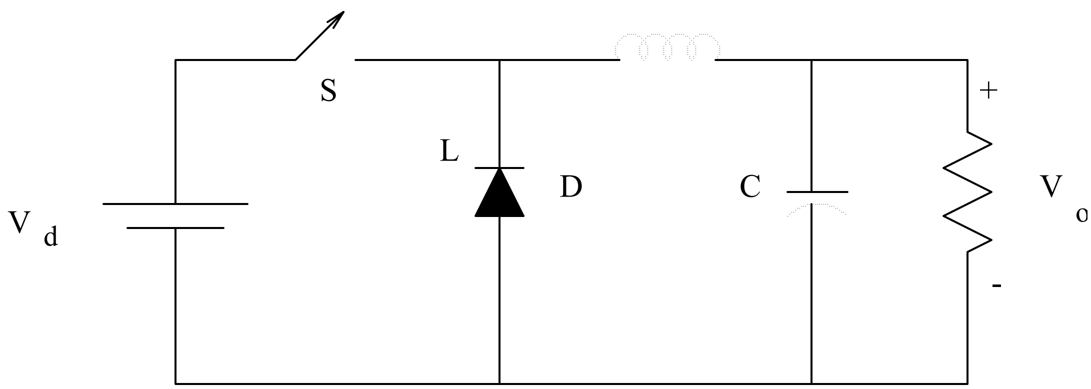
ECE 320: Lecture 39

Notes

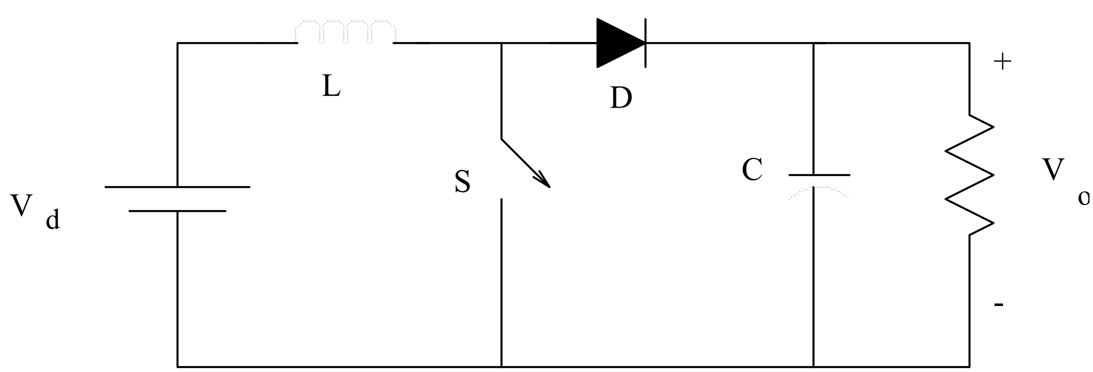
Single Switch DC-DC Converter Configurations:

1. Buck Converter (or down converter). The output voltage is less than or equal to the input volta



$$\frac{V_o}{V_d} = D \qquad \frac{I_o}{I_d} = \frac{1}{D}$$

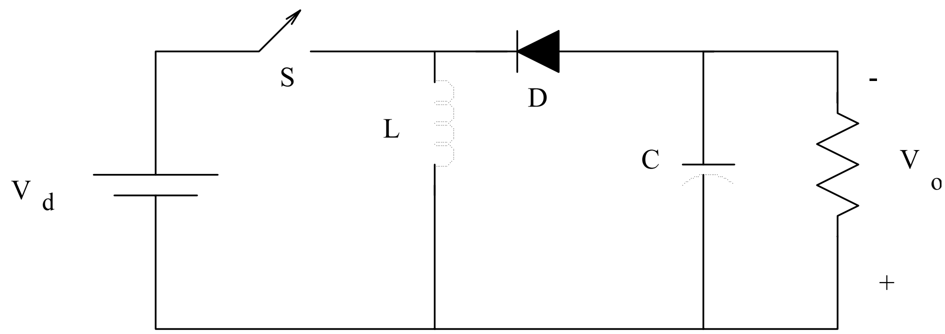
2. Boost Converter (up converter). The output voltage larger than the input voltage. The inductor current is on the input, and it is pumped up with the switch.



Ideal, steady-state continuous conduction:

$$\frac{V_o}{V_d} = \frac{1}{1 - D} \qquad \frac{I_o}{I_d} = 1 - D$$

3. Buck-Boost Converter (up/down converter). The output voltage can be smaller or larger than the input voltage. The inductor current is now an intermediate stage. Note output voltage polarity



Ideal, steady-state continuous conduction:

$$\frac{V_o}{V_d} = \frac{D}{1 - D} \qquad \frac{I_o}{I_d} = \frac{(1 - D)}{D}$$

Polarity of the voltage and the current is reversed from the other two topologies.

