VISHAY INDUCTORS DIVISION

Benefits of a Hybrid Planar Transformer Package

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Transformer Design at Higher Frequencies (200 – 500kHz)

Benefits

- **Size Reduction:** Improved efficiency enables smaller core sizes for a given output requirement.
- **Efficiency:** Deliver more power within a smaller footprint.
- **Cost Savings:** Material and labor efficiencies and be realized with commonly available materials and smaller footprints.

Design Constraints

- **Core Materials:** Careful selection of the magnetic core material is required to minimize the core losses.
- **Copper Losses:** Careful wire selection, winding patterns and techniques are required to minimize copper losses.
- **Parasitic capacitance and Leakage Inductance:** Careful winding structure and techniques and material selection are required to minimum parasitic capacitance and leakage inductance.
- **Thermal Management:** Higher frequency applications may lead to increased heat generation.

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Core Materials

Proper core material selection is essential for an optimized magnetics design. Improper material selection may lead to high core losses and excessive heat generated within the transformer. Core losses include of Hysteresis losses and Eddy Current losses.

Core materials that are commonly used for high frequency applications are:

- **Ferrite**
- Powdered Iron
- Nanocrystalline

Core Materials - Example

Ferrite Cores: i.e.: 3F36 material – A medium to high frequency power material for use in power and general-purpose transformers at frequencies of 0.5 – 1 MHz.

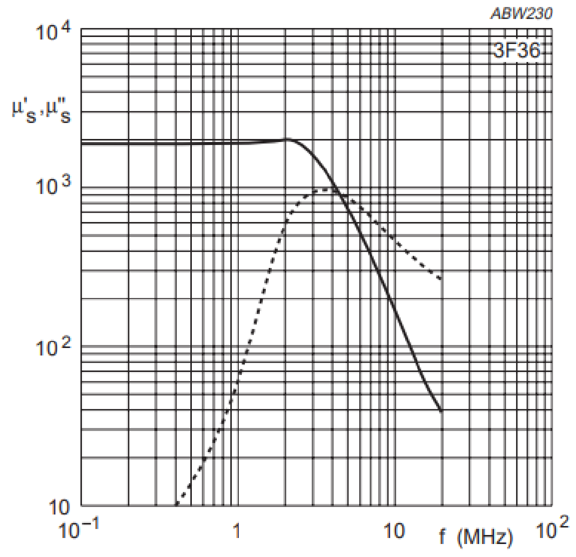


Fig.1 Complex permeability as a function of frequency.

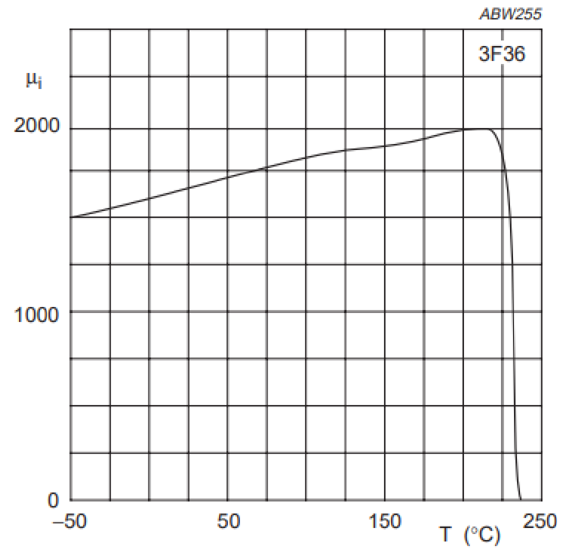


Fig.2 Initial permeability as a function of temperature.

