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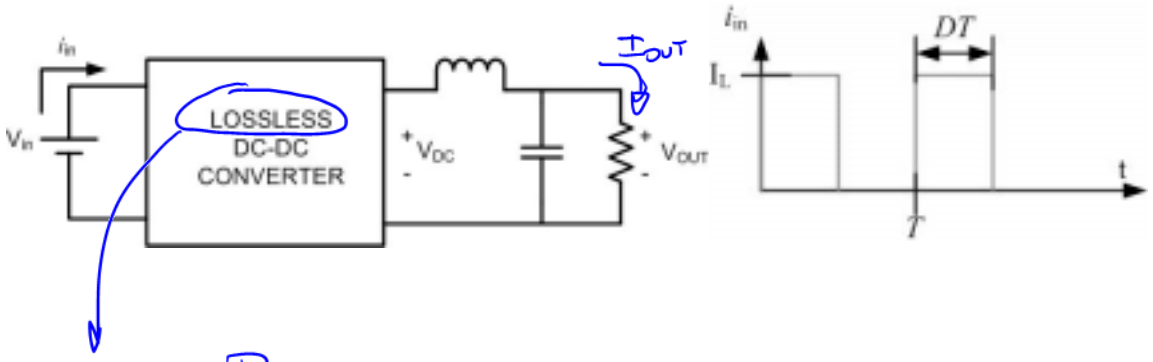
Please, show all your work on the test sheets. A correct answer without supporting work gets no credit. One sheet of notes is permitted. Write your name in all pages. Do not un-staple. You have 50 minutes to complete the test.

Problem 1 (15 points)

For the circuit shown below, what duty cycle *D* is needed to obtain an output voltage of 12 V if V_{in} is 20V? What is the output voltage V_{DC} of the converter box? Note: I_L is the average current in the inductor.
For extra credit (5 points): Please draw the circuit inside the converter box if there are only switches inside.



$P_{in} = P_{out}$

$P_{in} = V_{in} I_{in} = V_{in} D I_L$

Since $I_C = 0$, $I_L = I_{OUT}$

$P_{OUT} = V_{OUT} I_{OUT}$ | $P_{OUT} = V_{OUT} I_L$

Since $V_L = 0$

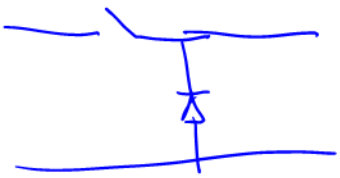
$V_{DC} = V_{OUT} = 12V$

$V_{in} D \cancel{I_L} = V_{OUT} \cancel{I_L}$

$D = \frac{V_{OUT}}{V_{in}} = \frac{12}{20} \simeq 0.6$

The circuit is a buck converter

(See the 1st class presentation)



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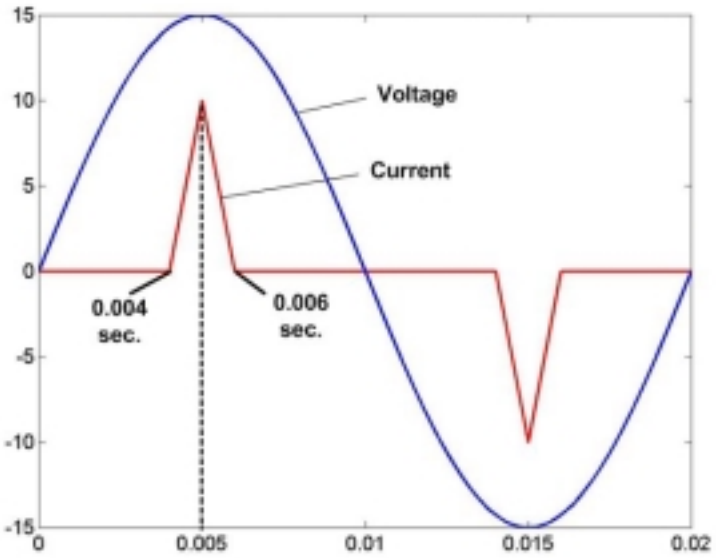
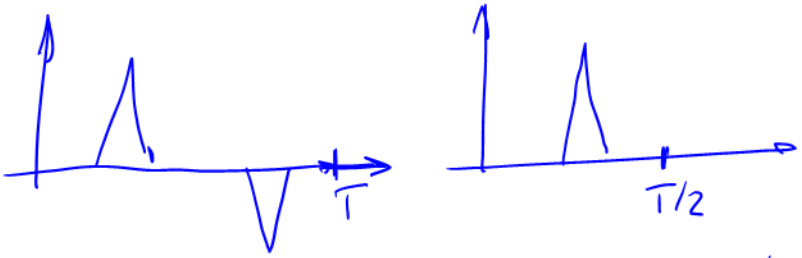
Problem 2 (25 points)

