Siemens Matsushita Components

Ferrites and Accesories

Design Parameters for Low-Distortion and Power Transformers
TT/PR Cores

Preliminary Data Sheet

Vakatseite

1 Fundamentals for low-distortion transformers for digital data transmission (ISDN, xDSL)

The new digital transmission technologies over copper like ISDN, HDSL (high-rate digital subscriber line) and ADSL (asymmetric digital subscriber line) require very small harmonic distortion in order to maintain maximal line length. This requirement can be calculated from material parameters for the third harmonic distortion with the Rayleigh model for small-signal hysteresis (sinusoidal current).

$$k_3 = \frac{u_3}{u_1} = 0,6 \cdot \tan\delta_h$$
$$= 0,6 \cdot \mu_e \cdot \eta_B \cdot \hat{B}$$

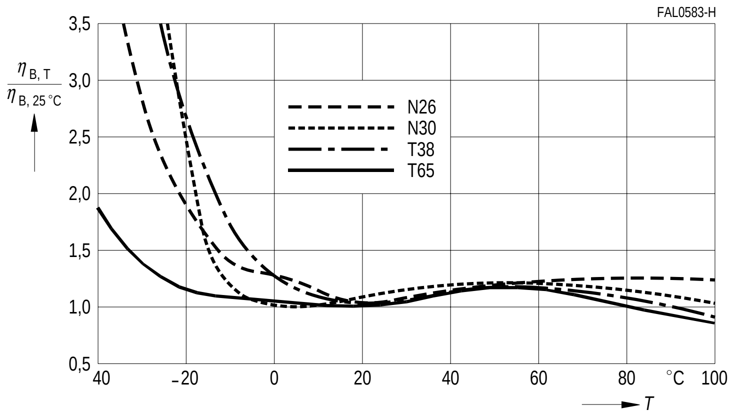
For a typical design a transformer has to be matched to a chipset via the turn ratios $N1 : N2 : N3$ …, the inductances L_1, L_2, L_3 … and the maximum dc resistances R_1, R_2, R_3 …

The third harmonic distortion for winding j can then be calculated as

$$k_3 = \frac{0,6}{\mu_0} \cdot \underbrace{\eta_B}_{\text{Material}} \cdot \underbrace{\frac{\hat{U}}{2\pi f}}_{\text{Circuit conditions}} \cdot \underbrace{L_j \cdot \left[\frac{\rho}{f_{Cu}} \sum_{j=1} \left(\frac{N_j}{N_1}\right)^2 \cdot \frac{1}{R_j}\right]^{3/2}}_{\text{Design constraints}} \cdot \underbrace{\underbrace{\frac{\sum_i l_i}{l_e} \cdot \frac{l_e}{{A_e}^2}}_{\text{Core}} \cdot \underbrace{\frac{{l_N}^{3/2}}{{A_N}^{3/2}}}_{\text{Coil former}}}_{\text{Geometry}}$$

This equation shows the contribution of the various design parameters:

a) The material is characterized by the hysteresis material constant η_B. Limit values for this parameter are given in the SIFERRIT material tables in the data book. The actual level for η_B varies for different cores. In order to select the best material for an application, the normalized temperature dependence $\eta_B(T)/\eta_B(25\ °C)$ is of great help (see graph below). Being mainly composition-dependent, these curves are thus material-specific.



	η_B 10^{-6}/mT
T38	< 1,4
N30	< 1,1
T65	< 1,1
N26	< 0,3

Normalized material hysteresis constant

b) The geometry can be taken into account by a core distortion factor (*CDF*) defined as

$$CDF = \frac{\sum l_i}{l_e} \cdot \frac{l_e}{A_e^{\;2}} \cdot \frac{l_N^{\;3/2}}{A_N^{\;3/2}}$$

The factor $\Sigma l_i / l_e$ is the closer to 1, the less the core section varies along the magnetic path (homogeneous core shape). For TT/PR cores without hole the factors are as follows:

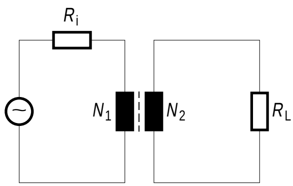
TT/PR 14 × 8	*CDF* = 0,205	$mm^{-4,5}$
TT/PR 18 × 11	*CDF* = 0,0561	$mm^{-4,5}$
TT/PR 23 × 11	*CDF* = 0,0217	$mm^{-4,5}$
TT/PR 23 × 18	*CDF* = 0,0119	$mm^{-4,5}$
TT/PR 30 × 19	*CDF* = 0,00465	$mm^{-4,5}$

$$CDF \sim \frac{1}{V_e^{3/2}}$$

I.e. the larger the core, the smaller is the distortion. Due to space restriction, however, the choice has to be made among the core shapes of a given size.

