

# **Title of the Project**

## **Development and Performance Study of a Microcontroller-Based Solar Radiation Measuring System**

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A Project Report Presented in Partial Fulfillment of the  
Requirements of the Degree Bachelor of Science in  
Electronics and Telecommunication Engineering



**Department of Electronics and Communication Engineering**

**EAST WEST UNIVERSITY, AFTABNAGAR,**

**DHAKA, BANGLADESH**

**DECEMBER, 2014**

## *Declaration*

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We hereby declare that this project is based on the results found by ourselves. We have completed the project on the topic entitled “**Developed and Performance Study of a Microcontroller Based Solar Radiation Measuring System**” as well as prepared as research report to the Department of Electronics and Communication Engineering of East West University in partial fulfillment of the requirement for the degree of B.Sc.in Electronic and Telecommunication Engineering, under the supervision of **Dr. Md. Habibur Rahman, Professor, Department of Applied Physics, Electronics and Communication Engineering, Dhaka University.**

Signature

.....  
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Professor, APECE,  
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**Md. Majadul Islam Lemon**  
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# *Acceptance*

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This project has been prepared and submitted by **Mahmud Anzir, ID:2011-1-55-013** and **Md. Majadul Islam Lemon, ID:2011-1-55-032**. This project report presented to the Department of Electronics and Communication Engineering, East West University is submitted in partial fulfillment of the requirement for the degree of B.Sc.in Electronic and Telecommunication Engineering, under complete supervision of the undersigned.

Signature

.....

**Dr. Md. Habibur Rahman**  
**Professor, APECE,**  
**Dhaka University.**

## *Acknowledgement*

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First of all we wish to convey our heartfelt thanks to almighty Allah because we have completed the project successfully. We have deeply done our project and we have gained various knowledge. We thank and express our gratitude to our supervisor, **Dr. Md. Habibur Rahman**. He has been a constant source of inspiration throughout the period of this work. We consider ourselves lucky for having the opportunity to work under his supervision during the total period of work. Finally, we are also very grateful to all of our teachers and friends for their encouragement throughout our project and our academic life. We are forever grateful to our parents for their patience and love.

## *Abstract*

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Measurement of solar radiation is essential for determining the viability of a solar system in a particular place. The conventional measuring system embraces some instruments which are very costly. The target of this project is to develop and study the performance of a microcontroller based solar radiation measuring system with locally available low cost components. In this project, ARDUINO UNO has been used as microcontroller and the source code has been written in arduino software by using arduino C programming. As the sensor of the system a tiny solar cell has been used. The cell converts the solar radiation into current. A current to voltage converter (C-V) has been used to get voltage for the microcontroller. The output voltage of the C-V unit is converted into digital value and then displayed in LCD. We have also applied our own logical policy and used some vital instruments to reach the destination of this project. The system has been calibrated using a standard pyranometer. Using the system we have measured the radiation for some days. The entire practical outcomes are presented in this report.

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# Chapter One

## INTRODUCTION



## **1.1 Motivation:**

Sun is the main source of power. And this power is called solar power. By using this power we easily make current. The sun is a sphere of intensely hot gaseous matter with a diameter of  $1.39 \times 10^9$  m and is, on the average  $1.5 \times 10^{11}$  m from the earth<sup>[1]</sup>. Solar energy technologies use the sun's energy and light to provide heat, light, hot water, electricity, and even cooling, for homes, business and industry<sup>[2]</sup>. The sun delivers large amount of energy to the surface of the earth. The work about microcontroller based solar radiation measuring system play an important role for self learning, knowing and experience.

## **1.2 Aim of the Project:**

Every project must have a definite aim in its way. An aimless way is just like a boat without a rudder. And a boat without a rudder cannot reach ashore. The aim of this project is find the suitable time at which that the solar power is most effective and can produce maximum electricity to be utilized. And observe how the solar intensity varies throughout the day and affect in different conditions.

## **1.3 Project in Brief**

### **1.3. A. Development of circuit**

At first, we have known about all the components, related to the work. Then we have gained the basic knowledge. Finally we have applied our merit and creative technical logical policy in order to develop the circuit properly.

### **1.3. B. Documentation of Data:**

All the data those had been collected have recorded. We have maintained sincerity during taking the data. After approval from the supervisor, all the data have been implemented into the final report.

## **1.4 Outline of the Project:**

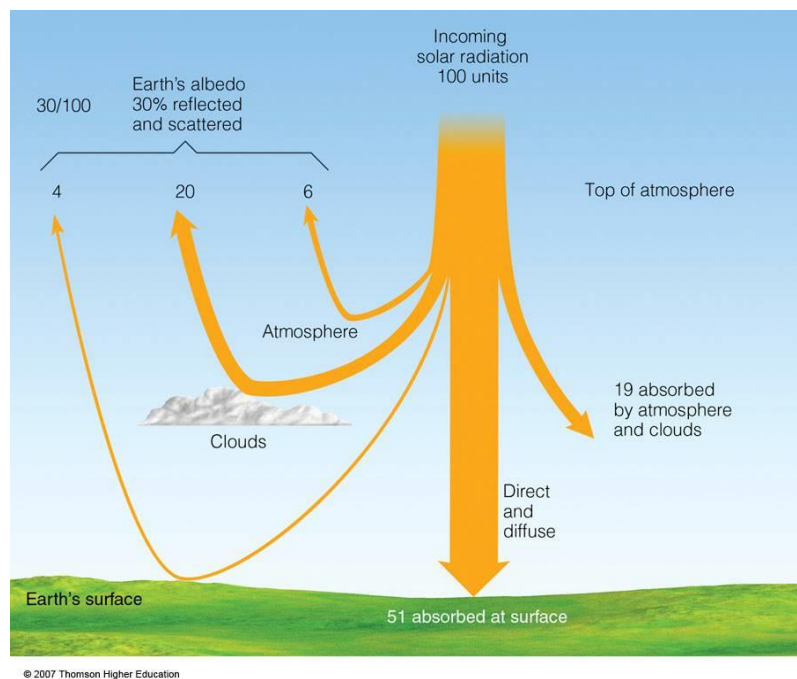
There are four chapters in this that describes in details. Chapter one is the introduction. It contains the motivation, aim of the project, development of circuit, documentation of data, and outline of the project. Chapter two contains the theoretical framework of the project. This chapter includes various important theoretical frameworks such as solar radiation, solar constant, measuring solar radiation, pyranometer, solar cell, microcontroller, ARDUINO-UNO device overview, LCD display etc. Chapter three contains the system design. Hardware design and software design are also shown here. Chapter four focuses the results of the project. Then conclusion has given. At last, reference has given.

## Chapter Two

# THEORETICAL FRAMEWORK

## 2.1 Solar Radiation

Solar radiation is the radiation, or energy we get from the sun. It is also known as short-wave radiation. Solar radiation comes in many forms, such as visible light, radio waves, heat (infrared), x-rays, and ultraviolet rays [3]. Measurements for solar radiation are higher on clear, sunny day and usually low on cloudy days. When the sun is down, or there are heavy clouds blocking the sun, solar radiation is measured at zero. The sum of the beam and the diffuse radiation on a surface is total solar radiation. The most common measurement of solar radiation is total radiation on a horizontal surface, often referred to as global radiation. The energy we get from sun is 125000 TW which is 8000 of world's need of electricity.



