

**JoVE: Science Education**  
**DC/DC Boost Converter**  
--Manuscript Draft--

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| <b>Corresponding Author:</b>                         | Ali Bazzi<br>UNITED STATES |
| <b>Corresponding Author Secondary Information:</b>   |                            |
| <b>Corresponding Author's Institution:</b>           |                            |
| <b>Corresponding Author's Secondary Institution:</b> |                            |
| <b>First Author:</b>                                 | Ali Bazzi                  |
| <b>First Author Secondary Information:</b>           |                            |
| <b>Order of Authors:</b>                             | Ali Bazzi                  |
| <b>Order of Authors Secondary Information:</b>       |                            |

**PI:** Ali Bazzi – University of Connecticut

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### Overview:

The objective of this experiment is to study different characteristics of a boost converter. The step-up capability of the converter will be observed under continuous conduction mode (CCM) where the inductor current is non-zero. Open-loop operation with a manually-set duty ratio will be used. An approximation of the input-output relationship will be observed.

**ATTENTION:** This experiment is designed to limit the output voltage to be less than 50V DC. Only use duty ratios, frequencies, input voltage, or loads that are given here.

### Principles:

Boost converters provide a versatile solution to stepping up DC voltages in many applications where a DC voltage needs to be increased without the need to convert it to AC, using a transformer, and then rectifying the transformer output. Boost converters use an inductor as an energy storage device which acts as a current source that supports the DC input source.

### Procedure:

This experiment will utilize the DC-DC converter board provided by HiRel Systems.

<http://www.hirelsystems.com/shop/Power-Pole-Board.html>

Information about the board components, schematics, and operation are available here:

[http://www.ece.umn.edu/groups/power/labs/pe/pe\\_manual.pdf](http://www.ece.umn.edu/groups/power/labs/pe/pe_manual.pdf)

The procedure followed here applies to any simple buck converter circuit that can be built on proto boards, bread boards, or printed circuit boards.

1. Board setup:
  - 1.1 Connect the  $\pm 12$  signal supply at the DIN connector but keep S90 OFF.
  - 1.2 Make sure that the PWM control selector is in the open-loop position.
  - 1.3 Set your DC power supply at 10V.
    - 1.3.1 Keep the output disconnected from your board until instructed otherwise.
  - 1.4 Before connecting your load resistor, adjusted it to 20 $\Omega$ .
  - 1.5 Build the circuit shown in Fig. 1 by using the lower MOSFET, upper diode, and BB magnetic board.
    - 1.5.1 Note down the inductance value shown on the board.
  - 1.6. Connect  $R_L$  across V1+ and COM.
    - 1.6.1. Note that the input and output connections are flipped compared to those in experiment #5.
    - 1.6.2. NEVER Disconnect your load during the experiment as the boost converter can become unstable and cause damage to the board.

- 1.6.3. Make sure the switch array for MOSFET selection (lower MOSFET), PWM selection, and other settings are correct to achieve a functional circuit as in Fig. 1.

