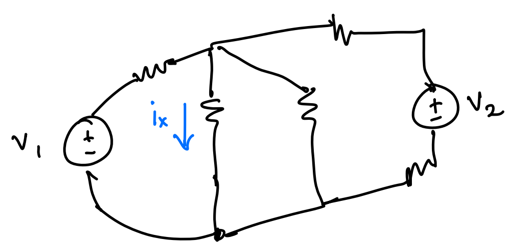
Lecture #21, 11/19/21

- Midterm — [max 98, min 45] avg 72.3

- Today
  -> Ch 11, inductor design

Recap of ckt superposition



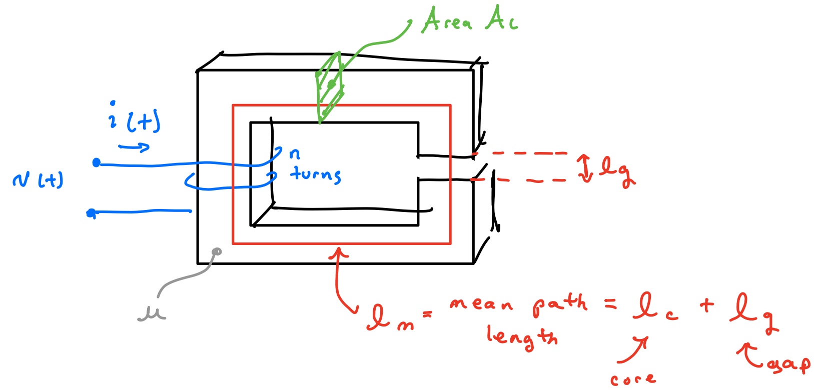
What is i_x?

① — Set $v_2 = 0$, $v_1 \neq 0$, solve for i_x'

② — Set $v_1 = 0$, $v_2 \neq 0$, solve for i_x''

③ — Final solution $i_x = i_x' + i_x''$

- Inductor w/ Air Gap Continued



$$\boxed{\frac{n^2}{\frac{1}{\mu_0 A_c}\left(\frac{l_c}{\mu_r} + l_g\right)} = L}$$ exact

same

$$L = \frac{n^2}{R_c + R_g}$$

* approx $\underbrace{\frac{l_c}{\mu_r \mu_0 A_c}}_{R_c} \ll \underbrace{\frac{l_g}{\mu_0 A_c}}_{R_g}$ b/c μ_r big

$$\approx \frac{n^2}{R_g} = \boxed{\frac{n^2 \mu_0 A_c}{l_g} \approx L}$$ approx ignores core reluctance

as $l_g \uparrow$, $L \downarrow$

- why use Air Gap? → Needed to prevent saturation

Saturation = all core magnetic dipoles fully aligned & Φ cannot increase further

- Look at saturation

let $I = I_{sat}$ ← solve for this

know B_{sat} from material datasheet

Ampere's Law (KVL-like eqn)

$$\overbrace{n I_{sat}}^{\text{MMF sources}} = \overbrace{\Phi_{sat} (\mathcal{R}_c + \mathcal{R}_g)}^{\text{drops}} \quad \Big\} \text{ exact}$$

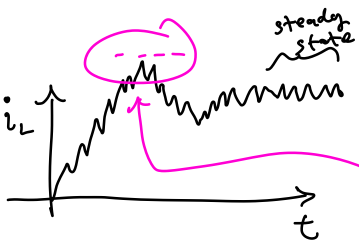
* know $\Phi_{sat} = B_{sat} A_c$

$$= B_{sat} A_c (\mathcal{R}_c + \mathcal{R}_g)$$

* again, $\mathcal{R}_g \gg \mathcal{R}_c$

$$\approx B_{sat} A_c \mathcal{R}_g \quad \Big\} \text{ approx where } \mathcal{R}_g \gg \mathcal{R}_c$$

