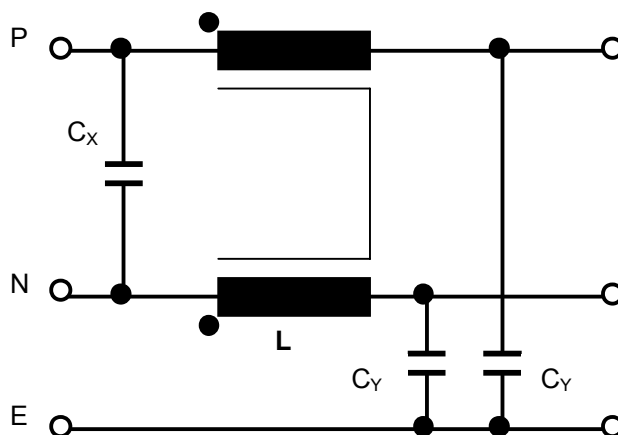


Tape-Wound Cores and Common Mode Chokes for RFI-filters

nanocrystalline VITROPERM® 500F



For several decades VACUUMSCHMELZE GmbH & Co. KG (VAC) has been one of the worldwide leading manufacturers of special metallic materials and inductive components manufactured from these alloys. In the field of electromagnetic compatibility (EMC), VAC has been supplying high performance products for more than 20 years.

VITROPERM® 500 F - the new Fe-based nanocrystalline soft magnetic high-tech material is the universal solution for a wide range of EMC problems. More finely differentiated, the brand VITROPERM covers graduated magnetic properties as well as a wide range of product designs. Ideally adapted solutions are thus available for practically every EMC problem. The most important applications for our Common Mode Chokes (CMC) are:

- Switched Mode Power Supplies
- Frequency converters
- All industrial applications i.e. UPS

Benefits of nanocrystalline CMC's

- ☑ **high permeabilities** for small choke size
- ☑ **very high induction swing** for high bias currents
- ☑ **extended temperature range** > 120°C
- ☑ **low temperature drift** for high linearity and reliability of the filter

VITROPERM 500 F – typical data

Saturation flux density	B_s	1.2 T
Saturation magnetostriction	λ_s	< 0.5 ppm
Electrical resistivity	ρ	1.15 $\Omega\text{mm}^2/\text{m}$
Curie temperature	T_c	600 °C
Upper operation temperature	T_{max}	> 120 °C
Permeability	μ_i	15000... 80000
Core Losses (100 kHz, 0.5 T)	P_{Fe}	105 W/kg

VITROPERM vs. ferrites

Rethinking is necessary in some respects in filter design, since the new material has a clearly different behaviour compared with manganese zinc ferrites. For better understanding of the theoretical and practical relationship the relevant physical and magnetic properties are demonstrated in the following diagrams.

The best way to present the excellent features of VITROPERM 500 F is the hysteresis loop (figure 1). The high saturation induction of 1.2 T is remarkable. Ferrites usually achieve not more than approx. 0.45 T. Consequently CMC's with cores made of VITROPERM 500 F offer a clearly higher margin for biasing DC-currents or voltages.

The permeability μ (which is equal to the slope of the hysteresis loop in first approximation) is indeed the most important material characteristic for Common-Mode Chokes.

High nominal inductances and consequently high initial permeabilities are indispensable for good damping properties of CMC's. Ferrite materials normally offer permeabilities of less than 15000. Their μ -level is only equivalent to the low permeability VITROPERM grades and this at clearly lower saturation induction (figure 2).

Another advantage of the nanocrystalline material results from the high curie temperature of more than 600 °C. The high saturation flux decreases only slightly in the operational temperature range (figure 3). Aging effects cause a decrease of permeability and other dynamic properties in the case of ferrites (and also high μ amorphous materials) and gives a limitation of the upper operation temperature below 100 °C.

In contrast, VITROPERM 500 F reveal negligible aging effects up to 120 °C (short time or hot spot up to 150 °C) due to the high thermal stability of the microstructure. Thus CMCs can be either designed for higher operating currents in the same component size or with the similar damping properties in much smaller volume.

