Micro-fabricated inductors on silicon for DC-DC converters operating at tens MHz

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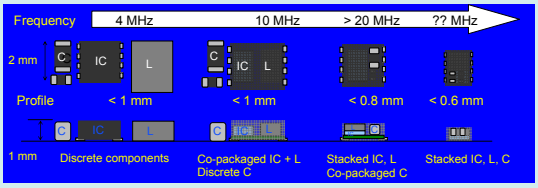
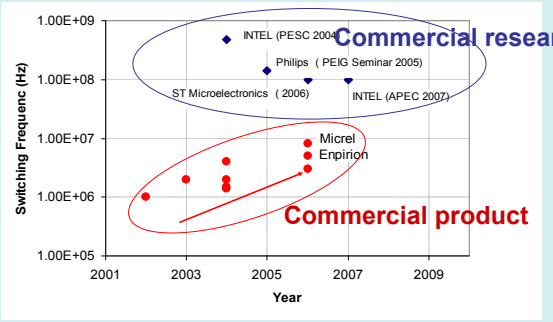
Background

Context : Miniaturisation and integration of power supply for portable electronics

- Magnetic component is largest part of the power supply and is typically not integrated
- Conventional magnetic components are difficult to miniaturise and integrate
- With technology developed in Tyndall magnetic components can be integrated on to Si
- Lead the way towards "Power Supply on Chip"





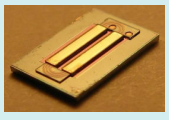
Current trends of increased switching frequency in low power dc/dc converter applications

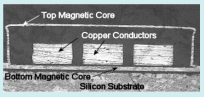
Modelling

- Analytical model developed for micro-inductors:
  - o Winding ac and dc resistance
  - o Core eddy current loss
  - o Core hysteresis loss
- Analytical model employed in device design and optimisation

Fabrication

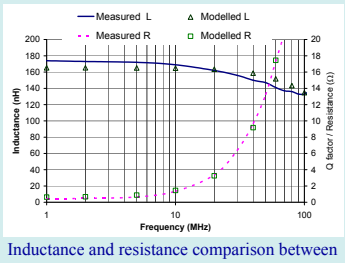
- Integrated on Si using MEMs type fabrication techniques
- High Aspect Ratio Cu coils sandwiched between magnetic cores
- Electroplated thin film $Ni_{45}Fe_{55}$ Cores
- Extreme low profile (0.15mm) and high power density



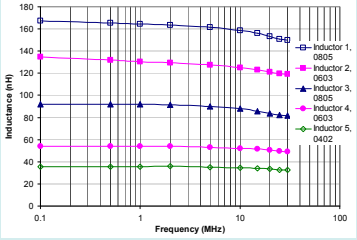


Results

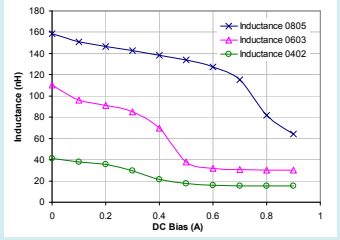
- Device size:
  - o 0.50 mm² (0402)
  - o 1.28 mm² (0603)
  - o 2.50 mm² (0805)
- R_{DC}: 0.08 - 0.79 Ohm.
- L: 20 – 200 nH
- Isat: up to 500mA



Inductance and resistance comparison between model and measurements



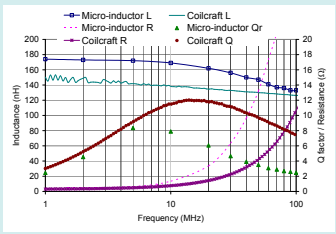
Measured inductance VS. frequency



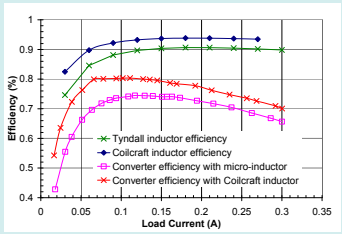
Measured inductance VS. DC bias current at 20MHz

Converter Performance with Micro-inductors

Converter Specifications: V_{in} = 3.0V, V_{out} = 1.5 V, Frequency = 20 MHz



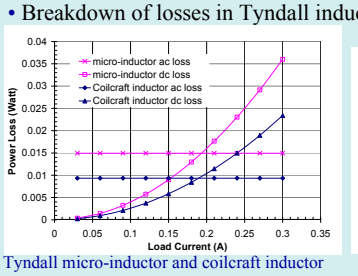
Inductance and resistance comparison between Tyndall inductor and Coilcraft inductor



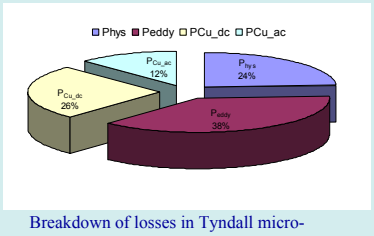
Tyndall micro-inductor tested against commercial chip inductor alternatives in a dc/dc converter.

Inductor Performance Analysis

- Peak Efficiency
  - o Converter peak efficiency: 80.3% using Coilcraft inductor and 74.5% using Tyndall inductor
  - o Inductor peak efficiency: 93.8% for Coilcraft and 90.6 for Tyndall inductor
- Losses of Coilcraft inductor calculated using provided S parameters
- Losses of Tyndall inductor calculated using measured R and L
- Breakdown of losses in Tyndall inductor at I_{load}=0.12 A



Tyndall micro-inductor and coilcraft inductor loss analysis for 20MHz operating frequency.



Breakdown of losses in Tyndall micro-inductor for 0.12 A dc current

Conclusions

- Micro-inductors can be integrated on Si with low DC resistance and maintain inductance design values up to 20 MHz.
- An Analytical model for micro-inductors has been developed and has been validated using measurements
- Tyndall micro-inductor has been implemented in a high frequency dc/dc converter and performance is comparable to commercial chip inductors

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