FAIR - RITE PRODUCTS CORP.

“Your Signal Solution”
Outline

1. Ferrite overview
   - What are ferrites?
   - How do they work?
2. Ferrite Applications
3. EMI Suppression Application
   - Material Characteristics
   - Selecting the Right Core
   - Material Selection / Control Performance
4. How are Ferrites Made?
5. Available Kits
6. 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 (sine, pulse, square, etc).

**CHEMICAL COMPOSITION**

(metal oxides) + (iron oxide)

\[(\text{Mn}0 + \text{Zn}0) + (\text{Fe}_2\text{O}_3) = (\text{Ni}0 + \text{Zn}0)\]

Manganese - Zinc

Nickel - Zinc
What Makes Ferrite Tick

- Ferrite Rod (internal structure)

“Small Magnets”

Arrows Indicate Direction of Magnetic Force
What Makes Ferrite Tick
continued

– Excitation Of Ferrites

All “small magnets” are aligned in the direction of flux produced by the coil.
When & Why To Use Ferrites

When - Frequencies above 1KHz (to 3GHz)

Why - Application Specific

Ferrites are used to process electronic signals. These signals can be filtered, transformed, absorbed or concentrated. A broad classification of the product applications are:

– EMI Suppression - High Impedance
– Power applications - Low Core Loss
– Low level signals (Sensors and antennas) – Increase Sensitivity
– Absorption of high frequencies (testing chambers & shielding)
EMI Suppression
Cable Filtering Applications

• Largest application of suppression ferrites.

• Industrial, computer, telecom, medical, aerospace applications

• Materials: #43; #44; #31; #61; #73; #51, #46

• Shield beads, snap-on cores and flat cable beads
Intrinsic Characteristics/Applications

EMI Suppression Applications

Intrinsic Characteristics

*Complex Permeability* \[ [u' \ & \ u''] \]

*High Impedance*

Applications

*Computers and peripherals*
*Communication Systems*
*Automobiles*
*Switch Mode Power Supplies*
*dc-dc converters*
*ignition coils*
Material Characteristics

### 43 Material

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Permeability</td>
<td></td>
<td>$\mu_1$</td>
<td>850</td>
</tr>
<tr>
<td>@ B &lt; 10 gauss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flux Density</td>
<td>gauss</td>
<td>B</td>
<td>2900</td>
</tr>
<tr>
<td>@ Field Strength</td>
<td>oersted</td>
<td>H</td>
<td>10</td>
</tr>
<tr>
<td>Residual Flux Density</td>
<td>gauss</td>
<td>$B_r$</td>
<td>1300</td>
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<tr>
<td>Coercive Force</td>
<td>oersted</td>
<td>$H_c$</td>
<td>.45</td>
</tr>
<tr>
<td>Temperature Coefficient of</td>
<td>%/ C</td>
<td></td>
<td>1.25</td>
</tr>
<tr>
<td>Initial Permeability (20-70 C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss Factor</td>
<td>$10^{-6}$</td>
<td>$\tan\delta/\mu_1$</td>
<td>250</td>
</tr>
<tr>
<td>@ Frequency</td>
<td>MHz</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Curie Temperature</td>
<td>°C</td>
<td>$T_c$</td>
<td>&gt;130</td>
</tr>
<tr>
<td>Resistivity</td>
<td>Ω cm</td>
<td>$\rho$</td>
<td>$1 \times 10^5$</td>
</tr>
<tr>
<td>Recommended Frequency Range</td>
<td>MHz</td>
<td></td>
<td>20 - 250</td>
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<tr>
<td>EMI Applications</td>
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Image: Graph showing the magnetic properties of 43 Material.
SELECTING THE RIGHT FERRITE CORE

THE SOURCE of EMI

FREQUENCY of DESIRED SIGNAL VS. NOISE

CIRCUIT IMPEDANCE [LOAD AND SOURCE]

