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Development of High Efficiency Integrated Micro-transformers on Silicon for Power & Signal Isolation

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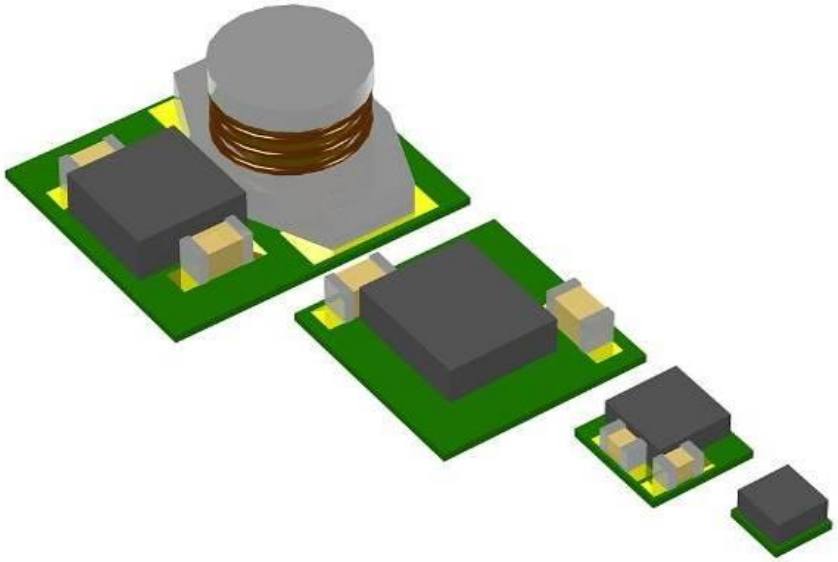
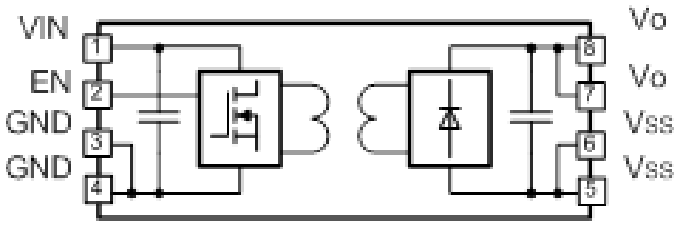
Background & Motivation



Footprint (mm^2)	Volume (mm^3)	Frequency MHz
50	150	**1**
30	25	**5**
7.0	3.5	**20**
2.0	**1.0**	**50-100**



Isolated Integrated bias supply

Isolated Converter Specs

Switching Frequency	20 MHz
Turns ratio	1:1
Footprint	<4 mm^2
Input Voltage	5V
Output Voltage	5V
Load Current	100 mA

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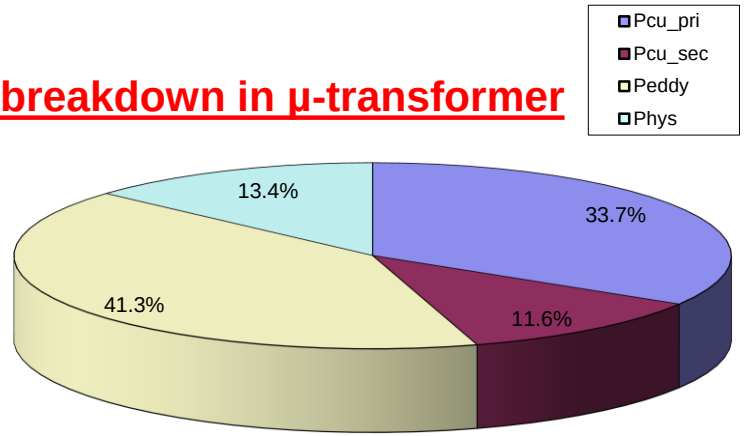
µ-transformers on Silicon technology- Design & Optimization

- In-house optimization tool
- Racetrack structure
  - higher magnetizing inductance
  - good coupling factor
  - anisotropic core
- $Ni_{45}Fe_{55}$ as core material

