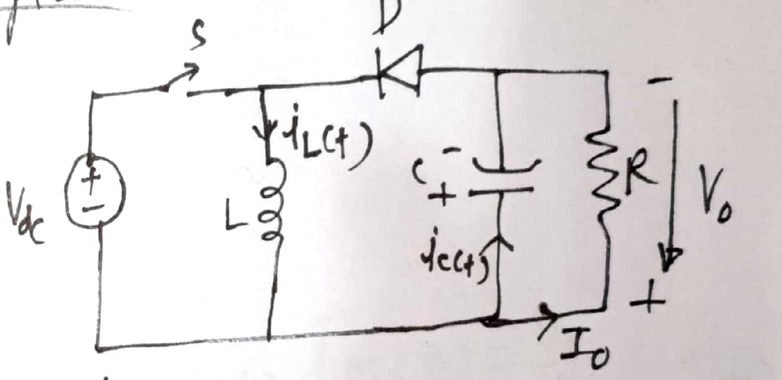
# Buck-Boost Converter / Step up & Step-down chopper:

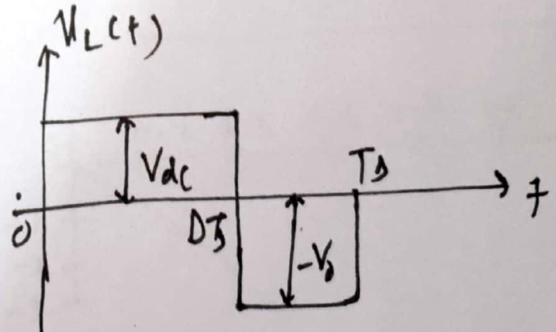
It is a cascade connection of Buck and Boost converters. It's main application is in regulated DC power supplies where a -ive polarity o/p voltage may be desired w.r.t. the common terminal of i/p voltage (for example -12V or -15V). As the name indicates, the o/p voltage can be either lower or higher than the i/p voltage, hence the name Buck-Boost converter.

## Power circuit Diagram:

### a) Ideal case:



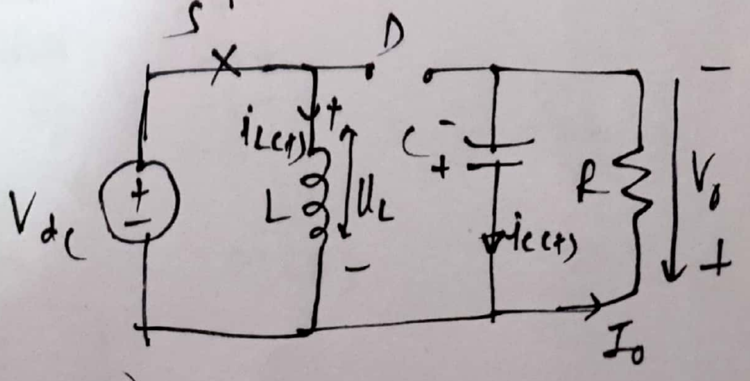
Assuming the inductor and devices to be ideal and DC o/p voltage to be constant and ripple-free.



During energy storage sub-interval ($0 \le t \le DT_s$), equiv. ckt. is as follows.

S is ON.

D is reverse-biased, hence OFF.

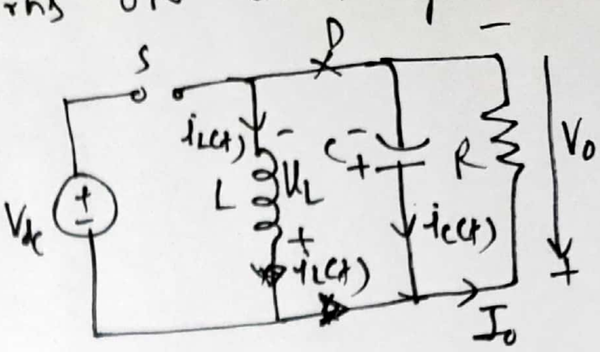


$\therefore u_L = V_{dc}$ — ①

$i_c = -I_o$

$\Rightarrow C\frac{dv_o}{dt} = -\frac{V_o}{R}$ — ②

During energy-transfer interval $(DT_s \le t \le T_s)$, S is OFF & D turns ON and equiv. ckt. is as below.



$\therefore V_L = -V_0$ — ③

$i_L = i_c + i_o$

$i_L = C\frac{dV_0}{dt} + \frac{V_0}{R}$ — ④

By inductor volt-sec. balance, average inductor-voltage is zero, i.e., $V_L = 0$

$\Rightarrow V_{dc} \cdot DT_s + (-V_0)(D')T_s = 0$ — (from waveforms above).

