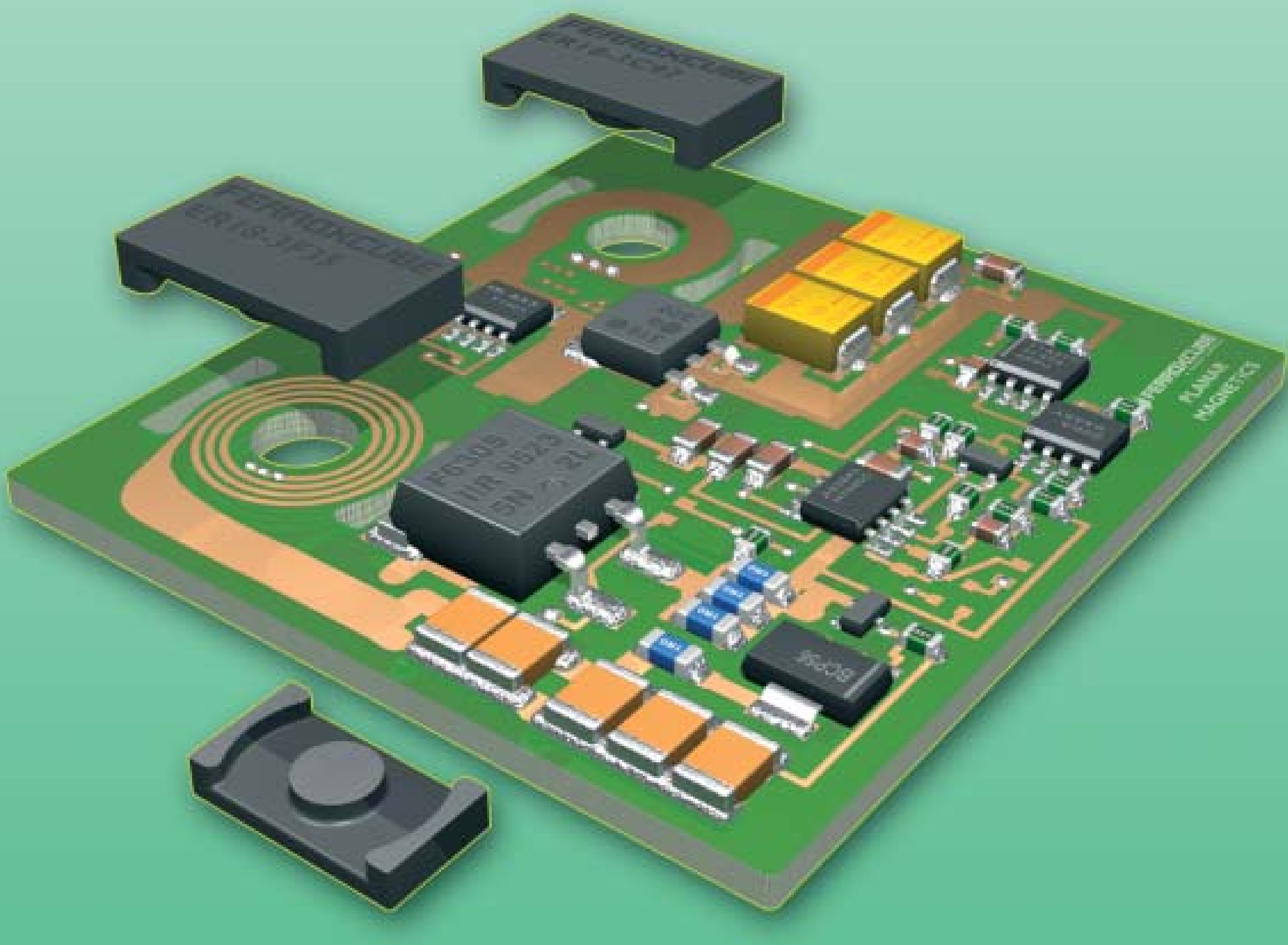
New ER cores for planar converters



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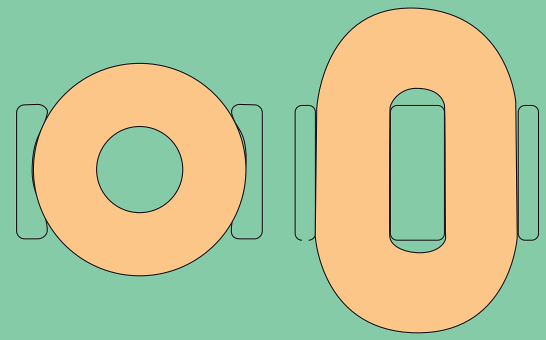
Features

The main features of the newly introduced cores are :

- *Round centre leg*
- *Short copper tracks, low DC resistance*
- *Small footprint area, high power density*
- *Large winding window, large output current*
- *Uniform core cross-section, maximum ferrite usage*
- *High grade ferrite materials, high saturation / high frequency*



ER planar circuit tracks **E planar circuit tracks**

Comparative data for planar E and planar ER cores

Core size	h (mm)	A_e (mm^2)	A_w (mm^2)	A_w / A_e	$l_{w\ avg}$ (mm)	A_{fp} (mm^2)	P_{thr}/A_{fp}
ER18	6.3	30.2	15.0	0.50	34.2	225	49
E18/PLT18	6.0	39.3	10.0	0.25	48.3	334	31
ER23	7.2	50.2	19.5	0.39	44.3	375	52
E22/PLT22	8.2	78.3	18.9	0.24	65.8	566	47

h = height of core set, A_e = effective core area, A_w = winding area, $l_{w\ avg}$ = average length of turn, A_{fp} = transformer footprint area, P_{thr} = throughput power in W

Design remarks

