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Design of a Simple Sun Radiation Measurement Device with Position Sensor

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ABSTRACT

This paper aims at designing a simple device that solves the challenges associated with identifying the best location and position that experiences relatively high solar intensity in comparison to another location within a particular zone. It is an embedded system, simple, handy and helps the Engineer to determine the point of highest solar radiation or intensity for solar panel installation, solar energy optimization, environmental monitoring and agricultural planning. GPS (Global Positioning System) sensor is included to help determine the time and distance of the location from the earth's equator (degree of latitude). Two circuits are built; one detects the sun irradiation while the second one senses the position of the location on the earth's surface. This design contains a NEO M3T GPS for positioning, an LCD that displays real time radiation level and position, an RS485 radiation sensor, an Arduino microcontroller system and a weather-resistant housing that protects the component etc. This design can use a solar-powered DC supply but for the sake of simplicity and portability, we are using a 12v battery to power it.

Key Words: position,pyranometer, microcontroller, LCD, Radiation, sensor, battery, weather, GPS, Solar.

I. INTRODUCTION

The sun radiates energy in all the wavelengths (0 to∞). Using Plank constant, the energy radiated by the sun considered as black body at a particular wavelength is given by the relation:

$$E_{b_\lambda} = \frac{C_1\lambda^{-5}}{[(e)^{C_2/\lambda T} - 1]} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$C_1 = 37.45 \times 10^{-7} \mathrm{W - m^2}$$

$$C_2 = 1.438 \times 10^{-2} \mathrm{mK}$$

Where 1Langley= $1\ \text{calories/cm}^2 = 0.04187\text{MJ/m}^2$. This is regarded as the unit of Solar Radiation. Most of the energy carried by sun rays is between 0.4 to 8μm (Domkundwar, 2014) wave length. The amount of energy available on the earth surface depends on the atmospheric condition. The atmosphere contains Carbon (iv)oxide, Carbon (II) oxide, Oxygen, Nitrogen (iv) oxide, Water, dust, vapour etc., so the capacity of each is different for absorption and reflection. Therefore, the presence of each component depends upon their concentration in the atmosphere. The measurement of global solar radiation are used in various applications for various purpose. Solar energy determines the efficiency of the panel because these panels will change the energy from the sun's energy to electrical energy.

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There are many solar equipment that help Engineers to track signals, energy and direction like the solar tracker, solarimeter, pyranometer, etc. but this particular design combines the work of the above systems and GPS to help the engineer determine position of greater solar energy irradiance and position on the earth surface. While some equipment like pyranometer measures the solar radiation by mainly measuring the temperature between two surfaces, this design concentrates more on both the energy in Watts per square meter and the position (latitude and Longitude) of the particular location within a zone.

The earth axis is inclined and rotates around itself about its axis and simultaneously around the sun. The surface position on the earth exposed to the sun also varies according to the position of earth with respect to the sun. Thus, it is necessary to study the different angles between the earth and the sun to find out the sun energy falling on the required surface or location. The amount of electromagnetic radiation on a solar panel can be measured to know how much power a solar panel can use from the sun and the location of the position/point of collection on the earth surface. To overcome this, a pyranometer sensor is used to track the irradiance of solar energy in the location while the GPS sensor is used to ascertain position of the location on the earth surface. This is exactly what this design is all about.

II. LITERATURE REVIEW

Existing methods for measuring solar radiation includes pyranometer, radiometer, solarimeter, photodiodes etc. pyranometer are widely used for because of their accuracy but can be expensive and complex. Photodiodes offer a more affordable solution but may lack the precision required for certain applications. This design aims to combine the best features of these technologies to create a cost effective, simple and accurate device.

DESIGN DESCRIPTION

To be able to achieve the design of this equipment, we first designed the block diagram, the circuit diagram of both the pyranometer (for sun irradiance) and the position sensing. We also built the circuits, assembled the components (BEME), wrote the programming using Arduino and assembled all of them in a casing (weather-resistant housing).

BLOCK DIAGRAM

This system design depicts the processes of solar energy collection from the source (sun) down to the display system and end results. It shows the graphical workings of this equipment.

