typ)

Operation: 15 mW (typ) (f = 1 MHz)

• Single 5 V supply

• Completely static memory

No clock or timing strobe required

• Equal access and cycle times

• Common data input and output

Three state output

• Directly TTL compatible

All inputs and outputs

• Battery backup operation capability

4. Octal D-type Latch 74HCT573

The external memory interfacing with the microcontroller needs a Latch IC for latching the status of Address lines from the Address/Data port.74HCT573 IC solves the purpose.

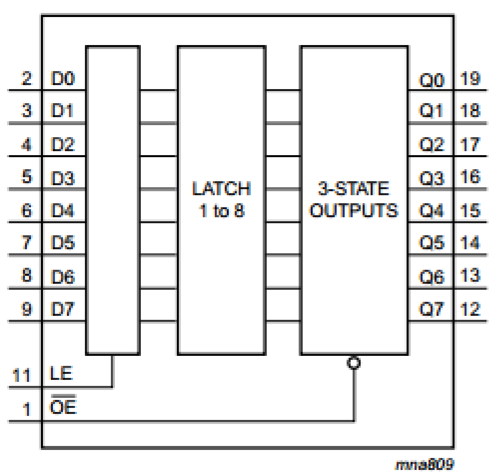
The 74HC573; 74HCT573 is a high-speed Si-gate CMOS device and is pin compatible with Low-power Schottky TTL (LSTTL). It is specified in compliance with JEDEC standard no. 7A.

The 74HC573; 74HCT573 has octal D-type transparent latches featuring separate D-type inputs for each latch and 3-state true outputs for bus-oriented applications.

A latch enable (LE) input and an output enable (OE) input are common to all latches.

When LE is HIGH, data at the Dn inputs enter the latches. In this condition, the latches are transparent, i.e. a latch output changes state each time its corresponding D input changes.

When LE is LOW the latches store the information that was present at the D-inputs a set-up time preceding the HIGH-to-LOW transition of LE. When OE is LOW, the contents of the 8 latches are available at the outputs. When OE is HIGH, the outputs go to the high-impedance OFF-state. Operation of the OE input does not affect the state of the latches [27].



. Functional diagram

FIGURE 4.2 Function diagram of Latch 74HCT573

➢ Features and Benefits:

- Input levels:
- For 74HC573: CMOS level
- For 74HCT573: TTL level
- Inputs and outputs on opposite sides of package allowing easy interface with microprocessors
- Useful as input or output port for microprocessors and microcomputers
- 3-state non-inverting outputs for bus-oriented applications
- Common 3-state output enable input
- Multiple package options
- ESD protection:
- HBM JESD22-A114F exceeds 2 000 V
- MM JESD22-A115-A exceeds 200 V
- Specified from 40 □C to +85 □C and from 40 □C to +125 □C

5. Real Time Clock (DS1307)

Since an approach of sensing the time of day has been used in this thesis, so there is the need of a Real time clock device.DS1307 IC is suitable for the purpose as it runs the clock as well as the calendar and provides this data which is available via its buffer memory. This RTC gets voltage backup from an interfaced battery, thus sustaining its functionality at power failures rather it is not at all dependent upon external power. The user needs to set the correct time and date once only through a suitable program code in the microcontroller after using the I2C interfacing method.

The DS1307 serial real-time clock (RTC) is a low power, full binary-coded decimal (BCD) clock/calendar plus 56 bytes of NV SRAM. Address and data are transferred serially through an I2C, bidirectional bus. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator. The DS1307 has a built-in power-sense circuit that detects power failures and automatically switches to the backup supply. Timekeeping operation continues while the part operates from the backup supply [28].

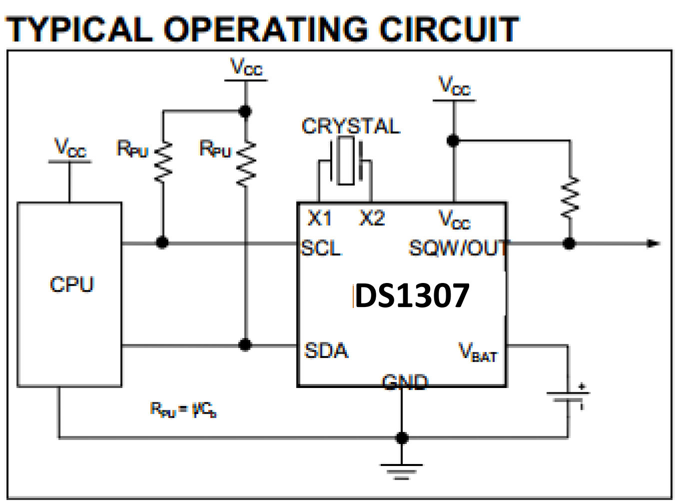


FIGURE 4.3 Typical operating circuit of DS1307

FEATURES

- Real-Time Clock (RTC) Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the week, and Year with Leap-Year Compensation Valid Up to 2100

- 56-Byte, Battery-Backed, General-Purpose RAM with Unlimited Writes
- I2C Serial Interface
- Programmable Square-Wave Output Signal
- Automatic Power-Fail Detect and Switch Circuitry
- Consumes Less than 500nA in Battery-Backup Mode with Oscillator Running
- Optional Industrial Temperature Range: -40°C to +85°C
- Available in 8-Pin Plastic DIP or SO
- Underwriters Laboratories (UL) Recognized

4.1.2 Hardware details of system designed

Figure below shows the schematic for the implementation of the hardware for this purpose.

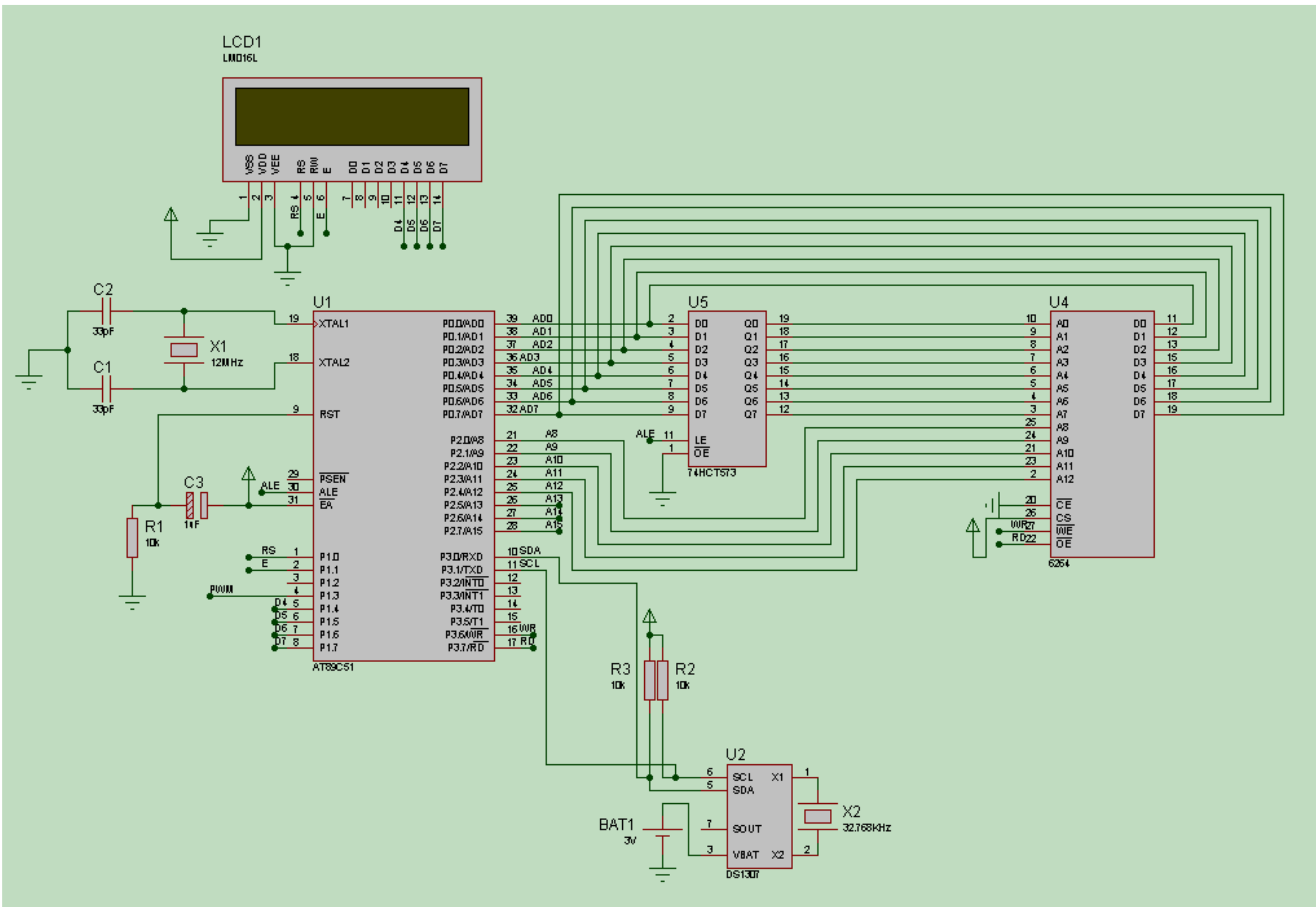


FIGURE 4.4 Schematic diagram of controller circuitry

Figure below shows the schematic of the Driver circuitry and the Street Light Load.

