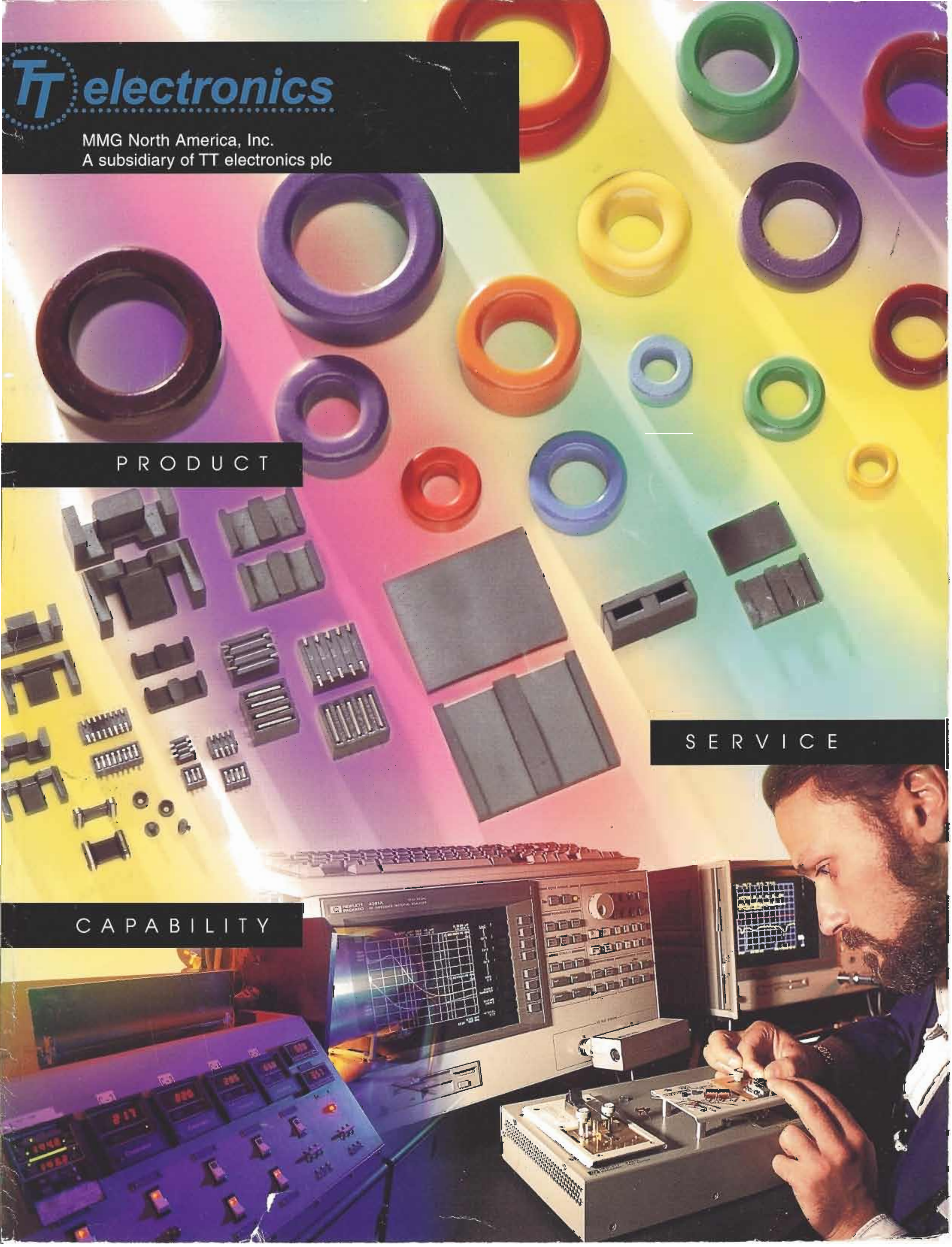
TT electronics
MMG North America, Inc.
A subsidiary of TT electronics plc
PRODUCT
SERVICE
CAPABILITY

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THE HISTORY OF MMG-NORTH AMERICA

MMG-North America was founded in 1954 by the acquisition of CGS Labs as Krystinel Corporation, located in Port Chester, New York. As a small private company, its specialized products included soft ferrite screw cores, beads, and antenna rods for the radio industry. Within six years of Krystinel's inception, the company went public, trading on the O.T.C. Exchange.

In the early 1960's, the company extended its product line to include cores suitable for the television industry. Toward the end of this decade, the fixed inductor coilform product line was developed and the company achieved a worldwide position of prominence for manufacturing quality and capacity.

The 1970's provided an opportunity for growth when the company developed an offshore facility to produce coilforms, to meet increasing demand for this product. In addition, the toroid product line was developed and introduced for application in the computer industry, the latest market to recognize the advantage of soft ferrite materials. This became a turning point for Krystinel, which marked us as a leader in specialty toroids, particularly for pulse transformers. In the late 1970's, 10,000 permeability toroids continued in periodic kilns, and our offshore facility's manufacturing capability now included wound cores.

- 1984—a major upgrade in quality and capacity to manufacture 10,000 permeability toroids was realized with the commissioning of a new, state-of-the-art continuous kiln. At this point, the company was clearly a world leader in small, high permeability toroids.
- 1989—Magnetic Materials Group PLC purchased Krystinel. MMG was a public company located in the U.K. Interaction between Krystinel and a sister company, Neosid LTD., in the U.K., began with this acquisition thereby strengthening the overall position of these companies.
- 1992—Another milestone in the company's history was the purchase of the MMG companies by TT Group PLC. The MMG companies were realigned and Krystinel was renamed MMG-North America.
- 1993—Increased capacity with the purchase of a new parylene coating machine.
- 1994—MMG-North America received ISO 9002 certification.
- 1995—Completed upgrade of press shop with the purchase of new, state-of-the-art, Dorst Presses.
- 1996—A complete line of EMI/RFI suppression components was introduced.
- 1997—MMG again upgraded the quality and overall flexibility of firing with the purchase of a new batch kiln. Today, MMG-North America continues as a leader in the manufacture and supply of ferrite cores and wound devices, and continues to succeed with sales and new developments throughout the world.

TECHNICAL INFORMATION

What is a Ferrite?

Ferrites are a chemical composition of various metallic oxides, e.g., nonmetals. The word ferrite derives from the Latin "ferrum" meaning iron, and iron oxide is the major constituent in all ferrites.

Ferrites, as they are commonly used today, were developed principally as the result of research work and studies done during and since World War II.

Ferrites may be, and are, "tailor-made" within technological limits to meet desired characteristics for electronic components. This is accomplished principally by varying the chemical composition of the materials and by making appropriate changes in processing procedures. MMG-North America has developed its line of proprietary formulations. Additionally, the company has availed itself of those formulations generally available to the industry.

Ferrites derive their usefulness from a combination of two principal characteristics:

1) high magnetic permeability which concentrates and reinforces the magnetic field
2) high electrical resistivity, which limits the amount of flow of electrical current in the ferrite. This is in contrast to some metals, such as iron, which, although they possess ferromagnetic characteristics similar to ferrites, are highly conductive, permitting large amounts of current to flow in the metal core resulting in high eddy current losses at high frequency.

The flow of electrical energy in the core, known as "eddy" current, runs counter to the desired flow and is converted into heat, resulting in overheating and lowered efficiency of the component. Ferrites, because of their unique combination of the two above-described characteristics, enjoy low energy losses, are highly efficient, and function at high frequencies, from approximately 1 kHz to 1GHz. These characteristics make the manufacture of miniaturized high frequency electronic components more practical.

MMG-North America manufactures ferrites that are used as materials in the construction of components for the electronics industry. A partial listing of ferrite shapes we manufacture are: unthreaded tuning cores, bobbins, coil forms (with and without axial leads), rods, tubes, sleeves, beads, cup cores and cover plates for magnetic shields, balun transformer cores and toroids (magnetic rings).

Many of the components using our ferrite bodies find their application in the following products: computers, computer peripherals, low power transformers, cable TV systems, radio, television receivers, EMI/RFI filters, specialized electronic instruments, switch-mode power supplies, aerospace navigational systems, and specialized commercial and military communication systems.

Two broad categories of ferromagnetic materials are soft ferrites and hard ferrites.

The term "soft ferrites" refers to the material being magnetically soft not physically soft. Several applications of soft ferrite are described above and are manufactured by MMG-North America.

"Hard ferrites" or permanent magnets are also available through MMG-North America but are manufactured by one of our sister companies. Permanent magnets are used in small dc motors and various magnetic holding devices.

All magnetic applications are supported by, and available through, MMG-North America whether manufactured at the Paterson facility or one of the affiliated TT Group companies.

Ferromagnetism

Ferrites are polycrystalline oxides manufactured by ceramic technology and belong to a class of materials which exhibit the technically useful property of ferromagnetism.

In a ferromagnetic material, magnetization occurs under the influence of an externally applied field. On removal of this field, the material returns to its non-magnetized state. This behavior is termed magnetically 'soft.'

Ferromagnetic materials are subdivided by internal energies into a great number of discrete regions, approximately one micron in size, called magnetic domains, in which the magnetic moments of adjacent atoms are aligned.

In the normal state (i.e., no external magnetic field), these domains are randomly orientated and it is not possible to detect any magnetization by measurement. When an external field is applied, domains tend to align themselves in the direction of the field. Some are capable of aligning themselves by rotation, even if the applied field is very weak, while others expand dimensionally at the expense of less favorably orientated neighbors. Other magnetic domains require much stronger fields as their direction is such that they must magnetically 'collapse' and reemerge with the orientation nearly opposite to the original one.

Because of internal energies acting on domains, due in part to composition and to the microstructure produced in processing, some of the changes in orientation will lag behind the external field. This, and the irreversible nature of some changes, contribute to the characteristic shape and hysteresis of a B versus H curve (induced vs. applied fields). In metals, ferromagnetism is due to the atomic exchange forces aligning adjacent electron 'spins' in parallel, creating very strong magnetic fields within a body. The magnetic moments of atoms are additive over the relatively large area of a single domain.

Ferrites differ from metals in that they are oxides with an ionically bonded 'spinel' crystalline structure. This structure contains two magnetically opposing systems and can be represented as successive lattice planes of metallic ions separated by oxygen ions. Exchange interactions between metal and oxygen neighbors result in a reduction of electron conductivity compared to a solely metallic material, giving ferrites their high resistivity and low eddy current losses at high frequencies. The exchange mechanism between metal and oxygen atoms also results in successive metal planes with an anti-parallel alignment of magnetic moments. Summation of moments over a single domain will, therefore, result in a lower polarization than for metals and correspondingly lower saturation flux densities.

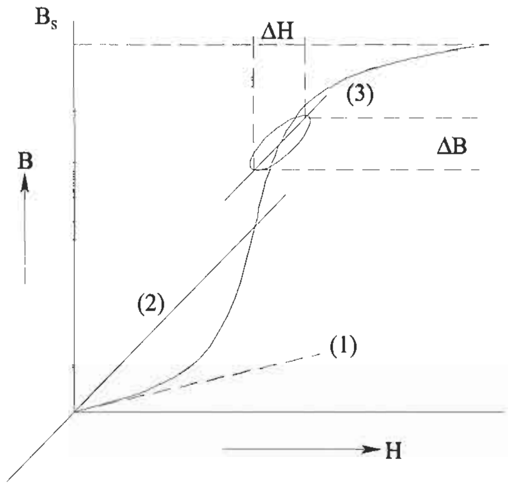
Strictly speaking, ferrites are termed ferrimagnetic, which is a subcategory of ferromagnetism. However, the numerical relationship between these two classes is such that ferrites can be, and generally are, treated as ferromagnetic materials.

Permeability

There are several unique properties which determine the technical performance of ferrite. One such property is permeability. Another is variation in response to an external field versus frequency and temperature.

Permeability is generally defined as the ratio between the induced magnetic flux density in the material and the magnetic force which causes it.

A schematic view of this relationship is shown below and has led to several concepts of permeability.



1) Intrinsic Permeability (ring core)
2) Amplitude Permeability
3) Incremental Permeability

Intrinsic Permeability

Intrinsic permeability is the ratio between flux density ΔB in a closed ring core, and the applied field strength ΔH at very low AC fields. ($\Delta H \rightarrow 0$).

$$\mu_i = \frac{1}{\mu_0} \cdot \frac{\Delta B}{\Delta H} (\lim . \Delta H \rightarrow 0)$$

where μ_0 is the magnetic field constant:

$$\mu_0 = 4\pi \times 10^{-7} \frac{H}{m} \quad \text{or} \quad \frac{T}{A/m}$$

Measurements are generally made at a flux density <0.1mT for ring cores and <1mT for components with a sheared flux path.

Intrinsic permeability is calculated from:

$$\mu_i = \frac{10^{-6}}{\mu_0} \cdot \frac{L}{n^2} \cdot \sum \frac{\ell}{A}$$

$\sum \frac{\ell}{A}$ Geometric core constant, C_1 (mm^{-1})

n = Number of Turns
L = Inductance (nH)

$$= \frac{1}{0.4\pi} \cdot \frac{L}{n^2} \cdot \sum \frac{\ell}{A}$$

The intrinsic permeability is also known as the initial permeability by reference to its position on the B vs. H magnetization curve, and as the 'toroidal' permeability by reference to its measurement on ring cores.

Geometric Core Constants

For a thin-walled toroid, a uniform and constant magnetic flux density may be assumed. For radially thick toroids and other practical components, particularly where the cross-sectional area varies along the flux path, it is necessary to calculate 'effective' magnetic dimensions.

The calculation is, in effect, a summation of partial magnetic path lengths and their corresponding areas of cross section with their associated change of flux density.

Geometric core constants are calculated from component dimensions according to the IEC document 205, giving constants:

$$C_1\left(\sum \frac{\ell}{A}\right) \text{and } C_2\left(\sum \frac{\ell}{A^2}\right)$$

accordingly, Geometric Core Constant:

$$\sum \frac{\ell}{A} = C_1 (mm^{-1})$$

Effective Length

$$\ell_e = \frac{C_1^2}{C_2} = \frac{\left(\sum \frac{\ell}{A}\right)^2}{\sum \frac{\ell}{A^2}} (mm)$$

Effective Area

$$A_e = \frac{C_1}{C_2} = \frac{\sum \frac{\ell}{A}}{\sum \frac{\ell}{A^2}} (mm^2)$$

Effective Volume

$$V_e = \frac{C_1^3}{C_2^2} = L_e \cdot A_e (mm^3)$$

Effective Permeability (μ_e)

In many cases ferrite cores contain an air gap, either purposely introduced to enhance a specific magnetic performance or caused by limitations of grinding at the mating faces.

In such cases, some of the applied magnetomotive force is lost in overcoming the reluctance of the air gap. This results in the permeability of the core being lower than the intrinsic permeability of the material. This reduced permeability is calculated from the measured inductance of a winding on the gapped core and is the effective or gapped permeability, μ_e.

$$\mu_e = \frac{1}{\mu_0} \cdot \frac{L}{n^2} \cdot \sum \frac{\ell}{A}$$

The effective permeability is used in the calculation of losses, temperature coefficient and disaccommodation.

The effective permeability can be approximated from the intrinsic permeability and the gap length, 'l_g', by:

$$\mu_e = \frac{\mu_i}{1 + \frac{\mu_i}{\ell_e} \cdot \frac{\ell_g}{k}}$$

where k is an approximate correction for the expansion of flux in an air gap.

Inductance Factor (A_L)

In order to facilitate the design of inductors based on toroidal, pot, E and U cores, it is necessary to provide information on the expected inductance when winding a specific core. This information is given by the inductance factor, A_L.

As inductance of a coil is proportional to the square of the number of turns, A_L is the inductance per turn squared.

$$A_L = \frac{L(nH)}{n^2} = \frac{\mu_e}{\sum \frac{\ell}{A}} \cdot 0.4\pi$$

A_L values are generally measured using fully wound coil formers.

It follows that the number of turns required to produce a specific inductance is:

$$n = \sqrt{\frac{L}{A_L}}$$

A_L values are given in the component data pages. This is given either as a minimum with maximum limit unspecified or as a nominal value with a tolerance.

For gapped cores, much closer tolerances are specified in the appropriate component data. Reference should be made to an MMG Sales Department if tighter tolerances are required.

Rod Permeability (μ_{rod})

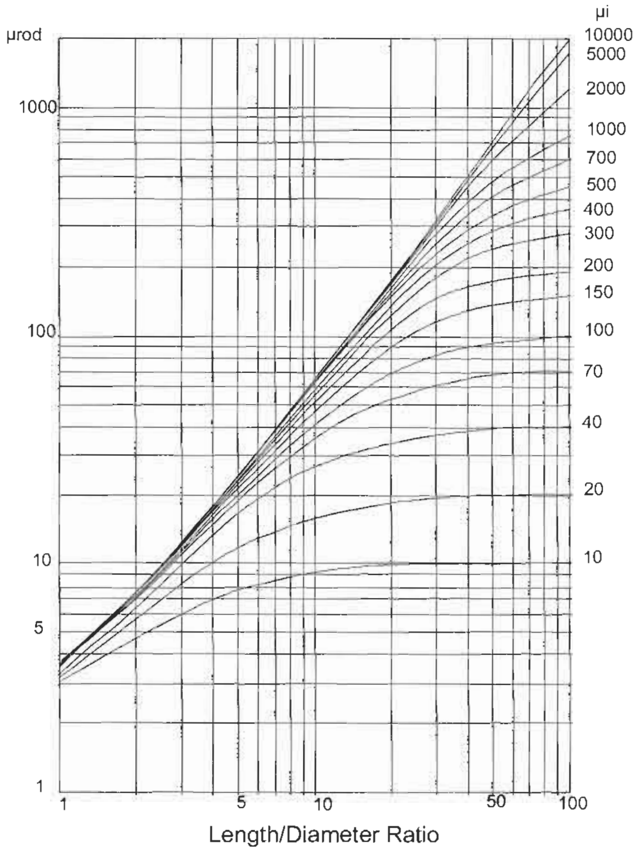
Many ferrite cores, of which aerial rods and screw cores are typical examples, are used in such a manner that the ferrite material only occupies part of the path of the magnetic lines generated by the current flowing in the winding. The magnetic circuit is then virtually open, and very strong demagnetizing fields appear at the end faces of the core. Depending on the geometry of the core, usually expressed as length-to-diameter ratio for cylindrical cores, the permeability (known in this case as the rod permeability) can be calculated from the intrinsic permeability of the material. Such a calculation would be very complex in a general case but is relatively easy for cylindrical cores which are approximated to ellipsoids.

For aerial rods, the rod permeability expresses the ability of the rod to concentrate the field lines arriving from a distant transmitter and is, therefore, one of the factors determining the pickup voltage. This permeability varies along the core, having its highest value in the mid-section and its lowest at the end faces. It is very rare for open circuit cores to operate at substantial flux densities, and rod permeabilities are always associated with very low field conditions. Because of the nature of the magnetic circuit, rod permeability is always much lower than the intrinsic permeability of the material, and the difference between these permeabilities increases as the length-to-diameter ratio decreases.

It should be noted that no known method exists for physically measuring values of rod permeability.

For guidance, a graph of μ_{rod} vs. length-to-diameter ratio follows.

μ_{rod} *vs. Length to Diameter Ratio*



Coil Permeability (μ_{coil}), (or Apparent Permeability)

The ratio between the inductance of a coil with a core (L) and of the same coil with the core removed (L_o) is termed the coil permeability.

Coil permeability is particularly significant for the design of open circuit components where only some of the magnetic lines are generated by a current flowing in a winding pass through the core.

$$\mu_{coil} = \frac{L}{L_0}$$

Coil permeability gives, for example, a direction indication of the range of variation of inductance of a coil with a screw core adjuster.

For an open magnetic circuit, coil permeability is a function of the geometry of the core and of the geometry and position of the winding, and decreases if, for example, a thick former is used, or the winding consists of several layers. It is only possible therefore to compare μ_{coil} of different materials if evaluated under identical conditions.

Amplitude Permeability (μ_a)

When a relatively high alternating magnetic field is applied, as in the case of power transformers, the curve of the B vs. H path causes the permeability to change during the cycle. The definition of permeability which is of greater use to the designer is the amplitude permeability, μ_a, generally at specific flux densities and temperatures.

$$\mu_a = \frac{1}{\mu_0} \cdot \frac{\hat{B}}{\hat{H}}$$

$\hat{B}$ is the peak flux density in Tesla (sinusoidal induction)
^ is the peak field strength in A/m.

In the case of measurements carried out on the winding of a gapped core, the result is an 'effective' amplitude permeability in which the amplitude permeability of an equivalent toroid is reduced by the reluctance of the air gap.

In the material data pages, amplitude permeabilities are indicated for toroidal cores. In the component specifications, the effective amplitude permeabilities are given.

For components where the cross sectional area of the flux path varies throughout its length, μ_a is measured setting the peak flux density in the minimum cross section (i.e., the voltage calculation uses A_{min} in place of A_e).

For ferrites used in power applications, information generally includes the bottom limit of the amplitude permeability at a stated room temperature, and the highest rated temperature for one or more values of the peak flux density in the measuring cycle.

Incremental Permeability (μ_Δ) or (Reversible Permeability)

Where a dc current is applied to a winding producing a biasing field (H_B), the operating point of a small ac excitation is moved to a higher point on the B-H curve. In such cases the inductance measurement may differ from that obtained from an ac current where there is no dc pre-magnetization.

The amplitude permeability of the ac excursion is termed the incremental permeability (or reversible permeability).

$$\overset{\hat{H}}{\mu_\Delta} = \frac{1}{\mu_0}\left[\frac{\Delta B}{\Delta H}\right] H_B (\lim . \Delta H \rightarrow 0)$$

The point on the B-H curve where the inductance begins to decrease (i.e., there is a change in the slope of the superimposed ac loop) marks the limit of permissible dc loading.

Saturation Induction (B_S)

The total flux density is composed of the flux density induced in the material because of its permeability and that due to the applied field strength itself. $B = H + 4\pi J$ where J is the magnetic polarization of the material. Saturation induction is reached when the ordering of domains under the influence of an applied field cannot proceed any further and the value of magnetization increases only by virtue of increase in the field strength. $B_S = H + 4\pi J_S$ Where J_S is the magnetic polarization of the material.

Typically the saturation flux density (B) is given as that value obtained for a field strength of 10 Oersted.

Losses (general)

When an alternating field is applied to a winding on a ferrite core, energy is expended in making the magnetic state follow the changes in field during each cycle, and in generating eddy currents which flow in the material itself.

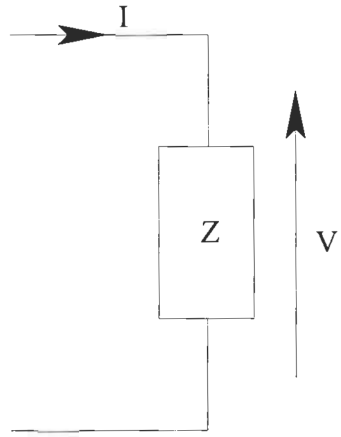
Because of the hysteresis of the magnetization loop (B=f(H)) a specified amount of energy related to the loop area is expended during each cycle. If the field strength is very low, this energy is very small and may be considered almost negligible, except in cases which have otherwise very low losses. The high flux density power losses caused by hysteresis are proportional to the number of cycles (frequency) and flux density. (The loss per cycle also tends to increase with frequency for a given flux density.)

Although the resistivity of ferrites is much higher than metals, some eddy currents are still induced and become a source of loss. This is proportional to the square of the frequency of the applied ac field. Even at very low field strength, changes in magnetic state occur accompanied by phenomena related to ferrite structure, such as resonance of domain rotation and relaxation of domain walls. The power expended in such effects is referred to as residual loss. Losses associated with a coil wound on a ferrite core can be represented by the resistive component of its impedance at any frequency and any field strength.

$$Z = R_{wind} + R_h + R_r + R_e + j\omega L$$

R_{wind} : winding resistance loss
R_h : hysteresis loss of the core
R_r : residual loss of the core
R_e : eddy current loss of the core
$j\omega L$: inductive reactance of the core

Impedance (Z)

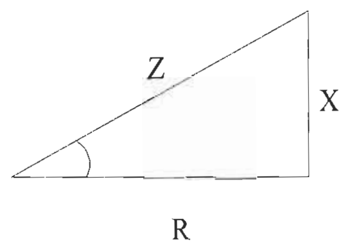


Where $Z = \frac{V}{I} = Z|\Phi$

The ratio of r.m.s. voltage over r.m.s. current in a circuit with sinusoidal excitation is defined as the impedance and is expressed in Ohms.

Φ is the angle by which voltage leads the current. Hence,
Resistance, R = ZCos Φ (ohms)
and Reactance, X = ZSin Φ (ohms)

This can be represented in the impedance triangle



$$Z^2 = R^2 + X^2$$
$$\bar{Z} = R \pm jX$$
$$|Z| = \sqrt{R^2 + X^2}$$

For suppression applications it is advantageous to maximize the resistive component at the interfering frequency. In the material data pages for F82 and F53 impedance is shown as the modulus value |Z| only. In some component pages and in the EMC section impedance may be expressed in ohms as R + jX, or Z|Φ or as the modulus value.

Complex Permeability (μ)

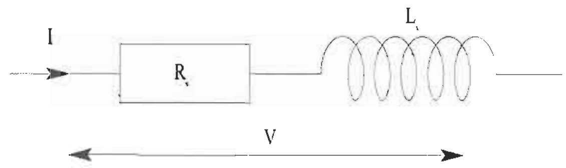
The complex permeability (μ) expands the permeability concept using complex notation to include both an inductive component as the real, inductive permeability, μ' and the loss component as the imaginary, resistive permeability, μ".

$$\bar{\mu} = \mu' - j\mu''$$

The impedance (Z) of a loss-free winding would be expressed as:

$$Z = j\omega\bar{\mu}L_0$$

where L_0 is the inductance of a winding on a core with unit permeability. For a wound ferrite component the impedance can be represented by an inductive reactance in combination with a loss resistance. For series representation:

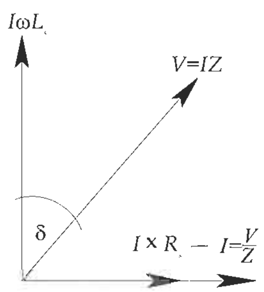


Hence:

$$R_s = \omega L_0 \mu''_s$$

$$\omega L_s = \omega L_0 \mu'_s$$

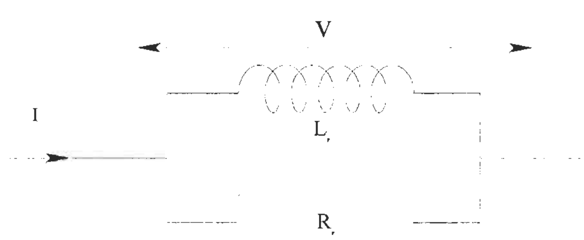
The inclusion of the resistive loss results in a reduction of the phase angle between voltage and current from 90° by an angle δ, the loss angle. From the voltage vector diagram of the series combination:



$$\tan\delta = \frac{R_s}{\omega L_s} = \frac{\mu''_s}{\mu'_s} = -$$

where Q is the magnification factor (see section 3.2). Curves of real and imaginary components of complex permeability (series representation) as a function of frequency are given in the material data pages. As measurements are made at low field strength (<0.1mT) the real component corresponds to the intrinsic initial permeability of the material.

For parallel representation:

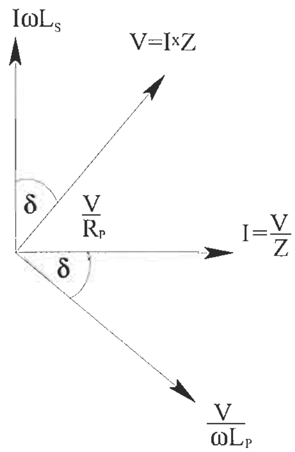


$$\frac{1}{Z} = \frac{1}{R_p} + \frac{1}{j\omega\ L_p} = \frac{1}{j\omega\ L_0}\left(\frac{1}{\mu'_p} - \frac{1}{j\mu''_p}\right)$$

giving: $R_p = \omega\ L_0 \mu''_p$,

$$\omega L_p = \omega\ L_0 \mu'_p$$

The vector diagram representation is:



$$\tan\delta = \frac{\omega L}{R} = \frac{\mu'}{\mu''} = \frac{1}{Q}$$

It follows that the conversion between series and parallel mode measurement is:

$$R_s = \frac{R_p}{\left(1 + Q^2\right)} = \frac{R_p}{\left(1 + \frac{1}{\tan^2\delta}\right)}$$

$$L_s = \frac{L_p}{\left(1 + \frac{1}{Q^2}\right)} = \frac{L_p}{\left(1 + \tan^2\delta\right)}$$

and

$$\mu'_p = \mu'_s\left(1 + \tan^2\delta\right)$$

$$\mu''_p = \mu''_s\left(1 + \frac{1}{\tan^2\delta}\right)$$

It is common practice to give curves of complex permeability in the series form. However, it should be noted that the series change in real permeability can be misleading, with graphs showing permeability falling off rapidly at high frequencies; this is only a mathematical representation and at this point parallel permeability should be used.

Although series representation befits suppression and wide band applications, it is physically more correct to consider the parallel form and conversion to this is preferable in transformer applications where a more useful expression of in-phase and out-of-phase current can be gained.

Q (Magnification Factor)

The quality of an inductor in a resonant circuit is commonly described by the Q factor, the ratio of reactance and resistance at a given frequency,

$$Q = \frac{\omega L}{R}$$

The saturation induction is an important parameter in the design of power transformers and is generally specified for ferrite grades used for this purpose. Although it is an intrinsic property, saturation induction is normally indirectly specified in component data pages for transformer cores as a minimum amplitude permeability at 400mT at room temperature and 320mT or 340mT at 100°C.

As the Q of capacitors is high, the Q of a resonant circuit, which is the ratio between the center frequency and the spacing between ±3dB points on the resonance curve, is determined by the Q of the inductor.

Inductors used in resonant circuits may be based on closed, air-gapped, or open-circuit cores in various configurations. In all these cases it is assumed that the field strength in the core is so low that hysteresis losses are negligible and only residual and eddy current losses occur in the core (in special cases dimensional resonance losses may exist).

In cores which represent closed magnetic circuits the relationship between the value of Q and the loss factors (residual & eddy current losses) is simple because

$$Q = \frac{1}{\mathrm{Tan}\delta}$$

Provided losses in this winding can be neglected, and this is frequently the case in high permeability closed magnetic circuits,

$$Q = \frac{1}{\mathrm{Tan}\delta} = \frac{1}{\mu_i \times \mathrm{LossFactor}}$$

When the core is gapped, its effective permeability is lower and it may not be possible to neglect the ac resistance of the winding. However, when it is possible to neglect this resistance,

$$Q = \frac{1}{\mu_e \times \mathrm{LossFactor}}$$

Finally, in cores having open-circuit configurations, it is generally not possible to neglect the resistance of the winding and the simple formula is not usable.

Hence in open-circuit cores, the true Q value is directly dependent on the properties of the ferrite material and shape and size of the core and can only be found by measuring the Q value of the combined coil and core (Q_{Total}), removing the core, measuring the Q of the winding at the same frequency (Q_{Wind}) and calculating the ac resistance of the winding. Therefore,

$$R_{Total} = R_{Ferrite} + R_{Wind} = \frac{\omega L}{Q_{Total}}$$

where L is the inductance of the coil with the core.

$$R_{Wind} = \frac{\omega L}{\mu_{Coil} \times Q_{Wind}}$$

as the inductance of the winding without the core is reduced by a factor of μ_{Coil}

$$R_{Ferrite} = \frac{\omega L}{Q_{Total}} - \frac{\omega L}{\mu_{Coil} \times Q_{Wind}} = \omega L \times \frac{\mu_{Coil} \times Q_{Wind} - Q_{Total}}{\mu_{Coil} \times Q_{Wind} \times Q_{Total}}$$

The above derivation is based on the assumption that the presence of the core does not affect the losses in the winding: However this is not strictly true as the flux distribution in the winding is bound to change.

In practical applications the construction of the winding and its conductor are invariant and when Q_{Total} is measured, its variations reflect the variations in the intrinsic properties of the core material. This is also true of the manufacturer's inspection methods for many types of core based on the use of specially made test coils.

For a specific core and winding, the measured value of Q varies with the measuring frequency. When this frequency is low the reactance is also relatively low, whereas the ac resistance of the winding may be appreciable and the Q is low. As the frequency of measurement is increased, the reactance rises much more rapidly than the resistance of the winding and Q rises with the frequency, in spite of the general trend of ferrite losses increasing with frequency. Finally, when the frequency is fairly high and the capacitance required to tune the measured inductance is low, the self-capacitance of the winding begins to affect the measurement and lower the value of Q, due to its very presence and its dielectric losses.

Thus the Q of an inductor is a function of the capacitance used for its tuning, or in other words, there is an optimum value of inductance for any given frequency.

Finally, it must be pointed out that the direct comparison of the values of Q is only possible when all conditions of measurement are strictly invariable.

Losses at Low Magnetizing Fields

For individual grades of ferrite information on losses at low field strengths is given by the loss factors normalized to unit intrinsic permeability. It is understood that the loss coefficients are always proportional to the effective permeability of such cores.

