

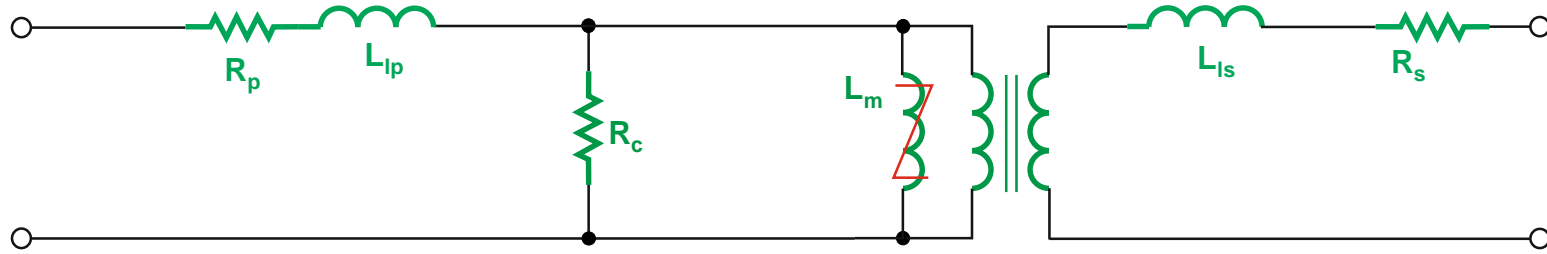
3. Winding Capacitance

Dr. Ray Ridley

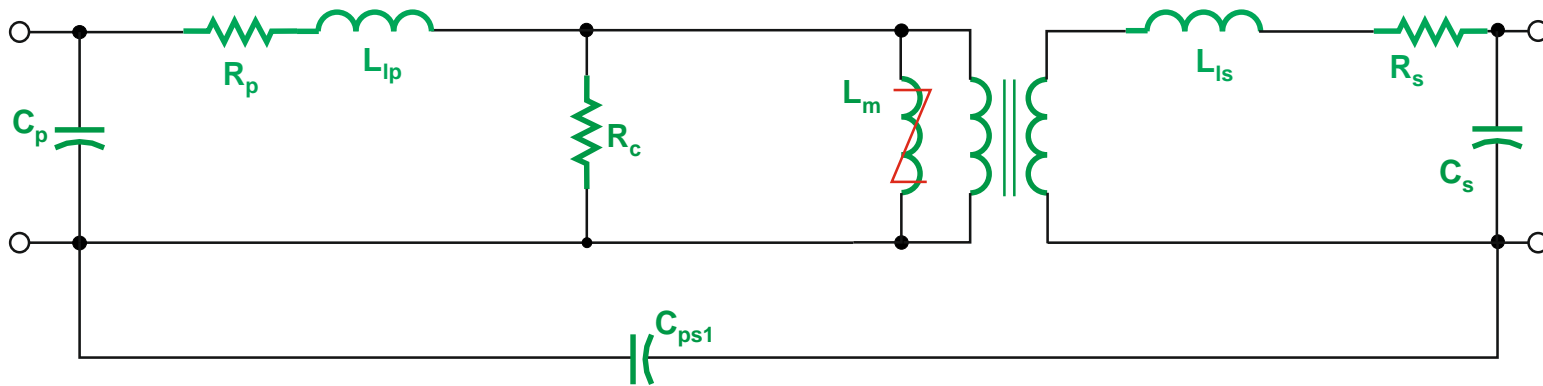
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**APEC Magnetics Industry Session
Tuesday March 6, 2018**

