INTEGRATED DC-DC CONVERTERS USING THIN-FILM MAGNETIC POWER INDUCTORS

DE-SC0009200

11/15/2012 THROUGH 05/14/2015

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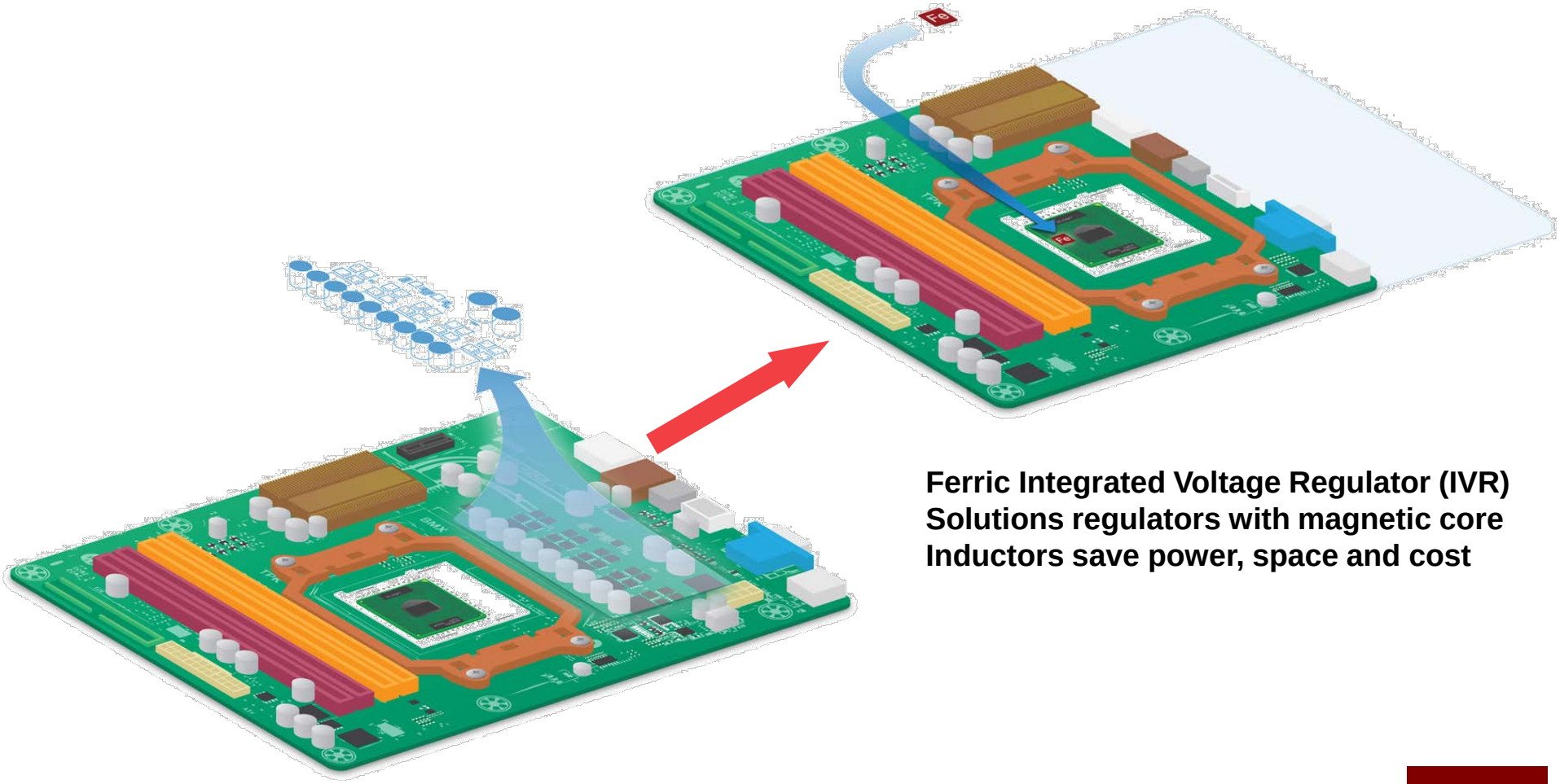
FERRIC TECHNOLOGY