Loss Factor (residual and eddy current)

Residual and eddy current losses are measured together at a flux density of <0.1mT for ring cores, and <1mT for components with a sheared flux path.

$$LF = \frac{R_{(r+e)}}{\omega\ L} \times \frac{1}{\mu_i}$$

$$= \frac{\mathrm{Tan}\delta_{(r+e)}}{\mu_i} = \frac{1}{\mu_i \times Q_{(r+e)}}$$

For a gapped core with an effective permeability μ_e, the residual & eddy current loss coefficient is:

$$\frac{\mathrm{Tan}\,\delta_{(r+e)}}{\mu_i} \times \mu_e,$$

i.e., it is reduced by a factor of μ_e/μ_i. Similarly, the $Q_{(r+e)}$ is increased by a factor of μ_i/μ_e

Hysteresis Loss (Low magnetizing fields)

With hysteresis loss it is necessary to normalize not only with respect to unit intrinsic permeability, but also with respect to unit flux density (or field strength). There are several definitions of such normalized hysteresis coefficients.

I) Hysteresis material constant (η_B)(IEC Publication 125, 128).

$$\eta_B = \frac{\mathrm{Tan}\delta_h}{\mu_i \times \hat{B}}\left(\mathrm{mT} \times 10^{-6}\right)$$

where $\tan\delta_h = R_h/\omega L$ and $\hat{B}$ is the peak flux density.

This definition is quoted in the material data pages where measurement of R_s and L_s are made on an impedance analyzer at two peak flux densities of 1.5 and 3.0mT.

Where a sheared or gapped core is involved, the hysteresis loss is reduced by a factor

$$\frac{\mu_e}{\mu_i} \mathrm{and} \delta_h = \eta_B \times \mu_e \times \hat{B}$$

II) DIN (German Standards Institution specification 41280) specifies the normalized hysteresis coefficient as h/μ_i^2 where,

$$h = \frac{R_h}{f L \Delta H_{rms}}$$

or

$$h = \frac{2\pi \mathrm{Tan}\delta_h}{\Delta H_{rms}}\left(\mathrm{cmA}^{-1} \times 10^{-6}\right)$$

III) Legg (Bell System research worker) specified the normalized hysteresis coefficient as,

$$a = \frac{R_h}{f L \mu_i B_{max}}$$

$$= \frac{2\pi \mathrm{Tan}\delta_h}{\mu_i B_{max}}\left(\mathrm{gauss}^{-1} \times 10^{-6}\right)$$

To convert the IEC coefficient to the Legg coefficient we multiply by $2\pi/10$. The DIN coefficient multiplied by 1.12×10^{-3}

All the above coefficients represent intrinsic properties of the materials as measured on ring cores.

In some instances the term 'hysteresis factor' (F_h) is used to describe the property of a core and is written as follows:

$$F_h = \frac{2\pi \mathrm{Tan}\delta_h}{I_{rms}\sqrt{L}}$$

According to the IEC definition, 'hysteresis core constant,' is defined by:

$$\eta_i = \frac{\mathrm{Tan}\delta_h}{I_{peak}\sqrt{L}}$$

The hysteresis factor (F_h") can be calculated from the DIN intrinsic hysteresis coefficient, h/μ_i^2, as follows:

$$F_h = \frac{h}{\mu_i^2} \cdot \mu_e^2 \left[\frac{n}{\ell_e \sqrt{L}}\right]$$

μ_e is the effective permeability
n is the number of turns
ℓ_e is the magnetic path
L is the inductance in Henrys

When the A_L factor is introduced, the above formula can be rewritten:

$$F_h = \frac{h}{\mu_i^2} \cdot \mu_e^2 \left[\frac{1}{\ell_e \sqrt{A_L}}\right]$$

These expressions are frequently encountered when dealing with gapped cores.

Losses at High Magnetizing Fields of Power Loss Density (P_v)

The previous hysteresis loss factors and coefficients can only be applied when the flux density in the core is relatively low (up to say, 20mT) and where the Rayleigh law is valid. When the flux density is high, as in power applications, the losses are specified as the power loss density (P_v) (i.e., total power losses per unit volume or unit weight of the core) at a given frequency and flux density. In this case, the losses are primarily due to the hysteresis effects, but they are not normally separated into various categories; they are, however, specified at two or more temperatures including the highest expected working temperature. The power loss density may be empirically expressed as a function of frequency and flux density by the relation:

$$P_v = kf^a B^b \quad \text{mW}/\text{cm}^3$$

where constant 'a' has values between 1.3 & 1.6. constant 'b' has values between 2.2 & 2.6, 'k' is a constant dependent upon temperature.

Power losses are expressed in the material data pages for power ferrites as the power loss density in mW/cm^3.

Frequency Range

The range of frequencies in which a particular grade of ferrite material may be usefully applied depends upon the specific conditions of the application and on the configuration of the core itself.

Sometimes the limits of the range are arbitrarily defined as those frequencies at which the value of Q of inductors wound on toroidal rings drops to 50 or, in other cases, to 20. Yet another definition of the upper limit of the range is based on the rapid rise of loss factor at and above a certain frequency, this point being easily measured for any given core; however, it should be borne in mind that this frequency will vary appreciably from batch to batch and it seems inadvisable to base any expectation of performance on its constancy.

If the core is to be used for a transformer, the circumstances are different. It is not only the loss in the core and winding that is significant but the relationship between the shunt reactance of the transformer winding and the impedance of the source or load circuit is also of fundamental importance. There is also the leakage inductance which largely determines the losses in the transformer at the high-frequency end of its working range. An ideal transformer would have an infinitely high parallel (shunt) inductance, such that its low-frequency response is perfect, and an infinitely low series (leakage) inductance, so that its high-frequency limit is not curtailed. High permeability grades of ferrite are therefore most suitable for transformer applications, because high shunt inductances with a small number of turns giving rise to low leakage inductances can be obtained. In fact, there is no reason to abstain from using a ferrite which has extremely high losses at the high frequency end of the working range of the transformer because the shunt resistance will be so high that these losses will be inconsequential.

The general rule in all applications is to use the grade of ferrite with the highest permeability and with losses not exceeding the level which can be tolerated.

It must be clearly stated that manufacturers test their products at frequencies specified in their tabulated publications and the behavior of ferrite material outside these frequencies cannot be guaranteed.

If a certain level of losses (or Q) is expected at a certain frequency, it is necessary to select the grade which is tested close to or above the frequency in question and not to rely on the results of measurements carried out on samples.

STABILITY

Temperature Factor and Temperature Coefficient

Temperature coefficient is the proportional inductance rise per °C.

$$T_c = \frac{\Delta L}{L\Delta T} = \frac{\Delta\mu}{\mu\Delta T}$$

Where ΔT is the temperature rise (°C) causing the change A_L in inductance (or $\Delta\mu$ permeability).

The material data pages specify temperature coefficients normalized per unit intrinsic permeability. This value is termed Temperature Factor and is expressed in PPM/°C and given for a specified range of temperature (25 °C to 55°C).

$$TF = \frac{\Delta\mu}{\mu_i^{\,2} \times \Delta T}$$

I.e., for a ring core, Temperature Coefficient = T.F. x μ_i

In the case of cores with a closed magnetic path but containing a gap the μ_e is used.

Temperature Coefficient = T.F. x μ_e

I.e., T.C. reduced by μ_e/μ_i.

In the case of open-circuit core configurations, it is not possible to calculate the temperature coefficient of inductors using such cores, simply by multiplying the temperature factor by the rod or coil permeability. The actual value can only be ascertained by the direct measurement in each specific case. The temperature coefficient of cores used at high flux density is rarely of interest as the coils wound on them are generally not tuned. The main temperature effect in such cores is the change in saturation induction.

Curie Temperature, (T_c)

The Curie temperature is that temperature above which the disruption of magnetic ordering in the crystal lattice by increasing thermal motion causes the material to lose its ferromagnetic character, and the permeability falls to near unity.

Curie temperature is defined in the material data pages at that temperature where the intrinsic permeability has fallen to 10% of its room temperature value.

Disaccommodation Factor

After a ferrite core has been subjected to a shock (thermal, mechanical, or magnetic) its permeability abruptly increases and immediately begins drifting downwards, continuing to do so for a very long period. This form of instability is termed disaccommodation.

The Disaccommodation Factor itself varies with temperature.

The decrease in permeability is linear when plotted against a logarithmic scale; that is, we can write:

$$D = \frac{\mu_2 - \mu_1}{\mu_1 \mathrm{Log}_{10} \frac{t_2}{t_1}}$$

where μ_1 is the permeability (intrinsic if measured on a toroid which is the usual practice) at the time t_1, and μ_2 is the permeability at the time t_2. This law has been derived empirically and is valid throughout all time except for the initial brief period following the shock. This means that the relative inductance drop in the period 1 to 10 hours after the shock is the same as in the period 1 to 10 years, so that the long-term instability of the inductance can be predicted from measurements over a relatively short interval of time

This instability of permeability is given in the material data pages for grades P10, P11 and P12, normalized to unit permeability and is termed Disaccommodation Factor. In measurement, t_1 and t_2 are selected as 10 min and 100 min, such that the term $\mathrm{Log}_{10}(t_2/t_1)$ becomes equal to 1.

$$DF = \frac{\mu_2 - \mu_1}{{\mu_2}^2} \text{ (expressed in PPM)}$$

In the case of a core with a closed magnetic path, but containing a gap the μ_e is used.

I.e., Disaccommodation = D.F. x μ_e
I.e., the coefficient is reduced by a factor μ_e/μ_i

The relationship in the case of open circuit cores is not so simple and it is generally not possible to predict the actual value of their disaccommodation coefficients.

Specified disaccommodation measurements in the data pages are carried out at 50°C to prevent the disturbing influence of the temperature coefficient.

Magnetostriction

An external magnetic field applied to a ferrite causes a change in mechanical dimensions known as magnetostriction. Conversely, mechanical deformation of a ferrite core changes its electrical properties. Encapsulation often results in this form of instability. Shrinkage can occur during curing of the encapsulated ferrite; this shrinkage can exert significant stress on the core. Another type of stress can occur due to temperature changes on the finished product. A mismatch of coefficients of linear expansion between the encapsulant and the ferrite can result in very high stresses in the core (see coefficient of linear expansion).

A ferromagnetic material consists of spontaneously created elementary units (magnets) called domains, which have finite dimensions; the polarity changes gradually from one domain to another neighboring one, over a finite thickness of so called domain (or block) walls. When a magnetic field is applied to a ferrite body the tendency to align its structure must lead to some changes in the direction pole axes of domains and/or virtual movement in the domain walls. Such changes must involve a degree of mobility within the material. It stands to reason that mechanical stressing of the material will affect this mobility.

Resistivity

Ferrites are semiconducting materials and their resistivity depends upon their composition, that is, it varies with the grade of ferrite .

For nickel-zinc ferrites, the resistivity is of the order of 10^5 to 10^7 ohm-cm. For manganese-zinc ferrites, it is appreciably lower, 10^1 to 10^3 ohm-cm, but nevertheless remaining very much higher than the resistivity of metals and metallic alloys.

Dielectric Constant

Manganese-zinc ferrites have high values of dielectric constant which in some cases may approach 10^6 at a frequency of 1 kHz. The value of the dielectric constant drops with the frequency, not very rapidly at first, but then more and more steeply until at very high frequencies it approaches a value of 10.

Combined with the high permeability, the very high dielectric constant causes the wavelength in the material to be reduced to such an extent that it may become comparable to the physical dimensions of the core and cause dimensional resonance and associated losses.

Because of the high value of the dielectric constant, the ferrite cores, especially manganese-zinc cores, should never be wound directly but should incorporate an insulating layer separating the wire from the core, to avoid losses from the increased self-capacitance which would result.

Physical Parameters

Exact values of the physical parameters of ferrites depend upon the composition and manufacturing conditions, especially the sintering temperature, and the values given below should be taken as indicating order of magnitude only. If precise values are required, they should be measured on the cores in question.

Tensile Strength	20 N/mm^2
Compressive Strength	100 N/mm^2
Hardness	10000 N/mm^2 (Vickers HV_{15})
Linear Expansion Coefficient	10 x 10^{-6}/°C (Room Temperature)
Youngs Modulus	1.5 x 10^5 N/mm^2
Thermal Conductivity	4 x 10^{-3} J/mm sec °C
Density	4 to 5 g/cm^3

The low coefficient of expansion may become the reason for very high stresses generated in ferrite cores encapsulated in epoxy resins or surrounded with plastic parts molded directed upon them.

Such stresses, if they occur, are usually detrimental to the magnetic characteristics of the cores. (See "Results of Mechanical Stressing")

Perminvar Ferrites

Perminvar ferrites are essentially nickel-zinc ferrites having the following manufacturing characteristics :

(a) Cobalt is added in small amounts.

(b) The basic composition contains an excess of Fe_2O_3. I.e. they are over-stoichiometric.

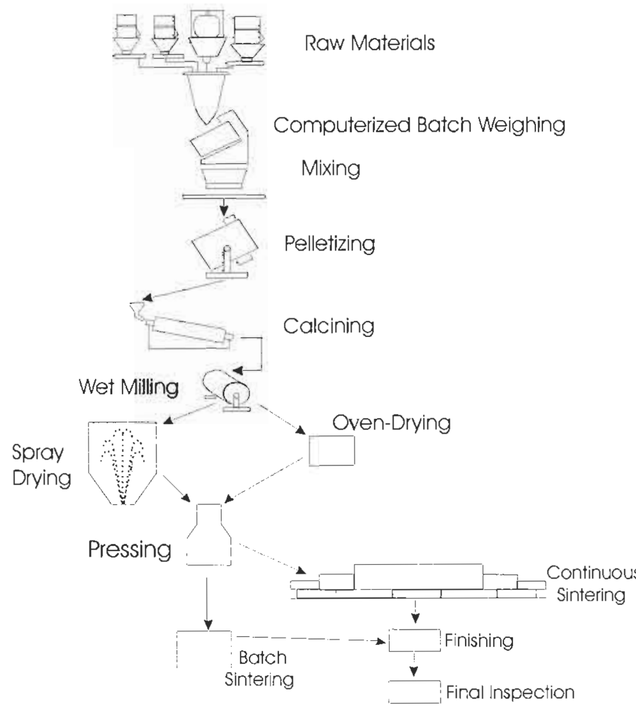
(c) Annealing is essential to obtain the specified electrical properties.

Magnetically perminvar ferrites are characterized by very low losses at relatively high frequencies, and they can be used to obtain high values of Q at the high frequency end of the spectrum of application. When perminvar ferrites are compared with non-perminvar nickel-zinc ferrites of similar permeability it becomes apparent that a higher value of Q is obtainable for the same permeability. The very low losses of perminvar ferrites are due to the fact that cobalt ferrite has an anisotropy constant of opposite sign to nickel and zinc ferrites and of much greater magnitude. There is therefore a possibility of mutual cancellation and the resultant anisotropy; energy can be greatly reduced by a small addition of cobalt.

The significance of anisotropy is that it gives a preferred crystallographic orientation which impedes the rotation of domains in certain directions and results in energy being spent on making the magnetic orientation follow the direction of the applied field. If the anisotropy can be reduced, less energy needs to be spent during each cycle and the losses are consequently lower.

In extremely weak fields, the magnetization of ferrite is carried out by the domains which are favored directionally, i.e., that they are in full or partial alignment with the field vector. These domains expand at the expense of their less-favored neighbors which results in movement of the domain walls and expenditure of energy to make them move.

In perminvar ferrite, individual domains can be imagined as being surrounded by low-energy trenches in which domain walls can move very easily with minimum expenditure of energy; however, when the field becomes too strong, the walls are ejected from the trenches and the perminvar structure is destroyed.



The structure of a perminvar ferrite consists of the usual spinel lattice with cobalt ions in some of the unoccupied octahedral sites to form an orderly independent sub-lattice. The ions of cobalt are brought into these sites by the internal forces of the main lattice very slowly and gradually and there is no known way of accelerating this process of migration except by elevated temperatures. This leads to the requirement for annealing. When ferrite is heated beyond its Curie point, the whole magnetic structure is disorganized and when the temperature drops below the Curie point, the magnetic structure is reformed and its internal forces begin to move the cobalt ions to their ultimate sites in a regular pattern, i.e., cobalt sub-lattice. This must happen because it corresponds to the least-energy state of ferrite and all matter tends towards this state of minimum energy. As the temperature is below the Curie point and relatively low, the mobility of ions is also low and the process of migration requires a long time.

To facilitate the migration of cobalt ions to their ultimate stations, the ferrite must have a large number of empty sites (vacancies) thus enabling cobalt ions to jump from stage to stage towards their goal. Empty sites exist if the oxygen content in the sintering atmosphere is high, i.e., firing of perminvar ferrites must be in air. This also leads to a relatively small number of divalent ions in the ferrite resulting in high resistivity. As the properties of perminvar ferrites depend upon the existence of their regular structure, anything which can possibly disturb this structure is disruptive to the electrical properties.

An adverse influence may be exerted by the application of a strong magnetic field (proximity of permanent magnets or excessive current through the winding), heating without slow cooling or a strong mechanical pressure which causes dislocations of the crystalline structure (grinding is one example of such a pressure and ultrasonic cleaning may be another). Under such influences the permeability increases and Q is lowered, especially at the higher frequencies, although the changes in Q at the lower frequencies may be very small.

Manufacturing Considerations

General Manufacturing Process

We consider the manufacture of ferrites to be a science involving the complex technologies of chemical molecular composition and crystallography. Commercially used ferrites suitable for application in inductors, transformers, tuned circuits, etc. fall into two classes: manganese-zinc ferrites and nickel-zinc ferrites. Both are ceramic materials made of metal oxides.

Pure metallic oxides and organic binders are precisely measured, mixed, and batched.

The mixture is Pelletized.

The mix of oxides are pre-fired at temperatures on the order of 1000°C in a process known as Calcining. The ferrite structure during this process is partially formed at this stage, however, the reaction is not complete.

The resultant formulation is intimately mixed with the addition of organic binders and its particles are reduced to submicron size during wet-milling creating a slurry.

The slurry is sampled, dried, and tested for the desired chemical and electrical properties and can be adjusted to meet specific requirements and receive batch qualification. The slurry is dried by continuous extraction of moisture by spray drying or by batch drying in a drying oven creating a powder suitable for automatic presses or into a form to facilitate extrusion or injection molding.

The powder is then molded to a desired shape or configuration by compacting in specialized powder metallurgy presses under high pressure. Pressing or extrusion results in shapes similar to those finally required but dimensions at this stage are significantly larger.

The compacted configuration is then heated to a high temperature on the order of 1200 °C –1350°C (often in a controlled atmosphere) causing densification and substantial shrinkage of all dimensions. This process completes the desired chemical reaction creating a specific chemical substance (the ferrite) having a definite crystal structure and unique magnetic characteristics.

Any required finishing is completed and the parts are ready for all the various electrical applications.

Chemical Composition

Most soft ferrites having practical application (with the exception of microwave ferrites) have a spinel lattice crystalline structure.

These have the molecular formula (where Me is a divalent metal)

$(MeO).\ Fe_2O_3$

The composition of various grades of ferrite varies with the properties required but generally speaking about 50% (molecular) of the material is Fe_2O_3 and the other 50% is divided between NiO and ZnO, or MnO and ZnO. Other components may be introduced in fairly small amounts when it is found that they are beneficial to certain properties that may be required.

Physical Shrinkage

The shrinkage that occurs during sintering of a ferrite core is a function of many manufacturing parameters and it is not possible to avoid its variations even within a single production batch, let alone from batch to batch.

The dimensional tolerances, therefore, as 'as-sintered' bodies are fairly large. If this is not acceptable for the ferrite component concerned, the only way to obtain finer tolerances is by grinding, since ferrite is too hard for other finishing processes. It is advisable to make due allowance in the design of components with ferrite cores to have maximum possible dimensional tolerances, thus keeping finishing and grinding costs to a minimum.

Achievable tolerances will depend on the shape and size of the components and on the material type. As a general guide for new designs the following dimensional tolerances are preferred.

Pressed Parts:
Between pressed faces: ± 2%+.005"
Between pressed-ground faces ±.002"

An MMG Sales department representative should be contacted in the early stages of design if closer tolerances than those shown above are required.

Distinctive Properties of MnZn and NiZn Ferrites

Although there is an overlap of properties between the manganese-zinc and nickel-zinc classes of ferrite, some general distinctive features are apparent.

The manganese-zinc ferrites are characterized by rather high intrinsic permeability and losses that rise rapidly at relatively low frequencies. Their resistivity is low although much greater than in metals and metal alloys. The Curie point is also low, generally decreasing as permeability increases. Manganese-zinc ferrites are mainly used for low-frequency applications, although there are some exceptions to this rule.

Nickel-zinc ferrites are of lower permeability, but their losses at higher frequencies are lower which make them more usable at frequencies up to, say, 200–250 MHz when maintaining low losses is vital. Their resistivity is higher by several orders of magnitude, and the Curie point is also higher.

Both classes of ferrite are subdivided into several grades having different compositions. The ratio of manganese to zinc or nickel to zinc constituents to a large extent determines the grade of ferrite. Other differences include small changes in the minor constituents and in the manufacturing techniques, particularly sintering. The grades of ferrite are usually classified in accordance with their intrinsic permeability but, obviously, other parameters will also differ. It should be pointed out in this context that because of the complexity of the manufacturing process, even with a single batch of ferrite cores a spread of properties such as permeability and losses will be encountered. The inevitable variation in dimensions has already been mentioned.

Under production conditions and with inspection methods adapted to the shape and expected application of the ferrite cores, it is not always possible to ensure that the intrinsic (or amplitude) permeability of a specific core is exactly the same as that of specially made toroids used for batch process control of ferrite powders from which such cores are made. The differences in some instances can be considerable, particularly if the cores are small, because the sintering conditions of a small body are different from those of a large body with a greater thermal capacity or, in the case of extruded cores, different powder preparations are employed for different shapes or, in the general case, when the cores are not expected to be wound toroidally.

Screw cores, for example, with through holes are not intended to be wound as toroids and are measured for coil permeability in standard coils.

Electrical Test Drive Level Considerations

A basic parameter specified for most ferrite and powdered iron cores is inductance factor A_L defined as inductance per turn squared. The units are nanohenries per turn squared (nH/N^2). A_L is usually specified for low flux density conditions and is consequently proportional to initial permeability. The inductance of a wound core may be predicted by multiplying A_L by the turns squared as long as the ac flux density does not increase beyond initial conditions, permeability and A_L increase until a peak is reached. This peak is referred to as the maximum permeability. Further increasing ac flux density results in a decrease in permeability and A_L. Another consideration is the material under test. For Perminvar ferrite a high drive level can change the electrical characteristics of the device under test permanently. A general rule of thumb for preventing such an occurrence is to keep the drive level below 20mT if possible and absolutely below 50mT.

Following is a list of MMG-North America materials with appropriate frequencies and drive level voltages equivalent to about 10 gauss magnetic flux density.

"N" denotes the number of turns wound on the core, and **"A"** is the cross-sectional area in square centimeters. Values of effective cross-sectional area for toroidal cores are listed in the catalog.

MATERIAL	FREQUENCY	VOLTAGE
F31, F21, F01,	1 MHz	0.4 NA
FT6, FT7, FTA	40 kHz	0.01 NA
All Other Materials	100 kHz	0.04 NA

The inductance factor of ferrite and powdered iron cores is usually constant over a wide frequency range. As the frequency is increased, a point is reached where the initial permeability starts to decrease and material losses begin to increase substantially. This is illustrated for each ferrite in the materials section in graphs of permeability versus frequency. If one is designing a high Q inductor, this point may be the maximum usable frequency; however, in other applications, such as broad band transformers, RF chokes, and attenuator beads, operation far beyond the high frequency limits is common. For attenuator beads, it is, in fact, where the bead becomes effective.

Application Notes

Cores for High Frequency Broad Band Transformers

MMG-North America supplies a variety of ferrite toroids, beads, and binocular shapes for use as broad band transformer cores for the Communication and Consumer Products industries. These transformers typically cover two decades in the MHz to GHz frequency spectrum.

When choosing a material, refer to the individual graphs of impedance and inductance vs. frequency. It is necessary to have a large impedance at the low end of the operating frequency. This is to supply sufficient winding shunt impedance while keeping the turns as low as possible. Fewer turns result in lower winding capacitance and raise the useful frequency limit of the transformer. The designer must consider that this shunt impedance is a complex function composed of resistance and inductive reactance in parallel. Through most of the high frequency operating range being discussed, the material Q is low and the two components are approximately equal.

The core must also supply the magnetic coupling between the windings at the low frequency end of the spectrum. The material chosen would therefore require as high a permeability as possible at that frequency.

Small beads and binocular cores are very efficient shapes for high frequency broad band transformers. The holes are kept as small as practical to increase the impedance. The actual dimensions are determined by the high frequency requirements for coupling between the windings. The permeability of the core is usually close to 1 (unity) at this point so that interwinding capacitance must supply most of the coupling.

Using Ferrite in Computer LAN Applications

Medium and high permeability ferrite toroids are commonly used in computer Local Area Network (LAN) systems. They function as the cores for pulse transformers located at each end of the communication lines between the computers. The transmission lines can be standard telephone twisted pairs or, in some systems, coaxial cables. The main function of the pulse transformers is to provide isolation, both dc and low frequency ac, between the computers. Another function can be impedance matching.

Basic Requirements for the Transformers

The LAN transformer is a pulse transformer and, as such, is essentially a broad band RF transformer. Digital pulses contain a wide spectrum of frequencies and the transformer must be able to pass all these frequencies with little attenuation in order to maintain the fidelity of the pulse. At the low end of the passband, the primary inductance is the main consideration. It must be high enough so it's impedance doesn't "load down" the low frequencies. At the high frequency end of the passband, leakage inductance and interwinding capacitance become important. Keeping turns to a minimum will generally maximize high frequency performance.

Core Material Considerations

Soft ferrite materials in the 5,000 to 10,000 permeability range are used extensively in pulse transformers for LAN applications. The high permeability provides the required low frequency inductance with a relatively few number of turns. As stated above, keeping turns to a minimum extends the high frequency end of the bandpass of the transformer. As permeability is increased, the required number of turns is reduced. Although a 10,000 permeability core will allow the lowest number of turns, it is more sensitive to encapsulation pressure and variation in ambient temperature.

100BaseTx LAN Systems

In recent years, the operating speed of common PC based LAN systems has been increased from 10 MBPS (megabits per second) (10BaseT) to the new 100BaseTx standard, operating at 100 MBPS. The pulse coding in 100BaseTx systems is such that a digital pulse train can occur which will not allow the pulse transformers in the system to recover fully between pulses. If the core material does not have sufficient unipolar delta B capability, that is, sufficient difference in flux density level between remanence and saturation, it will saturate in the non-recovery situation. The advent of 100BaseTx necessitated a new class of material to handle the non-recovery situation without saturation. MMG's designation for this new material is F65.

Common Mode Chokes in LAN Systems

Some LAN system designs utilize a broad band common mode RF choke at the input and output of the transformer module. The chokes reduce the passage of spurious common mode noise. The chokes must exhibit a relatively high impedance over the frequency range 100 kHz to 100 MHz. Typically, these chokes are constructed on a small ferrite toroid in nickel-zinc (NiZn) material. MMG F52 and F53 materials are widely used for this purpose.

High Frequency Broad Band Transformers

MMG-North America supplies a variety of ferrite toroids, beads, and binocular shapes for use as broad band transformer cores for the Communication and Consumer Products industries. These transformers typically cover two decades in the MHz to GHz frequency spectrum.

When choosing a material, refer to the individual graphs of impedance and inductance vs. frequency. It is necessary to have a large impedance at the low end of the operating frequency. This is to supply sufficient winding shunt impedance while keeping the turns as low as possible. Fewer turns result in lower winding capacitance and raise the useful frequency limit of the transformer. The designer must consider that this shunt impedance is a complex function composed of resistance and inductive reactance in parallel. Through most of the high frequency operating range being discussed, the material Q is low and the two components are approximately equal.

The core must also supply the magnetic coupling between the windings at the low frequency end of the spectrum. The material chosen would therefore require as high a permeability as possible at that frequency.

Small beads and binocular cores are very efficient shapes for high frequency broad band transformers. The holes are

kept as small as practical to increase the impedance. The actual dimensions are determined by the high frequency requirements for coupling between the windings. The permeability of the core is usually close to 1 (unity) at this point so that interwinding capacitance must supply most of the coupling.

Suppressing EMI / RFI with Ferrites

The proliferation of electronic devices has resulted in serious electromagnetic interference (EMI) with radio and data communications. Government agencies world wide have introduced regulations limiting radio frequency interference (RFI) that can be generated by electrical equipment. Ferrites, because of their unique magnetic characteristics have been extensively used to suppress unwanted signals in electronic circuits. MMG-North America manufactures cores which limit conduction of these signals. This signal suppression capability is also useful for decoupling in high frequency circuits, and preventing parasitics in fast switching devices.

The most economical and universally applied EMI attenuators are ferrite shield beads. These are usually small ferrite cylinders which are simply slipped over component leads or circuit wiring. The beads introduce a small inductance to low frequency current, but as frequency is increased a sharp reduction in magnetic permeability occurs. Simultaneously, the magnetic losses increase so that the unit now behaves like a resistor in the circuit. Effectively, the device is converting the high frequency signal energy to heat through magnetic losses, while at dc and low frequency there is little or no effect.

MMG-North America manufactures beads in principally two materials: F82 for applications up to 30 MHz, and F52 for over 30 MHz. Other materials can be supplied for special requirements. Graphs are included in this catalog which show variation of normalized impedance vs. frequency. Impedances for specific sizes of cores can be calculated from the graphs using the formula. For Z given in ohms

$$Z = \log_{10}\left(\frac{OD}{ID}\right) \times \text{length} \times N^2$$

where N is the number of turns.

High permeability MnZn ferrites such as F82 do not follow this relationship at frequencies much over 5 MHz. The high values of permittivity and permeability result in dimensional resonances above low MHz frequencies depending on the size of the bead.

Graphs also show the reduction in bead impedance caused by a superimposed dc current as it drives the bead to saturation. The effect decreases at higher frequencies as inductance is the smaller part of the total impedance. Larger ac currents would also require similar derating for the peak current values.

Beads are available in several component styles ready for automatic insertion. They can be packaged on standard reel tapes in bead on lead or surface mountable configuration.

There are several means to increase insertion impedance if single beads are not sufficient. The most obvious is to insert multiple beads in series, resulting in an increase proportional to the number of beads. Cores of different materials can also be mounted on the same leads to broaden the effective frequency spectrum. Still larger impedances are obtained by using multi-hole cores with a single lead looped through each hole (see the multi-aperture core and the 6-hole bead sections). MMG-North America manufactures 2-, 4-, and 6-hole cores. The latter is the most popular unit, and is usually supplied as a wound choke with either 1½ or 2½ turns.

Further increases in attenuation can be made by connecting a small capacitor across the load, between the ferrite choke and the load. This will also introduce resonant peaks in the value of impedance at certain frequencies, depending on the reactances inserted.

Attenuation of the signal or Insertion Loss (I.L) introduced in a circuit by a bead is measured by reading the voltage across the load with and without the bead inserted between the source (generator) and load.

Insertion loss (I.L.) = $20 \log_{10} (E_0/E_B)$ (dB)

where E_0 = voltage without bead inserted
E_B = voltage with bead inserted.

By substituting current and impedances for voltage and using voltage division the equation becomes:

I.L. = $20 \log_{10} \{ (Z_g + Z_L + Z_b / (Z_g + Z_L)$ (dB)

where the impedance designations are for

generator (g), load (L), and bead (b).

RFI is often generated on a pair of leads by electromagnetic or electrostatic coupling, appearing as a common mode signal. E.M. fields generated by contiguous pairs carrying normal mode signals tend to cancel, greatly reducing radiation. However, pairs carrying common mode EMI running in interconnecting cables or power leads will behave like efficient antennae for the interference signal.

MMG-North America manufactures large beads which may be mounted over cables near their terminals to attenuate common mode spurious signals. Toroids are also employed, usually with multiple turns, to increase the insertion impedance. High signal currents in the leads are not an irritation as the magnetic fields in normal mode cancel if the pairs are wound bifilar. When line current is high as in power cords, high permeability toroids are required to increase the coupling between the leads for effective cancellation of the power fields.

Thermal Ferrites

Thermal ferrites are materials that permit designers to specify the temperature at which the core loses its permeability. This characteristic allows the design of high reliability, low cost sensors, switches, fuses, and circuits, that must be temperature controlled. Typical applications include use in reed switch magnetic circuits. The sharp loss of permeability at the ferrite's curie point allows precision temperature controls to be designed. We now offer our FCT line of thermal ferrites. Switching temperatures from –10 to +400 °C are available. Please consult the MMG-North America Sales department for help with your particular application.

Custom Components

MMG-North America's nonstandard capabilities encompass many of the industry's soft ferrite requirements.

Utilization of the continuously variable length dimension of our extensive tooling inventory and the full range of experience and expertise of our tool designers and tool making staff permits us to produce shapes to a customer's design requirements.

Our ceramic engineering department's materials development team strives to remain on the cutting edge of this technology and has been called upon frequently to customize ferrite bodies for unique applications.

Your particular needs can and will be met in the most cost-effective way to help maximize your profits either by use of a catalog item or through design from "the floor up" of a totally new custom component.

If you don't see what you need listed in the following pages, a telephone call to our product development group will focus our 30 years of expertise on your immediate and future requirements.

We at MMG-North America are an eager and knowledgeable team, dedicated to meeting your needs. Be assured that we will work diligently to develop a close working relationship that will result in profitable growth for both of us.

