Google/IEEE requirements

GAN implementation

95% weighted efficiency

EMC Class B (RF noise <1mV)

DC voltage ripple(100hz)< 0,1V

Enclosure Max Temp <60°C

Volume < 600 cm^3

POWER

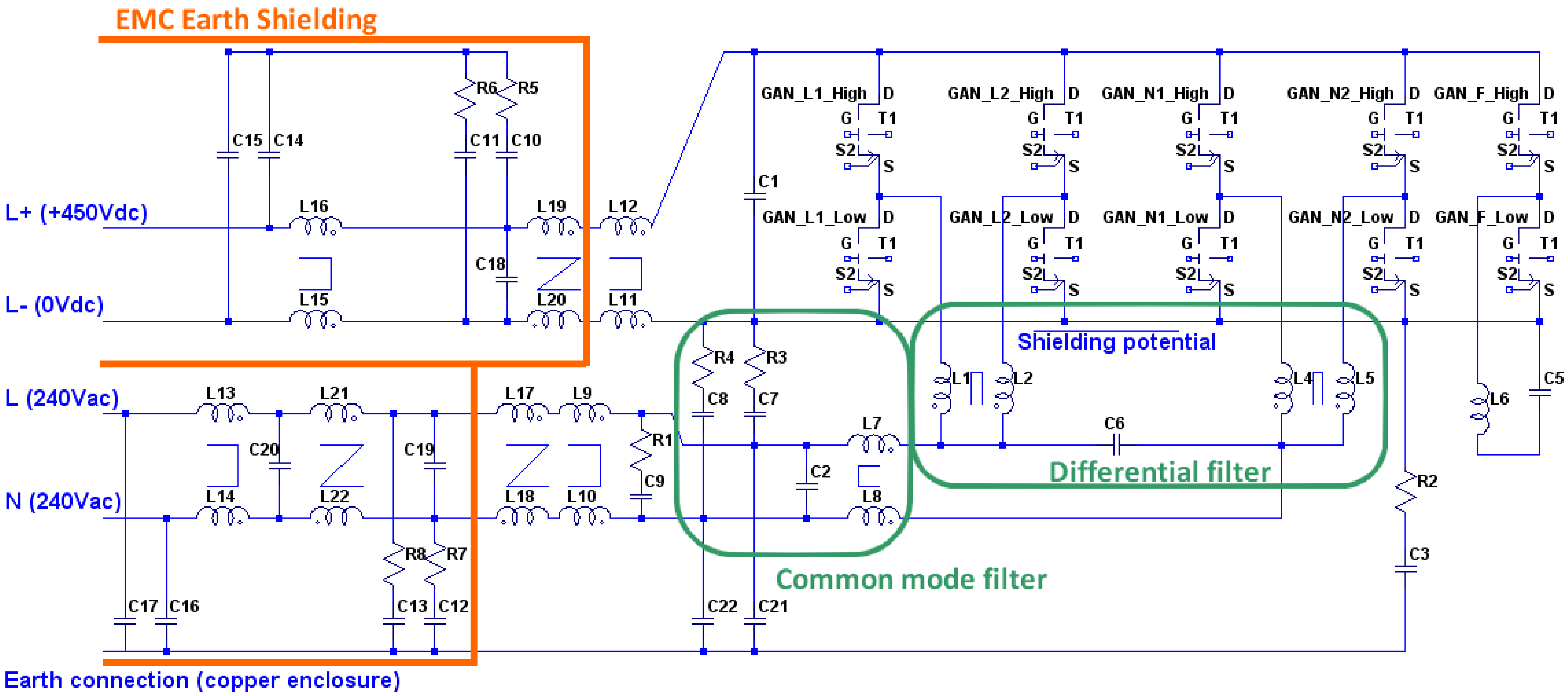
Leading AC Backup Technology

How to achieve It ?

* *Robust GaN driving sustaining high dV/dt (130V/ns)
* * Active filter & MLC storage
* * Soft switching (ZVS)
* * Output current limitation

* * High speed Current Measurement
* * Cu Honeycomb heatsink
* * Sandwich PCB structure
* * Shielded N-order filter

