7. A Spice Model for Windings

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APEC Magnetics Industry Session
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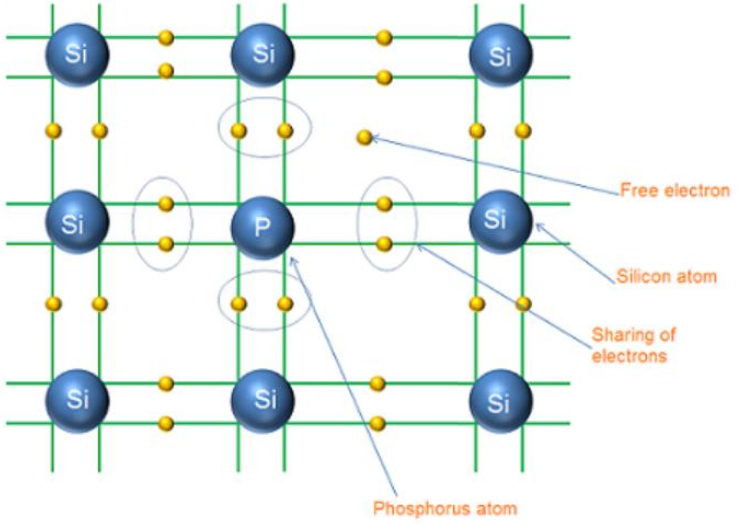
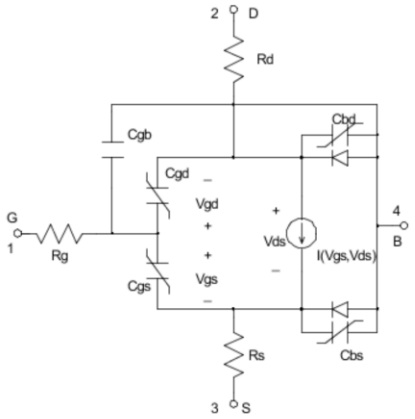
Semiconductor Devices and Models



$$\frac{\lambda^2(1-y^2)}{2}\left\{\left[n\left(y+\frac{\nu-\mu}{2n+\mu+\nu}\right)\left(\frac{\mu-2\beta}{1-y}-\frac{\nu-2\alpha}{1+y}\right)\right.\right.$$
$$+n(n+\mu+\nu+1)+(2\alpha\beta+\alpha+\beta)$$
$$-\alpha^2\frac{1-y}{1+y}-\beta^2\frac{1+y}{1-y}+\frac{2}{\lambda^2(1-y^2)}$$
$$\times\left[\frac{V_0}{q}(y+\gamma)(1-y^2)-E\right]\Big]\varphi_n$$
$$\left.-2\frac{(n+\mu)(n+\nu)}{2n+\mu+\nu}\left(\frac{\mu-2\beta}{1-x}-\frac{\nu-2\alpha}{1+x}\right)\frac{A_n}{A_{n-1}}\varphi_{n-1}\right\}=0,$$

These are impossibly complex structures to build and understand.

Yet they come with a spice model that's pretty useful and accurate



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Magnetics Devices and Models

Not so hard to build, although maybe hard to understand.

Doesn’t compare to Schroedinger’s equations…..

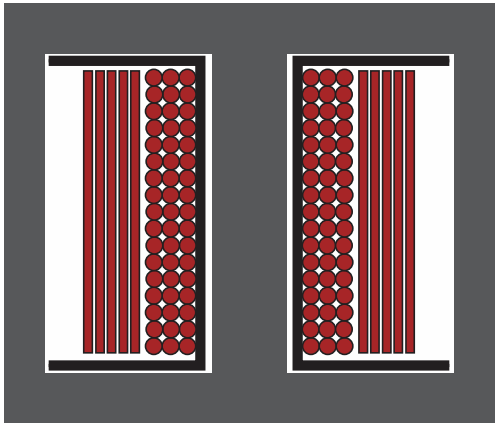
Where is the Spice model ?

