1. a) Battery chargers may measure if the voltage has reached a given threshold, or if there is a temperature rise in the battery, or if the voltage across the cell is dropping even though charging current still non-zero.

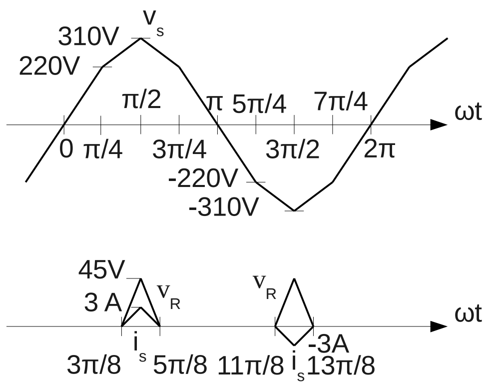
   b) The synchronous motor may have a permanent magnet as a rotor.

   c) If the voltage increase across the thyristor (large dv/dt) then it may turn on without a trigger pulse.

   d) GTO = Gate Turn-Off thyristor. That is, a thyristor than can both be turned on and off through control of the gate.

   e) Large inductive loads will act as a current source, and thus be modeled as such. The large inductance will keep the current almost constant in the steady state situation.

2. Note: The waveform $v_s$ is intended to be piece-wise linear, it is not a drawing problem.




| | | | | | |
|---|---|---|---|---|---|
| D1,D4 | Off | On | Off | Off | Off |
| D2,D3 | Off | Off | Off | On | Off |

   a) Resistor voltage will correspond to the current entering the $V_o$ voltage source. The current will be proportional to the voltage difference between the rectified source voltage and the output voltage as soon as it is positive. The current starts to be non-zero when $|v_s| \geq 265$V which happens at the angle 3π/8 to 5π/8, and 11π/8 to 13π/8. The diodes D1 and D4 conducts from 3π/8 to 5π/8, and D2 and D3 conducts from 11π/8 to 13π/8, otherwise are the diodes off. $V_R$ is always positive, while is in the same direction as $v_s$.

   b) Maximum voltage across resistor is 310-265=45V, => is peak is 45/15 = 3A.

   c) $i_s$ source current rms, average of the square can be calculated by only looking at a quarter of the cycle, where a single triangle from 0 to π/8 contributes to the average current:

$$i_{s(\mathrm{RMS})}=\sqrt{\frac{1}{T}\int_0^T i_s(t)^2\,dt}=\sqrt{\frac{2}{\pi}\int_0^{\frac{\pi}{8}}\left(\frac{3x}{\pi/8}\right)^2 dx}=\sqrt{\frac{2}{\pi}\,\frac{9\,8^2}{\pi^2}\int_0^{\pi/8} x^2\,dx}=\sqrt{\frac{128\,9}{\pi^3}\left[\frac{x^3}{3}\right]_0^{\pi/8}}=$$

$$=\sqrt{\frac{128\,9\,\pi^3}{\pi^3\,8\,3\,64}}=\sqrt{\frac{3}{4}}=0.866\,\mathrm{A}$$

3. a) Continuous conduction mode => $V_o = V_d{*}D = 12{*}0.25 = 3$V.

   b) At boundary case will the inductance current ripple be equal to twice the output average current (triangular shaped current, touching on i=0). $I_O = 1.5$A => $I_{LRipple} = 3$A. During the switch on-phase is the inductance voltage $V_L = 12-3 = 9$V, and the current change is then

$I_{LRipple} = T_s*D*V_L/L$. Minimum switching frequency $f_s = 1/T_s = V_L*D/(I_{LRipple}*L) = 9 * 0.25/ (3*37.5e-6) = 20$ kHz

4. Power flow: from 12 V input into the DC-DC converter, then from DC-DC converter into the processor.

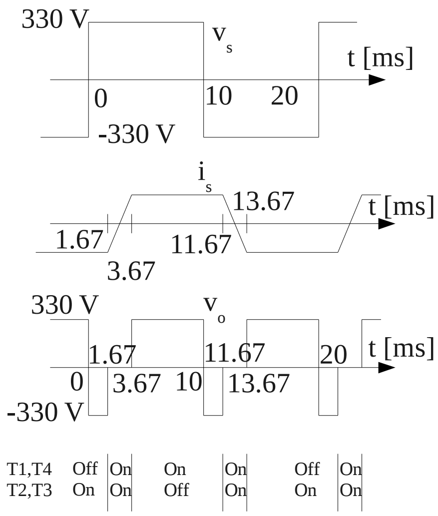
a) 90% DC-DC converter efficiency => $P_{in} = P_{out}/0.9 = 45/0.9$ The input current $I_{in} = P_{in}/U_{in} = (45/0.9)/12 = 4.17$ A

b) Power dissipated in converter is the loss equal to 10% of the input power => $P_{diss} = 45/0.9 *0.1 = 5$ W

c) $\Theta_{ca} = (T_c- T_a)/P = (55-25)/45 = 0.67$ °C/W

5. Assume thyristors T2 and T3 are on, and $v_s$ is changing from negative to positive. Then the current $i_s = -I_0$. When $v_s$ goes positive, the current still continuous to run through T2 and T3 (thyristors do not turn off unless the current is zero). When T1 and T4 are fired, then all thyristors will conduct. The voltage $v_0$ goes to 0, and the voltage across L is now equal to $v_s$ and $i_s$ changes. When $i_s$ has reached $I_0$, then T2 and T3 turns off. The time to change current direction through L (total change is $2I_0$) is $t_{sw} = 2I_0*L/v_s = 2*3*110e-3/330 = 2$ ms.

a)




b) $$V_{O(avg)}=\frac{1}{T}\int_0^{10} v_o(t)\,dt=\frac{1}{10}(330(10-3.67)-330\,1.67)=\frac{330}{10}(10-3.67-1.67)=154\text{ V}$$

c) Displacement angle found by looking at middle point of high output current: (11.67-3.67)/2 + 3.67 = 7.67 ms. Voltage peak middle point at 10/2 = 5 ms. Current displacement angle: $\varphi = \varphi_V - \varphi_I = (7.67-5)/10*180 = 48$ degrees. Displacement power factor DPF = $\cos(\varphi) = \cos(48) = 0.67$

6. a) Switching frequency $f_s = 50$ Hz (each switch turns on 50 times per second), $t_{on}/t_{off} = 50\%$

b) According to the book (equation 8-37): $V_{o1peak} = 4/\pi\ V_d * \sin(\beta) = 4/\pi*310*\sin(60) = 342$V