Quality Assurance

Quality is defined at our facility as servicing the customer's needs with products that meet or exceed requirements in a timely and cost-effective manner. We have achieved ISO-9002 certification through coordinated team efforts between all departments. The philosophy of teamwork is deeply ingrained into our culture and facilitates attainment of company goals.

In order to manufacture and deliver a quality product, the entire build process must be controlled. We strive to determine and monitor the capability of each process in accordance with standard SPC practices. Areas for control include raw powder materials, powder preparation, key characteristics of finished powder, pressing, sintering and finishing (as required). Parts are inspected on a sample basis per established industry standards, such as MIL-STD-105E or C = 0.

Depending on the part configurations, various mechanical and electrical characteristics may be verified. State-of-the-art electrical analyzers, bridges and precision mechanical hand tools are utilized by trained personnel to assure accurate data. Hewlett-Packard 4291A RF impedance/material analyzers provide inductance, impedance and capacitance data as required. Arithmetic functions built into the equipment allow for direct reading of values after initial setup. Measurements for capacitance testing of coilforms is accomplished with GenRad 1687 and 1689 precision RLC bridges. Utilizing in-house software, the bridge output is monitored and statistically compiled in order to assess the material under test. Inductance testing and sorting utilizes HP 4284A precision LCR meters. This equipment, utilizing in-house programming and fixturing, allows for accurate sort/test of inductance values. HP 4342A Q-meters provide Q values for coilforms. Values are obtained by fine tuning the frequency required to "peak" the Q meter. Quad-Tech 1870 ac/dc dielectric analyzers help perform traditional hi-pot testing and dc current resistance testing. This determination of voltage required to break down the insulation resistance allows us to verify the integrity of applied Parylene or epoxy coatings. Additionally, Quad-Tech 1633A incremental inductance bridges assist testing of our dc bias material. In this application the bridge measures Rs and Ls. Bridge frequency and alternating voltage are set and dc bias varied for the test conditions. The bridge will read the inductance with or without a superimposed direct current. Proper calibration status is maintained on mechanical and electrical equipment, traceable to NIST standards.

We continuously examine our facility for potential improvements. Vendor communications and customer support are an integral part of our business. It is through actions like these in an atmosphere of Total Quality Management that we plan to service our customers in the increasingly competitive global marketplace.

MMG Test Equipment

In order to provide our customers with consistent and high quality products MMG has instituted a regular calibration program which conforms to ISO 9002 standards.

Powder Lab
Computac Moisture Analyzer
10 mg resolution digital scale
battery of Tyler screens (35 to 325 mesh)
Stereo Microscope

Press Tool Crib
Hardness Tester
1 to 1000 micro-inch Surf indicator
Microscope
Bore Gauges
0.1 mg resolution digital scale
0.0001" resolution micrometers
0.0001" Digimatic Depth Gauges
0.001" Dial Calipers
0.001" Increment Pin Gauges

Production Departments
0.0001" resolution micrometers
0.0001" Digimatic Depth Gauges
0.0002" resolution profile projector
0.001" Dial Calipers
0.001" Increment Pin Gauges
Stereo Microscopes

Final Inspection
0.0001" resolution micrometers
0.0001" Digimatic Depth Gauges
7x to 30x Stereo Zoom Microscope
0.0001" resolution profile projector
HP 4275A LCR Meter
HP 4284A LCR Meter
GR1689 LCR Meter
GR1687 1MHz LCR Meter
GR1633 Incremental Inductance Test Set
Chatillon DFI-50 Force Gauge
–55 to +170 deg. C Temperature Chamber
0.0005" Digital Calipers
0.001" Increment Pin Gauges
0.0002" resolution toolmaker's microscope
Transformer turns ratiometer
HP 4191A Impedance Analyzer
HP 4332A LCR Meter
HP 4342A Q-Meter
HP 4815A Vector Impedance Meter
Quadtech 1870 Dielectric Analyzer
Wayne Kerr 4210S LCR Meter
Fluke 52 Digital Thermometer

Engineering Lab
HP 4291A Impedance Analyzer
HP 4753A Network Analyzer
HP 54501A Digital Oscilloscope
HP 8111A Signal Generator
Clarke Hess 258 VAW Meter
ENI 1500 Wide Band Amplifier
HP 4332A LCR Meter
–55 to +170 deg. C Temperature Chamber
Fluke 52 Digital Thermometer

MMG's Standard Quality Controls

All batches of material receive a full battery of intrinsic and extrinsic evaluations before being released for production.

X-ray Fluorescence Chemical Composition Analysis
Particle Size Distribution Characterization
Angle of Repose
Bulk Density
Mass Density
Specific Gravity
Permeability
Sintering Shrink Characterization
Loss Factor
Temperature Response

First Article Inspection is performed when a job is released to the Press Department. Samples from the first pressing are run through subsequent processes to evaluate adequacy of the pressing and sintering effects. New batches and jobs go through a Pilot evaluation.

In-process inspections are performed in the Press, Tumbling, Grinding, Parylene and Sorting Departments. Standard final inspection methods for closed magnetic structures are:

one-turn computer aided inductance test to Level I - 0.65% AQL
10-turn wound correlation for inductance, Q and/or impedance of stratified samples from the one-turn inductance test
Dimensional inspection to Level S3 - 1% AQL
Visual inspection to Level I - 0.65% AQL

Capabilities

At MMG-North America, our attention to detail and knowledgeable staff can meet your specific requirements, if not with our vast array of standard parts then with custom components. MMG is capable of providing custom manufacturing, finishing and packaging.

We utilize state-of-the-art batch and tunnel kilns in the manufacture of our ferrite parts. Our tunnel kilns provide the high degree of consistency of continuous firing, while the batch kilns provide the flexibility associated with periodic kilns. These two sintering methods allow us to provide you with specifically optimized firings to meet your special design requirements.

Our in-house grinding and machining operations allow us to provide high quality, very tight mechanical tolerenced parts. We can also provide tumbled parts which are free of all sharp edges.

We have in-house coating capabilities which we utilize to increase the high potential breakdown voltage of low resistivity parts and ease some of the problems associated with wire scrappage during winding operations.

Our color coating coding capabilities assist many of our customers with part or vendor identification.

MMG-North America's Shipping department can accommodate various shipping requirements. We can vacuum seal parts in required bag quantities. We can also provide shipping labels with required bar coding information.

MMG-North America Materials

Manganese-Zinc Ferrites for Industrial and Professional Applications

Applications Guide				Power / Switching Transformers, Differential Mode Chokes, Output Chokes			Wideband Transformers, Pulse Transformers, Common Mode Chokes, Current Sensing Devices, RFI Suppression						
Parameter	Symbol	Standard Test Conditions	Unit	F58	FB2	FB3	F9Q	F9N	F65*	F82	FT6	FT7	FTA
Initial Permeability (nominal)	μ_i	B<0. 1 mT 10 kHz 25°C	-	750 ±20%	2000 ±20%	2700 ±20%	2300 ±20%	4000 ±20%	4500 ±40%	5000 ±20%	6000 ±20%	7500 ±25%	10000 ±30%
Saturation Flux Density (typical)	Bsat	H=796 A/m 10 Oe 25°C	mT	>420	480	480	350*	410	350	460	430†	420	420
Remanent Flux Density (typical)	Br	H→0(from near saturation) 10 kHz 25°C	mT	-	140	140	190	270	100	170	150	130	180
Coercivity (typical)	Hc	B→0(from near saturation) 10 kHz 25°C	A/m	-	10	10	24	15	14	13	15	10	8
Loss Factor (maximum)	Tan ÷÷÷c÷ / ÷i	B<0.1mT 25°C	10^{-6}										
		10 kHz		-	30	15	-	-	-	-	-	6	6
		100 kHz		-	-	-	20	30	20	20	25	50	50
		200 kHz		-	-	-	-	-	-	-	-	-	-
		1 MHz		-	-	-	-	-	-	-	-	-	-
Temperature Factor	÷ ÷ / ÷i² ÷ ÷T	B<0.1mT 10kHz +25°C to +55°C	10^{-6}/°C	-	-	-	-	-	-	-1 to +2	-	-	-1 to 0
		B<0.1mT 10kHz 0°C to +25°C		-	-	-	-	-	-	-	-	-	-0.5 to +0.5
Curie Temperature (minimum)	T_c	B<0.1mT 10kHz	°C	310	230	230	140	140	>150	160	140	150	150
Resistivity (typical)	ρ	1V/cm 25°C	Ω-cm	100	100	100	20	20	20	50	20	10	10
Amplitude Permeability (minimum)	μ_a	400mT 25°C	μ_a	-	2500	2500							
		320mT 100°C		-	-	-							
		340mT 100°C		-	1900	1900							
Total Power Loss Density (maximum)	P_v	200mT; 16kHz 25°C	mW/cc	-	-	-							
		200mT; 16kHz 60°C		-	-	-							
		200mT; 16kHz 100°C		-	-	-							
		200mT; 25kHz 25°C		-	200	200							
		200mT; 25kHz 60°C		-	-	-							
		200mT; 25kHz 100°C		-	130	130							
		100mT; 100kHz 25°C		-	250	250							
		100mT; 100kHz 100°C		-	160	160							
		200mT; 100kHz 100°C		-	750	750							
		50mT; 400kHz 25°C		-	-	-							
		50mT; 400kHz 100°C		-	-	-							

*B_{sat} measured at H=400 A/m
†B_{sat} measured at H=200A/m
*F65 Material is a specialized material developed specifically for 100 base Tx LAN applications.
Data is derived from measurements on toroidal cores. These values cannot be directly transferred to products of another shape and size. The product-related data can be taken only from the relevant product specifications.

MMG-North America Materials

Nickel-Zinc Ferrites for Industrial and Professional Applications

Applications Guide				Short and medium wave antennae, EMI suppression, High frequency inductors and transformers								
Parameter	Symbol	Standard Test Conditions	Unit	FF1	F53	F52	FA1	F24	F14	F01[P]	F21[P]	F31[P]
Initial Permeability (nominal)	μ_i	B<0. 1 mT 10 kHz 25°C	-	1500 ±20%	1050 ±20%	850 ±20%	370 ±20%	350 ±20%	220 ±20%	120 ±20%	40 ±20%	15 ±20%
Saturation Flux Density (typical)	Bsat	H=796 A/m 10 Oe 25°C	mT	230*	210	210	310	350*	350	280†	240†	220†
Residual Flux Density (typical)	Br	H→0 (from near saturation) 10 kHz 25°C	mT	175	130	130	270	200	217	190	155	135
Coercivity (typical)	Hc	B→0 (from near saturation) 10 kHz 25°C	A/m	30	50	50	60	65	172	30	1200	1600
Loss Factor (maximum)	Tan ΠilΠeΠ / Πi	100 kHz B<0.1mT 25°c	10^{-6}	140	26	26	-	-	-	-		
		250 kHz		-	-	-	-	-	-	-		
		400 kHz		-	-	-	65	-	-	-		
		500 kHz		-	-	-	-	-	40	-		
		1 MHz		-	-	-	-	-	42	-		
		2 MHz		-	-	-	-	-	50	45	50	
		3 MHz		-	-	-	-	-	-	-	50	
		5 MHz		-	-	-	-	-	-	-	55	
		10 MHz		-	-	-	-	-	-	-	65	
		15 MHz		-	-	-	-	-	-	-	75	
		20 MHz		-	-	-	-	-	-	-	100	
		40 MHz		-	-	-	-	-	-	-	125	225
		100 MHz		-	-	-	-	-	-	-	300	
		200 MHz		-	-	-	-	-	-	-		
Temperature Factor	ΠΠ / Πi² ΠΠT	B<0.1mT 10kHz +25°C to +55°C	10^{-6} /°C	-	-	-	-	-	12 to 30	-	-	-
Curie Temperature (minimum)	T_c	B<0.1mT 10kHz	°C	95	100	135	180	240	140	300	300	400
Resistivity (typical)	ρ	1V/cm 25°C	Ω-cm	$5x10^8$	$1x10^6$	$1x10^6$	$1x10^8$	$1x10^5$	$1x10^8$	$1x10^7$	$1x10^6$	$2x10^4$

*B_{sat} Measured at H=1200 A/m
†B_{sat} Measured at H=4000 A/m

[P] Perminvar ferrites undergo irreversible changes to their electrical characteristics if subjected to strong magnetic fields or mechanical shock. The changes include an increase in permeability and loss factor. The increase in loss factor is especially pronounced at high frequency

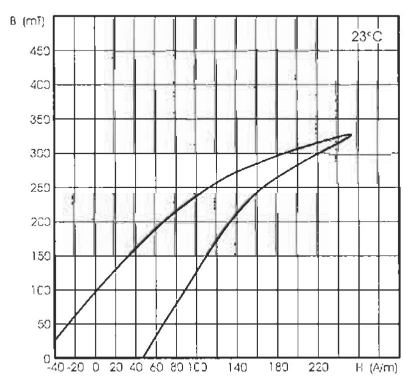
Data is derived from measurements on toroidal cores. These values can not be directly transferred to products of another shape and size. The product-related data can be taken only from the relevant product specifications.

F58 Material

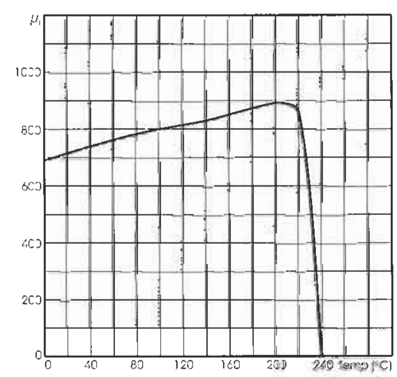
A Manganese-Zinc ferrite designed for filter applications, proximity switches and gate drive transformers for SMPS. Developed to optimize loss in the region 200 kHz – 1 MHz.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	750 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=199A/m =2.5Oe	450
Residual Flux Density (typical)	B_r	mT	10 kHz	94
Coercive force (typical)	H_c	A/m	10 kHz	47
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	200 kHz ~ 0.1mT	12 X 10^{-6}
Curie Temperature (minimum)	T_c	°C	1KHz~0.1mT	200
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	100

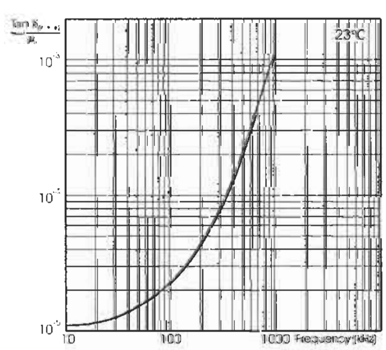
Dynamic Magnetization (BH) Loop



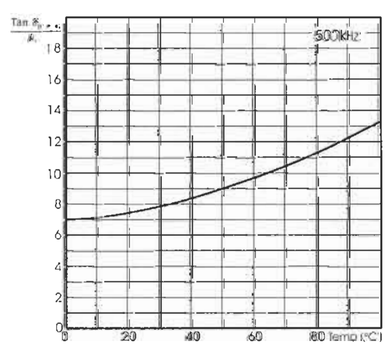
Initial Permeability vs. Temperature



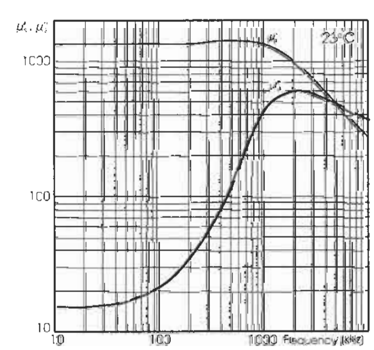
Relative Loss Factor vs. Frequency



Relative Loss Factor vs. Temperature



Complex Permeability vs. Frequency

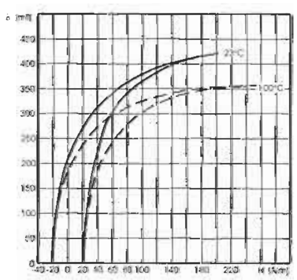


FB2 Material

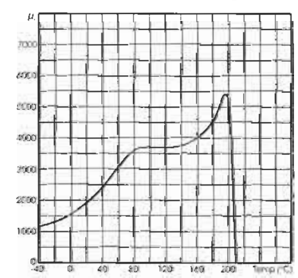
FB2 is a high saturation Manganese-Zinc ferrite designed for high flux power applications. The losses are optimized for the 60°–100°C range because most of the transformers of this type are designed to run hot where efficiency levels are highest. The frequency range for this material is between 10 kHz and 200 kHz. FB2 is available in a wide variety of shapes including toroids, slugs, bobbins, and cup and tack assemblies.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability	μ_i	—	10 kHz ~ 0.1mT	2000 ± 20%
Amplitude Permeability	μ_a	—	400mT 25°C 320mT 100°C	2400 1825
Saturation Flux Density	B_{sat}	mT	H=796A/m =10 Oe @ 25°C @100°C	470 350
Residual Flux Density	B_r	mT	H⇒0 (from near saturation) 10kHz 25°C	200
Coercive force	H_c	A/m	B⇒0 (from near saturation) 10kHz 25°C	21
Relative Loss Factor	Tan δ/μ_i		100 kHz ~ 0.1mT	30 X 10^{-6}
Curie Temperature	T_c	°C	B<0.1mT 10kHz	200
Total Power Loss Density	P_v	mW/cc	200mT 16kHz 25°C 200mT 16kHz 60°C 200mT 16kHz 100°C 200mT 25kHz 60°C 200mT 25kHz 100°C	120 110 110 190 190
Volume Resistivity	ρ	Ω-cm	1V/cm 25°C	100

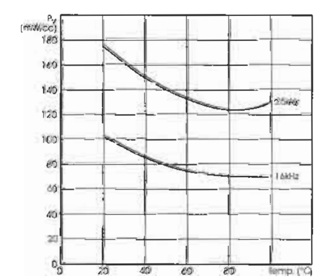
Dynamic Magnetization (BH) Loop



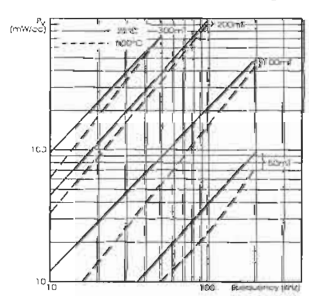
Initial Permeability vs. Temperature



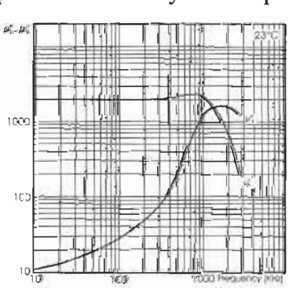
Power Loss Density vs. Temperature



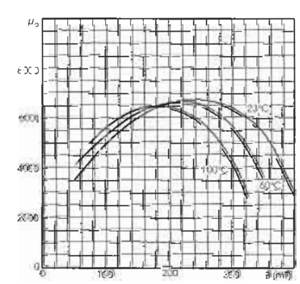
Power Loss Density vs. Frequency



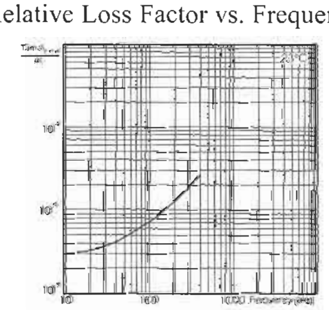
Complex Permeability vs. Frequency



Static Magnetization: Permeability vs. B



Relative Loss Factor vs. Frequency

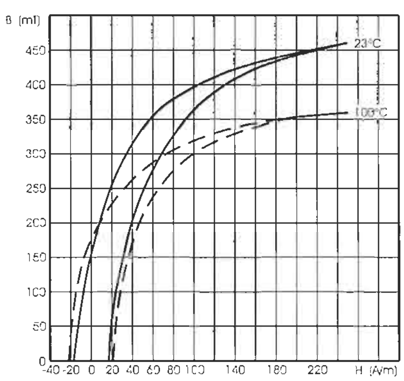


FB3 Material

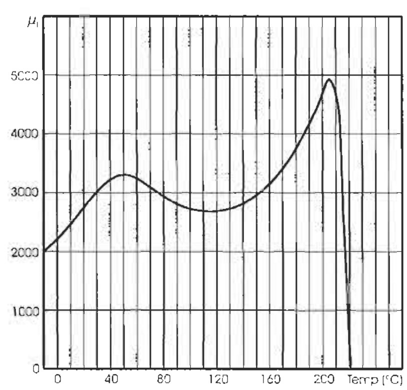
FB3 is a high saturation Manganese-Zinc ferrite designed for high flux power applications. The losses are optimized for the 40°–60°C range because most of the transformers of this type are designed to run hot where efficiency levels are highest. The frequency range for this material is between 10kHz and 200kHz. FB3 is available in a wide variety of shapes including toroids, slugs, bobbins, and cup and tack assemblies.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability	μ_i	—	10 kHz ~ 0.1mT	3000 ± 20%
Amplitude Permeability	μ_a	—	400mT 25°C 320mT 100°C	2400 1825
Saturation Flux Density	B_{sat}	mT	H=796A/m =10 Oe @ 25°C @100°C	460 330
Residual Flux Density	B_r	mT	H⇒0 (from near saturation) 10kHz 25°C	150
Coercive force	H_c	A/m	B⇒0 (from near saturation) 10kHz 25°C	18
Relative Loss Factor	Tan δ/μ_i	10^{-6}	100 kHz ~ 0.1mT	30 X 10^{-6}
Curie Temperature	T_c	°C	B<0.1mT 10kHz	180
Normalized Impedance	Z	Ω	10 MHz	—
Total Power Loss Density	P_v	mW/cc	200mT 16kHz 25°C 200mT 16kHz 60°C 200mT 16kHz 100°C 200mT 25kHz 60°C 200mT 25kHz 100°C	120 110 110 190 190
Volume Resistivity	ρ	Ω-cm	1V/cm 25°C	100

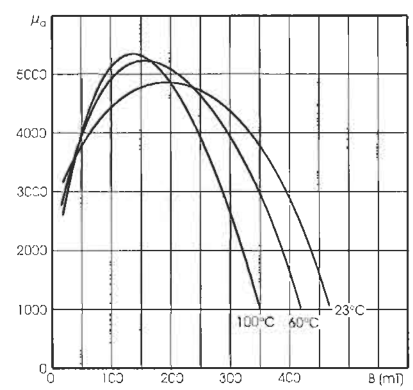
Dynamic Magnetization (BH) Loop



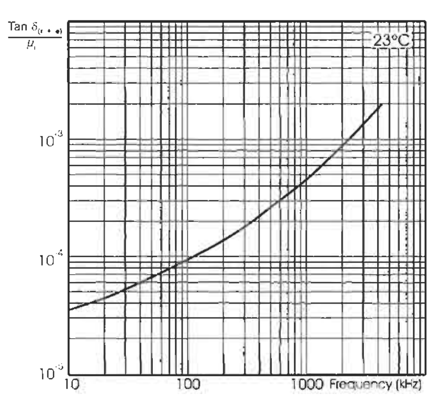
Initial Permeability vs. Temperature



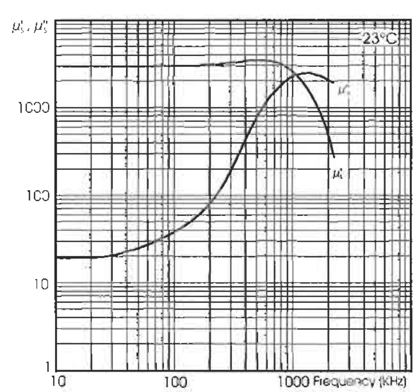
Static Magnetization: Permeability vs. B



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

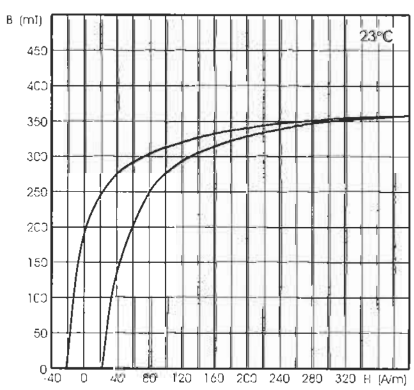


F9Q Material

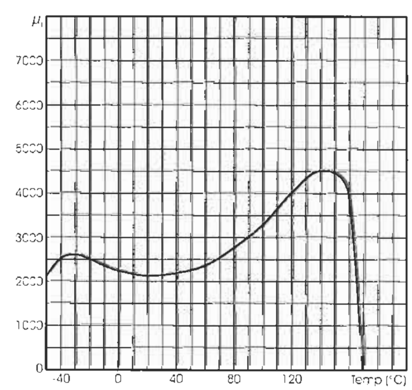
A Manganese-Zinc ferrite specially formulated to obtain a relatively stable initial permeability in the 0°C to 60°C range with the additional feature of maintaining that permeability down to very low temperatures. Suitable for application in pulse and broadband transformers, common-mode chokes and inductors. Available in a wide variety of ring cores, multiaperture and bead cores.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	2300 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=199A/m =2.5Oe	350
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	190
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	24
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	100 kHz ~ 0.1mT	20
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	140
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	20

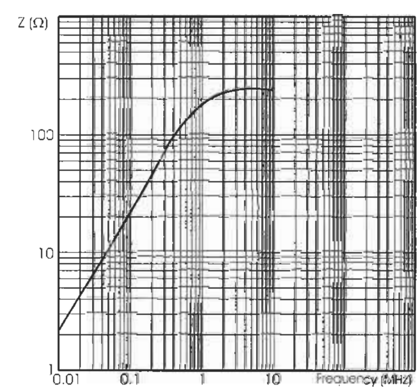
Dynamic Magnetization (BH) Loop



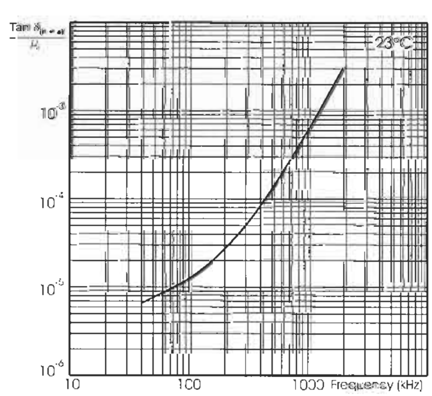
Initial Permeability vs. Temperature



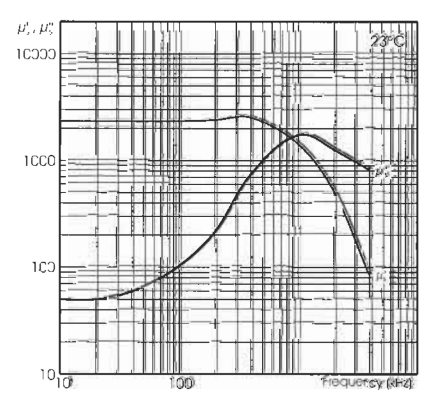
Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

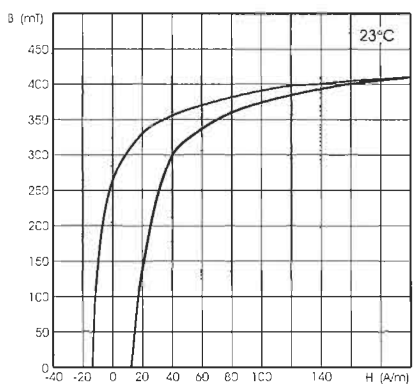


F9N Material

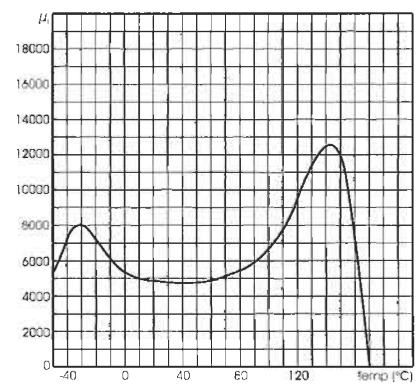
F9N is a Manganese-Zinc ferrite very similar in general characteristics to the main family of MMG high permeability Manganese-Zinc ferrites. This material was developed to obtain high permeability at very low temperatures (typically, 4000 at –55°C).

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	4000 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=199A/m =2.5Oe	410
Residual Flux Density (typical)	B_r	mT	10 kHz	270
Coercive force (typical)	H_c	A/m	10 kHz	15
Relative Loss Factor (maximum)	Tan δ/μ_i	—	100 kHz ~ 0.1mT	30 X 10^{-6}
Curie Temperature (minimum)	T_c	°C	1kHz ~0.1mT	100°C
Normalized Impedance	Z	Ω	10 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	100

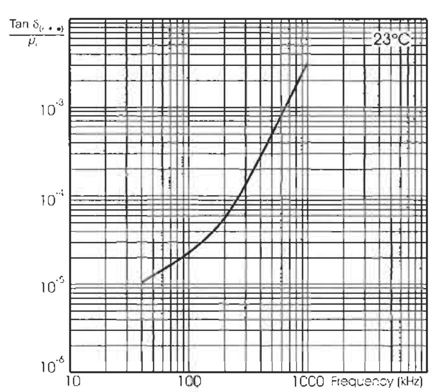
Dynamic Magnetization (BH) Loop



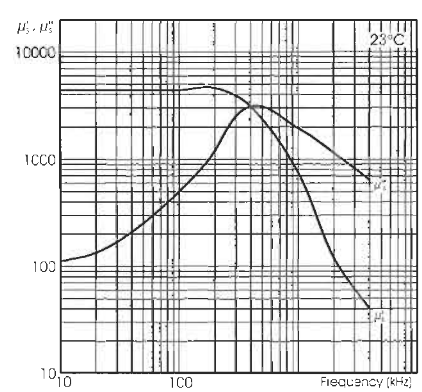
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

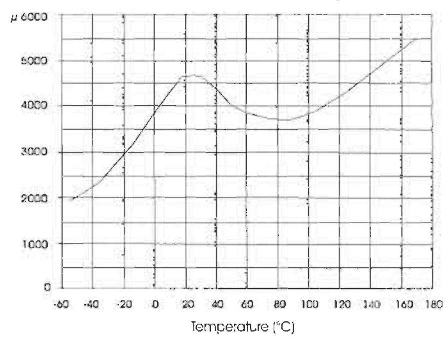


F65 Material

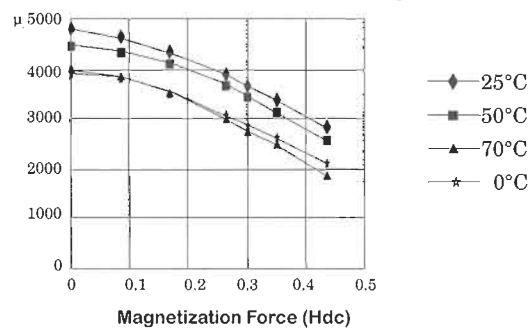
F65 is a Manganese-Zinc ferrite similar in general characteristics to the main family of MMG high permeability Manganese-Zinc ferrites. This material was developed for LAN applications, specifically 100 BaseTx. The permeability is typically 4400, and incremental permeability is controlled over temperature ranging from 0° to 70° C. F65 material is available in geometries ranging in size from approximately .1 inch to .23 inches.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	4400 ± 40%
Saturation Flux Density (typical)	B_{sat}	mT	H=400A/m	350
Residual Flux Density (typical)	B_r	mT	H=80A/m =1.0Oe	100
Coercive force (typical)	H_C	A/m	H=80A/m =1.0Oe	14
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	100 kHz ~ 0.1mT	20
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	>150
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	20

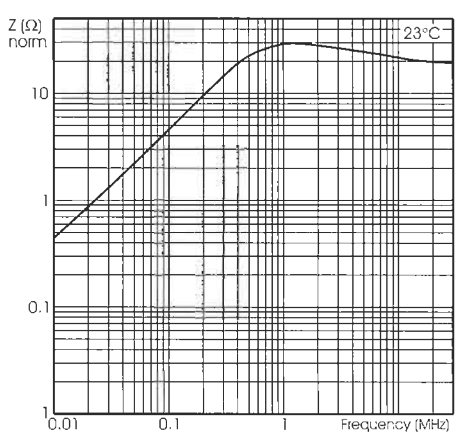
Initial Permeability vs. Temperature



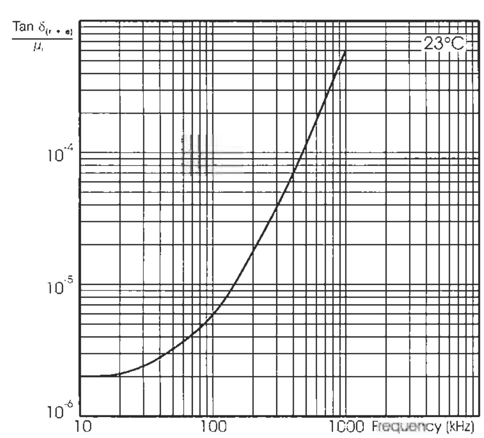
Incremental Permeability vs. Temperature



Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency

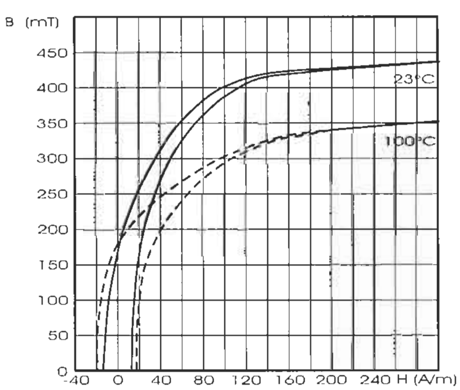


F82 Material

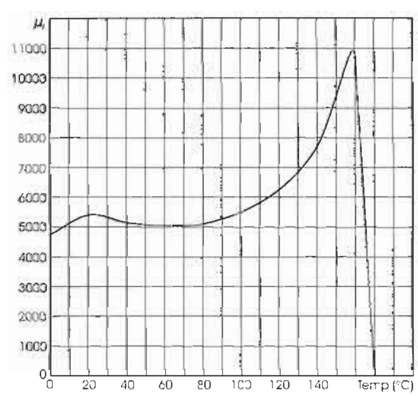
F82 is a high permeability Manganese-Zinc ferrite which exhibits a nominal permeability of 5000. This material offers a high saturation flux density as well as low losses at low frequency. These characteristics make F82 material well suited for use in wideband and pulse transformers and mains filtering applications.