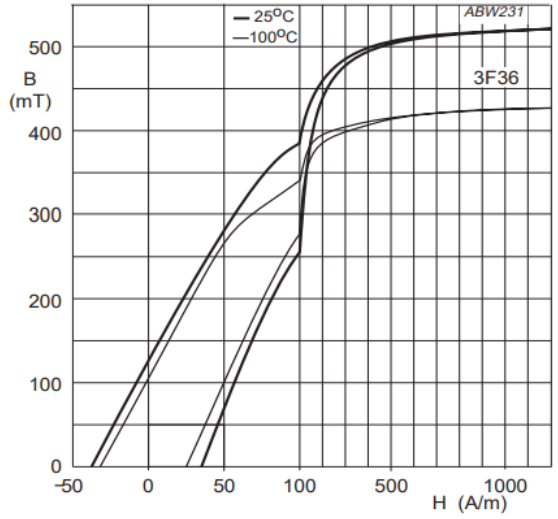


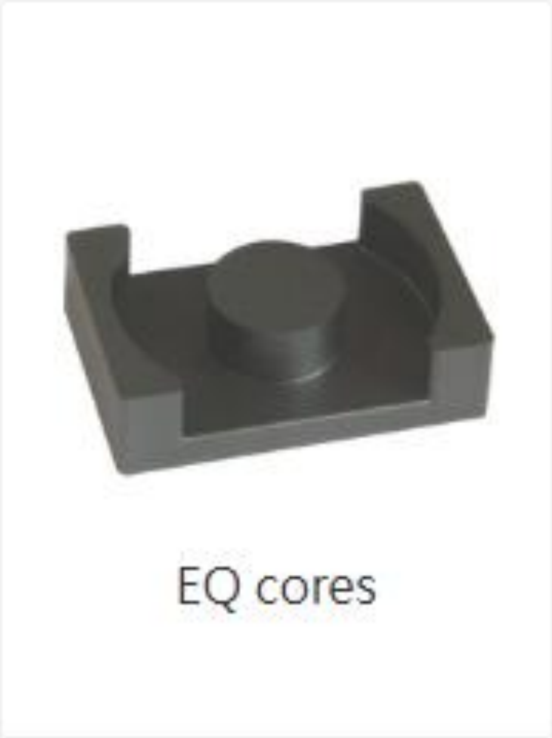
Fig.3 Typical B-H loops.

Core Shape Selection

Core shape selection is another aspect designers must consider during the magnetics design process. Magnetic devices used in harsh environments benefit from lower profile cores such as an ER or EQ styles.

These styles offer:

- Wider surface area on the printed circuit board assembly to aid in thermal management.
- Lower height profile improves survivability in vibration and shock environments.
- Large winding areas to facilitate higher power densities and copper fill percentages.



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Copper Losses

Copper losses are Ohmic losses due to the resistance of the copper windings in the transformer.

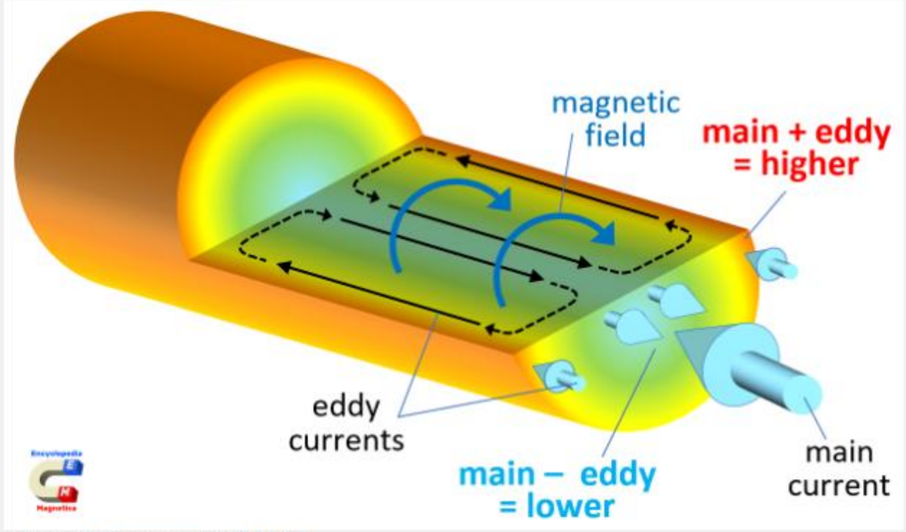
$$Copper\ Losses = Current^2 \times \text{Resistance}$$

As frequencies increase, Skin Effect and Proximity Effect play larger roles in the copper losses of a device.

