

# 1 Buck converter with input filter

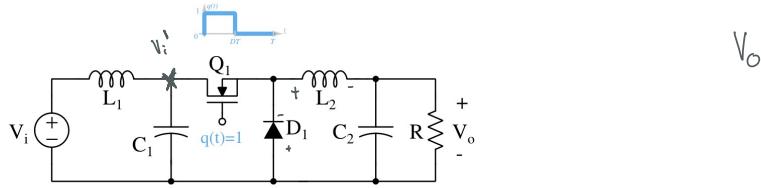


Figure 1.1: Buck Converter with input filter

We often need to include a filter at the input of a power converter to reduce the switching harmonics in the input current. Let's consider the converter of [Figure 1.1](#). We assume the converter operates at a constant frequency, continuous conduction mode (CCM), and has reached periodic steady state. We assume the MOSFET ( $Q_1$ ) has an on-resistance  $R_{ds,ON}$  when ON, and the forward conduction characteristics of the diode  $D_1$  can be modeled by a constant voltage  $V_D$  in series with a resistor  $R_D$ . For the inductors  $L_1$  and  $L_2$ , assume they are large and have a winding resistance of  $R_{L1}$  and  $R_{L2}$ . You can ignore any other loss components. Also, assume that the capacitors  $C_1, C_2$  are large in value.

- Derive the converter's DC averaged equivalent circuit model that incorporates the conduction loss in the semiconductors and the inductors.

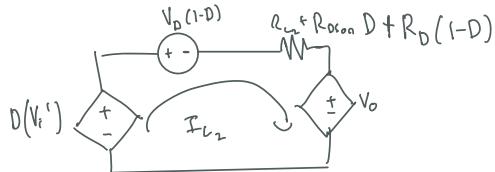
$$I_L |_{q=1} = V_i' - R_{ds,ON} I_{L2} - I_{L2} R_{L2} - V_o$$

$$V_{L2} |_{q=0} = -V_o - V_D - I_{L2} R_{L2}$$

Periodic steady state

$$0 = \langle V_{L2} \rangle = (V_i' - R_{ds,ON} I_{L2} - I_{L2} R_{L2} - V_o)D + (1-D)(-V_o - V_D - I_{L2} R_{L2} - I_{L2} R_{L2})$$

$$0 = V_i' D - V_o + -I_{L2} R_{L2} - V_D(1-D) - R_{ds,ON} I_{L2} D - R_D(1-D) I_{L2}$$



$$\begin{aligned} i_{C_1}(t) |_{q(t)=1} &= I_{L2} - \frac{V_o}{R_o} \\ i_{C_1}(t) |_{q(t)=0} &= I_{L2} - \frac{V_o}{R_o} \end{aligned}$$

Periodic steady state

$$\begin{aligned} \langle i_C \rangle &= 0 = \left( I_{L2} - \frac{V_o}{R_o} \right) D + (1-D) \left( -\frac{V_o}{R_o} \right) \\ I_{L2} - \frac{V_o}{R_o} &= 0 \end{aligned}$$



$$\langle V_{L1} \rangle^* |_{q(t)=1} = V_i - V_i' - I_{L1} R_{L1}$$

$$\langle V_{L1} \rangle |_{q(t)=0} = V_i - V_{C_1} - I_{L1} R_{L1}$$

$$V_{C_1} \approx V_i'$$

$$\langle V_{L1} \rangle = O = (V_i - V_i' - I_{L1} R_{L1})D + (V_i - V_i' + I_{L1} R_{L1})(1-D)$$

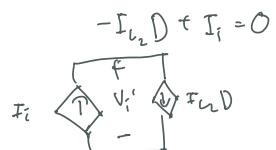
$$\begin{aligned} R_{C_1} &= V_i' + I_{L1} R_{L1}, \\ I_{L1} &= I_i \end{aligned}$$



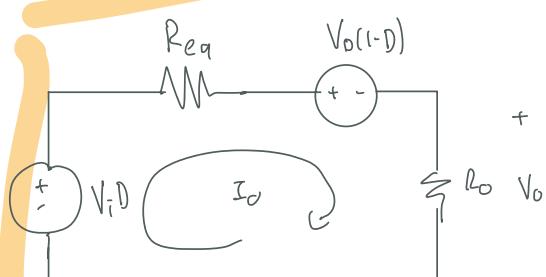
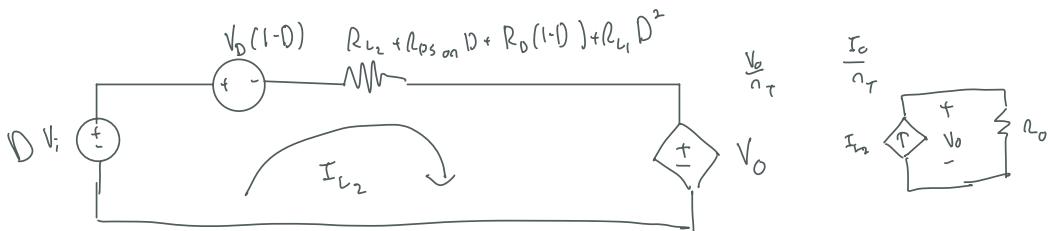
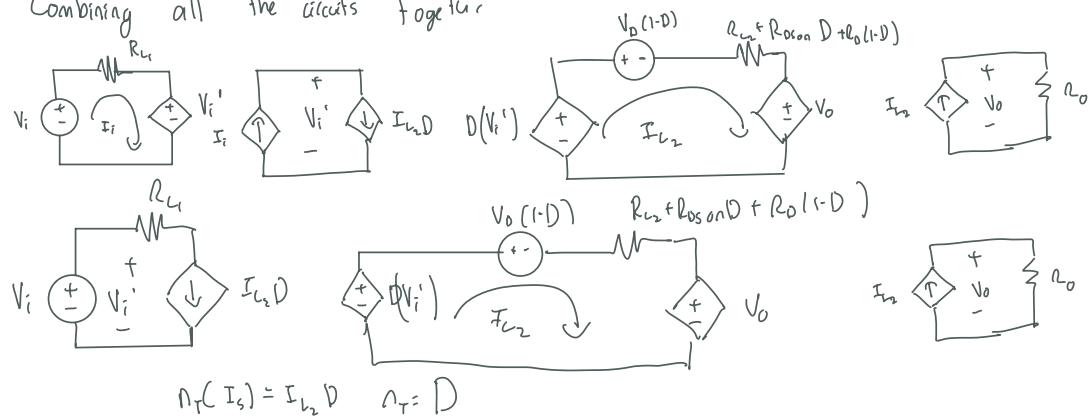
$$i_{C_1} |_{q(t)=1} = I_i - I_{L2}$$

