Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN 1093 – Laboratory Practice I

SOLAR TRACKER

Group 08

180265N P.S.C.JAYAPALA

180263G A.G.C.JAYANGA

180285B W.A.S.N.JAYAWAREDENA

180288L D.S.B.C.L.JAYAWEERA

This is submitted as a partial fulfillment for the module
EN1093: Laboratory Practice I
Department of Electronic and Telecommunication Engineering
University of Moratuwa

Abstract

Solar tracker is a device that directs solar panels towards the sun to capture a maximum energy from the sun changing its orientation throughout the day to follow the sun's path. There are dual axis solar trackers as well as single axis solar trackers. Our task was to build a single axis solar tracker and charge a battery using solar energy. We designed our own circuits and screen printed PCBs. Solar tracker was programmed using PIC microcontroller. Although there were several issues regarding the final outcome as newbies we got so many first hand experiences regarding robotics.

Content

1. Introduction

Solar tracking system is a device that changes its orientation throughout the day to keep solar panels facing directly to the sun. The solar panels generate more energy when they are aligned with the sun for a long time. Our task is building a single axis solar tracking system and here we have used a PIC microcontroller to program the system a lead acid battery would be charged by the energy generated by the solar panels.

Our solar tracking system consists of three main parts; the power supply unit, the main PCB which consists of PIC microcontroller and the ULN2003 motor drive module that gets the LDR readings and passes them to the stepper motor to change rotation direction accordingly and finally the charging and over charge protection circuit to protect the lead acid battery from overcharging. Here we have used PIC16f877A microcontroller and programming was done in C language using mikroC Pro IDE.

Apart from the electronics, charging and coding part we had to consider majorly the mechanism for the rotation of the solar panel. We used gear wheels and the design was done using Solidworks and got them laser cut.

2. Methodology

2.1. Basic aspects regarded

First of all we had to do a background search about the rechargeable batteries available in the market to be used as the battery that is getting charged by the solar panel. Then accordingly the solar panel was decided. Regarding the design of solar panel we had to think of a suitable motor and an appropriate mechanism to rotate the panel using the motor.

2.1.1. Selecting a battery

Lead Acid Batteries are one of the oldest rechargeable batteries available today. Due to their low cost (for the capacity) compared to newer battery technologies and the ability to provide high surge currents (an important factor in automobiles), Lead Acid Batteries are still the preferred choice of batteries in almost all.

WHY SHOULD WE USE LEAD ACID BATTERY?

- Lead-acid batteries are the cheapest secondary batteries, with unit energy costs about a third of those of lithium-ion or nickel-hydrogen batteries.
- The global output of recycled lead has exceeded the output of primary lead. The reuse rate of lead in waste lead-acid batteries in the United States has exceeded 98. Currently, the global average recycling rate of the aforementioned batteries is less than 20%, especially for lithium-ion batteries, which have not been effectively recycled and recycled in most countries.
- the battery with the longest industrial production time and the most mature technology has stable, reliable performance and good applicability

CHARGING PROCEDURE IN LEAD ACID BATTERY

Lead acid battery uses constant current constant voltage method (CCCV). If terminal voltage reached to the upper charge voltage limit then current drops due to the saturation.

Normally charging time period is 12- 16 hours. Higher charge currents and multi stage charging method. We can reduce the charging time to 8- 10 hours.

So we selected a lead acid battery of 6V/4.5Ah.

2.1.2. Selecting a solar panel

According to the ratings of the lead acid battery we used, it requires a Solar panel above 7.5V.But they are available in market in specific value. We bought a solar panel having a maximum voltage of 18V and maximum power of 5W.

2.1.3. Selecting a suitable motor

WHY SHOULD WE USE UNIPOLAR STEPPER MOTOR?

