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Simulation Assignment 02

1. Simulate a buck-boost converter with following specifications:

- **DC Voltage Source: 15 V**
- **L=0.5mH, C=0.1 mF**
- **Switching frequency: 10 kHz**
- **D=0.4 and 0.7 for the buck and boost converters, respectively**
- **Load: 2 Ω**

Measure the output voltage, and inductor current for each duty cycle, separately and explain the results. What is the peak-to-peak ripple of the output voltage (and the inductor current)?

Solution:

a) The circuit diagram for a buck-boost can be seen below:

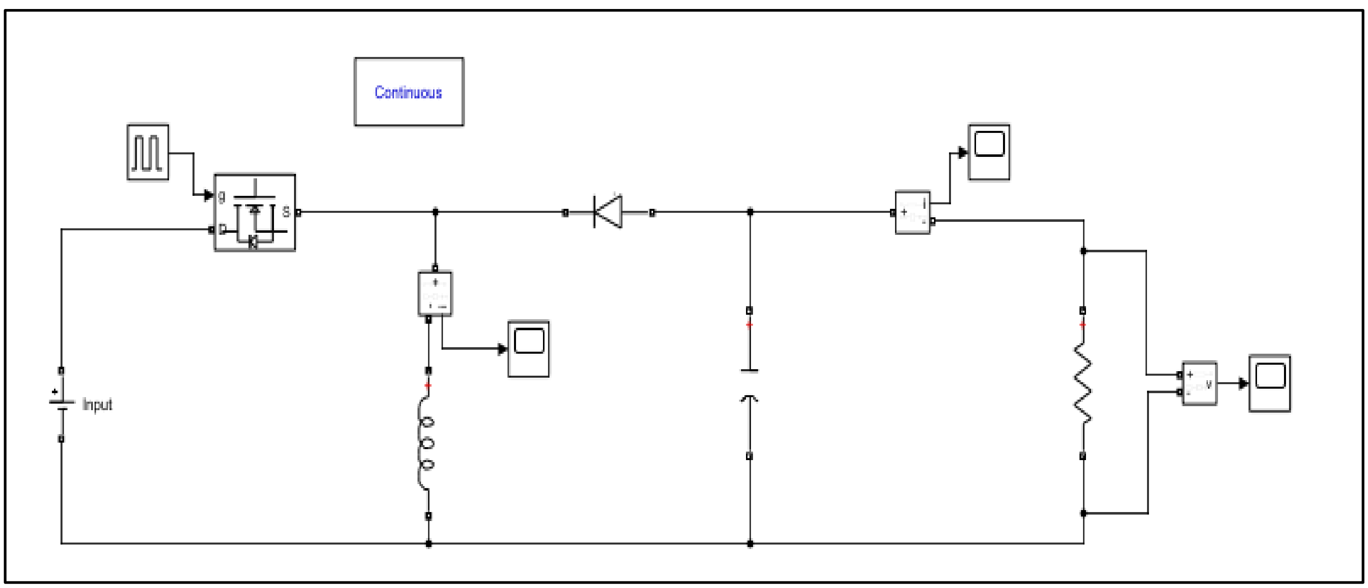

Figure 1: DC-DC Buck Boost Converter

Output Voltage with D = 0.4:

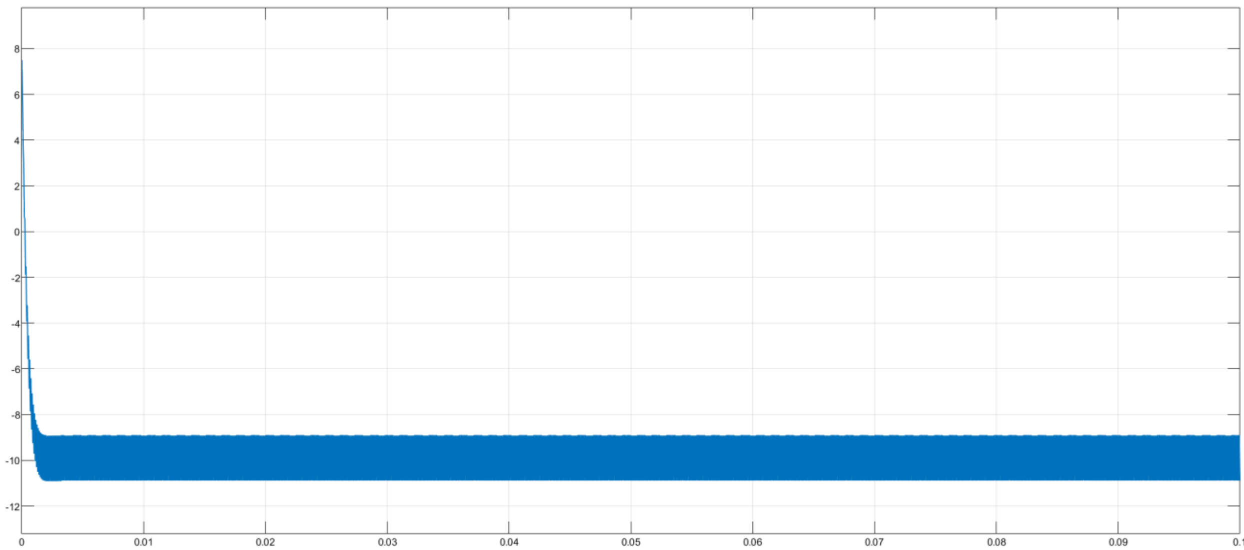

Figure 2: Output Voltage Waveform (D=0.4)

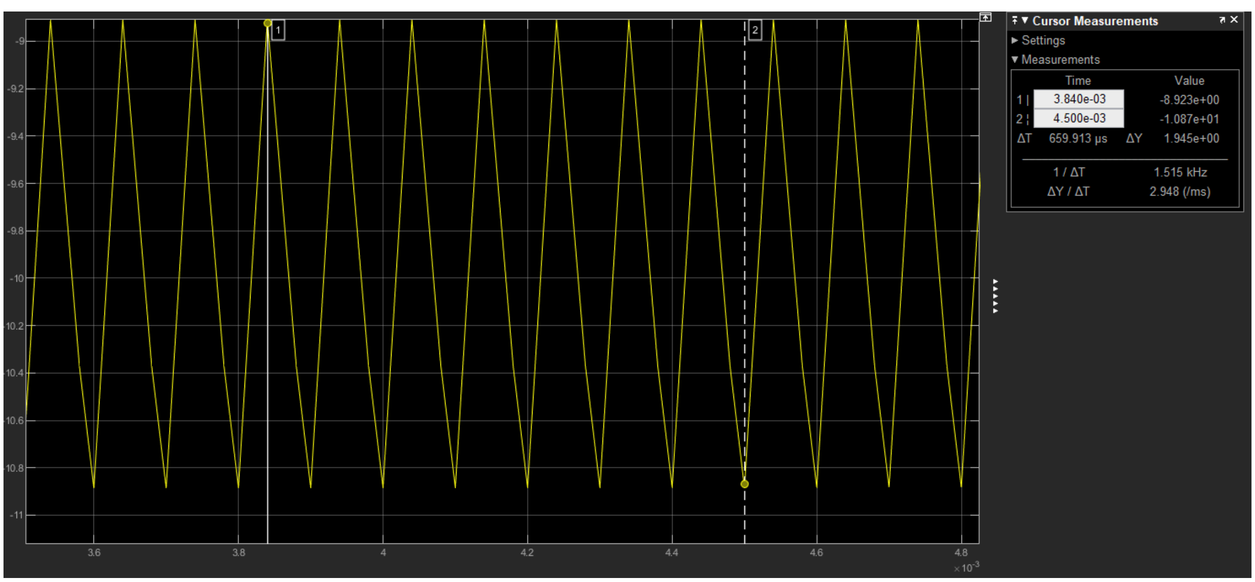

Figure 3: Voltage Output Waveform with Vp-p = 1.945 Volts

The load perceives an average output of 10 V, calculated as 15 times the ratio of 0.4 to 0.6 V, as depicted in Fig.3. Fig.1 provides an overview of the voltage measurement, with a closer look in Fig.2. Both images reveal voltage fluctuations between maximum and minimum values, ultimately influencing the average output experienced by the load. The peak-to-peak ripple in the output voltage is measured at 1.945 V.

