Fair-Rite Products Corp. Your Signal Solution®

www.fair-rite.com

nqa. ISO 9001 Registered
nqa. TS 16949 Registered

Solving Electromagnetic Interference (EMI) with Ferrites

- What are ferrites?
- How do ferrites help Suppress EMI?
- How to chose proper ferrite and component
  - Material Characteristics
  - Material and Core Selection
    - Frequency, bias, turns, temperature, size
- Q & A

What Is A Ferrite?

Ferrite is a ceramic material formed by reacting metal oxides into a magnetic material.

- Soft magnetic material is one that can be both easily magnetized and demagnetized, so that it can store or transfer magnetic energy in alternating or other changing wave forms

CHEMICAL COMPOSITION (metal oxides) + (iron oxide)

(MnO + ZnO)	**+ (Fe_2O_3) =**	**Manganese - Zinc**
(NiO + ZnO)	**+ (Fe_2O_3) =**	**Nickel - Zinc**
(MgO + ZnO)	**+ (Fe_2O_3) =**	**Magnesium - Zinc**

Definitions

- <u>EMI – Electromagnetic Interference</u> – Electromagnetic emissions from a device or system that interfere with the normal operation of another device or system.

- <u>EMC – Electromagnetic Compatibility</u> – The ability of a device or system to function without error in its intended electromagnetic environment.

EMI Suppression

Sources of EMI

- Digital System – Clock Pulses
- SMPS
- Oscillators
- Medical Equipment
- Microwave Equipment
- Radio & TV
- Frequency Converters
- Electronic Ballasts
- Switch Gear (contractors, relays)
- Household Appliances
- Power Supplies and Battery Chargers
- Motor Commutation
- Ignition Systems

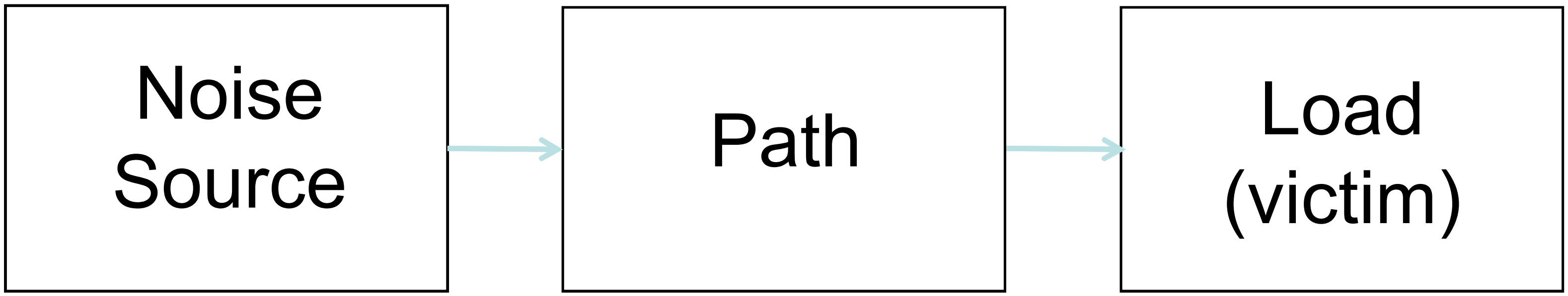
Victims (Susceptible)

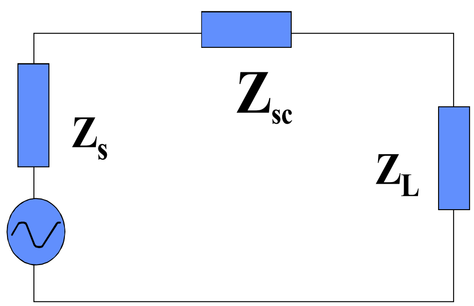
- Radio & TV Receivers
- Modems
- Engine Control Modules
- Data transmission systems
- Medical Equipment
- Computer

Properties of Ferrites – EMI Suppression

- A frequency dependant impedance that provides attenuation.
  - Formulations optimized for frequency bands
- Ferrites absorb EMI energy and dissipate as small amount of heat
- Powder compaction allows for a multitude of shapes
- High permeability concentrates magnetic filed in core allowing for a dense overall package
- High resistivity provides electrical isolation between multiple lines and minimizes eddy current losses

How Ferrites Are Used To Reduce Noise





$$\text{Attenuation} = 20\log_{10}\left[\frac{(Z_S + Z_{SC} + Z_L)}{(Z_S + Z_L)}\right] \text{dB}$$

Z_s = Source impedance
Z_{sc} = Suppressor Core impedance
Z_L = Load impedance

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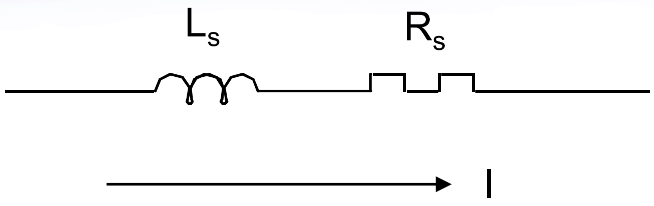
Magnetic Properties of Ferrite Materials

Property	Unit	Symbol	73	31	43	44	46*	61
Initial Permeability @ B <10 gauss		μ_i	2500	1500	800	500	500	125
Flux Density	gauss mT	B	3900 390	3400 340	2900 290	3000 300	3000 300	2350 235
@ Field Strength	oersted A/m	*H*	5 400	5 400	10 800	10 800	10 800	15 1200
Residual Flux Density	gauss mT	B_r	1500 150	2500 250	1300 130	1100 110	1900 190	1200 120
Resistivity	Ω cm	ρ	1×10^{2}	3×10^{3}	1×10^{5}	1×10^{9}	1×10^{8}	1×10^{8}
Curie Temperature	°C	T_c	>160	>130	>130	>160	>140	>300
Recommended Frequency Range	MHz							
Application Areas: Low flux density devices.			---	---	<10	---	---	<100
EMI suppression.			<30	<500	20 - 250	20 - 250	20 - 250	>200
Power magnetics.			---	---	---	---	---	---
Special square loop ferrite.			---	---	---	---	---	---



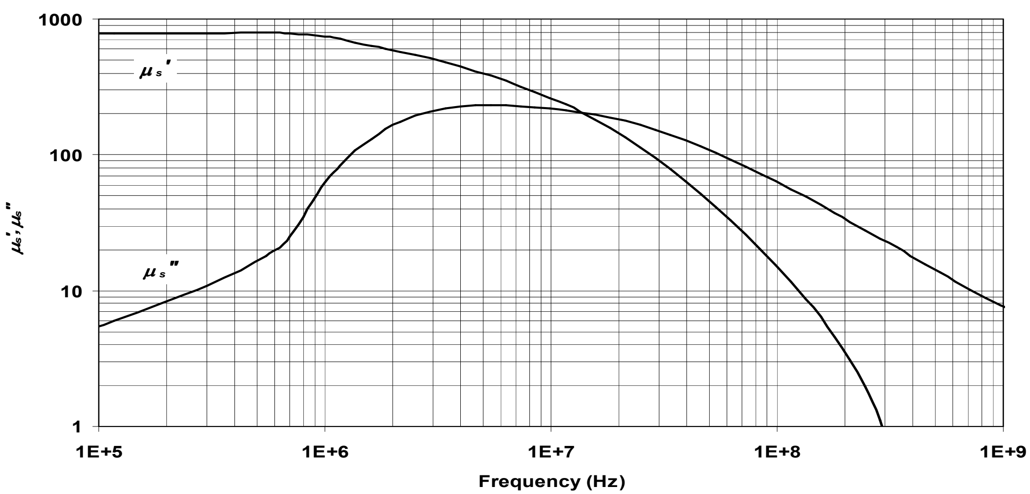
$$Z = R_s + j\omega L_s$$

$$R_s = \omega L_o \mu_s''$$

$$\omega L_s = \omega L_o \mu_s' = X_L$$

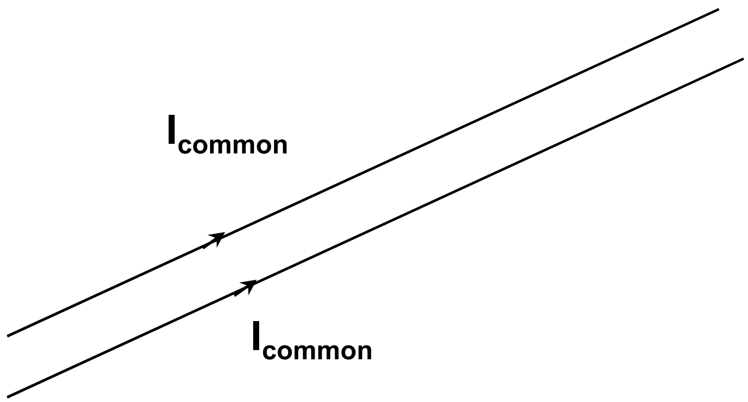
$$L_o = .0461\ N^2\ Ht\ \log_{10}\left(\frac{OD}{ID}\right) 10^{-8}\ [\,H\,]$$

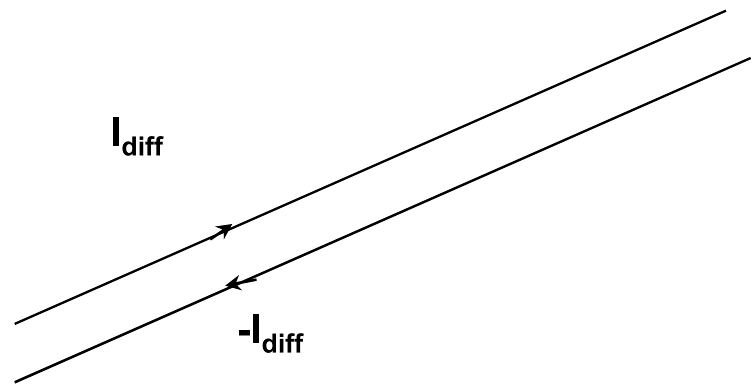
43 Material



[Dim – mm]

