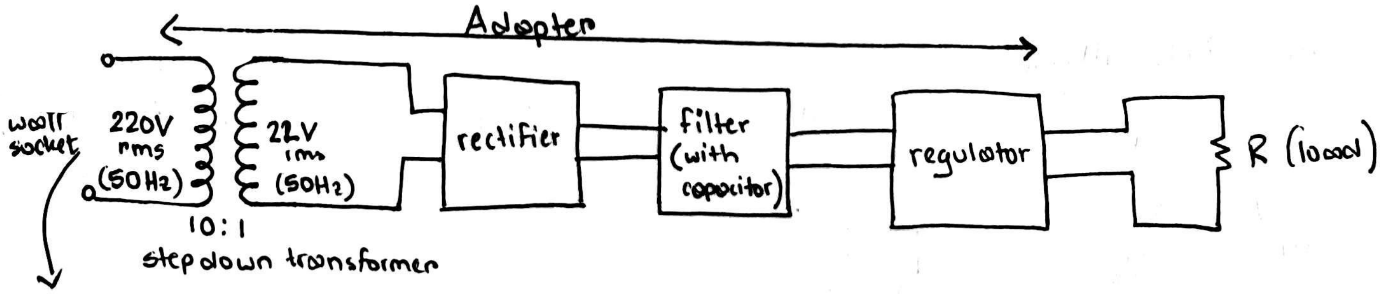
Diode Rectifiers

* pn junction ⟶ diode ⟶ diode ckt model ⟶ applications

* **Applications**: ① DL gates (Diode logic Gates)
② Rectification
↓
process of converting ac signals into one with unidirectional/limited polarity.
(+ve polarity will remain/convert to +ve, or -ve to -ve)

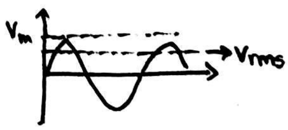
Uses of rectification: ① power supply (electronics require DC)
↳ providing a suitable DC.

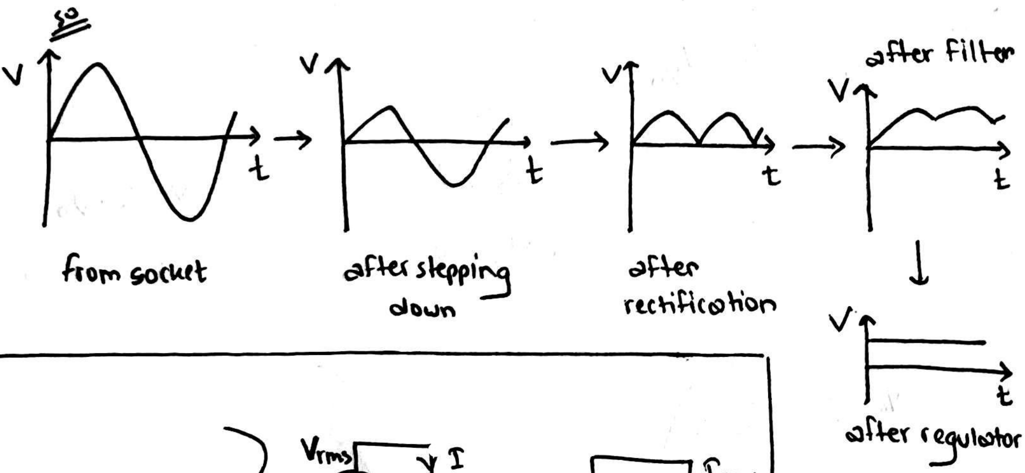
*rms → root mean squared
↳ used for AC power calculation.



220Vrms sinusoidal
↓
$\Rightarrow 220 = \frac{V_m}{\sqrt{2}}$

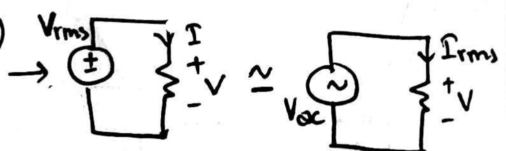
$V_m = 220\sqrt{2}$





DC power: $P = VI$

AC power: $P(t) = v(t)\,i(t)$
↳ function of time, not a useful measurement.



