

Switched Mode Power Conversion

Semester II Academic Year 2025-26

Lecture 31

10th April 2026

- How to design the isolation transformers?
- How to design the inductors?
- Which capacitors to select?

Transformers

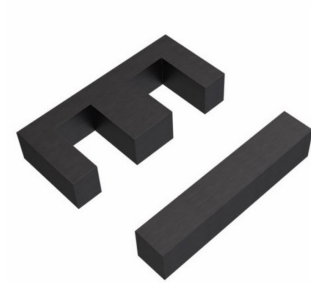
- Core
- Winding

Transformers

— Core



E type



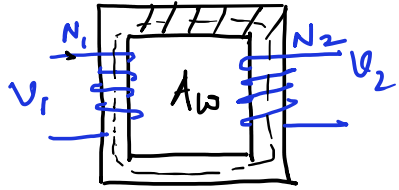
EI core



Toroidal

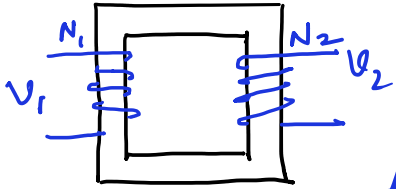
How to select core dimension?

Transformers



l_m = magnetic path length
 A_c = Core cross sectional area
 A_w = Window area

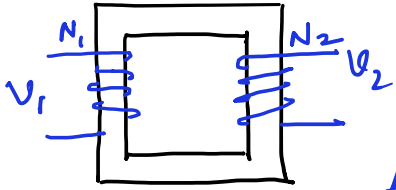
Transformers



l_m = magnetic path length
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Ampere's Law : $B \cdot l_m = \mu N i$
 $\Phi = B A_c = \frac{\mu N i}{l_m} A_c$
 $\Phi \propto i$

Transformers



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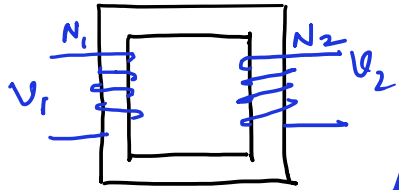
Faraday's Law : $e = -N \frac{d\Phi}{dt}$

$$e_{1pk} = N_1 \Phi_{pk} \omega$$
$$= N_1 B_{pk} A_c \omega$$

$$\therefore e_{1rms} = \frac{2\pi f}{\sqrt{2}} N_1 B_{pk} A_c \quad (\text{Assuming sine})$$

$$\Rightarrow N_1 = \frac{e_{1rms}}{\sqrt{2}\pi f} \cdot \frac{1}{B_{pk} A_c}$$
$$N_2 = \frac{e_{2rms}}{\sqrt{2}\pi f} \cdot \frac{1}{B_{pk} A_c}$$

Transformers



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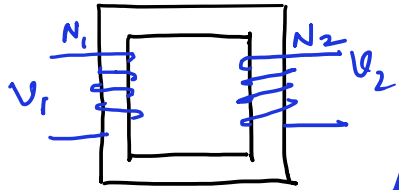
$$N_2 = \frac{e_{2rms}}{\sqrt{2} \pi f} \cdot \frac{1}{B_{pk} A_c}$$

Total area of conductor in window

$$= \frac{N_1 I_1}{J} + \frac{N_2 I_2}{J} = \frac{2 N_1 I_1}{J}$$

$$= \frac{2 (e_{rms} I_1)}{\sqrt{2} \pi f B_{pk} A_c J} = \frac{\sqrt{2} (VA)}{\pi f B_{pk} A_c J} = K_w A_w$$

Transformers



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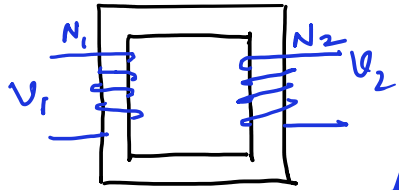
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Transformers



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K_w = Fraction of window area occupied by conductors

$$A_w A_c = \frac{\sqrt{2} (VA)}{\pi f B_{pk} J K_w} \quad [\text{Area product}]$$