<u>Inductor Current with D = 0.4:</u>

The simulation records the inductor current over the entire duration, with the findings visualized in Fig.4. The inductor current demonstrates fluctuations between its minimum and maximum values. Fig.5 provides a closer examination, complete with measurements, revealing a peak-to-peak current ripple of 1.183 A.

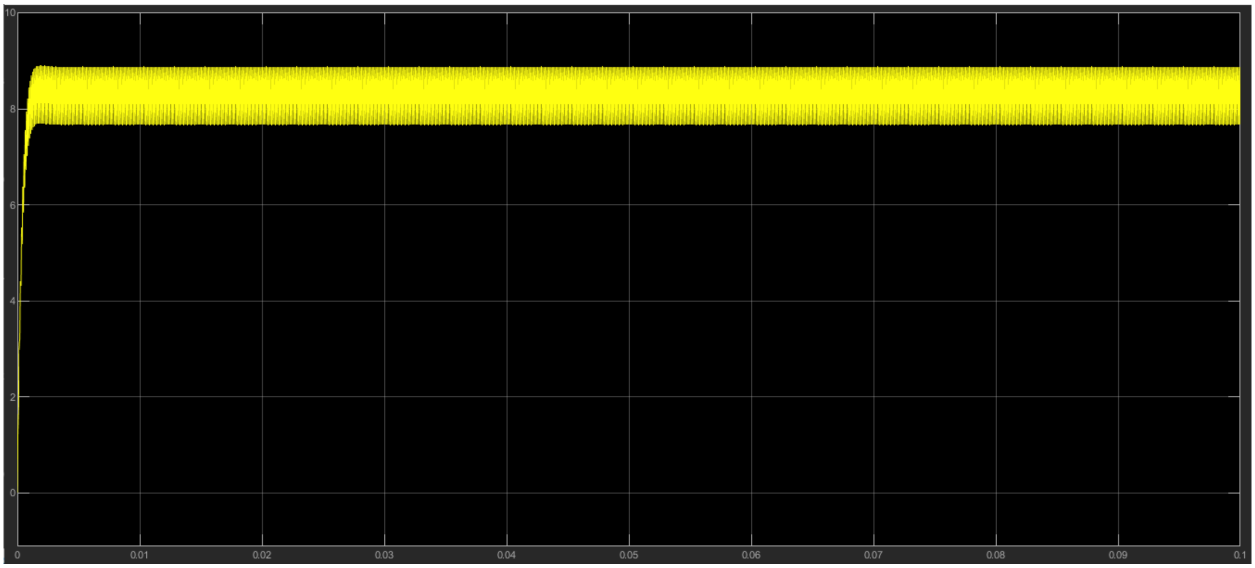

Figure 4: Output Inductor Current at D=0.4

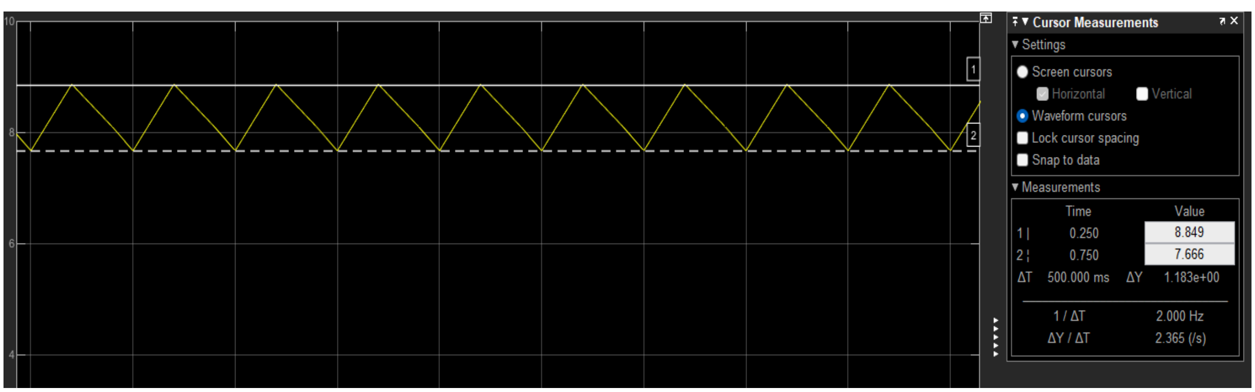

Figure 5: Output Inductor Current with Ip-p = 1.183 A

Output Voltage with D = 0.7:

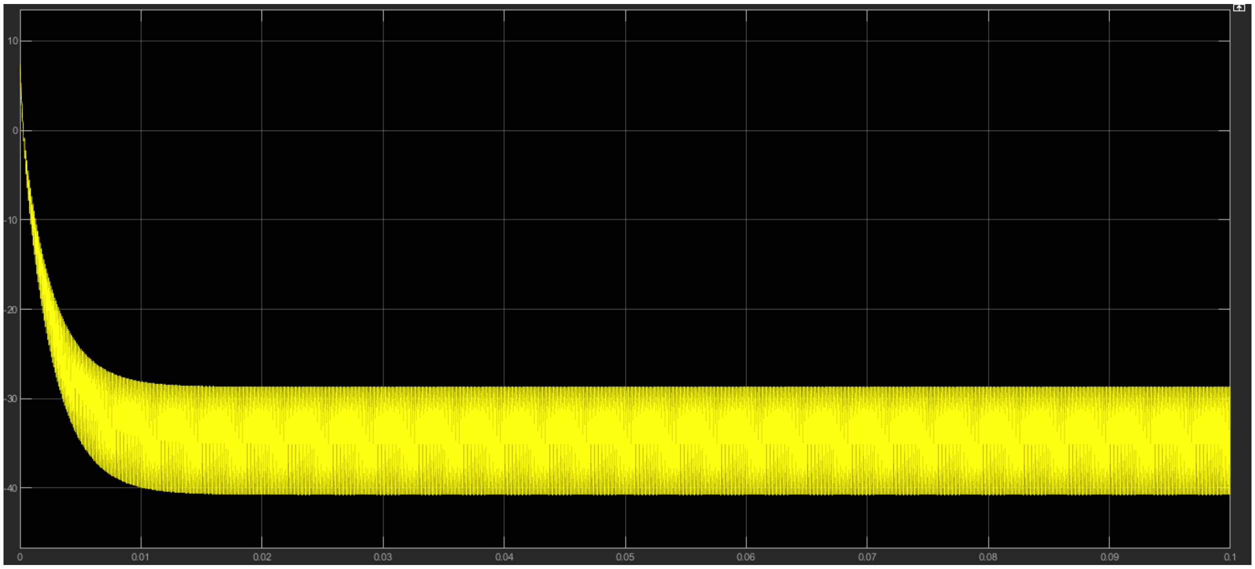

Figure 6: Output Voltage Waveform (D=0.7)