The initial permeability of VITROPERM has a high linearity with regard to the temperature. According to figure 4 the drift at 100 kHz in the temperature range from -40 °C to 120 °C is only a few percent.

The curve of a high permeability ferrite shows the typically non-linear behaviour, which needs to be considered during component design.

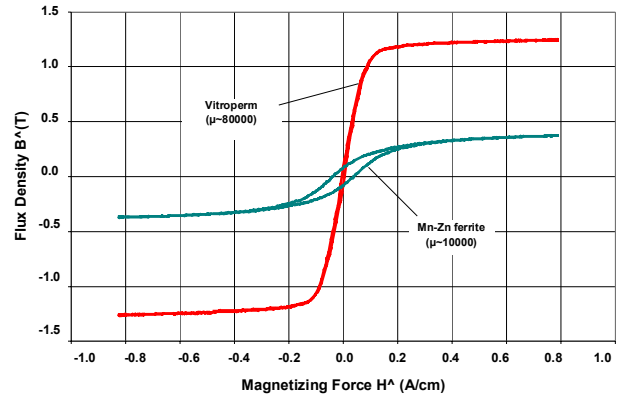


Figure 1: hysteresis loops of ferrite vs. VITROPERM

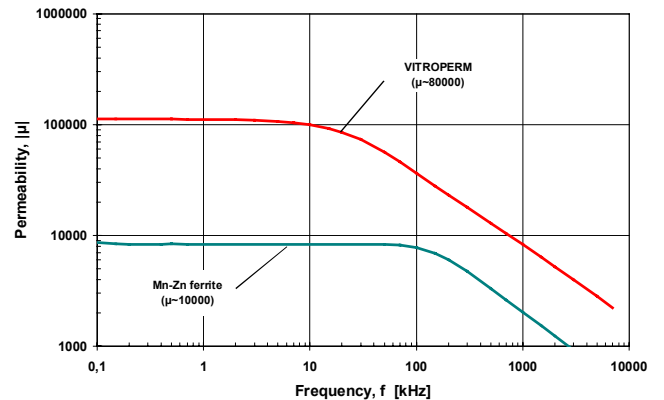


Figure 2: permeability vs. frequency

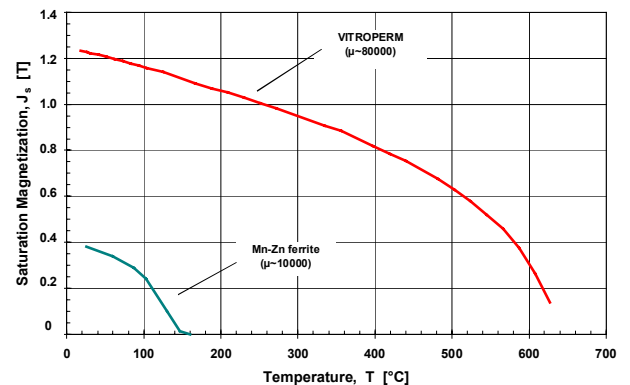


Figure 3: saturation induction vs. temperature

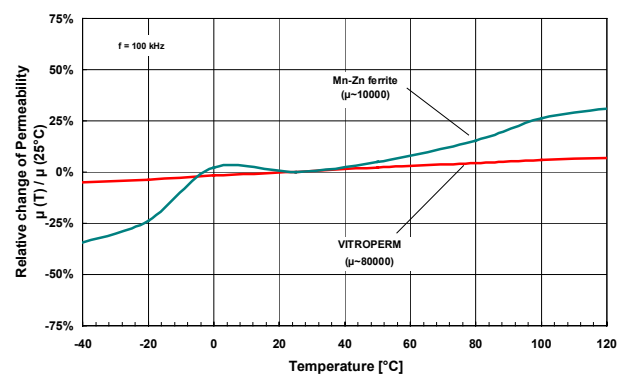


Figure 4: permeability vs. temperature

Design advantages with VITROPERM 500 F

Clear advantages in geometry and function can be achieved with tape wound cores made of VITROPERM 500F. These result from the outstanding material properties:

- *Highest initial permeability* ($\mu \approx 80000$) for SMPS.
- *Graded permeability levels* ($\mu \approx 18000, 30000, 50000$ and 80000) for various unbalance current requirements (e.g. in converters).
- *High saturation flux density* ($B_s = 1.2$ T).
- *High upper continuous temperature* (120 °C).
- *Highest linearity over temperature.*
- *Extreme low magnetostriction.*

These properties allow a high inductance or impedance of a Common-Mode Choke with only few turns. This results in low copper losses and small winding capacities.

