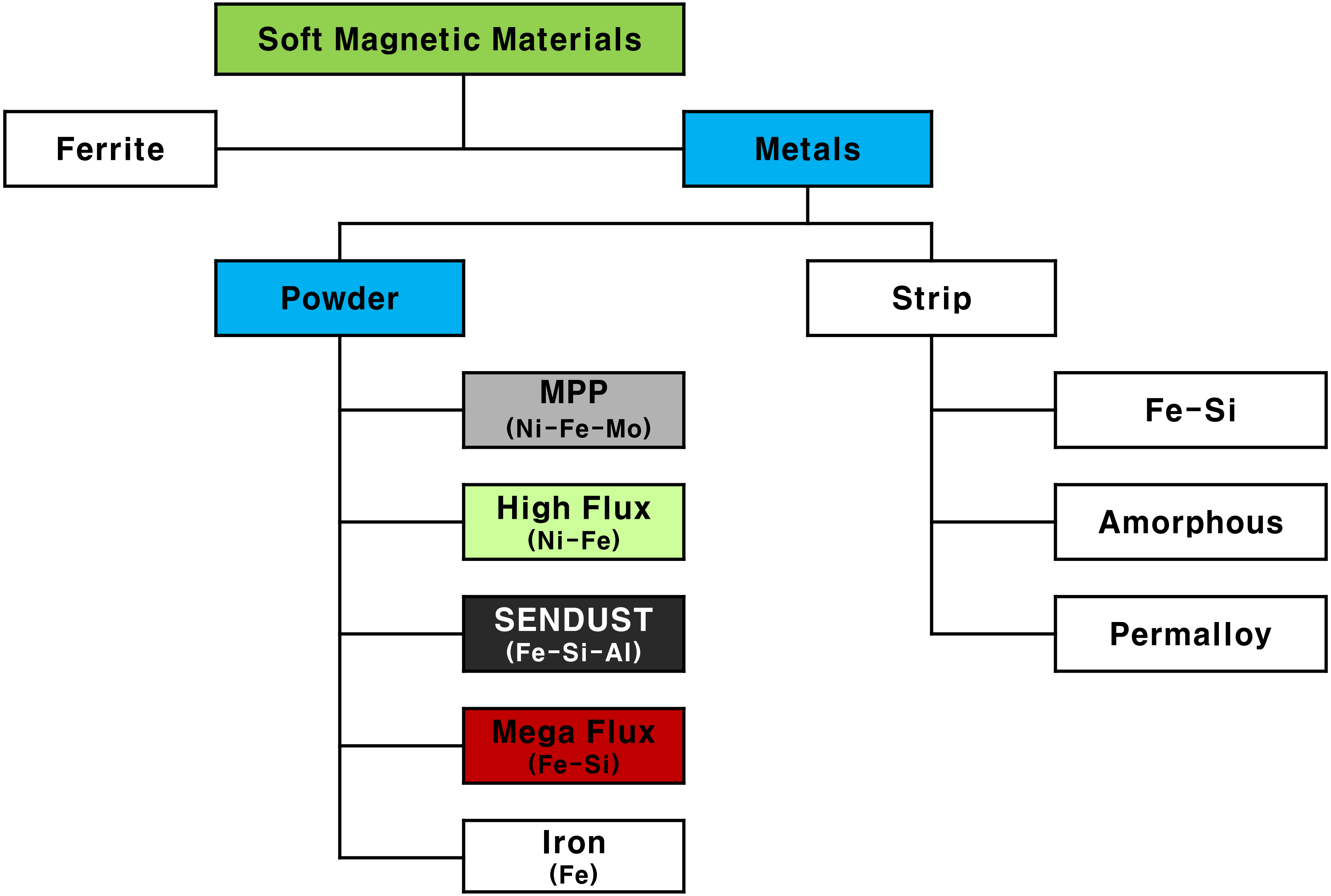
Changsung Corp.

Soft Magnetic Powder Core

1. Toroidal Core Design
2. Special Shape Powder Core
3. Solar Inverter & Magnetic Materials
4. Q & A

-CSC-

1. Soft Magnetic Materials

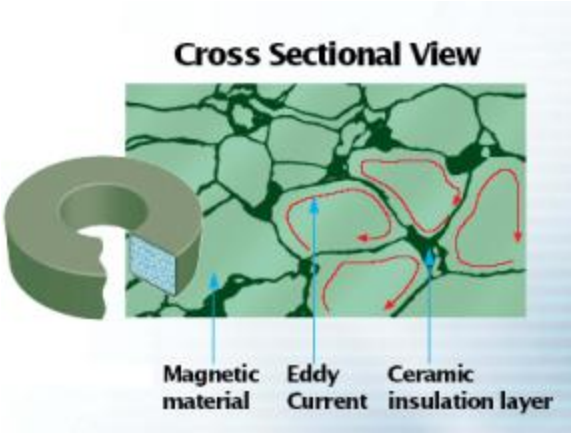


1. Toroidal Core Design

2. What is Powder Core ?

Powder Cores are distributed air gap cores made from ferrous alloy powders for low losses at elevated frequencies.

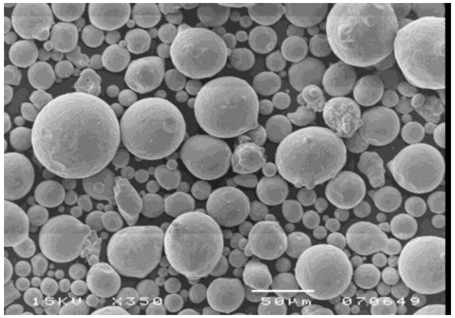
Small air gaps distributed evenly throughout the cores increase the amount of DC that can be passed through the winding before core saturation occurs.



3. Manufacturing process

Powder Making → Ceramic Insulation → Pressing → Core Annealing → Core Finish → Inspection

Material	Composition
High Flux	Ni + Fe Alloy
Sendust	Fe + Si +Al Alloy
Mega Flux	Fe + Si Alloy
MPP	Ni + Fe + Mo Alloy



4. Material Comparison

Materials	Perm. (μ_i)	Bs (kG)	Core Loss	DC Bias	Relative Cost	Temp. Stability	Curie Temp [℃]
MPP	26-200	7	Lower	Better	High	Best	450
High Flux	26-160	15	Low	Best	Medium	Better	500
Sendust	26-125	10	Low	Good	Low	Good	500
Mega Flux	26-90	16	Medium	Best	Low	Better	700
Iron	10-100	10	High	Poor	Lowest	Poor	770
Fe-Si Strip (Gap)		20	High	Better	Lowest	Good	740
Amorphous (Gap)		15	Low	Better	Medium	Good	399
Ferrite (Gap)		3-5	Lowest	Poor	Lowest	Poor	100~300

5. Core Design Required Information

(1) Inductance[μH or mH], Current [A]

→ For Calculating LI^2, Core Loss, Wire Size, Copper Loss

(2) Current Density (A/cm^2 or A/mm^2)

→ For Calculating Wire Size, Copper Loss

(3) Ripple Rate (%)

→ For Calculating ΔI, Core Loss

(4) Switching Frequency (kHz)

→ For Calculating Core Loss

6. Material Selection

•When you design and select the right material, core cost is the most important factor but there need many other consideration

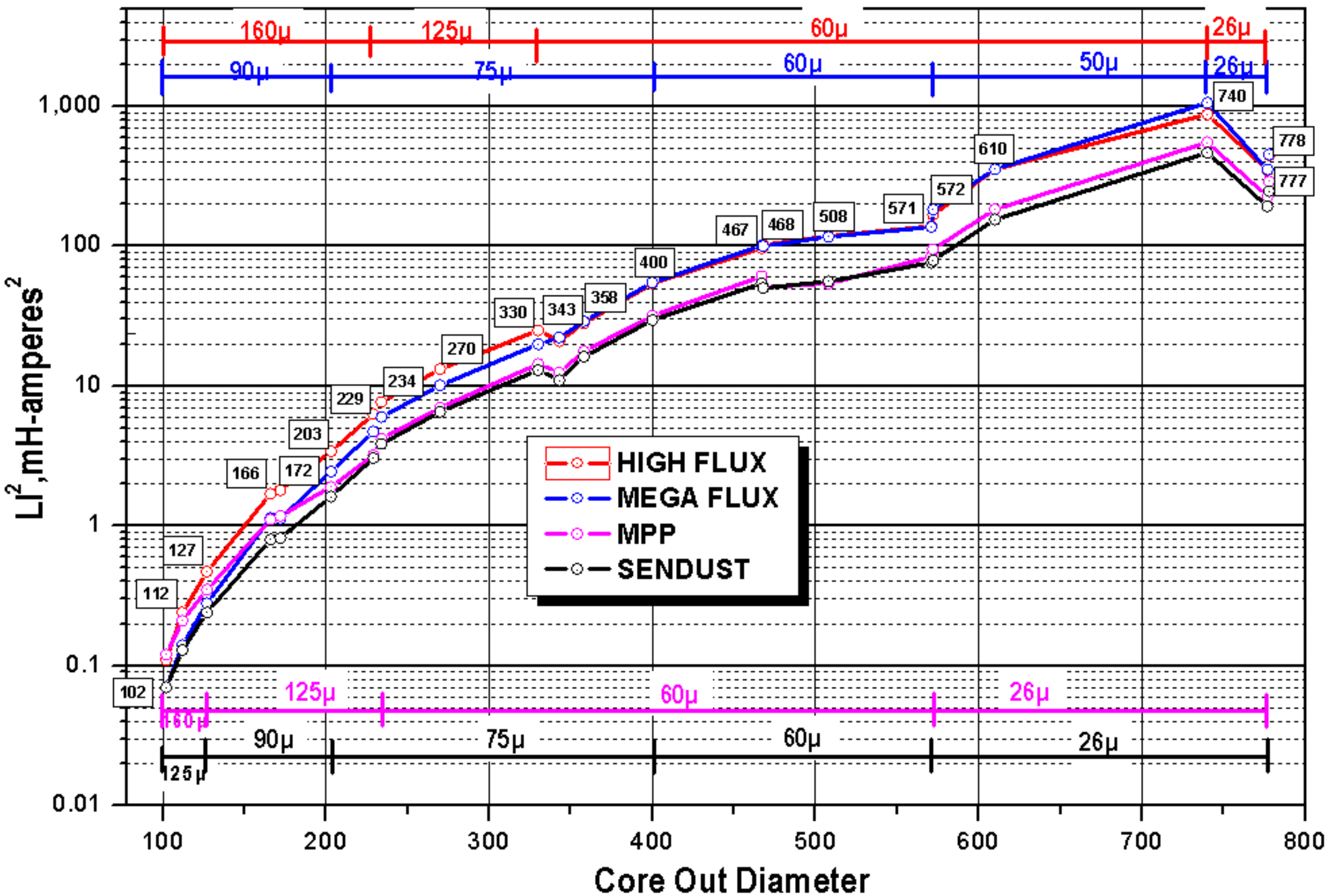
	Core Cost	Core Size (DCB)	Winding Turns (DCB)	Temp. Rising (Core Loss)	Temp. Stability
Low Small Good	Ferrite, Iron				
	Sendust	High Flux	High Flux	MPP	MPP
	Mega Flux	Mega Flux	Mega Flux	High Flux	High Flux
	High Flux	MPP	MPP	Sendust	Mega Flux
	MPP	Sendust	Sendust	Mega Flux	Sendust
High Large Bad		Ferrite, Iron	Iron	Iron	Ferrite, Iron

