

Examination**ENM060 Power Electronic Converters****Date and time**Tuesday August 25th, 2015, 14:00 – 18:00**Responsible Teacher:**

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Authorised Aids:

Chalmers-approved calculator (Casio FX82..., Texas Instruments Ti-30... and Sharp EL-W531...)

Grades:

U, 3, 4 or 5. (The limit for a 3 on the exam is 20p, a 4 is 30p and 5 is 40p. The maximum number of points is 50.)

Solutions:Course webpage (Ping-Pong), August 26th 2015**Review of Exam**September 17th and September 21st, 12:00-13:00.Fredrik Lamms Room. Division of Electric Power Engineering (1st floor).From September 22nd 2015, the exams can be picked-up at the exam office, Department of Energy and Environment.

Location: EDIT building, Maskingränd 2, 3Ö (east) floor, room 3434A.

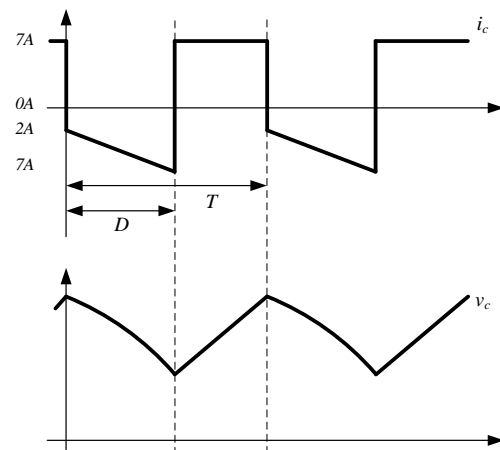
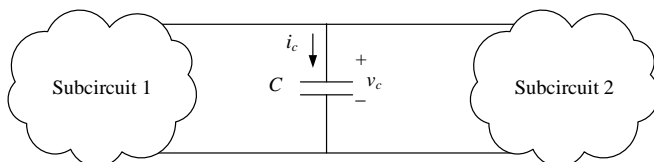
Opening hours during semesters: Monday-Friday 12:30-14:30

Observe that the questions are not arranged in any kind of order.

On the last pages there are some formulas that can be used in the examination. Always assume steady-state conditions in all tasks unless otherwise stated.

Please, read through the exam before you start.

- 1) For the circuit below with $T = 20\mu\text{s}$ and $D = 0.6$, draw the resulting voltage ripple and calculate the capacitance needed if the peak-to-peak voltage ripple is to be lower than 8mV. (3p)



The capacitor current is given and the resulting voltage over the capacitor can be calculated as:

$$v_c = v_c(t_1) + \frac{1}{C} \int i_c dt$$

Which means that the voltage will increase when the current is positive.

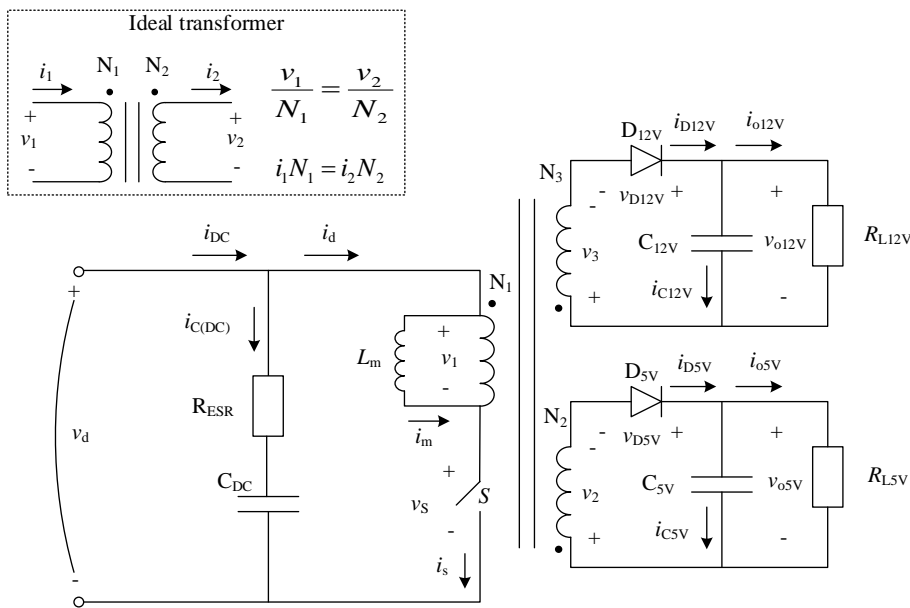
$$C = \frac{Q}{\Delta v_c} = \frac{0.4 \cdot 20\mu s \cdot 7A}{8mV} = 7mF$$

- 2) A flyback converter in a computer power supply has two secondary windings, see schematic below. Can both outputs be regulated with the duty ratio? If not, motivate which output that should be selected as the controlled one. (2p)

$$f_{sw} = 120kHz$$

$$C_{5V} = 470\mu F \quad I_{o(5V)} = 0 - 10A$$

$$C_{12V} = 470\mu F \quad I_{o(12V)} = 0 - 100mA$$



No, only one output can be controlled. Select the 5V output since this voltage will vary the most due to the largest variation in output current.

- 3) The flyback converter in (2) is designed with a transformer with 1:1:1 turns ratio ($L_m = 70\mu H$). If only the 5V-output is considered at a certain operating point ($I_{o(5V)} = 8A$, $V_d = 30V$, $T_a = 30^\circ C$), the converter will be operating in CCM. Draw the voltage over the diode on the secondary side (v_{D5V}), calculate the power loss in the diode using Simpsons formula and select a suitable diode from the attached datasheets. (6p)

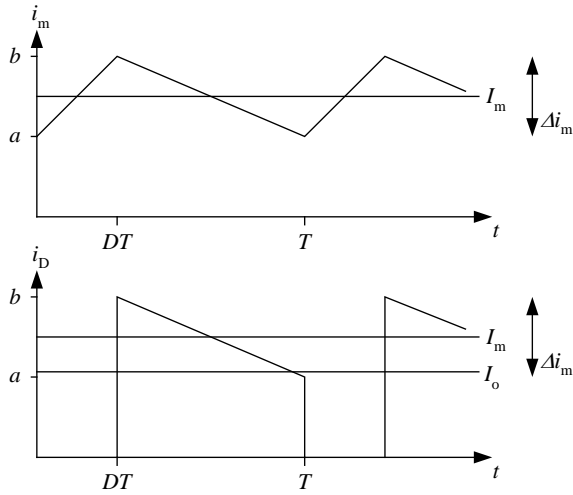
The ratio between the input and output voltage is:

$$V_L = \frac{1}{T_{sw}} \int_0^{DT_{sw}} V_d dt + \frac{1}{T_{sw}} \int_{DT_{sw}}^{T_{sw}} -V_o dt = \frac{1}{T_{sw}} (V_d DT_{sw} - V_o T_{sw} + V_o DT_{sw}) = 0$$

$$V_d D = V_o (1 - D) \rightarrow \frac{V_o}{V_d} = \frac{D}{1 - D} \rightarrow \frac{5V}{30V} = \frac{D}{1 - D} \rightarrow D = 0.143$$

If the converter is operating in CCM, the current ripple must be smaller than twice the average magnetizing current ($\Delta i_m = 2I_m$). The current ripple in the magnetizing current can be expressed as:

The magnetizing current (i_m) and the diode current (i_D) for CCM can be drawn as:



From the figure we see that the average magnetizing current can be calculated as:

$$I_m = \frac{1}{T_{sw}} \int_0^{T_{sw}} i_m(t) dt = \frac{1}{T_{sw}} \int_0^{DT_{sw}} i_m(t) dt + \frac{1}{T_{sw}} \int_{DT_{sw}}^{T_{sw}} i_m(t) dt = \frac{a+b}{2T} DT + \frac{a+b}{2T} (1-D)T = \frac{a+b}{2}$$

$$I_o = \frac{1}{T_{sw}} \int_0^{T_{sw}} i_D(t) dt = \frac{1}{T_{sw}} \int_{DT_{sw}}^{T_{sw}} i_m(t) dt = \frac{a+b}{2T} (1-D)T = I_m(1-D) \rightarrow I_m = \frac{8A}{1-0.143} = 9.33A$$

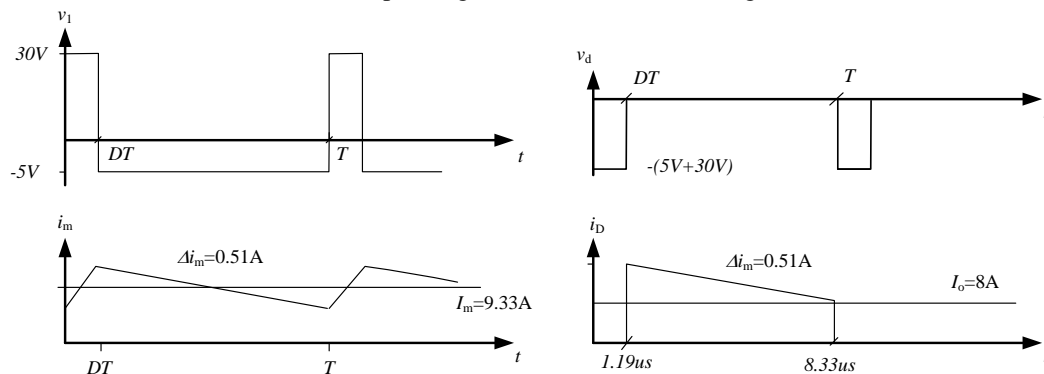
The border between CCM and DCM can now be calculated as:

$$\Delta i_m = 2I_m \rightarrow \frac{V_d D}{L_m f_{sw}} = \frac{2I_o}{(1-D)}$$

If solving for D and considering that for CCM, the current ripple has to be smaller than twice the average magnetizing current, the final answer is obtained:

$$D(1-D) < \frac{2I_o L_m f_{sw}}{V_d} \quad 0.143 \cdot (1-0.143) < \frac{2 \cdot 8A \cdot 70\mu H \cdot 120kHz}{30V}$$

Which means that the converter is operating in CCM. The diode voltage and current can now be drawn:



To calculate the power loss in the diode, only the constant voltage drop is accounted for, this gives a need to calculate the average current through the diode. The definition for Simpsons rule is:

$$\frac{1}{T} \int_{t_0}^{t_0+T} f(x) dx = \frac{1}{6} \left(f(t_0) + 4 \cdot f\left(t_0 + \frac{T}{2}\right) + f(t_0 + T) \right)$$

The AVG current can now be calculated as:

$$I_{diode(AVG)} = \frac{1}{8.33\mu} \left(1.19\mu \frac{1}{1.19\mu} \int_0^{1.19\mu} 0 dt + 7.14\mu \frac{1}{7.14\mu} \int_{1.19\mu}^{8.33\mu} i_{diode}(t) dt \right) =$$

$$= \frac{7.14\mu}{8.33\mu} \frac{1}{6} ((9.59A) + 4(9.33A) + (9.08A)) = 7.998A$$

Both diodes can handle the current which gives that the power dissipation can be calculated as

$$P_{conduction} = V_F I_{diode(AVG)} = 0.9V \cdot 8A = 7.2W \text{ for MBR20200CT}$$

$$P_{conduction} = V_F I_{diode(AVG)} = 0.41V \cdot 8A = 3.3W \text{ for FSV1045V}$$

The resulting component temperatures can be calculated as:

$$T_j = R_{\theta ja} \cdot P_{conduction} + T_a = (1.5 + 5.9)^\circ C/W \cdot 7.2W + 30^\circ C = 83^\circ C \text{ for MBR20200CT}$$

$$T_j = R_{\theta ja} \cdot P_{conduction} + T_a = 40^\circ C/W \cdot 3.3W + 30^\circ C = 162^\circ C \text{ for FSV1045V}$$

The diode MBR20200CT shall be used in this application due to the lower chip temperature.

- 4) **The Flyback converter in (3) is now used with a varying input voltage $20V \leq V_d \leq 34V$. Calculate the maximum power dissipation in the input capacitor if $R_{ESR} = 175m\Omega$. Assume that the capacitor is so large so that the input voltage is constant and that the input current is a pure DC-current. (5p)**

The output voltage and consequently also the output power is constant. This gives that the input power also becomes constant but since the input voltage will vary, the input current must also vary. The input current will be highest for the lowest input voltage.

$$V_d D = V_o(1 - D) \rightarrow \frac{V_o}{V_d} = \frac{D}{1 - D} \rightarrow \frac{5V}{20V} = \frac{D}{1 - D} \rightarrow D = 0.2$$

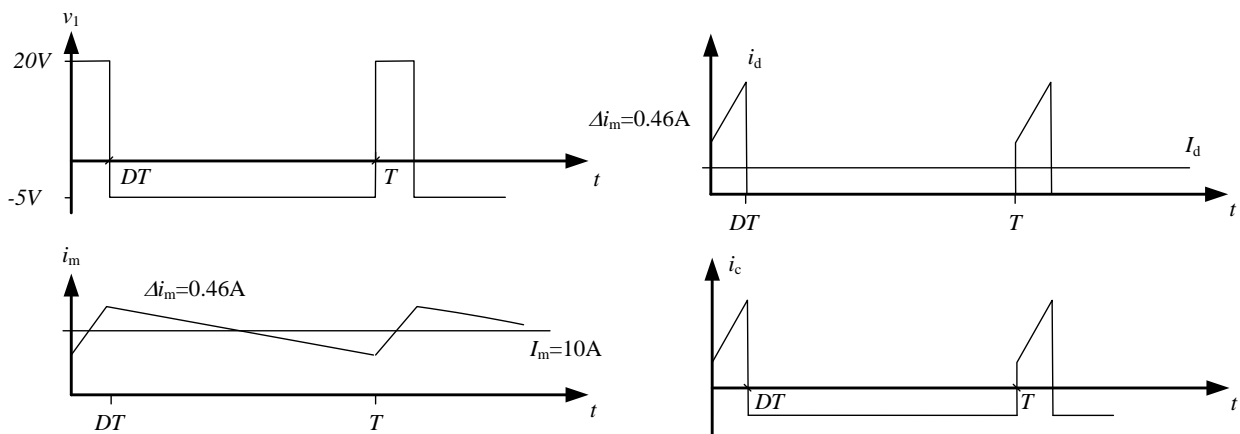
$$\Delta i_m = \frac{V_d D T_{sw}}{L_m} = \frac{V_d D}{L_m f_{sw}} = \frac{20V \cdot 0.2}{70\mu H \cdot 120kHz} = 0.476A$$

$$D(1 - D) < \frac{2I_o L_m f_{sw}}{V_d} \quad 0.2 \cdot (1 - 0.2) < \frac{2 \cdot 8A \cdot 70\mu H \cdot 120kHz}{20V}$$

$$I_m = \frac{8A}{1 - 0.2} = 10A$$

$$I_d = \frac{P_{in}}{V_{in}} = \frac{5V \cdot 8A}{20V} = 2A$$

Which means that the converter is still operating in CCM. The input current can now be drawn:



Since the input filter is well dimensioned, the current drawn from the DC-source can be considered a purely DC-current. If a pure DC-current is flowing from the DC-source, the entire ripple current must flow through the capacitor. The RMS-value of the capacitor current can be calculated according to the definition

$$I_{C(RMS)} = \sqrt{\frac{1}{8.33\mu} \int_0^{8.33\mu} i_c^2(t) dt =}$$

The definition for Simpsons rule is:

$$\frac{1}{T} \int_{t_0}^{t_0+T} f(x) dx = \frac{1}{6} \left(f(t_0) + 4 \cdot f\left(t_0 + \frac{T}{2}\right) + f(t_0 + T) \right)$$

The RMS-current can now be calculated as:

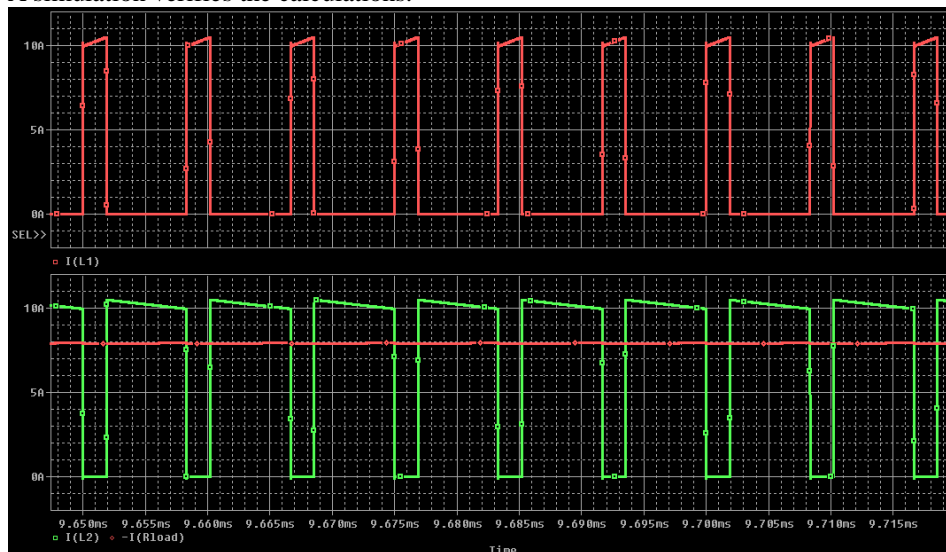
$$I_{C(RMS)} = \sqrt{\frac{1}{8.33\mu} \left(1.67\mu \frac{1}{1.67\mu} \int_0^{1.67\mu} i_c^2(t) dt + 6.67\mu \frac{1}{6.67\mu} \int_{6.67\mu}^{8.33\mu} i_c^2(t) dt \right) =}$$

$$= \sqrt{\frac{1.67\mu}{8.33\mu} \frac{1}{6} \left(\left(10A - \frac{0.46A}{2} - 2A \right)^2 + 4 \cdot (10A - 2A)^2 + \left(10A + \frac{0.46A}{2} - 2A \right)^2 \right) + \frac{6.67\mu}{8.33\mu} (2A)^2} = 4.0A$$

The power dissipation in the capacitor can now be calculated as:

$$P_C = R_{ESR} I_{C(RMS)}^2 = 175m\Omega \cdot 4.0A^2 = 2.8W$$

A simulation verifies the calculations.



- 5) **The transformer in the flyback converter in (2) needs to be designed. You have two different RM6R-cores made of material 3D3 to choose between; a core with 0.7mm airgap and a core without airgap (see attached datasheet). Calculate the primary magnetizing inductance for both cores if $N_1 = 33$ with both the A_L -value and the reluctance of the core. Which core is most suitable in a flyback transformer? Why? (4p)**

The inductance for each core is calculated with the specified A_L -value (which is the same for both the core with center hole and the core without center hole):

$$L_{ungapped} = A_L N^2 = 1000 \cdot 33^2 = 1089\mu H$$

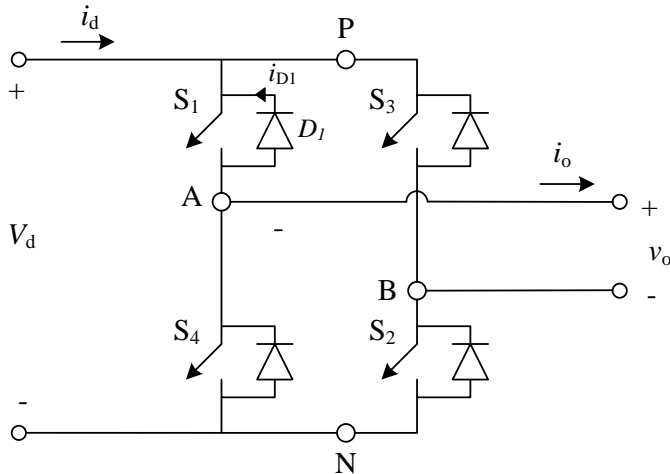
$$L_{gapped} = A_L N^2 = 63 \cdot 33^2 = 67\mu H$$

The inductance can also be calculated by first calculating the reluctance of the core. If the air gap is considered, the majority of the reluctance lies within the air gap, hence can the core be neglected in this case.

$$L = \frac{N^2}{\mathfrak{R}} = \begin{cases} L_{ungapped} = \frac{33^2}{l_e / \mu_r \mu_0 A} = \frac{33^2}{25.6\text{mm} / 650 \cdot 4\pi e^{-7} \cdot 32\text{mm}^2} = 1111\mu\text{H} \\ L_{gapped} = \frac{33^2}{l_g / \mu_0 A} = \frac{33^2}{0.7\text{mm} / 4\pi e^{-7} \cdot 32\text{mm}^2} = 62\mu\text{H} \\ L_{gapped} = \frac{33^2}{l_g / \mu_0 A} = \frac{33^2}{25.6\text{mm} / 41 \cdot 4\pi e^{-7} \cdot 32\text{mm}^2} = 70\mu\text{H} \end{cases}$$

The transformer in the flyback converter is used as an energy storage device which means that an air gap is preferred. A flyback transformer doesn't have the ampere-turn cancellation benefit of a forward converter, so the entire energy storage in the core moves the core up its hysteresis curve. The air gap flattens the hysteresis curve and allows more energy handling by decreasing the permeability of the core. You will of course need to add more turns to get your desired inductance compared to no-gap, but you avoid core saturation.

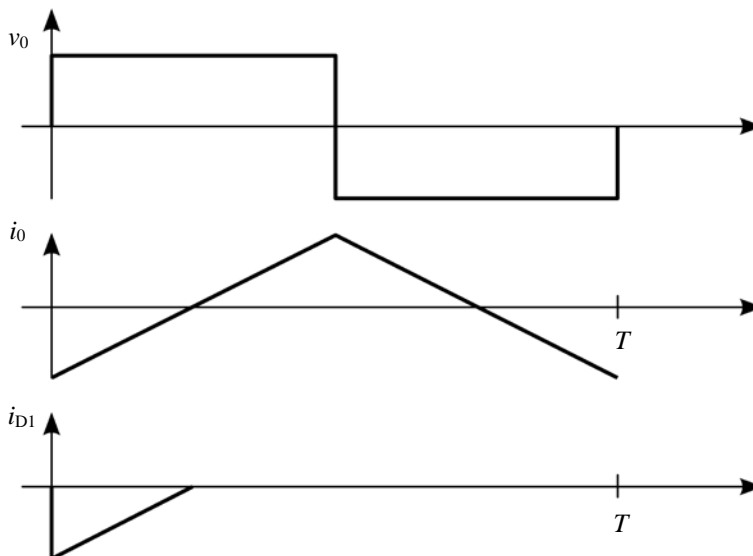
6) **The single phase inverter below is operating in square-wave mode. Draw the output voltage, v_o , the output current, i_o , and the diode current, i_{D1} , waveforms. Calculate also the average diode current, I_{D1} . (4p)**



Nominal values for square wave inverter

Source voltage	$V_d = 200\text{V}$
Load inductance	$L = 20\text{mH}$
Fundamental frequency	$f_{s,1} = 50\text{Hz}$

Due to the pure inductive load, the output current increases linearly while the output voltage is positive and decreases linearly while the output voltage is negative. The diode, D1, is only conducting while the output voltage is positive and the output current is negative.