$$i_{C_1} |_{q(t)=0} = I_i$$

$$\langle i_{C_1} \rangle = O = (I_i - I_{L2})D + (I_i)(1-D)$$



Combining all the circuits together



$$R_{eq} = R_{L_2} + R_{DS(on)} D + R_D(1-D) + R_{L_1} D^2$$

- Find an expression for the conversion ratio of the converter  $\frac{V_o}{V_i}$  as a function of the duty ratio and the other circuit parameters. (You may leave the expression in explicit form)

$$V_o = \left( V_i D - V_D(1-D) \right) \left( \frac{R_o}{R_o + R_{eq}} \right) \quad \text{where } R_{eq} = R_{L_2} + R_{DS(on)} D + R_D(1-D) + R_{L_1} D^2$$

$$\frac{V_o}{V_i} = \left( D \left( \frac{1 - \frac{V_D(1-D)/V_o}{R_{eq}}}{1 + \frac{R_{eq}}{R_o}} \right) \right)$$

- Find an expression for the efficiency of the converter.

$$\eta = \frac{P_o}{P_i} = \frac{\frac{V_o}{V_i} \frac{I_o}{I_i}}{1 + \frac{R_{\text{load}}}{D}} = \frac{1 - \frac{(V_o)(1-D)}{D V_i}}{1 + \frac{R_{\text{load}}}{D}}$$

where

$$R_{\text{load}} = \frac{R_L}{D^2} + \frac{R_{\text{load}}}{D} + \frac{R_D(1-D)}{D^2}$$

## 2 Dc-dc converter

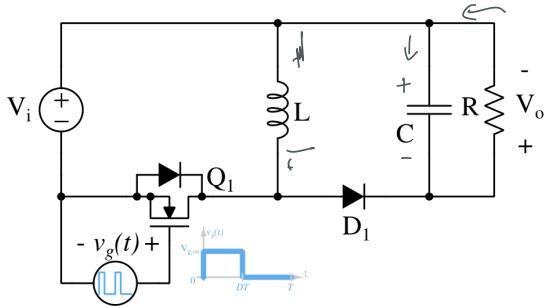


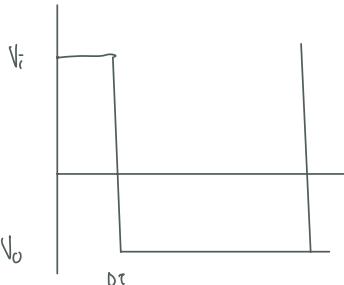
Figure 2.1: Dc-dc converter.

In this setup, we have  $V_i = 6$  V,  $V_o = 12$  V,  $P_o = 30$  W, and  $f_s = 145$  kHz.

- Assuming all components are ideal, find the value of the inductor to achieve an inductor ripple ratio  $\mathcal{R}_L = 10\%$ .

check sign ↗

$$\text{Inductor voltage } e = V_{L_i} |_{Q_1=0} = V_i$$



$$0 = V_i D - V_o (1-D)$$

$$\frac{V_i D}{(1-D)} = V_o$$

$$\Delta I = 2L_c I_c$$

$$I_c |_{Q_1=0} = -\frac{V_o}{R}$$

$$I_c |_{Q_1=D} = I_c + \frac{V_o}{R}$$

$$= \left( I_c + \frac{V_o}{R} \right) (1-D) + \frac{V_o}{R} (D)$$

$$I_o = I_c (1-D)$$

$$I_o = \frac{P_o}{V_o}$$

$$V = L \frac{\Delta I}{\Delta T}$$

$$\frac{V_i D T}{L} = \Delta I$$

$$\frac{V_i D T}{\Delta T} = L$$

$$\frac{V_i D}{f_s 2 R_c I_c} = L$$

$$\frac{V_o (1-D)}{f_s 2 R_c I_o} = L_{\min}$$

$$\frac{V_o (1-D)^2}{f_s 2 L_c I_o} = L_{\min}$$

$$\frac{V_i (D)}{1-D} = V_o$$

$$I_o = P_o / V_o$$

$$I_o = 2.5A$$

$$V_i D = 12 - 12 D$$

$$18D = 12$$

$$D = \frac{2}{3}$$

$$\frac{12 (1 - \frac{2}{3})^2}{(145 \times 10^{-3}) (2) (0.1) (2.5)} = 0.0000184$$

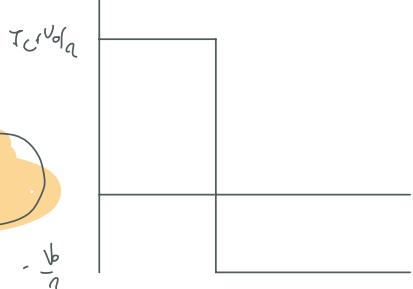
$$\boxed{18.4 \mu H}$$

- Find the capacitor value to achieve a capacitor ripple ratio of  $\% \mathcal{R}_C = 6\%$

$$\frac{I_o}{C} DT = \Delta V_0$$

$$\frac{I_o D}{f \Delta V_0} = C = \frac{I_o D}{2f_s R_C V_0} = \frac{\left(\frac{1}{3}\right)(2.5)}{2(145E3)(0.06)(12)} =$$

7.96 μF



The MOSFET ( $Q$ ) has an on-resistance  $R_{ds,ON}$  when ON, and the forward characteristics of the diode can be modeled by a constant voltage  $V_D$ . Also, assume the inductor  $L$  has a winding resistance  $R_L$ . Other losses can be neglected. The converter operates in Periodic Steady State (PSS).

- Derive the converter's dc averaged equivalent circuit model that incorporates the conduction loss in the semiconductors and the inductor.

