VAC Nanocrystalline Components – The EMI Solution

Southeastern Michigan IEEE EMC Society Chapter meeting

Evening of 18 October 2012

Dearborn MI

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ADVANCED MATERIALS – THE KEY TO PROGRESS

ABSTRACT

Within a background of VAC product offering and technical support by VAC, this paper illustrates how EMC performance can realize significant improvements in many situations.

Here we plan to use a Picoscope 3206B along with a few self-built accessories to quickly judge the improvement offered by a particular experimental configuration right at the designers own workstation.

We will also examine a few case studies where VAC's technical team improved cost and/or performance of ferrite based EMI filters by filter-order reduction based on broad-band feature of nanocrystalline CMC cores.

Additionally, we plan to demonstrate VAC's "CMC QuickDim" simulation program which predicts the impedance to expect from a given CMC design combination of Core + Turns + Wire + Current + Imbalance.

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VAC Supports EMI Compliant Designs

- VAC Overview
- Common Mode Chokes
  - Standard CMC Products
  - Nanocrystalline Cores for CMC
  - Analysis of Customer's data
  - CMC_Quick-dim3.0 Simulations
  - Custom CMC designs
  - Analysis of Customer's product
  - Samples
  - Series production
- EMI Shielding products

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The Company / Portrait

VACUUMSCHMELZE is one of the world's leading manufacturers of advanced magnetic materials and value added products.

In 1914 the first vacuum melting furnace laid the foundation for today's VACUUMSCHMELZE. Melting alloys under vacuum went into production on an industrial scale in 1923.

This initial operation located in Hanau, Germany, grew into a company active on a global basis,
- with 4 500 employees
- in more than 40 countries
- with annual sales of approx. 350 million Euro

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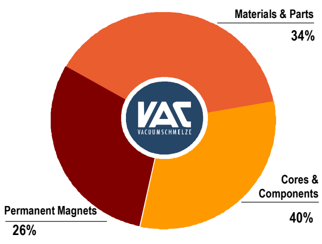
The Company / Portrait

Today VACUUMSCHMELZE manufactures a broad spectrum of high quality materials & parts, components and systems for numerous markets, from Swiss watch manufacturers to the aircraft industry.

The use of VACUUMSCHMELZE-products is widespread. Many of us use them every day – without even knowing it.



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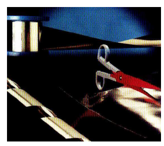
VAC Products FOR EMI APPLICATIONS

Cores for Common Mode Chokes

Common Mode Chokes



Shielding Metals

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Standard CMC Products

A tour of VAC's website

CORES for CMC

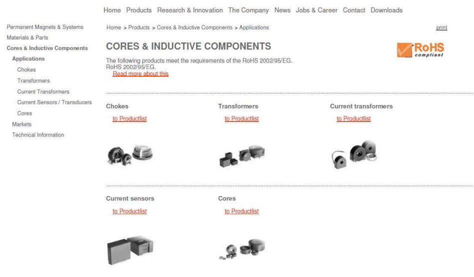
CMC 1ph

CMC 3ph

CMC core-stack

Shielding sheet material

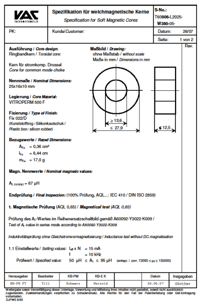
www.vacuumschmelze.com
A BRIEF OVERVIEW TOUR



CORES FOR CMC

VAC-Product	nominal core dimensions	limiting dimensions (incl. case)			iron cross section	mean path length	weight	A_L nominal		saturation current I_{cm}**, typical	
	d_a x d_i x h	D_a	D_i	H	A_{Fe}	l_{Fe}	m_{Fe}	10 kHz	100 kHz	10 kHz	100 kHz
	mm x mm x mm	mm	mm	mm	cm^2	cm	g	µH		A	
T60006-L2009-W914	9.8 x 6.5 x 4.5	11.2	5.1	5.8	0.06	2.6	1.1	25.5	6.4	0.2	0.4
T60006-L2012-W902	12 x 8 x 4.5	14.1	6.6	6.3	0.07	3.1	1.7	28.0	6.8	0.2	0.4
T60006-L2012-W498	12.5 x 10 x 5	14.3	8.5	7.0	0.05	3.5	1.3	10.0	3.6	0.4	0.8
T60006-L2014-V098	14.4 x 11.4 x 3.2	16.5	9.6	5.0	0.04	4.1	1.1	10.5	2.6	0.2	0.4
T60006-L2015-W865	15 x 10 x 4.5	17.1	7.9	6.5	0.09	3.9	2.6	27.0	6.7	0.3	0.5
T60006-L2016-W403	16 x 10 x 6	17.9	8,1	8.1	0.14	4.1	4.0	43.0	10.1	0.3	0.6
T60006-L2016-W308	16 x 10 x 6	17.9	8.1	8.1	0.14	4.1	4.0	11.7	6.5	1.2	1.7
T60006-L2016-V165	16 x 10 x 6	17.9	8.1	8.1	0.14	4.1	4.0	2.1	2.0	5.4	5.6
T60006-L2017-W515	17.5 x 12.6 x 6	19.0	11.0	8.0	0.12	4.7	4.1	30.0	6.9	0.3	0.7
T60006-L2019-V184	19 x 15 x 5	21.2	13.0	7.3	0.08	5.3	3.1	18.0	4.4	0.4	0.7
T60006-L2019-W838	19 x 15 x 10	21.2	13.0	12.3	0.16	5.3	6.3	36.1	8.8	0.4	0.7
T60006-L2020-W409	20 x 12.5 x 8	22.6	10.3	10.2	0.24	5.1	9.0	55.2	13.6	0.4	0.7
T60006-L2020-W450	20 x 12.5 x 8	22.6	10.3	10.2	0.24	5.1	9.0	14.3	9.1	1.4	2.1
T60006-L2025-W523	25 x 20 x 10	27.6	17.4	12.8	0.2	7.1	10	28.4	7.3	0.6	1.1
T60006-L2025-W380	25 x 16 x 10	27.9	13.6	12.5	0.36	6.4	17	65.5	15.5	0.4	0.9
T60006-L2025-W451	25 x 16 x 10	27.9	13.6	12.5	0.36	6.4	17	17.0	11.5	1.7	2.6
T60006-L2025-W980	25 x 16 x 10	27.9	13.6	12.5	0.36	6.4	17	3.2	3.1	9.3	9.6
T60006-L2030-W423	30 x 20 x 10	32.8	17.6	12.5	0.40	7.9	23	59.3	14.0	0.5	1.0
T60006-L2030-W358	30 x 20 x 10	32.8	17.6	12.5	0.40	7.9	23	15.5	11.1	2.1	3.1
T60006-L2030-W981	30 x 20 x 10	32.8	17.6	12.5	0.40	7.9	23	2.9	2.8	11.4	11.8
T60006-L2030-W514	30 x 20 x 15	32.8	17.5	17.8	0.57	7.9	33	88.0	20.0	0.5	1.1
T60006-L2030-V129	30 x 20 x 15	32.8	17.5	17.8	0.57	7.9	33	15.7	14.1	3.0	3.9
T60006-L2040-W422	40 x 32 x 15	43.1	28.7	18.5	0.46	11.3	38	47.2	11.1	0.8	1.5
T60006-L2040-V113	40 x 32 x 15	43.1	28.7	18.5	0.46	11.3	38	13.0	8.4	2.9	4.5
T60006-L2040-W452	40 x 32 x 15	43.1	28.7	18.5	0.46	11.3	38	12.2	7.9	3.7	5.1
T60006-L2040-W964	40 x 32 x 15	43,1	28,7	18.5	0.46	11.3	38	2.3	2.2	16.6	17.1
T60006-L2040-W424	40 x 25 x 15	43.1	22.5	18.5	0.86	10.2	64	101	23.1	0.7	1.4
T60006-L2040-W453	40 x 25 x 15	43.1	22.5	18.5	0.86	10.2	64	25.4	17.2	2.9	4.2
T60006-L2045-V102	45 x 30 x 15	48.3	26.4	18.2	0,86	11.8	74	87.5	20.3	0.8	1.6

