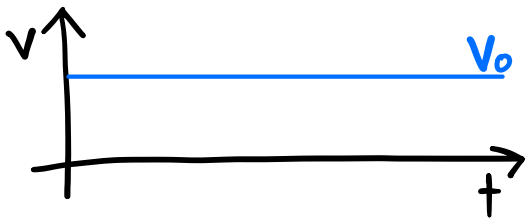
Power Electronics Fundamentals:

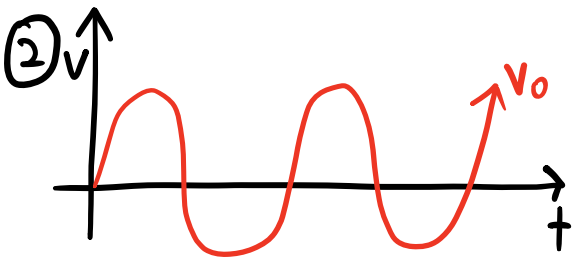
- Source Generates power
- Power Electronics (Delivers power Source - Load)
- Load Consumes power

Power Converters:

① DC Power



Ex: Charger (Laptop)

② 

Ex: Wall outlet

Convert between these two types of power depending on what source/load needs

TYPES:

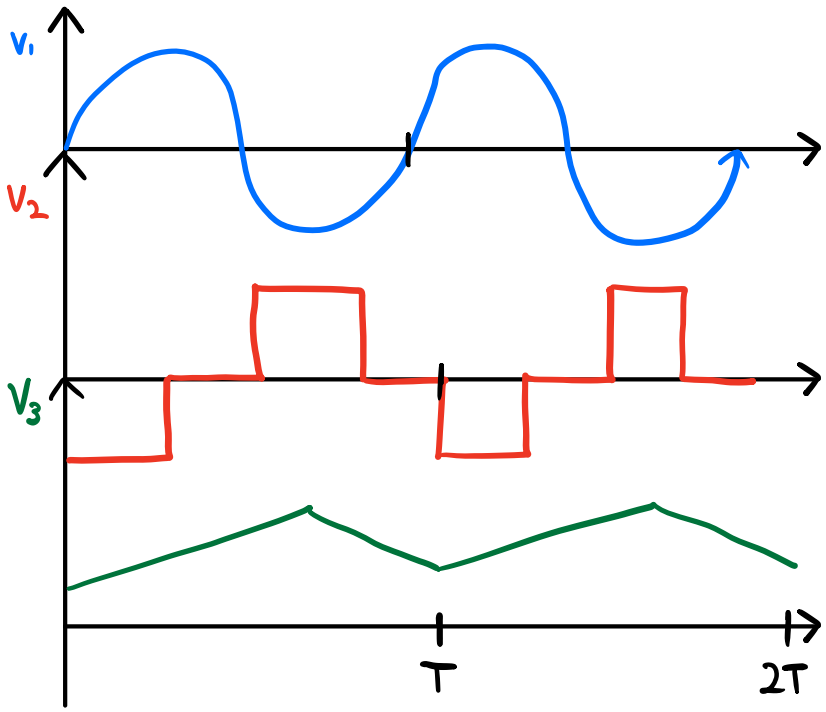
① AC - DC → "Reetifier"
source - load

② DC - DC → "Switch Mode"
Change Voltage level

③ DC - AC → "Inverter"

④ AC - AC
Exists, uncommon

Periodic Waveform (it repeats):



Average: (Mean)

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt$$

Notation:

$\langle v(t) \rangle = V_{avg}$

$V = v(t)_{RMS}$

Root Mean Square (RMS):

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\,dt}$$

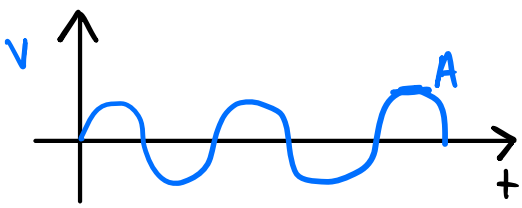
- Power seen over a resistor

$$\langle P \rangle = \left\langle \frac{v(t)^2}{R} \right\rangle = \frac{V_{rms}^2}{R}$$