* Core to be selected should have more area product than calculated

Transformers

Appendix II

Properties of Few Ferrite Cores

Cores without air gap	Mean length per turn (mm)	Mean magnetic length l_m (mm)	Core cross-section area A_c (mm ²)	Window area, A_w (mm ²)	Area product A_p (mm ⁴)
Pot Cores					
P18/11	35.6	26	43	27	1161
P26/16	52	37.5	94	53	4982
P30/19	60	45.2	136	75	10200
P36/22	73	53.2	201	101	20301
P42/29	86	68.6	264	181	47784
P66/56	130	123	715	518	370370
EE Cores					
E20/10/5	38	42.8	31	47.8	1481
E25/9/6	51.2	48.8	40	78	3120
E25/13/7	52	57.5	55	87	4785
E30/15/7	56	66.9	59.7	119	7104.3
E36/18/11	70.6	78	131	141	18471
E42/21/9	77.6	108.5	107	256	27392
E42/21/15	93	97.2	182	256	46592
E42/21/20	99	98	235	256	60160
E65/32/13	150	146.3	266	537	142842
UU Cores					
UU 15	44	48	32	59	1888
UU 21	55	68	55	101	5555
UU 23	64	74	61	136	8296
UU 60	183	184	196	1165	228340
UU 100	29.3	308	645	2914	1879530
Toroids					
T 10	12.8	23.55	6.2	19.6	121.52
T 12	19.2	30.4	12	44.2	530.4
T 16	24.2	38.7	20	78.5	1570
T 20	25.2	47.3	22	95	2090
T 27	34.1	65.94	42	165.1	6934.2
T 32	39.6	73	61	165.1	10071.1
T 45	54.7	114.5	93	615.7	57260.1

Appendix III

Wire Size Table

SWG	Diameter with enamel (mm)	Area of bare conductor (mm ²)	R/km @20°C Ω	Weight (kg/km)
45	0.086	0.003973	4,340	0.0369
44	0.097	0.005189	3,323	0.0481
43	0.109	0.006567	2,626	0.061
42	0.119	0.008107	2,127	0.075
41	0.132	0.009810	1,758	0.0908
40	0.142	0.011675	1,477	0.1079
39	0.152	0.013700	1,258	0.1262
38	0.175	0.018240	945.2	0.1679
37	0.198	0.023430	735.9	0.2202
36	0.218	0.029270	589.1	0.2686
35	0.241	0.035750	482.2	0.3281
34	0.264	0.042890	402	0.3932
33	0.287	0.050670	340.3	0.465
32	0.307	0.059100	291.7	0.5408
31	0.33	0.06818	252.9	0.6245
30	0.351	0.07791	221.3	0.7121
29	0.384	0.09372	184	0.8559
28	0.417	0.11100	155.3	1.014
27	0.462	0.13630	126.5	1.245
26	0.505	0.16420	105	1.499
25	0.561	0.20270	85.1	1.851
24	0.612	0.24520	70.3	2.233
23	0.665	0.29190	59.1	2.655
22	0.77	0.39730	43.4	3.607
21	0.874	0.51890	33.2	4.702
20	0.978	0.65670	26.3	5.939
19	1.082	0.81070	21.3	7.324

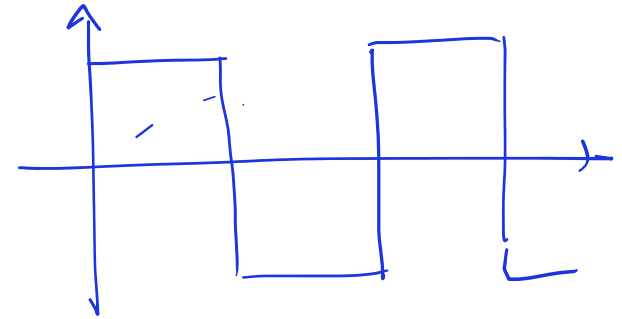
Example Design [With ferrite Core]