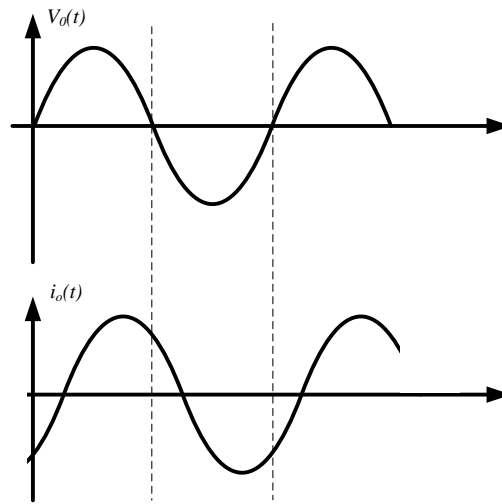
The output current “ripple” can be calculated as

$$\Delta i_o = \frac{V_d \Delta t}{L} = \frac{200V \cdot 0.5}{20mH \cdot 50Hz} = 100A$$

The average diode current is

$$I_{D1} = \frac{1}{T} \left(\frac{\Delta i_o}{2} \cdot \frac{T}{4} \cdot 0.5 \right) = 6.25A$$

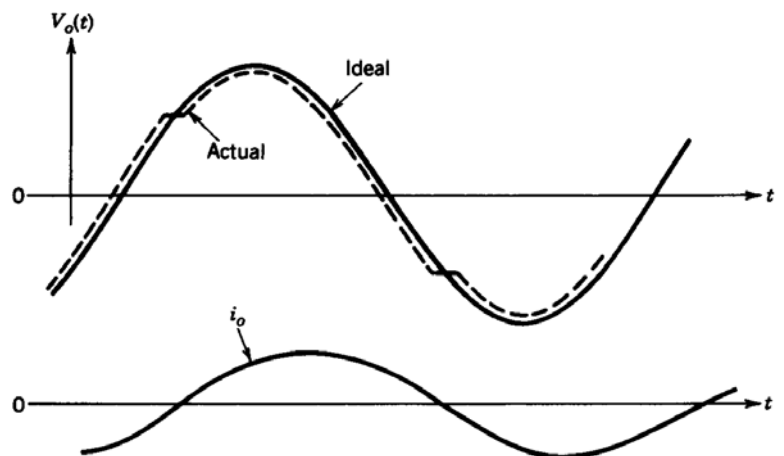
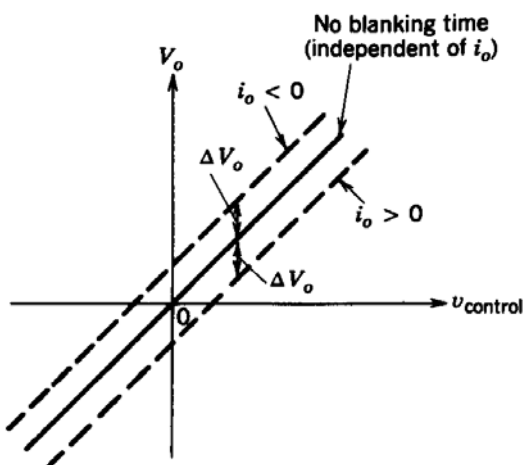
- 7) Consider a single phase inverter operating in PWM mode without blanking time where the output current is sinusoidal and lagging the voltage, see below. If blanking time is added, how will the output current and voltage be affected? Sketch the resulting waveforms and comment on the harmonic content. (4p)



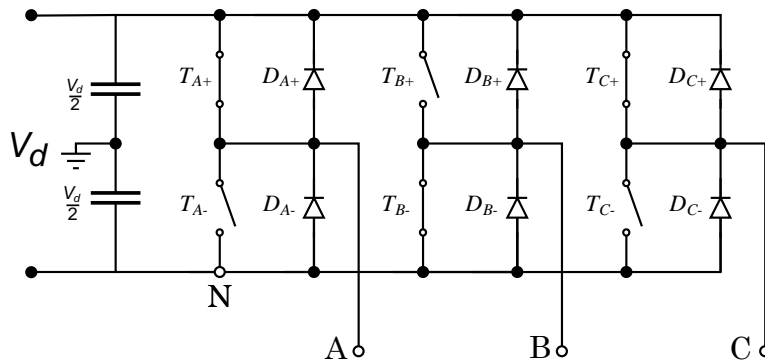
Blanking time is a short time period where both switches in one phase leg are turned off at the same time. This is needed to make sure that the source is not short-circuited due to the non-ideal switches.

For a positive output current, the output voltage will be increased slightly due to the blanking time and for a negative output current, the output voltage will be decreased slightly.

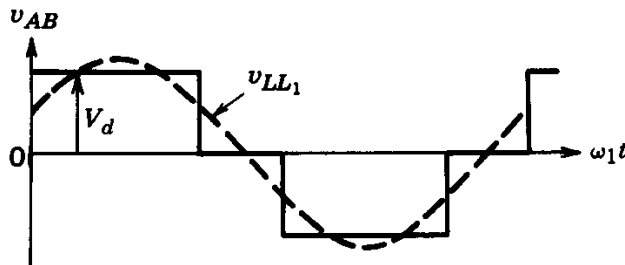
The effect is seen in the output voltage when i_o has a zero crossing, there will be a notch in the voltage which results in low order harmonics (3:d, 5:th and so on) in the inverter output.



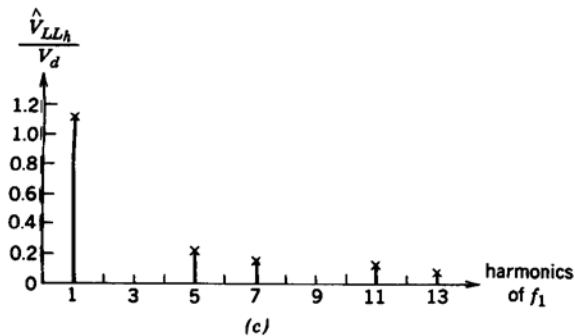
8) The three phase inverter below is operating in square wave mode with $V_d = 250V$ and a fundamental frequency component of 50Hz. Draw the resulting line-to-line voltage and calculate the amplitude of the first 9 harmonic components. (4p)



The resulting line-to-line voltage between phase A and B is made up by the difference between voltage v_{AN} and v_{BN} and has a quasi square wave shape.



The line-to-line voltage does not depend on the load. All even harmonics are cancelled out due to symmetry and all multiples of 3 are cancelled out due to the 3-phase system ($6n \pm 1, n=1,2,\dots$).



