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

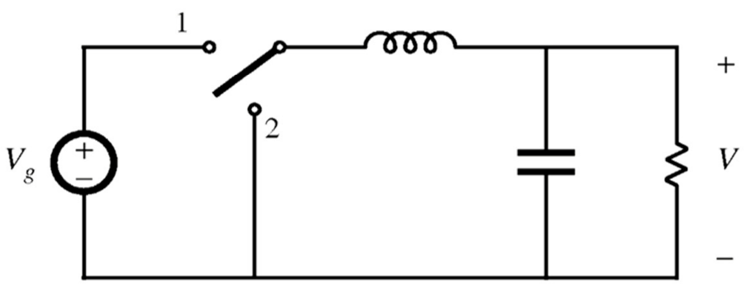
ac-dc converters

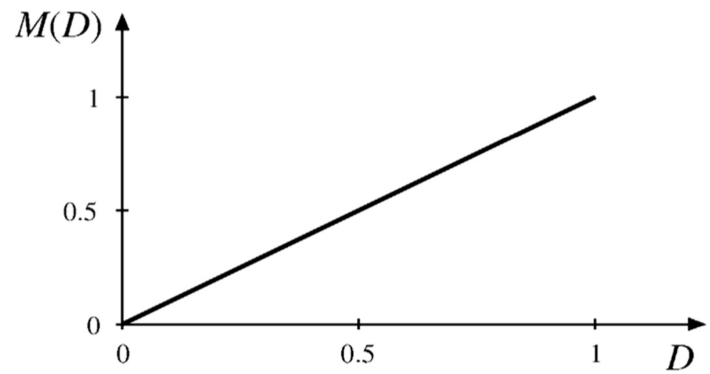
current-fed bridge inverse of Watkins-Johnson

