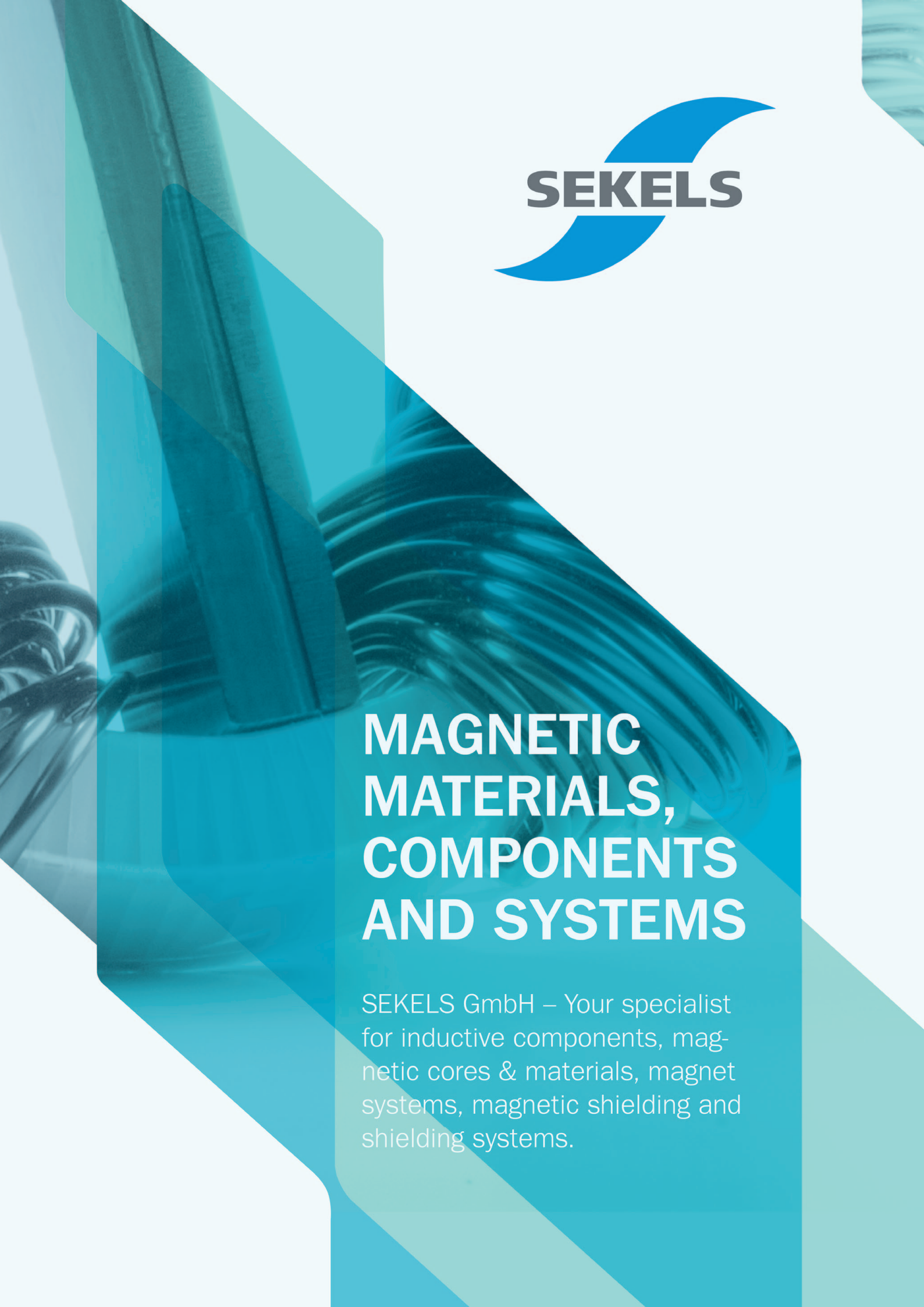


SEKELS

MAGNETIC MATERIALS, COMPONENTS AND SYSTEMS

SEKELS GmbH – Your specialist for inductive components, magnetic cores & materials, magnet systems, magnetic shielding and shielding systems.

Contents

Expert Distribution and Customer-Specific Solutions

SEKELS GmbH designs, produces and trades products which are mostly related to magnetism.

- Expert distributor of German VACUUMSCHMELZE GmbH & Co. KG
  - VITROPERM® & VITROVAC® tape-wound cores
  - VITROPERM® common mode chokes
  - Current sensors and current transformers
  - Power transformers and pulse transformers
  - MUMETALL®, PERMENORM®, CRYOPERM®, VACOFLUX®, TRAFOPERM®, laminations, core packages, semi-finished products
  - VACODYM® and VACOMAX® permanent magnets
- Soft magnetic material (ribbons, foils, rods, panel sheets, parts) from NiFe, CoFe and SiFe alloys
- Amorphous & nanocrystalline tape-wound toroidal and c-cores
- Customer-specific chokes and transformers
- Magnetic shielding
- Magnet systems
- Measuring systems

We offer:

- Extensive stock of tape-wound cores, components and semi-finished products
- Fast deliveries, world-wide logistics and professional consulting service
- Design, FEM simulations, measurements, prototyping
- Material processing and assembly
- Magnetic annealing
- Material analysis, basic design and system development
- Measurements and development service

SEKELS GmbH develops, produces and trades technical products which are mostly related to magnetism. With a team of about 25 employees, more than half of them being physicists or engineers, we presently serve more than 500 customers worldwide.

As an expert distributor of German VACUUMSCHMELZE GmbH & Co. KG we are familiar with their product lines and the applications, offer technical consultation and provide fast availability of samples or series by comprehensive stock keeping and worldwide logistics.

Nanocrystalline Tape-Wound Cores

Nanocrystalline VITROPERM® alloys feature unique soft magnetic properties in a wide temperature range.

Nanocrystalline alloys are manufactured in form of thin ribbons of about 20 µm thickness using rapid solidification technology. They offer:

- Highest permeabilities
- High saturation induction
- Wide temperature range
- Low loses
- Linear hysteresis loop

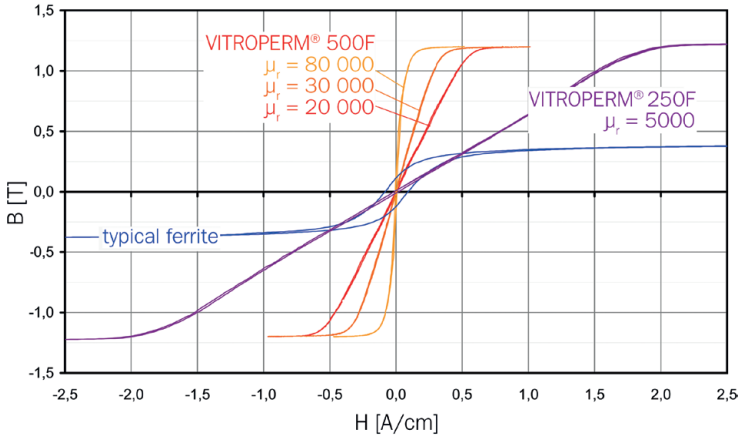
Saturation flux density	B_s [T]	1,2
Curie temperature	T_c [°C]	600
Magnetostriction	λ_s [ppm]	< 0,5
Specific electrical resistivity	ρ_{el} [µΩm]	1,2
Density	ρ [g/cm³]	7,35
Rel. permeability	μ_r [at 10kHz]	20 000 - 100 000
Core losses (0,3 T; 100 kHz)	P_{Fe} [W/kg]	80
Upper application temperature	T_+ [°C]	120
Lower application temperature	T_- [°C]	-40

Nanocrystalline cores are available in different standard core sizes of approximately 10 mm to 200 mm outer diameter, with epoxy coating (Fix 350) or plastic casing (Fix 022). Standard types are delivered directly from our stock. Customer-specific sizes including c-cores are available on demand. We have more than 25 years of experience with amorphous and nanocrystalline materials and cores and are looking forward to support your designs.

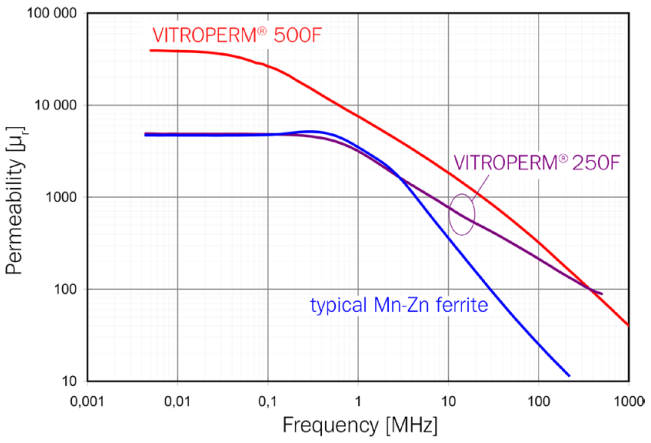
We stock standard cores for applications like:

- Common Mode Chokes
- Power Transformers
- Pulse Transformers
- Current Transformers
- Magnetic Amplifier Chokes

Typical magnetization curves



Permeability



Amorphous Tape-Wound Cores

Amorphous alloys have a “orderless” atomic structure without crystalline grains and grain boundaries. These are perfect preconditions for good soft magnetic behavior due to the absence of “magnetic disturbances” like crystal anisotropy and grain boundary pinning.