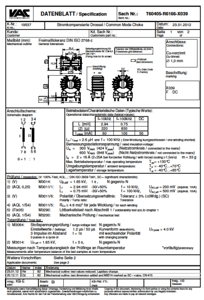
W380 core
25 x 16 x 10



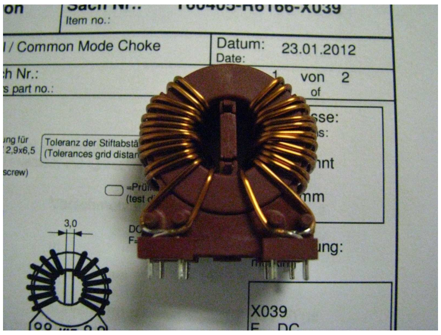
1-PH CMC

VAC-Product	I_N	Design	U_N	L_N	L_N	R_{cu}	|Z|	f_R	I_{cm}	Dimensions		
			OVCat III / II	10 kHz	100 kHz		100 kHz		10 kHz	l	w	h
	A		V	mH	mH	mΩ	Ω	MHz	mA	mm	mm	mm
T60405-R6131-X402	2	upright	300 / 600	2 x 12.1	2 x 2.8	101	3000	3.6	17	22	12	25
T60405-R6131-X204	4	upright	300 / 600	2 x 10.8	2 x 2.5	27.5	2320	1.2	12	22	12	25
T60405-R6161-X504	4,5	upright	300 / 600	2 x 28.3	2 x 6.6	36	6500	0.4	18	27	17	29
T60405-R6166-X206	6	upright	300 / 600	2 x 29.1	2 x 6.7	37.6	8500	0.25	14	35	21	37
T60405-R6166-X208	8	upright	300 / 600	2 x 16.4	2 x 3.7	19.1	4200	0.5	20	35	21	36.5
T60405-R6123-X210	10	low profile	300 / 600	2 x 11.4	2 x 2.6	12.2	3200	0.7	16	35	35	23
T60405-R6166-X210	10	upright	300 / 600	2 x 11.4	2 x 2.6	12.7	3150	0.7	16	35	21	37
T60405-R6126-X212	12	upright	300 / 600	2 x 11.4	2 x 2.6	8.9	950	0.7	22	38	22	35
T60405-R6123-X213	12	low profile	300 / 600	2 x 11.4	2 x 2.6	8.8	2950	0.7	22	35	35	25
T60405-R6122-X095	12	upright	600 / 1000	2 x 16.9	2 x 3.6	7.6	4000	0.7	33	41	21	37
T60405-R6122-X100	13	low profile	300 / 600	2 x 8.6	2 x 2.2	6.3	2250	1.1	28	35	35	22
T60405-R6123-X616	16	low profile	300 / 600	2 x 12.9	2 x 3.1	5.7	3000	3.0	37	40	40	24
T60405-R6126-X216	16	upright	600 / 1000	2 x 5.3	2 x 1.3	2.6	1200	2.4	57	40	23	40
T60405-R6166-X033	16	upright	300 / 600	2 x 6	2 x 1.5	4.6	1600	1.0	35	38	21	38
T60405-R6166-X039	16	upright	300 / 600	2 x 2.9	2 x 0.7	3.9	830	3.3	60	36	21	38
T60405-R6123-X220	20	low profile	300 / 600	2 x 1.8	2 x 0.4	3.2	500	11.5	40	35	35	23.5
T60405-R6123-X221	20	low profile	300 / 600	2 x 6.6	2 x 1.6	2.9	1470	5.7	35	43	43	24
T60405-R6128-X220	20	upright	600 / 1000	2 x 5.6	2 x 1.3	2.7	1300	3.1	50	42	27	46
T60405-R6123-X226	25	low profile	300 / 600	2 x 4.2	2 x 1	1.9	970	7.1	50	42.5	42.5	25
T60405-R6123-X227	25	low profile	600 / 1000	2 x 12	2 x 2.8	3.5	2900	2.4	55	52	52	32
T60405-R6128-X225	25	upright	300 / 600	2 x 4.2	2 x 1	1.9	970	4.9	50	42	27	40
T60405-R6128-X226	25	upright	600 / 1000	2 x 12	2 x 2.8	3.4	2900	1.9	40	52	27	48.5
T60405-R6123-X232	30	low profile	600 / 1000	2 x 3.9	2 x 0.9	2.4	920	7.0	50	52	52	29
T60405-R6128-X031	30	upright	600 / 1000	2 x 3.9	2 x 0.9	2.3	900	4.0	65	51	27	50
T60405-R6128-X230	30	upright	600 / 1000	2 x 6.3	2 x 1.5	2.3	1650	3.3	65	52	27	47
T60405-R6123-X241	40	low profile	600 / 1000	2 x 3.6	2 x 0.8	1.4	870	8.2	90	52	52	32
T60405-R6123-X248	48	low profile	600 / 1000	2 x 2.5	2 x 0.6	0.75	660	6.7	110	52	52	32
T60405-R6123-X263	63	low profile	600 / 1000	2 x 1.6	2 x 0.4	0.5	390	9.3	150	53.5	53.5	32
T60405-R6123-X285	85	low profile	600 / 1000	2 x 1.6	2 x 0.5	0.6	510	1.6	200	73	73	40

