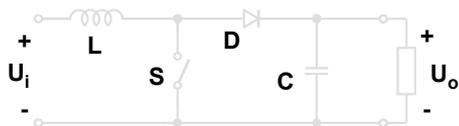


Corso di ELETTRONICA INDUSTRIALE

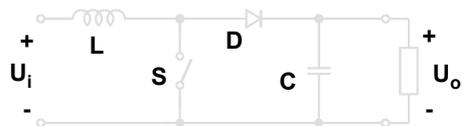
“Convertitore Boost”

Convertitore innalzatore di tensione (boost)

Convertitore innalzatore di tensione (boost)



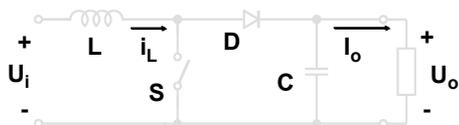
Convertitore innalzatore di tensione (boost)



Note:

- 1) Il diodo D collega direttamente ingresso e uscita e impone che sia $U_o \geq U_i$
- 2) La corrente assorbita dall'alimentazione è filtrata dall'induttanza L

Convertitore innalzatore di tensione (boost)



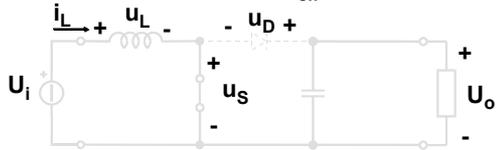
Ipotesi per lo studio:

- interruttore ideale ($u_{S\text{on}}=0$, $i_{S\text{off}}=0$, $t_{\text{swon}}=t_{\text{swoff}}=0$)
- diodo ideale ($u_{D\text{on}}=0$, $i_{D\text{off}}=0$, $t_{\text{swon}}=t_{\text{swoff}}=0$)
- L, C ideali ($R_L=0$, $\text{ESR}=0$, $\text{ESL}=0$)
- $u_i = U_i = \text{costante}$
- $u_o = U_o = \text{costante}$
- $i_o = I_o = \text{costante}$

Analisi del funzionamento continuo (CCM)

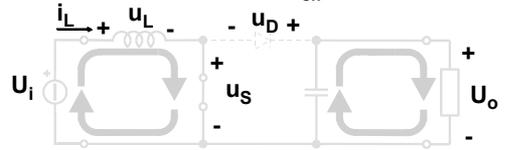
Analisi del funzionamento continuo (CCM)

Tempo di chiusura di S (t_{on}) S on - D off



Analisi del funzionamento continuo (CCM)

Tempo di chiusura di S (t_{on}) S on - D off

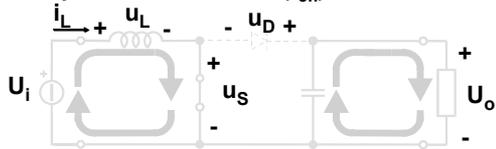


$$u_L = U_i$$

$$u_D = U_o$$

Analisi del funzionamento continuo (CCM)

Tempo di chiusura di S (t_{on}) S on - D off



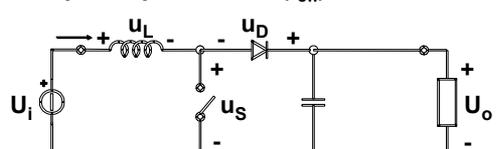
$$u_L = U_i$$

$$u_D = U_o$$

Durante questa fase viene trasferita energia dall'alimentazione all'induttanza

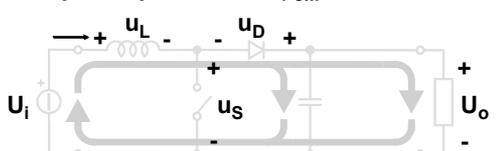
Analisi del funzionamento continuo (CCM)

Tempo di apertura di S (t_{off}) S off - D on



Analisi del funzionamento continuo (CCM)

Tempo di apertura di S (t_{off}) S off - D on

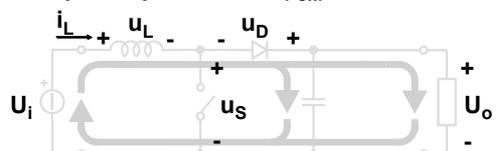


$$u_L = U_i - U_o$$

$$u_S = U_o$$

Analisi del funzionamento continuo (CCM)

