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Microtransformer for Point-of-Load High Frequency DC-DC Converters

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Abstract

- In this presentation, the design, fabrication, and characterization of on silicon integrated micro-transformers for high switching frequency power applications is shown.
- Microtransformer device has stable L vs. f characteristic up to 50 MHz.
- The microtransformer shows an inductivity of about 50 nH, and electrical resistance of 350 mΩ and can be applied for current higher than 1 A.
- The microtransformer device is tested in DC-DC buck converter MDCD073 at switching frequencies between 15 MHz and 30 MHz.
- The system efficiency of almost 80% was achieved with this device.

Introduction

- An increasing trend in power electronics is miniaturization of passive components, like inductors or transformers, for achieving a higher power density and to increase the functionality and mobility [1].
- A permanent increase of a switching frequency of electronic power circuits set new requirements on inductive components in regard to the size, inductance, and current capability.
- A method for miniaturization of passive components is increasing the switching frequency [2, 3] in the range of a few MHz to much higher frequencies.
- On the market are recently available commercial DC-DC converters with switching frequency of 20 MHZ.
- Decreasing of inductance causes a decreasing of the inductor size, profile height, therefore in thin-film micro-inductors and micro-transformers are ideal components for fulfill these issues [4].

Design

- The microtransformer design is shown in the Fig. 1.
- For design of the micro device Finite Element Method (FEM) with software tool Ansys Maxwell® is applied.
- Device footprint is 2.5mm x 2 mm.
- One coil consists of 5 turns with cross-section of 60 µm x 20 µm.
- Magnetic core has a thickness of 10 µm

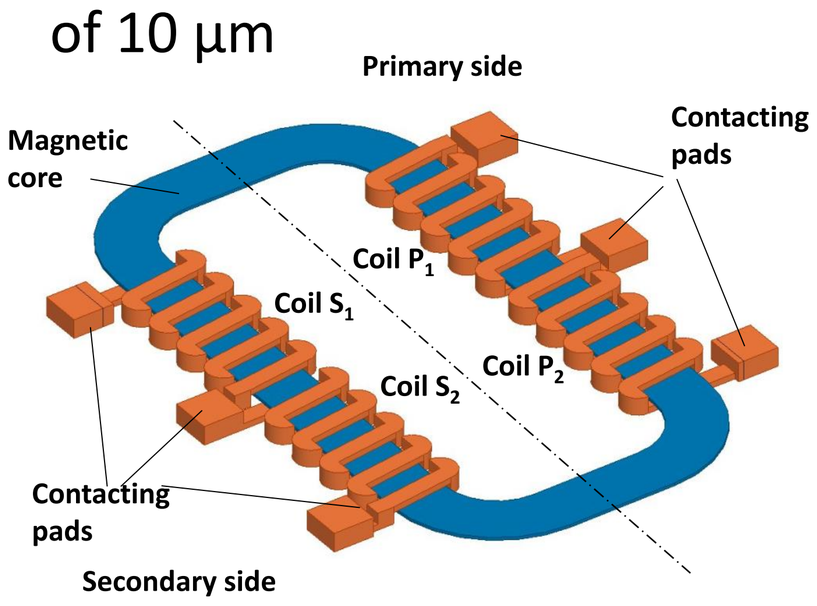

Fig.1: Proposed design of adjustable magnetic device

Fabrication

- The micro transformer is fabricated using high aspect ratio microstructure technology (HARMST)
- Process steps are shown in the Fig.2. Detailed fabrication process is described before [5].
- Electroplated CoFe alloy was used for fabrication of a magnetic core.
- Coils were fabricated using tick Cu electroplating.
- As an insulation and embedding material, a polyimide is applied
- Completed device is shown in the Fig.3.

