Summary:

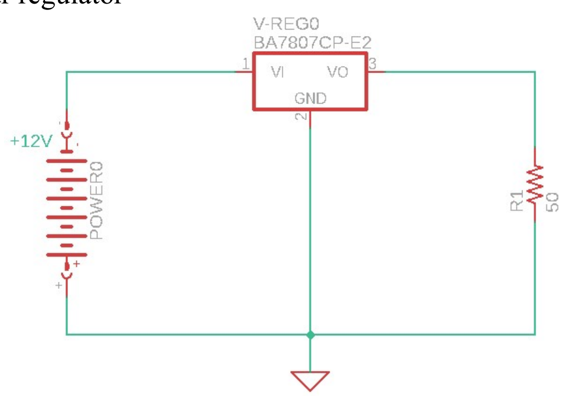
Students will measure the current draw of a simple and complex systems and calculate the power usage. Students will also create a power budget to display the wattage used and determine the appropriate battery pack for the budget.

Materials:

- 1x BA7807CP 7V Linear Regulator
- 1x PM05A065A 6.5 Non-Isolated DC/DC Converter
- Bench Power Supply
- Breadboard
- Jumper Wire
- High Wattage Resistors
- Light Bulb Holder
- 1W Light Bulb

Exercise 1:

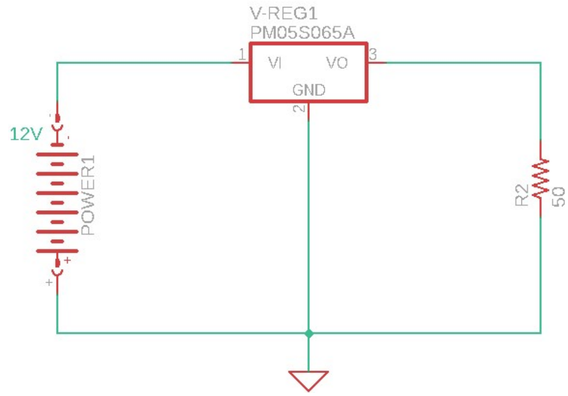
- Hook up the following circuit on the breadboard using the linear regulator and the resistor. Record the input voltage of the linear regulator



- Measure and record the voltage and current going through the resistor
- Calculate the power used by the linear regulator with the resistor as the load.
- Replace the resistor with the lamp bulb. Measure and record the voltage and current going through the lamp bulb.
- Calculate the power used by the linear regulator with the lamp bulb as the load.

$$P_{reg} = V_{in} * I_{load}$$

- Build the following circuit with the DC/DC converter.



- Measure and record the voltage and current through the resistor and lamp bulb
- The PM05S065A has a typical efficiency of 88% at 6.5V. Calculate the power used by the converter.

$$P_{reg} = \frac{P_{load}}{\eta} = \frac{V_{load} * I_{load}}{\eta}$$

The power draw you calculated is the instantaneous power of the system, the wattage consumed by the system at a given point of time. To calculate the wattage required to power the system for an extended duration, the instantaneous power is multiplied by the number of hours the circuit is powered.

- Calculate the power required for the linear regulator circuits to run for: 1 hour, 4 hours, 10 hours, and 3 days. Record your results on the table below.
- Calculate the power required for the DC/DC converter circuits to run for: 1 hour, 4 hours, 10 hours, and 3 days. Record your results on the table below.

	Instantaneous Power	1 Hour	4 hours	10 hours	3 Days
Linear Regulator – Resistor					
Linear Regulator – Lamp Bulb					
DC/DC Converter – Resistor					
DC/DC Converter – Lamp Bulb					

In some circumstances, it is valuable to power the system for only a portion of the total time period. The ratio of time powered over the total time period is known as the duty cycle. Calculating the duty cycle of a component in a system is necessary to provide an accurate estimate of the wattage consumed.

$$Duty\ Cycle = \frac{T_{powered}}{T_{period}}$$

Exercise 2: A small beacon broadcasts for ten seconds once every minute. The broadcast duration and the frequency of broadcast can be set by a user. Determine the duty cycle for the broadcasting beacon in the following scenarios:

- The beacon is set to broadcast for 10 seconds every minute. The beacon is powered for one hour. Duty Cycle: __________
- The beacon is set to broadcast for 30 seconds every minute. The beacon is powered for one hour. Duty Cycle: __________
- The beacon is set to broadcast for 10 seconds every five minutes. The beacon is powered for one hour. Duty Cycle: __________
- The beacon is set to broadcast for 10 second every five minutes. The beacon is powered for ten hours. Duty Cycle: __________
- The beacon is set to broadcast for 5 seconds every 30 seconds. The beacon is powered for ten hours. Duty Cycle: __________

Some components have multiple operational modes in which they will consume different amounts of power. For example, the beacon in the previous example has two operational modes: broadcast and idle. While the beacon is not broadcasting, the power draw drops significantly. When devices have two or more operational modes, each mode can be treated as a separate device for the purposes of calculating power consumption. The time powered in all operational modes should equal the total time the device is powered. Likewise, the sum of the duty cycles of each operational mode should equal to the total duty cycle of the device and should never exceed 100%.

When the duty cycle is less than 100%, the wattage consumed over time is less than the instant power times the total time period. To get a more accurate calculation, the duty cycle current must be calculated. The duty cycle current can be calculated by multiplying the measured current draw of the operational mode by the duty cycle of that mode.

$$I_{cycle} = I_S * Duty\ Cycle$$

Power consumption is then calculated by inserting the duty cycle current into the power equation.

$$P_{cycle} = V * I_{cycle}$$

Exercise 3: Assume the beacon from Exercise 1 draws 1A at 9V when broadcasting and 100mA at 9V when idle. Calculate the power consumption for both the broadcasting beacon and the idle beacon given the following scenarios:

- The beacon is set to broadcast for 10 seconds every minute. The beacon is powered for one hour.
  Broadcast Power Draw: __________
  Idle Power Draw: __________
- The beacon is set to broadcast for 30 seconds every minute. The beacon is powered for one hour.
  Broadcast Power Draw: __________
  Idle Power Draw: __________
- The beacon is set to broadcast for 10 seconds every five minutes. The beacon is powered for one hour.
  Broadcast Power Draw: __________
  Idle Power Draw: __________
- The beacon is set to broadcast for 10 second every five minutes. The beacon is powered for ten hours.
  Broadcast Power Draw: __________
  Idle Power Draw: __________
- The beacon is set to broadcast for 5 seconds every 30 seconds. The beacon is powered for ten hours.
  Broadcast Power Draw: __________
  Idle Power Draw: __________

After all calculations are done, the next step is to present the information in a readable format. This is normally done by a power budget. A power budget is a table listing all power consuming devices or subsystems in a system, their respective voltage, current draws, and power usage, and the sum of all power usage.

Example Power Budget					
Component Name	**Voltage**	**Current**	**Duty Cycle (%)**	**Duty Cycle Current**	**Power Consumed**
Power Converter	12 V	17 mA	100	17 mA	200 mW
Flight Computer	5 V	50 mA	100	50 mA	250 mW
GPS Module	5 V	140 mA	100	140 mA	700 mW
Transmitter (Standby)	5 V	80 mA	93	75 mA	372.5 mW
Transmitter (Transmit)	5 V	1050 mA	7	74 mA	367.5 mW
Total				**355 mA**	**1890 mW**

This example budget consumes 1.89 W of power each hour. For a ten hour duration, the system would consume 18.9 W of power.

Exercise 4: Create a power budget for the following system with the following information. Include the power draw of the power converters. How much power would be used by each hour? For the entire duration?

- The system is powered for ten hours
- The system contains one beacon powered at 9V. It draws 100 mA when idle and 1A while transmitting.
- The beacon broadcasts for 5 seconds every 30 seconds. It remains idle the other 25 seconds.
- The system contains a battery warmer that remains powered throughout the entire duration. It is powered with 9V and draws 50mA.
- The system contains a small microprocessor that consumes an average of 120 mA at 5V. The microprocessor is powered throughout the entire duration.
- There are ten temperature sensors that draw 5mA each at 5V. The sensors are powered throughout the entire duration.
- The power source to the system provides 12V.
- A DC/DC converter is used to convert 12V to 9V at 90% efficiency.
- A linear regulator is used to convert 12V to 5V.