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Demonstration of Microcontroller Based Sun Tracker System Capability

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ABSTRACT

The energy from the sun is rapidly gaining importance as an alternative source of energy, which is harnessed by the use of solar panels. To make solar energy more viable, efficiency of solar panel systems must be maximized in such a way that the rays emanating from the sun can be obtained optimally at any point in time as the direction of the earth and consequently the sun changed. A realizable approach to enhancing the efficiency of solar panel systems is sun tracking. In this project, two light dependent resistor (LDR) sensors were used, one of the sensor acts as a *pilot or tracker*, always looking for the direction of high intensity of light from the sun. The second sensor acts as *Omni directional sensor* which detects the presence of sun light at all times. These LDR combinations of signals is fed to the microcontroller Atmel 89C51 which directs a motor to change the position of the solar panel in accordance with the movement of the sun to ensure that light intensity from sun rays is tracked to give enough energy at any point in time, while a liquid crystal display (LCD) is used to display the charging voltage of the photovoltaic (PV) module at every point in time. The project also served as an investigation into the solar energy harvest system requirements for a UAV to boost its energy source or power needs during flight.
Keywords: Solar tracking system, Solar panel, Microcontroller AT89C51, LDR, DC Gear motor.

INTRODUCTION

The sun is one of the most important components in this world. Without it, life would have been impossible for human or living creatures to live. However, human beings nowadays feel uncomforted about the global warming situation. This kind of situation brings a lot of negative perception. One of the ways to reduce the global warming is to reduce the utilization of electrical voltage through the use of chemicals like burning of fuels or activities that promote ozone layer depletion, to a natural voltage source like wind, rain, tides, sunlight and geothermal heats. In trying to create new devices that can convert the natural energy to an electrical energy like solar panel for sunlight energy, wind turbines for wind energy, water turbines etc, our research has focused on one of the conversion methods using solar energy. In today's world, we have solar installations, wind turbine installations and many more but every solar installation has the solar panel, battery bank, charging control unit and the inverter. When a solar installation adequately charges the battery bank, the duration of service would be extended. This however depends on two important factors, the number of solar panels in the array and the size of surface areas exposed to the sun per unit time. It is worthy of note that introducing more solar panels in the array would increase the cost of the installation. The only option left is to control the surface area of the few available panels in the array, this would be good for UAV since weight is a factor when aircraft is involved. Again, we are faced with another challenge and that is the fact, that the sun is not stationary. The movement of the sun from east to west would definitely change the amount of sun rays deposited on the exposed surfaces of the solar cells. Therefore, static solar installations as currently used now limits the performance of the installations by reducing the level of charge the battery bank gets.

In this paper, a microcontroller based simple and easily programmed automatic sun tracker is presented to arrest this situation. The design and development of the system was microcontroller based, using Atmel 8051 microcontroller. The system was implemented for only two axis or degree of movement, considering the movement of the sun from east to west to provide support for solar installations enabling them to accumulate more charges so as to be useful particularly, in period of low radiation. The system would be able to receive enough sunlight to store more charges in the battery

Solar Energy

Solar energy is defined as energy provided by the sun. This energy is in the form of solar radiation, which makes the production of solar electricity possible**.** According to [2], electricity can be produced directly from photovoltaic (PV) cells. (Photovoltaic literally means “light” and “electric.”) These cells are made from a material which exhibit the “photovoltaic effect” meaning that when sunshine hits the PV cells; the photons of light excite the electrons in the cells and cause them to flow, generating electricity.[2]

Sunlight is made of photons, small particles of energy. These photons are absorbed, when they pass through the material of a solar cell or solar photovoltaic panel. The photons 'agitate' the electrons found in the material of the photovoltaic cell. As they begin to move or are dislodged, these are 'routed' into a current. This is electricity by the movement of electrons along a path. Solar panels are therefore, made of silicon to convert sunlight into electricity. Solar photovoltaic cells are used in a number of ways, primarily to power homes that are inter-tied or interconnected with the grid. [14].