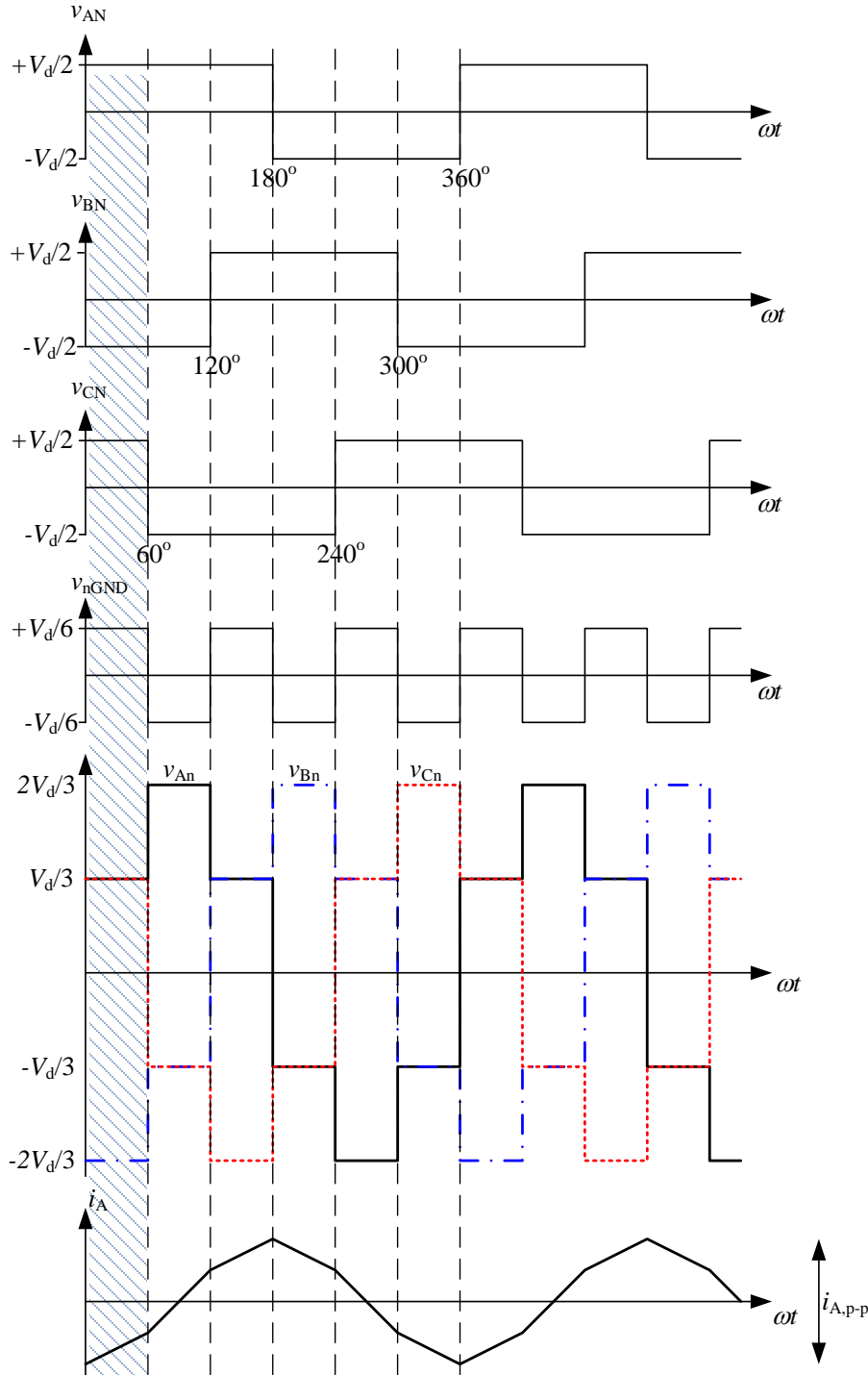
The Fourier components can be calculated according to the figure which says that the function can be defined as even and half-wave ($a_n=0$ for all values of n):

$$a_n = \frac{4}{\pi} \int_0^{\pi/2} v_{AB}(\theta) d\theta = \frac{4}{\pi} \left(\int_0^{\pi/3} V_d \cos(\theta) d\theta + \int_{\pi/3}^{\pi/2} 0 \cdot \cos(\theta) d\theta \right) \rightarrow V_{LL(n)RMS} = \frac{\sqrt{6}V_d}{n\pi}$$

Frequency	$u_{o,n}$ (peak)
50 Hz (n=1)	275V
250 Hz (n=5)	55.1V
350 Hz (n=7)	39.4V

- 9) The three phase inverter in (8) is operating in square wave mode ($V_d = 250V$ and $f_0 = 50Hz$) with a purely inductive load ($L = 1mH$). Draw both the input and the output current and calculate the peak ripple in both currents. (5p)

By applying a constant voltage over a purely inductive load, the current through the load will increase linearly when the voltage is positive and decrease linearly when the voltage is negative. The derivative depends on the applied voltage and since the load is inductive, no active power is transferred from the source.



To calculate the peak-to-peak value of the output current it can be noticed that the current increases with three slopes, two are the same. Use the differential equation for an inductor

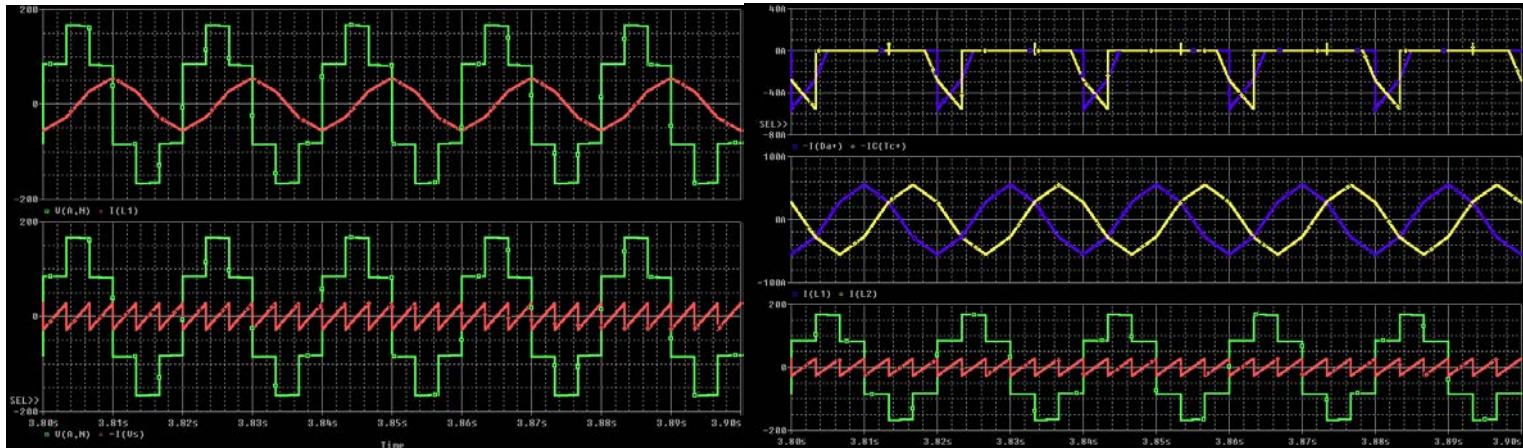
$$v_L = v_{An} = L_A \frac{di_A}{dt} \underset{\text{Constant voltage}}{=} L_A \frac{\Delta i_A}{\Delta t} \Rightarrow \Delta i_A = \frac{v_{An} \Delta t}{L_A}$$

$$\Delta t = \frac{\Delta \gamma}{360^\circ f_{s(1)}} T_{s(1)} = \frac{\Delta \gamma}{360^\circ f_{s(1)}} \Rightarrow \Delta i_A = \frac{v_{An} \Delta \gamma}{360^\circ f_{s(1)} L_A} \Rightarrow$$

$$\begin{aligned}
 i_{A,p-p} &= \Delta i_A(0^\circ - 60^\circ) + \Delta i_A(60^\circ - 120^\circ) + \Delta i_A(120^\circ - 180^\circ) = \\
 &= \frac{V_d}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} + \frac{2V_d}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} + \frac{V_d}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} = \frac{4 \cdot 250\text{V}}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} = \\
 &= 27.7\text{A} + 55.5\text{A} + 27.7\text{A} = 111\text{A}
 \end{aligned}$$

