Introduction

MAGNETICS Molypermalloy Powder (MPP) cores are distributed air gap toroidal cores made from a 79% nickel, 17% iron, and 4% molybdenum alloy powder for the lowest core losses of any powder core material.

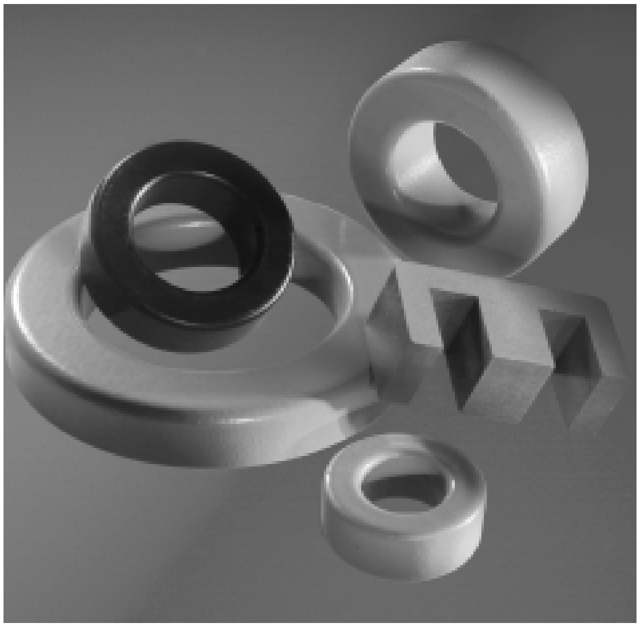
MPP cores possess many outstanding magnetic characteristics, such as high resistivity, low hysteresis and eddy current losses, excellent inductance stability after high DC magnetization or under high DC bias conditions and minimal inductance shift up to 2000 gausses under AC conditions.

MAGNETICS High Flux powder cores are distributed air gap toroidal cores made from a 50% nickel - 50% iron alloy powder for the highest available biasing capability of any powder core material.

High Flux cores have certain advantages that make them quite useful for applications involving high power, high dc bias, or high ac bias at high power frequencies. High Flux cores have a saturation flux density of 15000 gauss, as compared to 7500 gauss for standard MPP cores or 4500 gauss for ferrites. The core loss of High Flux powder cores is significantly lower than that of powdered iron cores. It is possible that High Flux cores will offer a reduction in core size over powdered iron cores in most applications.

MAGNETICS Kool Mµ® powder cores are distributed air gap cores made from a ferrous alloy powder for low losses at elevated frequencies. The near zero magnetostriction alloy makes Kool Mµ ideal for eliminating audible frequency noise in filter inductors.

In high frequency applications, core losses of powdered iron, for instance, can be a major factor in contributing to undesirable temperature rises. Hence, Kool Mµ cores are ideal because their losses are significantly less, resulting in lower temperature rises. It is possible that Kool Mµ cores will offer a reduction in core size over powdered iron cores in a similar application.



Kool Mµ E Cores have a distributed air gap which makes them ideally suited for switching regulator inductors, flyback transformers, and power factor correction (PFC) inductors. The 10,500 gauss saturation level of Kool Mµ provides a higher energy storage capability than can be obtained with gapped ferrite E cores, resulting in smaller core size. Kool Mµ E cores are competitively priced against gapped ferrite E cores and their distributed air gap eliminates gap loss problems associated with ferrites. Kool Mµ E cores have significantly lower losses and substantially better thermal properties when compared to powdered iron E cores.

MPP THINZ™, or Molypermalloy Powder washer cores, are distributed air gapped toroidal cores made from a 79% nickel, 17% iron, and 4% molybdenum alloy powder having the highest permeability of any powder core material and significantly higher saturation flux density compared to discrete gapped ferrite. THINZ™ offer an extremely low height self shielded power inductor core allowing finished inductor heights in the 1.5 mm to 2 mm range. Excellent temperature stability, superior inductance under DC bias, and low core losses highlight this product line's outstanding magnetic properties.

Applications

MAGNETICS powder cores are primarily used in power inductor applications, specifically in switch-mode power supply (SMPS) output filters, also known as DC Inductors. Other power applications include differential inductors, boost inductors, buck inductors, and flyback transformers.

While all three materials are used in these applications, each has it's own advantage. For the lowest loss inductor, MPP material should be used since it has the lowest core loss. For the smallest core size in a dc bias dominated design, High Flux material should be used since it has the highest flux capacity. For reasonably low losses and reasonably high saturation at a low cost, Kool Mμ® should be used since it has the lowest material costs.

