How SiC & GaN catching up to Planar Magnetics

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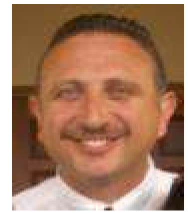

Jim Marinos, executive VP Engineering & Marketing for Payton Planar Magnetics, has been designing power supplies and involved in the magnetics business since 1982. Jim has worked in the power supply design capacity with Ceag, ILC, Superior and Novatronics. Jim was the director of engineering for Lambda Novatronics. Jim is a senior member of IEEE, President of the Power Sources Manufacturing Association and has written technical papers. He holds a BSEE from Pratt Institute in Brooklyn NY.

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APEC 2014 Session IS

Planar Structure

Ferrite (E, ER, …)

PCB or copper lam.
(up to 2mm)

Isolation
(bobbin, Kapton,…)

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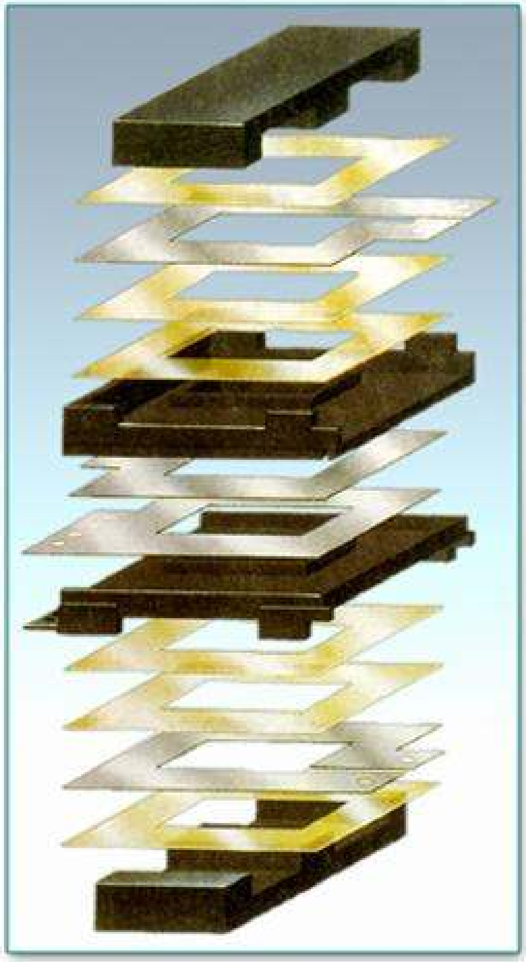
PCB or copper lam.

Ferrite (E, ER, …)



Ferrite with better Core Utilization factor allowing **less Ferrite losses**

Ferrite with round leg allowing lower **DCR and leakage inductance**

Thin copper layers so less copper allowing **less Copper losses**

Thin copper layers so **less skin effect and proximity losses** at high freq (up to 3Mhz).

Interleaving windings allowing **better efficiency (98%)**

Interleaving windings allowing **less magnetic field strength**

Interleaving windings allowing **lower leakage inductance (<2%)**

Bobbin allowing **safety** isolation (4kV primary to secondary)

Overall construction allowing **repeatability and consistency**

Embedded windings allowing **better EMI-RFI**

Dramatically **reduced size and weight** (approx. 5g per 100W)

