ECE314 Course Notes

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1 Introduction

2 DC-DC Converters

2.1 Buck Converter

2.1.1 Inductance

The value of the inductor can be selected to minimize inductor current ripple:

$$L = \frac{V_g - V}{2\Delta i_L} DT_s$$

2.2 DC-DC Conversion Ratios

Converter	$M(D)$
Buck	D
Boost	$\frac{1}{1-D}$
Buck-boost	$\frac{-D}{1-D}$
Cuk	$\frac{-D}{1-D}$

3 Conduction Modes

CCM, DCM

$$I > \Delta i_L \quad \text{for CCM}$$
$$I < \Delta i_L \quad \text{for DCM}$$

3.1 K

The dimensionless parameter K describes the tendency of a converter to operate in DCM. Specifically,

$$K < K_{crit} \Rightarrow \text{DCM} \qquad K > K_{crit} \Rightarrow \text{CCM}$$

3.2 R

The load resistance R can also be used to express the mode boundary:

$$R < R_{crit}(D) \Rightarrow \text{CCM} \qquad R > R_{crit}(D) \Rightarrow \text{DCM}$$

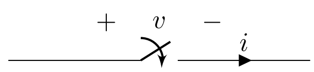
3.3 Conduction Mode Boundaries

For $D' = 1 - D$,

Converter	$K_{crit}(D)$	$\max\limits_{0 \leq D \leq 1}(K_{crit})$	$R_{crit}(D)$	$\max\limits_{0 \leq D \leq 1}(R_{crit})$
Buck	(D')	1	$\frac{2L}{(D')T_s}$	$2\frac{L}{T_2}$
Boost	$D(D')^2$	$\frac{4}{27}$	$\frac{2L}{D(D')^2 T_s}$	$\frac{27}{2}\frac{L}{T_s}$
Buck-boost	$(D')^2$	1	$\frac{2L}{(D')^2 T_s}$	$2\frac{L}{T_s}$

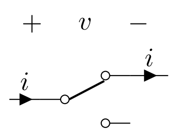
4 Switch Realization

4.1 Single-Pole Single-Throw (SPST)



Note: Ideal semiconductor power devices behave as SPST switches

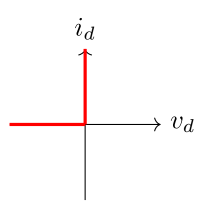
4.2 Single-Pole Double-Throw (SPDT)

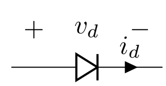


Note: Converter schematics frequently use SPDT switches

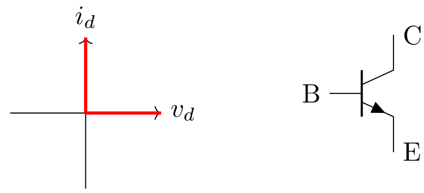
4.3 Single Quadrant Switches

4.3.1 Diode

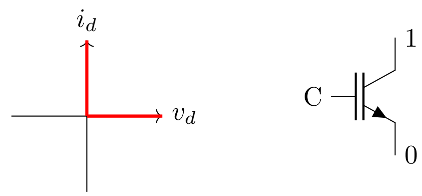




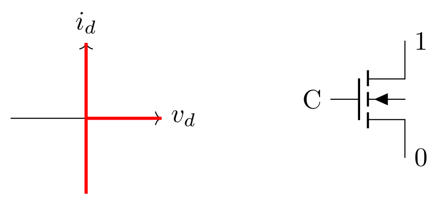
4.3.2 BJT



4.3.3 IGBT



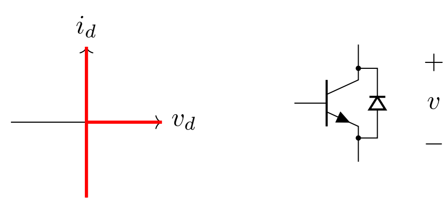
4.3.4 MOSFET



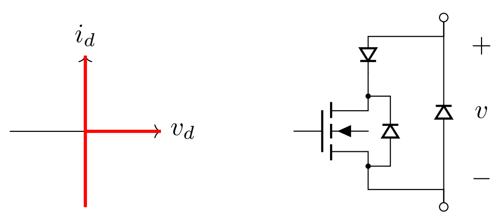
Note: The MOSFET is normally operated with $i \geq 0$

