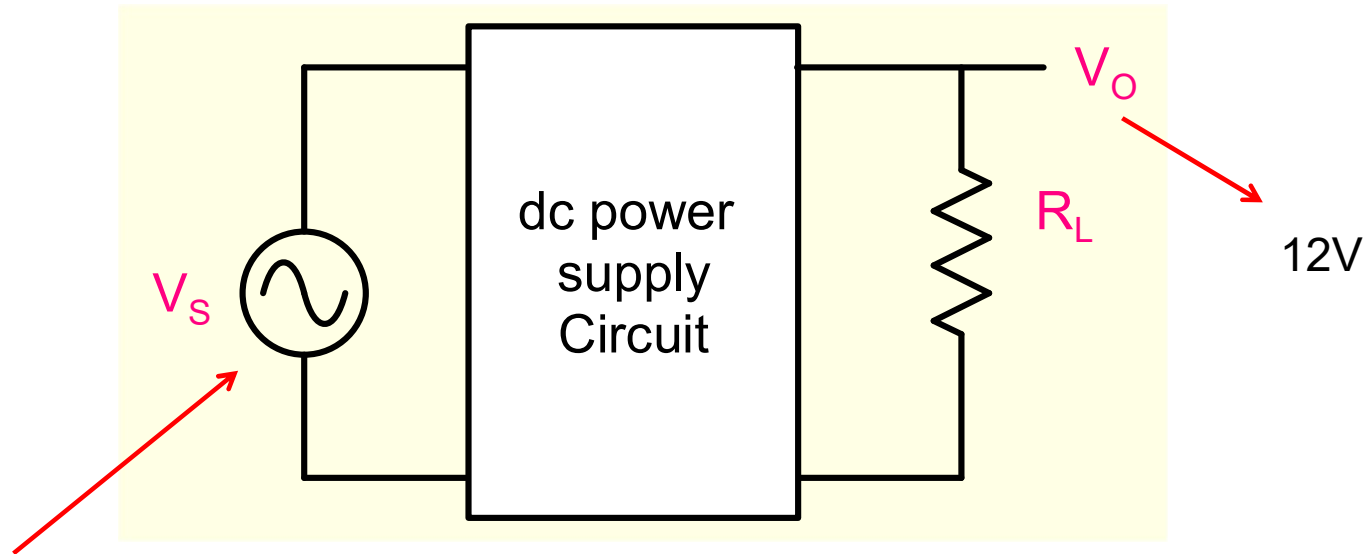


ESC201T : Introduction to Electronics

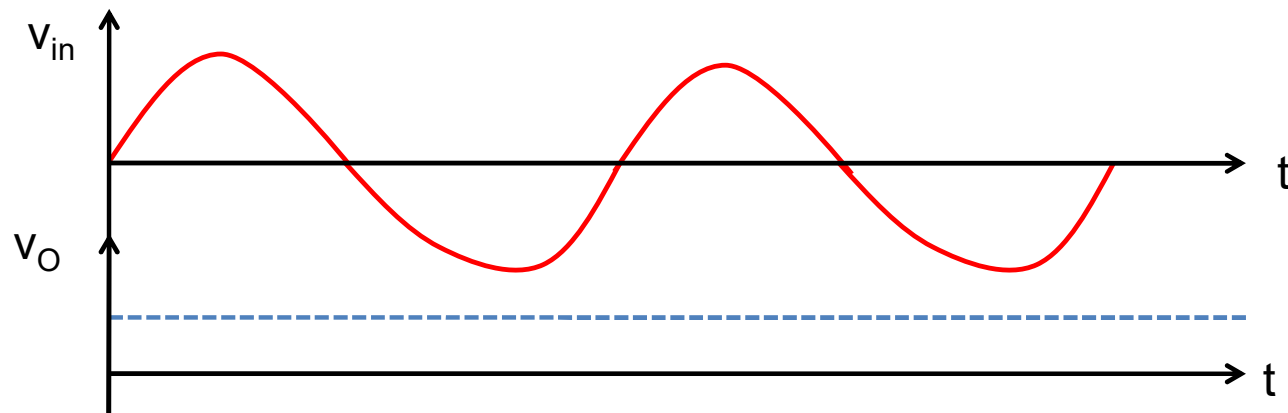
Lecture 23: Power Supply (part-1)

B. Mazhari
Dept. of EE, IIT Kanpur

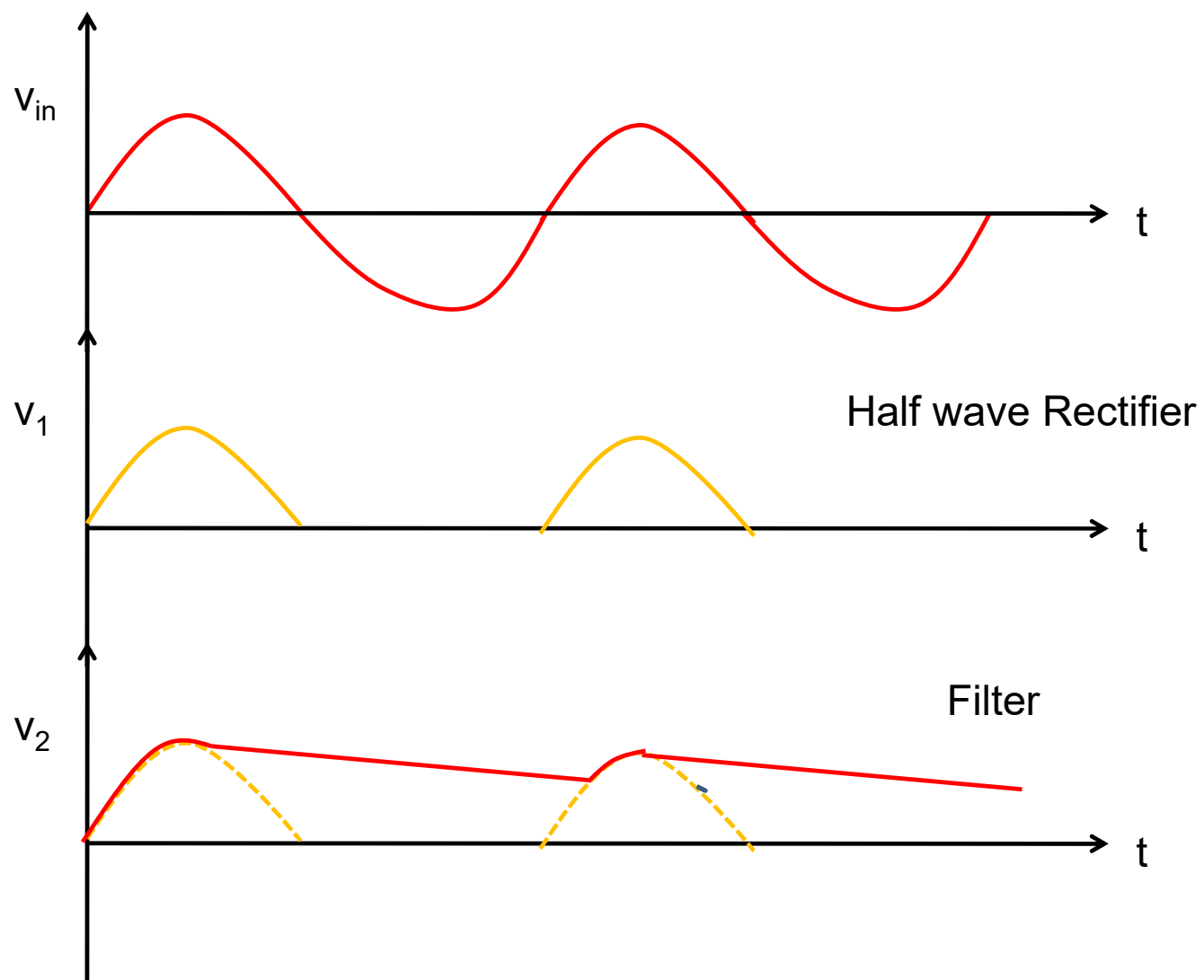
Power Supply



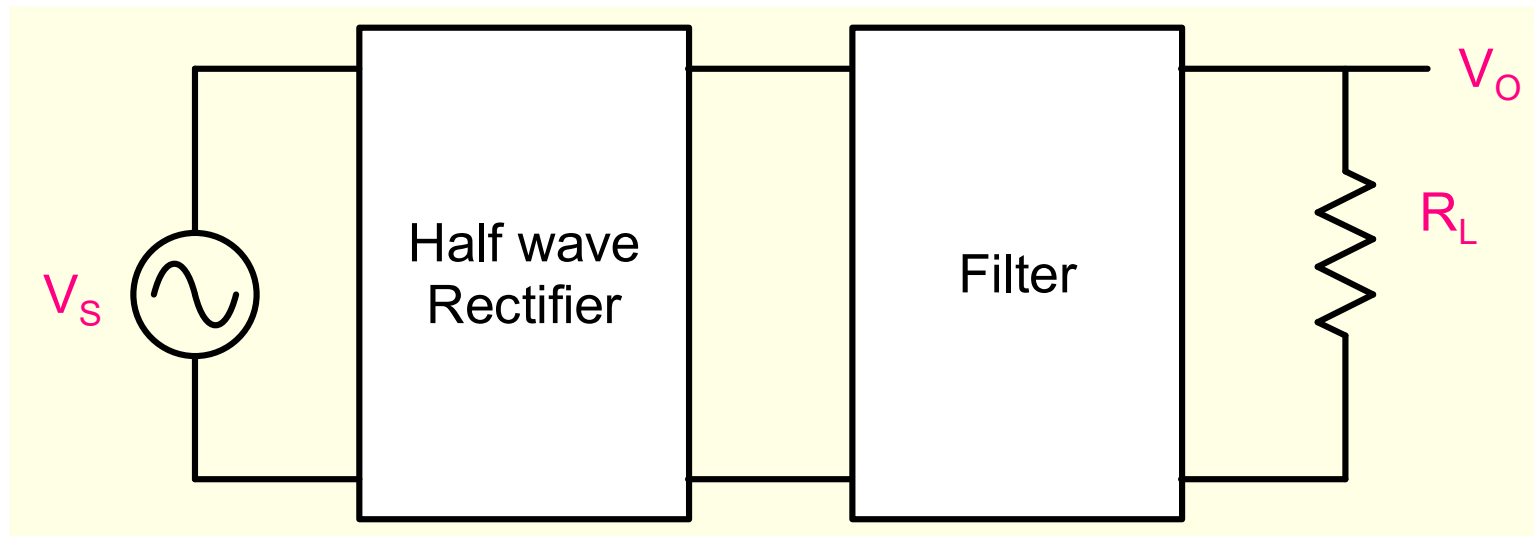
$220V_{rms} \Rightarrow 311.127V_{peak\ value}$