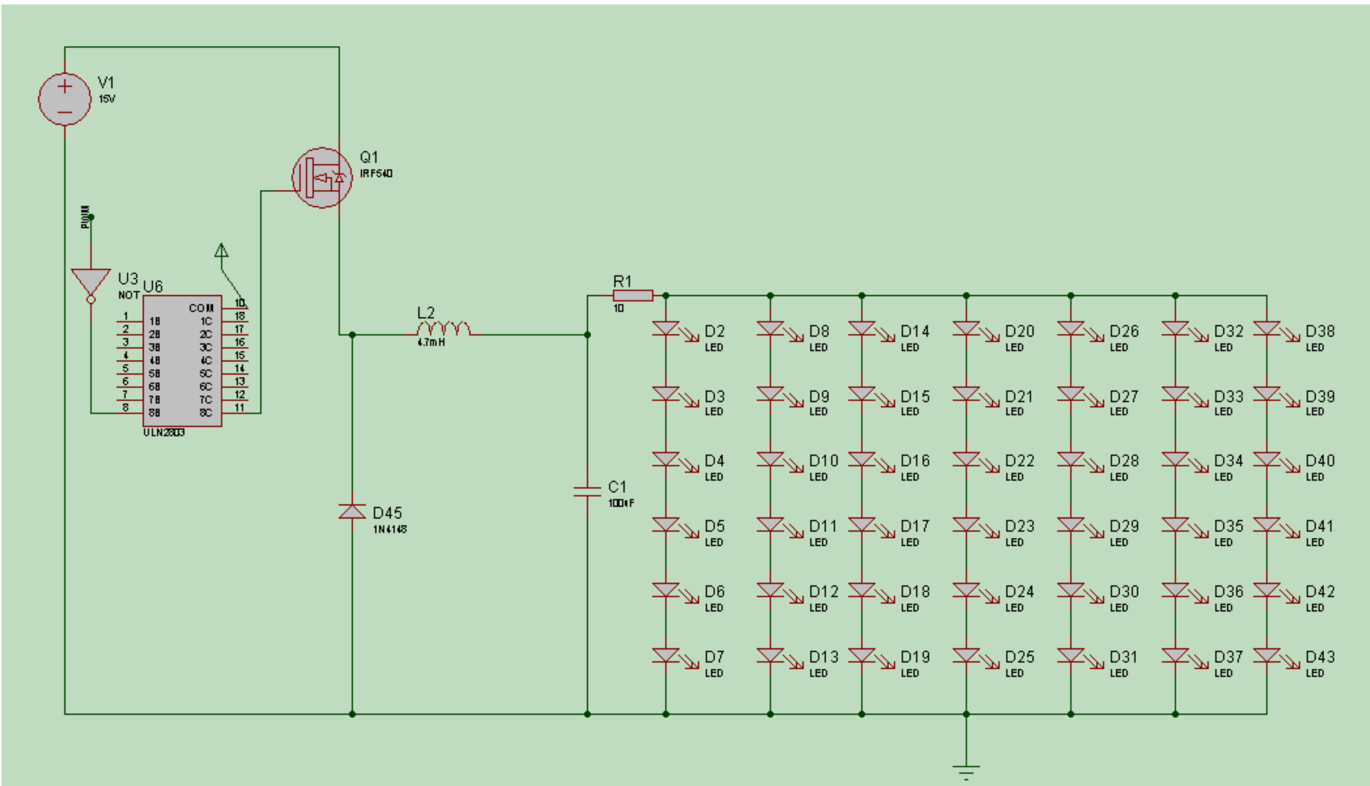


FIGURE 4.5 Schematic diagram of driver circuitry with LED array

Figure below shows the block diagram of the system hardware

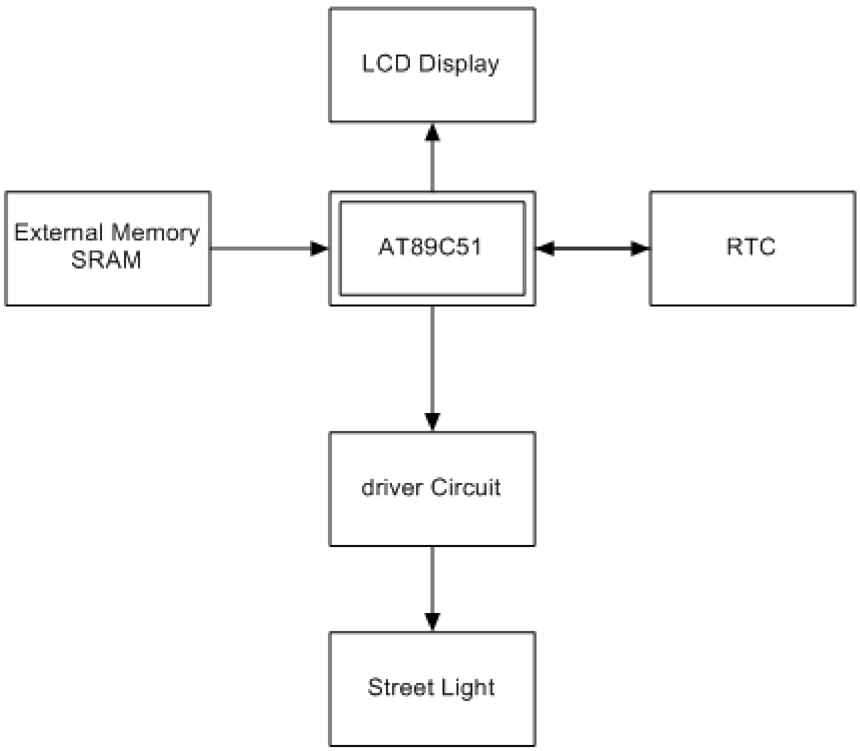


FIGURE 4.6 Block diagram of system hardware

The details of the circuit component connections are as given below:

- **Microcontroller AT89C51**

The four I/O ports of the microcontroller are used for interfacing the external peripherals. 8 bits of port 0 are interfaced to external memory 6264. The memory chip 6264 is interfaced to the microcontroller through the latch 74HCT573. 5 bits (A8 to A12) of port 2 are connected to the memory chip 6264. P1.4 to P1.7 are connected to the LCD.PIN P3.0 and P3.1 are connected to SCL and SDA pins of Real Time clock DS1307.P3.6 is connected to WE and P3.7 to OE of the external memory chip. Pin 18 and Pin 19 are connected to crystal and capacitors. Pin 30(ALE) is connected to LE of 74HCT573.Pin 31(External enable) is connected to VCC. Pin 1 & 2 are connected to RS and E of the LCD. Pin4 generates the PWM output signal. RST pin is connected across the resistor of a suitable capacitor 1 uF and 10K resistor circuitry, which is supplied with VCC.

- **External memory chip 6264**

8 data lines are connected to port 0.First 8 address lines are connected to Latch. The remaining address lines are connected to P2.0-P2.4. Chip enable pin is connected to ground. LE pin is connected ALE pin of microcontroller.

- **Latch 74HCT573**

It is used for the purpose of multiplexing the data. The 8 input pins are connected to address lines of memory. Data pins are connected port 0 of the controller chip. Latch enable pin of latch is connected to ALE pin of the microcontroller and the pin Output enable is connected to ground.

- **Hitachi HD44780 LCD**

The 4data pins of LCD (D4 to D7) are connected to the 4-bits of the port 1(P1.4 to P1.7) to send data to the LCD. The control signals of the LCD module RS and EN are connected to the pins P1.0 and P1.1.RW pin is connected to ground. Pin 1 is connected to GND and pin 2 to VCC. Pin3 is connected to ground via variable resistance that is used to adjust the contrast.

➢ RTC DS1307

Crystal of 32.768 KHZ is connected across pins 1 and 2 of RTC. Pin 5 and Pin6 are supplied VCC through 10K resistances. Pin 5 and Pin6 are also connected to P3.0 and P3.1 of microcontroller for I2C interface. Pin 3 is connected to lithium battery of 3V.

➢ Power supply section

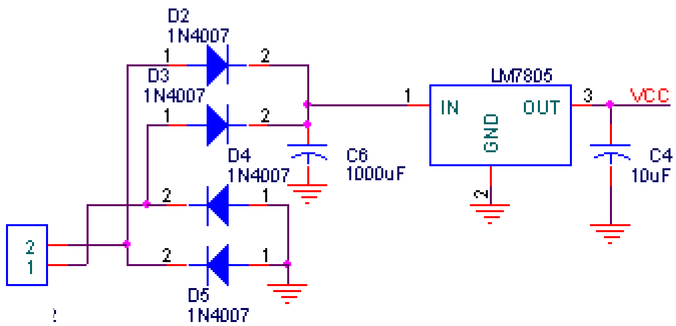


FIGURE 4.7 Power supply circuit

A power supply section is the regulated DC power supply of +5 Volts. +5 Volts is generated using LM7805 fixed voltage regulator. Rectification of the AC supply is carried out using 4 IN4007 diodes connected to pin 1 of LM7805.Pin 2 is connected to ground and Pin 3 is connected to VCC. The output of this section is free from ripples and distortions.

- **Driver Circuit with LED array**

15V DC power supply has been connected to source of ‘Q1’which is an n-channel MOSFET (IRF540). The Gate of the MOSFET is fired through Output pin of ULN2803 buffer IC which is getting an inverted PWM signal from the microcontroller. The diode IN4148, MOSFET (IRF540), inductance of 4.7mH and capacitor of 100uF combined in the circuitry form a Buck chopper (Output voltage is proportional to the input duty cycle).

The circuitry has been designed to generate a voltage of 12V and a load current of 900mA required for powering the LED array of nearly 10.7 Watt(High intensity LED specifications are –Forward voltage 2V and forward current 120mA). Suitable design criteria have been considered [29].

The LED array size has been intentionally reduced to 1/3rd of the actual size (32Watt) for simplification of the LED array fabrication. Thus accordingly the factors for driver circuit i.e. 12V output and 900mA for a load of 10.7 Watt have been considered.

4.2 Software design and development:

Software design includes developing algorithm for the system, writing the separate routines for different interfacing devices and testing them on the designed hardware. Interfacing of microcontroller with RTC, LCD, MEMORY, etc. has been carried out using various software modules. The control program is written in ‘C’ language. Keil Software has been used to write the Control program. Testing of the program has been done in Proteus Software which a Designing and Simulation

Software. The Proteus software is able to show the real time PWM output at a virtual instrument (CRO) for verification.

For designing the software for this work; the flow of software between the hardware components is to be understood first.

4.2.1 Algorithm for Control logic

For designing the Control Algorithm the main Prerequisites are:

1. Knowledge of Duty Cycle of PWM signal vs. illumination intensity in Lumens of LED array.

   This data has been sourced from [15] and is as Follows:

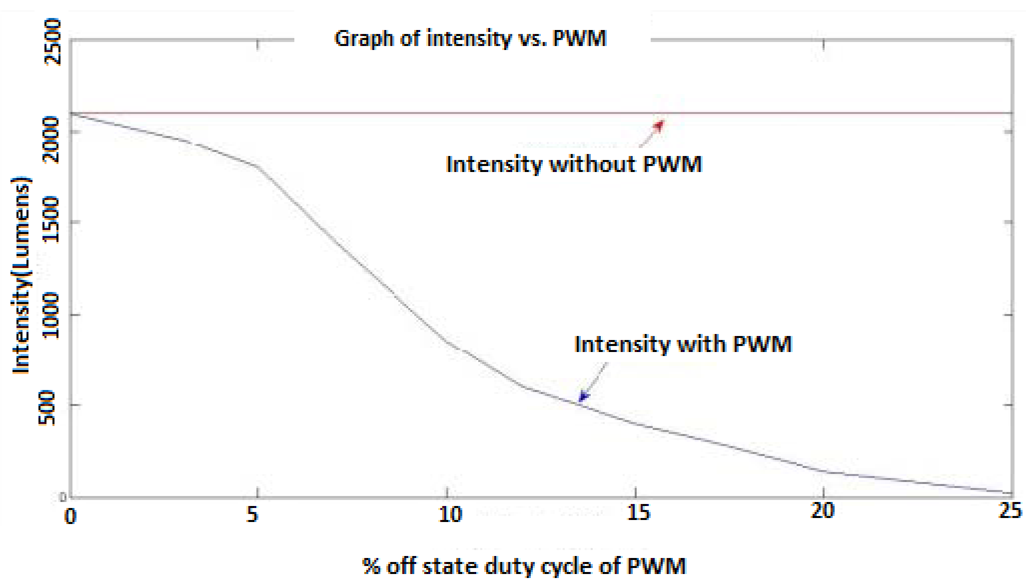


FIGURE 4.8 PWM vs. Luminous intensity characteristics of LED array

Thus it is found that the Luminous intensity becomes zero at 25% OFF state Duty cycle (75% ON state Duty cycle). Also, Luminous intensity reaches maximum at 100% ON state Duty cycle.