To obtain thin amorphous metallic ribbons out of suitable alloys a cooling rate of 1 million Kelvin per second is needed. This is possible with a rapid solidification technology, where the molten metal is squeezed through a ceramic nozzle onto a fast rotating, water-cooled casting wheel.

The ribbons are finally manufactured to tape-wound cores, either toroidal or rectangular, w/o and with cut or air gap. To reduce the inner stress and tension and to create special hysteresis loops a heat treatment below the crystallization temperature (typically about 450 °C - 500 °C for commercial amorphous alloys) is applied.

Two “families” of alloy compositions are available:

- Co based alloys VITROVAC® with extremely low magnetostriction
- Fe based alloys with high saturation induction and low costs

We stock standard cores for:

- Magnetic amplifiers
- Specific applications

C-cores and customer-specific sizes are available on demand.

Basic Material Data

		VITROVAC® 6025Z	VITROVAC® 6030F	Fe based amorphous
Saturation flux density	B_s [T]	0,58	0,82	1,56
Curie temperature	T_c [°C]	240	365	399
Magnetostriction	λ_s [ppm]	<0,2	<0,2	27
Spec. electrical resistivity	ρ_{el} [µΩm]	1,4	1,3	1,3
Density	ρ [g/cm³]	7,7	7,75	7,18
Rel. permeability	μ_r [at 10kHz]	–	3000	–
Core losses (0,3 T; 100 kHz)	P_{Fe} [W/kg]	120	100	900
Upper application temperature	T_+ [°C]	85	100	150
Lower application temperature	T_- [°C]	-40	-40	-40

Amorphous C-Cores

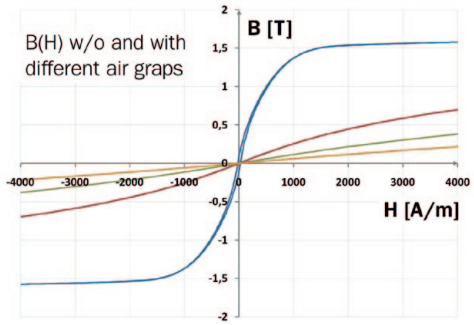
C-cores from amorphous Fe based alloys offer an interesting combination of high saturation induction and low losses. Therefore they are especially suitable for chokes in power applications.

Material data Fe-amorphous

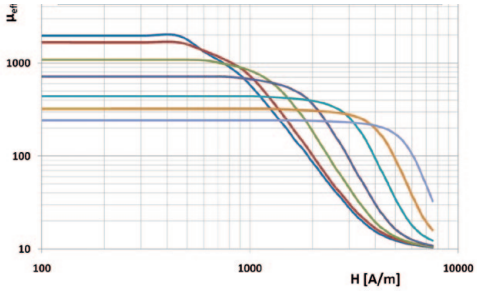
Saturation flux density	B_s [T]	1,56
Curie temperature	T_c [°C]	399
Magnetostriction	λ_s [ppm]	27
Specific electrical resistivity	ρ_{el} [µΩm]	1,3
Density	ρ [g/cm³]	7,18
Typ. stacking factor	FF [%]	82
Core losses (0,1 T; 25 kHz)	P_{Fe} [W/kg]	approx. 15
Core losses (0,2 T; 50kHz)	P_{Fe} [W/kg]	approx. 150
Upper application temperature	T [°C]	approx. 150

Amorphous Fe based alloys are produced in foils of approx. 20 µm thickness and widths up to 200 mm. Because of their relatively high magnetostriction they do not attain the excellent magnetic properties of nanocrystalline alloys, but they feature a high saturation induction and are cost-effective.

Interesting applications for amorphous c-cores are power chokes in a range of > 10 A at approx. 20 – 100 kHz. Because of the low losses the overall size of the choke can be optimized even for higher current ripples.



Typical B(H) characteristic of amorphous c-cores



Effective permeability for different air gaps

We offer the American AMCC types (selected sizes ex stock) and customized dimensions.

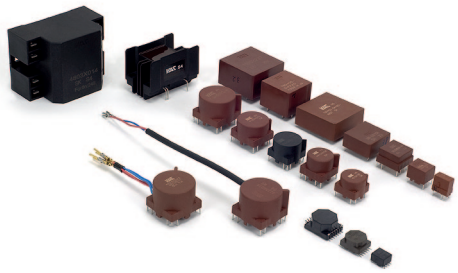
Amorphous c-cores: selection of standard sizes

type	length	width	height	inner length	inner width	leg buildup	l_{Fe}	A_{Fe}	m_{Fe}	LI^2_{eff}
	a [mm]	b [mm]	f [mm]	e [mm]	g [mm]	c [mm]	[cm]	[cm²]	[g]	[VAs]
AMCC 20	72	35	30	50	15	11	17,5	2,7	337	0,20
AMCC 32	82	41	30	56	15	13	20,0	3,2	454	0,29
AMCC 50	102	52	25	70	20	16	24,9	3,3	586	0,43
AMCC 80	102	52	40	70	20	16	25,4	5,2	938	0,59
AMCC 100	102	52	45	70	20	16	25,0	5,9	1055	0,65
AMCC 125	121	63	35	83	25	19	30,2	5,5	1166	0,81
SU 75b	125	72,4	40	78	25	23,7	31,0	7,7	1764	1,0

VAC - Inductive Components

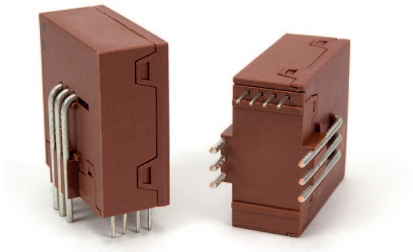
We are distributor of German VACUUMSCHMELZE GmbH & Co. KG (VAC)

Inductive components from VAC feature high efficiency and small construction volume by combining state of the art alloys like nanocrystalline materials with the latest design technologies. The high quality production sites are located in Eastern Europe and in Asia. The main applications are regenerative energy supply systems, automotive, mechanical engineering, medical technology etc.



Emphasis:

- Common Mode Chokes with nanocrystalline cores
- Active Current Sensors
- Current Transformers with amorphous and nanocrystalline cores
- Power Transformers and Pulse Transformers
- Linear Chokes and Saturable Reactors

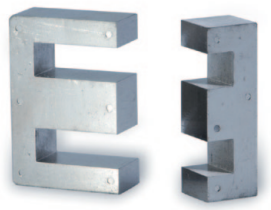


A wide scale of standard types can be found under: www.vacuumschmelze.com

We know the products and applications in order to be your ideal partner for consultation, selection of right standard types and development of your projects.

Laminations & Core Packages

SEKELS GmbH offers high-end laminations and core packages made of NiFe alloys (MUMETALL®, VACOPERM®, PERMENORM®) and SiFe alloys (TRAFOPERM®) from VACUUMSCHMELZE GmbH & Co. KG (Germany).



Standard laminations are described in DIN EN 60740 in a variety of sizes and grades. They are stamped from a primary material strip of the respective thickness and finished by a consequent annealing process to optimize the magnetic properties. A thin oxide layer which has formed during the annealing process is typically sufficient as interlayer isolation. Especially with thin laminations careful handling is required in order to not reduce or destroy the magnetic properties by elastic or plastic deformation.

Usually laminations are stacked in alternating directions in order to reduce the effective air gap. Besides, the possible effective permeability depends of course on the alloy and on the size and shape of the laminations, which both influence the ratio between the mean magnetic path length and the effective air gap (shearing). ED and U laminations exhibit the lowest shearing effect and allow the highest permeability values. In combination with the high permeability alloys MUMETALL® or VACOPERM® they are especially suitable for chokes or transformers which need a high inductivity.

Core packages are produced by stacking single laminations and finishing the package by impregnation, welding or mechanical interlocking. Combined with standard coil formers, this allows a fast and cost-effective production and assembly. Compared with alternated stacked individual laminations, core packages show lower effective permeabilities even when they are face grinded. They are however especially suitable for applications which need tolerated A_L values, like e. g. chokes with pre-magnetization.

Standard laminated core packages are described in DIN EN 61021. The EK types, stacked from EE laminations, are optimized for an effective build-up. They feature a square ground area and a square cross section of the middle leg. The ratio of the total core cross section to the winding space is 1:1,55. All EK types are geometrically similar.

In addition to the DIN standard types, SEKELS is offering customer-specific sizes and shapes, also from CoFe (VACOFLUX®) or SiFe (TRAFOPERM®). We design and produce according to your individual needs, from prototypes to series quantities.