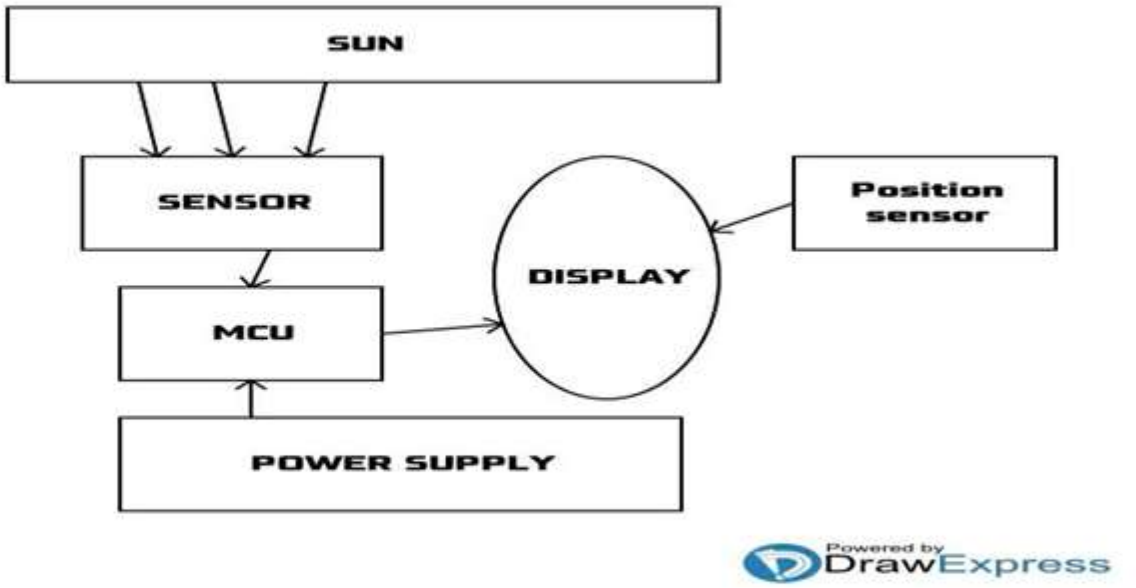

Fig 1 – block diagram

SUN
The sun is the source of solar energy, which is converted tophotovoltaic using the pyranometer.
SENSOR(Pyranometer)

This is a high precision photodiode or pyranometer sensor to detect solar radiation. A pyranometer is a type of sensor that measures the solar irradiance or the power of sunlight in watts per square meter (W/m²). They are

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widely used in meteorology, climatology, solar energy studies, and agriculture to monitor and study the available solar radiation.There are two types of Pyranometers, i.e. Thermopile Pyranometers and Silicon Pyranometers. In this project, we will use Thermopile Pyranometer from **Renkee**r. The sensor is designed to measure solar irradiance between 0-2000W/m² with a resolution of 1W/m². The sensor works on RS485 protocol (4-20mA,0-5V, 0-10V).

Fig 2 – Pyranometer Sensor

GPS MODULE**:** This a wireless sensor that is incorporated in the design to communicate the positioning of the location on the earth surface. This module will provide information of the location in Latitude and Longitude.

MICROCONTROLLER (MCU)

An Arduino Microcontroller is an electronic platform. It is able to read inputs like light on a sensor, touch on a button etc. and convert them to output. This board processes input information using a particular programming language. In the case of this design, we used C^{++} programming language to process the sensor data.

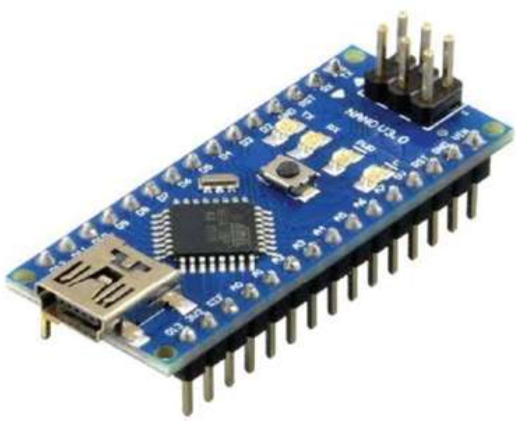
Fig 3 – Arduino MCU

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DISPLAY

This will give a physical interpretation of the data.it displays the results. An LCD or OLED display to show real-time radiation levels. However, the LCD is used.

