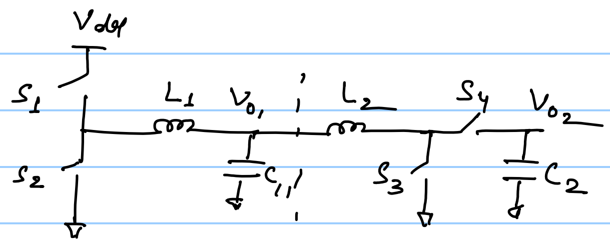
# Buck - Boost converter

$V_{dd} > V_o > V_{dd}$

$V_o = V_{dd}$

Buck - Boost = Buck + Boost




Buck

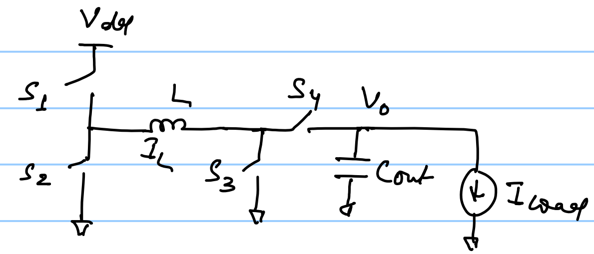
$V_{o_1} = D \cdot V_{dd}$

Boost

$V_{o_2} = \frac{V_{o_1}}{1-D}$

$$\boxed{V_{o_2} = \frac{D}{1-D} V_{dd}}$$

$\Rightarrow$




$V_o = \frac{D}{1-D} V_{dd}$

$I_L = \frac{1}{1-D} I_{load}$

For $V_o < V_{dd}$ $\longrightarrow$ Buck Mode
$D < 0.5$

For $V_o = V_{dd}$ $\longrightarrow$ Buck-Boost
$D = 0.5$

For $V_o > V_{dd}$ $\longrightarrow$ Boost
$D > 0.5$

$D = 0.4$

$$V_o = \frac{0.4}{0.6} V_{dd} = 0.67\, V_{dd}$$

$$I_L = \frac{I_{load}}{1-0.4} = \frac{I_{load}}{0.6} = 1.67\, I_{load}.$$

controlling $S_1, S_2$ & $S_3, S_4$ with single PWM is not efficient
$\left( I_L = \frac{I_{load}}{1-D} \right)$

So we need to control $S_1, S_2$ and $S_3, S_4$ independently

$S_1, S_2 \longrightarrow D_{buck}$
$S_3, S_4 \longrightarrow D_{boost}$

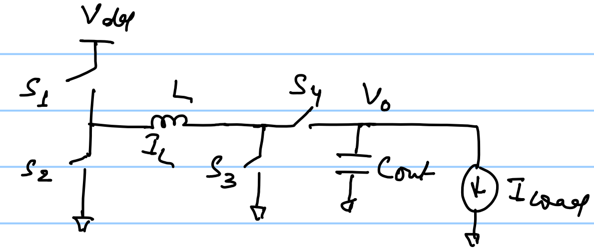
$$V_o = \frac{D_{buck}}{1-D_{boost}} V_{dd}$$

$$V_o = V_{dd}$$

$D_{buck} = 0.9$ & $D_{boost} = 0.1$

$V_o = V_{dd}$

$$I_L = \frac{1}{1-0.1} I_{Load} \simeq 1.1\, I_{Load} \rightarrow \text{more efficient.}$$




Tri-mode Buck-Boost

| Buck Mode ($V_o < V_{dd}$) | Buck-Boost Mode ($V_o \simeq V_{dd}$) | Boost Mode |
| --- | --- | --- |
| $S_3 = OFF$, $S_4 = ON$ | $S_1, S_2 \rightarrow PWM_{buck}$ | $S_1 = ON$, $S_2 = OFF$ |
| $S_1, S_3 \rightarrow PWM_{buck}$ <br> $D = D_{buck}$ | $S_3, S_4 \rightarrow PWM_{boost}$ | $S_3, S_4 \rightarrow PWM_{boost}$ |
| $V_o = D_{buck} \cdot V_{dd}$ | $V_o = \frac{D_{buck}}{1-D_{boost}} V_{dd}$ | $V_o = \frac{V_{dd}}{1-D_{boost}}$ |

max. $D_{buck} \rightarrow$ limited to 0.9

min. $D_{boost} \rightarrow$ limited to 0.1

$D_{buck} = 0$

Buck

$D_{buck} = 0.9$

Buck - Boost

$D_{boost} = 0.1$

Boost

$D_{boost} = 1$

$V_o = 3.3V$

$D_{buck} = 0.9, \quad V_{dd} = 3.67V$

Boost Mode

min $D_{boost} = 0.1, \quad V_o = \dfrac{3.67}{1-0.9} = 4.07V$

Large jump in $V_o$ if we go from buck to boost directly

So we need buck - boost.

$$V_o = \frac{D_{buck}}{1 - D_{boost}} V_{dd}$$

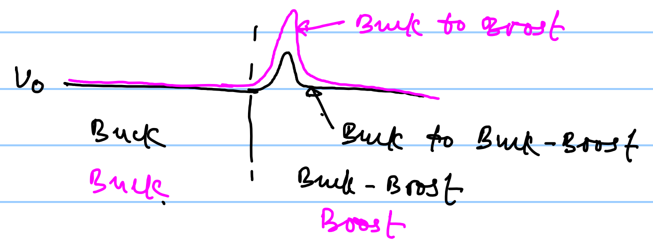
Boundary of Buck to Buck-Boost

$D_{buck} = 0.9$

$V_{dd} = 3.67V$ for $V_o = 3.3V$

min. $D_{boost} = 0.1$

$V_o = 3.67 V = V_{dd}$




$V_o = D_{buck\_max} V_{dd}$ at boundary

$$V_o = \frac{D_{buck}}{1 - D_{boost\_min}} V_{dd}$$

at boundary

$$D_{buck\_max} \times \cancel{V_{dd}} = \frac{D_{buck}}{1 - D_{boost\_min}} \cancel{V_{dd}}$$

$$\boxed{D_{buck} = D_{buck\_max} (1 - D_{boost\_min})}$$

Boundary condition.

$D_{buck\_max} = 0.9$

$D_{boost\_min} = 0.1$

$D_{buck} = 0.81$