The Multinational Power Electronics Association

PSMA Magnetics Committee Meeting

April 9TH 2025

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
April 9, 2025

- Introductions
- 2025 Workshop Summary
- 2026 Workshop Planning
- 2026 Industry Session Planning
- Special Projects
  - Electrical parameters of magnetic materials
  - Core Loss Database
- Magnetics Forum on PSMA Website
- Open Magnetics
- Power Technology Roadmap
- Next Meeting

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Power Magnetics at High Frequency Workshop
Logistics – Agenda - Scope

- Logistics
  - Venue:
    - APEC 2025
    - Atlanta GA
  - Technical Presentations - 29
    - AM Lectures
      - Keynote + 4 lectures
    - PM Lectures
      - Keynote + 3 lectures
    - Technology Demos - 16
    - Student Posters – 4
  - Partners
    - Platinum Partners – 4
    - Gold Partners -2
    - Media Partners - 2

- Agenda

10th Annual Magnetics @ High Frequency Workshop

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

Time	Event
7:00 AM - 8:00 AM	Breakfast
8:00 AM - 8:05 AM	Openning Remarks
8:05 AM - 8:50 AM	Keynote Presentation: Precision Power Magnetics Engineering: A Key Step Toward High Performance Power Electronics
8:50 AM - 9:25 AM	Technical Session - Physical Integration of Magnetics - Part 1
9:25 AM - 9:45 AM	Break
9:45 AM - 12:00 Noon	Technical Session - Physical Integration of Magnetics - Part 2
12:00 Noon - 2:00 PM	Lunch - Technology Demonstration - Posters Session
2:00 PM - 2:50 PM	Keynote Presentation: Electrical Parameter Integration
2:50 PM - 3:50 PM	Technical Session - Electrical Characteristics and Modelling of Integrated Magnetics - Part 1
3:50 PM - 4:10 PM	Break
4:10 PM - 5:10 PM	Technical Session - Electrical Characteristics and Modelling of Integrated Magnetics - Part 2
5:10 PM - 5:15 PM	Closing Remarks
5:15 PM - 6:15 PM	Networking Session

Scope

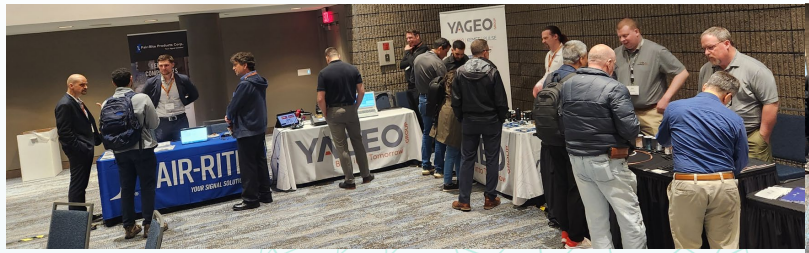
– This day-long event continued the workshop series' focus on identifying the latest improvements in magnetic materials, coil (winding) design, construction and fabrication, evaluation and characterization techniques and modelling and simulation tools to target the technical expectations and requirements of higher application frequencies while addressing two specific issues of interest: measurement and reporting of data to improve modelling of ac power loss measurements and the impacts of fringing effects on power magnetics performance. The target audience for this workshop is anyone working to achieve higher power densities, low profile aspect ratio, higher efficiencies and improved thermal performance.

Power Magnetics at High Frequency Workshop (Participation)

- Attendance
  - Total: 147
  - By Sector
    - 76% Industry, 24% Research
  - By Global Region
    - 54% NA, 28% Europe, 17% Asia Pacific, 1% SA
    - 21 Countries
- Participation
  - Highly interactive panel discussions
  - Synergy between lectures and demos
  - Focused questions
  - Technology demonstrations combined with lunch
  - Peak attendance post Covid

Power Magnetics at High Frequency Workshop (What's Next)

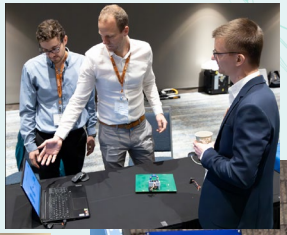
- What's Next
  - Preliminary Survey Results (77 responses) 52% response rate
    - Overall Rating:
      - 34% Excellent, 47% Very Good, 12% Good
    - Value
      - 41% Excellent, 53% Good, 5% Average
    - Skill of the presenters
      - 55% Superior, 42% Above Average 3% Average
    - Recommend workshop to a colleague
      - 91% Yes, 7% maybe, 2% No
    - First Time attendees 63%
    - Plan to attend next year 54% Yes 41% Maybe
    - General topics for next workshop based on survey
      - Thermal Design - Power Loss Density – Thermal Aging
      - Inductor Parameter Testing Modelling and Specification
      - EMC and Magnetics