Strategy



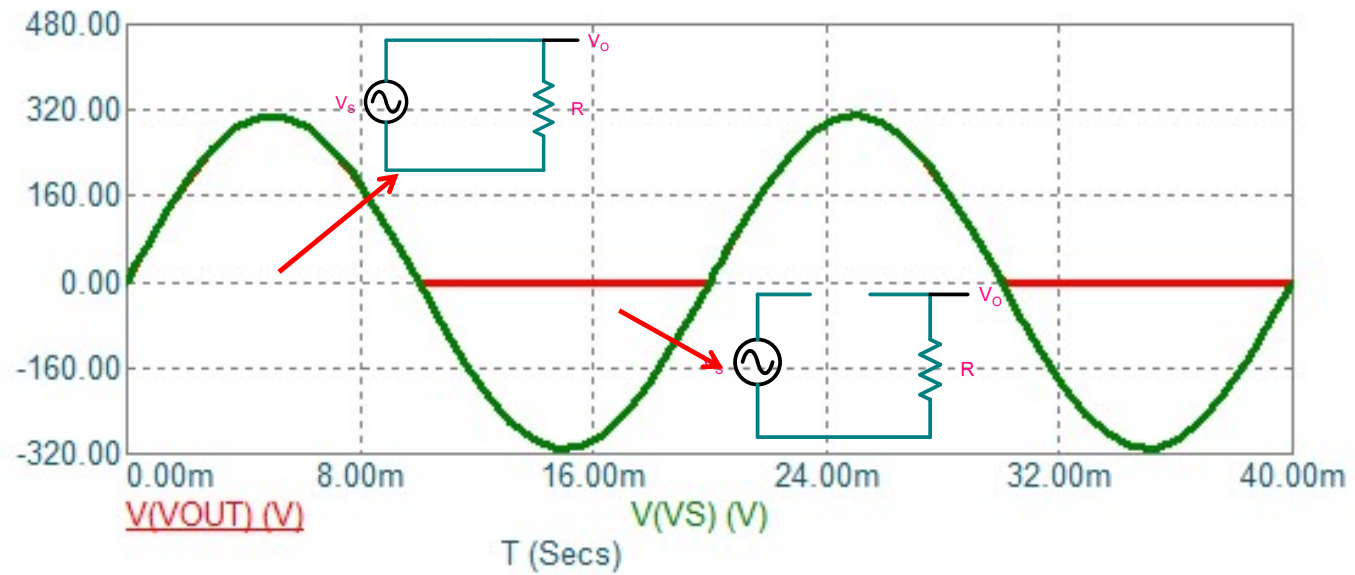
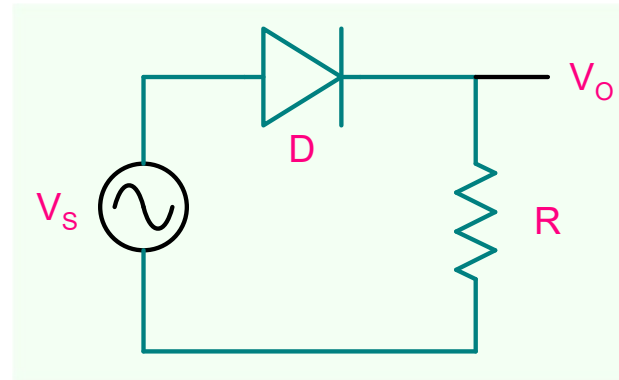
Power Supply: Block diagram



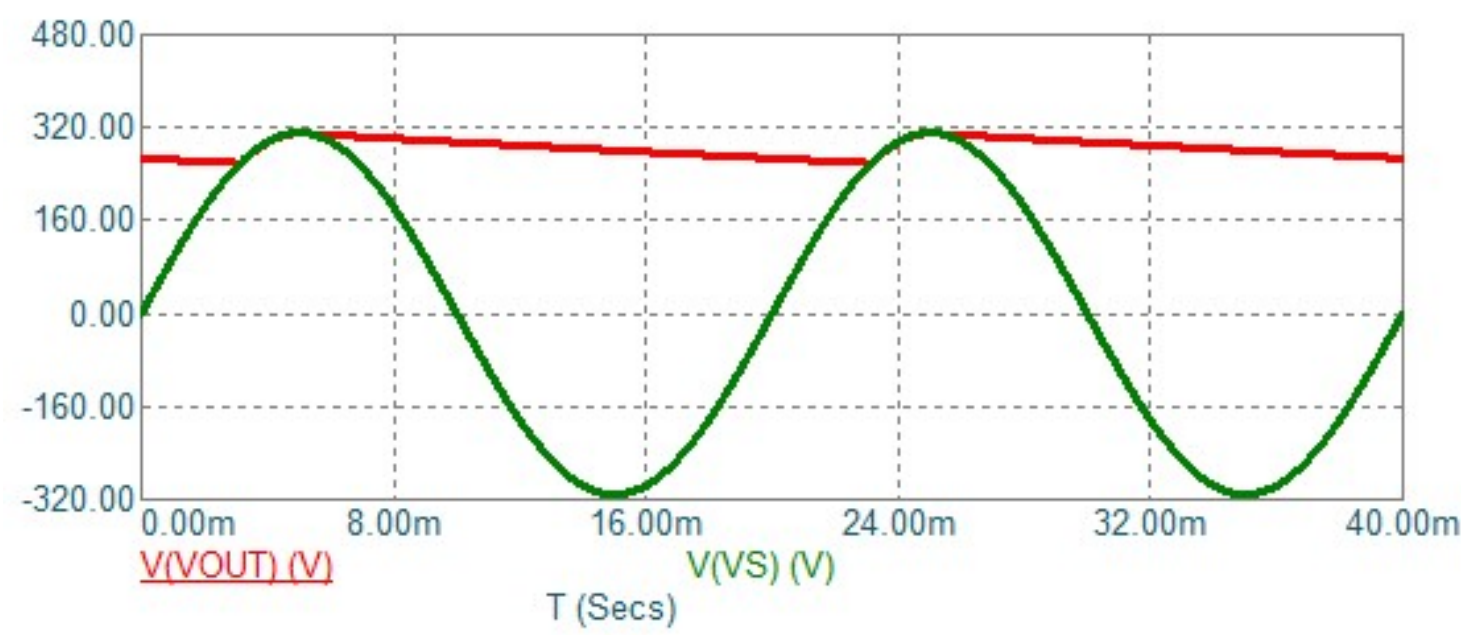
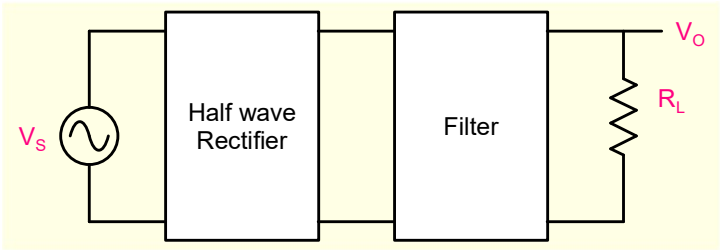
Half wave Rectifier circuit

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

$220V \text{ rms}$



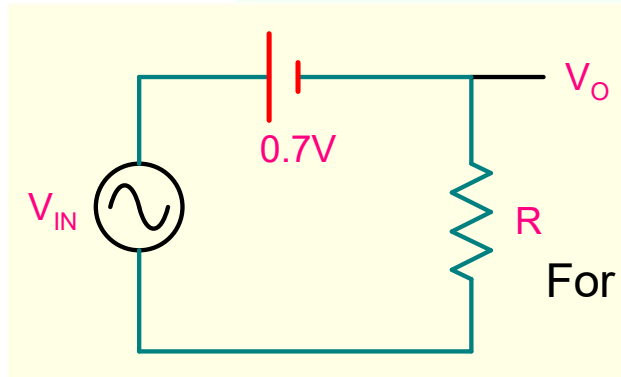
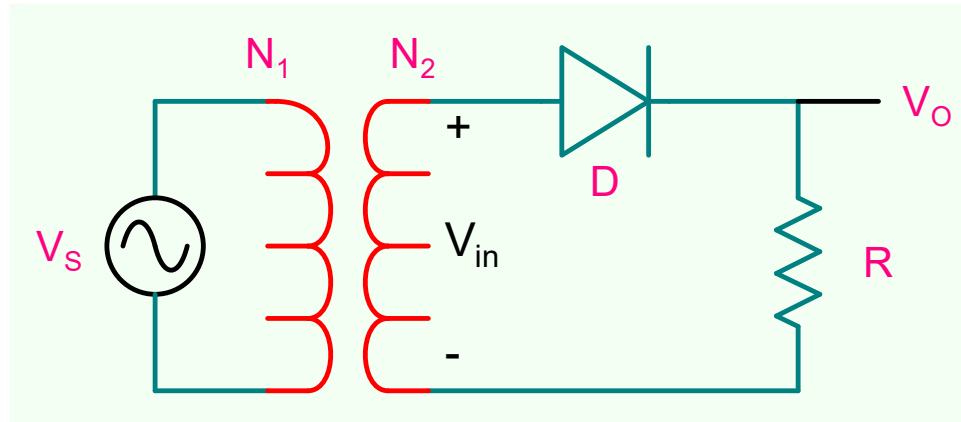
Filtered output voltage is too large !



