Magnetic design formulas

Inductance of wound cores

The Inductance for given numbers of turns can be calculated by using the following equation.

$$L = \frac{0.4\pi\mu N^2 A \times 10^{-2}}{l}$$

$$L_N = A_L \times N^2 \times 10^{-3}$$

L = Inductance(μH)

μ = Core permeability

N = Number of turns

A = Core cross section area(cm^2)

l = Mean magnetic path length(cm)

L_N = Inductance at N turns(μH)

A_L = Nominal inductance((ηH/N^2)

Permeability – Flux Density – Magnetizing Force

$$H = \frac{0.4\pi NI}{l} \quad \text{(Ampere's Law)}$$

$$Bmax = \frac{Erms \times 10^8}{4.44fAN} \quad \text{(Faraday's Law)}$$

$$\mu = \frac{B}{H}$$

H = Magnetizing force(oersteds)

N = Number of turns

I = Peak magnetizing current(amperes)

l = Mean magnetic path length(cm)

Bmax = Maximum flux density(gauss)

Erms = Voltage across coil(volts)

A = Core cross section area(cm^2)

f = Frequency(Hz)

μ = Material permeability

Inductance calculation by permeability vs. DC Bias Curves

- Inductor specification
  - Core part no.: OR400S125 ------- Sendust core
  - Number of winding : 20turns
  - Applied current : DC 10 Amperes
- Calculation procedure

  1) Inductance calculation at 0A

Magnetic design formulas

Inductance could be calculated by below equation.

$$L_N = A_L \times N^2 \times 10^{-3}$$

When permeability is 125, A_L value of OR400S125 would be 168nH/N² in the table at page 54, Therefore inductance at 0 ampere is calculated as below,

$$L \text{ at } 0A = 168 \times 20^2 \times 10^{-3} = 67.2(\mu H)$$

2) Magnetizing force(H:Oe) is calculated by Ampere's law to achieve the roll off.

$$H = \frac{0.4 \times \pi \times NI}{l} = \frac{0.4 \times \pi \times 20 \times 10}{9.84} = 25.53(Oe)$$

3) When the magnetizing force(H) is 25.53(Oe), yielding 68% of initial permeability on page 14. Therefore, the inductance at 10A is as below,

$$L(10A) = 67.2 \times 0.68 = 45.70(\mu H)$$

Core loss

Core loss may be subdivided into three principal components, hysteresis loss and eddy-current loss, residual loss. The energy consumed in magnetizing and demagnetizing magnetic material is called the hysteresis loss. It is proportional to the frequency and to the area inside the hysteresis loop for the material used. As far as hysteresis loss and residual loss in powder cores, they are exceptionally low.

$$\frac{Rac}{\mu L} = aBmaxf + cf + ef^2$$

- Eddy current loss
- Residual loss
- Hysteresis loss
- Total loss factor

Rac=effective resistance(ohms)
a= hysteresis loss coefficient
c= residual loss coefficient
e= eddy current loss coefficient
μ = material permeability
f = frequency(Hz)
L = inductance
Bmax = maximum flux density(gauss)

Magnetic design formulas

Effective Core Parameters

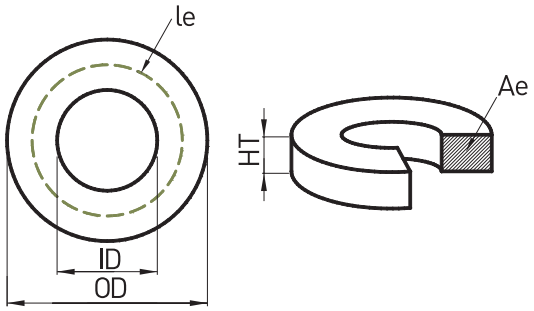
For toroidal powder cores, the effective area(A) is the same as the cross sectional area. By definition and Ampere's Law, the effective magnetic path length is the ratio of ampere-turns(NI) to the average magnetizing force across the core area from inside diameter to outside diameter. Using Ampere's Law and averaging the magnetizing force gives the formula for effective path length.

