What Does the Future Hold for Transformers and Inductors in Medium and High Power Applications

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President and CEO
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EDN INNOVATION
Honoring Excellence in Electronics
FINALIST 2009

ISO9001:2015
ISO13485 2016

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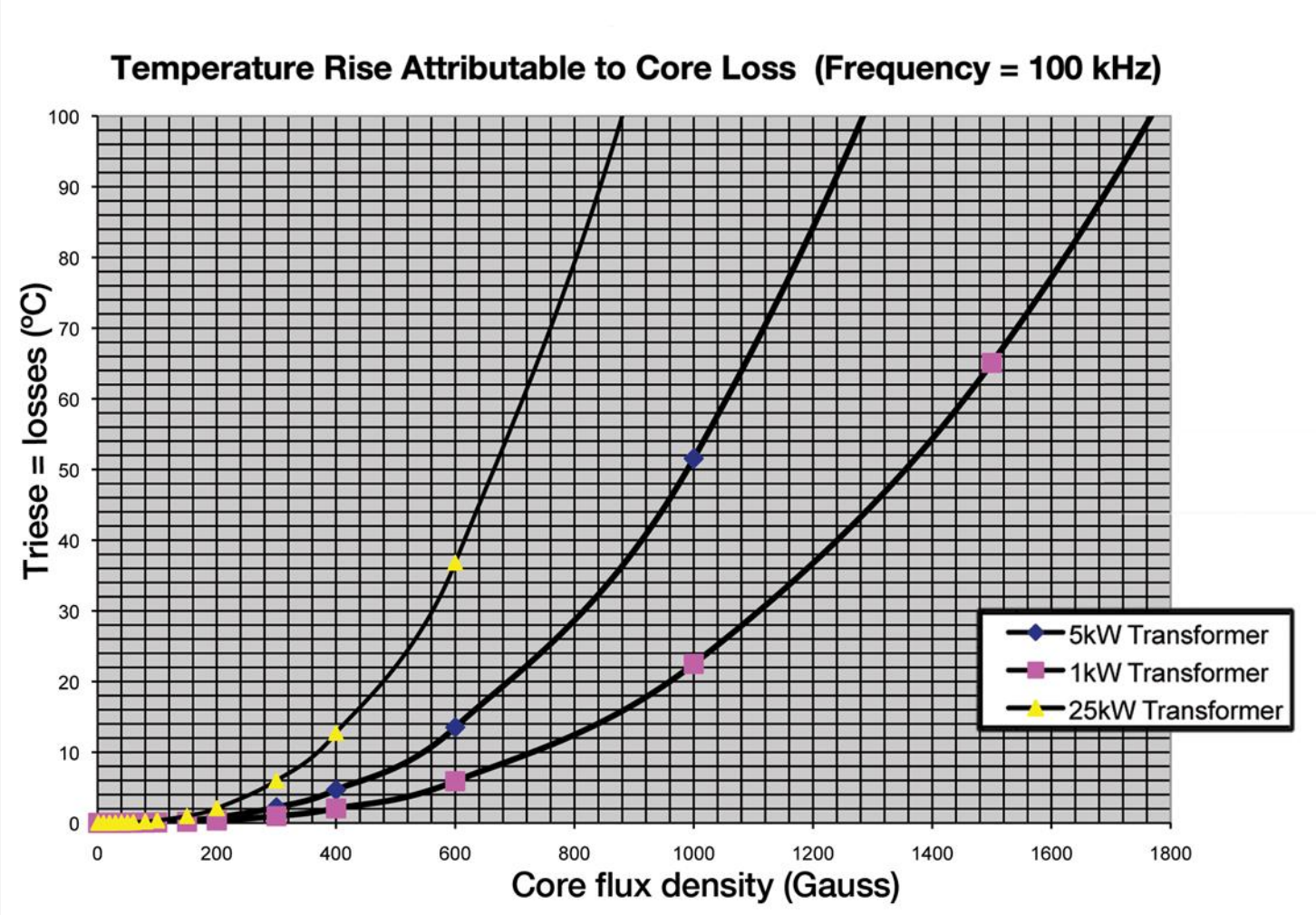
Medium to High Power Magnetics

Power levels increasing to 10 kW and higher.
Frequencies increasing beyond 100 kHz to 500 kHz
LLC resonant circuits becoming common

OUTLINE

- Highlight challenges
- 7 kW transformer design example
- Ferrites for higher frequencies
- Inductors for medium, high power

