The Multinational Power Electronics Association

PSMA Magnetics Committee Meeting

October 8TH 2024

Ed Herbert, George Slama, Matt Wilkowski
Committee Chairs

PSMA is a not-for-profit organization and a CO-SPONSOR OF APEC

PSMA Magnetics Committee Meeting Agenda
October 8, 2024

- Introductions
- 2025 Workshop Planning
- 2025 Industry Session Planning
- Power Technology Roadmap
- Special Projects
  - Electrical parameters of magnetic materials
  - Core Loss Database
- Magnetics Forum on PSMA Website
- Next Meeting

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PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes October 8, 2024

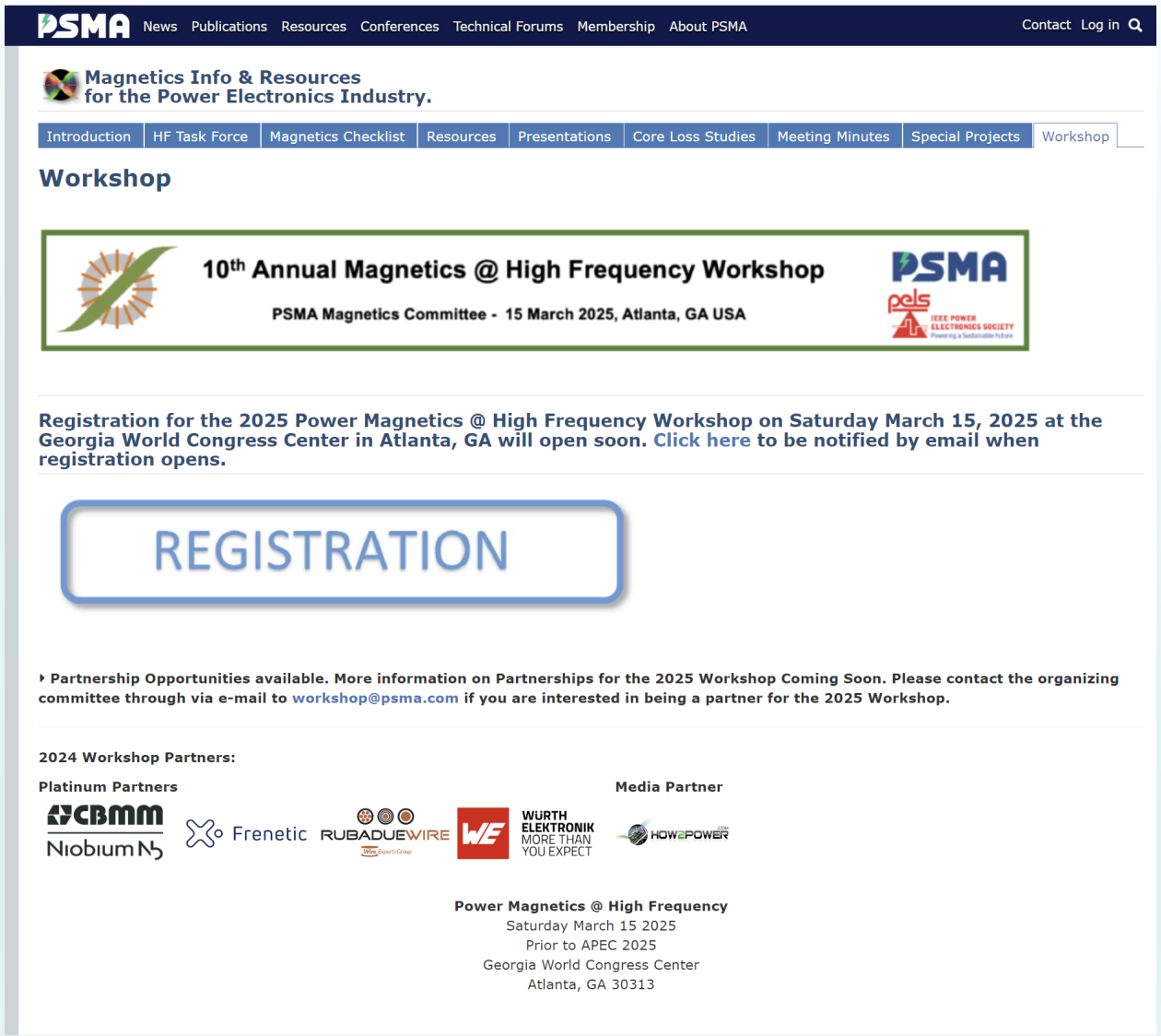
- Workshop Tab
  - Workshop partners
    - 2024 Workshop partners added

Add photos to 2024 workshop text.

