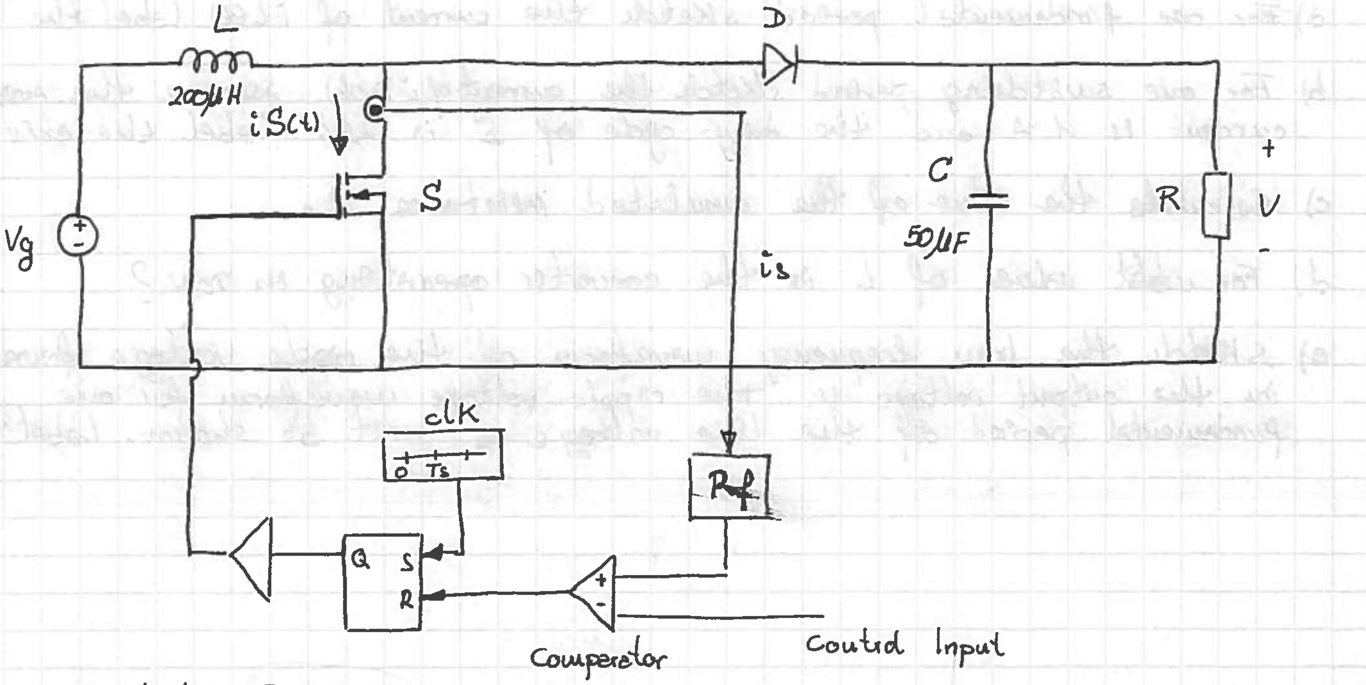
EXERCISE 2 (Switch mode)

Current Programmed Control of Boost converter, operation steady - state!