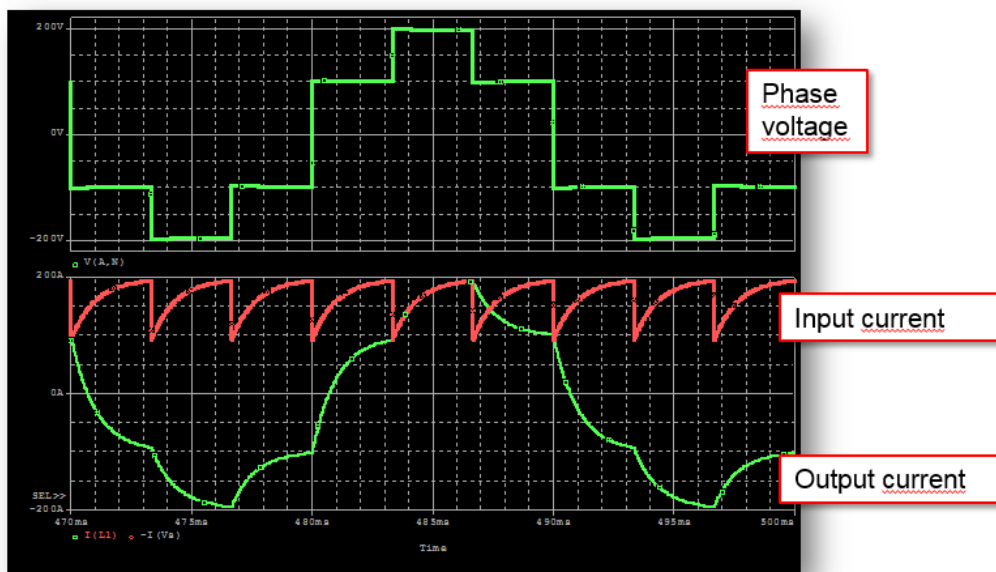
Now is the voltage over each inductor and the current through each inductor known. For the dashed time interval, the upper transistors in phase leg A and C are turned on which means that the current on the DC-link must be the sum of these two currents. Not that since the load current is defined as negative, DA+ will carry the current.

$$\Delta i_{input} = \frac{V_d}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} + \frac{V_d}{3} \frac{60^\circ}{360^\circ \cdot 50\text{Hz} \cdot 10\text{mH}} = 55.5\text{A}$$

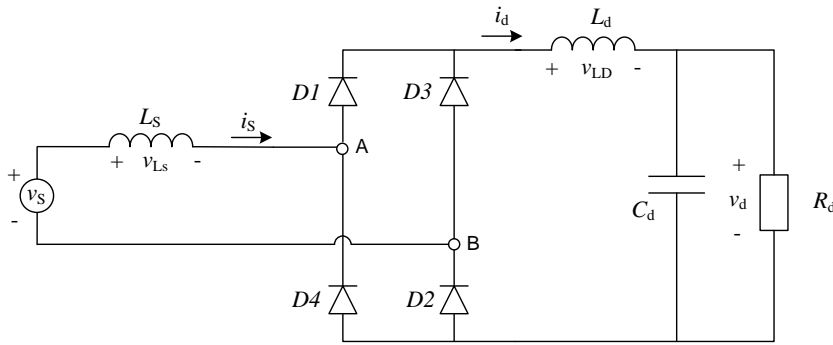


- 10) If the three phase inverter in (8) is operated with an RL-load, sketch the resulting input and output currents. No absolute values needs to be calculated, just approximate graphs. Compare the active and reactive power transfer to the load with task 10. (3p)

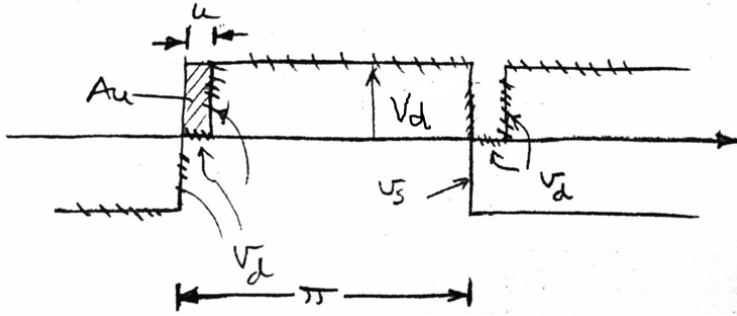
In the previous task where a purely inductive load was used, no active power was transferred to the load which resulted in an AC-current on the DC-link. If an RL-load is applied, active power will be transferred to the load which means that the input current (DC-link current) will be offset with a DC-level. Output current will consist of exponential increases/decreases which depend on the voltage applied over the inductor, the inductance and the resistance.



- 11) In the single phase diode rectifier below, the DC-side inductance is assumed to be so large that a constant current flows on the DC-side. The AC-voltage is a 50Hz square waveform with an amplitude of 250V, $I_d = 18\text{A}$ and $L_S = 820\mu\text{H}$. Calculate the commutation angle u and the power dissipation in the load resistor R_d . (3p)



The output voltage will be reduced at each current commutation due to the source inductance.



The area reduction due to commutation can be described as

$$A_u = \int_0^u 250V d\theta = \omega L_s \int_{-I_d}^{I_d} di_s = \omega 2L_s I_d$$

During the commutation from D1 to D3, the entire phase voltage will be applied over the inductance.

$$A_u = 250V \cdot u = 2\omega L_s I_d \rightarrow u = \frac{2 \cdot 2\pi \cdot 50\text{Hz} \cdot 820\mu\text{H} \cdot 18\text{A}}{250V} = 2.12^\circ$$

If no source inductance would have been present, the DC-link voltage would have been $V_{d0} = 250V$ but with output voltage reduction

$$V_d = V_{d0} - \frac{A_u}{\pi} = 250V - \frac{2\omega L_s I_d}{\pi} = 247V \rightarrow P_d = V_d I_d = 4.45\text{kW}$$

- 12) The diodes in the single phase diode rectifier in (11) are replaced by thyristors. Calculate the required delay angle in order to get an output power of 2kW. Calculation of the commutation angle is needed for full points. (3p)

The average output voltage must be

$$V_d = \frac{P_d}{I_d} = \frac{2\text{kW}}{18\text{A}} = 111\text{V}$$

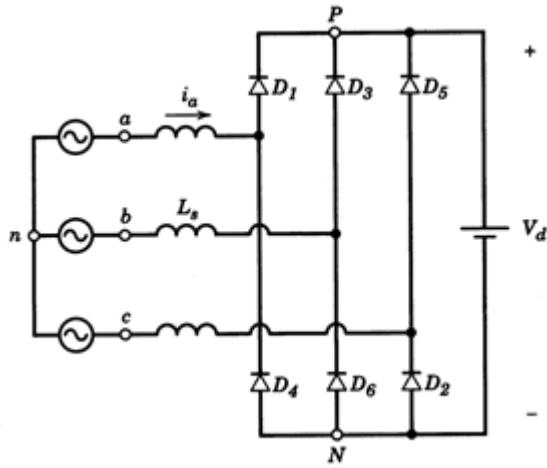
so

$$V_d = V_{d0} - \frac{A_\alpha}{\pi} - \frac{A_u}{\pi} = 250V - \frac{A_\alpha}{\pi} - \frac{2\omega L_s I_d}{\pi} \rightarrow A_\alpha = \left(250V - \frac{P_d}{I_d} - \frac{2\omega L_s I_d}{\pi}\right) \pi$$

