3) Buck-Boost Converter

Design a buck-boost converter to produce -100 V from a 20 V source. Assume $\Delta V_o \leq 1\%$ of V_o and $\Delta I_L \leq 50\%$ of I_L. The switching frequency is 80 kHz. $P_o = 200$ W

a) Determine L and C.
b) sketch $i_L(t)$, $i_{s_1}(t)$, and $i_{s_2}(t)$.
c) Sketch the topology
d) Switch ratings

Solutions

a) $V_o = \frac{D}{1-D} V_d \qquad D = \frac{V_o}{V_o + V_d} = \frac{100}{120} = 0.8333$

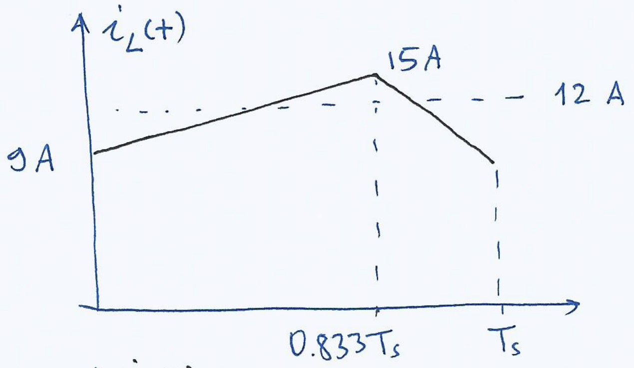
$$L \geq \frac{V_d D}{\Delta I_L f_s} = \frac{20(0.8333)}{\left[0.5 \times \left(\frac{200}{20} + \frac{200}{100}\right)\right](80000)} = 34.722\ \mu H$$

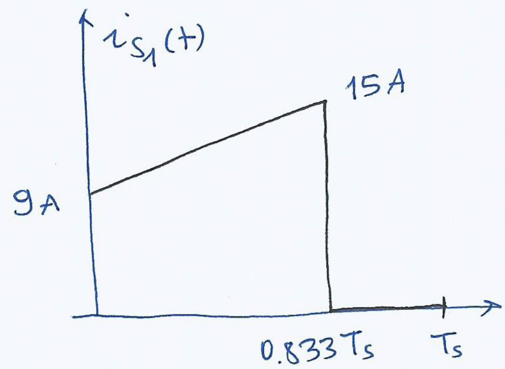
$$I_L = I_d + I_o = \frac{200}{20} + \frac{200}{100} = 12\ A$$

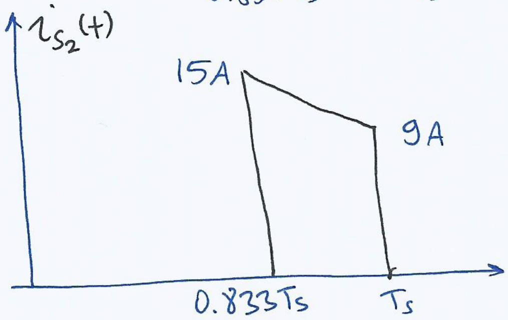
$I_d = 10$ A $\quad I_o = 2$ A

$$C \geq \frac{I_o D}{\Delta V_o f_s} = \frac{2(0.8333)}{(0.01 \times 100)(80000)} = 20.833\ \mu F$$

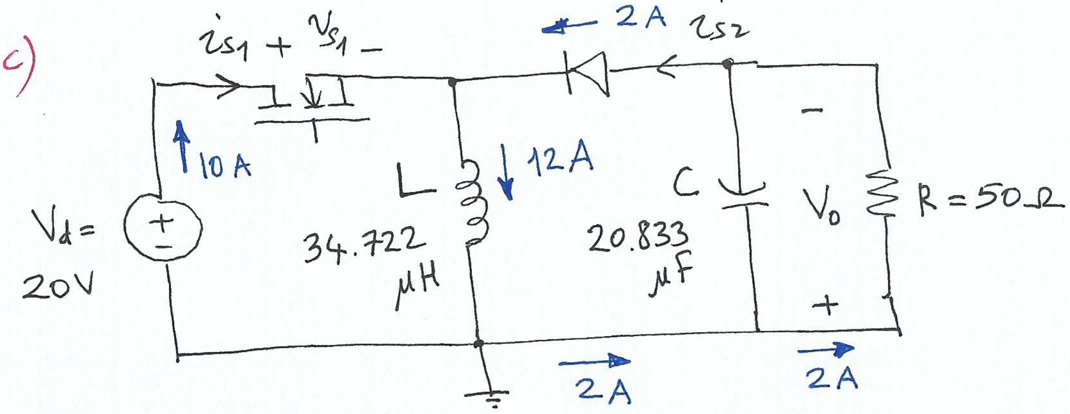
b) $\Delta I_L = 0.5 \times 12 = 6$ A







c)



