EE213 ELECTRICAL CIRCUITS LABORATORY
TERM PROJECT
SOLAR TRACKING SYSTEM

1. INTRODUCTION

Solar energy systems are a viable source of renewable energy and used for both domestic and industrial applications. A solar energy system collects the sunlight, i.e., solar energy, and converts it to electrical or thermal energy. The efficiency mostly depends on the intensity of light, i.e., the amount of solar energy. For this reason, alignment of solar panels plays crucial role in a solar energy system. Most of the panels are fixed to be in direct sunshine at midday. Even though this method is inefficient (because when the angle of incidence between the incoming light and the panel decreases, the amount of produced energy decreases as well), it is simple and satisfies the requirements of domestic applications. On the other hand, even small increase in the efficiency creates a significant amount of profit in an industrial application. For this purpose, solar tracking systems try to minimize the angle of incidence between the incoming light and the panel to increase the efficiency [1, 2].

There are two types of solar tracking systems, namely, single-axis and dual-axis systems. Sun moves on an arc from east to west, as seen in Figure 1. Hence one degree of freedom, i.e., a single-axis system, is enough to track the Sun on a daily basis. However, the arc shifts to the north and south directions during a year. Therefore, a dual-axis system is needed to handle seasonal changes.

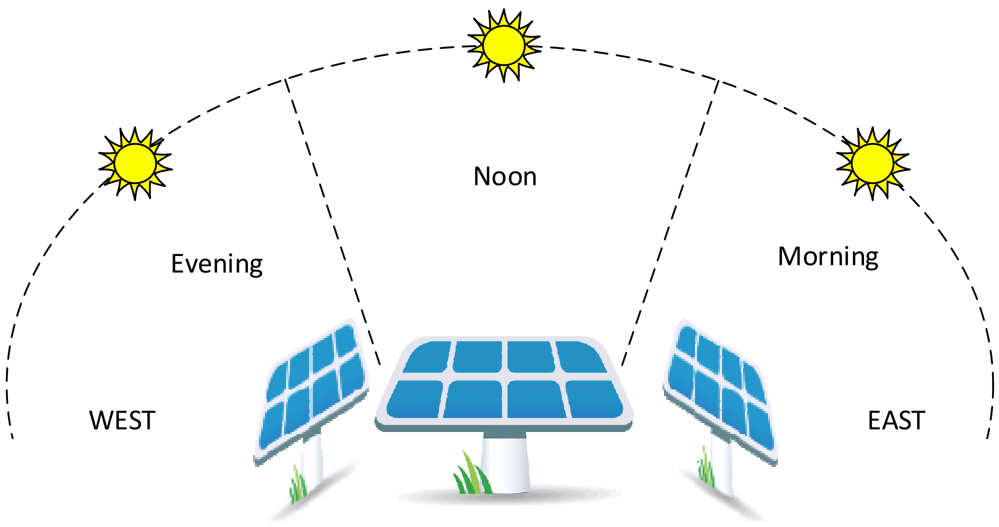

Figure 1: Different positions of the Sun in the sky during a day. [3]

2. PROJECT DESCRIPTION

In this project, you are required to design a single-axis solar tracking system. The system has a single panel which can take three positions. These positions, which are illustrated in Figure 2, are set in accordance with the Sun position. In Positions A and C, the panel is facing to west and east respectively.

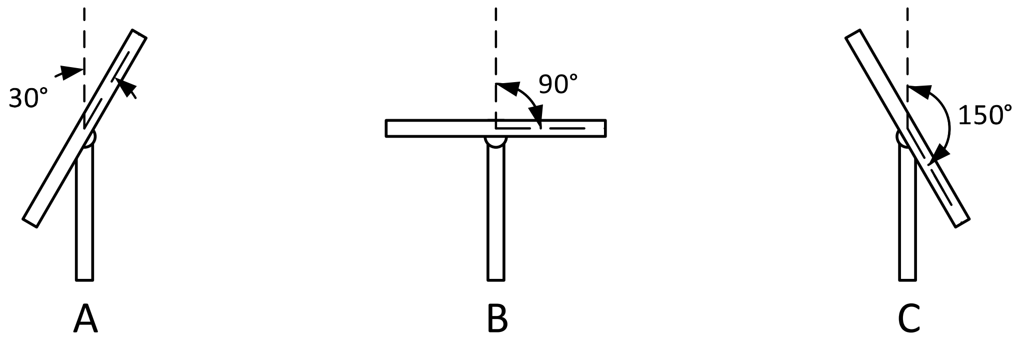

Figure 2: Available positions of the panel and corresponding angles.

