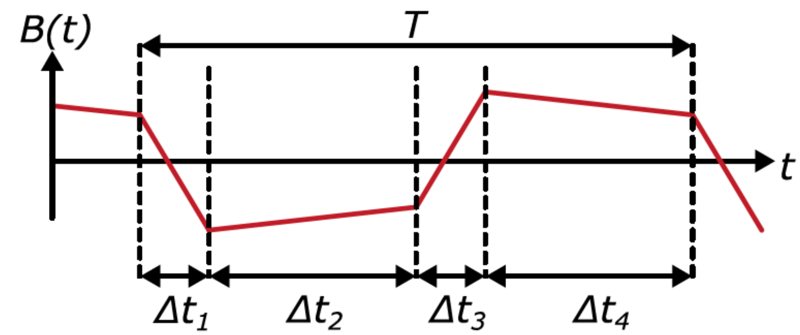
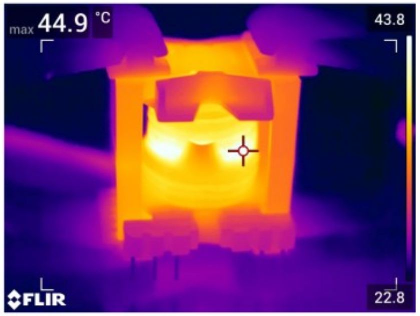
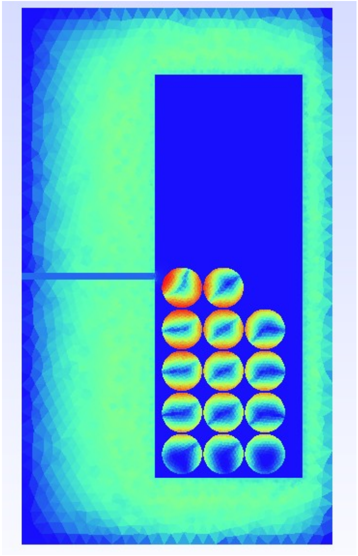
Leistungselektronik und Elektrische Antriebstechnik
Prof. Dr.-Ing. Joachim Böcker

UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft







Topic 4: FEM Magnetics Toolbox

Extension of the FEM Magnetics Toolbox for time domain simulation

6. April 2023

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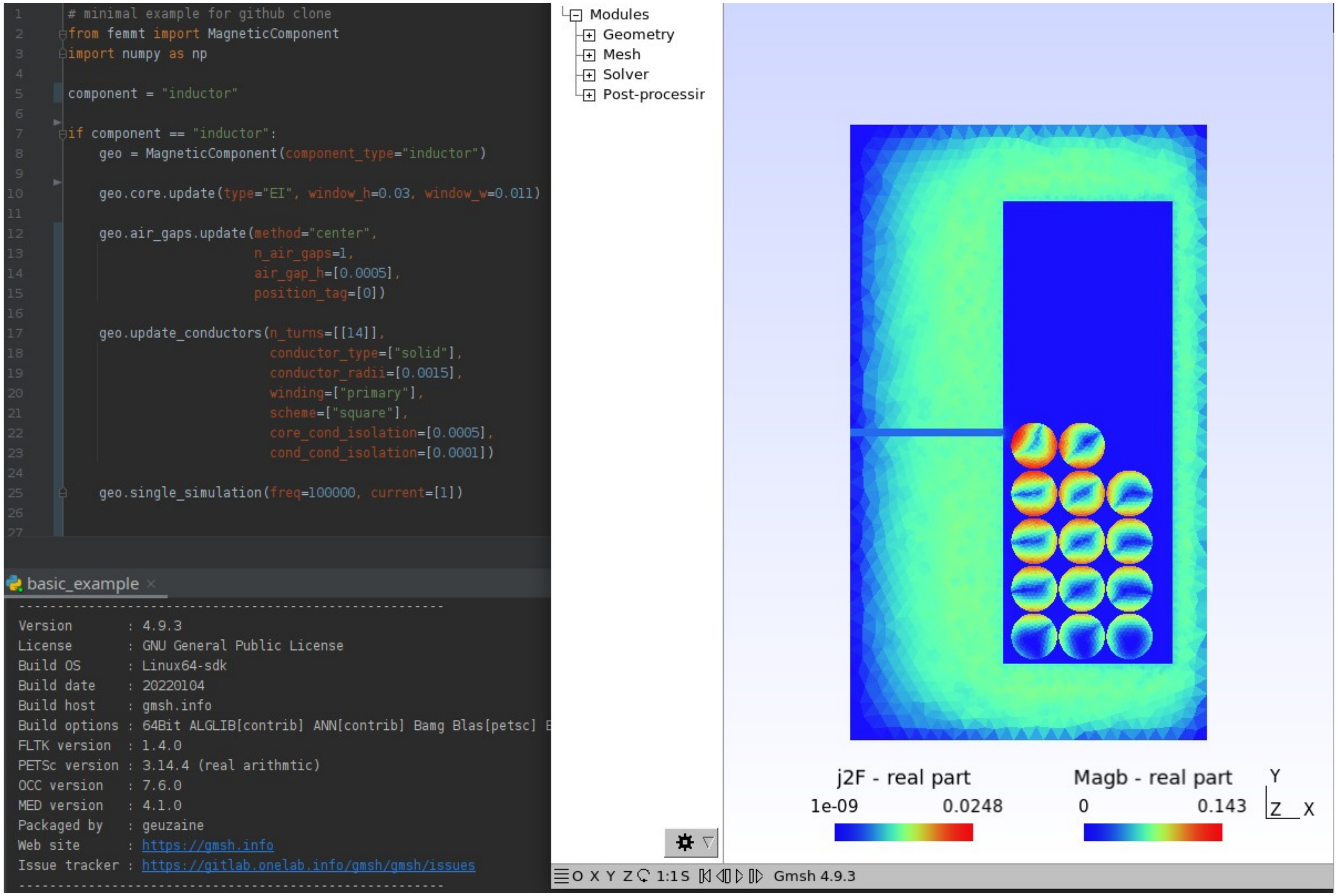
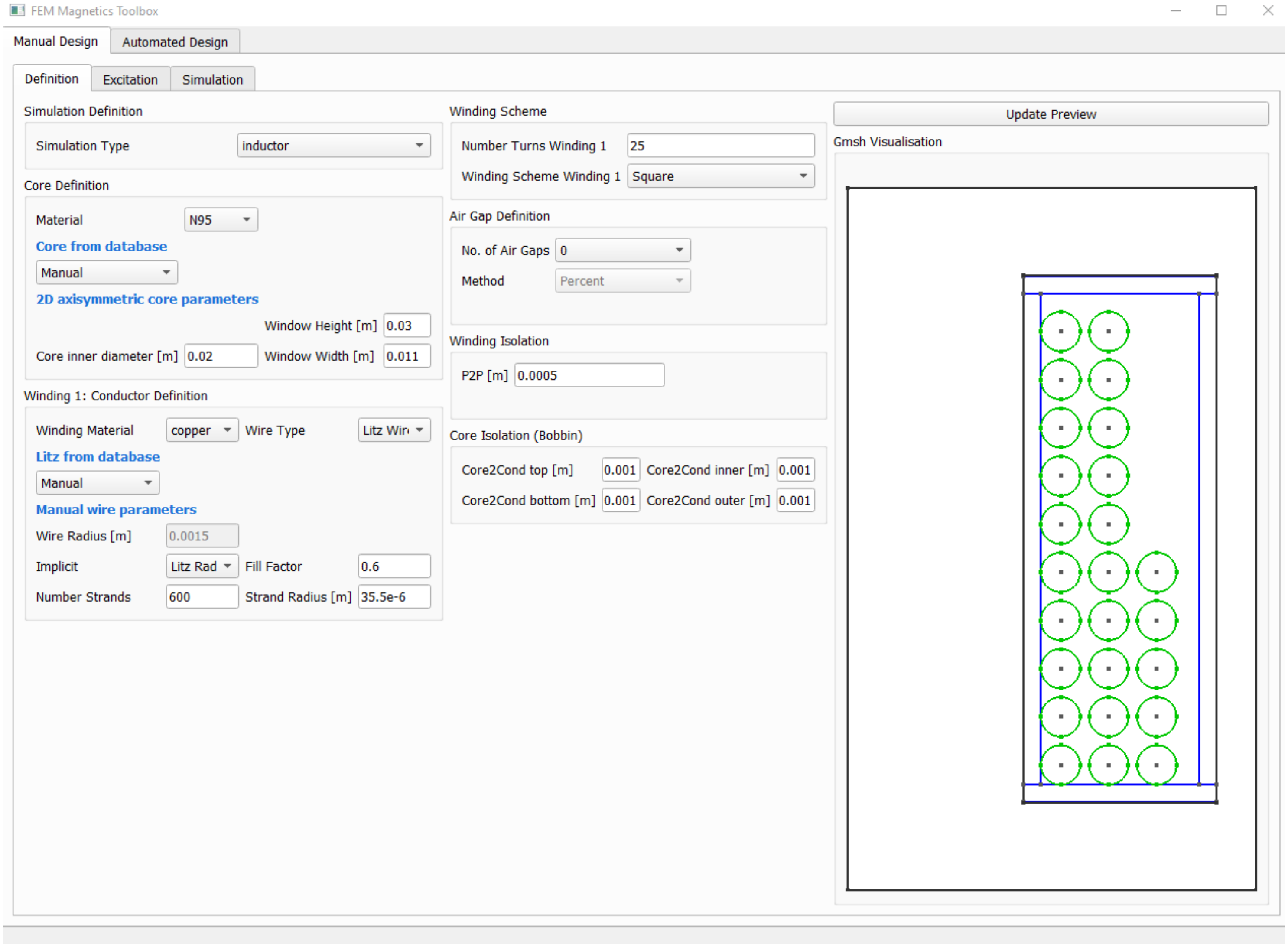
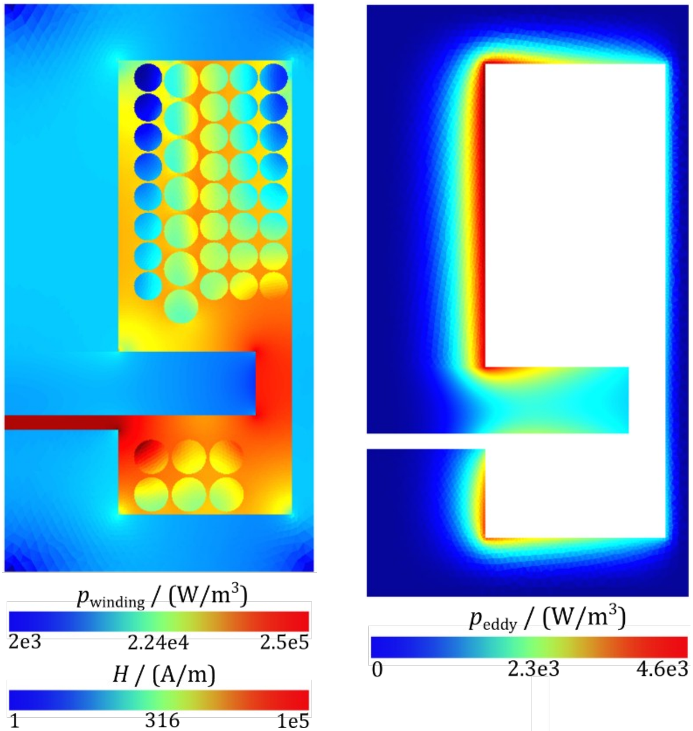
Intro: FEM Magnetics Toolbox