Larger Geometries Inherently Have Tendency to Higher Temperature Rise



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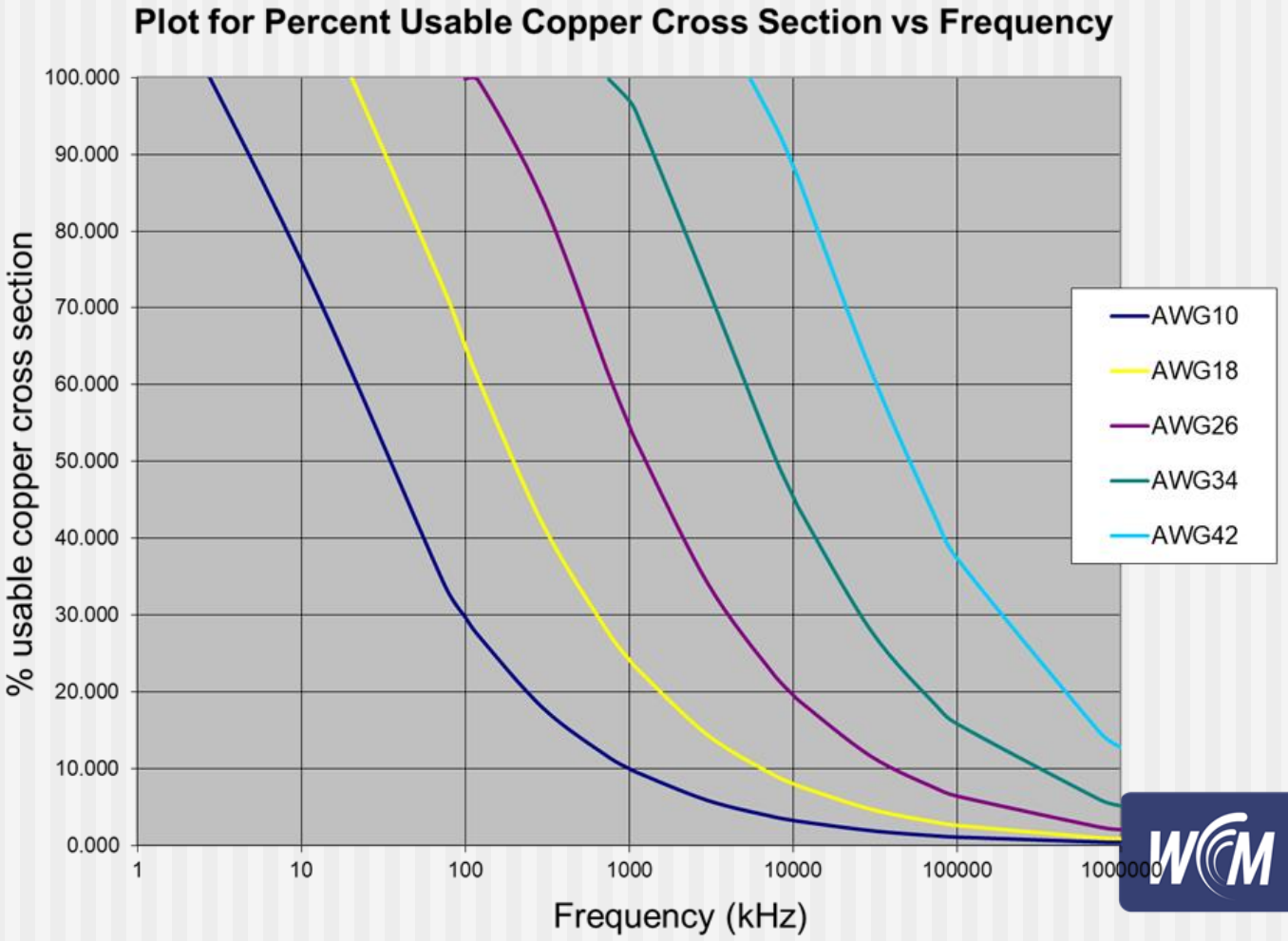
Higher Currents Require Design for AC Resistance Minimization



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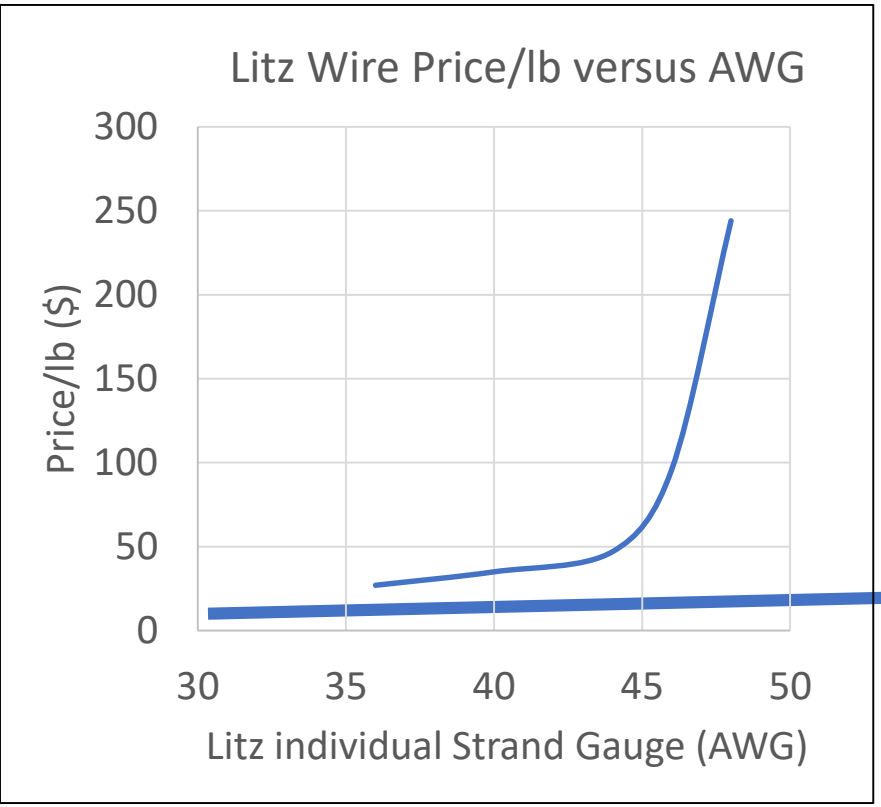
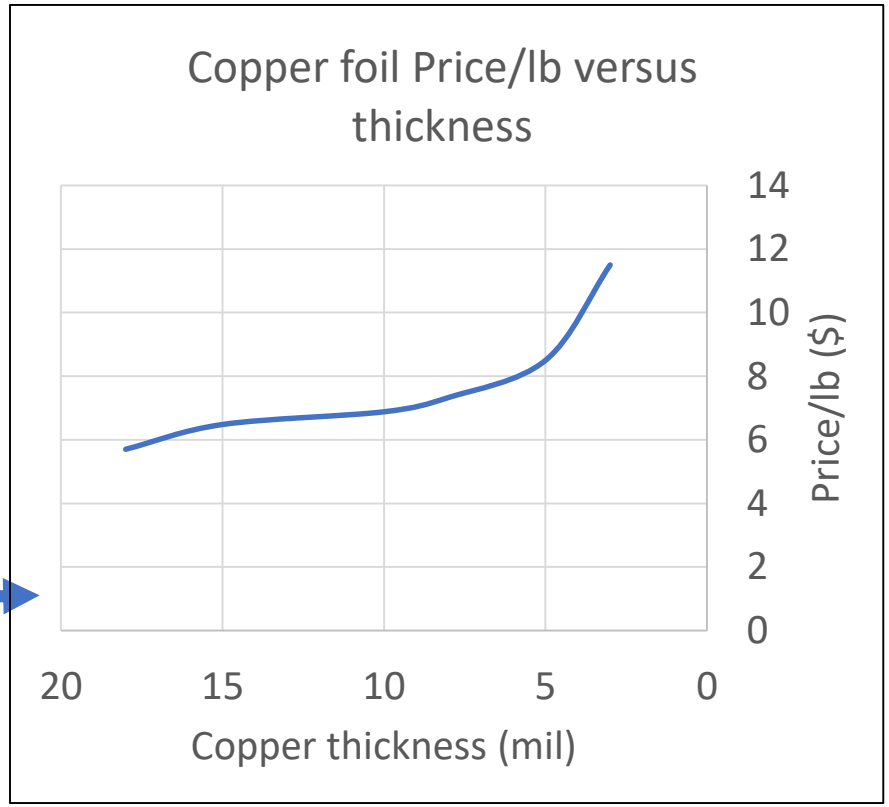
Cost of Litz Wire and Copper Foil