Must reduce the input voltage

Half Wave Rectifier

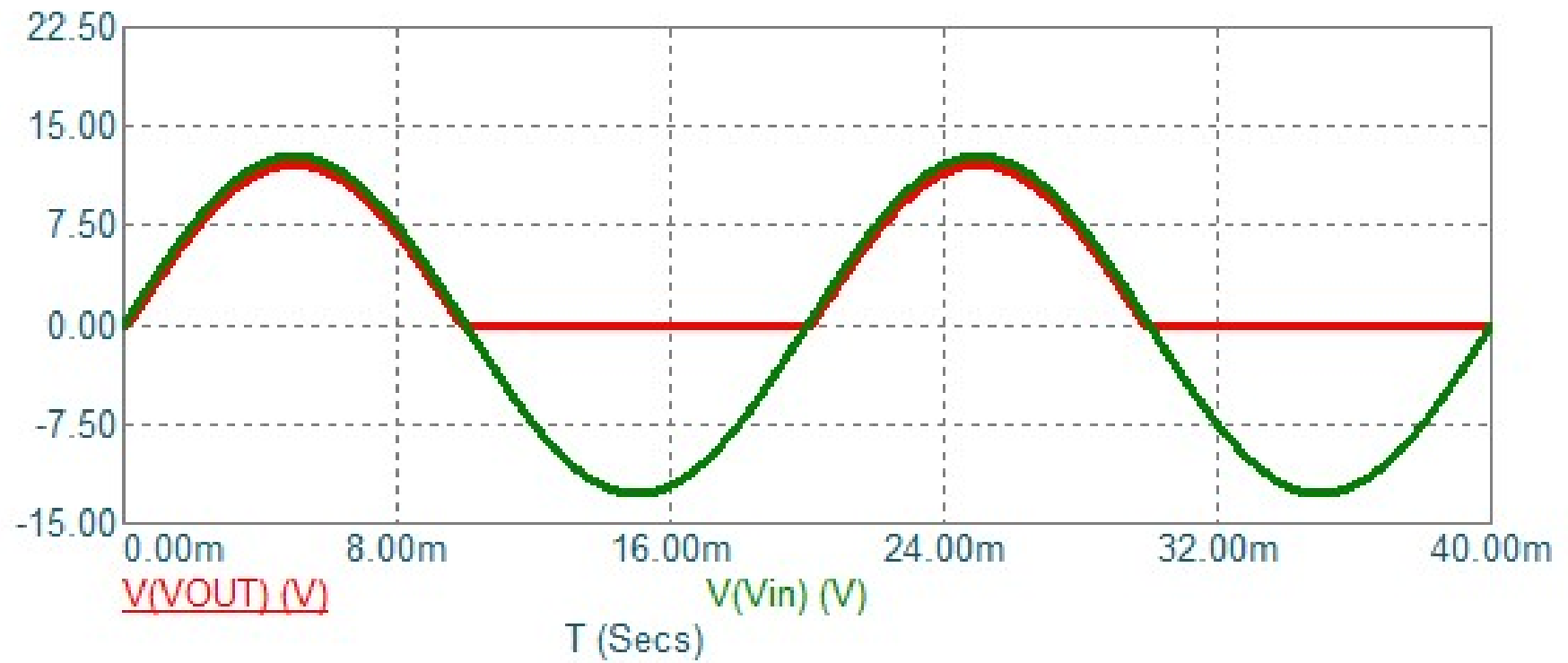
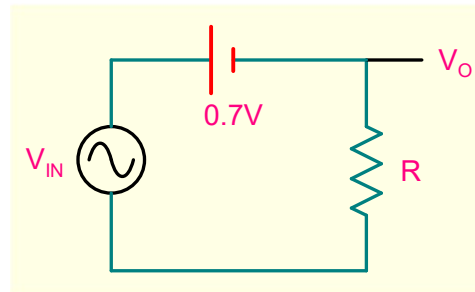
$$\frac{V_S}{V_{IN}} = \frac{N_1}{N_2}$$



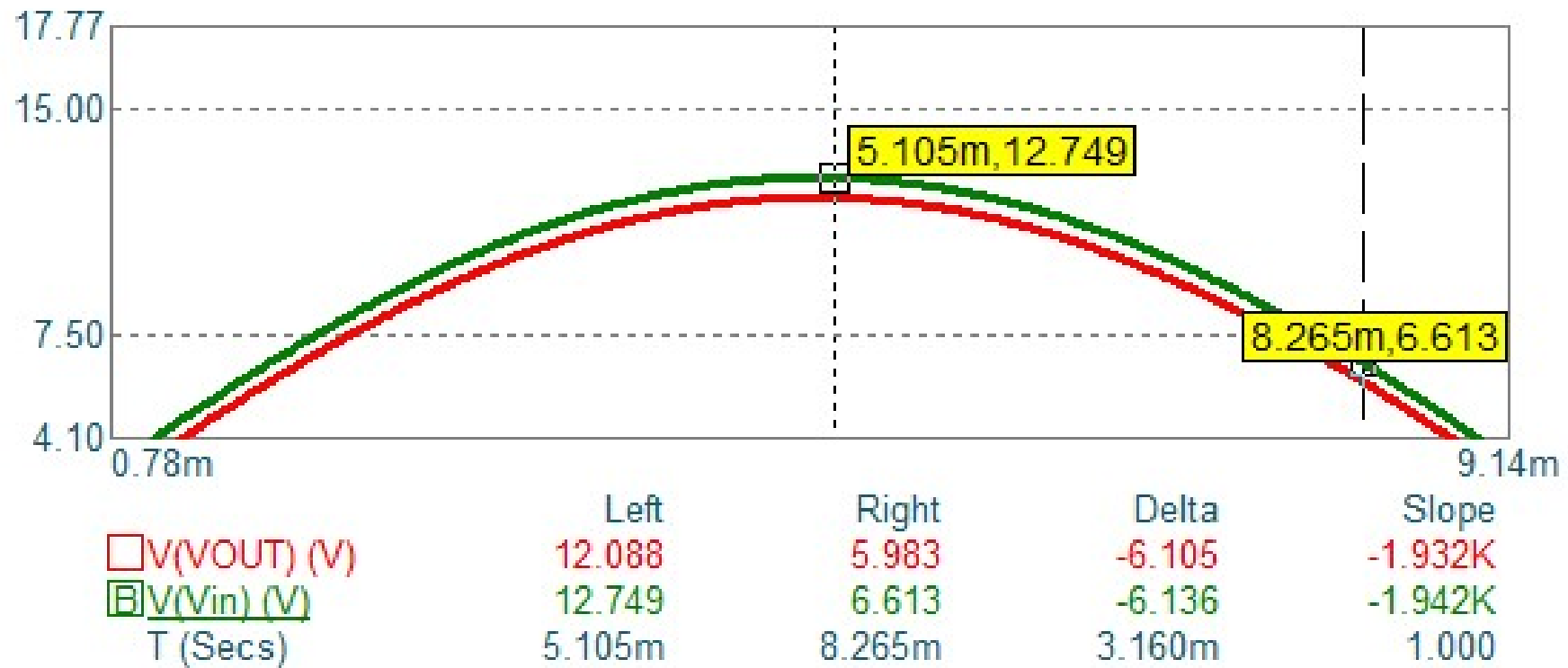
For V_O to be 12V, the input V_{IN} should be $\sim 12.7V$

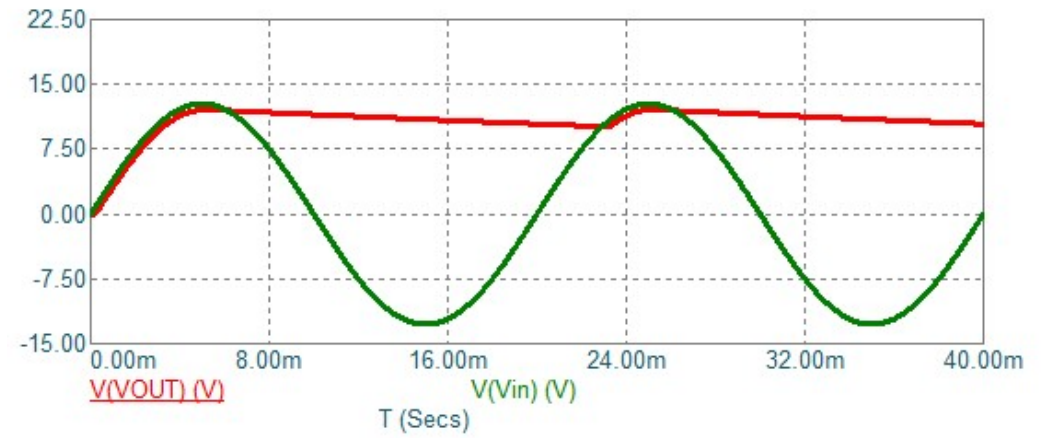
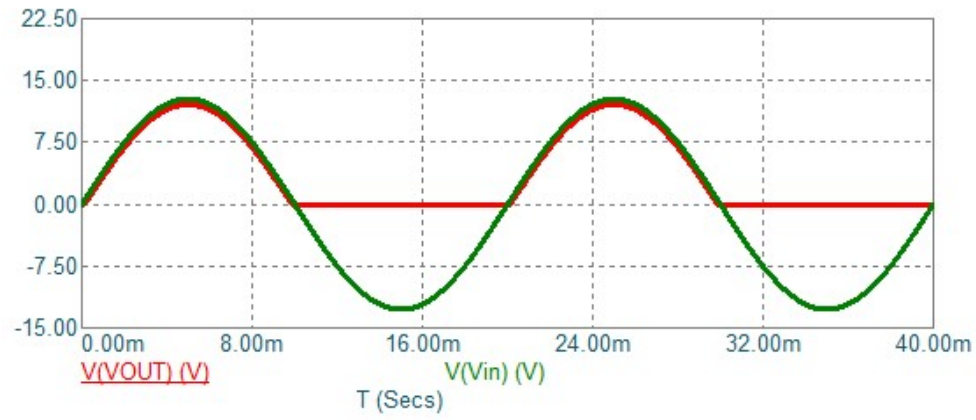
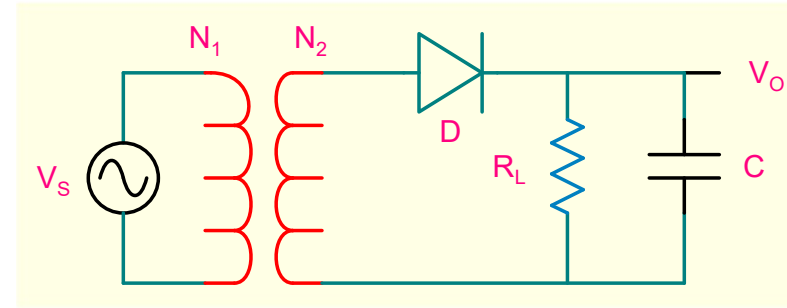
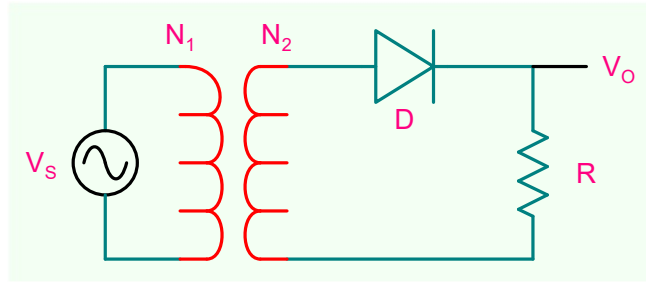
$$\begin{aligned} V_S &= 220V \times \sqrt{2} \\ &= 311.127V \text{ peak value} \end{aligned}$$

