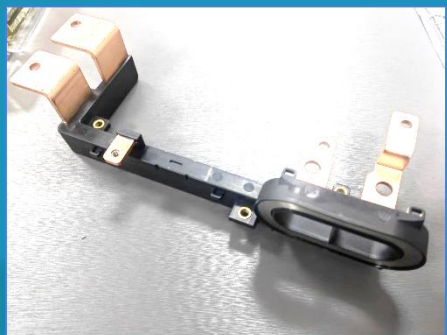
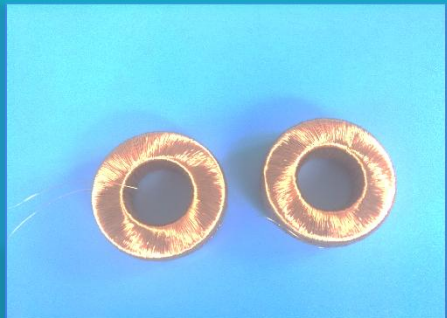
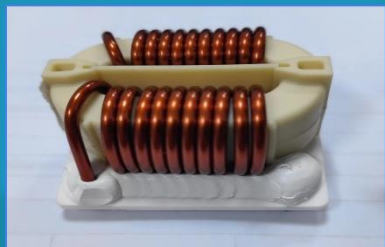




铁基纳米晶与传统铁氧体 应用比较性的介绍



编制：2024.4



高频开关电源功率变压器用纳米晶铁芯

Nanocrystalline cores for power transformer of high-frequency switching mode power supplies

- 1、非常低的铁损，而且损耗在-40~+120范围内不随温度变化而变化。
Very low core loss, and the core loss is independent of temperature within -40 °C -120 °C.
- 2、非常高的饱和磁通密度 (1.2T)，即使在高温条件也能保持。因此在电源设计中可考虑较低的工作频率，从而节省功率半导体和EMI滤波器件的成本； Very high saturation flux density ($B_s=1.2T$), even at high temperature . Switching power supply designer can consider a lower operating frequency, thus saving the cost of power semiconductors and EMI filter.
- 3、很高的导磁率，而且导磁率随温度的变化很小； High permeability, and permeability is less dependent of magnetic flux density and temperature.

功率变压器用纳米晶铁芯和软磁铁氧体磁特性比较
Comparisons of magnetic properties of nanocrystalline core and ferrite for power transformer

材料 Material	铁氧体 MnZn ferrite	纳米晶 Nanocrystalline
磁导率 Permeability	1500-2500	20000-30000
铁损 (f = 20kHz, B = 200mT) Core loss	9W/kg	1.4W/kg
铁损 (f = 100kHz, B = 200mT) Core loss	110W/kg	35W/kg
饱和磁通密度Bs Saturation flux density	0.48T	1.2T
最高工作温度 Max.operating temp.	120°C	120°C

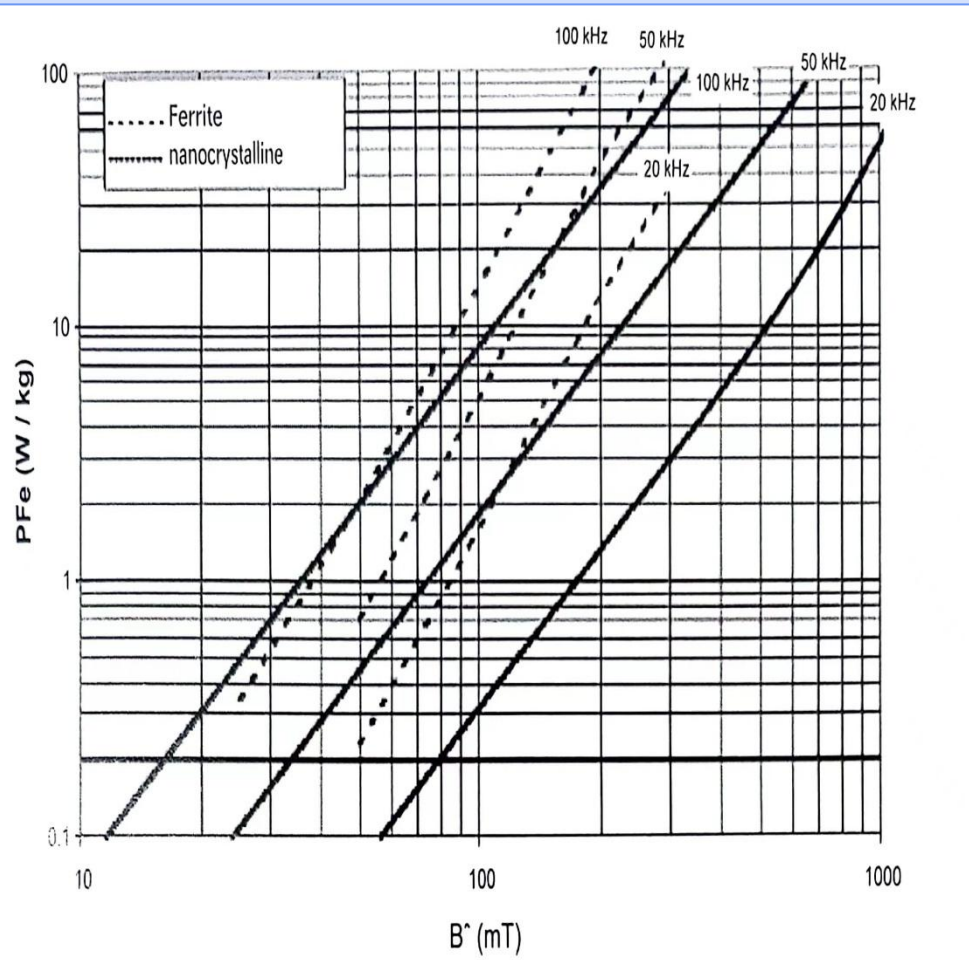
从上表可看出，纳米晶铁芯在铁耗和磁通密度方面远远优于铁氧体材料。在100°C铁氧体的工作温度下，20kHz，520mT时纳米晶材料的损耗与相同频率180mT时铁氧体材料的损耗相同。因此电源设计者在设计时可考虑选择较低的工作频率和较大的磁通密度，一方面可以达到减小变压器体积的目的，另一方面又可节省功率半导体（IGBT）和EMI滤波的成本。

As shown from the table, the core loss and magnetic flux density of nanocrystalline core is far superior to that of ferrite. Under the optimum operating temperature of 100 °C for ferrite, the core loss of nanocrystalline core at 20kHz, 520mT is the same with that of ferrite at 20kHz, 180mT. Lower operating frequency and higher flux density can be chosen by engineers to decrease the transformer size and to save the cost of power semiconductors (IGBT) and EMI filters.

