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Efficient Solar Tracking System using GPS

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***Abstract:** The efficiency of solar module depends on sun position. Since the position of sun continuously changes throughout the day, the intensity of sun rays is not uniform on PV module. So, for getting more sun rays on PV module solar tracker plays a much vital role. A solar tracker is a device for operating a solar photovoltaic panel, especially in solar cell applications and requires high degree of accuracy to ensure that the concentrated sunlight is dedicated precisely on to the power device. This work describes the design and development of two Prototype Solar Tracking Systems mounted with a single-axis and dual-axis. The rays from the sun should fall perpendicularly onto the solar panels to maximize the capture of the rays and this is done by pointing the solar panels towards the sun and following its path across the sky. The solar tracking systems :Tilted Single Axis Tracker (TSAT) and Dual Axis Tracker (DAT) are designed, implemented and experimentally tested. As well as the accelerometer present in the system ensures degree of accuracy. The control circuit for the systems is based on Atmega328P Microcontroller which is programmed to detect the sun position and then actuate the DC geared motor using L298N motor driver to position the solar panel where it can receive the maximum sunlight.*
***Keywords:** Arduino Uno, Accelerometer(Adxl335), Real Time Clock(DS3231), Servo Motor, Motor Driver(L298).*

I. INTRODUCTION

A solar tracker is a device used for orienting a photovoltaic array solar panel or for concentrating solar reflector or lens toward the sun. The position of the sun in the sky is varied both with seasons and time of day as the sun moves across the sky. Solar powered equipment work best when they are pointed at the sun. Therefore, a solar tracker increases how efficient such equipment are over any fixed position at the cost of additional complexity to the system. There are different types of trackers. Extraction of usable electricity from the sun became possible with the discovery of the photoelectric mechanism and subsequent development of the solar cell. The solar cell is a semiconductor material which converts visible light into direct current. Through the use of solar arrays, a series of solar cells electrically connected, there is generation of a DC voltage that can be used on a load. There is an increased use of solar arrays as their efficiencies become higher. They are especially popular in remote areas where there is no connection to the grid. Photovoltaic energy is that which is obtained from the sun[1].

A photovoltaic cell, commonly known as a solar cell, is the technology used for conversion of solar directly into electrical power. The photovoltaic cell is a non mechanical device made of silicon alloy. The photovoltaic cell is the basic building block of a photovoltaic system. The individual cells can vary from 0.5 inches to 4 inches across. One cell can however produce only 1 or 2 watts that is not enough for most appliances. Performance of a photovoltaic array depends on sunlight. Climatic conditions like clouds and fog significantly affect the amount of solar energy that is received by the array and therefore its performance. Most of the PV modules are between 10 and 20 percent efficient[2].

The sun delivers energy by means of electromagnetic radiation. There is solar fusion that results from the intense temperature and pressure at the core of the sun. Protons get converted into helium atoms at 600 million tons per second. Because the output of the process has lower energy than the protons which began, fusion gives rise to lots of energy in form of gamma rays that are absorbed by particles in the sun and re-emitted.

The total power of the sun can be estimated by the law of Stefan and Boltzmann.

$P=4\pi r^2\ \sigma\epsilon T^4$ Watts

T is the temperature that is about 5800K, r is the radius of the sun which is 695800 km and $\boldsymbol{\sigma}$ is the Boltzmann constant which is $1.3806488 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$. The emissivity of the surface is denoted by $\boldsymbol{\epsilon}$. Because of Einstein's famous law $E=mc^2$ about millions of tons of matter are converted to energy each second. The solar energy that is irradiated to the earth is 5.1024 Joules per year. This is 10000 times the present worldwide energy consumption per year.

Solar radiation from the sun is received in three ways: direct, diffuse and reflected radiation.

Direct radiation**:** is also referred to as beam radiation and is the solar radiation which travels on a straight line from the sun to the surface of the earth.

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Diffuse radiation: is the description of the sunlight which has been scattered by particles and molecules in the atmosphere but still manage to reach the earth's surface. Diffuse radiation has no definite direction, unlike direct versions.
Reflected radiation: describes sunlight which has been reflected off from non-atmospheric surfaces like the ground[3].