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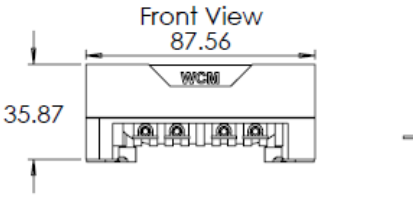
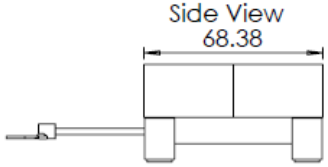
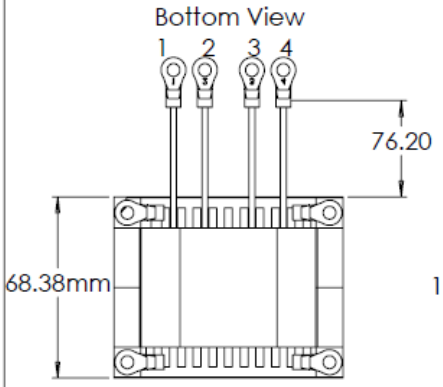
TRANSFORMER DESIGN EXAMPLE

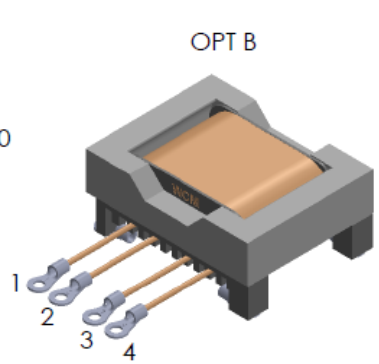




ELECTRICAL SPECIFICATIONS

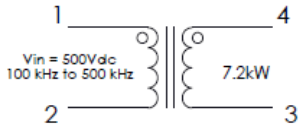
Vin = 100 to 500 Vdc
Power rating: 8 kW at 100 kHz
Efficiency ≥99.4%
Turns ratio: Pri:Sec 1.00:1.00
Frequency range: 100 kHz to 500 kHz
L primary = 450 uH nominal at 100 kHz.
Hypot: 3000 Vdc primary to secondary.
1000 Vdc both windings to core.
DCR primary = 9 milliohms nom. at 25°C
DCR secondary = 9 millliohms nom. at 25°C.
Leakage inductance: 5uH ± 10%





MATERIAL SPECIFICATIONS

All materials min. 155°C rated.
ROHS compliant.



Dimensions: mm

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MM TOLERANCES
DECIMALS
X. ± 0.50 mm
X.X ± 0.20 mm
X.XX ± 0.05 mm
DRAWING NOT TO SCALE UNLESS NOTED

WEST COAST MAGNETICS
4848 FRONTIER WAY, STE. 100
STOCKTON, CA 95215
800-628-1123

CUSTOMER	DESCRIPTION
West Coast Magnetics	Transformer
PART NUMBER	REV
RELEASED BY: DH	DATE: 01/25/2017
SHEET 1 OF 1	

5 4 3 2 1

Design Elements – 7 kW SMPS Transformer

- New WCM410-88 core
- Potting to thermally couple bobbin and core
- 155 C materials
- Use of ferrite tape for leakage layer
- Shape opt optimization
- Investigation of foil
- Foil leakage layer

