The Multinational Power Electronics Association

PSMA Magnetics Committee Meeting

May 14TH 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
May 14, 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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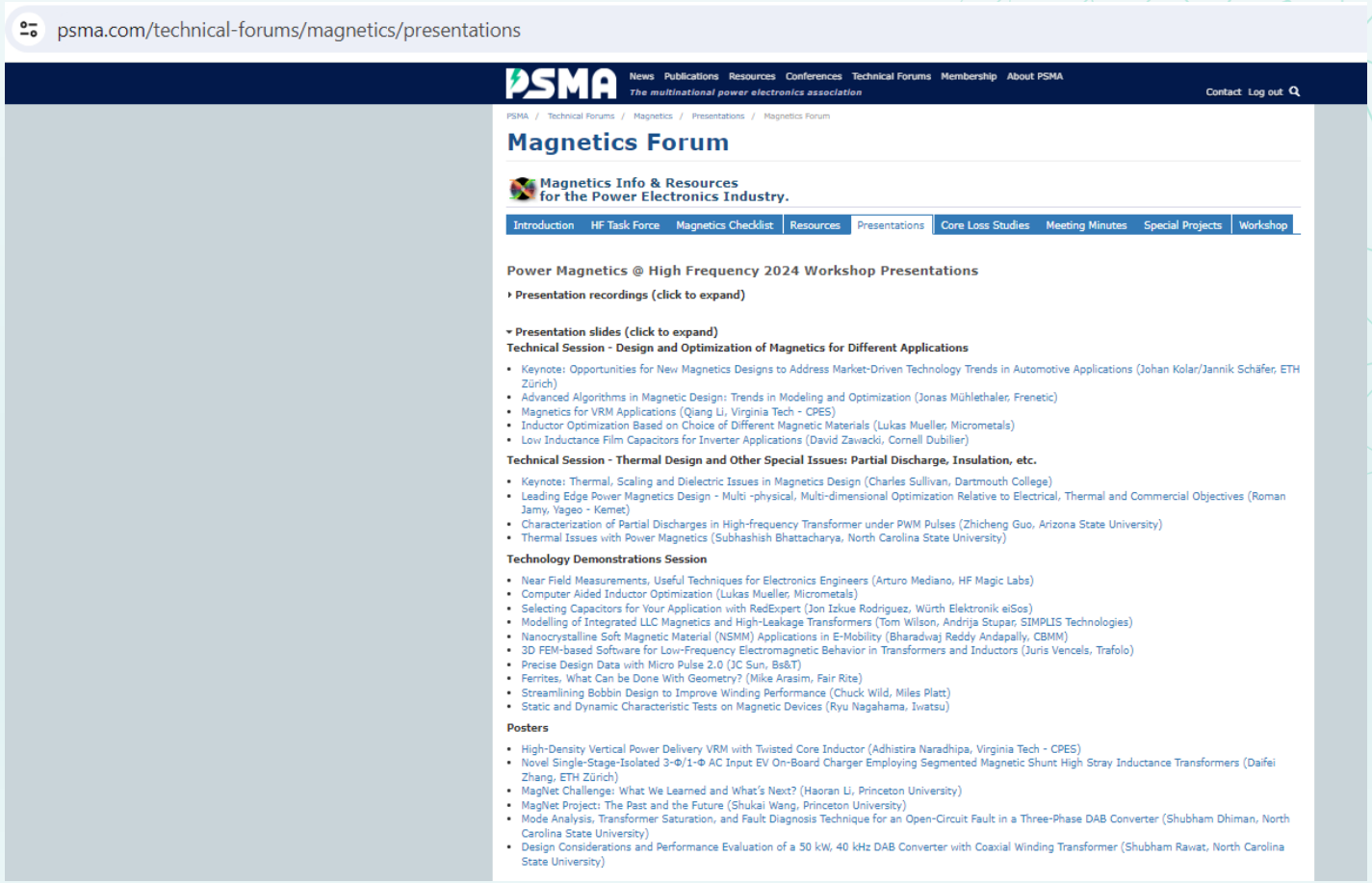
PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes May 14, 2024