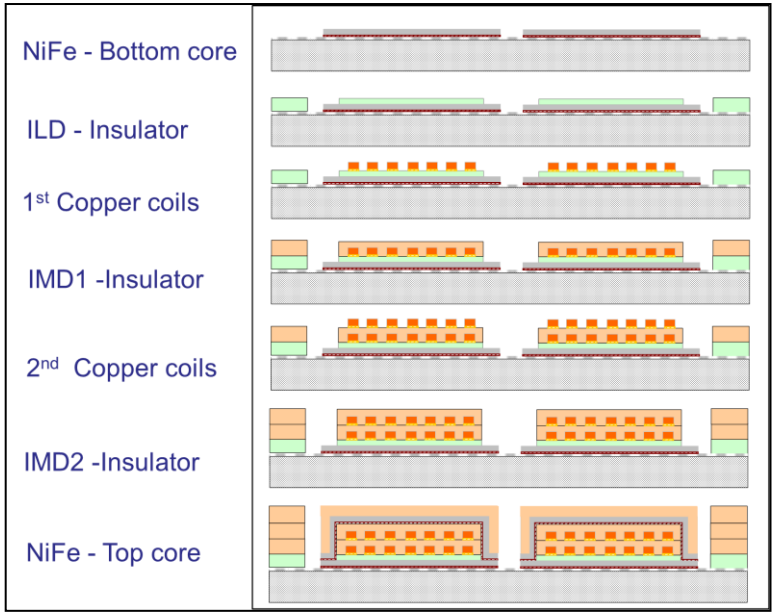
Schematic of racetrack structure

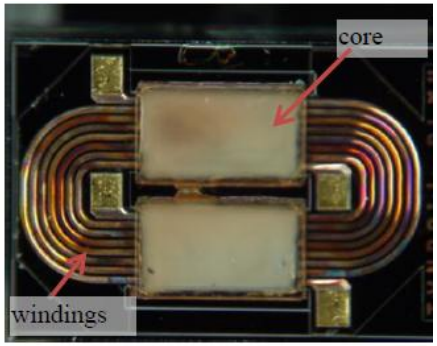
Transformer Prototype	Design 1	Design 2
Winding width, µm	40	45
Winding thickness, µm	15	15
Winding spacing, µm	15	15
Turns ratio,	6:6	7:7
Core thickness, µm	4.1	4.1
Core length, mm	1.32	1.58
Device length, mm	2.59	3
Device width, mm	1.15	1.35
DC resistance, Ohm	1.1	1.33
Inductance at 20MHz, nH	210	280