**Figure: Solar Radiation**

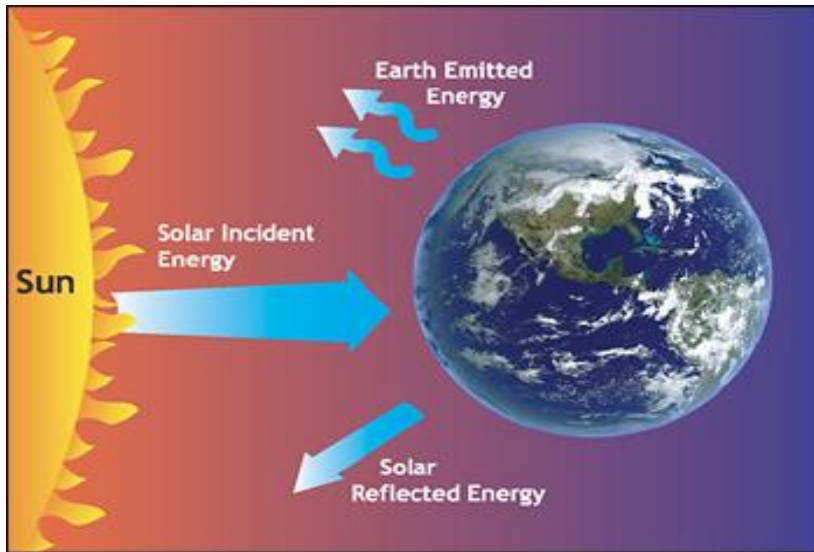


Figure: Solar Radiation [5]

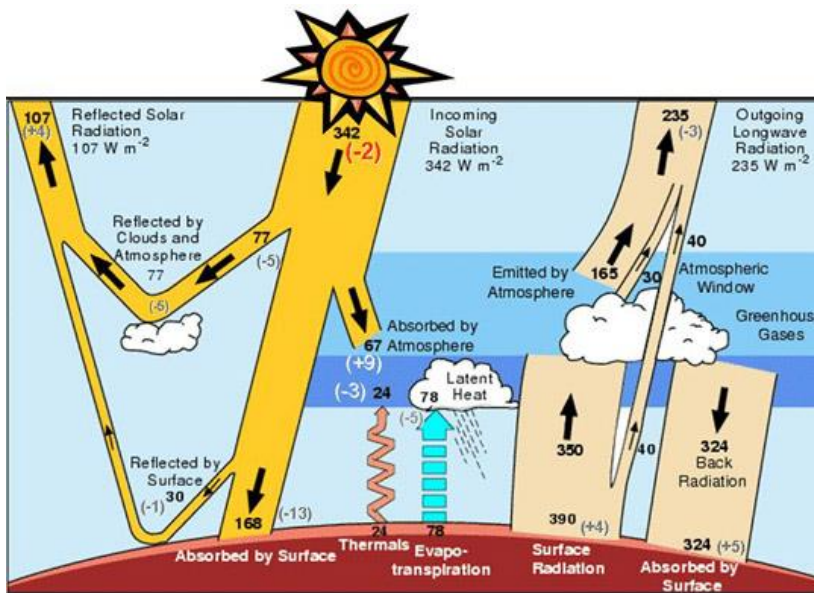


Figure: Solar Radiation [5]

## 2.2 The Solar Constant

The radiation emitted by the sun and its spatial relationship to the earth result in a nearly fixed intensity of solar radiation outside of the earth's atmosphere.

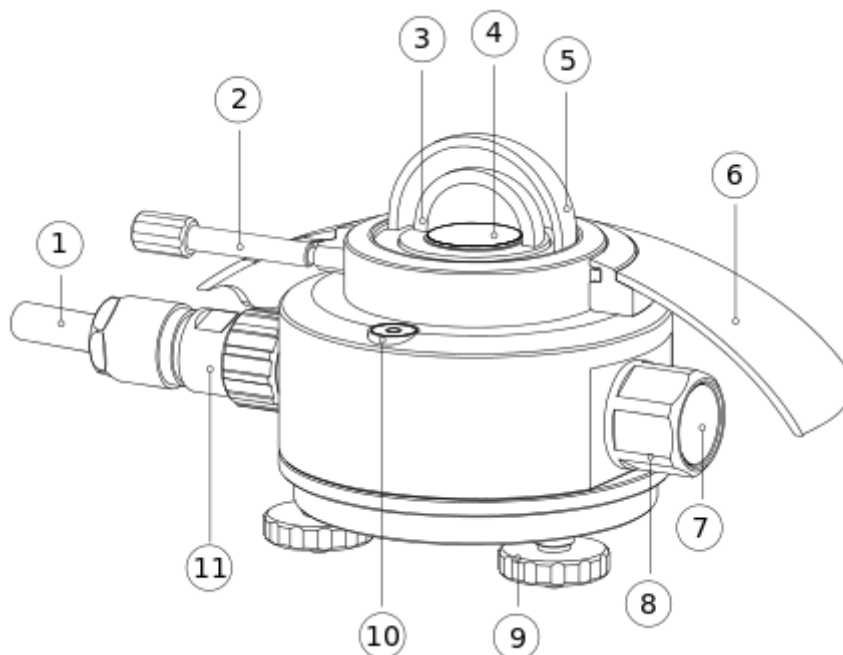
The solar constant  $G_{sc}$  is the energy from the sun, per unit time, received on a unit area of surface perpendicular to the direction propagation of the radiation, at the earth's mean distance from the sun outside of the atmosphere.

## 2.3 Measuring solar radiation

Two types of basic instruments are used to measuring solar radiation, pyranometer and pyrheliometer [6].

## 2.4 Pyranometer

### 2.4. A. Design and Function of Pyranometer

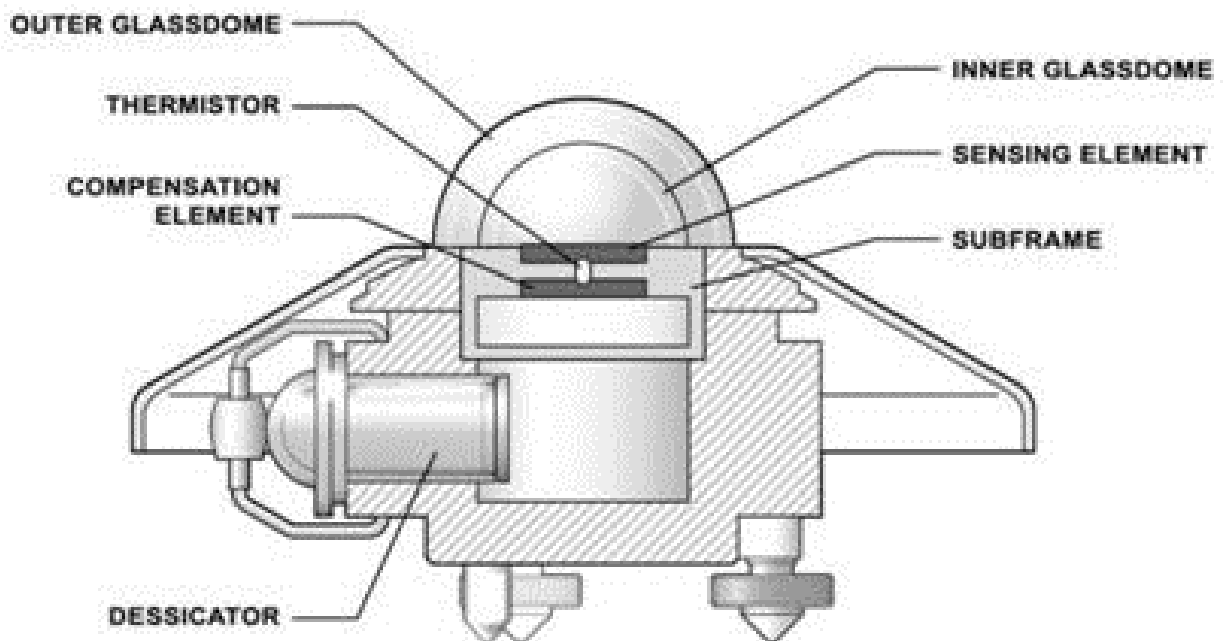


In order to attain the proper directional and spectral characteristics, a pyranometer's main components are:

A thermopile sensor with a black coating. This sensor absorbs all solar radiation, has a flat spectrum covering the 300 to 50,000 nanometer range, and has a near perfect cosine response.

A glass dome, this dome limits the spectral response from 300 to 2,800 nanometers (cutting off the part above 2,800 nm), while preserving the 180 degrees field of view. Another function of the dome is that it shields the thermopile sensor from convection.

The black coating on the thermopile sensor absorbs the solar radiation. This radiation is converted to heat. The heat flows through the sensor to the pyranometer housing. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation [7].



A typical analog pyranometer does not require power to operate and consists of a thermopile sensor beneath a glass dome. The thermopile absorbs all the solar radiation which encounters it and generates a small, proportional output voltage. Pyranometers are typically used on or near solar panels to facilitate optimum panel positioning.





**Figure: A handheld digital pyranometer.**

Digital pyranometers are used to record and analyze irradiation data. They are typically capable of outputting data in serial form. As shown in the image above, digital pyranometers may be handheld for taking field measurements<sup>[8]</sup>.

## **2.4.B. Eppley Precision Spectral Pyranometer**

The instruments for measuring total radiation are referred to as pyranometers, and from these instruments most of the available data on solar radiation are obtained. The detectors for these instruments have a response independent of wavelength of radiation over the solar energy spectrum<sup>[6]</sup>.

In addition they have a response independent of the angle of incidence. The detectors are covered with hemispherical glass covers to protect them from wind and other extraneous effects. In the Eppley precision spectral pyranometer uses a thermopile as detector. It has two concentric hemispherical optically ground covers and temperature compensation that results in temperature dependence of only 0.5% from -20°C to +40°C.



**Figure : Eppley Precision Spectral Pyranometer**

### **2.4.C. Uses of Pyranometer**

In fact, they are used in climatology, solar energy studies, building physics meteorology etc. Even they may be seen in many meteorological stations, classically installed horizontal and next to solar panels- classically mounted with sensor surface in the plane of the panel.

## **2.5 Solar Cell**

A solar cell produces more electricity in the shiner part of the cell. A solar cell is an electronic device which directly converts sunlight into electricity <sup>[9]</sup>. Light shining on the solar cell produces both a current and a voltage to generate electric power. The process of conversion first requires a material which absorbs the solar energy (photon), and then raises an electron to a higher energy state and then the flow of this high-energy electron to an external circuit. Silicon is one of the examples of such material that uses such process. Voltage is generated in a solar cell by a process known as the photovoltaic effect.

### **2.5.A. Efficiency of Solar Cell**

Solar cell efficiency refers to the amount of usable electricity can be produced from sunlight. There are two ways to evaluate photovoltaic solar cell efficiency. They are solar cell efficiency and solar panel efficiency <sup>[10]</sup>. Solar cell efficiency is the amount of light that the individual solar cell converts to electricity solar cells are placed next to one another on top and are covered by glass to make up a solar panel.

## **2.6 Microcontroller**

### **2.6.A. What is a Microcontroller?**

A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. Most programmable microcontrollers that are used today are embedded in other consumer products or machinery including phones, peripherals, automobiles and household appliances for computer systems. Due to that, another name for a microcontroller is “embedded controller.”

The term microcomputer is used to describe a system that includes at minimum a microprocessor, program memory, data memory, and an input-output (I/O) device. Some microcomputer systems include additional components such as timers, counters, and analog-to-digital converters <sup>[11]</sup>. Thus, a microcomputer system can be anything from a large computer having hard disks, floppy disks, and printers to a single chip embedded controller.

## **2.6. B. Merits of Microcontroller**

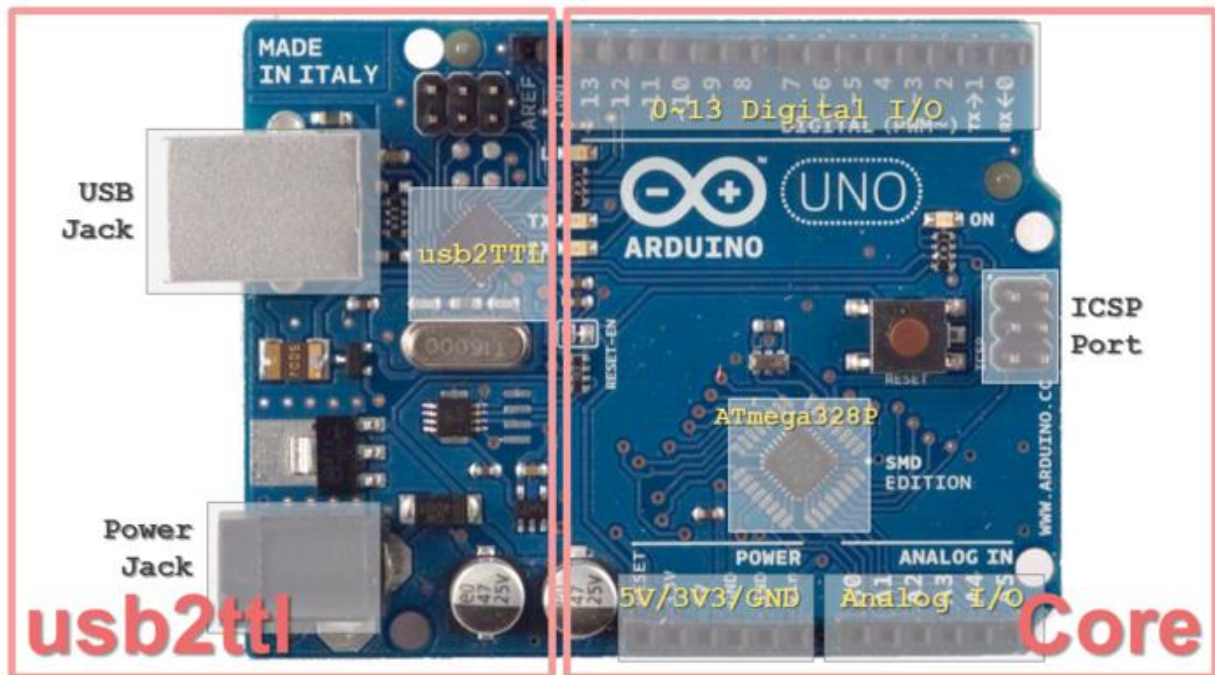
- Single Purpose
- For application for which cost, power and space are critical
- Easy integration with circuits
- Lots of I/O capabilities
- Programmable, Re-programmable
- Low Power consumption
- Low cost
- small packaging