- Workshop Tab
  - Needs to be updated to reflect date for 2025 workshop
  - Workshop presentations available to 2024 attendees
    - Available on Presentations tab if logged in



PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
May 14, 2024

- Integrated Magnetics
  - Physical Integration Types
    - Heterogeneous Integration
      - 2.5D Vs 3D
      - Lateral Vs Vertical
    - Embedded magnetics
      - PCB windings about a magnetic core
    - Power System in Package
      - Silicon + Discrete Magnetics in semiconductor packaging
    - Wafer level (on silicon) magnetics
      - Sputtered
      - Electroplated
  - Issues
    - Thermal Limitations
    - Assembly methods

Afternoon Session

- Integrated Magnetics
  - Electrical Characteristic Integration
    - LLC
    - Coupled Inductors
    - TLVR
    - VERT

Morning Session

Integration has different meaning for different audiences Need definition for workshop audience

Agreement of highlighted topics

- Wurth – Martin Sittner
- Tyndall
- Frenetic
- Bryce – Utah State
- Jose Cobos –
- Roshen, Waseem
- Rico, TriDelta

Lukas – LLC design
Open magnetics – simulation, design
Cuk – LLC, circuit concept
Virginia Tech – Understanding core Ae/Le
Dan Jitaru
Premo Power – 3D magnetics

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
May 14, 2024

- Plenary Speakers
  - Presenters from first workshop
    - Candidates to pursue
      - David Perreault
      - Charlie Sullivan
    - Topics
      - Advances in magnetics over the past ten years

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
May 14, 2024

- Tech Demos
  - Core Loss Database project
    - Demonstration of the website database
      - Visualization of core loss data
  - Our other project – core permittivity and permeability characteristics
    - Frederic either a tech demo or a poster
  - Zimmer wattmeter
  - JC Sun – integrated instrument to measure losses with Zimmer
  - Fair-Rite – dimensional resonance
  - PE System – dual pulse test
  - Open magnetics demo
  - MicroMetals – complex perm powder materials
  - Partial Discharge system (Chroma, Hipotronics, Hubbel, …)
  - Capacitor with magnetics (Alan) LLC – capacitor voltage rating
  - Build an integrated device
  - Component manufacturers of Integrated Magnetics
    - Premier Magnetics
    - Payton Magnetics

PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes
May 14, 2024

- Posters
  - HLSU - Frederic
    - Core permittivity and permeability characteristics

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PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes
May 14, 2024

- All aspects of fabricating a Solid-State Transformer (SST)
  - Conductor design
  - Insulation/Isolation Issues
    - *Paul Ohodnicki – UPITT – P3105 Subgroup 2 Isolation Issues for SST*
  - AC Power Loss
  - Magnetic Core materials
  - Thermal Design
  - Environmental Design
  - Capacitance
  - Coupling and Leakage Inductance
    - *Drazen Dujic – EPFL – Inductance and Leakage Inductance Measurements for MFT*
  - Other? SMART transformer?
- **Focus on the transformer of Solid-State Transformer**
  - Too many APEC and ECCE session on SST focus on topology rather than the transformer

What is definition of SST?
Per Kolar (1kHz to 20 kHz)

Jonathon Kimball – Missouri

North Carolina State

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

Charlie Sullivan – heat pipes

Jun Wang Univ. of Bristol – Core loss measurements

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

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2022/2023/2024 PSMA PTR Webinar Series
Potential Contributions from the Magnetics Committee

- Tyndall – Ranajit Sai
  - Core Loss Mechanisms
  - Presentation delivered November 30 √
- Utah State University – Reebal Nimri
  - High Power (1 MW) Charging
  - 2024 Q2/Q3
  - Confirmed 8/16/23
- Fraunhofer – Florian Ziegler
  - PowderMEMS – a novel technology for fabrication of functionalized MEMS structures
  - Spring 2024
  - Confirmed 1/16/24 – e-mail of introduction sent March 5, 2024
  - *Follow up sent on April 12 and May 9 2024*
- CBMM - Bharadwaj Reddy Andapally
  - Technology Roadmap for Nanocrystalline Cores
  - Spring 2024
  - Confirmed: 9/1/23 – reconfirmed during the 2024 workshop
  - Need to send follow up