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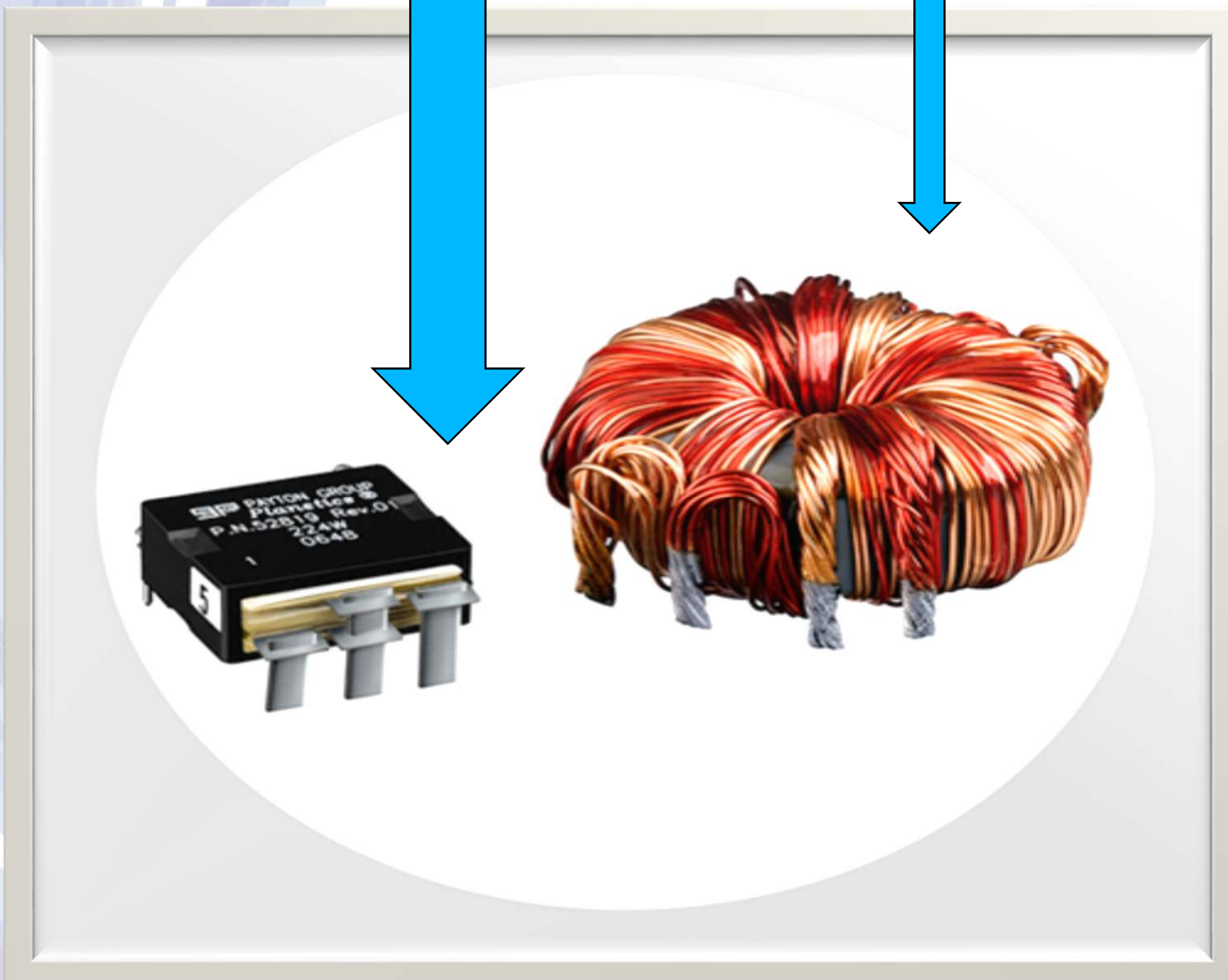
224 Watt Planar Transformer

224 Watt Toroid Transformer



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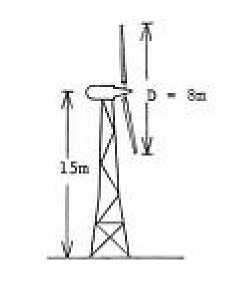
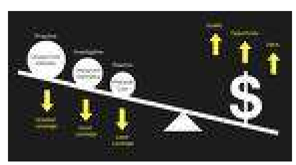
Design Objectives



