

LAMP AT 10cm!!

Physics 4050H: Project III

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1 Introduction

The goal was to determine current voltage and power voltage for the solar cell(s) at varying loads from an open circuit (maximum voltage, zero current) to a short (minimum voltage, maximum current). A circuit was successfully constructed to automatically accomplish this task and one of the solar cells was tested using the circuit with a range of incident light intensities.

2 Methods

It is very time consuming to manually measure both current and voltage produced by a solar panel (or any device) repeatedly under varying conditions. Instead of connected a voltmeter and ammeter to a solar panel with some kind of manually variable load in order to perform data collection a circuit containing an Arduino Uno R3 microcontroller was employed to handle load control and current-voltage measurement simultaneously. The circuit is comprised of two main “segments” one of which is responsible for measuring the voltage output, and one of which is responsible for measuring the current. Both segments share a MOSFET transistor connected in (almost) parallel with the solar cell (hereon referred to as the cell) which acts as a voltage controlled resistor with a very large resistance range. The positive terminal of the cell is connected to the drain of the MOSFET and to an analog read pin on the Arduino to measure the voltage produced by the cell. The negative terminal of the cell is connected to an op-amp wired as a current-to-voltage converter (also called a transimpedance amplifier, hereon referred to as the converter) as the Arduino cannot directly measure current. The output from the converter is then fed to the Arduino where it is converted back to the corresponding current in software.

2.1 Voltage Measurement

It is not quite possible to directly measure the voltage output of the solar cell with the arduino due both to the fact that the arduino itself can act as a load on the panel, influencing the results, and that the panel is capable of outputting more than 5 V which is beyond the measurement range for the Arduino. The first issue of measurement influencing the cell was solved by passing the output of the cell through a buffering voltage-follower op-amp. The second issue was solved by placing a voltage divider (configured in this case with a 1/2 division factor) before the voltage-follower. By passing the voltage produced by the cell through these stages its output was both stabilized against loading and withing the measurement range of the Arduino. The effects of the voltage divider were undone in the software running on the Arduino.

2.2 Current Measurement

As previously mentioned, the Arduino is not capable of directly measuring current. This was solved using a converter with a $100\ \Omega$ feedback resistor. Such a converter will have output $V_{out} = -I_{in}R_f$, however in this case the converter was wired to the negative terminal of the cell so that the op-amp acted as a current source rather than a sink which means it gave $V_{out} = I_{in}R_f$. This is important as the Arduino is restricted to positive voltage measurements. As the output voltage of the converter would never exceed a value which the Arduino was capable of measuring the output was fed directly into an analog pin on the Arduino and converted back to a current in software.

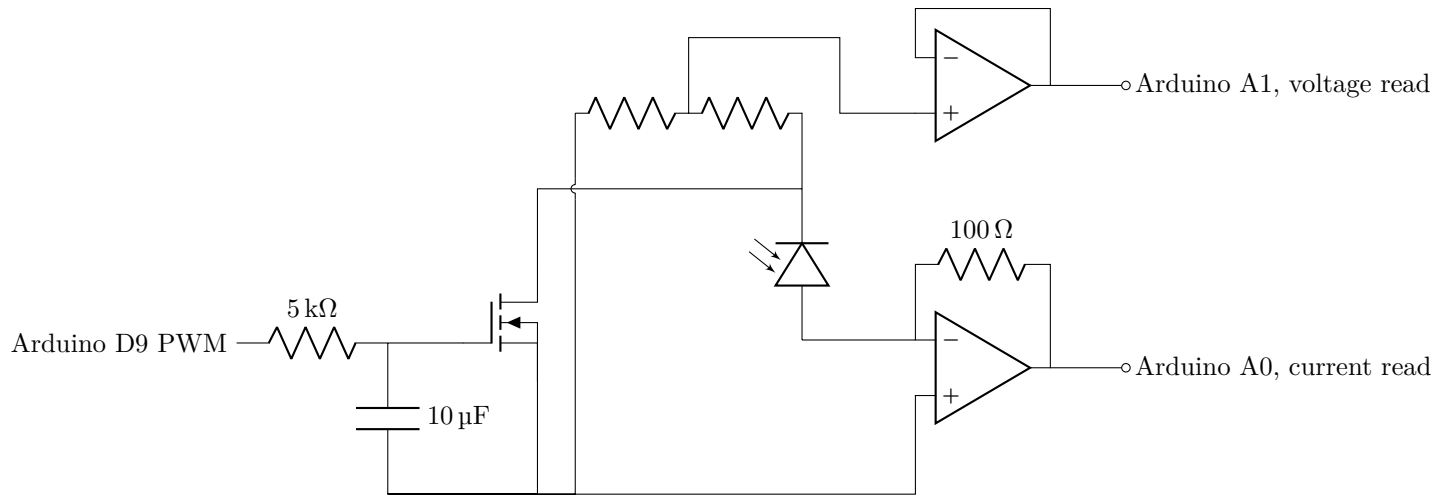


Figure 1: The measurement circuit. Note that the capacitor-resistor before the gate of the FET is a reconstruction filter to convert the PWM output from the Arduino to a DC voltage.

