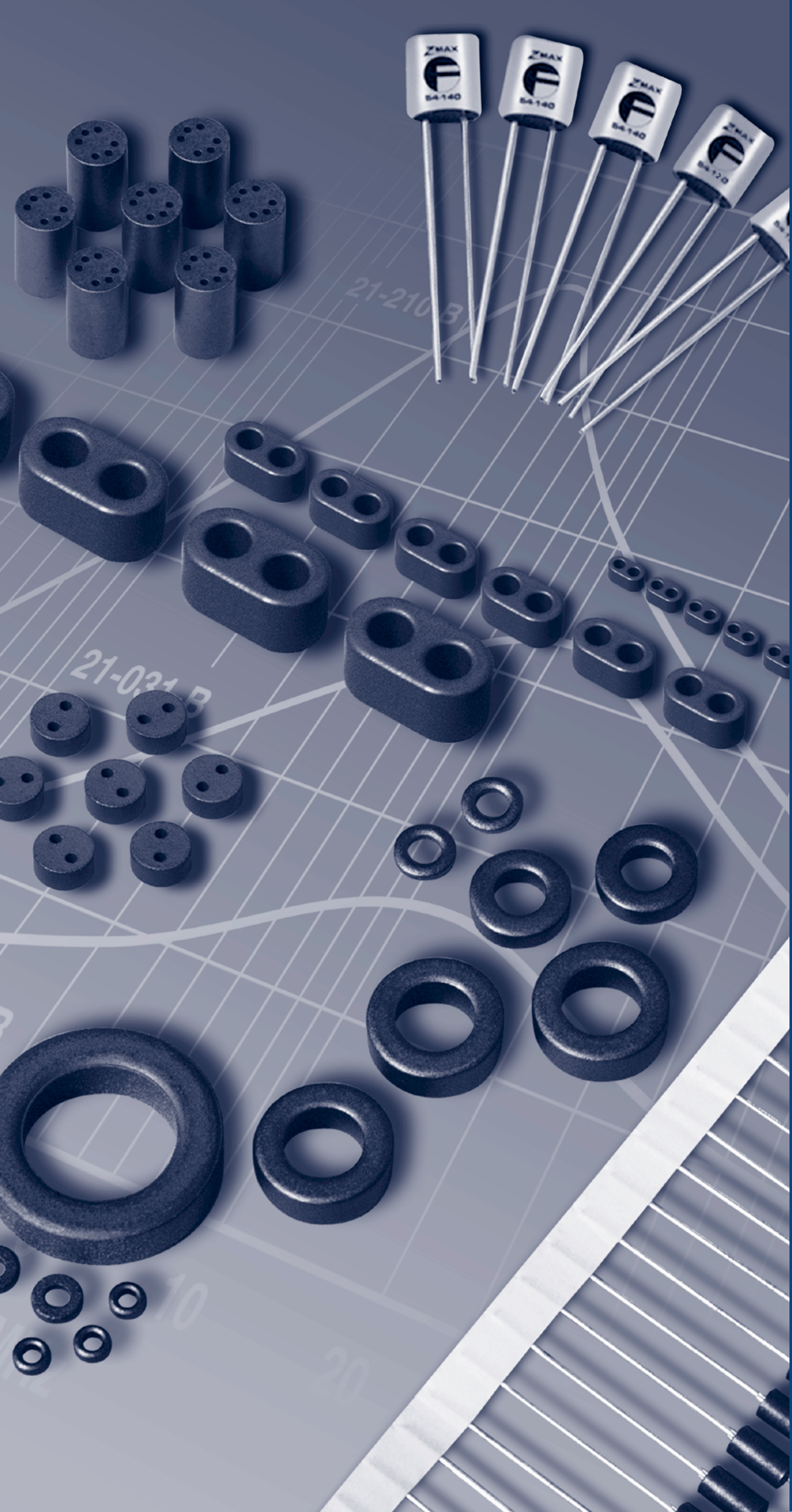


Quality Policy

Ferronics Incorporated is totally dedicated to the principle of continuous quality improvement in all areas of our operation as a means of providing long term satisfaction to the users of our products. This policy is based on each employee understanding the full requirements of our customers, and being committed to supplying nothing less than the best possible products and services.

FERRONICS INCORPORATED

Company Profile

Quality is the cornerstone of our existence
Ferronics Inc. is a U.S. based manufacturer of ferrite components and assemblies used in the computer, CATV, telecommunications, and other related electronics industries. Founded in 1968, the company is headquartered in modern, newly constructed manufacturing facilities located in Fairport, New York.

Ferronics manufactures ferrite components in several shapes, such as toroids, beads, baluns and multi-hole cores, as well as in a variety of sizes. The company also offers custom manufacturing of ferrite parts and wound components that are designed and finished according to exact customer needs and specifications.

Targeting both commercial and industrial markets, Ferronics sells its products to original equipment manufacturers who use the components as inductors, chokes, and transformers in televisions, CATV taps and peripheral devices. In addition to a strong sales base in North America, Ferronics also serves overseas markets in Europe, South America, and the Far East. The company sells its products through manufacturer representatives as well as through Dexter Magnetic Technologies, an international stocking distributor.

At Ferronics, we realize that an operational philosophy driven by quality is the best way we can provide long term satisfaction to the users of our products. A dedication to quality permeates everything we do and governs our relationships with suppliers and customers. In each step of the manufacturing and testing process at Ferronics, concern for quality is the guiding principle. We wouldn’t have it any other way.

The building blocks for today’s eletronics industry
The electronics industry as we know it today could not exist without the widespread use of ferrites. The term “ferrite” is derived from the Latin word “ferrum”, meaning iron. Ferrites are homogeneous ceramic materials composed of various oxides containing iron oxide as their main constituent. Being ceramic, ferrites are hard, inert, and free of organic substances. What makes ferrites especially useful in the electronics industry is a combination of two key characteristics: (1) high magnetic permeability which concentrates and reinforces the magnetic field and (2) high electrical resistivity which limits the amount of electric current flow in the ferrite. Thanks to these two characteristics, ferrites exhibit low energy losses, are highly efficient, and function at high frequencies (1 KHz to 1,000 MHz). These qualities make ferrites ideal building blocks in the manufacture of miniaturized high frequency electronic components.

Ferrites can be used in an ever widening range of electronic applications. Some of the more common applications include the following:

Magnetic Devices
Power transformers and chokes
Inductors and tuned transformers
Pulse and wide band transformers
Magnetic deflection
Recording heads
Rotating transformers
Shield beads and chokes
Transducers

Applications
HF Power supplies
Frequency selective circuits
Matching devices
TV sets and monitors
Storage devices
VCRs
Interference suppression
Vending machines
Datacom
Telecom
Game machines - Consumer & Commercial

Glossary of Terms

Ferronics soft ferrite products are made from both manganese-zinc and nickel-zinc materials, with a wide range of capabilities. The glossary of terms below defines the salient characteristics used to describe the various materials, and the Material Properties Table defines the parameters of each of Ferronics' seven materials.

The following pages provide some representative material curves further defining the characteristics of the various materials. Ferronics B,T and V materials (MnZn) are primarily used for frequencies below 2 MHz, and offer high initial permeability, low losses, and high saturation flux density. The rest of Ferronics' materials, e.g., G, J, K, & P (all NiZn) provide high resistivity, and operate in a range from 1 MHz to several hundred MHz.

Amplitude Permeability, μ_a. The quotient of the peak value of flux density and peak value of applied field strength at a stated amplitude of either, with no static field present.

Coercive Force, H_c (A/*m*).The magnetizing field strength required to bring the magnetic flux density of a magnetized material to zero.

Curie Temperature, T_c (°C).The transition temperature above which a ferrite loses its ferrimagnetic properties.

Effective Dimensions of a Magnetic Circuit, Area A_e (cm^2), Path Length le(cm), and Volume V_e (cm^3). For a magnetic core of given geometry, the magnetic path length, the cross sectional area and the volume that a hypothetical toroidal core of the same material properties should possess to be the magnetic equivalent to the given core.

Effective Permeability, μ_e. For a magnetic circuit constructed with an air gap or air gaps, the permeability of a hypothetical homogeneous material which would provide the same reluctance.

Field Strength, H (A/m). The parameter characterizing the amplitude of alternating field strength.

Flux Density, B (Tesla). The corresponding parameter for the induced magnetic field in an area perpendicular to the flux path.

Incremental Permeability, $\mu\Delta$. Under stated conditions the permeability obtained from the ratio of the flux density and the applied field strength of an alternating field and a super-imposed static field.

Inductance Factor, A_L (nH). Inductance of a coil on a specified core divided by the square of the number of turns. (Unless otherwise specified, the inductance test conditions for inductance factor are at a flux density 1mT).

Initial Permeability, μ_i. The permeability obtained from the ratio of the flux density, kept at 1*m*T, and the required applied field strength. Material initially in a specified neutralized state.

Loss Factor, $\tan \delta/\mu_i$. The phase displacement between the fundamental components of the flux density and the field strength divided by the initial permeability.

Magnetically Soft Material. A magnetic material with a low coercivity.

Magnetic Hysteresis. In a magnetic material, the irreversible variation of the flux density or magnetization which is associated with the change of magnetic field strength and is independent of the rate of change.

Power Loss Density, P (mW/cm^3). The power absorbed by a body of ferromagnetic material and dissipated as heat, when the body is subjected to an alternating field which results in a measurable temperature rise. The total loss is divided by the volume of the body.

Remanence, B_r (Tesla). The flux density remaining in a magnetic material when the applied magnetic field strength is reduced to zero.

Saturation Flux Density, B_s (Tesla). The maximum intrinsic induction possible in a material.

Material Properties

CHARACTERISTIC	V	T	B	G	J	K*	P*	UNITS
Initial Permeability (µi)	15,000	10,000	5000	1500	850	125	40	
Loss Factor (tan δ/µi)	≤ 7	≤ 7	≤ 15	60		150	85	X 10^{-6}
at frequency =	0.01	0.01	0.1	0.1	0.1	10	10	MHz
Hysteresis Factor (h/μ^2)	-	-	< 2	10	6	-	-	X 10^{-6}
Saturation Flux Density (B_S)	370	380	450	320	280	320	215	*m*Tesla
	3700	3800	4500	3200	2800	3200	2150	Gauss
at H max=	1000	1000	1000	1000	1000	2000	2000	A/*m*
	12.6	12.6	12.6	12.6	12.6	25	25	Oersted
Remanence (B_r)	150	140	100	150	180	160	40	*m*Tesla
	1500	1400	1000	1500	1800	1600	400	Gauss
Coercivity (H_C)	2.4	3.2	5.6	19.9	31.8	119	278	A/*m*
	0.03	0.04	0.07	0.25	0.4	1.5	3.5	Oersted
Curie Temperature (T_C)**	≥ 120	≥ 120	≥ 165	≥ 130	≥ 140	≥ 350	≥ 350	°C
Temperature Coefficient of µi (α) -40°C to +80°C (T.C.)	0.8	0.8	0.9	1.0	1.0	0.1	0.1	%/°C
Volume Resistivity (p)	25	40	≥ 10^2	≥ 10^6	≥ 10^5	≥ 10^7	≥ 10^6	Ω-cm

*In K and P materials, permeability and loss factor will irreversibly increase if excited with high magnetizing force. This should be considered when applying DC or high AC currents for test purposes.

**Consult factory for newest curie temperature update.

All values are typical and measured at 25°C except as noted.

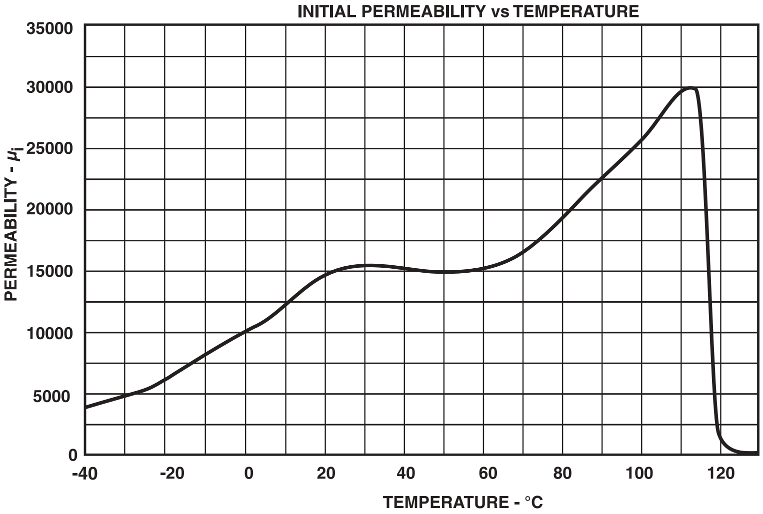
FERRITE MATERIAL CONSTANTS	
Specific heat	.25 cal/g/°C
Thermal conductivity	10 10^{-3} cal/sec/cm/°C
Coefficient of linear expansion	8-10 10^{-6}/°C
Tensile strength	7 10^3 lbs/in^2
Compressive strength	60 10^3 lbs/in^2
Youngs modulus	18 10^6 lbs/in^2
Hardness (Knoop)	650

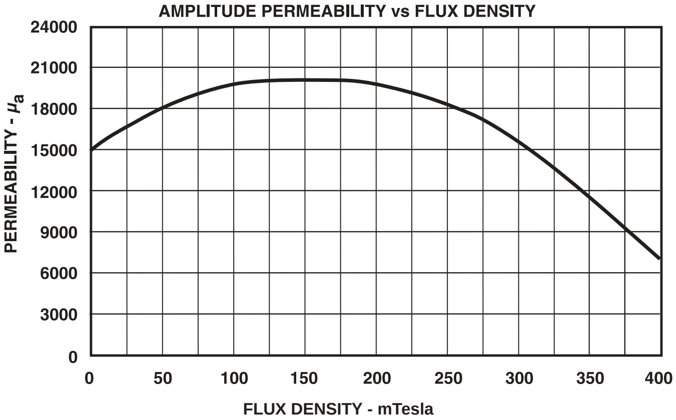
The above quoted properties are typical values on commercially available MnZn and NiZn ferrites.

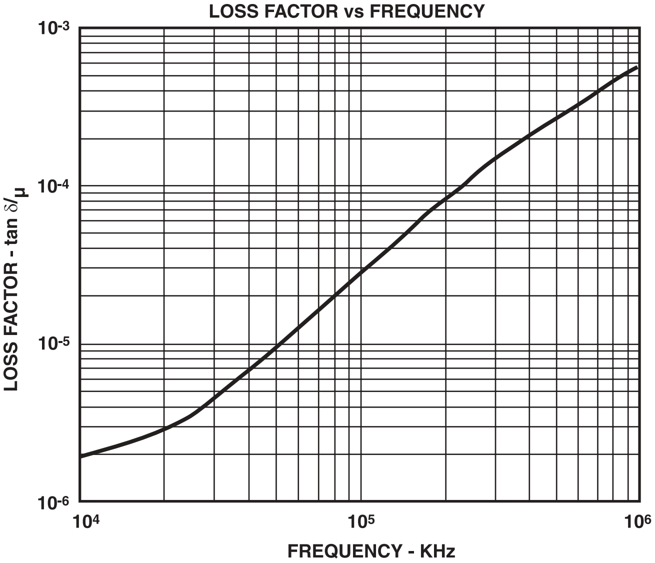
CONVERSION TABLE	
1 T (Tesla) = 1 Vs/m2	= 10^4 gauss
1 mT	= 10 gauss
1 A/m = 10^{-2} A/cm	= .01257 oersted
.1 mT	= 1 gauss
79.55 A/m	= 1 oersted

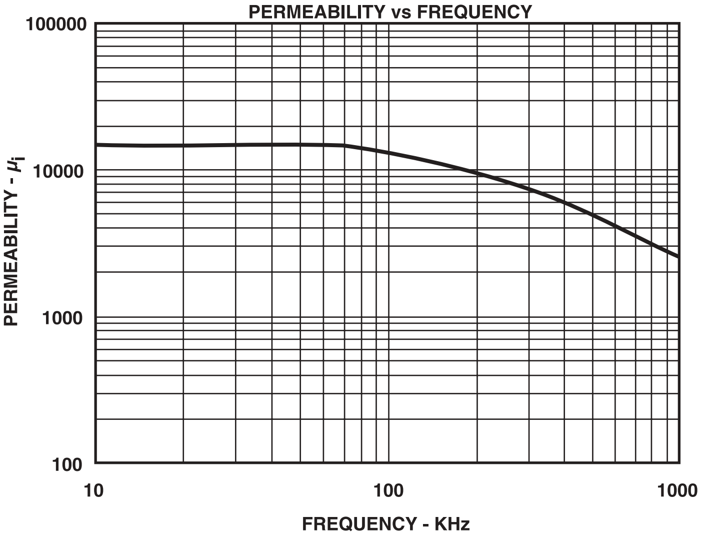
Material Properties

V MATERIAL (15,000μ_i) is a manganese-zinc ferrite characterized by high permeability with improved stability over temperature suitable for wide band filter and pulse applications.



