4. System Design and Simulation Results

The main idea of design of the solar-tracking system is to sense the sun light by using four light dependent resistors (LDRs). Each LDR is fixed inside the hallow cylindrical tubes. Two of them, controlling the angle of azimuth, positioned East-West direction and the other two, controlling the angle of tilt, are positioned South-North direction. The LDR assembly is fixed onto the flat-solar panel, shown in Figure (4.1). The tubes are making a degree of 45° with the plane of panel; so, the angle between the tubes is 90°. The differential signals of each pair of LDRs representing the angular error of the solar panel are employed to re-position the panel in such a way that the angular errors are minimized.

If the difference between LDR1 and LDR2 (or LDR3 and LDR4),error signal, is bigger than a certain value (tolerance), MCU generates driving signals for stepper motors. If the error signals are smaller than or equal to the value of tolerance, MCU generates no signal; which means that the solar panel is facing the sun and the light intensities falling on the four LDRs are equal or slightly different. In general applications, the panel should be rotated towards East direction in order to make it ready for operation on the next day.. The micro-controller unit is also skipped to sleep mode and consumes low energy. During the sun rise, the LDR senses the sunlight automatically and the panel is moved towards East direction in a short time; so, there is no need any extra circuitry and software to do this.

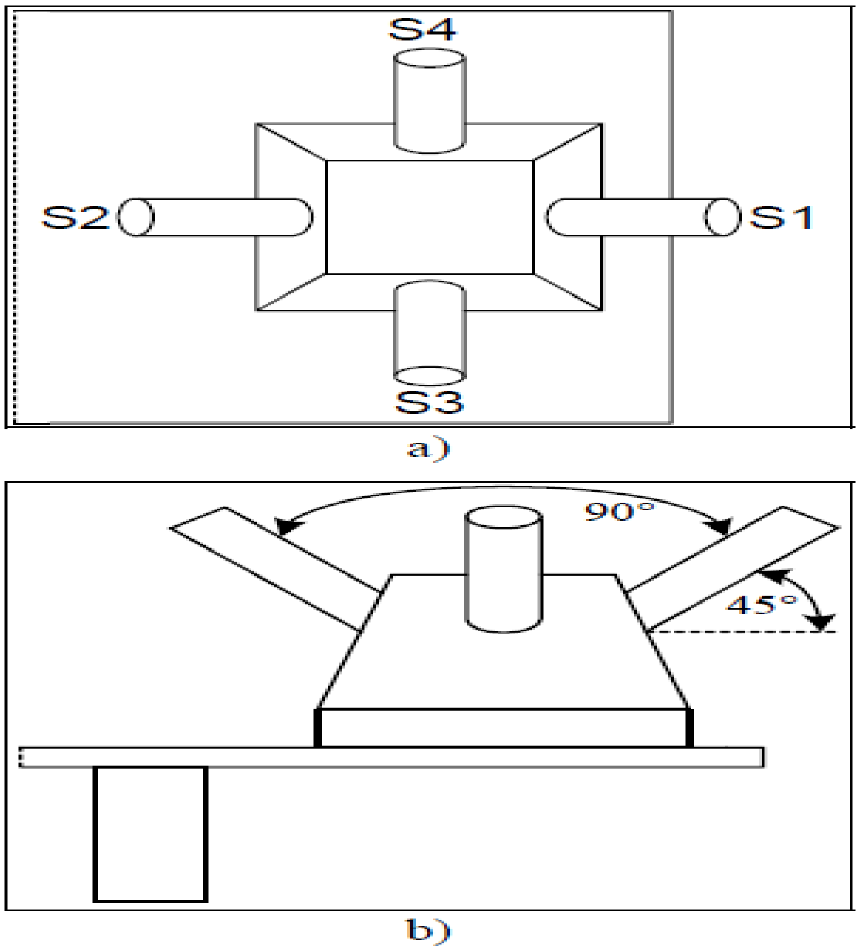

Figure (4.1) The LDRs assembly, a) Top view, b) Front view

4.1 Theory of operation:

To state the movement of motor1 which deal with East West motion and controlled by LDR1 and LDR2, LDR1 is connected to the MCU(U1) at port A (assigned to the ADC) at pin(0), while LDR2 connected to pin(1) the same port

Figure(4.4). By subtracting the readings received from both LDRs, the result will be either (+ve) or (-ve).Whatever the result is, it diverted to calculate the drift from the reference value (set point) ,the set point is the readings of all LDRs indicating the correct orientation of the solar panel towards the sun, that drift is later known as ERROR which is the main variable in the PID controller equation. the PID controller equation to calculate the value of (PID) and proportionally from it calculating the number of steps required for the correct position. The software can determine the direction of rotation and when the subtraction result is (+ve) it is in one direction while (–ve) it is the opposite direction. Motor 2 is controlled the same way of motor 1 but responsible of North-South positioning.