Transformer Model Without Capacitances



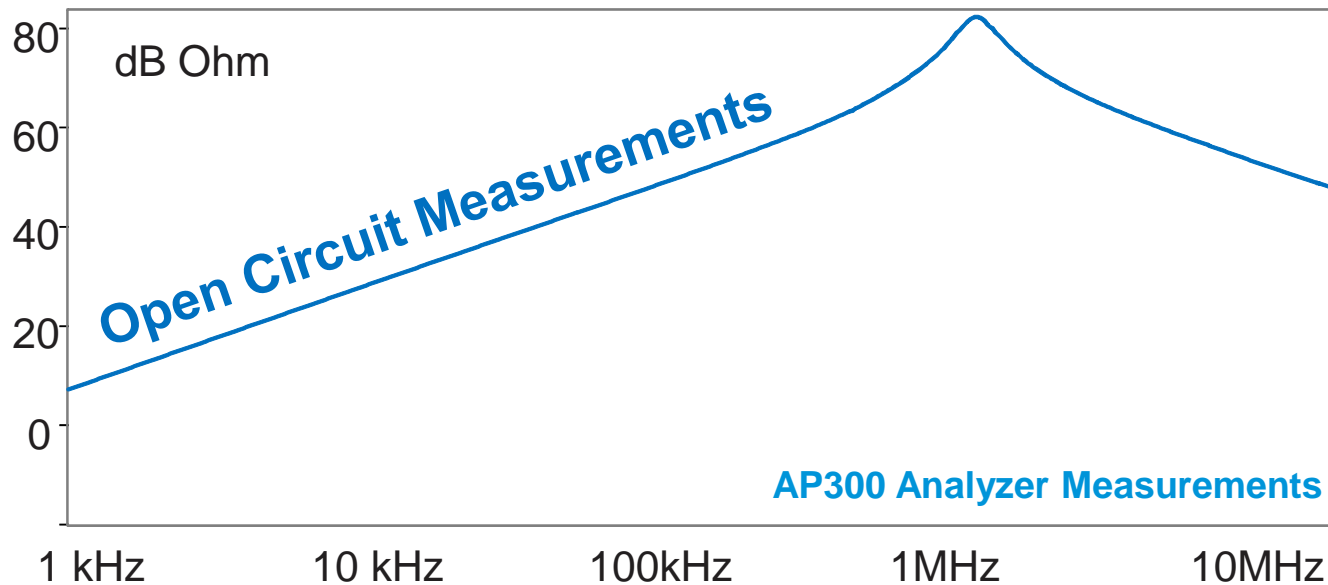
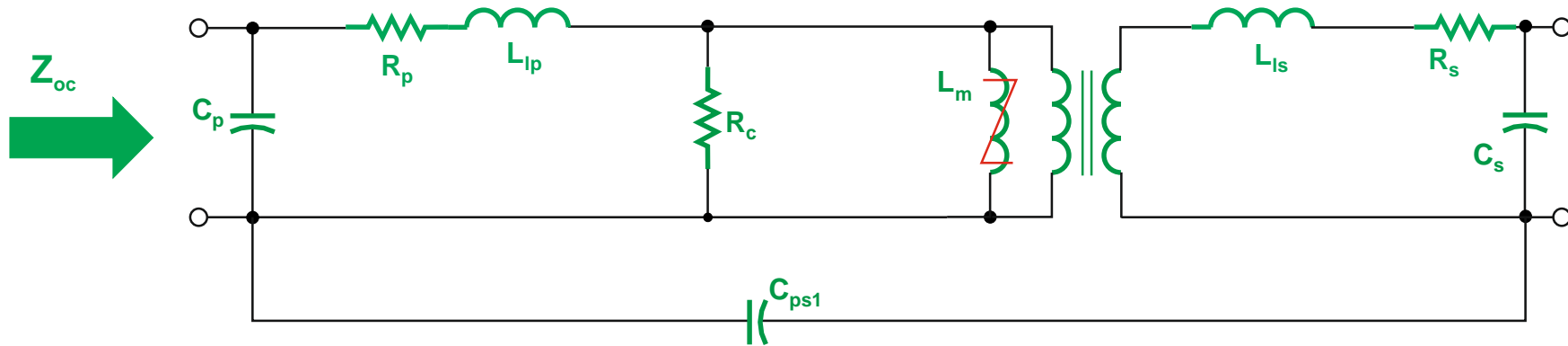
Adding Capacitances



