Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**EEE 202 Lab 7 Design Project  
DATA SHEET**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Part 1 (9 points): Voltage Divider Design** | | | | | | | | | | | | | | | | | | | | | |
| **What do you think the purpose of the diode rectifier is in this design?** | | | | | | | | | | | | | | | | | | | | | |
| **Hand calculations: consider the circuit as shown (i.e. without R1 and R2). Set the load resistor RL to 1k Ohms and calculate the voltage and current the solar panel can produce over different light conditions. Pick 4 different voltage values; the highest of which corresponds to the Full Sunlight, while the lowest to the Lab Light. Do not forget to consider the voltage drop on the diode.** | | | | | | | | | | | | | | | | | | | | | |
| **Light Condition** | | | | | | | | | **Assumed Solar Panel Voltage (V)** | | | | | | | | | **Calculated Solar Panel Current (mA)** | | | |
| **Full Sunlight** | | | | | | | | |  | | | | | | | | |  | | | |
| **Shaded Sunlight** | | | | | | | | |  | | | | | | | | |  | | | |
| **Lab Light Plus Phone Light** | | | | | | | | |  | | | | | | | | |  | | | |
| **Lab Light** | | | | | | | | |  | | | | | | | | |  | | | |
| **The CEO of Sparky Solar, Melanie Waters, has told you that the design criteria (in order of importance) are: 1. Availability, 2. Cost, 3. Accuracy. When designing the voltage divider circuit, which set of resistors will you use (1, 2, or 3) and why?** | | | | | | | | | | | | | | | | | | | | | |
| **Select R1 and R2 to ensure that the value of A1 does not exceed 5V for all light conditions. Calculate the maximum voltage your circuit can feed to Pin A1. Show your work here:** | | | | | | | | | | | | | | | | | | | | | |
| **R1 (Ohms)**  **(Make sure it is in your stock)** | | | | | | **R2 (Ohms)**  **(Make sure it is in your stock)** | | | | | | | | | | | **Max Voltage in to Pin A1 (V)** | | | | |
|  | | | | | |  | | | | | | | | | | |  | | | | |
| **Which light condition should be considered when selecting R1 and R2 and why?** | | | | | | | | | | | | | | | | | | | | | |
| **If your customer asked you to purchase another solar panel with a higher voltage, what is the maximum voltage that such a solar panel can have without exceeding the power rating of your selected R1 and R2? Assume your resistors are ¼ W resistors. *(Note: If such voltage happens to exceed the voltage corresponding to the Full Sunlight condition you specified above, you will need to reselect your R1 and R2 values to use them with the solar panel you have at hand).*** | | | | | | | | | | | | | | | | | **Max voltage for**   * **R1:** * **R2:** * **Vsolar (V):** | | | | |
| **Simulations: Create a simulation of your Voltage Divider circuit in LTSPICE or TinkerCAD. Choose one of the sunlight conditions you used above in your simulations. Mention which one you chose.**  **Include a screenshot of the simulated circuit here (Have a look at an example screenshot at the end of this document):** | | | | | | | | | | | | | | | | | | | | | |
| **Hardware: Build the circuit you simulated above.**  **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):**  **Do your measured Voltage Divider results (V of R2) from your built circuit match your simulated results? How much error are you seeing? What are some possible reasons for the difference in the real and theoretical results? Choose one of the sunlight conditions you used above to compare your results. Mention which one you chose.** | | | | | | | | | | | | | | | | | | | | | |
| **Part 2 (9 points): Op-Amp Design** | | | | | | | | | | | | | | | | | | | | | |
| ***\*\*\* Remember, when measuring current the portable multimeters have current limits (check the multimeter). If your calculations show you will be above the limit of the current input, use the 10A terminal!!! Failure to use the correct terminal will result in blowing the fuses of the multimeter. \*\*\**** | | | | | | | | | | | | | | | | | | | | | |
| 1. **What is the maximum current that the load resistor RL can take. Hint: The resistors provided are ¼ W resistors. Show your calculations.**   ***Max current of RL=­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***  ***If your solar panel can exceed this current value, you will need to use a load resistor with a higher power rating. Thus, also calculate the current your solar panel outputs at the maximum lighting conditions. Hints:***   1. ***You will need the value of RL.*** 2. ***Neglect R1 and R2 if you have chosen their values to be large compared to RL (i.e., if the current flowing through them would be negligible).***   ***Show your calculations.***  ***Max current that the Solar Panel can supply= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***  ***Do you need to use a different resistor that has a higher power rating? Yes/No.*** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Why do you think the current measurement needs to be done using an Op-amp rather than how we measured the voltage in Part 1?** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Using your highest load current, determine the maximum voltage into the + terminal of the Op-amp (i.e. the voltage over Rsh):** | | | | | | | | | | | | | | | | | | | | | |