2. Knowledge of Duty Cycle of PWM vs. Power consumption by LED array. Data has been sourced from [15] and is as follows:

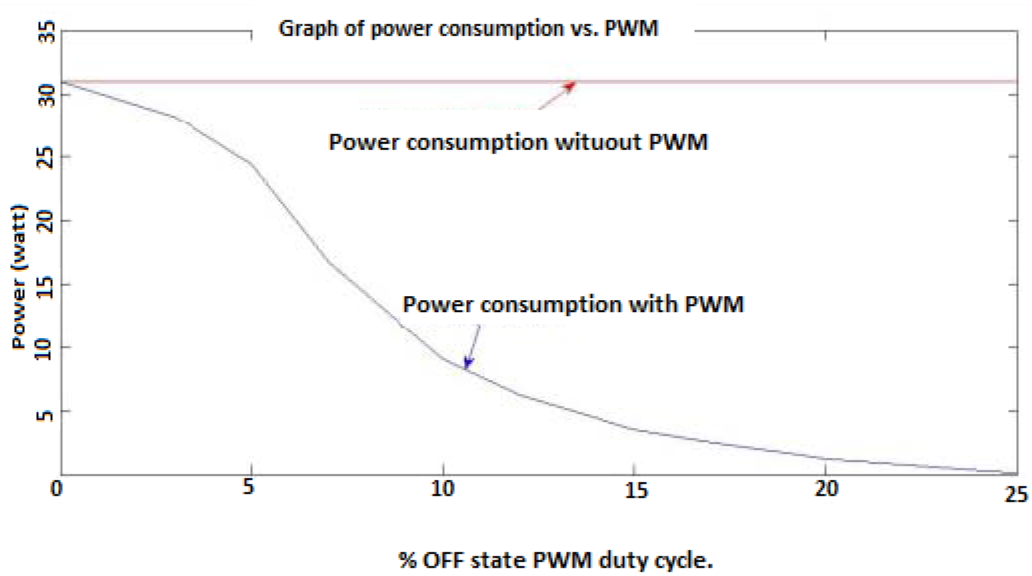


FIGURE 4.9 PWM vs. Power consumption characteristics of LED array

3. Daily sunrise sunset data of Chandigarh to be loaded in a look up table. The data has been sourced from [30] and [31] and is as follows for the 2014.

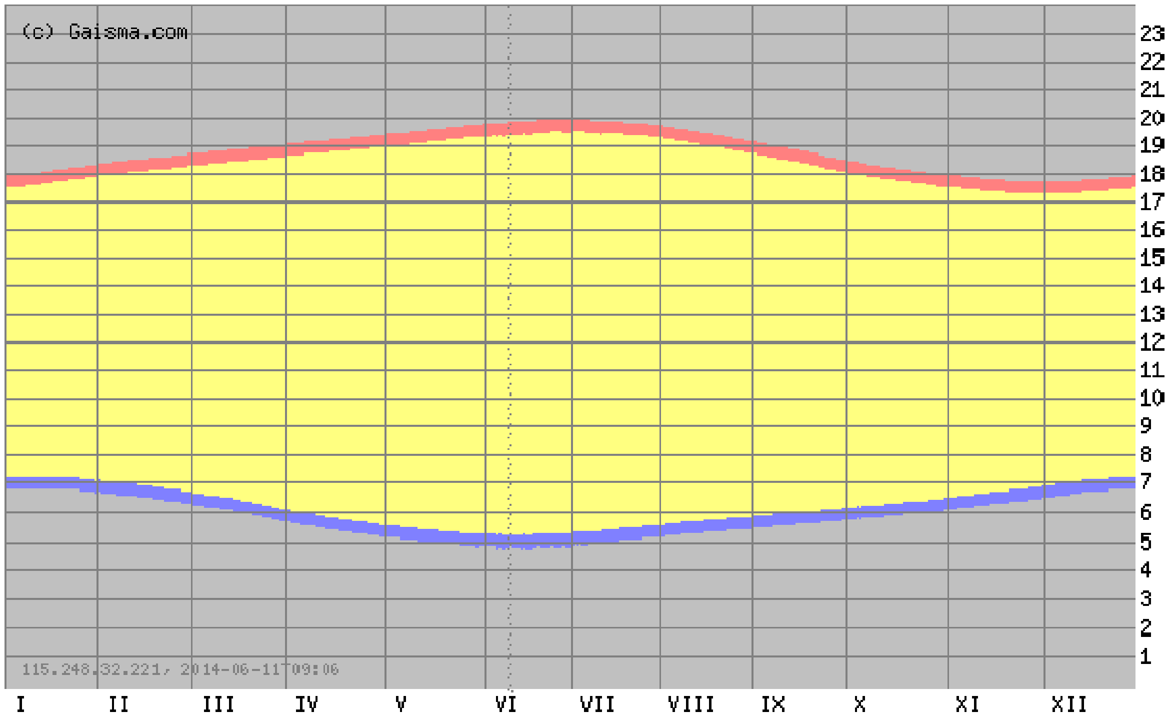


FIGURE 4.10 Sunrise Sunset data graph of Chandigarh for 2014

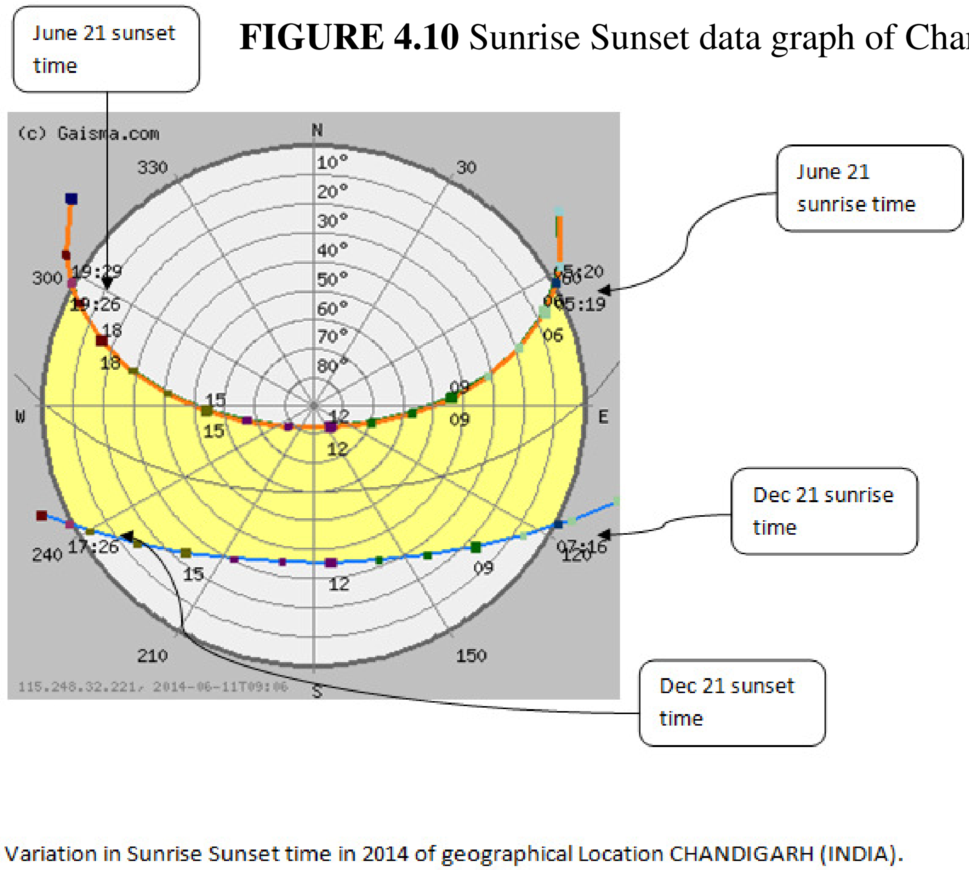


FIGURE 4.11 Variations in Sunrise sunset times of Chandigarh in 2014

Thus considering the above data following are the Steps of the Algorithm for Control logic:

Algorithm 1:

1. Set the Current Date and Time data.
2. Initialize the RTC for proper date and time.
3. End

Algorithm 2:

1. Define a Look up table with Daily sunrise sunset data in the form of an array of structure.
2. Initialize the LCD for Display of Date and time.
3. Initialize the Timer in microcontroller to function as a PWM output source.
4. Read the RTC data for determining the Current Date and time.
5. Display the Date and time on LCD.
6. Find out the data corresponding to the Current Date in the look up table.
7. Mark the data as Reference.
8. Start PWM in increasing duty cycle mode for Half Hour (Starting from 75% On State Duty Cycle up to 100% On State Duty Cycle) if the current time has become equal to the Reference Sunset time.
9. Keep the Output for Street Lamp fully ON after PWM cycle has finished.
10. Start PWM in decreasing duty cycle mode for Half Hour (From 100% Duty cycle to 75% Duty Cycle and after that immediately to 0%) if the current time has become equal to the Reference Sunrise time.
11. Keep the Output for Street Lamp fully OFF after PWM cycle has finished.
12. Go back to STEP 4.

After implementation of Algorithm1 and Algorithm2 the Control logic is then verified on Proteus Software.

PWM output can be monitored on a Virtual CRO instrument in the software and all the parameters can be monitored in Real time including the Date and time display on the LCD and the overall Control Circuit functionality.

Flowchart of the Algorithm 1 and 2 is shown in figure 4.12 and 4.13:

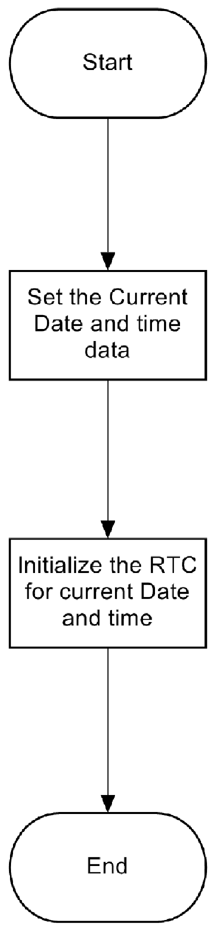


FIGURE 4.12 Flowchart of control logic Algorithm 1

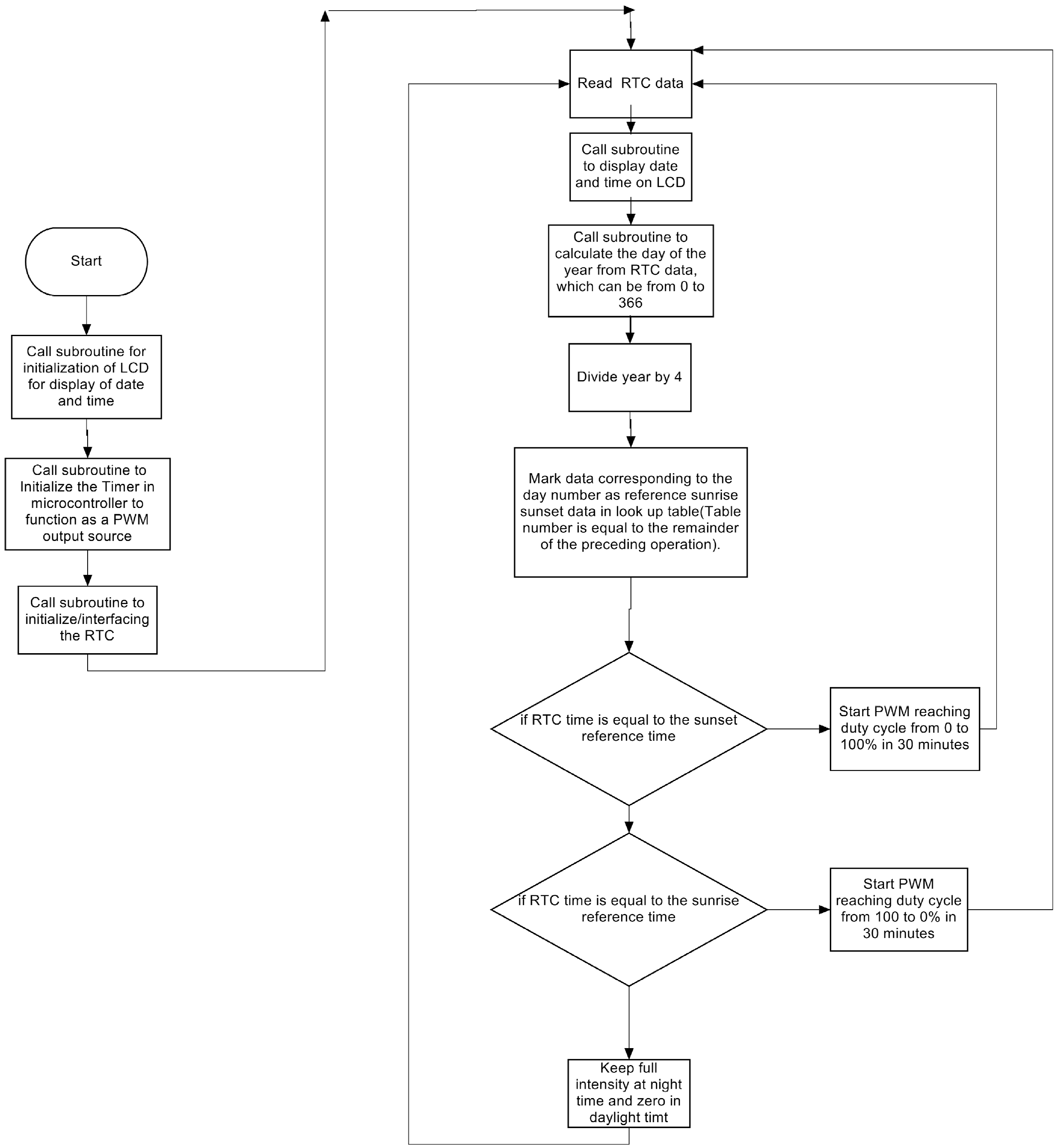


FIGURE 4.13 Flowchart of control logic Algorithm 2

4.2.2 Interfacing RTC with the Microcontroller

Algorithm for interfacing RTC with the microcontroller is as follows:

1. Initialize the I2C interface i.e. make SDA and SCK signals high.
2. Then generate a half bit delay.
3. Make SDA low.
4. Generate half bit delay.
5. Set the RTC time by writing hours data to the RTC
   Bit by bit.
6. Place the first data bit on the SDA pin.
7. If bit is high, make SDA high.
8. Data is transferred MSB first.
9. If bit is low, make SDA low.
10. Toggle SCK pin so that slave can latch data bit.
11. Get ACK from slave and return SDA.
12. Go back to Step 7 and place next data bit on SDA pin until all the 8 bits of first byte have been written.
13. Restart the I2C interface by making SDA and SCK high.
14. Go back to Step 7 until all the consecutive data bytes i.e. minutes, Seconds, Day, Date, Month, Year are written to the RTC.

Flowchart for interfacing RTC with Microcontroller is shown in figure 4.14:

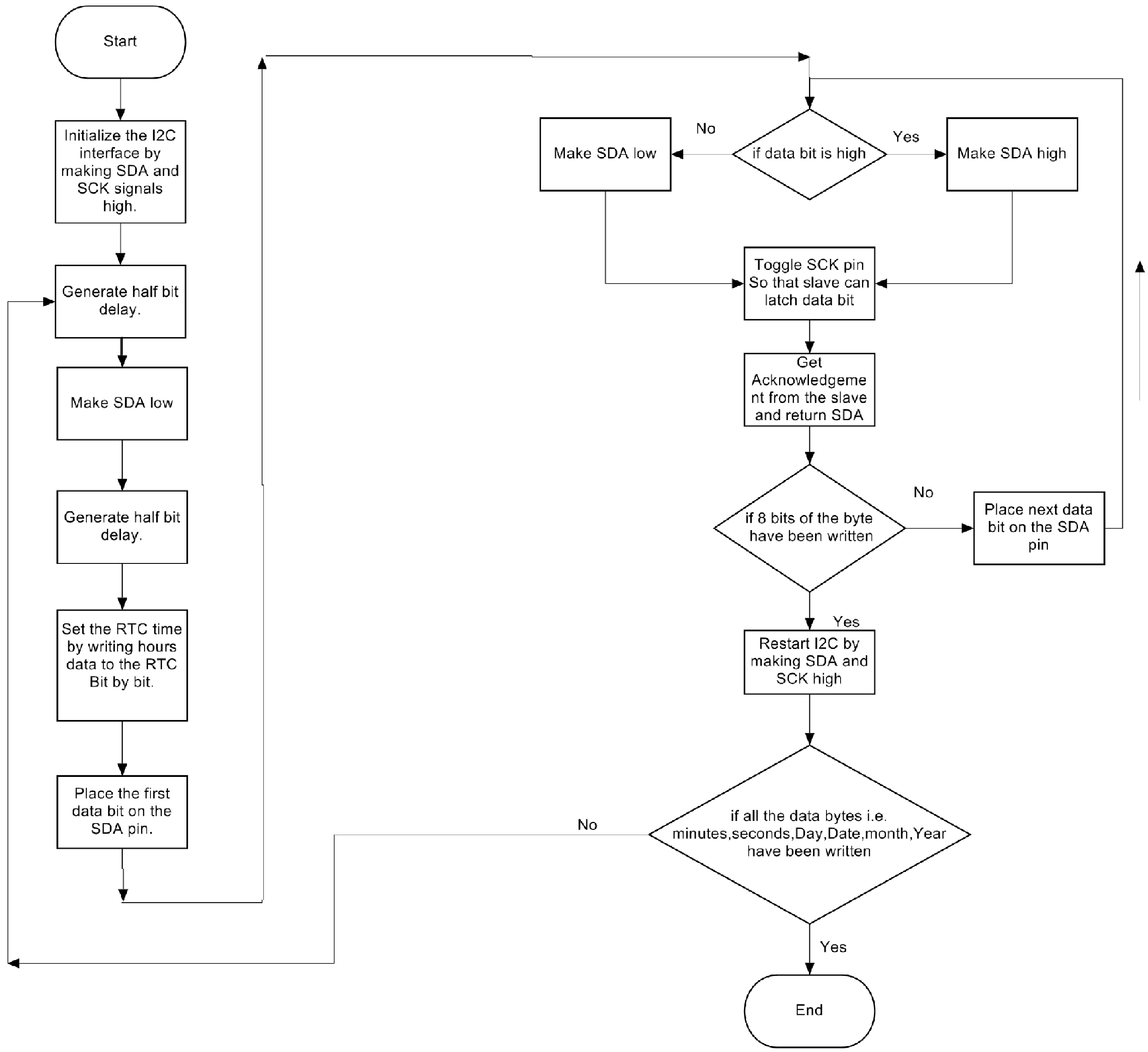


FIGURE 4.14 Flowchart of RTC interfacing with microcontroller

4.2.3 Interfacing LCD to the microcontroller

For interfacing a LCD to the microcontroller it has to be first initialized then command and data are sent to it.

Algorithm for initializing the LCD is as:

1.) Firstly, the interface length is set.

2.) A high to low pulse is applied to the pin ‘en_lcd’.

3.) A delay of 20 ms is then called.

4.) The display is turned on and a high to low pulse is again applied to the pin ‘en_lcd’.

5.) The cursor move direction is set in next step and shift of display is specified.

6.) A delay subroutine of 50 ms is called and a high to low pulse is applied to pin ‘en_lcd’.

Flowchart for initializing the LCD is shown in figure 4.15:

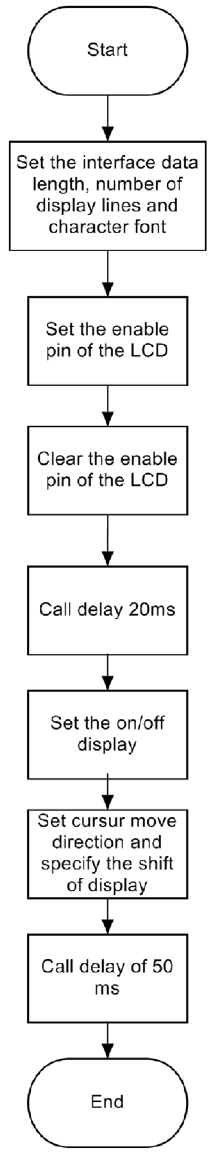


FIGURE 4.15 Flowchart for initialization of LCD

Algorithm for writing data to the LCD is as:

1.) In writing data to the LCD, register select pin (rs) is set to low.

2.) Then the cursor on/off and blink of cursor position character is set.

3.) A high to low pulse is sent to the enable pin 'en_lcd'. rs is then set.

4.) The contents of the accumulator are moved to port 0. A high to low pulse, in order for the LCD to latch in the data present at the data pins is applied to the enable pin 'en_lcd'.

Flowchart for writing data to LCD is shown in figure 4.16:

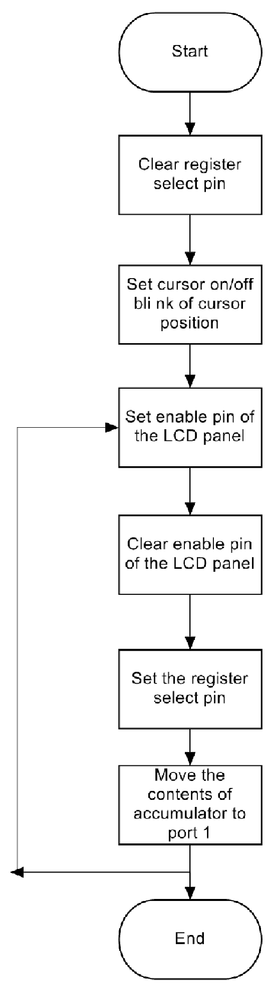


FIGURE 4.16 Flowchart for writing data to LCD

4.2.4 Interfacing External memory with the Microcontroller.

Since the Control Logic is made in 'C' language thus not much coding is needed for the interfacing of External Memory. The LOOKUP table values are read using variable addressing method.

The Default look up table values are written in the Start of Control logic into the External memory in the form of Array by the help of Keil compiler in built functionality itself.

4.2.5 Initialization of Timer to act as PWM output source.

Algorithm Steps are as follows:

1. Clear 4bit field for timer0 (TMOD=0xF0).
2. Set timer0 in mode 1 = 16bit mode (TMOD.0=1).
3. Set first time value of TH0 and TL0 to zero.
4. Enable Timer0 interrupts.
5. Global interrupt enable.

