3.1 INTRODUCTION

The sun moves across the sky during the day from the East to the West, so it's a good idea to make the solar panels tracks the location of the sun such that the panels are always perpendicular with the position of the sun.

In this chapter we are going to describe the methodology of solar tracker with the following characteristic:

- Two-axis tracking system changes both azimuth (horizontal) and altitude (vertical) degrees of solar panel.
- Measuring the solar radiation, the photovoltaic panel volt and current and the surrounding temperature
- Send the measured data to the owner of system
- Design a Graphical User Interface to visualize the sent data
- Store the data in a data base
- Remotely controlled the operation of the system

The system as shown in the block diagram Figure 3,1 consist of two part, hardware implements the algorithm as shown in the Figure 3,2, and GUI implement the algorithm in Figure 3,3.

The system has been simulated using Proteus program in 3 Sheets, Sheet One represent The main sheet contains the major component (Microcontrollers, Sensors, Motors, the Graphical Liquid crystal display (GLCD) and the Communication port). Sheet Two introduce The simulated PV Panel. The last Sheet include The Motors Drivers Circuits. A graphical User Interface (GUI) has been programmed using matlab, in order to monitor and control the design, and Data base to store all the data measured by the proteus design. As it shown in Figure 3.1 the system mainly consists of

- PC based Matlab GUI for controlling and monitoring.
- Two atmega32 microcontroller one for measuring and the other for controlling purpose.
- Proteus based simulated PV panel.
- Sensors to measure the current, the voltage and the temperature.
- Two potentiometer to measure the motors angles.
- Two stepper motors to perform the solar angle shifting.
- A communication link between the microprocessors and the GUI.

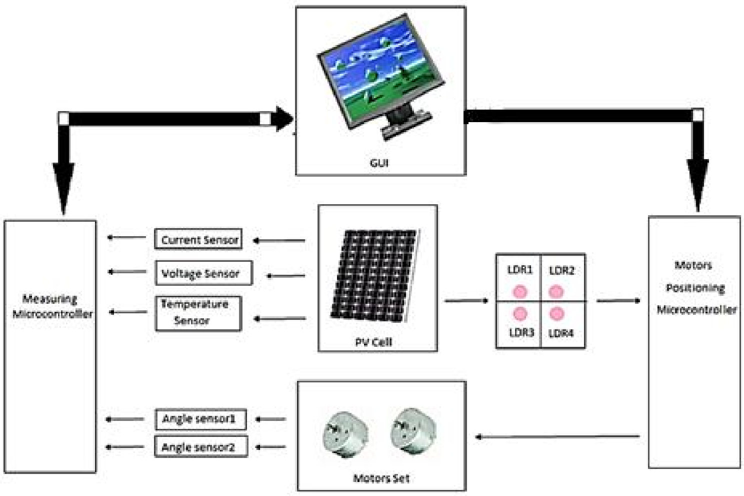

Figure 3.1 The System Block Diagram

The motors controlling algorithm is simple and has 3 actions

- Two axis case

  In proteus the motors will follow the procedures in the algorithm given in Figure 3,2. Any change in the LDR1 and LDR2 will make motor1 to change in position, and that change will be presented in zenith angle in the GUI. And any change in the LDR2 and LDR3 will make motor2 to change in position, and that change will be presented in tilt angle in the GUI.

- ❖ Annual

In the day one from each month a signal will be sent to the system to adjust the tilt angle through motor2 according to the reading of LDR3 and LDR4. Then any change in the LDR1 and LDR2 will make motor1 to change in position, and that change will be presented in zenith angle in the GUI.

- ❖ One Axis

A signal will be sent at 12:00:00 from the GUI to the system.