Common-Mode vs Differential-Mode





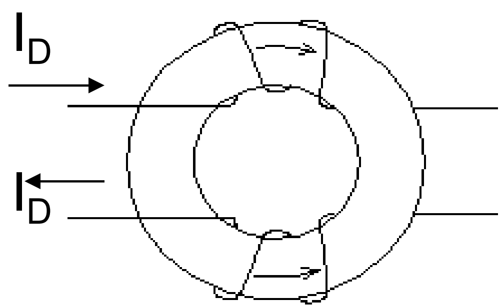
Common-Mode Currents

- **Noise Currents in phase (same direction) in the conductor pair.**
- **Usually found where radiated noise attaches itself to the conductor.**

Differential-Mode Currents

- **Can be Functional (desired) currents or Noise currents or combination of both.**

Common-Mode Choke

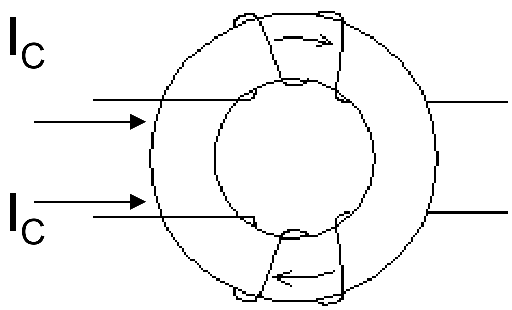


<u>Differential Mode (functional) Currents</u>

Fluxes cancel – * no inductance (impedance)

* no effect on currents

* core will not saturate with high I_D currents



<u>Common Mode Currents</u>

Fluxes Add – * inductance (impedance) in series with conductor

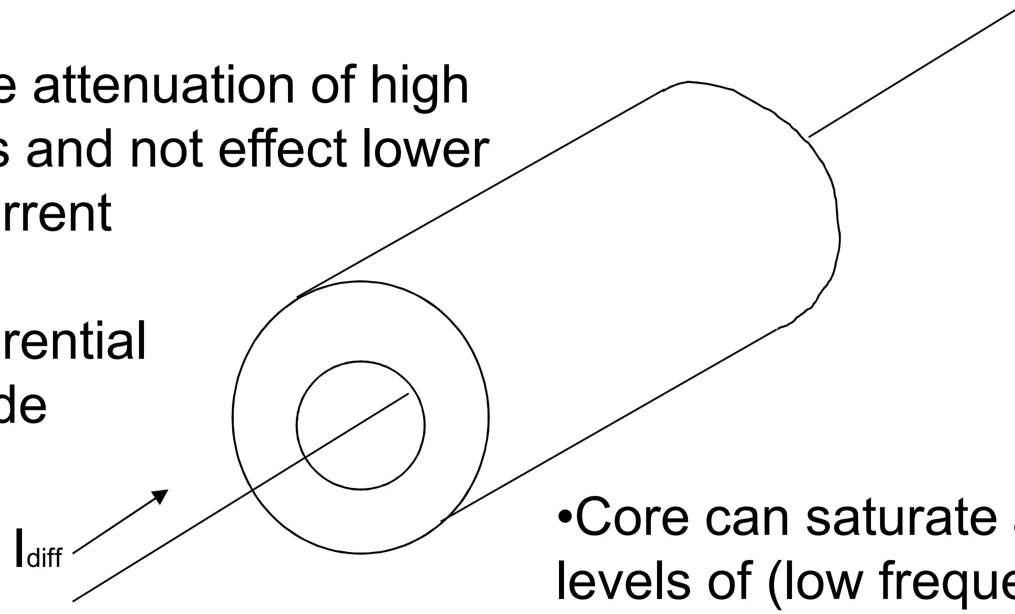
* effectively blocking Common Mode currents

Differential Mode Application

<u>Ferrite Bead</u>

•Provide selective attenuation of high frequency signals and not effect lower freq functional current

•Affects both Differential and Common Mode signals

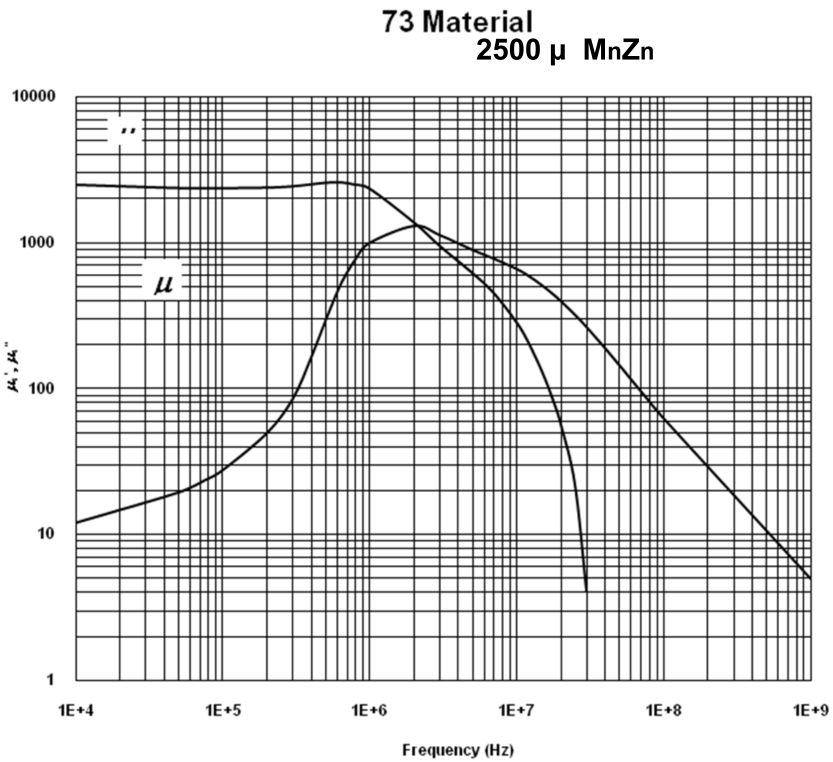


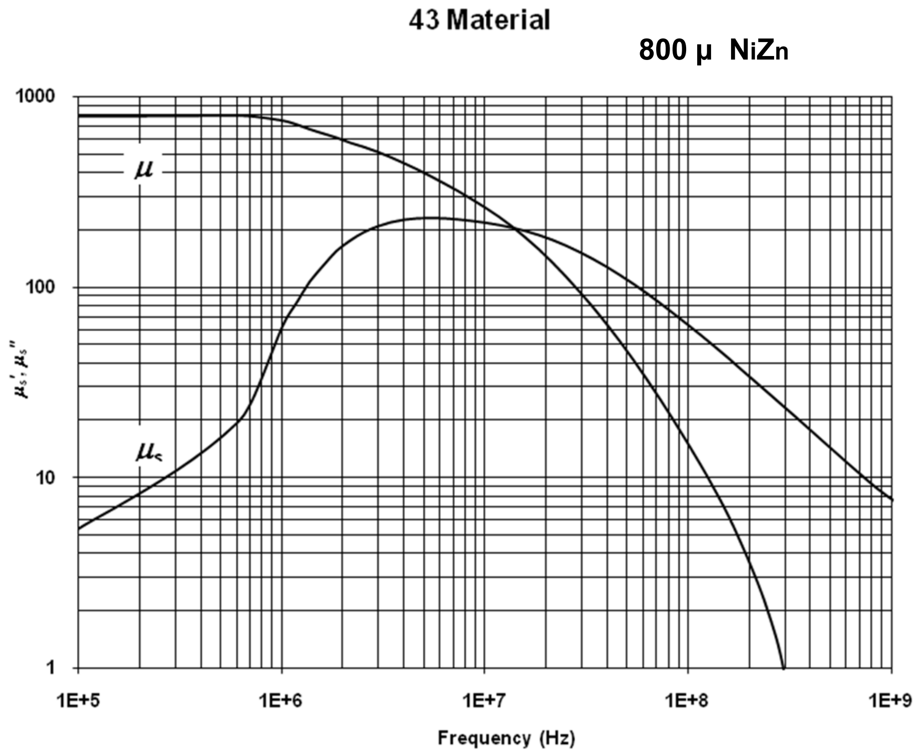
•Core can saturate at high levels of (low frequency) current

μ_s' & μ_s'' ARE AFFECTED BY:

- Frequency
- DC Bias
- Temperature

Complex Permeability vs. Frequency

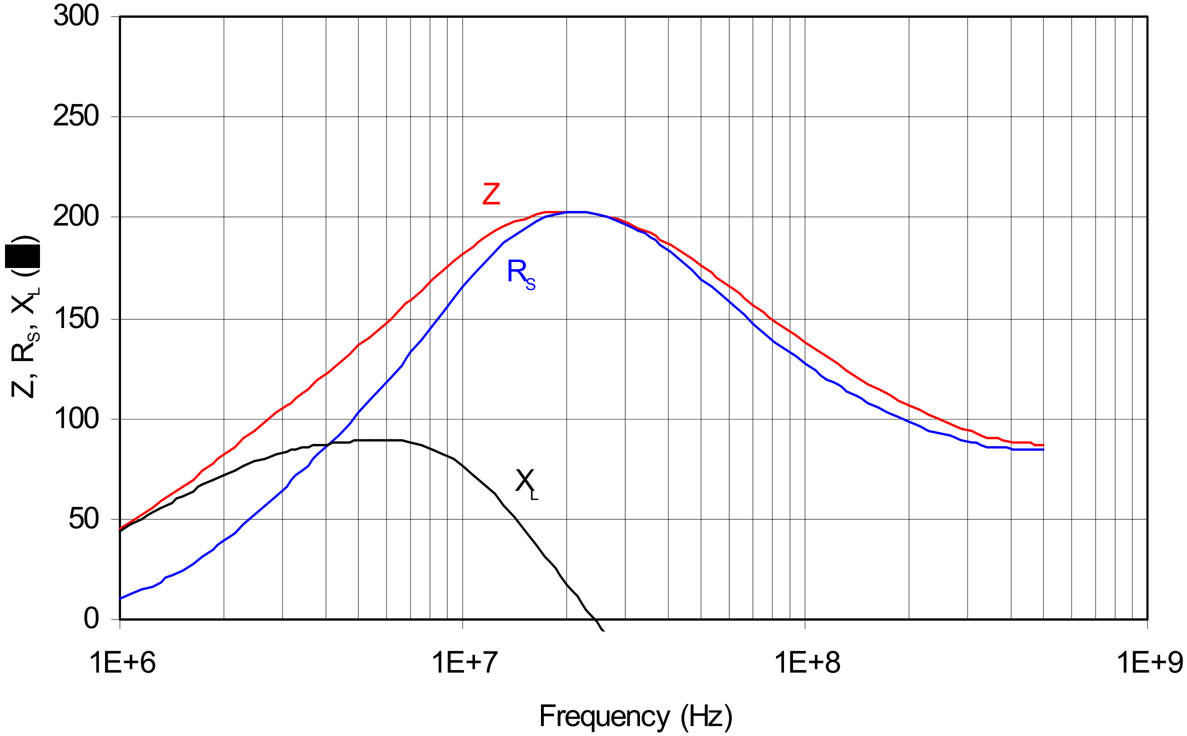




Impedance vs. Frequency

2773009112 Bead On Lead (1 turn)

73 mat'l 2500 µ MnZn



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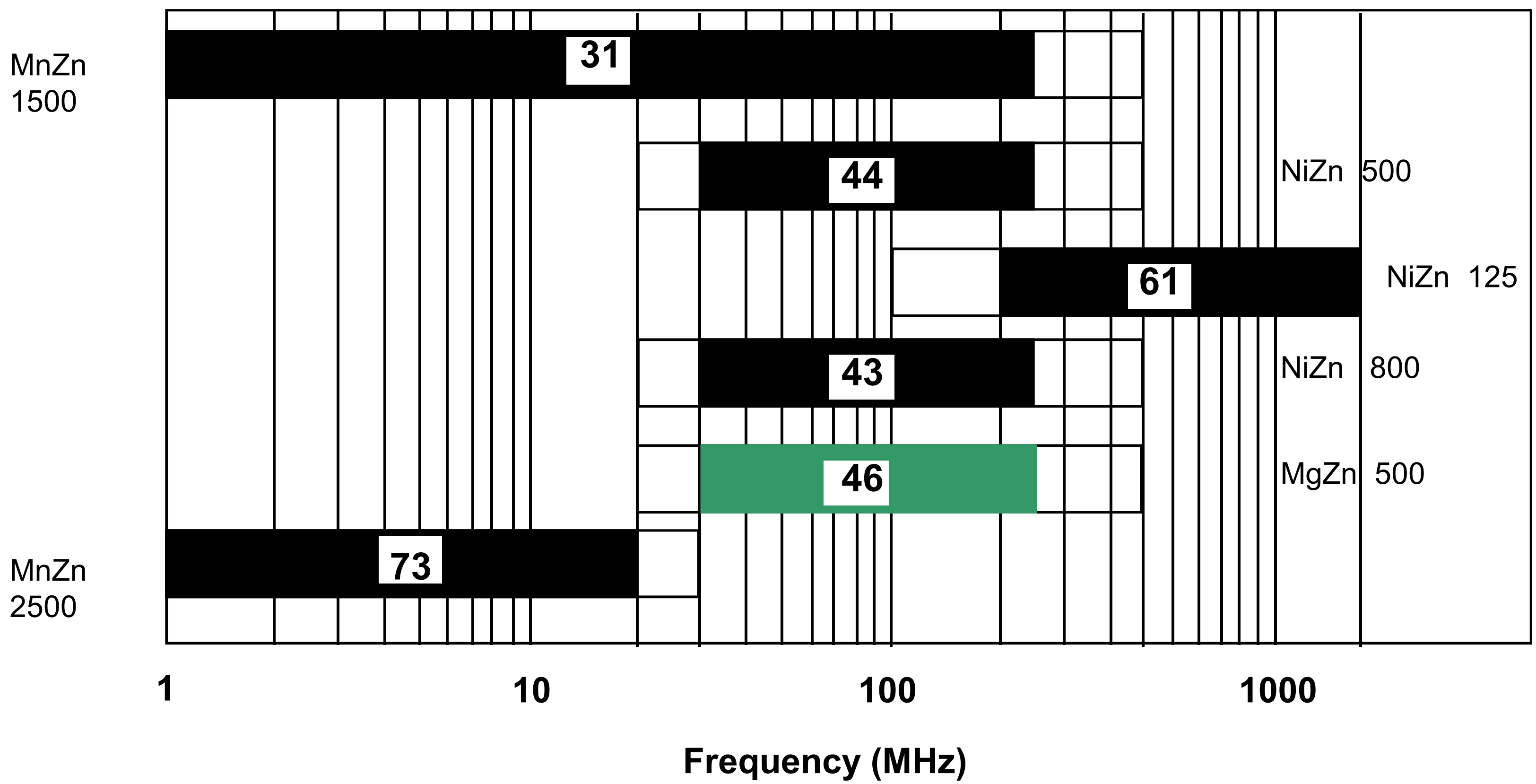
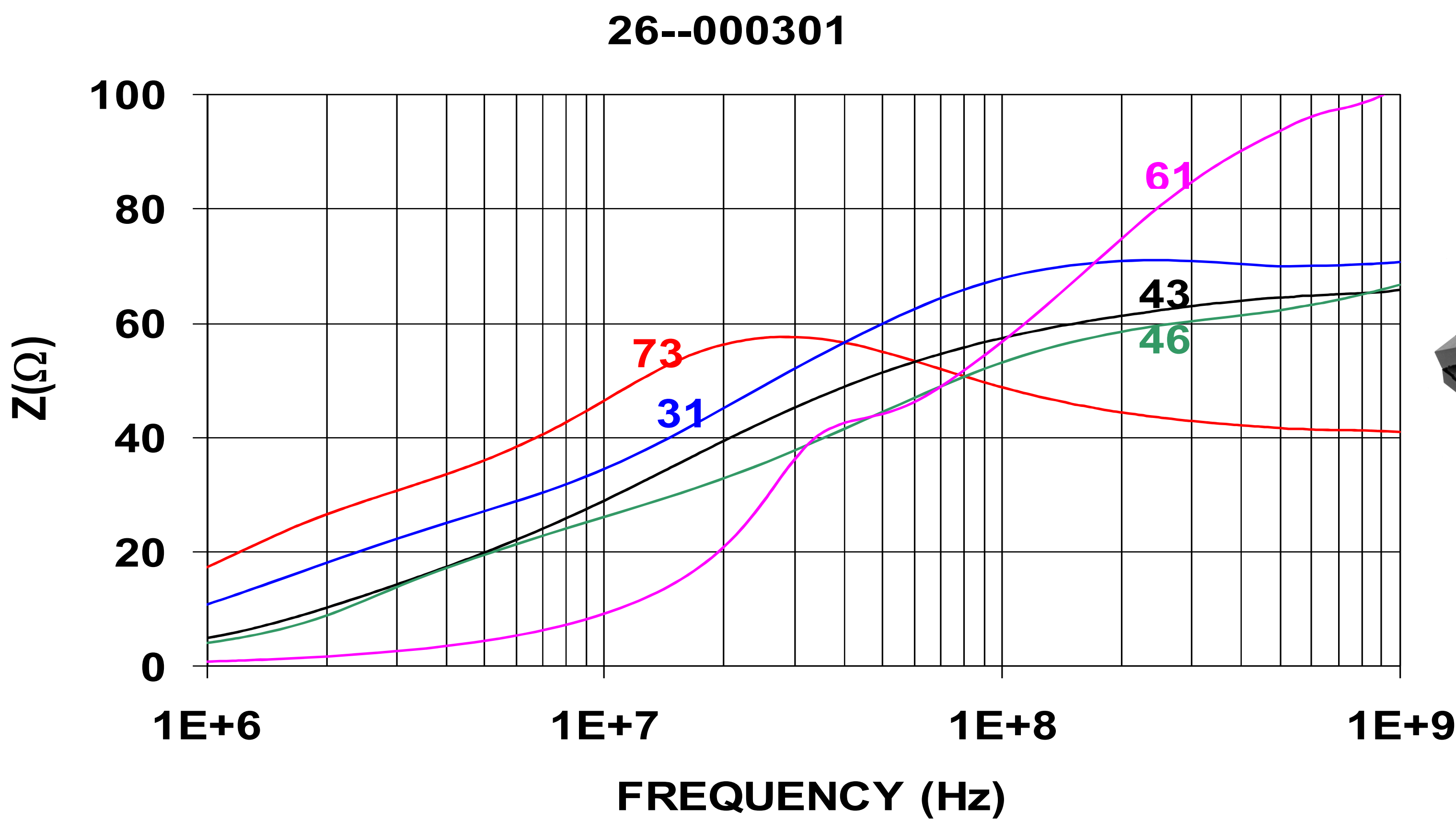
Suppression Materials Comparison