The blue coloured currents are average currents that flow through the elements.

d) $\hat{I}_{S1} = 15\ A$ $\qquad I_{S1\,rating} = 30\ A$

$\hat{V}_{S1} = V_d + V_o = 20 + 100 = 120\ V$ $\qquad V_{S1}\ rating = 240\ V$

$I_{S2} = 2\ A$ $\qquad I_{S2}\ rating = 4\ A$

$\hat{V}_{S2} = V_d + V_o = 120V$ $\qquad V_{S2}\ rating = 240\ V$

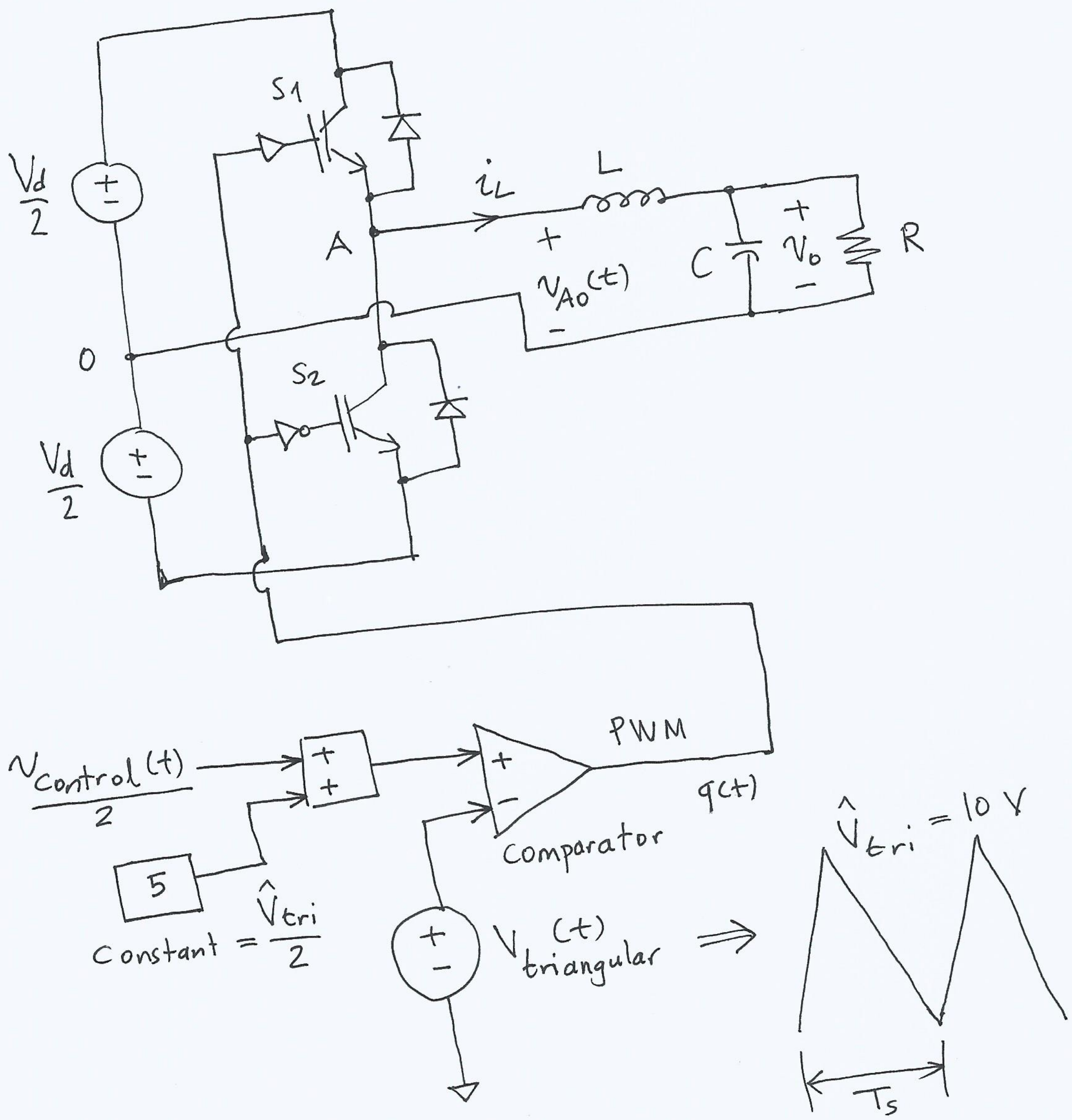
4) Half-Bridge DC/AC inverter

Design a half-bridge inverter to produce 230 V_{Rms} at 50 Hz.

