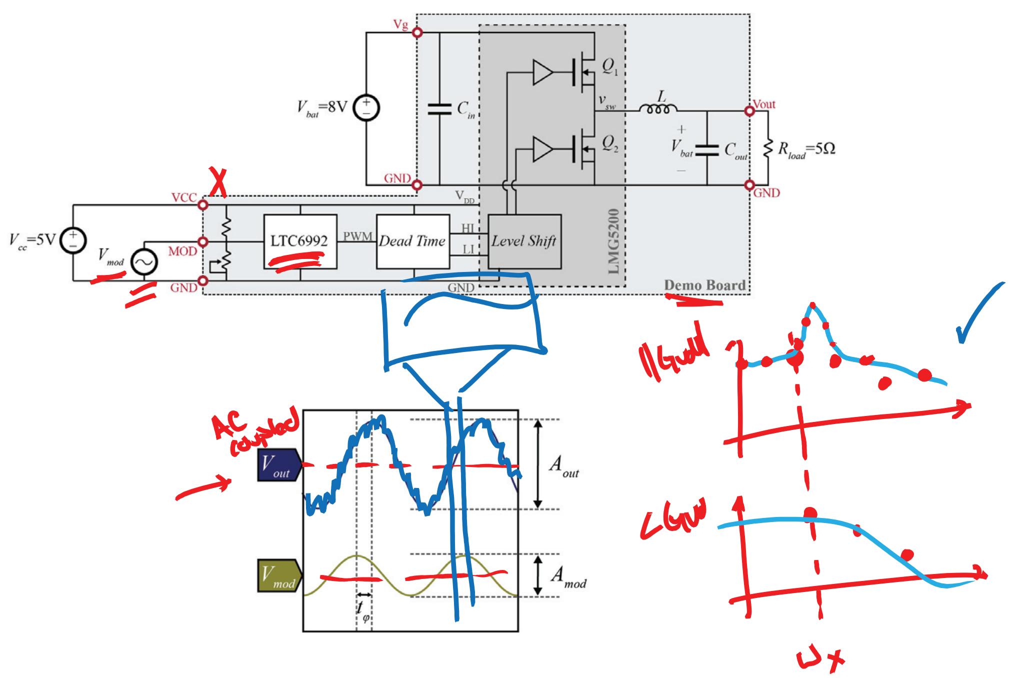
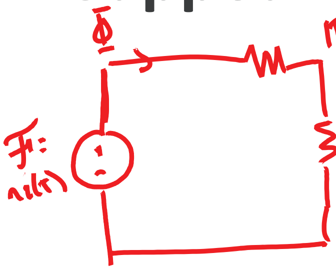
Announcements

- Experiment 3:
  - https://doodle.com/poll/3ke8ynnxk8x2ufzw
  - Transfer function characterization
  - Minimal writeup
- Homework 11:
  - Due Monday, Dec 4th

Experiment 3



Gapped Inductor Magnetic Circuit



$\mathcal{R}_c = \frac{l_m}{\mu A_c}$

$\mathcal{R}_g = \frac{l_g}{\mu_0 A_c}$

$\Phi = \frac{\mathcal{F}}{\mathcal{R}_c + \mathcal{R}_g}$

$\Phi = \frac{n\,i(t)}{\frac{l_m}{\mu A_c} + \frac{l_g}{\mu_0 A_c}}$

Faraday:

$$v(t) = n\frac{d\Phi}{dt} = n\frac{d}{dt}\left(\frac{n A_c\, i(t)}{\frac{l_m}{\mu} + \frac{l_g}{\mu_0}}\right) = \frac{n^2 A_c}{\frac{l_m}{\mu} + \frac{l_g}{\mu_0}}\frac{di(t)}{dt}$$

$$L = \frac{n^2 A_c}{\frac{l_m}{\mu} + \frac{l_g}{\mu_0}} \approx \boxed{\frac{n^2 A_c \mu_0}{l_g}}$$

L not dependent on μ → need large μ & unsaturated

Rough #'s

$l_g \approx 1\,mm$

$l_m \approx 10\,cm$

$\mu \approx 10{,}000$

$\frac{l_m}{\mu} = \frac{10\,cm}{10{,}000} \ll \frac{.1\,cm}{1} = \frac{l_g}{\mu_0} \rightarrow \boxed{\mathcal{R}_g \gg \mathcal{R}_c}$