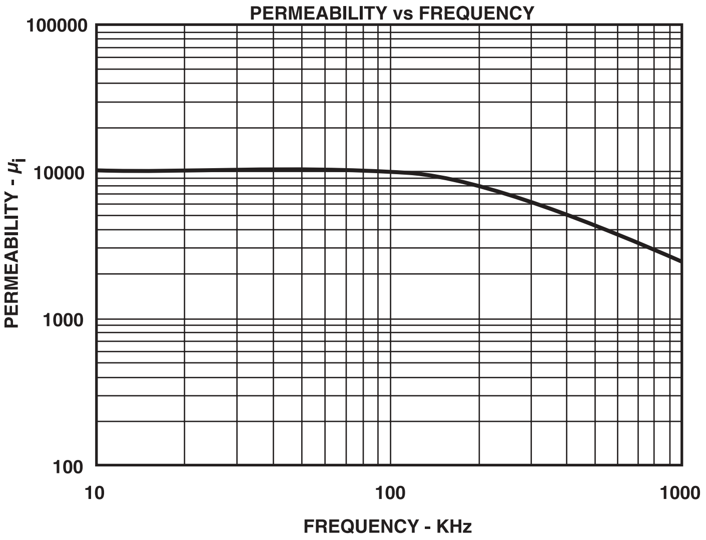


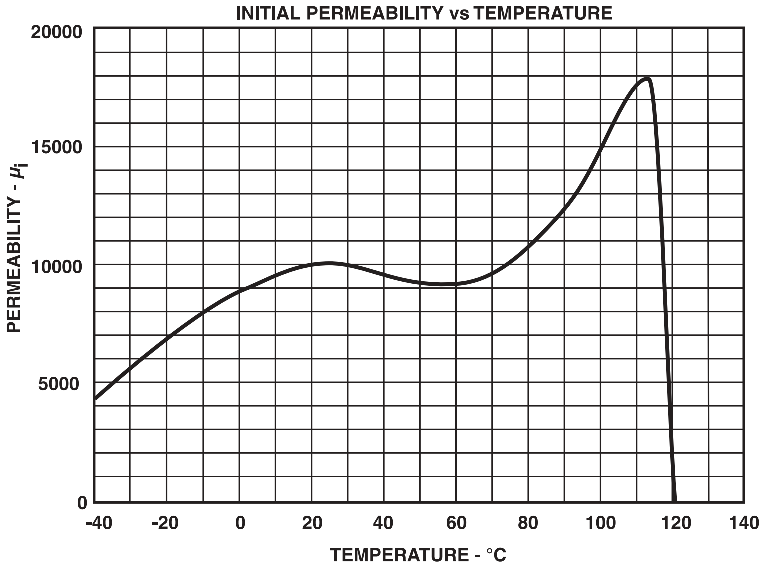


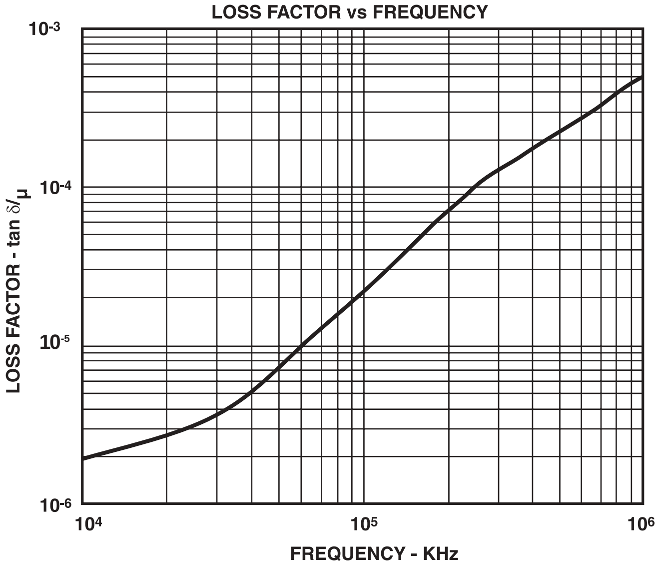


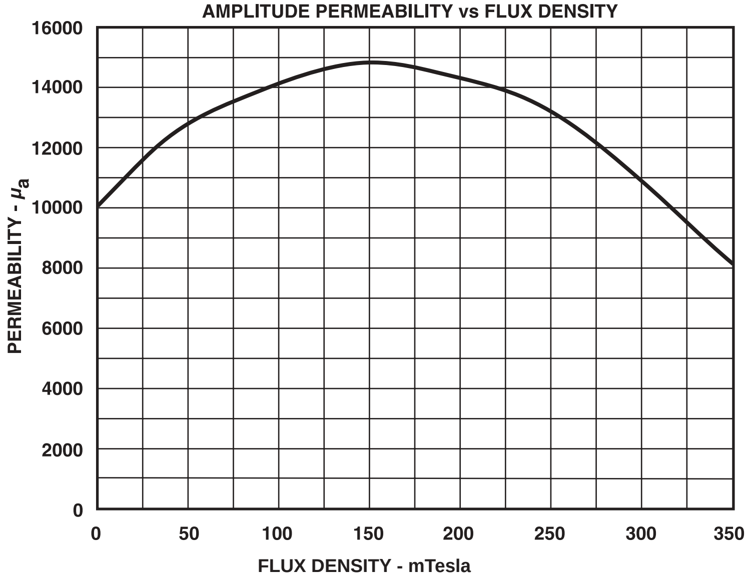
Material Properties

T MATERIAL (10,000μ_i) is a manganese-zinc ferrite characterized by high temperature stability suitable for wideband, filter and pulse applications.


PERMEABILITY vs FREQUENCY

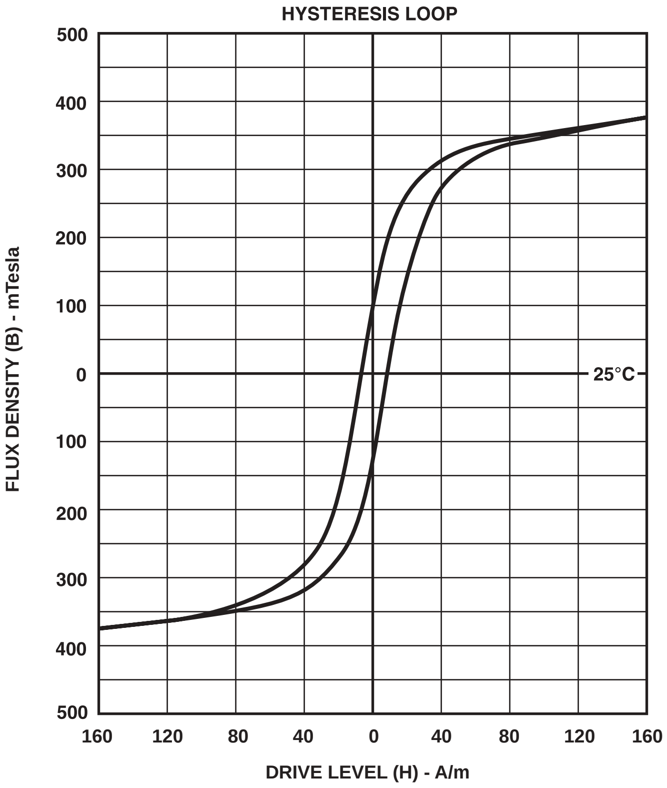

INITIAL PERMEABILITY vs TEMPERATURE

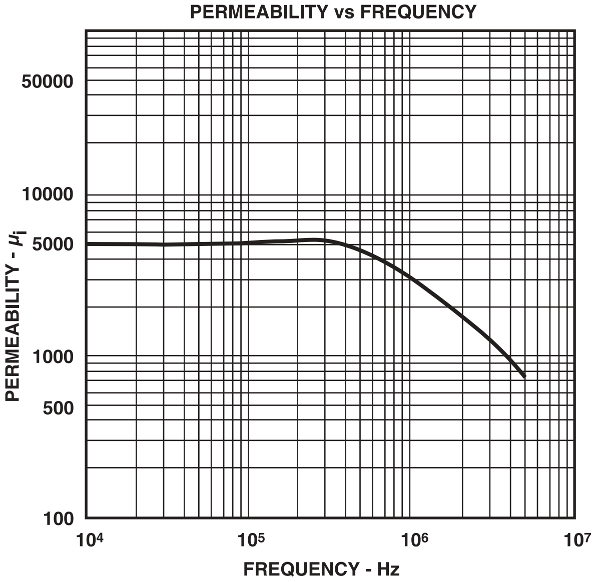

LOSS FACTOR vs FREQUENCY

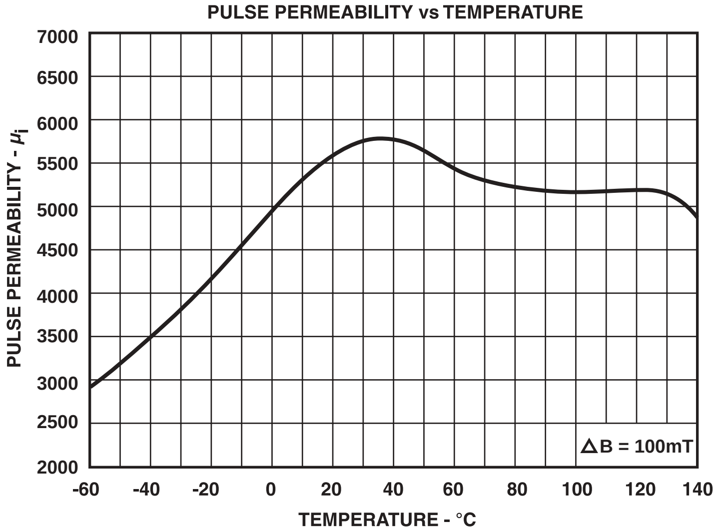

AMPLITUDE PERMEABILITY vs FLUX DENSITY

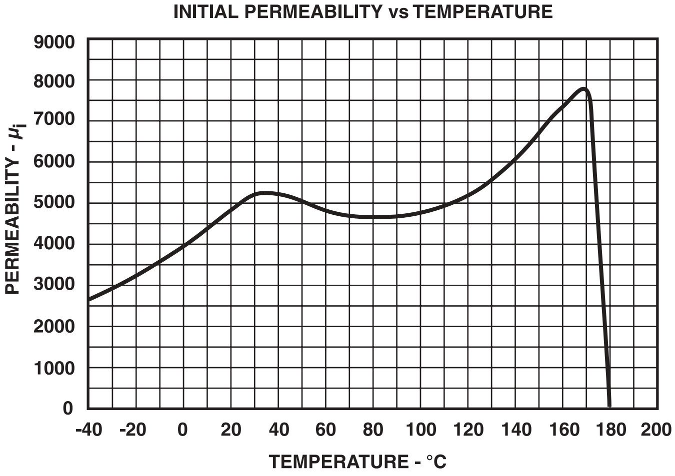
Material Properties

B MATERIAL (5,000μ_i) is a manganese-zinc ferrite suited for applications where high permeability and flux density and low power loss are required.

