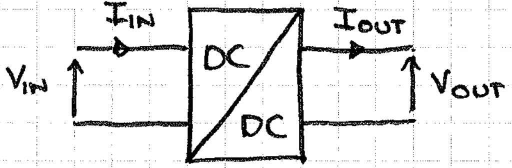
12R015 - INDUCTORS IN POWER ELECTRONICS 3-MAR-12

Aim - emphasize the importance of inductors in power electronic circuits and provide an introduction to their analysis

1. BACKGROUND

Without inductors or the inductance inherent in electromagnetic devices, many power electronic topologies such as DC/DC and inverters would not operate. They are more important than capacitors.



In a DC/DC converter, inductance is essential to produce either:

$V_{OUT} > V_{IN}$ or $I_{OUT} > I_{IN}$

(Note: it is not possible to achieve this with a linear circuit.)

2. ANALYSIS

The key equations for inductors are:

$$V = L\cdot\frac{di}{dt} \quad \text{and} \quad i = \frac{1}{L}\int v\cdot dt$$

The first equation is the key to producing $V_{OUT} > V_{IN}$. By producing large values of di/dt in the inductor we can obtain (theoretically) arbitrarily large output voltages.

The second equation is the key to inductor analysis. It states the inductor current is proportional to the integral of the inductor voltage.

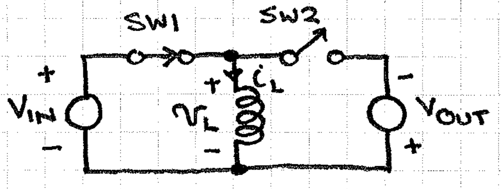
In a DC/DC converter, during one part of the switching cycle positive voltage is applied to the inductor and its current ramps up. In another part of the switching cycle, negative voltage is applied to the inductor, and its current ramps down.

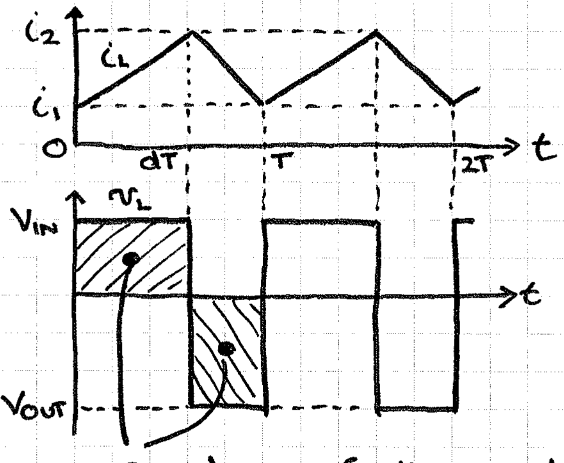
In the steady-state, it is assumed that the inductor current at the start and end of the switching cycle are equal.

Generally it is also assumed that the inductor current never goes to zero, that is, it is continuous.

3. BUCK-BOOST EXAMPLE

Consider a buck-boost DC/DC converter:





During the first part of the switching cycle, switch SW1 is closed and SW2 is open. The inductor voltage $v_L = V_{IN}$ and hence the inductor current increases linearly at a rate $di/dt = V_{IN}/L$.

Consider the switching cycle has a period T, and a duty-cycle

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d, so the first part of the cycle has an interval of dT, and the second part has an interval of (1-d)T.

During the second part of the cycle, switch SW1 is open and SW2 is closed. The inductor voltage $v_L = -V_{OUT}$ and hence the inductor current decreases linearly at a rate $di/dt = -V_{OUT}/L$.

In the steady-state, the current at the start and end of the cycle must be equal. For this to occur, in the voltage vs time curve for the inductor, the positive area under the curve, must equal the negative area. These areas are measured in volt-seconds and so this principle is referred to as the volt-seconds balance.

For the buck-boost converter this means:

$$\underbrace{V_{IN} \times dT}_{\text{positive area}} = \underbrace{V_{OUT} \times (1-d)T}_{\text{negative area}}$$

or, $$V_{IN}\,d = V_{OUT}(1-d)$$

thus $$V_{OUT} = V_{IN} \times \frac{d}{1-d}$$

Thus for the buck-boost converter we have used the volt-seconds balance principle to determine a simple relationship between the ratio of its output and input voltages which is affected by the duty-cycle.

"Jesus said to him, "I am the way, the truth, and the life. No one comes to the Father except through me. John 14:6 (NKJV)