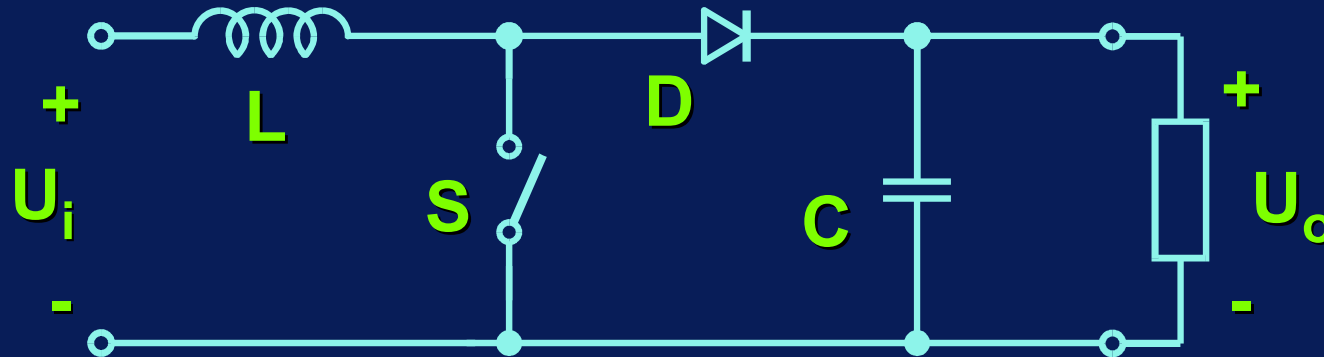


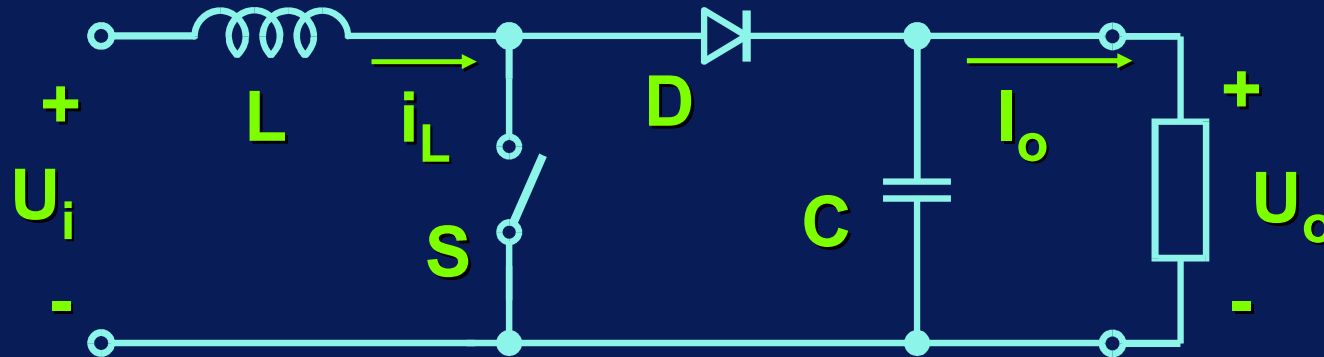
## Convertitore innalzatore di tensione (boost)



### 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 é filtrata dall'induttanza  $L$

## Convertitore innalzatore di tensione (boost)



### Ipotesi per lo studio:

interruttore ideale ( $u_{\text{Son}}=0$ ,  $i_{\text{Soff}}=0$ ,  $t_{\text{swon}}=t_{\text{swoff}}=0$ )

→ diodo ideale ( $u_{\text{Son}}=0$ ,  $i_{\text{Soff}}=0$ ,  $t_{\text{swon}}=t_{\text{swoff}}=0$ )

→  $L, C$  ideali ( $R_L=0$ ,  $\text{ESR}=0$ ,  $\text{ESL}=0$ )

