Inductor Resonances and EMI

OMICRON 14th Power Analysis & Design Symposium

Organized by,

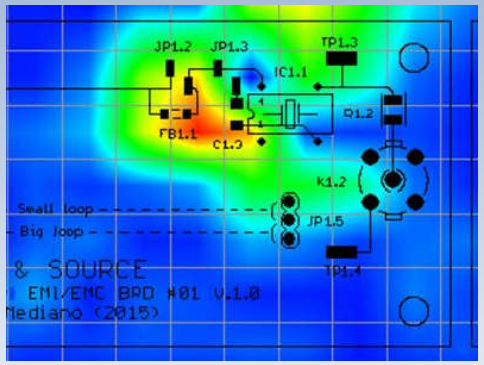
Arturo Mediano
Founder & EMI/EMC magician
HF MAGIC LAB S.L.
amediano@hfmagiclab.com

Prof. **Arturo Mediano**
I3A, **UNIVERSITY OF ZARAGOZA** (SPAIN)
amediano@unizar.es

April 9th, 2025

2025

A High Frequency Lab for design, diagnostic, troubleshooting and training



Interferences (**EMI**)
Electromagnetic Compatibility (**EMC**)
Signal Integrity (**SI**)
Radiofrequency(**RF**)

Contact: Arturo Mediano
HF MAGIC LAB S.L.
Bari, 31. Edificio TechnoCenter. Oficinas 216-217
50197 Zaragoza (Spain)
amediano@hfmagiclab.com

About the speaker ...

ARTURO MEDIANO – HF MAGIC LAB S.L.

- **Faculty member at the University of Zaragoza (SPAIN) for 30 years**
- **Founder HF Magic Lab S.L.**
- **Senior Member IEEE**
- **Chair IEEE EMC-S Spain Chapter**
- **Past Chair IEEE MTT-S Technical Committee 17**
- **amediano@unizar.es**

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Outline ...

1. **Introduction inductors everywhere.**
2. **Let's work with inductors in the ideal way.**
3. **Using cores.**
4. **Example Buck converter**
   - Ideal design and simulation
   - Prototype
   - EMI results
   - Inductor characterization and model
   - Using LTSPICE to analyze the problems
5. **Conclusions**

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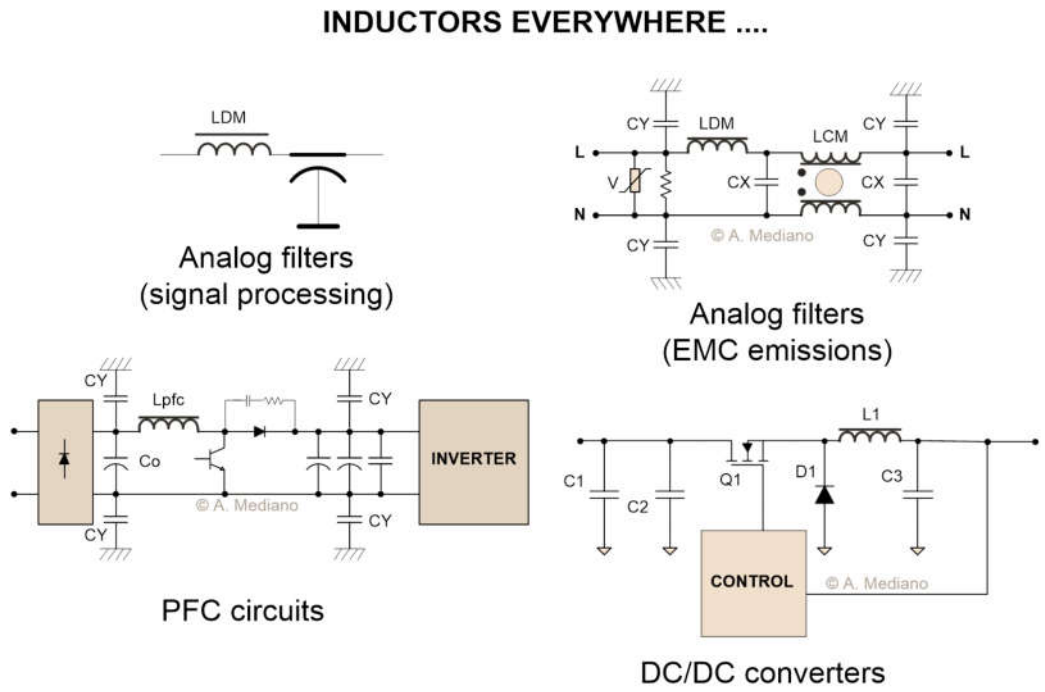
Inductors ... a common component



