PW ADVANCED POWER ELECTRONICS

PW 1
DC/ DC Converter
Chopper

Objective :

The objective of this practical work is to teach the student the design and simulation of different DC/DC converters using MATLAB/SIMULINK by considering the comparison between these models

Reminder

The role of a static converter in power electronics is to adapt the shape, voltage, current or frequency of a source of electrical energy to send it to a load with an efficiency close to 1.

Power components are transistors, thyristors, diodes, inductors, and capacitors.

In this lab, different types of choppers will be presented. A chopper transforms a positive DC voltage power source into a DC output voltage of different value.

The main applications are DC motor drives and low voltage switching power supplies.

1.1. Chopper BOOST

The step-up “Boost” chopper allows you to obtain an output voltage higher than the supply voltage.

The applications are also numerous, we can cite the flash of cameras, electronic systems powered by 1.5V, electric vehicles (200V batteries->500V motor). Conduction is assumed to be continuous in the inductor - output voltage is constant.

• When the transistor conducts from 0 to αT, Vt is 0, the diode is blocked, the inductor accumulates energy

• When it is blocked, from αT to T, the diode is conducting, the inductance restores the current into the load and therefore Vt=Vs

The average voltage across an inductor is zero, therefore:

$Vt_{moy}=Vi = (1-\alpha)\ Vo$ (with $0<\alpha<1$) and therefore:

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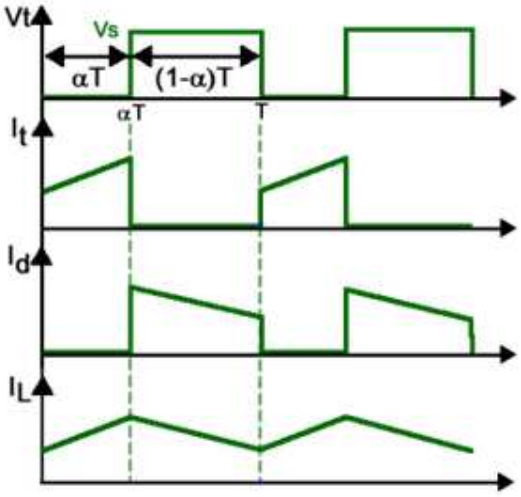
$$V_{smoy} = \frac{V_i}{1-\alpha} > (V_i)$$



1.2. Chopper Buck

The most common chopper is the serial step-down chopper:

The freewheeling diode allows the continuity of the current when the transistor blocks, and thus avoids an overvoltage across the inductance which is destructive to the transistor.

α is the duty cycle of mli (0 <α <1), if the conduction is continuous the average output voltage is:

$$V_{smoy} = \alpha V_i$$

Continuous conduction We speak of continuous conduction when the current is always strictly positive in the load and does not cancel out. From 0 to αT, the transistor is conducting, the output current increases exponentially with a time constant $\tau = \frac{L}{R}$:

$$I_o = \left(I_{min} + \frac{(E - V_i)}{R}\right) \times e^{\left(\frac{-t}{\tau}\right)} - \frac{(E - V_i)}{R}$$

- • From αT to T, the diode conducts, Vs is zero, the transistor is blocked, the current decreases exponentially through the diode:

$$I_o = \left(I_{MAX} + \frac{E}{R}\right) \times e^{\left(\frac{-t}{\tau}\right)} - \frac{E}{R}$$

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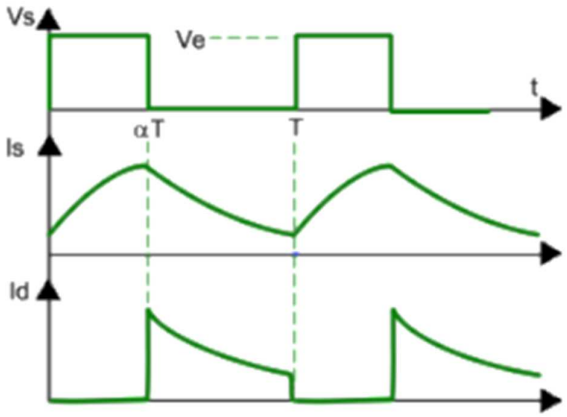

1.3. Chopper Buck-Boost

The buck–boost converter is also called a step-down–step-up converter due to its ability to provide a lower or higher voltage than that applied at its input. This depends on the value of the duty cycle.