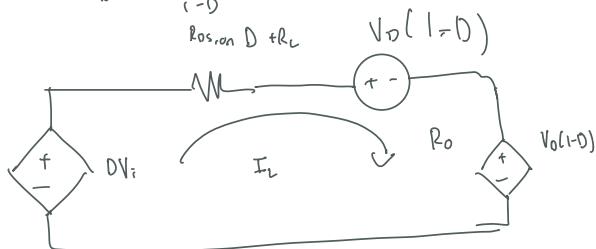
Inductor voltage

$$V_L |_{Q(t)=0} = V_i - R_{pcon} I_L - R_L I_L$$

$$V_L |_{Q(t)=0} = -V_o - R_L (I_L) - V_D$$

$$0 = D(V_i - R_{pcon} I_L - R_L I_L) + (1-D)(-V_o - R_L (I_L) - V_D)$$

$$0 = D V_i - R_{pcon} I_L^D - R_L I_L^D + -V_o + D V_o - R_L I_L + (1-D) R_L I_L - V_D (1-D)$$

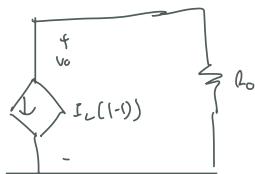


$$i_C |_{Q(t)=1} = +\frac{V_o}{R}$$

$$I_C |_{Q(t)=0} = I_L + \frac{V_o}{R}$$

$$0 = \left( I_L + \frac{V_o}{R} \right) (1-D) + \frac{V_o}{R} (D)$$

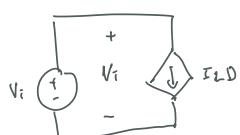
$$\rightarrow I_o = I_C (1-D)$$



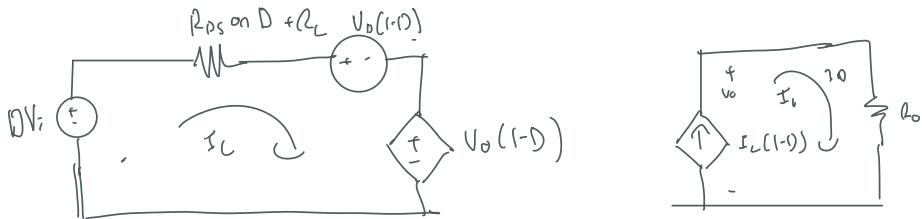
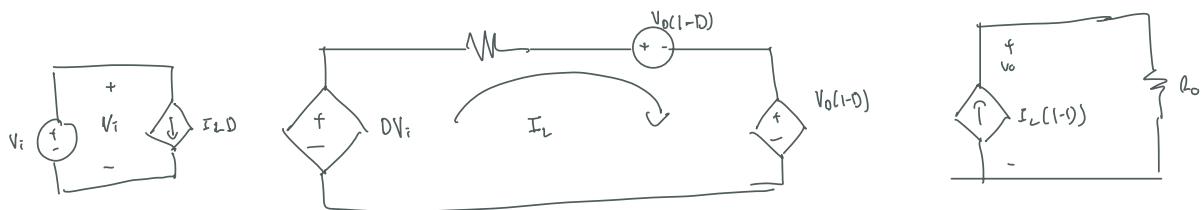
$$I_{C,Q(t)=1} = I_C$$

$$I_{C,Q(t)=0} = 0$$

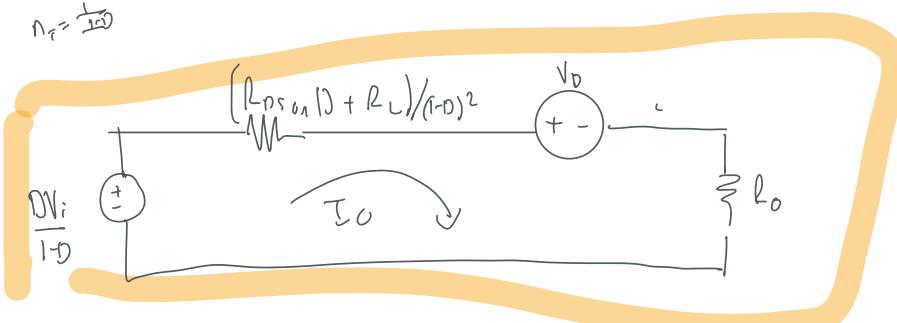
$$I_C D = I_o$$



$$R_{pcon} D + R_L$$



$$n_f = \frac{1}{2D}$$



- Find an expression for the conversion ratio  $\frac{V_o}{V_i}$  and the efficiency of the converter as a function of the duty ratio and the other circuit parameters.

$$V_o = \left( \frac{DV_i - V_D}{1-D} \right) \left( \frac{\frac{R_o}{R_o + (R_{\text{on}}D + R_u)/(1-D)^2}}{(1-D)^2} \right)$$

$$\frac{V_o}{V_i} = \left( \frac{DV_i - V_D}{1-D} \right) \frac{1}{1 + \frac{R_{\text{on}}D + R_u}{(1-D)^2 R_o}}$$

$$\frac{V_o}{V_i} = \frac{D \left( 1 - \frac{(1-D)V_o}{D V_i} \right)}{\left( 1 + \frac{R_{\text{on}}D + R_u}{(1-D)^2 R_o} \right) (1-D)}$$

$$I_i \approx I_o D \quad \frac{V_o}{V_i} = \frac{\left( 1 - \frac{(1-D)V_o}{D V_i} \right) D}{\left( 1 + \frac{R_{\text{on}}D + R_u}{(1-D)^2 R_o} \right) (1-D)}$$

$$P_i = V_i I_i = V_o I_o$$

$$P_o = V_o I_o$$

$$I_i \approx I_o D \quad \frac{V_o}{V_i} = \frac{\left( 1 - \frac{(1-D)V_o}{D V_i} \right) D}{\left( 1 + \frac{R_{\text{on}}D + R_u}{(1-D)^2 R_o} \right) (1-D)}$$

$$\frac{1-D}{D} \frac{V_o}{V_i} = \frac{\left( 1 - \frac{(1-D)V_o}{D V_i} \right)}{\left( 1 + \frac{R_{\text{on}}D + R_u}{(1-D)^2 R_o} \right)} = \eta$$

$$I_i = F_L D$$

$$I_o(1-D) = I_o$$

$$\frac{I_o}{1-D} = I_i$$

$$\frac{I_o}{I_i} = \frac{1-D}{D}$$

- Now, assuming the forward drop of the diode is  $V_D = 0.4V$  and the winding resistance of the inductor is  $10m\Omega$ .
- What is the MOSFET's  $R_{ds,ON}$  needed for the efficiency of the converter to reach 92%?
- What is the converter's duty cycle under this condition?

