جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Electrical Engineering

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Senior Design Project Report

Self-Maintained Solar Tracking System

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical Engineering

Team Members

	Student Name	Student ID
1	**Mohammed Alkaltham**	**201501590**
2	**Ahmed AlHarbi**	**201500092**
3	**Abdulaziz Alkhulaiwi**	**201201153**
4	**Hussain Alarnous**	**201400608**
5	**Faisal Almubayedh**	**201403528**

Project Advisors:

Advisor Name: Ahmed Abu Alhussain

Abstract

Saudi Arabia has a perfect exposure to the sun almost the entire year. The demand of power is rapidly increasing over the past thirty years. Furthermore, the sources of power are limited and could be used in more sufficient ways. As a result, solar power is a good field to implement a solar tracking system in the Kingdom of Saudi Arabia and it will sustain Saudi Arabia with a good amount of energy if implemented correctly.

In this paper, a solar tracking system using Arduino is designed and built. This system collects free energy from the sun and stores it in the battery and then converts this energy to the respective alternating current. It makes the energy usable in normal homes as an independent power source. This system is designed to react to its environment in the shortest amount of time. Any errors at software and hardware will be controlled or eliminated. Our system is tested for its real-time responsiveness, reliability, stability and safety. Our system is designed to be resistant to weather, temperature and some minor mechanical stresses.

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1. Introduction

1.1 Project Definition

To design a system that absorbs sun's light (photons) and it has the ability to rotate the solar panel direction towards the sun (one-axis). Furthermore, it has the ability to do self-cleaning which makes it a reliable system against dusty environment and for higher conversion efficiency. A real time clock is installed to measure the location of sun when LDR fail to measure. The system will carry sub-systems in the controlling, reading of the quality of the electricity and load and the mechanism of cleaning with the help of sensors.

1.2 Project Objectives

1. To show that tracking systems are more efficient that fixed ones.
2. To show that self-cleaning will improve the solar reliability and efficiency.
3. To make the solar panel automatically controlled by RTC to follow Sun’s trajectory during the day (in case of LDR failure).

1.3 Project Specifications

1. Approximate saves power consumed daily in lighting.
2. Operate through all seasons.
3. An automatic system and require little maintenance.
4. Battery duration of 10 hours.
5. One-axis solar tracker using a solar panel and servo motors.
6. Self-Cleaning when the dust covers the surface of solar panel using dust sensors.
7. The system is portable, uses clean energy and environmentally friendly.

1.4 Product Architecture and Components

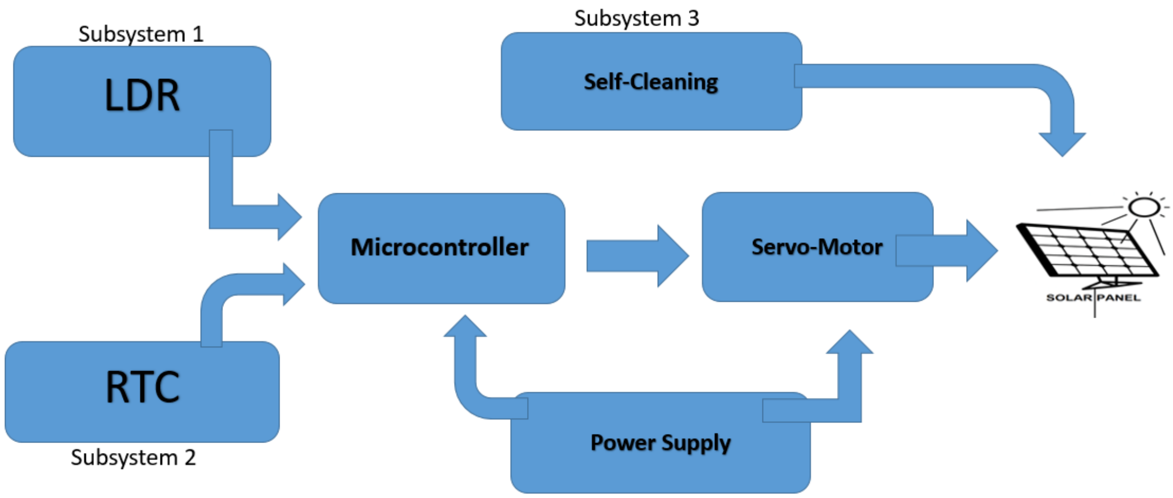


Fig. 1, Functional Diagram of the System

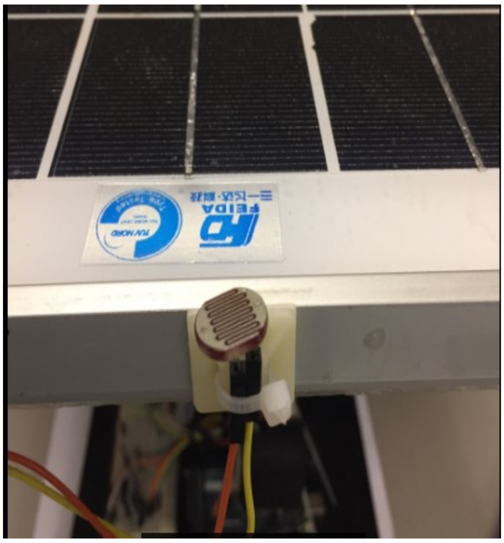


Fig. 2, LDR Attached to Solar Panel.

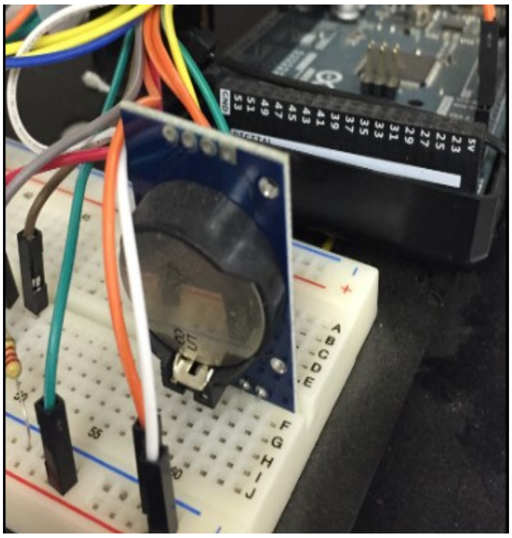


Fig. 3, RTC and Arduino Mega.

This is an automatic single axis solar tracker. The LDR is used for sensing the sun light direction figure 2. The LDR voltage is sensed by microcontroller and it sends signals to motor driver circuit to rotate the solar panel to the direction of sun light. When there is a failure in Subsystem 1, the system will start moving using a real time clock figure 3 (Sub System 2). Also, in case of dust accumulated on the panel. A method of self-cleaning will be generated to clean the panel (Sub System 3).

1.5 Applications

Solar Electric Power can be generated varying from 100 Watts small solar home systems to 100 MW Solar Power Plants:

1. Residential Applications.
    a) Conserve power for lightening.
    b) Back up power in case of power failure.
    c) Reduce the monthly power pill.
2. Industrial Applications.
    a) Back up power in case of power failure.
    b) Building a complete plant to produce power using the solar systems.
    c) Used as a utility for specific department or small equipment.
    d) Used to energize tea rooms and substations.
    e) Energize farms.
3. Governmental Applications.
    a) Used to lightening streets using solar panels on each lamp.
    b) Used for traffic lights systems.
    c) Help reducing the pills for major buildings like hospitals and citizen affairs buildings.

2. Literature Review

2.1 Project background

It has been estimated that the earth receives about 174 petawatts of solar radiation with about 70% being absorbed by land masses and oceans. In 2015, it was calculated that the earth absorbed 3,850,000 exajoules of solar energy [1], which was more energy than the entire world used in the entire year. Since the sun is projected to be around for at least 4.3 billion more years, investments and techniques for collecting solar energy is a reliable solution to the rapidly decreasing quantity of fossil fuels. Carefully constructed assemblies of photovoltaic cells, called solar panels, provide an effective means of collecting solar radiation and converting it into electricity. When correctly designed and attached to a well-engineered mechanical tracker, solar panels are able to provide power for commercial businesses and homeowners in a way that helps preserve the low supply of natural fossil fuels while drastically reducing the required cost. Renewable energy now provides 19% of electricity generation worldwide with a 15% increase projected by the year 2035 [2].

In comparison with other systems, this system has self-maintained features which make the system more reliable and require less maintenance especially with the environment in Saudi Arabia. Before proceeding, it is important to note that the amount of energy produced during solar collection is more productive and efficient when the sun is directed at the PV on a clear day.

2.2 Previous Work

There are many ways to implement tracking solar systems such as solar panel array figure 4, half cylinder solar tracking system figure 5 and low-tech water tracking system figure 6. Solar panel array is featured by low cost, simplicity and reliability but disfeatured by lack of freedom, high torque needed and large working space. Half cylinder solar tacking system array is featured by equipping many panels at the same time but disfeatured by hard to manufacture, very high torque needed and costly. low-tech water tracking system is featured by no power needed to energize the system and innovative but disfeatured by high maintenance required, weather dependent and handle one panel only.