Potential Source of Additional Presentations
Intermag Japan
Presentations
Measurement Techniques
New Materials

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PSMA Magnetics Committee Meeting Agenda – Special project
May 14, 2024

- Special Projects
  - In Process
    - Core Loss Database
    - Electrical parameters of magnetic materials
  - 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
May 14, 2024

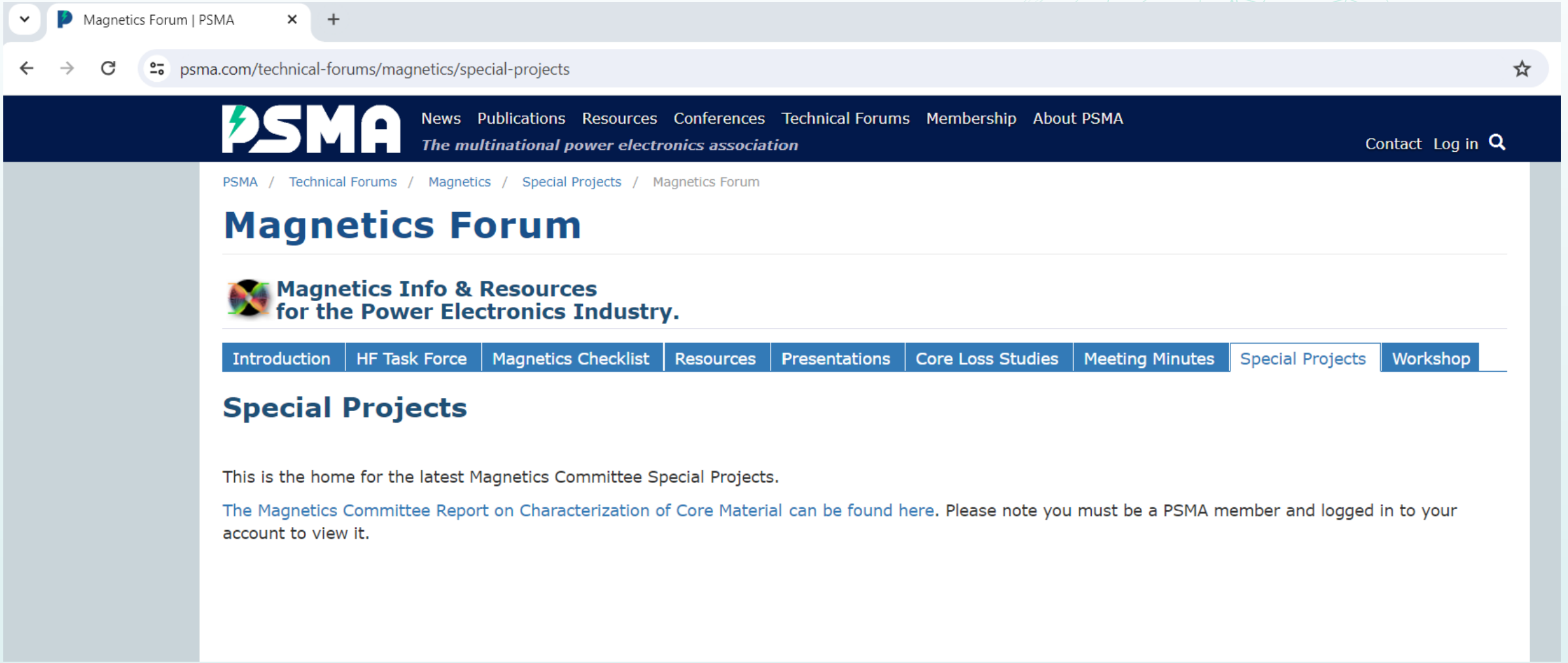
- Electrical parameters of magnetic materials
  - Proposal approved during PSMA BOD meeting on November 17
  - Preliminary results shared with PSMA Magnetics Committee during December 18 meeting
  - Draft report distributed by e-mail to attendees of January 24 PSMA Magnetics committee meeting
  - Final report approved for placement on a tab on the Magnetics Forum during meeting on Feb 28

