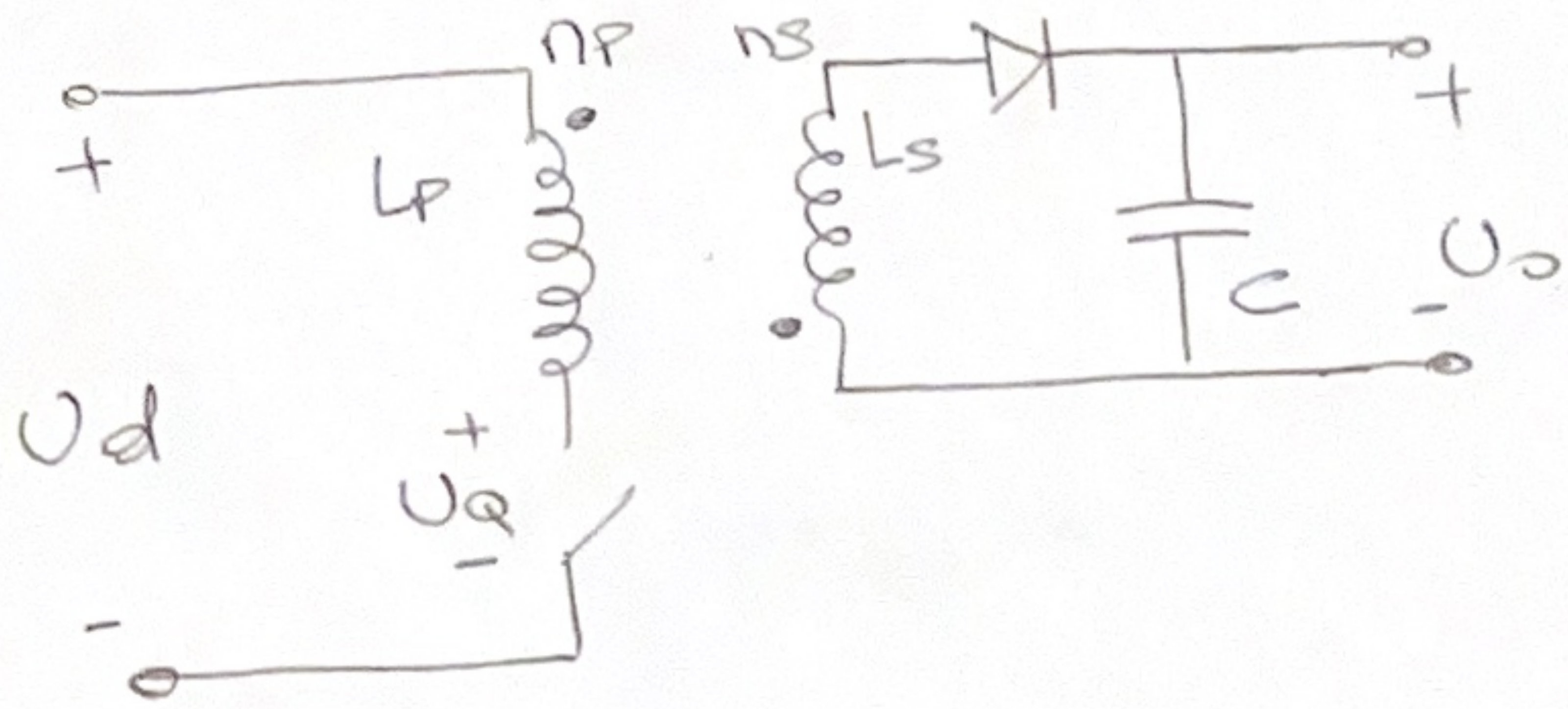
Examen de Electrónica de Potencia - mesa especial Abril 2024 (1')