Assume $m_{a\text{-}max} = 0.85$, $m_{f\text{-}max} = 100$, and $\hat{V}_{tri} = 10$.

Also assume $\Delta I_L \leq 40\%$ of $\hat{I}_L$

$P_o = 2300$ W where $\hat{I}_L = \sqrt{2}\, I_{oRms}$



$v_{control}(t) = \hat{V}_{control} \sin(2\pi f_1 t)$

Note: Design includes finding the following parameters

$\frac{V_d}{2}$, L, C, and $v_{control}(t) \rightarrow \hat{V}_{control}$, $\rightarrow f_1$, also f_s

The half-bridge inverter produces the following voltage at the output.

$$\bar{v}_{Ao}(t) = \frac{V_d}{2} m_a \sin(2\pi f_1 t) \qquad (1)$$

$\bar{v}_{Ao}(t)$ is the moving average of $v_{Ao}(t)$ and equal to $v_o(t)$

$v_{Ao}(t)$ is the sinusoidally modulated pulse train. $\bar{v}_{Ao}(t) = v_o(t)$

in (1),

m_a is the voltage modulation ratio and equal to

$$m_a = \frac{\hat{V}_{control}}{\hat{V}_{tri}}$$

The desired output is $v_o(t) = \sqrt{2}\, V_{oRms} \sin(2\pi f t)$

Assuming $\bar{v}_{Ao}(t) = v_o(t)$ $\qquad V_{oRms} = 230$ V

$f = 50$ Hz

$$\frac{V_d}{2} m_a = \sqrt{2}\, V_{oRms}$$

$m_a = 0.85$ maximum

So, the minimum $\frac{V_d}{2} = \frac{\sqrt{2}(230)}{0.85} = 382.67$ V

Also $f_1 = f = 50$ Hz

So

$$v_{control}(t) = m_a \hat{V}_{tri} \sin(2\pi f_1 t) \qquad \hat{V}_{control} = 8.5$$

$$v_{control}(t) = 8.5 \sin(2\pi 50 t)$$

$$\boxed{\frac{V_{dmin}}{2} = 382.67 \text{ V}}$$

$$\boxed{v_{control}(t) = 8.5 \sin(2\pi 50 t)}$$

Next, we will determine L and C

$$i_o(t) = \frac{v_o(t)}{R} = \frac{\sqrt{2}(230)\sin(2\pi 50t)}{23} = \sqrt{2}(10)\sin(2\pi 50t)$$

$$R = \frac{230^2}{2300} = 23\,\Omega \qquad \hat{I}_L = \hat{I}_o = \sqrt{2}(10)$$

$$\Delta I_L \leq 0.4 \times \sqrt{2}(10) = 5.66\text{ A}$$

The formula for peak-to-peak ripple in a half-bridge topology is

$$\Delta I_L = \frac{\left(\frac{V_d}{2} - \bar{v}_o\right) d}{L \cdot f_s} \quad (2) \qquad \bar{v}_o : \text{periodic average}$$

In each switching period (T_s), $\bar{v}_o$ is changing according to the following formula.

$$\bar{v}_o = \frac{V_d}{2}(2d-1) \qquad d \text{ is changing sinusoidally}$$

Using $\bar{v}_o$ in (2),

$$\Delta I_L = \frac{\left(\frac{V_d}{2} - \frac{V_d}{2}2d + \frac{V_d}{2}\right) d}{L f_s} = \frac{V_d(d - d^2)}{L f_s}$$

$$\frac{d\Delta I_L}{d(d)} = 1 - 2d = 0 \qquad d = \frac{1}{2}$$

The worst case is when $d = 0.5$, where $\bar{v}_o = 0$

$$\text{So,} \quad L \geq \frac{\left(\frac{V_d}{2}\right)(0.5)}{(5.66) f_s} = \frac{(382.67)(0.5)}{(5.66)(5000)} = 6.765\text{ mH}$$

where $f_s = m_f \cdot f_1 = 100(50) = 5000$ Hz

m_f is the frequency modulation index

The LC filter corner frequency should be less than

$$f_c = \frac{f_s}{10} = \frac{5000}{10} = 500\text{ Hz.} \quad \text{So, select } f_c = 500\text{ Hz}$$

$$\omega_c^2 = \frac{1}{LC} \qquad C = \frac{1}{\omega^2 L} = \frac{1}{(2\pi 500)^2(6.765\times 10^{-3})} = 14.98\,\mu\text{F}$$

$$\boxed{L \geq 6.765\,\mu\text{H}} \qquad \boxed{C \geq 14.98\,\mu\text{F}}$$