The Biggest Problem with Magnetics Design

The magnetics get too **HOT!**

99.9% of designs don't apply proximity loss properly

Example: Forward converter transformer



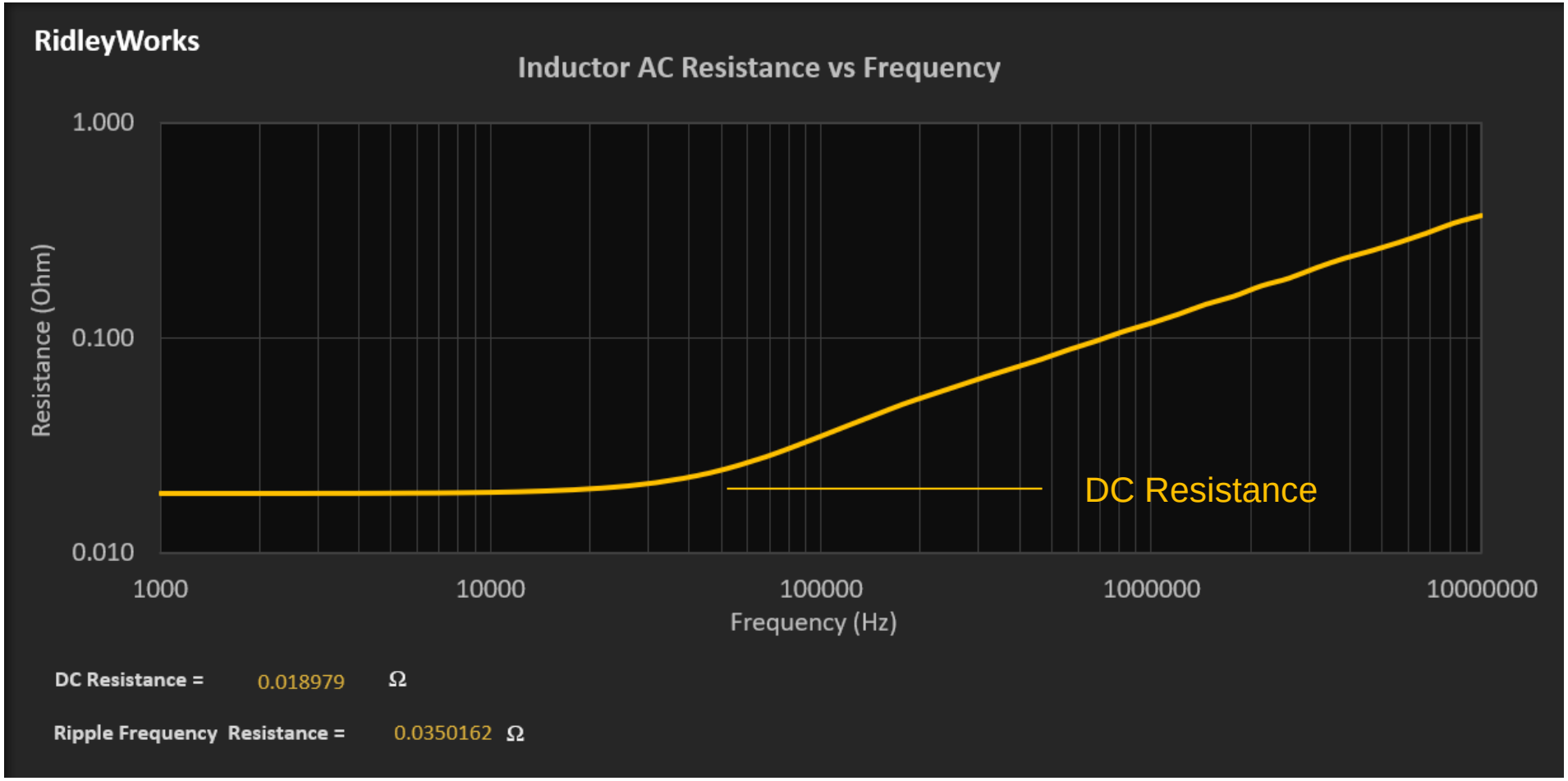
Winding loss if you don't do proximity analysis:

1.04 W

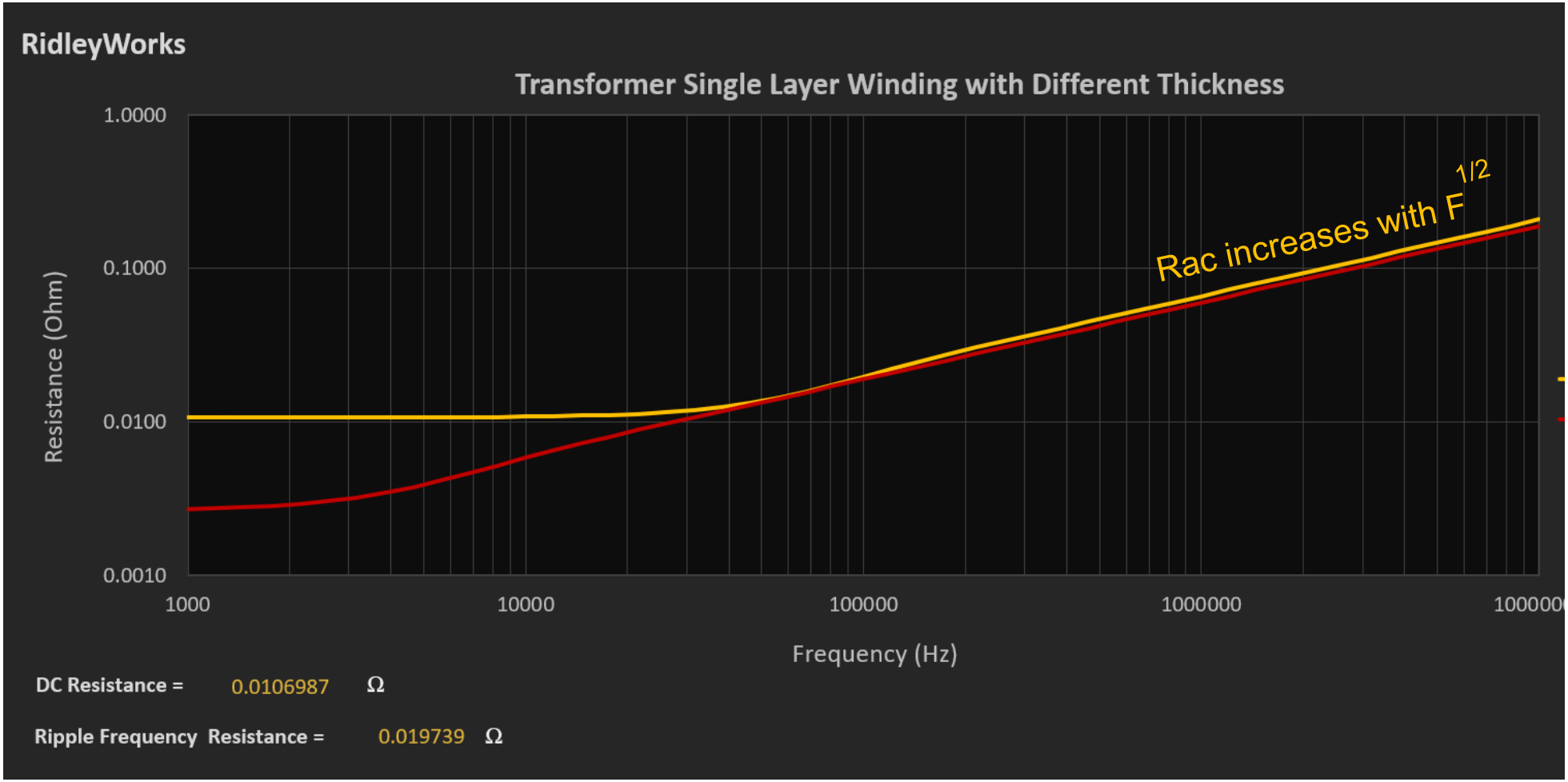
Winding loss with full harmonic proximity analysis