Size
Power Density
Efficiency – Highly Constant Parasitics
Value for Cost



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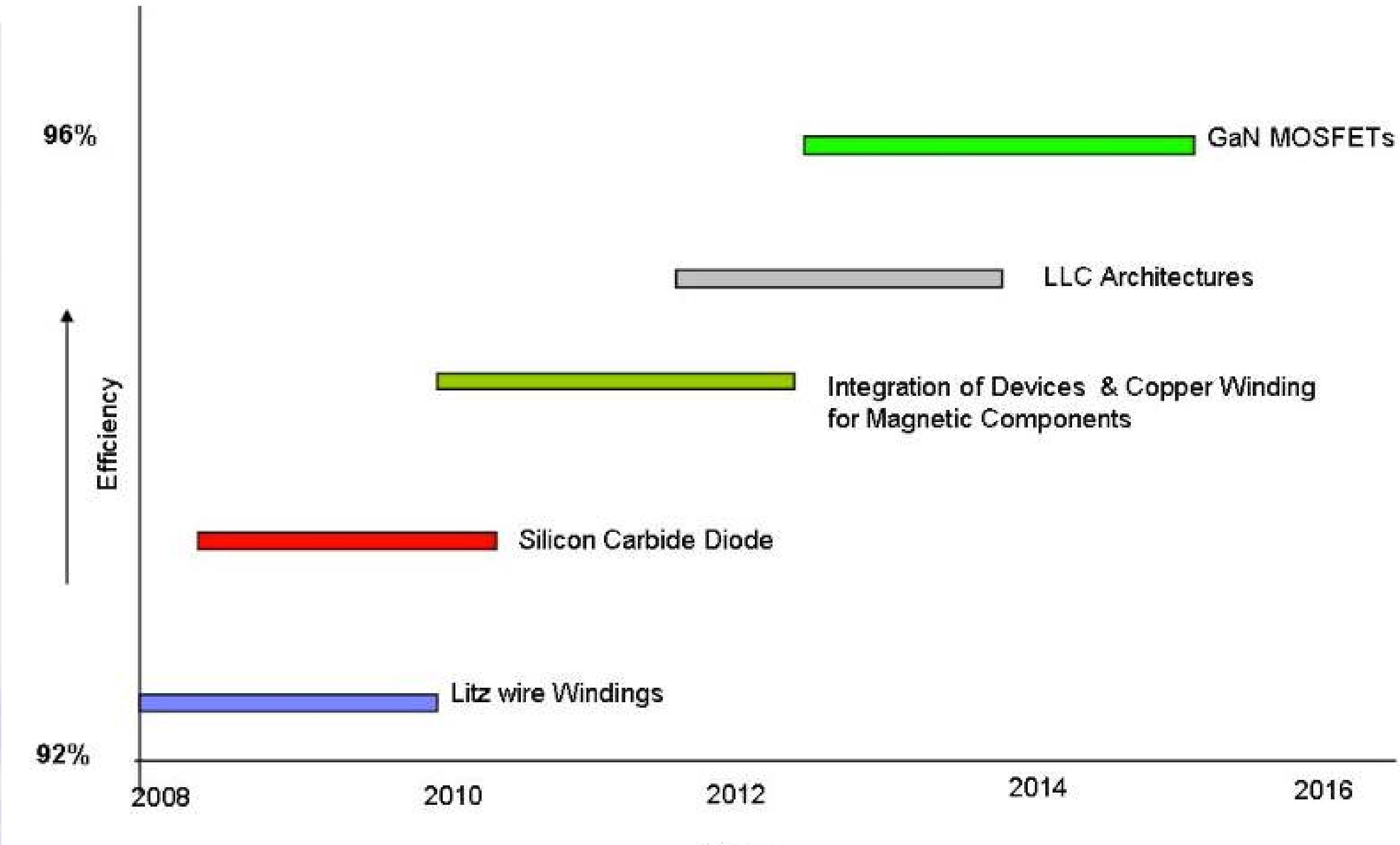

PSMA Webinar:

Title: Server Power Management Roadmap
Presenter: Randy Malik, Senior Technical Staff Member,
Power Technology and Qualifications, IBM, RTP, Raleigh, NC

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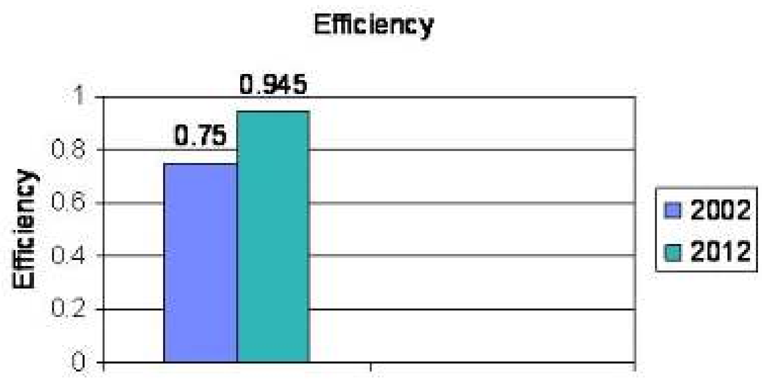

