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U.S. DEPARTMENT OF ENERGY

How a Buck Converters Works

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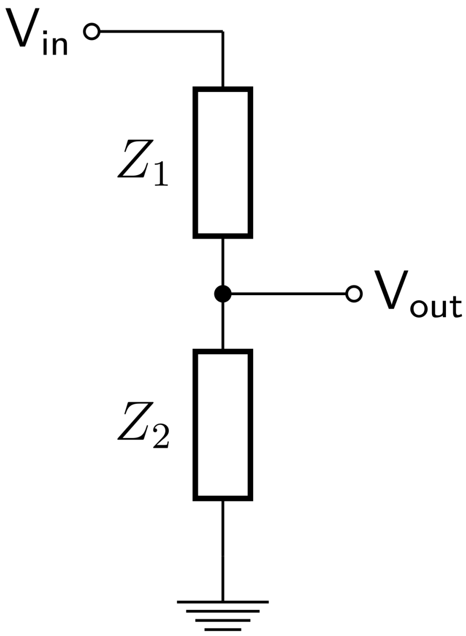
ATLAS EXPERIMENT

DCDC Converters

- **Linear Regulators**

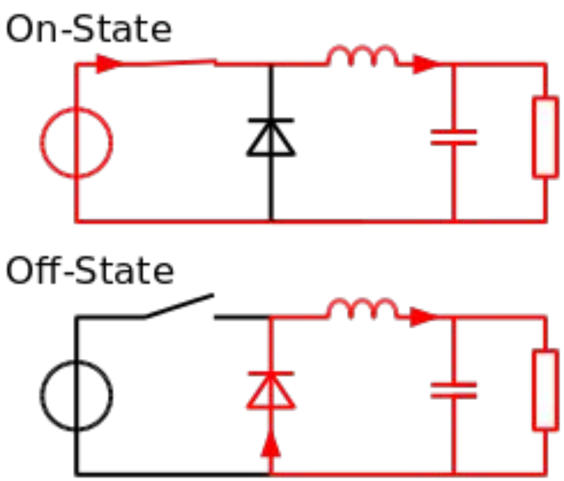
  Uses a series of resistors to drop down voltage by dissipating heat.



Example: Voltage divider

- **Switching Regulators**

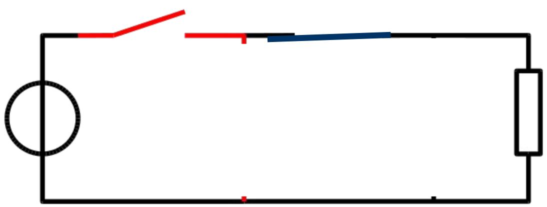
  Uses a series of switches to step down (or up) the average output voltage.



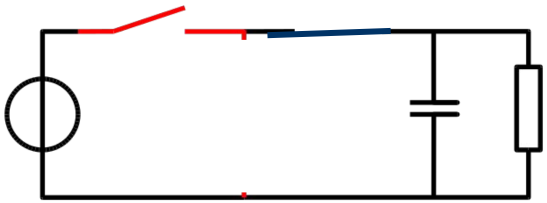
Example: Buck converter

Building up a Buck Converter

Start with a simple circuit with a switch. When looking at voltages we are looking at the average voltage. In this case we get a ripple the size of the input voltage.

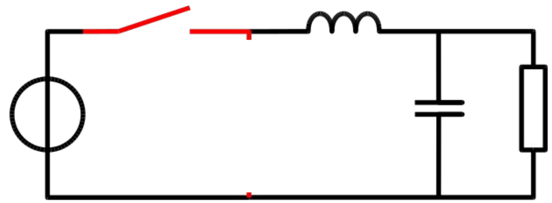


Add capacitor to flatten out the voltage, making it closer to the average. However, switching the current on instantaneously can fry the circuit.

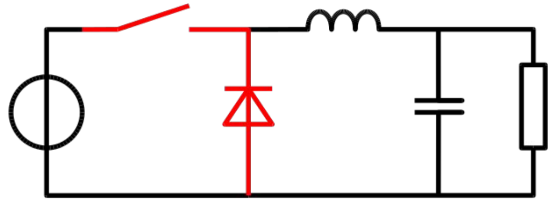


Building up a Buck Converter cont.

We can add inductor to help slow down the instantaneous flow of current. However, when the switch opens, a large negative voltage develops, which could potentially cause a spark.