Generally the calculation formulas used to design inductive components based on ER cores are the same as for planar E cores, only core parameters and dimensions differ. For the design procedure see our brochure “Design of planar power transformers”.

An approximation of the core loss density for any combination of operating temperature (T), frequency (f) and flux density (B), can be obtained from the following empirical fit formula: $P = C_m \cdot f^x \cdot B^y \cdot (ct_0 - ct_1 . T + ct_2 . T^2) / 1000$

In this formula f should be inserted in [Hz], B in [T] and T in [°C]. The losses are obtained in [kW/m^3] which is equal to [mW/cm^3.] Fit parameters for the power ferrites 3C92, 3C96 and 3F35 are given in the table below:

Power loss curve fit parameters

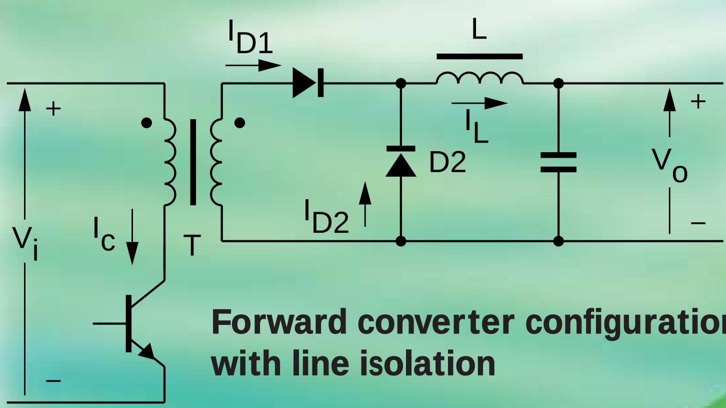
Material	f (kHz)	C_m	x	y	C_{t2}	C_{t1}	C_{t0}
3C92	20 – 100	26.5	1.19	2.65	2.68×10^{-4}	5.43×10^{-2}	3.75
	100 – 200	0.349	1.59	2.67	1.51×10^{-4}	3.05×10^{-2}	2.55
	200 – 400	1.19×10^{-4}	2.24	2.66	2.08×10^{-4}	4.37×10^{-2}	3.29
3C96	20 – 100	5.12	1.34	2.66	5.48×10^{-4}	1.10×10^{-1}	6.56
	100 – 200	8.27×10^{-2}	1.72	2.80	1.83×10^{-4}	3.66×10^{-2}	2.83
	200 – 400	9.17×10^{-5}	2.22	2.46	2.33×10^{-4}	4.72×10^{-2}	3.39
3F35	400 –1000	1.23×10^{-8}	2.95	2.94	1.38×10^{-4}	2.41×10^{-2}	2.03