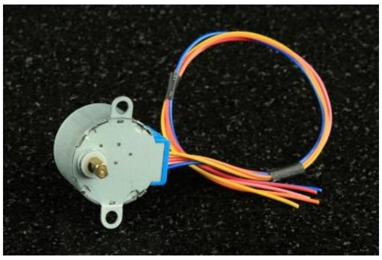
The Stepper Motor is commonly used in an Open Loop System that system don't require positional or torque feedback making the Stepper Motor. We need a torque to stable our solar panel. Also power off time period we need holding torque. Therefore, stepper motor is most suitable motor for that. It provides a constant holding torque without the need for the motor to be powered. Stepper motor has discrete rotation method. That means, one electric pulse it can rotate some specific degree. Our stepper motor rotates 5.624 degrees per pulse. Therefore, we can easily rotate some specific value and also we can easily stop the solar tracker at any point.

STEPPER MOTOR

A stepper motor, also known as step motor or stepping motor. It divides a full rotation into a number of equal steps. Motor is carefully selected to the application in respect to torque and speed.

There are two basic winding arrangements two phase stepper motors;

- Bipolar
- Unipolar



We used unipolar stepper motor for our project.

UNIPOLAR STEPPER

Pin configuration

- Orange – coil 1
- Pink – coil 2
- Yellow – coil 3
- Blue – coil 4
- Red – 5V

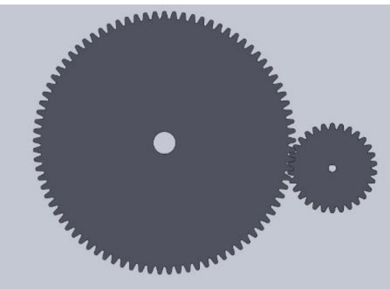
Specifications

- Rated voltage :5V DC
- Number of Phase: 4
- Speed Variation Ratio: 1/64
- Stride Angle: 5.625°/64
- Frequency: 100Hz

Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple for each winding. Resistance between common wire and coil-end wire is always half of what it is between coil-end and coil-end wires. A quick way to determine if the stepper motor is working is to short circuit every two pairs and try turning the shaft, whenever a higher than normal resistance is felt, it indicates that the circuit to the particular winding is closed and that the phase is working. Unipolar stepper motors with six or eight wires may be driven using bipolar drivers by leaving the phase commons disconnected, and driving the two windings of each phase together. It is also possible to use a bipolar driver to drive only one winding of each phase, leaving half of the windings unused.

2.1.4. Choosing a suitable mechanism to rotate the Solar panel

The supporting beams for the solar panel were made out of wood and mounted on a wooden plane. The solar panel was mounted on a steel cylindrical beam which was connected to the two supporting beams using razors. The gear wheels were designed using Solidworks and was made out of ackrylene using laser cutting. Gear wheels were mounted on the back side of the solar panel frame and the other on the motor. There is a separate box to contain the LDR array which was designed using Solidworks and made out of wood using laser cutting to enhance the accuracy of readings. The solar panel is driven by two gear wheels and a stepper motor connected to it.

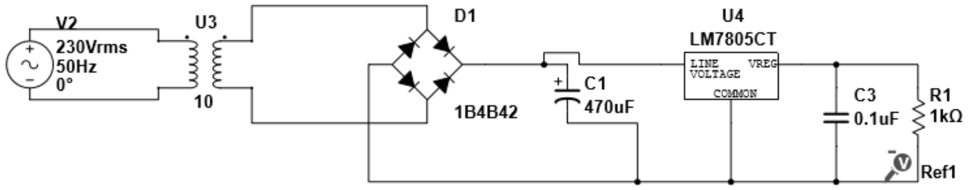


2.2. Circuits

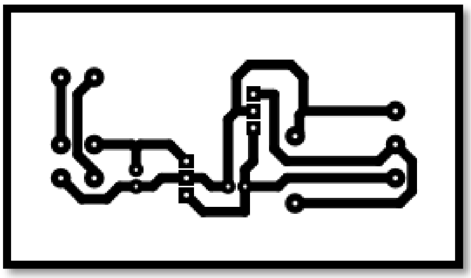
2.2.1. Power Supply Circuit

We used the power supply circuit to rectify the step down voltage, smooth it and regulate it to 5V DC and supply that 5V DC current for the PIC microcontroller and the motor drive.