Fees for 2025 workshop will be the same as for the 2024 workshop

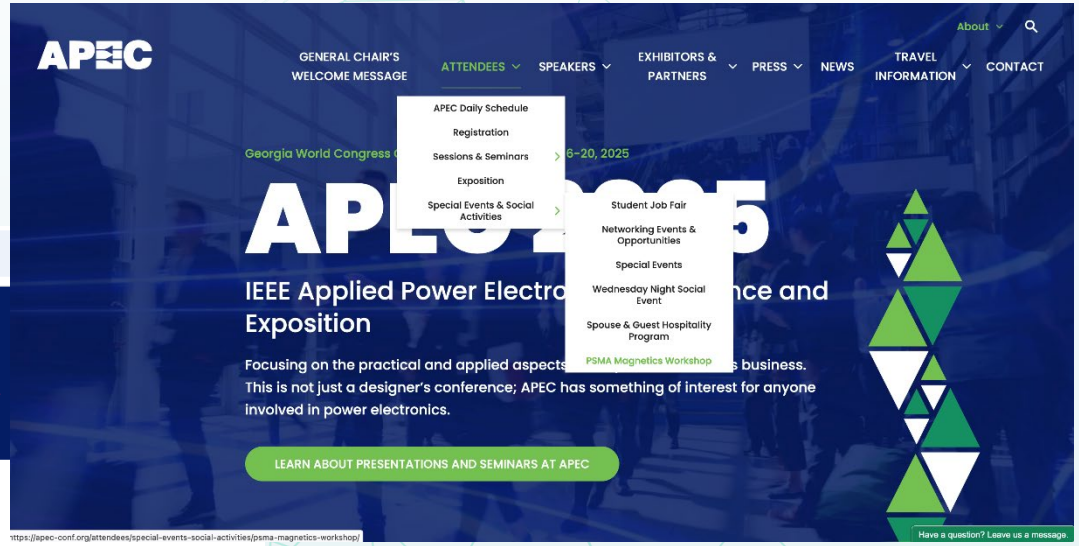
Previous Discussion:
Preserve partners for specific workshop years
Either by
1. Part of the running text on the workshop home page
2. Presentation pages for each workshop year

Presence on APEC website



PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes October 8, 2024

- APEC webpage
  - Not on first page as past workshops
  - need to drill down two menus before reaching workshop page



apec-conf.org/attendees/special-events-social-activities/psma-magnetics-workshop/

APEC

GENERAL CHAIR'S WELCOME MESSAGE | ATTENDEES | SPEAKERS

PSMA MAGNETICS WORKSHOP

Saturday, March 15, 2025
Location: To Be Announced

While not part of the official APEC Program the Magnetics Workshop, organized jointly by the Power Sources Manufacturers Association (PSMA) and the IEEE Power Electronics Society (PELS), held the Saturday before APEC begins, has become an established tradition. The 2025 workshop will be held on Saturday, March 15, 2025 at [Location To Be Announced].

Details of the workshop will be published as they become available.

Registration for this workshop is separate from the registration for the APEC conference.

Registration for the workshop is limited and will open on [Date To Be Announced].

The PSMA workshop page, with information on previous workshops, is here.

Each year at APEC, the IEEE Power Electronics Society (PELS) hosts a series of meetings, workshops, and events. One of the sponsoring organizations for APEC, PELS, has facilitated and guided the development and innovation in power electronics technology for more than 40 years. In striving to build knowledge and awareness of the latest technologies and other advances in power electronics, the goal of PELS is to keep members current and competitive in the workplace and provide them with the tools necessary to help them grow both personally and professionally.