New ER cores for planar converters

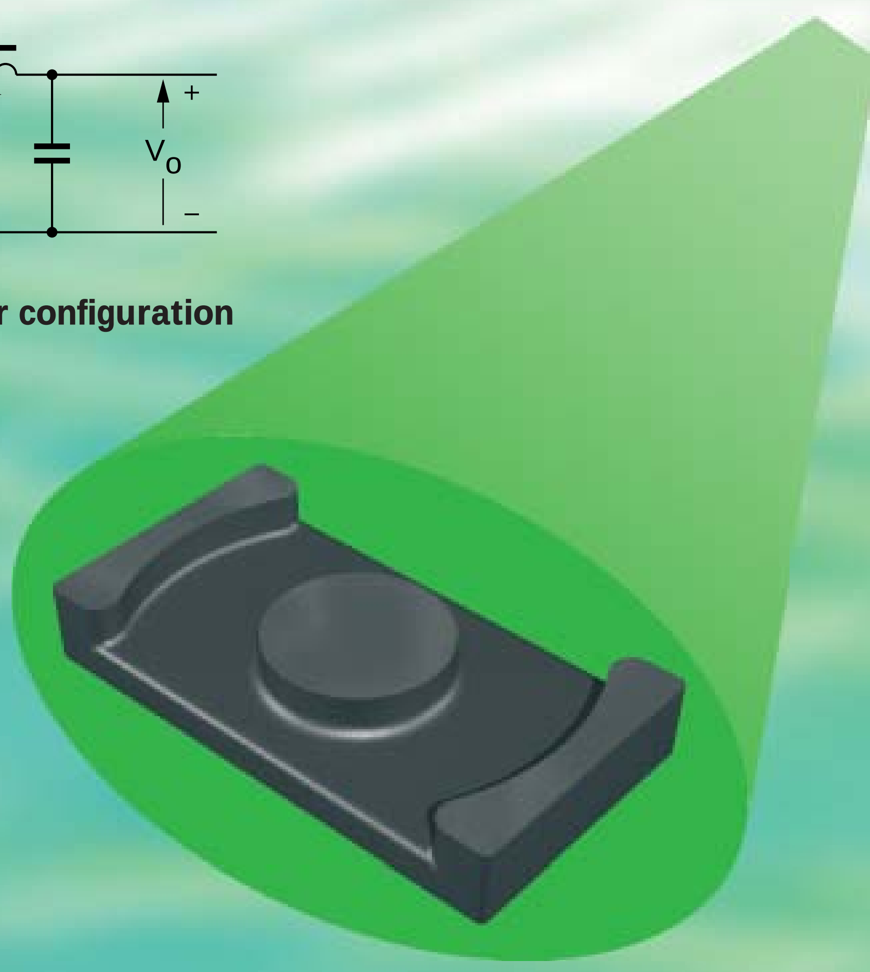
Planar inductive components have become a mainstream technology. For compact, low profile power converter modules (“bricks”) they are the standard. While the technology as such has been accepted, design optimization is still ongoing to strive for the highest power density. The first core shape that resulted in a standardized planar series was the planar E core, a low profile vertical variation of the conventional E core. Especially round centre leg shapes are well suited for compact designs. FERROXCUBE now introduces 2 new core sizes, ER18 and ER23. These are a logical continuation of the existing smaller ER cores ER9.5, ER11 and ER14.5, which can also be used in planar designs. Directing ourselves to the high density power conversion market, the new sizes are launched in the high saturation / high frequency materials 3C92, 3C96 and 3F35.