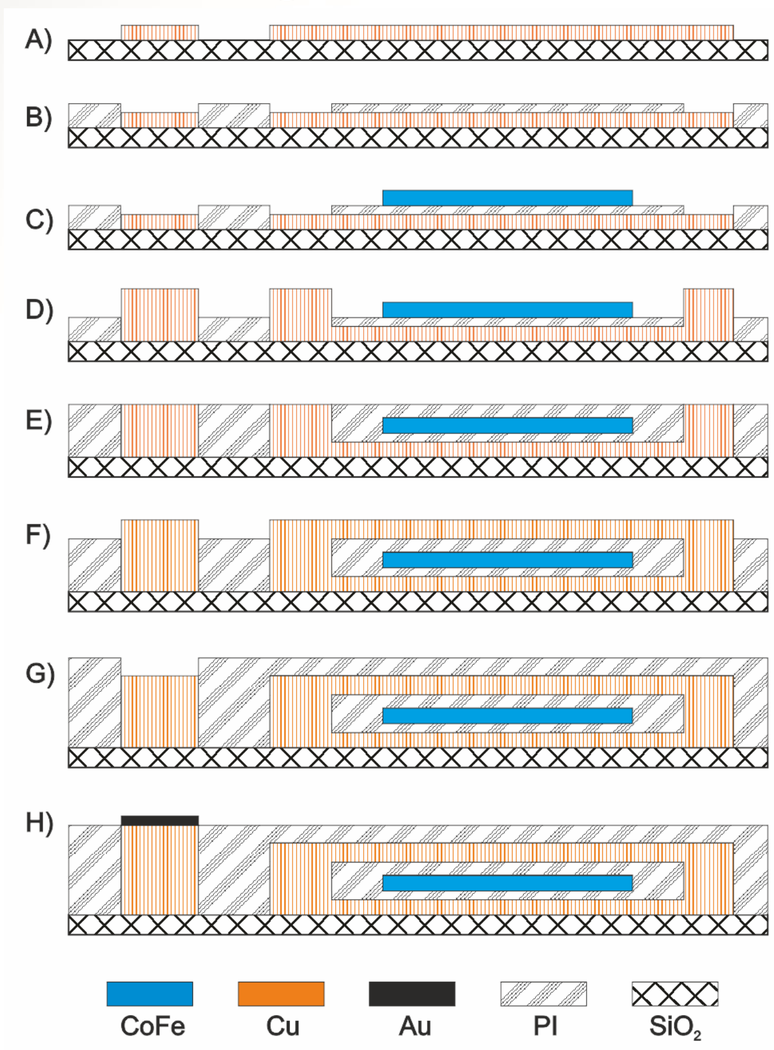

Fig.2: Process flow of micro-transformer device

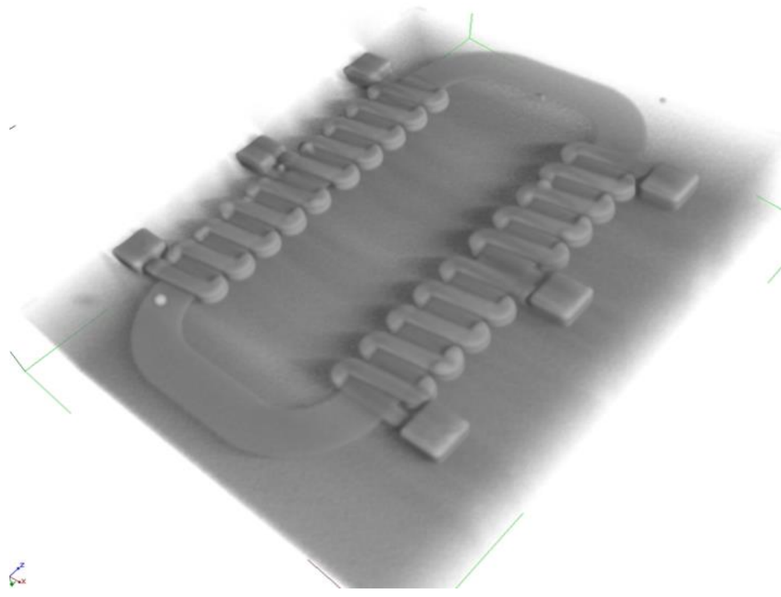

Fig.3: x-ray micrograph of completed microtransformer device

Test Results

- Figure 4 shows characteristics of an inductance and electrical resistance as a function of frequency.
- The measured electrical resistance of whole system is about 350 mΩ.