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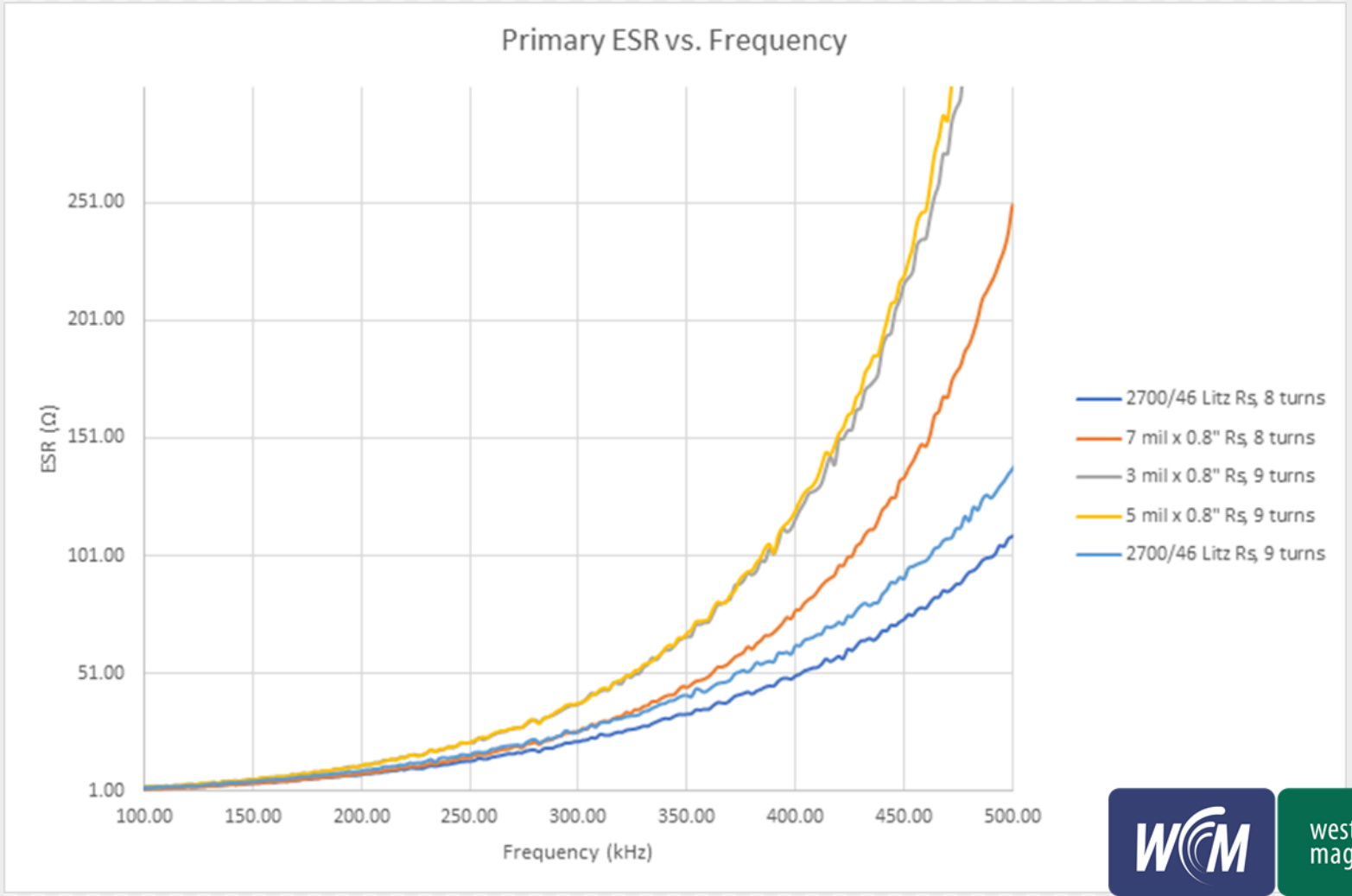
Loss Measurement for Different Windings



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Performance Factor - Core

$$AN = \frac{E_{rms}(10^8)}{4.44Bf}$$

Where:

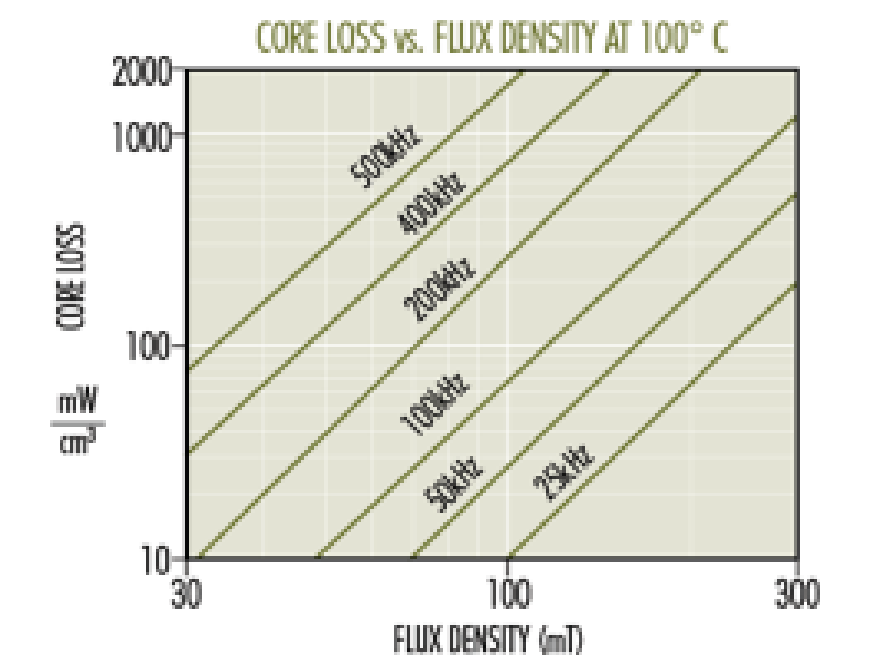
$B =$ peak AC flux density (gauss)

$E_{rms} =$ rms primary voltage

$A =$ core area, (cm^2)