All the actions will be briefly discussed in section 3.3

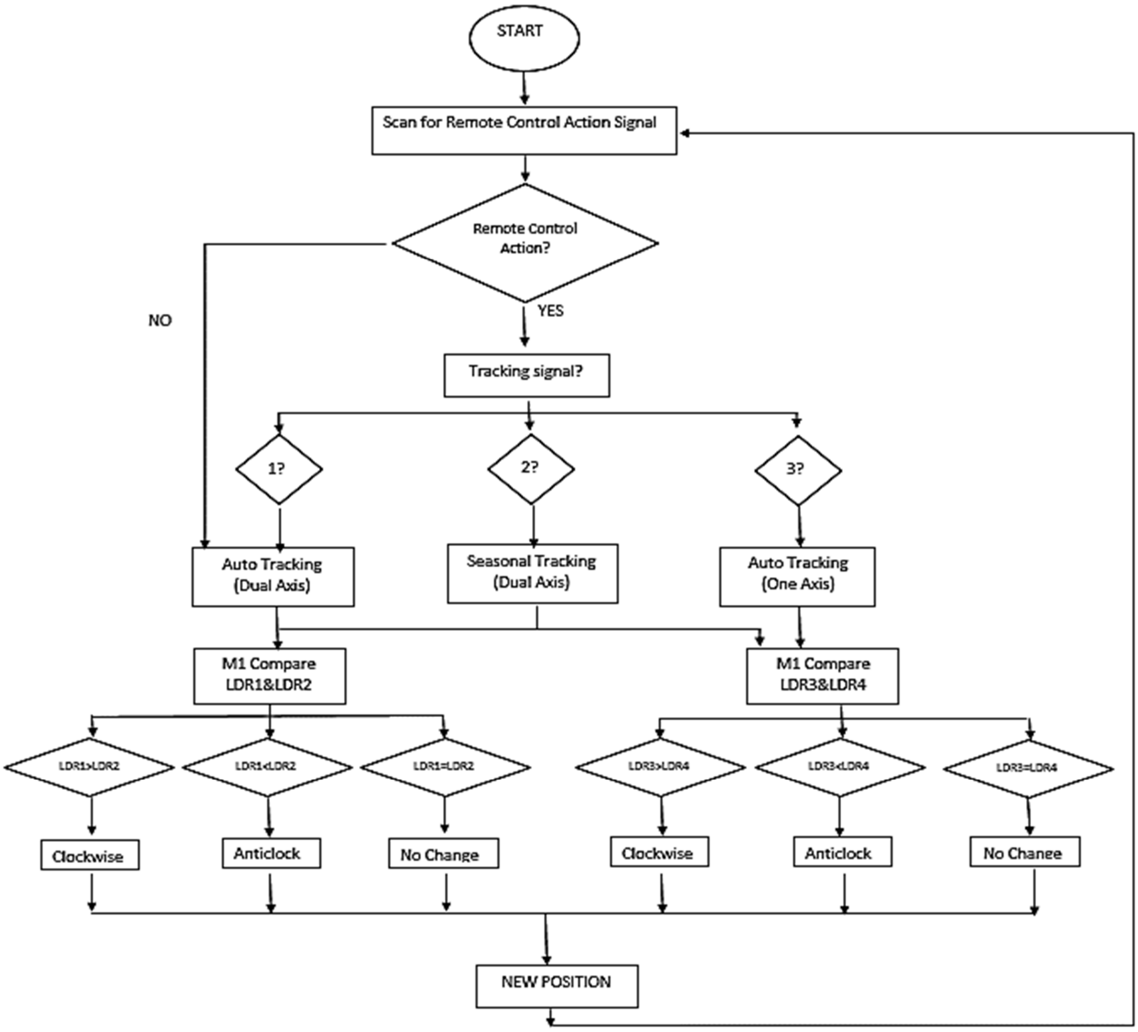

Figure 3.2 Motors Control Algorithm

The GUI algorithm as shown in Figure 3.3 has three panels

Panel 1: Just for welcoming the operator.

Panel 2: For authentication purpose.

Panel 3: For monitoring and controlling the PV system.