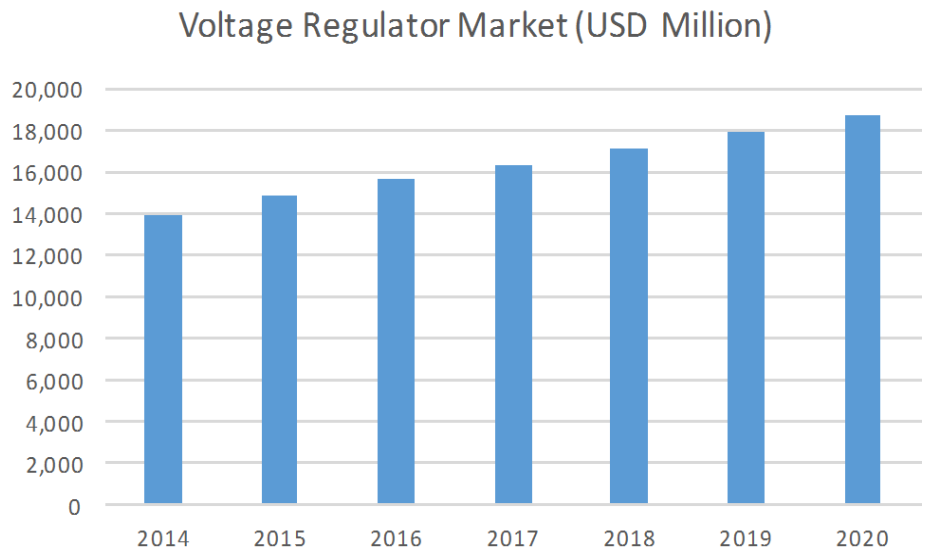
On-chip Magnetic Thin-Film Inductors Save Power, Space And Cost



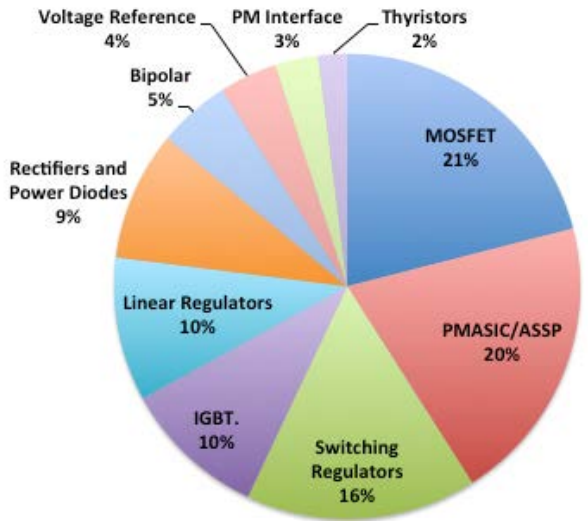
Ferric Integrated Voltage Regulator (IVR) Solutions regulators with magnetic core Inductors save power, space and cost

FERRIC IS ADDRESSING THE $15B/YR SWITCHING VOLTAGE REGULATORS MARKET

- Worldwide market for Power Electronic products growing to $50B in 2020
- Market for Switching Voltage Regulators is growing to be 18-20% of Power Management market: forecast to be more than $18B in 2020



Worldwide Power Management Semiconductor Market Share Forecast by Device (2010 Percentage Share Revenue in US Dollars)



Source: Ohr, S. (2015). Competitive Landscape: Standard Power Management IC Vendors, Worldwide, 2015, Gartner.

FERRIC
THE COMPANY

- Fabless semiconductor technology company, founded in 2011
  - Located in New York City
- Integrated magnetic component and power conversion technology
- Licensing partnership with TSMC
- Team expertise:
  - semiconductor device manufacturing
  - magnetic thin-films
  - RF device design, characterization and modeling
  - CMOS IC design for power conversion applications
- Chip Sales, Design IP and Process Licensing