THE UNIVERSITY OF TENNESSEE KNOXVILLE

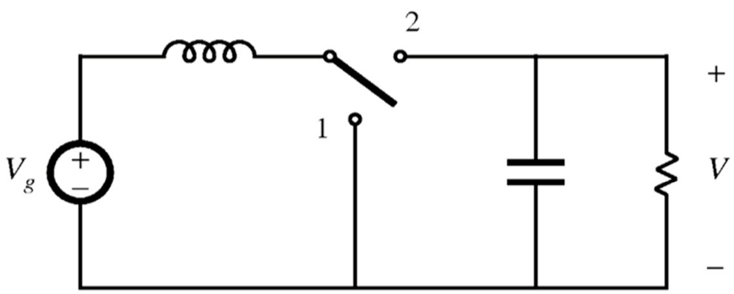
Unipolar Output Converters

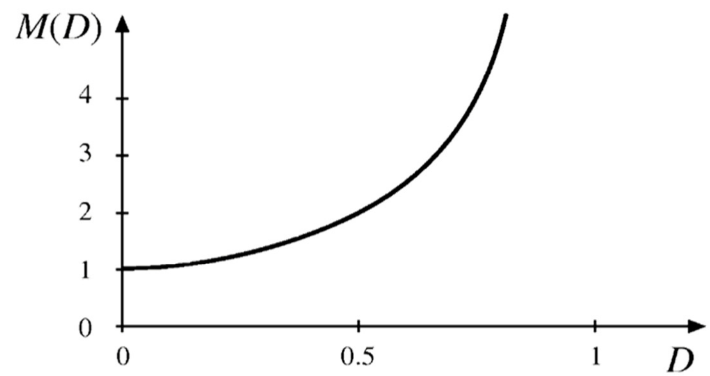
1. *Buck* $M(D) = D$





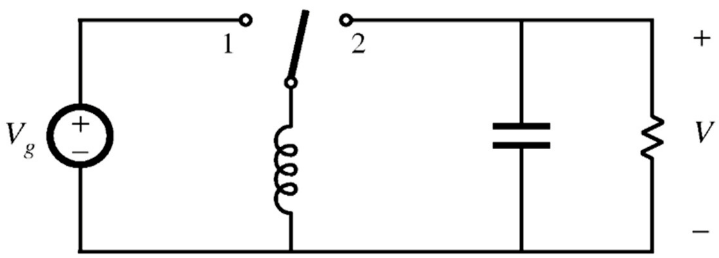
2. *Boost* $M(D) = \frac{1}{1-D}$

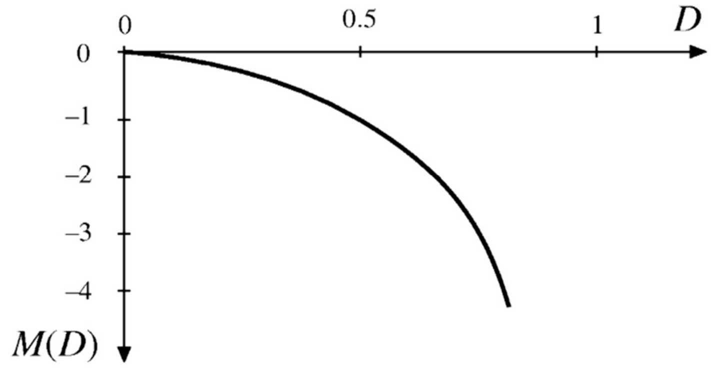




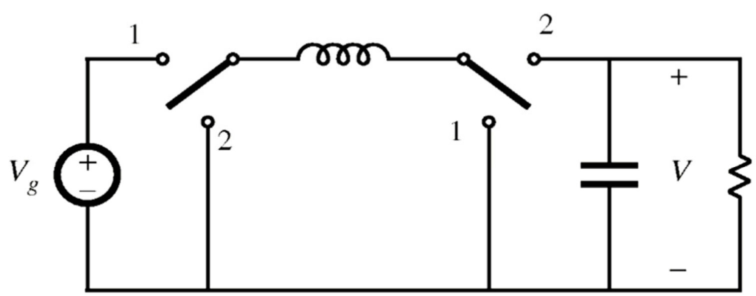
Unipolar Output Converters (cont.)

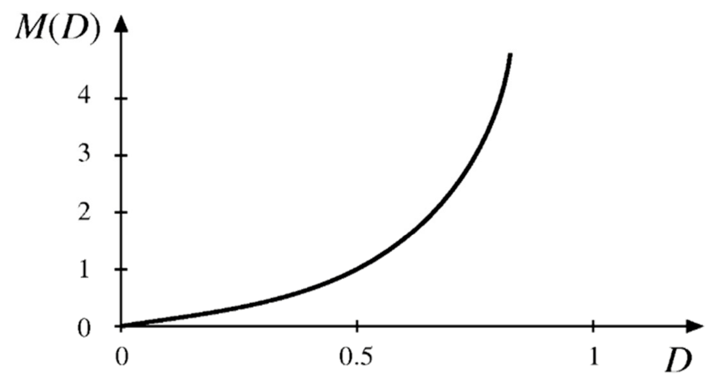
3. *Buck-boost* $M(D) = -\dfrac{D}{1-D}$





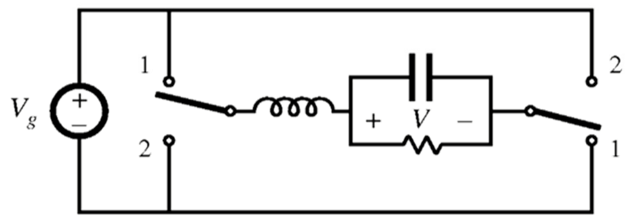
4. *Noninverting buck-boost* $M(D) = \dfrac{D}{1-D}$

