Renewable Energy and Green Engineering Projects for ENG6: Engineering Problem Solving

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Background and Approach

INTRODUCTION

Development of a new curriculum for an existing first-year engineering problem solving course (ENG 6). ENG 6 does not require prior programming experience.

GOAL

To increase students' awareness in the general area of design for sustainability, and to close the gap between introductory programming and solving real-world engineering problems.

THEME

Basic concepts in the areas of sustainable engineering will be introduced. Specific topics such as solar energy, energy efficient vehicles and building design will be emphasized.

INSPIRATION

The UC Davis Robert Mondavi Institute for Wine and Food Science will be the source of inspiration for laboratory exercises. The LEED Platinum-certified building (shown in Figure 1 below) makes use of solar panels, a rain water collection and storage system, natural lighting, and many other technologies to achieve sustainable wine making operations, which are excellent examples of sustainable engineering.

Figure 1. Robert Mondavi Institute for Wine and Food Science Winery.

APPROACH

Course Flow

Students will ***learn*** basic programming constructs and techniques in lecture, and they will ***practice*** those techniques by completing weekly homework problems. The students will ***apply*** the newly acquired programming technique in laboratory sessions by solving problems related to sustainable engineering.

Projects

Guided projects will give students an in-depth view of specific topics in sustainable engineering while open-ended projects will allow student to exercise creativity in problem solving.

Hands-on Experience

Custom electronic hardware will be designed to provide students hands-on experience in programming simple hardware for data gathering and measurement.

All materials developed are available online at: www.ece.ucdavis.edu/**sustainableENG6**

Laboratory Exercise Topics

One Dimensional Arrays

-Solar Spectrum Modeling Using Planck's Law of Black Body Radiation
-Rainwater Storage System
-Degree-day Calculation
-Ventilation System Design
-Solar Power on Satellite
-Renewable Gym
-Energy Harvesting Battery
-Investing in Solar Power

Figure 2. Rainwater Storage System.

Two Dimensional Arrays

-Analysis of Temperature, Precipitation, and Solar Data
-Modeling of Fabrication Defects in Solar Panel
-Modeling of Solar Cell Variations in Solar Panel
-Hybrid and Electric Vehicle Sales
-Means of Transportation to Work
-Alternative Fuel Vehicles

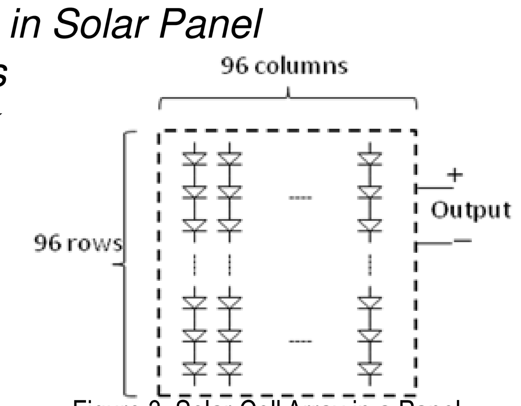

Figure 3. Solar Cell Array in a Panel.

Custom Functions, Flow Control Structures and Logical Operators

-Comparison of Fixed and Tracking Solar Array Configurations
-Comparison of Solar to Conventional Electricity
-Breakeven Analysis of Solar Power Investment
-Solar Cell Modeling using Taylor Series
-Solving Nonlinear Equations with Newton's Method
-Maximum Power Point Tracking of Solar Panels
-Savings from Solar Energy
-Solar Panel Rental
-Issues in Electric Vehicles
-Sizing of Solar Panel Array

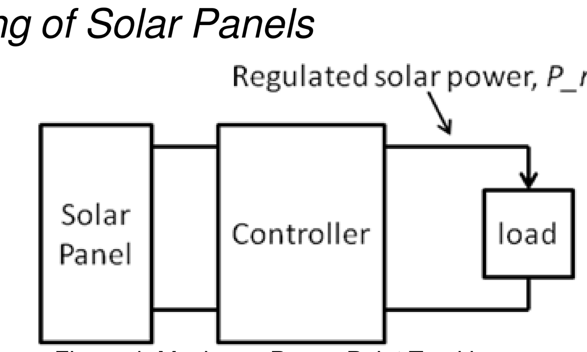

Figure 4. Maximum Power Point Tracking.