7. Inductance

• **After selecting material, core size and permeability should be selected**

(1) Core Selection Chart

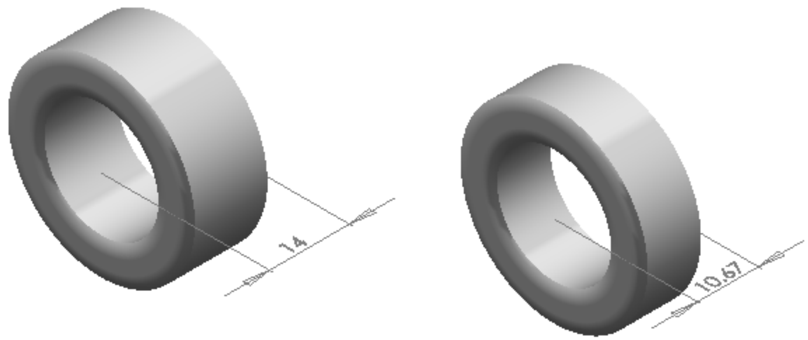
• **Energy Storage Capacity : LI^2 [L=Inductance(mH), I=Current(A)]**



7. Inductance

(2) Height Change & Stack

- **Energy Storage Capacity : LI^2 [L=Inductance(mH), I=Current(A)]**
- **Increase Energy Storage Capacity with same OD, ID size → Height Increase or Stacking**



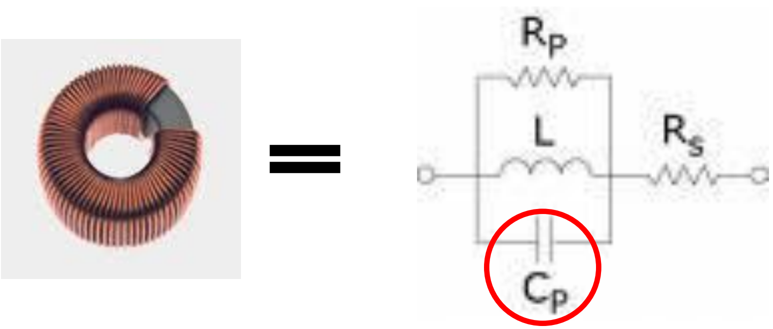
Part No.	B.F HT	AL Value	Storage Capacity
CH330060	10.67mm	61mH	25
CH330060E14	14.0mm	80mH	32
CH330060E18	18.0mm	103mH	42
CH330060 2Stack	10.67mm X 2	61 x 2 =122mH	50

8. Winding

(1) Winding Layer

- **Single Layer Winding : Low Winding Capacitance → Good High Freq. Response**
  Winding is Easy but Need more Large Size Core for Same L
- **Multi Layer Winding : Small Size Core for Same L but Winding is Hard**
  High Winding Capacitance → Need Special Winding Method

Stray Capacitance=Distributed Capacitance



End-to-end capacitance, sometimes called "distributed capacitance", appears in shunt with a winding. In a transformer, this capacitance results in series and parallel resonances with mutual inductance and leakage inductances. In a filter inductor, the end-to-end capacitance, above resonance, passes the high frequency components of the switched waveform through to the output.

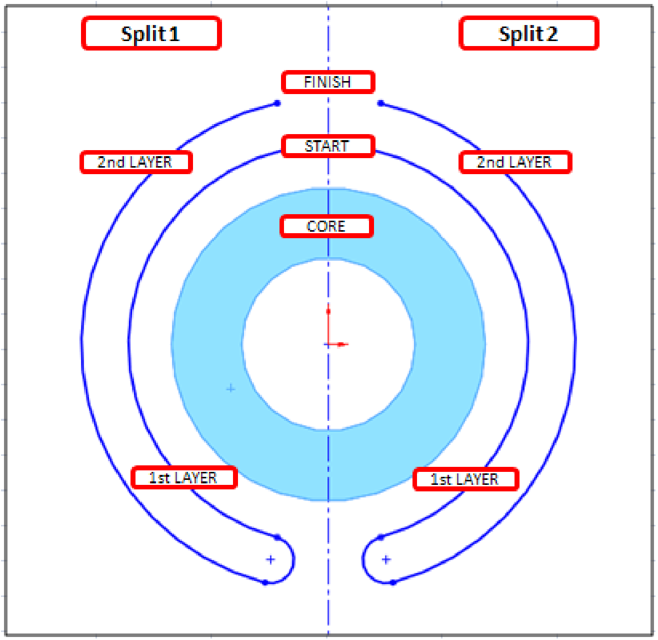
End-to-end capacitance has a negligible effect in low voltage, low impedance windings, but in high voltage windings, it is a serious problem. High voltage windings have many turns which are usually wound back and forth in multiple layers. Thus the end of the second layer is directly over the beginning of the first layer. The effect of the significant capacitance between these layers is magnified because of the large ac voltage across the many intervening turns.

8. Winding

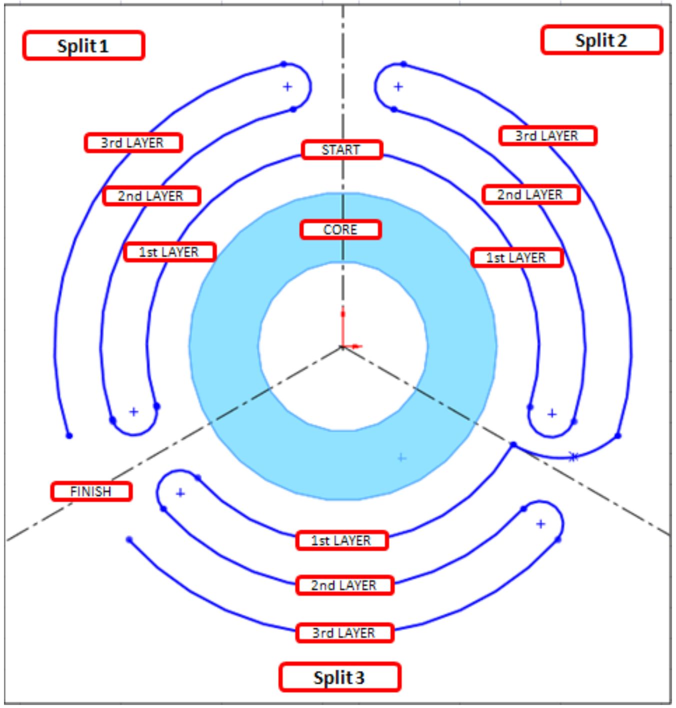
(2) Split Winding

- **Purpose : Minimize Stray Capacitance → Good High Freq. Response**
- **Two Layer Winding → Two Split Winding,**
  Three Layer Winding → Three Split Winding