10.77 W

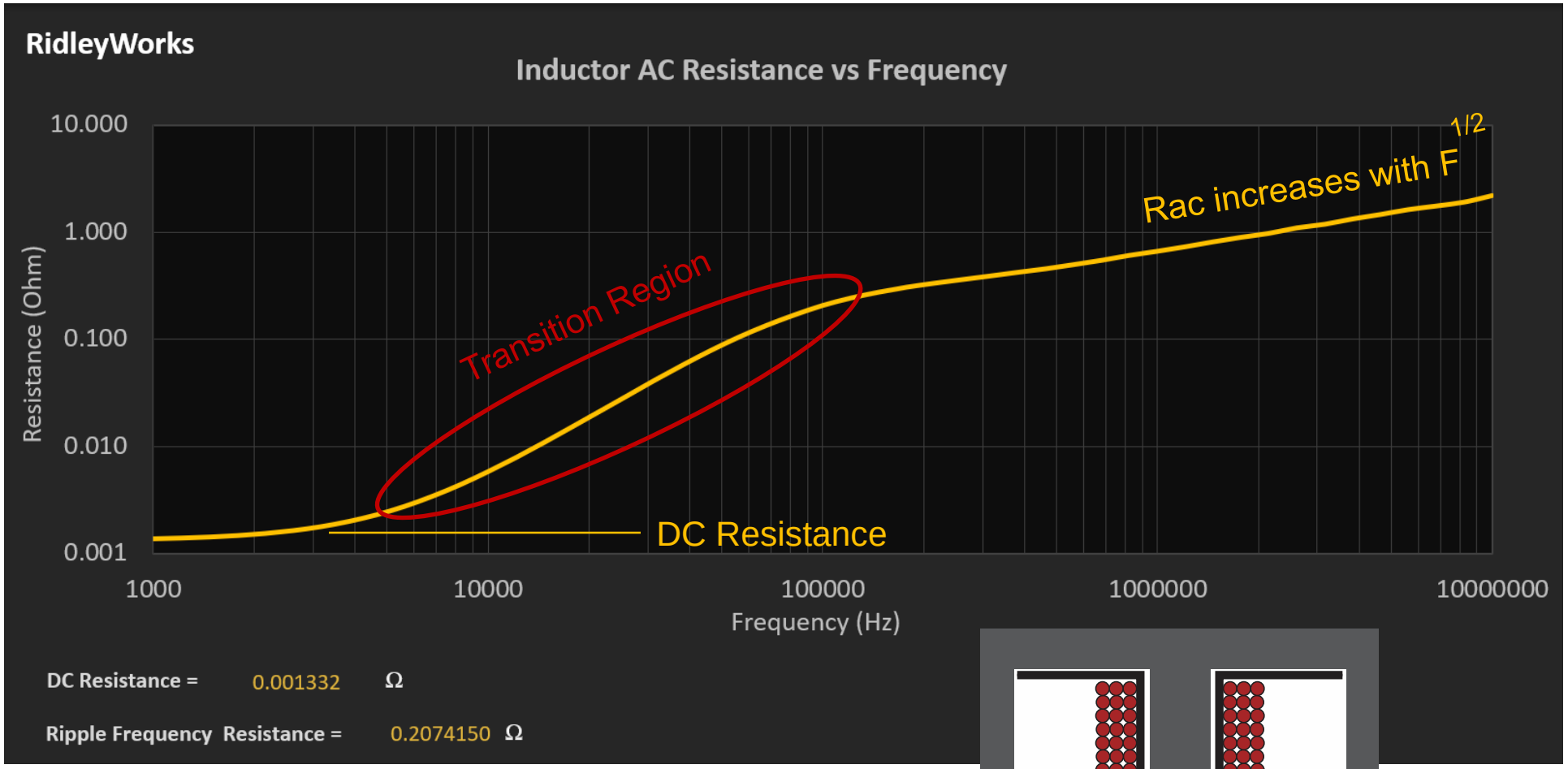
Every Magnetic Has a Unique Frequency-Dependent Resistance