| **Max Iload (mA)** | | | | | **Rsh (Ohms)** | | | | | | | | | | **Max V+ (mV)** | | | | | | |
|  | | | | | **5** | | | | | | | | | |  | | | | | | |
| 1. **The CEO of Sparky Solar, Melanie Waters, has told you that the design criteria (in order of importance) are: 1. Temp, 2. Cost, 3. Availability. When designing the op-amp circuit, which set of resistors Rf and Ri will you use (1, 2, or 3) and why?** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Select Ri and Rf to boost the output voltage, but ensure that the Op-Amp output voltage does not exceed 5V for all light conditions. (show your work here):** | | | | | | | | | | | | | | | | | | | | | |
| **Max Vo (V)** | | | | **Gain (V/V)** | | | | | | | **Rf (Ohms)** | | | | | | | | **Ri (Ohms)** | | |
|  | | | |  | | | | | | |  | | | | | | | |  | | |
| 1. **Why is a rail-to-rail Op-Amp required for this design? A rail-to-rail Op-Amp costs more than a standard Op-Amp, what value to the stakeholder does this extra feature add to the design?**   **[Explain the benefits of rail-to-rail Op-Amps in your own words]** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Do the values of Ri and Rf you proposed in part (e) need to be extremely accurate for your current measurement to be precise? Explain why or why not.** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Create a simulation of your Op-Amp circuit in LTSPICE or TinkerCAD.**   **Include a screenshot of the simulated circuit here (Have a look at an example screenshot at the end of this document):** | | | | | | | | | | | | | | | | | | | | | |
| 1. **Physically build and test your design.**   **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):**  **Do your measured results from your built circuit match your simulated results?**  **How much error are you seeing?**  **What are some possible reasons for the difference in the real and theoretical results?** | | | | | | | | | | | | | | | | | | | | | |
| **Part 3 (9 points): Controller Circuit Design – Hardware Implementation**  **For each question in Part 3, you are supposed to simulate the circuit using TinkerCad or LTSpice before implementing it on hardware. However, this is optional due to time limitations.** | | | | | | | | | | | | | | | | | | | | | |
| **Build your Controller circuit on hardware. For this question, you will need to build only the following circuit (i.e. controller without the voltage divider or any other part of the original circuit). You will need to supply voltage manually directly from the V1 and W1 of your AD2 to each of A0 and A1, respectively, to be able to answer the following questions.**  **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):** | | | | | | | | | | | | | | | | | | | | | |
| **Physical Results:** | | | | | | | | | | | | | | | | | | | | | |
| **A1 (V)** | **Voltage (V)**  **(From Serial Port reading)** | | | | | | **A0 (V)** | | | **Serial Port Current (mA)**  **(From Serial Port reading)** | | | | | | | | **Serial Port Power (mW)**  **(Calculated)** | | | |
| **1** |  | | | | | | **1** | | |  | | | | | | | |  | | | |
| **2** |  | | | | | | **2** | | |  | | | | | | | |  | | | |
| **3** |  | | | | | | **3** | | |  | | | | | | | |  | | | |
| **Now, build your Voltage Divider on hardware and connect it to the Controller circuit. Use a voltage source to replace your Solar Panel. For this question, you will test the voltage coming out of the voltage divider with a voltmeter and compare it to the reading the controller is providing via the serial port.**  **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):** | | | | | | | | | | | | | | | | | | | | | |
| **Physical Results:** | | | | | | | | | | | | | | | | | | | | | |
| **Vsolar max (V) (Voltmeter reading)** | | | | | | | | | | | | | **Voltage (V) (from serial port reading)** | | | | | | | | |
|  | | | | | | | | | | | | |  | | | | | | | | |
| **Do your measured results from your voltmeter and serial port match? How much error are you seeing? What are some possible reasons for the difference in the real and theoretical results?** | | | | | | | | | | | | | | | | | | | | | |
| **Now build your Op-Amp Circuit on hardware and connect it the Controller subcircuits while leaving the voltage divider subcircuit connected. For this question, you will test the current flowing in the RL with an ammeter and compare it to the current reading the controller is providing via the serial port.**  **Include a photo of your hardware circuit here (Have a look at an example photo at the end of this document):** | | | | | | | | | | | | | | | | | | | | | |
| **Physical Results:** | | | | | | | | | | | | | | | | | | | | | |
| **Vsolar (V)**  **(Voltmeter)** | | **Load Current (mA)**  **(Voltmeter)** | | | | | **Power (mW)**  **(Calculated)** | | | | | **Voltage (V)**  **(Serial port)** | | | | **Current (mA)**  **(Serial Port)** | | | | **Power (mW)**  **(Serial Port)** | |