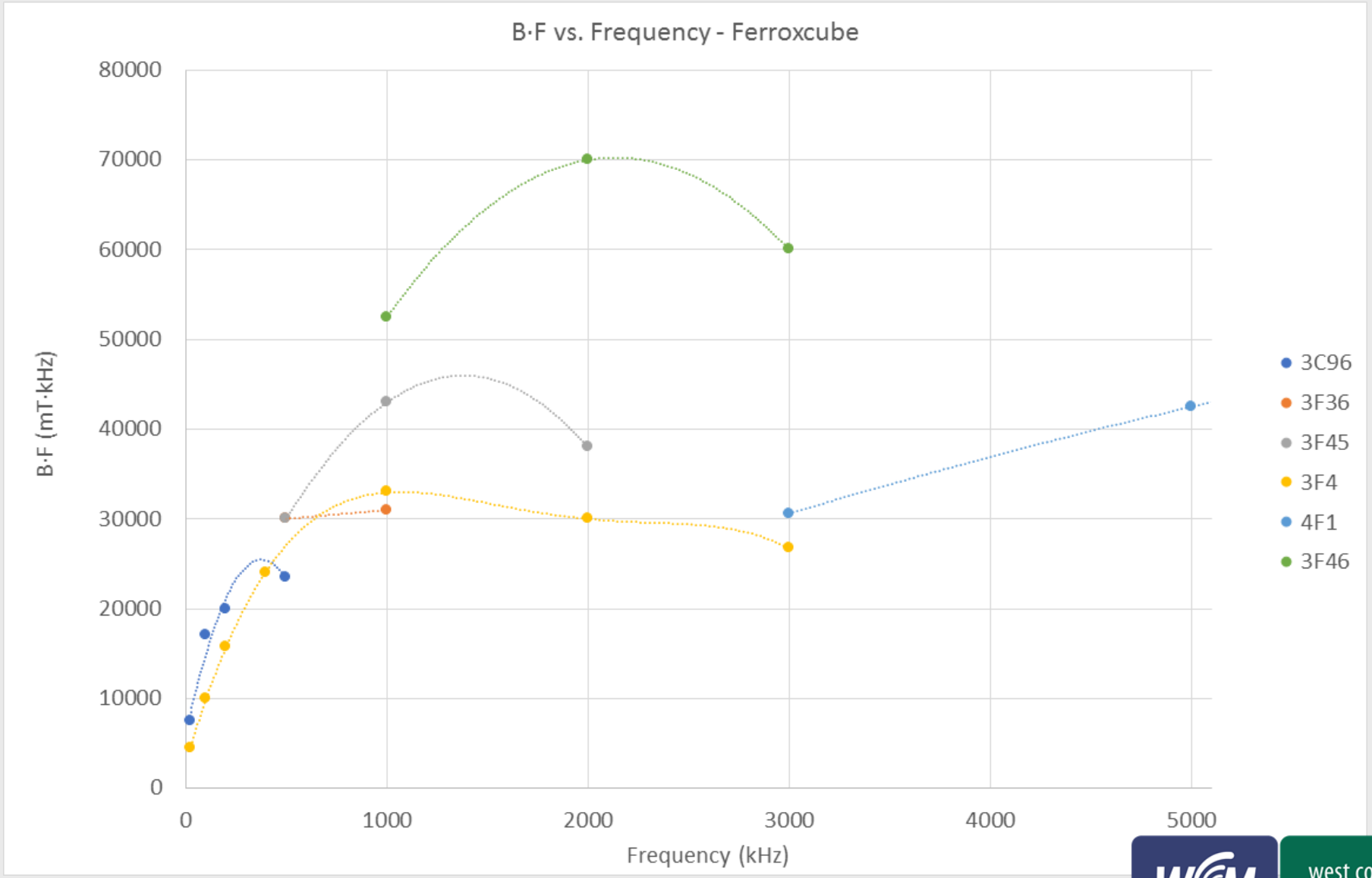
N = number of primary turns

f = operating frequency



To reduce the size of our transformer we want to find a better material that will allow us to increase the value of B while holding the frequency and core loss density constant. This enables the use of less turns (lower winding resistance) and a smaller core.

BF Product for MnZn Ferrites



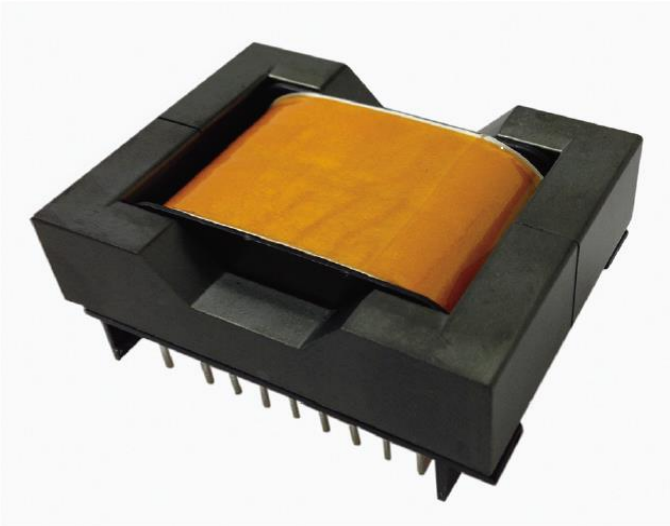
Inductors

- Must consider saturation in addition to core loss
- Inductor size, cost, loss dependent on L value and associated ripple
- Most designs are still powdered toroids until power levels are very high.
- At high power levels we are seeing more topologies using transformer leakage L for the inductor.
- More designs are requiring ferrite cores due to higher frequency and ripple requirements
- Gap effects create loss in ferrite based designs

WCM Shaped Foil Inductors

Low loss gapped ferrite core, shaped foil winding.

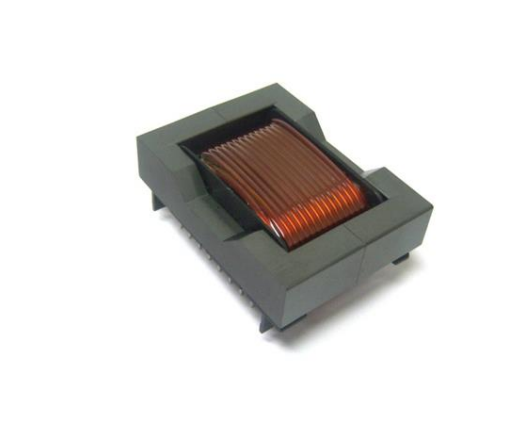
Product Code	Inductance (µH) ± 10%	DCR (mΩ)	idc amps INPUT	Schematic
WCM319-01	380.8	44.90	7.00	A
WCM319-02	169.0	16.95	12.00	A
WCM319-03	141.6	13.70	13.00	A
WCM319-04	116.4	10.58	15.00	A
WCM319-05	83.5	7.20	18.00	A
WCM319-06	49.7	4.40	22.00	A
WCM319-07	41.5	3.83	24.00	A
WCM319-08	36.1	3.25	26.00	A
WCM319-09	29.3	2.83	28.00	A
WCM319-10	23.6	2.30	32.00	B
WCM319-11	18.6	1.90	37.00	B
WCM319-12	14.4	1.53	41.00	B
WCM319-13	10.4	1.28	45.00	B