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
October 8, 2024

- Morning Session – Physical Integration
  - Plenary – Minjie Chen (Princeton) ✓
  - Magnetics Integration for 2.5D Vs 3D Packaging – Ranajit Sai (Tyndall) ✓
  - Wafer Level Magnetics Sputtered – Martin Haug/Martin Sittner (Wurth)?
  - ~~Magnetics for 3D Power Delivery – Patrick Fouassier Premo Power~~
  - Planar Magnetics – Payton Planar Magnetics? ~~Nicola Rosano Vicor~~
  - Assembly methods – Sandia? – Additives combining core/winding
  - Power System in Package – John McDonald (Atlas Magnetics) ✓
    - Silicon + Discrete Magnetics in semiconductor packaging - ???
  - Embedded and 3D Printing Rico Wachs (TriDelta)
- Afternoon Session - Electrical integration
  - Plenary – Charlie Sullivan (Dartmouth) ✓
  - VIRT – Mike Ranjram (ASU) ✓
  - Simulation – Alfonso Martinez (Wurth) ✓
  - Capacitor/Inductor – Phyo Kyaw (Resonant Link)?
  - TLVR – ADI, Eaton, TI, Carrera (Onsemi)?
  - ~~LLC – Runo Nielsen (runo.nielsen@tdcadsl.dk)~~
  - Coupled Inductors – Qiang Li (CPES)?

Morning Session need plenary presentation plus 5 lecture presentations

Afternoon Session need plenary presentation plus 4 lecture presentations

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
October 8, 2024

- Candidates for future workshop leadership
  - Candidates to pursue
    - Paul Ohodnicki – UPITT – confirmed interest
    - Mike Ranjram – ASU – confirmed interest
    - Andres Arias – Premier – confirmed interest
    - Identify another person from industry to have industry/academia balance

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
October 8, 2024

- Tech Demos - Confirmed
  1. Wattmeter – Gregg Schaeppi/Dave Stuart (Zimmer) ✓ *(George to re-verify)*
  2. Dimensional resonance, fringing mitigation, core design – Mike Arasim (Fair-Rite) ✓
  3. Open magnetics demo – Alfonso Martinez (open Magnetics) ✓
  4. Active damping of EMI filters using low Q powder materials – Lukas Mueller (Micrometals) ✓
  5. Double pulse testing of magnetic components – Kevin Hermanns (PE Systems) ✓
  6. Core permeability and permittivity measurements of shielding material – Akihko Saito (IEC TC51 WG10) ✓
  7. Electromagnetic wave shield measurement – Kosuke Yuasa (Daido Steel) ✓
  8. CMC and LLC - Andres Arias (Premier) ✓
  9. Triple Pulse Testing Open-source project - Jun Wang (UK Bristol) ✓
  10. AI-based Magnetics Database - Wilmar Martinez (KU Leuven) ✓
  11. Test Methodology to Validate Integrity and Reliability of Magnetic Core Insulation with Respect to High Frequency Voltage Stress - Efrain Bernal (Wurth Elektronik) ✓
  12. Linear versus non-linear magnetic characteristics – JC Sun (Bs&T) ✓

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
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- Tech Demos - Identified
  - Core Loss Database project
    - Demonstration of the website database
      - Visualization of core loss data
  - Our other project – core permittivity and permeability characteristics
    - Jonas' student either a tech demo or a poster
    - ~~University of Padaborn - Till Piepenbrock~~
    - Bruce Carsten
  - Partial Discharge system (Chroma, Hipotronics, Hubbel, …)
    - Doble Falk Werrner
  - Capacitor with magnetics (Alan) LLC – capacitor voltage rating
  - Build an integrated device
  - Component manufacturers of Integrated Magnetics
    - Payton Planar Magnetics pending outcome of lecture presenter for AM lecture session
  - Himet – Sputtered magnetic materials - Raj Nataraj

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
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- Posters
  - ASU – Jacob Anderson, Nick Kirkby
    - Automated Temperature-regulated High-frequency Core Loss Data Collection
  - MIT – Rachel Yang
    - *Optimization of Magnetics Design Across Broad Application Ranges*
  - HSLU – Frederic (maybe someone else – contact Jonas M)
    - Core permittivity and permeability characteristics
  - UPITT – TBD (Sturdivant?)
    - Application of multiple objective optimization relative magnetics integration or other magnetic design topic
  - Princeton – TBD
    - TBD but most likely related to machine learning of core loss measurement data

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PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes
October 8, 2024