c) The circuit conditions, i.e. voltage amplitude $\hat{u}$ and frequency *f* affect directly the flux density in the core. For increasing flux density, a deviation of the absolute value of k_3 from the calculated test value is expected, since the tan δ_h vs. $\hat{B}$ curve deviates from linear.

d) The distortion k_{3c} for a transformer in a circuit with given impedance conditions can be obtained from the following formula:



$$k_{3c} = \frac{k_3}{\sqrt{1 + \left[3\omega L_1 \cdot \left(\frac{1}{R_i} + \left(\frac{N_2}{N_1}\right)^2 \cdot \frac{1}{R_L}\right)\right]^2}}$$

R_i = internal resistance of generator
R_L = load resistance
L_1 = primary inductance

The actual circuit distortion k_{3c} will in general be smaller than the calculated sinusoidal current value k_3.

2 Power capacities

In order to calculate the transmissible power, the following relationship is used (transformer with two equal windings):

$$P_{trans} = C \Delta B f A_e \cdot A_N \cdot j$$

where C is a coefficient characterizing the converter topolgy, i.e.

C = 1: push-pull converter
C = 0,71: single-ended converter
C = 0,62: flyback converter

Both the core losses associated with the flux swing ΔB and the copper losses due to the current density j result in a temperature increase ΔT. Assuming that both loss contributions are equal and that $P_V \sim B^2$, the power capacity can be approximated by

$$P_{trans} \approx C \cdot \underbrace{\frac{PF}{\sqrt{P_V}}}_{\text{Material}} \cdot \underbrace{\frac{\Delta T}{R_{th}}}_{\text{Thermal design}} \cdot \underbrace{\sqrt{\frac{f_{Cu}}{\rho_{Cu}}}}_{\text{Winding}} \cdot \underbrace{\sqrt{\frac{A_N \cdot A_e}{l_N \cdot l_e}}}_{\text{Geometry}}$$

The equation shows how the different aspects in the design contribute to the power capacity:

a) The material term is the performance factor ($PF = f \cdot B_{max}$) divided by the square root of the specific core loss level for which it was derived. For a given core shape deviations from this value are possible as given by its data sheet.

b) The values for ΔT are associated with the material according to the following table.

	ΔT_{max} K
N87	50
N49	20
N59	30
N27	30

For actual designs the actual values for R_{th} should be determined and the tabulated P_{trans} values adjusted accordingly.

c) The winding design was taken into account in the calcualtions by f_{Cu} = 0,4 and ρ_{Cu} for DC. In actual design large deviations of the dc resistance due to high frequency effects (skin effect, proximity effect) occur, unless special wire types such as litz wires are used. If the R_{AC}/R_{DC} ratio for a given winding is known, this can be used to correct the tabulated power capacities accordingly.

d) The geometry term is related to the core shape and size. However, note that the thermal resistance is also size-dependent via the empirical relation:

$$R_{th} \sim \frac{1}{\sqrt{V_e}}$$

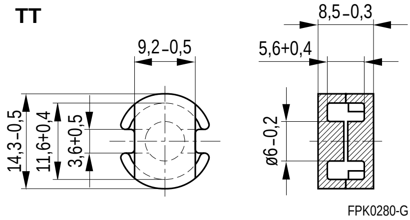
The tabulated power capacities provide a means for making a selection among cores, although the absolute values will not be met in practice for the reasons explained before.

Power capacities of TT/PR cores

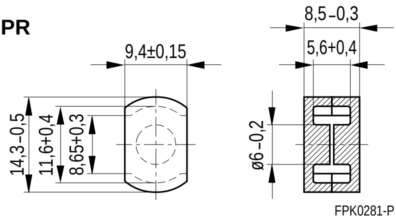
Core	R_{th} K/W	$\sqrt{\frac{A_N \cdot A_e}{l_N \cdot l_e}}$ mm	P_{trans} (N87/100 kHz) Wound transformer W
TT/PR 14 × 8	77	0,596	52
TT/PR 18 × 11	54	0,815	114
TT/PR 23 × 11	39	1,000	204
TT/PR 23 × 18	31	1,135	297
TT/PR 30 × 19	24	1,435	500