## Solución Problema 2




IRFPE 50

$f = 100kHz$  $\delta_{máx} = 0,6$

MCD. → $U_o = 24V$  $I_o = 5A$

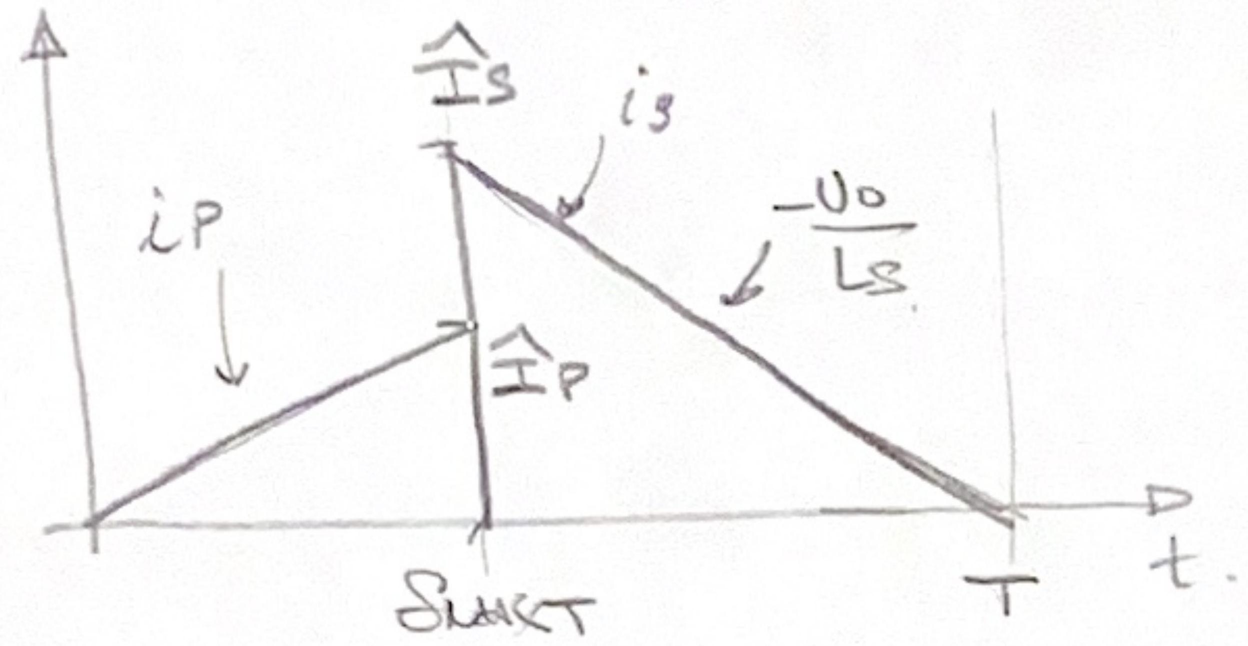
$T_{a\,máx} = 40°C$.

$\hat{I}_P = 7,8 \cdot 0,6 = 4,68A$ / $U_{Q\,máx} = 0,8 \cdot 800 = 640V$

protección: $\hat{I}_P \leq 7,8A$.

a) Para que funcione siempre en condiciones normales en MCD:

para carga máxima y $U_d = U_{d\,mín}$ ⇒ opero en el LCC




$$I_o = \frac{1}{\cancel{T}} \frac{1}{2} \hat{I}_S (1-\delta)\cancel{T} = \frac{\hat{I}_S(1-\delta)}{2}$$

$$\hat{I}_S = \frac{2 I_o}{1-\delta} = \frac{2 \cdot 5}{0,4} = 25A$$

A su vez: $\hat{I}_S = \frac{U_o}{L_S}(1-\delta)T$ ⇒ $L_S = \frac{U_o}{\hat{I}_S}(1-\delta)T = \frac{24 \cdot 0,4}{25 \cdot 100 \times 10^3}$

⇒ $\boxed{L_S = 3,84\,\mu H}$

b) Según el diseño, en LCC y carga máxima $\hat{I}_P = 4,68A$.

$n_P \hat{I}_P = n_S \hat{I}_S$ ⇒ $\frac{n_S}{n_P} = \frac{\hat{I}_P}{\hat{I}_S} = \frac{4,68}{25} = 0,1872$.

A su vez, en el LCC vale: $\frac{U_o}{U_{d\,mín}} = \frac{n_S}{n_P} \frac{\delta_{máx}}{1-\delta_{máx}}$

⇒ $U_{d\,mín} = \frac{U_o}{n_S/n_P} \frac{1-\delta_{máx}}{\delta_{máx}} = \frac{24 \cdot 0,4}{0,1872 \cdot 0,6}$ → $\boxed{U_{d\,mín} = 85,5V}$

Para $U_{d\,máx}$ considero la tensión máxima en bornes de la llave:

$U_{Q\,máx} = \frac{n_P}{n_S} U_o + U_{d\,máx}$ ⇒ $U_{d\,máx} = U_{Q\,máx} - \frac{n_P}{n_S} U_o$

$U_{d\,máx} = 640 - \frac{24}{0,1872}$ → $\boxed{U_{d\,máx} = 511,8V}$

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

$P_M = P_{enc} + P_{cond} + P_{ap}$ → en MCD: $P_{enc} = 0$.