All the actions of the GUI will be briefly discussed in section 4.2

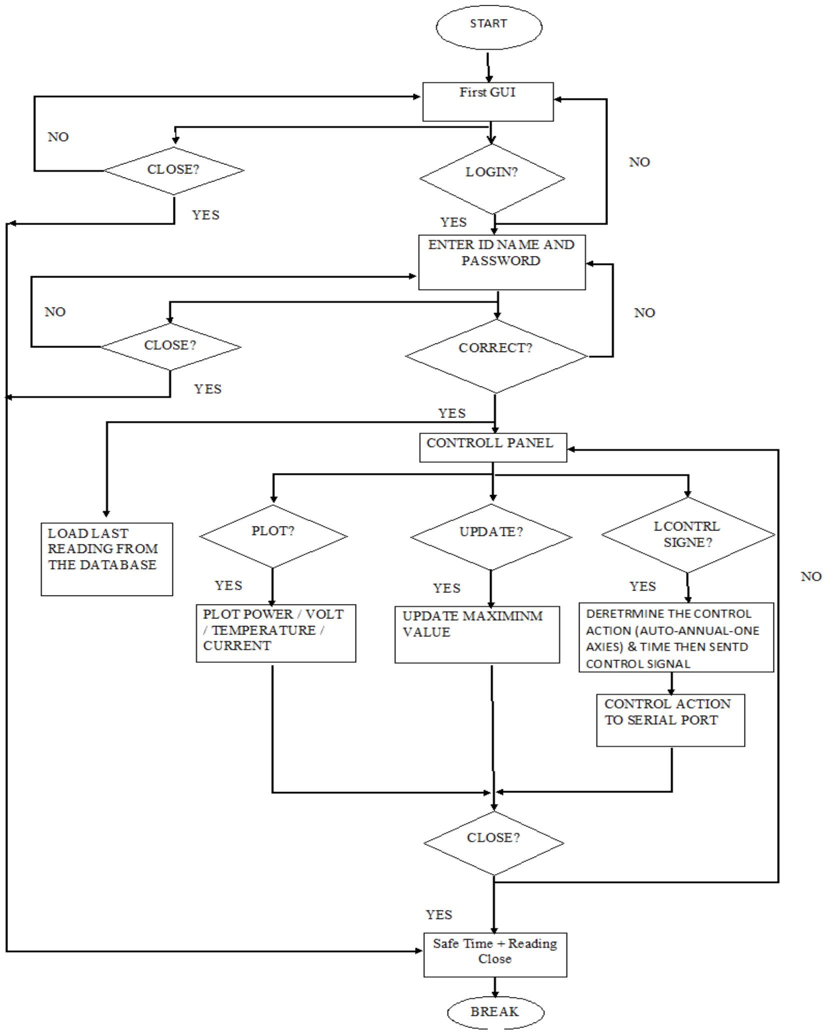

Figure 3.3 GUI Algorithm

3.2 PV PANEL SIMULATING

The PV panel used in this design was ALT50-12P50 WATTS, 12 VoLTS and from the electrical properties found in the data sheet of the chosen PV in Table (3.1) a PV cell has been simulated using the methodology discussed in section 2.1.2 through the Proteus in 20 cells in parallel to insure achieving the selected PV parameters program as shown in Figure 3.4.

voltage / current tests as shown in Figure 3,5 and Figure 3,6. have been made to insure the success of the fabrication

Table (3.1) PV Panel Specification's

Open-circuit Voltage (Voc)	22.3V
Optimum operating Voltage (Vmp)	18.0V
Short-circuit current (Isc)	3.03A
Optimum operating current (Imp)	2.78A
Maximum Power at (Pmax)	50Wp
Operating Temperature	-45°C to 85°C