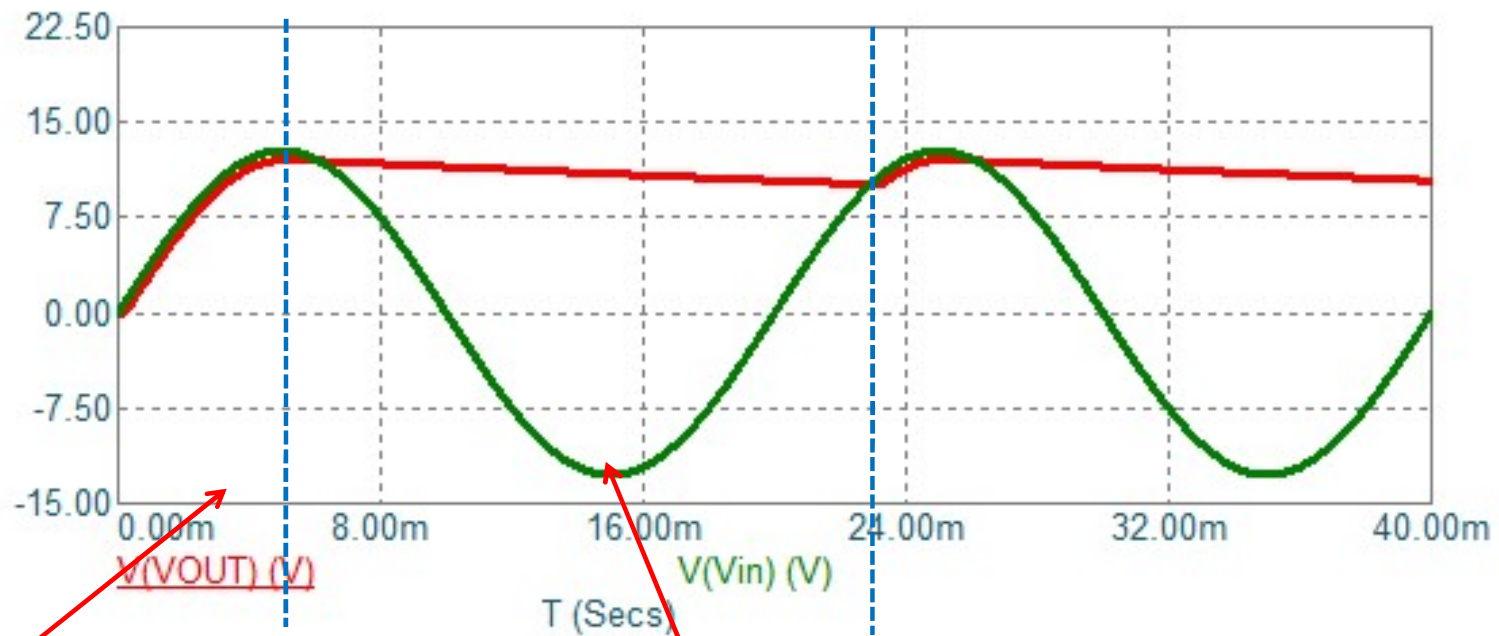
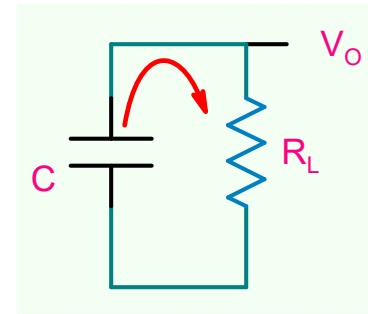
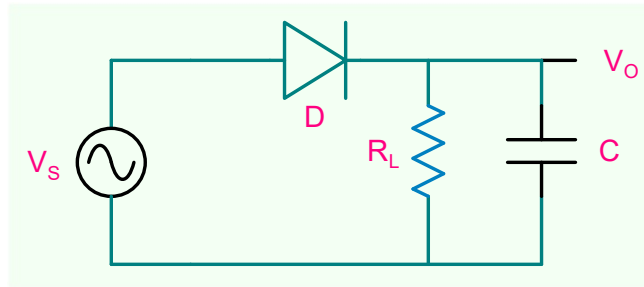
$$\frac{N_1}{N_2} = 24.5$$



Zoomed view







Diode is forward biased

Diode is reverse biased

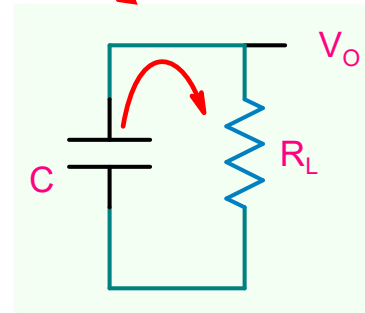
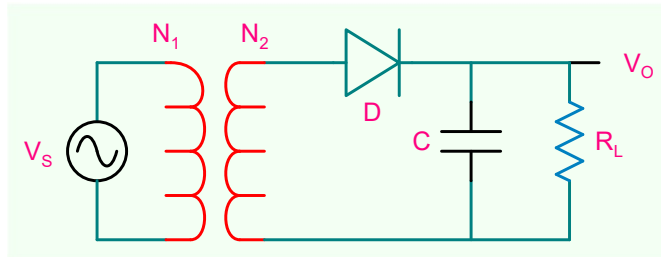
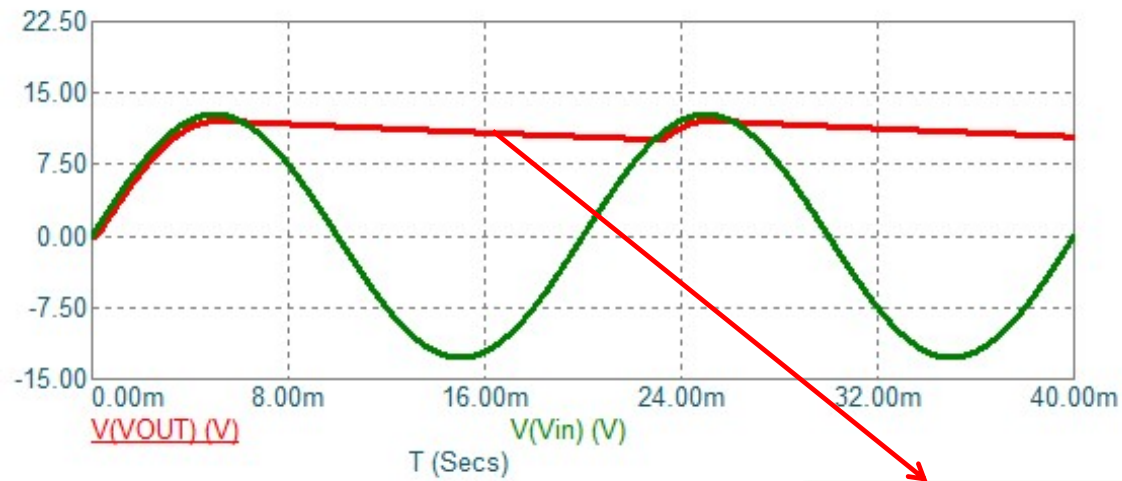
Output has a ripple



Ripple Voltage : $V_r = V_M - V_L$

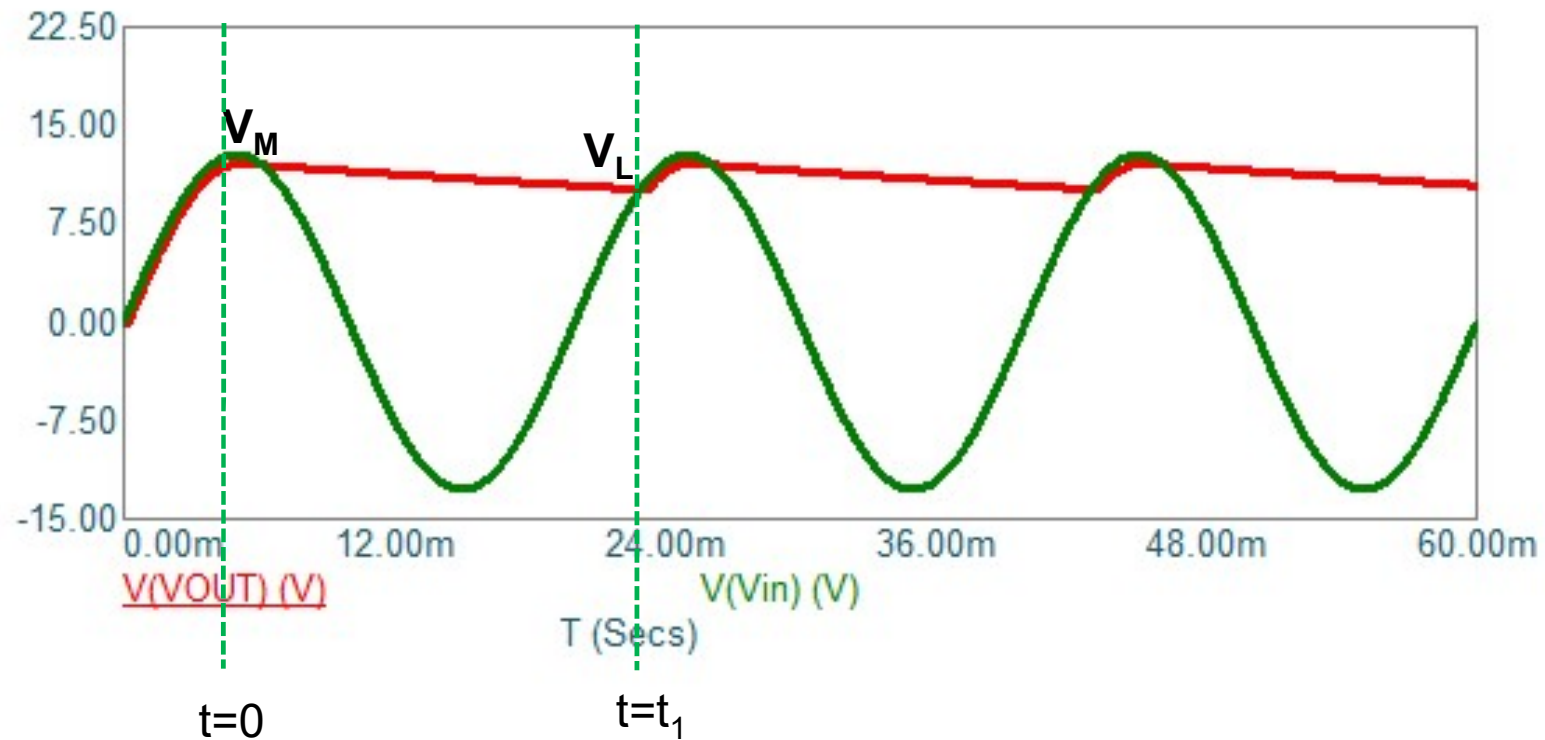
Average Output Voltage : $V_O(avg) \cong V_M - \frac{V_R}{2}$

