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Wide Bandwidth PCB Rogowski Coil Current Sensor with Droop Suppression and DC Restoration for In-Situ Inverter Measurements

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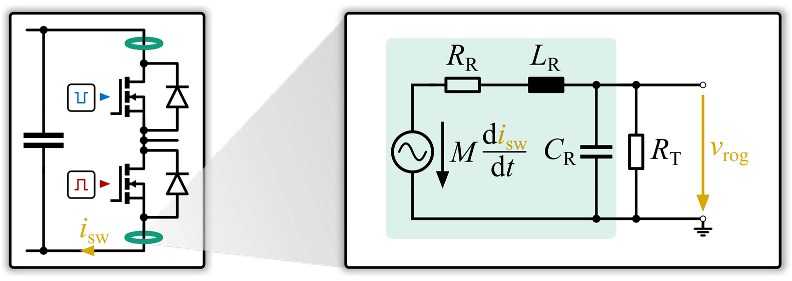
1 PCB Rogowski Coil Current Sensor (RCCS)

Drawbacks of Current Solutions

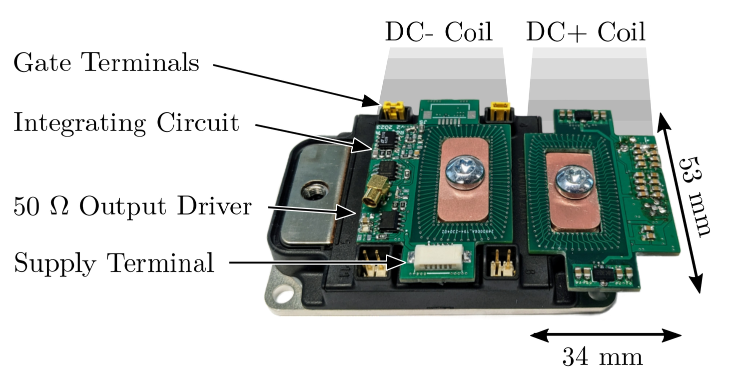
- Susceptible to droop effects
- Input stage sensitive to parasitic offsets
- Complex implementation of DC offset restoration



Arrangement of RCCS for current measurement in a half-bridge module

Proposed RCCS

- Minimally invasive WBG half-bridge switch current measurement
- All-in-one solution:
  - Switch characterization
  - Fast overcurrent protection
  - Phase current reconstruction



Implementation of the RCCSs for switch current measurement in a SiC half-bridge module