Common Mode Chokes with cores made of VITROPERM 500 F are typically characterized by a broadband insertion loss curve due to the high permeability in the kHz frequency range and the small winding capacities in the MHz range.

For practical use, i.e. for noise suppression, the impedance $|Z|$ or the insertion loss curve aE (50 Ohm

system) are generally used as measuring variable appropriate to the application.

The insertion loss of Common Mode Chokes made of VITROPERM 500 F and ferrite with similar core dimensions and same no. of turns are demonstrated in figure 5. Nanocrystalline VITROPERM offers a pronounced insertion loss peak with significantly better damping properties. In particular, the noise suppression at frequencies of about 10 - 500 kHz (where the noise in SMPS is usually generated) is by far higher compared to conventional ferrites.

Better damping properties and a higher operational temperature range allow a reduction of component volume up to factor of 3 or more under similar nominal data (see figure 6). Note that the insertion loss curve of the small VITROPERM choke in figure 6 performs similar to that of ferrite at frequencies of about 600 - 900 kHz but is still superior below 500 kHz.

Especially in the low frequency range of the interference spectrum, the noise suppression of one choke made of VITROPERM 500 F achieves such good results which previously could be obtained by complex filter circuits only.

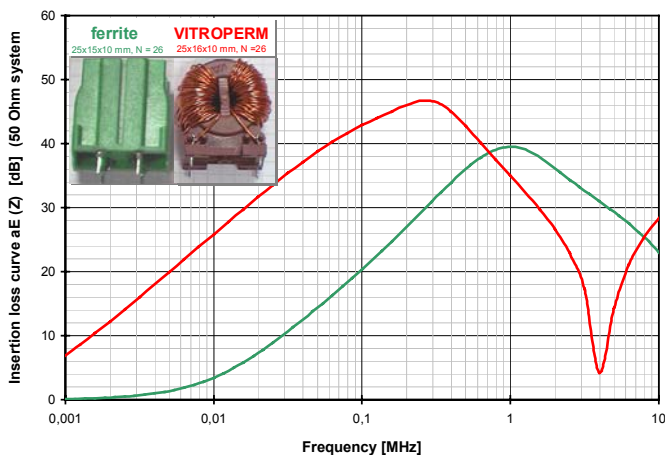


Figure 5: comparison of insertion loss curve of CMC with VITROPERM 500 F (red curve) and ferrite (green curve) of similar size and same no. of turns.

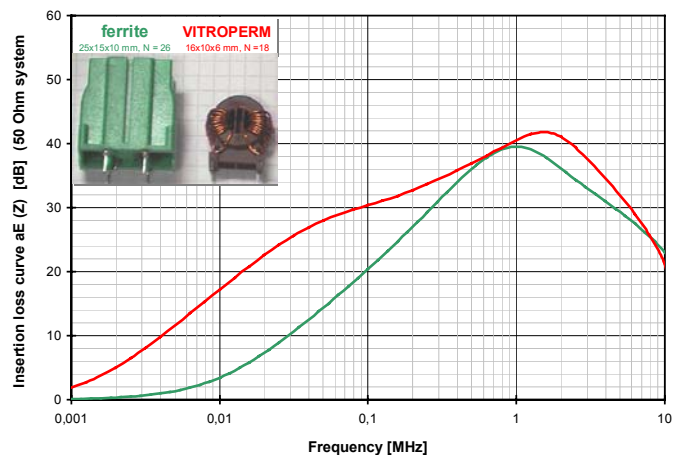


Figure 6: comparison of insertion loss curve of CMC with VITROPERM 500 F (red curve) and ferrite (green curve) of similar performance.

