The Multinational Power Electronics Association

PSMA Magnetics Committee Meeting

November 6TH 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
November 6, 2024

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

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PSMA Magnetics Committee Meeting Agenda – Special Project
November 6, 2024

- Special Projects
  - In Process
    - Electrical parameters of magnetic materials – interim activities since September 2024
    - Core Loss Database - active
  - Pending
    - Steinmetz Like Approximation
    - Electrical parameters of magnetic materials
    - Propagation in magnetic materials
    - Current driven core loss testing
    - Spice model

- Permittivity measurements with a saturating magnetic field
  - Background Info
    - We have a new student for the fall semester, Fabrice Locher. He is an undergraduate and will work under the supervision of Jonas Mühlethaler
    - Jonas has tailored the work under the project to the abilities of the student, the time and equipment available and the budget. Briefly, the work will continue the work started by Frédéric Mathieu, verifying it and extending the measurements to a higher frequency
  - Activities since September by Fabrice Lacher and Jonas Mühlethaler
    - Work on publication for APEC (The paper has been accepted for the Poster Session)
    - Re-did permeability measurements with DC field through extra wire, rather than through electromagnet (so we have a DC field in the same orientation as main flux
    - “4-wire” measurements with Bode 100 (so far the results were almost the same, so we have a high confidence in the results)
    - Prepared toroid for permittivity / conductivity measurements
    - Ed started making sense of the results with a literature review (still ongoing, needs time, and cannot be outsourced to student)

PSMA Magnetics Committee Meeting Agenda – Special Projects
November 6, 2024

- Permittivity measurements with a saturating magnetic field
  - Activities going forward
    - 4 November, 2024
      - Permittivity measurements on toroid, see whether we have same results and can go to higher frequencies
      - Work on APEC publication / Literature study by Jonas
    - 11 November, 2024
      - Work on APEC publication / Literature study by Jonas
      - Try to observe dimensional resonance with new measurement setup (4-wire, toroids)
      - Try to make sense on the abrupt changes of permittivity under DC bias at higher frequency (see Frédéric's work)
    - 18 November, 2024
      - APEC Deadline publication
      - Work on new PCBs for permittivity measurements (reduce skin effect) / see E. H. Email with some suggestions; Include study of skin effect here (a comment: skin effect is a well understood problem, and can be simulated with FEM; in other words: I suggest to do a FEM study of the PCB.Try to make sense on the abrupt changes of permittivity under DC bias at higher frequency (see Frédéric's work)
      - FEM is not good in non-linear core materials, but good in linear copper

PSMA Magnetics Committee Meeting Agenda – Special Projects
November 6, 2024

- Permittivity measurements with a saturating magnetic field
  - Activities going forward
    - 25 November, 2024
      - FEM/Skin effect study by Fabrice (Fabrice will most likely not find time to go into the flux propagation study)
        - *Here and in the following weeks Jonas can start thinking about flux propagation and 4-wire with scope, until here Jonas have to focus on the APEC paper which is related to the project as well*
    - 2 December, 2024
      - FEM/Skin effect study by Fabrice (Fabrice will most likely not find time to go into the flux propagation study)
    - 9 December, 2024
      - Flux propagation and 4-wire with scope by Jonas
    - 16 December, 2024
      - Flux propagation and 4-wire with scope by Jonas
    - Christmas break/Next year
      - We will work out a plan in detail, maybe with a graduate student. But keep in mind, the USD 10k is a limited budget and we did a lot already…

PSMA Magnetics Committee Meeting Agenda – Special Projects
November 6, 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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PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

- Workshop Tab
  - Workshop partners
    - 2025 Workshop partners updated

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

- Workshop Tab
  - Registration
    - Open

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2025 Power Magnetics @ High Frequency Workshop Registration

10th Annual Magnetics @ High Frequency Workshop

PSMA Magnetics Committee — 15 March 2025, Atlanta, GA USA

Registration Rates (Early Bird Pricing Deadline: Friday January 31, 2025)*

- Member Early/ Regular $295/ $345
- Non-Member Early/ Regular $395/ $445

Workshop Partners:

Frenetic, RUBADUEWIRE, WÜRTH ELEKTRONIK MORE THAN YOU EXPECT, YAGEO, CBMM Niobium, Bodo's Power Systems, HOW2POWER

