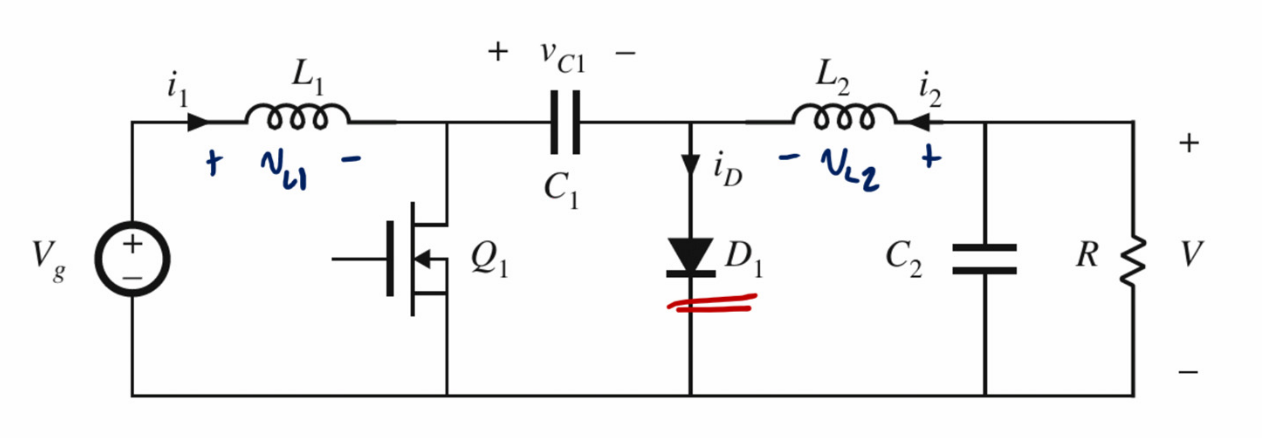
Cuk Converter in CCM



Recall CCM:

$$\langle v_{L1} \rangle = \phi = V_g - D' V_{C1} \longrightarrow V_{C1} = \frac{V_g}{D'}$$

$$\langle v_{L2} \rangle = \phi = D V_{C1} + V \longrightarrow V_{C1} = -\frac{V}{D}$$

$$V = V_g \left(\frac{-D}{D'} \right), \quad M = \frac{V}{V_g} = -\frac{D}{D'}$$

$$\langle i_{C1} \rangle = \phi = D(-I_2) + D' I_1 \longrightarrow I_1 = \frac{D}{D'} I_2$$

$$\langle i_{C2} \rangle = \phi = -I_2 - \frac{V}{R} \longrightarrow I_2 = -\frac{V}{R}$$

when diode is on, $i_D = I_1 + I_2$

CCM when $I_1 + I_2 > \Delta i_{L1} + \Delta i_{L2}$

$$\Delta i_{L1} = \frac{1}{2} \frac{V_g}{L_1} D T_s$$

$$\Delta i_{L2} = \frac{1}{2} \left(\frac{-V}{L_2} \right) D' T_s$$

Cuk Converter DCM Boundary

$$I_1 + I_2 = \left(\frac{-V}{R}\right)\left(1+\frac{D}{D'}\right) > \Delta i_{L1} + \Delta i_{L2} = \frac{T_s}{2}\left(\frac{V_g}{L_1}D + \frac{-V}{L_2}D'\right)$$

$$\cancel{\frac{V_g}{R}}\frac{D}{D'}\left(1+\frac{D}{D'}\right) > \frac{T_s}{2}\left(\frac{\cancel{DV_g}}{L_1} + \frac{\cancel{D}}{\cancel{D'}}\frac{\cancel{V_g}}{L_2}\cancel{D'}\right)$$

$$\frac{1}{RD'}\left(\frac{1}{D'}\right) > \frac{T_s}{2}\left(\frac{1}{L_1}+\frac{1}{L_2}\right)$$