$\langle v(t)^2 \rangle = V_{RMS}^2$ TRUE

$\langle v(t) \rangle^2 = V_{RMS}^2$ NOT TRUE

Sine Wave:



Average = 0

$$RMS = \frac{A}{\sqrt{2}}$$

$$v(t) = A\sin\left(\frac{2\pi t}{T}\right)$$

*$A = V_{peak}$

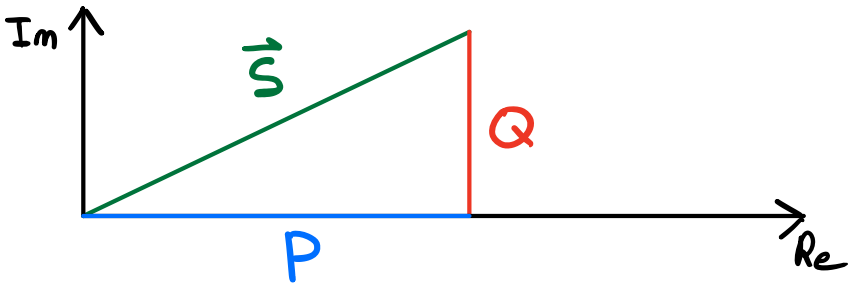
Types of Power:

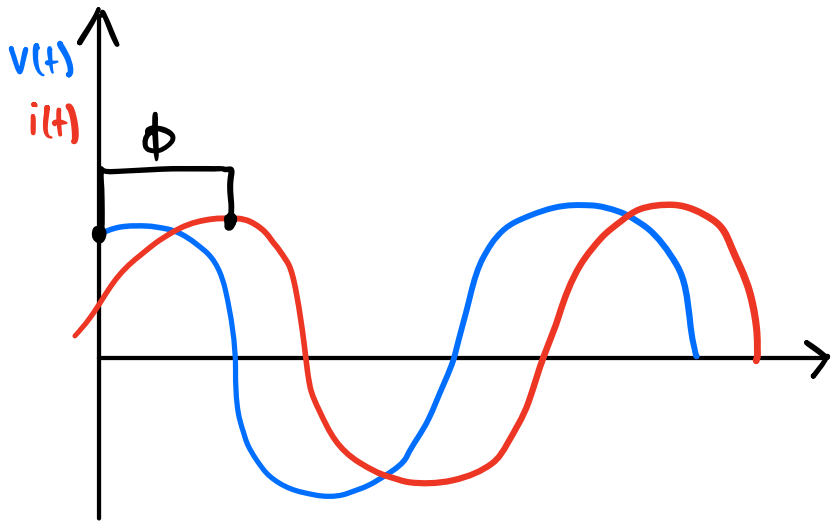
Real Power
P
(Watts)

Reactive Power
Q
Volt·Amp·Reactive

Apparent Power (Vector)
S
Volt·Amps

Power Triangle:





$$V(t) = \sqrt{2}\, V_{RMS} \cos(\omega t)$$

$$i(t) = \sqrt{2}\, I_{RMS} \cos(\omega t - \phi)$$

$$\phi = \phi_v - \phi_i$$

Instantaneous Power:

$$P(t) = V(t)\, i(t)$$

$$= \underbrace{V_{RMS} I_{RMS} \cos(\phi)}_{DC} + \underbrace{V_{RMS} I_{RMS} \cos(2\omega t - \phi)}_{\text{oscillation}}$$

$$P_{avg} = V_{RMS} I_{RMS} \cos(\phi)$$

Power Factor: $PF = \dfrac{\text{Real Power}}{\text{Apparent Power}}$

For General Periodic Waveforms: $PF = \dfrac{\langle P(t) \rangle}{V_{RMS} I_{RMS}}$