Winding capacitances are in the order of 1 pF to several 1000 pF

Very significant effect on EMI and resonances

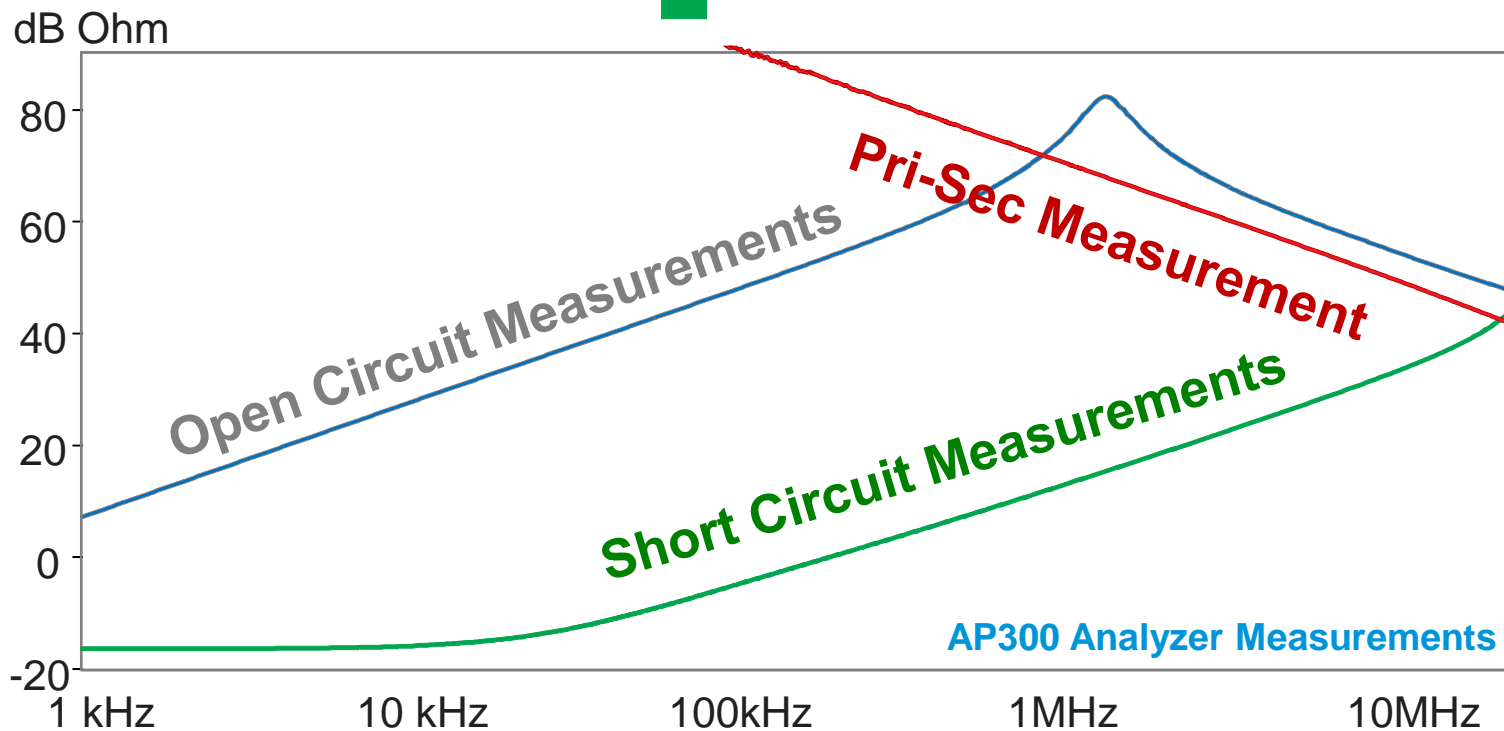
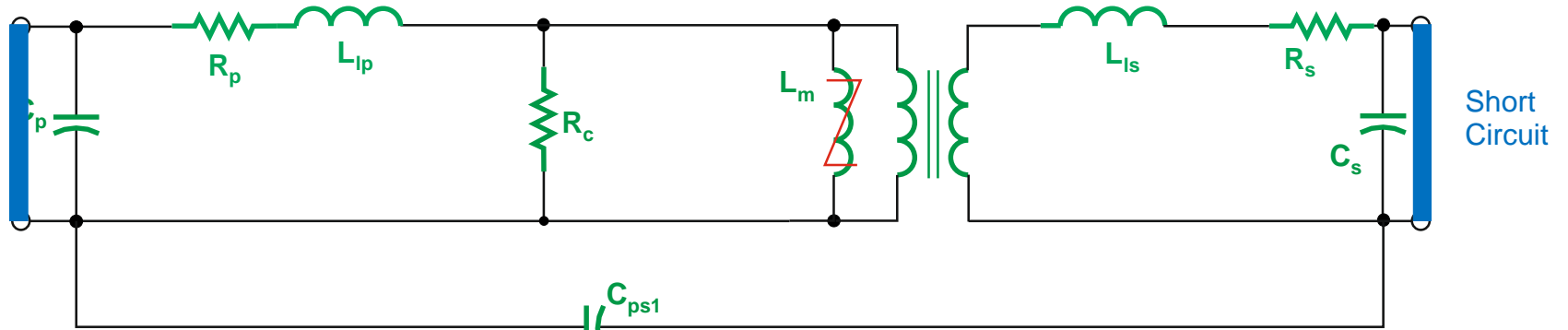
Measuring Impedances



Making impedance measurements was standard practice in the early days of 50/60 Hz magnetics – **what happened when we went to high frequency?**

