Large-signal inductor loss measurement on integrated inductors

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Abstract

A novel method is presented to measure inductor losses – based on an actual power conversion application.
Compared to commercial lab equipment, hard switching of the inductor is used to provide information about:

- AC loss
- DC loss
- Dynamic saturation
- Self heating prediction

This patented measurement method was implemented in a commercially available measurement system for discrete inductors, MADMIX.

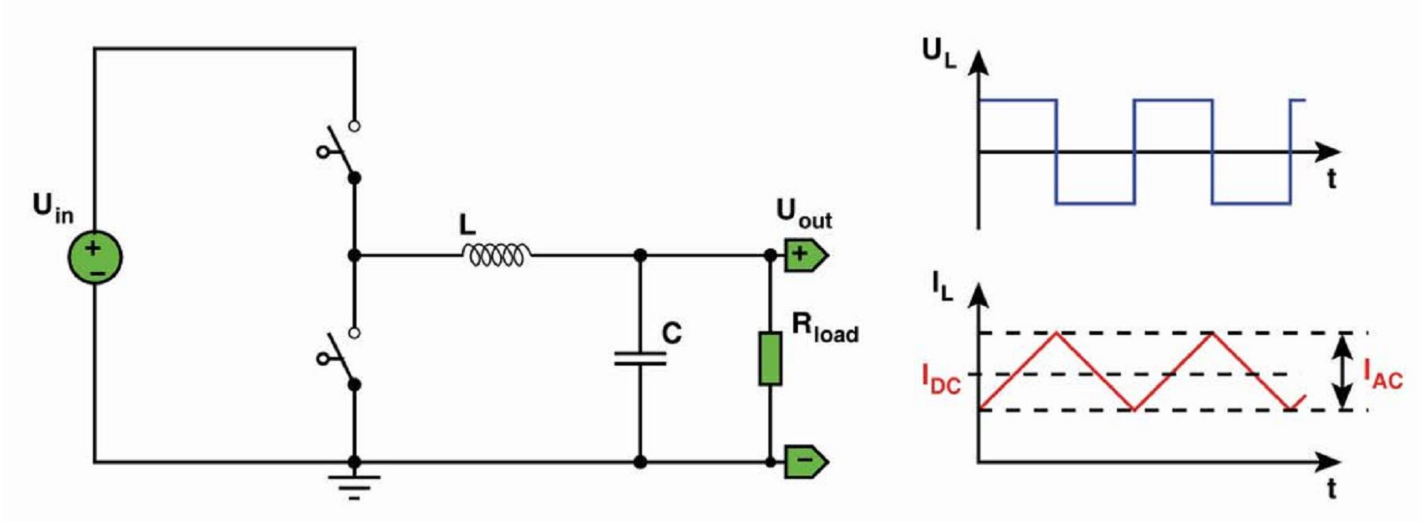
The described measurement method was proven using a custom developed high-speed driver with small footprint air-core and ferrite inductors, as a proof-of-concept for the measurement of fully-integrated inductors.

Objective

- High-speed and highly/fully integrated inductive convertors require a careful trade-off between the involved power losses in the power switches, and power inductor, to maintain converter efficiency .
- While fairly straightforward to assess the driver losses, it has become critical to understand saturation and loss dynamics involved in the power inductor.
- Existing methods for measuring inductors and their losses depend on small signal analysis, not representative for the switching application
- **Objective** : provide a method for measuring inductor losses, saturation effects and inductance variations depending on the operating point, suitable for integrated inductors.

Method

The inductor-under-test is hard switched, while measuring the transient inductor voltage and currents.



By post-processing of the transient inductor and current waveforms, the inductance, the AC and DC power loss and dynamic saturation can be calculated [3]:

$$L = \frac{R_{LS}.t_{on}}{ln\left[\frac{I_{min}.R_{LS} - U_{Lg1}}{I_{max}.R_{LS} - U_{Lg1}}\right]}$$

$$P_{loss} = \frac{1}{T}\cdot\int_0^T i_L(t).u_L(t)dt$$

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Measurements

The described measurement method was proven using a custom developed high-speed driver with small footprint air-core inductors, as a proof-of-concept for the measurement of fully-integrated inductors.

2 inductors were compared to quantify total P_{AC} over afrequency range of 6 – 20 MHz.