Effect of Sunlight Intensity

Kumar noted in their paper that the silicon atoms in a photovoltaic cell absorb energy from light wavelengths that roughly correspond to the visible spectrum. The cell, made up of silicon, is mixed with two different impurities that produce positive and negative charges. Kumar [6] was of the opinion that light intensity causes the charges to move the electrons, producing an electric current and the material containing different impurities, react to changes from different wavelengths. [6}

Oloka [3] proposed that changes in the light intensity, incident on a solar cell can change all the parameters, including the open circuit voltage, short circuit current, the fill factor, efficiency and impact of series and shunt resistances. Therefore, the increase or decrease has a proportional effect on the amount of power output from the panel. [3] Meanwhile, Oloka [3] noted that 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 hereby, regarded as a semiconductor material which converts visible light into direct current.

Through the use of solar arrays, a series of solar cells are electrically, connected to generate a DC voltage that can be used on a load. Hence, there is an increased use of solar arrays as their efficiencies become higher. These increase have made solar power popular in remote areas where there is no connection to the public or national grid.

Photovoltaic Energy

Photovoltaic energy is that which is obtained from the sun. 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.

Figure 1 the Solar Cell

The photovoltaic or solar cell is the basic building block of a photovoltaic system. The individual cells span varies from 0.5 inches to 4 inches across. One cell can however, produce only 1 or 2 watts, which is not enough for most appliances. Performances of a photovoltaic array depends on sunlight, hence, climatic conditions like clouds and fog significantly affect the amount of solar energy that is received by the array and its performance. Most of the PV modules are between 10 and 20 percent efficient. [3].

Efficiency of Solar Panels

The efficiency of solar panels is the parameter most commonly used to compare performance of one solar cell to another. It is the ratio of energy output from the solar panel to input energy from the sun. In addition to reflecting on the performance of solar cells, [3], noted that this will depend on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. As a result, conditions under which efficiency is to be measured must be controlled carefully to compare performance of the various devices. According to Oloka, [3] the efficiency of solar cells is determined as the fraction of incident power that is converted to electricity.

It is defined as:

$$P_{max} = V_{oc} I_{sc} FF \quad (1)$$

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}} \quad (2)$$

Equation 1 and 2 fraction of incident power on a solar cell.

Where Voc is the open-circuit voltage, Isc is the short-circuit current and FF is the fill factor and η is the efficiency.

Applications of Photovoltaic Power

The photovoltaic power or solar power applications are in transport, traditionally been used for auxiliary power in space. Photovoltaic power is also used to provide motive power in transport applications, but is being used increasingly to provide auxiliary power in boats and cars. It has been used as source of power in standalone devices like calculators and novelty devices. Improvements in integrated circuits and low power LCD displays make it possible to power a calculator for several years between battery changes, making solar calculators less common.In contrast, solar powered remote fixed devices have seen increasing usage recently, due to increasing cost of labour for connection of mains electricity or a regular maintenance programme, examples are parking meters, emergency telephones, and temporary traffic signs.[14].

Overview of Sun Tracking

A solar tracker is a device used for orienting a photovoltaic array or solar panel by concentrating solar reflector or lens toward the sun [3]. The position of the sun in the sky is varied both with seasons and time of day as the sun moves across the sky, hence, solar powered equipment work best when they are pointed at the sun. Therefore, a solar tracker will increase the efficient of such equipment over any fixed position at the cost of additional complexity to the system. [3].

Figure 2 the Rotation of the Earth [3].

The amount of sunlight exposed to the surface of the photovoltaic cell is affected by the movement of the earth as shown in Figure 2. The earth is a planet of the sun and revolves around it. Besides that, it also rotates around its own axis. There are thus two motions of the earth, rotation and revolution. The earth rotates on its axis from west to east. The axis of the earth is an imaginary line that passes through the northern and southern poles of the earth. The earth completes its rotation in 24 hours. This motion is responsible for occurrence of day and night. The solar day is a time period of 24 hours and the duration of a sidereal are 23 hours and 56 minutes. The difference of 4 minutes is because of the fact that the earth's position keeps changing with reference to the sun. [3].