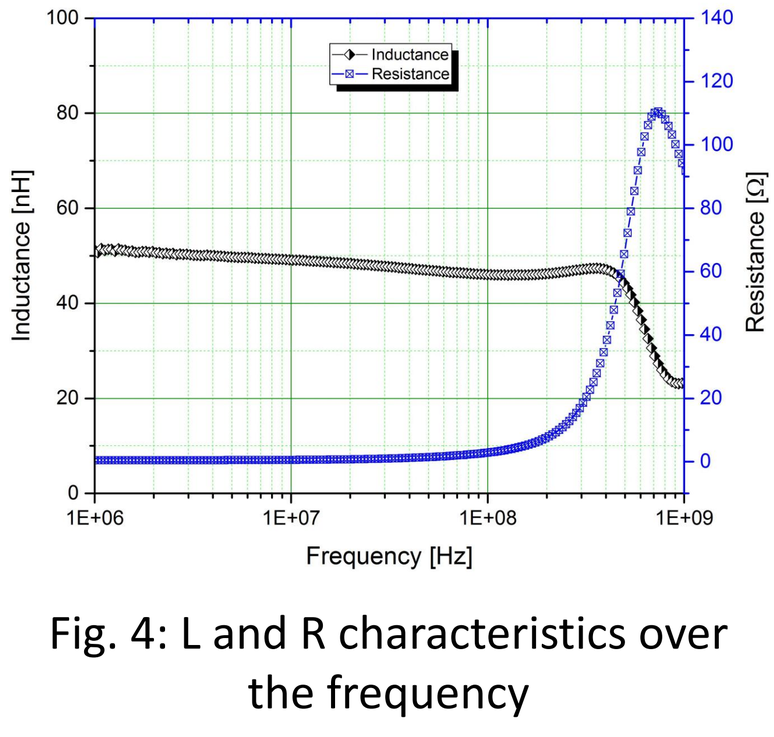

Fig. 4: L and R characteristics over the frequency

- The inductance is stable up to frequencies higher then 50 MHZ

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Test Results

- Figure 5 shows DC-Bias characteristics Isat and rated current Ir of microtransformer.
- The saturation current Isat of microtransformer is higher than is 1 A.
- Maximal Q-factor is 11 at frequency of 70 MHz (Fig. 6)

