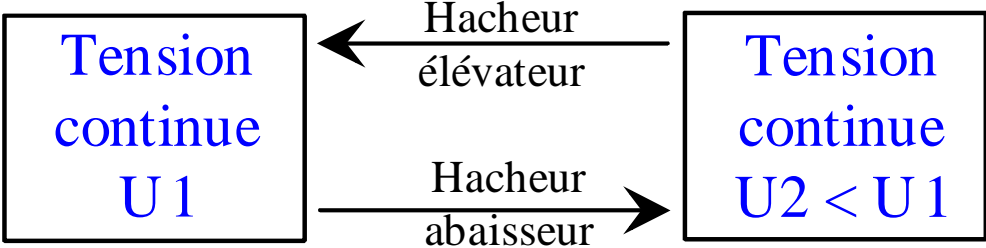
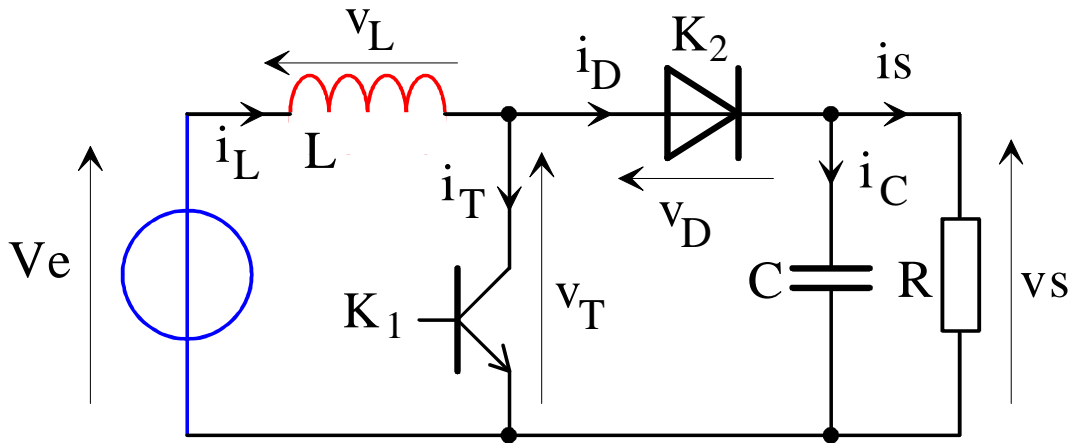


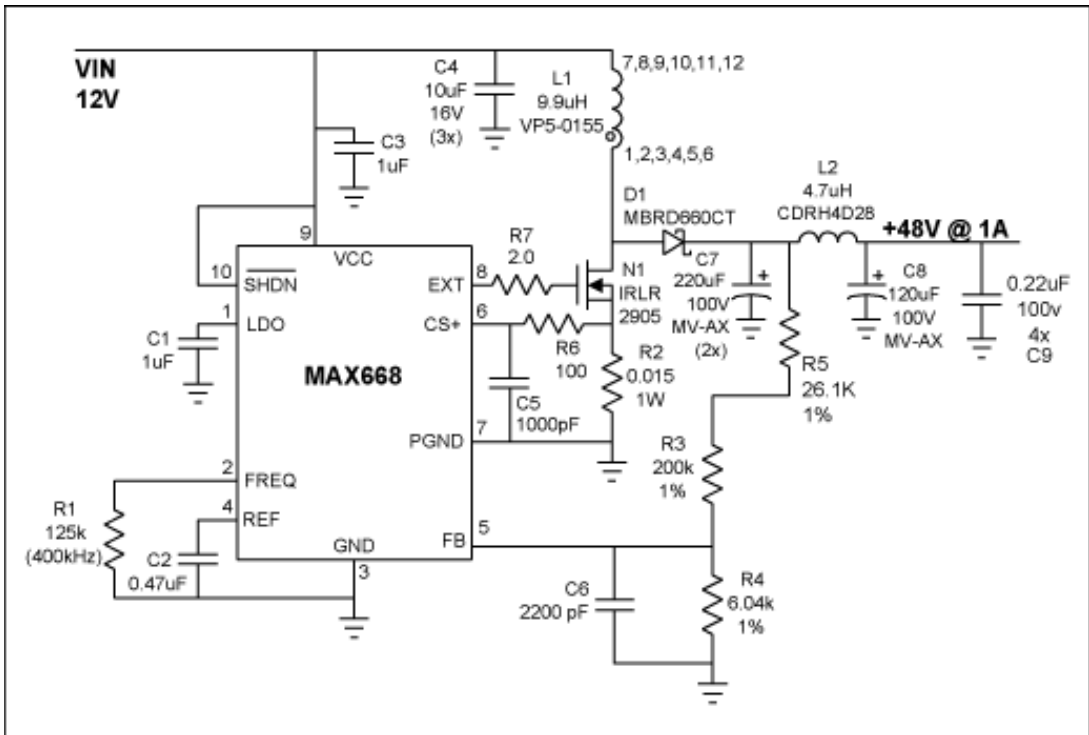
Les convertisseurs DC-DC : la fonction hacheur



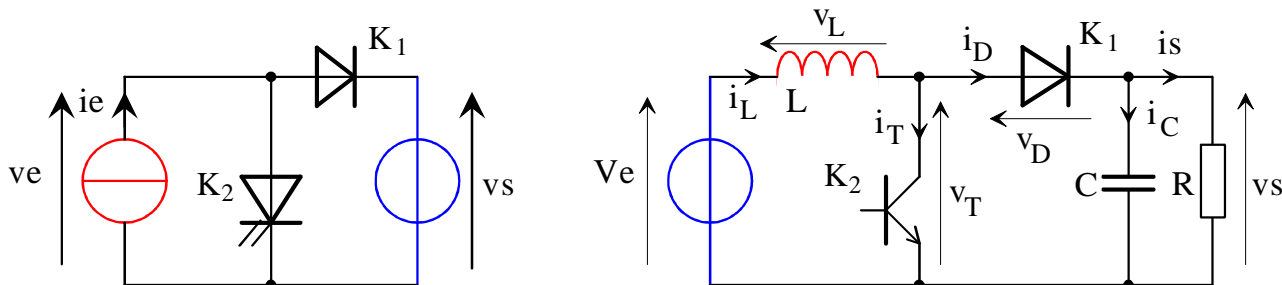
Le hacheur élévateur de type BOOST



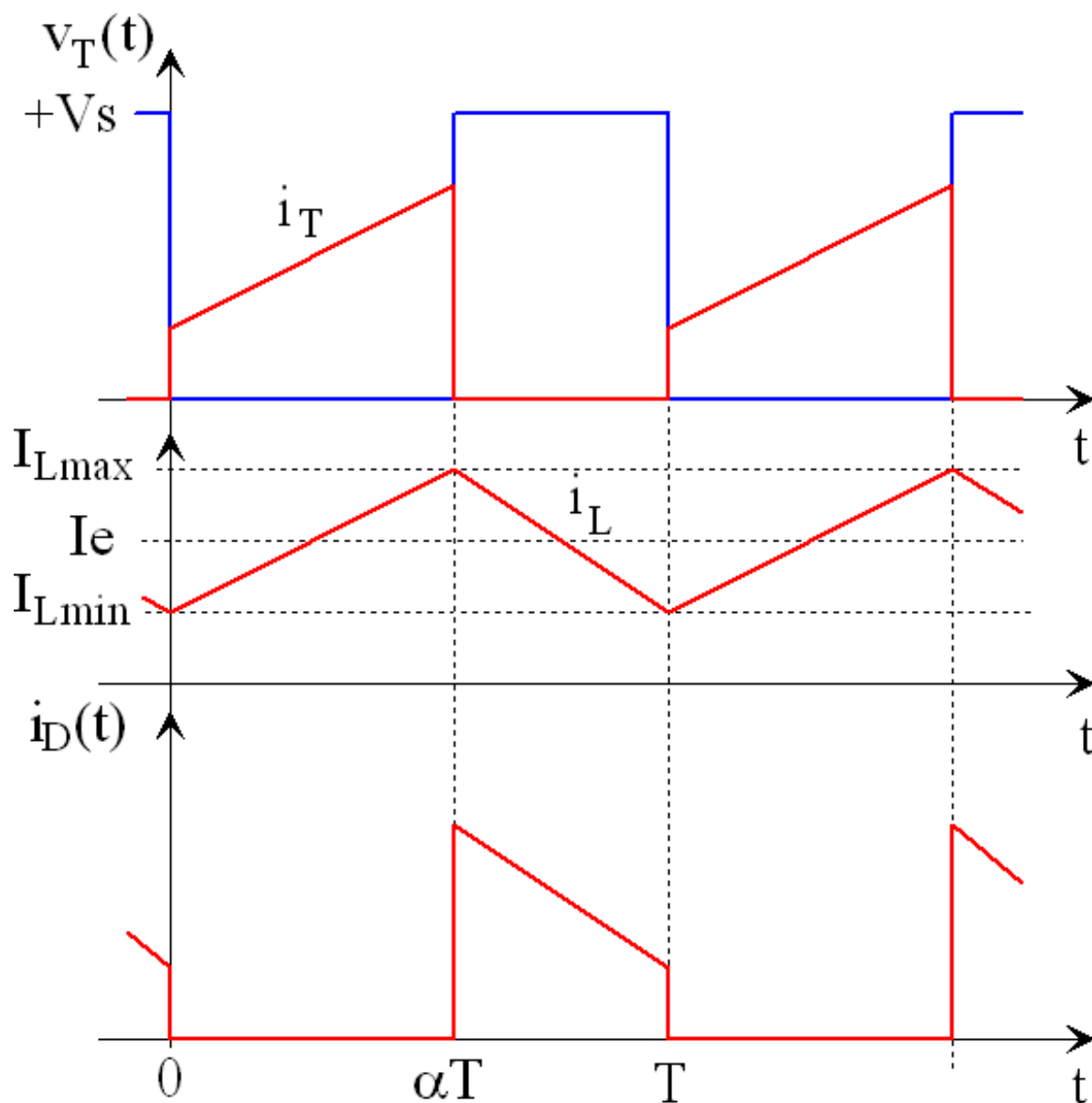
Exemple : Alimentation continue +48V à découpage