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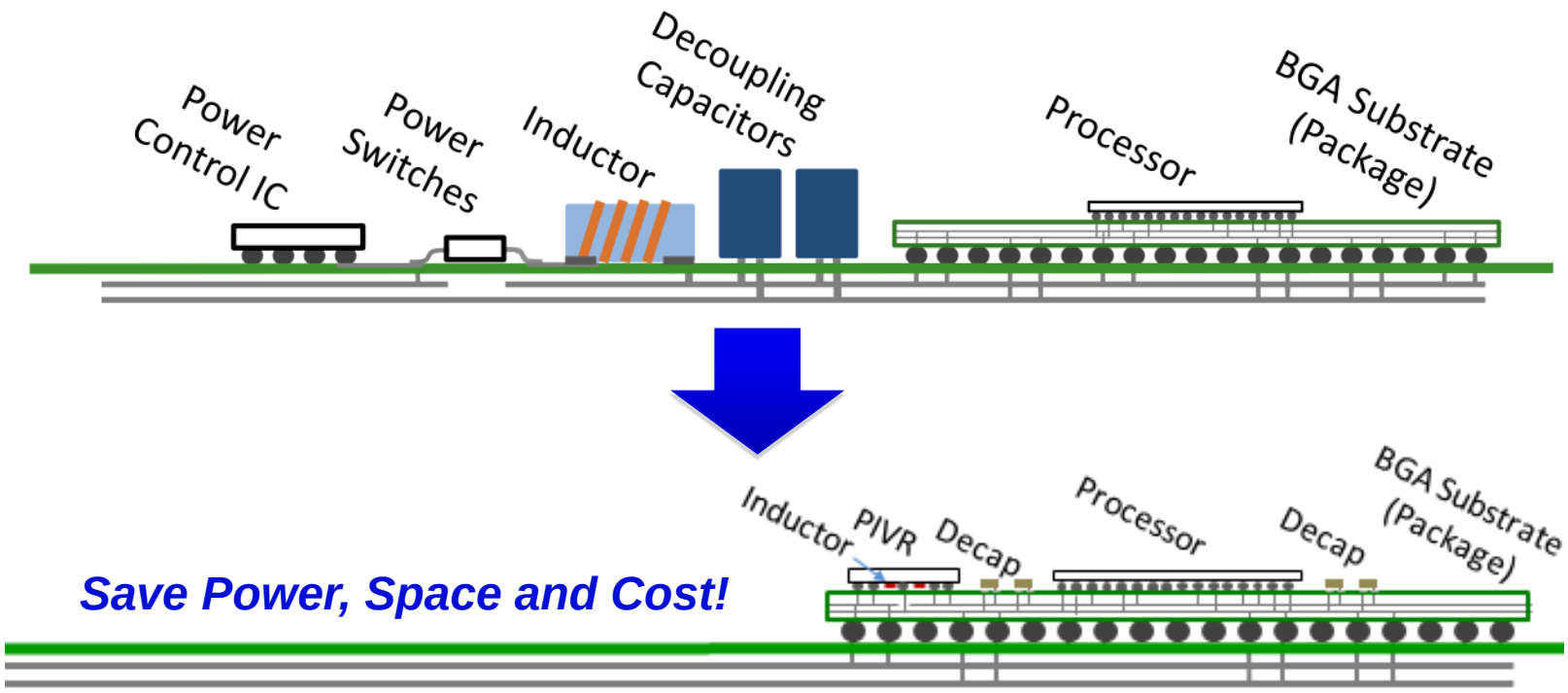
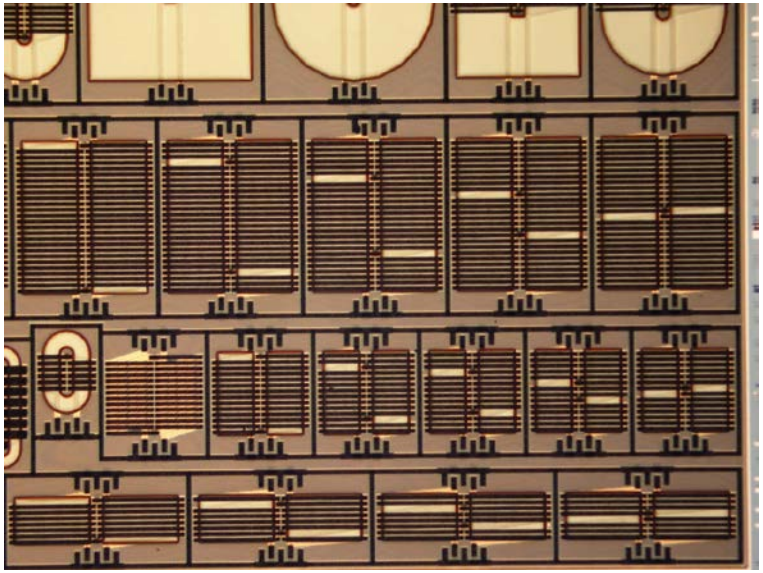
INTEGRATED VOLTAGE REGULATION

