Data Acquisition and Analysis of Solar Photovoltaic System

by

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A comprehensive project report has been submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

ELECTRONICS & COMMUNICATION ENGINEERING

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MAY, 2018

CERTIFICATE OF APPROVAL

This is to certify that the project titled "**Data Acquisition and Analysis of Solar Photovoltaic System**" carried out by

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for the partial fulfillment of the requirements for B.Tech degree in **Electronics and Communication Engineering** from **Maulana Abul Kalam Azad University of Technology, West Bengal**is absolutely based on his own work under the supervision of **Prof. Manas Ghosh**. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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DECLARATION

"We Do hereby declare that this submission is our own work conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute and that, to the best of our knowledge and belief, it contains no material previously written by another neither person nor material (data, theoretical analysis, figures, and text) which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text."

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CERTIFICATE of ACCEPTANCE

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1. ……………………………………………………………………

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ABSTRACT

Solar Energy is most useful resource of renewable energy. Using data processing and applying computer algorithms it can be possible to make this energy system more efficient. This paper represents the principle of on-grid photovoltaic cell system and characteristics of its components. A microcontroller based data acquisition system is used to collect data from the Solar Panel. The system comprises of Arduino Uno R3, Solar Panel, Current Sensor ACS712 5A Module, DC Power Supply, Resistor, LED (for the Hardware part). For the Software part we have used Arduino Uno 1.8.5 version, PLX-DAQ spread sheet. Using the components we have measured change of current with respect to time and was able to plot the graph of current vs time.

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Chapter 1

1.1 Introduction

Renewable energy resources are becoming one of primary sources of energy due to its abundance. Today, as civilization grows rapidly various challenges are occur in front of energy structure. Because of interest regarding pollution and global warming demand of renewable energy resources are increased. Solar energy is most promising source of renewable energy sources because of its abundance, versatility and environmental friendly nature. Evolution and utilization of this energy not only provide way to use of these resources but also produce efficient assessment to adjust resources in better way to overcome energy resource crisis. There are different environmental and geographical factors that affect resources, so measurement of solar resources under these factors make system cost effective and enhance usage rate of renewable solar energy. Data acquisition helps to measure status of solar systems under these factors. Accuracy of data acquisition system is also important because various instruments are used to obtain data from system and may produce different results that cause a serious impact on a large scale solar system.

1.2 Solar Energy

Solar Energy is radiant light and heat from the sun that is implemented using a range of evolving technologies such as photovoltaics, solar thermal energy, solar architecture, solar heating. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaics systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet. Most of the world's population live in areas with insolation levels of 150–300 watts/m^2, or 3.5–7.0 kWh/m^2 per day. In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared.

1.3 What is Data Acquisition?

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution.

Chapter 2

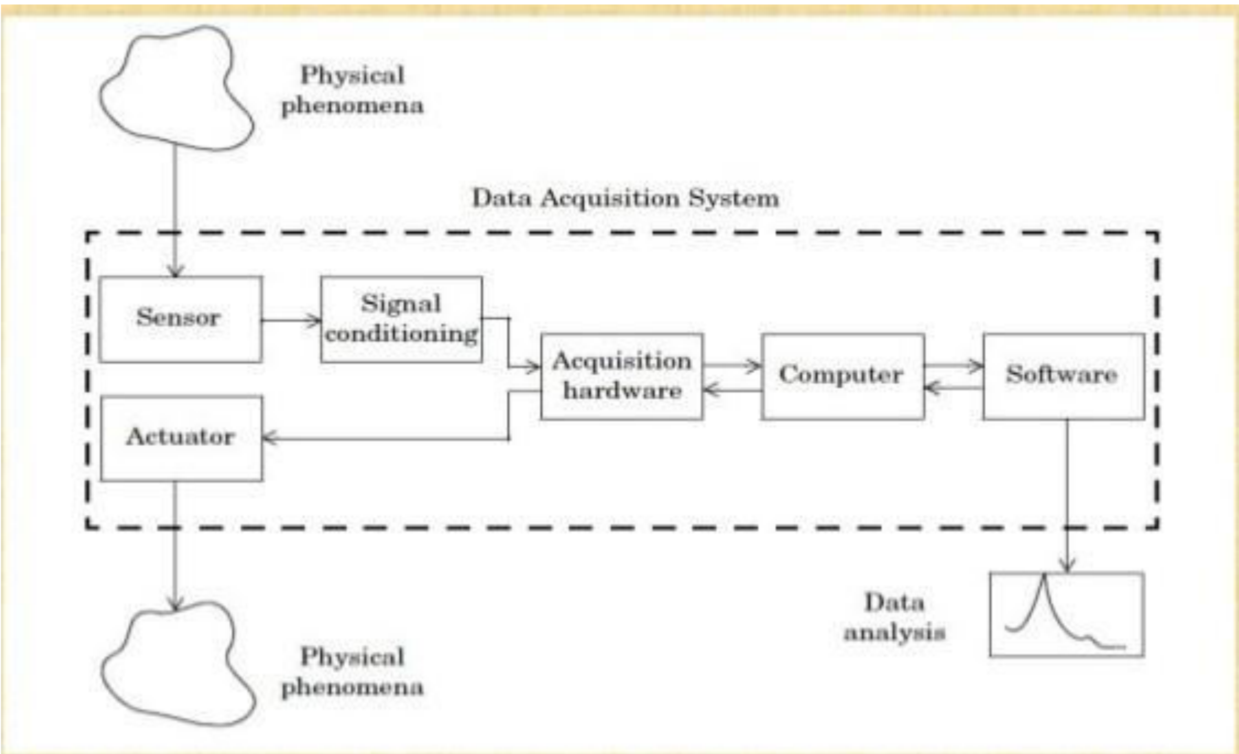
2.1 Problem Statement

Measurement of the change of current generating from a Solar Panel and to store the values in a data sheet using Arduino Uno and a current sensor. For storing the values use PLX-DAQ data sheet.