Tempo di apertura di S (t_{off}) S off - D on



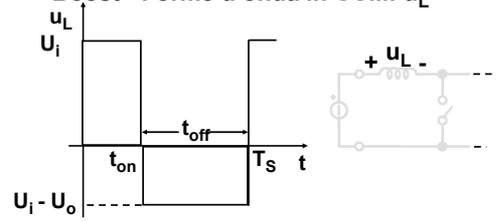
$$u_L = U_o - U_i$$

$$u_S = U_o$$

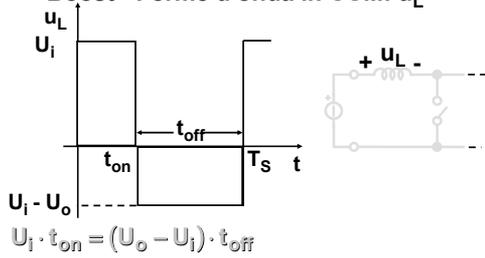
Durante questa fase la sorgente e l'induttanza forniscono energia allo stadio di uscita

Boost - Forme d'onda in CCM: u_L

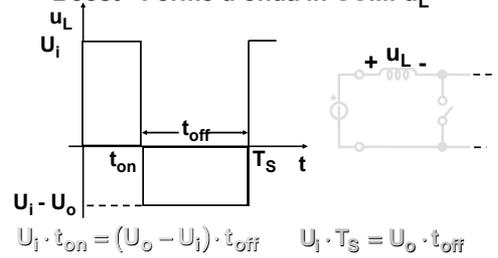
Boost - Forme d'onda in CCM: u_L



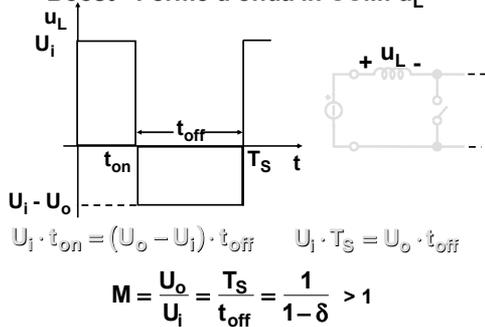
Boost - Forme d'onda in CCM: u_L



Boost - Forme d'onda in CCM: u_L

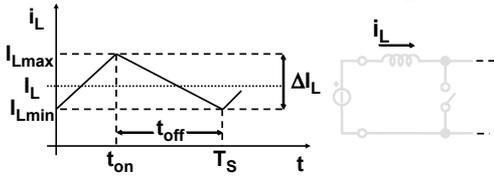


Boost - Forme d'onda in CCM: u_L

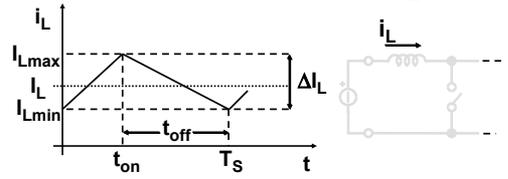


Boost - Forme d'onda in CCM: i_L

Boost - Forme d'onda in CCM: i_L

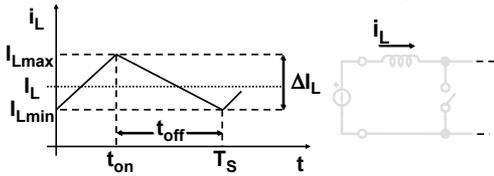


Boost - Forme d'onda in CCM: i_L



A regime:

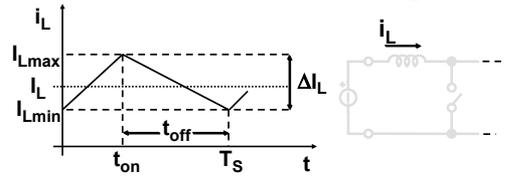
Boost - Forme d'onda in CCM: i_L



A regime:

$$\Delta I_{Lon} = \Delta I_{Loff} = \Delta I_L = \frac{U_i}{L} \cdot t_{on} = \frac{U_o - U_i}{L} \cdot t_{off}$$

Boost - Forme d'onda in CCM: i_L

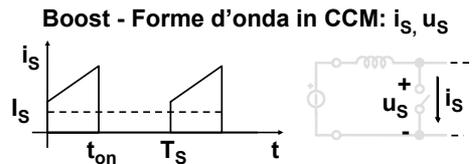


A regime:

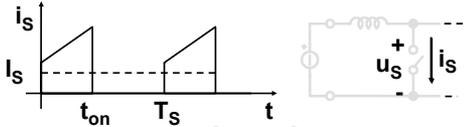
$$\Delta I_{Lon} = \Delta I_{Loff} = \Delta I_L = \frac{U_i}{L} \cdot t_{on} = \frac{U_o - U_i}{L} \cdot t_{off}$$

$$M = \frac{U_o}{U_i} = \frac{T_s}{t_{off}} = \frac{1}{1-\delta} > 1$$

Boost - Forme d'onda in CCM: i_s, u_s

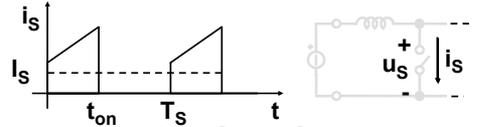


Boost - Forme d'onda in CCM: i_S, u_S

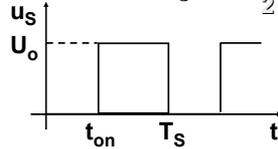


$$I_S = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S}, t_{on} = I_L \cdot \delta$$

Boost - Forme d'onda in CCM: i_S, u_S



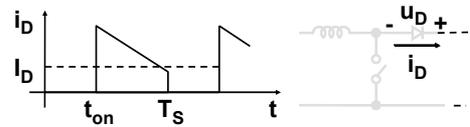
$$I_S = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S}, t_{on} = I_L \cdot \delta$$



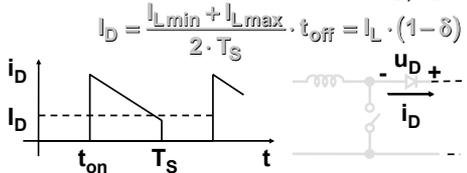
$$U_{Smax} = U_o$$

Boost - Forme d'onda in CCM: i_D, u_D

Boost - Forme d'onda in CCM: i_D, u_D

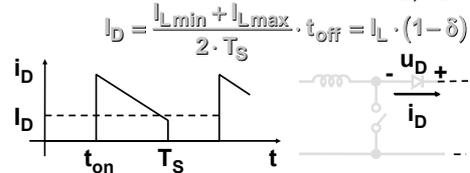


Boost - Forme d'onda in CCM: i_D, u_D

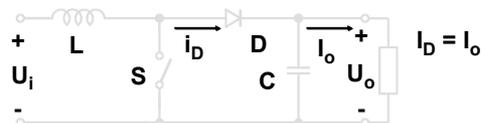


$$I_D = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S}, t_{off} = I_L \cdot (1 - \delta)$$

Boost - Forme d'onda in CCM: i_D, u_D

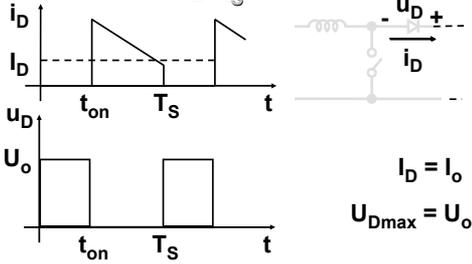


$$I_D = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S}, t_{off} = I_L \cdot (1 - \delta)$$



Boost - Forme d'onda in CCM: i_D , u_D

$$I_D = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S} \cdot t_{off} = I_L \cdot (1 - \delta)$$



Convertitore boost in CCM

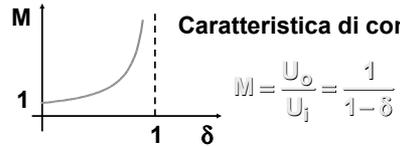
Convertitore boost in CCM

Caratteristica di controllo

$$M = \frac{U_o}{U_i} = \frac{1}{1 - \delta}$$

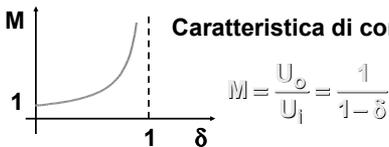
Convertitore boost in CCM

Caratteristica di controllo



Convertitore boost in CCM

Caratteristica di controllo

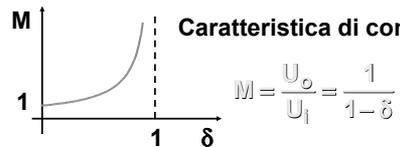


Ondulazione di corrente

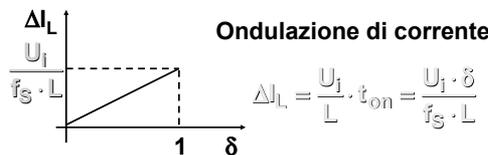
$$\Delta I_L = \frac{U_i}{L} \cdot t_{on} = \frac{U_i \cdot \delta}{f_S \cdot L}$$