The following figure shows the approximate input current and voltage of a DBR. Please, calculate the input power factor and the current THD. Consider that the input fundamental current equals 1.935 A.



For a triangle $I_{RMS} = \frac{I_{peak}}{\sqrt{3}}$

From slide 9 of the "waveform definitions" presentation the rms value of the following two curves is the same

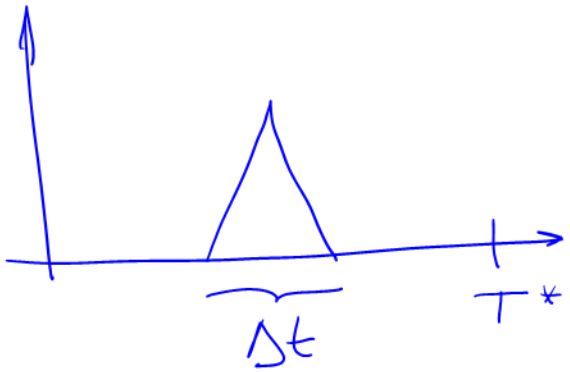


And remember that from the same presentation

slide 8 → $I_{rms}|_{sawtooth} = \frac{I_{peak}}{\sqrt{3}}$

slide 14 → $I_{rms}^2 = \alpha \frac{I_{peak}^2}{3}$

↳ where α is see next page



$$\alpha = \frac{\Delta t}{T^*}$$

Thus, in this problem $I_{rms}^2 = \frac{0.002}{0.01}\,\frac{10^2}{3}$

$$\Downarrow$$

$$I_{rms} = \frac{10}{\sqrt{15}} \cong 2.58\,A$$

From slide 14 of the DBR presentation:

$$p.f. = \frac{I_{50Hz}}{I_{rms}} = \frac{1.935/\sqrt{2}}{2.58} \cong 0.53$$

→ The p.f. is not 1 due to the presence of harmonics

From slide 23 of the "waveforms definitions" presentation:

$$(I_{rms})^2 = I_{avg}^2 + \sum_{h=1}^{\infty} \frac{I_h^2}{2}$$

$$\Downarrow$$

$$I_{rms}^2 = \frac{I_1^2}{2} + \sum_{h=2}^{\infty} \frac{I_h^2}{2} \longrightarrow \sum_{h=2}^{\infty} I_h^2 = 2I_{rms}^2 - I_1^2$$

$$\sum_{h=2}^{\infty} I_h^2 \cong 9.57$$

From slide 25 of the "waveforms definitions" presentation

$$THD = \sqrt{\frac{\sum_{h=2}^{\infty} I_h^2}{I_1^2}} = \sqrt{\frac{9.57}{(1.935)^2}} \cong 1.60$$

