# TSTE19

## Power Electronics

### Examination (TEN1)

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|---|---|
| Time: | Wednesday 8 April 2015 at 8.00 - 12.00 |
| Place: | U4, U6 |
| Resonsible teacher: | Martin Nielsen-Lönn, ISY, 070-361 52 44 (martin.nielsen.lonn@liu.se) |
| | Will visit exam location at 8:45 and 10. |
| Number of tasks: | 6 |
| Number of pages: | 4 |
| Allowed aids: | Calculator |
| Total points: | 70 |
| Notes: | A pass on the exam requires approximately 30 points. |
| | Remember to indicate the steps taken when solving problems. |
| Exam presentation: | Friday 17 April 2015 12:00-13:00 (Filtret, B-building) |

## Instructions

Write as detailed as you can and describe what you are doing. It is better to write if you are unsure about some step or equation instead of just using it.

## Questions

**Question 1**

(a) Will an ideal capacitor connected to a 220 V 50 Hz line outlet voltage get warm due to the current flowing through it? Motivate your answer. (2)

(b) Why do you want electrical isolation in a power supply? (2)

(c) What does the acronyms ZCS and ZVS mean? (2)

(d) When and why can a transistor used in a rectifier be better than a diode even if its behavior(on-/off times) is exactly the same. (2)

(e) What component (resistor, capacitor, inductor) can, in the right circumstances, be modeled as an ideal current source? (2)

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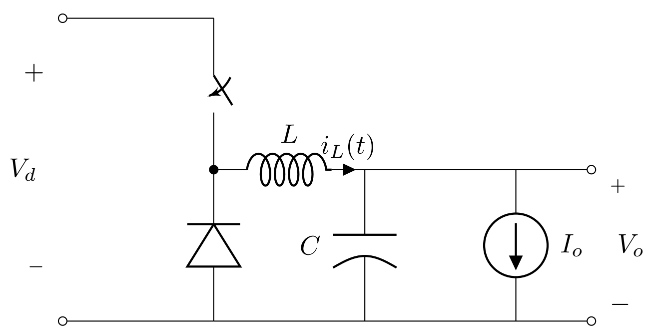


Figure 1: Circuit for question 2

**Question 2**

Consider the circuit in figure 1 with the following values: $V_d = 6$ V, L = 37.5 $\mu$H, D = 0.25, $I_o = 1.5$ A and $f_s = 100$ kHz. Assume that C is large and that it works in continuous conduction mode.

(a) What kind of circuit is this and what is the ratio between the output and input voltages? *Hint: Is $V_{out} > V_{in}$, vice versa or is the ratio arbitrary?* (2)

(b) Mention two other types of DC-DC converters and what their ratio between the output and input voltage are? *Hint: See part 1.* (4)

(c) What is the output voltage? (2)

(d) Sketch the waveforms for $v_L(t)$ and $i_L(t)$. Indicate the times, average values, all voltages and the peak-to-peak current. (3)

(e) Calculate the minimum switching frequency to keep continuous conduction mode. (6)

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**Question 3**

Consider the circuit and voltage graph in figure 2. The input voltage, $V_S$, is shown in the graph on the right and has a peak voltage of 340 V. L = 136 mH and $I_o = 5$ A.

(a) Draw the inductor voltage $V_L$ and current $I_L$. (3)

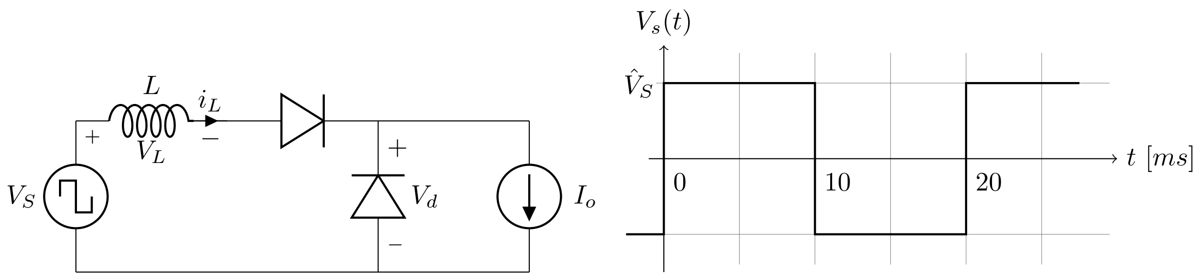


Figure 2: Circuit and waveform for question 3

(b) How long time does it take for the currenct commutation to complete? (5)

