Cuk DCM M(D,K)

$$D_2 = \frac{-V_g}{V} D_1$$

$$\phi = -\frac{1}{T_s}\left[\frac{1}{2}(D_1 + D_2) T_s^2 \left(\frac{-V}{L_2}\right) D_2 + \frac{1}{2} T_s^2 D_1 D_2 \left(\frac{V}{L_2} + \frac{V_g}{L_1}\right) \right] - \frac{V}{R}$$

$$\frac{2}{T_s}\frac{V}{R} = \left[\left(D_1 - D_1 \frac{V_g}{V}\right)\left(\frac{V}{L_2}\right)\left(\frac{-V_g}{V} D_1\right) - D_1 D_1 \left(\frac{-V_g}{V}\right)\left(\frac{V}{L_2} + \frac{V_g}{L_1}\right) \right]$$

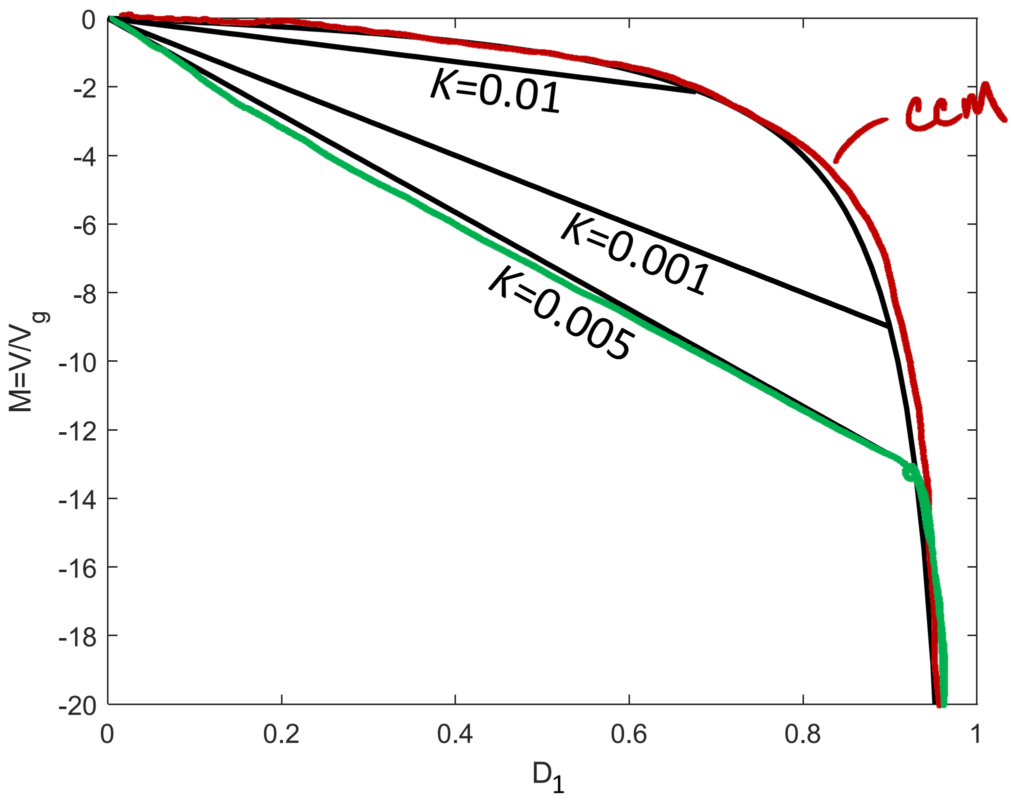
$$\frac{2}{RT_s} V = D_1^2 \frac{V_g}{V} \left[-\left(1 - \frac{V_g}{V}\right)\frac{V}{L_2} + \frac{V}{L_2} + \frac{V_g}{L_1} \right]$$

$$\frac{2}{RT_s} V = D_1^2 \frac{V_g}{V} \left[-\cancel{\frac{V}{L_2}} + \frac{V_g}{L_2} + \cancel{\frac{V}{L_2}} + \frac{V_g}{L_1} \right]$$

$$\frac{V^2}{V_g^2} = D_1^2 \frac{RT_s}{2} \left[\frac{1}{L_2} + \frac{1}{L_1} \right]$$

$$L_{eq} = L_1 \| L_2 = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2}}$$

$$M^2 = D_1^2 \frac{RT_s}{2L_{eq}} \rightarrow M^2 = \frac{D_1^2}{K} \rightarrow \boxed{M_{DCM} = -\frac{D_1}{\sqrt{K}}}$$