- The Transformer in the Solid-State Transformer
  - Accepted as IS07
    - Seven presentation session
    - Wednesday AM session
    - Need to populate presenter information by October 21
- Core Loss – Making Data Reliable and Relevant
  - Accepted as IS24
    - Four presentation session
    - Thursday AM session
    - Need to populate presenter information by October 21

PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes
October 8, 2024

Proposal for an Industry Session for APEC2025

Magnetics Industry Session

The Transformer in the Solid-State Transformer

(Seven presentations)

Georgia World Congress Center
Atlanta, GA

March 18, 19, or 20, 2025

PSMA Magnetics Committee
August 21, 2024

The PSMA Magnetics Committee is proposing a seven topic Industry Session for APEC2025. The subject will be all aspects of designing the transformer of a **solid-state transformer.** The session will have seven speakers addressing a variety of topics related to the magnetics transformer portion of the solid-state transformer. Solid-state transformers are an emerging technology that replaces the traditional line frequency transformer with additional functions and intelligence.

The Industry Session will target the specific interests of the PSMA and APEC audience who are designing, specifying and installing transformers in a solid-state transformer system in efforts to modernize the power grid and other high power medium voltage applications. The benefits of improved semiconductor devices, advanced control systems and high frequency are well known to improve the reliability, response and efficiency of power delivery systems. However, even though the design equations may be scalable from low power, low voltage applications to high power, high voltage applications; the specifics of the magnetics design to support solid-state transformer topologies drives a different pareto of design trade-offs for physical realization.

The topics of the seven presentations are as follows:

1. Overview of Magnetics Transformer Function as Part of the Solid-State Transformer
2. Conductor Design
3. Insulation/Isolation Issues
4. Magnetic Materials Options and Trade-Offs
5. Leakage Inductance and Coupling Issues
6. Capacitance Issues
7. Thermal Design

Session Chairs:
George Slama, George.Slama@we-online.com

Ed Herbert ed@eh-psma.com

Matt Wilkowski. Mattwilkow57@gmail.com

PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes
October 8, 2024

Solid State Transformers From Supply Chain to Qualified Installed Product
Solid State Transformers From Genesis to Backbone Product of the Smartgrid Revolution
Focus on Solid State Transformers
ABC's of Solid Sate transformers

The Transformer in the Solid State Transformer

- All aspects of fabricating a Solid-State Transformer (SST)
  1. Overview – *Dr Alex Huang (UT)?*
  2. Conductor design
  3. Insulation/Isolation Issues
     1. *Paul Ohodnicki – UPITT – P3105 Subgroup 2 Isolation Issues for SST* ✓
  4. Magnetic Core materials – *AMPED (NCSU, UPITT) CorePower Magnetics?*
  5. Coupling and Leakage Inductance
     1. *Drazen Dujic – EPFL – Inductance and Leakage Inductance Measurements for MFT?*
  6. Capacitance – *Hongbo Zhao (Aalborg University)*
  7. Thermal Design – *NCSU? UPM? Utah State University?*
  8. AC Power Loss - *either or with magnetic core materials*
  9. Environmental Design

North Carolina State

Coolmag – thermal potting (demo too)
url: https://coolmag.net/

- **Focus on the transformer of Solid-State Transformer**
  - Too many APEC and ECCE session on SST focus on topology rather than the transformer

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes October 8, 2024

Proposal for an Industry Session for APEC2024

Magnetics Industry Session

Core Loss – Making the Data Reliable and Relevant

(Four presentations)

Georgia World Congress Center
Atlanta, GA

March 18, 19, or 20, 2025

PSMA Magnetics Committee
August 21, 2024

The PSMA Magnetics Committee is proposing a four topic Industry Session for APEC2025. The subject will be meaningful **magnetic core loss measurements.** The session will have four speakers addressing a variety of topics related to correlation of magnetic core loss measurements made by different methods and the development of a database to collect verified core loss measurements made by qualified methods.

The Industry Session will target the specific interests of the PSMA and APEC audience. For this audience, the common subject of interest is to be able to reliably compare measurements made by different methods and organizations for use in the design of magnetic components regardless of the magnetic core material, magnetic core structure and the circuit topology.

This session includes the observations of the results from different standards and research initiatives to compare measurements made on a common set of magnetic core samples using different test sets developed by different organizations. The goal of the initiatives is to define a methodology to qualify the data made by different equipment and organizations. The methodology includes defining sources of error and variation and corresponding limits for each. Ultimately enabling a common resultant data base of core loss measurements that can be used to make magnetic material choices, component design decisions and technical performance predictions based on reliable and relevant empirical measurement data.