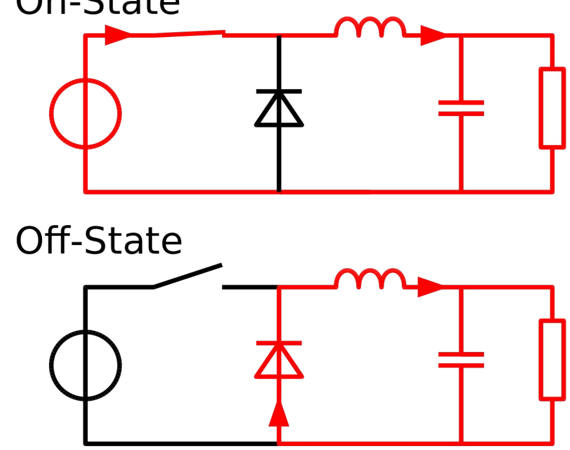


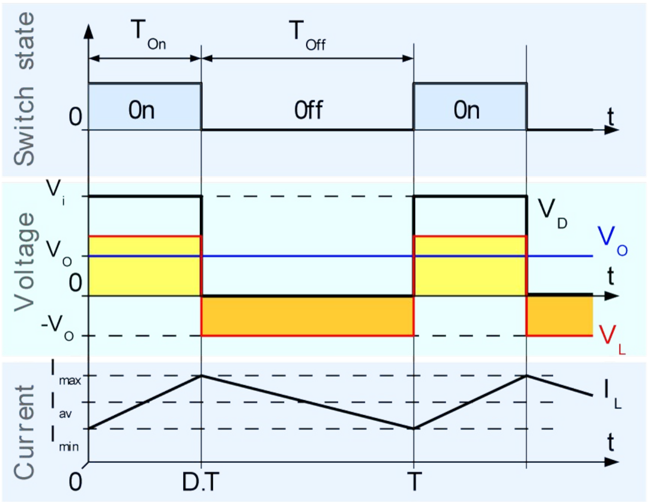
We can add a diode allowing a place for the charge to go.



Current flow through a buck converter

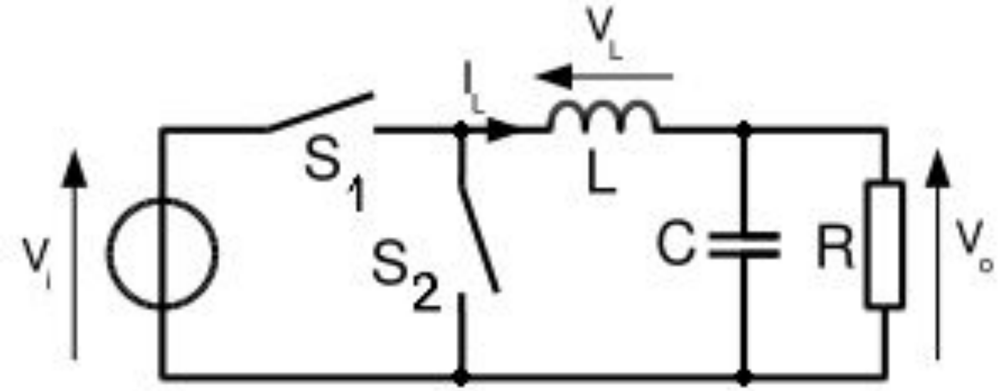
- With the switch closed, the diode is reverse biased, allowing current to flow through the inductor.
- The current increases until the switch is opened.
- The inductor keeps pushing current through, but the voltage across it switches, forward biasing the diode.





Powerboard FEAST

The FEAST replaces the diode with another switch. The two switches open and close opposite each other. This is often done as the power loss across the second switch is less than across a diode.