- Components
  - Bridge
  - LM7805
  - Capacitors(470 uF,0.1uF)
  - 1kOhm resistor
  - Connectors
    - Connect the transformer
    - Connect to the main circuit
- Schematic Design



- PCB Layout



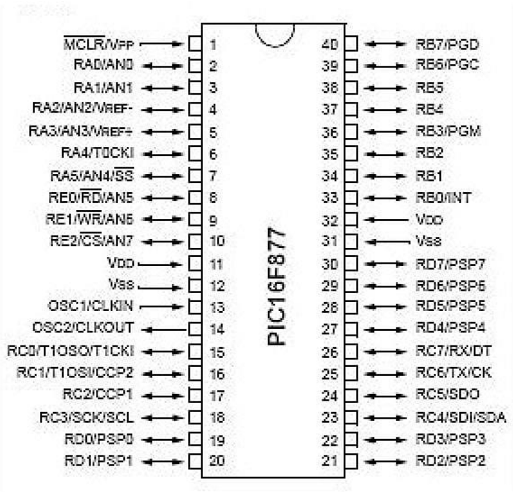
2.2.2. Main Circuit

The main task of the solar tracker is controlled through this main unit. The ldr readings are taken by the PIC micro controller (PIC16f877A) and accordingly the stepper motor is driven through the motor drive (ULN2003).

- Components
  - PIC base
  - Crystal oscillator
  - 22pF capacitors
  - Resistors
  - Connectors
  - supply power to circuit
  - connect the LDR to circuit
  - connect ULN2003 motor drive

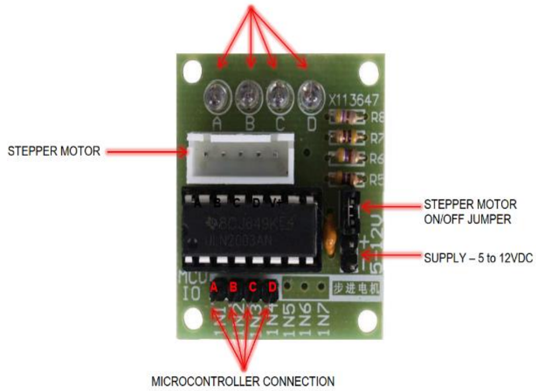
PIC16f877A

The micro controller IC we used here is PIC16f877A with 40 pin package. It is a powerful easy to program, CMOS FLASH based 8 bit microcontroller. It has a data memory of 368 bytes and EEPROM of 256 bytes. We used MikroC Pro IDE to program the IC and the program was uploaded to the IC using a pickit.