$P_{out} = VI \overset{same}{\longleftrightarrow} P_{out} = V_{rms} I_{rms} = P_{avg}$
$(V = V_{dc})$

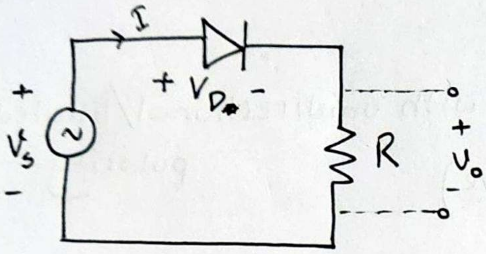
* V_{rms} is the effective value of AC signal that would result in same power dissipation for both ckts.

$$\boxed{V_{rms} = V_m/\sqrt{2}}$$
(V_m is peak voltage of sinusoidal wave)

Rectifiers

- Half wave
  - typical ✓
  - precision (uses op-amp; for very small v)
- full wave
  - centre tapped
  - bridge ✓

Half-wave Rectifier



V_s = source voltage

= $V_m \sin \omega t$ (for this analysis)

V_o = output voltage [V_p = peak output]

V_{D_o} = diode cut-in voltage = 0.7 for Si

V_D = diode voltage

AC revision:

$V_s = V_m \sin(\omega t + \varphi)$

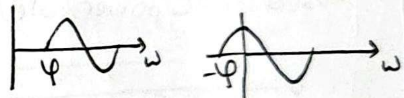
V_m = amplitude

$\omega = 2\pi f = \frac{2\pi}{T}$ = angular frequency

f = natural frequency

T = time period = $1/f$

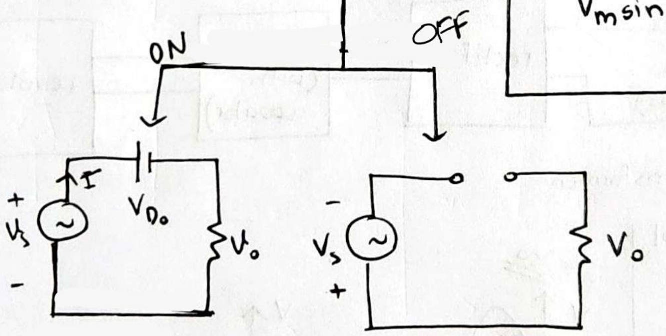
φ = initial phase



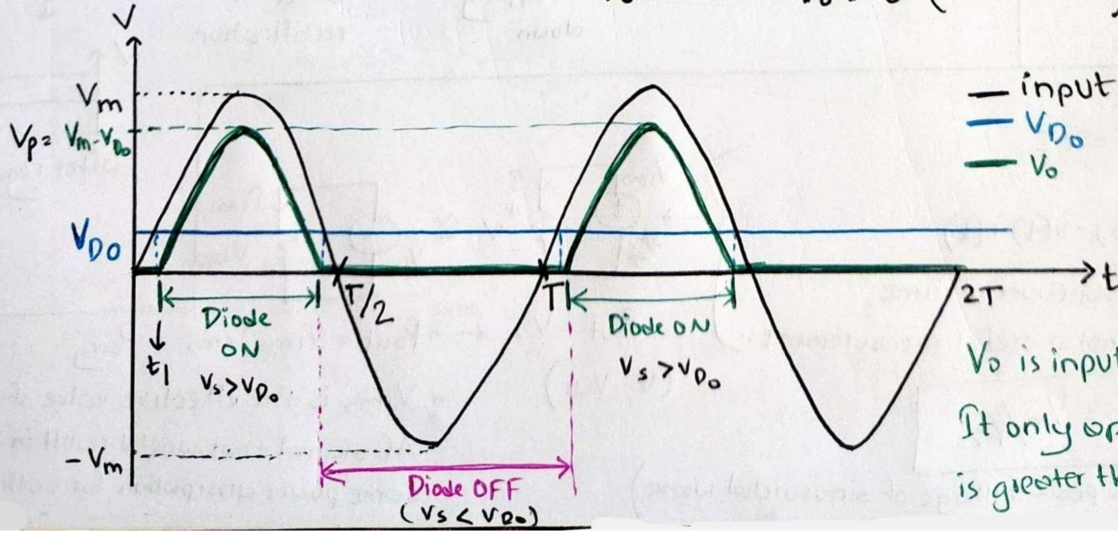
$V_m \sin(\omega t - \varphi)$ $\quad$ $V_m \sin(\omega t + \varphi)$