高频开关电源功率变压器用纳米晶铁芯

Nanocrystalline cores for power transformer of high-frequency switching mode power supplies

纳米晶铁芯和MnZn铁氧体在不同频率下
铁损和磁通密度的变化曲线



在频率为 $f = 20\text{kHz}$ ，环境温度 $\Delta T = 50\text{K}$ ，变压器纳米晶铁芯大小和所能传输的功率如下：When $f = 20\text{kHz}$, $T \leq 60^\circ\text{C}$, $\Delta T = 50\text{K}$, the core size and the transmitted power is as follows:

Core size(ODxIDxHT)	output power
50X40X20	1300
63X50X25	2800
80X63X25	4200
100X80X25	6100
100X80X50	9000
130X100X25	11000
130X100X50	16000
130X100X75	20000

功率变压器利用纳米晶铁芯使变压器具有体积小，重量轻，频率高，稳定性好等特点，它将越来越广泛地应用在域的开关电源上。

With small size, light weight, high operation frequency and good magnetic stability, nanocrystalline core for power transformer will be more widely applied in various fields of switching mode power supplies.

铁路运输开关电源
Switching mode power supply of the railway transportation

电动交通工具，电动充电器开关电源
Switching mode power supply for electric vehicles, electric charger.

轮船上用开关电源
Switching mode power supply for ships
400Hz 飞机电源
Switching mode power supply for 400Hz aircraft.

通讯电源
Communication switching mode power supply

焊接电镀电源
Switching mode power supply for welding and electroplating equipment

无线电及TV的发射器电源
Switching mode power supply for radio and TV transmitter

风力设备电源
Switching mode power supply for wind device

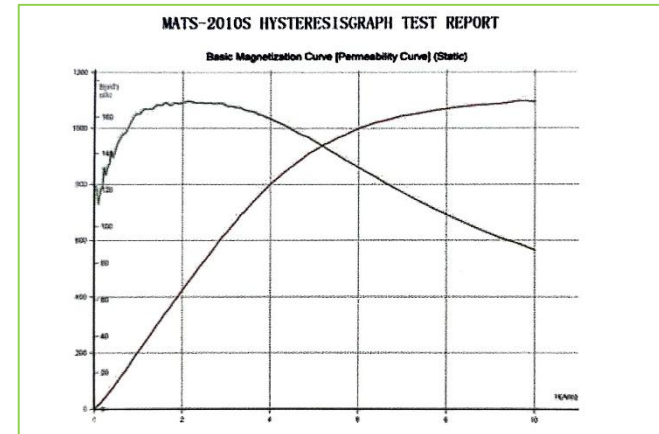
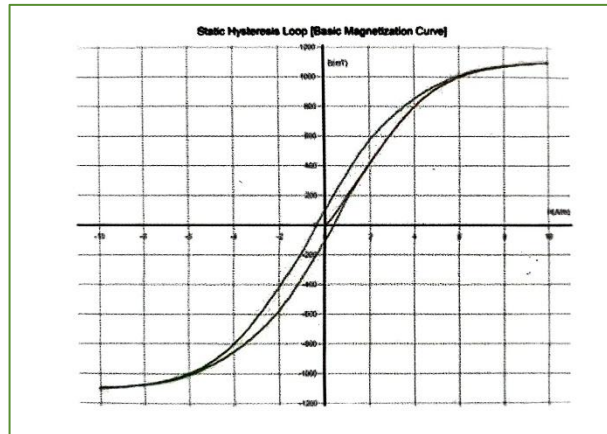
纳米晶铁芯和铁氧体磁性能和物理性能比较

Comparison of magnetic properties and physical properties between nanocrystalline cores and Mn-Zn ferrite.

属性 Properties	铁氧体 MnZn ferrite	纳米晶 Nanocrystalline
磁导率 Initial permeability at 100kHz	5000	20000
阻抗 Impedance permeability at 100kHz	5000	28000
饱和磁密 Saturation flux density Bs (T)	1.15	0.35
矫顽力 Coercivity Hc (A/m3)	30	0.35
晶化温度 Curic temperature Tc(°C)	200	570
饱和磁致伸缩 Saturation magnetostriction(x10 ⁻⁶)	-1.1	2.2
电阻率 Electrical resistivity (μΩm)	1.2	1.0*10 ⁶
密度 Density d(g/cm ³)	7.2	5

共模滤波器纳米晶铁芯的静态磁滞回线和磁化曲线

Static typical hysteresis loop and magnetization cure of nanocrystalline core for common mode chokes



和铁氧体相比,纳纳米晶铁芯具有以下优点:

1.在100kHz 下的纳米晶铁芯复数导磁率的实部是Mn-Zn铁氧体的2倍以上,纳米晶铁芯复数磁导率的虚部是Mn-Zn铁氧体的4倍以上, 因此再低频时达到与 Mn-Zn铁氧体相同的阻抗值, 纳米晶铁芯只需要一半的匝数,这将极大地降低寄生电容 在高制阻抗值。

1.The real part of complex permeability at 100kHz reaches more than twice as high as that of Mn-Zn ferrite cores. The impedance relative permeability including imaginary part of complex permeability reaches more than four times as high as that of Mn-Zn ferrite cores. As a result, nanocrystalline core can be reduced to 1/2 winding turns to obtain same impedance value as a Mn-Zn ferrite core in low frequency. And it will reduce stray capacitance significantly. Impedance in high frequency range becomes large.

2.温度变化对纳米晶铁芯初始导磁率随着频率的变化影响较小,因此由纳米晶铁芯制造的共模滤波器在宽频和大的温度范围电感和阻抗变化较小。

2.Frequency dependence of initial permeability is not significantly affected by temperature change. Consequently common mode chokes made of nanocrystalline cores have low temperature dependence of inductance and impedance over a wide frequency and temperature range.

