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

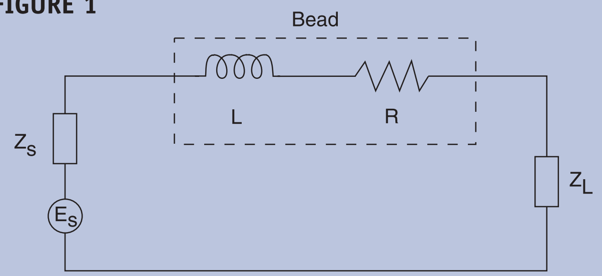
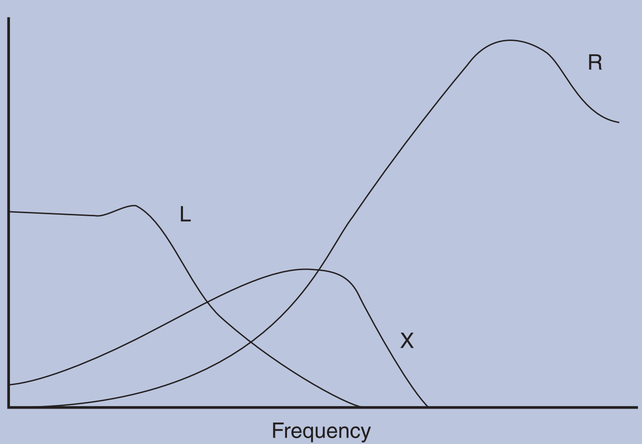


FIGURE 2



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

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

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

Design Considerations

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

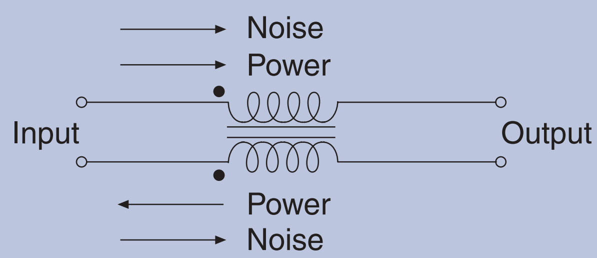
$$H = \frac{0.4\pi N I}{\ell_e} \times 79.55 \text{ A/m}$$

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.

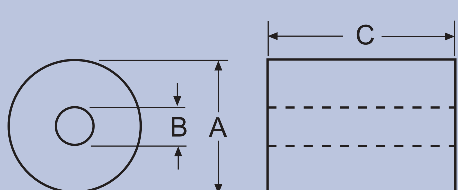
COATING:
Because of the high volume resistivity of nickel-zinc ferrites (G,J,K and P materials), these beads may be considered insulators in most applications. Manganese-zinc ferrites (B,material, for example) are semiconductors and may need to be insulated if they are free to short circuit two or more 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.

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

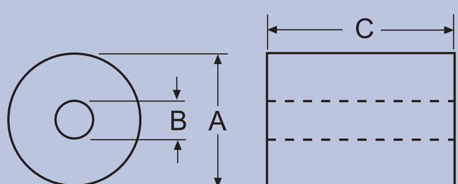
PART NUMBER[1]		B		J		K	
UNCOATED	COATED	A_L (nH/N²)[2]	Z@10 MHz (Ω)[3]	A_L (nH/N²)[2]	Z@100 MHz (Ω)[3]	A_L (nH/N²)[2]	Z@250 MHz (Ω)[3]
21-095	21-595	3491	43	594	39	87.3	50
21-172	21-672	889	11	151	10	22.2	13
21-170	21-670	2223	27	378	25	55.6	32
21-185	21-685	2240	28	381	25	56.0	32
21-060	21-560	1889	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

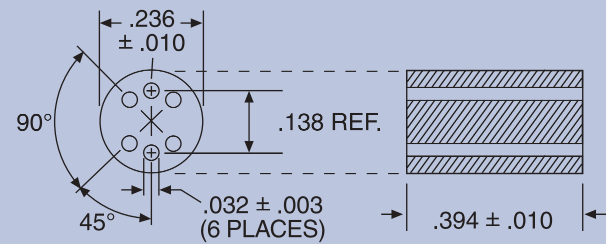
NOTES:

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	
UNCOATED	COATED	A inch	A mm	B inch	B mm	C(4) inch	C(4) 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/N²)[2]	Z@10 MHz (Ω)[3]	A_L (nH/N²)[2]	Z@100 MHz (Ω)[3]	A_L (nH/N²)[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						

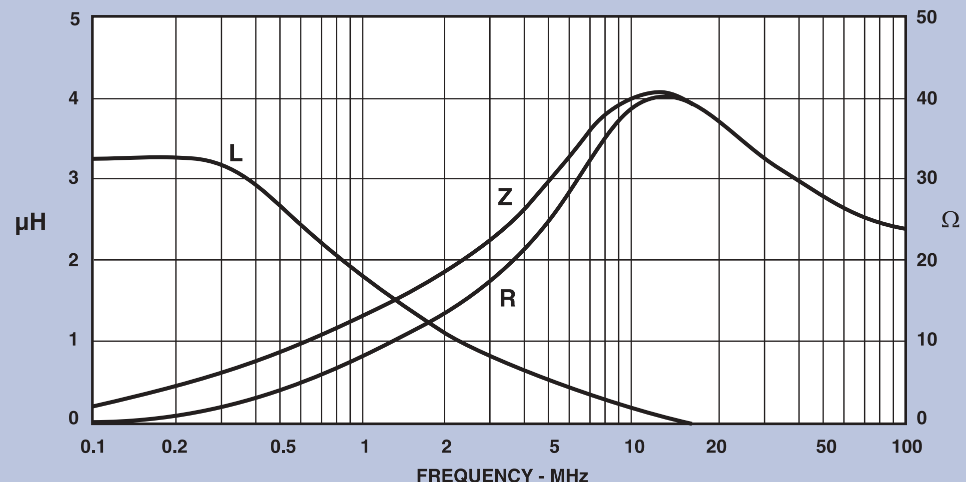
NOTES:

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

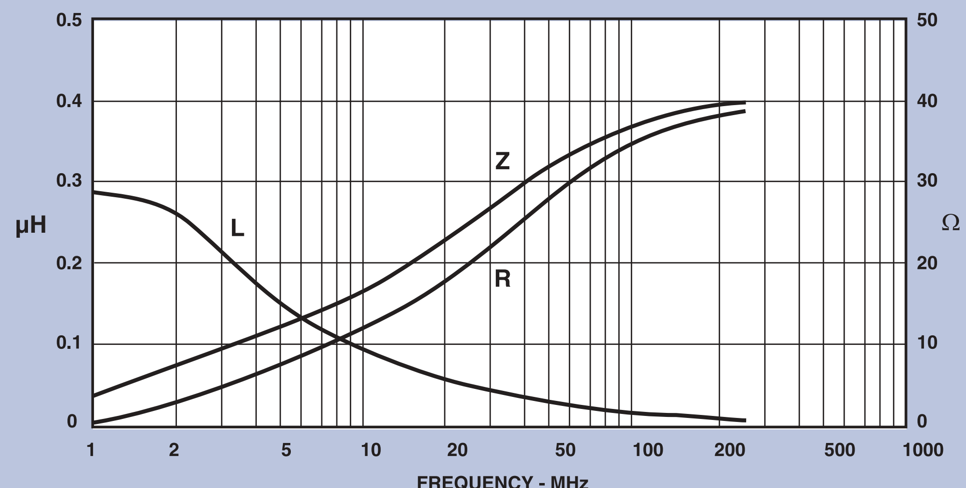
SERIES INDUCTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