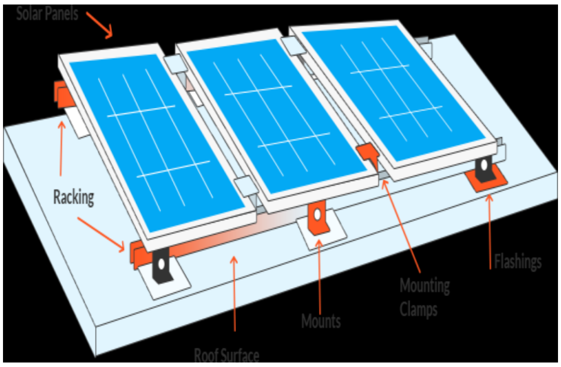


Fig. 4, Solar Panel Array

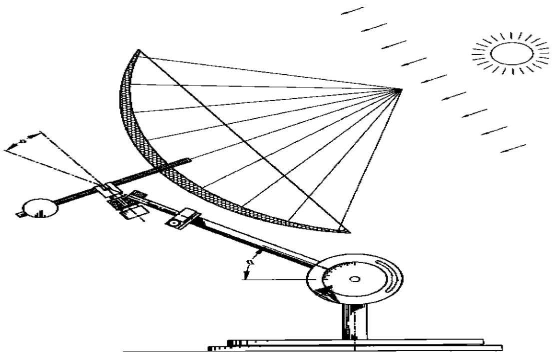


Fig. 5, Half Cylinder Solar

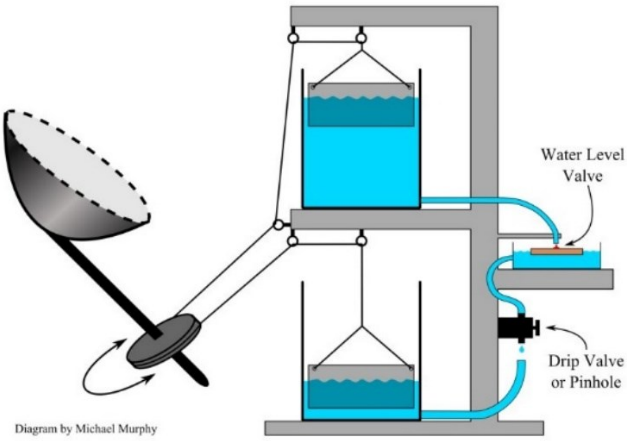


Fig. 6, Low-tech Water Tracking System

2.3 Comparative Study

In terms of design, student usually implements mounted solar systems and they show the output using a voltage display. According to the International Journal of Engineering Science and Innovative Technology (IJESIT) 2013 [3], a system with a single axis rotation could produce more volts that the mounted panel. Other students implement solar tracking system but without a self-cleaning and maintenance ideas. In comparison with other projects in the field of solar system tracking systems, this project has the advantages of reliability on continuous good output due to self-cleaning and Real Time Clock (RTC). Also, the results will be at max the entire time due to the feedback signal, self-cleaning method and single axis rotation.

The table and graph below show the output of mounted and single axis panels from 800 hours to 800 hours conducted by IJESIT.

Table 1. Fixed VS Single Axis.

HOUR	POWER FOR FIXED MOUNT(mW)	POWER FOR SINGLE-AXIS(mW)
0800	20.664	62.403
0900	39.780	67.473
1000	44.176	77.212
1100	70.616	93.772
1200	88.110	110.430
1300	104.960	137.160
1400	125.334	130.754
1500	105.342	120.335
1600	86.172	103.096
1700	70.620	89.910
1800	46.494	65.625

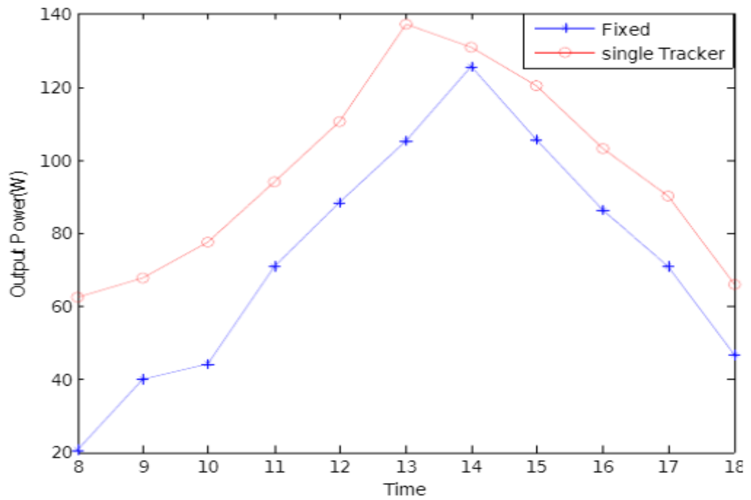


Fig. 7, Simulation Result for Comparison of Fixed mount and Single-Axis Tracker System.

3. System Design

3.1 Design Constraints

The main characteristics differentiating the solar tracker system are as follows:

- Sustainability.
- Environmental.
- Economic.

3.1.1 Design Constraints: Sustainability

In subsystem 1, a problem occurred regarding positioning the panel toward the sun precisely. Each few hours, the panel starts drifting from the sun angle by 3 degrees. After checking the Arduino program by our advisor Ahmed Abu Al Hussain, a modification on the program has taken place and the issue is solved.

In subsystem 2, different types of RTC control were on the table to select one. The most reliable one was DS 3231 due to its good quality and low consumption of battery.

Subsystem 3, a free power self-cleaning system was hard to install and make it reliable at the same time. Finally, an idea was generated from one of our group to make it power free and the movement will depend on the position of the solar

3.1.2 Design Constraints: Environmental

In subsystem 1, high wind and dusty environment could lead to serious damage to the entire system. A design change was required to overcome this issue. Therefore, the panel has been installed on a heavy square base which resist the average wind speed in Saudi Arabia.

In subsystem 2, positioning the real time clock on rainy environment might damage the ship. That's why a cover installation on the Arduino and the ship is implemented.

In subsystem 3: rainy weather will damage the brushes that is supposed to clean dust. Nano coating was the prime solution for this brushes to keep functioning on excellent condition.

3.1.3 Design Constraints: Economic

In subsystem 1, the cost of the project is quite high due to the number of electronics that are being used. In addition, solar panels that have considerable output is not cheap in the local market.

In subsystem 2, some real time clocks are very expensive and they are handy for big projects. In our case, a cheap one was selected to avoid financial crises to the group.

In subsystem 3, Simple hydraulic brushes are moving upward and downward without any power consumption to make the project power free and less costly.

3.2 Design Methodology

This project is divided into three phases, subsystem1 phase, subsystem2 phase and subsystem3 phase. In pahse1, Figure 1 shows block diagram of the project. The project is built using a balanced concept which is two signals from the different sensors are compared. Light Dependent Resistor (LDR) as a light sensor has been used. The two light sensors are attached to the panel which will create difference in voltages on one side of the light sensor if the solar panel is not perpendicular to the sun. For the controlling circuit, microcontroller (Arduino Mega) acts as a brain that controls the movement of the motor via Arduino Mega. Data received from the sensors and processed by the microcontroller (Arduino Mega). The microcontroller will send a data to the servo motors to ensure solar panel is perpendicular towards the Sun. The solar panel that attached to the motor will be reacted according to the direction of the motor. In phase2, a Real Time Clock (RTC) will be added to the system to function when LDR fails or there are weather changes preventing the LDR from Detecting. In phase3, a self-cleaning method will be added to the system by using dust sensor. The dust sensor will send a feedback signal to the microcontroller in the appearance of dust on the panel. In addition, an air tube is going to be attacked to clean the dust immediately.

3.3 Product Subsystems and Components

In subsystem1,2 and 3 many alternatives were studies scientifically and practically to achieve the final goal of this project which is maintaining the panel automatically.

3.3.1 Product Subsystem1: Sensors, panel and control

- Resistance varies continuously (analog) in photoresistor and are rugged in nature.
- Photodiodes are temperature sensitive and are uni-directional unlike photoresistors.
- Phototransistors are vulnerable to surges, spikes and EM energy.
- Polycrystalline has low efficiency and poorer aesthetics.
- Thin Film has Low efficiency and less proven
- Stepper motor has Low efficiency and draws substantial power regardless of load.
- Stepper motor has No feedback to indicate missed steps.
- Stepper motor gets very hot in high performance configurations.

3.3.2 Product Subsystem2: Types of Real Time Clocks

- RTC 1307 is an option but it has drifts from time to time.
- ISL 1208 is and option but it does not good in resisting temperature.
- RTC 2324 is an option but it has time drift and hard to control by Arduino.
- RTC 1302 is an option but it is old model and not good in resisting temperature.

3.3.3 Product Subsystem3: Electronic or Hydraulic

- Hydraulic Shaft controlled by the motion of solar panel.
- Electronic shaft controlled by Arduino to clean the system.
- Nano-Coating.
- Air Breather to flush dust.

3.4 Implementation

In this project include design and construction of an Arduino Mega based solar tracker. This solar tracker system uses the Arduino board, a servomotor, 2 LDR, 2 resistors, Real Time Clock (RTC), brushes and mono crystalline panel to rotate the solar panel towards the sun or a source of light. In subsystem 2, where Real Time Clock (RTC) will be installed to move the panel when LDR is not functioning correctly. In subsystem 3, cleaning the panel has the first priority by using air tube and dust sensor that sends a feedback signal to the controller to start the instrument air.

In this project, many alternatives have been considered such as stepper motor and different types of solar panels. Photoresistor, Photodiodes and Phototransistors sensors have been considered as alternatives. Different communication system such as Programable logic controller (PLC) and microcontrollers as well as rubber sweep have all been studied thoroughly. Different types of Real Time Clock (RTC) have been looked at but each one has its own characteristics. However, the one that has been chosen is the most fit to the final goal of this project.

In this project LDR was selected since it has no polarity, and easy to interface with circuit, cheap, reliable and is described by high spectral sensitivity, so that difference in high intensity is represented immediately by change in its resistance value. The block diagram of proposed system as shown in figure 8. RTC system has been also installed to minimize the risk of failure in LDRs and make the panel moves even when the weather changes. The mono panel type was selected due to its high efficiency, low cost and high resistivity to environment. The selection of servomotors comes due to the fact it could be programmed to swap in case of failure and this is the main objective of this project. Arduino Mega was selected because it is simple to program and cheap to buy.

