TRANSFORMER

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Magnetic circuit

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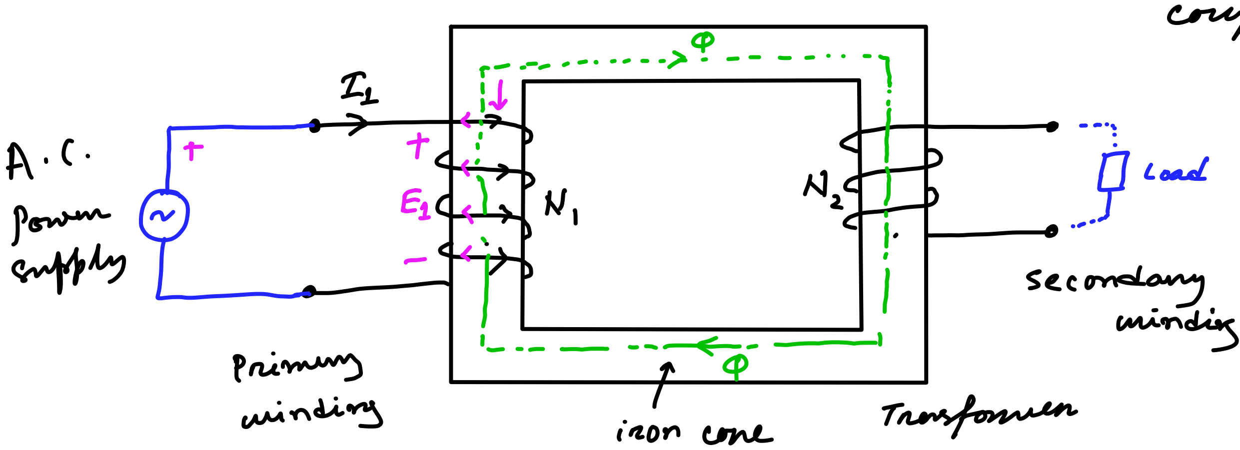
It transfer energy/power from one electric circuit to another, which are magnetically coupled.



(Fig-1)

- Connect transformer primary winding to an A.C. source

- The flux

$$\phi = \frac{\mathcal{F}}{\mathcal{R}_{total}} = \frac{N_1 I_1}{\mathcal{R}_E}$$

- The nature of flux is also time-varying since I_1 is time varying.

- Ideal Transformer (Assumptions)

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→ The resistance of the winding is neglected.

→ There is no leakage flux. The flux produced are all inside the core.

→ B is lineare function of H

$B = \mu_c H \Rightarrow \varphi$ is lineam with $\mathcal{F}$

* → There is no core-loss (no eddy current loss & no hystresis loss)

$I_1 = I_{max} \sin \omega t$ where $\omega = 2\pi f$ ← frequency 50Hz

$\varphi = \varphi_{max} \sin \omega t$ $\left(\sin \varphi = \frac{\mathcal{F}}{\mathcal{R}}\right)$

Emf in primary side (we have kept secondary open)

$$e_1 = -N_1 \frac{d\varphi}{dt}$$

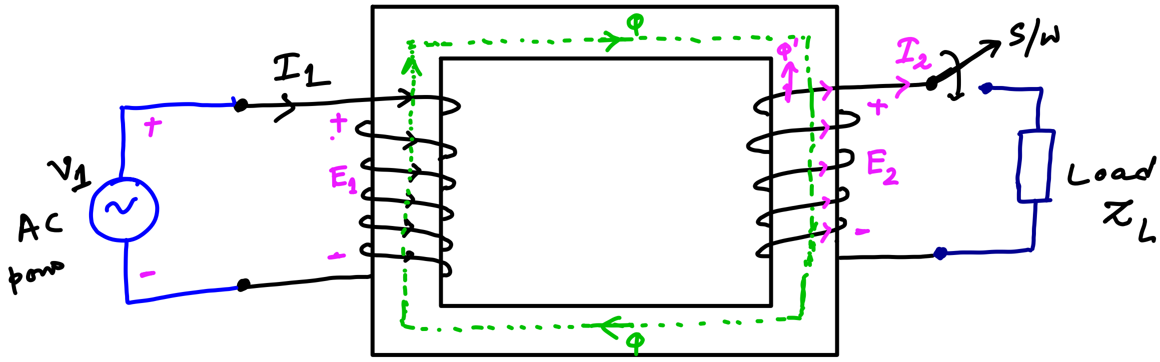
$$= -N_1 \omega \varphi_{max} \cos \omega t$$