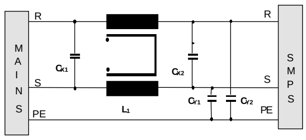
1-ph CMC 6166-X039
2.94mH x 16A approx size 38 x 21 x 36

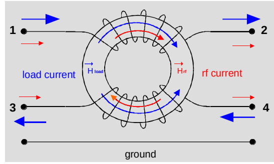


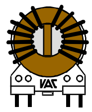
6166-X039



Operational principle of the CMC





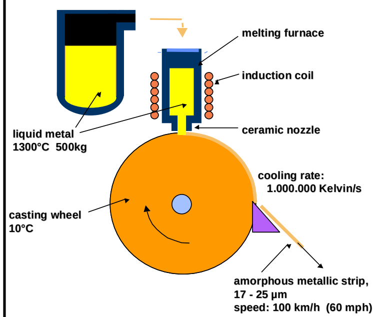


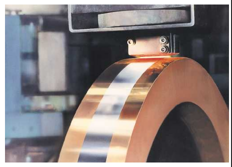
- equal no. of turns wound in opposite direction.
- only slight attenuation of symmetrical currents.
- strong „common-mode“ damping against asymmetric currents.
- µ and B_s must be safe against unbalanced currents.

Cores for CMC

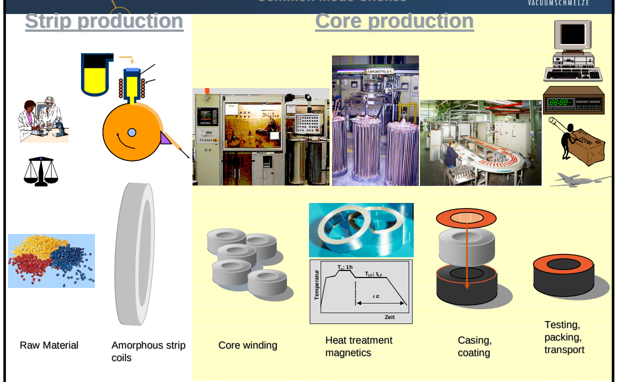
A discussion of why Nanocrystalline VP500F is the best core material for CMC application.

Rapid solidification process for amorphous strip



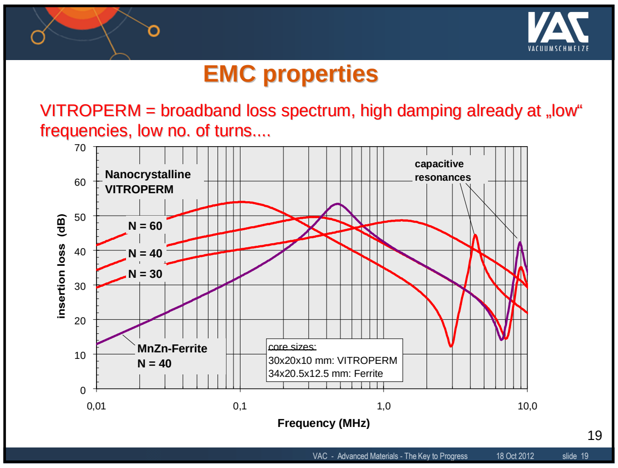


VITROPERM core for Common Mode Chokes



Materials for Common Mode Chokes

Material / Material basis	Co – based amorphous / approx. 70 % Co	NiFe Permalloys / 80 % Ni	MnZn Ferrite / Mn Zn	Nano-crystalline / approx. 73.5 % Fe
Permeability $\mu_{r,max}$ (10 kHz)	>90 000	< 20 000	15 000	15 000 ... > 100 000
Losses $P_{Fe,\ typ.}$ (25 kHz, 200 mT, 100°C)	5 W/kg	14 W/kg	17 W/kg	3 W/kg
Saturation Induction B_S	0.6 T	0.8 T	0.48 T	1.2 T
Curie Temperature T_C	210°C	400 °C	220°C	> 600°C
Upper Cont. Operation Temperature $T_{max.}$	90 °C	120 °C	< 100 °C	> 120 °C