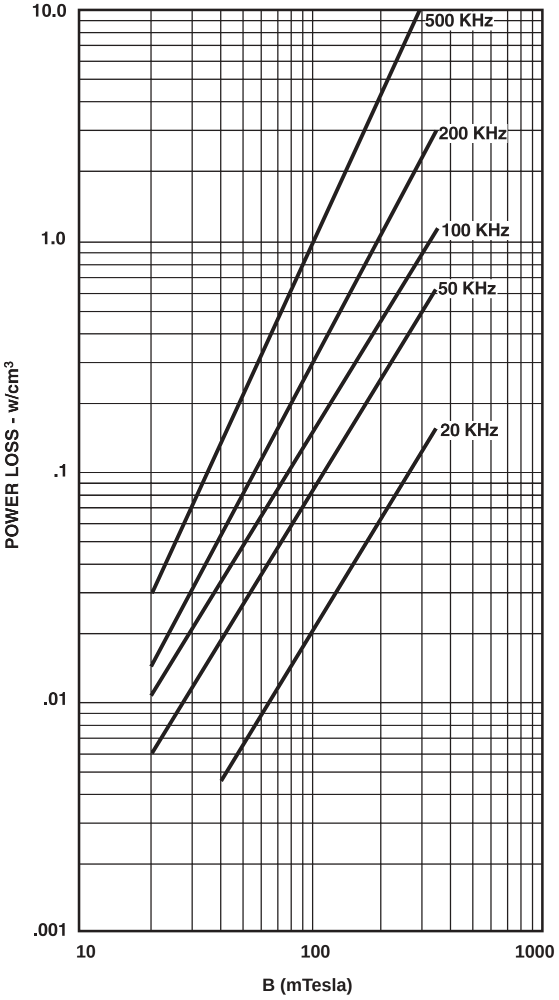


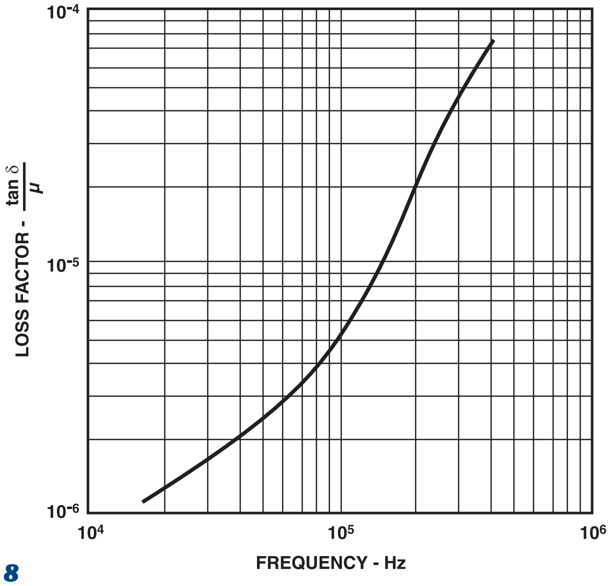


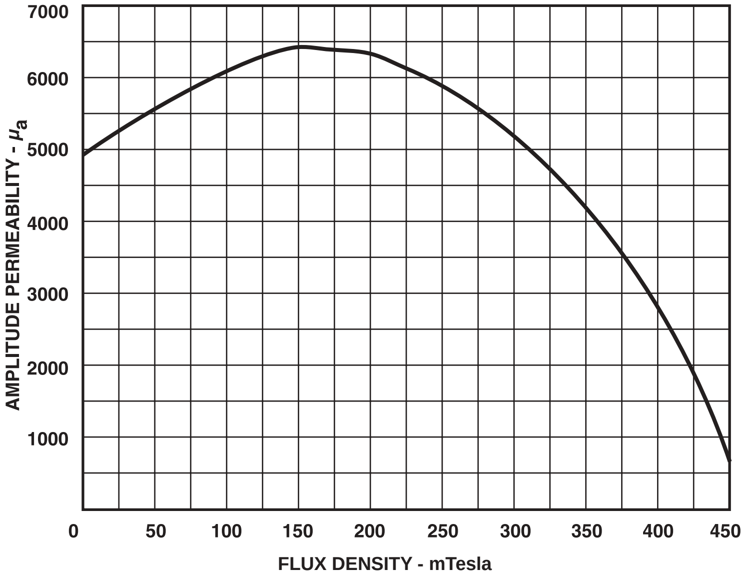


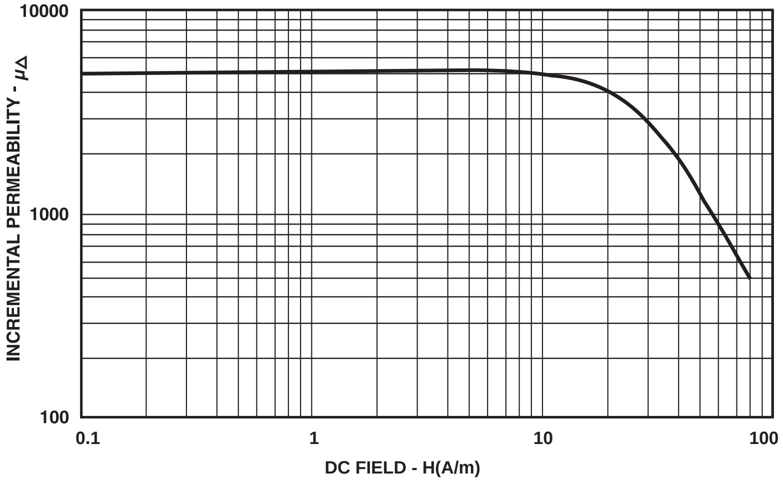


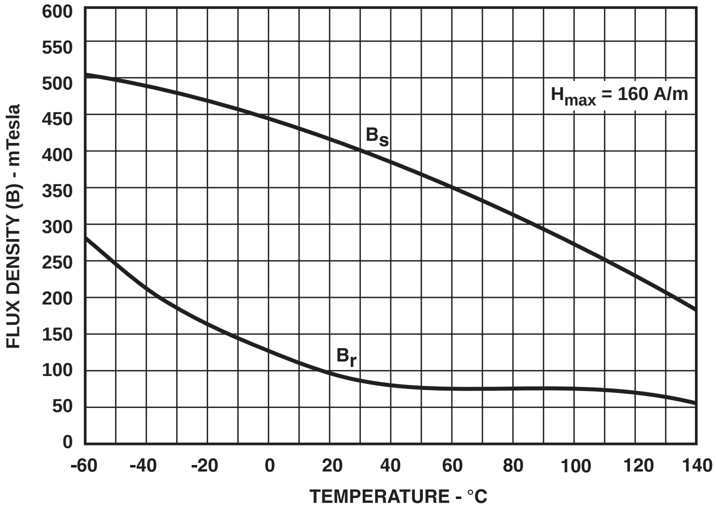
B MATERIAL


POWER LOSS vs FLUX DENSITY


LOSS FACTOR vs FREQUENCY

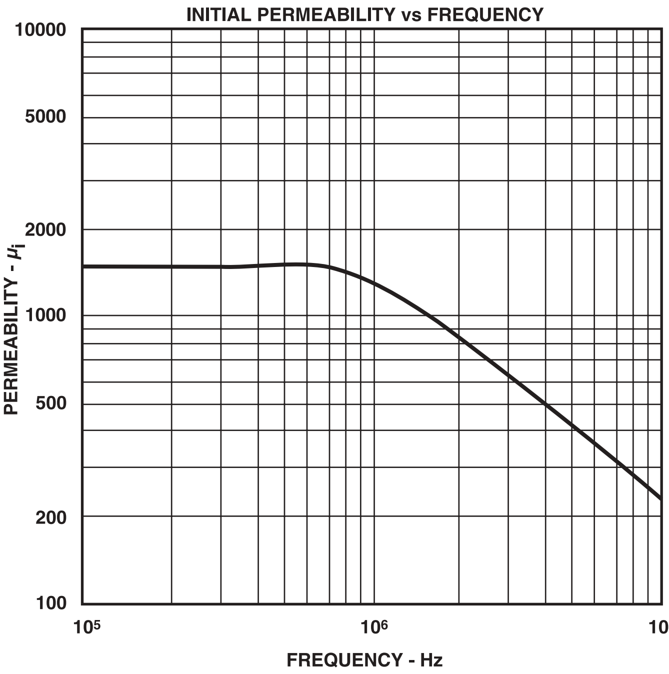

AMPLITUDE PERMEABILITY vs FLUX DENSITY

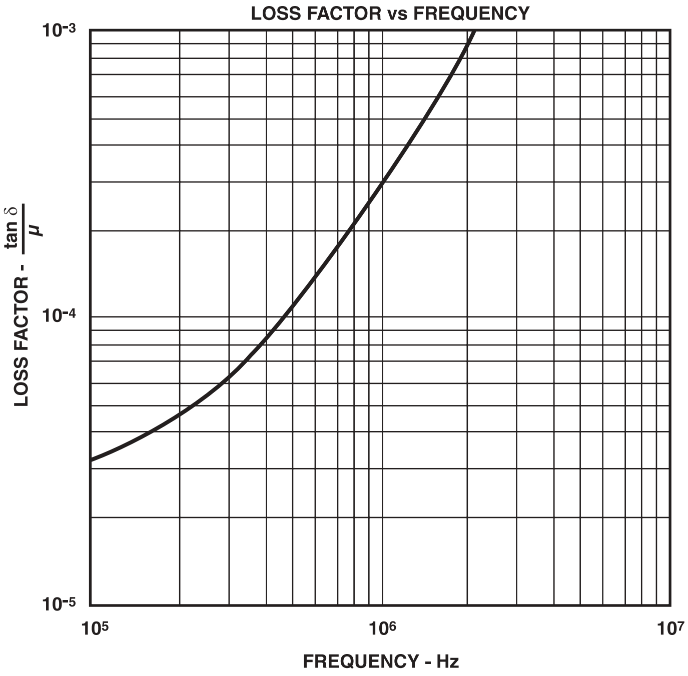

INCREMENTAL PERMEABILITY vs DC FIELD


FLUX DENSITY vs TEMPERATURE

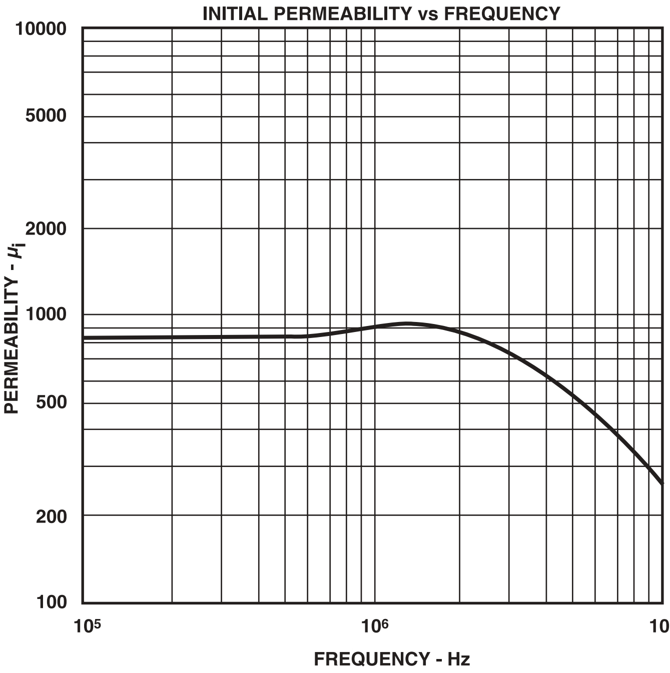
Material Properties

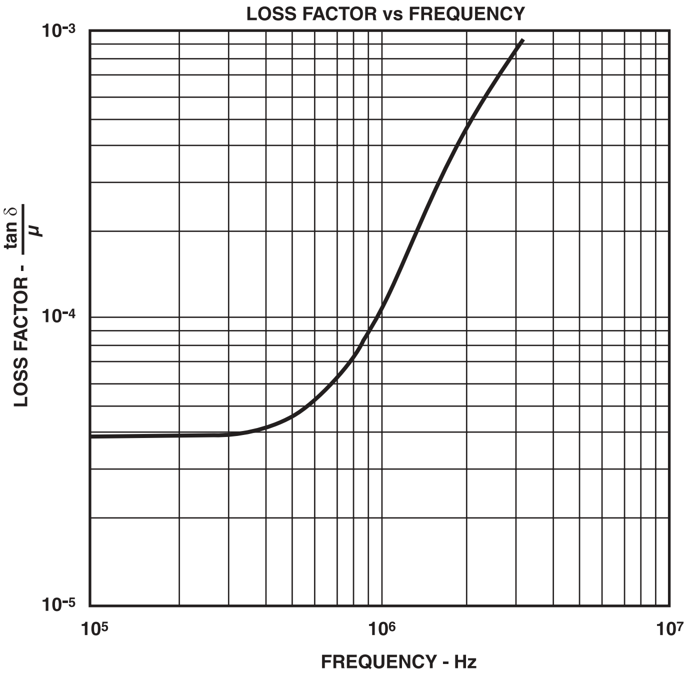
G MATERIAL (1,500μ_i) is a nickel-zinc ferrite with high permeability which allows for reduced core size enhancing high frequency performance in wideband applications.





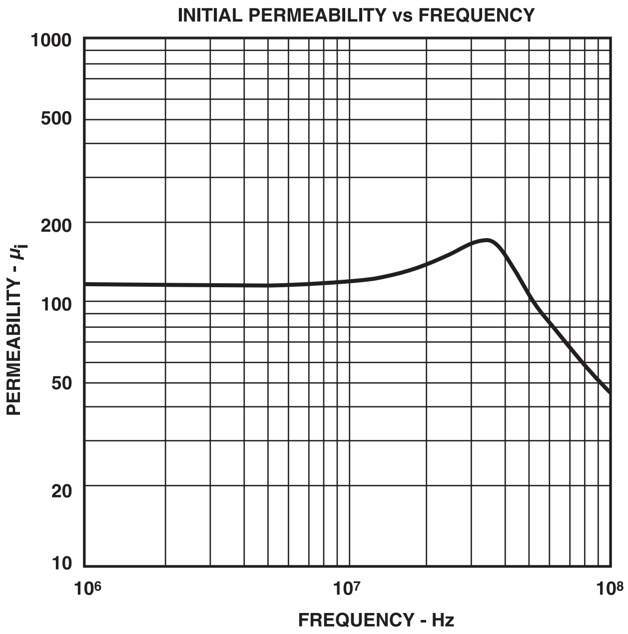
J MATERIAL (850μ_i) is a nickel-zinc ferrite useful at higher frequencies where high resistivity accounts for low eddy current losses. This makes it well suited for transformers and inductors operating above 500KHz and in particular for wideband devices above 5 MHz. It is also effective in 20 to 500 MHz noise suppression applications.

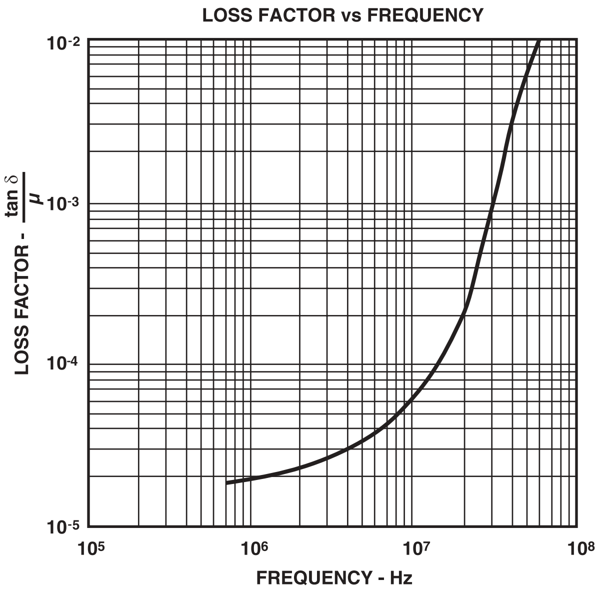




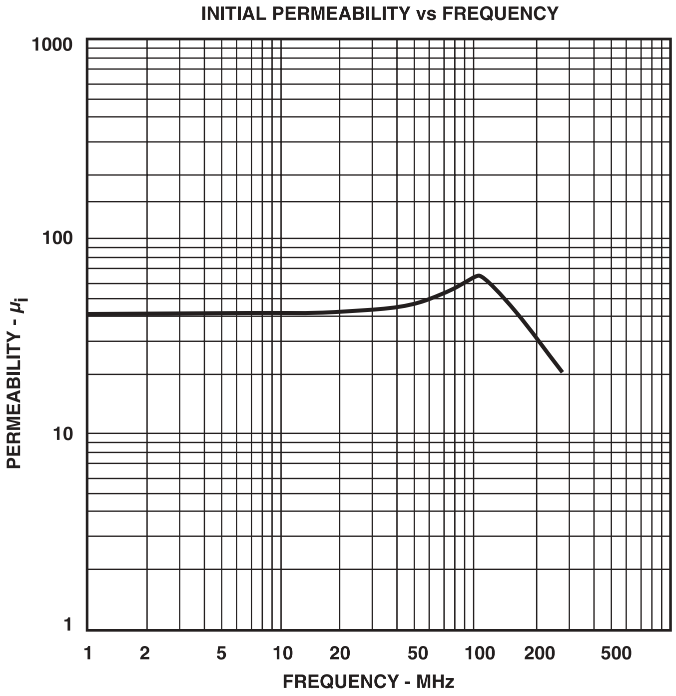
Material Properties

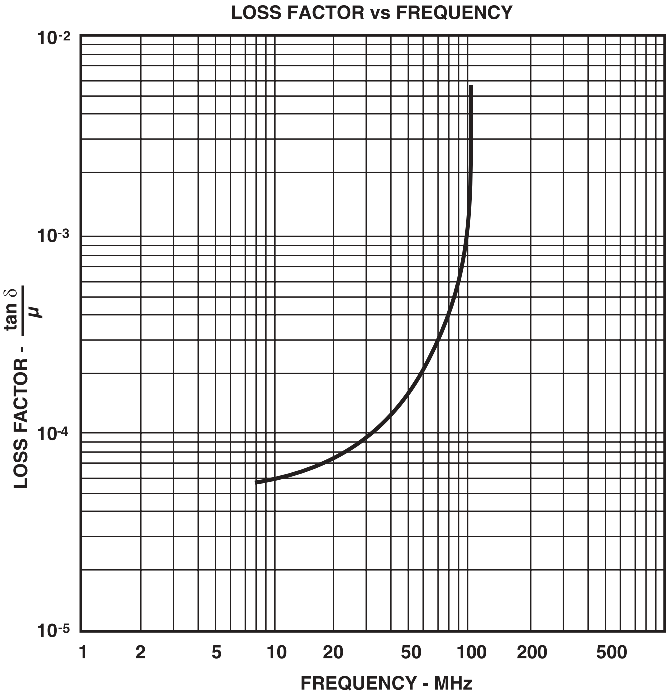
K MATERIAL (125μ_i) is a cobalt-nickel ferrite suited for higher frequency applications where low losses above 2MHz are required.





P MATERIAL (40μ_i) is a cobalt-nickel-zinc ferrite suited for the highest frequency applications where low losses above 10 MHz are required.





Design Considerations

Ferrite toroids provide an often convenient and very effective shape for many wide band, pulse and power transformers and inductors. The continuous magnetic path yields the highest effective permeability and lowest flux leakage of any shape.

Basic considerations:
The inductance may be calculated from:

$$L = \frac{0.4\pi \mu N^2 A_e}{\ell_e} \times 10^{-8} \text{ Henries} \qquad (1)$$

(the units are in CGS system which is used throughout this catalog). Here ℓ_e and A_e are the effective magnetic path length and cross sectional area of the core, μ is the effective permeability of the material, and N is the number of turns. This formula may be used for any shape under all conditions provided the correct value of μ is used and stray reactances are given proper consideration. In a toroidal core, this may be expressed as:

$$L = 2\mu N^2 2.54 \text{ H} \ln \frac{OD}{ID} \times 10^{-9} \text{ Henries} \qquad (2)$$

where OD, ID and H are the dimensions in inches. For low level conditions at comparatively low frequencies the formula may be simplified by using the Inductance Index, A_L, listed in this catalog. Then:

$$L = N^2 A_L \text{ nanohenries} \qquad (3)$$

The other value most frequently needed is peak flux density, which may be calculated from:

$$B = \frac{E}{4.44 A_e N f} \times 10^7 \text{ mTesla} \qquad (4)$$

Here E is the RMS voltage, 4.44 is a constant depending on the wave shape (use 4 when E is a symmetrical square wave and 1 where E is a unipolar pulse), and f is the frequency in hertz.

LOW LEVEL INDUCTORS:
This section considers those applications where nonlinearity and losses due to hysteresis are negligible. Generally this means flux densities below a few hundred Gauss. The first material choice is the one having both the highest permeability and lowest loss factor, tan δ/μ, at the operating frequency. Considering the space available, select a core from the table and, using its inductance index, A_L, calculate the number of turns required to give the desired inductance. Now select the largest practical wire size that will fit on the core. This is somewhat difficult for a toroid, but generally the total wire cross section in the winding can be 30-60% of the window opening. If there are Q or loss requirements calculate the resistance of the winding, taking into consideration the skin effect if the frequency is high, and add it to the equivalent series resistance contributed by the core losses. Equation 5 shows the relationship between loss factor, Q and resistance.

$$\tan \delta/\mu = \frac{1}{\mu Q} = \frac{R}{\mu 2\pi f L} \qquad (5)$$

If the calculated Q is inadequate you must reduce the total series resistance by selecting a larger core that will allow fewer turns of larger wire, select a less lossy material, or use Litz wire at high frequencies to minimize the skin effect.

If losses are critical it is important to remember that hysteresis losses have been assumed to be negligible. Above mTesla these losses are measurable and increase as approximately the 2.5 power of flux density. Also, remember that ferrites like other magnetic materials show variation in inductance from part to part, with temperature and with magnetizing force. Unlike powdered metals which have air gaps between the particles a ferrite toroid is a continuous magnetic material with variability effects undiluted by air gaps. This means that tight tolerances such as required for wave filters are not attainable in a toroid, but will generally require a gapped structure such as an E core, pot core, or slug.

POWER INDUCTORS:
In this section we consider inductors where the design is limited by saturation or heating due to core or winding losses. Although there is no systematic connection between permeability and losses, below about 1 MHz relatively high permeability manganese-zinc ferrites have the most desirable combination of high saturation flux density and low hysteresis losses. The first step is to select one of those materials having the desired properties (usually B material) and select a core based on space limitations. Then select a suitable operating flux density. As a general rule, at room temperature materials may be operated to the knee of the BH loop when the frequency is 20 kHz or less. At higher frequencies hysteresis losses produce enough heat to require that the flux density be decreased. As a first approximation, the product of flux density and frequency can be held constant above 20 kHz. Knowing the voltage, frequency, flux density and area of the chosen core the minimum number of turns may be calculated from equation 4.

Design Considerations

The inductance can then be estimated from equation 3 or calculated more exactly from equations 1 or 2 by using the appropriate value of permeability under these operating conditions. If this inductance is less than the desired value, the number of turns can be adjusted upward provided there is sufficient space for the winding. If the inductance is too great it will be necessary to choose a larger core whose cross sectional area is greater but whose ratio of A_e/ℓ_e is less, or a material with lower permeability.

For inductors operating above 1 MHz, the material choice becomes more difficult since other requirements such as return loss may be more important. The material choice and design procedure will depend on which factors predominate in your particular design. Inductors having dc current superimposed on the ac excitation must be given special treatment. The magnetizing force may be calculated using equation 6:

$$H = \frac{0.4\pi N I}{\ell_e} \times 79.55 \text{ A/m} \tag{6}$$

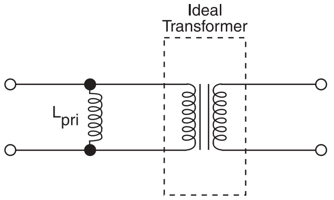
With this information it is possible to estimate from the BH curves how significant will be the effect of the dc current. Generally dc magnetizing forces less the coercive force will have only a small effect on permeability, moderate values will depress the permeability, and magnetizing forces approaching the knee of the BH loop will considerably reduce the permeability and severely limit the peak flux density available for ac excitation. In these cases, unless a higher inductance can be used it will be necessary to go to a core with a considerably longer magnetic path length or to provide an air gap such as by slotting the core.

In many power applications thermal considerations control the design. One rule of thumb that may be useful for first approximations is that core losses of 100 to 600 mW/cm3 produce an approximate 40° C temperature rise. The exact value depends on inductor geometry and thermodynamic considerations beyond the scope of this guide. You must also consider the power dissipated in the winding and its contribution to inductor heating. Heat sinking or coolants may be used to remove this heat, but the thermal conductivity of ferrite is relatively low, so the interior core temperature will be higher. Should a large temperature gradient develop, the core may crack from thermal stresses. Also, where considerable temperature excursions occur due either to self heating or ambient temperatures, the effect of these changes must also be considered with respect to changes in saturation flux density and inductance.

LOW LEVEL TRANSFORMERS:

The design procedure here is essentially the same as for **low level inductors** except, of course, that the winding space must be shared between the primary and secondary windings. Usually half the space is allotted to each.
In selecting the inductance required, it is easiest to envision the equivalent circuit as an ideal transformer (figure 1) with a primary self inductance shunting the transformer primary. When the impedance represented by this inductance is high compared to the primary and transformed secondary impedances it may be neglected and an ideal transformer results. Ordinarily this impedance is selected to be between 3 and 10 times the source impedance. At very high frequencies losses or winding capacitance and leakage inductance may predominate.

FIGURE 1

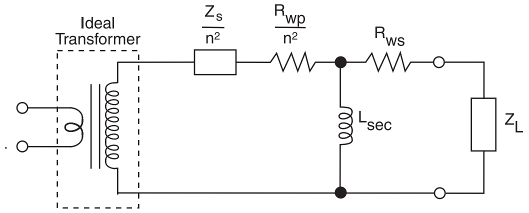


These situations are considered in later paragraphs.

CURRENT TRANSFORMERS:

This special class of low level (and sometimes power) transformers includes **ground fault interrupters (GFI)** sensors. In this case it is simpler to design around the secondary. Because there are often few primary turns (usually one) and many secondary turns, the transformed source impedance (Z_S) and primary winding resistance (R_{wp}) can not always be neglected. As shown in figure 2, these impedances are increased by $1/n^2$ (where n is the primary to secondary turns ratio) .

FIGURE 2



As n is decreased to raise the secondary voltage, all four internal impedances shown in figure 2 increase. This limits the available load voltage, so a compromise must be made for optimum performance. Since the core losses of high permeability ferrites are small at audio frequencies, they may often be neglected. For this reason, ferrite toroids are usually selected for grounded neutral transformers in GFIs-particularly when frequencies above 60 Hz are used for this test. Special manufacturing and test techniques can be used to enhance the properties of ferrite toroids for GFI differential fault transformers as well.