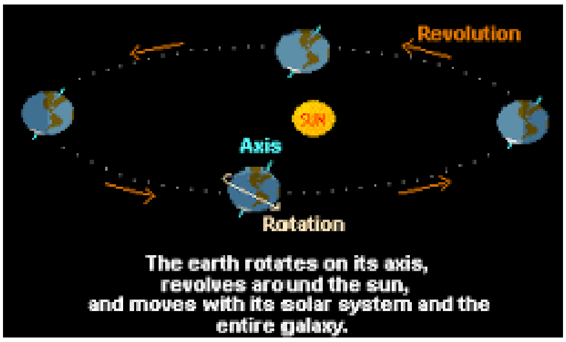

Figure 3 Revolution of the earth [3].

The movement of the earth round the sun is known as revolution as shown in Figure 3. It also happens from west to east and takes a period of 365 days. For the fact that the orbit of the earth is elliptical, the distance between the earth and the sun keeps changing. Thus, the apparent annual track of the sun via the fixed stars in the celestial sphere is known as the eclipse of the sun. With this the earth's axis makes an angle of 66.5 degrees to the ecliptic plane, making the earth attains four critical positions with reference to the sun [3].

Sunlight and Solar Constant

Since 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 but 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. [3].
The total power of the sun can be estimated by the law of Stefan and Boltzmann.

$$P = 4\pi r^2 \sigma \epsilon T^4 \text{ W} \quad (3)$$

Equation 3 Stefan and Boltzmann power Law

Where T is the temperature that is about 5800K, r is the radius of the sun which is 695800 km and σ is the Boltzmann constant which is 1.3806488 × 10-23 m2 kg s-2 K-1. The emissivity of the surface is denoted by ϵ. Based on Einstein's law E = mc2 millions of tons of matter are converted to energy each second.

Therefore, the solar energy that is radiated to the earth is 5.1024 Joules per year. This is 10,000 times the present worldwide energy consumption per year. From other studies, solar radiation from the sun is received in three ways: direct, diffuse and reflected. Direct radiation, which is also referred to as beam radiation is the solar radiation which travels on a straight line from the sun to the surface of the earth. [3].

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].

Sunlight and Photometry

Photometry enables us to determine the amount of light given off by the Sun in terms of brightness perceived by the human eye. In photometry, a luminosity function is used for the radiant power at each wavelength to give a different weight to a particular wavelength that models human brightness sensitivity. Photometric measurements began as early as the end of the 18th century resulting in many different units of measurement, some of which cannot even be converted owing to the relative meaning of brightness.

However, the luminous flux (or lux), which is the measure of the perceived power of light is commonly used. Its unit, the lumen, is concisely defined as the luminous flux of light produced by a light source that emits one candela of luminous intensity over a solid angle of one steradian. It is noted that a steradian is the SI unit for a solid angle; in essence, the two-dimensional angle in three-dimensional space that an object subtends at a point, the candela is the SI unit of luminous intensity and it is the power emitted by a light source in a particular direction, weighted by a luminosity function. One lux is equivalent to one lumen per square meter;

$$1 \text{ lux} = 1\text{lumen} / m \cdot m = 1 \text{ cd} \cdot \text{sr} \cdot m \quad (4)$$

Equation 4 Lumen and Candela conversions

i.e. a flux of 10 lumen, concentrated over an area of 1 square meter, lights up that area with illuninance of 10 lux. Thus, sunlight ranges between 400 lux and approximately 130000 lux, as summarized in the Table 1. [3].

Table 1 Range of the Brightness of Sunlight (lux)

Time of Day	Luminous flux (lux)
Sunrise or sunset on a clear day	400
Overcast day	1000
Full day (not direct sun)	10000 – 25000
Direct sunlight	32000 – 130000

METHODOLOGY

A physical model, which is the prototype of the sun tracker was realized, in two folds using locally sourced materials. These first, involved the microcontroller based circuit that provides the logic functions which determine when to tilt the PV cell to the direction of the sun and the second fold was the mechanical unit that takes control instruction from the log control circuit. These also included the Software aspect of writing a sort code for the microcontroller as an important as aspect of the project.

