Breakout Magnetics: How Far Can We Take the Next Generation of Components

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Outline

Where do device losses come from?

How much improvement is available from packaging?

Core material improvements, and future forecast.

How much power density improvement is available today?

What is the forecast for winding losses?

What can we expect from increasing the operating frequency?

Where will we be in 10 years?

Where are we headed in 20 years+?

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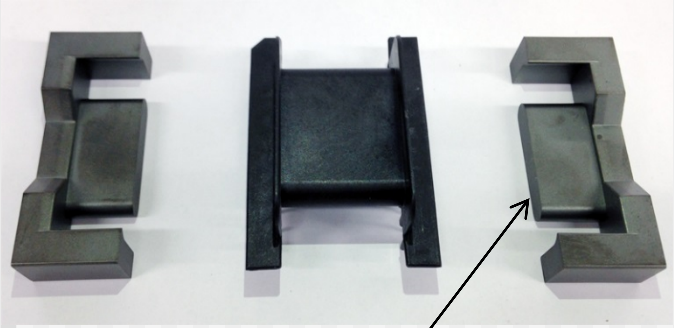
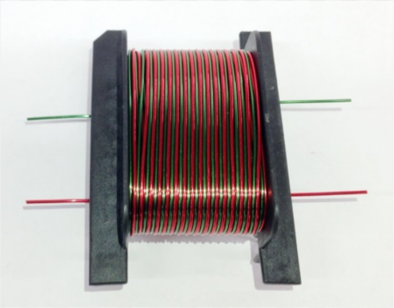
How Much Better Can we Get? How Quickly? Assumptions to Work From

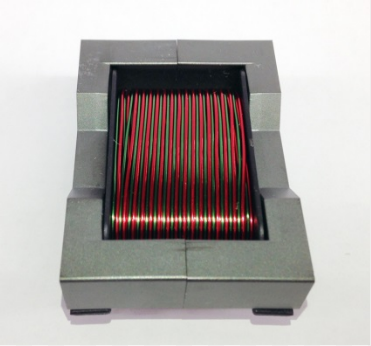
- This presentation considers transformers operating at SMPS frequencies although many of the same conclusions will apply to inductors.
- This trend analysis assumes that designs will be optimal, I am not considering the effect of non-optimal designs, which is considerable.
- Let's assume we are going to design to a given temperature rise and see how far we can reduce the device size.
- I will define a device by its power handling capability divided by total volume of the device (holding temperate rise constant).
- Transformer sizes for purposes of this presentation are based on 100 - 250 kHz 1-5 kW designs.

Where do Losses Come From? Typical 1500 W Transformer, 250 kHz



Core cross sectional area (Ae)





Core Loss: 4 Watts

Winding Loss: 3 Watts

Total Loss: 7 Watts

Efficiency 99.5%!

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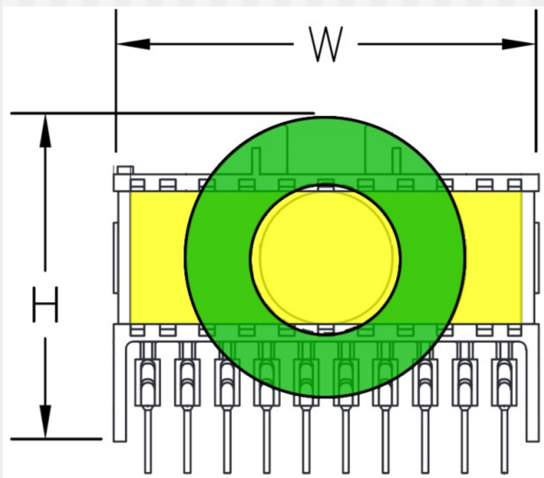
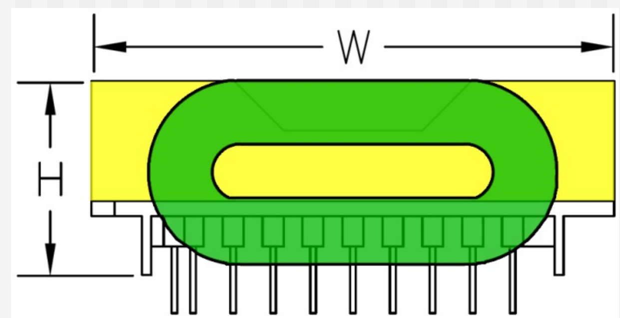
Effective Use of Available Volume

Current Typical ETD49



Full Cube = L x W x H = 101 cm3
Watts/cm3 = 11.2 *

New Design



Full Cube = L x W x H = 91 cm3
Watts/cm3 = 16.5 *

* Power rating based on constant temperature rise design same core and winding technology used for each device.