$$le = \frac{\pi(OD-ID)}{\ln\left(\frac{OD}{ID}\right)}$$

$$Ae = \frac{(OD-ID)}{2} \times HT$$

$$Ve = le \times Ae$$

$$\text{Window Area(Wa)} = \pi \times (ID/2)^2$$



OD = outside diameter of core, before coating(cm)
ID = inside diameter of core, before coating(cm)
HT = height of core, before coating(cm)
Ae = effective cross section area(cm^2)
le = effective mean magnetic path length(cm)
Ve = effective core volume(cm^3)

Q Factor

The Q factor is defined as the ratio of reactance to the effective resistance for an inductor and thus indicates its quality. The Q of wound core can be calculated using the following formula, when neglecting the effects of self-resonance caused by the distributed capacitance resulting from the differential voltage between adjacent turns.

$$Q = \frac{\omega L}{Rdc+Rac+Rd} = \frac{\text{Reactance}}{\text{Total Resistance}}$$

Q = quality factor
$\omega = 2\pi f$(Hz)
L = inductance(H)
Rdc =DC winding resistance (ohm)
Rac = resistance due to core loss (ohm)
Rd = resistance due to winding dielectric loss (ohm)

Wire Table

AWG Wire Size No	Resistance Ω /meter	Wire O.D. (cm) (Heavy)	Wire Area		Current Capacity, Amps (listed by columns of amps/sq.cm.)			
			cm^2 ($x10^{-3}$)	Cir-Mils	200	400	600	800
8	0.00207	0.334	87.62	17295	16.5	33.0	49.5	66.0
9	0.00259	0.298	69.75	13768	13.1	26.2	39.3	52.4
10	0.00328	0.267	55.99	11052	10.4	20.8	31.2	41.6
11	0.00413	0.238	44.49	8782	8.23	16.4	24.6	32.8
12	0.00522	0.213	35.63	7034	6.53	13.1	19.6	26.1
13	0.00656	0.190	28.41	5609	5.18	10.4	15.5	20.8
14	0.00827	0.171	23.07	4555	4.11	8.22	12.3	16.4
15	0.01043	0.153	18.36	3625	3.26	6.52	9.78	13.0
16	0.01319	0.137	14.72	2906	2.58	5.16	7.74	10.3
17	0.01657	0.122	11.77	2323	2.05	4.10	6.15	8.20
18	0.02100	0.110	9.417	1859	1.62	3.25	4.88	6.50
19	0.02640	0.0980	7.543	1489	1.29	2.58	3.87	5.16
20	0.03320	0.0879	6.068	1198	1.02	2.05	3.08	4.10
21	0.04200	0.0785	4.840	955.4	0.812	1.63	2.44	3.25
22	0.05310	0.0701	3.859	761.9	0.640	1.28	1.92	2.56
23	0.06660	0.0632	3.137	619.3	0.511	1.02	1.53	2.04
24	0.08430	0.0566	2.516	496.7	0.404	0.808	1.21	1.62
25	0.1063	0.0505	2.003	395.4	0.320	0.641	0.962	1.28
26	0.1345	0.0452	1.605	316.7	0.253	0.506	0.759	1.01
27	0.1686	0.0409	1.314	259.3	0.202	0.403	0.604	0.806
28	0.2140	0.0366	1.0521	207.7	0.159	0.318	0.477	0.636
29	0.2660	0.0330	0.8553	168.8	0.128	0.255	0.382	0.510
30	0.3410	0.0295	0.6835	134.9	0.100	0.200	0.300	0.400
31	0.4300	0.0267	0.5599	110.525	0.0792	0.158	0.237	0.316
32	0.5310	0.0241	0.4562	90.047	0.0640	0.128	0.192	0.256
33	0.6760	0.0216	0.3664	72.334	0.0504	0.101	0.152	0.202
34	0.8560	0.0191	0.2850	56.264	0.0397	0.0794	0.119	0.159
35	1.086	0.0170	0.2275	44.911	0.0314	0.0627	0.0940	0.125
36	1.362	0.0152	0.1824	36.009	0.0250	0.0500	0.0750	0.100
37	1.680	0.0140	0.1533	30.257	0.0203	0.0405	0.0608	0.0810
38	2.130	0.0125	0.1217	24.031	0.0160	0.0320	0.0480	0.0640
39	2.780	0.01092	0.0937	18.488	0.0123	0.0245	0.0368	0.0490
40	3.510	0.00965	0.0731	14.4375	0.00961	0.0192	0.0288	0.0384
41	4.330	0.00864	0.0586	11.5735	0.00785	0.0157	0.0236	0.0314
42	5.450	0.00762	0.0456	9.0022	0.00625	0.0125	0.0188	0.0250
43	7.020	0.00686	0.0370	7.2960	0.00484	0.00968	0.0145	0.0194
44	8.500	0.00635	0.0317	6.2515	0.00400	0.00800	0.0120	0.0160
45	10.99	0.00546	0.0234	4.6219	0.00309	0.00618	0.00927	0.0124