Parameter	Symbol	Units	Standard Test Conditions	Value
Initial Permeability	μ_i	—	10 kHz ~ 0.1mT	5000 ± 20%
Saturation Flux Density	B_{sat}	mT	H=199A/m =2.5Oe	460
Residual Flux Density	B_r	mT	10 kHz	170
Coercive force	H_c	A/m	10 kHz	13
Relative Loss Factor	$\tan\delta/\mu_i$	$x10^{-6}$	100 kHz ~ 0.1mT	20
Curie Temperature	T_c	°C	1kHz ~0.1mT	160
Normalized Impedance	Z	Ω	10 MHz	22
Volume Resistivity	ρ	Ω-cm	1V/cm 25°C	20

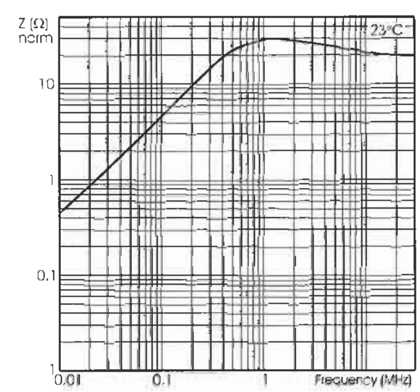
Dynamic Magnetization (BH) Loop



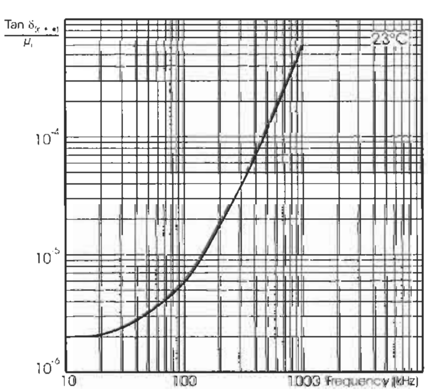
Initial Permeability vs. Temperature



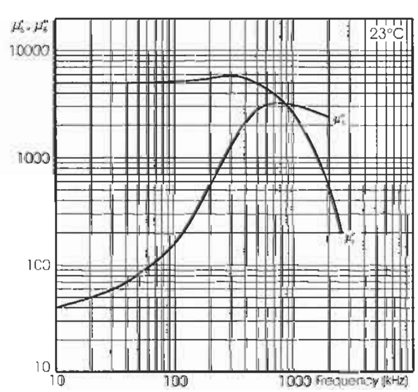
Normalized Impedance vs. Frequency



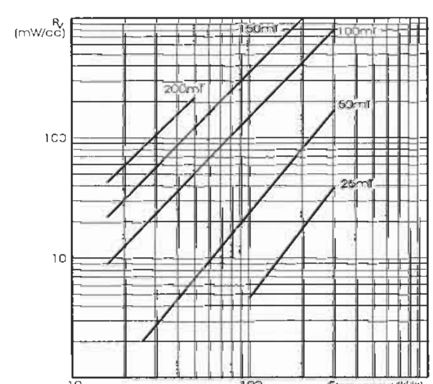
Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency



Power Loss Density vs. Frequency

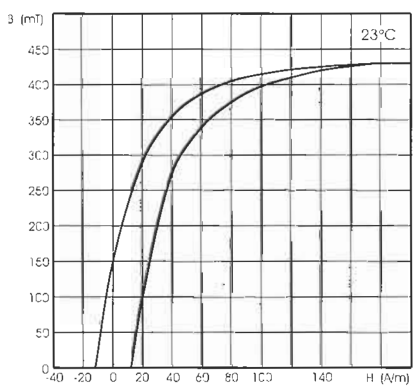


FT6 Material

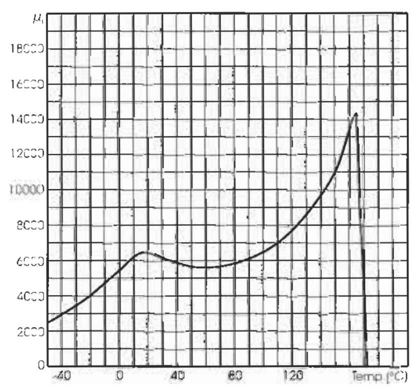
A high permeability Manganese-Zinc ferrite suitable for application in pulse and broadband transformers, common-mode chokes and inductors. Available in a wide variety of ring cores, multiaperture and bead cores.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	6000 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=200A/m 25°C	430
Residual Flux Density (typical)	B_r	mT	10 kHz	150
Coercive force (typical)	H_c	A/m	10 kHz	15
Relative Loss Factor (maximum)	$\tan\delta/\mu_i$	10^{-6}	100 kHz ~ 0.1mT	25 X 10^{-6}
Curie Temperature (minimum)	T_c	°C	B<0.010 mT 1kHz	140
Normalized Impedance	Z	Ω	10 MHz	240
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm @25°C	20

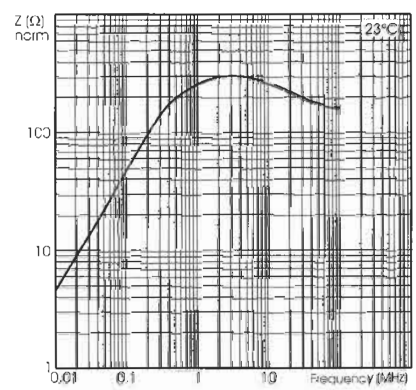
Dynamic Magnetization (BH) Loop



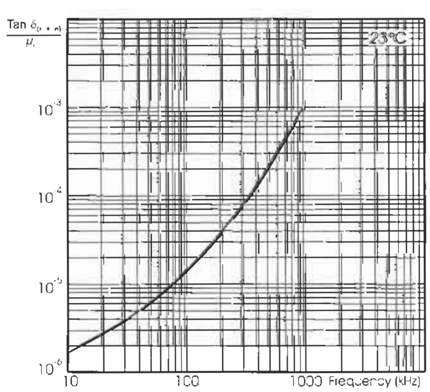
Initial Permeability vs. Temperature



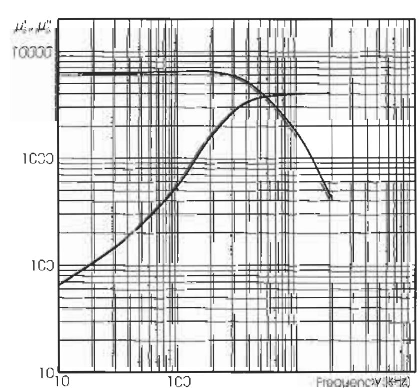
Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

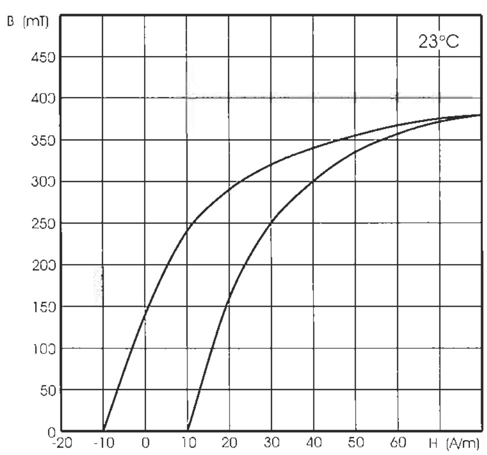


FT7 Material

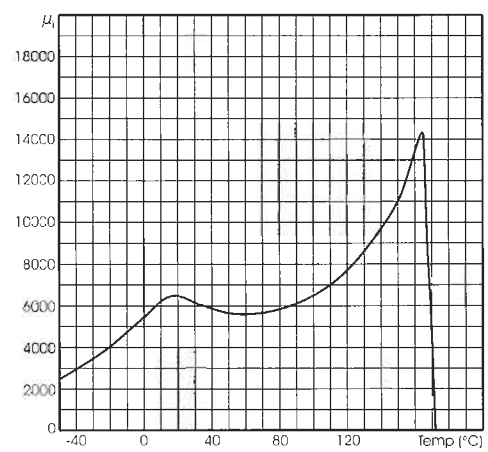
A high permeability Manganese-Zinc ferrite suitable for application in pulse and broadband transformers, common-mode chokes and inductors. Available in a wide variety of ring cores, multi aperture and bead cores.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	7500 ± 25%
Saturation Flux Density (typical)	B_{sat}	mT	H=796A/m =10Oe 25°C	420
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	130
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	10
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	10 kHz ~ 0.1mT 100 kHz ~ 0.1mT	6 X 10^{-6} 50 X 10^{-6}
Curie Temperature (minimum)	T_c	°C	B<0.010 mT 1kHz	>150°C
Normalized Impedance	Z	Ω	10 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm @25°C	10

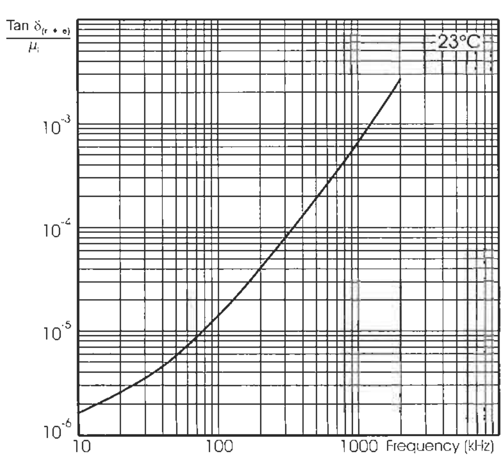
Dynamic Magnetization (BH) Loop



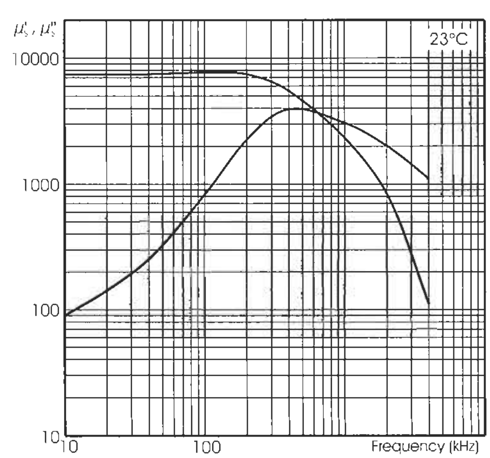
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

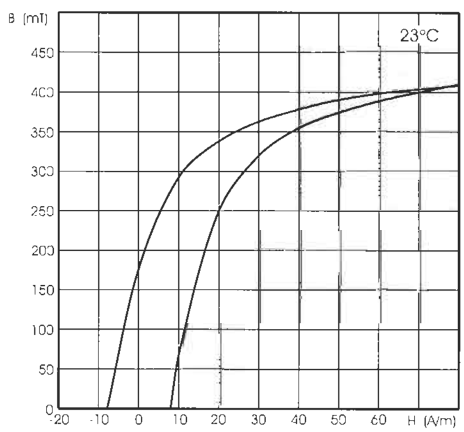


FTA Material

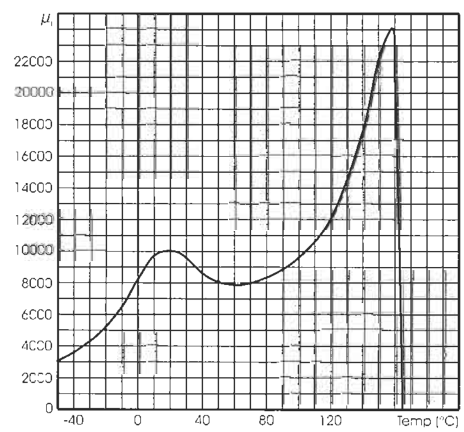
FTA is a high permeability Manganese-Zinc ferrite suitable for application in pulse and broadband transformers, common-mode chokes and inductors. Additional properties include a high curie temperature and high saturation flux density. Available in a wide variety of ring cores, multiaperture, and bead cores.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 kHz ~ 0.1mT	10000 ± 30%
Saturation Flux Density (typical)	B_{sat}	mT	H=199A/m =2.5Oe	410
Residual Flux Density (typical)	B_r	mT	10 kHz	270
Coercive force (typical)	H_c	A/m	10 kHz	15
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	100 kHz ~ 0.1mT	30 X 10^{-6}
Curie Temperature (minimum)	T_c	°C	1KHz~0.1mT	>150°C
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	100

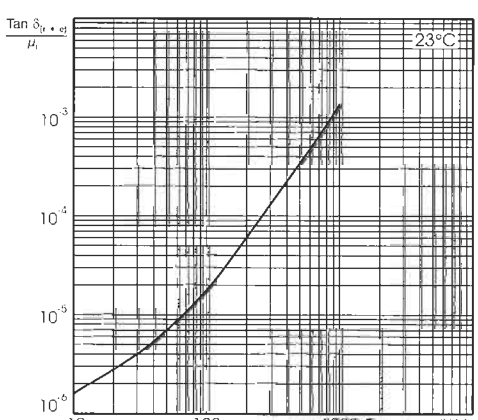
Dynamic Magnetization (BH) Loop



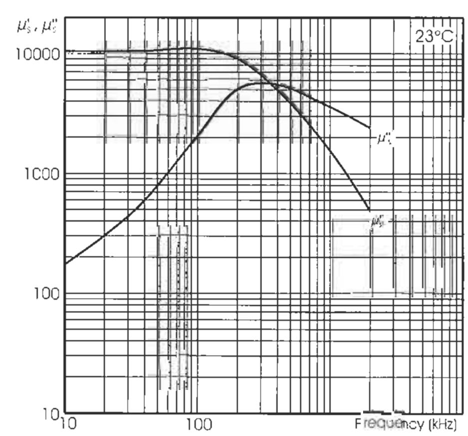
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

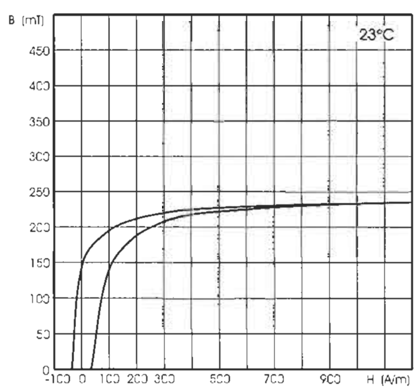


FF1 Material

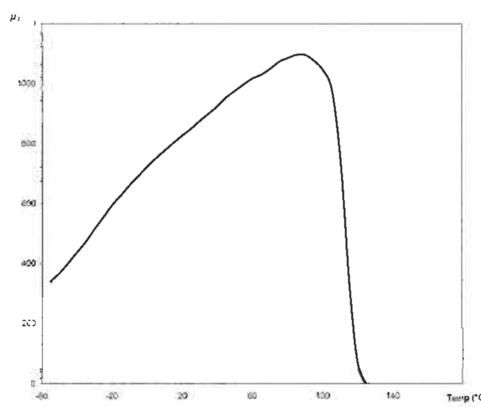
FF1 material is a high permeability Nickel-Zinc ferrite specially formulated for high inductance at low frequencies in broadband applications without having the dielectric constant of Manganese-Zinc ferrites. It can be used in broadband applications into the GHz region. It also features very high volume resistivity. FF1 is available in a variety of toroidal, multi-aperture, bead cores, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 10kHz 25°C	1500 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	230
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	175
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	30
Relative Loss Factor (maximum)	$\tan\delta/\mu_i$	10^{-6}	B<0.1mT 100kHz 25°C	140
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	95
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	5×10^6

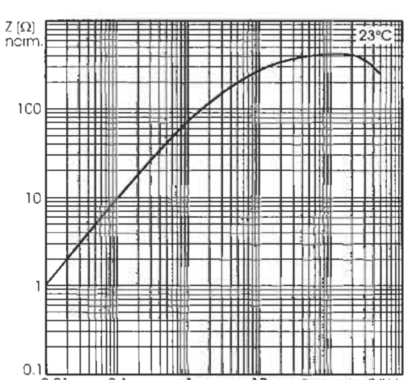
Dynamic Magnetization (B-H) Loop



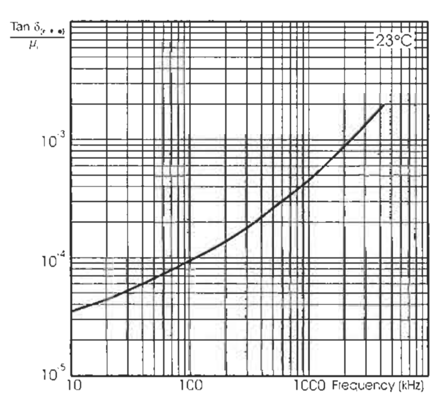
Initial Permeability vs. Temperature



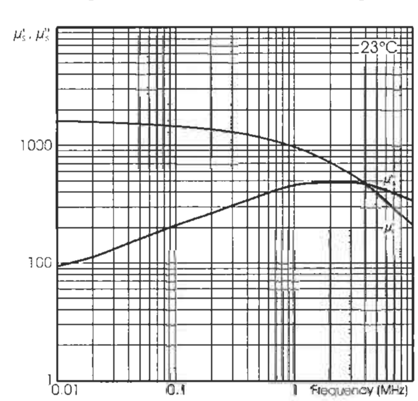
Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

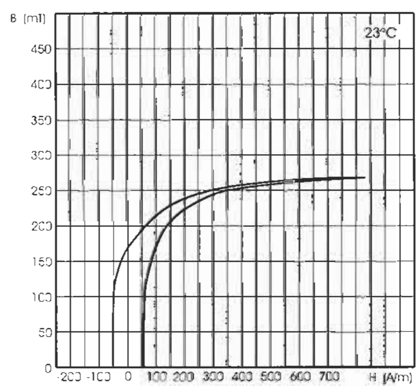


F53 Material

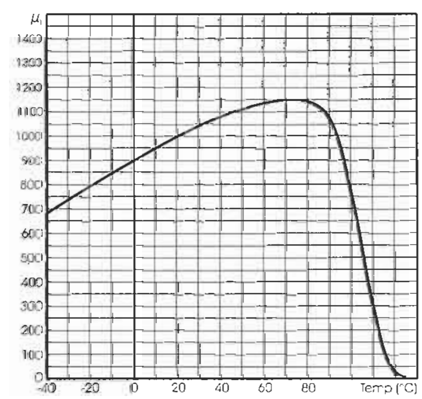
F53 exhibits an initial permeability of 1050. It is a high permeability Nickel-Zinc ferrite offering low losses in the frequency range 100 kHz to 2 MHz and having usable permeability out to 10 MHz and beyond. It can be used in broadband applications into the GHz region and provides high resistive impedance from 20 MHz to beyond 1 GHz for EMC suppression applications. F53 is available in a variety of toroidal multiaperture, and bead cores, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 10kHz 25°C	1050 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	210
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	130
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	50
Relative Loss Factor (maximum)	$Tan\delta/\mu_i$	10^{-6}	B<0.1mT 100kHz 25°C	30
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	115°C
Normalized Impedance	Z	Ω	100 kHz	75
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	100

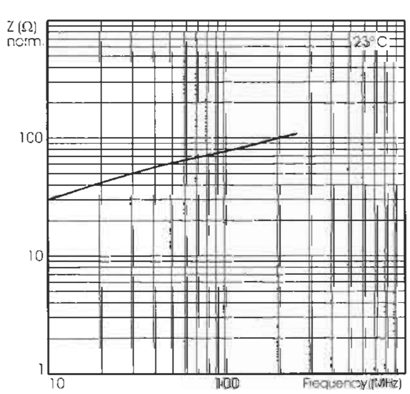
Dynamic Magnetization (BH) Loop



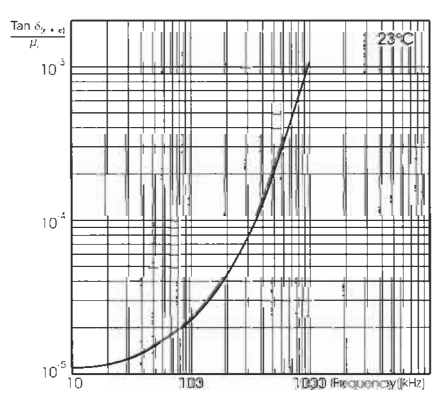
Initial Permeability vs. Temperature



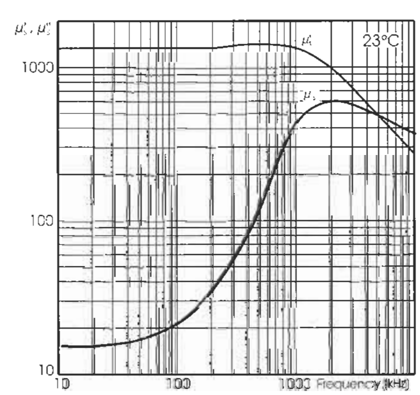
Normalized Impedance vs Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

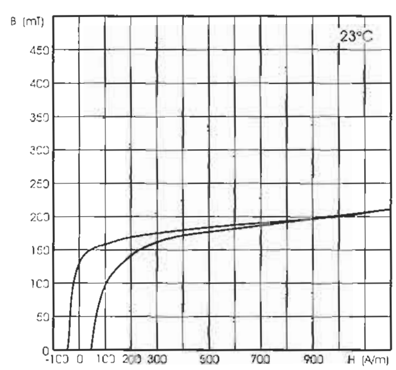


F52 Material

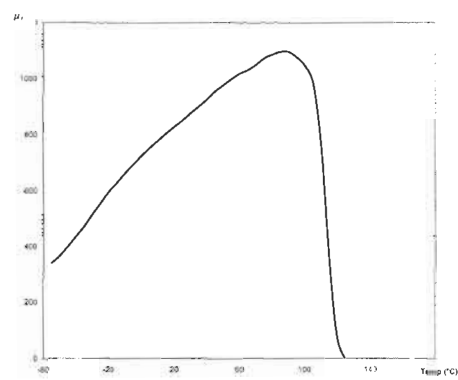
F52 exhibits an initial permeability of 850. It is considered a high permeability Nickel-Zinc ferrite offering low losses in the frequency range 100 kHz to 2 MHz and having usable permeability out to 10 MHz and beyond. It can be used in broadband applications into the GHz region and provides high resistive impedance from 20 MHz to beyond 1 GHz for EMC suppression applications. F52 is available in a variety of toroidal multiaperture, and bead cores, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	10 KHz ~ 0.1mT	850 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	210
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	130
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	50
Relative Loss Factor (maximum)	Tan δ/μ_i	$x10^{-6}$	B<0.1mT 100kHz 25°C	26
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	135
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	100

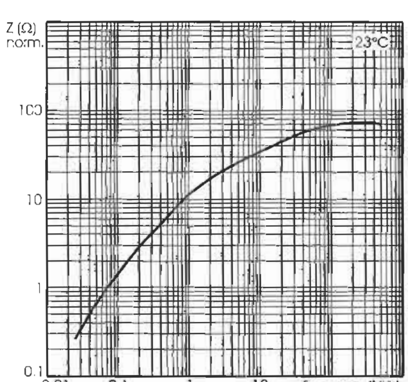
Dynamic Magnetization (BH) Loop



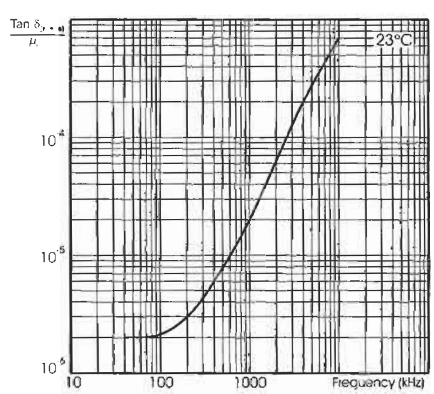
Initial Permeability vs. Temperature



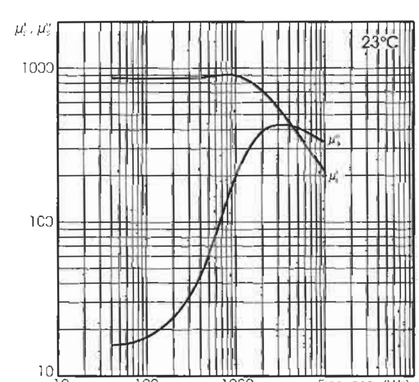
Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

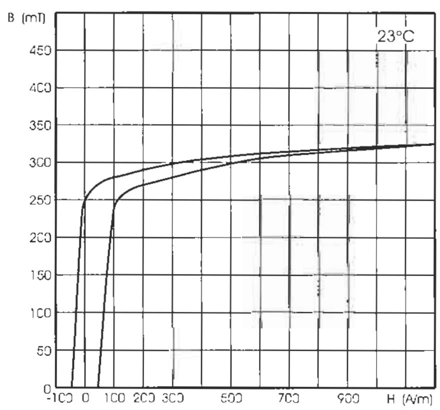


FA1 Material

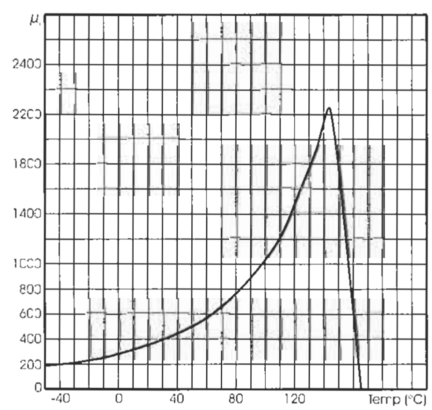
FA1 is a Nickel-Zinc ferrite which combines moderate initial permeability with high volume resistivity and low dielectric losses. These characteristics combine to provide optimum performance in some broadband RF applications. FA1 is generally used from the low kHz frequency to 10 MHz. This material is available in a wide variety of shapes and sizes including toroids, multiaperture cores, beads, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 10kHz 25°C	370 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	310
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	270
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	60
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	B<0.1mT 100kHz 25°C	65
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	145
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	1 X 10^8

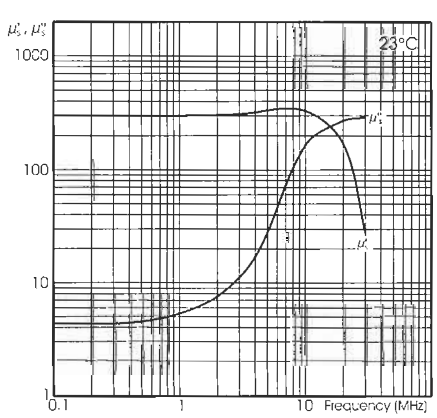
Dynamic Magnetization (BH) Loop



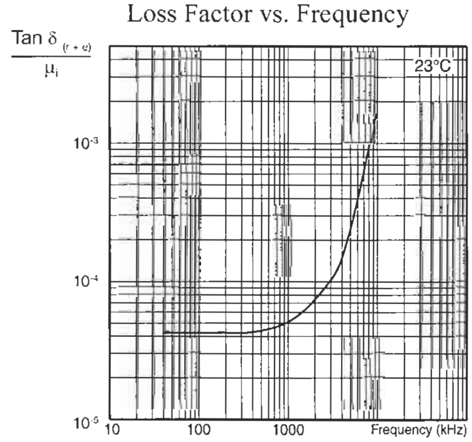
Initial Permeabilty vs. Temperature



Complex Permeability vs. Frequency



Loss Factor vs. Frequency

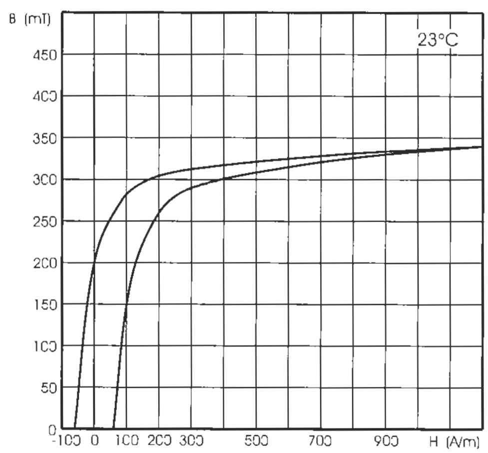


F24 Material

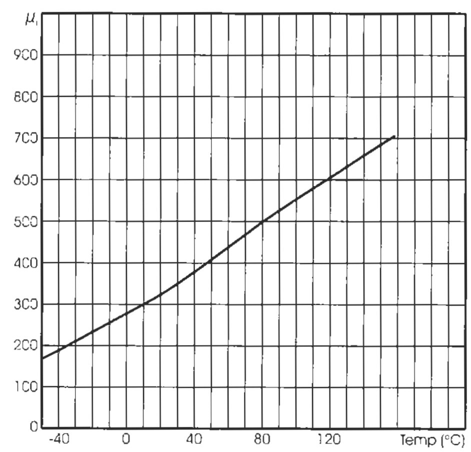
F24 is a Nickel-Zinc ferrite of moderate initial permeability specially formulated to provide low Hum Modulation in power choke applications. It is available in a variety of toroidal, multiaperture, bead, and rod cores.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 10kHz 25°C	350 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	350
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	200
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	65
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	B<0.1mT 100kHz 25°C	—
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	240
Normalized Impedance	Ω	—	B<0.1mT 100MHz 25°C	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	$1x10^5$

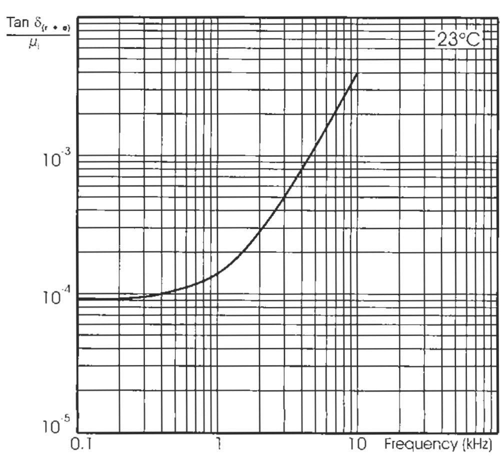
Dynamic Magnetization (BH) Loop



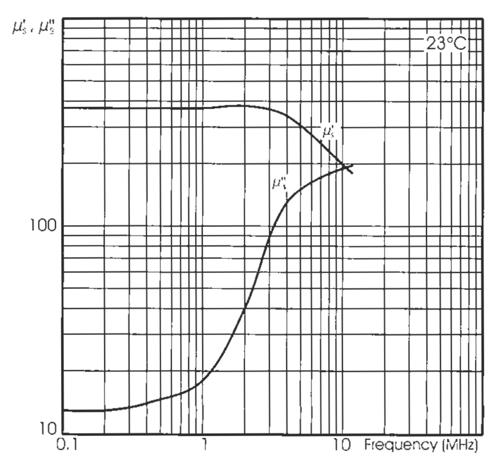
Initial permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

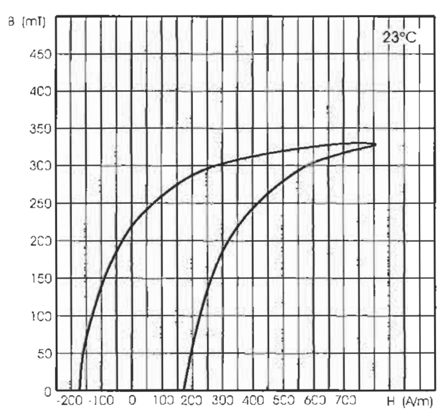


F14 Material

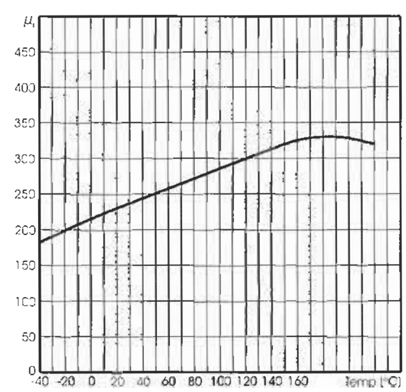
A Nickel-Zinc ferrite designed for the medium frequency range offering low losses up to 3 MHz, or for use in suppression applications up to 200 MHz. Typical applications: RF suppression, balun transformers, aerial rods, and medium frequency tuned circuits. This material was specially formulated for low Hum Modulation in power choke applications. Typical core shapes: Ring cores, rods, tubes, beads, choke cores, and balun cores.