Convertitore boost in CCM

Caratteristica di controllo



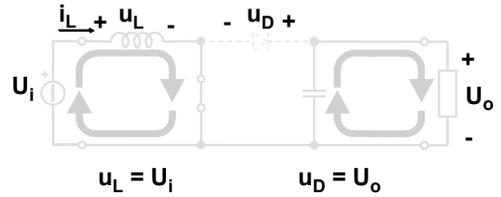
Ondulazione di corrente



Analisi del funzionamento discontinuo (DCM)

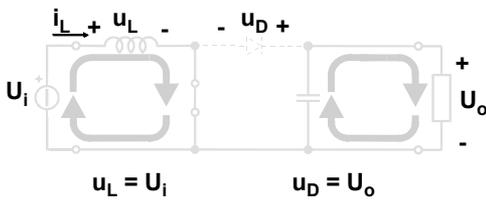
Analisi del funzionamento discontinuo (DCM)

Tempo di chiusura di S (t_{on}) S on - D off



Analisi del funzionamento discontinuo (DCM)

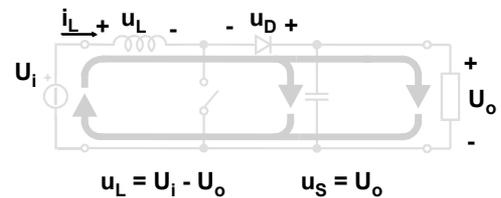
Tempo di chiusura di S (t_{on}) S on - D off



A differenza del funzionamento CCM la corrente i_L inizia con valore nullo.

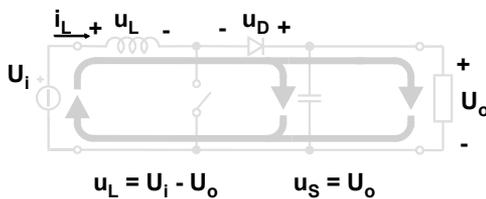
Analisi del funzionamento discontinuo (DCM)

Tempo di apertura di S (t'_{off}) S off - D on



Analisi del funzionamento discontinuo (DCM)

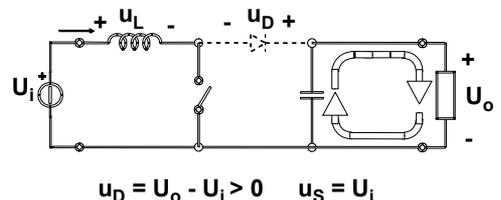
Tempo di apertura di S (t'_{off}) S off - D on



Alla fine di questa fase la corrente dell'induttanza si annulla

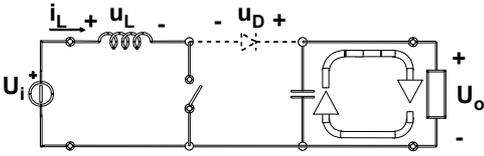
Analisi del funzionamento discontinuo (DCM)

Tempo di apertura di S (t''_{off}) S off - D off



Analisi del funzionamento discontinuo (DCM)

Tempo di apertura di S (t'_{off}) S off - D off

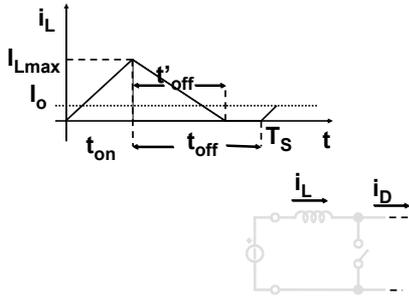


$$u_D = U_o - U_i > 0 \quad u_S = U_i$$

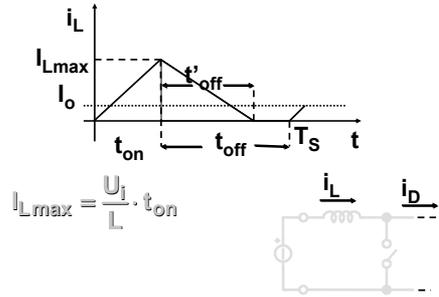
Durante questa fase il solo condensatore fornisce energia al carico

