Off the Grid Unit

Lesson 4: Exploring Buck and Boost Converters

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DESCRIPTION: This lab uses a variety of voltage conversion devices to output 5 Volts, the requirements for a USB charger such as for a cell phone. Students will take data on these devices and calculate, graph and compare efficiencies of different devices. Devices used in this lab are **buck converters, which** lower the input voltage and **Boost Converters, which** raise it (the Minty Boost® and Boost 500® are **boost converters** from Adafruit). These devices are available on the Internet and can be hard-wired to groups of series AA batteries. These devices frequently accept a range of input voltages, and some offer a range of output voltages. Students will be familiar with data collection from previous **Off the Grid Lessons 1 and Lesson 3**.

GRADE LEVEL(S): 7-8 or 9-12

SUBJECT AREA(S): Energy fundamentals, electrical circuits, efficiency, buck and boost converters

ACTIVITY LENGTH: 2-4 days or 2-4 hours

LEARNING GOAL(S):

1. Students will use **multimeters** to measure voltage and current in circuits.
2. Students will use collected data and be able to make power calculations from this data.
3. Students will also be able to calculate **efficiency** from their **power** calculations.
4. Students will be able to compare **efficiencies** in order to identify the circuit that is most efficient.
5. Students will be able to make circuits from a diagram and vice versa.

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.

COMMON CORE STATE STANDARDS:

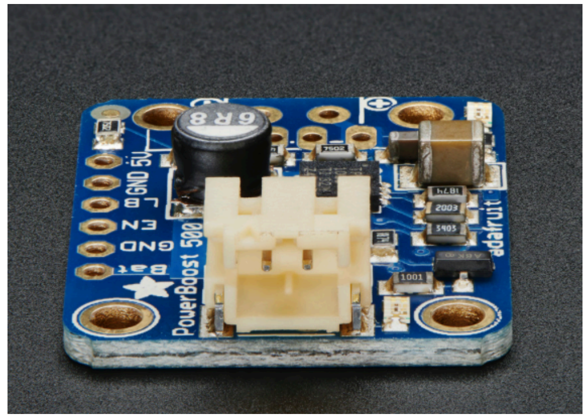
N-Q 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N-Q 2. Define appropriate quantities for the purpose of descriptive modeling.

Materials List (for groups of 2-3)

- Adjustable Boost Converters (see pics below) at least one per group (adjustable is optional)
- Adjustable Buck converters – at least one per group (adjustable is optional)
- AA battery holders – 2, 3, 4, 6 Batteries in series in (to modify input voltages) – 1 per group
- AA rechargeable batteries – 10-12 per group
- USB current/voltage meters
- Multimeters (2 per group – one for voltage and one for current)
- ATC fuse holders (used for measuring current) 1 per group (see pics below)
- Cell phone or device that uses a USB plug for charging – students can bring in a USB charging cord for their phone, or instructor can supply any USB charging device.

  (I used LED bike taillights that charge with a USB.)
- USB female plug with leads attached – I used small 5 Volt solar panels with USB leads and a female plug attached – these panels cannot directly charge most phones, so I cut the leads and used the USB female plug, and then use the panels to recharge our battery packs.
- Male and female DC power plugs with pigtails (1 each per group)



Adafruit Power Boost 500 - requires soldering!

All of the above materials can be found on Amazon.com. See photos in Off the Grid Lesson 3 to see how the circuit is put together and where the meters are used.

‹ Back to search results for "boost converters 5V"

RioRand LM2577 DC-DC Adjustable Step Up Converter 3-34V to 4-35V 5V/12V Voltage Regulator+LED Voltmeter
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Vocabulary

- Boost Converter
- Power: P = VI
- Efficiency: $e = P_{out}/P_{in}$
- ATC fuse
- Buck Converter
- Multimeter
- DC Power Plug
- Schematic or Circuit Diagram

Student and Educator Background

Both educators leading and students participating in this lesson should be familiar with the previous lesson. This lab functions best following Off the Grid Lesson 3: Phone Charger Efficiencies