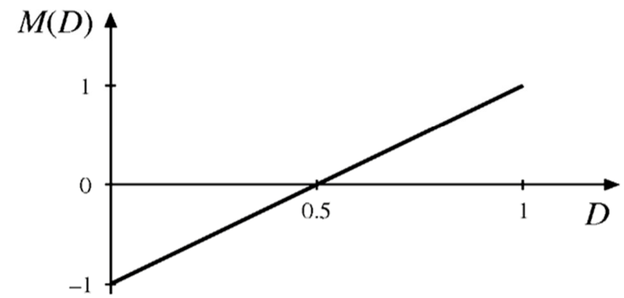




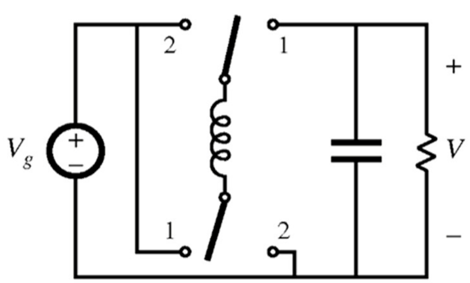
Bipolar Output Converters

5. *Bridge* $M(D) = 2D - 1$

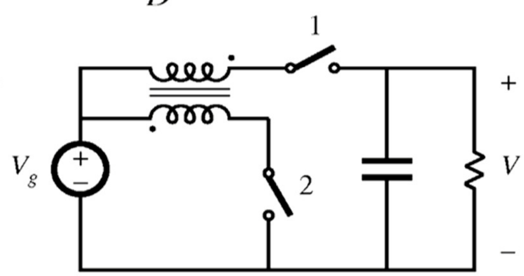


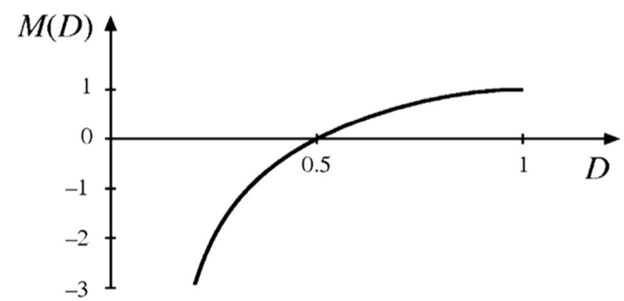


6. *Watkins-Johnson* $M(D) = \dfrac{2D - 1}{D}$



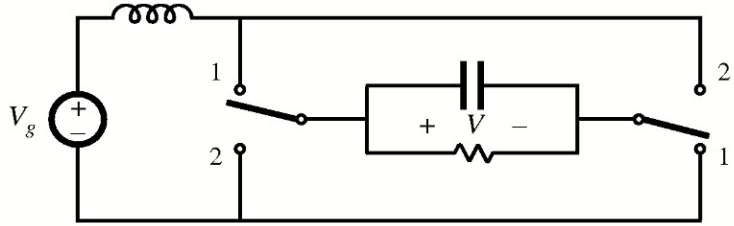
or

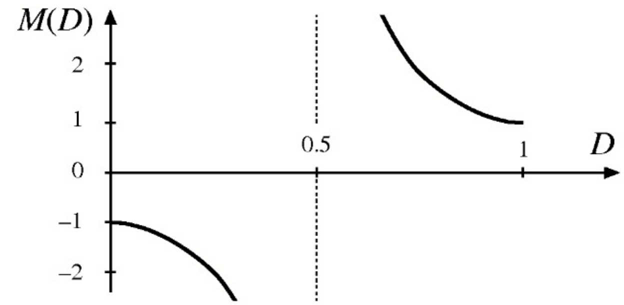




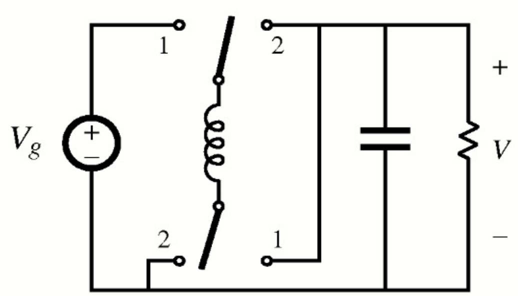
Bipolar Output Converters (cont.)