Design Considerations

POWER TRANSFORMERS:

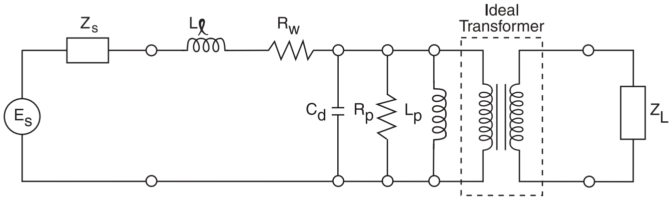
Here we are considering the same kinds of situations we covered under power inductors, that is, those cases where the design is limited by saturation flux density or self heating due to core and winding losses. At low frequencies, say below 1 MHz, the design procedure is the same as that for power inductors except, of course, that winding space must be allowed for both windings. Ordinarily allot half each to the primary and secondary, or with a push-pull primary, slightly less than one third to each primary half. In most cases the voltage and frequency are known (use the lowest operating frequency for design purposes). Select a material and flux density in the same manner as for power inductors. Then using equation 4, calculate the product of A_e and N required. It is then a simple matter to go down the list of suitable core sizes substituting for A_e, calculating the minimum number of turns required and checking the fit of the winding in that core. Calculating the primary inductance from equations 1, 2, or 3, you will ordinarily find that the inductance will be large enough that the magnetizing current may be neglected under full load. (This is the current drawn by the primary inductance which shunts the ideal transformer.) The rest of the transformer design is fairly straight-forward and is covered in other publications. Most devices of this type are limited by either saturation or heat dissipation, temperature rise and efficiency. Often winding losses are greater than core losses below 50 kHz. In some cases other considerations such as regulation may take precedence, but the considerations described above must still be met.

At higher frequencies in the MHz range other factors such as eddy currents influence the design. For this reason higher resistivity nickel zinc ferrites are ordinarily used. For example, the volume resistivity of G, J, K and P materials is typically 103 to 106 times greater than manganese zinc materials. Furthermore, winding design can be of major importance because of the critical nature of winding losses (including skin effects), leakage inductance and self capacitance. Again, cooling is often a major problem and increasing core size is limited by its effect on winding characteristics. It is sometimes helpful to assemble the core as a stack or two stacks of a number of smaller toroids since this facilitates cooling, and results in a compact winding. Occasionally oil cooling or heat sinking are used to improve heat transfer. Material selection is difficult because of the influence of several factors which do not lend themselves to analytical prediction. Lacking previous experience with a similar design, some guesses will have to be made. A good starting point is material having the lowest loss factor at the minimum operating frequency. A trial design can be worked up using the same core selection criteria as at lower frequencies. Usually the flux density will have to be limited to a few hundred Gauss or less. Care should be taken to select a core which will allow a compact winding so that leakage inductance and winding self capacitance will be small. Winding design requires careful consideration also because skin effects will make the winding resistance (and, hence, loss) much greater than at low frequencies. A technique popular when one winding is a single turn is to use tubing. The wall thickness should be chosen to be slightly more than the current penetration depth, and the secondary winding can go within the tubing. Litz wire can also be used to reduce the effective resistance. A trial design and a few iterations are usually required to optimize RF power transformer designs.

WIDE BAND TRANSFORMERS:

The best starting point is with the equivalent circuit shown in figure 3.

FIGURE 3



Here L_p and R_p are the parallel inductance and resistance (loss) of the wound core, R_w is the winding resistance, C_d is the distributed self capacitance of the winding, L_ℓ is the leakage inductance (representing flux that does not link the core), and Z_s and Z_L are the source and load impedances. At low frequencies the contribution of L_ℓ and Cd are so small they may be neglected. The low frequency cut-off, where insertion loss, VSWR or source loading become unacceptable, is then determined by L_p, R_p, and R_w. Since the reactance of L_p ($X = 2\pi f L_p$) is proportional to frequency, it is usually the determining factor. The objective is then to choose a core, material and winding that will have the highest L_p and R_p at the lower frequency while keeping R_w small. To do this, select a material having high permeability and low loss at that frequency. Choosing a core with a high A_L, it must be wound so that L_p and R_p are high enough and R_w low enough to meet the insertion loss, VSWR, return loss or loading requirements. At the high frequency cut-off, L_p can usually be neglected while L_ℓ and C_d assume critical importance. These elements depend almost entirely on the winding and very little on the core. They can not be readily calculated, but are minimized by keeping the winding length and number of turns low. The optimum core is difficult to select since it must balance these considerations with winding space, ease of winding, integer turns, space limitations and core manufacturing constraints. Generally, it is best to choose a core with a large OD/ID ratio and the greatest practical height. For this reason high frequency wide band transformers are often wound on cores found in the **BEAD** and **MULTI-HOLE** sections.

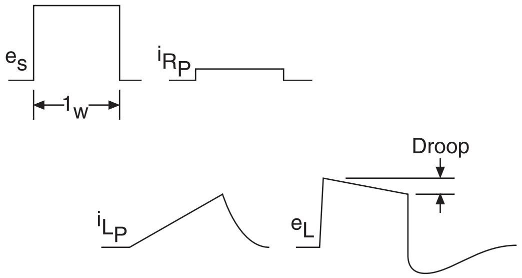
There are also techniques covered in the literature on winding transformers with transmission lines such that at low frequencies the device operates conventionally as above. At higher frequencies coupling is via the transmission line enabling extension of the upper operating limit.

In this section you will find curves of X_p, R_p and Z versus frequency for certain cores. This data simplifies material, core and winding selection. With the exception of the highest frequencies, these curves may be shifted upward or downward to fit a given application by the ratio of N^2 of the new winding to N^2 indicated on the graph.

PULSE TRANSFORMERS:

In many ways pulse transformers are a special case of wide band transformer because the pulse train can be represented by a number of sine waves of different frequencies. The turns ratio, though, is usually determined by voltage or current ratios rather than impedance matching, so the design approach is governed by pulse fidelity requirements rather than insertion or return loss. The equivalent circuit of figure 3 can help illustrate the elements influencing fidelity. Looking first at the flat top (low frequency) portion of a rectangular pulse (e_s), figure 4 shows some of the voltage and current wave shapes.

FIGURE 4



Neglecting the rise and fall portions (high frequencies), current through R_p is constant during the pulse and current through L_p flows according to equation 7.

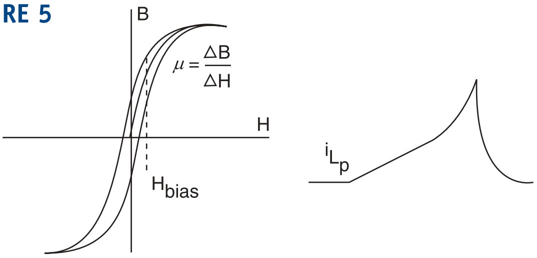
$$i_{L_p} = \int \frac{e}{L_p}\,dt \approx \frac{e\,t}{L_p} \quad \text{Amperes} \tag{7}$$

If the voltage and inductance are constant the current will rise linearly with time. This produces a drop across Z_s accounting for droop of the load voltage pulse (e_L). In order to minimize droop, L must be made large. This can be accomplished by choosing the highest permeability material (typically B,T or V material) and largest core practical. To determine the A_L value under pulse conditions, multiply the sine A_L by 1.1. L_p can then be calculated from equation 3. Also, flux density must be considered. Equation 4 may be rewritten:

$$B = \frac{e\,t}{A_e\,N} \times 10^7 \ \text{mTesla} \tag{8}$$

It can be seen that flux density rises linearly with time. As this approaches the knee of the hysteresis B-H) loop, permeability and inductance start to fall and the current begins to rise rapidly (figure 5).

FIGURE 5



From equation 3 and 8, you can see that increasing N will both raise L and diminish B. However, rise and fall time are limited by leakage inductance(L_ℓ) and distributed self capacitance (C_d) in the same way as high frequency response in a wide band transformer. Therefore, the number of turns must be balanced between these conflicting requirements. The tools available are higher permeability and flux density material, and a larger core.

High pulse repetition rate can have two effects. The dc level represented by averaging the pulses produces magnetizing force (H) to bias the starting point of each pulse to the right on the B-H loop (figure 5) . This can significantly reduce the available flux density. One possible solution is described under **Slotted Toroids**. Second, each pulse traverses a minor hysteresis loop producing an energy loss. This can cause core heating that will affect saturation flux density and permeability.

SLOTTED TOROIDS:

In a number of applications described earlier the design is limited either by dc current, excessive inductance, or variability effects of the ferrite. A slot cut through the cross section can sometimes be used to advantage.

Design Considerations

The effect of the gap is magnified by the material permeability according to:

$$\ell_e = \ell_m + \mu \ell_g \tag{9}$$

Where ℓ_m and ℓ_g are the path length in the magnetic material and the gap respectively and, μ is the material permeability. This can be used to reduce the effect of dc bias when the ℓ_e calculated above is substituted into equation 6. For example 1 Adc flowing through 10 turns on a core with a path length of 2 cm produces a magnetizing force (H) of 500 A/m. This is enough to saturate most high permeability materials. Now if a .010" (.0254 cm) slot is cut and the material permeability is 5000, the effective path length (from equation 9) is 129 cm. The magnetizing force from the dc is reduced to 7.7 A/m and the effect of the dc bias is very small.

In similar fashion a gap can be used to reduce inductance to the required value when the minimum turns are dictated by flux density considerations. The effective permeability of a gapped core can be calculated from:

$$\mu_e = \frac{\mu \ell_m}{\ell_m + \mu \ell_g} \tag{10}$$

This value of m can be used with equations 1 or 2 to calculate inductance. It is also apparent from equation 10 that as ℓg is increased, relative ℓ_m changes in μ will have a smaller effect on μe. This can be used to reduce changes in inductance caused by permeability variations due to temperature, flux density, bias, stress, time, etc. For example, with 5000 permeability material and $\ell_g / \ell_m = .01$, a 20% change in μ will result in only a 0.2% change in μ_e.

Equations 9 and 10 are exact only when there is no flux fringing in the gap. This is a good assumption when $A \gg \ell_g$, but as the gap increases the actual μe will be greater than the calculated value and actual μe will be less. More elaborate equations can extend the range of accuracy somewhat, but with larger gaps some experimentation is necessary. A wide range of slot widths are available. Consult the factory regarding your application.

OTHER APPLICATIONS:
Most other uses for toroids are variations on the above classes. Toroids used for noise or RFI suppression are covered in the **BEADS** section. If you have a special problem, Ferronics engineers will be happy to assist you.

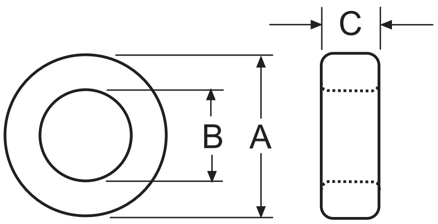
COATINGS:
Ferrites are hard, abrasive ceramic materials which can abrade wire insulation films during winding. Ferronics toroids are ordinarily tumbled so that sharp edges are rounded. However, if a higher level of insulation protection is desired, a smooth as well as an insulating coating can be provided. This coating should be soft to prevent stressing the core upon curing or during temperature cycling, have a low coefficient of friction, withstand normal environments (including cleaning solvents) and provide some additional insulation. We use two materials which admirably fill these requirements. Parylene® C is used for smaller cores. It is vapor deposited - a process well suited to bulk coating and produces an exceptionally uniform coating normally about .0007 inches thick. Epoxy is used on larger cores. It is sprayed producing a variable thickness of about .001-.005 inches, and has better physical and chemical properties than other choices.

Standard minimum voltage breakdown for both Parylene®and epoxy coated cores is 500VAC. If a higher level of protection is required, please consult with our engineering department.

Parylene is a registered trademark of Union Carbide.

Dimensions

PART NUMBER (1)			PHYSICAL DIMENSIONS							EFFECTIVE DIMENSIONS	
UNCOATED	COATED(2)		A inch	A mm	B inch	B mm	C(4) inch	C(4) mm		A_e(cm^2)	l_e(cm)
11-005	11-505		.080	2.03	.050	1.27	.025	.64		.0024	.500
			±.005	±.13	±.005	±.13	±.005	±.13			
11-010	11-510		.100	2.54	.050	1.27	.030	0.76		.0047	.553
			±.005	±.13	±.005	±.13	±.005	±.13			
11-012	11-512		.100	2.54	.050	1.27	.050	1.27		.0078	.553
			±.005	±.13	±.005	±.13	±.005	±.13			
11-013	11-513		.100	2.54	.059	1.50	.039	1.00		.0050	.606
			±.005	±.13	±.005	±.13	±.005	±.13			
11-020	11-520		.100	2.54	.070	1.78	.030	0.76		.0029	.664
			±.005	±.13	±.005	±.13	±.005	±.13			
11-106	11-606		.120	3.05	.050	1.27	.050	1.27		.0106	.599
			±.005	±.13	±.005	±.13	±.005	±.13			
11-024	11-524		.120	3.05	.070	1.78	.060	1.52		.0095	.723
			±.005	±.13	±.005	±.13	±.005	±.13			
11-040	11-540		.135	3.43	.070	1.78	.060	1.52		.0121	.762
			±.005	±.13	±.005	±.13	±.005	±.13			
11-032	11-532		.138	3.51	.051	1.30	.128	3.25		.0331	.643
			±.005	±.13	±.005	±.13	±.005	±.13			
11-149	11-649		.155	3.94	.070	1.78	.065	1.65		.0169	.810
			±.005	±.13	±.005	±.13	±.005	±.13			
11-009	11-509		.155	3.94	.079	2.00	.040	1.02		.0094	.867
			±.005	±.13	±.005	±.13	±.005	±.13			
11-050	11-550		.155	3.94	.088	2.24	.050	1.27		.0105	.920
			±.005	±.13	±.005	±.13	±.005	±.13			
11-080	11-580		.190	4.83	.090	2.29	.050	1.27		.0154	1.020
			±.005	±.13	±.005	±.13	±.005	±.13			
11-081	11-581		.194	4.93	.095	2.41	.125	3.18		.0383	1.060
			±.005	±.13	±.005	±.13	±.005	±.13			
11-082	11-582		.194	4.93	.095	2.41	.250	6.35		.0765	1.060
			±.005	±.13	±.005	±.13	±.007	±.18			
11-090	11-590		.163	4.14	.063	1.60	.125	3.18		.0374	.779
			±.005	±.13	±.005	±.13	±.005	±.13			



Electricals

PART NUMBER (1)			INDUCTANCE INDEX, A_L(nH/N^2)(3)						
UNCOATED	COATED(2)		V(5)	T(5)	B	G	J	K	P
11-005	11-505		896	597	298	90	50.7	7.5	2.4
11-010	11-510		1584	1056	528	158	89.8	13.2	4.2
11-012	11-512		2640	1760	880	264	150	22.0	7.0
11-013	11-513		1569	1046	523	157	89.8	13.1	4.2
11-020	11-520		816	544	272	82	46.2	6.8	2.2
11-106	11-606		3336	2224	1112	334	189	27.8	8.9
11-024	11-524		2465	1643	821	246	140	20.5	6.6
11-040	11-540		3003	2002	1001	300	170	25.0	8.0
11-032	11-532		9708	6472	3236	971	550	80.9	25.9
11-149	11-649		3938	2625	1312	394	223	32.8	10.5
11-009	11-509		2055	1370	685	205	116	17.1	5.5
11-050	11-550		2157	1438	719	216	122	18.0	5.8
11-080	11-580		2847	1898	949	285	161	23.7	7.6
11-081	11-581		6801	4534	2267	680	385	56.7	18.1
11-082	11-582		13602	9068	4534	1360	771	113	36.3
11-090	11-590		9054	6036	3018	905	513	75.5	24.1

NOTES:

1. Complete part number includes material designation. i.e., 11-010-B.

2. Part numbers from 11-510 through 11-759 are Parylene coated.
Part numbers from 11-760 through 11-795 are epoxy coated.
Coatings will marginally alter core dimensions.

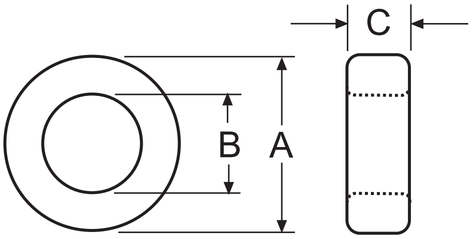
3. Inductance tolerance: ±20%.
A_L measured at low frequency: T and V material - 10KHz, B = 1 mTesla.
B, G and J materials - 100KHz, B = 0.5 mTesla, P and K materials - 10MHz.

4. Special heights can be manufactured without tooling costs.
Consult the factory for additional information.

5. T and V material toroids available coated only.

Dimensions

PART NUMBER (1)			PHYSICAL DIMENSIONS							EFFECTIVE DIMENSIONS	
UNCOATED	COATED(2)		A inch	A mm	B inch	B mm	C(4) inch	C(4) mm		A_e(cm^2)	l_e(cm)
11-091	11-591		.163	4.14	.063	1.60	.250	6.35		.0748	0.78
			±.005	±.13	±.005	±.13	±.005	±.13			
11-120	11-620		.230	5.84	.120	3.05	.060	1.52		.0206	1.30
			±.005	±.13	±.005	±.13	±.005	±.13			
11-122	11-622		.230	5.84	.120	3.05	.120	3.05		.0411	1.30
			±.005	±.13	±.005	±.13	±.005	±.13			
11-160	11-660		.300	7.62	.125	3.18	.188	4.78		.0996	1.50
			±.006	±.15	±.005	±.13	±.005	±.13			
11-170	11-670		.354	9.00	.236	6.00	.118	3.00		.0443	2.29
			±.008	±.20	±.007	±.18	±.005	±.13			
11-220	11-720		.375	9.53	.187	4.75	.125	3.18		.0728	2.07
			±.007	±.18	±.005	±.13	±.005	±.13			
11-260	11-759		.500	12.70	.281	7.14	.188	4.78		.129	2.95
	11-760		±.010	±.25	±.007	±.18	±.005	±.13			
11-261	11-761		.500	12.70	.281	7.14	.250	6.35		.172	2.95
			±.010	±.25	±.007	±.18	±.007	±.18			
11-251	11-751		.500	12.70	.312	7.92	.125	3.18		.0744	3.12
			±.010	±.25	±.008	±.20	±.005	±.13			
11-250	11-750		.500	12.70	.312	7.92	.250	6.35		.149	3.12
			±.010	±.25	±.008	±.20	±.007	±.18			
11-247	11-747		.551	14.00	.354	9.00	.197	5.00		.123	3.50
			±.012	±.30	±.008	±.20	±.005	±.13			
11-270	11-770		.625	15.88	.350	8.89	.185	4.70		.160	3.68
			±.014	±.36	±.008	±.20	±.005	±.13			
11-280	11-780		.870	22.10	.540	13.72	.250	6.35		.261	5.42
			±.017	±.43	±.012	±.30	±.007	±.18			
11-282	11-782		.870	22.10	.540	13.72	.500	12.70		.522	5.42
			±.017	±.43	±.012	±.30	±.012	±.30			
11-295	11-795		.906	23.00	.551	14.00	.276	7.00		.310	5.58
			±.020	±.51	±.012	±.30	±.007	±.18			



Electricals

PART NUMBER (1)		INDUCTANCE INDEX, A_L(nH/N^2)(3)						
UNCOATED	COATED(2)	V(5)	T(5)	B	G	J	K	P
11-091	11-591	18108	12.072	6036	1811	1026	151	48.3
11-120	11-620	2973	1982	991	297	169	24.8	7.9
11-122	11-622	5949	3966	1983	595	337	49.6	15.9
11-160	11-660	12542	8361	4181	1254	711	105	33.4
11-170	11-670	3645	2430	1215	365	207	30.4	9.7
11-220	11-720	6627	4418	2209	663	376	55.2	17.7
11-260	11-759	----	----	2752	826	468	68.8	22.0
	11-760			2752	826	468	68.8	22.0
11-261	11-761	----	----	3659	1098	622	91.5	29.3
11-251	11-751	----	----	1497	449	255	37.4	12.0
11-250	11-750	----	----	2995	898	509	74.9	24.0
11-247	11-747	----	----	2214	664	376	55.4	17.7
11-270	11-770	----	----	2725	817	463	68.1	21.8
11-280	11-780	----	----	3028	909	515	75.7	24.2
11-282	11-782	----	----	6057	1817	1030	151	48.5
11-295	11-795	----	----	3486	1046	593	87.2	27.9

NOTES:

1. Complete part number includes material designation. i.e., 11-010-B.

2. Part numbers from 11-510 through 11-759 are Parylene coated.
Part numbers from 11-760 through 11-795 are epoxy coated.
Coatings will marginally alter core dimensions.