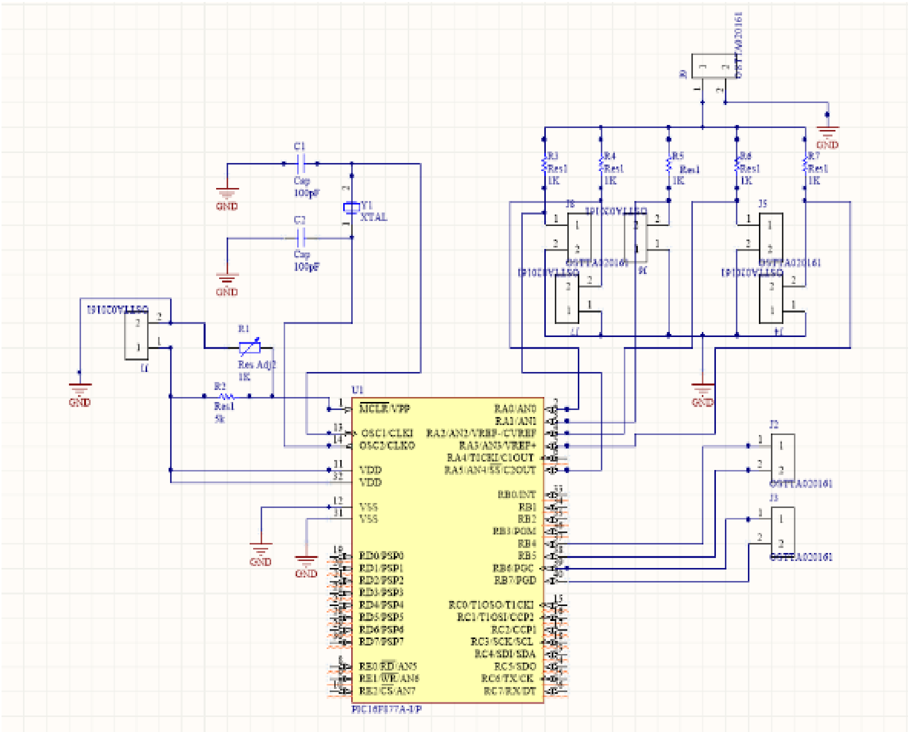


ULN2003

PIC microcontroller output current is very small. But our unipolar stepper motor needs high current more than PIC output. Therefore, we need to amplifier our current before supplying to the stepper motor. Actually logically ULN2003 module is an amplify circuit. It has 4 inputs as well as 4 pin out for stepper motor. ULN2003 module amplification is sufficient for unipolar stepper motor.

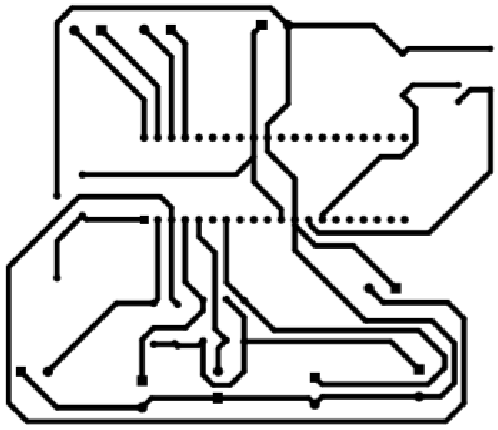


- ❖ Schematic Design



The ports A and B of PIC micro controller are regarded as input and output ports respectively. LDRs are connected to Port A pins while the motor driver is connected to B0, B1, B2, B3 pins.

❖ PCB Layout



2.2.3. Charging and Over-charge Protection Circuit

The circuit harvests solar energy to charge a 6 volt 4.5 Ah rechargeable lead acid battery. The charger has voltage and current regulation and over voltage cut-off facilities.
The circuit uses 18 volt solar panel and a variable voltage regulator IC LM 317.
18 volt DC is available from the panel to charge the battery. Charging current passes through D1 to the voltage regulator IC LM 317. By adjusting its Adjust pin, output voltage and current can be regulated.

