ESc201 : Introduction to Electronics

DC Power Supply

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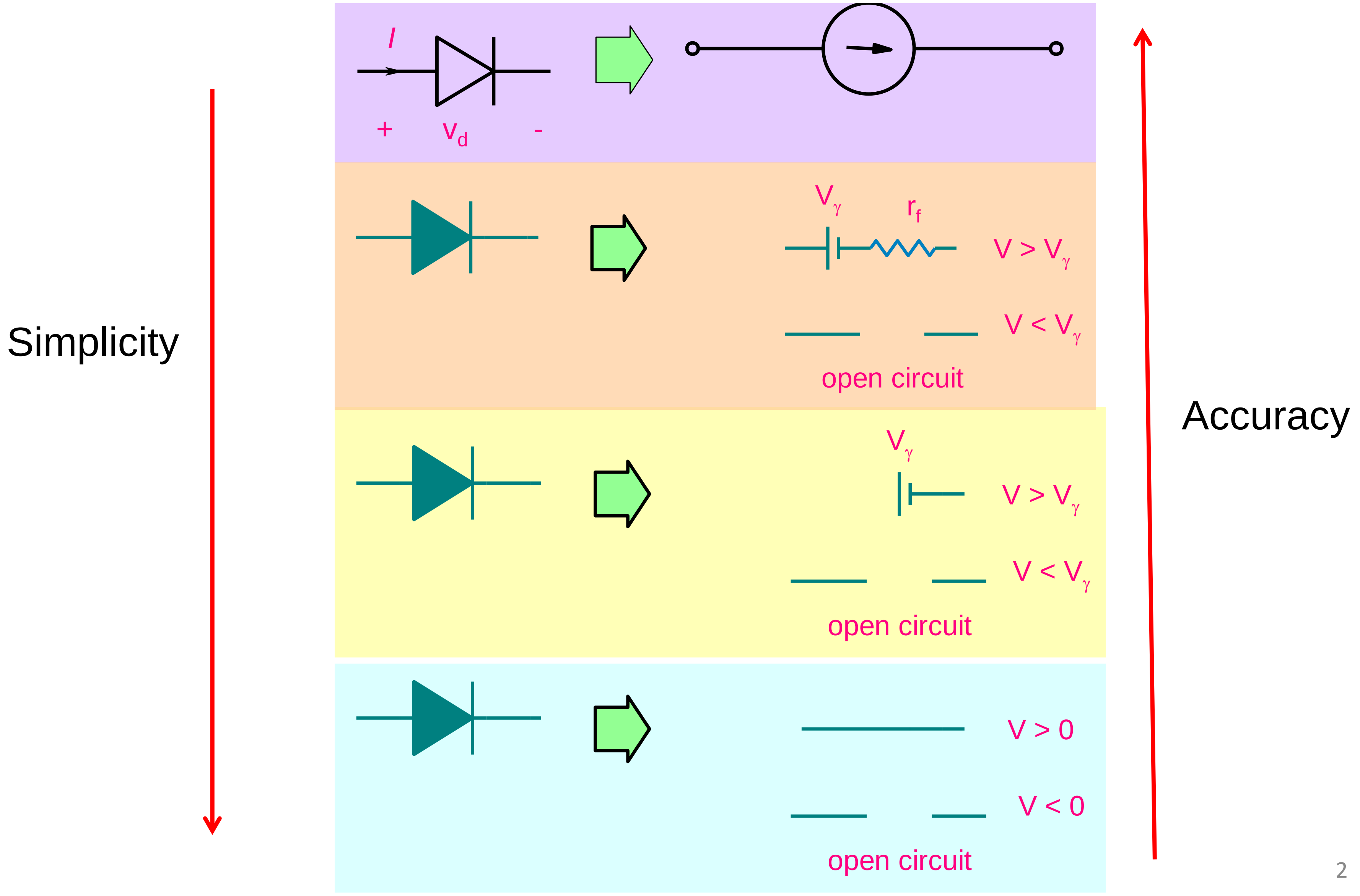
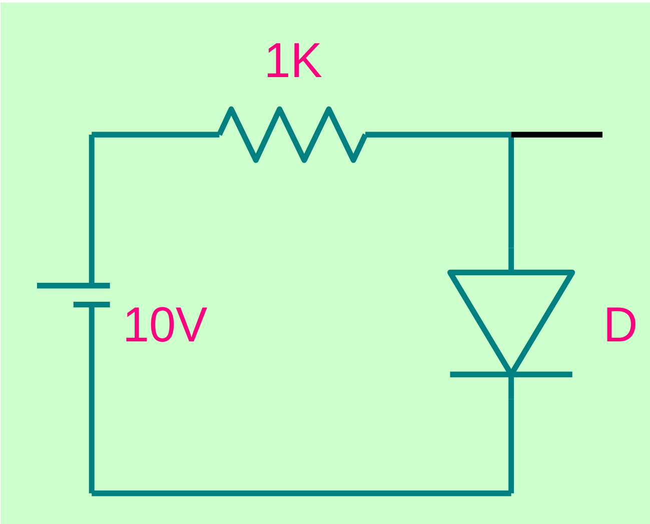
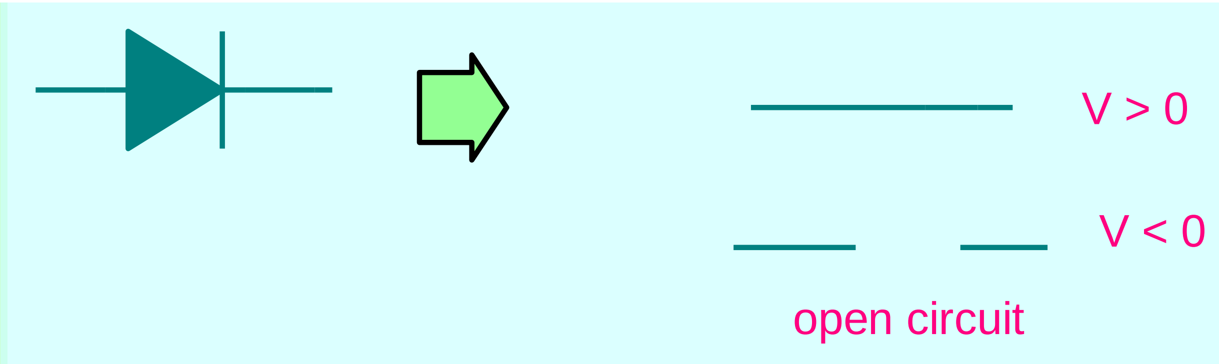
Recap: **Diode Models**

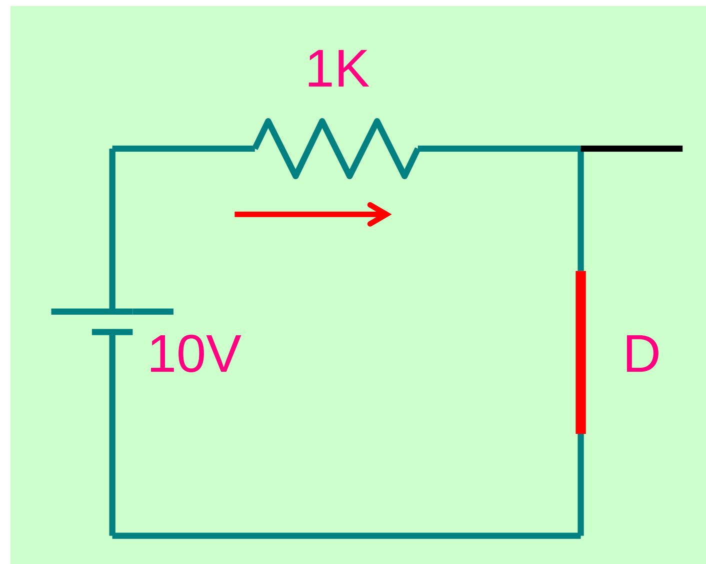
$$i_D = I_S \times \{\exp(\frac{v_d}{V_T}) - 1\}$$



Analysis using ideal diode model

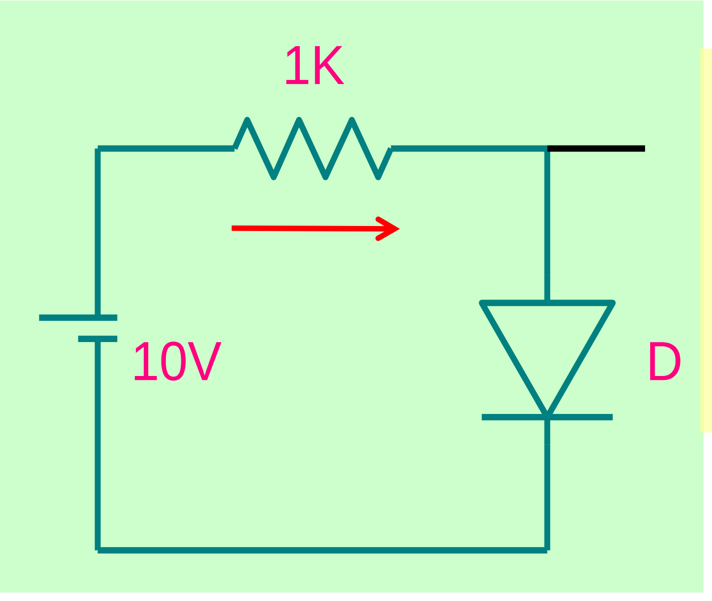


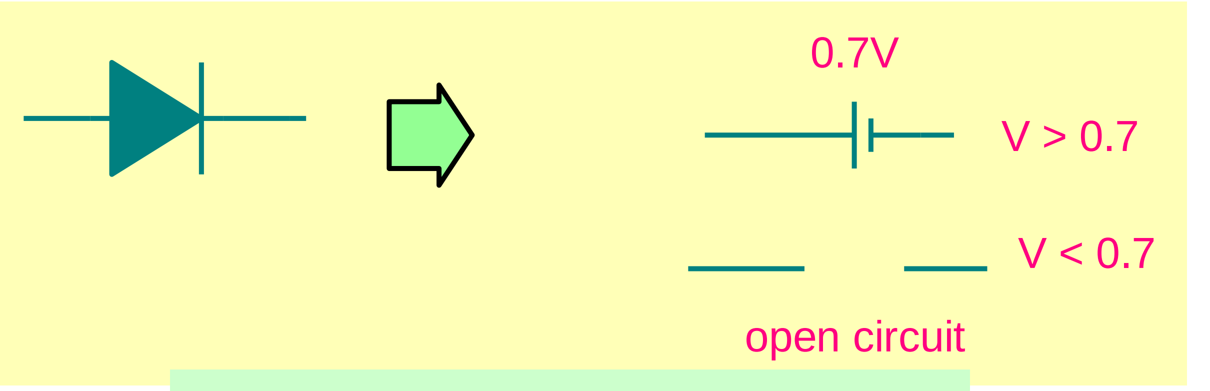


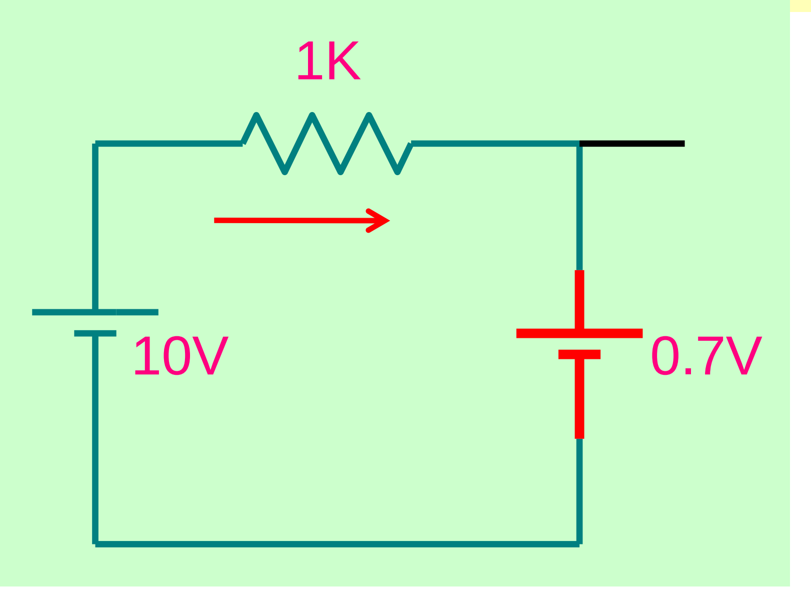


$$I = \frac{10}{1k} = 10mA$$

Analysis with a constant voltage diode model

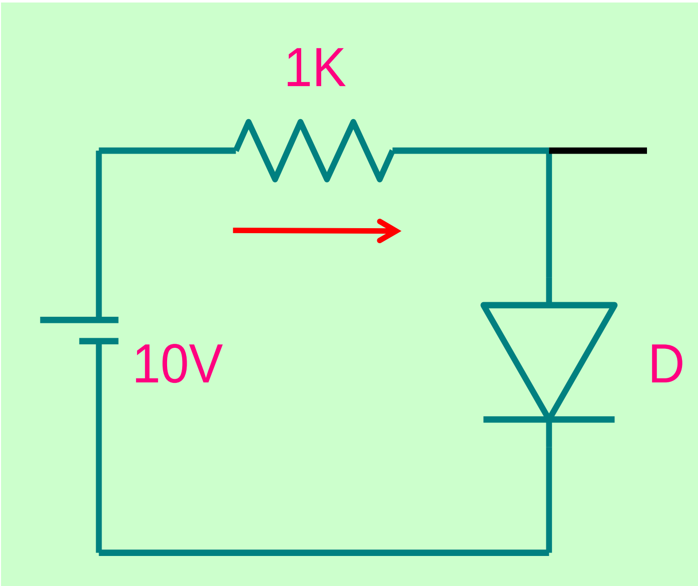


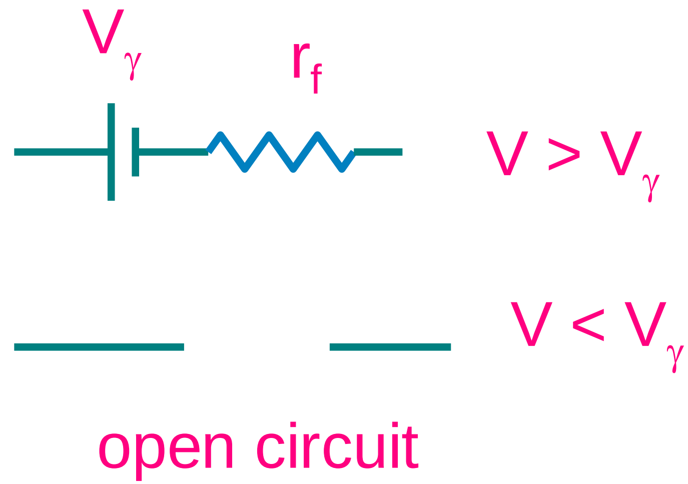




$$I = \frac{10 - 0.7}{1k} = 9.3mA$$

Analysis with a constant voltage plus resistor diode model

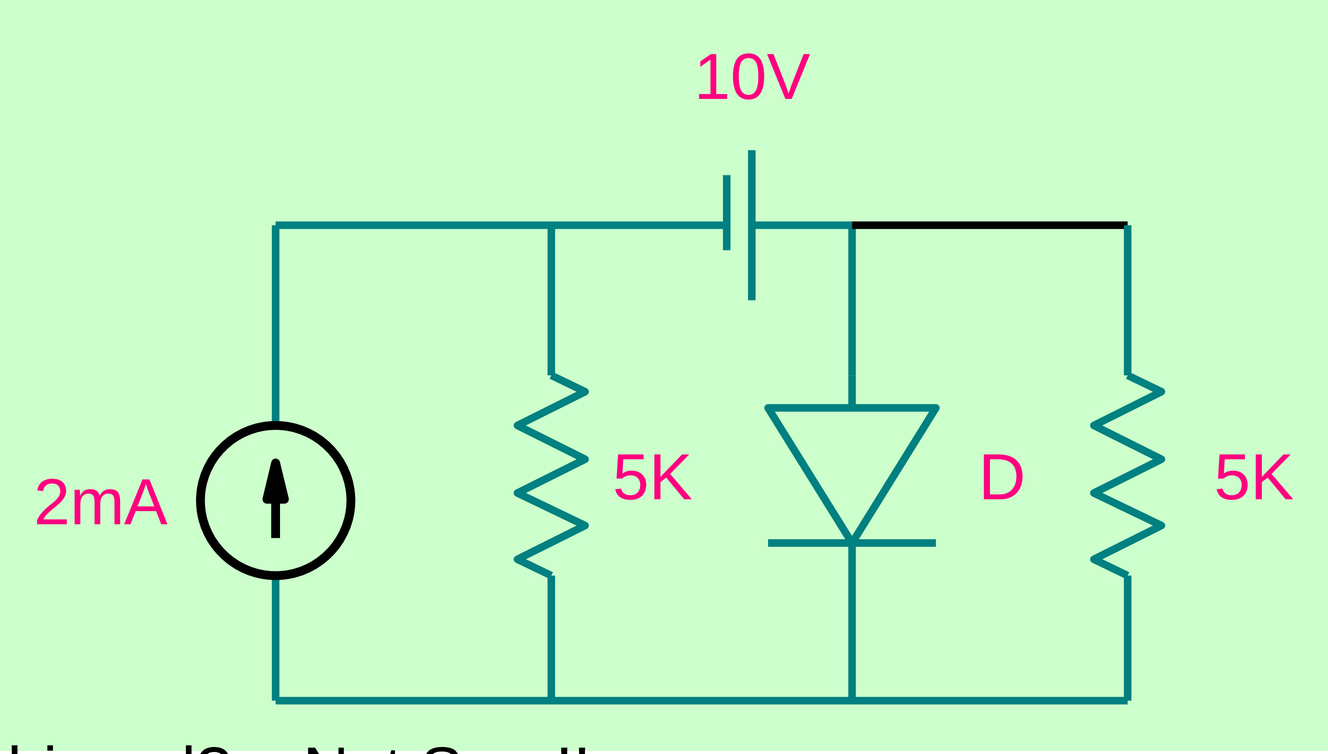




$$I = \frac{10-0.7}{1000+10} = 9.208mA$$

Example

Find the current through the diode using ideal diode model



Is the diode forward biased? – Not Sure!!