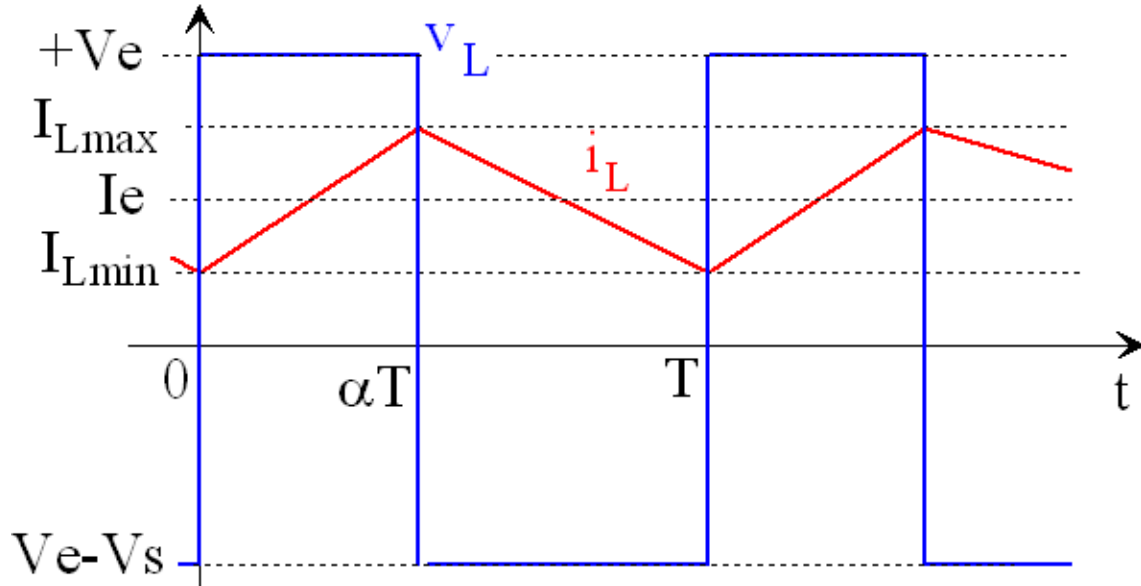
Le hacheur élévateur de type BOOST



Formes d'ondes du hacheur BOOST



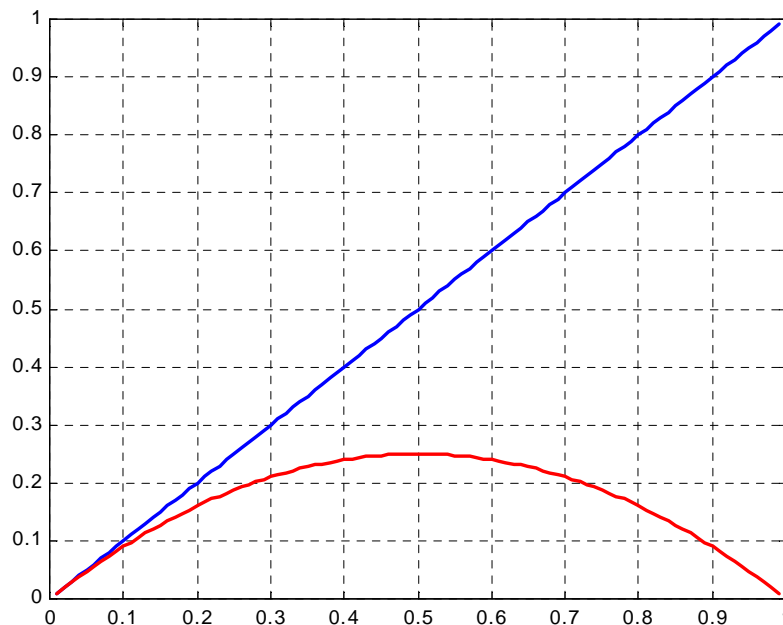
Tension et courant de l'inductance (BOOST)



Ondulation du courant

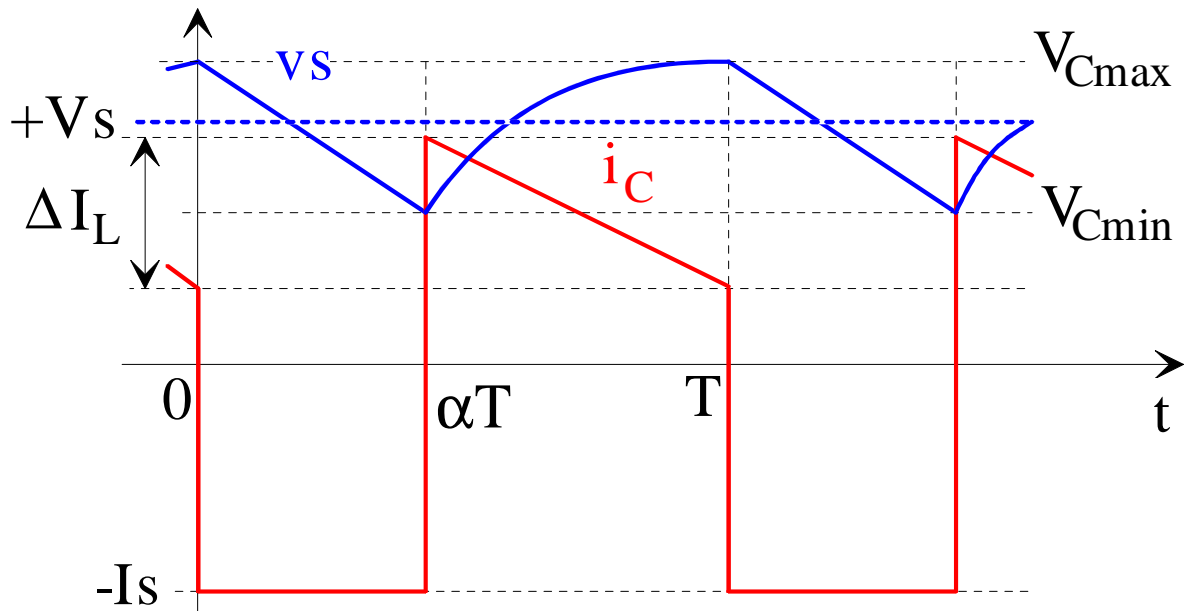
$$\Delta I_L = I_{Lmax} - I_{Lmin} = \frac{V_e}{L} \cdot \alpha T = \frac{V_e}{LF} \cdot \alpha$$

Evolution de ΔI_L en fonction de α



Ondulation de la tension (BOOST)

$$i_D(t) = i_C(t) + i_S(t) = I_{Dmoy} + \partial i_D(t)$$



$$\text{Pour } t \in [0 ; \alpha T] : v_C(t) = \frac{1}{C} \int i_C(t) \cdot dt = V_{Cmax} - \frac{I_S}{C} (t - 0)$$

$$\text{Pour } t \in [\alpha T ; T] : i_C(t) = I_{Lmax} - I_S + \frac{V_e - V_S}{L} (t - \alpha T) - I_S$$

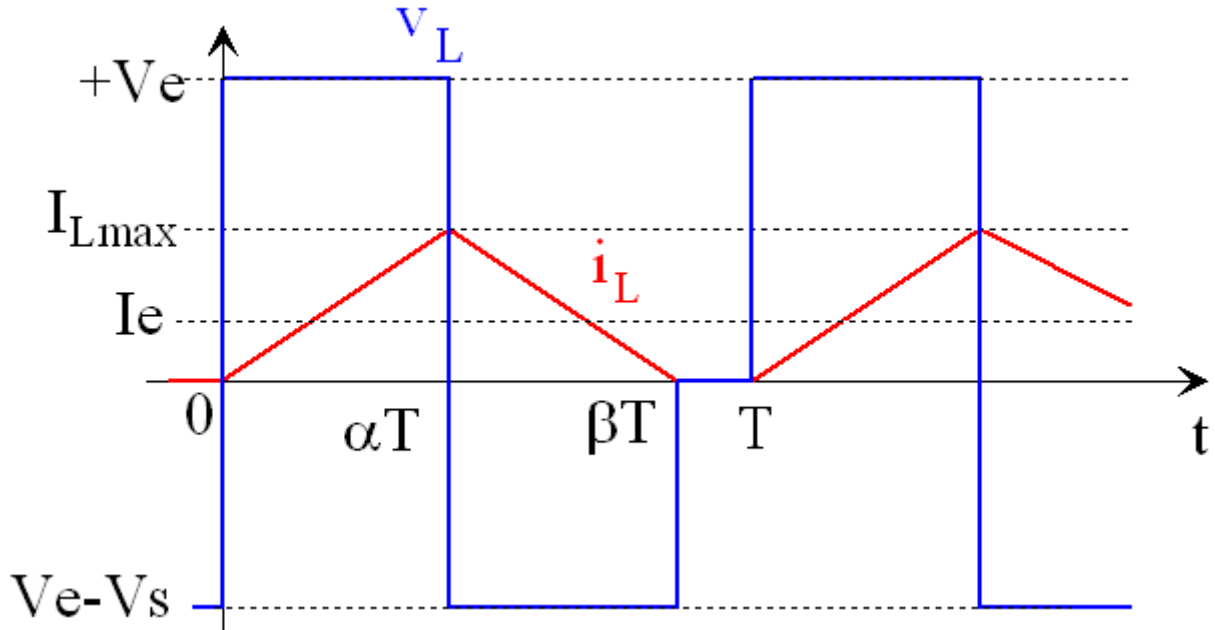
$$v_C(t) = \frac{1}{C} \int i_C(t) \cdot dt = V_{Cmin} + \frac{1}{C} \left[(I_{Lmax} - I_S) \cdot (t - \alpha T) + \frac{V_e - V_S}{L} \cdot \frac{(t - \alpha T)^2}{2} \right]_{\alpha T}^t$$

$$v_C(t) = \frac{(I_{Lmax} - I_S)}{C} \cdot (t - \alpha T) + \frac{V_e - V_S}{LC} \cdot \frac{(t - \alpha T)^2}{2} + V_{Cmin}$$