$$\frac{2\,\frac{1}{\frac{1}{L_1}+\frac{1}{L_2}}}{RT_s} > (D')^2$$

$$\frac{1}{\frac{1}{L_1}+\frac{1}{L_2}} = L_{eq} = L_1 \| L_2$$

$$K = \boxed{\frac{2L_{eq}}{RT_s} > (D')^2} = K_{crit}(D)$$

Cuk Converter in DCM

1

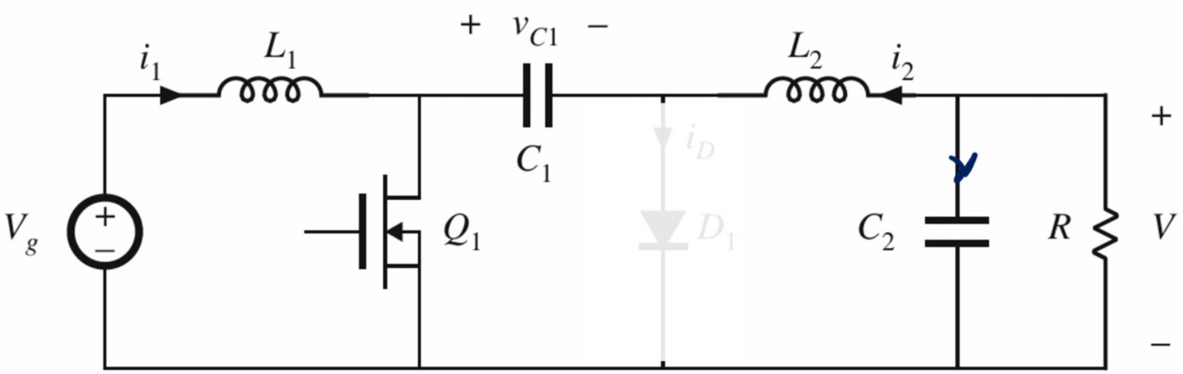
$v_{L1} = V_g$

$v_{L2} = v(t) + v_{C1}(t) \rightarrow V + V_{C1}$

$i_{C1} = -i_2(t)$

$i_{C2} = -i_2(t) - \frac{v(t)}{R}$

$i_{C2} = -i_2(t) - \frac{V}{R}$



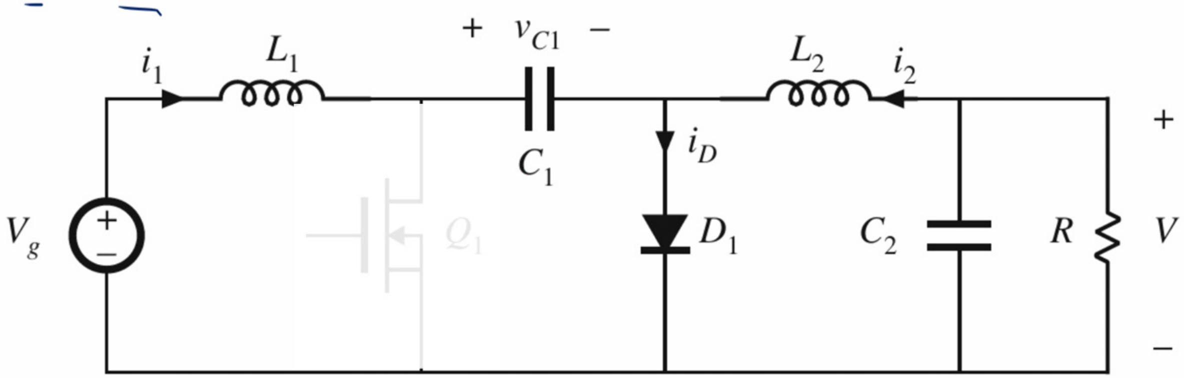
2

$v_{L1} = V_g - V_{C1}$

$v_{L2} = V$

$i_{C1} = i_1(t)$

$i_{C2} = -i_2(t) - \frac{V}{R}$



3

$v_{L1} = \emptyset$

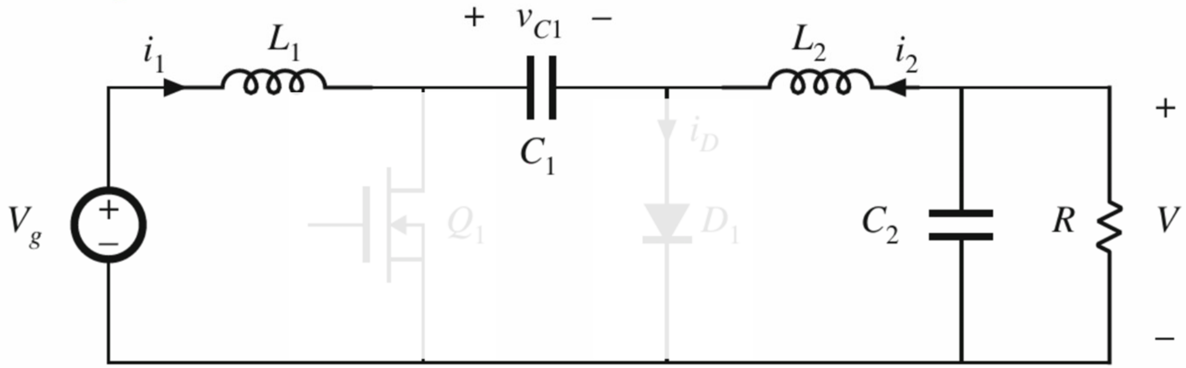
$v_{L2} = \emptyset$

$\downarrow$

