Switching Power Supply Component Selection

7.2b Inductor Selection – Application

Role of Inductor in SMPS:

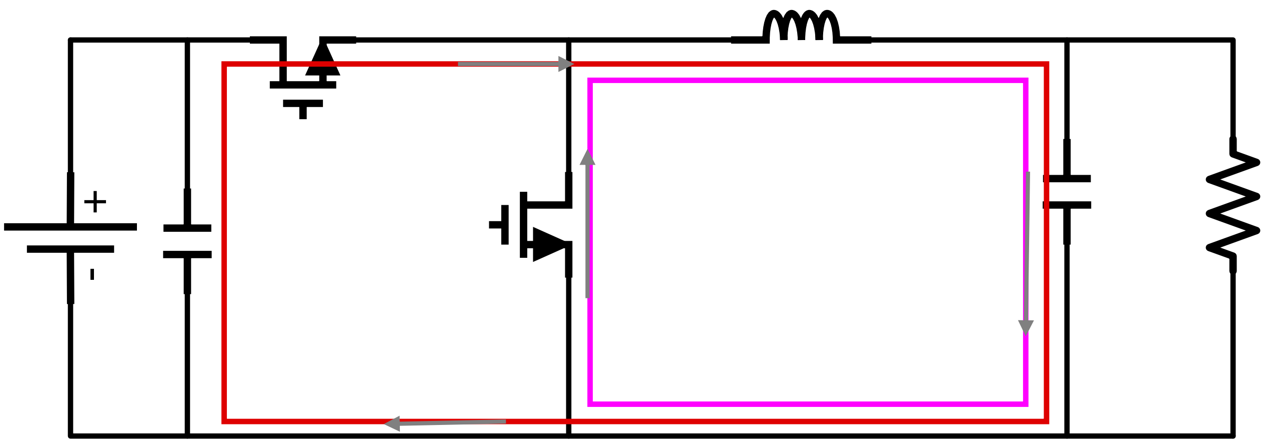
Buck Converter

$$v_L = L \times \frac{\mathrm{di}}{\mathrm{dt}}$$

Applied Voltage

a) Vg-Vo for high side turn on

b) -Vo when low side is on.



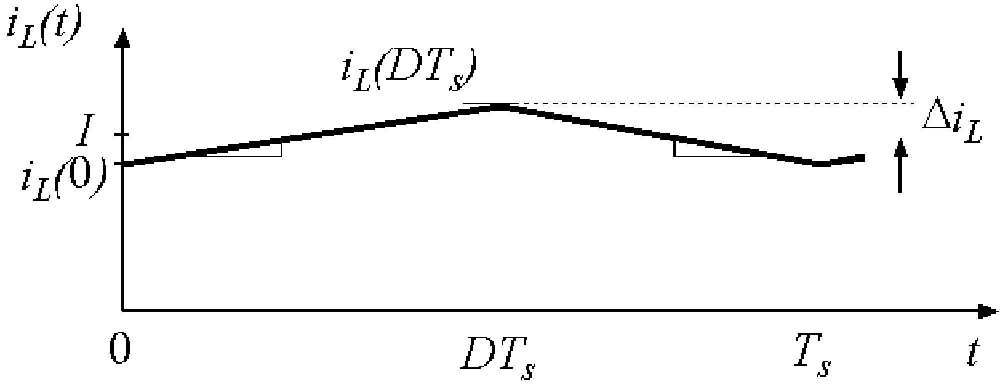
Inductor Selection Analysis

The AC ripple current in the inductor due to switching can be calculated as:

$$2\Delta i_L = \frac{V_g - V}{L} DT_s$$

You can rewrite this equation and solve for the inductance by determining the allowed current ripple in your design.

$$L = \frac{V_g - V}{2\Delta i_L f_s} D = \frac{V_g - V}{2\Delta i_L f_s} \frac{V}{V_g} = \frac{V}{2\Delta i_L} \frac{1}{f_{s\min}} \left(1 - \frac{V}{V_{g\max}}\right)$$



Inductor Selection Analysis

- Using the analysis of the previous page and a sample regulator specification, an inductor value will now be calculated.
- Consider the buck regulator product specifications shown below:

Buck Regulator Specs	Min	Typ	Max	Units
Vin	2.8		5.5	V
Vout		1.8		V
Fs	1.6	2	2.6	MHz
I lim	830	1020	1150	mA
Iout = 600mA				

- So as to not exceed the switch current limit, the maximum allowable I_{out} plus one half of the ripple current together can not exceed the minimum specified switch current limit.