α is the duty cycle of mli (0 <α <1), if the conduction is continuous the average output voltage is:

$$V_o = -\frac{\alpha V_i}{(1-\alpha)}$$

- When the transistor conducts from 0 to αT, the controlled switch is closed (passing). The diode is opened and the inductor stores the energy supplied by the input generator.

$$V_L = L\frac{di_L}{dt} = V_i > 0$$

- When it is blocked, from αT to T we open the controlled switch and the diode becomes conducting. The inductor returns its energy to the load.

$$V_L = L\frac{di_L}{dt} = V_o$$

Note: Note that the direction of the output voltage is reversed compared to the two cases.

$$I_o = \left(I_{TMAX} - \frac{\Delta i_L}{R2}\right)$$

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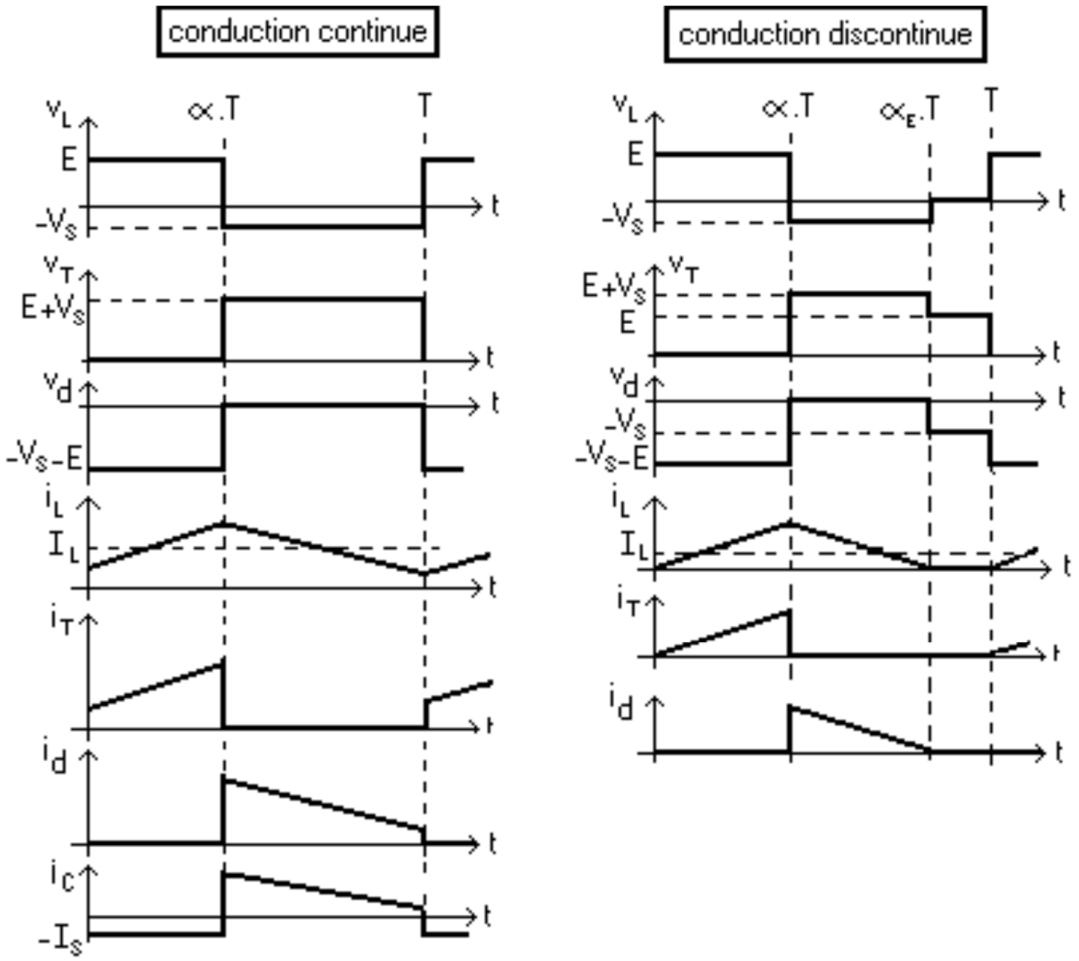

1- <u>Handling :</u>

Questions :

• Carry out the assembly of the following figures independently by PC on Matlab/SIMULINK.

• View the current, the voltage at the switch terminals as well as the pulsations at the trigger terminal.

<u>2.1- DC /DC Converter step-up (Boost chopper)</u>

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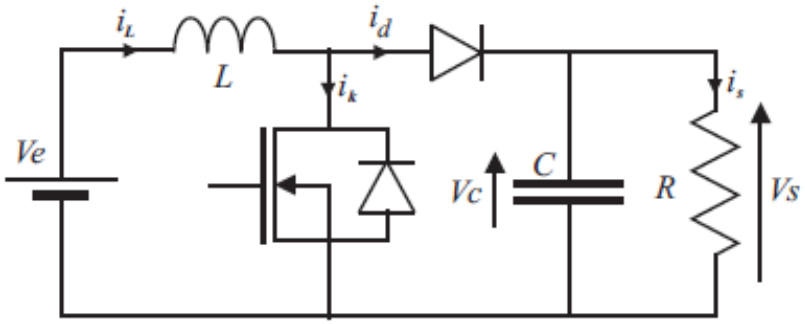

Figure 1. BOOST Chopper.