First name* **Last name***

First name for name badge, if different from above

Title/ Job Function

Company/ Organization*

Address*

Address 2

City/Town* **State/Province** **ZIP/Postal Code**

- None -

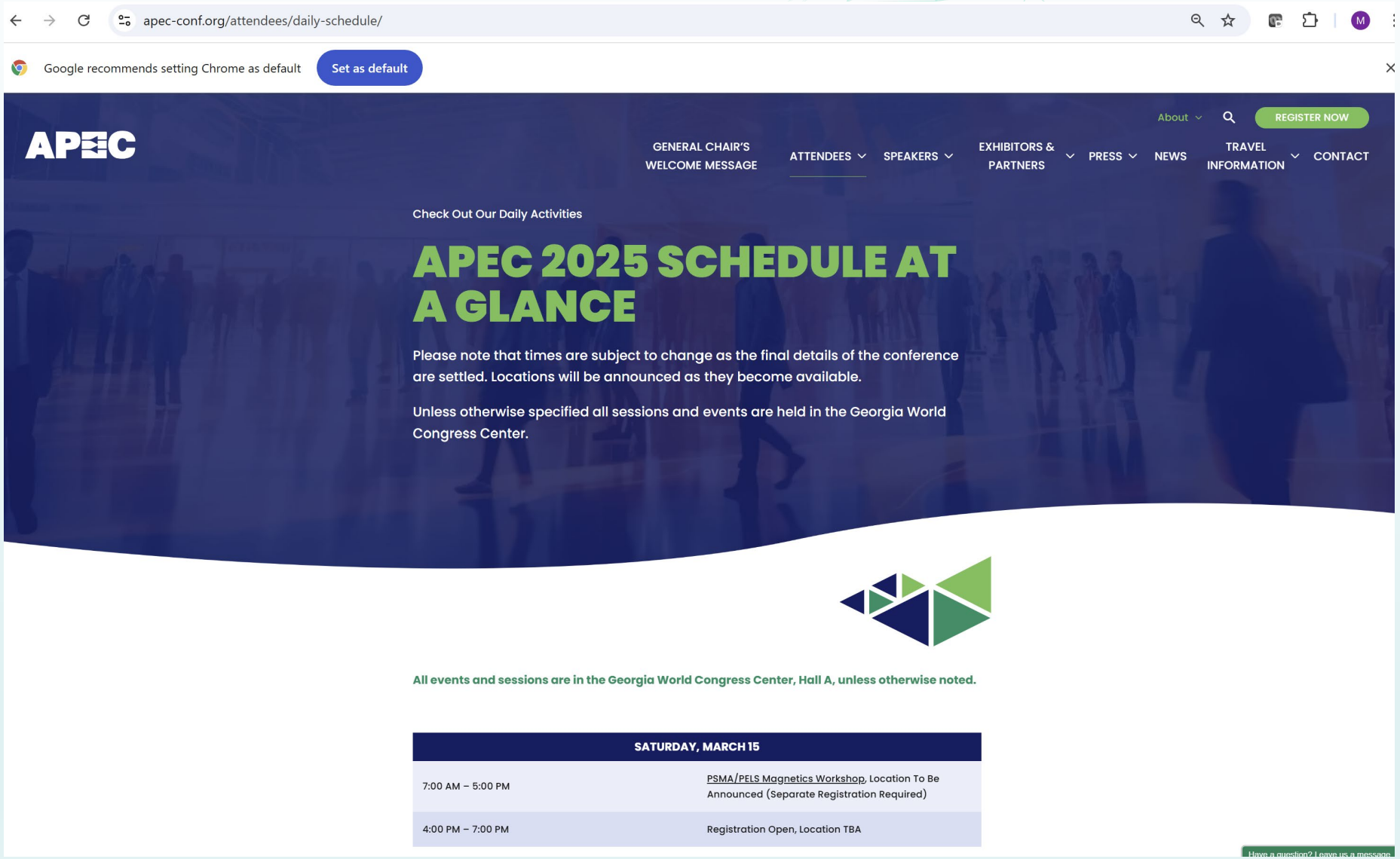
Country*

- Select -

Telephone:*

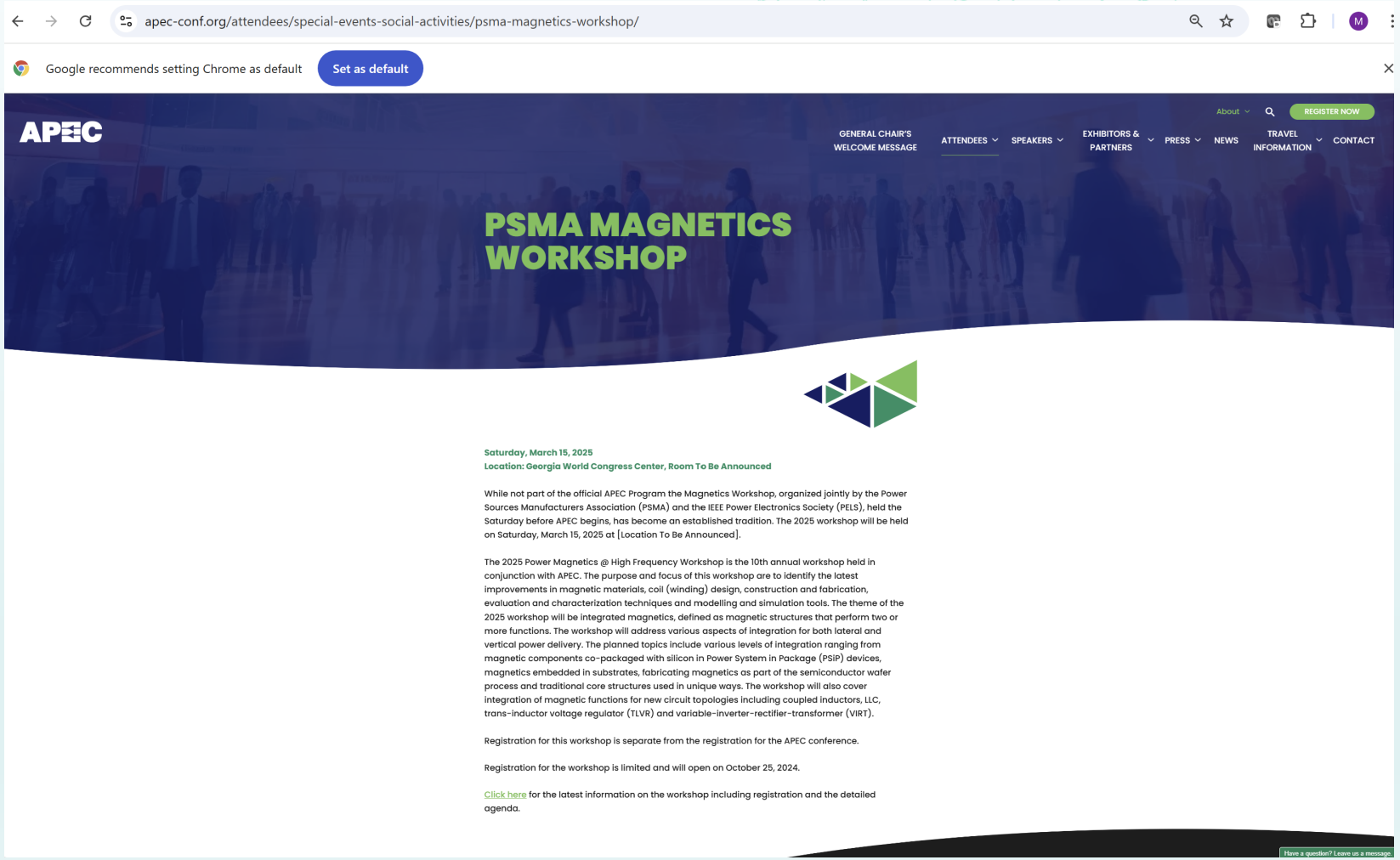
PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

- APEC webpage
  - Schedule at a glance



PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

- APEC webpage
  - PSMA Magnetics Workshop



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Power Magnetics @ High Frequency Workshop 2025 Agenda

Date: Saturday, March 15, 2025

Location: Georgia World Congress Center, Atlanta, GA

Preliminary Agenda, Subject to change

7:00 AM - 8:00 AM **Registration, Technical Demonstrations, Posters and Breakfast**

8:00 AM - 8:05 AM **Opening Remarks**

8:05 AM - 9:25 AM **Technical Session - Physical Construction and Structure for Integration of Power Magnetic Devices Part I**

- **Keynote:** Trends of Physical Structures of Magnetic Devices for Power Applications Over the Past Ten Years; *Minjie Chen, Princeton University*
- Magnetics Integrations for 2.5D and 3D Packaging; *Ranajit Sai, Tyndall*

9:25 AM - 9:45 AM **Break**

9:45 AM - 12:00 Noon **Technical Session - Physical Construction and Structure for Integration of Power Magnetic Devices Part II**