Filters & 5 legs topology



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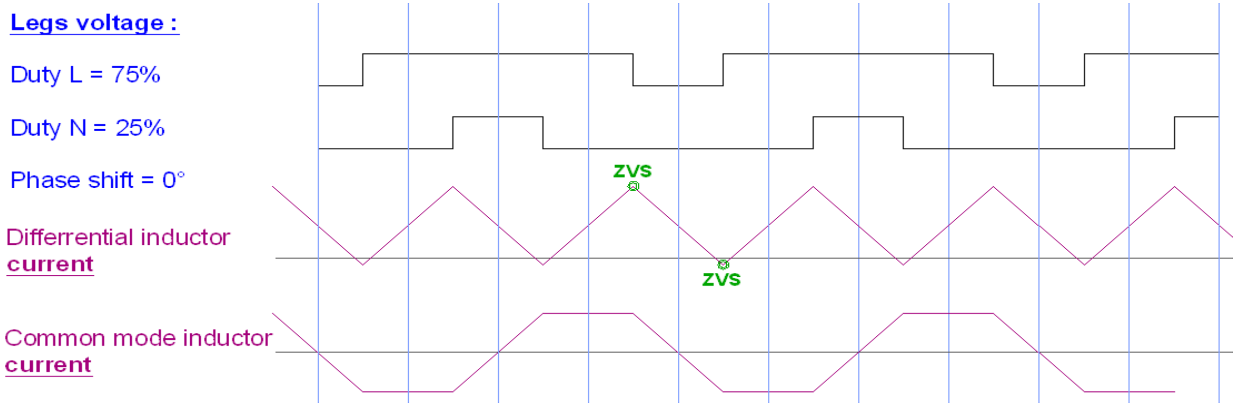
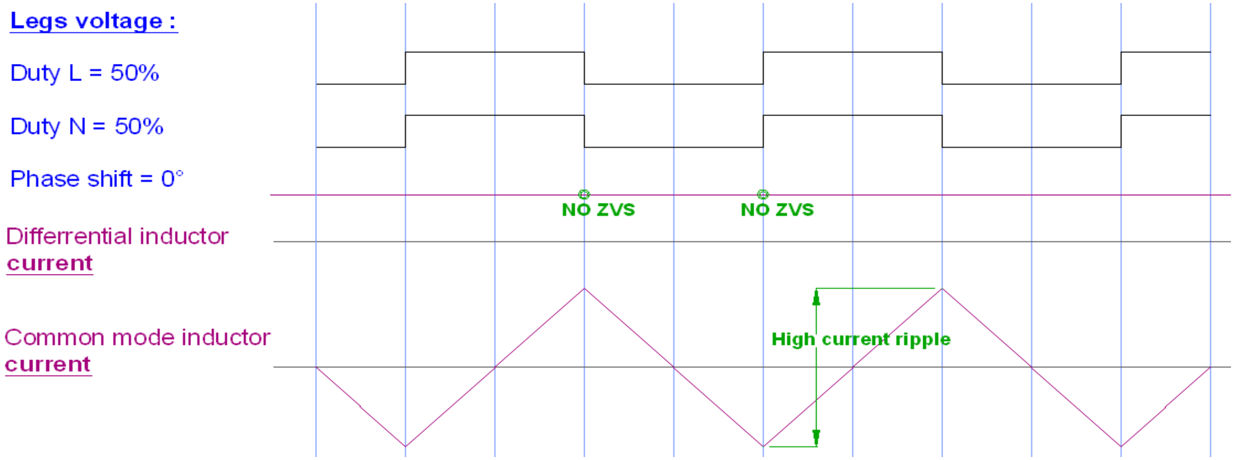
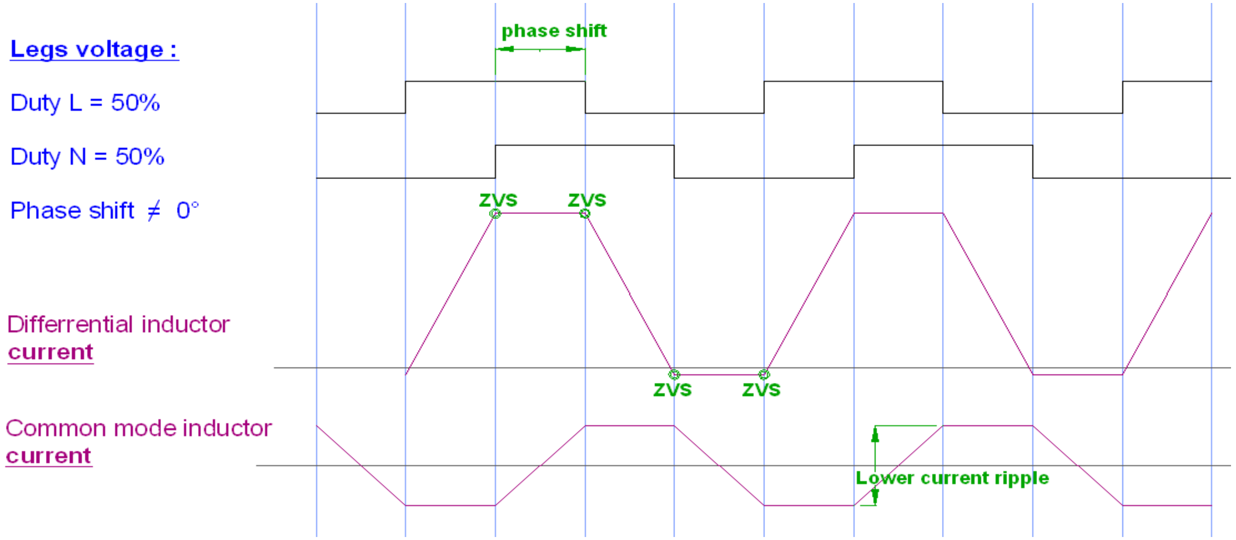
ZVS & Phase shift







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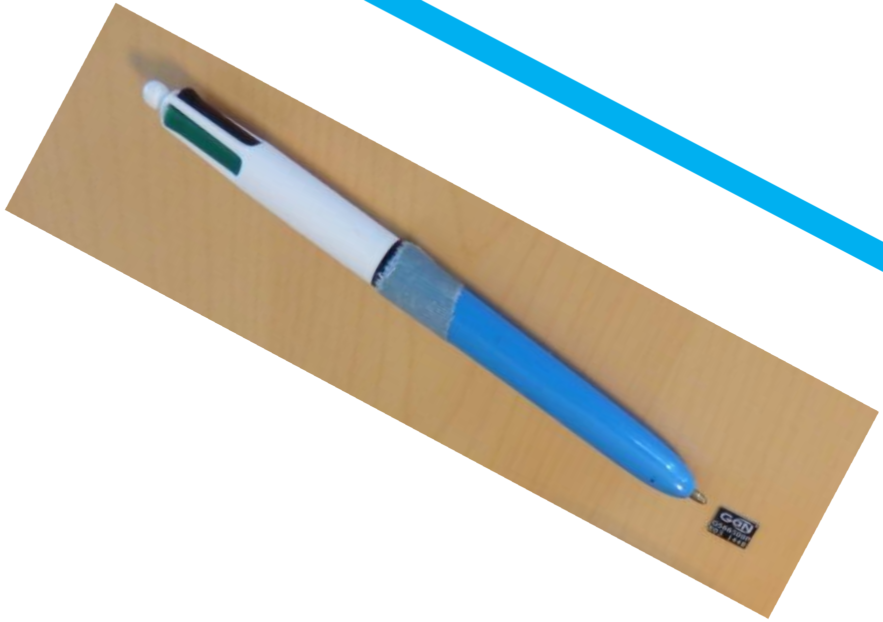
How to use New Switches ?