Fig 4 - LCD

POSITION SENSOR

NEO M3T GPS is used for positioning in this design.

POWER SUPPLY

A battery pack or solar panelcan be used to power the device. But in the case of this design, we used a 12V power supply.

CASING OR ENCLOSURE**:** A weather-resistant housing to protect the components. The device will measure the intensity of solar radiation and display the data in real-time. It will also have the capability to log data for later analysis.

CIRCUIT DIAGRAM

The circuit diagrams are drawn for both the sensing position and the pyranometer.

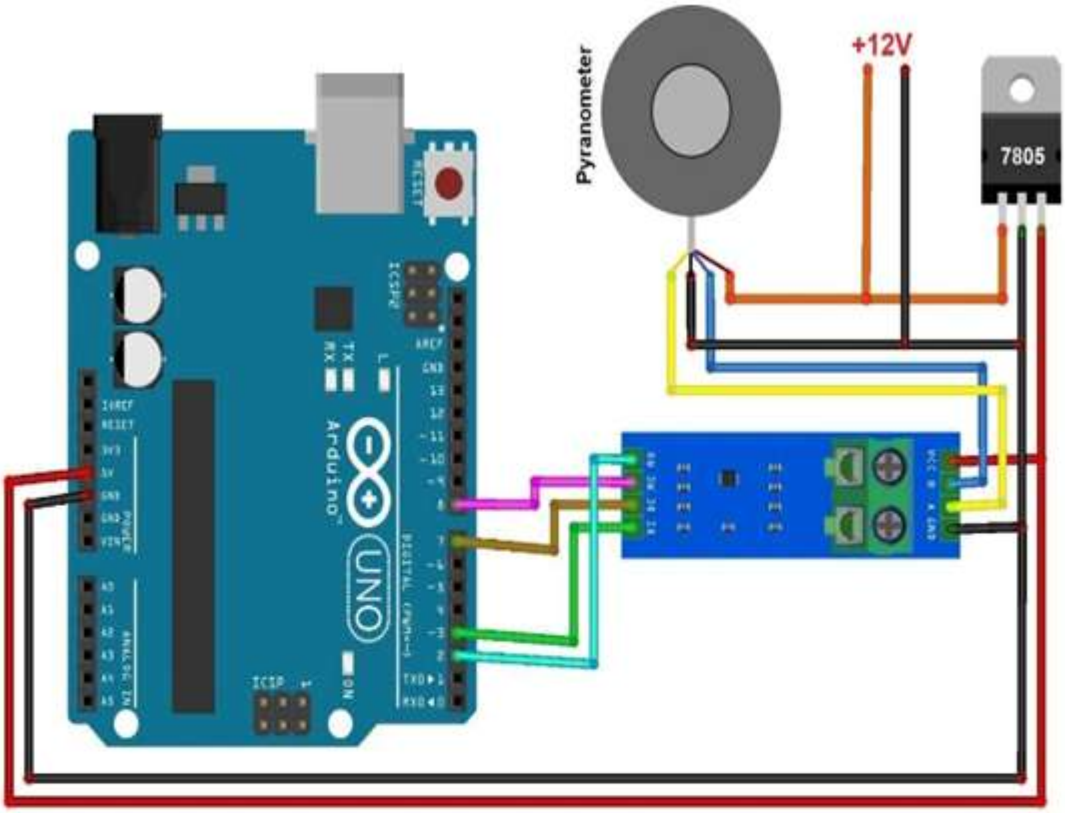

Fig5 – Arduino/Pyranometer interfaceCircuit

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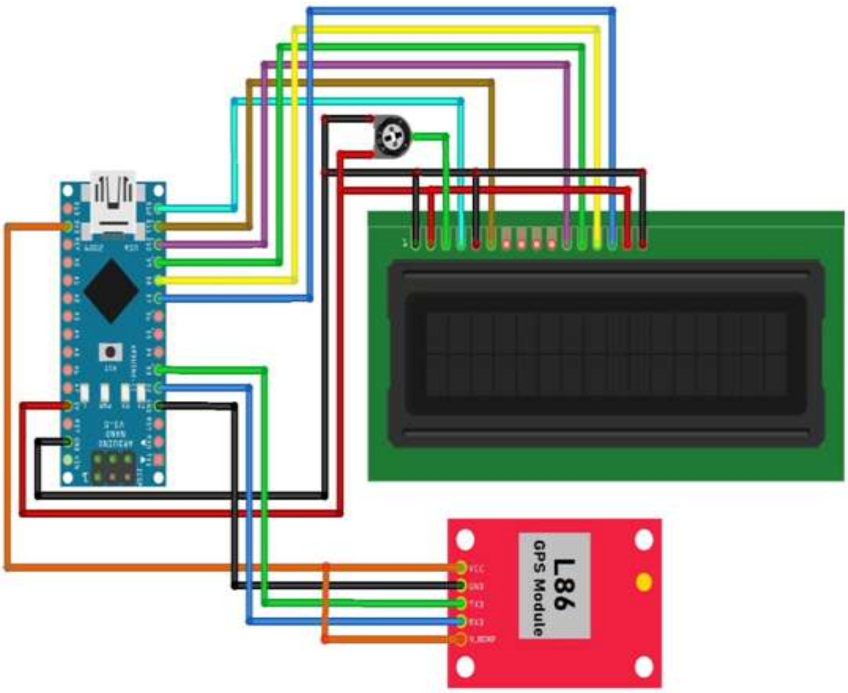