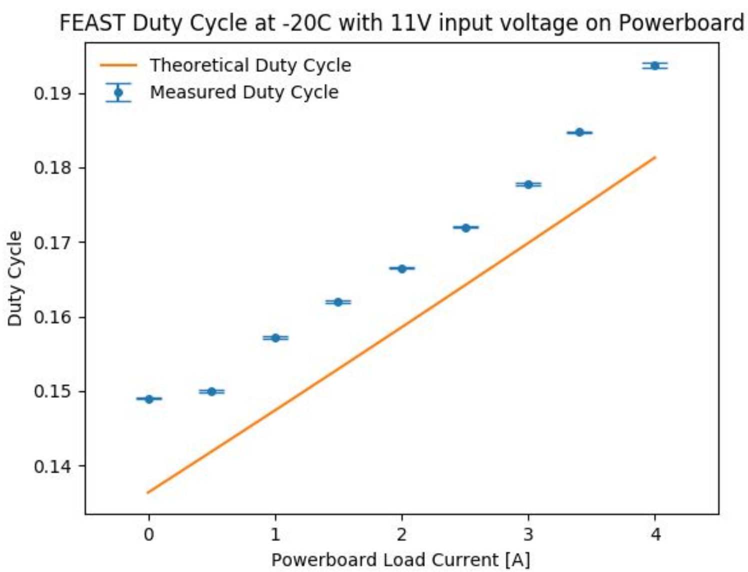
Output voltage transfer function

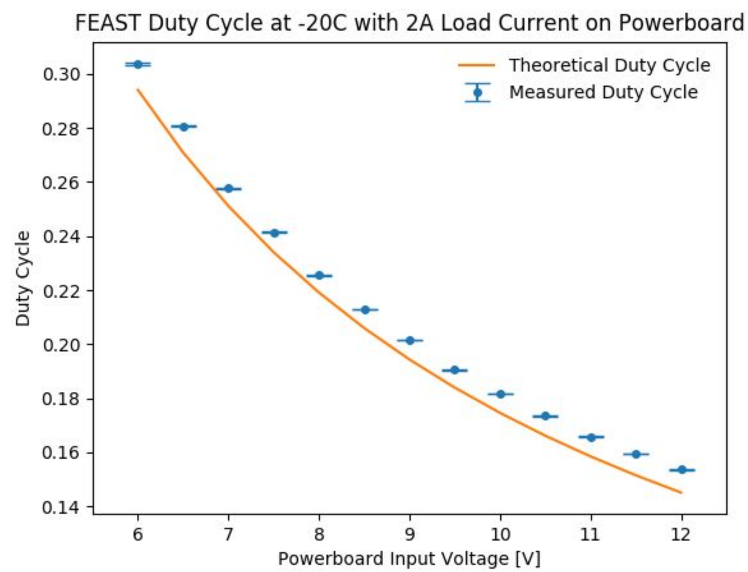
- For the case with just a switch, power supply, and load clearly the average output is equal to the duty cycle times the input voltage.
- For the full buck converter it can be shown that the output voltage is given by the same equation.

$$D = \frac{V_o}{V_i}$$

$$t_{on} = DT$$

Non Ideal duty cycle

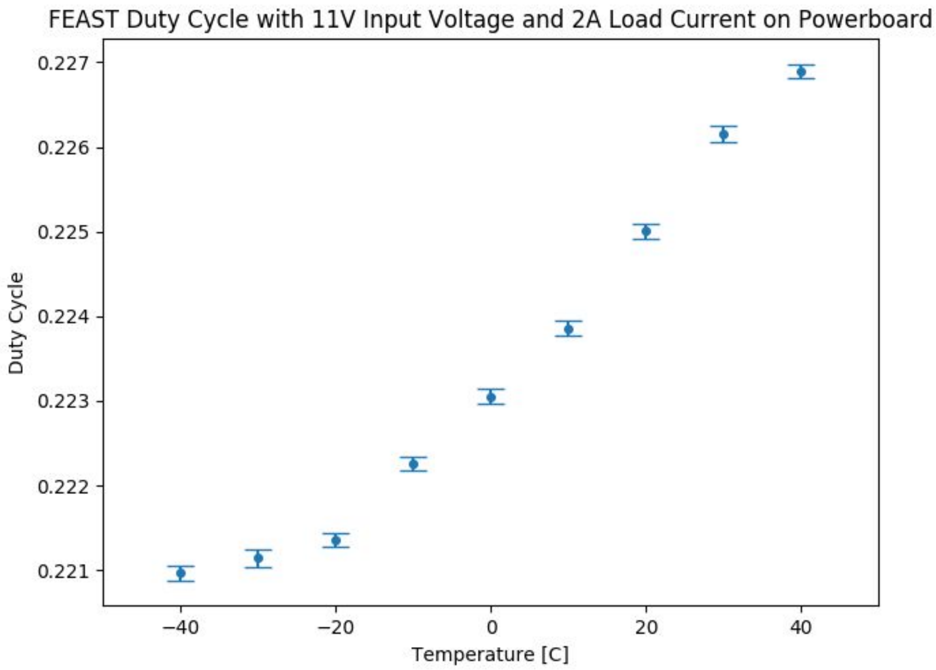




$$D = \frac{V_o + (V_{sw,sync} + V_L)}{V_i - V_{sw} + V_{sw,sync}}$$

- *V_{sw} is the voltage drop on the power switch,*
- $V_{sw,sync}$ is the voltage drop on the synchronous switch or diode
- V_L is the voltage drop on the inductor.

Temperature effects on the duty cycle



$$D = \frac{V_o + (V_{sw,sync} + V_L)}{V_i - V_{sw} + V_{sw,sync}}$$

- **As the temperature increases, so does the resistance of the two switches and the coil.**
- **With a set output voltage, input voltage, and load current, we see from the above equation that the duty cycle can only increase.**