The topics of the four presentations are as follows:

1. Scientific Network of Magnetics (ScN -Magnetics) Core Evaluation Kit Project
2. HFEMAG European Metrology Labs Correlation Project
3. Triple Pulse Core Loss Testing
4. PSMA – Core Loss Database Website

Session Chairs:
George Slama, George.Slama@we-online.com
Matt Wilkowski. Mattwilkow57@gmail.com

Core Loss – Ensuring the Quality of the Data
Core Loss – Consolidating Too Much Data
Core Loss – Making All the Data Useable

Core Loss – Making the Data Reliable and Useable

- Additional four-presentation industry session
  - Core Loss Testing & Modelling
    - Scientific Network of Magnetics – Jens Friebe – Kassel ✓
    - HFEMAG European Metrology Labs Correlation Project – Massimo Pasquale – INRIM ✓
    - Triple Pulse Core Loss Testing - Jun Wang – University of Bristol ✓
    - PSMA – Core Loss Database website – George Slama – Wurth Elektronik ✓
    - ETTC P393 Core Loss measurement proposal – Matt Wilkowski – Wurth Elektronik
    - Impact of machine learning to predict core loss – Minjie Chen - Princeton

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2025 Edition PSMA Power Technology Roadmap
Magnetics Section

- 2022 Topics (Published)
  - Energy Harvestings
  - Integrated Voltage Regulators (IVR)
  - Fully Integrated Voltage Regulators (FIVR)
  - Hybrid Integrated Voltage Regulators (HIVR)
  - Isolated Signal and Low Power Transformers
  - Power Supply on Chip (PwrSoC)
  - Power Management Integrated Circuits (PMIC)
  - Power Systems in Package (PSiP)
  - Mother Board Voltage Regulators (MBVR)
  - Wireless Power Transfer (WPT)
  - Solid State Transformers (SST)

- 2025 Topics (Proposed)
  - Embedded Magnetics
    - Integrated Voltage Regulators (IVR)
    - Fully Integrated Voltage Regulators (FIVR)
    - Hybrid Integrated Voltage Regulators (HIVR)
    - Isolated Signal and Low Power Transformers
    - PwrSoC (Power Supply on Chip)
    - Power Systems in Package (PSiP)
  - Solid State Transformers (SST)
  - Trans-Inductor Voltage Regulators (TLVR)
  - Mother Board Voltage Regulators (MBVR)
    - Lateral Power Delivery (LPD)
    - Vertical Power Delivery (VPD)
    - Dual Phase Power Block (DPPB)
  - Wireless Power Transfer (WPT)
    - EV Charging
  - Core Loss Measurement Methods & Databases
  - Magnetic Material Alternatives Opportunities and Limitations

