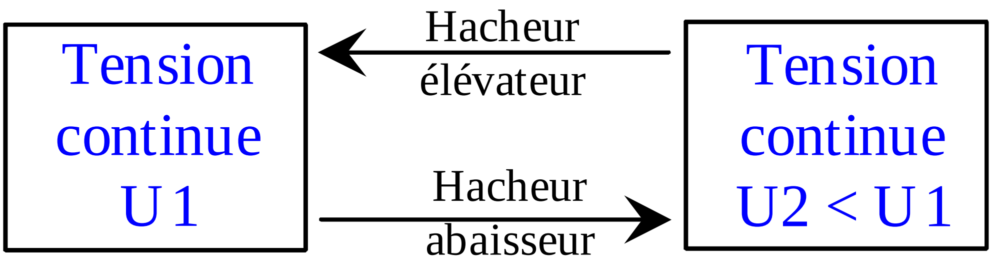
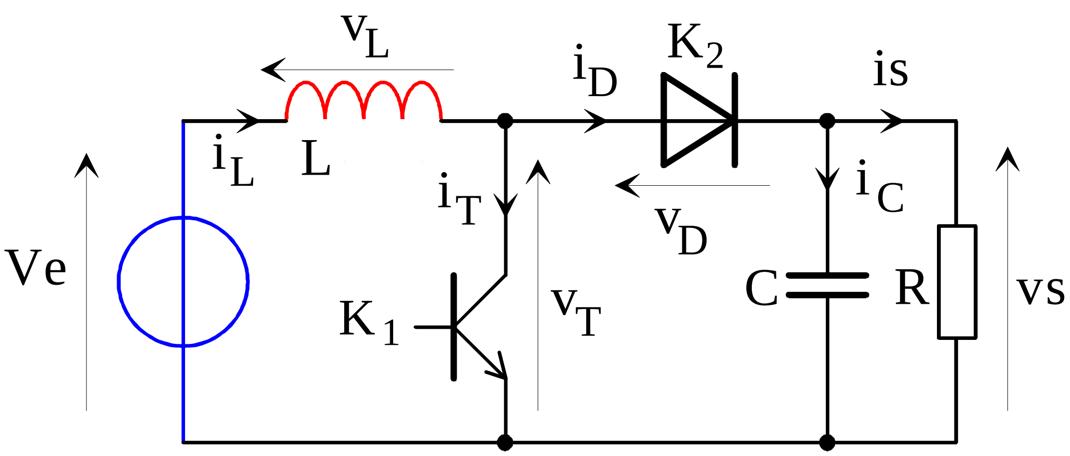
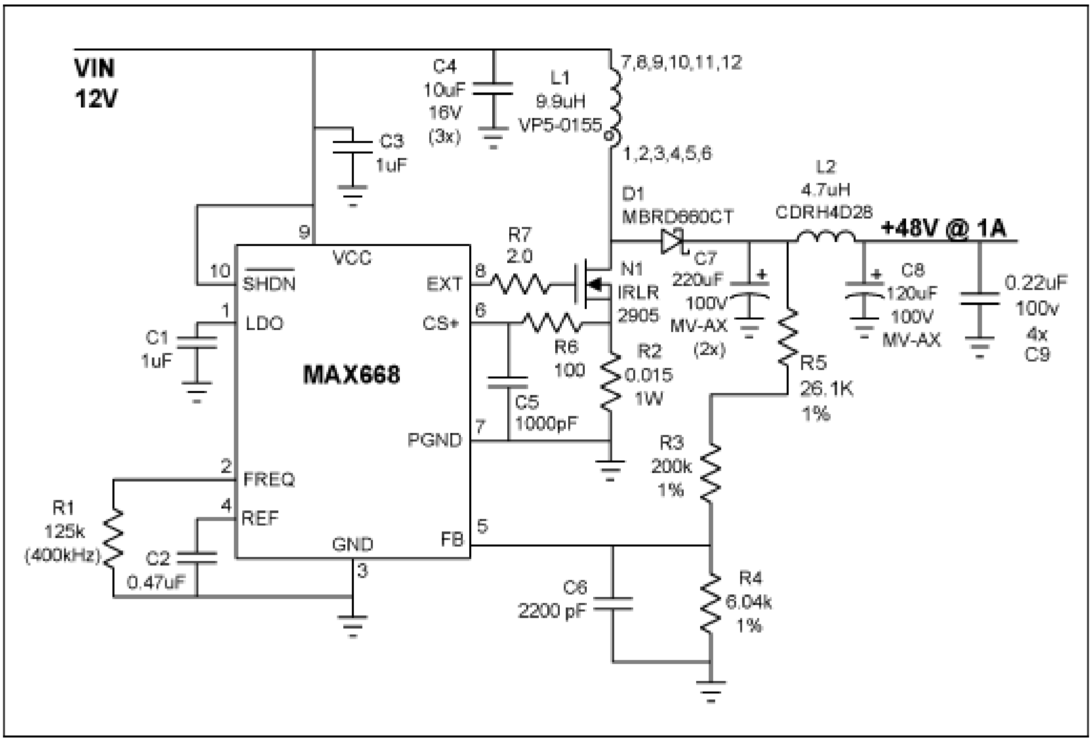
Les convertisseurs DC-DC : la fonction hacheur



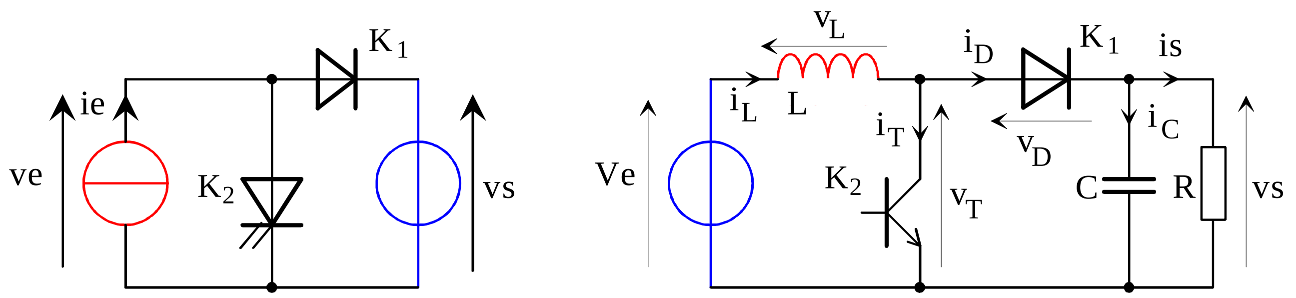
Le hacheur élévateur de type BOOST



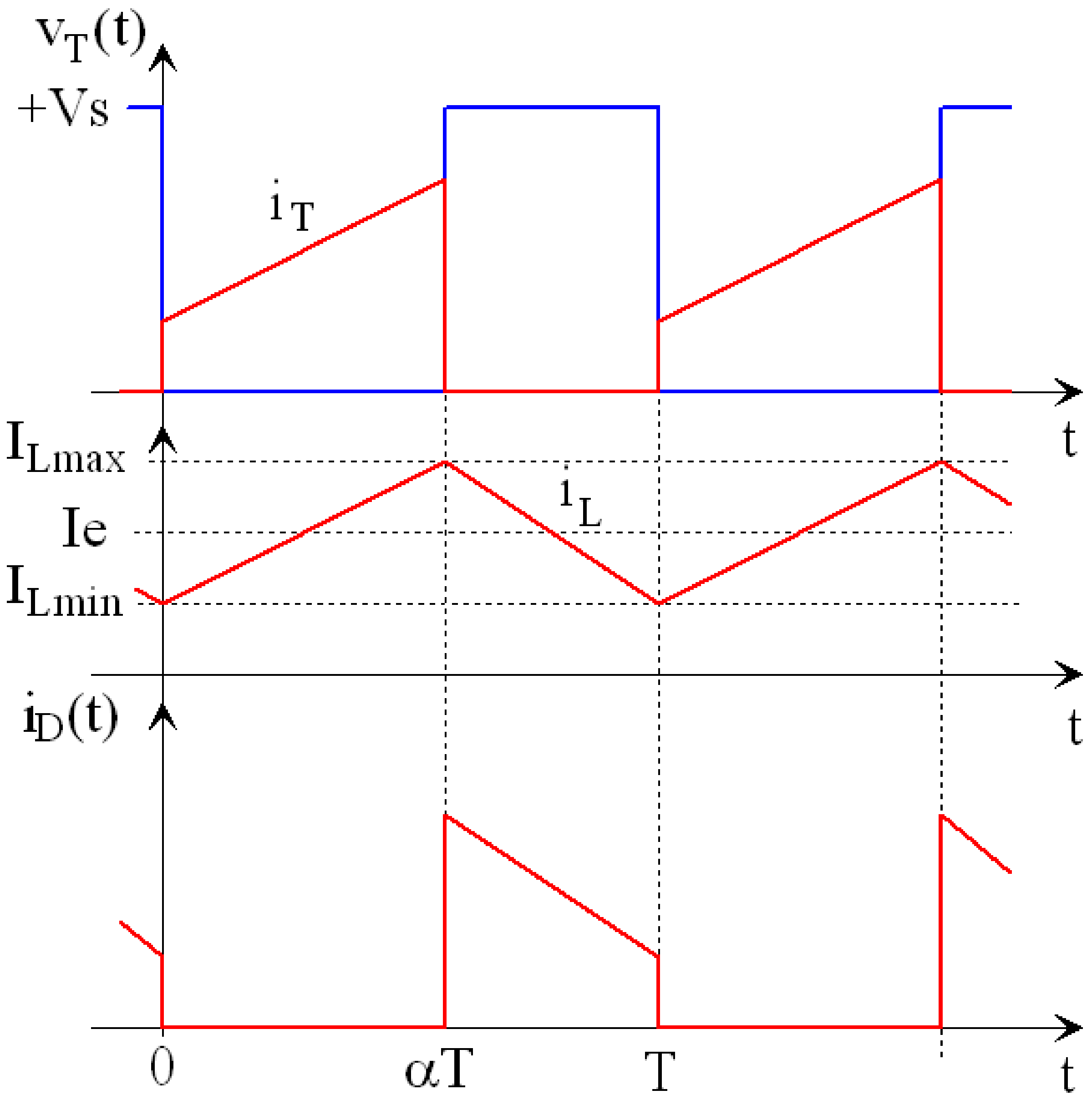
Exemple : Alimentation continue +48V à découpage