共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

共模滤波纳米晶铁芯的材料特性
Materials of Common Mode chokes (CMC s)

材料 Materia	铁氧体 MnZn ferrite	纳米晶 Nanocrystalline
材料基础 Material base	≈70%Fe	MnZn
矫顽力 Coercivity H. (A/m)	<3	5...60(...2000)
Losses P _{Feryp} (w/kg) 100kHz,300mT,100°C	80	140
饱和磁密 Saturation flux density Bs (T)	>1.2	<0.48
Initial permeability ui	4000...200 000	10...10 000(20 000)
Saturation magnetostriction	$\mu > 10000:10^{-8} \dots 10^{-6}$ $\mu < 8 \cdot 10^{-6}$	$10^{-6} \dots 2 \times 10^{-5}$
Max.operating temp.Top	120...140°C and higher	<120°C

和铁氧体共模滤波器相比较 纳米晶共模滤波器具有以下优点:

NbCuFeSiB nanocrystalline common mode chokes have superior characteristics when compared with Mn-Zn ferrite chokes. These characteristics are as follows:

1. 具有高的磁导率和低的Q值 宽频范围高的阻抗, 因此共模滤波器在宽频范围具有较好的噪音抑制作用。在100kHz下, 具有相同电感的纳米晶和铁氧体共模滤波器, 纳米晶共模滤波器具有2倍于铁氧体共模滤波器的阻抗值。而且由于纳米晶共模滤波器只需要比铁氧体共模滤波器较少的匝数就能获得相同的电感值, 这将极大地降低共模滤波器的寄生电容在大于1MHz的高频下能获得高的阻抗值。

2. 由于温度的变化对纳米晶共模滤波器阻抗的影响较小 因此在较宽的温度范围具有较好的噪音抑制作用

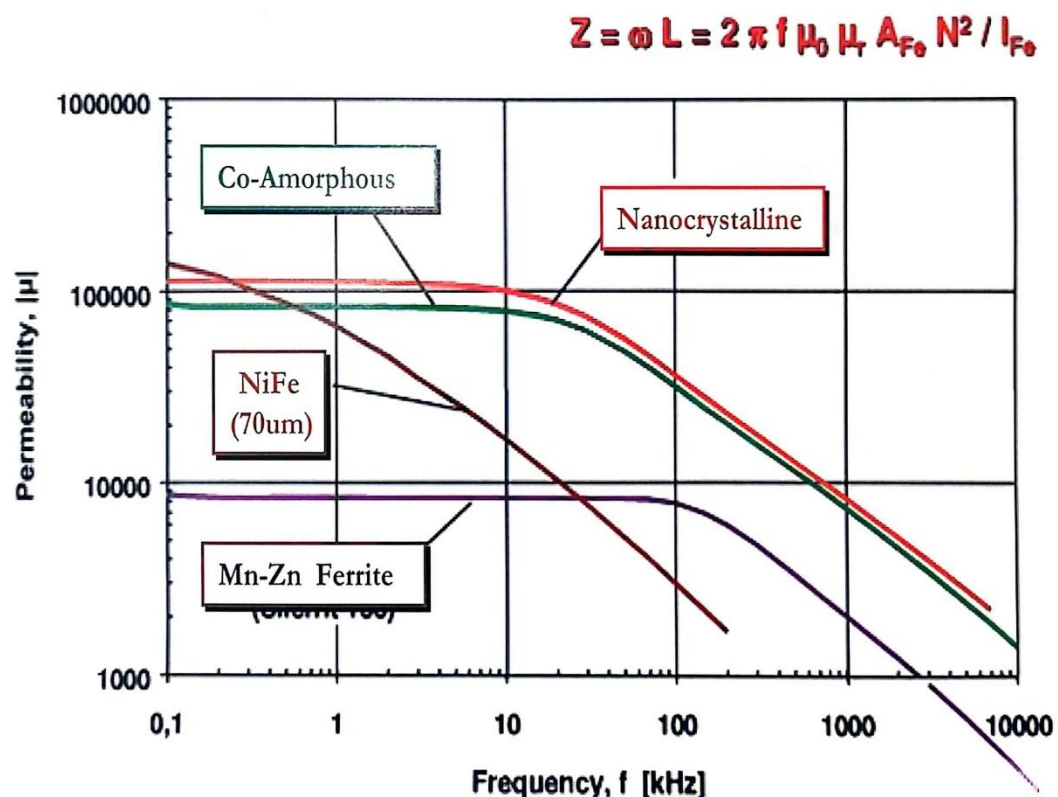
1.Higher permeability and low Q factor. Nanocrystalline CMC has higher impedance over a wide frequency range ,which result in offering excellent noise suppression performance at wide frequency range . When nanocrystalline common mode chokes and ferrite chokes have same inductance at 100kHz,nanocrystalline common mode chokes show impedance two times higher than that of ferrite chokes.Futhermore , since nanocrystalline common mode chokes require fewer windings to obtain the same inductance as Mn-Zn ferrite chokes, stray capacitance can be reduced and it allows high impedance at high frequencies than 1MHz.

2.Their frequency characteristics of impedance are not greatly affected by temperature change.As a resuit, it offers high noise suppression effect over a wide temperature range.

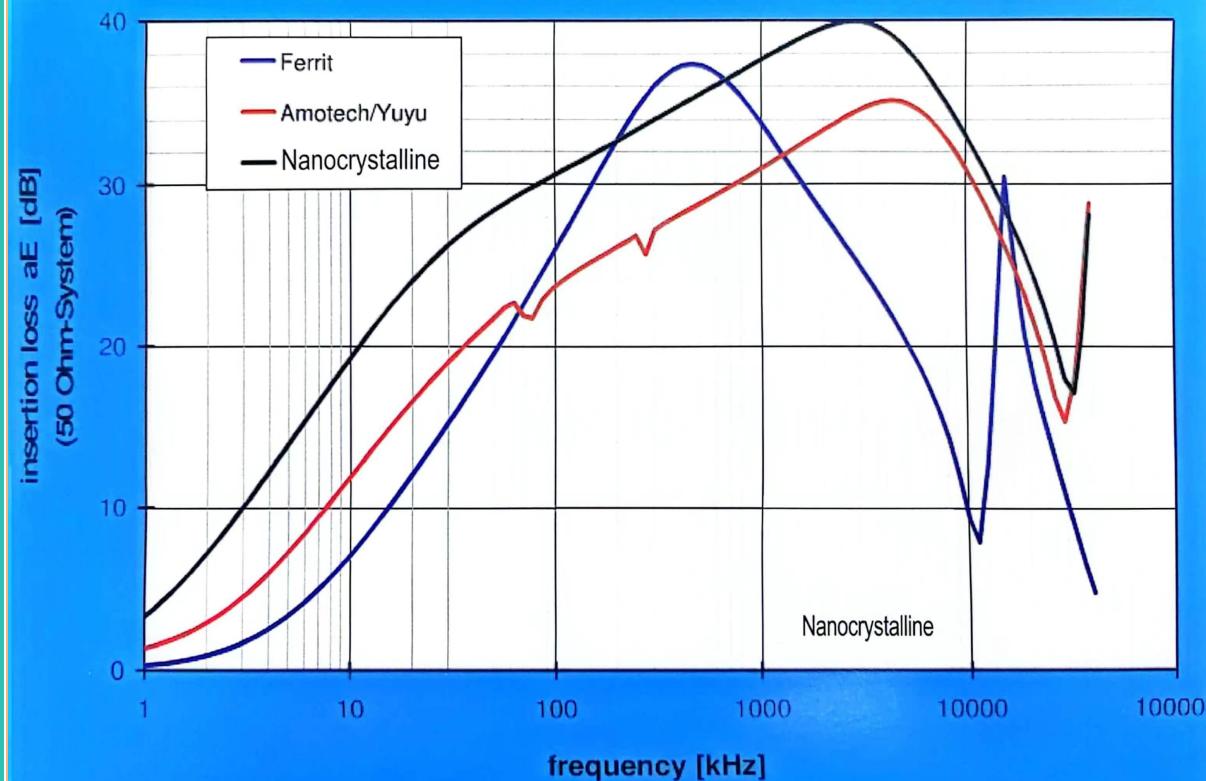
共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