Applications

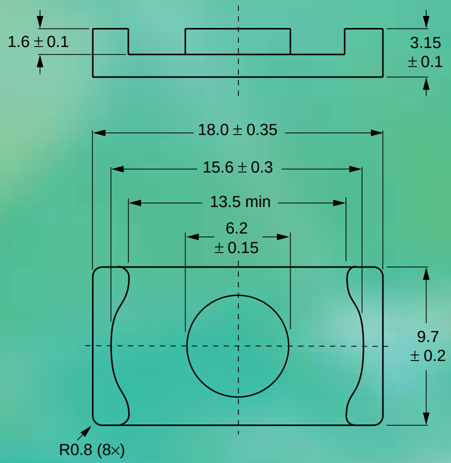
A typical application for the ER18 and ER23 can be found in dc/dc converter modules in telecom switches. They convert the intermediate dc supply voltage (12 – 48 V) to the PCB board level (1.0 – 3.3 V). Trends are increasing throughput power density and large output currents because semiconductor voltages go down. This requires a uniform core cross-section and high grade materials, but also more effective copper conductors. A round centre leg has principally the shortest copper tracks for a given core cross-section and therefore the lowest dc resistance and smallest footprint area. The winding window must be kept sufficiently large to limit the current density, which relates directly to the temperature rise due to the copper losses. The core cross-section is less dominant for lowe voltages, so the ratio of core cross-section to winding area can go down. All together these requirements lead to an ER-like core shape. The ER18 is intended for quarter brick designs (110 W, 40 – 60 A) and the ER23 for half brick designs (150 W, 60 – 80 A).



Forward converter configuration with line isolation



ER18 planar core



Effective core parameters

Symbol	Parameter	Value	Unit
Σ I/A	core factor (C_1)	0.730	mm^{-1}
V_e	effective volume	667	mm^3
l_e	effective length	22.1	mm
A_e	effective area	30.2	mm^2
A_{min}	minimum area	30.1	mm^2
m	mass of core set	3.2	g

Core sets

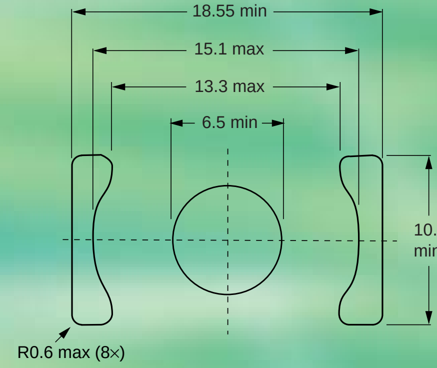
Material	AL (nH)	Type number
3C92	160 ± 3 %	ER18-3C92-A160-S
	250 ± 5 %	ER18-3C92-A250-S
	400 ± 8 %	ER18-3C92-A400-S
	1900 ± 25 %	ER18-3C92-S
3C96	160 ± 3 %	ER18-3C96-A160-S
	250 ± 5 %	ER18-3C96-A250-S
	400 ± 8 %	ER18-3C96-A400-S
	2400 ± 25 %	ER18-3C96-S
3F35	160 ± 3 %	ER18-3F35-A160-S
	250 ± 5 %	ER18-3F35-A250-S
	400 ± 8 %	ER18-3F35-A400-S
	1800 ± 25 %	ER18-3F35-S