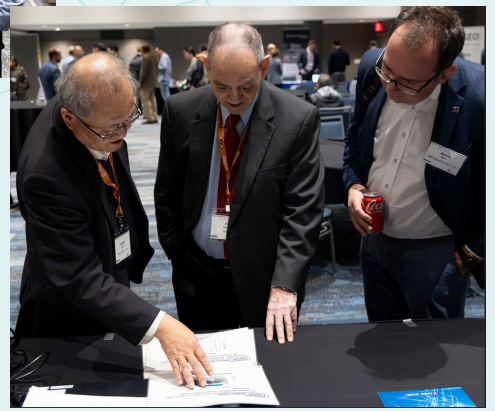
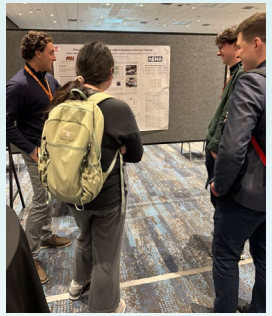


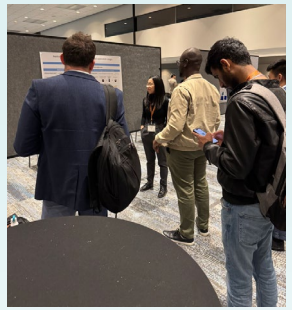
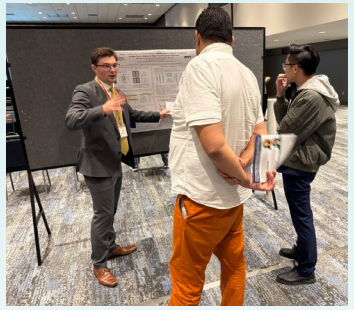




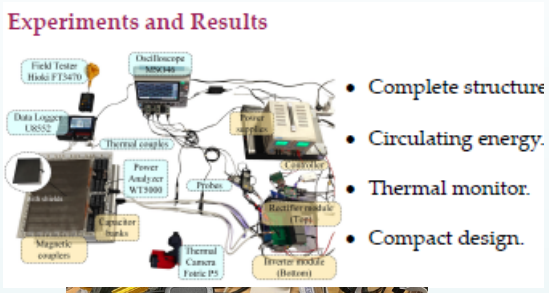


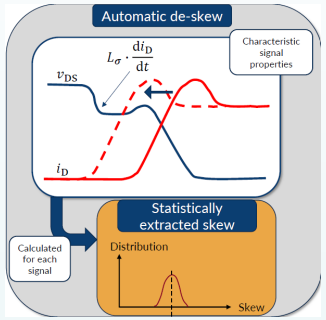



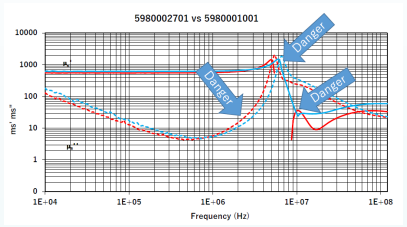




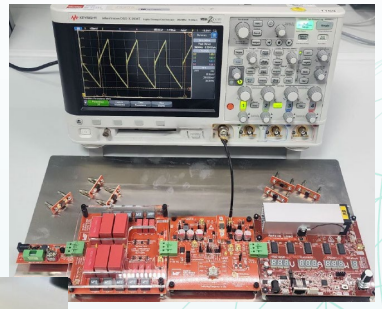



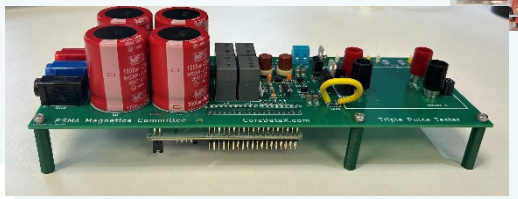
Power Magnetics at High Frequency Workshop
(Depth & Relevance of Topics)