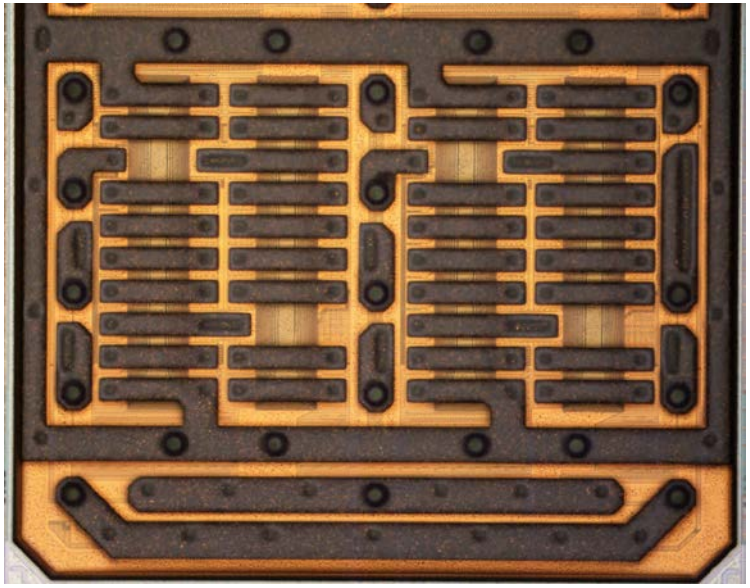
- High power density (10W/mm^3) low voltage (< 12V) DC-DC converters
- Reduce I^2R losses associated with high current levels in microprocessors
  board + socket + package
- Enable delivery of many independently scalable supplies, taking advantage of power savings from fine-grain DVFS



FERRIC TECHNOLOGY ELEMENTS

- **Integrated Inductors**
  - Inductance density
    - > 300nH/mm^2, > 8,500nH/mm^3
  - Current density > 12A/mm^2
  - DC Resistance < 100mΩ
  - Magnetic Coupling k > 0.95
- **Integrated Circuit Designs**
  - High switching frequency
  - High bandwidth controller
  - Optimization for high efficiency
  - Optimization for high density