0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
M=V/Vg
0
0.2
0.4
0.6
0.8
1
D1
K=0.01
K=0.001
K=0.005
ccm

Summary of DCM Characteristics

Table 5.2. Summary of CCM-DCM characteristics for the buck, boost, and buck-boost converters

Converter	$K_{crit}(D)$	DCM $M(D,K)$	DCM $D_2(D,K)$	CCM $M(D)$
Buck	$(1-D)$	$\frac{2}{1+\sqrt{1+4K/D^2}}$	$\frac{K}{D}M(D,K)$	D
Boost	$D(1-D)^2$	$\frac{1+\sqrt{1+4D^2/K}}{2}$	$\frac{K}{D}M(D,K)$	$\frac{1}{1-D}$
Buck-boost	$(1-D)^2$	$-\frac{D}{\sqrt{K}}$	$\sqrt{K}$	$-\frac{D}{1-D}$

with $K = 2L/RT_s$. DCM occurs for $K < K_{crit}$.

Chapter 6

CONVERTER TOPOLOGIES

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

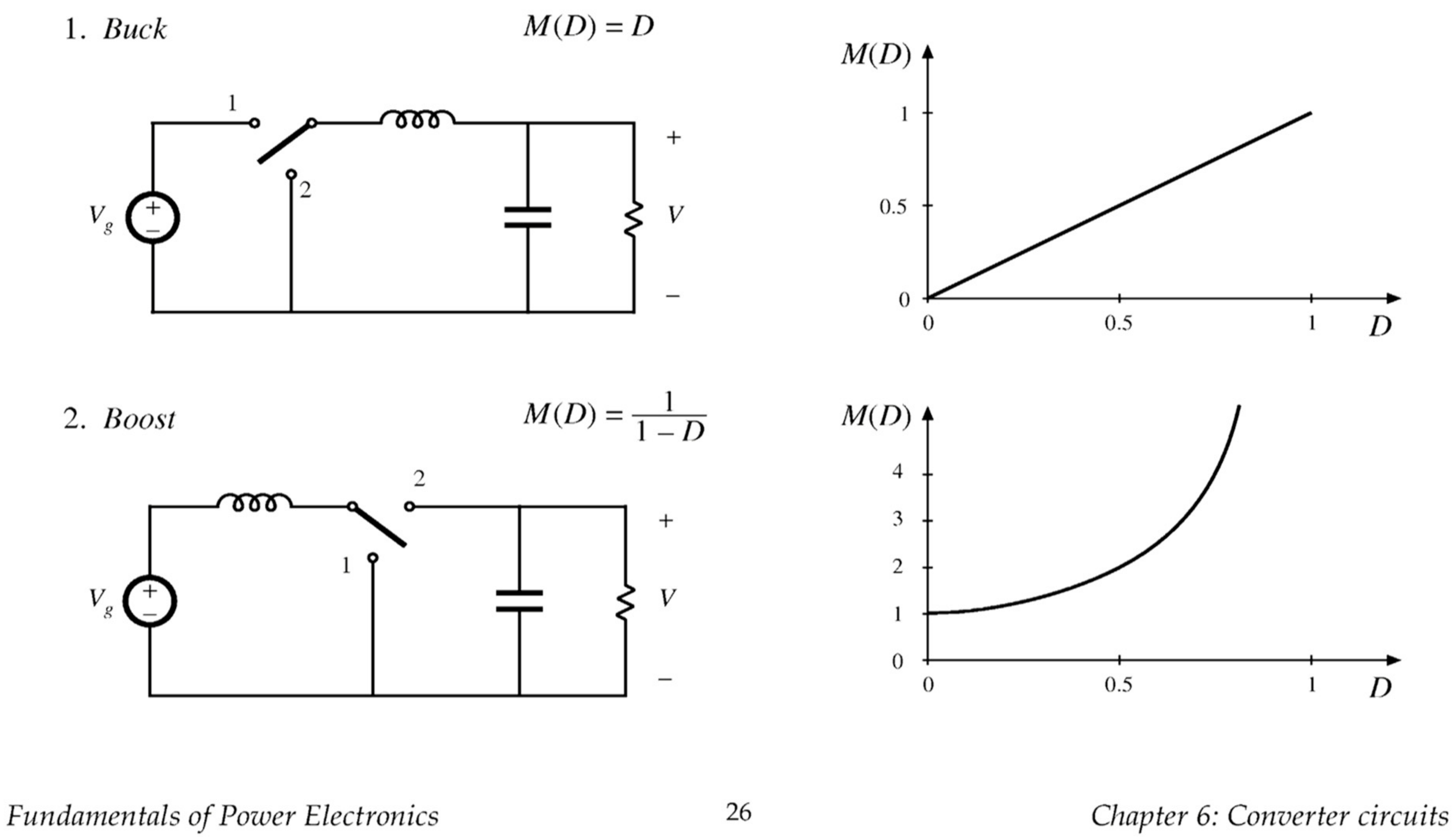
dc-ac converters

bridge   Watkins-Johnson

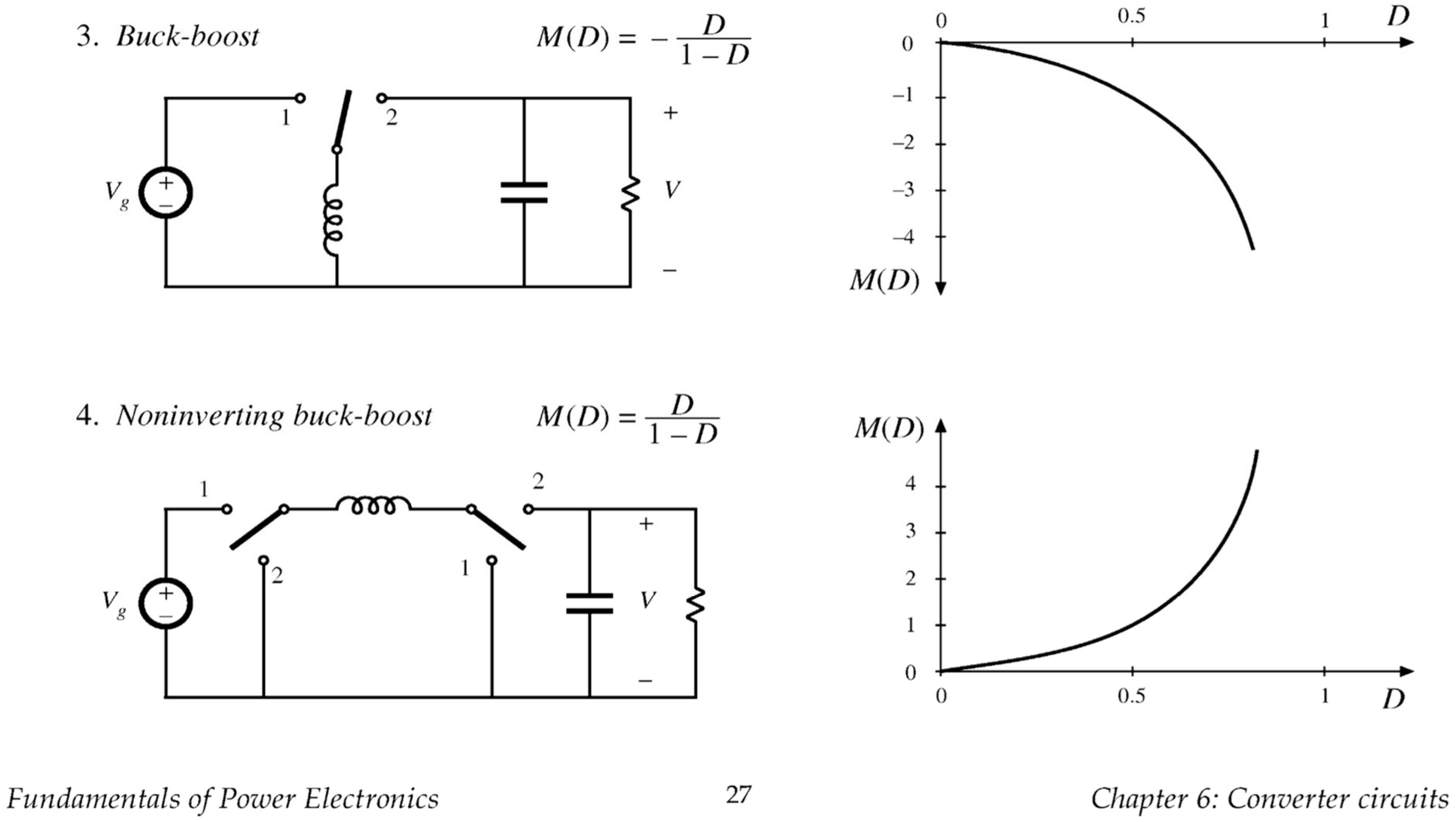
ac-dc converters

current-fed bridge   inverse of Watkins-Johnson

Unipolar Output Converters

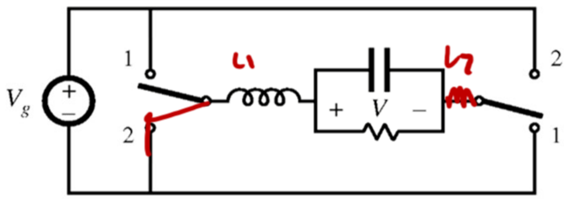


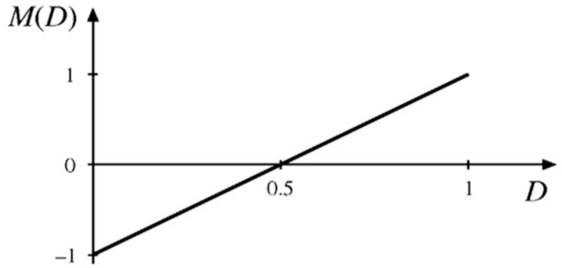
Unipolar Output Converters (cont.)