Short Circuit

Measuring Impedances



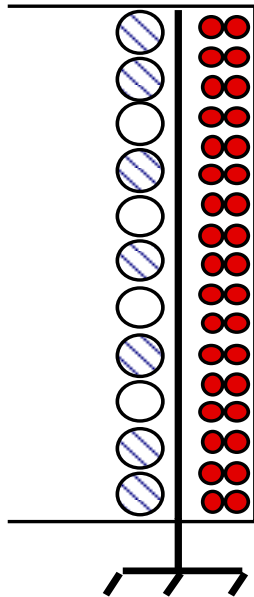
Transformer Capacitance (Lumped)

$$C = \frac{\epsilon_0 \epsilon A}{d}$$

A is the exposed surface area of the winding
d is the distance between windings

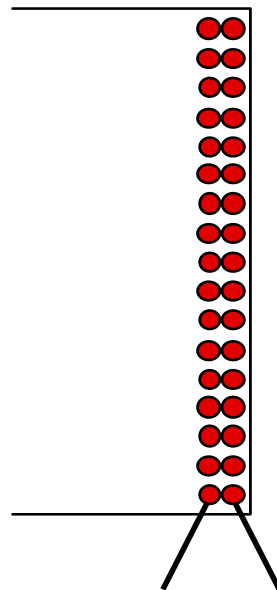
Problem: decreasing interwinding capacitance with these parameters increases the leakage inductance.

Faraday shield between layers gives largest reduction

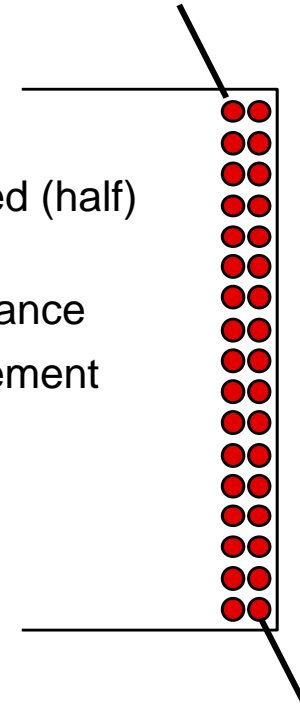


(Not a complete turn!)

Intra-winding capacitance Stop



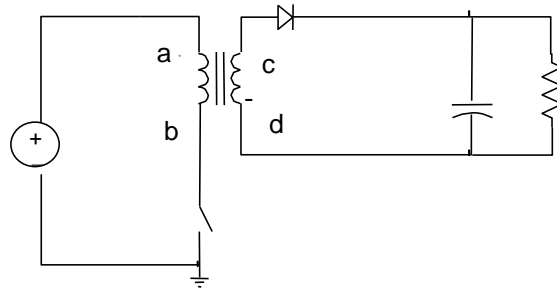
Reduced (half)
winding
capacitance
arrangement



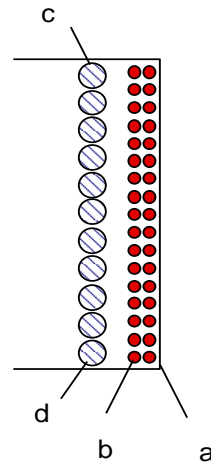
Transformer Capacitance

Problem: lumped capacitance value is a very crude measure of winding performance

Need to consider capacitance of different sections of winding for improved design

