Announcements

- ECCE Conference

- Homework 6 and Lab Report Due Friday
  - LTSpice example posted

Chapter 6: Converter Circuits

6.1. Circuit manipulations
6.2. A short list of converters
6.3. Transformer isolation
6.4. Converter evaluation and design
6.5. Summary of key points

- Where do the boost, buck-boost, and other converters originate?
- How can we obtain a converter having given desired properties?
- What converters are possible?
- How can we obtain transformer isolation in a converter?
- For a given application, which converter is best?
6.2 - A Short List of Converters

An infinite number of converters are possible, which contain switches embedded in a network of inductors and capacitors.

Two simple classes of converters are listed here:

- Single-input single-output converters containing a single inductor. The switching period is divided into two subintervals. This class contains eight converters.
- Single-input single-output converters containing two inductors. The switching period is divided into two subintervals. Several of the more interesting members of this class are listed.

Single Input/Output/Inductor Converters

- Use switches to connect inductor between source and load, in one manner during first subinterval and in another during second subinterval
- There are a limited number of ways to do this, so all possible combinations can be found
- After elimination of degenerate and redundant cases, eight converters are found:
  
  * dc-dc converters
    - buck
    - boost
    - buck-boost
    - noninverting buck-boost
  * dc-ac converters
    - bridge
    - Watkins-Johnson
  * ac-dc converters
    - current-fed bridge
    - inverse of Watkins-Johnson
Unipolar Output Converters

1. Buck

\[ M(D) = D \]

2. Boost

\[ M(D) = \frac{1}{1-D} \]

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Unipolar Output Converters (cont.)

3. Buck-boost

\[ M(D) = -\frac{D}{1-D} \]

4. Noninverting buck-boost

\[ M(D) = \frac{D}{1-D} \]

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Bipolar Output Converters

5. Bridge

\[ M(D) = 2D - 1 \]

\[ M(D) \]

6. Watkins-Johnson

\[ M(D) = \frac{2D - 1}{D} \]

\[ M(D) \]

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Bipolar Output Converters (cont.)

7. Current-fed bridge

\[ M(D) = \frac{1}{2D - 1} \]

\[ M(D) \]

8. Inverse of Watkins-Johnson

\[ M(D) = \frac{D}{2D - 1} \]

\[ M(D) \]

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**Example Two-Inductor Converters**

1. Čuk
   
   \[ M(D) = -\frac{D}{1-D} \]
   
   ![Čuk Converter Diagram]

2. SEPIC
   
   \[ M(D) = \frac{D}{1-D} \]
   
   ![SEPIC Converter Diagram]

3. Inverse of SEPIC
   
   \[ M(D) = \frac{D}{1-D} \]
   
   ![Inverse SEPIC Converter Diagram]

4. Buck
   
   \[ M(D) = D^2 \]
   
   ![Buck Converter Diagram]

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**Example Two-Inductor Converters (cont.)**

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**Chapter 6: Converter circuits**
6.3 - Transformer Isolation

Objectives:

- Isolation of input and output ground connections, to meet safety requirements
- Reduction of transformer size by incorporating high frequency isolation transformer inside converter
- Minimization of current and voltage stresses when a large step-up or step-down conversion ratio is needed —use transformer turns ratio
- Obtain multiple output voltages via multiple transformer secondary windings and multiple converter secondary circuits

Ideal Transformer Model

![Diagram of multiple winding transformer]

\[
\frac{v_1(t)}{n_1} = \frac{v_2(t)}{n_2} = \frac{v_3(t)}{n_3} = ... \\
0 = n_1i_1(t) + n_2i_2(t) + n_3i_3(t) + ...
\]

Real XF has:

1. Magnetizing Inductance \( L_m \)
2. Leakage Inductance \( L_{ki} \)
3. Core material saturation \( X \)
Transformer Saturation

Transformer core B-H characteristic

Transformer Reset

- “Transformer reset” is the mechanism by which magnetizing inductance volt-second balance is obtained
- The need to reset the transformer volt-seconds to zero by the end of each switching period adds considerable complexity to converters
- To understand operation of transformer-isolated converters:
  - replace transformer by equivalent circuit model containing magnetizing inductance
  - analyze converter as usual, treating magnetizing inductance as any other inductor
  - apply volt-second balance to all converter inductors, including magnetizing inductance
Buck-derived Isolated Converters

![Buck-derived Isolated Converter Diagram]

Full Bridge Converter

![Full Bridge Converter Diagram]

- \( L_n \) is parasitic
- Design so that \( L_n \) is "large"
- \( i_n \ll n I_1 \)
- Need to make sure it doesn't saturate
- No DC voltage at \( V_T(\cdot) \)