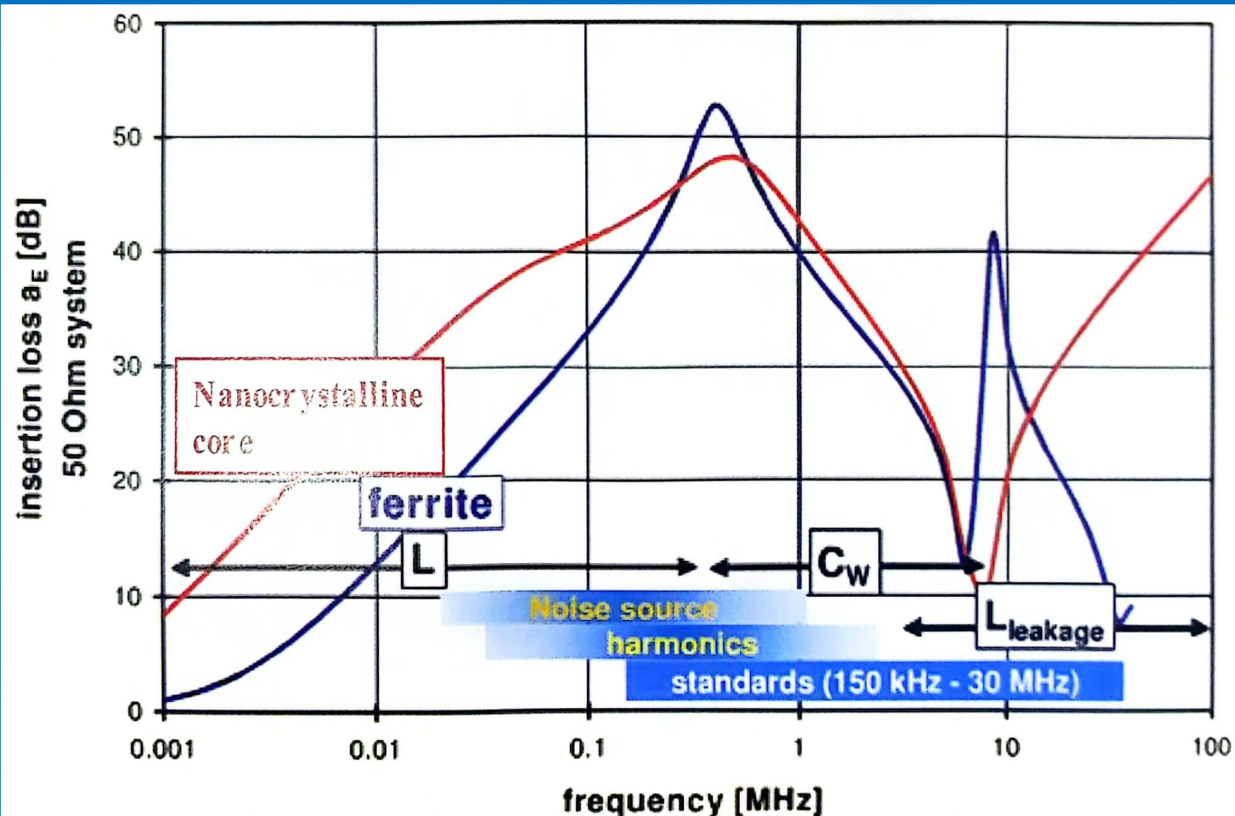
纳米晶材料整个频段范围都有搞的导磁率
Nanocrystalline Materials high μ over whole frequency range



纳米晶材料整个频段范围都有搞的导磁率
Nanocrystalline Materials high insertion loss over whole frequency range



影响插入损耗的因素 Insertion loss affected factors



纳米晶共模电感的优点 Benefits of nanocrystalline CMC's

1, 高的初始磁导率 High initial permeability μ

◆相同的体积的情况下, 用少的绕线圈数就可获得高的电感, 使其在低频范围有更高的共模衰减

Much higher attenuation in LF-range at small no of turns(N) and same volume or

◆圈数更少或磁芯体积更小的情况下, 在低频范围可获得基本相同的共模衰减

Similar attenuation in LF-range at smaller no of turns (N) and or smaller size.