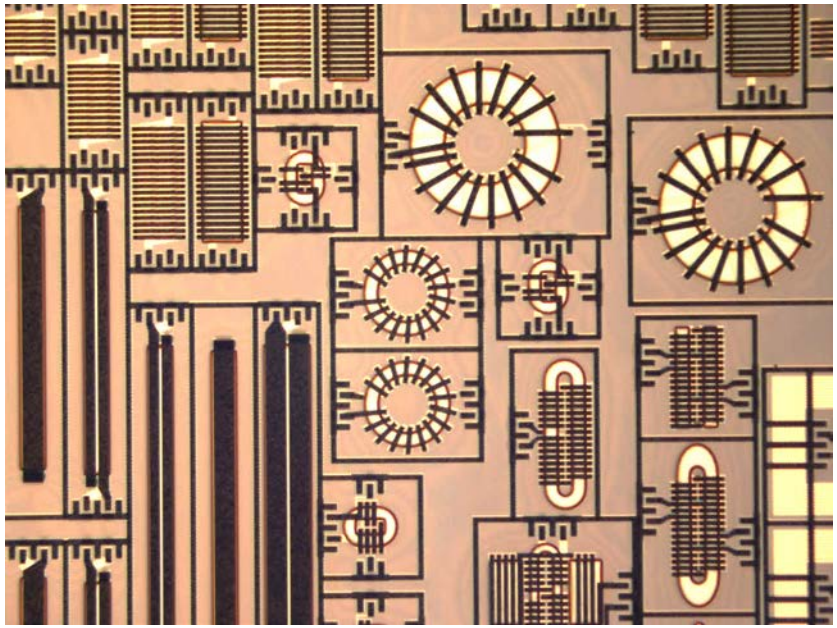


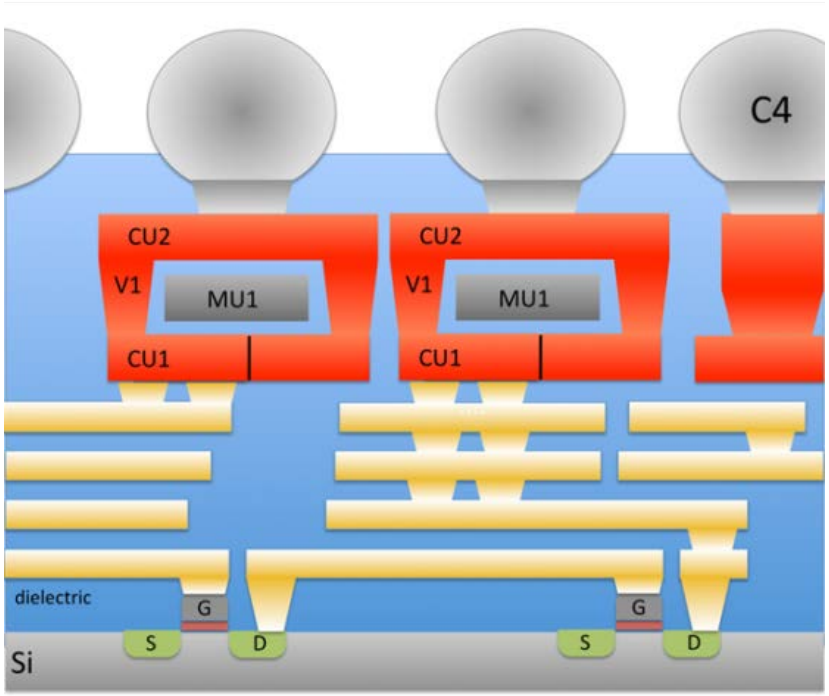


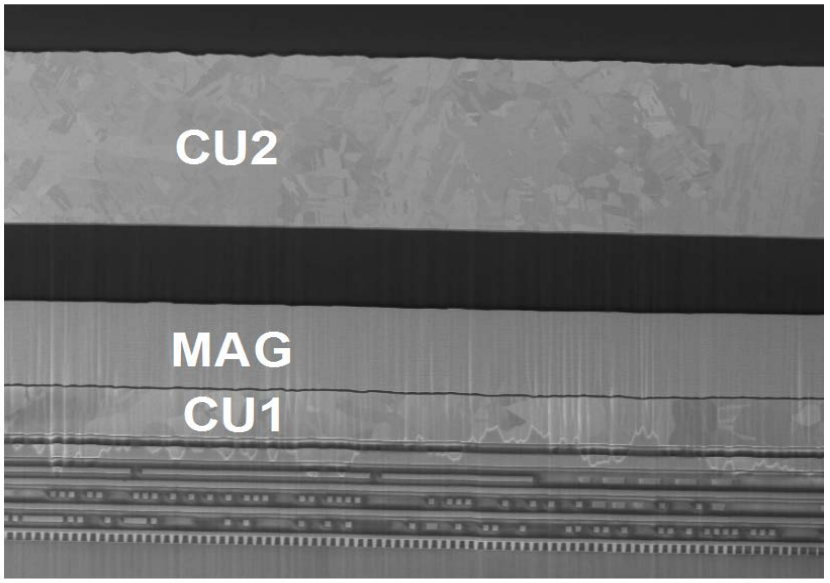
FERRIC INDUCTORS

Ferric CMOS integrated magnetic thin-films enable high-quality, high density, low-profile on-chip/on-package inductive components