Project Topics

Guided Project Topic

-Analysis of Solar, Wind, and Precipitation Data of Various U.S. States

Open-Ended Project Topics

-Solar Power and Cost Estimation
-Renewable Energy CAD and Visualization Tool
-Traffic Simulator and Carbon Emission Calculator
-Solar Survey of UC Davis/City of Davis
-Geographical Area Estimation Using Numerical Integration and Monte Carlo Methods (see Figures 5a and 5b below)

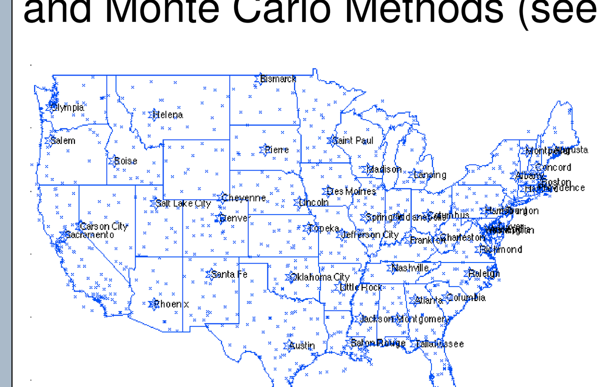

Figure 5a. Map of the USA generated based on state boundary and city data. (shown with cities labeled). (adapted from Team MathMechanics Final Project Report, ENG6, Summer Session II, 2011)

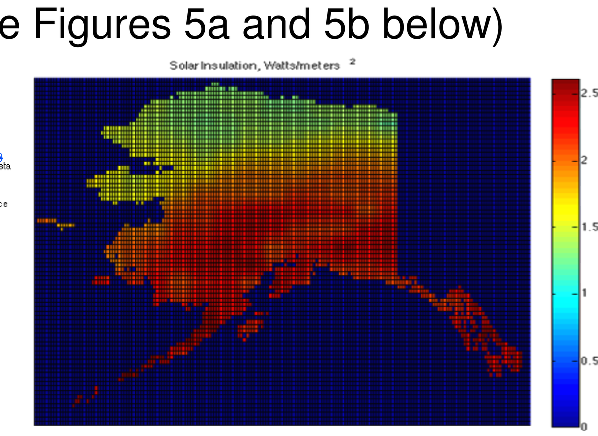

Figure 5b. Map of Alaska shown with average solar radiation in March. (adapted from Team Alpha Final Project Report, ENG6, Summer Session II, 2011)

Hardware Development

To give students hands-on experience working with and controlling electronic hardware, we designed a USB module capable of characterizing and sampling the output of a solar cell. The module can be controlled from MATLAB.

The hardware module is based on the Arduino UNO ("UNO") board and the solar cell shown in Figures 6 and 7 below.

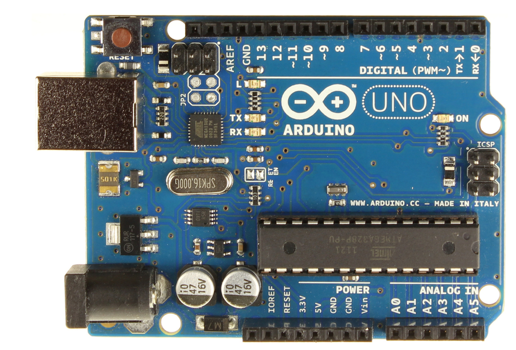

Figure 6. Arduino UNO.

Open circuit Voltage: 3.4V
Short-circuit current: 12mA
Maximum power: 17.5mW @ 500Ohms
Size: 24x22mm (0.94" x 0.87")

source: www.solarbotics.com

Figure 7. Solar cell used.

The UNO communicates directly with MATLAB as a serial object. The serial protocol is emulated on the universal serial bus (USB). See Figure 10 for the software/firmware configurations.

The wiring diagram of the system is shown in Figure 8 below and the assembled system is in Figure 9. All components are placed and soldered on an Arduino shield (daughter board). The shield interfaces to the UNO by stacking directly on top of the UNO board, through the two rows of headers. The variable resistor ranges from 60 Ohms to 10 kilo-Ohms. The digital control is 8 bits wide, allowing the resistance to be adjusted in steps of ~40 Ohms. The second resistor inside the package is used as a current limiting resistor to limit the output current of the solar cell (the absolute maximum current of the wiper terminal is 1mA).