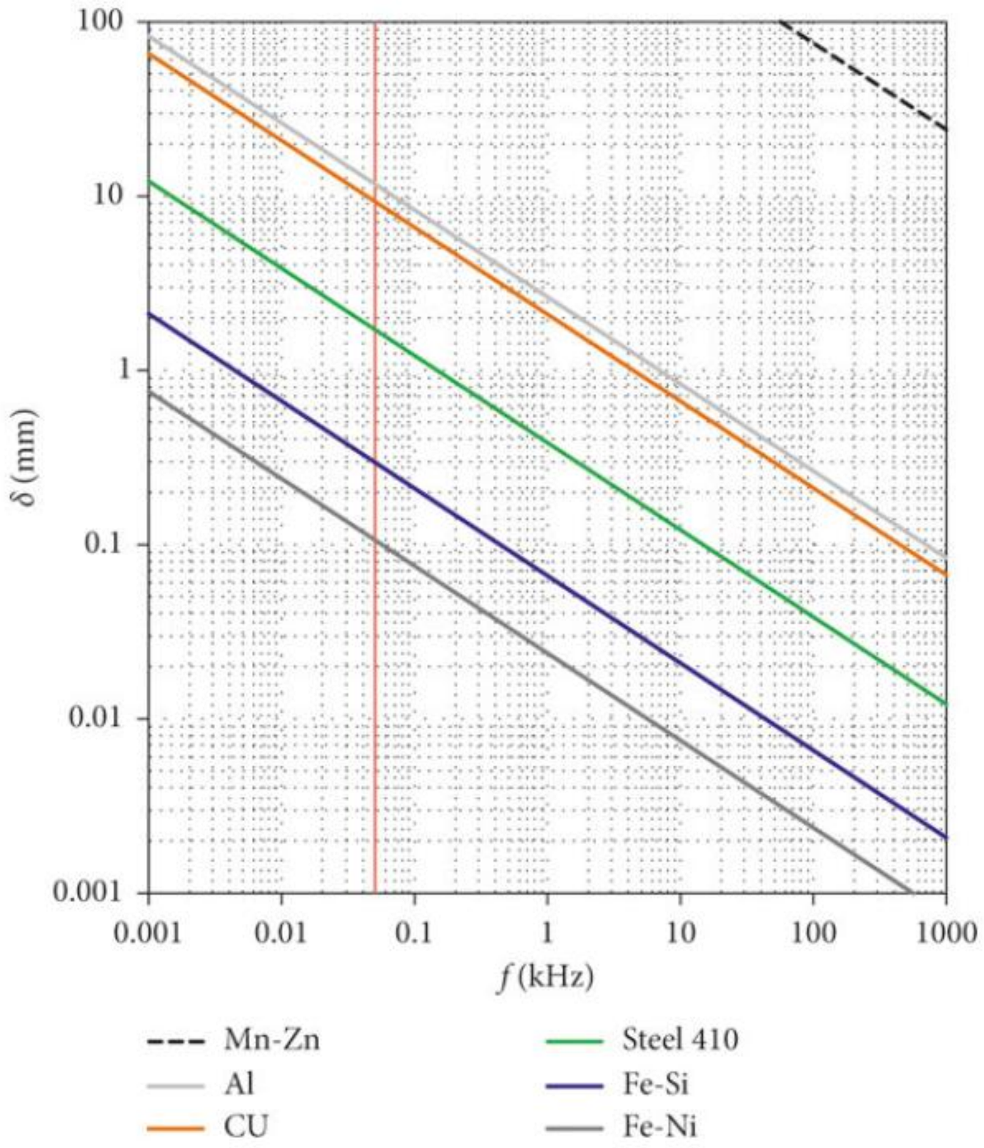
Copper Losses – Skin Effect

Skin Effect: is the tendency of an AC current to become distributed within a conductor such that the current density is largest near the surface of the conductor and decreases exponentially with greater depths in the conductor. As the frequency increases the skin depth significantly decreases, effectively lowering the current capability of the conductor or increasing the temperature rise within the design (Jimenez et. al., 2019).

Mechanism of skin effect



S. Zurek, E-Magnetica.pl, CC-BY-4.0

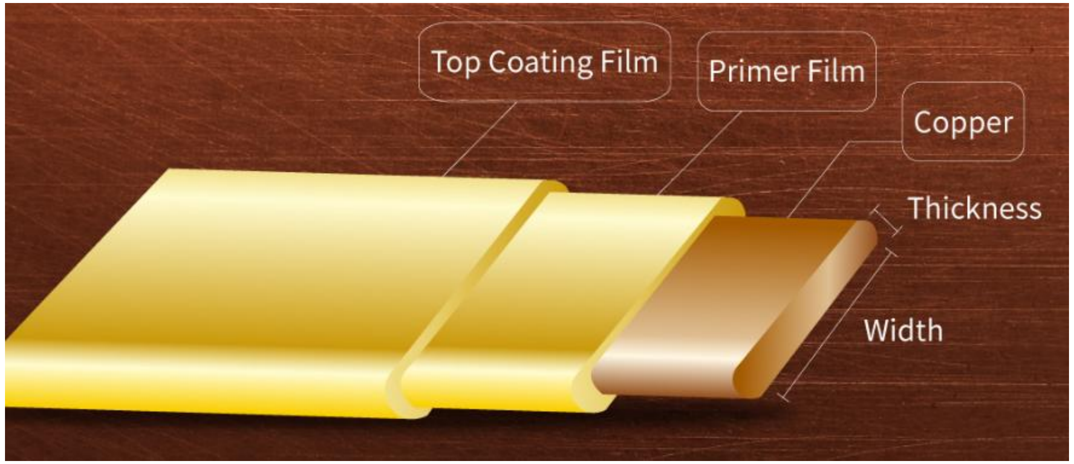


Copper Losses – Skin Effect

Reducing Skin Effects:

- Designers can move away from traditional round magnet wire to thin foil or rectangular magnet wire. Traditional planar style magnetics achieve this through thin, wide copper layers/traces. Thin conductors have less cross-sectional area for the current to crowd into, reducing the uneven current distribution.

- Litz wire is another alternative in which bundles of separately insulated strands are braided into a uniform pattern. This concept equalizes flux linkages and reactance of the individual strands causing the current to spread uniformly throughout the entire braided conductor.