Aim of the system is to decide in which position the panel produces more energy. In order to make accurate decisions, the system measures the intensity of light for all three positions. For this purpose, three light sensors are placed for each Positions A, B and C as shown in Figure 3.

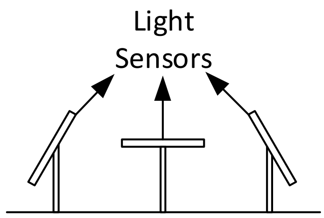

Figure 3: Placement of the three light sensors.

The system can be divided into three subsystems, which are the sensing unit, the control unit and the angle adjustment unit. The sensing unit measures the intensity of light for all three positions. Then the control unit compares them and decide which one is the highest. After that, the angle adjustment unit rotates the panel to the appropriate position.

2.1 Sensing Unit

The sensing unit contains analog light sensors to measure the light intensity. There are three sensors corresponding to the three positions as mentioned above. As a light sensor Light Dependent Resistor (LDR) will be used. The resistance of an LDR decreases with the increase in the intensity of light.

2.2 Control Unit

The control unit contains decision and function subunits. The decision subunit compares the measurements taken by the sensing unit, and finds the position corresponding to the highest intensity, which is also indicated by a LED. The function subunit, then, generates a PWM (Pulse Width Modulation) signal that drive the motor with respect to the output of the decision subunit.

2.3 Angle Adjustment Unit

The angle adjustment unit uses the signal that is generated by the control unit to rotate the panel. This unit contains a servo motor, which can rotate at a specific angle. The rotation angle is controlled by a PWM signal and the duration of the pulse determines the angle.

2.3.1. Pulse Width Modulation

PWM is a technique used to encode information for transmission and refers to rectangular pulses of variable width. A PWM signal can be defined with two components, which are duty cycle and period. Consider a rectangular waveform having high and low voltage levels. Duty cycle, D, given by:

$$D = \frac{T_H}{T}$$

where T_H is the duration when the signal is at the high level, and T is the period of the signal. Different duty cycles are exemplified in Figure 3.

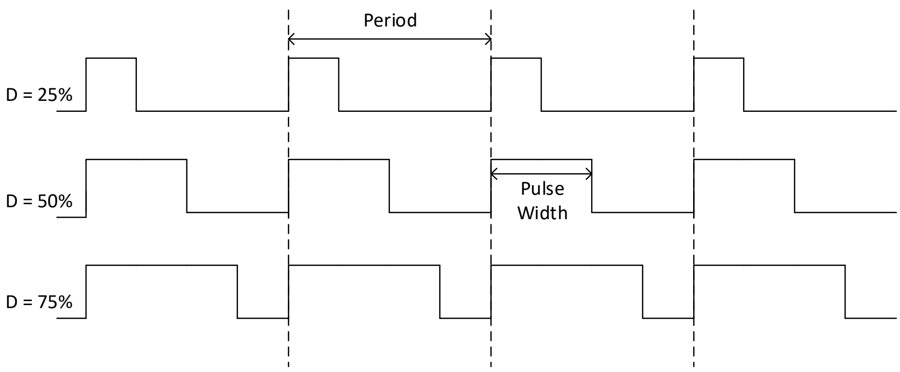

Figure 3: Examples for duty cycle

Most servo motors have three pins, which are power, ground and control signal pins. The control signal is a PWM and the servo's angular position is determined by the pulse width of the control signal, i.e. duty cycle. Typically, servo motors require a PWM signal with 20 ms period and a pulse width between 1-2 ms [4]. Although the values are right for most servo motors, you should check datasheet of your servo motor.

3. RULES AND REGULATIONS

3.1 Allowed Components

You are allowed to use +/-25 V output of DC power supply and you may use all types of resistors, capacitors, inductors, diodes, LEDs, LDRs, op-amps, transistors and servo motors do not having encoder.