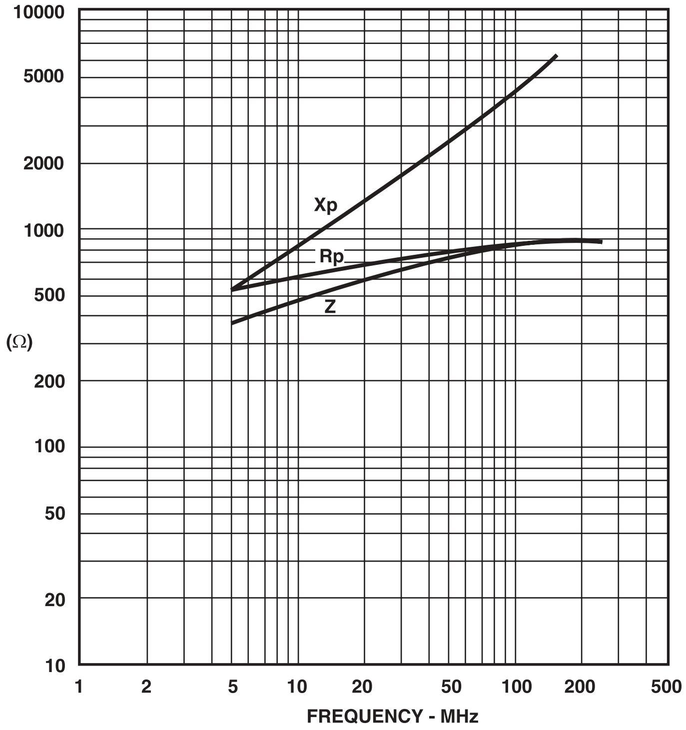
3. Inductance tolerance: ±20%.
A_L measured at low frequency: T and V material - 10KHz, B = 1 mTesla.
B, G and J materials - 100KHz, B = 0.5 mTesla, P and K materials - 10MHz.

4. Special heights can be manufactured without tooling costs.
Consult the factory for additional information.

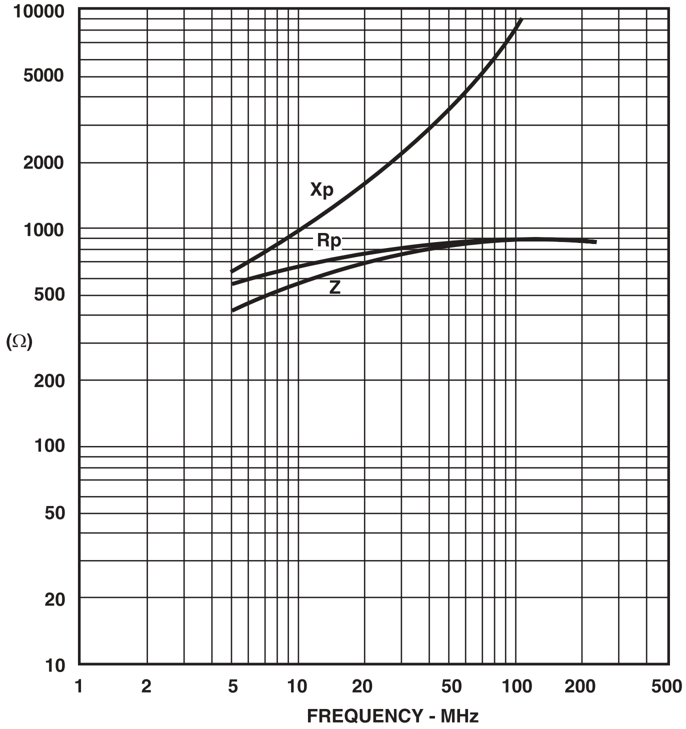
5. T and V material toroids available coated only.

Wide Band Curves

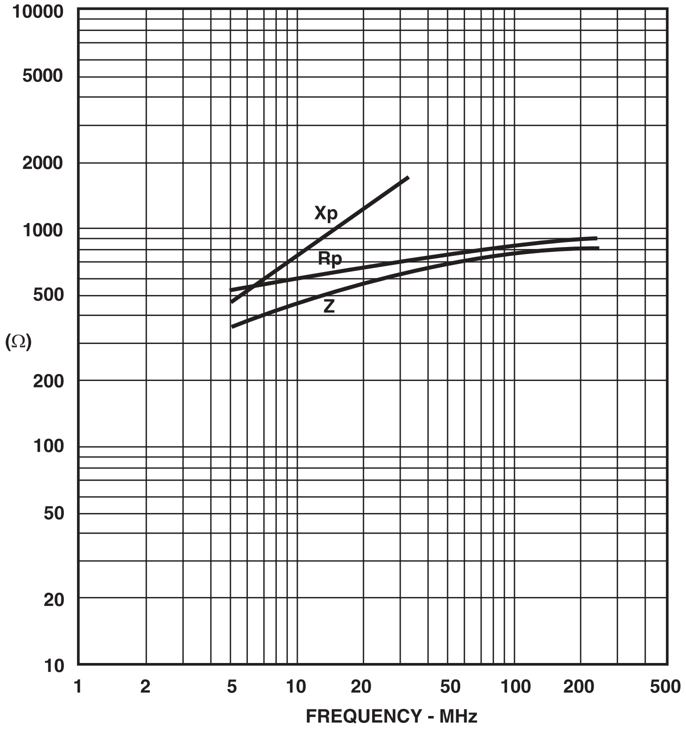
REACTANCE, RESISTANCE AND IMPEDENCE vs FREQUENCY (for a sampling of typical wideband toroids)



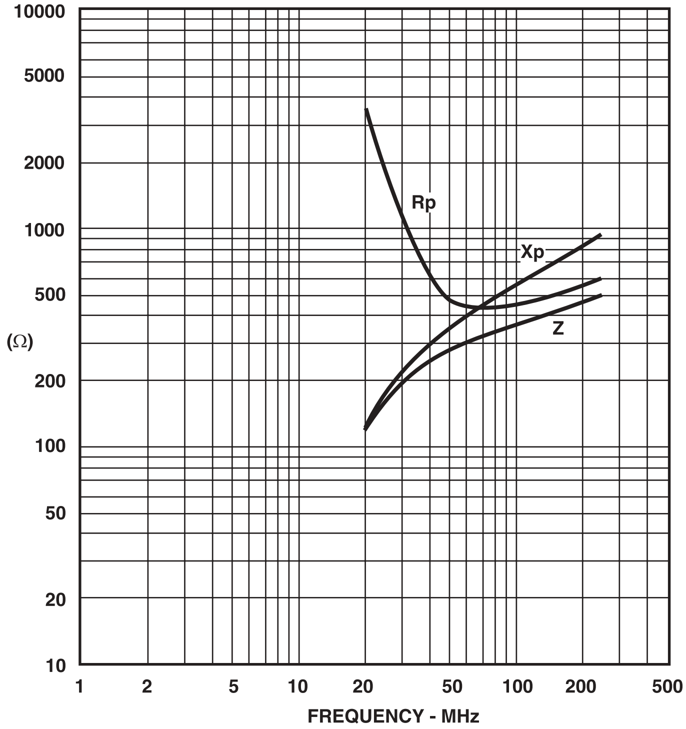
11-081-J
6 TURNS



11-091-J
4 TURNS



11-120-J
9 TURNS



11-120-K
4 TURNS

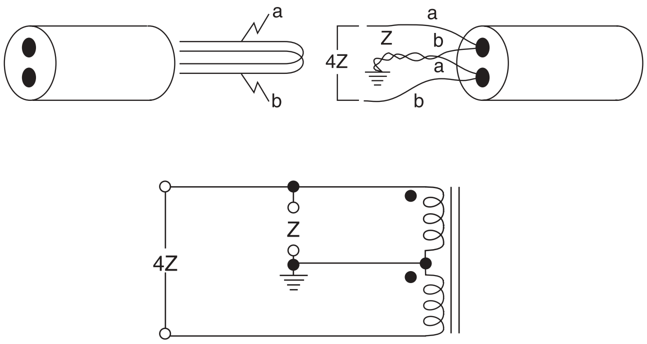
Design Considerations

APPLICATION NOTES:
Multi-hole cores provide specialized shapes that are sometimes more useful than single hole devices. One example is wide band transformers where good coupling between short windings is needed over a wide frequency range. Since most of these cores are used in applications of this kind, our standard tests are performed at critical frequencies within their practical operating range. This assures that the cores will operate properly in your application.

In this section you will find curves of X_p, R_p and Z versus frequency for many of these cores. This data was taken with a single winding passing through both holes, the number of turns being chosen for convenience in testing. Except for the highest frequencies, where results are controlled by stray reactances rather than the core, characteristics for other numbers of turns may be determined by multiplying by the square of the turns ratio-$(N_{new}/N_{curve})^2$. The effect is to shift the curves up or down by this ratio.

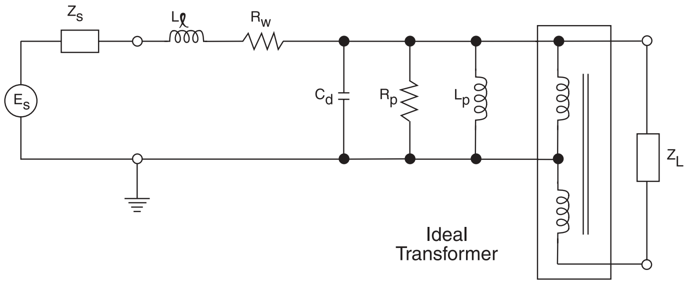
BALUNS:
These are transformers used for impedance matching, usually with one side balanced to ground and the other unbalanced (hence the name). They may be wound on any core shape, but often a two-hole core is used. Both cylindrical types and “binocular” or “shotgun” types (commonly called “balun cores”) are available. Many possible winding arrangements are used, but one simple type is shown in figure 1. Two U-shaped wires (a, b) are inserted and connected as shown. Then one winding, consisting of a single (two hole) turn, forms the low impedance connection, while two turns in series form the high impedance winding. Since impedance transformation is proportional to the turns squared ratio, it is 4:1. The center-tap may be grounded or left floating. As with other wide band transformers (see TOROID section) the lower frequency limit is determined by the shunting effect of the reactance produced by the winding inductance, as shown in figure 2.

FIGURE 1



Balun Transformer

FIGURE 2

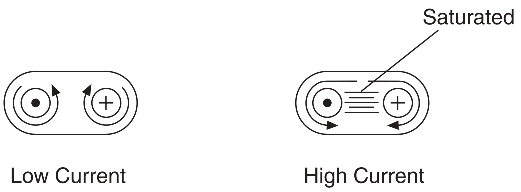


The upper frequency limit is determined by the leakage inductance (L_ℓ) and distributed self capacitance (C_d). Insertion loss is determined by core losses (R_p), winding losses (R_w) and L_p.

TWO-TRANSFORMER DEVICES:
There are a number of devices requiring two transformers in conjunction, such as wide band cable (CATV, MATV) directional taps, splitters and other hybrids. Although two toroids or beads are sometimes used, a two hole core is often more convenient. Each device is wound through one hole and around the outside. The leads are then in convenient and consistent locations for interconnection. There will be a small amount of coupling between the core halves which should be experimentally examined in your application for its influence on performance.

COMMON MODE CHOKES:
Simple noise suppression devices for power lines can be made by passing each side of a wire pair through one hole of a two hole core. At low current levels each half of the core acts as a choke on its own conductor. But at higher currents, when individual beads would saturate, only the web between the holes saturates (figure 3).

FIGURE 3



The power frequency currents in the outer portion cancel so that the outer ring may function as a choke to common mode noise signals. For further information, see the **BEAD** section.

Dimensions

PART NUMBER (1)	A		H		B(4)		E		C	
	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
12-315(2)	.136	3.45	.034	.86	.093	2.36	.057	1.45	.079	2.01
	±.010	±.25	±.005	±.13	±.010	±.25	REF	REF	±.007	±.18
12-322	.200	5.08	.047	1.19	.120	3.05	.105	2.67	.120	3.05
	±.010	±.25	±.005	±.13	±.005	±.13	REF	REF	±.007	±.18
12-328	.248	6.30	.047	1.19	.125	3.18	.115	2.92		
	±.012	±.30	±.006	±.15	±.010	±.25	±.015	±.38		
12-330	.248	6.30	.047	1.19	.255	6.48	.115	2.92		
	±.012	±.30	±.006	±.15	±.016	±.41	±.015	±.38		
12-332	.248	6.30	.047	1.19	.472	11.99	.115	2.92		
	±.012	±.30	±.006	±.15	±.016	±.41	±.015	±.38		
12-340(2)	.275	6.99	.073	1.85	.125	3.18	.115	2.92	.160	4.06
	±.012	±.30	±.006	±.15	±.010	±.25	REF.	REF	±.010	±.25
12-345(2)	.275	6.99	.073	1.85	.250	6.35	.115	2.92	.160	4.06
	±.012	±.30	±.006	±.15	±.015	±.38	REF.	REF.	±.010	±.25
12-350(2)	.275	6.99	.073	1.85	.300	7.62	.115	2.92	.160	4.06
	±.012	±.30	±.006	±.15	±.015	±.38	REF.	REF.	±.010	±.25
12-360(3)	.525	13.34	.150	3.81	.260	6.60	.225	5.72	.295	7.49
	±.025	±.64	±.010	±.25	±.010	±.25	±.010	±.25	±.015	±.38
12-365(3)	.525	13.34	.150	3.81	.565	14.35	.225	5.72	.295	7.49
	±.025	±.64	±.010	±.25	±.020	±.51	±.010	±.25	±.015	±.38
12-430	.257	6.53	.052	1.32	.255	6.48	.108	2.74		
	±.010	±.25	±.005	±.13	±.016	±.41	±.007	±.18		
12-432	.257	6.53	.052	1.32	.472	11.99	.108	2.74		
	±.010	±.25	±.005	±.13	±.016	±.41	±.007	±.18		

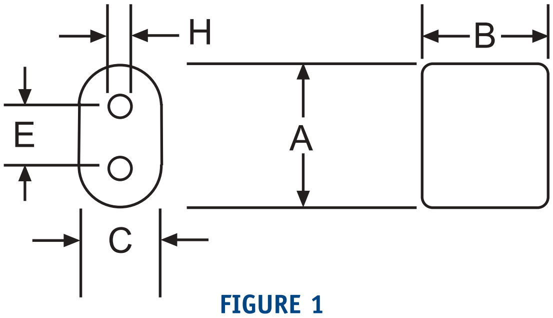


FIGURE 1

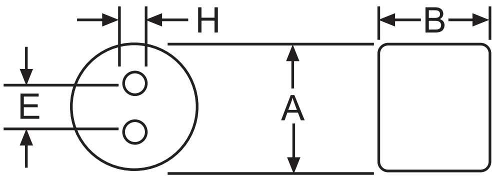


FIGURE 2

Electricals

NOMINAL ELECTRICALS

PART NUMBER(1)	B		G		J		K		FIG.
	A_L (5) (nH/N^2)	Z@10 MHz (6)	A_L (5) (nH/N^2)	Z@100 MHz (6)	A_L (5) (nH/N^2)	Z@100 MHz (6)	A_L (5) (nH/N^2)	Z@250 MHz (6)	
12-315(2)	3,700	50	1110	42	629	37	92.5	----	1
12-322	5,639	----	1692	----	959	----	141	----	1
12-328	7,508	88	2252	----	1276	----	188	94	2
12-330	15,300	----(7)	4590	---	2601	----	383	----	2
12-332	28,350	----	8505	----	4820	308	709	----	2
12-340(2)	4,576	----	1373	52	961	----	114	64	1
12-345(2)	9,152	----	2746	103	1922	91	229	----	1
12-350(2)	10,983	136	3295	124	2306	----	275	156	1
12-360(3)	8,312	----	2491	94	1745	----	208	127	1
12-365(3)	18,062	139	5419	204	3793	175	452	262	1
12-430	13,433	----	4030	----	2821	----	336	----	2
12-432	24,864	----	7459	----	5222	260	622	----	2

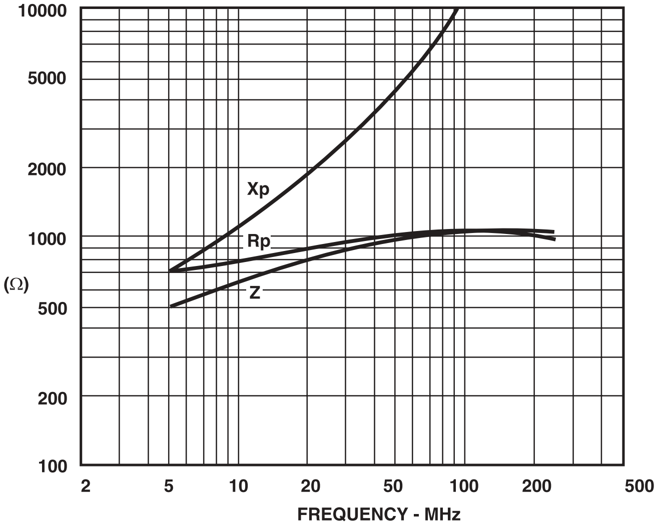
NOTES:

1. Complete part number includes material designation. i.e., 12-345-G.
2. Part is tumbled to remove sharp edges.
3. Part has chamfered edges.
4. Special heights can be manufactured without tooling costs.
5. Inductance tolerance varies with part number. Consult the factory for further information.
6. Impedance data shown is nominal, measured on a short length of 20AWG wire wound hole-to-hole at frequency shown. Normal tolerance is ±25%.
7. Impedance data not available at time of printing. Consult the factory for further information.