CVD model

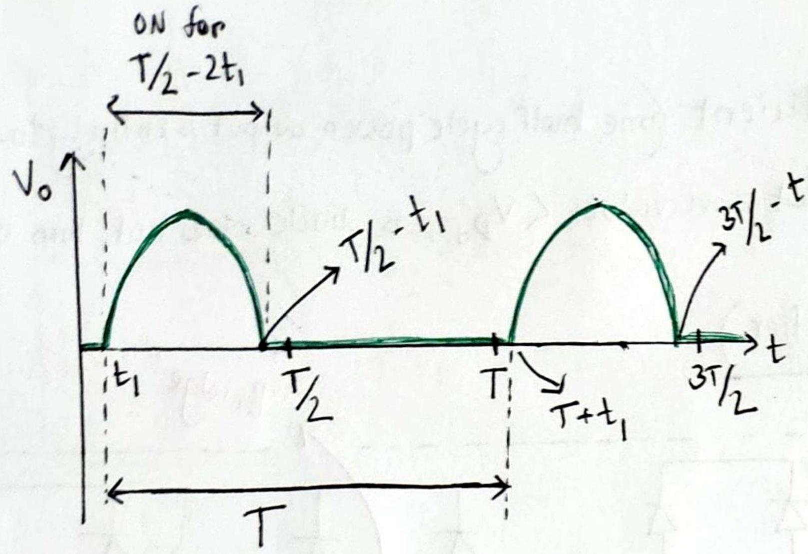
ON	OFF
$I_D > 0$	$I_D = 0$
$V_D > V_{D_o}$	$V_D < V_{D_o}$



ON	OFF
$I > 0$	$I = 0$
$V_s > V_{D_o}$	$V_s < V_{D_o}$
* $V_o = V_s - V_{D_o}$	* $V_o = 0$ (no current)



V_o is input minus V_{D_o}. It only appears when input is greater than V_{D_o}.



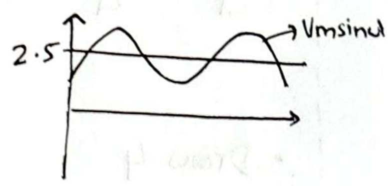
* input T = output T

To find t_1 –

at $t = t_1$

$V_m \sin\omega t_1 = V_{D_0}$

$\therefore\ t_1 = \frac{1}{\omega}\sin^{-1}\left(\frac{V_{D_0}}{V_m}\right)$



$\underbrace{\underbrace{2.5}_{DC} + \underbrace{V_m \sin\omega t}_{AC}}$

entirely DC, with its average / DC part = 2.5

To find the DC component or average,

$V_{dc} = \frac{1}{T}\int_0^T v_o(t)\,dt$ (integrate over given time period)

$= \frac{1}{T}\int_0^T \left(v_s(t) - V_{D_0}\right)dt$

$= \frac{1}{T}\int_{t_1}^{T/2 - t_1} \left\{V_m \sin\omega t - V_{D_0}\right\}dt$ (change the limits to fit the function)

$\simeq \frac{1}{T}\int_0^{T/2} \left\{V_m \sin\omega t - V_{D_0}\right\}dt \longrightarrow$ * **conditions:**

① $t_1 \ll T$

OR ② $V_{D_0} \ll V_m$

↳ or $V_P \simeq V_m$

① is a consequence of ②.

$= -\frac{V_m}{\omega T}\left[\cos\omega t\right]_0^{T/2} - \frac{V_{D_0}}{T}\left[t\right]_0^{T/2}$

$= -\frac{V_m}{\omega T}\times\left(\cos\frac{2\pi}{T}\times\frac{T}{2} - \cos 0\right) - \frac{V_{D_0}}{T}\left[T/2 - 0\right]$

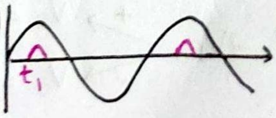
$= -\frac{V_m}{\frac{2\pi}{T}\times T}\times(-1-1) - \frac{V_{D_0}}{2}$

$= +\frac{V_m}{\pi} - \frac{V_{D_0}}{2}$

Even though V_o is on for $(T/2 - 2t_1)$ amount of time,

* if t_1 is small enough, we can ignore for an approximate result.

* if V_{D_0} was large...



Approx. would not work.

