# DESIGN AND DEVELOPMENT OF PROGRAMMABLE AND AUTOMATED TIME DEPENDENT SOLAR TRACKER

ISSN: 2141 – 3290
www.wojast.com

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## ABSTRACT

The design and development of Programmable and automated time dependent solar tracker has been carried out. The solar tracker was designed and programmed using proteus electronic software; the C programming language was used to develop the code for the system microcontroller. The active components used in the design were the transistors. Microcontroller, resistors, voltage regulator, Liquid Crystal Display (LCD), push button switches were as passive components. Solar panel, lithium dc battery and dc motor were also used in the construction respectively. The simulation test results showed that when the system is automated at 1hour mode, the system started generating 1 second pulse for 10 cycles, and therefore generate another 10 seconds pulse. This implies that, the solar tracker uses the 1 second pulse to tilt the solar panel at $10^0$ from East to West for 10 cycles from (7:00am – 5:00pm) local time.

## INTRODUCTION

The rotation of the earth which causes day and night also proof that the sun usually rises from the East and sets at the West (Philip and Deborah, 2014). But since the magnitude of solar panel output is as a function of solar irradiance and most solar panels are stationary irrespective of the solar irradiance, the solar panel output components such as voltage and current (output efficiency) becomes poor (Davud and Daryush 2014), depending on the type of solar panel used.

Also, sometimes West African countries like Nigeria, Ghana and Togo do experience longer raining and short dry season and their solar energy cannot be properly harnessed and maximized. This is because at low sun intensity during raining season, fixed solar panels may not face the direction of the sun. This may lead to low or poor solar panel efficiency. Coupling solar panel to a dynamic system (solar tracker) consequently increases solar panel output efficiency (Gordo *et al*, 2015).

Interestingly, natural plant holds the most promising scientific and engineering concept ever in solar tracking history. This can be seen through the behavior of sunflower plant in the day time. The sunflower plant orientates their leaves so they will be perpendicular to the solar radiation from mornings till evenings to enhance photosynthesis through the process of heliotropism (Mark, 2012). It has been discovered that, an innate circadian clock control, may also contribute to activation of the tracking movements, which continues if the light cycle is interrupted, or the movements may initiate prior to dawn in apparent anticipation of sunrise (Mark, 2012). Therefore the great concept is then used in the development of this programmable and automated time dependent solar tracker, which would track the sun across the sky throughout the day. The tracker is designed with few electronic components as it will require less electrical power during system operation. This is done such that the tracker system will be configured by the user to either 1hour (default mode) or 2 hours mode.

## MATERIALS AND METHOD

The solar tracker consists of electronics components and electromechanical devices. The electronic components are: PNP transistors ($Q_1$, $Q_2$, $Q_3$ and $Q_4$; 2N2905), Resistors (1kΩ and 10kΩ; 1%/1/4W), Microcontroller Integrated circuit (AT89C52). While DC motor (2.5V) were employed as electromechanical device as well as push button switches. Other device and materials includes Liquid Crystal Display (LCD), two solar panels (11V/2.5W; polycrystalline) and dc battery (6 volts lithium).

The method employed in actualizing this research work involved the design of block and circuit diagram as well as programming the microcontroller with basic language (C- language) and system simulation, before proceeding to system implementation.

The system design involves the block diagram, programming of microcontroller chip as well as circuit diagram which is used to describe the hidden details and components interconnectivity.

