Lecture # 22 , 11/22/21

- HW 6 due tommorow night
- HW 7 will be assigned tommorow, due ≈ Friday 12/3
- Today, Ch 11 (sec 11.2).
- Look ahead: Loss mechanisms in ch 10. (magnetics)
- Summarize 4 constraints

$$\boxed{\begin{aligned} n I_{max} &\approx B_{max} \frac{l_g}{\mu_o} && \text{saturation} \\ L &\approx \frac{\mu_o A_c n^2}{l_g} && \text{inductance} \\ K_u W_A &\geq n A_w && \text{window area} \\ R &= \rho \frac{n (MLT)}{A_w} && \text{resistance} \end{aligned}}$$

$A_c$, $W_A$, MLT : core geometry

$I_{max}$, $B_{max}$, $\mu_o$, $K_u$, $R$, $\rho$ : knowns/specs

$\underbrace{n,\ l_g,\ A_w}$ : unknowns

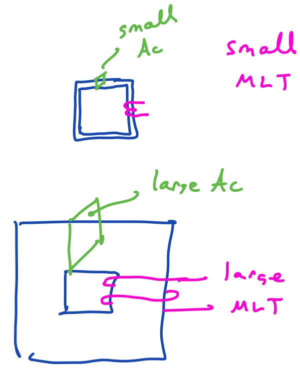
↳ strategy to solve:
Eliminate 3 unknowns to get
1 eqn w/ other quantities

- Core Geometrical Constant "$K_g$"

Eliminate $n, l_g, A_w$ to get ... skip algebra

$$\boxed{\underbrace{\frac{A_c^2 W_A}{(MLT)}}_{\text{fcn of geometry}} \geq \underbrace{\frac{\rho L^2 I_{max}^2}{B_{max}^2 R K_u}}_{\text{known specs}}}$$

$$\overbrace{\text{"}K_g\text{"}} = \frac{A_c^2 W_A}{MLT}$$




$K_g$ is a FOM which is $\propto$ to core physical size

smaller core ... how ?

- use material w/ higher $B_{sat}$
- allow for larger $R \Rightarrow$ more copper loss

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- Step by step Procedure :

units for formulas

| | |
|---|---|
| $\rho$ | $[\Omega\text{-cm}]$ |
| $I_{max}$ | $[A]$ |
| $L$ | $[H]$ |
| $R$ | $[\Omega]$ |
| $K_u$ | [no units] |
| $B_{max}$ | $[T]$ |
| $A_c$ | $[cm^2]$ |
| $W_A$ | $[cm^2]$ |
| $(MLT)$ | $[cm]$ |

$\left.\begin{matrix} A_c \\ W_A \\ (MLT) \end{matrix}\right\} \rightarrow$ causes scaling factors in design eqns.

<u>Step #1)</u> Pick core big enough

$$K_g \geq \frac{\rho L^2 I_{max}^2}{B_{max}^2 R K_u} 10^8 \quad \text{in } [cm^5]$$

$\hookrightarrow$ take note of values available in catalog

**Step #2)** Pick air gap

$$l_g = \frac{\mu_0 L I_{max}^2}{B_{max}^2 A_c} 10^4 \quad \text{in } [m]$$

**Step #3)** Pick turns

$$n = \text{roundup}\left(\frac{L I_{max}}{B_{max} A_c} 10^4\right)$$

**Step #4)** Check wire size

$$A_w \leq \frac{k_u W_A}{n} \quad \text{in } [cm^2]$$

- usually pick largest possible wire that fits
- must account for insulation
- use American Wire Gauge (AWG) table

also

$$R = \frac{\rho n (MLT)}{A_w} \leftarrow \text{Sanity check}$$

— Thoughts

- Procedure above accounts for saturation, fill factor limits, etc.
- Sanity checks
  1) Look @ "$A_L$" value of datasheet, plug in your $l_g$ calculated from procedure above
  2) Measure w/ LCR meter