Two Split Winding

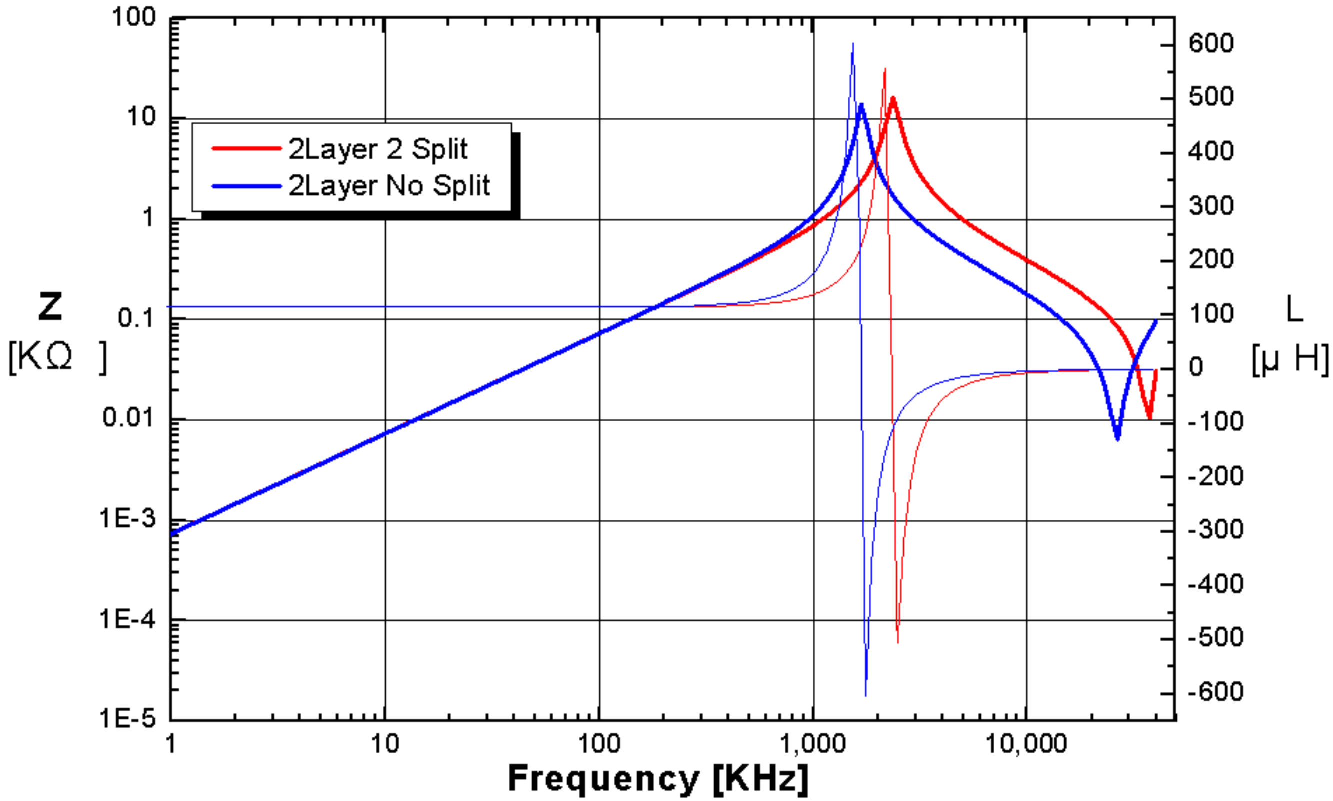


Three Split Winding



8. Winding

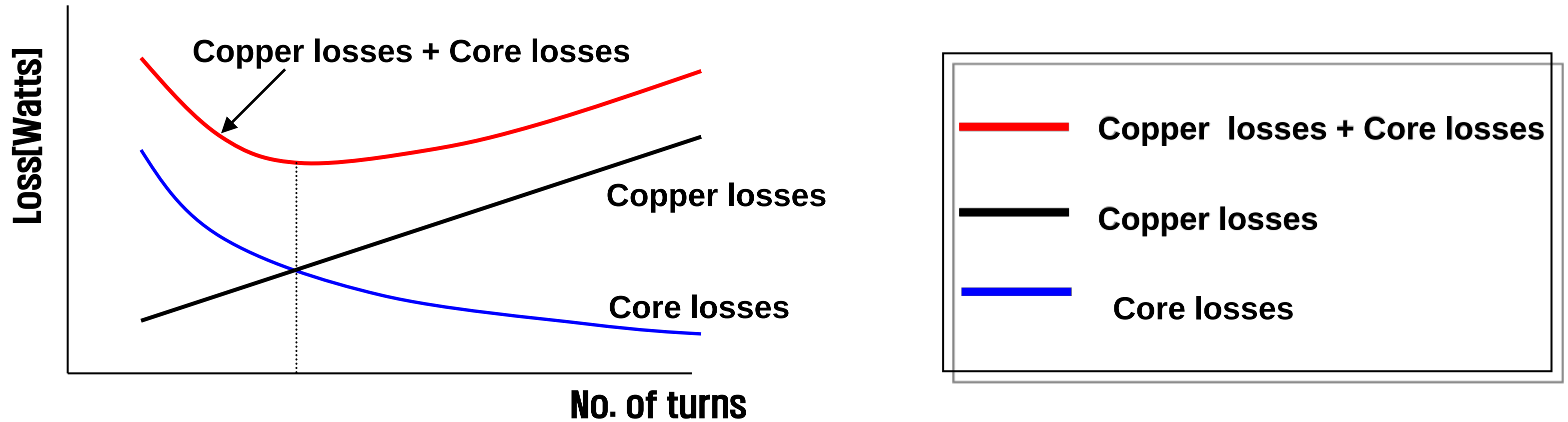
(3) Winding Method vs Impedance



9. Temperature Rising

(1) Total Loss

• **No. of Turns ↑ → Copper Loss ↑ , Core Loss ↓**



Copper loss = $I^2 \cdot R$ (R : resistance of copper, I : rated current)

(2) Temperature Rising

Temperature Rise(ΔT)

The increase in surface temperature of a component in free-standing air due to the total power dissipation (both copper and core loss).

Approximate temperature rise is as follows ;

$$\Delta T\,(^\circ C) = \left[\frac{\text{Total Power Dissipation(Miliwatts)}}{\text{Surface Area}(cm^2)}\right]^{0.833}$$

Total Power Dissipation = Copper Losses + Core Losses

■ **Core Dimension Table(milimeters)**

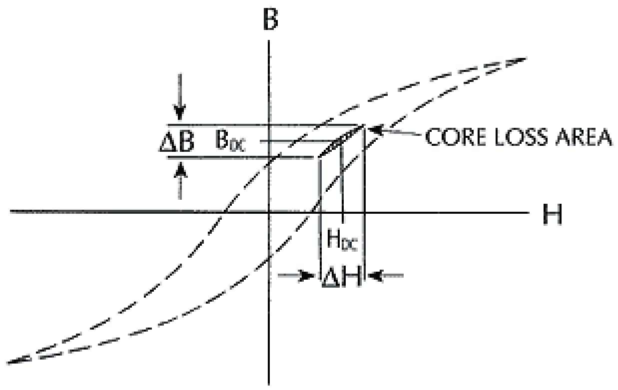
Part Number	Magnetic Path Length ℓ(cm)	Cross Section A(cm²)	Window Area (cm²)	Surface Area(cm²)	
				after finish	40% winding factor
C□ 203□□□	5.09	0.226	1.14	12.1	18.95
C□ 229□□□	5.67	0.331	1.41	15.7	24.13
C□ 234□□□	5.88	0.388	1.49	17.9	26.78
C□ 270□□□	6.35	0.654	1.56	24.7	34.42
C□ 330□□□	8.15	0.672	2.93	31.5	49.01
C□ 343□□□	8.95	0.454	4.01	29.3	52.34

9. Temperature Rising

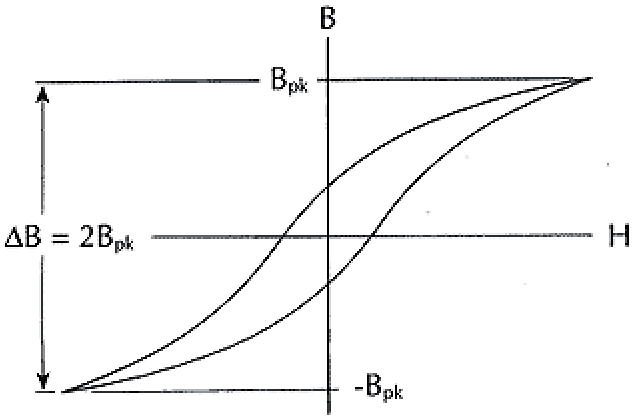
(3) Core Loss

- P=f(B, f) : P=Core Loss[mW/cc], B=Flux Density[kGauss], f=Switching Frequency[kHz]
  Core Loss Curve fit Equation ➔ $P=a\Delta B^b f^c$ (a, b, c = constants)
- B_{pk}=f(L, I) : B_{pk}= B=Flux Density[kGauss], L=Inductance[μH], I=Current[A]
  $B_{pk}=(L_{DC} \times \Delta I \times 100) / (2 \times N \times Ae)$: L_{DC}=Biased Inductance, ⊿I=Ripple Current,
  N=No. of Turns, Ae=Core Cross Section Area [cm^2]
  DC Application (Normal Inductor, Output Choke) → Use $\Delta B = B_{pk}$
  AC Application (PFC, Sine wave Application, Inverter) → Use $\Delta B = 2B_{pk}$

DC Application



AC Application



10. Inductor Design Tool

Inductor Design

Material	OD
CH	330
STACKING	1

Core Dimension

	OD(max)	ID(min)	HT(max)	Stack HT
Before coating(mm)	33.02	19.94	10.67	10.67
After coating(mm)	33.83	19.3	11.61	11.61

Path length(㎝)	8.15
Cross Section Area(㎠)	0.672
Window Area(㎠)	2.93
Volume(cc)	5.477

Design Parameter

Turns	77	Winding Factor(%)	39	DC R(mΩ) @ 20℃	42.83
Wire Area(㎟)	1.50	Rated Current (A)	9.0	Temp of Copper(℃)	20
Wire Eff Area(㎟)	1.50	Peak Current (A)	10.1	DC R(mΩ) @ T(℃)	42.83
Wire length/T(㎝)	3.78	Frequency(kHz)	50	Copper loss(Watt)	3.47
Current Density	6.00 A/㎟	Current Ripple Rate(%)	25%	Required Inductance(uH)	250.0
Wire Dia(mm)	1.38	Ripple Current(ΔI)	2.25		
Surface Area(㎠)	31.5	Graph range	0 A	11 A	

Total Loss & Delta T

Perm	Total Loss(w)		Delta T	
	DC	AC	DC	AC
26	3.86	5.35	55	72
60	3.82	5.16	54	70
125	3.89	5.37	55	72
147	4.00	5.71	56	76
160	4.00	5.71	56	76
	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A

