The Multinational Power Electronics Association

# PSMA Magnetics Committee Meeting

June 12TH 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*
# *June 12, 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 June 12, 2024*

- Workshop Tab
  - Needs to be updated to reflect date for 2025 workshop –complete
    - Note comment on next slide regarding workshop partners
  - Workshop presentations available to 2024 attendees
    - Available on Presentations tab if logged in

Discussion:
Preserve partners for specific workshop years
Either by

1. Part of the running text on the workshop home page
2. Presentation pages for each workshop year

Matt W to work with John H for the most practical approach

# *PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes June 12, 2024*

- Workshop Tab
  - Workshop partners
    - 2024 Workshop partners removed
    - 2023 Workshop partners still listed

Add photos to 2024 workshop text.

Example of preserving workshop partners for 2023 workshop

# *PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes June 12, 2024*

- Special Project Nomination Form For 2025 Magnetics Workshop

**PSMA Special Project Nomination Form**

Date: June 12, 2024

Committee sponsoring the project: PSMA Magnetics Committee
Project Champion
Individual sponsoring the project: Matt Wilkowski, Co-Chairman; Ed Herbert, Co-Chairman

Team Members identified: George Slama,
Potential Team Members: Rodney Rogers Mike Arasim, Lukas Mueller, Paul Ohodnicki, Mike Ranjram
Project Description and Scope: "10TH Annual Power Magnetics @ High Frequency Workshop 2025"
A workshop on High Frequency Magnetics.

**PSMA Mission**

To enhance the stature of member companies and their products and to improve their knowledge of industry developments.

How will this Project support the mission of PSMA?
This project will bring together experts from aspects of power magnetics design ranging from magnetic and conductor materials thru fabricators of transformers and inductors, designers of power magnetic components and users of power magnetic components to establish common terminology, identify mature, state of the art and roadmap materials and techniques for power magnetics design and manufacture.

Who will benefit from this project? What will be the benefits?
Designers of power magnetics for electronics power applications will benefit since they will have an opportunity to voice their needs to their supply chain (magnetic materials and cores, transformer and inductor manufacturers, test equipment suppliers and providers of modelling and simulation tools).
The supply chain for power magnetics will benefit as they will have access to the concerns and needs of their ultimate customers so as to identify areas of improvement that can address in both the short term and in the long term.

What will be the output of the project? (report, workshop, award, etc.)
The tangible output of the workshop will be the presentation slides and recordings of the presentations themselves.

What is the budget for this project? Not to exceed $30,000. We expect to recover all or most of this expense though attendance charge, tentatively $295 for PSMA members and $395 for nonmembers (early registration) increasing by $50 for late registration and $100 for walk-ins. And Partnership income.

Breakdown of expected income.

| Description | Estimated Income |
|---|---|
| Estimated registrations | 100 |
| Estimated average fee | $300 |
| Estimated registration income | $30,000 |
| Estimated partnership income | $2,500 |
| Total | $32,500 |

Please provide a breakdown for the expected expenses.

| Description | Estimated Cost |
|---|---|
| Administration | $2,500 |
| Credit card expense | $1,000 |
| Breakfast | $1,500 |
| Lunch | $3,500 |
| Breaks | $1,200 |
| Network Hour | $4,000 |
| Audio Visual | $5000 |
| Recording Fees | $1500 |
| Registration expenses | $300 |
| Travel Expenses, Co-Chairmen | $2,000 |
| Miscellaneous | $1,000 |
| Total | 23,500 |
| Requested budget | Not to exceed $30,000 |

Based on the 2024 workshop.

We expect to recover all of the expenses and make a profit, as we have every year in the past.

Project Milestone Targets

| Milestone | Target Date |
|---|---|
| Workshop | Saturday March 15, 2025 |
| Workshop slides and recordings | Saturday April 19, 2025 |

Measure of success for this project:

- Past Workshops o The workshops of 2016 through 2024 were very successful growing each year in attendance. A summary of a survey done at the 2024 workshop is attached.