Material Comparison Impedance vs. Frequency



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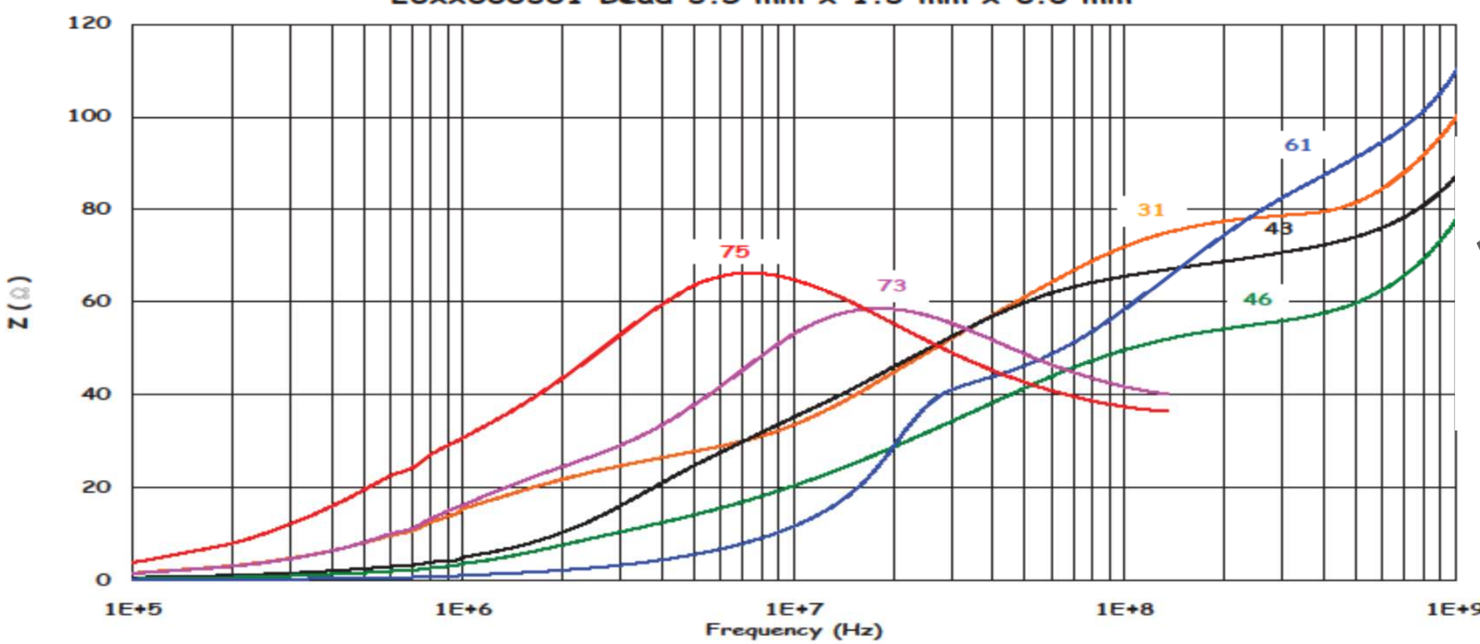
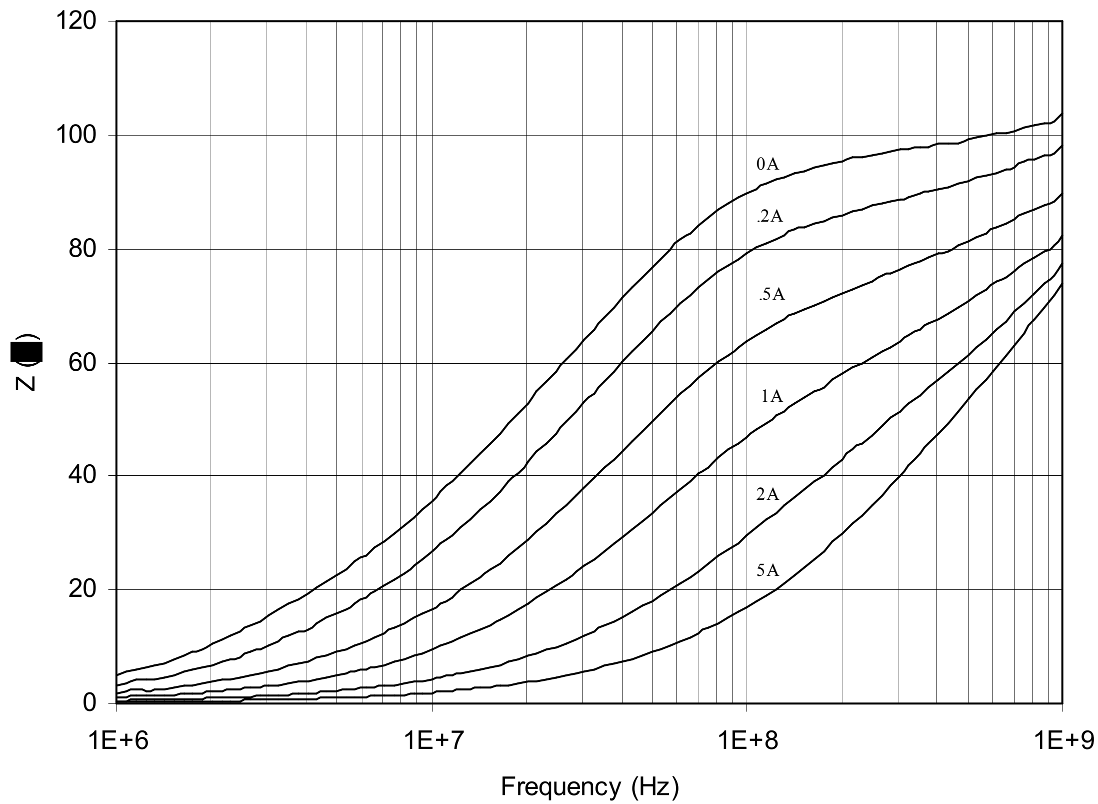
26xx000301 Bead 3.5 mm x 1.3 mm x 6.0 mm



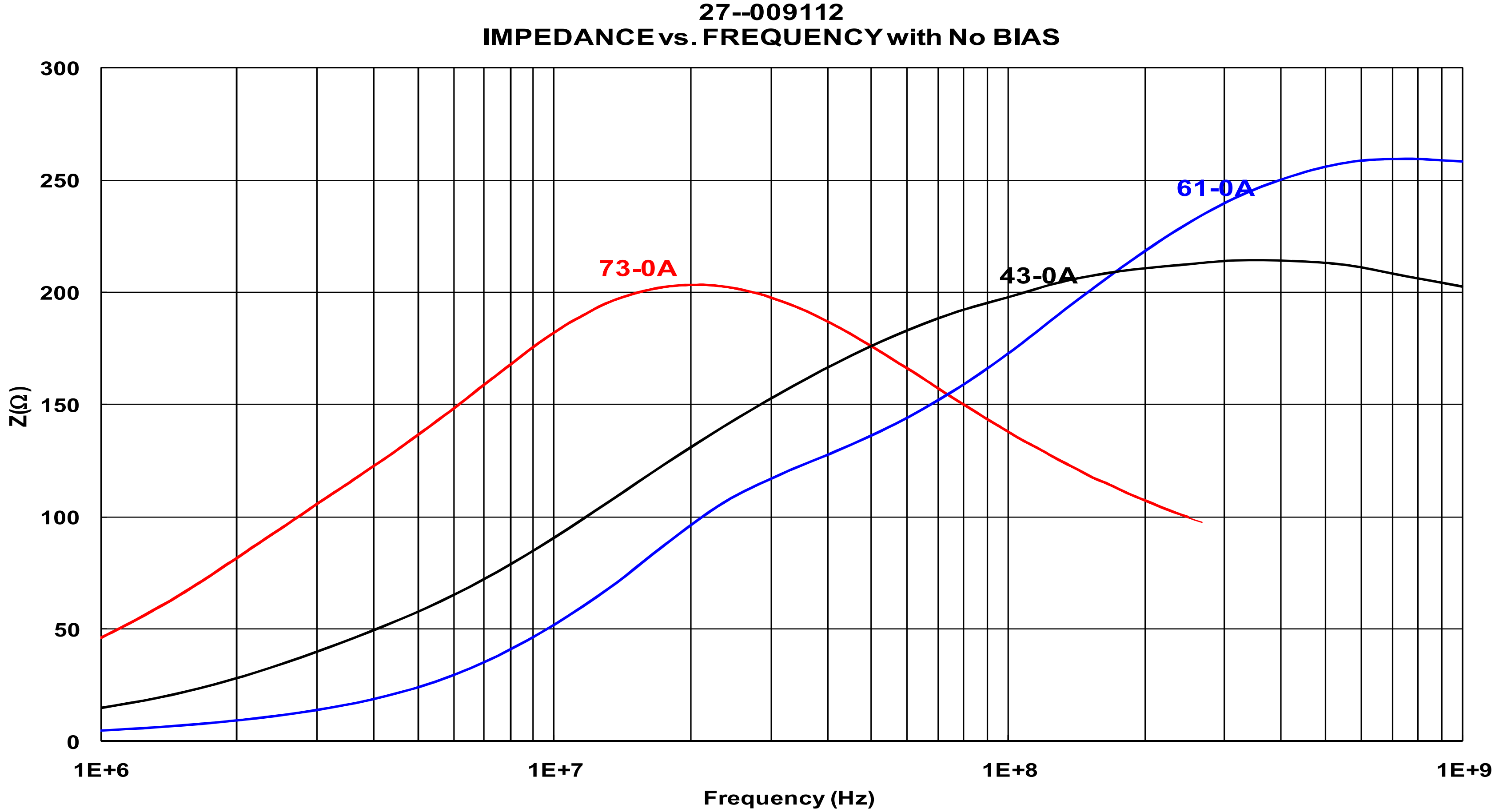
Fair-Rite Products Corp.
PO Box 288, 1 Commercial Row, Wallkill, NY 12589 | www.fair-rite.com
(888) FAIRRITE (324-7748) or (845) 895-2055 | Fax (845) 895-2629