(www.wellascent.com, 2025)

(www.litzwire.com, 2025)

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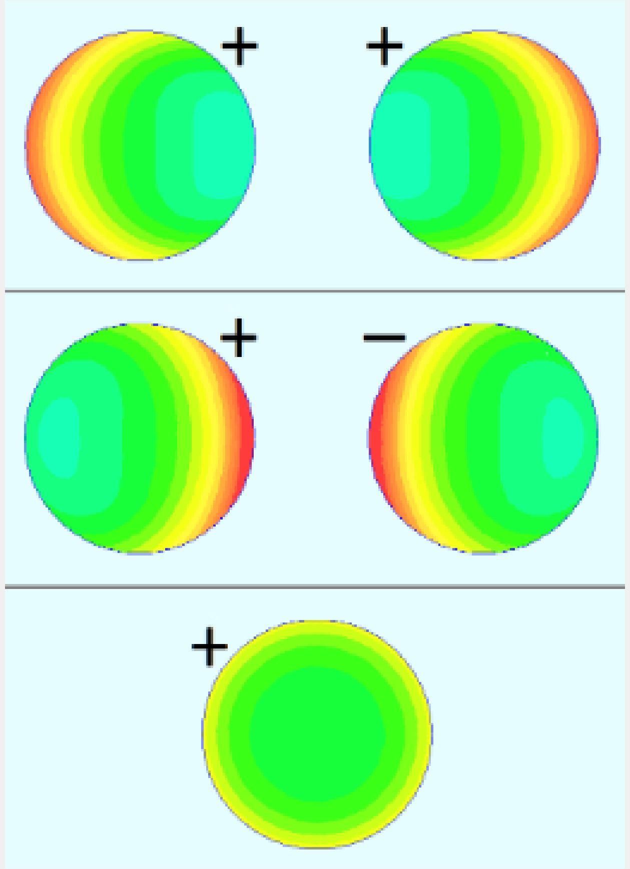
Copper Losses – Proximity Effect

Proximity Effect: is an electromagnetic phenomenon causing non-uniform distribution of AC current in mult-turn windings or nearby conductors, which can lead to significant power loss (Zurek, 2025). This effect becomes more pronounced as the frequency increases because of stronger induced eddy currents in the nearby conductors (Kazimierczuk, 2011).

Proximity effect in round wires, with the same amplitude of sinusoidal current: same phase (top), opposite phase (middle), and skin effect in a single wire (bottom)

