Designing a buck converter

Specifications are given:

1. V_{in}
2. V_{out}
3. Line & load regulation
4. Line & load transient
5. Output ripple
6. Accuracy
7. Load current
8. Switching frequency may or may not be given
9. Efficiency may or may not be given (>90%)

Deciding Switching Frequency, L & C

→ Switching losses should be negligible at higher load currents.

→ $\eta > 90\% \Rightarrow$ total loss $\simeq 10\%$.

$V_{in} = 1.8V$, $V_{out} = 1.2V$, $I_{load\_max} = 1A$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{loss}}$$

$$1 + \frac{P_{loss}}{P_{out}} = \frac{1}{\eta}$$

$$\Rightarrow P_{loss} = \left(1/\eta - 1\right) \times P_{out} = \left(\frac{1}{0.9} - 1\right) \times P_{out}$$

$$\approx 11\%$$

11% of $1.2W = 132 mW$

$$P_{loss-total} = P_{loss-cond} + P_{loss-sw} + P_{loss-magnetic} + P_{loss-Q}$$

At higher load currents.

$P_{loss-cond}$ should be dominant.

$P_{loss-cond} \geq 90\%$ of total loss.

$$P_{loss-cond} \approx 120\,mW$$

$$P_{loss-total} - P_{loss-cond} \approx 12\,mW$$

$$P_{loss-cond} = I_{load}^2 \times R_{loss}$$

$$R_{loss} = \frac{120\,mW}{(1)^2} = 120\,m\Omega$$

$$R_{loss} = R_{dcr} + R_{on}$$

→ Choosing lower R_{on} will increase area & switching loss.

→ We look for inductors with smallest possible R_{dcr}.

Let's say $R_{dcr} = 50\,m\Omega$

$R_{on} = 70\,m\Omega$

we need to size power FETs to have $R_{ds\text{-}on} = 70\,m\Omega$

$$R_{on} = D \cdot R_{onp} + (1-D)\,R_{onn}$$

$D = 0.7$

<u>Case-1:</u> $R_{onp} = R_{onn} = 70\,m\Omega$

$R_{on} = 70\,m\Omega$

<u>Case-2</u> $R_{onp} \neq R_{onn}$

$R_{onp} = 50\,m\Omega$

$R_{onn} = 90\,m\Omega$

$$R_{on} = 0.7 \times 50\,m\Omega + (1-0.7)\,90\,m\Omega$$

$$= 35\,m\Omega + 27\,m\Omega = 62\,m\Omega$$

$$I_d = \mu C_{ox} \frac{W}{L}\left[(V_{gs}-V_{th})V_{ds} - \frac{V_{ds}^2}{2}\right]$$

for linear region $V_{ds} <<$

$$\frac{V_{ds}^2}{2} \simeq 0$$

$$I_d \approx \mu C_{ox} \frac{W}{L}(V_{gs}-V_{th})V_{ds}$$

$$R_{ds} = \frac{\partial V_{ds}}{\partial I_d} = \frac{1}{\mu C_{ox}\frac{W}{L}\underbrace{(V_{gs}-V_{th})}_{\text{overdrive votage.}}}$$

$V_{dd} = 1.8V$, $V_{th} \simeq 0.5V$

$$R_{ds} = \frac{1}{\mu C_{ox}\frac{W}{L}(1.3)}$$

$$R_{ds} = 70m\,\Omega$$

$$W/L = \frac{1}{\mu C_{ox}(70m\Omega)(1.3)}$$

$\mu_p C_{ox} = 70\, \mu A / V^2$

$\left(\frac{W}{L}\right)_{PMOS} = \frac{1}{70 \times 10^{-6} (70 \times 10^{-3})(1.3)} = \frac{10^9}{70 \times 70 \times 1.3}$

$\approx 1.6 \times 10^5 = W/L$

$L = 180\, nm$

$W = 0.288 \times 10^5\, \mu m$

$\underline{= 28.8\, mm}$