- Inductive Components on Silicon Substrate 300mm Wafer; *Jens Kehl, Wurth Elektronik*
- Ferrite Technology in Transition - Process and Shaping; *Sebastian Bachman, Tridelta Weichferrite*
- Magnetics for Power System in Package (PSiP); *John McDonald, Atlas Magnetics*
- Panel Discussion

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PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

12:00 Noon - 2:00 PM Technology Demonstration and Poster Session

- Wattmeter for AC Power Loss Measurements; *Gregg Schaeppi, ZES Zimmer*
- Active Damping of EMI Filters Using Low Q Powder Materials; *Lukas Mueller, Micrometals*
- Open Magnetics Demo; *Alfonso Martinez, Open Magnetics*
- Double Pulse Testing of Magnetic Components; *Kevin Hermanns, PE Systems*
- Core Permeability and Permittivity Measurements of Shielding Materials; *Akihiko Saito, Daido Steel*
- Construction of an Electromagnetic Wave Shielding Effect Measurement Method Using a Loop Antenna; *Kosuke Yuasa, Daido Steel*
- Integrated Magnetics, Optimization Common Mode Chokes (CMC) Integrated with Differential Mode Chokes (DMC), and Review of LLC Transformer with Integrated Inductor; *Andres Arias, Risha Yu, Premier Magnetics*
- Triple Pulse Testing Open-Source Project; *Jun Wang, University of Bristol*
- PowerBrain: AI-based Magnetic Database: Experimental and Generative Data; *Wilmar Martinez, KU Leuven*
- Linear Versus Non-Linear Magnetic Characteristics; *JC Sun, Bs&T*
- Dimensional Resonance and Fringing Mitigation Considerations for Magnetic Core Design; *Mike Arasim, Fair-Rite Products Corp.*
- Simple and Effective Technique to Verify Impact of High Temperature and High Voltage High Frequency Stresses on Inductor Electrical Performance; *Efrain Bernal, Wurth Elektronik*

Posters:

- Automated Temperature Regulated Core Loss Testing with High-Frequency Class D Amplifiers; *Jacob Anderson, Nick Kirkby, Arizona State University (ASU)*
- Optimization of Magnetics Design Across Broad Application Ranges; *Rachel Yang, MIT*
- *TBD*
- *TBD*

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes November 6, 2024

2:00 PM - 3:50 PM **Technical Session - Electrical Parameter Integration - Part I**

- **Keynote:** Trends of Electrical Requirements, Modelling and Simulation Over the Past Ten Years; *Charles Sullivan, Dartmouth College*
- Variable-Inverter-Rectifier-Transformer (VIRT) Hybrid Electronics; *Mike Ranjram, Arizona State University*
- Simulation Techniques for Integrated Magnetic Functions; *Alfonso Martinez, Wurth Elektronik*

3:50 PM - 4:10 PM **Break**

4:10 PM - 5:10 PM **Technical Session - Electrical Parameter Integration - Part II**

- Trans-Inductor Voltage Regulator Inductors; *Alberto Carrera, Onsemi*
- Panel Discussion

5:10 PM - 5:30 PM **Closing Remarks**

5:30 PM - 6:30 PM **Networking Hour**

- **Technology Demonstrations and Posters**

REGISTRATION

Workshop Partners:

Frenetic RUBADUEWIRE Wire Experts Group WE WÜRTH ELEKTRONIK MORE THAN YOU EXPECT YAGEO Built into Tomorrow CBMM Niobium Nb Bodo's Power Systems HOW2POWER .COM

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PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes November 6, 2024

Wednesday, March 19, 2025

8:30 AM – 11:55 AM ET	IS07 - The Transformer in the Solid-State Transformer Industry Session Chair: George Slama – Wurth Elektronik Industry Session Chair: Ed Herbert, BEEE – None PSMA Session
8:30 AM – 8:55 AM ET	IS07.1 - Recommended Practices for Solid State Transformer Design and Testing Location: A412 Industry Session Presenter: Paul Ohodnicki – University of Pittsburgh
8:55 AM – 9:20 AM ET	IS07.2 - Addressing Insualtion and Isolation Issues in the Solid State Transformer Location: A412 Industry Session Presenter: Zhicheng Guo – Arizona State University
9:20 AM – 9:45 AM ET	IS07.3 - Enabling High Power Transformer Design With Advanced Magnetic Mmaterials Location: A412 Industry Session Presenter: Veda Duppalli – CorePower Magnetics
9:45 AM – 10:10 AM ET	IS07.4 - Thermal Design and Limits of the Transformer in the Solid State Transformer Location: A412 Industry Session Presenter: Subhashish Bhattacharya, PhD – North Carolina State University
10:40 AM – 11:05 AM ET	IS07.5 - Managing Trade-Offs in Design of High-Power Medium Frequency Transformers for Solid-State Transformers Location: A412 Industry Session Presenter: Drazen Dujic – PEL EPFL
11:05 AM – 11:30 AM ET	IS07.6 - Medium Frequency Transformers for Data Centers Location: A412 Industry Session Presenter: Isaac Wong – North Carolina State University
11:30 AM – 11:55 AM ET	IS07.7 - Evolution of the Solid State Transformer for Different Applications Location: A412

