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

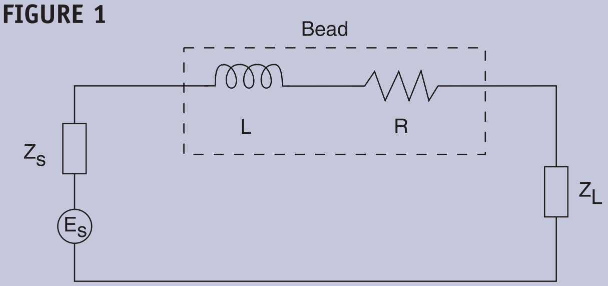
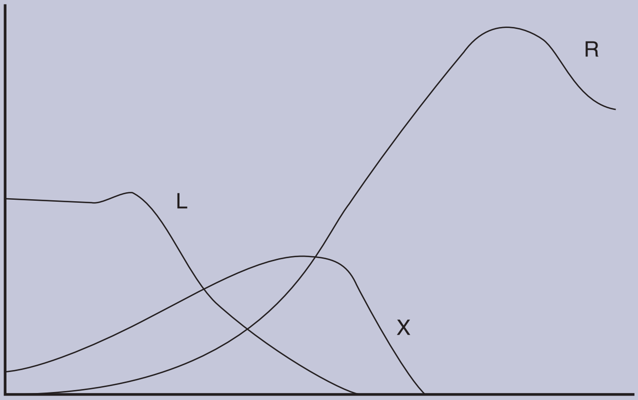


FIGURE 2



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

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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.

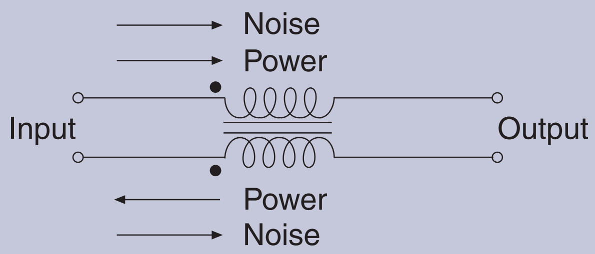
3
$$H = \frac{0.4\pi N I}{\ell_e} \times 79.55 \text{ A/m}$$

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.