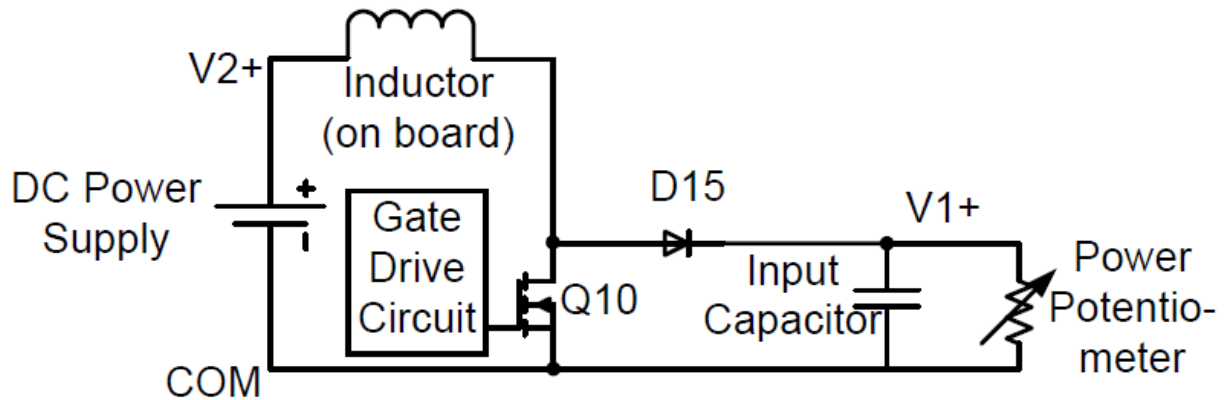


Fig. 1. Boost converter circuit

2. Adjusting the Duty Ratio and Switching Frequency
  - 2.1 Connect the differential probe across the gate-to-source of the lower MOSFET.
  - 2.2 Turn ON S90. A switching signal should appear on the scope screen.
    - 2.2.1 Adjust the signal time axis to see two or three periods.
    - 2.2.2 Adjust the frequency potentiometer to achieve a frequency of 100kHz (period of 10 $\mu$ s).
  - 2.3 Adjust the duty ratio potentiometer to achieve a 10% duty ratio (on-time of 1 $\mu$ s).
3. Boost Converter Testing for Variable Input
  - 3.1 Connect your input DC power supply which you already set at 10V to V2+ and COM.
  - 3.2 Connect your differential probe to measure the inductor current at CS5.
    - 3.2.1 Connect the other probe across the load. Make sure the ground connector is connected to COM.
    - 3.2.2 Capture the waveforms and measure the output voltage mean, inductor current ripple, and inductor current mean.
    - 3.2.3 Record the input current and voltage readings on the DC power supply.
  - 3.3 Adjust your input voltage to 8V, 12V and 14V, and repeat the above steps for each of these voltages.
  - 3.4 Disconnect your input DC supply and adjust its output to 10V.
4. Boost Converter Testing for Variable Duty Ratio
  - 4.1 Connect your differential probe across the gate to source of the lower MOSFET.
    - 4.1.1 Connect the other probe across the load. Make sure the ground connector is connected to COM.
    - 4.1.2 Connect the input DC supply to V2+ and COM.

- 4.1.3 Capture the waveforms and measure the output voltage mean and on-time of the gate-to-source voltage (also the duty ratio).
  - 4.1.4 Record the input current and voltage readings on the DC power supply.
- 4.2 Adjust your duty ratio to 20%, 40%, and 60%. Repeat the above steps for each of these three duty ratios.
- 4.3 Reset your duty ratio to 10%.
- 4.4 Disconnect your input DC supply.
- 5. Boost Converter Testing for Variable Switching Frequency
  - 5.1 Connect your differential probe across the gate to source of the lower MOSFET.
    - 5.1.1 Connect the other probe across the load with the ground connector connected to COM.
  - 5.2 Connect the input DC supply to V2+ and COM.
  - 5.3 Adjust the switching frequency to 70kHz.
  - 5.4 Capture the waveforms and measure the output voltage mean and on-time of the gate-to-source voltage (also the duty ratio).
    - 5.4.1 Record the input current and voltage reading on the DC power supply.
  - 5.5 Adjust your switching frequency to 40kHz, 20kHz, and 10kHz (or minimum possible if you cannot reach 10kHz).
    - 5.5.1 Repeat the above steps for each of these three switching frequencies.
  - 5.6 Turn OFF the input DC supply and S90, and then disassemble your circuit.

### **Representative Results:**

The boost converter output-input voltage relationship is proportional to the duty cycle in the sense that higher  $D$  will yield higher output voltages for a given input voltage. If the input voltage is  $V_{in}$  and the output voltage is  $V_{out}$ ,  $V_{out}/V_{in}=1/(1-D)$ , where  $0 \leq D \leq 100\%$ . Therefore, for an input voltage of 10V,  $V_{out} \approx 12.5$  V for  $D=20\%$ ,  $V_{out} \approx 16.67$  V for  $D=40\%$ , and  $V_{out} \approx 25$  V for  $D=60\%$ . Nevertheless, the output voltage will be lower than expected from the ideal relationship which is linear with the duty ratio, and the main reason is that the ideal converter model from which the  $V_{out}/V_{in}$  relationship can be derived does not account for non-idealities and voltage drops in the converter. Theoretically, as  $D \rightarrow 100\%$ ,  $V_{out} \rightarrow \infty$ ; practically, a theoretical limit on the boosting capability is around 3-4x the input voltage, and after a certain level of  $D$ , the output voltage of the converter starts to drop rather than being boosted due to parasitic and non-ideal elements in a real converter.

### **Applications:**

Boost converters are very common in solar photovoltaic applications where the input voltage from the solar panel varies with weather conditions and available solar energy, and a boost converter can always boost from the PV panel voltage. Power factor correction to improve power quality as seen from the utility grid with power electronic loads which may require significant reactive power, e.g. motors, is another major application of boost converters.