The Design Block Diagram

The research project work started with a block diagram representing the Sun

Tracker design where the control unit was the main heart of the design as illustrated in Figure 4

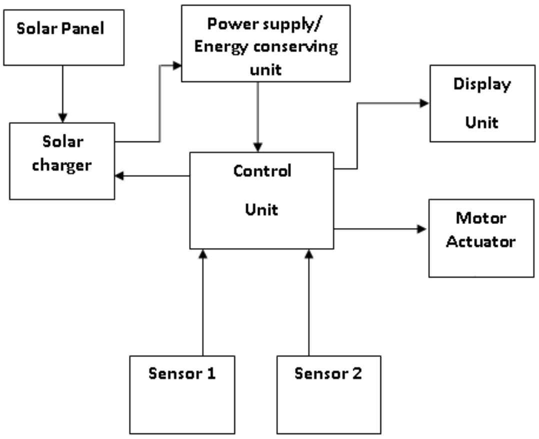

Figure 4 Block Diagram of Sun Tracker Design

The block diagram of the sun tracker shows the microcontroller as the major control element because it runs the control program, which is the algorithm embedded into the controller. Other units that achieves the objectives are interfaced to the control unit. The individual blocks represent the respective sub units (modules) in the system, where all the input modules are shown pointing into the control unit, while the output units are shown pointing outwards.

Stepwise Approach

A stepwise approach for the research project, which took three months was followed, where the construction of mechanical frame was initiated. It was followed by the development of the microcontroller circuit interfacing the inputs and outputs after testing. Thereafter, the overall system testing and integration was done. The final testing and re-evaluation was carried out and it was found that the project meets specifications. The project materials used were simply a microcontroller (Atmel89C51), LCDHitachiHD44780 or HD44580, LM 358 operational amplifier, Relays 12v 10 amps, Transformers, ADC0804, two voltage regulators, LM317T and LM 7801v Power supply and a source code for the Control Program.

Design Implementation

The design implementation relied heavily on the design of the various sub systems as indicated in the block diagram description. The specification focused on fulfilling the conditions of Input voltage 12V, input current 6A, and maximum angle of rotation of 240 degrees. The input interface design was the sensor. The sensor was made of Light Dependent Resistor (LDR). Here two LDR sensors were used. The operational principle of the LDR was exploited in this design where resistance of LDR decreases with the presence of light. If light is prevented from reaching the LDR the resistance increases. Generally, LDR is a variable resistor varying with light intensity. So there was need to convert varying resistor to a voltage that the microcontroller can measure. This was done by using the LDR and other Resistors in a potential divider circuit.

The top of the potential divider is 5V, the bottom is at 0V and was connected to port1 pin 4 and 6 of the microcontroller with some values between 5V and 0V that varies as the LDR resistance varies according to the light level. The LDR and Resistors are in series with the applied voltage (5V), so the current flowing through them is the same. So the current through the resistors is;

$$I = 5 / R_1 + R_2 \quad (5)$$

Equation 5 Current through the resistors in the potential divider circuit

Where R_1 is the omni-directional sensor and R_2 is the tracker sensor. The output voltage was calculated using Ohm's law;

$$V = I \times R_1 \quad (6)$$

Equation 6 Output voltage of the LM7805v voltage regulator

This was worked out to obtain the voltage at the output by substituting Eqn. (5) in Eqn. (6)

$V_o = 5 \times R_1 / (R_1 + R_2)$ (7)

Equation 7 Output voltage regulator value

Where V_o is the output voltage and R_2 is the top Resistor value, R_1 is the bottom Resistor value;

$V_o = 5 \times 10000/10000 + 5000 = 5 \times 10/15 = 3.33V$ (8)

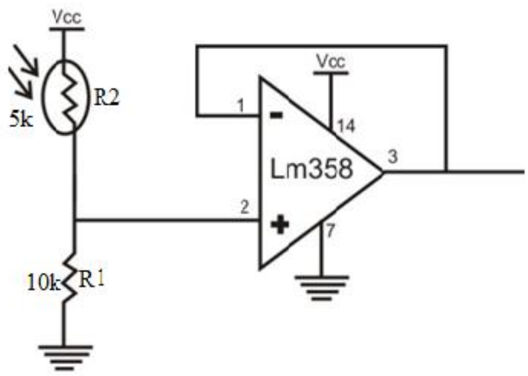

Figure 5 Input Interface Design

Each of the LDR interfaced with LM 358 operational amplifier as shown in Figure 5, and the output of the amplifier was connected to the microcontroller port. One of the sensors acts as a pilot or tracker, always looking for the direction of sun intensity. The second sensor acts as Omni directional sensor, which detects the presence of sun light at all, times. The LM 358 is a dual single supply operational amplifier because of differences in voltage. As it is a single supply it eliminates the need for a dual power supply, thus simplifying design and basic application use.

