Name: Solutions Page:1

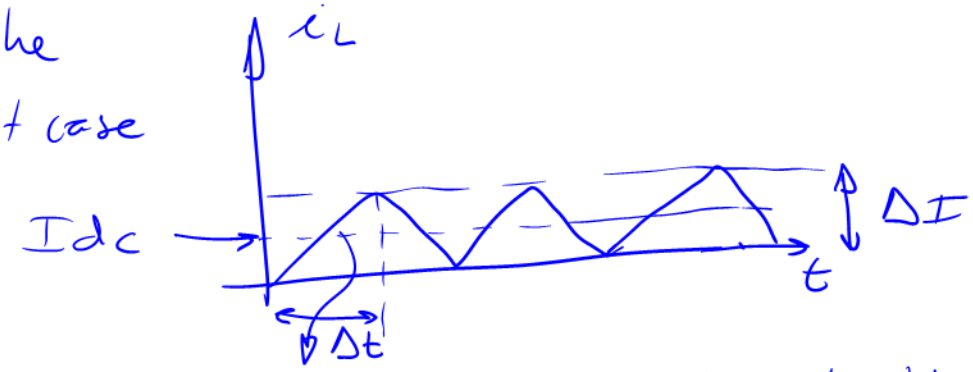
EE362L – Spring 2008, Test 2

Please, show all your work on the test sheets. A correct answer without supporting work gets no credit. One sheet of notes is permitted. Write your name in all pages. Do not un-staple. You have 50 minutes to complete the test. Hint for most of the problems: KVL and KCL apply in the average sense. Also always consider that you are operating in steady-state with ideal components.

Problem 1 (25 points)

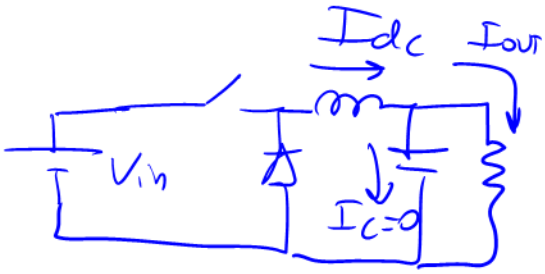
Consider a buck converter with V_{in} = 20 V, V_{out} = 10 V, L = 100 µH, C = 100 µF, and the switching period is 10 µsec. What is the (dc) current output in the limit case between continuous and discontinuous conduction? What is the load resistance in the limit case between continuous and discontinuous conduction? What happens if the capacitance is doubled?

In the limit case



Switch is on $\longrightarrow V_L = V_{in} - V_{OUT} = L\frac{\Delta I}{\Delta t}$

$\Delta t = D T_{sw}$ where $D = \frac{V_{OUT}}{V_{in}} = 0.5$



$\Delta I = \frac{(V_{in}-V_{OUT})}{L} D T_{sw} = \frac{10 \cdot 0.5 \cdot 10 \cdot 10^{-6}}{100\,10^{-6}}$

$\Delta I = 0.5$

$I_{dc} = \frac{\Delta I}{2} = 0.25\ A$

$I_{dc} = I_{OUT}$

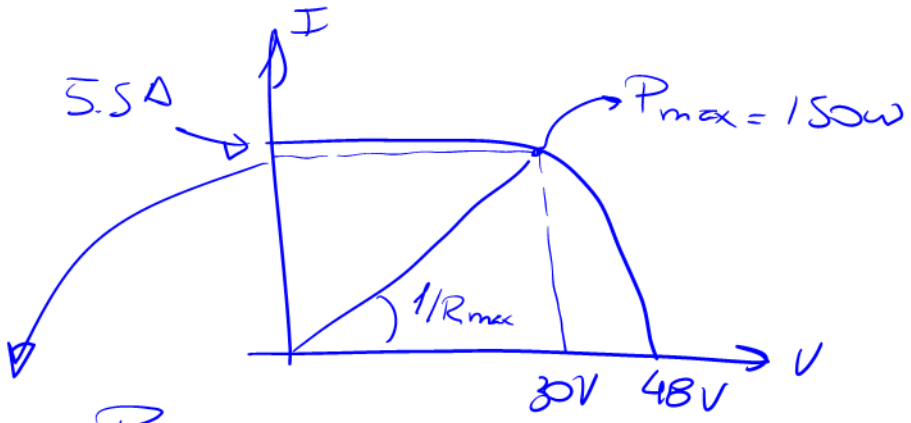
$R = \frac{V_{OUT}}{I_{OUT}} = \frac{10}{I_{dc}} = \frac{10}{0.25} = 40\ \Omega$

The capacitance has no effect in the above calculations

EE362L – Spring 2008, Test 2

Problem 2 (25 points)

Consider a PV module with the following characteristics: V_{OC} = 48 V, I_{CC} = 5.5 A, P_{max} = 150 W with V = 30 V. What is the "maximum power resistance?" If your actual load resistance varies between 40 and 80 ohms what is the simplest converter (the one with the fewer number of components) you can use so you can still operate the PV panel at the maximum power point? What will be the operating range of the converter duty cycle?