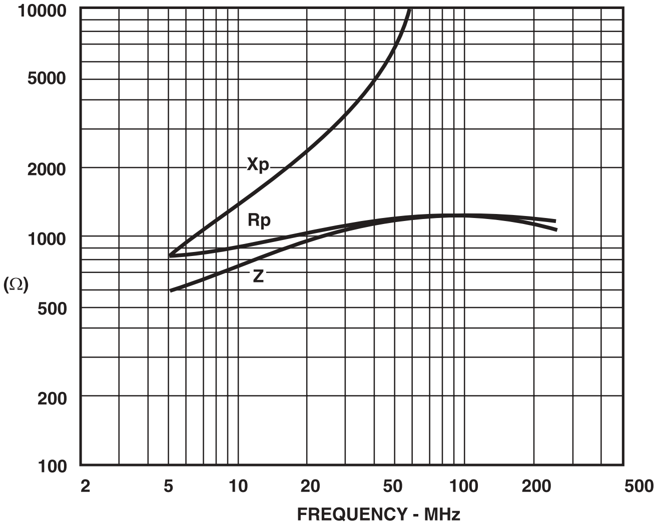
Material Curves

REACTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

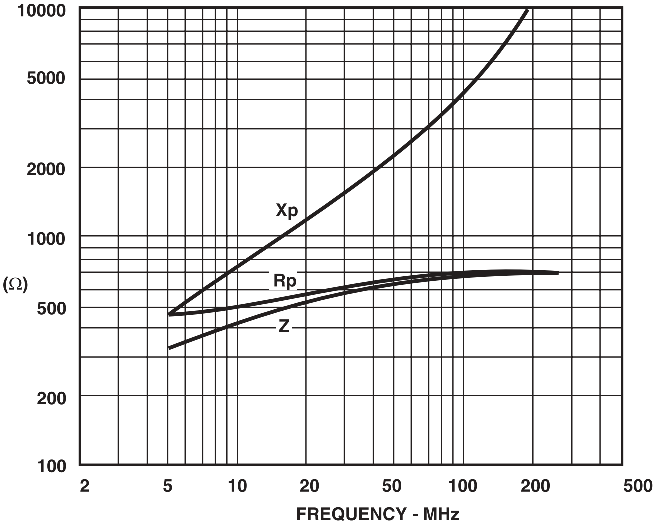
J MATERIAL



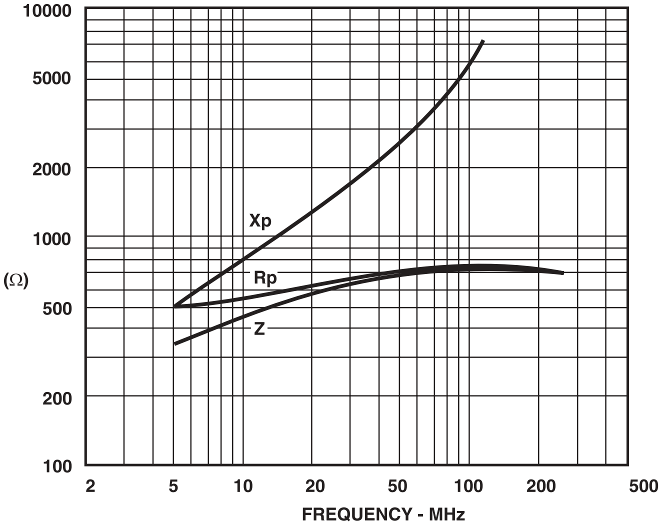
12-328-J
4 TURNS



12-330-J
3 TURNS



12-340-J
4 TURNS

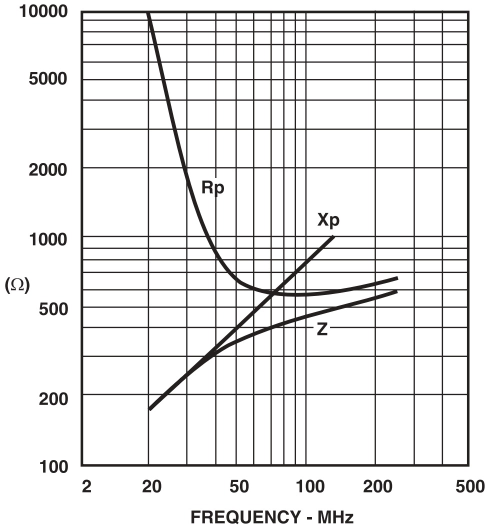


12-345-J
3 TURNS

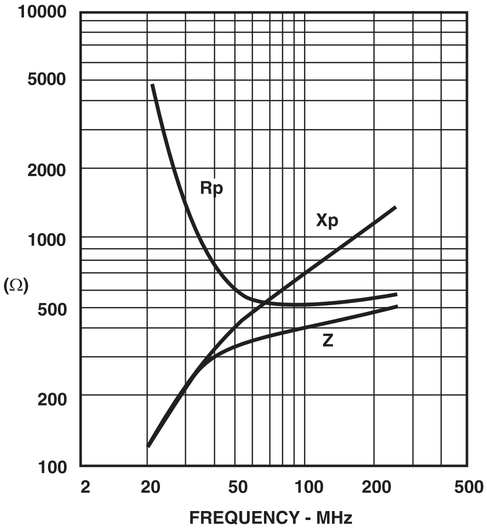
Material Curves

REACTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

K MATERIAL



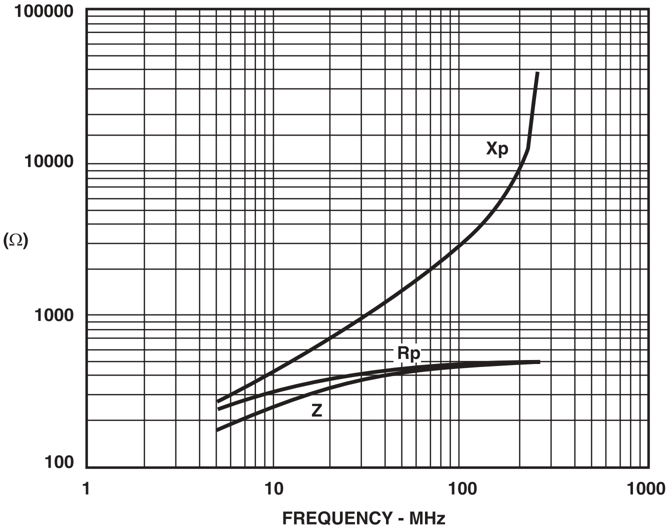
**12-340-K
3 TURNS**



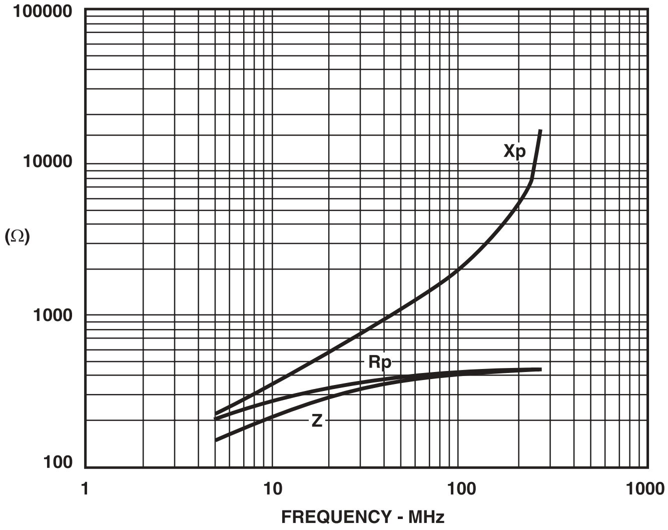
**12-345-K
2 TURNS**

REACTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

G MATERIAL



**12-340-G
3 TURNS**



**12-345-G
2 TURNS**

Design Considerations

Ferrite beads provide a simple, economical method for attenuating high frequency noise or oscillations. By slipping a bead over a wire, a RF choke or suppressor is produced which possesses low impedance at low frequencies and relatively high impedance over a wide high frequency band. The effectiveness of this impedance in reducing EMI or RFI depends on the relative magnitudes of the source, suppressor and load impedances. Beads are also available fixed on a wire, taped and reeled for automatic insertion.

HOW THEY WORK:

At high frequencies the permeability and losses of ferrite vary with frequency. The permeability declines while the losses rise to a broad peak. The equivalent circuit and curves in figures 1 and 2 show how this property can be used as a broad band filter.

FIGURE 1

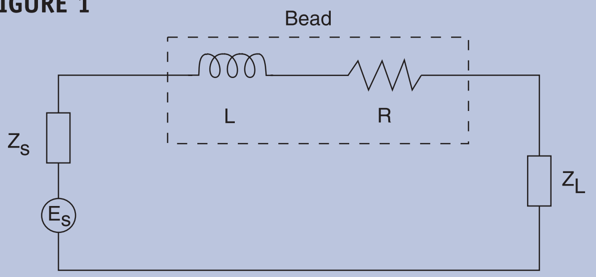
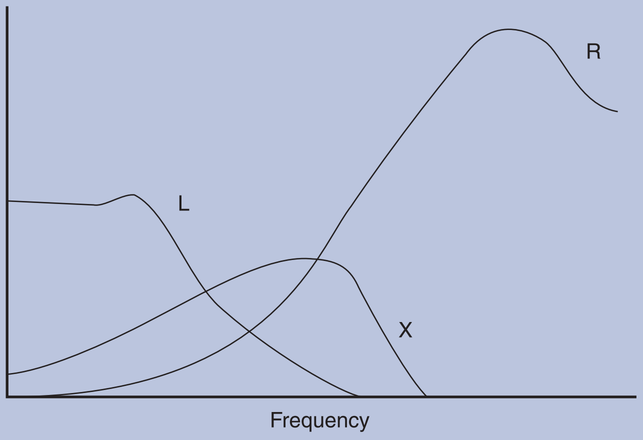


FIGURE 2



Ordinarily, beads of ferrite are slipped over a wire producing a one-turn device. To low frequencies the component presents a small inductance whose reactance can often be neglected, while to high frequencies the device presents a higher series resistance with near zero reactance. Since this resistance is a result of material losses, it is a true dissipative element. Furthermore, since the reactance is low, there is little chance for resonance with stray capacitance which would spoil the suppression.

DETERMINING IMPEDANCE:

In this catalog curves are presented for some standard parts. They show inductance, resistance and impedance versus frequency for a single straight-through conductor (1 turn). Similar values for other sizes in the same materials can be calculated by the ratio of A_e/ℓ_e (equation 1) for the two cores.

1

$$\frac{A_e}{\ell_e} = \frac{2.54\ H\ \ln OD/ID}{2\pi}$$

Here OD, ID and H are the dimensions in inches of a cylindrical bead. Also, ℓ_e and A_e (in cm and cm^2) are listed in this catalog for all standard parts. As an example, suppose you want to know L and R for a 21-110-J at 20 MHz. Curves for a similar core, 21-030-J, are given and its A_e/ℓ_e is .033/.64 = .0516. Also from the table , for 21-110-J, A_e/ℓ_e is .029/.73 = .0397. Therefore, the L and R on the curves should be multiplied by .0397/.0516 = .770, giving .06m H inductance and 13.1 ohms resistance. For standard beads we also list an impedance for each core. This consists of a measurement near the peak impedance frequency using a single turn of short #20 AWG wire. This makes an excellent incoming QC test, as well as a means for comparing the effectiveness of various core choices.

CHOOSING A BEAD:

The best material is one that gives high impedance or resistance at the noise frequencies and low at the desired signal frequencies. Since the frequency range for high resistance is quite wide - about two decades - this choice is simple and non-critical. It also is necessary that the impedance presented by the bead at noise frequencies be large enough compared to other circuit impedances to provide the desired attenuation. Frequently the source and load impedance are unknown, but if they are known, insertion loss may be calculated from:

2

$$IL = 20 \log \frac{Z_S + Z_L}{Z_S + Z_L + Z_{core}} \text{ db}$$

INCREASING SUPPRESSION:

Bead impedance is directly proportional to the total height dimension and may be increased either by using longer beads or by stringing more than one. The effect of height on J material beads is shown in the Bead Electrical Performance pages. Either method giving the same total height is equivalent. Since the magnetic field is totally contained, it does not matter whether the beads are touching or separated. This approach is valid at all frequencies through VHF, but reliable measurements are difficult at higher frequencies. Impedance is also proportional to A_e/ℓ_e (equation 1) and this may be used to estimate the parameters for various cores.

Higher impedances can also be obtained by winding the wire through the core more than once. Resistance and inductance are proportional to the number of turns squared. Because of capacitance between turns this technique is most effective at lower frequencies. Also, since a greater length of smaller cross section wire is used, dc resistance will increase.

A different approach can be taken at low frequencies where there is significant inductance. The filter can be tuned for maximum attenuation at a specific frequency by simply connecting a resonating capacitor from the output side to ground. Because of the high ac resistance, oscillation is rarely a problem and attenuation is also present at other frequencies.

EXCITATION LEVEL:

High currents,which are most likely to occur at dc or low frequencies because of the low impedance, can cause significant magnetizing force.

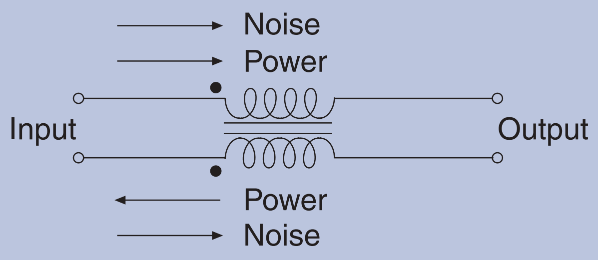
$$H = \frac{0.4\pi N I}{\ell_e} \times 79.55 \text{ A/m} \qquad (3)$$

This can reduce the impedance and suppression. Since beads are often used with only one turn, fairly high currents can be tolerated before saturation is approached. At saturation, inductance and resistance will be low, but will recover upon removal of the high field. Curves in the Bead Electrical Performance pages show the effect of dc current on impedance for certain beads. If the magnetizing force (H) of low frequencies is too great, it will be necessary to increase the effective magnetic path length (ℓ_e). Parts listed in the **TOROID** section generally have larger ℓ_e for similar A_e/ℓ_e ratios. For further increases in ℓ_e see the discussion on **Slotted Toroids** in the Toroid section.

Another solution to problems concerning low frequency current takes advantage of the fact that much conducted RFI is common-mode. Then it is practical to wind the core as a common-mode choke. The dots in figure 3 indicate the winding sequence, that is, both windings are put on the same way (bifilar). Then the magnetic fields of the two windings cancel for normal power currents but aid for common-mode noise currents.

High RF levels can cause excitation greater than that used for data in this catalog. Often these will increase the effective resistance because of the contribution of hysteresis losses.

FIGURE 3



COMMON-MODE CHOKE

ENVIRONMENT:

Ferrites are inert ceramics free of any organic substances. They will not be degraded by most environments, including temperatures up to a few hundred degrees centigrade. Magnetic properties vary somewhat with temperature. Generally, inductance increases with increasing temperature while the effect on resistance is small. Above the Curie temperature the bead is non-magnetic and no suppression can be expected. This effect is completely reversible and once the temperature is reduced below that point, normal performance is regained.

COATING:

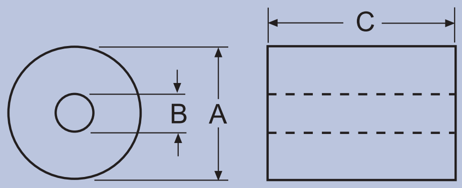
Because of the high volume resistivity of nickel-zinc ferrites (G,J,K and P materials), these beads may be considered insulators in most applications. Manganese-zinc ferrites (B,material, for example) are semiconductors and may need to be insulated if they are free to short circuit two or more conductors. Insulating coatings may be applied. This coating should be soft enough to not stress the core upon curing or during temperature cycling, withstand normal environments (including cleaning solvents) and provide insulation.

We offer Parylene® C, a vapor deposited conformal coating. Parylene produces an exceptionally uniform coating, normally about .0007" thick.

Standard minimum voltage breakdown is 500VAC. If a higher level of protection is required, please consult with our engineering department.