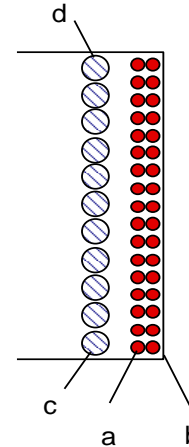


High-noise configuration



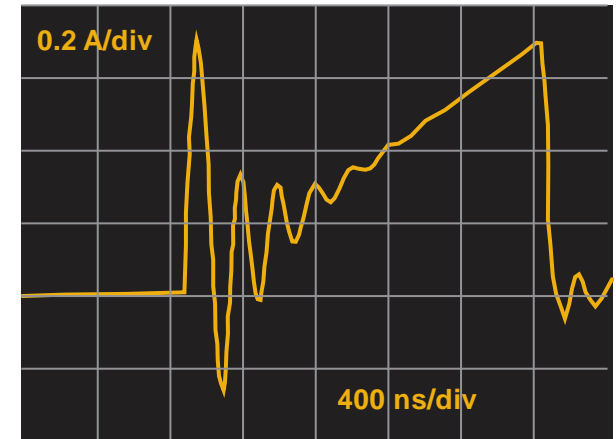
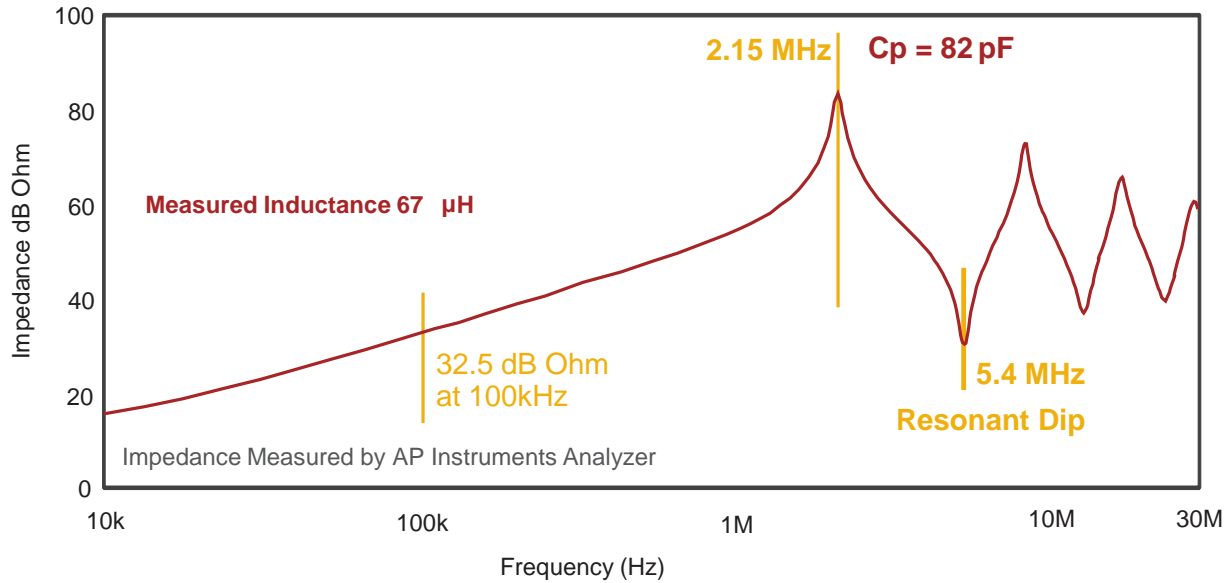
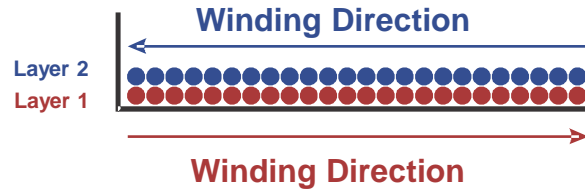
Largest signal turn is
closest to output ground