Decision:
5-0 to submit special project nomination form for 2025 Magnetics Workshop for consideration at the PSMA BOD meeting on June 21 2024

# *PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes June 12, 2024*

- Special Project Nomination Form For 2025 Magnetics Workshop

## Magnetics workshop:

## Survey notes for 2024 workshop.

- Attendance
  - Total: 132
    - By Sector
      - 73% Industry, 27% Research
    - By Global Region
      - 68% NA, 22% Europe, 9% Asia Pacific, 1% SA
    - 18 Countries
- Survey Results (82 responses)
  - Response Rate: 62%
  - Overall Rating:
    - 35% Excellent, 46% Very Good, 17% Good
  - Value
    - 48% Excellent, 40% Good, 11% Average
  - Skill of the presenters
    - 58% Superior, 33% Above Average 9% Average
  - Recommend workshop to a colleague
    - 83% Yes, 15% maybe, 2% No
  - First Time attendees 60%
  - Plan to attend next year 63% Yes 35% Maybe
  - General topics for next workshop based on survey
    - Thermal Design - Power Loss Density  Thermal Aging
    - Core Loss testing, modelling & specification
    - Integrated Magnetics

- Survey Results – General topics for 2025

| Topic | Score |
|---|---|
| Thermal Aging Thermal Design and power loss density | 301 |
| Core Loss testing, modelling and specifications | 299 |
| Integration of Magnetic Functions | 277 |
| Temperature testing and temperature coefficients | 264 |
| Specific Testing of Magnetics | 256 |
| Artificial Intelligence for simualtion and design | 255 |
| Verification Vs Qualification Vs Manufacturing Test Procedures | 250 |
| Specific Topologies | 244 |
| Specific Applications | 235 |

# *PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes June 12, 2024*

- Special Project Nomination Form For 2025 Magnetics Workshop

- Potential Specific Topics for 2025 Workshop
  - Pared down list of 65 items to 15 items by combining similar items

    1. Magnetic integration
    2. Best practices on testing
    3. AC winding loss modeling
    4. Core testing
    5. Database sharing
    6. Core modeling
    7. AI for modeling and design
    8. Manufacturing of magnetics, DFM
    9. Planar magnetics
    10. Insulation materials and failures
    11. Medium voltage magnetics
    12. New magnetic materials
    13. Electroplated, thin film, 3D printed magnetic materials
    14. Wireless, EV, coupled, multi phase magnetics
    15. Cooling concepts

- Chosen Topics for 2025 Workshop
  - Integrated Magnetics
    - Physical Integration
      - Heterogeneous Integration
        - 2.5D Vs 3D
      - Thermal Limitations
      - Assembly methods
      - Power System in Package
      - Embedded magnetics
        - PCB windings about a magnetic core
      - Wafer level magnetics
        - Sputtered
        - Electroplated
  - Electrical Characteristic Integration
    - LLC
    - Coupled Inductors
    - TLVR
    - VERT

# *PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes*
# *June 12, 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*
# *June 12, 2024*

- Plenary Speakers
  - Presenters from first workshop
    - Candidates to pursue
      - David Perreault
      - Charlie Sullivan
    - Topics
      - Advances in magnetics over the past ten years
        - » Electrical performance
        - » New structures
- Candidates for future workshop leadership
  - Candidates to pursue
    - Andres Arias – Premier Magnetics – still need to contact
    - Paul Ohodnicki – UPITT – confirmed interest
    - Mike Ranjram – ASU – confirmed interest

***PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes***
***June 12, 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*
# *June 12, 2024*

- Posters
  - HLSU – Frederic (maybe someone else – contact Jonas M)
    - Core permittivity and permeability characteristics
  - UPITT – TBD (Sturdivant?)
    - Application of multiple objective optimization relative magnetics integration or other magnetic design topic
  - ASU – TBD
    - TBD
  - MIT – Rachel Yang
    - TBD

