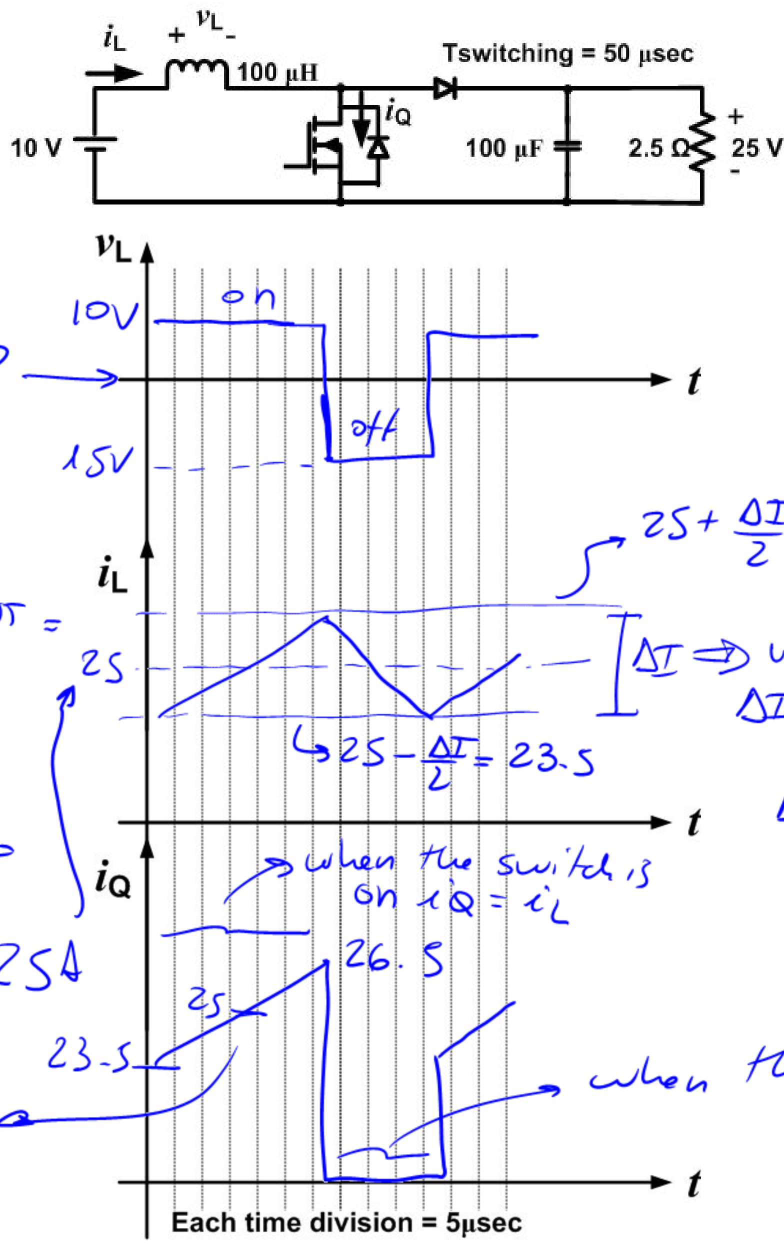
Consider the boost converter in the figure. On the graph below, carefully and neatly draw the following variables: i_L, v_L, and current in the main switch (i_Q). Also specify the most significant values (peaks and average value). Consider that you are operating in continuous conduction. What is the output voltage ripple (expressed in any way you prefer)?



$D' = \frac{10}{25} = 0.4$

$D = 0.6$

$V_{L_{avg}} = 0$

$P_{in} = P_{OUT}$

$V_{in} I_{in} = V_{OUT} I_{OUT} = \frac{V_{OUT}^2}{R_{OUT}}$

$I_L = I_{in} = \frac{V_{OUT}^2}{V_{in} R_{OUT}} = \frac{25^2}{2.5 \cdot 10} = 25A$

