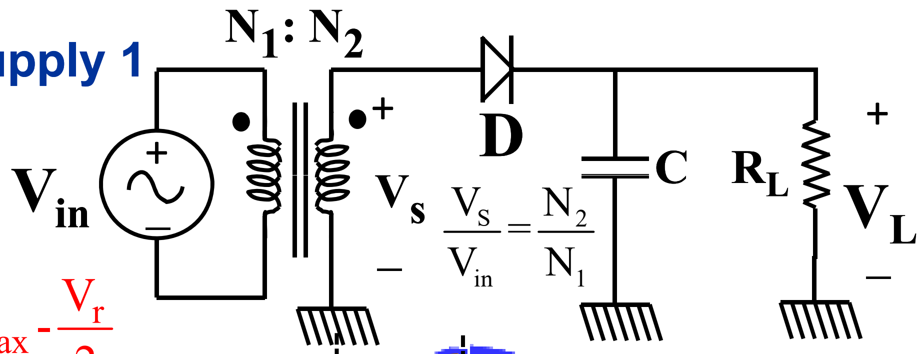
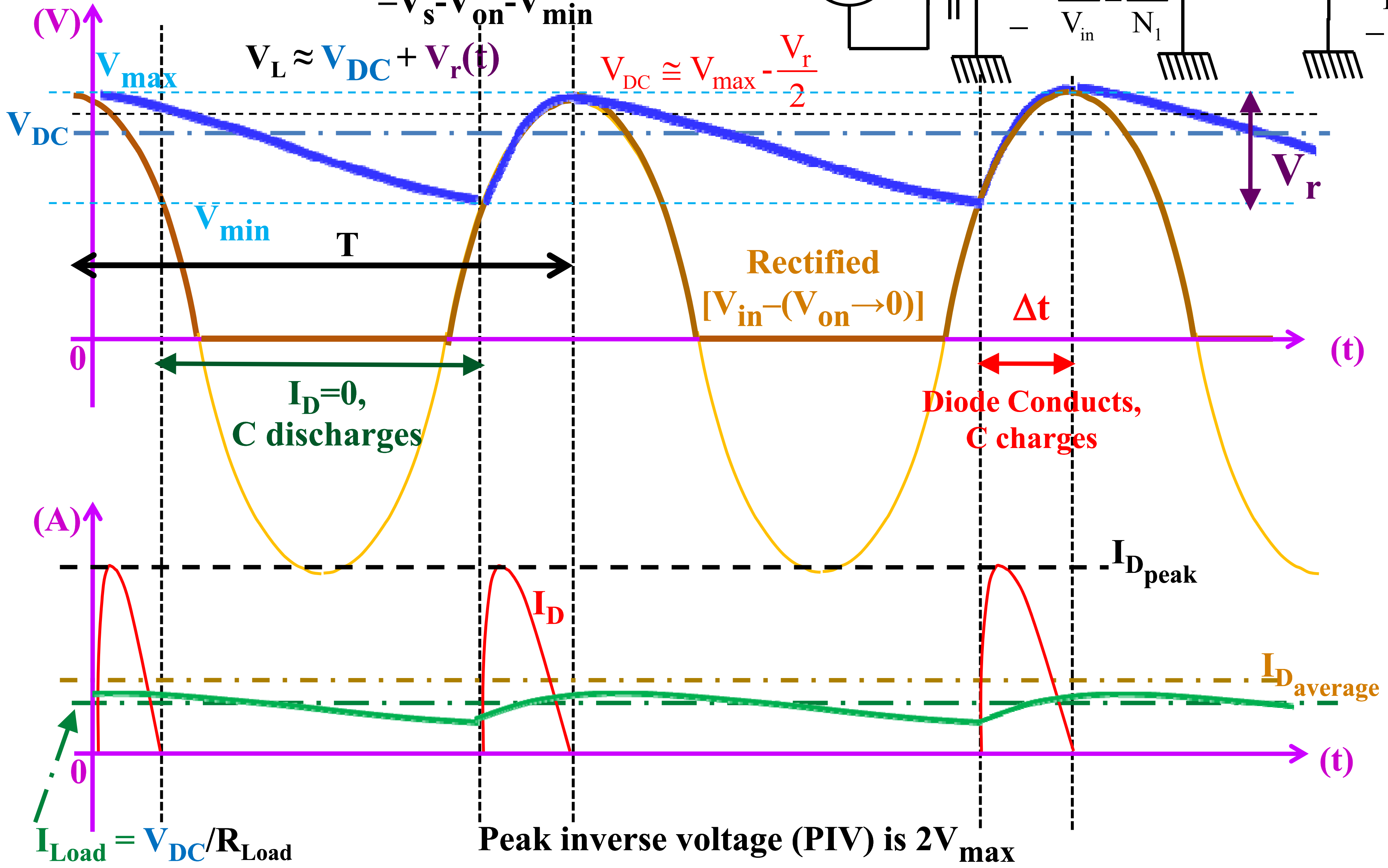
ESc201, Lecture 15: Unregulated Power Supply 1