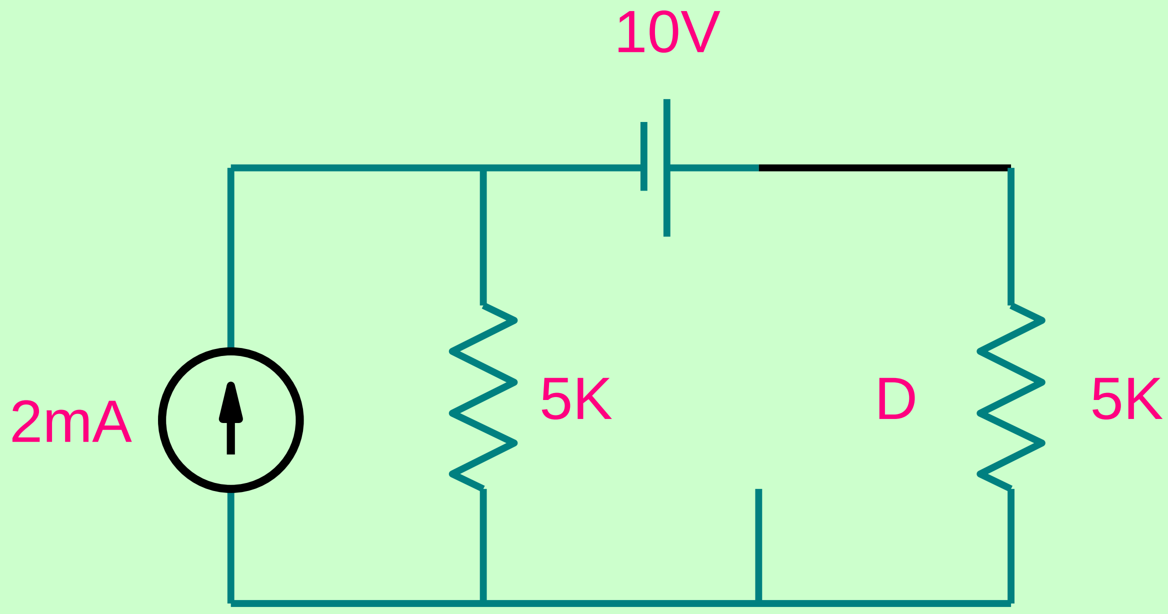
Assume that it is forward biased ☺

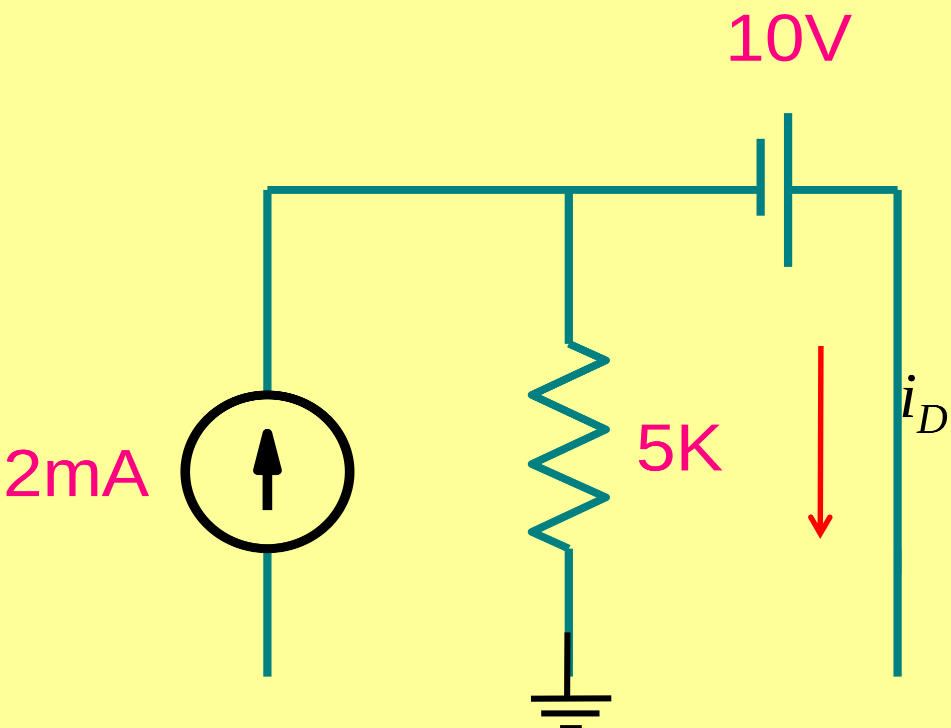
Carry out analysis and then check if current through the diode is in **appropriate** direction.

If not, diode is reverse biased and we carry out the analysis again!!

Example

Assume forward bias



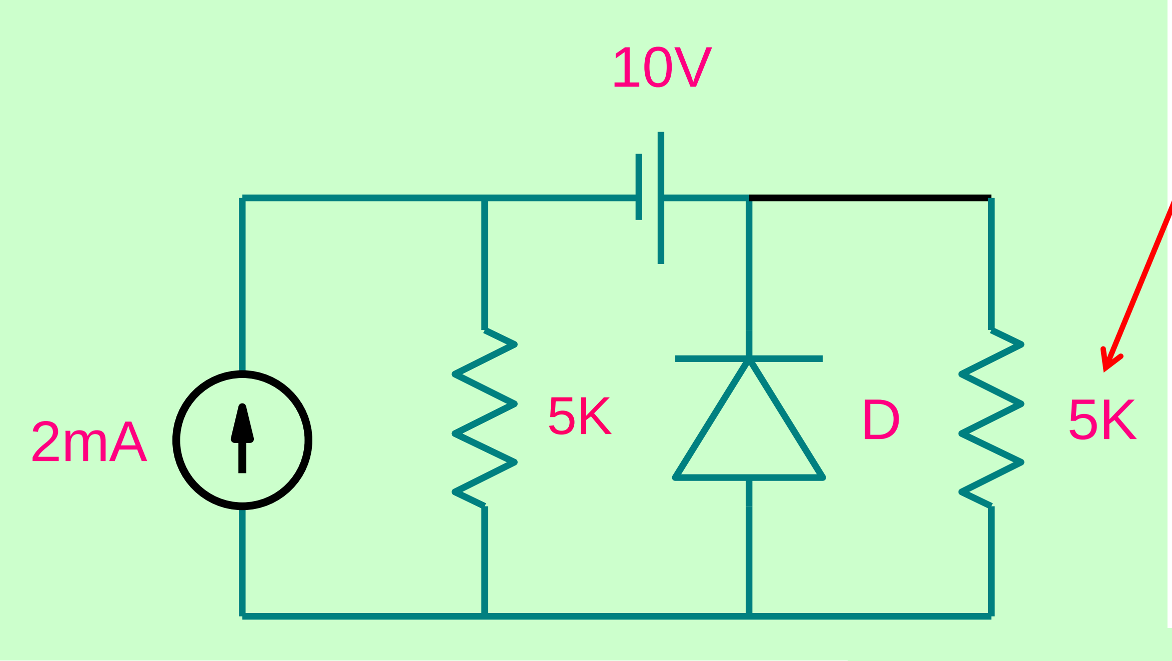


$$-2mA + \frac{-10}{5K} + i_D = 0$$

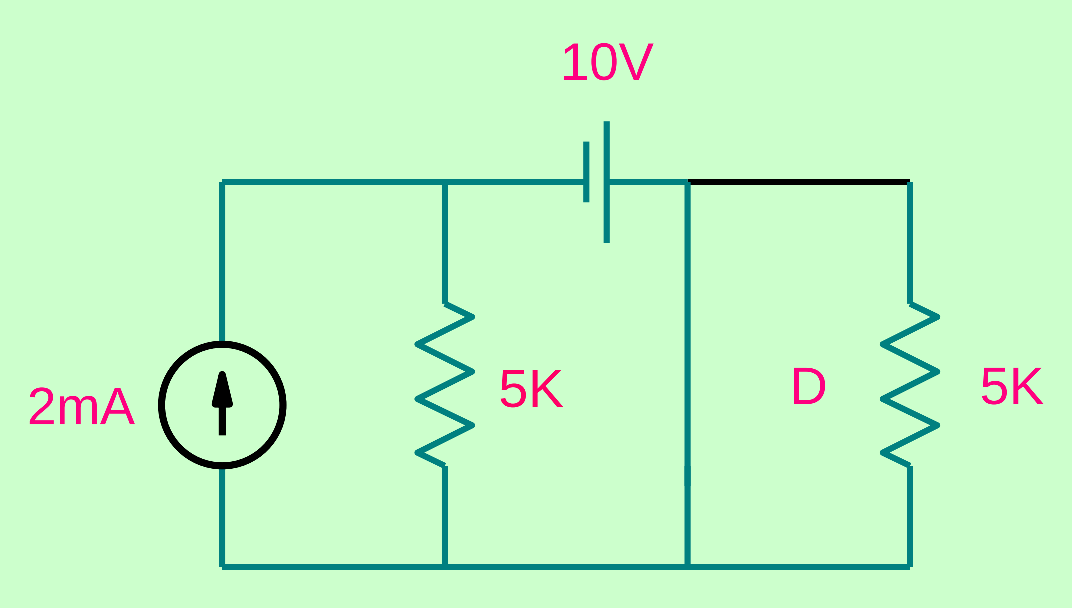
$$i_D = 4mA$$

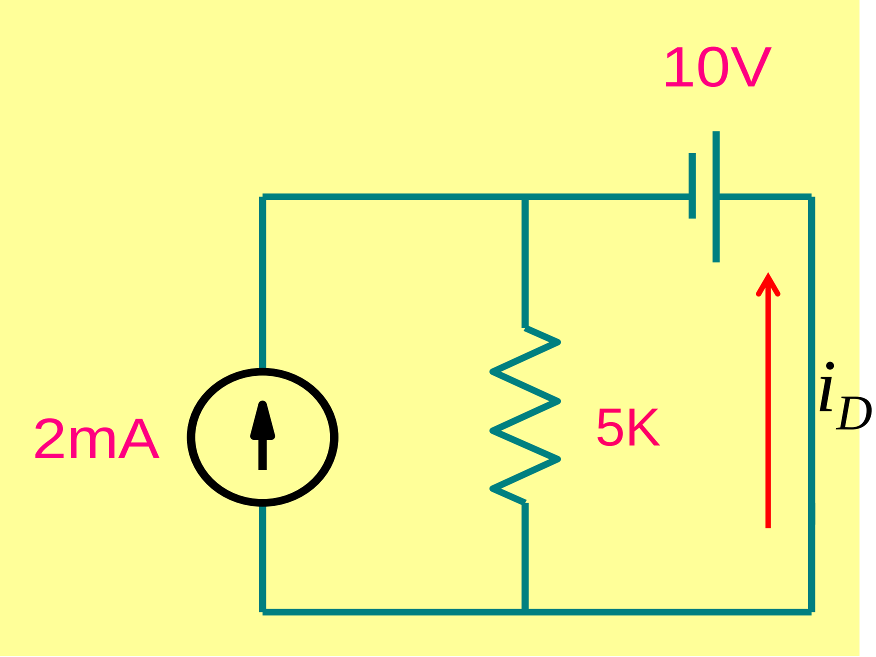
Current is positive, so our assumption is correct

Example Find the current through the 5K resistor using ideal diode model



Assume forward bias



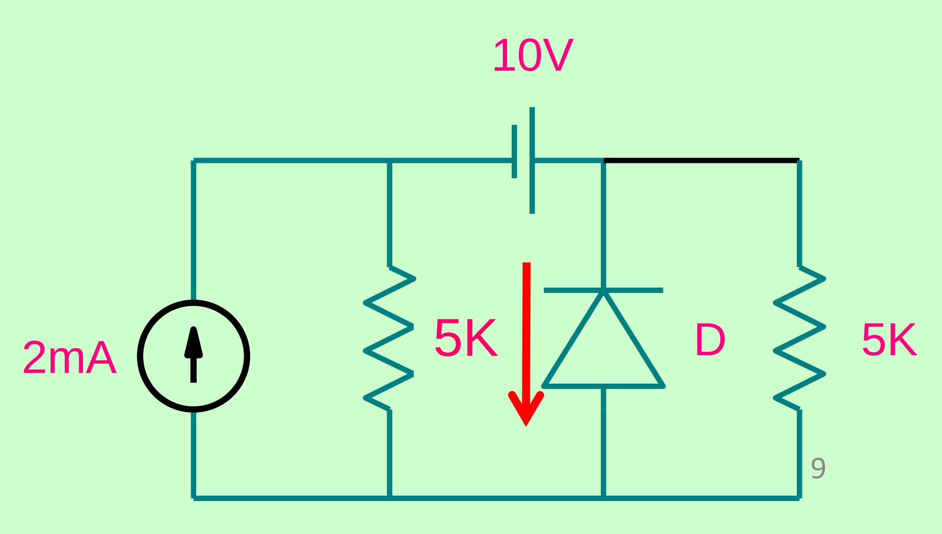


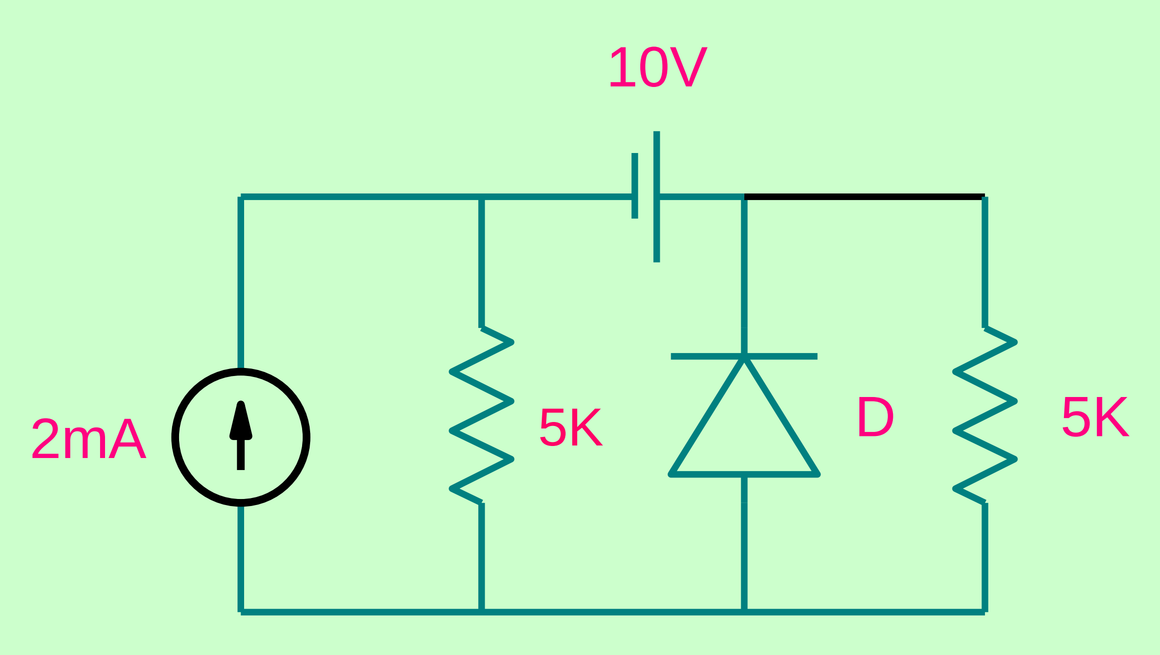
$$-2mA + \frac{-10}{5K} - i_D = 0$$

$$i_D = -4 \quad mA$$

This is not possible.