2.2 Problem Definition

It is not possible to use solar energy in direct way because of its discontinuous nature or other environmental factors as dust, cloud, rain, etc. So there is a need of a mechanism to control the charge and storage that has capability of absorbing and delivering power. Charge controller works between battery and solar panel and maintains voltage of both components. If generated voltage through panel is higher Data Acquisition and Analysis of Solar Photovoltaic System 1455 than battery allow battery to charge and if voltage through panel becomes lower than cutoff panel from battery. So it protects system from overcharge and reverse leakage. Battery energy storage methods can be used that abate solar power generation issues as ramp-rate, frequency or voltage issue. A number of batteries are used through serial or parallel, this choice depends upon capacity of the components of solar cells. A DC-AC inverter used to convert DC power produced by panel into AC power to allow for electrical appliances. The data acquisition system consists of a microcontroller AT89C51 and some of its peripheral equipments as ADC analog to digital converter ADC0831, LCD (Liquid Crystal Display), and some communication modules as Zigbee and RS-232. Zigbee allows system to transmission of data wirelessly. RS-232 makes a bridge of communication between host computer and data acquisition modules. Host system contains some software modules as keil, proteus and visual basic 6.0 to allow collecting data and creating chart to take decisions. Hardware and Software in Data Acquisition

Figure 2.1.1: Simple Block Diagram of a DAQ/DAS



2.3 **Components Table:**

Table 2.3.1: Hardware components

Serial No.	Components Name	Maker's Name	Specification
1.	Arduino Uno		16 MHz
2.	Solar Panel		
3.	Current Sensor		5 V, -5A to 5A
4.	Resistor		30 ohm
5.	Load (LED)		
6.	Dc Power Supply		
7.	Bread Board		

Table 2.3.1: Software components

Serial no.	Components name	Maker's Name	Specification
1.	Arduino Uno IDE		
2.	PLX-DAQ Spread Sheet		

2.4 Detailing of Components

Arduino Uno: Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller.

Pin Description:

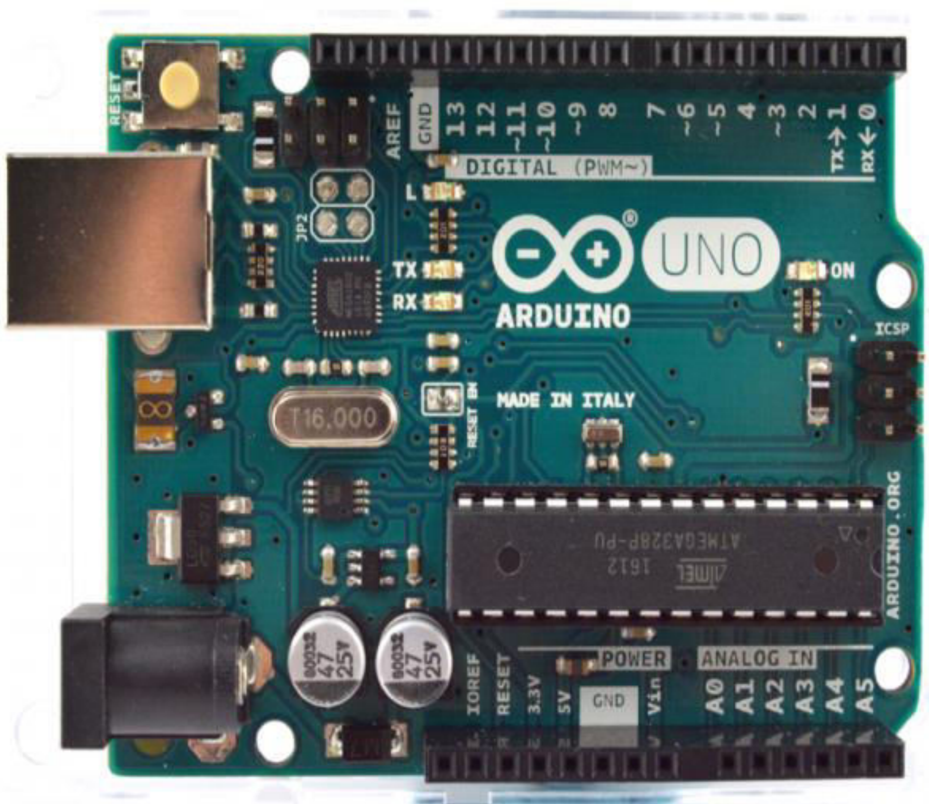
- 1.1.1 VCC Digital supply voltage.
- 1.1.2 GND Ground.
- 1.1.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2 Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit. Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier. If the Internal Calibrated RC Oscillator is used as chip clock source, PB7..6 is used as TOSC2..1

input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

- 1.1.4 Port C (PC5:0) Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.
- 1.1.5 PC6/RESET If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C. If the RSTDISBL Fuse is not programmed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. The minimum pulse length is given in Table 28-3 on page 308. Shorter pulses are not guaranteed to generate a Reset. The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.
- 1.1.7 AVCC is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6. It should be externally connected to VCC, even if the

ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that PC6..4 use digital supply voltage, VCC. 1.1.8 AREF is the analog reference pin for the A/D Converter. 1.1.9 ADC7:6 (TQFP and QFN/MLF Package Only) In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

Figure 2.4.1: IC of an Arduino Uno



Peripheral Features of Arduino Uno:

- Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
- – One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
- – Real Time Counter with Separate Oscillator
- – Six PWM Channels
- – 8-channel 10-bit ADC in TQFP and QFN/MLF package Temperature Measurement
- – 6-channel 10-bit ADC in PDIP Package Temperature Measurement
- – Programmable Serial USART – Master/Slave SPI Serial Interface
- – Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- – Programmable Watchdog Timer with Separate On-chip Oscillator
- – On-chip Analog Comparator – Interrupt and Wake-up on Pin Change
- Temperature Range: – -40°C to 85°C

Solar Panel: A **solar cell**, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels.

Features:

• Outstanding Low Light Performance • Solar cells laminated with TPT/EVA bi-layer for long life

• High Efficiency with high transparency low iron tempered glass cover

• Sealed for protection from harsh environments • Enclosed junction box for wired connections

Applications:

• Battery Charging Applications • Surveillance Cameras • Wireless Base Stations • Outdoor Lighting • Remote Sensors • Backup Power Systems

Figure 2.4.2: Solar Panel

Table 2.4.1: Physical Data of Solar Panel

CELL TYPE	Crystalline Silicon
CELL NUMBER	12Cells
OPERATING TEMP	-20℃ ~ +60℃
DIMENSION	60mm x 50mm X 3.0mm
BACK COVER	PCB
LAMINATED	PET
WEIGHT	12g

Table 2.4.2: Electrical Data of Solar Panel

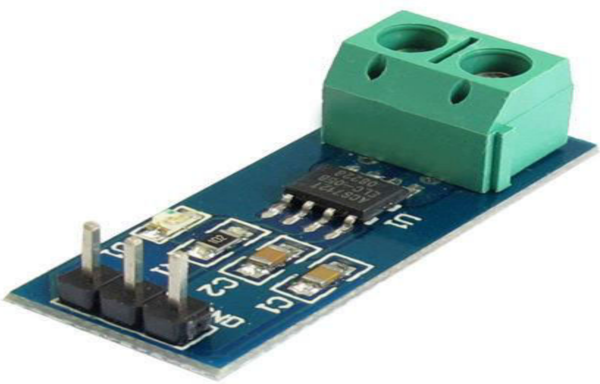
MAXIMUM POWER (Pmax)	0.9W
MAXIMUM POWER VOLTAGE (Vmp)	6V
MAXIMUM POWER CURRENT(Imp)	150mA
OPEN CIRCUIT VOLTAGE(Voc)	6.706V
SHORT CIRCUIT CURRENT(Isc)	0.055A

Current Sensor: A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. The generated signal could be analog voltage or current or even a digital output. The generated signal can be then used to display the measured current in an ammeter, or can be store for further analysis in a data acquisition system, or can be used for the purpose of control.

Specifications:

- Supply Voltage (VCC)- 5V DC
- Measurement Range -5 to +5 Amps
- Scale Factor 185 mV per Amp
- Chip ACS712ELC-05A
- On board power indicator

Figure 2.4.3: Current Sensor



Features and Benefits:

▪ Low-noise analog signal path

▪ Device bandwidth is set via the new FILTER pin

▪ 5 μs output rise time in response to step input current

▪ 80 kHz bandwidth

▪ Total output error 1.5% at TA = 25°C

▪ Small footprint, low-profile SOIC8 package

▪ 1.2 mΩ internal conductor resistance

▪ 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8

▪ 5.0 V, single supply operation

▪ 66 to 185 mV/A output sensitivity

▪ Output voltage proportional to AC or DC currents

▪ Factory-trimmed for accuracy

▪ Extremely stable output offset voltage

▪ Nearly zero magnetic hysteresis

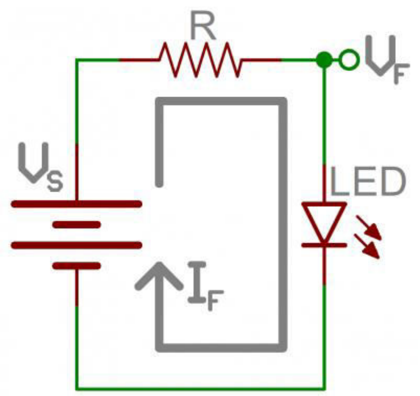
▪ Ratiometric output from supply voltage

Resistor: Resistors are electronic components which have a specific, never-changing electrical resistance. The resistor's resistance limits the flow of electrons through a circuit.

They are passive components, meaning they only consume power (and can't generate it). Resistors are usually added to circuits where they complement active components like op-amps, microcontrollers, and other integrated circuits. Commonly resistors are used to limit current, divide voltages, and pull-up I/O lines.