Half Wave Rectifier

Ripple Voltage : $V_r = V_{max} - V_{min}$
$= V_s - V_{on} - V_{min}$





Peak inverse voltage (PIV) is $2V_{max}$

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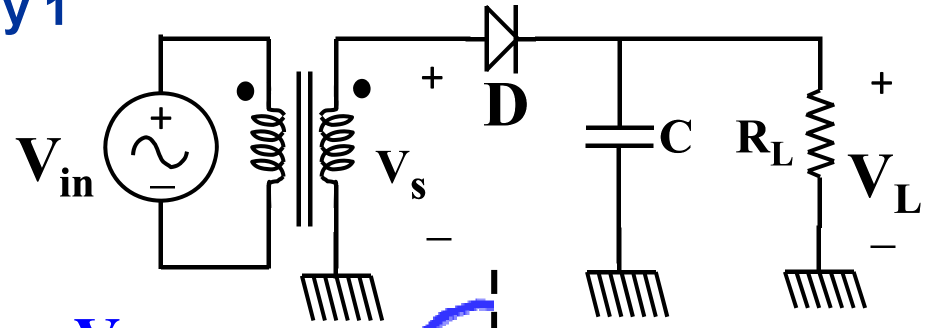
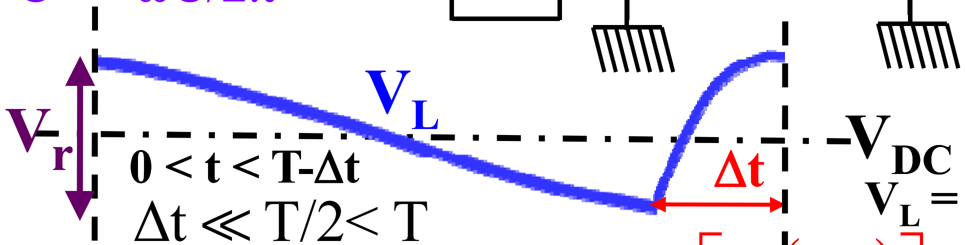
220V rms V→ 311.13 Peak V



$$V_{DC} \cong V_{max} - \frac{V_r}{2}$$

$$CV_r = I_L(T-\Delta t) \cong I_L T \quad \text{or } V_r = \frac{I_L T}{C} = \frac{I_L}{\omega C/2\pi}$$

For very small V_r, $V_{DC} \cong V_{max}$



$$V_L = V_{DC} + V_r(t)$$

$$v_C(t) = v_C(\infty) + \{v_C(0^+) - v_C(\infty)\}\, e^{-\frac{t}{RC}}$$

$$V_{min} = V_{max} - V_r = V_{max} e^{[-(T-\Delta t)/\tau]}$$

$$\cong V_{max} e^{[-T/\tau]} \cong V_{max}[1-T/\tau]$$

$$T/\tau \ll 1, \quad e^{-T/\tau} \cong [1-T/\tau]$$

$$V_{max}\cos[\omega(\Delta t)] = V_{max} - V_r$$

For small θ, $\cos(\theta) \simeq 1 - \theta^2/2$

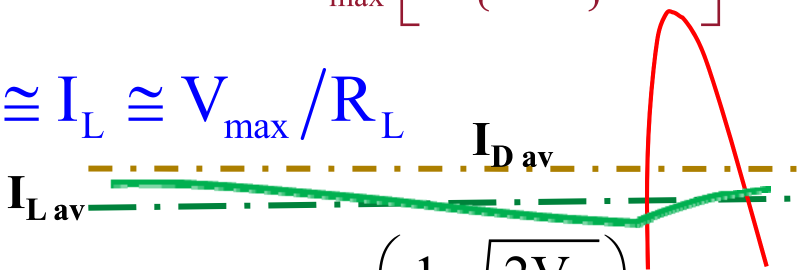
$$C = \frac{(V_{max} - V_{on})}{V_r}\frac{T}{R_L}$$