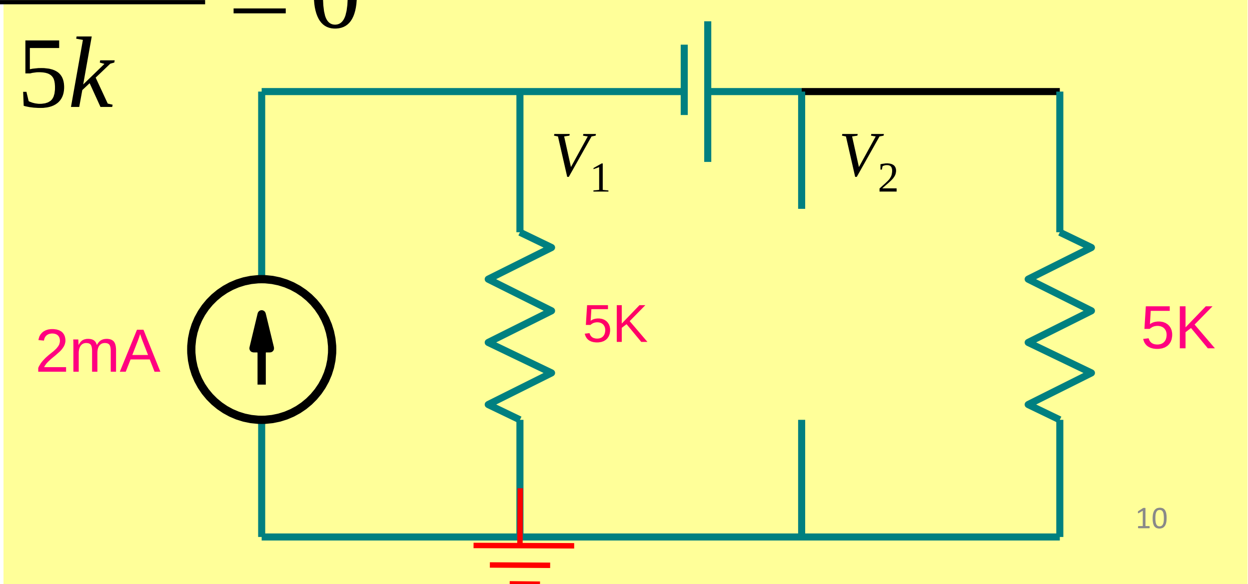
Therefore, our assumption is incorrect





Assume reverse bias

$$-2mA + \frac{V_1}{5k} + \frac{V_1 + 10}{5k} = 0$$



$$V_1 = 0$$

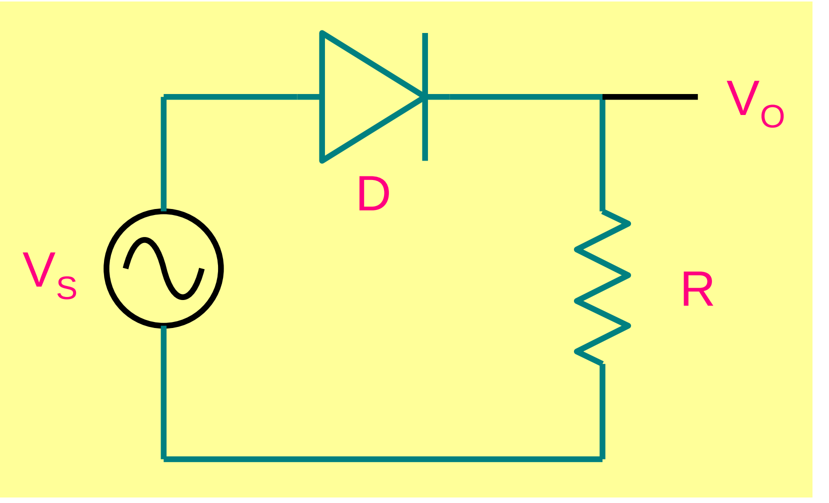
$$V_2 = 10V$$

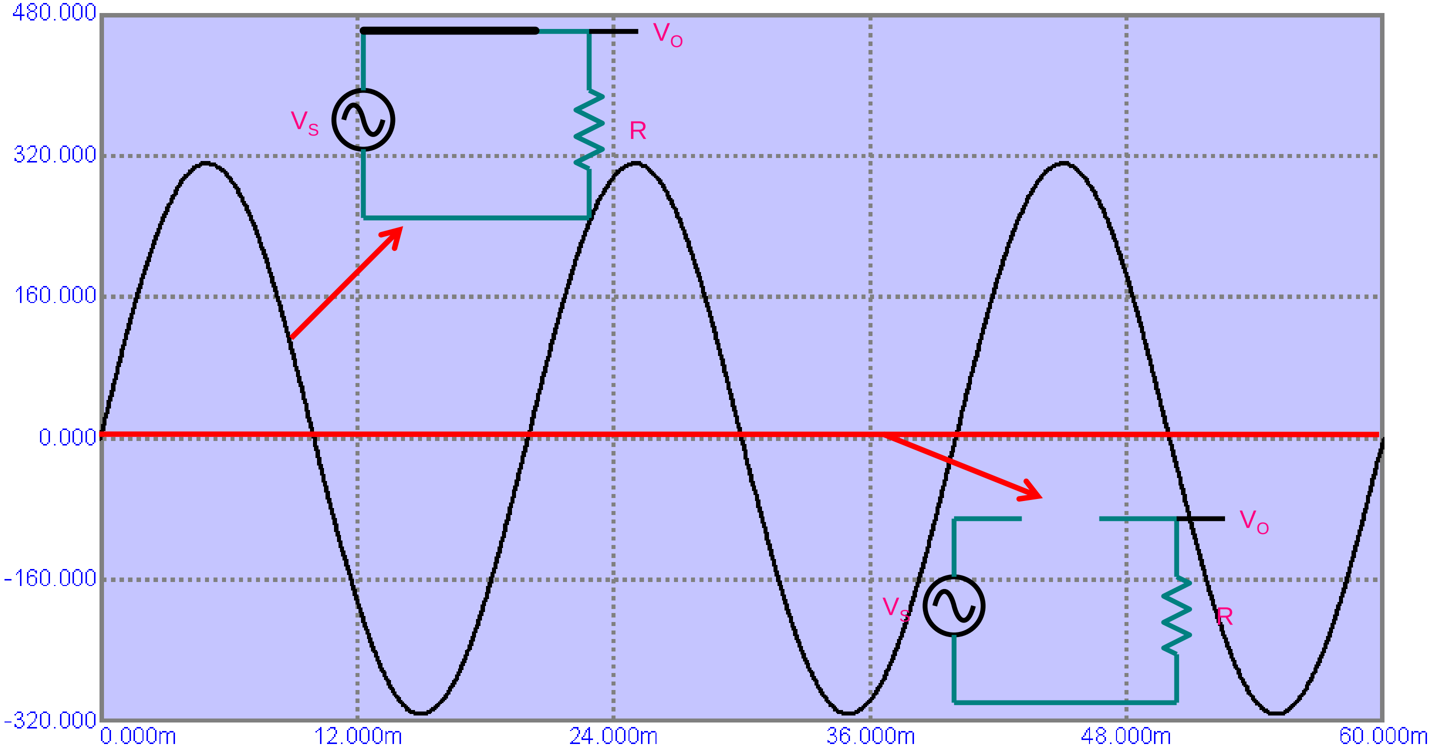
DC Power Supply

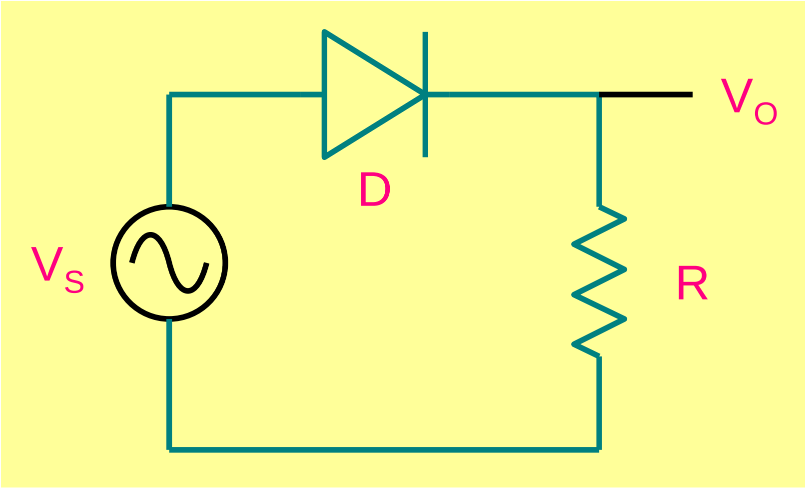
Half wave Rectifier circuit

$$220V\ rms$$

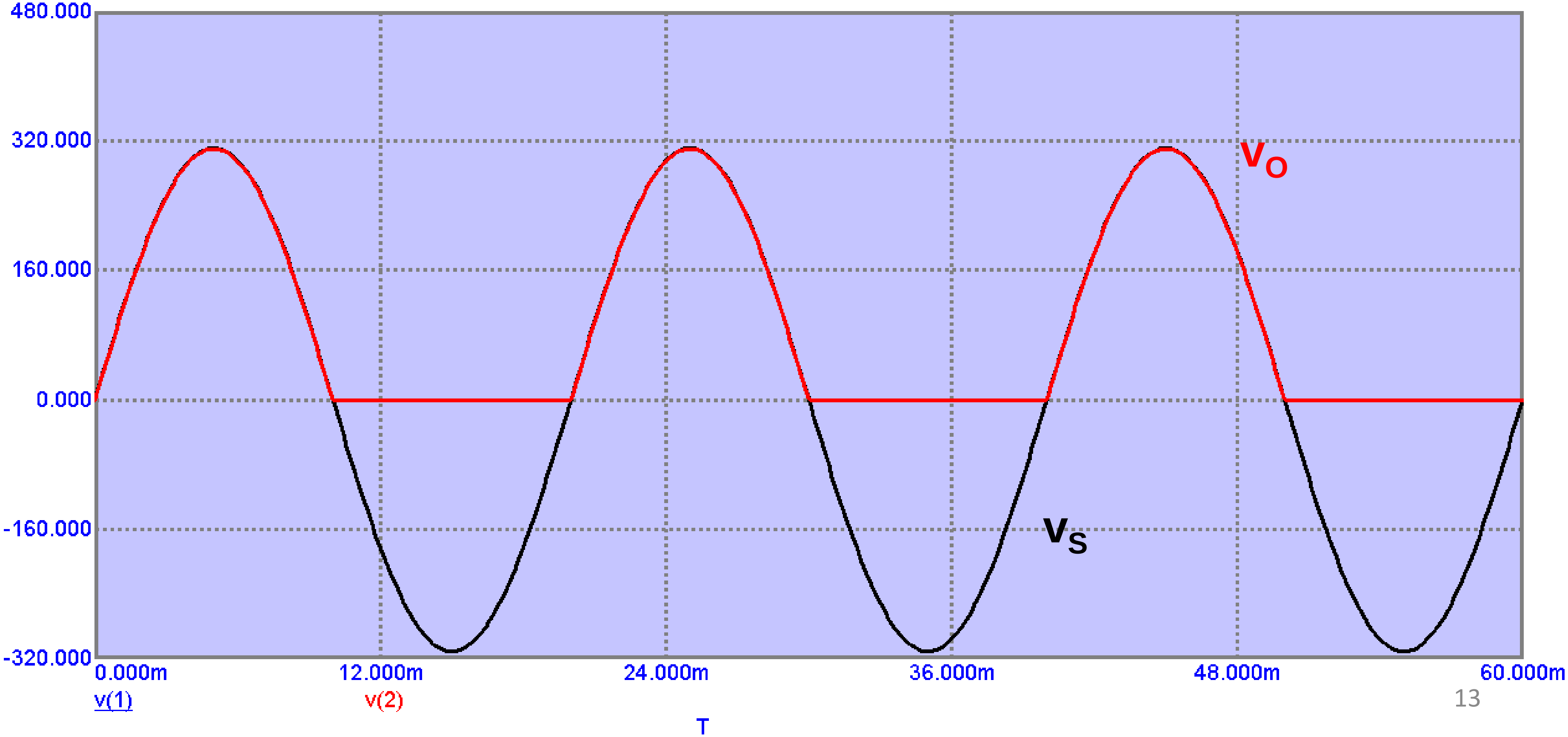
$$220V \times \sqrt{2}$$
$$= 311.127V\ \ peak\,value$$





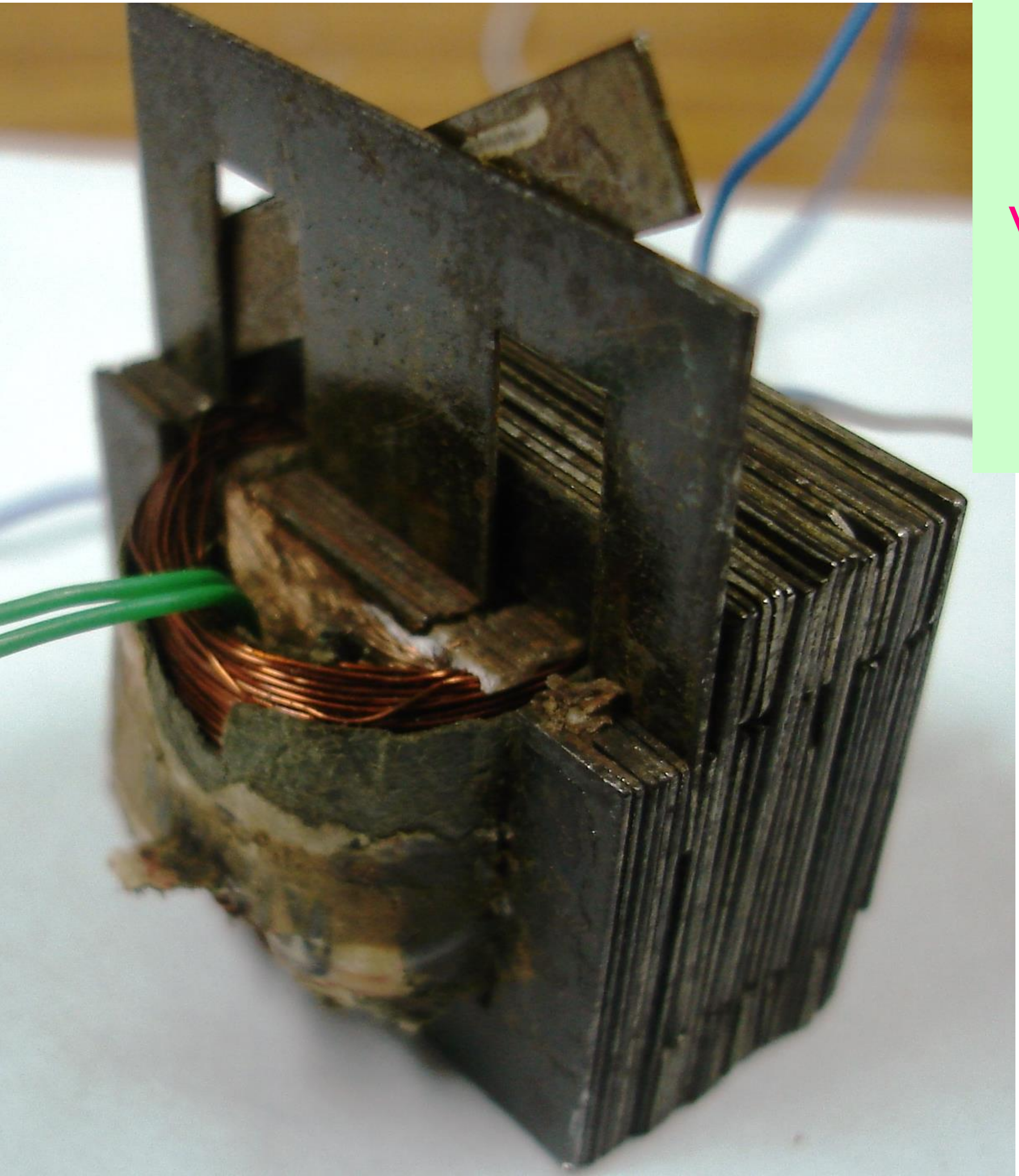


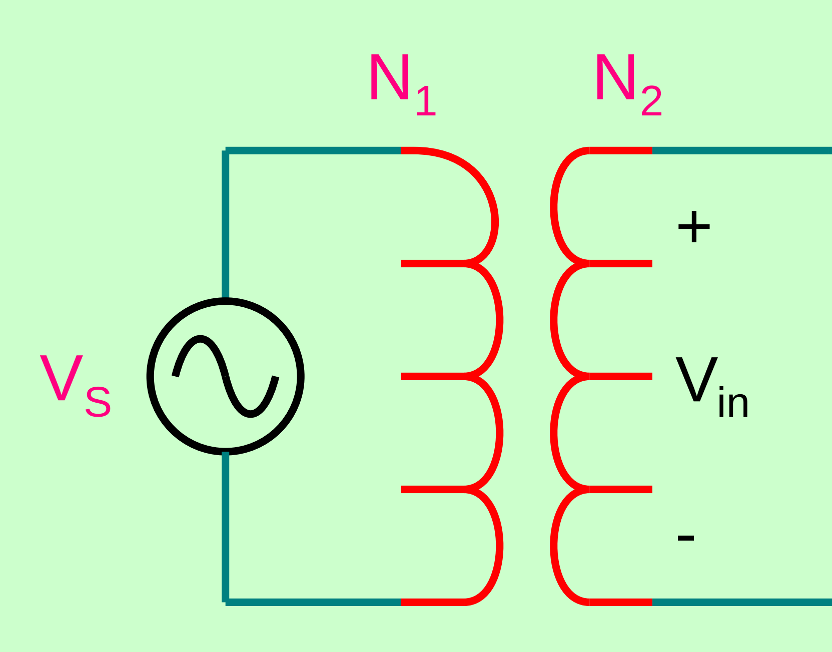
V_O
D
V_S
R



480.000
320.000
160.000
0.000
-160.000
-320.000
0.000m
12.000m
24.000m
36.000m
48.000m
60.000m
v(1)
v(2)
T
v_O
v_S