In constructing the solar tracking system, LDRs are used to determine solar light intensity. The 2 LDRs are connected to pin A0 and A1 on the board. If you are going to be installing the solar tracker permanently then you may want to solder the resistors and LDRs together so that they cannot come loose [4]. RTC model No. 3231 DS is selected due to its reliability and long life battery. It is also resistible to temperature and could be programmed easily to fulfill our project requirement perfectly. If you are simply trying this project for fun then a breadboard is perfect. One servo motor is used for rotation part and the other one is a backup. Usually the servo has a yellow wire that is used to control the cycle and it must be associated on pin 9 on the board [5]. If you are using a servo larger than 9 grams then the Arduino will probably not be able to supply it enough power to achieve its full torque capability, you will need to supply the servo directly with its own 5V power source. When light falls on the LDR, its resistance differs and a potential divider circuit is used to obtain corresponding voltage value from the resistance of LDR [5]. The voltage signal is sent to the microcontroller. Constructed on the voltage signal, a corresponding PWM signal is send to the servo motor which origins it to rotate and finally attains a position where intensity of light falls on the solar panel is maximum. The schematic diagram of proposed system. In this project the angles are designed by finding which LDR is in shadow. For example, if high source is right with respect to right LDR will receive maximum light and left LDR will be in shadow. Make sure that you connect the external power sources ground to the Arduinos GND as well otherwise the PWM control signal to the servo will not work. Now you can upload your sketch onto your Arduino.

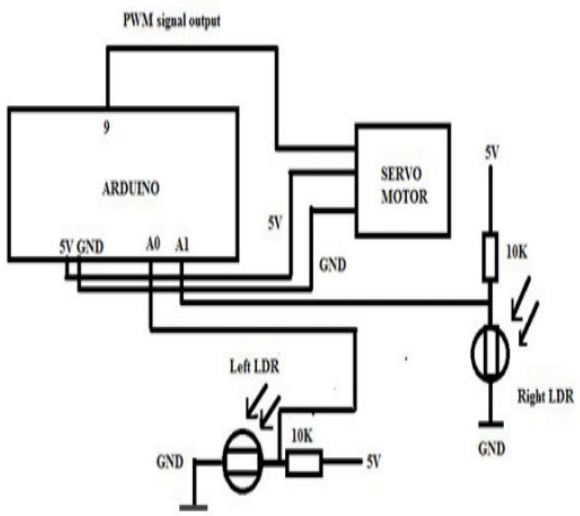


Fig. 8, Schematic Diagram of Project.

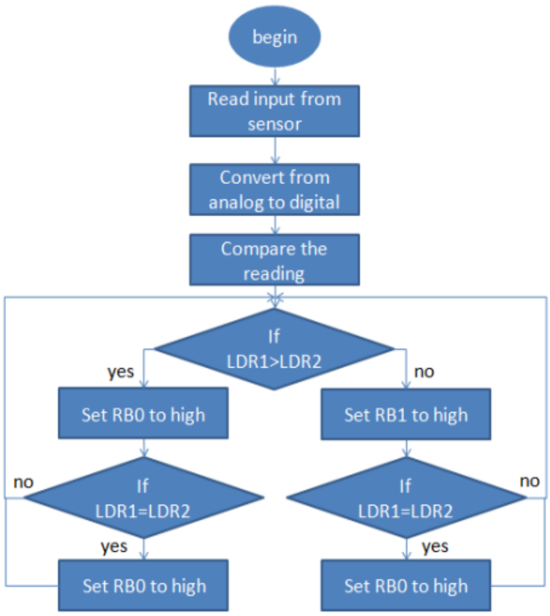


Fig. 9, Flow Chart of the Program.

Because of differences between the LDRs, resistors and the resistance of the wire used, there will be a difference between the signal received from both sensors even when they are receiving the same amount of light. This is taken into account by introducing a calibration offset into the calculation, this number will need to be adjusted in your code according to your setup. Adjust this calibration factor where it is declared in the code.

The most accurate way to determine this factor is to shine a light equally between both sensors and then use the Serial monitor on your computer to read the values output by the east and west sensor. The difference between these two values will be the calibration offset [6]. The LDRs are very sensitive so the tracker only moves when the difference between them is greater than 15 in the code otherwise it would be continuously tracking forwards and backwards and wasting power.

Finally, while this instruct able is centered more around the Arduino control and is not intended to detail making a tracking stand because of the extremely diverse range and size of panels available, here is a brief outline on the design along with some key pointers. Your stand should look something like the attached image when it is complete. Ideally the stand should be made from aluminum angle as it is strong, durable and suitable for outdoor use but it can also be made from wood, plywood or PVC piping [7]. The stand is essentially made in two parts, the base and the panel support. They are joined around a pivot point on which the panel support rotates. The servo is mounted onto the base and the arm actuates the panel support. The panel should protrude from the panel support as little as possible to keep the out of balance load on the servos to a minimum. Ideally, the pivot point should be placed at the center of gravity of the panel and panel support together so that the servo has an equal load placed on it no matter which direction the panel is facing although this is not always practically possible.

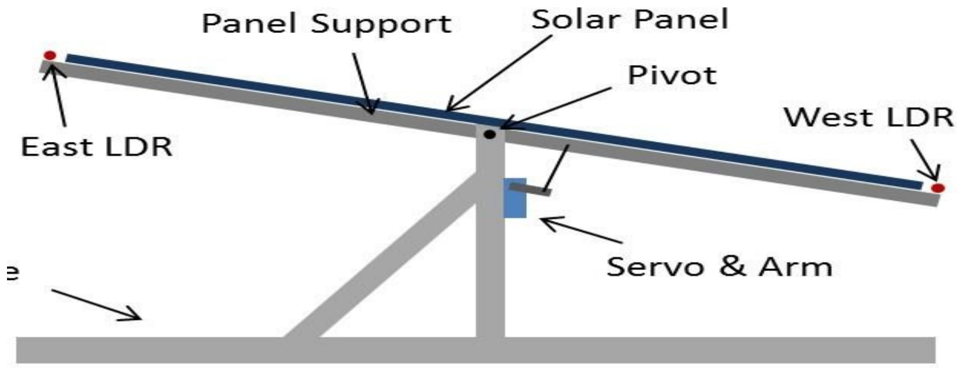


Fig. 10, Project Prototype.

4. System Testing and Analysis

4.1 Subsystem 1: Tracking System

Objectives:

To make sure the system is following the sun direction precisely and to verify that the system has no drift. Also, to ensure all connections are correct and there is no miss wiring shortage.

Setup:

To test the solar panel rotation and functioning, our team needed the following instruments:

1- Multimeter.
2- Different Batteries with different currents.
3- Laptop to verify the codes.
4- Screw drivers and nuts.
5- Aluminum Drill.

The resting has been conducted in the university's labs.

Results:

For the servomotors, they were tested using Arduino. After uploading the program, we connected to the motor to the Arduino as shown below:

- Servo red wire – 5V pin Arduino
- Servo brown wire – Ground pin Arduino
- Servo yellow wire – PWM(9) pin Arduino

Then, the rotation of the motor was verified. The codes output was checked using the laptop and finally, table 2 shows the output voltage of the crystalline solar panel with different angles. Both LDRs have been tested using a multimeter via their resistance, check table 3 for more information.

Table 2. Data for Testing Solar Panel.

Parameters	Quantity
Peak Power	20 W
Max Power Voltage	20 V
Max System Current	1.3 A
Number of Cells	36 Cells
Weight	1.5 Kg
Panel Dimension (H/W/D)	360x600x2 mm

Table 3. Data for Testing LDRs.

At light	At Dark
500 Ohms	200 Ohms

One more test was subjected by the team is to monitor the output for entire day and try this test twice. The first test when the panel is fixed and the other test is when the panel is rotating following the sun rays. The result was measured in different times during day and afternoon time. The line chart below shows the difference in output between case one and case two.

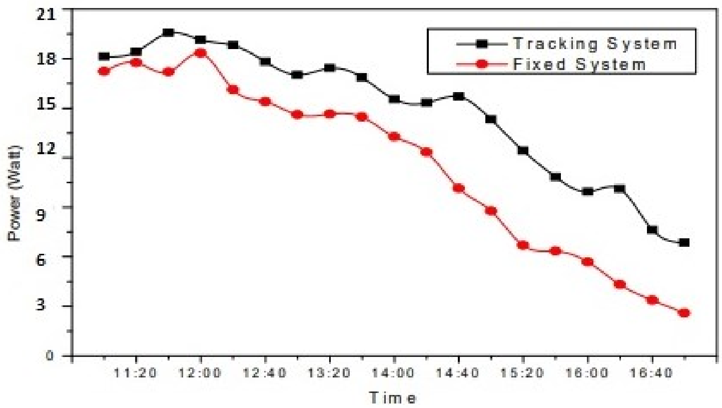


Fig. 11, Variation of power with time.

To measure open circuit voltage, Volts (Voc):

- Disconnect the solar panel completely from the battery and regulator
- Angle the solar panel towards the sun
- Ensure that the multimeter is set to measure Volts

- Measure the voltage between the +ve and -ve terminals by connecting the negative contact from the voltmeter to the negative on the panel and the positive contact on the voltmeter to the positive on the panel.

Refer to table 3 to find voltage results for six different times through the day.

Table. 3, Voltage Test.

Time	Tracking system	Fixed angle/ position
10:30 a.m.	19.5 V	19.05 V
12:00 p.m.	20.62 V	20.01 V
1:30 p.m.	19.82 V	18.62 V
2:00 p.m.	18.80 V	15.81 V
3:25 p.m.	19.61 V	14.55 V
5:15 p.m.	10.13 V	5.82 V

To measure short circuit current, Amps (Isc):

- Disconnect the solar panel completely from the battery.
- Angle the solar panel towards the sun.
- Ensure that the multimeter is set at 10A, at least to start with. You can change the setting later if required.
- Measure the current by connecting the +ve lead on the voltmeter to the +ve on the panel and the -ve from the voltmeter to the -ve on the panel.

Refer to table 4 to find short circuit current results for six different times through the day.

Table. 4, Short Circuit Test.

