Valero

For: EXAM 1 | ECEN 438 Date: 02/18/2025

Subject: JOAQUIN SALAS | 731000141 By:

① $V_o = 8V$ to $15V$ in CCM

$V_{in} = 12V$

$f_s = 5kHz$ Find min L (uH)

$R_L = 8\Omega$

① Find D.

$$\frac{V_o}{V_{in}} = \frac{\cancel{D}}{1-D} \cdot \frac{1}{\cancel{D}} \quad \frac{V_o}{DV_{in}} = \frac{1}{1-D} \rightarrow D \cdot \frac{V_{in}}{V_o} = 1-D$$

minimum so $V_o = 8V$

$$D = 0.4 \quad \text{Buck Converter}$$

$$L_{min} = \frac{R(1-D)^2}{2 \cdot f}$$

$$= \frac{8(1-0.4)^2}{2 \cdot (5k)}$$

$$\boxed{L = 288\,\mu H}$$

CASE 2 $V_o = 15$

$D = 0.556$ Boost

$$L_{min} = \frac{D(1-D)^2 R}{2 \cdot f} = 87.6 \times 10^{-6}$$

② $V_{in} = 43$

$V_{out} = 3.3$

$P_o = 41W$

$f_s = 259kHz$

$R_{ds(on)} = 42m\Omega$

$t_r = 9.1ns$

$t_f = 10.4ns$

(a) Total loss = Conduction loss + Switching loss

$$P_{sw\text{-}on\text{-}loss} = \frac{1}{2} V_{in} \cdot I_o \cdot (t_{on}) \cdot f$$

$t_r + t_f$

$$I = \frac{P_o}{V_o} = \frac{41}{3.3} = 12.42 = \frac{1}{2}(43)(12.42)(2 \cdot (9.1+10.4)ns) \cdot (259k)$$

$$P_{sw\text{-}on\text{-}loss} = 2.697$$

$$P_{cond} = d(R_{DS(on)} I_o^2) = (12.42)^2 \cdot (42 \times 10^{-3})$$

$$= 6.478$$

$$\boxed{\text{Total Loss} = 9.175W}$$

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Q3 $V_{in} = 194V$

$V_o = 298V$ IN CCM

$R = 32\Omega$

Ripple < 10% $\left(\frac{\Delta V_o}{V_o}\right)$

$t_r = 103\,ns$, $t_f = 51\,ns$

Find max f, Do not exceed 5% of P_o.

① Find D, Duty Cycle

$$V_o = \frac{V_{in}}{1-D} = 0.349 = D \qquad I_o = V_o/R = \frac{298}{32}$$

② $$L_{min} = \frac{D(1-D)^2 R}{2 \cdot f} \qquad P_o = \frac{V_o^2}{R} = \frac{298^2}{32} =$$

$P_o = 2775.125\,W$

③ Switching Loss

$2775.125(0.05)$

$$P_{sw-loss} = \frac{1}{2} V_{in} \cdot I_o \cdot (t_{c,on}) \cdot f \qquad P_{loss} \neq 138W$$

$$138 = \frac{1}{2}(194) \cdot (9.3125) \cdot (103 + 51)\,ns\,(x)$$

$x = 992019.8$ $\qquad f = 992\,kHz$

or $f = 496\,kHz$?

$$L_{min} = \frac{0.349(1-0.349)^2(32)}{2 \cdot (992k)}$$

$\boxed{\text{Answer} \quad f = 992\,kHz}$

Q4 Boost Converter

$V_{in} = 11V$

$V_o = 28V$ Find $I_{L,MAX}$

$P_o = 93W$

$f_s = 100kHz$

$L = 2\mu H$

① Find D

$$V_o = \frac{V_{in}}{1-D} \rightarrow \frac{V_o}{V_{in}} = \frac{1}{1-D} \rightarrow \frac{V_{in}}{V_o} = 1-D$$

$$D = 0.607$$

② DCM or CCM?

$$R_{crit} = \frac{2 \cdot f \cdot L}{D(1-D)^2} = 4.266, \quad R = \frac{V_o^2}{P_o} = \frac{28^2}{93} = 8.43$$

$R > R_{crit}$ so, DCM

③ Find New D.

$$V_o = \frac{V_{in}}{2}\left[1+\sqrt{1+4m}\right] \Rightarrow m = 3.9338$$

$$m = \left(\frac{R}{2Lf_s}\right)D^2 \rightarrow 3.9338 = \left(\frac{8.43}{2Lf_s}\right)D^2$$

$\rightarrow D = 0.432$ IN DCM.

④ Find $I_{L,MAX}$

$$\Delta I_L = \frac{V_{in} \cdot D}{Lf} = \frac{11(0.432)}{(2\mu H)(100k)} = 23.76A$$

$$I_L = \frac{V_o \cdot I_o}{V_{in}}$$

$I_L = 8.45$

$\Delta I_L = 23.76A$

$$I_L = \frac{28 \cdot (3.32)}{11}$$

$$I_o = \frac{93}{28} = 3.32$$

$$I_L = 8.45$$

$$I_{Lmax} = I_L + \frac{\Delta I_L}{2} = 8.45 + 11.88 \quad \frac{\Delta I_L}{2} = 11.88$$

$$\boxed{I_{L,MAX} = 20.33A}$$

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Q5 Buck Converter

$V_{in} = 30V$

$V_o = 15V$

$L = 9\mu H$

$P_o = 10W$

$f_s = 300kHz$

Find D.