7. *Current-fed bridge* $M(D) = \dfrac{1}{2D - 1}$

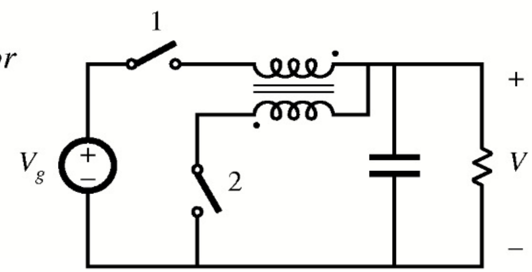


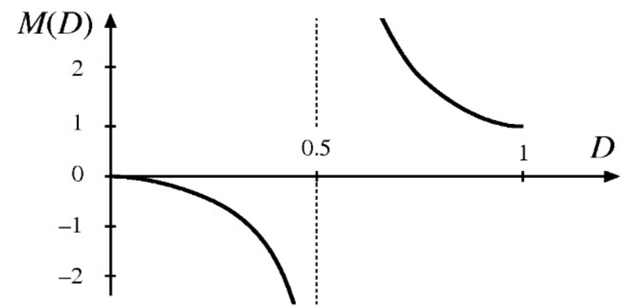


8. *Inverse of Watkins-Johnson* $M(D) = \dfrac{D}{2D - 1}$



or

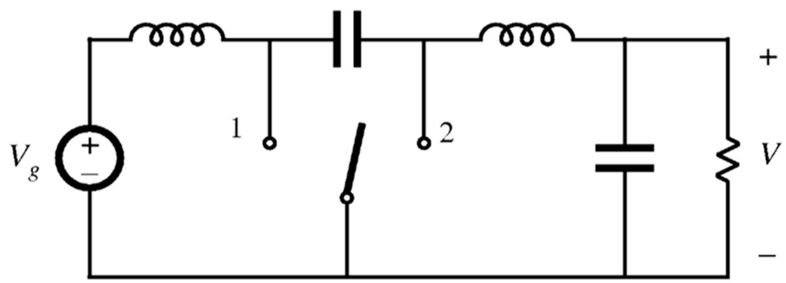


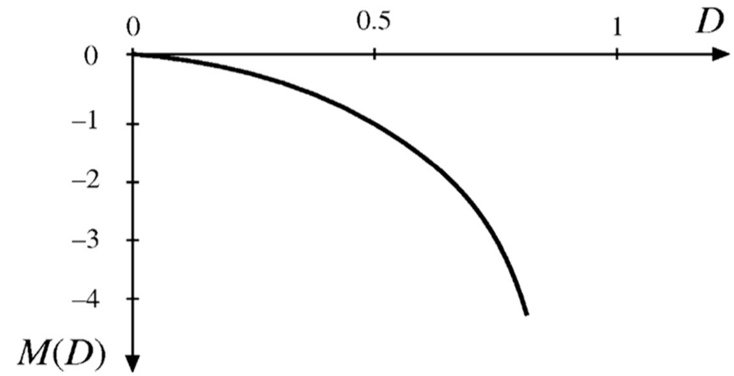


THE UNIVERSITY OF TENNESSEE KNOXVILLE