$$V_p = 400V \text{ (square wave)}$$

$$f_{sw} = 100 \text{ kHz}$$

$$V_s = 60V \text{ (square wave)}$$

$$VA = \underline{\underline{1.6 \text{ kVA}}}$$



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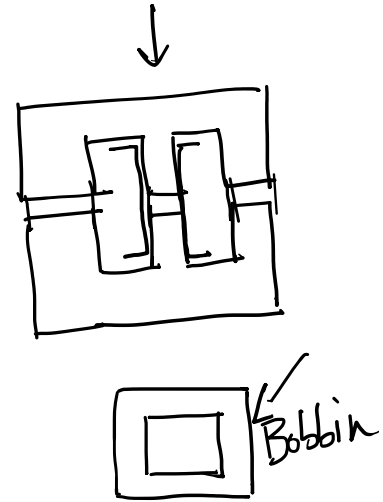
Step-1

$$A_w A_c = \frac{\sqrt{2} (VA)}{\pi f B_{pk} J K_w}$$

$$= 2.4 \times 10^{-8} \text{ m}^4$$

$$= 24000 \text{ mm}^4$$

$$= 2.4 \text{ cm}^4$$



$$B_{pk} = 0.2 \text{ T}$$

$$f = 100 \text{ kHz}$$

$$J = 5 \text{ A/mm}^2$$

$$K_w = 0.3$$

Transformers

Step - 2

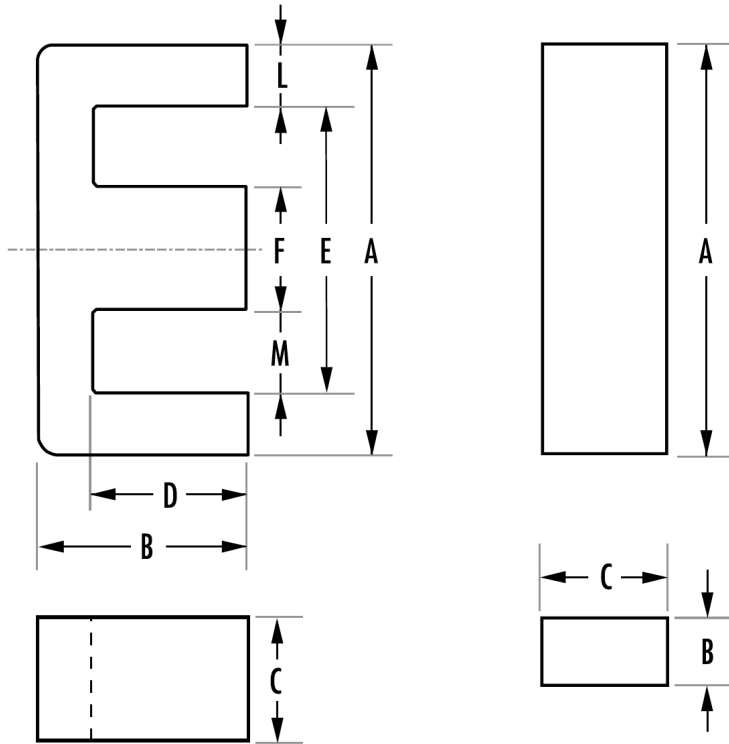
TYPE/SIZE	ORDERING CODE	MAGNETIC DATA						HARDWARE
		l_c (mm)	A_c (mm ²)	A_c min (mm ²)	V_c (mm ³)	$W_a A_c$ (cm ⁴)	Weight (grams per set)	Bobbins
E 40/17/11	0_44011EC	76.7	127	114	9,780	1.26	49	
E 42/21/9	0_44016EC	98.4	107	106	10,500	1.65	52	
→ E 43/21/15	0_44020EC	97.0	178	175	17,300	3.55	87	PCB4020N1
I 43/6/15	0_44020IC	67.1	177	176	11,900	1.36	60	PCB4020N1
E 43/21/20	0_44022EC	97.0	233	233	22,700	4.22	114	PCB4022N1
E 42/33/20	0_44033EC	145	236	234	34,200	6.36	164	
E 41/17/12	0_44317EC	77.0	149	142	11,500	1.88	57	PCB4317M1
E 47/20/16	0_44721EC	88.9	234	226	20,800	3.3	103	PCB4721M1
E 56/28/21	0_45528EC	124	353	345	44,000	9.78	212	PCB5528WC
E 56/28/25	0_45530EC	123	420	411	52,000	12.1	255	PCB5530FA
E 56/24/19	0_45724EC	107	337	337	36,000	6.98	179	PCB5724M1
E 60/22/16	0_46016EC	110	248	240	27,200	5.74	135	
E 65/32/27	0_46527EC	147	540	530	79,000	23.5	410	00B652701
E 70/33/32	0_47133EC	149	683	676	102,000	23.3	495	
E 72/28/19	0_47228EC	137	368	363	50,300	15.0	250	00B722801
E 80/38/20	0_48020EC	184	392	392	72,300	31.6	357	00B8020B1
E 100/59/27	0_49928EC	274	738	692	202,000	90.6	980	