$u_i = U_i = \text{costante}$

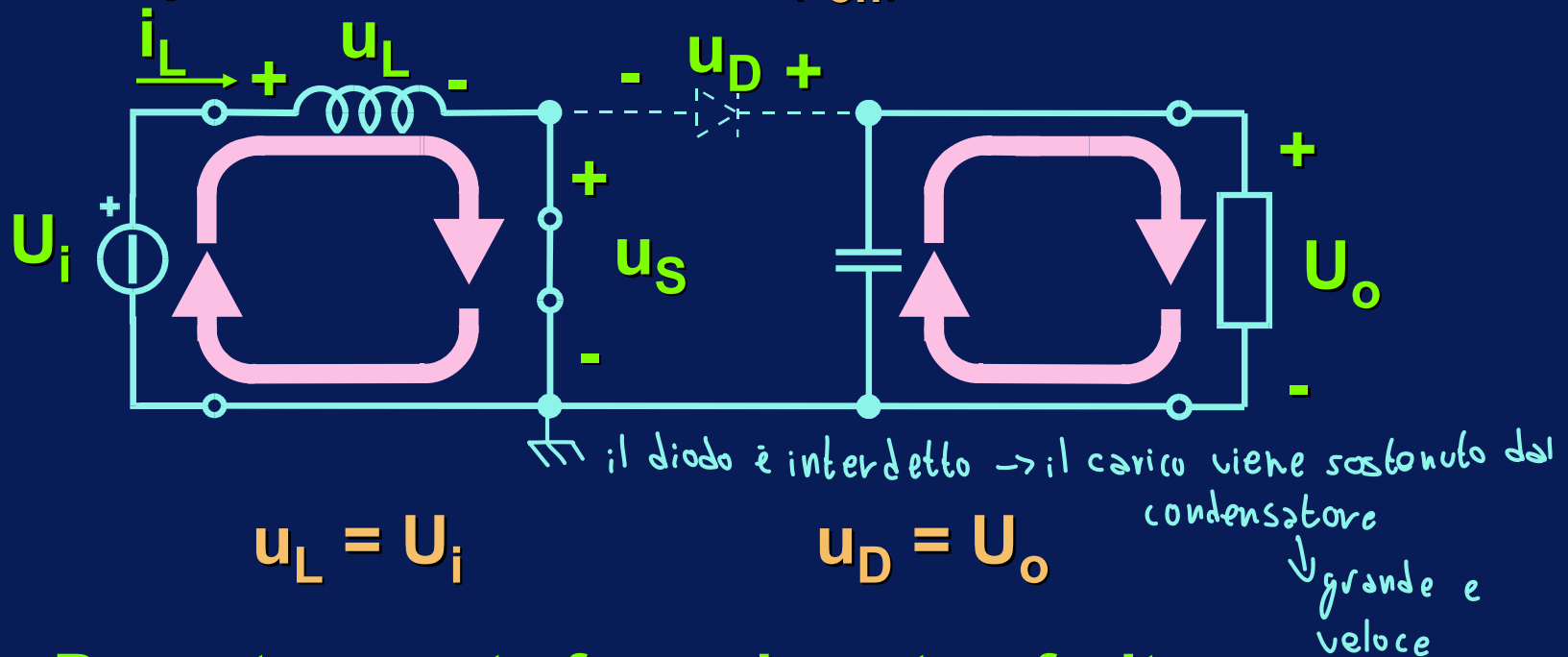
$u_o = U_o = \text{costante}$

$i_o = I_o = \text{costante}$

} sul periodo

## Analisi del funzionamento continuo (CCM)

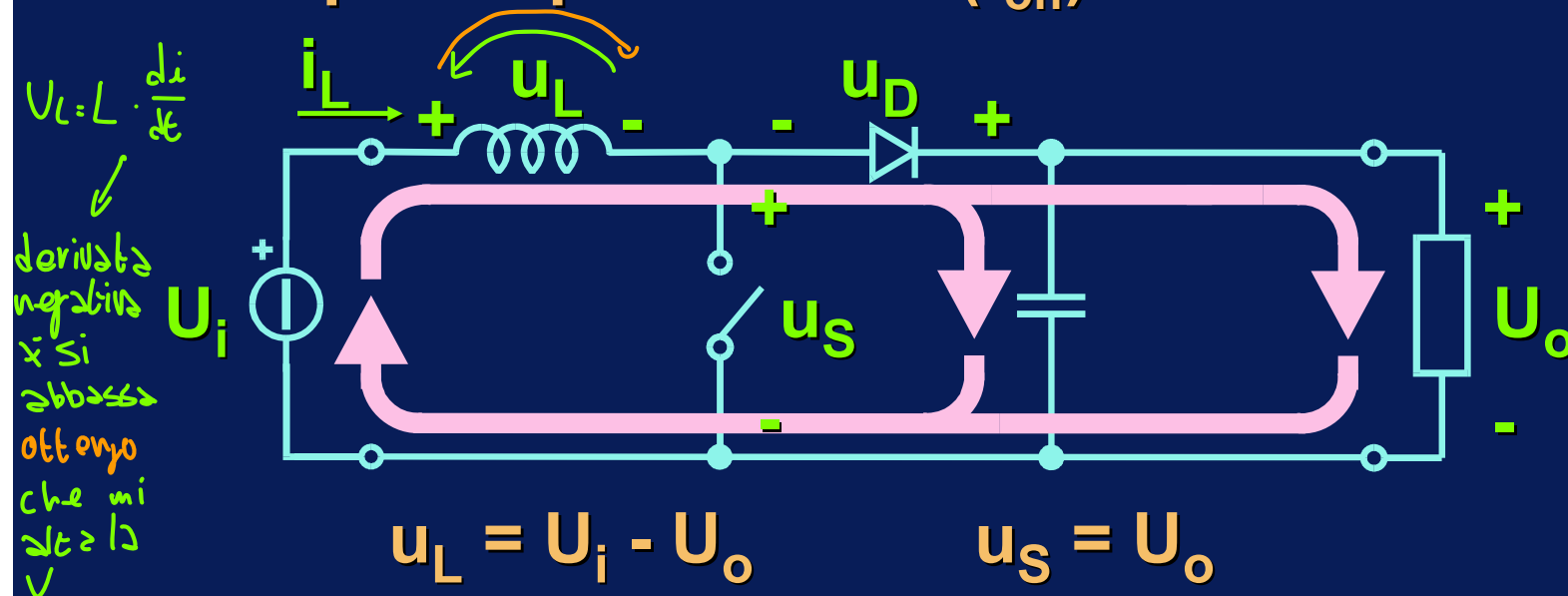
Tempo di chiusura di S ( $t_{on}$ )    S on - D off



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

# Analisi del funzionamento continuo (CCM)

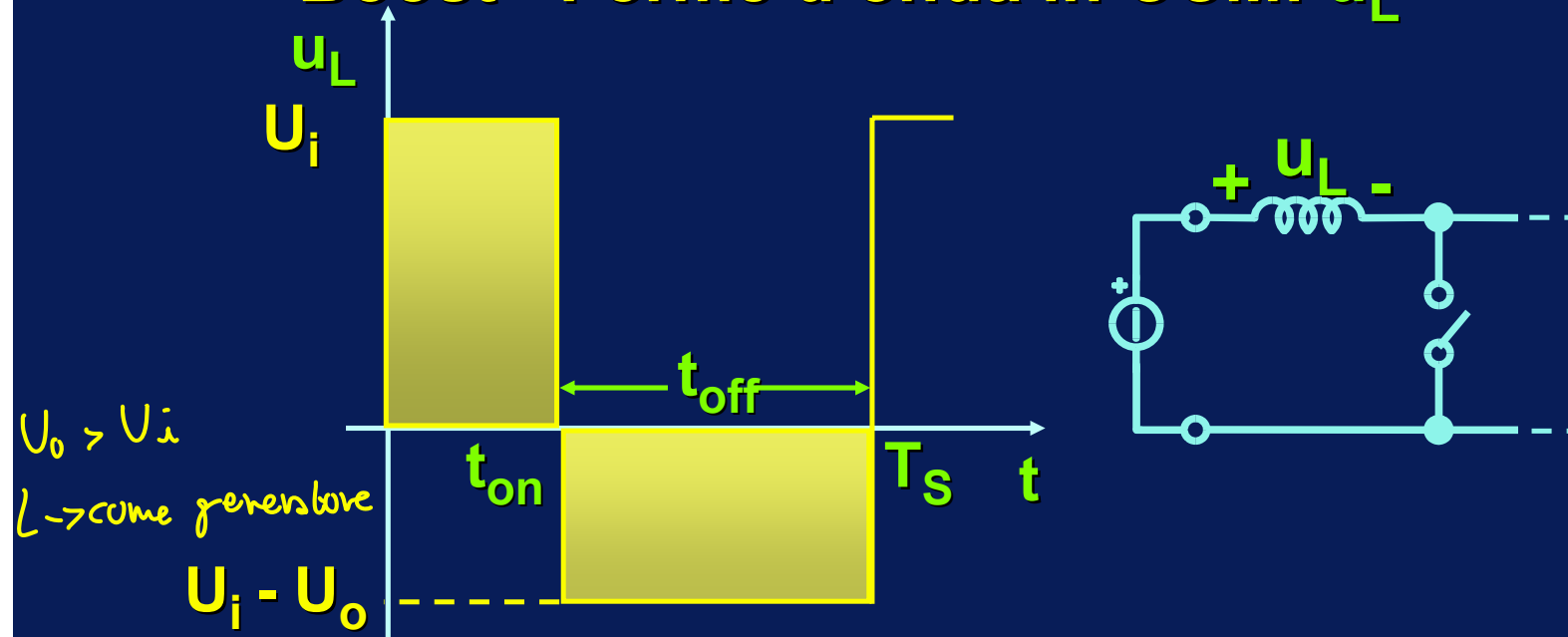
Tempo di apertura di S ( $t_{\text{off}}$ )    S off - D on



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

→ che un momento in cui la  $u$  è indefinita e potrebbe essere molto alta mi serve un diodo veloce

