Midterm Exam **ENM061 Power Electronic Converters**
Monday November 26, 2018

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Help: CTH approved calculator (Casio FX82, Texas TI30, Sharp EL531)

The bonus points are awarded as follows.
0: 0 – 3.5 pts.
1: 4 – 8.5 pts.
2: 8 – 11.5 pts.
3: 12 – 15.5 pts.
4: 16 – 20.0 pts.

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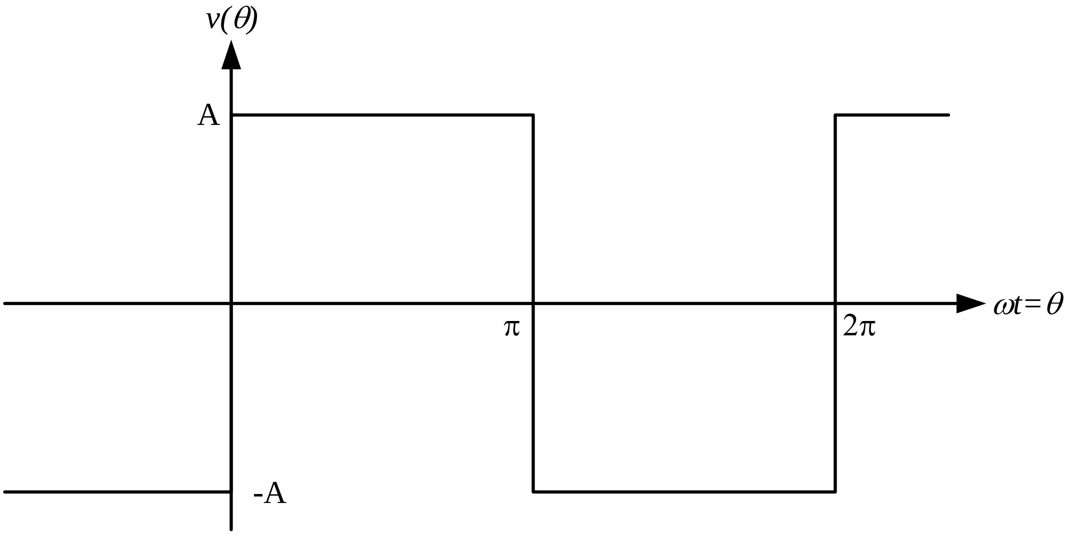
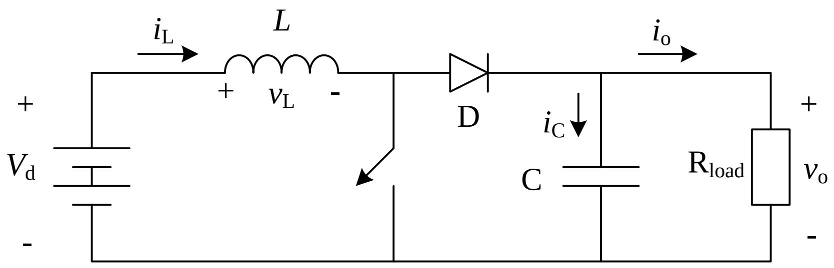
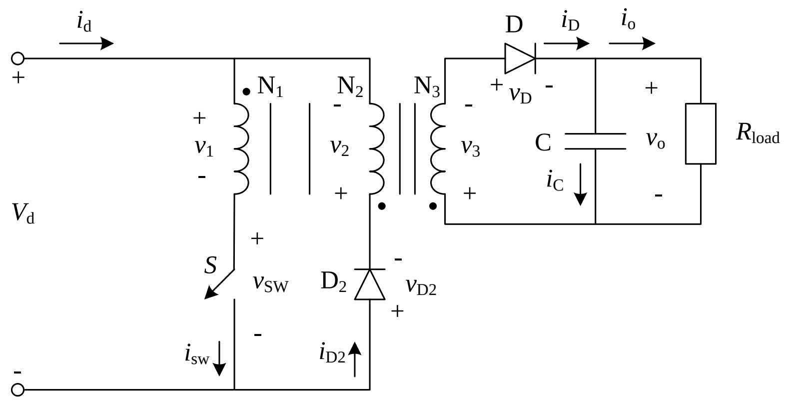
1. **For the voltage waveform shown in the figure below, calculate the average value, the RMS-value of the fundamental and the total harmonic distortion of the voltage signal. (5 points)**



2. **For DC/DC converter shown below and operating in CCM mode, derive the expression of the output voltage to input voltage ratio (V_o/V_d) and identify what kind of converter it is. For the boundary condition between CCM and DCM, roughly sketch the waveforms for i_L, i_C *and* i_o. (5 points)**