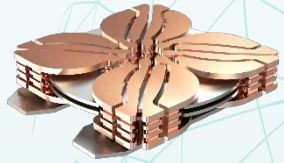


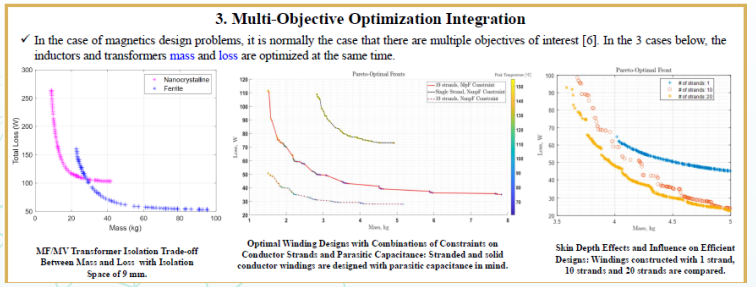


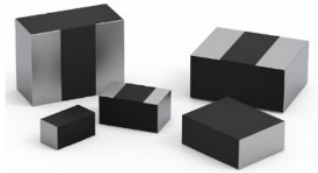












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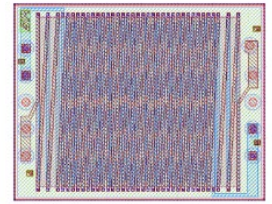
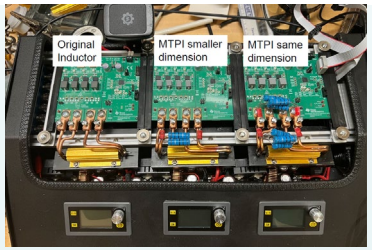
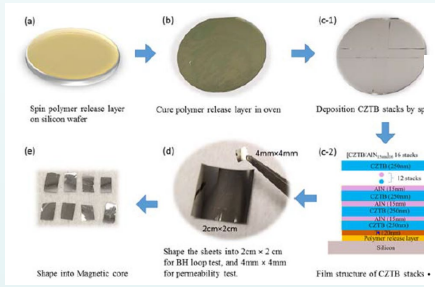
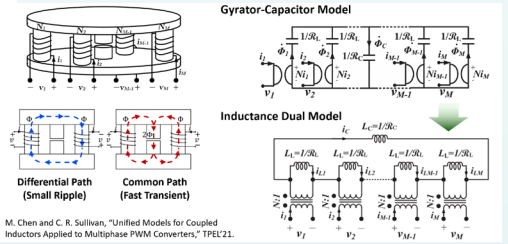
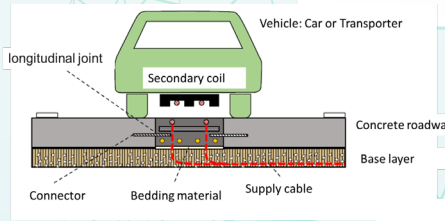
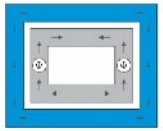


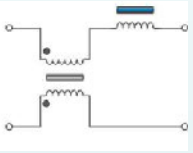


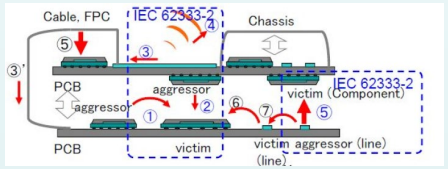


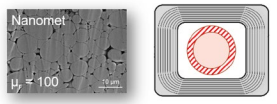


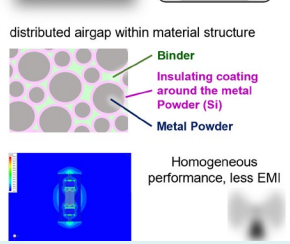


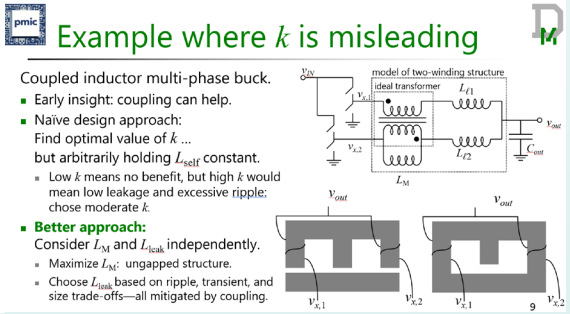


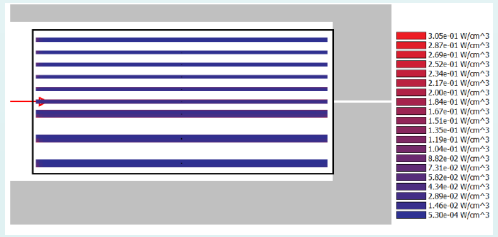


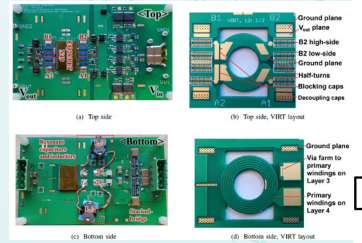


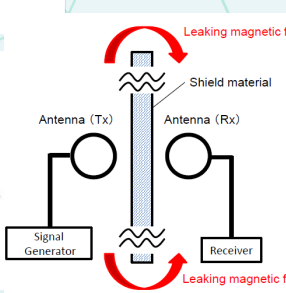


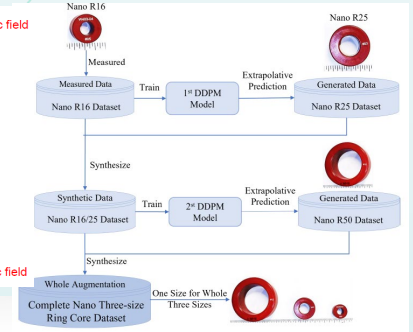










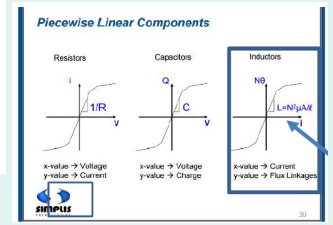


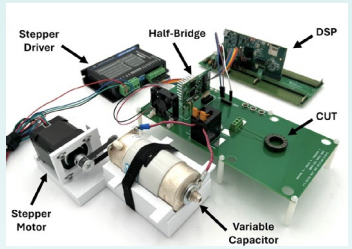
"Direct" damped filter:

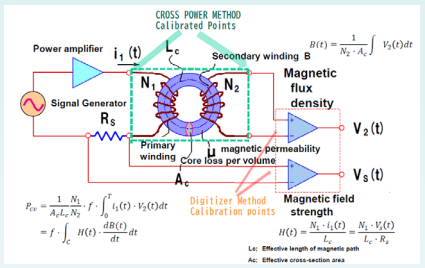
$$H_{peak} \approx Q$$

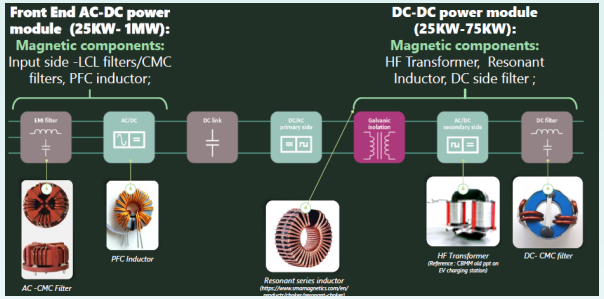
$$Z_{out,peak} \approx Q_L Z_0 + j Z_0$$

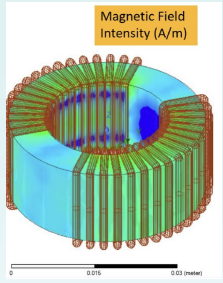
$$Q \approx Q_L = \frac{\mu'}{\mu''}$$

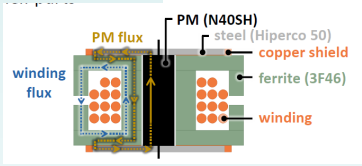












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PSMA Magnetics Committee Meeting Agenda – 2025 Workshop Summary
April 9, 2025

Q1: Overall how would you rate the workshop

	Excellent	Very Good	Good	Fair	Poor	Sum
Sum	26	37	12	2	0	77
	0.34	0.48	0.16	0.03	0.00	1.00

Q2: Was the event length: too short, about right or too long?

	Too Short	About Right	Too Long	Sum
Sum	1	70	6	77
	0.01	0.91	0.08	1.00

Q3: How skilled in the subject were the presenters?

	Superior	Above average	Average	Fair	Sum
Sum	42	32	2	0	76
	0.55	0.42	0.03	0.00	1.00

Q4: Was the workshop a good value?

	Excellent	Good	Average	Poor	Sum
Sum	32	40	5	0	77
	0.42	0.52	0.06	0.00	1.00

For 2026 post workshop survey
Q4 Change categories to
Excellent – very Good – Good – Average - Poor

PSMA Magnetics Committee Meeting Agenda – 2025 Workshop Summary
April 9, 2025

Q5: Would you attend a workshop on Saturday before APEC 2026 in San Antonio TX March 21, 2025

	Yes	Maybe	No	Sum
Sum	41	31	4	76
	0.54	0.41	0.05	1.00

Q6: Would you recommend the Power Magnetics workshop to a colleague?

	Yes	Maybe	No	Sum
Sum	69	5	2	76
	0.91	0.07	0.03	1.00

Q7: How many of your objectives for this year's workshop were met?

	All	Most	Half	Some	None	Sum
Sum	15	40	11	8	2	76
	0.20	0.53	0.14	0.11	0.03	1.00

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PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
April 9, 2025

- Identify Themes
  - Workshop
  - Industry Session(s)
  - Proposed topics - 55
    - Align proposed topics with topic categories
  - Presenter pool
    - Proposed presenters – 15
    - Volunteer presenters - 12

Workshop themes
Converting Measurement Data to Models
Design Basics to Design Automation

Industry Session themes
Manufacturing Challenges and Directions
Magnetic Materials

Industry Session themes
Co-sponsor with Capacitors
Pairing Inductors and Capacitors to Create Better Solutions

- Next steps
  - Make post workshop presentation available to workshop attendees – April 11
  - Submit special projects report – May or June PSMA BOD meeting
  - Identify themes for workshop and industry session
  - Coordinate with capacitor committee
    - Parallel workshops
    - Co-sponsored industry session
      - Filtering
      - EMI

PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
April 9, 2025

Topic	Score
Thermal Design, Power Loss Density, Aging Effects	276
Challenges of Magnetic Core Manufacturing and Tolerance	244
Inductor Parameter Testing Modelling and Specification	265
RF Power Magentics	208
Parasitic Parameters	234
3D Printing for Magnetics	228
EMC and Magnetics	264
Safety Compliance Across Applications and Markets	181
Atificial intelignence for Modelling Simulation and Design	208