Flowchart of Algorithm is shown in figure 4.17:

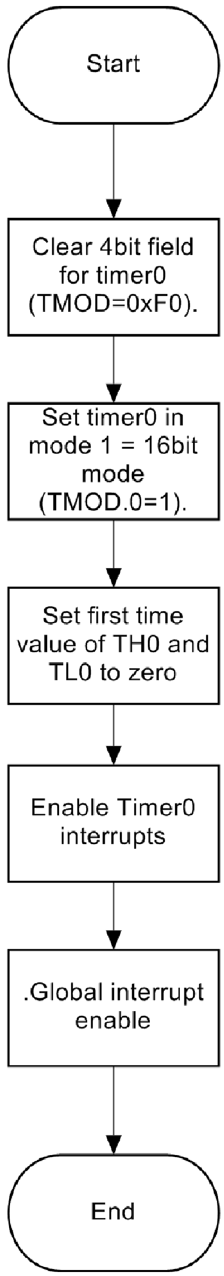


FIGURE 4.17 Flowchart of initialization of Timer to act as PWM output source

Algorithm inside the Interrupt Service Routine:

1. If PWM output bit is high then toggle it's status and go to Next Step else go to Step 5.
2. Calculate TH0 and TL0 values required for the next Timer interrupt occurrence depending upon the desired OFF state time of the Duty cycle.
3. Load the Calculated values into TH0 and TL0.
4. Go to Step 6.
5. Toggle PWM bit status and calculate the values required for the next interrupt occurrence depending upon the desired ON state time of the Duty cycle.
6. Clear the interrupt flag TF0.
7. Start Timer 0.
8. End.

Flowchart of the Timer interrupt Service routine is shown in fig 4.18:

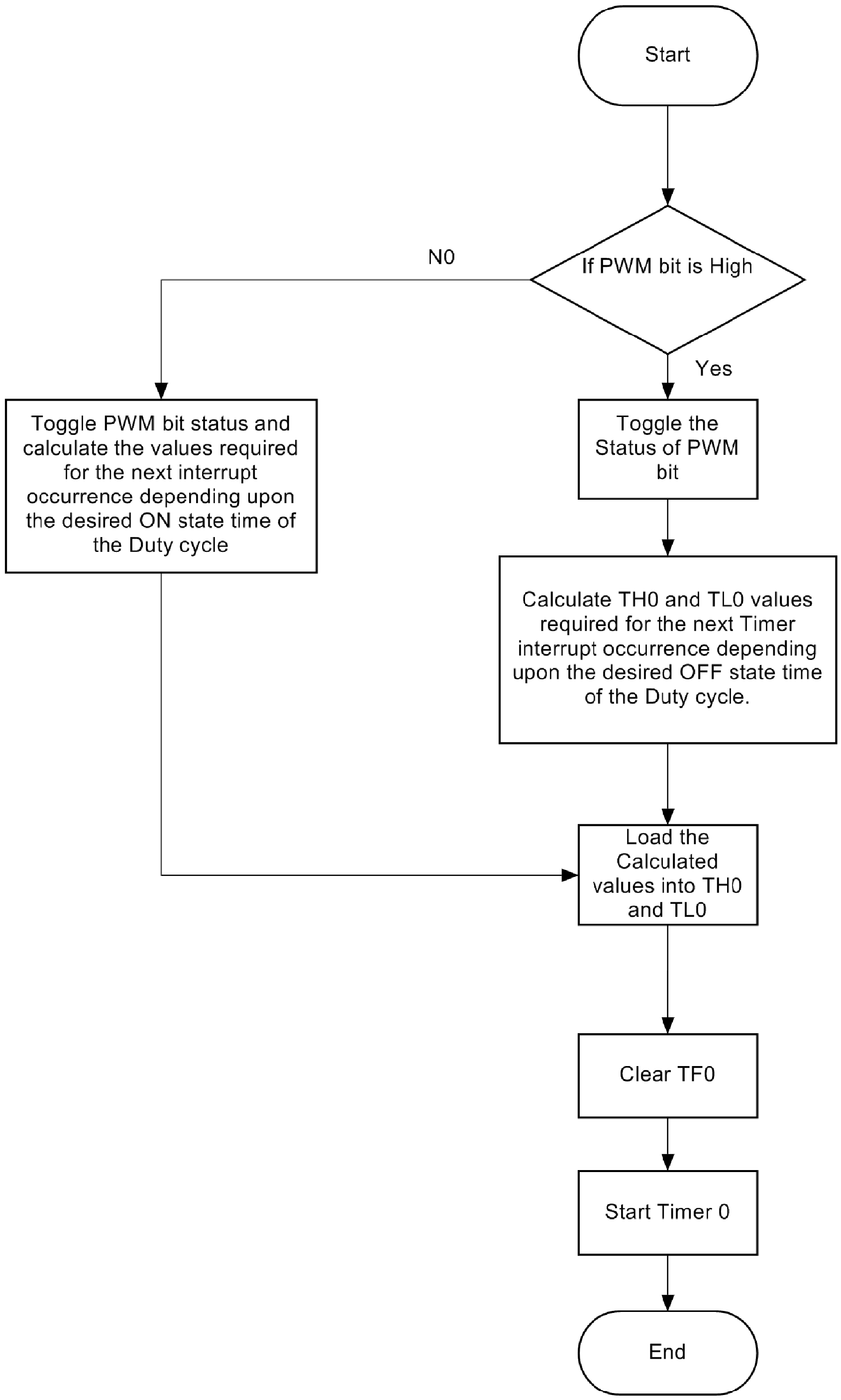


FIGURE 4.18 Flowchart of Timer interrupt Service Routine

4.2.6 Calculating Day of year number from date:

Algorithm for calculating day of year from date:

1. Define an array of 12 elements of type integer.
2. Put number of days in January in element1, number of days in feb in element 2 and so on until the last month i.e. December.
3. Get month, day , year number from RTC.
4. Sum up the value of all the elements starting from first element to the element whose number is one less than the month number.
5. Add the day number to the above result to get the final Day of year number which can be from 0 to 365.
6. Divide year by 4 . If the remainder is 0 i.e. the current year is a leap year and current month is greater than 2 (Feb) then add '1' to the result of Step5 to get the day of year number which can now be from 0 to 366.
7. Return the value of day of the year to the main logic .
8. End.

Flowchart of the algorithm is shown in figure 4.19:

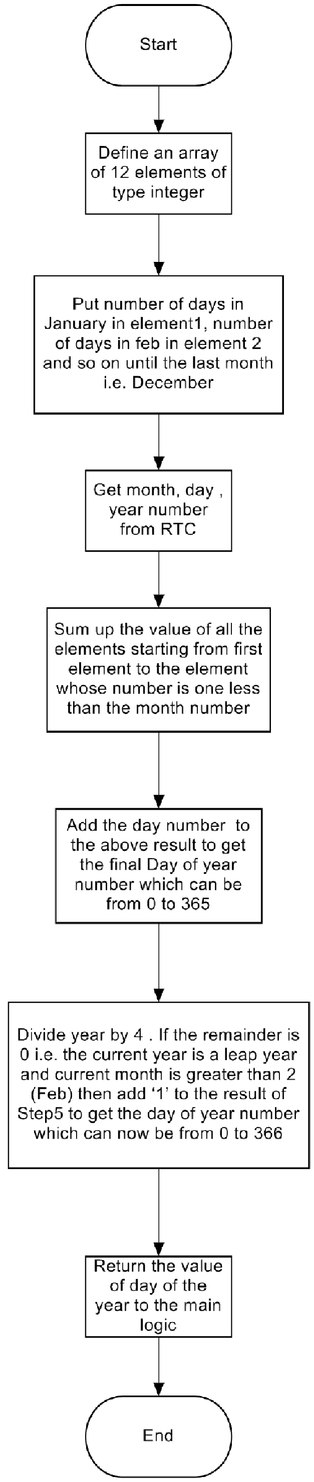
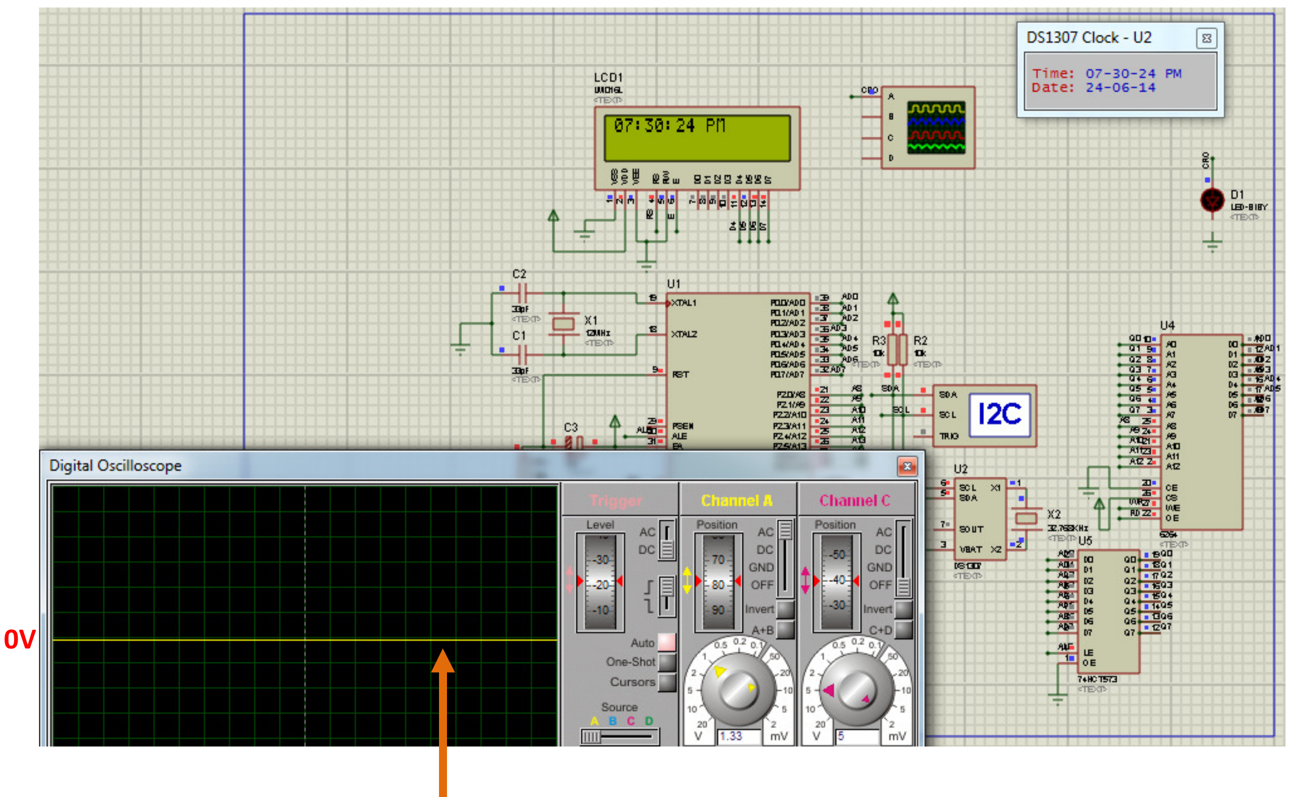