$25 + \frac{\Delta I}{2} = 26.5$

$\Delta I \Rightarrow$ when switch is on

$\Delta I = \frac{V_L}{L} \Delta t = \frac{V_{in}}{L} D T_{sw}$

$\Delta I = \frac{10}{100 \cdot 10^{-6}} 0.6 \cdot 50 \cdot 10^{-6}$

$\Delta I = 3A$

$25 - \frac{\Delta I}{2} = 23.5$

when the switch is on $i_Q = i_L$

$i_{Q_{avg}} = 25.06$

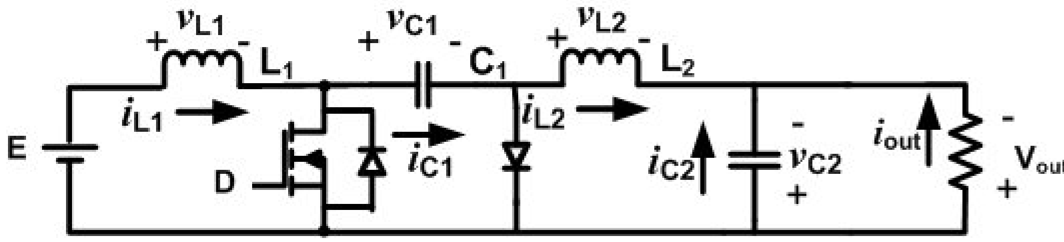
$i_{Q_{avg}} = 15A$

when the switch is off $i_Q = 0$

When the switch is on $I_C = I_{OUT}$

$I_C = C \frac{\Delta V}{\Delta t} \Rightarrow \Delta V_{p-p} = \frac{I_{OUT} D T_{sw}}{C} = 3V$

The figure below shows the circuit of a Ćuk converter. Please, derive the steady state expression for E/V_{out} in terms of the duty cycle D.



- Consider the state when the main switch is closed

$v_{L_1} = E$, $v_{L_2} = -V_{C_1} + V_{OUT}$

- When the main switch is open → diode is closed

$v_{L_1} = E - V_{C_1}$, $v_{L_2} = V_{OUT}$

Consider the outter loop → $E - \cancel{V_{L_1}}^{0} - V_{C_1} - \cancel{V_{L_2}}^{0} + V_{OUT} = 0$

$V_{C_1} = E + V_{OUT}$

$V_L = 0$, then

$V_{L_1} = 0 \rightarrow EDT + (E - V_{C_1})(1-D)T = 0$

$ED + (\cancel{E} - \cancel{E} - V_{OUT})(1-D) = 0$

↳ $\frac{V_{OUT}}{E} = \frac{D}{1-D}$

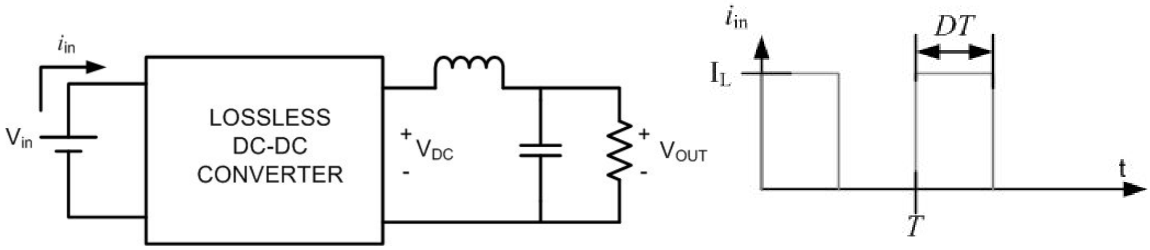
or

$V_{L_2} = 0 \rightarrow (V_{OUT} - V_{C_1})DT + V_{OUT}(1-D)T = 0$

$(\cancel{V_{OUT}} - E - \cancel{V_{OUT}})D + V_{OUT}(1-D) = 0$

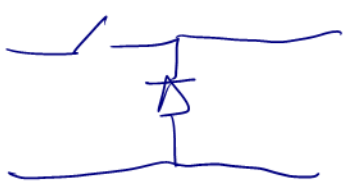
↳ $\frac{V_{OUT}}{E} = \frac{D}{1-D}$

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. Please draw the circuit inside the converter box if there are only switches inside.



Since $V_L = 0 \rightarrow V_{DC} = V_{OUT}$

$$V_{in} \underbrace{I_L D}_{I_{in}} = V_{OUT} I_L \rightarrow D = \frac{V_{OUT}}{V_{in}} = \frac{12}{20} = \frac{3}{5} = 0.6$$



Consider a PV module with the following characteristics: V_{OC} = 48 V, I_{CC} = 5.5 A, P_{max} = 150 W when V = 30 V. What is the "maximum power resistance?" If your actual load resistance varies between 2 and 12 ohms which one of the three dc-dc converters discussed in class (buck, boost, and SEPIC) will you choose to operate the PV panel at its maximum power point? What will be the operating range of the converter duty cycle?

$$R_{MPP} = \frac{V_{MPP}^2}{150} = 6\ \Omega$$

Since I am looking to compensate load resistances that are both higher and lower than R_{MPP} I need a SEPIC.