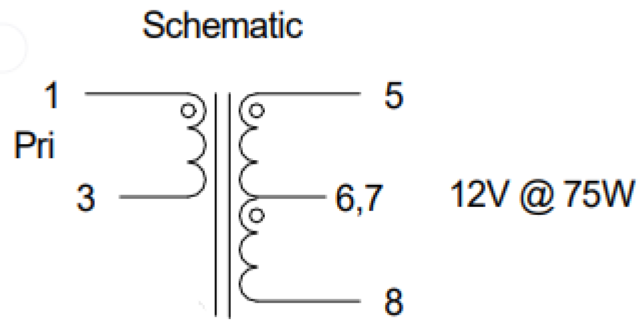


S. Zurek, E-Magnetica.pl, CC-BY-4.0

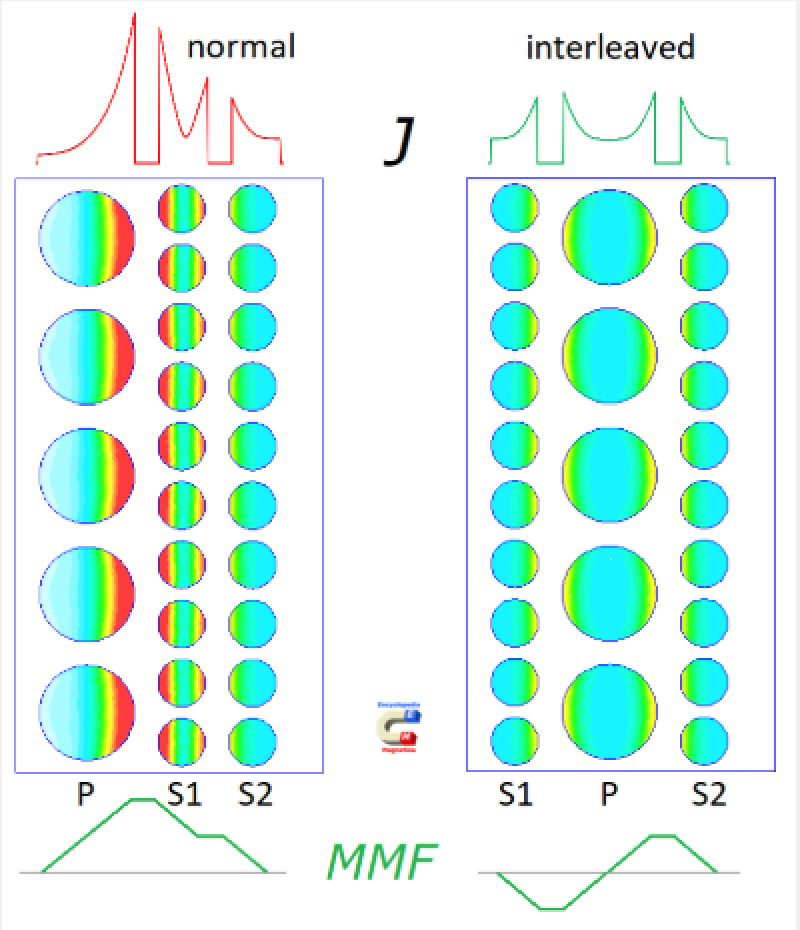
Copper Losses – Proximity Effect

Reducing Proximity Effects:

- Designing the winding "stackup" within a transformer using interleaved primary and secondary windings or increasing separation between the conducts can reduce the effects of Proximity Effect (Zurek, 2025).



Proximity effect in a transformer with normal and interleaved primary and secondary windings, the graphs show relative amplitude of current density distribution *J* and magnetomotive force *MMF*



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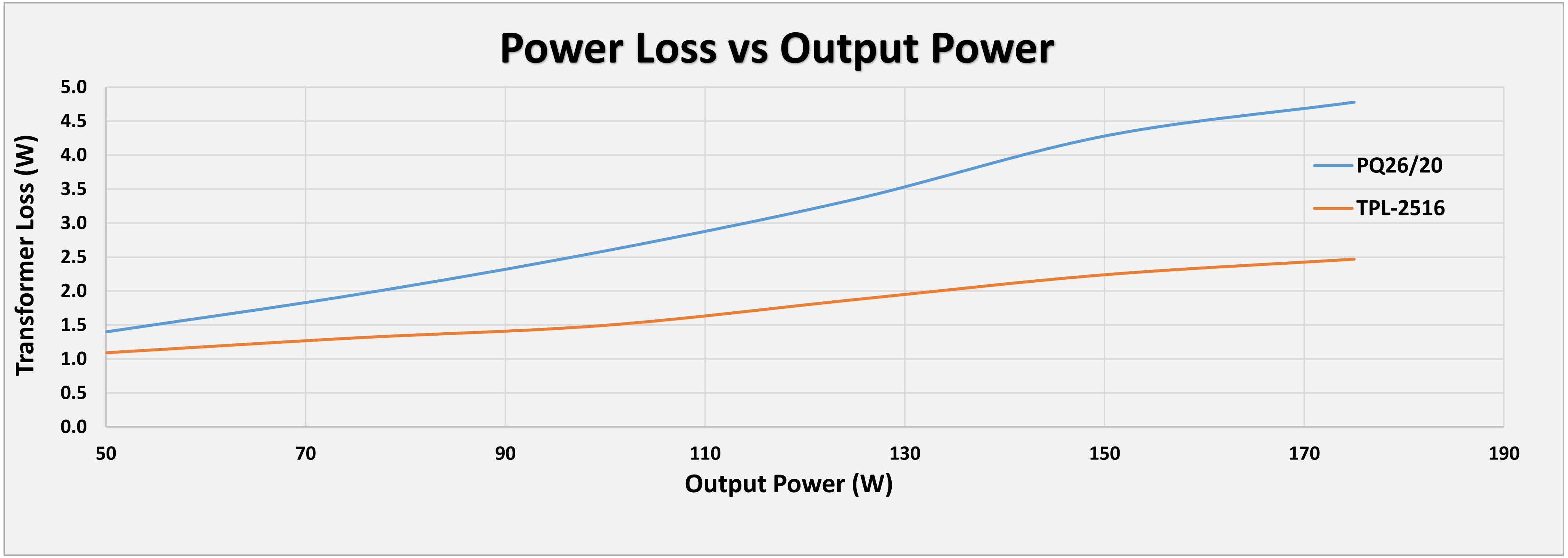
Vacuum Impregnation and Encapsulation

- Transformers are often designed to be vacuum impregnated or encapsulated with a varnish, epoxy, or adhesive which may provide:
  - Environmental Protection – protects the windings from moisture, dust, debris, and other potential harmful contaminants.
  - Dielectric Strength – some encapsulants have excellent dielectric strength.
  - Improved Durability – in general, encapsulation may increase a parts survivability in shock and vibration environments.
  - Heat Dissipation – encapsulants designed with improved thermal transfer characteristics can reduce temperature rise and "hot spots" by transferring heat to other surfaces.