$P_{cond} = R_{DS(on)} I_{Q\,ef}^2$

Solución Problema 2 (cont)

$$P_{ap} = \frac{1}{2} U_Q . \hat{I}_Q . t_f . f$$

– De las hojas de datos:

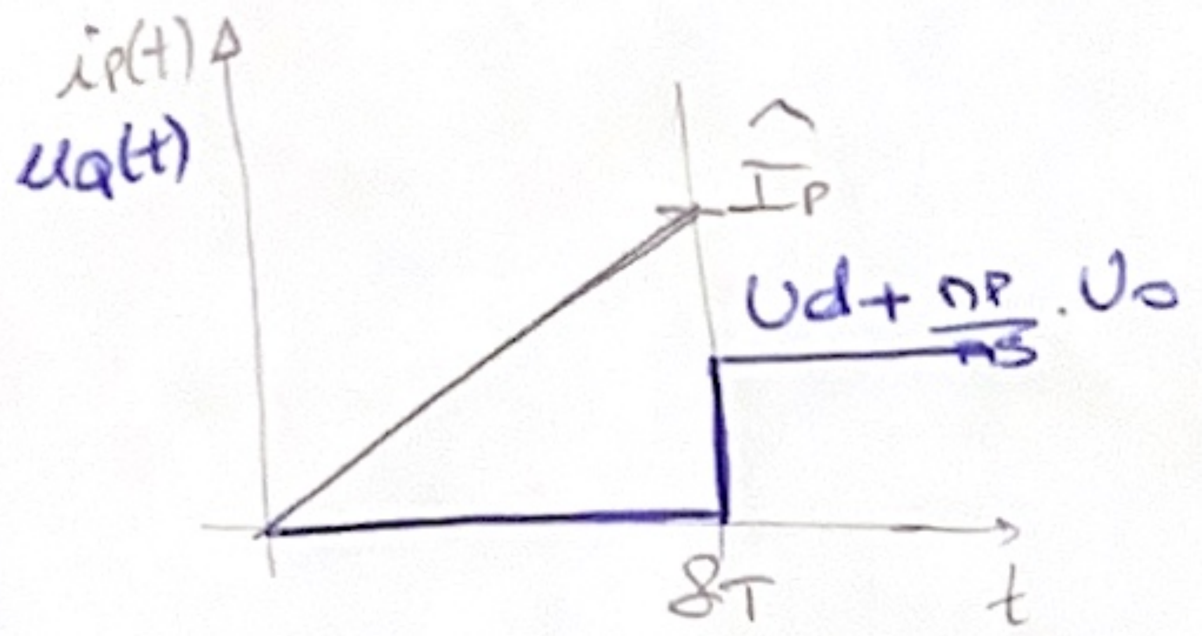
$T_{j\,max} = 150\,°C$

$R_{DS(on)} @150°C = 1{,}2 . 2{,}7 = 3{,}24\,\Omega$

$R_{\theta jc} = 0{,}65\,°C/W$

$R_{\theta cs} = 0{,}24\,°C/W$

$t_f = 39\,ns$




$$I_{Q\,eff}^2 = \frac{1}{T}\int_0^T i_P^2(t)dt = \frac{1}{T}\int_0^{\delta T} \frac{\hat{I}_P^2}{\delta^2 T^2} t^2 dt = \frac{\hat{I}_P^2}{\cancel{\delta^2} \cancel{T^3}} . \frac{\delta^{\cancel{3}} \cancel{T^3}}{3} \Rightarrow I_{Q\,eff}^2 = \frac{\hat{I}_P^2 . \delta}{3}$$

$$\Rightarrow P_{cond} = R_{DS(on)} . \frac{\hat{I}_P^2 . \delta}{3}$$

$$P_{ap} = \left(U_d + \frac{n_P}{n_S} . U_o\right) \hat{I}_P . t_f . f$$

Como $U_d$ y $\delta$ están relacionados, expreso todo en función de $U_d$:

$$\hat{I}_P = \frac{U_d}{L_P} . \delta T \Rightarrow \delta = \frac{L_P \hat{I}_P . f}{U_d}$$

$$\Rightarrow P_{cond} = R_{DS(on)} . \frac{\hat{I}_P^3 . L_P f}{3\, U_d} \longrightarrow L_P = \left(\frac{n_P}{n_S}\right)^2 . L_S = \frac{3{,}84}{0{,}1872^2} \Rightarrow \underline{L_P = 109{,}58\,\mu H}$$

$$P_H = P_{cond} + P_{ap} = A . U_d + B + \frac{C}{U_d} \longrightarrow \text{calculo para } U_{d\,min} \text{ y para } U_{d\,max}$$