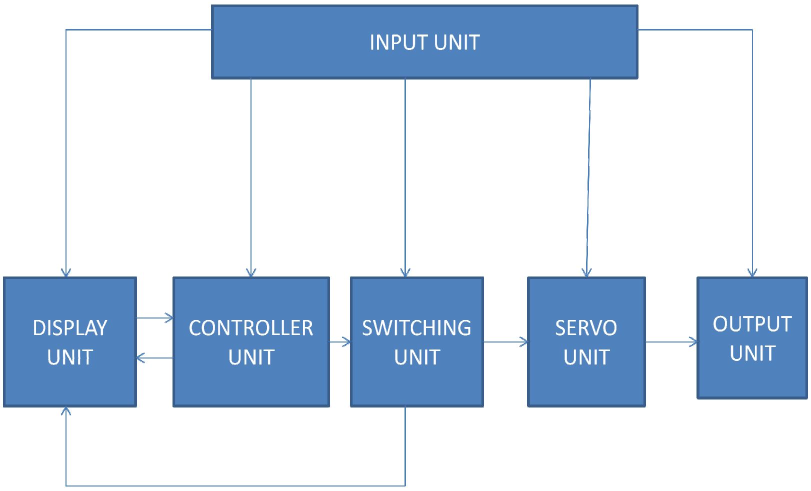



Figure 1: Block diagram of Programmable Automated Time Dependent Solar Tracker

**Circuit Diagram Operation**

The principle of programmable automated time dependent solar tracker is based on time. The circuit diagram (Figure 3) shows details of an automated time dependent solar tracking system. The entire circuit components are connected to the microcontroller device which is the brain controlling the system. The four other units are linked to the microcontroller. In this case, the four PNP transistors switching unit which is configured in H-bridge connection with the dc motor is linked to microcontroller unit to receive sequential pulse for the dc motor. Although, the microcontroller is configured to four have four outputs, where two outputs connected to transistor $Q_2$ and $Q_4$ are to receive equal pulses and followed by transistor $Q_1$ and $Q_{4.}$ However, since the circuit is time based, the two transistors $Q_2$ and $Q_4$ will receive pulse from the microcontroller and go "HIGH" for one at every one hour interval for 10 cycles which will turn the dc motor coupled to the solar panel clockwise at $10^0$ as shown in Figures 5(a) and (b). After 10 cycles, the microcontroller sends 10 seconds pulse to transistor $Q_1$ and $Q_4$ where the dc motor will return the solar panel at sun rise. Moreover, the two push buttons (mode and timing buttons) which are also connected to the controller are used to configure to either one hour or two hours mode. While the 1kΩ variable resistor and 10kΩ fixed resistor are used as current limiter and LCD brightness adjuster.