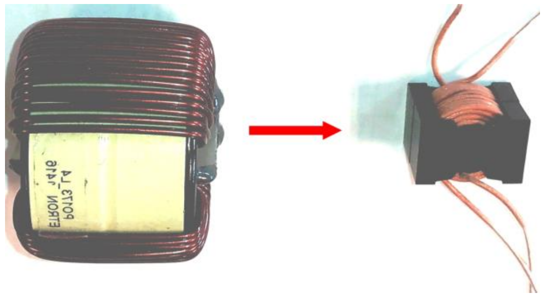
GaN

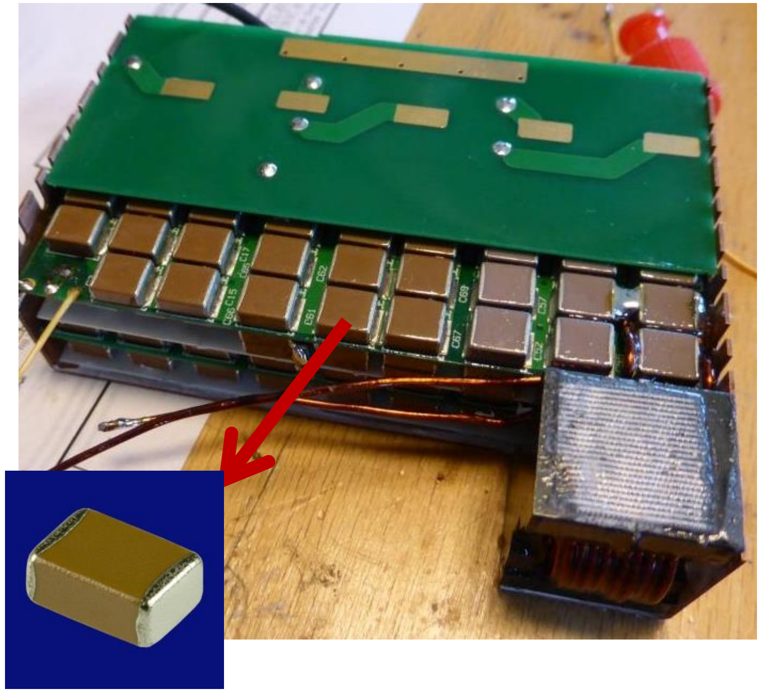
IGBT



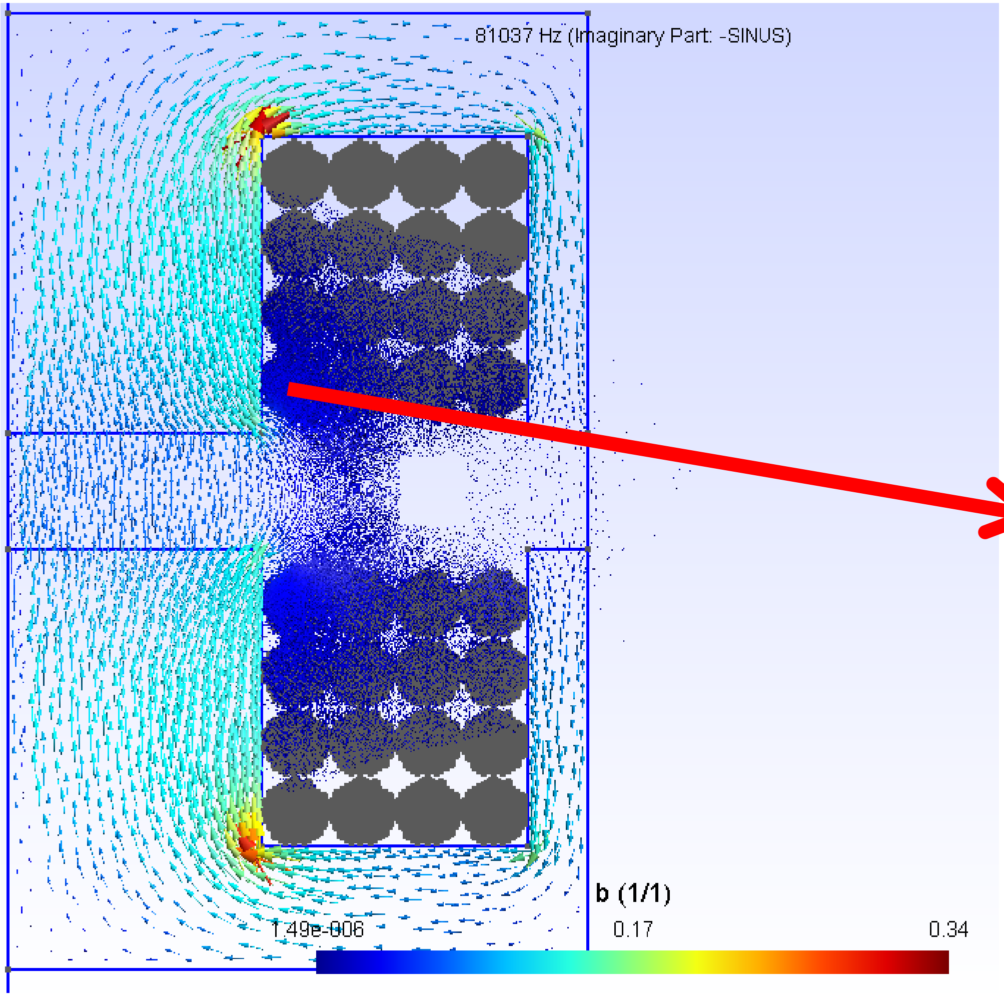
Challenge : Size Reduction

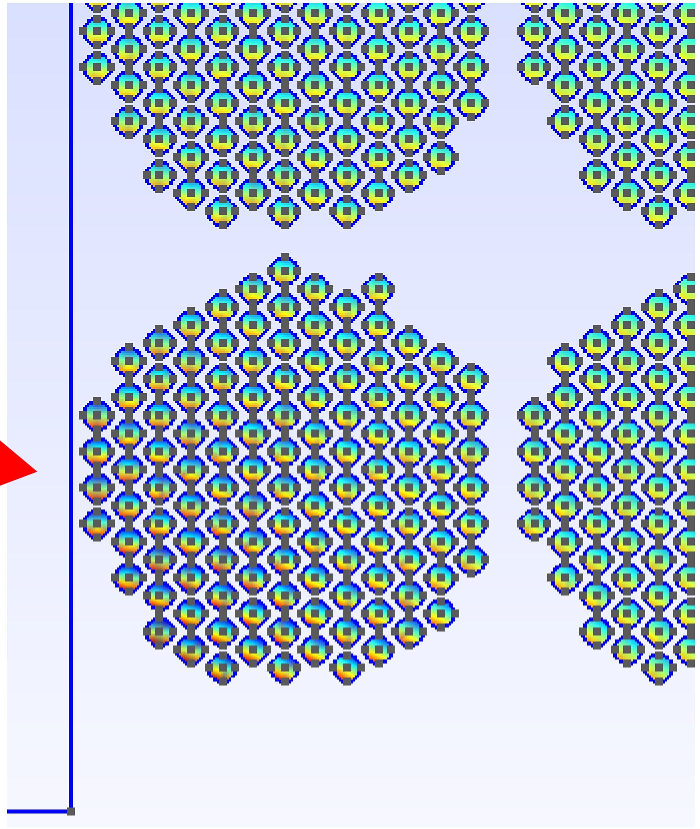
- No electrolytic capacitor (too big & less reliable)
- Use of MLCC -> compacity, efficiency, lifetime