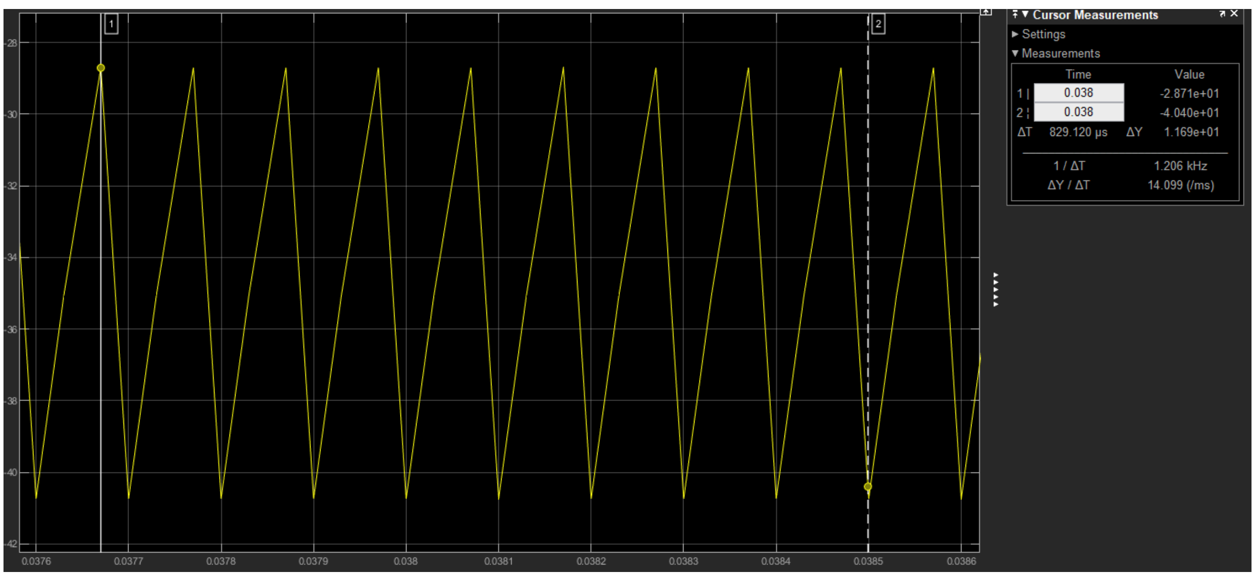

Figure 7: Voltage Output Waveform with Vp-p = 11.69 Volts

By adjusting the pulse width parameter to 70%, a transformation in the converter's operation occurs, shifting it from a buck to a boost converter. This modification results in an increased input voltage, reflected in the output. The output voltage measures 35 V, calculated as 15 times the ratio of 0.7 to 0.3 V, as illustrated in Fig.6. The impact of this change is further evident in Fig.7, where the peak-to-peak voltage ripple is observed to be 11.69 V.

Inductor Current with D = 0.7:

The inductor current is monitored in the context of a buck-boost converter with a duty cycle ratio set to 0.7. The comprehensive representation of inductor current is depicted in the subsequent figures. Notably, the peak-to-peak inductor current ripple is measured at 2.07 A.