Low-noise configuration

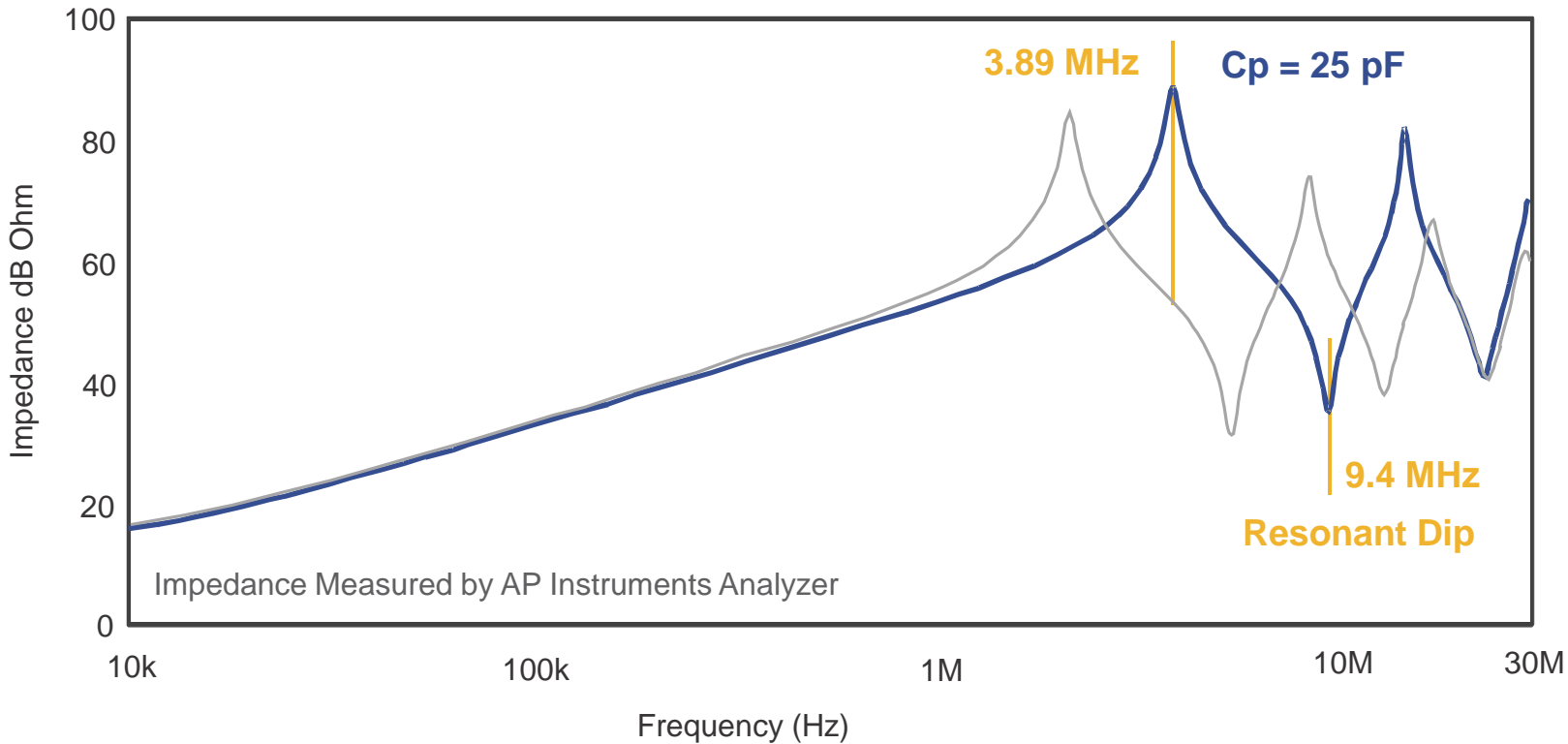
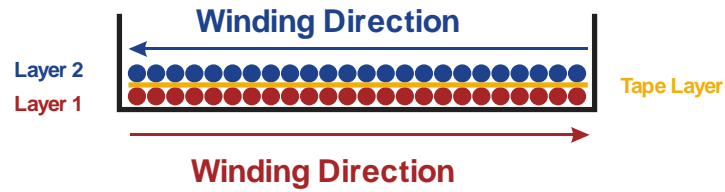