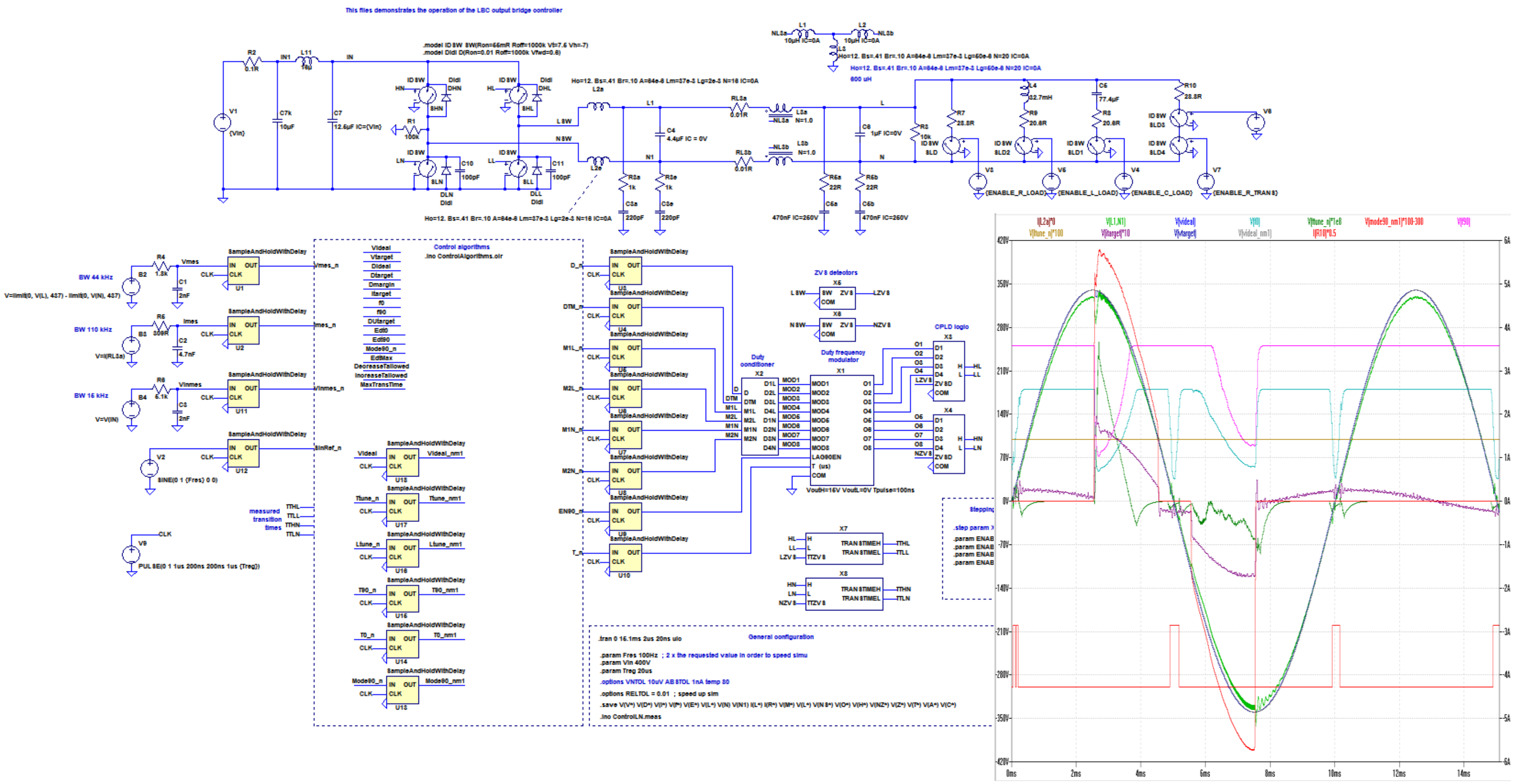


Simulations: Output Inductor

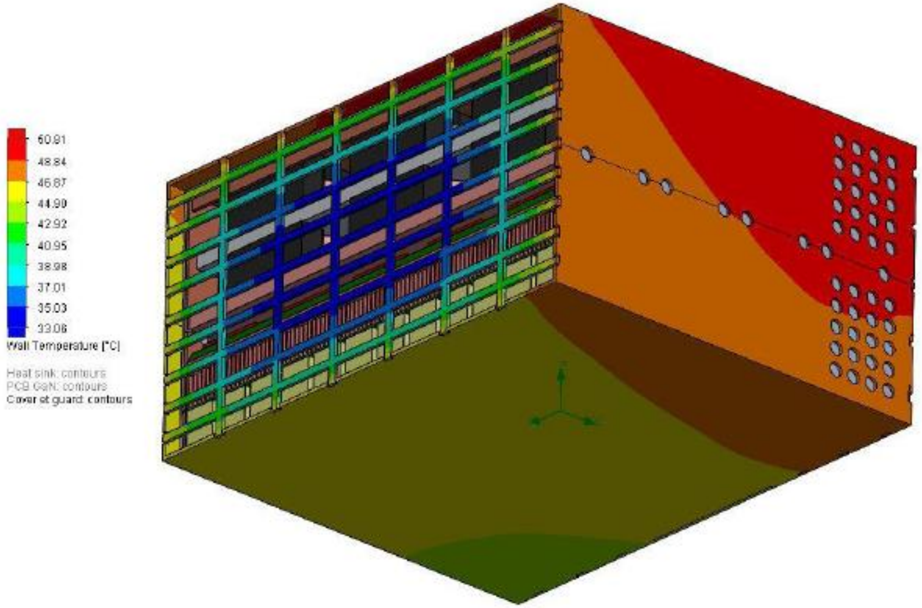


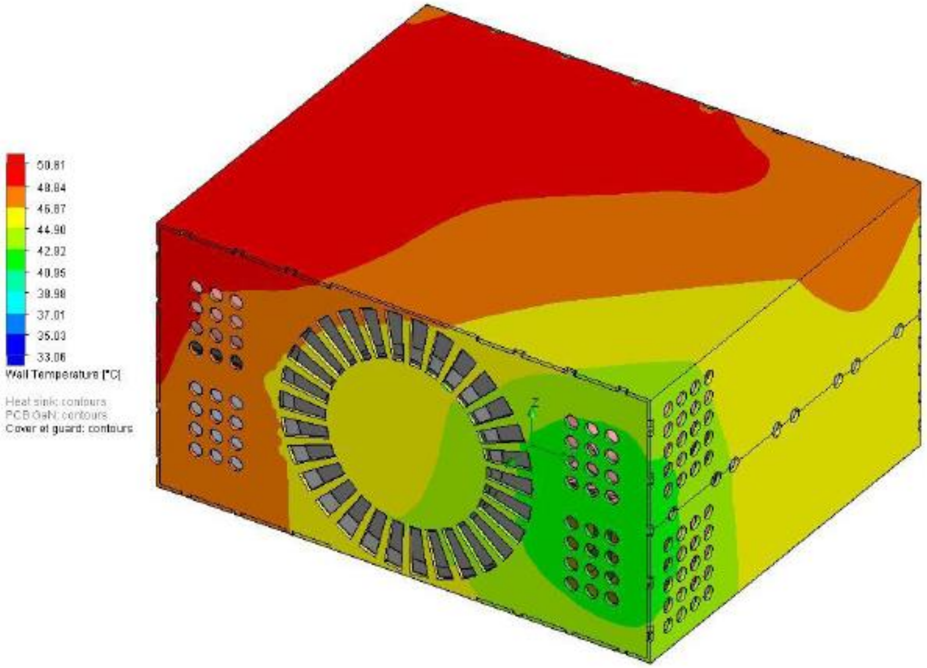


Simulations: Circuit & Control

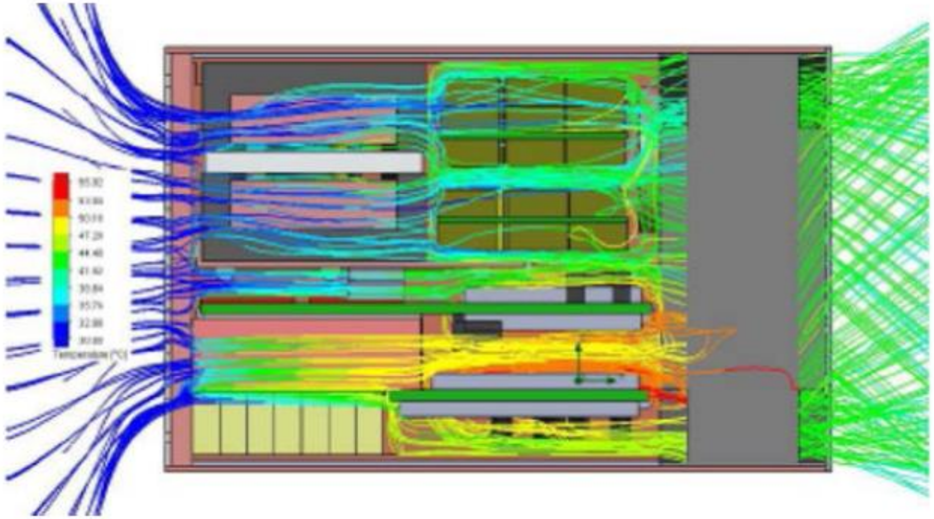