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# *PSMA Magnetics Committee Meeting Agenda - Industry Session Planning Notes*
# *June 12, 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

***PSMA Magnetics Committee Meeting Agenda Workshop Planning Notes***
***June 12, 2024***

- 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
  - Re-Confirmed June 3
    - October 2024 timeframe
- Fraunhofer – Torben Dankwort
  - PowderMEMS – a novel technology for fabrication of functionalized MEMS structures
  - Thursday June 13
- CBMM - Bharadwaj Reddy Andapally
  - Technology Roadmap for Nanocrystalline Cores
  - Tentatively scheduled for Thursday July 25

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

# 2022/2023/2024 PSMA PTR Webinar Series
# Fraunhofer ISIT – Thursday June 13

**Presenter:** Dr.-Ing. Torben Dankwort, Agglomerierte Mikrosysteme

**Abstract:** PowderMEMS is a technology platform developed at Fraunhofer ISIT, which offers an industrial relevant procedure to integrate functional porous 3D structures in micron dimensions on wafer-level or PCB. technology allows to integrate magnetic materials for a wide area of applications concerning the field of power electronics and MEMS. This includes the fabrication of soft magnetic cores for micro-inductors, M magnetic actuators and magnetic field sensors using hard magnetic NdFeB.

For demonstration, micro-inductors were fabricated having a core sizes typically around 3.4mm x 1mm x 0.6mm. To prove the functionality of the micro-inductances a boost converter with a GaN FET was designe a switching frequency of 20 MHz. An input voltage of 15 V is boosted to 25 V on the output while a load current of 481 mA is applied. In this case the converter reaches an efficiency of 87 %. The porous nature o core material allows for active cooling of the coil. During operation of the above-described boost converter a significant reduction in temperature was achieved during operation.

Beyond the application for soft magnetic cores, also hard magnetic NdFeB can be integrated on silicon. Here applications of a magneto-mechanical MEMS energy harvester and MEMS sensors will be presented.

**Date: Thurs. June 13, 2024**
Time:
8:00 A.M. - 9:00 A.M.Pacific
9:00 A.M. - 10:00 A.M. Mountain
10:00 A.M. - 11:00 A.M. Central
11:00 A.M. - 12:00 P.M. Eastern
3:00 PM - UTC

**Web Meeting:** https://us06web.zoom.us/webinar/register/2017176234132/WN_Cva5UQecSWOQM6wkfA1_Bg

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# *PSMA Magnetics Committee Meeting Agenda – Special project*
# *June 12, 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