Parameter	Symbol	Unit	Standard Conditions of Test	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 10kHz 25°C	220 ± 20%
Saturation Flux Density (ttypical)	B_{sat}	mT	H=1200 A/m =15 Oe 25°C, 100°C	350
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	217
Coercive force (Typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	172
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	B<0.1mT 1 MHz 25°C	42
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	140
Normalized Impedance	Z	Ω	—	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	1 X 10^8

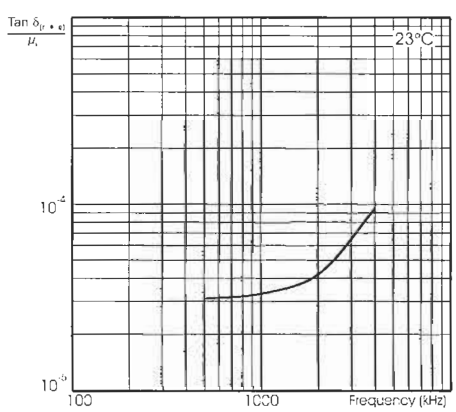
Dynamic Magnetization (BH) Loop



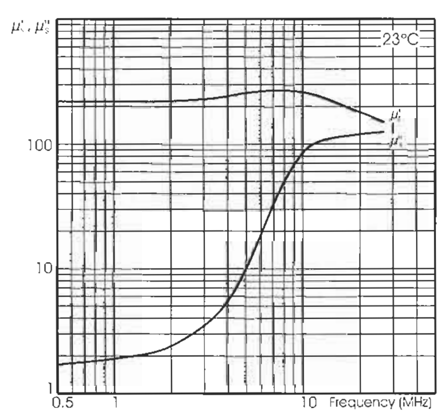
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

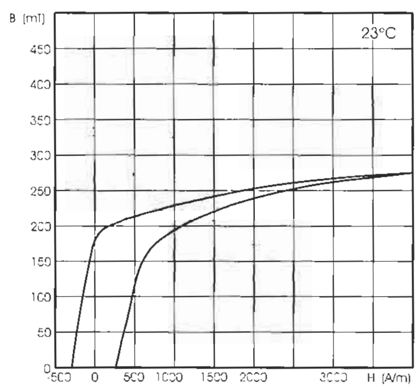


F01 Material

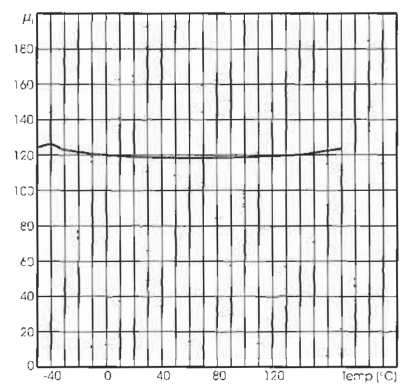
F01 is a perminvar Nickel-Zinc ferrite with a permeability of 120. It has excellent temperature stability and superior Q characteristics. F01 is especially well suited for use in high Q components in the 0.5 MHz to 20 MHz region. Also well suited for EMC noise suppression applications wherein it yields optimum resistive impedance above 200 MHz. This material is available in a wide variety of shapes including toroidal, multiaperture, bead, coilform, and bobbin.

Parameter	Symbol	Unit	Standard Conditions of Test	Value
Initial Permeability (Nominal)	μ_i	—	B<0.1mT 2MHz 25°C	120 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=4000 A/m =15 Oe 25°C, 100°C	280
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	190
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	30
Relative Loss Factor (maximum)	Tan δ/μ_i	10^{-6}	B<0.1mT 2MHz 25°C	45
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	300
Normalized Impedance	Z	Ω	B<0.1mT 100MHz 25°C	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	$1x10^7$

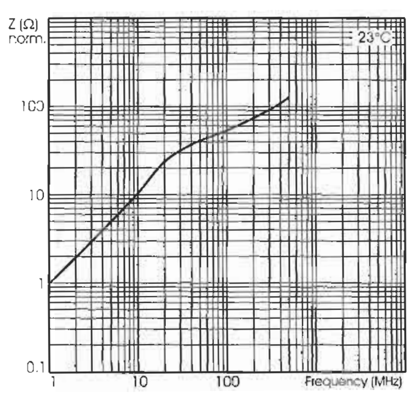
Dynamic Magnetization (BH) Loop



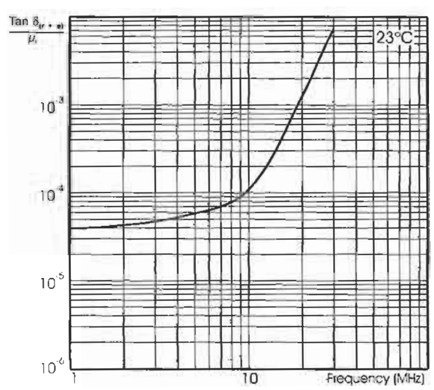
Initial Permeability vs. Temperature



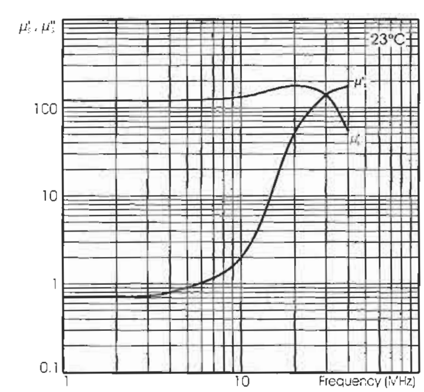
Normalized Impedance vs. Frequency



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

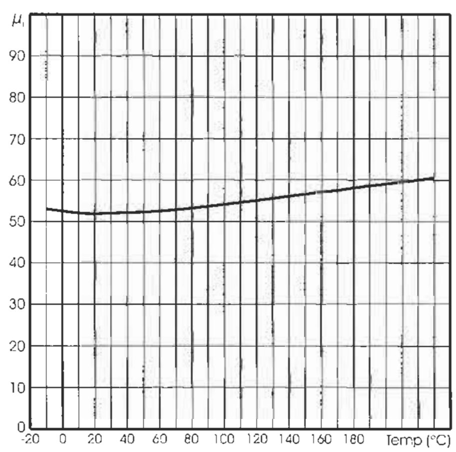


F21 Material

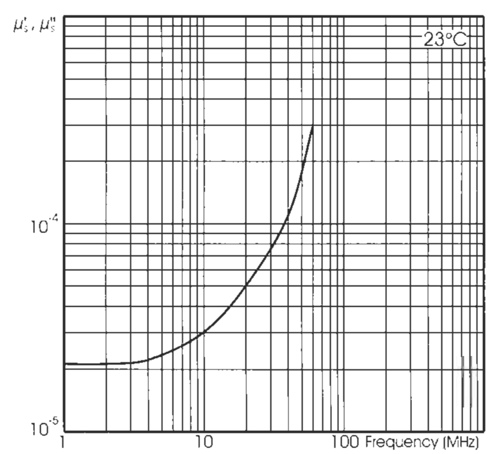
F21 is a perminvar Nickel-Zinc ferrite with a permeability of 40. It is well suited for use in high frequency applications due to Q optimization from 1 MHz to 40 MHz. F21 is typically used in high frequency tuned circuits. This material is available in a wide variety of shapes including toroidal, multiaperture, bead, rods, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	1MHz < 0.1mT	40 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=4000 A/m =15 Oe 25°C, 100°C	240
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	155
Coercive force (Typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	1200
Relative Loss Factor (maximum)	Tan δ/μ_i	$x10^{-6}$	B<0.1mT 15MHz 25°C	75
Curie Temperature (minimum)	T_c	°C	B<0.1mT 1kHz	300
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	$1 x10^6$

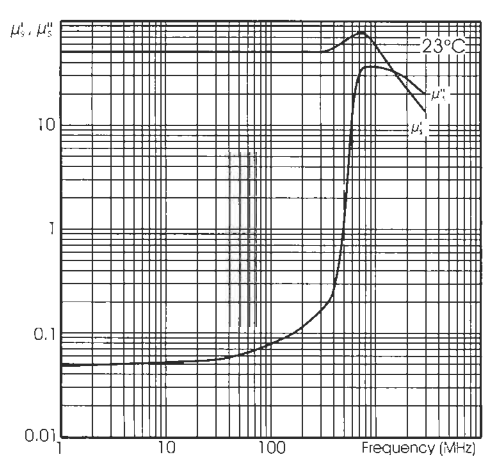
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



Complex Permeability vs. Frequency

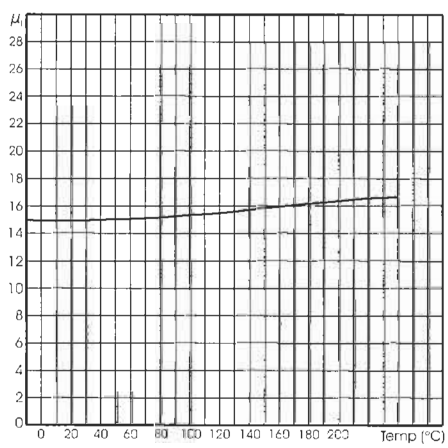


F31 Material

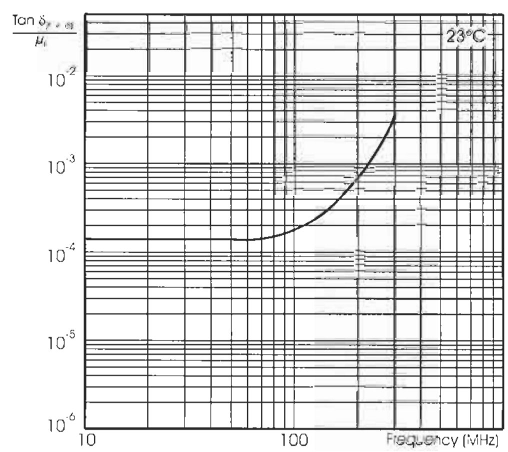
F31 is a Nickel-Zinc ferrite yielding very high Q values to 200 MHz. This material is used extensively in antenna and other RF applications in the 50 MHz to 200 MHz region. It is available in a variety of toroidal, multiaperture, bead cores, coilforms, and bobbins.

Parameter	Symbol	Unit	Standard Test Conditions	Value
Initial Permeability (Nominal)	μ_i	—	2 MHz ~ 0.1mT	15 ± 20%
Saturation Flux Density (typical)	B_{sat}	mT	H=4000 A/m =50 Oe 25°C, 100°C	220
Residual Flux Density (typical)	B_r	mT	H⇒0 (from near Saturation) 10kHz 25°C	135
Coercive force (typical)	H_c	A/m	B⇒0 (from near Saturation) 10kHz 25°C	1600
Relative Loss Factor (maximum)	$\tan\delta/\mu_i$	$x10^{-6}$	B<0.1mT 40MHz 25°C	225
Curie Temperature	T_c	°C	B<0.1mT 1kHz	400°C
Normalized Impedance	Z	Ω	100 MHz	—
Volume Resistivity (typical)	ρ	Ω-cm	1V/cm 25°C	$2 X 10^4$

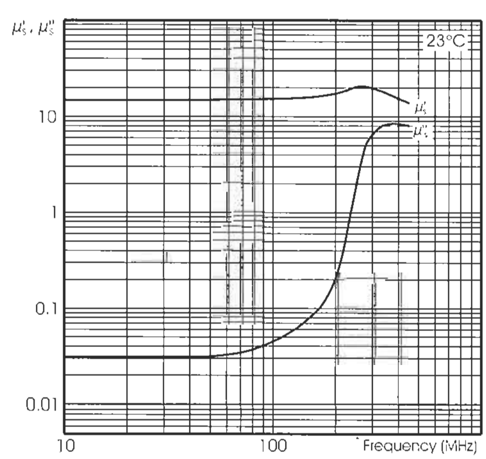
Initial Permeability vs. Temperature



Relative Loss Factor vs. Frequency



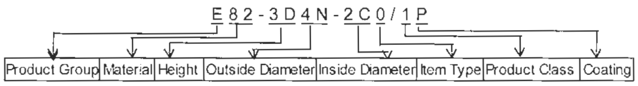
Complex Permeability vs. Frequency



MMG-North America Ferrite Parts

Part Numbering System

1] The first character of the part number 'E' Refers to the product group.



2] The second two digits,'82' refer to the material used to form the part.
3] The next six digits are the part geometry code given in a base thirty-five numbering system.
4] This place refers to the specific type (not used in all of the product groups).
5] The '/1' indicates a standard catalog part. All tolerances and nominal parameters are defined by MMGNA. A number other than '1' following the '/' indicates a special requirement defined by a specific customer.
6] The 'P' refers to coating requirements.

Number Systems

The MMG part number system uses the base thirty-five number system in order to extend the information given in a limited number of digits. Similar to the base ten system which is the most commonly used system, base 35 expresses values as multiples of its base.

For example:
Base 10 employs digits 0 to 9.
Each digit expresses a value. Base 10 can express 10 values including null in a single digit. 0,1,2,3,4,5,6,7,8,9.
By using multiple columns a number system can express any number to infinity.
Base 10 Columns would be...

Example
73_{10} is a 3 in the one's column and a 7 in the ten's column.
: $[7 \times 10^1 = 70] + [3 \times 10^0=3]$ ...70+3=73

1s Column	10's Column	100's Column
10^0	10^1	10^2
$1x10^0=1$	$1x10^1=10$	$1x10^3=100$

Base 35 employs digits 0 to 9 then A to Z. (Note the Letter O is omitted to avoid confusion with Null.)

Each digit expresses a value. Base 35 can express 35 values including null in a single digit.

0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,G,H,I,J,K,L,M,N,P,Q,R,S,T,U,V,W,X,Y,Z.
similar to Base 10 using multiple columns allows the expression of any number to infinity.

Base 35 Columns would be...Example:
$6K_{35}$ is a 6 in the one's column and a K in the thirty-five's column:

1's Column	35's Column	1225's Column
35^0	35^1	35^2
$1x35^0=1$	$1x35^1=35$	$1x35^2=1225$

$[6_{35}(=6_{10}) \times 35^1 = 210_{10}] + [K(=20_{10}) \times 35^0=20_{10}]$ ...$210+20=230_{10}$

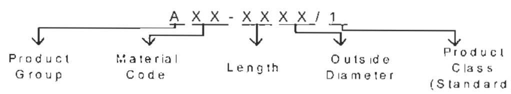
Base 35 Conversion Table

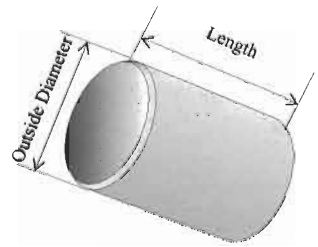
$1X10^0$	$1X35^0$	$1X10^1$	$1X35^1$	$1X10^2$	$1X35^2$
0	0			1225	100
1	1	35	10	1260	110
2	2	70	20	1295	120
3	3	105	30	1330	130
4	4	140	40	1365	140
5	5	175	50	1400	150
6	6	210	60	1435	160
7	7	245	70	1470	170
8	8	280	80	1505	180
9	9	315	90	1540	190
10	A	350	A0	1575	1A0
11	B	385	B0	1610	1B0
12	C	420	C0	1645	1C0
13	D	455	D0	1680	1D0
14	E	490	E0	1715	1E0
15	F	525	F0	1750	1F0
16	G	560	G0	1785	1G0
17	H	595	H0	1820	1H0
18	I	630	I0	1855	1J0
19	J	665	J0	1890	1I0
20	K	700	K0	1925	1K0
21	L	735	L0	1960	1L0
22	M	770	M0	1995	1M0
23	N	805	N0	2030	1N0
24	P	840	P0	2065	1P0
25	Q	875	Q0	2100	1Q0
26	R	910	R0	2135	1R0
27	S	945	S0	2170	1S0
28	T	980	T0	2205	1T0
29	U	1015	U0	2240	1U0
30	V	1050	V0	2275	1V0
31	W	1085	W0	2310	1W0
32	X	1120	X0	2345	1X0
33	Y	1155	Y0	2380	1Y0
34	Z	1190	Z0	2415	1Z0

Standard Ferrite Core Geometries

A: Slug Cores
C: Coilforms
D: Power/Dataline Suppression Ferrites
E: Beads
F: Cup Cores
G: Balun Cores
H: Bobbin Cores
L: Toroids
P: Sleeves
S: Miscellaneous
W: Wound Components

Product Group A : Slug Cores

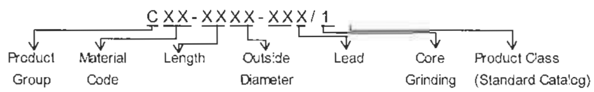


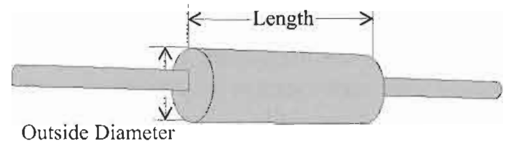


The most popular usage of ferrite slugs is in power applications, EMI suppression, and as antenna rods. MMG offers core sizes ranging from 0.030″ to approximately 2 inches in a variety of materials. Ferrite slugs are a popular design alternative due to the ease of assembly as well as the electrical stability. Slugs can be easily wound using simple mechanical machinery. Below is a list of popular core sizes and with MMG's pressing and thrufeed grinding capabilities we can customize to fit most applications.

Core Part No	Units	Length	Outside Diameter	L:D Ratio	A(cm2)
A_ _-2V0V/1	in.	0.100	0.030	3.333	
	mm	2.540	0.762		0.0046
A_ _-501K/1	in.	0.175	0.055	3.182	
	mm	4.445	1.397		0.0153
A_ _-B31R/1	in.	0.388	0.061	6.361	
	mm	9.855	1.549		0.0189
A_ _-B32G/1	in.	0.388	0.086	4.512	
	mm	9.855	2.184		0.0375
A_ _-D32V/1	in.	0.458	0.100	4.580	
	mm	11.633	2.540		0.0507
A_ _-TK49/1	in.	1.020	0.149	6.846	
	mm	25.908	3.785		0.1125
A_ _-VA78/1	in.	1.066	0.253	4.213	
	mm	27.076	6.426		0.3243
A_ _-1F08X/1	in.	1.745	0.313	5.575	
	mm	44.323	7.950		0.4964
A_ _-1F0AN/1	in.	1.745	0.373	4.678	
	mm	44.323	9.474		0.7050
A_ _-13KEA/1	in.	1.357	0.500	2.714	
	mm	34.468	12.700		1.2668

Product Group C: Coilforms





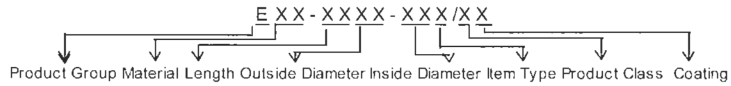
In their simplest form, chokes are ferrite rods with a single winding, preferably close to the rod because distant turns hardly couple to the rod and contribute very little to the inductance of a choke. Such chokes may be used as LC filter components or inserted in the lines to and from devices producing (asymmetrical) interference. At low frequencies, the reactance is low and does not affect the flow of desired currents, but at higher frequencies the reactance is high enough to attenuate the interference, generating in or endangering the protected device.

Ferrite ring, pot, RM and other closed cores can provide much higher inductance values required for suppression at lower frequencies, but they are more prone to saturation when high operational currents have to be handled. In some conditions, iron powder toroids, having much higher saturation induction than any ferrite grade, may be useful—refer to MMG Sales for details of iron powder core availability.

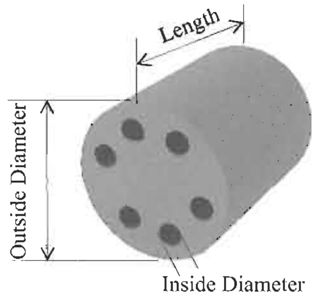
Core Part No.	Units	Length	Outside Diameter	L:D Ratio	A(cm2)	Available Lead AWG#
C_ _-4X1B-_ _ _/1	in mm	0.172 4.369	0.046 1.168	3.739	0.0918	24
C_ _-5C1N-_ _ _/1	in mm	0.187 4.750	0.058 1.473	3.224	0.1157	24
C_ _-5C1R-_ _ _/1	in mm	0.187 4.750	0.061 1.549	3.066	0.1217	24
C_ _-5Q1R-_ _ _/1	in mm	0.200 5.080	0.061 1.549	3.279	0.1217	24
C_ _-7520-_ _ _/1	in mm	0.250 6.350	0.070 1.778	3.571	0.1396	24, 22
C_ _-9725-_ _ _/1	in mm	0.322 8.179	0.075 1.905	4.293	0.1496	24, 22
C_ _-9B26-_ _ _/1	in mm	0.326 8.280	0.076 1.930	4.289	0.1516	24, 22
C_ _-9E26-_ _ _/1	in mm	0.329 8.357	0.076 1.930	4.329	0.1516	24, 22
C_ _-DV3K-_ _ _/1	in mm	0.485 12.319	0.125 3.175	3.880	0.2494	24, 22
C_ _-EA4M-_ _ _/1	in mm	0.500 12.700	0.162 4.115	3.086	0.3232	22, 21, 20
C_ _-HV3K-_ _ _/1	in mm	0.625 15.875	0.125 3.175	5.000	0.2494	22, 21, 20
C_ _-HV5C-_ _ _/1	in mm	0.625 15.875	0.187 4.750	3.342	0.3730	22, 21, 20
C_ _-Q075-_ _ _/1	in mm	0.875 22.225	0.250 6.350	3.500	0.4987	22, 21, 20
C_ _-HV4G-_ _ _/1	in mm	0.625 15.875	0.156 3.962	4.006	0.3112	22, 21, 20
C_ _-X575-_ _ _/1	in mm	1.125 28.575	0.250 6.350	4.500	0.4987	22, 21, 20, 18
C_ _-Q070-_ _ _/1	in mm	0.875 22.225	0.245 6.223	3.571	0.4888	22, 21, 20, 18
C_ _-TK75-_ _ _/1	in mm	1.000 25.400	0.250 6.350	4.000	0.4987	22, 21, 20, 18
C_ _-10Q70-_ _ _/1	in mm	1.250 31.750	0.245 6.223	5.102	0.4888	22, 21, 20, 18

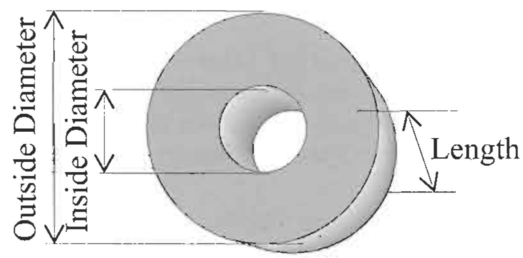
Product Group E : Bead Cores

Ferrite beads are very similar in shape to toroids. The greatest distinguishing characteristic of beads is the application in which they are used. Beads generally have a length to outside diameter ratio greater than one. The most popular uses of ferrite beads are as EMI suppressors. They can be placed over the leads of an electrical component to prevent spurious signals. This application dictates that impedance rather than inductance be controlled. Thus bead specifications will often reference inductance but have a definite impedance minimum. Beads are offered in a variety of materials and can be manufactured in any of MMG's materials in order to optimize the part for a given application.



Core Part No.	Units	Length	Outside Diameter	Inside Diameter	C_1 (cm)	l_o (cm)	A_o (cm)	V_o (cm)
E__-1420-100/1	in	0.039	0.070	0.035	91.5	0.3872	0.00423	0.00164
	mm	0.991	1.778	0.889				
E__-3D4N-290/1	in	0.118	0.163	0.079	28.9	0.8860	0.03061	0.02712
	mm	2.997	4.140	2.007				
E__-3K4N-1S0/1	in	0.125	0.163	0.062	20.5	0.7718	0.03770	0.02909
	mm	3.175	4.140	1.575				
E__-3K4N-1T0/1	in	0.125	0.163	0.063	20.8	0.7790	0.03742	0.02915
	mm	3.175	4.140	1.600				
E__-3N3Y-0X0/1	in	0.128	0.138	0.032	13.2	0.4859	0.03674	0.01785
	mm	3.251	3.505	0.813				
E__-383Y-1E0/1	in	0.113	0.138	0.049	21.1	0.6278	0.02969	0.01864
	mm	2.870	3.505	1.245				
E__-7V4N-2G0/1	in	0.275	0.163	0.086	14.1	0.9289	0.06603	0.06133
	mm	6.985	4.140	2.184				
E__-EAAQ-5C0/1	in	0.500	0.375	0.187	7.1	2.0711	0.29128	0.60326
	mm	12.700	9.525	4.750				
E__-EAEA-870/1	in	0.500	0.500	0.287	8.9	2.9843	0.33486	0.99933
	mm	12.700	12.700	7.290				
E__-X5G2-750/1	in	1.125	0.562	0.250	2.7	2.9108	1.07232	3.12131
	mm	28.575	14.275	6.350				
E__-6R3Y-1C0/1	in	0.236	0.138	0.047	9.7	0.6126	0.06295	0.03856
	mm	5.994	3.505	1.194				
E__-4K5Q-1F0/1	in	0.160	0.200	0.050	11.2	0.7375	0.06613	0.04877
	mm	4.064	5.080	1.270				
E__-BF5Q-2V0/1	in	0.400	0.200	0.100	8.9	1.1062	0.12399	0.13716
	mm	10.160	5.080	2.540				
E__-754N-1S0/1	in	0.250	0.163	0.062	10.2	0.7718	0.07540	0.05819
	mm	6.350	4.140	1.575				
E__-3N3Y-1C0/1	in	0.128	0.138	0.047	17.9	0.6126	0.03414	0.02092
	mm	3.251	3.505	1.194				
E__-3N3Y-1G0/1	in	0.128	0.138	0.051	19.4	0.6426	0.03310	0.02127
	mm	3.251	3.505	1.295				
E__-3N3Y-1S0/1	in	0.128	0.138	0.062	24.2	0.7188	0.02976	0.02139
	mm	3.251	3.505	1.575				
E__-4K4Q-1F0/1	in	0.160	0.200	0.050	11.2	0.7375	0.06613	0.04877
	mm	4.064	5.080	1.270				
E__-4K5Q-2V0/1	in	0.160	0.200	0.100	22.3	1.1062	0.04960	0.05486
	mm	4.064	5.080	2.540				
E__-4Y3Y-0X0/1	in	0.173	0.138	0.032	9.8	0.4859	0.04966	0.02413
	mm	4.394	3.505	0.813				
E__-5Q64-400/1	in	0.200	0.214	0.140	29.1	1.3709	0.04703	0.06448
	mm	5.080	5.436	3.556				
E__-755F-2H0/1	in	0.250	0.190	0.087	12.7	1.0003	0.07897	0.07899
	mm	6.350	4.826	2.210				
E__-755F-2K0/1	in	0.250	0.190	0.090	13.2	1.0196	0.07700	0.07850
	mm	6.350	4.826	2.286				
E__-758X-1F0/1	in	0.250	0.312	0.050	5.4	0.8699	0.16098	0.14004
	mm	6.350	7.925	1.270				
E__-9C3Y-0X0/1	in	0.327	0.138	0.032	5.2	0.4859	0.09387	0.04561
	mm	8.306	3.505	0.813				
E__-AQ3Y-1G0/1	in	0.375	0.138	0.051	6.6	0.6426	0.09697	0.06231
	mm	9.525	3.505	1.295				
E__-B96R-106/1	in	0.394	0.236	0.035	8.5	0.0888	0.01040	0.00092
	mm	10.008	5.994	0.889				
E__-BF60-1H0/1	in	0.400	0.210	0.052	4.4	0.7698	0.17376	0.13376
	mm	10.160	5.334	1.321				
E__-BF75-250/1	in	0.400	0.250	0.075	5.1	1.0294	0.20040	0.20628
	mm	10.160	6.350	1.905				
E__-CH5Q-1S0/1	in	0.437	0.200	0.062	4.8	0.8398	0.17374	0.14590
	mm	11.100	5.080	1.575				
E__-EAAK-3K0/1	in	0.500	0.370	0.125	4.6	1.6347	0.35856	0.58614
	mm	12.700	9.398	3.175				





CORE P/N		F31	F01	FA1	F52	F53	FB2	F82	FTA
	Init perm	15	120	370	850	1050	2000	5000	10000
	Znorm	17	72	575	75	75	150	220	270
E _ _ -1420-100/1	A_L	2.1	16.5	50.8	116.8	144.2	274.7	686.8	1373.6
	Z Typical	0.2	0.8	6.3	0.8	0.8	1.6	2.4	3.0
E _ _ -3D4N-290/1	A_L	6.5	52.1	160.7	369.1	456.0	868.6	2171.4	4342.8
	Z Typical	0.6	2.5	19.9	2.6	2.6	5.2	7.6	9.3
E _ _ -3K4N-1S0/1	A_L	9.2	73.7	227.2	521.9	644.6	1227.9	3069.8	6139.5
	Z Typical	0.8	3.5	28.1	3.7	3.7	7.3	10.7	13.2
E _ _ -3K4N-1T0/1	A_L	9.1	72.5	223.4	513.2	634.0	1207.6	3018.9	6037.9
	Z Typical	0.8	3.5	27.6	3.6	3.6	7.2	10.6	13.0
E _ _ -3N3Y-0X0/1	A_L	14.3	114.1	351.7	808.0	998.1	1901.1	4752.9	9505.7
	Z Typical	1.3	5.4	43.5	5.7	5.7	11.3	16.6	20.4
E _ _ -383Y-1E0/1	A_L	8.9	71.3	220.0	505.3	624.3	1189.1	2972.6	5945.3
	Z Typical	0.8	3.4	27.2	3.5	3.5	7.1	10.4	12.8
E _ _ -7V4N-2G0/1	A_L	13.4	107.2	330.6	759.4	938.1	1786.9	4467.3	8934.6
	Z Typical	1.2	5.1	40.9	5.3	5.3	10.7	15.6	19.2
E _ _ -EAAQ-5C0/1	A_L	26.5	212.1	654.1	1502.6	1856.2	3535.6	8839.0	17678.1
	Z Typical	2.4	10.1	80.9	10.5	10.5	21.1	30.9	38.0
E _ _ -EAEA-870/1	A_L	21.2	169.2	521.8	1198.8	1480.9	2820.7	7051.8	14103.7
	Z Typical	1.9	8.1	64.5	8.4	8.4	16.8	24.7	30.3
E _ _ -X5G2-750/1	A_L	69.5	555.7	1713.3	3935.9	4862.0	9261.0	23152.6	46305.2
	Z Typical	6.3	26.5	211.8	27.6	27.6	55.3	81.0	99.5
E _ _ -6R3Y-1C0/1	A_L	19.4	155.0	477.9	1097.9	1356.2	2583.3	6458.2	12916.4
	Z Typical	1.7	7.4	59.1	7.7	7.7	15.4	22.6	27.7
E _ _ -4K5Q-1F0/1	A_L	16.9	135.2	417.0	958.0	1183.4	2254.1	5635.3	11270.6
	Z Typical	1.5	6.5	51.6	6.7	6.7	13.4	19.7	24.2
E _ _ -BF5Q-2V0/1	A_L	21.1	169.1	521.3	1197.5	1479.3	2817.6	7044.1	14088.2
	Z Typical	1,9	8.1	64.4	8.4	8.4	16.8	24.7	30.3
E _ _ -754N-1S0/1	A_L	18.4	147.3	454.3	1043.7	1289.3	2455.8	6139.5	12279.0
	Z Typical	1.7	7.0	56.2	7.3	7.3	14.7	21.5	26.4
E _ _ -3N3Y-1C0/1	A_L	10.5	84.1	259.2	595.5	735.6	1401.1	3502.7	7005.5
	Z Typical	0.9	4.0	32.0	4.2	4.2	8.4	12.3	15.0
E _ _ -3N3Y-1G0/1	A_L	9.7	77.7	239.5	550.3	679.8	1294.9	3237.1	6474.3
	Z Typical	0.9	3.7	29.6	3.9	3.9	7.7	11.3	13.9
E _ _ -3N3Y-1S0/1	A_L	7.8	62.4	192.5	442.3	546.4	1040.8	2602.0	5204.0
	Z Typical	0.7	3.0	23.8	3.1	3.1	6.2	9.1	11.2
E _ _ -4K4Q-1F0/1	A_L	16.9	135.2	417.0	958.0	1183.4	2254.1	5635.3	11270.6
	Z Typical	1.5	6.5	51.6	6.7	6.7	13.4	19.7	24.2
E _ _ -4K5Q-2V0/1	A_L	8.5	67.6	208.5	479.0	591.7	1127.1	2817,6	5635.3
	Z Typical	0.8	3.2	25.8	3.4	3.4	6.7	9.9	12.1
E _ _ -4Y3Y-0X0/1	A_L	19.3	154.2	475.4	1092.0	1349.0	2569.5	6423.8	12847.6
	Z Typical	1.7	7.4	58.8	7.7	7.7	15.3	22.5	27.6
E _ _ -5Q64-400/1	A_L	6.5	51.7	159.6	366.5	452.8	862.5	2156.1	4312.3
	Z Typical	0.6	2.5	19.7	2.6	2.6	5.1	7.5	9.3
E _ _ -755F-2H0/1	A_L	14.9	119.1	367.1	843.4	1041.9	1984.5	4961.3	9922.6
	Z Typical	1.3	5.7	45.4	5.9	5.9	11.8	17.4	21.3
E _ _ -755F-2K0/1	A_L	14.2	113.9	351.2	806.8	996.7	1898.4	4746.0	9491.9
	Z Typical	1.3	5.4	43.4	5.7	5.7	11.3	16.6	20.4
E _ _ -758X-1F0/1	A_L	34.9	279.1	860.6	1977.0	2442.2	4651.8	11629.6	23259.1
	Z Typical	3.1	13.3	106.4	13.9	13.9	27.8	40.7	50.0
E _ _ -9C3Y-0X0/1	A_L	36.4	291.4	898.5	2064.1	2549.8	4856.8	12142.1	24284.1
	Z Typical	3.3	13.9	111.1	14.5	14.5	29.0	42.5	52.2
E _ _ -AQ3Y-1G0/1	A_L	28.5	227.6	701.8	1612.2	1991.6	3793.5	9483.8	18967.6
	Z Typical	2.6	10.9	86.8	11.3	11.3	22.6	33.2	40.7
E_ _-B96R-106/1	A_L	21.0	168.2	518.6	1191.5	1471.8	-	-	-
	Z Typical	3.6	15.3	122.4	16.0	16.0	-	-	-
E _ _ -BF60-1H0/1	A_L	42.6	340.5	1049.7	2411.5	2978.9	5674.2	14185.5	28370.9
	Z Typical	3.8	16.3	129.8	16.9	16.9	33.9	49.7	60.9
E _ _ -BF75-250/1	A_L	36.7	293.6	905.4	2080.0	2569.4	4894.1	12235.4	24470.7
	Z Typical	3.3	14.0	111.9	14.6	14.6	29.2	42.8	52.6
E _ _ -CH5Q-1S0/1	A_L	39.0	312.1	962.2	2210.5	2730.6	5201.2	13003.1	26006.2
	Z Typical	3.5	14.9	119.0	15.5	15.5	31.0	45.5	55.9
E _ _ -EAAK-3K0/1	A_L	41.4	330.8	1020.1	2343.5	2894.9	5514.1	13785.3	27570.6
	Z Typical	3.7	15.8	126.1	16.5	16.5	32.9	48.3	59.2

Product Group G: Balun Cores

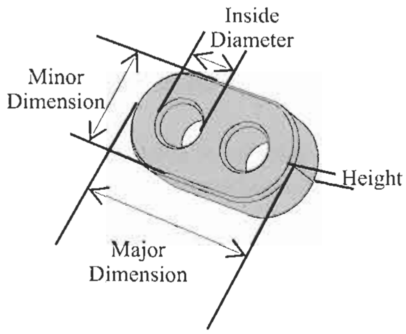
G XX - XXXX - XXX / XX

Product Group · Material · Height · Major Outside Dimension · Minor Outside Dimension · Item Type · Product Class · Coating

Originally designed for balun transformers, matching balanced to unbalanced circuits in the television frequency spectrum, these cores can also be used for wideband and pulse transformers and interference suppression.