Other specialty applications, such as High Q low level filters, load coils, and temperature stabilized inductors, MPP material is used.

	MPP	High Flux	Kool Mμ
Core Loss	Lowest	Moderate	Low
Perm vs. DC Bias	Better	Best	Good
Flux Density (Gauss)	7,500	15,000	10,500
Nickel Content	80%	50%	0%
Relative Cost	High	Medium	Low

Core Identification

MAGNETICS powder cores are marked with a part number which identifies its properties and core finish. The cores are also stamped with a date code, ensuring traceability of core history and performance characteristics. Cores smaller than 0.250" OD are not stamped. Cores with an OD between .250" and .310" are stamped with the catalog number (three digits).

TOROIDS

55 206- A2

- **A2** — Core finish:

A7	= Coating	@	500	vbd for Kool Mµ
A2	= Coating	@	500	vbd for MPP and High Flux
A5	= Coating	@	1000	vbd for MPP and High Flux
A9	= Coating	@	4000	vbd for MPP and High Flux
AY	= Parylene-C	@	300	vbd for MPP, High Flux and Kool Mµ
D4	= Coating	@	500	vbd, Temperature Stabilized for MPP
L6	= Coating	@	500	vbd, Linear Stabilized for MPP
M4	= Coating	@	500	vbd, Temperature Stabilized for MPP
W4	= Coating	@	500	vbd, Temperature Stabilized for MPP

- **206** — Catalog number (designates size and permeability)
- **55** — Material Code: 55 = MPP; 58 = High Flux; 77 = Kool Mµ

E CORES

K-5528-E060

- **E060** — Permeability Code . . . . . .First digit is always E. Last three digits equal permeability, e.g. E060 for 60µ
- **5528** — Size Code . . . . .First two digits equal approximate length in mm. Last two digits equal approximate height in mm
- **K** — Material Code . . . . .K = Kool Mµ

THINZ

M-0301-T125

- **T125** — Permeability Code . . . . . .First digit is always T. Last three digits equal permeability, e.g. T125 for 125µ
- **0301** — Size Code . . . . .First two digits equal approximate outside diameter in mm. Last two digits equal approximate inside diameter in mm
- **M** — Material Code . . . . .M = MPP

Core Inductance Tolerance/Grading

MAGNETICS powder cores cores are precision manufactured to an inductance tolerance of ±8%*, using standards obtained from Kelsall Permeameter Cup measurements and a precision series inductance bridge.

Except where noted on specific part numbers, MPP and High Flux Cores are graded into 2% inductance bands as a standard practice at no additional charge. Grading into 1% bands is available on certain sizes by special request. Core grading minimizes winding adjustments, and thus reduces coil costs. When 1% bands are required, the wound cores must be processed for inductance stability (see Page 1-8).

Graded MAGNETICS MPP and High Flux cores are also available with tolerances less than the standard ±8%. Please contact the plant for special pricing.

GRADE Stamped on Core OD	INDUCTANCE % Deviation from Nominal		TURNS % Deviation from Nominal	
	From	To	From	To
+8	+8	+7	-4.0	-3.5
+6	+7	+5	-3.5	-2.5
+4	+5	+3	-3.5	-1.5
+2	+3	+1	-0.5	+0.5
+0	+1	-1	-0.5	+0.5
-2	-1	-3	+0.5	+1.5
-4	-3	-5	+1.5	+2.5
-6	-5	-7	+2.5	+3.5
-8	-7	-8	+3.5	+4.0

* Kool Mμ cores with outside diameters less than 12mm have wider tolerances.

Core Finish

MAGNETICS powder cores are coated with a special finish that provides a tough, wax tight, moisture and chemical resistant barrier having excellent dielectric properties. Each material has a unique color coating:

- MPP – Gray
- High Flux – Khaki
- Kool Mμ – Black

The finish is tested for voltage breakdown by inserting the core between two weighted wire mesh pads. Force is adjusted to produce a uniform pressure of 10 psi, simulating winding pressure. The test condition to guarantee the minimum breakdown voltage (500 volts rms from wire to core) is a 60 Hz voltage equal to 2.5 times the minimum (or 1250 volts rms wire to wire). Higher minimum voltage breakdown finishes can be provided upon request.