$$\Rightarrow THD(\%) \simeq 160\,\%$$

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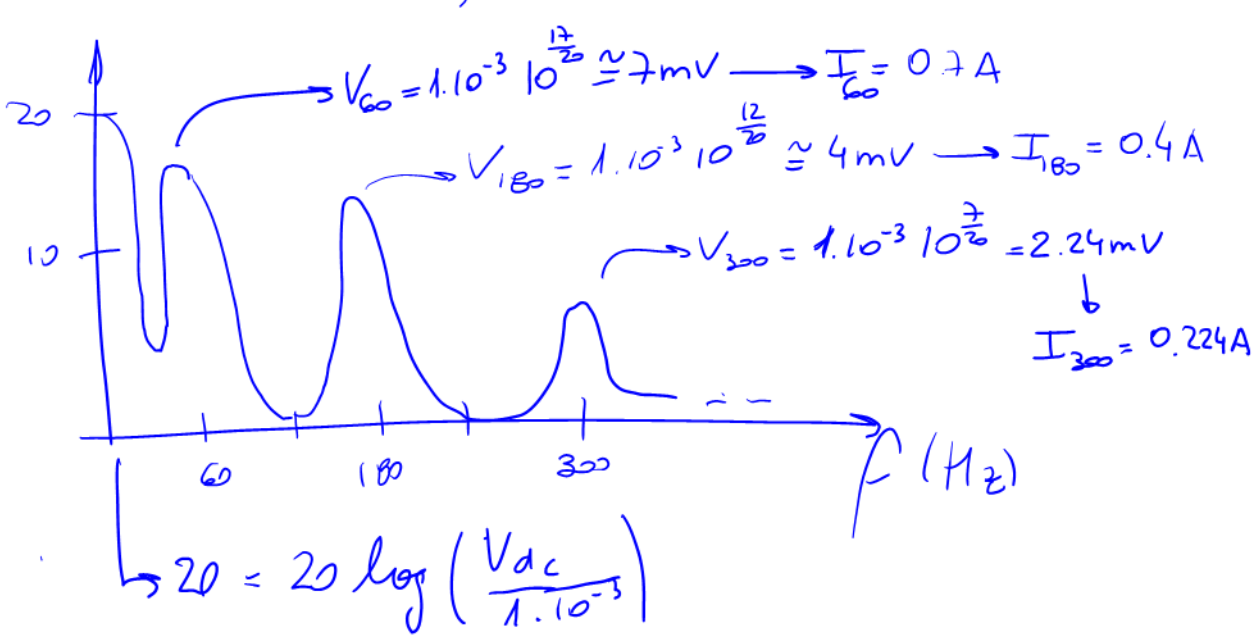
Problem 3 (30 points)

Consider that you are measuring the harmonic content of a current signal with a 10 A, 100 mV shunt resistance, and your measurements with respect to a 1 mVrms reference are:

V (0 Hz) = 20 dB
V (60 Hz) = 17 dB
V (180 Hz) = 12 dB
V (300 Hz) = 7 dB

Sketch the FFT graph and calculate the current corresponding to each component. If the source is composed of a 100 Wh (i.e. Watt.hour), 12 V battery, what is the power drained from this battery? Assuming a linear discharge characteristic (which is not usually true in actual batteries), how long will it take to fully discharge the battery?



$$20 = 20 \log\left(\frac{V_{dc}}{1.10^{-3}}\right)$$

$$V_{dc} = 1.10^{-3}\, 10^{1} = 10mV$$

If 10 A → 100 mV
1 A ← 10 mV

$$P = 1.12 = 12W$$

$$T_d = \frac{100}{12} = 8.33h$$

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Problem 4 (5 points each)

Please, select the correct answer for the following questions. Provide a brief justification for your answer.

4.1) Is it possible to identify <u>exactly</u> and in a <u>simple</u> way the proper orientation of a solar panel at night?

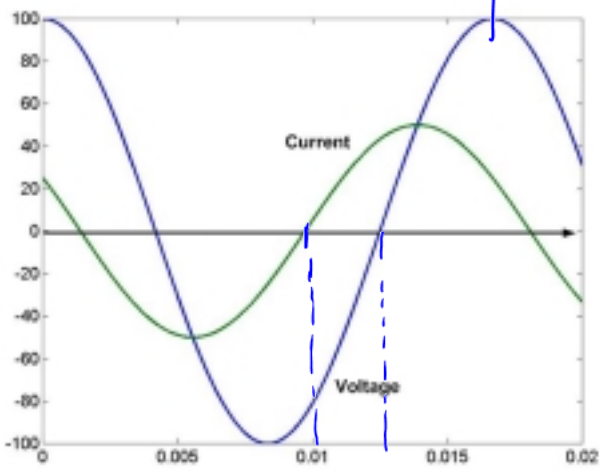
a) No, I can't see the sun
b) Yes, I use the moon instead
c) Yes, but only if there are no clouds
d) Yes, with a compass.