$$V_{max}\left[1 - \{\omega\Delta t\}^2/2\right] \simeq V_{max} - V_r$$

$$V_r = V_{max}\frac{T}{\tau} = V_{max}\frac{T}{R_L C}$$

$$\Delta t \simeq \frac{1}{\omega}\sqrt{\frac{2V_r}{V_{max}}}$$

$$I_{C,\,av} = I_{D,\,av} - I_{L,\,av} \qquad I_{L,\,av} \cong I_L \cong V_{max}/R_L$$



Charge conservation gives

Gained **Lost**

$$I_{C,\,av}\Delta t = (I_{D,\,av} - I_L)\Delta t = CV_r$$

$$\text{Or} \quad (I_{D,\,av} - I_L)\left(\frac{1}{\omega}\sqrt{\frac{2V_r}{V_{max}}}\right) = I_L T = \frac{I_L}{\omega/2\pi} = \frac{2\pi I_L}{\omega}$$

KCL at the output node at t = - Δt

$$I_{D,\,av} = I_L\left[1 + \pi\sqrt{\frac{V_{max}}{2V_r}}\right]$$

$$I_{D,\,max} = C\left.\frac{dV_S}{dt}\right|_{t=-\Delta t} + I_L = -C\omega V_{max}\sin(-\Delta t\omega) + I_L \cong C\omega V_{max}\Delta t\omega + I_L$$

$$V_S = V_{max}\cos[\omega t]$$

$$I_{D,\,max} = I_L\left[1 + 2\pi\sqrt{\frac{2V_{max}}{V_r}}\right] = I_L\left[1 + 2\pi\sqrt{2fCR_L}\right]$$

$$V_r \frac{I_L}{fC} \quad I_L \cong \frac{V_{max}}{R_L}$$

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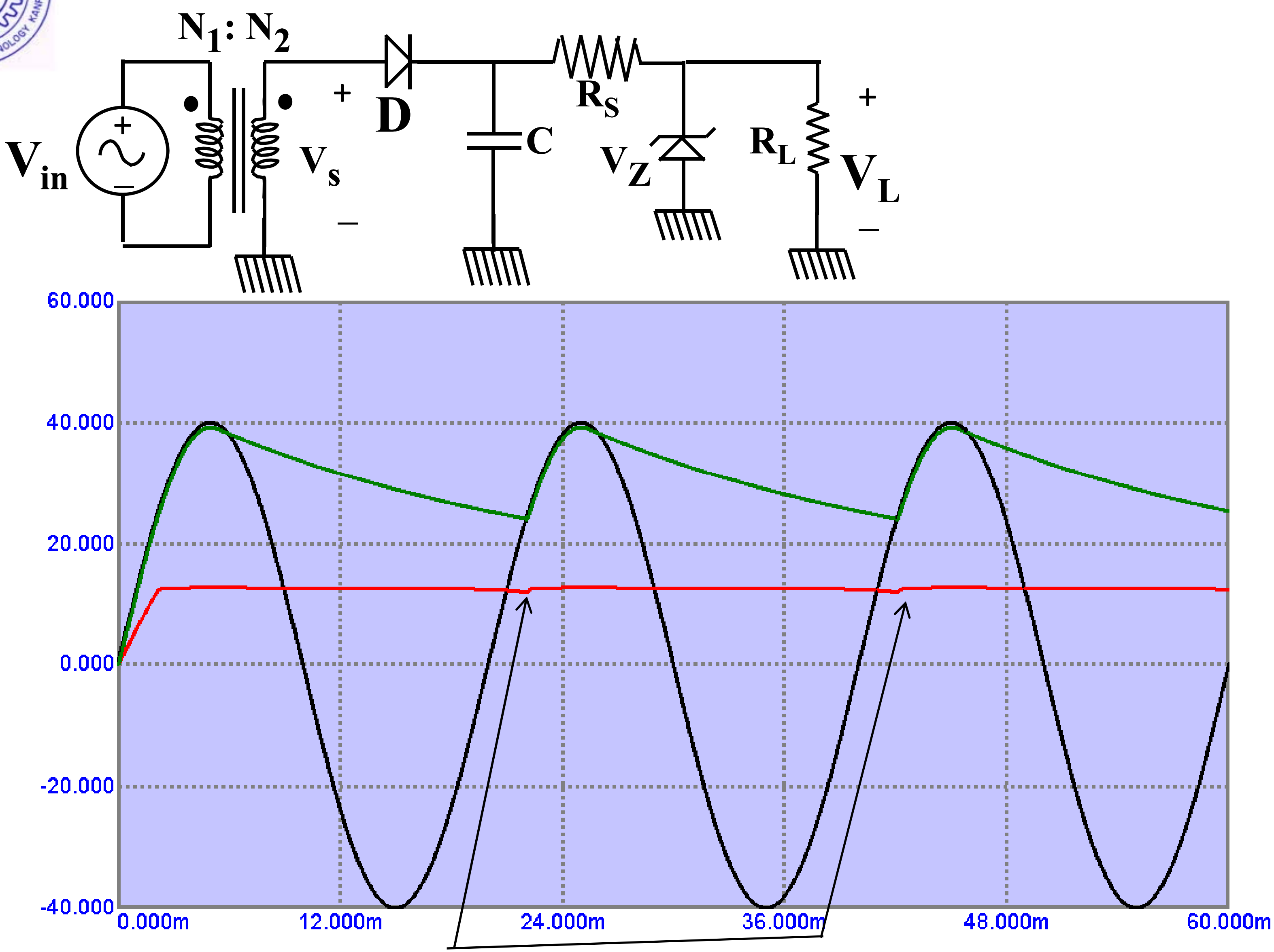