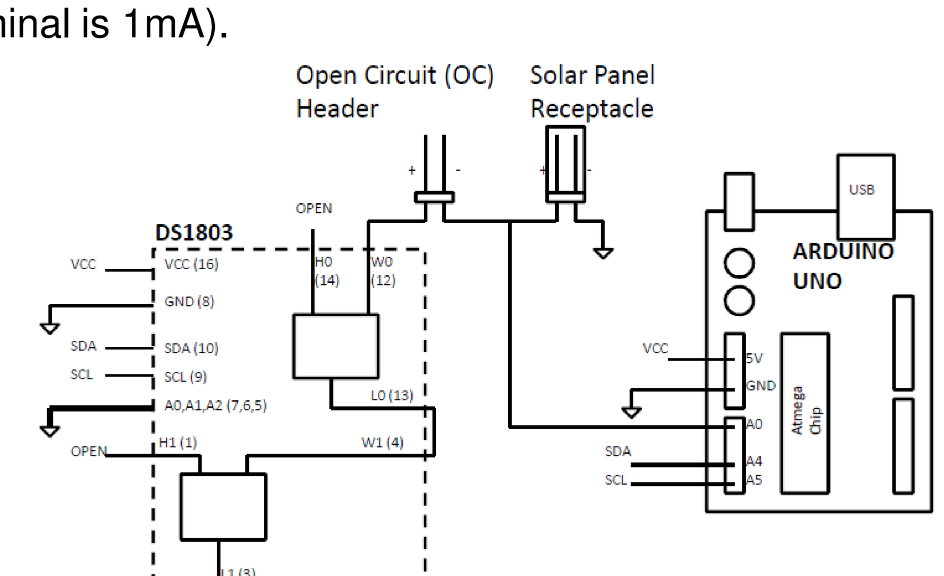

Figure 8. System Wiring Diagram.

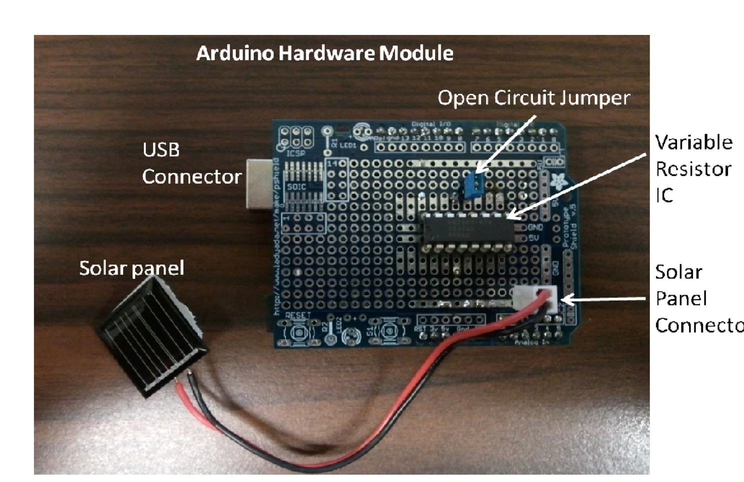

Figure 9. Assembled System.

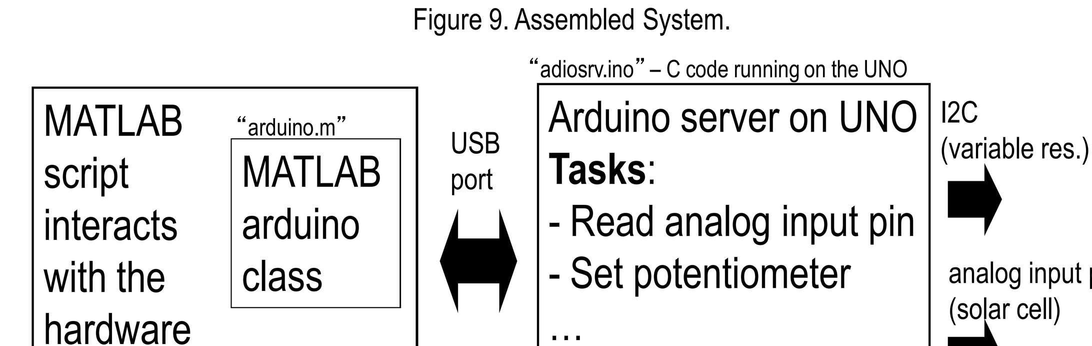

Figure 10. Software/firmware interaction.

Sample Hardware Output

The hardware module is used to obtain characterize the attached solar cell at various illuminations. The current-voltage (IV) curves of the solar cell are shown in figures 11 and 12 below.