EMC properties
VITROPERM = broadband loss spectrum, high damping already at „low“ frequencies, low no. of turns....
Nanocrystalline
VITROPERM
capacitive
resonances
N = 60
N = 40
N = 30
insertion loss (dB)
MnZn-Ferrite
N = 40
core sizes:
30x20x10 mm: VITROPERM
34x20.5x12.5 mm: Ferrite
0,01
0,1
1,0
10,0
Frequency (MHz)
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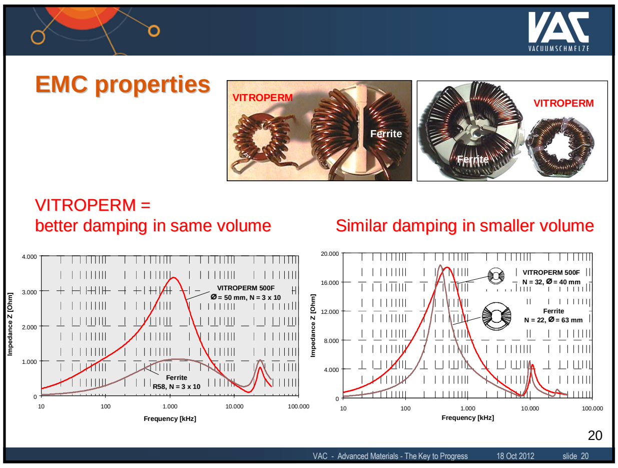
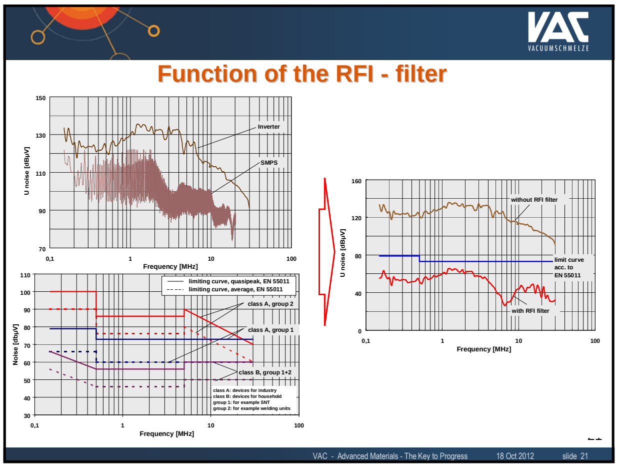
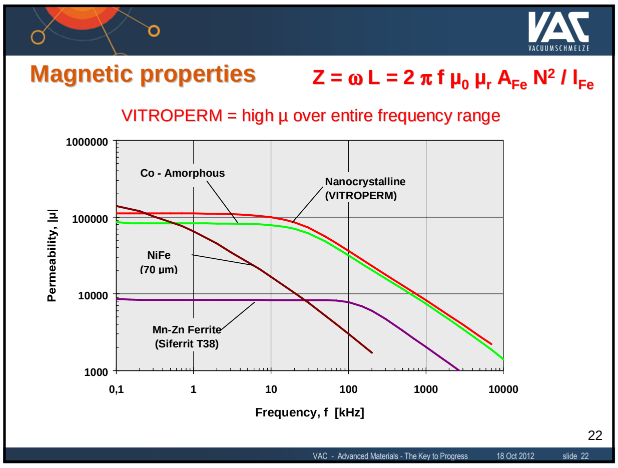
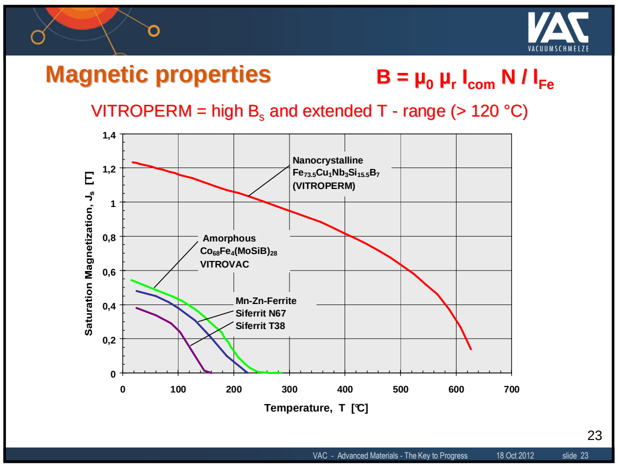

EMC properties
VITROPERM
Ferrite
VITROPERM
Ferrite
VITROPERM =
better damping in same volume
Similar damping in smaller volume
Frequency [kHz]
Frequency [kHz]
20
VAC - Advanced Materials - The Key to Progress 18 Oct 2012 slide 20


Function of the RFI - filter
Frequency [MHz]
Frequency [MHz]
Frequency [MHz]
VAC - Advanced Materials - The Key to Progress 18 Oct 2012 slide 21


Magnetic properties
Z = ω L = 2 π f μ0 μr AFe N² / lFe
VITROPERM = high μ over entire frequency range
Co - Amorphous
Nanocrystalline
(VITROPERM)
NiFe
(70 μm)
Mn-Zn Ferrite
(Siferrit T38)
Permeability, |μ|
Frequency, f [kHz]
22
VAC - Advanced Materials - The Key to Progress 18 Oct 2012 slide 22


Magnetic properties
B = μ0 μr Icom N / lFe
VITROPERM = high Bs and extended T - range (> 120 °C)
Nanocrystalline
(VITROPERM)
Amorphous
VITROVAC
Mn-Zn-Ferrite
Siferrit N67
Siferrit T38
Saturation Magnetization, Js [T]
Temperature, T [°C]
23
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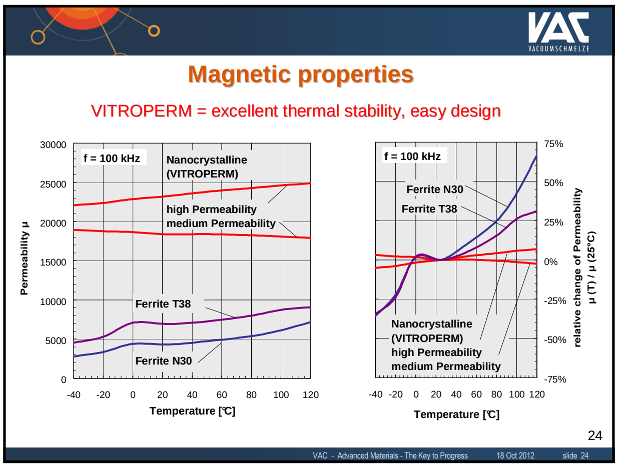
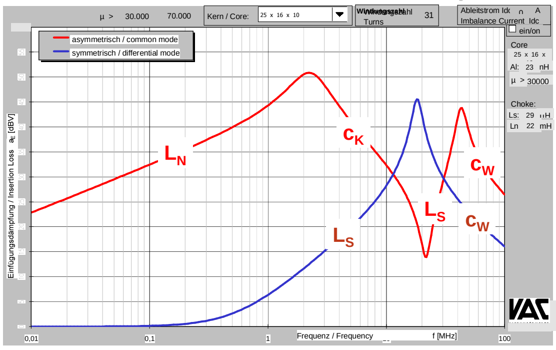

Magnetic properties
VITROPERM = excellent thermal stability, easy design
f = 100 kHz
Nanocrystalline
(VITROPERM)
high Permeability
medium Permeability
Ferrite T38
Ferrite N30
Permeability μ
Temperature [°C]
f = 100 kHz
Ferrite N30
Ferrite T38
Nanocrystalline
(VITROPERM)
high Permeability
medium Permeability
relative change of Permeability
Temperature [°C]
24
VAC - Advanced Materials - The Key to Progress 18 Oct 2012 slide 24

Insertion loss curve - theoretical aspects



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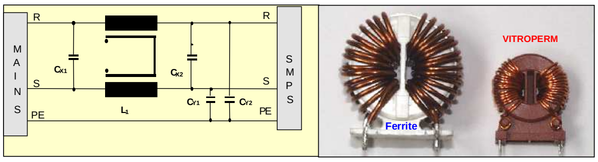
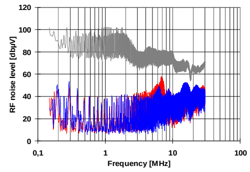
Example: SMPS for Telecom, 250 W

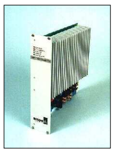




Application: 250 W – SMPS for Telecom
Rated voltage: 230V
Current: 1 A
Switching frequency: 100kHz

Upper plot: noise level without filter

Lower plots: same filter result with L_1 options:
a) Ferrite choke with core 25x15x10 mm
m = 18g, N = 2 x 22 turns., L = 2 x 6 mH
b) VITROPERM-choke; with core 16x12,5x6
m = 9g, N = 2 x 32 turns., L = 2 x 24 mH



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Analysis of Customer's data

A couple of case studies

Broadband CMC reduced multi-stage filter by one stage.