- Align topics categories to proposed presentations topics
- Suggestion for Post 2026 workshop survey
  - Add sector (research/industry) to survey
  - Enable sort of topics by sector

PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
April 9, 2025

Similar Topics

Converting Measurement Data to Models

1. Magnetics modelling - not including AI
2. Physics based modelling
3. Materials based modelling
4. Modelling of inductor losses in power electronics
5. Measurment of inductor and data collection
6. Modelling & Simulation
7. Magnetics modelling - resistance and inductance matrices FEA Simulations
8. Inductor spice models that include frequency, saturation, core loss, thermal characterisitics together suitable for frequency domain and time domain analysis

Related Topics
Subtopics
Tech Demos?

1. Transformer design validation qualification testing or performance analysis across several parameters Test techniques and analysis instruments
2. Large signal testing above 10 MHz - challenges and progress
3. Application testing for magnetics

PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
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Similar Topics

Related Topics
Subtopics
Tech Demos?

Applying Design for Automation from the Basics
1 Back to basics
2 Practical Magnetics Design
3 Open Source Magnetics Design Tools
4 Design automation
5 Multi Leg Transformer Design
6 Multiphase transformers
7 Using powder cores to replace air gaps - Lukas Mueller
8 AI Optimization and Design
9 AI Really Useful

1 High Power applications
2 High power magnetics and high voltage
3 Challenges for high voltage high frequency transformers
4 High Power > 100 kW

1 Winding strategies in pcb magnetics
2 Parasitic capacity reduction in pcb magnetics
3 Parastic parameters

1 High Temperature Electronics
2 Thermal design in an IVR
3 Thermal management

PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
April 9, 2025

Similar Topics

Related Topics
Subtopics
Tech Demos?

Magnetic Material and Structure Characterization

1 Core Loss
2 Non-uniform flux efffects on HF Core Loss
3 Core sizing effect on performance
4 Geometric Characterizations
5 Mechanical dimensional resonance of cores
6 Characterizing magnetic materials/devices - large signal 10 - 100 MHz
7 Transformer Parasitic Capacitance - Measuring Modelling and Characterizations

1 Magnetic material
2 Design Parameters for Nanocrystalline Cores - Tobias Trupp

1 Tri-Delta High Temperature Ferrites
2 3D Print Core

PSMA Magnetics Committee Meeting Agenda – 2026 Workshop Planning
April 9, 2025

Related Topics
Subtopics
Industry Session
Tech Demos?

1 Process engineering
2 Manufacturing processes
3 Deep dive on what drives magnetic costs in different applications
4 Tranformer design for manufacturability DFM or automation
5 Safety

Potential Industry Session

1 Conducted emission suppression
2 Common Mode EMI Design

Potential Co-Sponsored Industry Session With Capacitors

1 Magnetics IC do-design
2 Discussion on integrating magnetics with capacitors and FETS

1 Future Trends
2 Magnetics for PDN in data center/server/pCs
3 Advanced structures - Matrix integrated transformers
4 Planar Magnetics
5 Wireless power transfer

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PSMA Magnetics Committee Meeting Agenda – 2026 Industry Session Planning
April 9, 2025

- Identified theme(s)
  - Magnetic Materials
  - Manufacturing Challenges and Directions
  - Other
- Coordination with Capacitors' Committee
  - Pairing Inductors with Capacitors to Form Better Solutions
    - EMC
    - Input/Output Filters

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PSMA Magnetics Committee Meeting Agenda – Special Projects
April 9, 2025

From Meeting on March 18 at APEC

- 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

Discussion:

- Next phase of electrical parameters of magnetic materials - start Fall 2025
  - Use inventory of drilled cores from previous projects
- Discuss pending projects during next meeting on April 9 after APEC
- Future projects will most likely require financial sponsor

PSMA Magnetics Committee Meeting Agenda – Special Projects – Permittivity Measurements
April 9, 2025 – November 5, 2024 Update

From Meeting on March 18 at APEC

- 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 – Permittivity Measurements
April 9, 2025 – November 5, 2024 Update

From Meeting on March 18 at APEC

- 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 – Permittivity Measurements
April 9, 2025 – November 5, 2024 Update

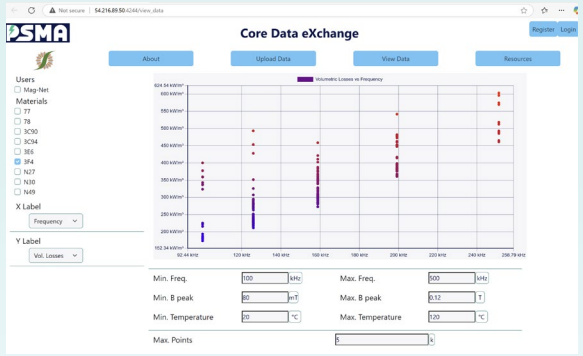
From Meeting on March 18 at APEC

- 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 – Permittivity Measurements
April 9, 2025 – November 5, 2024 Update