Cores as large as 0.650″ OD can be coated with parylene to minimize the constriction of the inside diameter dimensions. The parylene coating has a minimum breakdown voltage guarantee of 300 volts rms from wire to core (tested at 750 volts rms wire to wire at 60 Hz). All finished dimensions in this catalog are for the color coating. When choosing a parylene coated core, the maximum OD and HT are reduced by 0.18 mm (0.007″), and the minimum ID may be increased by 0.18 mm (0.007″).

The maximum steady-state operating temperature for the coating is 200°C. The maximum steady-state operating temperature for the parylene coating is 130°C, but can be used as high as 200°C for short periods, such as during infrared solder reflow. High temperature operation of the cores does not affect the magnetic properties.

Inductance versus Turns

MAGNETICS inductance standards are measured in a Kelsall Permeameter Cup. Actual wound inductance measured outside a Kelsall Cup is greater than the calculated value due to leakage flux and flux developed by the current in the winding. The difference depends on many variables — core size, permeability, core finish thickness, wire size, and number of turns, in addition to the way in which the windings are put on the core. This difference is negligible for permeabilities above 125 and turns greater than 500. However, the lower the permeability and/or number of turns, the more pronounced this deviation becomes.

The following table is presented as a guide to the differences that may be experienced with various numbers of turns on a 1-inch O.D. 125μ core:

Number of Turns	Actual Inductance
1000	+0.0%
500	+0.5%
300	+1.0%
100	+3.0%
50	+5.0%
25	+8.5%

The following formula can be used to approximate the leakage flux to add to the expected inductance. This formula was developed from historical data of cores tested at MAGNETICS. Be aware that this will only give an approximation based on evenly spaced windings. You may expect as much as a ±50% deviation from this result.

$$L_{LK} = \frac{292\, N^{1.065} A_e}{l_e \times 10^5}$$

where : L_{LK} = leakage inductance (mH)
N = number of turns
A_e = core cross-section (cm^2)
l_e = core magnetic path length (cm)

A_L and Inductance Considerations

The inductance of a wound core can be calculated from the core geometry by using the following equation:

$$L = \frac{.4\, \pi \mu N^2 A_e}{l_e \times 10^8}$$

where : L = inductance (Henries)
μ = core permeability
N = number of turns
A_e = core cross section (cm^2)
l_e = core magnetic path length (cm)

The inductance for a given number of turns is related to the nominal inductance (as listed in the catalog as mH/1000 turns) by the following:

$$L_n = \frac{L_{1000} N^2}{10^6}$$

where : L_n = inductance for N turns (mH)
L_{1000} = nominal inductance (mH/1000 turns)

Temperature & Linear Stabilization

(Only applies to MPP cores)

MAGNETICS MPP cores are provided in three basic temperature stabilizations; Standard, Controlled, and Linear. Typical and guaranteed inductance limits for these temperature stabilizations are illustrated on the following pages.

Standard cores are offered with three different finishes (2, 5, or 9). Controlled and Linear cores are offered with a 4 and 6 finish, respectively. See page 1-7 for further finish information.

The inductance of MPP cores is affected by temperature changes, which cause variations in the amount of distributed air gap (insulating material). The expansion characteristics of powdered metal, insulating material, and core finish all contribute to the inductance change arising from temperature changes.

The temperature coefficient of inductance can be controlled by the addition of a small percentage of special compensating alloys, which have curie points within the temperature range being controlled. When each curie point is exceeded, these particles become non-magnetic and act as additional air gaps; thus the change in inductance is minimized over a predetermined temperature range. MPP cores can thus be utilized in precision circuits requiring extremely high inductance stability over wide temperature ranges.

MAGNETICS standard cores (-A Stabilization) offer the expected temperature performance shown on page 1-7. If guaranteed temperature performance is necessary, Controlled or Linear cores are recommended. MAGNETICS 550µ cores are available only as standard cores.

MAGNETICS MPP cores are offered in three controlled stabilizations, D, W, and M to provide high levels of inductance stability over temperature per the chart listed below. Stabilization is effective only to initial permeability or when cores are driven at low induction (<100 gauss).

MPP cores are also offered with linear temperature characteristics, type L6. Linear cores provide a temperature coefficient, from -55°C to +85°C, which can be matched with a 100ppm polystyrene capacitor to yield extremely stable tuned circuits. Temperature coefficient values are referenced to 25°C.