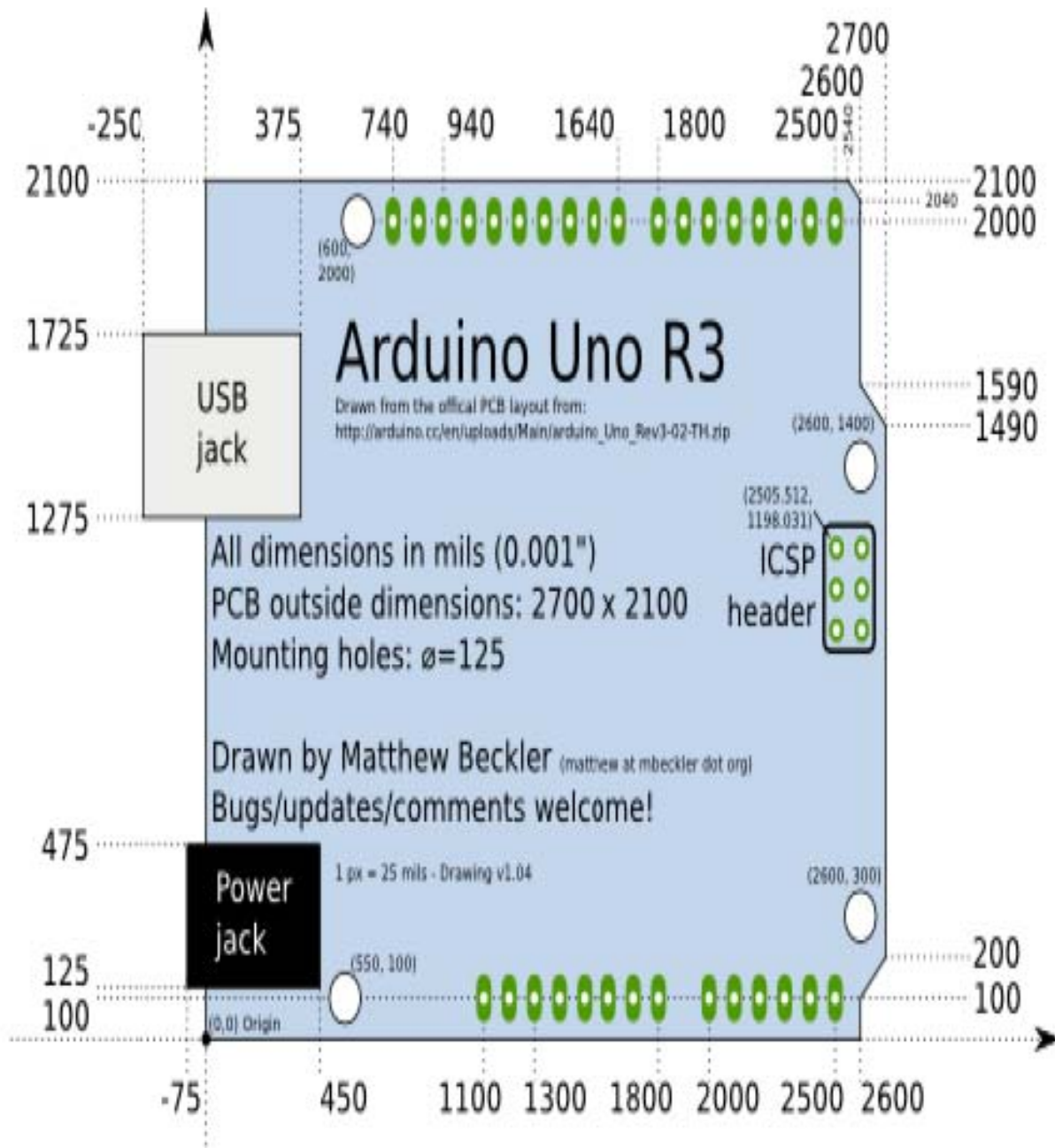
## 2.6.C. How can we select a microcontroller?

- Amount of RAM and ROM on chip.
- Wide availability and reliable sources of the MCU
- Meeting the computing needs of task at hand efficiently and cost effectively
- Maximum speed of the microcontroller
- Availability of software and hardware development tools such as compilers, assembler etc.
- A timer module to allow the microcontroller to perform tasks for certain time period.
- A serial I/O port to allow the data to flow between microcontroller and other device that support serial interface such as PC or others microcontroller.
- An ADC to allow the microcontroller to accept analogue input data for processing.

## 2.7 ARDUINO- UNO

It is a microcontroller. Arduino refers to an open-source electronics platform or board and the software used to program it. Arduino is designed to make electronics more accessible to artists, designers, hobbyists and anyone interested in creating interactive objects or environments <sup>[12]</sup>. An Arduino board can be purchased pre-assembled or because the hardware design is open source, built by hand. Either way, users can adapt the boards to their needs, as well as update and distribute their own versions.







## 2.7.A. Device Overview

An Analog to Digital Converter (ADC) is a very useful feature that converts an analog voltage on a pin to a digital number. By converting from the analog world to the digital world, we can begin to use electronics to interface to the analog world around us. Not every pin on a microcontroller has the ability to do analog to digital conversions. On the Arduino board, these pins have an 'A' in front of their label (A0 through A5) to indicate these pins can read analog voltages. ADCs can vary greatly between microcontroller. The ADC on the Arduino is a 10-bit ADC meaning it has the ability to detect 1,024 ( $2^{10}$ ) discrete analog levels. Some microcontrollers have 8-bit ADCs ( $2^8 = 256$  discrete levels) and some have 16-bit ADCs ( $2^{16} = 65,535$  discrete levels). The way an ADC works is fairly complex. There are a few different ways to achieve this feat, but one of the most common techniques uses the analog voltage to charge up an internal capacitor and then measure the time it takes to discharge across an internal resistor. The microcontroller monitors the number of clock cycles that pass before the capacitor is discharged. This number of cycles is the number that is returned once the ADC is complete.

The microcontroller on the Arduino board has 512 bytes of EEPROM: memory whose values are kept when the board is turned off (like a tiny hard drive).

This library enables we to read and write those bytes.

The Atmega controllers used for the arduino contain an on board 6 channel analog to digital (A/D) Converter. The converter has 10 bit resolution returning

integers from 0 to 1023. The analog pins can be used identically to the digital pins, using the aliases AO (for analog input O) AL etc. The analog pins also have pull-up registers which work identically to pull-up resistors on the digital pins. The pins on the Arduino can be configured as either inputs or outputs. This document explains the functioning of the pins in those modes. While the title of this document refers to digital pins, it is important to note that vast majority of Arduino (Atmega) analog pins, may be configured, and used, in exactly the same manner as digital pins.

Ultimately the analogue and digital grounds are at the same potential. However in order to prevent noise being injected from the digital side to the analogue side all analogue sources should be connected to the analogue ground and only connected to the digital side at one point. This is done on the PCB. When laying out a PCB for low noise operation this should be done with a so called starred ground.