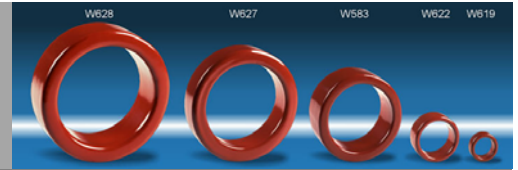
Recommendation chart for Standard or VF cores (components)

Core material (Component)		Application		
		Converter (with unbalance currents)	UPS	SMPS
Standard type	low AI-value	+	-	-
	high AI-value	0	++	++
VF-type	low AI-value	++	0	0
	high AI-value	+	+	+

(for small unbalance currents only)

core dimensions	finished dimensions			cross-section	mean path-length	Al (10kHz)	Al (100kHz)	thermal resistance	part number
$d_a \times d_i \times h$ mm ³	OD mm	ID mm	H mm	A_e cm ²	l_e cm	nominal value μH	value* μH	R_{th} K/W	T6000...

VF-series of nanocrystalline VITROPERM 500 F
tape wound cores
(volume and frequency optimized, epoxy coated)



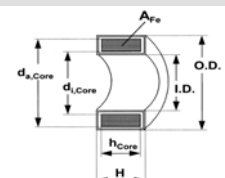
16 x 12.5 x 6	17.8	10.7	8	0.08	4.48	6.0 15	3.9 4.8	40	4-L2016-W619 4-L2016-W620
25 x 20 x 10	27.3	17.5	12.3	0.19	7.1	9.0 22.5	5.8 7.2	26	4-L2025-W621 4-L2025-W622
30 x 25 x 15	32.3	22.7	17.5	0.27	8.64	6.8 26.5	5.1 8.5	13	4-L2030-W675 4-L2030-W676
40 x 32 x 15	42.3	29.1	17.8	0.438	11.3	13.0 32.5	8.4 10.3	11	4-L2040-W623 4-L2040-W624
50 x 40 x 20	52.3	37.1	22.8	0.73	14.1	11.2 17.0 43.0	10.0 11.2 13.8	7	4-L2050-W583 4-L2050-W625 4-L2050-W626
63 x 50 x 20	65.5	46.6	22.8	0.95	17.8	11.5 18.0	10.4 11.6	5	4-L2063-W721 4-L2063-W627
80 x 63 x 20	83	59.5	22.8	1.24	22.5	11.9 18.5	10.7 12.0	4	4-L2080-W722 4-L2080-W628
100 x 80 x 20	104	75	23	1.46	28.3	11.2 17.3	10.0 11.2	3	4-L2100-W723 4-L2100-W629
130 x 100 x 25	134.5	95	28.5	2.74	36.1	16.4 25.4	14.7 16.5	2	4-L2130-W587 4-L2130-W630
160 x 130 x 25	165	125	28.5	2.74	45.6	13.0 20.0	11.7 13.1	2	4-L2160-W720 4-L2160-W631

Standard series of nanocrystalline VITROPERM 500 F
tape wound cores
plastic case



12.5x10x5	14.0	8.5	6.7	0.050	3.53	10.0		55	6-L2012-W498
16x10x6	17.8	8.6	8.0	0.140	4.10	41.4 11.7		40	6-L2016-W403 6-L2016-W308
17.5x12.6x6	19.0	11.0	8.0	0.118	4.73	30.0		35	6-L2017-W515
20x12.5x8	22.5	10.4	10.1	0.240	5.10	55.2 14.3		26	6-L2020-W409 6-L2020-W450
25x20x10	27.6	17.4	12.8	0.200	7.07	28.4		26	6-L2025-W523
25x16x10	27.8	13.7	12.7	0.360	6.44	65.5 17.0		26	6-L2025-W380 6-L2025-W451
30x20x10	32.7	17.7	12.5	0.400	7.85	59.3 15.5		13	6-L2030-W423 6-L2030-W358
40x32x15	43.1	28.7	18.5	0.456	11.3	47.2 12.2		11	6-L2040-W422 6-L2040-W452
40x25x15	43.1	22.5	18.5	0.855	10.2	98.0 25.4		11	6-L2040-W424 6-L2040-W453
50x40x20	53.5	36.3	23.4	0.760	14.1	45.3		7	6-L2050-W516
63x50x25	67.3	46.5	28.6	1.240	17.8	58.6		5	6-L2063-W517
80x50x20	86.0	44.7	25.7	2.280	20.4	35.0		4	6-L2080-W531
90x60x20	95.4	56.1	24.7	2.280	23.6	81.0		4	6-L2090-W518
102x76x25	108.1	70.0	30.3	2.470	28.0	≥ 55.0		3	6-L2102-W468