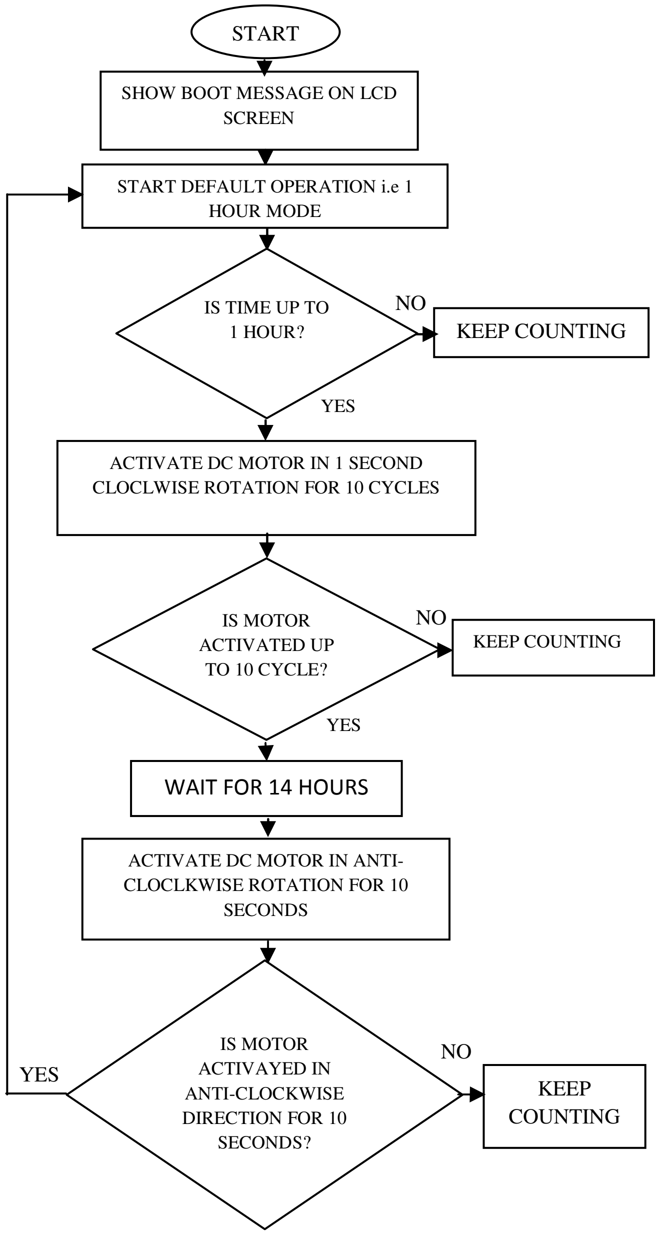



Figure 2: Flowchart of Programmable and Automated Time Dependent Solar Tracker

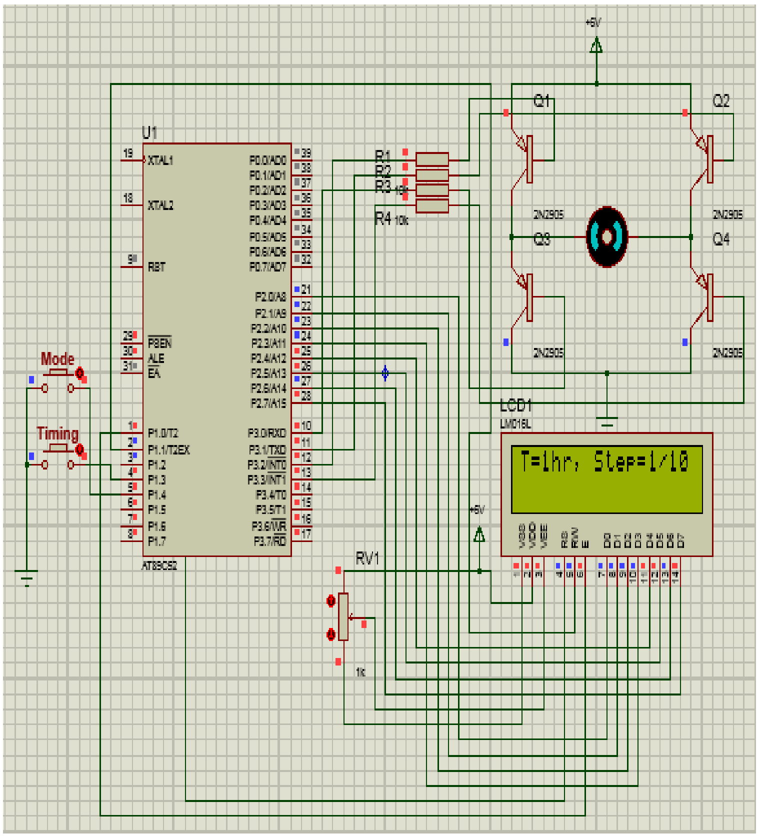



Figure 3: Circuit Diagram of Programmable Automated time Dependent Solar Tracker

**System Implementation**

This involves building, constructing of circuit and proceeding to the architecture structure respectively. The circuit components were tested to ascertain the healthy ones, polarities, fixing them on a Vero board and soldering before coupling to a plastic glass support as shown in Figure 4.