$T_s = 10\mu s$; $R = 20\Omega$

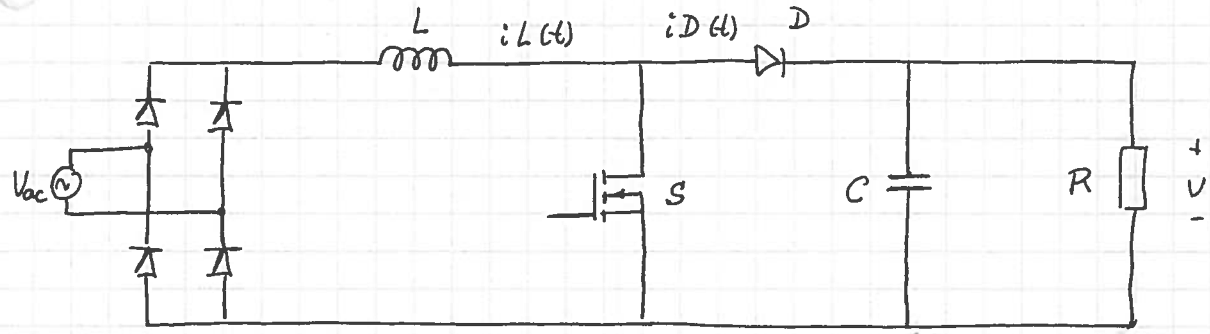
$V_g = 20V$; $V = 100V$; $R_f = 1\Omega$

Assume ideal components (⇒ no power loss in power conversion)

a) Calculate the average current of the switch S

b) Add a stabilizing ramp and calculate the minimum slope of the artificial ramp m_a that will give stability

Desing a boost converter,



Specification:

Output voltage 390V
Output power 500 W
Rms input voltage 230V
Efficiency 0.95
Fundamental frequency 50 Hz
Switching frequency 100 KHz

In question a, b assume converter operate CCM and switching frequency ripple current in L is very small - so small you may ignore it.

a) For one fundamental period sketch the current of $i_L(t)$. Label the axes.

b) For one switching period sketch the current of $i_D(t)$ assume the average current is 1 A and the duty-cycle of S is 25%. Label the axis.

c) Calculate the value of the emulated resistance R_e.

d) For what values of L is the converter operating in DCM?

e) Sketch the low frequency waveform of the ripple voltage found on the output voltage V. The ripple voltage waveform for one fundamental period of the line voltage must be shown. Label the axis

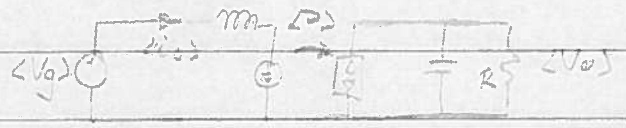
- EXAN -

EJERCICE 2

Boost

a) $\langle I_a \rangle = D \langle I_L \rangle$ $\qquad D = \frac{V_0 - V_g}{V_0} = \frac{100 - 20}{100} = 0.8$

$\langle I_L \rangle = \frac{P_o}{V_g} = \frac{500}{20} = 25\ A$



$\langle I_a \rangle = 0.8 \cdot 25$

$\boxed{\langle I_a \rangle = 20\ A}$

$P_i = V_g\, i_L$ $\qquad P_o = \frac{V_o^2}{R} = \frac{100^2}{20} = 500\ W$

$P_i = P_o$

$\langle i_L \rangle = \frac{500}{V_g}$

b)

$\alpha = \frac{m_2 - m_a}{m_1 + m_a} = |\alpha|$ (stable $|\alpha| < 1$) (Slide 15)

For a boost (Slide 5 T1)

$$\begin{cases} m_1 = \frac{V_g}{L} = \frac{20}{200 \cdot 10^{-6}} = 0.1\ A/\mu s \\ m_2 = -\frac{V_g - V_o}{L} = -\frac{20 - 100}{200 \cdot 10^{-6}} = 0.4\ A/\mu s \end{cases}$$

So: $m_a + m_1 = m_2 - m_a \Rightarrow m_a = \frac{m_2 - m_1}{2} = \frac{0.4 - 0.1}{2} = 0.15\ A/\mu s$