The MCU , through a program code ,obtaining the ERROR ,calculates PID value and translates it into a number of steps with the desired direction(CW or CCW).

The driver is a set of Darlington pairs which receive the low power pulses and amplify them to the required power level needed to drive the stepper motor.

Stepper motor receives pulses from the diver; translate them to a number of steps or half steps according to the sequence in the program code.

A gear with a certain number of teeth grater than the number of teeth in stepper with known GEAR RATIO is directly couple to motor to increase it’s torque against the speed and to increase the positioning precision.

Solar panel is mounted to a free joint to allow it to move EAST- WEST and NORTH- SOUTH.

A battery 12V to maintain enough current for the motors, later it will be charged from the solar panel.

A regulator 5V output is to supply the four sensors and the remains send to the MCU.

4.2 Block Diagram:

The first block includes the LDRs which allowing current to pass according to intensity of light .Second block is the MCU that translating the differece in readings of LDRs into a numer of steps and direction to the stepper motor . third one is the driver that can supply enough current for the motor . Last is the stepper motor responsible for the solar panel directivity, figure (4.2).

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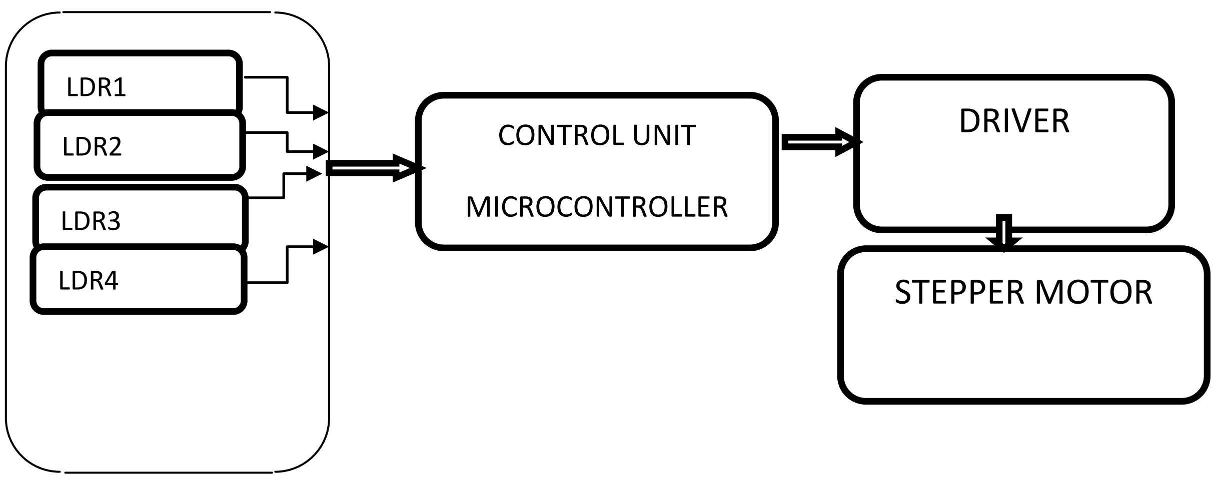


Figure (4.2) system block diagram

4.3 Flowchart:

The program start on power ON, reseting all variables, checking data IN from LDRs, refer to the reference value (r).

Conditions:

- LDR1-LDR2>r the motor1 will rotate CW ,steps proportional to how far is the value(LDR1-LDR2) from (r).
- LDR2-LDR1>r the motor1 will rotate CCW ,steps proportional to how far is the value(LDR2-LDR1) from (r).
- LDR3-LDR4>r the motor1 will rotate CW ,steps proportional to how far is the value(LDR3-LDR4) from (r).
- LDR4-LDR3>r the motor1 will rotate CCW ,steps proportional to how far is the value(LDR4-LDR3) from (r).

The system is programmed to repeat this cycle in intervals equal (dt) ,figure (5.3).

