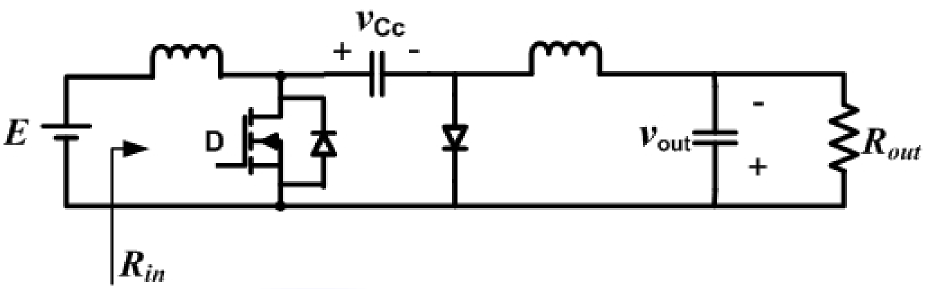
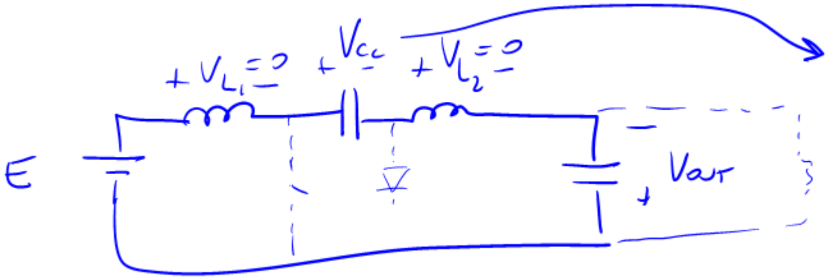
EE362L – Spring 2010, Test 2

Please, read the following notes carefully. Please, show all your work on the test sheets. A correct answer without supporting work gets no credit. One new sheet of notes is permitted but you can also have the one you prepared for the first test. Write your name in all pages. Do not un-staple. Please **be neat**. Otherwise, you may end up loosing credit for correct answers if I cannot find or understand them. Unless otherwise noted assume that all converters operate in continuous conduction mode. You have 50 minutes to complete the test.

Problem 1 (30 points)

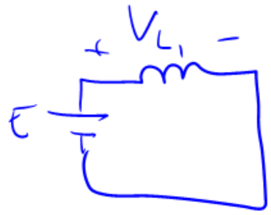
The figure shows a Ćuk converter. Find the steady state average voltage in the center capacitor (V_{Cc}) and derive the relationships between steady state average input and output voltage (V_{out}/E), and input and output resistances (R_{out}/R_{in}) as a function of D.





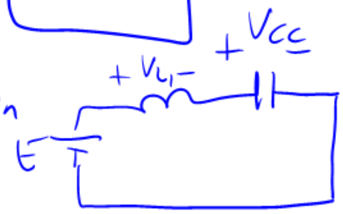
$E - V_{Cc} + V_{out} = 0 \longrightarrow V_{Cc} = E + V_{out}$

When the switch is closed (DT)



$\longrightarrow V_{L_1} = E$

when the switch is open (1-D)T



$\longrightarrow V_{L_1} = E - V_{Cc} = -V_{out}$

$DT \cdot E + (1-D)T(-V_{out}) = 0$

$$\boxed{\frac{V_{out}}{E} = \frac{D}{(1-D)}}$$

$P_{in} = P_{out} \longrightarrow E I_{in} = V_{out} I_{out} \longrightarrow \frac{I_{out}}{I_{in}} = \frac{E}{V_{out}} = \frac{1-D}{D}$

$$\frac{R_{out}}{R_{in}} = \frac{V_{out}/I_{out}}{E/I_{in}} = \frac{V_{out} I_{in}}{E\, I_{out}} = \left(\frac{D}{1-D}\right)\left(\frac{D}{1-D}\right) = \left(\frac{D}{1-D}\right)^2$$

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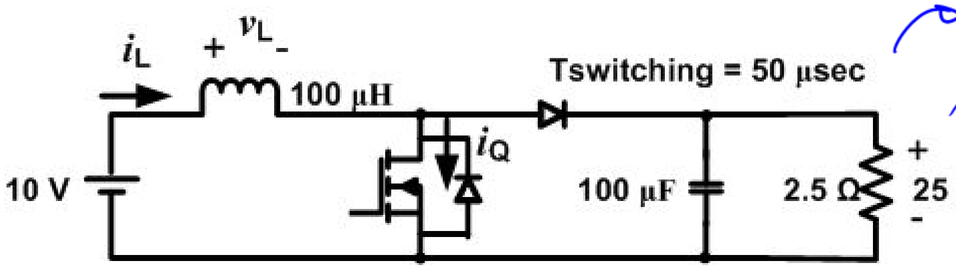
Problem 2 (30 points)

For the boost converter in the figure below calculate the input current ripple and the output voltage ripple (notice that this is not the worst case condition used for design purposes). Assuming that only the switching frequency changes and the other parameters remain unchanged, at which frequency the converter operates at the limit between continuous and discontinuous conduction mode?