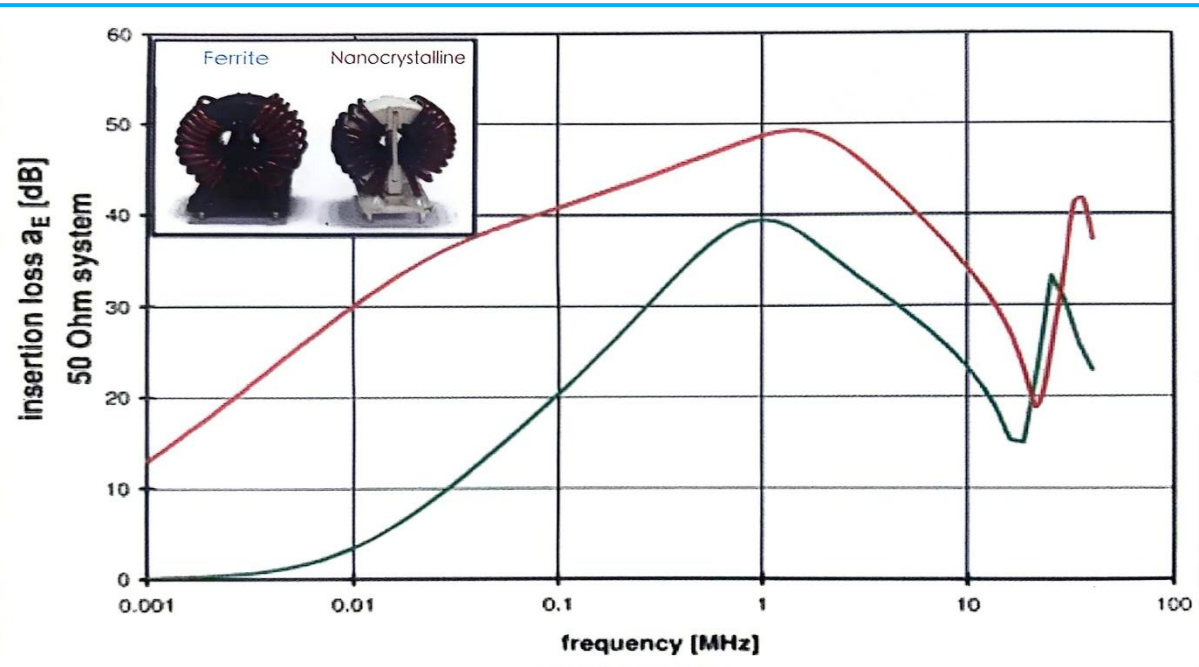
而且: 少的圈数N→更少的分布电容C_w = 高频范围 (HF-range) 有更好的性能

AND: small N → smaller C_w much better performance in HF-range

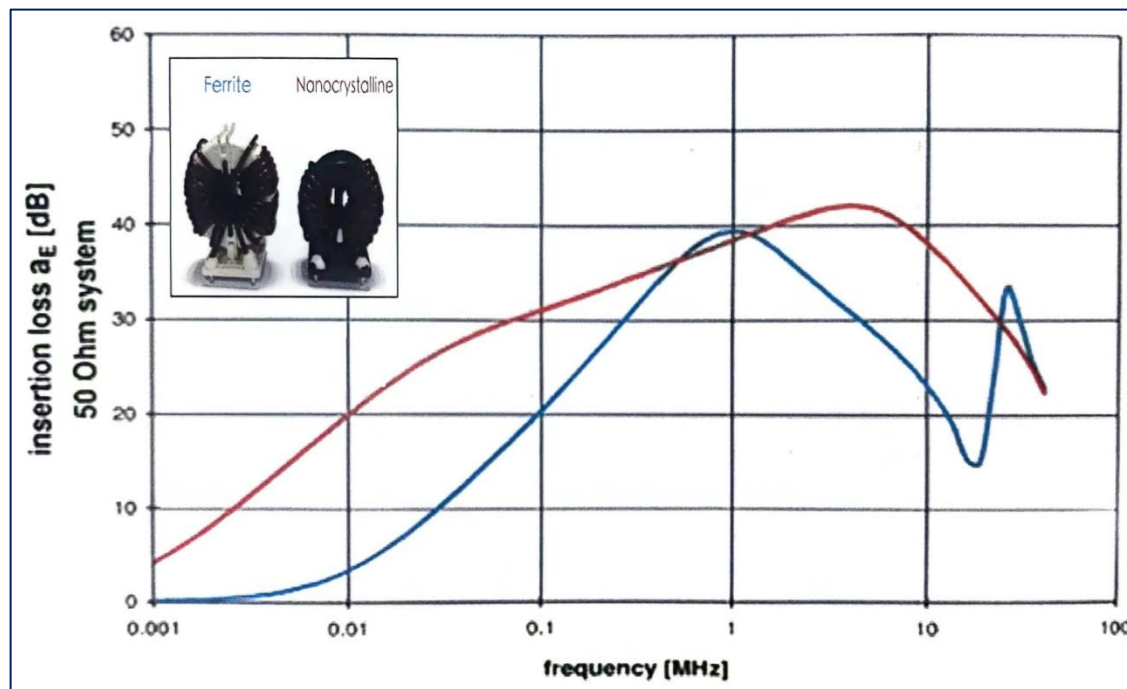
共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

纳米晶共模电感：相同体积更高的共模衰减
Nanocrystalline Common Mode Chokes:
Higher attenuation in same volume



纳米晶共模电感：近似的衰减更小的体积（3-4倍）
Nanocrystalline Common Mode Chokes:
Similar attenuation in smaller volume



纳米晶共模电感的优点 Benefits of nanocrystalline CMC's

2、高的饱和磁通密度 High Saturation flux density B_s (T)

Core saturation at higher field strength (for same μ)

◆好的抗饱和能力 Good to take high unbalance currents and / or

◆更小的体积 Smaller size

3、高的工作温度，优异的温度特性

High operational temperatures excellent thermal properties

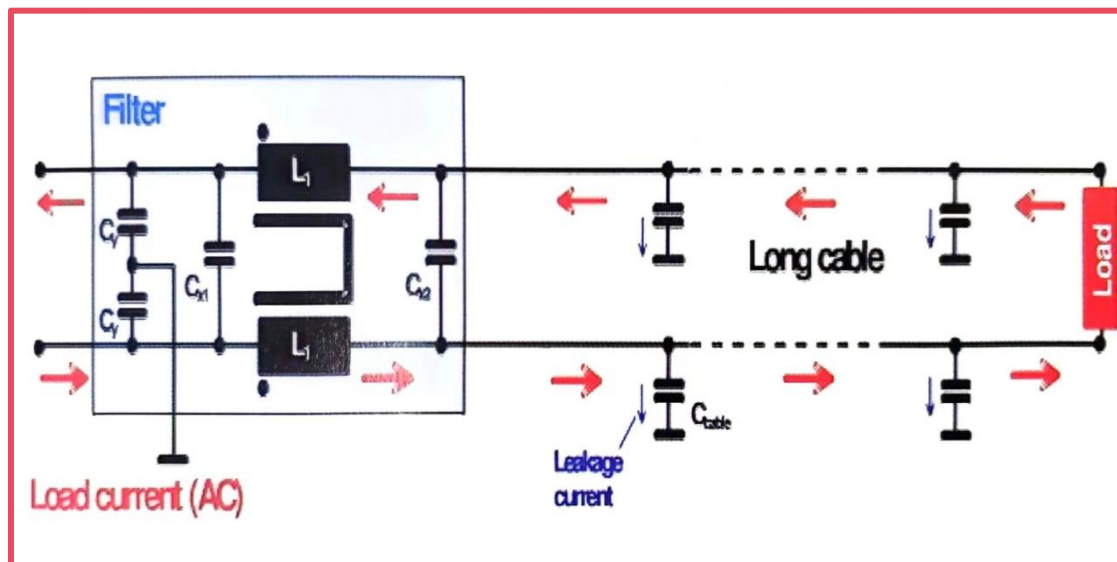
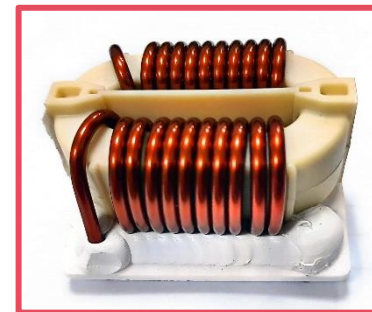
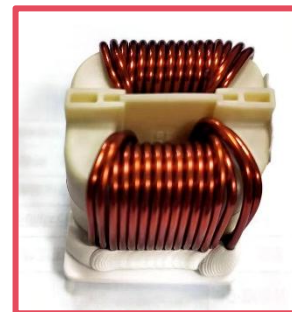
◆更小的体积，易于设计 Smaller size , easy design