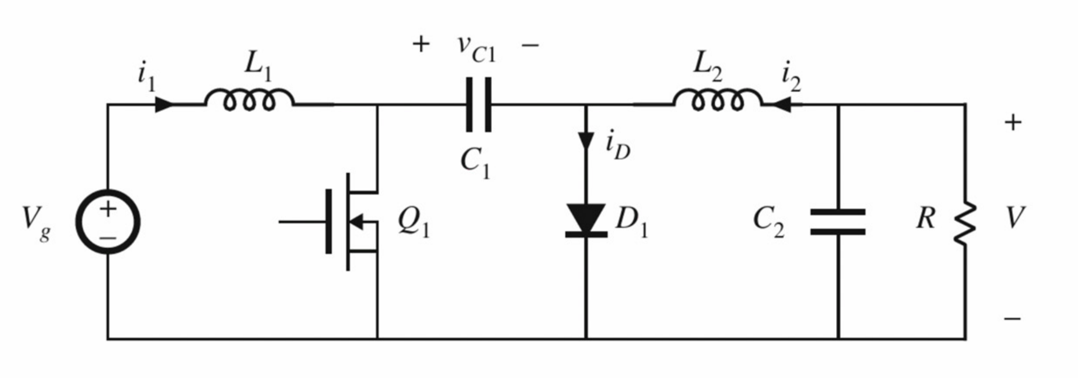
$V_{C1} = V_g - V$

$i_{C1} = i_1 = -i_2 = I_x$

$i_{C2} = -i_2(t) - \frac{V}{R}$



Cuk Waveforms in DCM



$$\langle v_{L1} \rangle = 0 = D_1 V_g + D_2 (V_g - V_{c1})$$

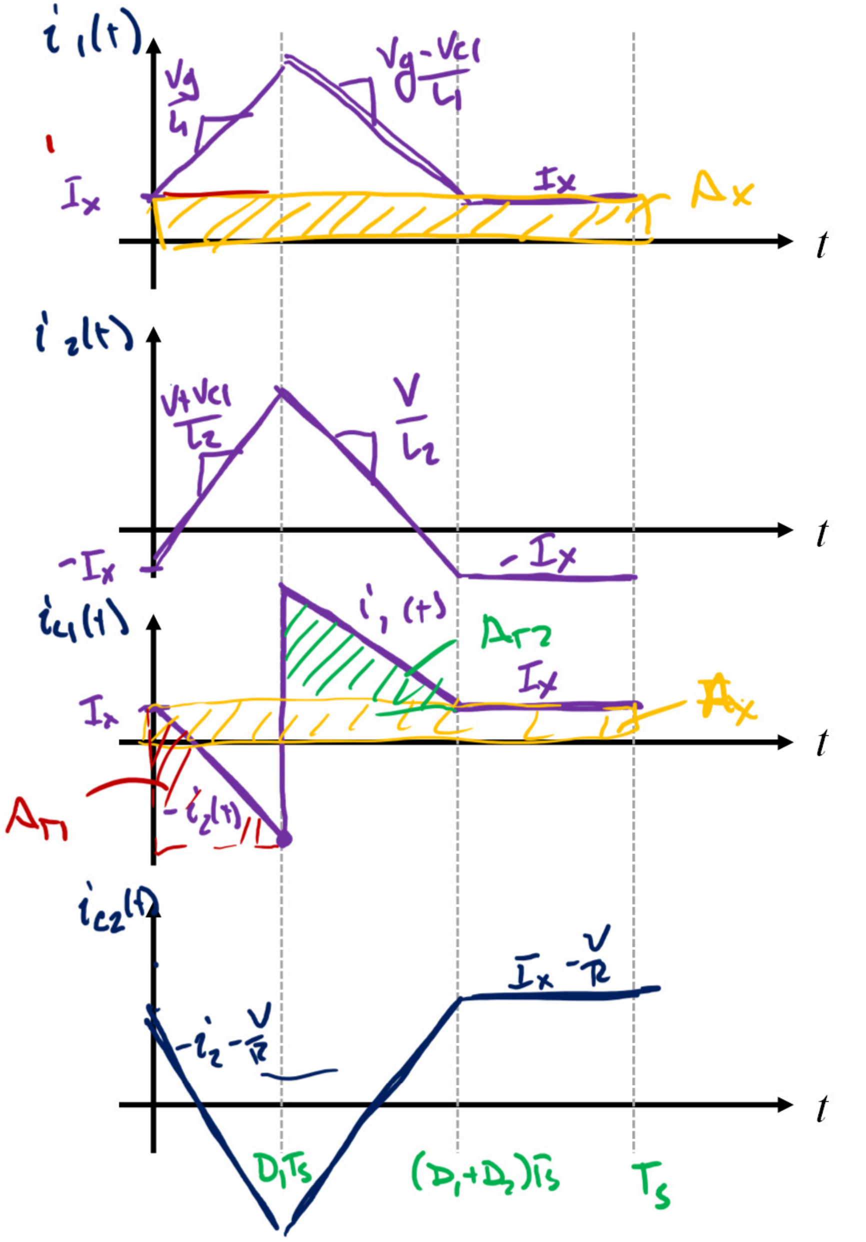
$$0 = (D_1 + D_2) V_g - D_2 V_{c1}$$

$$V_{c1} = V_g \frac{D_1 + D_2}{D_2}$$

$$\langle v_{L2} \rangle = 0 = V (D_1 + D_2) + V_{c1} (D_1)$$

$$V_{c1} = -V \frac{D_1 + D_2}{D_1}$$

$$\boxed{V = -V_g \frac{D_1}{D_2}} \rightarrow D_2 = -\frac{V_g}{V} D_1$$



Cuk Conversion Ratio

$$\langle i_{c1} \rangle = 0 = \frac{1}{T_s}\int_0^{T_s} i_{c1}(t)\,dt = \frac{1}{T_s}\left[A_{T1} + A_{T2} + A_x\right]$$

