Freshman Engineering Project and Design Contest with an Electronics Focus: Solar Cell Powered Mini-Vehicles

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Abstract

An important goal of the introduction to engineering course is to provide incoming engineering students with a wide exposure to engineering fields, concepts, and design projects. These modules are often presented in the format of a team-based contest. It is often easier to create such contests with a mechanical rather than an electrical focus.

At Loyola College all freshman engineering students take a common introductory course and it was desirable for them to have some exposure to electronics. This had to be achieved within a number of constraints. The project had to take the form of a design contest, it could not demand extensive prior knowledge of electronics (e.g. designing circuits from scratch), and the budget for new equipment and materials was limited. This paper describes the solar mini-car contest that was established with a basic circuit and materials from Solarbotics®[1]. Students learned about basic electronic components such as resistors, capacitors, transistors, and solar cells. The basic circuit schematic was provided with a few design choices. Student teams developed soldering and design skills as they built the basic solar-powered motor circuit and then experimented with designing the most efficient "solar roller". The project culminated in a drag race contest open to all of the department's students. This project met all of our original goals for the course. The format is flexible enough to allow for many possible variations and learning objectives.

Introduction

An engineering design contest was needed, both for the first year engineering class and for a department-wide contest during Engineer's Week. It was desirable for this project to have an electronics focus without demanding extensive prior knowledge of electronics. After research of racing and robotics type contests, material from a company called Solarbotics was decided to form the basis for the class's design contest. (This company has an Internet web site at http://www.solarbotics.com/index.html.)

The basic "solar engine" kit was available at discounted rates for bulk orders from an educational institution and contains an instruction booklet, transistors, printed circuit board, capacitor, solar cell, and motor from a standard cassette player. In addition, a larger capacitor, a larger solar cell, and a pager motor to provide design options for the students were acquired from the same source. Students learned soldering skills and trouble-shooting skills in developing the basic solar engine circuit, which is covered in the instruction booklet. There were a limited number of design choices for the solar engine, primarily as to which motor and which capacitor each student team would use.

All student teams chose to use the two solar cells, as well as the larger capacitor and the cassette motor. Beyond that, the actual design of the dragster is open-ended. The only constraint was physical size, which was limited to a six inch cube. A two lane raceway with two halogen lamps (500 watts each) mounted approximately one meter above each lane of the raceway was constructed for the races.

The most interesting design challenges were in learning how to transfer power from the solar engine to the dragster. Wheels, gears and body parts were taken from the cassette recorder mechanism provided with the kit as well as other readily available and inexpensive materials that the students found for themselves. An example of such a mini-vehicle is shown in Figure 1. This is where the most interesting decisions and discussions occurred in the student teams. No explanations or "blueprints" were provided for powering a wheel, car body design, or steering. Understanding was required at the level of "intuitive" or "experiential" knowledge of the mechanical world, and ample time both in and out of class was provided for self-discovery. Experimentation revealed interesting problems with steering, minimizing weight, collecting maximum light, and providing an appropriate gearing mechanism from motor to wheel. Some constructed large wheels out of cardboard, but need addition traction provided by a rubber band around the cardboard, others opted for small hard rubber wheels and so on. This is where the design elements are truly open to creativity and most appropriate to the prior experiences of most first year students. Since there is generally less experience on the part of the students with electronic components, discussion and design decisions were limited. The main choice of capacitor was explained in terms of energy storage, and the trade-off between longer charging times for more energy out in any one cycle of the circuit. The other engine design discussion revolved around the cassette motor, which provided more torque but was slower than the pager motor. Transistors were introduced essentially as switches and solarcells as energy collection and conversion devices.