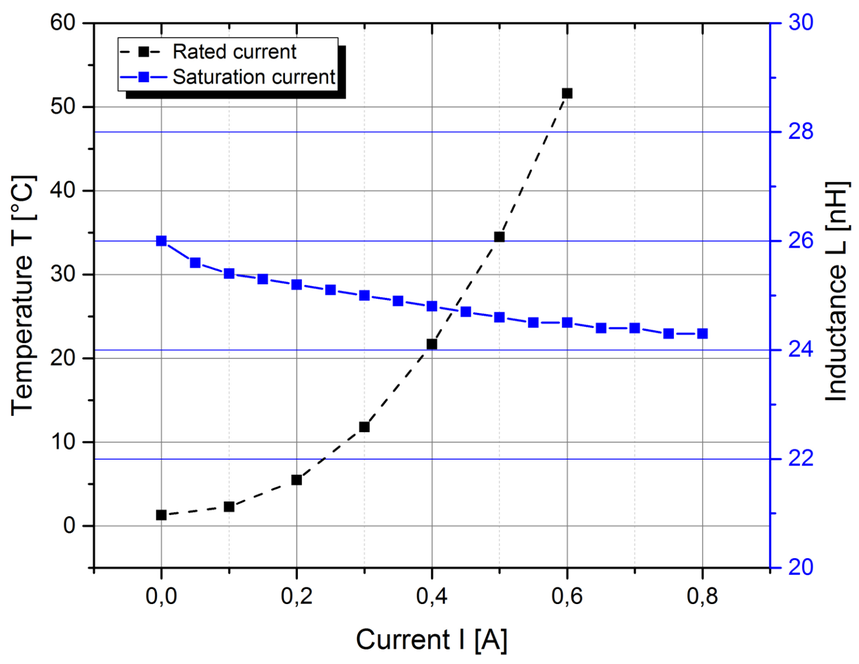

Fig.5: Inductance-Frequency behavior

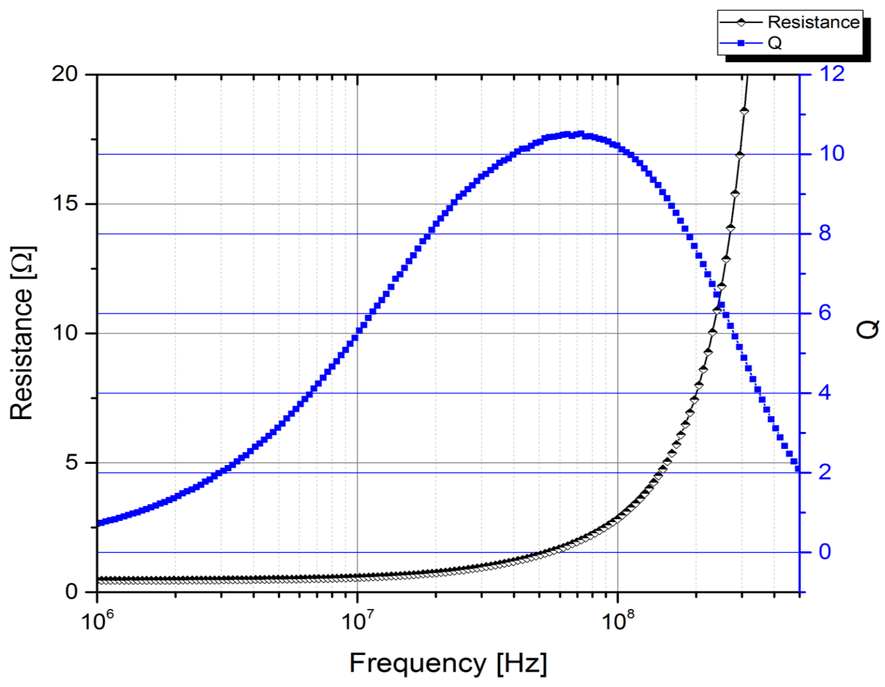

Fig.6: Rdc and Q-factor vs. frequency of microtransformer

- Microtransformer samples are tested in HF buck DC-DC converter.
- Switcher MDCD073 a dual 7V PN half bridge with pre-drivers in 180 nm SOI technology is developed and applied for testing of micro device (Fig. 7).
- Efficiency of almost 80% by is measured at switching frequencies between 15 MHz and 30 MHz (Fig. 8).
- Core loss of microtransformer shows the value of about 100 mW.

Test Results

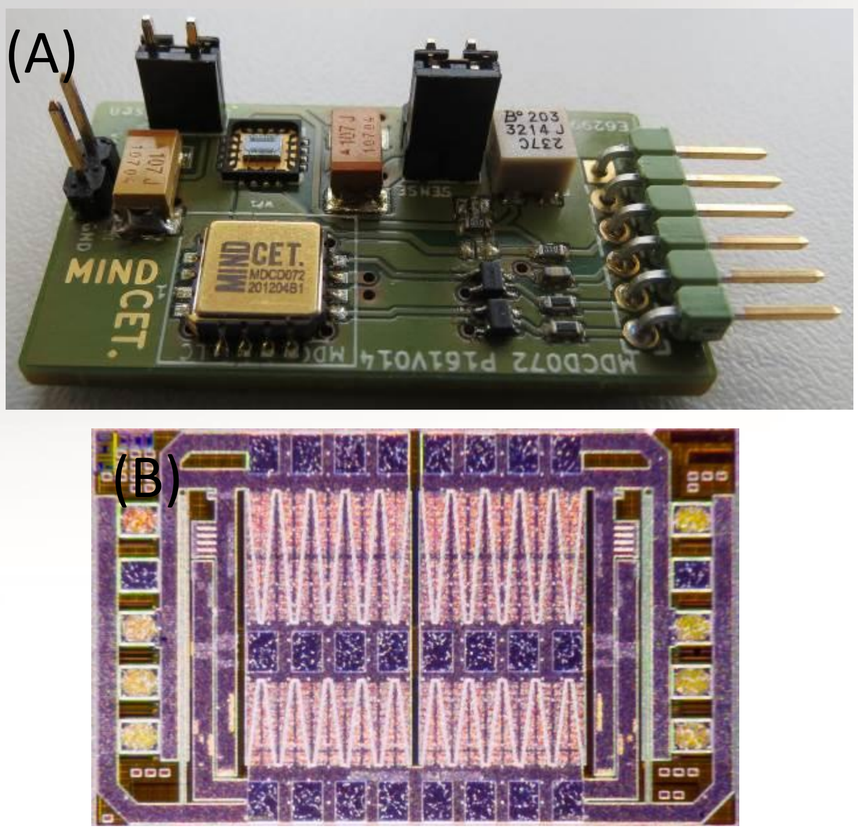

Fig.7: MCDC073 DC-DC Buck controler (a) and ASIC chip used for efficiency measurements (b)