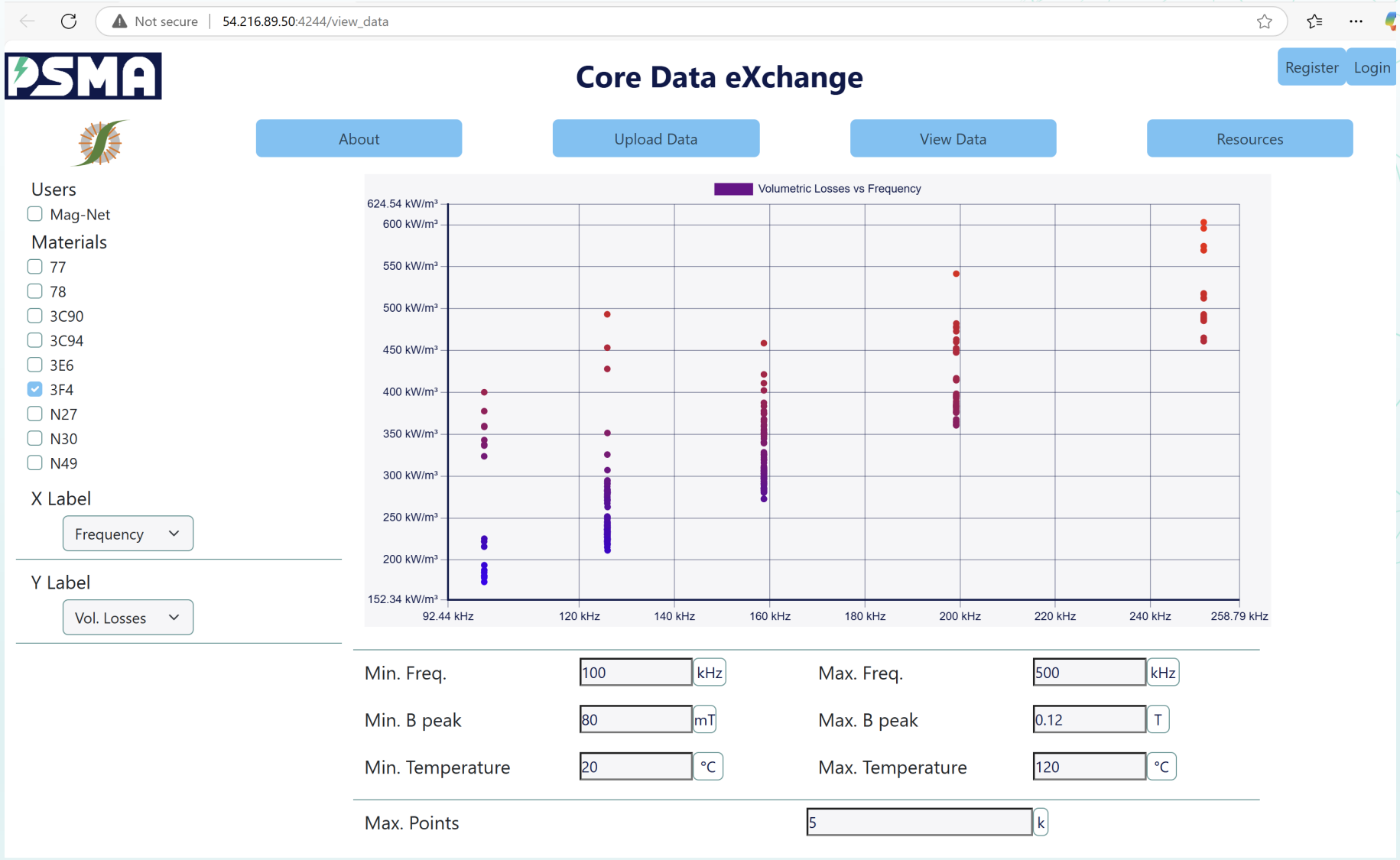
From Meeting on March 18 at APEC

- 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 started in November 2024
      - Most previous meeting: Monday January 13, 2025 10:00 AM CST
      - Next meeting: Monday February 10, 2025 10:00 AM CST
  - Development URL: http://54.216.89.50:4244/view_data



