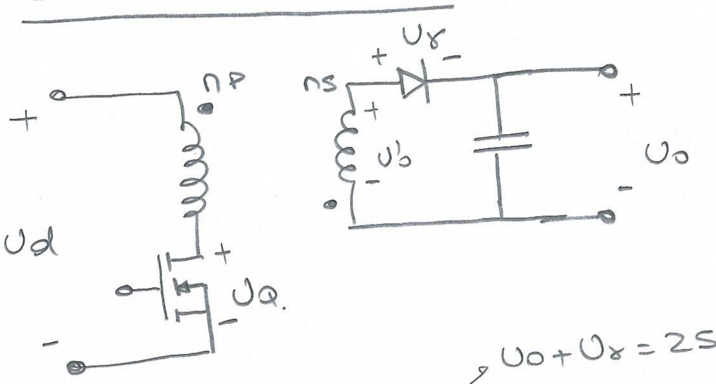
Examen de Electrónica de Potencia – DICIEMBRE 2021

Solución Problema 2.



$f = 50\,kHz$

$V_o = 24\,V.$

$L_P = 200\,\mu H$

$V_{d\,máx} = 1{,}2 \times 110 = 132\,V$

$V_{d\,min} = 0{,}8 \times 110 = 88\,V.$

$V_\gamma = 1\,V$

$V_{Q\,máx} = 0{,}7 \times 500 = 350\,V$

$I_{P\,máx} = 0{,}5 \cdot 20 = 10\,A.$

$R_{\theta sa} = 0{,}25\,°C/W.$

$T_a = 50\,°C.$

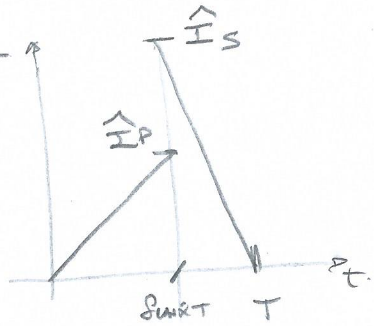
$V_o + V_\gamma = 25\,V$

a) $V_Q = V_d + \frac{n_P}{n_S} \cdot V'_o$

$V_{Q\,máx} = V_{d\,máx} + \frac{n_P}{n_S} \cdot V'_o \leq 350\,V.$

$\Rightarrow \frac{n_P}{n_S} = \frac{V_{Q\,máx} - V_{d\,máx}}{V'_o}$

$\frac{n_P}{n_S} = \frac{350 - 132}{25} \Rightarrow \boxed{\frac{n_P}{n_S} = 8{,}72}$



b) En el L.c.c. vale : $\frac{V'_o}{V_d} = \frac{n_S}{n_P} \frac{\delta}{1-\delta}$

$\frac{V'_o}{V_{d\,min}} = \frac{n_S}{n_P} \cdot \frac{\delta_{máx}}{1-\delta_{máx}}$

$\delta_{máx} = \frac{n_P}{n_S} \cdot \frac{V'_o}{V_{d\,min}} (1 - \delta_{máx})$

$\Rightarrow \delta_{máx} = \frac{n_P}{n_S} \frac{V'_o}{V_{d\,min}} \left(\frac{1}{1 + \frac{n_P}{n_S}\frac{V'_o}{V_{d\,min}}} \right) = \frac{8{,}72 \cdot 25}{88} \left(\frac{1}{1 + \frac{8{,}72 \cdot 25}{88}} \right)$

$\Rightarrow \boxed{\delta_{máx} = 0{,}712}$

$P_{in} = P_{out} + P_D \rightarrow$ potencia disipada en el diodo

$P_{in} = \frac{1}{2} L_P \cdot \hat{I}_P^2 \cdot f$

$\hat{I}_P = \frac{V_d}{L_P} \cdot \delta T = \frac{V_{d\,min} \cdot \delta_{máx}}{L_P \cdot f} = \frac{88 \cdot 0{,}712}{200 \times 10^{-6} \cdot 50 \times 10^3} \Rightarrow \hat{I}_P = 6{,}27\,A$

$P_{in} = P_{out} + P_D = V_o \cdot I_o + V_D \cdot I_o.$

Solución Problema 2 (cont.)