Material characteristics of soft-magnetic alloys for laminations and core packages

Alloy	Composition	μ_r	$H_{c,\,stat}$	B_s	T_c	Density
		(0,4 A/m, 50 Hz)	[A/m]	[T]	[°C]	[g/cm³]
VACOPERM 100®	80 % NiFe	ca. 60 000	2	0,78	400	8,7
MUMETALL®	80 % NiFe	ca. 30 000	3	0,8	400	8,7
PERMENORM 5000 H2®	50 % NiFe	ca. 10 000	10	1,55	440	8,25
TRAFOPERM N2®	3 % SiFe	ca. 1600 (1,2 A/m)	25	2,03	750	7,65

Semi-finished Soft Magnetic Materials

These are foils, ribbons, panel sheets and rods from alloys like MUMETALL®, PERMENORM®, VACOFLUX®, pure iron, SiFe etc. in either standard sizes or customer-specific dimensions.

Soft magnetic materials are used e. g. for shielding of magnetic fields or to concentrate and carry magnetic flux in magnet systems (see chapters “magnetic shielding” and “magnet systems”). We stock different special alloys in various shapes, forms, conditions (hard or deep-drawable) and dimensions. Strip material and foils are available in customized widths, rods in specific lengths and panel sheets in required dimensions (e. g. by laser-cutting).

SEKELS GmbH also produces parts according to customer specifications and technical drawings, including the required heat treatment.

We are familiar with alloy specific machining methods, from simple pre-cut parts to sophisticated composite systems. Our service comprises the material selection based on all requirements, pre-cutting, machining, magnetic annealing, assembling to subsystems etc.

Typical magnetic properties after annealing

Alloy	Composition	μ_r	$H_{c,\,stat}$	B_s	T_c	Density
		(static)	[A/m]	[T]	[°C]	[g/cm³]
MUMETALL®	80 % NiFe	30000	3	0,8	400	8,7
PERMENORM® 5000 H2	50 % NiFe	4000	10	1,55	440	8,25
Pure Iron	99,9 % Fe	500*	80	2,15	770	7,86
VACOFLUX® 50	50 % CoFe	1000*	200	2,35	950	8,12
VITROVAC® 6025X	80 % Co	20000	1	0,55	225	7,7

μ_r at 0,4 A/m * μ_r at 4 A/m

Typical sizes of soft magnetic “semis”

Product	Thickness/Diam.	Width	Length	Materials
	[mm]	[mm]	[mm]	Add. Information
Magnetic sheets	0,35 - 3	< 750**	< 3000**	MUMETALL® PERMENORM® 5000 H2 Pure Iron
Magnetic tape (crystalline)	0,05 - 0,1	< 640**	as demanded	MUMETALL® Adhesive layer possible
Magnetic tape (amorphous)	~ 0,02	2,5 - 50	as demanded	VITROVAC® 6025X Adhesive layer possible
Magnetic rods	1 - 215	–	< 4000**	MUMETALL® VACOFLUX® 50 PERMENORM® 5000 H2 Pure Iron

** smaller standard sizes are available

Magnetic Shielding

The shielding of magnetic fields is based on the principle of “field deviation” via magnetic conductive materials.

Typical applications for magnetic shielding range from static magnetic fields (terrestrial magnetic field, industrial DC currents, nuclear magnetic resonance...) via 16 2/3 Hz (railroad systems) and line frequency to about 91 kHz (e. g. to fulfill industrial safety regulations as BGR B11 by the German workers’ compensation board). Additional conductivity shielding is necessary for higher frequencies.

The field strengths cover several orders of magnitude and range from nano- to milli-Tesla (nT-mT). Required are practically field-free spaces for scientific experiments, very low field strengths for sensitive sensors or electronic equipment or moderate field strengths to avoid the distraction of ferromagnetic or electronic parts.

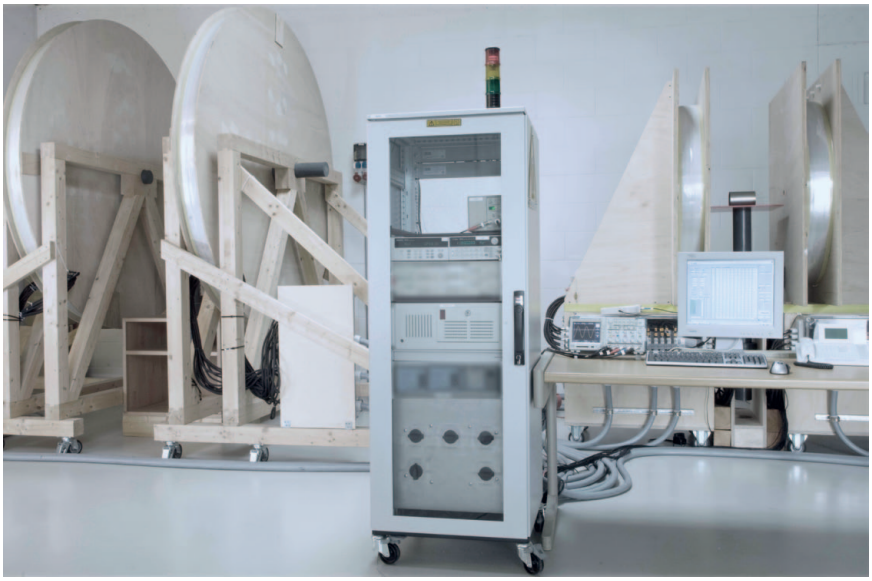
As indicated, shielding problems are manifold. Although the solutions are all based on the flux concentration principle, they can be highly differential. Simple problems can often be solved using standard shielding foils or shielding cups. Complex measures are customized casings or chambers with multiple layer designs and if required additional field homogenization devices.

For complex shielding problems SEKELS GmbH offers a well grounded, long-term experience with theoretical and practical approaches. We measure and analyze interfering fields on site or in our lab and define the ideal design and alloy by utilizing state-of-the-art 2D and 3D FEM Simulations.

Our engineering services range from prototype design to series deliveries, including the necessary magnetic annealing. We maintain a large inventory of different shielding alloys like MUMETALL®, amorphous VITROVAC®, PERMENORM®, SiFe electrical steel, pure iron and CRYOPERM® for low temperature applications. Furthermore we are familiar with alloy specific machining methods, from simple pre-cut parts to sophisticated composite systems and magnetic annealing.

Measuring Systems and Services

SEKELS GmbH possesses devices to generate large scale homogenous magnetic fields.



Modern 2D and 3D FEM simulation programs feature a particular flexible method to resolve electromagnetic problems by a mathematical approach. However, with these programs influences like material variation, the modification of magnetic properties by machining and dimensional accuracy problems due to the annealing process are hard to take into account. Therefore additional measurements of the shielding effect are necessary in many cases to obtain a justified certainty.

Experimental verification of the achieved shielding factors is essential especially for bigger units where the mechanical design has some influence on the possible magnetic properties. For this purpose SEKELS GmbH has installed specific equipment allowing the measurement of shielding factors in a wide 3D domain with a high spatial resolution, using the so called “Helmholtz”-geometry.

We use Helmholtz coils with a diameter of up to two meters for measurements of the shielding effect on static and low-frequency magnetic shielding screens and shielding systems. Furthermore they are used to test and verify stray radiation or noise immunity of electronic equipment or devices.

Although this equipment is used for research, development and quality conformance tests, measuring services are available.

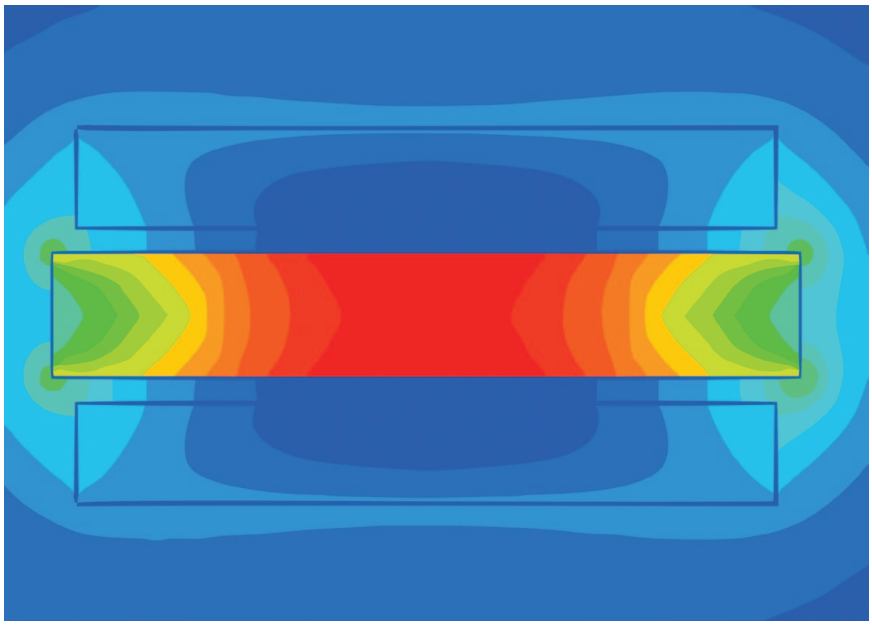
Our Helmholtz systems and operating devices generate strong homogeneous magnetic fields in a huge space. Automated computer controlled measurements in a wide frequency and amplitude range with a high spatial resolution via sensor arrays (up to 40 channels) and field sensors of various types and sizes are available (Fluxgate-, Hall- and search coils, linear and 3D sensors).

