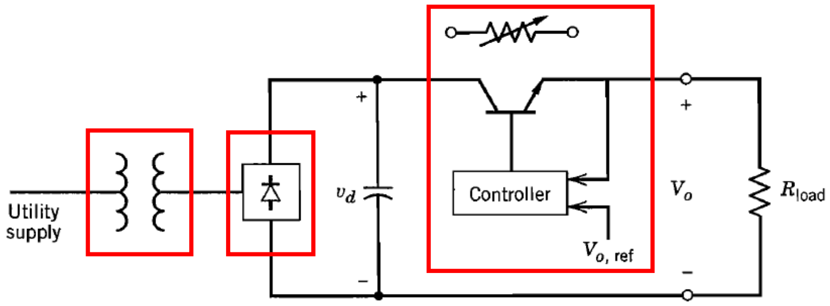
EE4532, Part II
Tutorial 1, Introduction & DC-DC Buck Converters

1. Name the following converter. Describe the functionalities of the highlighted blocks. Describe the disadvantages of this converter.



2. A DC-DC buck converter with an input voltage of 100V supplies power to a DC motor, whose back-emf is 70V. The armature resistance of the DC motor is 0.1Ω and its armature inductance is large enough to guarantee the continuous conduction mode (CCM) operation of the buck converter. The average current supplied to the DC motor is 100A, and the buck converter is switching at 1kHz. Determine the required ON time of the buck converter and the system conversion efficiency. **[0.8ms, 87.5%]**

3. A DC-DC buck converter is designed with the following specifications: input voltage 10V to 40V, filter inductance 40μH, filter capacitance 330μF, switching frequency 50kHz. Assuming CCM operation for parts (a) to (e).

   a. Derive expressions for the voltage across the inductor and use them to derive expressions for the input-to-output voltage and current ratios.
   b. Find the range of variation of the converter duty ratio when the converter output is kept constant at 5V. **[0.125 to 0.5]**
   c. Find the maximum output voltage that can continuously be supplied by the converter, and the corresponding range of duty ratio variation. **[10V, 0.25 to 1]**
   d. Sketch over two switching periods the voltage and current waveforms across the inductor, capacitor, switch, and diode.
   e. With the output voltage kept at 5V and the output power maintained at 50W, calculate the average input current and peak-to-peak current ripple flowing through the inductor when the input voltage dips to 10V. **[5A, 1.25A]**
   f. With the output voltage and input voltage kept at 5V and 10V respectively, determine the load power/resistance/current that will guarantee the boundary conduction mode (BCM) operation of the converter. **[3.125W, 8Ω, 0.625A]**

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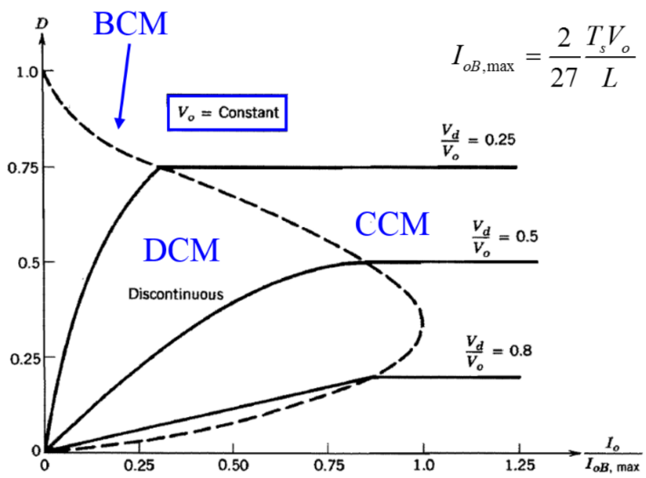
Tutorial 2, DC-DC Boost Converters

1. A DC-DC boost converter is designed with the following specifications: input voltage 8V to 16V, filter inductance 400μH, filter capacitance 470μF, switching frequency 20kHz. Assuming CCM operation for parts (a) to (e).

   a. Derive expressions for the voltage across the inductor and use them to derive expressions for the input-to-output voltage and current ratios.
   b. Find the range of variation of the converter duty ratio when the converter output is kept constant at 24V. **[1/3 to 2/3]**
   c. Find the minimum output voltage that can continuously be supplied by the converter, and the corresponding range of duty ratio variation. **[16V, 0 to 0.5]**
   d. Sketch over two switching periods the voltage and current waveforms across the inductor, capacitor, switch, and diode.
   e. With the input and output voltages kept at 10V and 24V respectively. The output power maintained at 50W, calculate the average values of the input current, switch current, and diode current. Determine the peak-to-peak current ripple flowing through the inductor and the output voltage ripple across the capacitor. **[5A, 2.90A, 2.10A, 0.73A, 0.13V]**
   f. The Figure below shows the step-up boost converter characteristics by keeping constant output voltage. Write the normalized current $I_o/I_{oB,\max}$ as a function of the duty ratio D under BCM operation. The duty ratio under DCM is given by,

$$D = \sqrt{\frac{4}{27}\frac{V_o}{V_d}\left(\frac{V_o}{V_d}-1\right)\frac{I_o}{I_{oB,\max}}}$$



   g. Referring to part (e) with the same input and output voltages but now the output power is reduced to 4W. Determine the duty ratio the boost converter. **[0.61]**

EE4532, Part II
Tutorial 3, DC-DC Buck-Boost and Full-Bridge Converters

1. A DC-DC buck-boost converter, switching at 20kHz, is used for powering a 6Ω resistive load. The converter is supplied by a dc source of 40V and constructed using an inductor of 20μH. The output capacitor is very large and can keep the output voltage constant at 80V.

   a. Derive an expression for the load resistance under boundary conduction mode (BCM) in terms of the switching frequency, inductance, and duty ratio of the converter. Calculate the critical load resistance under BCM. **[7.2Ω]**
   b. Discuss whether the conditions given above result in continuous or discontinuous mode of operation. **[Continuous conduction mode]**
   c. Draw the current flowing through the diode and the voltage across it.
   d. If the output capacitor is lowered to a finite value of 470μF, calculate the output voltage ripple. **[0.95V]**

2. Derive the topologies of buck, boost, and buck-boost DC-DC converters based on a half-bridge converter.

3. A DC-DC full-bridge converter with an input voltage of V_d = 100V is shown in the Figure below. The duty ratio applied to the switch T_{A+} is 0.75.
   a. If the full-bridge converter is modulated by bipolar voltage switching, determine the average output voltage, rms value of the output voltage, and rms value of the ripple component in the output voltage. **[50V, 100V, 86.60V]**
   b. Repeat part (a) if the unipolar voltage switching technique is used and briefly describe its advantages. **[50V, 70.71V, 50V]**