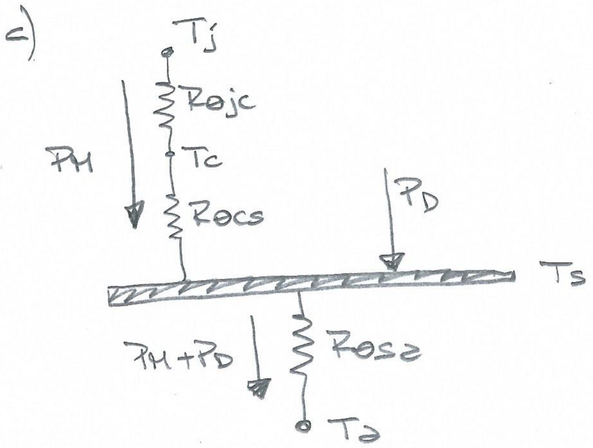
$$\hat{I}_s = \frac{n_P}{n_S}\cdot\hat{I}_P = 8,72 \times 6,27 = 54,67\,A$$

$$I_o = \frac{1}{T}\int_{\delta T}^{T} i_s(t)\,dt = \frac{1}{\cancel{T}}\,\frac{1}{2}\,(1-\delta_{max})\cancel{T}\cdot\hat{I}_s = \frac{(1-\delta_{max})\hat{I}_s}{2} = \frac{(1-0,712)\,54,67}{2}$$

$\Rightarrow I_o = 7,87\,A.$

$\Rightarrow P_{out} = 24 \cdot 7,87 \Rightarrow \boxed{P_{out} = 188,9\,W}$

c)



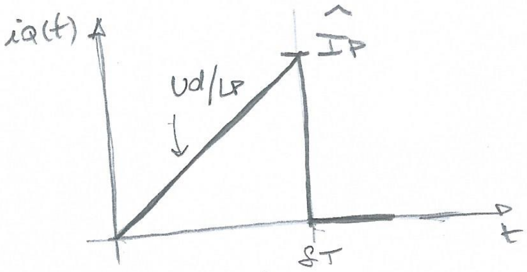
$$T_j - T_s = P_M\,(R_{\theta jc}+R_{\theta cs})$$

$$T_s - T_a = (P_M+P_D)\cdot R_{\theta sa}$$

$$\Rightarrow T_j - T_a = P_M\,(R_{\theta jc}+R_{\theta cs}) + (P_M+P_D)\cdot R_{\theta sa}$$

$$R_{\theta sa} = \frac{T_j - T_a - P_M\,(R_{\theta jc}+R_{\theta cs})}{P_M+P_D}$$

Para la potencia máxima de salida: $P_D = 1\times 7,87 = 7,87\,W$.



$$P_M = P_{ON} + P_{cond} + P_{OFF}$$

* $P_{ON} = 0$ por estar en MCD
* $P_{cond} = R_{DS(on)}\, I_{Q ef}^2$

$$I_{Q ef}^2 = \frac{1}{T}\int_0^{\delta T}\left(\frac{\hat{I}_P}{\delta T}\cdot t\right)^2 dt = \frac{1}{\cancel{T}}\,\frac{\hat{I}_P^2}{\cancel{\delta^2 T^2}}\cdot\frac{\cancel{\delta^3 T^3}}{3} \Rightarrow I_{Q ef}^2 = \frac{\hat{I}_P^2\cdot\delta}{3}$$

* $P_{OFF} = \frac{1}{2}U_Q\cdot\hat{I}_P\cdot t_f\cdot f = \frac{1}{2}\left(U_d + U'_o\frac{n_P}{n_S}\right)\cdot\hat{I}_P\cdot t_f\cdot f$

$$P_M = R_{DS(on)}\,\frac{\hat{I}_P^2\cdot\delta}{3} + \frac{1}{2}\left(U_d + U'_o\frac{n_P}{n_S}\right)\cdot\hat{I}_P\cdot t_f\cdot f$$

Como δ varía con U_d $\Rightarrow \hat{I}_P = \frac{U_d}{L_P f}\,\delta \Rightarrow \delta = \frac{L_P\cdot f\cdot\hat{I}_P}{U_d}$

$$P_M = R_{DS(on)}\cdot\frac{\hat{I}_P^3\cdot L_P\cdot f}{3U_d} + \frac{1}{2}U_d\,\hat{I}_P\cdot t_f\cdot f + \frac{1}{2}U'_o\,\frac{n_P}{n_S}\cdot\hat{I}_P\cdot t_f\cdot f$$

Por la evolución de $P_M = f(U_d)$ es necesario evaluar para $U_{d\,máx}$ y $U_{d\,mín}$ para determinar la potencia máxima disipada por el MOSFET

Solución Problema 2 (cont.)