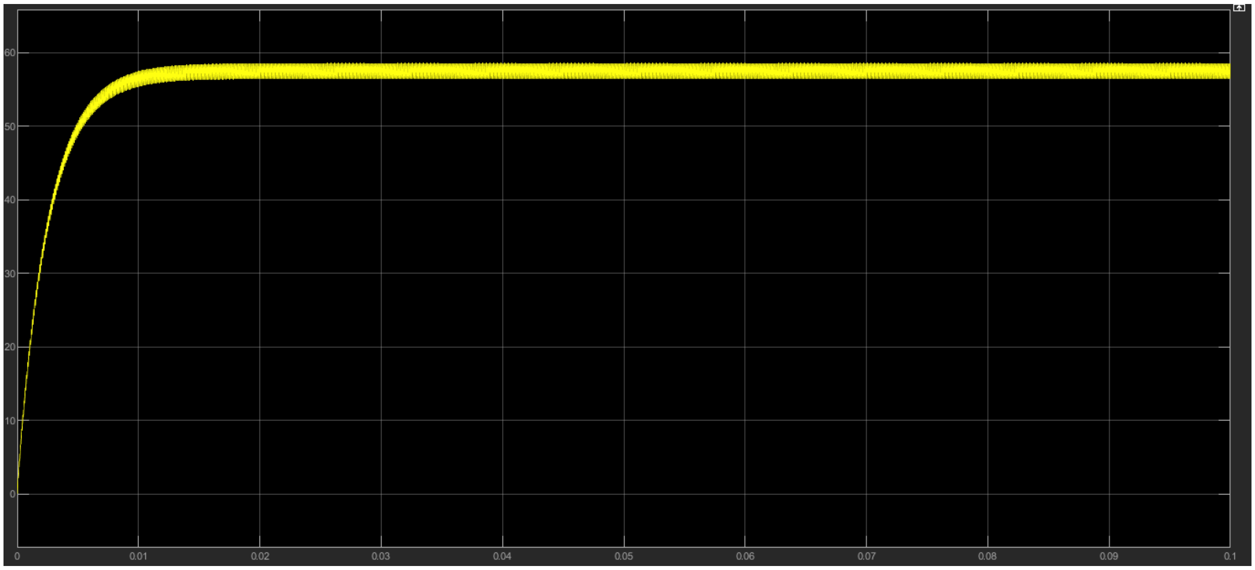

Figure 8: Output Inductor Current at D=0.7

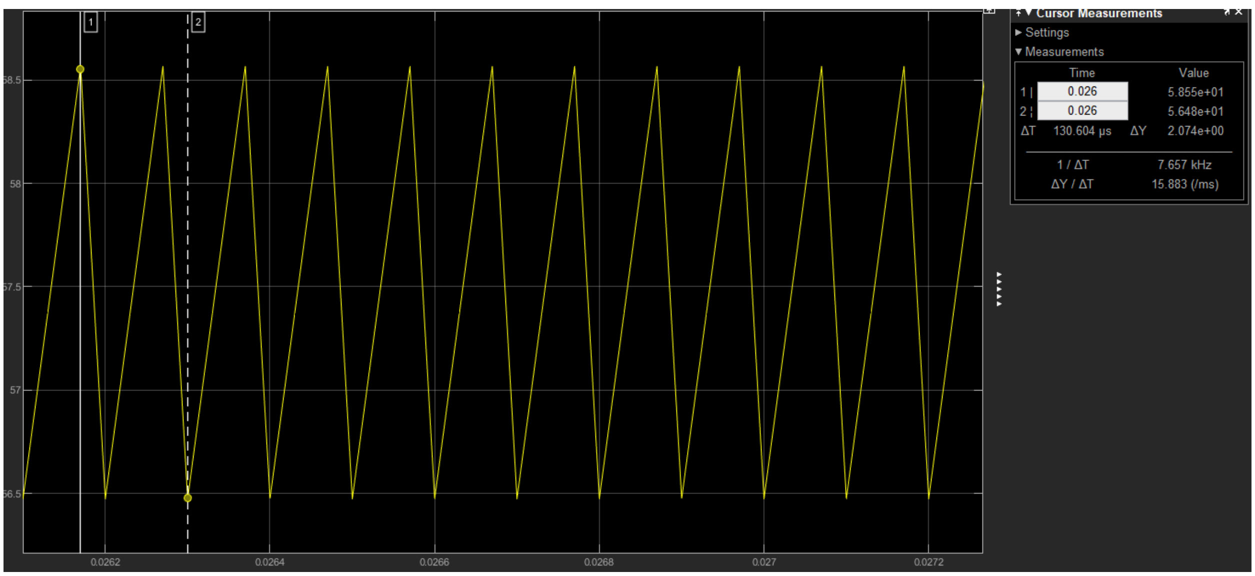

Figure 9: Output Inductor Current with Ip-p = 2.07 A

2. **Simulate single-phase bipolar and unipolar PWM inverters separately with following specifications:**

   - **DC Voltage Source: 250 V**
   - **Load: R=10 Ω, and L=10 mH**
   - **Nominal frequency: 50 Hz**
   - **Amplitude modulation ratio: 0.9**
   - **Frequency modulation ratio: 20**

Show the output voltage and current of each case (i.e. bipolar and unipolar PWM inverters) in your report. Also, measure the THD of the load current in each case and compare the results.

<u>Solution:</u>

The circuit diagram for a single-phase unipolar PWM can be seen below:

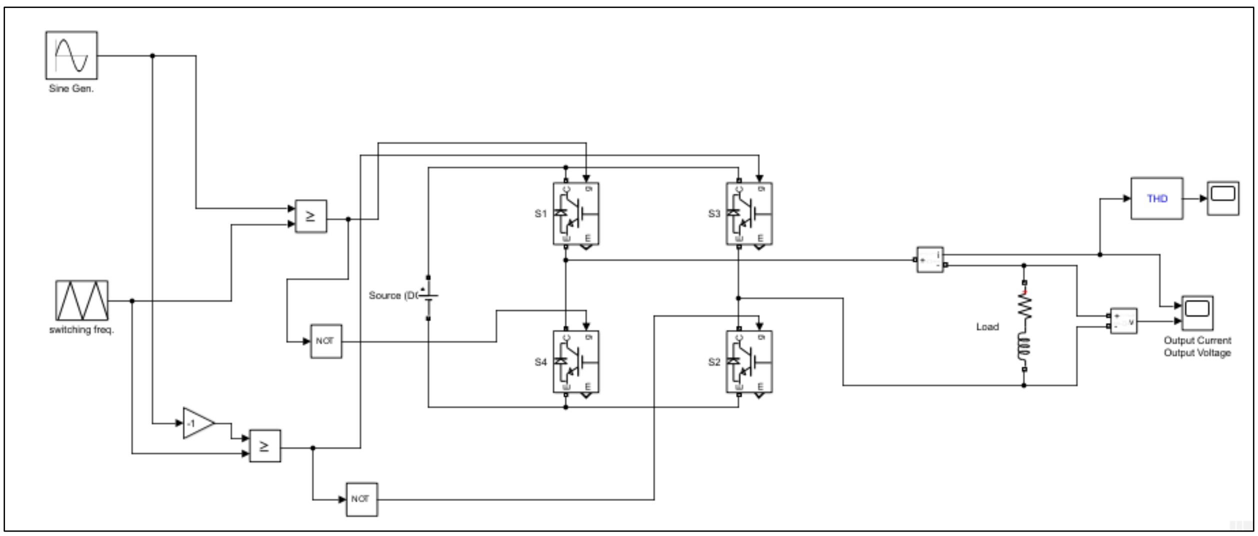

Figure 11: Single Phase Unipolar PWM

In the context of this switching technique in inverters, the output voltage levels dynamically fluctuate between +Vdc, -Vdc, and zero. Single-phase inverters employ four switches, each receiving distinct PWM signals derived from the reference and carrier signals.

The operational logic is as follows:

1. Switch 1 turns ON when the reference signal surpasses the carrier signal.
2. Switch 4 turns ON when switch 1 is in the OFF state, preventing short circuit conditions.
3. Switch 3 activates when the negative of the reference signal exceeds the carrier signal.
4. Switch 2 is triggered only when switch 3 is in the OFF state.

Fig.12 (a) provides a comprehensive view of the output voltage and current waveforms, while Fig.12 (b) focuses on the waveform from t=0.02 to 0.06 seconds. The output voltage exhibits variable widths, including zero levels, resulting in an approximate sinusoidal waveform delivered to the load. The output voltage alternates between +Vdc, zero, and -Vdc. Additionally, the output current manifests as an approximate sinusoidal waveform.

The total harmonic distortion of the load (output) current is quantified at 0.021, equivalent to approximately 2%.

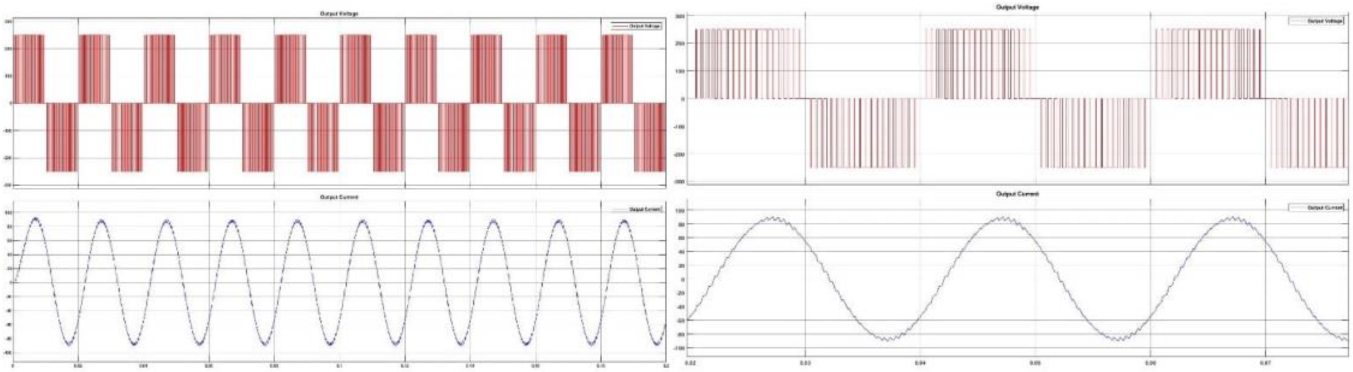

Figure 12 (a) & (b): Output Voltage and Current of a Unipolar PWM

The circuit diagram for a single-phase bipolar PWM can be seen below:

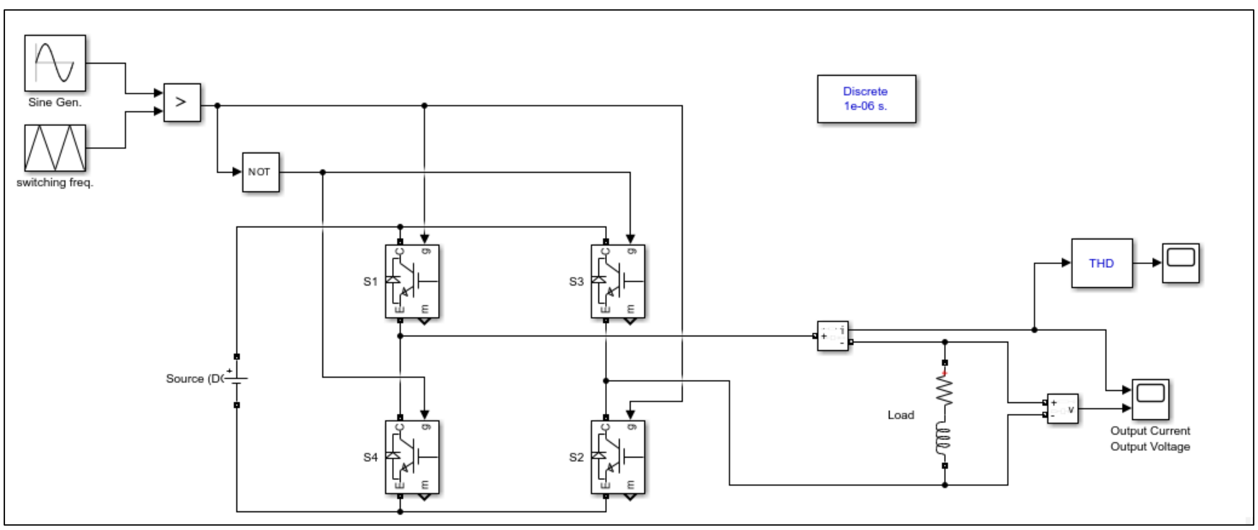

Figure 13: Single Phase Bipolar PWM

As indicated earlier, the output voltage levels are observed at +250V and -250V. The switching pattern is determined by comparing the reference signal with the carrier signal. Specifically, when the reference signal exceeds the carrier signal, the output is +Vdc; otherwise, it is -Vdc.

Fig.14 (b) specifically illustrates the output voltage and current waveforms from t=0.02 to 0.06 seconds. The varying widths of the output voltage contribute to an approximate sinusoidal voltage waveform delivered to the load. Notably, the output voltage oscillates between +Vdc and -Vdc. Simultaneously, the output current exhibits an approximate sinusoidal pattern.

The total harmonic distortion of the load (output) current is quantified at 0.07, approximately corresponding to 7%.

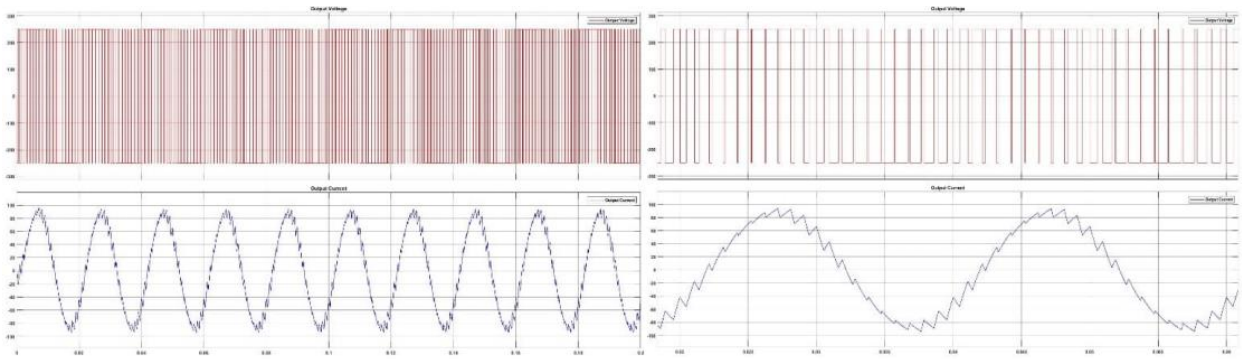

Figure 14 (a) & (b): Output Voltage and Current of a Bipolar PWM