Performance data of the Sekels Helmholtz systems:

Coil system	1000 mm	2000 mm
Frequency range	DC and 0,1 – 2000 Hz	DC and 0,1 – 2000 Hz
Amplitude range	7,74 mT (DC) – 0,08 mT (2000 Hz)	3,34 mT (DC) – 0,05 mT (2000 Hz)

Magnet Systems

The term “magnet system“ describes devices that alter physical properties as for example current into a different physical property like force.



The concept and design of complex magnet systems mostly consists of theoretical calculation, well-grounded experience and a gradual experimental approach. Besides the initial electromagnetic problem, environmental conditions, material specific properties and joining technologies play a major role.

A professional approach considerably reduces the expenses and facilitates the ideal technical solution.

We offer:

- Professional consultation
- Calculation, FEM simulation
- Prototypes, tests, measurements
- Profound knowledge of magnetic materials and their machining
- Long term experience with magnet systems used under influence of unusual, problematic environmental conditions

Our area of expertise:

- Magnetic circuits for sensors and actuators
- Permanent magnet machines for motors
- Eddy current-, hysteresis- and permanent magnet couplings
- Magnetic circuits for deflection, focusing or acceleration of particles
- Bonding-, attenuation systems and signal record systems
- Optimized power supplies for fast switching systems
- Magnetic shielding, stray field measurements and characteristic curves
- Consulting and conceptual design of magnetic measurement and testing technology
- Field generating systems for technical use and scientific applications

SEKELS GmbH has a profound knowledge through well grounded long term activity on system technology, adequate materials and bonding techniques. We design and produce from prototypes to large-scale production.

Terms and Definitions

Symbol	Explanation	Unit	Symbol	Explanation	Unit
B_s	Saturation flux density (1 T = 10 000 Gauss)	T = Vs/m^2	A_{Fe}	Effective iron cross section	m^2
H	Field Strength (1 A/m = 4π/1000 Oerstedt)	A/m	A_{Cu}	Effective copper cross section	m^2
μ_0	Magnetic constant ($B = \mu_r \mu_0 H$)	$4\pi 10^{-7}$ Vs/Am	l_{Fe}	Mean magnetic path length (geometric)	m
μ_r	Rel. permeability		N	Winding number	
λ_s	Magnetostriction	ppm	I	Current	A
ρ_{el}	Specific electrical resistivity	Ωm	S	Current density	A/m^2
ρ	Density	kg/m^3	f	Frequency	Hz
T_c	Curie temperature	°C	A_L	Inductance of a core with one winding	H = Vs/A
P_{Fe}	Core losses	W/kg	L	Inductance	H

Tables

VITROPERM® cores for common mode chokes

µ level (nominal)		Part number	Nominal size	Max. size (incl. fixation)		
10 kHz	100 kHz		d_a x d_i x h [mm x mm x mm]	D_a [mm]	D_i [mm]	H [mm]
95000	22500	T60006-L2009-W914	9,8 x 6,5 x 4,5	11,2	5,1	5,8
		T60006-L2012-W902	12 x 8 x 4,5	14,1	6,6	6,3
		T60006-L2014-V098	14,4 x 11,4 x 3,2	16,5	9,6	5
		T60006-L2015-W865	15 x 10 x 4,5	17,1	7,9	6,5
		T60006-L2016-W403	16 x 10 x 6	17,9	8,1	8,1
		T60006-L2017-W515	17.5 x 12,6 x 6	19,0	11,0	8,0
		T60006-L2019-W838	19 x 15 x 10	21,2	13,0	12,3
		T60006-L2020-W409	20 x 12,5 x 8	22,6	10,3	10,2
		T60006-L2025-W380	25 x 16 x 10	27,9	13,6	12,5
		T60006-L2025-W523	25 x 20 x 10	27,6	17,4	12,8
		T60006-L2030-W423	30 x 20 x 10	32,8	17,6	12,5
		T60006-L2030-W514	30 x 20 x 15	32,8	17,5	17,8
		T60006-L2040-W424	40 x 25 x 15	43,1	22,5	18,5
		T60006-L2040-W422	40 x 32 x 15	43,1	28,7	18,5
		T60006-L2045-V102	45 x 30 x 15	48,3	26,4	18,2
		T60006-L2054-V172	54 x 40 x 20	57,5	37,7	24,1
65000	20000	T60006-L2012-W498	12,5 x 10 x 5	14,3	8,5	7,0
		T60006-L2050-W516	50 x 40 x 20	53,5	36,3	23,4
		T60006-L2063-W517	63 x 50 x 25	67,3	46,5	28,6
		T60006-L2080-V140	80 x 50 x 20	85,8	44,6	25,5
		T60006-L2090-W518	90 x 60 x 20	95,4	54,7	24,7
		T60006-L2100-V082	100 x 80 x 25	105,5	75,0	29,6
		T60006-L2102-W468	102 x 76 x 25	108,1	70,0	30,3
25000	17000	T60006-L2016-W308	16 x 10 x 6	17,9	8,1	8,1
		T60006-L2020-W450	20 x 12.5 x 8	22,6	10,3	10,2
		T60006-L2025-W451	25 x 16 x 10	27,9	13,6	12,5
		T60006-L2030-W358	30 x 20 x 10	32,8	17,6	12,5
		T60006-L2040-W452	40 x 32 x 15	43,1	28,7	18,5
		T60006-L2040-W453	40 x 25 x 15	43,1	22,5	18,5
		T60006-L2045-V118	45 x 30 x 15	48,3	26,4	18,2
		T60006-L2050-W565	50 x 40 x 20	53,5	36,3	23,4
		T60006-L2054-V178	54 x 40 x 20	57,5	37,7	24,1
		T60006-L2063-V110	63 x 50 x 25	67,3	46,5	28,6
		T60006-L2080-W531	80 x 50 x 20	86,0	44,7	25,7
		T60006-L2160-V074	160 x 130 x 25	166,9	123,9	30,5
		T60006-L2160-V088	160 x 130 x 25	166,9	123,9	30,5
17000	15500	T60006-L2030-V129	30 x 20 x 15	32,8	17,5	17,8
		T60006-L2045-V101	45 x 30 x 15	48,3	26,4	18,2
		T60006-L2100-V081	100 x 80 x 25	105,5	75,0	29,6
		T60006-L2102-V080	102 x 76 x 25	108,1	70,0	30,3
		T60006-L2160-V066	160 x 130 x 25	166,9	123,9	30,5

standard series (plastic casing)

Effective iron cross section	Mean magnetic path length	Core weight (nominal)	A_L (nominal)	A_L (nominal)	$I_{Diff.-Mode}$ / Winding (guide value)	
A_{Fe}	l_{Fe}	m_{Fe}	10 kHz	100 kHz	10 kHz	100 kHz
[cm^2]	[cm]	[g]	[µH]	[µH]	[mA]	[mA]
0,06	2,56	1,12	25,5	6,4	200	400
0,072	3,14	1,66	28,0	6,8	200	400
0,04	4,1	1,10	10,5	2,6	200	400
0,09	3,9	2,70	27,0	6,7	300	500
0,14	4,1	4,42	43,0	10,1	300	600
0,118	4,73	4,10	30,0	6,9	300	700
0,16	5,34	6,28	36,1	8,8	400	700
0,24	5,1	9,00	55,2	13,6	400	700
0,36	6,44	17	65,5	15,5	400	900
0,20	7,07	10,4	28,4	7,3	600	1100
0,40	7,85	23	59,3	14,0	500	1000
0,57	7,9	33	88,0	20,0	500	1100
0,855	10,2	64	101,0	23,1	700	140
0,456	11,3	38	47,2	11,1	800	1500
0,86	11,8	74	87,5	20,3	800	1600
1,06	14,8	115	87,0	19,9	700	1400
0,05	3,5	1,30	10,0	3,6	400	800
0,76	14,1	79	45,3	14,0	1400	2700
1,24	17,8	161	58,6	18,1	1800	3500
2,28	20,4	342	94	28	1400	2800
2,28	23,6	395	81,0	25,1	2400	4500
1,90	28,3	379	56,3	16,9	2800	5300
2,47	28,0	508	68,8	21,6	3800	6700
0,14	4,1	4,3	11,7	6,5	1200	1700
0,24	5,1	9,0	14,3	9,1	1400	2100
0,36	6,44	17	17,0	11,5	1700	2600
0,40	7,85	23	15,5	11,1	2100	3100
0,456	11,3	38	12,2	7,9	3700	5100
0,855	10,2	64	25,4	17,2	2900	4200
0,86	11,8	74	24,3	15,9	3000	4500
0,76	14,1	79	18,0	10,0	3500	5300
1,06	14,8	115	24,0	15,7	3700	5700
1,24	17,8	161	23,3	13,5	4400	6700
2,28	20,4	342	35,0	24,0	5500	8200
2,74	45,6	917	26,8	13,7	8400	13 600
2,74	45,6	917	20,1	13,1	11 300	17 100
0,57	7,9	33	15,7	14,1	3000	3900
0,86	11,8	74	15,7	14,3	4600	5800
1,90	28,3	379	14,5	13,1	10 900	13 800
2,47	28,0	508	19,1	17,2	10 700	13 600
2,74	45,6	917	12,9	11,7	17 600	22 300