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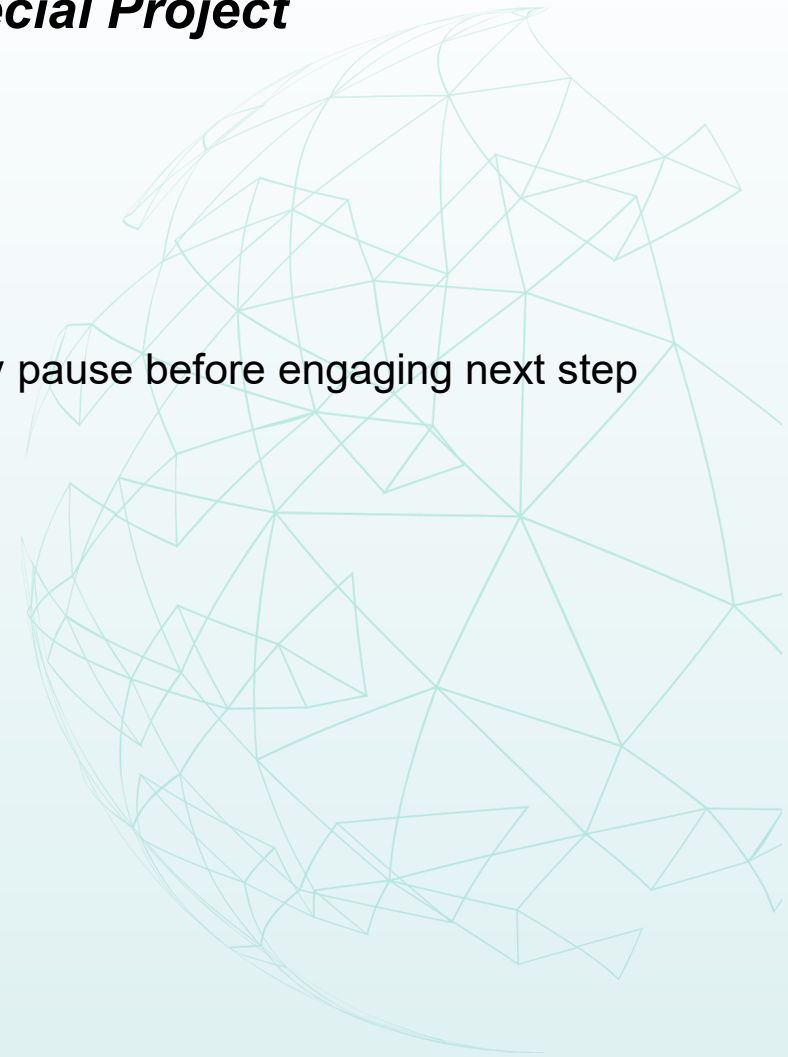
PSMA Magnetics Committee Meeting Agenda – Special Project
October 8, 2024

- Special Projects
  - In Process
    - Core Loss Database - active
    - Electrical parameters of magnetic materials – temporary pause before engaging next step
  - Pending
    - Steinmetz Like Approximation
    - Electrical parameters of magnetic materials
    - Propagation in magnetic materials
    - Current driven core loss testing
    - Spice model



PSMA Magnetics Committee Meeting Agenda – Special Projects
October 8, 2024

- Core Loss Database
  - Database should be on its own website
    - Link to the website on a tab in the PSMA Magnetics Forum
  - Project meetings separate from monthly magnetics committee meeting
    - Initial meeting during last week of September
      - September 25 10:00 AM CDT
    - Regular monthly project updates starting in November
      - November 13 10:00 AM CST (noting standard time begins on November 3)

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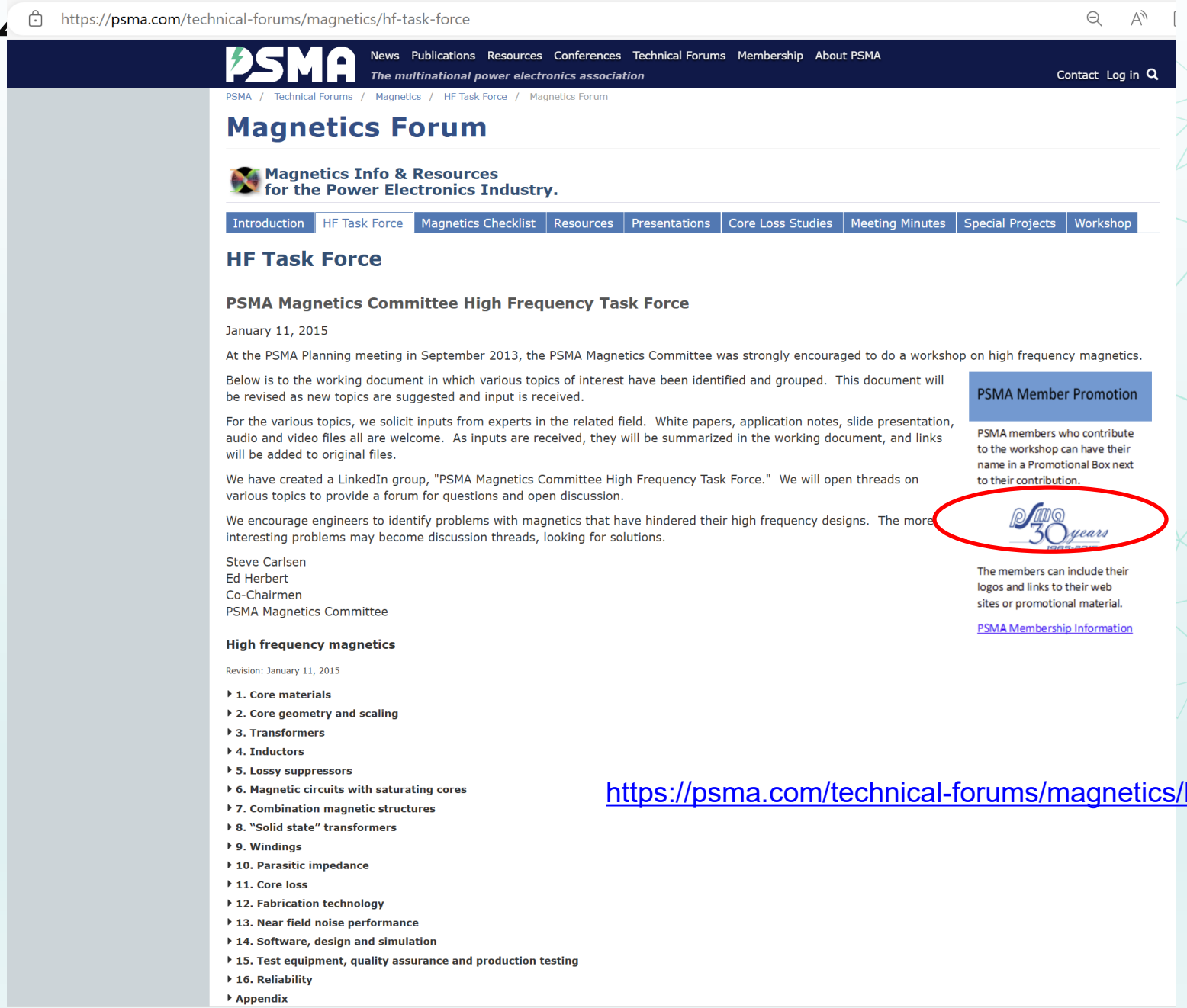
  - Core Loss Database – Separate monthly meeting beginning on November 13
- Magnetics Forum on PSMA Website
- Next Meeting

