

## Cheat Sheet for EE464

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

$$DistortionFactor = \frac{I_{rms}}{I_{rms}}$$

$\phi$  : phase difference between fundamentals of current and voltage

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

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

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

## Converters

$$\begin{aligned} V_o &= V_s \left( \frac{D}{1-D} \right) \left( \frac{N_2}{N_1} \right) & \frac{\Delta V_o}{V_o} &= \frac{D}{RCf} & (L_m)_{min} &= \frac{(1-D)^2 R}{2f} \left( \frac{N_1}{N_2} \right)^2 \\ I_{L_{m,max}} &= I_{L_m} + \frac{\Delta i_{L_m}}{2} & L_m &= \frac{V_s DT}{\Delta i_{L_m}} = \frac{V_o D}{\Delta i_{L_m} f} \\ &= \frac{V_s D}{(1-D)^2 R} \left( \frac{N_2}{N_1} \right)^2 + \frac{V_s DT}{2L_m} & I_s &= \frac{(I_{L_m})DT}{T} = I_{L_m} D \\ I_{L_{m,min}} &= I_{L_m} - \frac{\Delta i_{L_m}}{2} & \text{equate this to zero for dcm boundary} & & \begin{aligned} \left( \Delta i_{L_m} \right)_{open} &= -V_o(1-D)T \left( \frac{N_1}{N_2} \right) \\ \left( \Delta i_{L_m} \right)_{closed} &= \frac{V_o D T}{L_m} \end{aligned} \\ &= \frac{V_s D}{(1-D)^2 R} \left( \frac{N_2}{N_1} \right)^2 - \frac{V_s DT}{2L_m} & I_c &= I_o - i_a = I_{L_m} \left( \frac{N_1}{N_2} \right) \\ \Delta V_{o,ESR} &= \Delta i_C r_C = I_{L_{m,max}} \left( \frac{N_1}{N_2} \right) r_C & \begin{aligned} I_c &= I_o - i_a = I_{L_m} \left( \frac{N_1}{N_2} \right) \\ I_s &= \frac{V_o D T}{L_m} \end{aligned} & \end{aligned}$$

Figure 1: Flyback Formulas

$$\begin{aligned} V_o &= V_s D \left( \frac{N_2}{N_1} \right) & \frac{\Delta V_o}{V_o} &= \frac{1-D}{8L_s C f^2} & D \left( 1 + \frac{N_1}{N_2} \right) &< 1 \\ \Delta V_{o,ESR} &= \Delta i_C r_C = \Delta i_{L_s} r_C = \left[ \frac{V_o(1-D)}{L_s f} \right] r_C \\ \Delta i_{L_m} &= \frac{V_s DT}{L_m} & I_{L_s} &= \frac{V_o}{R} & \Delta i_{L_s} &= \frac{V_o(1-D)}{L_s f} \end{aligned}$$

Figure 2: Forward (single switched) Converter Formulas

$$\begin{aligned} V_o &= 2V_s \left( \frac{N_s}{N_p} \right) D & \frac{\Delta V_o}{V_o} &= \frac{1-2D}{32L_s C f^2} & I_{L_s} &= \frac{V_o}{R} \\ \Delta V_{o,ESR} &= \Delta i_{L_s} r_C = \left[ \frac{V_o \left( \frac{1}{2} - D \right)}{L_s f} \right] r_C \end{aligned}$$

Figure 3: Push Pull Formulas

$$\begin{aligned} V_o &= V_s \left( \frac{D}{1-D} \right) & \Delta V_{C1} &= \frac{I_o DT}{C} = \frac{V_o D}{RC_1 f} \\ \Delta i_{L1} &= \frac{V_s DT}{L_1} = \frac{V_o D}{L_1 f} & \Delta V_o &= \Delta V_{C2} = \frac{V_o D}{RC_2 f} \\ \Delta i_{L2} &= \frac{V_s DT}{L_2} = \frac{V_o D}{L_2 f} & C_1 &= \frac{D}{R(\Delta V_{C1}/V_o) f} \\ I_{L1} &= I_s = \frac{V_o I_o}{V_s} = \frac{V_o^2}{V_s R} & C_2 &= \frac{D}{R(\Delta V_{C2}/V_o) f} \\ I_{L2} &= I_o \end{aligned}$$

Figure 4: Sepic Converter Formulas

$$SwitchUtilization = \frac{Po}{P_{sw}} = \frac{I_o V_o}{q \cdot V_{swmax} \cdot I_{swmax}} \quad (1)$$