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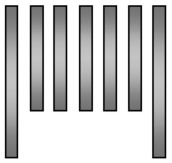
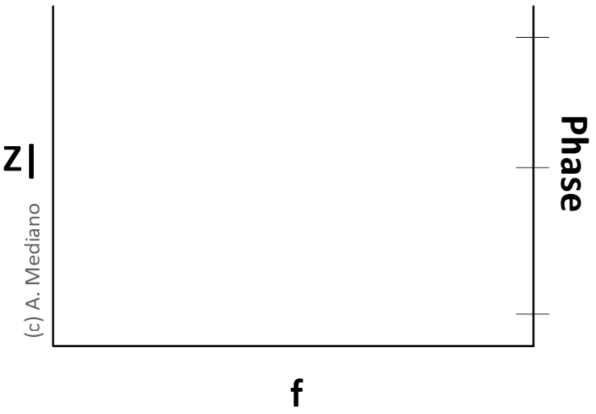
Inductors ... ideal way.

How to work with inductors .... IDEAL MODEL

Take a wire and create a simple model:



Air core inductor



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Inductors ... they are not ideal

The ideal behavior of an inductor is a **fantasy**.
Its parasitics define your EMI/EMC reality.

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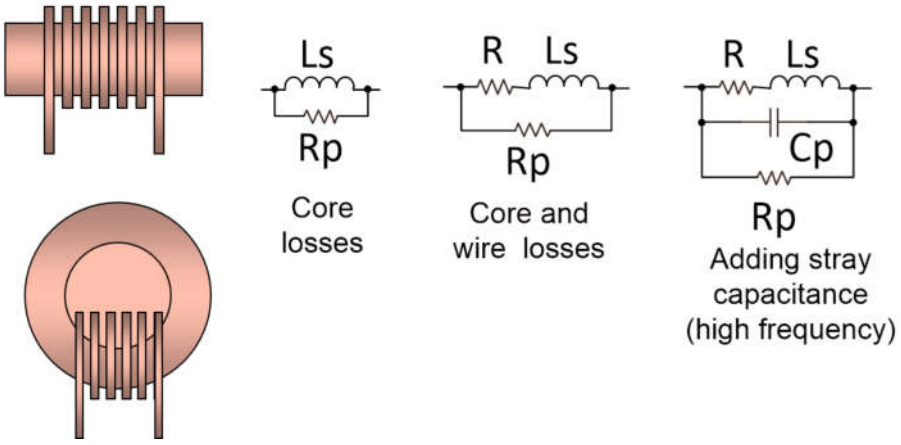
Inductors ... using core.

A core is used for a higher inductance without the need for big sized inductors.



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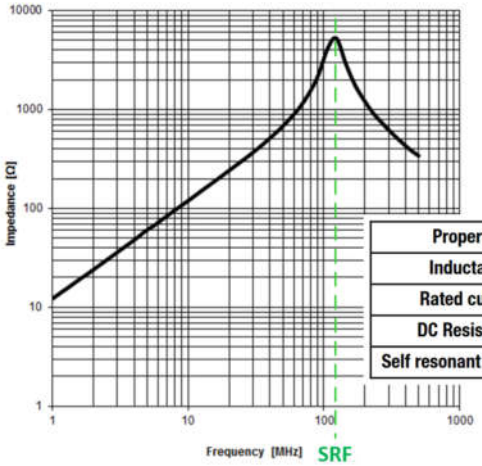
Inductors ... commercial example