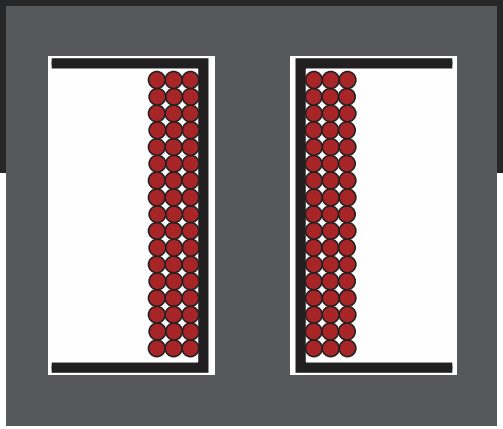


Single Layer AC Resistance with Different Thickness

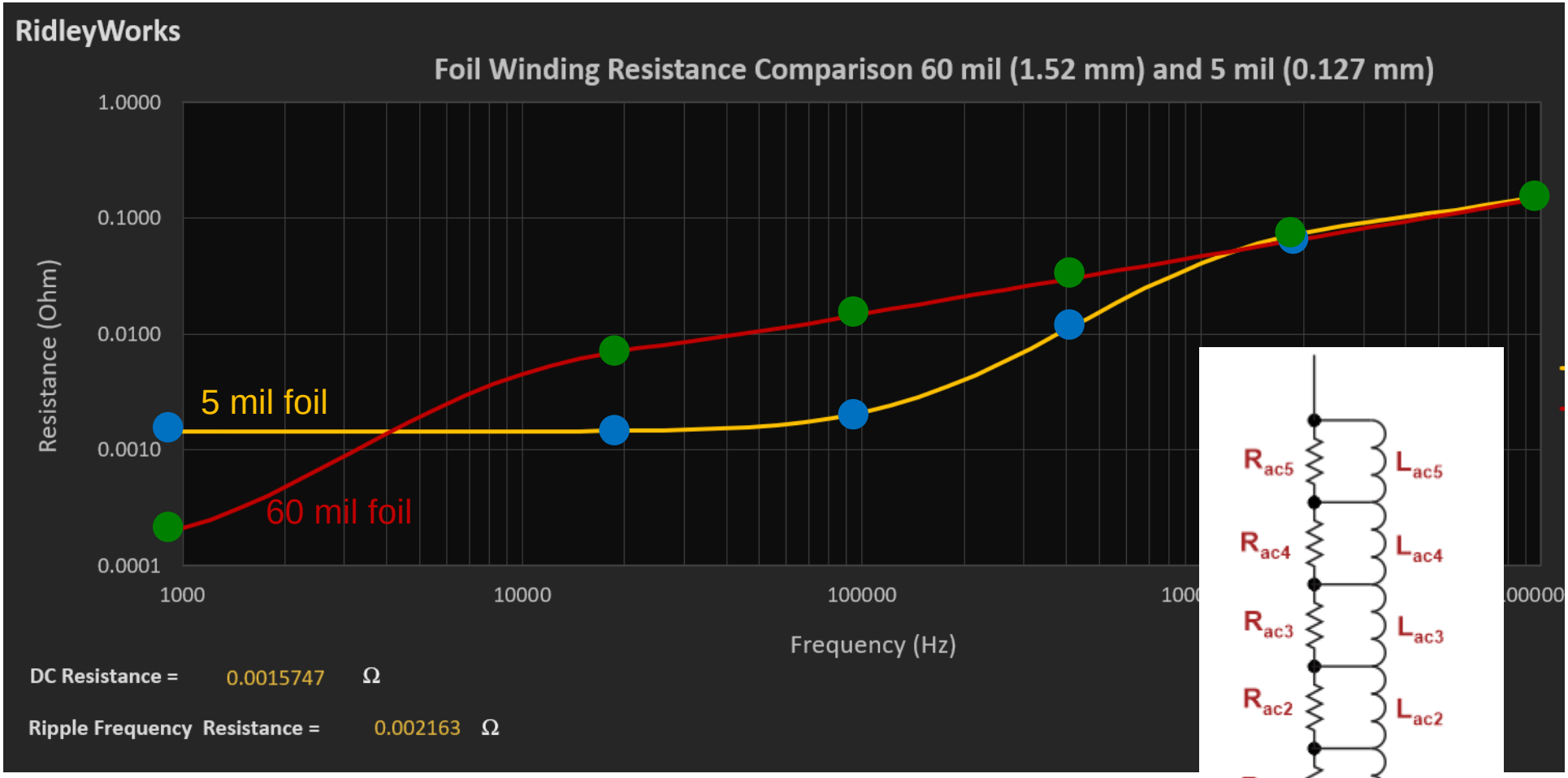


Multilayer Winding AC Resistance Characteristic Curve





Next Step – Generate a Spice Model to Match the Resistance



New Rac Model

Set each Rac to be incremental resistance between sample frequencies multiplied by 1.4142