Requirement and specifications :

1. Output voltage= 30V.
2. Input voltage=12v.
3. Output voltage ripple = 1%.
4. Resistance=50Ω.
5. Output voltage :

$$V_o = \frac{V_i}{1-D}$$

So : *D=0,6.*

• If the switching frequency is 25 KHz, the minimum direct current inductance is determined as follows:

$$L_{min} = \frac{D(1-D)^2 R}{2f} = 96\mu H$$

- • To ensure direct current, we put L=120µH.

The inductance current:

$$I_L = \frac{V_o}{(1-D)^2 R} = 1.5A$$

• The minimum capacitance requires limiting output voltage ripples to 1% is:

$$C \geq \frac{D}{R\left(\Delta V_o / V_o\right) f} = 48\mu F$$

2.2- DC/DC Convertisser Step-down (Buck chopper)

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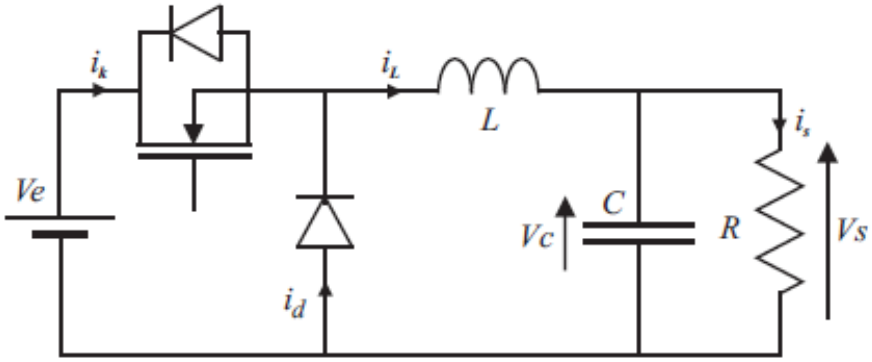

Figure 2. BUCK Chopper.

Requirement and specification :

1. Input voltage (Ve)= 20V.
2. Output voltage (Vs)=10V.
3. Frequence=10KHz.
4. Output power (Ps)= 10W.
5. Ripple of current= 5%.
6. Ripple of voltage= 10%.

Data :

- If Vi=20V and Vo=10V therefore D=0.5.
- The output current :

$$Io = \frac{P}{V_s} = \frac{10}{10} = 1A$$

- Ripple of courant :

$$\Delta I_L = 0.05$$

- Input current :

$$I_i = D \times I_o = 0.5 \times 1 = 0.5A$$

- Inductance :

$$L = \frac{V_o(1-D)}{\Delta I_L \times f} = 10mH$$

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- Capacitance :

$$C = \frac{\Delta I_L}{8 \times \Delta V_o \times f} = 6.25\mu F$$

- Resistance of load :

$$R = \frac{V_o}{I_o} = 10\Omega$$

2.3- DC/DC Converter (Buck/ Boost chopper)

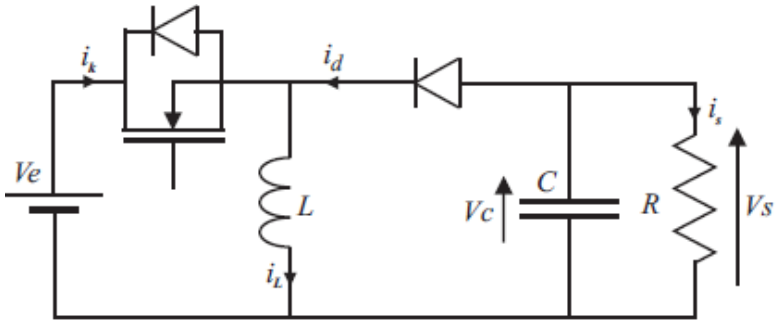

Figure 3. BUCK-BOOST Chopper.

Requirement and specification :

1. Output voltage (Vs)=16V.
2. Input voltage (Ve)=24V.
3. Resistance R=5Ω.
4. Frequence =100KHZ.
5. Ripple of output voltage (ΔVo)=1%.

- Calculation of peak-to-peak current ripple in inductor L.

$$\Delta i_L = \frac{\alpha E}{Lf}$$

- Calculation of output voltage ripple.

$$\Delta V_s = \frac{\alpha^2 V_e}{(1-\alpha)RCf}$$

- Calculation of inductor.

$$L = -\frac{\alpha^2 {V_e}^2}{2V_s If}$$