Still some ripple due to finite resistance of the Zener is observed.

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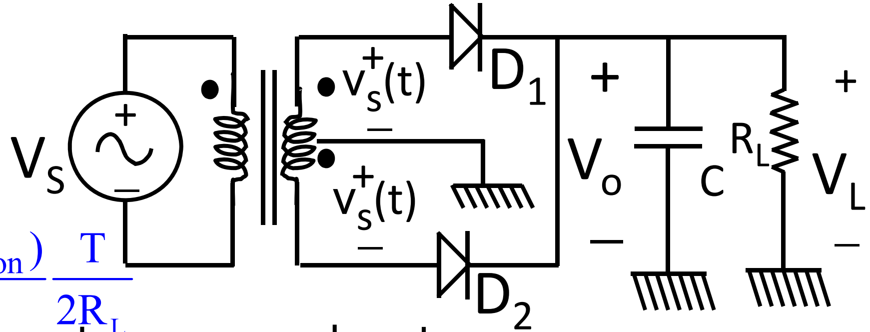
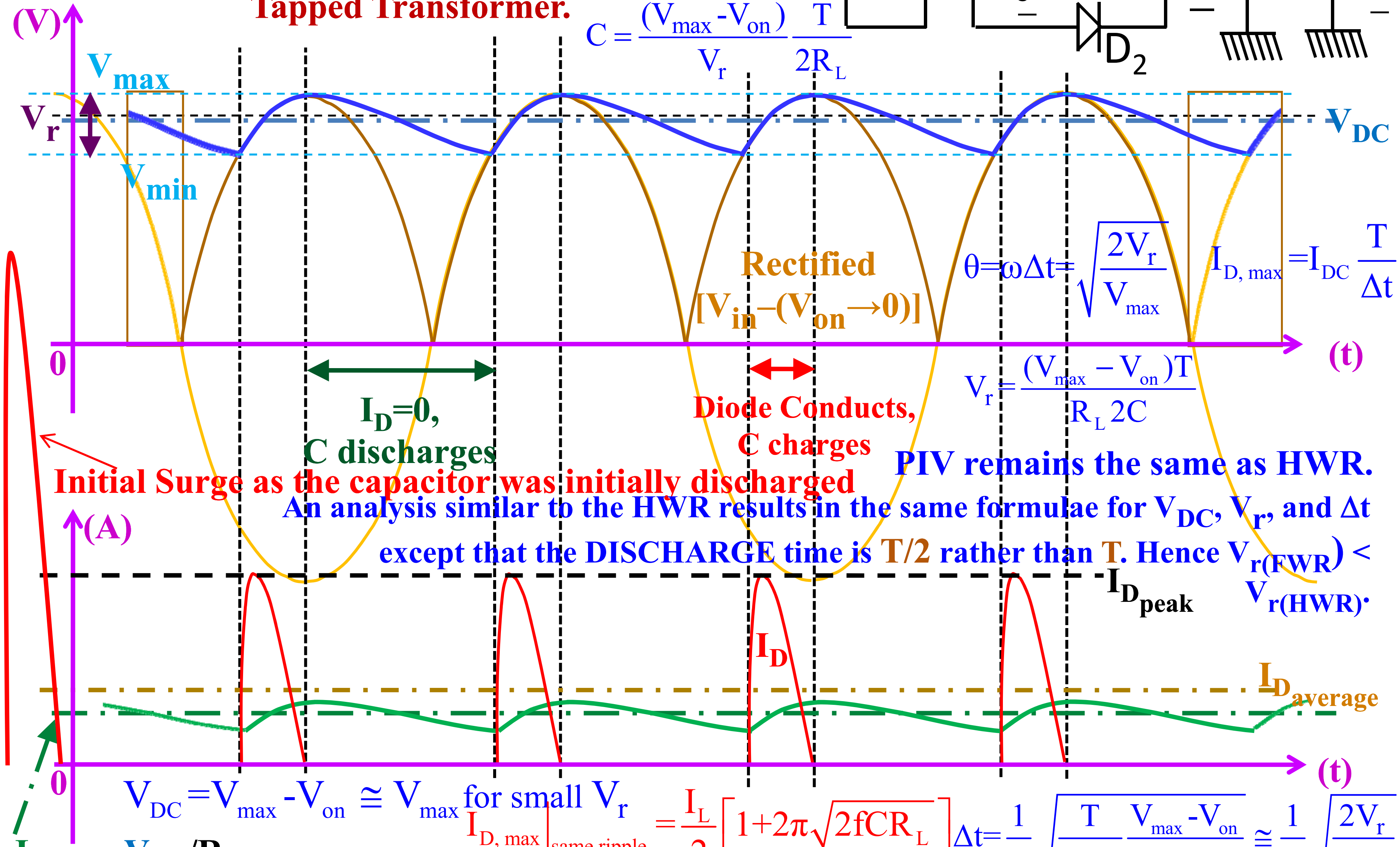
DC Unregulated Power Supply

Full Wave Rectifier using a Center Tapped Transformer.



$$C = \frac{(V_{max} - V_{on})}{V_r}\frac{T}{2R_L}$$



$$\theta = \omega\Delta t = \sqrt{\frac{2V_r}{V_{max}}}$$

$$I_{D,\,max} = I_{DC}\frac{T}{\Delta t}$$

$$V_r = \frac{(V_{max} - V_{on})T}{R_L\,2C}$$

PIV remains the same as HWR.

An analysis similar to the HWR results in the same formulae for V_{DC}, V_r, and Δt except that the DISCHARGE time is T/2 rather than T. Hence $V_{r(FWR)} < V_{r(HWR)}$.

$$V_{DC} = V_{max} - V_{on} \cong V_{max} \text{ for small } V_r$$

$$I_{Load} = V_{DC}/R_{Load}$$

PIV=2V_{max}.

$$I_{D,\,max}\Big|_{same\ ripple} = \frac{I_L}{2}\left[1+2\pi\sqrt{2fCR_L}\right]$$