One drawback noticed is that the single supply does not offer a negative voltage supply, due to this the output is not able to go below 0V otherwise, the waveform would cutoff given a phenomenon known as clipping of the circuit.

Indeed, clipping happens when a sine wave hasn't reached the max amplitude and stops at a point and stays constant causing a flat peak. Clipping can often be heard in audio amplifiers when the speaker distorts, however, small clipping percentages may go unnoticed to the ear so this should also be taken into account when using LM358 for an audio pre amplifier etc. For smaller signals that need a more useful reading, we could amplify it using the op amp, this is commonly used in sensors such as the LDR.

It is worthy of note that assuming the sensor output is 50mV and we wanted to interface it with a Microcontroller or we needed to amplify it till we get 5V this would allow a small change of the sensor to have a big change on the Microcontrollers input which means we would have had greater accuracy of data that had been sampled.

Thus, this is a voltage follower or buffer amplifier circuit, where the output is simply equal to the input. The advantage of this circuit is that the op-amp can provide current and power gain; where the op-amp draws almost no current from the input. Here it provides low output impedance to any circuit using the output of the follower, meaning that the output will not drop under load. The designated load in this case is a 1k resistor; the op-amp provided all the current needed to drive the load, without requiring any current from the input.

Process Flow Chart

The process flow chart presented here shows the flow sequence that determines when the solar panel tray should rotate and to what direction. It provided an algorithm of the operation

Table 2 Logic Table of the Sensor

SN	Pilot	Omni Sensor	Action
	0 (no light)	0 (no light)	Rest Position
	0	1 (light)	Start tracking the sun
	1	0	Stop tracking

The logic table above was used in the development of the flow chart shown below.

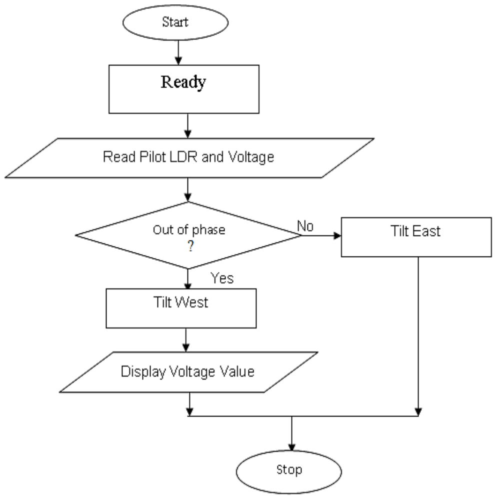

Figure 6 System Process Flow Chart Algorithm

The Figure 6 represents the flow chart of Table 2. It shows the design of the logic followed in the development of the program that determines the direction of the tracker. Two LDR sensors were used, one of the sensor acts as a pilot or tracker, as earlier stated always looking for the direction of high intensity of light. The second sensor, on the other hand acts as Omni directional sensor which detects the presence of sun light at all times.

At the initialization (start), microcontroller reads the state of pilot (LDR1). If out of phase with light intensity, microcontroller command the motor to tilt the solar module to West, assuming the module had been in the East position and stop ones high intensity of light is sensed and display the voltage value of the solar module at that point. If pilot (LDR) is in phase with the light intensity, microcontroller commands the motor to tilt the solar module to East, stop and display the charging voltage**.**

Output Interface Design

The output interface design consisted of a dc motor configuration used to implement a motorized jack, made of two transistors coupled with relays. Figure 7 shows the circuit diagram or connections. The relay enables mechanical switching that activates the motor. At the base a pull-up resistor is used to switch the transistor on when the system is powered ON.