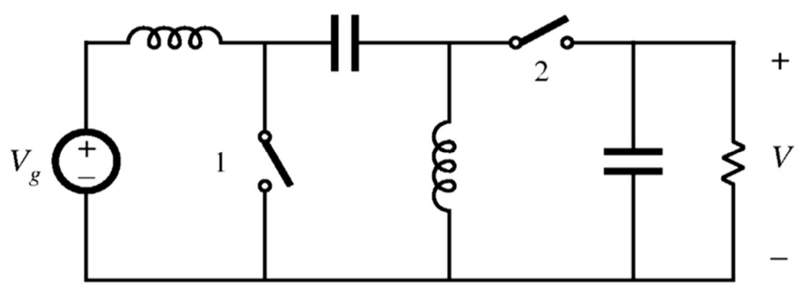
Example Two-Inductor Converters

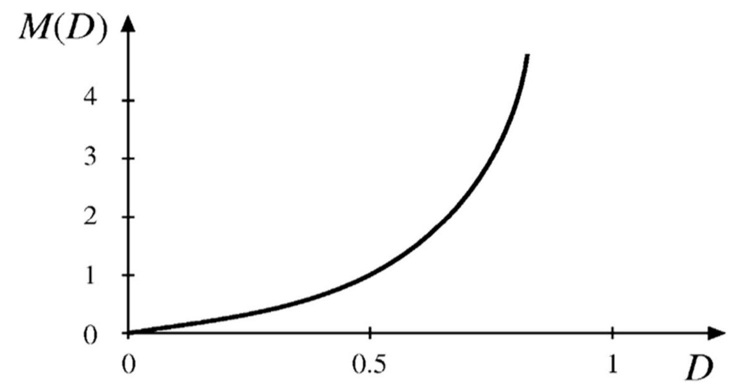
1. *Ćuk* $M(D) = -\frac{D}{1-D}$





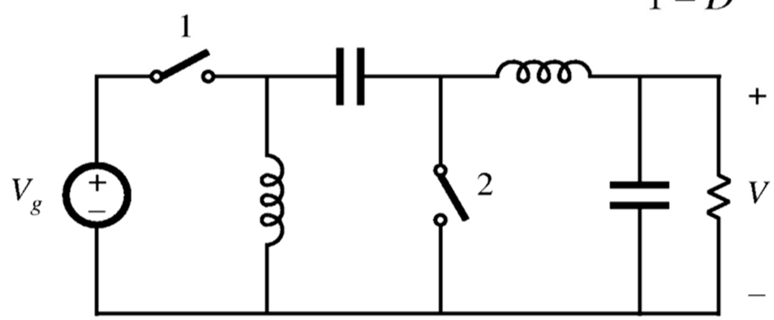
2. *SEPIC* $M(D) = \frac{D}{1-D}$

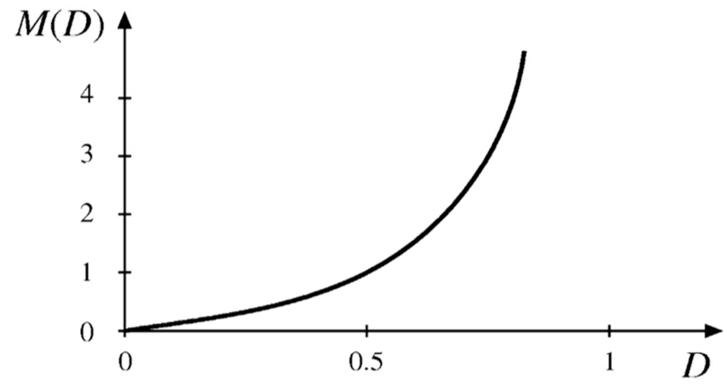




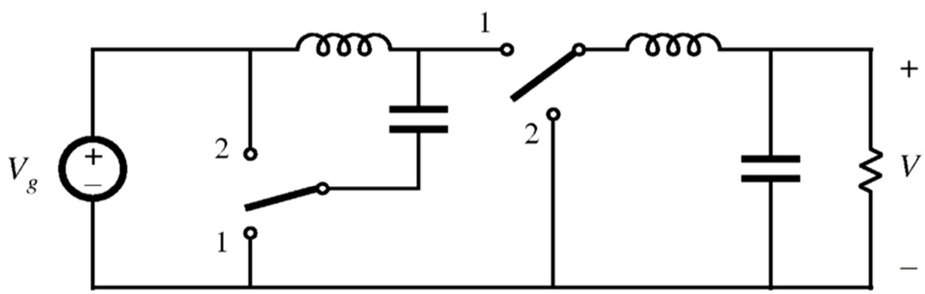
Example Two-Inductor Converters (cont.)