Material	B (mT) at	Core loss (W) at			
	H = 1200 A/m f = 25 kHz T = 100 °C	f = 100 kHz B = 100 mT T = 100 °C	f = 100 kHz B = 200 mT T = 100 °C	f = 500 kHz B = 50 mT T = 100 °C	f = 500 kHz B = 100 mT T = 100 °C
3C92	≥ 415	≤ 0.052	≤ 0.35	–	–
3C96	≥ 380	≤ 0.035	≤ 0.26	≤ 0.22	–
3F35	≥ 380	–	–	≤ 0.078	≤ 0.61

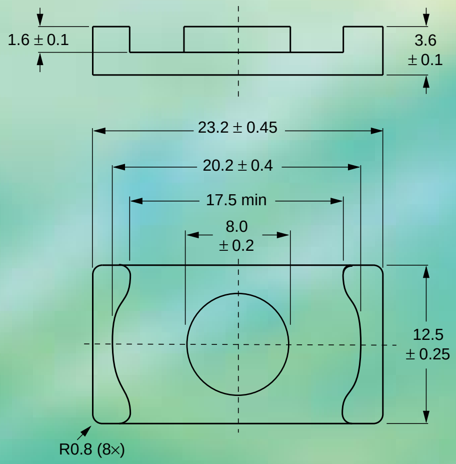
PCB coil parameters

Symbol	Parameter	Value	Unit
A_w	winding window	15.0	mm^2
l_w	average track length	34.2	mm
A_{fp}	footprint area *	225	mm^2

* Including copper tracks outside core



ER23 planar core



Effective core parameters

Symbol	Parameter	Value	Unit
Σ I/A	core factor (C_1)	0.530	mm^{-1}
V_e	effective volume	1340	mm^3
l_e	effective length	26.6	mm
A_e	effective area	50.2	mm^2
A_{min}	minimum area	50.0	mm^2
m	mass of core set	6.4	g

Core sets

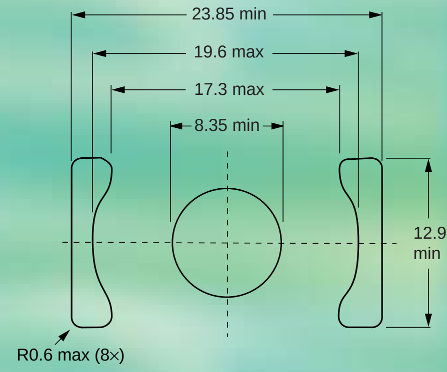
Material	AL (nH)	Type number
3C92	250 ± 3 %	ER23-3C92-A250-S
	400 ± 5 %	ER23-3C92-A400-S
	630 ± 8 %	ER23-3C92-A630-S
	2800 ± 25 %	ER23-3C92-S
3C96	250 ± 3 %	ER23-3C96-A250-S
	400 ± 5 %	ER23-3C96-A400-S
	630 ± 8 %	ER23-3C96-A630-S
	3400 ± 25 %	ER23-3C96-S
3F35	250 ± 3 %	ER23-3F35-A250-S
	400 ± 5 %	ER23-3F35-A400-S
	630 ± 8 %	ER23-3F35-A630-S
	2600 ± 25 %	ER23-3F35-S

Material	B (mT) at	Core loss (W) at			
	H = 1200 A/m f = 25 kHz T = 100 ºC	f = 100 kHz B = 100 mT T = 100 ºC	f = 100 kHz B = 200 mT T = 100 ºC	f = 500 kHz B = 50 mT T = 100 ºC	f = 500 kHz B = 100 mT T = 100 ºC
3C92	≥ 415	≤ 0.11	≤ 0.70	–	–
3C96	≥ 380	≤ 0.070	≤ 0.52	≤ 0.44	–
3F35	≥ 380	–	–	≤ 0.16	≤ 1.2

PCB coil parameters

Symbol	Parameter	Value	Unit
A_w	winding window	19.5	mm^2
l_w	average track length	44.3	mm
A_{fp}	footprint area *	375	mm^2

* Including copper tracks outside core



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