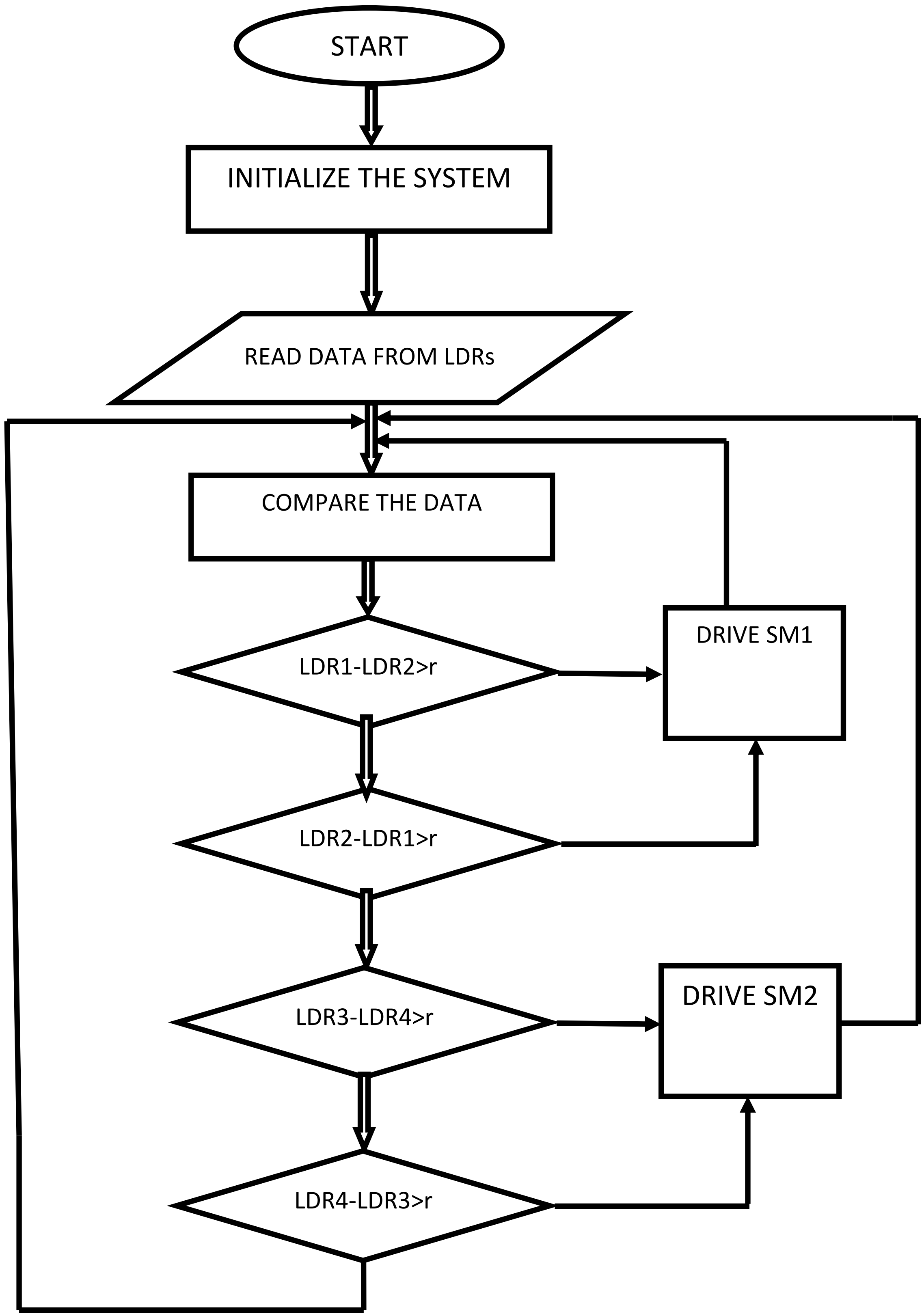


Figure (4.3) System flowchart

4.4 Schematic Diagram:

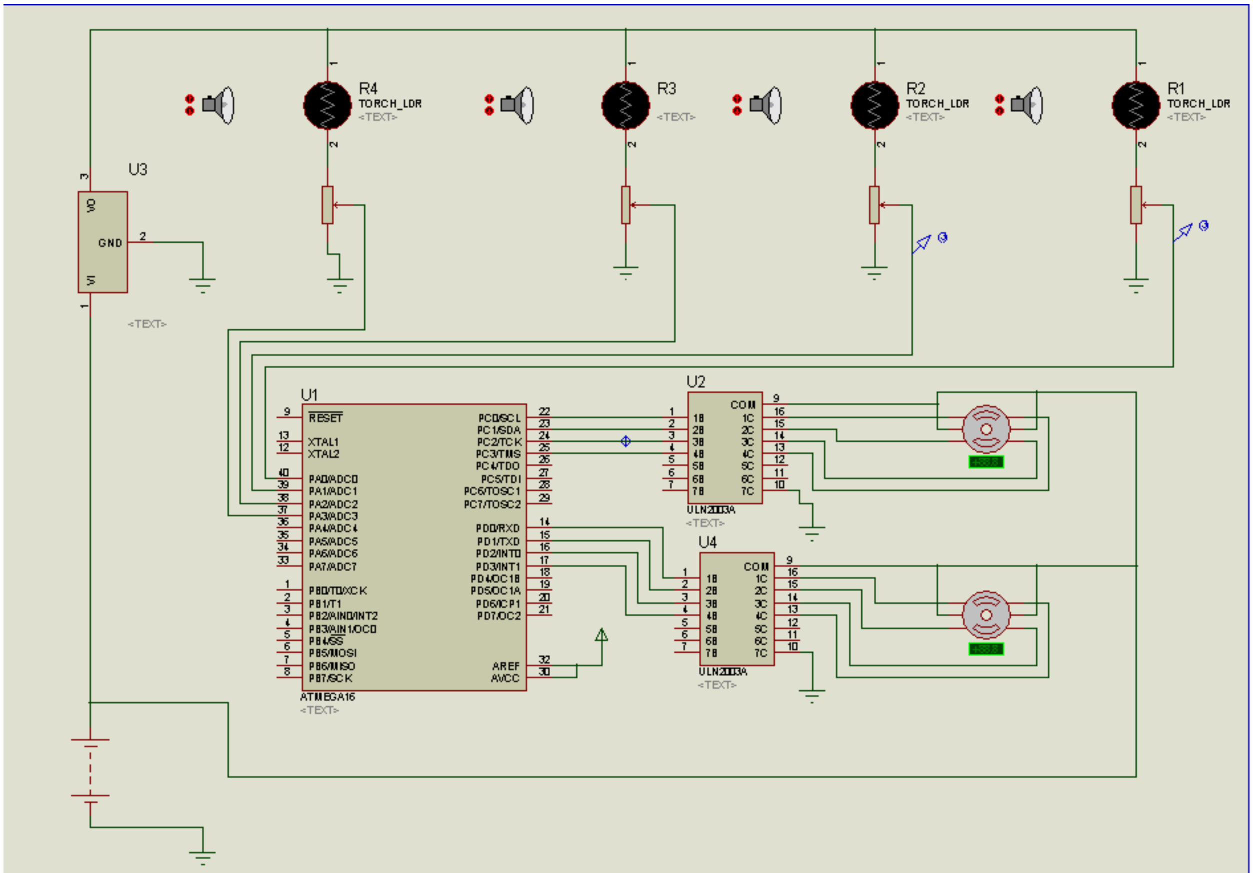


Figure (4.4) Schematic representation to the system

4.4.1 List of components:

I - Photo sensors, 4- LDRs (10 lux – 100 lux).

II - MCU (at mega 16L).

III - Drivers (ULN2003).

V - Stepper motors (step of (5.6^0

IV - Set of mechanical gears.

IIV -Solar panel.

IIIV - Battery of 12V.

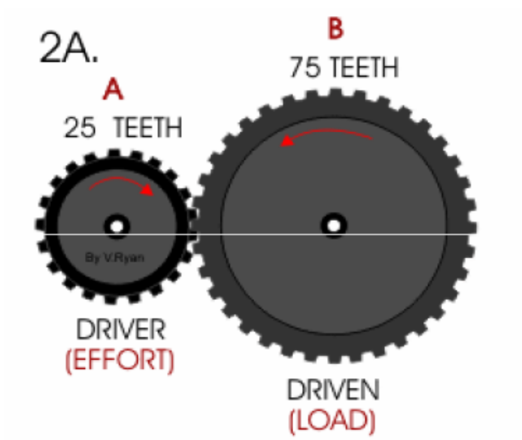
X - Regulator 5V (7805)

4.5 Gear Ratio:

Considering gear (A) as the one of the stepper motor and gear (B) is to be directly coupled to it as shown in Figure (4.5) so as to increase the torque and reduce the speed , as we interest in torque rather than speed.

Gear (B) is useful to increase the accuracy of positioning i.e. if the stepper is chosen as 60 for step that will be transferred to the solar panel through gear (B) as 6/3= (2^0).If the panel is directly coupled to the stepper it will move (6^0) each step, while with gear(B) the move will be only (2^0) which is more precise.

Gear Ratio - Examples



$$\frac{Driven}{Driving} = \frac{75}{25} = \frac{3}{1} \rightarrow 3:1$$

What does this mean? For every 3 rotations of the driving gear, the driven gear makes one rotation.

Figure (4.5) Gear ratio calculation

4.6 Simulation results:

It is clear that from Figure(4.6) the LDR(R1) is exposed to light while LDR2(R2) is not ,that makes a different in readings of pin(0) and pin(1) at port(A) of the MCU,that difference is transferred as a clockwise rotation at the motor denoted by the number (+227).