$\rightarrow$ $\underline{U_d = U_{d\,min}}$

$$\left.\begin{aligned} P_{ap} &= \left(85{,}5 + \frac{24}{0{,}1872}\right) . 4{,}68 . 39\times10^{-9} . 100\times10^3 = 3{,}9\,W \\ P_{cond} &= \frac{3{,}24 . 4{,}68^3 . 109{,}58\times10^{-6} . 100\times10^3}{3 . 85{,}5} = 14{,}2\,W \end{aligned}\right\} \Rightarrow \underline{P_H = 18{,}1\,W}$$

$\rightarrow$ $\underline{U_d = U_{d\,max}}$

$$\left.\begin{aligned} P_{ap} &= \left(511{,}8 + \frac{24}{0{,}1872}\right) . 4{,}68 . 39\times10^{-9} . 100\times10^3 = 11{,}7\,W \\ P_{cond} &= \frac{3{,}24 . 4{,}68^3 . 109{,}58\times10^{-6} . 100\times10^3}{3 . 511{,}8} = 2{,}4\,W \end{aligned}\right\} \Rightarrow \underline{P_H = 14{,}1\,W}$$

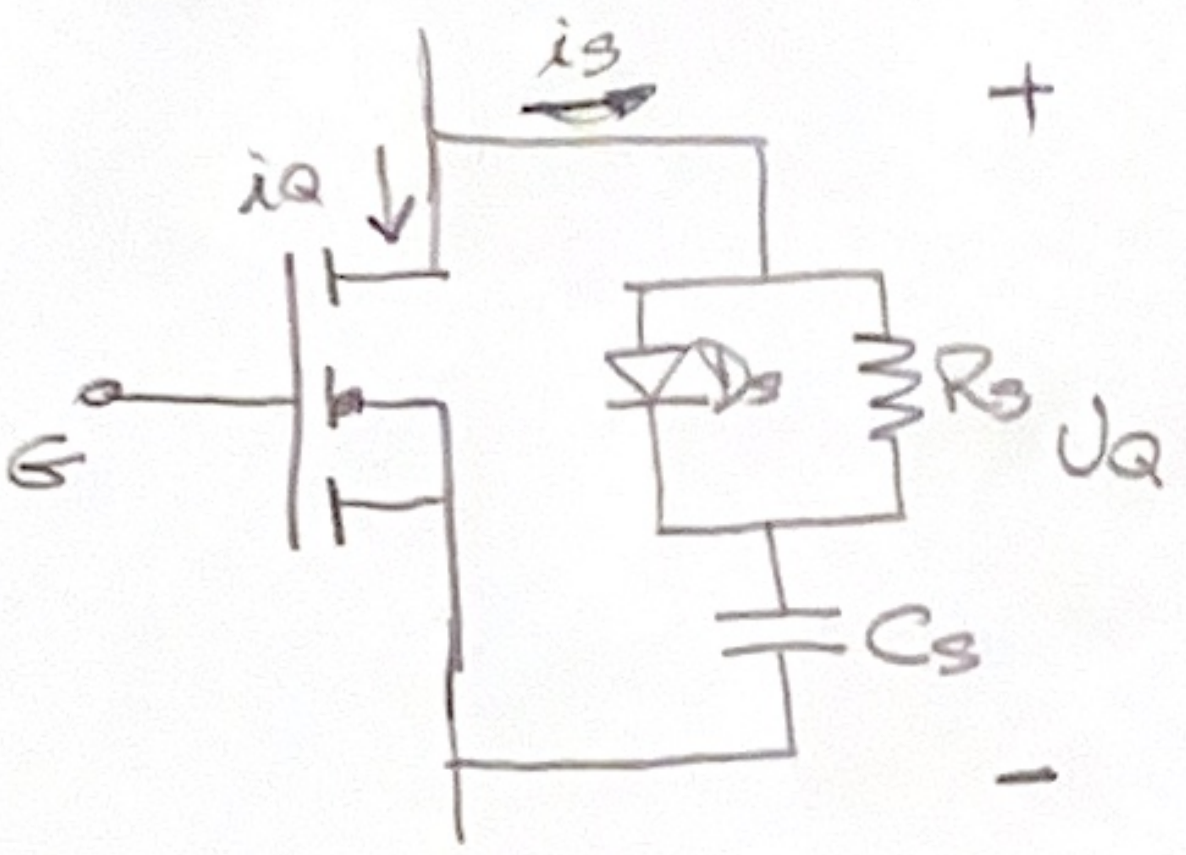
Las pérdidas son máximas en la llave con $U_d = U_{d\,min}$.