Time	Tracking system	Fixed angle/ position
10:30 a.m.	1.15 A	1.00A
12:00 p.m.	1.22A	1.19 A
1:30 p.m.	1.11 A	1.05 A
2:00 p.m.	1.03 A	0.89 A
3:25 p.m.	0.85 A	0.44 A
5:15 p.m.	0.77 A	0.3 A

To measure operating current, Amps (IL):

- Connect the panel to the regulator and battery.
- Ensure that the multimeter is set at 10A, at least to start with. You can change the setting later if required.
- Disconnect the positive cable between the battery and the regulator
- Measure the operating current by connecting the +ve from the multimeter to the positive cable from the regulator, and the -ve from the meter to the positive battery terminal.
- This measures the current that the panel (and charge controller) are passed to the battery. If you connect the meter the wrong way round then you will get a negative current showing.
- Remember, if the battery is full it may not be accepting current, resulting in a low reading

Refer to table 4 to find Operational current results for six different times through the day.

Table. 5, Load Circuit Test.

Time	Tracking system	Fixed angle/ position
10:30 a.m.	1.01 A	0.95 A
12:00 p.m.	1.13A	1.06 A
1:30 p.m.	1.09 A	0.91 A
2:00 p.m.	1.00 A	0.77 A
3:25 p.m.	0.89 A	0.32 A
5:15 p.m.	0.75 A	0.22 A

Table. 5, Power Produced Test

Time	Tracking System	Fixed angle / position
10:30 A.M	21.715 W	19.874 W
1:30 P.M	21.6038 W	16.9442 W
2 P.M	18.8 W	12.1737 W
3:25 P.M	17.4529 W	4.656 W
5:15 P.M	7.5975 W	1.2804 W

Power efficiency

Power produced (Average Tracking) by the solar = 18 W

Power consumed by the solar for rotation for single rotation for 3 Sec = 1.575 W

Net power Gain = Power produced – Power consumed

Net power Gain = 18 – 1.575 = 16.425

η = 91.25 % for solar tracking System

4.2 Subsystem 2: Real Time Clock (RTC)

Objectives:

In case of LDR failure, there is a switch to swap to RTC mode. This mode is to make sure the system is following the sun direction precisely and to verify that the system has no drift. Also, to ensure all connections are correct and there is no miss wiring shortage.

Setup:

- You must install the library of DS3231.
- The module can work on either 3.3 or 5V. The battery input is 3V and a typical CR2032 3V battery can power the module and maintain the information for more than a year.
- Do the connection like figure 12.

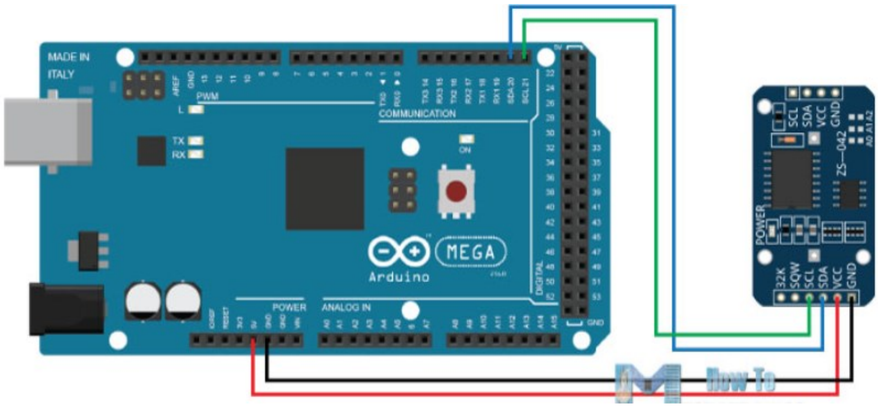


Fig. 12, RTC Connection.

- Upload your code and calibrate time.

Results:

For the Real time clock, they were tested using Arduino. After uploading the program, we connected to the RTC to the Arduino as shown below:

- VCC Brown wire – 5V pin Arduino
- Ground Red wire – Ground pin Arduino
- SDA Green wire – PWM(9) pin Arduino

The RTC code was checked and serial was following the actual time. Also, the rotation of the panel was according to our inputs. The output of the RTC can be seen in figure 13.

Fig. 13, RTC Output.

4.3 Subsystem 3: Self-Cleaning

Objectives:

To remove the dust once a day by swapping the panel without using any electrical input. This will ensure the healthiness of panel's output and prevent a dust failure in the future.

Setup:

- Install Hydraulic brushes Figure 14.
- Check their angles and friction.
- Rotate the Panel 135 degrees and 35 degrees.
- Apply some stiffness to the brushes for more reliability.

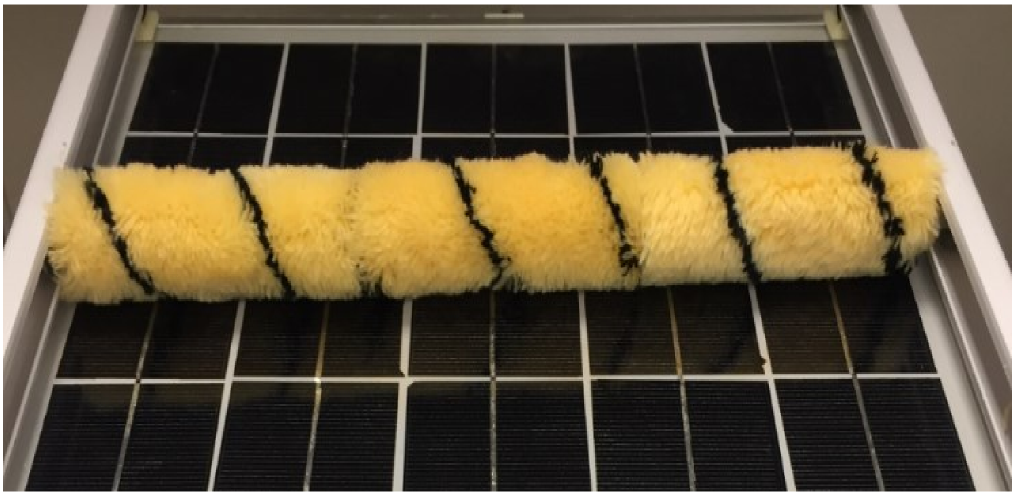


Fig. 14, Brush Cleaning.

Results:

Once the panel resets itself to night position the brush will swap it automatically using the panel's angel to move. The movement of the brush at first was exceedingly hard but after few adjustment the movement got smoother and smoother. The swapping principle shall take place daily and it should be able to remove all dusty material on the panel to improve its productivity the next day.

4.4 Overall Results, Analysis and Discussion

To test the performance of the system was built, several experiments were carried out by comparing the output power generated by the PV panels of both fixed and tracking system where two PV panels used in the experiments have the same specifications and characteristics. Figure 11 illustrates the comparison of output energy generated by two different systems (tracking vs. Fixed PV panel) for one-day i.e starting from 11.20 AM until 16.40 PM, the data are taken every 30 minutes, while the sky is clear with maximum illumination intensity, air temperature and the average wind speed are 110 600 lux, 36.3°C and 2 m/s, respectively. The location of the experiment is in Dammam, Saudi Arabia. Based on the experiment results, it can be known that the largest power increase achieved by the solar tracking system is 192.5% of the fixed PV panel which occurred at 11.50 AM. The RTC tracking System was also tested and proven that it is actually reliable and could track the sun for an entire year without fail. The result of the swapping principle shall take place daily and it should be able to remove all dusty material on the panel to improve its productivity the next day.

5. Project Management

5.1 Project Plan

Table 4. Project Plan.

SN	Tasks & Responsibilities	Team Members	Week number	% of Work completion
1	Group members selection Organization the team work Assign the team leader	ALL	1	100 %
2	Generating ideas Selection the project's topic Discussion the idea and the topic	ALL	2	100 %
3	Communicate with the project advisor Discussion the topic with the advisor Inform the instructor about the situation	ALL	3	100 %
4	Collect more information about the project Prepare and submit the project proposal	AH, AK & MK	4	100 %
5	Project management Plan Define roles and related activities Project presentation	HA, MK & AH	5	100 %
6	Searching for the project components Communicate with the project advisor Prepare working place	ALL	6	100 %
7	Evaluate project components Prepare the material purchasing Prepare the progress report	AK, HA & MK	7	100 %
8	Design the hardware framework Evaluate the sizing and measurements	MK, AH & HA	8	100 %
9	Communicate with the project advisor Analyze & arrange the project components Prepare the progress report	HA, AK & FM	9	100 %
10	Build up the project components Evaluate the general condition	ALL	10	100 %
11	Comparing the project with similar projects Complete the building of project Prepare the progress report	AH & AK	11	100 %
12	Preparing the required programs Communicate with the project advisor	AH, AK & MK	12	100 %
13	Project will be almost ready Preparing for project test Simulate the project Prepare the progress report	AK, AH & MK	13	100 %
14	Test the project behavior Evaluate the project results Inform the project advisor	AH, HA & MK	14	100 %
15	Final revisions Prepare the final report & simulation	ALL	15	100%

SN	Tasks & Responsibilities	Team Members	Week number	% of Work completion
1	Group Meeting and Supervisor	ALL	1	100 %
2	Method of implementation for Subsystem 2	ALL	2	100 %
3	Method of implementation for Subsystem 3	ALL	3	100 %
4	Gathering information about subsystem 2 and 3	ALL	4	100 %
5	Plan the Jobs	ALL	5	100 %
6	Selecting the components for subsystem 2 and 3	HA, AH & MK	6	100 %
7	Comparing the prices and make sure of their availability	AH & FM	7	100 %
8	Discussing the outcome of the previous 7 weeks with supervisor	MK, AH & HA	8	100 %
9	Implementing subsystem 2	HA, AK & FM	9	100 %
10	Implementing subsystem 2 and testing it	ALL	10	100 %
11	Implementing subsystem 3	AH, HA & AK	11	100 %
12	Implementing subsystem 3 and testing it	AH, HA & MK	12	100 %
13	Group Meeting with supervisor and checking his advises.	ALL ALL ALL	13	100 %
14	Test the project behavior Evaluate the project results Inform the project advisor	ALL	14	100 %
15	Final revisions Prepare the final report & simulation	ALL	15	100%

5.2 Contribution of Team Members

Table 5. Contribution of Team Members.