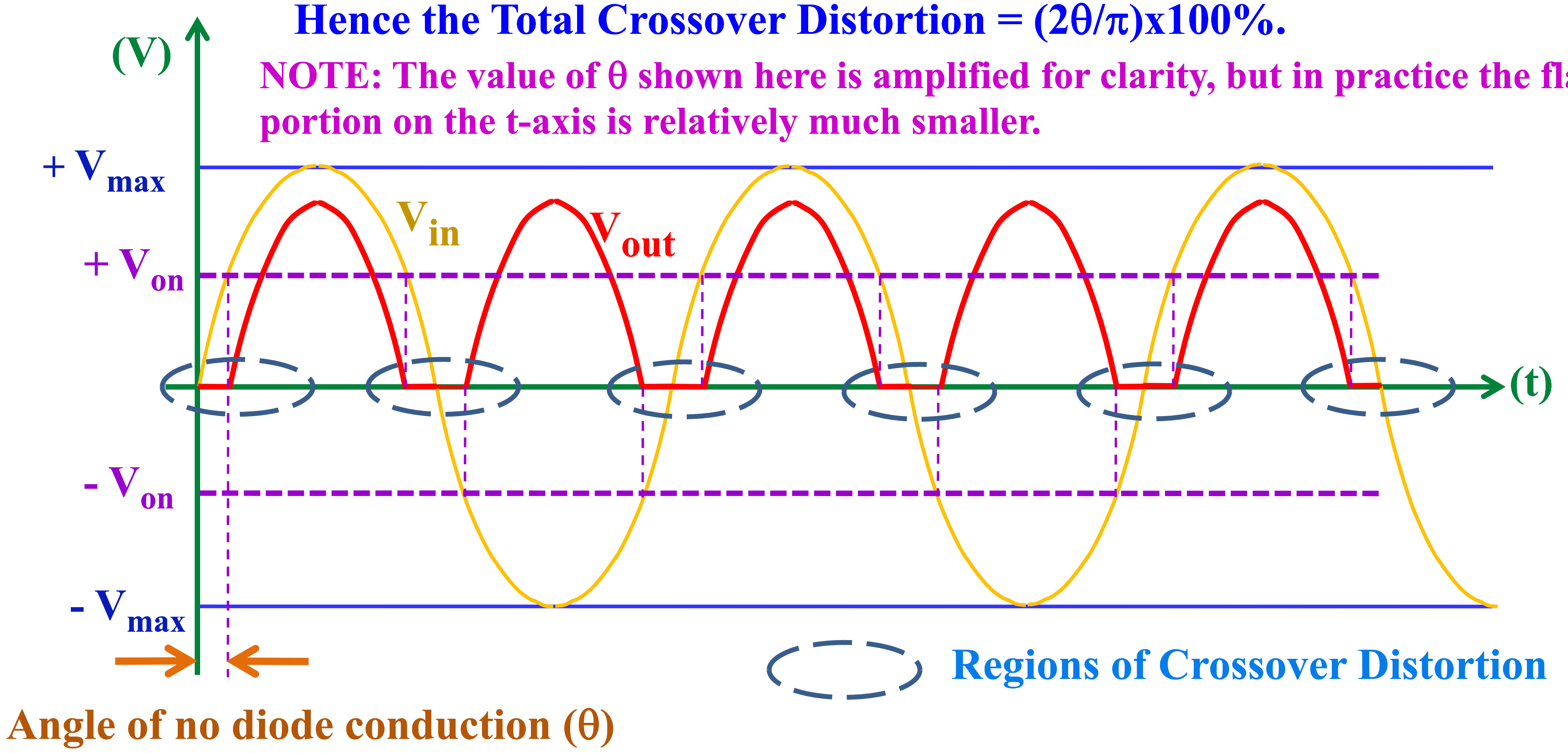
$$\Delta t = \frac{1}{\omega}\sqrt{\frac{T}{R_L C}\,\frac{V_{max}-V_{on}}{V_{max}}} \cong \frac{1}{\omega}\sqrt{\frac{2V_r}{V_{max}}}$$

Crossover Distortion : For diodes, generally $V_{on} \neq 0$, even if r_F=0 is assumed, and cannot conduct until $V_{in}=V_D \geq V_{on}$. This creates a dead-band of around $2V_{on}$ at all the crossover points (i.e., points where the input signal crosses zero in the time axis). This problem becomes more acute if V_{max} is not much larger than V_{on} and for $V_{max} \sim V_{on}$, the entire signal is mixed up.

$\theta = \sin^{-1}(V_{on}/V_{max})$= Angle of Crossover Distortion, appears 4 times in a complete cycle.

Hence the Total Crossover Distortion = $(2\theta/\pi)$x100%.

NOTE: The value of θ shown here is amplified for clarity, but in practice the flat portion on the t-axis is relatively much smaller.



