K_g and K_{gfe} Methods

- Two closed-form methods to solve for the optimal inductor design *under certain constraints/assumptions*
- Neither method considers losses other than DC copper and (possibly) steinmetz core loss
- Both methods particularly well suited to spreadsheet/iterative design procedures

	K_g	K_{gfe}
Losses	DC Copper (specified)	DC Copper, SE Core Loss (optimized)
Saturation	Specified	Checked After
B_{max}	Specified	Optimized

K_g Method

- Method useful for filter inductors where ΔB is small
- Core loss is not included, but may be significant particularly if large ripple is present
- Copper loss is specified through a set target resistance
- The desired B_{max} is given as a constraint
- Method does not check feasibility of design; must ensure that air gap is not extremely large or wire size excessively small
- Simple first-cut design technique; useful for determining approximate core size required
- Step-by-step design procedure included on website

The following quantities are specified, using the units

Wire resistivity	ρ	(Ω-cm)
Peak winding current	I_{max}	(A)
Inductance	L	(H)
Winding resistance	R	(Ω)
Winding fill factor	K_u	
Core maximum flux density	B_{max}	(T)

The core dimensions are expressed in cm:

Core cross-sectional area	A_c	(cm^2)
Core window area	W_A	(cm^2)
Mean length per turn	MLT	(cm)

$$K_g \geq \frac{\rho L^2 I_{max}^2}{B_{max}^2 R K_u} 10^8 \qquad (\text{cm}^5)$$

$$\ell_g = \frac{\mu_0 L I_{max}^2}{B_{max}^2 A_c} 10^4 \qquad (\text{m})$$

$$n = \frac{L I_{max}}{B_{max} A_c} 10^4$$

$$A_W \leq \frac{K_u W_A}{n} \qquad (\text{cm}^2)$$

$$R = \frac{\rho n \,(MLT)}{A_w} \qquad (\Omega)$$

K_{gfe} Method

- Method useful for cases when core loss and copper loss are expected to be significant
- Saturation is not included in the method, rather it must be checked afterward
- Enforces a design where the sum of core and copper is minimized

K_{gfe} Procedure

The following quantities are specified, using the units noted:

Wire effective resistivity	ρ	(Ω-cm)
Total rms winding current, ref to pri	I_{tot}	(A)
Desired turns ratios	n_2/n_1, n_3/n_1, etc.	
Applied pri volt-sec	λ_1	(V-sec)
Allowed total power dissipation	P_{tot}	(W)
Winding fill factor	K_u	
Core loss exponent	β	
Core loss coefficient	K_{fe}	(W/cm^{3}T$^\beta$)

Other quantities and their dimensions:

Core cross-sectional area	A_c	(cm^2)
Core window area	W_A	(cm^2)
Mean length per turn	MLT	(cm)
Magnetic path length	ℓ_e	(cm)
Wire areas	$A_{w1}, \ldots$	(cm^2)
Peak ac flux density	ΔB	(T)

$$K_{gfe} \geq \frac{\rho \lambda_1^2 I_{tot}^2 K_{fe}^{(2/\beta)}}{4 K_u \left(P_{tot}\right)^{((\beta+2)/\beta)}} 10^8$$

$$\Delta B = \left[10^8 \; \frac{\rho \lambda_1^2 I_{tot}^2}{2 K_u} \; \frac{(MLT)}{W_A A_c^3 \ell_m} \; \frac{1}{\beta K_{fe}} \right]^{\left(\frac{1}{\beta+2}\right)}$$

$$n_1 = \frac{\lambda_1}{2 \Delta B A_c} 10^4 \qquad n_k = n_1 \frac{n_k}{n_1}$$

$$\alpha_k = \frac{n_k I_k}{n_1 I_{tot}} \qquad A_{wk} \leq \frac{\alpha_2 K_u W_A}{n_2}$$

Verify

K_{gfe} Method: Summary

- Method enforces an operating ΔB in which core and copper losses are minimized
- Only takes into account losses from standard Steinmetz equation; not correct unless waveforms are sinusoidal
- Does not consider high frequency losses
- Step-by-step design procedure included on website