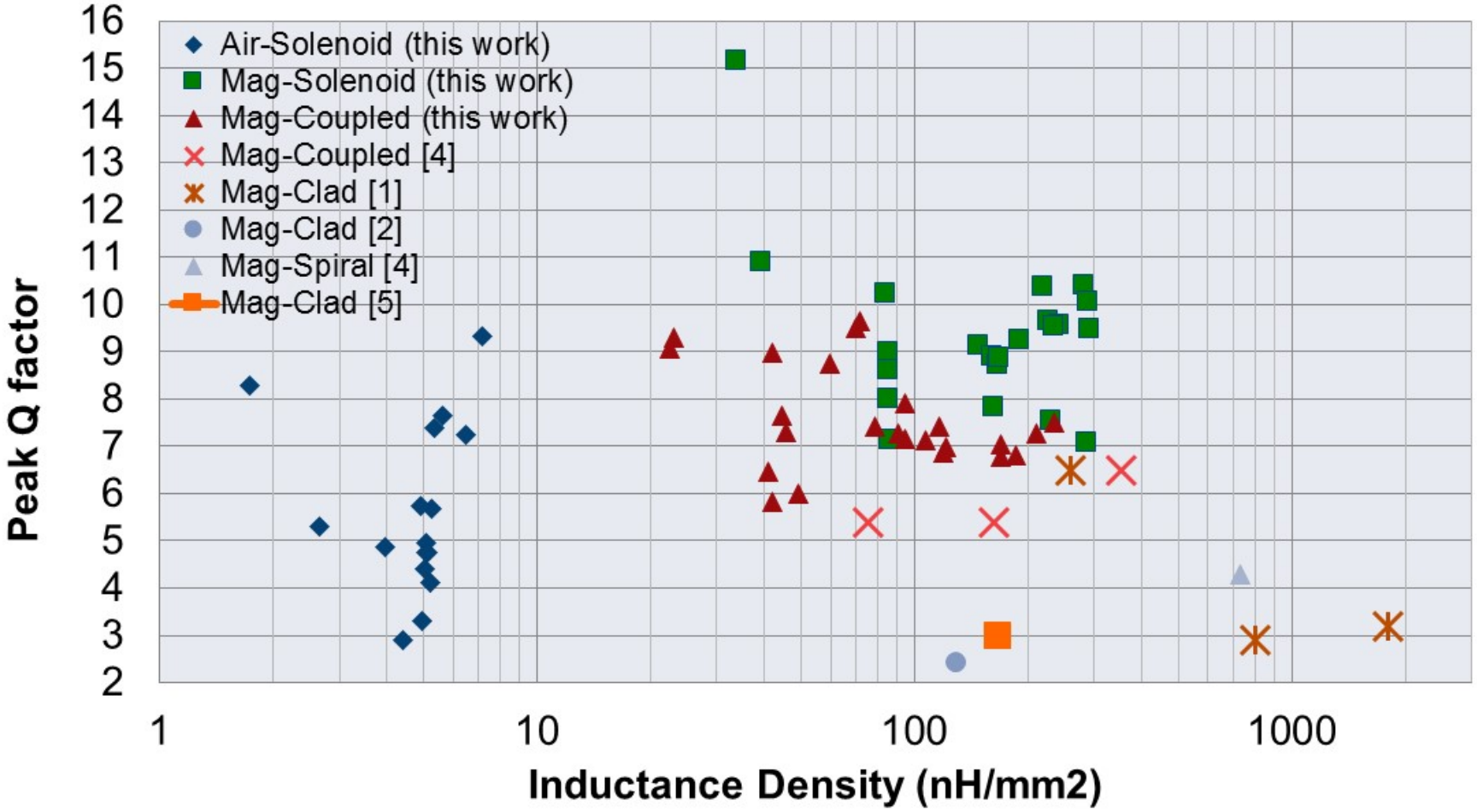
- **Proven Technology**
- **Integrated with Standard CMOS Flow**
  - Inductor layers available as BEOL process option (similar to MIM)
  - Circuit models, LVS, DRC







FERRIC INDUCTORS | *ELECTRICAL PERFORMANCE*



[1] D. S. Gardner et al., IEEE Trans. Magnetics, vol. 45, no.10, 2009
[2] N. Wang et al., J. Appl. Phys. 111, 07E732, 2012.
[3] J. Mullenix et al., IEEE Trans. Magnetics, vol. 49, no.7, 2013
[4] Z. Ni et al., IEEE Trans. Electron Devices, vol.60, no.4, 2013
[5] P. Morrow et al., IEEE Trans. Magnetics, vol.47, no.6, 2011