$$\Longrightarrow \boxed{n I_{sat} \approx \frac{B_{sat} l_g}{\mu}}$$

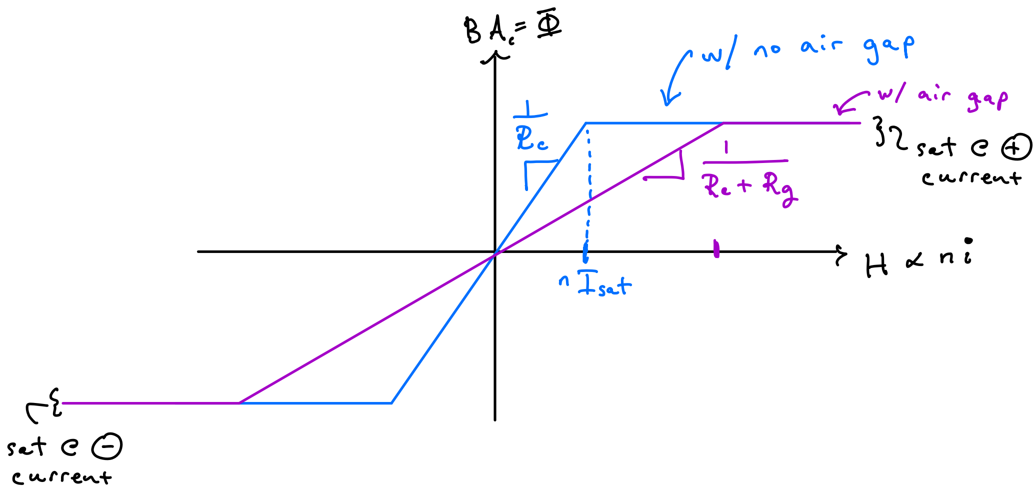


as $l_g \uparrow$, $I_{sat} \uparrow$

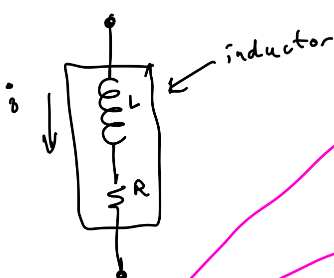
↳ want max expected current, known from ratings, to never exceed I_{sat}. Account for ripple & transients too!

IF $I > I_{sat}$

↳ the inductor behaves as a short ckt.



Ch ~~14~~ 11 Filter Design



Goals

- Want some inductance L to hit $\frac{\Delta i}{I}$ target
- Carry current $i \le I_{max}$ w/o saturating
- Keep copper losses low

$$P_{cu} = I_{rms}^2 R$$

- Design Constraints

#1) Max flux density

From ratings

$$n I_{max} \approx B_{max} \frac{l_g}{\mu_0} \quad (*)$$

? ? core

from material data sheet

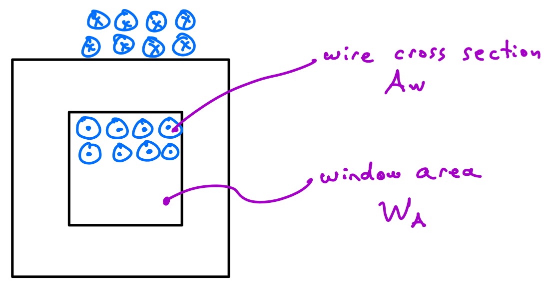
#2) Inductance Target

$$L \approx \frac{n^2}{R_g} = \frac{\mu_0 A_c n^2}{l_g} \quad (*)$$

? ? ?

from $\frac{\Delta i}{I}$ target

#3) Winding Area:



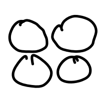
total wire area $= n A_w$

available area $= K_u W_A$ ← utilization factor aka Fill Factor

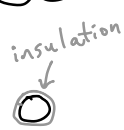
$K_u < 1$ depends how tightly you can pack windings into area

$\Rightarrow$ Design constraint $\quad K_u W_A \geq n A_w \quad (*)$

Typical K_u values



← round wires reduce K_u to $\approx 0.5 - 0.7$



lose $\boxed{\approx 5\%}$ for low voltage magnetics ← our

lose $\approx 45\%$ for " " "

#4) Winding Resistance

know $R = \rho \dfrac{l_b}{A_w}$ ← wire length

$* \; l_b = n \underbrace{(MLT)}$ mean length/turn

$= \rho \dfrac{n(MLT)}{A_w} = R \quad (*)$

$* =$ 4 key eqns