Improvement Available Today = 47%

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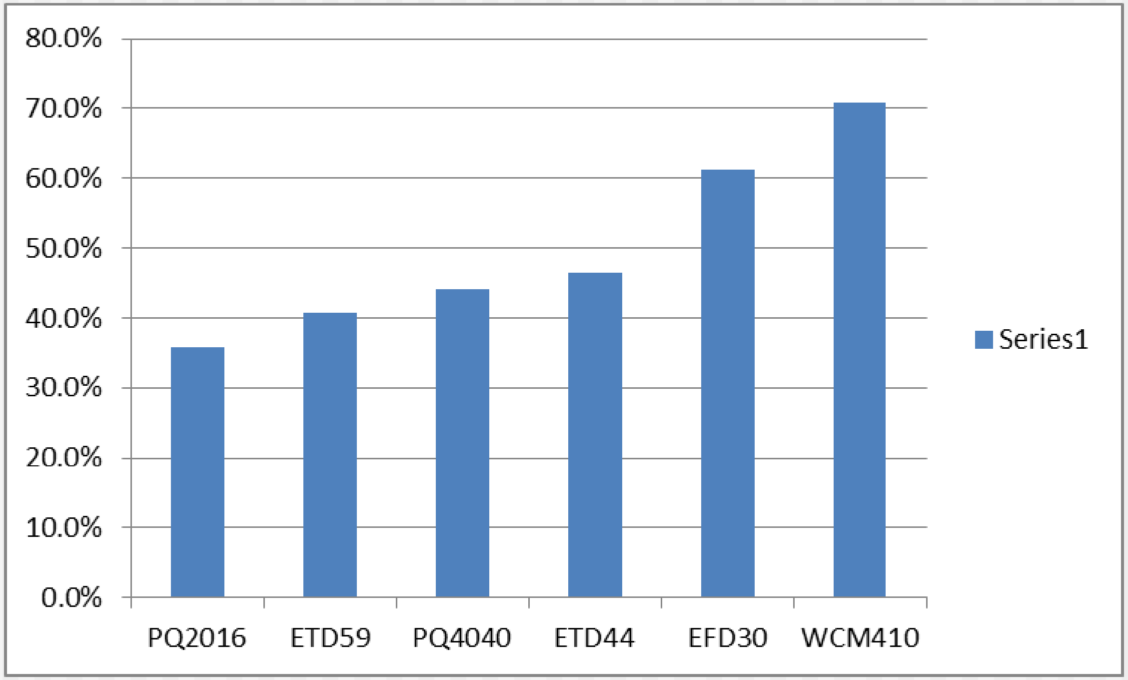
What is the Potential for Improved Packaging?

% of Total Device Cube That is Core Volume and Winding Volume Only



Improvements to 80% or higher will be possible with improved insulating materials and better use of existing materials.

Core Losses

$$B = \frac{E_{rms}(10^8)}{4.44 A_e N f}$$

Where:

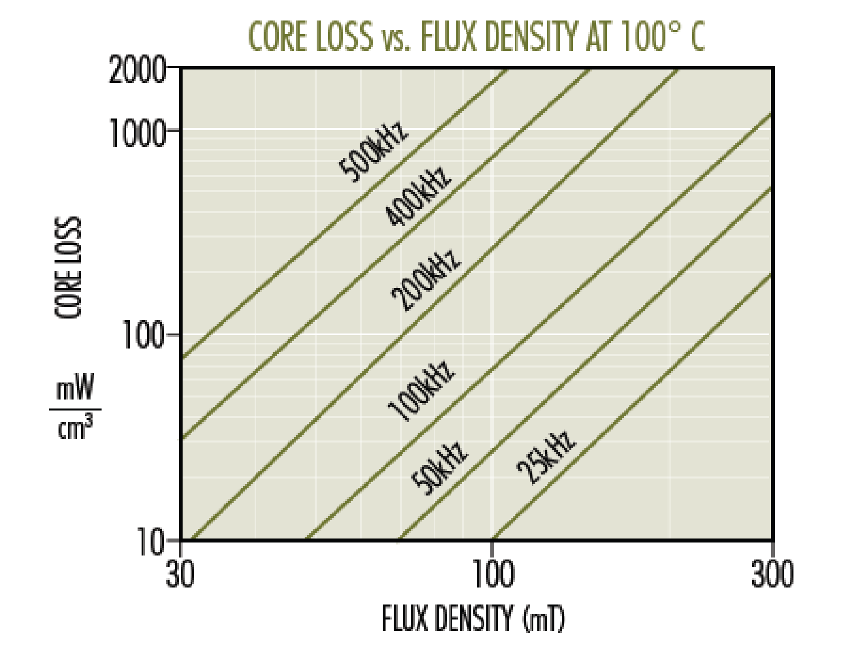
$B =$ peak AC flux density (gauss)

E_{rms} = rms primary voltage

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

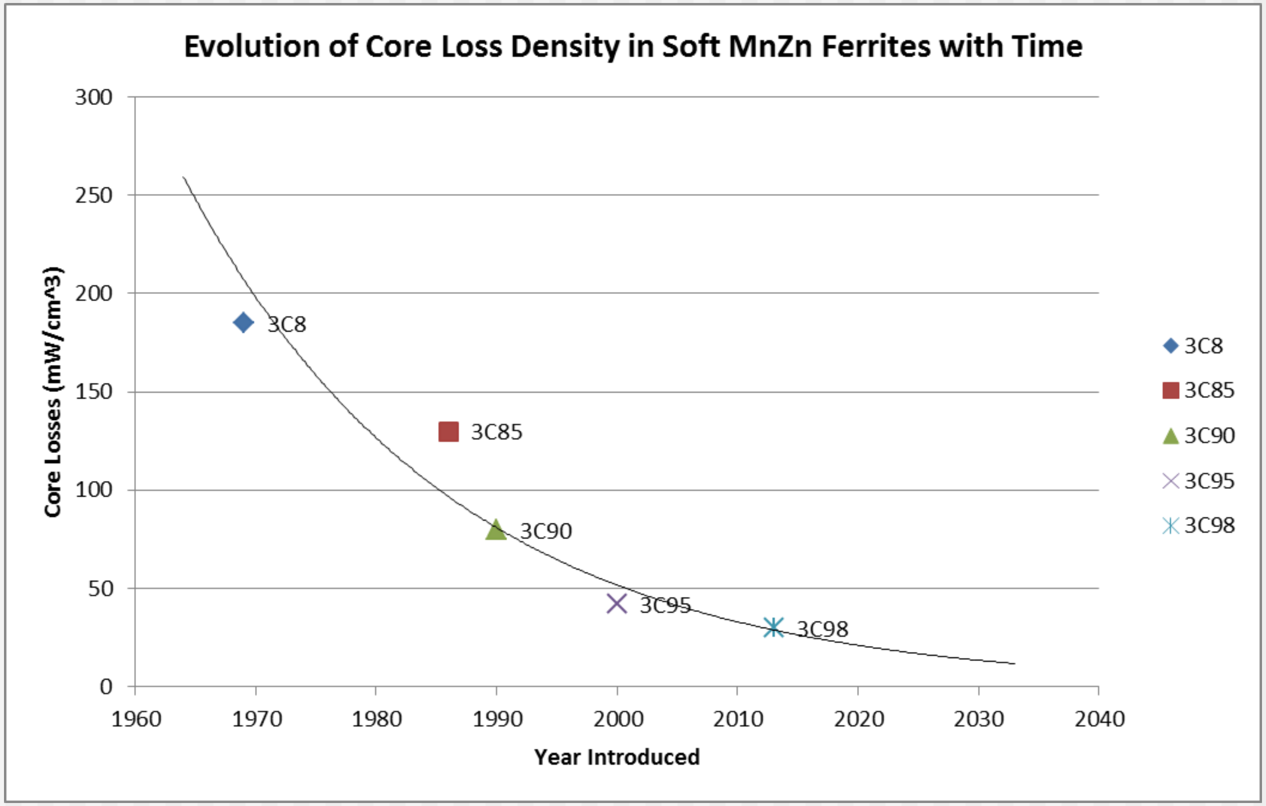
N = number of primary turns

f = operating frequency



Conclude: we want to decrease the product of Ae and N or increase the product of B and F without increasing core loss density.