- Also available with center hole
- Types with special A_L value on request
- TT/PR cores are supplied in sets
- Coil formers available on request

TT



PR



Magnetic characteristics (per set)

$\Sigma l_e/A_e$ = 0,84 mm^{-1}
l_e = 25,3 mm
A_e = 25,3 mm^2
A_{min} = 22,1 mm^2
V_e = 539 mm^3

Approx. weight TT 3,5 g/set
PR 3,2 g/set

Ungapped [1)]

Material	A_L value nH	μ_e	A_{L1min} nH	P_V W/set	Ordering code	Type
N87	2000 + 30/– 20 %	1340	1350	< 0,35 (200 mT, 100 kHz, 100 °C)	B65754-J-R87 B65755-J-R87	TT PR
N26	2000 + 30/– 20 %	1400			B65754-J-R26 B65755-J-R26	TT PR
N30	4000 + 30/– 20 %	2680			B65754-J-R30 B65755-J-R30	TT PR
T65	5200 + 30/– 20 %	3480			B65754-J-R65 B65755-J-R65	TT PR
T38	8500 + 40/– 30 %	5695			B65754-J-Y38 B65755-J-Y38	TT PR

1) Preliminary data

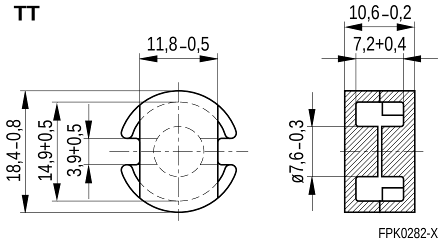
- Also available with center hole
- Types with special A_L value on request
- TT/PR cores are supplied in sets
- Coil formers available on request

Magnetic characteristics (per set)

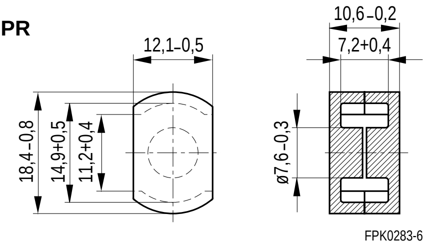
$\Sigma l_e/A_e$ = 0,68 mm^{-1}
l_e = 27,3 mm
A_e = 40,3 mm^2
A_{min} = 36,0 mm^2
V_e = 1100 mm^3

Approx. weight TT 6,4 g/set
PR 6,2 g/set

TT



PR



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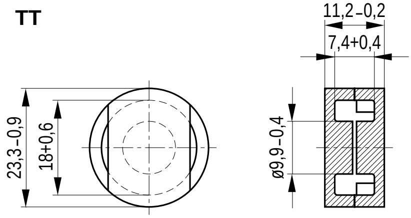
Material	A_L value nH	μ_e	A_{L1min} nH	P_V W/set	Ordering code	Type
N87	2800 + 30/– 20 %	1510	1670	< 0,7 (200 mT, 100 kHz, 100 ˚C)	B65756-J-R87 B65757-J-R87	TT PR
N26	2600 + 30/– 20 %	1400			B65756-J-R26 B65757-J-R26	TT PR
N30	5000 + 30/– 20 %	2695			B65756-J-R30 B65757-J-R30	TT PR
T65	7200 + 30/– 20 %	3880			B65756-J-R65 B65757-J-R65	TT PR
T38	10800 + 40/– 30 %	5820			B65756-J-Y38 B65757-J-Y38	TT PR

1) Preliminary data

- Also available with center hole
- Types with special A_L value on request
- TT/PR cores are supplied in sets
- Coil formers available on request

TT



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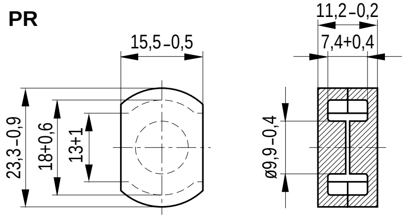
Magnetic characteristics (per set)

$\Sigma l_e/A_e$ = 0,45 mm^{-1}
l_e = 31,2 mm
A_e = 68,8 mm^2
A_{min} = 62,8 mm^2
V_e = 2144 mm^3

Approx. weight TT 13,8 g/set
PR 11,4 g/set

PR



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Ungapped [1)]