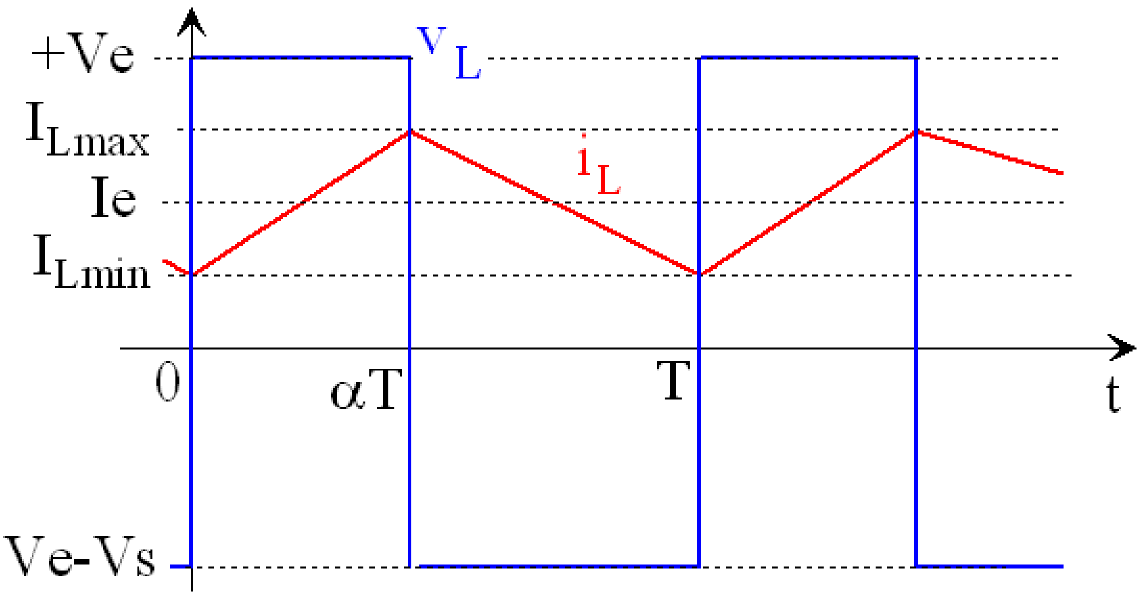
Le hacheur élévateur de type BOOST



Formes d'ondes du hacheur BOOST



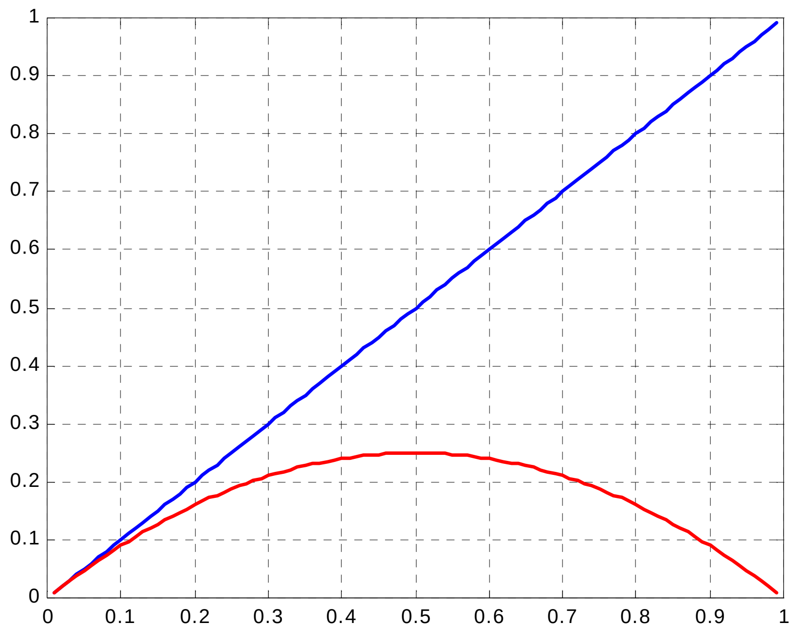
Tension et courant de l'inductance (BOOST)



Ondulation du courant

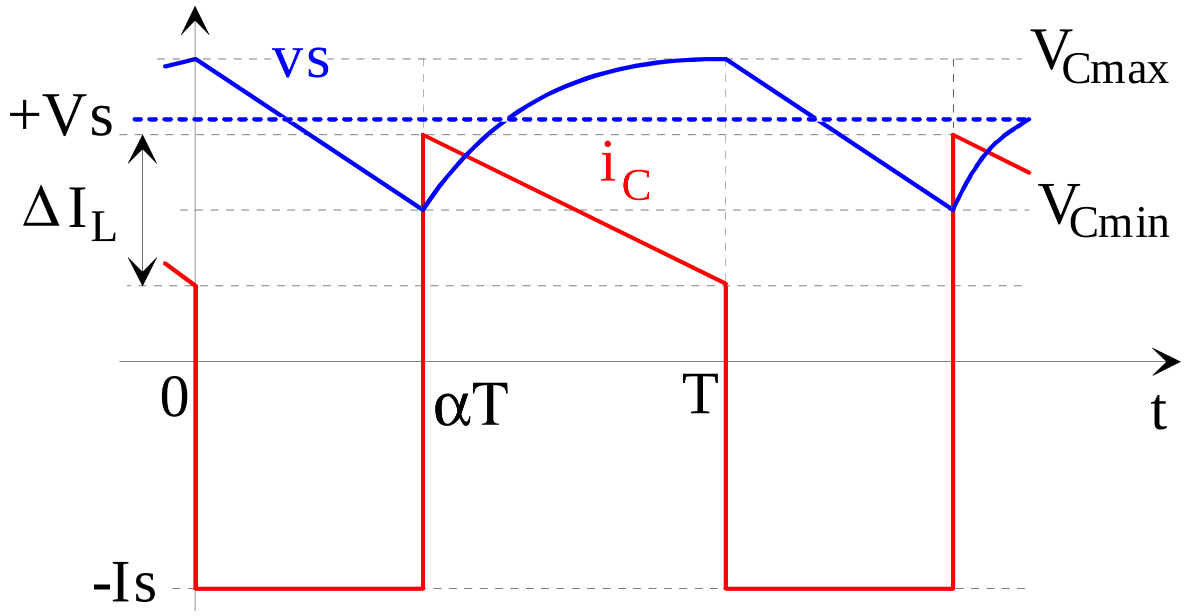
$$\Delta I_L = I_{L\,max} - I_{L\,min} = \frac{Ve}{L} \cdot \alpha T = \frac{Ve}{LF} \cdot \alpha$$

Evolution de ΔI_L en fonction de α



Ondulation de la tension (BOOST)

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



Pour t ∈ [0 ; α T] : $v_C(t) = \frac{1}{C}\int i_C(t)\cdot dt = V_{C\,max} - \frac{Is}{C}(t-0)$

Pour t ∈ [α T ; T] : $i_C(t) = I_{L\,max} - Is + \frac{Ve - Vs}{L}(t - \alpha T) - Is$

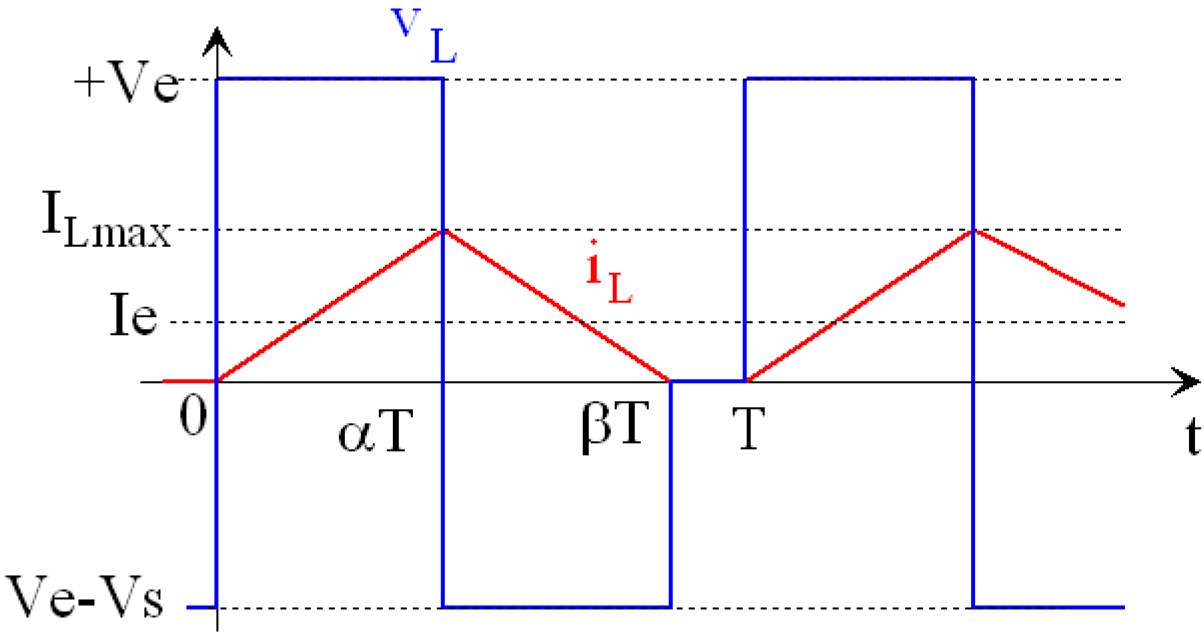
$$v_C(t) = \frac{1}{C}\int i_C(t)\cdot dt = V_{C\,min} + \frac{1}{C}\left[(I_{L\,max} - Is)\cdot(t-\alpha T) + \frac{Ve - Vs}{L}\cdot\frac{(t-\alpha T)^2}{2}\right]_{\alpha T}^{t}$$

$$v_C(t) = \frac{(I_{L\,max} - Is)}{C}\cdot(t-\alpha T) + \frac{Ve - Vs}{LC}\cdot\frac{(t-\alpha T)^2}{2} + V_{C\,min}$$