Impedance vs. Frequency with DC Bias

2743021447 Surface Mount Bead



Material Comparison w/ DC Bias



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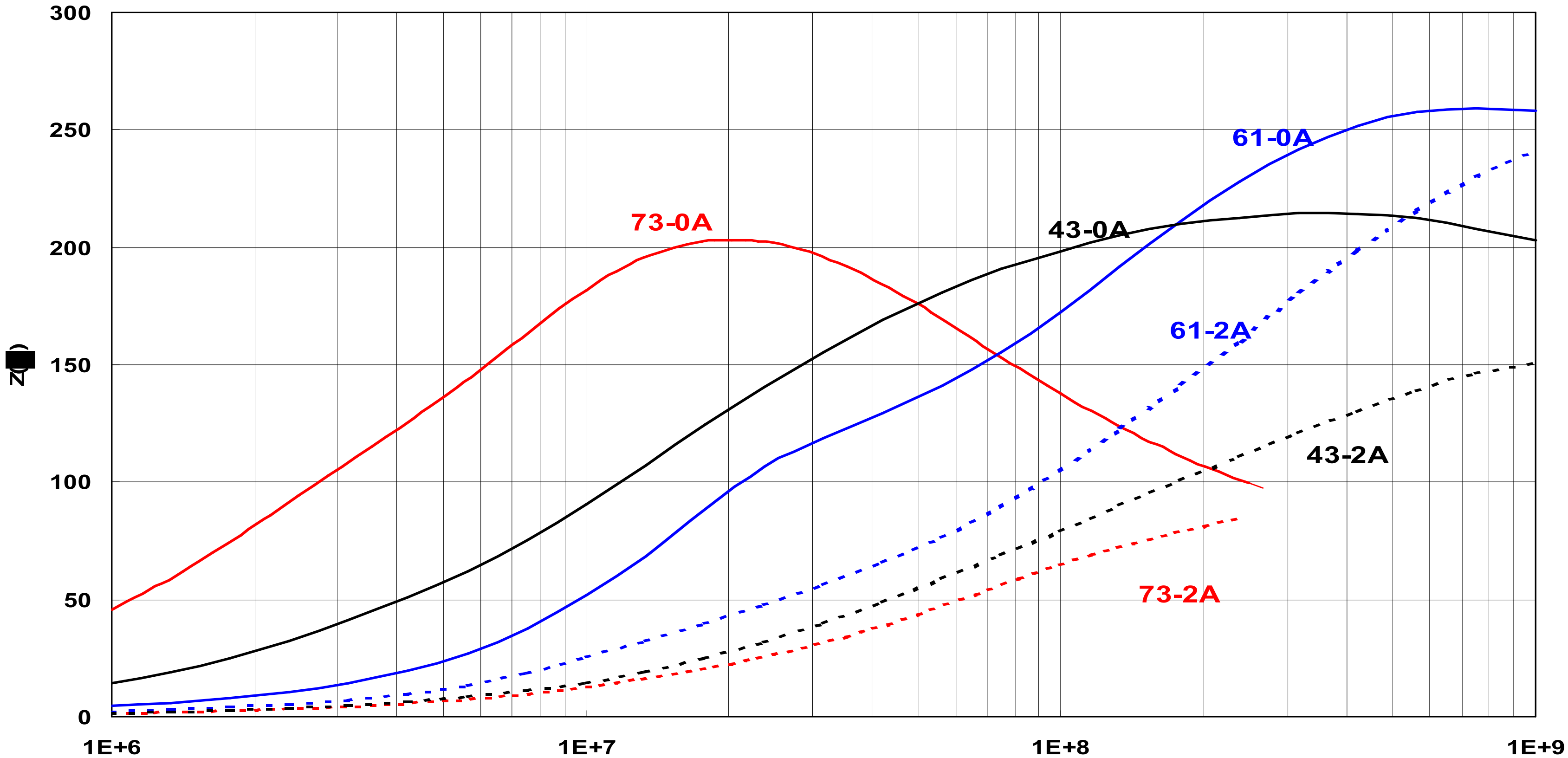
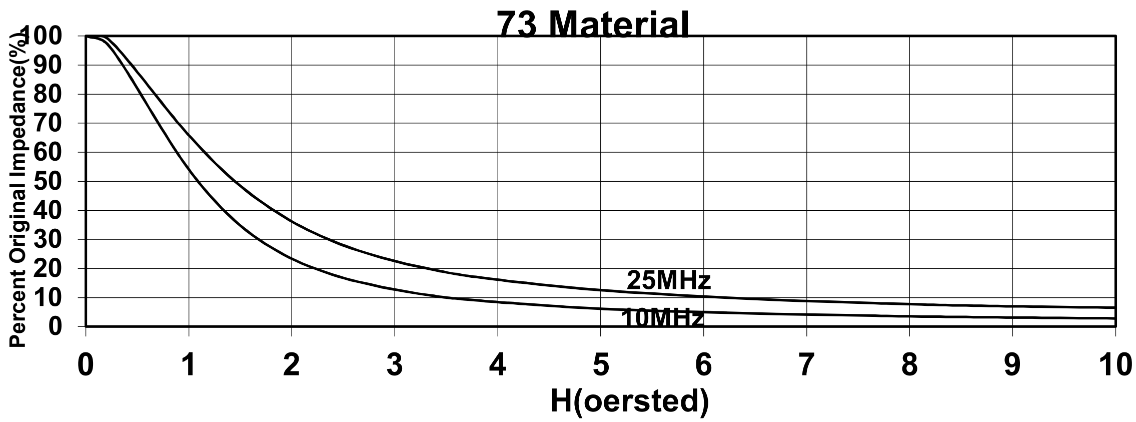
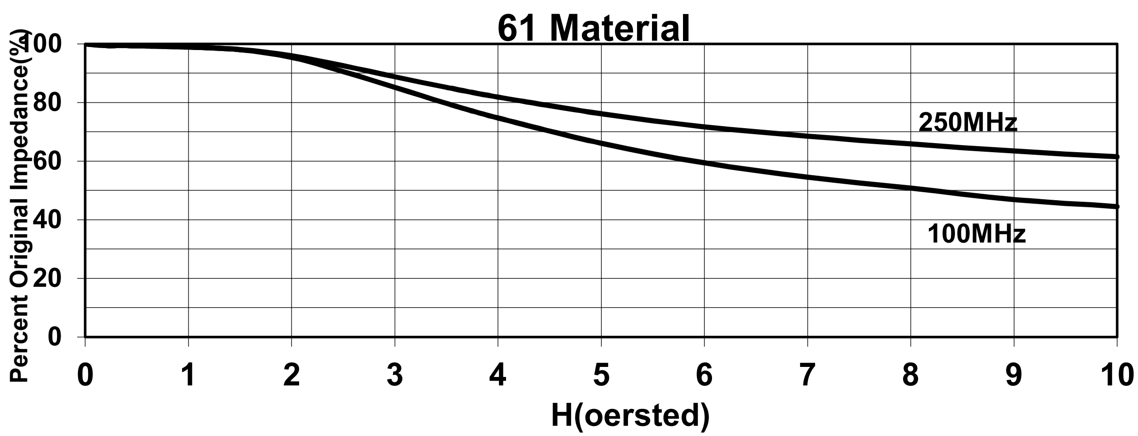
Material Comparison w/ DC Bias