Winding Data

Core Size	Window Area		Wire Length / Turn				Wound Dimension(unity)			
			100% (unity)		0%		OD(max)		HT(max)	
	cm^2	Cir-Mils	cm	ft	cm	ft	cm	in	cm	in
OR035	0.018	3,600	0.70	0.023	0.59	0.019	0.50	0.20	0.27	0.11
OR039	0.031	6,080	1.05	0.034	0.89	0.029	0.58	0.23	0.48	0.19
OR046	0.029	5,780	1.14	0.037	0.99	0.032	0.67	0.26	0.49	0.20
OR063	0.041	8,100	1.35	0.044	1.16	0.038	0.88	0.35	0.54	0.21
OR066	0.041	8,100	1.33	0.044	1.13	0.037	0.91	0.36	0.51	0.20
OR067	0.038	7,570	1.75	0.057	1.62	0.053	0.92	0.36	0.74	0.29
OR068	0.094	18,500	1.79	0.059	1.56	0.051	0.96	0.38	1.00	0.39
OR078	0.092	18,200	1.60	0.052	1.27	0.042	1.10	0.43	0.67	0.27
OR096	0.143	28,200	1.79	0.059	1.37	0.045	1.34	0.53	0.74	0.29
OR097	0.143	28,200	1.93	0.063	1.52	0.050	1.34	0.53	0.82	0.32
OR102	0.164	32,400	1.99	0.065	1.54	0.051	1.41	0.55	0.85	0.33
OR112	0.273	53,800	2.20	0.072	1.55	0.051	1.57	0.62	0.90	0.35
OR127	0.383	75,600	2.49	0.082	1.75	0.057	1.82	0.72	1.15	0.45
OR166	0.712	140,600	3.22	0.106	2.20	0.072	2.37	0.93	1.52	0.60
OR172	0.638	126,000	3.67	0.120	2.33	0.076	2.49	0.98	1.63	0.64
OR203	1.143	225,600	3.67	0.120	2.33	0.076	2.92	1.15	1.74	0.68
OR229	1.407	277,700	4.29	0.141	2.70	0.089	3.26	1.28	1.98	0.78
OR234	1.488	293,800	4.49	0.147	3.00	0.098	3.35	1.32	2.14	0.84
OR270	1.560	308,000	5.23	0.172	3.76	0.123	3.73	1.47	2.40	0.94
OR330	2.926	577,600	5.93	0.195	3.78	0.124	4.67	1.84	2.80	1.10
OR343	3.994	788,500	5.87	0.193	3.23	0.106	5.01	1.97	2.90	1.14
OR358	3.643	719,100	6.22	0.204	3.78	0.124	5.11	2.01	2.96	1.17
OR400	4.269	842,700	7.38	0.242	4.81	0.158	5.64	2.22	3.52	1.39
OR467	4.269	842,700	8.66	0.284	6.22	0.204	6.38	2.51	3.87	1.53
OR468	6.109	1,206,000	8.34	0.274	5.20	0.171	6.63	2.61	3.98	1.57
OR508	7.518	1,484,000	8.51	0.279	4.95	0.162	7.24	2.85	4.06	1.60
OR571	5.137	1,014,000	9.02	0.296	6.46	0.212	7.57	2.98	3.40	1.34
OR572	9.478	1,871,000	9.33	0.306	5.30	0.174	8.13	3.20	4.44	1.75
OR777	17.98	3,550,000	10.40	0.341	5.90	0.194	11.20	4.40	5.43	2.14