The temperature stability of MPP cores can be affected by external factors such as moisture, winding stresses and potting compounds. These effects can be minimized by using suitable stability procedures during the coil fabrication process. Please see inductance stability considerations on page 1-8.

STABILIZATION CODE	INDUCTANCE STABILITY LIMITS Below 100 Gauss	INDUCTANCE STABILITY TEMPERATURE RANGE
M*	±0.25%	-65°C to +125°C
W	±0.25%	-55°C to +85°C
D	±0.10%	0°C to +55°C

* M cores meet the W core limits and may be substituted in place of W.

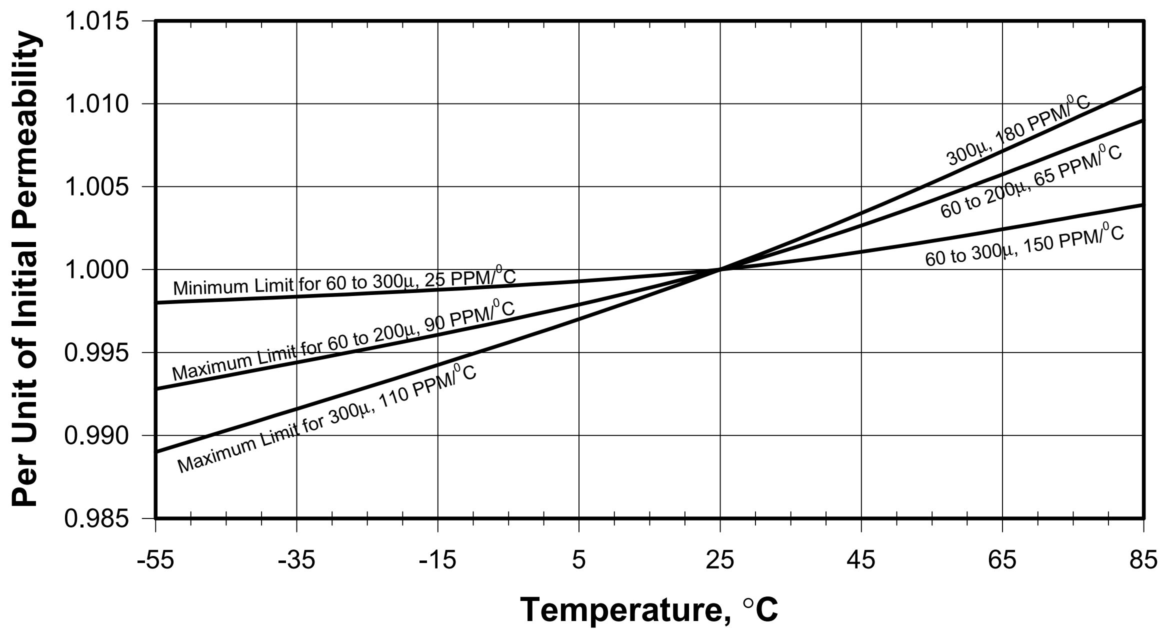
Temperature and Linear Stabilization

(Only applies to MPP cores)

Part No. Suffix	Stabilization Type	Inductance Stability Limits	Stabilized Temperature Range	Guaranteed Minimum Breakdown*
-A2	Standard	See Page 3-12	-	500 volts**
-AY	Standard	See Page 3-12	-	300 volts
-A5	Standard	See Page 3-12	-	1000 volts
-A9	Standard	See Page 3-12	-	4000 volts***
-D4	Controlled	+0.1%	0°C to +55°C +32°F to 130°F	500 volts
-W4	Controlled	+.25%	-55°C to +85°C -67°F to +185°F	500 volts
-M4	Controlled	+.25%	-65°C to +125°C -85°F to +257°F	500 volts
-L6	Linear	See Below	-55°C to +85°C -67°F to 185°F	500 volts

*From wire to bare core **except on cores smaller than .200" OD ***Add .015" to OD, HT and subtract .015" from ID to finished core dimensions chart shown on core data pages.

MPP Linear Cores Guaranteed Limits



Inductor Stabilization Procedure

(Only applies to MPP cores)

MAGNETICS MPP cores possess excellent inductance/time stability. Under typical shelf life conditions the inductance of an unpotted core will shift less than 0.5%.

If maximum stability is desired, the following precautions and procedures will remove winding stresses and core moisture and provide inductance stabilities better than 0.05%.

