Saturation Limits (~~Gapless~~ Inductor)

Process: first assume inductor is not saturated, analyze using $B = \mu H$ → afterwards check if $|B(t)| > B_{sat}$

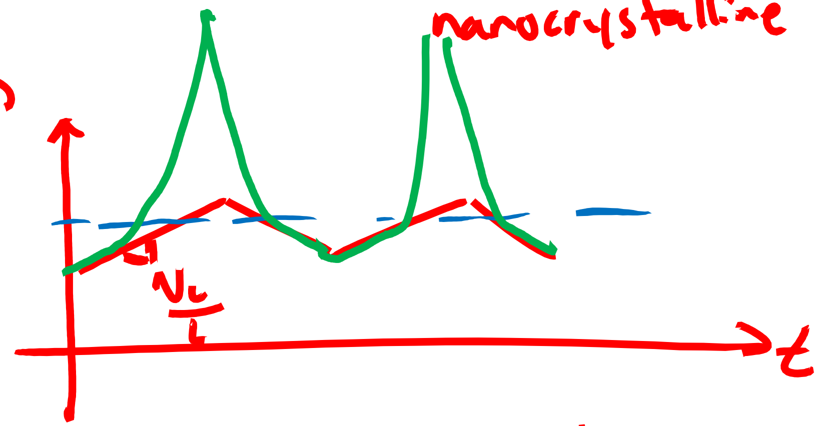
typical B_{sat} $\begin{cases} 0.2 - 0.8\,T & \text{for ferrite} \\ 1 - 2.2\,T & \text{for laminated iron} \\ & \text{nanocrystalline} \end{cases}$

previous example:

$$L = \frac{\mu n^2 A_c}{l_m}$$

saturation $\mu \downarrow \sim 1000$

so $L \downarrow \sim 1{,}000$



$$v(t) = n A_c \frac{dB}{dt} \longrightarrow \boxed{B(t) = \frac{1}{n A_c} \int_0^t v(t)\, dt}$$

$$v(t) = L \frac{di}{dt} = n A_c \frac{dB}{dt}$$

$$LI = n A_c B$$

$$I = \frac{n A_c B}{L}$$

@ B_{sat}

$$\boxed{I_{sat} = \frac{l_m}{\mu n} B_{sat}}$$

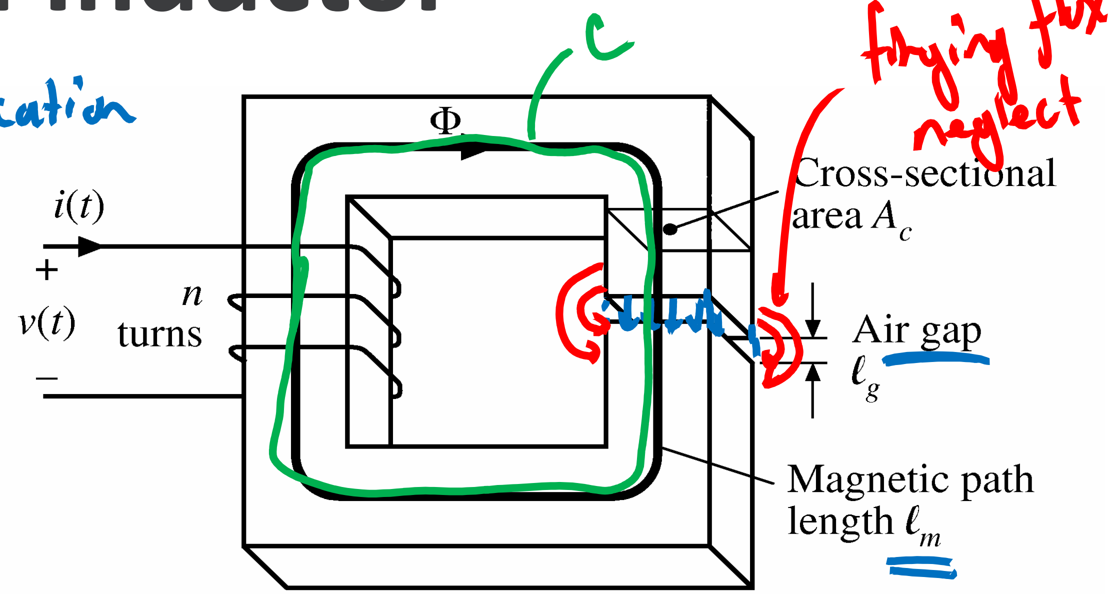
for ungapped inductor

to ↑ I_{sat}

(1) ↑ B_{sat}
(2) ↑ l_m
(3) ↓ μ
(4) ↓ n

also ↓ L

Example: Gapped Inductor



Additional assumption/simplification

(4) No fringing flux

Faraday:

$$v(t) = n\frac{d\Phi}{dt} = nA_c\frac{dB}{dt}$$

Ampere:

$$\oint_C H\cdot dl = I_{enclosed} = n\,i(t) = H_c(l_m - l_g) + H_g l_g$$

Material Characteristics:

in core $B = \mu H_c$ (unsaturated), in air $B = \mu_0 H_g$

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

$l_m \gg l_g$

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

$$v(t) = nA_c\frac{d}{dt}\left(\frac{n\,i(t)}{\frac{l_m}{\mu} + \frac{l_g}{\mu_0}}\right),$$

$$\boxed{v(t) = \underbrace{\frac{n^2 A_c}{\frac{l_m}{\mu} + \frac{l_g}{\mu_0}}}_{L}\frac{di}{dt}}$$