- Typically the ripple current is allowed to be 20%-50% of I_{out}. If total ripple current is 40% of I_{out}, then the maximum current value reached is $1.2*I_{out}$.

Inductor Selection Analysis

- Maximum load current current value can not exceed the minimum specified switch current limit minus the ripple current. Therefore the maximum I_{out} gets limited to $I_{lim\text{-}min}$ divided by 1.2.
- Using the specification table above and maximum ripple current of 40%, the maximum allowable I_{out} is 830mA/1.2, or roughly 690mA.
- To keep some safety margin, the maximum I_{out} allowable is chosen to be 600mA for the following calculation. This means that the total ripple current, 40% of I_{out}, is 240mA.
- Plugging relevant values from the table above and this ripple current, into the inductor selection equation from the previous page in this chapter, the inductor value selected would be roughly 3.15uH as shown below.

$$L \geq \frac{V}{2\Delta i_L} \frac{1}{f_{smin}} \left(1 - \frac{V}{V_{gmax}}\right) = 3.15\mu H$$

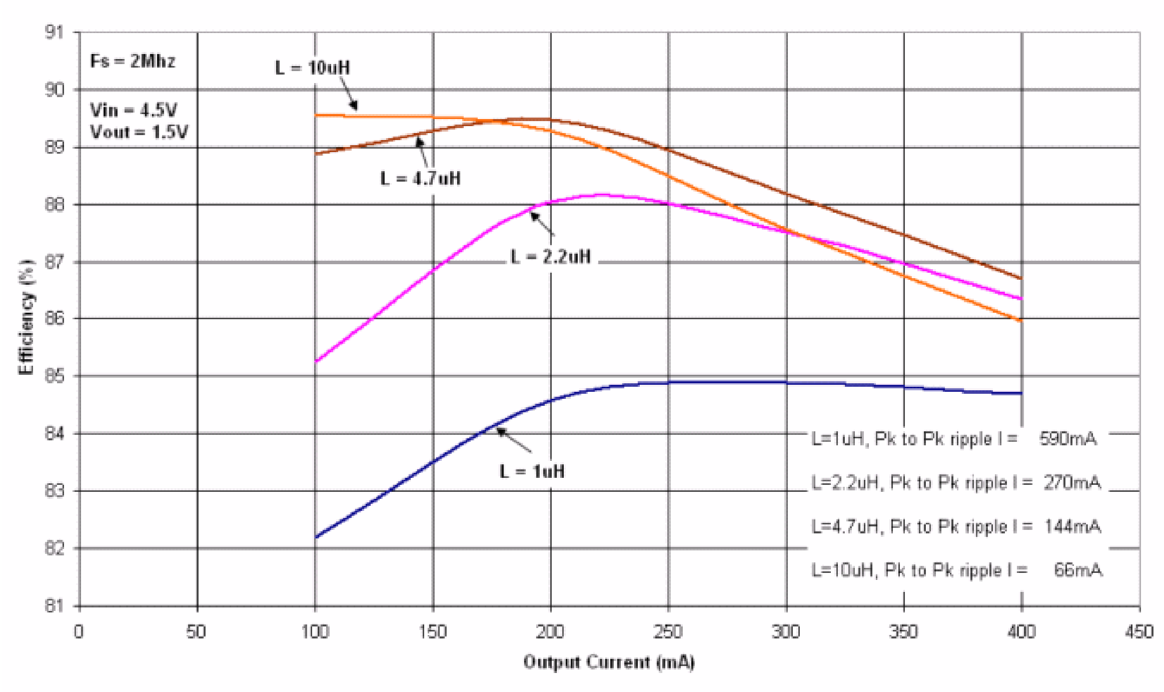
$$\frac{1.8V}{240\,mA} * \frac{1}{1.6\,MHz} * \left(1 - \frac{1.8V}{5.5V}\right) = 3.15\,\mu H$$