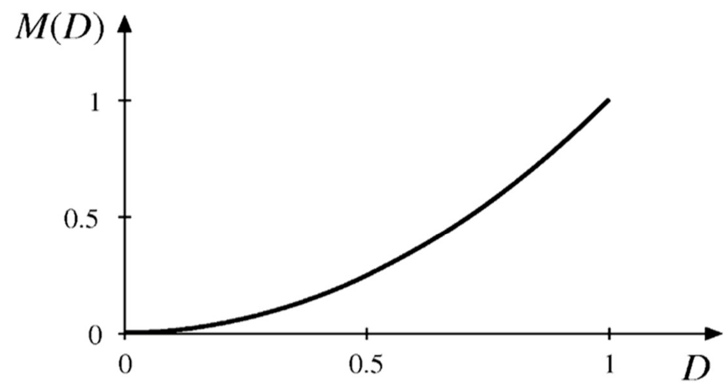
3. *Inverse of SEPIC* $M(D) = \frac{D}{1-D}$





4. *Buck* [2] $M(D) = D^2$



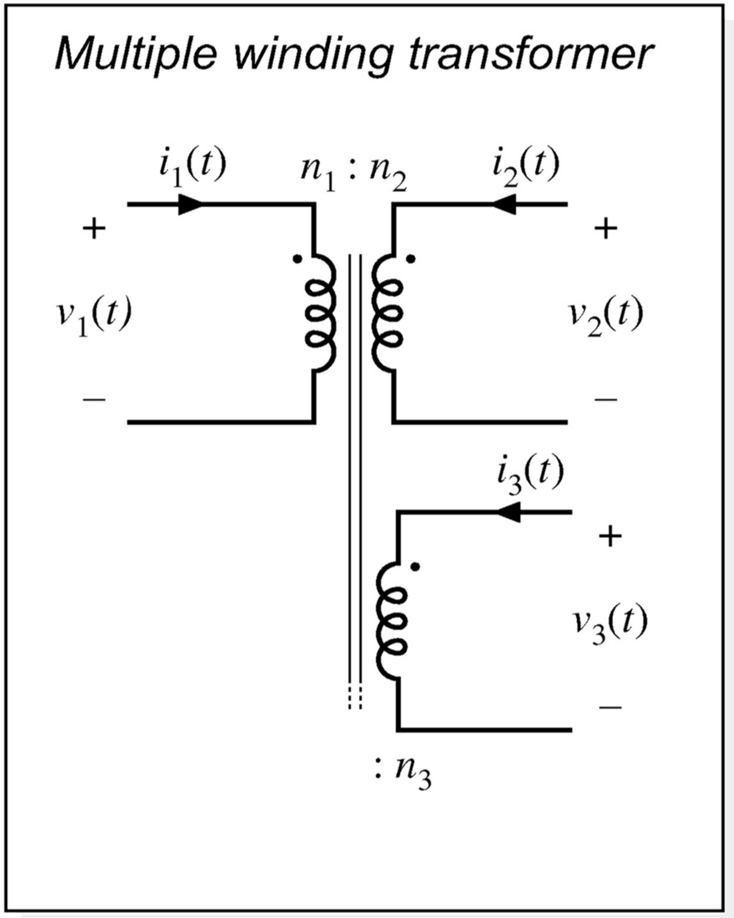


6.3 - Transformer Isolation

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

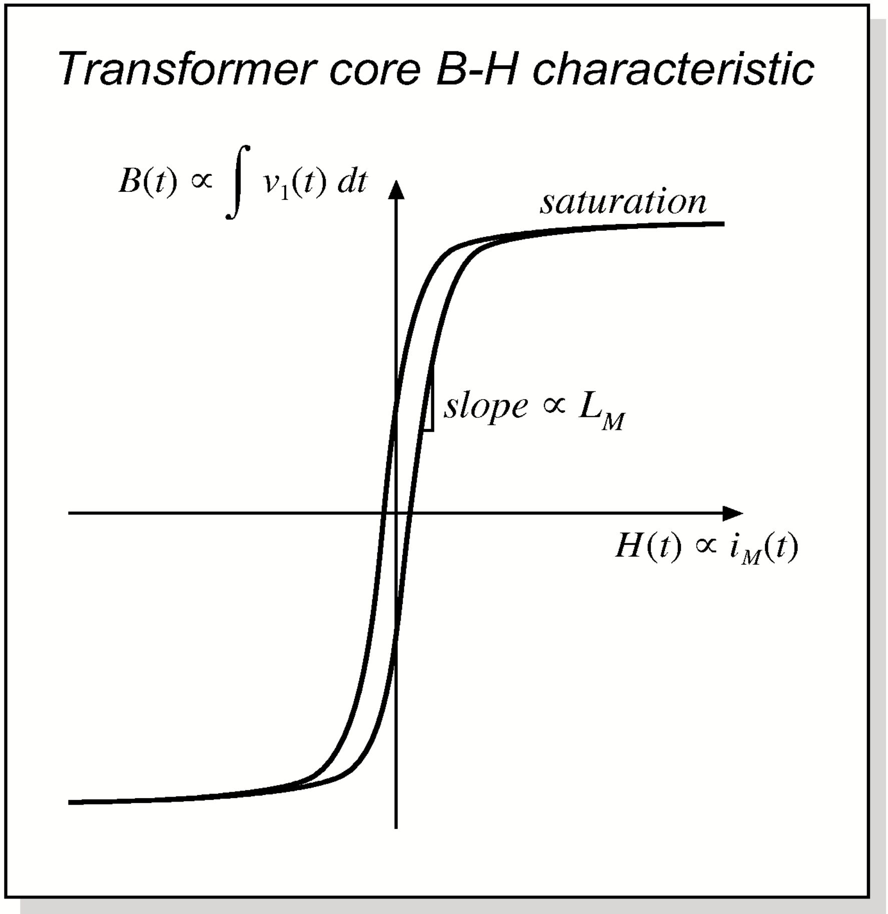
Ideal Transformer Model