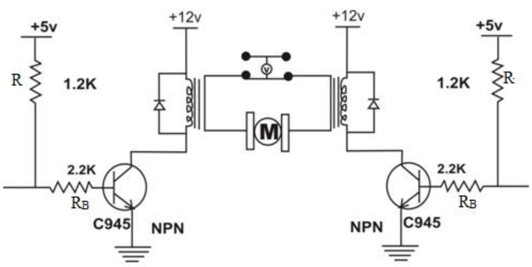

Figure 7 DC Motor Configuration

The transistor used is NPN, whose operating mode in digital form is that the collector produces logic 1 when the base is not biased. When the base is biased, the output of the collector is logic 0. Thus, the relay is connected to Vcc on one terminal, the other terminal is controlled by the collector output. In this case, the transistor is biased; the collector reads 0 and completes the circuit for the relay to switch ON. The following formula is used to calculate the value of base resistor used:

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} \quad (9)$$

Equation 9 Calculation of the value of base resistor

From the data book some assumed value were obtained as Q_1 = C945, I_{Cmax} = 100mA, $h_{fe(min)}$ = 40, $h_{fe(max)}$ =500. From

$$I_E = I_C + I_B \quad (10)$$

$$h_{fe} = \frac{I_C}{I_B} \quad (11)$$

$$V_B = V_{CC} - V_{BE} \quad (12)$$

Where I_E = Emitter current, I_C = Collector current, I_B = Base current and $I_E \equiv I_C$, hfE = current ratio transfer.

If a typical value of hfe for Q_1 was taking to be 40, substituting the values in equation (13)

Therefore

$$I_B = \frac{I_C}{hfe} \quad (14)$$

$$\frac{100\,mA}{40} = 2.5mA. \quad (15)$$

When Q_1 is ON (i.e at saturation), $V_B = V_{CC} - V_{BE}$ = 5−0.7 = 4.3V.

Substituting the value of V_B (4.3V) in equation (9)

Therefore

$$R_B = \frac{V_B}{I_B} \quad (16)$$

$\frac{4.3}{2.5mA}$ = 1720Ω, but 2.2kΩ was chosen as the closest resistor value in data book.

Output Interface Design for LCD

Another output interface used was the Liquid Crystal Display (LCD) shown in Figure 8. The most commonly used Character based LCDs are based on Hitachi's HD44780 controller or others which are compatible with HD44580. In this project, character based LCDs, their interfacing with various microcontrollers, various interfaces (8-bit/4-bit), programming, were put into use.

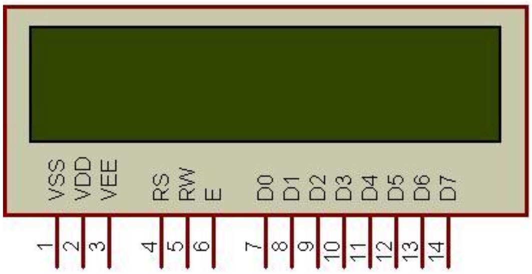

Figure 8 Typical LCD

Table 3 LCD Pin Out

Pin No.	Name	Description
Pin no. 1	**VSS**	Power supply (GND)
Pin no. 2	**VCC**	Power supply (+5V)
Pin no. 3	**VEE**	Contrast adjust
Pin no. 4	**RS**	0 = Instruction input 1 = Data input
Pin	**R**	0 = Write to LCD

no. 5	**/ W**	module 1 = Read from LCD module
Pin no. 6	**EN**	Enable signal
Pin no. 7	**D0**	Data bus line 0 (LSB)
Pin no. 8	**D1**	Data bus line 1
Pin no. 9	**D2**	Data bus line 2
Pin no. 10	**D3**	Data bus line 3
Pin no. 11	**D4**	Data bus line 4
Pin no. 12	**D5**	Data bus line 5
Pin no. 13	**D6**	Data bus line 6
Pin no. 14	**D7**	Data bus line 7 (MSB)

Microcontroller System

The microcontroller used was a single chip microcomputer made through VLSI fabrication as shown in Figure 9. It is an embedded system because the microcontroller and its support circuits are often built into, or embedded in the devices they control. This microcontroller is available in different word length-like microprocessors as 4bit, 8bit, 16bit, 32bit, 64bit and 128 bit microcontrollers today. There are four parts, P0, P1, P2, and P3 in the microcontroller. Any part can be used as input and output part depending on how it was programmed.