Discussion Decisions

- Draft dated January 22, 2024 is ready to placed in the Special projects Tab on Magnetics Forum
  - Confirmed by Ed Herbert and Jonas Muhlethaler
  - This report should be behind a members only firewall
  - Reference Ed Herbert e-mail of February 25, 2024
- Maintain Core Loss Studies as a Separate Tab
- Create a new Special Projects tab for all this and all future special projects
- In the future Core Loss Data Base may be a separate tab from Core Loss Studies

Special Projects Tab
Has Been Created
Need to Populate with Report "Characterization of Core Material" by Frederic Mathieu dated January 22, 2024
Need to resolve access issue
Completed

PSMA Magnetics Committee Meeting Agenda – Special Projects
May 14, 2024



PSMA Magnetics Committee Meeting Agenda – Special Projects
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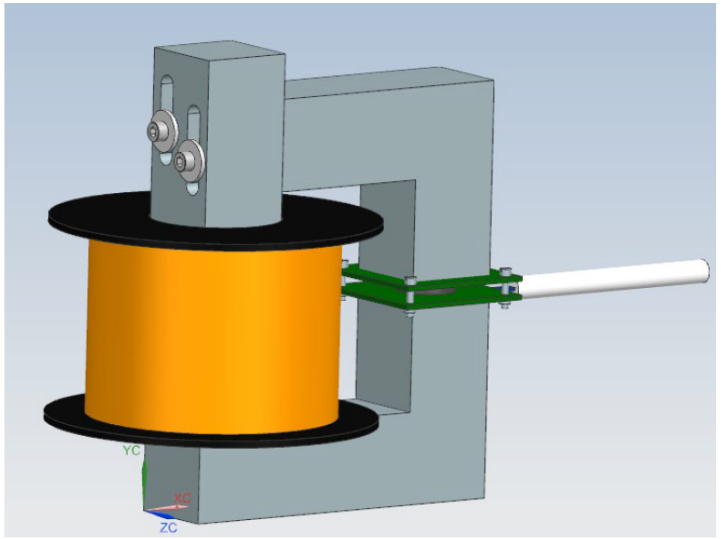
Lucerne University of Applied Sciences and Arts

Lucerne School of Engineering and Architecture



Characterization of Core Material

Author: Frédéric Mathieu

Supervisor: Prof. Dr. Jonas Mühlethaler

Expert: Dr. Severin Nowak

Industrial partner: Power Sources Manufactures Association (PSMA)

January 22, 2024

Confidentiality level: Public

JC Sun will provide existing standards that can be used to test material as well for comparison

Lukas Mueller will contact a university that is about to publish a paper on the same topic to try get an early copy

IEC 62631 – measure permittivity (to 10 MHz)

- Core Loss Database
  - Database should be on its own website
    - Link to the website on a tab in the PSMA Magnetics Forum