Benefits of Planar Style Designs

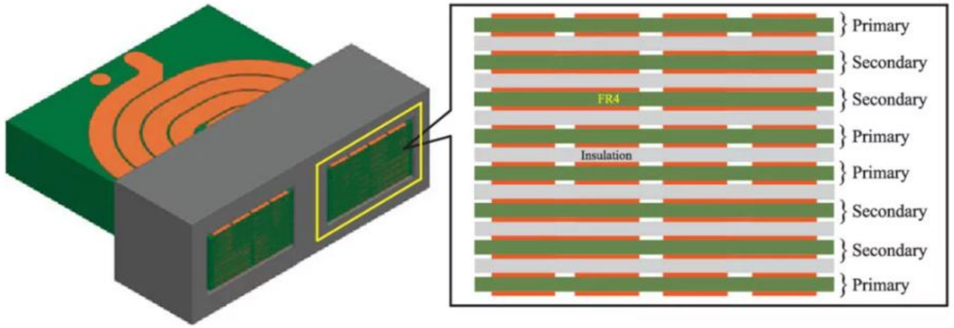
- Planar Style transformers can achieve lower losses when compared to traditional bobbin style designs while also having a smaller overall footprint. These benefits are achieved from:
  - Utilize wide, thin conductors to minimize Skin Effect losses.
  - Interleave windings to reduce Proximity Effect.
  - Encapsulation (molding) improves dielectric strength, mechanical stability, and thermal management of the transformer.



BLUE = TRADITIONAL BOBBIN STYLE, ORANGE = PLANAR STYLE

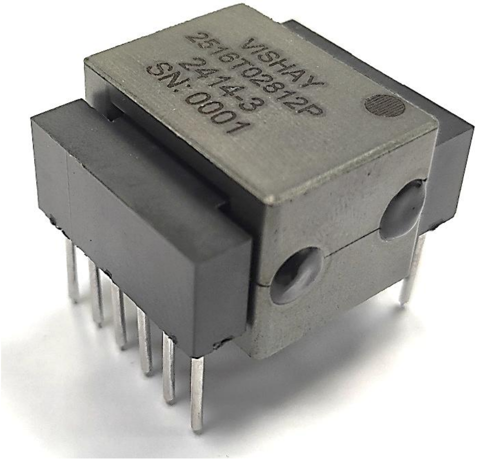
Hybrid Planar vs. Traditional Planar Style

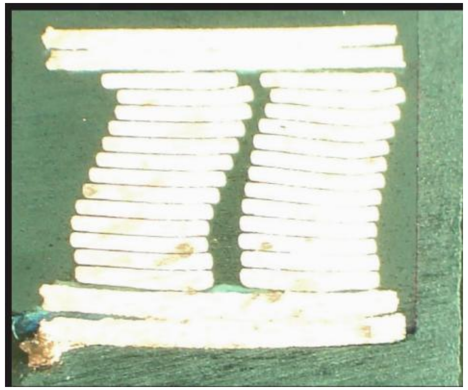
Traditional Planar Style



(Amaldev, 2023)

Hybrid Planar Style (Vishay's SGTPL)





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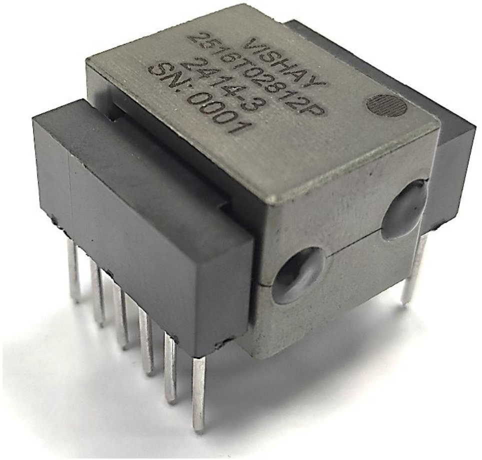
Hybrid Planar vs. Traditional Planar Style

Traditional Planar Style

(Amaldev, 2023)

- Low profile core.
- Wide, thin traces for windings.
- Windings are encapsulated within the circuit board (FR4 laminate, insulating layers, substrate layers.
- Windings can be interleaved.

Hybrid Planar Style (Vishay's SGTPL)



- Low profile core.
- Utilizes thin, wide rectangular magnet wire, foils, or stampings.
- Windings are encapsulated with a mineral filled epoxy.
- Insulators can be added between windings for added dielectric strength.
- Windings can be interleaved.