## Boost - Forme d'onda in CCM: $u_L$

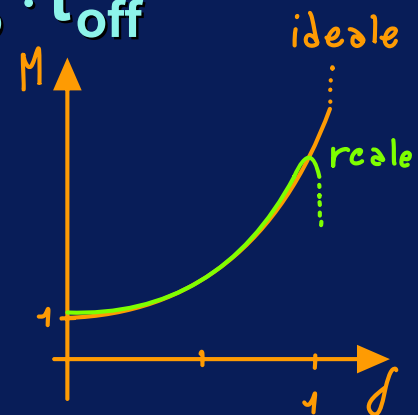


$$U_i \cdot t_{on} = (U_o - U_i) \cdot t_{off}$$

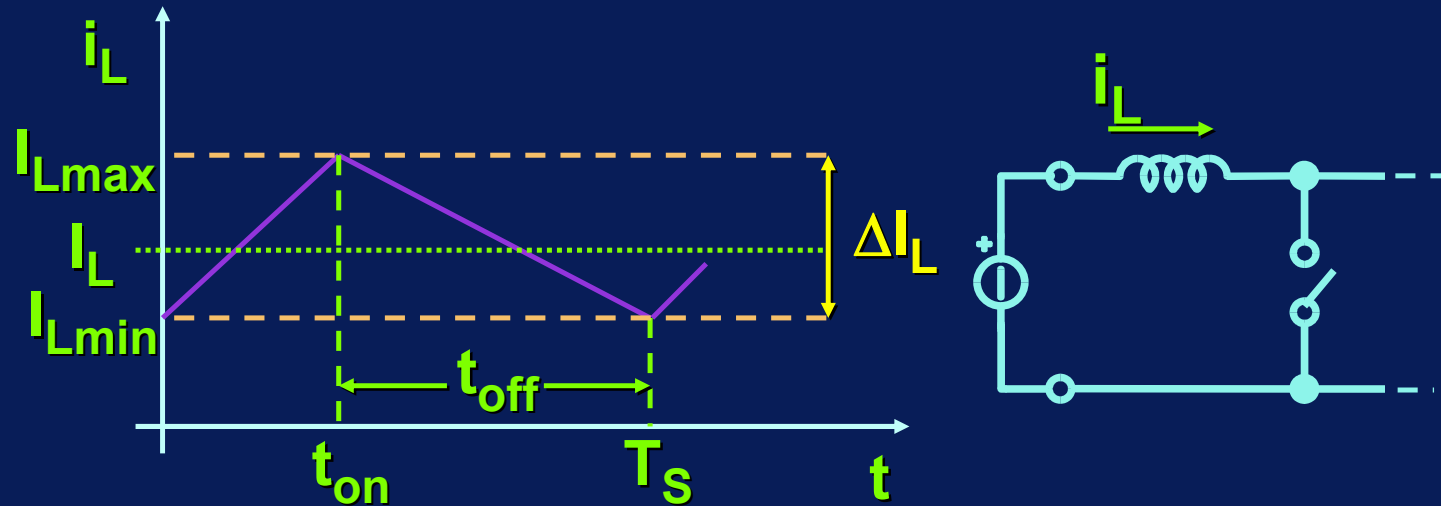
$$U_i \cdot T_s = U_o \cdot t_{off}$$

$$M \neq \delta$$

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



## Boost - Forme d'onda in CCM: $i_L$

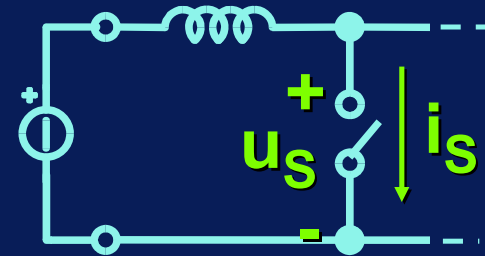
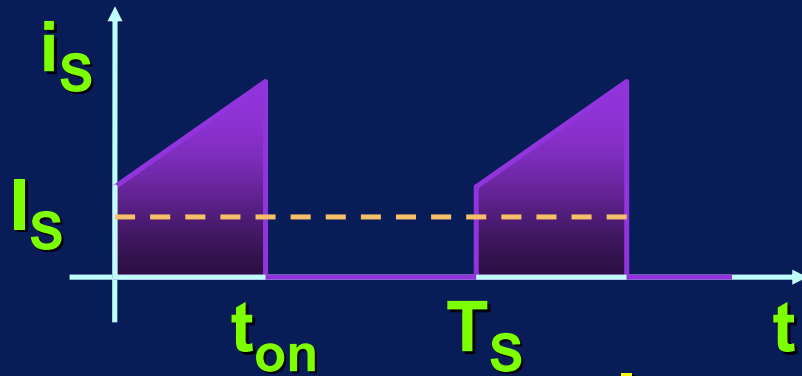


**A regime:**

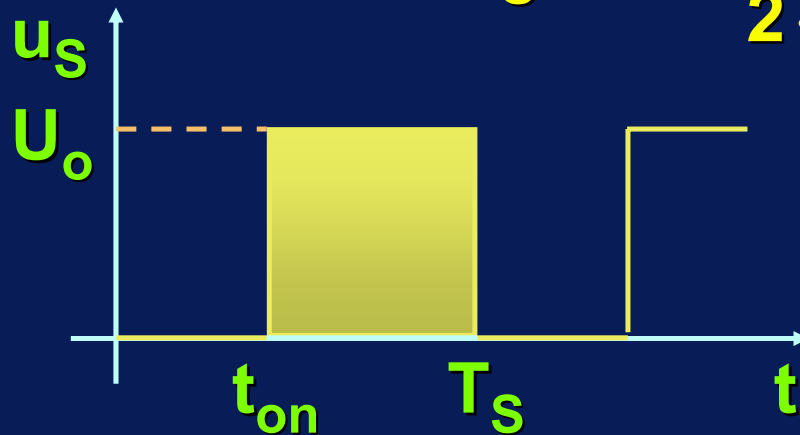
$$\Delta I_{Lon} = \Delta I_{Loff} = \Delta I_L = \frac{U_i}{L} \cdot t_{on} = \frac{U_o - U_i}{L} \cdot t_{off}$$

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

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



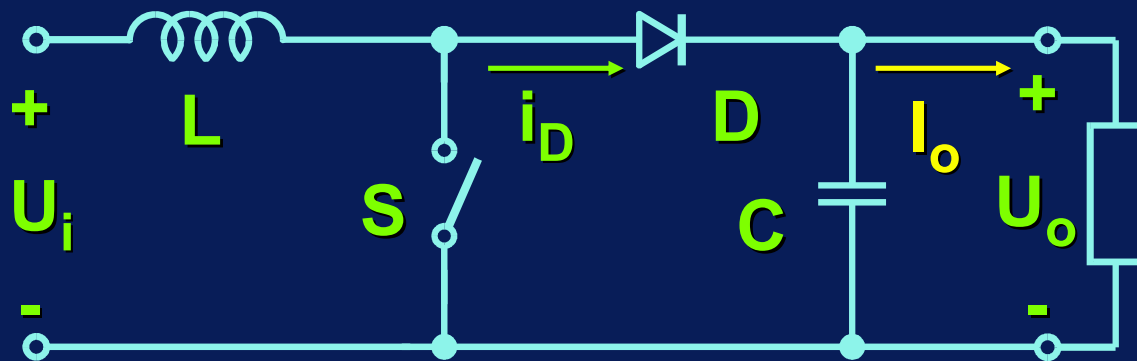
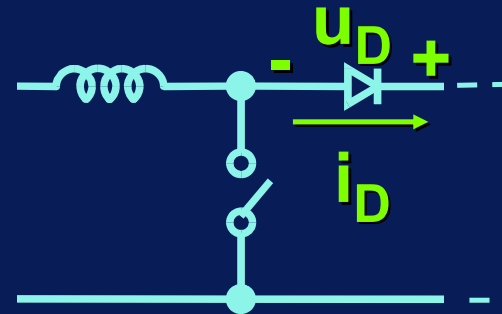
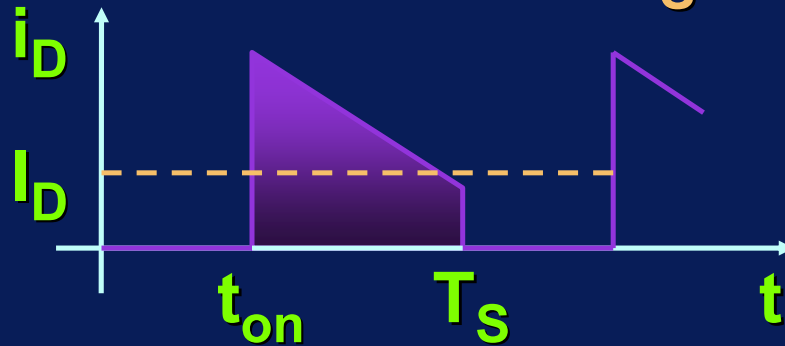
$$I_S = \frac{I_{Lmin} + I_{Lmax}}{2 \cdot T_S} \cdot t_{on} = I_L \cdot \delta$$



$$U_{Smax} = U_o$$

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

$$I_D = \frac{I_{L\min} + I_{L\max}}{2 \cdot T_S} \cdot t_{\text{off}} = I_L \cdot (1 - \delta)$$