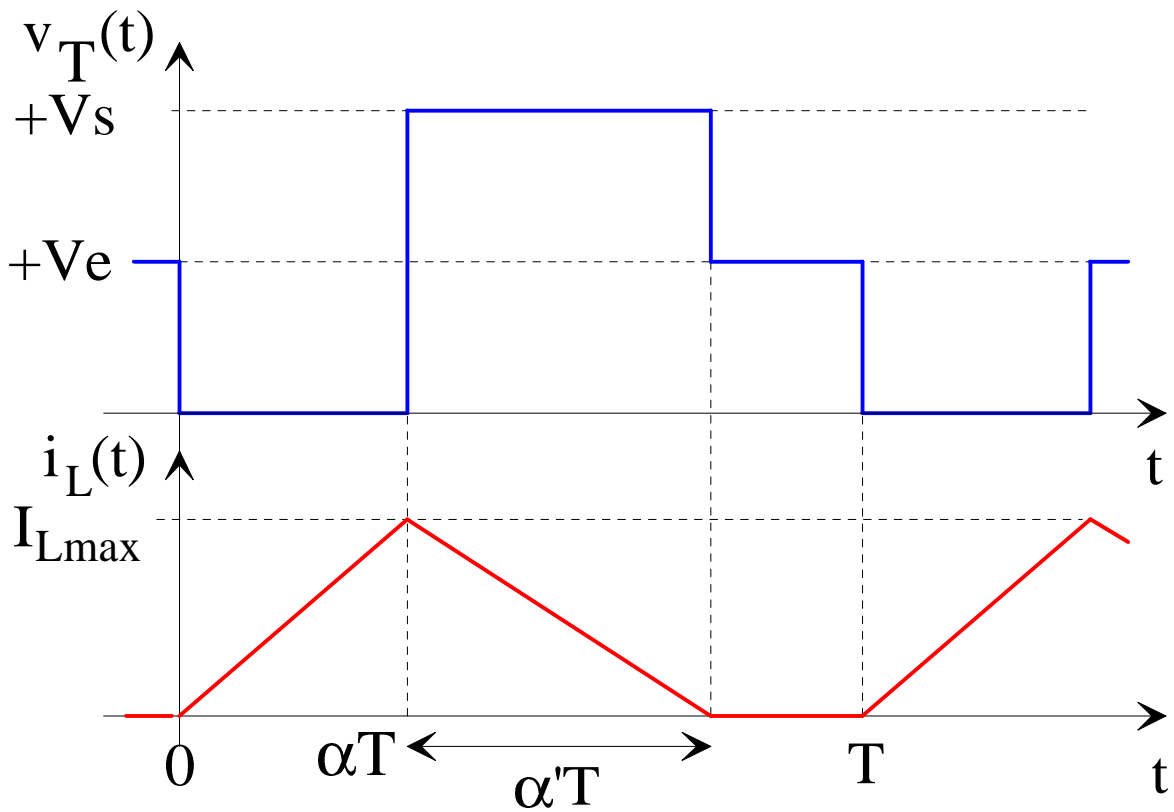
Valeur ΔV_S de l'ondulation de tension (BOOST)

$$\Delta V_S = V_{Cmax} - V_{Cmin} = \frac{I_S}{C} \alpha T = \frac{I_S}{CF} \alpha$$

Fonctionnement en conduction discontinue (BOOST)



Tension aux bornes du transistor en conduction discontinue

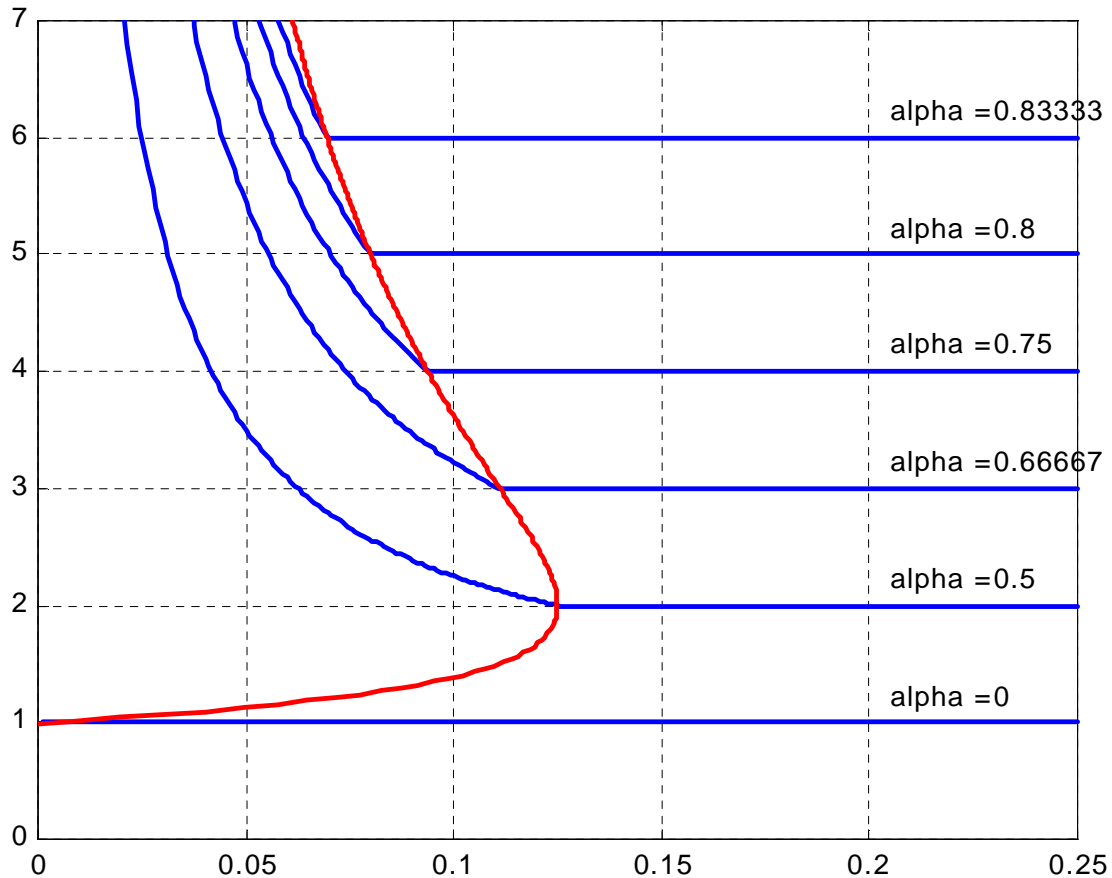


Caractéristiques de sortie du hacheur de type BOOST

Tension normalisée ou tension réduite : $y = \frac{V_s}{V_e}$

Courant de charge normalisé ou réduit : $x = \frac{LF}{V_e} \cdot I_s$

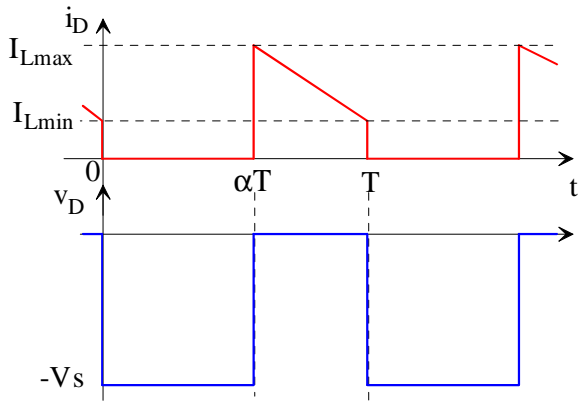
$$y = 1 + \frac{\alpha^2}{2 \cdot x}$$



$$I_{s\text{limite}} = \frac{I_{L\text{max}}}{2} \alpha' = \frac{V_e}{2LF} \cdot \alpha(1-\alpha) ; x_{\text{limite}} = \frac{y-1}{2 \cdot y^2} ; \begin{cases} x_{\text{limite}} = \frac{\alpha(1-\alpha)}{2} \\ y_{\text{limite}} = \frac{1}{1-\alpha} \end{cases}$$

Contraintes sur les interrupteurs (BOOST)

Interrupteur K1 : la diode



$$I_{Dmax} = I_{FRM} = \langle i_L \rangle + \frac{\Delta I_L}{2}$$

$$= \frac{I_s}{1-\alpha} + \frac{\alpha \cdot V_e}{2LF}$$

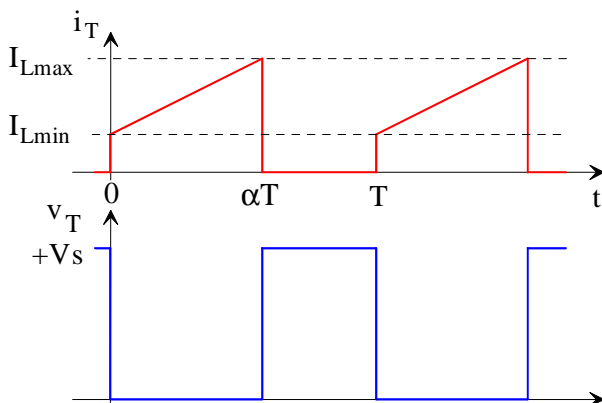
$$I_{Dmoy} = I_{F(AV)} = I_s$$

$$V_{Dinvmax} = V_{RRM} = +V_s$$

$$I_{Deff} = \sqrt{\left(\left(\frac{I_s}{1-\alpha} \right)^2 + \frac{\Delta I_L^2}{12} \right) \cdot (1-\alpha)}$$

Pertes statiques dans la diode : $P_0 = R_D \cdot I_{F(RMS)}^2 + V_{D0} \cdot I_{F(AV)}$

Interrupteur K2 : le transistor



$$I_{Tmax} = I_{Dmax} = \frac{I_s}{1-\alpha} + \frac{\alpha \cdot V_e}{2LF}$$

$$I_{Tmoy} = \frac{I_s}{1-\alpha} = I_{emoy}!$$

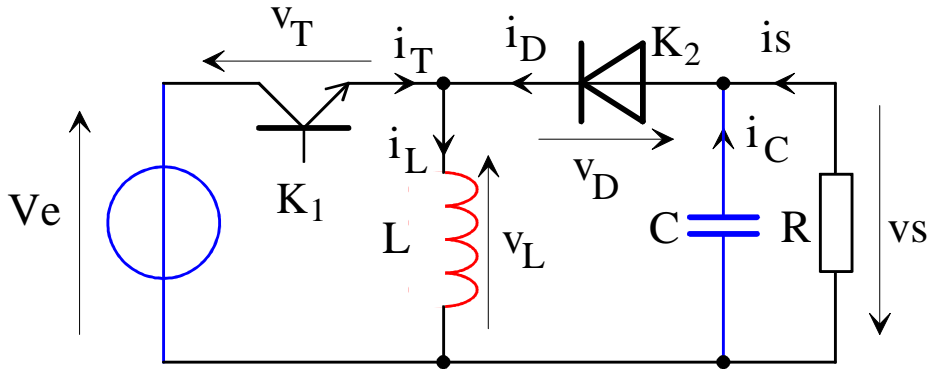
$$V_{Tmax} = +V_s$$

$$I_{Teff} = \sqrt{\left(\left(\frac{I_s}{1-\alpha} \right)^2 + \frac{\Delta I_L^2}{12} \right) \cdot \alpha}$$

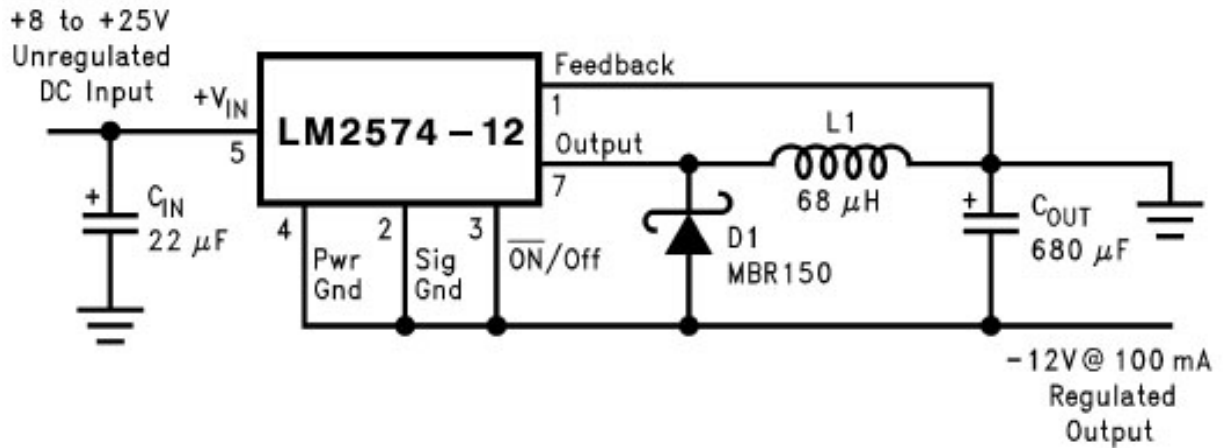
Pertes statiques du MOSFET : $P_0 = R_{DSon} \cdot I_{DS(RMS)}^2$.