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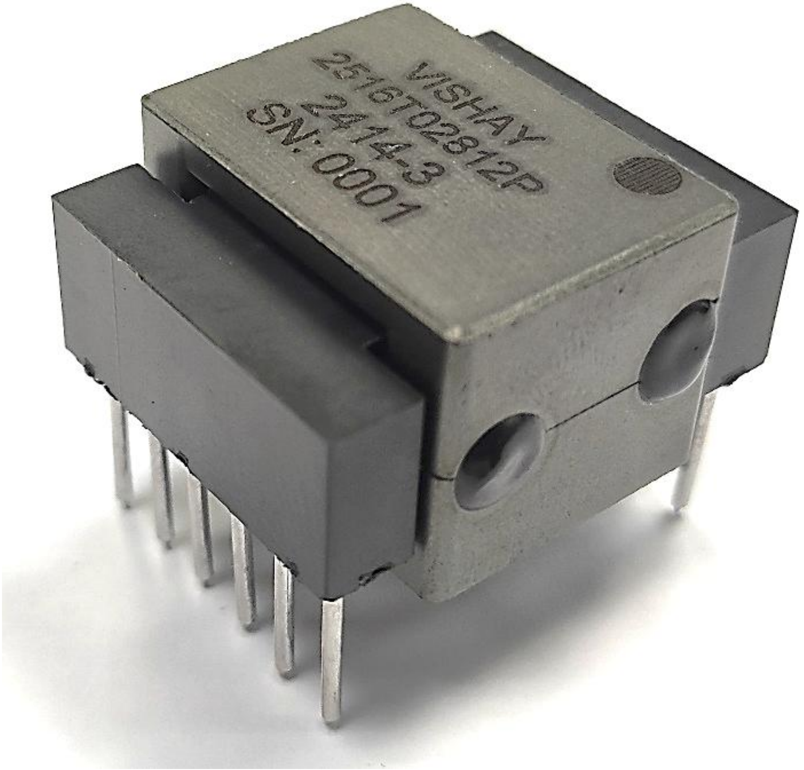
Hybrid Planar vs. Traditional Planar Style; Benefits of Hybrid Planar Magnetics

- Hybrid styles can achieve higher copper fill percentages compared to PCB style planar transformers which improves efficiencies.
- Easily customized often without footprint or printer circuit board changes.
- Greater flexibility within the winding structure, not dependent on physical properties and limitations of PCBs.
- Can achieve high levels of dielectric strength by using enameled magnet wire, insulators, and encapsulation.
- Solder joints are easily inspectable prior to encapsulation (pre-cap inspection).
- Eliminates tradeoffs and failure modes of PCBA based designs, e.g., etchback, solder fill, delamination, CTE issues with thicker boards.



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Magnetic Screenings for Space Applications

- **MIL-STD-981**: Department of Defense's Standard for Custom Electromagnetic Devices for Space Applications.
  - Class S
  - Class B
- **ESCC 3201**: European Space Components Coordination Generic Specification for Coils, RF and Power, Fixed.
  - Class B, Levels 3, 2, and/or 1
  - Class B, Levels 3, 2, and/or 1
- **EEE-INST-002:** – Screening developed by NASA for use on their Goddard Space Flight Center projects.
  - Level 1, 2 or 3
- **MIL-PRF-27**: Military Specification for power, audio and high-power pulse transformers and inductors.
  - Product Level C, M, or T
- **AEC-Q200**: Automotive Electronics Council's Stress Test Qualification for Passive Components.
- **Custom Screening Plans**: Screening plans coordinated between the end customer and the component supplier.

Vishay’s Space Screening Standard Offerings

SCREENING BREAKDOWN TABLE						
	P = PRODUCTION SCREENED	L = LOW EARTH ORBIT (LEO) SCREENED	E3 = EEE-INST-002 Level 3 Screened	E2 = EEE-INST-002 Level 2 Screened	B = MIL-STD-981 TABLE VI CLASS B SCREENED	S = MIL-STD-981 TABLE VI AND XII CLASS S SCREENED
PRODUCTION SCREENING (sample size = 100 %)						
Electrical characteristics (continuity, inductance (Ls), turns ratio (TR), phase, leakage inductance, DWV, insulation resistance, DCR)	✓	✓	✓	✓	✓	✓
Mechanical inspection	✓	✓	✓	✓	✓	✓
Visual inspection	✓	✓	✓	✓	✓	✓
QUALITY CONFORMANCE SCREENING (group A) (sample size = 100 %)						
5 cycle thermal shock (-55 °C to +130 °C)	n/a	n/a	✓	n/a		
10 cycle thermal shock (-55 °C to +130 °C)	n/a	✓	n/a	✓	n/a	n/a
96 hour burn-in at 130 °C (unpowered)	n/a	✓	n/a	n/a	n/a	n/a
25 cycle thermal shock (-55 °C to +130 °C)	n/a	n/a	n/a	n/a	✓	✓
96 hour burn-in at 130 °C (powered) (130 °C = ambient temp. + temp. rise)	n/a	n/a	n/a	✓	✓	✓
Induced voltage	n/a	n/a	✓	✓	✓	✓
Dielectric withstanding voltage (DWV)	n/a	✓	✓	✓	✓	✓
Dielectric withstanding voltage (DWV) at Altitude	n/a	n/a	✓	✓	n/a	n/a
Insulation resistance (IR)	n/a	✓	✓	✓	✓	✓
Electrical characteristics (continuity, LS, TR, phase, leakage inductance, DCR)	n/a	✓	✓	✓	✓	✓
Radiographic inspection	n/a	n/a	n/a	n/a	n/a	✓
Mechanical inspection (sampled per table V; MIL-STD-981)	n/a	✓	n/a	n/a	✓	✓
Visual inspection (100 %)	n/a	✓	✓	✓	✓	✓
QUALIFICATION INSPECTION (group B) (lot sampling)						
MIL-STD-981 table XII	n/a	n/a	n/a	n/a	n/a	✓
EEE-INST-002 Table 3	n/a	n/a	n/a	Optional	n/a	n/a