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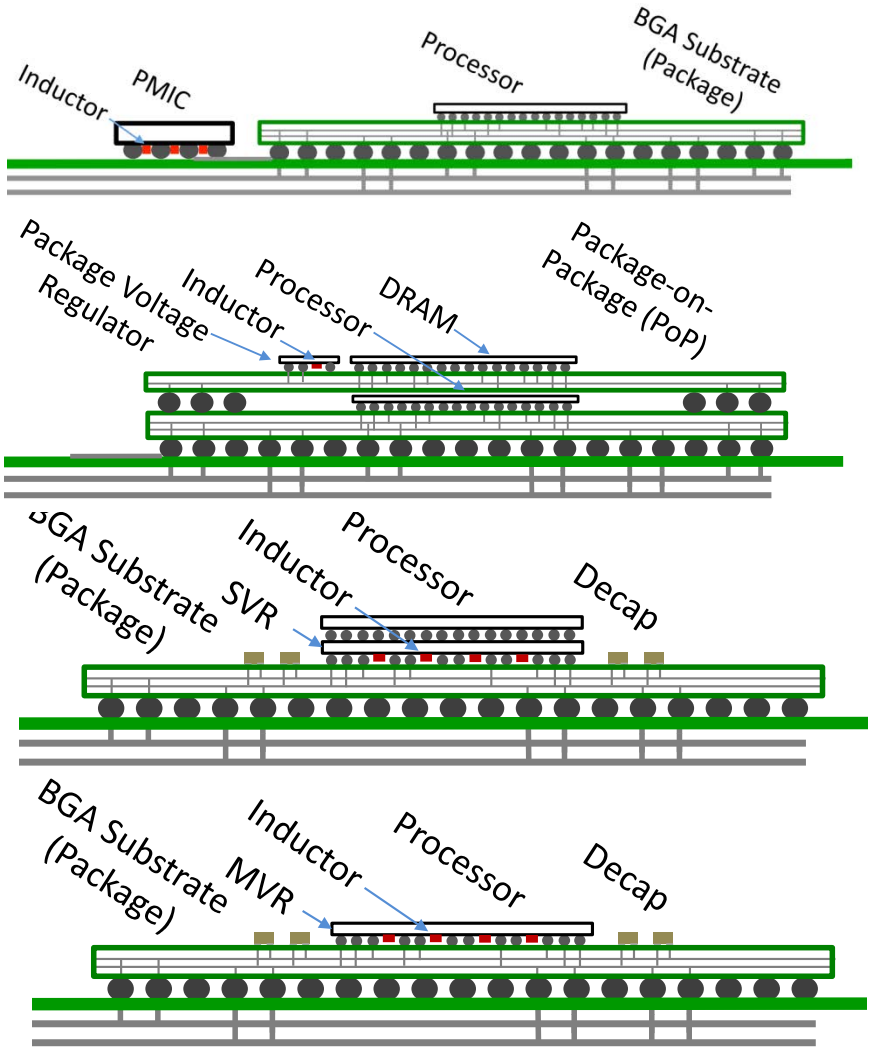
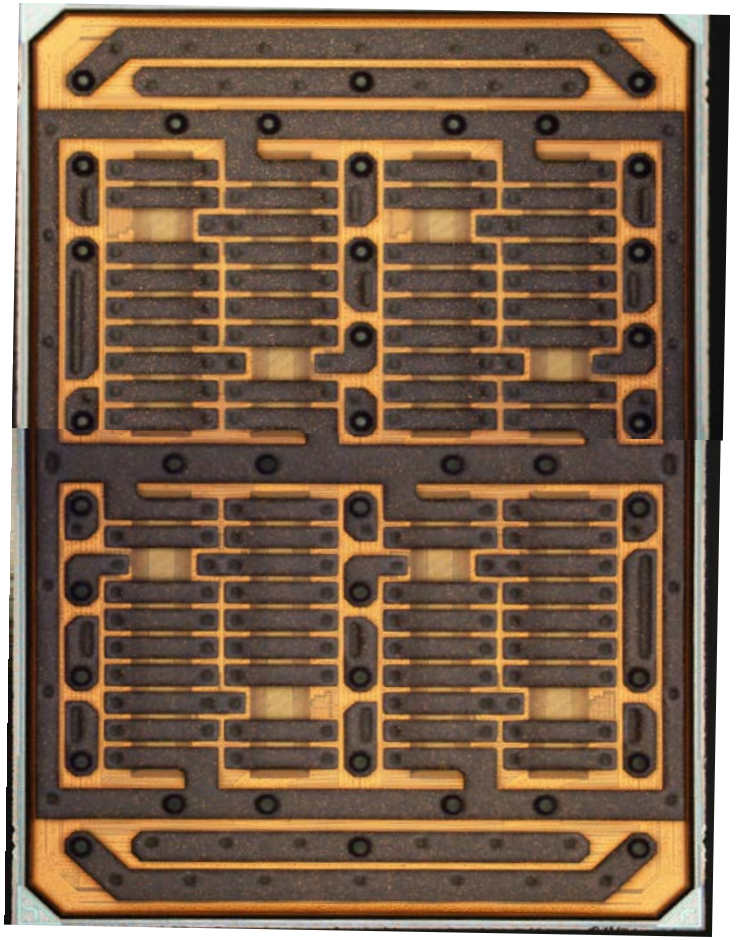
FERRIC TECHNOLOGY | PRODUCT IMPLEMENTATION



- Power Management IC (**PMIC**)
- Package Integrated Voltage Regulators (**PVR**)
- Interposer or IPD Voltage Regulator
- Monolithic Integrated Voltage Regulator (**MVR**)

FERRIC CIRCUITS

Ferric thin-film power inductors integrated with TSMC CMOS enable efficient, high density on-chip/on-package DC-DC power conversion



