Review of Integrated Magnetics for Power Supply on Chip (PwrSoC)

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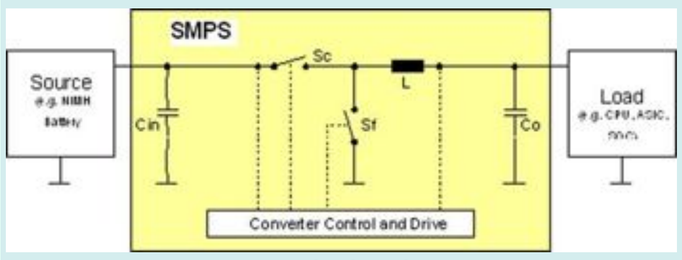
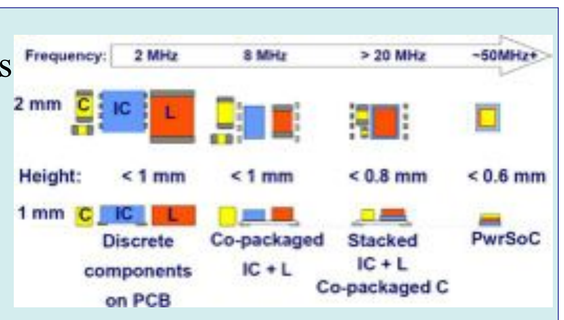
Background



Typical POL SMPS

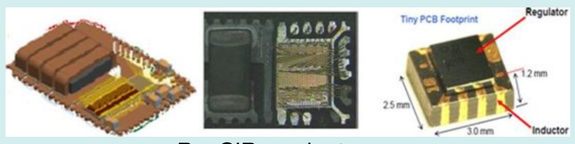
Context : Miniaturisation & integration of power supply for portable electronics

- Integration of magnetic components on silicon
- High frequency low loss magnetics
- Review of SoA in Integrated magnetics for PwrSiP & PwrSoC
- Detail comparison of different inductor technologies
- Highlight key technology challenges & present evolution roadmap



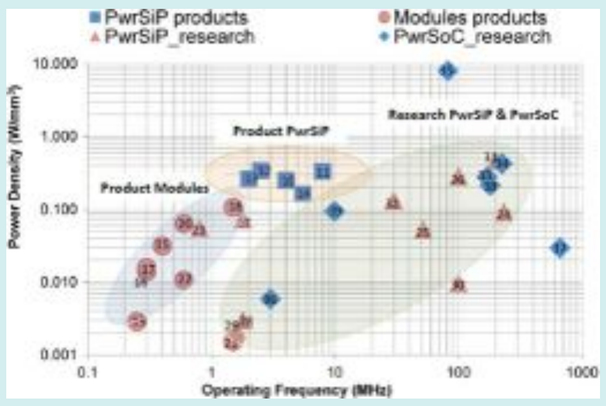
Evolution of PwrSoC technology

Trends towards PwrSiP & PwrSoC

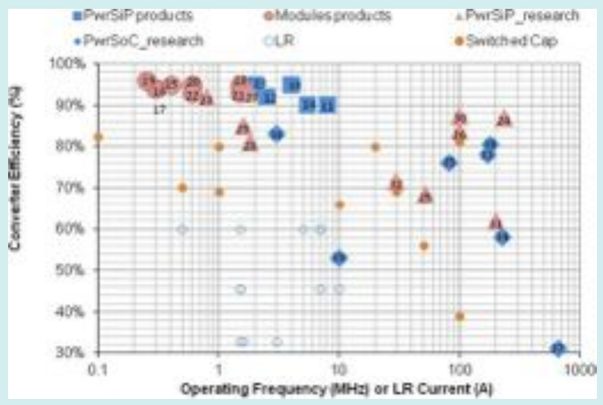


PwrSiP products

- Increasingly OEM companies moving from a Power Supply module platform to Power Supply in Package solution
- PwrSiP products have higher power density than power modules
- SMPS have higher efficiency compared to Linear regulators & Switched Cap
- Switched Cap converters typically work at < 100 mA, efficiency of <80%



Power density vs frequency

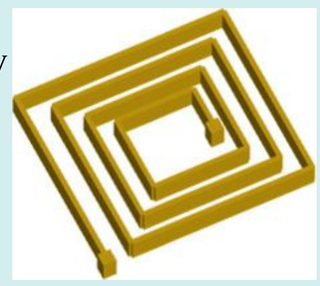


Efficiency vs frequency/Curent(LR)

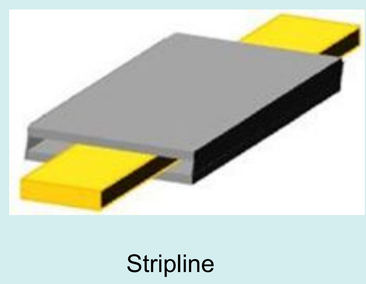
Review of Magnetics for PwrSiP & PwrSoC

- Best arrangement of winding & core with consideration to inductance, efficiency, footprint & process technology
- Typical inductor structures: Spiral, Stripline, Toroid & Solenoid
- Key component of inductors is soft magnetic core required to achieve reasonable inductance enhancement
- Thin film cores typically have higher flux density & permeability compared to ferrite cores
- Different deposition techniques for soft magnetic cores include Screen-printing, sputtering & electroplating