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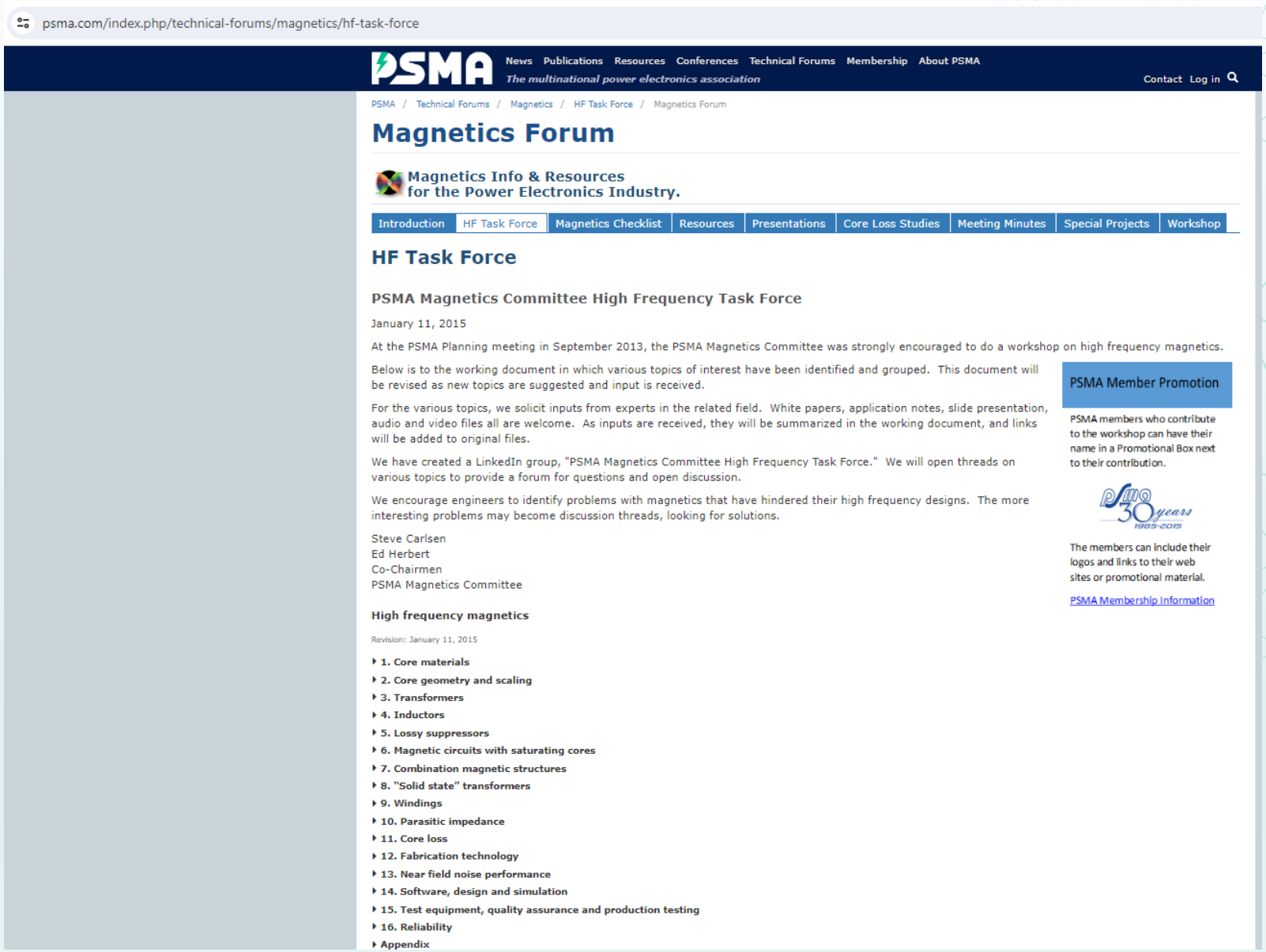
PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
May 14, 2024

- Ongoing discussion to create a Short Videos Tab on Magnetics Forum to address specific topics of general interest
  - This could be the home of a “Magnetics Are Everywhere” introductory video
  - These can be simple redirects to URLs already established by PSMA members
    - Helps traffic to magnetics forum
    - Increases audience access for PSMA member companies