What does ripple voltage depend on?



$$C \frac{dV_o}{dt} + \frac{V_o}{R_L} = 0 \Rightarrow \frac{dV_o}{dt} = -\frac{V_o}{R_L C}$$

$$V_o(t) = V_M \times e^{-\frac{t}{R_L C}}$$

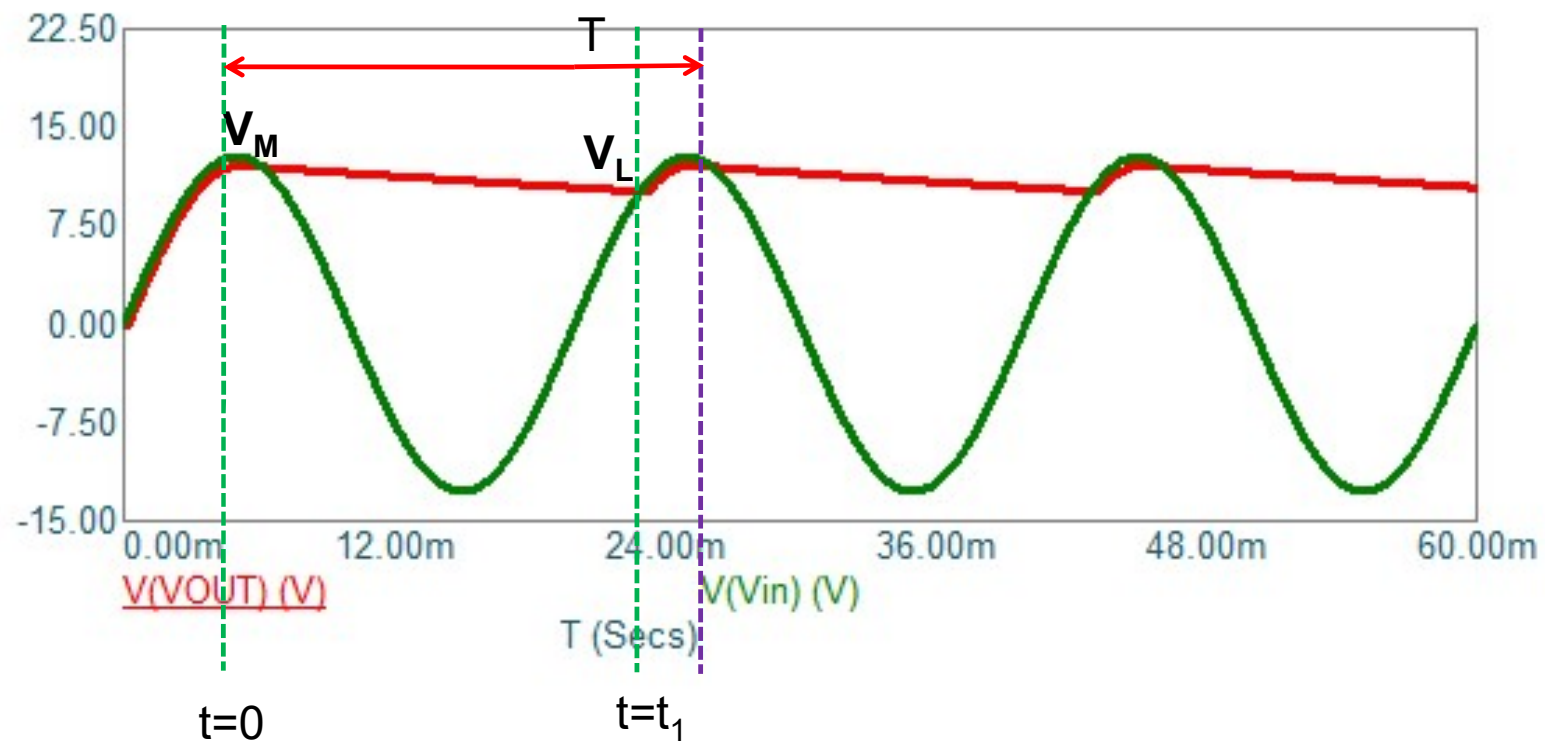


$$V_L = V_M \times e^{-\frac{t_1}{R_L C}}$$

Assuming that $t_1 \ll R_L C$

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

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

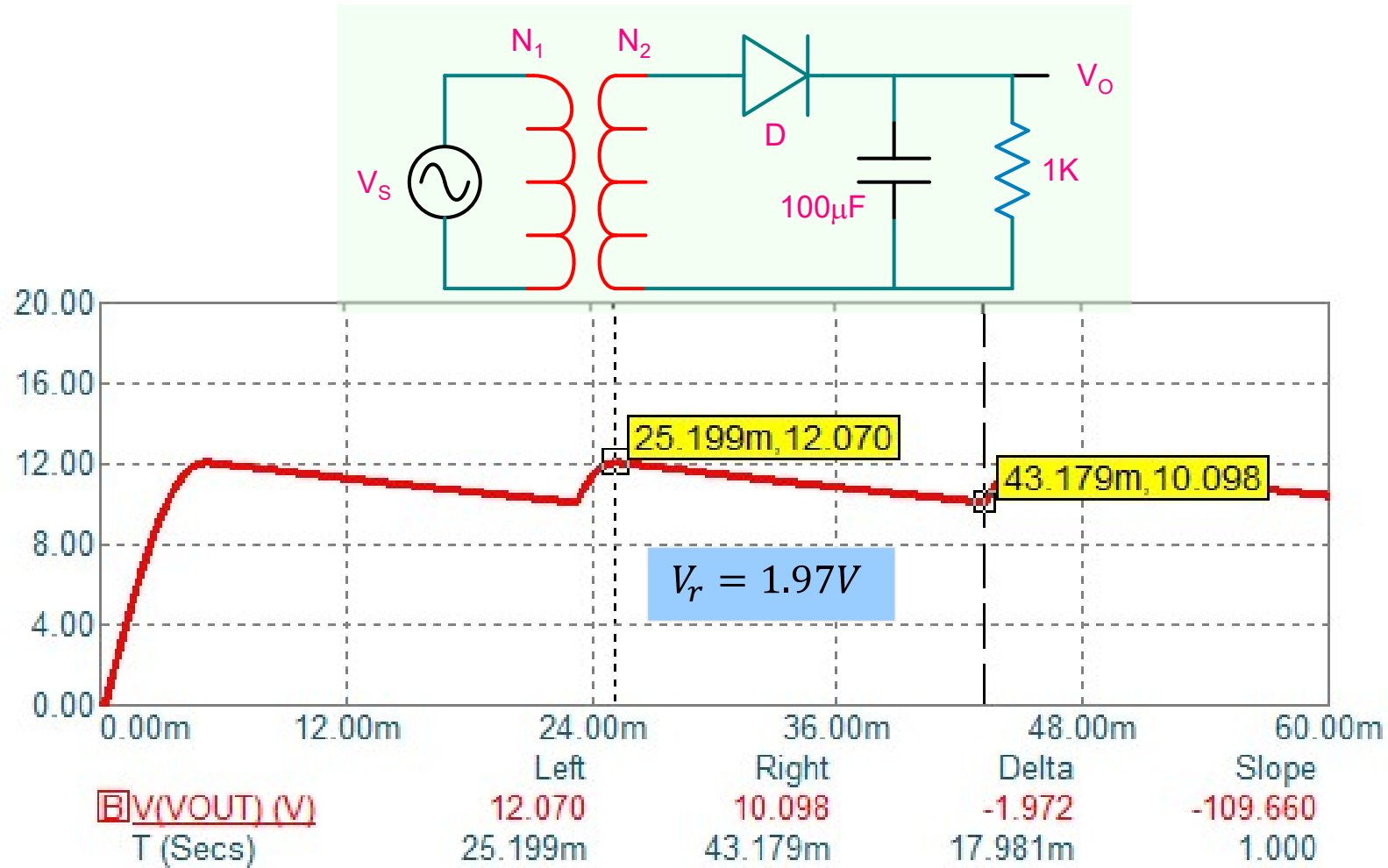


$$t_1 \cong T$$

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

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

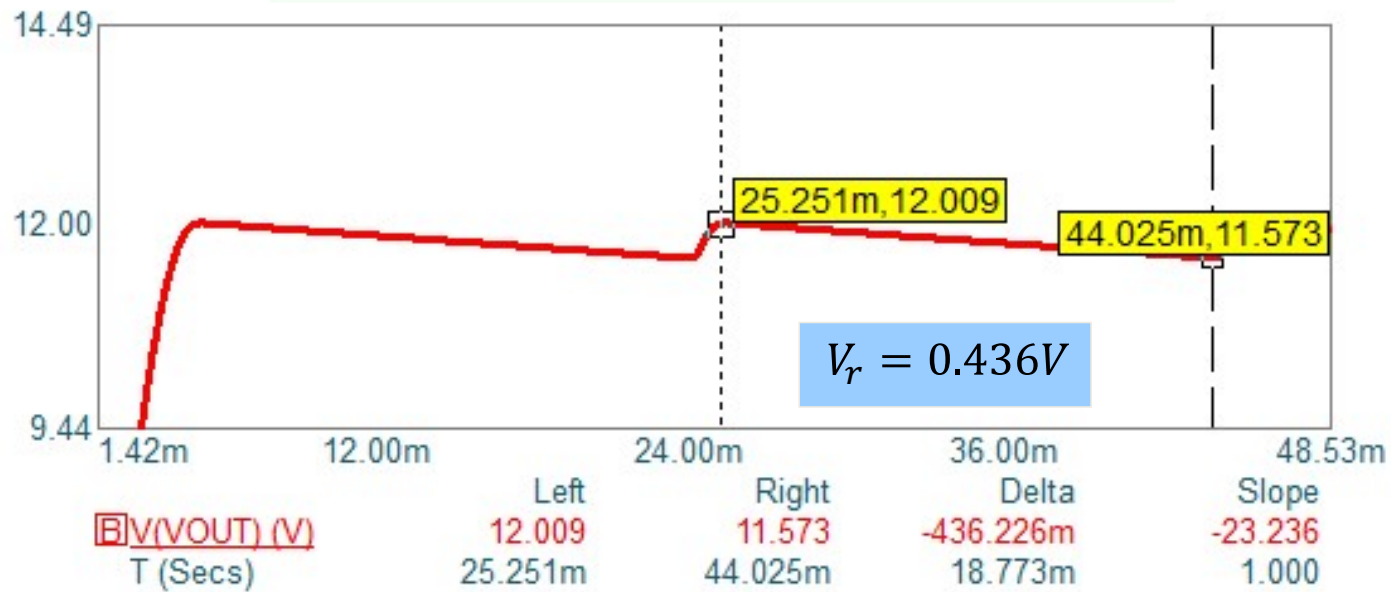
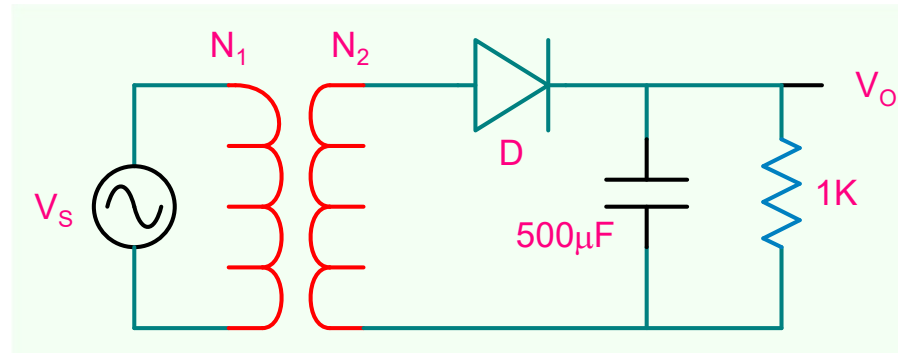
Example



$$V_r \cong \frac{V_M}{f \times R_L C} = \frac{12.070}{50 \times 10^3 \times 100 \times 10^{-6}} = 2.4V$$

$$\frac{R_L C}{T} = 5$$

Example

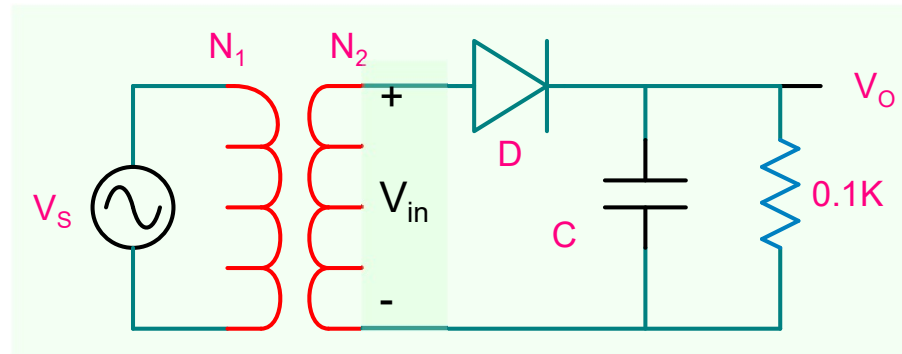


$$V_r \cong \frac{V_M}{f \times R_L C} = \frac{12}{50 \times 10^3 \times 500 \times 10^{-6}} = 0.48V$$

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

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 $\sim 6.7V$

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

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

How do we choose a diode for this application?

Diode Specifications



1N4001/L - 1N4007/L

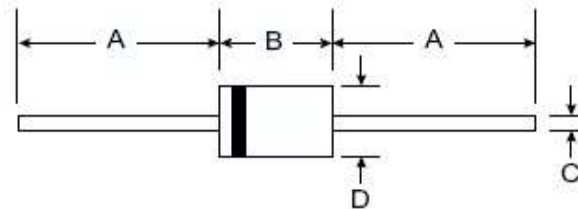
1.0A RECTIFIER

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- Plastic Material: UL Flammability Classification Rating 94V-0

Mechanical Data

- Case: Molded Plastic