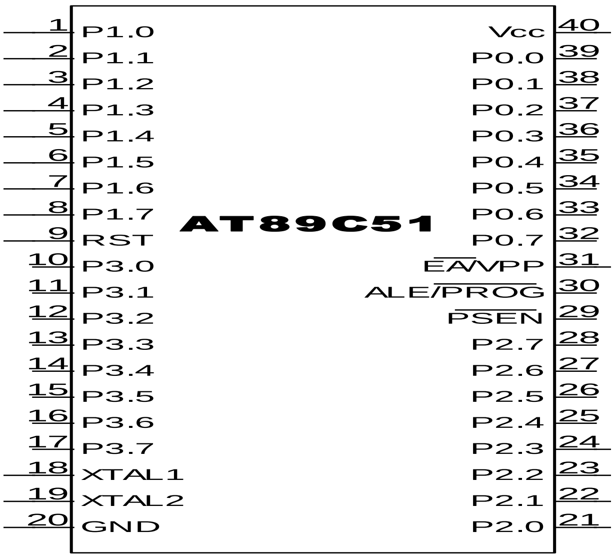

Figure 9 Atmel 89c51 Microcontroller pin out

Complete Circuit Diagram and Integration

The complete circuit diagram as shown in Figure 10 shows the integration of all the sub units to the microcontroller. The microcontroller ports were used to interface the various units. The ADC was interfaced to the port 0 of the microcontroller, the LCD interfaced to the port 2, the motor unit was interface to port 3 and the operational amplifiers connected to port 1.

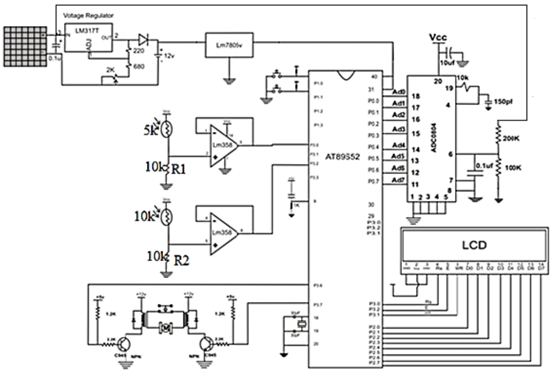

Figure 10 Complete Circuit Diagram. Of the Design Work.

Testing, Results and Conclusion

The circuit diagram and integration of would be components were simulated using procerus Software and thereafter, a model construction of the work was done.

Testing and Result

The circuit was completed and the control program was downloaded into the microcontroller. The system was installed and tested in the month of July 2017. While tracing the sun, the values of the LDR of both fixed panel and tracking panel at various instances were read through the ADC. The programs on the microcontroller converted the values back to voltage value and were hence displayed on the LCD. The values were obtained for different hours from 6AM to 6PM in the month of July as shown in Table 4. The readings were recorded accordingly. The month of July was chosen because it is the month or period when average cloudy and sunny conditions were observed in Kaduna. Table 4 shows the recorded results of both tracking panel and fixed panel values for 2nd July 2017 in Kaduna, Nigeria where the research work was conducted.

	Readings for a Static Panel	**Readings for a Tracking Panel**
Time	**Flat panel**	**Tracking Panel**
0630Hrs	0.196	1.477
0730Hrs	0.249	2.104
0830Hrs	0.225	3.411
0930Hrs	0.723	3.783
1030Hrs	2.011	3.900
1130Hrs	3.910	4.657
1230Hrs	4.888	4.990
1330Hrs	3.803	4.990
1430Hrs	3.456	4.985
1530Hrs	3.930	4.892
1630Hrs	1.544	4.694
1730Hrs	0.980	2.456
1830Hrs	0.718	0.968

With the result obtained in the Table 4, there was tremendous differences in voltage increase that was obtained from the tracking panel or sensor in line with the direction of the sun with respect to that obtained without tracking using the Flat panel. It was seen that at a point the voltages of both panel were almost the same. This was as a result of both panels facing the sun at the same inclination. It normally happened at middays when the sun is directly overhead.