(Conducted Emission / Bearing current / Susceptibility)

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Example 1: 90 W Adapter for Notebook

Input: 100-240V ; 50-60 Hz ; 1.5A

Ouput: 19Vdc ; 4.74A
(90 Watt)

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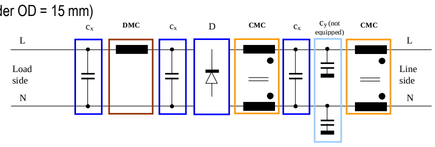
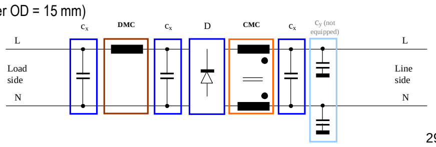
Example 1: 90 W adapter

Original filter: 2 –stage filter, 2 ferrite CMC (CMC1 OD=13 mm, CMC2 OD = 15 mm), 1 DMC (Fe powder OD = 15 mm)



VAC solution: 1 stage filter, 1 CMC (nanocrystalline core W902 OD = 12 mm), 1 DMC (Fe powder OD = 15 mm)



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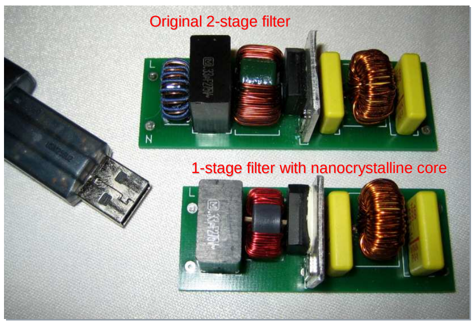
Filtersample



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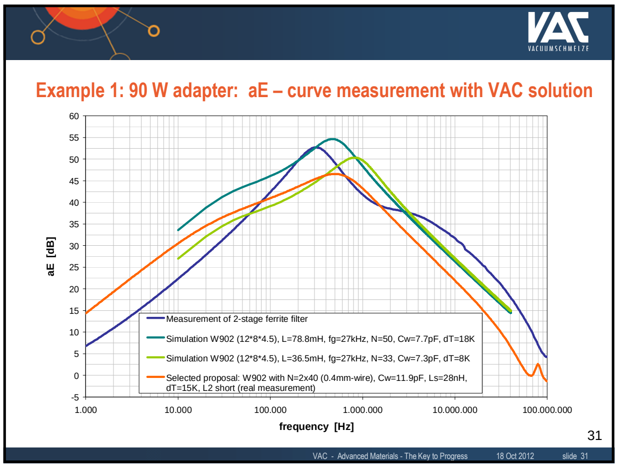

Example 1: 90 W adapter: aE – curve measurement with VAC solution
aE [dB]
frequency [Hz]
Measurement of 2-stage ferrite filter
Simulation W902 (12*8*4.5), L=78.8mH, fg=27kHz, N=50, Cw=7.7pF, dT=18K
Simulation W902 (12*8*4.5), L=36.5mH, fg=27kHz, N=33, Cw=7.3pF, dT=8K
Selected proposal: W902 with N=2x40 (0.4mm-wire), Cw=11.9pF, Ls=28nH, dT=15K, L2 short (real measurement)
31
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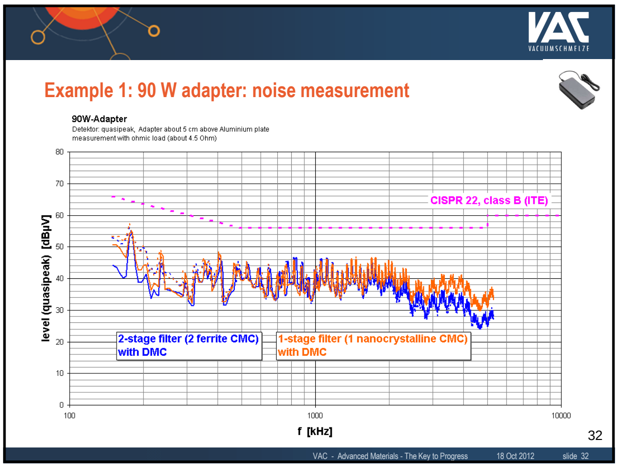

Example 1: 90 W adapter: noise measurement
90W-Adapter
level (quasipeak) [dBµV]
f [kHz]
CISPR 22, class B (ITE)
2-stage filter (2 ferrite CMC) with DMC
1-stage filter (1 nanocrystalline CMC) with DMC
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Example 2: 350 W SMPS
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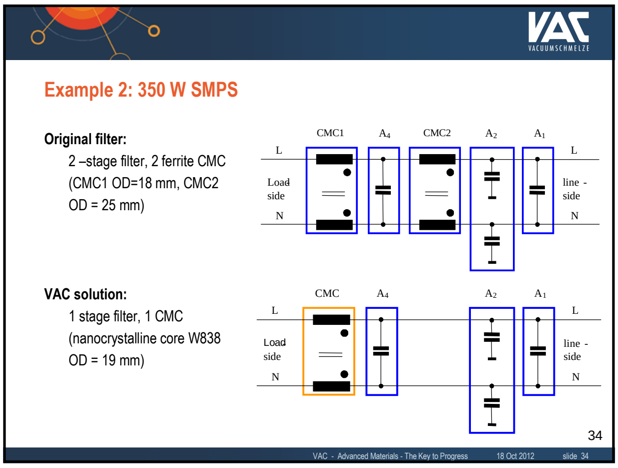