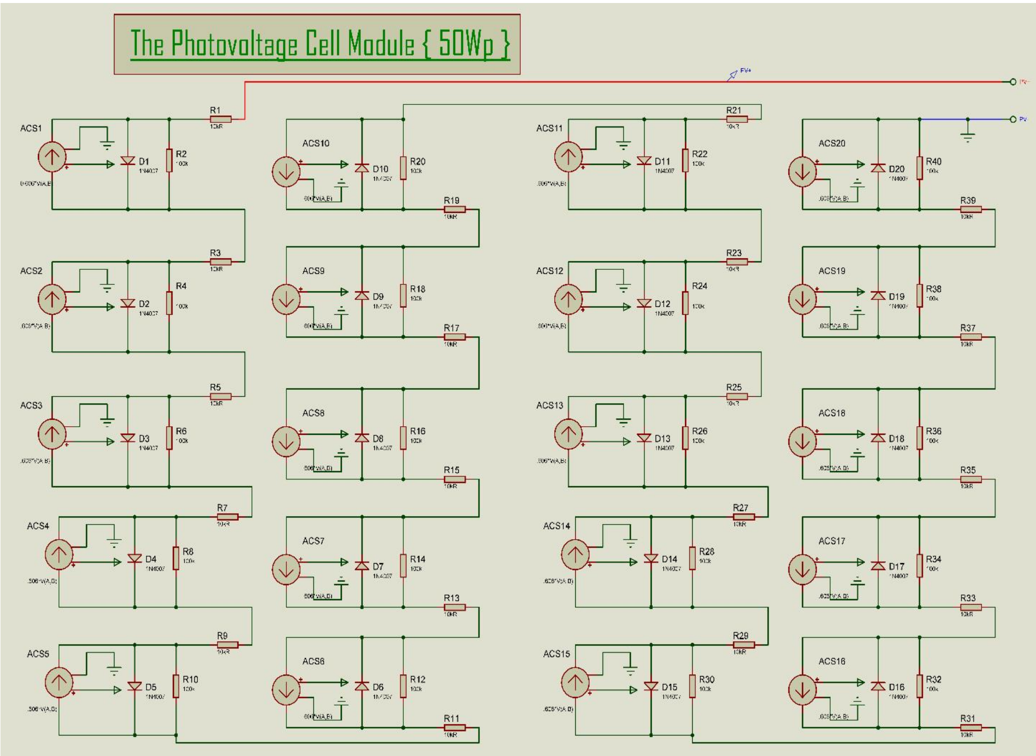

Figure 3.4 Simulated PV Panel

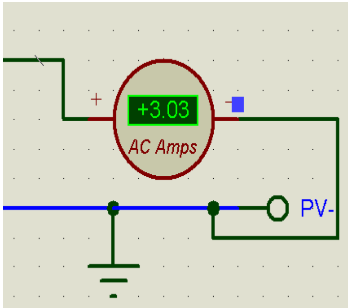

Figure 3.5 PV Volt Reading

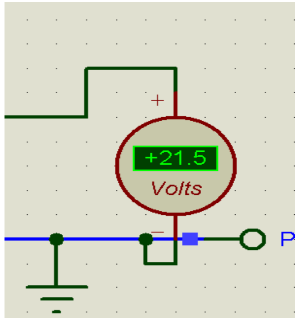

Figure 3.6 PV Current Reading

3.3 FINDING THE SUN POSITION

LDR sensors are used for measuring light intensity and generating a corresponding analog voltage signal that can be used by the micro controller to determine the sun location.

a pair of LDR is used as light sensors to track the sun's daily motion continuously from east to west. and another pair to track the sun's annual motion, that is, from north to as shown in Figure 3.7.

<u>The logic of movement</u>

- If LDR1>LDR2 then M1 is clockwise rotate.
- If LDR1=LDR2 then M1 is no action.
- If LDR1<LDR2 then M1 is anti-clockwise rotate.
- If LDR3>LDR4 then M2 is clockwise rotate.
- If LDR3=LDR4 then M2 is no action.
- If LDR3<LDR4 then M2 is clockwise rotate.

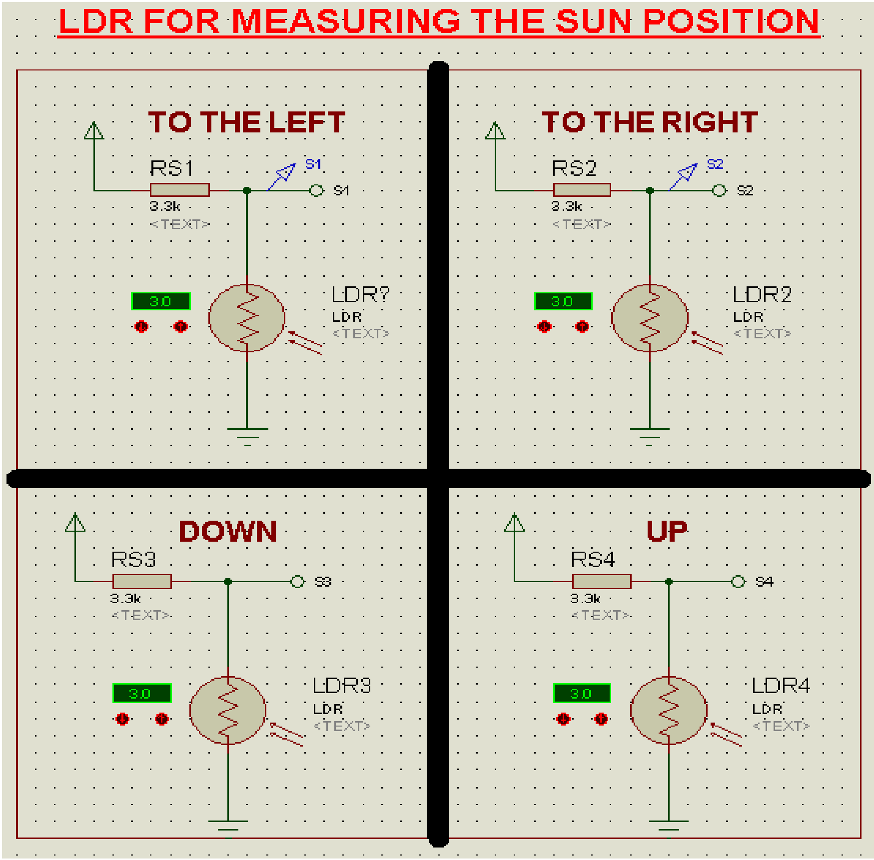

Figure 3.7 LDR to Determine the Sun Position

3.4 VOLTAGE SENSOR

Measuring panel voltage is an important thing to track the panel performance, many type of voltage sensors are available in the market, but in order to minimize the overall cost, a simple voltage divider with unity gain high speed buffer has been designed as shown in Figure 3,8.