DC Bias Characteristics

A	H(Oe)	26 μ	60 μ	125 μ	147 μ	160 μ	μ	μ
0	-	166.0	361.7	753.0	889.4	966.4	#N/A	#N/A
2	27	157.5	354.4	707.8	820.6	879.4	#N/A	#N/A
5	53	156.2	341.4	599.6	654.7	674.2	#N/A	#N/A
7	80	153.8	317.5	451.0	436.3	439.9	#N/A	#N/A
9	107	150.4	285.3	319.3	271.0	274.6	#N/A	#N/A
10	120	148.3	267.5	267.0	213.8	218.4	#N/A	#N/A
Lrated / Linitial		91%	79%	42%	30%	28%		

Core Loss

perm	ΔI	L@Irated	Flux Density(G)		Core Loss(mW/cc)		Core Loss(W)	
			DC(ΔB/2)	AC(ΔB)	DC	AC	DC	AC
26	3.7	150	544	1,087	71	344	0.39	1.88
60	2.0	285	544	1,087	64	309	0.35	1.69
125	1.8	319	544	1,087	77	348	0.42	1.91
147	2.1	271	544	1,087	96	409	0.53	2.24
160	2.0	275	544	1,087	96	409	0.53	2.24
					#N/A	#N/A	#N/A	#N/A
					#N/A	#N/A	#N/A	#N/A

2. Special Shape Powder Core

Ni-Fe alloy
Khaki Color
Lower Core Loss,Excellent DC Bias
Large Energy Storage Capability
Perm 26, 60, 125, 147, 160u

Ni-Fe-Mo alloy
Gray Color
Lowest Core Loss
Excellent Temperature Stabiliy
Perm 26, 60, 125, 147, 160, 173, 200u

High Flux Cores

MPP Cores

Mega Flux Cores

Sendust Cores

Fe-Si-Al alloy
Black Color
Low Core Loss
Moderate Price
Perm 26, 60, 75, 90, 125u

Fe-Si alloy
Dark Brown Color
Excellent DC Bias
Large Energy Storage Capability
Moderate Price
Perm 26, 40, 50, 60, 75, 90u

(1) Features

- Out Diameter 100, 132, 165mm
- MPP, High Flux, Sendust, Mega Flux
- Electrical Characteristics are Same with Small toroid cores

(2) Application

- Uninterruptible Power Supply (UPS)
- Solar Inverter
- High Power System

(3) Product Identification

CK 13 25 060

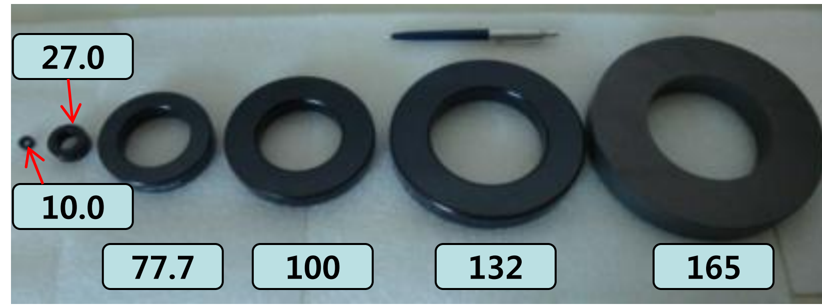
060	Permeability : 60 μ	Available Perm : 26, 50, 60, 125 μ
25	Height : 25mm	
13	OD Size : 130mm	Available Size : 100 ~ 165mm
CK	Mega Flux Core	CH: High Flux, CS: Sendust

2. Special Shape Powder Core

1. Big Toroidal Core

(4) Material Comparison

Material	Advantage	Disadvantage
Mega Flux	High DCB Moderate Price	Core Loss
High Flux	High DCB Low Core Loss	Cost
SENDUST	Moderate Price Low Core Loss	DCB



(5) Dimension

Part No. (□□□ : perm.)	Dimensions(mm)						Path length (㎝)	Cross Section Area (㎠)	A_L value (nH/n^2)±8%		
	Before Finish OD(Max)xID(Min)xHT(Max)			After Finish OD(Max)xID(Min)xHT(Max)					026μ	060μ	125μ
CS1013□□□	101.6	57.2	13.6	103.1	55.7	14.9	24.27	2.972	40	92	192
CS1016□□□	101.6	57.2	16.5	103.1	55.7	17.8	24.27	3.522	47	112	228
CS1027□□□	101.6	57.2	27.2	103.1	55.7	28.5	24.27	5.944	80	184	384
CS1033□□□	101.6	57.2	33.0	103.1	55.7	34.3	24.27	7.044	94	224	456
CS1320□□□	132.5	78.6	20.3	134.2	77.0	21.7	32.42	5.347	54	124	259
CS1325□□□	132.5	78.6	25.4	134.2	77.0	26.8	32.42	6.710	68	156	325
CS1333□□□	132.5	78.6	33.0	134.2	77.0	34.4	32.42	8.717	88	202	422
CS1340□□□	132.5	78.6	40.6	134.2	77.0	42.0	32.42	10.694	108	248	518
CS1625□□□	165.0	88.9	25.4	167.2	86.9	27.3	38.65	9.460	80	184	384

2. Special Shape Powder Core

(6) Design Example

Core Stacking

(OD : 132mm)

Wound Product

(Application : UPS)

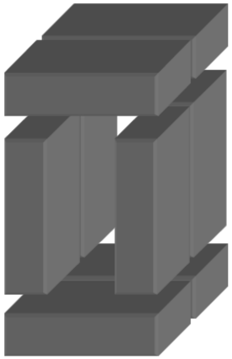
2. Block Core

(1) Features

- Easy to Assemble
- Good Temperature Stability
- Low Core Loss
- Free From Leakage Flux
- Good Design Flexibility

(2) Application

- Solar Inverter
- Uninterruptible Power Supply (UPS)
- Hybrid, Electric Vehicle
- High Power System



(3) Product Identification

BK 6 3 20 - 060

060	Permeability : 60μ	Available Perm : 26, 40, 60μ
20	Height : 20mm	Available Size : 15,20mm
3	Width : 30mm	
6	Length : 60mm	Available Size : 50 ~ 80mm
BK	Mega Flux Block Core	BH: High Flux, BS: Sendust

(4) Material Comparison

Block Material	Advantage	Disadvantage	60μ DCB%		Core Loss @25kHz, 1,000G
			@100 Oe	@200 Oe	
Mega Flux	High DCB Moderate Price	Core Loss	76%	42%	219mW/cc
High Flux	High DCB Low Core Loss	Cost	76%	43%	102mW/cc
SENDUST	Moderate Price Low Core Loss	DCB	45%	21%	106mW/cc

(5) Dimension

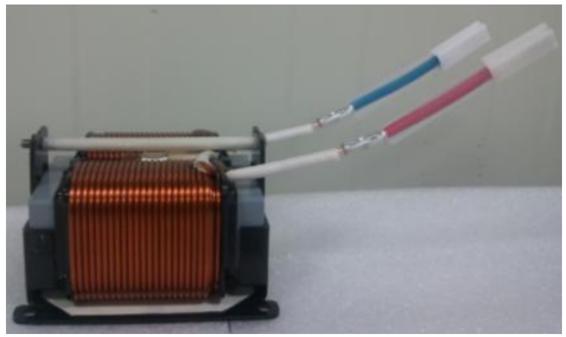
P/N	Dimensions			Path length (cm)	Cross Section Area (cm^2)	4pcs AL value (nH/n^2)±12%		
	Length (mm)	Width (mm)	Height (mm)			026u	040u	060u
BK5315	50.5±0.5	30.3±0.3	15±0.2	18.71	4.5	95	121	181
BK5320	50.5±0.5	30.3±0.3	20±0.2	18.28	6	130	165	247
BK6315	60.5±0.5	30.3±0.3	15±0.2	22.71	4.5	79	100	149
BK6320	60.5±0.5	30.3±0.3	20±0.2	22.28	6	107	135	203
BK7315	70.5±0.5	30.3±0.3	15±0.2	26.71	4.5	67	85	127
BK7320	70.5±0.5	30.3±0.3	20±0.2	26.28	6	91	115	172
BK8315	80.5±0.5	30.3±0.3	15±0.2	30.71	4.5	58	74	110
BK8320	80.5±0.5	30.3±0.3	20±0.2	30.28	6	78	100	149

2. Special Shape Powder Core

2. Block Core

(6) Design Example

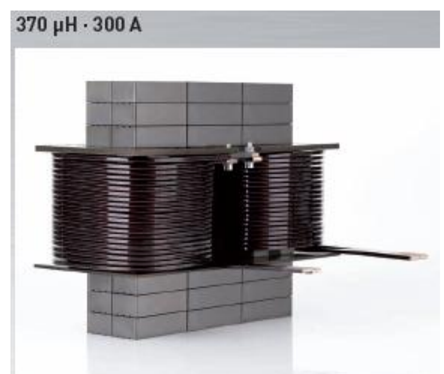
1)Solar Inverter



2)UPS

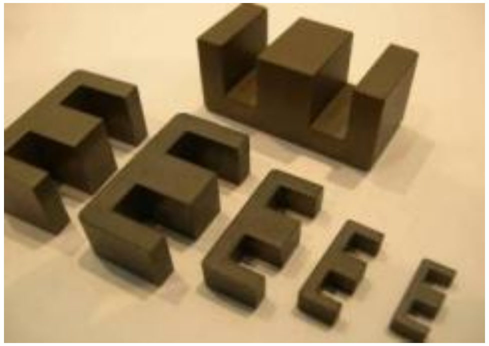
3)Hybrid, Electric Vehicle

4)High Power System



(1) Features

- Easy Winding
- Sendust, Mega Flux Available
- Good Temperature Stability
- No Bulk Gap
- Minimized Audible Noise