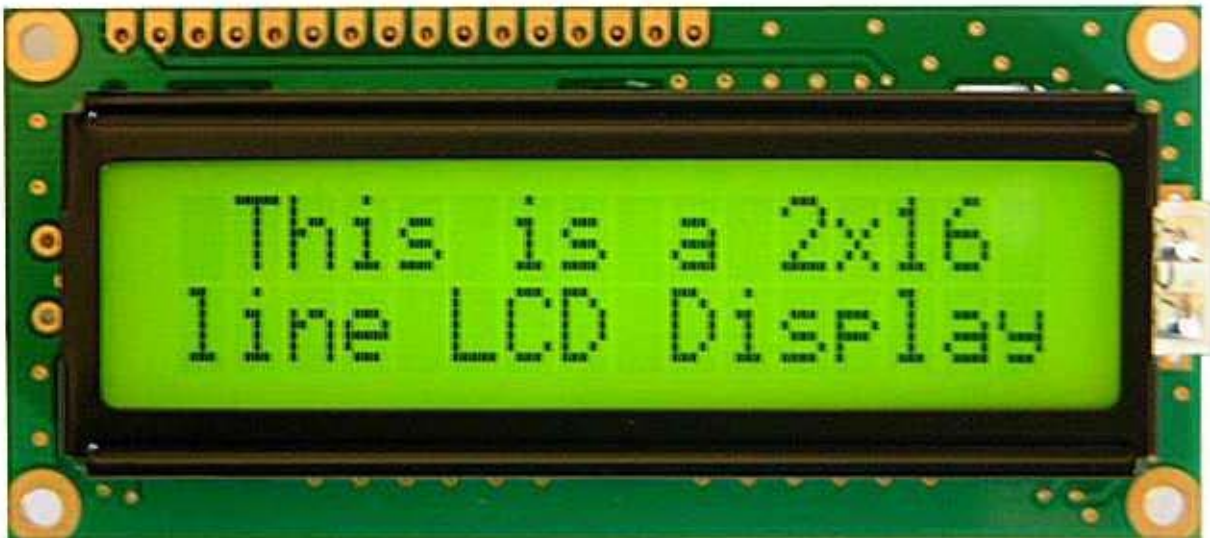
## 2.7.B. Merits of Arduino Uno

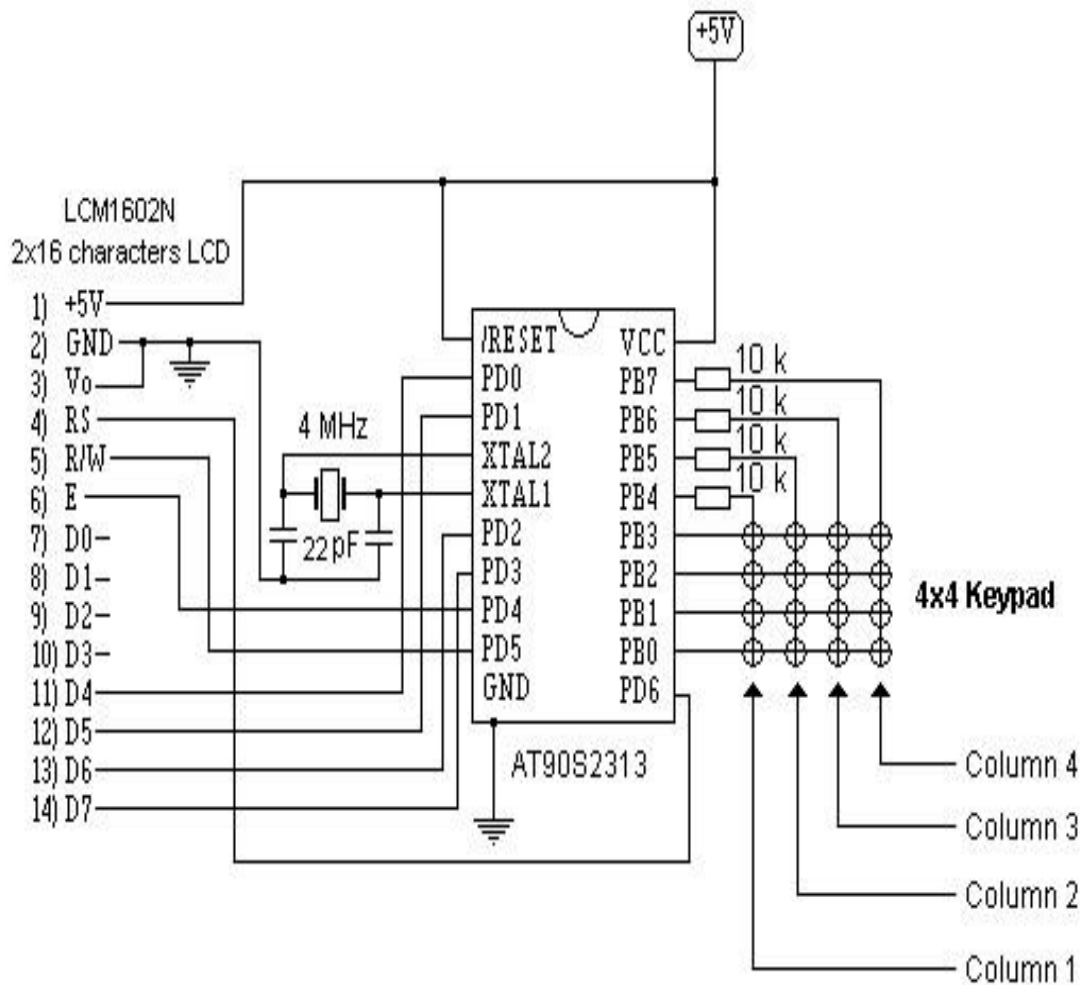
The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board<sup>[12]</sup>. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a wire library to simplify use of the I2C bus. For SPI communication, use the SPI library.

## 2.8 LCD Display (2×16)





27-05-2003 By Serasidis Vasilis  
[www.serasidis.gr](http://www.serasidis.gr)  
[info@serasidis.gr](mailto:info@serasidis.gr)

### **LCD (2×16):**

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 2x16 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs<sup>[5]</sup>. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A **2x16 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

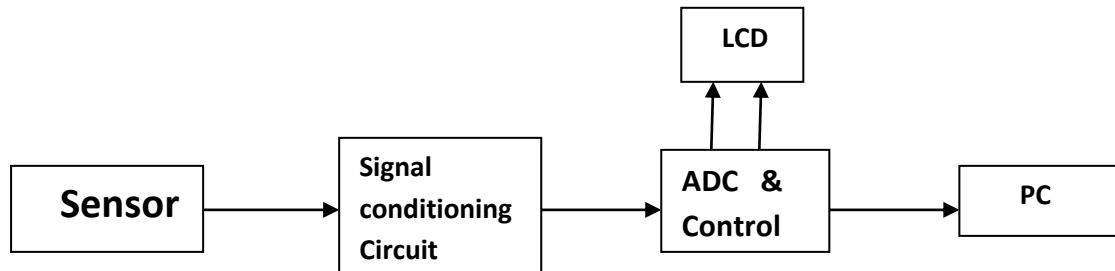
The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD <sup>[4]</sup>. The data is the ASCII value of the character to be displayed on the LCD. We can learn more about internal structure of a LCD.

