# EE4643: Power Electronics

# Laboratory 4: DC-DC Buck and Boost Converters

## *Objectives*

The main objectives of this experiment are to build and examine DC-DC conversion circuits as a single-stage high-frequency switched converters, as well as to investigate the operational properties of the Buck and Boost converters. Also, this lab aims to introduce the Pulse width modulation technique for operating Buck and Boost converters.

## *Review*

The general two-input two-output switch network is composed of four switches (recall the full wave AC-DC and AC-AC converters). There are classical designs for DC converters (two and four quadrant DC choppers) that share similar designs and performances with full-wave AC-DC and AC-AC converters. However, most industrial DC-DC conversion is implemented using the switch mode single-stage Buck, Boost or Buck-Boost converters (commonly called single-quadrant converters). The majority of switch mode DC-DC converters are designed with high switching elements (FETs, MOSFETs, IGBTs, etc.). These switches can provide good voltage stability and low leakage currents during the OFF state, along with ability to high high and extra high switching frequencies.

In general, DC-DC converters are depicted as providing energy transfer between an unregulated DC source to feed a load with regulated DC power. In practice, one of the sources is almost always implemented as an electrical energy storage element. For example, the buck converter stores energy in an inductor when the controlling switch is ON, and discharges that energy through the load when the controlling switch is OFF. An objective is to keep energy flow into the load nearly constant as the switches operate. Many converters apply nearly constant voltages or currents to the storage elements.

A special advantage of DC-DC switch mode converters is the arbitrary value of the switching frequency $f$. This frequency can be chosen in any manner, as long as the desired duty ratio can be provided. Some common constraints used to select the switching frequency $f$ include:

1. The switching times (the ON-time and the OFF-time) specifications for the used switching elements;
2. Allowed ratings and values of the used inductors and capacitors in the converter circuit;
3. Radio-frequency interference caused by high-frequency components.

As the switching frequency increases, values of $\frac{dv}{dt}$ and $\frac{di}{dt}$ also increase, and smaller inductors and capacitors can be used without sacrificing the converter performance.

CAUTION:

*Do not connect or disconnect any component, supply, device while the power switch is on.*

## *Description of the Circuit*

*Instruments and Components*

- DC variable voltage supply: In the lab bench with $ON - OFF$ switch, output pins 7 and N for the variable DC supply;
- Resistive load;
- IGBT Chopper/Inverter module;
- Connection Leads (different lengths);
- The LabVolt Data Acquisition Module (DAM);
- Smoothing Inductor;

- Filter Capacitor.

## *Experimental Work: The Buck Converter*

The Buck DC-DC converter is constructed using the LABVOLT IGBT Chopper/Inverter Module. The switching pulses for the used IGBT switch are generated by the *Buck Chopper (high-side switching) control feature of the DAM.*

STEP 1: Construct the circuit shown in Figure 1.

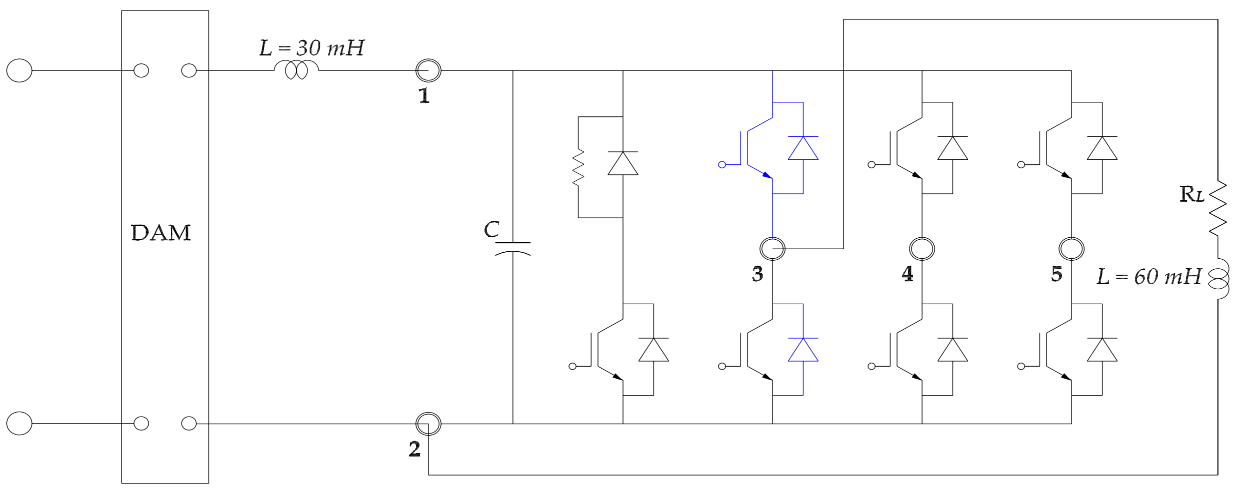


Figure 1: The connection diagram of the Buck DC converter.