VITROPERM® cores for common mode chokes

μ level (nominal)		Part number	Nominal size	Max. size (incl. fixation)		
10 kHz	100 kHz		d_a x d_i x h [mm x mm x mm]	D_a [mm]	D_i [mm]	H [mm]
66500	20000	T60004-L2016-W620	16 x 12,5 x 6	17,8	10,7	8,0
		T60004-L2022-W868	22 x 17 x 10	24,0	15,2	12,0
		T60004-L2022-W867	22 x 17 x 6	24,0	15,2	8,0
		T60004-L2025-W622	25 x 20 x 10	27,3	17,5	12,3
		T60004-L2030-W676	30 x 25 x 15	32,3	22,7	17,5
		T60004-L2030-W911	30 x 20 x 10	32,5	17,8	12,5
		T60004-L2040-W624	40 x 32 x 15	42,3	29,1	17,8
		T60004-L2050-W626	50 x 40 x 20	52,3	37,1	22,8
		T60004-L2130-W567	130 x 100 x 25	134,5	95,0	28,5
		T60004-L2194-V105	194 x 155 x 25	200,0	149,0	28,5
26500	17250	T60004-L2016-W619	16 x 12,5 x 6	17,8	10,7	8,0
		T60004-L2025-W621	25 x 20 x 10	27,3	17,5	12,3
		T60004-L2030-W483	30 x 20 x 10	32,5	18	12,5
		T60004-L2040-W623	40 x 32 x 15	42,3	29,1	17,8
		T60004-L2045-W886	45 x 32 x 15	47,3	29,8	17,8
		T60004-L2050-W625	50 x 40 x 20	52,3	37,1	22,8
		T60004-L2063-W627	63 x 50 x 20	65,5	46,6	22,8
		T60004-L2080-W628	80 x 63 x 20	83,0	59,5	22,8
		T60004-L2100-W629	100 x 80 x 20	104,0	75,0	23,0
		T60004-L2130-W630	130 x 100 x 25	134,5	95,0	28,5
		T60004-L2160-W631	160 x 130 x 25	165,0	125,0	28,5
17250	15250	T60004-L2030-W675	30 x 25 x 15	32,3	22,7	17,5
		T60004-L2050-W583	50 x 40 x 20	52,3	37,1	22,8
		T60004-L2063-W721	63 x 50 x 20	65,5	46,6	22,8
		T60004-L2080-W722	80 x 63 x 20	83,0	59,5	22,8
		T60004-L2100-W723	100 x 80 x 20	104,0	75,0	23,0
		T60004-L2130-W587	130 x 100 x 25	134,5	95,0	28,5
		T60004-L2160-W720	160 x 130 x 25	165,0	125,0	28,5
		T60004-L2194-W908	194 x 155 x 25	200,0	149,0	28,5

VF series (epoxy coating)

The VF series offers weight-optimized dimensions with larger winding space

Effective iron cross section	**Mean magnetic path length**	**Core weight**	**A_L (nominal)**	**A_L (nominal)**	**$I_{Diff.-Mode}$ / Winding (guide value)**	
A_{Fe}	**l_{Fe}**	**m_{Fe}**	**10 kHz**	**100 kHz**	**10 kHz**	**100 kHz**
[cm^2]	[cm]	[g]	[µH]	[µH]	[mA]	[mA]
0,08	4,5	2,6	15,0	4,8	500	800
0,20	6,1	9,39	27,4	7,1	600	1200
0,12	6,1	5,4	16,4	4,3	600	1200
0,19	7,1	9,9	22,5	7,2	700	1400
0,27	8,64	17,4	26,5	8,5	900	1700
0,40	7,85	23,1	56,0	13,4	600	1200
0,44	11,3	36	32,5	10,3	1100	2200
0,73	14,1	76	43,0	13,8	1400	2700
2,85	36,1	757	50,0	19,4	4800	8500
3,71	54,8	1490	45,3	14,7	6500	12 500
0,08	4,48	2,6	6,0	3,9	1100	1700
0,19	7,1	9,9	9,0	5,8	1700	2700
0,40	7,85	23,1	18,8	-	1900	-
0,44	11,3	36	13,0	8,4	2800	4300
0,71	12,1	63,3	19,7	12,8	3000	4600
0,73	14,1	76	17,0	11,2	3600	5400
0,95	17,8	124	18,0	11,6	4400	6700
1,24	22,5	205	18,5	12,0	5600	8500
1,46	28,3	303	17,3	11,2	7100	10 700
2,74	36,1	727	25,4	16,5	9000	13 600
2,74	45,6	917	20,1	13,1	11 300	17 100
0,27	8,64	17,4	6,8	5,1	3000	4000
0,73	14,1	76	11,2	10,0	5400	7000
0,95	17,8	124	11,5	10,4	6900	7800
1,24	22,5	205	11,9	10,7	8700	11 000
1,46	28,3	303	11,2	10,0	10 900	13 800
2,74	36,1	727	16,4	14,7	14 000	17 700
2,74	45,6	917	13,0	11,7	17 600	22 300
3,71	54,8	1490	14,7	13,2	20 700	26 400

VITROPERM® cores for common mode chokes

µ level (nominal)	Part number	Nominal size	Max. size (incl. fixation)		
100 kHz		d_a x d_i x h	D_a	D_i	H
		[mm x mm x mm]	[mm]	[mm]	[mm]
4000	T60006-L2016-V165	16 x 10 x 6	17,9	8,1	8,1
	T60006-L2025-W980	25 x 16 x 10	27,9	13,6	12,5
	T60006-L2030-W981	30 x 20 x 10	32,8	17,6	12,5
	T60006-L2040-W964	40 x 32 x 15	43,3	28,8	18,3
	T60006-L2050-V166	50 x 40 x 20	53,5	36,6	23,4
	T60006-L2063-W985	60 x 50 x 25	67,3	46,5	28,6
	T60006-L2080-V091	80 x 50 x 20	86,0	44,6	25,5
	T60006-L2090-W984	90 x 60 x 20	95,4	56,1	24,7
	T60006-L2102-W947	102 x 76 x 25	108,1	70	30,3
	T60006-L2137-W946	137 x 87 x 25	143,8	81,3	30,6
	T60006-L2160-W982	160 x 130 x 25	166,7	124,1	30,6
	T60006-L2194-W983	194 x 155 x 25	202,5	147,5	32,1

VITROPERM® cores for power transformers

Part number	Nominal size		Max. size (incl. fixation)	
	d_a x d_i x h	D_a	D_i	H
	[mm x mm x mm]	[mm]	[mm]	[mm]
T60004-L2016-W373	16 x 10 x 6	17,6	8,3	8,0
T60004-L2020-W374	20 x 12,5 x 8	22,0	10,5	10,0
T60004-L2025-W375	25 x 16 x 10	27,0	14,0	12,0
T60004-L2030-W376	30 x 20 x 15	32,3	17,8	17,8
T60004-L2040-W433	40 x 25 x 15	42,3	22,5	17,3
T60004-L2050-W434	50 x 40 x 20	52,3	37,1	22,8
T60004-L2052-W827	52 x 40 x 25	54,3	37,1	27,8
T60004-L2055-W848	55 x 40 x 25	57,5	37,1	27,8
T60004-L2063-W435	63 x 50 x 25	65,6	46,6	27,8
T60004-L2080-W436	80 x 63 x 25	83,5	59,3	27,8
T60004-L2100-W342	100 x 80 x 25	104,5	74,5	28,5
T60004-L2130-W352	130 x 100 x 25	135,5	94,5	28,5
T60004-L2160-W758	160 x 110 x 25	165,0	105,0	28,5

VP 250 (μ_r approx. 4000)

VITROPERM® 250F is a special alloy variant for high non-symmetric currents

Effective iron cross section	Mean magnetic path length	Core weight	A_L (nominal)	A_L (nominal)	$I_{Diff.-Mode}$ / Winding (guide value)	
A_{Fe}	l_{Fe}	m_{Fe}	10 kHz	100 kHz	10 kHz	100 kHz
[cm²]	[cm]	[g]	[µH]	[µH]	[A]	[A]
0,144	4,08	4,4	2,1	2	5,4	5,6
0,36	6,44	17,3	3,2	3,1	9,3	9,6
0,40	7,9	23,4	2,9	2,8	11,4	11,8
0,46	11,3	38,4	2,3	2,2	16,6	17,1
0,76	14,1	79	3,1	3	19,5	20,5
1,24	17,8	163	3,3	3,2	30,2	30,9
2,28	20,4	347	7,1	6,9	26,4	27,3
2,28	23,6	400	4,6	4,5	40,9	41,8
2,47	28,0	515	4,3	4,2	47,4	48,5
4,75	35,2	1250	–	6,3	–	63,3
2,85	45,6	967	3,0	2,9	79,3	81,1
3,71	54,8	1510	–	3,1	–	100,0

standard series (epoxy coated)

The relative permeability of standard cores for power transformers is approx. 25000, the magnetic losses are remarkably low.