- 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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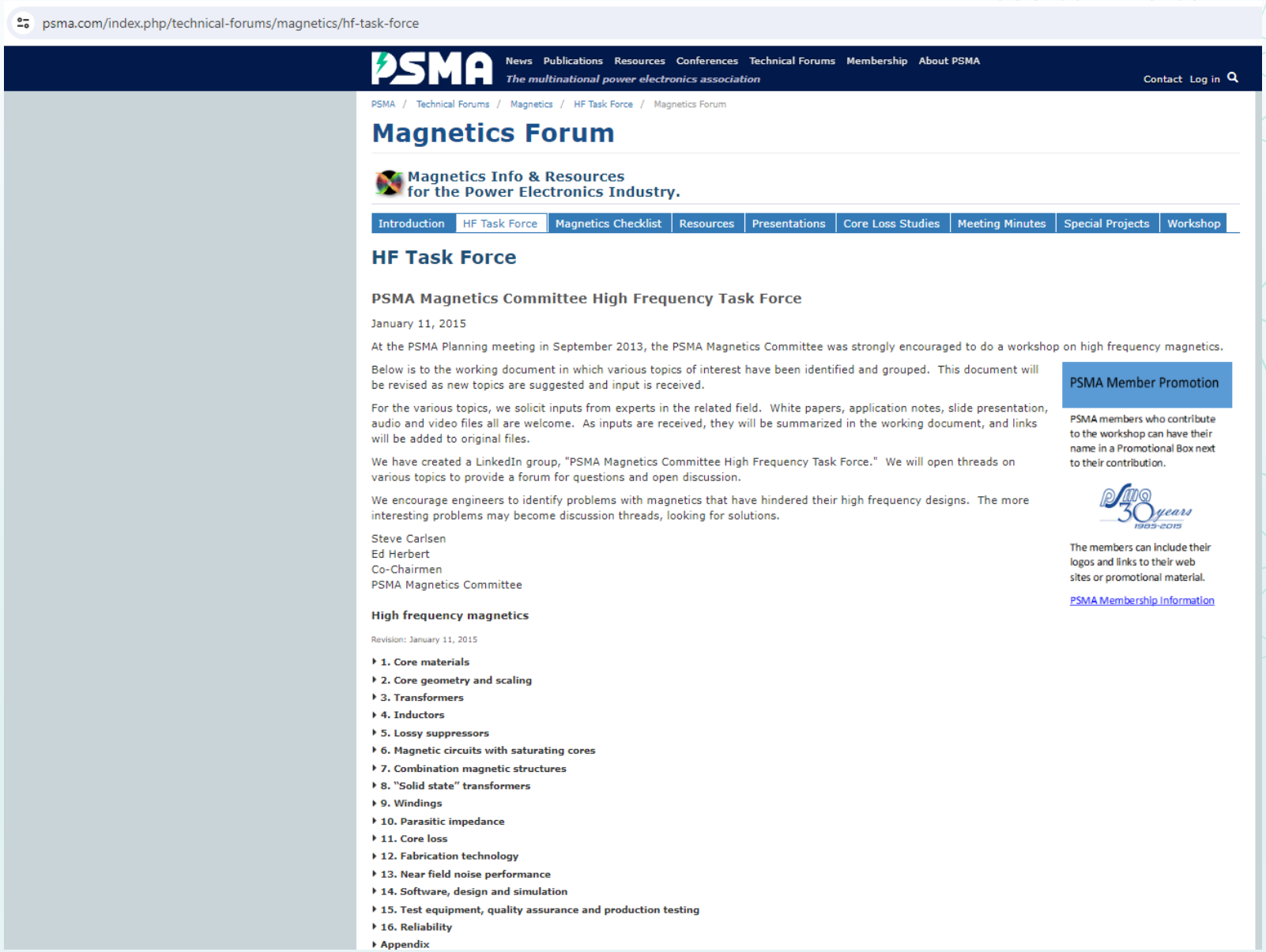
# *PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website*
# *June 12, 2024*