27--009112
IMPEDANCE vs. FREQUENCY WITH DC BIAS

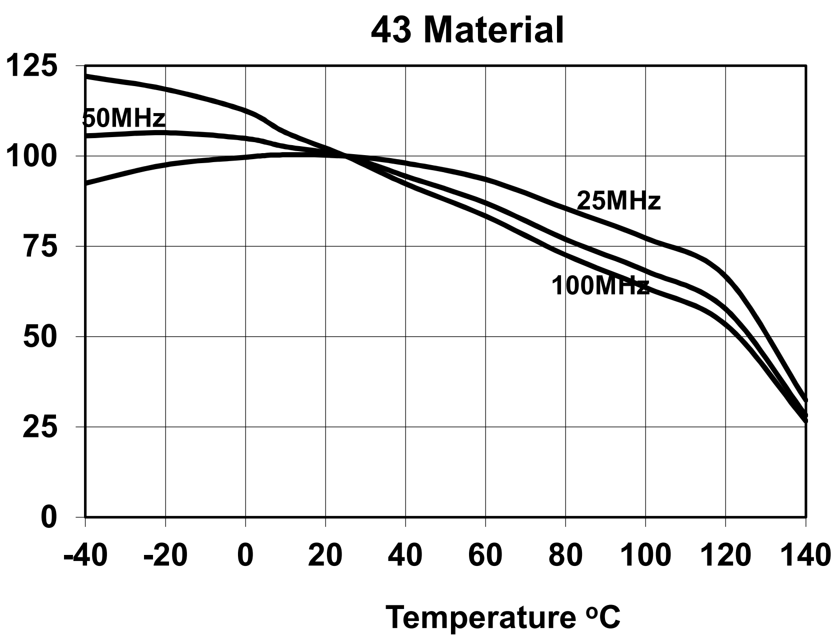


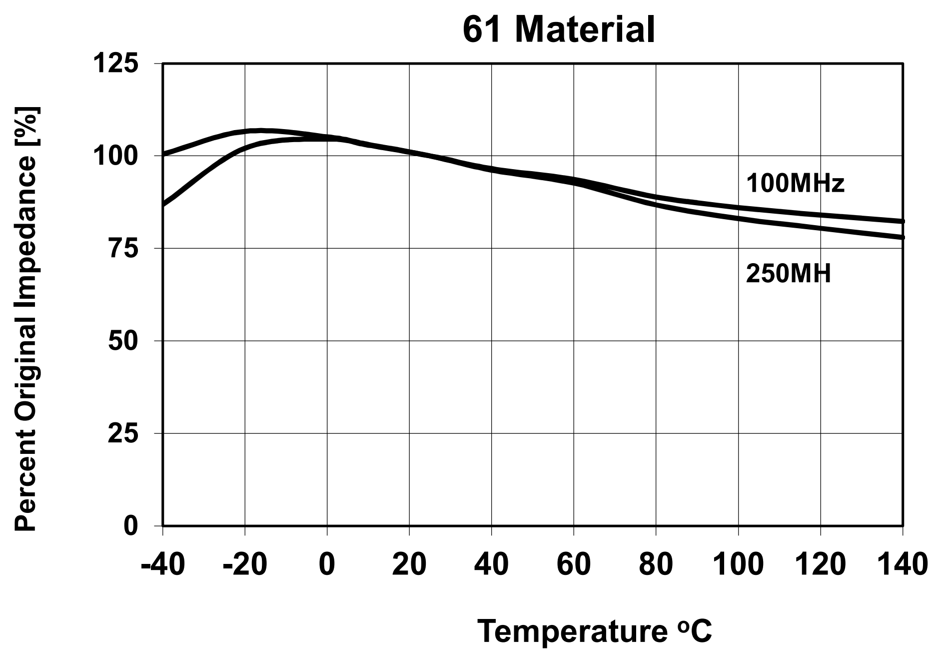

73 Material
Percent Original Impedance(%)
100
90
80
70
60
50
40
30
20
10
0
25MHz
10MHz
0
1
2
3
4
5
6
7
8
9
10
H(oersted)

$$H = (0.4\,\pi\,N\,I)\,/\,l_e$$

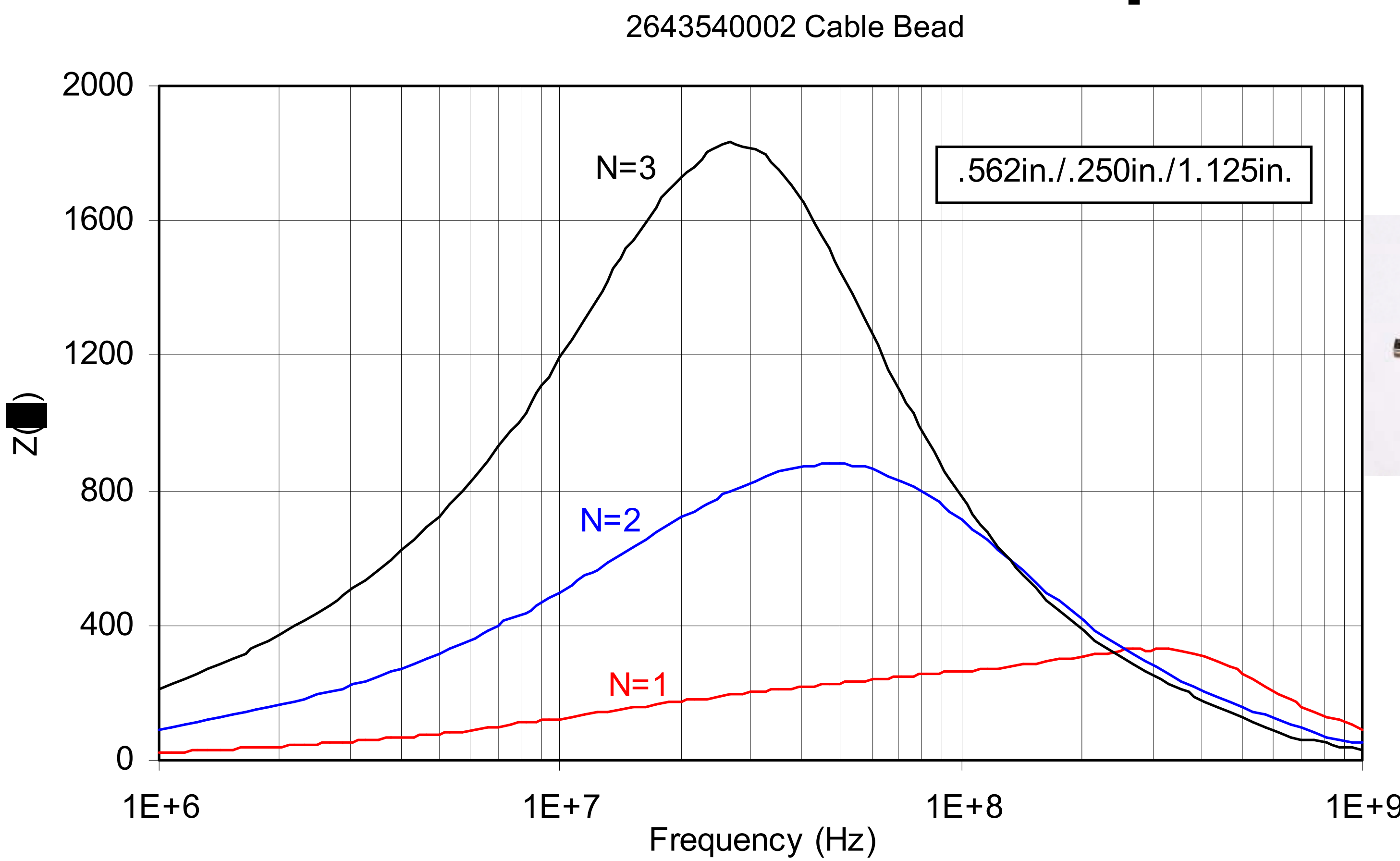

61 Material
Percent Original Impedance(%)
100
80
60
40
20
0
250MHz
100MHz
0
1
2
3
4
5
6
7
8
9
10
H(oersted)

Impedance vs. Temperature





The Effect of Turns on Impedance



Board Level – SMD ferrites

Chip Beads

Package sizes
0402, 0603, 1206, 1806, 1812

Y Std , Z High , H GHz

Impedance Rated at 100MHz
10Ω to 2000Ω

Current Rated 100mA to 6A

SM Beads

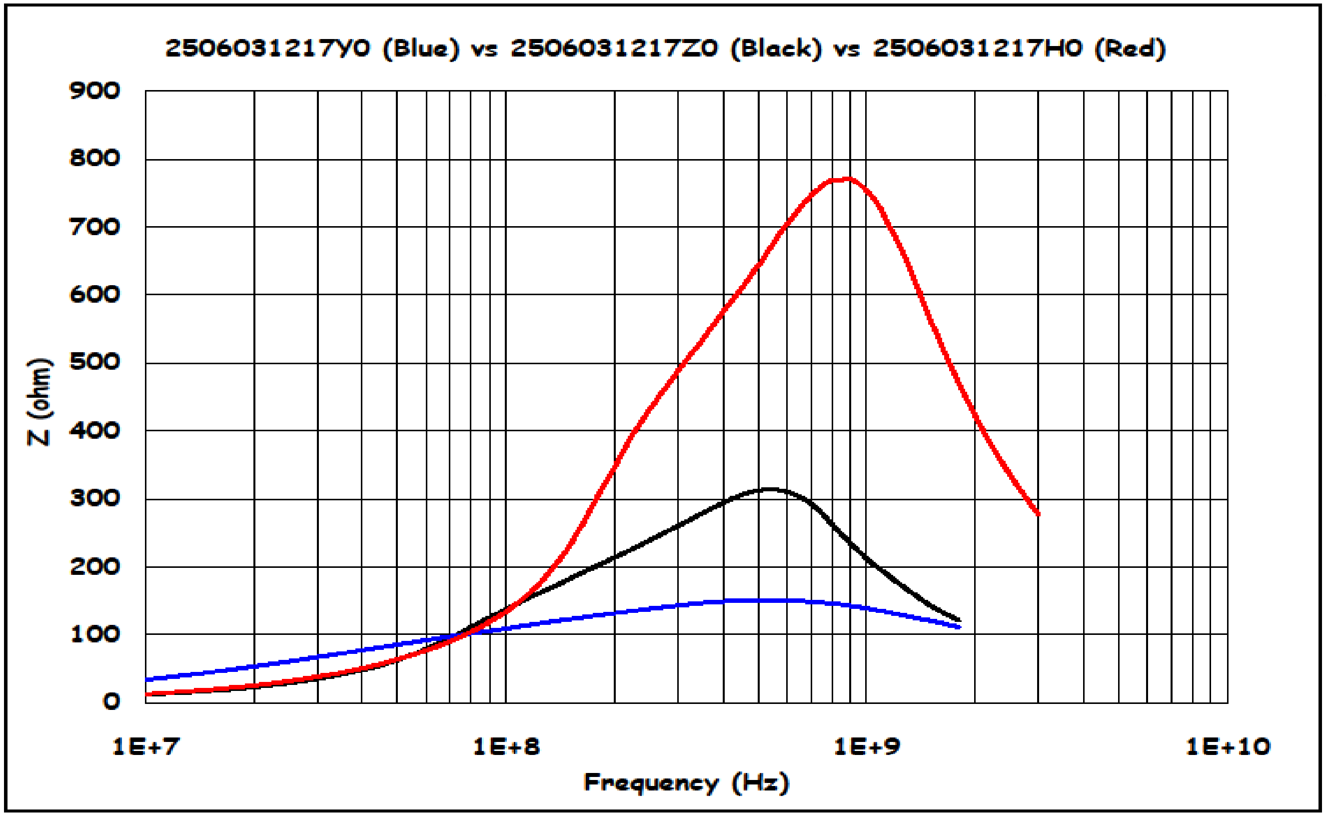
Package sizes
.184 x .120 up to .58 x .27 DM & CM

73(<50MHz), 43/44 (25-300MHz), 61 & 52 (250MHz-1GHz)

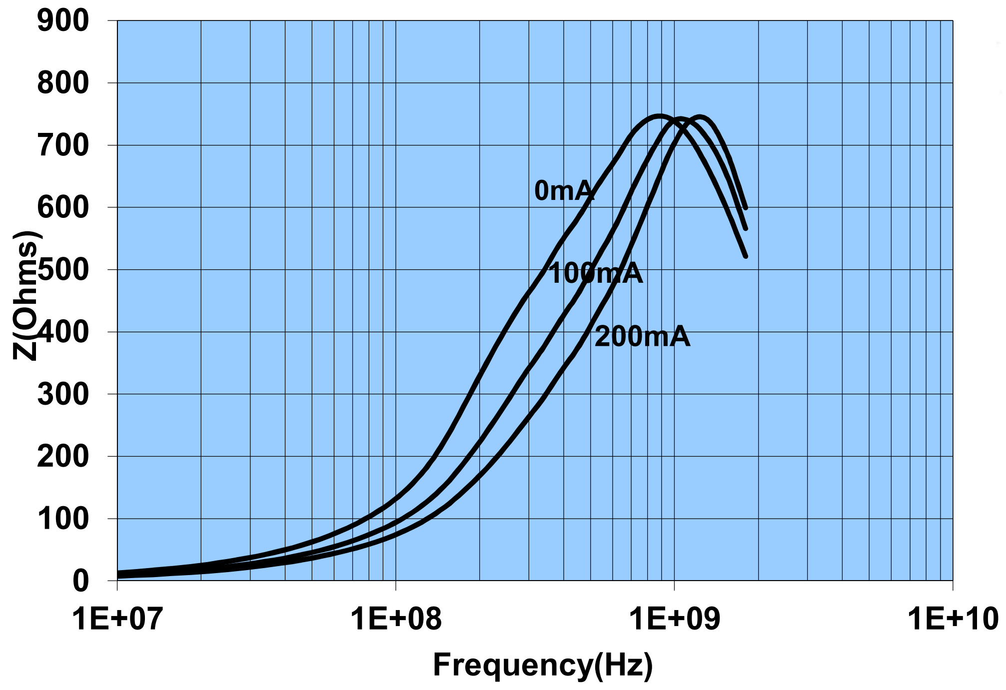
Impedance Rated at 1MHz to 1GHz
9Ω to 600Ω

Current Rated 5A (to 10A)