What Does the Future Hold for Improved Core Materials?



4.7% avg. annual reduction in core loss from 1969 to 3C98 introduction in 2013.

Source: Ferroxcube, Core Loss at 1 kGauss, 100 kHz

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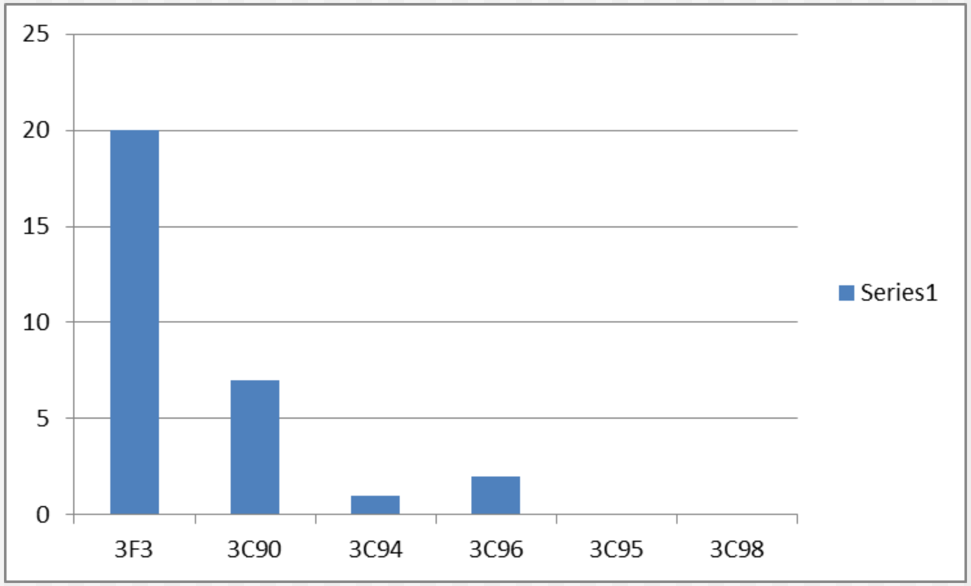
What Core Materials are Being Chosen for Today's Designs

Stocking Quantities through U.S. Distribution



1985 1996 1998 2000 2007 2013

Year of Introduction

The presenter is certain that many new designs use core materials from 10+ old releases

Improvement available today: 50%

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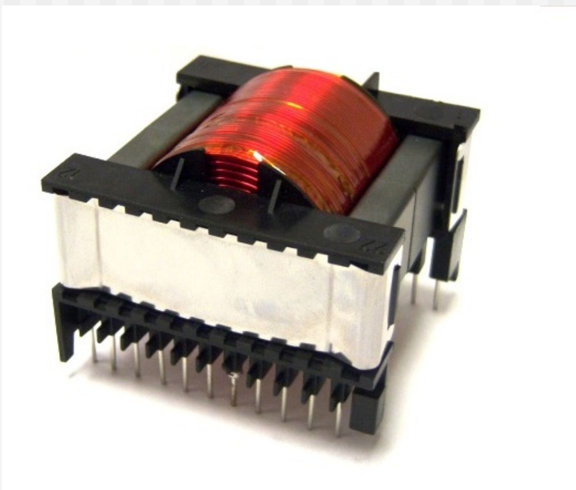
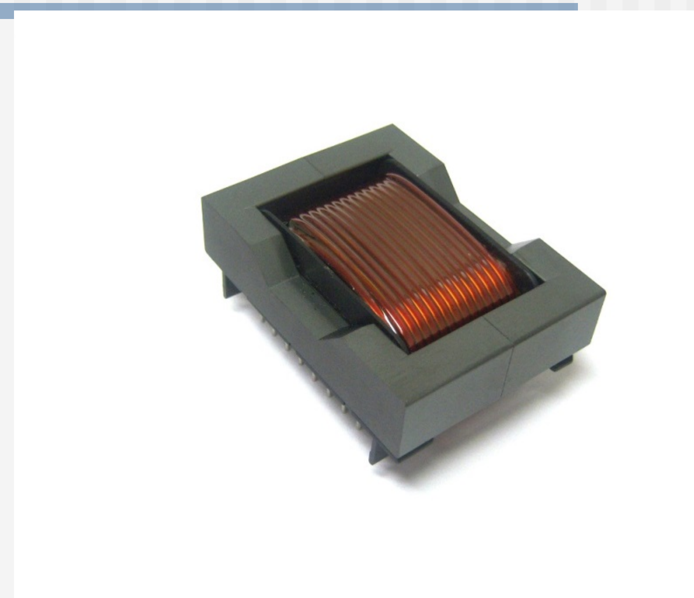
Improvement Available Today – More Efficient Packaging and Lower Loss Core