$$\frac{\left(1 - \frac{(1-D)V_D}{D V_{in}}\right)}{1 + \frac{L_{on} D + R_o}{(1-D)^2 R_o}} = 0.92$$

$D = 0.685 \quad V_o = 12$   
 $V_i = 6$   
 $P_o = V_o^2 / R$

$\boxed{R_{DS,ON} = 0.0227 \Omega}$

$$\frac{V_o}{V_i} = \frac{D \left(1 - \frac{(1-D)V_o}{D V_{in}}\right)}{1 + \frac{L_{on} D + R_o}{(1-D)^2 R_o} (1-D)}$$

$$\frac{12}{6} = \frac{D - \frac{0.4(1-D)}{6}}{\left((1-D) + \frac{0.0227(D+0.01)}{4.8(1-D)}\right)}$$

$$\frac{(1-D)V_o}{D V_i} = 0.92$$

$$\frac{1-D}{D} = 0.46$$

$$1-D = 0.46D$$

$$\frac{1}{D} = 1.46D$$

$\boxed{D = 0.685}$

- Simulate the circuit of Fig. [Figure 2.1](#) on LTspice with the inductor and capacitor values you found, including the losses in the inductor, MOSFET and diode in your simulation.
- Save 5 complete periods of the following waveforms once the converter has reached periodic steady state:  $i_L(t)$ ,  $i_{Q1}(t)$ ,  $i_{D1}(t)$ ,  $v_o(t)$
- What are the inductor and capacitor ripple ratios in your simulation?
- What's the simulated efficiency of the converter? Compare the simulated efficiency to the one obtained using the averaged circuit model.
- Find the average power losses in all the devices. Compare (in %) the simulated values to the losses obtained using the average circuit model.

2. see pdf

b. Inductor current ripple

$$\Delta I_L = 1.46 \text{ A}$$

$$I_{L\text{avg}} = 7.902$$

$$R_L = \frac{\Delta I_L}{2I_{L\text{avg}}} = 9.24\%$$

Capacitive voltage ripple

$$\Delta V_C = 1.46 \text{ V}$$

$$\Delta V_{C\text{avg}} = 11.963$$

$$R_C = \frac{\Delta V_C}{2V_{C\text{avg}}} = \frac{1.46}{2(11.963)} = 6.10\%$$

c.  $P_{o\text{avg}} = V_{o\text{avg}} \cdot I_{o\text{avg}}$

$$I_o = 2.492 \quad V_o = 11.963 \text{ A}$$

$$I_f = 5.4123 \quad V_i = 6 \text{ V}$$

$$\frac{V_o \cdot I_o}{V_i \cdot I_i} = 0.918$$

$$\boxed{\eta = 91.8\%}$$

The two efficiencies are very similar. However, they are not exactly aligned because the average circuit model can underestimate error because it does not account for the ripple. The ACM is a good estimation usually

• d. MOSFET loss ACM

$$P_{loss} = I_c^2 D R_{ds,ON}$$

$$D = 0.685$$

$$I_0 = 2.5$$

$$I_c(1-D) = I_0$$

$$I_c = 7.936$$

$$(7.936)^2 D (22.7E-3)$$

ACM:  $P_{loss_{mos}} = 0.979 \text{ W}$

$$I_{10m \text{ sim}} \quad I_{rms} = 6.5473 \text{ A}$$

Simulation  $(I_{c,rms})^2 R_s = 0.973 \text{ W}$

Inductor loss

$$(I_c^2)(R_L) = P_{loss}$$

$$(7.936)^2 (10 \text{ m}\Omega) = 0.6296 \text{ W}$$

Simulation  $(I_{c,rms})^2 R_L = 0.626$

$$I_c = 7.9135$$

MOS:  $\frac{P_{ACM}}{P_{loss}} = 0.9439$

$\frac{P_{ACon}}{P_{loss}} = 0.994$

The loss should be more for simulations. The  $I_c$  calculated from ACM may be too high. Still some excess

- Search for the following commercial components on either Digikey or Mouser (include part number and datasheet). Check and familiarize yourself with the different packages:
  - N-MOSFET on Digikey or Mouser (in stock) with a 25V drain-source rating and with the  $R_{ds,ON}$  you calculated assuming a 125°C case temperature. Ensure that the device can handle the power dissipation at 125°C.
  - Schottky Diode with a minimum 25 V maximum reverse voltage and the ability to carry 150% of the average current you calculated at 125°C.

On google sheet

### 3 Indirect Boost-buck converter

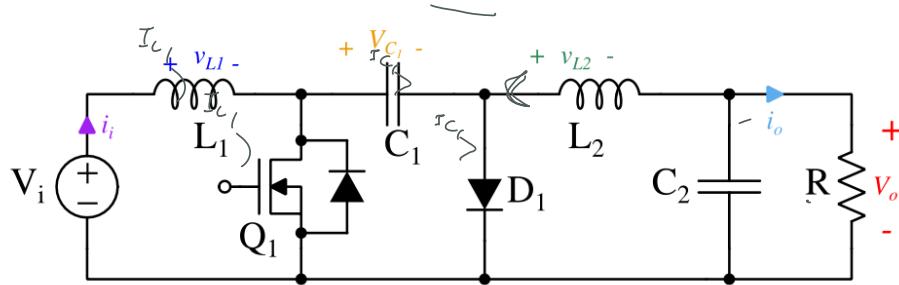


Figure 3.1: Indirect Boots-buck converter

Consider the converter of [Figure 3.1](#). Assume that the MOSFET ( $Q_1$ ) has an on-resistance  $R_{ds,ON}$  when it is *ON*, and the forward characteristics of the diode ( $D_1$ ) can be modeled by a constant voltage  $V_D$ . You can assume the inductors and capacitors in the circuit are ideal.