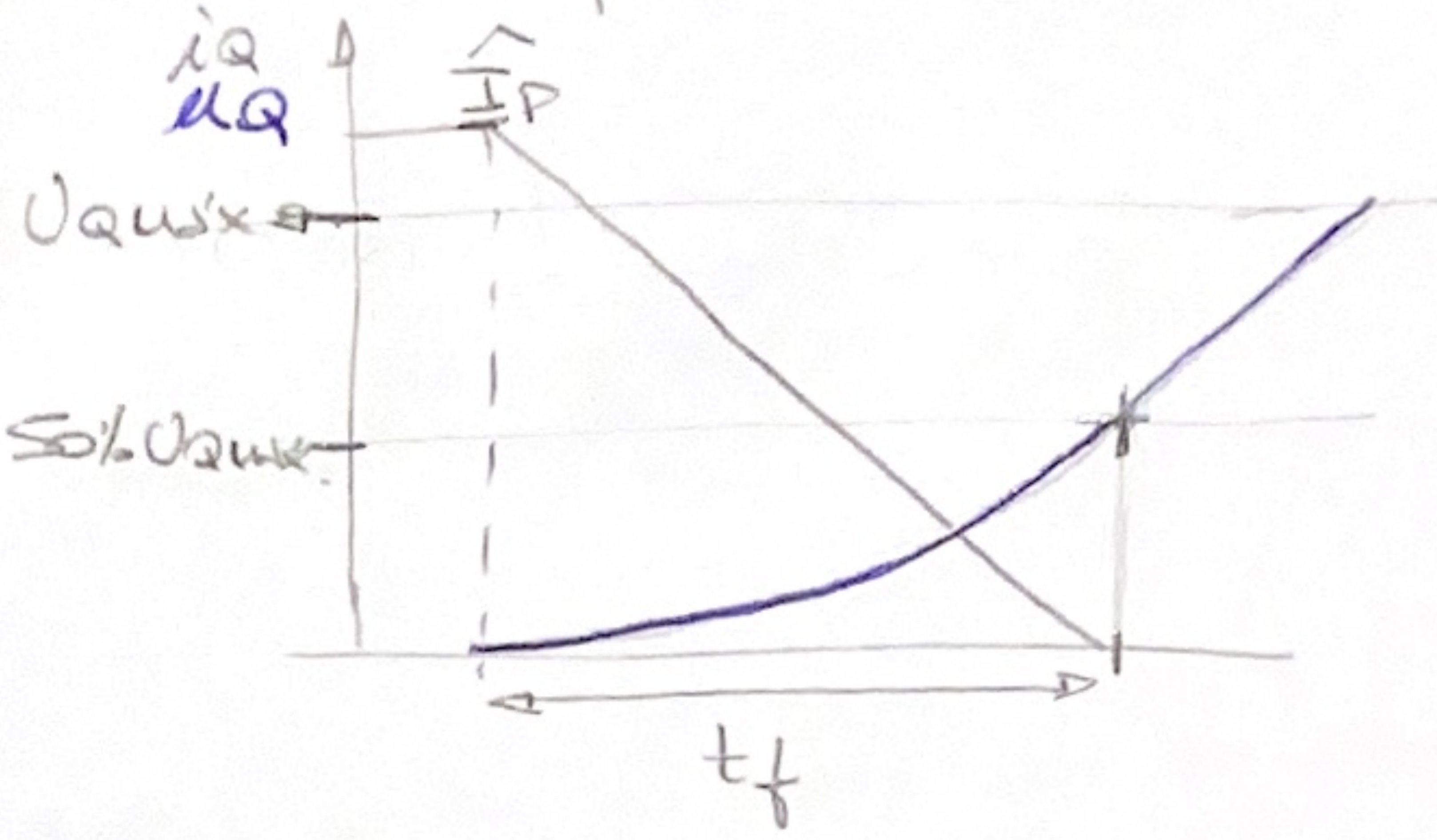
$$R_{\theta sa} = \frac{T_j - T_a}{P_H} - R_{\theta jc} - R_{\theta cs} = \frac{150 - 40}{18{,}1} - 0{,}65 - 0{,}24 \Rightarrow \boxed{R_{\theta sa} = 5{,}2\,°C/W}$$