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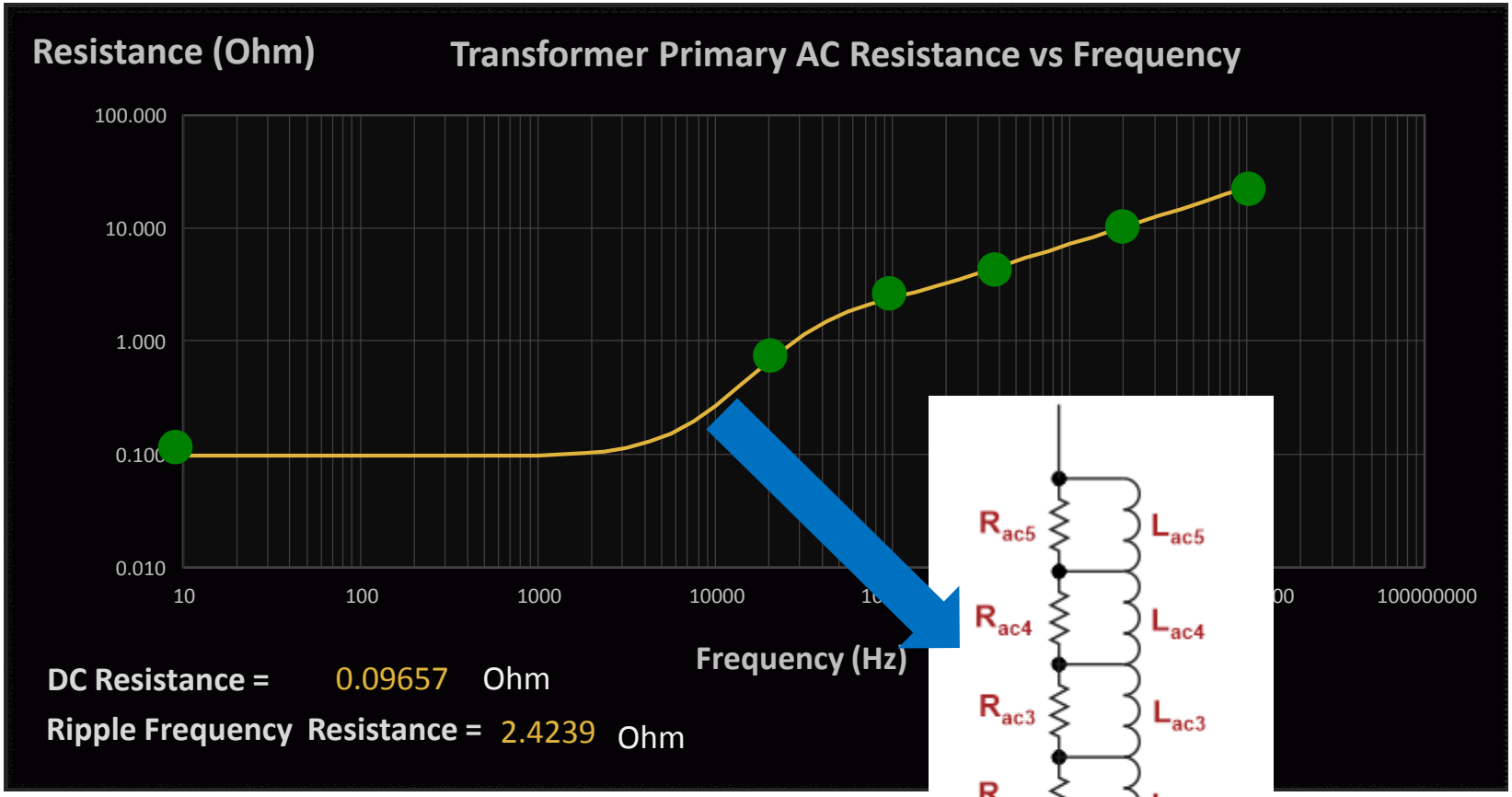
Primary Proximity Loss Example



