

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

**DE-SC0009200**

**11/15/2012 THROUGH 05/14/2015**

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U.S. DOE Advanced Manufacturing Office Program Review Meeting

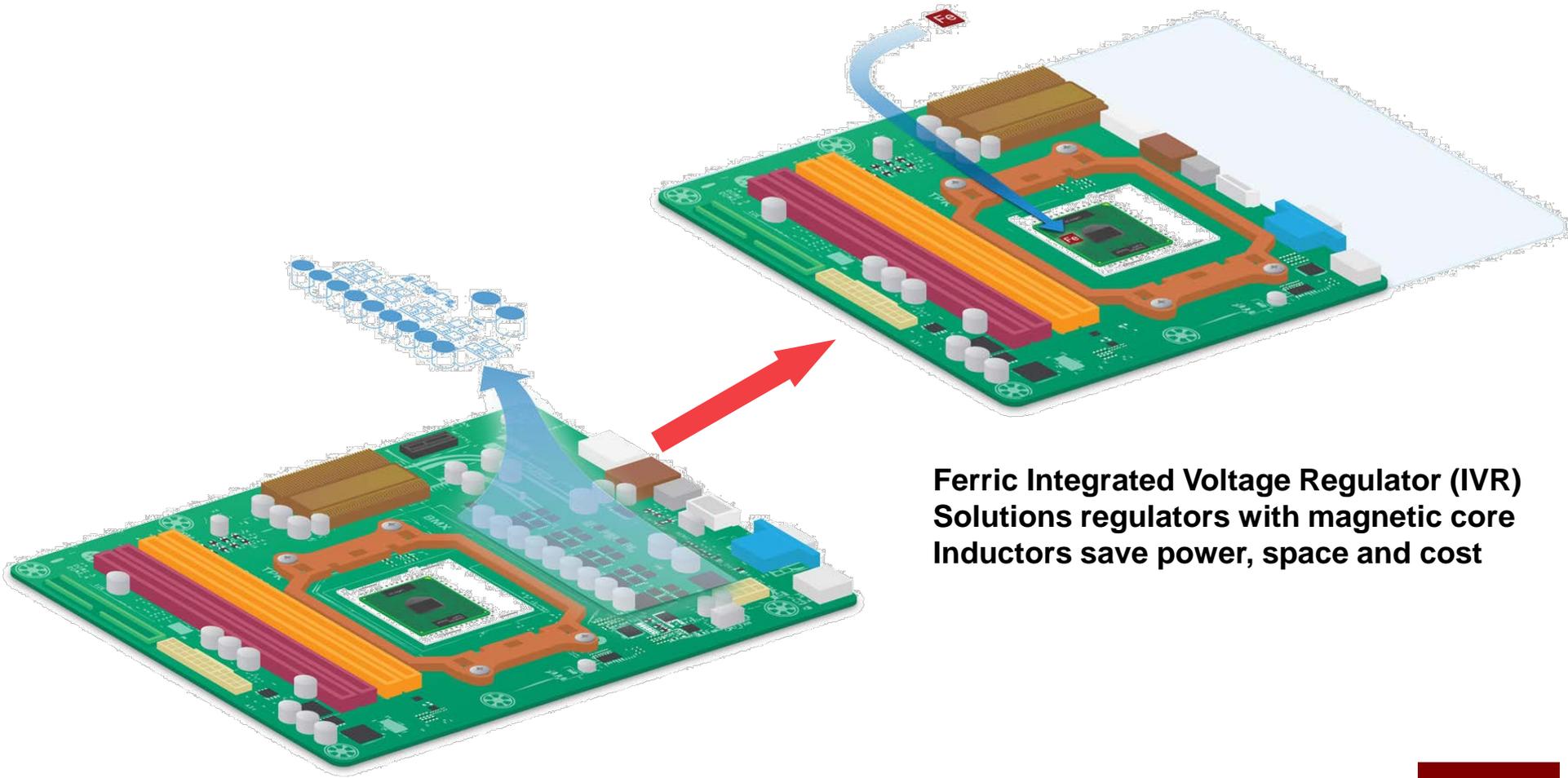
Washington, D.C.