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

$1-D = \frac{10}{25}$

$D = 1 - \frac{10}{25} = 0.6$

– output voltage ripple: When the switch is on the capacitor holds the output current

$C = \frac{\Delta Q}{\Delta V} = \frac{\Delta Q}{\Delta t}\frac{\Delta t}{\Delta V} = I_{OUT}\frac{DT}{\Delta V} = \frac{V_{OUT}}{R}\frac{DT}{\Delta V}$

$\Delta V = \frac{V_{OUT}}{R}\frac{DT}{C} = \frac{25}{2.5}\cdot\frac{0.6\cdot 50\cdot 10^{-6}}{100\cdot 10^{-6}} = 3V$

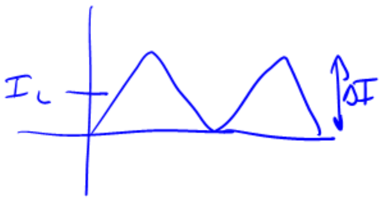
– Input ripple

when switch is on

$V_L = L\frac{\Delta I}{\Delta t} \rightarrow \Delta I = \frac{V_L}{L}\Delta t = \frac{EDT}{L} = \frac{10\cdot 0.6\cdot 50\cdot 10^{-6}}{100\cdot 10^{-6}} = 3A$

Limit case $\rightarrow$ $I_L = \frac{V_{OUT}^2}{R}\frac{1}{E} = \frac{25^2}{2.5}\frac{1}{10} = 25A$

At the limit case $\frac{\Delta I}{2} = I_L \rightarrow \Delta I = \frac{EDT}{L} = 2I_L \rightarrow f = \frac{1}{T} = \frac{ED}{L\,2I_L}$



$f = \frac{10\cdot 0.6}{100\cdot 10^{-6}\,2\cdot 25} = 1200\,Hz$

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Problem 3 (25 points)

Consider a PV module with the following characteristics: V_{OC} = 48 V, I_{CC} = 5.5 A, P_{max} = 150 W when V = 30 V. What is the "maximum power resistance?" If your actual load resistance varies between 2 and 12 ohms which one of the three dc-dc converters discussed in class (buck, boost, and SEPIC) will you choose to operate the PV panel at its maximum power point? What will be the operating range of the converter duty cycle?

$$R_{MPP} = \frac{V_{MPP}^2}{150} = 6\ \Omega$$

Since I am looking to compensate load resistances that are both higher and lower than R_{MPP} I need a SEPIC.

For a SEPIC

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

For $R_{OUT} = 2\ \Omega$ and $R_{in} = R_{MPP} = 6\ \Omega$

$$\frac{D}{1-D} = \sqrt{\frac{2}{6}} = 0.577 \longrightarrow D + 0.577D = 0.577$$

$$\hookrightarrow D = 0.366$$

For $R_{OUT} = 12\ \Omega$ and $R_{in} = R_{MPP} = 6\ \Omega$

$$\frac{D}{1-D} = \sqrt{\frac{12}{6}} = 1.414 \longrightarrow 2.414D = 1.414$$

$$\hookrightarrow D = 0.5858$$

$$\boxed{0.366 \leq D \leq 0.5858}$$

Problem 4 (5 points each)

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

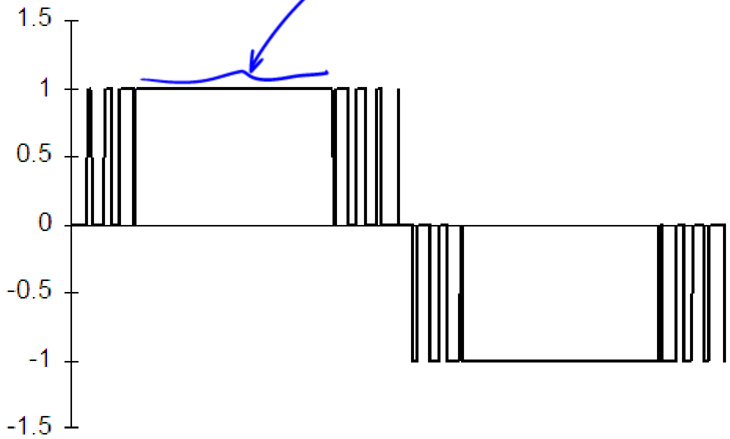
4.1) Consider an H-bridge single-phase inverter. Its input voltage is 48 V and its output voltage is 27.15 Vrms. The modulation index is

- a) 0.56
- b) 0.7
- [✓ c) 0.8]
- d) 1
- e) 1.25
- f) 1.76
- g) None of the above

$$m_a = \frac{\sqrt{2}\, V_{1rms}}{V_{dc}} = \sqrt{2}\, \frac{27.15}{48} = 0.8$$

4.2) What is the approximate modulation index for an H-bridge inverter if the output voltage is the one shown in the figure below?

- a) 0.5
- b) 0.8 } Linear
- c) 1
- [✓ d) 1.5] → overmodulation
- e) 25 → Saturation
- f) None of the above



4.3) Which is the maximum possible output peak voltage that can be observed in an H-bridge inverter with an input voltage of 1 V?

a) 0.9
b) 1
c) 1.11
[✓ d) 1.27]
e) There is no maximum voltage (no upper limit)
f) None of the above

$$V_{1rms\,max} = \frac{4}{\pi}\frac{V_{dc}}{\sqrt{2}} = \frac{4}{\pi}\frac{1}{\sqrt{2}} = 0.9$$

$$V_{1\,peak\,max} = \sqrt{2}\,V_{1rms\,max} = \sqrt{2}\times 0.9 = 1.2732$$