<u>Application of resistor in our project: LED Current Limiting</u>

Resistors are key in making sure LEDs don't blow up when power is applied. By connecting a resistor **in series** with an LED, current flowing through the two components can be limited to a safe value.



When sizing out a current-limiting resistor, look for two characteristic values of the LED: the **typical forward voltage**, and the **maximum forward current**. The typical forward voltage is the voltage which is required to make an LED light up, and it varies (usually somewhere between 1.7V and 3.4V) depending upon the color of the LED. The maximum forward current is usually around 20mA for basic LEDs; continuous current through the LED should always be equal to or less than that current rating.

Once you've gotten ahold of those two values, you can size up a current-limiting resistor with this equation:

$$R = \frac{V_S - V_F}{I_F}$$

V_S is the source voltage – usually a battery or power supply voltage. V_F and I_F are the LED's forward voltage and the desired current that runs through it.

For example, assume you have a 9V battery to power an LED. If your LED is red, it might have a forward voltage around 1.8V. If you want to limit the current to 10mA, use a series resistor of about 720Ω.

$$R = \frac{V_S - V_F}{I_F} = \frac{9 - 1.8}{0.010} = 720\Omega$$

LED: A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through it. The light is not particularly bright, but in most LEDs it is monochromatic, occurring at a single wavelength. The output from an LED can range from red (at a wavelength of approximately 700 nanometers) to blue-violet (about 400 nanometers). Some LEDs emit infrared (IR) energy (830 nanometers or longer); such a device is known as an *infrared-emitting diode* (IRED).

An LED or IRED consists of two elements of processed material called *P-type semiconductor*s and *N-type semiconductor*s. These two elements are placed in direct contact, forming a region called the *P-N junction*. In this respect, the LED or IRED resembles most other diode types, but there are important differences. The LED or IRED has a transparent package, allowing visible or IR energy to pass through. Also, the LED or IRED has a large PN-junction area whose shape is tailored to the application.

Benefits of LEDs and IREDs, compared with incandescent and fluorescent illuminating devices, include:

- **Low power requirement**: Most types can be operated with battery power supplies.
- **High efficiency:** Most of the power supplied to an LED or IRED is converted into radiation in the desired form, with minimal heat production.
- **Long life:** When properly installed, an LED or IRED can function for decades.

Fig 2.4.6: Red LED

Typical applications include:

- **Indicator lights:** These can be two-state (i.e., on/off), bar-graph, or alphabetic-numeric readouts.

- **LCD panel backlighting:** Specialized white LEDs are used in flat-panel computer displays.

- **Fiber optic data transmission:** Ease of modulation allows wide communications bandwidth with minimal noise, resulting in high speed and accuracy.

DC Power Supply: DC (direct current) is the unidirectional flow or movement of electric charge carriers (which are usually electrons). The intensity of the current can vary with time, but the general direction of movement stays the same at all times. As an adjective, the term DC is used in reference to voltage whose polarity never reverses.

In a DC circuit, electrons emerge from the negative, or minus, pole and move towards the positive, or plus, pole. Nevertheless, physicists define DC as traveling from plus to minus.

Direct current is produced by electrochemical and photovoltaic cells and batteries. In contrast, the electricity available from utility mains in most countries is AC (alternating current). Utility AC can be converted to DC by means of a power supply consisting of a transformer, a rectifier (which prevents the flow of current from reversing), and a filter (which eliminates current pulsations in the output of the rectifier).

Virtually all electronic and computer hardware needs DC to function. Most solid-state equipment requires between 1.5 and 13.5 volts. Current demands can range from practically zero for an electronic wristwatch to more than 100 amperes for a radio communications power amplifier. Equipment using vacuum tubes, such as a high-power radio or television broadcast transmitter or a CRT (cathode-ray tube) display, require from about 150 volts to several thousand volts DC.

Bread Board: A breadboard is a solderless device for temporary prototype with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate. The breadboard has strips of metal underneath the board and connect the holes on the top of the board. The metal strips are laid out as shown below. Note that the top and bottom rows of holes are connected horizontally and split in the middle while the remaining holes are connected vertically.

Arduino Uno IDE: This is an open source software (IDE) that makes easy to write code and upload it to the board. It runs on windows, linux and mac os. The environment is written in java based on processing and other open source software**.** A program written in this software is called a sketch.

PLX-DAQ Spread Sheet: PLX-DAQ is a Parallax microcontroller data acquisition add-on tool for Microsoft Excel. Any of our microcontrollers connected to any sensor and the serial port of a PC can now send data directly into Excel.