Task	Mohammed	Ahmed	Abdelaziz	Faisal	Hussain	Task Total
Search & acquire components	**25%**	**25%**	**15%**	**20%**	**15%**	**100%**
Design Subsystems	**20%**	**35%**	**15%**	**10%**	**20%**	**100%**
Test Subsystems	**25%**	**20%**	**15%**	**10%**	**30%**	**100%**
Write Reports & Presentations	**15%**	**15%**	**25%**	**25%**	**20%**	**100%**

5.3 Project Execution Monitoring

During the last semester, many meetings have been conducted with Mr. Ahmed Abu AL Hussain to establish the foundation and start building this project. In the meetings, the team and Mr. Ahmed negotiated countless ideas about each individual subsystem and how to make the project attractive for the audience. A place of improvement for this project was essential to start because, a project without integration ideas is a false project. During the meetings, various testing was taken place for different reasons. Sometimes, the testing was conducted with Mr. Ahmed and some with other team members. Mr. Ahmed have helped us greatly in terms of coding and using the Arduino Mega. Other members have done a great job reading about power and electronics and different articles to achieve the success of this project. The final test with Mr. Ahmed was executed 3 weeks ago. The Second semester, the team has worked hard in selecting, evaluating and countless meeting have taken place with our supervisor. The outcome of second semester is a second way of tracking sunlight and a hydraulic swapping technique has been implemented. Currently the project has been completed and its waiting for the final test by the inspectors.

5.4 Challenges and Decision Making

Challenges:

- In selecting components, the team has faced the following problems:
  a. Servo Motor torque issues.
  b. Resisters Values.
  c. The size for the panel that we should select.
  d. Type of panel Material.
- To attach the solar panel and servos, we have gone through a hard finding a mechanist.
- LDRs not sensing the light accurately.
- Time management problem with team.
- RTC types are very complicated and it hard to calibrate.
- Self-cleaning technique was hard to implement and make it clean efficiently.

Decision Making:

In selecting components, reading different datasheets and Mr. Ahmed's advices were helpful to overcome this issue. For example, regarding the torque issues we had to select another type with higher torque. For the panel type, a monocrystalline type is selected due to its high efficiency in comparison with its price. Regarding the LDR problem, one of them was defective and after testing it. It was replaced with new one. The problem with time management is solved by meeting sometimes on weekend time since all team members would be available during weekends. A second method of sunlight tracking system is selected in order to swap from LDR to real time clock method. This decision was made to make the panel as accurate as we can. Finally, a self-cleaning method was implemented to prove that in self-cleaning system attached to the system the productivity would be better than a normal one.

5.5 Project Bill of Materials and Budget

The estimated budget for this project is 4000 SR all three subsystems included. Table 6 below shows the exact price for all material that have been bought already:

Table 6. Contribution of Team Members.

Component Name	Type (Hard/Software)	Price (SR)
Microcontroller	Hardware	120
2 servomotors	Hardware	300
Solar Panel	Hardware	300
Breadboard	Hardware	30
Resistors	Hardware	5
Wires	Hardware	5
4 LDRs	Hardware	40
Batteries	Hardware	100
RTC	Hardware	50
Brushes	Hardware	20
Shaft	Hardware	60
Total		1030

6. Project Analysis

6.1 Life-long Learning

During constructing, designing and communicating, may skills have been acquired by all team members and these skills are a life-long learning skill because, each member has experienced himself the practice of constructing a single axis solar tracker system. Below, some of the aspects that have been gained during this project:

- Many new hardware devices such as Arduino, Servo Motors and different types of solar panels. The outcome of knowing the differences between these devices will encourage the student to come up with his own design.
- The used software is simply in this project and all team members have participated in writing the codes which have gained them a knowledge how to read codes in general. Also, the team is now capable of fixing errors in codes.
- Time management has been previously mentioned but the team has forsaken his own weekend to complete this project successfully.
- Other tools have been used such as internet. Google Scholar was a good help in finding information about different devices and it is a trusted source of information.
- Since, this project requires a lot of datasheets to be read. The team assumes their skills have greatly increased in reading datasheets.

6.2 Impact of Engineering Solutions

The most commonly known fact about solar energy is that it represents a clean, green source of energy. Solar power is a great way to reduce your carbon footprint. There's nothing about solar power that pollutes Mother Nature. Solar power doesn't release any greenhouse gasses, and except for needing a source of clean water to function, it uses absolutely no other resources. Hence, it's safe and environmentally-friendly [8]. Yet, people are still in doubt why solar energy is good.

6.3 Contemporary Issues Addressed

Solar electricity prices serve as a great example of why there should be an increase in the use of solar energy. Traditional electricity relies heavily on fossil fuels such as coal and natural gas. Not only are they being bad for the environment, but they are also limited resources [9]. This translates into a volatile market, in which energy prices alter throughout the day.

Electricity needs to be transported from big power plants to end-consumers via extensive networks. Long distance transmissions equal power losses [10]. Ever wondered what are solar panels used for? They're on your roof to get energy from the sun. Rooftop solar power is helpful in increasing electricity efficiency, considering the short distance [11]. Your energy becomes domestic and as a result you're in control of your own bill sand energy usage. Furthermore, solar power systems are durable, thus chances of service interruption are reduced.

7. Conclusions and Future Recommendations

7.1 Conclusions

The goal of the project was to design and implement a small-scale prototype of a single axis solar tracker with basic tracking functions. Designing and implementing processes have been accordingly completed for the work of the project. The final result was a complete design of such a system, with functionality that met the design requirements. While the project has succeeded in creating a device with basic required features, there are still considerable drawbacks and limitations with the performance of the device, as discussed in the implementation work of the project. It is possible to overcome these limitations and to improve the performance of the device in future development.

The project was a successful effort in fulfilling the purpose when I started it that is to research and catch up with current technologies in this field of energy exploitation. It is a useful reference for those who needs to develop similar systems. The knowledge and information from this project can also become the starting point for future development of several of applications.

7.2 Future Recommendations

The goals of this project were purposely kept within what was believed to be attainable within the allotted timeline and resources. As such, many improvements can be made upon this initial design. That being said, it is felt that this design represents a functioning miniature scale model which could be replicated to a much larger scale.

The following recommendations are provided as ideas for future expansion of this project:

1- Applying the maximum power point (MPP) to the design which is the point on a power (I-V) curve that has the highest value of the product of its corresponding voltage and current, or the highest power output. Maximum power point tracker (MPPT) A device that continually finds the MPP of a solar panel or array.

2- Increase the sensitivity and accuracy of tracking by using a different light sensor such as radiation sensor figure 15. This sensor detects solar radiation at wavelengths of 300 to 1100 nanometers. Solar radiation data is required (along with an anemometer and a temperature/humidity sensor) enables the weather station to report ET and THSW Index.

3- Finding new subsystems which are more suitable for Saudi's environment by implementing dust sensors. More than one option is available to detect dust such as camera, pointed at cells, with software to compare surface refection, adjusted for time of day and sun angle/intensity or a small photoelectric cell, kept clean, to measure available solar energy and give you a reference value to compare against the array such as DustIQ Soiling Monitoring System. DustIQ monitors the loss of light transmission caused by dust on PV panels using Kipp & Zonen's new and innovative Optical Soiling Measurement OSM) technology. It has no moving parts and it does not need sunlight to make its measurements.
4- There is a design issue that the cleaning system covers one serially connected cell. This has to be illuminated to approach the target of this project and to have the maximum output of the solar cell.
5- Connecting a battery to the cell and charge it in a circle where it could help in powering the panel itself. This part is hard to accomplish since the panel is relatively small.
6- The motor size and torque problems due to the size of panel. This could be done with some use of easy to bend cables which don't necessarily exert any force on the motor when it is turning the solar panel. Alternatively, a smaller gauge wire, a larger motor with more torque, or a combination of some or all of these ideas.

Fig. 15, Light Radiation Sensors.

Fig. 16, DustIQ Soiling Monitoring System

8. References

[1] A.K. Saxena and V. Dutta, "A versatile microprocessor based controller for solar tracking," in Proc. IEEE, 1990, pp. 1105 – 1109.

[2] Tamara A. Papalias and Mike Wong, "Making Sense of Light Sensors", Application notes, CA: Intersil Americas Inc. 2007.

[3] David Appleyard, "Solar Trackers: Facing the Sun", Renewable Energy World Magazine, UK: Ralph Boon, June 1, 2009.

[4] S. J. Hamilton, "Sun-tracking solar cell array system," Department of Computer Science and Electrical Engineering, University of Queensland, Bachelors Thesis, 1999.

[5] N. Amin, W. C. Yung and K. Sopian, "Low Cost Single Axis Automated Sunlight Tracker Design for Higher PV Power Yield" ISESCO Science and Technology Vision, Volume 4, November 2008.

[6] Han Wan Siew, "Solar Tracker" SIM University, 2008.

[7] Jyotirmay Gadewadikar, "Microprocessor Based Solar Tracking System Using Stepper Motor" S.G.S. Institute of Tech. & Science, Indore.

[8] A.K. Saxena and V. Dutta, "A versatile microprocessor based controller for solar tracking," in Proc. IEEE, 1990, pp. 1105 – 1109.

[9] Tamara A. Papalias and Mike Wong, "Making Sense of Light Sensors", Application notes, CA: Intersil Americas Inc. 2007.

[10] David Appleyard, "Solar Trackers: Facing the Sun", Renewable Energy World Magazine, UK: Ralph Boon, June 1, 2009.

[11] S. J. Hamilton, "Sun-tracking solar cell array system," Department of Computer Science and Electrical Engineering, University of Queensland, Bachelors Thesis, 1999.

