Cours 2 :

Analyse de Fourier :

\# 1

composante DC :

$$\langle v_s \rangle = \frac{1}{T_s} \cdot \int_0^{T_s} v_s(t)\, dt$$

$$= \frac{1}{\cancel{T_s}} \cdot D \cdot \cancel{T_s} \cdot V_g = D \cdot V_g$$

$$\therefore \langle v_s \rangle = \underbrace{D}_{[0,1]} \cdot V_g \Rightarrow \langle v_s \rangle < V_g \Rightarrow \boxed{\text{buck}}$$

f_s : 1kHz – 1MHz

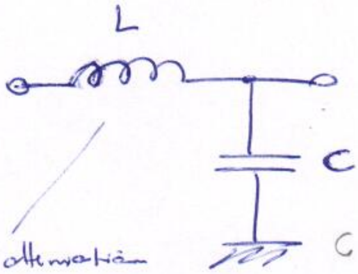
$T_s = \frac{1}{f_s}$

D : rapport cyclique

\# 2

filtre passe-bas :

$Z = j\omega L$

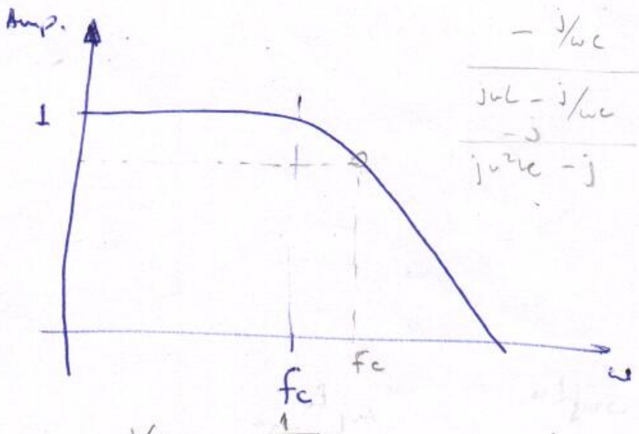


$Z = \frac{1}{j\omega C}$

$C = -\frac{j}{\omega C}$

more attenuation at high f

$\omega \uparrow \quad Z_L \uparrow \quad Z_C \downarrow$



$$\frac{-j/\omega C}{j\omega L - j/\omega C}$$

$$\frac{-j}{j\omega^2 LC - j}$$

convertion ratio (facteur de conversion)

$M(D) = V_{out}/V_{in}$

$M(D) = D$: buck

$M(D) = \frac{1}{1-D}$: boost

$$\frac{V_{out}}{V_{in}} = \frac{\frac{1}{j\omega C}}{j\omega L + \frac{1}{j\omega C}} = \frac{1}{-\omega^2 LC + 1}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 - \omega^2 LC}$$

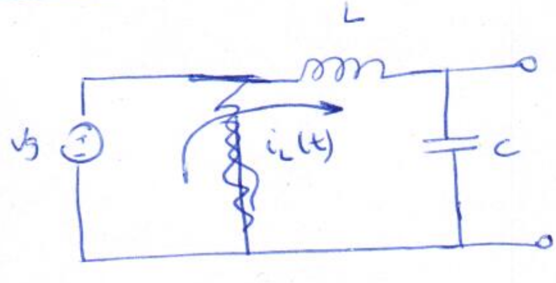
$$-j \cdot \frac{1}{j \cdot j\omega C}$$

$$\frac{j \cdot \omega L}{j\omega C}$$

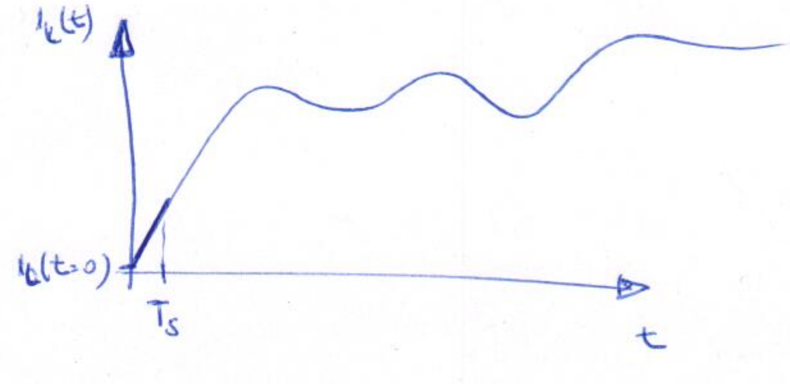
$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