$$= \underbrace{N_1 \omega \varphi_{max}}_{E^1_{max}} \sin(\omega t - \pi/2)$$

R.M.S. value of primary side emf

$$E_1 = \frac{E^1_{max}}{\sqrt{2}} = \frac{2\pi f N_1}{\sqrt{2}} \varphi_{max}$$

$$\boxed{E_1 = \sqrt{2}\pi f N_1 \varphi_{max}}$$



(Fig - 2)

Secondary side emf

$$e_2 = -N_2 \frac{d\varphi}{dt}$$

$$= -N_2 \omega \varphi_{max} \cos \omega t$$

$$= \underbrace{N_2 \omega \varphi_{max}}_{E^2_{max}} \sin(\omega t - \pi/2)$$

secondary side emf

R.M.S. $E_2 = \dfrac{E^2_{max}}{\sqrt{2}} = \sqrt{2}\pi f N_2 \varphi_{max}$

$$\boxed{E_2 = \sqrt{2}\pi f N_2 \varphi_{max}}$$

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}} \Rightarrow \boxed{E_2 = \left(\frac{N_2}{N_1}\right) E_1}$$

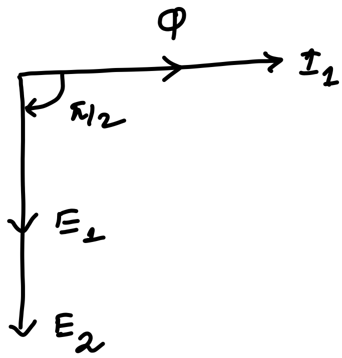
- When $N_1 < N_2$ (Step-up transformer)
- when $N_2 < N_1$ (Step-down transformer)

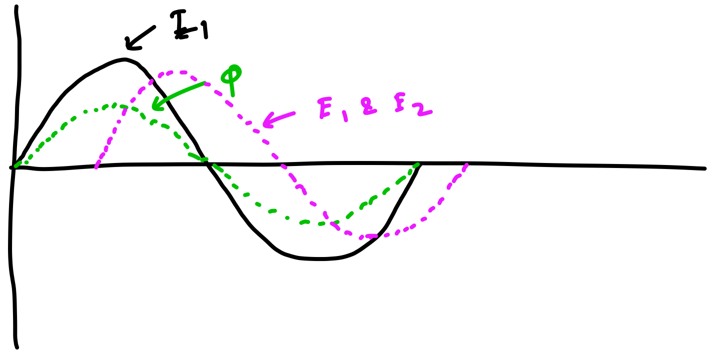
$$I_1 = I_{max} \sin \omega t$$

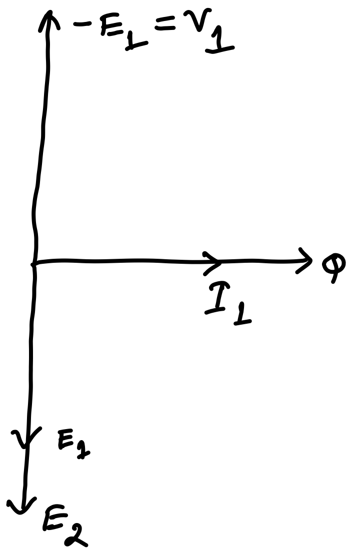
$$\varphi = \varphi_{max} \sin \omega t$$

$$E_1 = E^1_{max} \sin(\omega t - \pi/2)$$

$$E_2 = E^2_{max} \sin(\omega t - \pi/2)$$







- By neglecting the resistance of the winding

$$V_1 = E_1$$

$$E_1 = \sqrt{2}\pi f N_1 \varphi_{max}$$

- For ideal transformer (winding resistance is neglected)

$$V_1 = E_1 = \sqrt{2}\pi f N_1 \varphi_{max}$$

$$\boxed{\varphi_{max} = \frac{V_1}{\sqrt{2}\pi f N_1}}$$

- The flux in the core is completely determined by V_1, f, N_1.
- As long as the applied/supplied voltage remains const., the flux in the core will also remain const.