Dimensions

PART NUMBER [1]		PHYSICAL DIMENSIONS						EFFECTIVE DIMENSIONS	
		A		B		C[4]			
UNCOATED	COATED	inch	mm	inch	mm	inch	mm	A_e(cm^2)	l_e(cm)
21-095	21-595	.075	1.91	.030	76	.150	3.81	.020	.37
		±.005	±.13	±.002	±.05	±.010	±.25		
21-172	21-672	.095	2.41	.053	1.35	.060	1.52	.008	.56
		±.005	±.13	±.005	±.13	±.005	±.13		
21-170	21-670	.095	2.41	.053	1.35	.150	3.81	.020	.56
		±.003	±.08	±.003	±.08	±.005	±.13		
21-185	21-685	.098	2.49	.047	1.19	.120	3.05	.019	.53
		±.004	±.10	±.004	±.10	±.005	±.13		
21-060	21-560	.110	2.79	.067	1.70	.150	3.81	.020	.68
		±.005	±.13	±.004	±.10	±.010	±.25		
21-020	21-520	.120	3.05	.047	1.19	.125	3.18	.027	.58
		±.005	±.13	±.003	±.08	±.008	±.20		
21-130	21-630	.138	3.51	.031	.79	.128	3.25	.037	.48
		±.008	±.20	±.003	±.08	±.010	±.25		
21-134	21-634	.138	3.51	.031	.79	.175	4.45	.050	.48
		±.008	±.20	±.003	±.08	±.010	±.25		
21-132	21-632	.138	3.51	.031	.79	.256	6.50	.074	.48
		±.008	±.20	±.003	±.08	±.010	±.25		
21-133	21-633	.138	3.51	.031	.79	.350	8.89	.101	.48
		±.008	±.20	±.003	±.08	±.015	±.38		
21-142	21-642	.138	3.51	.037	.94	.150	3.81	.042	.53
		±.008	±.20	±.002	±.05	±.010	±.25		
21-140	21-640	.138	3.51	.037	.94	.175	4.45	.049	.53
		±.008	±.20	±.002	±.05	±.010	±.25		
21-042	21-542	.138	3.51	.049	1.24	.236	5.99	.062	.63
		±.008	±.20	±.004	±.10	±.010	±.25		
21-049	21-549	.138	3.51	.051	1.30	.118	3.00	.031	.64
		±.008	±.20	±.004	±.10	±.010	±.25		



Electricals

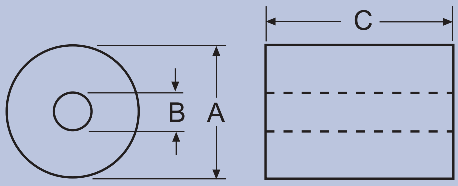
PART NUMBER[1]		B		J		K	
UNCOATED	COATED	A_L (nH/N^2)[2]	Z@10 MHz (Ω)[3]	A_L (nH/N^2)[2]	Z@100 MHz (Ω)[3]	A_L (nH/N^2)[2]	Z@250 MHz (Ω)[3]
21-095	21-595	3491	43	594	39	87.3	50
21-172	21-672	889	11	151	10	22.2	13
21-170	21-670	2223	27	378	25	55.6	32
21-185	21-685	2240	28	381	25	56.0	32
21-060	21-560	1889	23	321	21	47.2	27
21-020	21-520	2976	37	506	33	74.4	42
21-130	21-630	4855	60	825	54	121	69
21-134	21-634	6638	82	1128	74	166	94
21-132	21-632	9710	120	1651	108	243	138
21-133	21-633	13275	164	2257	147	332	189
21-142	21-642	5015	62	853	56	125	71
21-140	21-640	5851	72	995	65	146	83
21-042	21-542	6207	77	1055	69	155	88
21-049	21-549	2983	37	507	33	74.6	42

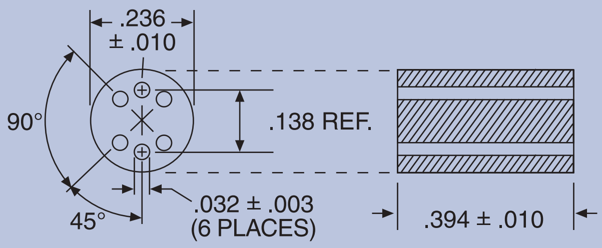
NOTES:

1. Complete part number includes material designation., i.e. 21-030-J.
2. A_L is measured at low frequency; B and J materials - 100 KHz, K material ≤ 20 MHz.
   Normal tolerance is ±30%.
3. Impedance data shown is nominal, measured on a short length of 20 AWG wire at the frequency shown.
   Normal tolerance ±20%.
4. Special heights can be manufactured without tooling costs. Consult the factory for additional information.
   Coatings will marginally alter core dimensions.

Dimensions

PART NUMBER (1)		PHYSICAL DIMENSIONS						EFFECTIVE DIMENSIONS	
		A		B		C (4)			
UNCOATED	COATED	inch	mm	inch	mm	inch	mm	A_e(cm^2)	l_e(cm)
21-030	21-530	.138	3.51	.051	1.30	.128	3.25	.033	.64
		±.008	±.20	±.004	±.10	±.010	±.25		
21-031	21-531	.138	3.51	.051	1.30	.256	6.50	.066	.64
		±.008	±.20	±.004	±.10	±.010	±.25		
21-110	21-610	.138	3.51	.063	1.60	.128	3.25	.029	.73
		±.008	±.20	±.004	±.10	±.010	±.25		
21-111	21-611	.138	3.51	.063	1.60	.256	6.50	.059	.73
		±.008	±.20	±.004	±.10	±.010	±.25		
21-121	21-621	.148	3.76	.060	1.52	.128	3.25	.034	.73
		±.005	±.13	±.005	±.13	±.010	±.25		
21-119	21-619	.148	3.76	.060	1.52	.256	6.50	.068	.73
		±.005	±.13	±.005	±.13	±.010	±.25		
21-120	21-620	.148	3.76	.060	1.52	.500	12.70	.133	.73
		±.004	±.10	±.005	±.13	±.015	±.38		
21-200	21-700	.200	5.08	.062	1.52	.250	6.35	.099	.84
		±.015	±.38	±.010	±.25	±.025	±.64		
21-201	21-701	.200	5.08	.062	1.52	.440	11.18	.175	.84
		±.015	±.38	±.010	±.25	±.025	±.64		
21-083	21-583	.200	5.08	.094	2.39	.437	11.10	.143	1.07
		±.010	±.25	±.010	±.25	±.030	±.76		
21-129	21-629	.230	5.84	.120	3.05	.236	5.99	.081	1.30
		±.010	±.25	±.005	±.13	±.010	±.25		
21-212	21-712	.316	8.03	.057	1.45	.375	9.53	.247	.95
		±.008	±.20	±.005	±.13	±.010	±.25		
21-210	21-710	.323	8.20	.058	1.47	.450	11.43	.303	.97
		±.008	±.20	±.005	±.13	±.010	±.25		
21-227	21-727	.375	9.53	.187	4.75	.375	9.53	.218	2.07
		±.010	±.25	±.010	±.25	±.010	±.25		
12-390	(Fig.2)	.236	6.00	.032	.81	.394	10.00		
		±.010	±.25	±.003	±.08	±.010	±.25		





Electricals

PART NUMBER(1)		B		J		K	
UNCOATED	COATED	A_L (nH/N^2)(2)	Z@10 MHz (Ω)(3)	A_L (nH/N^2)(2)	Z@100 MHz (Ω)(3)	A_L (nH/N^2)(2)	Z@250 MHz (Ω)(3)
21-030	21-530	3236	40	550	36	80.9	46
21-031	21-531	6473	80	1100	72	162	92
21-110	21-610	2549	32	433	28	63.7	36
21-111	21-611	5099	63	867	56	128	72
21-121	21-621	2935	36	499	33	73.4	42
21-119	21-619	5871	73	998	65	147	83
21-120	21-620	11466	142	1949	127	287	163
21-200	21-700	7437	92	1264	82	186	106
21-201	21-701	13089	162	2225	145	327	186
21-083	21-583	8381	104	1425	93	210	119
21-129	21-629	3900	48	663	43	97.5	55
21-212	21-712	16313	202(5)	2773	181	408	232
21-210	21-710	19628	243(5)	3337	218	491	279
21-227	21-727	6628	52	1127	74	166	94
12-390	SEE PAGE 36						

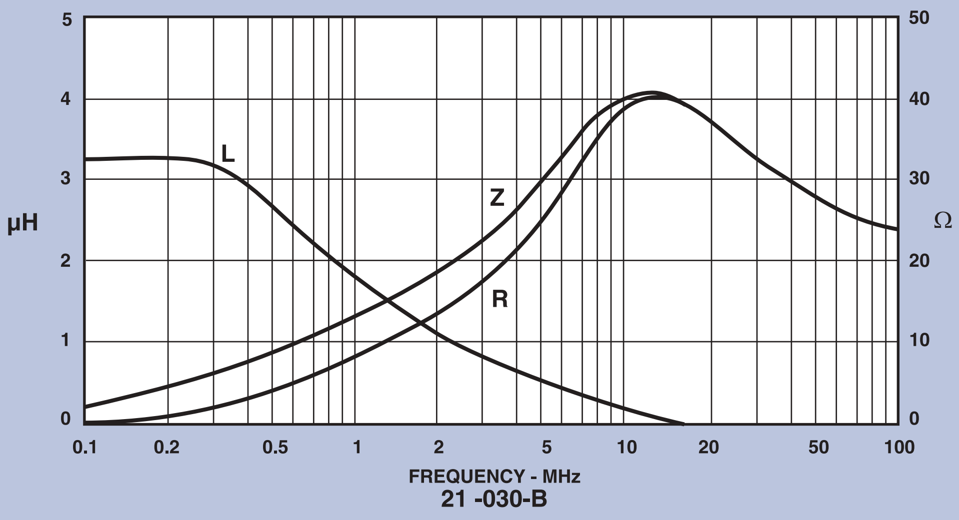
NOTES:

1. Complete part number includes material designation., i.e. 21-030-J.
2. A_L is measured at low frequency; B and J materials- 100 KHz, K material ≤ 20 MHz.
   Normal tolerance is ±30%.
3. Impedance data shown is nominal, measured on a short length of 20 AWG wire at the frequency shown.
   Normal tolerance ±20%.
4. Special heights can be manufactured without tooling costs. Consult the factory for additional information.
   Coatings will marginally alter core dimensions.
5. Measured at 3.5 MHz.

Material Curves

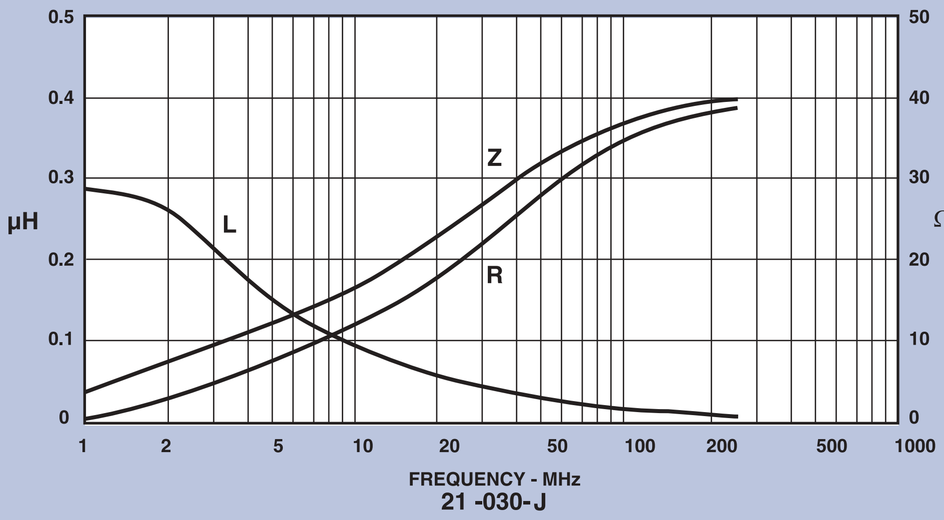
SERIES INDUCTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

B MATERIAL



21 -030-B

J MATERIAL

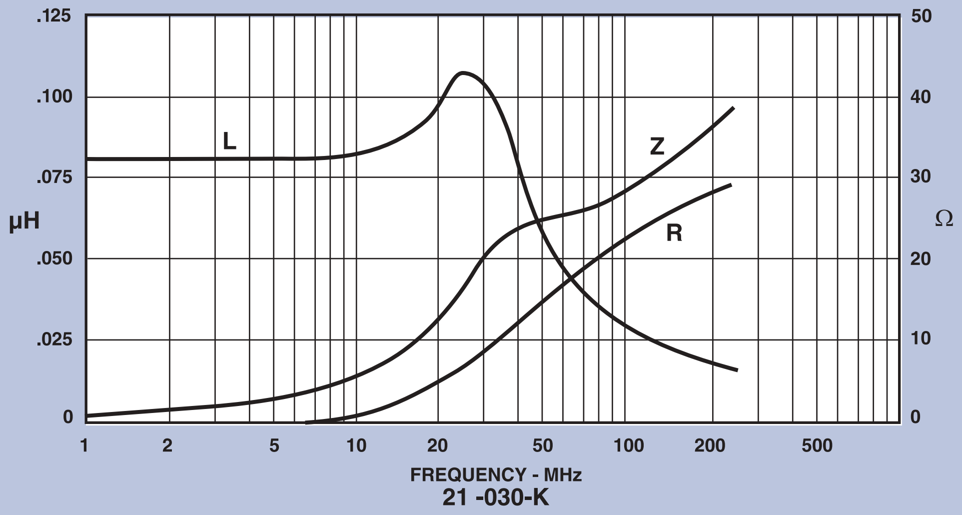


21 -030- J

Material Curves

SERIES INDUCTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

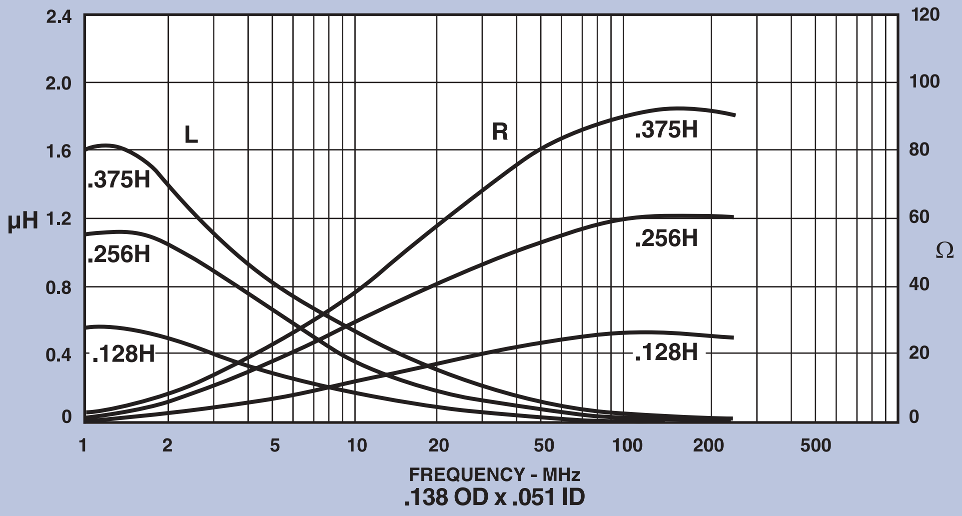
K MATERIAL



21 -030-K

THE EFFECT OF HEIGHT ON INDUCTANCE AND RESISTANCE

J MATERIAL

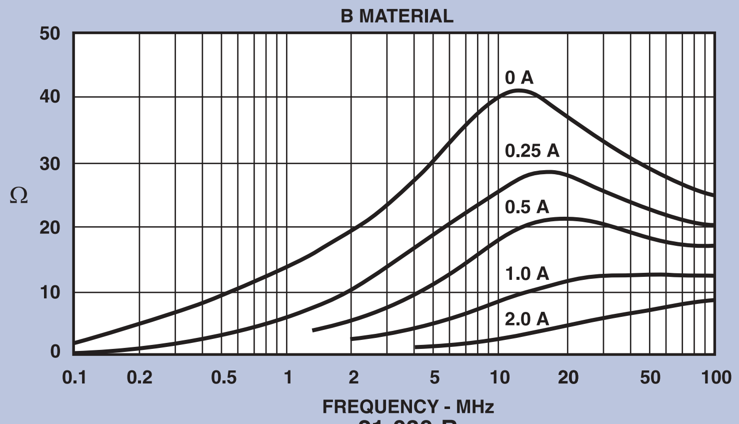


.138 OD x .051 ID

Material Curves

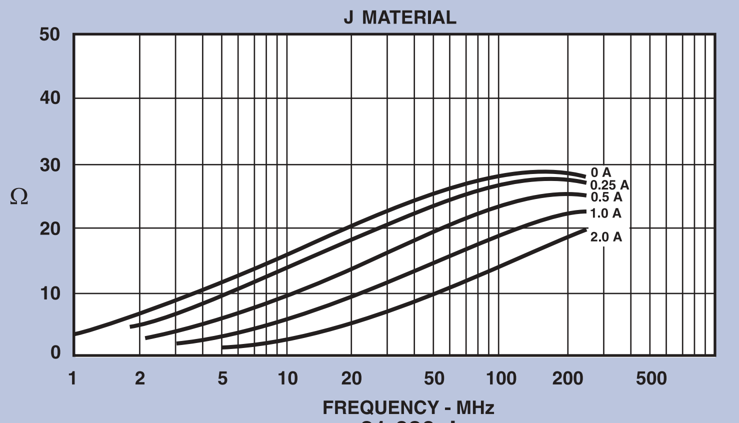
IMPEDANCE vs FREQUENCY WITH DC CURRENT

B MATERIAL



21-030-B

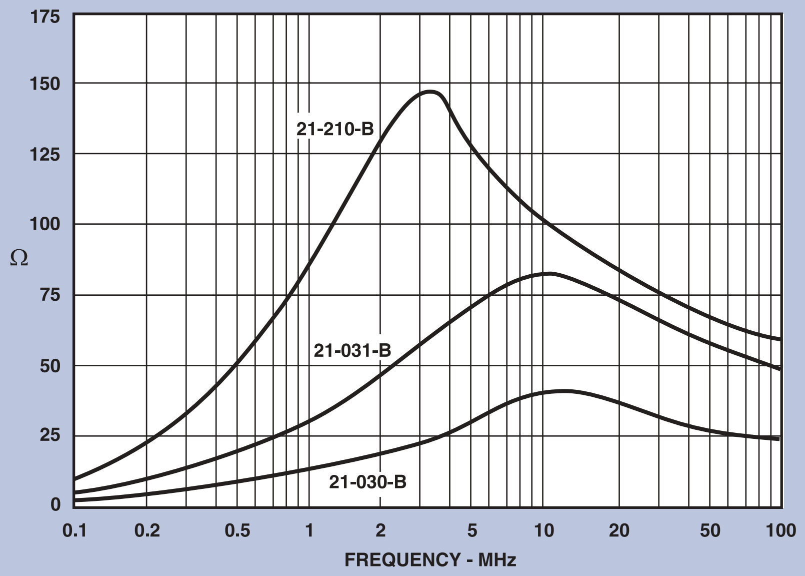
J MATERIAL



21-030-J

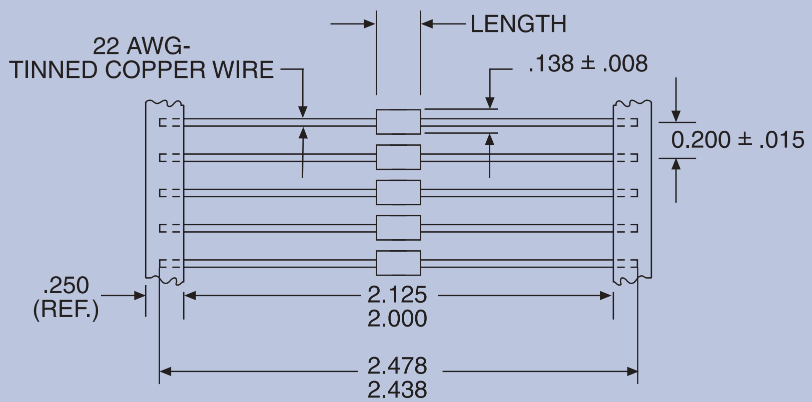
IMPEDANCE vs FREQUENCY FOR VARIOUS SIZES

B MATERIAL



Ferronics offers beads on leads in two materials and six different bead lengths. The 82 Series bulk packaged axial wire beads facilitate manual operations while the 92 Series, taped and reeled per RS-296-(Latest Revision), is intended for automatic component insertion applications.