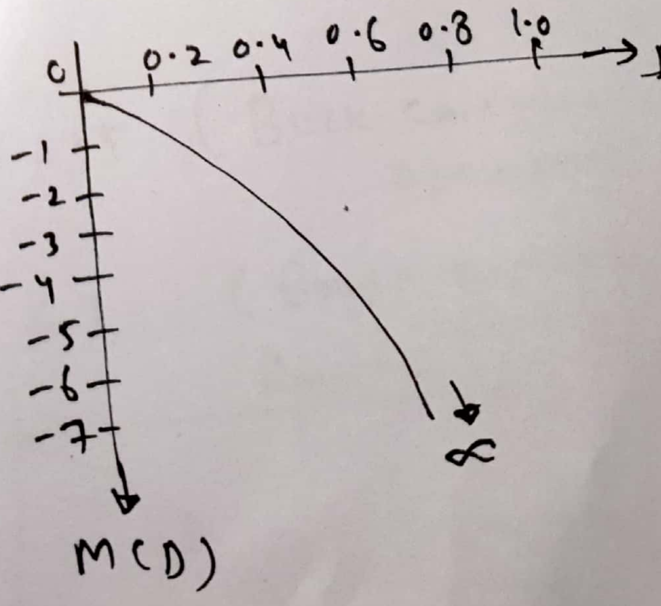
$\Rightarrow V_{dc} D T_s - (V_0)(1-D) T_s = 0$

$\Rightarrow V_{dc} D \cancel{T_s} - V_0 \cancel{T_s} + V_0 D \cancel{T_s} = 0$

$V_{dc} \cdot D = V_0(1-D)$

$\Rightarrow \boxed{V_0 = V_{dc} \cdot \frac{D}{(1-D)}}$

or, $\boxed{M(D) = \frac{V_0}{V_{dc}} = \frac{D}{1-D}}$



So, we can say that in steady-state, the transfer-function of Buck-Boost converter is the product of of transfer functions of two converters (Buck & Boost) in cascade,

i.e., $\boxed{\frac{V_0}{V_{dc}} = D \cdot \frac{1}{1-D}}$

Also, converter i/p power = converter o/p power

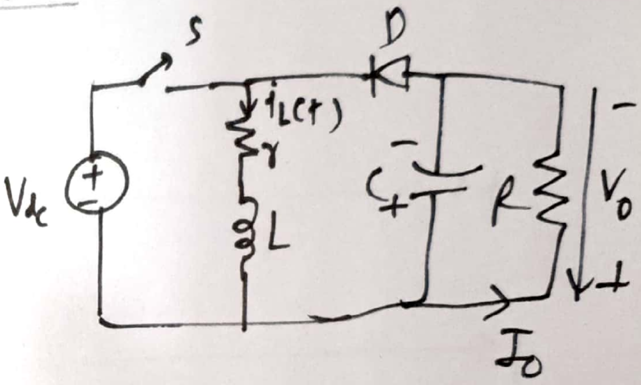
$$\Rightarrow V_{dc} \cdot I = V_o I_o$$

$$\boxed{\frac{I_o}{I} = \frac{V_{dc}}{V_o} = \frac{1-D}{D}}$$

$$\boxed{\frac{I}{I_o} = \frac{V_o}{V_{dc}} = \frac{D}{1-D}}$$

b) <u>Non-ideal (Practical) case:</u>

Using same methodology as in Boost converter, we get converter average o/p voltage as,

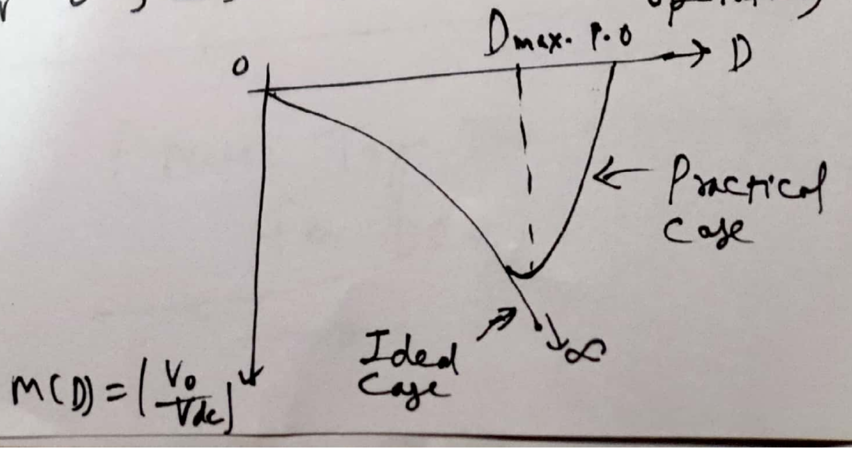


$$\boxed{V_o = \frac{V_{dc} D(1-D)}{\frac{r}{R} + (1-D)^2}} \rightarrow \text{(Left as an exercise to students)}$$