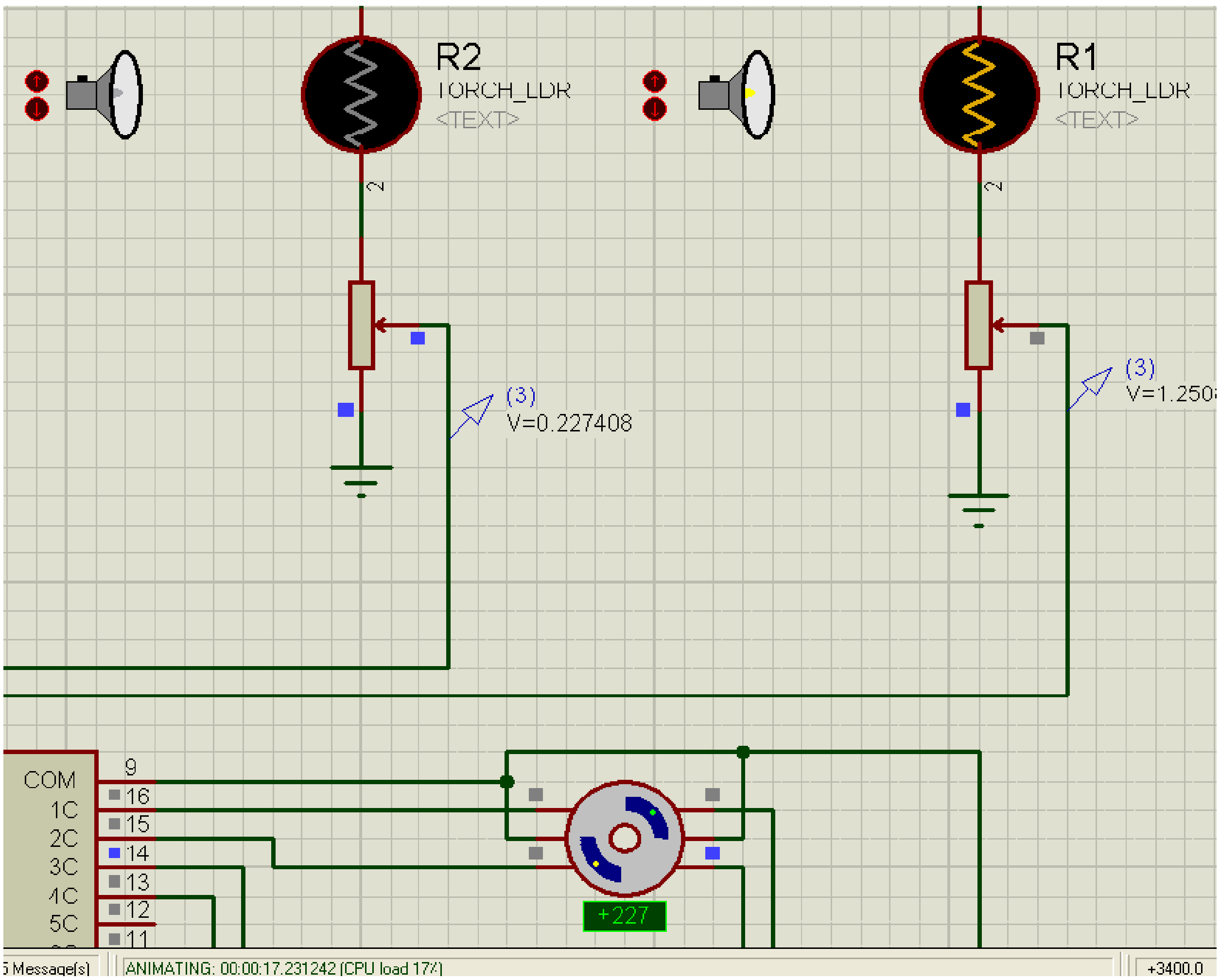


Figure (4.6) shows the clockwise rotation of the motor

In Figure(4.7) LDR(R2) is exposed to light while LDR1(R1) is not ,that makes a different in readings of pin(0) and pin(1) at port(A) of the MCU, that difference is transferred as a counterclockwise rotation at the motor denoted by the number

(-227).