## Inverters

$$\begin{aligned} m_f &= \frac{f_s}{f_1}, m_a = \frac{V_{control}}{V_{triangle}} \\ m_a &< 1 : linear, m_a > 1 : overmodulation \end{aligned}$$

$$\begin{aligned} V_o &= -V_s \left( \frac{D}{1-D} \right) & \frac{\Delta V_o}{V_o} &= \frac{1-D}{8L_2 C_2 f^2} \\ \Delta v_{C1} &\approx \frac{1}{C_1} \int_{DT}^T I_{L1} d(t) = \frac{I_{L1}}{C_1} (1-D)T = \frac{V_s}{RC_1 f} \left( \frac{D^2}{1-D} \right) \\ \Delta v_{C1} &\approx \frac{V_o D}{RC_1 f} \\ \Delta i_{L1} &= \frac{V_s DT}{L_1} = \frac{V_o D}{L_1 f} & \Delta i_{L2} &= \frac{V_s DT}{L_2} = \frac{V_o D}{L_2 f} & I_{L2} &= \left| \frac{P_o}{-V_o} \right| \\ L_{1,min} &= \frac{(1-D)^2 R}{2Df} & L_{2,min} &= \frac{(1-D)R}{2f} & I_{L1} &= \frac{P_s}{V_s} \end{aligned}$$

Figure 5: Cuk Converter Formulas

### Switch Selection

Peak Switch Current

$$\hat{I}_{sw} = \frac{1}{(1-D)} \frac{N_2}{N_1} I_o + \frac{N_1}{N_2} \frac{(1-D)T_s}{2L_m} V_o$$

Peak Switch Voltage

$$\hat{V}_{sw} = V_d + \frac{N_1}{N_2} V_o = \frac{V_d}{(1-D)}$$

Figure 6: Flyback switch considerations

$$\begin{aligned} V_o &= 2V_s \left( \frac{N_s}{N_p} \right) D & V_o &= V_s \left( \frac{N_s}{N_p} \right) D \\ \text{Full Bridge} & & \text{Half Bridge} & \end{aligned}$$

Figure 7: Full and Half Bridge Relations

$$(V_o)_h = \frac{1}{\sqrt{2}} \cdot 2 \cdot \frac{V_d}{2} \frac{(\hat{V}_{Ao})_h}{V_d/2} = \frac{V_d}{\sqrt{2}} \frac{(\hat{V}_{Ao})_h}{V_d/2}$$

Figure 8: Rms Voltage of Harmonics Full Bridge Inverter

## Cuk Converter

$$V_{C1} = V_o + V_d \quad (2)$$

$$V_{rms} = \frac{2\pi}{\sqrt{2}} \cdot N_2 \cdot f \cdot B_{max} \cdot A \quad (3)$$

## Signal Analysis

Linearization with State-Space Averaging

$$\mathbf{A} = d\mathbf{A}_1 + (1-d)\mathbf{A}_2$$

$$\mathbf{B} = d\mathbf{B}_1 + (1-d)\mathbf{B}_2$$

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}V_d \text{ (for switch off, (1-d)Ts)}$$

$$\mathbf{v}_o = \mathbf{C}\mathbf{x}$$

$$\mathbf{C} = d\mathbf{C}_1 + (1-d)\mathbf{C}_2$$

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}V_d + \mathbf{A}\tilde{\mathbf{x}} + [(\mathbf{A}_1 - \mathbf{A}_2)\mathbf{x} + (\mathbf{B}_1 - \mathbf{B}_2)V_d]\bar{d}$$

$$\frac{V_o}{V_d} = -\mathbf{C}\mathbf{A}^{-1}\mathbf{B}$$

$$T_v(s) = \frac{\bar{v}_o(s)}{\bar{d}(s)}$$

$$= \mathbf{C}[\mathbf{s}\mathbf{I} - \mathbf{A}]^{-1}[(\mathbf{A}_1 - \mathbf{A}_2)\mathbf{x} + (\mathbf{B}_1 - \mathbf{B}_2)V_d] + (\mathbf{C}_1 - \mathbf{C}_2)\mathbf{x}]$$

$$I_o = I_{lm}(1-D) \quad I_s = I_{lm}(D)$$

Topology	$V_{sw}$	$I_{sw}$	$V_{01,max}$	q
Push Pull	$2V_{d,max}$	$\sqrt{2} \frac{I_{o,max}}{n}$	$\frac{4}{\pi\sqrt{2}} \frac{V_{d,max}}{2} n$	2
Half B.	$V_{d,max}$	$\sqrt{2} I_{o,max}$	$\frac{4}{\pi\sqrt{2}} \frac{V_{d,max}}{2}$	2
Full B.	$V_{d,max}$	$\sqrt{2} I_{o,max}$	$\frac{4}{\pi\sqrt{2}} V_{d,max}$	4

Table 1: Swith Utilization doesnt change for n:1 trans. ratio