ENVIRONMENTAL CONDITIONS

ALLOWABLE SPACE
Attenuation = $20 \log_{10} \left[ \frac{(Z_s + Z_{sc} + Z_L)}{(Z_s + Z_L)} \right] \text{ dB}$

where

$Z_s = \text{Source impedance}$

$Z_{sc} = \text{Suppressor Core impedance}$

$Z_L = \text{Load impedance}$
\[ \begin{align*}
I \omega L_s &= V = jZ \\
I &= \frac{V}{Z} \\
R_s &= \omega L_o \mu_s'' \\
\omega L_s &= \omega L_o \mu_s' \\
\tan \delta &= \frac{R_s}{\omega L_s} = \frac{\mu_s''}{\mu_s'} \\
L_o &= \frac{4\pi N^2 10^{-9}}{C_1} \quad [H] \\
\text{Toroidal Core} \quad L_o &= 0.0461 N^2 Ht \log_{10} \left( \frac{OD}{ID} \right) 10^{-8} \quad [H] \\
\end{align*} \]
Material Parameters

$\mu_s'$ & $\mu_s''$  
Complex Permeability

$\rho$  
Resistivity

$T_c$  
Curie Temperature

Product Parameters

$C_1$  
Core Configuration

$N^2$  
Number of Turns
\( \mu_s' \) & \( \mu_s'' \) ARE AFFECTED BY:

- Frequency
- DC Bias
- Temperature
- Flux Density
Complex Permeability vs. Frequency

73 Material

$\mu_s'$, $\mu_s''$

Frequency (Hz)
Impedance vs. Frequency

2773009112 Bead On Lead (1 turn)
Suppression Materials Comparison

Frequency (MHz)

MnZn

NiZn

NiZn

NiZn

MnZn

31

44

43

46

73

61

1

10

100

1000

100

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Comparison Impedance vs. Frequency

26--000301

FREQUENCY (Hz)

Z(Ω)

1E+6 1E+7 1E+8 1E+9

0 20 40 60 80 100

73 31 61 46 43

“Your Signal Solution”
Impedance vs. Frequency with DC Bias

2743021447 Surface Mount Bead
Material Comparison w/ DC Bias

27–009112
IMPEDEANCE vs. FREQUENCY WITH DC BIAS

Z(Ω)
Frequency (Hz)

73-0A
43-0A
61-0A
61-2A
43-2A
73-2A

Fair-Rite Products Corp.
"Your Signal Solution"
Impedance vs. Temperature
Percent of Original 25°C
73 Material

%

0 20 40 60 80 100 120
-40 -20 0 20 40 60 80 100 120 140
Temperature (°C)

10MHz
25MHz
Amplitude Permeability vs. Flux Density

43 Material

$\mu_a$ vs. $B$ (gauss)

$25^\circ\text{C}$

Measured on a .690"/.390"/.230" toroid at 10kHz.
The Effect of Turns on Impedance
2643540002 Cable Bead

Z(I)

N=3

N=2

N=1

-frequency (Hz)

0

400

800

1200

1600

2000

1E+6

1E+7

1E+8

1E+9

.562in./.250in./1.125in.
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)

• Resistance to thermal shock
Effect of Test Method on Impedance

Competitive suppliers cores, same dimensions, similar materials

O.D. = 12.7mm [.50"], I.D. = 7.9mm [.312"], Ht = 6.35mm [.25"]

<table>
<thead>
<tr>
<th></th>
<th>Z @ 25MHz</th>
<th>Z @ 100MHz</th>
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</thead>
<tbody>
<tr>
<td>W 74270116</td>
<td>45</td>
<td>154</td>
</tr>
<tr>
<td>26438011102</td>
<td>26</td>
<td>41</td>
</tr>
</tbody>
</table>

Catalog Published Data, Typical Values of Impedance
Effect of Test Method on Impedance

Competitive suppliers cores, same dimensions, similar materials

2643801102(Blk) 1" test lead vs W 74270116(Red) 6.5" test lead
O.D= 12.7mm [.50"], I.D.=7.9mm [.312"], Ht=6.35mm [.25"]

Frequency(Hz)

Z(Ω)

10^6 10^7 10^8 10^9

0 100 200 300 400 500
Effect of Test Method on Impedance

Competitive suppliers cores, same dimensions, similar materials

2643801102(Blk) vs W 74270116(Red)
N=1 #26AWG WL=6.5" - Test as Performed by vendor W