For a SEPIC

$$\frac{R_{OUT}}{R_{in}} = \left(\frac{D}{1-D}\right)^2$$

For $R_{OUT} = 2\ \Omega$ and $R_{in} = R_{MPP} = 6\ \Omega$

$$\frac{D}{1-D} = \sqrt{\frac{2}{6}} = 0.577 \longrightarrow D + 0.577D = 0.577$$

$$\hookrightarrow D = 0.366$$

For $R_{OUT} = 12\ \Omega$ and $R_{in} = R_{MPP} = 6\ \Omega$

$$\frac{D}{1-D} = \sqrt{\frac{12}{6}} = 1.414 \longrightarrow 2.414D = 1.414$$

$$\hookrightarrow D = 0.5858$$

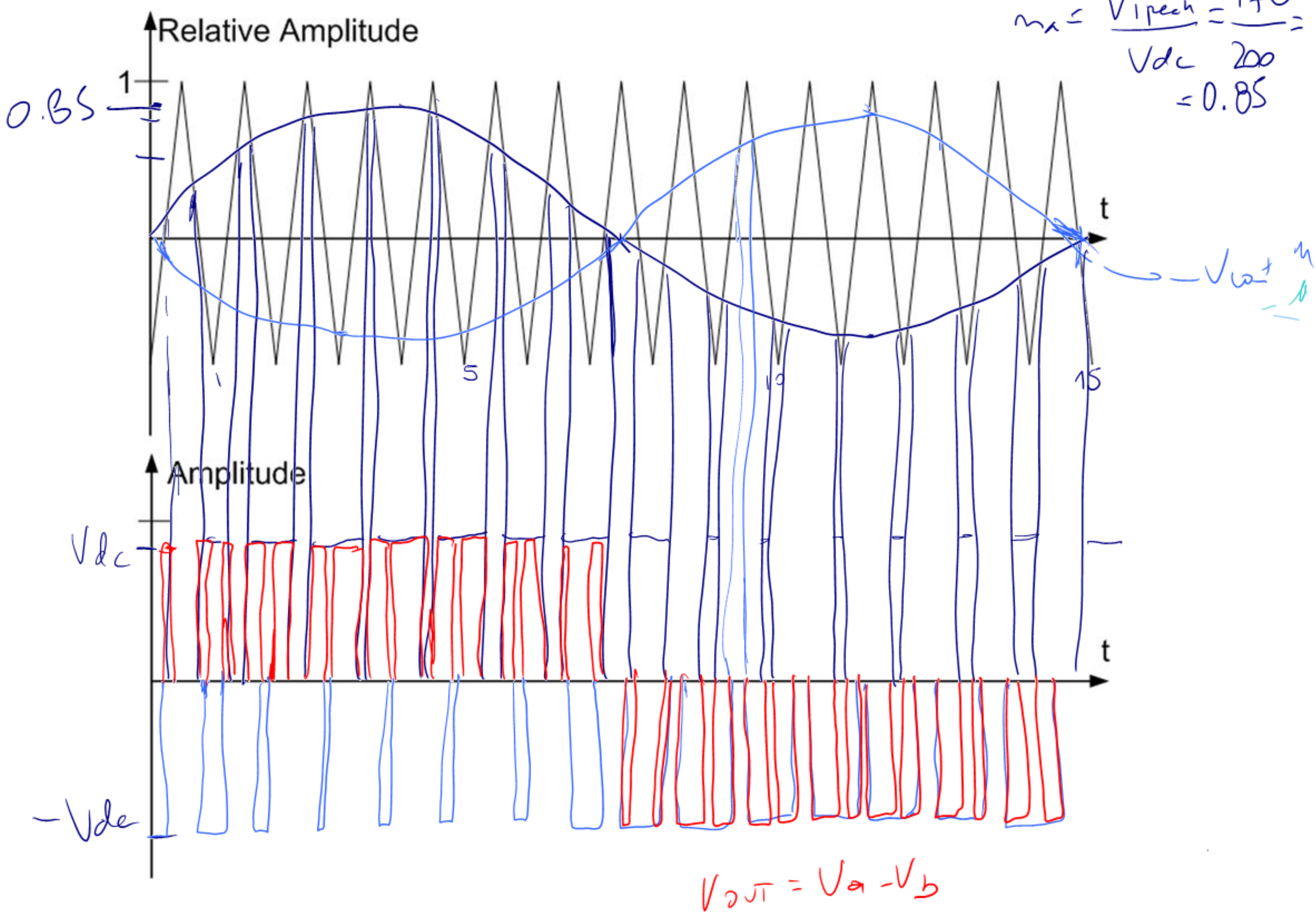
$$\boxed{0.366 \leq D \leq 0.5858}$$

Using this triangle waveform as your guide, sketch the output voltage of an inverter with an input voltage of 200 V dc and an output voltage with the following characteristics:

- Peak voltage = 170 V
- Frequency = 1/15 that of the triangle

Indicate in the figures all important values. Assume that there is not filter at the inverter output.