4.4 Current-Bidirectional Two Quadrant Switches

4.4.1 BJT and Diode

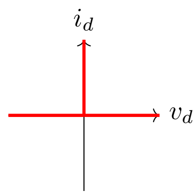


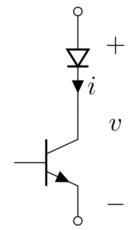
4.4.2 MOSFET and External Diodes



4.5 Voltage-Bidirectional Two-Quadrant Switches

4.5.1 BJT and Diode





4.6 Four Quadrant Switches

5 Fourier Series

$$\omega = 2\pi \cdot f$$

$$x(t) = \sum_{n=1}^{\infty} a_k \cos(\omega_k t) + b_k \sin(\omega_k t)$$

$$a_k = \frac{2}{T} \int_{-T/2}^{T/2} x(t) \cos(k\omega t) dt$$

$$b_k = \frac{2}{T} \int_{-T/2}^{T/2} x(t) \sin(k\omega t) dt$$

6 RMS

$$X_{RMS}(t) = \sqrt{\frac{1}{T} \int_0^T x(t)^2 dt} = \sqrt{x_o^2 + \sum_{n=1}^{\infty} \frac{x_n^2}{2}}$$

7 Total Harmonic Distortion (THD)

$$\text{THD} = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$$

8 Distortion Factor (DF)

$$\text{DF} = \frac{1}{\sqrt{1 + \text{THD}^2}}$$

9 Power Factor

$$\text{PF} = \text{Distortion Factor} \cdot \text{Displacement Factor}$$

$$\text{PF} = \frac{I_1/\sqrt{2}}{\sqrt{I_o^2 + \sum_{n=1}^{\infty} \frac{I_n^2}{2}}}$$

10 Magnetics

10.1 Ampere's Law

$$\oint_C H \cdot dl = \int_S J \cdot da = H \cdot l_c = N \cdot i$$

10.2 Faraday's Law

$$\oint E \cdot ds = -\frac{d}{dt} B \cdot ds$$

$$e(t) = A \frac{dB(t)}{dt}$$

$$e = N \frac{d\phi}{dt} = \frac{d\lambda}{dt} \qquad \lambda = N\phi$$

10.3 Flux and Flux Density

$$\phi = \int_S B \cdot dA$$

$$B_g = \frac{\phi_g}{A_g} \quad B_c = \frac{\phi_c}{A_c}$$

10.4 MMF

$$\mathbb{F} = \oint_C \vec{H} \cdot dl = N \cdot i = H_c \cdot l_c$$

10.5 BH Relationship

$$\vec{B} = \mu \vec{H}$$

10.6 Magnetic Kirchoff's Law

$$\mathbb{F} = \phi \cdot \mathbb{R}$$

10.7 Inductance

$$L = \frac{\lambda}{i} = \frac{N\phi}{i}$$

For a solenoid

$$L = \frac{N^2}{\mathbb{R}} = \frac{N^2 \mu_0 A_g}{g}$$

10.8 Induced Voltage

$$e = L\frac{di}{dt} + i\frac{dL}{dt}$$

If L is static:

$$e = L\frac{di}{dt}$$

10.8.1 Instantaneous Power

$$P = i \cdot e = i\frac{d\lambda}{dt}$$

10.9 Power and Energy

$$\delta W = \int_{t_1}^{t_2} pdt = \int_{lambda_1}^{lambda_2} id\lambda$$

$$W = \frac{1}{2L}\lambda^2 = \frac{L}{2}i^2$$