$$\frac{v_1(t)}{n_1} = \frac{v_2(t)}{n_2} = \frac{v_3(t)}{n_3} = \ldots$$

$$0 = n_1 i_1'(t) + n_2 i_2(t) + n_3 i_3(t) + \ldots$$

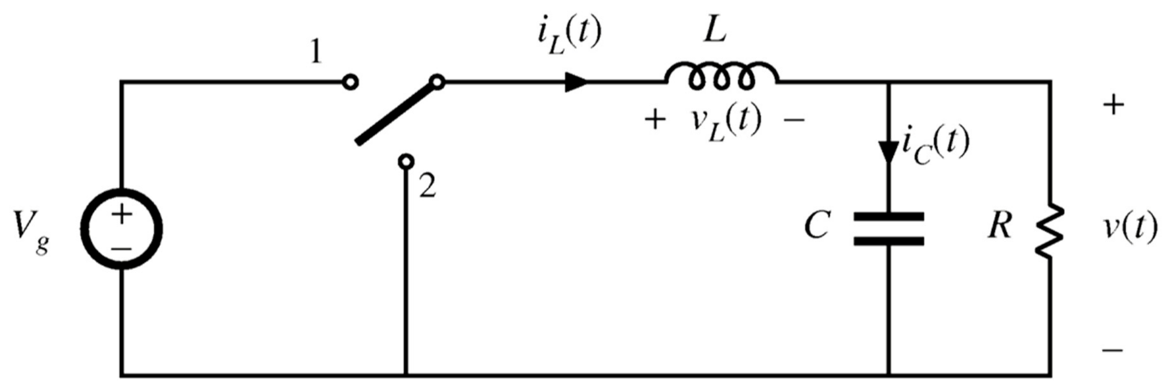
Transformer Saturation

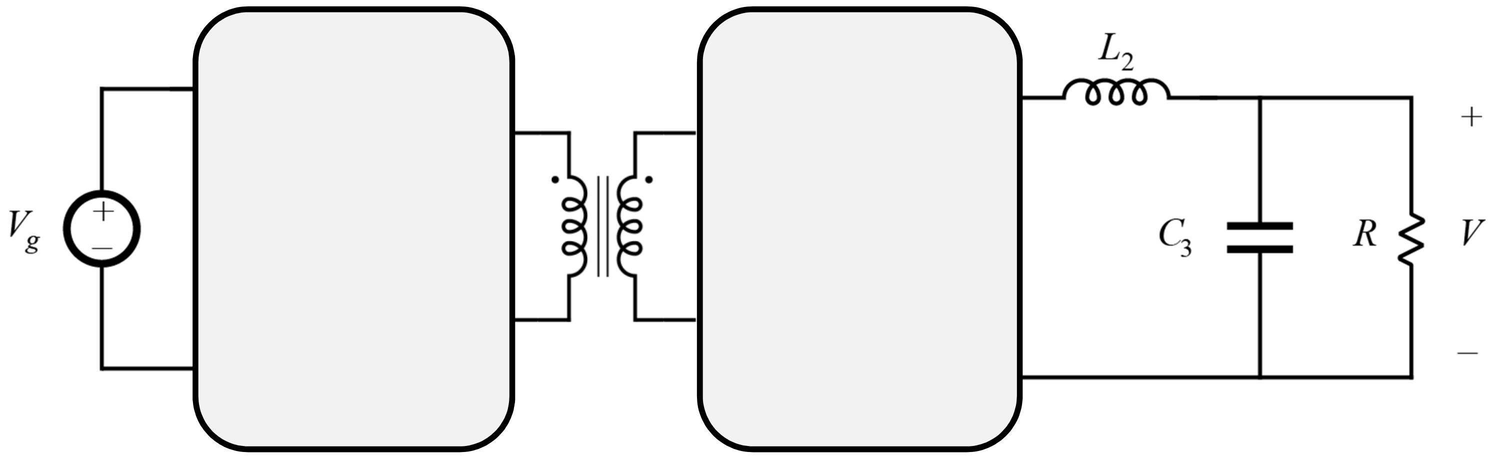


Transformer Reset

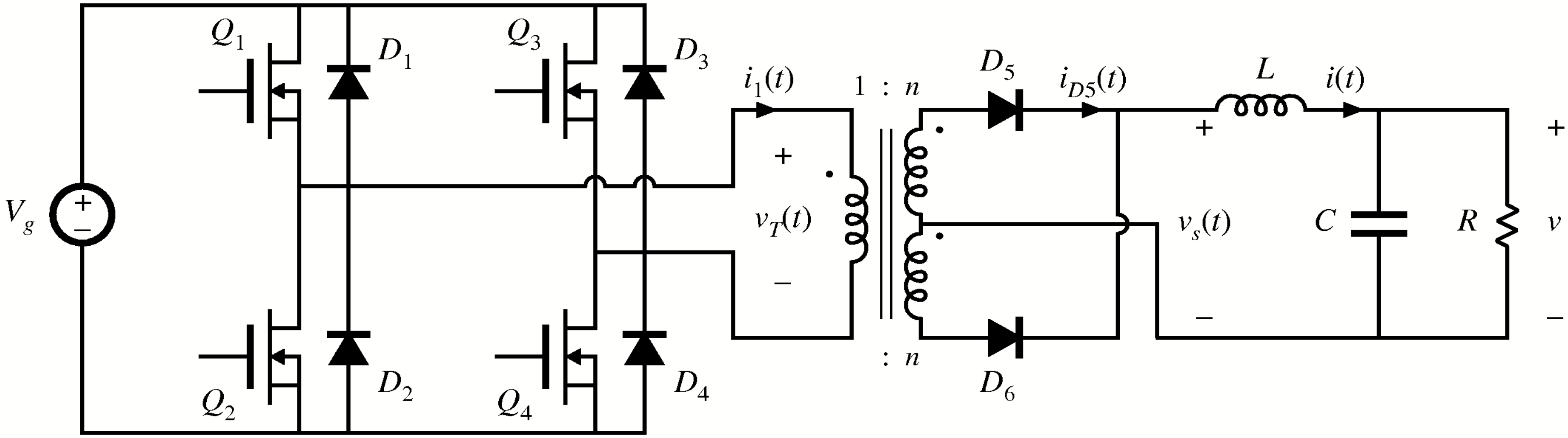
- "Transformer reset" is the mechanism by which magnetizing inductance volt-second balance is obtained
- The need to reset the transformer volt-seconds to zero by the end of each switching period adds considerable complexity to converters
- To understand operation of transformer-isolated converters:
  - 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





Full Bridge Converter



Full Bridge Converter