**Non-assessed Example Sheet (Part 3: DC-DC Converters)**

*Step-down Buck converter:*

1. For an ideal Buck converter switching at a sufficiently high frequency, sketch the steady state waveforms for its
   1. inductor current
   2. switch voltage
   3. switch current
   4. diode current.
2. Derive the output-input relationships of the voltage and current for an ideal Buck Converter.
3. The output voltage of an ideal Buck converter should vary only between 20 and 30V and its input is maintained constant at 60V.
   1. What is the range of switching duty ratios required for the converter?
   2. If the converter has a load of 20 Ω, determine the maximum value of the input current for the converter. Assume the output voltage can still vary between 20 and 30V.
4. The semiconductor switch in an ideal Buck converter has a minimum effective off time of 30.5 μs. If the converter input is applied with 1200 V and the converter operates at a switching frequency of 3500 Hz, calculate the maximum duty cycle and the maximum output voltage that can be obtained.
5. An ideal Buck converter (as shown in the handout) operates at a switching frequency of 100 kHz, with a inductor current ripple of 0.1 A, average input current of 1A, an input voltage of 50 V and an output voltage of 20V. What are the value of the average output current and that of the inductor in mH?
6. A battery powered electric car is cruising at a constant speed and this is achieved by connecting an ideal Buck converter between the battery and the electric motor of the car. The converter output where the motor is connected is rated at 96 V and the input where the battery is connected is at 120 V. The converter operates at a switching frequency of 2 kHz and duty ratio of 0.8. At a certain motor speed, the resistance looking into the motor is 3 Ω. and the converter has an inductance of 20 mH. Determine
   1. the average current supplied by the battery (or the converter input current)
   2. the amount of the inductor current ripple
7. An ideal step-down Buck converter operating at 1.5 kHz and a duty cycle of 0.7 supplies the load with a current of 120 A. The converter has an inductor of 10 mH and the output capacitor has been chosen to be 100 μF. The input voltage is 450 V. Determine
   1. the output voltage ripple across the capacitor.
   2. the maximum and minimum voltages occurring across the capacitor.
8. An ideal step-down Buck converter operates at a constant switching frequency. Its input voltage, inductor and load are unchanged for all operations but the duty ratio can vary between 0 and 1. Under these conditions, analytically show that the maximum value of the inductor current ripple (Δ*iL*) is maximum at *K* = 0.5. Find the expression for the maximum Δ*iL* in terms of the converter’s input voltage, inductor & switching frequency.

*Step-up Boost converter:*

1. For an ideal Boost converter switching at a sufficiently high frequency, sketch the steady state waveforms for its
   1. inductor current
   2. switch voltage
   3. switch current
   4. diode current
2. Derive the output-input relationships of the voltage and current for an ideal Boost Converter.
3. An ideal step-up Boost converter supplies a load of 100Ω at 48V from a 12V battery. The converter operates at a switching frequency of 10 kHz. Determine
   1. the minimum output capacitance for the converter so that the peak-to-peak output voltage ripple is kept to be below 2% of the converter output voltage.
   2. the minimum inductance for the converter so that the peak-to-peak input current ripple is kept to be below 10% of its average value.
4. An ideal step-up Boost converter is used to connect a solar panel to a battery plus load. The voltage across the solar panel varies between 100 and 120 V (converter input) whilst the battery voltage is fixed at 320 V (converter output). Determine
   1. the operating range of the duty ratios
   2. the minimum inductor required if the input current ripple must not be more than 5% of its average value when the solar panel generates its rated power of 1500 W at 110V. The converter operates at a switching frequency of 20 kHz.

1. An ideal Boost converter operates at a switching frequency of 50 kHz, with an output capacitor of 1 μF and input voltage of 50 V. It operates under continuous conduction mode and the duty ratio is set such that the switch is turned on for 6.5 μs for every switching cycle. What is the minimum resistance which can be connected at the converter output so that the output voltage ripple does not exceed 10% of its average value?
2. It is known that the current of a Boost converter input is higher than that of the output. Determine the maximum value of the converter input current for Question 13?
3. What is the average voltage experienced by the switch in the converter of Question 13?

Guidance and outline solutions are available in the VLE of this module.

Please also re-attempt the questions discussed in lectures and in Example classes.