Power Electronics Applications, Midterm I

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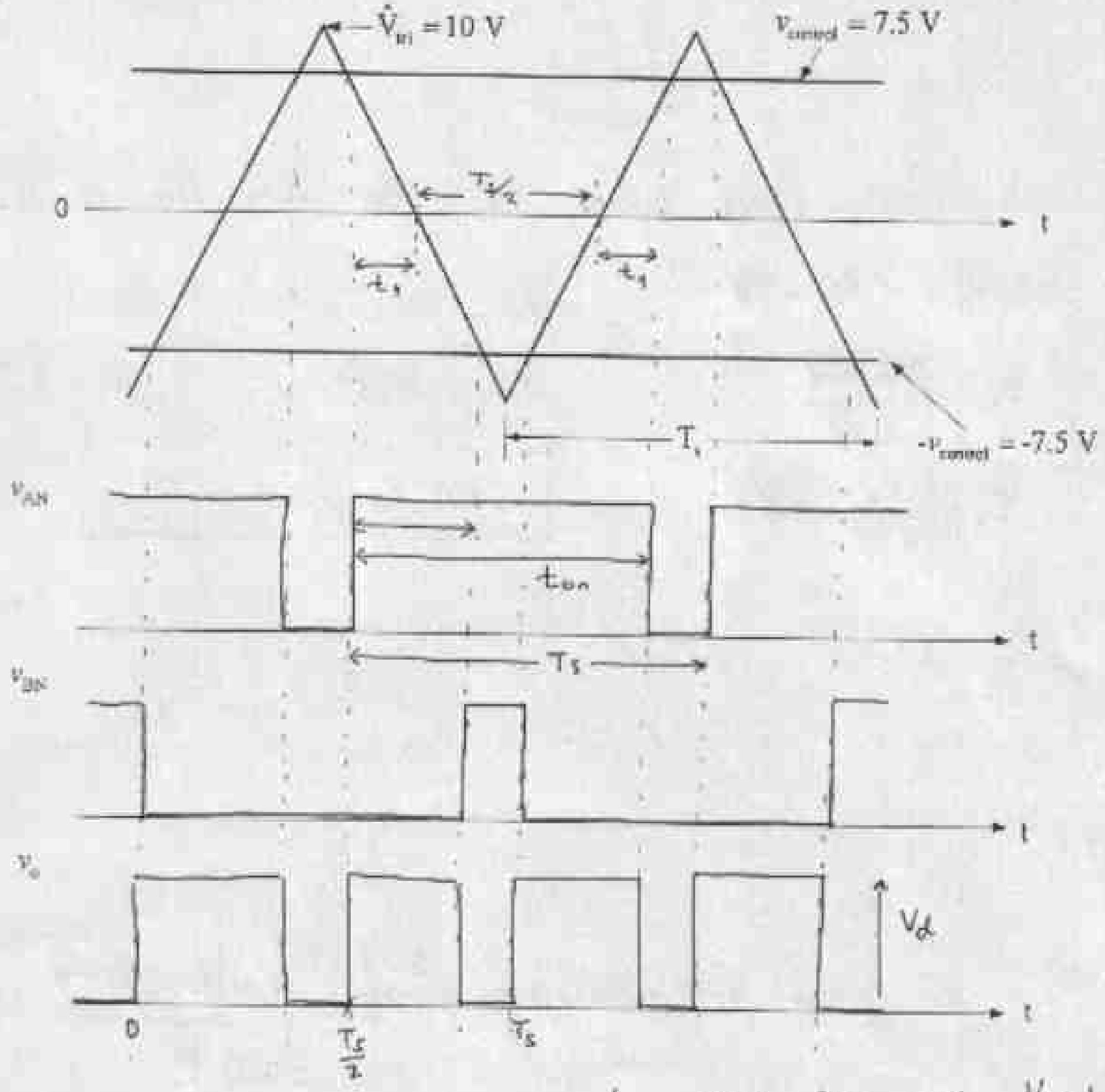
(35pt)

1) The following graph shows the control signals of PWM with **unipolar** voltage switching method used for a full-bridge dc/dc converter. The average input voltage to the converter is $V_d = 40$ V, and the switching frequency is 10 kHz.

20pt a. Plot the instantaneous voltages shown in the graph.

10pt b. Find the average output voltage $V_o = \langle v_o(t) \rangle$.

5pt c. What is the frequency of output voltage waveform $v_o(t)$?



b) $V_o = (2D_1 - 1)V_d$ $\qquad D_1 = \frac{t_{on}}{T_s} = \frac{(2t_1 + \frac{T_s}{2})}{T_s} = \frac{\frac{T_s}{2}\left(1 + \frac{V_{control}}{\hat{V}_{tri}}\right)}{T_s}$

$$D_1 = \frac{1}{2}\left(1 + \frac{V_{control}}{\hat{V}_{tri}}\right) = 0.5\left(1 + \frac{7.5}{10}\right) = 0.875$$