Boost - Forme d'onda in DCM: i_L

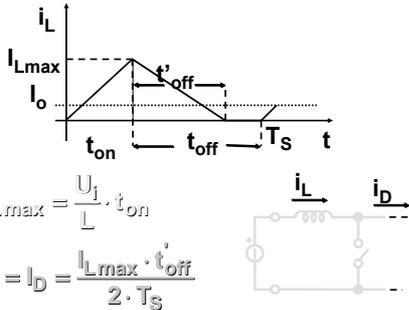
Boost - Forme d'onda in DCM: i_L



Boost - Forme d'onda in DCM: i_L

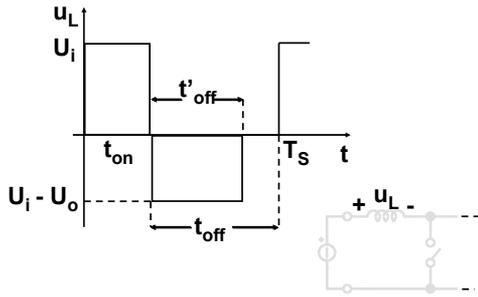


Boost - Forme d'onda in DCM: i_L

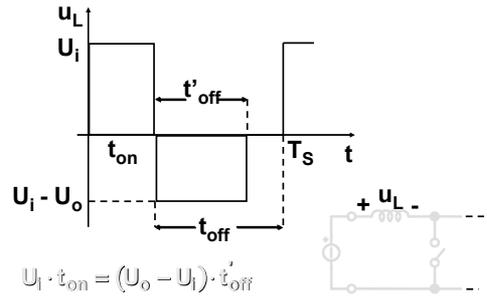


Boost - Forme d'onda in DCM: u_L

Boost - Forme d'onda in DCM: u_L



Boost - Forme d'onda in DCM: u_L



Boost: Caratteristica di controllo in DCM

Boost: Caratteristica di controllo in DCM

$$I_o = \frac{I_{Lmax} \cdot t'_{off}}{2 \cdot T_S}; \quad I_{Lmax} = \frac{U_i}{L} \cdot t_{on};$$

$$t'_{off} = \frac{U_i}{U_o - U_i} \cdot t_{on}$$

Boost: Caratteristica di controllo in DCM

$$I_o = \frac{I_{Lmax} \cdot t'_{off}}{2 \cdot T_S}; \quad I_{Lmax} = \frac{U_i}{L} \cdot t_{on};$$