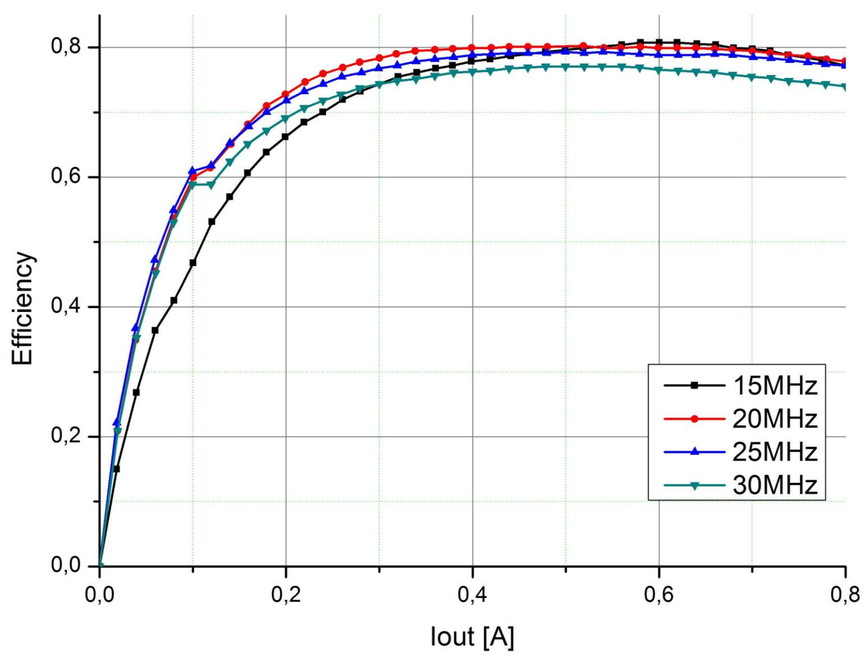

Fig.8: Efficiency measurement for input voltage 3.6 V and output voltage 2.5 V

Packaging

- Two packaging approach were already tested
  - WLP (eWLB)
  - Embedding in PCB
- Package size: 3.2mm x 2.3mm x 1mm
- Design of both packages are shown in the Fig.6.

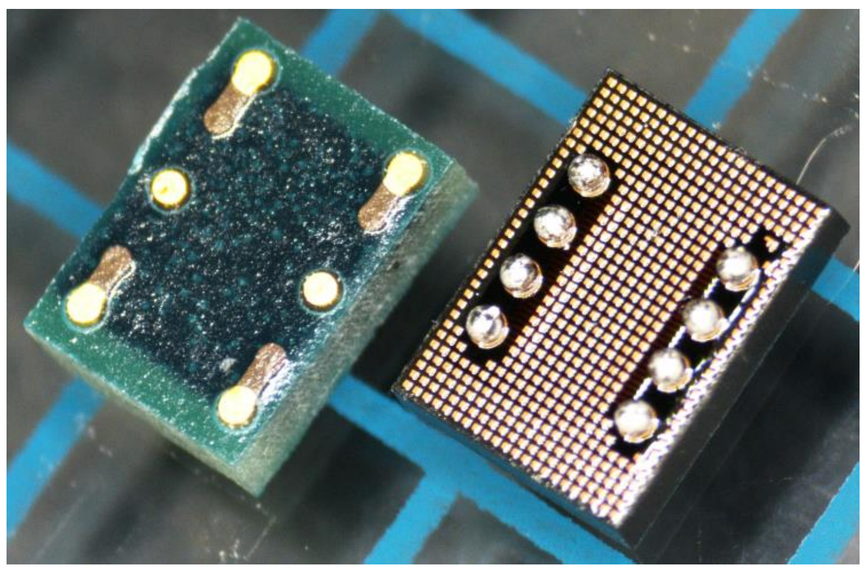

Fig.9: Packaging approach for microtransformer devices

Conclusion

- Microtransformer with improved performance was completed using thin-film technology.
- The device shows stable inductance characteristic up to frequencies higher than 50 MHz.
- The maximal inductance of device is about 50 nH
- Efficiency of almost 80% was realized with microtransformer device and MCDC073 ASIC in DC-DC Buck application at frequencies between 15 and 30 MHZ.
- Recent developments are focused on packaging of the transformer and integration with the ASIC chip.

Acknowledgment

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