- Develop the dc averaged equivalent circuit model for the converter, taking into account the conduction loss in the semiconductors.
  - Determine an expression for the conversion ratio  $\frac{V_o}{V_i}$  and the efficiency of the converter as functions of the duty ratio and the other circuit parameters.
  - What are the relationship between the operating parameters of your converter ( $V_i, R, D$ ) and your component parameters ( $L, C, R_{ds,ON}, V_D$ ) that you need to achieve high efficiency?

Assuming PSS

$$I_{C_1} \Big|_{q(t)=0} = -I_{L_2}$$

$$I_{C_1} \Big|_{q(t)=1} = I_{L_1}$$

$$I_{C_2} \Big|_{q(t)=1} = I_{L_2} - V_0/R$$

$$I_{C_2} \Big|_{q(t)=0} = I_{L_2} - V_0/R$$

$$-I_{L_2}D + I_{L_1}(1-D) = 0$$

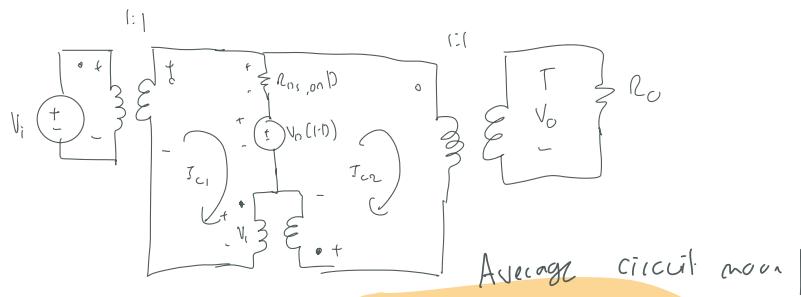
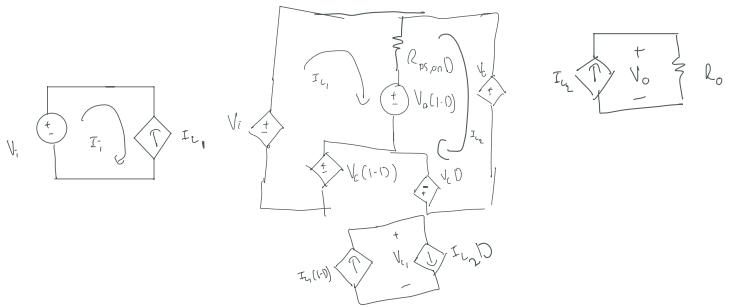
$$I_{L_1}(1-D) = I_{L_2}D$$

$$I_{C_2} = \left( I_{L_2} - \frac{V_0}{R} \right) D + \left( I_{L_2} - \frac{V_0}{R} \right) 1 \cdot D$$

$$I_{C_2} = 0 = I_{L_2} - \frac{V_0}{R}$$

$$\frac{V_0}{R} = I_{L_2}$$

$I_{L_1}(1-D) + I_{L_2}(1-D) = \angle_i(t)$



$\text{I}_{L1} = \frac{\text{I}_{L1}(1-D) + \text{I}_{L2}(D)}{1-D}$

 $\text{I}_{L1}(1-D) = -\text{I}_{L2}D$ 
 $\text{I}_{L1} = \frac{-\text{I}_{L2}D}{1-D}$ 
 $\text{I}_{L1} - \text{I}_{L2} = \frac{-\text{I}_{L2}}{1-D}$ 
 $\text{I}_{L1} = \frac{\text{V}_o}{R_o}$

- Determine an expression for the conversion ratio  $\frac{V_o}{V_i}$  and the efficiency of the converter as functions of the duty ratio and the other circuit parameters.

b.

$$\begin{aligned} V_i - R_{Dson,D}(\text{I}_{L1} - \text{I}_{L2}) - V_D(1-D) - V_i &= 0 \\ -V_o - V_2 + V_D(1-D) + R_{Dso,D}(\text{I}_{L1} - \text{I}_{L2}) &= 0 \end{aligned}$$

$$D V_i = V_2(1-D)$$

$$D(V_i + R_{Dson,D} \frac{V_o}{1-(1-D)}) - V_2(1-D) = (1-D)(R_{Dson,D} \left( \frac{V_o}{1-(1-D)} \right) + V_2(1-D) - V_o)$$

$$DV_i - V_2 D^2 D - V_2 D^2 = -R_{Dson,D} \frac{V_o}{1-(1-D)} - R_{Dson,D} \frac{V_o^2}{1-(1-D)}$$

$$DV_i \left[ \frac{-V_2(1-D)}{V_i} \right] - \frac{V_2(1-D)^2}{D} = -D^2 V_2 \left( R_{Dson,D} \frac{V_o}{R D^2} + 1 + \frac{R_{Dson,D}^2}{R(1-D)^2} \right)$$

$$\frac{V_o(1-D)}{V_i} \left(1 - \frac{1-D}{D}\right) = \frac{D R_{ds,ON}}{D' R} \left(1 + \frac{D}{1-D}\right)$$

$$D V_i \left(1 - \frac{V_o(1-D)}{D V_i}\right) = -D' V_o \left(\frac{R_{ds,ON}}{(D')^2 R} + 1\right)$$

$$I_{L1}(1-D) = I_{L2} D$$

$$I_{L1}(1-D) = I_o D$$

$$\frac{I_o}{I_{L1}} = \frac{1-D}{D}$$

$$\frac{V_o}{V_i} = \frac{-D \left(1 - \frac{V_o(1-D)}{D V_i}\right)}{(1-D) \left(1 + \frac{R_{ds,ON}}{(D')^2 R}\right)}$$

$$\eta = \frac{V_o I_o}{V_i I_i} = \frac{V_o}{V_i} \frac{(1-D)}{D} = \frac{\left(1 - \frac{V_o(1-D)}{D V_i}\right)}{\left(1 + \frac{R_{ds,ON}}{(D')^2 R}\right)}$$

- What are the relationship between the operating parameters of your converter ( $V_i, R, D$ ) and your component parameters ( $L, C, R_{ds,ON}, V_D$ ) that you need to achieve high efficiency?

$$V_i \gg V_D$$

$$R \gg R_{ds,ON}$$

$L$  and  $C$  don't dictate efficiency

If would be better if  $D$  is larger because denominator is  $R_{ds,ON} / (1-D)^2 R$

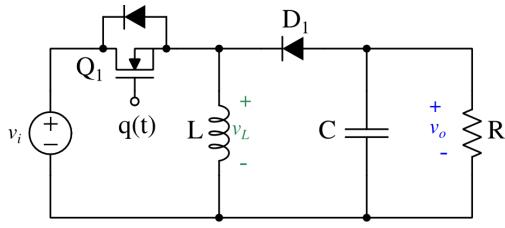


Figure 4.1: Buck-boost dc-dc converter.