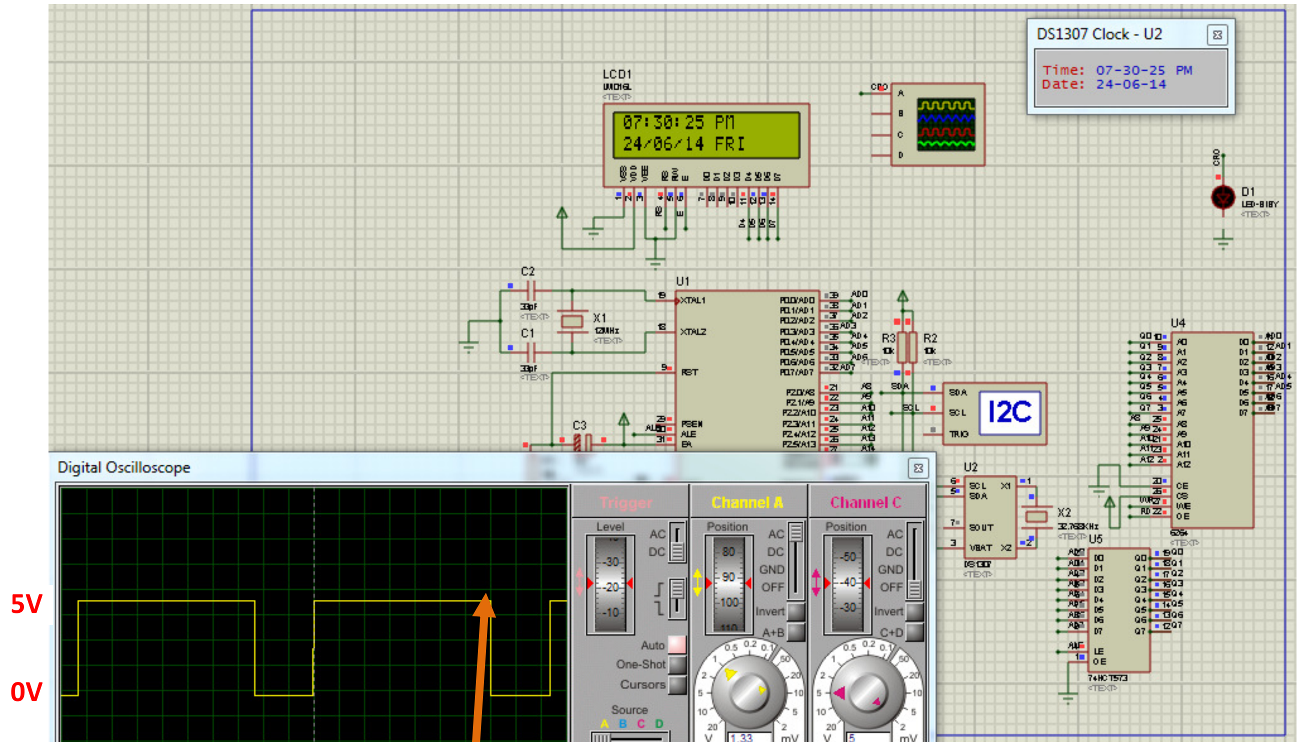
FIGURE 4.19 Flowchart for calculating day of year number from date

5.1 Results

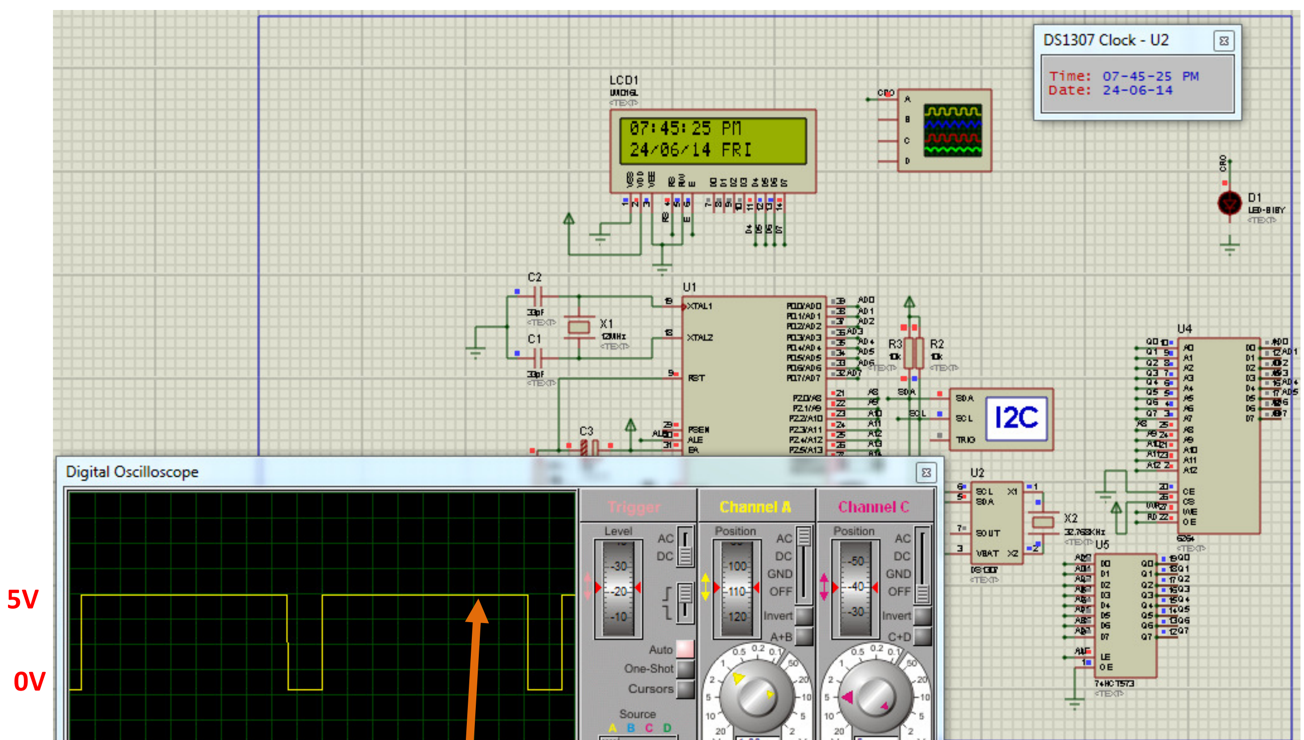
The Control Logic has been tested in Proteus Simulation Environment. When tested for a given date (24 June, 2014) with Dusk time begin data as 7:30:25 PM and Sunrise data of next day as 4:55:11 AM, the Following Real time results have been achieved:



The above Snapshot shows that LED Array is Completely OFF at 7:30:24 PM.

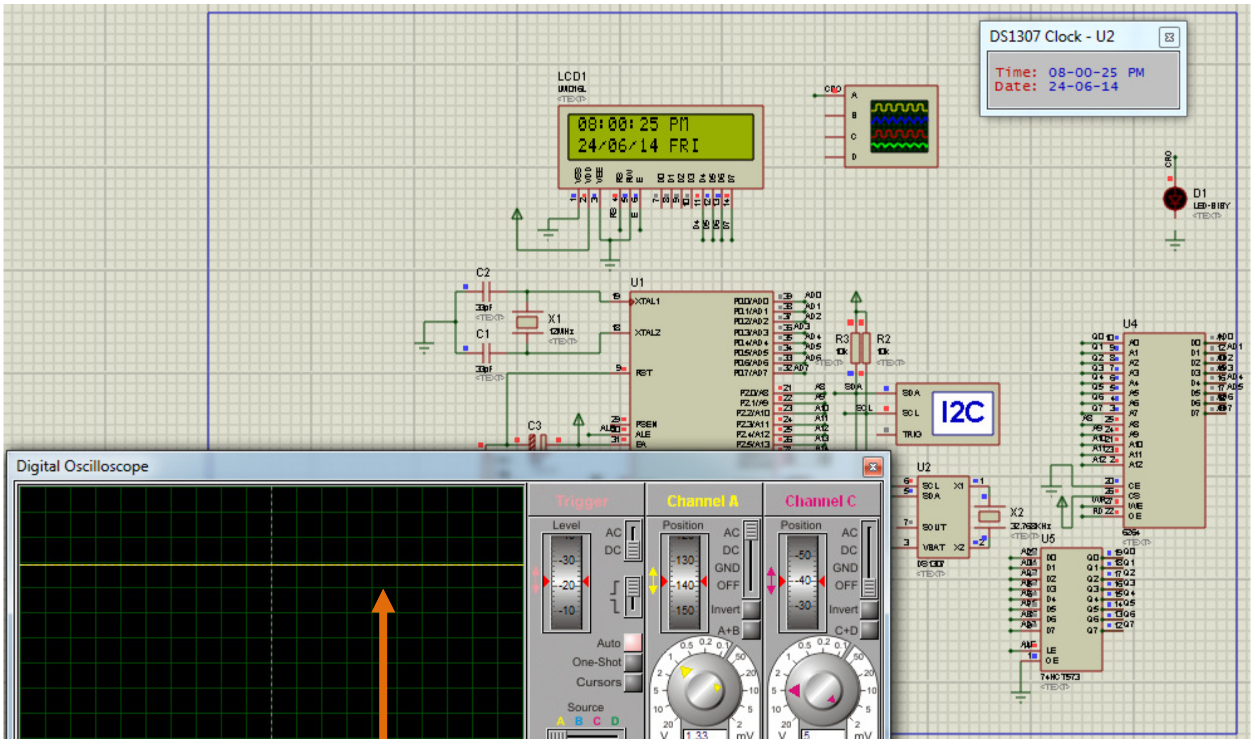


The above Snapshot shows Start of PWM cycle with 75% ON state Duty Cycle at 7:30:25 PM



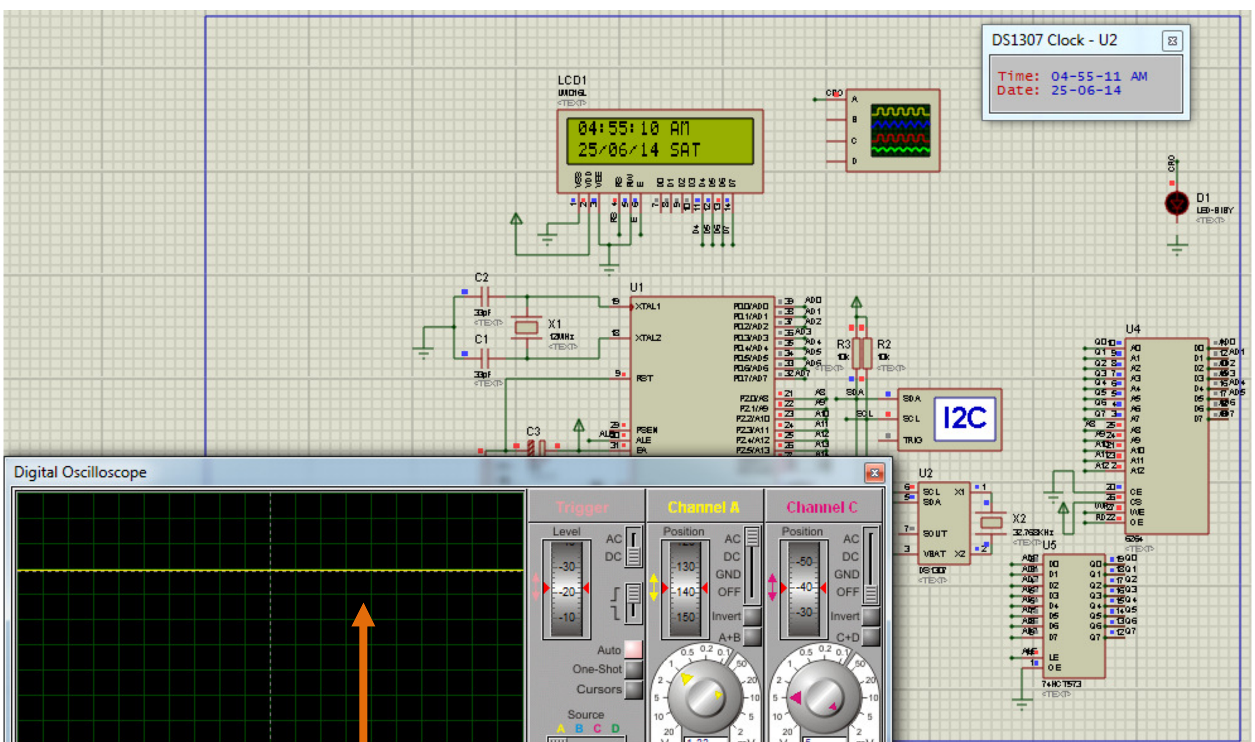
The above Snapshot shows PWM ON state Duty Cycle reaching 87% by 7:45:25PM.