De hojas de datos:
- $R_{DS(on)}@120°C = 0{,}27 \times 2{,}1 = 0{,}567\,\Omega$
- $t_f = 59\,ns$
- $R_{\theta jc} = 0{,}45\,°C/W$ / $R_{\theta cs} = 0{,}24\,°C/W$

→ $U_d = U_{d\,máx} = 132V.$

$$\underline{P_M} = 0{,}567 \cdot \frac{6{,}27^3 \cdot 200\times10^{-6} \cdot 50\times10^3}{3 \cdot 132} + \left(132 + 25 \cdot 8{,}72\right) \cdot 6{,}27 \cdot 59\times10^{-9} \cdot 50\times10^3 = 3{,}52 + 6{,}47 = \underline{9{,}99\,W}.$$

→ $U_d = U_{d\,mín} = 88V.$

$\underline{P_M} = 5{,}29 + 5{,}66 = \underline{10{,}95W}$ → El peor caso es con $U_d = U_{d\,mín}$.

$$R_{\theta sa} = \frac{120 - 50 - 10{,}95\,(0{,}45 + 0{,}24)}{10{,}95 + 7{,}87} \Rightarrow R_{\theta sa} = 3{,}31\,°C/W$$

La resistencia térmica del disipador seleccionado es menor que la necesaria para mantener la temperatura media máxima por debajo de 120°C ⇒ el disipador instalado es adecuado.

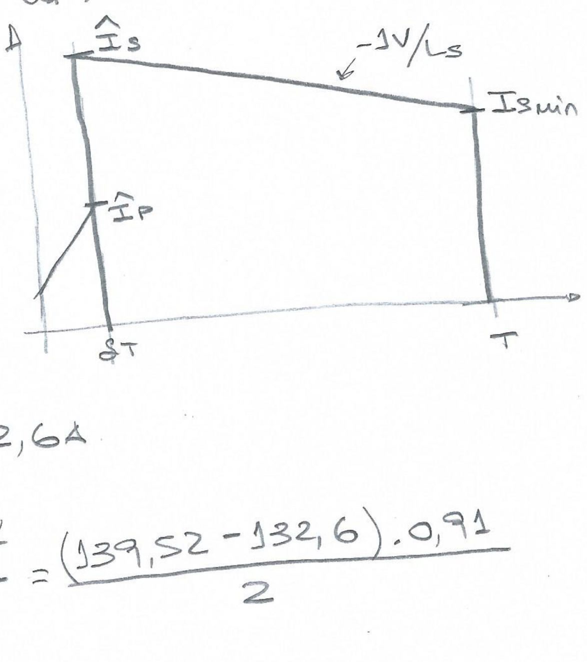
d) Cortocircuito a la salida ⇒ $U_o = 1V.$
Por protección - $\hat{I}_P = 0{,}8 \cdot 20 = 16\,A.$
} en esta situación el convertidor estará funcionando en MCC

$$\frac{U_o}{U_d} = \frac{n_P}{n_S}\frac{\delta}{1-\delta} \Rightarrow \delta = \frac{n_P}{n_S}\frac{U_o}{U_d}\left(\frac{1}{1 + \frac{n_P}{n_S}\frac{U_o}{U_d}}\right) = \frac{8{,}72 \cdot 1}{88}\left(\frac{1}{1 + \frac{8{,}72 \cdot 1}{88}}\right)$$

$\delta = 0{,}09$

$\hat{I}_S = \frac{n_P}{n_S} \cdot \hat{I}_P = 8{,}72 \cdot 16 = 139{,}52\,A.$

$L_S = \left(\frac{n_S}{n_P}\right)^2 \cdot L_P = \frac{200\times10^{-6}}{8{,}72^2} = 2{,}63\,\mu H$



$$I_{S\,mín} = \hat{I}_S - \frac{U_o}{L_S}(1-\delta)T$$

$$I_{S\,mín} = 139{,}52 - \frac{1 \cdot (1 - 0{,}09)}{2{,}63\times10^{-6} \cdot 50\times10^3} = 132{,}6A$$

$$I_o = \frac{1}{T}\int_0^T i_o(t)\,dt = \frac{1}{\cancel{T}}\frac{(\hat{I}_S - I_{mín}) \cdot (1-\delta)\cancel{T}}{2} = \frac{(139{,}52 - 132{,}6) \cdot 0{,}91}{2}$$

$I_o = 123{,}8\,A$ ⇒ $\boxed{P_o = 123{,}8\,W.}$