Fig 6 – Positioning Circuit

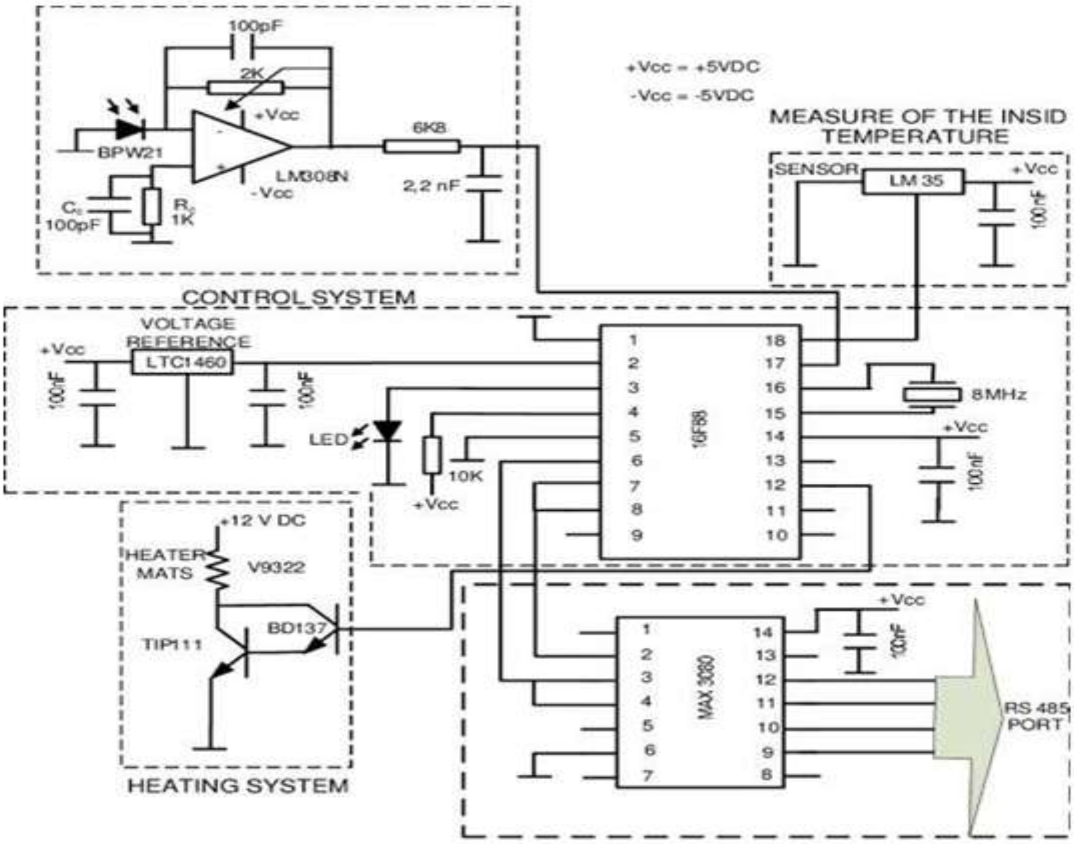

Fig 7 – The circuit Diagram of the design (Sun radiation measurement device).

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1. **The Programming in Words**

This design is programmed using the C^{++} programming language. The programming is as shown below.

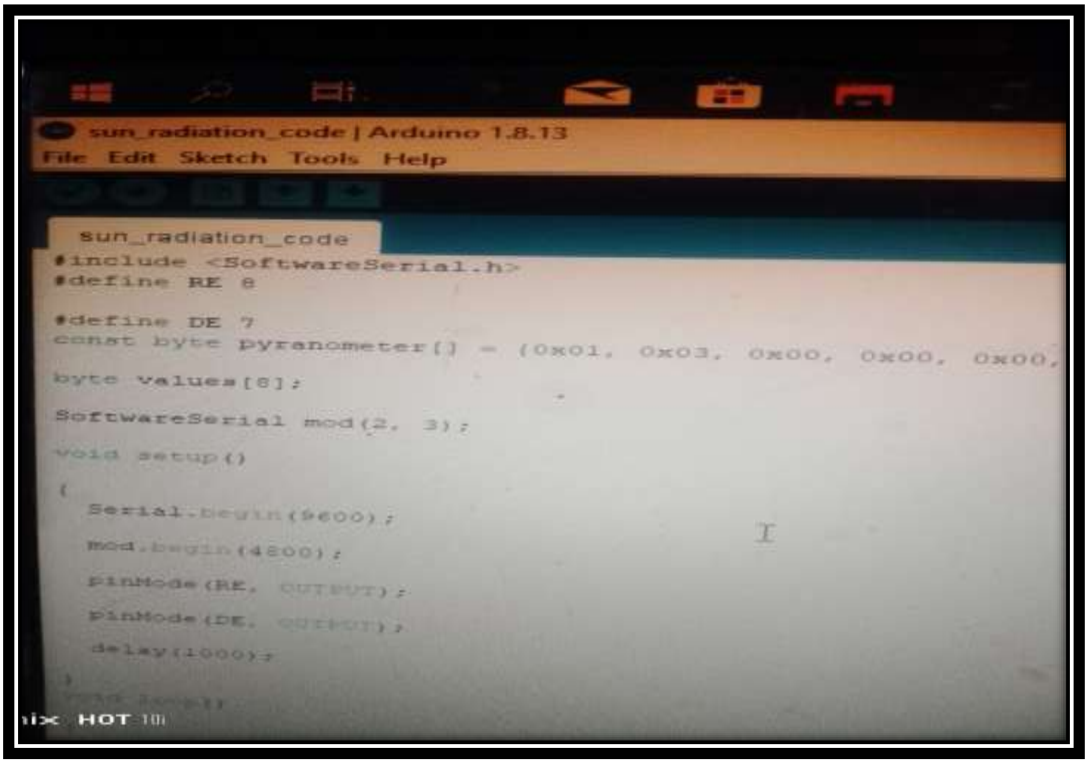
```
sun_radiation_code
Include <softwareserial.h>
define RE 8
define DE 7
const byte pyranometer[ ] = {0x01, 0x03, 0x00, 0x00, 0x00
byte values[8];
Software Serial mod(2,3):
void setup ()
{
Serial.begin(9600);
mod.begin(4800):
pinMode(RE, OUTPUT);
pinMode(DE, OUTPUT):
delay(1000);
}
void loop()
{
// transmit the request to the sensor
digitalWrite(DE,HIGH);
digitalWrite(RE,HIGH):
delay(10):
mod.write(pyranometer.sizeof(pyranometer));

digitalWrite (DE, LOW);
digitalWrite (RE, LOW);
delay(10): // give some time for the sensor to respond

// wait until we have the expected number of bytes or timeout
unsignedlong startTime = millis();
while (mod.available() < 7 &&millis() – startTime< 1000)
// read the response
Byte index = 0;
while (mod. available () && index < 8)
(
values (index) = mod. read();
serial. Print (values(index), HEX) ;
serial .print( ‘‘ ‘’) ;
index ++;
)
Serial. Printin();

// parse the solar radiation value
IntSolar_Radiation =
```