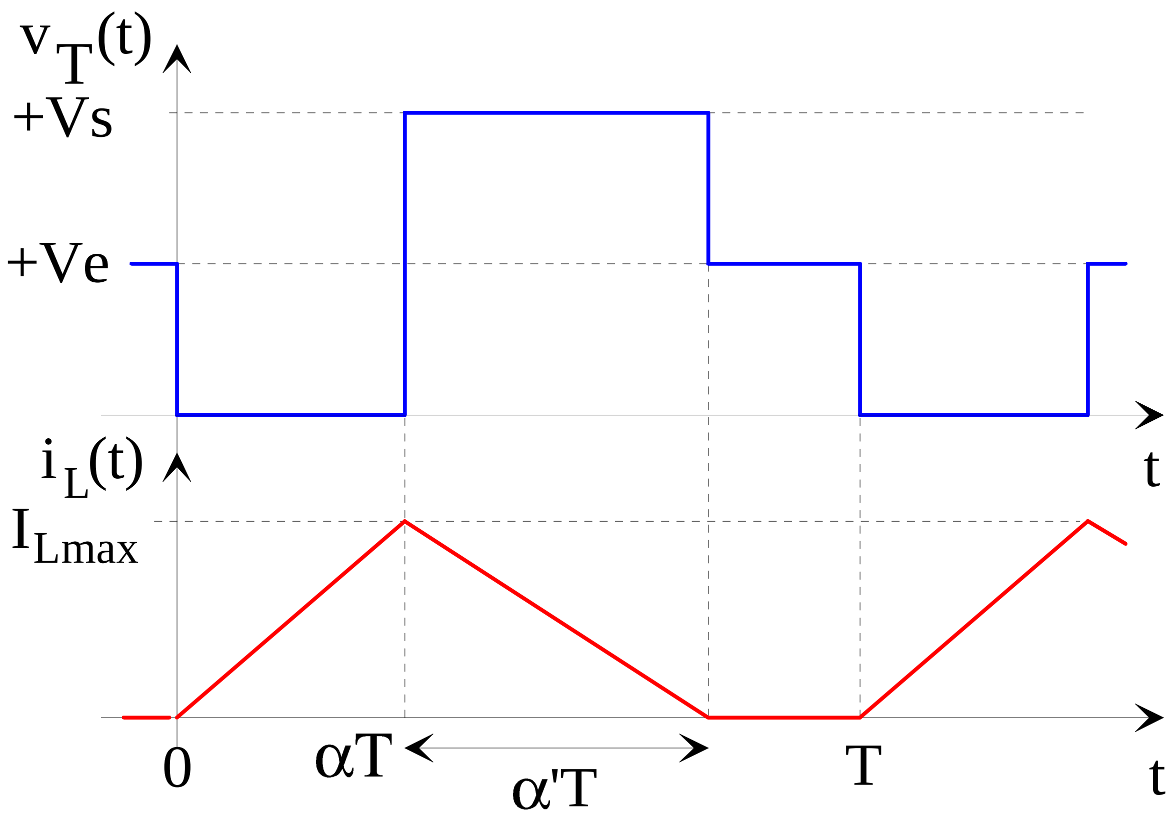
Valeur ΔVs de l'ondulation de tension (BOOST)

$$\Delta Vs = V_{C\,max} - V_{C\,min} = \frac{Is}{C}\alpha T = \frac{Is}{CF}\alpha$$

Fonctionnement en conduction discontinue (BOOST)



Tension aux bornes du transistor en conduction discontinue

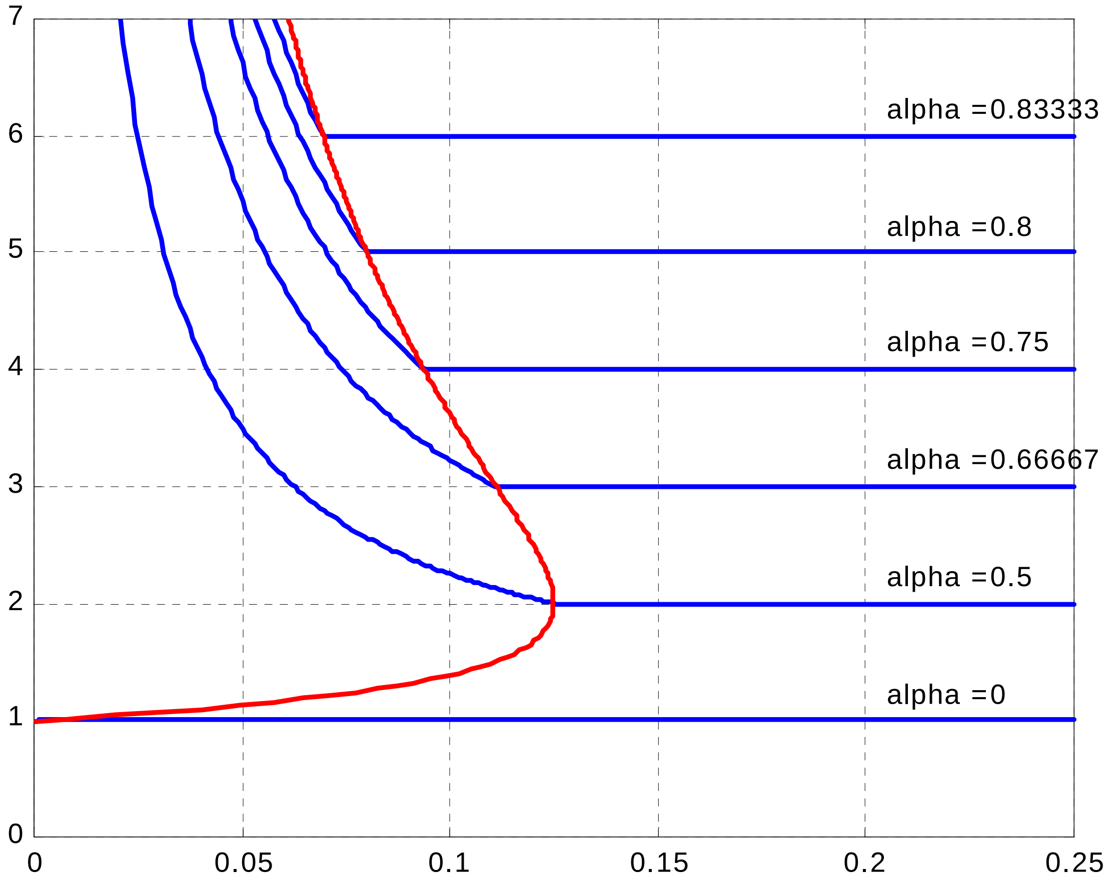


Caractéristiques de sortie du hacheur de type BOOST

Tension normalisée ou tension réduite : $y = \frac{Vs}{Ve}$

Courant de charge normalisé ou réduit : $x = \frac{L\,F}{Ve} \cdot Is$

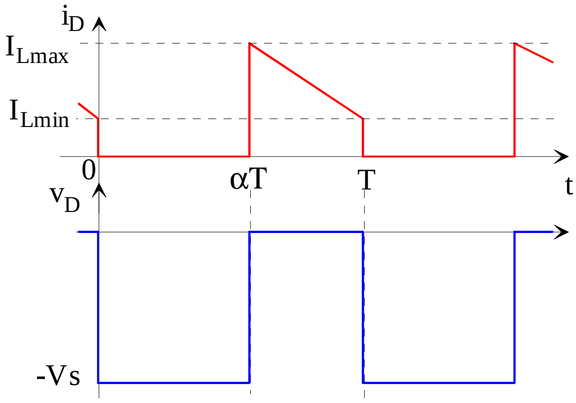
$$y = 1 + \frac{\alpha^2}{2 \cdot x}$$



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

Contraintes sur les interrupteurs (BOOST)

Interrupteur K1 : la diode



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

$$= \frac{Is}{1-\alpha} + \frac{\alpha \cdot Ve}{2LF}$$

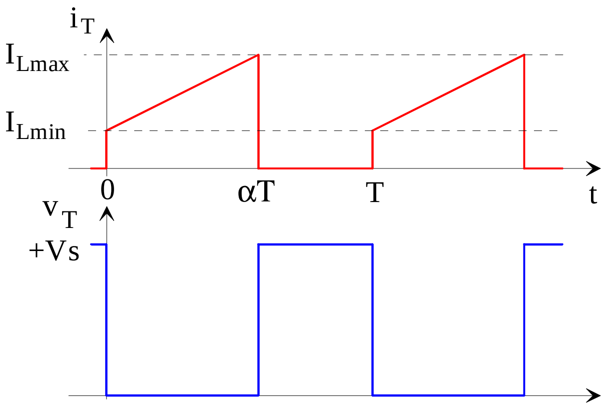
$$I_{Dmoy} = I_{F(AV)} = Is$$

$$V_{D\,inv\,max} = V_{RRM} = +Vs$$

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

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

Interrupteur K2 : le transistor



$$I_{T\,max} = I_{D\,max} = \frac{Is}{1-\alpha} + \cdot \frac{\alpha \cdot Ve}{2LF}$$

$$I_{Tmoy} = \frac{Is}{1-\alpha} = Ie_{moy}!$$

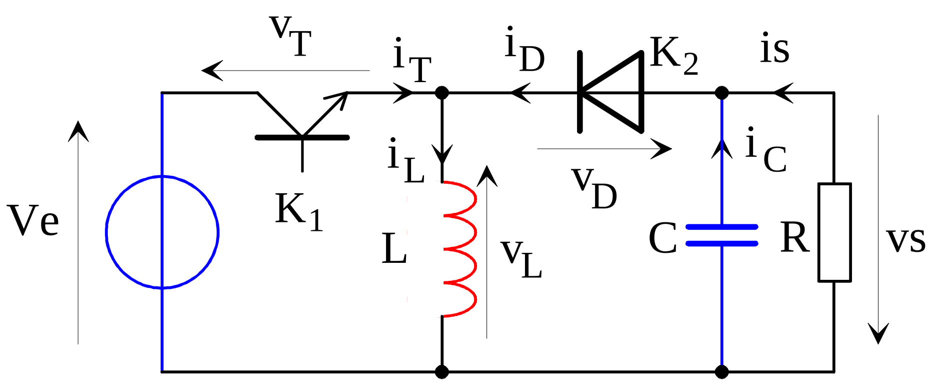
$$V_{Tmax} = +Vs$$

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

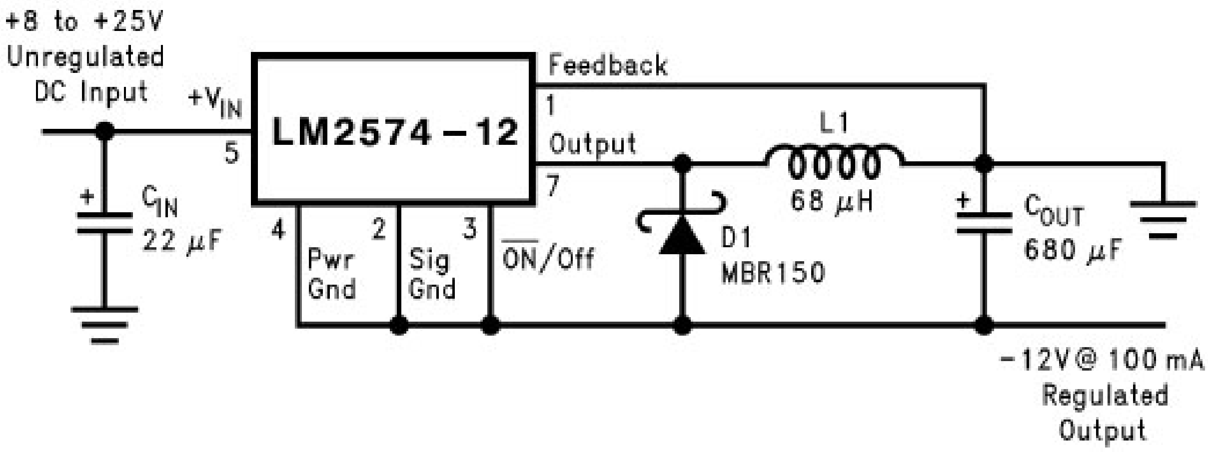
Pertes statiques du MOSFET : $P_0 = R_{DSon} \cdot I_{DS(RMS)}^2$.