II. PROPOSED METHOD

The proposed system consists of solar panels mounted one top of another. Each of the panels is connected with servo motors driven by microcontroller built in Arduino. The sun tracking system starts with a Real Time Clock that calculates time, the clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The microcontroller reads time from RTC and compares the sunrise and sunset times from the set of equation fed into the microcontroller and sends signal to the motor to rotate the panels. The actuator is activated around midday after the sun passes the angle ϕ which is the maximum position for the upper and lower panels for full exposure. At sunset the whole system resets coming back to its original orientation via the actuator in fig .1.

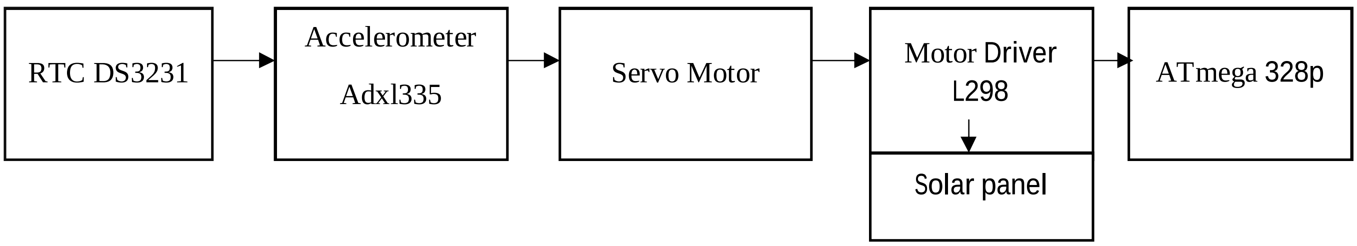

Fig.1. Block Diagram of Solar Tracking

III. IMPLEMENTATION METHODOLOGY

A. Hardware Description

This deals with the physical entities used in the system. The heart of the system is Atmega 328p, which controls and monitors the overall behaviour of the system. The Hardware's are

1) Arduino UNO: Arduino Uno is one of the most common and widely used Arduino processor boards as shown in Fig .2. There are a wide variety of shields (plug in boards adding functionality).The Arduino Uno is microcontroller board based on a removable, dual-inline-package (DIP) ATmega328p AVR microcontroller. It has 20 digital input/output pin (of which 6can be used PWM outputs and 6 can be used as analog inputs). Programs can be loaded on to it from the easy-to-use Arduino computer program. The Arduino has an extensive support community, which makes it a very easy way to get started working with embedded electronics. The ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. It has 28 pins. There are 14 digital I/O pins from which 6 can be used as PWM outputs and 6 analog input pins. The I/O pins account for 20 of the pins. The 20 pins can act as input to the circuit or as output. Whether they are input or output is set in the software. Two of the pins are for the crystal oscillator and are supposed to provide a clock pulse for the Atmega chip.

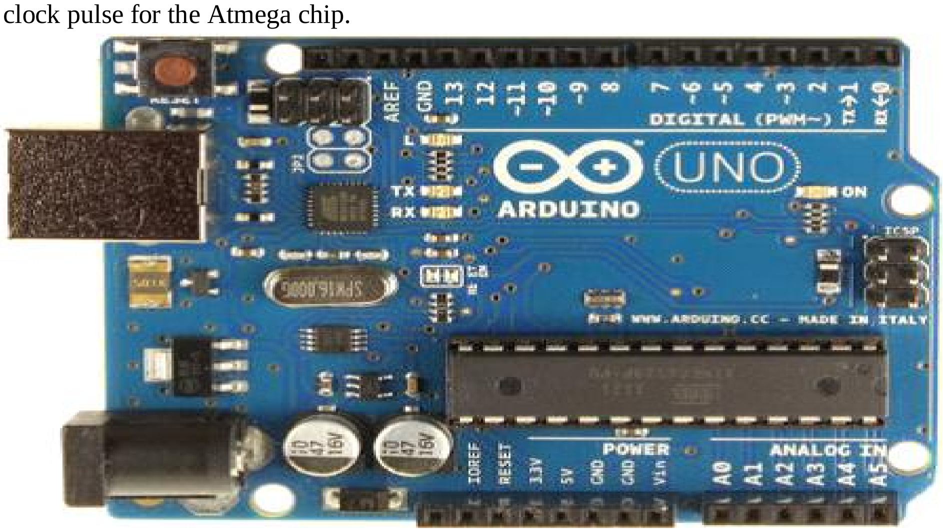

Fig.2. Arduino UNO Board

2) Solar Panel: A solar cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect is shown in Fig.3. It is a form of photoelectric cell, defined as a device whose electrical characteristics -e.g. current, voltage, or resistance vary when exposed to light. If a number of photovoltaic cells are assembled together it forms solar modules which generate electrical power from sunlight. Multiple cells in an integrated group, all oriented in one plane, constitute a solar photovoltaic panel. The efficiency of solar panels goes hand in hand with purity, but the processes used to enhance the purity of silicon are expensive. Since electricity generation efficiency and space efficiency is our primary concern we should select such a solar panel which will best suit these two major requirements. Cost is also a major factor to be considered. There are a number of different types of solar panels and there are differences between these various types of panels, that are worth knowing about but, in the end, it is the total overall power that makes the biggest difference.