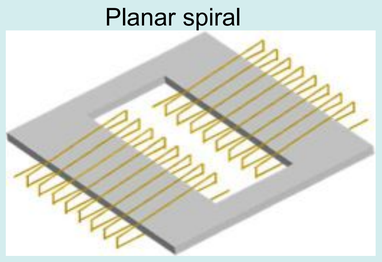
$$E = \frac{Li^2}{2A_r} \qquad \frac{L}{R_{\mathrm{dc}}} = \frac{P_o \times (1-D)}{f \times I_r \times \mathrm{Powerloss_{dc}}} \qquad Q = \frac{2\pi f L}{R_{\mathrm{ac}}}$$



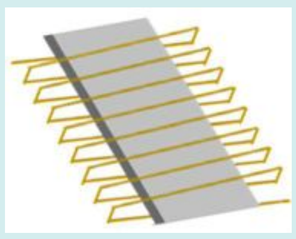
Planar spiral



Stripline

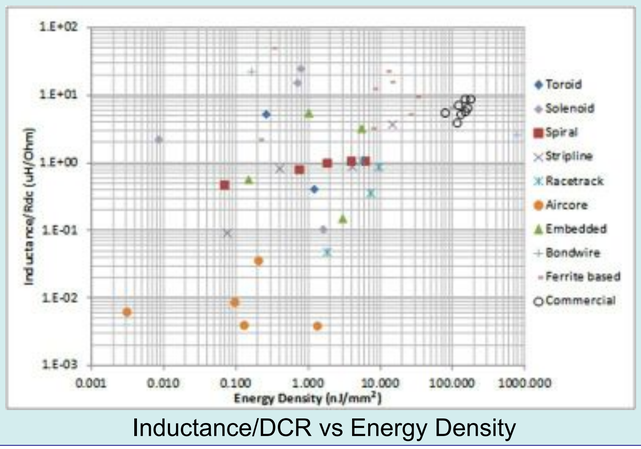


Toroids



Solenoid

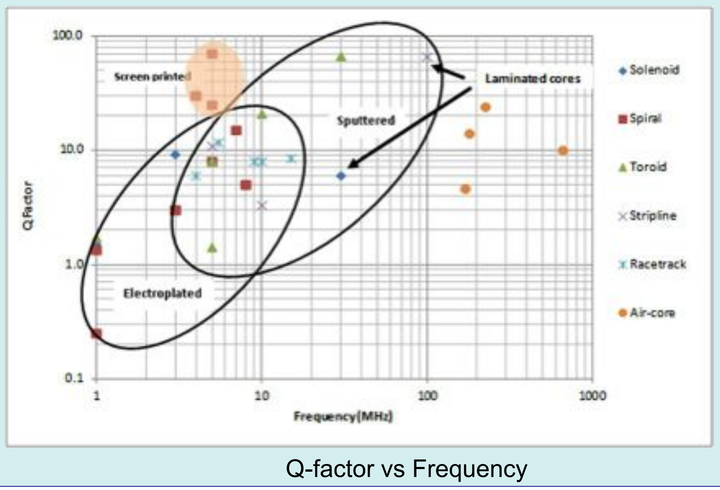
- Performance comparison is done using two Figures of Merit: DC performance & AC performance
- DC performance: Key parameters include inductance, DCR, current, footprint
- DC performance compares Inductance/DCR vs Energy density
- AC performance: Key parameters include quality factor, ac losses
- AC performance compares Q-factor vs frequency



Inductance/DCR vs Energy Density

- Spiral & toroidal structures suited for lower frequencies (<10MHz)
- Solenoid & racetrack structures typically for frequencies <50MHz
- Stripline suited for higher frequencies >100 MHz

- AC performance primarily depends on magnetic core loss
- Screen-printed materials- Higher Q at frequencies < 5 MHz
- Electrodeposited cores- Suited for frequencies ~ 10 MHz
- Sputtered cores- Suited for higher frequencies > 10 MHz



Q-factor vs Frequency

Technology Roadmap & Challenges

Market Drivers

- Key market drivers- Magnetics on Silicon
- Point-of-load SMPS: need higher efficiencies from micro-inductor
- Granular on-chip power management system archieture for SoC
- Typically for high current applications including µ-processor power delivery
- Commercial product: Enpirion power converter with stacked µ-inductor with single magnetic core
- µ-transformer for signal isolation
- Commercial products: i-coupler from Analog devices using air-core transformers

PowerSoC Supply chain challenges

- Key challenge is lack of supply chain infrastructure mainly thin film magnetic technology
- Magnetic thin films have been employed in high volume, cost-sensitive disk-head industry
- Both captive & commercial foundries can be developed for high volume production
- Other issues in supply infrastructures include
  - Micro-magnetic design environment to interface with standard IC CAD
  - Magnetic material development and quality control tool
  - Large area characterization

PowerSoC Technology platform

- Key challenge for PwrSoC is low loss, high flux density thin film magnetic core
- With CMOS compatible deposition (Electroplating)
- Further understanding required on impact of magnetic component on underlying PMIC (thermo-mechanical)
- Integration of capacitor technology with magnetic processing, '*LC interposer*'
- Trench capacitor technologies with 400 nF/mm2, allow potential solution for LC interposer as part of PwrSiP platform

Acknowledgement

- We wish to acknowledge the support of Enterprise Ireland, Science Foundation Ireland and European Union for funding of this work
- **Further details are published in, C.Ó Mathúna et al, IEEE transaction on Power Electronics, 27 (11), 4799-4816 (2012)**