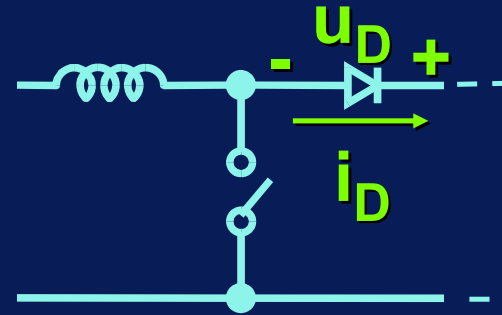
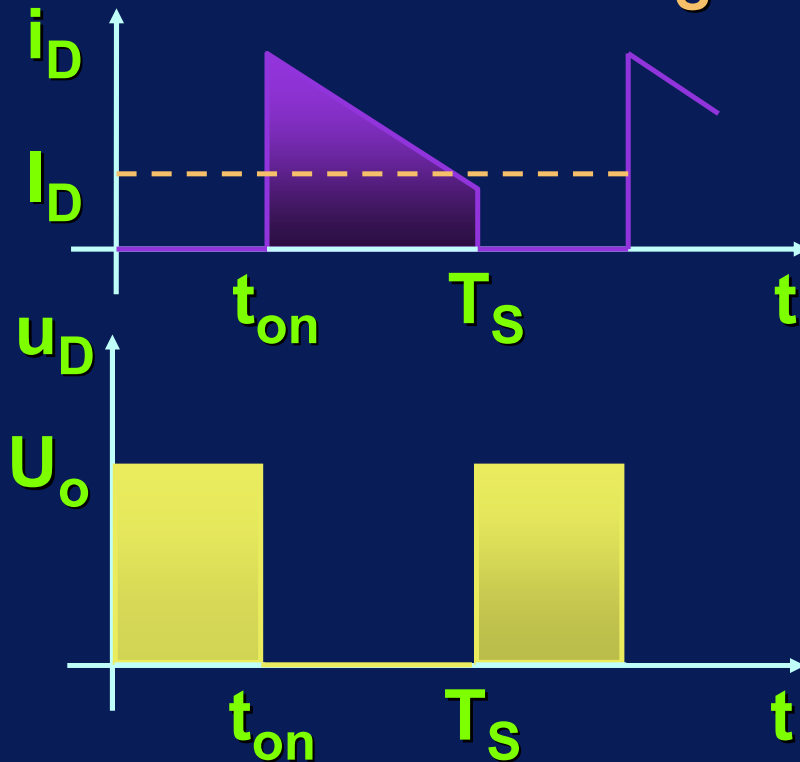


$$I_D = I_o$$



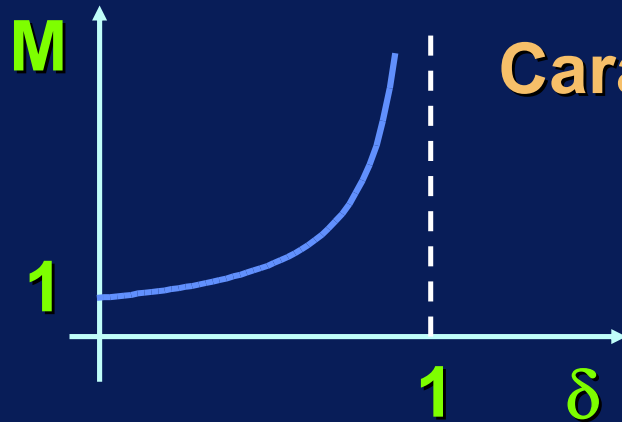
## Boost - Forme d'onda in CCM: $i_D$ , $u_D$