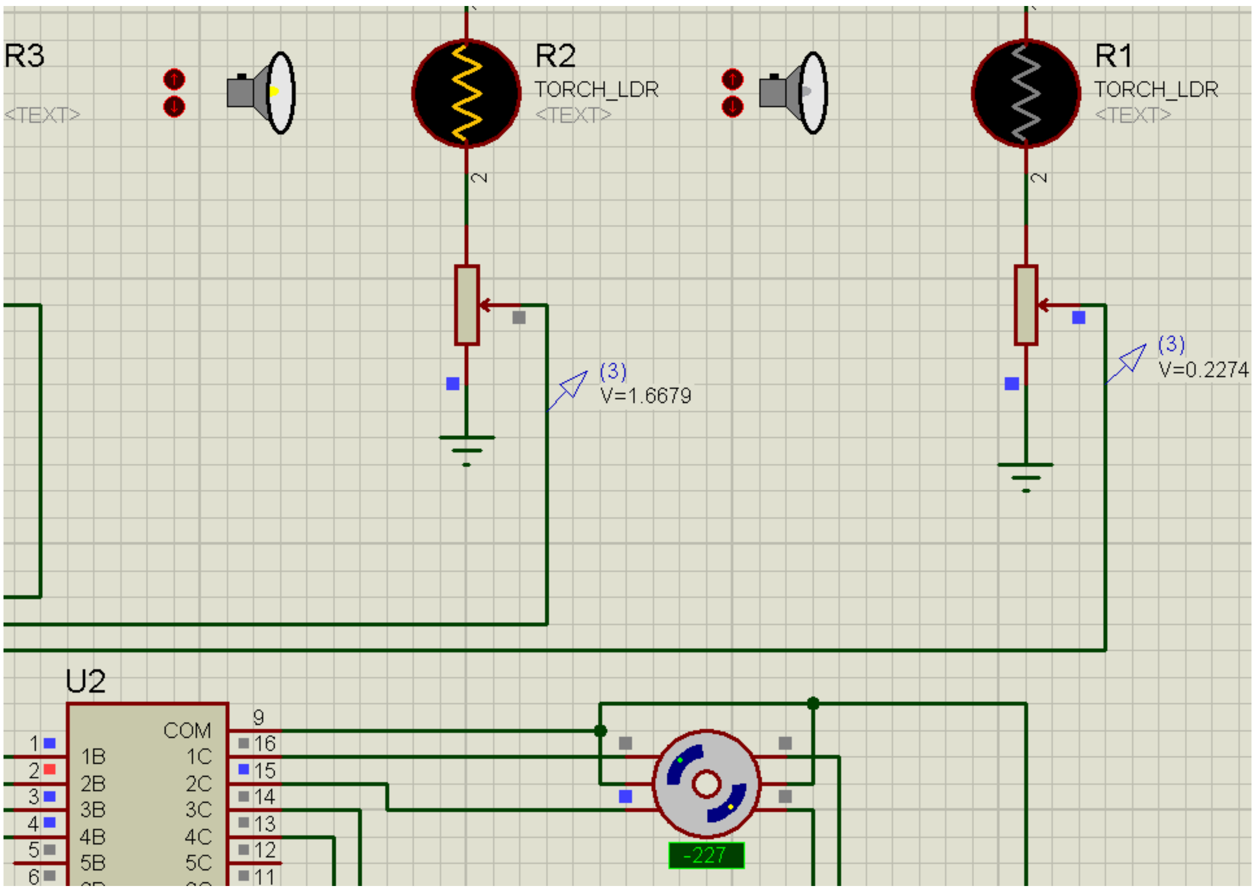


Figure (4.7) shows the counterclockwise rotation of the motor

In the Figure(4.8) the MCU output port C pin(22)(23)(24)(25) where pin(24) is high (red) are connected to driver ULN2003A at pin(1)(2)(3)(4) where pin(3) is directly connected to pin(24) of the MCU. All the windings of the stepper motor are connected to +12V DC from the BATTERY, so for energizing they only need to be grounded through a Darlington pair that can withstand the motor current flowing to ground. The motor is connected to the driver at pin(13)(14)(15)(16) where pin(14) is grounded(blue) i.e. winding(4) is energized.

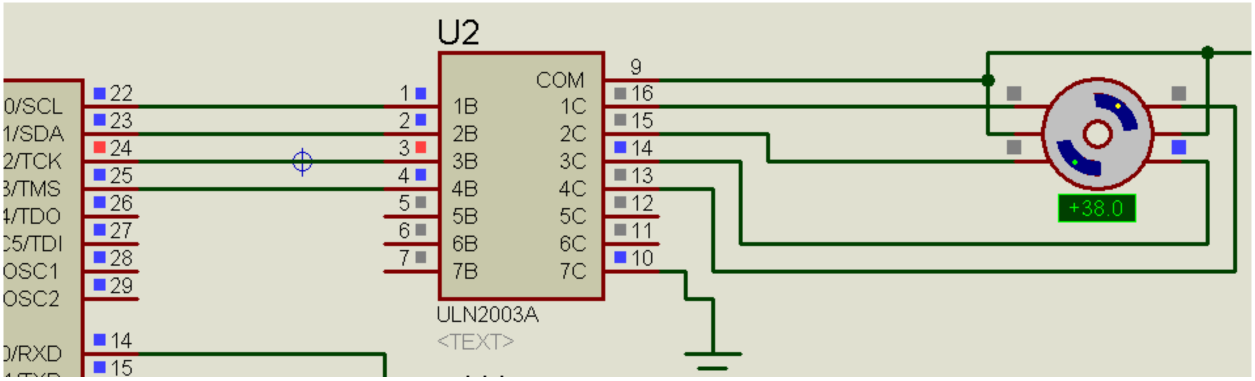


Figure (4.8) stepper motor driving

Figure (4.9) shows the stepper motor rotates for a number of steps due to the difference in the readings of R1 and R2,the reading of R1 is greater than that of R2 that makes the motor to rotate clockwise. The difference is about (0.6V).