2.3 Software

The measurement and control software is fairly simple. The core program waits for a button press from a user on the breadboard to signal that it should begin measurement. When the button is pressed the program enters a loop which runs through voltages which are set across the gate and source pins of the MOSFET and control the resistance between the drain and source pins of the MOSFET. At each iteration of this loop the program measures both the current and voltage (in that order, though order is inconsequential) and outputs them over serial. The only complication in the program is that the default analog write resolution of the Arduino Uno R3 is 8 bits which means the voltage step is $V_{ref} \cdot 2^{-8}$ which, for the standard analog reference voltage which was used in this report of 5 V, means a step of only 0.02 V which did not produce a satisfactorily high resolution for the resistance step on the MOSFET. The code at [1] was used to increase this resolution to 10 bits giving a voltage step of approximately 0.005 V which produced high enough resolution. The full program is available in the appendix.

Formalize

2.4 Physical Setup

To perform the measurements with a range of incident intensities a dimmable incandescent bulb was used. Due to challenges relating to accurate measurement of the emitted “useful” power of the incandescent bulb an intensity system based off of the position of the dimmer on the lamp housing the bulb was used. Results presented later use this system to indicate incident light intensity. Throughout all measurements the lamp and cell were held at a fixed distance of 10 cm and were axially aligned relative to one another.

Integrate

3 Results

Both current and voltage were successfully collected automatically

4 References

- [1] Edgar Bonet. Increase pwm bit resolution. Arduino Stack Exchange, 2015. Online: <https://arduino.stackexchange.com/a/12719>.

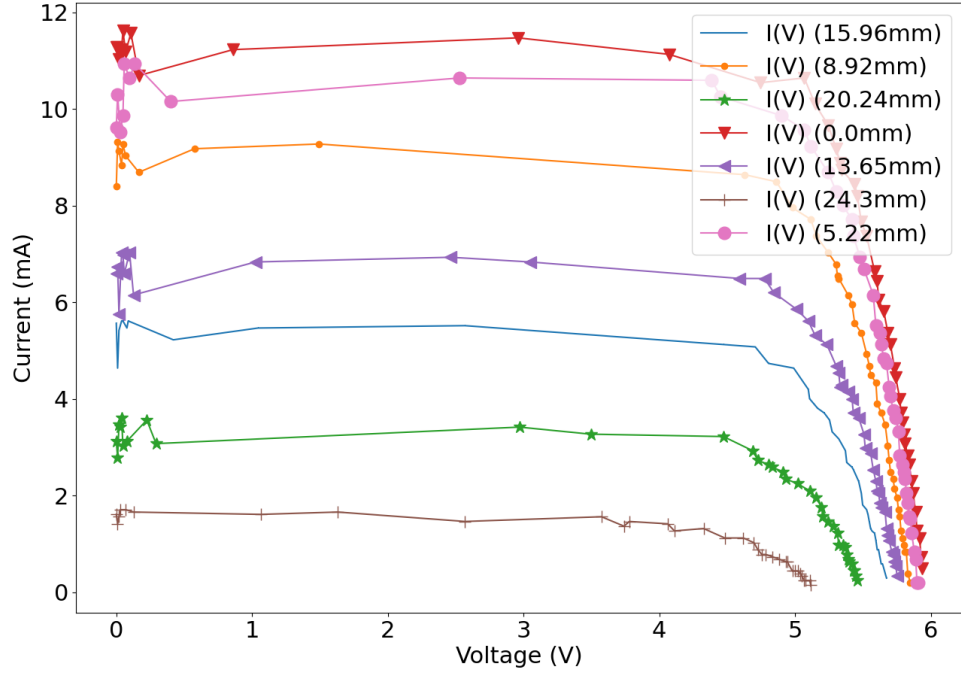


Figure 2: Current as a function of voltage of the cell. Indicated distance is the distance of the end of the lamp intensity control from its maximum position, 0 mm being the maximum intensity.

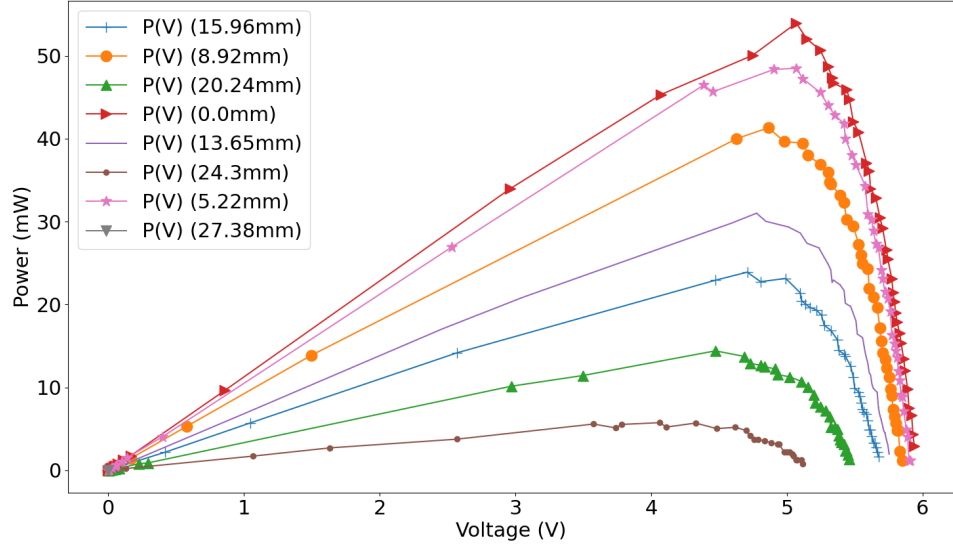


Figure 3: Power as a function of voltage of the cell. Indicated distance is the distance of the end of the lamp intensity control from its maximum position, 0 mm being the maximum intensity. Calculated directly from fig. 2 with $P = IV$.