Max Power Point of an Indoor Solar Cell: Creating the Infrastructure to Measure the Max Power Point of a Cell in different lighting Conditions

Ian Raber[1] *Alan Teran*[2] *Professor Jamie Phillips*[3]
1. MECHE Photovoltaic Cells 2. EECS Photovoltaic Cells 3. EECS Optoelectronics

MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

Introduction

Wireless sensor nodes and the means of powering them, mainly photovoltaic energy from indoor lighting, have become inherent in the development of the internet of things. The purpose of this project is **to develop a system for the measurement of the current and voltage generated through different types of nano-solar cells in varying conditions indoors.** The project involves developing the code, building the circuit that takes these measurements on an Arduino and Keithley, and taking data from multiple measuring environments indoors. The specs of these cells must be measured accurately as they will be used to power the next era of wireless devices. Developing this measurement system is crucial to determining the efficiency of these cells in an indoor environment where the light is artificial and therefore has a different spectrum than the sun.

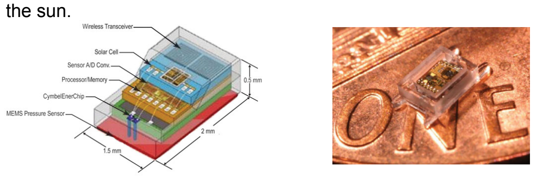


Figure 1 & 2: Internal characteristics of a wireless sensor node as well as a scale for these nodes[1]

Project Objectives

1. Develop the software and circuitry to take this data for a silicon cell in different locations throughout a building.
2. Create a long lasting system to measure more than one type of solar cell in real time.

Approach

After learning to code the Arduino, we built the circuit (Figure 3) to take the measurements. However, the circuit did not function as it was supposed to, so, the Arduino and its subsequent code could only measure the Open Circuit Voltage(V_{oc}) of the solar cell. Because of this problem, a Keithley 2400 was coded in Matlab. The Keithley allowed me to perform a voltage sweep and record the voltage and current data as well as the power together.

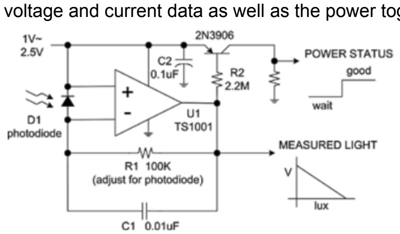


Figure 3: The circuit we tried to build for the better part of the semester[2]

Results and Discussion

The Open Circuit Voltage(V_{oc}) of a nano-silicon cell indoors was characterized due to the Arduino code that was developed. Below is a photo of the Arduino solar cell system (Figure 4) that was used to collect the data in Figures 5, 6 & 7.

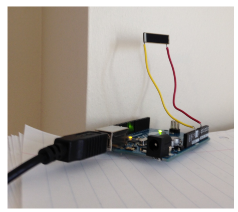


Figure 4: Arduino and solar cell

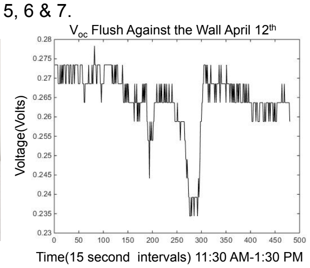
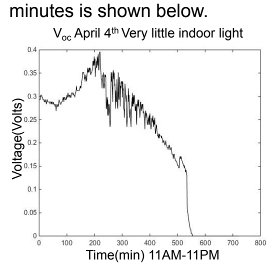
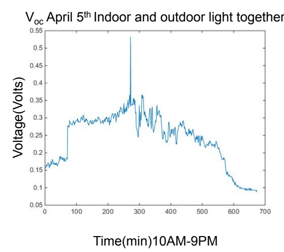


Figure 5

In Figure 5, the cell was flush against the wall near the ceiling(as shown above) at around midday in a room with lighting and a window. This arrangement gave a mean of .2646 volts. This system probably a good estimate for how these cells will be used in real world applications. They should be very out of the way. Two graphs of the cell the same room on a desk facing the ceiling vs time in minutes is shown below.





As the day progresses, the voltage increases then decreases with the amount of natural light in the room. For the plot on April 4th, the mean voltage was .2054 volts. The max was .3956 volts. The min was about 0 volts and the standard deviation was .1305 volts. For the plot on April 5th, towards the end of the day, the V_{oc} approaches .09 volts which is about the contribution of the dim indoor light throughout the plot. The mean of this plot is .2412 volts.. The max is .5322 volts. The min is .0879 volts and the standard deviation was .0736 volts. This overall higher mean is due to the addition of the indoor light. Notice that the average maximum V_{oc} is about .31 and the minimum average voltage is about .09 which correspond relatively well to the V_{oc} values in the Keithley data in Figures 8 and 9.

Below are plots of the Keithley data in a bright light condition (Figure 8) as well as a dim condition(Figure 9). Note the change in axes.

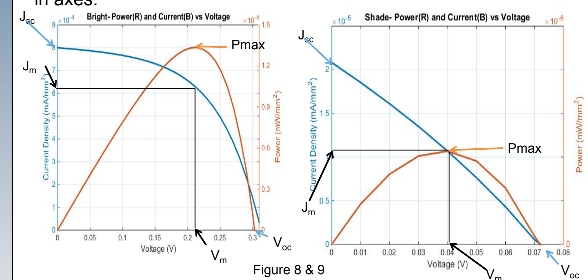


Figure 8 & 9

These figure show the plot of a silicon nano-cell with an area of 154 mm^2 and the curves the current versus voltage(B) and the power (current*voltage) versus voltage(R) in bright and shaded indoor conditions. The important points marked are the max power (Pmax) voltage and current at the max power point, (V_m and J_m), open circuit voltage (V_{oc}) and short circuit current(J_{sc}). As you can see on the blue curve, the fill factor or "squareness" of the graph decreases as the amount of light decreases($FF = Jm*Vm/Voc*Jsc$). Because the fill factor is a measure of efficiency, we can see that the ideal fill factor is 1 or 100% efficiency from the equation. This means that for our silicon nano-cell indoors, the efficiency decreases with decreasing brightness. The maximum power produced by the bright condition was .134 μWatts/mm^2 or 20.6 μWatts while the power produced by the dim condition was 4.27 X 10^{-4} μWatts/mm^2 or 6.58*10^{-2} μWatts

Conclusions

I have successfully created the software to do real time measurements with an Arduino as well as to interpret data from a solar cell using a Keithley to perform a voltage sweep. This software will not only be useful for characterizing different types of solar cells in different light conditions indoors, but, it could also be used for some data analytics as well.

Acknowledgements

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References

1-*Millimeter Scale Energy Harvesting Based Sensors.* N.d. *Digikey*. Web. 10 Apr. 2015.(Figures 1&2 have the same source)
2-*Using Analog Components to Manage Power in Low - Power Solar Systems.* N.d. *Touchston Semiconductors.* Web. 10 Apr. 2015.