Notes: R_{th} = heat transfer resistance of the reactor by free convection
Al = inductance for N = 1
* Tolerance +45% / -25%



I_N	L_N	I_{bias} at 10 kHz typical	$ Z $ at 100kHz typical	pins \varnothing mm	dimensions w x d x h mm (max)	component, part number T6040...	suitable core, part number T6000...
A	mH	A	Ω	mm	mm (max)	T6040...	T6000...

Single-phase Common Mode Chokes
with nanocrystalline cores made of
VITROPERM 500 F **VF-series**

upright design



2.0	2 x 15.0	0.02	3085	0.63	23 x 14 x 25	5-R6161-X016	4-L2016-W620
2.5	2 x 5.0	0.05	2050	0.63	23 x 14 x 25	5-R6161-X017	4-L2016-W619
3.5	2 x 4.5	0.03	870	0.71	23 x 14 x 25	5-R6161-X018	4-L2016-W620
4.0	2 x 7.0	0.02	1460	0.80	23 x 14 x 25	5-R6161-X019	4-L2016-W620
5.0	2 x 1.5	0.08	625	0.80	23 x 14 x 25	5-R6161-X022	4-L2016-W619
5.0	2 x 5.0	0.03	975	0.80	23 x 14 x 25	5-R6161-X020	4-L2016-W620
6.0	2 x 3.0	0.04	590	0.90	23 x 14 x 25	5-R6161-X021	4-L2016-W620
6.0	2 x 20.0	0.03	4070	0.80	38 x 21 x 38	5-R6166-X047	4-L2025-W622
6.0	2 x 8.0	0.07	3280	0.90	38 x 21 x 38	5-R6166-X048	4-L2025-W621
8.0	2 x 4.5	0.10	1760	0.90	38 x 21 x 38	5-R6166-X054	4-L2025-W621
10.0	2 x 2.5	0.12	1050	1.00	38 x 21 x 38	5-R6166-X049	4-L2025-W621
10.0	2 x 6.5	0.05	1300	1.00	38 x 21 x 38	5-R6166-X050	4-L2025-W622
10.0	2 x 9.0	0.04	1800	1.12	38 x 21 x 38	5-R6166-X051	4-L2025-W622
12.0	2 x 4.0	0.06	765	1.12	38 x 21 x 38	5-R6166-X053	4-L2025-W622
16.0	2 x 2.5	0.08	550	1.25	38 x 21 x 38	5-R6166-X052	4-L2025-W622

Single-phase Common Mode Chokes
with nanocrystalline cores made of
VITROPERM 500 F **standard series**