STEP 2: Connect and prepare the data acquisition module (DAM) unit to measure supply voltage, supply current, output voltage and output current.

STEP 3: Select Chopper/Inverter Control functions for the DAM, and select the Buck Chopper (these settings will display the switching frequency and the duty cycle.

STEP 4: Set the switching frequency at $f_s = 12$ kHz, and set the load at $R_L = 600\,\Omega$.

STEP 5: Switch ON the power Supply, and increase the supply voltage to 60 V.

STEP 6: Using the metering feature of DAM, measure the input current, output voltage, and output current. Complete the data in Table 1

Table 1: *DATA FOR THE BUCK DC CONVERTER (FIXED $R_L$).*

| $D$ | $P_{in}$ | $I_S$ | $P_O$ | $V_O$ | $I_O$ | $\eta$ |
|---|---|---|---|---|---|---|
| 0.1 | | | | | | |
| 0.2 | | | | | | |
| 0.3 | | | | | | |
| 0.4 | | | | | | |
| 0.5 | | | | | | |
| 0.6 | | | | | | |
| 0.7 | | | | | | |
| 0.8 | | | | | | |
| 0.9 | | | | | | |

STEP 7: for $D = 0.6$, observe and record the waveforms of the input voltage and current, as well as the the output voltage and current. Save an image for each spectrum, and attach it to your report

STEP 8: Decrease the supply voltage to 0 V, and switch OFF the power Supply.

***The Characteristics of the Buck DC Converter***

STEP 1: Use the same circuit in the previous part.

STEP 2: Set the switching frequency at $f_s = 8$ kHz, and the duty-cycle at $D = 0.5$.

STEP 3: Connect the input voltage and current through the DAM. Also, connect the output voltage and current through the DAM unit.

STEP 4: Switch ON the power Supply, and increase the supply voltage to 100 V.

STEP 5: Using the metering feature of DAM, measure the input power, input current, output voltage, output current, and output power. Complete the data in Table 2.

Table 2: *DATA FOR THE BUCK DC CONVERTER (FIXED $D$).*

| $R_L$ | $P_{in}$ | $I_S$ | $P_O$ | $V_O$ | $I_O$ | $\eta$ |
|---|---|---|---|---|---|---|
| $\infty$ | | | | | | |
| 1200 | | | | | | |
| 600 | | | | | | |
| 1200//600 | | | | | | |
| 300 | | | | | | |
| 300//1200 | | | | | | |
| 300//600 | | | | | | |
| 300//600/1200 | | | | | | |

STEP 6: for $R_L = 300\ \Omega$, observe and record the waveforms of the input voltage and current, as well as the the output voltage and current. Save an image for each spectrum, and attach it to your report

STEP 7: Decrease the supply voltage to 0 V, and switch OFF the power Supply.

## *Experimental Work: The Boost Converter*

The Boost DC-DC converter is constructed using the LABVOLT IGBT Chopper/Inverter Module. The switching pulses for the used IGBT switch are generated by the *Boost Chopper (high-side switching) control feature of the DAM*.

STEP 1: Construct the circuit shown in Figure 2.

STEP 2: Connect and prepare the data acquisition module (DAM) unit to measure supply voltage, supply current, output voltage and output current.

STEP 3: Select Chopper/Inverter Control functions for the DAM, and select the Buck Chopper (these settings will display the switching frequency and the duty cycle.

STEP 4: Set the switching frequency at $f_s = 18$ kHz, and set the load at $R_L = 600\ \Omega$.

STEP 5: Switch ON the power Supply, and increase the supply voltage to 60 V.