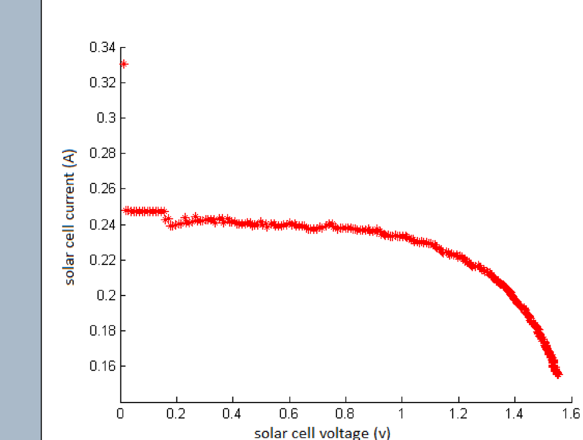

Figure 11. Solar cell IV curve at fixed illumination.

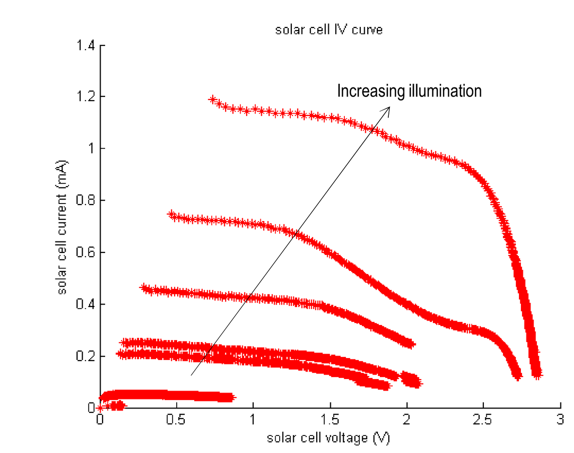

Figure 12. Solar cell IV curves at various illuminations.

Summary and Future Work

- Wireless data transfer and control interface using TI-EZ430-RF2500 wireless kit.
- Implement simple wireless networking functionality.
- Replace Arduino UNO with the low-cost Texas Instrument Launchpad board.

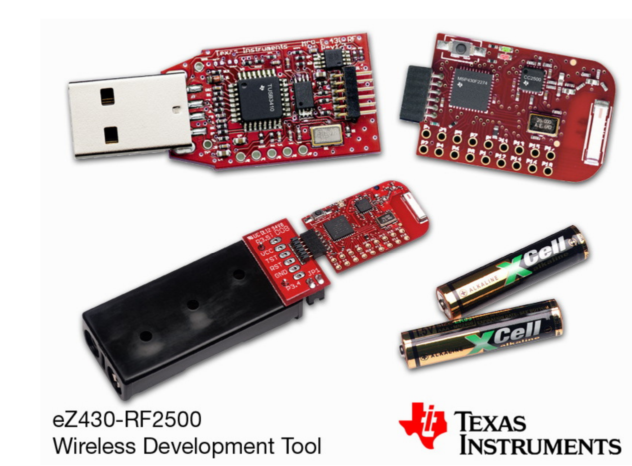

Figure 13. TI-EZ430-RF2500 kit.

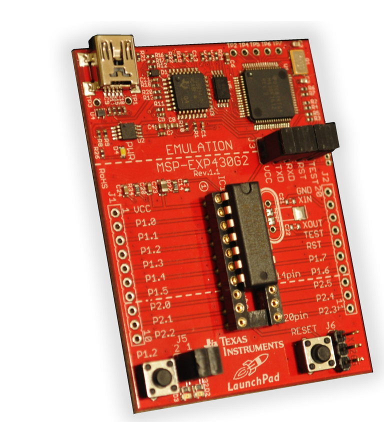

Figure 14. TI Launchpad.

- Implement a programmable gain analog front-end (AFE) circuit that allows the hardware module to interface to different solar panels that have different output ranges.

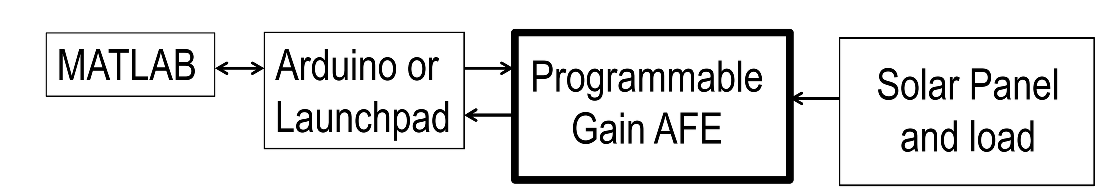

Figure 15. Programmable Gain AFE for interfacing to different solar panels.

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