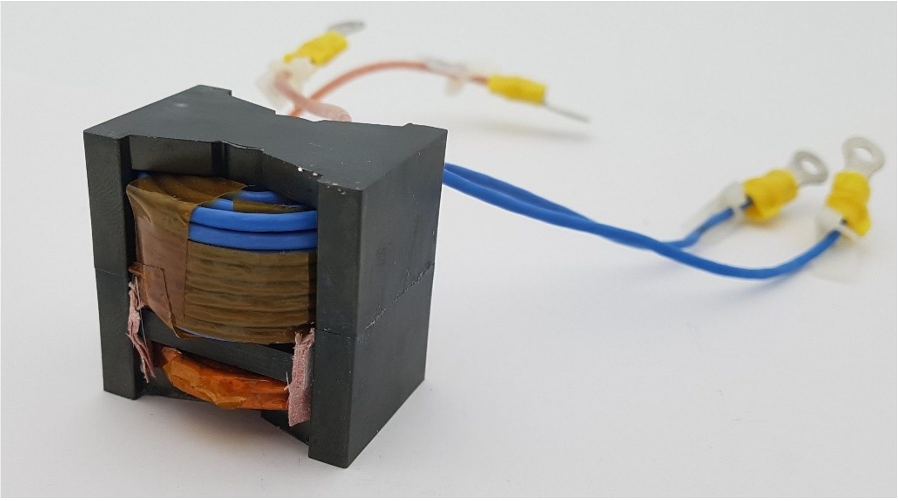


Intro: FEM Magnetics Toolbox



Previous Work Example

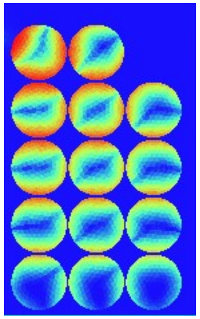




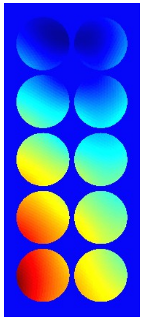
Basics: Losses in Magnetic Components

windings

solid



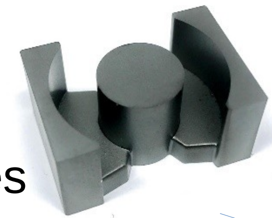
strands



skin effect and proximity effect

Basics: Losses in Magnetic Components

(ferrite) cores



type: empirical | physical

frequency domain

approach:

Steinmetz equation

$$P = \frac{1}{T}\int_0^T k_i \left|\frac{dB}{dt}\right|^a (\Delta B^{b-a})dt$$

eddy currents

$$p_{eddy} = -\omega\Im(\underline{\tilde{\varepsilon}})|\underline{\boldsymbol{E}}|^2$$

hysteresis

$$p_{hysteresis} = -\omega\Im(\underline{\mu})|\underline{\boldsymbol{H}}|^2$$

data:

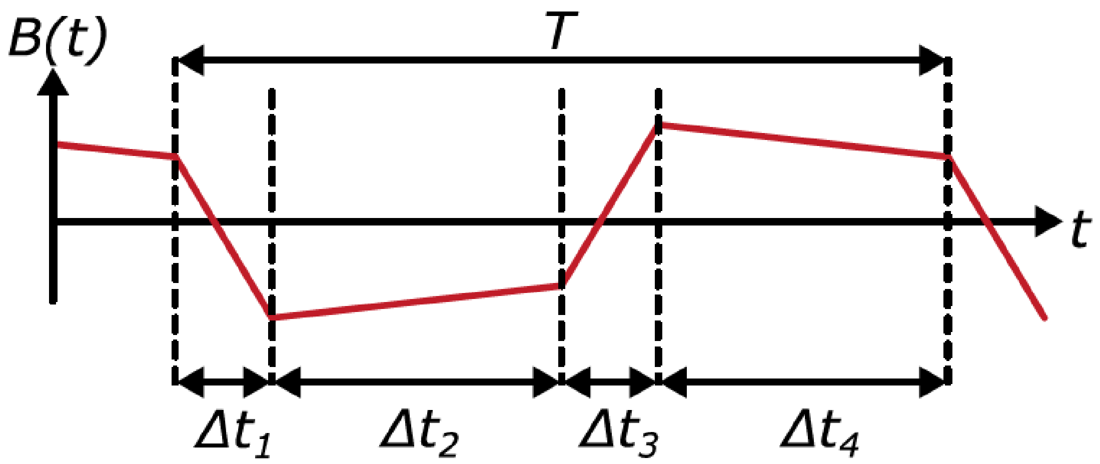
$$k_i, a, b$$

$$\underline{\varepsilon} = \varepsilon' - \mathrm{j}\varepsilon''$$

$$\underline{\mu} = \mu' - \mathrm{j}\mu''$$

This project: time domain simulation

Example: Dual Active Bridge



in PE often non-sinusoidal flux:

- for **linear** material: **superposition**
- For **non-linear** material: **time domain**