IS Committee		IS072: "*The Transformer in the Solid State Transformer*"				
REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED
8:30 AM	8:55 AM	Recommended Practices for Solid State Transformer Design and Testing	Paul	Ohodnicki	PRO8@pitt.edu	University of Pittsburg
8:55 AM	9:20 AM	*Addressing Insualtion and Isolation Issues in the Solid State Transformer*	*Zhicheng*	*Guo*	Zhicheng.Guo@asu.edu	*Arizona State University*
9:20 AM	9:45 AM	*Impact of Standards on Design Choices and Material Options*	*Veda*	*Duppalli*	veda.duppalli@corepo	*CorePower Magnetics*
9:45 AM	10:10 AM	*Thermal Design and Limits of the Transformer in the Solid State Transformer*	*Subhashish*	*Bhattacharya*	sbhatta4@ncsu.edu	*North Carolina State University*
10:40 AM	11:05 AM	Managing Trade-Offs in Design of High-Power Medium Frequency Transformers for Solid-State Transformers	Drazen	Dujic	drazen.dujic@epfl.ch	EPFL
11:05 AM	11:30 AM	Medium Frequency Transformers for Data Centers	Isaac	Wong	twong3@ncsu.edu	*North Carolina State University*
11:30 AM	11:55 AM	Evolution of the Solid State Transformer for Different Applications	Rafal	Wojda	wojdarp@ornl.gov	Oak Ridge National Laboratory

PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes
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8:00 AM – 9:40 AM ET	IS24 - Core Loss - Making the Data Reliable and Relevant Industry Session Chair: Matt Wilkowski, MSEE – Wurth Elektronik Industry Session Chair: Ed Herbert, BEEE – None PSMA Session
8:00 AM – 8:25 AM ET	IS24.1 - Core Evaluation Kit Initiative for the comparison of core loss measurement Location: A404-405 Industry Session Presenter: Jens Freibe – University of Kassel Co-Author: Wilmar Martinez, PhD – KU Leuven - EnergyVille
8:25 AM – 8:50 AM ET	IS24.2 - HFEMAG European Metrology Labs Correlation Project Location: A404-405 Industry Session Presenter: Massimo Pasquale – Istituto Nazional Di Ricerca Metrologica
8:50 AM – 9:15 AM ET	IS24.3 - Triple Pulse Core Loss testing Location: A404-405 Industry Session Presenter: Jun Wang, PhD – University of Bristol
9:15 AM – 9:40 AM ET	IS24.4 - PSMA Core Loss Data Base Location: A404-405 Industry Session Presenter: George Slama – Wurth Elektronik

IS Committee		IS24: "*Core Loss - Making the Data Reliable and Relevant*"				
REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED	REQUIRED
8:00 AM	8:25 AM	*Core Evaluation Kit Initiative for the comparison of core loss measurement*	*Jens*	*Freibe*	Friebe@uni-kassel.de	*University of Kassel*
8:25 AM	8:50 AM	*HFEMAG European Metrology Labs Correlation Project*	*Massimo*	*Pasquale*	m.pasquale@inrim.it	*Istituto Nazional Di Ricerca Metrologica*
8:50 AM	9:15 AM	*Triple Pulse Core Loss testing*	*Jun*	*Wang*	jun.wang@bristol.ac.uk	*University of Bristol*
9:15 AM	9:40 AM	*PSMA Core Loss Data Base*	*George*	*Slama*	george.slama@we-online.c	*Wurth Elektronik*