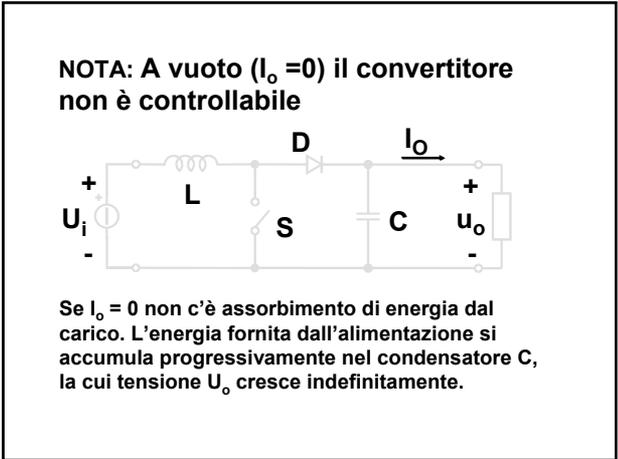
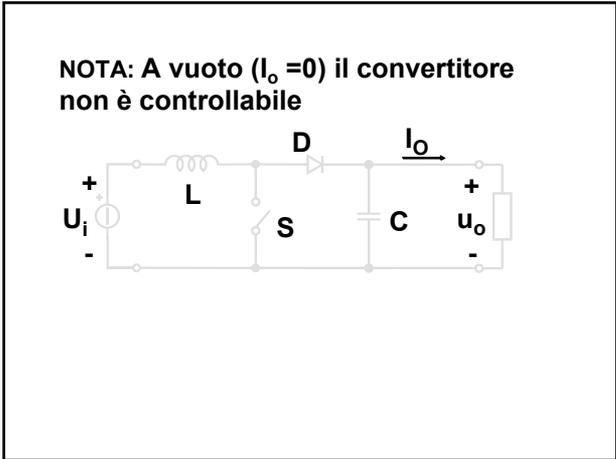
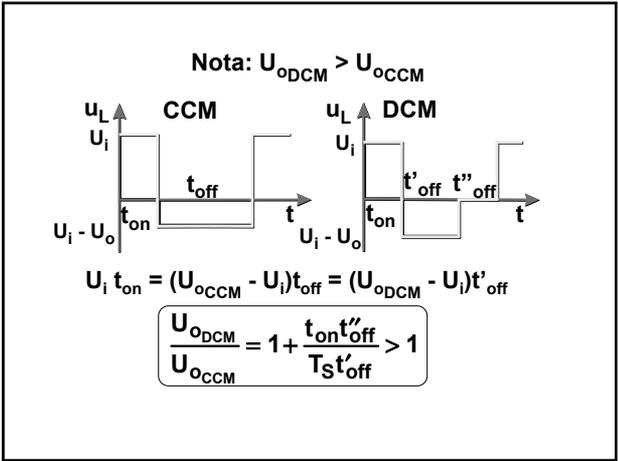
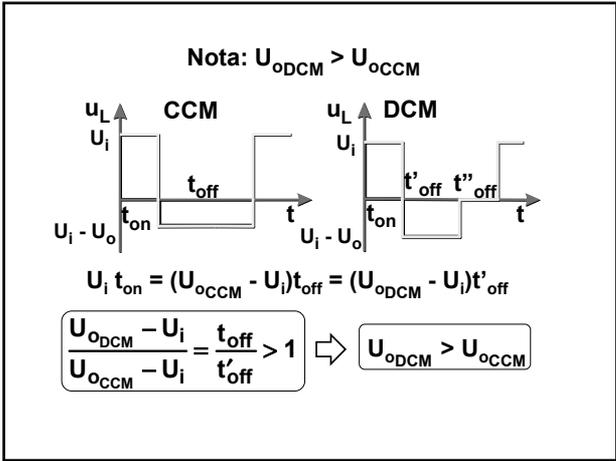
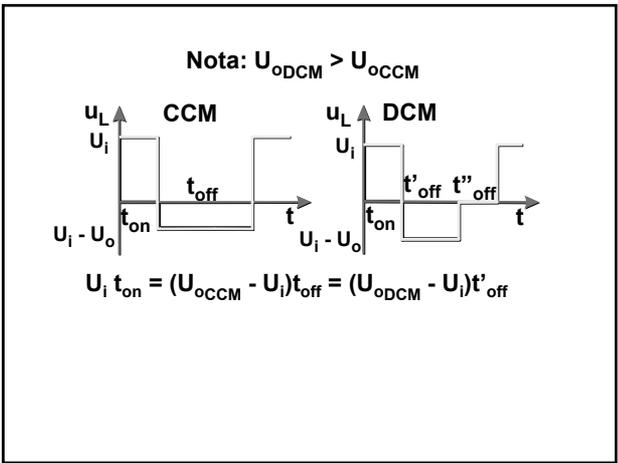
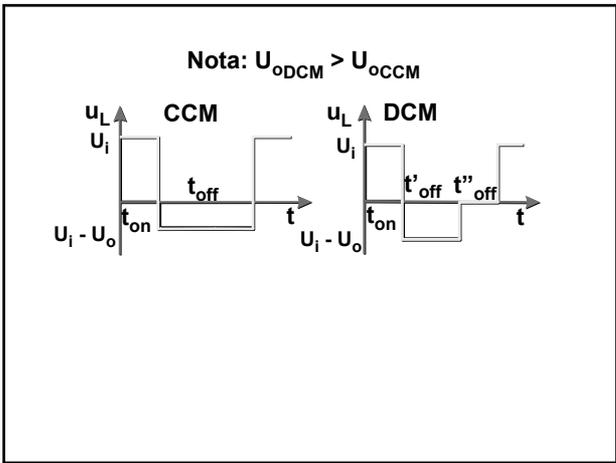
$$t'_{off} = \frac{U_i}{U_o - U_i} \cdot t_{on}$$

$$\Downarrow$$

$$M = \frac{U_o}{U_i} = 1 + \delta^2 \cdot \frac{U_i}{2 \cdot f_s \cdot L \cdot I_o} = 1 + \delta^2 \cdot \frac{I_N}{I_o}$$