June 14-15, 2016

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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 PRODUCTS PROVIDE COST, POWER, AREA SAVINGS FOR SERVERS, MOBILE DEVICES, WEARABLES AND IOT**

- Ferric's technology improves upon existing power delivery infrastructure by down-converting power in immediate proximity to the load
- Worldwide market for discrete power components plus integrated switching voltage regulator components is forecast at US\$36B in 2020



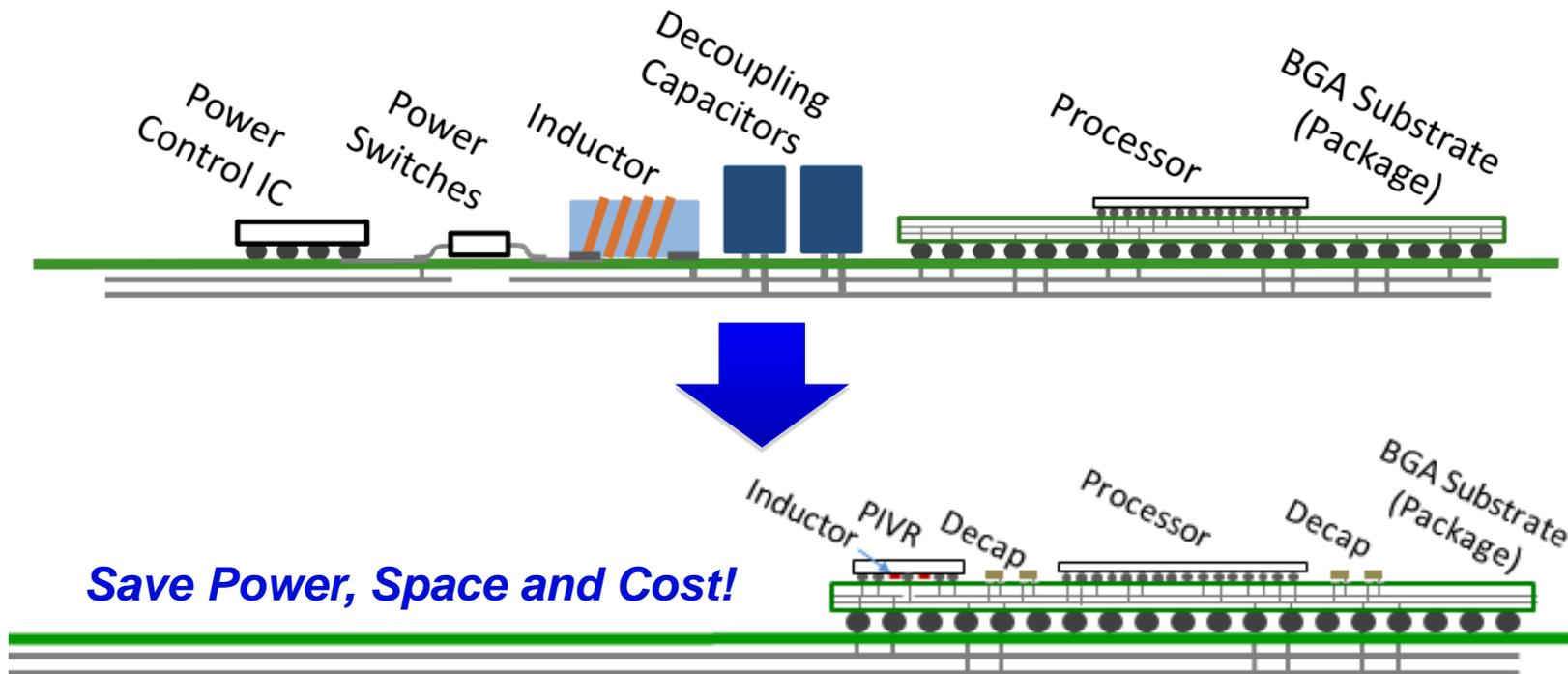
# ***FERRIC***

## ***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

# INTEGRATED VOLTAGE REGULATION

- High power density ( $10\text{W}/\text{mm}^3$ ) low voltage ( $< 12\text{V}$ ) 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