3.2 Design Specifications

Will be announced later.

3.3 Bonus

Will be announced later.

3.4 Groups

The project will be carried out in groups of two students. The students in the same group should be in the same laboratory session.

3.5 Important Dates

- November 16 : Project Announcement
- November 21 : Announcement of design specifications and evaluation rubric
- December 15 : Deadline for pre-reports (till 17.00)
- December 18-22 : First project sessions
- December 25-29 : Second project sessions
- January 1-5 : Last project sessions – Theoretical knowledge test
- January 5 : Submission of demo-videos (till 17.00)
- January 6-7 : Demonstrations
- January 12 : Submission of the final report (till 17:00)

3.6 Documentation

You **must** submit two reports and a video for the term project.

3.6.1 Reports

As stated in report guideline, pre-report should include an introduction, pre-design of the project with circuit diagrams, theory, formulations, simulation and experimental results and a conclusion.

Final report should also include all the parts in the pre-report for the overall design. In other words, final report should explain the overall design with an introduction, a block diagram and circuit schematic, operation of each sub-block with theory, formulations, simulation and experimental results. Final report should also include analyses for the cost and power consumption of the project and you should justify the use of each component. Conclusion of the final report is very important since it reflects your understanding of the project and the experiences you gained during the overall process. The objectives, results and the experiences should be clearly presented. This does not necessarily mean a long report, but definitely a well-organized one.

Late submissions for both reports will lower your report grades as:

- 20% off for one-day late submission
- 50% off for two-day late submission
- 90% off for three-day late submission
- Zero credit for more than three-day late submission.

You are referred to the report guideline, which is available on the ODTUCLASS, for further details.

3.6.2 DEMONSTRATION VIDEO

You should prepare a 6-8 minute video where partners of each group present the project in a collaborative manner. The video should include the explanation of main blocks, why they are used and how they are designed. This video should be regarded as a formal presentation to the related assistant. Note that you should always appear in the video together with your presentation material.

3.7 GRADING

- Pre-Report : 15%
- Final Report : 20%
- Presentation Video : 10%
- Design and Performance : 55% (partial credits are possible)
- Bonus : up to 30%

3.8 REGULATIONS

- Attending to the demonstration is a must for both team members, otherwise, you will fail the course.
- Each student will use the laboratory in his/her own class hour. Using laboratory in any other time will not be allowed.
- Cheating is strongly forbidden and any indication of cheating will cause you to get zero credit from the project. You can collaborate with your friends by exchanging ideas, not copying the design details or the reports. Using the design of another group with slightly modified component values will also be regarded as cheating.
- Both members of the group are responsible for every single detail of their circuit. If you get a credit lower than the pre-score from the design test you will get zero from the overall project grade. Pre-score will be announced later.

REFERENCES

[1] Lee, C. Y., Chou, P. C., Chiang, C. M., & Lin, C. F. (2009). Sun tracking systems: a review. Sensors, 9(5), 3875-3890.

[2] Bushong, S. (2014, May 30). 2014 Trends: Solar Tracking. Retrieved November 07, 2017, from https://www.solarpowerworldonline.com/

[3] Loeffler, M. (2013, September 16). Orientation of solar panels. Retrieved November 07, 2017, from http://solar-trap.com/

[4] Pinckney, N. (2006). Pulse-width modulation for microcontroller servo control. IEEE potentials, 25(1), 27-29.

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1. DESIGN SPECIFICATIONS

1.1. SPECIFICATIONS FOR SENSING UNIT

The sensing unit measures the light intensity of three different directions shown in Figure 1. Therefore, three LDRs are required and should be placed as illustrated in Figure 1.