B MATERIAL



21 -030-B

J MATERIAL

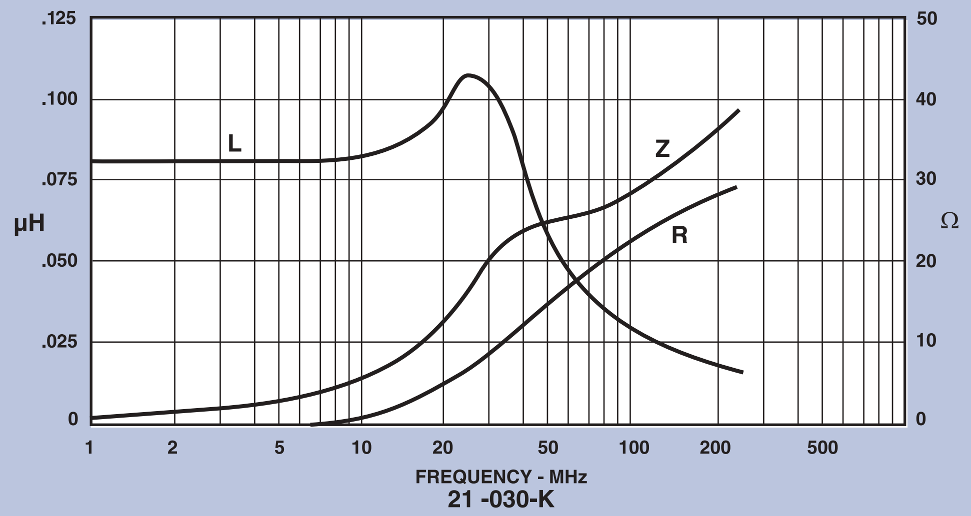


21 -030- J

Material Curves

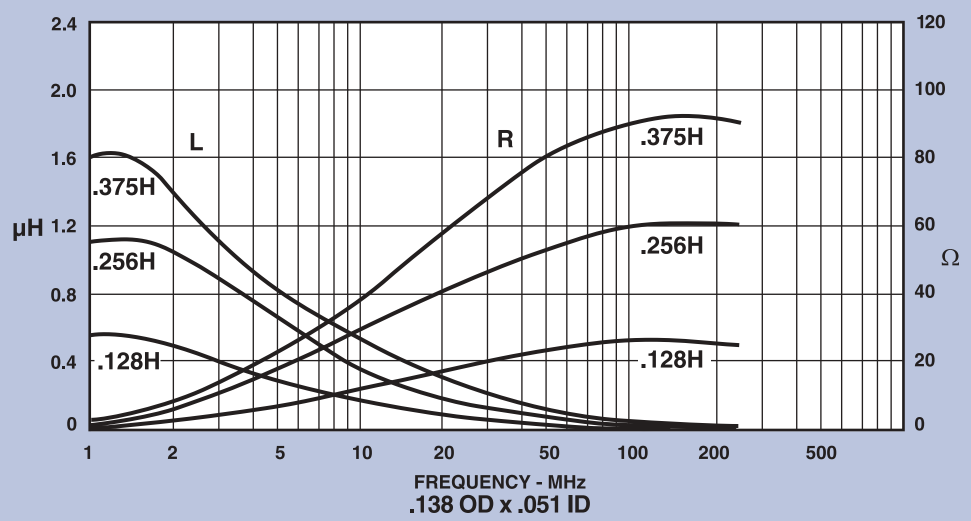
SERIES INDUCTANCE, RESISTANCE AND IMPEDANCE vs FREQUENCY

K MATERIAL



THE EFFECT OF HEIGHT ON INDUCTANCE AND RESISTANCE

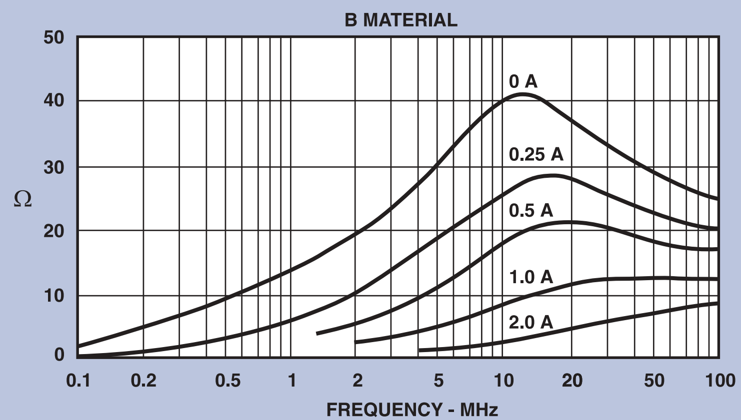
J MATERIAL



