ECE 320: Lecture 33

Notes

Exam #2

- Friday in class
- Will review to prepare for it on Wednesday
- Sample exam will be posted

Homework #7

- Due in class on Wednesday

Buck Converter:

Continuous Conduction Mode

- Inductor current
    1. In this case, inductor current is the same as the output current
    2. Input current is discontinuous.

$$i_L = I_o + \frac{1}{L}\left(\int_0^{t_{on}} v_L\, dt + \int_{t_{on}}^{T_s} v_L\, dt\right) = I_o + \left[\int_0^{D\cdot T_s} \left(V_d - V_o\right) dt + \int_{D\cdot T_s}^{T_s} \left(0 - V_o\right) dt\right]$$

- Note that for a duty ratio of 0.5, the 2 slopes
- For a large duty ratio, Vo is closer to Vd, so the rising slope is more gradual and the falling slope is steeper.

- Average voltage across the inductor needs to be zero.

$$\int_0^{T_s} v_L\, dt = \int_0^{t_{on}} v_L\, dt + \int_{t_{on}}^{T_s} v_L\, dt = \int_0^{D\cdot T_s} \left(V_d - V_o\right) dt + \int_{D\cdot T_s}^{T_s} \left(0 - V_o\right) dt = 0$$

- This implies that equal and opposite areas for the two parts of the conduction period

$$\left(V_d - V_{oAVE}\right)\cdot D\cdot T_s = -V_{oAVE}\cdot\left(T_s - D\cdot T_s\right) \qquad \text{Volt-second balance}$$

- We can rewrite this to also produce

$$\frac{V_{oAVE}}{V_d} = \frac{D\cdot T_s}{T_s} = D$$

- The average current flows through the inductor.
- However, the inductor current will vary about this average based on:

$$\int_0^{D\cdot T_s} (V_d - V_o)\,dt + \int_{D\cdot T_s}^{T_s} (0 - V_o)\,dt = 0$$

- This variable part of the current will flow into the filter capacitor. Only the average part wil to the load.
- This variation in the current is called the current ripple. Peak to peak current ripple is usuall specified item.
- The variation depends on the size of the L
- Input current will have a large ripple, since current is zero while the switch is open.

Boundary Between Continuous and Discontinuous Conduction

- It is possible to create an operating condition where the inductor current goes to zero before t next time the switch would turn on.
- In many cases it is desirable to operate this at or above this level, so it important to determine boundary of this zone.
- At this boundary, the instantaneous current will be zero at the instant the switch turns on.
- The average current at this boundary will be:

$$I_{LB} = I_{OB} = \frac{1}{2}\cdot I_{Lpeak} = t_{on}\cdot\frac{(V_d - V_o)}{2L} = D\cdot T_s\cdot\frac{(V_d - V_o)}{2L}$$

- Note that this boundary depends on the following
  1. Input voltage
  2. Duty ratio
  3. L
- The duty ratio usually depends on values of V_d and V_o.
- Need to consider allowable variation of input voltage and limits of output variation.
- The circuit designer needs to find the minimum value of the inductance to maintain continuou conduction for all allowable values of input voltage and D.

Example: Lets say that the input voltage varies between 50 and 100V, and the output voltage is regulated at 40V. The converter switches at 10kHz, and we have an inductor of 0.5 mH

$Vdmin := 50V$ $\quad Vdmax := 100V$ $\quad Vo := 40V$ $\quad Lfilt := 0.5mH$

$$Dmax := \frac{Vo}{Vdmin} \qquad Dmax = 0.8 \qquad Dmin := \frac{Vo}{Vdmax} \qquad Dmin = 0.4$$

$$fs := 10kHz \qquad Ts := \frac{1}{fs} \qquad Ts = 1 \times 10^{-4} s$$

$$ILB1 := \frac{Dmin \cdot Ts}{2 \cdot Lfilt} \cdot (Vdmax - Vo) \qquad ILB1 = 2.4\,A$$

$$ILB2 := \frac{Dmax \cdot Ts}{2 \cdot Lfilt} \cdot (Vdmin - Vo) \qquad ILB2 = 0.8\,A$$

- So the minimum current at the boundary is 2.4A to guarantee that it is always in continuous conduction for all values of input current.
- However, in many cases, the output current is known, and instead we want to find the minimum inductance.