Effect of Test Method on Impedance

Z(Ω)

Frequency(Hz)

0 100 200 300 400 500

10^6 10^7 10^8 10^9
Effect of Test Method on Impedance

Competitive suppliers cores, same dimensions, similar materials

2643801102(Blk) vs W 74270116(Red)
N=1 #22AWG WL=1" - Test as Performed by F/R - Shortest conductor
Possible

Frequency(Hz)

Z(Ω)

10^6 10^7 10^8 10^9

0 10 20 30 40 50 60
Why So Many Different Shapes?
Answer: Each shape has unique feature(s) which are required in each specific application.

- Low cost
- Easy to wind the coil
- Simple to assemble
- Good magnetic shielding
- Availability of standard sizes

Why So Many Different Materials?
Answer: Each material has unique properties which are required for a specific application

- High permeability
- High saturation
- Low losses (except in EMI)
- Low variability (temp & time)
- High Curie temperature
How Is Soft Ferrite Made?

Iron Oxide + Zinc Oxide + Manganese Oxide or Nickel Oxide

Powder Department

Pressing

Firing

Finishing

Ferrite Core
Injection Molded Ferrite Cores
51 and 78 material
Engineering Evaluation - Bookshelf Kits
Bookshelf Kits for EMI Suppression

**Expanded Cable and Connector EMI Suppressor Kit** Part Number 0199000005
This kit provides a broad sampling of suppression cores, specifically designed to attenuate EMI between all types of cable connected systems.

**Snap-It Cable Suppressor Kit** Part Number 0199000017
This kit contains six sets of round cable snap-its in two of our materials; the high resistivity NiZn 44 material and the MnZn 31 material. Either material in these round cable snap-its can be used to suppress frequencies up to 500 MHz. The snap-its can accommodate round cables with dia.s from .160 to .750 inches.

**Chip Bead Kit** Part Number 0199000018
This kit contains 20 different chip bead parts in four different EIA standard package sizes. This kit contains low current, medium and high current beads. Also included in this kit are standard and high signal speed parts.

**EMI Suppression Bead Kit** Part Number 0199000019
This kit contains 20 different EMI suppression beads in two different materials; 73 and 43 material. The beads range from a hole dia of 0.85mm up to 5.0 mm.

**Connector Plate Kit** Part Number 0199000020
This kit contains 20 different suppression plates in high resistivity NiZn 44 material.

**RFID Kit** Part Number 0199000024
This Kit contains 10 different sizes in materials 78 (for 125 kHz) & 61 (for 13.56 MHz) and is specifically designed for use in transponders in RFID devices.

**Surface Mount Kit** Part Number 0199000025
This kit contains 20 differential and common-mode surface mount beads. Supplied in several sizes and four Fair-Rite material (73, 43, 44, 61), these beads attenuate conducted EMI from 1 MHz into the GHz frequencies. these SM beads have lower dcr and higher current carrying capacities than plated beads.

**Wound Bead Kit** Part Number 0199000027
Contains an assortment of 6 and 11 hole beads, wound in several configurations. These beads in Fair-Rite's 44 and 61 materials, provide an impedance of hundreds of ohm over a 5 to 800 MHz frequency range, with or without a dc bias current of up to 5 ampere.

**Bead-On-Lead EMI Suppressor Kit** Part Number 0199000028
Three popular core sizes in materials 43, 61& 73 are included in this evaluation kit. These nine Fair-Rite engineering evaluation kits are available from Fair-Rite in Wallkill, NY. They can also be purchased from our distributors. Please refer to our web site at www.fair-rite.com for a complete list of our distributors.

**Expanded Snap-It Kit** Part Number 0199000034
This kit contains an assortment of snap on cores fitting cables ranging from 5mm (.196”) to 19mm (.750”) dia. In 31,43,44 & 61 mat'l's

**Chip Inductor Kit** Part Number 0199000035
This kit contains multi-layer SM chip inductors. Full monolithic structure on either ferrite or ceramic body. All offer excellent Q