Programme Writing in Arduino Platform



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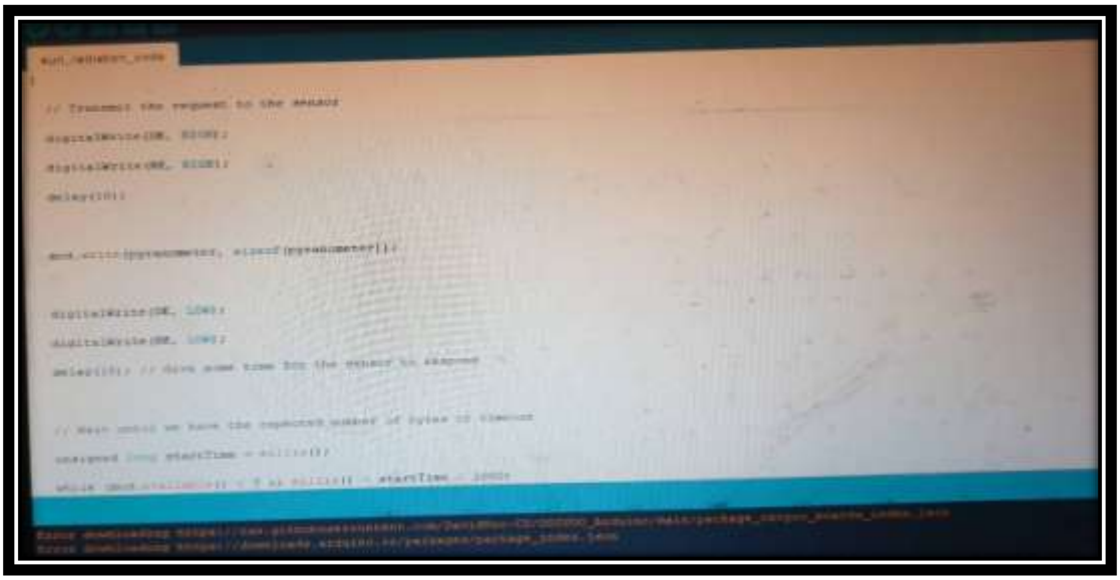
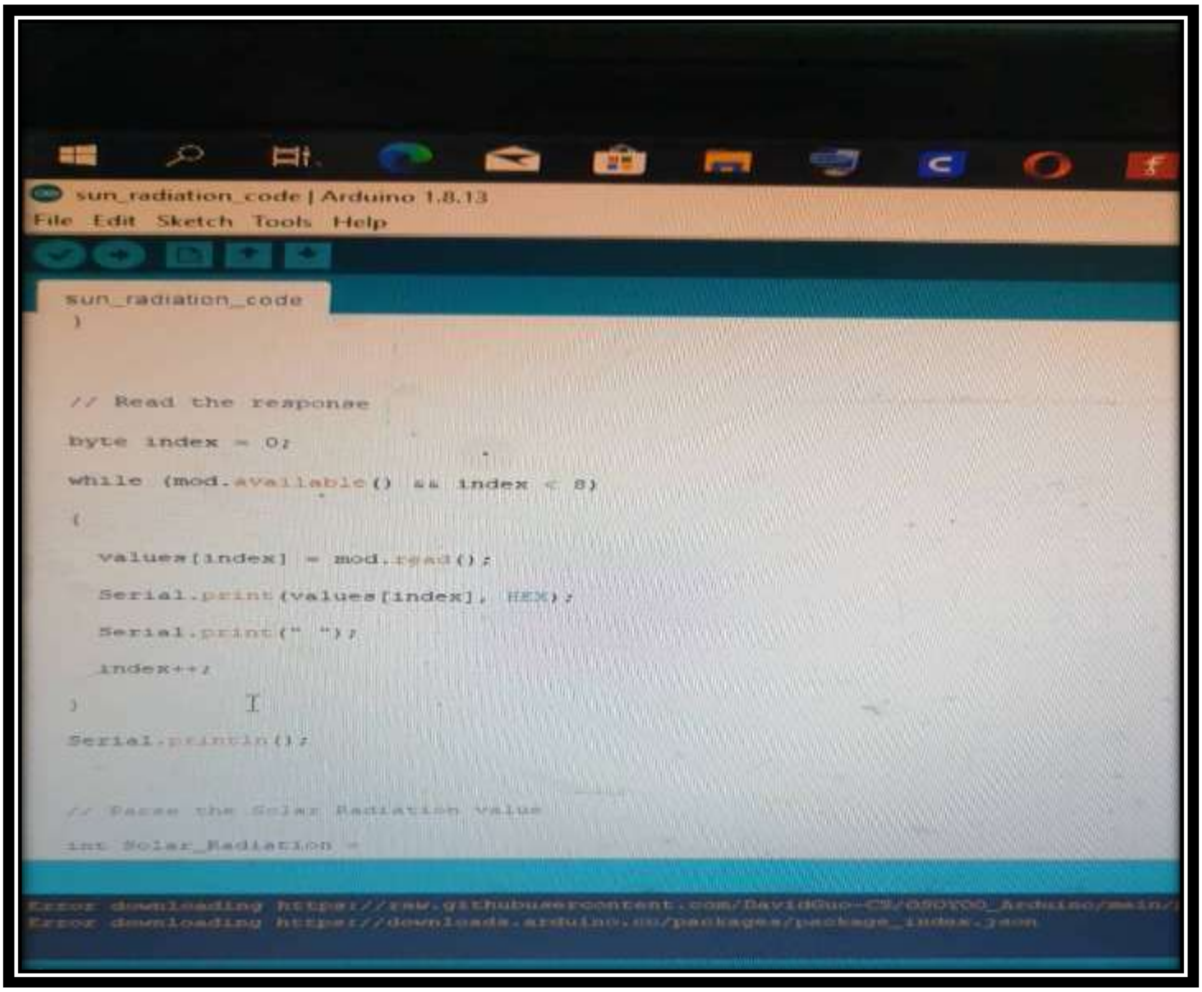