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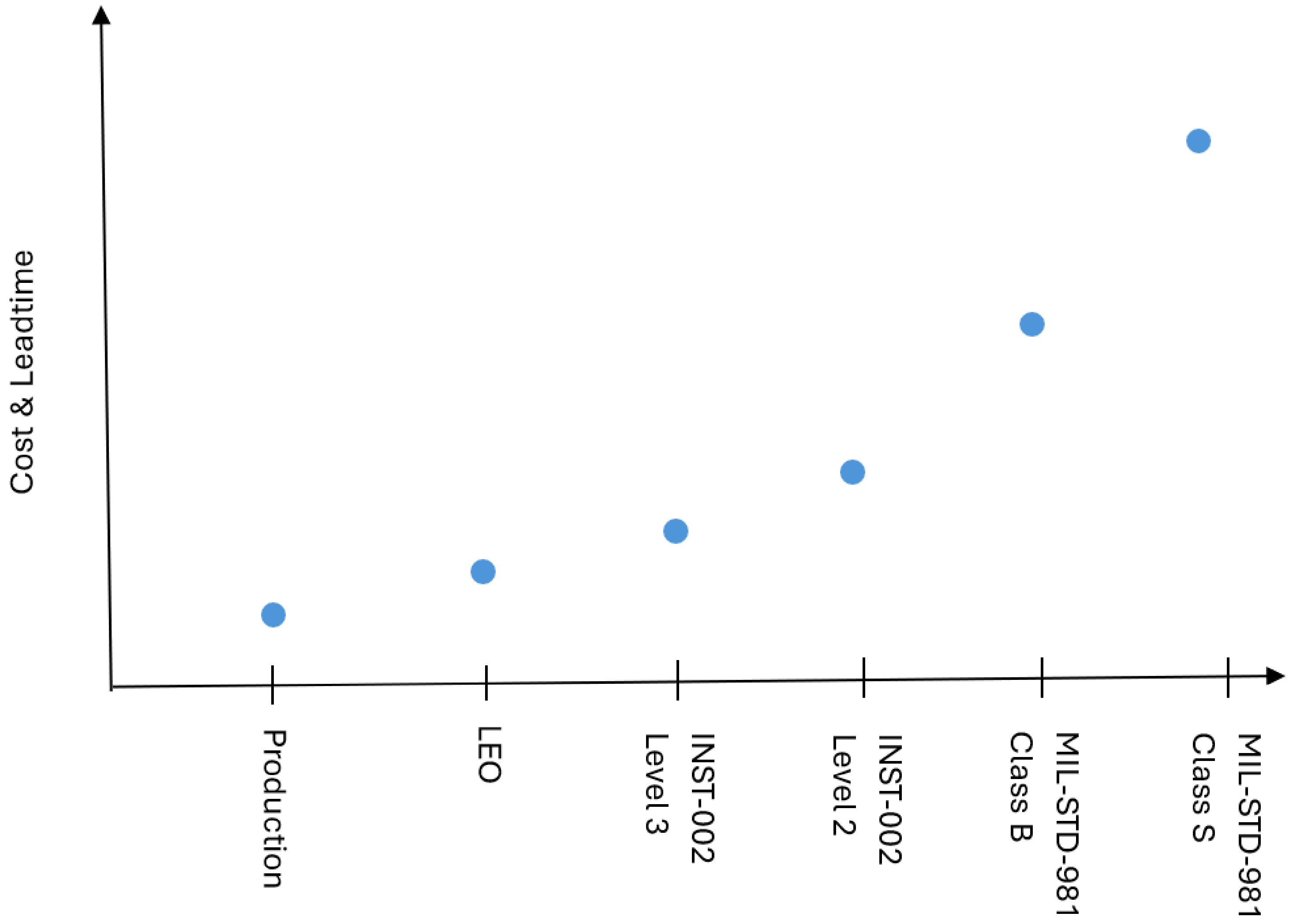
Vishay's Space Screening Standard Offerings



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Thank you
Questions?