Inductor Overview

	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size	Actual size
	0603PS Shielded	**0805PS Shielded**	**DS1608 Shielded**	**LPO4812**	**LPO4815**	**LPO3010**	**LPO3310**	**MSS4020 Shielded**	**LPO6013**	**LPO6610**	**DO3314**
Base (mm)	2.6 × 2.1	3.4 × 3.0	6.6 × 4.5	4.8 × 4.8	4.8 × 4.8	3.0 × 3.0	3.3 × 3.3	4.0 × 4.0	6.0 × 5.6	6.6 × 5.5	3.3 × 3.3
Height (mm)	1.8	1.8	2.9	1.2	1.5	0.9	1.0	2.0	1.3	1.0	1.4
Inductance											
0.33 µH							2.8 0.040				
0.56 µH							2.3 0.042				
0.68 µH							1.9 0.068				
0.78 µH	0.55 0.24										
1.0 µH	0.40 0.26	0.90 0.14	1.4 0.04	1.3 0.055	1.6 0.036	1.7 0.140	1.6 0.076		1.9 0.06		2.1 0.11
1.2 µH						1.6 0.160				2.1 0.08	
1.5 µH		0.85 0.18	0.93 0.045	1.0 0.080	1.5 0.085	1.3 0.200	1.4 0.12		1.6 0.07	1.9 0.10	2.0 0.14
1.8 µH	0.39 0.54										
2.2 µH	0.33 0.75		0.92 0.050	0.80 0.090	1.1 0.088	1.2 0.265	1.1 0.15		1.3 0.08	1.6 0.12	1.6 0.20
2.7 µH	0.33 0.75	0.60 0.33									
3.3 µH	0.32 0.88	0.55 0.46	0.75 0.055	0.70 0.12	0.90 0.12	0.96 0.335	0.95 0.20	1.10 0.085	1.1 0.11	1.3 0.16	1.4 0.26
3.9 µH	0.27 1.00	0.50 0.72			0.86 0.13				1.0 0.13		
4.7 µH	0.26 1.08	0.43 0.81	0.58 0.060	0.60 0.155	0.77 0.15	0.76 0.570	0.80 0.27	0.80 0.115	0.90 0.15	1.1 0.20	1.2 0.32
5.6 µH	0.25 1.23	0.38 0.91						0.73 0.130			
6.8 µH	0.23 1.37	0.32 1.26	0.58 0.065	0.45 0.225	0.65 0.18		0.66 0.36	0.66 0.175	0.70 0.20	0.90 0.32	0.92 0.44
8.2 µH	0.22 1.43							0.60 0.19	0.70 0.22		
10 µH	0.21 1.60	0.27 1.45	0.37 0.075	0.40 0.30	0.50 0.23	0.50 1.15	0.57 0.52	0.54 0.21	0.60 0.30	0.80 0.41	0.80 0.52
12 µH					0.45 0.31			0.50 0.28			
15 µH	0.16 1.92	0.22 1.90	0.31 0.090	0.32 0.46	0.42 0.36	0.42 1.57	0.45 0.80	0.44 0.33	0.55 0.38	0.65 0.55	0.68 0.86
18 µH								0.40 0.36			
22 µH	0.13 2.96	0.18 2.48	0.30 0.11	0.28 0.64	0.37 0.46	0.37 2.20	0.37 1.20	0.36 0.48	0.45 0.52	0.50 0.86	0.56 1.20

Inductor Selection Analysis

- The inductor value chosen from the previous page was 4.7uH.
- The current it must carry (I_{out}*1.2) was 720mA.
- The Coilcraft table shows that 7 inductors can meet these two requirements.
- We can pick based upon size, efficiency, cost or our other critical parameters.



Inductor Selection Analysis

What happens if a different inductor is chosen?

- If an inductor is chosen that is of lower-value (e.g. 1.5uH) than the equations above suggest, following problems may be encountered:
  - Higher inductor ripple current, so that the inductor current limit is engaged at a lower-than-expected load current.
  - Higher ripple voltage on the output, which may be seen as excessive noise by the load;
- If an inductor is chosen with lower I_{sat} or I_{rms}, the reduction in the inductor value at higher actual current level (e.g. $I_{out} > I_{sat}$) could also have same issue as choosing a lower value inductor (see above discussion).
- Conversely, if an inductor with higher I_{sat} or I_{rms} is chosen but it has higher DCR, it leads to higher DC losses in the inductor and consequent lower overall efficiency. The higher ripple current, the first issue in the lower value inductor discussion above, also has an increases the AC loss in the inductor.

Thank you!