



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



PSMA Magnetics Committee Meeting Agenda – Special Projects

November 6, 2024

- 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

The screenshot shows the PSMA website's Magnetics Forum page. At the top, there is a navigation bar with links for News, Publications, Resources, Conferences, Technical Forums, Membership, and About PSMA. Below this is a breadcrumb trail: PSMA / Technical Forums / Magnetics / Workshop / Magnetics Forum. The main heading is "Magnetics Forum" with a sub-heading "Magnetics Info & Resources for the Power Electronics Industry." A horizontal menu contains links for Introduction, HF Task Force, Magnetics Checklist, Resources, Presentations, Core Loss Studies, Meeting Minutes, Special Projects, and Workshop. The "Workshop" link is highlighted. Below the menu is a banner for the "10th Annual Magnetics @ High Frequency Workshop" organized by the PSMA Magnetics Committee on March 15, 2025, in Atlanta, GA. The banner includes the PSMA logo and the PELS (IEEE Power Electronics Society) logo. Below the banner, a text block states: "Registration for the 2025 Power Magnetics @ High Frequency Workshop on Saturday March 15, 2025 at the Georgia World Congress Center in Atlanta, GA is now open." Two large, blue-outlined buttons labeled "REGISTRATION" and "AGENDA" are positioned below the text. A paragraph of text provides partnership opportunities and contact information: "Partnership Opportunities available. Sign up to be a Workshop Partner Please contact the organizing committee through via e-mail to workshop@psma.com for more information. Click here for the pricing and benefits:". At the bottom, a section titled "2025 Workshop Partners:" lists Platinum Partners (Frenetic, RUBADUEWIRE, WURTH ELEKTRONIK, YAGEO), Gold Partner (CBMM, Niobium N5), and Media Partners (HOW2POWER, Bodo's Power Systems).

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes

November 6, 2024

- Workshop Tab
 - Registration
 - Open

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Home

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:

   WURTH ELEKTRONIK MORE THAN YOU EXPECT   Niobium N₅  

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**

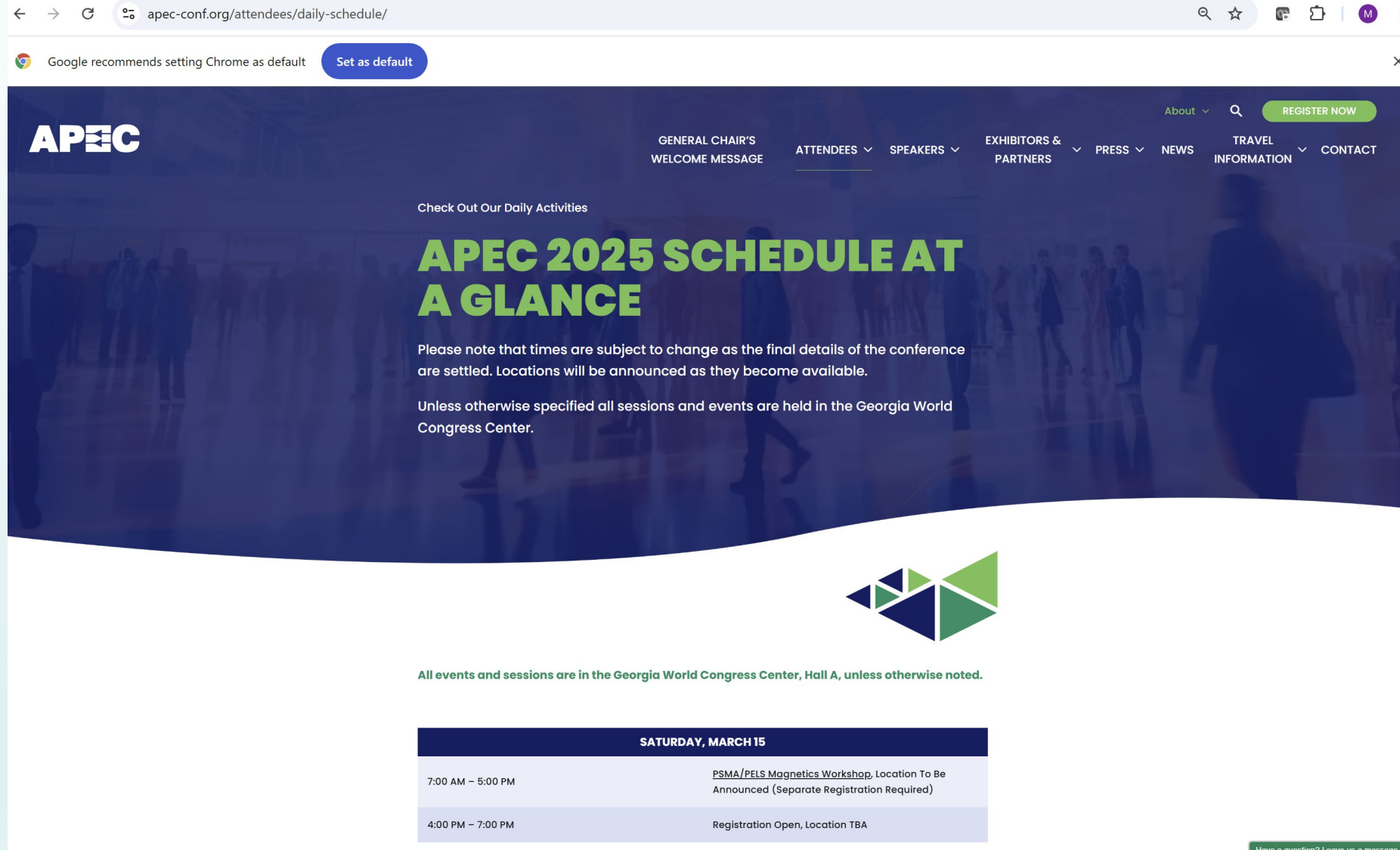
Country*

Telephone:*

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes

November 6, 2024

- APEC webpage
 - Schedule at a glance



The screenshot shows a web browser window with the URL apec-conf.org/attendees/daily-schedule/. The page features the APEC logo in the top left and a navigation menu in the top right with items: About, GENERAL CHAIR'S WELCOME MESSAGE, ATTENDEES, SPEAKERS, EXHIBITORS & PARTNERS, PRESS, NEWS, TRAVEL INFORMATION, and CONTACT. A 'REGISTER NOW' button is also present. The main heading reads 'Check Out Our Daily Activities' followed by 'APEC 2025 SCHEDULE AT A GLANCE' in large green letters. Below this, a disclaimer states: 'Please note that times are subject to change as the final details of the conference are settled. Locations will be announced as they become available. Unless otherwise specified all sessions and events are held in the Georgia World Congress Center.' A graphic of a stylized APEC logo is shown below the text. A note states: 'All events and sessions are in the Georgia World Congress Center, Hall A, unless otherwise noted.' A table lists the schedule for Saturday, March 15:

| SATURDAY, MARCH 15 | |
|--------------------|--|
| 7:00 AM – 5:00 PM | PSMA/PELS Magnetics Workshop , Location To Be Announced (Separate Registration Required) |
| 4:00 PM – 7:00 PM | Registration Open, Location TBA |

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes

November 6, 2024

- APEC webpage
 - PSMA Magnetics Workshop

APEC GENERAL CHAIR'S WELCOME MESSAGE ATTENDEES SPEAKERS EXHIBITORS & PARTNERS PRESS NEWS TRAVEL INFORMATION CONTACT REGISTER NOW

PSMA MAGNETICS WORKSHOP

Saturday, March 15, 2025
Location: Georgia World Congress Center, Room 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].

The 2025 Power Magnetics @ High Frequency Workshop is the 10th annual workshop held in conjunction with APEC. The purpose and focus of this workshop are to identify the latest improvements in magnetic materials, coil (winding) design, construction and fabrication, evaluation and characterization techniques and modelling and simulation tools. The theme of the 2025 workshop will be integrated magnetics, defined as magnetic structures that perform two or more functions. The workshop will address various aspects of integration for both lateral and vertical power delivery. The planned topics include various levels of integration ranging from magnetic components co-packaged with silicon in Power System in Package (PSIP) devices, magnetics embedded in substrates, fabricating magnetics as part of the semiconductor wafer process and traditional core structures used in unique ways. The workshop will also cover integration of magnetic functions for new circuit topologies including coupled inductors, LLC, trans-inductor voltage regulator (TLVR) and variable-inverter-rectifier-transformer (VIRT).