Effective iron cross section	Mean magnetic path length	Core weight	A_L (nominal)	Effective winding space (guide value)	Mean copper length (guide value)	Heat transfer resistance (guide value)
A_{Fe}	l_{Fe}	m_{Fe}	100 kHz	A_{Cu}	l_{Cu}	R_{th}
[cm²]	[cm]	[g]	[µH]	[cm²]	[cm]	[K/W]
0,14	4,1	4,3	11	0,20	3,2	33
0,24	5,1	9,0	14	0,32	4,0	23
0,36	6,4	17	17	0,58	4,8	16
0,57	7,9	33	20	0,93	6,4	11
0,86	10,2	64	23	1,49	7,2	7,5
0,76	14,1	79	15	4,05	9,0	4,5
1,14	14,5	121	22	4,05	10,2	4,1
1,43	14,9	156	26	4,05	10,5	3,9
1,24	17,8	161	19	6,40	11,1	3,1
1,62	22,5	267	20	10,4	12,6	2,2
1,9	28,3	395	19	16,4	14,6	1,6
2,85	36,1	757	22	26,3	17,2	1,1
4,75	36,1	1480	31	32,5	19,9	0,8

VITROPERM® cores for MagAmp chokes

Part number	Nominal size		Max. size (incl. fixation)		Effective iron cross section
	d_a x d_i x h	D_a	D_i	H	A_{Fe}
	[mm x mm x mm]	[mm]	[mm]	[mm]	[cm^2]
T60006-L2010-W759	10 x 7 x 4,5	11,7	5,5	6,1	0,05
T60006-L2011-W760	11 x 8 x 4,5	14,1	6,6	6,3	0,05
T60006-L2012-W761	12 x 8 x 4,5	14,1	6,6	6,3	0,07
T60006-L2012-W762	12,5 x 10 x 4,5	14,1	8,5	6,8	0,045
T60006-L2012-W803	12,8 x 9,5 x 3,2	14,7	7,9	4,8	0,04
T60006-L2016-W763	16 x 10 x 6	18,0	8,0	8,1	0,14
T60006-L2016-W764	16,5 x 12,5 x 6	19,1	10,9	8,1	0,10
T60006-L2017-W765	17,5 x 12,5 x 6	19,1	10,9	8,1	0,12
T60006-L2019-W766	19 x 15,2 x 4,5	21,2	12,9	7,2	0,07
T60006-L2020-W767	20 x 15 x 8	22,6	10,3	10,2	0,16
T60006-L2020-W768	20 x 12,5 x 8	22,6	10,3	10,2	0,24

VITROPERM® / VITROVAC® cores for electronic energy meters

Part number	Nominal size		Max. size (incl. fixation)		Effective iron cross section
	d_a x d_i x h	D_a	D_i	H	A_{Fe}
	[mm x mm x mm]	[mm]	[mm]	[mm]	[cm^2]
T60004-L2022-W836	22,3 x 17,3 x 6,2	23,8	15,8	7,8	0,12
T60004-L2025-W835	25 x 20 x 6,2	26,5	18,6	7,8	0,12
T60004-L2019-W979	19 x 15 x 6,2	20,5	13,6	7,8	0,10
T60004-E3019-W592	19 x 15 x 6,5	20,5	13,8	7,8	0,10
T60004-E3019-W800	19,7 x 15,5 x 8,3	21,1	14,1	9,8	0,15
T60004-E3022-W639	22,3 x 17 x 6,5	23,7	15,8	7,8	0,11
T60004-E3025-W588	25 x 20 x 6,5	26,5	18,8	7,8	0,13
T60004-E3031-W774	31 x 26 x 6,5	32,8	24,5	8,0	0,13
T60006-L2038-W968	38,1 x 31,8 x 6,2	41,0	29,2	8,7	0,16

standard series (plastic casing)

Cores with „rectangular“ hysteresis loop for saturable chokes. Also available made of VITROVAC® 6025Z

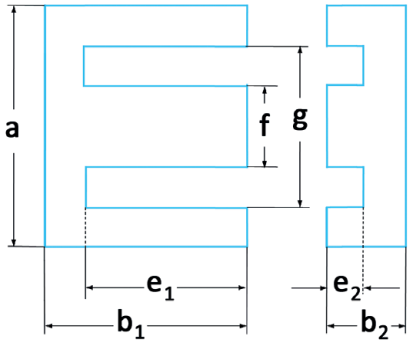
Mean magnetic path length	Core weight	Saturation flux density (nominal)		Effective winding space (guide value)	Mean copper length (guide value)	Heat transfer resistance (guide value)
l_{Fe}	m_{Fe}	(25 °C)	(90 °C)	A_{Cu}	l_{Cu}	R_{th}
[cm]	[g]	[µWb]	[µWb]	[cm^2]	[cm]	[K/W]
2,7	1,1	12,7	11,9	0,06	2,3	57
3,0	1,2	12,7	11,9	0,09	2,5	46
3,1	1,7	16,9	15,8	0,09	2,5	46
3,5	1,2	10,6	9,9	0,14	2,6	42
3,5	1,1	9,9	9,3	0,12	2,3	44
4,1	4,3	33,8	31,7	0,12	3,3	34
4,6	3,2	22,6	21,1	0,23	3,3	30
4,7	4,2	28,8	26,4	0,23	3,3	30
5,4	2,7	16,1	15,0	0,32	3,3	27
5,5	6,5	37,6	35,2	0,21	4,1	26
5,1	9,0	56,4	52,8	0,21	4,1	26

Current transformers with linear hysteresis loop for maximum accuracy. Available in versions according to American and European standards.

Mean magnetic path length	Core weight	Minimum permeability	Maximum permeability	Current range	DC compliance
l_{Fe}	m_{Fe}			I	Î
[cm]	[g]	[μ_{min}]	[μ_{max}]	[A_{rms}]	[A_{Op}]
6,2	5,7	80000	–	60	–
7,1	6,4	80000	–	100	–
5,3	3,9	80000	–	20	–
5,3	4,3	2550	3450	20	20
5,5	6,4	1600	1900	40	40
6,1	6,7	1600	1900	60	60
7,1	7,3	1300	1600	100	100
9,0	9,2	1300	1600	120	120
11,0	12,6	94000	–	320	–

Nominal sizes of the EK type series

DIN-type	IEC-type	a	b1	b2	e1	e2	f	g	$h_{p,min}$
EK 12,6	YEE 2-4 d K	12,6	8,6	4	6,7	–	3,8	8,8	3,8
EK 16	YEE 2-5 d K	16	11	5	8,6	–	4,8	11,2	4,8
EK 20	YEE 2-6 d K	20	14	6	11	14	6	14	6
EK 25	YEE 2-8 d K	25	17	8	13,2	17,4	7,6	17,4	7,6
EK 25 L	YEE 2-8 d K L	25	17	17	13,2	26,4	7,6	17,4	7,6
EK 32	YEE 2-10 d K	32	22	10	17,2	22,4	9,6	22,4	9,6
EK 32L	YEE 2-10 d K L	32	22	22	17,2	34,4	9,6	22,4	9,6
EK 40	YEE 2-12 d K	40	28	12	22	28	12	28	12
EK 40L	YEE 2-12 d K L	40	28	28	22	44	12	28	12



Terms see drawing.
h_p is the height of the core package.

Form parameters of EK core packages

The values are valid for PERMENORM® 5000 H2 in strip thickness of 0,35 mm. For other thicknesses or alloys, the core cross section A_{Fe} need to be corrected by the stacking factor, and the core weight m_{Fe} need to be corrected by the specific weight.

DIN-type	$h_{p,min}$	l_{Fe}	A_{Fe}	m_{Fe}	l_{Cu}	A_{Cu}	m_{Cu}	A_R
	[mm]	[cm]	[cm²]	[g]	[cm]	[cm²]	[g]	[µΩ]
EK 12,6	3,8	3,0	0,14	3,4	2,8	0,06	1,6	74,7
EK 16	4,8	3,8	0,22	6,9	3,5	0,12	3,7	49,8
EK 20	6,0	4,8	0,34	13,4	4,3	0,19	7,3	38,8
EK 25	7,6	6,0	0,54	26,8	5,3	0,31	14,8	29,0
EK 25L	7,6	7,8	0,54	34,8	5,3	0,49	23,0	18,4
EK 32	9,6	7,7	0,87	54,9	6,8	0,53	32,0	21,9
EK 32L	9,6	10,0	0,87	72,0	6,8	0,83	50,0	13,9
EK 40	12,0	9,6	1,35	107,2	8,4	0,86	64,0	16,7
EK 40L	12,0	12,7	1,35	142,9	8,4	1,39	104,0	10,3

Standard magnetic qualities for core packages without air gap

Lower tolerance limit -15 %, measuring frequency 50/60 Hz, excitation B_{peak} = 2 mT for MUMETALL® and PERMENORM®, 6 mT for TRAFOPERM®.