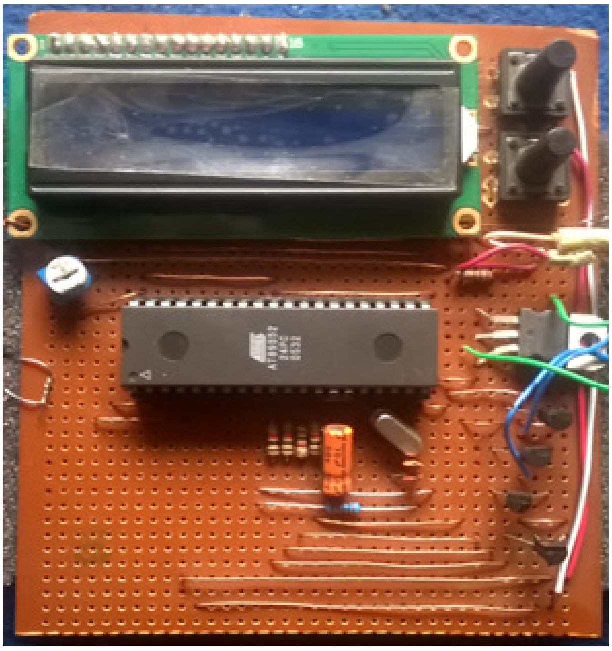


Figure 4: Circuit Construction of Solar Tracker

**System Analysis**
**Motor Torque**
Torque developed during operation is calculated using the equation in 1.1 (Niloy, (2016);
$T = mr^2(\frac{\omega}{t})$ 1.1
Where
m = mass of the solar panel used = 0.7kg x 2 = 1.4kg
r = Raduis of the shaft coupled to the dc motor = 0.012m,
$r^2 = 1.44 \times 10^{-4}$m
t = Time taken for the dc motor to rotates and make $10^0$
= 1 sec
θ = Angle in Radian $10^0$, $10 \times \frac{\pi}{180}$ = 0.175 radian**,** (Jan, 2012)
ω = Angular speed in m/s = $\omega = \frac{\Theta}{t}$, (Jan, 2012) 1.2
Putting equation (1.2) into (1.1), we arrived;
$T = mr^2(\frac{\theta}{t^2})$ 1.3
$T = 1.4 \times (1.44 \times 10^{-4}) \times (\frac{0.175}{1})$
$\therefore T = 3.5 \times 10^{-5}$Nm

Therefore, the torque of 3.5 x $10^{-5}$Nm is required to turn the solar panel of mass 1.4kg for 1 seconds.

**(a) Angular Speed ($\omega$)**
The angular speed is calculated using the expression (Pittman, 2015);
$\omega = \frac{2\pi N}{60}$ 1.4
Where N = Speed of the dc motor in revolution per minute = 35 rpm
$\omega = \frac{2\pi X 35}{60}$
$\therefore \omega = 3.7$ rad/s

**(b) Mechanical Power ($P_{mech}$)**
Mechanical power is calculated using the equation (Glep, 2008);
$P_{mech} = T\omega$ 1.5
$P_{mech} = 3.5 \times 10^{-5} \times 3.7$
$P_{mech} = 1.3 \times 10^{-4}$W
$P_{mech} = 0.13$mW

Since the power delivered to the load (solar panel = 1.4kg) is 0.13mW, the mechanical power must be twice or doubled so as to overcome the load of 1.4kg. Thus, we have;
$P_{mech} = 2 \times 1.3 \times 10^{-4}$
$\therefore P_{mech} = 0.26$mW

**(Electrical power ($P_{elect}$)**
The dc motor is considered or expected to rotate at maximum efficiency of 75%, therefore equation in (1.6) below is used to find electrical power consumed by the dc motor (Jan, 2012).
Efficiency (Π) = $\frac{P_{mect}}{P_{elect}} = \frac{P_{out}}{P_{in}}$ 1.6
Where; $P_{mect}$ = Mechanical power in watt
$P_{elect}$ = Electrical power in watt
$P_{out}$ = Output power in watt
$P_{in}$ = Input power in watt

Recall; $P_{mect} = P_{out} = 0.26$mW
Efficiency (Π) = 75
$P_{elect} = P_{in} = ?$
$P_{elect} = P_{in} = 0.26 \text{ x } 10^{-4} \text{ x } 75$
$P_{elect} = P_{in} = 1.95 \text{ x } 10^{-3}$W
$\therefore P_{elect} = P_{in} = 2$mW

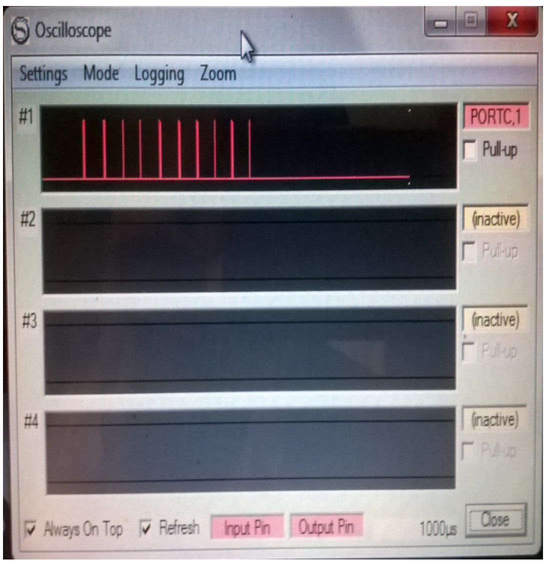
However, since the dc motor consume 2mW per rotation of $10^{0}$ for one second, therefore the time t for dc motor to rotates an angle of $100^{0}$ will be,
1 second = $10^{0}$
t (seconds) = $100^{0}$
$t = \frac{1 \text{ X } 100}{10}$
$\therefore$ t = 10 seconds