The voltage that is removed during the delay is $2 \cdot 250V$

$$A_\alpha = 2 \cdot 250V \cdot \alpha = \left(250V - \frac{P_d}{I_d} - \frac{2\omega L_s I_d}{\pi}\right) \pi \rightarrow \alpha = \left(250V - \frac{P_d}{I_d} - \frac{2\omega L_s I_d}{\pi}\right) \pi / (2 \cdot 250V) = 48.94^\circ$$

- 13) The diode rectifier below is supplied with a sinusoidal voltage. The DC-side current is a constant current (I_d), the source voltages are 230V ($\pm 5\%$) at 50Hz and the source inductance (L_s) is 800μH in each phase. Calculate the maximum commutation angle and resulting average output voltage (V_d) that is obtained for $P_{DC} = 5\text{kW}$. (4p)



The commutation angle can be calculated as:

$$\int_0^u \frac{v_{an} - v_{cn}}{2} d\omega t = \int_0^{I_d} \omega L_s di_u = \omega L_s I_d = A_u$$

$$u = \arccos\left(1 - \frac{2\omega L_s I_d}{\sqrt{2}V_{LL}}\right)$$

The average power through the converter can be described as:

$$P_d = V_d I_d = \left(1.35V_{LL} - \frac{3\omega L_s I_d}{\pi}\right) I_d$$

Solving the second order polynomial equation and insertion of numerical values for both max and min input voltage gives:

$$1.35V_{LL}I_d - \frac{3\omega L_s}{\pi}I_d^2 = P_{DC} \quad \rightarrow \quad I_d^2 = (1.35V_{LL}I_d - P_{DC}) \cdot \frac{\pi}{3\omega L_s}$$

$$0 = I_d^2 - \frac{\pi 1.35V_{LL}I_d}{3\omega L_s} + \frac{P_{DC} \cdot \pi}{3\omega L_s}$$

$$I_{d(min)}: \quad 0 = I_d^2 - \frac{\pi \cdot 1.35 \cdot 230V \cdot \sqrt{3} \cdot 1.05 \cdot I_d}{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H} + \frac{5kW \cdot \pi}{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H} \quad \rightarrow \quad I_{d(min)} = 8.89A$$

$$I_{d(max)}: \quad 0 = I_d^2 - \frac{\pi \cdot 1.35 \cdot 230V \cdot \sqrt{3} \cdot 0.95 \cdot I_d}{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H} + \frac{5kW \cdot \pi}{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H} \quad \rightarrow \quad I_{d(max)} = 9.83A$$

A greater current gives a greater commutation angle.

$$u_{min} = \arccos\left(1 - \frac{2 \cdot 2\pi \cdot 50Hz \cdot 800\mu H \cdot 8.89A}{\sqrt{2} \cdot 230V \cdot \sqrt{3} \cdot 1.05}\right) = 7.0^\circ$$

$$u_{max} = \arccos\left(1 - \frac{2 \cdot 2\pi \cdot 50Hz \cdot 800\mu H \cdot 9.83A}{\sqrt{2} \cdot 230V \cdot \sqrt{3} \cdot 0.95}\right) = 7.8^\circ$$

$$V_{d\alpha(min)} = V_{do} - \frac{A_u}{\pi} = 1.35 \cdot 1.05 \cdot 230V \cdot \sqrt{3} - \frac{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H \cdot 8.89A}{\pi} = 562.6V$$

$$V_{d\alpha(max)} = V_{do} - \frac{A_u}{\pi} = 1.35 \cdot 0.95 \cdot 230V \cdot \sqrt{3} - \frac{3 \cdot 2\pi \cdot 50Hz \cdot 800\mu H \cdot 9.83A}{\pi} = 508.6V$$

Diode 1:



FSV1045V 10 A, 45 V Ultra-Low VF Schottky Rectifier

Features

- Ultra-Low Forward Voltage Drop:
 - 0.41 V Typical at 10 A, $T_A = 25^\circ\text{C}$
 - 0.44 V Maximum at 10 A, $T_A = 25^\circ\text{C}$
- Low Thermal Resistance
- Very Low Profile: Typical Height of 1.1 mm
- RoHS Compliant
- Halogen Free
- Meets MSL 1 per JESD22-A111 Full-Body Solder Immersion

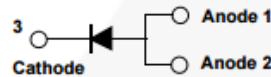
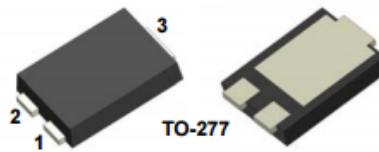
Applications

- Mobile Charger
- Solar Panel
- Reverse Polarity Protection

Description

The FSV1045V schottky rectifier offers break-through size and performance. The device is optimized for mobile charger applications. It sinks only 18 mA reverse current at high temperature and provides forward voltage drop of 0.18 V at 1 A operating current in a charger design.

All this capability is packed into a small, flat-lead, TO-277 package, optimized for space-constrained applications. The FSV1045V supports a typical Z height of 1.1 mm. It is RoHS compliant and halogen free. It is also qualified for a wave soldering process.



Electrical Characteristics

Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{BR}	Breakdown Voltage	$I_T = 500 \mu\text{A}$	45			V
V_F	Forward Voltage Drop	$I_F = 1 \text{ A}$		0.28	0.44	V
		$I_F = 10 \text{ A}$		0.41		
		$I_F = 1 \text{ A}$	$T_A = 125^\circ\text{C}$	0.18	0.39	
		$I_F = 10 \text{ A}$	$T_A = 125^\circ\text{C}$	0.36		
I_R	Maximum Leakage	$V = V_{RWM}$	$T_A = 25^\circ\text{C}$	0.065	0.220	mA
			$T_A = 125^\circ\text{C}$	19	32	

Thermal Characteristics⁽⁴⁾

Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Minimum Land Pattern	Maximum Land Pattern	Unit
$R_{\theta JA}$	Junction-to-Ambient Thermal Resistance	100	40	$^\circ\text{C/W}$
Ψ_{JL}	Junction-to-Lead Thermal Characteristics, Thermocouple Soldered to Anode	15	12	$^\circ\text{C/W}$
	Junction-to-Lead Thermal Characteristics, Thermocouple Soldered to Cathode	6	5	

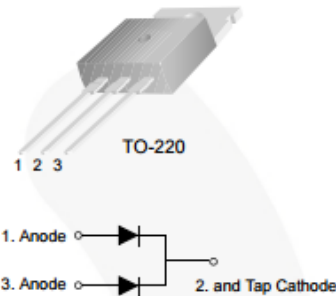
Diode 2:



MBR20200CT Dual High Voltage Schottky Rectifier

Features

- Low Forward Voltage Drop
- Low Power Loss and High Efficiency
- High Surge Capability
- RoHS Compliant
- Matte Tin (Sn) Lead Finish
- Terminal Leads Surface is Corrosion Resistant and able to Withstand to 260°C
- Wave Soldering or per MIL-STD-750 Method 2026.