# Chapter-Three

## System Design

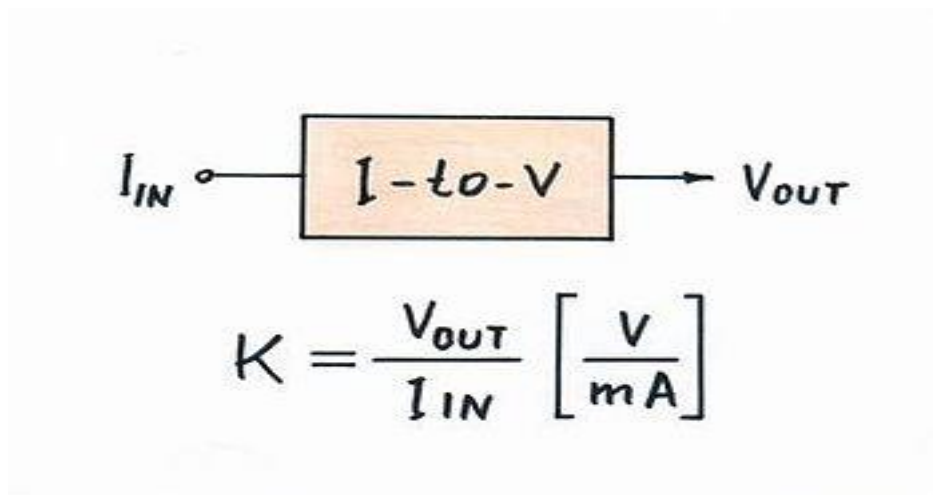
## 3.1 Hardware Design

### 3.1.A. System Block Diagram :



### Sensor

This sensor converts into current to voltage. As regards the circuit inputs, we prefer current to voltage as an input quantity. Only, some devices have a current input. In these cases, we connect a current-to-voltage converter before the device; as a result, it acquires a current input and voltage output.



**Basic electrical idea: *Current causes voltage***



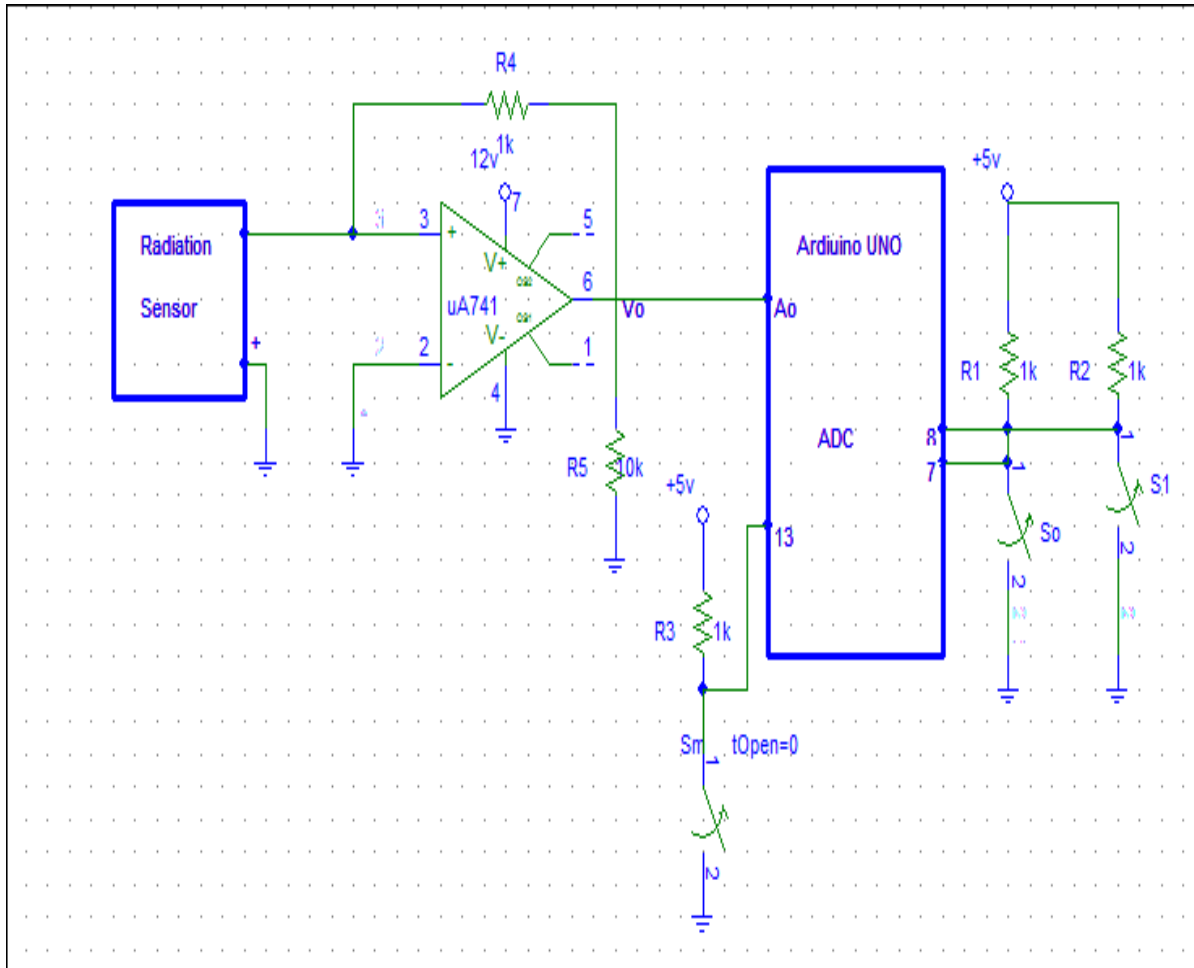
# Signal conditioning Circuit

This circuit converts an input current to a proportional amount of voltage. Use the two switches to select an input current. This current flows across a 1k resistor. The op-amp outputs a voltage equal to the voltage drop across the resistor in order to ensure that the – terminal is at ground, which means that the output voltage is proportional to the resistor voltage (and therefore to the input current).