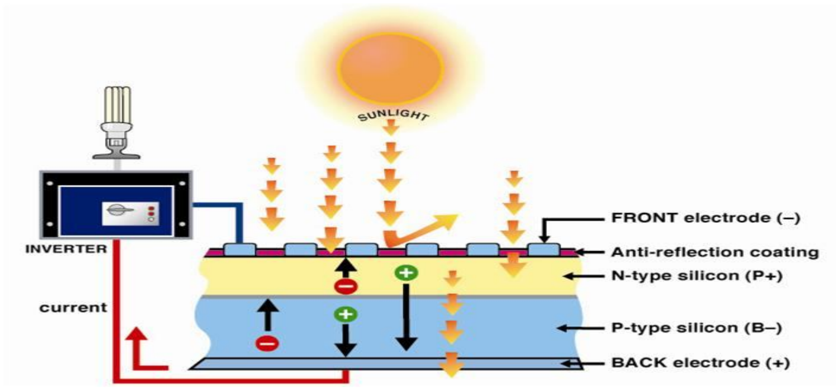

Fig.3.Solar Panel

3) Accelerometer(Adxl335): Accelerometer is an electromechanical device that measures the acceleration or g-force. Accelerometer measures the static acceleration or non-Gravitational acceleration of an object like in tilting an object are shown in Fig.4. It can also measure the dynamic acceleration when an object gains a velocity from standstill due to movement, vibrations or shock. The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration. The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing. As it is a simple robot moving in different directions, data from only 2 of the 3 axis is being captured.

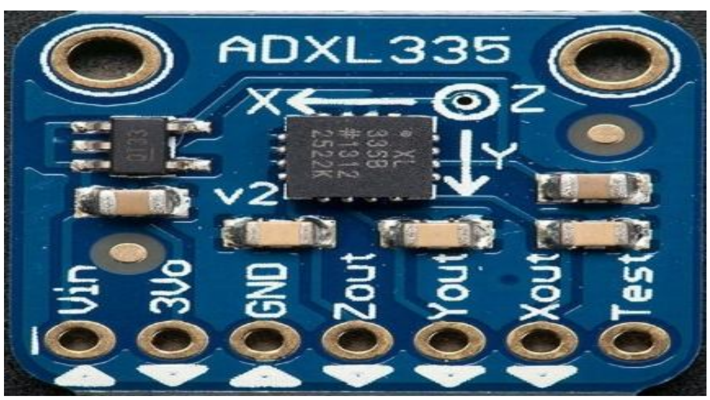

Fig.4. Accelerometer - ADXL335

4) Real Time Clock(DS3231): Real time clocks (RTC), as the name recommends are clock modules. The DS3231 real time clock IC is an 8 pin device using an I2C interface are shown in Fig.5. The DS3231 is a low-power clock/calendar with 56 bytes of battery backup SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month and year qualified data. The end date of each

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month is automatically adjusted, especially for months with less than 31 days. They are available as integrated circuits (ICs) and supervise timing like a clock and also operate date like a calendar. The main advantage of RTC is that they have an arrangement of battery backup which keeps the clock/calendar running even if there is power failure. An exceptionally little current is required for keeping the RTC animated. RTCs are found in many applications like embedded systems and computer mother boards, etc. In this project real time clock DS3231 is discussed and used in implementation of solar tracking system.