→ <u>After closing S/W</u>

Under Load-connected condition

- A secondary current I_2 will flow, which is determined by the load.

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- A flux φ' will create to oppose the existing flux φ in the core.

• Since $\Phi_{max} = \dfrac{V_1}{\sqrt{2}\pi f N_1}$,

$\downarrow$

the flux ϕ in the core will remain const. as long as V_1 is const.

• Sim $\phi = \dfrac{N_1 I_1}{\mathcal{R}_c}$ $\qquad \phi' = \dfrac{N_2 I_2}{\mathcal{R}_c}$,

$\downarrow$

To maintain const. flux ϕ in the core, there will be more current flow from primary side. I_1'

$$I_1 = I_\phi + I_1'$$

I_ϕ $\downarrow$ to magnetize the core

$\Downarrow$

to maintain flux ϕ in the core

I_1' $\rightarrow$ Load component of primary current.

- In an ideal transformer,

  $I_1 = I_1'$ & I_φ is neglected in comparison to I_1'.

- To maintain the const flux in the core the mmf of both side must be balanced.

$$N_1 I_1' = N_2 I_2 \qquad \varphi = \frac{N_1 I_1}{\mathcal{R}} \qquad \varphi' = \frac{N_2 I_2}{\mathcal{R}}$$

for ideal transfor

$$\boxed{N_1 I_1 = N_2 I_2}$$

$$\Rightarrow \boxed{I_1 = \left(\frac{N_2}{N_1}\right) I_2}$$

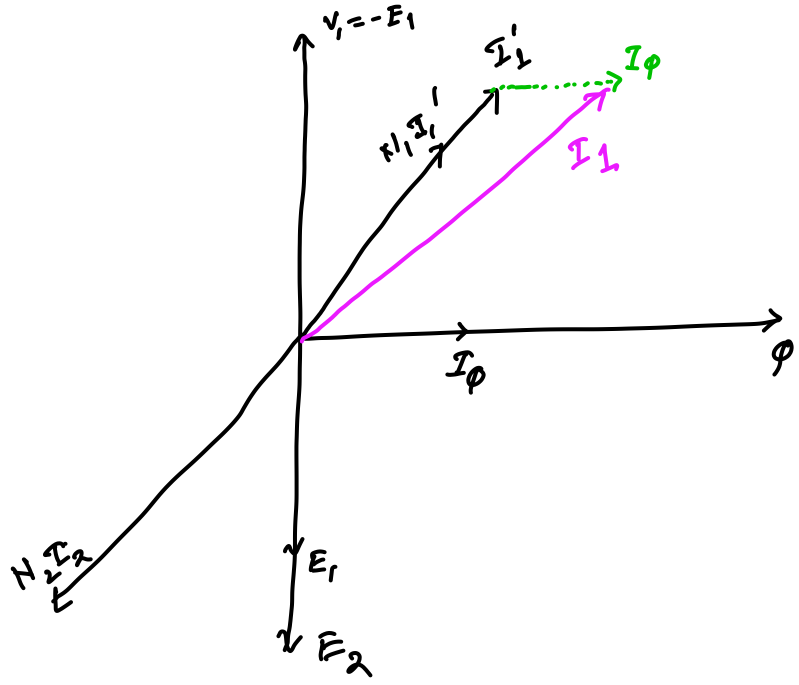
- $E_2 = \left(\frac{N_2}{N_1}\right) E_1$

$$\frac{E_2}{I_1} = \frac{E_1}{I_2} \Rightarrow \boxed{E_2 I_2 = E_1 I_1}$$

- The volt-ampere of primary side is equal to the volt-amp. in secondary side.

$$\boxed{e_2 i_2 = e_1 i_1}$$

$$\boxed{v_1 i_1 = v_2 i_2} \text{ for ideal transform}$$



$$N_1 I_1' = N_2 I_2$$

$$I_1 = I_\varphi + I_1'$$

- For an ideal transformer:

  The instantaneous power at primary & secondary will remain equal.