## CORES

### Effective core parameters

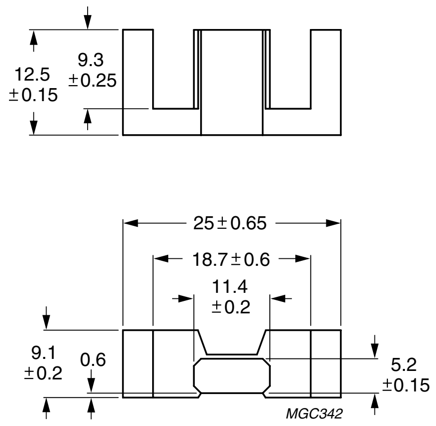
| SYMBOL | PARAMETER | VALUE | UNIT |
|---|---|---|---|
| $\Sigma(I/A)$ | core factor (C1) | 1.00 | $mm^{-1}$ |
| $V_e$ | effective volume | 3300 | $mm^3$ |
| $l_e$ | effective length | 57.0 | mm |
| $A_e$ | effective area | 58.0 | $mm^2$ |
| $A_{min}$ | minimum area | 55.0 | $mm^2$ |
| m | mass of core half | ≈ 8 | g |

$$L = \underbrace{A_L(l_g)}_{A_L \text{ is a fcn of } l_g \text{ as in chart}} n^2$$

from design procedure

should be close-ish to target L value.

specifies nH/turns²




Dimensions in mm.

Fig.1 EFD25/13/9 core half.

### Core halves and sets

$A_L$ measured as a set or in combination with a non-gapped core half, clamping force for $A_L$ measurements, 40 ±20 N.

| GRADE | $A_L$ (nH) | $\mu_e$ | AIR GAP (μm) | TYPE NUMBER |
|---|---|---|---|---|
| 3C90 | 160 ±3% | ≈ 125 | ≈ 570 | EFD25/13/9-3C90-A160 |
| | 250 ±3% | ≈ 196 | ≈ 320 | EFD25/13/9-3C90-A250 |
| | 315 ±5% | ≈ 246 | ≈ 240 | EFD25/13/9-3C90-A315 |
| | 400 ±8% | ≈ 313 | ≈ 180 | EFD25/13/9-3C90-A400 |
| | 630 ±10% | ≈ 493 | ≈ 100 | EFD25/13/9-3C90-A630 |
| | 2200 ±25% | ≈ 1720 | ≈ 0 | EFD25/13/9-3C90 |
| 3C94 | 160 ±3% | ≈ 125 | ≈ 570 | EFD25/13/9-3C94-A160 |
| | 250 ±3% | ≈ 196 | ≈ 320 | EFD25/13/9-3C94-A250 |
| | 315 ±5% | ≈ 246 | ≈ 240 | EFD25/13/9-3C94-A315 |
| | 400 ±8% | ≈ 313 | ≈ 180 | EFD25/13/9-3C94-A400 |
| | 630 ±10% | ≈ 493 | ≈ 100 | EFD25/13/9-3C94-A630 |
| | 2200 ±25% | ≈ 1720 | ≈ 0 | EFD25/13/9-3C94 |
| 3C95 des | 2660 ±25% | ≈ 2085 | ≈ 0 | EFD25/13/9-3C95 |
| 3C96 des | 2000 ±25% | ≈ 1560 | ≈ 0 | EFD25/13/9-3C96 |