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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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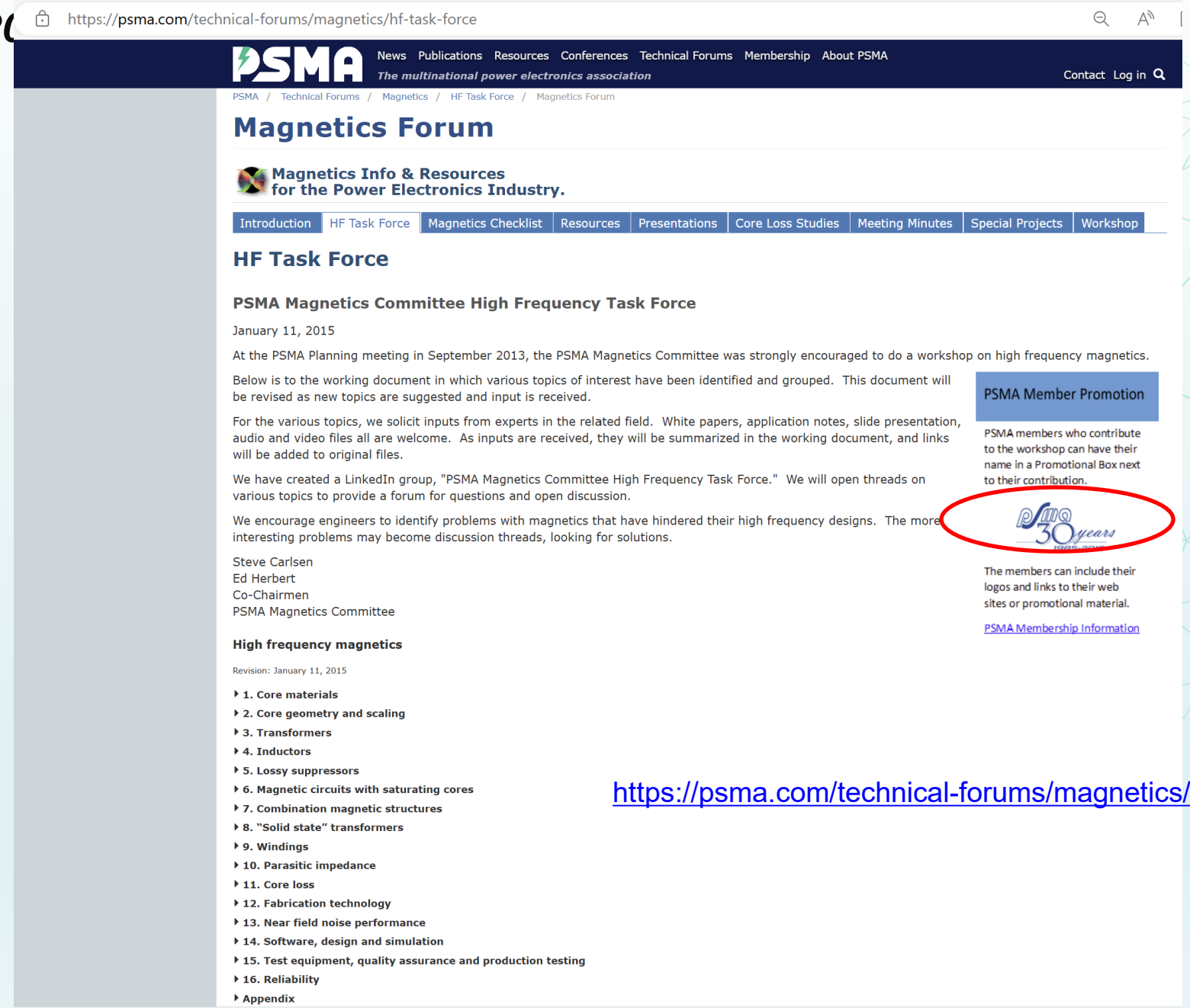
- In process
  - Section 1.3 Powdered metal
    - Proposal by Lukas Mueller has been accepted
    - Need to add to HF task force tab under magnetics Technical Forum on PSMA website
- Proposed additions/updates
  - Section 1 Core Materials
    - Sputtered (addition)
    - Electroplated (addition)
    - 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 November 6, 20



Update

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

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website November 6, 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

PSMA Member Promotion

Tyndall National Institute

Populate section 1.3 and 1.7 with content proposed by Lukas Mueller

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

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 November 6, 2024

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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- xxxday December x 10:00 AM CST – 11:00 AM CST

PSMA Magnetics Committee Meeting
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- Attendance (12)
  - John Horzepa
  - Mike Arasim
  - Alan Cooper
  - 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

PSMA