01-12-2023

$$D = t_{on} \cdot f_s = \frac{t_{on}}{T}$$

Source → AC comp. → Load

DC V, I — No harmonic — DC V, I

Current with some ripple — Needs Filtering — V with some ripple

Widely used low V, P

Synchronous version and resonant derivatives provide eff.

CCM → Inductor current + always

DCM → " " remains 0 for some time.

$V_o = D \cdot V_s$

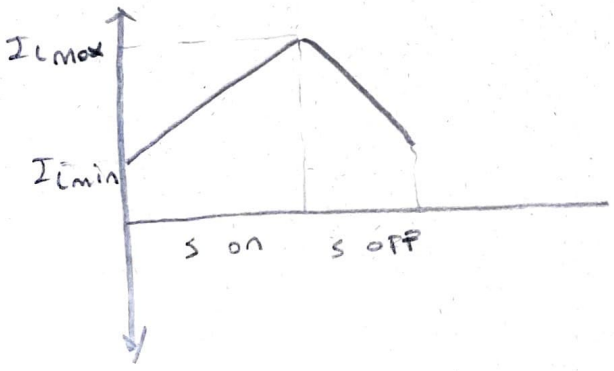
!! Sizing components

Mosfet ⇒ V_{ds} and I_d

Diode ⇒ V_{rrm}, I_f

inductor ⇒ L and I_{pk}

caps ⇒ C, V and I_{rms}



→ Use critical inductance

$$I_{Lmin} = V_o \cdot \left(\frac{1}{R} - \frac{(1-D)}{2Lf}\right)$$

$$I_{Lmax} = V_o \left(\frac{1}{R} + \frac{1-D}{2Lf}\right)$$

$$L_c = \frac{(1-D_{max})\, R_{max}}{2f}$$

For set $I_{Lmin} = 0$

$L > 1.05 \times L_c$

$f \uparrow \Rightarrow$ small L

D ⇒ $V_{switch-max} = V_{inmax} + V_f$ (max forward) safety Y.20

Mospet ⇒ $V_{DS\,max}$

current rating (Mospet) = Average value

$I_L = I_S + I_D$

$I_{switch-max} > I_{Dmax} \times D_{max}$

Mospet rating ex

14A, 500V, $R_{DS(on)}$ ⇒ N channel power mospet

Diode V rating

V_{RRM} ⇒ Peak inverse voltage

$V_{rrm} = V_{inmax} + V_{sw}$ ⇒ Y.20 ! safety factor

calc at load current

Diode Current Rating ⇒ schottky rectifier diode

$\bar{I}_f > \bar{I}_{Dmax}(1 - D_{min})$

Sizing Cap

V rating

ideally $V_{cmax} = V_o + \Delta V_o/2$

Real C has ESR(Eq. series R)

output V ripple = ESR x ΔI_L

Reduce ESR ⇒ Parallel caps

" ΔI_L ⇒ ↑ freq, ↑ L

Min C (output)

$$C = \frac{1 - D_{min}}{8 L f^2 (\Delta V_o / V_o)} \rightarrow \text{Percent } V_{opp}$$

RMS current

$$i_{Crms} = \frac{(1 - D_{min}) V_o}{2\sqrt{3}\, L f}$$

V rating (input)

$V_{cmax} = V_{inmax}$ ⇒ ideal

with ESR ⇒ caps loss

Min C (input)

$$C = \frac{(1-D) \cdot D \cdot I_{omax}}{f \cdot \Delta V_{in}}$$

I_c RMS (input)

$$\sqrt{\left[I_o V_D \sqrt{1 + \frac{\Delta i_L}{2 I_o}}\right]^2 - (D I_o)^2}$$

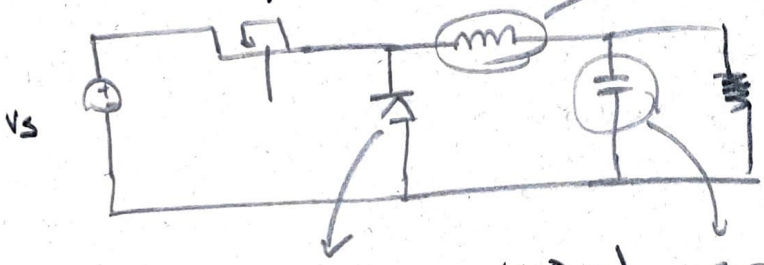
Summerize

$\bar{I}_{smax} > \bar{I}_{omax} \cdot D_{max}$

$V_{smax} = V_{inmax}$

$$I_{Lmax} = V_o \left[\frac{1}{R_{min}} + \frac{1 - D_{min}}{2Lf}\right]$$

$$L_c = \frac{(1 - D_{max}) \cdot R_{max}}{2f}$$



$I_f > I_{omax} \cdot (1 - D_{min})$

$V_{irm} = V_{inmax}$

$$C = \frac{1 - D_{min}}{8 L f^2 (\Delta V_o / V_o)}$$

$V_{cmax} = V_o + \Delta V_o / 2$

$$i_{Crms} = \frac{(1 - D_{min}) V_o}{2\sqrt{3}\, L}$$

Losses

Static loss of Mosfet

Switching loss of Mosfet

MOSFET Gate drive loss

Static loss of diode

Switching loss of diode

L copper loss

C ESR loss

Static loss for Mosfet $R_{DS\,on}$

$$P_{static} = \left[I_o \sqrt{D \left(1 + \frac{\Delta i_L}{2 I_o}\right)^2} \right] R_{DS\,on}$$

$$P_{switching} = \frac{I_o V_{in}}{6T} (t_{on} + t_{off})$$

$$\left.\begin{aligned} P_{Coss} &= \frac{1}{2} C_{oss} V_{in}^2 f \\ P_{gate} &= \frac{1}{2} Q_{gate} V_{gate} f \end{aligned}\right\}$$ switching loss of Mosfet, Gate drive loss

Static loss diode (Forward)

$$P_{Forward} = V_f \times \bar{I}_f + I_f^2 \cdot r_d$$

$\bar{I}_f \rightarrow (1-D) I_o$

$I_f^2 \rightarrow \sqrt{\frac{1-D}{3} [I_{max}^2 + I_{min}^2 + I_{max} I_{min}]}$

$$P_{reverse} = V_r I_r (1-D)$$

Switching loss of diode

Turn on $\Rightarrow P_{on} = 0.4 (V_{fp} - V_f) + t_{rr} I_f \cdot f$

V_{fp} → peak forward V

t_{rr} → forward recover time

Copper Loss

$$P_L = I_L^2 \cdot R_L$$

$$\hookrightarrow I \times \sqrt{1 + \frac{1}{3} \left(\frac{\Delta i_L}{2I}\right)^2}$$

Core loss/unit $= K1 \times B^{K2} + f^{K3}$

ESR loss

$$\tilde{I}_c^2 \times \bar{E}SR$$

$$\hookrightarrow \frac{\Delta i_L}{2\sqrt{3}}$$