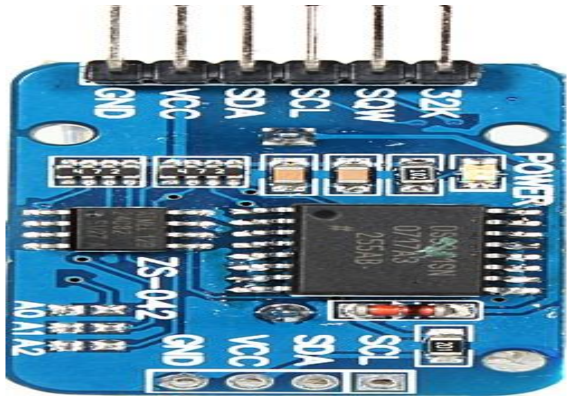

Fig. 5. Real Time Clock DS3231

5) Servo Motor: Servo motors are used for various applications. They are normally small in size and have good energy efficiency. The servo circuitry is built inside the motor unit and comes with a position able shaft that is fitted with a gear. The motor is controlled with an electric signal that determines the amount of shaft movement. Inside the servo there are three main components; a small DC motor, a potentiometer and a control circuit. Gears are used to attach the motor to the control wheel. As the motor rotates, the resistance of the potentiometer changes so the control circuit can precisely regulate the amount of movement there is and the required direction. When the shaft of the motor is at the desired position, power supply to the motor is stopped. If the shaft is not at the right position, the motor is turned in the right direction. The desired position is sent through electrical pulses via the signal wire. The speed of the motor is proportional to the difference between the actual position and the position that is desired. Therefore, if the motor is close to the desired position, it turns slowly. Otherwise, it turns fast. This is known as proportional control.

6) Motor Driver(L298): Voltage regulators are designed to automatically maintain voltages at a constant level. The L298 voltage regulator is used. It is a member of the 78xx series of fixed linear voltage regulator ICs. Voltage sources in circuits could be having fluctuations and thus not be able to give fixed voltage output. The voltage regulator IC maintains the output voltage at a value that is constant. The L298 provides +5V regulated power supply. Capacitors are connected at the input and output depending on respective levels of voltage.

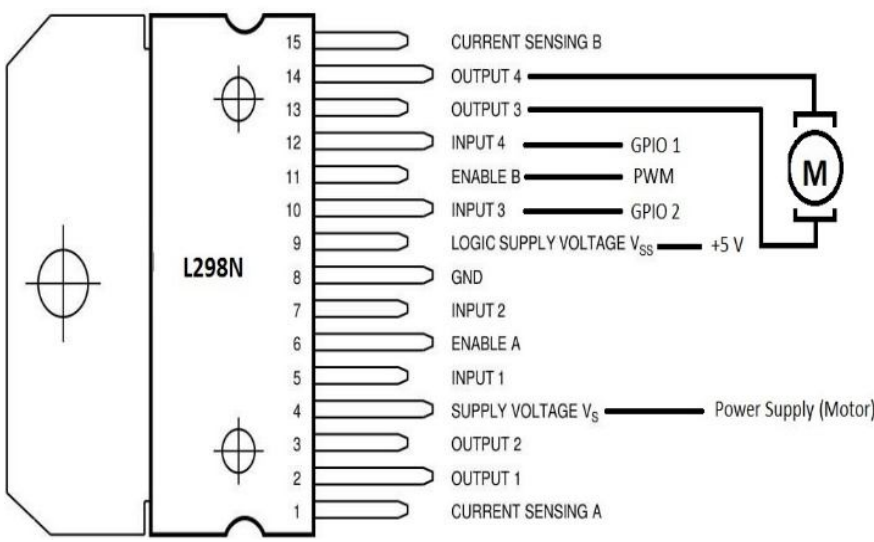

Fig.6. Pin Diagram of L298

B. Software Description

It deals with the Windows Operating System (OS) that is used in the Arduino Uno, C language which is used for programming of Arduino.

1) *Arduino IDE:* The software design was done using Arduino IDE which was used for the programming. The program was written using the C language. In our proposed system we have used Arduino 1.0.3 version for programming. That is an open project that allows writing and debugging codes efficiently which is also immensely supported by vast library files. The library files assisted us in designing algorithms from a sketch books and example's directory. Verification and compilation of error is smooth and easily accessible.

IV. EXPERIMENTAL RESULT

The Fig.7 shows the Hardware working module. It consists of Arduino Uno,Solar Panel, Accelerometer(Adxl335), Real Time Clock(DS3231), Servo Motor, Motor Driver(L298).