NO NEED

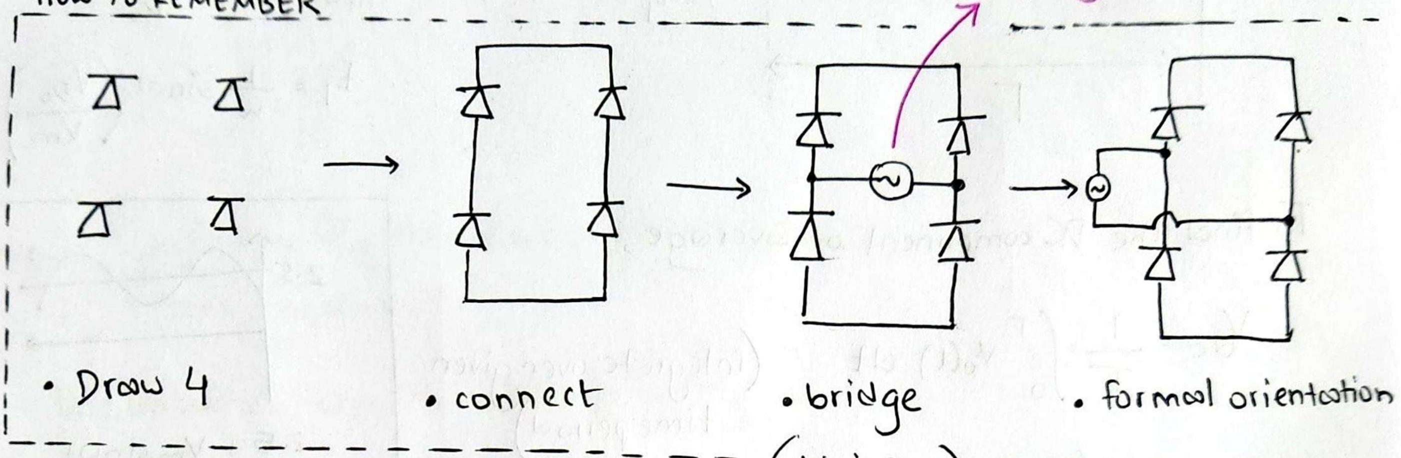
$*V_{rms} = \left[\frac{1}{T}\int_{t_1}^{T/2 - t_1} v_o^2(t)\,dt\right]^{1/2} = \left[\frac{V_m^2}{4} - \frac{2V_m V_{D_0}}{\pi} - \frac{V_{D_0}^2}{2}\right]^{1/2}$

root

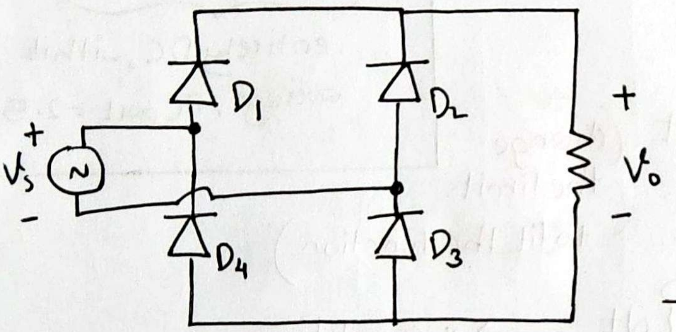
* HW rectifiers are very inefficient (one half cycle power output is entirely lost!)
* cannot rectify signals that have values < V_{Do}, as diode does not turn ON at all.

Full-wave (bridge rectifier)

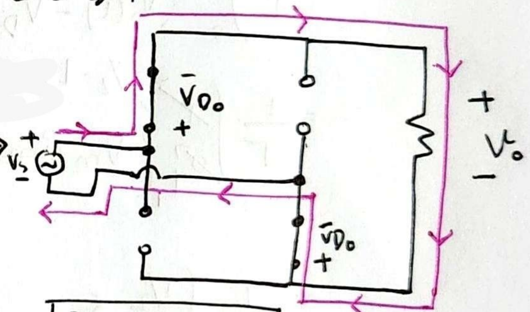
HOW TO REMEMBER



(this is fine!)