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

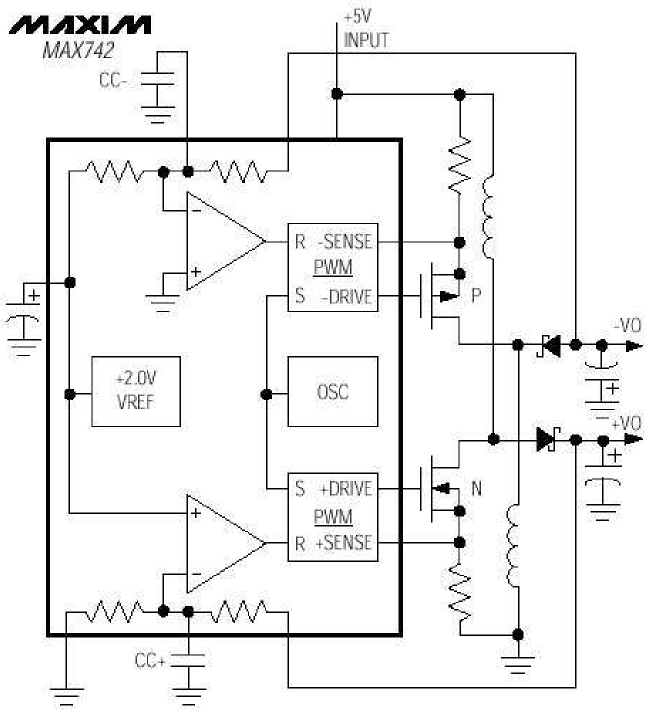


Exemple 1 : alimentation continue –12 V à découpage

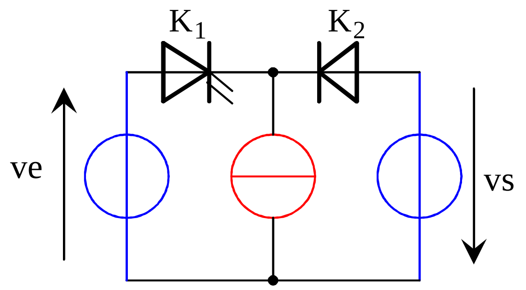


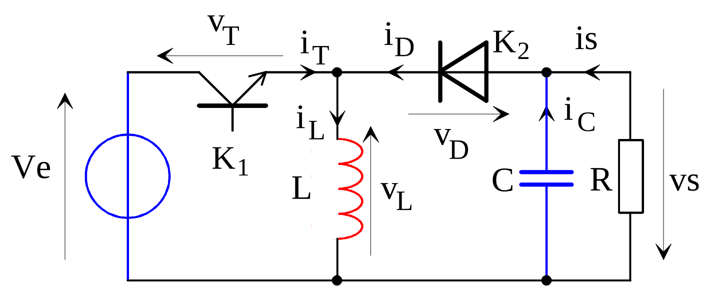
Exemple 2 :

Alimentation double +12 V / -12 V à découpage

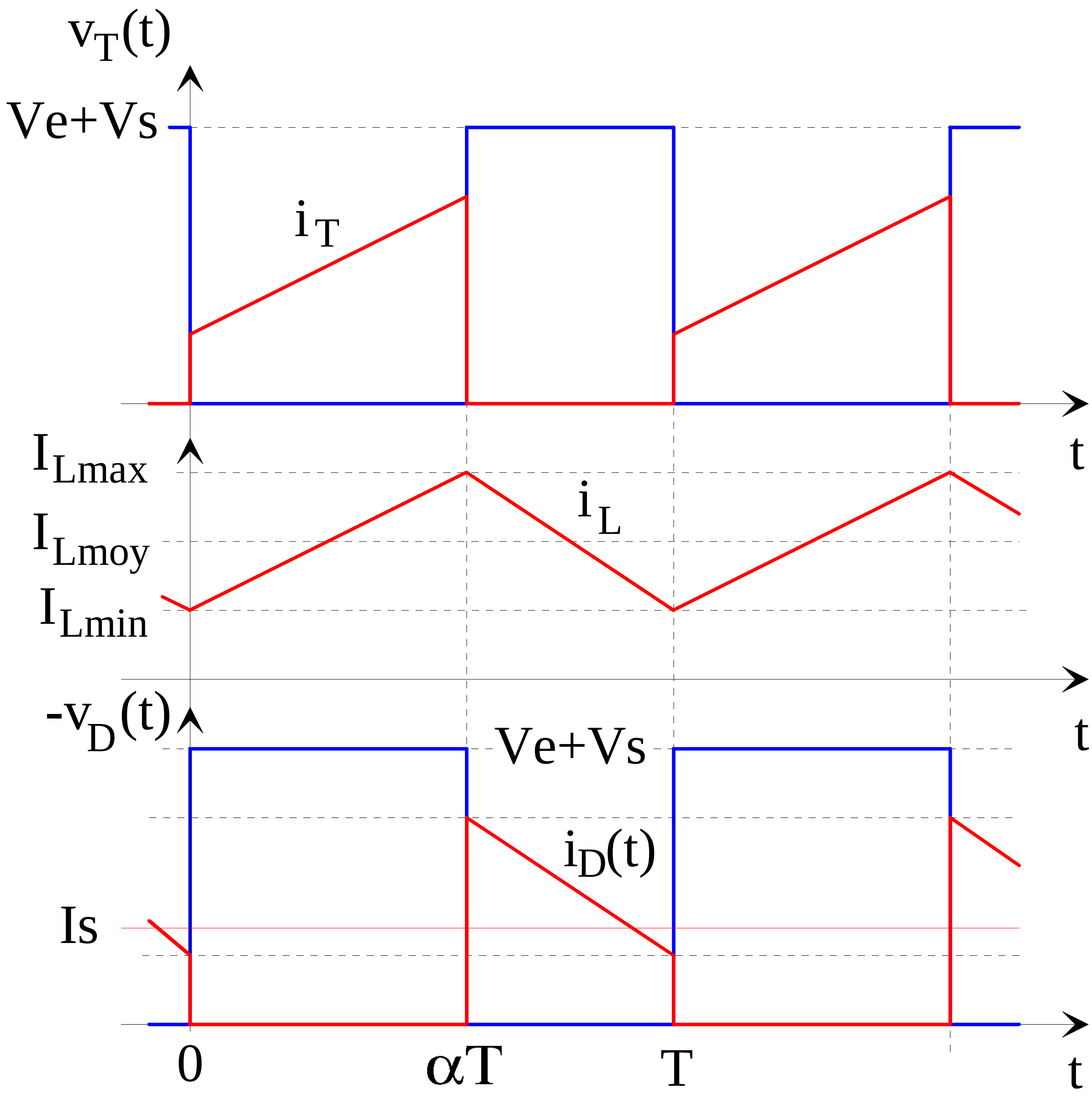


Structure du hacheur inverseur

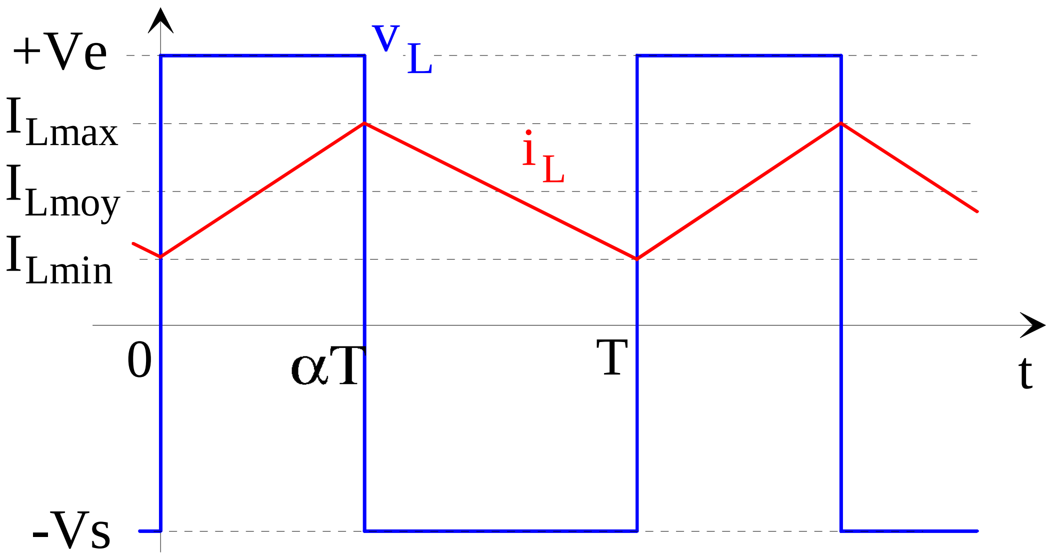




Formes d'ondes



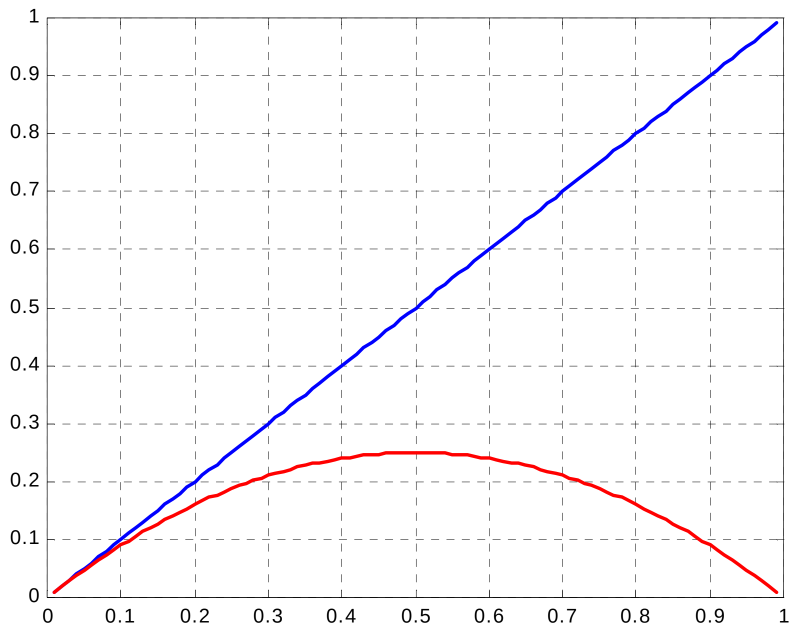
Tension et courant de l'inductance (BUCK–BOOST)



