Optimal filter design for power electronic converters

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Research background

- The power-density of power electronic converters has roughly doubled every ten years since 1970.
- In modern systems, electrical power distribution and actuation replace mechanical, hydraulic or pneumatic systems.
- An estimated 30% of world's electrical energy was processed by power electronic systems in 2005. A prediction of 80% by 2030.
- An understanding of future capabilities of power electronics & bottlenecks limiting increases in performance of such systems is required.
- Designing a filter/converter is a complex engineering task that balances many interacting and often conflicting pressures.
- A computational tool that accounts for them while seeking optimal (power-dense) designs is of high value for designers.
- This research aligns with the **Design Tools and Modelling** theme of the **CPE**, overlapping with the **Components** & **Converters** themes.

Aims & objectives

- Development and implementation of **Optimal Design Framework** for the optimal filter design of power electronic converters.
- Development and implementation of accurate yet computationally **efficient electrical models** of filter and its passive components.
- Development and implementation of accurate yet computationally **efficient thermal models** of filter and its components.
- Use of the developed methodology to **investigate** the **power density** and other aspects of the optimal designs that result from a variety of design parameters (input variables).

Industrial partners

Rolls-Royce · IMV CORPORATION · Microsemi

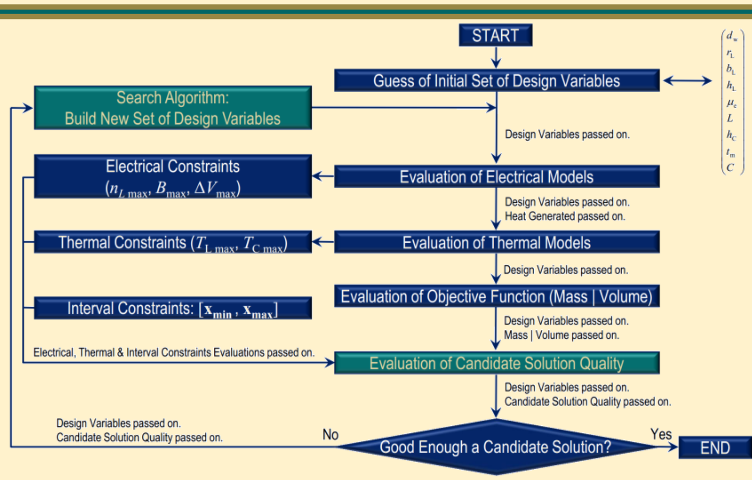
- **Rolls-Royce** is a world-leading provider of power systems and services for use on land, at sea and in the air. Power electronics systems are under extensive development at Rolls Royce.
- **IMV Corporation** is a Global corporation with headquarters in Osaka, Japan. IMV also has its Europeans R&D office in Letchworth, UK and is beginning manufacturing operations in the UK. At the heart of these systems are power electronic converters.
- **Microsemi Corporation** is a manufacturer of defense, security, aerospace, enterprise, communications, medical, alternative energy, and industrial products for power-related applications.

Research overview

Optimal Design Framework

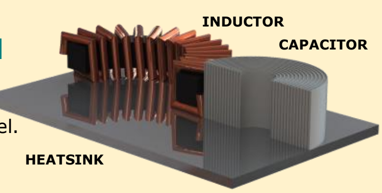
Minimise either Mass or Volume.

Subject to:
- Max number wire turns (n_L)
- Max magnetic flux density (B_{max})
- Max ripple voltage (ΔV_{max})
- Max hotspot temperature in L ($T_{L\ max}$)
- Max hotspot temperature in C ($T_{C\ max}$)
- Max & min values of design variables



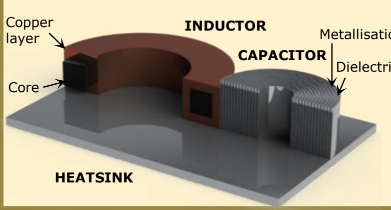
Electrical model

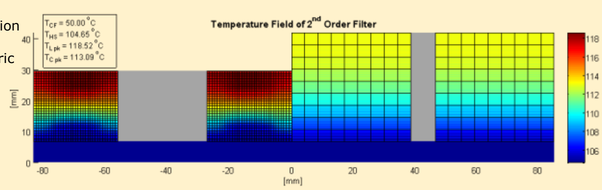
First three constraints require evaluation of filter electrical model.



Thermal model

Fourth & fifth constraints require evaluation of filter thermal model.





Simplifying assumptions

- Decoupled electrical & thermal models.
- Copper wire replaced by copper layer.
- Orthotropic homogeneous material in thermal model of capacitor.
- Axisymmetric thermal models of passive components.
- Heatsink at constant temperature.
- Convective heat dissipation at bottom face of heatsink.
- All other faces are insulated.

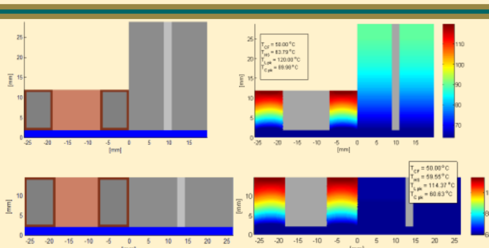
Key results to date

- Electrical constraints are typically active for optimal designs.
- Hotspot temperature in inductor is typically active for optimal designs.
- Hotspot temperature in capacitor typically active for **minimal mass** designs.
- Filter mass is inversely proportional to the frequency.
- Gravimetric power density is almost constant over a broad range of output power.

Example problem

Mass Minimisation

Volume Minimisation



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