Pertes statiques du bipolaire : $P_0 = R_D \cdot I_{C(RMS)}^2 + V_{CEsat} \cdot I_{C(AV)}$

Le hacheur inverseur de type BUCK-BOOST

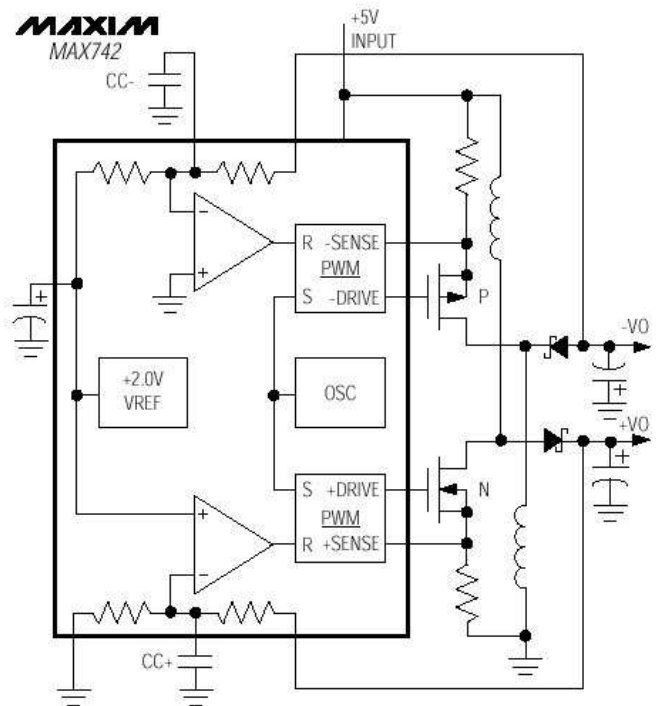


Exemple 1 : alimentation continue -12 V à découpage

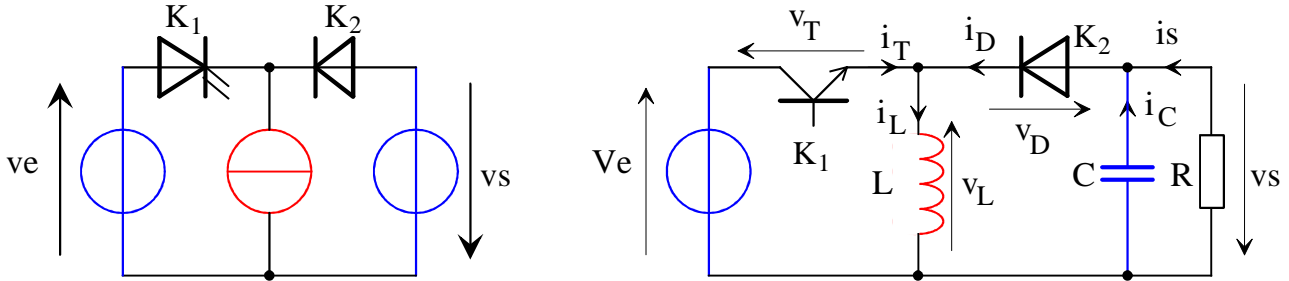


Exemple 2 :

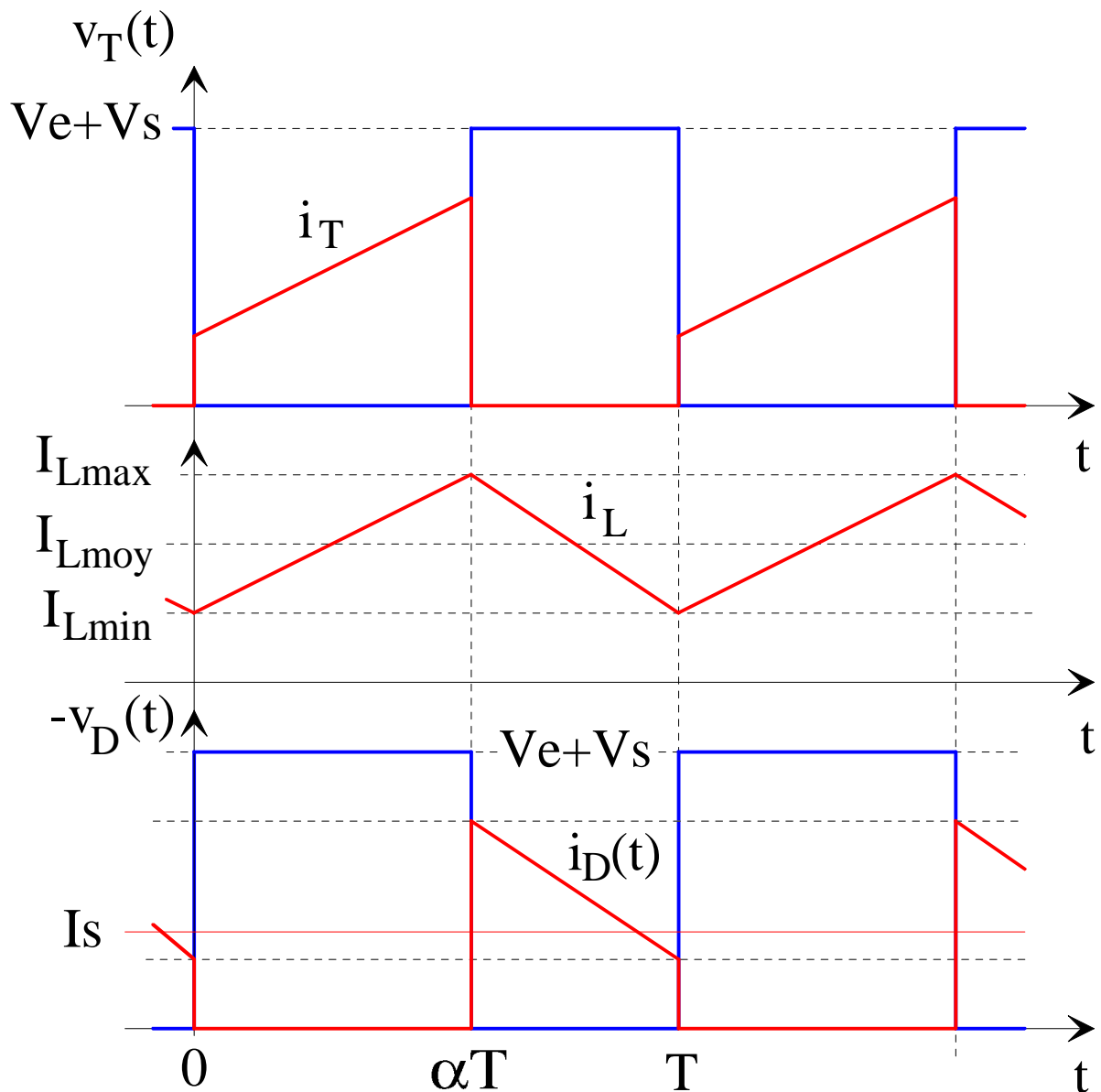
Alimentation double +12 V / -12 V à découpage



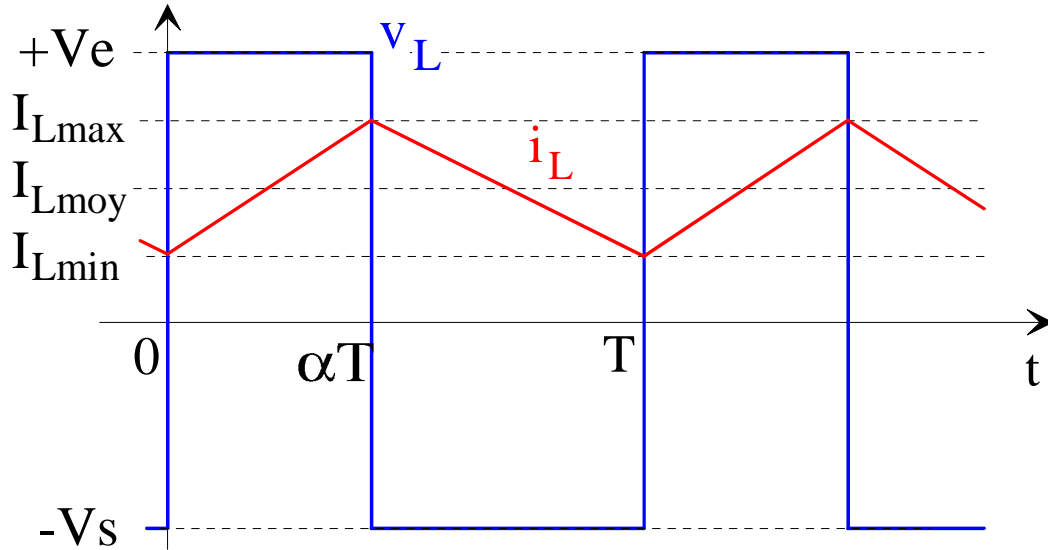
Structure du hacheur inverseur



Formes d'ondes



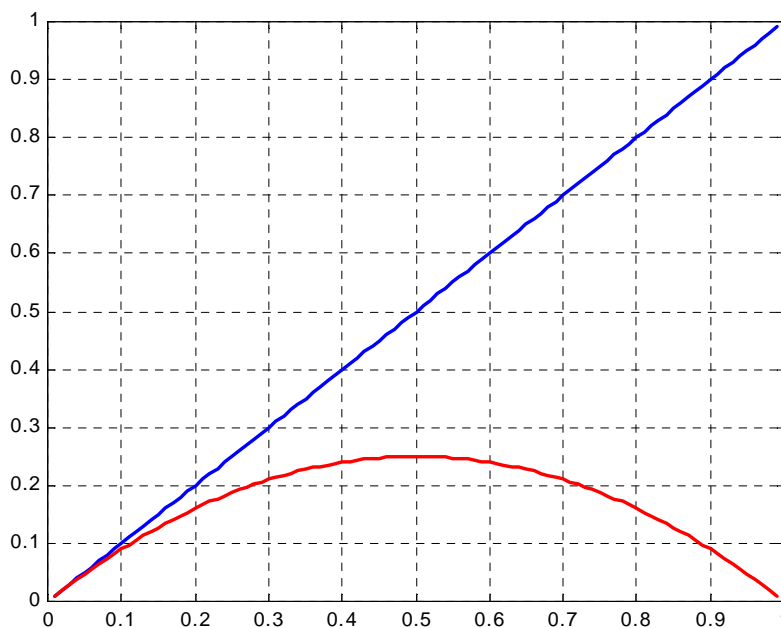
Tension et courant de l'inductance (BUCK-BOOST)