Figure (4.10) shows the stepper motor rotates for a number of steps due to the difference in the readings of R1 and R2, the reading of R1 is greater than that of R2 that makes the motor to rotate clockwise. The difference is about (1.02V).

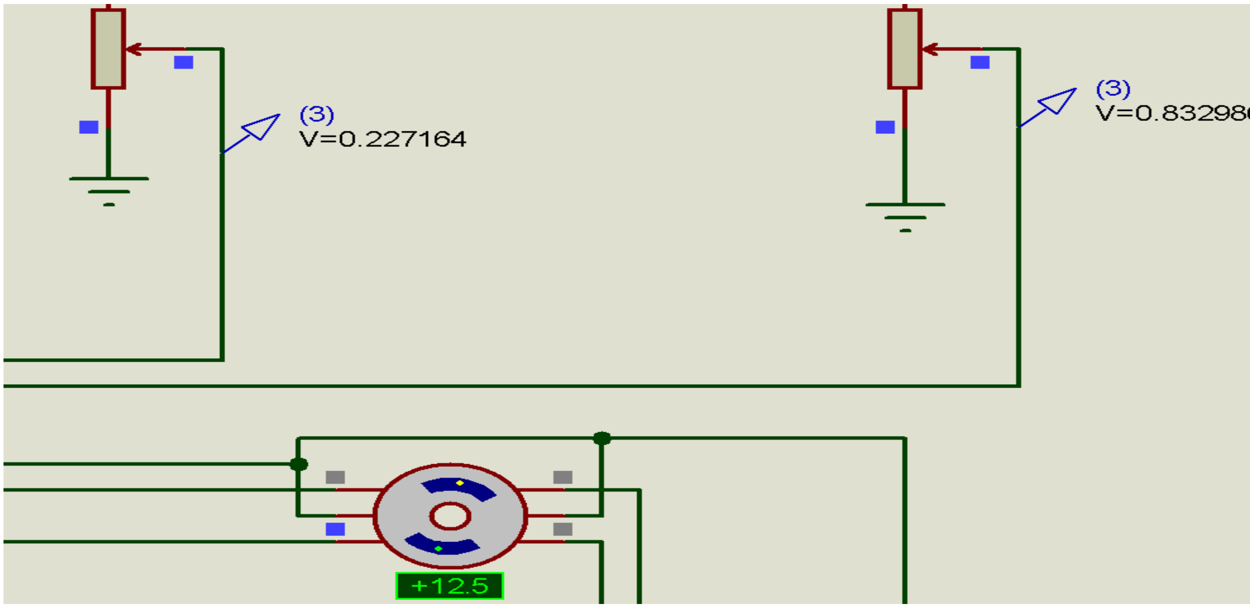


Figure (4.9) stepper motor rotates for a number of steps with (0.6V)