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



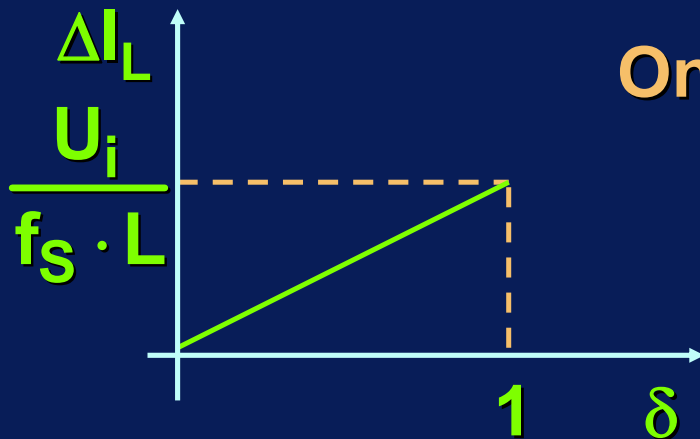
$$I_D = I_o$$
$$U_{Dmax} = U_o$$

## Convertitore boost in CCM



Caratteristica di controllo

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

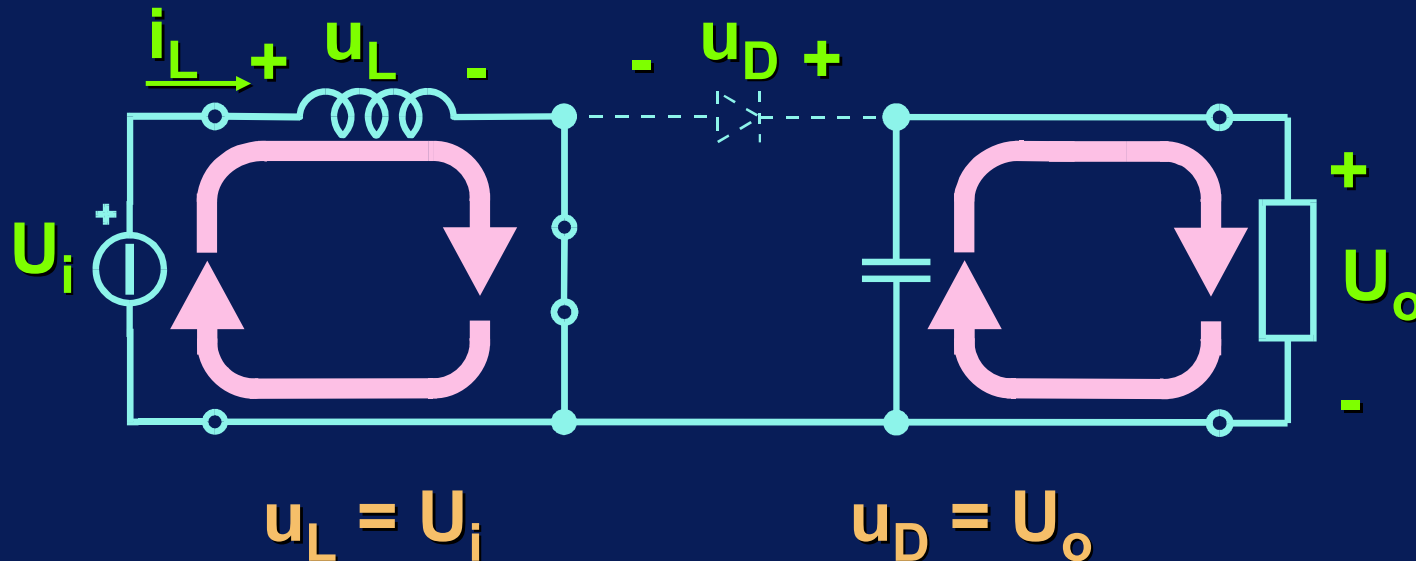


Ondulazione di corrente

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

## Analisi del funzionamento discontinuo (DCM)

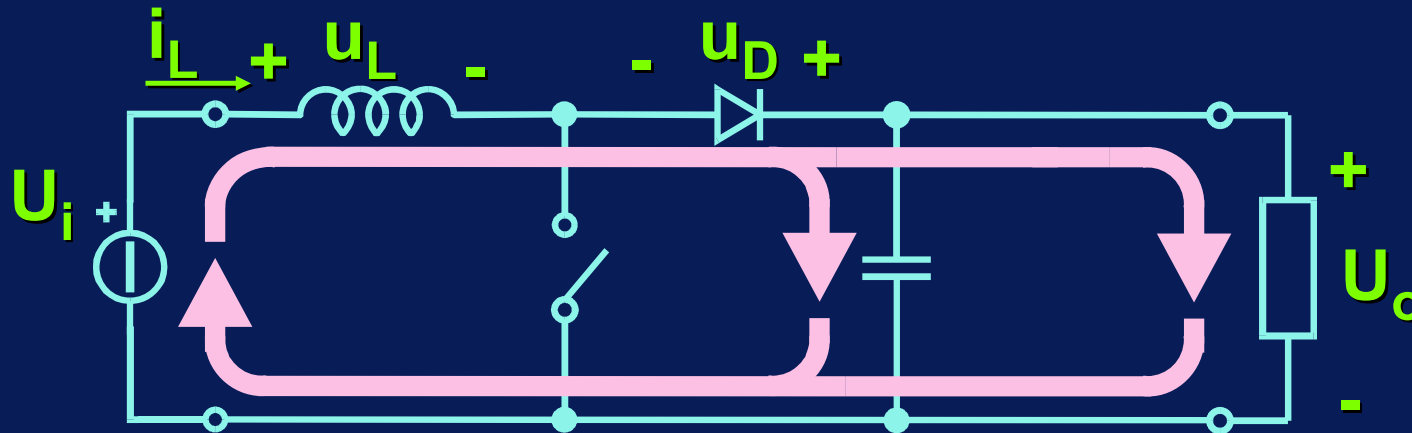
Tempo di chiusura di S ( $t_{on}$ )    S on - D off



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

## Analisi del funzionamento discontinuo (DCM)

Tempo di apertura di S ( $t'_{\text{off}}$ )    **S off - D on**



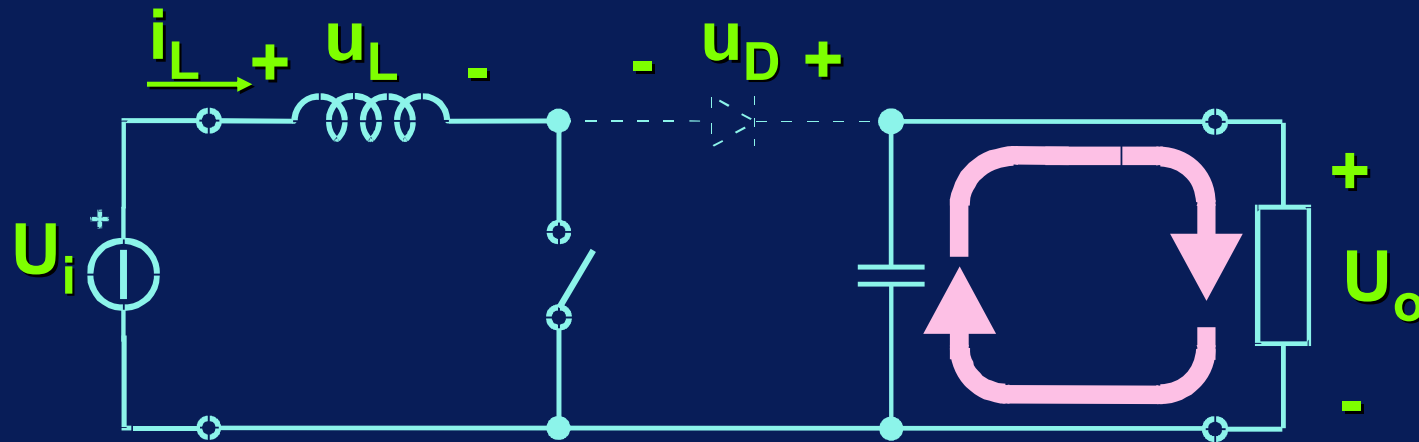
$$u_L = U_i - U_o$$

$$u_S = U_o$$

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

## Analisi del funzionamento discontinuo (DCM)

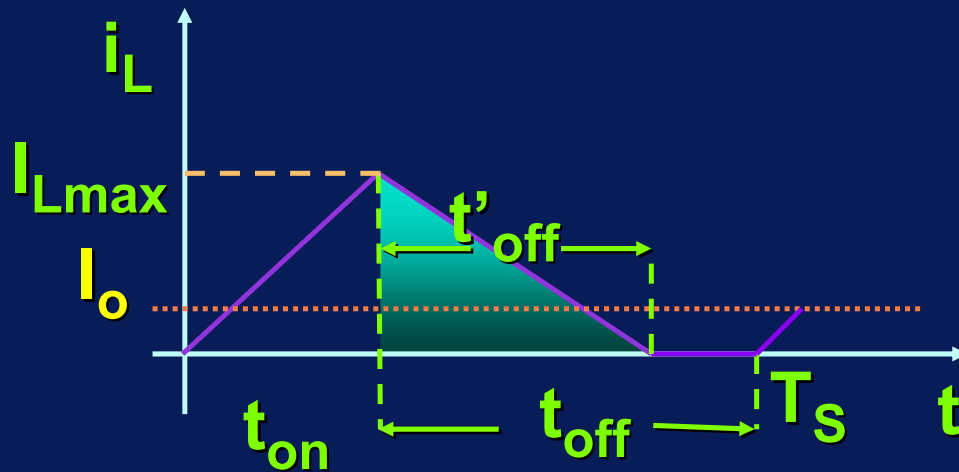
Tempo di apertura di S ( $t''_{\text{off}}$ )    **S off - D off**



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

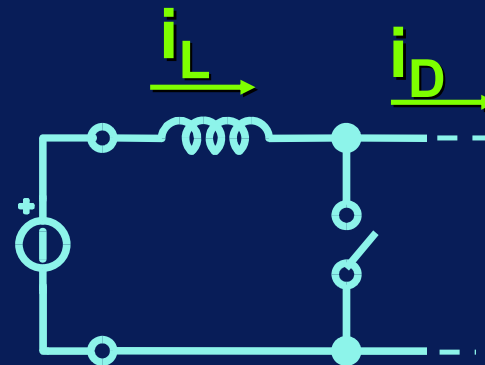
**Durante questa fase il solo condensatore  
fornisce energia al carico**