## ADC & Control

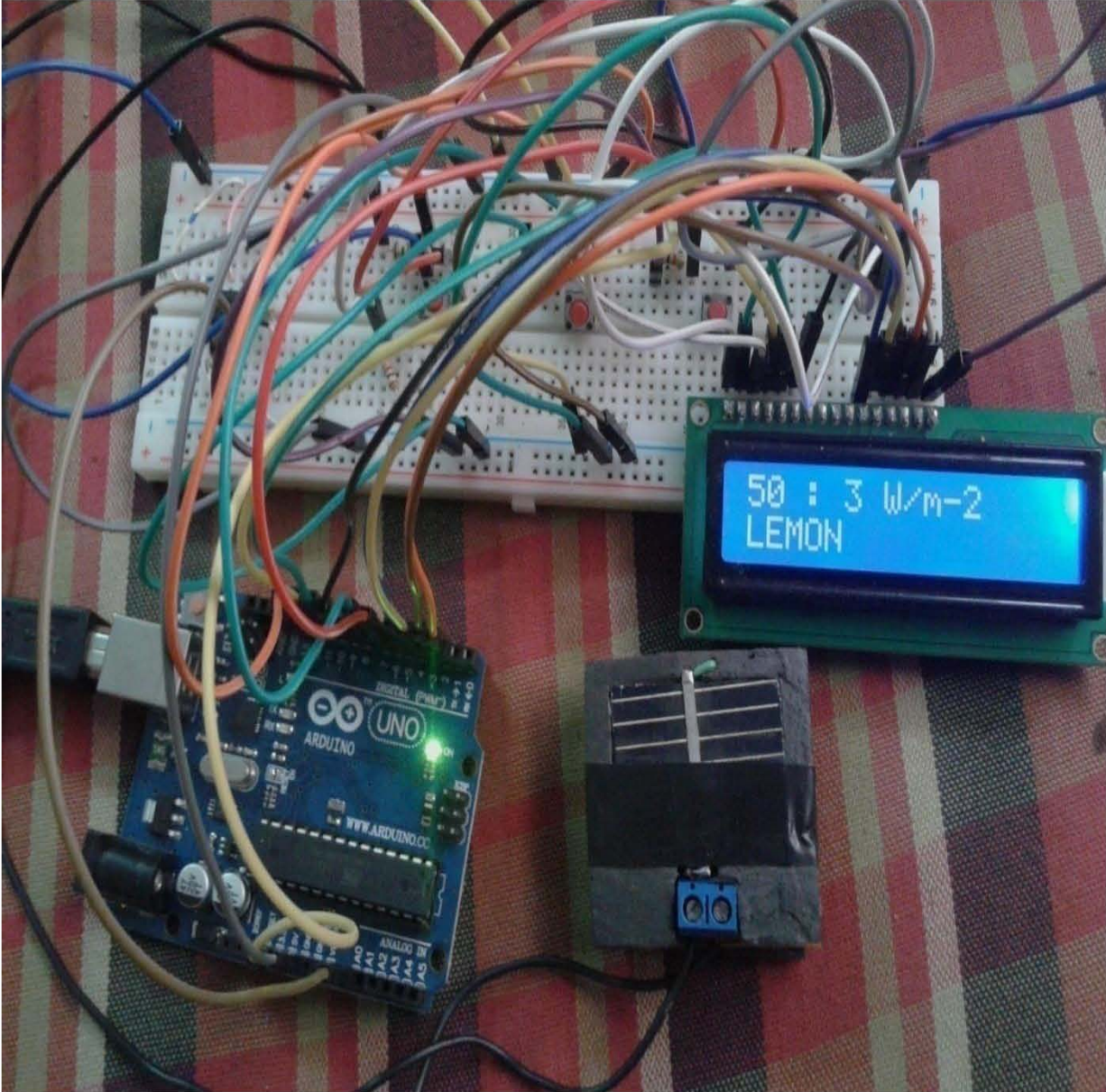
Analog to digital converted to the Radiation Data and control the programming system of total overview of system. The switch  $S_m$  is high, rather than the LCD display, is showing the output value and the switch  $S_m$  is low, rather than the output value, is showing the PC.

### 3.1.B. Schematic Diagram of the Circuit



The circuit is connected into three switch and one sensor, connected into op-amp (741) with Arduino UNO. The sensor converts current into voltage. The switch  $S_m$ , controls mode selection and switch ( $S_0, S_1$ ), control the time delay. Here,  $A_0$  is analog pin and number 13, 7 and 8 is digital pin. An **analog-to-digital converter (ADC)** is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude.

### 3.1.C. System Circuit



## 3.1. D. System Connection

- ◆ At first, Arduino A<sub>0</sub> , is connected with number 6 pin of amplifier.
- ◆ After that radiation sensor (-) point connected with amplifier (-) point .
- ◆ After that ground connected with sensor and amplifier (+) point .
- ◆ Then 10K register connected with number 2 & 6 pin of amplifier and ground connected with number 3& 4 pin of amplifier.
- ◆ +5V is connected with number 7 pin of amplifier.
- ◆ After that switch S<sub>m</sub>, is connected with number 13pin of arduino , switch S<sub>0</sub> is connected with number 7 pin of arduino and switch S<sub>1</sub>, is connected with number 8 pin Arduino.
- ◆ Arduino +5V is connected with 1k register switch (S<sub>m</sub>, S<sub>0</sub>, S<sub>1</sub>) and ground of arduino is another side.
- ◆ Display connection shown in below:

LCD Pin Connect to

1 (VSS) GND Arduino pin\*

2 (VDD) + 5v Arduino pin

3 (contrast) Resistor or potentiometer to GND Arduino pin\*

4 RS Arduino pin 12

5 R/W Arduino pin 11

6 Enable Arduino pin 10

7 No connection

8 No connection

9 No connection

10 No connection

11 (Data 4) Arduino pin 5

12 (Data 5)Arduino pin 4

13 (Data 6) Arduino pin 3

14 (Data 7) Arduino pin 2

15 Backlight +

Resistor to Arduino pin 13\*\*

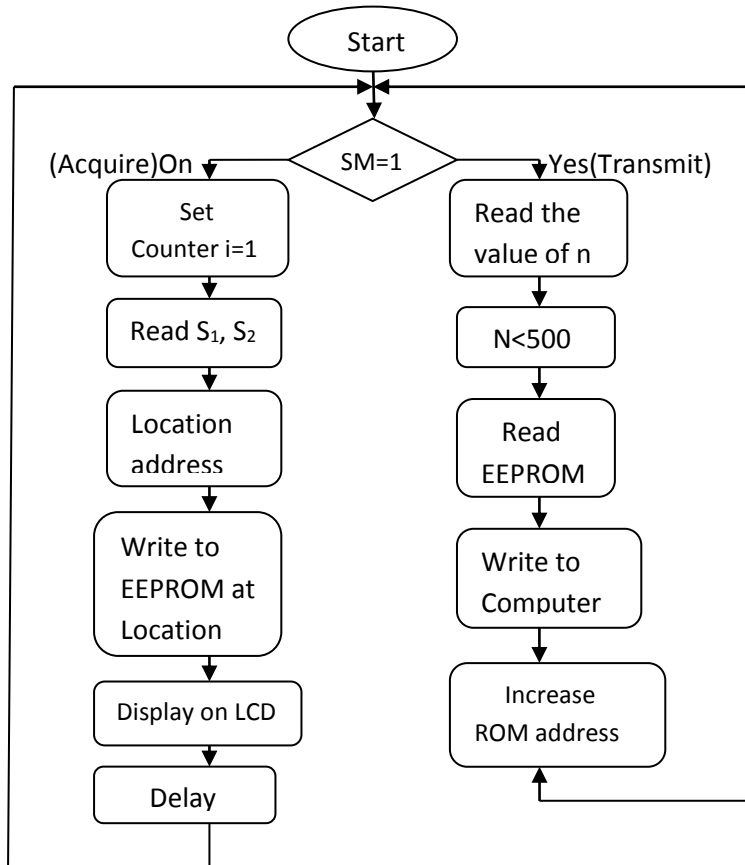
16 Backlight GNDGND Arduino pin\*

## **3.2 Software Design**

### **3.2.A. Programming Language**

It is not possible to reach the destination of this project without programming. In fact, a huge knowledge is necessary for programming language. It is not only very important but also very necessary to study programming properly. Without completing the program, it is not possible to run the project. Arduino C programming is used in this project. We have used arduino-uno software. Programs codes are written there. For arduino C programming--- EEPROM read, EEPROM write, serial. begin, serial. print, delay, for loop, if else-----etc are very necessary. Before doing the programming code, logical concept has applied very carefully.