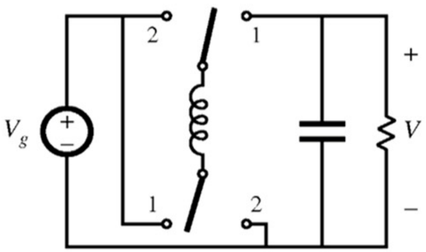
Bipolar Output Converters

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

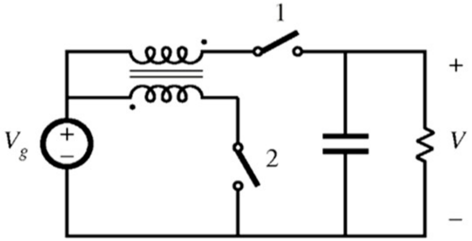


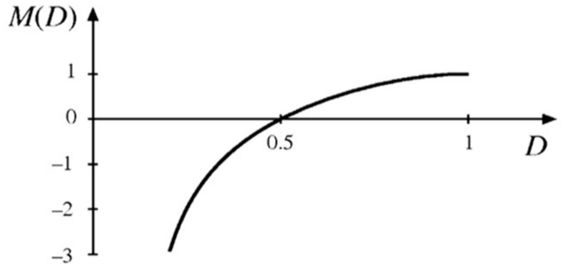


6. *Watkins-Johnson* $M(D) = \frac{2D - 1}{D}$



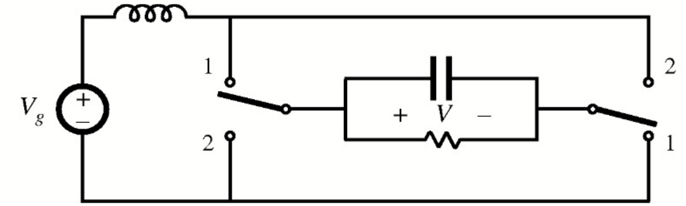
or

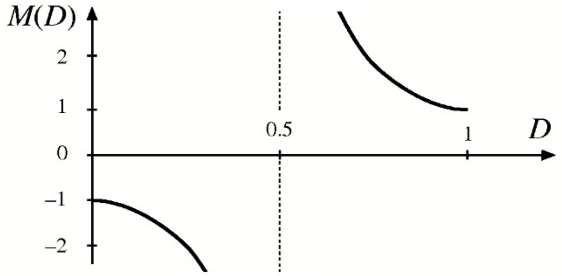




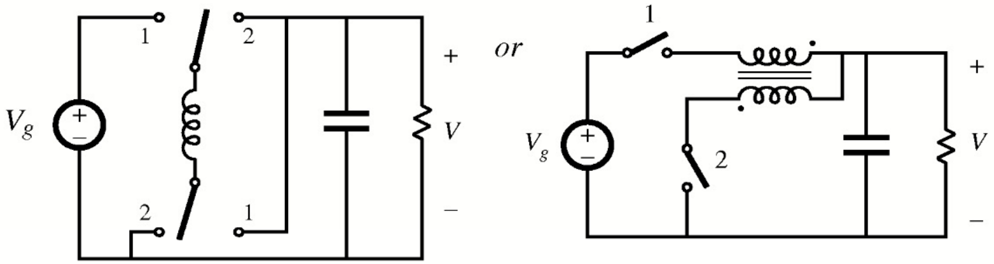
Bipolar Output Converters (cont.)

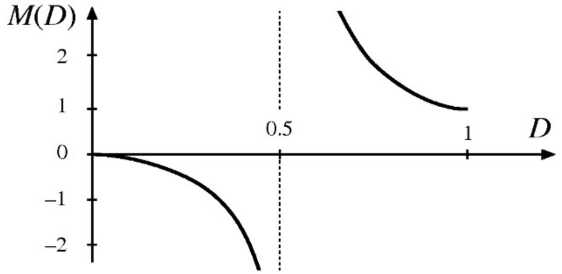
7. *Current-fed bridge* $\quad M(D) = \frac{1}{2D-1}$