No, the moon and the sun don't follow the same path in the sky with the stars you can exactly know lattitude, and azimuth by just looking at the sky and identifying the celestial pole

You don't neccessarily know the lattitude and celestial pole and magnetic poles do not coincide

4.2) The next figure shows the voltage and currents of a given load. The load is:

a) A pure resistive load
b) A pure capacitive load
c) A pure inductive load
d) A resistive and capacitive load
e) A resistive and inductive load



$T = \frac{1}{60} = 16.6\,msec \rightarrow 2\pi$

Current leads voltage

Capacitive load + Resistive load

$0.003 \rightarrow \frac{3\,msec}{16.6\,msec} = 0.18 \rightarrow \frac{1}{3}\pi \neq \frac{\pi}{2}$

2π

(60°)

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4.3) For the load in problem 4.2, the average power dissipated through the load is:

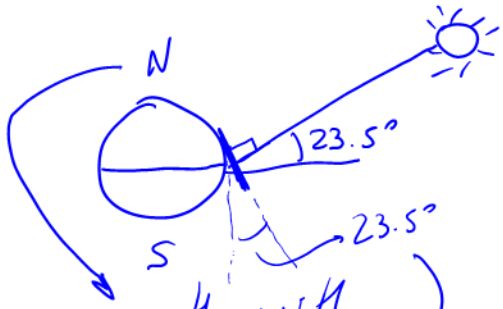
a) 0 W
b) 1 kW
c) 1.5 kW
d) 2.5 kW
e) None of the above

$$P = V_{rms} I_{rms} \cos\varphi = \frac{100}{2} \cdot \frac{50}{2} \cdot \cos(60) = 1.25\,kW$$

4.4) Suppose you are on the equator and you want to maximize the solar radiation received on a solar panel on June 21. Then you will orient the panel in the following way:

a) Azimuth 180°, Tilt 23.45°
b) Azimuth 0°, Tilt 23.45°
c) Azimuth 180°, Tilt 0°
d) Azimuth 0°, Tilt 0°
e) None of the above

Remember that azimuth 0° = North



It needs to face north with a tilt of 23.5°

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4.5) For each of the following statements referring to a DBR capacitive filter, choose the correct answer

a) If the load is increased the voltage ripple also increases
TRUE FALSE

b) If the ac line frequency is increased then the filter capacitance needs also to be increased to achieve the same voltage ripple.
TRUE FALSE

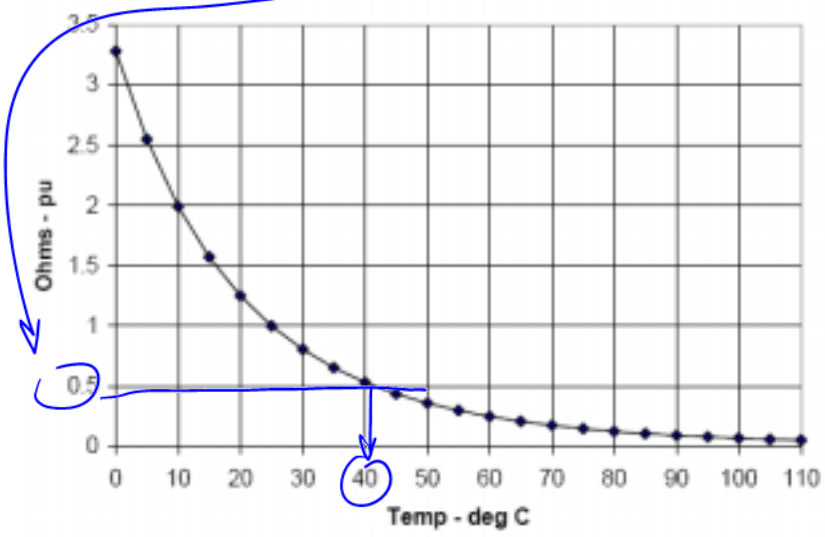
c) If the capacitance is increased the average input current also increases.
TRUE FALSE → Not necessarily true (i.e. false) because even though the current peak increases the current pulse width decreases

d) If the capacitance is increased, the voltage ripple increases
TRUE FALSE

For these questions remember that $V_{ripple-p-p} \cong \frac{P}{2fCV_{peak}}$

4.6) What it the approximate temperature of a 100 ohms thermistor measuring 50 ohms and with the following characteristic?

$\frac{50}{100} = 0.5$



a) 10 C
b) 20 C
c) 25 C
d) 40 C
e) 60 C
f) None of the above