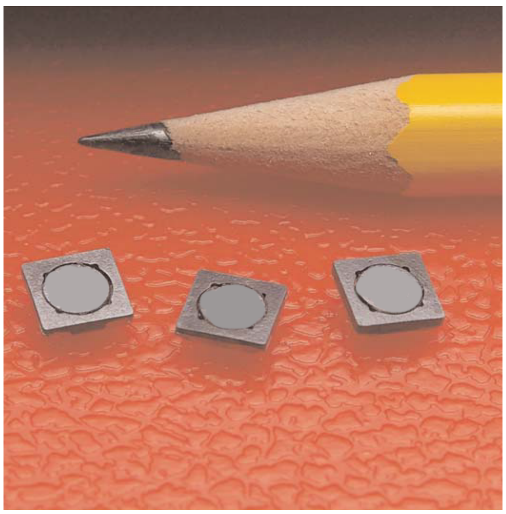
Inductor selection for switching regulators



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 **Energy = ½L.I²** (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 **Vl = L.di/dt:**

- Vl 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.

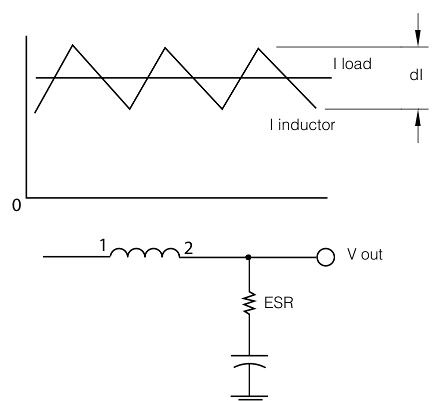


Figure 1. Buck inductor operation

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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

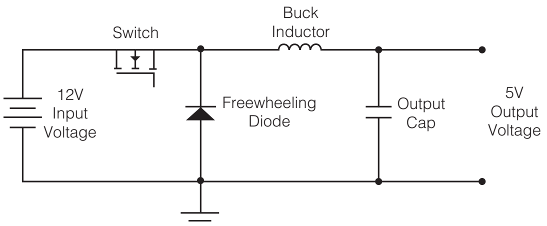


Figure 2. Buck inductor example.

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 = output voltage
- V_i = 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 V
- $V_1 = -V_0$ (Switch off)
- $V_1 = -V_0$ = - 5 V

Step 3. Calculate the Required Inductance

- $L = V_l.dt/di$
- L = (8.2 x 0.379/250 x 10^3)/0.22
- L = 56 µH

Inductor selection: Boost inductor

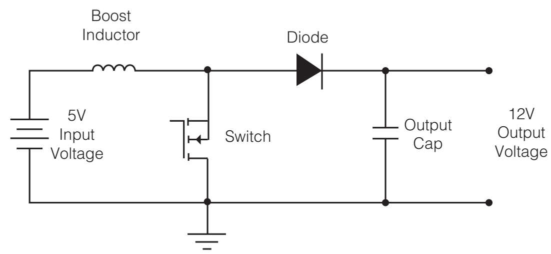


Figure 3. Boost inductor example.

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:

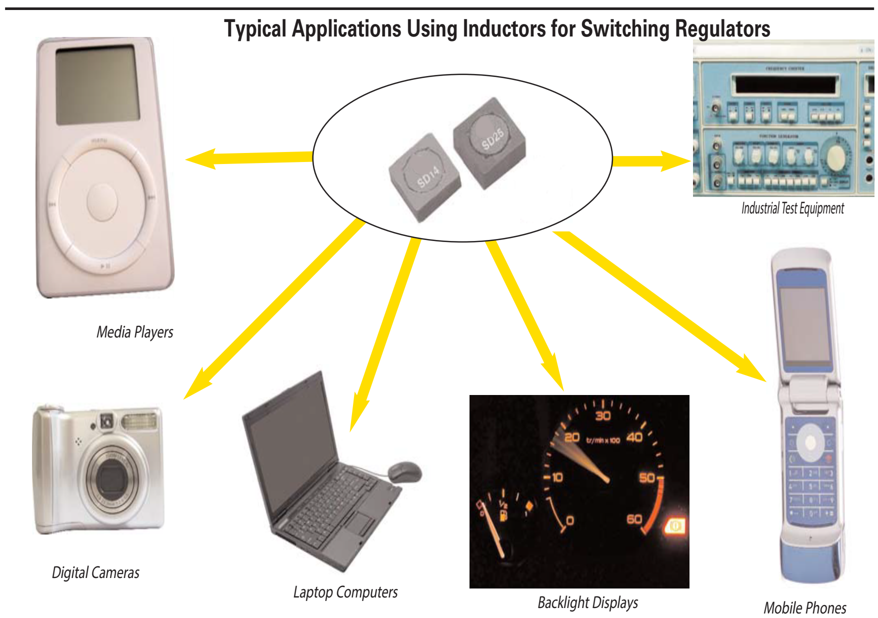
- V_0= output voltage
- V_i = Max input voltage
- $D = 1 - (V_i / V_0)$
- D = 1 – (5.5/12.0) = 0.542