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
October 8, 2024

- In process
  - Section 1.3 Powdered metal
    - Proposal by Lukas Mueller has been accepted
    - Need to add to HF task force tab under magnetics Technical Forum on PSMA website
- Proposed additions/updates
  - Section 1 Core Materials
    - Sputtered (addition)
    - Electroplated (addition)
    - Section 1.4 Nanocrystalline and amorphous metals (populate)
  - Section 4 Inductors
    - TLVR inductors (addition)
  - Section 8 “Solid state” transformers (populate)
  - Section 12 Fabrication Technology
    - Section 12.3.2 Substrate embedded (populate)
    - Section 12.6 PSiP (populate)
    - Section 12.7 PwrSoc (populate)

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website October 8, 202



Update

https://psma.com/technical-forums/magnetics/hf-task-force

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website October 8, 2024

PSMA Membership Information

High frequency magnetics

Revision: January 11, 2015

1. Core materials

This section discusses the characteristics of various materials used to make inductor and transformer cores. Manufacturers are encouraged to provide their catalogs and data sheets to be included. Manufacturers who are PSMA members may have a promotional block placed in this report.

A good over-view of the various magnetic materials and their selection criteria can be found in "Magnetic Core Materials in HF Applications."[1]

1.1. Ferrite

1.2. Low temperature cured ferrites

1.3. Powdered metal

1.4. Nanocrystalline and amorphous metals

1.5. Composite cores

1.6. Tape-wound cores

1.7. Selection criteria

[1] Magnetic Core Materials in HF Applications; Dr. Jonas Mühlethaler, Gecko-Simulations, AG; an APEC2014 Industry Session

2. Core geometry and scaling
3. Transformers
4. Inductors
5. Lossy suppressors
6. Magnetic circuits with saturating cores
7. Combination magnetic structures
8. "Solid state" transformers
9. Windings
10. Parasitic impedance
11. Core loss
12. Fabrication technology
13. Near field noise performance
14. Software, design and simulation
15. Test equipment, quality assurance and production testing
16. Reliability
Appendix

Populate section 1.3 and 1.7 with content proposed by Lukas Mueller

PSMA Member Promotion

Tyndall National Institute

MICROMETALS™ POWDER CORE SOLUTIONS

Add Micrometals logo with link to Micrometals website to this section of HF task force

https://psma.com/technical-forums/magnetics/hf-task-force

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
October 8, 2024

Proposal By Lukas Mueller on June 28, 2024

Section 1.3 Powder Materials

Powdered metal-based cores are made from small particles of magnetic material that are insulated, mixed with a binder and pressed into a solid core shape. The defining characteristic of powder cores is their low starting permeability ranging from 4 to 550 and soft-saturation characteristic. Unlike a gapped high permeability material, a powder material will gradually lose its permeability with increasing magnetization force. Coupled with powder materials with high saturation flux density, these materials can store higher amounts of energy per unit volume than ferrite. Core loss is generally higher for powder materials than ferrite.