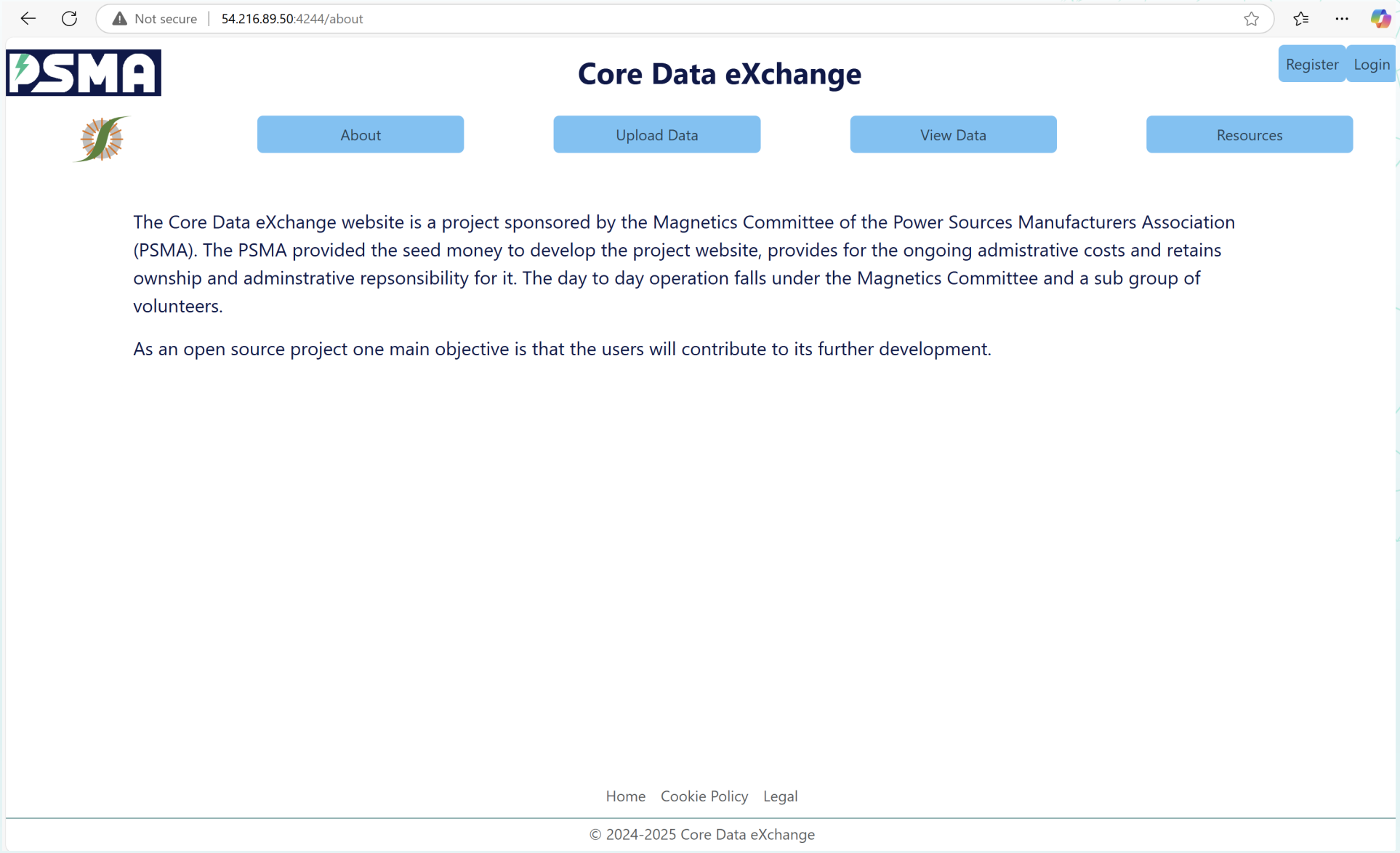
PSMA Magnetics Committee Meeting Agenda – Special Projects – Core Loss Data Base
April 9, 2025

From Meeting on March 18 at APEC



PSMA Magnetics Committee Meeting Agenda – Special Projects – Core Loss Data Base
April 9, 2025

From Meeting on March 18 at APEC



PSMA Magnetics Committee Meeting Agenda
April 9, 2025

- Introductions
- 2025 Workshop Summary
- 2026 Workshop Planning
- 2026 Industry Session Planning
- Special Projects
  - Electrical parameters of magnetic materials
  - Core Loss Database
- Magnetics Forum on PSMA Website
- Open Magnetics
- Power Technology Roadmap
- Next Meeting