Ondulation du courant

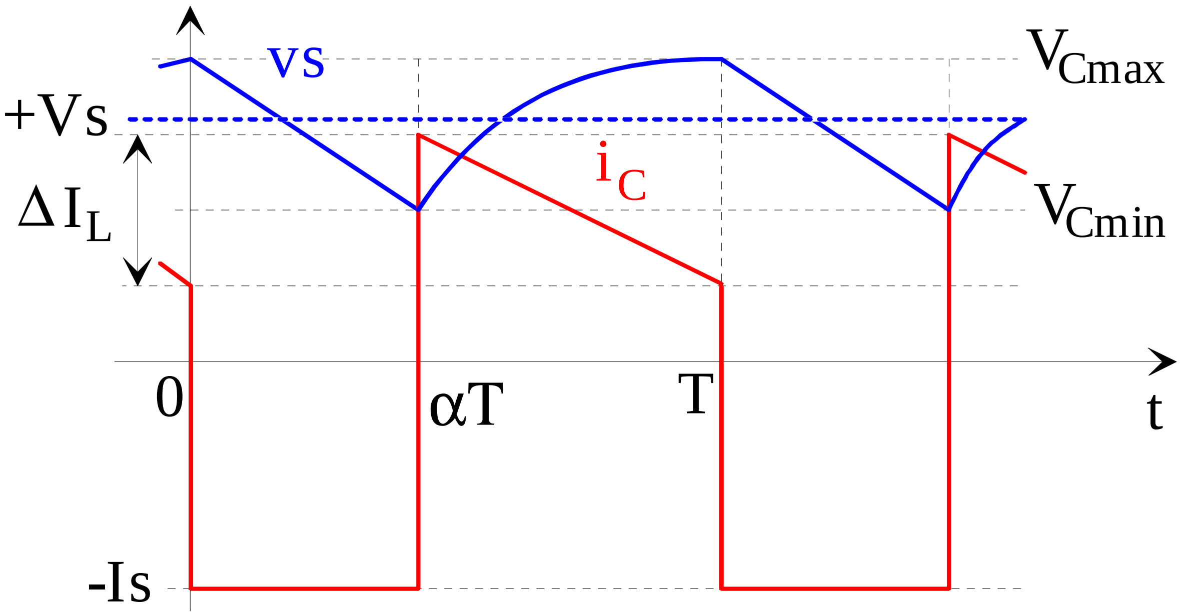
$$\Delta I_L = I_{L\,max} - I_{L\,min} = \frac{Ve}{L} \cdot \alpha T = \frac{Ve}{LF} \cdot \alpha$$

Evolution de ΔI_L en fonction de α



Ondulation de la tension (BUCK–BOOST)

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



Pour t ∈ [0 ; α T] : $v_C(t) = \frac{1}{C}\int i_C(t)\cdot dt = V_{C\,max} - \frac{Is}{C}(t-0)$

Pour t ∈ [α T ; T] : $i_C(t) = I_{L\,max} - Is - \frac{Vs}{L}(t-\alpha T) - Is$

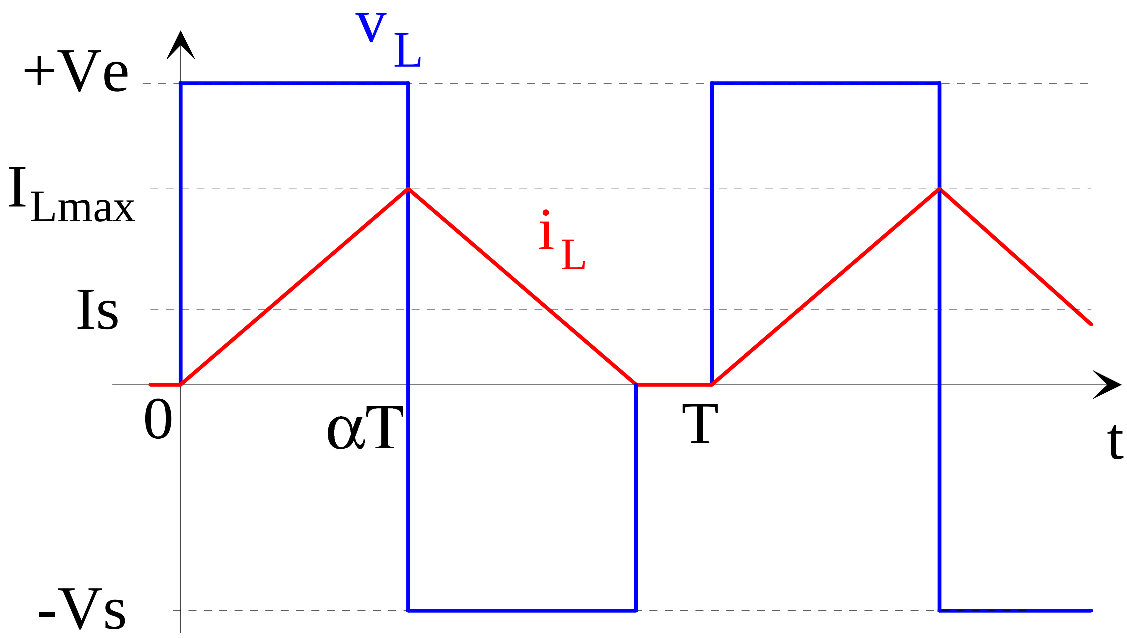
$$v_C(t) = \frac{1}{C}\int i_C(t)\cdot dt = V_{C\,min} + \frac{1}{C}\left[(I_{L\,max} - Is)\cdot(t-\alpha T) - \frac{Vs}{L}\cdot\frac{(t-\alpha T)^2}{2} \right]_{\alpha T}^{t}$$

$$v_C(t) = \frac{(I_{L\,max} - Is)}{C}\cdot(t-\alpha T) - \frac{Vs}{LC}\cdot\frac{(t-\alpha T)^2}{2} + V_{C\,min}$$

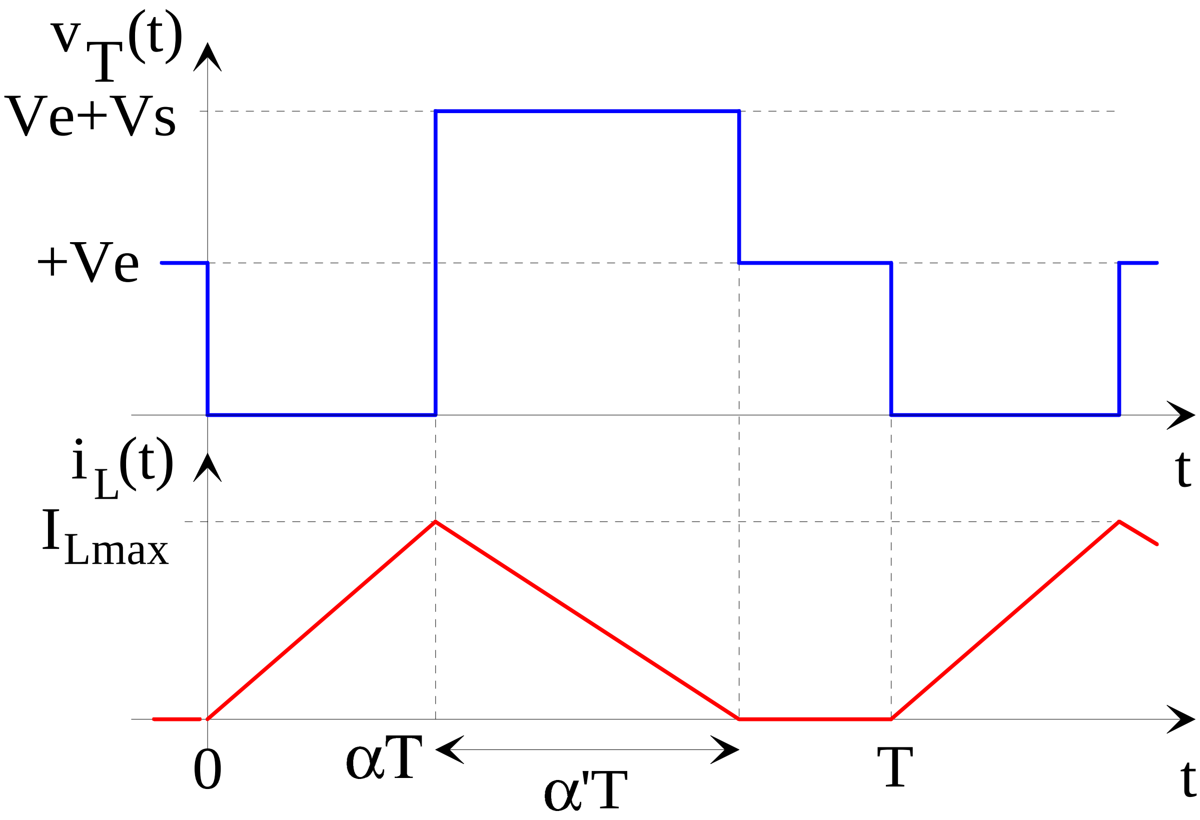
Valeur ΔVs de l'ondulation de tension

$$\Delta Vs = V_{C\,max} - V_{C\,min} = \frac{Is}{C}\alpha T = \frac{Is}{CF}\alpha$$

Fonctionnement en conduction discontinue (BUCK–BOOST)