$$0 = \frac{1}{\cancel{T_s}}\left[\frac{1}{2} D_1 \cancel{T_s} \frac{V}{L_2} D_2 T_s + \frac{1}{2} D_2 \cancel{T_s} \frac{V_g}{L_1} D_1 T_s + I_x \cancel{T_s}\right]$$

$$-I_x = \frac{1}{2} D_1 D_2 T_s \left(\frac{V}{L_2} + \frac{V_g}{L_1}\right)$$

$$\langle i_{c2} \rangle = 0 = \frac{1}{T_s}\int_0^{T_s} i_{c2}(t)\,dt = \frac{1}{T_s}\int_0^{T_s} -i_2 - \frac{V}{R}\,dt = -\frac{1}{T_s}\int_0^{T_s} i_2\,dt - \frac{V}{R}$$

$$0 = -\frac{1}{T_s}\left[\frac{1}{2}(D_1+D_2)T_s \frac{V}{L_2} D_2 T_s - I_x T_s\right] - \frac{V}{R}$$

$$0 = -\frac{1}{T_s}\left[\frac{1}{2}(D_1+D_2)T_s \frac{V}{L_2} D_2 T_s + T_s \frac{1}{2} D_1 D_2 T_s \left(\frac{V}{L_2} + \frac{V_g}{L_1}\right)\right] - \frac{V}{R}$$