3.4.1 Highlighted MAX4222 features include:

- Gains of +2V/V or -1V/V.
- Single 3.3V/5.0V Operation.
- Outputs Swing Rail-to-Rail.

- Low Differential Gain/Phase Error 0.03%/0.04°.
- Low Distortion at 5mHz.
- High Output Drive ±120mA.
- Low 5.5mA Supply Current.

Using this buffer with only 5 v input will insure no more than 5 v will be implemented to the microcontroller input gate

Since the ADC of the microcontroller has maximum 5volt input and the PV voltage is about 22volt so the designed gain of the voltage divider will be

$$Voltage\ Devider\ output = PV\ voltage * \frac{10k}{10k+40k} \ldots\ldots\ldots\ldots 3.1$$

$$Voltage\ Devider\ output = PV\ voltage * \frac{1}{5} \ldots\ldots\ldots\ldots 3.2$$

$$PV\ Voltage\ D = voltageevider\ output * 5 \ldots\ldots\ldots\ldots 3.3$$

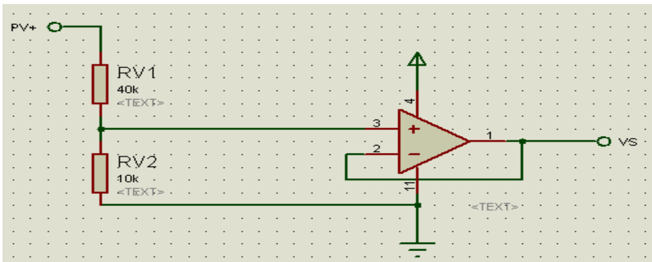

Figure 3.8 The Voltage Sensor

3.4.2 Sensor Calibration

A slight reading deviation was found in the voltage sensor reading so in order to eliminate that deviation a calibration test has been made to find the voltage sensor reading error through Table (3,2).

$$Standard\ Deviation = \sqrt{\frac{\sum(Reading\ Errors - Average\ Errors)^2}{Number\ of\ Reading - 1}} \ldots\ldots\ldots.3.4$$

Table (3.2) Voltage Sensor calibration

Input current	The Reading	Error	Errors-average Errors	(Reading Errors - average Errors)^2
4	3.8142	0.1858	-0.0312	0.0009734
8	7.7986	0.2014	-0.0156	0.0002434
10	9.7741	0.2259	0.008915	7.948E-05
14	13.775	0.2247	0.00765	5.852E-05
20	19.752	0.248	0.03095	0.0009579
Average Error		0.217	Summation	0.002313

$$Standard\ Deviation = \sqrt{\frac{0.002313}{4}} \ldots\ldots\ldots.3.5$$

$$Standard\ Deviation = 0.024045 \ldots\ldots\ldots.3.6$$

By adding the Standard Deviation to formula 3.4

$$PV\ Voltage\ D = voltageevider\ output * 5 + 0.2276775 \ldots\ldots\ldots.3.7$$

3.5 THE CURRENT SENSOR

Fully integrated ACS712, hall effect-based linear current sensor with Low-Resistance Current Conductor was used to measure the PV current, as shown in Figure 3.9 the sensor has 8 ports.

- 1 and 2 IP+ Terminals for current being sampled; fused internally.
- and 4 IP– Terminals for current being sampled; fused internally.
- GND Signal ground terminal.

- FILTER Terminal for external capacitor that sets bandwidth.
- VIOUT Analog output signal.
- VCC Device power supply terminal.

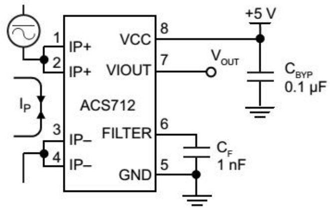

Figure 3.9 IC current sensor ACS712

3.5.1 Highlighted ACS712 features include:

- Low-noise analog signal path.
- 5 μs output rise time in response to step input current.
- 80 *Khz* bandwidth.
- Total output error 1.5% at TA= 25°*C*.
- 5.0 *V*, single supply operation.
- Output voltage proportional to AC or DC currents.

