Cheat Sheet for EE463

Performance Parameters

$$I_{rms} = \sqrt{\frac{1}{T}\int i^2 dt}$$

$$CrestFactor = \frac{V_{peak}}{V_{rms}}$$

$$DistortionFactor = \frac{I_{1rms}}{I_{rms}} = \frac{1}{\sqrt{1+THD^2}}$$

ϕ : phase difference between fundamentals of current and voltage

$$DisplacementPowerFactor = \cos(\phi)$$

$$TruePowerFactor = \frac{P}{S} = DPF\frac{I_{1,RMS}}{I_{RMS}}$$

$$THD = \sqrt{(\frac{I_{rms}}{I_{1rms}})^2 - 1}$$

Single Phase Diode Rectifier

$$V_{av} = \frac{2\sqrt{2}V_s}{\pi}(Fullwave), V_{av} = \frac{\sqrt{2}V_s}{\pi}(Halfwave)$$

u: commutation period

$$\cos(u) = 1 - \frac{2\omega L_s I_d}{\sqrt{2}V_s} \qquad \text{(Full wave)}$$

$$\cos(u) = 1 - \frac{\omega L_s I_d}{\sqrt{2}V_s} \qquad \text{(Half wave)}$$

$$A_u = \int_0^u V_s\sqrt{2}sin(\omega t)d\omega t = \omega L_s I_d$$

$$\text{Commutation Loss}: \frac{2\omega L_s I_d}{2\pi} \qquad \text{(Full wave)}$$

$$\frac{\omega L_s I_d}{2\pi} \qquad \text{(Half wave)}$$

$$I_{d,avg} = \frac{\int_b^f i(\theta)d\theta}{\pi}$$

$$I_{d,shortcircuit} = \frac{V_s}{\omega L_s}$$

Three Phase Rectifier

- Half Wave

$$V_{av} = \frac{3\sqrt{6}V_s}{2\pi} = \frac{3\sqrt{2}V_{ll}}{2\pi}$$

- Full Wave

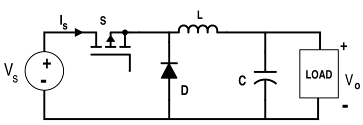
  Full Bridge Rectifier Average Output V_s:rms value of source voltage

$$V_{av} = \frac{3\sqrt{6}V_s}{\pi} - \frac{3wL_sI_d}{\pi}$$

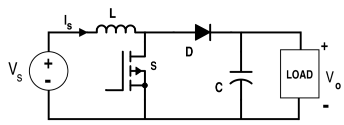
Comparison of Rectifiers

Type	Vout	ΔVout	f_{ripple}
Single Phase	$\frac{2\sqrt{2}}{\pi}V_{ph}$ = 207 V	$\sqrt{2}V_{ph} = 325V$	100 Hz
3-phase Half Bridge	$\frac{3\sqrt{2}}{2\pi}V_{l-l}$ = 270 V	$\frac{\sqrt{2}}{2}V_{ph} = 162.5V$	150 Hz
3-phase Full Bridge	$\frac{3\sqrt{2}}{\pi}V_{l-l}$ = 540 V	$(1-\frac{\sqrt{3}}{2})\sqrt{2}V_{l-l} = 75.8V$	300 Hz

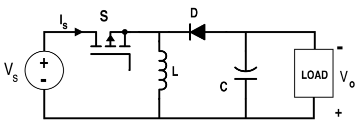
Converters



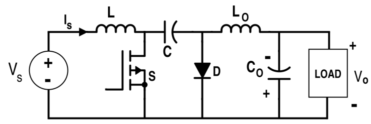
Buck Converter



Boost Converter



Buck-Boost Converter



Cuk Converter

Buck Converter (Step-Down)

$$\text{Gain:} \quad V_o = DV_d$$

$$V_L = V_d - V_o \text{ (On)}, \quad V_L = -V_o \text{ (Off)}$$

$$\text{Inductor Ripple:} \quad \Delta I_L = \frac{V_o(1-D)}{Lf_s}$$

$$\text{Voltage Ripple:} \quad \frac{\Delta V_o}{V_o} = \frac{1-D}{8LCf_s^2}$$

$$\text{CCM/DCM Boundary:} \quad I_{LB} = \frac{\Delta I_L}{2} = \frac{DT_s(V_d)(1-D)}{2L}$$

$$\text{CCM/DCM Boundary:} \quad L_{min} = \frac{DT_s(V_d - V_o)}{2I_{LB}} = \frac{RT_s(1-D)}{2}$$