5V

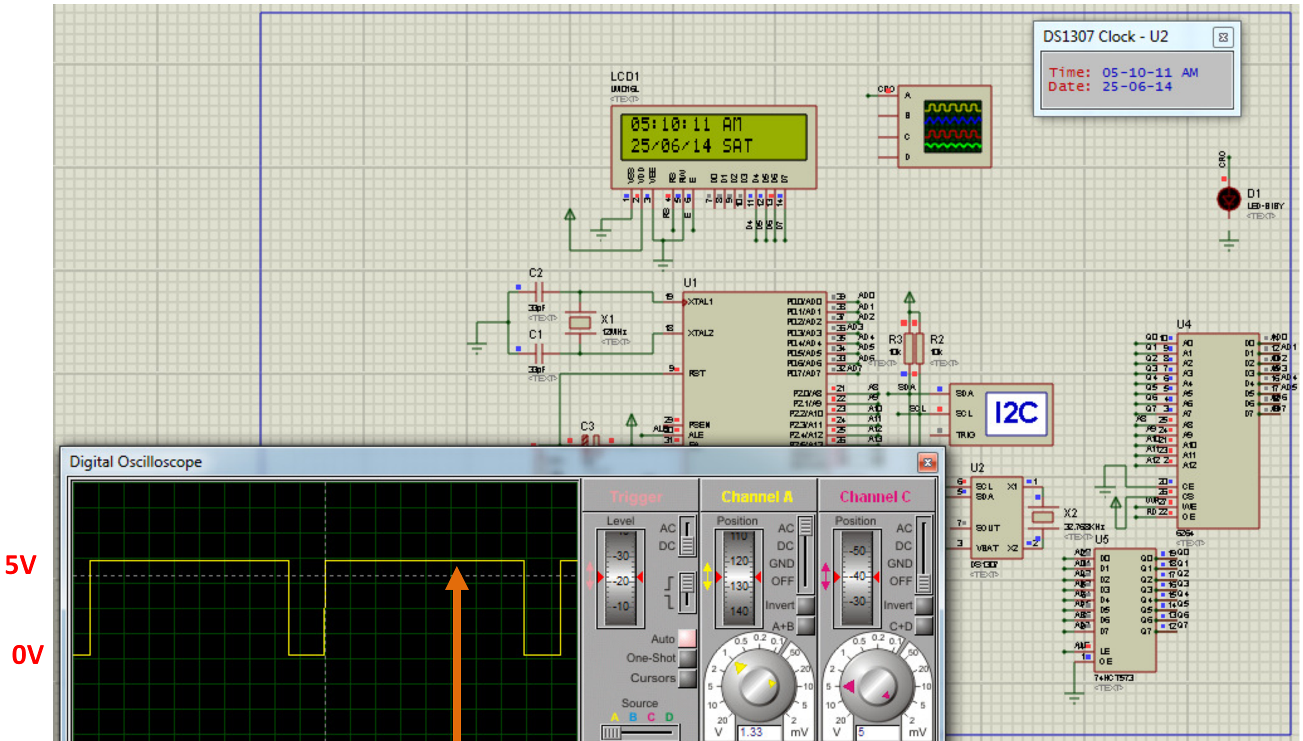


Above Snapshot shows LED array Fully ON by 8:00:25 PM.

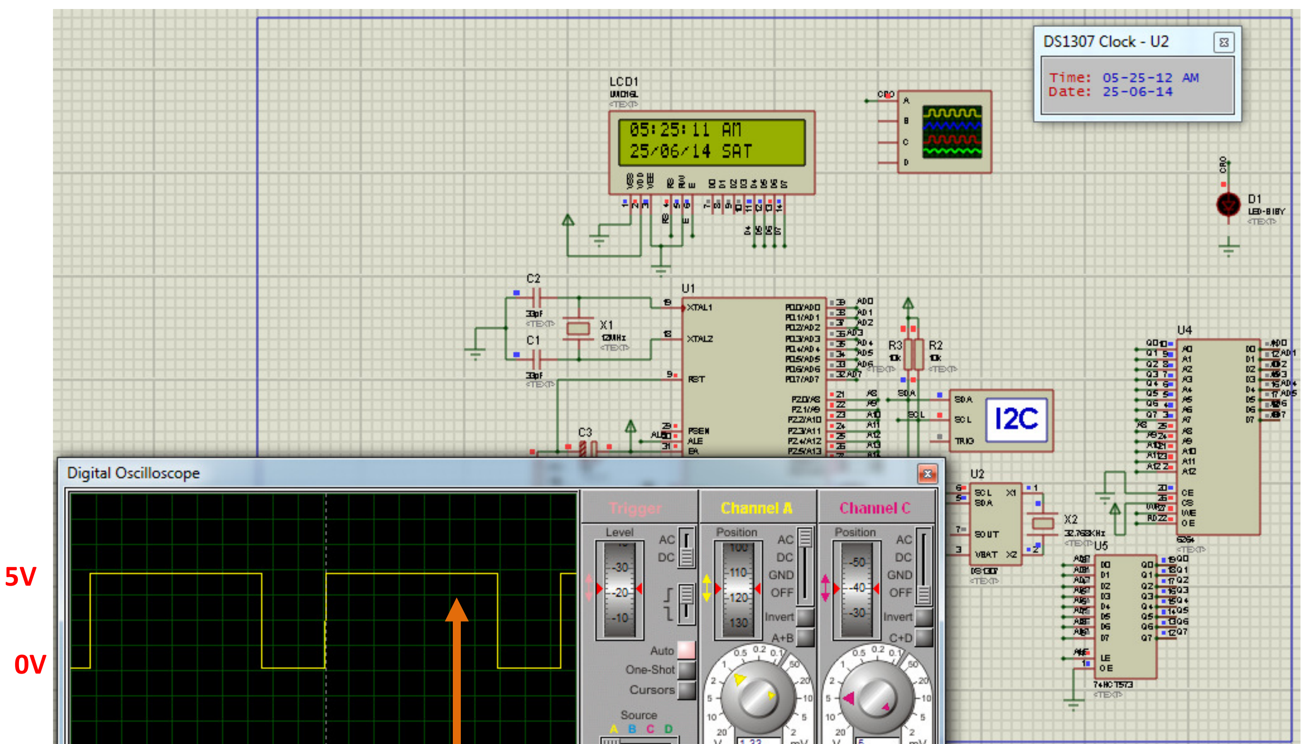
5V



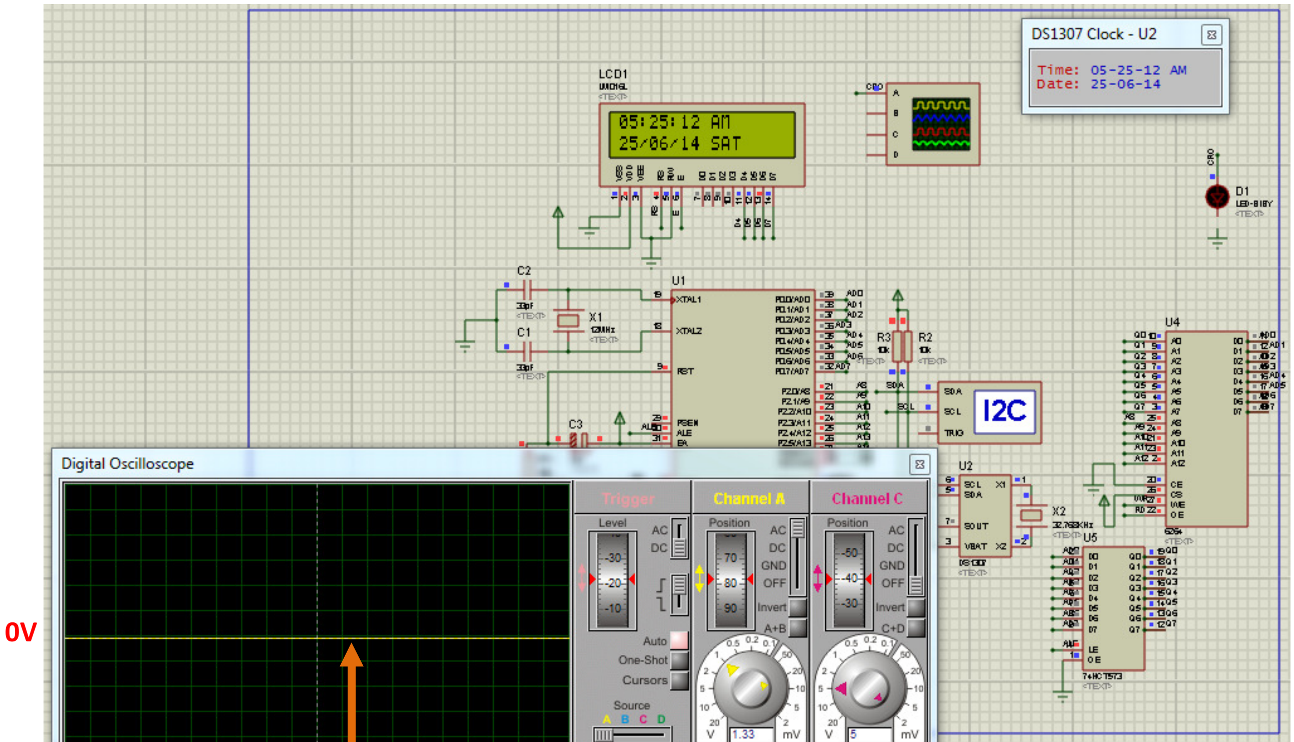
Above Snapshot shows LED array Still Fully On at 4:55:10 AM.



Above Snapshot shows PWM Duty Cycle decreased to 87% by 5:10:11 AM.



Above Snapshot shows PWM Duty cycle reduced to 75% BY 5:25:11 AM.



Above Snapshot shows LED array Fully OFF at 5:25:12AM.

5.2 Calculations related to the amount of Power Saved

Calculations must be done against some reference (Like if the Street light timings are controlled manually).

Hence Power saving has been calculated by Subtracting the amount of Power consumed in Case 1 from the amount of Power consumed in Case 2.

Case 1: Street light operation is controlled as per control logic designed in this Thesis.

Case 2: Street light ON OFF timings are controlled through a hardware timer whose time settings are adjusted manually time to time (i.e. after a period of few months) without any intensity control of Street light LED Lamp, as is presently done in big cities of INDIA.

