Robotic Sunflower Lesson 5: Integrating Solar Power

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DESCRIPTION: At this point students should have a working robotic sunflower that will track the sun with 2 degrees of freedom. This next lesson powers the whole system with a photovoltaic module. A Zener diode is used to charge a 6V motorcycle battery which then supplies a voltage regulator which in turn supplies the 5V needed by the microprocessor.

GRADE LEVEL(S): 9, 10, 11, 12

SUBJECT AREA(S): Electricity, electronics, computer science, applied physics

ACTIVITY LENGTH: 1 hour, 40 minutes

LEARNING GOAL(S):
Students will create voltage regulator and construct a solar battery charger.

STANDARDS MET:
Common Core:
- CCSS.ELA-Literacy.RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- CCSS.ELA-Literacy.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- CCSS.ELA-Literacy.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Next Generation Science Standards:
- HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3. Evaluate a solution to a complex real-world problem-based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

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Student Background:

This lesson was developed as the fifth in a unit that culminates in the construction of a robotic sunflower that tracks the sun. My students will already have completed the following lessons beforehand:

- Robotic Sunflower Lesson 1: Measuring Voltage with a Microcontroller
- Robotic Sunflower Lesson 2: Controlling a Servo
- Robotic Sunflower Lesson 2.1: Extension to Controlling a Servo
- Robotic Sunflower Lesson 3: Creating a Light-Tracking Servo
- Robotic Sunflower Lesson 4: Dual Axis Tracking

Educator Background:

Circuit 7 consists of two parts. The charging side with the solar panels, left of C1, and the 5V step down converter, right of the 6V battery, which supplies the microprocessor. First let's look at the charging side. A voltage gets established in the solar panel. This drives the current (conventionally) from the positive side through diode D3, which should have a high power rating. This acts like a one-way gate so at night when no current is created by the solar panel the battery doesn't drain into the panel. The current then goes through a power resistor. It will become apparent why this resistor needs to have a large power rating in a second. The current then encounters D1, the Zener diode and the battery. The Zener diode is designed in such a way that it becomes reversed biased when the voltage exceeds a particular value. Our Zener had been chosen to breakdown at around 6.8 V. In full sunlight the panels will have a voltage of around 12 volts. That means current will flow into the battery until it reaches 6.8 V. At this point the voltage across the Zener will cause the diode to become reversed biased. Then current will flow through the Zener and back to the panel. This is why we need a large power resistor and diode. The resistor will generate some heat, which can be used to help maintain temperature in the control housing for the sunflower installation. In this way the battery will be maintained at 6.8V during the day. At night the battery will discharge but remember that the will be no servo motions so current demand will be negligible.

On the other side of the circuit is the TI LM2574. This circuit is outlined in the data sheet, which is located at http://www.ti.com/product/lm2574. This arrangement is called a "buck converter." This simply means that the voltage is stepped down and DC to DC. Here's the basic idea of how the chip works. The chip has an oscillating switch that rapidly turns on and off the current. This current goes through an inductor in which an opposing voltage is created. This drop in voltage with the voltage already coming through creates a net lower average voltage across the load.

i.e. 6.8V in, 5V out. The capacitors placed in parallel smooth out the voltage changes while the current is being turned on and off.

Science Kit Materials List:

- Multimeter (2/team)

Other Materials List:

- "Student Guide" handout
- "Texas Instruments LM2574 Datasheet" handout
- Texas Instruments LM2574 0.5 A Step Down Voltage Regulator (1 per team + several spares)
- 220 micro Henry inductor (1 per team)
- 6V lead acid motorcycle battery (3 per class)
- Solar panels with 9 to 12 V output (1 per class)
- 22 & 220 micro Farad electrolytic capacitors (1 each per team)
- 1N5817 Diode, one 2W (2 per team + several spares)
- 1N4736 Zener Diode (1 per team + several extras)
- 100 ohm, 2 Watt resistor (1 per team)
- Breadboard (1 per team)
- Jumper wires (1set per team)

Vocabulary:

- Inductor
- Capacitor
- "Buck" Converter
- Diode
- DC to DC Converter

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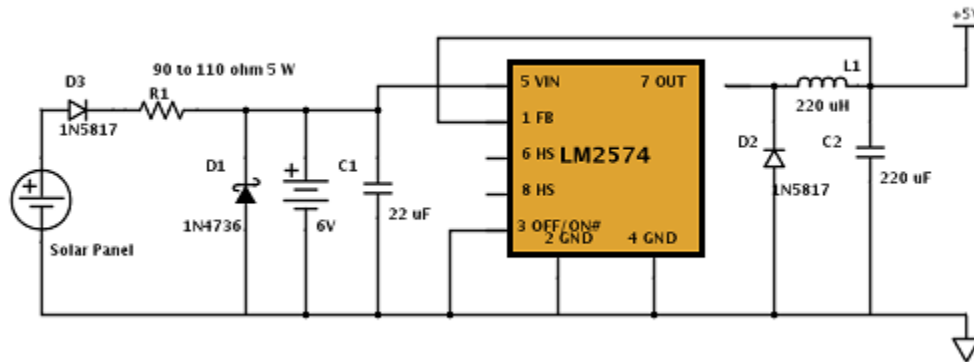
Lesson Details:

Planning and Prep

Have student watch this video prior to coming into class for this activity:
http://www.youtube.com/watch?v=STDICdZnIsw

Circuit 7: Solar Charger Circuit Diagram

Class Sequence

Theory—Day 1

First refresh the class on parallel and series circuits. Depending on the class, a discussion on how the buck converter works should follow. In this discussion a thorough explanation of the inductor coil should be explored. The teacher can set up two demonstrations of induction coils to facilitate the discussion. The first could be an induction coil connected to a current source that provides both steady and oscillating currents. In addition, a hall sensor and current sensor connected to an oscilloscope or a Vernier LabQuest to show how the magnetic field in the coil changes with current. Then, using the right hand rule, the teacher can demonstrate the induced current change. The second demonstration could be a solenoid and current supply. This would give a physical action associated with the inductor. After the demonstration, discuss capacitors in the circuit and how they are used to smooth out the current. Follow up with a discussion of the diodes and their roles in the circuit.

Build—Day 2

Give each build team the parts for the circuit and a breadboard. Quality-test each build by hooking up a multimeter to the output for the circuit. Additionally an oscilloscope can be hooked up the output of the IC on pin 7. Use a high wattage light source for testing.

Assessment

The rubric below can be used to evaluate the final product.

Program	Max Pts	Pts Earned	Grading Criteria		Instructor Initial
Power Supply	3		Circuit is wired correctly.	___/3	
Teamwork	2		Worked well and contributed.	___/2	
Total:					

Table 1: Solar Power Source