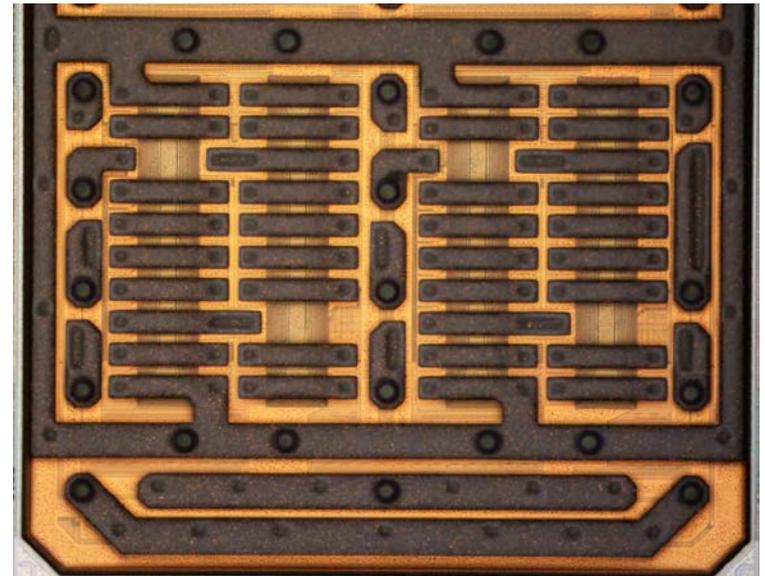
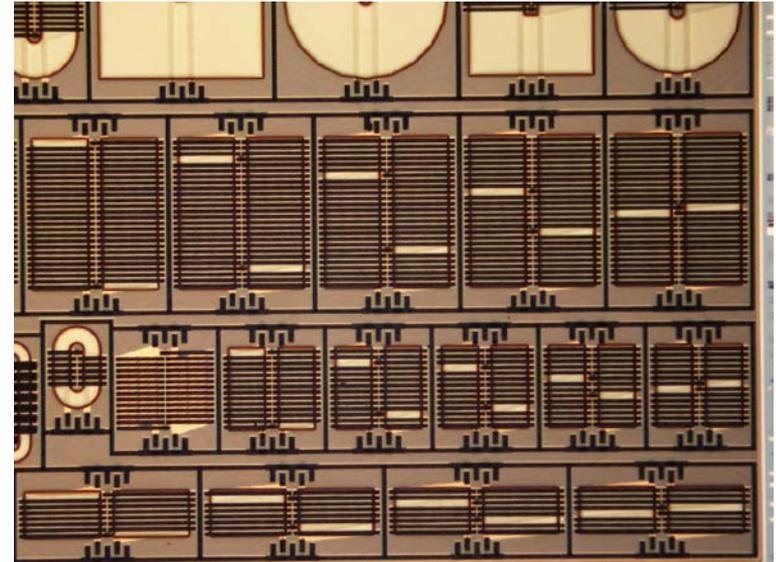
# FERRIC TECHNOLOGY ELEMENTS

## ■ Integrated Inductors

- Inductance density
  - $> 300\text{nH}/\text{mm}^2$ ,  $> 8,500\text{nH}/\text{mm}^3$
- Current density  $> 12\text{A}/\text{mm}^2$
- DC Resistance  $< 100\text{m}\Omega$
- Magnetic Coupling  $k > 0.95$