Core Size		035	039 046	063	066 067	068 078	096 097	102	112	127	166	172	203	229	234	270	330	343	358	400	467	468	508	571	572	610	777
ID (mm)		1.58	2.04	2.29	2.29	3.45	4.27	4.57	5.89	6.99	9.53	9.02	12.07	13.39	13.77	14.10	19.30	22.60	21.50	23.30	23.32	27.90	30.90	25.60	34.70	31.37	48.00
Wire No.	Wire Ø (mm)	Turns / Single Layer																									
8	3.340																15	18	17	18	18	23	25	20	29	25	41
9	2.980														11	11	17	20	19	21	21	26	29	23	33	29	47
10	2.670													12	13	13	19	23	22	24	24	29	33	26	37	33	53
11	2.380												12	14	15	15	22	26	25	27	27	33	37	30	42	37	60
12	2.130												14	16	17	17	25	30	28	31	31	37	42	34	48	42	67
13	1.902										12	11	16	18	19	20	28	34	32	35	35	42	47	39	54	47	76
14	1.714										14	13	18	21	22	22	32	38	36	39	39	47	53	43	60	53	84
15	1.529										16	15	21	24	25	25	36	43	41	44	44	54	60	49	68	60	95
16	1.369								10	12	18	17	24	27	28	29	41	48	46	50	50	60	67	55	76	67	106
17	1.224								11	14	21	19	27	31	32	33	46	54	52	56	56	68	76	62	85	75	119
18	1.095								13	16	24	22	31	35	36	37	52	61	58	63	63	76	85	70	96	85	134
19	0.980								15	19	27	25	35	39	40	42	58	69	65	71	71	86	95	78	108	95	150
20	0.879						12	13	17	21	30	29	39	44	46	47	65	77	73	80	80	96	107	88	120	106	168
21	0.785						13	15	20	24	34	32	45	50	51	53	74	87	82	90	90	108	120	99	135	119	188
22	0.701						15	17	23	28	39	37	50	56	58	60	83	98	93	101	101	121	135	111	152	134	211
23	0.632						18	19	26	31	44	41	56	63	65	66	92	109	103	112	112	135	150	124	169	149	235
24	0.566					15	20	22	29	35	49	46	63	71	73	75	103	122	116	126	126	152	168	138	189	165	263
25	0.505					18	23	25	33	40	56	52	71	80	82	84	116	137	130	141	141	170	188	156	212	185	295
26	0.452			12	12	20	26	28	37	45	63	59	80	89	92	94											
27	0.409			14	13	23	29	31	42	50	70	66	89	99	102	105											
28	0.366		13	16	16	26	33	36	47	56	78	74	100	111													
29	0.330	11	15	18	17	29	37	40	52	63	87	82															
30	0.295	13	17	21	20	33	42	45	59	71	98	92															
31	0.267	14	20	23	22	37	47	50	66	79																	
32	0.241	16	22	26	25	41	52	56	73	87																	
33	0.216	18	25	30	28	46	58	63	82	98																	
34	0.191	21	29	34	33	53	67	72	93	112																	
35	0.170	24	33	38	37	60	75	81																			
36	0.152	28	37	44	42	67	84	91																			
37	0.140	31	41	48	46	73																					
38	0.125	35	43	54	52																						
39	0.109	40	53	62	60																						
40	0.097	46	61	71	68																						