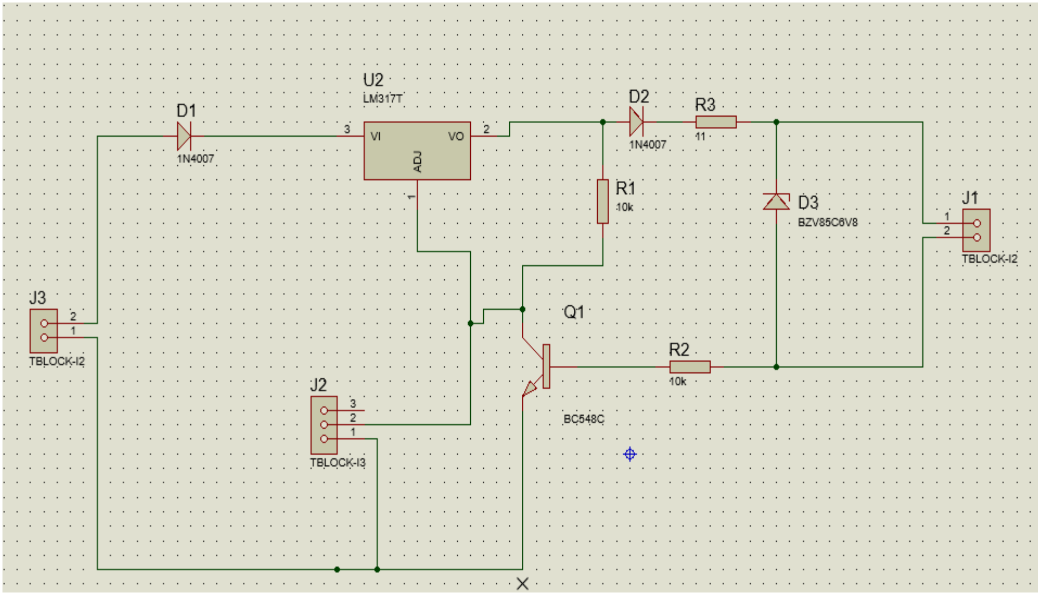
Variable resistor is placed between the adjust pin and ground to provide an output voltage of 7.5 volts to the battery. Resistor R3 Restricts the charging current and diodes D1 and D2 prevents discharge of current from the battery.

Transistor Q1 and Zener diode act as a cutoff switch when the battery is full. Normally Q1 is off and battery gets charging current. When the terminal voltage of the battery rises above 6.8 volts, Zener conducts and provides base current to Q1. It then turns on grounding the output of LM317 to stop charging.

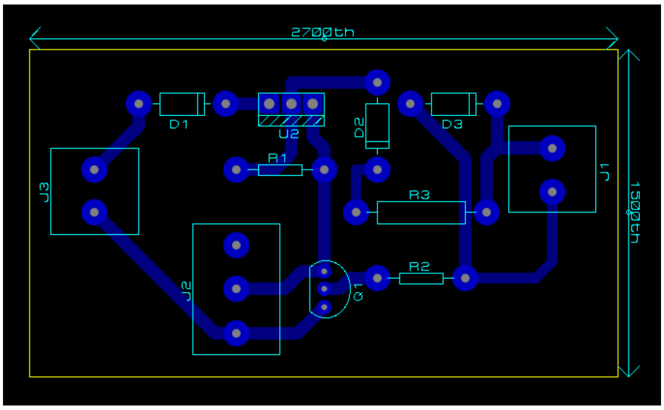
❖ Components

- LM317 variable voltage regulator
- BC548 transistor
- Zener diode (6.8V/1W)
- 1N4007 diodes
- Variable resistor
- Resistors
- Connectors
    - Connect the solar panel
    - Connect the battery