Loss breakdown in µ-transformer

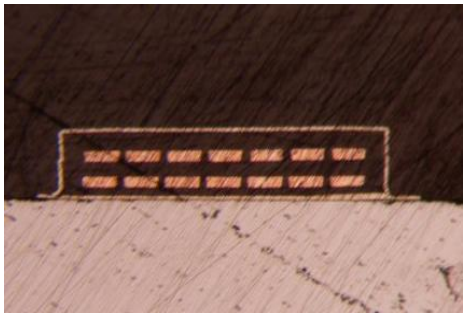


μ-transformers on Silicon technology- Fabrication & Characterization

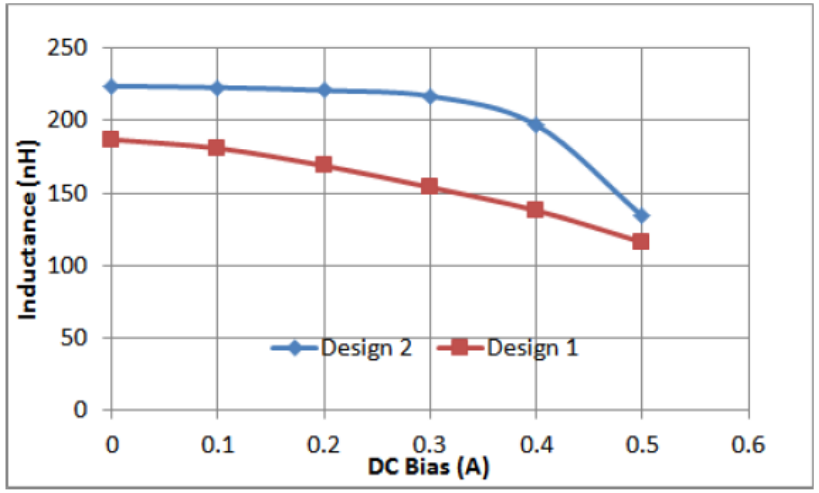


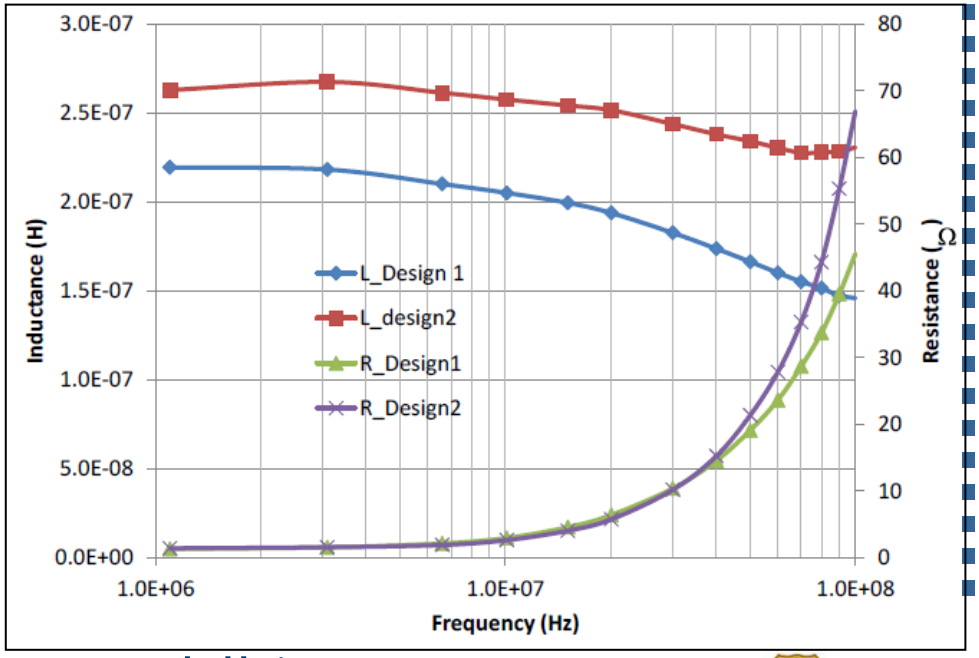


Top View



Cross-section





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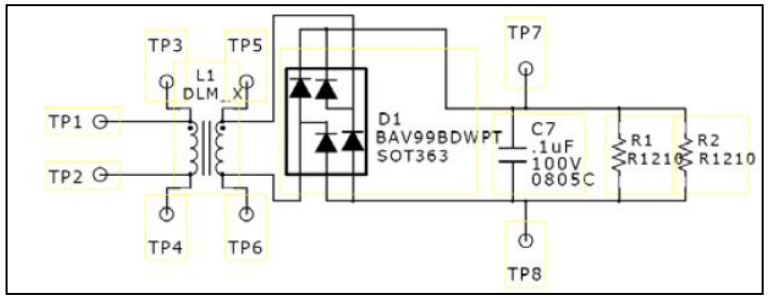
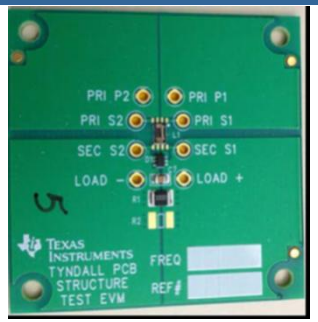
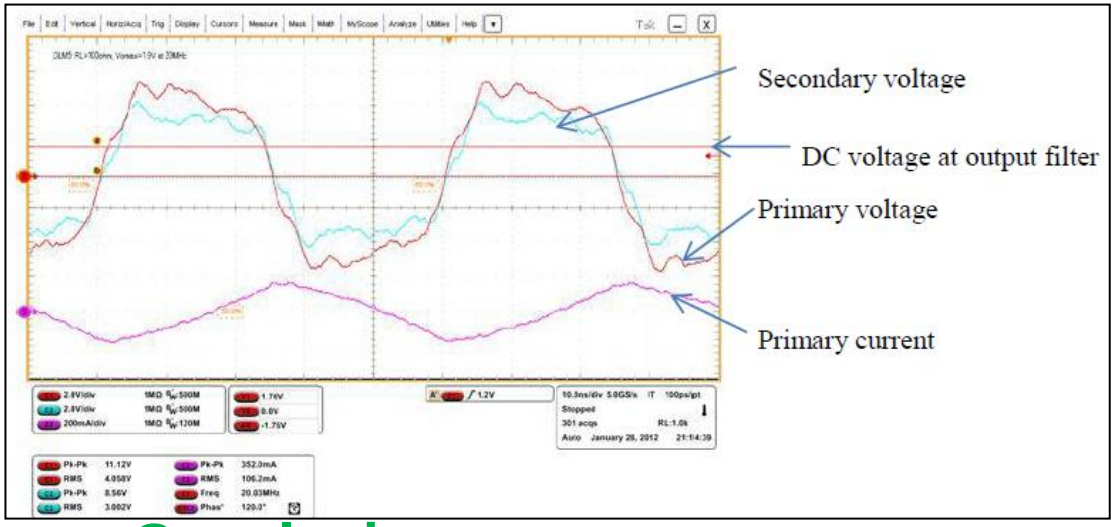
µ-transformers on Silicon technology- Converter tests & Conclusion







Converter test results

Technology	Air-core	This Work
Footprint	2mm^2	3mm^2
Inductance	8 nH	270 nH
Inductance density	17nH/mm^2	80nH/mm^2
Frequency	180 MHz	20 MHz
Coupling	0.85	0.97
Efficiency	70%	78.2%

Conclusions

- ✓ *Batch micro-fabricated transformers with advanced double layer metal process*
- ✓ *High Voltage Gain >-1dB at 10~40MHz*
- ✓ *High measured efficiency of 78% at 20MHz*
- ✓ *Higher converter efficiency @ 20MHz (> 60%) than air-core based solutions*
- ✓ *Small footprint area (<3mm^2); Power density- 110 W/cm^3*

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