Please design a discontinuous conduction mode (DCM) buck-boost converter ([Figure 4.1](#)) with the following operating requirements:

Converter's operating requirements

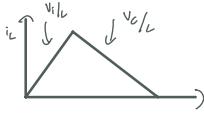
Parameter	Value
$V_i$	150 V-200 V
$V_o$	-170 V
$\mathcal{R}_C$ (Capacitor Ripple Ratio)	0.5%
$f_s$	145 kHz
$P_o$	50 W-150 W

- Find the inductor values  $L$  that minimize the peak inductor current
- Find the maximum and minimum values of the duty cycle  $D$
- What's the maximum inductor current  $i_{L,max}$
- The output capacitor value  $C$

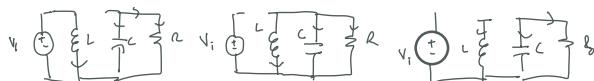
$$\Delta i_L = -\frac{V_o}{C} D^2 T$$

$$i_L \leq \frac{\Delta i_L}{2}$$

$$-\frac{V_o}{VR} \leq -\frac{V_o}{2L} D^2 T$$



$$\frac{2L}{P_o T} \leq (D^2)^2 \text{ for DCM}$$



$$\angle v_L(t) = \alpha = DV_i + D_2 V_o$$

$$D_2 = -D \frac{V_i}{V_o}$$

$$T_d = T_o = \frac{V_o}{2L}$$

$$T_d = \frac{1}{T} \int_0^T i_L(t) dt$$

$$\frac{1}{2T} (D^2 T)^2 = D^2 T$$

$$\frac{D_2 V_i D T}{2} \frac{V_o D T}{L} = -\frac{V_o}{2L}$$

$$\frac{D V_i V_o D T}{2L} = \frac{V_o}{R}$$

$$\frac{D^2 R T}{2L} = \left( \frac{V_o}{V_i} \right)^2$$

$$-D \sqrt{\frac{V_o^2}{2L}} = \frac{V_o}{V_i}$$

$\frac{V_o}{V_i} = -D \sqrt{\frac{R_o}{Z_L}}$  therefore as we TD, we decrease  $L$ . If we graphed it out,  $\sqrt{L} \propto D$ . We must minimize  $V_o$  because  $D = \frac{V_o}{V_i}$  so we know that  $\frac{D}{L}$  must be as small as possible. Therefore,  $D$  must be as large as possible.



For output resistance, we know that

Output voltage is  $-170$

$$\text{Given that } P = V^2/R$$

We know

$$R_o = V^2/P$$

$$R_o = \boxed{\frac{192.67 - 576\sqrt{2}}{P_o}}$$

$P_o = 150 \text{ W}$

We also know that the maximum Duty cycle we can have is just below boundary condition (BCM)

$$\begin{aligned} -170 &= \frac{P_o}{P_D} (150) & 150V \\ -170 + 170 &= -150D & D < 0.53125 \\ D &= 0.53125 & D > 0.459 \\ -170 &= \frac{P_o}{P_D} (200) & D < 0.459 \\ D &= 0.459 \end{aligned}$$

We'll use the smaller  $R_o$  because it will give tighter design requirements. I'll use the  $D < 0.53125$  because it will be able to create the  $\frac{V_o}{V_i} = \frac{170}{200}$  conversion ratio at BCM. The other duty cycle will not be able to create the larger  $\frac{170}{150}$  at BCM.

$$L < \frac{R_o D^2}{2f_s}$$

$$L < \frac{192.67 (1 - .53125)^2}{2f_s} \Rightarrow L = 1.46 \cdot 10^{-4} \text{ H}$$

Therefore to create the smallest inductance peak ripple, inductor value

$$L = 1.46 \cdot 10^{-4} \text{ H}$$

1. Find the inductor values  $L$  that minimize the peak inductor current  
 2. Find the maximum and minimum values of the duty cycle  $D$

Min use  $R_D = 578$ ,  $L = 1.46 \cdot 10^{-4} \text{ H}$  @ 200V input

$$\frac{V_0}{V_i} = -D \sqrt{\frac{R_{\text{tot}}}{2L}}$$

$$D_{\min} = 0.2300$$

Max use  $R_D = 192.67$ ,  $L = 1.46 \cdot 10^{-4} \text{ H}$  @ 180 V<sub>i,n</sub>

$$\frac{V_0}{V_i} = -D \sqrt{\frac{R_{\text{tot}}}{2L}}$$

$$D_{\max} = 0.531$$

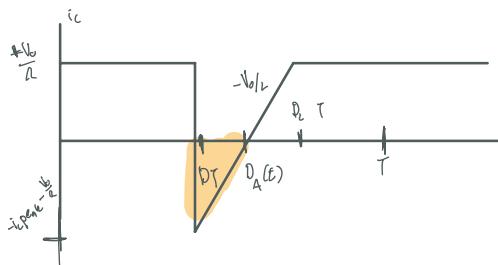
(same as calc above)

3. What's the maximum inductor current  $i_{L,\max}$

$$i_{L,\max} = \frac{V_i}{L} DT = \frac{150}{146 \cdot 10^{-6}} (0.531) \left(\frac{1}{146 \cdot 3}\right) = 3.76 \text{ A}$$