Ondulation du courant

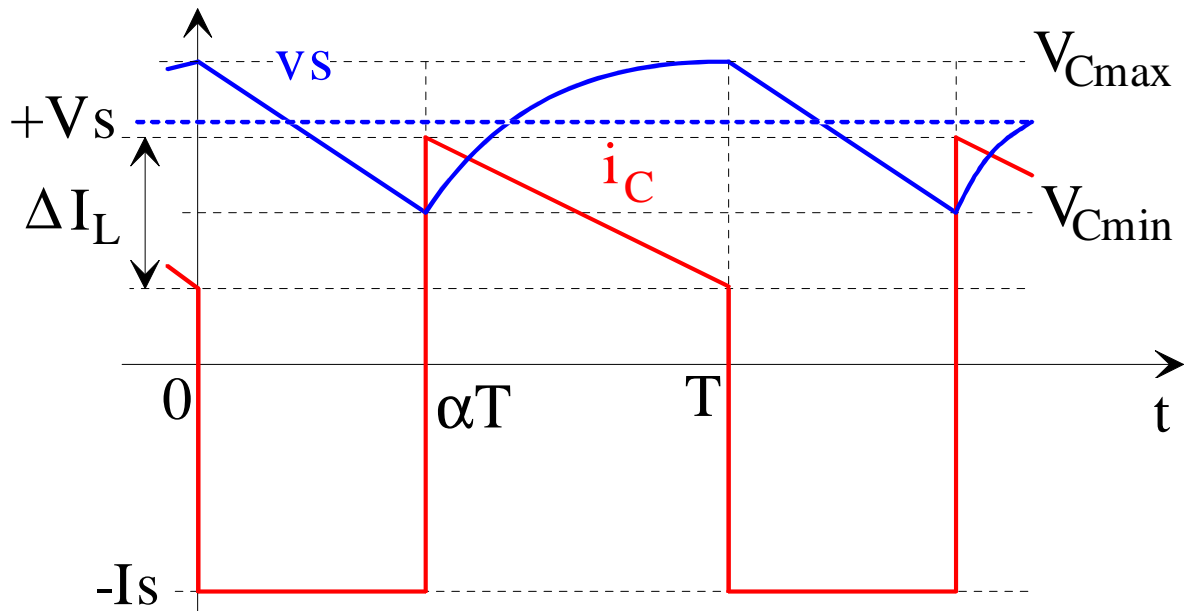
$$\Delta I_L = I_{Lmax} - I_{Lmin} = \frac{V_e}{L} \cdot \alpha T = \frac{V_e}{LF} \cdot \alpha$$

Evolution de ΔI_L en fonction de α



Ondulation de la tension (BUCK-BOOST)

$$i_D(t) = i_C(t) + i_S(t) = I_{Dmoy} + \partial i_D(t)$$



$$\text{Pour } t \in [0 ; \alpha T] : v_C(t) = \frac{1}{C} \int i_C(t) \cdot dt = V_{Cmax} - \frac{I_S}{C} (t - 0)$$

$$\text{Pour } t \in [\alpha T ; T] : i_C(t) = I_{Lmax} - I_S - \frac{V_S}{L} (t - \alpha T) - I_S$$

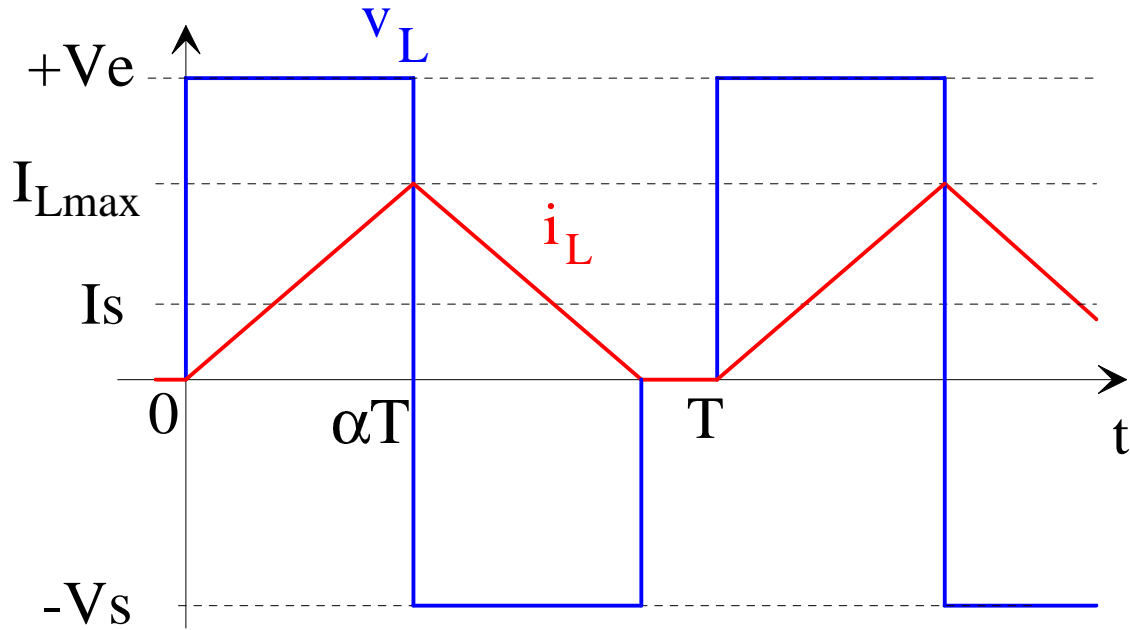
$$v_C(t) = \frac{1}{C} \int i_C(t) \cdot dt = V_{Cmin} + \frac{1}{C} \left[(I_{Lmax} - I_S) \cdot (t - \alpha T) - \frac{V_S}{L} \cdot \frac{(t - \alpha T)^2}{2} \right]_{\alpha T}^t$$

$$v_C(t) = \frac{(I_{Lmax} - I_S)}{C} \cdot (t - \alpha T) - \frac{V_S}{LC} \cdot \frac{(t - \alpha T)^2}{2} + V_{Cmin}$$

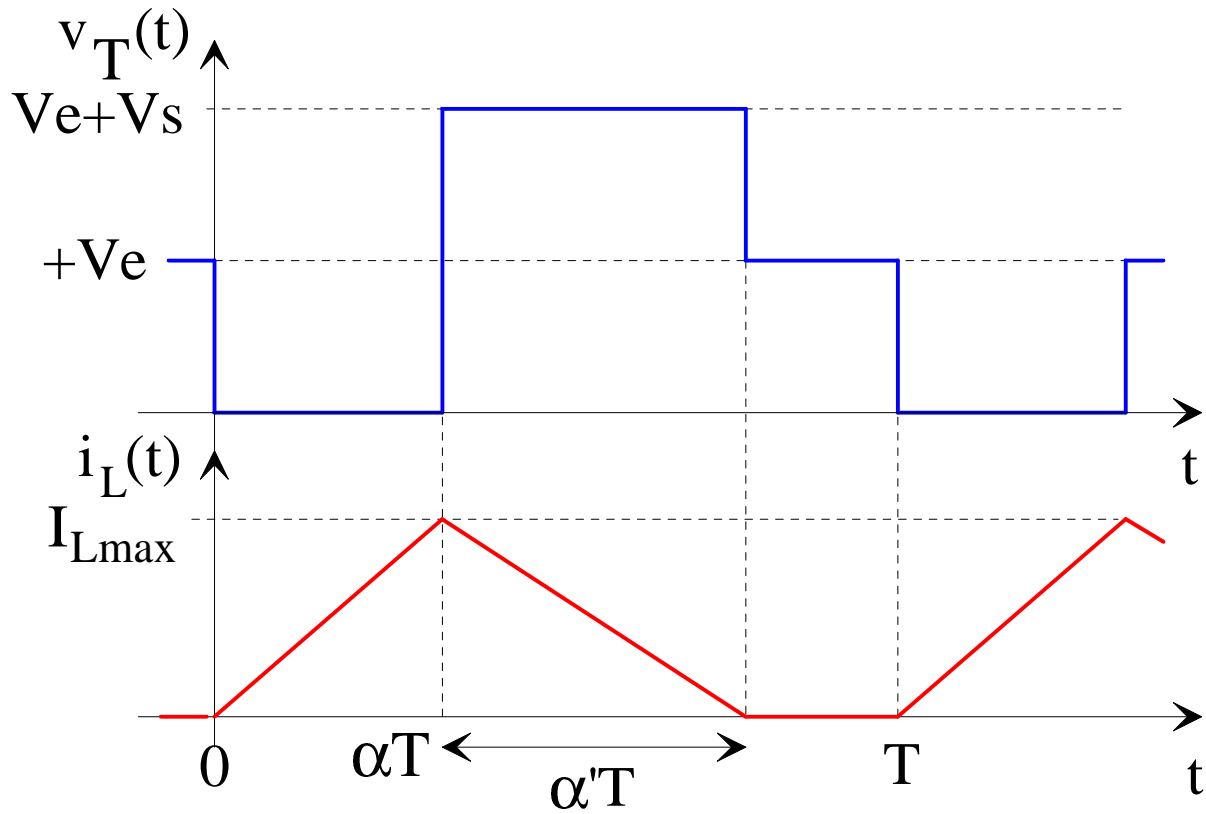
Valeur ΔV_S de l'ondulation de tension

$$\Delta V_S = V_{Cmax} - V_{Cmin} = \frac{I_S}{C} \alpha T = \frac{I_S}{CF} \alpha$$

Fonctionnement en conduction discontinue (BUCK-BOOST)