1. Wind cores to the approximate specified inductance (slightly over the desired value).
2. Cool wound cores to -60°C. Maintain at temperature for 20 minutes to help relieve winding stresses caused by high winding tension, large wire, or many turns.
3. Heat cores slowly (<2°C/minute) to 115°C. Maintain at temperature for 20 minutes.
4. Steps 2 and 3 should be repeated twice.
5. Bake at 115°C for 16 hours.
6. Cool to room temperature and adjust turns to obtain specified inductance.
7. Cores must be kept dry until potted or hermetically sealed.
8. If the cores are to be potted, they should be covered first with a cushioning material, such as silicone rubber. This material minimizes the possibility of the potting compound stressing the core and changing the inductance value.
9. Potting compounds should be chosen with care, as even semi-flexible resins can cause core stresses and reduce stability. Selection should be based on minimum shrinkage and minimum moisture absorption.

Winding Considerations

Winding Factors

MAGNETICS core winding factors can vary from 20% to 60%, a typical value in many applications being 40%.

MAGNETICS has chosen to normalize winding data by basing R_{dc}, ohm/mh, and winding-turn-length on unity winding factor. This approach provides the coil designer with a means of calculating realistic design parameters for his choice of winding factor.

Please note that unity values are theoretical values, not attainable in practice. The highest winding factor possible, even with hand winding, is 65% - 75%, due to the spacing between the turns of wire.

Winding Turn Length

Winding turn lengths have been computed, using empirical relationships, for five winding factors. This permits an estimate of the actual length/turn for any winding factor.

Wound Coil Dimensions

Wound coil dimensions are listed for unity winding factor, as these are the largest dimensions necessary for packaging the wound coil. These dimensions are attainable, as a 70% winding factor (no residual hole) yields the same overall coil dimensions as a 100% (unity) winding factor (no interstices).

Coil dimensions for coils wound to 40% winding factor can be estimated as follows:

$$OD_{40\%} = .5\,(OD_{core} + OD_{unity})$$

where : OD_{core} = core OD after finish

OD_{unity} = wound coil OD

$$Hgt_{40\%} = .45\,(Hgt_{core} + Hgt_{unity})$$

where : Hgt_{core} = core OD after finish

Hgt_{unity} = wound coil OD

Nominal DC Resistance

Nominal DC Resistance, in ohms/millihenry (listed on core size pages), is useful in calculating DC winding resistance (R_{dc}) for any value of inductance. The value of nominal DC Resistance is essentially independent of wire size and the number of turns of wire. The value of Nominal DC Resistance for any given winding factor can be computed as follows:

$$\Omega/mh_{wf} = \frac{\Omega mh_u}{wf} \times \frac{K_{wf}}{K_u}$$

where : Ω/mh_{wf} = Ω/mh for chosen winding factor
Ω/mh_u = unity value, listed for each core size
wf = chosen winding factor
K_{wf} = length/turn for chosen wf*
K_u = length/turn for unity (100%) wf*

*see "Winding Turn Length" on core size pages

The value of R_{dc} for any given winding factor can be computed as follows:

$$R_{dcwf} = R_{dcu} \times wf \times \frac{K_{wf}}{K_u}$$

where : R_{dcwf} = R_{dc} for chosen winding factor
R_{dcu} = unity value, listed for each size (ohms)
wf = chosen winding factor
K_{wf} = length/turn for chosen wf*
K_u = length/turn for unity (100%) wf*

Sample Calculation

Using a 55930 core, we can calculate the value of R_{dc} for 50 mh and 40% winding factors as follows, using parameter values listed on page 4-19:

$$\Omega/mh_{40\%} = \frac{\Omega/mh_u}{wf} \times \frac{K_{40\%}}{K_u} = \frac{.0524}{.40} \times \frac{.1344}{.1714} = .103\Omega/mh$$

The value of ohms/mh yields a value of R_{dc} at 50 mh, of 5.1 ohms (50mh x .103)

The value R_{dc} for the 55930 core can also be obtained by noting the unity values for No. 28 wire (i.e. 1400 turns and 15.67 ohms) can be converted to 40% winding factor values as follows:

$$N_{40\%} = N_{unity} \times wf$$

$$= 1400 \times .40$$

$$= 560 \text{ turns}$$

$$R_{dc40\%} = R_{dcu} \times wf \times \frac{K_{40\%}}{K_u}$$

$$= 15.67 \times .40 \times \frac{.1344}{.1714}$$

$$= 4.9 \text{ ohms}$$