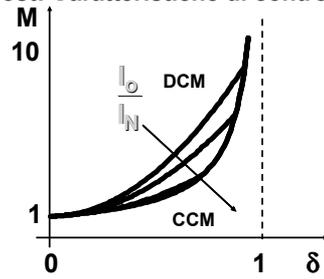
dove: $I_N = \frac{U_i}{2 \cdot f_s \cdot L}$

Nota: $U_{oDCM} > U_{oCCM}$

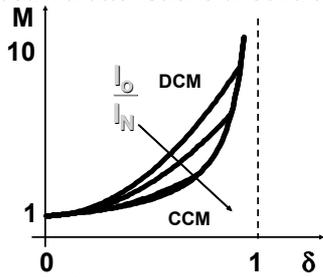


Boost: Caratteristiche di controllo

Boost: Caratteristiche di controllo

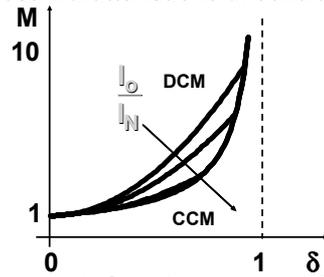


Boost: Caratteristiche di controllo



Anche in questo caso valgono le curve che danno tensione d'uscita più elevata

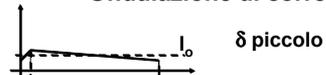
Boost: Caratteristiche di controllo



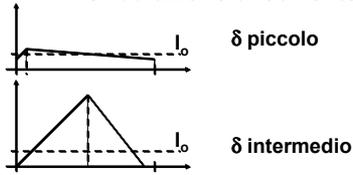
Il funzionamento è continuo per valori di δ estremi, discontinuo per valori intermedi

Ondulazione di corrente

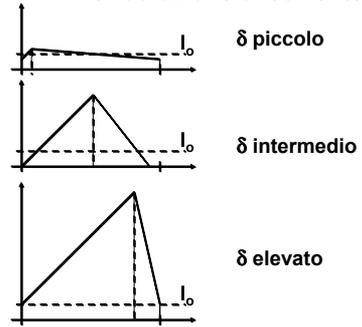
Ondulazione di corrente



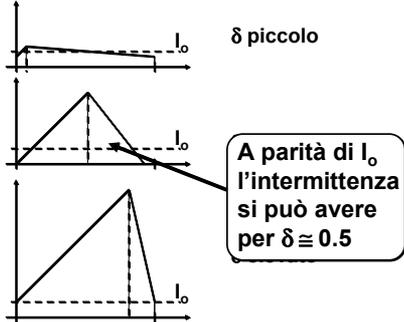
Ondulazione di corrente



Ondulazione di corrente

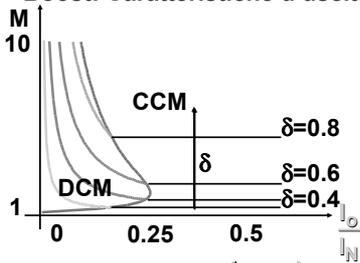


Ondulazione di corrente



Boost: Caratteristiche d'uscita

Boost: Caratteristiche d'uscita



Curva limite:
$$\frac{I_o}{I_N} = \frac{1}{M} \cdot \left(1 - \frac{1}{M}\right)$$

Caratteristica di controllo in DCM per carico resistivo

Caratteristica di controllo in DCM per carico resistivo

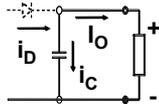
$$M = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{\delta^2}{k}}$$

dove: $k = \frac{2 \cdot f_s \cdot L}{R_o}$

Corrente del condensatore di filtro: i_C

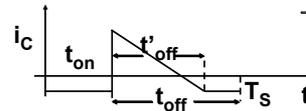
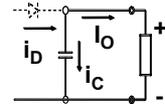
Corrente del condensatore di filtro: i_C

$$i_C = i_D - I_o$$



Corrente del condensatore di filtro: i_C

$$i_C = i_D - I_o$$



i_C ha fronti ripidi; l'induttanza parassita di C (ESL) deve quindi essere minima

Note

- Le tecniche di controllo sono le stesse del convertitore Buck
- La risposta dinamica è però difficile da dominare (caratteristica statica nonlineare, modello ai piccoli segnali a parametri variabili e zero a parte reale positiva)
- Schemi a trasformatore basati sulla topologia boost risultano complessi e sono poco usati