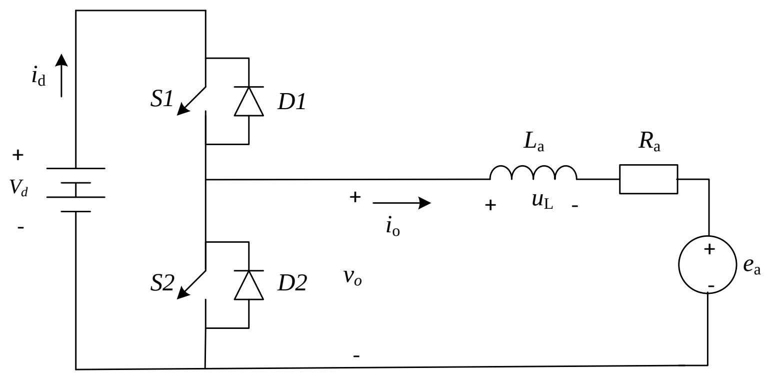


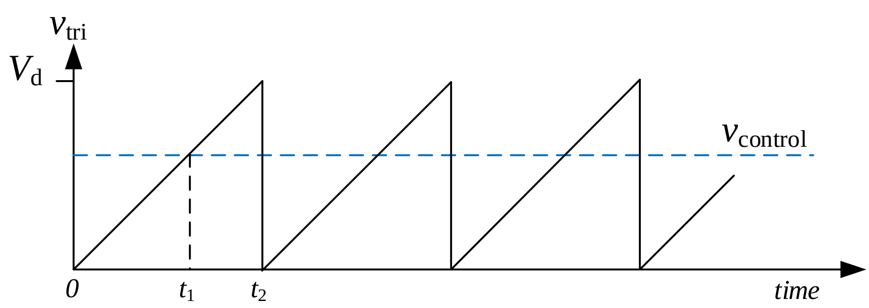
3. **The flyback converter below has a protective winding (N_2) with the total turns ratio of the transformer given by N_1: N_2: N_3 (5 points)**



For CCM and DCM operation, derive the relationship between the output and input voltage (in terms of switching frequency f_{sw}, duty cycle D, mutual inductance L_m and load resistance R_{load}). From the expressions, what is the output voltage when there is no load connected, i.e. $R_{load} = \infty$.

4. **The half-bridge DC/DC converter shown below uses a PWM voltage switching (i.e., when $v_{control} \geq v_{tri}$, *S1* is on and *S2* is off.; when $v_{control} < v_{tri}$, *S2* is on and *S1 is* off). For $\hat{v}_{tri} = V_d = 15V$, $v_{control} = 9\ V$ and $i_o = 5A$ (5 points)**





(a) Which active components are conducting for the interval $0 \leq t \leq t_1$ and $t_1 \leq t \leq t_2$.
(b) Plot the output voltage waveform v_o and input current waveform i_d for $0 \leq t \leq t_2$.
(c) Calculate the average output voltage V_o and the average input current I_d.

Formula sheet for the midterm exam of Power Electronic Converters (ENM061)

Fourier calculations

Table 3-1 Use of Symmetry in Fourier Analysis

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; $b_h = \begin{cases} \frac{4}{\pi}\int_0^{\pi/2} f(t)\sin(h\omega t)\, d(\omega t) & \text{for odd } h \\ 0 & \text{for even } h \end{cases}$

Definition of RMS-value:

$$F_{RMS} = \sqrt{\frac{1}{T}\int_{t_o}^{t_o+T} f(t)^2 dt}$$

Definition of RMS-value with Fourier-series:

$$F_{RMS} = \sqrt{F_0^2 + \sum_{n=1}^{\infty} F_n^2} = \sqrt{\left(\frac{a_0}{2}\right)^2 + \sum_{n=1}^{\infty}\left(\frac{\sqrt{a_n^2 + b_n^2}}{\sqrt{2}}\right)^2}$$

Trigonometry

$$\sin^2(\alpha) + \cos^2(\alpha) = 1$$

$$\sin(\alpha+\beta) = \sin(\alpha)\cos(\beta) + \cos(\alpha)\sin(\beta) \qquad \sin(\alpha-\beta) = \sin(\alpha)\cos(\beta) - \cos(\alpha)\sin(\beta)$$

$$\cos(\alpha+\beta) = \cos(\alpha)\cos(\beta) - \sin(\alpha)\sin(\beta) \qquad \cos(\alpha-\beta) = \cos(\alpha)\cos(\beta) + \sin(\alpha)\sin(\beta)$$

$$\sin(\alpha)\sin(\beta) = \frac{1}{2}\left(\cos(\alpha-\beta) - \cos(\alpha+\beta)\right) \qquad \sin(\alpha)\cos(\beta) = \frac{1}{2}\left(\sin(\alpha-\beta) + \sin(\alpha+\beta)\right)$$

$$\cos(\alpha)\cos(\beta) = \frac{1}{2}\left(\cos(\alpha-\beta) + \cos(\alpha+\beta)\right)$$

$$\int \sin(ax)dx = -\frac{1}{a}\cos(ax), \quad \int x\sin(ax)dx = \frac{1}{a^2}\left(\sin(ax) - ax\cos(ax)\right), \quad \int \cos(ax)dx = \frac{1}{a}\sin(ax)$$

$$\int x\cos(ax)dx = \frac{1}{a^2}\left(\cos(ax) + ax\sin(ax)\right)$$

$$PF = \frac{P}{S} = \frac{V_s I_{s1}\cos\phi_1}{V_s I_s}, \quad DPF = \cos\phi_1, \quad \%THD_i = 100\frac{I_{dis}}{I_{s1}} = 100\frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} = 100\sqrt{\sum_{h\neq 1}\left(\frac{I_{sh}}{I_{s1}}\right)^2}$$

Electromagnetics

$$e = \frac{d}{dt}\psi \qquad \psi = N\phi \qquad \phi = BA \qquad R = \frac{l}{A\mu_r\mu_0} \qquad L = \frac{\Psi}{i}$$

$$NI = R\phi = mmf \qquad N\phi = LI \qquad L = N^2/R \qquad W = \frac{1}{2}Li^2$$

Capacitor and inductor current-voltage relationship

$$i_C = C\frac{dv_C}{dt} \qquad v_L = L\frac{di_L}{dt}$$