Material	A_L value nH	μ_e	A_{L1min} nH	P_V W/set	Ordering code	Type
N87	4800 + 30/– 20 %	1730	2500	1,4 (200 mT, 100 kHz, 100 °C)	B65716-L-R87 B65738-L-R87	TT PR
N26	4400 + 30/– 20 %	1590			B65716-L-R26 B65738-L-R26	TT PR
N30	7900 + 30/– 20 %	2850			B65716-L-R30 B65738-L-R30	TT PR
T65	11800 + 30/– 20 %	3880			B65716-L-R65 B65738-L-R65	TT PR
T38	16400 + 40/– 30 %	5920			B65716-L-Y38 B65738-L-Y38	TT PR

1) Preliminary data

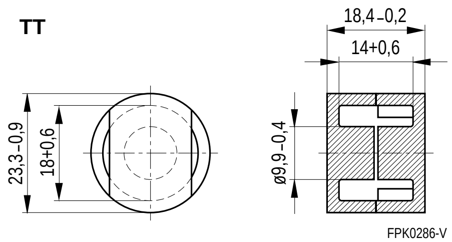
- Also available with center hole
- Types with special A_L value on request
- TT/PR cores are supplied in sets
- Coil formers available on request

Magnetic characteristics (per set)

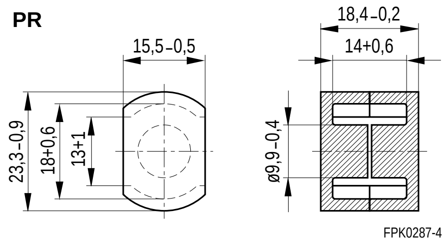
$\Sigma l_e/A_e$ = 0,62 mm^{-1}
l_e = 45,1 mm
A_e = 73,1 mm^2
A_{min} = 67,4 mm^2
V_e = 3293 mm^3

Approx. weight TT 20,6 g/set
PR 16,6 g/set

TT



PR



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Material	A_L value nH	μ_e	A_{L1min} nH	P_V W/set	Ordering code	Type
N87	3800 + 30/– 20 %	1870	1830	< 2,2 (200 mT, 100 kHz, 100 ˚C)	B65716-J-R87 B65738-J-R87	TT PR
N26	3600 + 30/– 20 %	1770			B65716-J-R26 B65738-J-R26	TT PR
N30	6500 + 30/– 20 %	3190			B65716-J-R30 B65738-J-R30	TT PR
T65	9200 + 30/– 20 %	4520			B65716-J-R65 B65738-J-R65	TT PR
T38	13800 + 40/– 30 %	6770			B65716-J-Y38 B65738-J-Y38	TT PR

1) Preliminary data

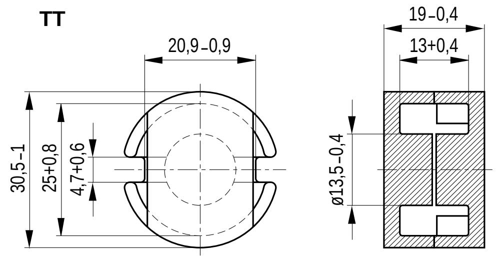
- Also available with center hole
- Types with special A_L value on request
- TT/PR cores are supplied in sets
- Coil formers available on request

Magnetic characteristics (per set)

$\Sigma l_e/A_e$ = 0,39 mm^{-1}
l_e = 46,4 mm
A_e = 119 mm^2
A_{min} = 99,4 mm^2
V_e = 5534 mm^3

Approx. weight TT 33,3 g/set
PR 29,6 g/set

TT



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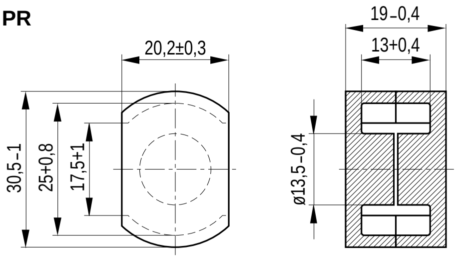
PR



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Material	A_L value nH	μ_e	A_{L1min} nH	P_V W/set	Ordering code	Type
N87	5400 + 30/– 20 %	1680	2900	< 2,8 (200 mT, 100 kHz, 100 °C)	B65730-J-R87 B65735-J-R87	TT PR
N26	5900 + 30/– 20 %	1830			B65730-J-R26 B65735-J-R26	TT PR
N30	9400 + 30/– 20 %	2920			B65730-J-R30 B65735-J-R30	TT PR
T65	14000 + 30/– 20 %	4340			B65730-J-R65 B65735-J-R65	TT PR
T38	22800 + 40/– 30 %	7075			B65730-J-Y38 B65735-J-Y38	TT PR

1) Preliminary data

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