Tension aux bornes du transistor en conduction discontinue

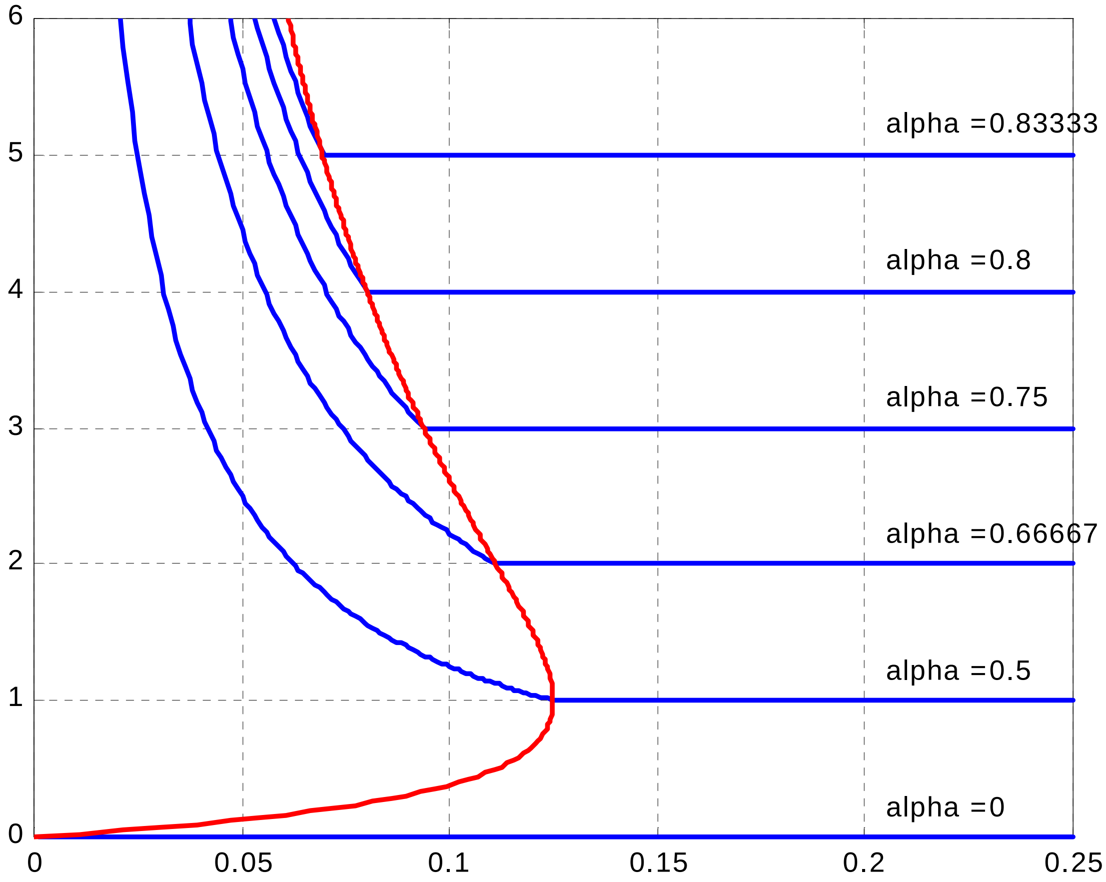


Caractéristiques de sortie du hacheur BUCK–BOOST

Tension normalisée ou tension réduite : $y = \frac{Vs}{Ve}$

Courant de charge normalisé ou réduit : $x = \frac{L\,F}{Ve} \cdot Is$

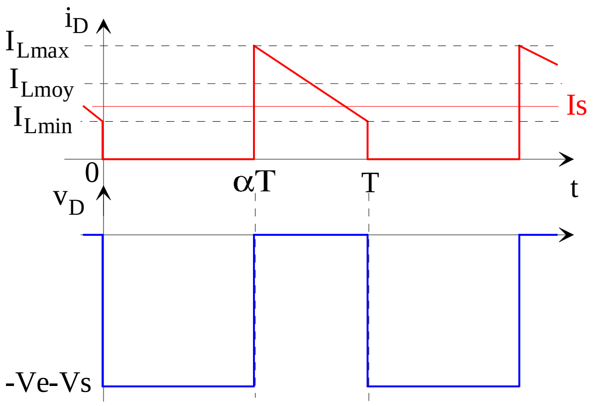
$$y = \frac{\alpha^2}{2 \cdot x}$$



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

Contraintes sur les interrupteurs (BUCK–BOOST)

Interrupteur K2 : la diode



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

$$= \frac{Is}{1-\alpha} + \frac{\alpha \cdot Ve}{2LF}$$

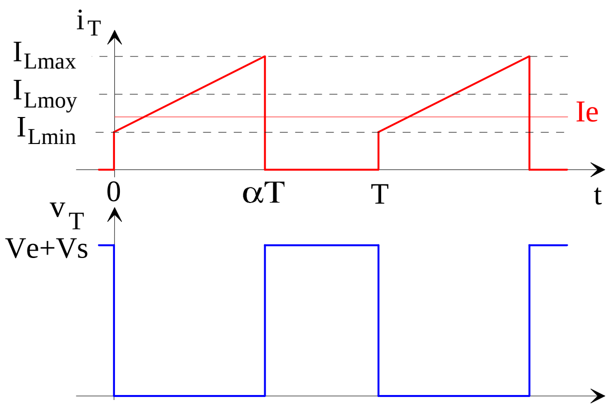
$$I_{Dmoy} = I_{F(AV)} = Is$$

$$V_{D\,inv\,max} = V_{RRM} = Ve + Vs$$

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

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

Interrupteur K1 : le transistor



$$I_{T\,max} = I_{D\,max} = \frac{Is}{1-\alpha} + \frac{\alpha \cdot Ve}{2LF}$$

$$I_{Tmoy} = \frac{\alpha}{1-\alpha} Is = Ie_{moy}!$$

$$V_{Tmax} = Ve + Vs$$

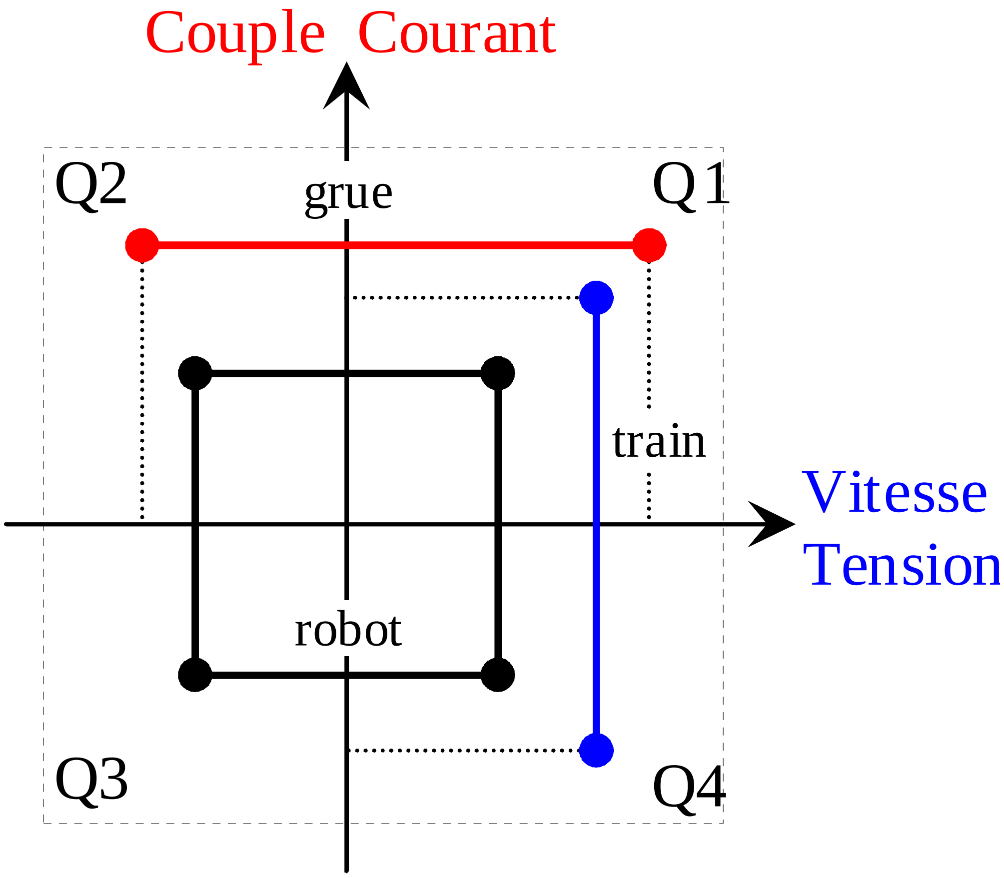
$$I_{Teff} = \sqrt{\left(\left(\frac{Is}{1-\alpha}\right)^2 + \frac{\Delta I_L{}^2}{12}\right) \cdot \alpha}$$

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

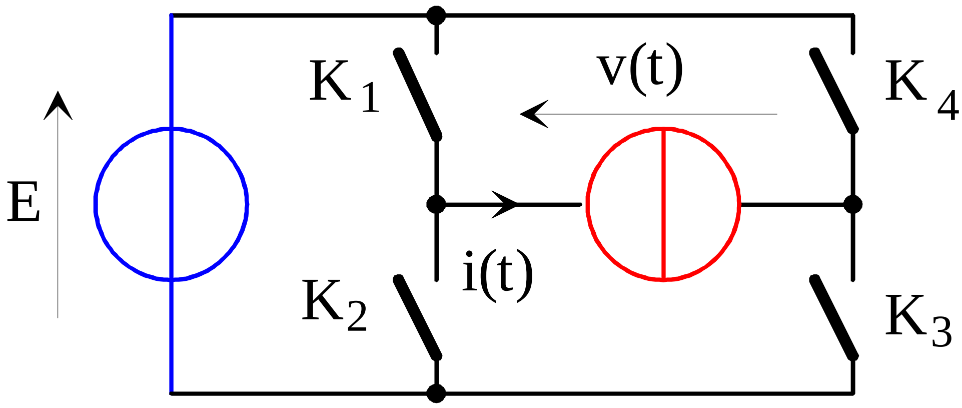
Pertes statiques du bipolaire : $P_0 = R_D \cdot I_{C(RMS)}^2 + V_{CEsat} \cdot I_{C(AV)}$

Quadrants de fonctionnement

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

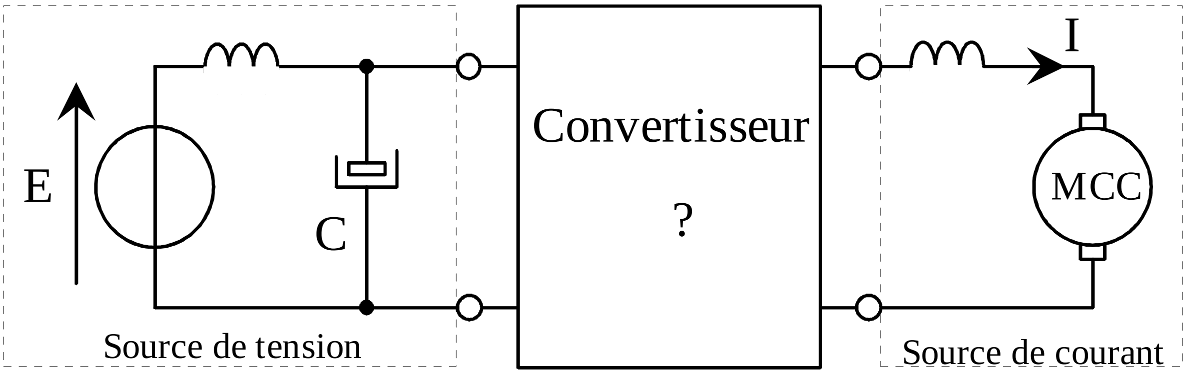


Conversion continue/continue - Fonction hacheur.