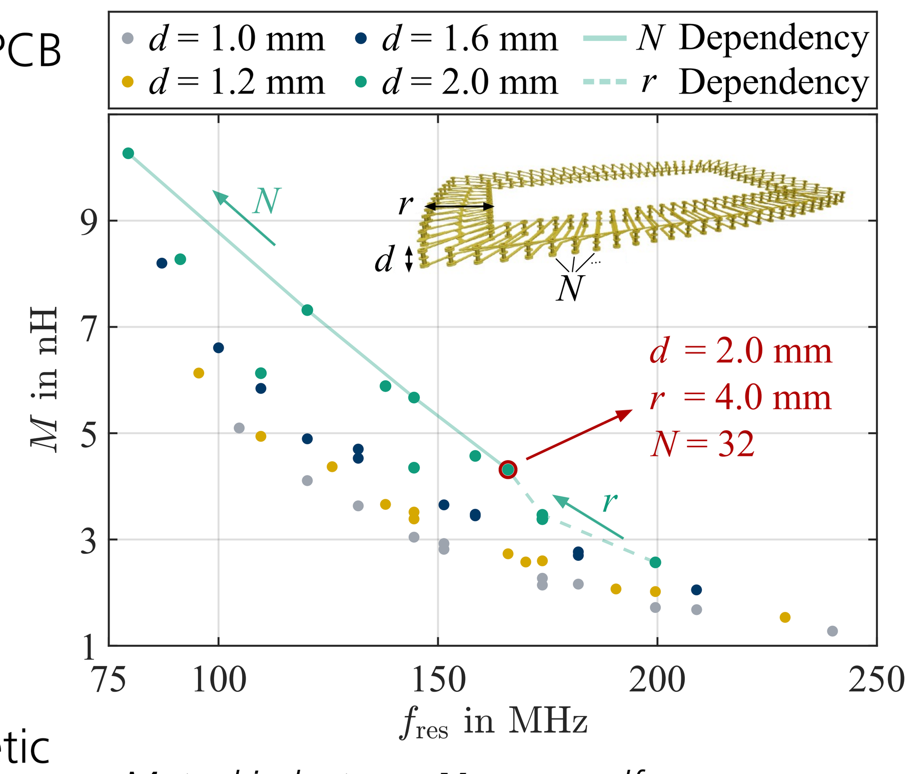
2 Design of PCB Rogowski Coil

Mechanical Boundaries

- Module space → rectangular PCB
- Minimally invasive placement → preserve commutation cell

Coil Study

- Simulation of 48 coil designs using Ansys HFSS 3D FEM
- Evaluation of sensitivity (~ M) versus bandwidth (~ f_{res})
- Enhanced immunity to magnetic stray fields via internal return path



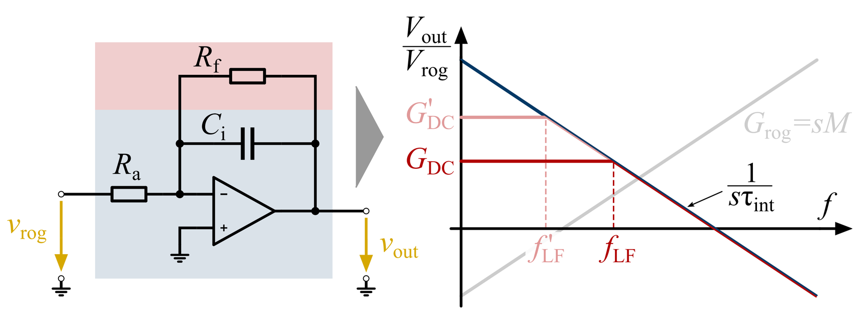
Mutual inductance M versus self-resonance-frequency f_{res} for different parameter sets

→ **PCB thickness d eliminates the trade-off between M and f_{res}**

3 Design of Novel Integrating Circuit

Conventional Integrator Design

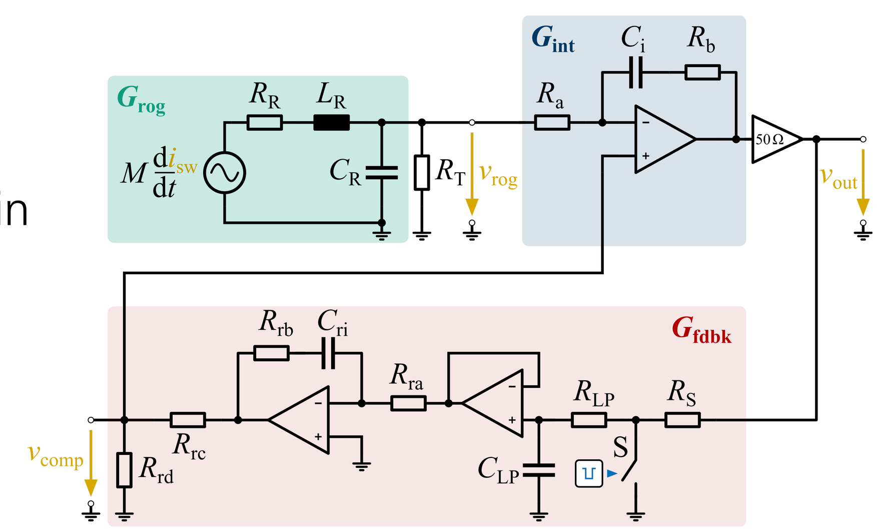
- DC gain (G_{DC}) and lower cutoff frequency (f_{LF}) linked
- Inherent tradeoff: droop vs parasitic offset