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

Registration for the workshop is limited and will open on October 25, 2024.

[Click here](#) for the latest information on the workshop including registration and the detailed agenda.

[Have a question? Leave us a message.](#)



PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes

November 6, 2024



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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

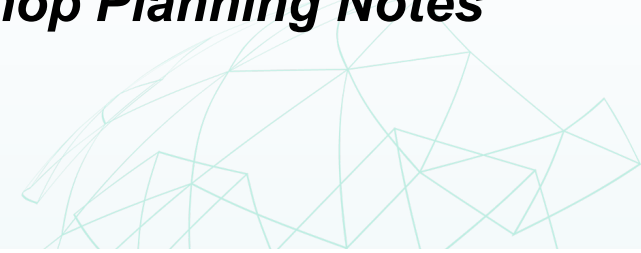
9:45 AM - 12:00 Noon Technical Session - Physical Construction and Structure for Integration of Power Magnetic Devices Part II

- Inductive Components on Silicon Substrate 300mm Wafer; *Jens Kehl, Würth 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



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, Würth 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, Würth 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:



PSMA Magnetics Committee Meeting Agenda

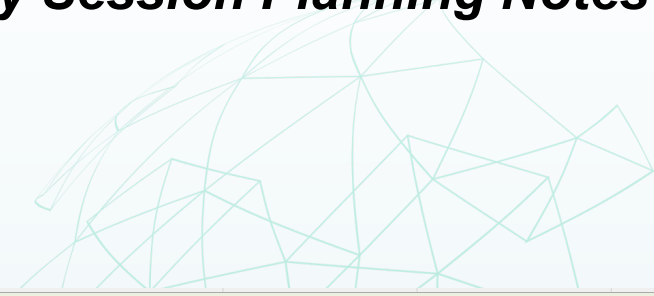
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PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes

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 Insulation 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

November 6, 2024

| | | |
|----------------------|--|--------------|
| 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 Nazionale 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 Nazionale 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.com | 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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PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website November 6, 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


November 6, 2015

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

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Magnetics Forum

 **Magnetics Info & Resources**
for the Power Electronics Industry.

Introduction HF Task Force **Magnetics Checklist** Resources Presentations Core Loss Studies Meeting Minutes Special Projects Workshop

HF Task Force

PSMA Magnetics Committee High Frequency Task Force

January 11, 2015

At the PSMA Planning meeting in September 2013, the PSMA Magnetics Committee was strongly encouraged to do a workshop on high frequency magnetics. Below is to the working document in which various topics of interest have been identified and grouped. This document will be revised as new topics are suggested and input is received.

For the various topics, we solicit inputs from experts in the related field. White papers, application notes, slide presentation, audio and video files all are welcome. As inputs are received, they will be summarized in the working document, and links will be added to original files.

We have created a LinkedIn group, "PSMA Magnetics Committee High Frequency Task Force." We will open threads on various topics to provide a forum for questions and open discussion.

We encourage engineers to identify problems with magnetics that have hindered their high frequency designs. The more interesting problems may become discussion threads, looking for solutions.

Steve Carlsen
Ed Herbert
Co-Chairmen
PSMA Magnetics Committee


High frequency magnetics

Revision: January 11, 2015

- ▶ 1. Core materials
- ▶ 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

PSMA members who contribute to the workshop can have their name in a Promotional Box next to their contribution.



The members can include their logos and links to their web sites or promotional material.

[PSMA Membership Information](#)

Update

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website November 6, 2024

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

Populate section 1.3 and 1.7 with content proposed by Lukas Mueller

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
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[PSMA Membership Information](#)

PSMA Member Promotion



Tyndall National Institute



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 November 6, 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, Molypermalloy and Silicon Steel.

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website November 6, 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, Molypermalloy and Silicon Steel.

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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.

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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 Ferrite | |
| 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 | |

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**



PSMA Magnetics Committee Meeting Agenda November 6, 2024 – Next Meeting

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



PSMA Magnetics Committee Meeting

November 6, 2024

- 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



PSMA Magnetics Committee
November 6, 2024

Thank You