Therefore, the power ($P_{10}$) consumed when the dc motor rotates an angle of $100^{0}$ for 10 seconds will be calculated using the expression below; (Joydev, 2013)
$P_{10}$ = Power x time 1.7
$P_{10}$ = 2mW x 10sec
$P_{10} = 20 \text{ x} 10^{-3}$Wsec
$\therefore P_{10}$ = 20mWsec

Since the values and rating of the dc motor has been calculated and known, the dc motor rating are then chosen because the calculated values are not standard, as such the dc with the following rating was considered for construction;
Voltage = 2.5V
Current =0.17A
Torque = 13.4Nm
Motor speed = 500rpm

## RESULTS AND DISCUSSION

Figures 5a and 5b shows the signal waveform obtained from proteus simulator during the one minute mode simulation of the time dependent automated solar tracker system. However, figure 5a and b, displays the signal waveform obtained via the output (port $C_1$) of the microcontroller ($U_1$).



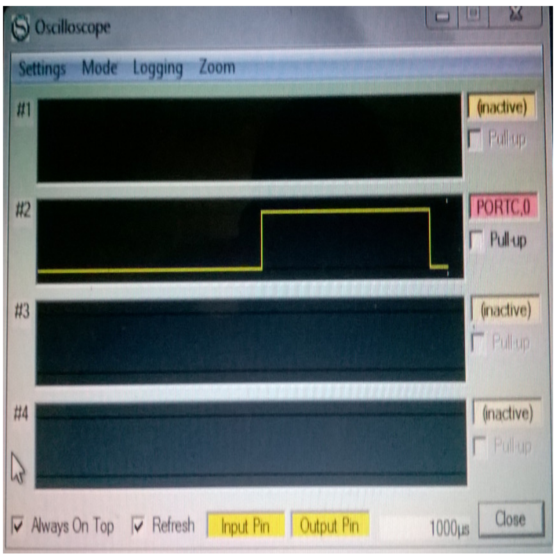




Fig. 5a: Signal Waveform for Clockwise Rotation Fig. 5b**:** Signal Waveform for Anti-Clockwise Rotation

This means that, at every one minute interval, the signal become high for one second then return low for 59 seconds. That is making time interval to be one minute per switching, hence the process is repeated for ten times (10 cycle). In other words, the microcontroller ($U_1$) trigger the base of the transistor ($Q_1$) with 5V per second signal (pulse), hence causing the 2.5V dc motor to rotate the solar panel for $10^0$ in a clockwise direction (East to West direction).

Figure 5 shows the signal responsible for the reverse rotation after ten complete forward rotations. This signal is obtained through port $C_0$ terminal of the microcontroller ($U_1$). In this case, the 5V signal goes high ten seconds then turn low until the small condition is made again. According to the circuit diagram in Figure 3, the signal is fed through the base of transistor ($Q_2$), which is configured to change the dc motor direction. At this point, the dc motor will take 10 seconds to return to the initial position at angle $100^0$ from the normal.

## CONCLUSION AND RECOMMENDATION

A programmable and automated time dependent solar tracker has been designed, simulated, automated and constructed. The solar tracker has been tested and it shows that the electrical system consume less power for it operations. Results of the simulation test also showed that it take 10 seconds to rotates the solar panel clock wisely for 10 cycles and later returns to its initial position after 3 seconds. It is therefore recommended that more research should be carried out such that part of the electrical power generated by the solar panel would not be used to control the electrical system of the solar tracker as it will help to achieve an ideal solar tracker (i.e 100% output efficiency).

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