|  | |  | | | | |  | | | | |  | | | |  | | | |  | |
| **Do your measured results from your voltmeter match your results from serial port? How much error are you seeing? What are some possible reasons for the difference in the real and theoretical results?** | | | | | | | | | | | | | | | | | | | | | |
| **What adjustments can you suggest to the code to increase the accuracy of the voltage, current, and power that display in the serial port? For this question, only provide suggestions without needing to implement them. Hints: which resistors do you think are not provided in the code accurately? Any other potential source for errors?** | | | | | | | | | | | | | | | | | | | | | |
| **[Optional] Bonus Opportunity – 5 Points – Read the Manual. Make sure to include your modified code and any screenshots that show that the added features work:** | | | | | | | | | | | | | | | | | | | | | |
| **Part 4 (4 points): Complete Automated Solar Panel Power Meter Design** | | | | | | | | | | | | | | | | | | | | | |
| **On your hardware circuit, mimic the change in the lighting conditions of your solar panel by changing the voltage of your voltage source and record the corresponding measurements in the following table. Include screenshots for your Serial Port Readout at the end of this part.** | | | | | | | | | | | | | | | | | | | | | |
| **Solar Panel Light Condition**  **Voltage (V)** | | | **Solar Panel**  **Supplied Voltage (V)**  **(Voltmeter)** | | | | | **Solar Panel Supplied Current (mA)**  **(Ammeter)** | | | | | | **Serial Port Voltage Readout (V)** | | | **Serial Port Current Readout (mA)** | | | | **Serial Port Power Readout (mW)** |
| **Full Sunlight** | | |  | | | | |  | | | | | |  | | |  | | | |  |
| **Shaded Sunlight** | | |  | | | | |  | | | | | |  | | |  | | | |  |
| **Lab Light Plus Phone Light** | | |  | | | | |  | | | | | |  | | |  | | | |  |
| **Lab Light** | | |  | | | | |  | | | | | |  | | |  | | | |  |
| **Did you have to make any component or code changes? If so, what changes were made? If not, comment on how you changed the lighting conditions on your solar panel to reach the voltage values on the voltage column in the previous table.** | | | | | | | | | | | | | | | | | | | | | |
| **Do your measured results from your multimeter current and voltage match your Serial Port Readout results? How much error are you seeing? What are some possible reasons for the difference in the real and theoretical results?** | | | | | | | | | | | | | | | | | | | | | |
| **Serial Port Readout screenshots for all 4 lighting conditions (1 screenshot for each condition – make sure your computer’s date and time are showing up in your screenshot):** | | | | | | | | | | | | | | | | | | | | | |
| **Part 5 (2 point): Load Resistor Discharge Rate** | | | | | | | | | | | | | | | | | | | | | |
| **Using the First Order Differential method or First Order Step-by-Step method, determine the size of the load capacitor to meet the design specifications - determine an appropriate capacitor value (from your available parts) to ensure the load will discharge in about 0.1sec with a solar panel supply of 9V and 50mA. You will still assume the load resistance (RL) of 1k Ohms.**  **(Show your work here. Calculations only. No simulations or hardware implementations needed.)** | | | | | | | | | | | | | | | | | | | | | |
| **Part 6 (7 points): Report** | | | | | | | | | | | | | | | | | | | | | |
| **Briefly answer the following questions. Your answers should be qualitative in nature to demonstrate your understanding. This part of the project trains you on how to write a report to the stakeholders of this project showing your contributions, how your design is useful and how it could be further improved for more advanced use-cases:**   1. **Who is this device designed for and what considerations were made for the user(s)?** 2. **How does the final design work - give a detailed description with images?** 3. **What components did you specifically determine and explain your reasoning for your choices?** 4. **What trade-offs were made in this design?** 5. **What did you learn about theoretical design versus physical design?** 6. **If this design were scaled up for large solar panel systems, what environmental, technological, societal, and/or financial considerations would need to be made?** 7. **What skills have you developed in working on this project that will help you in your future career?** | | | | | | | | | | | | | | | | | | | | | |
| **LTSpice Screenshot Example (Note your name, date and time, readable circuit, and labelled nodes – screenshots might vary based on the operating system you are using) – This applies to screenshots of circuits only. Screenshots of graphs/plots/anything else can include only the date and time.**    **Hardware Image Example. Note your name:**   1. **on a piece of paper; OR**   **typed electronically (must be typed on the breadboard WITHOUT any “text background”. Breadboard must show up in the background of your name.)** | | | | | | | | | | | | | | | | | | | | | |