$|\alpha| < 1 \Rightarrow \boxed{m_a \geq 0.15\ A/\mu s}$

- EXAM -

EXERCISE 3

Boost

$V_o = 390\,V \quad P_o = 500\,W \quad \Big\} \; \eta = \frac{P_o}{P_i} = 0.95$

$V_g = 230\,V_{rms} \quad f = 50\,Hz$

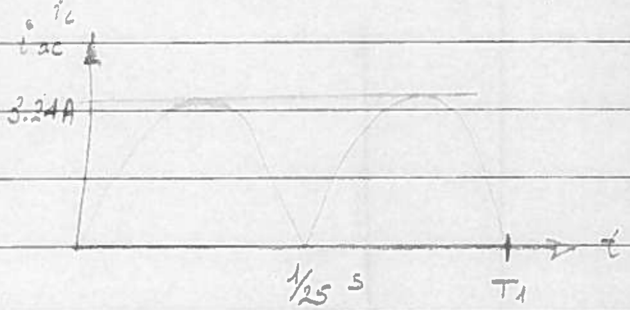
$f_s = 100\,kHz \Rightarrow T_s = 10^{-5}\,s$

a) Sketch $i_L(t)$. $i_L(t) = i_{ac}(t)$

$i_{ac} = \frac{P_{ac}}{V_{ac}} = \frac{500/0.95}{230} = 2.29\ A_{rms}$

$f_1 = 50\,Hz \Rightarrow T_1 = \frac{1}{50}\,s$

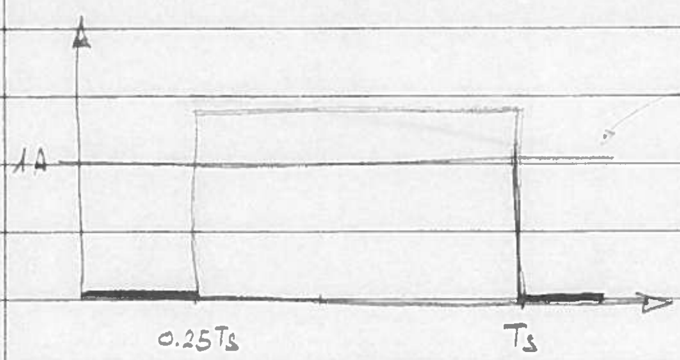
$\boxed{\hat{i}_{ac} = \sqrt{2} \cdot i_{ac\,rms} = 3.24\,A}$



b) $T_s \Rightarrow i_D(t) \quad \langle i_D \rangle = 1\,A \quad D = 25\%$

$D = \frac{t_{on}}{T_s} \Rightarrow t_{on} = 0.25\,T_s$

$t_{OFF} = 0.75\,T_s$



$\langle i_D \rangle = 0 \cdot 0.25 + 0.75 \cdot i_{D\,max} = 1$

$\boxed{i_{D\,max} = \frac{1}{0.75} = 1.33\,A}$

c) Re

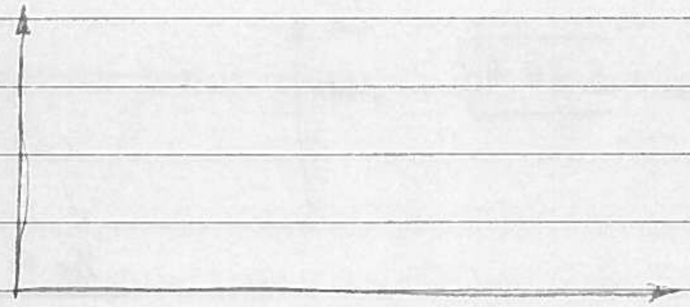
$Re = \frac{V_g}{I_g} = \frac{230}{2.29} = 100.5\,\Omega$

d) Values of L for DCM

For DCM $\quad R_e > \dfrac{2L}{T_s\left(1 - \frac{V_{i(pico)}}{V_o}\right)} \Rightarrow L < \dfrac{R_e \cdot T_s\left(1 - \frac{V_i}{V_o}\right)}{2}$

$$L < \frac{100.5 \cdot 10^{-5}\left(1 - \frac{230\sqrt{2}}{340}\right)}{2} = 83.4\ \mu F$$