## Boost - Forme d'onda in DCM: $i_L$



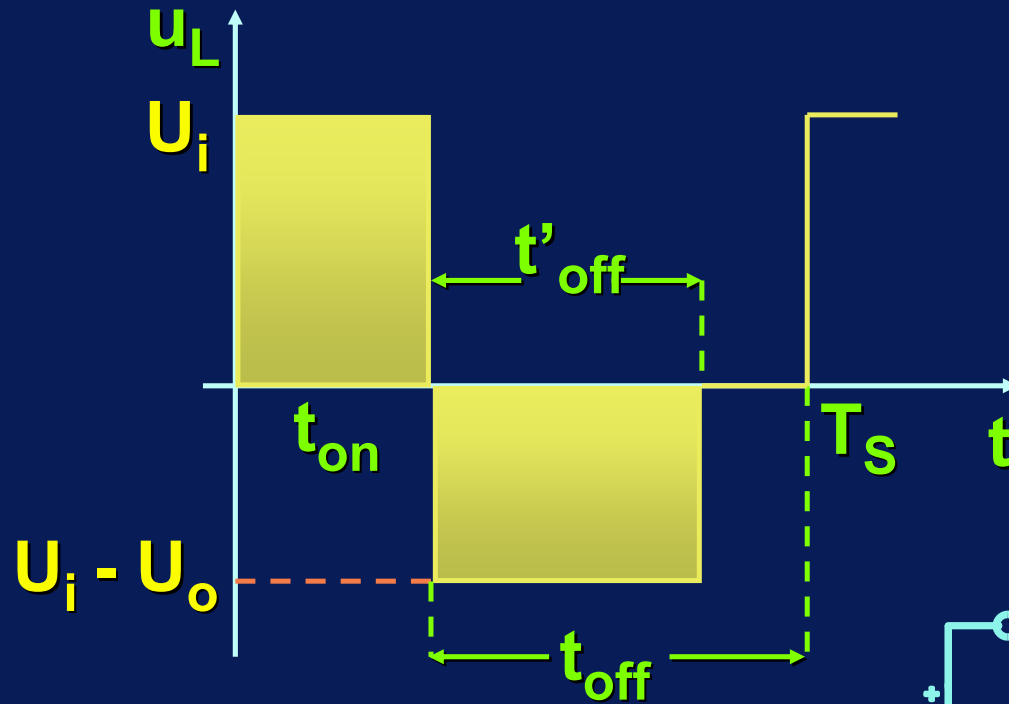
$$I_{Lmax} = \frac{U_i}{L} \cdot t_{on}$$

$$I_o = I_D = \frac{I_{Lmax} \cdot t'_{off}}{2 \cdot T_s}$$

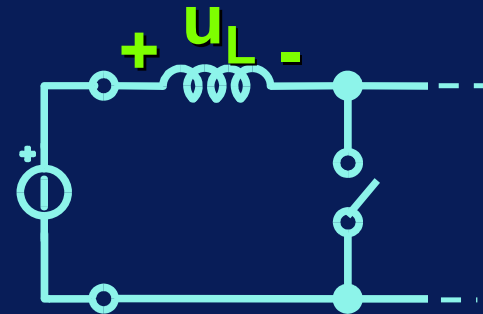


**Boost - Forme d'onda in DCM:  $u_L$**

## Boost - Forme d'onda in DCM: $u_L$



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





## Boost: Caratteristica di controllo in DCM

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

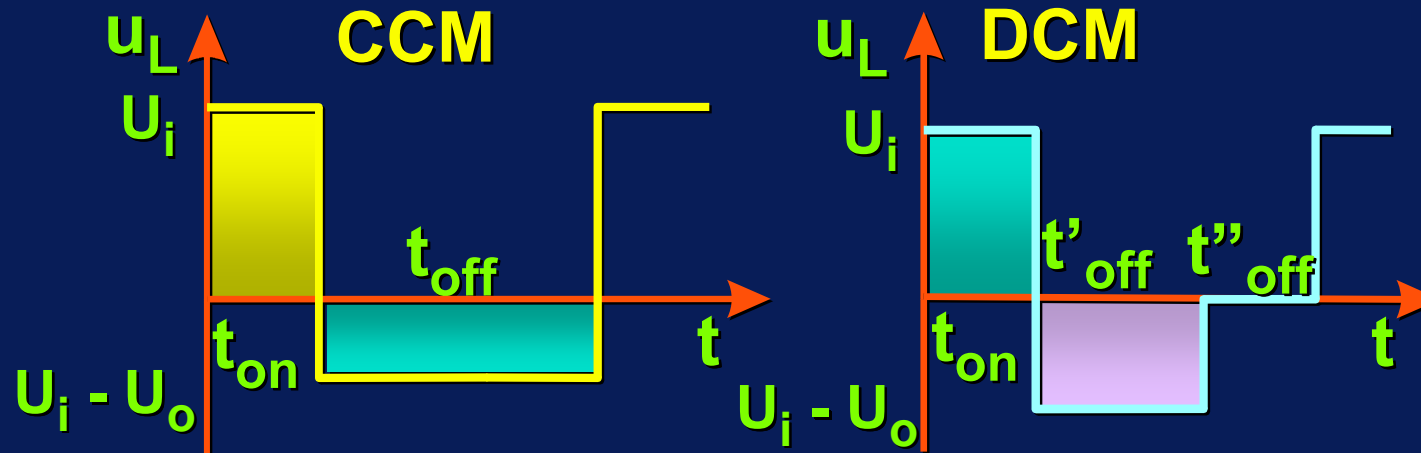
$$t'_{off} = \frac{U_i}{U_o - U_i} \cdot t_{on}$$



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

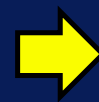
dove:  $I_N = \frac{U_i}{2 \cdot f_S \cdot L}$

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



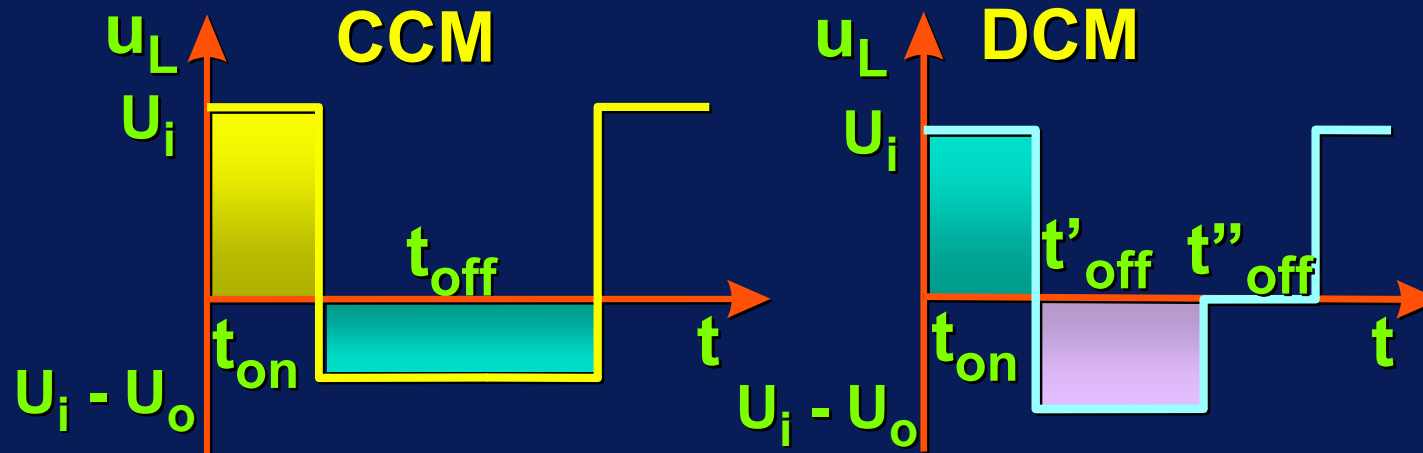
$$U_i t_{on} = (U_{oCCM} - U_i) t_{off} = (U_{oDCM} - U_i) t'_{off}$$

