Inductor selection for switching regulators

Overview

In switching regulator applications the inductor is used as an energy storage device. When the semiconductor switch is on the current in the inductor ramps up and energy is stored. When the switch turns off energy is released into the load. The amount of energy stored is calculated by the formula

\[ \text{Energy} = \frac{1}{2} LI^2 \] (Joules), where:

- \( L \) is the inductance in Henrys
- \( I \) is the peak value of inductor current

The amount by which the current changes during a switching cycle is known as the ripple current. Ripple current is defined as

\[ V_l = L \frac{di}{dt} \]

where:
- \( V_l \) is the voltage across the inductor
- \( di \) is the ripple current
- \( dt \) is the duration for which the voltage is applied

Inductor current is made up of AC and DC components (Figure 1). The AC component is high frequency and will flow through the output capacitor because it has a low HF impedance. A ripple voltage is produced due to the capacitor 'equivalent series resistance' (ESR) that will appear at the output of the switching regulator. This ripple voltage needs to be sufficiently low as not to effect the operation of the circuit the regulator is supplying, normally in the order of 10-500 mVpk-pk. Selecting the correct ripple current impacts the size of the inductor and output capacitor. The capacitor needs to have a sufficiently high ripple current rating or it will overheat and dry out. To achieve a good compromise between inductor and capacitor size a ripple current value of 10-30% of maximum inductor current should be chosen. The current in the inductor will be continuous for output currents greater that 5-15% of full load.

Figure 1. Buck inductor operation
The following parameters need to be defined or calculated to select an inductor:
- Maximum input voltage
- Output voltage
- Switching frequency
- Maximum ripple current
- Duty cycle

**Inductor selection: Buck converters**

![Buck inductor example](image)

**Figure 2.** Buck inductor example.

**Figure 2 Application Parameters:**
- Switching frequency: 250 kHz
- Input voltage range: 12 V ± 10%
- Max ripple current: 220 mA
- Output Voltage: 5.0 V

**Step 1. Calculate the Duty Cycle**
- \( V_0 = \text{output voltage} \)
- \( V_i = \text{Max input voltage} \)
- \( D = V_0 / V_i \)
- \( D = 5/13.2 = 0.379 \)

**Step 2. Calculate the Voltage Across the Inductance**
- \( V_1 = V_i - V_0 \) (Switch on)
- \( V_1 = 13.2 - 5 = 8.2 \text{ V} \)
- \( V_1 = -V_0 \) (Switch off)
- \( V_1 = - V_0 = -5 \text{ V} \)

**Step 3. Calculate the Required Inductance**
- \( L = V_1 \cdot dt/di \)
- \( L = (8.2 \times 0.379/250 \times 10^3)/0.22 \)
- \( L = 56 \mu\text{H} \)

**Inductor selection: Boost inductor**

![Boost inductor example](image)

**Figure 3.** Boost inductor example.

**Figure 3 Application Parameters:**
- Switching frequency: 100 kHz
- Input voltage range: 4.5-5.5 V
- Max ripple current: 100 mA
- Output Voltage: 12.0 V

**Step 1. Calculate the Duty Cycle**
- \( V_0 = \text{output voltage} \)
- \( V_i = \text{Max input voltage} \)
- \( D = 1 - (V_i / V_0) \)
- \( D = 1 - (5.5/12.0) = 0.542 \)

**Step 2. Calculating the voltage across the inductance**
- \( V_1 = V_i \) (Switch on)
- \( V_1 = 5.5 \text{ V} \)
- \( V_1 = V_0 - V_i \) (Switch off)
- \( V_1 = 12 - 5.5 = 6.5 \text{ V} \)

**Step 3. Calculating the required inductance**
- \( L = V_1 \cdot dt/di \)
- \( L = (5.5 \times 0.542/100 \times 10^3)/0.1 \)
- \( L = 298 \mu\text{H} \)

**Typical Applications Using Inductors for Switching Regulators**

- Industrial Test Equipment
- Media Players
- Digital Cameras
- Laptop Computers
- Backlight Displays
- Mobile Phones
Inductor selection for switching regulators

### SD Inductor Families

**SD14 & SD25 Dimensions - mm**

**SD14 & SD25**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Rated Inductance (µH)</th>
<th>± 20%</th>
<th>Part Marking</th>
<th>I_{rms} Amps</th>
<th>I_{sat} Amps</th>
<th>DCR Ω</th>
<th>Typical</th>
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**Note:** SD10, 12, 18 and 20 not shown. For full product information and a listing of all available inductor values, visit [http://www.eaton.com/electronics](http://www.eaton.com/electronics), Data sheet number PM4311

**Typical SD Series Applications**

- Mobile phones
- Digital cameras
- Industrial test equipment
- Computers
- Uninterruptible power supplies
- Televisions

**Typical SD Series Uses**

- Buck and boost converters
- LED Drivers
- EL panel drivers
- Backlighting
- Noise filtering chokes