This project: time domain simulation

Integrate an existing code example into our framework

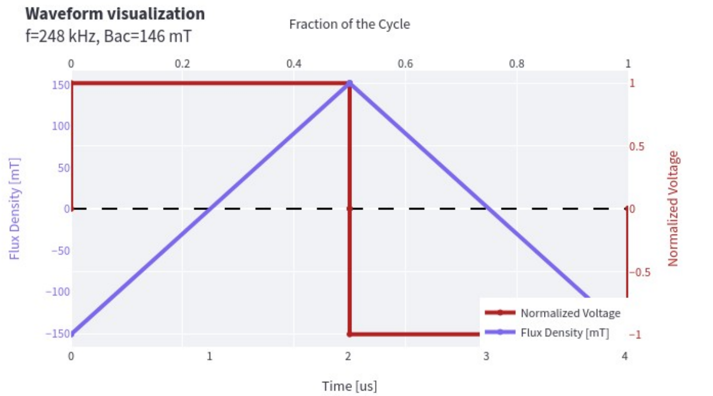
```
Operation {
  CreateDirectory[resPath];
  If(Flag_FrequencyDomain)
    Generate[A]; Solve[A]; SaveSolution[A];
  Else
    InitSolution[A]; // provide initial condition
    TimeLoopTheta[TimeInit, TimeFinal, DeltaTime, 1.]{
      // Euler implicit (1) -- Crank-Nicolson (0.5)
      Generate[A]; Solve[A];
      If(NbrRegions[Vol_NL_Mag])
        Generate[A]; GetResidual[A, $res0];
        Evaluate[ $res = $res0, $iter = 0 ];
        Print[{$iter, $res, $res / $res0},
          Format "Residual %03g: abs %14.12e rel %14.12e"];
        While[$res > NL_tol_abs && $res / $res0 > NL_tol_rel &&
              $res / $res0 <= 1 && $iter < NL_iter_max]{
          Solve[A]; Generate[A]; GetResidual[A, $res];
          Evaluate[ $iter = $iter + 1 ];
          Print[{$iter, $res, $res / $res0},
            Format "Residual %03g: abs %14.12e rel %14.12e"];
        }
      EndIf
      SaveSolution[A];
    }
  EndIf
}
```

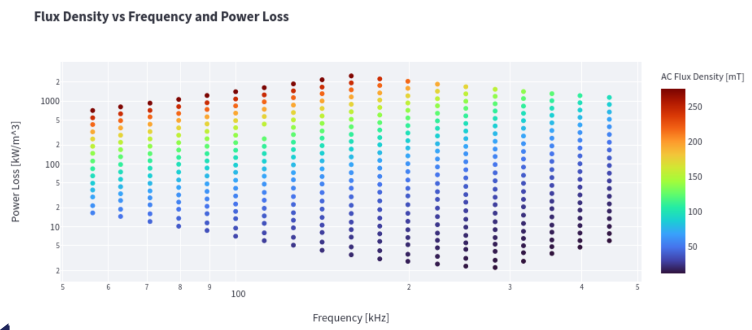
✓

This project

Getting material data for time domain simulations

- Magnet database, contains lot of real-world measurements
- Use neuronal networks / machine learning to get the data for different wave forms





Princeton MagNet
Princeton Power Electronics Research Lab

This project: time domain simulation

Goals

- Extend the FEMMT project with the capability for time domain simulations
- Use MagNet database to provide material data for the time domain simulation
- Validate the simulations with a commercial FEM tool (ANSYS Maxwell or Comsol Multiphysics)

This Project: time domain simulation

Skills (you can learn / improve)

- FEM (open source environment ONELAB)
- Neuronal networks / machine learning
- Python
- Version Control System (Git)
- Power Electronics

This Project

Deadlines / Organisation

- Make appointment for mandatory interview via mail to **piepenbrock@lea.upb.de** until **Tuesday Apr 11th, 8am**

- Interviews take place on **Wednesday Apr 12th**

- If you have time limits for April 12th, please include that in the email. We will try to take it into account.

- Possible topics in interview:
    - Power electronics
    - Law of induction
    - ….

Contact:
Till Piepenbrock, M.Sc.
Research Assistant
Email: piepenbrock@lea.upb.de

Power Electronics and Electrical Drives
Paderborn University
D-33098 Paderborn, Germany
Web: lea.upb.de

GENERAL INFORMATION

- Self managed group work
- You are responsible for your results
- 9 credits (= 270 h workload)
- Time range ≈ 6 month with 10 h per week
- Meetings are held every week
- Not every applicant can be admitted to the project, since the number of participants is limited

Questions?