New Rac Model

Clea

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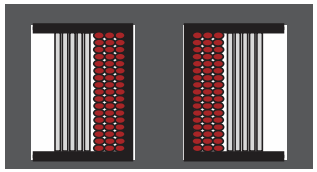
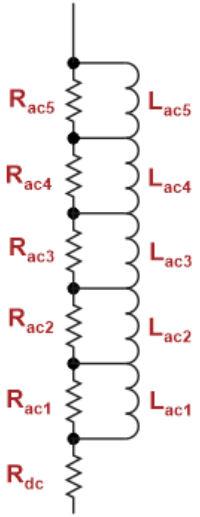
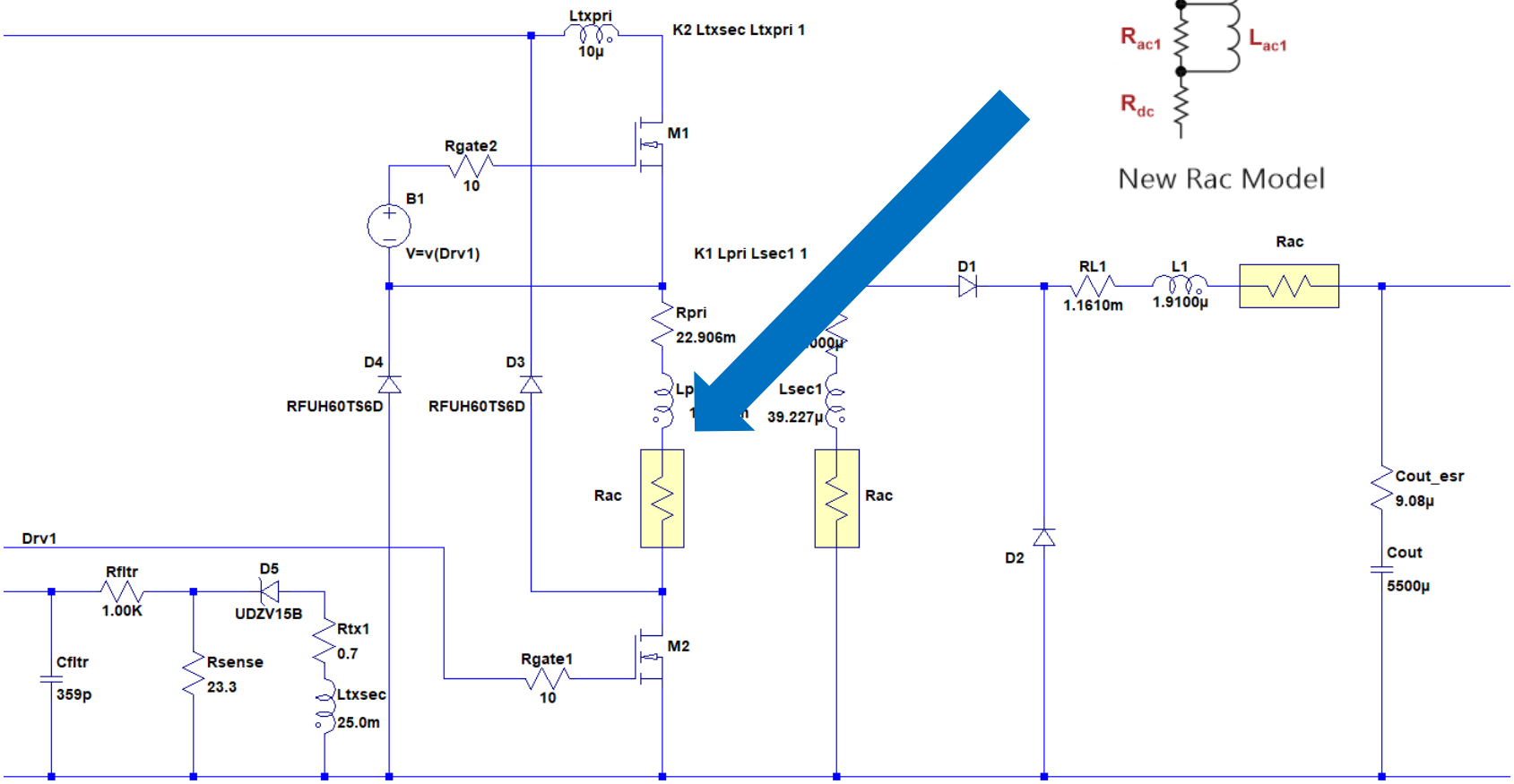
Primary Proximity Loss



