Q1.

a. You are required to design a DCDC buck-boost converter for a mobile phone. The mobile phone battery input voltage varies between 4V to 6V. The output is a constant 5V, with a variable current between 0.3A and 1A when the phone is turned on. It is required that the converter should operate in the Continuous Conduction Mode (CCM) all the time. You may assume ideal devices for all parts in this question.

i) Sketch the converter and calculate the maximum and minimum duty cycles?

(5 marks)

ii) If the inductor value for this converter is 20uH and the switching frequency is 500kHz, calculate the peak to peak inductor currents at high line (V_{in_max}) and low line (V_{in_min}).

(5 marks)

iii) If the maximum voltage ripple allowed is 30mV in the whole working range, suggest an output capacitor for the DCDC converter.

(5 marks)

Q1.

a. i) Sketch buck-boost converter. (1 mark)

Duty cycle range $\frac{V_{out}}{V_{inmin}} = \frac{D_{max}}{1-D_{max}}$, $D_{max} = \frac{5}{9} = 0.56$ (2 mark)

$\frac{V_{out}}{V_{inmin}} = \frac{D_{min}}{1-D_{min}}$, $D_{min} = \frac{5}{11} = 0.454$ (2 mark)

ii) Inductor peak to peak current is independent of output current. From equation

$$V_{in} = L\frac{\delta i}{DT}$$

At high line $\delta i = \frac{V_{in\_max} D_{min}}{L*f} = \frac{6*0.454}{20u*500k} = 0.2724$ A

At low line $\delta i = \frac{V_{in\_min} D_{max}}{L*f} = \frac{4*0.56}{20u*500k} = 0.224$ A

(5 marks)

iii) Worst case current ripple at high line

$\delta v = \frac{I_{omax} D_{max}}{C*f}$, $30\text{mV} = \frac{1*0.56}{C*500k}$ C>37.3 uF

(5 marks)

b. A boost converter has an input voltage range of 48V to 60V dc, and constant output voltage 130V. It provides output current I_o in the range 0.5A to 4A. The converter operates in the Continuous Conduction Mode (CCM) with inductance L=60uH. The switching frequency f_s is 50kHz. You may assume ideal devices.

i) Calculate the maximum and minimum duty cycles.

(5 marks)

ii) If the output peak to peak voltage ripple must be less than 2V in the whole working range. Find out the worst case and calculate the output capacitor needed.

(5 marks)

b. i) Boost converter duty cycle

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

$D = 1 - \frac{V_{in}}{V_o}$ At high line $D_{min} = 1 - \frac{60}{130} = 0.5385$

At low line $D_{max} = 1 - \frac{48}{130} = 0.63$

ii) Output ripple is maximum at full load Dmax

$\delta v = \frac{I_o D}{C*f}$ $2 = \frac{4*0.63}{C*50k}$ C>25.2uF

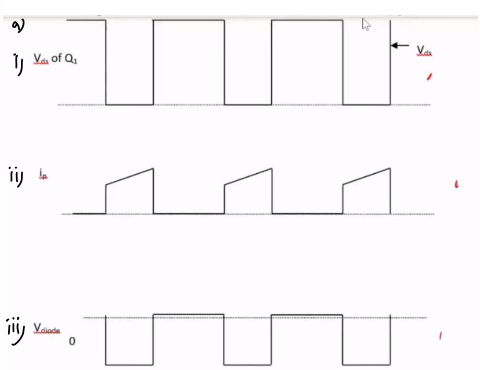
Q2.

a. A Flyback converter operates in the Continuous Conduction Mode (CCM). Sketch the

i. voltage Vds waveform ignoring voltage spike caused by leakage inductance,
ii. current waveform through the primary winding
iii. and then the voltage across the output diode

all on the same time axis.

(7 marks)



b. Write down an equation to show the turn off voltage of the diode on your waveform sketch in part (a) in terms of the input voltage V_{in}, output voltage V_o and turns ratio $n = \frac{N_s}{N_p}$.

(3 marks)

b. Turn off of $v_{diode} = V_{in} * n + V_{out}$

c. A Flyback converter has input voltage range 130Vdc to 375 Vdc. The output is kept constant by PWM at 19V delivering 2 A. The switching frequency is 80kHz and the converter operates in CCM. You may assume ideal devices.

i) Calculate the transformer turns ratio if the maximum duty cycle is kept below 0.48.

(5 marks)

ii) Hence calculate the minimum duty cycle.

(3 marks)

iii) What is the diode voltage rating required in the converter? Also what is the MOSFET voltage rating required?

(7 marks)

c. i) Voltage equation for the flyback CCM

$$\frac{V_o}{V_{in}} = n\frac{D}{1-D}$$

At low line

$\frac{19}{130} = n\frac{0.48}{1-0.48}$ n=0.1583

ii) Min duty cycle

$$\frac{19}{375} = 0.1583\frac{Dmin}{1-Dmin}$$

Dmin = 0.2425

iii) Diode voltage rating required

$$V_{in\_max} * n + V_{out} = 375 * 0.1583 + 19 > 78.36V$$

MOSFET rating $V_{in} + \frac{V_o}{n} = 375 + \frac{19}{0.1583} > 495V$