(2) Application

- Solar Inverter
- PFC Choke
- Output Choke

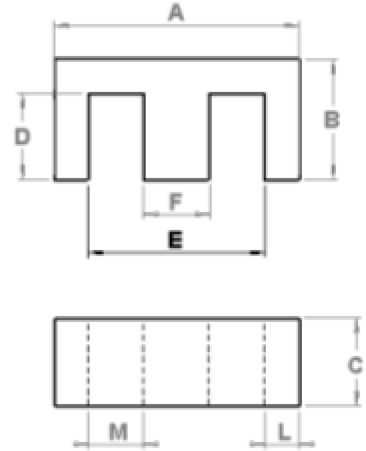
(3) Product Identification

ES 43 21 C – 060

- 060 — Permeability : 60 μ — Available Perm : 26, 40, 60 μ
- C — Height
- 21 — Width : 21mm
- 43 — Length : 43mm — Available Size : 19 ~ 80mm
- ES — SENDUST E Core — EK : MEGA FLUX

(4) Material Comparison

Material	Advantage	Disadvantage	60μ DCB%		Core Loss @25kHz, 1,000G
			@50 Oe	@100 Oe	
Mega Flux	High DCB Moderate Price	Core Loss	91%	76%	219mW/cc
SENDUST	Moderate Price Low Core Loss	DCB	76%	50%	106mW/cc



(5) Dimension

P/N	Dimensions								Path length (㎝)	Cross Section Area (㎠)	AL value (nH/n²)±12%		
	A (mm)	B (mm)	C (mm)	D[min] (mm)	E[min] (mm)	F (mm)	L[nom] (mm)	M[min] (mm)			026u	040u	060u
ES1908A	19.3±0.3	8.1±0.2	4.8±0.2	5.5	13.9	4.8±0.2	2.3	4.7	4.01	0.228	26	35	48
ES2510A	25.1±0.3	9.6±0.2	6.5±0.2	6.2	18.8	6.1±0.2	3.0	6.3	4.85	0.385	39	52	70
ES3015A	30.1±0.3	15.0±0.2	7.1±0.2	9.7	19.5	7.0±0.2	5.1	6.4	6.56	0.601	33	46	71
ES3515A	34.5±0.3	14.1±0.2	9.3±0.2	9.6	25.3	9.3±0.2	4.4	7.9	6.94	0.840	56	75	102
ES4117A	40.9±0.6	16.5±0.3	12.5±0.3	10.4	28.3	12.5±0.3	6.0	7.9	7.75	1.520	88	119	163
ES4321A	42.8±0.7	21.1±0.4	10.8±0.3	15.0	30.4	11.7±0.3	5.9	9.5	9.84	1.280	56	76	105
ES4321B	42.8±0.7	21.1±0.4	15.4±0.3	15.0	30.4	11.7±0.3	5.9	9.5	9.84	1.830	80	108	150
ES4321C	42.8±0.7	21.1±0.4	20.0±0.3	15.0	30.4	11.7±0.3	5.9	9.5	9.84	2.370	104	140	194
ES5528A	54.9±0.8	27.6±0.4	20.6±0.4	18.5	37.5	16.8±0.4	8.4	10.3	12.30	3.500	116	157	219
ES5528B	54.9±0.8	27.6±0.4	24.6±0.4	18.5	37.5	16.8±0.4	8.4	10.3	12.30	4.170	138	187	261
ES6533A	65.1±1.0	32.5±0.5	27.0±0.4	22.2	44.2	19.7±0.4	10.0	12.1	14.70	5.400	162	230	300
ES7228A	72.4±1.1	27.9±0.5	19.0±0.4	17.8	52.6	19.1±0.4	9.5	16.9	13.70	3.680	130	173	236
ES8038A	80.0±1.2	38.1±0.6	19.8±0.4	28.1	59.3	19.8±0.4	9.9	19.8	18.50	3.890	103	145	190

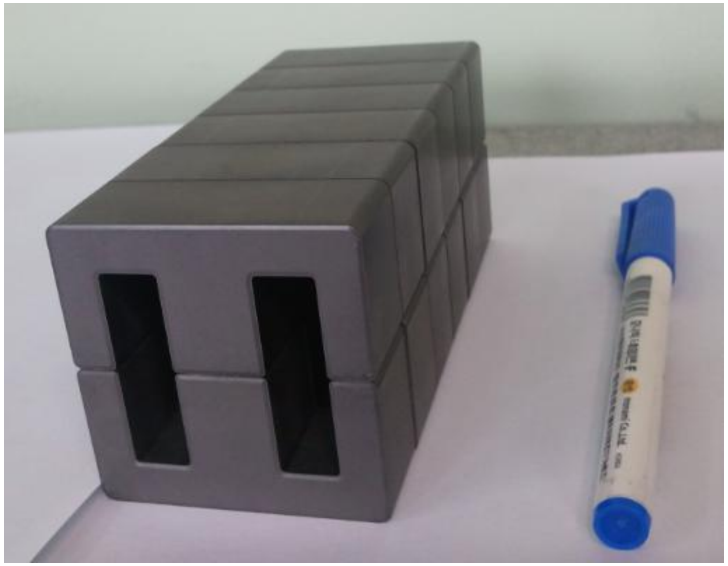
2. Special Shape Powder Core

(6) Design Example

1)E Core Stacking

: EK5528A-060 6Layer, AL=1314mH

55mm x 55mm x 124mm



2) Wound Product (PFC, Solar)

(1) Features

- Round Center Leg
- High Flux, Mega Flux Available
- Good Temperature Stability
- No Bulk Gap
- Rectangular Winding is Possible (DCR Reduction)

(2) Application

- High Current, Low Inductance Application
- Hybrid, Electrical Vehicle
- PFC Choke
- Output Choke

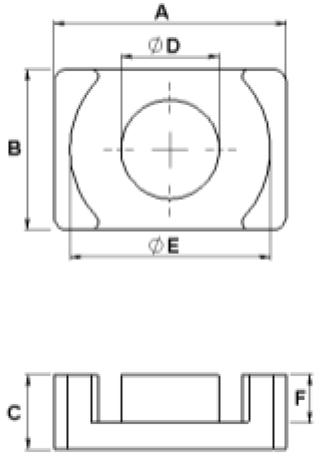
(3) Product Identification

HEQ 32 22 B – 060

- 060 — Permeability : 60 μ — Available Perm : 26, 40, 60 μ
- B — Height
- 22 — Width : 22mm
- 32 — Length : 32mm — Available Size : 20 ~ 50mm
- HEQ — High Flux EQ Core — KEQ : MEGA FLUX

(4) Material Comparison

Material	Advantage	Disadvantage	60μ DCB%		Core Loss @25kHz, 1,000G
			@100 Oe	@200 Oe	
Mega Flux	High DCB Moderate Price	Core Loss	76%	42%	219mW/cc
High Flux	High DCB Low Core Loss	Cost	76%	43%	102mW/cc

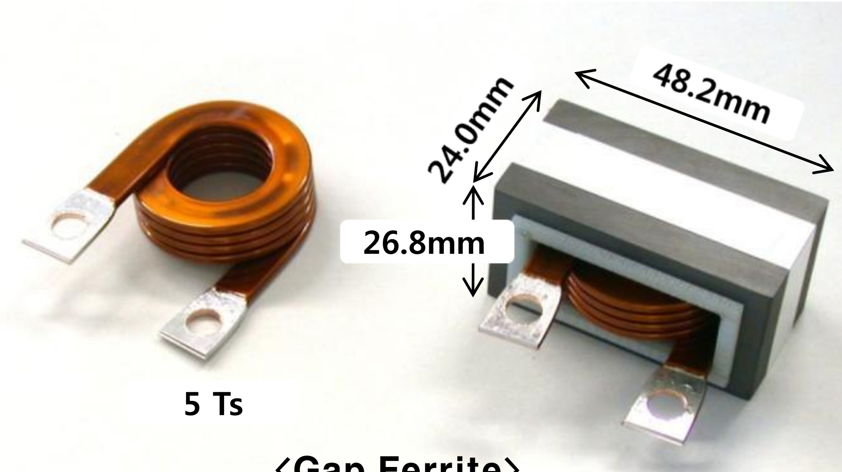


(5) Dimension

P/N	Dimensions						Path length (㎝)	Cross Section Area (㎠)	AL value (nH/n^2)±12%		
	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)			026u	040u	060u
HEQ2014A	20.5±0.3	14.0±0.2	8.1±0.2	8.8±0.2	18.0±0.2	5.7±0.3	4.52	0.608	44	68	101
HEQ2014B	20.5±0.3	14.0±0.2	10.1±0.2	8.8±0.2	18.0±0.2	7.7±0.3	5.32	0.608	37	57	86
HEQ2619A	26.5±0.3	19.0±0.2	10.1±0.2	12.0±0.2	22.6±0.3	6.8±0.3	5.47	1.198	72	110	165
HEQ2619B	26.5±0.3	19.0±0.2	12.4±0.2	12.0±0.2	22.6±0.3	9.1±0.3	6.39	1.198	61	94	141
HEQ3222A	32.0±0.4	22.0±0.3	10.3±0.2	13.5±0.2	27.6±0.3	6.6±0.3	6.03	1.523	83	127	190
HEQ3222B	32.0±0.4	22.0±0.3	15.2±0.2	13.5±0.2	27.6±0.3	11.5±0.3	7.99	1.523	62	96	144
HEQ3626A	36.0±0.5	26.0±0.3	17.4±0.3	14.4±0.2	32.0±0.4	13.4±0.3	9.47	1.808	62	96	144
HEQ4128A	41.5±0.5	28.0±0.4	19.9±0.3	14.9±0.2	36.5±0.4	15.4±0.3	11.52	1.997	57	87	131
HEQ5032A	50.0±0.6	32.0±0.4	25.0±0.4	20.0±0.3	44.0±0.5	19.5±0.4	13.34	3.141	77	118	178