flat and upright designs



2.0	2 x 12	0.02	760	0.56	22 x 12 x 25	5-R6131-X036	6-L2016-W403
4.0	2 x 5.0	0.03	320	0.63	22 x 12 x 25	5-R6131-X037	6-L2016-W403
4.0	2 x 71	0.02	4615	0.80	38 x 21 x 38	5-R6166-X016	6-L2025-W380
4.5	2 x 32	0.03	1825	0.80	32 x 30 x 22	5-R6122-X007*	6-L2025-W380
5.0	2 x 2.2	0.08	140	0.71	22 x 12 x 25	5-R6131-X040	6-L2016-W308
5.0	2 x 7.5	0.03	445	0.71	22 x 12 x 25	5-R6131-X046	6-L2016-W403
6.0	2 x 3.3	0.04	215	0.71	22 x 12 x 25	5-R6131-X038	6-L2016-W403
6.0	2 x 32	0.03	1825	1.00	38 x 21 x 38	5-R6166-X017	6-L2025-W380
8.0	2 x 17	0.04	1090	1.00	38 x 21 x 38	5-R6166-X018	6-L2025-W380
10.0	2 x 1.5	0.06	95	1.00	22 x 12 x 25	5-R6131-X047	6-L2016-W403
10.0	2 x 9.0	0.05	545	1.20	31 x 20 x 32	5-R6122-X006	6-L2025-W380
10.0	2 x 12	0.04	740	0.80	38 x 21 x 38	5-R6166-X019	6-L2025-W380
12.0	2 x 11.7	0.04	740	1.18	38 x 21 x 38	5-R6166-X035	6-L2025-W380
16.0	2 x 2.9	0.12	185	2.40	$\varnothing 35 \times h19$	5-R6100-X205*	6-L2025-W380
16.0	2 x 3.6	0.09	185	1.00	38 x 21 x 38	5-R6166-X039	6-L2025-W380
16.0	2 x 6.0	0.06	375	1.12	38 x 21 x 38	5-R6166-X033	6-L2025-W380
20.0	2 x 1.6	0.12	95	2.10	35 x 35 x 22	5-R6122-X009*	6-L2025-W380
25.0	2 x 0.5	0.20	35	1.18	38 x 21 x 38	5-R6166-X028	6-L2025-W380
35.0	2 x 6.6	0.08	425	3.30	$\varnothing 56 \times h28$	5-R6100-X212*	6-L2040-W422

I_N	L_N	I_{bias} at 10 kHz typical	$ Z $ at 100kHz typical	pins \varnothing mm	dimensions w (x d) x h mm (max)	component, part number	suitable core, part number
A	mH	A	Ω			T6040...	T6000...

3 - phase Common Mode Chokes with nanocrystalline cores made of VITROPERM 500 F **VF-series**

flat design



3	3 x 10.0	0.05	1900	0.8	\varnothing 37 x h 22	5-S6122-X013	4-L2030-W676
6	3 x 8.0	0.06	1550	1.0	\varnothing 45 x h 22	5-S6122-X014	4-L2030-W676
8	3 x 9.0	0.08	1870	1.6	\varnothing 51 x h 31	5-S6122-X015	4-L2040-W624
12	3 x 4.0	0.10	782	1.8	\varnothing 51 x h 31	5-S6122-X016	4-L2040-W624
16	3 x 3.5	0.28	1380	1.8	\varnothing 59 x h 32	5-S6122-X017	4-L2050-W625
20	3 x 5.0	0.15	1050	2.0	\varnothing 59 x h 32	5-S6122-X018	4-L2050-W626
33	3 x 2.5	0.44	1050	3.0	\varnothing 77 x h 37	5-S6122-X019	4-L2063-W627
40	3 x 1.5	0.53	590	cs	\varnothing 77 x h 37	5-S6122-X020	4-L2063-W627

3 - phase Common Mode Chokes with nanocrystalline cores made of VITROPERM 500 F **standard series**

flat design



3	3 x 11.0	0.02	750	0.7	23 x 23 x 16	5-S4615-X027	6-L2016-W403
3	3 x 2.7	0.08	195	0.7	23 x 23 x 16	5-S4615-X036	6-L2016-W454
6	3 x 5.0	0.04	345	0.7	28 x 28 x 20	5-S4185-X015	6-L2020-W409
6	3 x 2.5	0.17	90	0.7	28 x 28 x 20	5-S4185-X020	6-L2020-W450
10	3 x 1.4	0.24	85	1.12	32 x 32 x 25	5-S4220-X311	6-L2025-W451
13	3 x 0.8	0.35	40	1.18	32 x 32 x 25	5-S4220-X310	6-L2025-W451
20	3 x 1.0	0.42	60	2.5	51 x 51 x 39	5-S4207-X007	6-L2040-W452
25	3 x 5.5	0.11	395	3.3	51 x 51 x 39	5-S4200-X223	6-L2040-W424
25	3 x 1.6	0.42	100	3.3	51 x 51 x 39	5-S4207-X008	6-L2040-W453
30	3 x 0.94	0.56	55	4.0	51 x 51 x 39	5-S4207-X009	6-L2040-W453
40	3 x 0.4	0.84	25	4.0	51 x 51 x 39	5-S4207-X010	6-L2040-W453

Common Mode Chokes for higher currents and/or different properties are available on request.