<u>PLX-DAQ has the following features:</u>

- Plot or graph data as it arrives in real-time using Microsoft Excel
- Mark data with real-time (hh:mm:ss) or seconds since reset
- Read/Write any cell on a worksheet
- Read/Set any of 4 checkboxes on control the interface
- Example code for the BS2, SX (SX/B) and Propeller available
- Supports Com1-15
- Baud rates up to 128K

- System Requirement : Microsoft Windows 98 , Microsoft Office/Excel 2000 to 2003

<u>Steps of using PLX-DAQ Spred Sheet:</u>

- connect your Arduino as you normally would
- DO NOT OPEN THE SERIAL MONITOR in Arduino IDE, it will not work with excel if you do
- open the shortcut to your PLX-DAQ Spreadsheet
- excel will say "This application is about to initialize ActiveX…", just click OK
- a new window named Data Acquisition for Excel will appear
- select the USB port your Arduino is connected to (if it doesn't work at first, go through the list of ports)
- where it says Baud, just select the number you put in your code at Serial.begin(), in my case that would be 9600
- create an empty graph
- select which columns of data you want on the graph for the x and y axis (the way to do this is a little different depending on your version of excel, but it's not too hard to figure out)
- -click collect data on PLX-DAX and it should start collecting the data
- -excel will plot the information as it gets sent from the Arduino to excel in real time

- Depending on how precise you want your graph to be, you can change the characteristics of the graph. You can closely examine a section of the graph by shutting down data collecting, right click on the x or y axis and set it to a smaller frame. (normally it's set to automatic)
- You can also right click on the curve that connects the points on your chart and select the color and thickness of the curve.

Figure 2.4.4: PLX-DAQ Spread Sheet Example

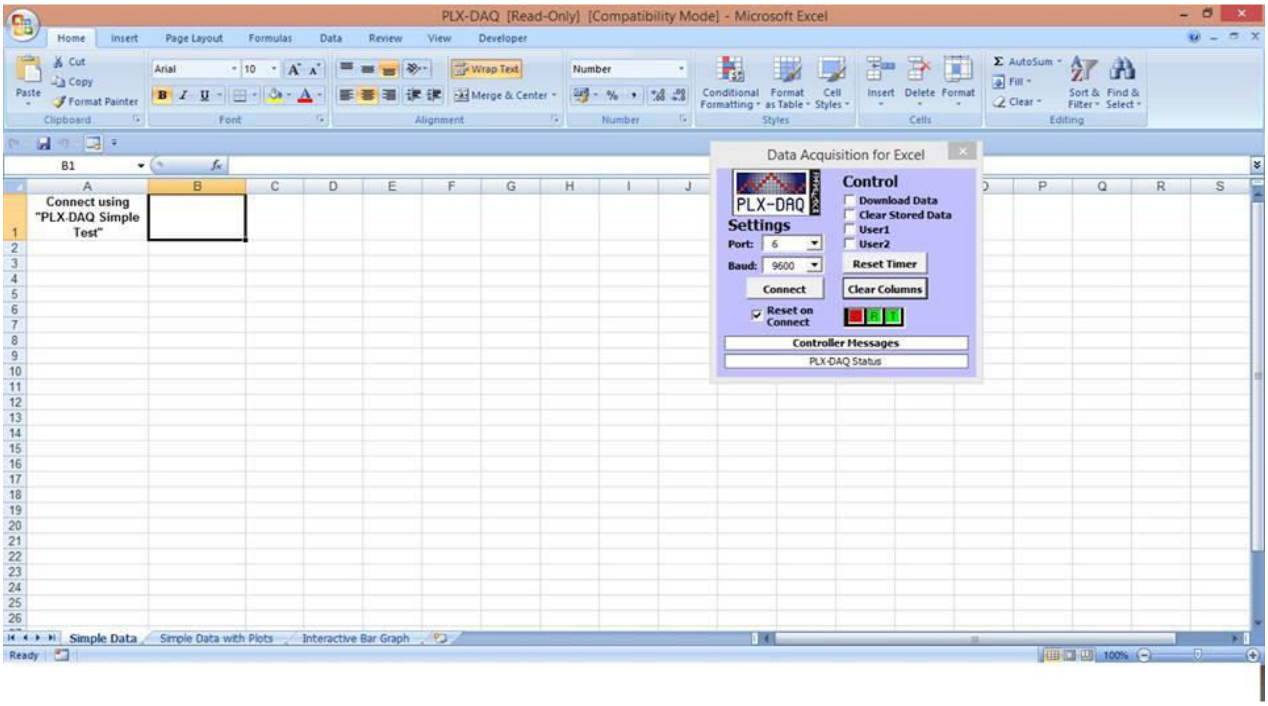
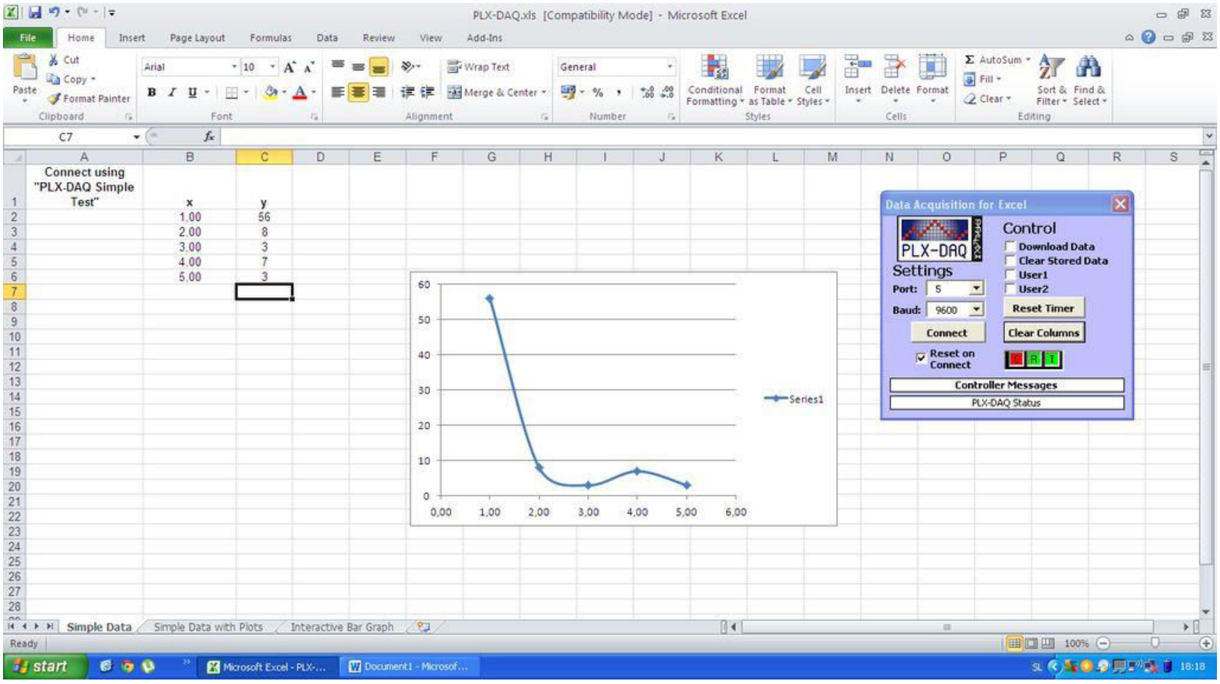
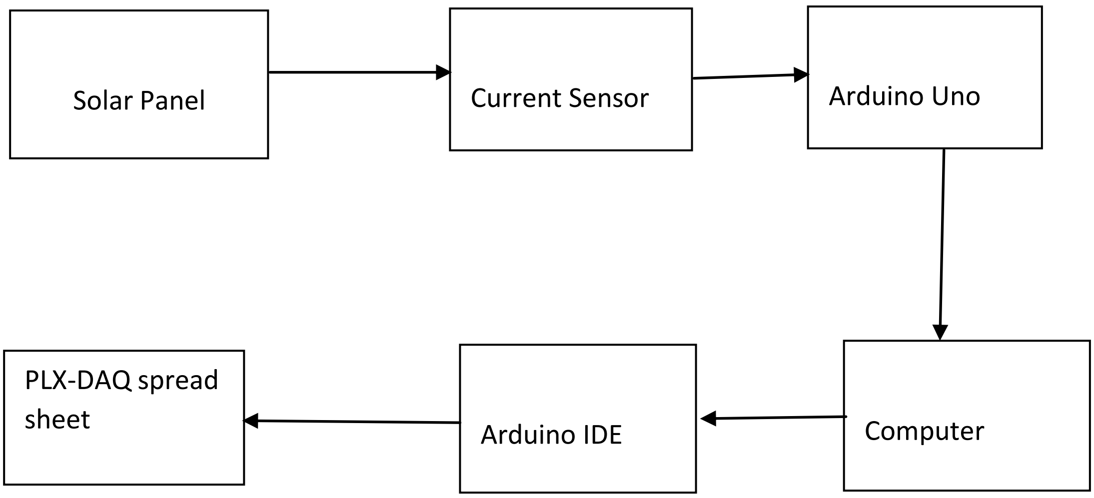


