Sample Exam Part 2 Solution

Here are a few dc-dc converter related questions:

1. You are given a buck converter. You measure the input voltage to be 15 V from a 100W source, and have an output current of 4 A. Assuming no power losses determine: average input current, output voltage, duty ratio. The filter inductance is 100 $\mu$H and the switching frequency is 10 kHz. Will this converter be in continuous conduction. If not suggest two options to make it to continuous conduction.

\[
V_d := 50V \\
L := 100\mu H \\
I_o := 4A \\
P_o := 100W \\
f_s := 10kHz \\
D := \frac{V_o}{V_d} \\
T_s := \frac{1}{f_s}
\]

Therefore we find:

\[
V_o := \frac{P_o}{I_o} \\
V_o = 25V \\
D := \frac{V_o}{V_d} \\
D = 0.5 \\
I_d := I_o \cdot D \\
I_d = 2A
\]

As a check:
\[
P_d := V_d \cdot I_d \\
P_d = 100W
\]

\[
ILB := \frac{D\cdot T_s}{2\cdot L} (V_d - V_o) \\
ILB = 6.25A
\]

This converter will not be in discontinuous conduction. Options to make it continuous:

1. Increase $L$

\[
L_{min} := \frac{D\cdot T_s}{2\cdot I_o} (V_d - V_o) \\
L_{min} = 156.25\mu H \\
ILBn := \frac{D\cdot T_s}{2\cdot L_{min}} (V_d - V_o) \\
ILBn = 4A
\]

2. Increase switching frequency (keep the original $L$), recall: $f_s = 1/T_s$

\[
f_{\text{new}} := \frac{D}{2\cdot I_o \cdot L} (V_d - V_o) \\
f_{\text{new}} = 15.625kHz \\
T_{\text{sn}} := \frac{1}{f_{\text{new}}}
\]

\[
ILB_{n2} := \frac{D\cdot T_{\text{sn}}}{2\cdot L} (V_d - V_o) \\
ILB_{n2} = 4A
\]
2. Short Answer:

A. Why is it important to always provide an alternate current path when opening a switch in series with an inductor? What happens if you don't?

Solution: The inductor will act as a current source in the short term (you can't change the current through an inductor instantaneously). Therefore, if you open a switch in series with an inductor (the switch in a buck converter), you need an alternate path (like the diode in the buck converter) to pick up the current.

If this is missing, there will be a large voltage from

\[ v = L \frac{d}{dt} i \]

This will be large enough to cause insulation to fail, most likely the switch itself.

B. Why isn't the current through the inductor in the buck converter constant (since the average output current is constant)?

Solution: While the switch is on, the voltage across the inductor is \( V_d - V_{oave} \), while the switch is open, it is \(-V_{oave}\). Since neither voltage is zero, the current will ramp up while the switch is closed, and down while it is open. Increasing L or increasing the switching frequency will make the variations smaller, but not zero (unless the switch is always closed or always open).