| GRADE | $A_L$ (nH) | $\mu_e$ | AIR GAP ($\mu$m) | TYPE NUMBER |
|---|---|---|---|---|
| 3F3 | 160 ±3% | ≈ 125 | ≈ 570 | EFD25/13/9-3F3-A160 |
| | 250 ±3% | ≈ 196 | ≈ 320 | EFD25/13/9-3F3-A250 |
| | 315 ±5% | ≈ 246 | ≈ 240 | EFD25/13/9-3F3-A315 |
| | 400 ±8% | ≈ 313 | ≈ 180 | EFD25/13/9-3F3-A400 |
| | 630 ±10% | ≈ 493 | ≈ 100 | EFD25/13/9-3F3-A630 |
| | 2000 ±25% | ≈ 1560 | ≈ 0 | EFD25/13/9-3F3 |
| 3F35 des | 1500 ±25% | ≈ 1170 | ≈ 0 | EFD25/13/9-3F35 |
| 3F4 des | 160 ±3% | ≈ 125 | ≈ 500 | EFD25/13/9-3F4-A160 |
| | 250 ±3% | ≈ 196 | ≈ 270 | EFD25/13/9-3F4-A250 |
| | 315 ±5% | ≈ 246 | ≈ 290 | EFD25/13/9-3F4-A315 |
| | 400 ±8% | ≈ 313 | ≈ 130 | EFD25/13/9-3F4-A400 |
| | 630 ±10% | ≈ 493 | ≈ 60 | EFD25/13/9-3F4-A630 |
| | 1000 ±25% | ≈ 780 | ≈ 0 | EFD25/13/9-3F4 |
| 3F45 prot | 1000 ±25% | ≈ 780 | ≈ 0 | EFD25/13/9-3F45 |

**Properties of core sets under power conditions**

| GRADE | B (mT) at | CORE LOSS (W) at | | | | |
|---|---|---|---|---|---|---|
| | H = 250 A/m; f = 25 kHz; T = 100 °C | f = 25 kHz; $\hat{B}$ = 200 mT; T = 100 °C | f = 100 kHz; $\hat{B}$ = 100 mT; T = 100 °C | f = 100 kHz; $\hat{B}$ = 200 mT; T = 25 °C | f = 100 kHz; $\hat{B}$ = 200 mT; T = 100 °C | f = 400 kHz; $\hat{B}$ = 50 mT; T = 100 °C |
| 3C90 | ≥330 | ≤ 0.35 | ≤ 0.38 | – | – | – |
| 3C94 | ≥330 | – | ≤ 0.30 | – | ≤ 1.8 | – |
| 3C95 | ≥330 | – | – | ≤ 1.95 | ≤ 1.85 | – |
| 3C96 | ≥330 | – | ≤ 0.22 | – | ≤ 1.4 | ≤ 0.6 |
| 3F35 | ≥300 | – | – | – | – | ≤ 0.28 |
| 3F3 | ≥315 | – | ≤ 0.38 | – | – | ≤ 0.66 |
| 3F4 | ≥300 | – | – | – | – | – |

**Properties of core sets under power conditions (continued)**

| GRADE | B (mT) at | CORE LOSS (W) at | | | | |
|---|---|---|---|---|---|---|
| | H = 250 A/m; f = 25 kHz; T = 100 °C | f = 500 kHz; $\hat{B}$ = 50 mT; T = 100 °C | f = 500 kHz; $\hat{B}$ = 100 mT; T = 100 °C | f = 1 MHz; $\hat{B}$ = 30 mT; T = 100 °C | f = 1 MHz; $\hat{B}$ = 50 mT; T = 100 °C | f = 3 MHz; $\hat{B}$ = 10 mT; T = 100 °C |
| 3C90 | ≥330 | – | – | – | – | – |
| 3C94 | ≥330 | – | – | – | – | – |
| 3C95 | ≥330 | – | – | – | – | – |
| 3C96 | ≥330 | ≤ 1.2 | – | – | – | – |
| 3F35 | ≥300 | ≤ 0.42 | ≤ 3.4 | – | – | – |
| 3F3 | ≥315 | – | – | – | – | – |
| 3F4 | ≥300 | – | – | ≤ 1.0 | – | ≤ 1.6 |
| 3F45 | ≥300 | – | – | ≤ 0.75 | ≤ 2.8 | ≤ 1.25 |

Our cores look like