Transformer

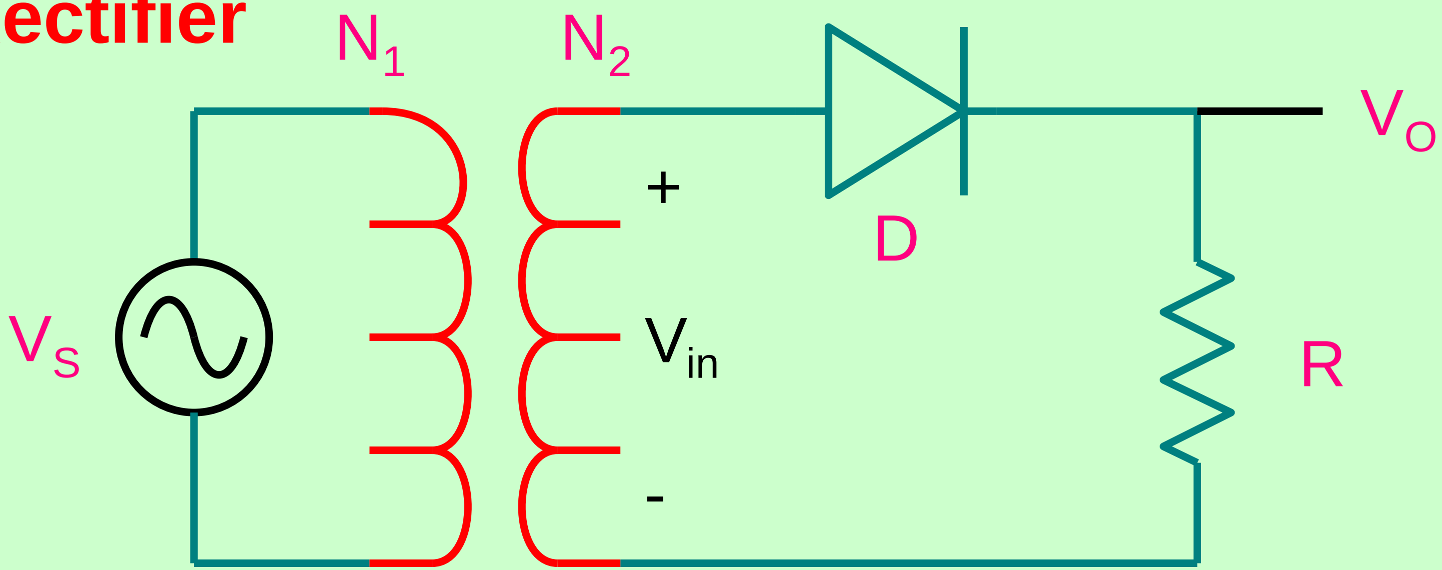


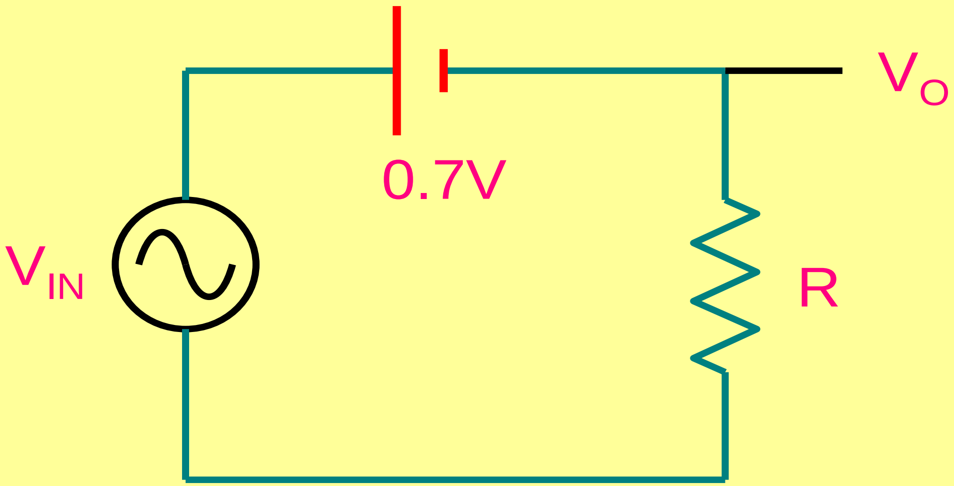


$$\frac{V_S}{V_{IN}} = \frac{N_1}{N_2}$$

Half Wave Rectifier

$$\frac{V_S}{V_{IN}} = \frac{N_1}{N_2}$$





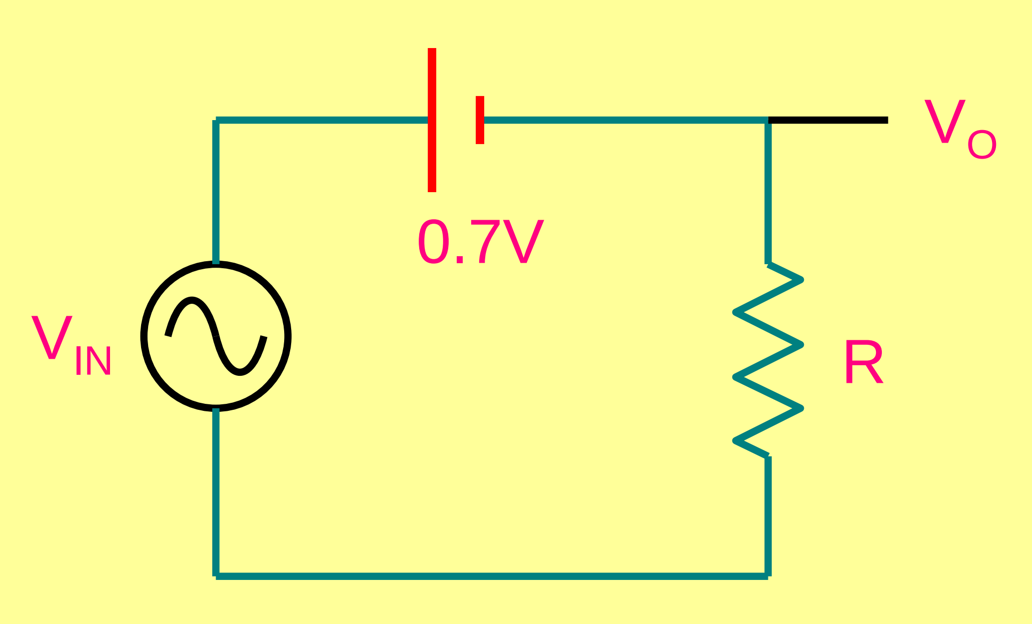
$$V_S = 220V \times \sqrt{2}$$

$$= 311.127V \ \ peak\ value$$

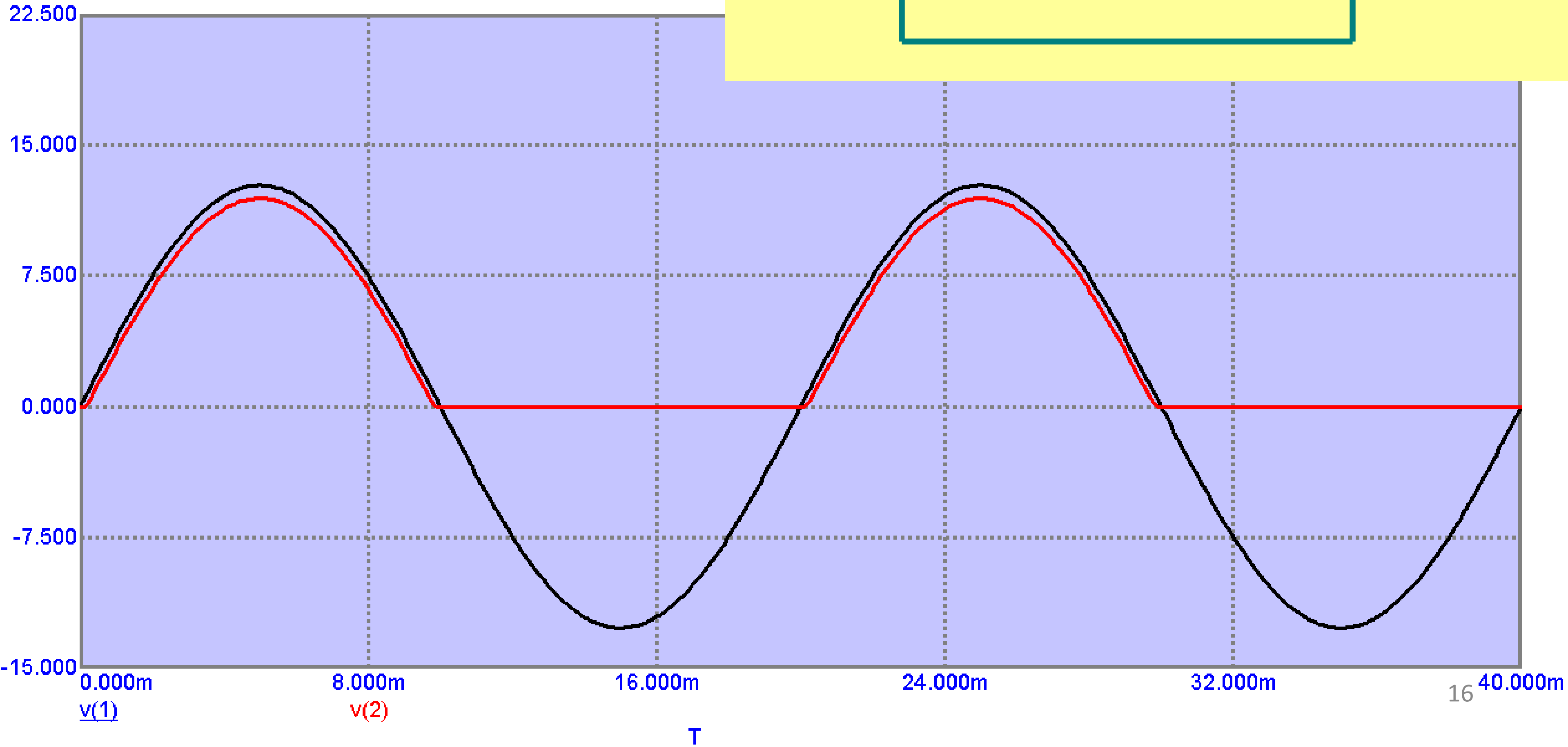
For V_O to be 12V, the input V_{IN} should be ~12.7V

$$\frac{N_1}{N_2} = \frac{311}{12.7} = 24.5$$

$$V_0 = V_{IN} - 0.7$$



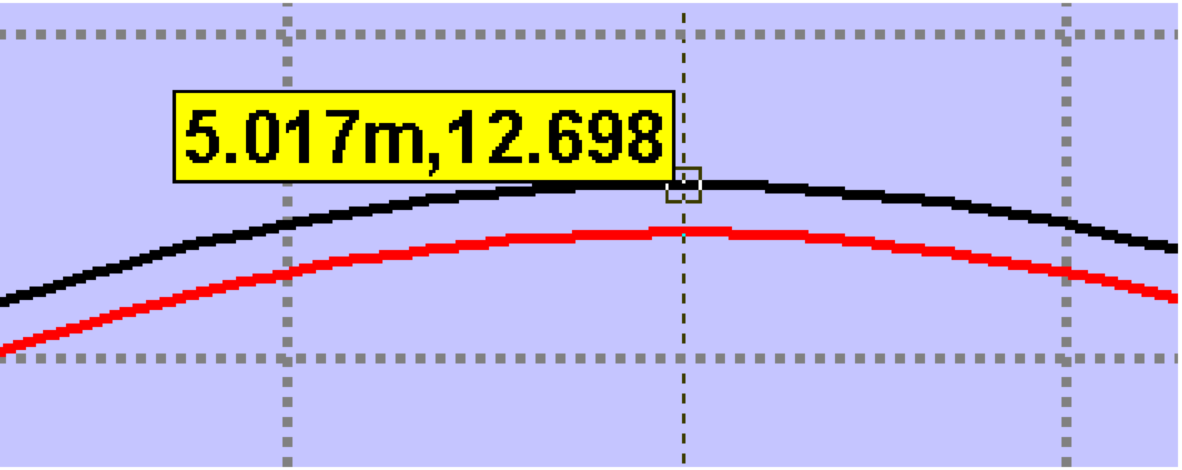
0.7V
VO
VIN
R

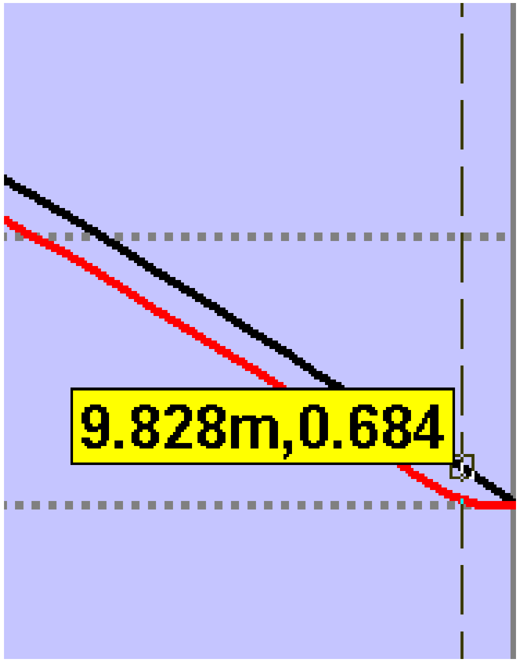


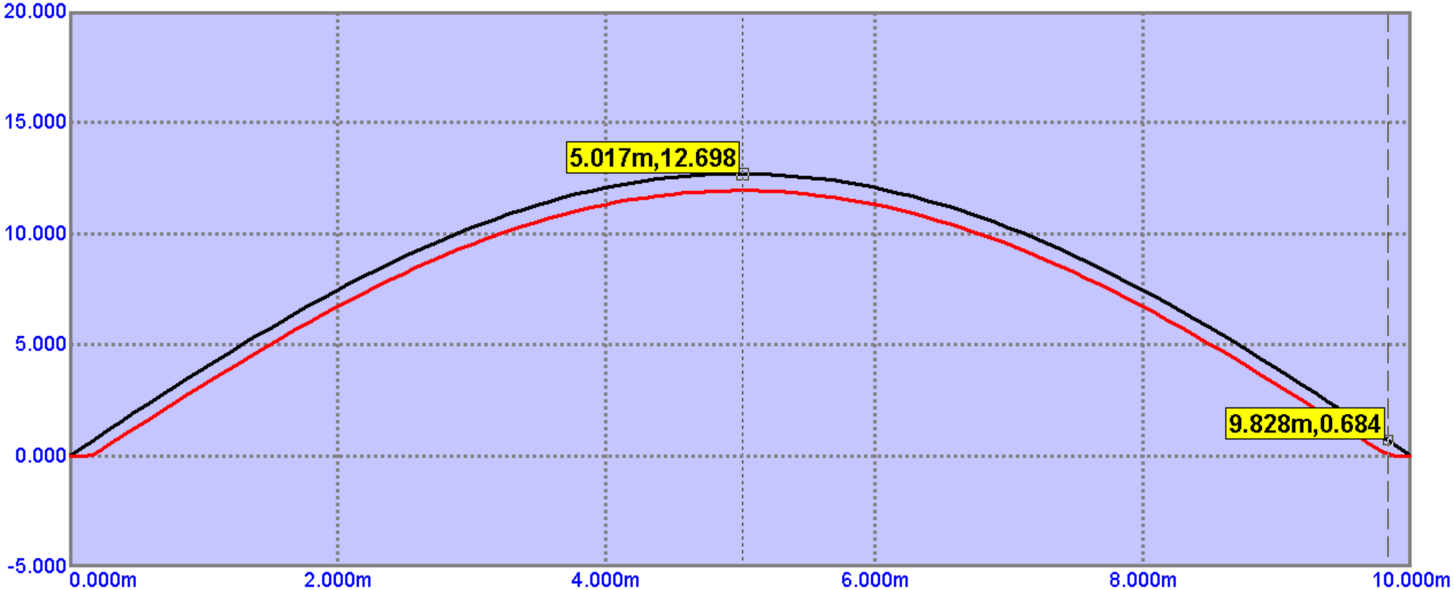
22.500
15.000
7.500
0.000
-7.500
-15.000
0.000m
8.000m
16.000m
24.000m
32.000m
40.000m
v(1)
v(2)
T