WÜRTH ELEKTRONIK

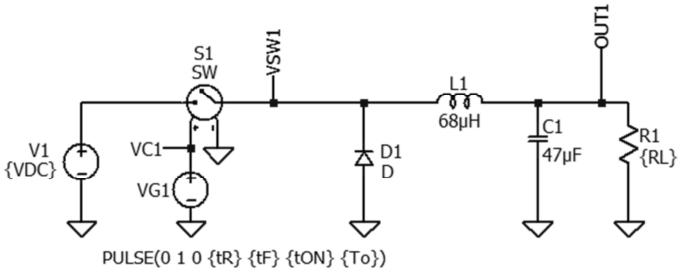
WE-SD Rod Core Choke

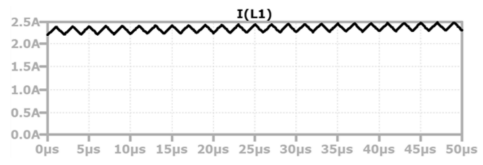
744710203

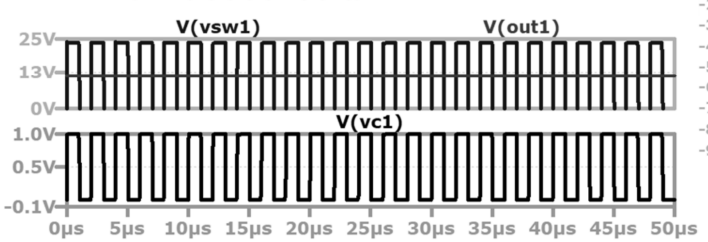
Properties	Test conditions		Value	Unit	Tol.
Inductance	10 kHz / 5 mA	L	2.0	µH	±25%
Rated current	ΔT = 40 K	I_R	2.5	A	typ.
DC Resistance		R_{DC}	11.0	mΩ	±20%
Self resonant frequency		SRF	110	MHz	typ.