- Terminals: Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Weight: DO-41 0.30 grams (approx)
A-405 0.20 grams (approx)
- Mounting Position: Any
- Marking: Type Number



	DO-41 Plastic		A-405	
Dim	Min	Max	Min	Max
A	25.40	—	25.40	—
B	4.06	5.21	4.10	5.20
C	0.71	0.864	0.53	0.64
D	2.00	2.72	2.00	2.70
All Dimensions in mm				

"L" Suffix Designates A-405 Package
No Suffix Designates DO-41 Package

Maximum Ratings and Electrical Characteristics @ $T_A = 25^\circ\text{C}$ unless otherwise specified

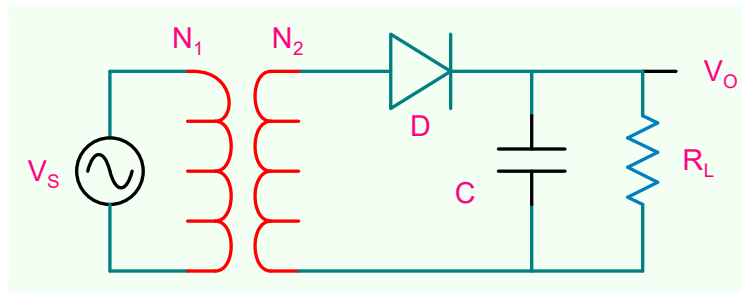
Single phase, half wave, 60Hz, resistive or inductive load.

For capacitive load, derate current by 20%.

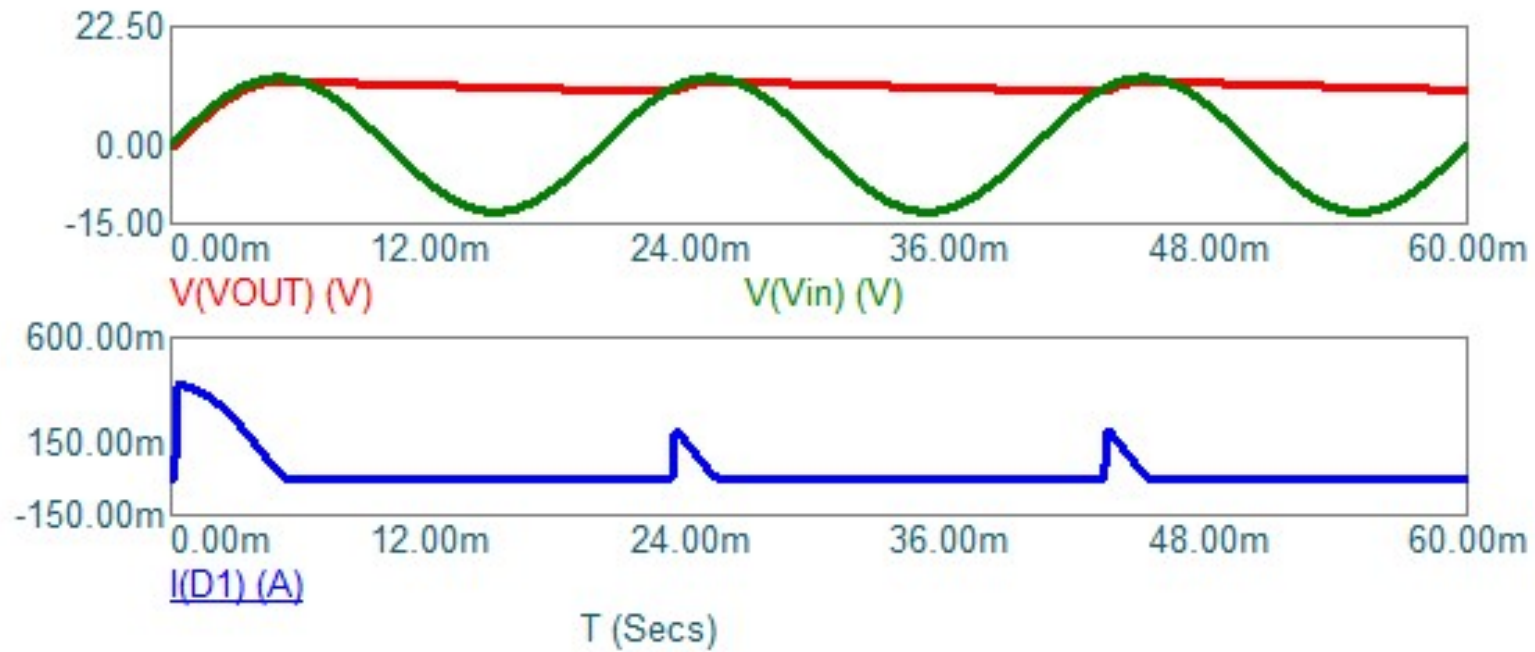
Characteristic	Symbol	1N 4001/L	1N 4002/L	1N 4003/L	1N 4004/L	1N 4005/L	1N 4006/L	1N 4007/L	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ $T_A = 75^{\circ}\text{C}$	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load (JEDEC Method)	I_{FSM}	30							A
Forward Voltage @ $I_F = 1.0\text{A}$	V_{FM}	1.0							V
Peak Reverse Current @ $T_A = 25^{\circ}\text{C}$ at Rated DC Blocking Voltage @ $T_A = 100^{\circ}\text{C}$	I_{RM}	5.0 50							μA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							$^{\circ}\text{C}$
Operating and Storage Temperature Range (Note 3)	T_j, T_{STG}	-65 to +175							$^{\circ}\text{C}$

- Notes:
1. Leads maintained at ambient temperature at a distance of 9.5mm from the case.
 2. Measured at 1. MHz and applied reverse voltage of 4.0V DC.
 3. JEDEC Value.