Appendix A: Progress Reports

Prince Mohammad Bin Fahd University (PMU)
Department of Electrical Engineering

Design Methodology & Project Management
Instructor: Dr. Chedly B. Yahya

Fall 2018-19

Project Proposal

Self-maintained solar tracking system

Team:

Name	ID
Abdulaziz Alkhulaiwi	201201153
Ahmed Alharbi	201500092
Hussain Alarnous	201400608
Mohammed Alkaltham	201501590
Faisal Almubayedh	201403528

Project Advisor(s)

Mr. Ahmad Abu Husain

Date September 26, 2018

1. Project Definition:

To design a system that absorbs sun's light (photons) and it has the ability to rotate the solar panel direction towards the sun one-axis. Furthermore, it has the ability to do self-cleaning which makes it a reliable system against dusty environment and for higher conversion efficiency. A feedback signal of motion detection is going to be installed and programmed. The system will carry subsystems in the controlling, reading of the quality of the electricity and load and the mechanism of cleaning with the help of sensors.

2. Project Objectives:

1. Show that using a controlled solar tracking system produces greater voltage output than a fixed panel

2. Increase the efficiency of solar Panels by using a micro-controller based solar tracking mechanism.

3. Design and implement a micro-controller based solar ultra-violet light tracking system that can direct a solar panel towards the sun.

4. Show that the use of self-cleaning increases the efficiency of solar panels considerably.

5. Improve the quality of output voltage by sending feedback signal .

3. Project Specifications (c1):

The project will involve the design and testing of different subsystems. Each subsystem will perform to the following target specifications:

a) Measures power consumed daily light approximate
b) Communicator that sends data to an Arduino Mega to know at desired time from display.
c) Monitors power quality.
d) Dust Sensors,
e) one-axis solar tracker using a solar panel
f) Feedback signal show if the solar panel follow the sun direction
g) Self-Cleaning when the dust cover the surface of solar panel using dust sensors

4. Introduction:

Solar panels are fast becoming a very attractive renewable energy option, which could end up being incredibly beneficial to the environment. The process of converting sunlight to electrical energy is one that has improved dramatically over the last few decades, and is now more efficient than ever. The use of solar energy has been around for years in small devices such as calculators, but now many are talking about powering houses and businesses off of these panels.

Solar energy is created using the energy which has been generated by the sun. A solar power panel is able to function using the solar energy which is derived from the sun. Every solar power panel contains many different silicon cells or solar cells. They are building blocks of solar panels. The energy from the sun is absorbed by these solar cells. The solar energy derived from the sun is converted into electricity with the help of a solar power panel.

The most common problems affecting solar cells are dust and maintenance so that the giant farms solar cell are in the deserts, that need periodic maintenance , In nowadays we can solve some problems through modern technology by our projects will provide the solution. Some of these benefits include:

a) Enhancing the efficiency of solar power collection by photovoltaic cells by up to 30-40%.
b) Solar trackers generate more electricity in roughly the same amount of space needed for fixed tilt systems, making them ideal optimizing land usage.
c) As we know Saudi Arabia is sunny all year which makes sun tracker the perfect target to reduce the consumption of fuel foils.

5. Applications

The proposed system can be used:

i. In residential homes to prevent high cost bills from electrical company.
ii. In Factories that need high demand on electricity.
iii. In educational purpose for developed by students.

6. Design Methodology

This project was divided into two main parts: the distribution and installation of equipment and the other part for developing and more functionality.

Phase 1 (Term 1, Design M.):

- Design **subsystem I** (Sun tracker)
    - This subsystem needs these components:
        - LDRs
        - Solar panel

- Servo Motor
- Microcontroller
- Real Time Clock

- Design **subsystem II** (Motion Detection).
  - This subsystem needs these components:
    - XBee module

Phase 2 (Term 2, ASSE III):

- Design other **subsystems III** (self-Cleaning).
  - This subsystem needs these components:
    - Dust sensor
    - Air-tube to clean the dust
- Test and analyze each subsystem and make necessary improvements.
- Integrate all subsystems and perform final testing.
- Write final report and presentation.

A block diagram for the smart system is shown in Fig. 1.

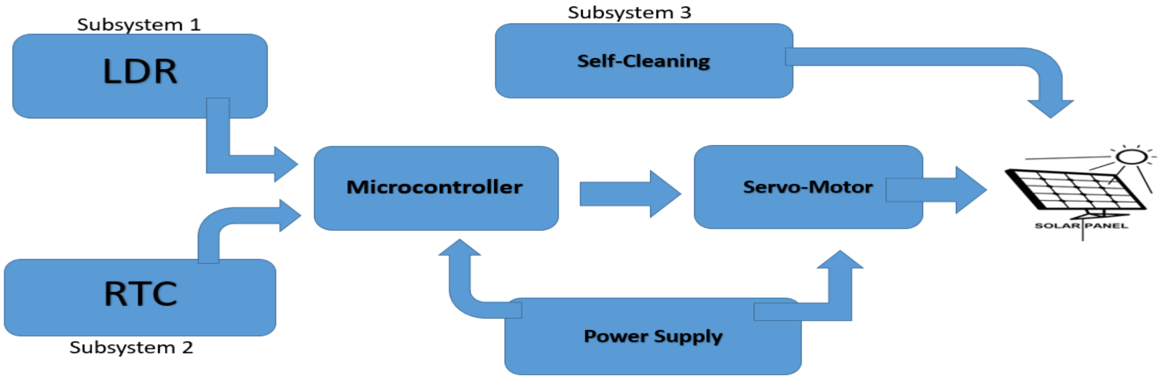


Fig. 1: Block diagram

7. Budget Estimate

No.	Description	Quantity	Unit Cost (SR)	Total Cost (SR)
1	Microcontroller	1	150	150
2	Solar panel	1	200	200
3	Motor	1	150	150
4	Display	1	30	30
5	Chips & Components (LDR, capasitors .. etc)		300	300
			Totals	**830**

	Project Management: Plan	
	Electrical Engineering Department	
	EEEN4311: Design Methodology & Project Management	
	Instructor: Dr. Chedly B. Yahya	Fall 2018-19

Project Title: **Solar Tracking System with Self Cleaning**		
Team:	Abdulaziz Alkhulaiwi **(AK)** Ahmed Alharbi **(AH)** Faisal Almubayedh **(FM)**	Hussain Alarnous **(HA)** Mohammed Alkaltham **(MK)**

SN	Tasks & Responsibilities	Team Members	Week number	% of Work completion
1	Group members selection Organization the team work Assign the team leader	ALL	1	100 %
2	Generating ideas Selection the project's topic Discussion the idea and the topic	ALL	2	100 %
3	Communicate with the project advisor Discussion the topic with the advisor Inform the instructor about the situation	ALL	3	100 %
4	Collect more information about the project Prepare and submit the project proposal	AH, AK & MK	4	100 %
5	Project management Plan Define roles and related activities Project presentation	HA, MK & AH	5	100 %
6	Searching for the project components Communicate with the project advisor Prepare working place	ALL	6	100 %
7	Evaluate project components Prepare the material purchasing Prepare the progress report	AK, HA & MK	7	100 %
8	Design the hardware framework Evaluate the sizing and measurements	MK, AH & HA	8	100 %
9	Communicate with the project advisor Analyze & arrange the project components Prepare the progress report	HA, AK & FM	9	100 %
10	Build up the project components Evaluate the general condition	ALL	10	100 %
11	Comparing the project with similar projects Complete the building of project Prepare the progress report	AH & AK	11	100 %
12	Preparing the required programs Communicate with the project advisor	AH, AK & MK	12	100 %

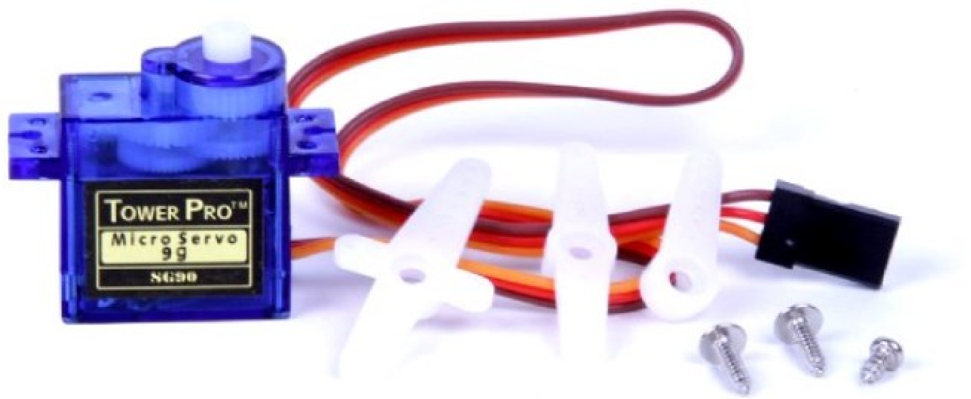
13	Project will be almost ready Preparing for project test Simulate the project Prepare the progress report	AK, AH & MK	13	100 %
14	Test the project behavior Evaluate the project results Inform the project advisor	AH, HA & MK	14	100 %
15	Final revisions Prepare the final report & simulation	ALL	15	100%
SN	**Tasks & Responsibilities**	**Team Members**	**Week number**	**% of Work completion**
1	Group Meeting and Supervisor	ALL	1	100 %
2	Method of implementation for Subsystem 2	ALL	2	100 %
3	Method of implementation for Subsystem 3	ALL	3	100 %
4	Gathering information about subsystem 2 and 3	ALL	4	100 %
5	Plan the Jobs	ALL	5	100 %
6	Selecting the components for subsystem 2 and 3	HA, AH & MK	6	100 %
7	Comparing the prices and make sure of their availability	AH & FM	7	100 %
8	Discussing the outcome of the previous 7 weeks with supervisor	MK, AH & HA	8	100 %
9	Implementing subsystem 2	HA, AK & FM	9	100 %
10	Implementing subsystem 2 and testing it	ALL	10	100 %
11	Implementing subsystem 3	AH, HA & AK	11	100 %
12	Implementing subsystem 3 and testing it	AH, HA & MK	12	100 %
13	Group Meeting with supervisor and checking his advises.	ALL ALL ALL	13	100 %
14	Test the project behavior Evaluate the project results Inform the project advisor	ALL	14	100 %
15	Final revisions Prepare the final report & simulation	ALL	15	100%