❖ Schematic Design



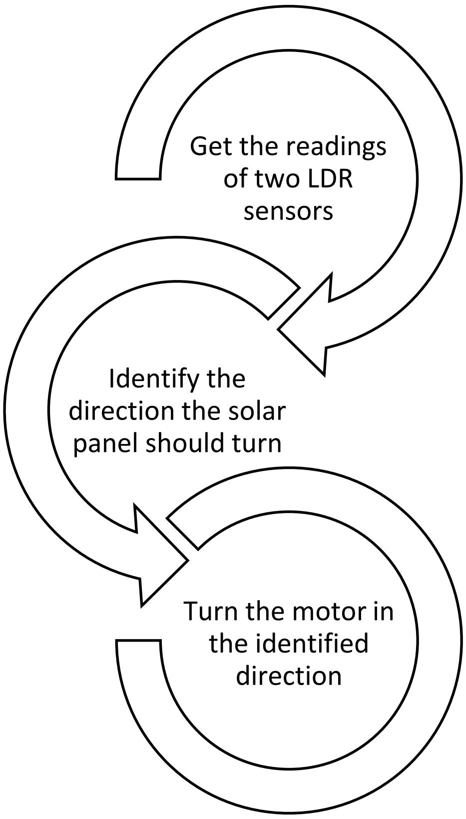
❖ PCB Layout



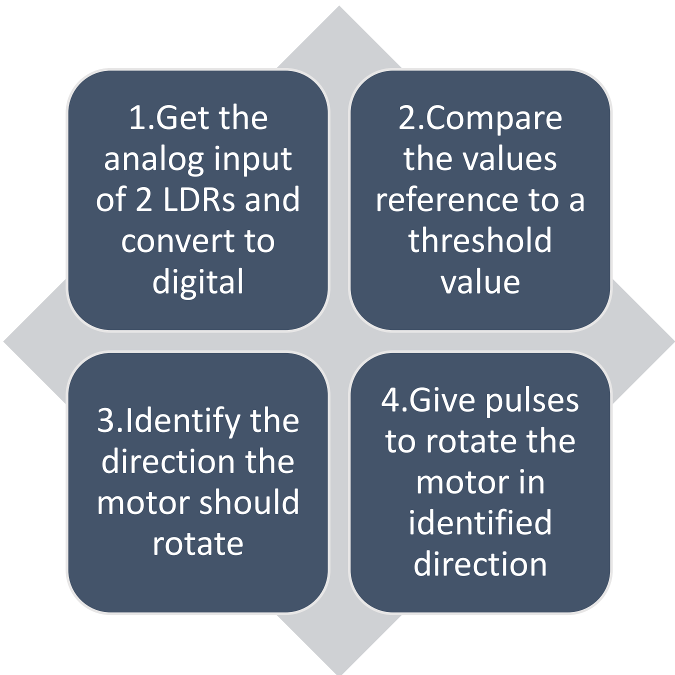
2.3. Algorithm

❖ Logic

The following figure illustrates the logic behind developing the code for the solar tracker.