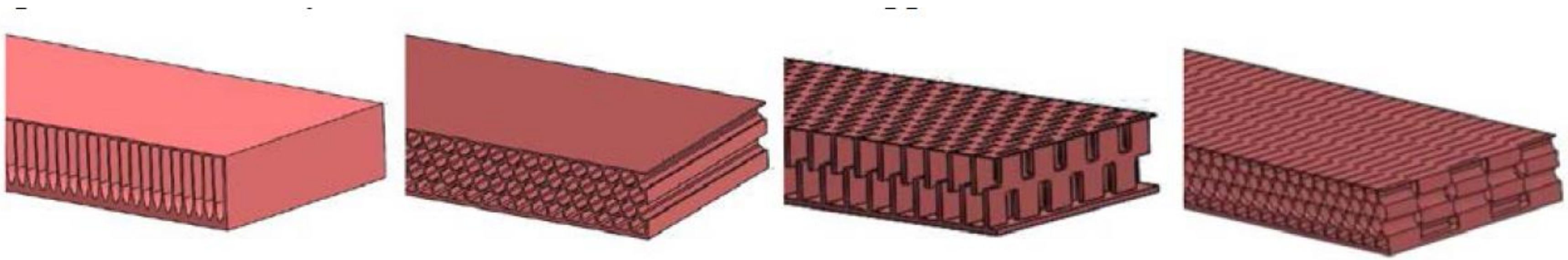
Thermal analysis : max 60°C enclosure





Airflow : simulation: Pierre





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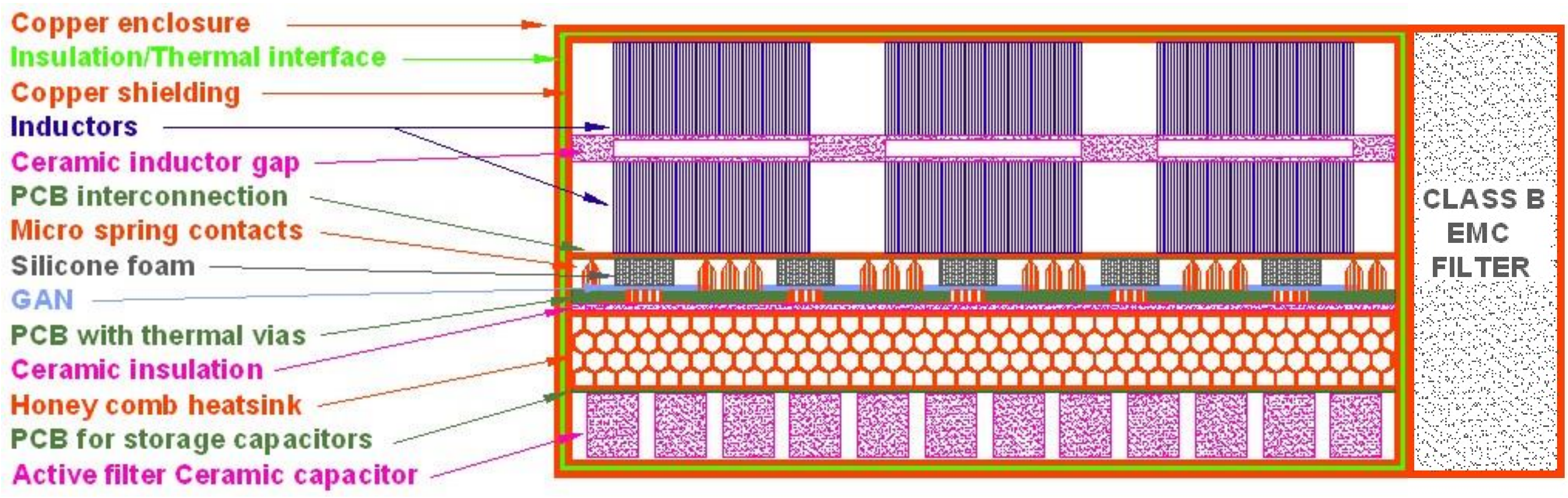
Sandwich Structure



