Grade 4 Power Electronics Lab: Improving Efficiency in Electrical Systems (Teacher Guide)

The following engineering transfer tasks have been created to be used in conjunction with the URI Power Electronics Lab Video. The tasks are designed to be completed in order as they build upon one another.

Teacher Notes:

- Please note printed copies will be in black and white, but projected documents will be in color.
- You may consider doing this together as a think aloud
    - Have students turn and talk/think-pair-share/discuss their ideas
- You may consider having students complete with a partner
    - Have a sense-making discussion with the whole group after students complete the task
- You may consider having students complete independently
    - Have a sense-making discussion with the whole group after students complete the task
- This is an engineering task where students will need to consider the efficiency of energy systems. Students will need to understand that higher temperatures in an energy system mean the system (or component) is less efficient because more energy has been transferred out as heat.

Teacher Guiding Questions: You may use these guiding questions for all of the tasks, depending on how you scaffold it.

- What information did you get from the text?
- What information do we get from the data table?
- What information did you get from the image?
- What information do we get from the key?
- What is the task?
- What are the components in the system?
- Which system (or component) is most/least efficient?
- How will you know which system (or component) is most/least efficient?
- How can we use the colors from the infrared image to determine efficiency?
- How do you know? How did you figure that out?
- Does anyone have a different idea?
- Does anyone have any ideas to add?

GEMS-Net & The UConn-URI Navy STEM Coalition would like to acknowledge funding and support from the Department of Defense National Defense Education Program (NDEP) grant #HQ00342110016

URI Power Electronics Lab: Improving Efficiency in Electrical Systems

Dr. Jeong is an electrical engineer at the University of Rhode Island. He is testing the efficiency of a buck converter power conversion system. A buck converter changes the way electricity is transferred from the input component (like a D-cell) to the output component (like a bulb or motor). He is interested in learning more about the energy transfer in the system when two switches are being used. Some of the system components are labeled in the photo (Figure 1) from Dr. Jeong's lab below.

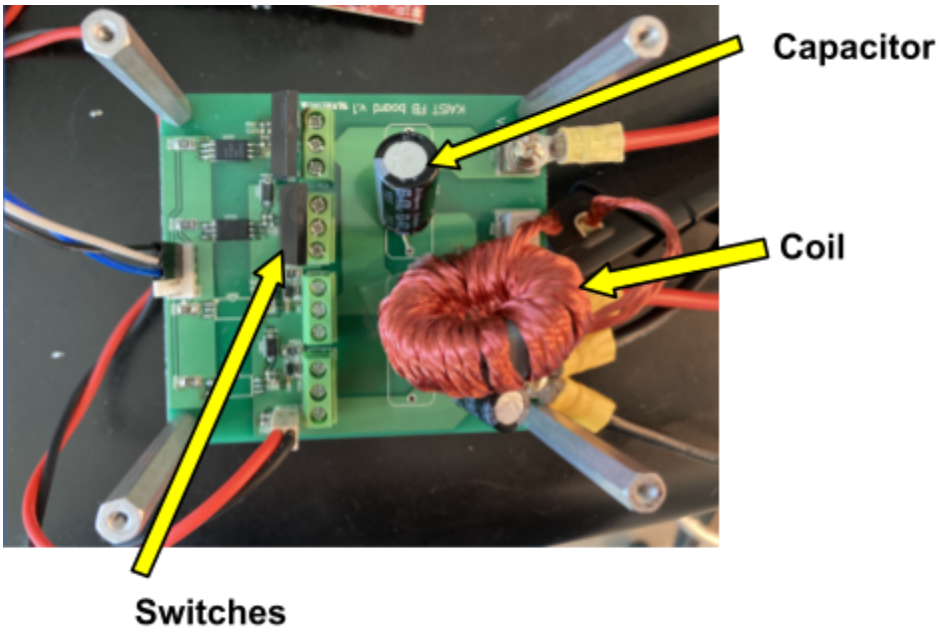

Figure 1: Image of buck converter

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Task 1: To test the efficiency, Dr. Jeong changed the frequency at which the switches open and close the circuit. First, he ran the system using a frequency of 200 K-hertz (TEST 1). At 200 K-hertz the switches open and close very quickly. Then he ran the system using a frequency of 50 K-hertz (TEST 2). At 50 K-hertz the switches open and close at a slower rate. Dr. Jeong measured the temperature at the switches as they opened and closed at different rates. The results of Dr. Jeong's investigations are found below.

Test	Frequency	Temperature
1	200 K-hertz	99.6 ℃
2	50 K-hertz	41.2 ℃

1) A higher temperature means that energy is being transferred out of the system as heat. The more energy transferred out of the system, the less efficient it is. Based on Dr. Jeong's data, at which frequency is the system more efficient? What is your evidence? Explain your thinking.

Teacher Note: Answers will vary. See sample response below for guidance.

I think the system is more efficient when the frequency is 50 k-hertz. My evidence is during Test 1 the frequency of the switches was 200 k-hertz and the temperature of the system was 99.6 ℃. Whereas, during Test 2 the frequency was 50 k-hertz and the temperature of the system was 41.2 ℃. The lower temperature in Test 2 means that less heat was transferred out of the system. Therefore, when the frequency of the switches was 50 k-hertz the system was more efficient.