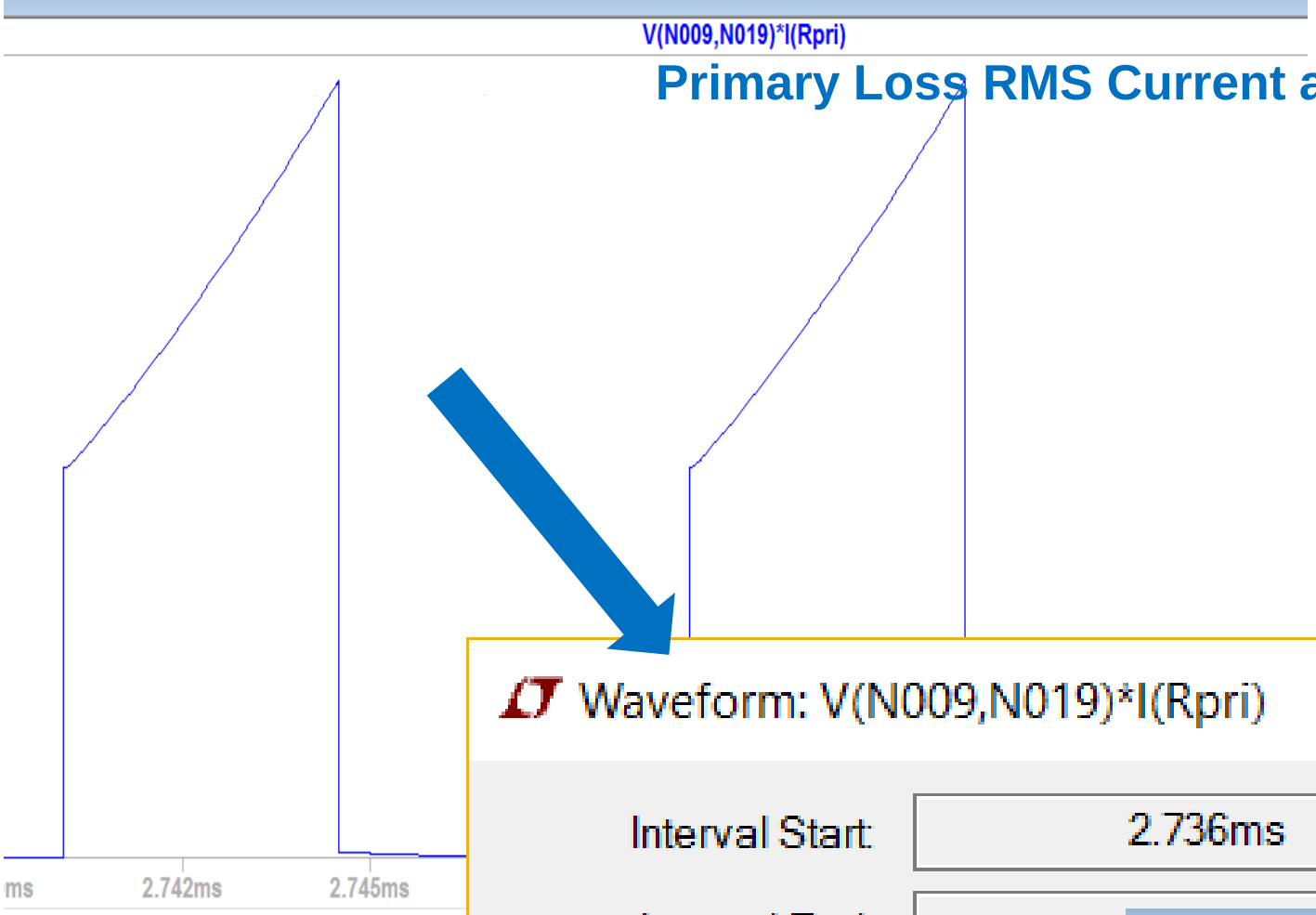


New Rac Model



Clea

Primary Loss RMS Current and DC Resistance



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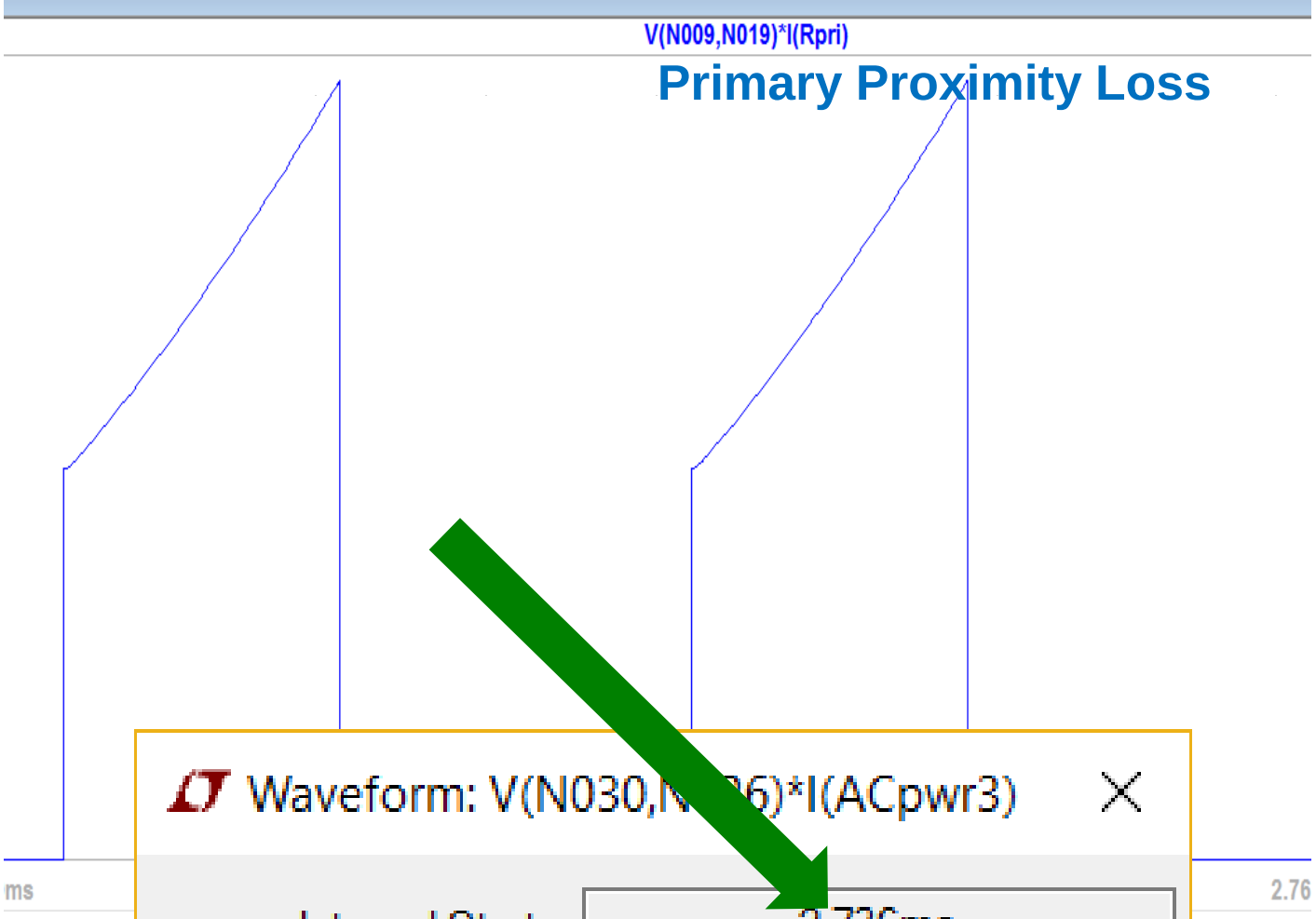
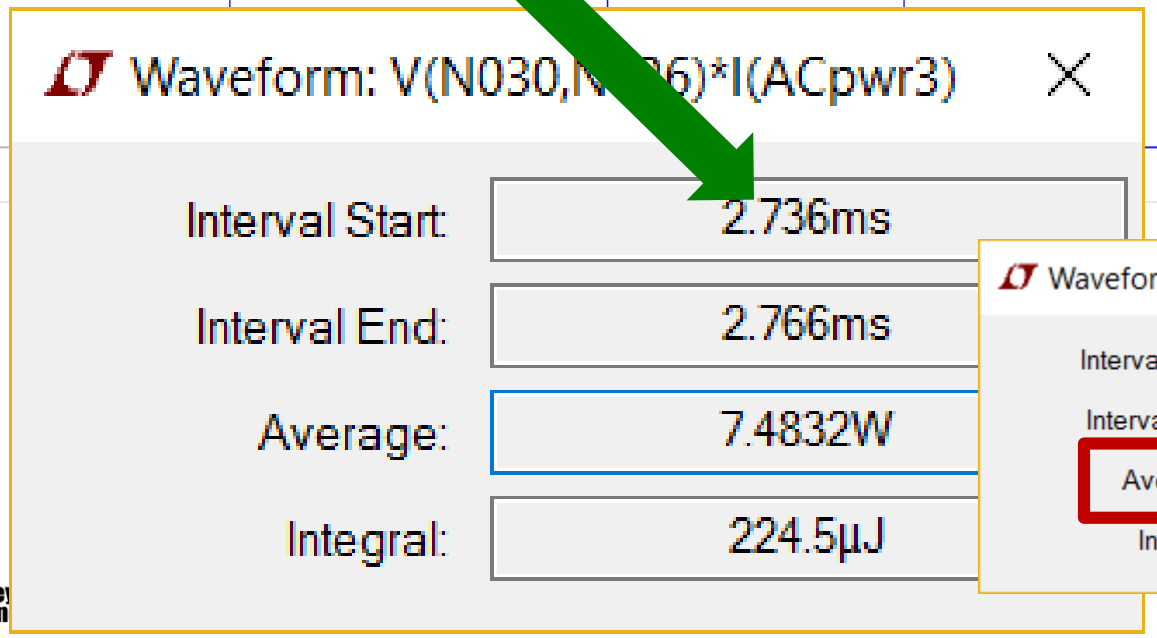
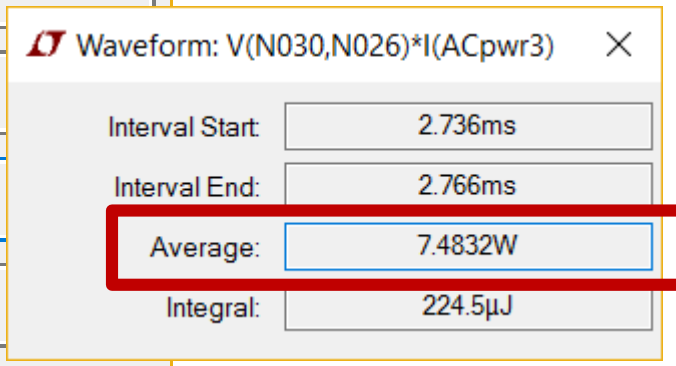
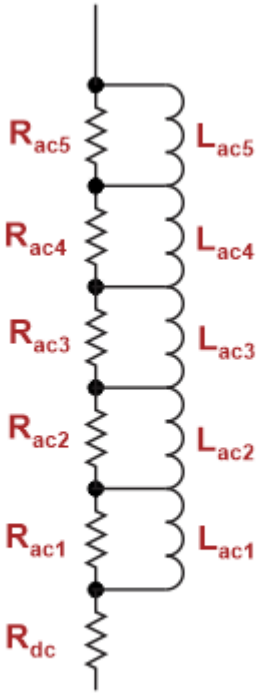
Primary Proximity Loss







Magnetics Winding Spice Model Summary



New Rac Model

A simple spice circuit will predict ac losses in a winding with arbitrary circuit waveforms

Model generation is fully automatic. What used to take hours of work is now done in minutes, freeing the designer for more creative work.

Magnetics Core Loss Project

We are working on similar models for the core loss

Crowd-programming project – help us with data

Download free version of RidleyWorks Buck Designer, look for the core loss Open Programming page in next version.

Ridleyengineering.com software intro page