Step 2. Calculating the voltage across the inductance

- $V_1 = V_i$ (Switch on)
- V_1 = 5.5V
- $V_1 = V_0 - V_i$ (Switch off)
- V_1 = 12 – 5.5 = 6.5 V

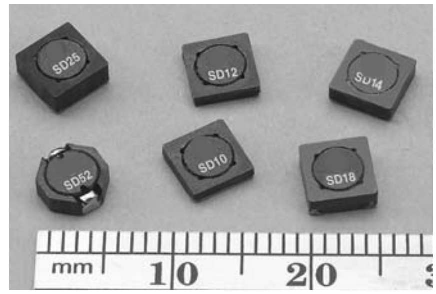
Step 3. Calculating the required inductance

- $L = V_l.dt/di$
- L= (5.5 x 0.542/100 x 10^3)/0.1
- L= 298 µH



SD14 & SD25 Part Number	Rated Inductance (µH)	OCL ± 20% µH	Part Marking	I_{rms} Amps	I_{sat} Amps	DCR Ω Typical
SD14-1R2-R	1.2	1.23	C	2.7	3.35	0.0344
SD14-1R5-R	1.5	1.63	D	2.53	2.91	0.0390
SD14-3R2-R	3.2	3.19	G	1.94	2.08	0.0663
SD14-6R9-R	6.9	6.98	J	1.35	1.41	0.1363
SD14-100-R	10	9.93	L	1.1	1.18	0.2058
SD14-220-R	22	21.93	N	0.806	0.793	0.3853
SD14-330-R	33	32.55	O	0.654	0.651	0.5852
SD14-470-R	47	47.57	P	0.525	0.538	0.9055
SD14-101-R	100	99.25	S	0.386	0.373	1.68
SD14-221-R	220	222	U	0.258	0.249	3.77
SD14-331-R	330	335.1	V	0.206	0.203	5.92
SD14-471-R	470	471.4	W	0.173	0.171	8.34
SD14-102-R	1000	1008	Z	0.126	0.117	15.8
SD25-1R2-R	1.20	1.15	C	3.33	3.81	0.0240
SD25-1R5-R	1.50	1.61	D	3.12	3.23	0.0274
SD25-2R2-R	2.20	2.14	E	2.93	2.80	0.0311
SD25-3R3-R	3.30	3.43	F	2.64	2.21	0.0384
SD25-4R7-R	4.70	5.03	G	2.39	1.83	0.0467
SD25-100-R	10.0	10.35	K	1.80	1.27	0.0824
SD25-220-R	22.0	22.81	M	1.34	0.857	0.1478
SD25-330-R	33.0	33.07	N	1.11	0.711	0.2149
SD25-470-R	47.0	47.89	O	0.919	0.592	0.3156
SD25-101-R	100	100.79	R	0.670	0.398	0.5937
SD25-151-R	150	148.4	S	0.553	0.328	0.8723
SD25-221-R	220	222.4	T	0.446	0.268	1.34
SD25-331-R	330	332.2	U	0.359	0.219	2.07
SD25-471-R	470	472.4	V	0.293	0.184	3.10

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, Data sheet number PM4311



SD Inductor Families

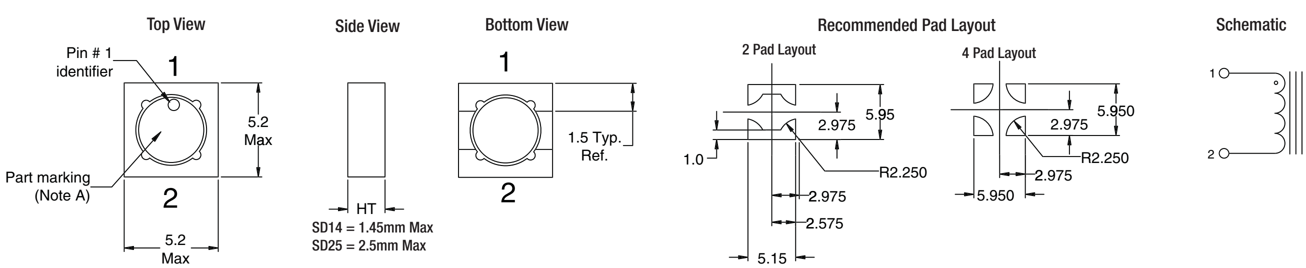
Typical SD Series Applications

- 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

SD14 & SD25 Dimensions - mm



Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
www.eaton.com/electronics

Printed in USA
Publication No. 4031
December 2017

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