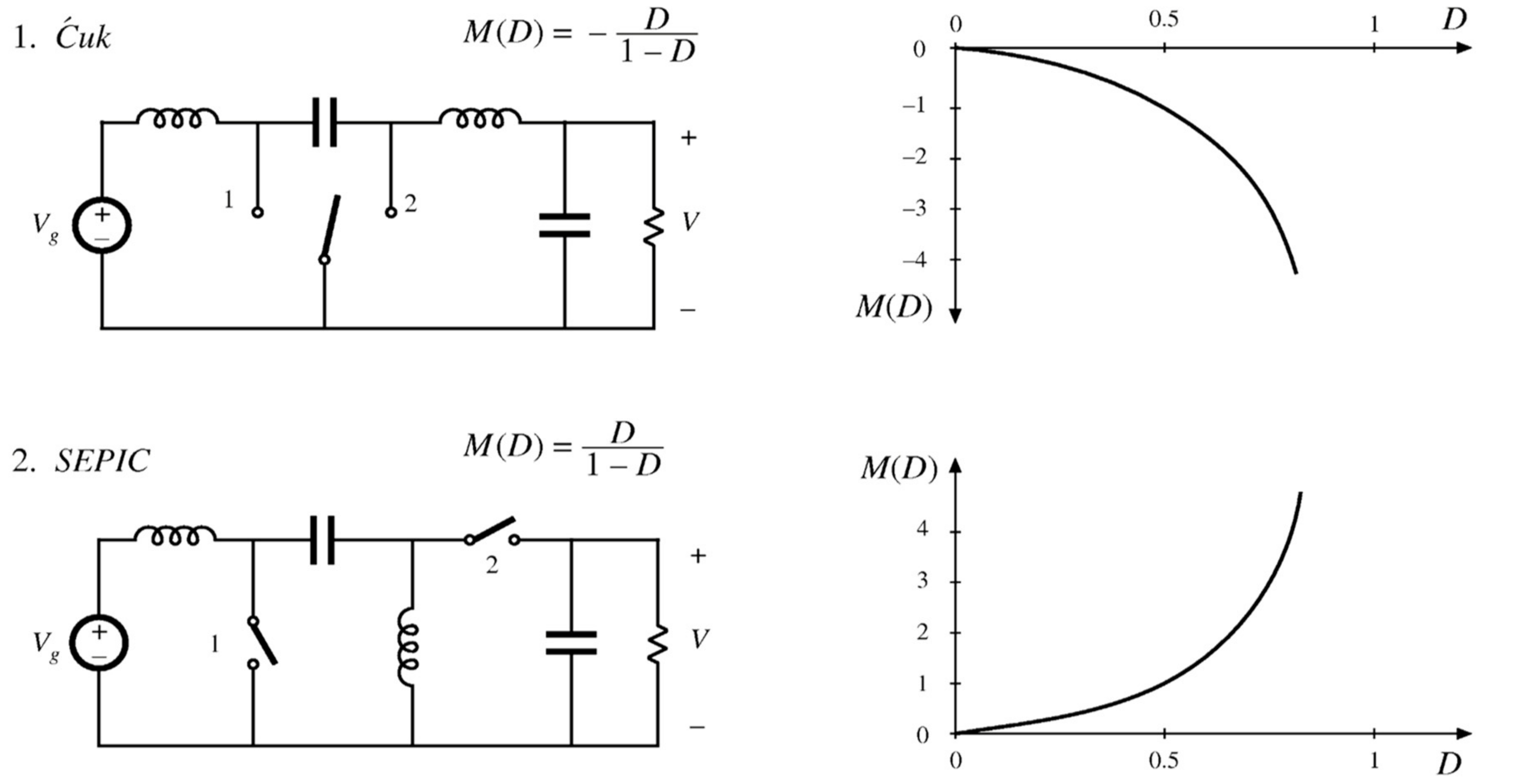


8. *Inverse of Watkins-Johnson* $\quad M(D) = \frac{D}{2D-1}$



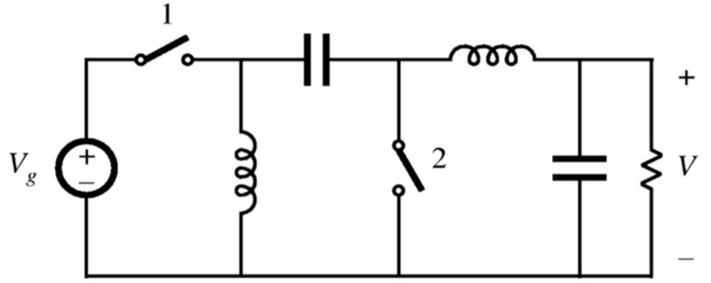


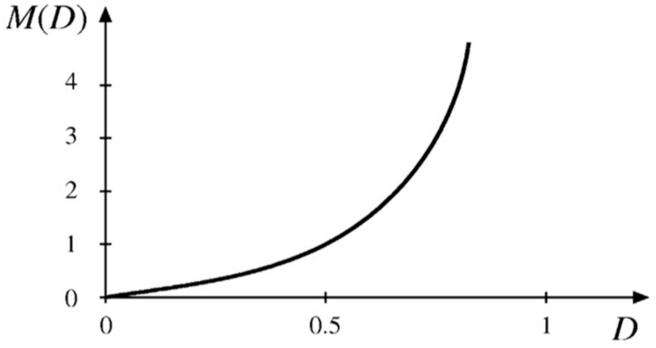
Example Two-Inductor Converters



Example Two-Inductor Converters (cont.)

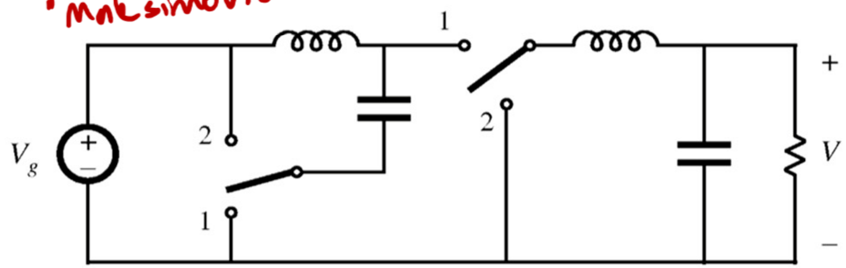
3. *Inverse of SEPIC* $M(D) = \frac{D}{1-D}$