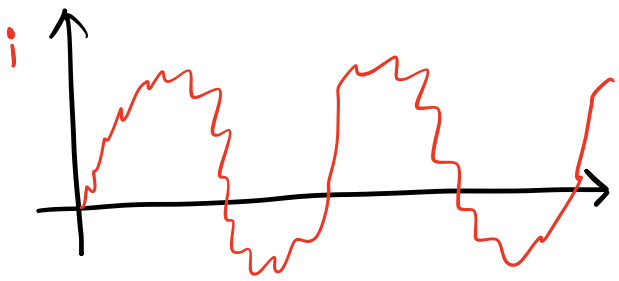
For Sine Waves: $PF = \dfrac{P_{RMS}}{|S|} = \dfrac{V_{RMS} I_{RMS} \cos(\phi)}{V_{RMS} I_{RMS}} = \cos(\phi)$

Fourier Series Expansion:

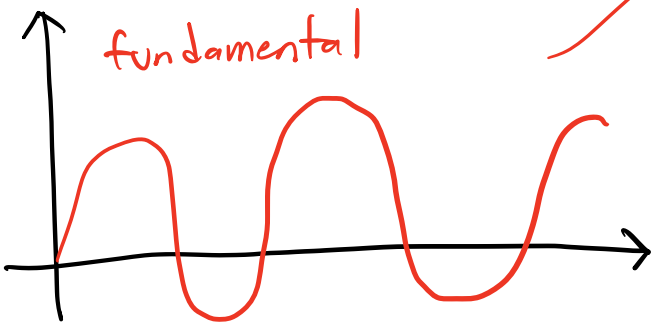
$$I_{RMS} = \sqrt{I_0^2 + I_1^2 + I_2^2 \cdots\cdots}$$

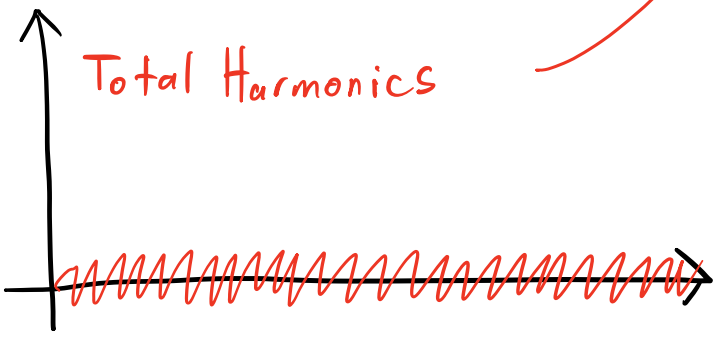
$$V_{RMS} = \sqrt{\underbrace{V_0^2}_{DC} + \underbrace{V_1^2}_{\text{Fundamental}} + \underbrace{V_2^2 \cdots\cdots}_{\text{Higher-order harmonics}}}$$

Total Harmonic Distortion:



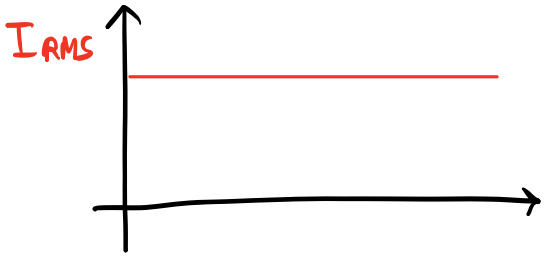
$$i = i_f + i_h + I_{DC}$$



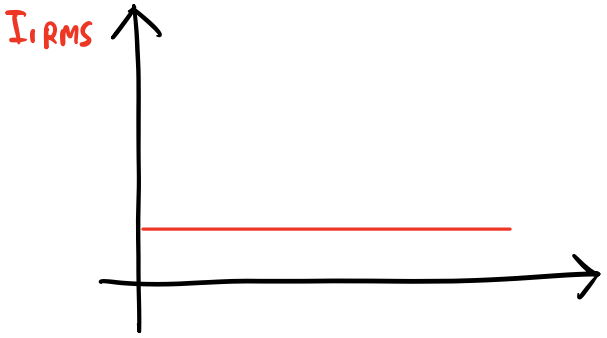


$$THD = \frac{\text{RMS of Total Harmonics}}{\text{RMS value of fundamental}}$$

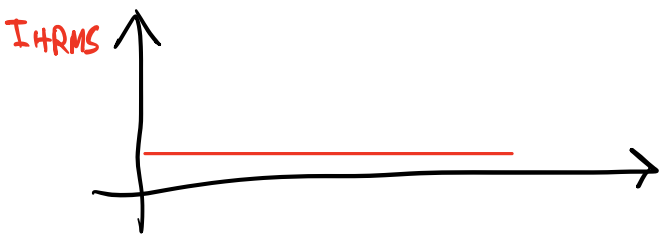
- $THD \geq 0$
- No units



$$THD = \frac{\sqrt{I^2 - I_1^2}}{I_1}$$



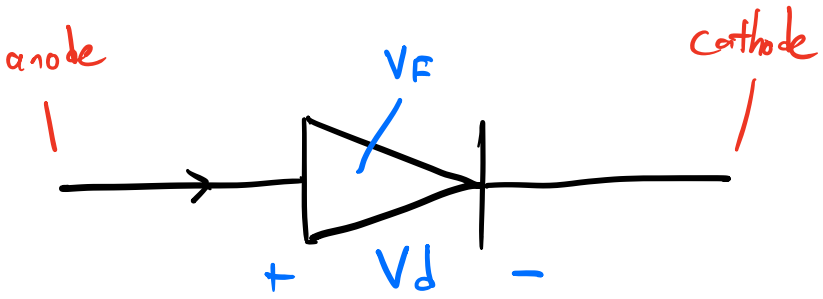
$$THD_v = \frac{\sqrt{V^2 - V_1^2}}{V_1}$$

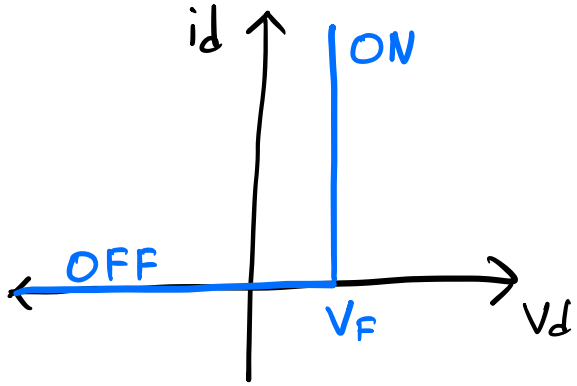


For a perfect Sinusoid:

$$THD = 0$$

Ideal Diode:



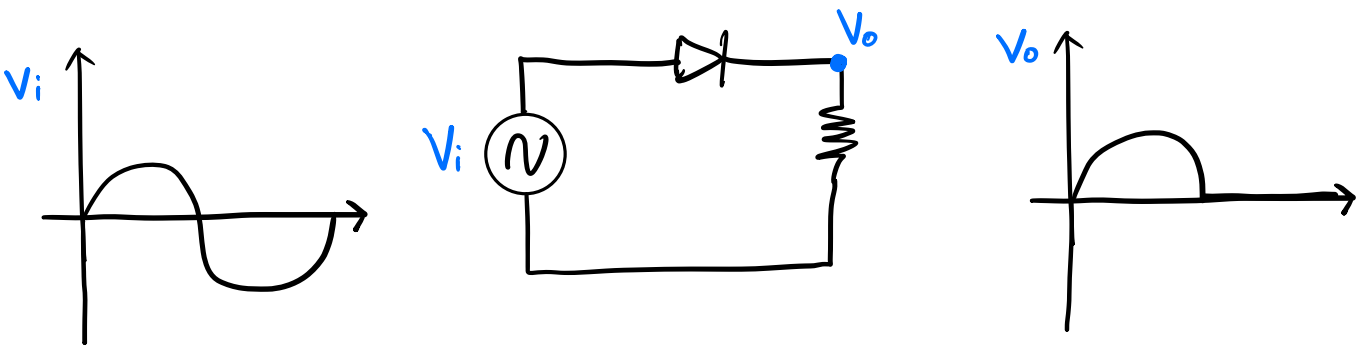


Conduction Losses:

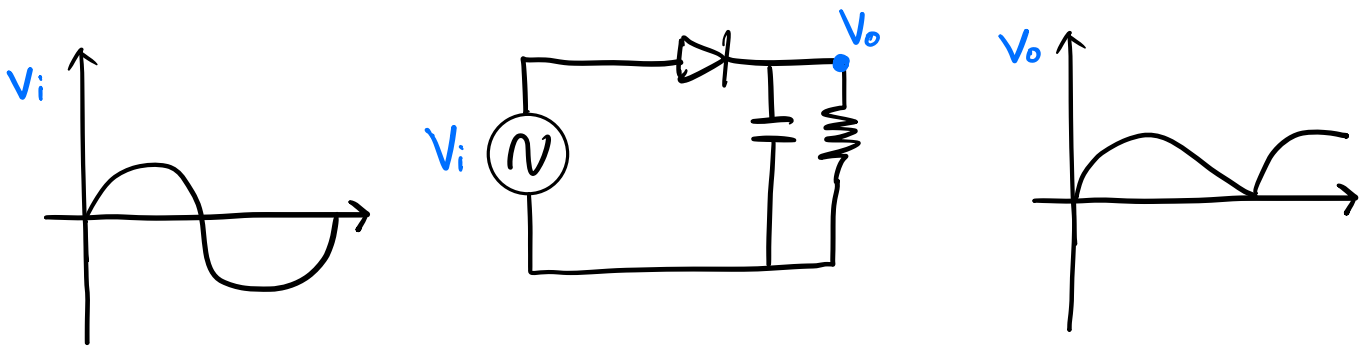
$P = IV$

$P_{cond} = i_d \cdot V_F \rightarrow 0$ if Ideal

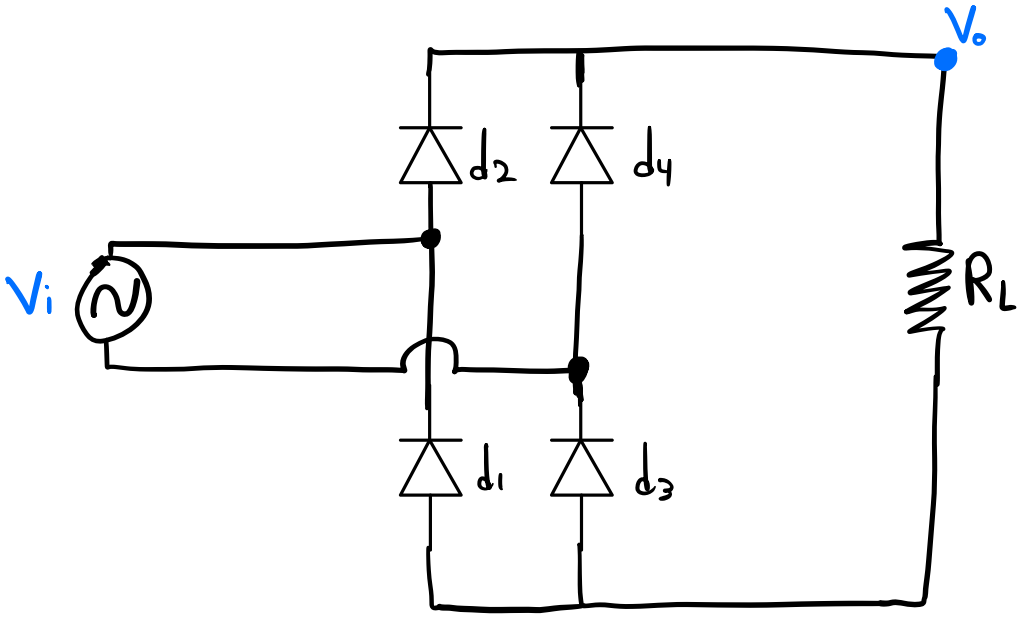
Single Diode AC-DC Converter:



Diode and Capacitor AC-DC Converter:



4 Diode Rectifier: Full-Bridge



Positive Flow:

$D_2 \rightarrow D_3$

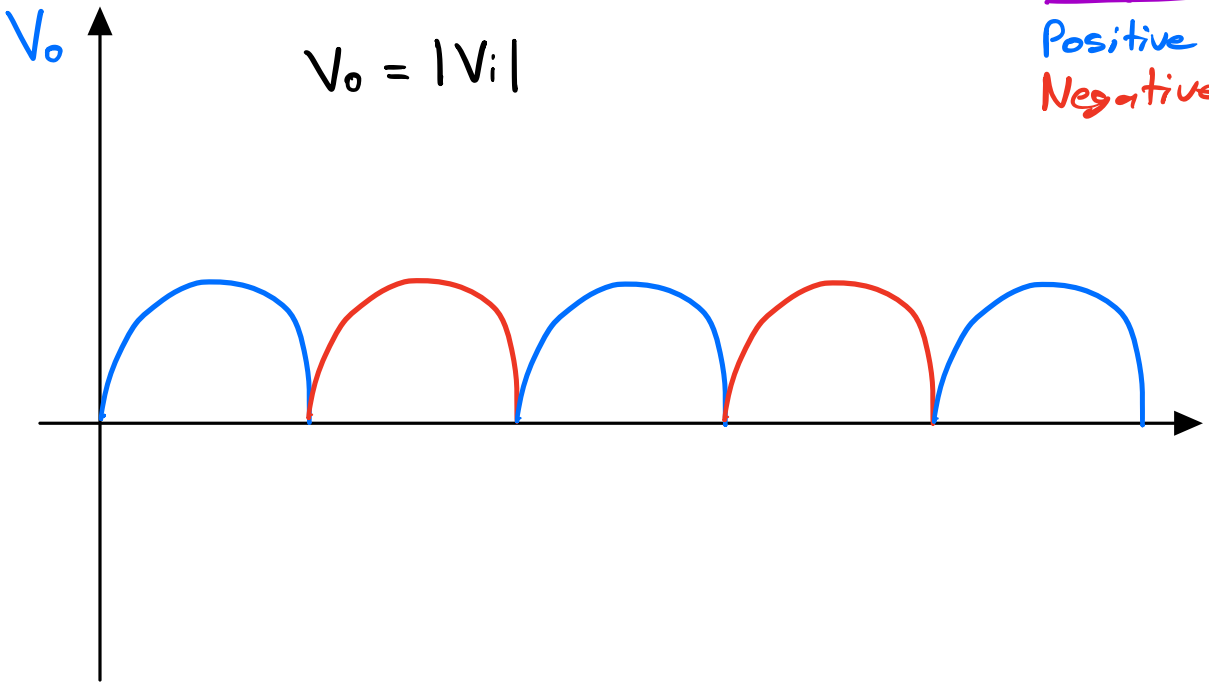
Negative Flow:

$D_4 \rightarrow D_1$

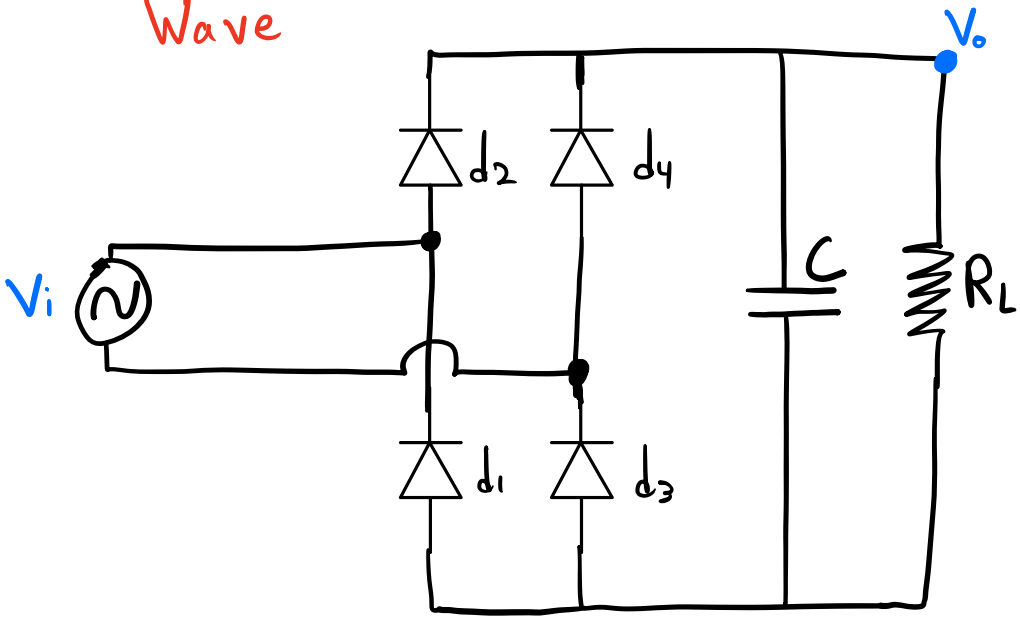
Legend:

Positive Cycle

Negative Cycle



Full ~~Bridge~~ Wave w/ Capacitor:



Positive Flow:

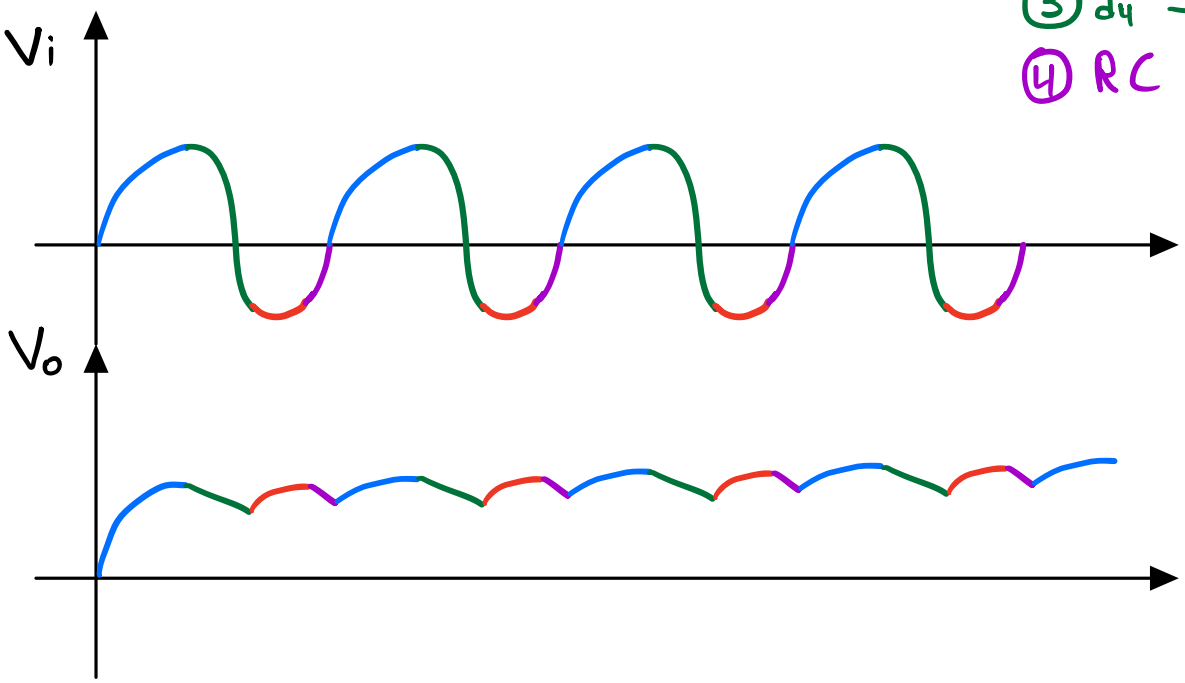
$D_2 \rightarrow D_3$

Negative Flow:

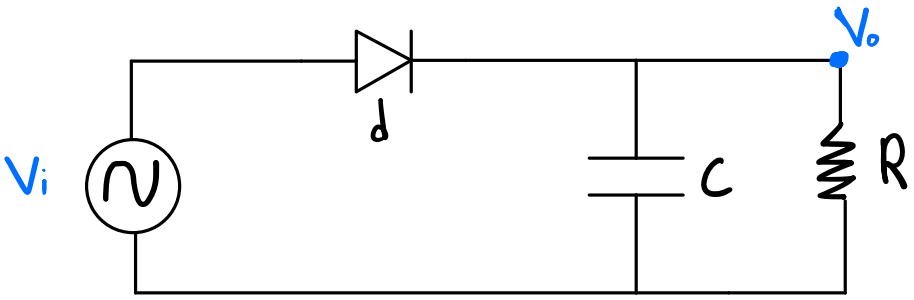
$D_4 \rightarrow D_1$

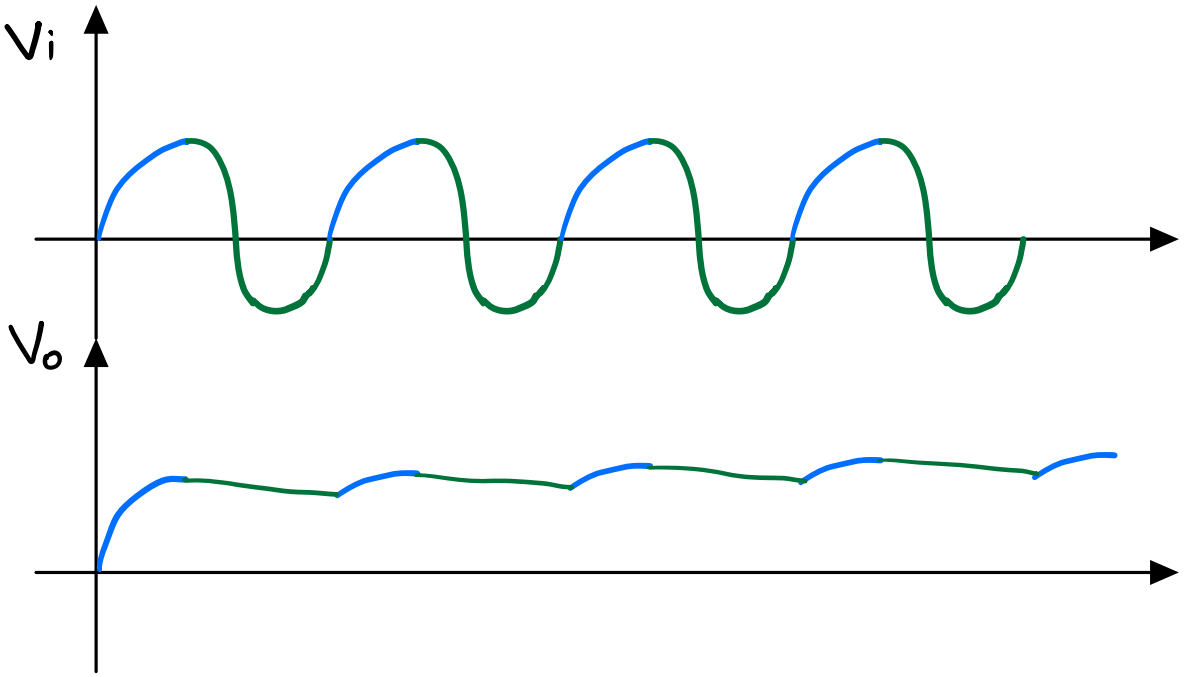
Regions:

1. $d_2 \rightarrow d_3$
2. RC CW (Cap discharge)
3. $d_4 \rightarrow d_1$ (Cap charge)
4. RC CW (Cap discharge)



Half-Wave Rectifier w/capacitor:





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