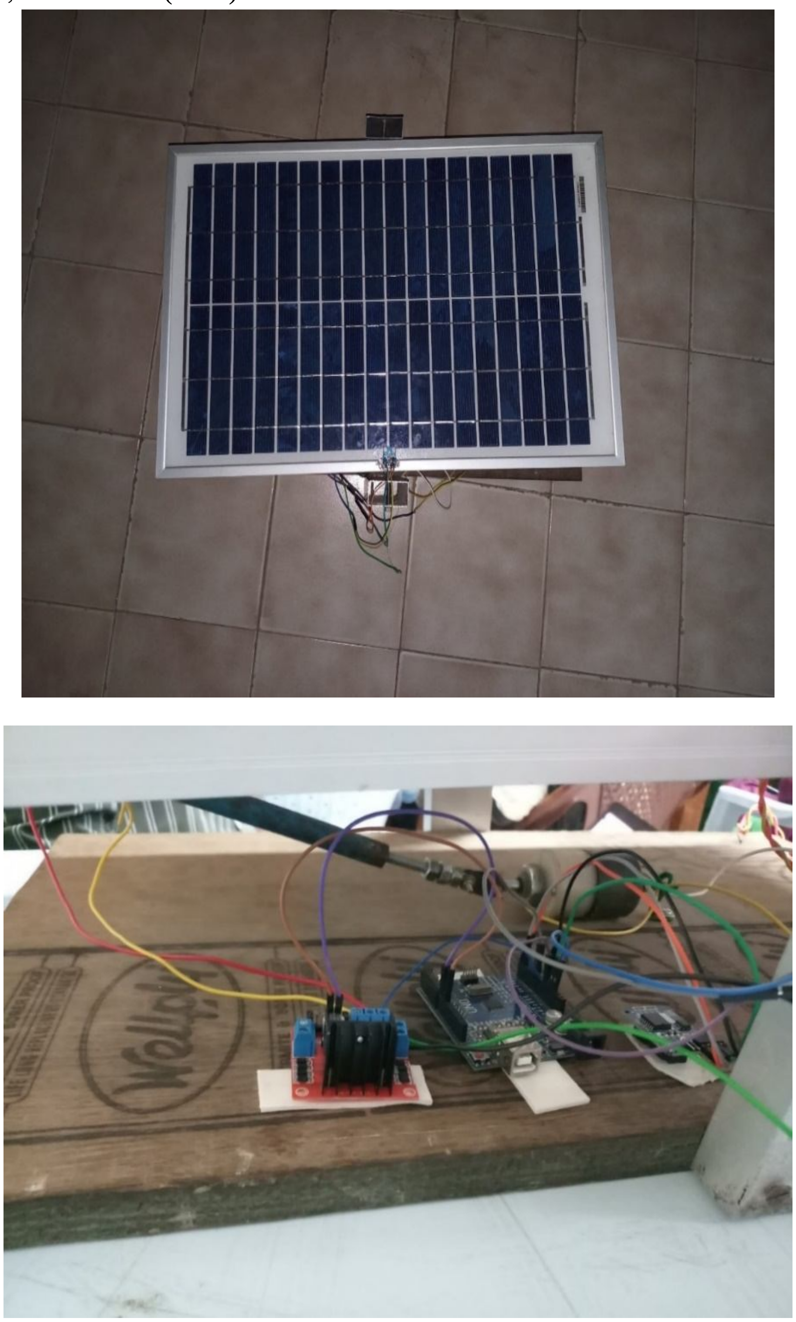

FIG.7. HARDWARE WORKING MODULE

The Output of the Accelerometer as shown in the Fig.8 gives the direction of the solar panel.

```
COM6

0.67    1.31    1.17
0.61    0.93    1.17
0.61    1.29    1.17
0.63    1.33    1.19
4.68    4.55    4.99
4.93    4.64    5.00
4.93    4.56    4.88
4.94    4.56    4.85
4.87    4.47    4.78
4.87    4.47    4.82
4.85    4.47    4.88
4.87    4.50    4.97
4.87    4.50    4.99
4.79    4.46    4.99
4.84    2.60    4.99
4.88    3.10    4.91
4.84    3.96    4.70
4.71    3.91    4.58
4.81    4.19    4.67
4.84    4.20    4.65
4.68    4.14    4.52
4.73    4.29    4.88
4.70    4.32    4.99
4.62    4.31    4.99
2.90    2.79    2.93
3.11    2.96    3.22
3.14    2.49    3.46
3.28    2.34    3.53
4.44    4.12    4.91
3.14    2.88    3.35
3.34    3.05    3.59
3.34    3.02    3.56
4.06    3.64    4.32
4.52    4.11    4.96
4.58    4.31    4.99
3.79    3.49    3.91
3.14    2.97    3.16
4.28    3.97    4.56
4.84    4.43    5.02
4.90    4.41    4.71
4.84    3.78    4.84

Autoscroll
```