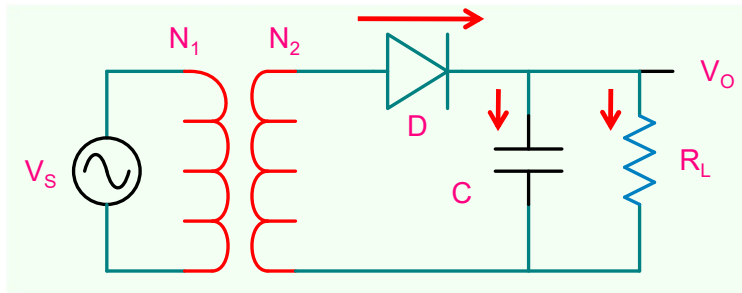
How do we choose a diode for this application?



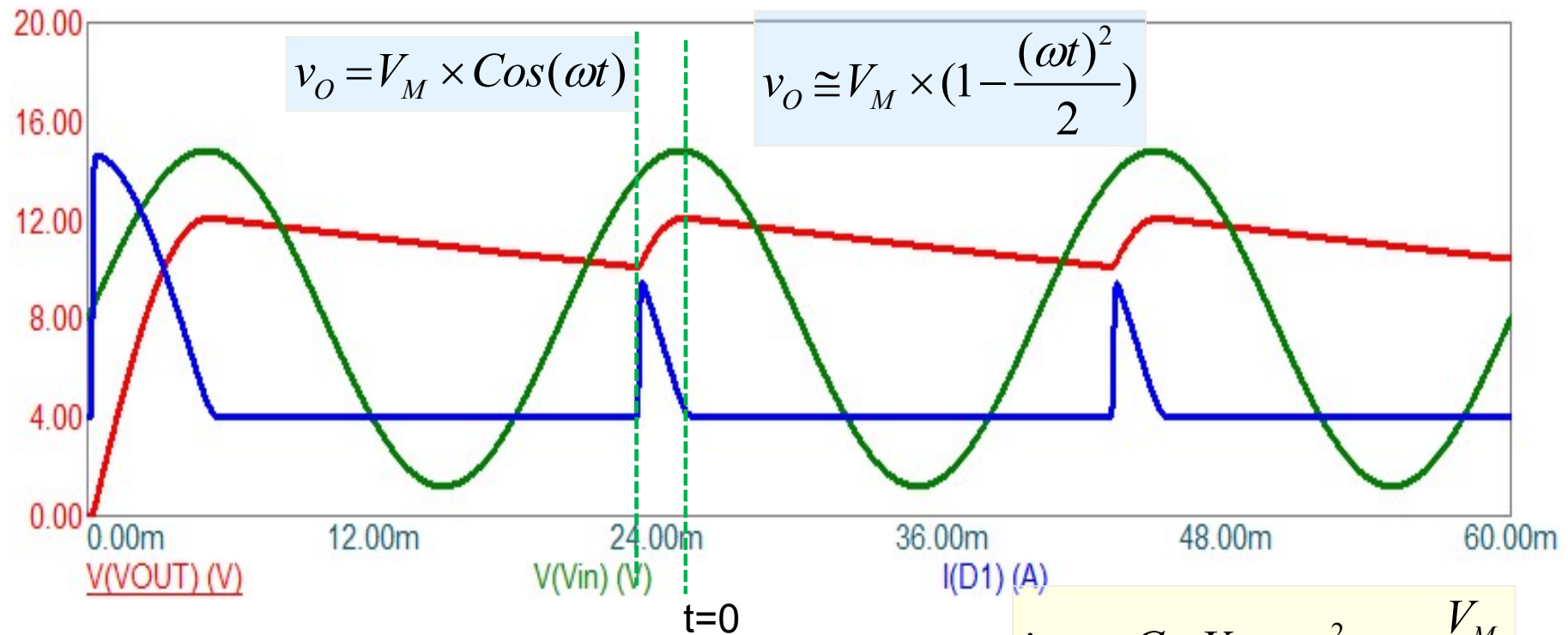
Determine peak and average diode currents; peak inverse voltage



Diode forward bias current



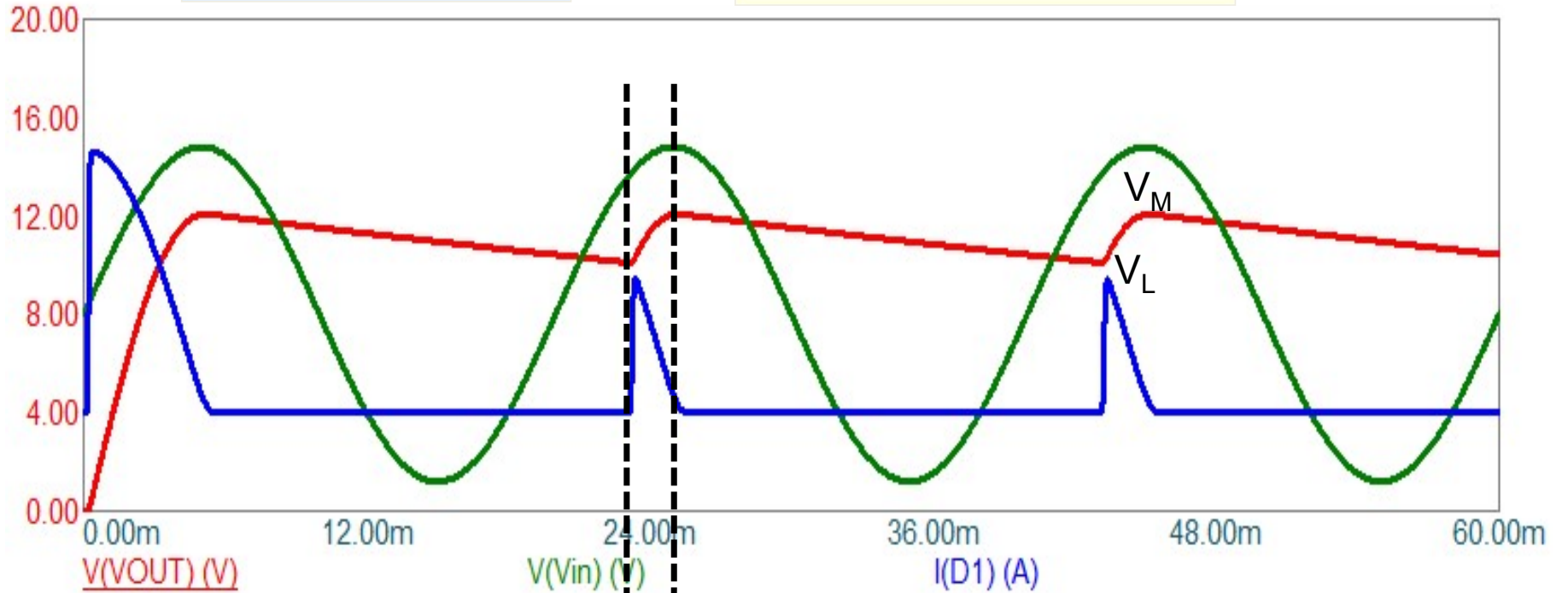
$$i_D = C \times \frac{dv_o}{dt} + \frac{v_o}{R_L}$$



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

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

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



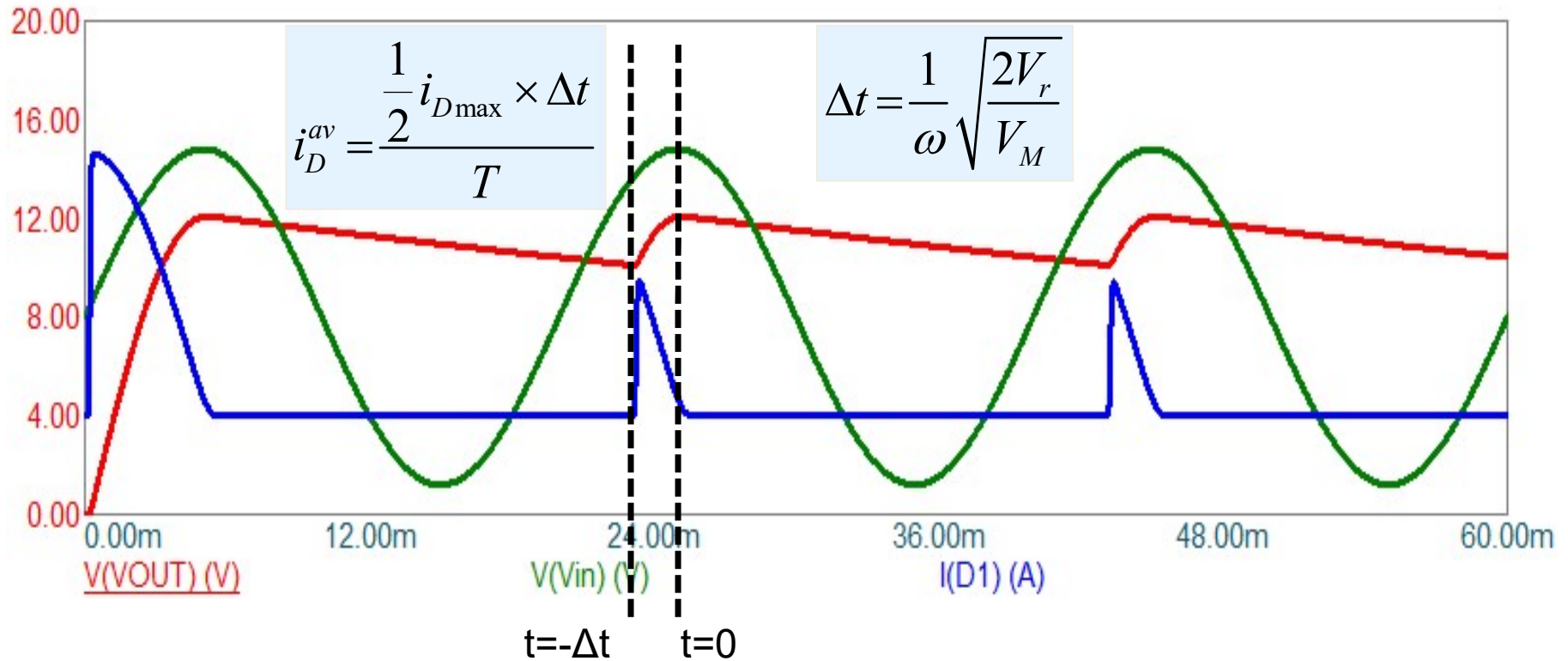
$$i_{D_{\max}} \cong C \times V_M \times \omega^2 \times \Delta t + \frac{V_M}{R_L} \quad t = -\Delta t \quad t = 0$$