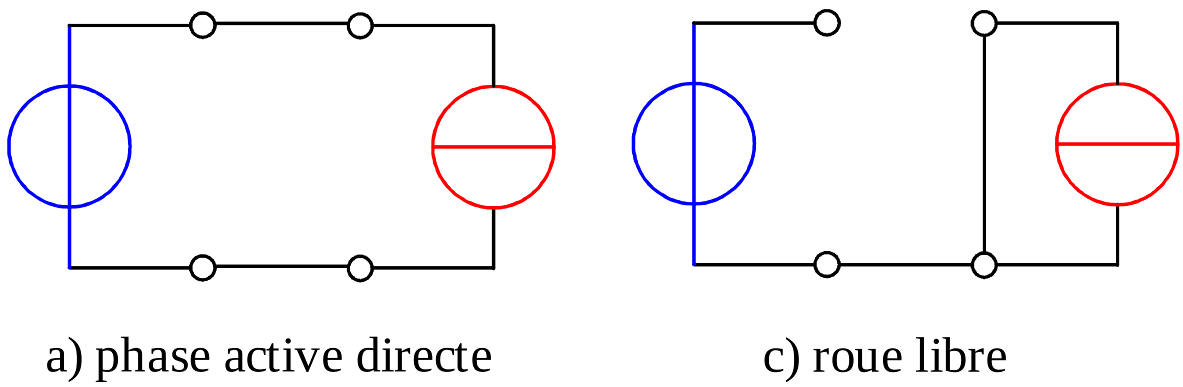


Synthèse du hacheur série de type BUCK

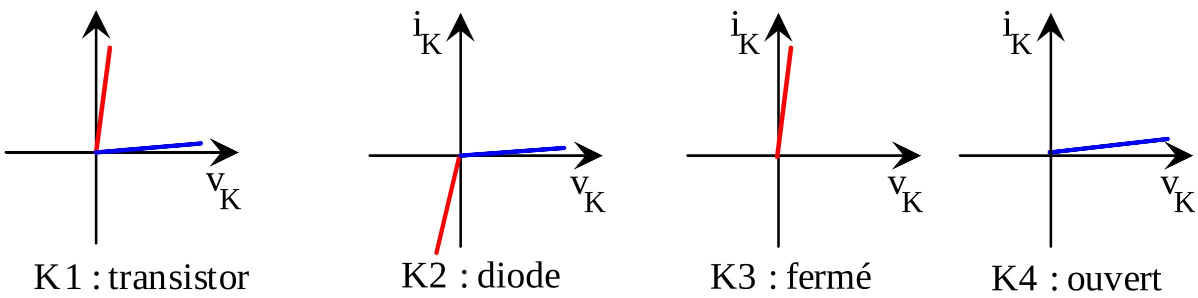
Cahier des charges :



Graphe de fonctionnement :

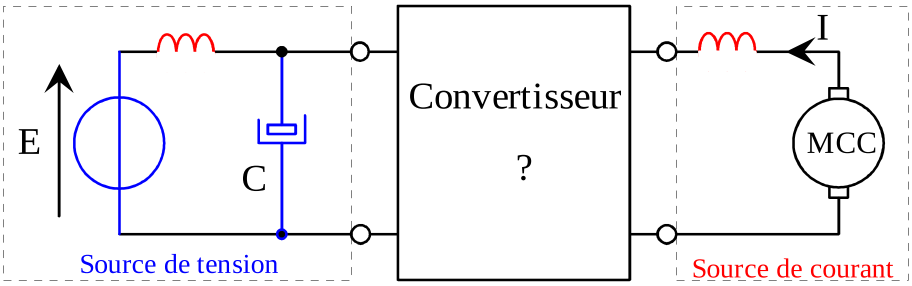


Nature des interrupteurs

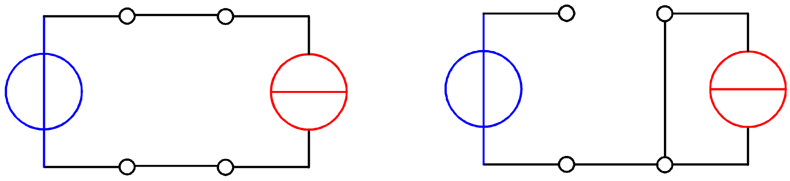


Synthèse du hacheur élévateur de type BOOST

Cahier des charges :



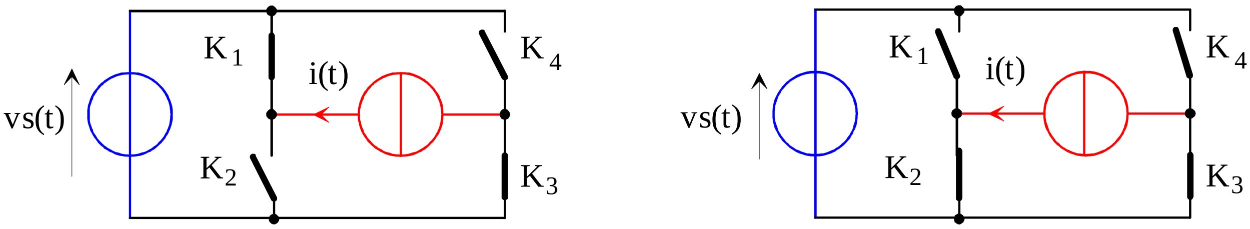
Graphe de fonctionnement :



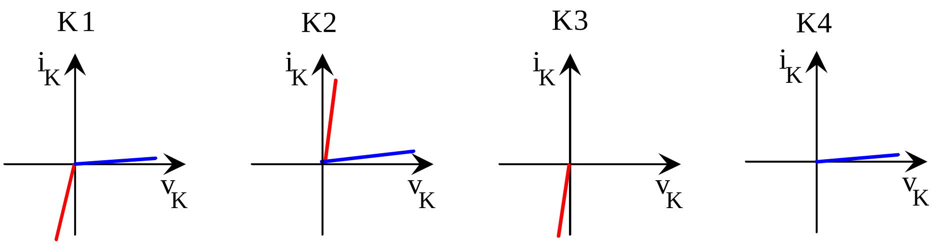
a) phase active directe

c) roue libre

Séquence de fonctionnement :



Nature des interrupteurs :



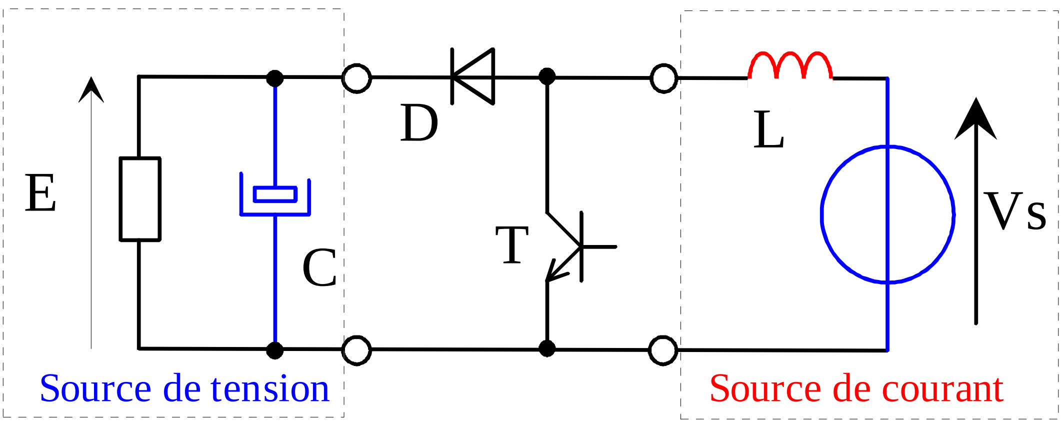
K1 : diode

K2 : transistor

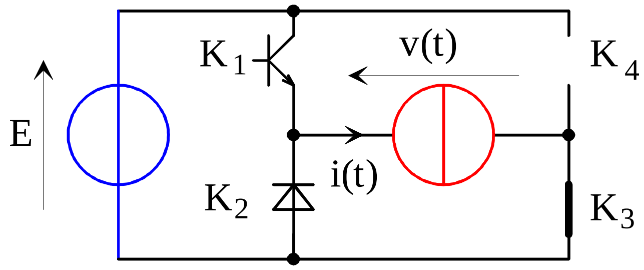
K3 : fermé

K4 : ouvert

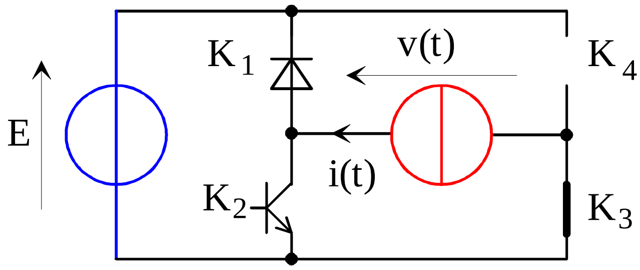
Structure du hacheur élévateur :