DIN-type	Contact pressure ±10 % N	A-066 MUMETALL®		H2-066 PERMENORM® 5000 H2		N2-066 TRAFOPERM® N2	
		A_L [nH]	μ_r	A_L [nH]	μ_r	A_L [nH]	μ_r
EK 12,6	6,3	2000	3630	1000	1820	–	–
EK 16	10	3150	4500	1250	1780	–	–
EK 20	16	5000	5750	2000	2300	1000	1150
EK 25, 25L	25	6300	5730	2500	2270	1250	1140
EK 32, 32L	40	10000	7140	3150	2250	1600	1140
EK 40, 40L	63	12500	7350	4000	2350	2000	1170

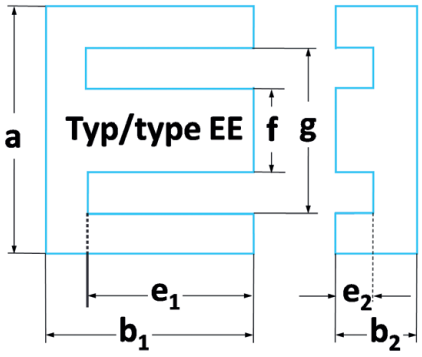
Standard magnetic qualities for core packages with air gap

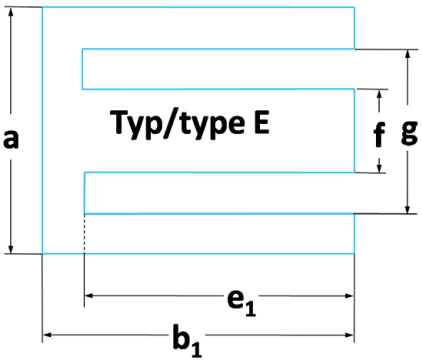
Measuring frequency 50 Hz or 300 Hz, excitation B_{peak} = 2 mT

DIN-type		MUMETALL®: A-060 ; PERMENORM® 5000 H2: H2-060 ; TRAFOPERM® N2: N2-060 ± tolerance in % for A_L-values in nH								
A_L-values		160	200	250	315	400	500	630	800	1000
EK 12,6	A - 060	16	16	20	20	25	–	–	–	–
	H2 - 060	12,5	16	20	–	–	–	–	–	–
	N2 - 060	10	16	–	–	–	–	–	–	–
EK 16	A - 060	12,5	12,5	12,5	16	16	20	20	25	–
	H2 - 060	10	10	12,5	16	20	–	–	–	–
	N2 - 060	10	10	12,5	16	–	–	–	–	–
EK 20	A - 060	10	10	12,5	12,5	12,5	16	16	16	20
	H2 - 060	8	10	10	10	12,5	16	20	–	–
	N2 - 060	8	10	10	10	12,5	16	–	–	–
EK 25, 25L	A - 060	10	10	10	10	12,5	12,5	12,5	16	16
	H2 - 060	8	8	10	10	10	10	12,5	16	20
	N2 - 060	8	8	10	10	10	10	12,5	16	–
EK 32, 32L	A - 060	10	10	10	10	10	10	10	12,5	12,5
	H2 - 060	8	8	8	8	10	10	10	10	12,5
	N2 - 060	8	8	8	8	8	10	10	10	10
EK 40, 40L	A - 060	–	10	10	10	10	10	10	10	10
	H2 - 060	–	8	8	8	8	10	10	10	10
	N2 - 060	8	8	8	8	8	8	10	10	10

Nominal sizes of DIN laminations (selection)

DIN type	IEC-Typ	a [mm]	b(1) [mm]	b2 [mm]	C(1) [mm]	e(1) [mm]	e2 [mm]	f [mm]	g [mm]
EE 12,6	YEE 2-4	12,6	8,6	4	-	6,7	2,1	3,8	8,8
EE 16	YEE 2-5	16	11	5	-	8,6	2,6	4,8	11,2
EE 20	YEE 2-6	20	14	6	-	11	3	6	14
EE 25	YEE 2-8	25	17	8	-	13,2	4,2	7,6	17,4
EE 32	YEE 2-10	32	22	10	-	17,2	5,2	9,6	22,4
EE 40	YEE 2-12	40	28	12	-	22	6	12	28
ED 12,6	YED 2-4	12,6	17	-	-	12,9	-	3,8	8,8
ED 16	YED 2-5	16	21	-	-	16,1	-	4,8	11,2
ED 20	YED 2-6	20	26	-	-	20	-	6	14
ED 25	YED 2-8	25	33	-	-	25,2	-	7,6	17,4
ED 32	YED 2-10	32	42	-	-	32,2	-	9,6	22,4
E 12,6	YES 2-4	12,6	12,6	-	-	10,7	-	3,8	8,8
E 16	YES 2-5	16	16	-	-	13,6	-	4,8	11,2
E 20	YES 2-6	20	20	-	-	17	-	6	14
E 25	YES 2-8	25	25	-	-	21,2	-	7,6	17,4
E 32	YES 2-10	32	32	-	-	27,2	-	9,6	22,4
EI 30	YEI 1-10	30	20	-	5	15	-	10	20
EI 38	YEI 1-13	38,4	25,6	-	6,4	19,2	-	12,8	25,6
EI 42	YEI 1-14	42	28	-	7	21	-	14	28
EI 48	YEI 1-16	48	32	-	8	24	-	16	32
M 20	YM 1-5	20	20	-	3,5	13	-	5	13
M 22	-	22	20	-	3,5	15	-	5	13
M 30	YM 1-7	30	30	-	5	20	-	7	20
M 30z	-	30	28	-	5	20	-	7	18
M 42	YM 1-12	42	42	-	6	30	-	12	30
M 55	YM 1-17	55	55	-	8,5	38	-	17	38
M 65	YM 1-20	65	65	-	10	45	-	20	45
M 74	YM 1-23	74	74	-	11,5	51	-	23	51
M 85	YM 1-29	85	85	-	14,5	56	-	29	56
M 102	YM 1-34	102	102	-	17	68	-	34	68
U 25/10	-	25	10	-	5	2,5	-	-	-
U 35/14	-	35	14	-	7	3,5	-	-	-
U 51/20	-	51	20	-	10	5	-	-	-
U 71/28	-	71	28	-	14	7	-	-	-
U 102/40	-	102	40	-	20	10	-	-	-
U 41/20	-	41	20	-	10	5	-	-	-
U 57/28	-	57	28	-	14	7	-	-	-
U 82/40	-	82	40	-	20	10	-	-	-
UI 30	YUI 1-10	30	40	-	10	30	-	-	-
UI 39	YUI 1-13	39	52	-	13	39	-	-	-
UI 48	YUI 1-16	48	64	-	16	48	-	-	-
UI 60	YUI 1-20	60	80	-	20	60	-	-	-