e) Low frequency waveform of the ripple voltage in the output



$v_c = \frac{1}{C}\int i_c\, dt$

SMN 2012 HVDSMC

Exercise 2

a)
$$I_R = \frac{V}{R} \qquad I_R = \frac{100}{20} = \underline{5A}$$

$$P_{out} = I_R V \qquad P_{out} = 5 \cdot 100 = 500W$$

$$I_L = \frac{P_g}{V_g} \qquad I_L = \frac{500}{20} = \underline{25A}$$

$$V = V_g \frac{1}{1-D} \qquad V - VD = V_g \qquad D = \frac{V - V_g}{V}$$

$$I_S = D \cdot I_L \qquad D = \frac{100-20}{100}$$

$$I_S = 0.8 \cdot 25 \qquad \underline{D = 0.8}$$

$$\underline{I_S = 20A}$$

b)
$$m_1 = \frac{V_g}{L} \qquad m_2 = \frac{V - V_g}{L}$$

$$m_2 = \frac{100-20}{200e-6} \qquad m_1 = \frac{20}{200e-6}$$

$$m_2 = 0.4 A/\mu s \qquad m_1 = 0.1 A/\mu s$$

$$\alpha = -\frac{m_2 - m_a}{m_1 + m_a} \qquad |\alpha| < 1 \Rightarrow \text{stabile converter.}$$

sc
$$-1 = -\frac{m_2 - m_a}{m_1 + m_a} \qquad m_1 + m_a \overset{>}{=} m_2 - m_a$$

$$m_a \overset{>}{=} \frac{m_2 - m_1}{2}$$

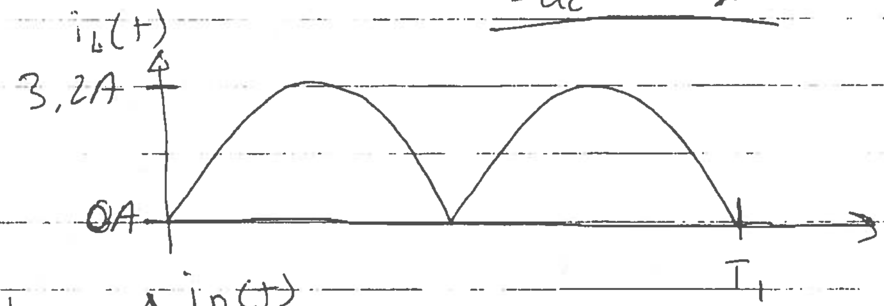
$$\underline{m_a \geq 0.15 A/\mu s} \Leftarrow m_a \geq \frac{0.4 A/\mu s - 0.1 A/\mu s}{2}$$

SMN 2012 HVDSMC

Exercise 3 : Design a boost converter.

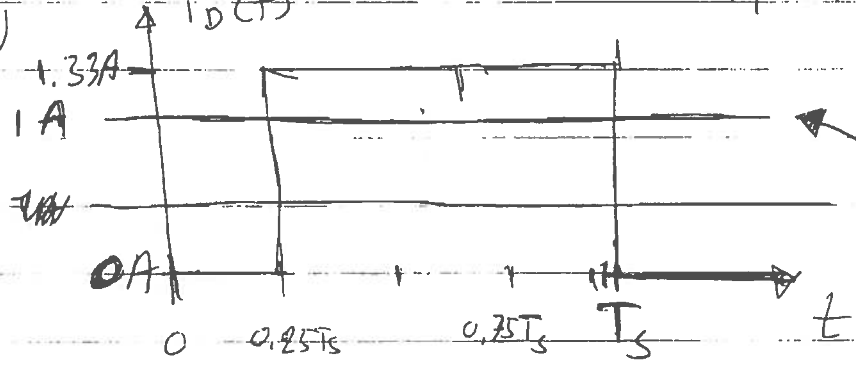
a) $P_{ac} = \frac{500W}{0{,}95}$ $\quad I_{ac} = \frac{P_{ac}/\eta}{V_{ac}}$ $\quad I_{ac} = \frac{500/0{,}95}{230}$