From IGBT to GaN…

GAN implementation

95% weighted efficiency

EMC Class B (RF noise <1mV)

DC voltage ripple(100hz)< 0,1V

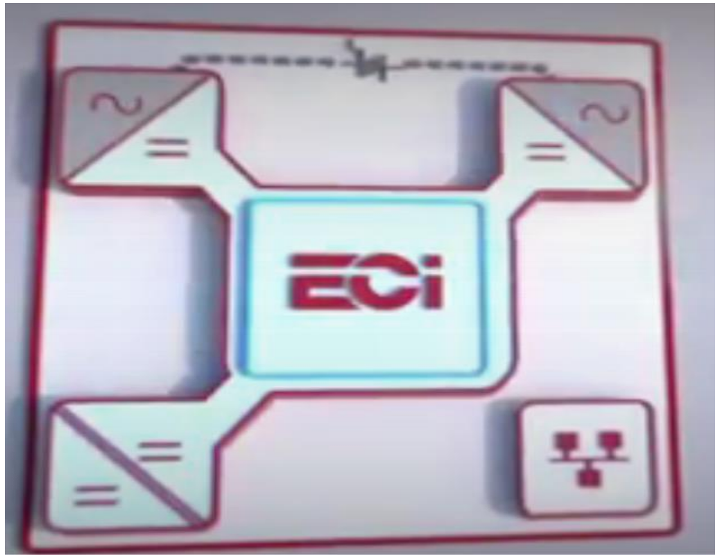
Enclosure Max Temp <60°C

Volume < 220 cm^3 for 2kW

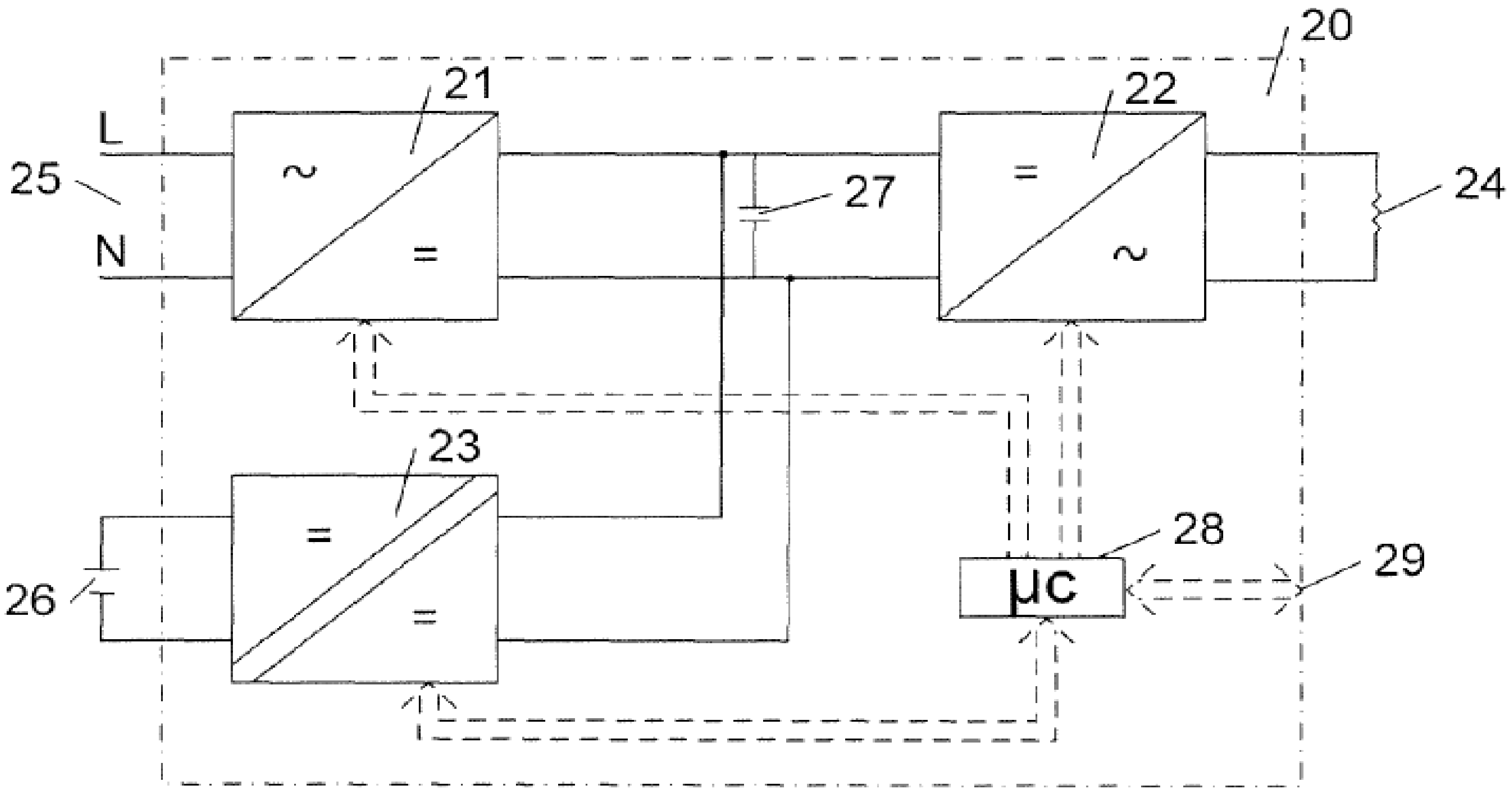
How to Reuse Results ?