Notes about CMC tables:

* flat design

I_N = nominal current in each winding

L_N = nominal inductance at 10 kHz, tolerance +50% / -30 %

I_{bias} at 10 kHz

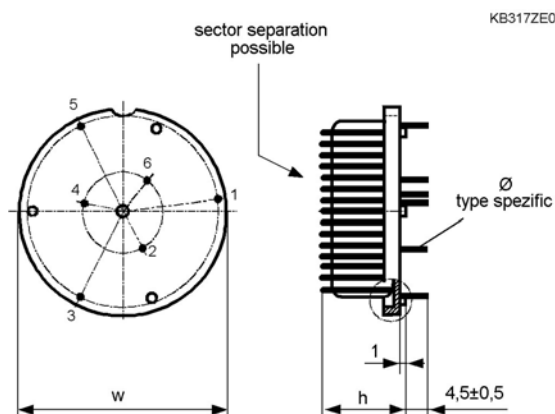
Operation temperature -40°C...+120°C (short time +150°C)

Ambient temperature -40°C...+60°C (short time +90°C)

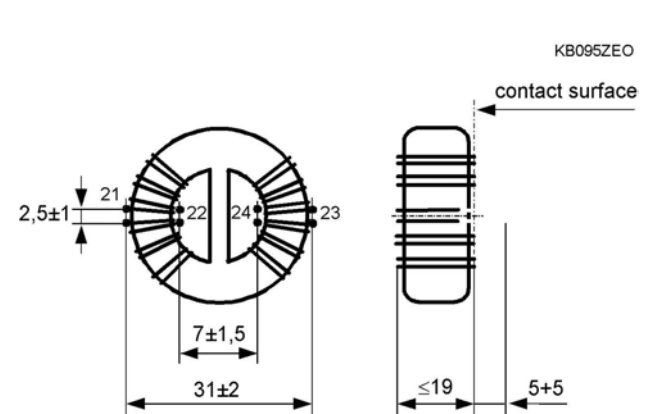
UL listed plastic material

cs = cable shoes

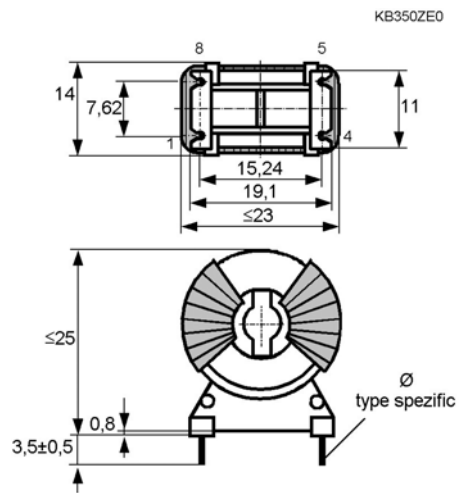
Drawings



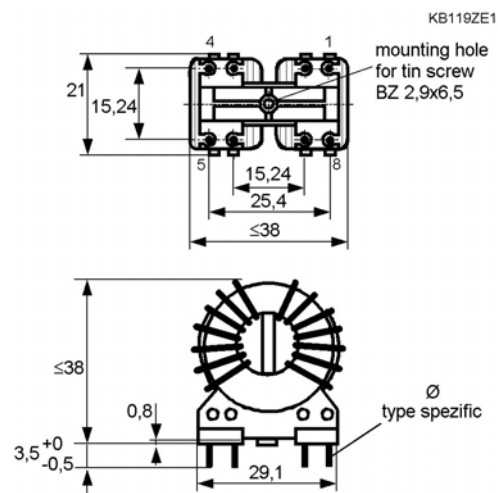
Design T60405-S6122-X...