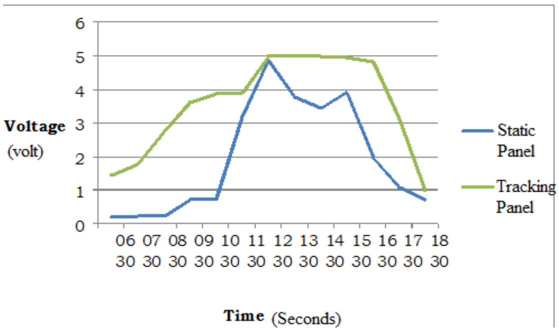

Figure 11Graph of Results obtained on 2ndJuly

The graphical representation of voltage of both the fixed PV panel and tracking PV panel against day time is shown in Figure 11. From the graph, it was seen that solar intensity increases with day time to maximum at 12PM and then starts decreasing. Some fluctuations notable in the graph were as a result of some cloudy sky and abnormal atmospheric conditions.

Analysis

From the curves, it was observed that the maximum sunlight occurs at around midday, with maximum values obtained between 12 noon hours and 2 pm. In the morning and late evening, intensity of sunlight diminishes and the values obtained are less than those obtained during the day. After sunset, the tracking system is switched off to save energy. It is switched back on in the morning. For the panel fitted with the tracking system, the values of the LDRs are expected to be close. This is because whenever they are in different positions there is an error generated that enables its movement. The motion of the panel is stopped when the values are the same, meaning the LDRs receive the same intensity of sunlight. For the fixed panel, the values vary because the panel is at a fixed position. Therefore, at most times the LDRs are not facing the sun at the same inclination. The graph also shows that at a point, the voltages of both panels are almost the same. This is as a result of both panels facing the sun at the same time. In terms of the power output of the solar panels for tracking and fixed systems, it is evident that the tracking system will have increased power output. This is because the power generated by solar panels is dependent on the intensity of light. The more the light intensity the more the power that will be generated by the solar panel. After examining the information obtained in the data table section and in the plotted graph, it was concluded that the sun tracking system can collect maximum energy than a fixed panel system collects and high efficiency is achieved through this tracker method of maximizing the light energy system received from the sun. This is an efficiency tracking system for solar energy collection for UAVs and other energy harvest products.

Construction and the Finished Product

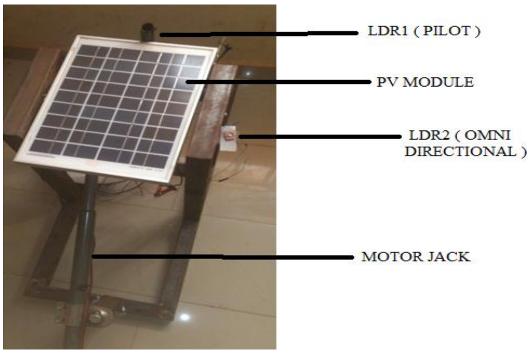

Figure 12: Construction and Built Product

Summary of Achievements

The objective of the project was to design a system that tracks the sun for a solar panel. This was achieved through using light sensors that are able to detect the amount of sunlight that reaches the solar panel. The values obtained by the LDRs are compared and if there is a significant difference, there is actuation of the panel using a servo motor to the point where it is almost perpendicular to the rays of the sun.

This was achieved using a system with three stages or subsystems. Each stage has its own role. The stages were;

1. An input stage that was responsible for converting sunlight to a voltage.
2. A control system that was responsible for controlling actuation and decision making.
3. An actuation stage that was responsible for driving the motorized jack.

The input stage is designed with a voltage divider circuit so that it gives desired range of illumination for brighter illumination conditions or when there is dim lighting. This made it possible to get readings whenever there was a cloudy weather. The potentiometer was also adjusted to cater for such changes. The LDRs were found to be most suitable for this project because their resistance values varies with light. They are readily available and are cost effective. Implementing with other temperature sensors for instance would have been more costly.

The control stage on its part has a microcontroller that receives voltages from the LDRs and determines the action to be performed. The microcontroller was programmed to ensure it sends a signal to the servo motor that moves in accordance with the generated error.

The final stage was the actuator circuitry that consisted mainly of the dc motor. The dc motor was used as servo motor to produce enough torque to drive the panel. Servo motors are noise free and are affordable, making them the best choice for the project.

CONCLUSION

At the end of this project, microcontroller based solar tracker using Atmel AT89S51 Microcontroller was actualized. The system was able to track the position of the sun where maximum intensity could be found. The system was also able to measure and display the current battery levels.

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