(6) Design Example

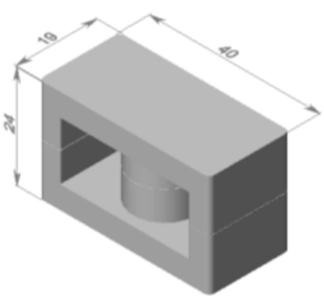
1) HEV Application



5 Ts

<Gap Ferrite>

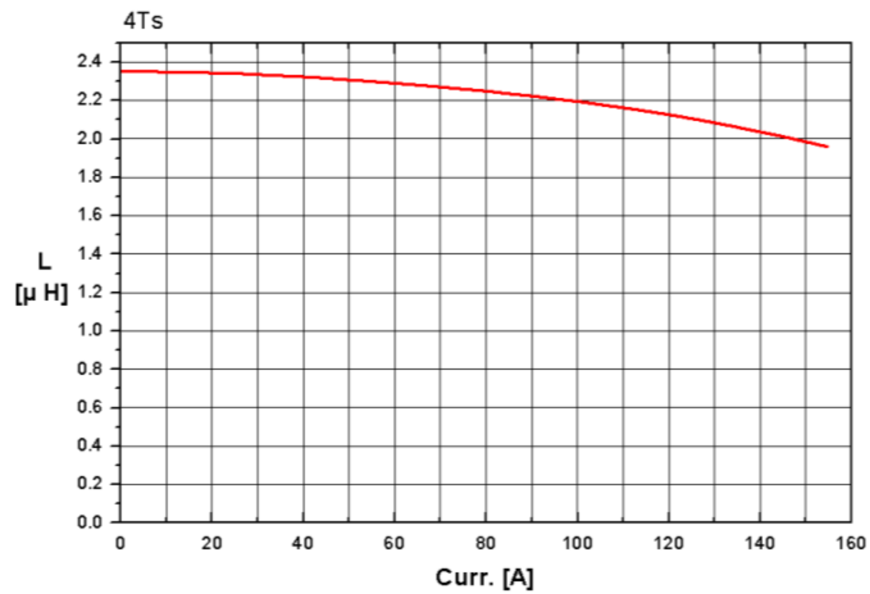
4 Ts



<MegaFlux EER Core>

2) DCB Graph

: L(120A)=2μH



(1) General Information

Ellipse Core(LK Series)

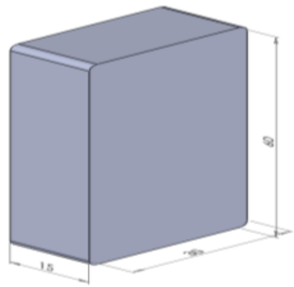
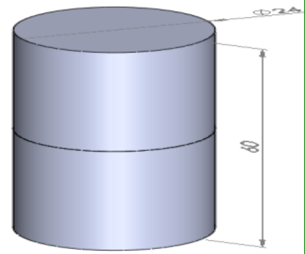
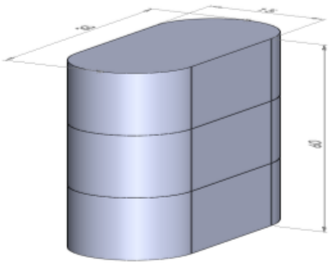
Permeability(μ)	26, 40, 60
Bmax(G)	16,000
Curie Temp[℃]	700
Operating temp[℃]	-40 to 150

(2) Identification

LK 70 35 A - 060

Permeability : 60μ	Available Perm : 26, 40, 60μ
Height :	Available Size : A=13.5,B=18.5mm
Width : 35mm	
Length : 70mm	Available Size : 60 ~ 70mm
Ellipse Core	LK: Mega Flux

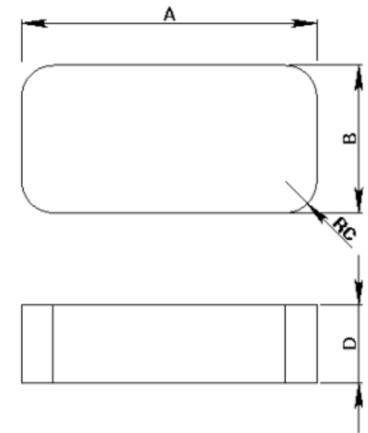
(3) Advantage

Post Core Type	 Block Cores	 Cylinder Cores	 Ellipse Cores
Cross sectional Area(cm^2)	4.5	4.5	4.5
Size	30mm x 15mm	φ24mm	33mm x 15mm (Corner 7.2R)
Wire length per turn(cm)	9	7.53	8.31
Reference	1)Easy assembly	1)Smaller window area	1) Wider window area than assembled blocks with cylinders 2) Wire length of 1 turn 8% decreased than a block core

(4) Part List

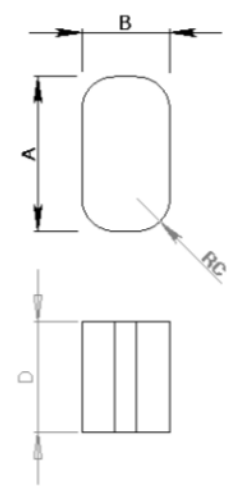
1) Plates

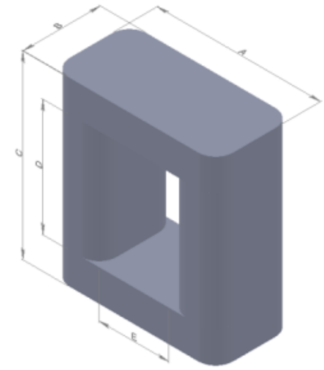
P/N	Dimensions				Cross Section Area (㎠)
	A Length (mm)	B Width (mm)	RC Radius (mm)	D Height (mm)	
LK6035A	60.5±0.5	35.3±0.3	7.5±0.2	13.5±0.2	4.77
LK6035B	60.5±0.5	35.3±0.3	7.5±0.2	18.5±0.2	6.52
LK7035A	70.5±0.5	35.3±0.3	7.5±0.2	13.5±0.2	4.77
LK7035B	70.5±0.5	35.3±0.3	7.5±0.2	18.5±0.2	6.52



2) Posts

P/N	Dimensions				Cross Section Area (㎠)
	A Length (mm)	B Width (mm)	RC Radius (mm)	D Height (mm)	
LK3515A	35.3±0.3	15.2±0.2	7.5±0.2	20.0±0.2	4.77
LK3515B	35.3±0.3	15.2±0.2	7.5±0.2	25.0±0.2	4.77
LK3520A	35.3±0.3	20.2±0.2	7.5±0.2	20.0±0.2	6.52
LK3520B	35.3±0.3	20.2±0.2	7.5±0.2	25.0±0.2	6.52