Technical Specifications and Circuit Diagram

The components of the basic solar engine kit as provided by Solarbotics were as follows:

- 1 motor/cassette mechanism
- 1 2N3904 NPN Transistor
- 1 2N3906 PNP Transistor
- 1 2200 ohm resistor
- 1 4700 microfarad capacitor
- 1 LED
- 1 solarcell (22X24 mm - produces 3.5 volt (open) @ 6 mA(short circuit))
- some heat-shrink tubing (to cover the LED)

In addition a second solar cell, a pager motor, and a second capacitor were also provided. These additional items were:

- solarcell (24X33 mm - produces 2.7 volt (open) @ 16 mA(short circuit))
- capacitor (.047 or .47 Farad capacitor, other sizes also available)
- pager motor (1.3 V, 30 mA, 3/4" long, 7/32" diameter)

The basic circuit of the solar engine is shown in Figure 2. The basic idea is a relaxation oscillator which charges up to a threshold voltage and then discharges through the motor. This "Solarengine"® circuit is a patented design by Mark Tilden of Los Alamos National Labs. Although the first year students did not spend time analyzing this circuit in any detail, that could be an optional classroom activity for more advanced students. Such a circuit could be reintroduced once these same students have progressed in their study of basic linear circuits and electronics.

Classroom Activities

A video purchased from the Solarbotics company provided a launching pad for discussion about the electronics and robotics involved in these engines and the principle of "BEAM" ®. BEAM is an acronym standing for: Biology, Electronics, Aesthetics, Mechanics coined by this group to describe a field of robotics that focuses on small, adept, relatively simple, and inexpensive intelligent machines. The essence of the "BEAM" robotics concept is an energy storage circuit using a relaxation oscillator. The basic design stores energy in a large capacitor until a preset voltage threshold is reached, when the energy is released into the motor. This basic solar engine can be used for a large number of solar energy based robotic projects, all the way to sophisticated light-seeking, obstacle avoiding, walking robots. This contrasts with other uses of robotics that rely on the use of large power sources, microcontrollers and the programming of complex systems. Looking through the basic web site and associated site gives one a feeling for the rich potential of these materials for undergraduate education[1]. There is a great deal of information available on the Internet which expands upon the basic solar engine circuit into ideas of nonlinear analog control and what is called nervous net technology, the basic idea of creating robust adaptive systems inherent to circuit characteristics rather than relying on software expert systems, CPU, high power and high cost approaches. It takes its inspiration from the adaptive, flexible "intelligence" of biological organisms without a central processor (e.g. the insect).

The basic structure of student activities over the four weeks of in and out of class time for the solar car project were:

- video and discussion
- soldering workshop
- construction of solar engine
- design and construction of mini-car
- building race track
- drag race - Engineers' Week - with video taping of contest, which is useful for review, improvement of the contest and departmental promotion.
- student written report

Discussion and Results

This project was a major component of an Introduction to Engineering course for all prospective engineering majors. The course is the first exposure that students have to engineering and design in the undergraduate curriculum at Loyola, while they are taking a core of basic science, math and liberal arts courses. Because this is a small engineering department in the context of a liberal arts college, student success, retention, and satisfaction receive a great deal of attention. Such a design project, even in the context of a larger, specialized, engineering college would probably aid in student interest and success. Informal discussions with students indicated a great deal of satisfaction with the project. In general, the course is intended to provide an introduction to engineering as a discipline and profession. Through case studies, readings, discussions, teamwork, design contests, and student portfolios the processes of design, creative problem solving and innovation are studied. Emphasis is given to the historical and social context of engineering design and its impact on our society. Skills necessary for success such as creativity, teamwork, oral and written communication are developed. An introduction to campus computing facilities and software applications used for subsequent courses is also provided.

Project teams consisted of 3-4 students and grading was based on student "portfolios" for the course. Although collaboration was encouraged throughout the course and for this project, each student had to submit a portfolio of all their work, which included written reports on team projects such as the solar car, as well as individual assignments and essays. Grading of portfolios encouraged attention to written expression to demonstrate understanding of technical concepts. Other kind of follow-ups for team projects include poster presentations or oral presentations. Thus students get reinforcement of important academic and career skills.

Students learned a number of valuable lessons applicable for their first year and beyond in the engineering curriculum:

- Mechanical skills (soldering).
- Basics about solar cells and other electrical components.
- Electro-mechanical design issues - how to convert the motion and power of the motor to useful motion of a vehicle.
- Other small scale design issues with materials at hand.
- Confidence, retention, interest. The sophomore class looks back with appreciation and affection to this freshman year experience. Some comments were that in addition to being fun, their appreciation for the solar mini-car project has deepened with time.
- Technical writing, communication, teamwork

Overall the advantages to the engineering curriculum were that this project proved to be inexpensive and enjoyable while providing an introduction to numerous topics such as electronics, mechanics, design, electro-mechanical integration, robotics. The amount of time and focus on these various topics is up to the engineering educator and departmental needs, and is what allows for the great flexibility and potential of this project.