Conventional inverting integrator

Novel Integrator Design

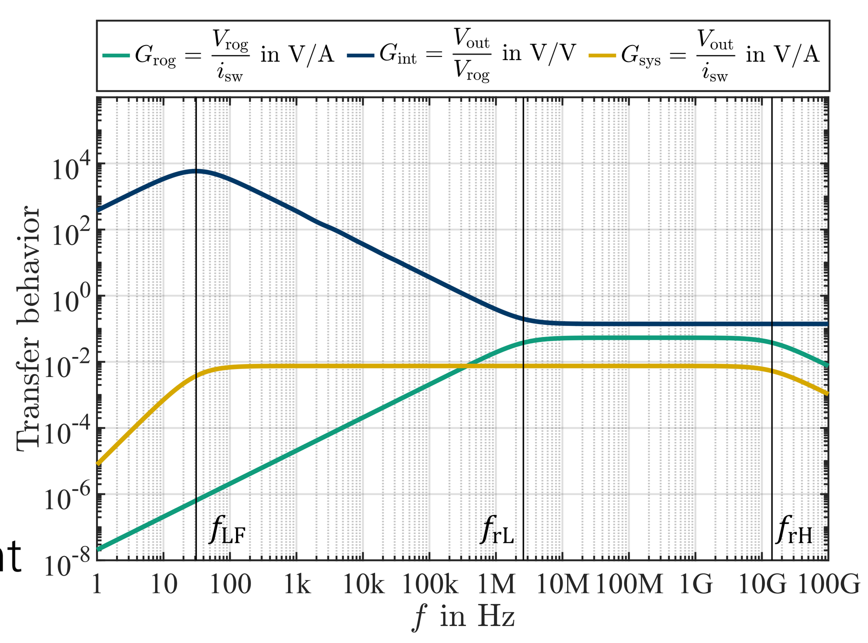
- Loopback: Cancellation of parasitic DC gain
- Elimination of the droop-offset compromise
- No hard boundary for lower frequency
- Low-impedance termination: Reduction of dynamic range enables high overall bandwidth



Proposed integrating circuit

DC Signal Restoration

- Leveraging zero-current state in switched applications
- Preservation of DC signal component by disabling loopback during nonzero current



Simulated transfer behavior of proposed RCCS

→ **Benefits through combination: Parasitic DC offset cancelation and low-impedance termination allow wide bandwidth operation & DC signal preservation**