Thermal Characteristics⁽¹⁾

Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Value	Unit
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case per Leg	1.5	$^\circ\text{C/W}$
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient per Leg	62.5	$^\circ\text{C/W}$

Note:

1. MIL standard 883-1012 and JESD51-10.

$$R_{thCA} = 5.9^\circ\text{C/W}$$

Electrical Characteristics⁽²⁾

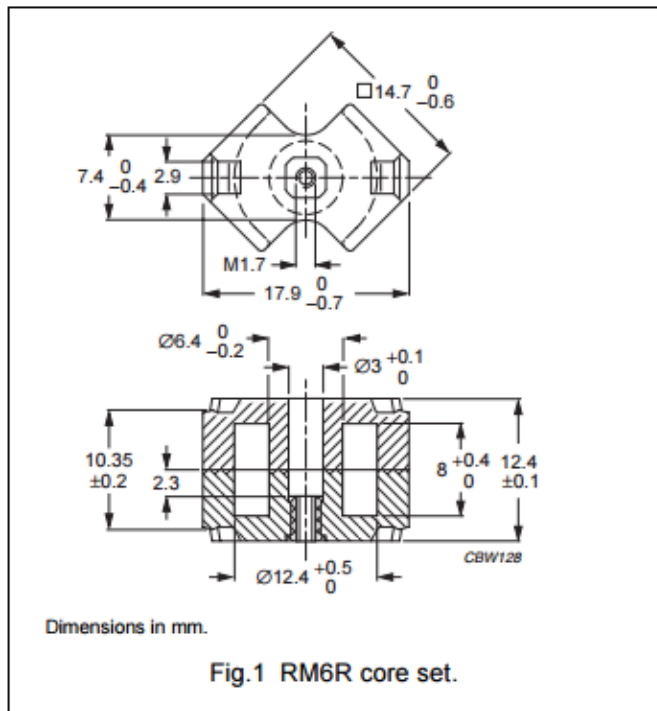
Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Max.	Unit
I_R	Reverse Current	$V_R = 200\text{ V}, T_C = 25^\circ\text{C}$		0.2	mA
		$V_R = 200\text{ V}, T_C = 125^\circ\text{C}$		2.0	
V_F	Forward Voltage	$I_F = 10\text{ A}, T_C = 25^\circ\text{C}$		0.9	V
		$I_F = 10\text{ A}, T_C = 125^\circ\text{C}$		0.8	
		$I_F = 20\text{ A}, T_C = 25^\circ\text{C}$		1.0	
		$I_F = 20\text{ A}, T_C = 125^\circ\text{C}$		0.9	

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
$\Sigma(l/A)$	core factor (C1)	0.810	mm ⁻¹
V_e	effective volume	810	mm ³
l_e	effective length	25.6	mm
A_e	effective area	32.0	mm ²
A_{min}	minimum area	23.8	mm ²
m	mass of set	= 4.5	g



Core sets for filter applications

Clamping force for A_L measurements, 40 ±20 N.

GRADE	A_L (nH)	μ_e	TOTAL AIR GAP (μm)	TYPE NUMBER (WITH NUT)	TYPE NUMBER (WITHOUT NUT)
3D3 ^{sup}	40 ±3%	= 26	= 1200	RM6R-3D3-E40/N	RM6R-3D3-E40
	63 ±3%	= 41	= 700	RM6R-3D3-E63/N	RM6R-3D3-E63
	100 ±3%	= 65	= 400	RM6R-3D3-E100/N	RM6R-3D3-E100
	160 ±3%	= 103	= 200	RM6R-3D3-A160/N	RM6R-3D3-A160
	1000 ±25%	= 650	= 0	–	RM6R-3D3
3H3 ^{sup}	160 ±3%	= 103	= 230	RM6R-3H3-A160/N	RM6R-3H3-A160
	250 ±3%	= 161	= 110	RM6R-3H3-A250/N	RM6R-3H3-A250
	315 ±3%	= 203	= 90	RM6R-3H3-A315/N	RM6R-3H3-A315
	400 ±3%	= 258	= 70	RM6R-3H3-A400/N	RM6R-3H3-A400
	2200 ±25%	= 1420	= 0	–	RM6R-3H3

Formulas for Examination in Power Electronic Converters (ENM060)

Table 3-1 Use of Symmetry in Fourier Analysis

Symmetry	Condition Required	a_h and b_h
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	$f(t) = -f(t + \frac{1}{2}T)$	$a_h = b_h = 0$ 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 quarter-wave	Even and half-wave	$b_h = 0$ for all h $a_h = \begin{cases} \frac{4}{\pi} \int_0^{\pi/2} f(t) \cos(h\omega t) d(\omega t) & \text{for odd } h \\ 0 & \text{for even } h \end{cases}$
Odd quarter-wave	Odd and half-wave	$a_h = 0$ for all h $b_h = \begin{cases} \frac{4}{\pi} \int_0^{\pi/2} f(t) \sin(h\omega t) d(\omega t) & \text{for odd } h \\ 0 & \text{for even } h \end{cases}$

Definition of RMS-value:

$$F_{RMS} = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} f(t)^2 dt}$$

Definition of RMS-value with Fourier-series:

$$F_{RMS} = \sqrt{F_0^2 + \sum_{n=1}^{\infty} F_n^2} = \sqrt{\left(\frac{a_0}{2}\right)^2 + \sum_{n=1}^{\infty} \left(\frac{\sqrt{a_n^2 + b_n^2}}{\sqrt{2}}\right)^2}$$

$$\sin^2(\alpha) + \cos^2(\alpha) = 1$$

$$\sin(\alpha + \beta) = \sin(\alpha)\cos(\beta) + \cos(\alpha)\sin(\beta)$$

$$\cos(\alpha + \beta) = \cos(\alpha)\cos(\beta) - \sin(\alpha)\sin(\beta)$$

$$\sin(\alpha)\sin(\beta) = \frac{1}{2}(\cos(\alpha - \beta) - \cos(\alpha + \beta))$$

$$\cos(\alpha)\cos(\beta) = \frac{1}{2}(\cos(\alpha - \beta) + \cos(\alpha + \beta))$$

$$\int \sin(ax) dx = -\frac{1}{a} \cos(ax), \quad \int x \sin(ax) dx = \frac{1}{a^2} (\sin(ax) - ax \cos(ax)), \quad \int \cos(ax) dx = \frac{1}{a} \sin(ax)$$

$$\int x \cos(ax) dx = \frac{1}{a^2} (\cos(ax) + ax \sin(ax))$$

$$PF = \frac{P}{S} = \frac{V_s I_{s1} \cos \phi_1}{V_s I_s}, \quad DPF = \cos \phi_1, \quad \%THD_i = 100 \frac{I_{dis}}{I_{s1}} = 100 \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} = 100 \sqrt{\sum_{h \neq 1} \left(\frac{I_{sh}}{I_{s1}}\right)^2}$$

Electromagnetics

$$e = \frac{d}{dt} \psi \quad \psi = N\phi \quad \phi = BA \quad R = \frac{l}{A\mu_r\mu_0} \quad L = \frac{\Psi}{i}$$

$$NI = R\phi = mmf \quad N\phi = LI \quad L = A_L N^2 \quad W = \frac{1}{2} LI^2$$

Simpson's rule

Let $f(x)$ be a polynomial of maximum third degree, this means

$$f(x) = a_1 + a_2x + a_3x^2 + a_4x^3$$

For this function the integral can be calculated as

$$\frac{1}{T} \int_{t_0}^{t_0+T} f(x) dx = \frac{1}{6} \left(f(t_0) + 4f\left(t_0 + \frac{T}{2}\right) + f(t_0 + T) \right)$$