Full Cube = L x W x H = 101 cm3
Watts = 2400 at 100 kHz
Watts/cm3 = 23.7

Full Cube = L x W x H = 91 cm3
Watts = 4300 at 100 kHz
Watts/cm3 = 47.3

IMPROVEMENT 2.0 times power density

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How About Winding Losses, What Can We Expect in the Future?

- Copper and Aluminum are going to remain the materials of choice for at least 10 years.
- Good News: Cu and Al have relatively low resistivity and low cost.
- Good News: Litz wire can be used to manage high frequency winding losses up to about 1 MHz without an increasing penalty to DCR
- Bad News: Not much improvement forecast for winding loss, and the problem above 1 MHz requires new solutions (not litz)

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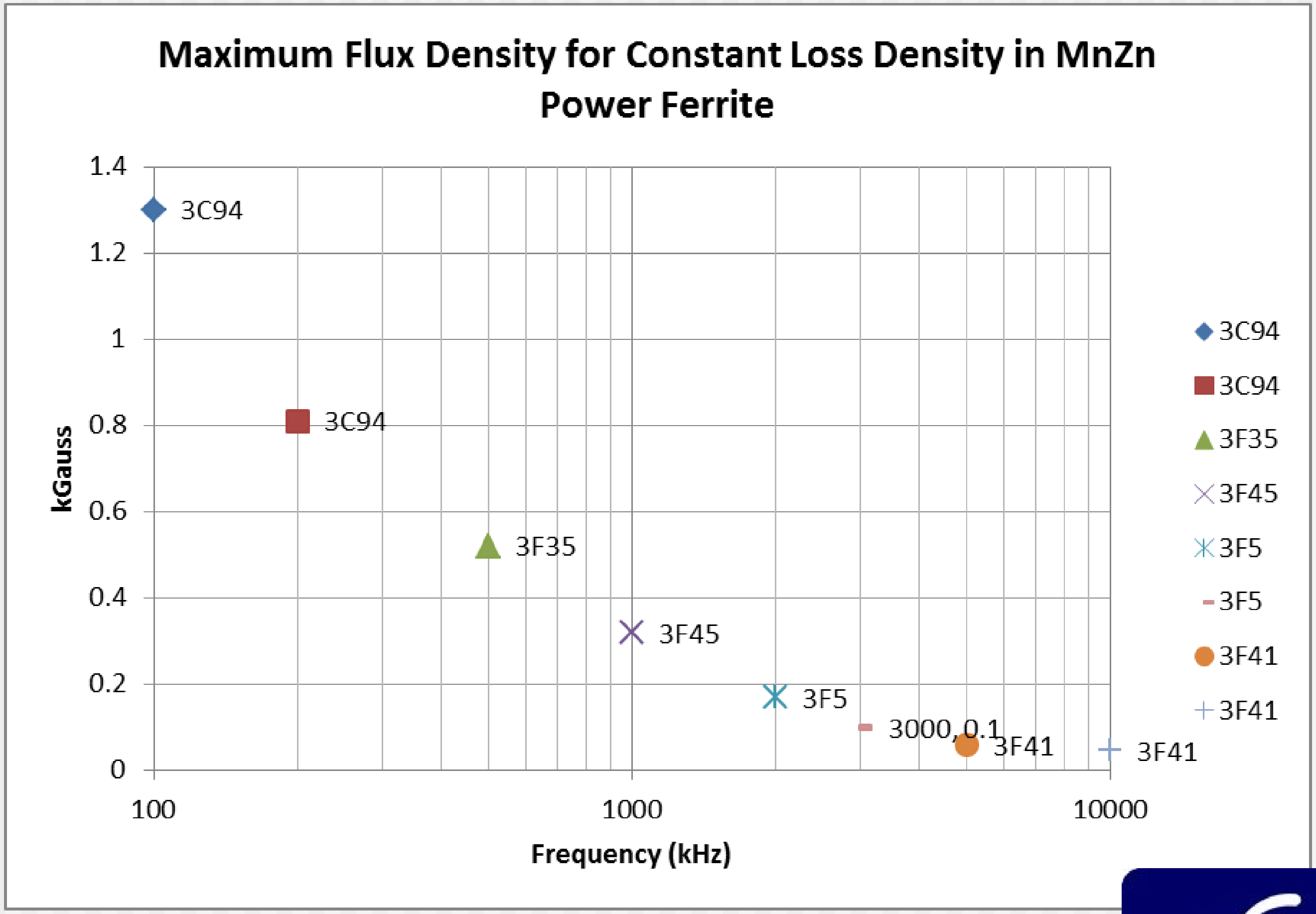
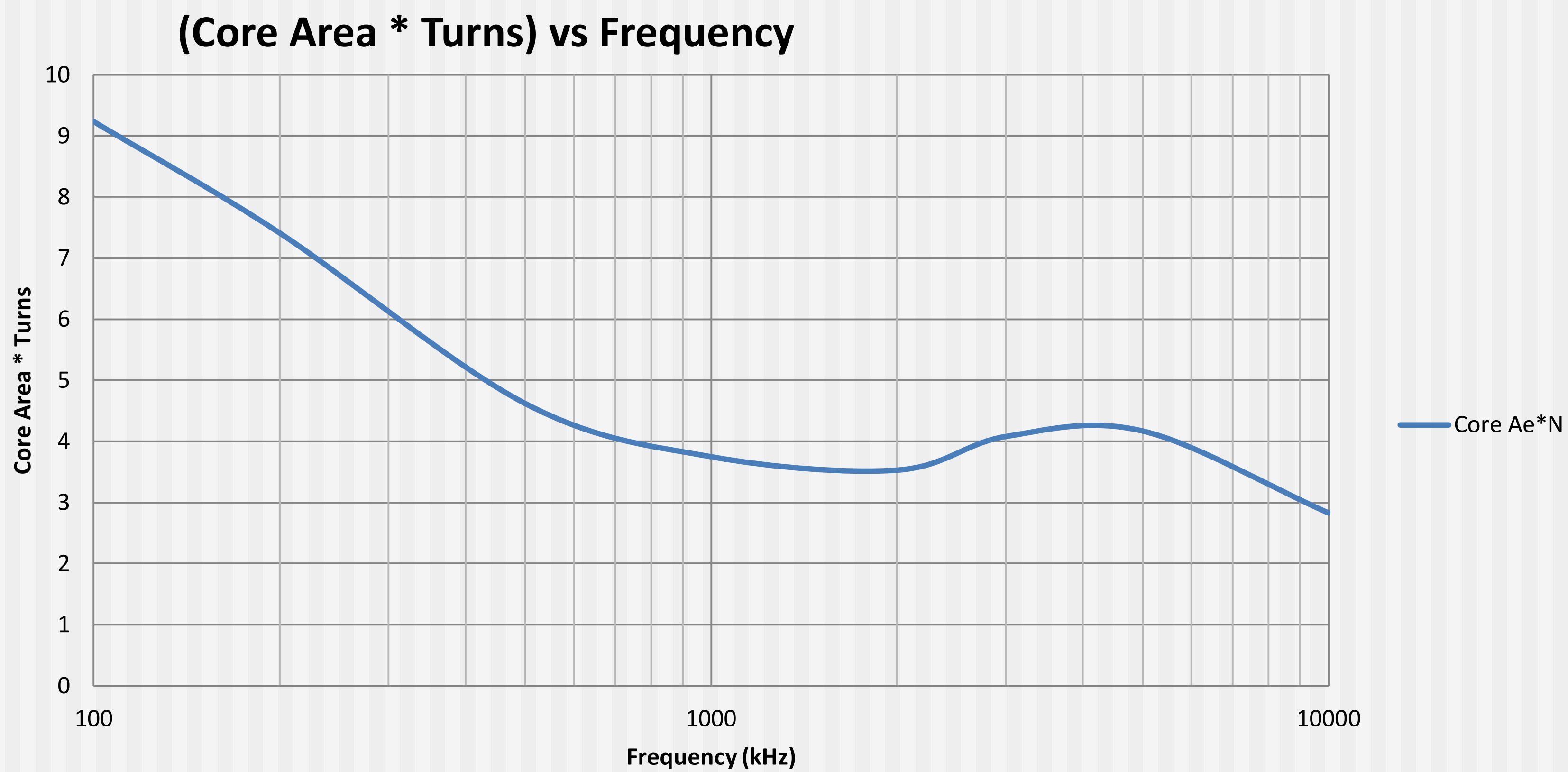
What About the Effect of Increasing the Operating Frequency?