Tension aux bornes du transistor en conduction discontinue

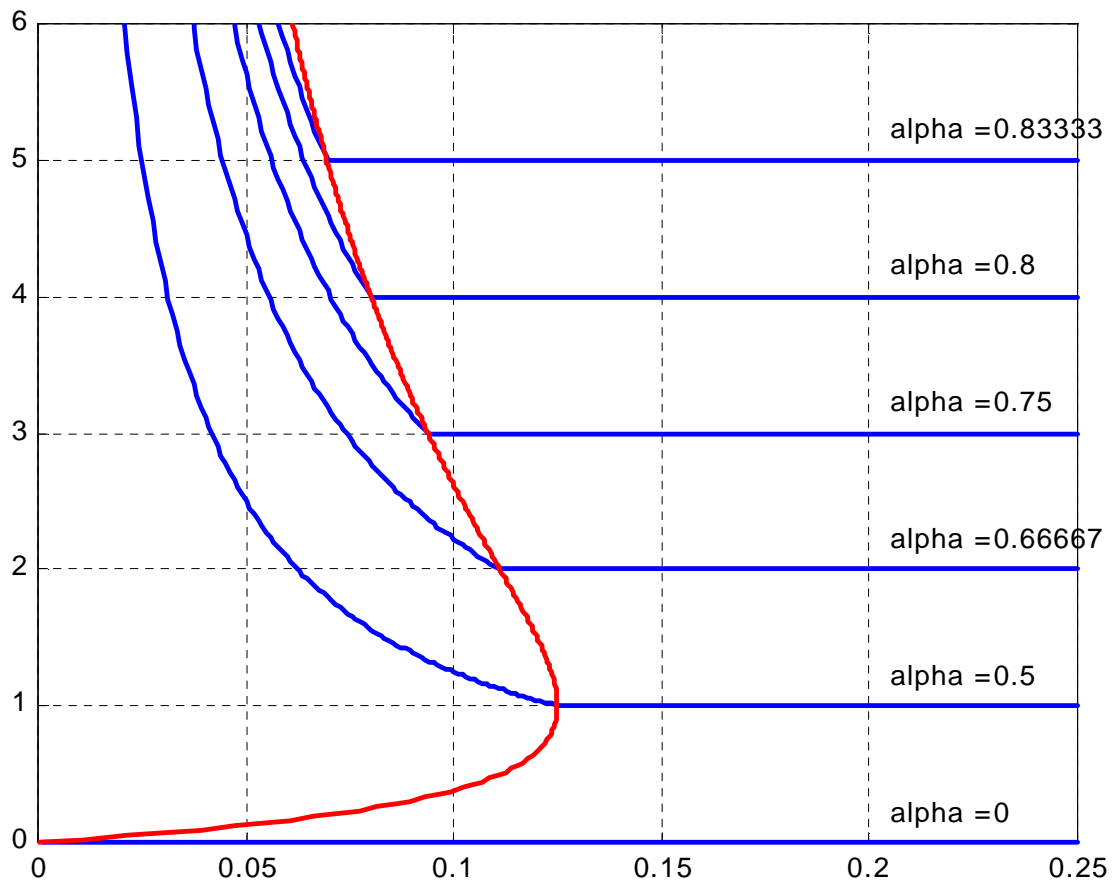


Caractéristiques de sortie du hacheur BUCK-BOOST

Tension normalisée ou tension réduite : $y = \frac{V_s}{V_e}$

Courant de charge normalisé ou réduit : $x = \frac{LF}{V_e} \cdot I_s$

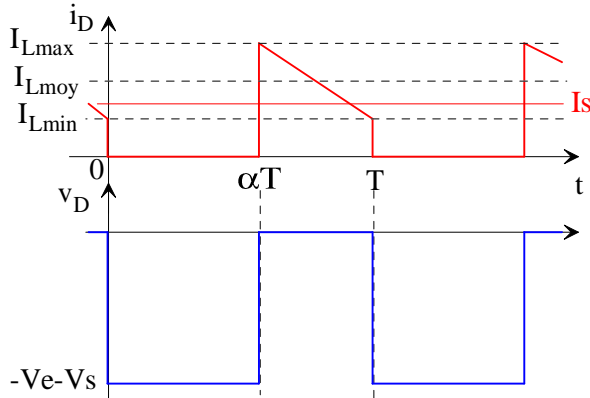
$$y = \frac{\alpha^2}{2 \cdot x}$$



$$I_{s\text{limite}} = \frac{I_{L\text{max}}}{2} \alpha' = \frac{V_e}{2LF} \cdot \alpha(1-\alpha) ; x_{\text{limite}} = \frac{y}{2 \cdot (1+y)^2} ; \begin{cases} x_{\text{limite}} = \frac{\alpha \cdot (1-\alpha)}{2} \\ y_{\text{limite}} = \frac{\alpha}{1-\alpha} \end{cases}$$

Contraintes sur les interrupteurs (BUCK–BOOST)

Interrupteur K2 : la diode



$$I_{D \max} = I_{FRM} = \langle i_L \rangle + \frac{\Delta I_L}{2}$$

$$= \frac{I_s}{1-\alpha} + \frac{\alpha \cdot V_e}{2LF}$$

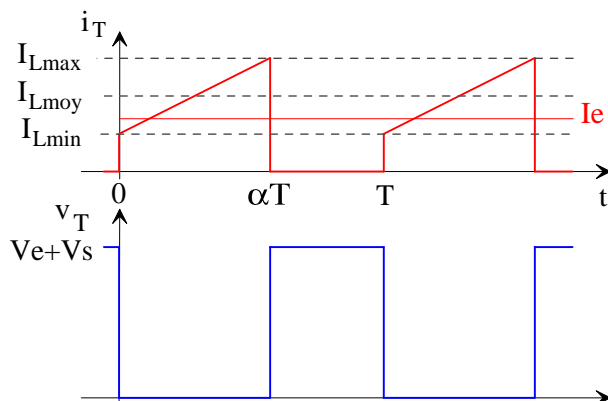
$$I_{D \text{moy}} = I_{F(AV)} = I_s$$

$$V_{D \text{inv max}} = V_{RRM} = V_e + V_s$$

$$I_{D \text{eff}} = \sqrt{\left(\left(\frac{I_s}{1-\alpha} \right)^2 + \frac{\Delta I_L^2}{12} \right) \cdot (1-\alpha)}$$

Pertes statiques dans la diode : $P_0 = R_D \cdot I_{F(RMS)}^2 + V_{D0} \cdot I_{F(AV)}$

Interrupteur K1 : le transistor



$$I_{T \max} = I_{D \max} = \frac{I_s}{1-\alpha} + \frac{\alpha \cdot V_e}{2LF}$$

$$I_{T \text{moy}} = \frac{\alpha}{1-\alpha} I_s = I_{e \text{moy}}!$$

$$V_{T \max} = V_e + V_s$$

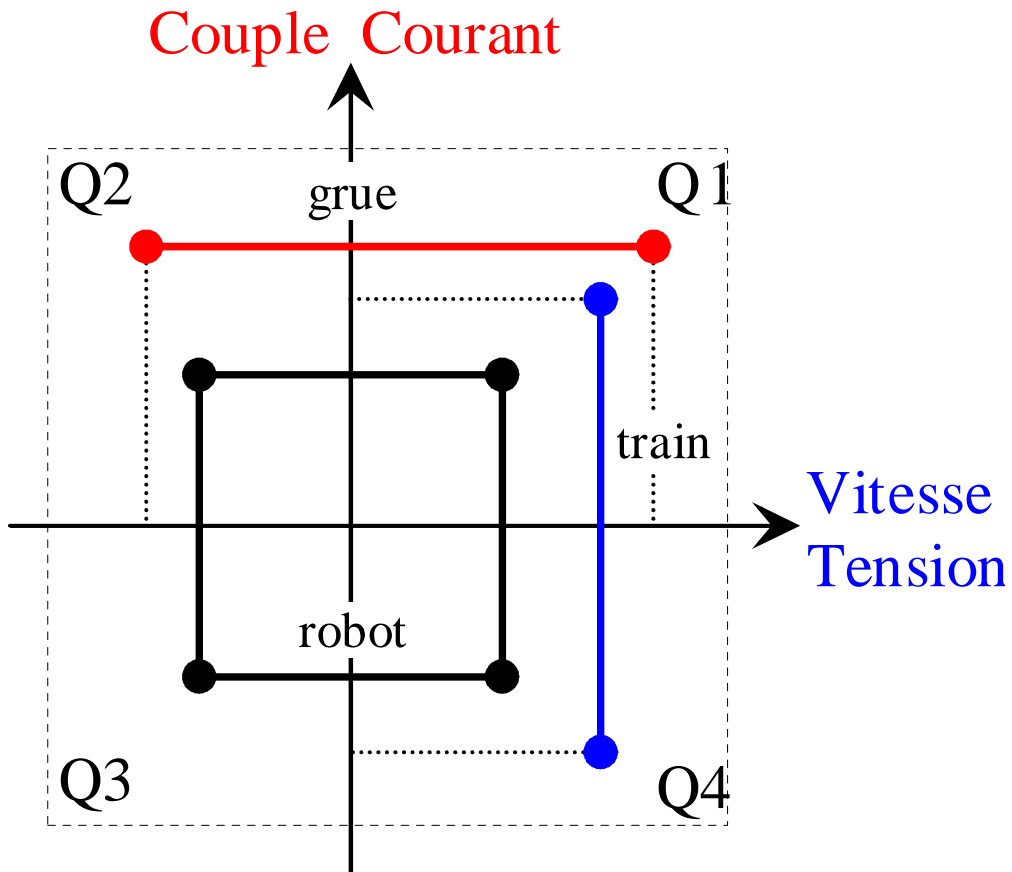
$$I_{T \text{eff}} = \sqrt{\left(\left(\frac{I_s}{1-\alpha} \right)^2 + \frac{\Delta I_L^2}{12} \right) \cdot \alpha}$$

Pertes statiques du MOSFET : $P_0 = R_{DSon} \cdot I_{DS(RMS)}^2$.