Multiaperture cores are designed as suppression components which are compact in size and provide high resistive impedance over a wide frequency band. These cores avoid the self resonance effects experienced with single aperture cores wound with multiple turns. The components listed below are available in a wide variety of materials.

Core Part No.	Units	Height	Major Outside Dimension	Minor Outside Dimension	Inside Diameter	C_1 (cm)	L_e (cm)	A_e (cm)	V_e (cm)
G_ _-153Y-2B1/1	in	0.040	0.138	0.081	0.034	44.5	4.0589	0.09116	3.70020
	mm	1.016	3.505	2.057	0.864				
G_ _-1I41-2D1/1	in	0.053	0.141	0.083	0.034	32.7	4.1015	0.12548	5.14676
	mm	1.346	3.581	2.108	0.864				
G_ _-1K3Y-2B1/1	in	0.055	0.138	0.081	0.034	32.4	4.0589	0.12535	5.08777
	mm	1.397	3.505	2.057	0.864				
G_ _-1Q3Y-2B1/1	in	0.060	0.138	0.081	0.034	29.7	4.0589	0.13674	5.55030
	mm	1.524	3.505	2.057	0.864				
G_ _-1Q41-2D1/1	in	0.060	0.141	0.083	0.034	28.9	4.1015	0.14206	5.82652
	mm	1.524	3.581	2.108	0.864				
G_ _-203Y-2B1/1	in	0.070	0.138	0.081	0.034	25.4	4.0589	0.15953	6.47535
	mm	1.778	3.505	2.057	0.864				
G_ _-2V3Y-2B1/1	in	0.100	0.138	0.081	0.034	17.8	4.0589	0.22790	9.25050
	mm	2.540	3.505	2.057	0.864				
G_ _-2V41-2D1/1	in	0.100	0.141	0.083	0.034	17.3	4.1015	0.23676	9.71087
	mm	2.540	3.581	2.108	0.864				
G_ _-3K7Q-4F1/1	in	0.125	0.270	0.155	0.073	16.4	8.2909	0.50473	41.84635
	mm	3.175	6.858	3.937	1.854				
G_ _-3K7V-4F1/1	in	0.125	0.275	0.155	0.073	16.4	8.2909	0.50473	41.84635
	mm	3.175	6.985	3.937	1.854				
G_ _-5Q4Q-2I1/1	in	0.200	0.165	0.098	0.037	7.9	4.6202	0.58217	26.89737
	mm	5.080	4.191	2.489	0.940				
G_ _-6Z80-4Q1/1	in	0.244	0.280	0.165	0.073	7.8	8.5196	1.09648	93.41530
	mm	6.198	7.112	4.191	1.854				
G_ _-757Q-4F1/1	in	0.250	0.270	0.155	0.070	7.8	8.0970	1.04080	84.27305
	mm	6.350	6.858	3.937	1.778				
G_ _-8K7V-4F1/1	in	0.300	0.275	0.155	0.073	6.8	8.2909	1.21135	100.43125
	mm	7.620	6.985	3.937	1.854				
G_ _-FKFA-8Q1/1	in	0.545	0.535	0.305	0.170	4.9	17.9140	3.69112	661.22674
	mm	13.843	13.589	7.747	4.318				
G_ _-1F33-1Q1/1	in	0.050	0.108	0.060	0.022	30.8	2.7810	0.09024	2.50950
	mm	1.270	2.743	1.524	0.559				
G_ _-1V3Y-2B1/1	in	0.065	0.138	0.081	0.034	27.4	4.0589	0.14814	6.01282
	mm	1.651	3.505	2.057	0.864				
G_ _-3K80-4Q1/1	in	0.125	0.280	0.165	0.073	15.2	8.5196	0.56172	47.85620
	mm	3.175	7.112	4.191	1.854				
G_ _-BQF0-8F1/1	in	0.410	0.525	0.295	0.150	5.6	16.4700	2.95404	486.53085
	mm	10.414	13.335	7.493	3.810				

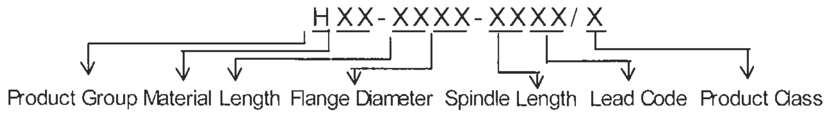


Typical A_L Values in nH/turn^2

	Ni-Zn								
	F31	F21	F01	F14	F24	FA1	F52	F53	FF1
MMG Part No.	15	40	120	220	350	370	850	1050	1500
G__-153Y-2B1/1	4	11	34	62	99	104	240	296	423
G__-1I41-2D1/1	6	15	46	85	135	142	327	404	577
G__-1K3Y-2B1/1	6	16	47	85	136	144	330	407	582
G__-1Q3Y-2B1/1	6	17	51	93	148	157	360	445	635
G__-1Q41-2D1/1	7	17	52	96	152	161	370	457	653
G__-203Y-2B1/1	7	20	59	109	173	183	420	519	741
G__-2V3Y-2B1/1	11	28	85	155	247	261	600	741	1058
G__-2V41-2D1/1	11	29	87	160	254	268	617	762	1088
G__-3K7Q-4F1/1	11	31	92	168	268	283	650	803	1148
G__-3K7V-4F1/1	11	31	92	168	268	283	650	803	1148
G__-5Q4Q-2T1/1	24	63	190	348	554	586	1346	1663	2375
G__-6Z80-4Q1/1	24	65	194	356	566	598	1375	1698	2426
G__-757Q-4F1/1	24	65	194	355	565	598	1373	1696	2423
G__-8K7V-4F1/1	28	73	220	404	643	679	1561	1928	2754
G__-FKFA-8Q1/1	39	104	311	570	906	958	2201	2719	3884
G__-1F33-1Q1/1	6.1	16.3	48.9	89.7	142.7	150.9	346.6	428.1	611.6
G__-1V3Y-2B1/1	6.9	18.3	55.0	100.9	160.5	169.7	389.8	481.6	687.9
G__-3K80-4Q1/1	12.4	33.1	99.4	182.3	290.0	306.6	704.3	870.0	1242.8
G__-BQF0-8F1/1	33.8	90.2	270.5	495.9	788.9	833.9	1915.8	2366.6	3380.8

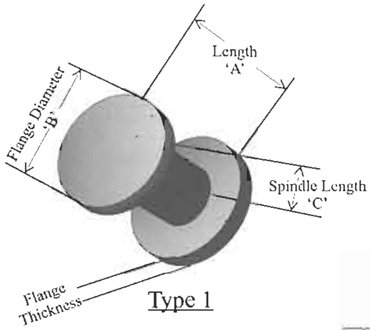
	Mn-Zn								
	F58	FB2	F9Q	FB3	F9N	F82	FT6	FT7	FTA
MMG Part No.	750	2000	2300	2700	4000	5000	6000	7500	10000
G__-153Y-2B1/1	212	564	649	762	1129	1411	1693	2117	2822
G__-1I41-2D1/1	288	769	884	1038	1538	1922	2307	2883	3845
G__-1K3Y-2B1/1	291	776	893	1048	1552	1940	2328	2911	3881
G__-1Q3Y-2B1/1	318	847	974	1143	1693	2117	2540	3175	4233
G__-1Q41-2D1/1	326	870	1001	1175	1741	2176	2611	3264	4352
G__-203Y-2B1/1	370	988	1136	1334	1976	2470	2963	3704	4939
G__-2V3Y-2B1/1	529	1411	1623	1905	2822	3528	4233	5292	7056
G__-2V41-2D1/1	544	1451	1668	1959	2902	3627	4352	5441	7254
G__-3K7Q-4F1/1	574	1530	1760	2066	3060	3825	4590	5738	7650
G__-3K7V-4F1/1	574	1530	1760	2066	3060	3825	4590	5738	7650
G__-5Q4Q-2T1/1	1188	3167	3642	4275	6334	7917	9500	11876	15834
G__-6Z80-4Q1/1	1213	3235	3720	4367	6469	8086	9704	12130	16173
G__-757Q-4F1/1	1211	3231	3715	4361	6461	8076	9692	12115	16153
G__-8K7V-4F1/1	1377	3672	4223	4957	7344	9180	11016	13770	18360
G__-FKFA-8Q1/1	1942	5179	5955	6991	10357	12946	15536	19419	25893
G__-1F33-1Q1/1	305.8	815.5	937.8	1100.9	1631.0	2038.7	2446.5	3058.1	4077.4
G__-1V3Y-2B1/1	344.0	917.3	1054.8	1238.3	1834.5	2293.1	2751.8	3439.7	4586.3
G__-3K80-4Q1/1	621.4	1657.1	1905.6	2237.0	3314.1	4142.7	4971.2	6214.0	8285.3
G__-BQF0-8F1/1	1690.4	4507.8	5183.9	6085.5	9015.6	11269.4	13523.3	16904.2	22538.9

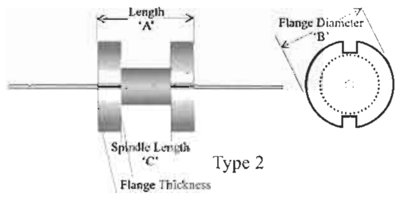
Product Group H: Bobbin Cores

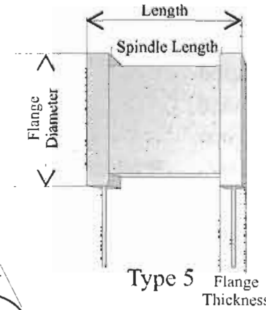


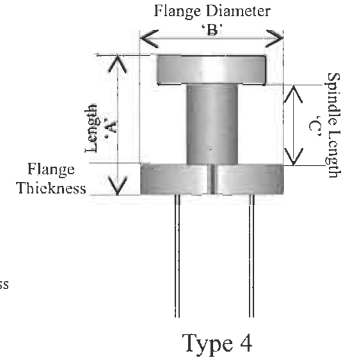
Common applications of ferrite bobbins include power applications, filtering, EMI suppression, and high Q inductors. MMG offers ferrite bobbins in a variety of materials and sizes. The ferrite bobbin design is a popular geometry due to its high current handling capabilities, the stability of inductance, and ease of winding, as well as the electrical stability. Ferrite bobbins can be easily wound with high numbers of turns yielding high inductance, high stability inductors. MMG-North America manufactures bobbins, both leaded and unleaded, in several configurations, surface mountable, axial leaded, and radial leaded. Parts can be packed on tape and reel for auto-insertion. Below is a list of popular core sizes.

Part Number	Units	Type	Length	Flange Diameter	Spindle Length	Flange Thickness	Aw(in^2)
H01-1A22-0F/1	in	1	0.045	0.072	0.045	0.014	0.00023
	mm		1.143	1.829	1.143	0.356	
H01-2F2K-1A/1	in	1	0.085	0.090	0.040	0.020	0.00113
	mm		2.159	2.286	1.016	0.508	
HA1-2F2K-1A/1	in	1	0.085	0.090	0.040	0.020	0.00113
	mm		2.159	2.286	1.016	0.508	
H01-594F-2MM4/1	in	2	0.184	0.155	0.079	0.046	0.00350
	mm		4.674	3.937	2.007	1.168	
H21-594F-2MM4/1	in	2	0.184	0.155	0.079	0.046	0.00350
	mm		4.674	3.937	2.007	1.168	
H01-5A4E-2V/1	in	1	0.185	0.154	0.079	0.058	0.00259
	mm		4.699	3.912	2.007	1.473	
H01-6M5Q-3VPR/1	in	4	0.232	0.200	0.100	0.048	0.00680
	mm		5.893	5.080	2.540	1.219	
H52-6M5Q-3VPR/1	in	4	0.232	0.200	0.100	0.048	0.00680
	mm		5.893	5.080	2.540	1.219	
H01-75AQ-6FPC/1	in	5	0.375	0.250	0.225	0.075	0.00281
	mm		9.525	6.350	5.715	1.905	
HA1-75AQ-6FPC/1	in	5	0.375	0.250	0.225	0.075	0.00281
	mm		9.525	6.350	5.715	1.905	
H52-75AQ-6FPC/1	in	5	0.375	0.250	0.225	0.075	0.00281
	mm		9.525	6.350	5.715	1.905	
H01-7A8A-4FMN/1	in	4	0.257	0.290	0.130	0.034	0.01512
	mm		6.528	7.366	3.302	0.864	
H52-7A8A-4FMN/1	in	4	0.257	0.290	0.130	0.034	0.01512
	mm		6.528	7.366	3.302	0.864	
H01-9F32-6KM4/1	in	2	0.330	0.107	0.070	0.050	0.00426
	mm		8.382	2.718	1.778	1.270	
HA1-9F32-6KM4/1	in	2	0.330	0.107	0.070	0.050	0.00426
	mm		8.382	2.718	1.778	1.270	
H52-9F32-6KM4/1	in	2	0.330	0.107	0.070	0.050	0.00426
	mm		8.382	2.718	1.778	1.270	
H01-EA5Q-BFK2/1	in	2	0.500	0.200	0.110	0.050	0.01800
	mm		12.700	5.080	2.794	1.270	
H52-EA5Q-BFK2/1	in	2	0.500	0.200	0.110	0.050	0.01800
	mm		12.700	5.080	2.794	1.270	
HB2-EA5Q-BFK2/1	in	2	0.500	0.200	0.110	0.050	0.01800
	mm		12.700	5.080	2.794	1.270	









Part Number	Units	Type	Length	Flange Thickness	Spindle Diameter	Flange Diameter	Aw(in2)
H01-HVAF-EAK2/1	in	2	0.625	0.063	0.208	0.365	0.03917
	mm		15.875	1.600	5.283	9.271	
HA1-IOAN-BFK2/1	in	2	0.630	0.115	0.230	0.373	0.02860
	mm		16.002	2.921	5.842	9.474	
HB2-BFA0-8KK2/1	in	2	0.400	0.050	0.150	0.350	0.03000
	mm		10.160	1.270	3.810	8.890	
H72-BFA0-8KK2/1	in	2	0.400	0.050	0.150	0.350	0.03000
	mm		10.160	1.270	3.810	8.890	
H01-EA5L-BFK2/1	in	2	0.500	0.050	0.107	0.196	0.01780
	mm		12.700	1.270	2.718	4.978	
H52-EA5L-BFK2/1	in	2	0.500	0.050	0.107	0.196	0.01780
	mm		12.700	1.270	2.718	4.978	
HB2-EA5L-BFK2/1	in	2	0.500	0.050	0.107	0.196	0.01780
	mm		12.700	1.270	2.718	4.978	
H01-LFAQ-EAK2/1	in	2	0.750	0.125	0.197	0.375	0.04450
	mm		19.050	3.175	5.004	9.525	
H52-LFAQ-EAK2/1	in	2	0.750	0.125	0.197	0.375	0.04450
	mm		19.050	3.175	5.004	9.525	
HB2-LFAQ-EAK2/1	in	2	0.750	0.125	0.197	0.375	0.04450
	mm		19.050	3.175	5.004	9.525	
H01-LFAN-EAK2/1	in	2	0.750	0.125	0.187	0.373	0.04650
	mm		19.050	3.175	4.750	9.474	
H52-LFAN-EAK2/1	in	2	0.750	0.125	0.187	0.373	0.04650
	mm		19.050	3.175	4.750	9.474	
HB2-LFAN-EAK2/1	in	2	0.750	0.125	0.187	0.373	0.04650
	mm		19.050	3.175	4.750	9.474	

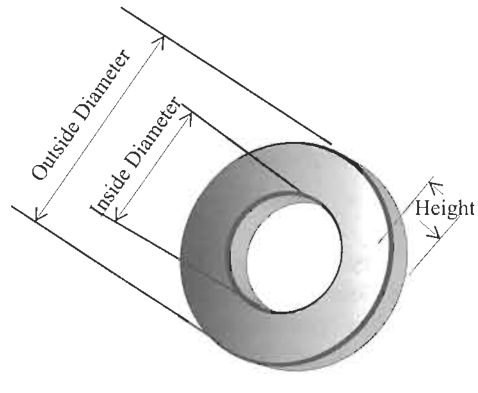
Product Group L: Toroid Cores

L XX - XXXX - XX / XX

Product Group | Material | Outside Diameter | Inside Diameter | Height | Product Class | Coating

Ferrite toroids are ring-shaped components which can be used in a great variety of applications including EMI suppressors, chokes, transformers and inductors. Toroids have many design advantages, for instance, they have a uniform cross section which makes predicting electrical parameters a simple calculation. The closed magnetic structure of toroids confines magnetic flux within the core body which gives the structure good shielding characteristics as well as optimal inductance to core volume ratio. MMG manufactures toroids in a wide range of materials and sizes from .08 inches to greater than 1 inch in diameter and that can be manufactured in any of our materials in order to optimize the part for a given application.

Core Part No.	Outside Diameter (in.)	Outside Diameter (mm)	Inside Diameter (in)	Inside Diameter (mm)	Height (in)	Height (mm)	C_1 (mm^{-1})	L_e (mm)	A_e (mm^2)	V_e (mm^3)
L__-2A1F-0V/1	0.08	2.03	0.05	1.27	0.03	0.762	17.63	4.998	0.284	1.42
L__-2A1F-14/1	0.08	2.03	0.05	1.27	0.039	0.9906	13.53	4.998	0.369	1.85
L__-2A1F-1F/1	0.08	2.032	0.05	1.27	0.05	1.27	10.55	4.998	0.474	2.37
L__-2V1F-0V/1	0.1	2.54	0.05	1.27	0.03	0.762	11.93	5.531	0.464	2.56
L__-2V1F-14/1	0.1	2.54	0.05	1.27	0.039	0.9906	9.16	5.531	0.604	3.34
L__-2V1F-1F/1	0.1	2.54	0.05	1.27	0.05	1.27	7.14	5.531	0.775	4.29
L__-2V20-0V/1	0.1	2.54	0.07	1.778	0.03	0.762	23.25	6.645	0.286	1.90
L__-2V20-14/1	0.1	2.54	0.07	1.778	0.039	0.9906	17.85	6.645	0.372	2.47
L__-2V20-1F/1	0.1	2.54	0.07	1.778	0.05	1.27	13.92	6.645	0.478	3.17
L__-3F1F-0V/1	0.12	3.048	0.05	1.27	0.03	0.762	9.41	5.985	0.636	3.81
L__-3F1F-14/1	0.12	3.048	0.05	1.27	0.039	0.9906	7.24	5.985	0.826	4.95
L__-3F1F-1F/1	0.12	3.048	0.05	1.27	0.05	1.27	5.65	5.985	1.060	6.34
L__-3V20-0V/1	0.135	3.429	0.07	1.778	0.03	0.762	12.55	7.615	0.607	4.62
L__-3V20-14/1	0.135	3.429	0.07	1.778	0.039	0.9906	9.65	7.615	0.789	6.02
L__-3V20-1F/1	0.135	3.429	0.07	1.778	0.05	1.27	7.53	7.615	1.011	7.70
L__-3Y20-0V/1	0.138	3.5052	0.07	1.778	0.03	0.762	12.18	7.704	0.633	4.87
L__-3Y20-14/1	0.138	3.5052	0.07	1.778	0.039	0.9906	9.35	7.704	0.824	6.35
L__-3Y20-1F/1	0.138	3.5052	0.07	1.778	0.05	1.27	7.29	7.704	1.057	8.15
L__-4F20-0V/1	0.155	3.937	0.07	1.778	0.03	0.762	10.41	8.105	0.779	6.31
L__-4F20-14/1	0.155	3.937	0.07	1.778	0.039	0.9906	7.99	8.105	1.015	8.22
L__-4F20-1F/1	0.155	3.937	0.07	1.778	0.05	1.27	6.23	8.105	1.302	10.55
L__-4F29-0V/1	0.155	3.937	0.079	2.0066	0.03	0.762	12.28	8.676	0.706	6.13
L__-4F29-14/1	0.155	3.937	0.079	2.0066	0.039	0.9906	9.43	8.676	0.920	7.98
L__-4F29-1F/1	0.155	3.937	0.079	2.0066	0.05	1.27	7.35	8.676	1.180	10.24
L__-4F2H-0V/1	0.155	3.937	0.087	2.2098	0.03	0.762	14.27	9.134	0.640	5.85
L__-4F2H-14/1	0.155	3.937	0.087	2.2098	0.039	0.9906	10.98	9.134	0.832	7.60
L__-4F2H-1F/1	0.155	3.937	0.087	2.2098	0.05	1.27	8.56	9.134	1.067	9.74
L__-5F2K-14/1	0.19	4.826	0.09	2.286	0.039	0.9906	8.50	10.21	1.201	12.26
L__-5F2K-1F/1	0.19	4.826	0.09	2.286	0.05	1.27	6.63	10.21	1.540	15.72
L__-5F2K-2K/1	0.19	4.826	0.09	2.286	0.09	2.286	3.68	10.21	2.777	28.35
L__-6K3F-1Q/1	0.23	5.842	0.12	3.048	0.06	1.524	6.36	13.029	2.047	26.67
L__-6K3F-3F/1	0.23	5.842	0.12	3.048	0.12	3.048	3.17	13.029	4.108	53.52
L__-6K3F-3K/1	0.23	5.842	0.12	3.048	0.125	3.175	3.04	13.029	4.282	55.75
L__-8K3K-3K/1	0.3	7.62	0.125	3.175	0.125	3.175	2.26	14.983	6.627	99.29
L__-8K3K-5C/1	0.3	7.62	0.125	3.175	0.187	4.7498	1.51	14.983	9.899	148.32
L__-AQ5C-3K/1	0.375	9.525	0.187	4.7498	0.125	3.175	2.84	20.716	7.300	151.24
L__-AQ5C-5C/1	0.375	9.525	0.187	4.7498	0.187	4.7498	1.90	20.716	10.905	225.90
L__-EA87-5C/1	0.5	12.7	0.287	7.2898	0.187	4.7498	2.38	29.844	12.524	373.76
L__-EA87-75/1	0.5	12.7	0.287	7.2898	0.25	6.35	1.78	29.844	16.742	499.66
L__-EA8X-5C/1	0.5	12.7	0.312	7.9248	0.187	4.7498	2.80	31.217	11.144	347.87
L__-EA8X-75/1	0.5	12.7	0.312	7.9248	0.25	6.35	2.10	31.217	14.898	465.05



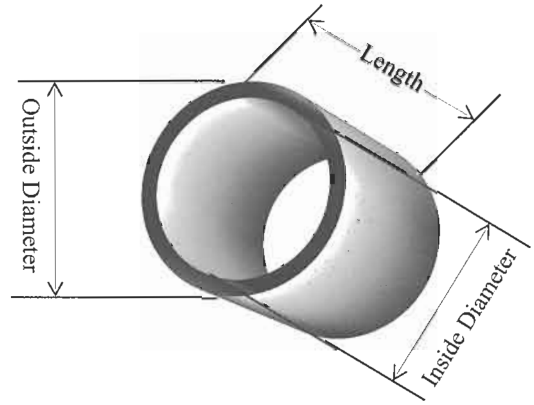
Typical A_L Values nH/Turn^2

Material / Permeability	NickelZinc							Manganese Zinc									
	F31	F21	F01	FA1	F52	F53	FF1	F58	FB2	F9Q	FB3	F9N	F65	F82	FT6	FT7	FTA
Part Number	15	40	120	370	850	1050	1500	750	2000	2300	2700	4000	4500	5000	6000	7500	10000
L__-2A1F-0V/1	1.1	2.9	9	26	61	75	107	53	143	164	192	314	356	356	428	535	713
L__-2A1F-14/1	1.4	3.7	11	34	79	98	139	70	186	214	251	409	464	464	557	696	929
L__-2A1F-1F/1	1.8	4.8	14	44	101	125	179	89	238	274	322	524	596	596	715	894	1191
L__-2V1F-0V/1	1.6	4.2	13	39	90	111	158	79	211	242	284	464	527	527	632	790	1054
L__-2V1F-14/1	2.1	5.5	16	51	117	144	206	103	274	316	371	604	686	686	823	1029	1372
L__-2V1F-1F/1	2.6	7.0	21	65	150	185	264	132	352	405	475	775	880	880	1056	1320	1760
L__-2V20-0V/1	0.8	2.2	6	20	46	57	81	41	108	124	146	238	270	270	324	405	540
L__-2V20-14/1	1.1	2.8	8	26	60	74	106	53	141	162	190	310	352	352	422	528	704
L__-2V20-1F/1	1.4	3.6	11	33	77	95	135	68	181	208	244	397	452	452	542	677	903
L__-3F1F-0V/1	2.0	5.3	16	49	114	140	200	100	267	307	361	588	668	668	801	1002	1335
L__-3F1F-14/1	2.6	6.9	21	64	148	182	260	130	347	399	469	764	868	868	1041	1302	1736
L__-3F1F-1F/1	3.3	8.9	27	82	189	234	334	167	445	512	601	979	1112	1112	1334	1668	2224
L__-3V20-0V/1	1.5	4.0	12	37	85	105	150	75	200	230	270	441	501	501	601	751	1001
L__-3V20-14/1	2.0	5.2	16	48	111	137	195	98	260	300	352	573	651	651	781	977	1302
L__-3V20-1F/1	2.5	6.7	20	62	142	175	250	125	334	384	451	734	834	834	1001	1252	1669
L__-3Y20-0V/1	1.5	4.1	12	38	88	108	155	77	206	237	279	454	516	516	619	774	1032
L__-3Y20-14/1	2.0	5.4	16	50	114	141	202	101	269	309	363	592	672	672	807	1008	1344
L__-3Y20-1F/1	2.6	6.9	21	64	147	181	259	129	345	397	466	759	862	862	1035	1294	1725
L__-4F20-0V/1	1.8	4.8	14	45	103	127	181	91	242	278	326	531	604	604	725	906	1208
L__-4F20-14/1	2.4	6.3	19	58	134	165	236	118	315	362	425	692	787	787	944	1180	1573
L__-4F20-1F/1	3.0	8.1	24	75	172	212	303	151	404	464	545	888	1009	1009	1211	1514	2018
L__-4F29-0V/1	1.5	4.1	12	38	87	107	153	77	205	235	276	450	512	512	614	767	1023
L__-4F29-14/1	2.0	5.3	16	49	113	140	200	100	267	306	360	586	666	666	800	999	1333
L__-4F29-1F/1	2.6	6.8	21	63	145	179	256	128	342	393	462	752	855	855	1026	1282	1709
L__-4F2H-0V/1	1.3	3.5	11	33	75	92	132	66	176	203	238	387	440	440	528	660	881
L__-4F2H-14/1	1.7	4.6	14	42	97	120	172	86	229	263	309	504	572	572	687	858	1144
L__-4F2H-1F/1	2.2	5.9	18	54	125	154	220	110	294	338	396	646	734	734	881	1101	1468
L__-5F2K-14/1	2.2	5.9	18	55	126	155	222	111	296	340	399	650	739	739	887	1108	1478
L__-5F2K-1F/1	2.8	7.6	23	70	161	199	284	142	379	436	512	834	948	948	1137	1422	1896
L__-5F2K-2K/1	5.1	13.7	41	126	291	359	513	256	684	786	923	1504	1709	1709	2051	2564	3418
L__-6K3F-1Q/1	3.0	7.9	24	73	168	207	296	148	395	454	533	869	987	987	1185	1481	1975
L__-6K3F-3F/1	5.9	15.9	48	147	337	416	594	297	793	911	1070	1744	1981	1981	2378	2972	3963
L__-6K3F-3K/1	6.2	16.5	50	153	351	434	620	310	827	951	1116	1819	2067	2067	2480	3100	4134
L__-8K3K-3K/1	8.3	22.2	67	206	472	584	834	417	1112	1278	1501	2445	2779	2779	3335	4168	5558
L__-8K3K-5C/1	12.5	33.2	100	307	706	872	1245	623	1660	1909	2241	3652	4150	4150	4980	6225	8300
L__-AQ5C-3K/1	6.6	17.7	53	164	376	465	664	332	886	1018	1196	1948	2214	2214	2657	3321	4428
L__-AQ5C-5C/1	9.9	26.5	79	245	562	694	992	496	1323	1521	1786	2910	3307	3307	3968	4960	6614
L__-EA87-5C/1	7.9	21.1	63	195	448	554	791	396	1055	1213	1424	2320	2637	2637	3164	3955	5273
L__-EA87-75/1	10.6	28.2	85	261	599	740	1057	529	1410	1621	1903	3101	3524	3524	4229	5286	7048
L__-EA8X-5C/1	6.7	17.9	54	166	381	471	673	336	897	1032	1211	1974	2243	2243	2692	3365	4486
L__-EA8X-75/1	9.0	24.0	72	222	510	630	900	450	1200	1380	1620	2639	2999	2999	3599	4499	5998

Product Group P: Sleeve Cores

P XX - XXXX - XX / X

Product Group Material Length Outside Diameter Inside Diameter Product Class



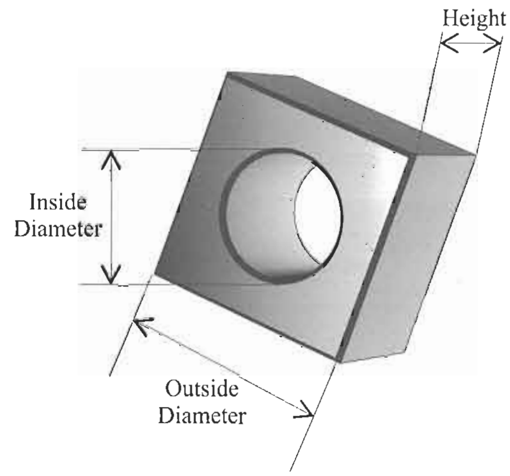
Ferrite sleeves are very similar in shape to toroids. Sleeves generally have thin walls and close mechanical tolerances. They can be placed over the windings of an open magnetic structure component to shield nearby components from stray magnetic flux. Sleeves have an added benefit, in some cases a sleeve slipped over a bobbin can significantly raise the inductance.

Core Part No.	Units	Length	Tolerence	Outside Diameter	Tolerence	Inside Diameter	Tolerence
P01-5Q2I-1X/1	In.	0.200	0.007	0.088	0.002	0.067	0.003
	mm	5.080	0.178	2.235	0.051	1.702	0.076
P01-672T-24/1	In.	0.217	0.010	0.098	0.002	0.074	0.003
	mm	5.512	0.254	2.489	0.051	1.880	0.076
P01-752T-24/1	In.	0.250	0.010	0.098	0.002	0.074	0.003
	mm	6.350	0.254	2.489	0.051	1.880	0.076
P01-873D-2M/1	In.	0.287	0.008	0.118	0.002	0.092	0.002
	mm	7.290	0.203	2.997	0.051	2.337	0.051
P01-9F49-2T/1	In.	0.330	0.010	0.149	0.002	0.098	0.003
	mm	8.382	0.254	3.785	0.051	2.489	0.076
P01-A549-35/1	In.	0.355	0.007	0.149	0.002	0.110	0.002
	mm	9.017	0.178	3.785	0.051	2.794	0.051
PA1-AI49-3D/1	In.	0.368	0.007	0.149	0.002	0.118	0.002
	mm	9.347	0.178	3.785	0.051	2.997	0.051
PA1-AI4C-3D/1	In.	0.368	0.007	0.152	0.002	0.118	0.002
	mm	9.347	0.178	3.861	0.051	2.997	0.051
P52-DV7A-5U/1	In.	0.485	0.015	0.255	0.005	0.204	0.004
	mm	12.319	0.381	6.477	0.127	5.182	0.102
P52-EA7A-60/1	In.	0.500	0.015	0.255	0.005	0.210	0.003
	mm	12.700	0.381	6.477	0.127	5.334	0.076

Squaroids

S XX - XXXX -XX/ XX

Material Code — Height — Outer Diameter — Inside Diameter — Product Class — Coating



Squaroids are toroids with a square-shaped outer dimension. Unlike toroids their square shape allows them to be mounted vertically on a board without using a header or mounting device. These cores can also be used in various applications including EMI suppressors, chokes, transformers and inductors. Squaroids also have a closed magnetic structure which confines magnetic flux within the core body giving the structure good shielding characteristics as well as optimal inductance to core volume ratio.