### 3.2.B. Flowchart of the program



## 3.2. C. Program Code

```
#include <LiquidCrystal.h>
#include <EEPROM.h>
LiquidCrystal lcd(12, 11,10, 5, 4, 3, 2);
int lcdMode = 9;
int deo=8;
int de1= 7;
int sm = 13;
int mode =0;
int s0=0;
int s1=0;
int n=0; // start reading from the first byte (address 0) of the EEPROM
int address = 0;
byte value;
long int delayValue;
float rad;
const int analogInPin = A0; // Analog input pin that the potentiometer is attached to
int sensorValue = 0; // value read from the pot
int valueL, valueH;
int isFirst = 0;
void setup(){
  lcd.begin(16, 2);
  pinMode(deo,INPUT);
  pinMode(de1,INPUT);
  pinMode(ms,INPUT);
  pinMode(lcdMode,OUTPUT);
  Serial.begin(9600);
}
void loop(){
  mode=digitalRead(sm);
  if(mode == HIGH)
  {
    address=0;
    for (int count = 0; count < 500; count++)
    {
      valueL = EEPROM.read(address);
      address++;
      valueH = EEPROM.read(address);
      address++;
      sensorValue=valueH*10+valueL;
      rad=sensorValue*1.173;
      Serial.print(address-2);
      Serial.print("\t");
      Serial.print(rad);
      Serial.print(" W/m-2");
    }
  }
}
```

```

Serial.println();
}
}
else
{
address = 0;

isFirst=0;
for (int count = 0; count < 500; count++)
{
sensorValue = analogRead(analogInPin);
Serial.print(count);
Serial.print("\t");
s0=digitalRead(de0);
s1=digitalRead(de1);
delayValue=10000*(s1*2+s0)+5000;
valueL=sensorValue%10;
valueH=sensorValue/10;

EEPROM.write(address,valueL);
Serial.print(EEPROM.read(address),DEC);
Serial.print("\t");
address++;
EEPROM.write(address,valueH);
Serial.print(EEPROM.read(address),DEC);
Serial.print("\t");
address++;
digitalWrite(lcdMode, HIGH);
lcd.clear();
lcd.setCursor(0,0);
lcd.print(n+1);lcd.print(" : ");
// Print a message to the LCD.
lcd.print(sensorValue);

lcd.print(" W/m-2");

n++;
delay(delayValue);
}
}
label :
goto label;

}

```



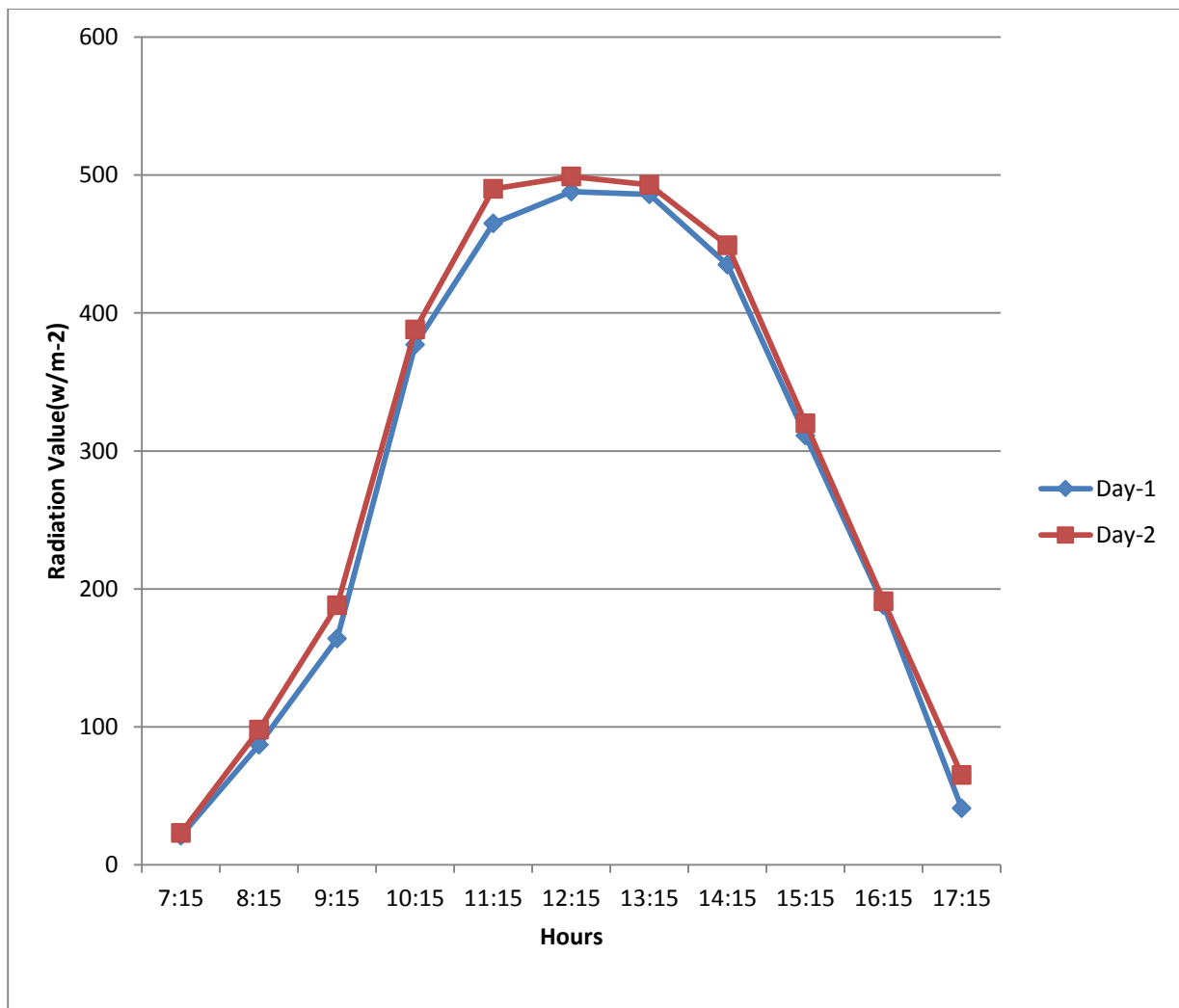
# Chapter-4

## Results

## 4.1. A. Data Analysis

<b>Hours</b>	<b>Day 1 (w/m<sup>2</sup>)</b>	<b>Day 2 (w/m<sup>2</sup>)</b>
7:15	23	21
8:15	98	87
9:15	188	164
10:15	388	377
11:15	490	465
12:15	499	488
13:15	493	486
14:15	449	435
15:15	320	311
16:15	191	188
17:15	65	41

## 4.1.B. Graphically Representation



## **During the project we have seen some factors that decrease solar intensity :**

- Atmospheric conditions also decrease the intensity of the sunlight before it reaches the surface of the earth.
- Shadows from trees and other tall obstacles can decrease the efficiency of the system.
- At deep noon, the angle at which the sun's beam strikes the earth's surface is most direct and the sunlight feels hot. At sunrise and sunset, the angle is less direct and the sunlight feels puny.

## **Conclusion**

During the project work, an effective process has invented by using arduino-UNO microcontroller. Hardware design and software design have implemented in this project. In fact, it is intended to find a method of solar radiation measurement which is more sophisticated and more accurate than the old fashioned method. Atmospheric conditions are reduce the intensity of the sunlight before it reaches the surface of the earth, shadows from trees and other tall obstacles can reduce the efficiency of the system.

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