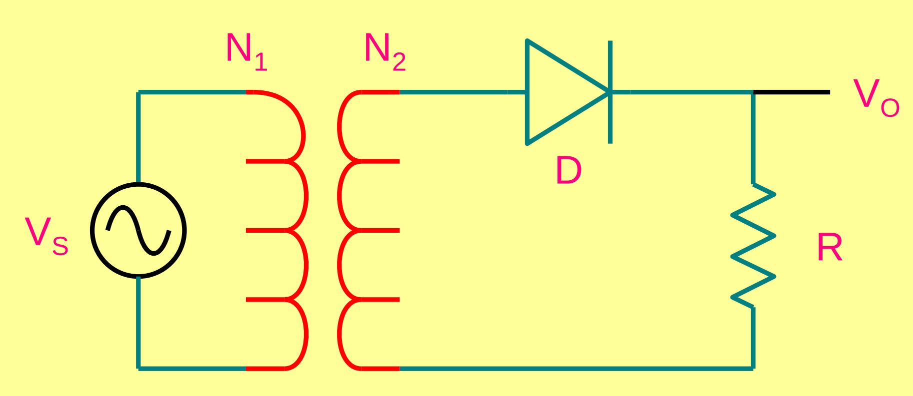
Zoomed view

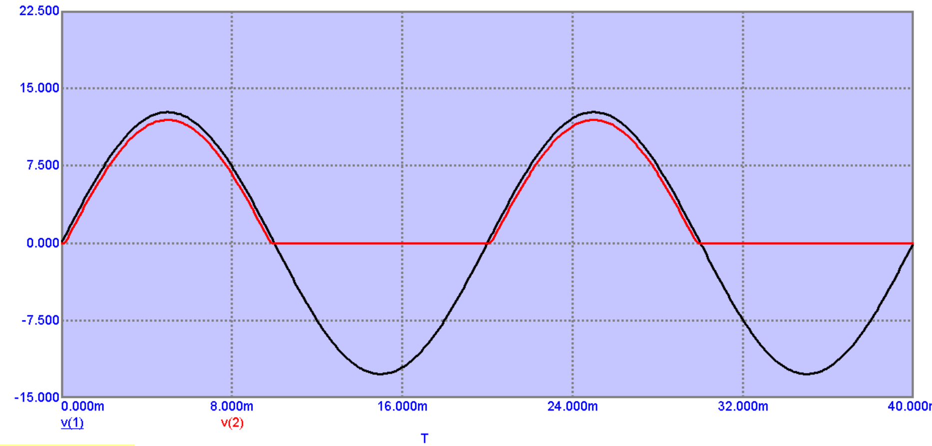
$$V_0 = V_{IN} - 0.7$$

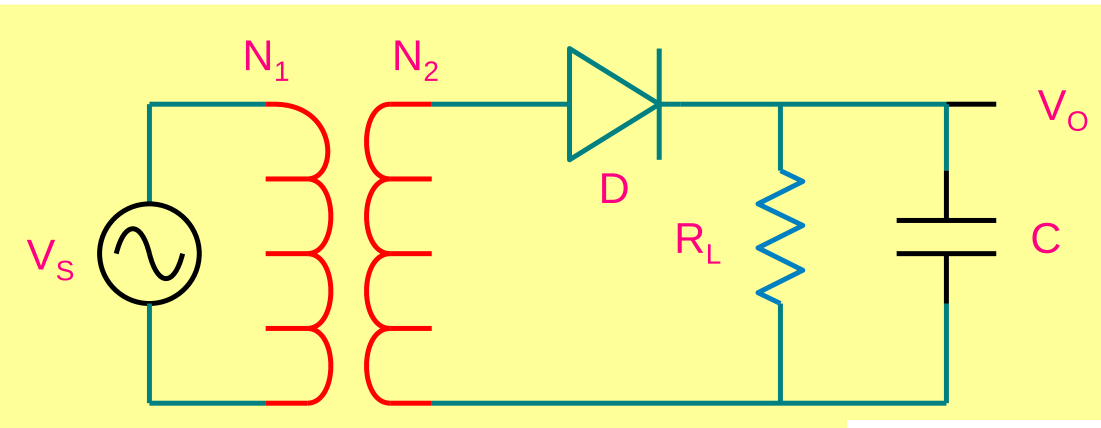




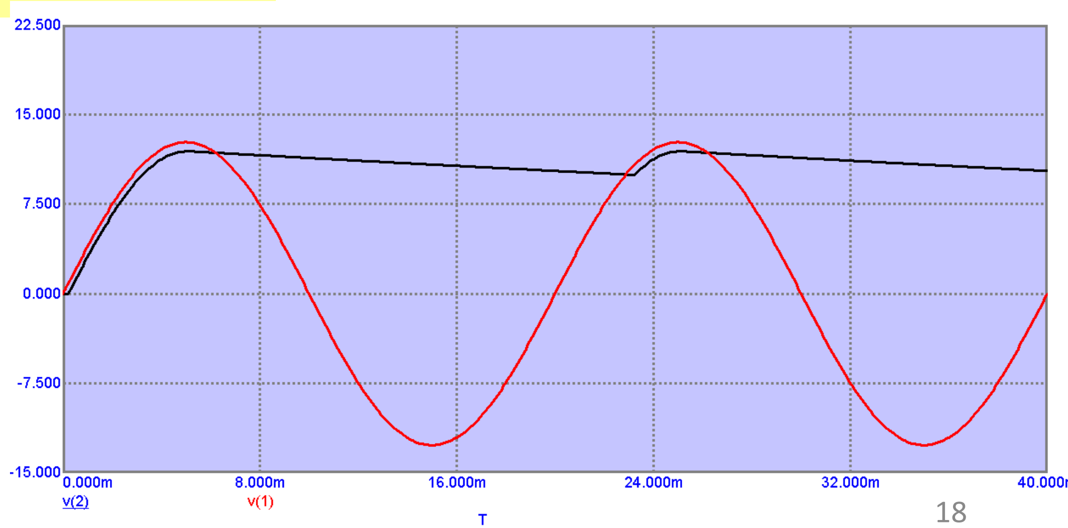


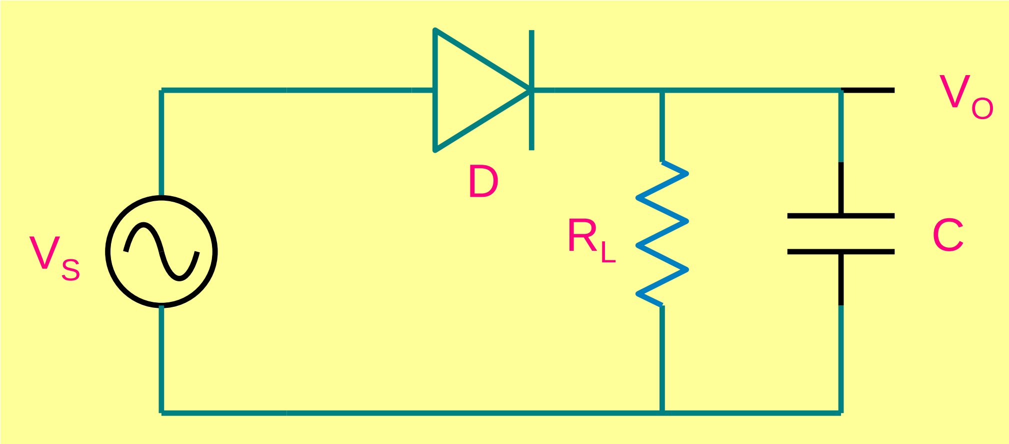


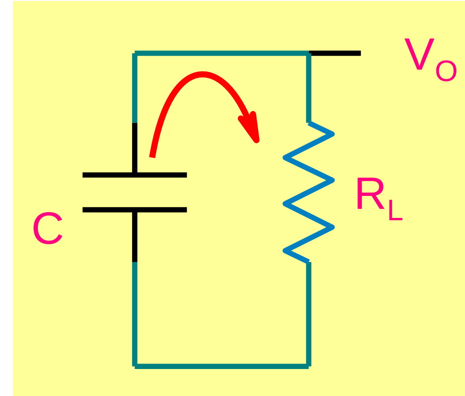


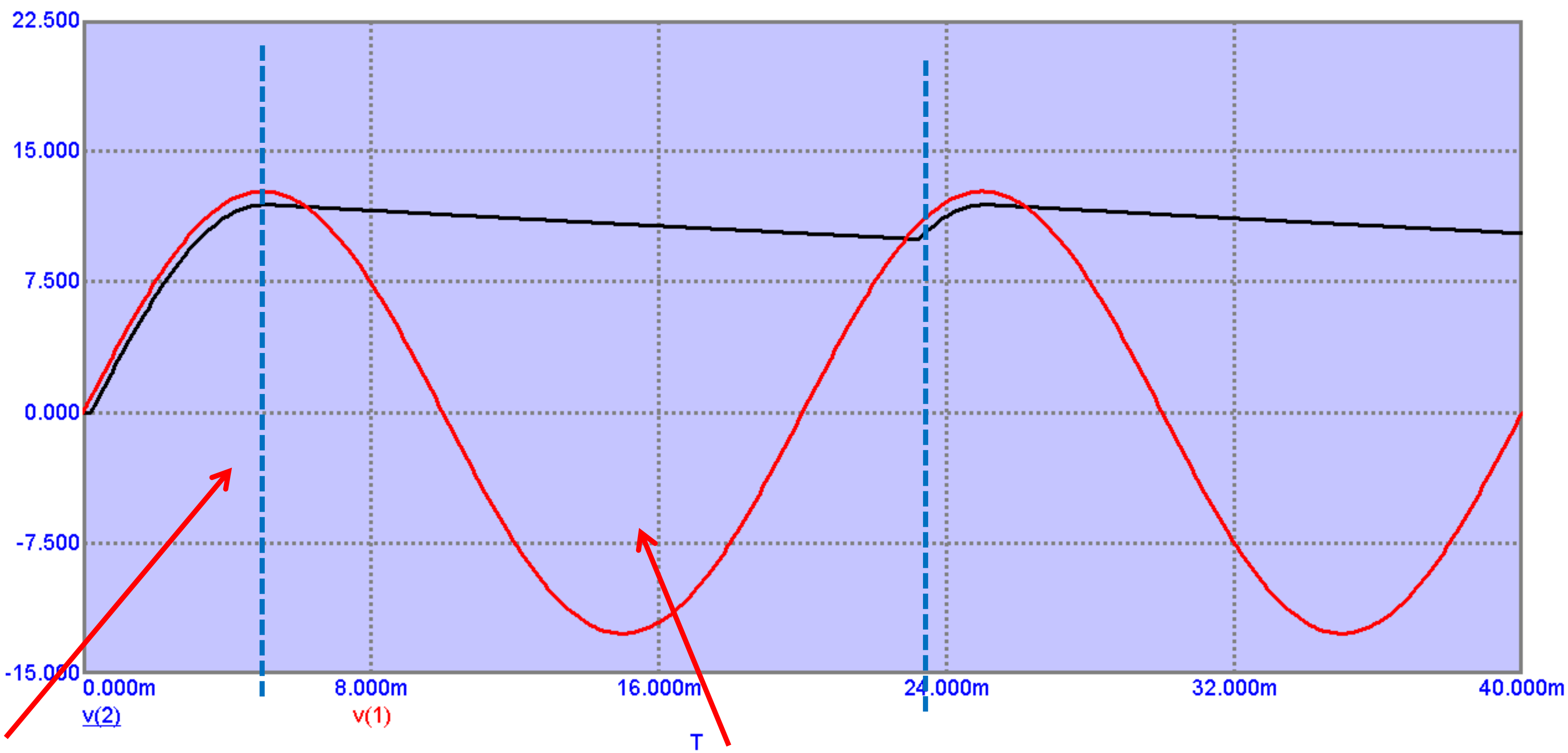


Want to hold that voltage during negative half cycle





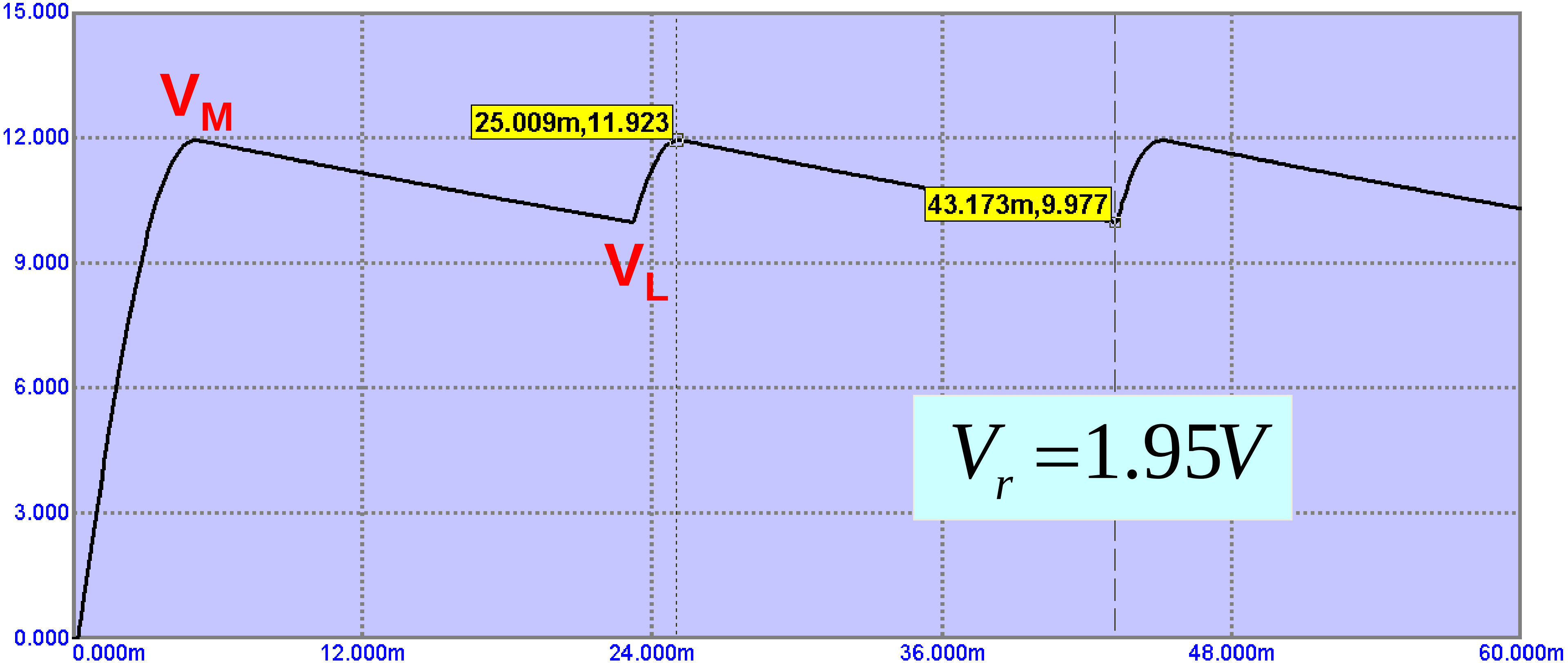




Diode is forward biased

Diode is reverse biased

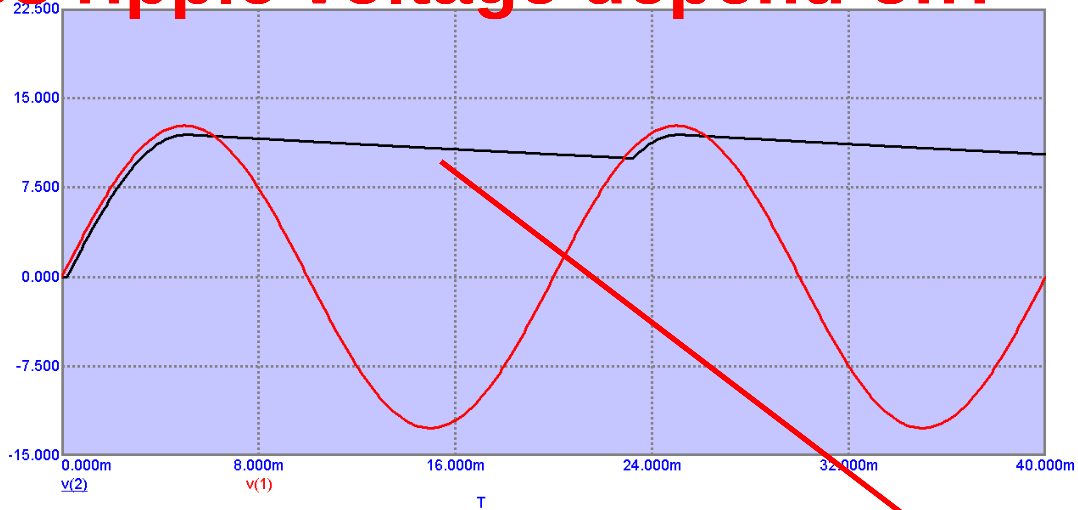
Output has a ripple

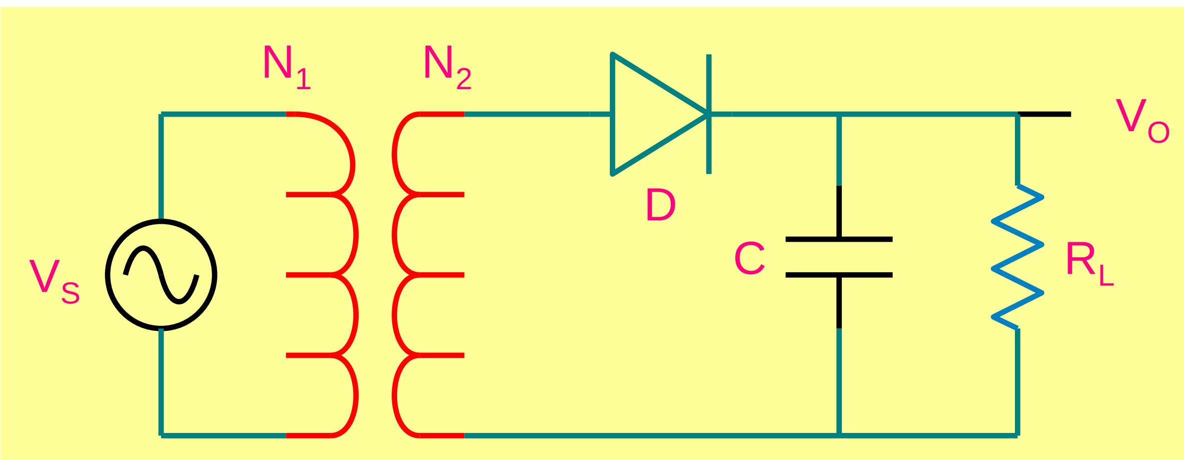


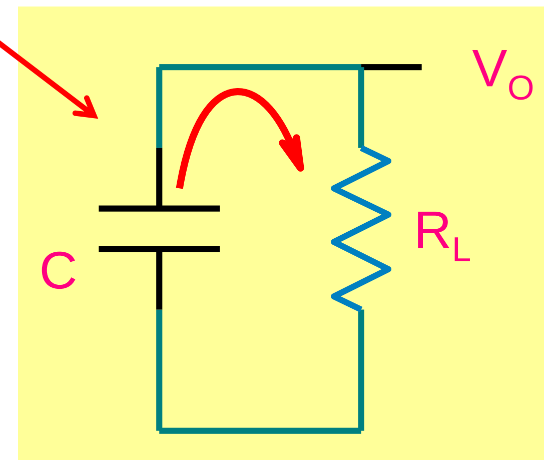
Ripple Voltage : $V_r = V_M - V_L$

Average Output Voltage : $V_O(avg) \cong V_M - \frac{V_R}{2}$

What does ripple voltage depend on?