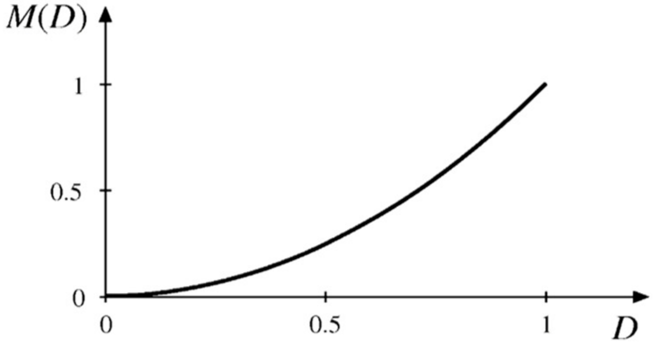




4. *Buck* [2] $M(D) = D^2$

"Maksimovic"

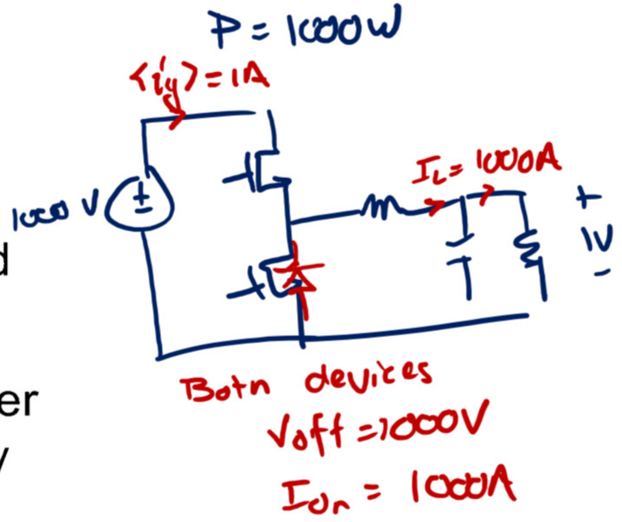




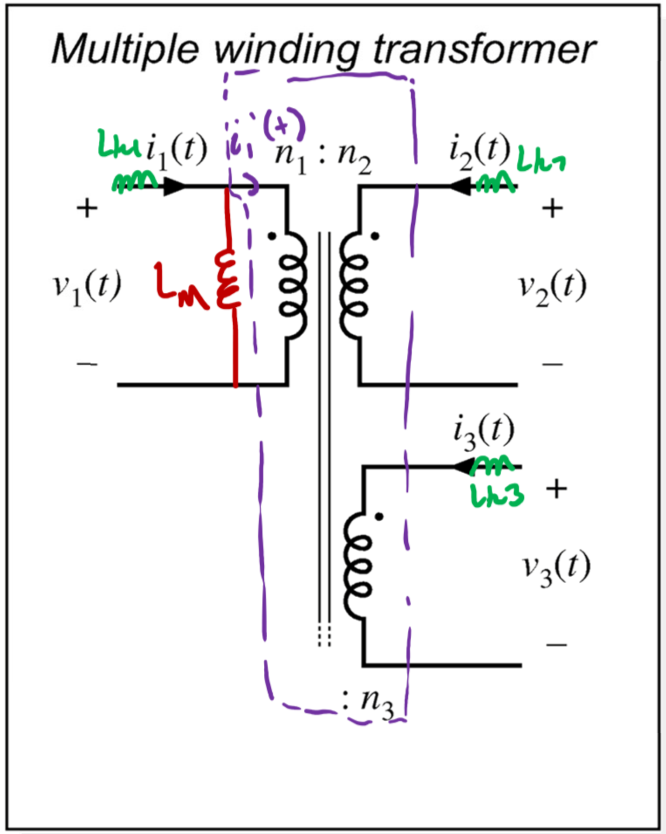
6.3 - Transformer Isolation

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



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

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

L_{ki} → leakage inductance

L_m → magnetizing inductance

Ideal
$L_{ki} \to 0$
$L_m \to \infty$
} $k_{ij} \to 1$ & L_m "very large"

Core is unsaturated

Cannot apply DC to any XF winding

Transformer Saturation

$L_M = \frac{\mu N_1^2 A_c}{l_m}$

$B = \mu H$