Typ/type EE
a
f
g
e1
e2
b1
b2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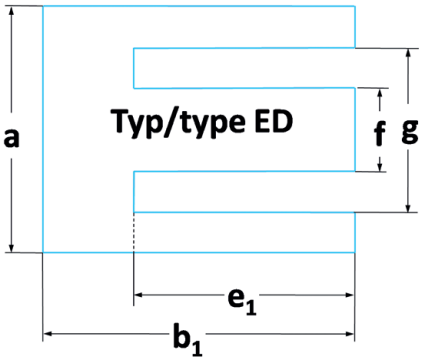
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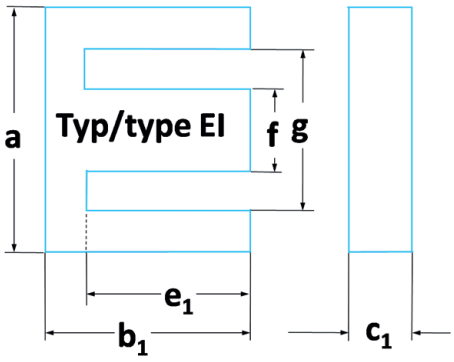
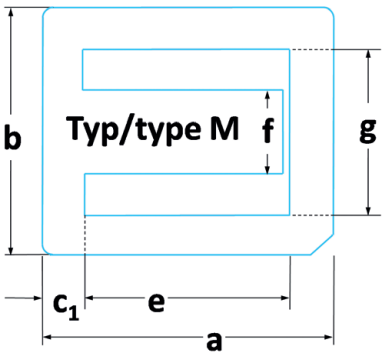
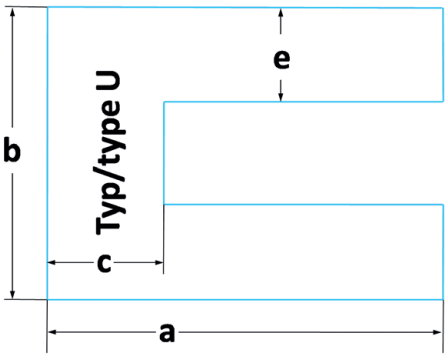
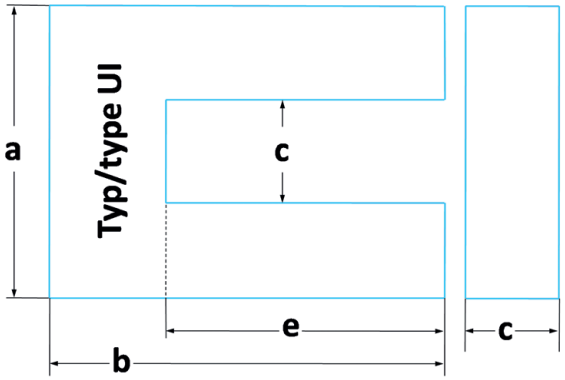
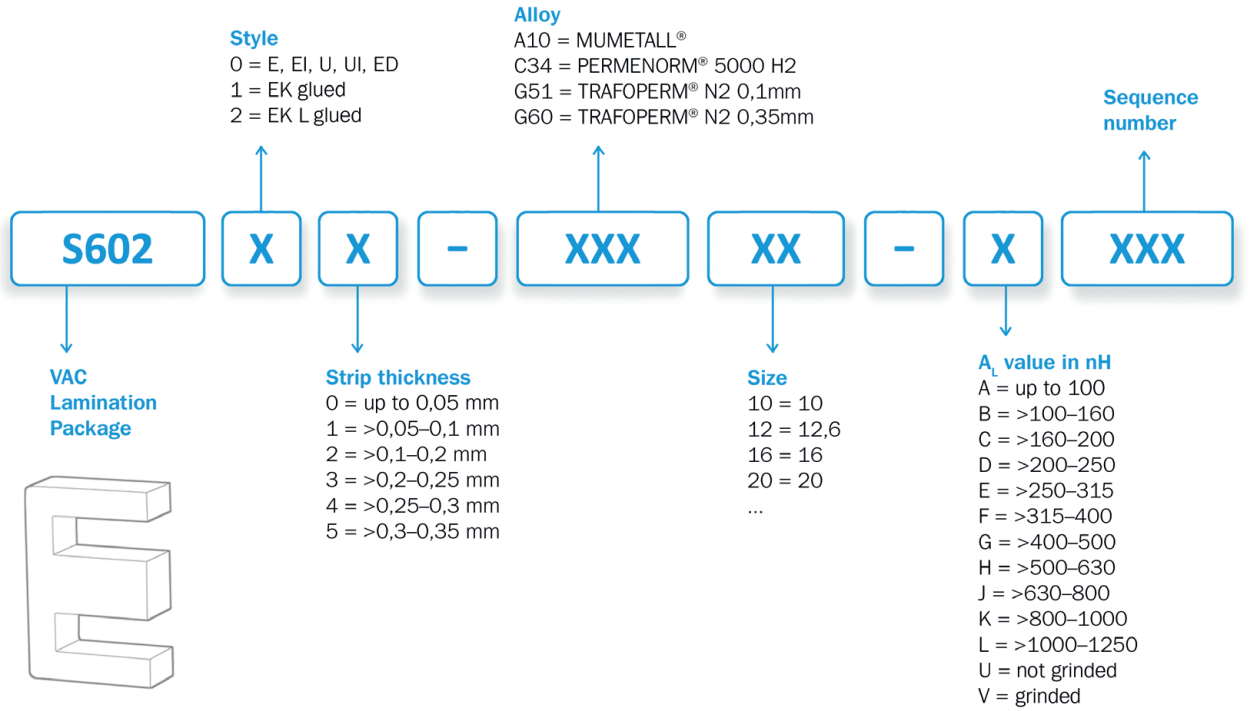

Typ/type EI
a
f
g
e1
b1
c1


Typ/type M
b
f
g
c1
e
a

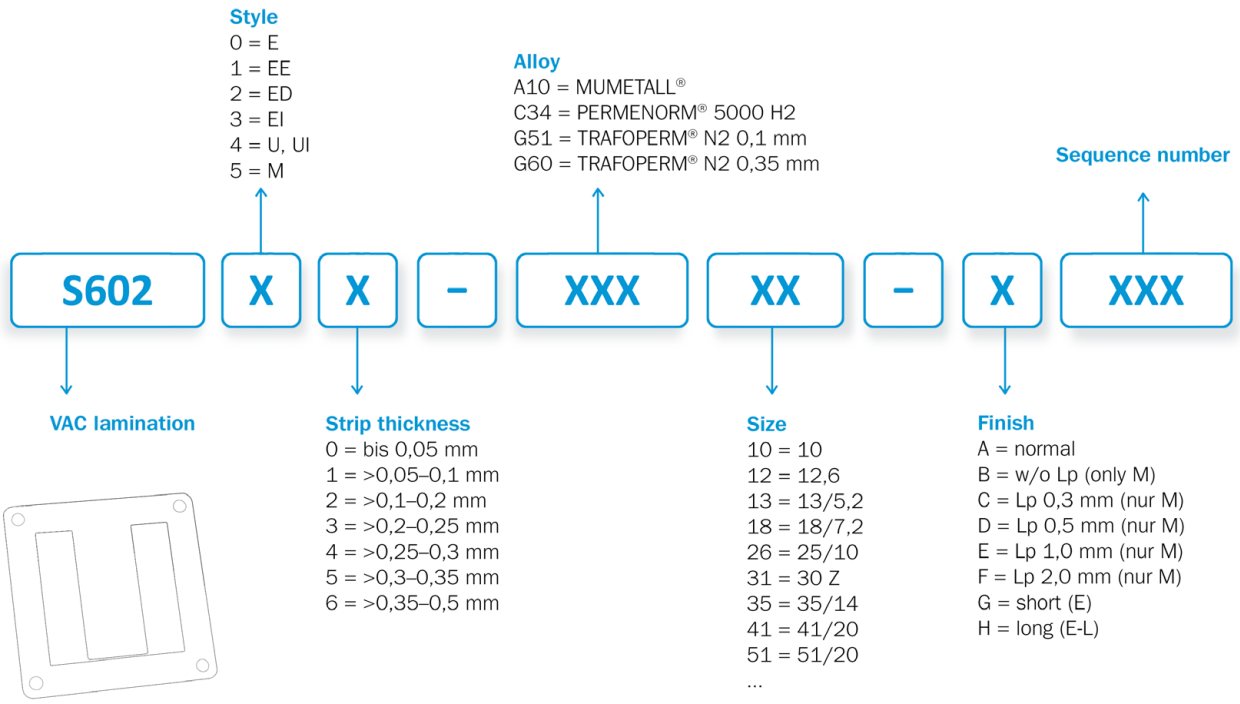

Typ/type U
e
b
c
a


Typ/type UI
a
c
e
b
c

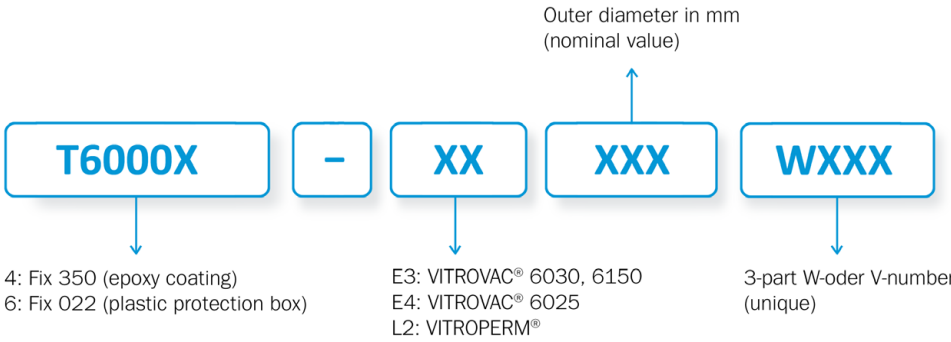
How to read the PN of lamination packages (VAC)



How to read the PN of laminations (VAC)



How to read the PN of cores (VAC)



Fix 022: Plastic protection box, Ultramid (PA 66), glass fibre enforced
UL-File-No. E41871 (M), flamability class UL 94 V-0
Temperature class 120 °C (electrical), 115 °C mechanical with impact,
130 °C mechanical w/o impact, form stability 250 °C
Upper application temperature (20 000 hours, 50 % reduced
tensile strength) 139 °C

Fix 350: Coating, Resicoat EL ES FB
UL-File-No. E214934, flamibility class UL 94 V-0
Temperature class 105 °C (electrical), 105 °C mechanical with impact,
105 °C mechanical w/o impact
Electrical strength for functional isolation: 2,0 kVrms
Electrical strength for basic and higher isolation degrees: additional isolation
by tape or usage of isolated special wire

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