Largest signal turn is
furthest from output ground

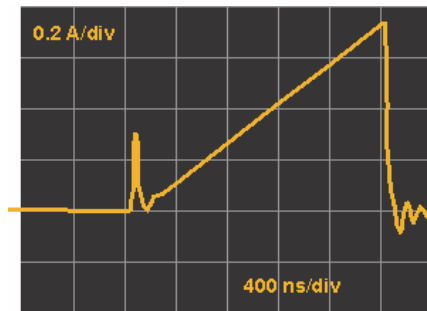
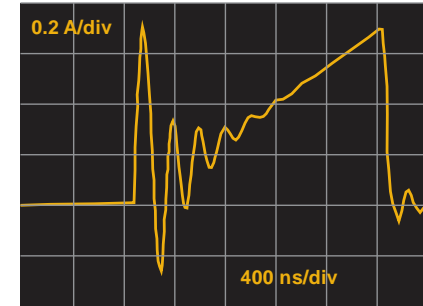
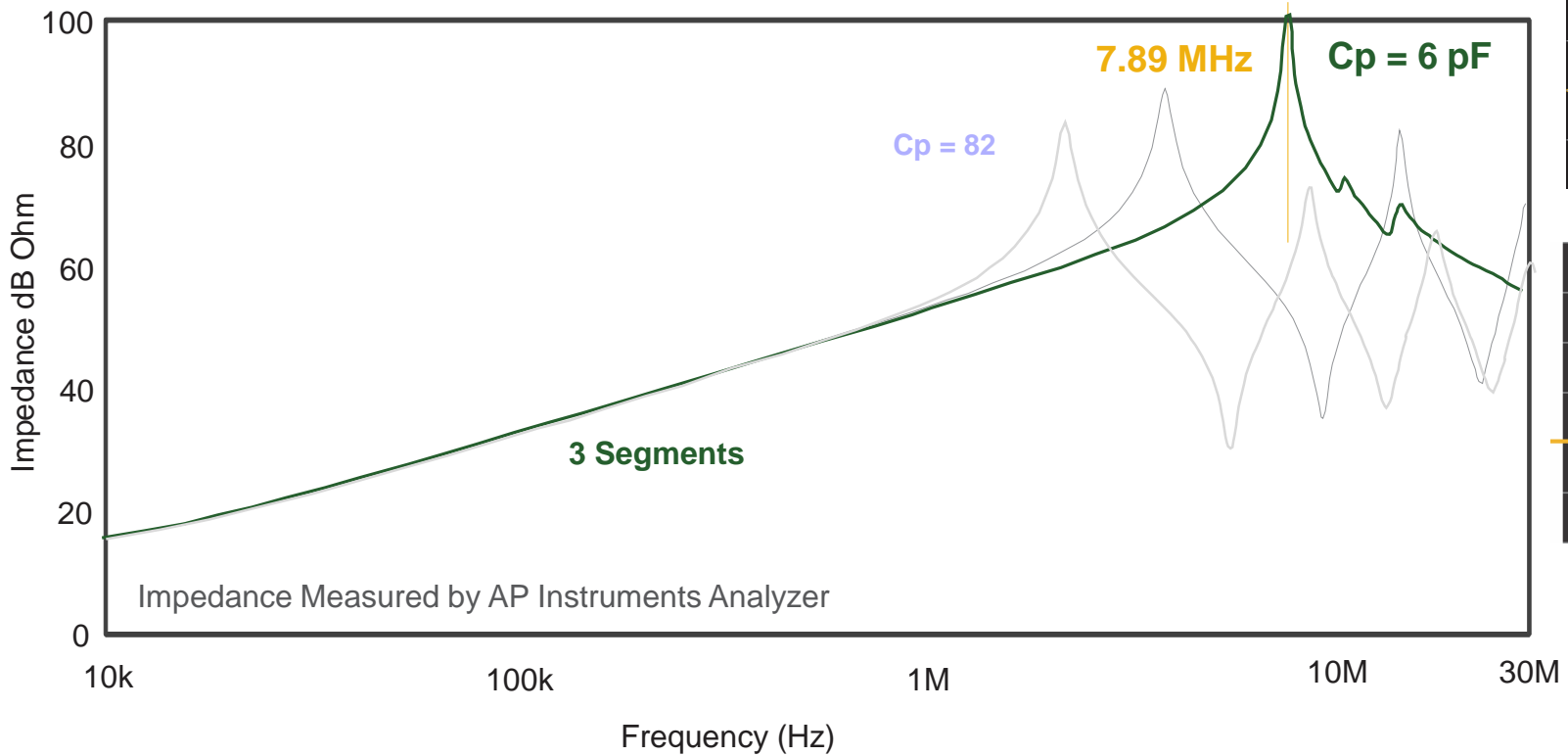
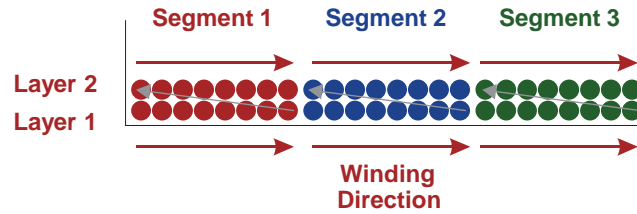
Increasing Complexity - Two Layer Primary No Tape