Patent pending: Dartmouth and WCM

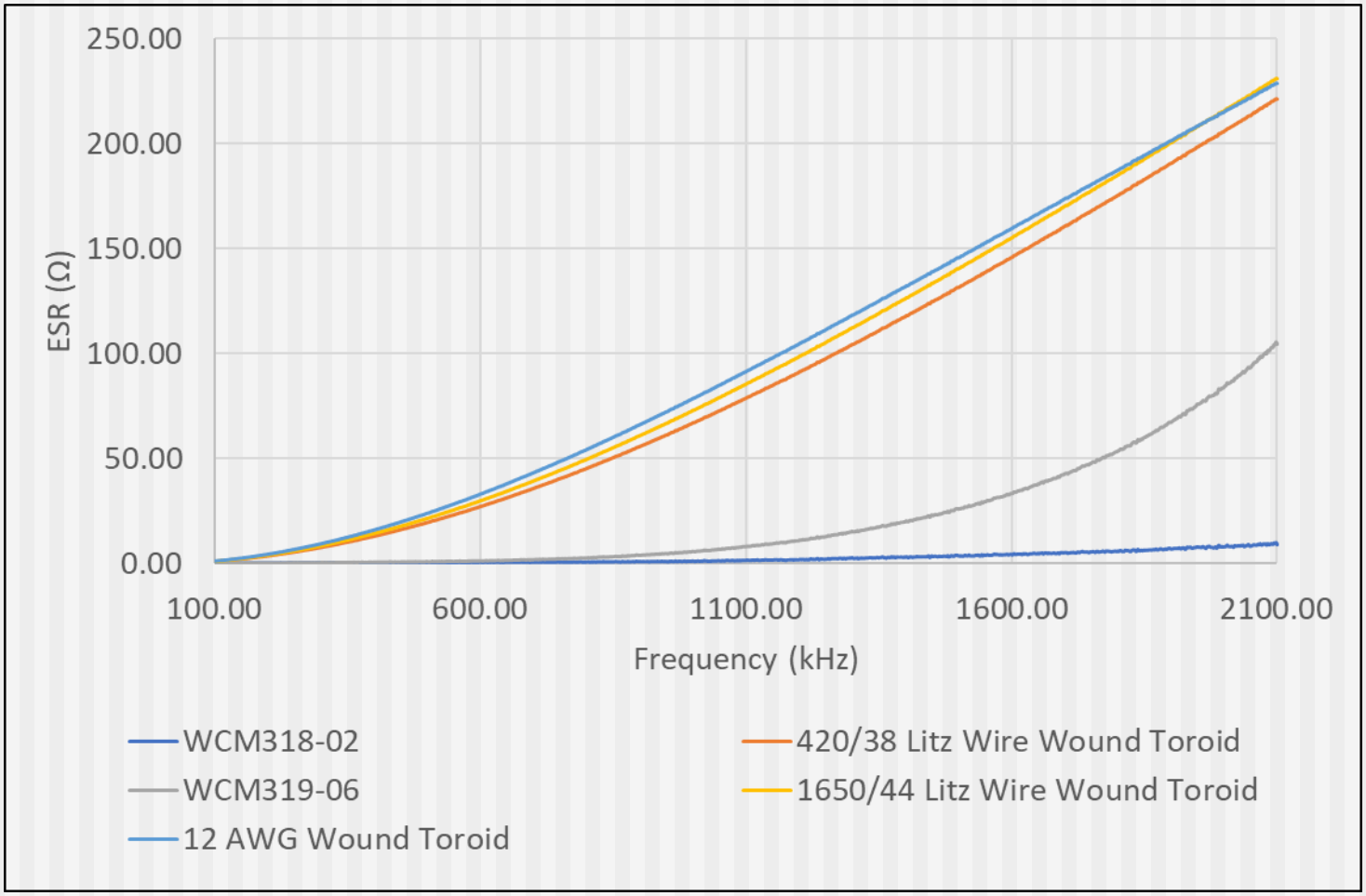
WCM Shaped Foil vs. Powdered Toroid

- Specs: 50 uH, Max 10 amps RMS
- Toroid: Fe Al Si core
- WCM319 and WCM318 gapped ferrite

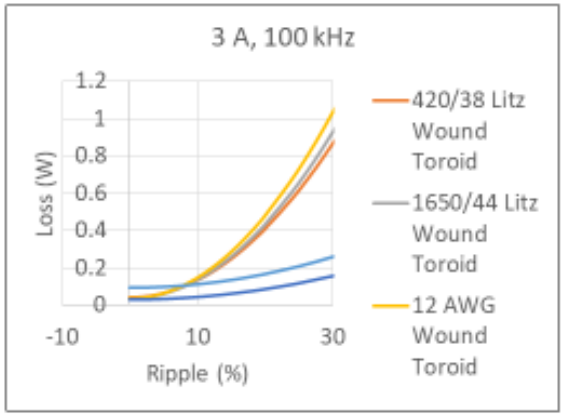


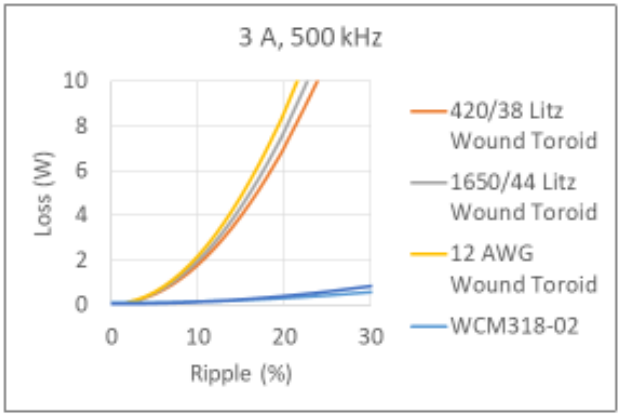
Design toroidal inductor to match inductance of WCM318, 319 and have the same DCR