To find where  $i_L$  is max, look at conditions for max D

4. The output capacitor value  $C$



$$-3.76 - \frac{150}{146 \cdot 10^{-6}} = -i_{L,\max} - \frac{V_o}{L} = -2.476$$

$$\int i dt = \Delta Q$$

$$\Delta Q = C \Delta V$$

$$-2.476 + \frac{150}{146 \cdot 10^{-6}} (D_A - D_2) T = 0$$

$$D_A - D_2 = 0.358$$

Area of triangle

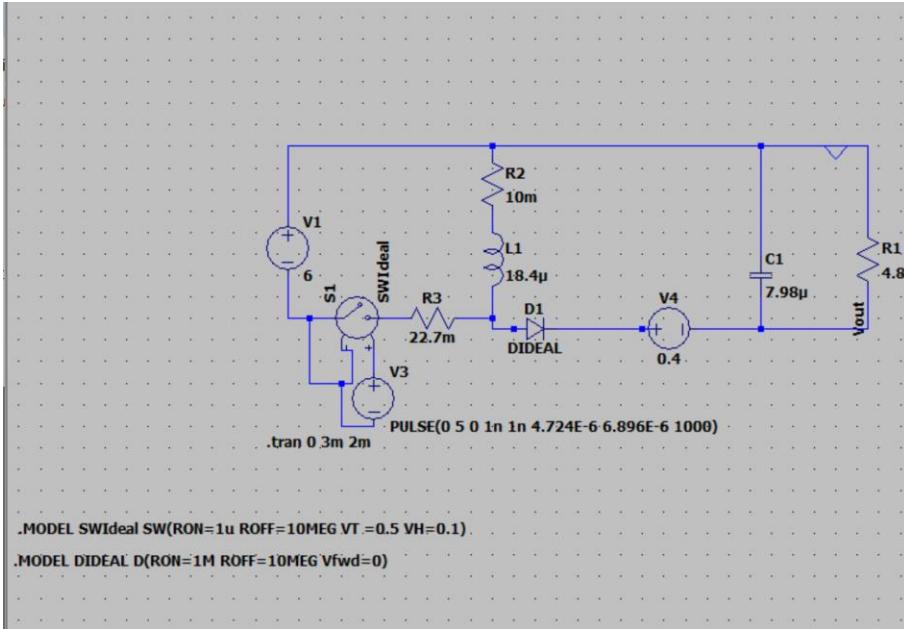
$$\frac{1}{2} (0.358) (-2.476) = 0.5157$$