Continuation



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Built-in Circuit assembly

The practical assembly session of this design is shown below. There are two assemblage shown below: the assembly of the Pyranometer section and that of the GPS section.

Fig 8 –Pyranometer Assembly and Coupling

Fig 9 – Position Sensing Assembly and Coupling

BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

The BEME is an evaluation table that describes the design cost, materials/models and quantity in engineering. This tool helps us to guess in advance the cost of the equipment to be designed.A reader may find it difficult to evaluate the content of the work without the BEME. In this design, due to the uncertainty that characterises the cost of materials in the Nigerian markets because of the fluctuation in dollar cost, the BEME of this design do not contain cost and is shown below.

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Table 1

Components	**Model**	**Quantity needed**
Microcontroller	Arduino	2
Radiation Sensor	RS485	1
Position Sensor	GPSLS20031	1
Power Converter	DC/DC 12V	1
Display Screen	16/4 LCD	1
Capacitor	104	4
Resistor	1k, 220, 10k	3
Jumper Wires	Arduino Wire	4
Power Supply	12v AC power box	1

Applications

The aim of designing this project is to develop an electronic equipment that will help to read solar irradiance, intensity or signal and help convert the signal to useful photovoltaic energy in W/m^2. This device also helps to determine the positon of the location where this energy is recorded in the earths equator whereby recording the longitude and the latitude. This is why a GPS sensor is incorporated. It can be used in solar panel installation, solar energy optimization, environmental monitoring and agricultural planning.

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