slide ~~8~~ 7

#3



$$\begin{cases} v_L = L\dfrac{di}{dt} \\ i_C = C\dfrac{dv}{dt} \end{cases}$$



$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

$$\begin{cases} f_c \ll f_s \\ T_c \gg T_s \end{cases}$$

⇒ approximation : ligne droite

small ripple = linear ripple

Variable ne peut pas etre discontinue

On l'applique pour : $\begin{cases} i_L \\ v_C \end{cases}$ ⇒ peut approximer par une ~~courbe~~ ligne droite.

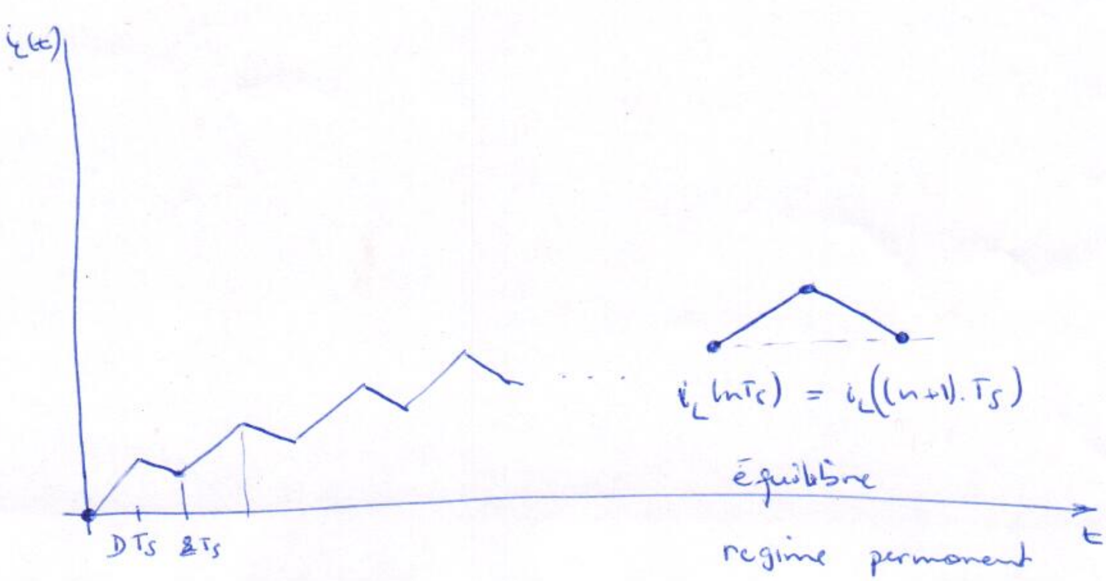
* Cela marche grace a la commutation rapide

slide 13 :

#4

periode 1 : $\frac{V_g - V}{L} > 0$

periode 2 : $-\frac{V}{L} < 0$



$i_L(nT_s) = i_L((n+1).T_s)$

équilibre

régime permanent

<u>Slide 14</u>

$$v_L(t) = L \cdot \frac{di_L(t)}{dt}$$

$$\int_0^{T_s} v_L(t) = \int_0^{T_s} L \, \frac{di_L(t)}{dt} =$$

$$\therefore \; i_L(T_s) - i_L(0) = \frac{1}{L} \cdot \int_0^{T_s} v_L(t) \, dt$$