Appendix B: Bill of Materials

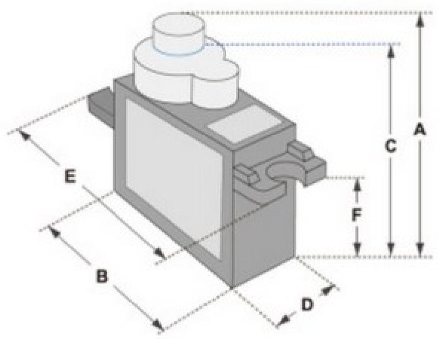
Component Name	Type (Hard/Software)	Quantity	Price (SR)
Microcontroller	Hardware	1	120
2 servomotors	Hardware	2	300
Solar Panel	Hardware	1	300
Breadboard	Hardware	1	30
Resistors	Hardware	2	5
Wires	Hardware	20	5
4 LDRs	Hardware	4	40
Batteries	Hardware	6	100
RTC	Hardware	1	50
Brushes	Hardware	1	20
Shaft	Hardware	1	60
Total		Total	1030

Appendix C: Datasheets

SERVO MOTOR SG90 DATA SHEET

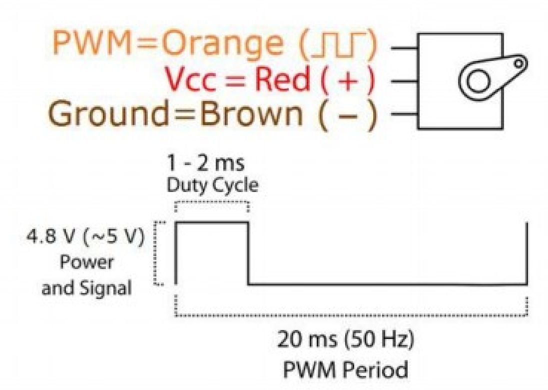


Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6

Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is middle, is all the way to the right, "-90" (~1ms pulse) is all the way to the left.



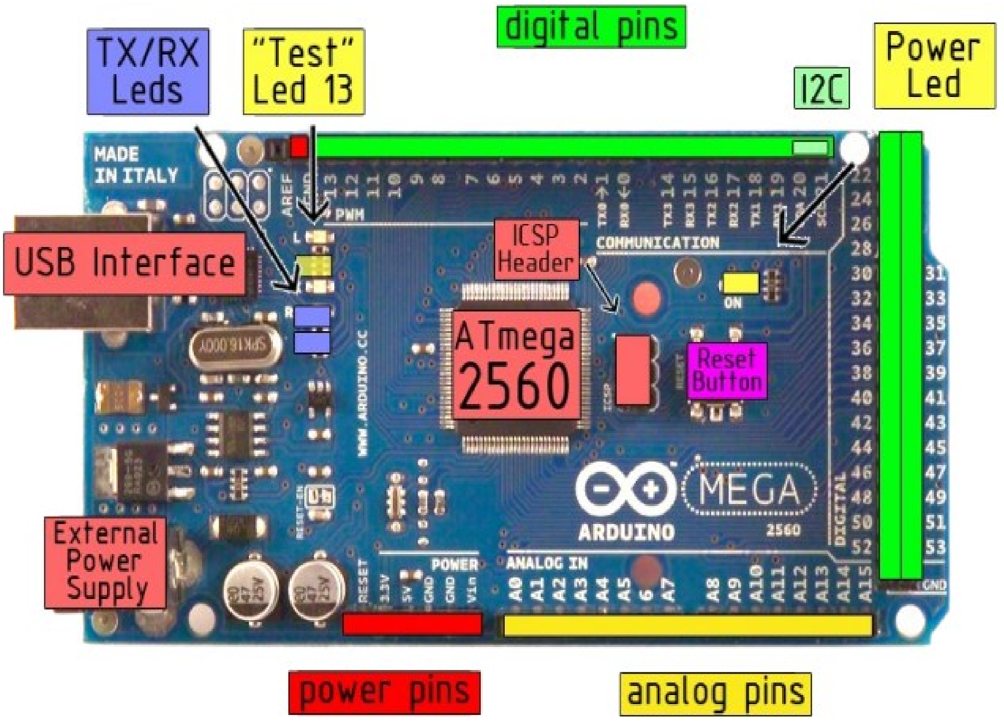
Technical Specification

EAGLE files: arduino-mega2560-reference-design.zip Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

the board



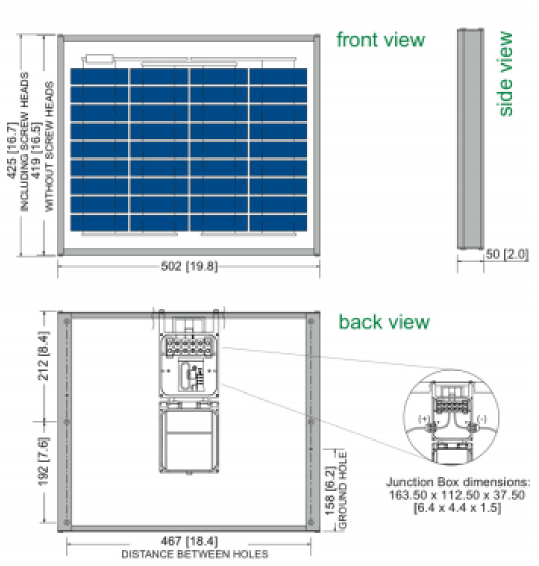
20W Photovoltaic module – 420J

Electrical characteristics

	(1) STC 1000W/m²	(2) NOCT 800W/m²
Maximum power (P_{max})	20W	14.4W
Voltage at Pmax (V_{mpp})	16.8V	15.0V
Current at Pmax (I_{mpp})	1.19A	0.95A
Short circuit current (I_{sc})	1.29A	1.04A
Open circuit voltage (V_{oc})	21.0V	19.1V
Module efficiency	9.4%	
Tolerance Pmax	± 10%	
Nominal voltage	12V	
Efficiency reduction at 200W/m²	<5% reduction (efficiency 8.9%)	
Limiting reverse current		1.29A
Temperature coefficient of I_{sc}		0.105%/ °C
Temperature coefficient of V_{oc}		0.360%/ °C
Temperature coefficient of P_{max}		-0.45%/ °C
(3) NOCT		47 ±2 °C
Maximum series fuse rating		3A
Application class		Class C (according to IEC 61730-2007)
Maximum system voltage		20V

1: Values at Standard Test Conditions (STC): 1000W/m² irradiance, AM1.5 solar spectrum and 25°C module temperature
2: Values at 800W/m² irradiance, Nominal Operation Cell Temperature (NOCT) and AM1.5 solar spectrum
3: Nominal Operation Cell Temperature: Module operation temperature at 800W/m² irradiance, 20°C air temperature, 1m/s wind speed

All solar modules are individually tested prior to shipment; an allowance is made within our factory measurement to account for the typical power degradation (LID effect) which occurs during the first few days of deployment.

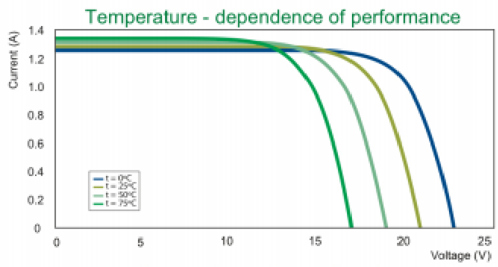


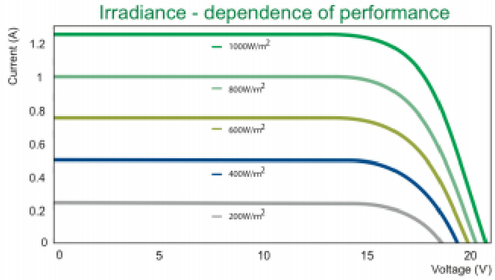
Dimensions in mm [in].

SES MAPPS Solar Module Mechanical characteristics

Solar cells	36 monocrystalline silicon cut cells in series
Front cover	High transmission 3.2mm (1/8") glass
Encapsulant	EVA
Back cover	White polyester
Frame	Silver anodized aluminum
Junction box	IP65 with 4 terminal screw connection block; accepts PG 13.5, M20 13mm (½") conduit, or cable fittings accepting 6-12mm diameter cable.
Terminals	accept 2.5-10mm2 (8-14 AWG) wire
Dimensions	839 x 537 x 50mm / 33.0 x 21.1 x 2in
Weight	6kg / 13.2lbs

All dimensional tolerances within ±1% unless otherwise stated.





Warranty*

- Free from defects in materials and workmanship for 2 years
- 90% Min power output for 12 years
- Optional 25 years available *Refer to limited warranty certificate for terms and conditions

SES MAPPS Solar Module Certification

Certified according to the extended version of the IEC 61215 (ed. 2), EC 61215:2005-08 (Crystalline silicon terrestrial photovoltaic modules - Design qualification and type approval)

Certified according to IEC 61730-1 and IEC 61730-2 (ed. 1), EN 61730-1:2007-05 and EN 61730-2:2007-05. (photovoltaic module safety qualification, requirements for construction and testing).

Listed to UL 1703 & ULC ORD-C1703 Standard for Safety by Intertek ETL. Class C Fire Rating.

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Visit us at http://www.sunrom.com

Document: Datasheet | Date: 28-Jul-08 | Model #: 3190 | Product's Page: www.sunrom.com/p-510.html

Light Dependent Resistor - LDR

Two cadmium sulphide(cds) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Applications

Photoconductive cells are used in many different types of circuits and applications.