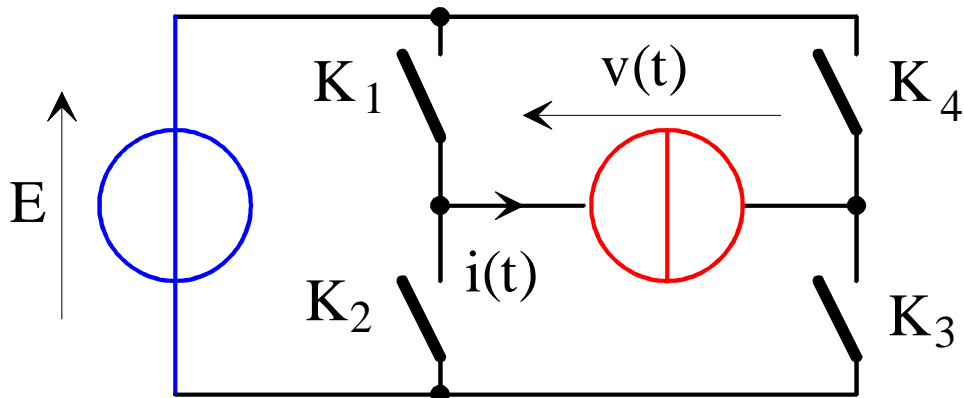
Pertes statiques du bipolaire : $P_0 = R_D \cdot I_{C(RMS)}^2 + V_{CEsat} \cdot I_{C(AV)}$

Quadrants de fonctionnement

Plan (vitesse , couple) et/ou (tension , courant) $\begin{cases} E = K \cdot \Phi \cdot \Omega \\ \Gamma = K \cdot \Phi \cdot I \end{cases}$

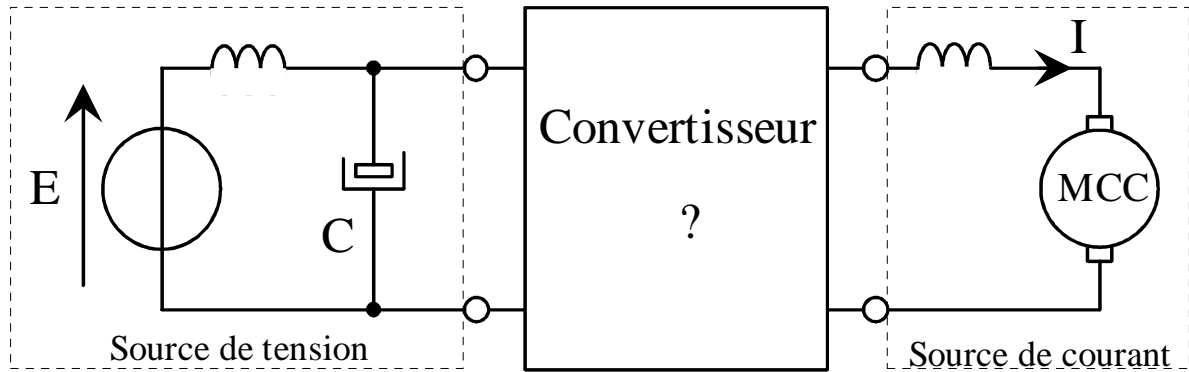


Conversion continue/continue - Fonction hacheur.

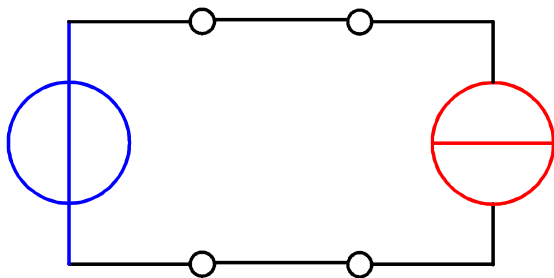


Synthèse du hacheur série de type BUCK

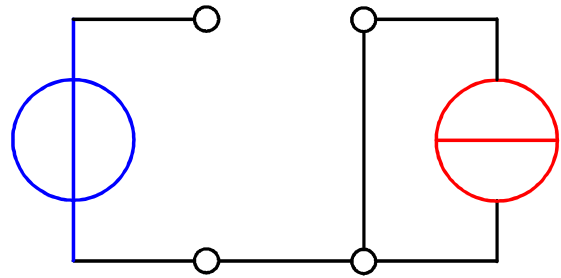
Cahier des charges :



Graphe de fonctionnement :

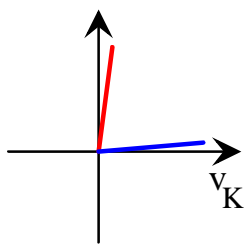


a) phase active directe

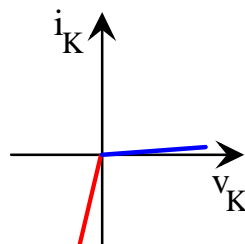


c) roue libre

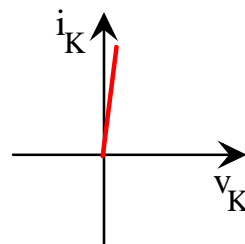
Nature des interrupteurs



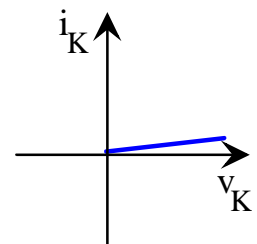
K1 : transistor



K2 : diode



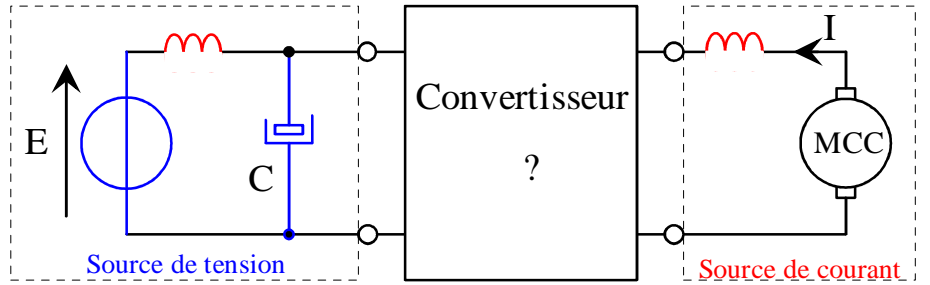
K3 : fermé



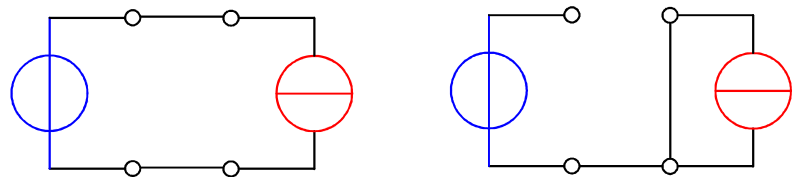
K4 : ouvert

Synthèse du hacheur élévateur de type BOOST

Cahier des charges :



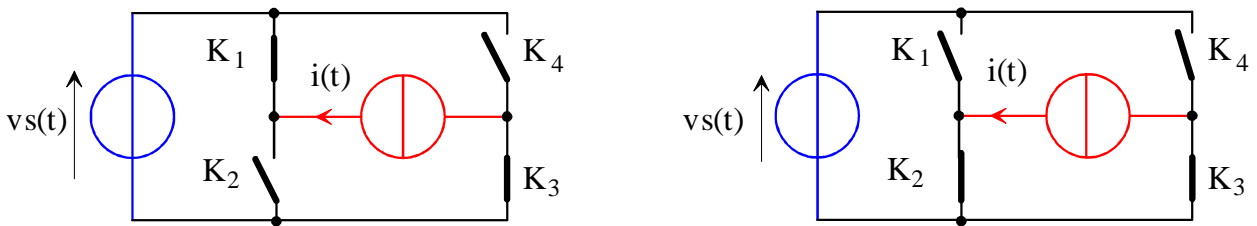
Grappe de fonctionnement :



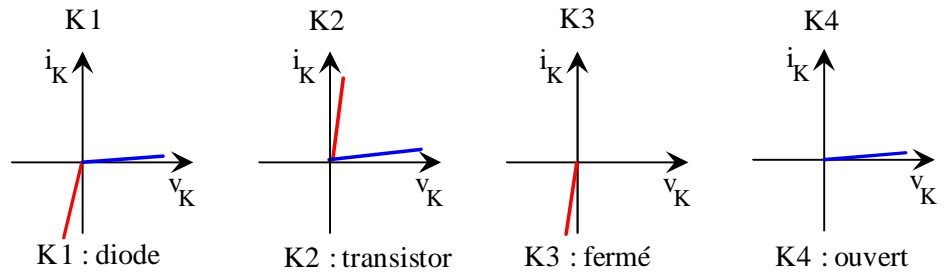
a) phase active directe

c) roue libre

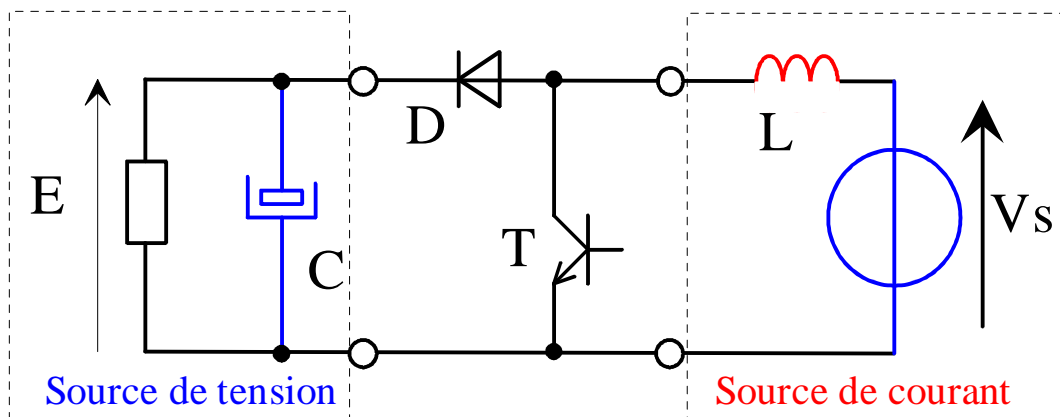
Séquence de fonctionnement :



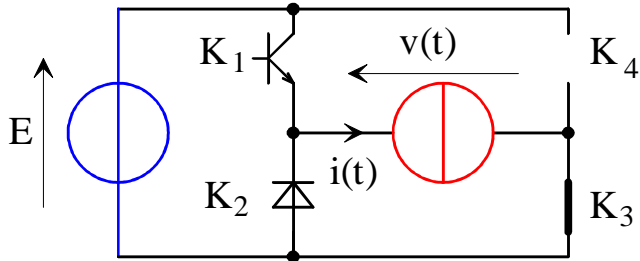
Nature des interrupteurs :



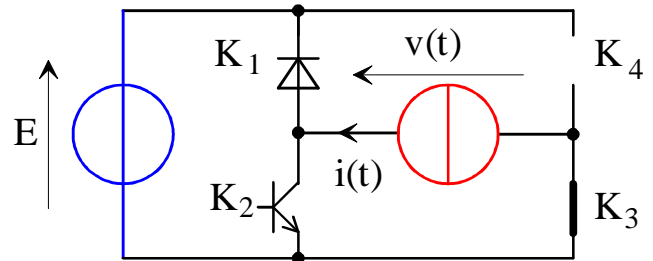
Structure du hacheur élévateur :