◆磁特性基本不受温度的影响

nearly temperature independent properties' ($Z, L, Q, \alpha E, \dots$)

◆提高了产品的可靠性

improved product reliability



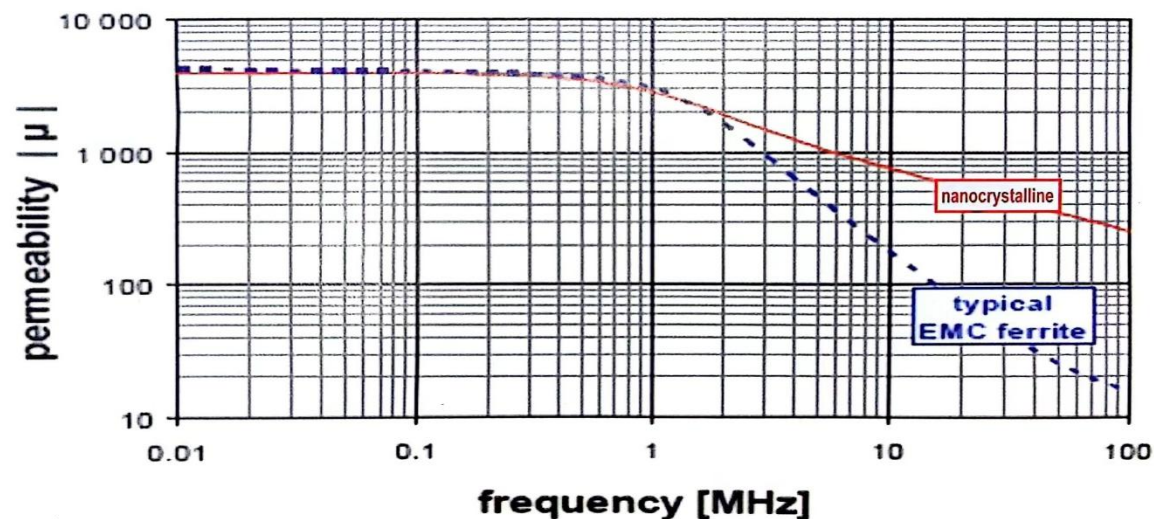
共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

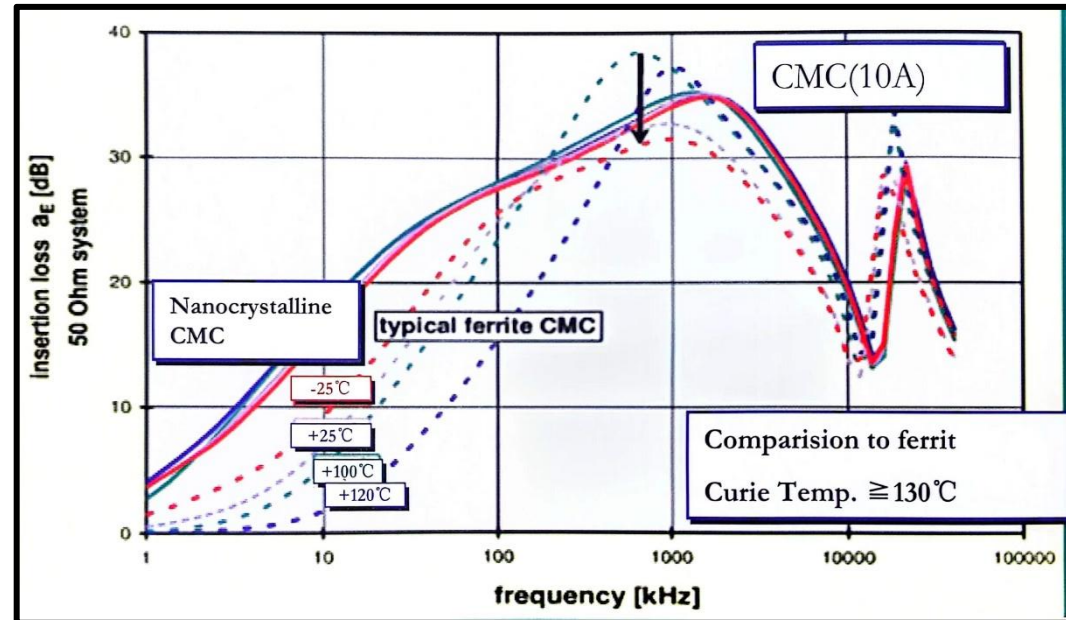
高的饱和能力纳米晶铁芯磁特性

Magnetic properties of nanocrystalline core for higher unbalanced current.,

Permeability vs. Frequency: MnZn-Ferrite – VP250F



纳米晶材料：磁特性不受温度的影响
(nanocrystalline Cores) :
temperatures independent properties'