$> 2.4 \text{ cm}^4$

$$N_1 = \frac{E_{rms}}{\sqrt{2} \pi f} \frac{1}{B_{pm} A_c} = 23$$

$$N_2 = 4$$

Step-3



Transformers

TYPE/SIZE	ORDERING CODE	DIMENSIONS (mm)							
		A	B	C	D	E	F	L	M
E 43/21/15	0_44020EC	43.0 + 0/-1.7	21.0 ± 0.2	15.2 + 0/-0.6	14.8 + 0.6/-0	29.5 + 1.4/-0	12.2 + 0/-0.5	6.75 nom	8.65 nom

Conductor area %

$$A_1 = \frac{4.4}{5} = 0.89 \text{ mm}^2 \quad [\text{AWG 18} \quad 0.823 \text{ mm}^2]$$

$$A_2 = 5.93 \text{ mm}^2 \quad [\text{AWG 10} \quad 5.26 \text{ mm}^2]$$

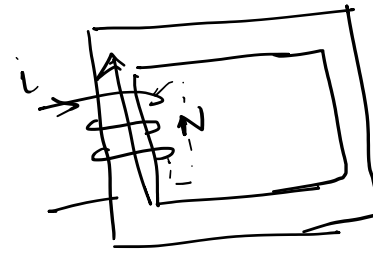
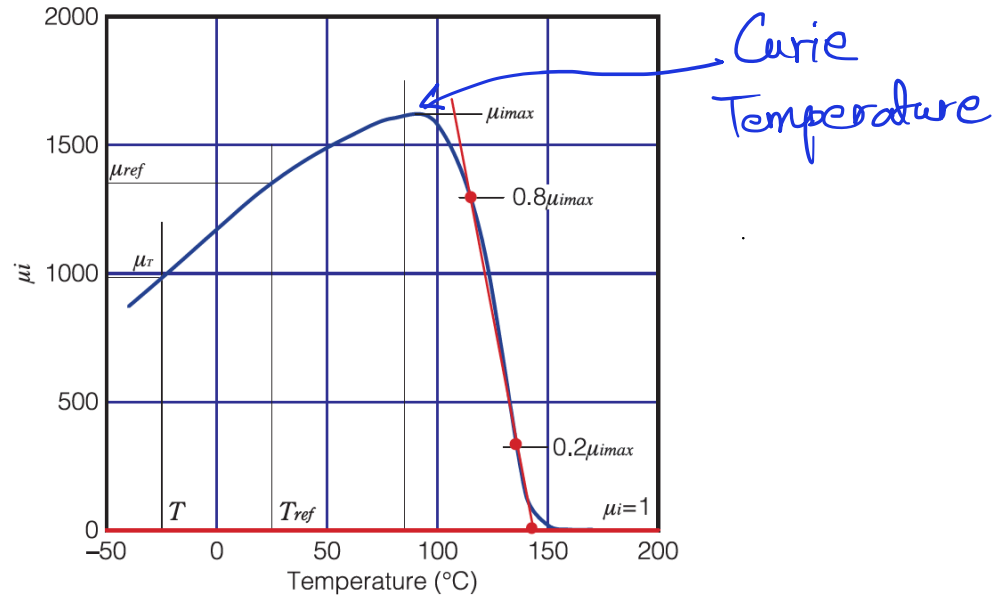
Total area of cond.