$\hat{I}_{ac} = 3.2A$ $\quad I_{ac} = 2{,}29\ A$



$T_1 = \frac{1}{50Hz}$

b)



$\hat{i}_D \cdot 0{,}75 = 1$ $\quad \hat{i}_D = \frac{4}{3}\ A$ $\quad \hat{i}_D = 1{,}33A$

c) $R_e = \frac{V_{ac}}{I_{ac}}$ $\quad R_e = \frac{230}{2{,}29}$ $\quad \underline{R_e = 100.5\ \Omega}$

d) DCM mode

$$R_e > 2L/T_s \left(1 - \frac{V_M}{V}\right)$$

$$R_e T_s \left(1 - \frac{V_M}{V}\right) > 2L$$

$$L < \frac{1}{2} R_e T_s \left(1 - \frac{V_M}{V}\right)$$

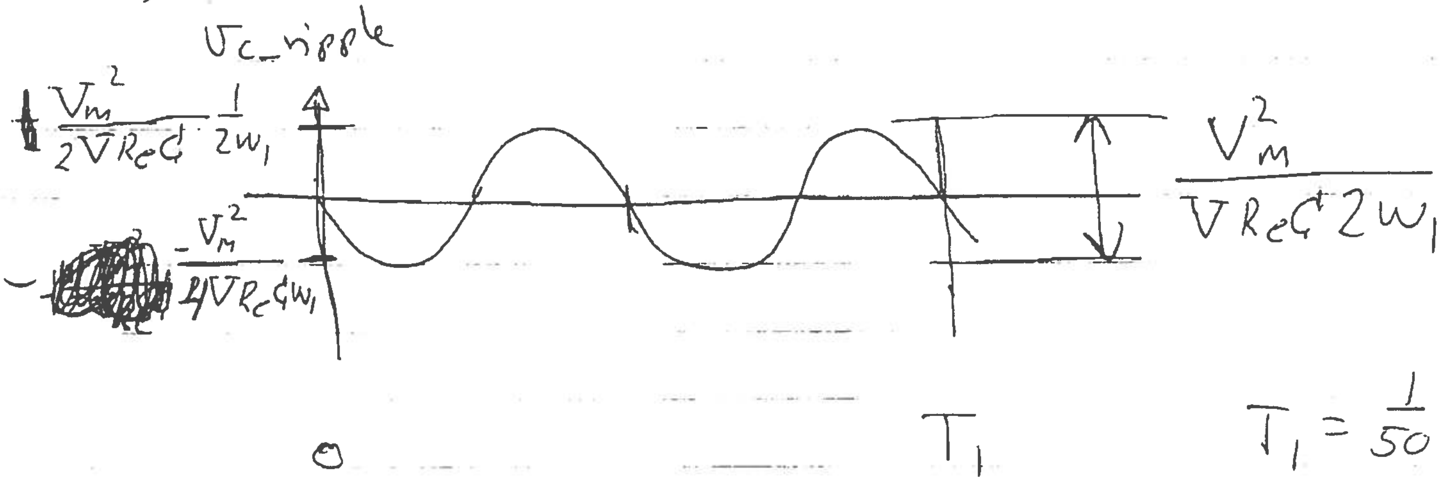
$$L < \frac{1}{2} \cdot 100.5 \cdot 10\mu s \left(1 - \frac{230 \cdot \sqrt{2}}{390}\right)$$

SMN 2012 HV DSMC

Cont: Exercise 3 Design a boost converter

$$\underline{\underline{L < 83\,\mu H}}$$

e)



$$i_c = -\frac{V_M^2}{2VR_e}\cos(2wt)$$

$$v_{c\_ripple} = \frac{1}{C}\int i_c\,dt$$

$$v_{c\_ripple} = -\frac{V_M^2}{2VR_eC'}\frac{1}{2w_1}\sin(2w_1t)$$