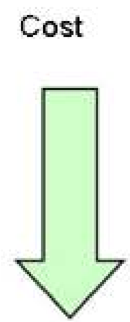

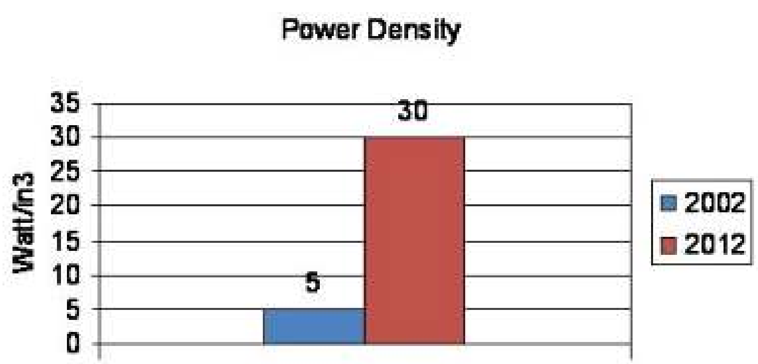

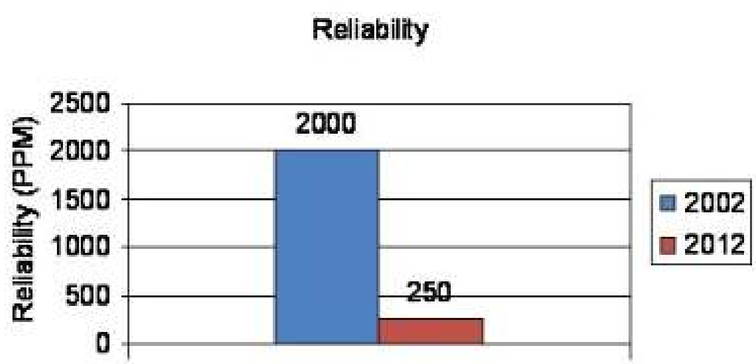

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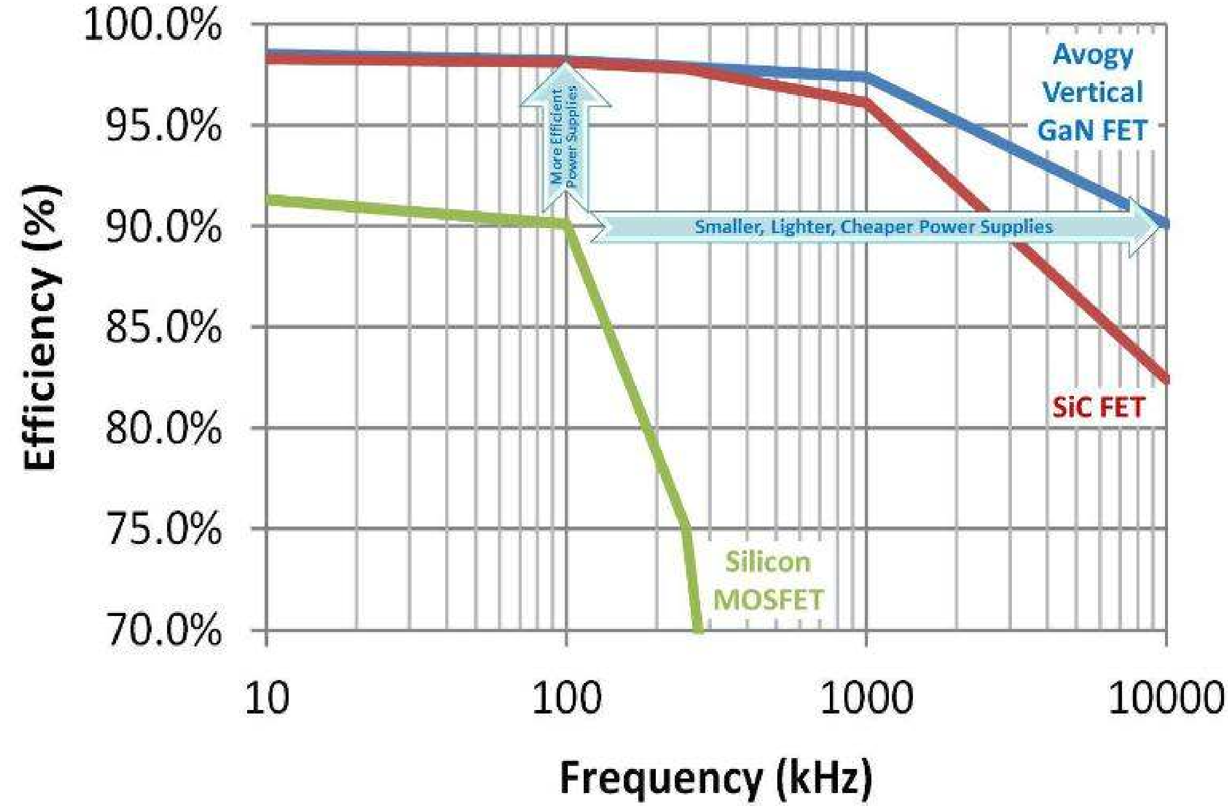
U.S. **Department of Energy's Advanced Research Projects Agency – Energy** (ARPA–E)