$$\frac{U_{oDCM} - U_i}{U_{oCCM} - U_i} = \frac{t_{off}}{t'_{off}} > 1$$



$$U_{oDCM} > U_{oCCM}$$

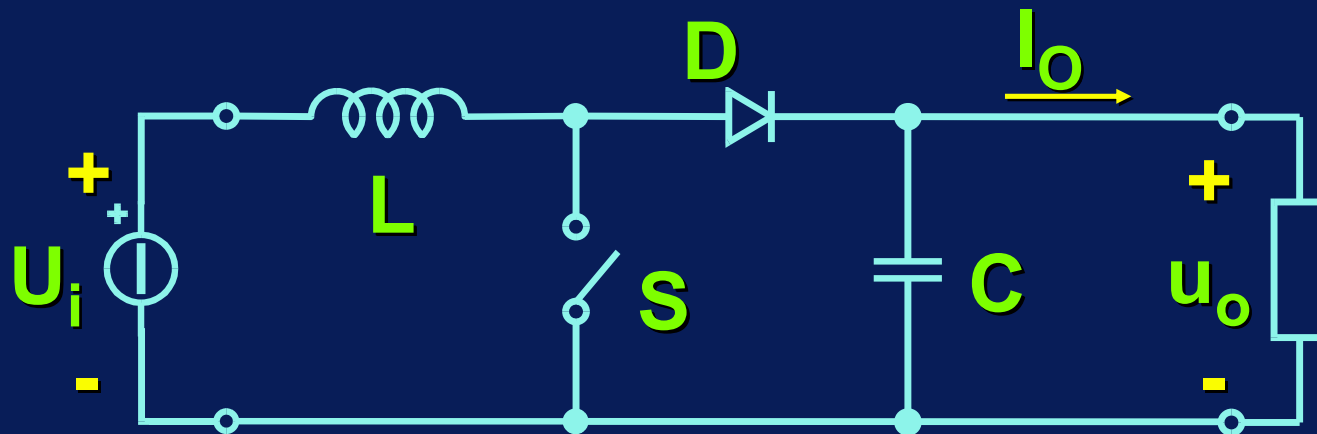
Nota:  $U_{oDCM} > U_{oCCM}$



$$U_i t_{on} = (U_{oCCM} - U_i)t_{off} = (U_{oDCM} - U_i)t'_{off}$$

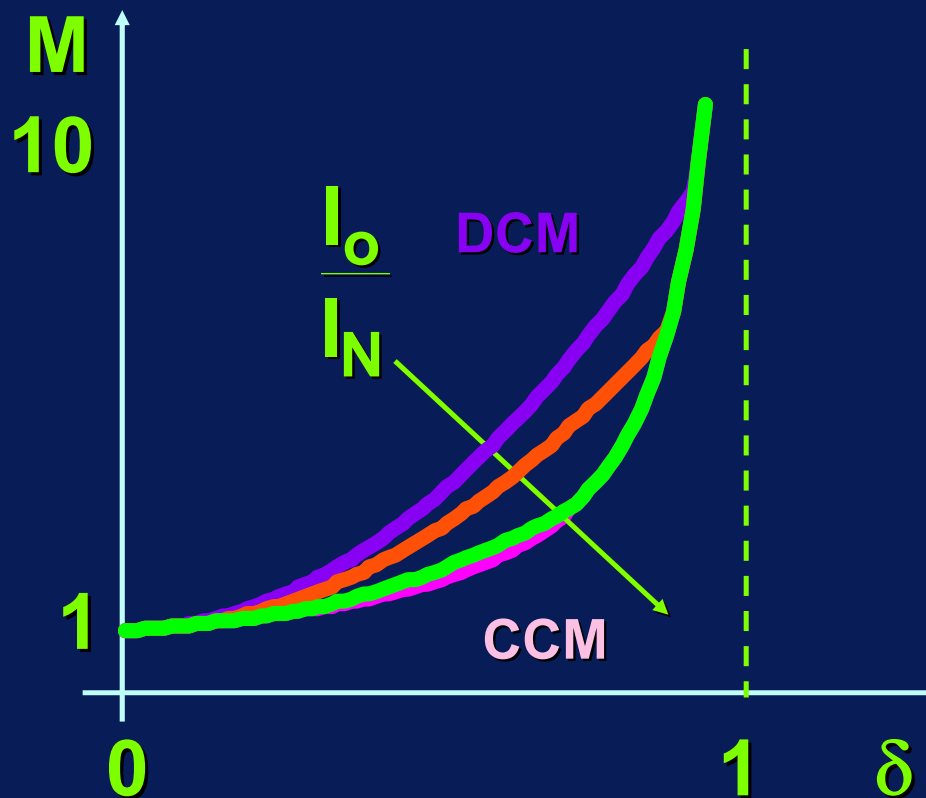
$$\frac{U_{oDCM}}{U_{oCCM}} = 1 + \frac{t_{on}t'_{off}}{T_S t'_{off}} > 1$$

**NOTA: A vuoto ( $I_o = 0$ ) il convertitore non è controllabile**



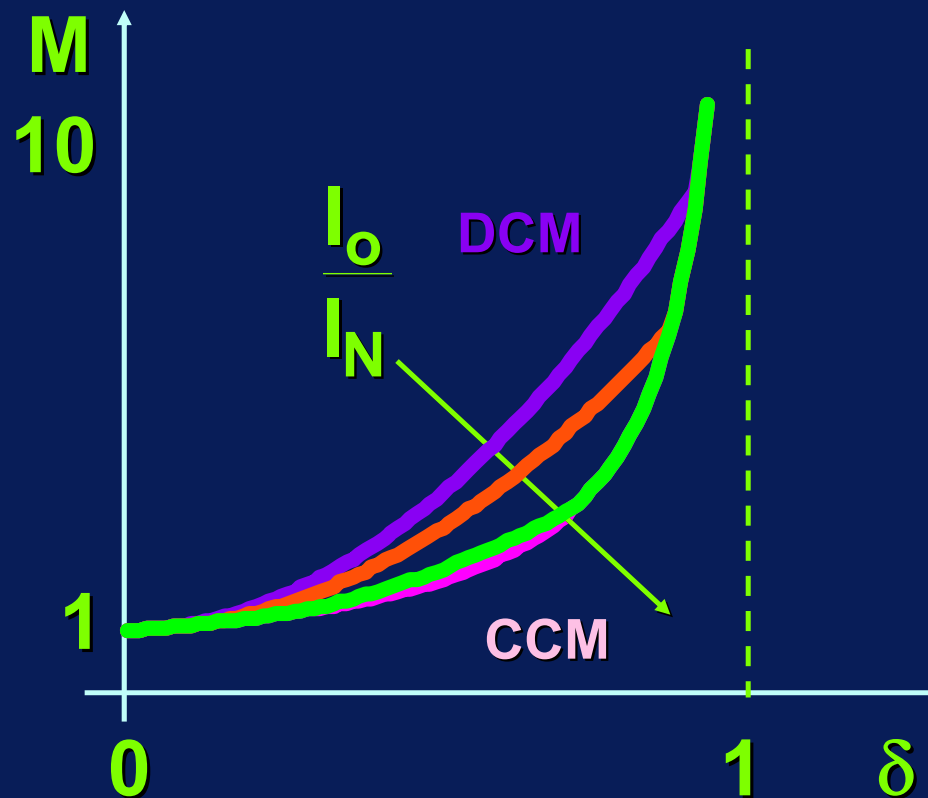
**Se  $I_o = 0$  non c'è assorbimento di energia dal carico. L'energia fornita dall'alimentazione si accumula progressivamente nel condensatore  $C$ , la cui tensione  $U_o$  cresce indefinitamente.**

## Boost: Caratteristiche di controllo



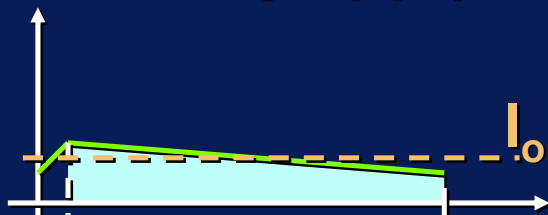
Anche in questo caso valgono le curve che danno tensione d'uscita più elevata