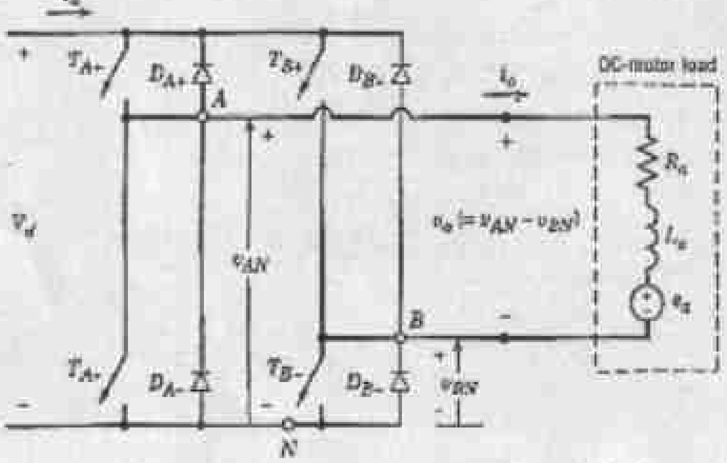
Then $V_o = [2(0.875) - 1] \times 40$

$= 30$ V

c) The frequency of the output voltage waveform is twice the switching frequency; so, it is 20 kHz

(20pt)

2) The full-bridge converter shown below is controlled using PWM with **bipolar** voltage switching. The dc motor load shown in the figure requires a dc voltage between -24 V and +24 V in order to achieve speed control. Find the range of duty ratio of the switch T_A that would provide the desired output. The average input voltage to the converter is $V_d = 100$ V, and the switching frequency is 10 kHz.



$\langle v_o \rangle = (2D_1 - 1)V_d$ where D_1 is the duty ratio of T_{A+}

$2D_1 V_d = \langle v_o \rangle + V_d$

$D_1 = \dfrac{V_o + V_d}{2V_d}$

$D_1 = \left(\dfrac{V_o}{2V_d} + 0.5\right)$

for $V_o = +24$: $D_1 = 0.62$

for $V_o = -24$: $D_1 = 0.38$

$0.38 \leq D_1 \leq 0.62$

(15pt)

3) In a single-phase full-bridge PWM inverter, the input dc voltage comes from a stack of batteries that are connected in series. The number of series connected batteries is 30, and a fully charged battery voltage is approximately 13.5 V. Because of the low distortion required in the output $v_o(t)$, the inverter should be operated in the linear region ($m_a \leq 1.0$). The desired output voltage is 220 Vrms. Based on these conditions, answer the following questions:

7pt a. What is the minimum level of discharge that can be allowed for the batteries?

8pt b. What will be the range of modulation index (m_a) that controller needs to generate in order to produce 220 Vrms at the output of the inverter?

a) $V \text{(minimum battery voltage)} = \dfrac{220 \times \sqrt{2}}{30} = 10.371 \text{ V}$

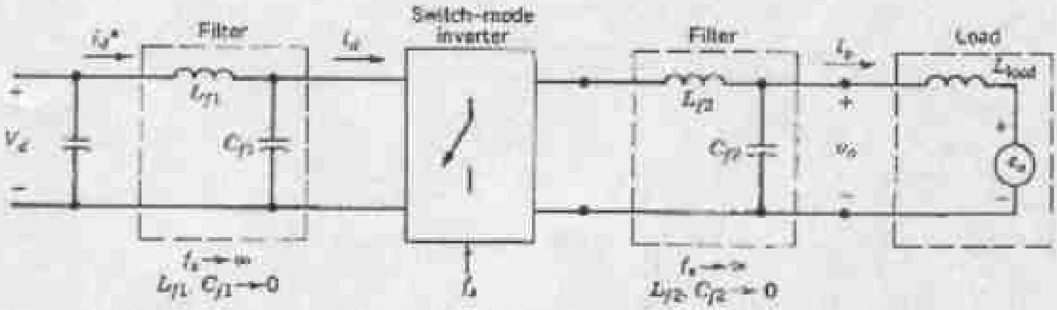
23.17 %

b) $(V_o)_{1,Rms} = \dfrac{m_a \cdot V_d}{\sqrt{2}}$ when $V_d = 405$ $m_a = \dfrac{220\sqrt{2}}{405}$

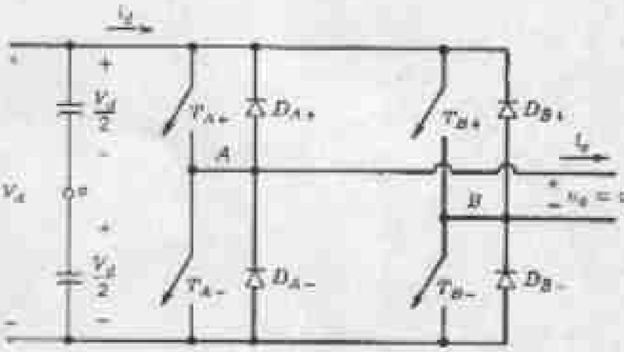
$m_a = 0.768$

$405 \leq V_d \leq 311.13$

$0.768 \leq m_a \leq 1.0$ → to generate $220 V_{Rms}$ at the output.



(30pt) 4) The switch-mode inverter shown in the figure above can be represented by the following full-bridge topology.



20pt a) Draw the waveform of the dc side current (i_d) when the inverter is operated with PWM **bipolar** voltage switching.

10pt b) Indicate the devices conducting during each interval of the switching cycle for only 3 cycles.