(c) What is the average output voltage $V_d$? (3)

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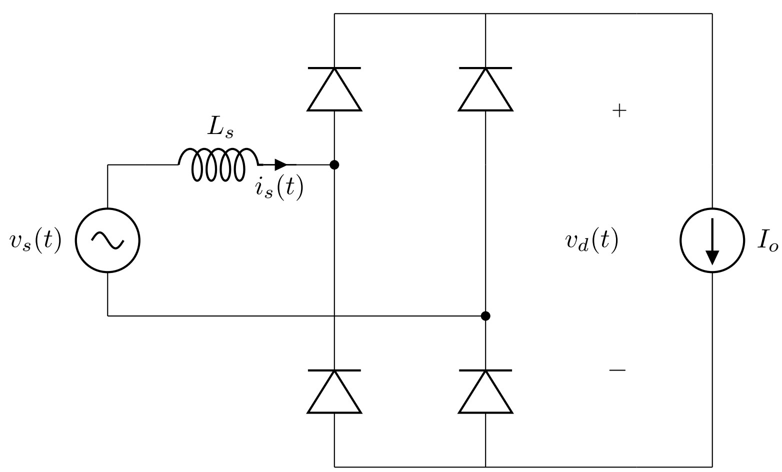


Figure 3: Circuit for question 4

**Question 4**

The rectifier in figure 3 have a load current $I_o$ of 2 A. Assume that all the diodes are ideal.

(a) Draw the waveforms of $v_s(t)$ and $i_s(t)$ if $L_s$ would be zero and $v_s$ is a sinusoidal voltage with 240 $V_{RMS}$ at 50 Hz, and describe which diodes are conducting at each interval and why. (2)

(b) Calculate the 3 first harmonics of $i_s$, that is the fundamental and the two following harmonics, and present them in table with frequency and amplitude. Assume $L_s$ is still zero. (3)

(c) Draw the waveforms of $v_s(t)$ and $i_s(t)$ if $L_s$ is 150 mH and $v_s$ is a square wave with 300 V ampltiude at 50 Hz, and describe which diodes are conducting at each interval and why. (3)

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**Question 5**

Recently smart watches has become more and more popular. They commonly use Li-Ion batteries with 3.7 V between the poles and a SoC (System-on-chip) which runs at a lower supply voltage. Because of this a DC-DC converter has to be used to step-down the voltage. Assuming the supply voltage to the SoC is 1.2 V and the watch consumes 400 mW in total (including the power converter), it is your job to design the heatsink for the power converter. You can assume that the efficiency always is 90% and the ambient temperature can be up to 50°C.

(a) What is the maximum power dissipated by the DC-DC converter? (2)

(b) Draw the thermal equivalent circuit and calculate the required $\Theta_{ca}$ for the heat sink assuming that $\Theta_j$ is 1°C/W and that the maximum case temperature is 70°C. (5)

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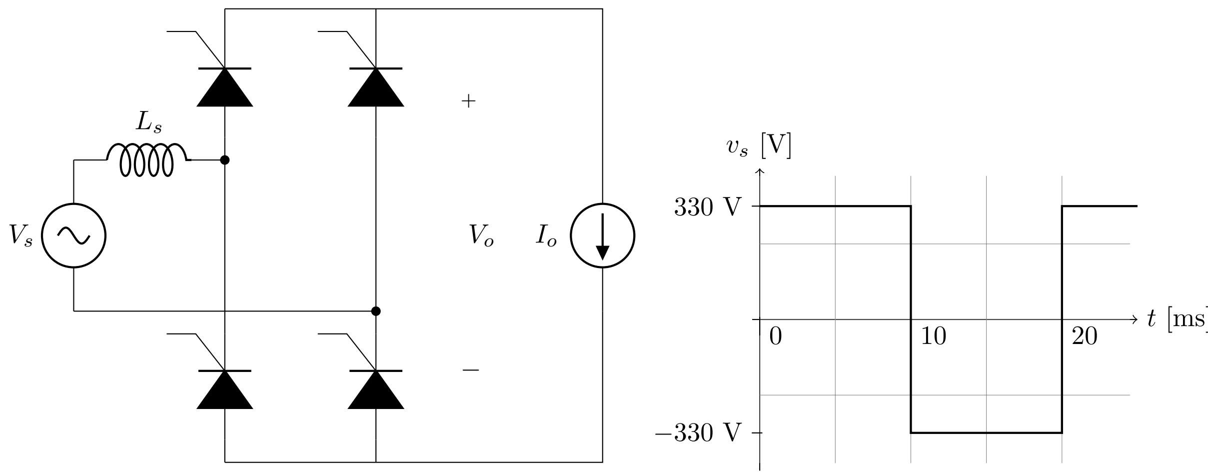