- 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 June 12, 2024*



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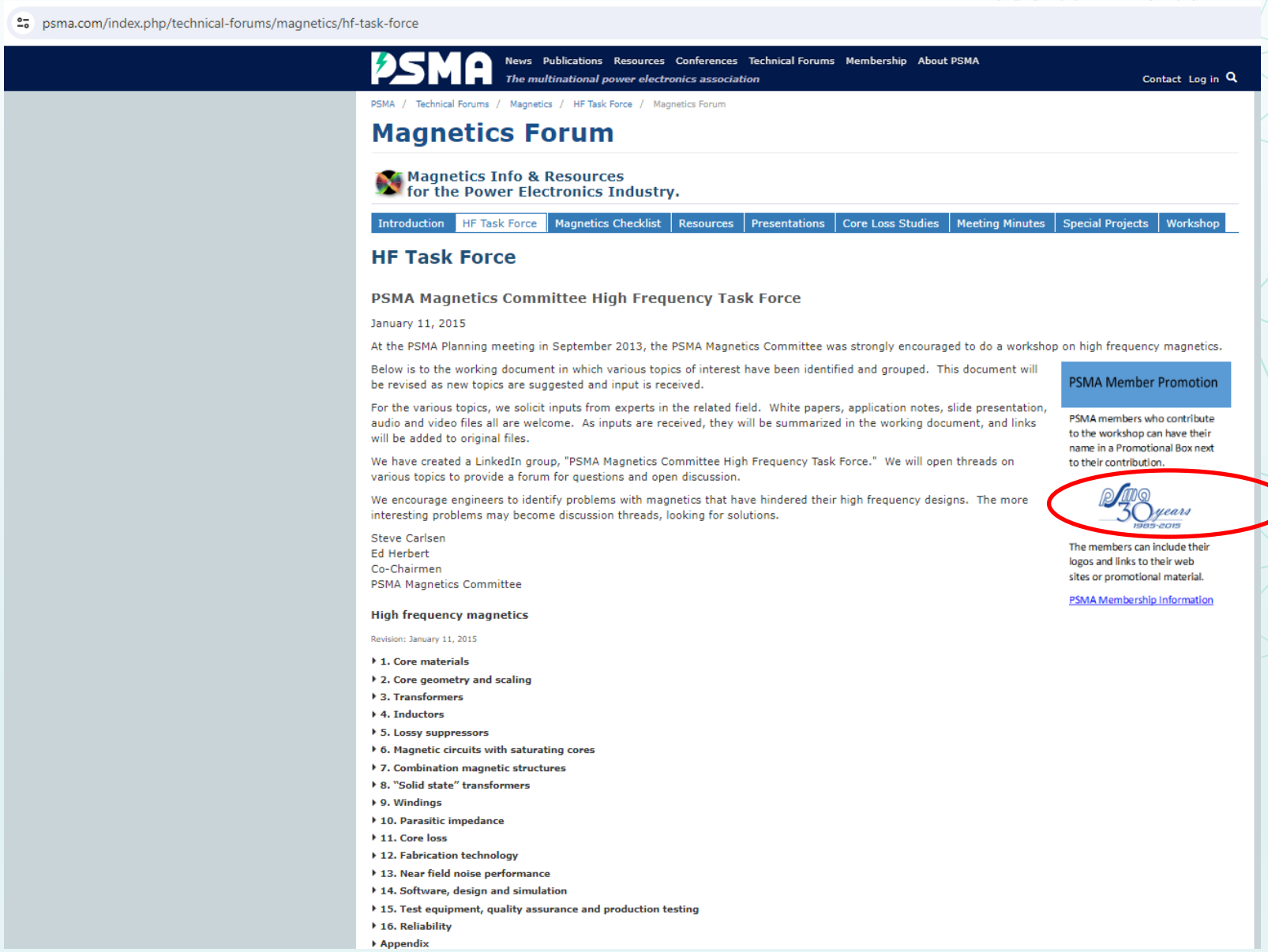


**Update**

# *PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website*
# *June 12, 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 June 12, 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

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

PSMA Member Promotion

Payton American Group

Payton Sales Video

Payton Products Catalog

# *PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website June 12, 2024*

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

PSMA Member Promotion

GECKO SIMULATIONS

Gecko-Simulations AG

**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

# *PSMA Magnetics Committee –Magnetics Committee Forum on PSMA Website*
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**Consider updating to members that are active in psma magnetics committee and/or magnetics workshop**

**▾ 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."

PSMA Member Promotion

"We Will Wind Anything"
CWS
Coilws.com, Inc.
Coil Winding Specialist

Coil Winding Specialist, Inc.

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- Next Meeting – Avoid third Wednesday of the month

# *PSMA Magnetics Committee Meeting*
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- Attendance (7)
  - John Horzepa
  - Mike Arasim
  - Fred Feng – Collins Aerospace
  - Ed Herbert
  - Rodney Rogers
  - Ranajit Sai
  - Matt Wilkowski

# Thank You

PSMA