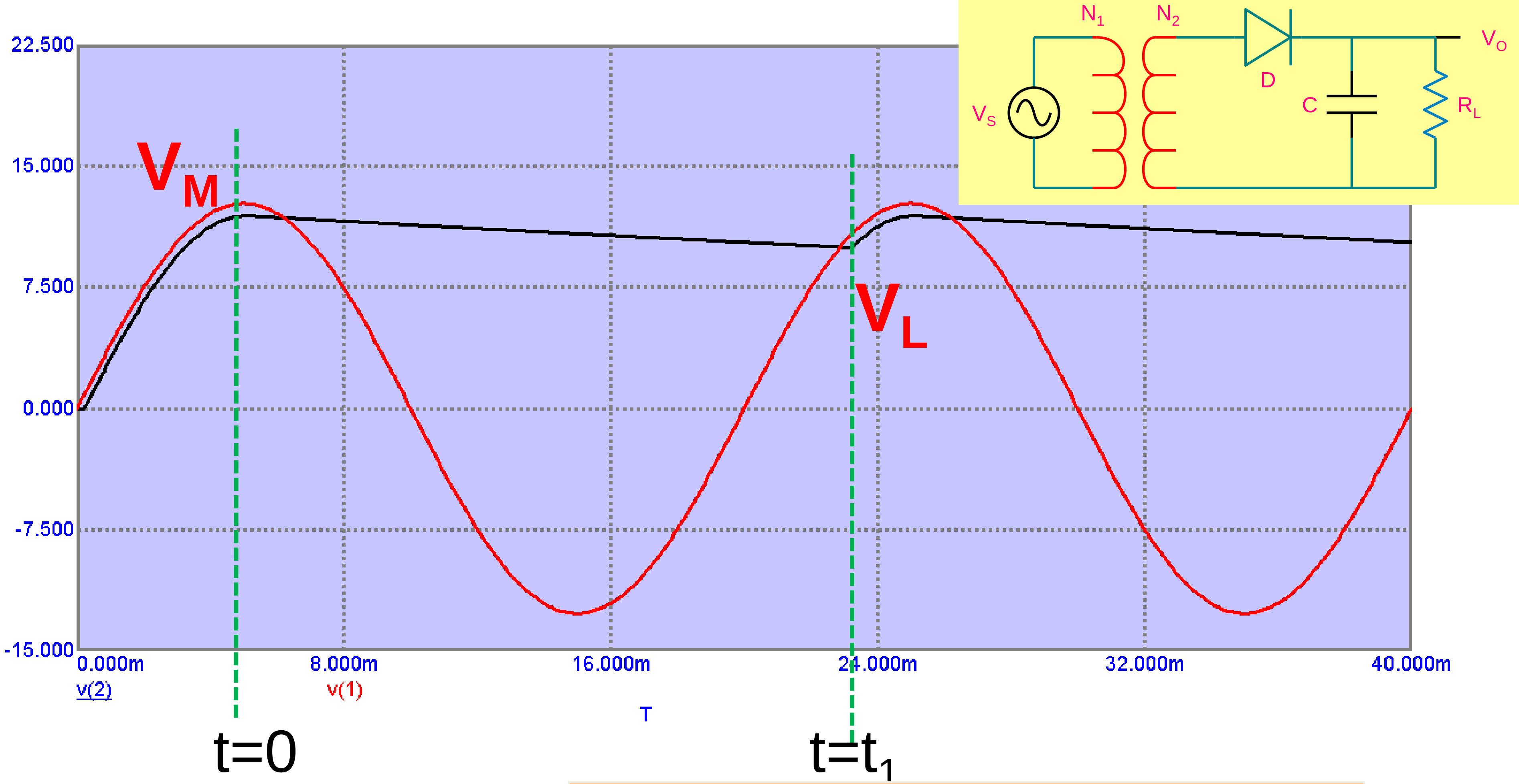






$$C\frac{dV_O}{dt}+\frac{V_O}{R_L}=0\Rightarrow\frac{dV_O}{dt}=-\frac{V_O}{R_LC}$$

$$V_O(t)=V_M\times e^{-\frac{t}{R_LC}}$$

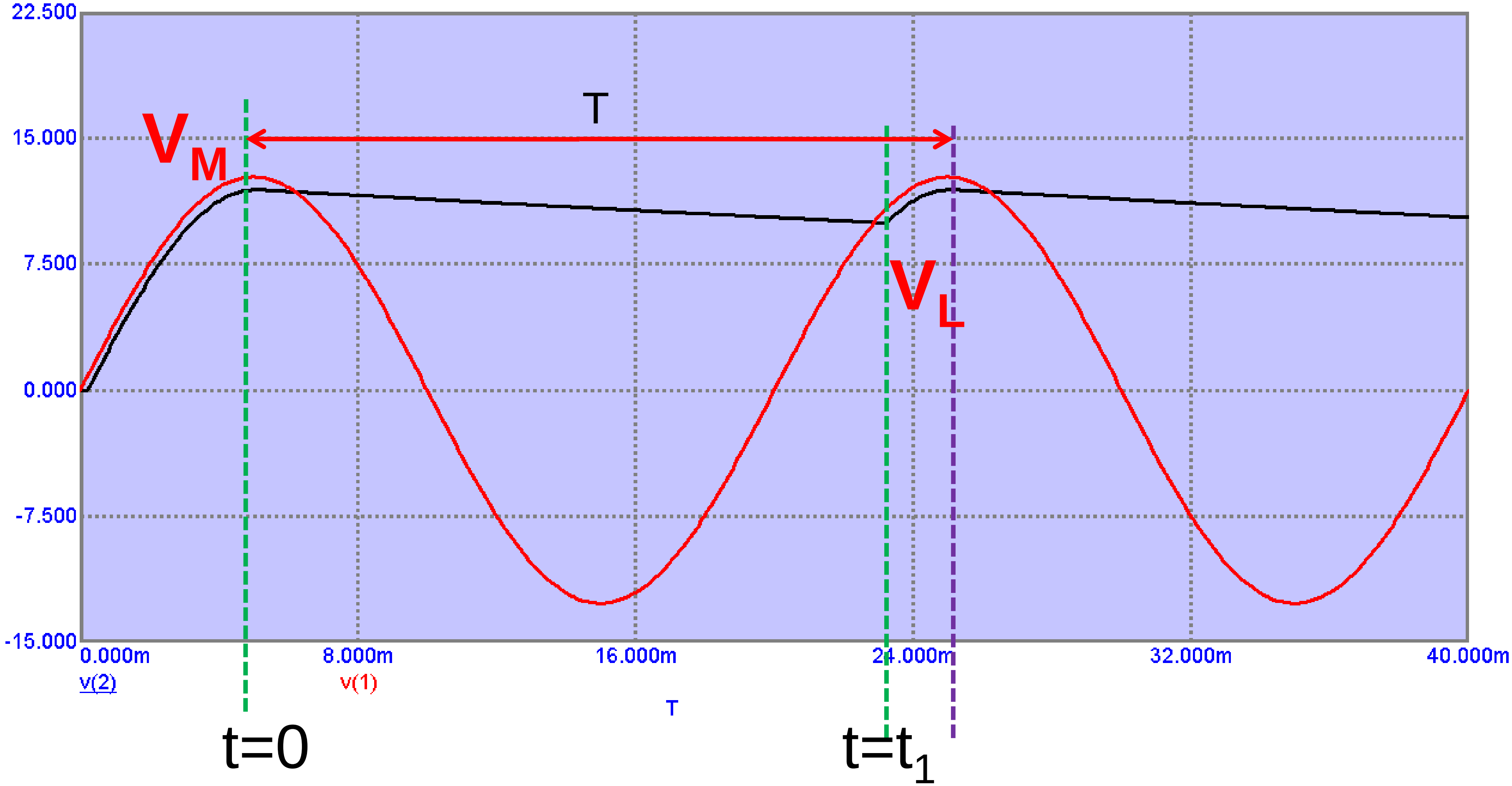


$$V_L = V_M \times e^{-\frac{t_1}{R_L C}}$$

$$V_r = V_M - V_L = V_M \times (1 - e^{-\frac{t_1}{R_L C}})$$

Assuming that $t_1 << R_L C$

$$V_r \cong V_M \times \{1 - (1 - \frac{t_1}{R_L C})\} = \frac{V_M t_1}{R_L C}$$

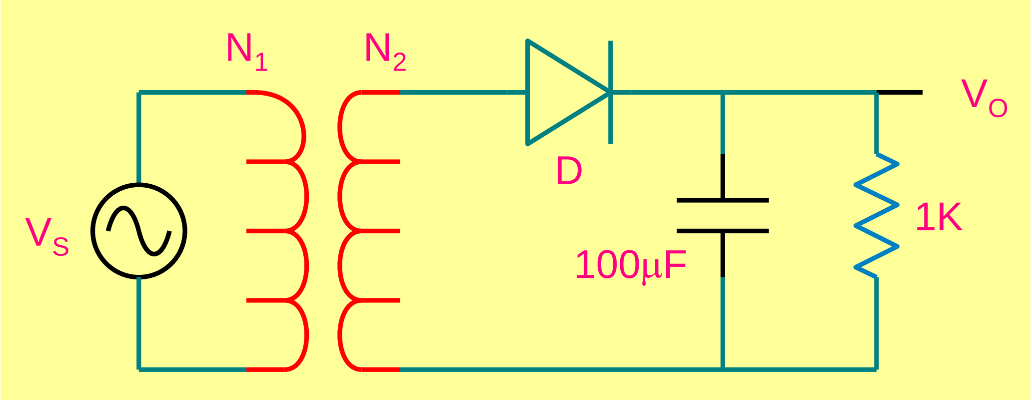


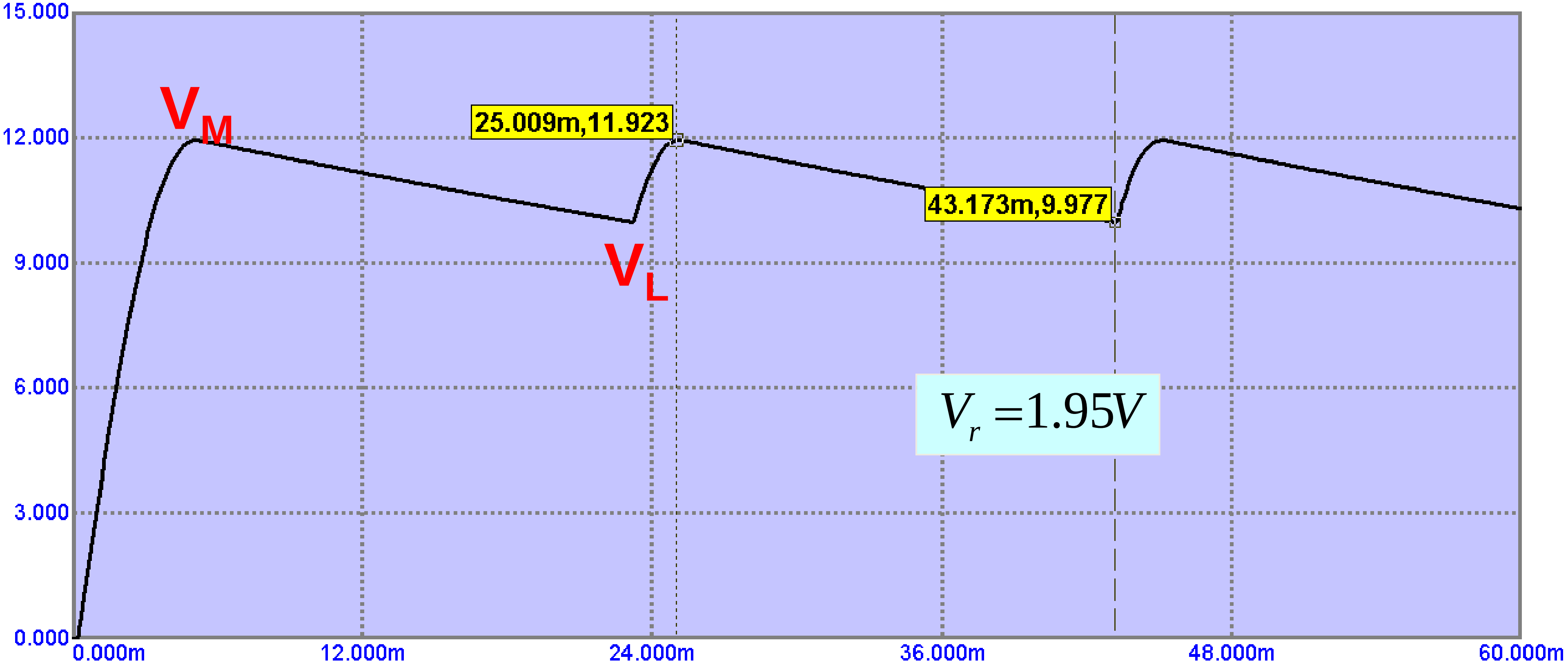
$$t_1 \cong T$$

$$V_r = \frac{V_M t_1}{R_L C} \cong \frac{V_M T}{R_L C}$$

$$V_r \cong \frac{V_M}{f R_L C}$$

Example

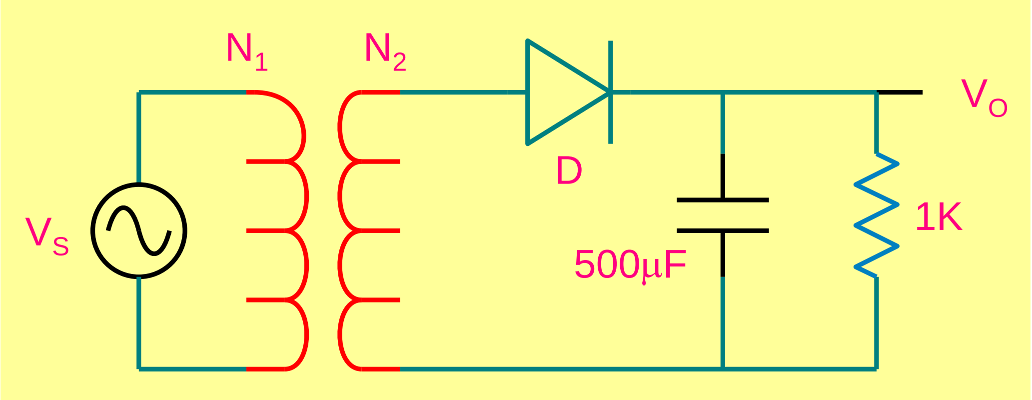


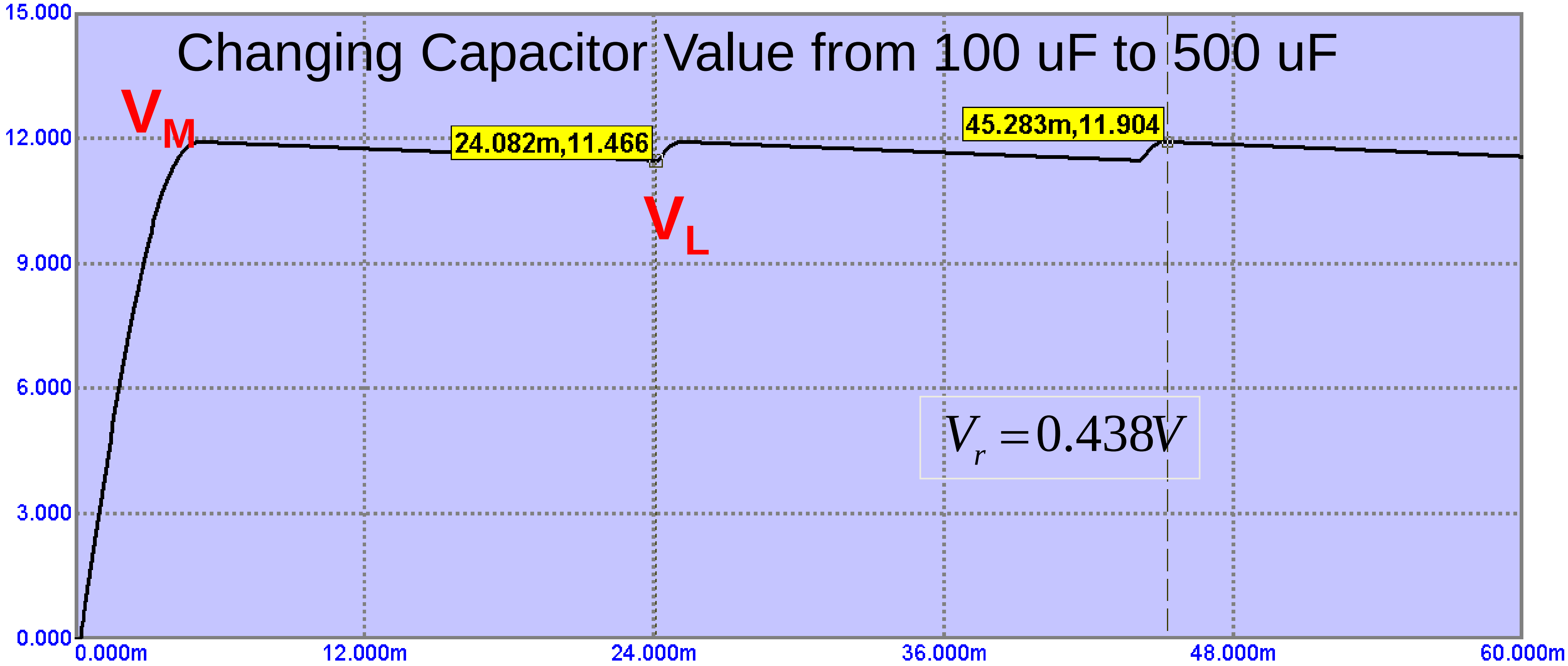


$$V_r \cong \frac{V_M}{fR_LC} = \frac{11.923}{50\times10^3\times100\times10^{-6}} = 2.385V$$

$$\frac{R_LC}{T} = 5$$

Example





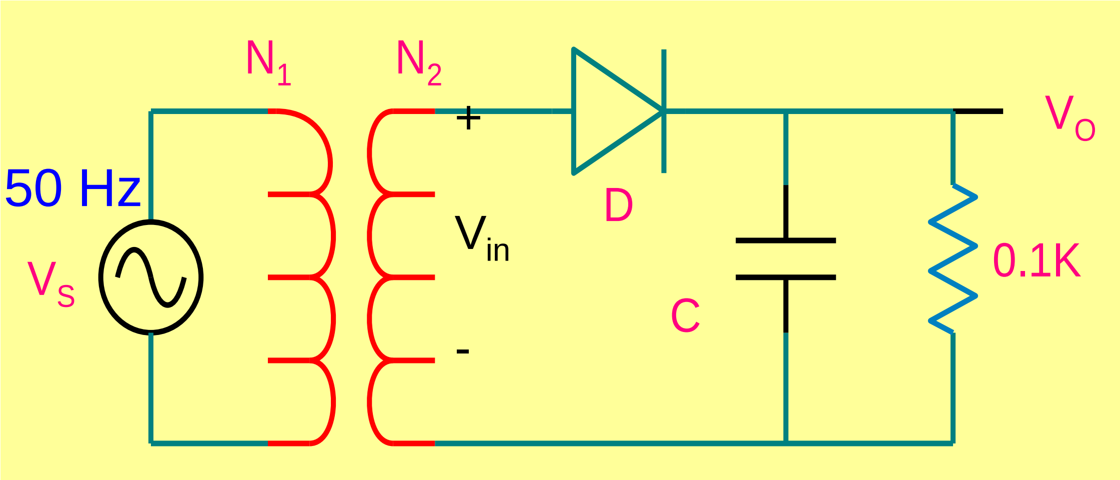
$$V_r = 0.438V$$

$$V_r \cong \frac{V_M}{fR_L C} = \frac{11.904}{50\times 10^3 \times 500\times 10^{-6}} = 0.476V$$

$$\frac{R_L C}{T} = 25$$

Design Example

Design a power supply that will supply 6V to a load of 100Ω with ripple voltage less than 0.1V.