## Boost: Caratteristiche di controllo

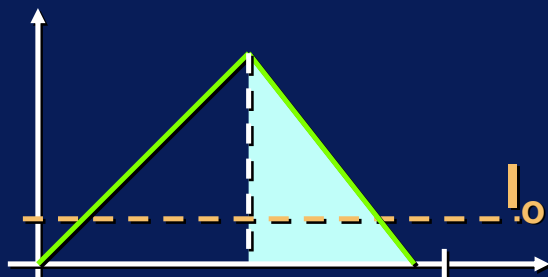


Il funzionamento è continuo per valori di  $\delta$  estremi, discontinuo per valori intermedi

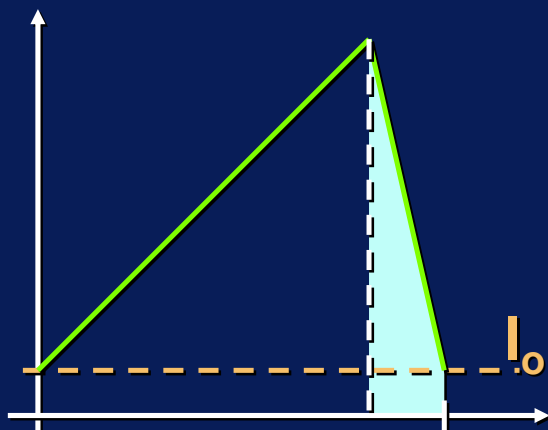
## Ondulazione di corrente



$\delta$  piccolo

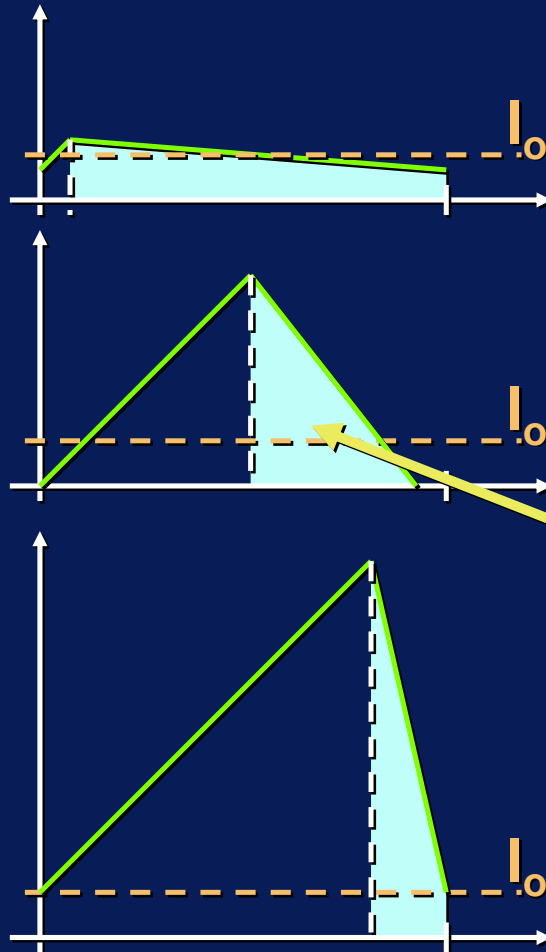


$\delta$  intermedio



$\delta$  elevato

## Ondulazione di corrente

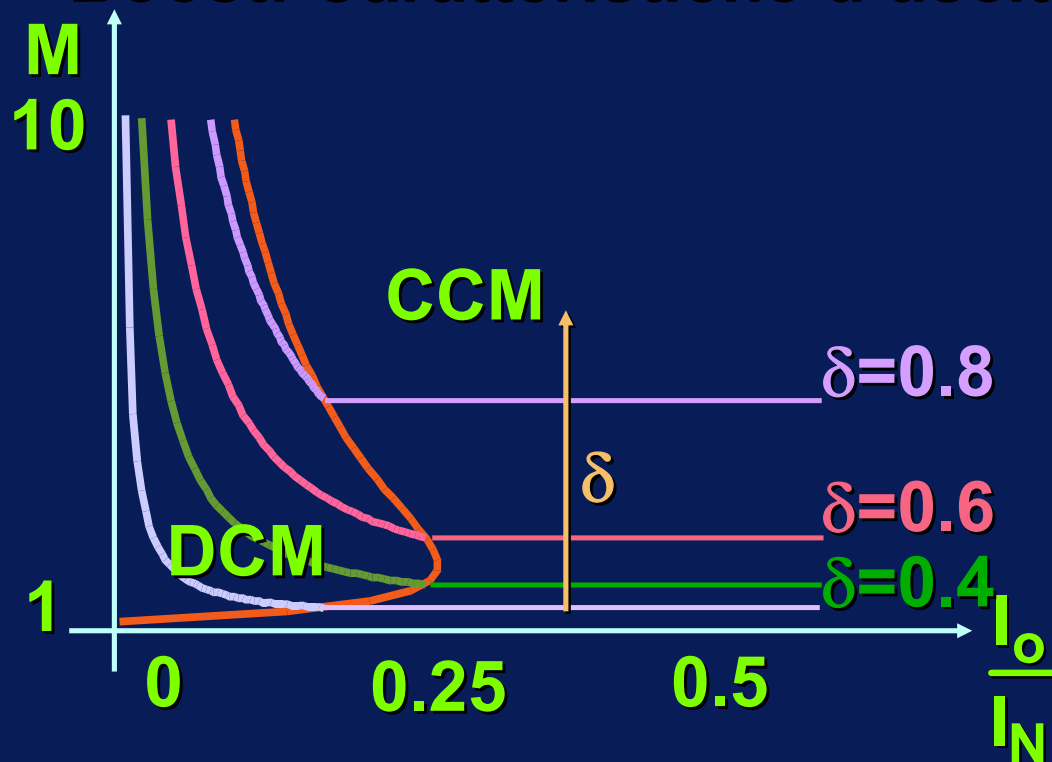


$\delta$  piccolo

A parità di  $I_o$   
l'intermittenza  
si può avere  
per  $\delta \cong 0.5$



## 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

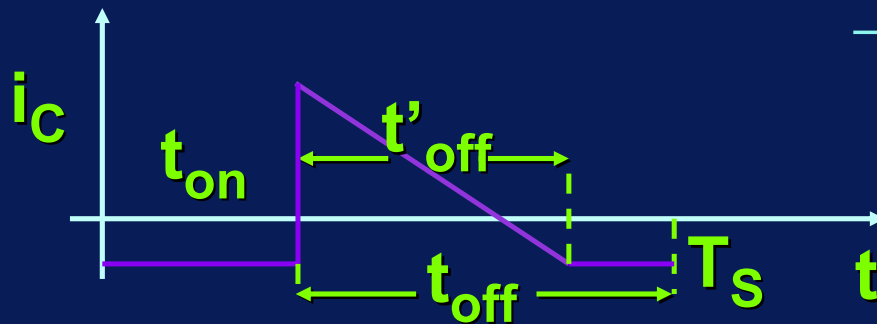
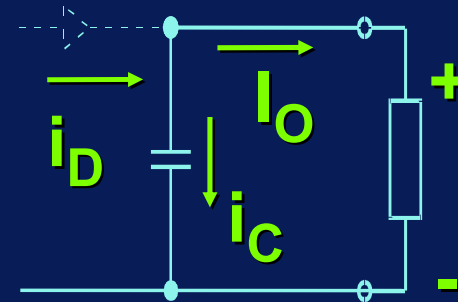
$$M = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{\delta^2}{k}}$$

dove:

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

## Corrente del condensatore di filtro: $i_C$

$$i_C = i_D - I_o$$



$i_C$  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