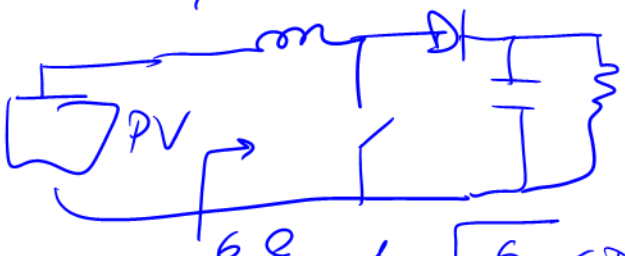
$$I_{max} = \frac{P_{max}}{V_{max}} = \frac{150}{30} = 5A$$

$$R_{max} = \frac{V_{max}}{I_{max}} = \frac{30}{5} = 6\Omega$$

There are two solutions for the simplest converter

1) Boost

1 Inductor
1 Capacitor
1 switch
1 Diode

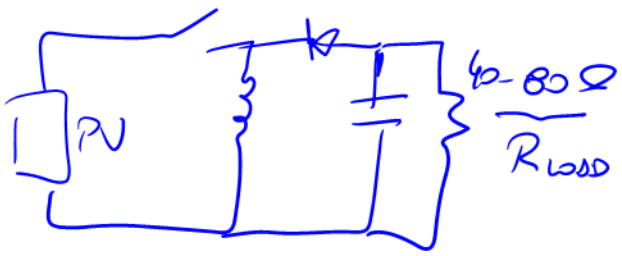


$$1-\sqrt{\frac{6}{40}} \le D \le 1-\sqrt{\frac{6}{80}}$$

$$0.61 \le D \le 0.72$$

2) Buck-Boost

1 Inductor
1 Capacitor
1 switch
1 Diode



$$\left(\frac{1-D}{D}\right)^2 = \frac{6}{R_{LOAD}}$$

↓ Solving the 2nd order eq.

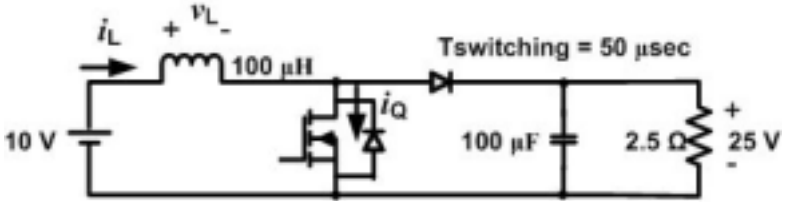
$$0.72 \le D \le 0.78$$

EE362L – Spring 2008, Test 2

Problem 3 (30 points)