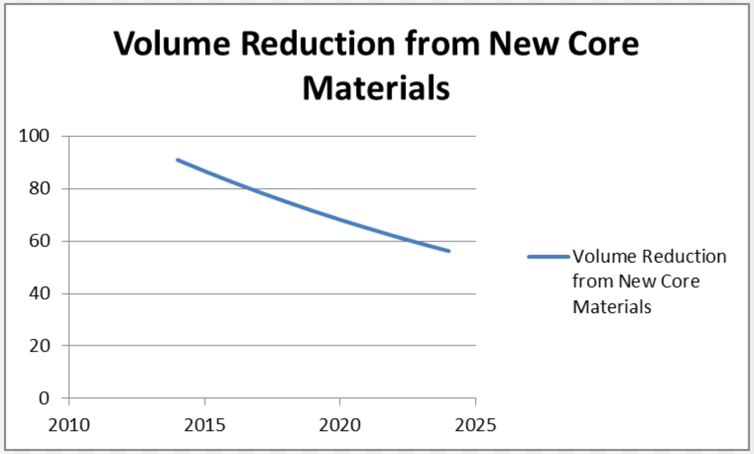


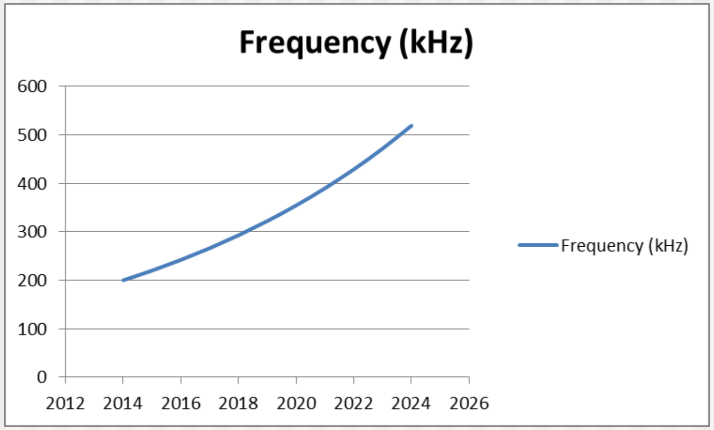
Source: Ferroxcube

Device Size vs. Frequency – State of the Art Today



10 Year Forecast





38% overall reduction in device volume

Operating frequency will increase more quickly at 10% per year. This will result in an additional 30% reduction in device volume.

Conclude: we can expect a decrease in device volume or increase in power density of at least 50% over the next 10 years as a result of better core materials and increased operating frequencies.

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Further Out Approaching 20 Years and Beyond

Approaching 20 years I expect to see device sizes in the range 20% to 30% of today's volumes from more efficient use of available volume, improved core technology, improved winding technology and increasing frequency of operation to the 1 MHz range.

Current ferrite core technology does not lead to reduced device size over 1.5 MHz.

Litz wire is too costly and makes poor use of winding area for gauges suitable for frequencies over 1.5 MHz.

Development of new core materials, and new winding technologies is needed or device size will plateau as we approach the 20 year mark. This development will happen.

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Conclusions

For many designs it is possible to double the power density with material options available today.

Over the next 10 years it is expected average device volume will be cut in half due to improvements in core materials and increases in switching frequencies.

This improvement is expected to extend out to 20 years with device sizes as small as 20% of todays typical devices.

From 1.5 MHz to 10 MHz more development work is needed for further size reduction on both the core material side and the winding side.   This is expected to occur.

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Thank you for your time

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