$\Rightarrow$ $i_L(T_s) = i_L(0)$ in steady - state $\Rightarrow$

$$0 = \cancel{\frac{1}{L}} \int_0^{T_s} v_L(t) \, dt$$

thus

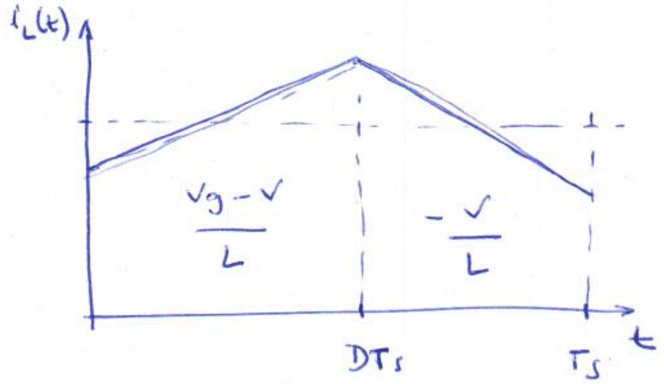
$$\frac{1}{T_s} \int_0^{T_s} v_L(t) \, dt = \langle v_L \rangle_{T_s} = 0$$

$$\therefore \; \boxed{\langle v_L \rangle \Big|_{\text{une periode}} = 0}$$

SLIDE 15

Revenons sur les ripples de courant :

\# 6



$$\Delta i_L^1 = \frac{V_g - V}{L} \times DT_s$$

$$\Delta i_L^2 = -\frac{V}{L} \times (1-D) \cdot T_s = \frac{-V + VD}{L} \; T_s$$

$$= \frac{-V/D + V}{L} \cdot D.T_s$$

$$= \frac{-V_g + V}{L} \times DT_s$$

$$\Uparrow$$

$$V_g = \frac{V}{D}$$

$$\therefore \; \Delta i_L^1 = -\Delta i_L^2 \Rightarrow \text{régime stationnaire}$$

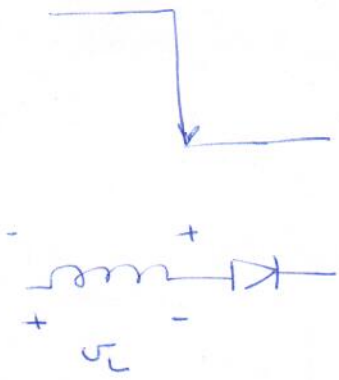
Slide 17

why diode ?

$$v_L = L \frac{di}{dt}$$

on $\longrightarrow$ off $\quad \underbrace{\frac{di}{dt}}_{-\infty}$

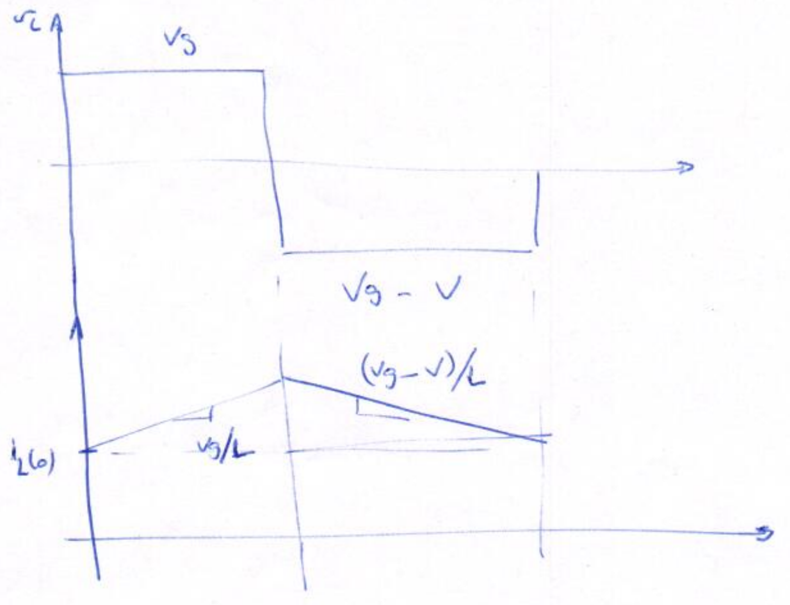
$\therefore\ v_L \rightarrow -\infty$



- diode conducts
- inductor current flows
- parfois $\Rightarrow$ roue libre

(*) cellule de commutation n'a pas besoin de 2 composants actifs.