Analog Applications

- Camera Exposure Control
- Auto Slide Focus - dual cell
- Photocopy Machines - density of toner
- Colorimetric Test Equipment
- Densitometer
- Electronic Scales - dual cell
- Automatic Gain Control – modulated light source
- Automated Rear View Mirror

Digital Applications

- Automatic Headlight Dimmer
- Night Light Control
- Oil Burner Flame Out
- Street Light Control
- Absence / Presence (beam breaker)
- Position Sensor

Electrical Characteristics

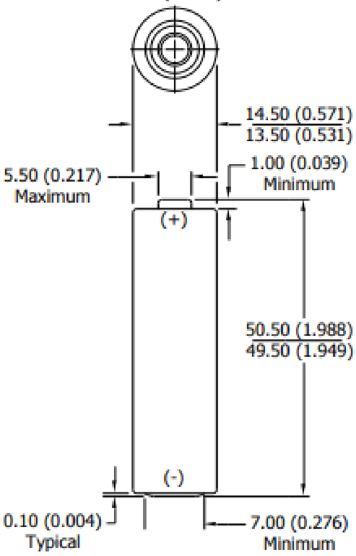
Parameter	Conditions	Min	Typ	Max	Unit
Cell resistance	1000 LUX 10 LUX	- -	400 9	- -	Ohm K Ohm
Dark Resistance	-	-	1	-	M Ohm
Dark Capacitance	-	-	3.5	-	pF
Rise Time	1000 LUX 10 LUX	- -	2.8 18	- -	ms ms
Fall Time	1000 LUX 10 LUX	- -	48 120	- -	ms ms
Voltage AC/DC Peak		-	-	320	V max
Current		-	-	75	mA max
Power Dissipation				100	mW max
Operating Temperature		-60	-	+75	Deg. C

Specifications

Classification:	Alkaline
Chemical System:	Zinc-Manganese Dioxide (Zn/MnO_2) No added mercury or cadmium
Designation:	ANSI-15A, IEC-LR6
Nominal Voltage:	1.5 volts
Nominal IR:	150 to 300 milliohms (fresh)
Operating Temp:	-18°C to 55°C (0°F to 130°F)
Typical Weight:	23.0 grams (0.8 oz.)
Typical Volume:	8.1 cubic centimeters (0.5 cubic inch)
Jacket:	Plastic Label
Shelf Life:	10 years at 21°C
Terminal:	Flat Contact

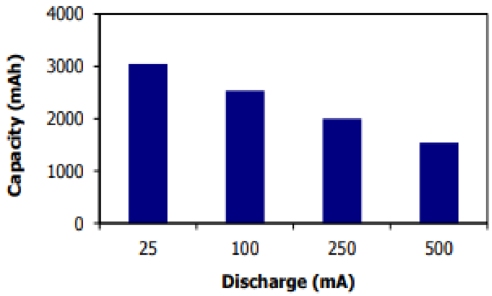
Industry Standard Dimensions

mm (inches)

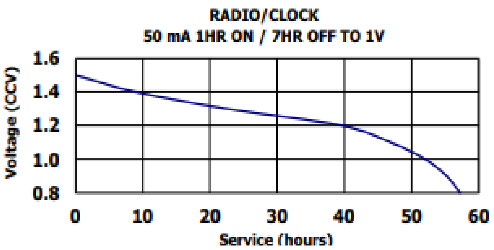


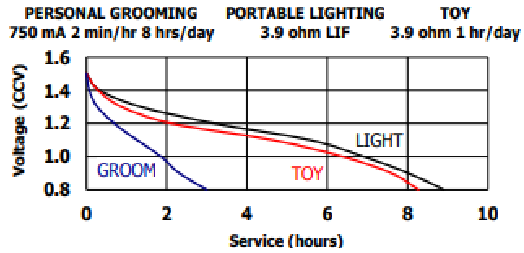
Milliamp-Hours Capacity

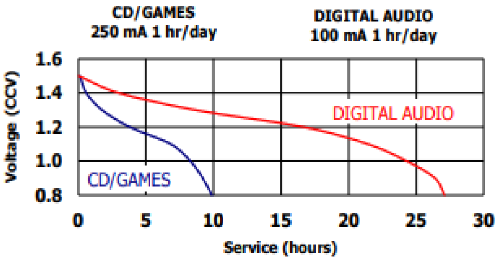
Continuous discharge to 0.8 volts at 21°C

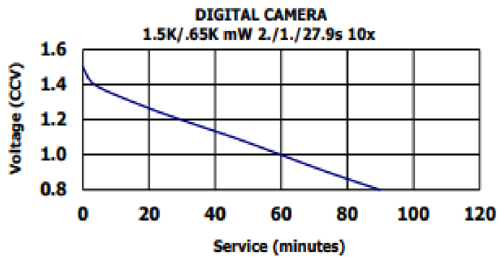


Industry Standard Tests (21°C)









Important Notice

This data sheet contains typical information specific to products manufactured at the time of its publication.
Contents herein do not constitute a warranty and are for reference only.

ence and comparator circuit monitors the status of V_{CC} to detect power failures, to provide a reset output, and to automatically switch to the backup supply when necessary. Additionally, the $\overline{RST}$ pin is monitored as a pushbutton input for generating a reset externally.

Applications

Servers	Utility Power Meters
Telematics	GPS

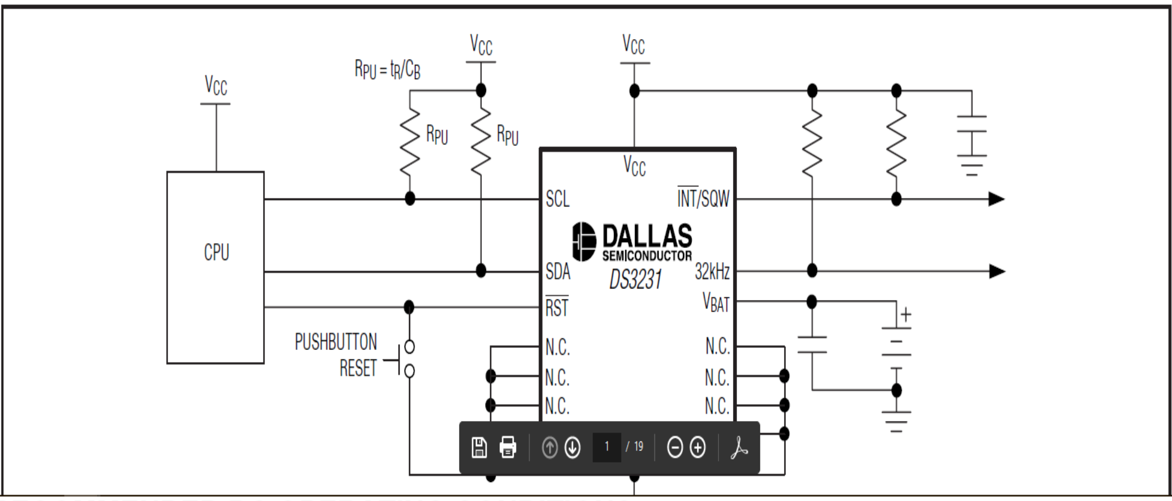
Pin Configuration appears at end of data sheet.

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
DS3231S	0°C to +70°C	16 SO	DS3231
DS3231SN	-40°C to +85°C	16 SO	DS3231N
DS3231S+	0°C to +70°C	16 SO	DS3231+
DS3231SN+	-40°C to +85°C	16 SO	DS3231N+

+Denotes lead-free

Typical Operating Circuit



RECOMMENDED DC OPERATING CONDITIONS

($T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.) (Notes 1, 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}		2.3	3.3	5.5	V
	V_{BAT}		2.3	3.0	5.5	V
Logic 1 Input SDA, SCL	V_{IH}		0.7 x V_{CC}		V_{CC} + 0.3	V
Logic 0 Input SDA, SCL	V_{IL}		-0.3		+0.3 x V_{CC}	V
Pullup Voltage (SDA, SCL, 32kHz, $\overline{INT}$/SQW)	V_{PU}	V_{CC} = 0V			5.5V	V

ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.3V to 5.5V, $V_{CC} > V_{BAT}$, $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.) (Typical values are at V_{CC} = 3.3V, V_{BAT} = 3.0V, and T_A = +25°C, unless otherwise noted.) (Notes 1, 2)

Appendix D: Program Codes

```
//The DIY Life
//10 October 2016
//Michael Klements

#include <Servo.h>

Servo tracker;  // create servo object to control a servo
int eastLDRPin = 0;  //Assign analogue pins
int westLDRPin = 1;
int eastLDR = 0;   //Create variables for the east and west sensor values
int westLDR = 0;
int error = 0;
int calibration = 204;  //Calibration offset to set error to zero when both sensors receive an equal amount of light
int trackerPos = 90;    //Create a variable to store the servo position

void setup()
{
  tracker.attach(11);  // attaches the servo on pin 11 to the servo object
}


void loop()
{
  eastLDR = calibration + analogRead(eastLDRPin);    //Read the value of each of the east and west sensors
  westLDR = analogRead(westLDRPin);
  if(eastLDR<350 && westLDR<350)  //Check if both sensors detect very little light, night time
  {
    while(trackerPos<=160)  //Move the tracker all the way back to face east for sunrise
    {
      trackerPos++;
      tracker.write(trackerPos);
      delay(100);
    }
  }
  error = eastLDR - westLDR;          //Determine the difference between the two sensors.
  if(error>15)        //If the error is positive and greater than 15 then move the tracker in the east direction
  {
    if(trackerPos<=160)  //Check that the tracker is not at the end of its limit in the east direction
    {
      trackerPos++;
      tracker.write(trackerPos);  //Move the tracker to the east
    }
  }
  else if(error<-15)  //If the error is negative and less than -15 then move the tracker in the west direction
  {
    if(trackerPos>20)  //Check that the tracker is not at the end of its limit in the west direction
    {
      trackerPos--;
      tracker.write(trackerPos);  //Move the tracker to the west
    }
  }
  delay(100);
}
```

Appendix E: Operation Manual