Fig.8. Result of Accelerometer

The output of the Real Time Clock is shown in the Fig.9. Here the Real Time Clock function performs time allocation to the Arduino which makes the solar panel tilt.

```
2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31

2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31

2165/165/165 (Monday) 165:165:85
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2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31

2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31

2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31

2165/165/165 (Monday) 165:165:85
 since midnight 26/8/2017 = 1552261585s = 17965d
 now + 7d + 30s: 2019/3/18 12:16:31
```

Fig.9. Result of Real Time Clock

The Fig. 10 shows that Result for Global positioning system. The information obtained from the GPS at Arduino is visible at the Output display.

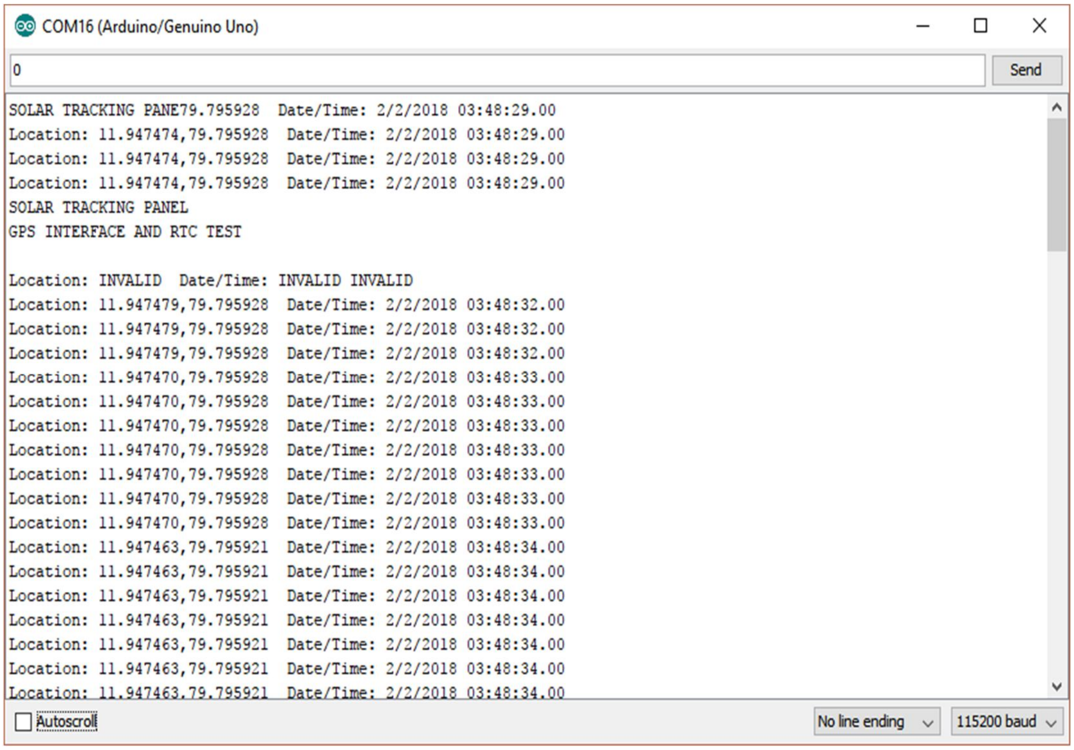

Fig.10. Result of GPS

V. CONCLUSION

From the concept of solar tracking system, this is well suited to utilize more energy than a fixed solar panel. We have tried to make a simple and low cost tracking system. Modification of the same system can be used for big application. However, the system was not easy to made. We faced several problems and failed in different times. We used full rotation servos first, later exchanged with DC motor to meet actual purpose. The required program was written that specified the various actions required for the project to work. As a result, tracking was achieved. The system designed was a dual axis tracker. While dual axis trackers are more efficient in tracking the sun, the additional circuitry and complexity was not required in this case. This is because India is situated north of the equator between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude and therefore there is a significant changes in the apparent position of the sun during the various seasons. Dual trackers are most suitable in regions where there is a change in the position of the sun. This project was implemented with minimum resources. The circuitry was kept simple, while ensuring efficiency is not affected.

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