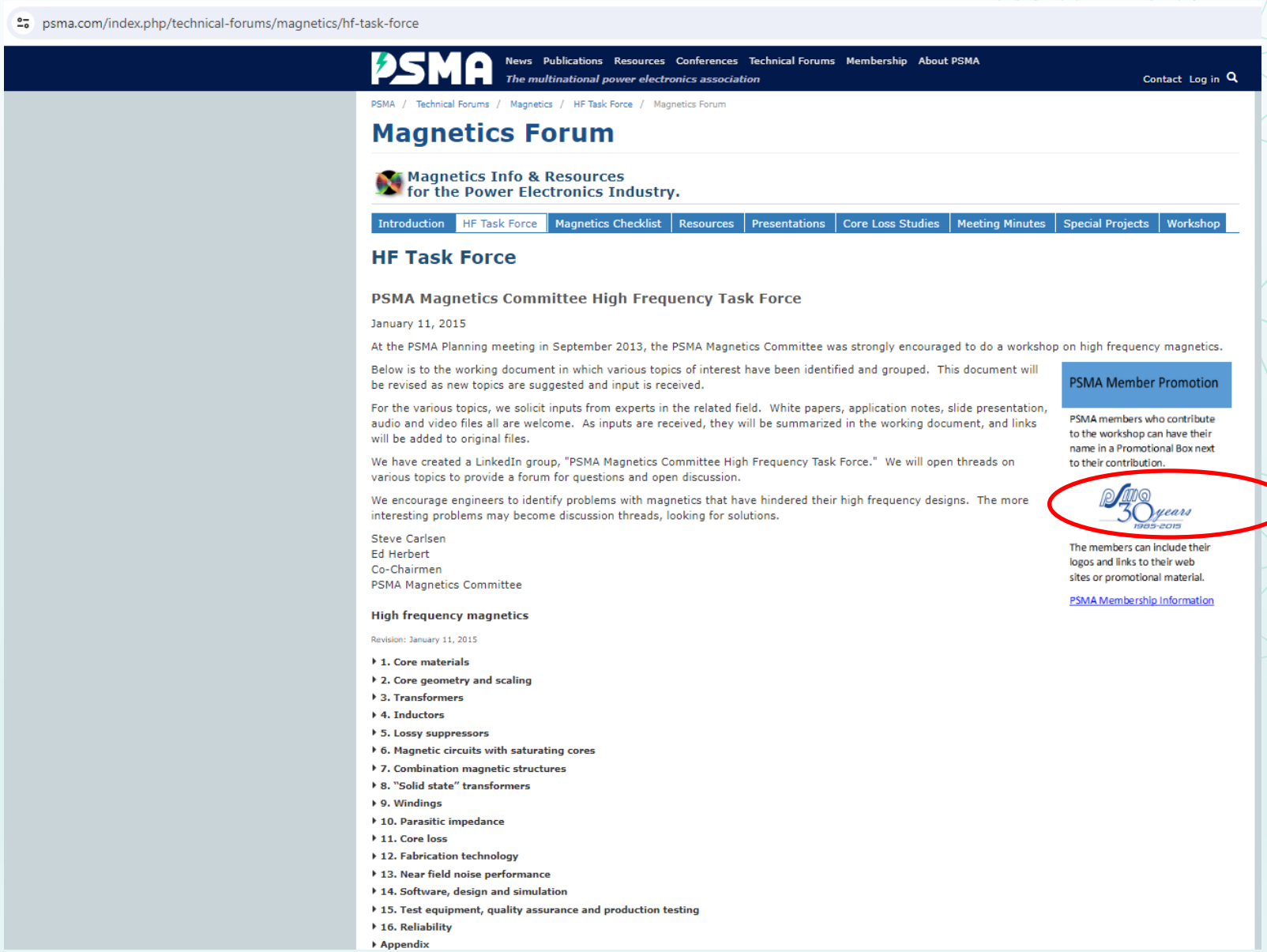
- **Action item for members to review HF task force page for whether to keep, it update it, add to it – could be used to organize information**

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

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website May 14, 2024



PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
May 14, 2024



Update

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
May 14, 2024

▼ 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

Consider updating to members that are active in psma magnetics committee and/or magnetics workshop

PSMA Member Promotion

Tyndall National Institute

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
May 14, 2024

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

▾ 12. Fabrication technology

12.1. Wire wound

12.1.1. Bobbin

12.1.2. Bobbin less

12.1.3. Litz wire

12.2. Foil wound

12.3. Planar: Planar transformers and inductors are low profile, with a two-part core. The windings usually are printed wiring boards or stamped copper. An aluminum shell may provide heat-sinking.