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source: AVOGY INC

There are two main elements in the design of a Planar Magnetic Structure

1) Control of Parasitics:

- Designing Planar Transformers is no different than designing conventional magnetics when it comes to core saturation and turns ratio. The big difference is the knowledge to control the parasitic effects, such as leakage and interwinding capacitance, at different operating frequencies. For example, Payton engineers will design completely different stacks of layers at 250KHz and at 500KHz. The core material, dielectric thickness, amount of copper and interleaving of the primary and secondary are different for the same output power with different frequencies of at least 50KHz apart. In the same planar structure 2oz, 4oz, 5oz, 6oz, 8oz and 12oz of copper are used for the best performance.
- The cost of the materials has been dramatically reduced in the last few years, which makes the planar a cost competitive solution.

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2) Optimum size and Frequency depends on the maximum environmental temperature:

- My personal experience shows that the transformer size versus the frequency reduces the most when the frequency is in the range of 100khz to 500khz. At frequencies higher than 500KHz the size reduction is not noticeable, unless the thermal and efficiency aspects are addressed. The planar technology, with the large surface area and the close to 99.5% efficiency, provides the solution.

- For example: Table 1. shows the typical thermal impedance for different cooling conditions for Payton size 250..

Table 1.

NATURAL COOLING (Hot Spot - Air)	BLOWING AIR 3m/sec (Hot Spot - Air)	ONE SIDE HEATSINK (Hot Spot - Heatsink	TWO SIDES HEATSINK (Hot Spot - Heatsink)
9° /W	5.5° /W	3.4° /W	1.7° /W

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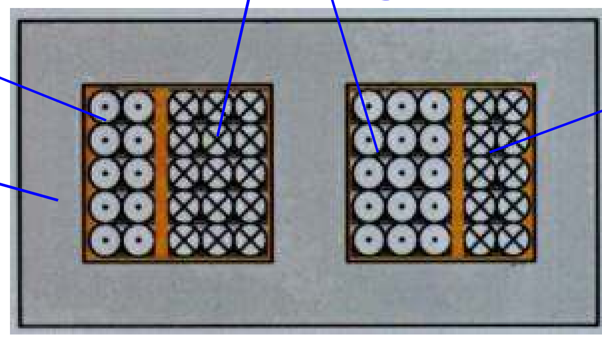
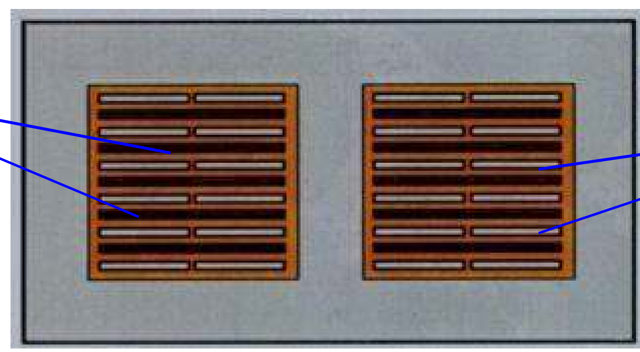
Flat Pre-Tooled Winding