Effect of Air Gap

$I_{sat} = \frac{l_g}{\mu_0 n} B_{sat}$ $\mathcal{R}_g = \frac{l_g}{\mu_0 A_c}$

$\mathcal{R}_g \gg \mathcal{R}_c$

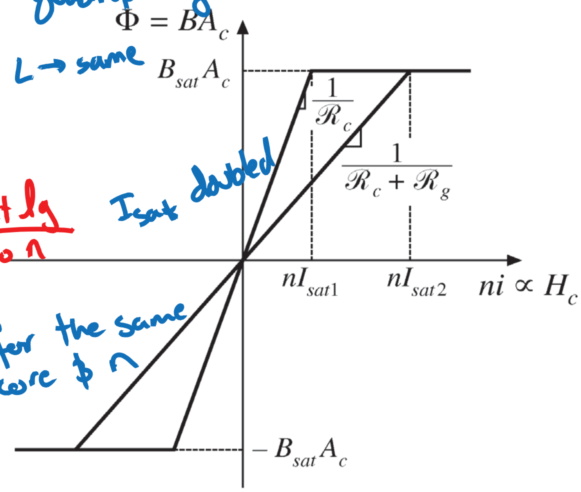
$$ni = \Phi\left(\mathcal{R}_c + \mathcal{R}_g\right)$$

$$L = \frac{n^2}{\mathcal{R}_c + \mathcal{R}_g} = \frac{n^2 \mu_0 A_c}{l_g}$$

$$\Phi_{sat} = B_{sat} A_c$$

$$I_{sat} = \frac{B_{sat} A_c}{n}\left(\mathcal{R}_c + \mathcal{R}_g\right) = \frac{B_{sat}\, l_g}{\mu_0\, n}$$

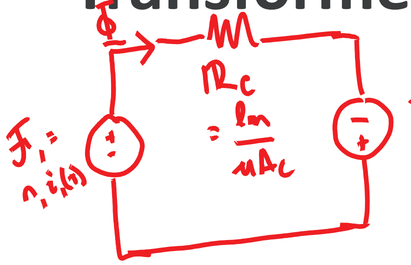
example: double n, quadruple l_g, L → same, I_{sat} doubled

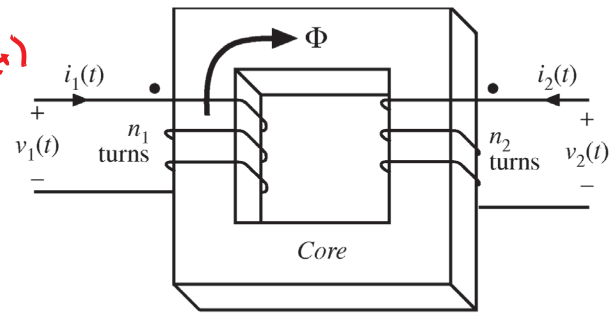


Effect of air gap:

- decrease inductance → for the same core & n
- increase saturation current
- inductance is less dependent on core permeability (μ)

Transformer Example





$$\Phi = \frac{\mathcal{F}_1 + \mathcal{F}_1}{\mathcal{R}_c}$$

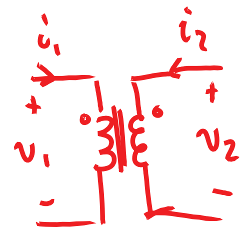
$$\mathcal{R}_c \Phi = n_1 i_1(t) + n_2 i_2(t)$$

Ideal XF case: $\mu \to \infty$, $\mathcal{R}_c \to \emptyset$

$$\emptyset = n_1 i_1(t) + n_2 i_2(t)$$

Faraday:

$$v_1(t) = n_1 \frac{d\Phi}{dt}, \quad v_2(t) = n_2 \frac{d\Phi}{dt} \;\Rightarrow\; \frac{v_1(t)}{n_1} = \frac{v_2(t)}{n_2}$$



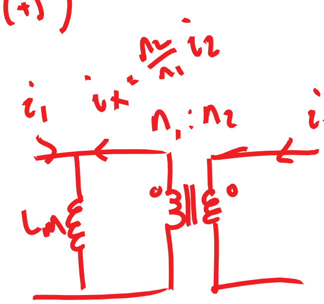
Nonideal Transformer

μ is finite

$$v_1 = n_1 \frac{d\Phi}{dt} = n_1 \frac{d}{dt}\left(\frac{n_1 i_1(t) + n_2 i_2(t)}{\frac{l_m}{\mu A_c}}\right)$$

$$v_1 = \frac{n_1^2 \mu A_c}{l_m} \frac{d}{dt}\left(i_1(t) + \frac{n_2}{n_1} i_2(t)\right)$$

magnetizing inductance $L_m = \frac{n_1^2 \mu A_c}{l_m}$



XF saturation:

only current through L_m increases core $B(t)$

i_1 & i_2 do not

$$B(t) = \frac{1}{n_1 A_c}\int v_1(t)\,dt = \frac{1}{n_2 A_c}\int v_2(t)\,dt$$

$$I_{m,sat} = \frac{l_m}{\mu n_1} B_{sat}$$