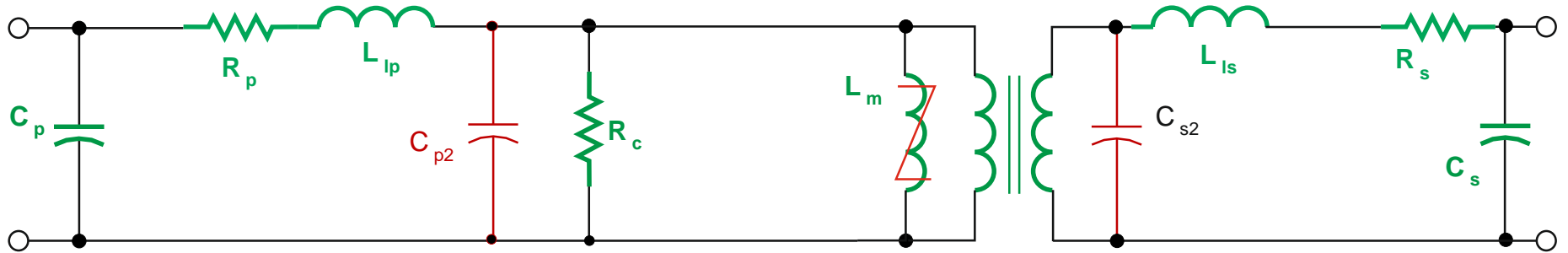
Two Layer Primary One Layer Tape



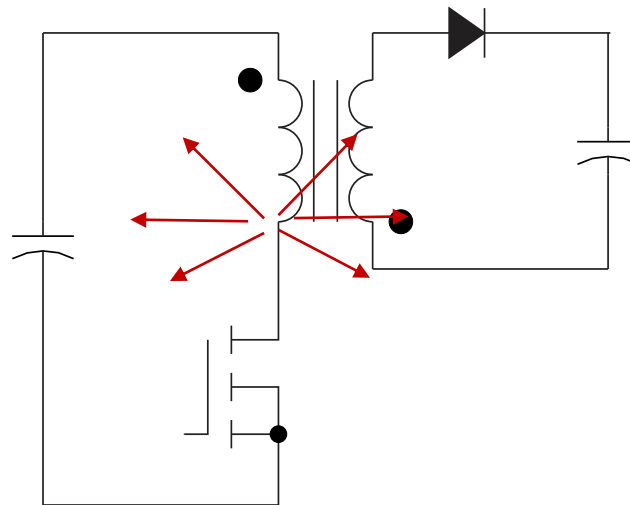
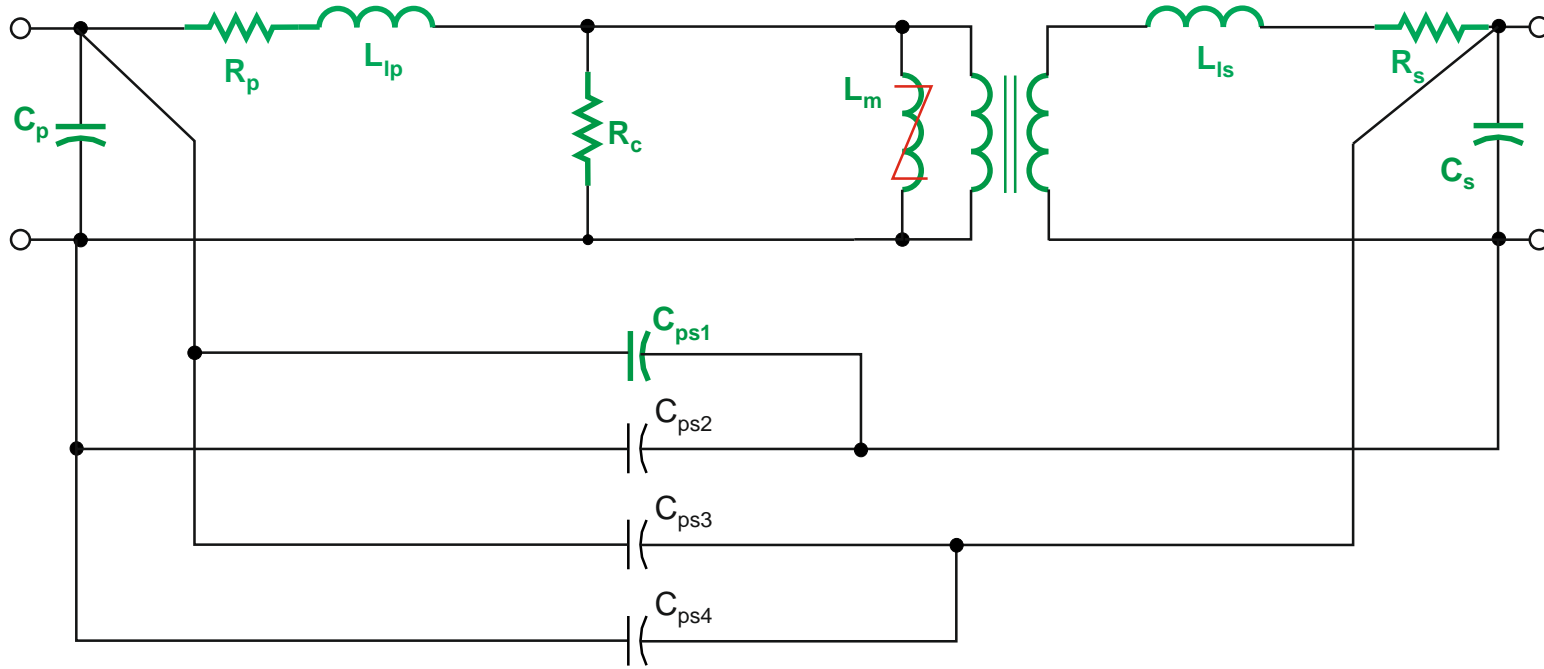
Two Layer Primary Three Segments



More Complex Model



Additional Common-Mode Capacitances



Capacitance Summary

Winding capacitances tend to be small

Noise interactions are very complex and difficult to track down

Specification, design, and measurement of capacitance in transformers and inductors are all very inadequate for predicting EMI performance.

There is tremendous opportunity for design improvement once you understand capacitance interactions.