$m_a = \frac{V_{1peak}}{V_{dc}} = \frac{170}{200} = 0.85$



1.1) Consider an H-bridge single-phase inverter. Its input voltage is 48 V and its output voltage is 27.15 Vrms. The modulation index is

a) 0.56
b) 0.7
c) 0.8
d) 1
e) 1.25
f) 1.76
g) None of the above

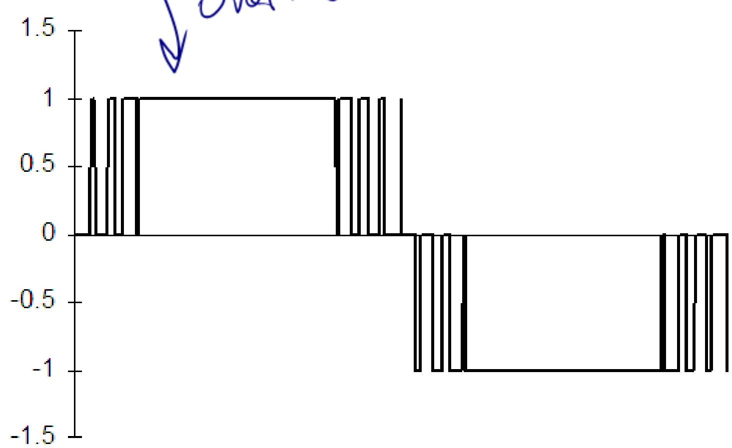
$$m_a = \sqrt{2}\,\frac{V_{1rms}}{V_{dc}} = \sqrt{2}\,\frac{27.15}{48} = 0.8$$

1.2) What is the approximate modulation index for an H-bridge inverter if the output voltage is the one shown in the figure below?

a) 0.5
b) 0.8 Linear
c) 1
d) 1.5
e) 25
f) None of the above

Overmodulation

Saturation



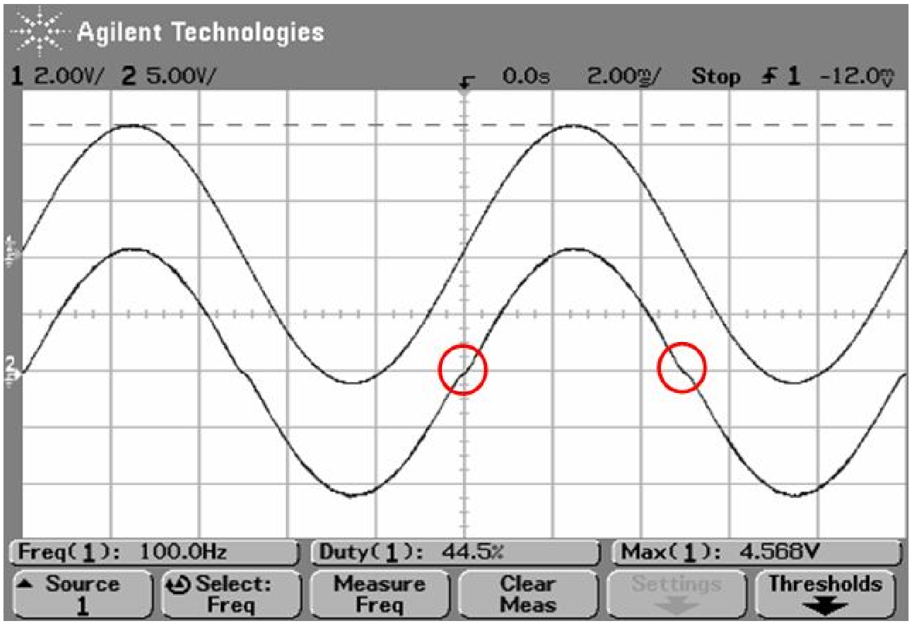
1.3) Which is the maximum possible output peak voltage that can be observed in an H-bridge inverter with an input voltage of 1 V?

a) 0.9
b) 1
c) 1.11
d) 1.27
e) There is no maximum voltage (no upper limit)
f) None of the above

$$V_{1rms\,max} = \frac{4}{\pi}\,\frac{V_{dc}}{\sqrt{2}} = \frac{4}{\pi}\,\frac{1}{\sqrt{2}} = 0.9$$

$$V_{peak\,max} = \sqrt{2}\,V_{1rms\,max} = \sqrt{2}\,0.9 = 1.2732$$

1.4) What is the origin of the distortion indicated by the circles at the output of an H-Bridge inverter? Will this effect be more or less noticeable at higher switching frequencies?



Waveform generator output

Inverter output

- Caused by dead time
- It is more noticeable at higher frequencies