It is often difficult to find contest or project ideas for first year engineering students that can accomplish multiple goals at a reasonable cost and use of equipment. This experience with solarcell-based mini-vehicles fits the bill as an engaging project for undergraduates that can be appreciated on a number of levels.

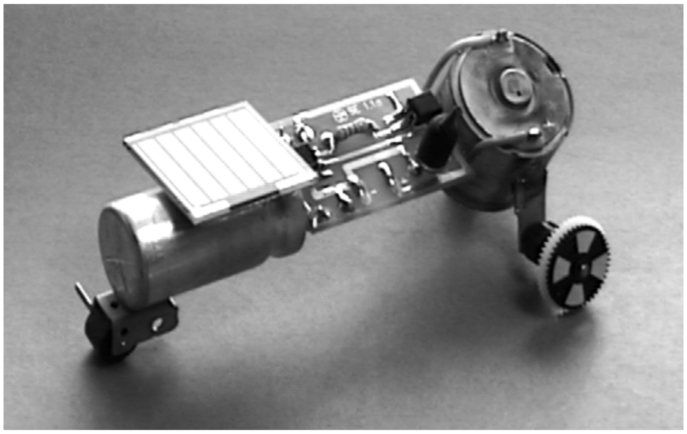

Figure 1. Basic solar engine/solar roller design. From http://www.solarbotics.com/kit_1.html. All parts for construction of this car come from a cassette recorder mechanism.

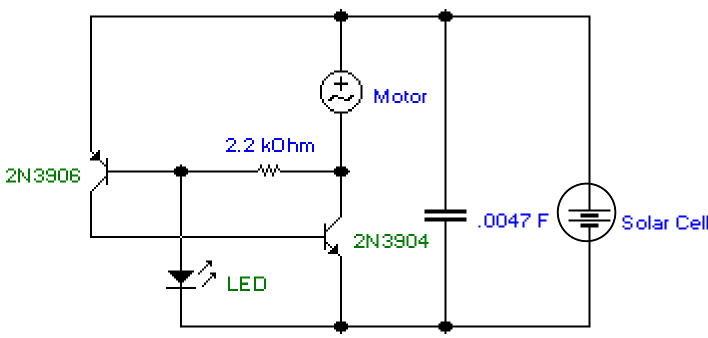

Figure 2. A schematic of the basic solar engine circuit. The basic idea is a relaxation oscillator which charges up to a threshold voltage and then discharges through the motor. This “Solarengine”® circuit is a patented design by Mark Tilden of Los Alamos National Labs.

References/Acknowledgments

1. The kit is a collaborative effort between Solarbotics and AM Innovations.
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179 Harvest Glen Way, N.E.
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“BEAM” and “Solarengine” are registered trademarks of Mark Tilden and BEAM Robotics. The Solarengine Circuit is patented internationally by Mark Tilden. More information can be found at various web sites, starting with:
http://www.webconn.com/~mwd/beam/mwt/patent.html
http://www.webconn.com/~mwd/beam.html
http://www.golden.net/~amiller/

http://www.solarbotics.com/
http://www.webconn.com/~mwd/beam/beam_bib.html
http://www.webconn.com/~mwd/topiclist.html#SOLAR

Biographical Sketch

SUZANNE KEILSON obtained her B.A. in Physics from Yale University and her M.S. and Ph.D. degrees in Applied Physics from Columbia University. Her research interests are in the areas of biomedical engineering, signal processing, acoustics and auditory sciences. Following a post-doctoral appointment at the Johns Hopkins Center for Hearing Sciences, she has been an assistant professor at Loyola College in the Department of Electrical Engineering and Engineering Science since 1994. She is currently the newsletter editor of the Mid-Atlantic section of the ASEE.