Slide 22



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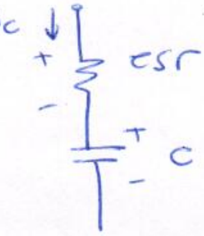


ripple:

$\Delta i_C \times ESR + \Delta v_C$

Boost :

70 positive volt-second

volt-second balance

$$\boxed{\frac{1}{T_s}\int_0^{T_s} v_L(t)\,dt = \langle v_L \rangle}$$

1) $\underline{v_L = V_g}$ $\quad i_C = -\frac{v}{R} = -\frac{V}{R}$

$v \approx V$

2) $v_L = V_g - v \approx V_g - V$ ⇒ must be negative! ⇒ $V > V_g$

$i_C = i_L - \frac{v}{R} = i_L - \frac{V}{R} = I - \frac{V}{R}$

steady - state

$$\frac{1}{T_s}\int_0^{T_s} v_L(t)\,dt = \frac{V_g DT + (V_g - V) D'T}{T} = 0$$

$$V_g \underbrace{(D + D')}_{1} = VD'$$

$$\boxed{\frac{V}{V_g} = \frac{1}{1-D}}$$

DC current: capacitor charge balance principle

inductor current.

$$0 = \frac{1}{T_s}\int_0^{T_s} i_C(t)\,dt = \langle i_C \rangle = -\frac{V}{R}\frac{DT_s}{T_s} + \left(I - \frac{V}{R}\right)\frac{D'T_s}{T_s} = 0$$

$$-\frac{V}{R}\underbrace{(D + D')}_{1} + I D' = 0$$

$$\therefore\ I = \frac{V}{D'R} = \frac{V_g}{D'^2 R}$$

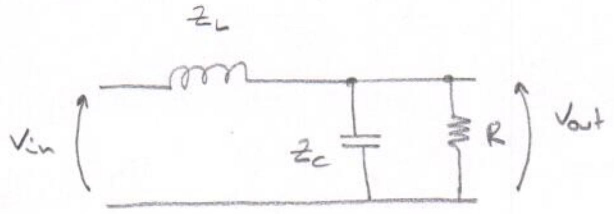
Sketch inductor current :

1) $\frac{di_L}{dt}(t) = \frac{v_L(t)}{L} = \frac{V_g}{L}$ positive slope

2) $\frac{di_L}{dt}(t) = \frac{V_g - V}{L}$

$2\Delta i_L = \frac{V_g}{L} D \cdot T_s \Rightarrow \Delta i_L = \frac{V_g}{2L} \cdot D \cdot T_s$

RLC filters



$$Z = Z_L + Z_C // R$$

1) $$Z_C//R = \frac{R/j\omega C}{R + \frac{1}{j\omega C}}$$

$$= \frac{R}{j\omega RC + 1}$$

2) $$Z_L + Z_C//R = j\omega L + \frac{R}{j\omega RC + 1}$$

$$= \frac{-\omega^2 RLC + j\omega L + R}{j\omega RC + 1}$$

$$\therefore V_{out} = \frac{V_{in} . (Z_C//R)}{Z_L + Z_C//R}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{R/\cancel{j\omega RC + 1}}{\frac{R - \omega^2 RLC + j\omega L}{\cancel{j\omega RC + 1}}}$$

$$= \frac{1}{1 - \omega^2 LC + j\omega L/R}$$

$$|Den| = \sqrt{(1 - \omega^2 LC)^2 + \frac{\omega^2 L^2}{R^2}}$$

$$1 - \omega^2 LC = \frac{\omega L}{R}$$

$$\omega^2 LC + \frac{L}{R}\omega - 1 = 0$$

$$\omega = \frac{-\frac{L}{R} \pm \sqrt{\frac{L^2}{R^2} + 4 LC}}{2LC}$$

$$\omega = -\frac{1}{2RC} \pm \sqrt{\frac{1}{4C^2R^2} + \frac{1}{LC}}$$