Synthèse du hacheur réversible en courant

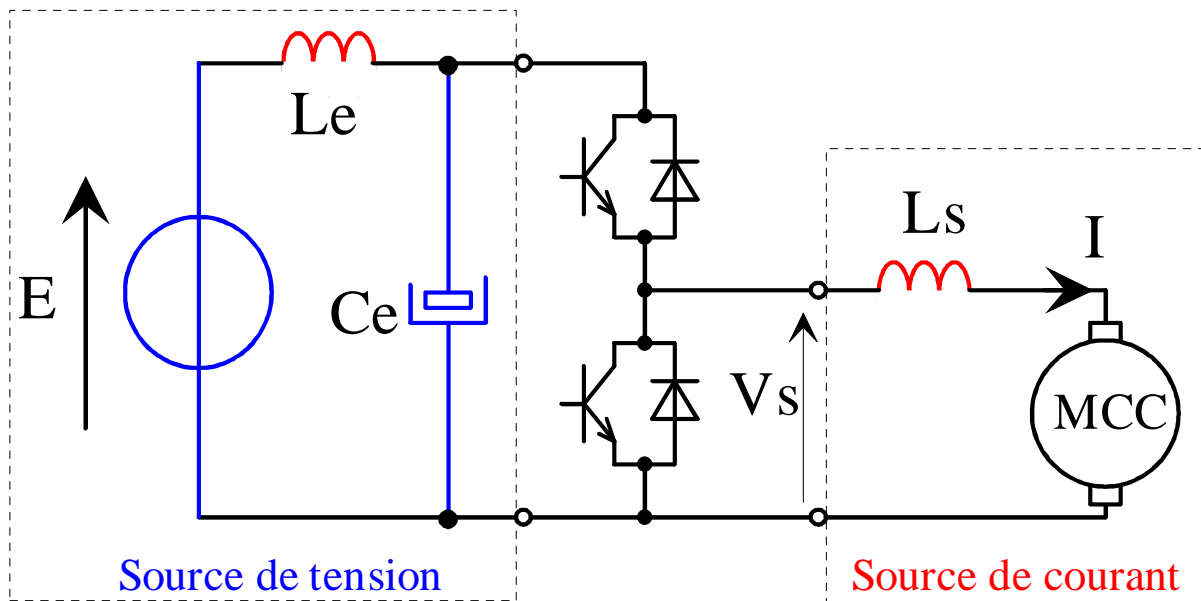


a) Hacheur série



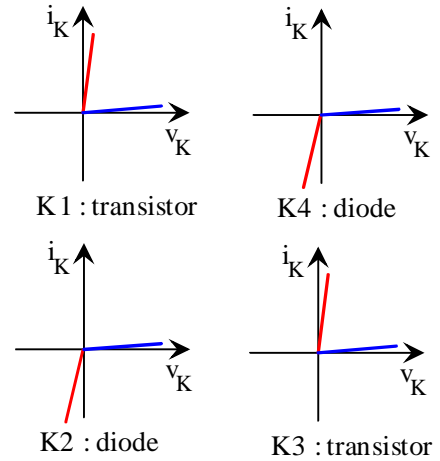
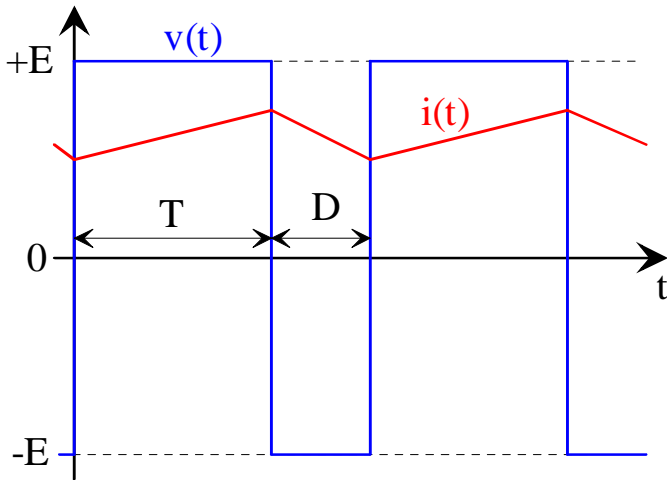
b) Hacheur élévateur

Structure du hacheur réversible en courant :

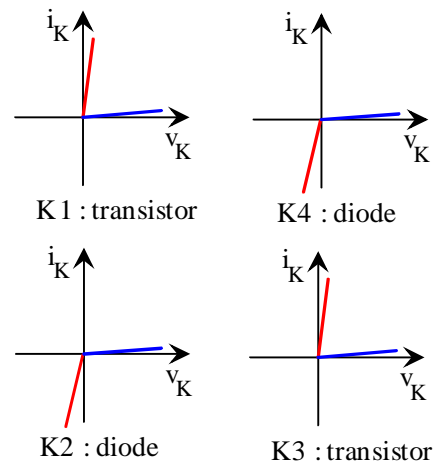
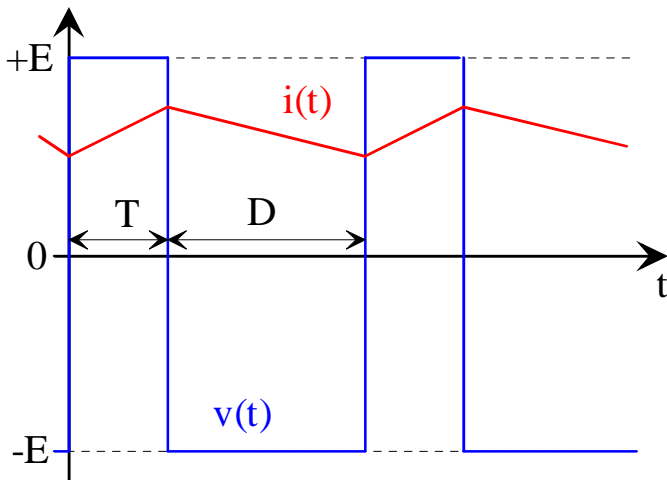


Synthèse du hacheur réversible en tension

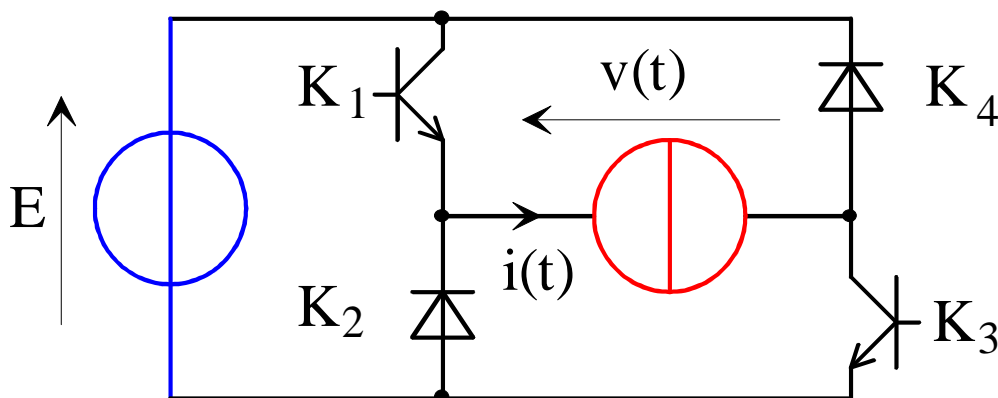
Cas où la puissance est positive $P > 0$ - Quadrant 1 :



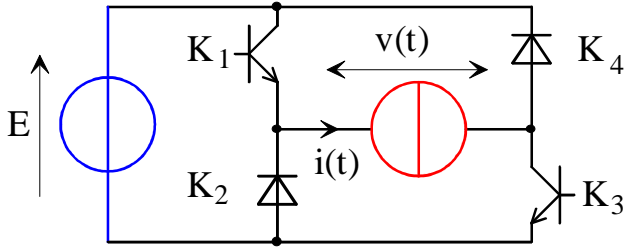
Cas où la puissance est négative $P < 0$ - Quadrant 2 :



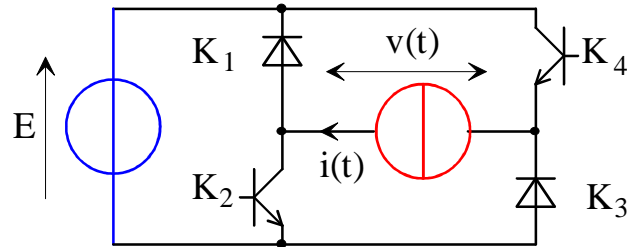
Réalisation pratique du hacheur :



Synthèse du hacheur 4 quadrants

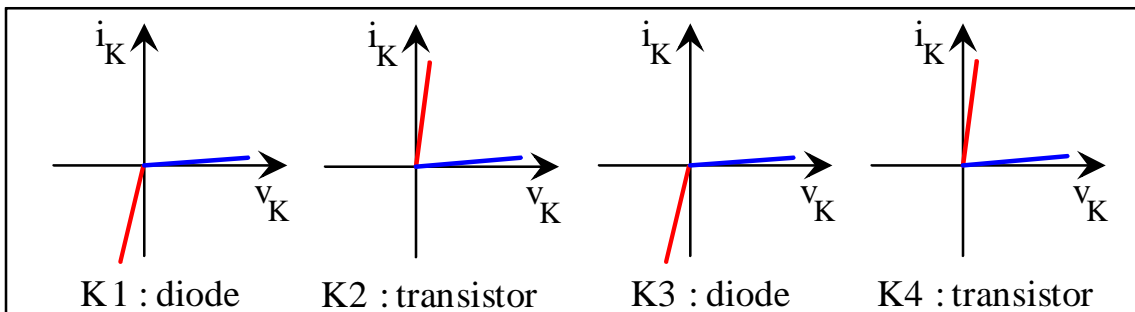
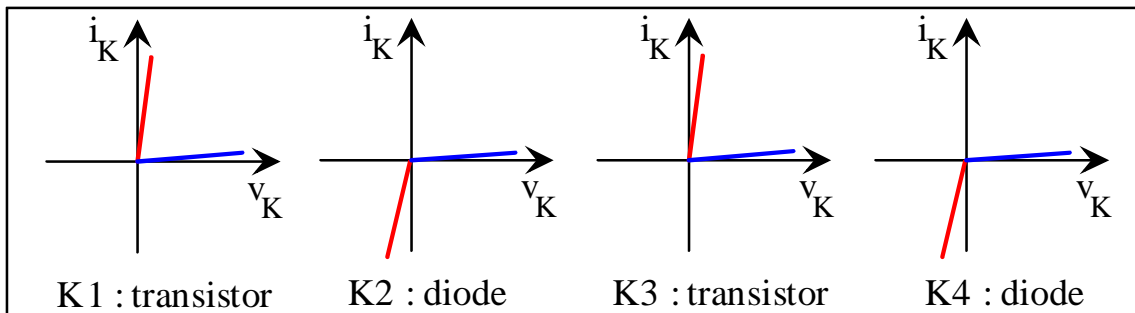


a) Phase I : quadrants Q1-Q2



b) Phase II : quadrants Q3-Q4

Caractéristiques des interrupteurs :



Le convertisseur 4 quadrants :