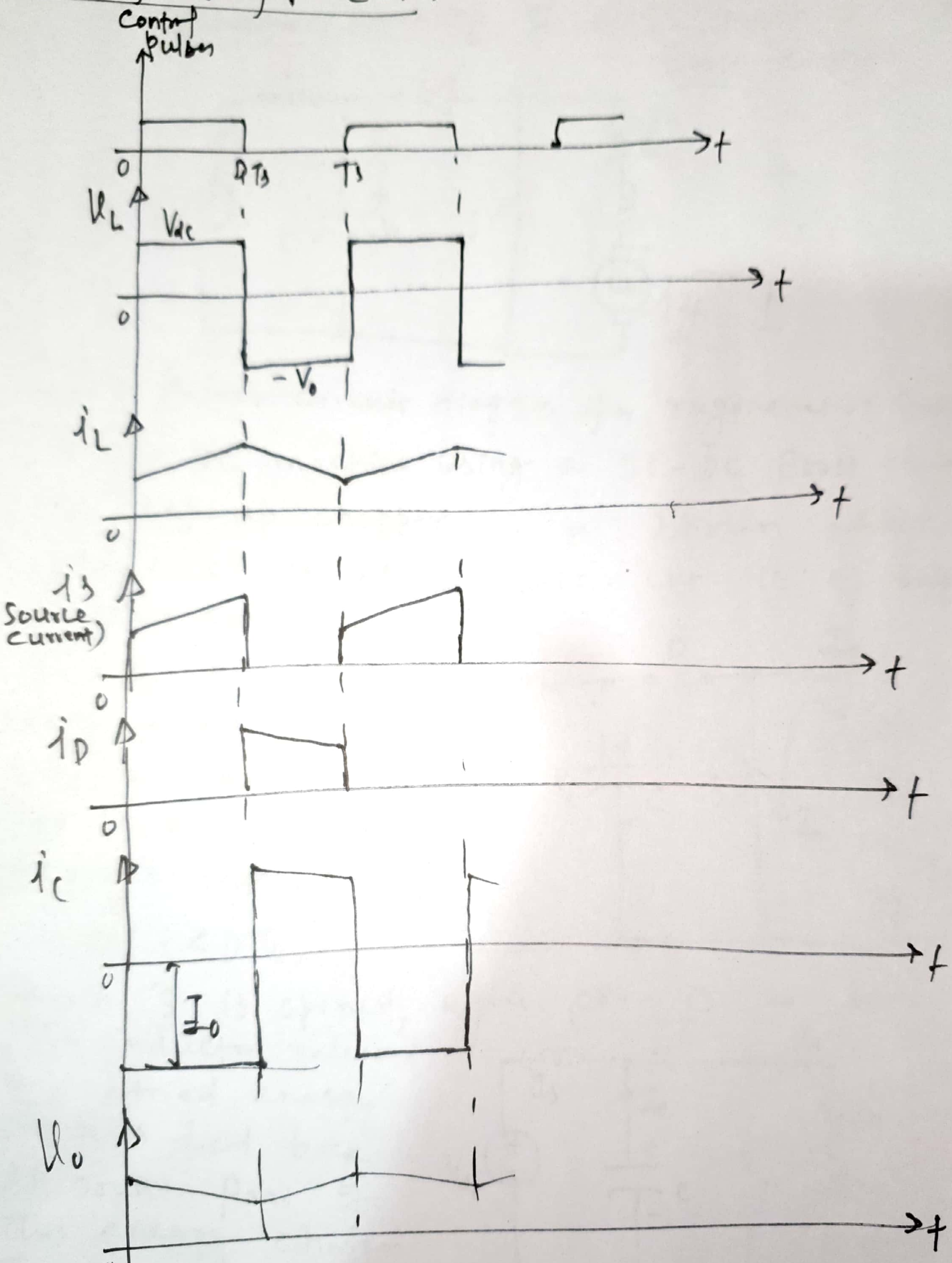
$$\left|\frac{V_o}{V_{dc}}\right| < 1 \text{ for } 0 < D < 0.5$$ (Buck converter operation)

$$\left|\frac{V_o}{V_{dc}}\right| > 1 \text{ for } 0.5 < D < 1$$ (Boost converter operation)

Cse.