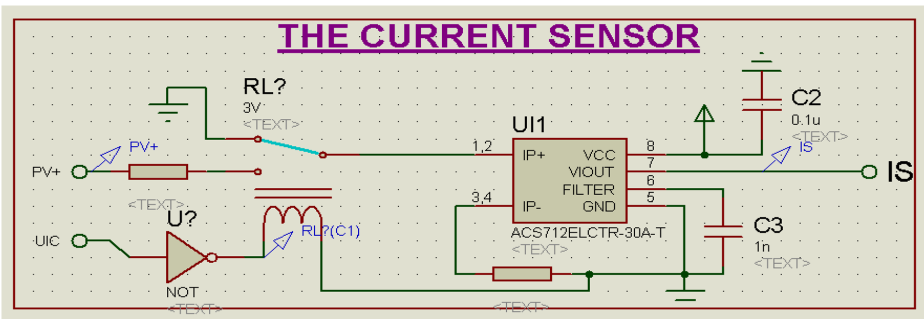

Figure 3.10 The Current sensor

3.5.2 Sensor Calibration

In order to convert the voltage output of the sensor into its equivalent current input the sensor data sheet was used to find the relation 3.8.

$$Current\ Reading = \frac{Output\ sensor\ Reading - 2.5}{0.066} \ldots\ldots\ldots\ldots 3.8$$

A calibration test has been made to find the sensor reading error Table (3,3), using the Standard Deviation formula 3.4

Table (3.3) Current Sensor calibration

Input current	The Reading	Error	Errors-average Errors	(Reading Errors - average Errors)^2
0	-0.002	0.0015	-0.00048485	0.00000024
1	0.9994	0.0006	-0.00139394	0.00000194
2	1.9988	0.0012	-0.00078788	0.00000062
3	2.9982	0.0018	-0.00018182	0.00000003
4	3.9976	0.0024	0.00042424	0.00000018
Average Error		0.002	Summation	0.00000301

So the equation 3.8 will be updated to be

$$Standard\ Deviation = \sqrt{\frac{0.00000301}{4}} \ldots\ldots\ldots\ldots 3.9$$

$$Standard\ Deviation = 0.000686 \ldots\ldots\ldots\ldots 3.10$$

$$Current\ Reading = \frac{Output\ Reading - 2.5}{0.066} + 0.000686 \ldots\ldots\ldots\ldots 3.10$$

3.6 TEMPERATURE SENSOR

A simple LM35 temperature sensor has been used to measure the environment temperature shown in Figure 3.11.

3.6.1 Highlighted LM35 features include:

- Calibrated directly in ˚ Celsius (Centigrade).
- Linear + 10.0 mv/˚C scale factor.
- 0.5˚C accuracy guarantee able (at +25˚C).
- Rated for full −55˚ to +150˚C range.
- Suitable for remote applications.
- Low cost due to wafer-level trimming.
- Operates from 4 to 30 volts.
- Less than 60 μa current drain.

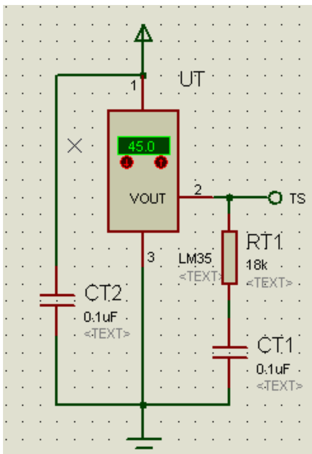

Figure 3.11 The Temperature Sensor

$Temperature = Sensor\ output\ voltage * 100$…………………3.11

3.7 ANGLE SENSOR

Measuring the PV panel position is significant factor in determining the success of the design, a simple and cheap way to do that is by using linear potentiometer, two angle sensors were used as in Figure 3.12 one for the day and night use to measure the angle from east to west, while the other to measure the tilte angle.

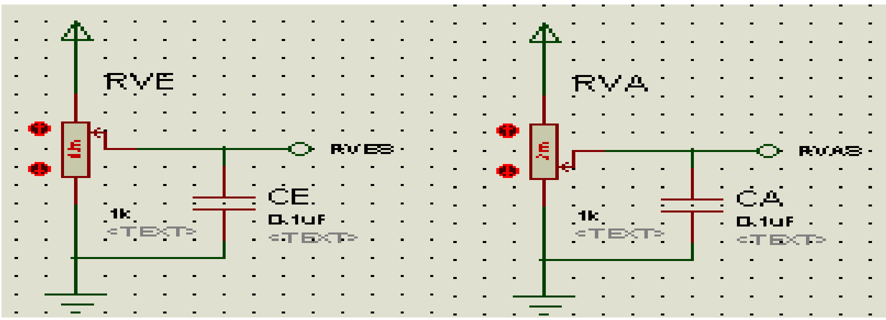

Figure 3.12 The Angle Sensors

3.8 STEPPER MOTOR

Stepper motors are commonly used in precision positioning control applications.[35] Five characteristics of stepper motor have been considered while choosing stepper motor for solar tracker.