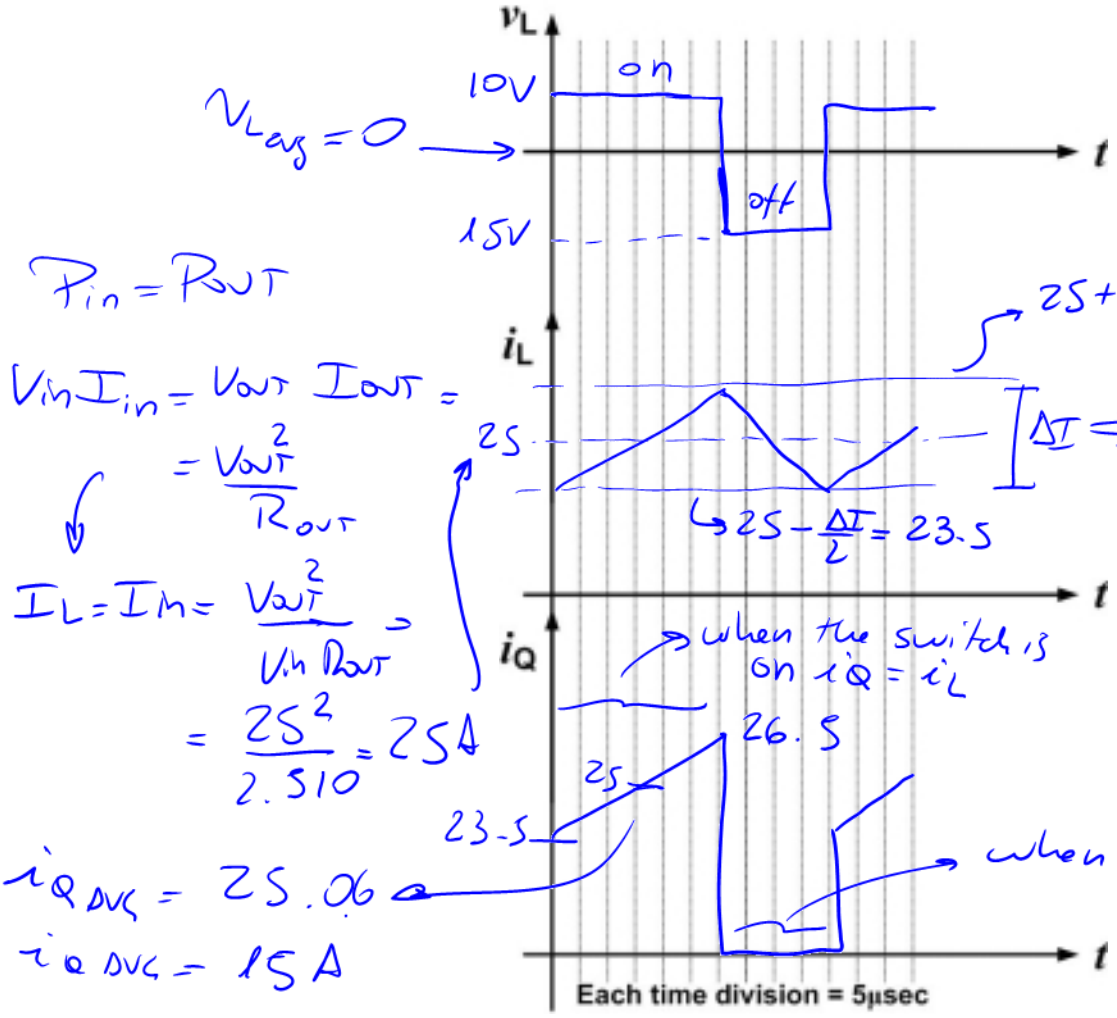
Consider the boost converter in the figure. On the graph below, carefully and neatly draw the following variables: i_L, v_L, and current in the main switch (i_Q). Also specify the most significant values (peaks and average value). Consider that you are operating in continuous conduction.

5 Points – extra credit: What is the output voltage ripple (expressed in any way you prefer)?



$D' = \frac{10}{25} = 0.4$

$D = 0.6$



$P_{in} = P_{out}$

$V_{in} I_{in} = V_{out} I_{out} = \frac{V_{out}^2}{R_{out}}$

$I_L = I_{in} = \frac{V_{out}^2}{V_{in} R_{out}} = \frac{25^2}{2.510} = 25A$

$\Delta I = \frac{V_L}{L} \Delta t = \frac{V_{in}}{L} D T_{sw}$

$\Delta I = \frac{10}{100 \cdot 10^6} 0.6 \cdot 50 \cdot 10^6$

$\Delta I = 3A$

$i_{Q\,avg} = 25.06$

$i_{Q\,avg} = 15A$

(Extra credit) When the switch is on $I_C = I_{out}$

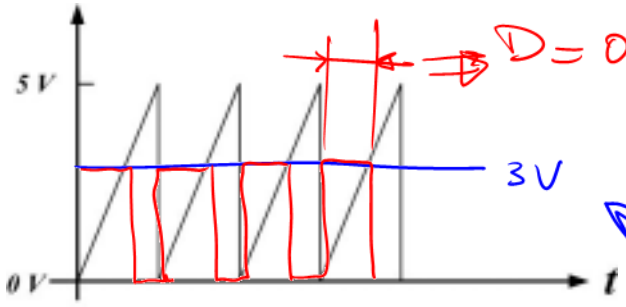
$I_C = C \frac{\Delta V}{\Delta t} \Rightarrow \Delta V_{pp} = \frac{I_{out} D T_{sw}}{C} = 3V$

EE362L – Spring 2008, Test 2

Problem 4 (5 points each)