There are three broad subtypes of powder metal cores depending on the base raw material used: iron, carbonyl iron and alloy.

1.3.1 Powder iron cores are made from reduced iron. The main advantage of powder iron is the materials high saturation flux density, high amplitude permeability, high damping and low cost. The main disadvantage of powder iron is its high core loss compared to other materials, making it more suitable for low frequency power conversion, line reactor or EMI filtering applications

1.3.2 Carbonyl iron-based cores feature low eddy current losses due its unique magnetic particle structure. This gives these types of materials a stable permeability over a wide frequency range. The main application for carbonyl iron-based cores is in high Q resonant inductors and broadband transformers at frequencies above 1MHz.

1.3.3 Alloy powder cores feature lower hysteresis losses than powder iron cores. The stability of these materials' permeability versus magnetization force is also significantly better. Alloy powder cores excel in DC inductors in filtering and power conversion applications. There is a large variety of alloy cores including but not limited to: Sendust, Permalloy, Mollypermalloy and Silicon Steel.

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
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Proposal By Lukas Mueller on June 28, 2024

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Proposal By Lukas Mueller on June 28, 2024

Section 1.7 Selection criteria

The defining selection criteria for magnetic materials are: core loss, saturation flux density, inductance stability, temperature range and mechanical ruggedness.
For AC applications like high Q resonant inductors or transformers low core loss at the intended switching frequency is the primary concern. The performance factor of different material grades can be used to identify the material with the lowest core loss at a certain frequency.
For DC switching inductors, like PFC inductors, a mixture of inductance stability and core loss is desirable.
For EMI filter inductors, high damping is beneficial to limit parasitic resonances in the filter. In addition, a high impedance over the desired filtering frequency range is crucial. For DC filter inductors, a high DC bias stability is desired. The material saturation constant can be used to evaluate different materials in this regard. For AC line filter inductors, a high saturation flux density and high amplitude permeability are beneficial.

Proposal By Lukas Mueller on June 28, 2024

Section 1.7 Selection criteria (Continued)

Application	Material 1	Material 2	Material 3	Note
Common Mode Choke	MnZn Ferrite	Nanocrystalline	NiZn Ferrite	Carbonyl iron above 500MHz an option as well
DC Filter Choke	Powder Alloy	MnZn Ferrite	Powder Iron	
AC Line Choke	Power Iron	Powder Alloy	Fe-Si (laminated)	
AC Filter Choke	Carbonyl iron	Powder Alloy	MnZn Ferrute	
CCM Switching inductor	Powder Alloy	MnZn Ferrite	Nanocrystalline	Evaluate DC bias stability vs. core loss
DCM Switching Inductor	MnZn Ferrite	NiZn Ferrite	Carbonyl Iron	Carbonyl iron has higher core loss but lower AC copper loss due to distributed air gap
Tuned RF inductor	Carbonyl Iron	NiZn Ferrite	Air	
Transformer	MnZn Ferrite	Nanocrystalline	NiZn Ferrite	

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- Next Meeting - avoid third Wednesday of month

PSMA Magnetics Committee Meeting Agenda
October 8, 2024 – Next Meeting

- Wednesday November 6 10:00 AM CDT – 11:00 AM CDT

PSMA Magnetics Committee Meeting
October 8, 2024

- Attendance (12)
  - John Horzepa
  - Mike Arasim
  - Jim Cox
  - Doug Eaton
  - Frank Feng
  - Ed Herbert
  - Alfonso Martinez
  - Lukas Mueller
  - Mike Ranjram
  - Rodney Rogers
  - Ranajit Sai
  - George Slama
  - JC Sun
  - Mark Swihart
  - Jun Wang
  - Matt Wilkowski

Thank You