Stepper motor is brushless: The commutator and brushes of conventional motors are some of the most failure-prone components, and they create electrical arcs that are undesirable or dangerous in some environments

Load independent: Stepper motors will turn at a set speed regardless of load as long as the load does not exceed the torque rating for the motor.

Has open loop positioning capability: Stepper motors move in quantified increments or steps. As long as the motor runs within its torque specification, the position of the shaft is known at all times without the need for a feedback mechanism.

Good holding torque: Stepper motors are able to hold the shaft stationary.

Excellent response characteristics: to start-up, stopping and reverse

The stepper motor has used in the system has specifications of 12volts, 1º per step, 4 phases unipolar, given in Figure 3.13.

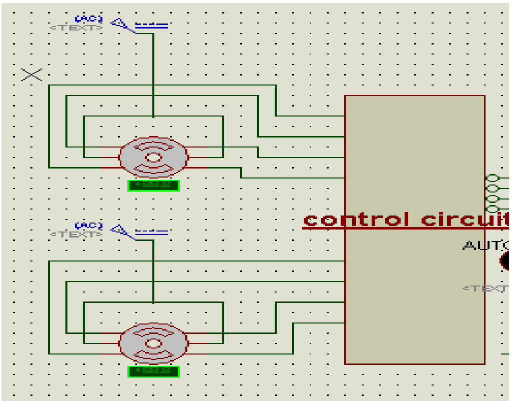

Figure 3.13 The System Motors

3.9 MOTORS CONTROL CIRCUIT

To control the both steppers a combination of the Integrated L297 and L298 has been designed.

3.9.1 The L297 Stepper Motor Controller

Integrates all the control circuitry required to control bipolar and unipolar stepper motors a shown in Figure 3.14. Used with a dual bridge driver such as the L298N forms a complete microprocessor-to-bipolar stepper motor interface with very few components are required (so assembly costs are low, reliability high and little space required).

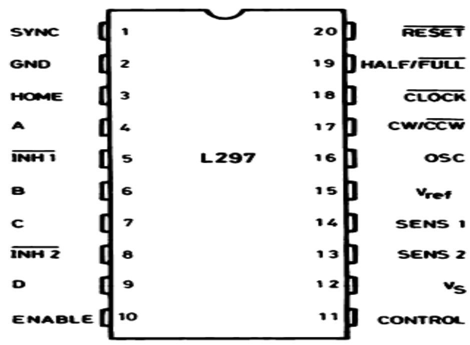

Figure 3.14 The L297 Stepper Motor Controller

- SYNC: Output of the on-chip chopper oscillator.
- GND: Ground connection.
- HOME: Open collector output that indicates when the L is in its initial state (ABCD = 00).
- A: Motor phase A drive signal for power stage.
- INH: Active low inhibit control for driver stage of A and B phases.
- CONTROL: input is low.

- B: Motor phase B drive signal for power stage.
- C: Motor phase C drive signal for power stage.
- INH: Active low inhibit control for drive stages of C and D phases.
- D: Motor phase D drive signal for power stage.
- ENABLE: Chip enable input. When low (inactive) INH, INH, A, B, C and D are brought low.
- CONTROL: Control input that defines action of chopper.
- Vs: V supply input.
- Vref: Reference voltage for chopper circuit.
- OSC: An RC network (R to VCC, C to ground).
- CW/CCW: Clockwise/counterclockwise direction control input.
- CLOCK: Step clock.
- HALF/FULL: Half/full step select input.
- RESET: Reset input.

3.9.2 Dual Full-Bridge Driver L298

It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. given in Figure 3.15.

- Operating supply voltage up to 46 v.
- total dc current up to 4.
- low saturation voltage.
- over temperature protection.
- logical ”0” input voltage up to 1.5 v (high noise immunity).

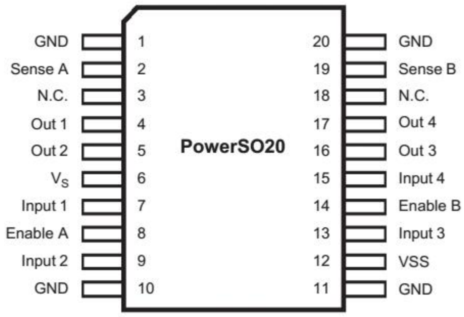

Figure 3.15 Dual Full-Bridge Driver L298

- Sense A Sense B: Between this pin and ground is connected the sense resistor to control the current of the load.
- Out1 and Out2: Outputs of the Bridge A, the current that flows through the load connected between these two pins is monitored at pin.
- VS: Supply Voltage for the Power Output Stages.
- Input1 and Input2: TTL Compatible Inputs of the Bridge A.
- Enable A Enable B: TTL Compatible Enable Input: The L state disables the bridge A (enable A) and/or the bridge B (enable B).
- GND: Ground.
- VSS: Supply Voltage for the Logic Blocks.
- Input1 and Input2: TTL Compatible Inputs of the Bridge B.
- Out1 and Out2: Outputs of the Bridge B. The current that flows through the load
- N.C: Not Connected

The two IC's were connected together in order to drive the both motors in two sets as shown in Figure 3.16.