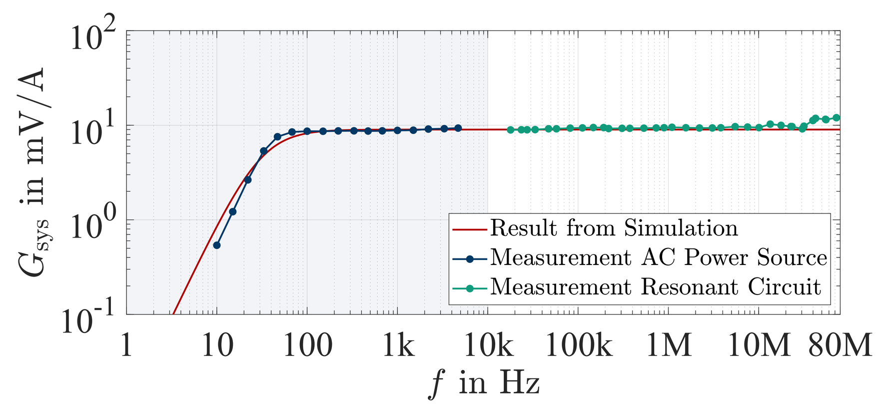
4 Verification of Design

Verification in Frequency Domain

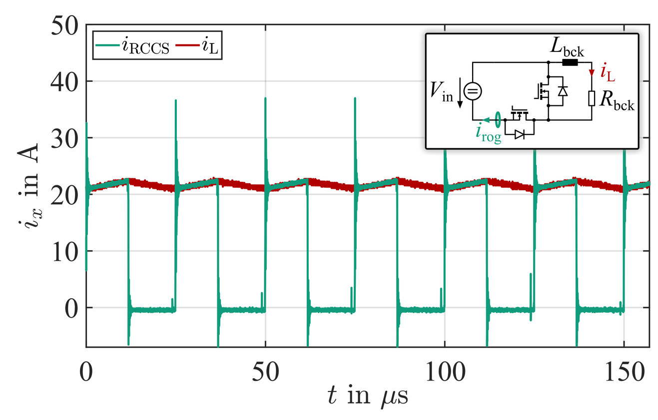
- LC resonant circuit for monofrequent excitation
- Constant amplitude up to at least **75 MHz**

Verification in Time Domain

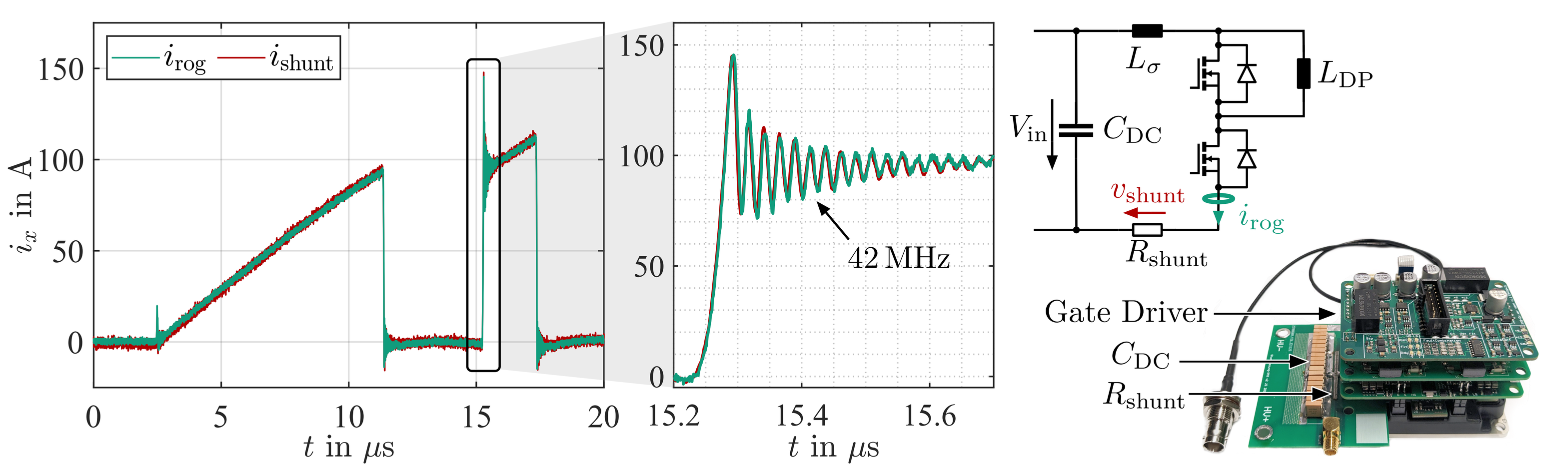
- Measurement in buck converter → Signal offset remains
- Accurate low inductance double pulse with ringing of 42 MHz



Measured transfer characteristics of proposed RCCS



Buck mode steady state



Double-pulse test measurement with 100mΩ SMD shunt resistor array as reference

Conclusion

- Minimally invasive PCB sensor
- Cost-effective and versatile: Characterization, protection & phase current
- High bandwidth: > 75 MHz

- Integration into power module
- Modelling and measurement of upper bandwidth limit
- Further investigation of external field influence