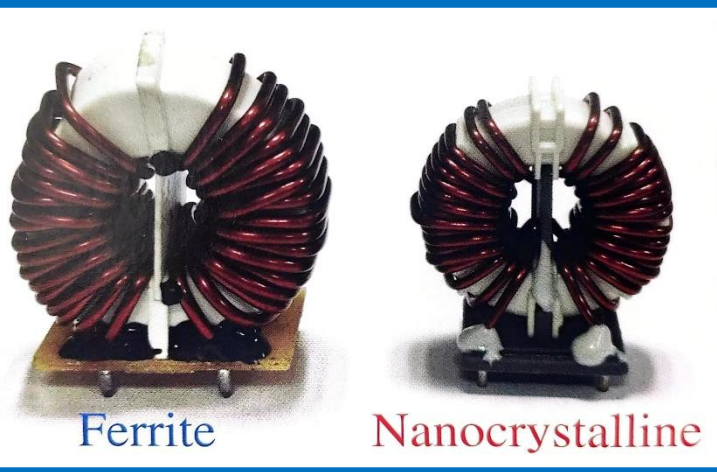


共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

案例一: 25A 变频空调用开关电源

Example I: SMPS for 25A frequency conversion air-conditioner



25A变频空调开关电源

原铁氧体方案Original filter:

MnZn ferrite **40X25X20** $\mu=10000$ (100kHz), $N=2 \times 17$, $d = 2.0$

纳米晶解决方案Nanocrystalline solution:

Nanocrystalline **35x23x15** $\mu=30000$ (100kHz), $N = 2 \times 15$, $d = 2.0$

用较小尺寸的纳米晶共模电感代替铁氧体共模电感后插入损耗降低4dB。

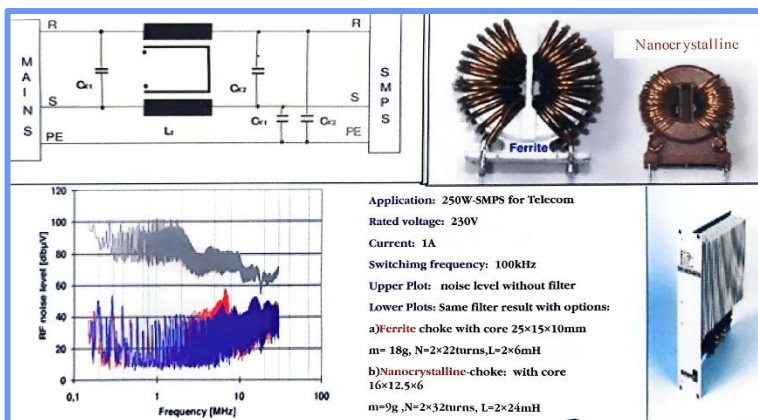
4dB of insertion loss is decreased after replacing ferrite choke with smaller size nanocrystalline choke.

共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

案例二：电信用开关电源，250瓦

Example2: SMPS for telecom, 250w



应用: 250w-SMP 的液位。

额定电压: 230伏

电流: 1A

开关频率: 100kHz

上图: 无滤波器的噪声水平如下图: 相同的滤波器结果与选项:

a) 铁氧体铁芯 25x15x10mm = 18g, N-2x22TS, L = 2x6mH

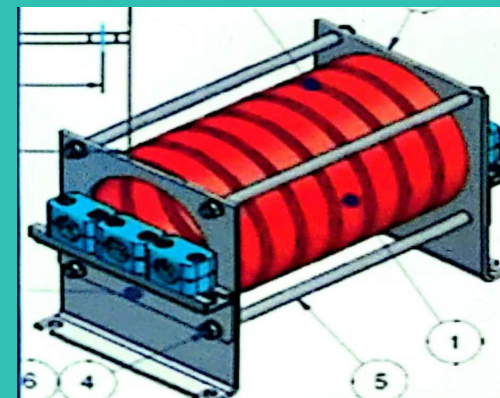
b) 纳米晶铁芯 16x12.5 x6m = 9g, N-2x32TS, L = 2x24mH

案例三：1.5MW 风力发电机级装

Example3: 1.5 MW wind turbine stage installation



Core(Φ 160* Φ 130*30)



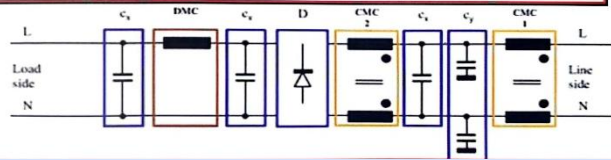
共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

案例四：90W 笔记本电脑适配器

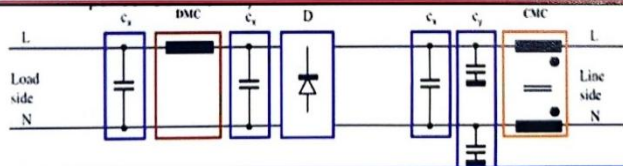
Example 4: 90W Adaptor for notebook

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



原过滤: 2级过滤, 2个铁氧体 CMC (CMC1 OD = 13mm, CMC2 OD = 15mm), 1个 DMC (Fe 粉芯 OD = 15mm)

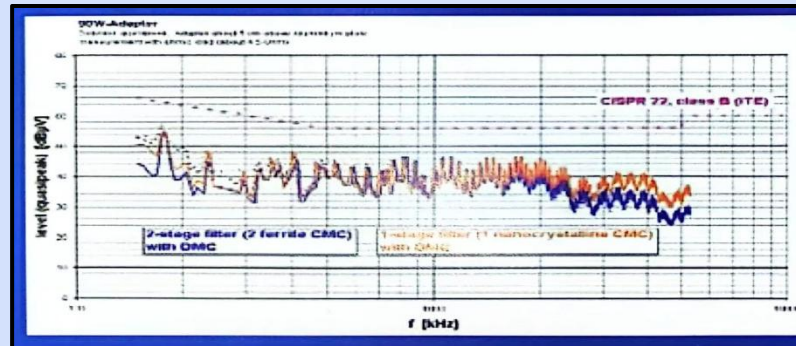
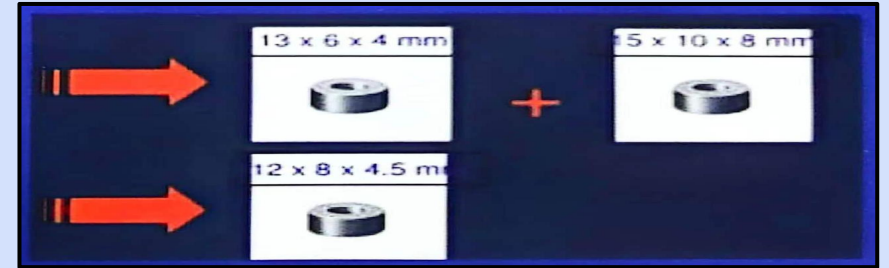
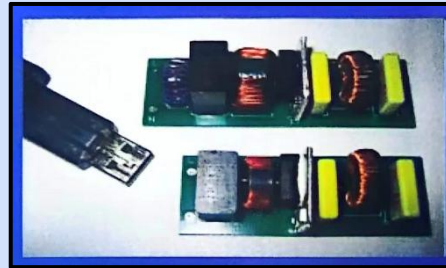
Nanocrystalline CMC: 1 stage filter, 1 CMC (nanocrystalline core OD=12mm), 1 DMC (Fe Powder OD=15mm)