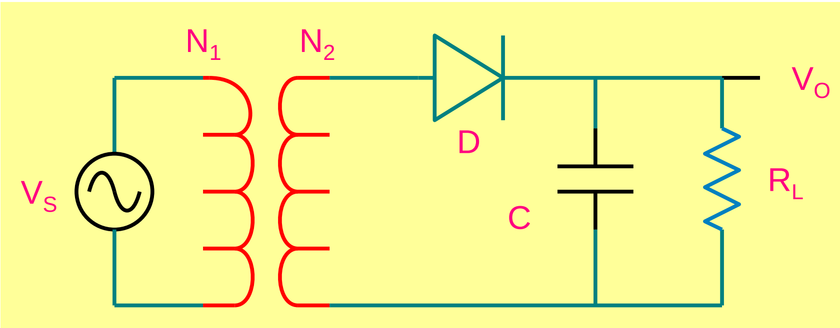
For V_O to be 6V, the input V_{IN} should be ~6.7V

$$\frac{N_1}{N_2} = \frac{311.127}{6.7} = 46.4$$

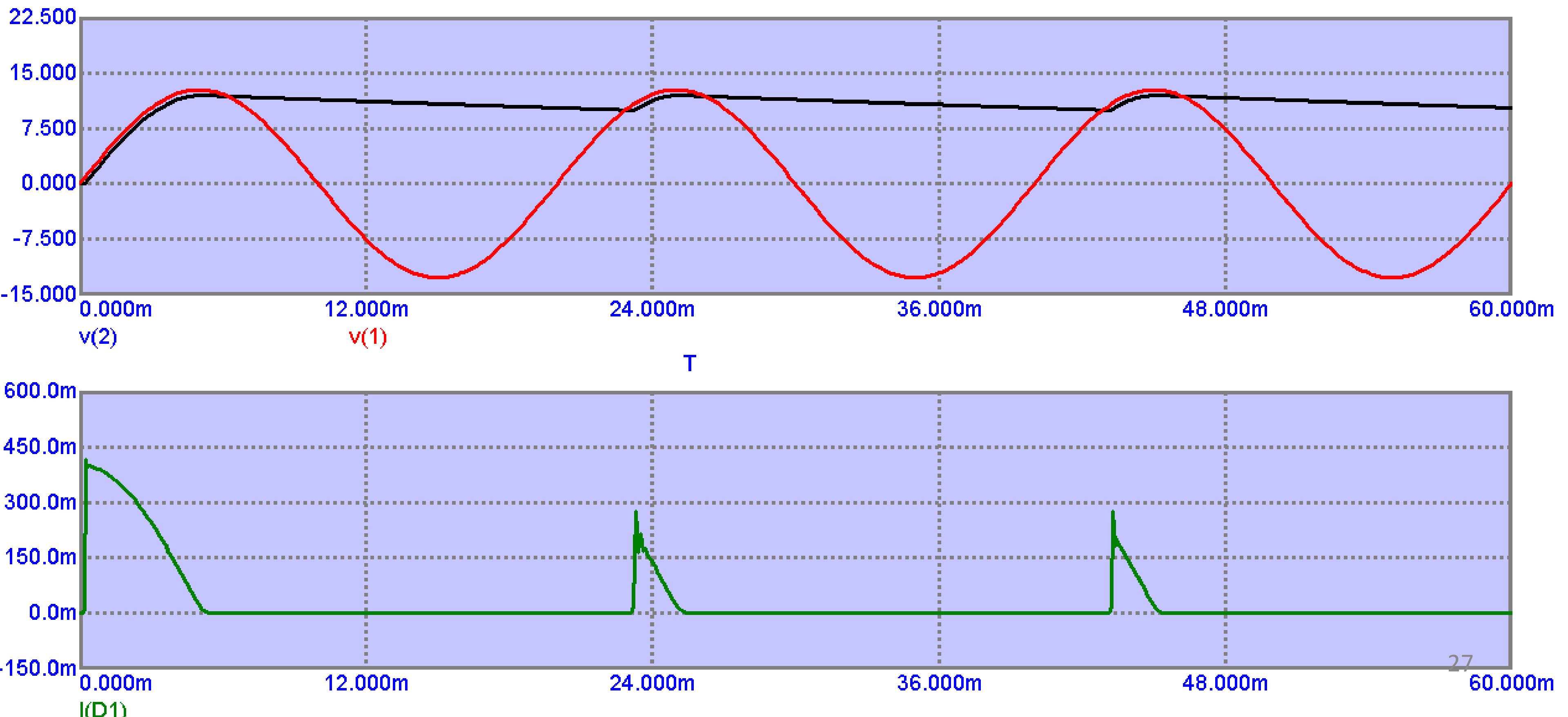
$$V_r \cong \frac{V_M}{fR_L C} = 0.1 \Rightarrow C = 12mF$$

How do we choose a diode for this application?

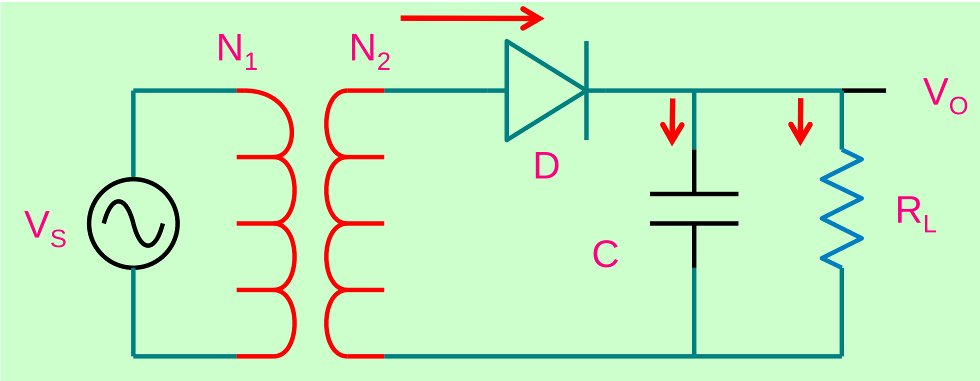
How do we choose a diode for this application?



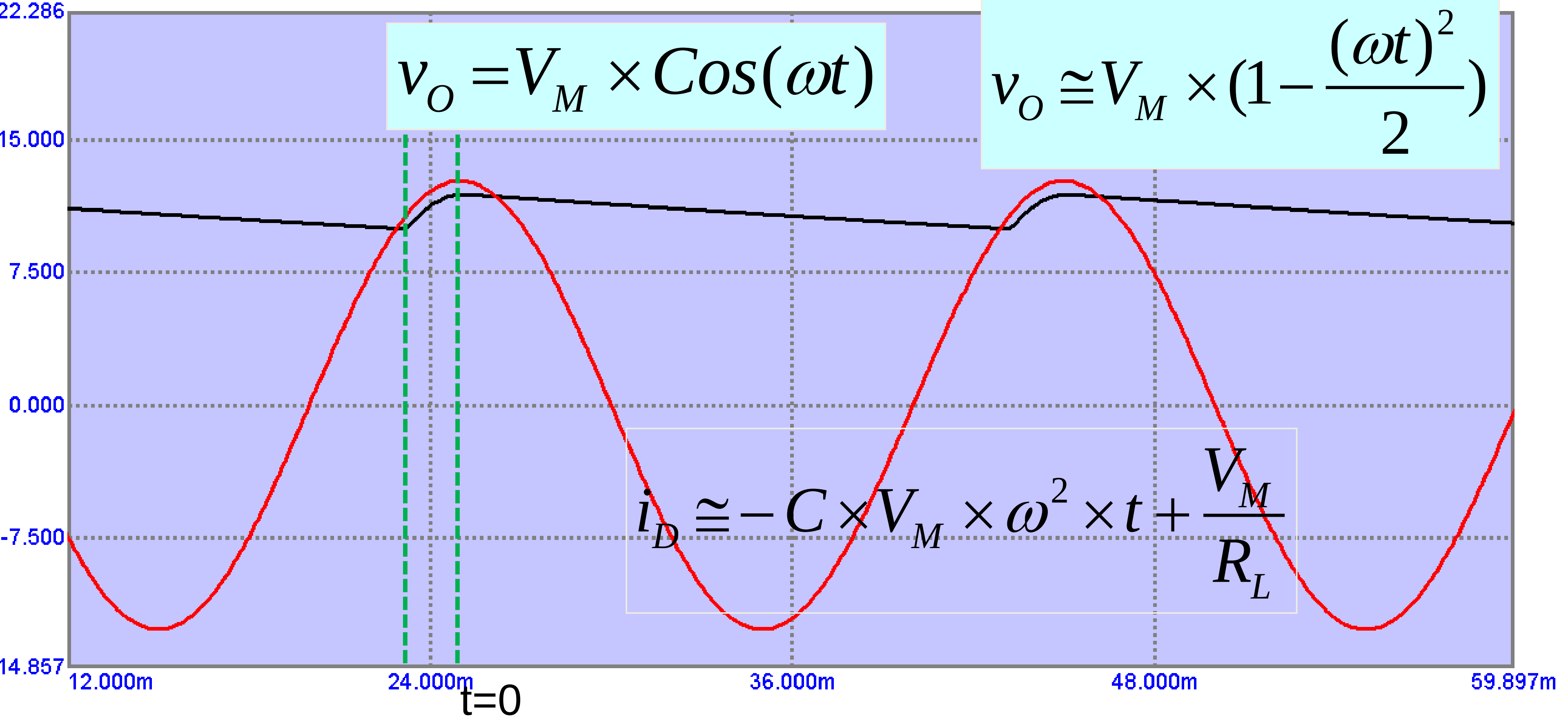
Peak diode current, average diode current and peak inverse voltage



Diode forward bias current



$$i_D = C \times \frac{dv_O}{dt} + \frac{v_O}{R_L}$$



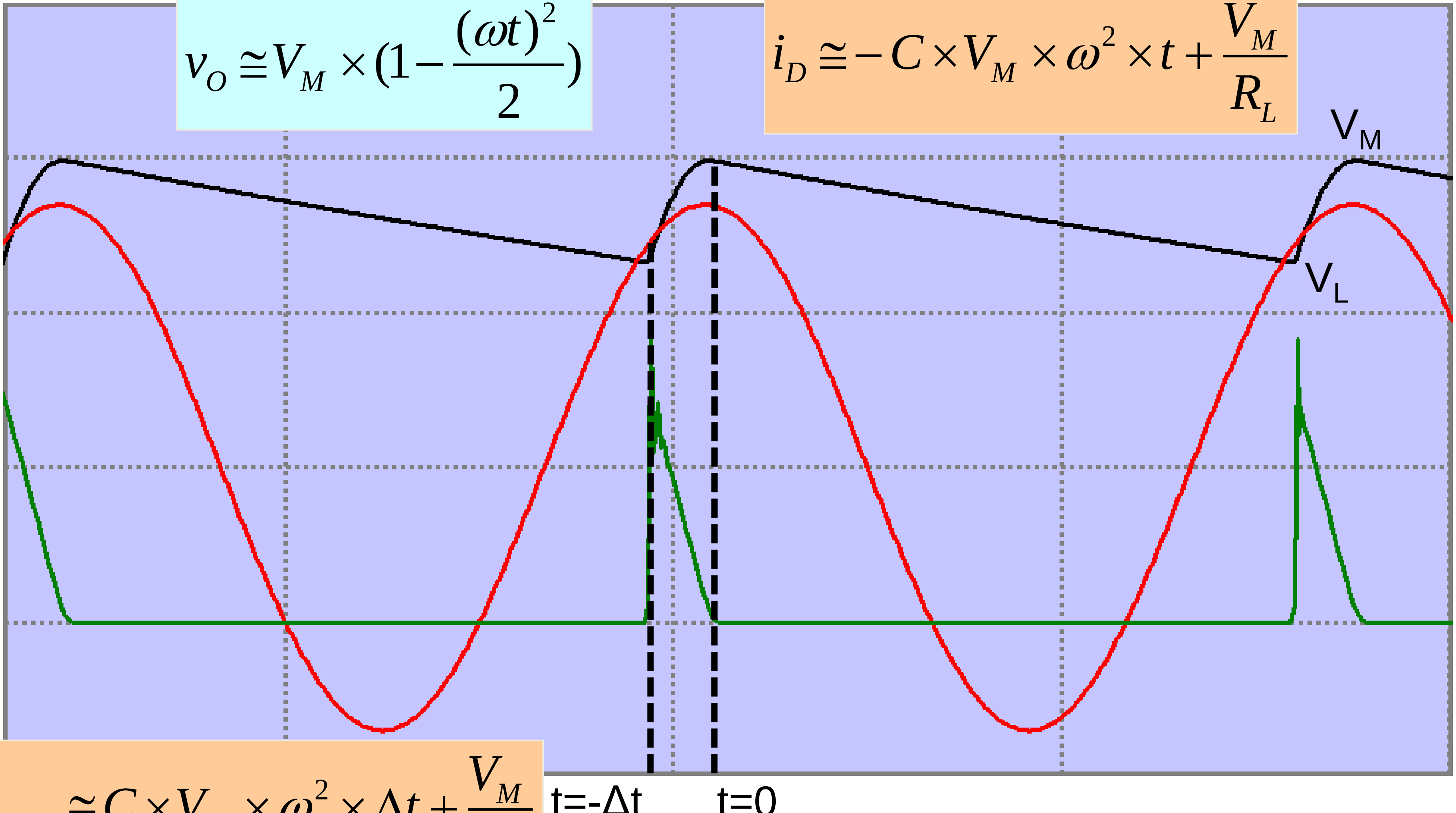
$$v_O = V_M \times Cos(\omega t)$$

$$v_O \cong V_M \times (1 - \frac{(\omega t)^2}{2})$$

$$i_D \cong -C \times V_M \times \omega^2 \times t + \frac{V_M}{R_L}$$

$$v_O \cong V_M \times \left(1 - \frac{(\omega t)^2}{2}\right)$$

$$i_D \cong -C \times V_M \times \omega^2 \times t + \frac{V_M}{R_L}$$



$$i_{D\max} \cong C \times V_M \times \omega^2 \times \Delta t + \frac{V_M}{R_L}$$

$$V_L \cong V_M \times \left(1 - \frac{(\omega \Delta t)^2}{2}\right) \Rightarrow \Delta t = \frac{1}{\omega}\sqrt{\frac{2V_r}{V_M}}$$