Conventional transformer geometry



Planar transformer geometry

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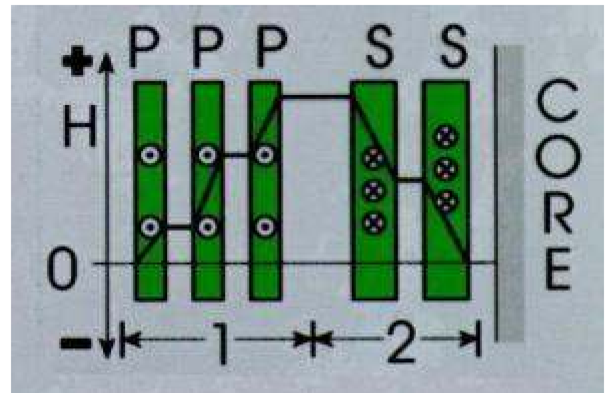
Winding Geometry

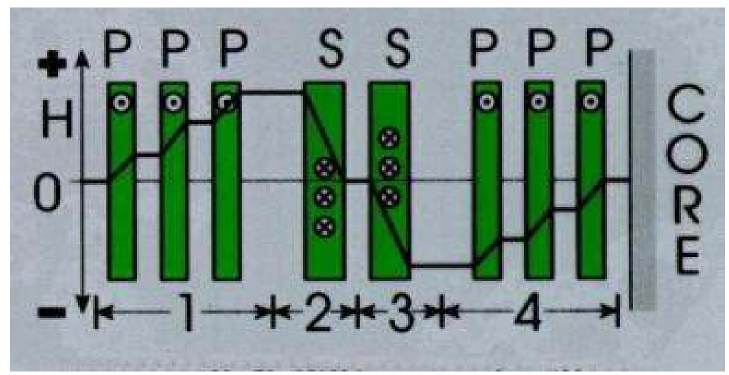
- **Easy Assembly.**
- **Winding Configuration – in Series Or Parallel.**
- **Easy Multiple Interleaving:**
  - **>Reduces Magnetic Field Strength**
  - **> Reduces Losses**
  - **>Low Leakage Inductance**

Interleaving Reduces the Magnetic Field Strength and the Losses in the Transformer.

Magnetic Field Distribution



Transformer Windings



Transformer With Split Primary

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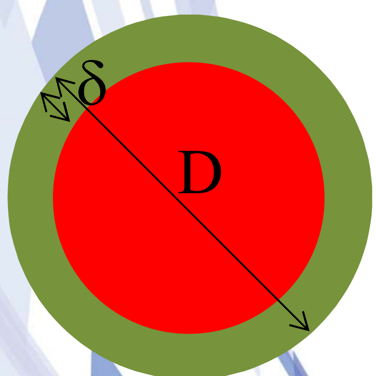
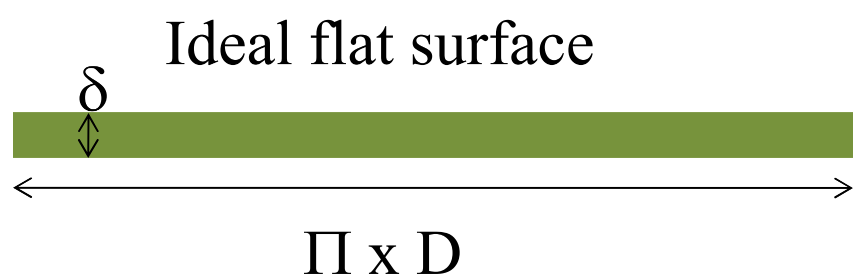
- ✓ **Skin effect** is the tendency of an alternating electric **current** (AC) to **distribute** itself within a conductor with the current density being largest **near the surface of the conductor**, decreasing at greater depths.
- ✓ δ**- Skin depth**: the distance into the conductor, where the current density decreased to 1/e of the surface value.
  In copper, the skin depth can be seen to fall according to the square root of frequency (660μm at 10Khz and 210μm at 100kHz)

A) **Round wires**



B) **Planar conductors**



As δ is very small, the effective cross sectional area for round conductor is:

$S_{eff} = \Pi \times \delta \times D$ **Red** part is NOT used

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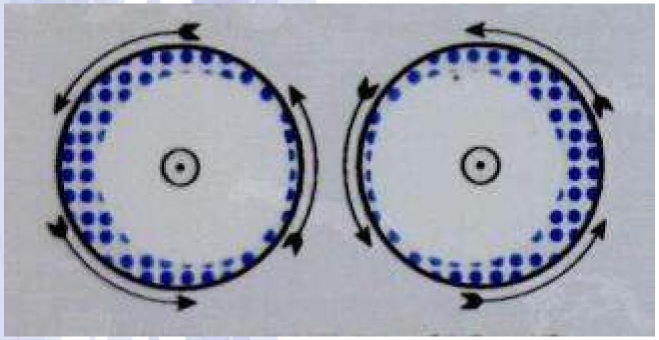
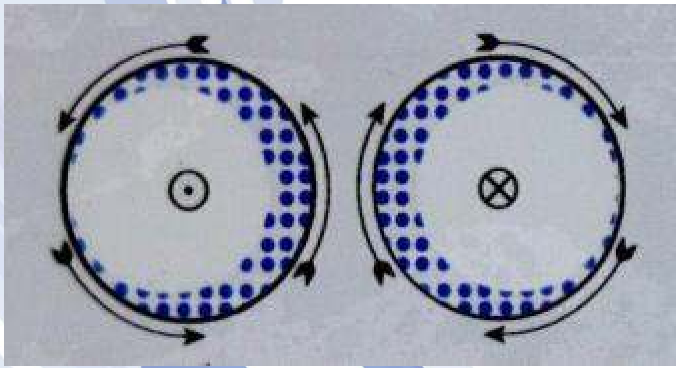
Proximity

•Magnetic field direction



•Currents same direction

•Magnetic field direction



•Currents opposite direction

Reduced conductor thickness (with the same copper square area) allows minimizing skin and proximity losses at higher frequencies.

Frequency range: 20-7000 kHz

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CONVERTER TECHNOLOGY

Full Bridge Converter

- Full bridge converter running at 200kHz
- High performance planar magnetics
- Optimised for 400Vdc supply from upstream PFC stage
- Secondary side synchronous rectifier option
- Low profile design

The full bridge converter is designed to partner with the high performance dual phase PFC front end to form a complete high performance technology demonstrator for GaN Systems technology. The full bridge topology provides high efficiency coupled with high utilisation of the power magnetic components.

The system has been designed to operate from a nominal 400Vdc input and once benchmarking performance at 200kHz switching frequency has been undertaken, the switching frequency will be increased to demonstrate the superior performance of the GaN Systems technology compared with MOSFETs in this application.

GaN Systems

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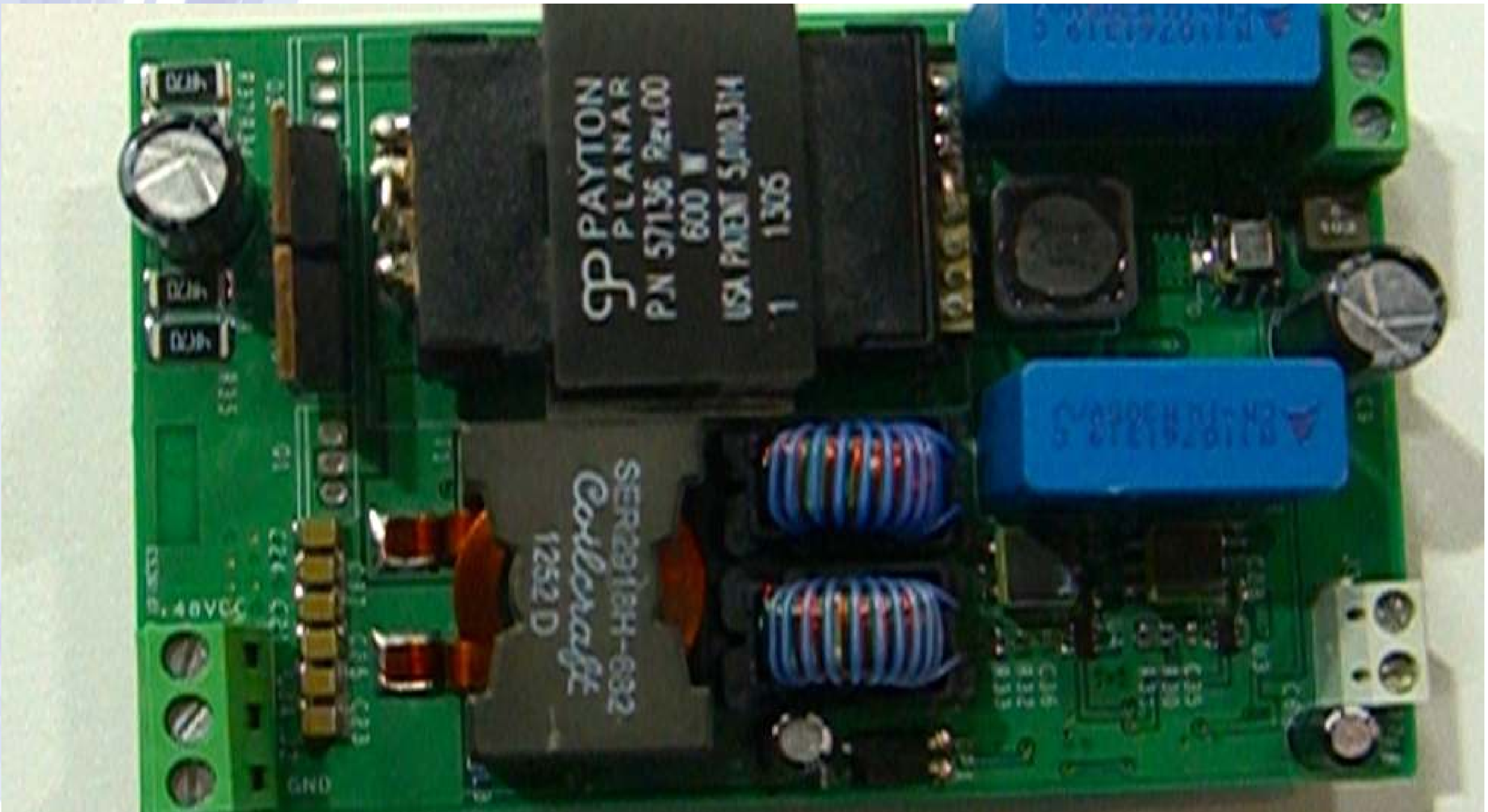
GaN Systems reference design