$$= (23 \times 0.823) + (4 \times 5.26) \cong 40 \text{ mm}^2$$

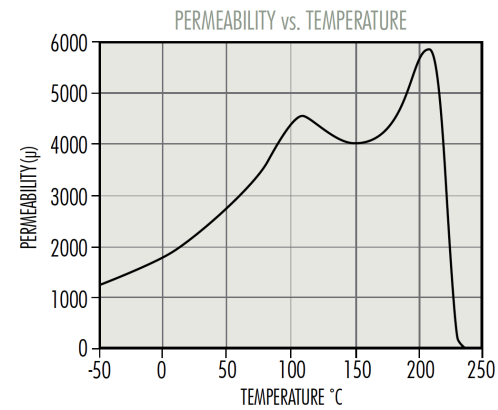
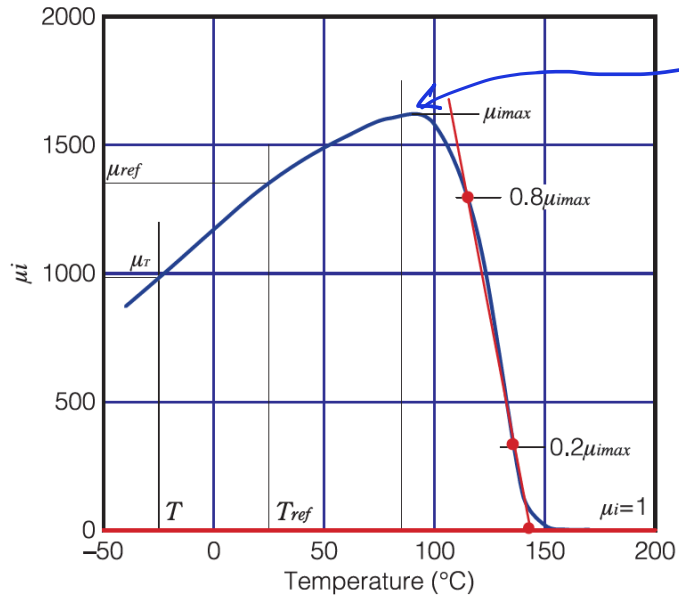
$$A_w = 2(8.65 \times 14.8) = 256.04 \text{ mm}^2$$