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Task 2: Electrical engineers, like Dr. Jeong, use infrared cameras as tools to measure the heat energy transferred out of a system. Inefficient components will have a higher temperature due to energy loss in the form of heat. Dr. Jeong used an infrared camera to further investigate TEST 2 by analyzing the individual components. He wants to make the system as efficient as possible. Below is the infrared image (Figure 2) that Dr. Jeong took during TEST 2.

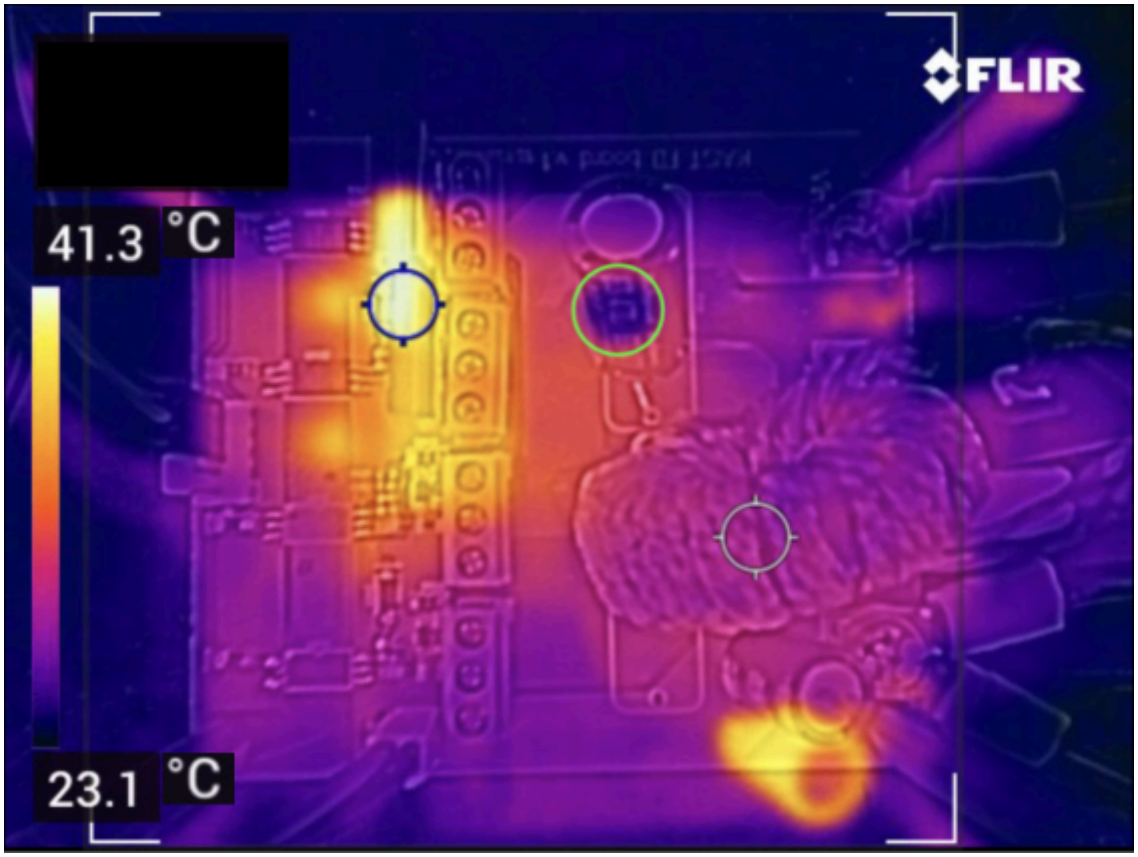

Figure 2: Image of buck converter taken during Test 2 (Infrared)

Teacher Notes:

- Each component is highlighted by a color circle: switches (blue), capacitor (green), coil (white).
- Encourage students to use Figure 1 to identify highlighted components in Figure 2.
- Students will need to estimate the temperature of the components using the color scale on the left hand side of Figure 2. Answers will vary. See sample response below for guidance.

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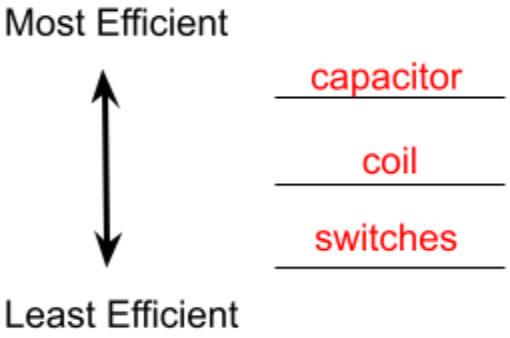
1) Using the data and information from the infrared image above, estimate the temperature of the following components?

   The switches ___41_____(℃)

   The coil ____28_____(℃)

   The capacitor ____25_____(℃)

2) Based on your analysis and knowledge of the system. Order the components from most to least efficient.



3) Write a letter to Dr. Jeong recommending which component or components he should consider improving to make the system even more efficient. Be sure to use evidence from the test results to explain your thinking.

Teacher Note: Answers will vary. See sample response below for guidance.

Dear Dr. Jeong,

I would recommend that you improve the switches to make the system more efficient. According to the infrared image, the switch was about 41 ℃, the coil was about 28 ℃, and the capacitor was about 25 ℃. Because the switch had the highest temperature this means that it lost the most energy in the form of heat. Therefore, I would recommend improving the switches so less energy is lost making the system more efficient.

Sincerely,
Eliana Smith

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This task supports students in working toward:

NGSS Energy

4-PS3-2
Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4
Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

NGSS Engineering Design

3-5-ETS1-1
Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

3-5-ETS1-3
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

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