d) Las pérdidas máximas en el apagado se dan para $U_d = U_{d\,máx}$

$P_{ap} = 11{,}7\,W$

$U_{d\,máx} + \frac{n_p}{n_s} U_o = U_{Q\,máx}$




$$i_Q(t) = \hat{I}_P - \frac{\hat{I}_P}{t_f} \cdot t \qquad i_S(t) = \frac{\hat{I}_P}{t_f} \cdot t$$

$$u_Q(t) = \frac{1}{C_S} \int_t i_S(t)\,dt \Rightarrow 0{,}5\,U_{Q\,máx} = \frac{1}{C_S} \int_0^{t_f} \frac{\hat{I}_P}{t_f} \cdot t\,dt = \frac{1}{C} \frac{\hat{I}_P\,t_f}{2}$$

$$\Rightarrow C_S = \frac{\hat{I}_P \cdot t_f}{2 \cdot 0{,}5\,U_{Q\,máx}} = \frac{4{,}68 \times 39 \times 10^{-9}}{2 \cdot 0{,}5 \cdot 640} \Rightarrow \boxed{C_S = 285\,pF}$$

$$\delta_{mín} T \leq 3 R_S C_S$$

$$\hat{I}_P = \frac{U_{d\,máx} \cdot \delta_{mín} T}{L_P} \Rightarrow \delta_{mín} = \frac{L_P \cdot \hat{I}_P \cdot f}{U_{d\,máx}} = \frac{109{,}58 \times 10^{-6} \cdot 4{,}68 \cdot 100 \times 10^3}{511{,}8} = 0{,}1$$

$$R \geq \frac{0{,}1}{3 \cdot 285 \times 10^{-12} \cdot 100 \times 10^3} \Rightarrow \boxed{R \geq 1170\,\Omega}$$

A su vez $P_{RS} = E_{CS} \cdot f = \frac{1}{2} C_S U_Q^2 \cdot f = \frac{1}{2} \cdot 285 \times 10^{-12} \cdot 640^2 \cdot 100 \times 10^3$

$$\boxed{P_{RS} = 5{,}8\,W}$$

e) Ahora $Ud = 400V$ $Ro = 0{,}5\Omega$

¿MCC o MCD?

Asumo MCD.

$$\frac{Uo}{Ud} = \sqrt{\frac{R}{Lp2f}} \cdot \delta \Rightarrow \delta = \frac{Uo}{Ud}\sqrt{\frac{2Lp \cdot f}{R}} = \frac{24}{400}\sqrt{\frac{2 \times 109{,}58 \times 10^{-6}\ 100 \times 10^{3}}{0{,}5}}$$

$$\delta = 0{,}397$$

$$\hat{I}_P = \frac{Ud}{Lp} \cdot \delta T = \frac{400 \cdot 0{,}397}{109{,}58 \times 10^{-6} \cdot 100 \times 10^{3}} = 14{,}49A$$ ⇒ la protección del circuito

no permitirá que $\hat{I}_P$ llegue a este valor. ⇒ $\hat{I}_P = 7{,}8A$.

$$\delta = \frac{\hat{I}_P \cdot Lp \cdot f}{Ud} = \frac{7{,}8 \cdot 109{,}58 \times 10^{-6} \cdot 100 \times 10^{3}}{400} = 0{,}21$$

Ahora: $$Uo = \sqrt{\frac{R}{2Lpf}} \cdot \delta \cdot Ud = \sqrt{\frac{0{,}5}{2 \times 109{,}58 \times 10^{-6} \cdot 100 \times 10^{3}}} \cdot 0{,}21 \cdot 400$$

$$\underline{Uo = 12{,}7V}$$

$$\hat{I}_S = \frac{np}{ns} \cdot \hat{I}_P = \frac{7{,}8}{0{,}1872} = 41{,}7A$$

$$\hat{I}_S = \frac{Uo}{Ls}(1-\delta)T \Rightarrow 1-\delta = \frac{\hat{I}_S \cdot Ls \cdot f}{Uo} = \frac{41{,}7 \cdot 3{,}84 \times 10^{-6} \cdot 100 \times 10^{3}}{12{,}7} = 1{,}26 \text{ ✗}$$

el convertidor está en MCC

Si $Uo = 24V \Rightarrow Io = \frac{24}{0{,}5} = 48A$.

pero $\hat{I}_{S\,max} = 41{,}7 \Rightarrow$ la fuente no va a poder mantener los 24V a la salida