Figure 4: Circuit and waveform for question 6

**Question 6**

The thyristor based inverter showed in figure 4 have the input voltage $v_s$ shown to the right in the same figure. All thyristor have a 30° firing angle. The current source load $I_o$ is 3 A and the inductor $L$ is 110 mH.

(a) Draw the output voltage $v_o$ and the source current $i_s$, indicating which thyristor is on (conducting) and off (not conducting). (6)

(b) Calculate the average output voltage. (6)

(c) Calculate the displacement power factor (DPF) for the input power. (5)

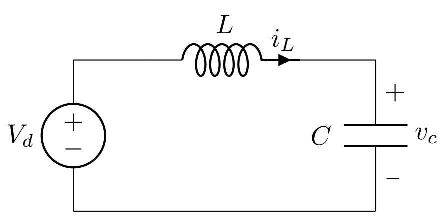
# Formula collection TSTE19 Power Electronics

## Fourier series coefficients using symmetri, Table 3.1

| | | | |
|---|---|---|---|
| Even | $f(-t) = f(t)$ | $b_h = 0$ | $a_h = \frac{2}{\pi}\int_0^{\pi} f(t)cos(h\omega t)d(\omega t)$ |
| Odd | $f(-t) = -f(t)$ | $a_h = 0$ | $b_h = \frac{2}{\pi}\int_0^{\pi} f(t)sin(h\omega t)d(\omega t)$ |
| Half-wave | $f(t) = -f\left(t + \frac{1}{2}T\right)$ | $a_h = b_h = 0$ 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 quart-wave | Even and half-wave | $b_h = 0$ for all $h$ | |
| | | $a_h = \frac{4}{\pi}\int_0^{\frac{\pi}{2}} f(t)cos(h\omega t)d(\omega t)$ for odd h, $a_h = 0$ for even h | |
| Odd quarter-wave | Odd and half-wave | $a_h = 0$ for all $h$ | |
| | | $b_h = \frac{4}{\pi}\int_0^{\frac{\pi}{2}} f(t)sin(h\omega t)d(\omega t)$ for odd h, $b_h = 0$ for even h | |

## Undamped resonant circuits

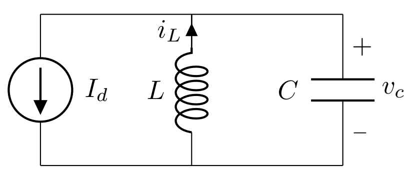
Undamped series resonant circuit, equation 9-3, 9-4




$$i_L(t) = I_{L0}cos(\omega_0(t - t_0)) + \frac{V_d - V_{c0}}{Z_0} sin(\omega(t - t_0))$$

$$v_c(t) = V_d - (V_d - V_{c0})cos(\omega(t - t_0)) + Z_0 I_{L0} sin(\omega_0(t - t_0))$$

Undamped parallel resonant circuit, equation 9-20, 9-21




$$i_L(t) = I_{L0}cos(\omega_0(t - t_0)) + \frac{V_d - V_{c0}}{Z_0} sin(\omega(t - t_0))$$

$$v_c(t) = V_d - (V_d - V_{c0})cos(\omega(t - t_0)) + Z_0 I_{L0} sin(\omega_0(t - t_0))$$

## Integration rules

$\int_a^b f(x)dx = \int_A^B f(g(t))g'(t)dt$ if $a = g(A)$, $b = g(B)$ and $g$ is monotone in [A,B]

$\int_a^b sin(x)dx = [-cos(x)]_a^b$

$\int_a^b cos(x)dx = [sin(x)]_a^b$