MMG Part No.	Units	Outside Diameter	Inside Diameter	Height	C1	L_e (cm)	A_e (cm)	V_e (cm)
S_ _- 1A23-13/1	in	0.073	0.038	0.045	84.2	0.413	0.005	0.202
	mm	1.854	0.965	1.143				
S_ _- 1C22-10/1	in.	0.072	0.035	0.047	73.0	0.392	0.005	0.211
	mm	1.829	0.889	1.194				
S_ _- 4F22-10/1	in.	0.072	0.035	0.155	22.1	0.392	0.005	0.202
	mm	1.829	0.889	3.937				
S_ _- 202V-1K/1	in.	0.100	0.055	0.070	59.1	0.583	0.005	0.286
	mm	2.540	1.397	1.778				

Standard Material Permeability

	FA1	F52	F53	F9Q	F9N	F82	FT6	FT7	FTA
	370	850	1050	2300	4400	5000	6000	7500	10000
MMG Part No.	Nominal AL Values nH/N2								
S_ _- 1A23-13/1	55	127	157	343	657	746	896	1120	1493
S_ _- 1C22-10/1	64	146	181	396	758	861	1034	1292	1723
S_ _- 4F22-10/1	210	483	597	1307	2500	2841	3409	4261	5681
S_ _- 202V-1K/1	79	181	223	489	936	1063	1276	1595	2126

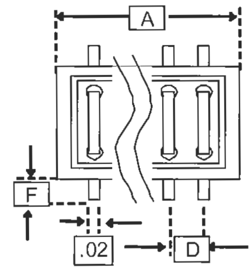
Surface Mount Power/Data Line Suppression Ferrites

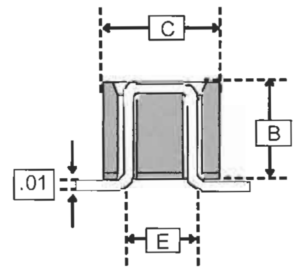
Mechanical Parameters

Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-	E	tol +/-	F	tol +/-
H	DS52-3A5F-R6ES5	3 line sm	in.	0.190	0.005	0.115	0.005	0.177	0.005	0.050	typ	0.100	typ	0.039	typ
		suppressor	mm.	4.83	0.13	2.92	0.13	4.5	0.13	1.27		2.54		0.99	
I	DS52-3A6V-R8ES4	4 line sm	in.	0.240	0.005	0.115	0.005	0.177	0.005	0.050	typ	0.100	typ	0.039	typ
		suppressor	mm.	6.1	0.13	2.92	0.13	4.5	0.13	1.27		2.54		0.99	
J	DS52-3ACV-RGES3	8 line sm	in.	0.450	0.010	0.115	0.005	0.177	0.005	0.050	typ	0.100	typ	0.039	typ
		suppressor	mm.	11.43	0.25	2.92	0.13	4.5	0.13	1.27		2.54		0.99	

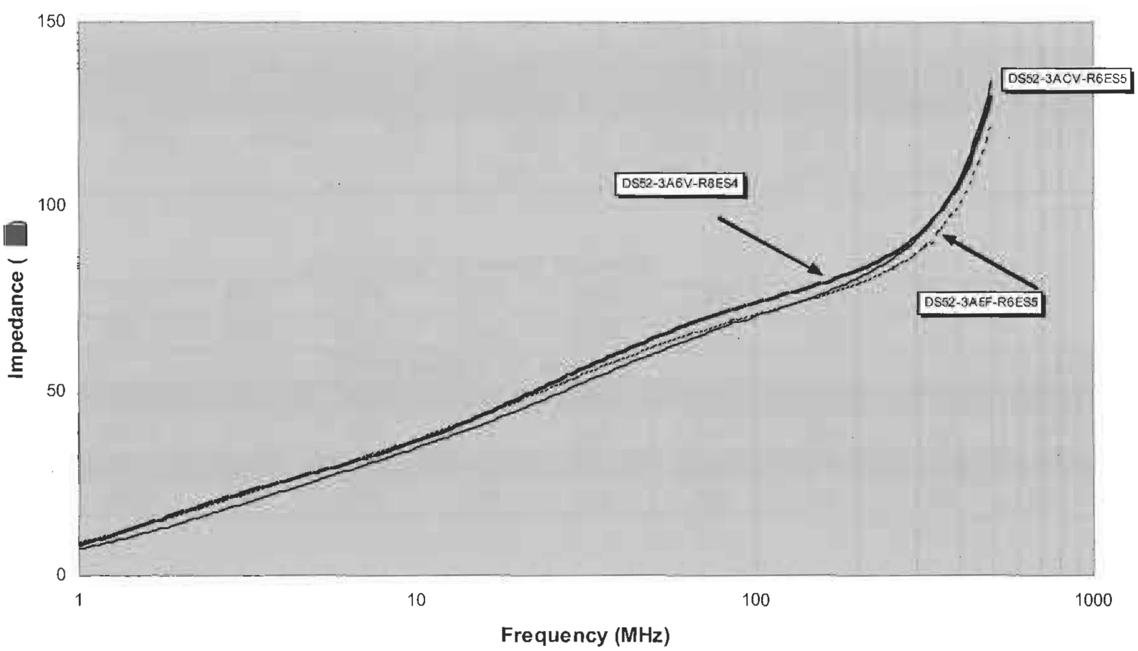
Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz
H	DS52-3A5F-R6ES5	3 line sm suppressor	75
I	DS52-3A6V-R8ES4	4 line sm suppressor	75
J	DS52-3ACV-RGES3	8 line sm suppressor	75





Impedance vs. Frequency

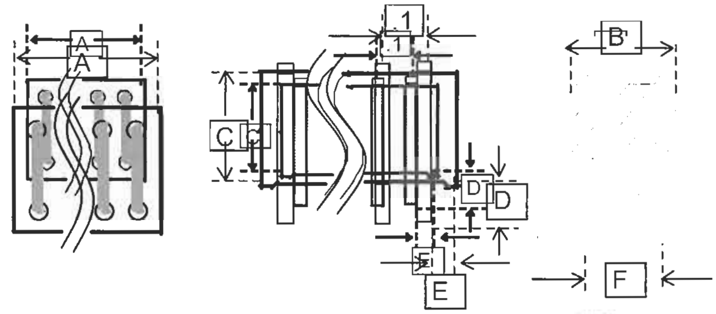


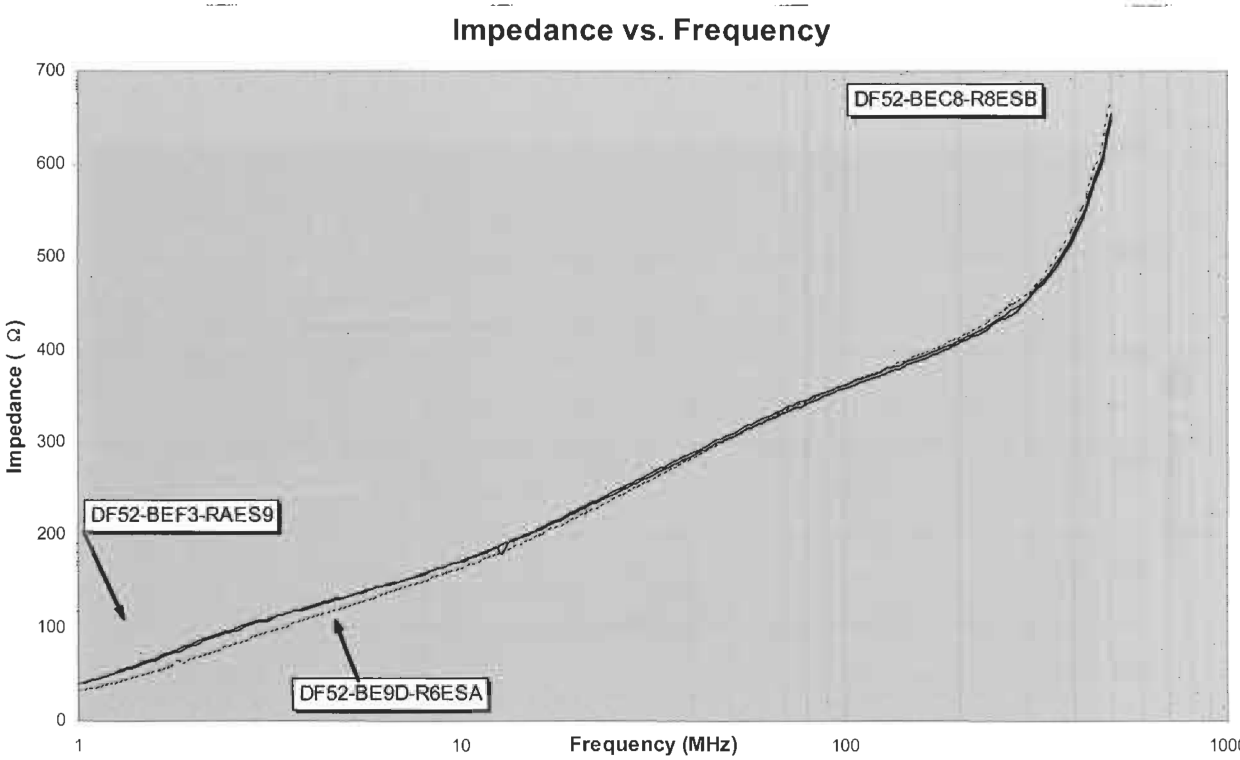
Power/Data Line Suppression Ferrites

Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-	E	tol +/-	F	tol +/-
A	DF52-BEF3-RAES9	5 line P.C.	in.	0.528	0.010	0.428	0.010	0.399	0.010	0.125	typ	0.064	typ	0.300	typ
		mt suppressor	mm.	13.41	0.25	10.87	0.25	10.13	0.25	0.43		1.63		7.62	
B	DF52-BEC8-R8ESB	4 line P.C.	in.	0.428	0.010	0.428	0.010	0.399	0.010	0.125	typ	0.064	typ	0.300	typ
		mt suppressor	mm.	10.87	0.25	10.87	0.25	10.13	0.25	0.43		1.63		7.62	
D	DF52-BE9D-R6ESA	3 line P.C.	in.	0.328	0.010	0.428	0.010	0.399	0.010	0.125	typ	0.064	typ	0.300	typ
		mt suppressor	mm.	8.33	0.25	10.87	0.25	10.13	0.25	0.43		1.63		7.62	

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz
A	DF52-BEF3-RAES9	5 line P.C. mt suppressor	360
B	DF52-BEC8-R8ESB	4 line P.C. mt suppressor	360
D	DF52-BE9D-R6ESA	3 line P.C. mt suppressor	360





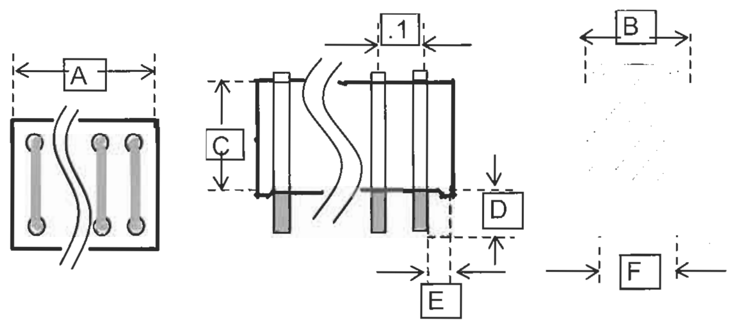
Power/Data Line Suppression Ferrites

Mechanical Parameters

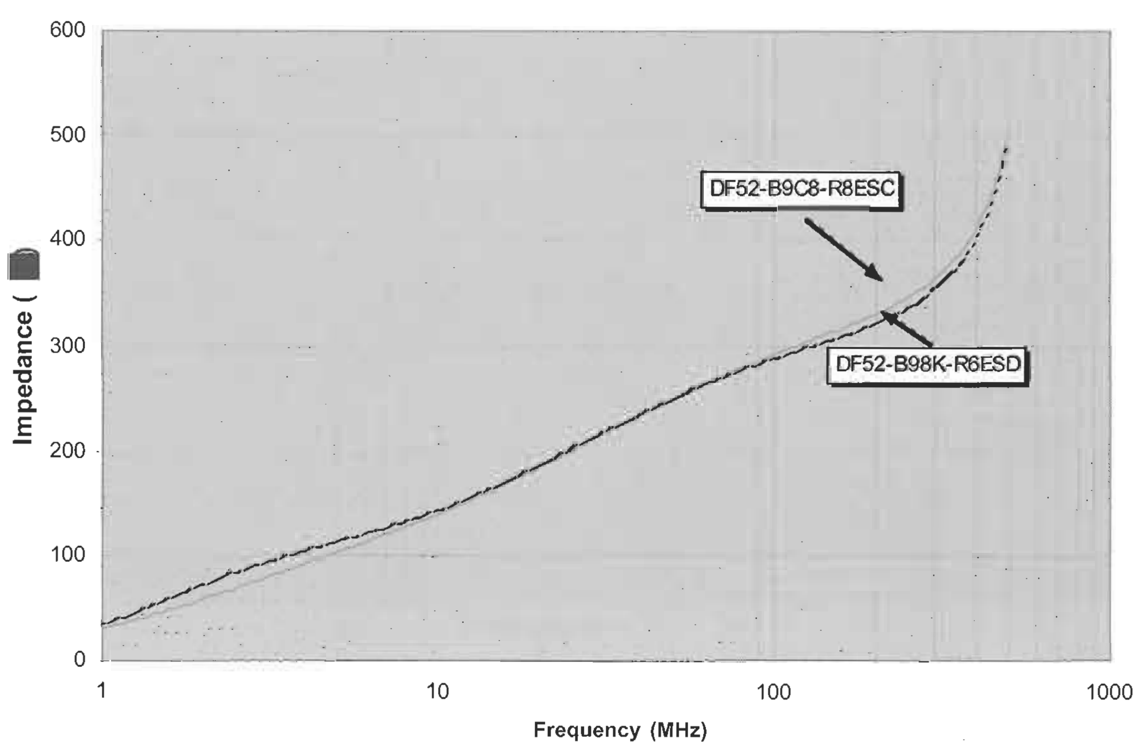
Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-	E	tol +/-	F	tol +/-
C	DF52-B9C8-R8ESC	4 line P.C.	in.	0.428	0.010	0.216	0.010	0.394	0.010	0.125	typ	0.064	typ	0.100	typ
		mt suppressor	mm.	10.9	0.25	5.49	0.25	10	0.25	0.43		1.63		2.54	
E	DF52-B98K-R6ESD	3 line P.C.	in.	0.300	0.010	0.200	0.010	0.394	0.010	0.125	typ	0.050	typ	0.100	typ
		mt suppressor	mm.	7.62	0.25	5.08	0.25	10	0.25	0.43		1.27		2.54	

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz
C	DF52-B9C8-R8ESC	4 line P.C. mt suppressor	300
E	DF52-B98K-R6ESD	3 line P.C. mt suppressor	280



Impedance vs. Frequency



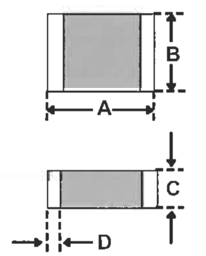
Multilayer Chip Impedance Devices

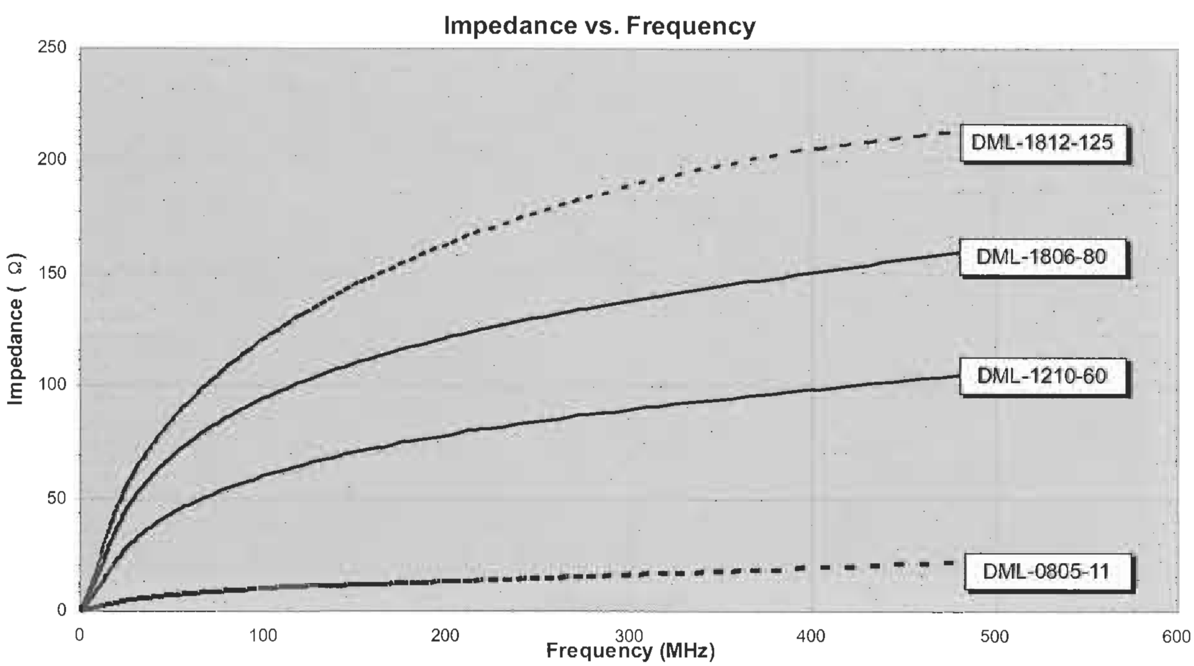
Mechanical Parameters

Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-
Q	DML-0805-11	Chip Inductor	in.	0.079	0.008	0.049	0.008	0.035	0.008	0.015	0.008
			mm.	2.01	0.2	1.24	0.2	0.89	0.2	0.38	0.2
R	DML-1210-60	Chip Inductor	in.	0.126	0.008	0.098	0.008	0.051	0.008	0.015	0.008
			mm.	3.2	0.2	2.49	0.2	1.3	0.2	0.38	0.2
S	DML-1806-80	Chip Inductor	in.	0.177	0.010	0.063	0.010	0.063	0.010	0.015	0.008
			mm.	4.5	0.25	1.6	0.25	1.6	0.25	0.38	0.2
T	DML-1812-125	Chip Inductor	in.	0.177	0.01	0.126	0.01	0.059	0.01	0.015	0.008
			mm.	4.5	0.25	3.2	0.25	1.5	0.25	0.38	0.2

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz	DC Resistance (Ω) Max.	Rated Current (mA) Max.
Q	DML-0805-11	Chip Inductor	11	0.1	600
R	DML-1210-60	Chip Inductor	60	0.3	400
S	DML-1806-80	Chip Inductor	80	0.5	200
T	DML-1812-125	Chip Inductor	125	0.4	300





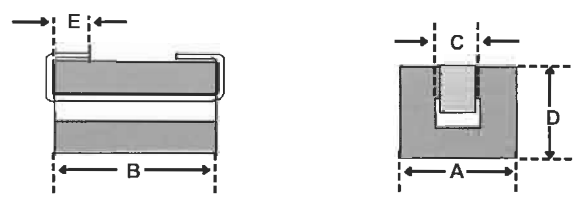
Surface Mount Beads

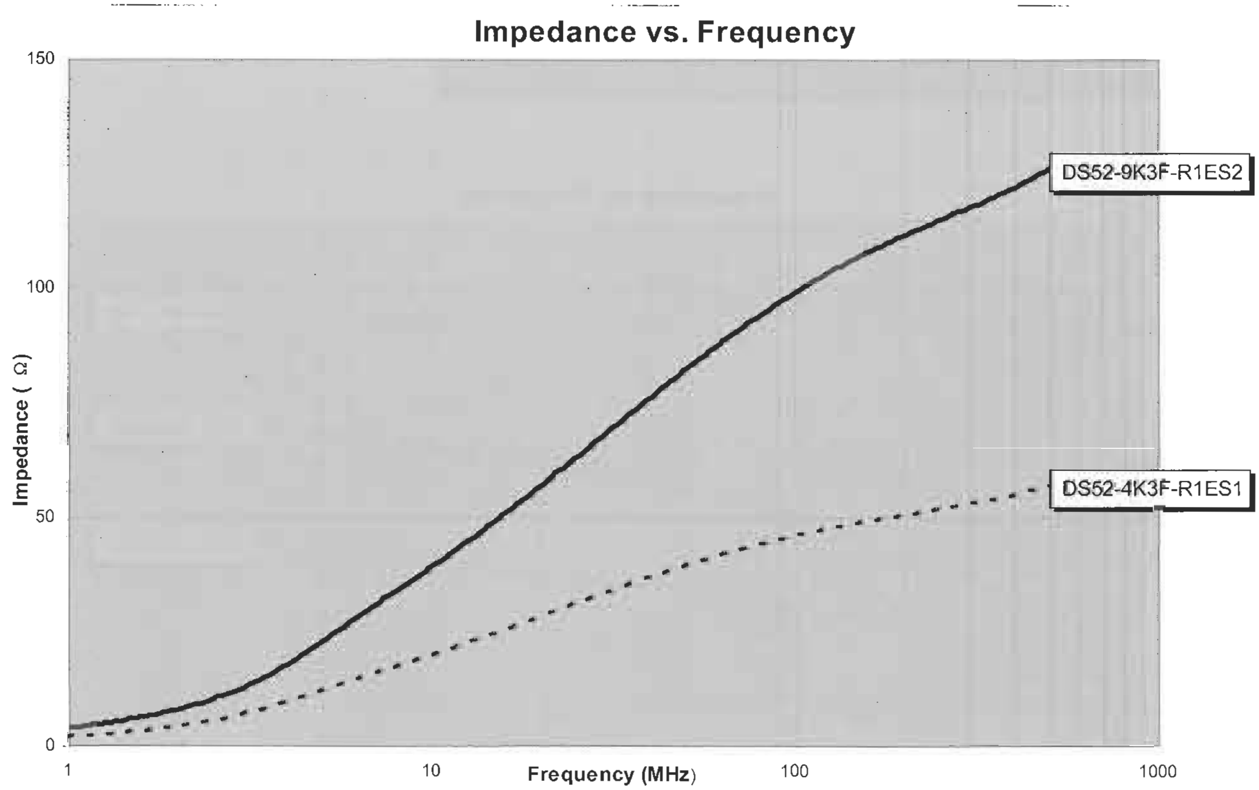
Mechanical Parameters

Kit Section	MMG Part No.	Description		Dimension A	Tolerance +/-	Dimension B	Tolerance +/-	Dimension C	Tolerance +/-	Dimension D	Tolerance +/-	Dimension E	Tolerance +/-
U	DS52-4K3F-R1ES1	Surface mount	in.	0.120	0.005	0.160	0.010	0.058	0.003	0.100	0.005	0.062	typ
		bead	mm.	3.05	0.13	4.06	0.25	1.46	0.08	2.54	0.13	1.57	
V	DS52-9K3F-R1ES2	Surface mount	in.	0.120	0.005	0.335	0.010	0.058	0.003	0.100	0.005	0.062	typ
		bead	mm.	3.05	0.13	8.51	0.25	1.46	0.08	2.54	0.13	1.57	

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz
U	DS52-4K3F-R1ES1	Surface mount bead	50
V	DS52-9K3F-R1ES2	Surface mount bead	90





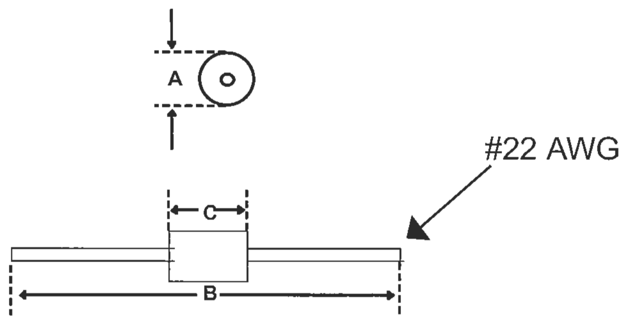
Axial Lead Ferrites

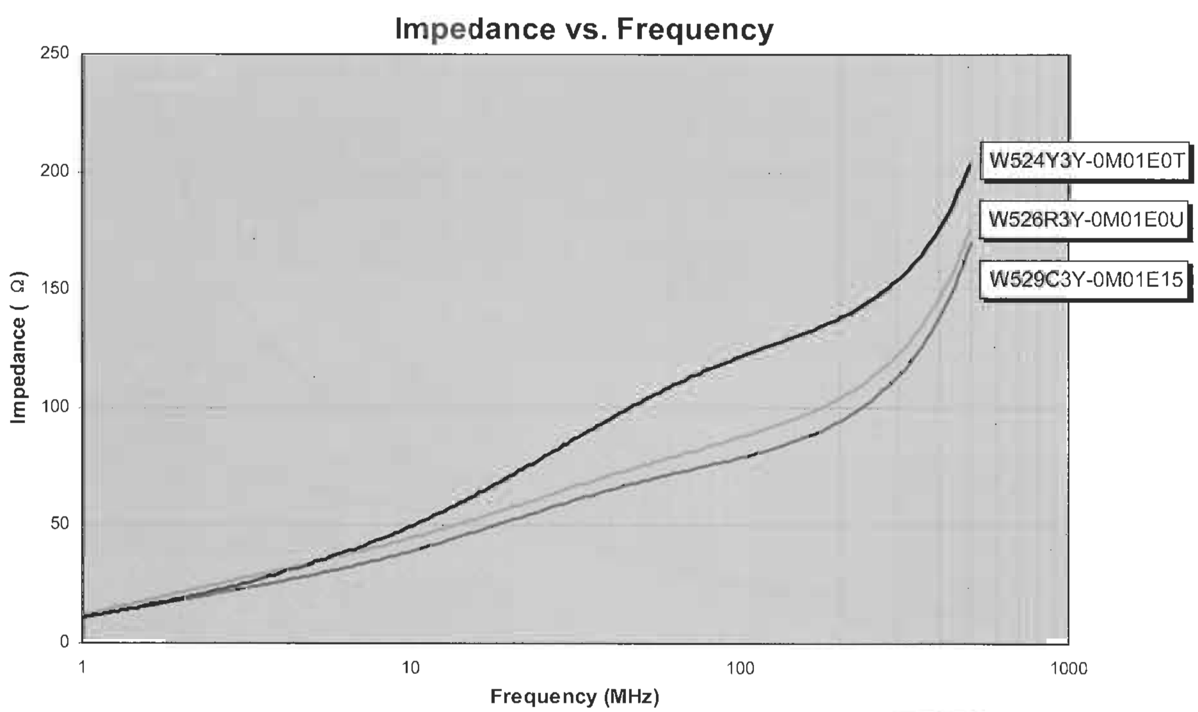
Mechanical Parameters

Kit Section	MMG Part No.	Description		Dimension A	Tolerance +/-	Dimension B	Tolerance +/-	Dimension C	Tolerance +/-
N	W524Y3Y-0M01E0T	Bead on lead	in.	0.138	0.008	2.656	typ	0.173	0.010
			mm.	3.51	0.2	67.5		4.39	0.25
N1	W526R3Y-0M01E0U	Bead on lead	in.	0.138	0.008	2.656	typ	0.236	0.010
			mm.	3.51	0.2	67.5		5.99	0.25
N2	W529C3Y-0M01E15	Bead on lead	in.	0.138	0.008	2.656	typ	0.327	0.010
			mm.	3.51	0.2	67.5		8.31	0.25

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100 MHz
N	W524Y3Y-0M01E0T	Bead on lead	60
N1	W526R3Y-0M01E0U	Bead on lead	80
N2	W529C3Y-0M01E15	Bead on lead	110





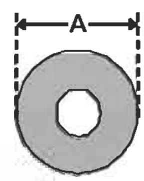
Ni-Zn Bead & Toroid

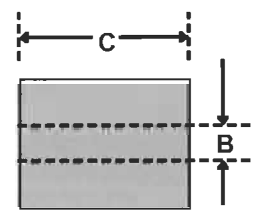
Mechanical Parameters

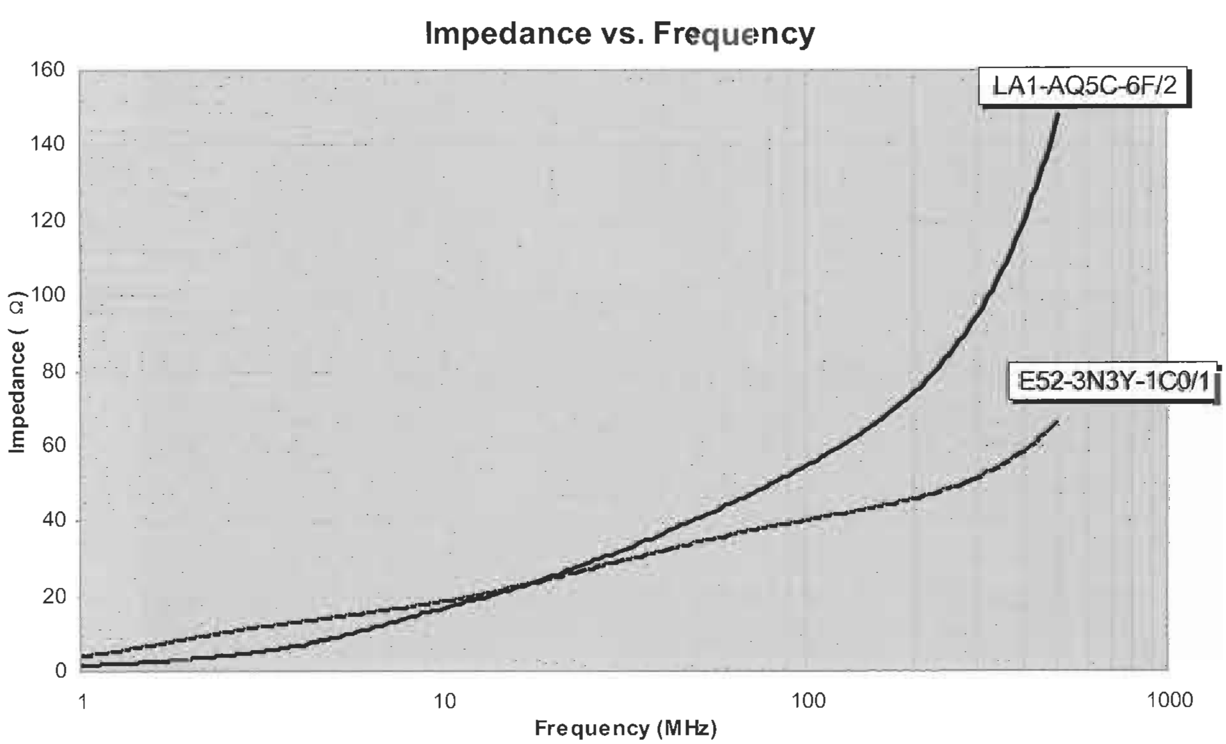
Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-
G	**LA1-AQ5C-6F/2**	Ni-Zn Toroid	in.	0.375	0.015	0.187	0.010	0.23	0.010
			mm.	5.84	0.25	9.53	0.38	4.75	0.25
X	**E52-3N3Y-1C0/1**	Ni-Zn Bead	in.	0.138	0.008	0.047	0.006	0.128	0.008
			mm.	3.51	0.2	1.19	0.15	3.25	0.2

Electrical Parameters

Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100
G	**LA1-AQ5C-6F/2**	Ni-Zn Toroid	55
X	**E52-3N3Y-1C0/1**	Ni-Zn Bead	35



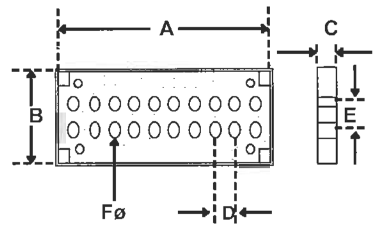




Connector Shields

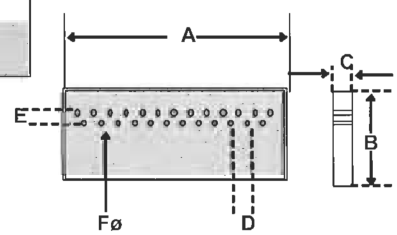
Mechanical Parameters

Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-	E	tol +/-	F	tol +/-
Y	**CSA1-20170-CS/1**	25 hole connector shield	in.	1.470	0.030	0.447	0.010	0.070	0.010	0.054	0.003	0.112	0.003	0.030	0.003
		staggered hole spacing	mm.	37.34	0.76	11.35	0.25	1.78	0.25	1.37	0.08	2.84	0.08	0.76	0.08
Z	**CSA1-3KTK-B7/1**	20 hole connector shield	in.	1.000	0.020	0.392	0.010	0.125	0.010	0.100	0.005	0.100	0.005	0.045	0.003
		in-line hole spacing	mm.	25.4	0.51	9.96	0.25	3.18	0.25	2.54	0.13	2.54	0.13	1.14	0.08