Provides multiple options for true Point-of-Load power conversion for ICs

- Improve voltage regulation (broadband power supply impedance as-low-as 500μΩ)
- Improved energy efficiency with enhanced power management (DVFS and reduced DC power margins)
- Reduced current levels in upstream PDN (board, socket, package)
- Reduced board-level power conversion BOM and area

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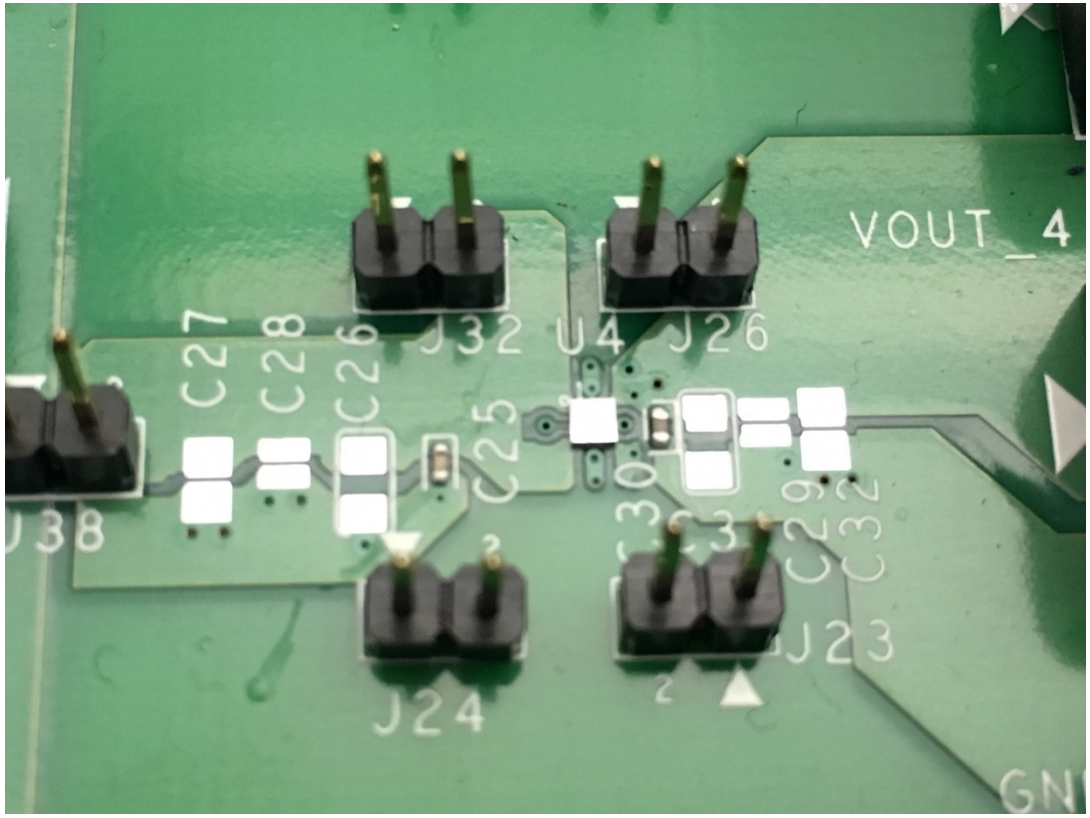
FERRIC CIRCUITS | BOOST CONVERTER

- Total Solution Size: 2.5mm^2
  - 1x Dachshund Chip (1x 1.5mm^2)
  - 2x 0402 Discrete Capacitors(2x 0.5mm^2)



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PROJECT MANAGEMENT & BUDGET

- This development project has been active since 2013 and will continue until Ferric IVR technology sees wide scale commercial adoption
- U.S. Department of Energy (DE-EE0002892)

Milestone	Timeframe	Financing Approach	Received/Anticipated funding
A. Magnetic thin-film process development on large wafers	Q1–Q2'13	DOE SBIR Phase I	150,000
B. Development of PVR products with integrated magnetic inductors	Q3'13 – Q3'16	NSF SBIR Phase II	750,000
C. Technology transfer to major foundry	Q3'14 – Q2'16	Venture Capital DOE SBIR Phase II	500,000 750,000
D. Development and Qualification of advanced IVR circuits and systems	Q2'14 – Q3'16	Venture Capital NSF SBIR Phase IIB	1,000,000 750,000
E. Development, Productization and marketing of PVRs, IPDs and other technology implementations	Q2'16 – Q4'18	Venture Capital, DOE SBIR Phase IIB	3,000,000 1,000,000