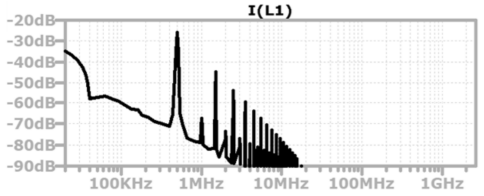
Example: Buck converter

A Buck converter is designed for Vin=24V, Vout=12V and RL=5ohm



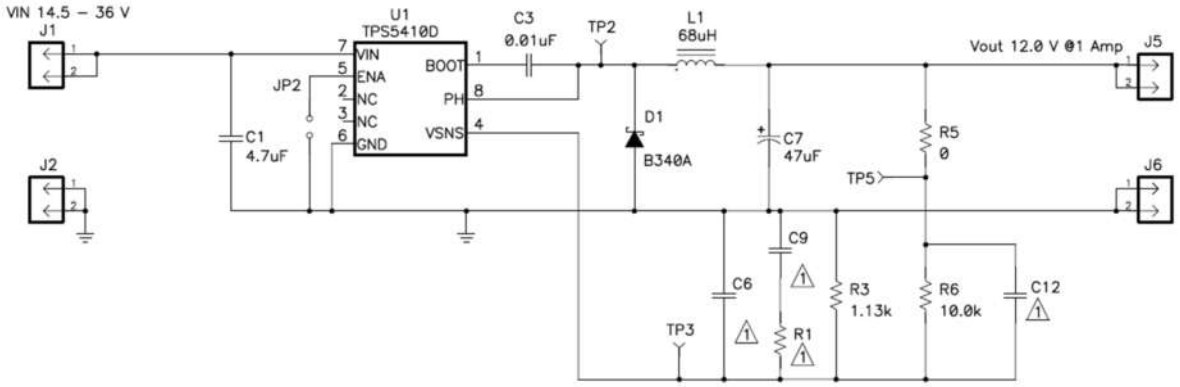






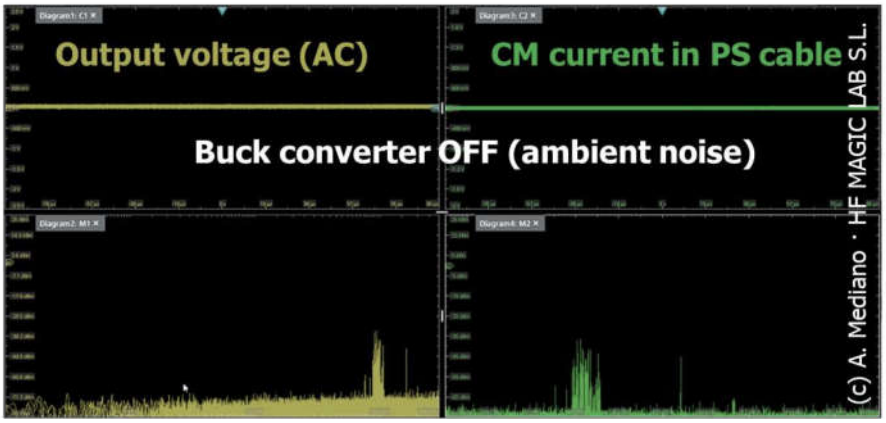
Example: Buck converter and EMC

A prototype is built …



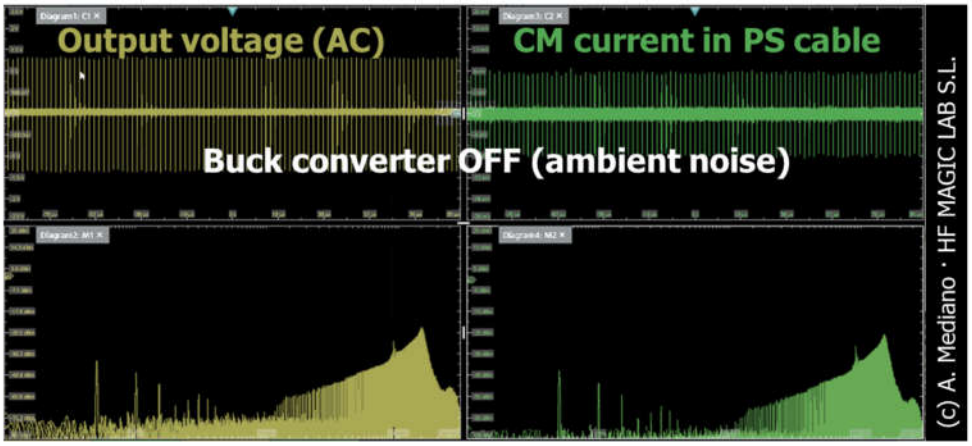
Example: Radiated emissions

Let's measure output voltage and CM current in power supply cable:



Example: Radiated emissions

Turn ON buck converter and radiated emissions fail in VHF because CM current in input voltage cable:



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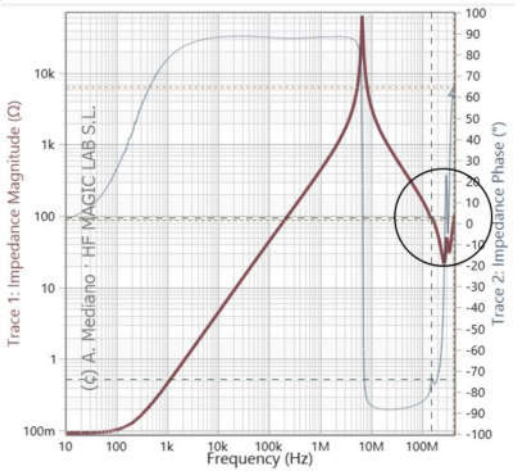
Example: Inductor characterization

Let's measure response of our inductor (INDUCTOR #1):