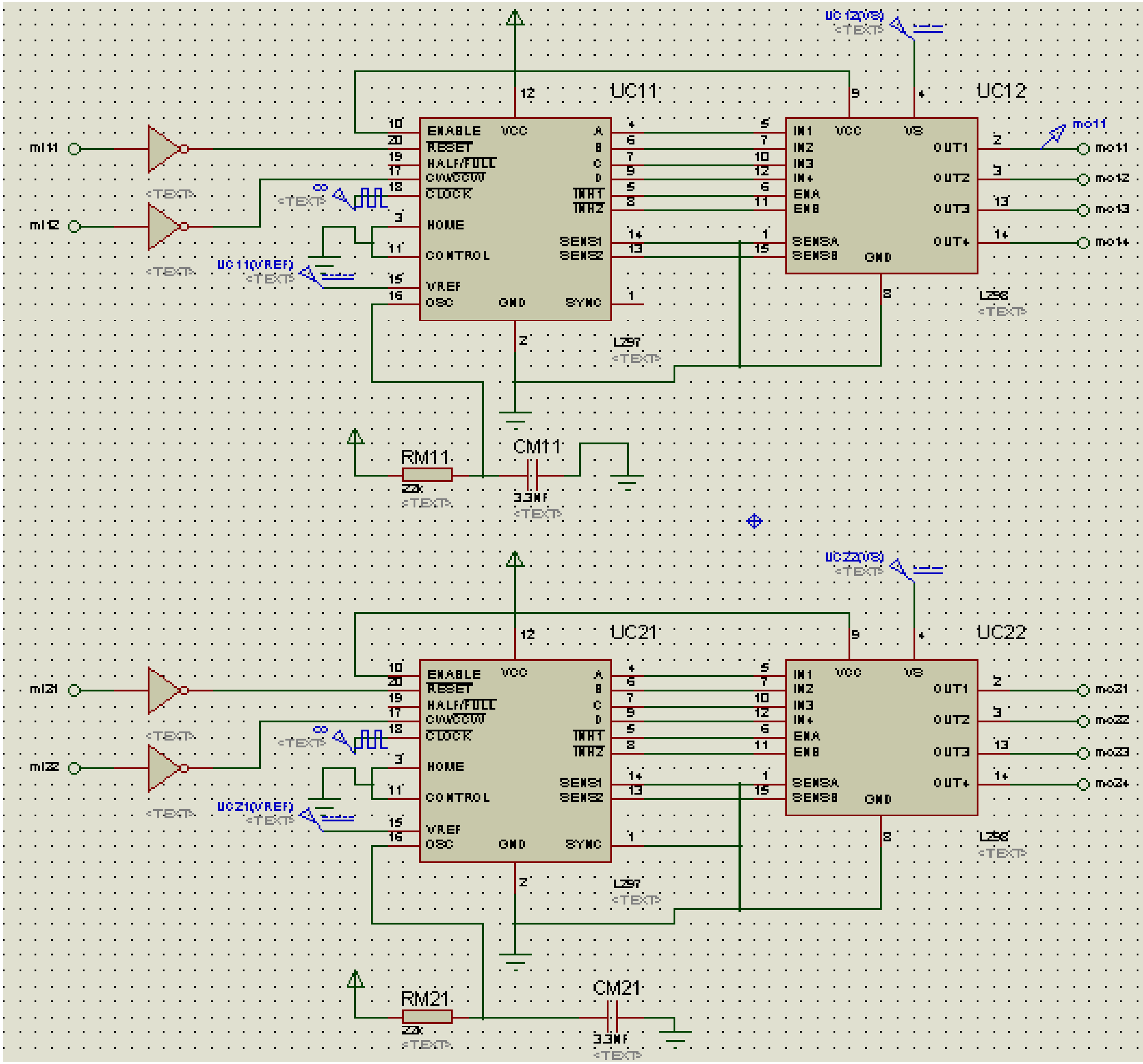

Figure 3.16 motors Driving Circuits