Synthèse du hacheur réversible en courant

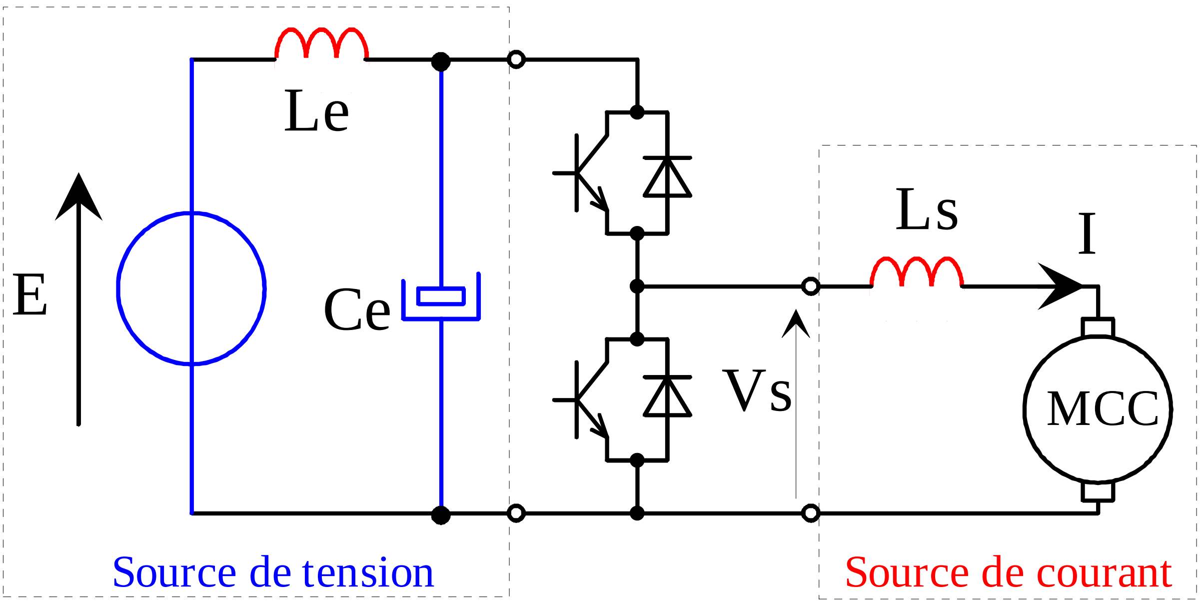


a) Hacheur série



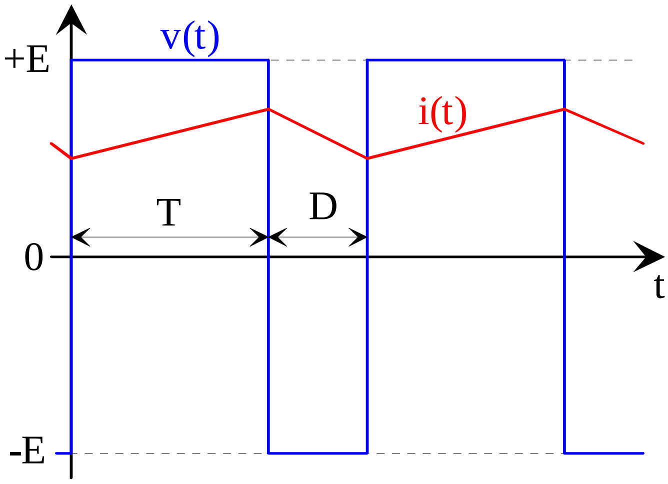
b) Hacheur élévateur

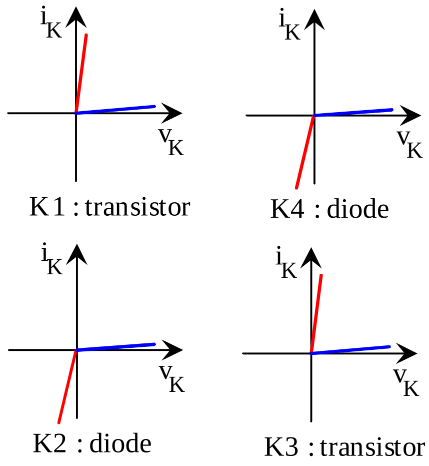
Structure du hacheur réversible en courant :



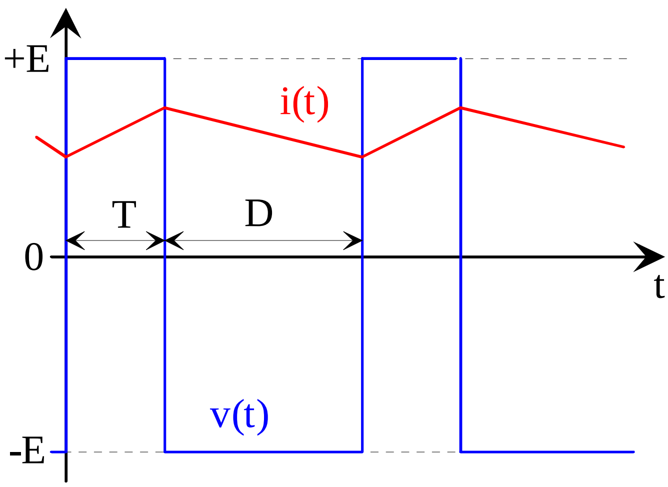
Synthèse du hacheur réversible en tension

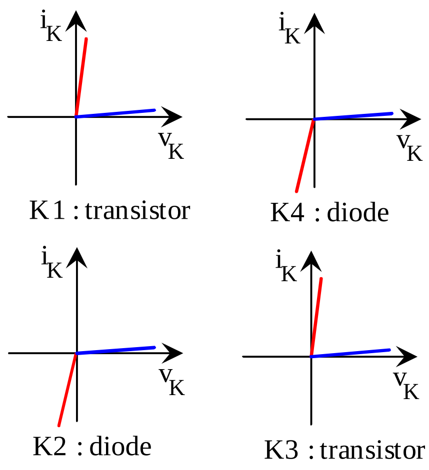
Cas où la puissance est positive P>0 - Quadrant 1 :



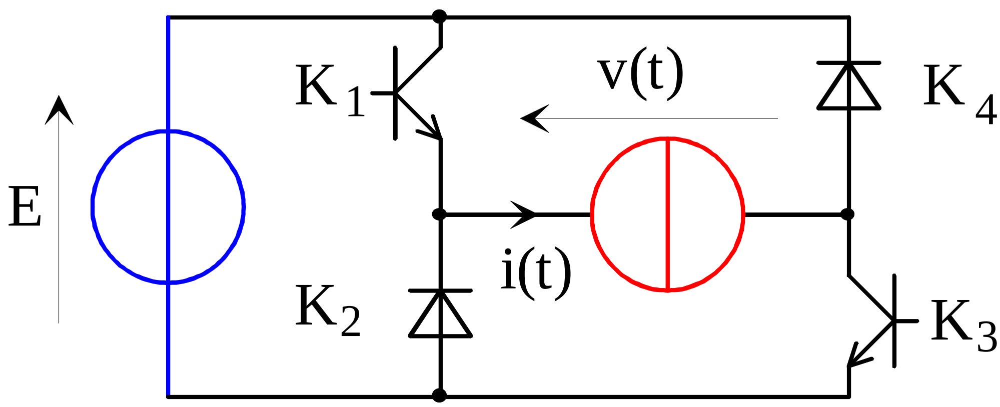


Cas où la puissance est négative P<0 - Quadrant 2 :

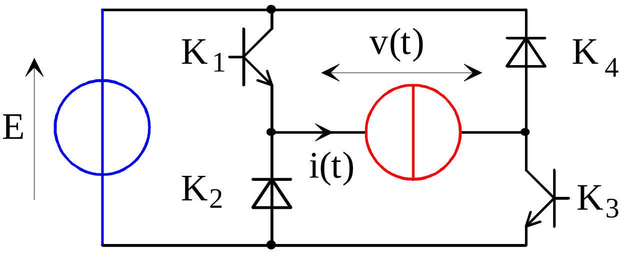




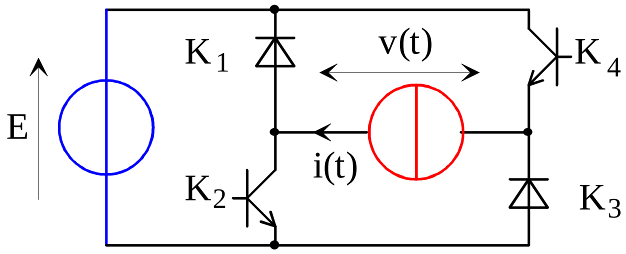
Réalisation pratique du hacheur :



Synthèse du hacheur 4 quadrants

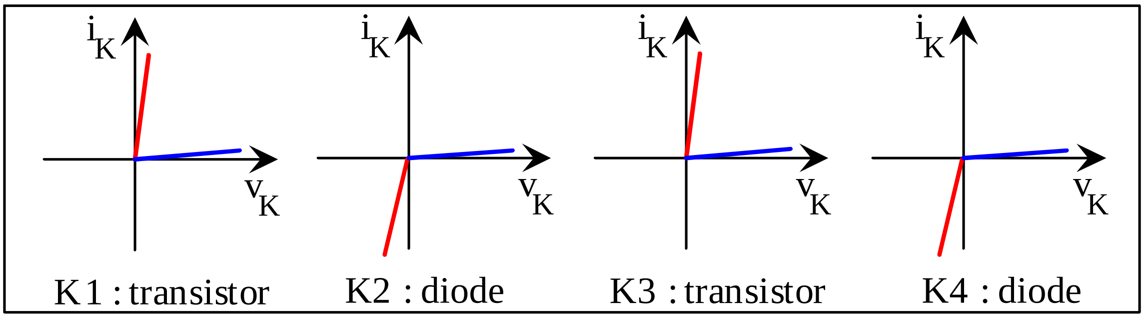


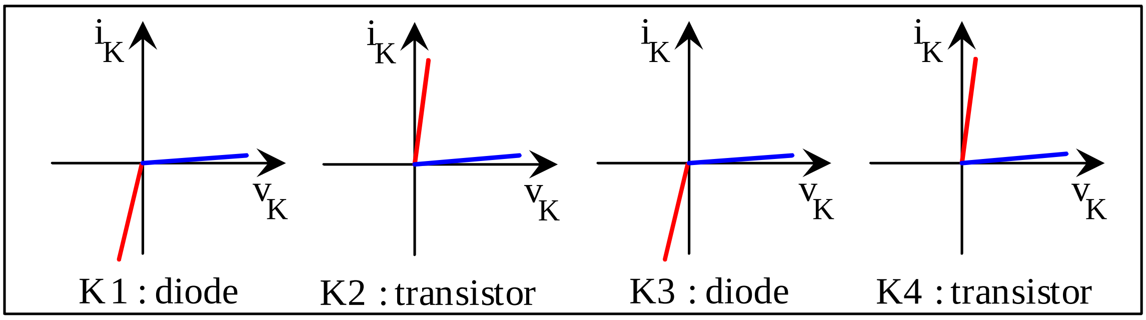
a) Phase I : quadrants Q1-Q2



b) Phase II : quadrants Q3-Q4

Caractéristiques des interrupteurs :





Le convertisseur 4 quadrants :