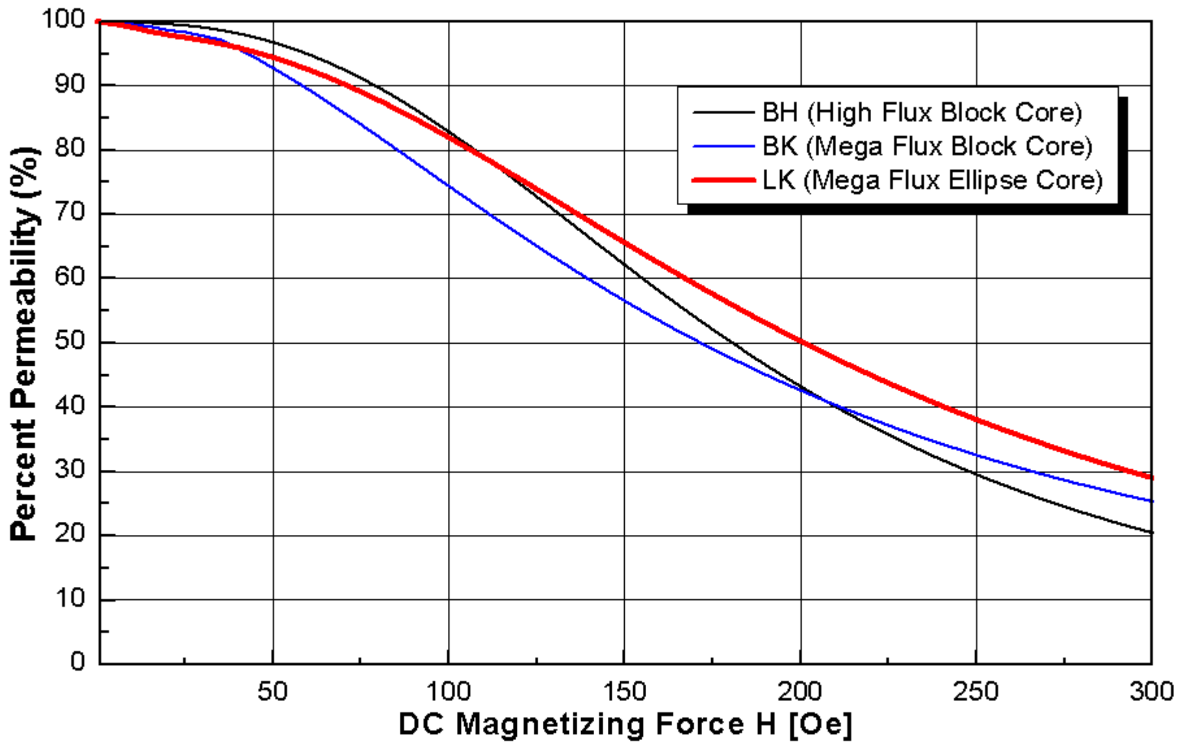
(5) Assembling

PLATE P/N	POST		Dimensions					Path Length (㎝)	Cross Section Area (㎠)	Window Area (㎠)	AL value (nH/n²)±12%		
	P/N	1 LEG STACK	A Length (mm)	B Width (mm)	C Height (mm)	D Inner Height (mm)	E Inner Length (mm)				026u	040u	060u
LK6035A	LK3515A	2	60.5±0.5	35.3±0.3	67.0±0.5	40.0±0.4	30.0±0.4	18.47	4.77	12	101	130	195
	LK3515B	2	60.5±0.5	35.3±0.3	77.0±0.5	50.0±0.4	30.0±0.4	20.47	4.77	15	91	117	176
	LK3515A	3	60.5±0.5	35.3±0.3	87.0±0.5	60.0±0.4	30.0±0.4	22.47	4.77	18	83	107	160
LK6035B	LK3520A	2	60.5±0.5	35.3±0.3	77.0±0.5	40.0±0.4	20.0±0.4	18.04	6.52	8	141	182	273
	LK3520B	2	60.5±0.5	35.3±0.3	87.0±0.5	50.0±0.4	20.0±0.4	20.04	6.52	10	127	164	245
	LK3520A	3	60.5±0.5	35.3±0.3	97.0±0.5	60.0±0.4	20.0±0.4	22.04	6.52	12	115	149	223
LK7035A	LK3515A	2	70.5±0.5	35.3±0.3	67.0±0.5	40.0±0.4	40.0±0.4	20.47	4.77	16	91	117	176
	LK3515B	2	70.5±0.5	35.3±0.3	77.0±0.5	50.0±0.4	40.0±0.4	22.47	4.77	20	83	107	160
	LK3515A	3	70.5±0.5	35.3±0.3	87.0±0.5	60.0±0.4	40.0±0.4	24.47	4.77	24	76	98	147
LK7035B	LK3520A	2	70.5±0.5	35.3±0.3	77.0±0.5	40.0±0.4	30.0±0.4	20.04	6.52	12	127	164	245
	LK3520B	2	70.5±0.5	35.3±0.3	87.0±0.5	50.0±0.4	30.0±0.4	22.04	6.52	15	115	149	223
	LK3520A	3	70.5±0.5	35.3±0.3	97.0±0.5	60.0±0.4	30.0±0.4	24.04	6.52	18	106	136	204

(6) Material Comparison

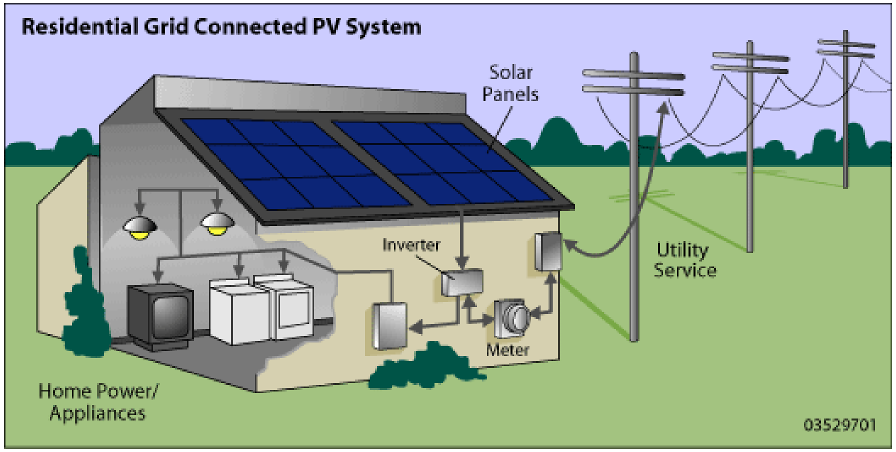
Material	60μ DCB%		
	@100 Oe	@150 Oe	@200 Oe
BH (High Flux Block)	83%	62%	43%
LK (Mega Flux Ellipse)	82%	66%	50%
BK (Mega Flux Block)	74%	56%	42%

(7) DCB Graph

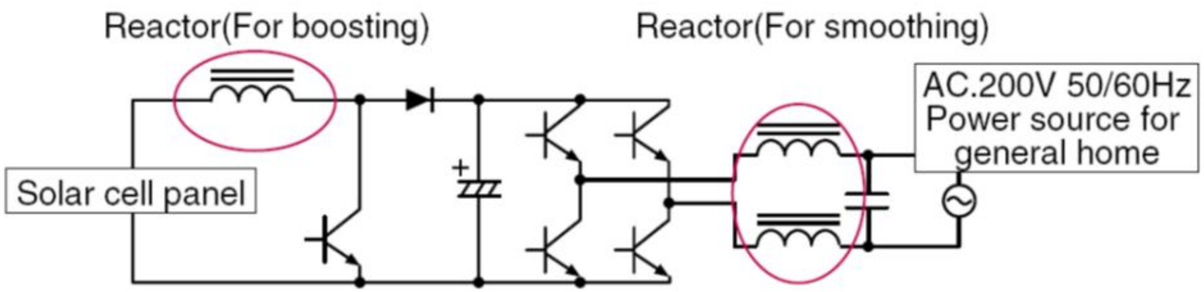


3. Solar Inverter & Magnetic Materials

1. Photovoltaic Power Generation



2. Solar Inverter



※In Solar Inverter, Reactors are used for Boosting or Smoothing

3. Efficiency

(1)The efficiency of the power conditioner is easily reduced due to loss by the semiconductor and reactor

1) Core loss related to the core (Iron loss)

2) Copper loss related to wire electrical resistance

(2)High efficiency Reactor Design

	Core Material	Core Shape
Core Loss ↓	Low Core Loss	Minimize the Gap Loss
Copper Loss ↓	High Saturation Flux Density →Reduce #of Turns	Shorter 1Turn Length

3. Efficiency

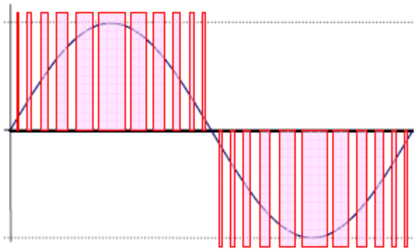
(3) Available Core Materials for Solar Inverter

	Metal				Ferrite
	Mega Flux	High Flux	SENDUST	Amorphous C Cores	
Composition	Fe – 6.5%Si	Fe-50%Ni	Fe-9%Si-6%Al	Fe – 10% Si-5% B	
Saturation Flux Density	16,000 Gauss	15,000 Gauss	10,000 Gauss	15,600 Gauss	4,300 Gauss
Curie Temp	700℃	500℃	500℃	399℃	250℃
Available Perm.	26, 40, 60μ			Depend on the Gap Size	Depend on the Gap Size
Special Core Shape	Block, EE, UU, Ellipse, Cylinder			UU Type	Block, EE, Cylinder
Gap Type	Distributed Air Gap			Bulk Air Gap	Bulk Air Gap
Advantage	*High Saturation Flux Density *Low Cost	*High Saturation Flux Density *Low Core Loss	*Low Core Loss *Low Cost	*High Saturation Flux Density	*Low Core Loss *Low Cost

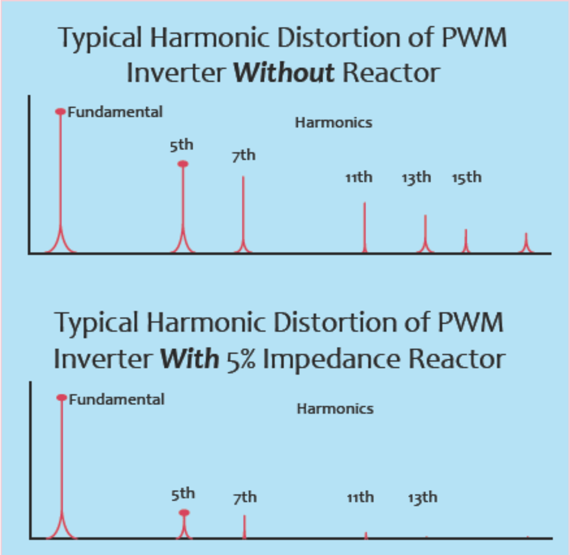
※Except Efficiency, Size and Cost are also Important

4. Power Quality

(1) Harmonics & Reactor



PWM control scheme



Recent studies show that by using a commercial power conditioner system (PCS), harmonics from PV systems do not become a big issue at the current installed PV capacity. Since the harmonics generated from a PCS are much lower than from other appliances, it is possible that the PCS filters the harmonics from other electronic loads to improve the power quality. R&D projects have been carried out to ascertain the impact of harmonics from a PV community, and to develop a more advanced PCS to minimize harmonics.

Electronic devices such as series reactors or static capacitors, installed at indoor substations of factories or office buildings for power quality, are harmonic filters. If the harmonics are severe, beyond the filtering capability, this leads to overheating and in the worst case, a fire could result.

The impact on demand-side equipment includes vibration of elevators, flickering of TV monitors and fluorescent lamps, degradation of sound quality, and malfunctioning of control devices.

If the disturbance occurs in the odd numbers of harmonics 3, 5 or 7th, it could even result in a high current running in the neutral wire. If the wire has been reduced in size compared to the active wires it could in worst case be overheated.