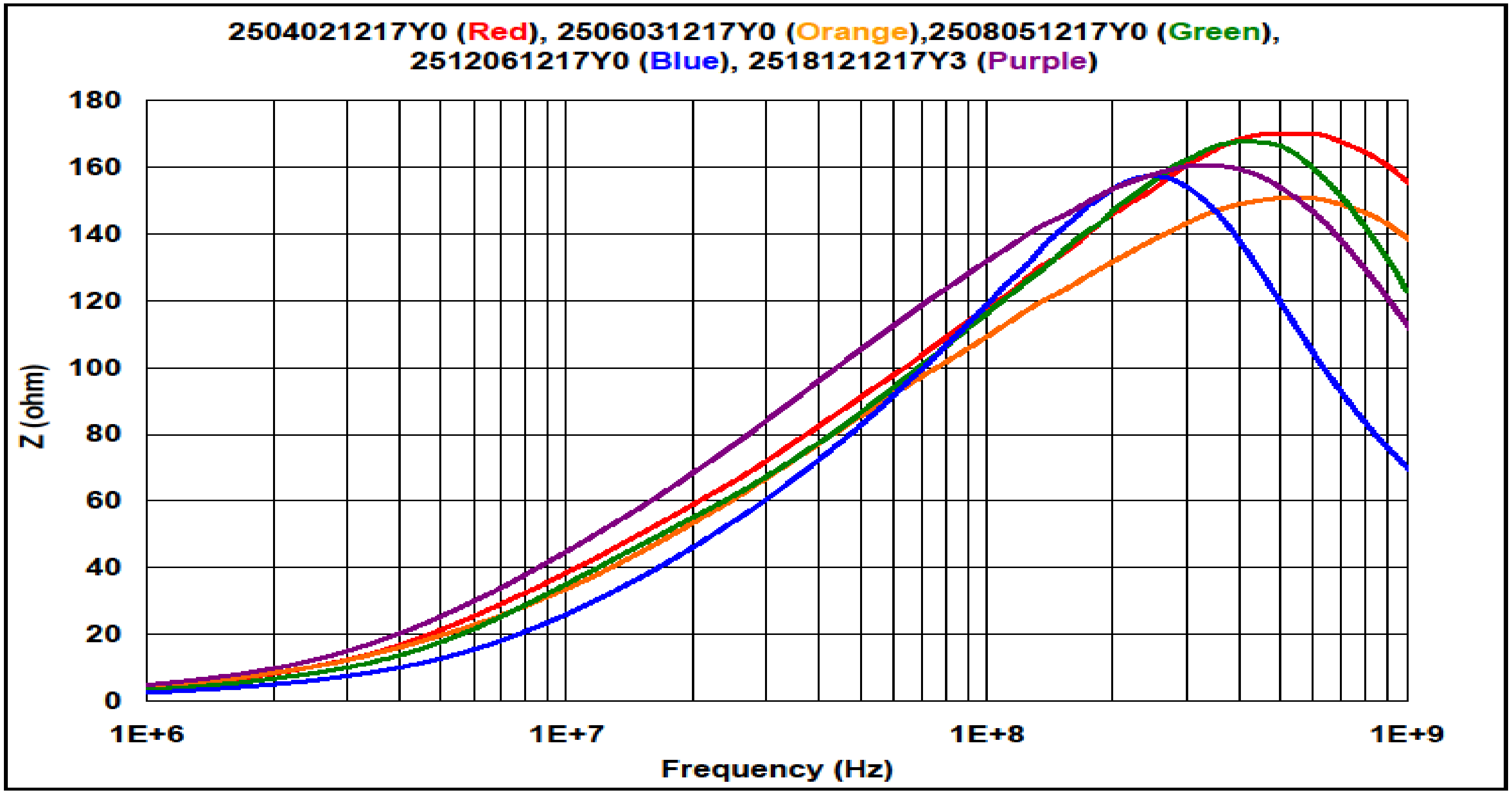
0603 size 120Ω +/-25% Y Std speed vs Z High Speed vs H GHz Speed



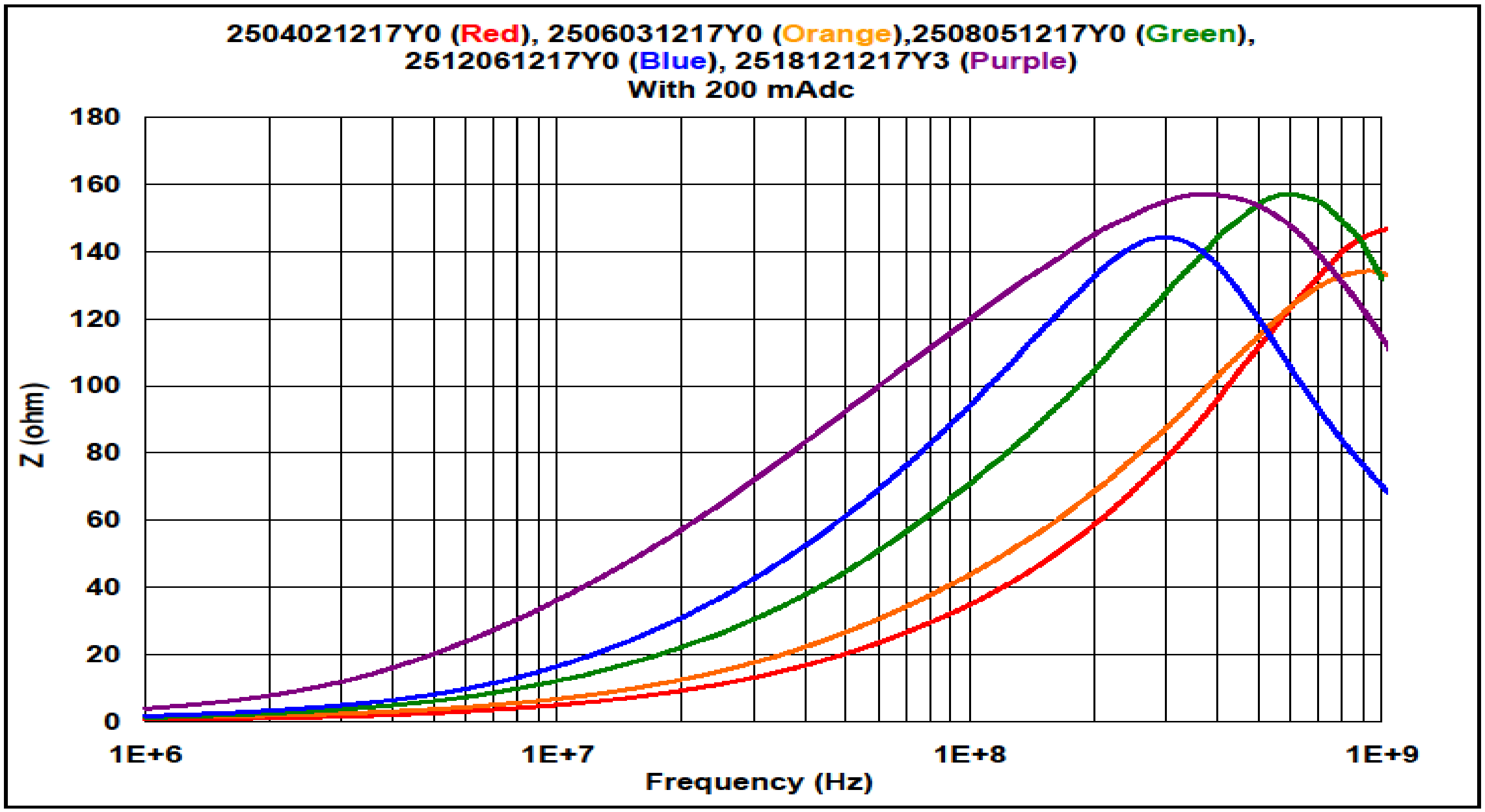
0603 size 120Ω H GHZ speed 200mA Device



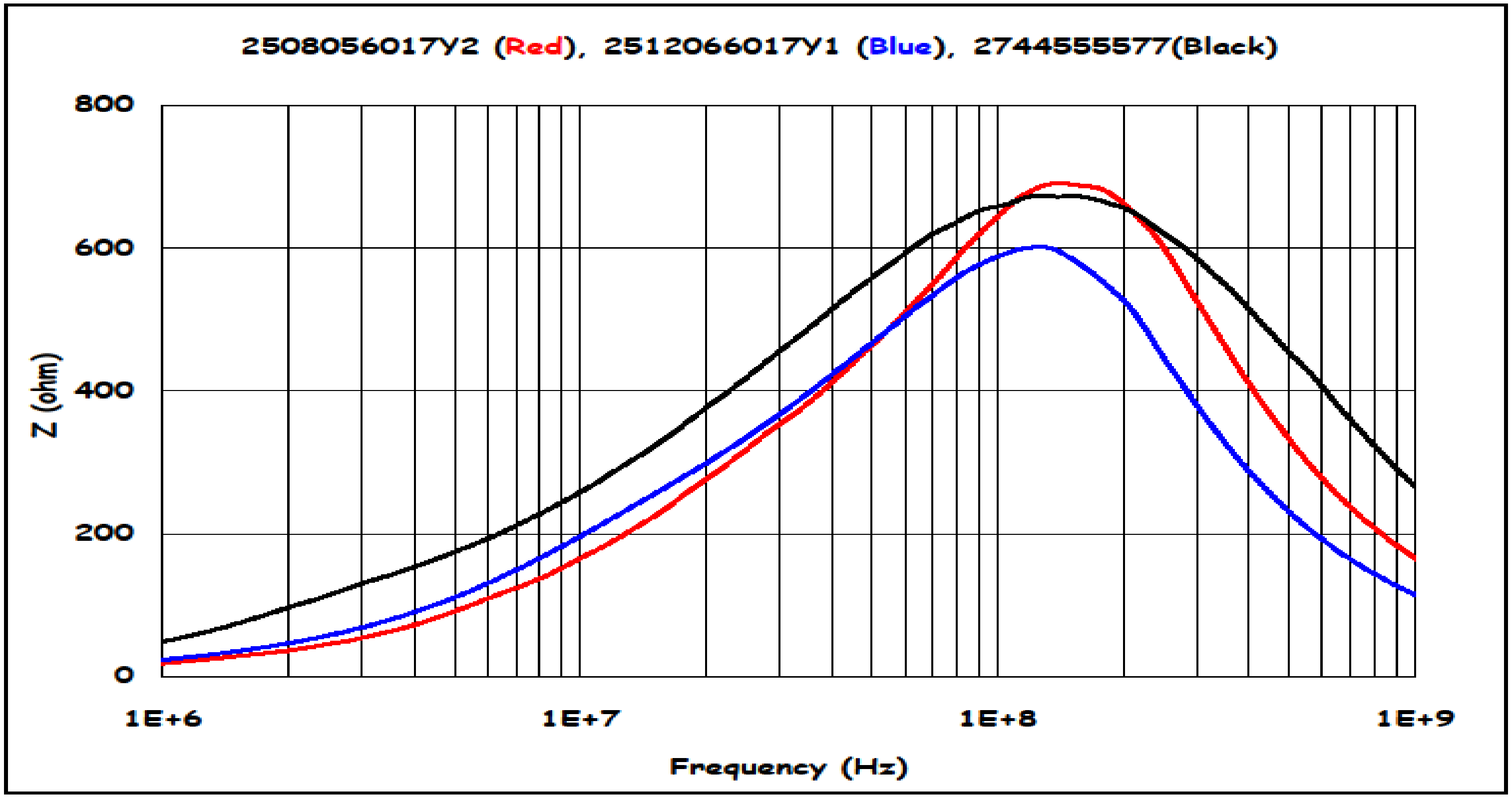
Size Matters all 120Ω 0402 to 1812 packages