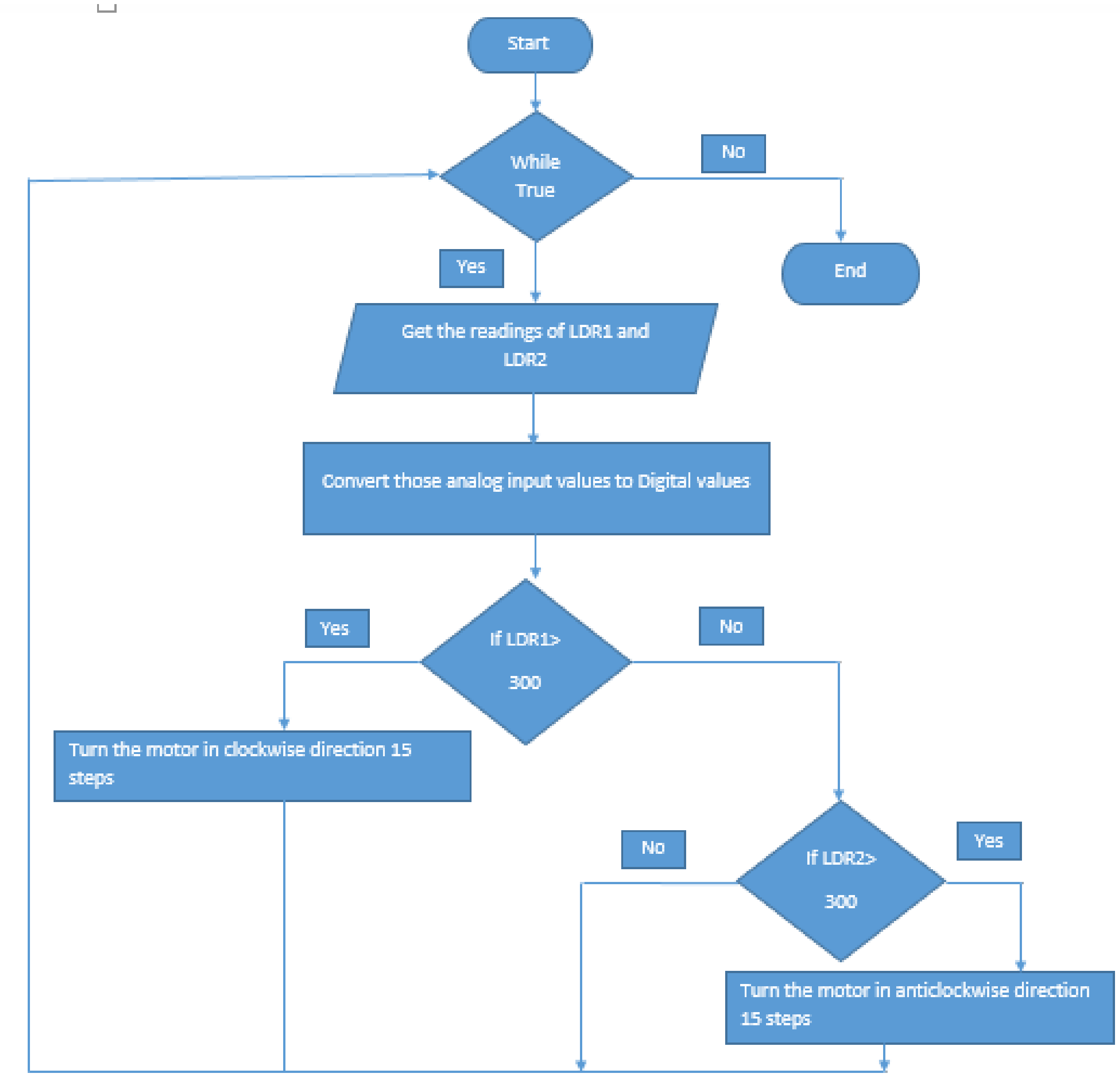
- Main parts of the code



❖ Algorithm

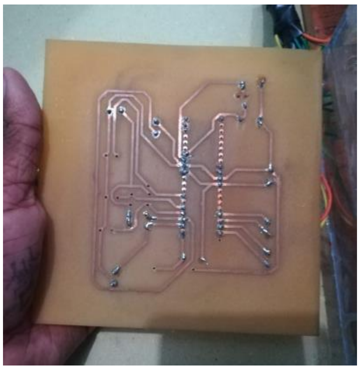
Before going for the coding we developed an algorithm. Here it is drawn using a flowchart.

Here the threshold value is taken as 300 considering the data we obtained by testing.



3. Results

The following figures represent the final outcome of our solar tracker.



Main Circuit

Over Charge Protection Circuit

We checked the solar panel under following circumstances and we could obain the following results.

When solar panel is set parallel to the table and without solar tracker system

Time	Output current	Input voltage	Output voltage
10.00am	126mA	19.12V	7.41V
10.30am	134mA	19.92V	7.35V
11.00am	143mA	20.39V	7.42V
11.30am	145mA	21.32V	7.42V
12.00am	167mA	22.34V	7.43V
12.30pm	156mA	22.54V	7.41V

When Solar panel is set perpendicular to the sunlight and with the solar tracker system

Time	Output current	Input voltage	Output voltage
10.00am	154mA	22.43V	7.43V
10.30am	156mA	22.65V	7.41V
11.00am	159mA	22.76V	7.44V
11.30am	158mA	22.54V	7.43V
12.00am	163mA	22.78V	7.32V
12.30pm	170mA	22.56V	7.37V

More current and voltage was generated under same conditions with a solar tracker. Accordingly it is obvious that solar tracking system is a successful method to capture a large amount of solar energy.