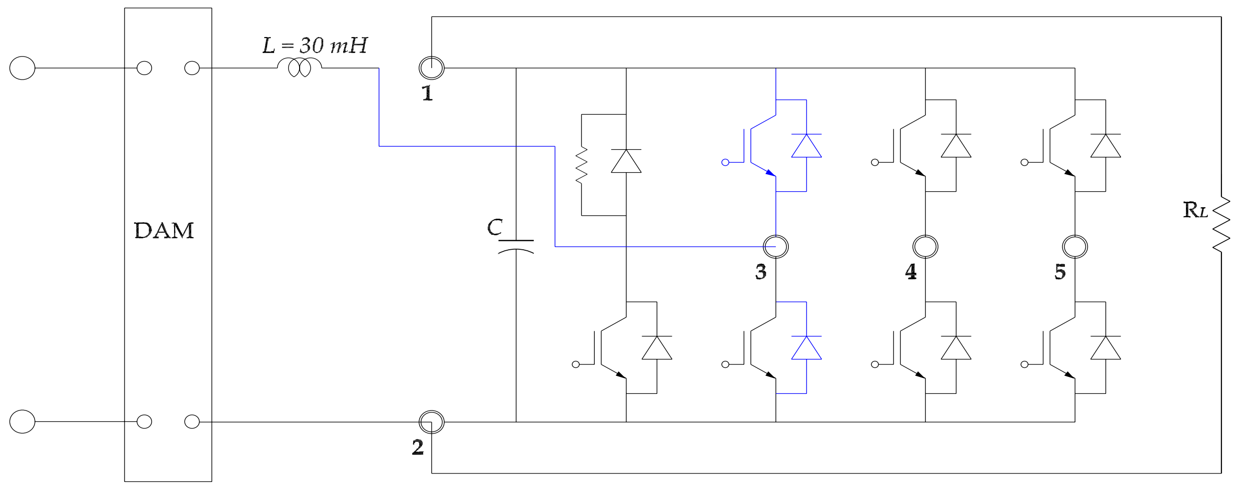


Figure 2: The connection diagram of the Buck DC converter.

STEP 6: Using the metering feature of DAM, measure the input current, output voltage, and output current. Complete the data in Table 3

Table 3: *DATA FOR THE BOOST DC CONVERTER (FIXED $R_L$).*

| $D$ | $P_{in}$ | $I_S$ | $P_O$ | $V_O$ | $I_O$ | $\eta$ |
|---|---|---|---|---|---|---|
| 0.1 | | | | | | |
| 0.2 | | | | | | |
| 0.3 | | | | | | |
| 0.4 | | | | | | |
| 0.5 | | | | | | |
| 0.6 | | | | | | |
| 0.7 | | | | | | |
| 0.8 | | | | | | |
| 0.9 | | | | | | |

STEP 7: for $D = 0.8$, observe and record the waveforms of the input voltage and current, as well as the the output voltage and current. Save an image for each spectrum, and attach it to your report

STEP 8: Decrease the supply voltage to 0 V, and switch OFF the power Supply.

***The Characteristics of the Boost DC Converter***

STEP 1: Use the same circuit in the previous part.

STEP 2: Set the switching frequency at $f_s = 12$ kHz, and the duty-cycle at $D = 0.667$.

STEP 3: Connect the input voltage and current through the DAM. Also, connect the output voltage and current through the DAM unit.

STEP 4: Switch ON the power Supply, and increase the supply voltage to 50 V.

STEP 5: Using the metering feature of DAM, measure the input power, input current, output voltage, output current, and output power. Complete the data in Table 4.

Table 4: *DATA FOR THE BOOST DC CONVERTER (FIXED $D$).*

| $R_L$ | $P_{in}$ | $I_S$ | $P_O$ | $V_O$ | $I_O$ | $\eta$ |
|---|---|---|---|---|---|---|
| $\infty$ | | | | | | |
| 1200 | | | | | | |
| 600 | | | | | | |
| 1200//600 | | | | | | |
| 300 | | | | | | |
| 300//1200 | | | | | | |
| 300//600 | | | | | | |
| 300//600/1200 | | | | | | |

STEP 6: for $R_L = 300\ \Omega$, observe and record the waveforms of the input voltage and current, as well as the the output voltage and current. Save an image for each spectrum, and attach it to your report

STEP 7: Decrease the supply voltage to 0 V, and switch OFF the power Supply.

## *Calculations and Questions*

**Q1–** Using the data in Table 1, create graphs for $D$ vs $V_O$, $D$ vs $P_{in}$, and $D$ vs $\eta$.

**Q2–** Using the data in Table 2,create graphs for $I_O$ vs $V_O$, and $I_O$ vs $\eta$.

**Q3–** Comment on the graphs created in Q1 and Q2.

**Q4–** From the data in Table 3, create graphs for $D$ vs $V_O$, $D$ vs $P_{in}$, and $D$ vs $\eta$.

**Q5–** Using the data in Table 4,create graphs for $I_O$ vs $V_O$, and $I_O$ vs $\eta$.

**Q6–** Comment on the graphs created in Q4 and Q5.

## *Conclusions*

The last part of the report has to be the conclusions. In this part, has to be a summary of the observations made during the experimental work. Also, it should reflect on the agreement or disagreement between the theoretical (calculated) and measured values.