① Find duty cycle

$V_o = DV_{in} \rightarrow D = 0.5$

② Check DCM AND CCM

$R_{crit,buck} = \frac{2Lf}{(1-D)} = 10.8\Omega$

$R = \frac{V_o^2}{P_o} = \frac{15^2}{10} = 22.5$

$R > R_{crit}$ So, DCM

③ Find new ~~D~~ D in DCM

$V_o = \frac{V_{in}}{2}\left(\sqrt{m\cdot(m+4)} - m\right)$

$\rightarrow m = 0.500$

$m = \left(\frac{R}{2\cdot L\cdot f}\right)\cdot D^2 \rightarrow D = 0.346$

$\boxed{\text{ANSWER } D = 0.346}$

Buck Converter

1- $V_o = D V_{in}$

2- $\Delta I_L = \frac{V_o(1-D)}{L\cdot f}$, $I_{c,rms} = \frac{\Delta I_L}{2\cdot\sqrt{3}}$

$I_{L,rms} = \sqrt{I_L^2 + \left(\frac{\Delta i_L/2}{\sqrt{3}}\right)^2}$

3- $L_{min} = \frac{(1-D)R}{2f}$

4- $I_L = I_o = V_o/R$

$T = 1/f$

5- [INPUT POWER] $V_{in} I_{in} = V_o I_o$ [OUTPUT POWER]

$I_{in} = \frac{V_o}{V_{in}}\cdot I_o = D\cdot I_o = D\cdot I_L$

6- $C = \frac{(1-D)}{\left(\frac{\Delta V_o}{V_o}\right)\cdot 8\cdot L\cdot f^2}$

r_L: $V_o = \frac{V_{in}\cdot D}{1+r_L/R}$, $\eta = \frac{1}{1+r_L/R}$

DCM: if $R > R_{crit,buck}$

$R_{crit,buck} = \frac{2Lf}{(1-D)}$, $R = \frac{V_o^2}{P_o}$

DCM Duty Cycle (D):

$V_o = \frac{V_{in}}{2}\left(\sqrt{m\cdot(m+4)} - m\right)$

where $m = \left(\frac{R}{2\cdot L\cdot f}\right)\cdot D^2$

Boost Converter

$V_o = \frac{V_{in}}{1-D}$

$\Delta I_L = \frac{V_{in}\cdot DT}{L}$; $L = \frac{V_{in}\cdot DT}{\Delta I_L} = \frac{V_{in}\cdot D}{f\cdot\Delta I_L}$

$L_{min} = \frac{D(1-D)^2 R}{2\cdot f}$

$V_{in}\cdot I_L = V_o\cdot I_o$

$I_{diode} = I_o = V_o/R$

$I_{switch} = I_L\cdot D$

$C = \frac{I_o\cdot DT}{\Delta V_o} = \frac{D}{R\cdot\left(\frac{\Delta V_o}{V_o}\right)f}$

r_L: $\frac{V_o}{V_{in}} = \frac{1}{(1-D)}\cdot\left(\frac{1}{1+\frac{r_L}{R(1-D)^2}}\right)$

$\eta = \frac{1}{1+\frac{r_L}{R(1-D)^2}}$

DCM Begins at:

$P_o = V_o^2/R_{crit}$

DCM: if $R > R_{crit,boost}$

$R_{crit,boost} = \frac{2\cdot f\cdot L}{D\cdot(1-D)^2}$

DCM DUTY CYCLE

$V_o = \frac{V_{in}}{2}\left[1+\sqrt{1+4m}\right]$ in DCM

$m = \left(\frac{R}{2Lf_s}\right)\cdot D^2$

Buck/Boost Converter

$\frac{V_o}{V_{in}} = \frac{D}{1-D}$ $\quad 0<D<0.5 \to$ Buck; $0.5<D<1 \to$ Boost

ΔI_L, L AND "C" SAME AS BOOST $\quad L_{min} = \frac{R(1-D)^2}{2\cdot f}$

$V_{in}\cdot I_{in} = V_o\cdot I_o$

$I_{in} = \frac{V_o}{V_{in}} I_o = \frac{D}{1-D} I_o$

$I_L = I_{in} + I_o$

$I_L = I_{in} + I_o = \frac{1}{1-D} I_o = \frac{1}{1-D}\cdot\frac{V_o}{R}$

DCM: $V_o = D V_{in}\sqrt{\frac{R}{2Lf_s}}$

EFFICIENCY - η

$P_{in} = P_{out} + P_{loss}$, $P_{in} = I_o\cdot D$; $\eta = \frac{P_o}{P_{in}} = \frac{P_o}{P_o+P_{loss}}$; $P_{loss} = P_o\left(\frac{1}{\eta}-1\right)$

Switching Loss

$P_{sw\text{-}on\text{-}loss} = \frac{1}{2} V_{in}\cdot I_o\cdot(t_{c,on})\cdot f$ $\quad t_{c,on/off} = t_r + t_f$, $i_{diode} = I_o - i_o$

Ohm's Law

$P = V^2/R$, $P = R\times I^2$, $P = V\cdot I$

$I = \sqrt{P/R}$, $I = P/V$, $I = V/R$

$V = R\cdot I$, $V = P/I$, $V = \sqrt{P/R}$

$R = V/I$, $R = V^2/P$, $R = P/I^2$

$P_{cond} = d(R_{DS(on)} I_o^2)$

Conduction Loss $= I_L^2\cdot R_{DS(on)}$

Inductor Quality Factor: $Q = \frac{2\pi f L}{r_L}$

Rms current ratings - $I_{MOS,rms} = \sqrt{D}\cdot I_{L,rms}$ LARGER D

- $I_D = \sqrt{1-D}\cdot I_{L,rms}$ Small D