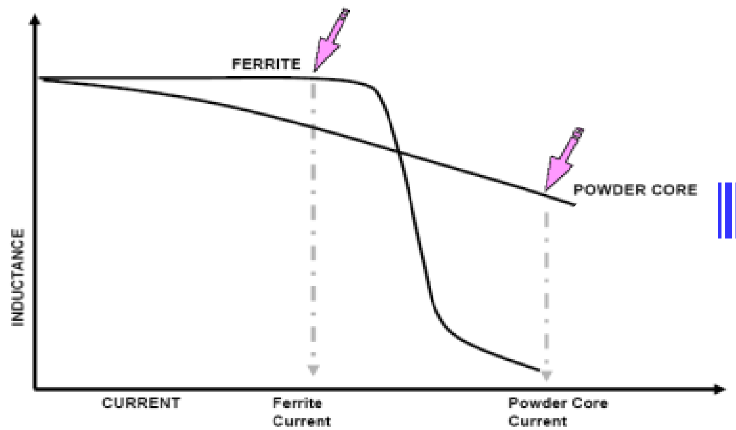
4. Power Quality

(2) Reactor Impedance & DCB Characteristics

$$Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$$

Z : Impedance
R : Resistance
$2\pi fL = X_L$: Inductive Reactance
$2\pi fC = X_C$: Capacitive Reactance
f : Frequency
L : Inductance

An AC Line Reactor is typically used as a protective device for filtering any harmful line disturbances that can cause failure to some electrical components. An AC Line Reactor introduces a highly controlled impedance to a given electrical circuit. With this impedance, the AC Line Reactor reduces any harmonic distortion



To Minimize the Harmonic Distortion or Overheating, Reactor should have Soft Saturation DCB Characteristics at High Current for the enough Inductance

5. Design Example : Mega Flux Ellipse Core vs Amorphous C Core

1) Current = 40A, Inductance = 900μH min, fs=18 kHz

2)Assembled Core Size

Length = 60mm max, Width = 40mm max, Height = 110mm max

3) Total Weight = 2.0 kg max

4) DCR = 38mΩ max

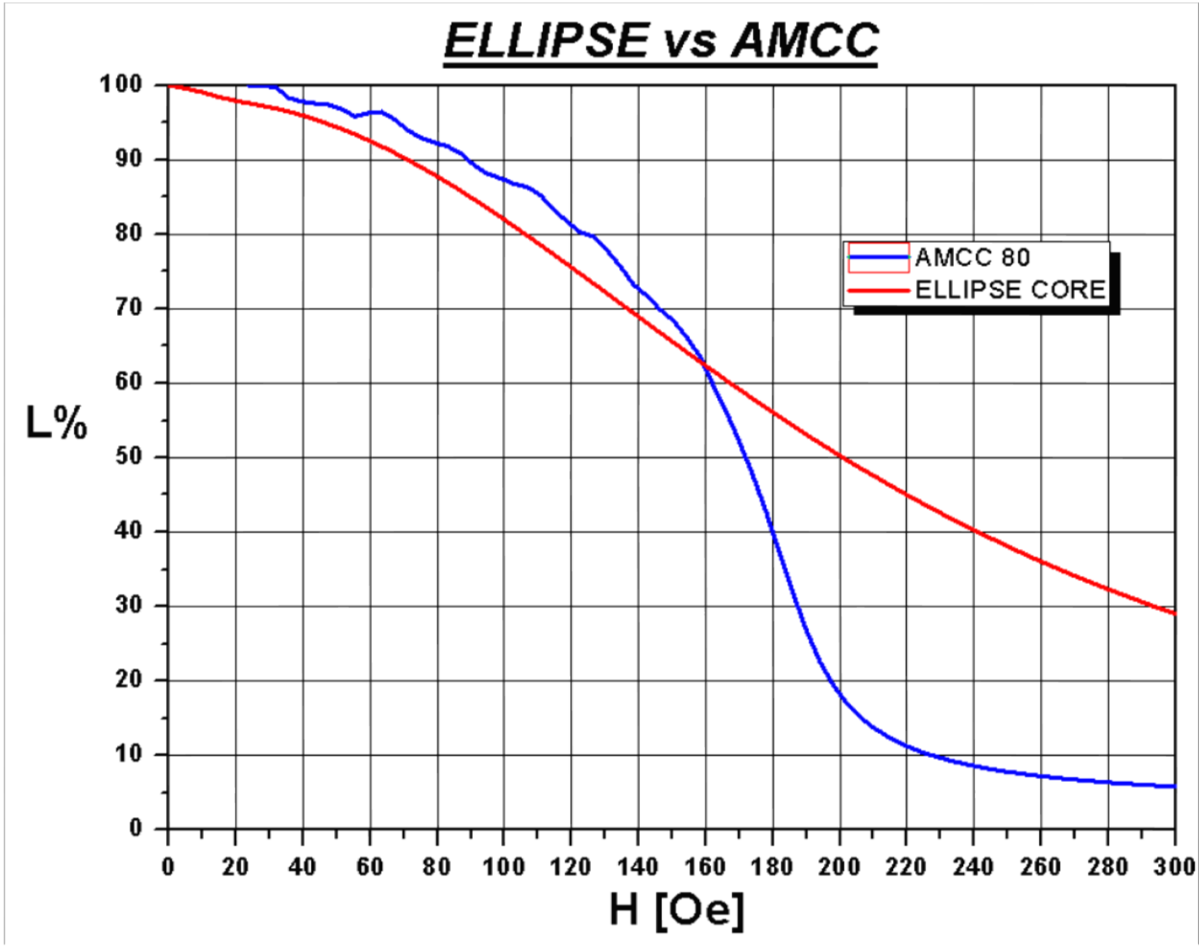
5) Core Loss = 40W max

6) Total Loss = 100W max

Material Comparison

	Mega Flux Ellipse Cores	Amorphous C Cores
Composition	Fe – 6.5%Si	Fe – 10% Si-5% B
Raw Material Shape & Size	Below 100μm size Powder	25μm Thickness Sheet
Density	7.0 g/cc	7.18 g/cc
Bmax	16,000 Gauss	15,600 Gauss
Available Perm.	26, 40, 60μ	Depend on the Gap Size
Gap Type	Distributed Air Gap	Bulk Air Gap
Post Shape	Ellipse	Rectangle
Cost	70	100

DCB Characteristics



Mega Flux Ellipse Core

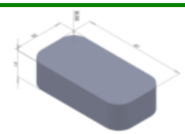
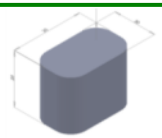
: Soft Saturation

Amorphous C Core

: Sharp Saturation

3. Solar Inverter & Magnetic Materials

Core Size & Weight

		Mega Flux Ellipse Cores	Amorphous C Cores
Plate	Unit Shape	 LK6035B-060	AMCC 80
	Unit Size	60mm x 35mm x 18.5mm	52mm x 40mm x 51mm
	pcs	Upper 1pcs, Lower 1pcs Total 2pcs	Total 2pcs
	Weight	267g x 2pcs = 534g	469g x 2pcs = 938g
Post	Unit Shape	 LK3520A-060	
	Size	35mm x 20mm x 20mm	
	pcs	1 post stack 3pcs Total 6pcs	
	Weight	92g x 6pcs = 552g	
Total	Size	60mm x 35mm x 97mm	52mm x 40mm x 102mm
	Weight	534g + 552g = 1086g	938g

Core Parameter

	Mega Flux Ellipse Cores	Amorphous C Cores
Path Length	22.04cm	25.4cm
Section Area	6.52㎠	6.4㎠
Volume	143.7㎤	162.56㎤
Bulk Gap	No	2mm x 2 = 4mm
Perm.	60 μ	72 μ
AL Value	223mH	229mH
Window Area	12㎠	10.56㎠ (use bobbin)

3. Solar Inverter & Magnetic Materials

Wire & Inductance

		Mega Flux Ellipse Cores	Amorphous C Cores
Bobbin		No	Thickness 2mm
1 Turn Length		97mm	128mm
Current Capacity		6.1 A/㎟	6.1 A/㎟
Wire Size		6.0mm x 1.1mm	6.0mm x 1.1mm
Winding Turns		92Ts	80Ts
Total Wire Weight		607g	787g
Winding Factor		50%	50%
DCR		26.6 mΩ	34.5 mΩ
Inductance	0A	1887 μH	1465 μH
	30A	1210 μH	1270 μH
	40A	911 μH	988 μH
	50A	678 μH	290 μH

Loss

		Mega Flux Ellipse Cores	Amorphous C Cores
Condition	fs	18kHz	
	⊿I(20%)	8A	
	Section Area	6.52	6.4
	Ts	92	80
	Volume	143.7㎤	162.56㎤
	Current	40A	
	DCR	26.6 mΩ	34.5 mΩ
⊿B (Lx⊿Ix100/NxA)		1.214 kGauss	1.544 kGauss
Core Loss Formula		$P=5.92B^{2.16}f^{1.12}$	$P=2.04B^{2.11}f^{1.31}$
Core Loss	mW/cc	229	225
	W	32.9	36.6
Copper Loss [W]		42.5	55.2
Total Loss [W]		75.4	91.8

Cost

		Mega Flux Ellipse Cores	Amorphous C Cores
Core	Unit Cost	70	100
	Total Weight	1.086 kg	0.938 kg
	Total Cost	76	94
Copper	Unit Cost	46	46
	Total Weight	0.607 kg	0.787 kg
	Total Cost	28	36
Total Cost		104	130

3. Solar Inverter & Magnetic Materials

Summary

		Mega Flux Ellipse Cores	Amorphous C Cores
Inductance [μH]	L(0A)	1,887	1,465
	L(30A)	1,210	1,270
	L(40A)	911	988
	L(50A)	678	290
Size (Core)		60mm x 35mm x 97mm	52mm x 40mm x 102mm
Weight	Core	1.086 kg	0.938 kg
	Copper	0.607 kg	0.787 kg
	Total	1.693 kg(98%)	1.725 kg(100%)
Loss [W]	Core	32.9	36.6
	Copper	42.5	55.2
	Total	75.4(82%)	91.8(100%)
Cost	Core	87	94
	Copper	33	43
	Total	104 (80%)	130(100%)

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