* No cost limit on Google Challenge
* Single DC/AC => «Energy Router»

Bidirectionnel AC/DC + DC//DC +DC//AC



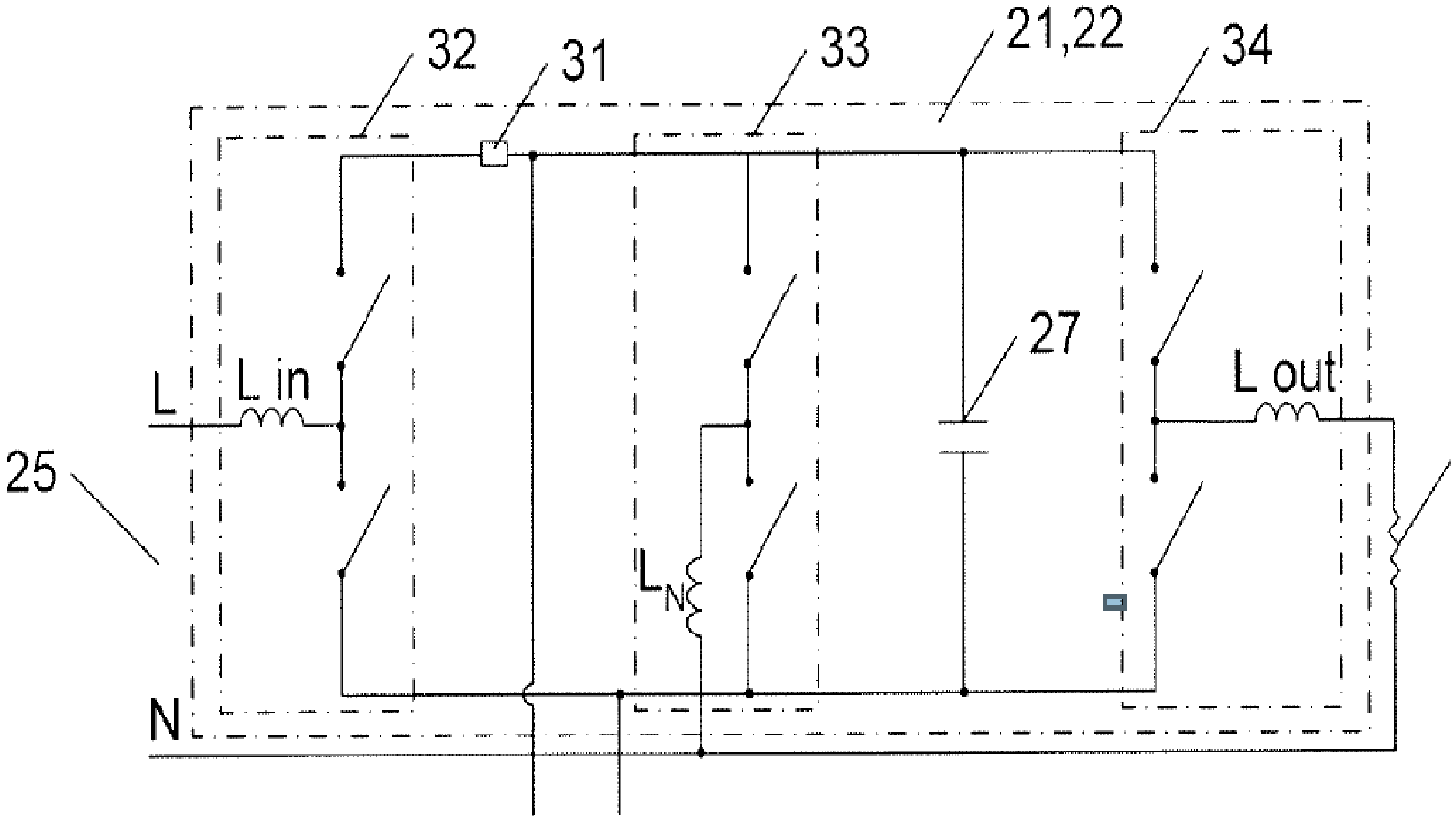
From IGBT to GaN ...