Example 2: 350 W SMPS
Original filter:
2 –stage filter, 2 ferrite CMC
(CMC1 OD=18 mm, CMC2
OD = 25 mm)
CMC1
CMC2
Load side
line - side
VAC solution:
1 stage filter, 1 CMC
(nanocrystalline core W838
OD = 19 mm)
CMC
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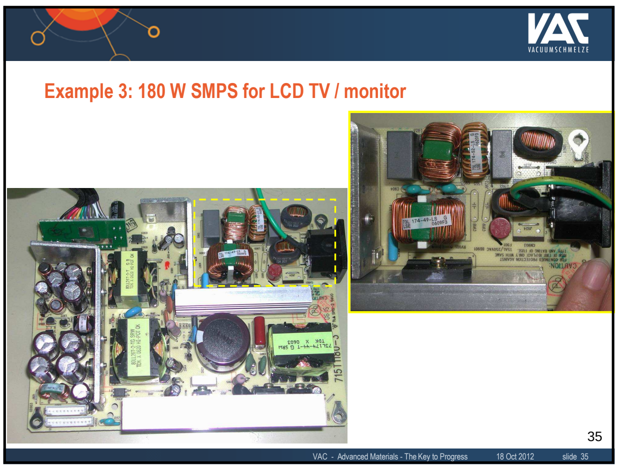

Example 3: 180 W SMPS for LCD TV / monitor
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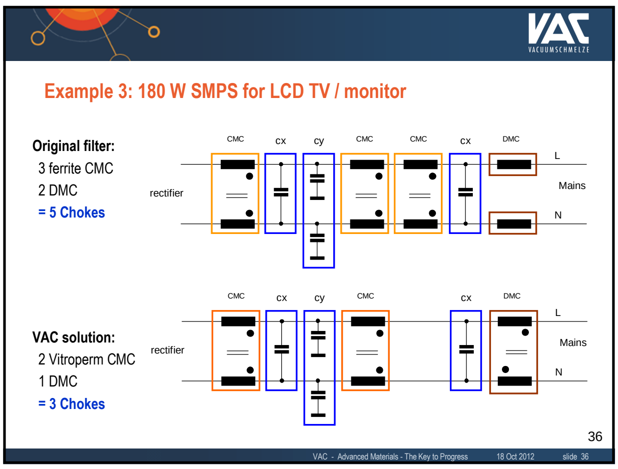

Example 3: 180 W SMPS for LCD TV / monitor
Original filter:
3 ferrite CMC
2 DMC
= 5 Chokes
rectifier
Mains
VAC solution:
2 Vitroperm CMC
1 DMC
= 3 Chokes
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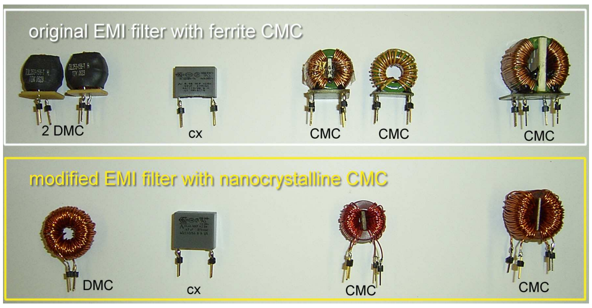
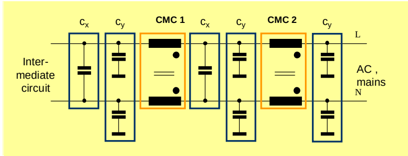
Example 3: 180 W SMPS for LCD TV / monitor – modified components

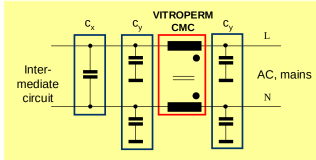


Example 4: Solar Inverter

Original filter:
- 2 ferrite CMC
- 2 cx
- 6 cy



VAC solution:
- 1 Vitroperm CMC
- 1 cx
- 4 cy

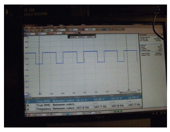


Analysis of Customer's product

A discussion of LISN

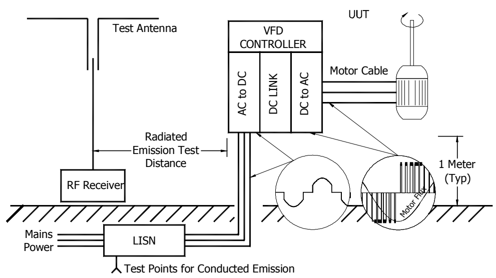
and

A demo of measurement for conducted mission



Subpart B - Unintentional Radiators

Section 15.101 Equipment authorization of unintentional radiators.
Section 15.102 CPU boards and power supplies used in personal computers.
Section 15.103 Exempted devices.
Section 15.105 Information to the user.
Section 15.107 Conducted limits.
Section 15.109 Radiated emission limits.
Section 15.111 Antenna power conducted limits for receivers.
Section 15.113 Power line carrier systems.
Section 15.115 TV interface devices, including cable system terminal devices.
Section 15.117 TV broadcast receivers.



(a) Except for Class A digital devices, for equipment that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50 µH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the band edges.

Frequency of Emission (MHz)	Conducted Limit (dBuV)	
	Quasi-peak	Average
0.15-0.5	66 to 56 *	56 to 46 *
0.5-5	56	46
5-30	60	50

* Decreases with the logarithm of the frequency.

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(b) For a Class A digital device that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz shall not exceed the limits in the following table, as measured using a 50 µH/50 ohms LISN. Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Frequency of Emission (MHz)	Conducted Limit (dBuV)	
	Quasi-peak	Average
0.15-0.5	79	66
0.5-30	73	60

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(h) Class A digital device. A digital device that is marketed for use in a commercial, industrial or business environment, exclusive of a device which is marketed for use by the general public or is intended to be used in the home.

(i) Class B digital device. A digital device that is marketed for use in a residential environment notwithstanding use in commercial, business and industrial environments. Examples of such devices include, but are not limited to, personal computers, calculators, and similar electronic devices that are marketed for use by the general public. Note: The responsible party may also qualify a device intended to be marketed in a commercial, business or industrial environment as a Class B device, and in fact is encouraged to do so, provided the device complies with the technical specifications for a Class B digital device. In the event that a particular type of device has been found to repeatedly cause harmful interference to radio communications, the Commission may classify such a digital device as a Class B digital device, regardless of its intended use.

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(k) Digital device. (Previously defined as a computing device). An unintentional radiator (device or system) that generates and uses timing signals or pulses at a rate in excess of 9,000 pulses (cycles) per second and uses digital techniques; inclusive of telephone equipment that uses digital techniques or any device or system that generates and uses radio frequency energy for the purpose of performing data processing functions, such as electronic computations, operations, transformations, recording, filing, sorting, storage, retrieval, or transfer. A radio frequency device that is specifically subject to an emanation requirement in any other FCC Rule Part or an intentional radiator subject to Subpart C of this Part that contains a digital device is not subject to the standards for digital devices,

provided the digital device is used only to enable operation of the radio frequency device and the digital device does not control additional functions or capabilities. Note: Computer terminals and peripherals that are intended to be connected to a computer are digital devices.