See "How SiC & GaN catching up to Planar Magnetics,"[1] a slide presentation prepared for an Industry Session at APEC2014 but not presented.

See also "Payton Technical Video,"[2] a movie on Payton planar transformers with technical content.

12.3.1. Discrete

12.3.2. Substrate embedded

12.4. Matrix transformers: The "Matrix Transformer," later called "Flat Transformer," is a transformer having many cores. Usually the secondary winding is a single turn, which may be bonded to the core. An early (1990) tutorial shows the theory and examples. "Design and Application of Matrix Transformers and Symmetrical Converters."[3]

12.4.1. Matrix coaxial

12.5. Coaxial

12.6. Psip

12.7. Pwrsoc

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PSMA Member Promotion

Payton American Group

Payton Sales Video

Payton Products Catalog

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website May 14, 2024

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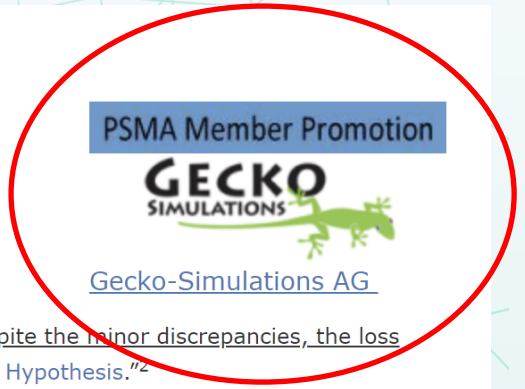

14. Software, design and simulation

14.1. Design aids

14.1.1. Ask Jonas to supply material for his design software.

14.1.2. Nomographs, caution.

14.2. Core loss

14.2.1. Composite waveform hypothesis

The Pilot Project core loss study sponsored by PSMA at Dartmouth analyzed the **composite waveform hypothesis** and determined that: "Despite the minor discrepancies, the loss prediction method yields higher accuracy, and is easier to use, than other methods for non-sinusoidal waveforms."[1] See "Composite Waveform Hypothesis."[2]

14.2.2. Steinmetz-like equations

Chris Oliver derived a very good set of equations to characterize powdered metal cores: "Measurement and Modeling of Core Loss in Powder Core Materials,"[3] Micrometals has also provided a spreadsheet, "Micrometals, Inc. Curve Fit Coefficients, Rev. September 18, 2014."[4]

Dr. Charles Sullivan derived a Steinmetz-like equation for square wave and rectangular wave excitation: "Steinmetz Curve Fits."[5]

Edward Herbert derived a Steinmetz-like equation for square wave excitation: ""Steinmetz-like" Equation for Ferrites."[6] The derivation of the equation is explained, with a number of examples of manipulating log-log curves for graphical analysis.

14.3. Spice models

A very simple but surprisingly good SPICE model for core loss is described in "Proposed SPICE model for core loss." [7] The SPICE model is shown, with an extensive explanation of how it was derived and tested.

14.4. Finite element analysis

PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website
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▼ Appendix

A1. Application notes

A1.1. CWS app notes: "How to choose Iron Powder, Sendust, Koolmu, High Flux and MPP Cores as output inductor and chokes."

A1.2. CWS app note: "How Transformers, Chokes and Inductors Work, and Properties of Magnetics."

A2. Formulae

A2.1. Equations showing electrical units, and case for

A2.2. "Matrix" conversion

A3. Glossary

A3.1. Definitions

A3.2. Units

A4. References

A4.1. A spreadsheet summarizes the references "Workshop References."

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PSMA Magnetics Committee Meeting
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- Attendance (11)
  - John Horzepa
  - Mike Arasim
  - Alan Cooper
  - Doug Eaton
  - Ed Herbert
  - Alfonso Martinez
  - Lukas Mueller
  - Rodney Rogers
  - George Slama
  - Mark Swihart
  - Matt Wilkowski

Thank You

PSMA