纳米晶 过滤CMC: 1级过滤器, 1级 CMC (纳米晶芯 OD = 12mm), 1级 DMC (铁粉芯 OD = 15mm)

案例五：3500W 太阳能逆变器

Example 5: 3500W Solar Inverter

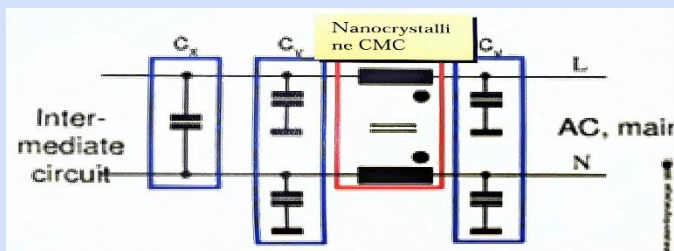
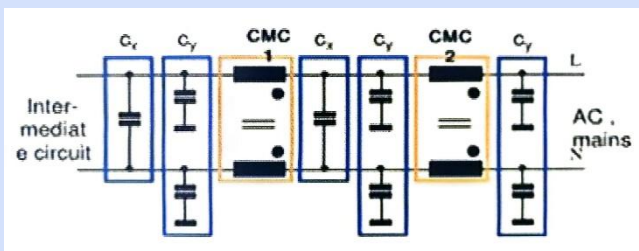


共模滤波用纳米晶铁芯

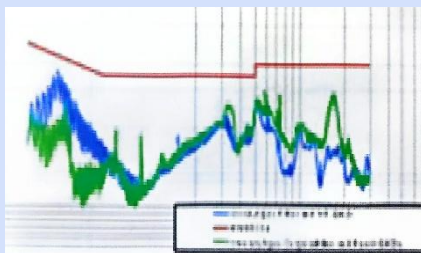
Nanocrystalline cores for common mode chokes

案例六： 3500W 太阳能逆变器

Example 5: 3500W Solar Inverter



原有方案：
2铁氧体 CMC
2CX
6CY
original filter
2ferrite CMC
2cx
6cy



efficiency=95.6%
效率 = 95.6%

解决方案:1纳米晶体1CX × 4CY
solution
1 Nanocrystalline CMC
1cx
4cy

案例七： 用于 LCD TV 输入的180W 开关电源:

Example 7:180W SMPS for LCD TV

输入input: : 100.240V/50 ~ 60Hz/1.8 A



原始滤波器:

CMC1: MnZnT18, $\mu = 10000$, $N = 2 \times 32$, $d = 0.7$ mm

CMC2: MnZnT18, $\mu = 10000$, $N = 2 \times 32$, $d = 0.7$ mm

纳米晶铁芯解决方案。

CMC1: 纳米晶铁芯(12x8x4.5 mm), $\mu = 80000$, $N = 2 \times 45$, $d = 0.4$ mm

CMC2: 纳米晶铁芯(12x8x4.5 mm), $\mu = 80000$, $N = 2 \times 32$, $d = 0.28$ mm

Original filter:

CMC1:MnZn T18, $\mu=10\ 000$, $N=2 \times 32$, $d=0.7$ mm

CMC2:MnZn T18, $\mu=10\ 000$, $N=2 \times 32$, $d=0.7$ mm

Nanocrystalline solution.

CMC1:Nanocrystalline core(12x8x4.5mm), $\mu=80\ 000$, $N=2 \times 45$, $d=0.4$ mm

CMC2: Nanocrystalline core(12x8x4.5mm), $\mu=80\ 000$, $N=2 \times 32$, $d=0.28$ mm

共模滤波用纳米晶铁芯

Nanocrystalline cores for common mode chokes

产品代码, 零件名称和规格 Product code ,Part name and specifications												
CMC dimensions	额定电流 Rated Current(A)	L(mH) 1KHZ PEF	L(mH) 100KHZ PEF	Wire diameter						DC Resistance (MAX.m Ω)	Temp, rise (°C)	shape
					A max	B max	C max	F max	G max			
ANMG10A-16mH	10	18	3.2	1.2	36	22	36	18	22	20	43	Fig.1
ANMG18A-9mH	18	16	2.6	1.6	42	22	43	18	22	20	74	Fig.2
ANMG15A-16mH	15	16	3.5	1.4	42	25	46	18	22	20	43	Fig.2
ANMG15A-22mH	15	25	3.0	1.8	44	25	46	18	22	20	55	Fig.2
ANMG22A-8mH	22	9	2.0	1.8	44	23	44	18	22	20	60	Fig.2
ANMG22A-2.5mH	22	8	1.2	1.8	44	23	44	18	22	20	60	Fig.2
ANMG25A-8mH	25	15	3.0	1.8	53	33	53	18	22	20	63	Fig.3
ANMG35A-1.5mH	35	2.5	0.7	2.5	53	34	54	18	22	20	74	Fig.3
ANMG30A-8mH	30	10	1.8	2.3	53	33	53	18	22	20	69	Fig.3
ANMG15A-5mH	15	7	1.2	1.5	33	22	35	11	17	20	43	Fig.4
ANMG10A-3.5mH	10	13	3.2	1.2	33	22	35	11.5	17	20	43	Fig.4
ANMG18A-9mH	18	16	2.5	1.8	58	42	56	-	-	20	74	Fig.5
ANMG35A-3.5mH	35	10	2.5	1.8	60	30	70	30	40	20	73	Fig.6
ANMG45A-2.5mH	35	8.5	2.5	2.0	65	35	72	30	40	20	70	Fig.6

Common Mode Choke



Common Mode Choke



Recommended core dimensions as a function of nominal current values		
铁芯 Core	两相扼流圈 two phase choke	三相扼流圈 three phase choke
20*12*8	up to apprx .6Ampere	up to apprx .3Ampere
25*16*10	up to apprx .10Ampere	up to apprx .6Ampere
27*17*10	up to apprx .15Ampere	up to apprx .10Ampere
32*20*10	up to apprx .20Ampere	up to apprx .15Ampere
38*22*12	up to apprx .25Ampere	up to apprx .18Ampere
42*27*12	up to apprx .35Ampere	up to apprx .20Ampere
49*31*18	up to apprx .45Ampere	up to apprx .30Ampere