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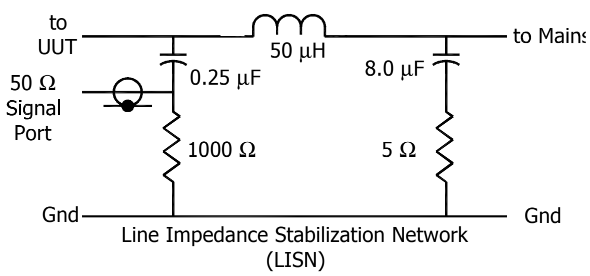

Line Impedance Stabilization Network (LISN)

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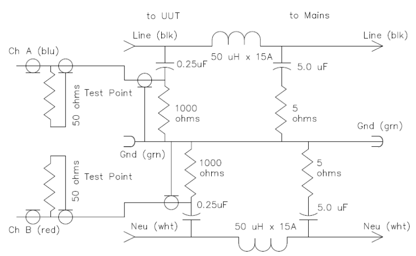

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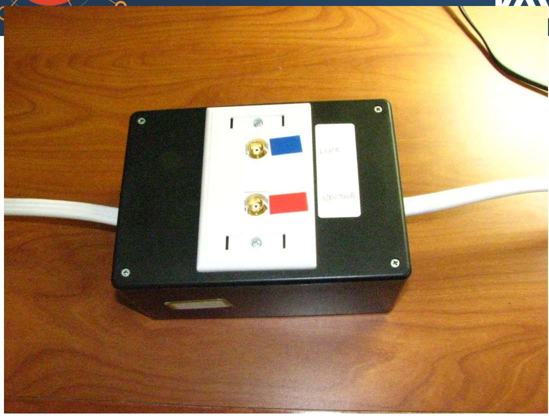

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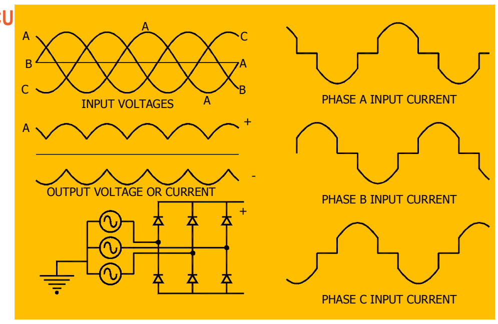
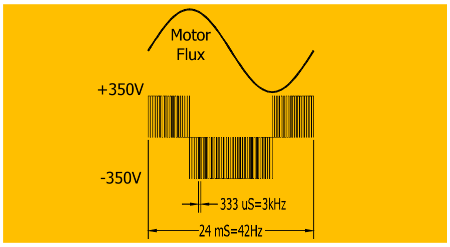
CU



50

PWM
EMI SOURCE



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Optimizing your CMC

Calculate emission limits in terms of *rf* currents.

Measure actual *rf* currents.

Estimate voltage of noise generator.

Determine impedance to limit *rf* current.

Select/design CMC for proper impedance.

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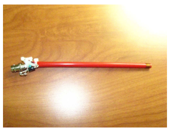

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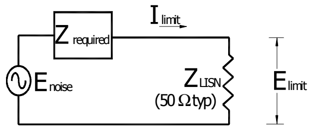
Calculate emission limits in terms of *rf* currents.



f=150 kHz-500kHz

$E_{limit} = 79\ dB\mu V = 8913\mu V = .0089\ Volts$

$I_{limit} = \frac{E_{limit}}{Z_{LISN}} = \frac{.0089\ Volts}{50\ ohms} = 178\ \mu A\ max$

55

Measure actual *rf* currents.

Extracted data from test report

	150 kHz	500 kHz
Peak Reading	102 dBµV	99 dBµV
Probe Insertion Loss Correction	+17.0 dB	+10.1 dB
Actual measurement	119 dBµV	109.1 dBµV
convert to volts	0.891 Volts	.285 Volts

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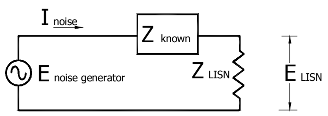
Estimate voltage of noise generator



Z_{known} = zero (no filtering present) therefore:

$E_{noise\ generator} = E_{LISN}$

	150 kHz	500 kHz
$E_{noise\ generator}$	0.891 Volts	.285 Volts

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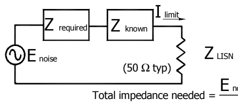
Determine impedance to limit rf current.



Total impedance needed = $\frac{E_{noise\ generator}}{I_{limit}} = Z_{total}$

	150 kHz	500 kHz
$Z_{total} =$	$\frac{.891\ V}{178\ \mu A}$	$\frac{.285\ V}{178\ \mu A}$
$Z_{total} =$	5060 ohms	1601 ohms
less known Z's	50 ohms	50 ohms
$Z_{required} =$	5010 ohms	1551 ohms
$L_{indicated}$	5.4 mH	0.51 mH

inductive reactance $(X_L) := 2\pi fL$

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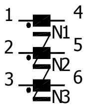
Select/design CMC for proper impedance.

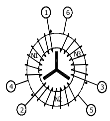
RATING: 127 AMPS, 480V, 3ϕ

Design:
Core: quad stack T60006-L2102-W468
(102x76x25 NANOCRYSTALLINE VITROPERM® 500F)
Winding: 7 turns litz 3x80xØ.4 mm

Impedance tests at 5 Vrms:
150 kHz: 6865 ohms at 9.4°
250 kHz: 6960 ohms at -30.2°
500 kHz: 3540 ohms at -69.4°

Other tests:
Inductance at 10kHz: 13.86 mH
DCR: 1.33 milliohms
Hipot at 2500 Vrms: OK
WT: 4.2 kG





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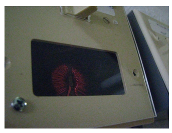

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CMC_Quick-dim3.0 Simulations

A demonstration of QuickDim 3.0

and

Discussion of CM, DM, and Imbalance current has on CMC selection,

Remarks about Amperage rating and environmental condition.