Figure 2.4.5: PLX-DAQ Spread Sheet Plotting



2.5 Block Diagram



2.6 Analysis

A. Hardware Part:

The main aim of our project is to log data that we are getting from our solar panel that we have used in our project. While performing our project we came across that the current sensor ACS 712 5a module that we are using, is giving a constant value reading between 2.4 -2.5 and the graph is constant.

This is because our sensor can sense ampere value reading, but the reading that the solar panel is giving is in v/ma which is too low for our sensor.

So we have tested the solar panel differently to see that whether it is working or not. We have used a resistor of 30ohm and a load (LED) and have connected the panel and a power supply of 5v is given. While we are applying some light on the panel the intensity of the load changes. So the panel works perfectly.

So the next module of current sensor cost about Rs 2000.That is a bit expensive. As our main part of the project was to log data, so we used a dc power supply and connected it to our sensor . Then by changing the value of the power supply we are getting the data which varies differently and by plotting this data we are getting a perfect graph.

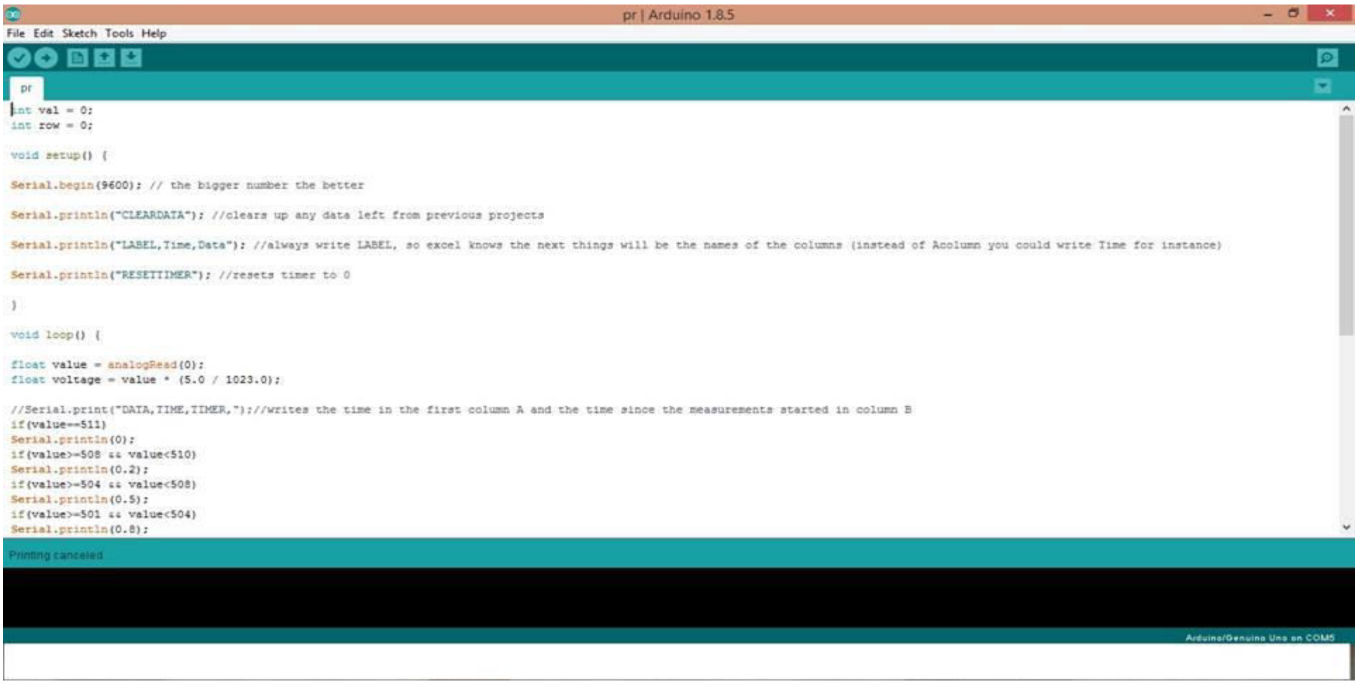
B. Software Part:

A Program written in Arduino IDE is called Sketch. Sketches are saved on the development computer as text files with the file extension .ino. Arduino Software (IDE) pre-1.0 saved sketches with the extension .pde. A minimal Arduino code written C/C++ consists of only two functions.

Setup (): This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch.

Loop (): After setup () has been called, function loop () is executed repeatedly in the main program. It controls the board until the board is powered off or is reset.