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

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

Peak and Average Diode Currents

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



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

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

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

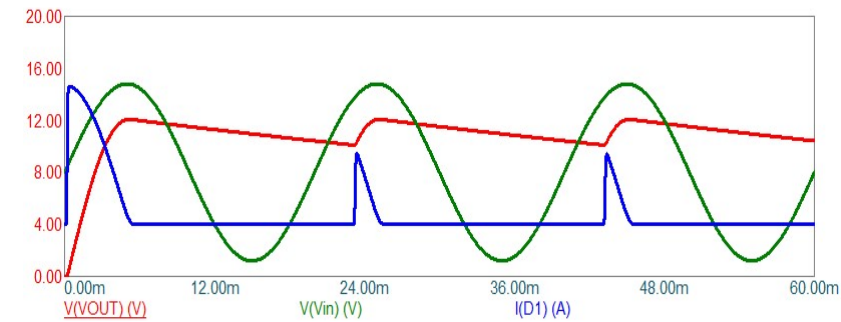
$$V_r \cong \frac{V_M}{fR_L C}$$

$$i_{Davg.} \cong \frac{V_M}{R_L}$$

$$i_{D\max} \cong 2\pi \times \sqrt{2f \times C \times V_M \times i_{Davg.}} + i_{Davg.}$$

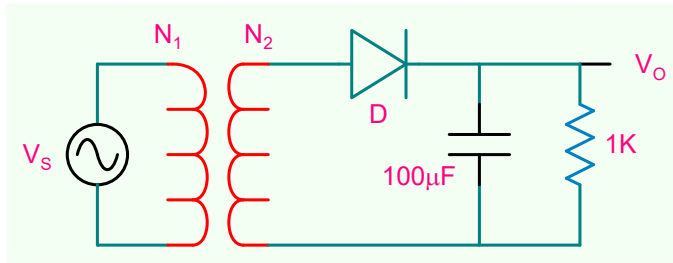
$$i_{D\max} \cong 2\pi \times \sqrt{2f \times C \times V_M \times i_{Davg.}}$$

$$\left(\frac{i_{Dmax}}{i_{Davg}} \right) \times \sqrt{\frac{V_r}{V_M}} = 2\sqrt{2}\pi$$



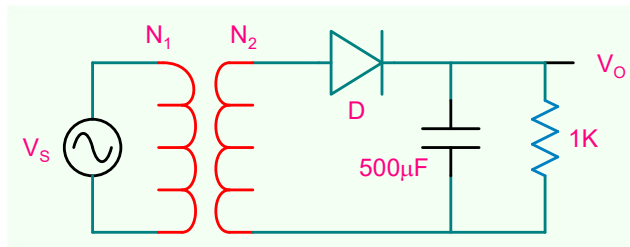
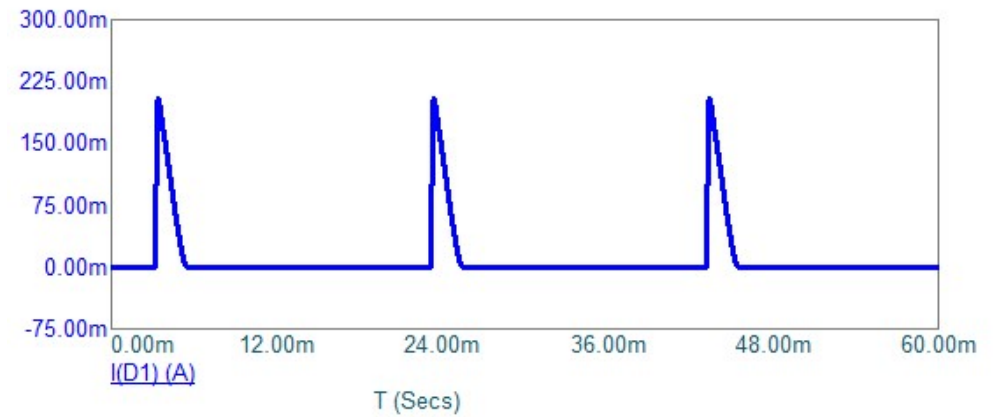
One can see a tradeoff between ripple voltage and peak diode current

Peak and Average Diode Currents



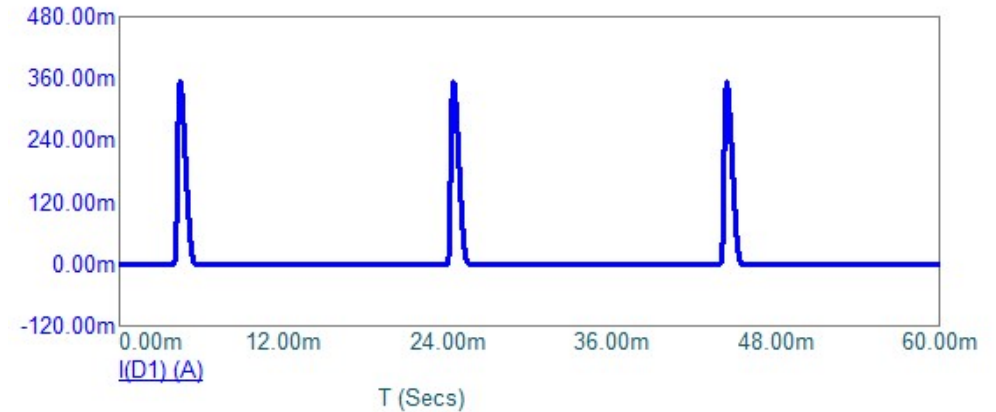
$$V_r = 1.95V$$

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



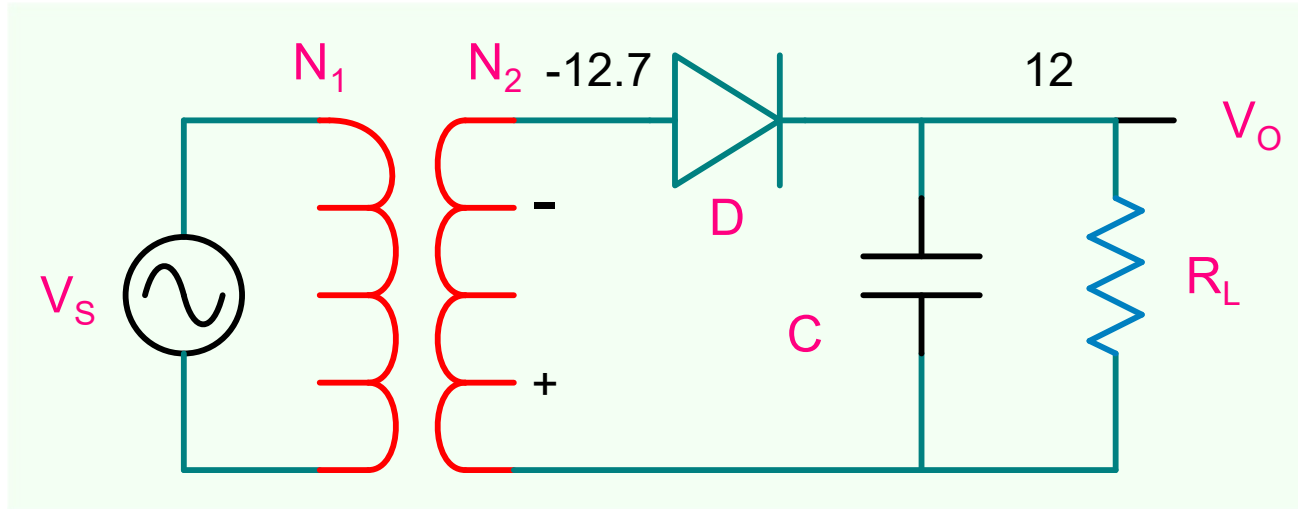
$$V_r = 0.438V$$

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



Peak diode current increases as ripple reduces

Peak Inverse Voltage

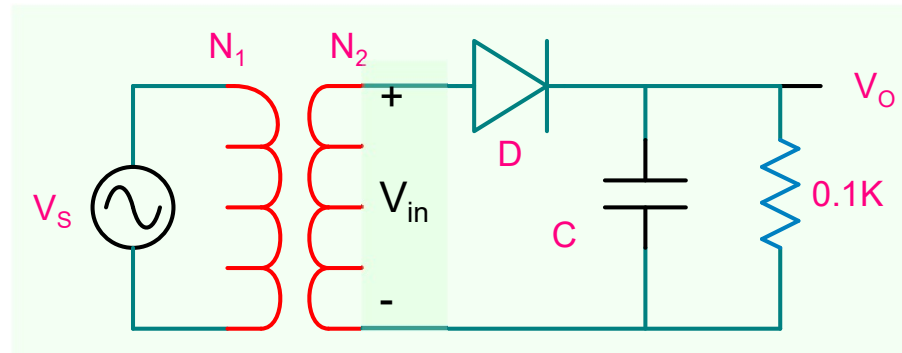


$$12 + 12.7 = 24.7\text{V}$$

$$PIV \cong 2v_o + 0.7$$

Design Example

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



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

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?

$$i_{Dmax} \approx \omega C \times \sqrt{2V_r \times V_M} + \frac{V_M}{R_L} = 344A$$

$$i_D^{av} \cong \frac{V_M}{R_L} = 60mA$$

$$PIV \cong 2v_O + 0.7 = 12.7V$$