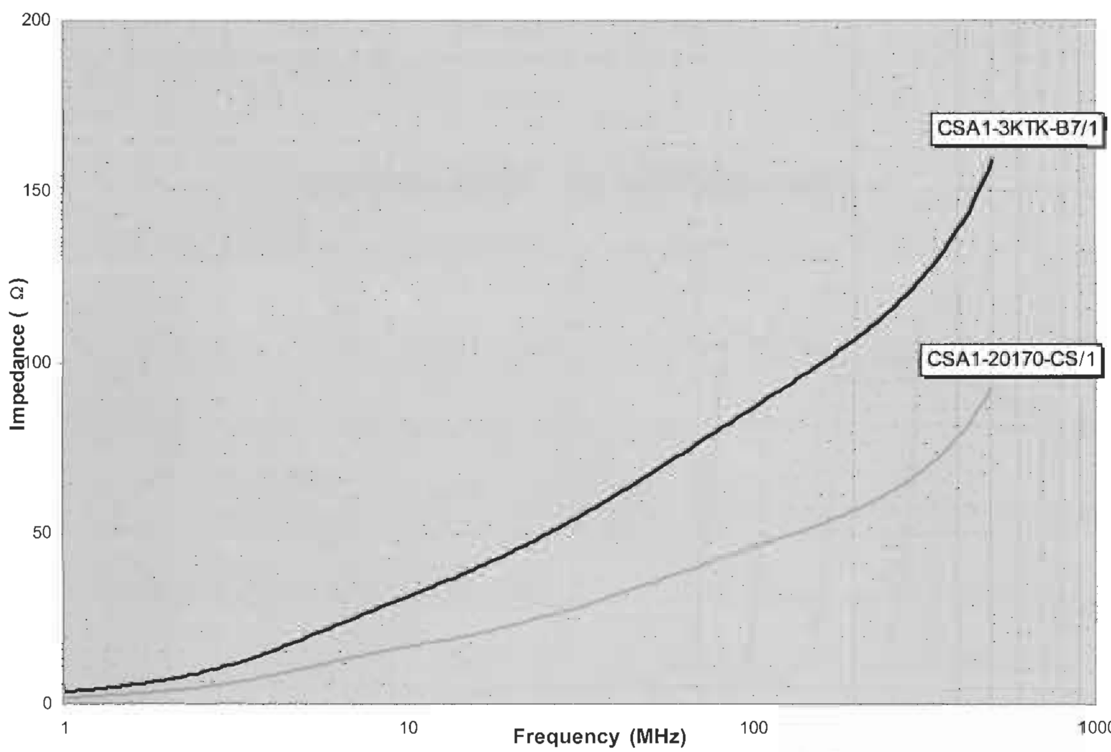


Electrical Parameters

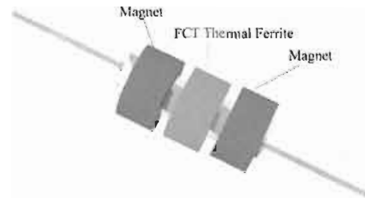
Kit Section	MMG Part No.	Description	Typical Impedance (Ω) @100
Y	CSA1-20170-CS/1	25 hole connector shield staggered hole spacing	300
Z	**CSA1-3KTK-B7/1**	20 hole connector shield in-line hole spacing	280



Impedance vs. Frequency



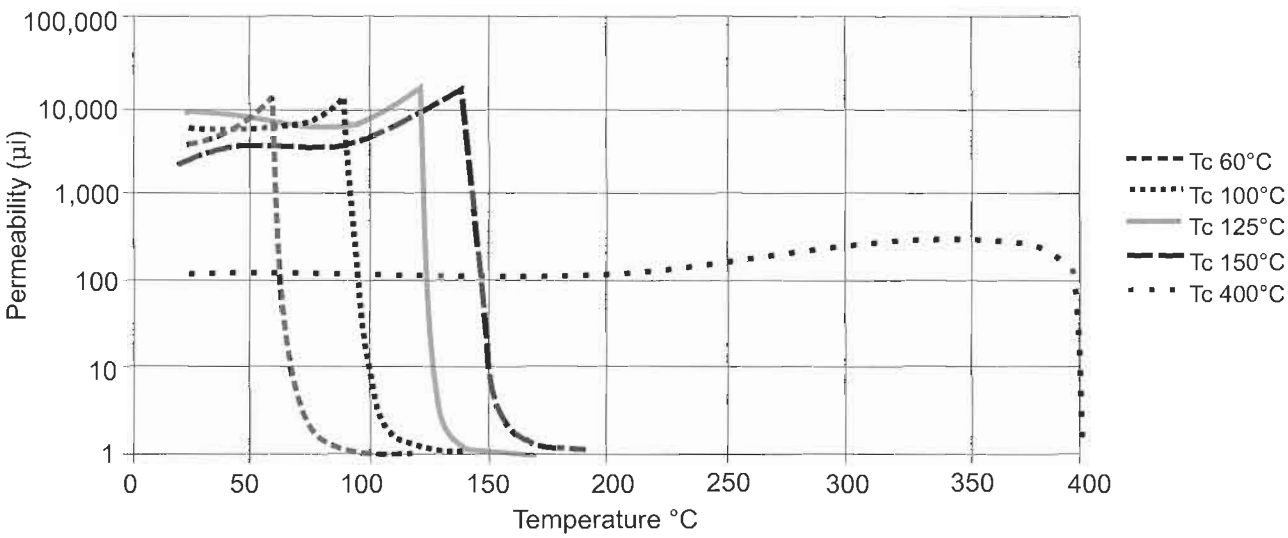
Thermal Ferrite



Thermal ferrites are materials which change from ferrimagnetic to paramagnetic at specified temperatures. This characteristic allows for the design of temperature-controlled, low-cost, highly reliable sensors, switches, fuses and circuits. A typical application is reed switch magnetic circuits. The sharp loss of permeability at a specified temperature allows for precision temperature controls to be designed. MMG-North America offers FCT material with switching temperatures ranging from 0° to 400° C in non-mated geometries.

Parameter	Symbol	Units	Test Conditions	Typical Value NiZn	Typical Value MnZn
Initial Permeability	μ_i	-	10kHz- 2MHz~0.1mT	100	5000
Saturation Flux Density	B_{sat}	mT	H=199A/m =2.5Oe	220	460
Residual Flux Density	B_r	mT	10 kHz	190	110
Coercive force	H_c	A/m	10 kHz	300	10
Curie Temperature	T_c	°C	1kHz~0.1mT	400	150
Volume Resistivity	ρ	Ω-cm	1V/cm 25°C	1×10^7	20

Permeability vs. Temperature

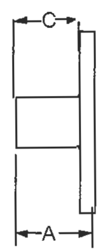


Surface Mount Cup/Tack Cores

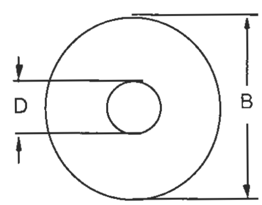
Mechanical Parameters

Kit Section	MMG Part No.	Description		A	tol +/-	B	tol +/-	C	tol +/-	D	tol +/-	E	tol +/-
W	FB2-1R3Z-372/1	surface mount	in.	0.061	0.004	0.139	0.005	0.112	0.003	0.047	0.004	0.050	0.002
		cup core	mm.	1.55	0.1	3.53	0.13	2.84	0.08	1.19	0.1	1.27	0.05
W	SB2-2C3Z-1YTB/1	surface mount	in.	0.082	0.004	0.138	0.005	0.068	0.004	0.046	0.002		
		tack core	mm.	2.08	0.1	3.51	0.13	1.73	0.1	1.17	0.05		

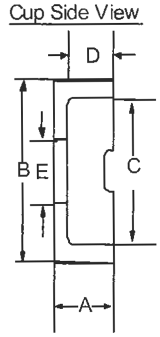
Tack Side View



Tack Top View



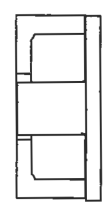
Cup Side View



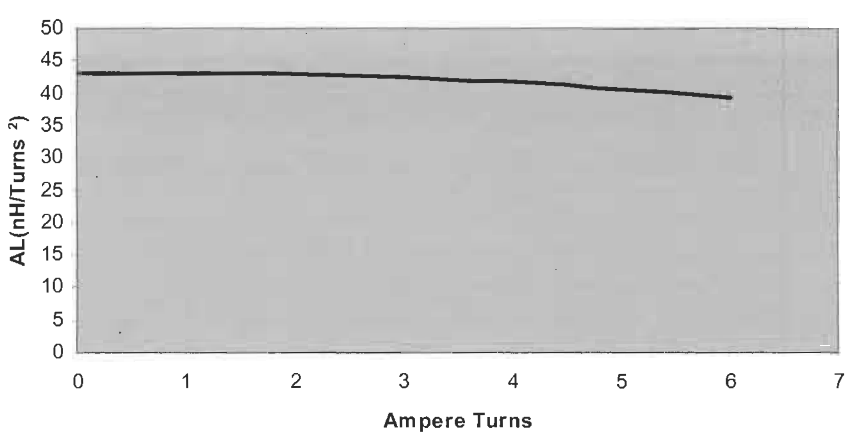
Electrical Parameters

Kit Section	MMG Part No.	Description	A_L (nH/turn^2) @10kHz
W	FB2-1R3Z-372/1	surface mount cup core	N/A
W	SB2-2C3Z-1YTB/1	surface mount tack core	N/A
W		Cup & Tack Assembly	43

Cup & Tack Assembly

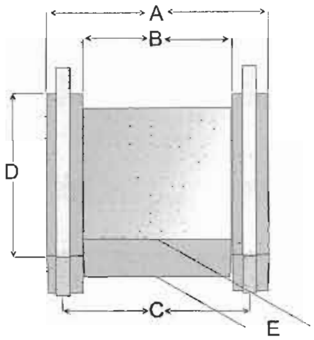


Inductance Factor vs DC Ampere Turns @ 10kHz

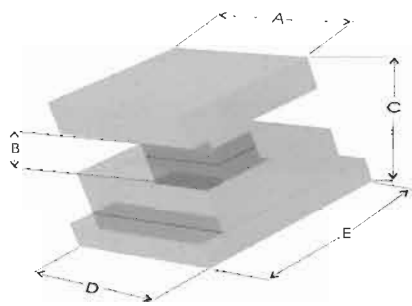


Miscellaneous Core Geometries

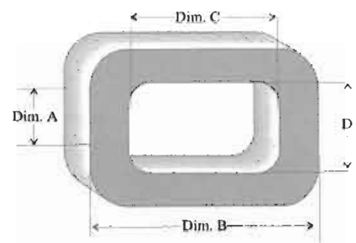
MMG-North America is capable of providing custom components to meet specific design requirements. Utilizing the continuously variable length dimension of existing tooling and the high precision of our state-of-the-art automated presses we can provide special length parts. If more radical geometries are required MMG has expert tool designers who can produce complete tooling to press required designs. Represented below are some special ferrite part designs. If you require a geometry not represented in this catalog please speak with our sales department. We will work with you to provide the most cost-effective way to meet your design requirements.



Type 2



Type 1



Type R

Core Part No.	Units	Type	Dimension A	Dimension B	Dimension C	Dimension D	Dimension E
HOI-75AQ-6FM2P	in	2	0.375	0.225	0.300	0.250	0.050
	mm		9.525	5.715	7.620	6.350	1.270
SFI-3F4V-1Q1/1	in	1	0.125	0.050	0.140	0.121	0.170
	mm		3.175	1.270	3.556	3.074	4.318
S52-152A-1QR/1	in	R	0.040	0.080	0.046	0.018	—
	mm		1.016	2.032	1.168	0.457	—
SB2-2530-0V1/1	in	1	0.075	0.030	0.700	0.075	0.105
	mm		1.905	0.762	17.780	1.905	2.667

Wound Components

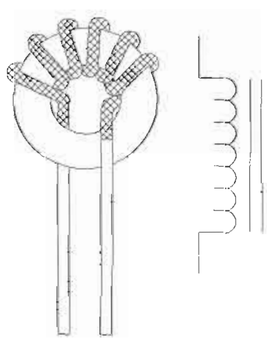
MMG-North America offers a single source for cores and wound components.

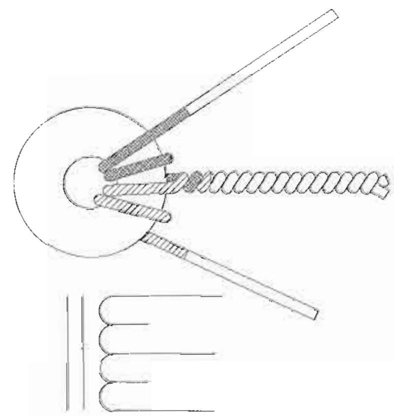
These include high frequency splitters, matching transformers, auto transformers, parasitic suppressors, chokes, and inductors.

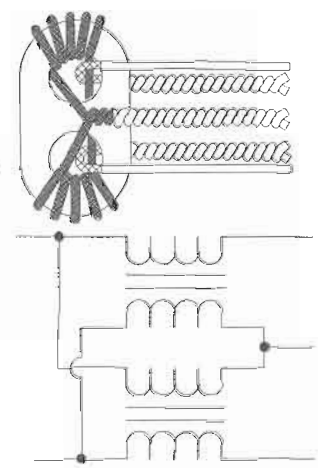
Hand and machine wound toroids are delivered in quantity on cores ranging from .090" dia to 1.500". Baluns and beads are available in all common sizes. Solenoidally wound chokes are available from .048"–.375" diameters. As the world's largest producer of ferrite coilforms, small and large chokes and inductors can be economically and reliably supplied in practically all lengths and diameters.

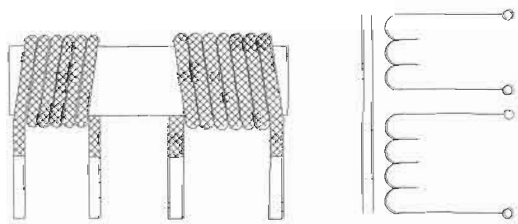
Potting, coating, reel-taping, soldering of components and other assembly processes are available.

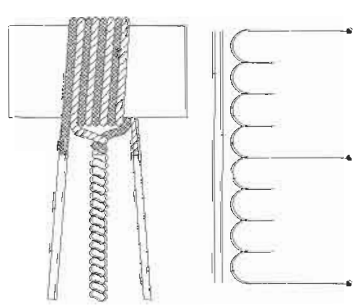
The following illustrate only a few of the many core and winding combinations possible. To discuss your particular application or to request specifications for an existing stock part, please consult MMG-North America's Sales Department.

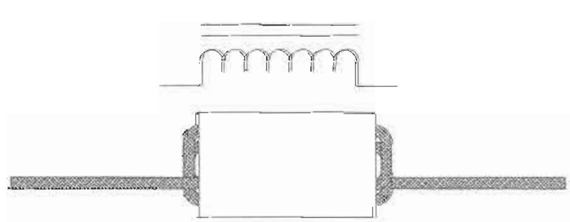


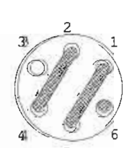












Standard Coatings

MMG offers a wide range of coating options on ferrite parts. The most popular coating alternatives are epoxy coating for larger cores and parylene coating for smaller parts.

MMG utilizes Union Carbide parylene C or a qualified equivalent. Parylene coating provides a high dielectric strength film to the surface of the ferrite core. MMG can provide other types of coating upon request. Below is a table of standard coatings and the associated part number code.

Suffix	Description	Specification
/1P	Parylene Coated	500 Volts ac Minimum Breakdown
/1D	Parylene Coated	1000 Volts ac Minimum Breakdown
/1Y	Parylene & Color Coded	Color Must be Visible & Minimum Breakdown 500 Vac
/1Z	Parylene & Color Coded	Color Must be Visible & Minimum Breakdown 1000 Vac
/1H	Thermal Degauss & Parylene Coated	Minimum breakdown 500 Vac Parts must be thermal degaussed

NOTE: 1) The above requirements are for /1 parts. These specifications only apply to other / numbers when NO OTHER requirement is stated on QC test spec.

2) For all coated parts (parylene, epoxy, ect...) full mechanical inspection must be performed AFTER coating as part of final inspection.

Definition of Symbols

Symbol	Units	Definition
A	mm^2	Cross sectional area at a given part of a core
A_e	mm^2	Effective cross sectional area
A_L	nH/N^2	Inductance Factor
B	mT	Momentary value of flux density
B_r	mT	Residual Flux Density
B_{sat}	mT	Saturation Flux Density
C1	mm^{-1}	Geometric Core Constant According to IEC document 205
C2	mm^{-3}	Geometric Core Constant According to IEC document 205
D_f	numeric	Dissaccomodation factor
H	A/m	Momentary value of field strength
H_C	A/m	Coercive force
I	Amperes	Electrical current
L	H	Inductance
l_e	mm	Effective magnetic path length
L_F	numeric	Loss Factor
L_P	H	Parallel Inductance
L_S	H	Series Inductance
N	numeric	Number of turns
Q	numeric	Quality Factor
P_L	mW/cc	Power Loss
R	Ω (Ohms)	Resistance
R_P	Ω (Ohms)	Parallel Resistance
R_S	Ω (Ohms)	Series Resistance
T_c	Degrees Celsius	Curie Temperature
V	mm^3	Volume
V_e	mm^3	Effective Volume
Z	Ω (Ohms)	Impedance
μ	numeric	Magnetic Permeability
μ_a	numeric	Amplitude Permeability
μ_i	numeric	Initial Permeability
μ_{max}	numeric	Maximum Permeability
$\mu\Delta$	numeric	Incremental Permeability
ρ	Ohm-cm	Resistivity

Reference IEC Standard 205

Conversion Factors

Conversion from		Factor	To Get	
CGS Units		***Multiply by***	***SI Units***	
Gauss	(G)	0.1	milliTesla	(mT)
Gauss	(G)	10^{-4}	Tesla	(T)
Oersted	(Oe)	80	Ampere-Turns/meter	(AT/m)
SI Units		→	***CGS Units***	
milliTesla	(mT)	10	Gauss	(G)
Tesla	(T)	10^{4}	Gauss	(G)
Ampere-Turns/meter	(AT/m)	0.01256	Oersted	(Oe)
English Units		→	***Metric Units***	
Inches	(in)	25.4	millimeter	(mm)
Fahrenheit	(°F)	(°F-32)/1.8	Centigrade	(°C)
pounds	(lbs)	0.4536	kilograms	(kg)
gallons	(gal) US	4	liters	l
Metric Units		→	***English Units***	
millimeters	(mm)	0.0394	inches	(in)
Centigrade	(°C)	(°C x 1.8) +32	Fahrenheit	(°F)
kilograms	(kg)	2.2046	pounds	(lbs)
liters	l	0.2642	gallons	(gal) US

Metric Table

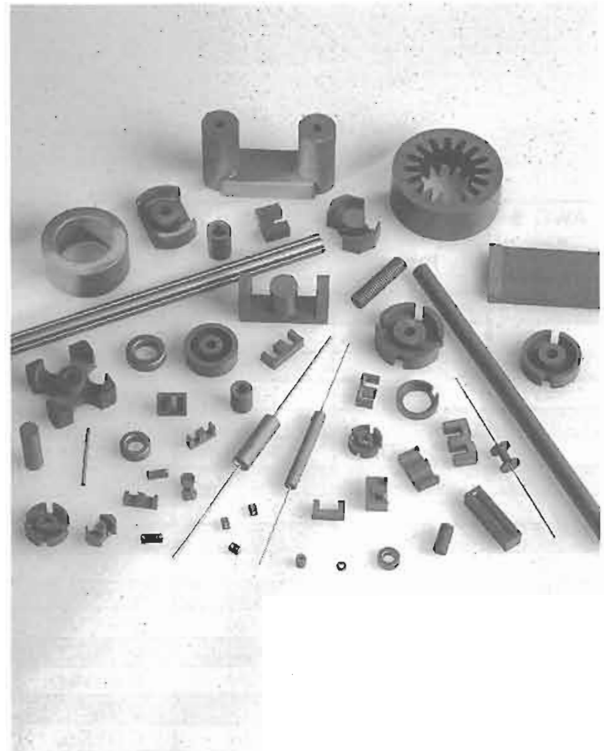
Units	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Wire Table

AWG & B&S Gauge	Outside Diameter		Cross-Sectional Area,		Feet / Ω @ 20°C	Ω / 1000 Ft. @ 20°C	Amperes for 1mA / cir mil	Amperes for 1000A/ Sq.In.	Turns per Inch^2
	Inches	Millimeters	(Inch^2)	Circular mils					
10	0.1019	2.588	0.00815	10380	1001	1.00	10.40	8.15	92
11	0.0907	2.304	0.00647	8234	794	1.26	8.25	6.47	118
12	0.0808	2.052	0.00513	6530	630	1.59	6.54	5.13	146
13	0.0719	1.826	0.00407	5178	499	2.00	5.18	4.07	180
14	0.0641	1.628	0.00322	4107	396	2.53	4.11	3.22	231
15	0.0571	1.450	0.00256	3257	314	3.18	3.26	2.56	275
16	0.0508	1.290	0.00203	2583	249	4.02	2.59	2.03	346
17	0.0453	1.151	0.00161	2048	198	5.06	2.05	1.61	432
18	0.0403	1.024	0.00127	1624	157	6.39	1.62	1.27	544
19	0.0359	0.912	0.00101	1288	124	8.05	1.29	1.01	679
20	0.0320	0.813	0.000804	1022	98.5	10.20	1.03	0.80	854
21	0.0285	0.724	0.000638	810.1	78.1	12.80	0.81	0.64	1065
22	0.0254	0.645	0.000505	642.4	62.0	16.10	0.64	0.51	1345
23	0.0226	0.574	0.000400	509.5	49.1	20.40	0.51	0.40	1675
24	0.0201	0.511	0.000317	404.0	39.0	25.70	0.40	0.32	2095
25	0.0179	0.455	0.000252	320.4	30.9	32.40	0.321	0.252	2630
26	0.0159	0.404	0.000200	254.1	24.5	40.80	0.255	0.200	3325
27	0.0142	0.361	0.000158	201.5	19.4	51.40	0.201	0.158	4110
28	0.0126	0.320	0.000126	159.8	15.4	64.90	0.160	0.126	5210
29	0.0113	0.287	0.000100	126.7	12.2	81.90	0.128	0.100	6385
30	0.0100	0.254	0.0000785	100.5	9.70	103.10	0.100	0.079	8145
31	0.0089	0.226	0.0000622	79.7	7.70	130.10	0.079	0.062	10,097
32	0.0080	0.203	0.0000503	63.2	6.10	163	0.064	0.050	12,270
33	0.0071	0.180	0.0000396	50.1	4.80	206	0.050	0.040	15,615
34	0.0063	0.160	0.0000312	39.8	3.83	261	0.040	0.031	19,655
35	0.0056	0.142	0.0000248	31.5	3.04	330	0.0316	0.0248	25,530
36	0.0050	0.127	0.0000196	25.0	2.41	415	0.0250	0.0196	31,405
37	0.0045	0.114	0.0000159	19.8	1.91	524	0.0203	0.0159	39,570
38	0.0040	0.102	0.0000126	15.7	1.52	670	0.0160	0.0126	49,070
39	0.0035	0.089	0.00000962	12.5	1.20	832	0.0122	0.0096	65,790
40	0.0031	0.079	0.00000755	9.89	0.953	1049	0.0098	0.0075	82,180
41	0.0028	0.071	0.00000616	7.84	0.756	1323	0.0079	0.0062	98,860
42	0.0025	0.064	0.00000491	6.20	0.598	1672	0.0062	0.0049	121,175
43	0.0022	0.056	0.00000380	4.93	0.476	2101	0.0048	0.0038	158,245
44	0.0020	0.051	0.00000314	3.88	0.374	2674	0.0039	0.0031	205,515
45	0.0018	0.046	0.00000254	3.10	0.299	3344	0.0032	0.0025	249,855
46	0.0016	0.041	0.00000201	2.46	0.238	4202	0.0025	0.0020	310,205

Other products offered by MMG Companies through MMG-North America:

Soft Ferrite Cores	Iron Powder
Toroids > 10mm	Coil Forms
Pot Cores	E Cores
RM Cores	Toroids
Touch-tone Cores	Slugs
E Cores	
ETD Cores	
EP Cores	**MPP (Genalex)**
EFD Cores	
U Cores	Toroids
Beads	
Tubes	
Rods	**Magnets**
Impeder Rods	
Slabs	Rings
Blocks	
Plastic Bobbins	Discs
Surface Mount Beads	Bars



For more information on these products please contact the MMG-North America Sales Department at 1-800-664-7712 or E-mail us at sales@mmgna.com.

Applications Guide				Power / Switching Transformers, Differential Mode Chokes, Output Chokes			Wideband Transformers, Pulse Transformers, Common Mode Chokes, Current Sensing Devices, RFI Suppression										
Parameter	Symbol	Standard Test Conditions	Unit	F47	F44	F5	F5A	F6	F9	F9C	F10	F57	F39	F8	P10	P11	P12
Initial Permeability (nominal)	μ_i	B<0. 1 mT 10 kHz 25°C	-	1800 ±20%	1900 ±20%	2000 ±20%	2500 ±20%	1800 ±20%	4400 ±20%	5000 ±20%	6000 ±20%	7500 ±25%	10000 ±30%	1200 MIN	2000 ±20%	2250 ±20%	2000 ±20%
Saturation Flux Density (typical)	Bsat	H=796 A/m 10 Oe 25°C	mT	470 350	500 400	470 350	470 350	350	380	460	380	380	380	380	-	-	-
Residual Flux Density (typical)	Br	H→0(from near saturation) 10 kHz 25°C	mT	130	270	200	150	-	180	170	100	250	200	-	120	70	35
Coercivity (typical)	Hc	B→0(from near saturation) 10 kHz 25°C	A/m	24	27	21	15	-	13	13	14	17	16	-	22	18	7
Loss Factor (maximum)	Tan □□ · □ / □i	B<0.1mT 25°C 10 kHz 100 kHz 200 kHz 1 MHz	10^{-6}	- - - -	- - - -	- - - -	- - - -	- - - -	- 20 - -	- 20 - -	- 20 - -	- - - -	- - - -	- - - -	6 15 - -	1.5 5 - -	0.8 2.5 - -
Temperature Factor	□□ / □i² □□T	B<0.1mT 10kHz +25°C to +55°C B<0.1mT 10kHz 0°C to +25°C	10^{-6}/°C	- -	- -	- -	- -	- -	0 to 2 -	-1 to +2 -	-1 to +2 -	- -	- -	- -	0 to 2 -	.5 to 1.5 -	.4 to 1.0 0
Curie Temperature (minimum)	T_c	B<0.1mT 10kHz	°C	200	230	200	200	180	130	160	130	125	125	130	150	150	150
Resistivity (typical)	ρ	1V/cm 25°C	Ω-cm	100	100	100	100	100	50	50	50	100	100	100	100	100	100
Amplitude Permeability (minimum)	μ_a	400mT 25°C 320mT 100°C 340mT 100°C	μ_a	- - -	2500 - 1900	2500 - 1900											
Total Power Loss Density (maximum)	P_v	200mT; 16kHz 25°C 200mT; 16kHz 60°C 200mT; 16kHz 100°C 200mT; 25kHz 25°C 200mT; 25kHz 60°C 200mT; 25kHz 100°C 100mT; 100kHz 25°C 100mT; 100kHz 100°C 200mT; 100kHz 100°C 50mT; 400kHz 25°C 50mT; 400kHz 100°C	mW/cc	- - - - - - - - - - -	- - - 200 - 130 250 160 750 - -	- - - 200 - 130 250 160 750 - -											

Other Ferrite Products available from the MMG Group

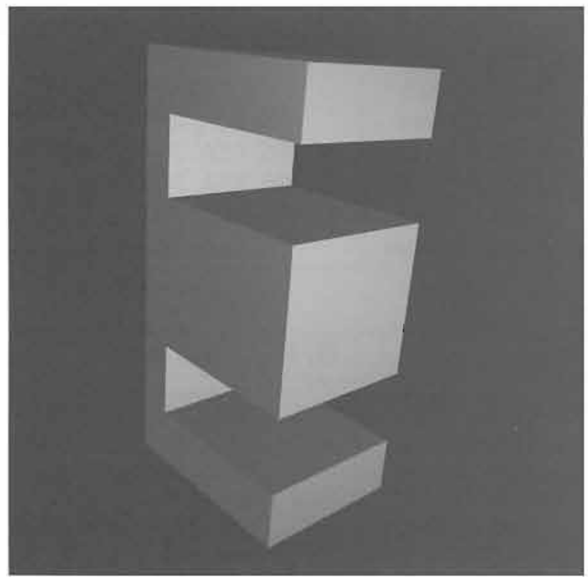
EFD CORES	
Core Type	**Material Grade**
EFD 15	F47, F44, F5A
EFD 20	F47, F44, F5A
EFD 25	F47, F44, F5A

STANDARD E CORES	
Core Type	**Material Grade**
13x11x3 (E+I)	F8
13x13x3 (2E)	F8
19x16x4.75 (2E)	F5A, F6, F9
25x13x6 (E+I)	F5A, F6
25x19x6 (2E)	F5A, F6

STANDARD E CORES	
Core Type	**Material Grade**
E20	F44, F5, F9
E30	F44, F5, F9
E42/15	F44, F5, F9C
E42/20	F44, F5A
E55/21	F44, F5A
E55/25	F44, F5A
E65	F44, F5A

EF CORES	
Core Type	**Material Grade**
EF 6.3	F44, F5, F9
EF 13	F44, F5, F9
EF 16	F44, F5, F9
EF 20	F44, F5, F9
EF 25	F44, F5, F9

ETD CORES	
Core Type	**Material Grade**
ETD 29	F47, F44, F5, F5A
ETD 34	F47, F44, F5, F5A
ETD 39	F47, F44, F5, F5A
ETD 44	F47, F44, F5, F5A
ETD 49	F47, F44, F5, F5A



MMG-North America
126 Pennsylvania Avenue
Paterson, New Jersey 07503-2512
Telephone: (973) 345-8900
Facsimile: (973) 345-1172
Toll Free: 1-800-664-7712
www.mmgna.com

In order to service your needs more effectively, please complete the following response Checklist and mail or fax to the above address, attention: New Customer Development.

RESPONSE CHECKLIST

Name: ______________________ Current User?: Yes______ No______

Position: Buyer______ Engineer______ other ____ If yes, please list shapes and ______________

Company: ______________________ volume/year: ______________

Address: ______________________ ______________________

______________________ ______________________

Phone Number: ______________________ ______________________

Fax Number: ______________________ ______________________

Product/Project ______________________ ______________________

1. ______ I would like to receive the Magnetic Component Catalog (E Cores, U Cores, Pot Cores, RM Cores, ETD Cores, EFD Cores, EP Cores.)

2. ______ I would welcome a visit by the local MMG-North America Sales Representative to discuss my application.

3. ______ I would like an Applications Engineer to call to assist in product selection.

4. ______ I would like a quotation and samples. (Please note volume if a quote is requested.)

A subsidiary of TT Group PLC

MMG Worldwide

MMG North America Inc.
126 Pennsylvania Avenue
Paterson, NJ 07503-2512
USA
Toll Free: 1-800-664-7712
Tel: +1 (973) 345-8900
Fax: +1 (973) 345-1172
www.mmgna.com
E-mail: sales@mmgna.com

Neosid Australia Pty. Ltd.
23-25 Percival Street
Lilyfield
Sydney, NSW, 2040
Australia
Tel: +61 (0) 29 660 4566
Fax: +61 (0) 29 5521748
E-mail: sales@neosid.com.au

MMG Linton & Hirst Ltd.
Parsonage Rd., Stratton St. Margaret
Swindon, Wiltshire SN3 4RN
United Kingdom
Tel: +44(0) 1793 825000
Fax: +44(0) 1793 827802
www.linton-hurst.co.uk
E-mail: sales@linton-hurst.co.uk

TT Electronics Far East Sales Office
514 Chai Chee Lane #02-01
Bedok Industrial Estate
Singapore 469029
Tel: +65 6 444 5667
Fax: +65 6 442 5471
E-mail: sales@ttelectronics.com.sg

MMG GB Ltd.
Icknield Way West
Letchworth,
Hertfordshire SG6 4AS
United Kingdom
Tel: +44 (0) 1462 481000
Fax: +44 (0) 1462 481008
www.mmggb.com
E-mail: sales@mmggb.com

MMG IOM Ltd.
Industrial Estate, Ramsey Road
Peel
Isle of Man, IM5 1RE
British Isles
Tel: + 44 (0)1624 842749
Fax: +44 (0) 1624844025
www.mmg-iom.co.im
E-mail: sales@mmg-iom.co.im

MMG Mag Dev Ltd.
Magnet House
Blackworth Industrial Estate
Highworth, Swindon
Wiltshire SN6 7NA
United Kingdom
Tel: +44 (0) 1793 766001
Fax: +44(0) 1793 765576
www.magdev.co.uk
E-mail: sales@magdev.co.uk

MMG Canada Ltd.
10 Vansco Road
Toronto, Ontario M8Z SJ4
Canada
Tel: +1 (416) 251-2831
Fax: +1 (416) 251-6790
www.mmgca.com
E-mail: sales@mmgca.com

MMG India Pvt Ltd.
144 Seevaram, Thoralpakkam,
Chennai 600-096,
India
Tel: +91 44 4961759
Fax: +91 44 4960986
www.mmgni.com
E-mail: sales@mmgni.com

MMG Deutschland
Am Hofstück 8
44227 Dortmund, Germany
Tel: +49 (0) 231 72 59 26 27
Fax: +49 (0) 231 10 60 998
www.mmg-deutschland.com
E-mail: sales@mmg-deutschland

www.TTelectronicsMMG.com

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