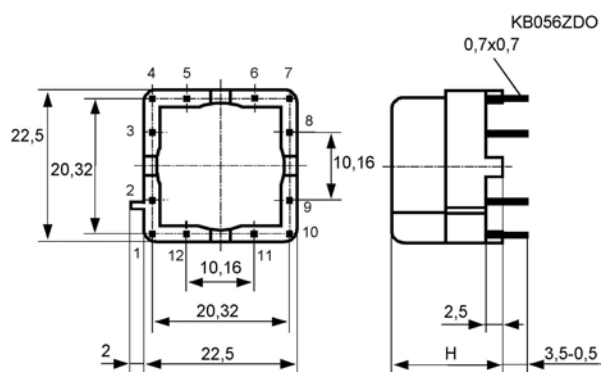
Design T60405-R6100-X...



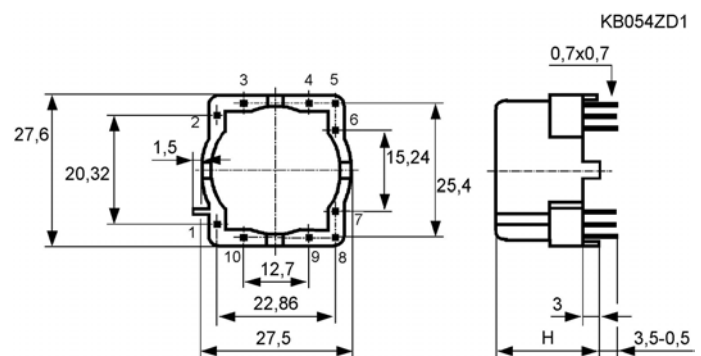
Design T60405-R6161-X...
Design T60405-R6131-X...



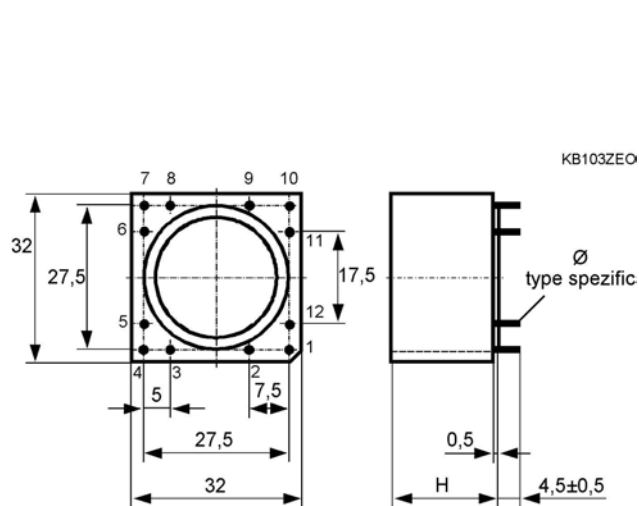
Design T60405-R6166-X...



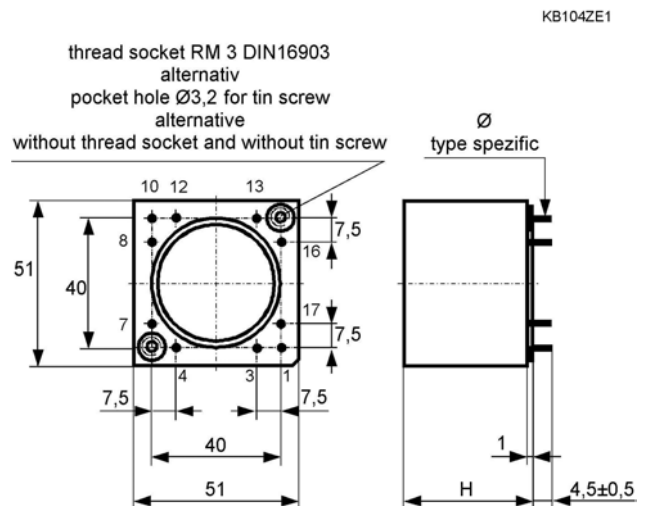
Design T60405-S4645-X...



Design T60405-S4185-X...



Design T60405-S4220-X...



Design T60405-S4207-X...

VACUUMSCHMELZE GmbH & Co. KG



Advanced Materials – The Key to Progress

P.O.B. 2253
D-63412 Hanau, Germany
☎ (**49) 6181 / 38-0
Fax (**49) 6181 / 38-2780
E-Mail: Info@vacuumschmelze.com
Internet: <http://www.vacuumschmelze.com>
001002