	Frequency	Trace 1	Trace 2
Cursor 1	157,891825 MHz	94,889 Ω	-73,837 °
Cursor 2	437,213565 MHz	87,688 Ω	64,712 °
Delta C2-C1	279,32174 MHz	-7,201 Ω	138,55 °



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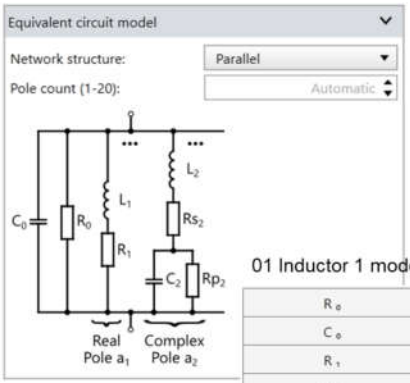
01 Inductor 1 measurement.bode3

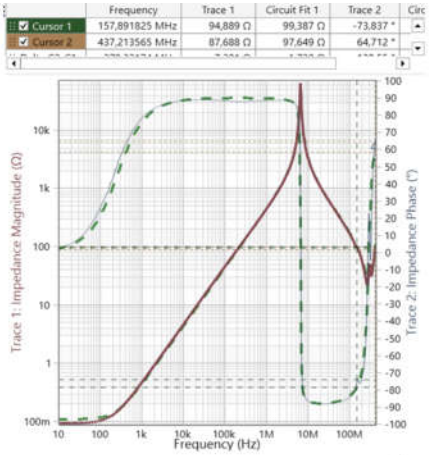
Example: Inductor model

Let's calculate inductor #01 model:



01 Inductor 1 model.fit

R 0	-4,841 kΩ
C 0	1,73 pF
R 1	108,33 mΩ
L 1	66,309 µH
Rp 2	4,533 kΩ
Rs 2	25,365 Ω
L 2	43,839 nH
C 2	6,383 pF



01 Inductor 1 SPICE model.cir

```
.SUBCKT Circuit_Fit_1 Pin1 Pin2
C0 Pin1 Pin2 1.7297352145981011E-012
R0 Pin1 Pin2 -4.8406711348112995E+003
L1 Pin1 N1 6.6309204221147092E-005
R1 N1 Pin2 1.0833009535897445E-001
L2 Pin1 N2 4.3838990902004872E-008
Rs2 N2 N3 2.5364959897561288E+001
C2 N3 Pin2 6.3828648600856162E-012
Rp2 N3 Pin2 4.5329868053672653E+003
.ENDS Circuit_Fit_1
.END
```

Delete line

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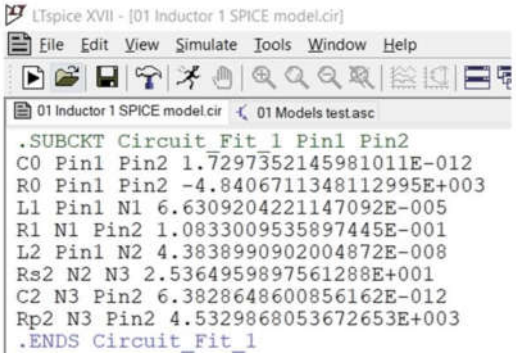
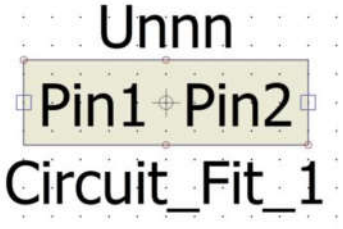
Example: Inductor model

Open the .CIR file with LTSPICE:



Use clik+right mouse button for crating symbol and save in project folder:



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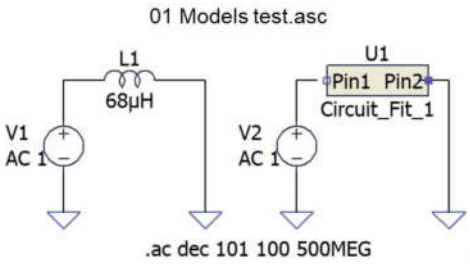
Example: Test model in simulation