$$K_w = \frac{40}{256.04} = \underline{\underline{0.16}}$$

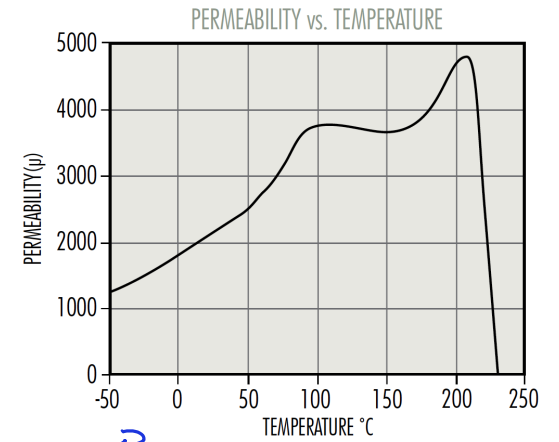
Core Characteristics



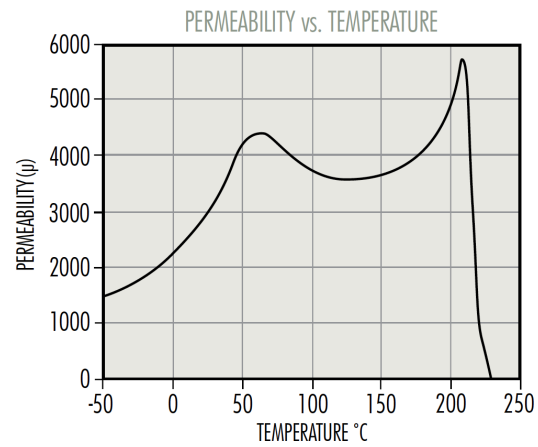
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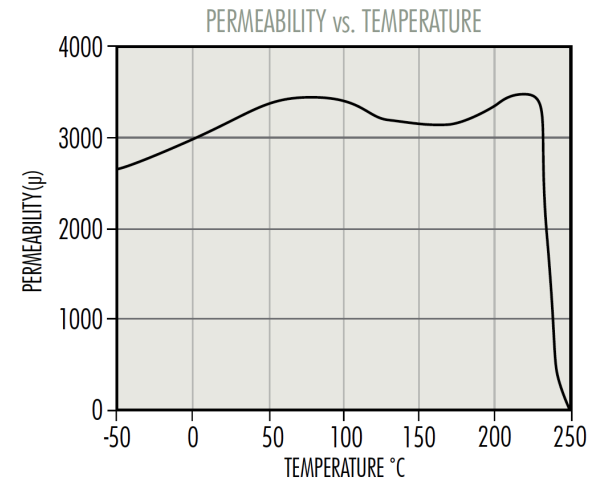
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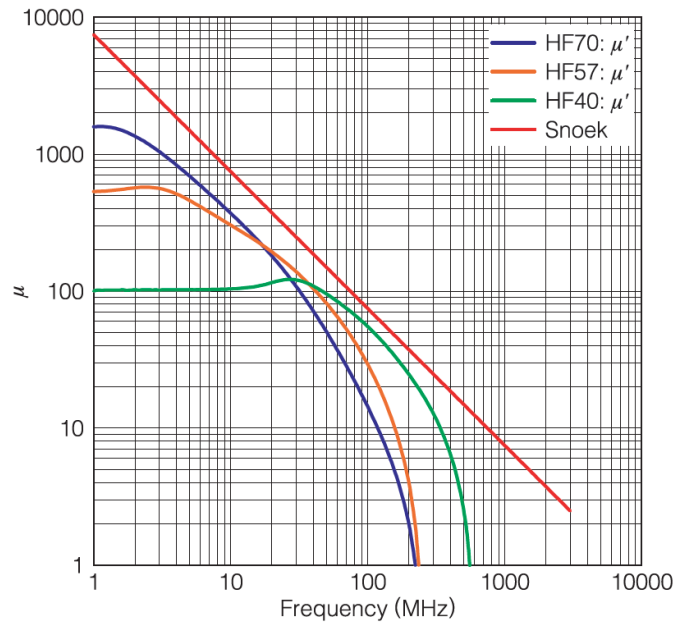


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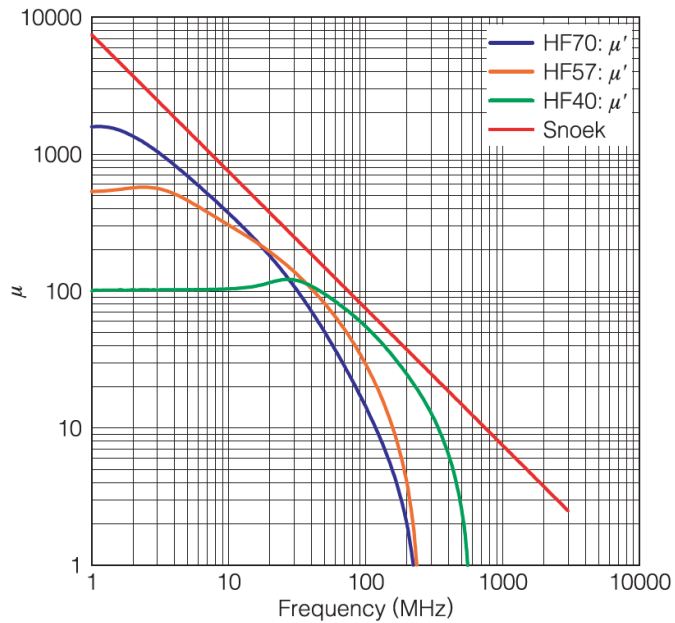
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Core Characteristics



Snoek's limit

Core Characteristics



Snoek's limit