Boost Converter (Step-Up)

$$\text{Gain:} \quad V_o = \frac{V_d}{1-D}$$

$$V_L = V_d \text{ (On)}, \quad V_L = V_d - V_o \text{ (Off)}$$

$$\text{Inductor Ripple:} \quad \Delta I_L = \frac{V_d D}{Lf_s}$$

$$\text{Voltage Ripple:} \quad \frac{\Delta V_o}{V_o} = \frac{D}{RCf_s}$$

$$\text{CCM/DCM Boundary:} \quad I_{LB} = \frac{\Delta I_L}{2} = \frac{V_d DT_s}{2L}$$

$$\text{Min Inductance:} \quad L_{min} = \frac{D(1-D)^2R}{2f_s}$$

Buck-Boost Converter

$$\text{Gain:} \quad V_o = -V_d\frac{D}{1-D}$$

$$V_L = V_d \text{ (On)}, \quad V_L = V_o \text{ (Off)}$$

$$\text{Inductor Ripple:} \quad \Delta I_L = \frac{V_d D}{Lf_s}$$

$$\text{Voltage Ripple:} \quad \frac{\Delta V_o}{V_o} = \frac{D}{RCf_s}$$

$$\text{CCM/DCM Boundary:} \quad I_{LB} = \frac{\Delta I_L}{2} = \frac{V_d DT_s}{2L}$$

$$\text{Min Inductance:} \quad L_{min} = \frac{(1-D)^2R}{2f_s}$$

Cuk Converter

$$\text{Gain:} \quad V_o = -V_d\frac{D}{1-D}$$

$$V_{L1} = V_d \text{ (On)}, \quad V_{L1} = V_d - V_{C1} \text{ (Off)}$$

$$\text{Inductor Ripple } (L_1)\text{:} \quad \Delta I_{L1} = \frac{V_d D}{L_1 f_s}$$

$$\text{Inductor Ripple } (L_2)\text{:} \quad \Delta I_{L2} = \frac{V_d D}{L_2 f_s}$$

$$\text{Voltage Ripple } (C_o)\text{:} \quad \frac{\Delta V_o}{V_o} = \frac{1-D}{8L_2C_2f_s^2}$$

$$\text{CCM/DCM Boundary:} \quad I_{LB1} = \frac{V_d DT_s}{2L_1} \quad \text{(for } L_1\text{)}$$

$$\text{Min Inductance } (L_1)\text{:} \quad L_{1,min} = \frac{(1-D)^2R}{2Df_s}$$

$$\text{Min Inductance } (L_2)\text{:} \quad L_{2,min} = \frac{(1-D)R}{2f_s}$$

Cuk Feature: Input and Output currents are continuous (low ripple) due to inductors on both sides.

Symmetry	*Condition Required*	a_h **and** b_h
Even	$f(-t) = f(t)$	$b_h = 0 \quad a_h = \frac{2}{\pi}\int_0^\pi f(t)\cos(h\omega t)\, d(\omega t)$
Odd	$f(-t) = -f(t)$	$a_h = 0 \quad b_h = \frac{2}{\pi}\int_0^\pi f(t)\sin(h\omega t)\, d(\omega t)$
Half-wave	$f(t) = -f(t + \frac{1}{2}T)$	$a_h = b_h = 0$ for even h $a_h = \frac{2}{\pi}\int_0^\pi f(t)\cos(h\omega t)\, d(\omega t)$ for odd h $b_h = \frac{2}{\pi}\int_0^\pi f(t)\sin(h\omega t)\, d(\omega t)$ for odd h
Even quarter-wave	Even and half-wave	$b_h = 0$ for all h $a_h = \begin{cases} \frac{4}{\pi}\int_0^{\pi/2} f(t)\cos(h\omega t)\, d(\omega t) & \text{for odd } h \\ 0 & \text{for even } h \end{cases}$
Odd quarter-wave	Odd and half-wave	$a_h = 0$ for all h $b_h = \begin{cases} \frac{4}{\pi}\int_0^{\pi/2} f(t)\sin(h\omega t)\, d(\omega t) & \text{for odd } h \\ 0 & \text{for even } h \end{cases}$