Simulates important parameters of CMC which are based on VAC's nanocrystalline VITROPERM®-cores. Comparison of different calculated designs lead to the optimum solution.

frequency characteristic

Temperature rise

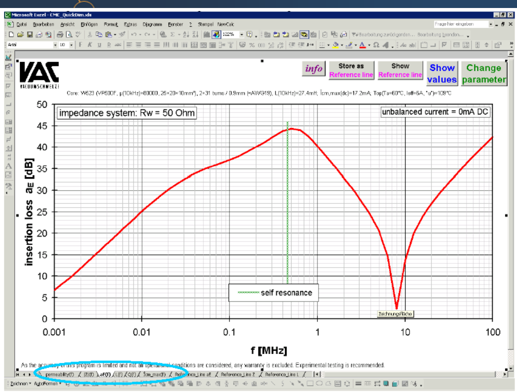
winding capacitance

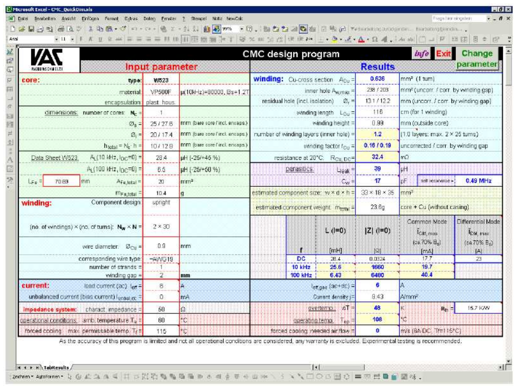
Self resonance

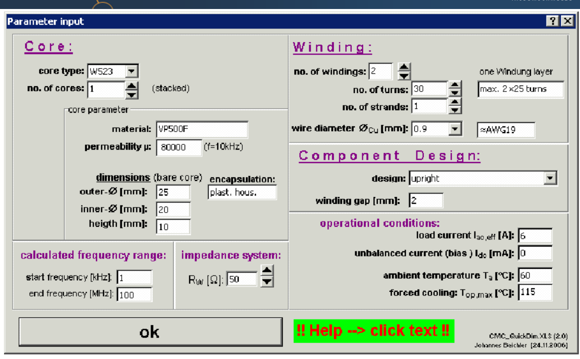
DCR,

winding factor

unbalanced current limitation







Custom CMC designs

A discussion of CMC CheckList

and

A demonstration about Common Mode Current impact on CMC selection

VAC CMC CHECKLIST

CMC Design Checklist — Aug 2008

NOTE: The yellow fields are mandatory. Additional informations should be added in the white fields.

Company name:		**Contact person:**	
Address:		**Tel.:**	
	☐ New project ☐ Replacement for: ____________	**E-Mail:**	
Application (please specify in more detail):	☐ SMPS/UPS: ____________ ☐ Drives/Inverter: ____________ ☐ Solar/Photovoltaic: ____________ ☐ Welding: ____________ ☐ Other: ____________	**Date:**	
		Project name(s), description:	
Expected annual usage [pcs.]:	Year 1 ____ Year 2 ____ Year 3 ____ Year 4 ____	**Target price [€]:** **Product life cycle [years]:**	________ ________
Sample quantity:	____________ pcs.	**sample date:**	________
QM-Requirement:	☐ **ISO 9000** ☐ **TS16949** ☐ **Others:** ____________		

CMC CHECKLIST (cont'd)

Filter Design:

Filter:	1-stage ☐ 2-stage ☐ multi-stage ☐ (No. of stages: ______)
Schematic:	draft on page 2 ☐ separate attachment ☐

Important Operational Characteristics

(No.of windings) × Load current (nom.):	____ × ______ **A**	**System voltage[1] [V]:**	________
Max. load current [A]:	____ for ___ **sec**	**Working voltage[2] [V]:**	________
Switching frequency [kHz]:	____________	**Pollution degree** (typically 2)**:**	________
Nominal inductance [mH]:	____ @ 10 kHz ____ @ 100 kHz	**Max. amb. temperature [°C]:** **Max. operating temp. [°C]:**	________ ________
Nominal impedance [Ω]:	____ @ ____ kHz	**Convection:**	☐
Max. unbalanced current / max. Common Mode Current [mA]:	____ @ f < 50 kHz ____ @ ____ MHz	**Fan:** **Heat sink:**	☐ ____ [m/s] ☐ ____ [K/W]
Max. dimensions: W × D × H [mm]:	____________	**Pinning already fixed ?**	☐ yes ☐ no
Electrical standards:	☐ EN 61800 ☐ EN 50178 ☐ UL ____ ☐ other: ______ ☐ none		

[1] connected to mains [2] not connected to mains

CMC CHECKLIST (concluded)

Additional Specifications

Environmental demands:	Vibration:	____	Humidity:	________	Dust:	______
Leakage inductance [µH]:	__________		**Copper resistance R_{Cu} [Ω]:**		__________	
Casing construction:	__________		**Core / N / d_{Cu}** (from own tests)**:**		__________	

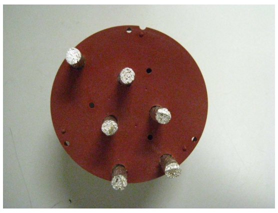
Further comments:

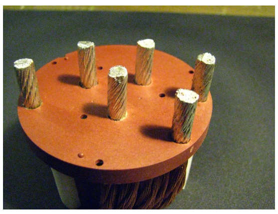
Draft of filter schematic:

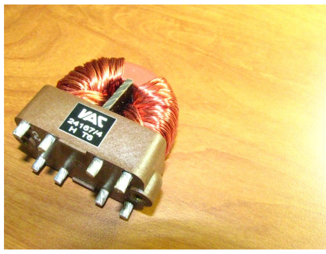
Samples

Photos of a few custom CMC's

Discussion of "Customer-Specific" products



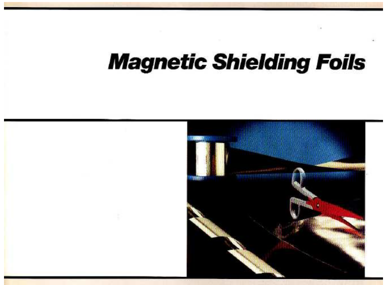




Series production

A discussion about PPAP, agency audit (eg UL), FEMA, etc

Shielding



EMI Shielding products

Vacoperm 70 (crystalline NiFe)
- Stamped parts
- Sheets

Vitrovac 6025R (amorphous CoFe)
- Amorphous Strip
- Adhesive back strip

Vitroperm sheet (nanocrystalline SiFe)
- Annealed parts