Our charging and over charge protection circuit functioned successfully. The output voltage was regulated at a voltage of 7.4V and a current of 160mA. The battery was protected from over charging successfully. But due to the solar panel being charged through the circuit the current is dropped. Hence it takes much time to get charged. We should have directly charged the solar panel with the over charge protection circuit beside.

4. Discussion

As beginners we went through several problems while doing this project. We learnt almost everything from basics: MikroC, circuit designing, simulation of circuits using Proteus, PCB layout designing using Altium and Proteus, hardware designing and Solidworks.

The problems we faced while carrying on the project, the causes, how we overcame them and wa :

- The major problem we faced was identifying an obvious difference between the intensity of sunlight in different directions. When searches in an online store there was a sensor with a high sensitivity for the intensity of sunlight but it was very costly. So we applied the concept used in that sensor and made a box containing an LDR array with a narrow hole on the lid perpendicular to the LDRs center axis. But then the LDRs and their connecting wires created noise due to inductionand this affected in reliability of the readings. So we reduced the number of LDRs to two. Then that became less accurate.
- First we laser cut the PCB layouts. During the process we had to convert the Altium file to Autocad DXF file and that is done using Linkspace but instead we did that using an online converter. But when testing the circuits malfunctioned. Later we realized that is due to some issues in the online converter. So we screen printed one PCB and due to the insufficiency of time we had two other PCBs ironed. Even then we faced issues due to loose connections and bad soldering.
- The solar panel we selected was nearly 700g in weight. The torque we obtained from the Unipolar stepper was not enough to rotate the solar panel directly. So then we decided to use two gear wheels with 1:4 ratio.
- We charged the solar panel through the over chrge protection circuit itself. But when connected directly there was less than 7.5 V between the two polars of the battery which makes direct connection of no harm. When charged through our circuit we are limiting the charging current and thus it takes much time for the charging process.

5. Acknowledgement

When looking back although it seemed easy, the completion of the solar tracker was not an easy task for us as newbies for the concepts of robotics. We faced so many problems and challenges and could overcome most of them thanks to many personnel behind us.

First we are very grateful to our supervisor Mr.Kasun Pathirage who always guided and helped us.He helped us to clear our doubts issues regarding the task.

In addition, we would like to convey our sincere gratitude to all the lecturers and instructors who were always willing to share their knowledge with us.

We are thankful to all the personal in-charge of laboratories and workshop for allowing us to use the instruments and laboratories and also for helping us in technical problems.

We are very thankful to our batchmates as well who always helped us regarding any issue aroused. Everyone in our batch helped each other and learnt everything together.

6. References

- https://ww1.microchip.com/downloads/en/devicedoc/39582b.pdf
- https://circuitdigest.com/microcontroller-projects/interfacing-stepper-motor-with-pic16f877a
- https://www.mpoweruk.com/leadacid.htm

7. Appendix

1.1 Code

```
int i;

int ldr1;

int ldr2;

int voltage ;


void main() {

ADC_init();

ADCON1=7;

TRISA=1;
```

```
CMCON = 0x07;
TRISB = 0;
PORTB = 0x0F;
 i=0;
delay_ms(200);

while(1)
{
 Ldr2=  ADC_Get_Sample(1);
 ldr 1= ADC_Get_Sample(2);
 delay_ms(50);

if (ldr1>300)
    {       i=0;
            while (i<15)
            { i=i+1;
              PORTB=(0b00001001);
              Delay_ms(5);
              PORTB=(0b00001100);
              Delay_ms(5);
              PORTB=(0b00000110);
              Delay_ms(5);
              PORTB=(0b00000011);
              Delay_ms(5);

                }
}
else{
    if(ldr2>300)
        {
```

```
        i=0;
        while (i<15)
        {   i=i+1;
            PORTB=(0b00000011);
            Delay_ms(5);
            PORTB=(0b00000110);
            Delay_ms(5);
            PORTB=(0b00001100);
            Delay_ms(5);
            PORTB=(0b00001001);
            Delay_ms(5);
          }
         }
    }
    }
```