OUTLINE DRAWING



Per EIA Std. RS-296-Latest revision.

PART NUMBER (2) (4)		LENGTH(3)			
TAPED AND REELED	BULK PACKAGED	inch	mm	Z Ω @10 MHz (1)	Z Ω @100 MHz (1)
92-130-B	82-130-B	.128	3.25	60	–
92-130-J	82-130-J	±.010	±.25	–	48
92-132-B	82-132-B	.256	6.50	120	–
92-132-J	82-132-J	±.010	±.25	–	96
92-133-B	82-133-B	.350	8.89	164	–
92-133-J	82-133-J	±.015	±.38	–	131
92-134-B	82-134-B	.175	4.45	82	–
92-134-J	82-134-J	±.010	±.25	–	66
92-135-B	82-135-B	.450	11.43	210	–
92-135-J	82-135-J	±.015	±.38	–	169
92-136-B	82-136-B	.550	13.97	257	–
92-136-J	82-136-J	±.015	±.38	–	206

NOTES:

1. Impedance tolerance ±20%.

2. Parylene® coated cores - change 1 to a 6, i.e., 92-132-B to 92-632-B. For additional information on Parylene coating,refer to the **BEADS** section.

3. Bead length can be varied without tooling costs. Consult the factory for additional information.

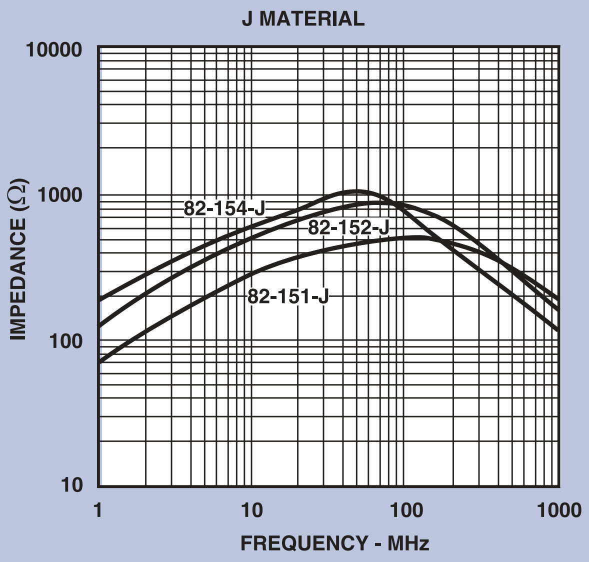
4. Available in other materials. Consult the factory.

Ferronics offers a line of 6 hole beads and chokes for applications where a single hole bead does not provide the impedence level desired. Ferronics provides six-hole beads in the following materials:

J Material - The best choice in 20-300MHz noise suppression applications.

K Material - Suited for 50-500MHz applications.

The standard chokes are offered in 1.5, 2.5 and 3 turn versions. Ferronics also offers a common mode choke version with 2 x 1.5 turns. (See Table 1 and accompanying figures.) An industry standard, the six-hole bead can be custom wound to meet your particular requirements.



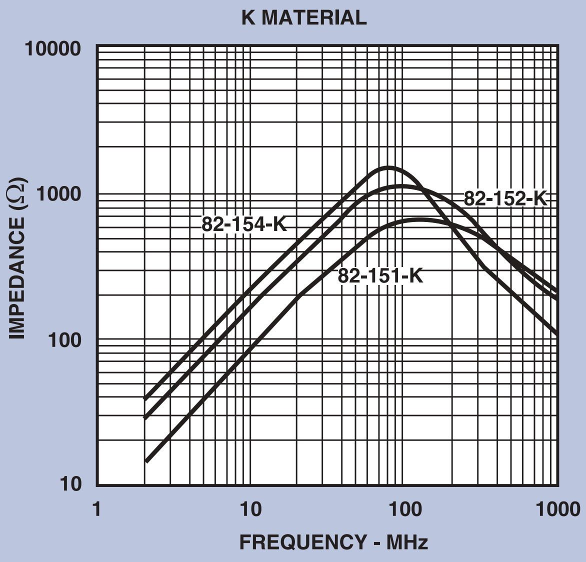


FIGURE 1

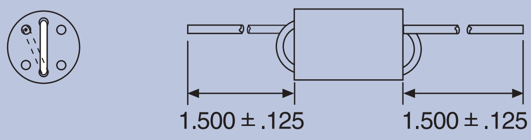


FIGURE 2

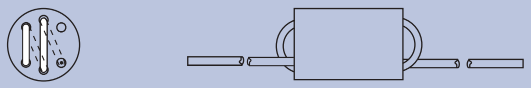


FIGURE 3

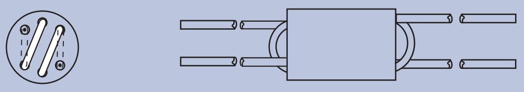


FIGURE 4

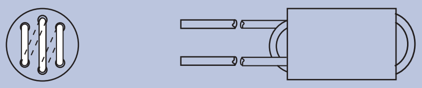


TABLE 1

PART NUMBER	DESCRIPTION	MIN Z (Ω)	FREQ (MHz)	FIG.
82-151-J	12-390-J WITH 1½ TURNS*	400	100	1
82-151-K	12-390-K WITH 1½ TURNS*	450	100	1
82-152-J	12-390-J WITH 2½ TURNS*	600	100	2
82-152-K	12-390-K WITH 2½ TURNS*	675	100	2
82-153-J	12-390-J WITH 2 x 1½ TURNS*	400	100	3
82-153-K	12-390-K WITH 2 x 1½ TURNS*	450	100	3
82-154-J	12-390-J WITH 3 TURNS*	800	50	4
82-154-K	12-390-K WITH 3 TURNS*	1000	70	4

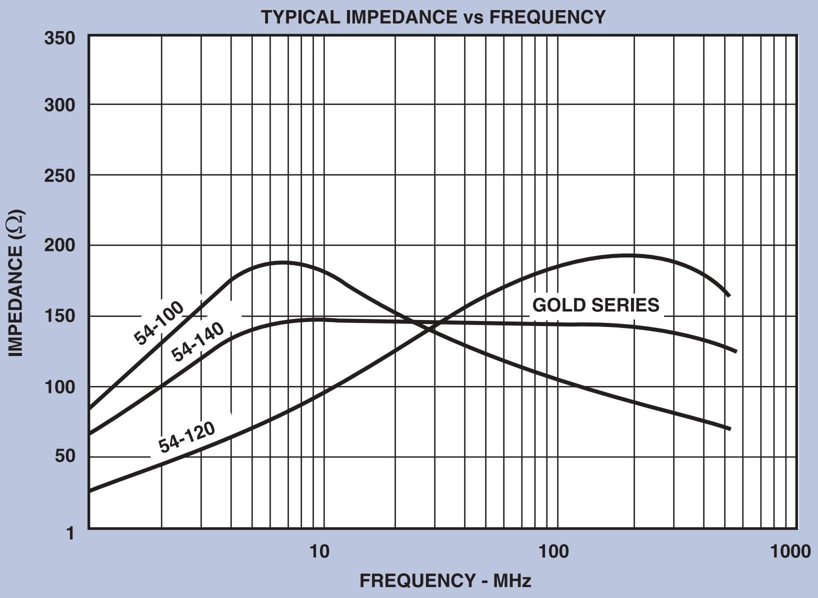
*#24AWG tinned copper wire is standard.
Refer to Part Number 12-390 in BEADS section for dimensional data.

Ferronics has developed a line of ferrite chokes called Z-MAX that are specifically engineered for maximum impedance to more effectively suppress high frequency noise or oscillations. Z-MAX begin where simple beads leave off. They have two to three times the impedance of a standard bead occupying the same space. This is a major benefit when you consider the value of space on a circuit board.

Z-MAX chokes are both color coded and marked to facilitate inventory control and production. This feature alone translates into substantial savings . At the top of the Z-MAX line is the “Gold series...so effective over a wide range of frequencies it’s patented. Z-MAX “Gold” has the unique capability of providing a very flat impedance profile across a broad range of frequencies, from 5 to 500 MHz.

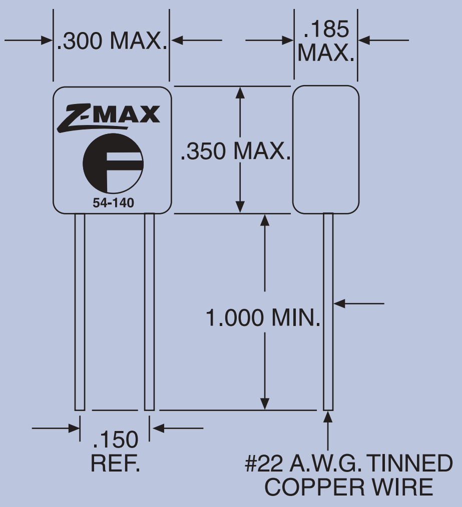
The “Gold” series Z-MAX chokes take the guesswork out of noise suppression. You no longer need to know the precise frequencies of the noise causing EMI/RFI problems. By using a “Gold” series Z-MAX choke right off the shelf, you can dampen a full range of frequencies necessary to eliminate most noise.

To suit your needs even further, Ferronics can adjust the amplitude of impedance to accommodate most practical requirements. Z-MAX chokes are available bulk packaged or radially taped on reels.



Note: Impedance measured with leads trimmed to simulate typical application.

SPECIFICATIONS	54-100 “BLUE”	54-120 “RED”	54-140 “GOLD”	UNITS
MINIMUM IMPEDANCE @	140 10	145 100	105 10 & 100	Ω MHz
MINIMUM IMPEDANCE OVER RANGE	100 2-40	100 25-500	100 5-500	Ω MHz
RATED CURRENT	3	3	3	A
MAXIMUM STORAGE/ OPERATING TEMPERATURE	105	105	105	°C



Ferronikits

FERRONIKITS
Provide a handy selection of ferrite cores for prototype designing and emergency “debugging”. Each kit contains a variety of standard cores useful in particular groups of applications.

11-V (V TOROIDS)
This kit contains toroids manufactured from 15,000µi material and is suited for applications requiring high permeability with temperature stability. Pulse transformers and filters are typical applications.

11-T (T TOROIDS)
This kit contains toroids manufactured from 10,000µi material and is suited for applications requiring high permeability. Pulse transformers and filters are typical applications.

11-B (B TOROIDS)
This kit contains toroids manufactured from 5000µi material and is suited for applications where high permeability and low power losses are required. Typical applications are pulse transformers, converters, power transformers, inductors, and wide band transformers operating at low frequencies.

11-G (G TOROIDS)
This kit contains toroids manufactured from 1500µi material and is suited for applications where high levels of broadband impedance is desired. Filters and RF transformers are typical applications.

11-J (J TOROIDS)
This kit contains toroids manufactured from 850µi material. Typical applications include wide band transformers and RF chokes operating above 5 MHz.

11-K (K TOROIDS)
This kit contains toroids manufactured from 125µi material and is suited for high frequency applications where high Q above 1 MHz is required. Typical applications are RF inductors, RF power transformers, tuned inductors and transformers, impedance matching transformers, and wide band transformers operating above 20 MHz.

11-P (P TOROIDS)
This kit contains toroids manufactured from 40µi material. It is suited for very high frequency applications, such as transformers or inductors, where high Q above 10 MHz is required.

12-J (J TWIN HOLE CORES)
This kit contains twin hole beads and baluns manufactured from 850µi material. These parts are particularly suited for wide band transformers, baluns splitters and taps operating in the 5 MHz to 1,000 MHz range.

12-K (K TWIN HOLE CORES)
This kit contains twin hole beads and baluns manufactured from 125µi material. These parts are best suited as wide band transformers, baluns, splitters and taps operating above 20 MHz.

21-O BEADS
This kit contains ferrite beads manufactured from Ferronics B and J materials and is suitable for noise suppression applications. Ferronics B is best for attenuating unwanted signals in the 1 to 100 MHz range. Ferronics J is useful from 10 MHz up.

EMI/RFI
This kit contains a variety of products commonly utilized to solve EMI/RFI problems at the board level. Parts include single and multi-hole beads, beads on leads, six hole chokes and Z-MAX chokes. Materials covered are B, J, and K.

24-0 EMI/RFI
Kits Contain:

24 Each 12-340-J
24 Each 12-345-B
24 Each 12-345-J
24 Each 12-345-K
12 Each 12-390-J
12 Each 12-390-K
24 Each 21-031-B
24 Each 21-031-J
12 Each 21-201-B
12 Each 21-201-J
4 Each 21-227-B
4 Each 21-227-J
12 Each 54-100-1
12 Each 54-120-1
12 Each 54-140-1
12 Each 82-151-J
12 Each 82-151-K
12 Each 82-152-J
12 Each 92-130-J
12 Each 92-132-J

21-0 BEAD
Kits Contain:

24 Each P/N 21-030-B
24 Each P/N 21-031-B
24 Each P/N 21-030-J
24 Each P/N 21-031-J
24 Each P/N 21-110-J
12 Each P/N 21-201-J
12 Each P/N 21-210-B

12-K BALUN
Kits Contain:

24 Each P/N 12-328-K
12 Each P/N 12-330-K
24 Each P/N 12-315-K
24 Each P/N 12-340-K
12 Each P/N 12-345-K
12 Each P/N 12-360-K
6 Each P/N 12-365-K

12-J BALUN
Kits Contain:

24 Each P/N 12-328-J
12 Each P/N 12-330-J
24 Each P/N 12-340-J
12 Each P/N 12-345-J
12 Each P/N 12-350-J
12 Each P/N 12-360-J
6 Each P/N 12-365-J

11-V(1,2)TOROID
Kits Contain:

24 Each P/N 11-510-
24 Each P/N 11-543-
24 Each P/N 11-550-
24 Each P/N 11-562-
24 Each P/N 11-620-
24 Each P/N 11-622-
12 Each P/N 11-660-

11-G AND 11-T(1,2) TOROID
Kits Contain:

24 Each P/N 11-510-
24 Each P/N 11-512-
24 Each P/N 11-540-
24 Each P/N 11-550-
24 Each P/N 11-580-
24 Each P/N 11-620-
24 Each P/N 11-622-

11-B,11-K,11-J AND 11-P(1) TOROID
Kits Contain:

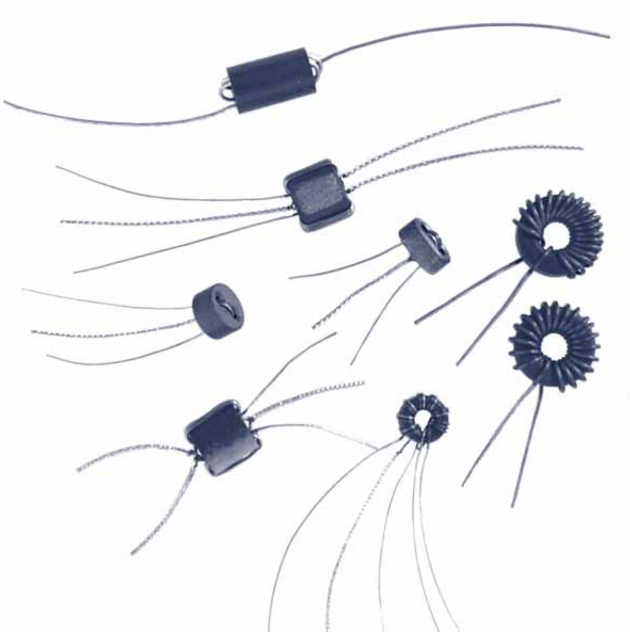
24 Each P/N 11-040-
24 Each P/N 11-050-
24 Each P/N 11-080-
24 Each P/N 11-120-
12 Each P/N 11-220-
6 Each P/N 11-250-
6 Each P/N 11-260-

NOTES:

1. Complete P/N includes material designation, i.e. 11-220-B. Each toroid kit contains one material type. Properties, effective dimensions and A_L values for each size are included.

2. All kit parts are Parylene C coated. G toroids are available uncoated. T and V toroids are available coated only.

Winding Service



All ferrites manufactured by Ferronics are produced under strict quality control supervision and tested in accordance with the most demanding standards. The core winding service we offer is the result of many years of careful planning and development on everything from site location to inventory and quality control methods.

Each winding job is fully analyzed and customized to your requirements. For each job, winding models, winding sequence procedures, workmanship specifications, lot identification methods, in-process inspection points and final inspection requirements are developed and documented.

Everything we do is specifically designed to meet your individual ferrite component requirements in a timely and cost-effective fashion.

Ferronics is also a firm believer in passing savings along to its customers. For our customized hand winding service, we established an offshore facility with low labor rates and competitive deliveries.

A MONEY SAVING ALTERNATIVE

Ferronics offers you a money-saving alternative to the way you have traditionally been procuring your wound magnetic components. Forget about separate purchase orders for ferrite cores,wire, solder, etc. as well as inspecting and stocking all these items. And forget about the uncertainty and high cost of having to find someone reliable to do hand winding.

With Ferronics you can satisfy your ferrite needs from a single, dependable source. In addition to our extensive line of ferrite products, we offer an economical way to hand wind ferrite cores to your exact specifications. This eliminates the “middleman” and makes it very cost effective for you to purchase your completed TRANSFORMER, INDUCTOR, CHOKE, or any configuration you require directly from us. You not only save time, but overhead, inspection, and inventory costs as well.

HIGH QUALITY AT LOW COST

What makes Ferronics the value leader in the industry is a unique blend of high quality products combined with customized service... available at low cost.