Lesson Details

Planning and Prep

This lesson functions very similarly to Off the Grid Lesson 3: Phone Charger Efficiencies. However, this lesson dives more deeply into voltage conversion. In Lesson 3, students used pre-fabricated USB car chargers that lowered input voltage from 12 V to the necessary 5 V of a USB charger. Students may not have learned the terminology in last lesson. These types of converters are called **Buck** Converters, which lowers (or **bucks**) the input voltage. This lesson introduces students to an additional converter, the **boost converter**, which increases (or **boosts**) the input voltage. The circuits will be set up nearly identically to those in **Lesson 3**, so refer to the pictures in that lesson for assistance. This Lab will focus on **Boost** and **Buck converters** that are adjustable – they can be adjusted to take an input voltage and either raise it or lower it to your desired value – which for us will always be 5.0 Volts for USB charging. As electrical engineers experience in their daily lives, students may realize that they may not be able to output *exactly* 5.0 V, so they will attempt to match that value as close as possible. There are many devices out there that can do this and the few I used are in the photos below. They can convert a wide variety of input DC voltages to 5 Volts DC. Note that in general it is less efficient to Boost than to Buck. However, some old or inexpensive **Buck Converters** can be as low as 50% efficient – half on the incoming energy is lost to heat! If the **Boost** starts with a voltage very close to 5.0 V it will be tend to be more efficient than if it has 3 Volts Input.

In order to simplify the use of these I have used Female **DC Power Plugs** on the input side which enables us to quickly change input voltage since we have standardized all of our battery packs to have a **DC male Power Plug**. For the output side of the converters we have attached a USB female plug *using the conventional positive and negative terminals to match the positive and negative of the output of the converter* – this is critical as you may damage devices that are being charged if you reverse the polarity of the USB female plug. You will need small electronics repair size screwdrivers to adjust the converters and to fasten the wires into the terminal blocks. The Boost 500 is not adjustable, and it has a built in USB female plug – it can run off of 2 or 3 AA batteries.

Lesson sequence

This Lesson is a logical next step from Lesson 3. Students will create schematics of the circuits for both Boost and Buck circuits, and draw the data table in their Journals. Students can do some research to find out why a **Boost** converter is less efficient than a **Buck** converter. Then, students will collect data on the boost and buck converters in the classroom. Usually the **Boost** converters will be less efficient with values from 45-65% and **Buck** converters from 60-85%. These values will vary depending on the quality of the device you use.

Also, if students have set up solar modules with our **DC male power plugs**, then they can be plugged directly into the buck converters and the converter can be adjusted to be a "Charge Controller" by limiting the charging voltage. This can be tried as an extension or as the final activity of this lab.

If students are wiring and setting up the converters you will need an extra 1-2 hours. If the set up has already been done, the entire lab can be done in 2 hours, with the possibility of going longer if you get into using the **Buck** converters as solar charge controllers. In general, you will want to limit voltage for charging AA NiMH batteries to 1.45 V per cell – so if you are charging a 3 AA series battery pack, you will want to set the converter to **Buck** down to 4.35 Volts. Note that series charging works well when all the batteries in the pack are the same age and condition – you can create trouble if one battery shorts out, with very little voltage across it, then the other batteries can reach too high of a voltage. With small input currents, (less than 0.2 Amps) and short times this will not be much of a problem, and you can check individual cells with your multimeters.

Students should create the following table in their Journals and write the questions below. They will record data for each of the chargers they will be testing. The table has space for 2 of each types of converters.

Description of Device Tested	Cell Phone side of circuit					Battery Pack side of circuit		
	Voltage	Current	Power P_{out}	Efficiency(%) $(P_{in}/P_{out}) \times 10^2$		Voltage	Current	Power P_{in}
Boost Converter 1								
Buck Converter 1								
Boost Converter 2								
Buck Converter 2								

After you have calculated your efficiencies, compare your values with other groups and answer the following questions:

1. Which is the more efficient, buck or boost?

2. List 3 questions you could ask that would help you understand why one type of converter would be more efficient than the other type.

    1.

    2.

    3.

3. Do you think you could use these converters to modify the Voltage of a solar module?

4. Put the Buck Converter on a 6V – 12V module and see if it can lower the voltage to 5 Volts when it is in the sun. Explain how the converter could be adjusted to charge a low voltage battery pack and make sure the voltage never went beyond a certain point – lets say you were charging two AA in parallel and you did not want the charging voltage to exceed 1.45 volts.

Try this and record what you found:

Lesson Extensions

One easy extension to this activity is to compare input voltages for the Boost converters and take data to see if overall efficiency is affected by input voltage – this could be done by using different battery pack configurations.