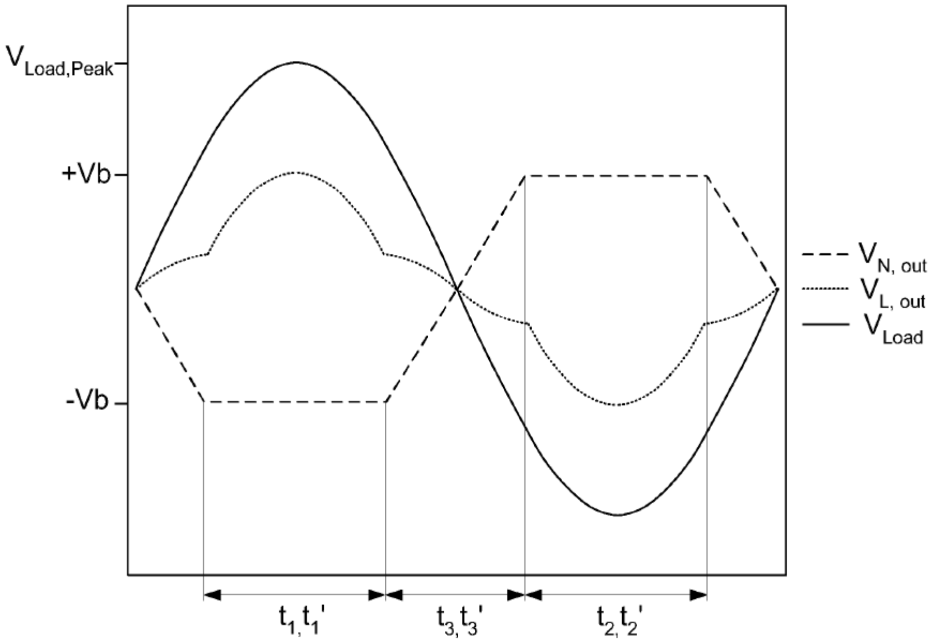


On Energy Router

InRel NPower

AC/AC OF Energy Router





...to GaN w/ H2020 InRel NPower

<u>Goals</u>: Test Reliability of GaN on real application

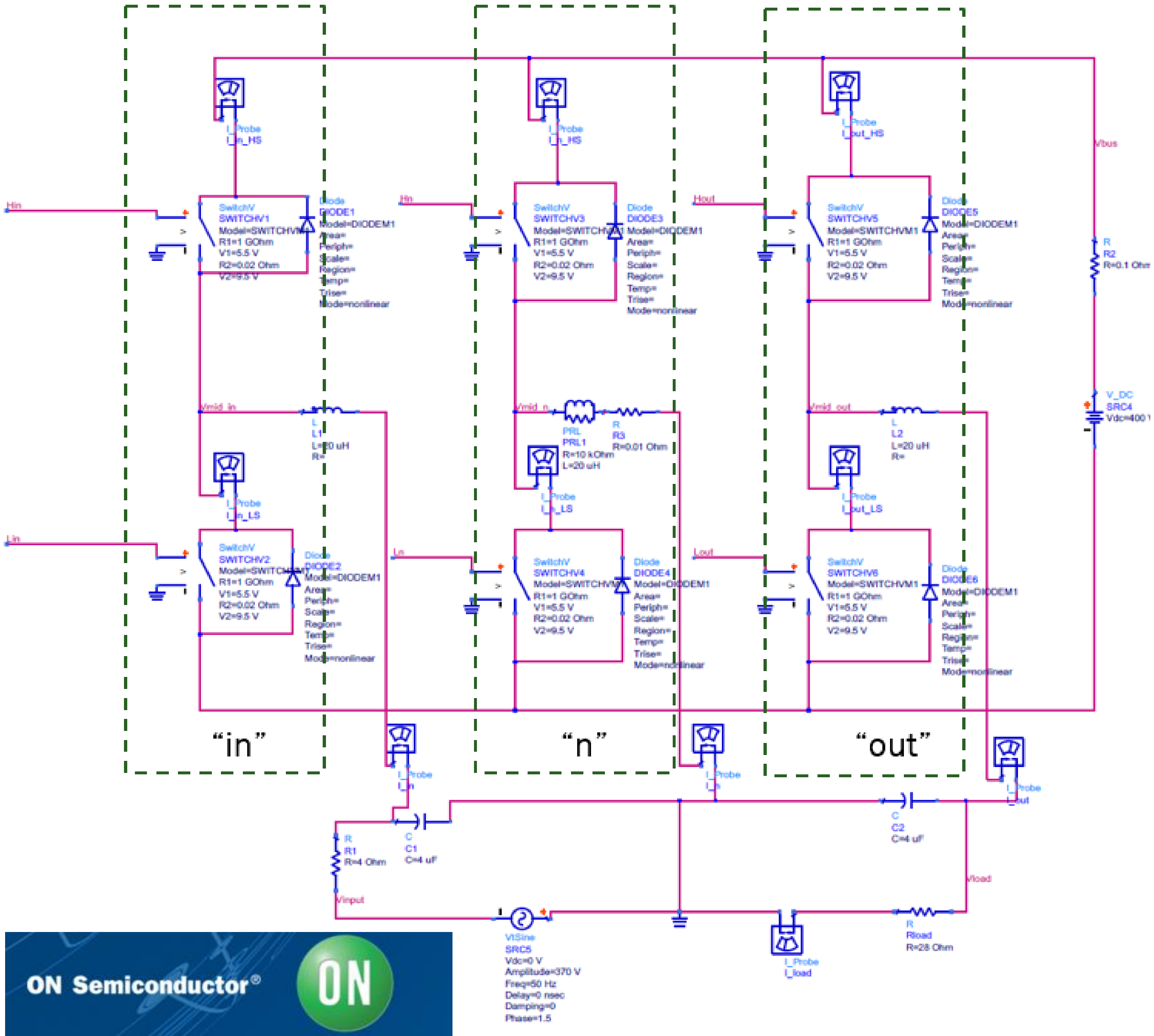
Compare OnSemiconductor GaN Cascode / E-mode types with IGBT on AC/AC working conditions:

+ Virtual Prototyping of GaN switches with U/I working conditions from Spice simulation [done]

+ Real Prototyping for max Efficiency comparison (CE+T) 3 demoboards : Cascode & E-mode GaN and SiC [in progress]

+ Evaluate Reliability on small batch (10 pieces) at high [to be done]

- V_{DC}=400V, P=1900W
- V_{AC}=230V_{RMS}, 50Hz
- 3 Half-bridges: input, neutral and output
  - 6 voltage controlled switches with hysteresis:
    Vgs>9.5V →Ron=20mOhm
    Vgs<5.5V→ Roff=1GOhm
  - 6 diodes: Vf=0.6V
- Rload = 28 Ohm
- 2xC=4uF
- Control signals (Hin, Lin, Hn, Ln, Hout and Lout) are generated by means of a modulation function (see back-up slides) and achieve partial soft-switching in the input/output HB and complete ZVS turn-on in the neutral HB
- Spice simulations provide the boundary conditions for the virtual prototyping methodology
  - VDC=400V
  - Inductor currents: I_ni, I_n, I_out
  - Voltage switch control signals:Hin, Lin, Hn, Ln, Hout, Lout



Power loss distribution: Gen.3 cascode vs e-mode (45mΩ)

- **Conclusions:**
  - Identical conduction losses between E-mode and GaN cascode (same Ron devices)
  - E-mode shows lower switching losses (keep in mind that current TCAD deck is very optimistic in terms of e-mode device capacitance)
  - However, lower Qoss of the device will postpone the transition from full ZVS turn-on to partial ZVS turn-on and hence reduce the switching losses
  - In addition Eoss is also important when operating in the range of the hard switched transition.
  - The neutral HB leg benefits the most by selecting a lower Ron device since conduction losses dominate and total switching losses are practically not affected by the larger device size.
  - When operating the converter at Tj=75C and with a f_{sw}=140kHz, the total losses in the converter, between a 45mΩ e-mode and a 22.5mΩ e-mode solution, are roughly identical in the input HB and output HB.

Conclusions

1. On AC/AC converter, GaN losses@70kHz Cascode/140kHz e-mode evaluated w/ Virtual Prototyping are about half of IGBT losses @20kHz but magnetics losses are not yet included

2. For the user, GaN implementation needs more EMC filter introducing extra losses so efficiency shall be considered globally

3. GaN switches are still expansive (compare to IGBT & MOS) to be used in Industry but since Google challenge the reduction is about 10 but still need a 5 ratio if focusing on switch.