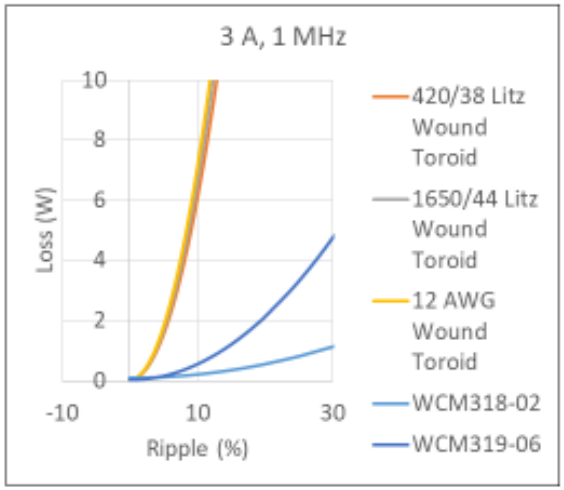
ESR vs. Frequency

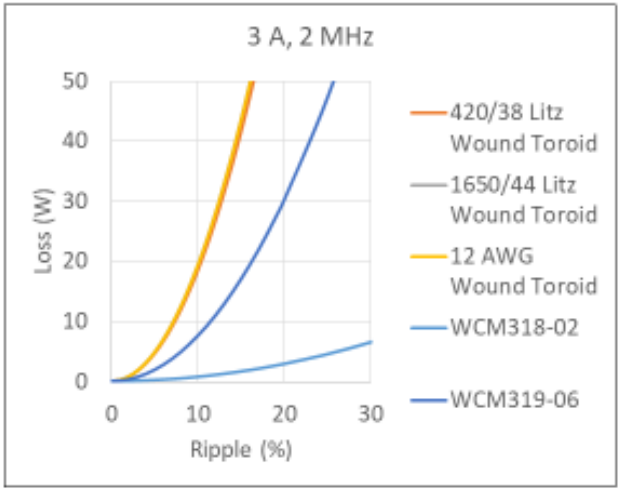


Loss vs. Ripple, no DC



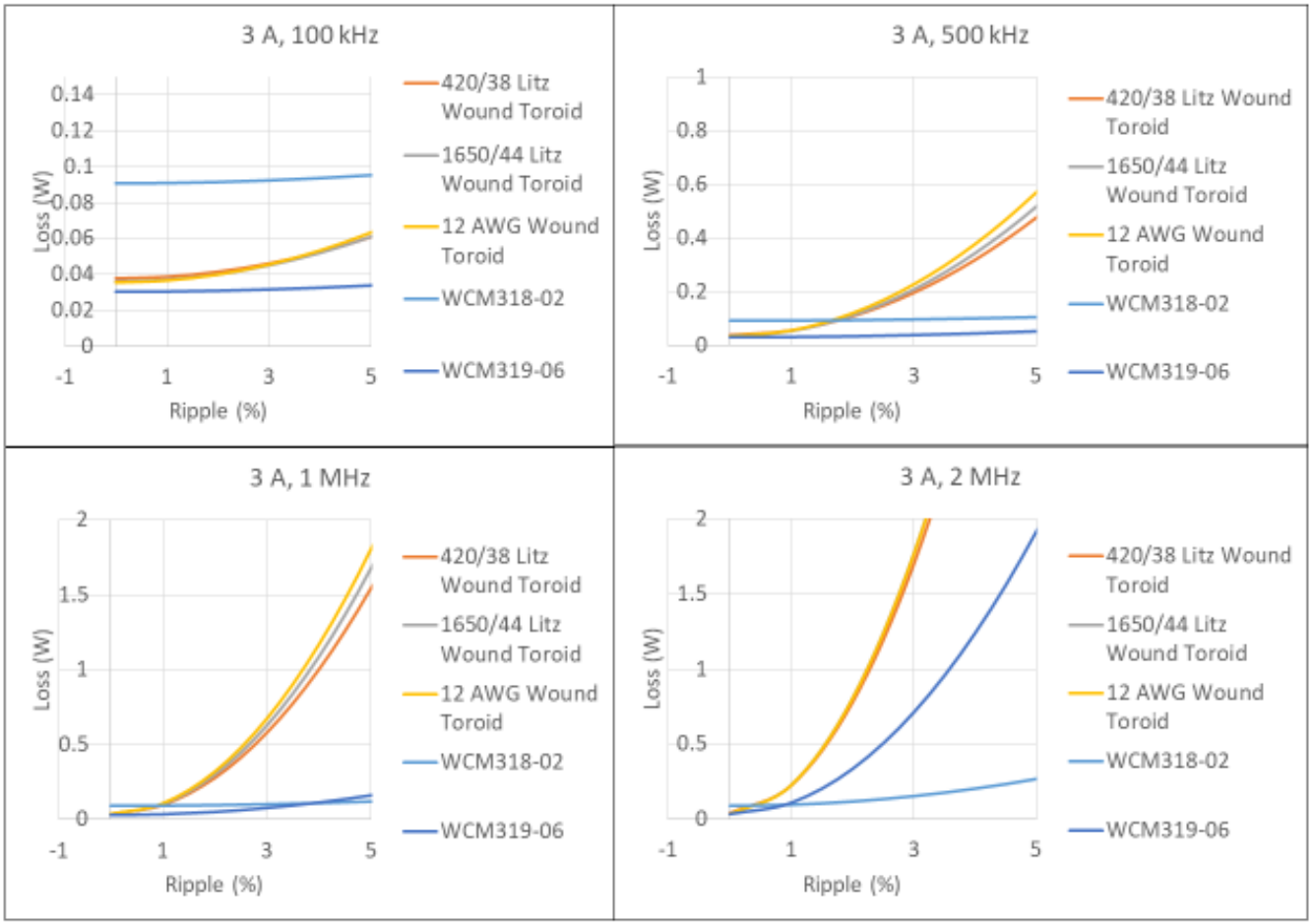






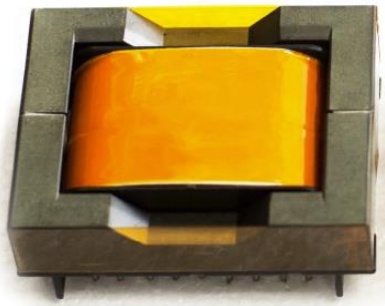
As frequency increases, 318-02 becomes least lossy option despite higher DCR than other options.

Loss vs. Ripple, Zoom to 5%



Comparison of 10 uH, 55 amp inductors

Shaped Foil



Iron Nickel Toroid

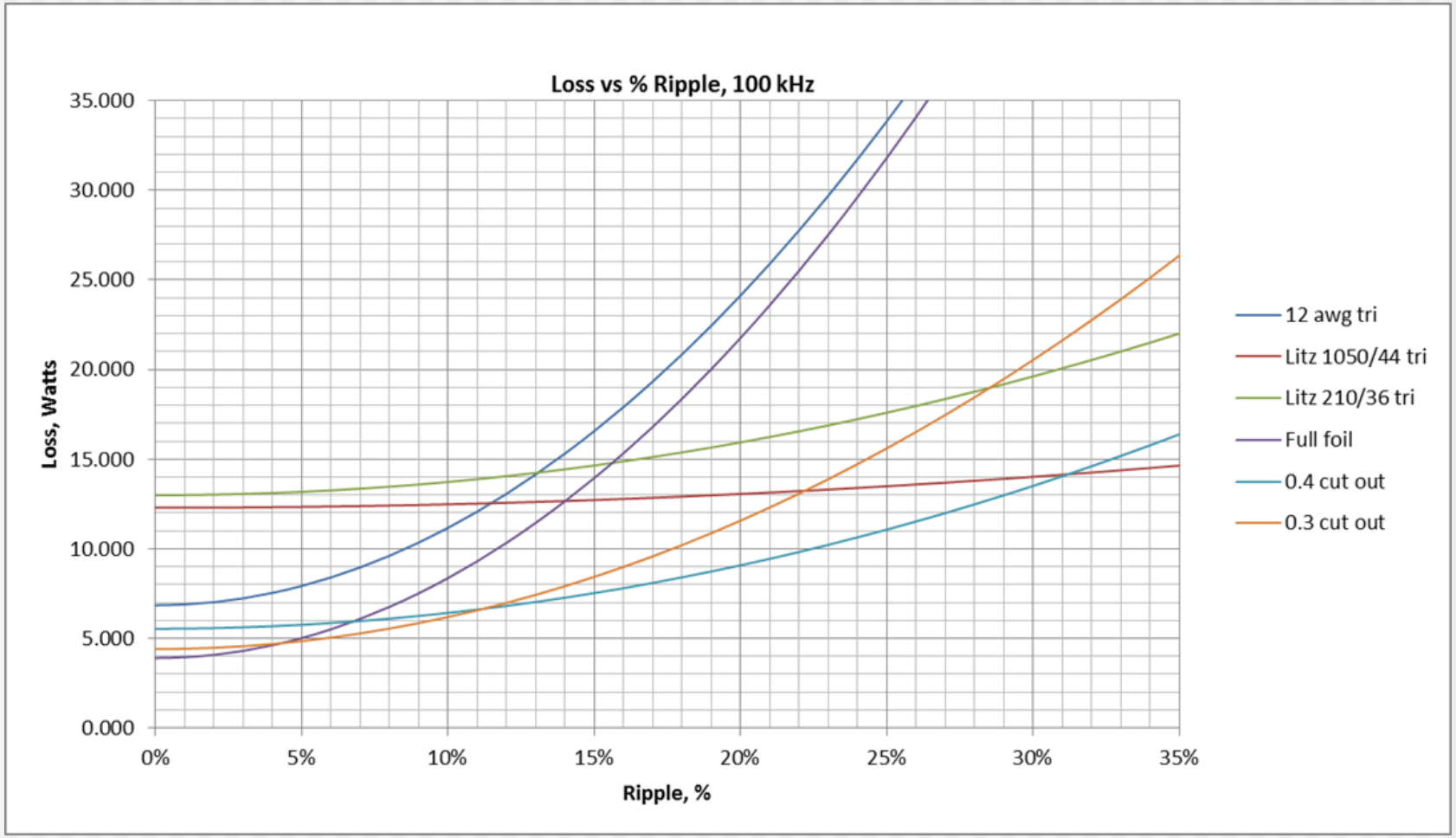
High Iron Toroid

Helical Coil

Inductor Design	100 kHz losses (W)	250 kHz losses (W)	Total Volume (cm^3)	Weight (g)	Cost per Part ($)
Shaped Foil	5.45	7.65	93.72	303.45	$4.69
Iron Nickel Toroid	10.35	13.89	99.87	295.29	$16.18
High Iron Toroid	14.19	16.40	130.65	475.59	$9.48
22 Turn Helical	50.74	61.73	109.55	449.06	$6.69
12 Turn Helical	15.67	27.28	109.55	447.92	$6.66

Based on 2015 WCM study, copies available

Winding Loss: Gapped Ferrite



Cutout Patent issued: Dartmouth and WCM

Thank you for your time

Weyman Lundquist, President

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