Check model with LTSPICE:




```
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L2 Pin1 N2 4.3838990902004872E-008
Rs2 N2 N3 2.5364959897561288E+001
C2 N3 Pin2 6.3828648600856162E-012
Rp2 N3 Pin2 4.5329868053672653E+003
.ENDS Circuit_Fit_1
```

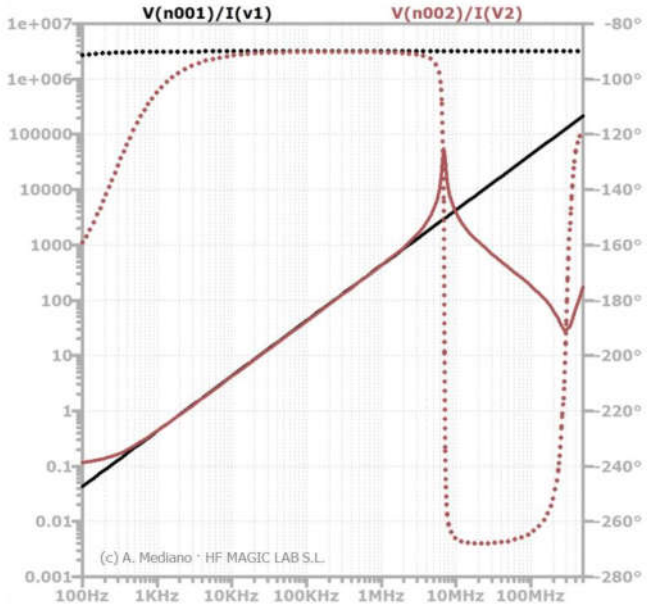

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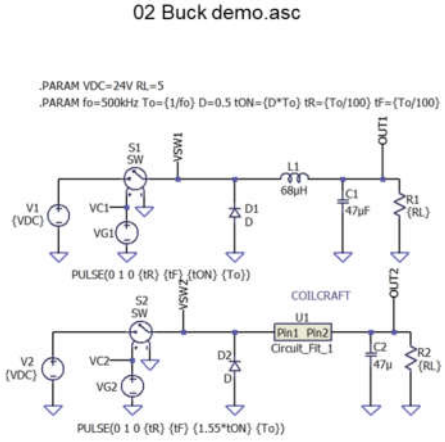
Example: Test model in simulation

Create a model of the DC/DC converter with the "real" inductor:




```
.SUBCKT Circuit_Fit_1 Pin1 Pin2
C0 Pin1 Pin2 1.7297352145981011E-012
R0 Pin1 Pin2 -4.8406711348112995E+003
L1 Pin1 N1 6.6309204221147092E-005
R1 N1 Pin2 1.0833009535897445E-001
L2 Pin1 N2 4.3838990902004872E-008
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```

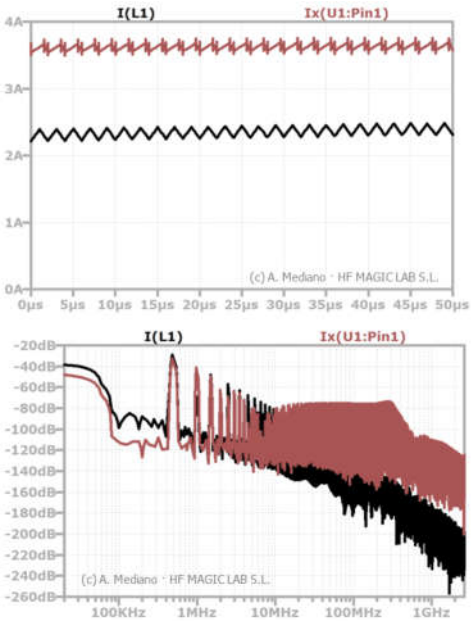

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THANK YOU!

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