Figure 2.6.B.1: Screenshot of Code used

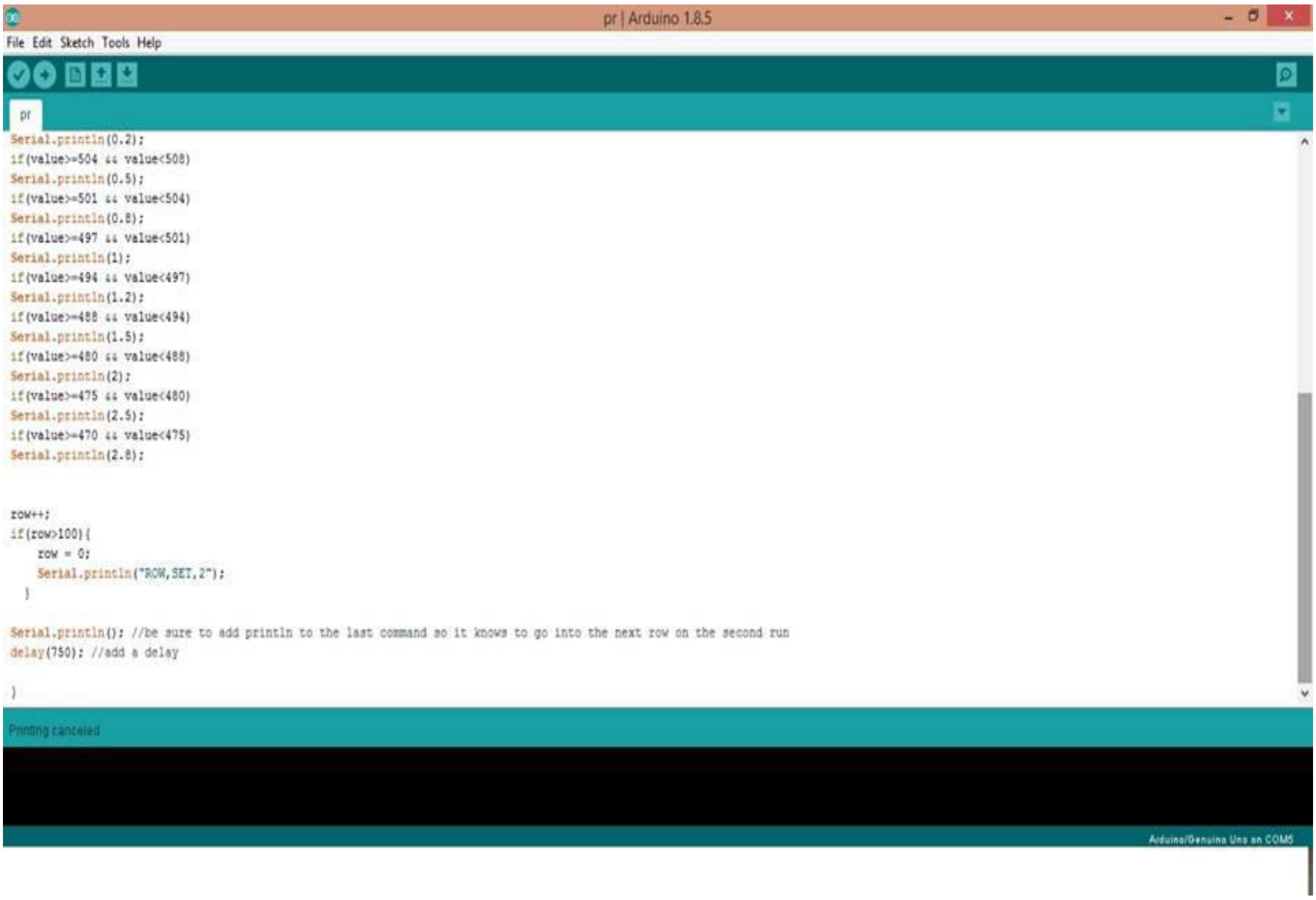


Code:

```
int val = 0;
int row = 0;

void setup() {

Serial.begin(9600); // the bigger number the better

Serial.println("CLEARDATA"); //clears up any data left from previous projects

Serial.println("LABEL,Time,Data"); //always write LABEL, so excel knows the next
things will be the names of the columns (instead of Acolumn you could write Time
for instance)

Serial.println("RESETTIMER"); //resets timer to 0

}

void loop() {

float value = analogRead(0);
float voltage = value * (5.0 / 1023.0);

//Serial.print("DATA,TIME,TIMER,");//writes the time in the first column A and the
time since the measurements started in column B
if(value==511)
Serial.println(0);
if(value>=508 && value<510)
Serial.println(0.2);
if(value>=504 && value<508)
Serial.println(0.5);
if(value>=501 && value<504)
Serial.println(0.8);
if(value>=497 && value<501)
Serial.println(1);
if(value>=494 && value<497)
Serial.println(1.2);
if(value>=488 && value<494)
Serial.println(1.5);
if(value>=480 && value<488)
Serial.println(2);
if(value>=475 && value<480)
```

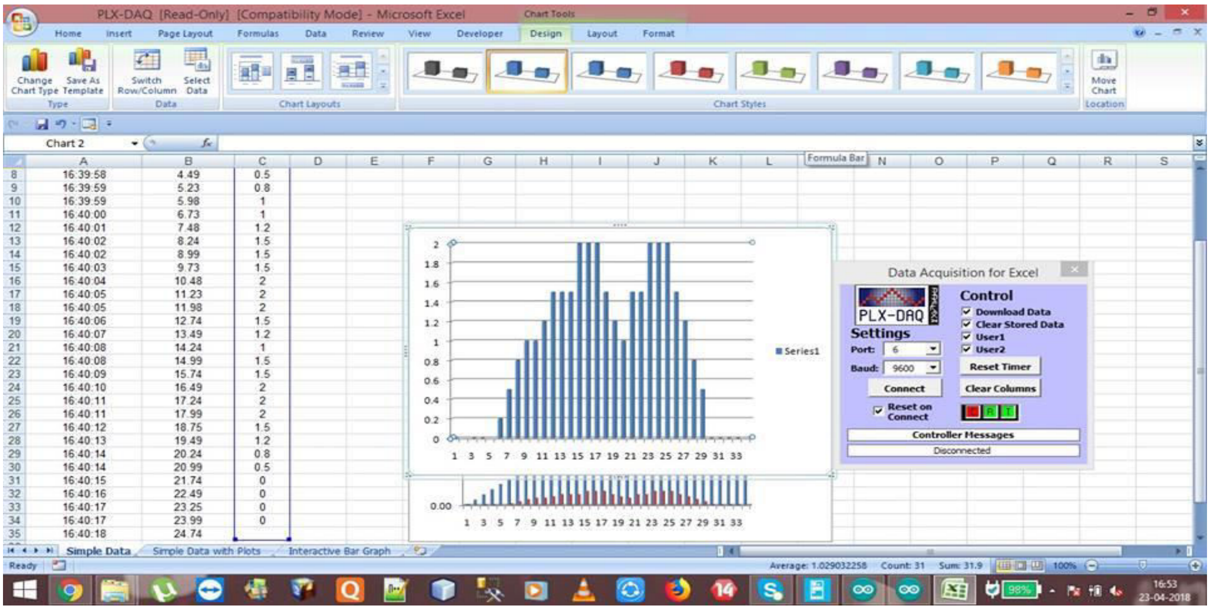
```
Serial.println(2.5);
if(value>=470 && value<475)
Serial.println(2.8);
row++;
if(row>100){
   row = 0;
   Serial.println("ROW,SET,2");
 }

Serial.println(); //be sure to add println to the last command so it knows to go into the next row on the second run
delay(750); //add a delay
}
```

Figure 2.6.B.2: Screenshot of used Code



2.7 Outcome:

Figure 2.7.1: Stored Data in spreadsheet and obtained graph



Column A denotes the time, Column B denotes the time since measurement, column C denotes the data. A delay of 750ms has been added.

Thus we are able to show that each of the components are working perfectly. When the solar panel is connected the data has been logged but the output we are getting is not satisfactory. When it is connected to DC power supply it is working all fine. So, we can understand the data is logged and we have reached our aim.

Reference:

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THANK YOU