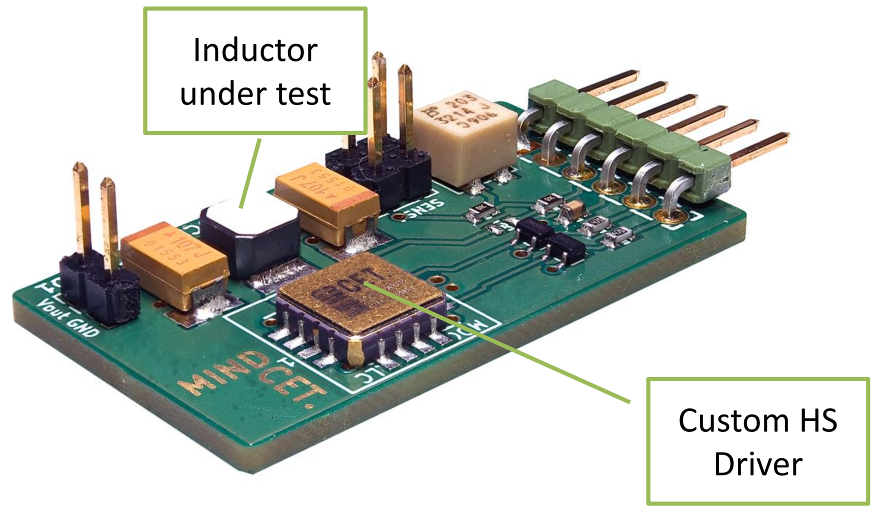
Inductor A :

- 150nH aircore inductor, with RDC = 590mOhm

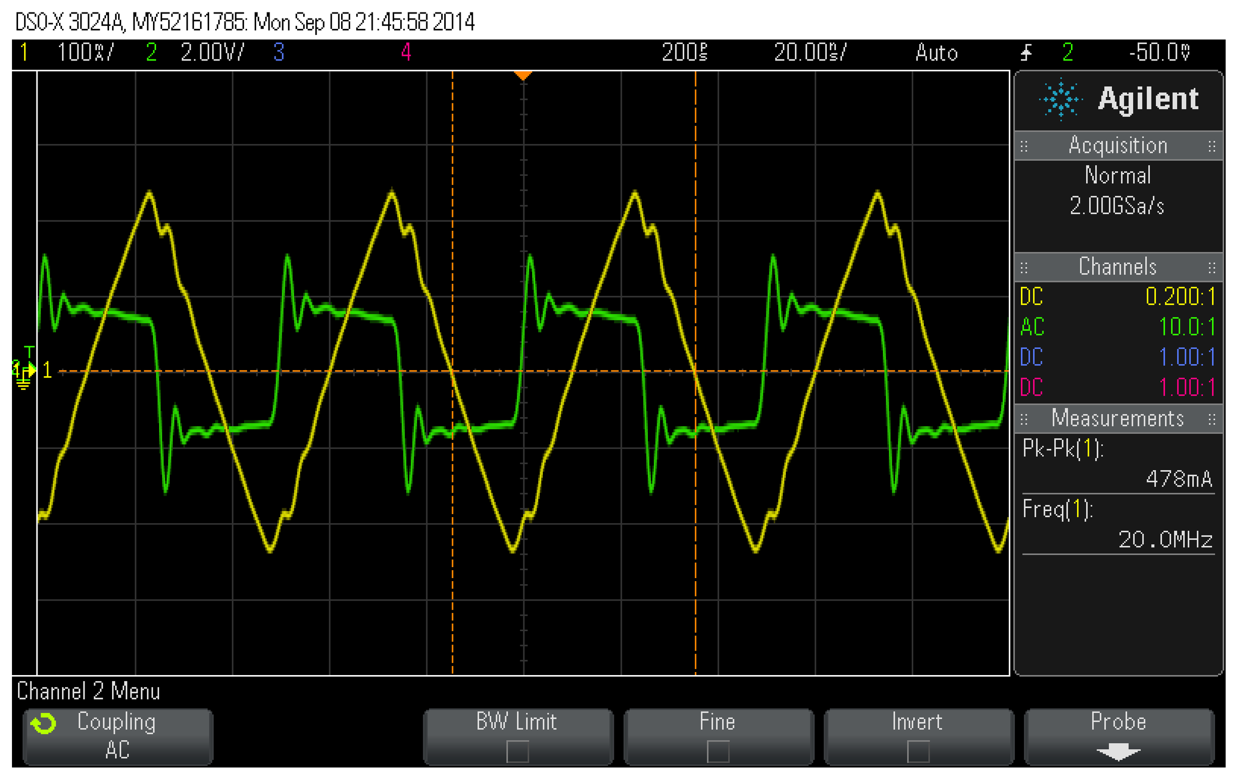
Inductor B:

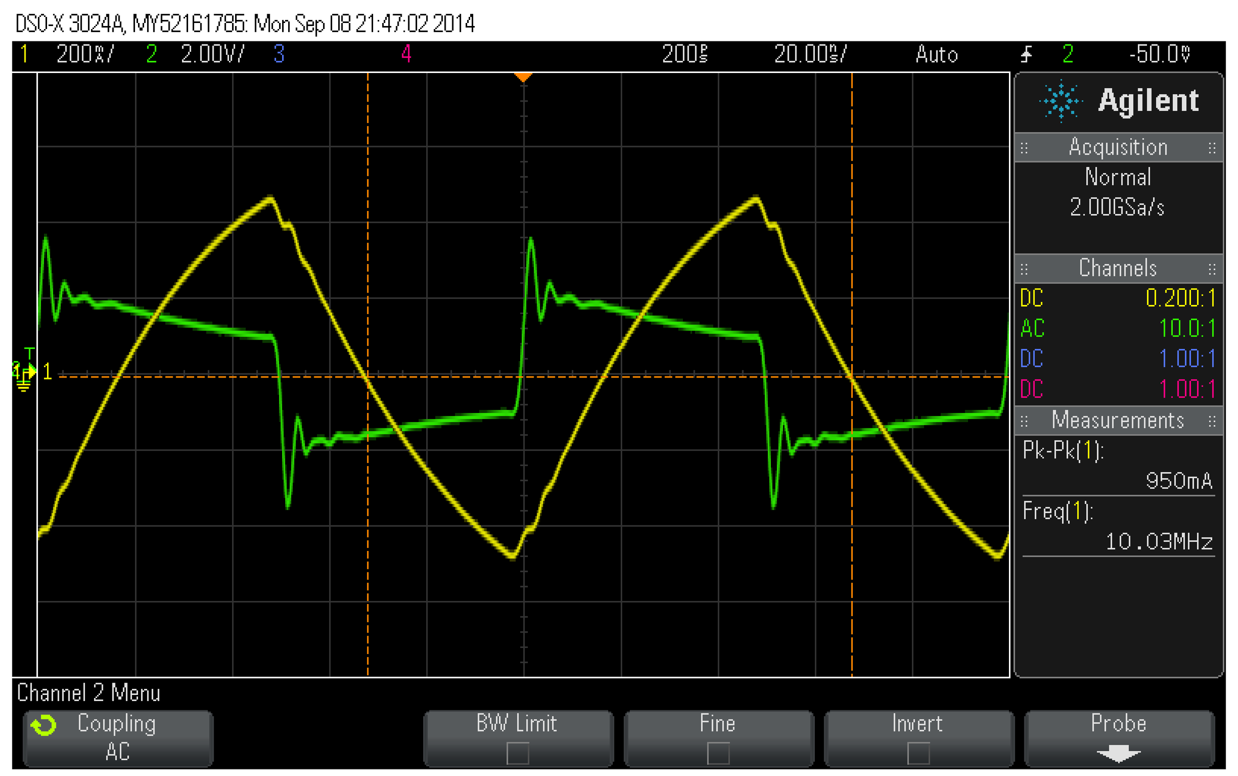
- 180 nH ferrite inductor, with RDC = 1.6mOhm