Material Curves

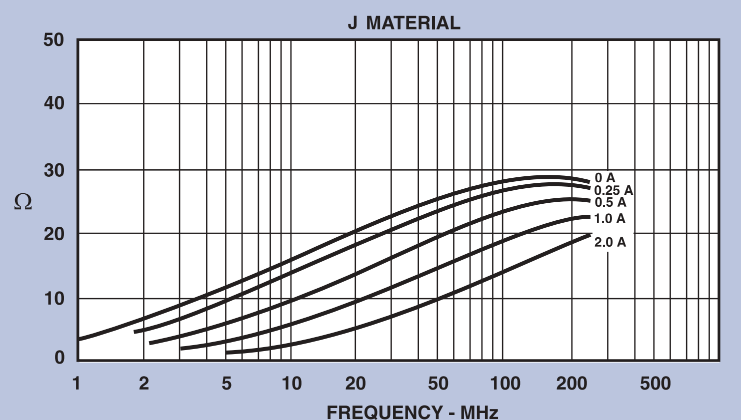
IMPEDANCE vs FREQUENCY WITH DC CURRENT

B MATERIAL



21-030-B

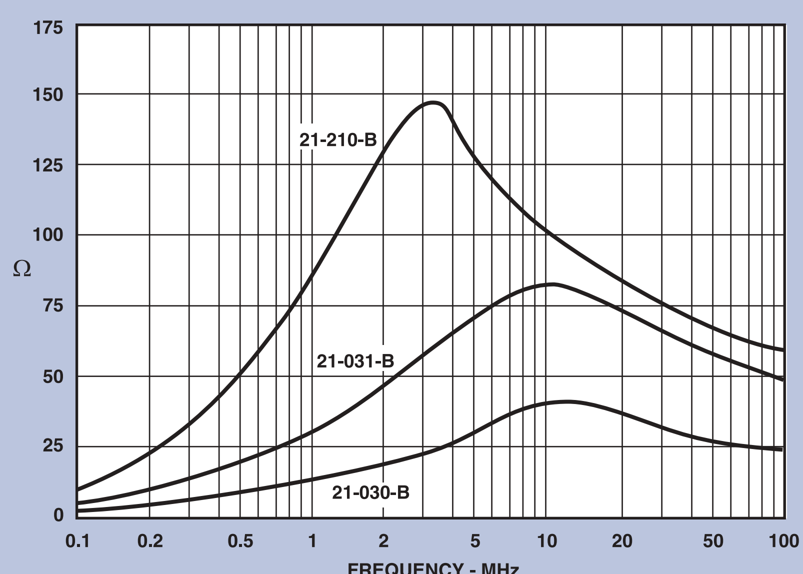
J MATERIAL



21-030-J

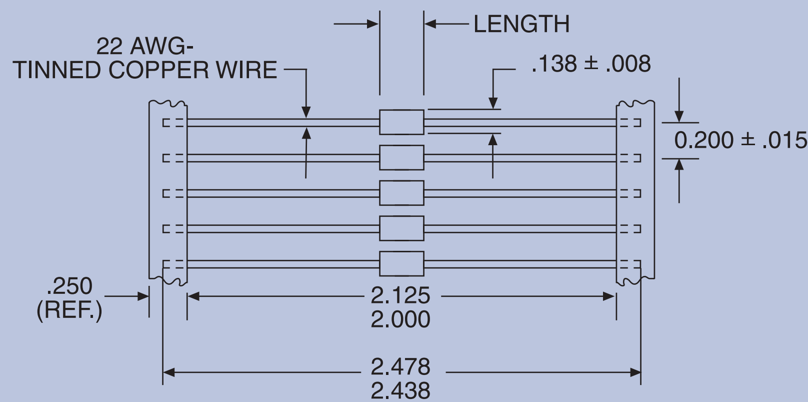
IMPEDANCE vs FREQUENCY FOR VARIOUS SIZES

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.