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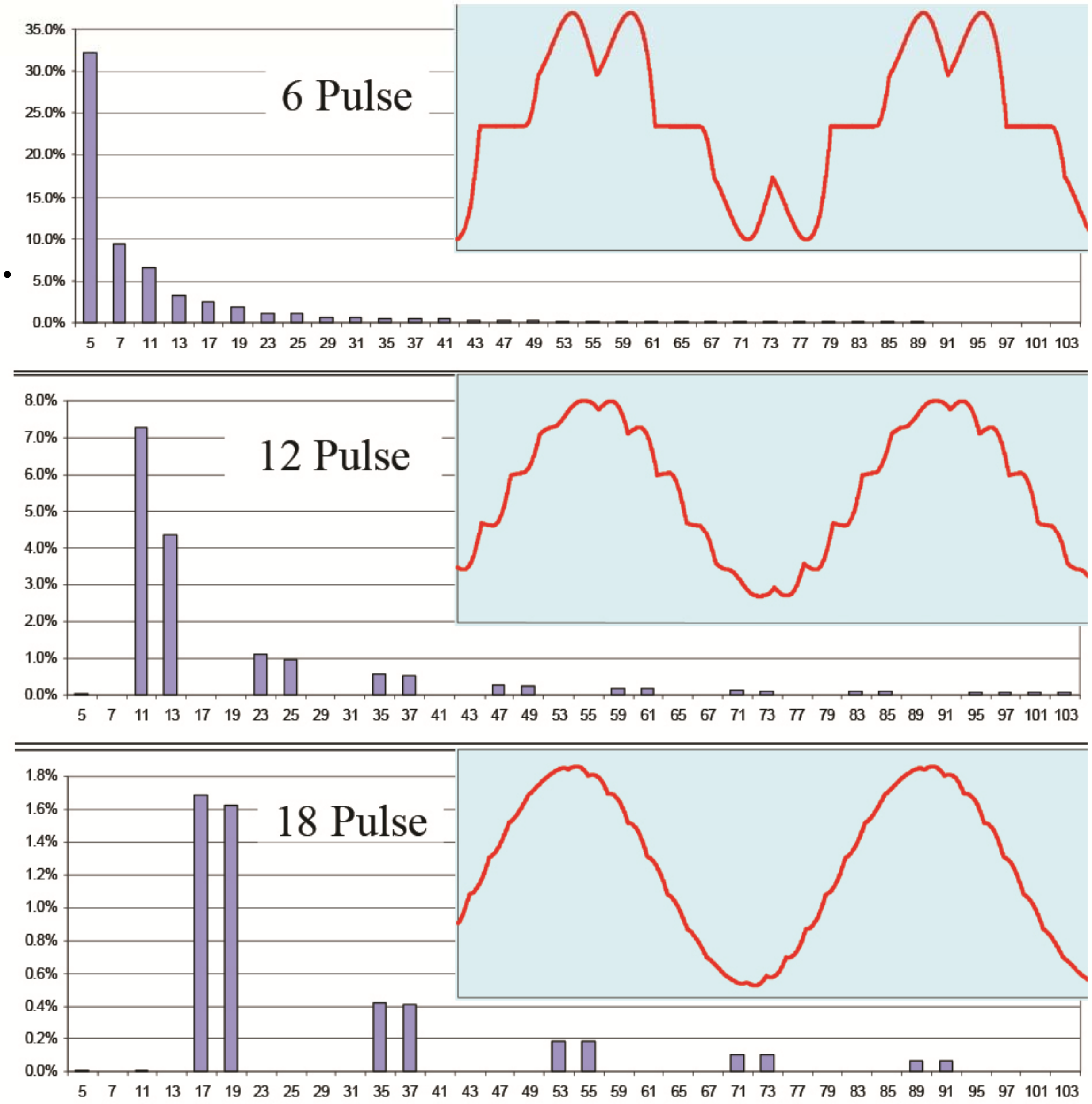
h = P.n ± 1

where:

n = an integer (1, 2, 3, 4… ∞).

h = harmonic order.

P = the number of pulses of the rectifier.



characteristic harmonics

There are some residual non-characteristic harmonics such as the 5th and 7th in 12 and 18-pulse topologies due to the non-ideal behaviour of the transformer causing angle phase errors