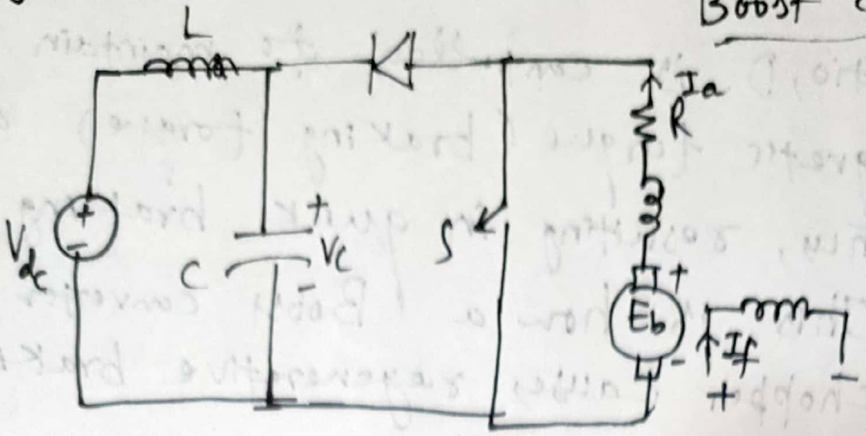


## Waveforms for CCM:



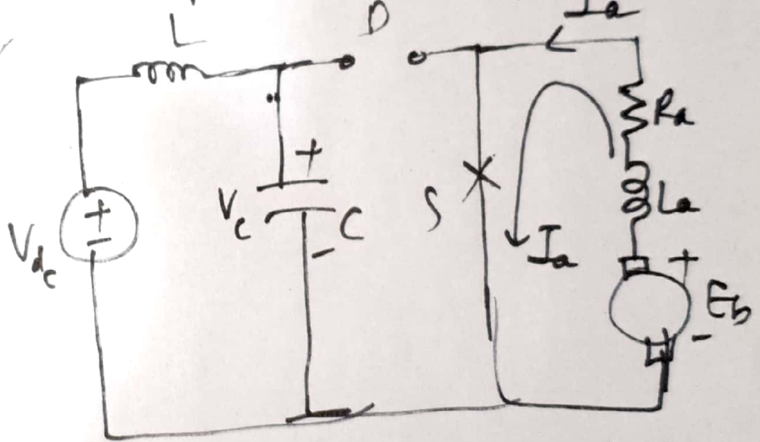
(Note: Try the waveform for DCM).

# Regenerative Braking of a DC Machine using Boost converter:



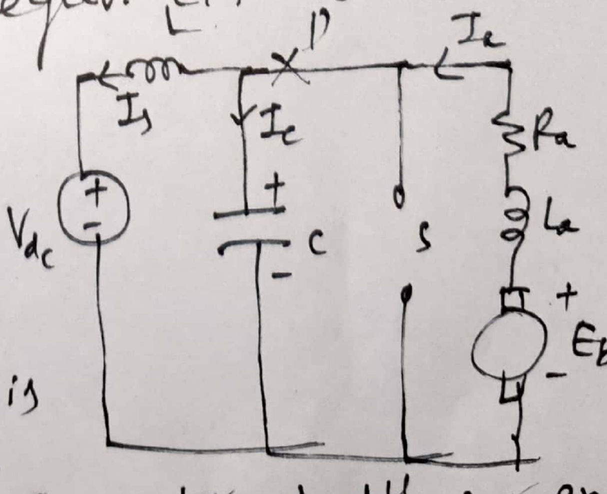
The power circuit diagram for regenerative braking of a DC machine using a DC-DC Boost converter or step-up chopper is as shown above.

When 'S' is closed, equiv. ckt. is as below:



Armature current, Ia flows, Thus, storing energy in armature circuit inductance, La. This is energy storage interval $(0 \leq t \leq DT_s)$.

When 'S' is opened, equiv. ckt. is as below:



The inductor released the stored energy which is fed back to source. Part of this energy charges the capacitor and part is fed back to source.

Thus, m/c acts as a generator, supplying energy back to source and, thus, braking torque is applied to the machine. This is energy-transfer interval ($DT_s \leq t \leq T_s$).

Duty ratio, D is controlled to maintain the electromagnetic torque (braking torque) as constant, Thus, resulting in quick braking of motor. This is how a Boost converter or Step-up chopper causes regenerative braking of motor.