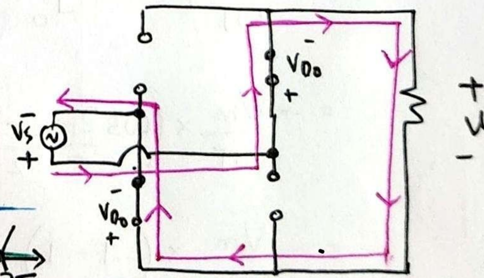
+ve



D_1, D_3 ON
D_2, D_4 OFF

→ due to source polarity

−ve

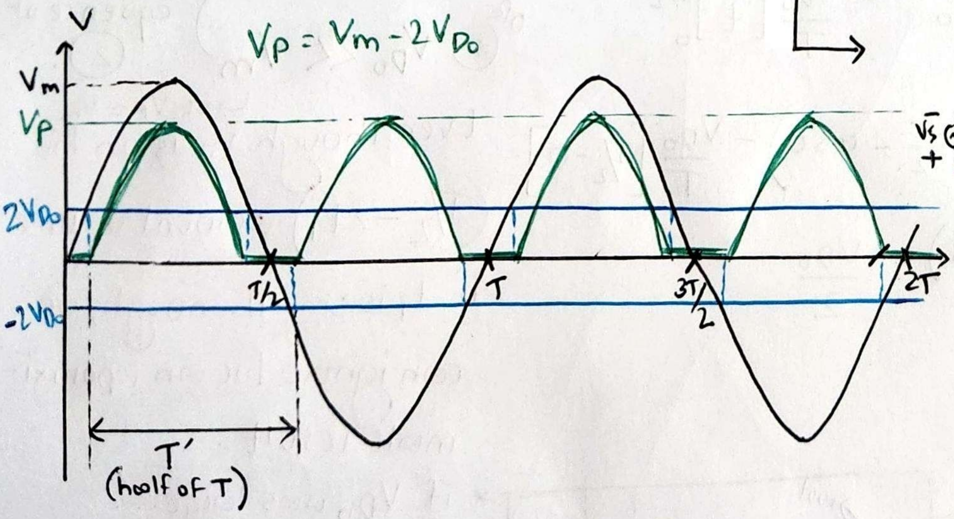


D_1, D_3 OFF
D_2, D_4 ON

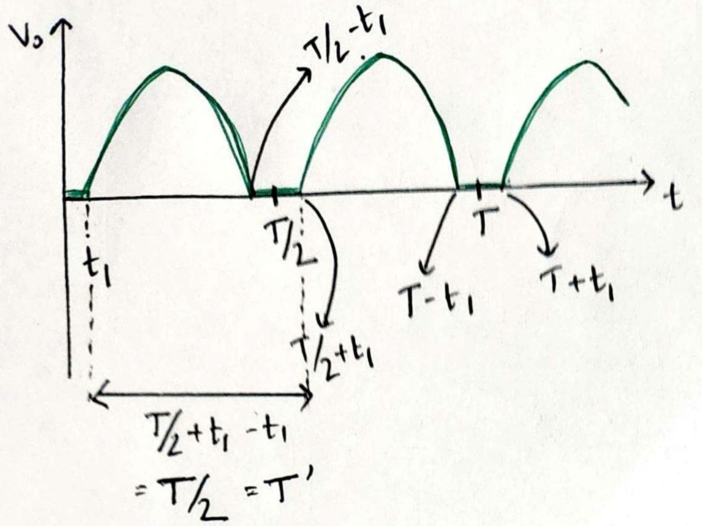
↓

in both + and − cycles, the current direction through the load remains same.

$V_p = V_m - 2V_{Do}$



$$V_o = V_s - 2V_{Do} \;\begin{cases} + \rightarrow V_o = V_s - 2V_{Do} \\ - \rightarrow V_o = +V_s - 2V_{Do} \end{cases}$$ mathematically same



T' = time period of output

$$T' = \frac{1}{2} \times T$$
$$= T/2$$

<u>To find t_1</u> -

$$V_m \sin \omega t_1 = 2V_{D_0}$$

$$\therefore t_1 = \frac{1}{\omega} \sin^{-1}\left(\frac{2V_{D_0}}{V_m}\right)$$

* <u>note</u>: switching direction of all diodes will give you a negative DC.

* the obtained output is called pulsating DC.

* DC component,

$$V_{dc} = \frac{1}{T/2} \int_0^{T/2} V_o(t)\, dt$$

$$= \frac{1}{T/2} \int_{t_1}^{T/2 - t_1} \left\{V_m \sin \omega t - 2V_{D_0}\right\} dt$$

$$\simeq \frac{2}{T} \int_0^{T/2} \left\{V_m \sin \omega t - 2V_{D_0}\right\} dt \quad \left[\text{assuming } V_{D_0} << V_m / t_1 << T\right]$$

$$\vdots \quad \text{(similar to before)}$$

$$= \frac{2V_m}{\pi} - 2V_{D_0}$$