$$i_{D\max} \cong \omega C \times \sqrt{2V_r V_M} + \frac{V_M}{R_L}$$

Peak Diode Current

$$i_{D\max} \cong \omega C \times \sqrt{2V_r V_M} + \frac{V_M}{R_L}$$

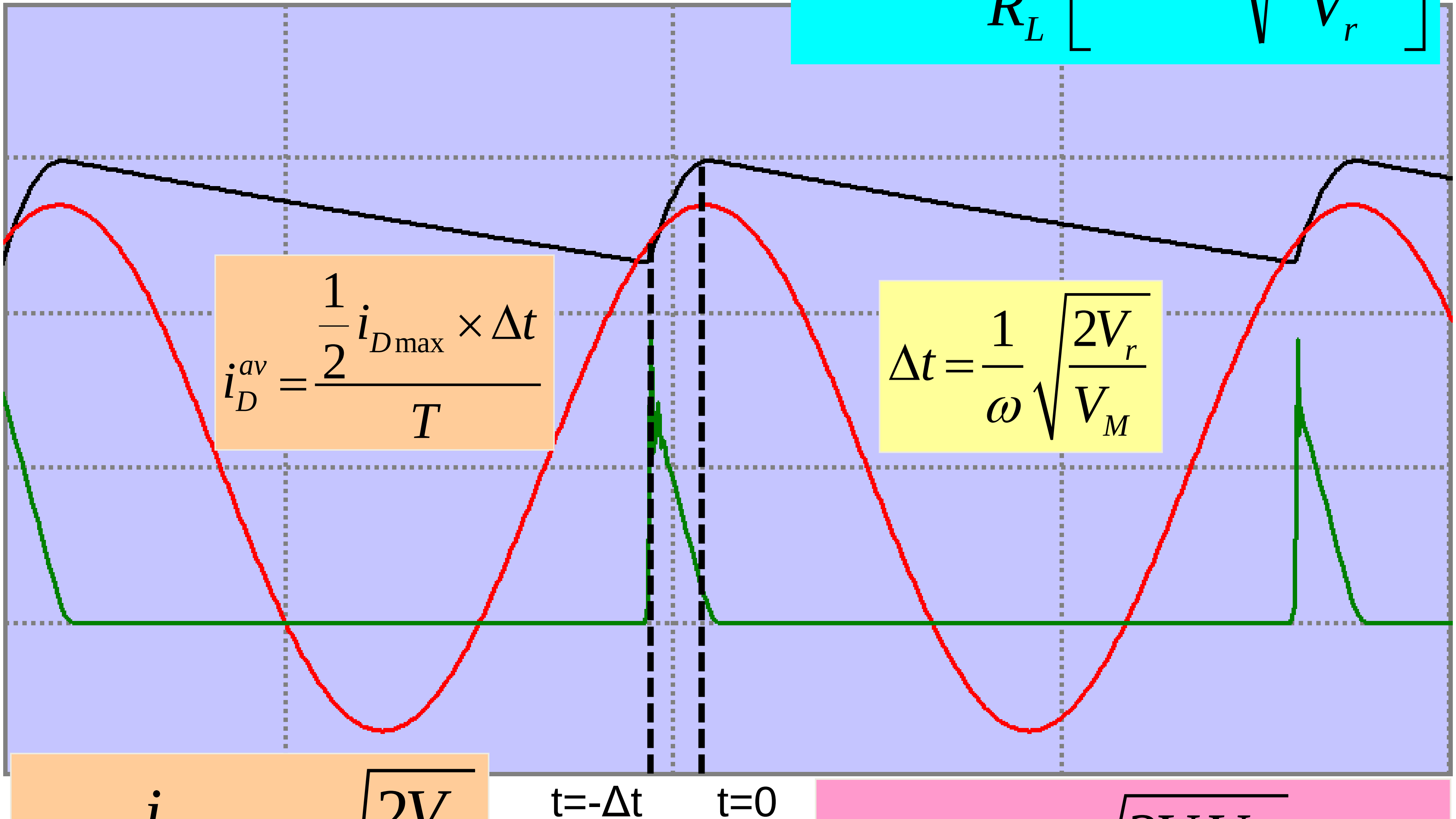
$$V_r \cong \frac{V_M}{fR_L C}$$

$$\Delta t = \frac{1}{\omega}\sqrt{\frac{2V_r}{V_M}}$$

$$i_{D\max} = \frac{V_M}{R_L}\left[1 + 2\pi\sqrt{\frac{2V_M}{V_r}}\right]$$

Average Diode Currents

$$i_{D\max} = \frac{V_M}{R_L}\left[1 + 2\pi\sqrt{\frac{2V_M}{V_r}}\right]$$



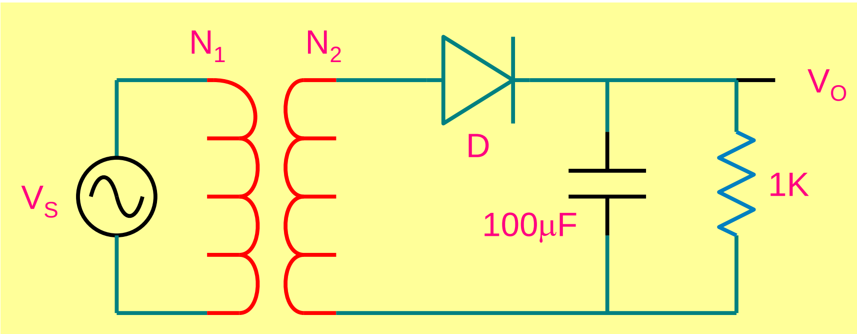
$$i_D^{av} = \frac{\frac{1}{2}\, i_{D\max} \times \Delta t}{T}$$

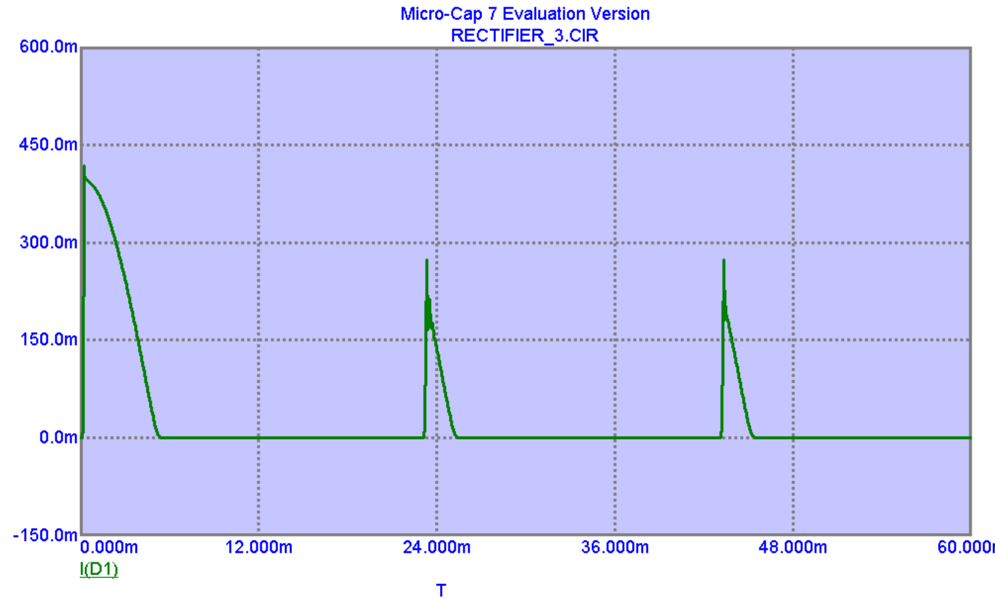
$$\Delta t = \frac{1}{\omega}\sqrt{\frac{2V_r}{V_M}}$$

$$i_D^{av} = \frac{i_{D\max}}{4\pi} \times \sqrt{\frac{2V_r}{V_M}}$$

$$i_D^{av} = \frac{V_M}{R_L} + \frac{\sqrt{2V_r V_M}}{4\pi R_L} \cong \frac{V_M}{R_L}$$

Peak and Average Diode Currents

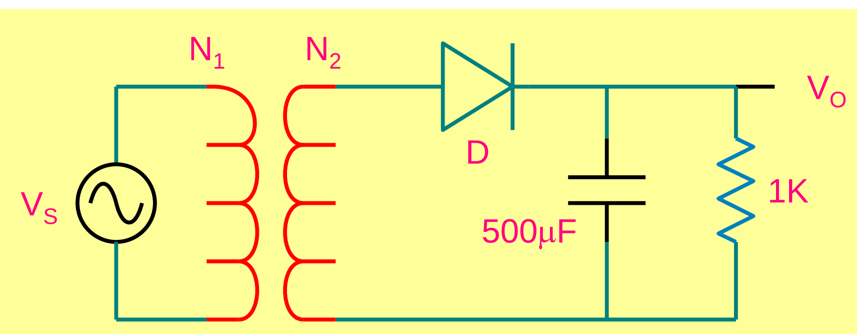


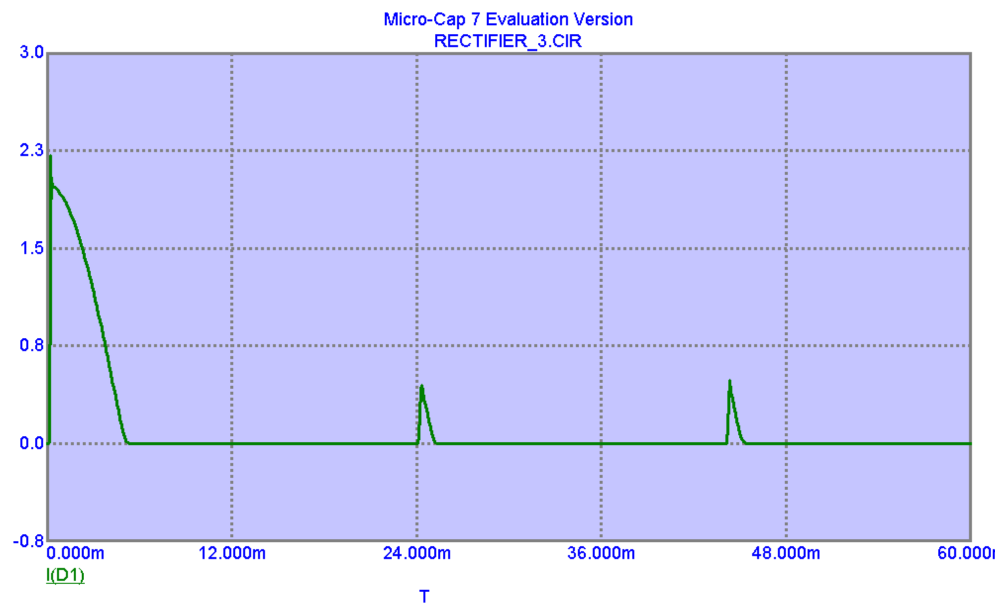


$$V_r = 1.95V$$

$$i_D^{av} \cong \frac{V_M}{R_L} = 12mA$$

$$i_{D\max} \cong 250mA$$





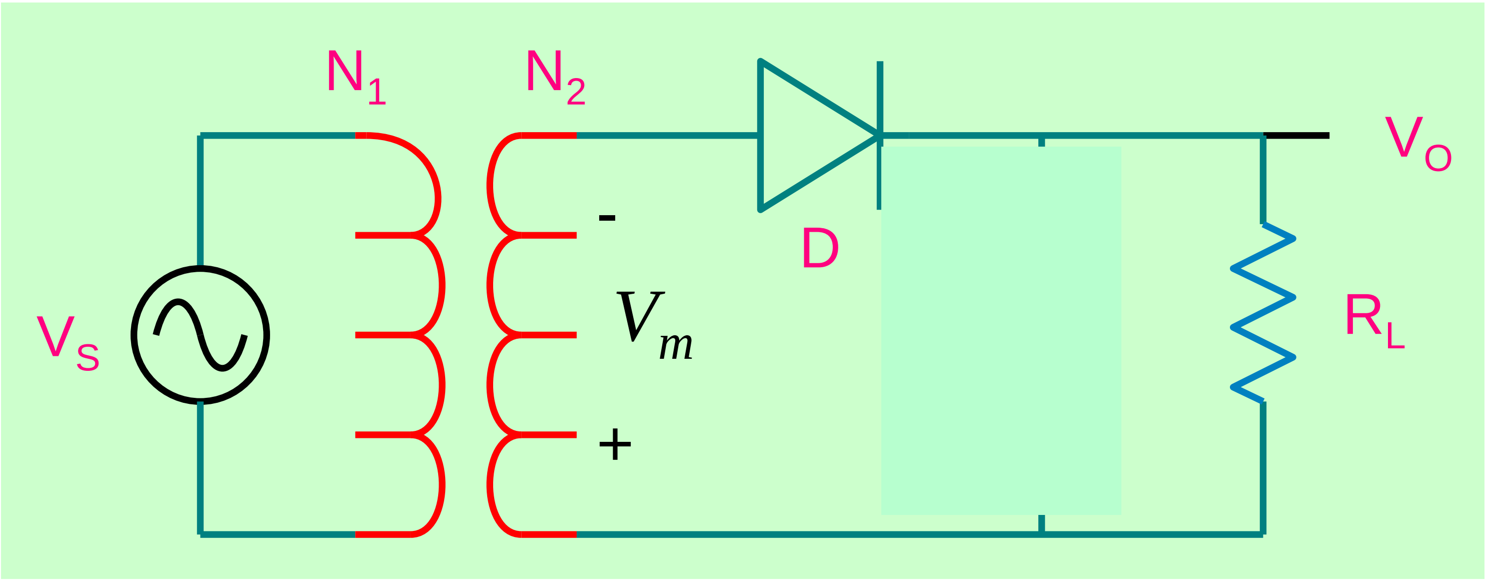
$$V_r = 0.438V$$

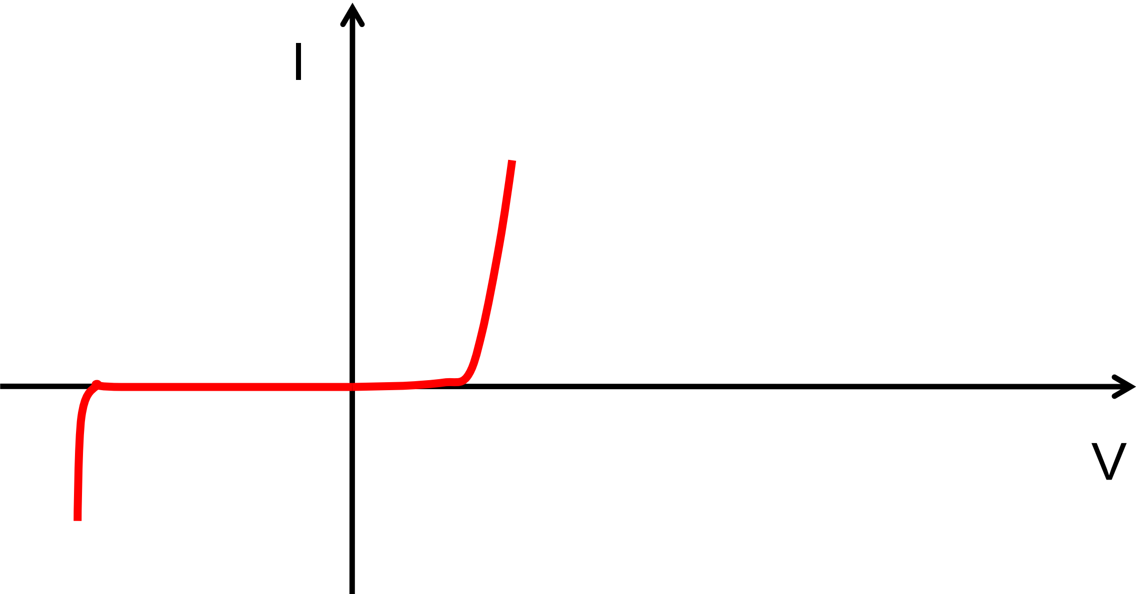
$$i_D^{av} \cong \frac{V_M}{R_L} = 12mA$$

$$i_{D\max} \cong 545mA$$

Peak diode current increases as ripple reduces

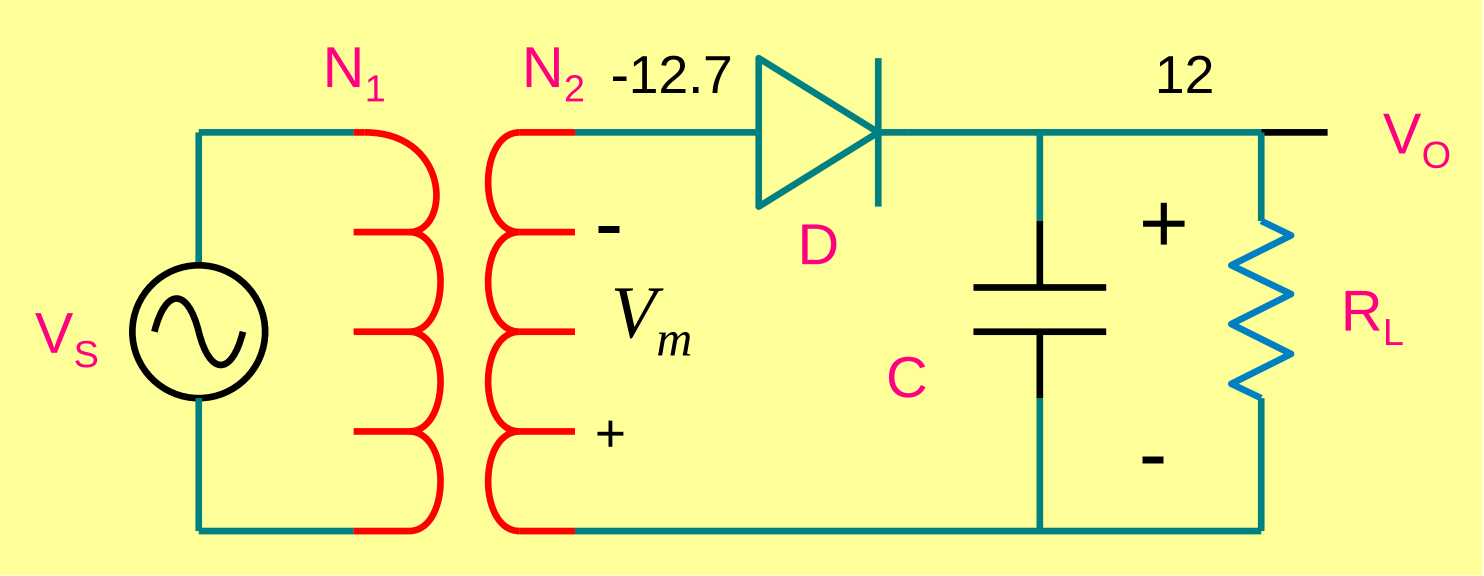
Peak Inverse Voltage





$$PIV = V_m$$

Peak Inverse Voltage



12+12.7=24.7V

$$V_m = 12.7$$

$$PIV \cong 2v_O + 0.7$$

$$PIV = 2V_M + V_\gamma$$