Analyzing interpretation of Case1 & Case2 with Sunrise Sunset data graph of Chandigarh:

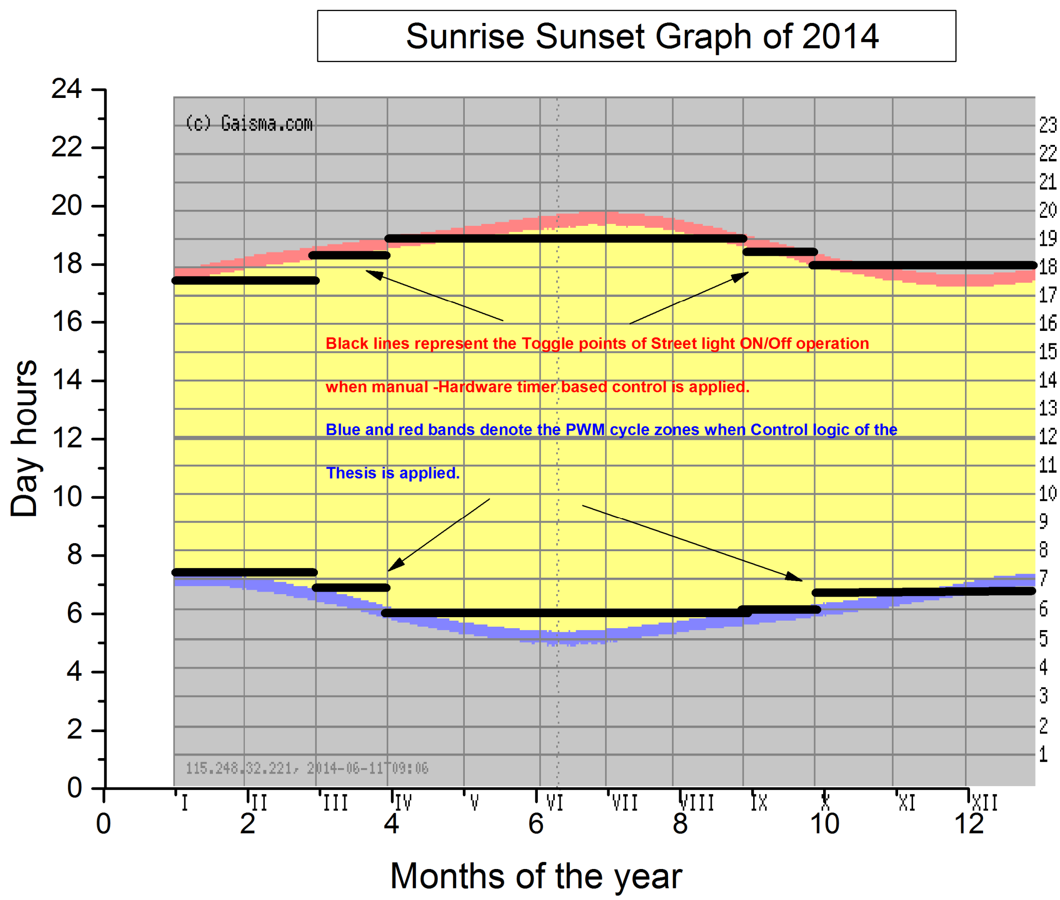


FIGURE 5.1 Interpretation of manual vs. automatic control on Sunrise sunset graph of Chandigarh for the year 2014

Now, Electric power saved in a Year (2014)

$$= \sum_{Day=1}^{Day=365} \text{power saved in a Day.}$$

Power saved in a Day= Power consumed if manual control is applied – Power consumed if Control logic of the thesis is applied.

- Power consumed by street light load in a PWM cycle of 30 minutes=5Watt

,(Calculated by first measuring the individual wattages against 64 equidistant points along the Duty cycle axis in the graph fig. 4.9 and then summing them up.)

'64' is the increment count of the register used in microcontroller for varying PWM duty cycle from 75% to 100%.

- So, Power saved on the first day of 2014 i.e. 1/1/2014

= (power consumed in manual mode from 5:30:20 PM to 6:00:20 PM

- Power consumed by control logic from 5:30:20 PM to 6:00:20 PM)

+ (power consumed in manual mode from 6:35:10 AM to 7:05:10 AM

- Power consumed by control logic from 6:35:10 AM to 7:05:10 AM)

= 36 x 0.5 – 5 x 0.5 + 36 x 0.5 – 5 x 0.5

= 31 Whr

Similarly calculations for each and every day of 2014 have been done and the

Data has been compiled in Tabular format in the following table:

TABLE 5.1 Calculations for amount of power saved in 365 days of the year 2014

Day No.▼	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	31	41.8	31	15	38	49.23	56	38	31	24.68	3.1	-1.1
2	31	41.8	31	15.25	38.45	49.46	55.2	37.7	30.37	24.36	2.8	-1.0
3	31	41.85	31	15.5	38.9	49.69	54.4	37.3	29.74	24.04	2.8	-0.8
4	31.5	41.9	31.5	15.75	39.35	49.92	53.6	37	29.11	23.72	2.2	-0.7
5	31.5	41.9	31.5	16	39.8	50.15	52.8	36.6	28.48	23.4	2.2	-0.6
6	31.6	41.95	31.6	16.25	40.25	50.38	52	36.3	27.85	23.08	2.0	-0.5
7	31.6	41.95	31.6	16.5	40.7	50.61	51.2	36	27.22	22.76	1.8	-0.5
8	31.6	41.2	31.7	16.75	41.15	50.84	50.4	35.5	26.59	22.44	1.5	-0.4
9	31.7	42	31.7	17	41.6	51.07	49.6	34.9	25.96	22.12	1.5	-0.2
10	31.7	42.8	31.8	17.25	42.05	51.3	48.8	34.2	25.33	21.8	1.4	-0.2
11	31.7	43.6	31.8	17.5	42.5	51.53	48	33.5	24.7	21.48	1.35	-0.1
12	31.8	44.4	32	17.75	42.95	51.76	47.2	33	24.07	21.16	1.2	0.0
13	31.8	45.2	32.5	18	43.4	51.99	46.4	32.4	23.44	20.84	1.1	0.1
14	31.8	46	33	18.25	43.85	52.22	45.6	31.7	22.81	20.52	1.1	0.5
15	32	46.8	33.5	18.5	44.3	52.45	44.8	31	22.18	20.2	1.1	0.6
16	32	47.6	34	18.75	44.75	52.68	44	30.1	21.55	19.88	1.1	0.7
17	32	48.4	34.6	19	45.2	52.91	43.2	29.2	20.92	19.56	0	0.7
18	32.5	49.2	35.2	19.25	45.65	53.14	42.4	28.8	20.29	19.24	0	0.8
19	33	50	35.8	19.5	46.1	53.37	41.6	27.7	19.66	18.92	0	0.9

20	33.5	51	36.4	20	46.55	53.6	40.8	26.5	19.03	18.6	-0.5	0.9
21	34	52	37	21	47	53.38	40	25.7	18.4	18.28	-0.5	1.0
22	34.5	53	37.6	22	47.45	54.06	39.2	24.1	17.77	17.96	-0.6	1.1
23	35	54	38.2	23	47.9	54.29	38.4	23	17.14	17.64	-1	1.1
24	35.5	55	38.8	24	48.35	54.52	37.6	22	16.51	17.32	-2	1.1
25	36	56	39.4	25	48.8	54.75	36.8	21	15.88	17	-3	1.15
26	36.5	57	40	26	49.25	54.98	36	19.8	15.25	16.68	-4.5	1.6
27	37	58	40.6	27	49.7	55.21	35.2	18.2	14.62	16.36	-4.8	1.9
28	37.5	59	41.2	28	50.15	55.44	34.4	17	13.99	16.04	-6.0	2.5
29	38	X	41.8	29.5	50.6	55.67	33.6	16	13.36	15.72	-7.0	2.8
30	38.5	X	42.4	30	51.05	55.9	32.8	15	12.73	15.4	-8.5	2.9
31	39	X	43	X	51.5	X	32	15.5	X	15.08	-9.0	2.9
Total	1037.8	1335.35	1378.5	603.25	1387.55	1576.5	1364	884.7	655.95	616.28	-19.15	19.16

Total Power Saved in 2014 = Sum of all the entries of the above table

= **10.84 KWhr**

Note: If Timings of doing correction of ON /OFF settings in manual control (Case 2) of Street Light are taken as per the author of [15] then the Amount of power saved in 2014 comes out to **18.766 KWhr**

TABLE 5.2 Comparison Summary of results derived from the System Designed in this Thesis with some already published Research Papers:

	Energy saved yearly per Lamp in KWhr	Inclusion of Astronomical Sunrise sunset database	Reliability and ease of maintenance	Cost effectiveness	Degree of preciseness of control logic
This Thesis	18.766/10.84*	Yes	Yes	Yes	High
Paper[15]	15.96	Partially	Yes	Yes	Good
Paper[14]	_ _ _	no	Yes	Yes	Low
Paper [12]	_ _ _	no	No (due to LDR)	Yes	Good
Paper [11]	_ _ _	no	No (due to LDR)	Yes	High
Paper[10],[5]	High		no	No(due to zigbee nodes, Central server e.t.c	high
Paper[3],[4],[7],[8]	High	no	No(wireless sensor networks)	no	high
Paper[1]	Low	no	Yes	Yes	Low

*10.84 KWhr per year as per reference standards assumed in this Thesis & 18.766 KWhr if reference standards are taken as per author of [15].

5.3 Discussion

Thus from the above Results and Calculations we find that 10.84 KWhr power will be saved in an year(2014) by Control logic of this Thesis against manual control in which the correction of Time setting of hardware timer is done 5 times in the year(i.e. beginning of January, March, April, September, October) by the technician.

If data of timings of doing correction of Street light ON/OFF settings in Manual control mode is taken as per the author of [15] then the amount of power saving comes out to be 18.766 KWhr for the year 2014.

Even if the technician does correction of time settings more frequently and precisely, the maximum frequency in that case can be on a daily basis, there will still be a power saving of ((36 x 1 -5 x 1) x 365)=11.3KWhr due to gradient intensity control of LED street light followed in the Control logic of Thesis.

Chapter 6: Conclusion and Future Scope

6.1 Conclusion

In the proposed thesis an attempt has been made to design a microcontroller based Street light Control system.

The proposed system uses a Microcontroller AT89C51, RTC DS1307 and external memory SRAM 6464 .The control logic is written in 'C' language using 'KEIL' compiler. The evaluation of the circuit and code has been done in Proteus software. Calculations have been done for annual power savings. It has been found out that energy saved per Street lamp is 10.84KWhr per year (as per reference standards assumed in this Thesis) and 18.766 KWhr (If reference standards are taken as per Joshi et al. [15]).

A time based intensity control system of LED Street lighting has been successfully designed. The system is simple and cost effective as compared to wireless sensor network based systems. Moreover its performance does not depend upon dust, moisture, temperature unlike sensor based systems.

If this system is used with existing grids in India with thousands of lights per grid, there would be a huge energy saving.

6.2 Future Scope

1. The data of duration of time band between dawn to sunrise and dusk to sunset is not available precisely at present over the internet and other resources.

Also the rate at which luminous intensity received by sun at the surface of particular location on the Surface of earth rises and falls during dawn to sunrise and dusk to sunset is also not elaborated.

Thus, the Control logic can be modified after considering the above data in Future.

2. The system designed is not adaptable to the unknown and unpredictable variations like Clouds, Humidity variations in environment, changes in refractive index of atmosphere, Wind speed on the earth surface, big volcano eruptions e.t.c which affects the Sunrise time and duration of daylight.

Thus future modification would be to design an artificial Intelligence based system which may be used in such situations.

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