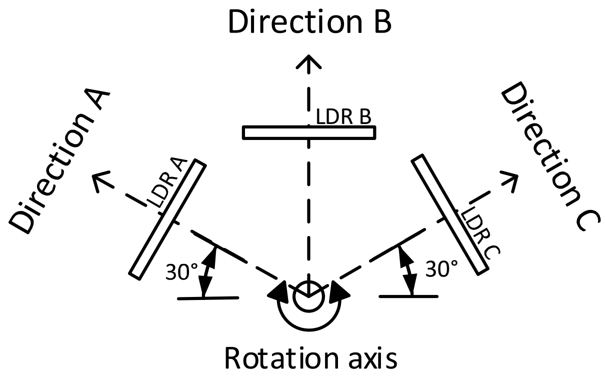

Figure 1: Placement of the LDRs in the Sensing Unit

1.2. SPECIFICATIONS FOR CONTROL UNIT

The control unit contains a decision and a function subunits. The decision subunit finds the direction having the highest light intensity by comparing the outputs of the light sensors, then informs the function subunit accordingly. The function subunit, then, indicates this direction using an RGB LED and generates the PWM signal that drives the servo motor. A, B and C directions shown in Figure 1 must be indicated with the colors of yellow, purple and orange respectively.

1.3. SPECIFICATION FOR ANGLE ADJUSTMENT UNIT

The angle adjustment unit contains a servo motor to rotate the panel. The motor and the panel must be placed as illustrated in Figure 2.

Position of the panel is defined by the rotation angle, θ, as shown in Figure 2. There are three available values for θ since the panel can take three positions. According to the directions specified in Figure 1, those values are 150^0, 90^0 and 30^0 for Positions A, B and C respectively.

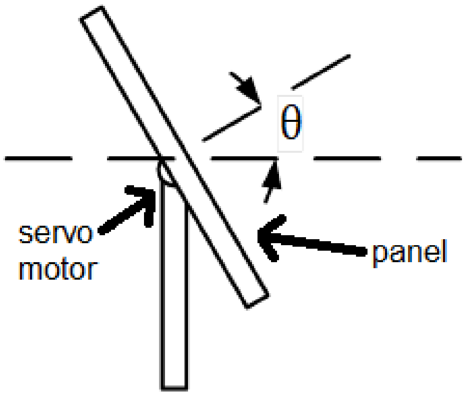

Figure 2: Rotation Angle of the Panel

As a result, there are three states, namely, States A, B and C. The system decides current state by comparing measurement results and indicates the current state by using an RGB LED. According to specifications mentioned above, state conditions and procedures are listed in Table 1.

Table 1: Conditions and Procedures for State A, B and C

State	Condition	RGB LED color	θ
A	V_a> (V_b and V_c)	yellow	150^o
B	V_b> (V_a and V_c)	purple	90^o
C	V_c > (V_a and V_b)	orange	30^o

2. BONUS

A student cannot get any bonus credit, unless all steps that are announced in the project document are accomplished. In other words, you must get full credit from the design test to be able to get bonus credit.

Further information will be announced later.

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1. BONUS

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1.1. INDICATING THE LOWEST INTENSITY DIRECTION

For this step, you need to design an additional unit that indicates the direction having the lowest light intensity. For this purpose, additional RGB LED is required. It means that the system have to contain two RGB LEDs that indicate the direction having the highest and the lowest light intensity at the same time. Table 2 shows conditions and procedures when this step is added.

State	Condition	RGB LED color for the Highest	RGB LED color for the Lowest	θ
A1	$V_a > V_b > V_c$	yellow	orange	150^o
A2	$V_a > V_c > V_b$	yellow	purple	150^o
B1	$V_b > V_a > V_c$	purple	orange	90^o
B2	$V_b > V_c > V_a$	purple	yellow	90^o
C1	$V_c > V_a > V_b$	orange	purple	30^o
C2	$V_c > V_b > V_a$	orange	yellow	30^o

1.2. LIGHT INTENSITY INDICATOR

For this step, you need to design an indicator that shows the level of the efficiency for all three directions. Each indicator must distinguish and indicate three different levels of the efficiency by an RGB LED. For this purpose red, yellow and green colors will be used to indicate the low, medium and high levels respectively.

This part will be tested with an external light source in the laboratory. If the external light source is off, the system should indicate the low efficiency level. When the external light source is on, the efficiency level is defined by the distance between the external light source and the LDR. If the distance is less than 10 cm, the system should indicate the high efficiency level and if the distance is between 10 cm and 20 cm, the system should indicate the medium efficiency level.