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Why Gallium Nitride?

- In speed, temperature and power handling, gallium nitride is set to take over as silicon power devices reach their limits. GaN is the technology that will allow us to implement essential future cleantech innovations where <u>efficiency</u> is a key requirement.
- GaN devices offer five key characteristics: high dielectric strength, high operating temperature, high current density, high speed switching and low on-resistance. These characteristics are due to the properties of GaN, which, compared to silicon, offers ten times higher electrical breakdown characteristics, three times the bandgap, and exceptional carrier mobility.

http://www.gansystems.com/

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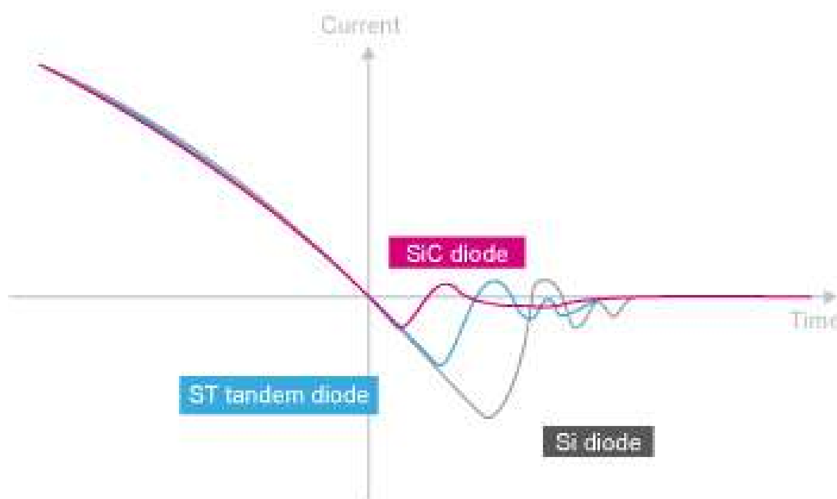
Silicon Carbide Diodes

- SiC's superior physical characteristics over Si, with 4 times better dynamic characteristics and 15% less forward voltage, V**F**.
- Their low reverse recovery characteristics make silicon-carbide diodes a key contributor to energy savings in SMPS applications.



SiC diodes provide zero recovery time
with negligible switching losses

http://www.st.com

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Payton America Inc

Tack
Vielen Dank
Obrigado
Merci
ありがとうございます
Bedankt
Takk
感謝您
Terima Kasih
谢谢
Grazie
ขอบคุณ
Спасибо
Thank You
Kiitos
Tak
Teşekkür Ederiz
감사합니다
Gracias
Dziękujemy
Σας ευχαριστούμε

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