## ■ Integrated Circuit Designs

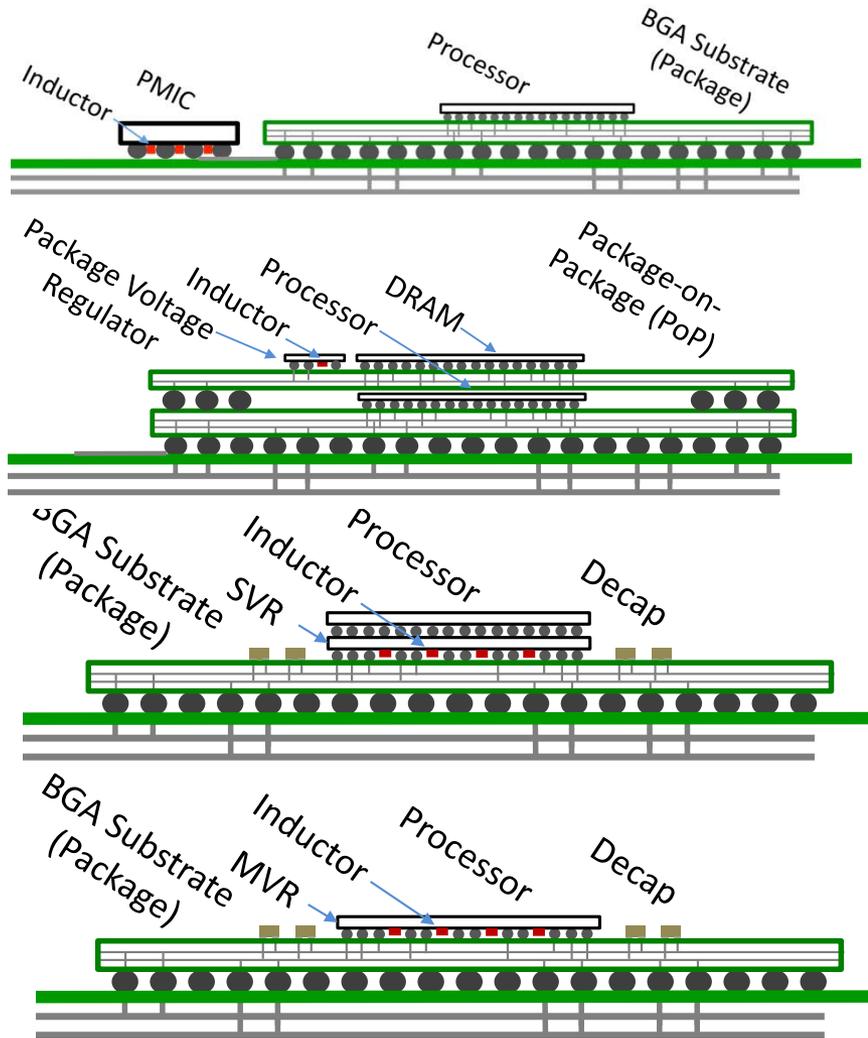
- High switching frequency
- High bandwidth controller
- Optimization for high efficiency
- Optimization for high density







# FERRIC TECHNOLOGY | PRODUCT IMPLEMENTATION



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

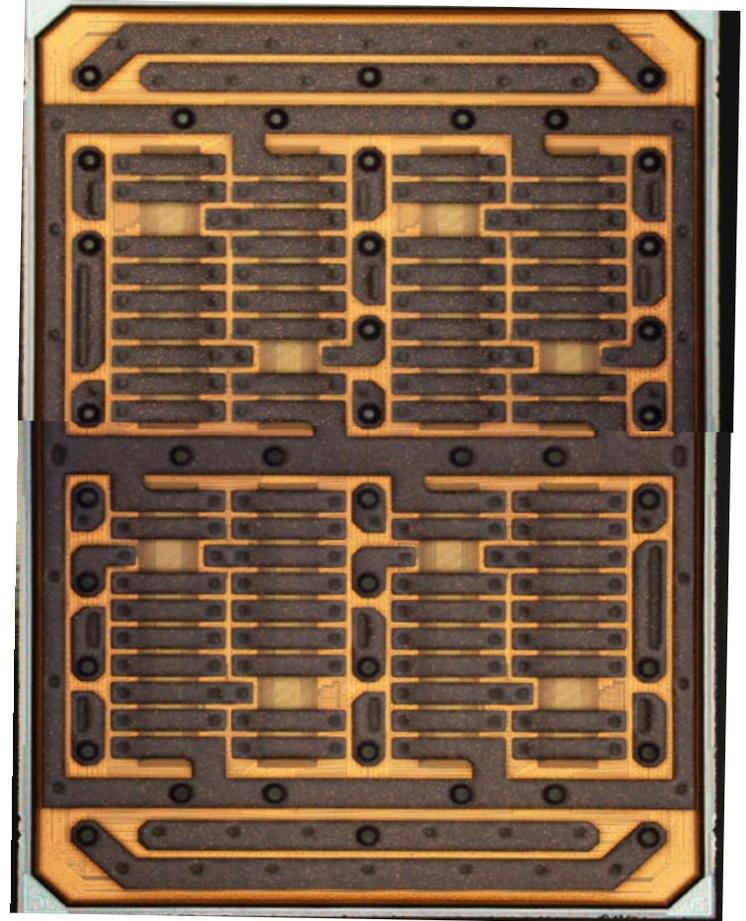


# FERRIC CIRCUITS

*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  $500\mu\Omega$ )
- 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



# FERRIC CIRCUITS / BOOST CONVERTER

- Total Solution Size: 2.5mm<sup>2</sup>
  - 1x Dachshund Chip (1x 1.5mm<sup>2</sup>)
  - 2x 0402 Discrete Capacitors(2x 0.5mm<sup>2</sup>)