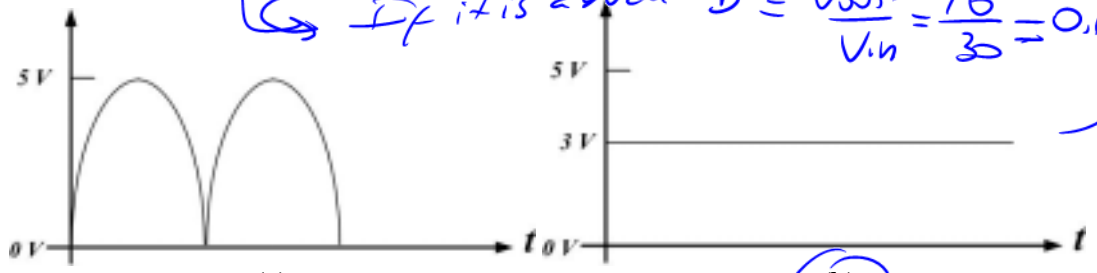
Please, select the correct answer for the following questions. Provide a brief justification for your answer.

4.1) Suppose that you are generating a PWM signal to drive a MOSFET in a dc-dc buck converter. The sawtooth input of the PWM comparator is shown below.



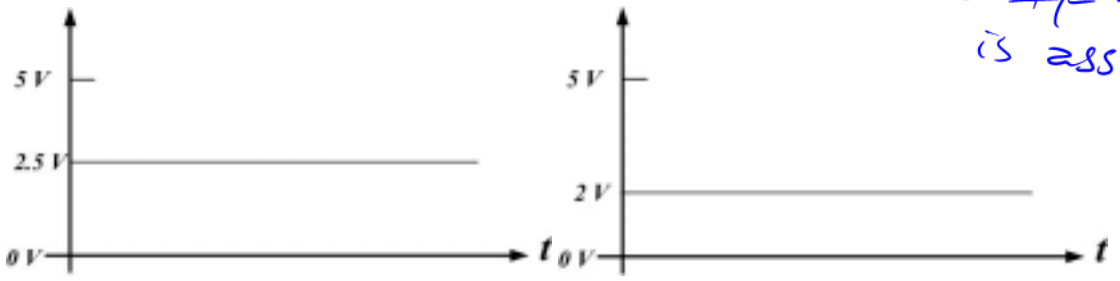
Which of the following control signals needs to be used to obtain 18 V at the output if the input is 30 V?

If it is a buck $D = \frac{V_{out}}{V_{in}} = \frac{18}{30} = 0.6$



(a) (b)

If no inversion is assumed

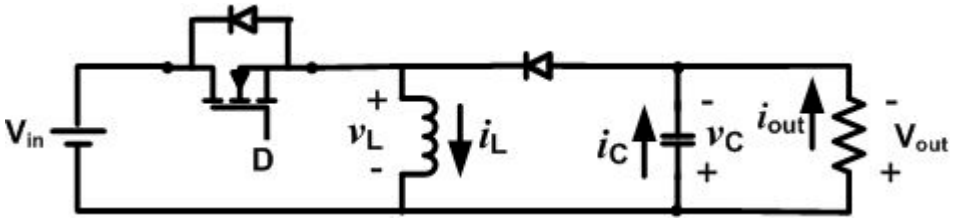


(c) (d)

e) None of the above

EE362L – Spring 2008, Test 2

4.2 to 4.4) The following figure shows a dc-dc converter with all the currents and voltage references. (For all 3 questions consider that you are operating in continuous conduction).



4.2) What is the inductor average voltage when the main switch is closed?

a) Vin
b) VinD
c) Vin/D
d) Vout/(1-D)
e) 0
f) None of the above

→ When the switch is closed I have

4.3) What is the inductor average voltage when the main switch is open?

a) -Vout
b) -Vout/(1-D)
c) Vin
d) -VoutD
e) -Vout(1-D)
f) None of the above

when the switch is open I have

4.4) What is V_{out}/V_{in} as a function of the main switch duty cycle?:

a) Vout/Vin = D
b) Vout/Vin = 1-D
c) Vout/Vin = D/(1-D)
d) Vout/Vin = (1-D)/D
e) 1
f) None of the above

In steady state and over 1 period

$V_L = 0$ → switch closed → switch open

$$V_L = 0 = \underbrace{D\,V_{in}}_{\text{From 4.2}} - \underbrace{(1-D)\,V_{OUT}}_{\text{From 4.3}}$$

Hence,

$$\frac{V_{OUT}}{V_{in}} = \frac{D}{1-D}$$