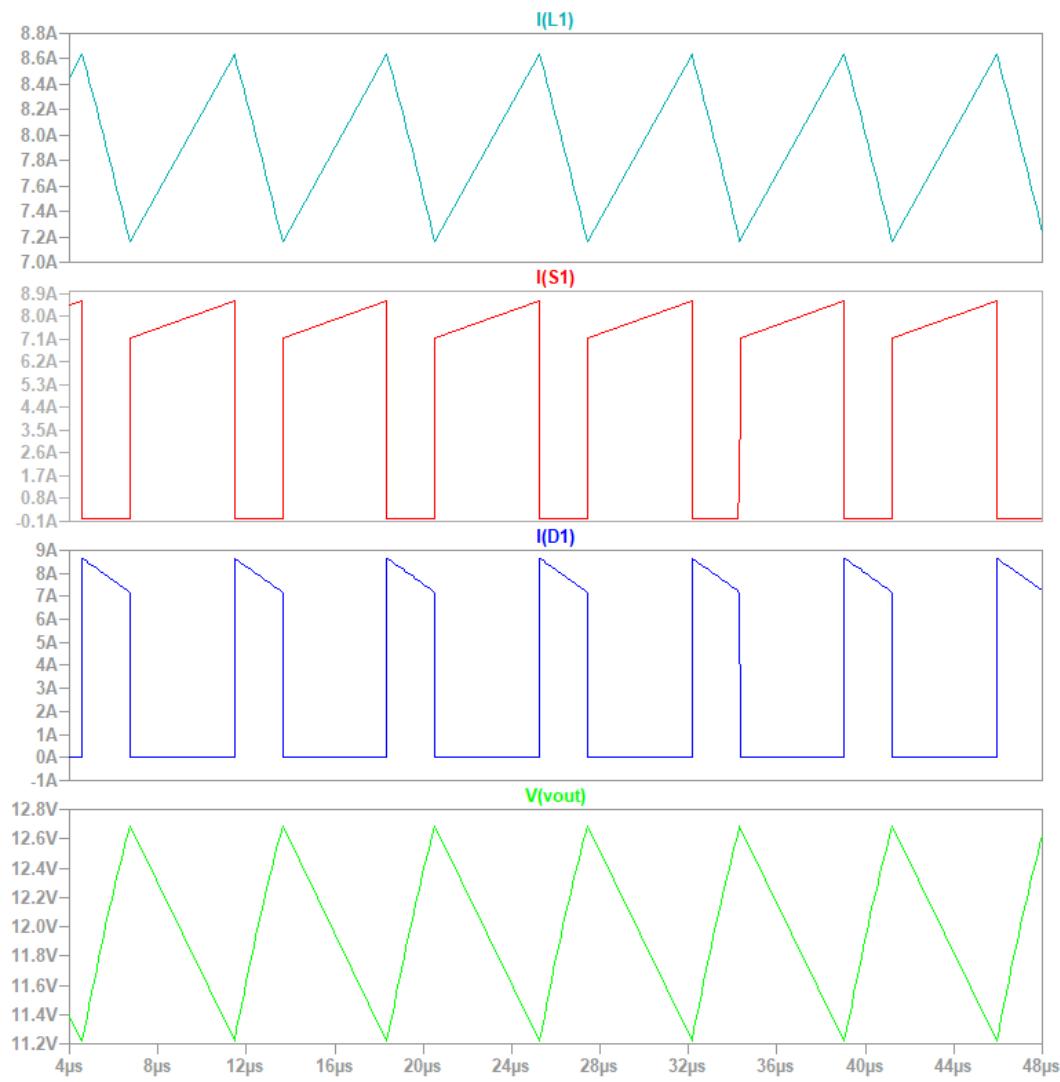
$$\frac{\Delta V}{2} = R$$

$$.005 \cdot 2 = \Delta V$$

$$\frac{0.5157}{\Delta V} = 3.56 \cdot 10^{-4}$$

$$356 \mu F$$





NMOS

<https://www.digikey.com/en/products/detail/qorvo/UJ4C075018K3S/13557749>

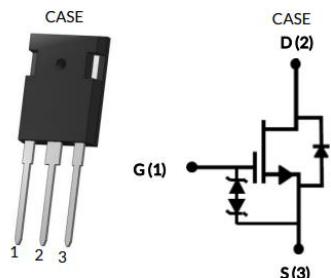
Part number: UJ4C075018K3S

# DATASHEET

## UJ4C075018K3S

### 750V-18mΩ SiC FET

Rev. A, October 2020



Part Number	Package	Marking
UJ4C075018K3S	TO-247-3L	UJ4C075018K3S

#### Description

The UJ4C075018K3S is a 750V, 18mΩ G4 SiC FET. It is based on a unique 'cascode' circuit configuration, in which a normally-on SiC JFET is co-packaged with a Si MOSFET to produce a normally-off SiC FET device. The device's standard gate-drive characteristics allows for a true "drop-in replacement" to Si IGBTs, Si FETs, SiC MOSFETs or Si superjunction devices. Available in the TO-247-3L package, this device exhibits ultra-low gate charge and exceptional reverse recovery characteristics, making it ideal for switching inductive loads and any application requiring standard gate drive.

#### Features

- On-resistance  $R_{DS(on)}$ : 18mΩ (typ)
- Operating temperature: 175°C (max)
- Excellent reverse recovery:  $Q_{rr} = 102\text{nC}$
- Low body diode  $V_{FSD}$ : 1.14V
- Low gate charge:  $Q_G = 37.8\text{nC}$
- Threshold voltage  $V_{GS(th)}$ : 4.8V (typ) allowing 0 to 15V drive
- Low intrinsic capacitance
- ESD protected, HBM class 2

#### Typical applications

- EV charging
- PV inverters
- Switch mode power supplies
- Power factor correction modules
- Motor drives
- Induction heating



Datasheet: UJ4C075018K3S

Rev. A, October 2020

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#### Maximum Ratings

Parameter	Symbol	Test Conditions	Value	Units
Drain-source voltage	$V_{DS}$		750	V
Gate-source voltage	$V_{GS}$	DC	-20 to +20	V
Continuous drain current <sup>1</sup>	$I_D$	$T_C = 25^\circ\text{C}$	81	A
		$T_C = 100^\circ\text{C}$	60	A
Pulsed drain current <sup>2</sup>	$I_{DM}$	$T_C = 25^\circ\text{C}$	205	A
Single pulsed avalanche energy <sup>3</sup>	$E_{AS}$	$L=15\text{mH}, I_{AS}=3.6\text{A}$	97.2	mJ
Power dissipation	$P_{tot}$	$T_C = 25^\circ\text{C}$	385	W
Maximum junction temperature	$T_{J,max}$		175	°C
Operating and storage temperature	$T_J, T_{STG}$		-55 to 175	°C
Max. lead temperature for soldering, 1/8" from case for 5 seconds	$T_L$		250	°C

1. Limited by  $T_{J,max}$

2. Pulse width  $t_p$  limited by  $T_{J,max}$

3. Starting  $T_J = 25^\circ\text{C}$

## Schottky diode

### RBQ10NL45BFHHTL Schottky Diode

**ROHM** RBQ10NL45BFHH  
Schottky Barrier Diode

(AEC-Q101 qualified) Data sheet

$V_R$	45	V
$I_0$	10	A
$I_{F5M}$	150	A

**● Features**  
High reliability  
Power mold type  
Low  $I_R$

**● Application**  
Switching power supply

**● Structure**  
Silicon epitaxial planar

**● Absolute Maximum Ratings ( $T_c=25^\circ\text{C}$  unless otherwise specified)**

Parameter	Symbol	Conditions	Limits	Unit
Repetitive peak reverse voltage	$V_{RM}$	Duty $\leq 0.5$	45	V
Reverse voltage	$V_R$	Reverse direct voltage	45	V
Average rectified forward current	$I_0$	60Hz half sin waveform, resistive load, $T_c=165^\circ\text{C Max}$	10	A
Peak forward surge current	$I_{F5M}$	60Hz half sin waveform, non-repetitve, $T_j \geq 25^\circ\text{C}$	150	A
Junction temperature <sup>(1)</sup>	$T_j$	-	175	°C
Storage temperature	$T_{stg}$	-	-55 ~ 175	°C

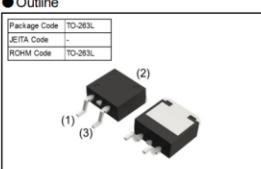
Note(1) To avoid occurrence of thermal runaway, actual board is to be designed to fulfill  $dV/dT_j < 1/R_{th(j)}$ .

**Attention**  
Compared with PN junction diodes, Schottky Barrier Diode is generally high reverse current (IR). The reverse loss of the diode might increase as temperature increasing that causes heat-up and further IR. This phenomenon might end up the thermal destruction(thermal runaway). Therefore please give consideration to the reverse loss and the ambient temperature when using this product.

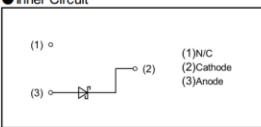
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**● Outline**



**● Inner Circuit**



**● Packaging Specifications**

Packing	Embossed Tape
Reel Size(mm)	330
Taping Width(mm)	24
Quantity(pcs)	1000
Taping Code	TL
Marking	RBQ10NL45B

**RBQ10NL45BFHH** Data sheet

**● Electrical Character (T<sub>j</sub>=25°C unless otherwise specified)**

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Forward voltage	$V_F$	$I_F=10\text{A}$	$T_j=25^\circ\text{C}$	-	-	0.62 V
			$T_j=125^\circ\text{C}$	-	-	0.57 V
Reverse current	$I_R$	$V_R=45\text{V}$	$T_j=25^\circ\text{C}$	-	-	100 $\mu\text{A}$
			$T_j=125^\circ\text{C}$	-	6.0	15 mA