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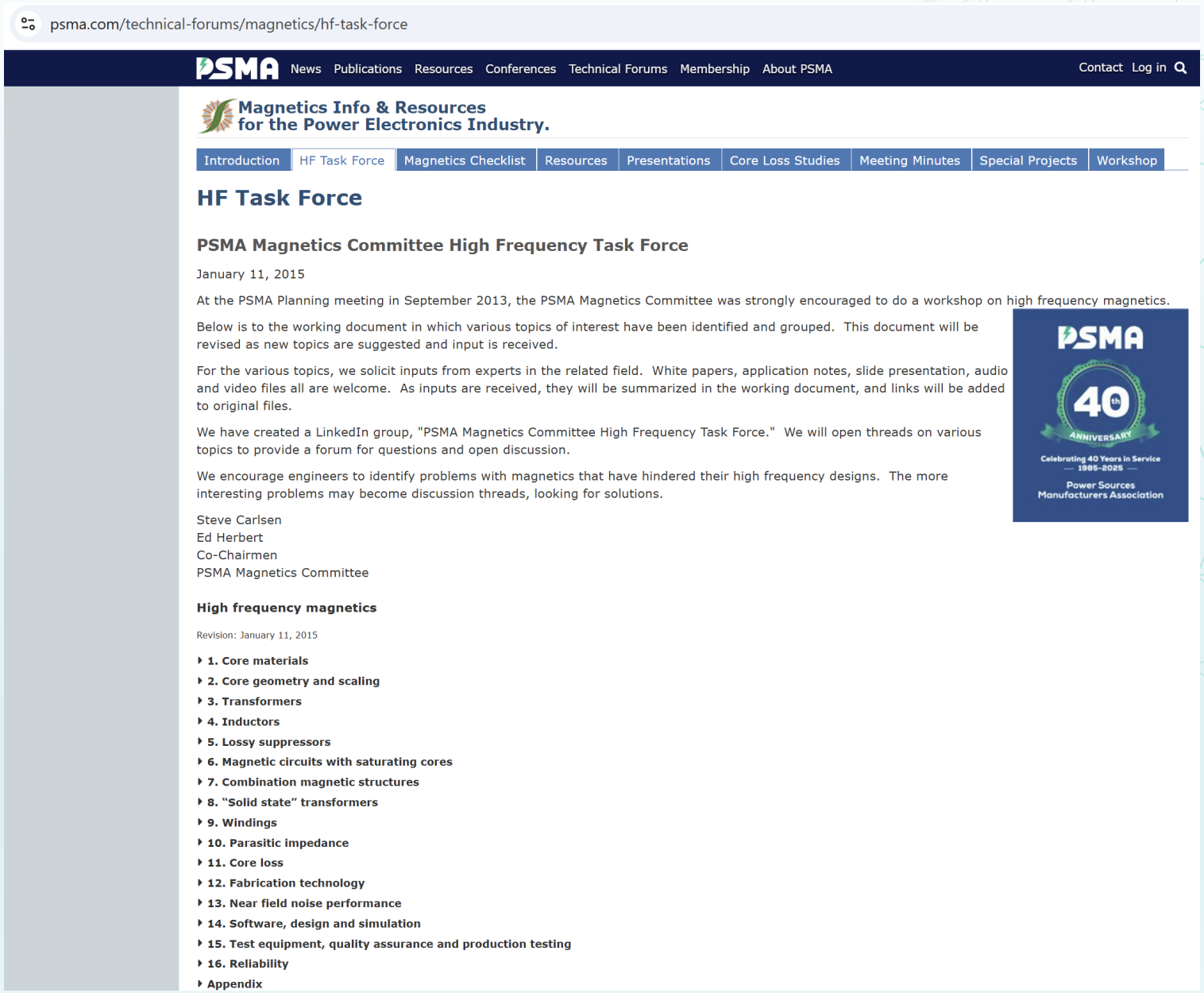
- In process
  - Section 1.3 Powdered metal
    - Proposal by Lukas Mueller has been accepted
    - Need to add to HF task force tab under magnetics Technical Forum on PSMA website
- Proposed additions/updates
  - Section 1 Core Materials
    - Sputtered (addition)
    - Electroplated (addition)
   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

Address
sections 1, 4, 8 and 12
after APEC 2025

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
April 9, 2025

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



PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
April 9, 2025

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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

PSMA Member Promotion

MICROMETALS

MicroMetals

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

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
April 9, 2025

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

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.

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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From Meeting on March 18 at APEC

- What's next?
  - Distribute Nov 6 presentation to the PSMA Magnetics Committee – complete
  - Decide to proceed then integrate into PSMA webpage
    - need final decision
    - need to discuss with PSMA webmaster

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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)

Identify webinar topics for next PTR round during next meeting in May

- 2025 Topics (Submitted)
  - 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
April 9, 2025 – Next Meeting

- Wednesday May 7 10:00 AM CDT – 11:00 AM CDT Virtual

PSMA Magnetics Committee Meeting
April 9, 2025

- Attendance (17)
  - John Horzepa
  - Mike Arasim
  - Andres Arias
  - Hasan Ahmadian Baghbaderani
  - Alan Cooper
  - Jim Cox
  - Doug Eaton
  - Frank Feng
  - Michael Freitag
  - Ed Herbert
  - Bryce Hesterman
  - Alfonso Martinez
  - Frank Oberlitner
  - Paul Ohodnicki
  - Lukas Mueller
  - Mike Ranjram
  - Rodney Rogers
  - Ranajit Sai
  - George Slama
  - JC Sun
  - Mark Swihart
  - Jun Wang
  - Matt Wilkowski

Thank You