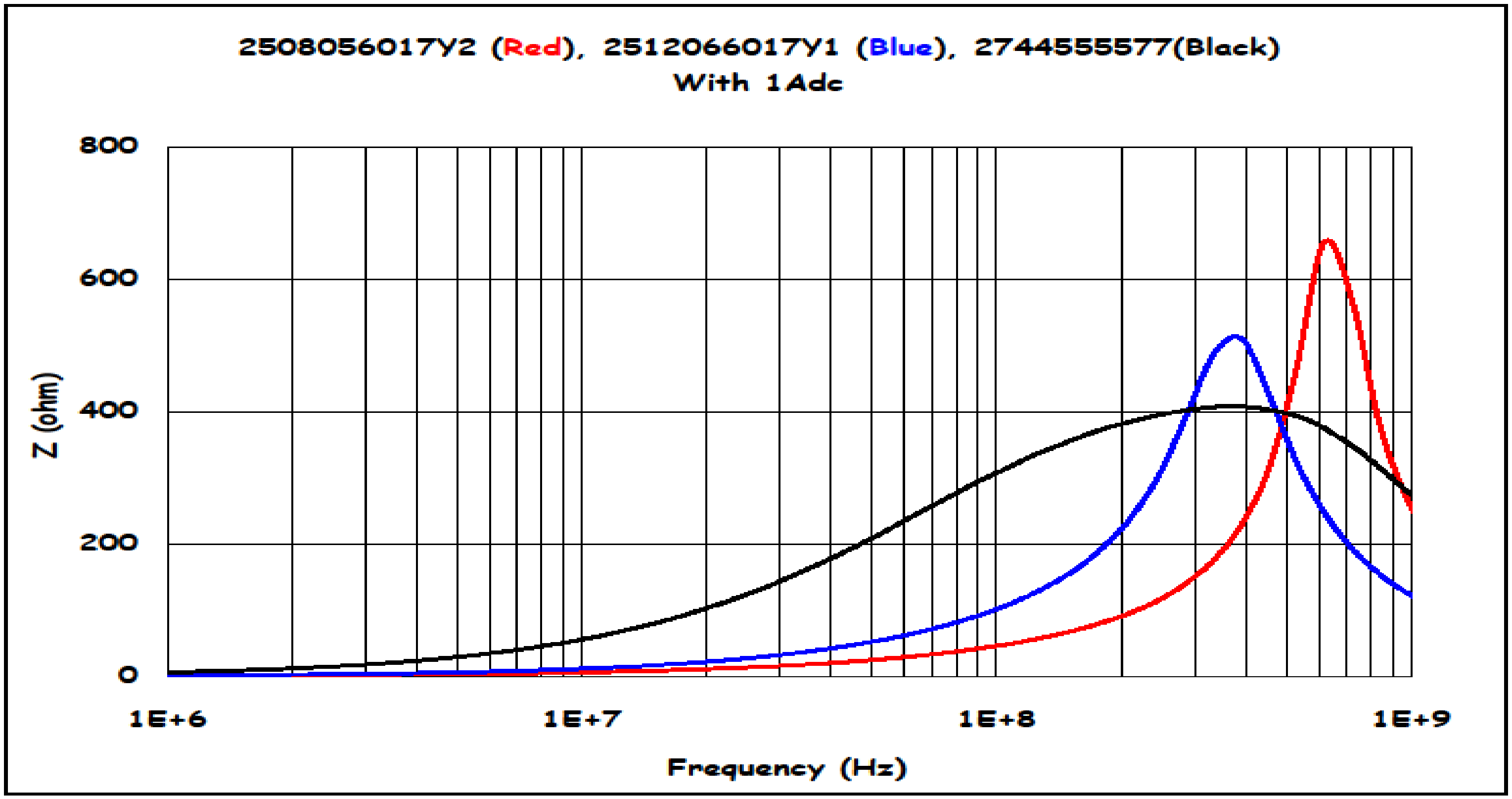
Size Matters all 120Ω 0402 to 1812 packages w/ bia



Chip Beads 0805 600Ω vs 1206 600Ω vs SM Bead .43″ x .20″ 600Ω



Chip Beads 0805 600Ω vs 1206 600Ω vs SM Bead .43 x .20 600Ω



Review - Desirable Material Properties For EMI Suppression

- High core loss (u”) in the intended frequency range (magnetic losses)

  Note: low eddy current loss (high resistivity)
- High permeability at the low frequency range (high u’)
- Resistance to dc-bias (i.e. high incremental permeability vs. H)
- Good thermal stability (Z vs. T)
- High Curie Temperature (Tc)

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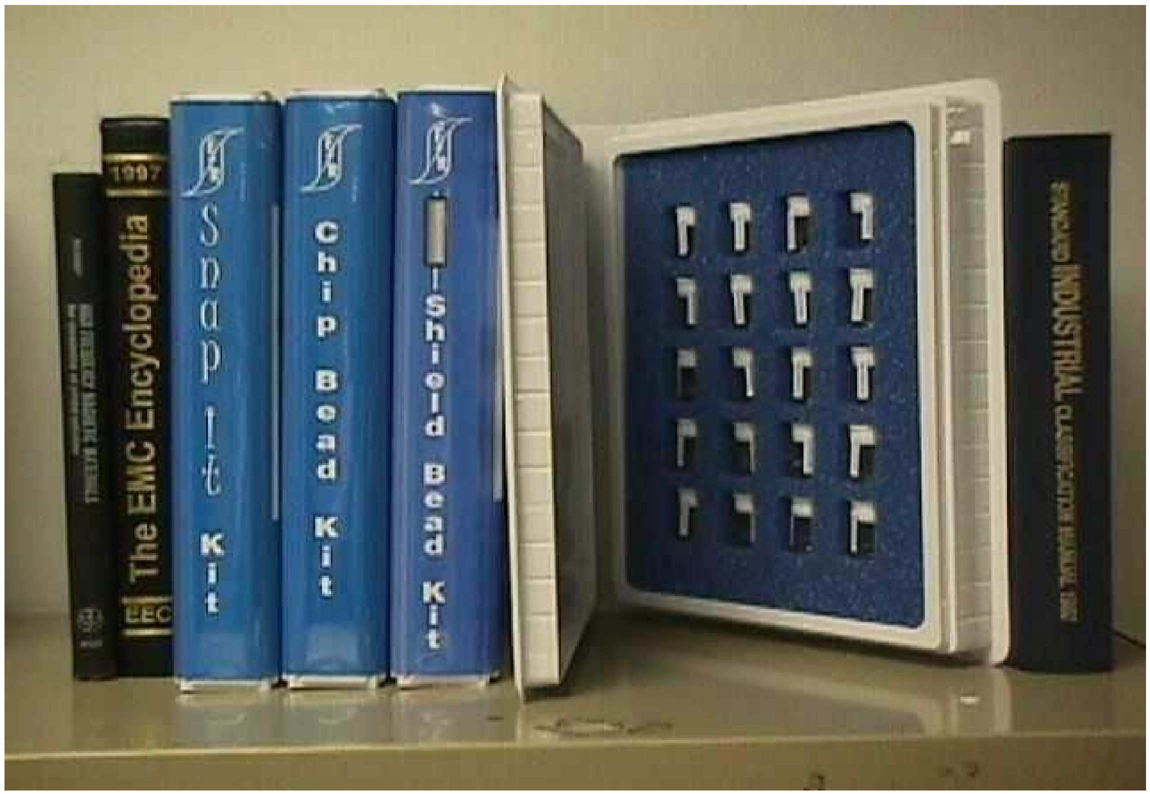
Mounting Plate 35.75" X 19"
Total weight is approx. 47 lbs

Engineering Evaluation - Bookshelf Kits



Product Range – Power/Inductive Components

Open Magnetic Circuit

- Rods
- Antenna/RFID Rods
- Bobbins

Closed Magnetic Circuit

- Toroids
- Pot Core (P)
- PQ
- E
- EFD
- Planar EE, EI, ER
- ETD, EER
- EP
- U
- Custom shape / customer specification

Power Applications

HF Ferrite Power Transformers and Inductors

Materials: 78, 98, 95, 97, 79

Core Shapes:

Pot (P) , E, U, RM, EP, PQ EFD, ETD , EER
Planar EI, EE and ER
Toroid

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Power Materials

FR material grade	78	98	95	97	79	units
Initial Permeability μ i	2300	2400	3000	2000	1400	
Bmx	4800	5000	5000	5000	4700	gauss
at H	5	5	5	5	5	oersted
Br	1500	1800	800	1500	1700	gauss
Hc	0.2	0.17	0.13	0.16	0.4	oersted
Loss Factor(tan δ/μ) at 0.1MHz	4.5	3.5	3	3.5	4	1e -6
Temperature Factor 25-60°C	4.2	5.8	2.5	6.5	3.4	1e -6
Curie Temperature Tc	200	215	220	220	225	ºC.
Resistivity p	100	200	200	200	200	ohm-cm
Specific Power Loss (typical)						
PL at 25kHz	**80**					mW/cc
at Flux Density / Temperature	2000 / 100					gauss / °C.
PL at 100kHz	**100**	**50**	**50**	**50**	**100**	mW/cc
at Flux Density / Temperature	1000 / 100	1000 / 100	1000 / 100	1000 / 100	1000 / 100	gauss / °C.
PL at 200kHz		**190**	**180**	**175**		mW/cc
at Flux Density / Temperature		1000 / 100	1000 / 100	1000 / 100		gauss / °C.
PL at 500kHz					**80**	mW/cc
at Flux Density / Temperature					500 / 100	gauss / °C.
Comparable competitor materials						
Ferroxcube	3C90	3C94/96	3C95	3F3	3F35	
EPCOS	N67	N87	N95	N97	N49	
TDK	PC40	PC44	PC95		PC50	
Magnetics Inc.		R			K	
ACME	P4	P41			P5/P51	

Thank you

Q & A