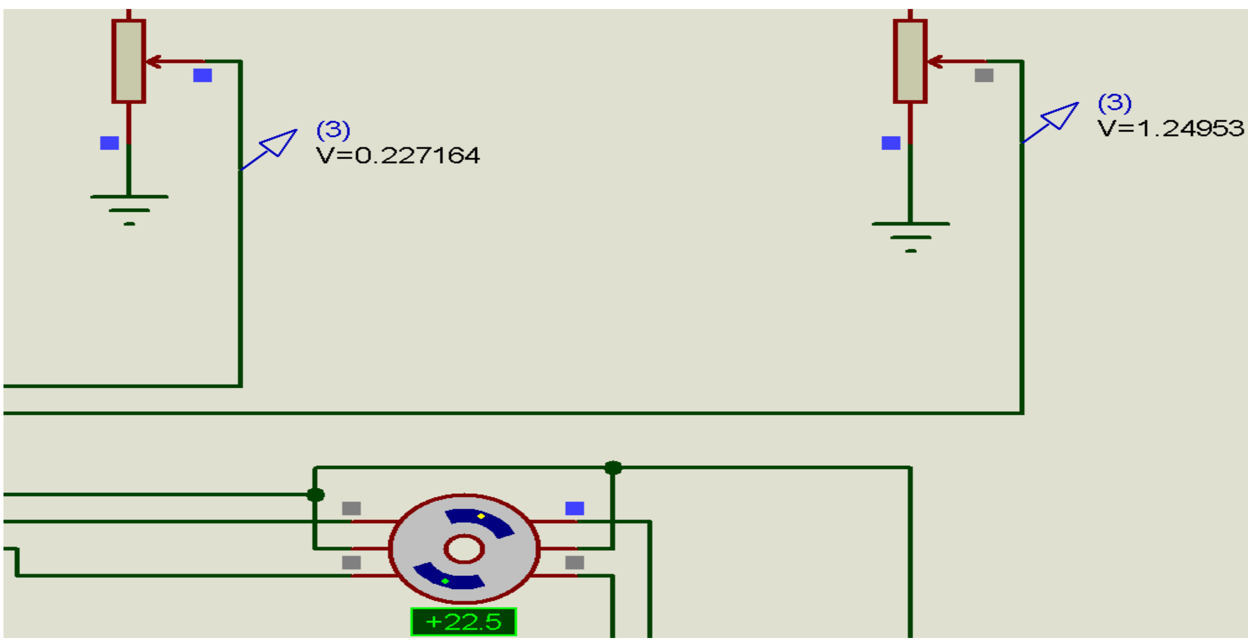


Figure (4.10) stepper motor rotates for a number of steps with (1.02V)

4.7 Experimental results:

A solar panel of the following rating is tested at two modes, fixed and tracking mode:

Ratings are:

- 36W continuous output power.
- 18V max. Output voltage.
- 3A continuous output current.
- 4.2A short circuit current.
- ***Fixed mode*** in which the orientation of the panel is horizontal to the earth surface throughout the test period. In this mode the max. Power can be achieved in only (1.5-2hours) through the 12hours of the test period as indicated in Figure (4.11).
- ***Tracking mode*** in this mode the panel is adjusted to be at right angle with the sun light through the 12hours with time apart of 1hour, the result is about 8-10hours of max. power generation as in Figure (4.11).

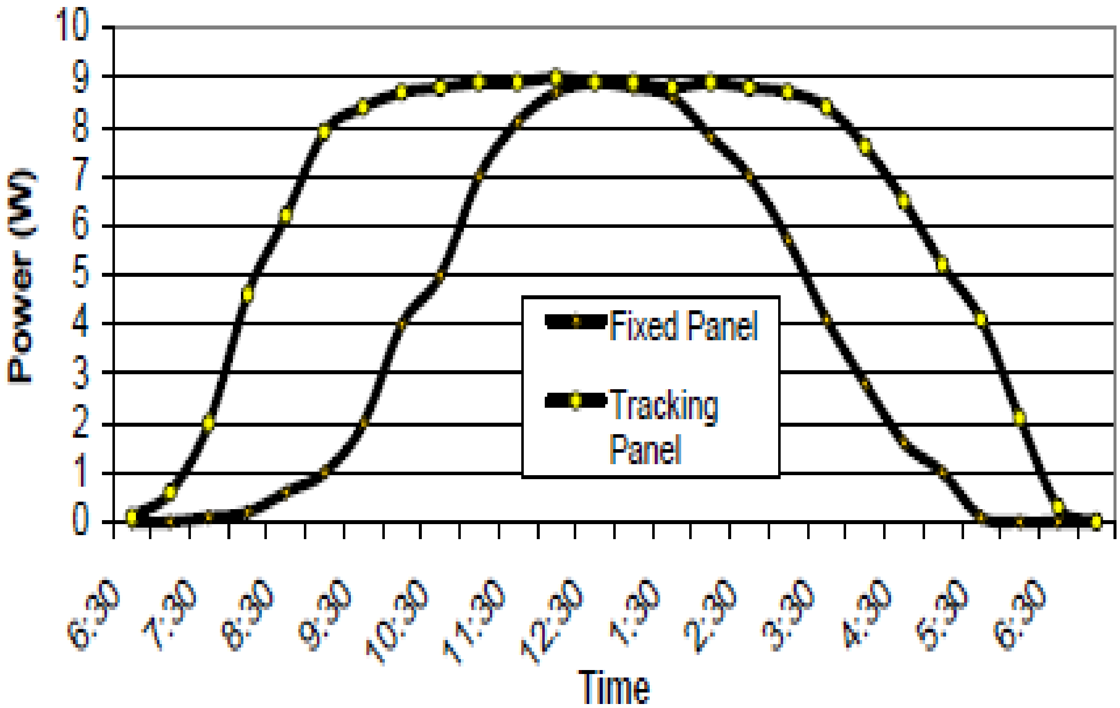


Figure (4.11) solar panel experimental two mode test