Measurement setup



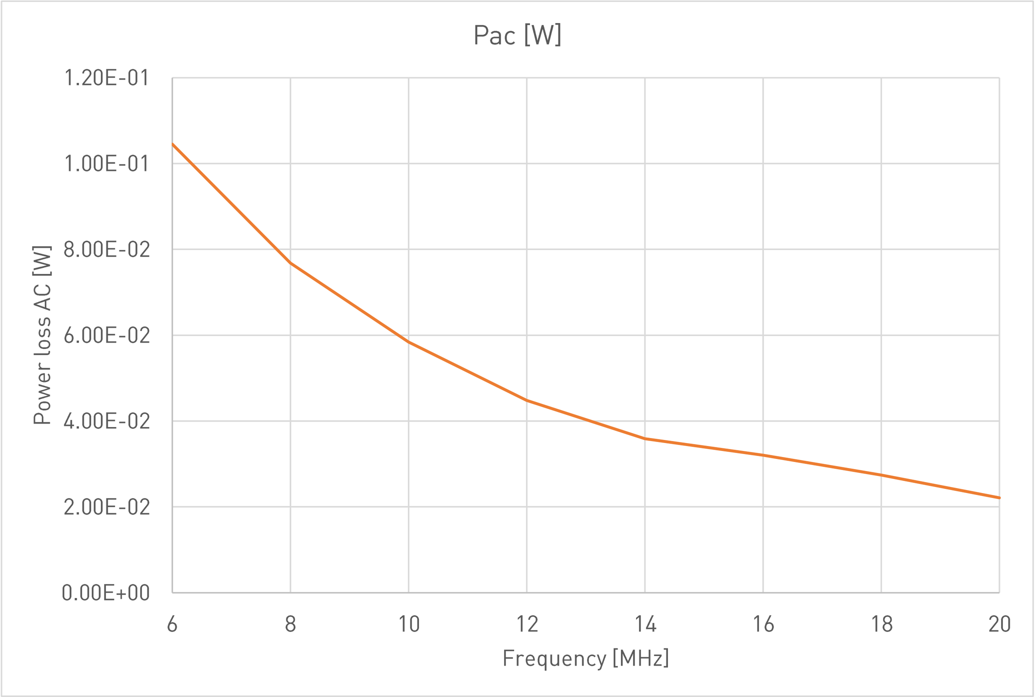
Inductor V/I waveforms





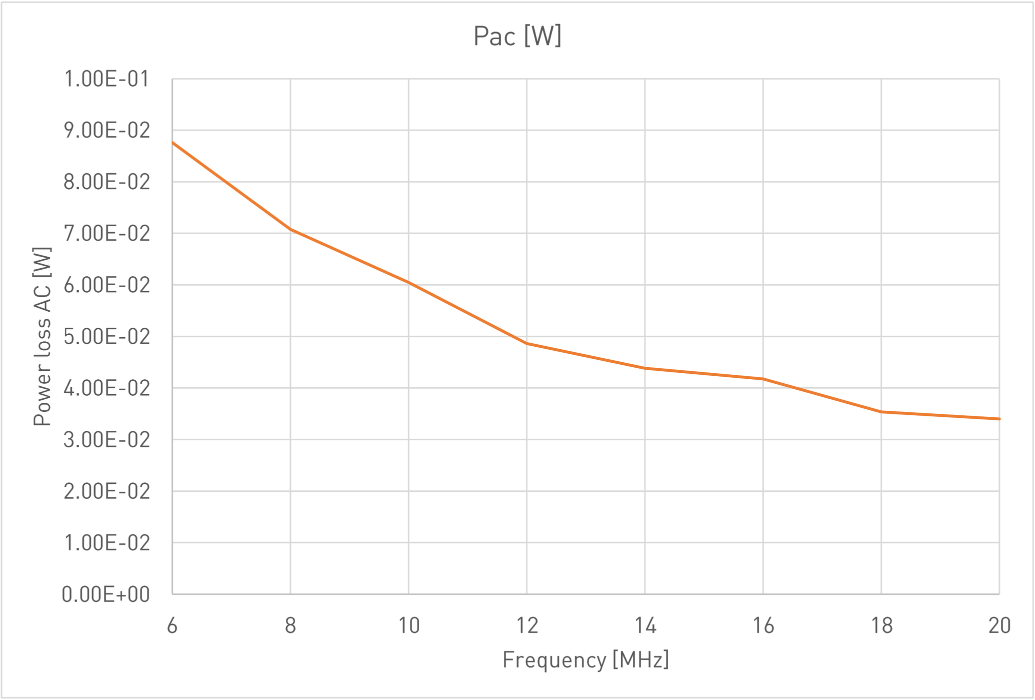
Inductor A

AC losses vs frequency



Inductor B

AC losses vs frequency



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Interpretation

For a given inductance, the ripple current decreases with an increasing switching frequency.

Inductor A (aircore)

- AC Power losses are determined by the total resistance (DC resistance and skin effect) and the RMS current.

Inductor B (ferrite core)

- AC Power losses are determined by the ferrite core losses, which depend largely on the current ripple magnitude.

Conclusion

Conventional inductor loss measurement use small signal impedance analysis, at sinewave excitation [1] or core loss estimation through B-H curve measurement [2]. These methods do not reflect the actual power conversion application with hard-switched waveforms.

The proposed method provides the power designer the proper data to maximally optimize its converter design: inductor power loss, inductance, dynamic saturation, self-heating prediction, … at any given operating point.

References

[1]http://cp.literature.agilent.com/litweb/pdf/5950-2367.pdf
[2]https://www.iti.iwatsu.co.jp/en/products/sy/bh_ana_e.html
[3]http://worldwide.espacenet.com/publicationDetails/biblio?CC=WO&NR=2013110145A1&KC=A1&FT=D