Boundary of Discontinuous Conduction Through The Inductor:

- Boost Converter

When switch is closed, the slope of the inductor current is: :

$$\frac{\Delta i_L}{t} = \frac{Vd}{L}$$

When the switch is open, the slope is:

$$\frac{\Delta i_L}{t} = \frac{Vd - Vo}{L}$$

Since the current follows these slopes while the switch position is maintained, in continuous counduction the steady-state Current Ripple in inductor is:

$$\Delta i_L = \frac{Vd}{L} \cdot D \cdot T_s = \frac{(Vd - Vo)}{L} \cdot (1 - D) \cdot T_s$$

The average input current is now the average current through the inductor

Power Balance:

$$Po = \frac{Vo^2}{R} \quad \text{and} \quad \frac{V_o}{V_d} = \frac{1}{1-D}$$

So:

$$Po = \frac{Vd^2}{(1-D)^2 \cdot R}$$

But: $Po = Pi = Vd \cdot I_{Lave}$

Therefore: $$\frac{Vd^2}{(1-D)^2 \cdot R} = Vd \cdot I_{Lave} \quad \text{or} \quad I_{Lave} = \frac{Vd}{(1-D)^2 \cdot R}$$

Adding on the current ripple, the minimum current through the inductor is:

$$I_{Lmin} = I_{Lave} - \frac{\Delta i_L}{2}$$

Adding on the current ripple, the maximum current through the inductor is:

$$I_{Lmax} = I_{Lave} + \frac{\Delta i_L}{2}$$

At the boundary of discontinuous conduction we see:

$$I_{Lmin} = 0 = \frac{Vd}{(1-D)^2 \cdot R} - \left(\frac{Vd}{2 \cdot L}\right) \cdot D \cdot T_s$$

So, we can determine Lmin by solving this equation for L:

$$Lmin = \frac{D \cdot (1-D)^2 \cdot R \cdot T_s}{2}$$

We can also state this in terms of voltages and currents using:

$$R = \frac{Vo}{Io} \qquad I_{oB} = (1 - D)\cdot Id = (1 - D)\cdot I_{LB}$$

$$Lmin = \frac{D\cdot(1 - D)^2\cdot Vo\cdot T_s}{2\cdot I_{oB}} = \frac{D\cdot(1 - D)\cdot Vo\cdot T_s}{2\cdot I_{LB}}$$

or in terms of the output current at the boundary:

$$I_{oB} = \frac{D\cdot(1 - D)^2\cdot Vo\cdot T_s}{2\cdot Lmin}$$

- Buck-Boost Converter

When switch is closed, the slope of the inductor current is: :

$$\frac{\Delta i_L}{t} = \frac{Vd}{L}$$

When the switch is open, the slope is:

$$\frac{\Delta i_L}{t} = \frac{Vo}{L}$$

Since the current follows these slopes while the switch position is maintained, in continuous counduction the steady-state Current Ripple in inductor is:

$$\Delta il = \frac{Vd}{L}\cdot D\cdot T_s = \frac{(-Vo)}{L}\cdot(1 - D)\cdot T_s$$

Now the inductor current isn't the input current or the output current. It is only an intermediate ste|

- At the boundary between continuous and discontinuous conduction, we will have:

$$I_{LB} = \frac{1}{2}\cdot I_{Lpeak} = \frac{\Delta i_L}{2} = \left(\frac{1}{2\cdot L}\right)\cdot D\cdot T_s\cdot Vd$$

or we could also write this in terms of Vo as:

$$I_{LB} = \left(\frac{1}{2\cdot L}\right)\cdot D\cdot T_s\cdot\left(\frac{1-D}{D}\right)\cdot Vo = \left(\frac{1}{2\cdot L}\right)\cdot T_s\cdot(1-D)\cdot Vo$$

or

$$Lmin = \left(\frac{1}{2\cdot I_{LB}}\right)\cdot T_s\cdot(1-D)\cdot Vo$$

However we usually want this in terms of the output current. If we write a node equation at the terminal of the inductor

$$Io = I_L - Id \qquad \text{or}$$

$$I_L = Io + Id = Io + Io\cdot\left(\frac{D}{1-D}\right) = Io\left(\frac{1-D+D}{1-D}\right) = \frac{Io}{1-D}$$

$$I_{LB}(1-D) = \left[\left(\frac{1}{2\cdot L}\right)\cdot T_s\cdot(1-D)\cdot Vo\right]\cdot(1-D)$$

$$I_{oB} = \left(\frac{Vo}{2\cdot L}\right)\cdot T_s\cdot(1-D)^2$$

Uncontrolled Rectifier Circuits (Chapter 5)

- We have discussed the use of DC-DC converters to regulate a dc voltage to level different tha the input dc voltage.
- But we haven't discussed where this dc voltage comes from.
- In most applications we start with the 120Vrms from a wall outlet
- Now we want to convert that dc with a rectifier circuit
- Next week we will combine the rectifier with a transformer and a dc-dc converter in one circu