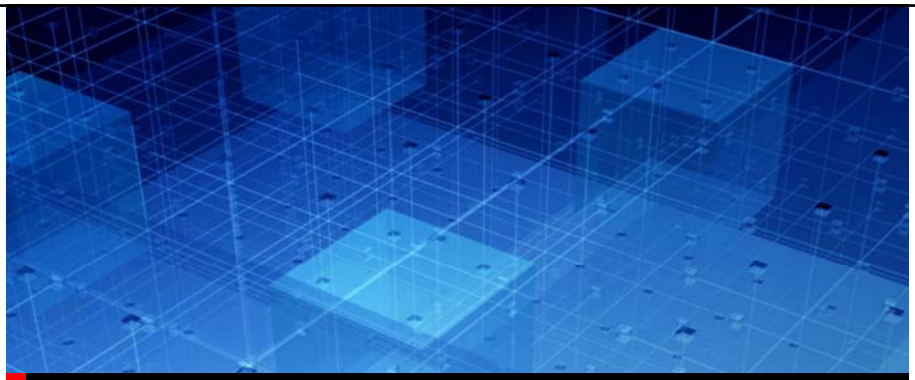

Power Delivery Network Analysis

Erik Nijeboer / Bram Bruekers

Oktober 2017

CB Distribution

cadence

Agenda

11 OKT BELGIË
12 OKT NEDERLAND
D&E event 2017

- Why Power Delivery Network Analysis?
- Analysis types,
  - DC simulation
  - Thermal aware simulation
  - AC simulation
- PDN analysis at Prodrive Technologies
- Tools and integration

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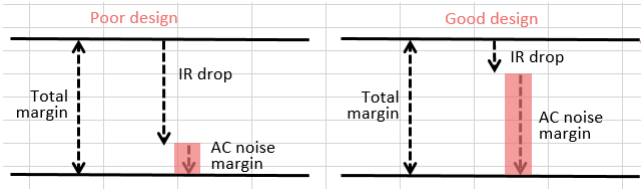
Why Is Power Distribution Analysis ?

- DC voltage is the most fundamental criterion for the operation of the circuitry in the system
  - The voltage supply is allowed to deviate by an amount specified by the vendor
  - This deviation (or fluctuation) of the supply is composed of DC loss and AC noise
  - The total voltage tolerance is commonly 5% (or less) of the nominal operating voltage
  - If the tolerance is constant, then a reduction in DC loss yields a larger AC noise budget



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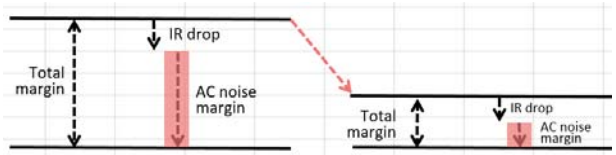
Why Power Analysis Is Important?

- Numerous factors have combined to exacerbate the problem
  - Core voltage levels continue to drop: 1.2V and less are now common. Total margin drops from 250mv to 60mv
  - As voltage is reduced, current requirements typically increase: IR drop = I * R
  - Miniaturization of electronics results in fewer layers and higher densities thus reducing the available area for power net



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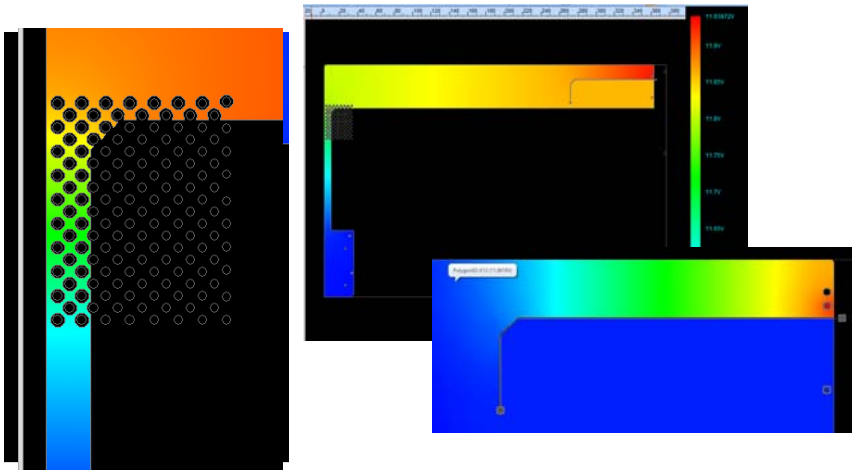
DC analysis

- With IR drop analysis you see
  - Voltage levels across the board



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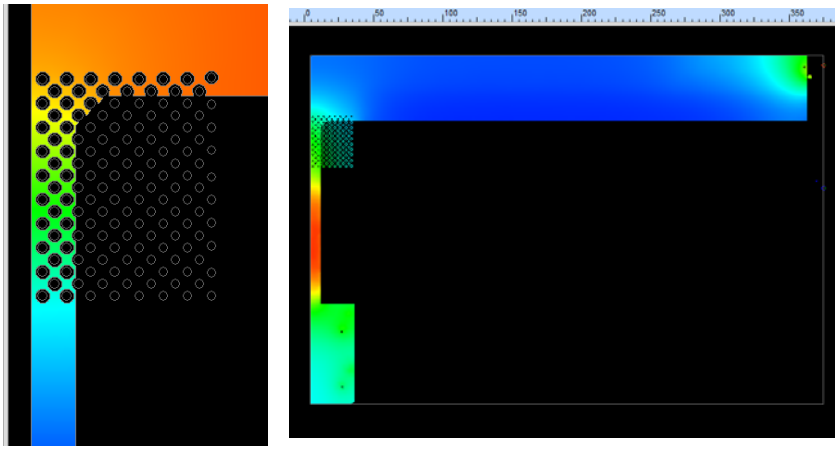
DC analysis

- With IR drop analysis you see
  - Voltage levels across the board
  - Current density



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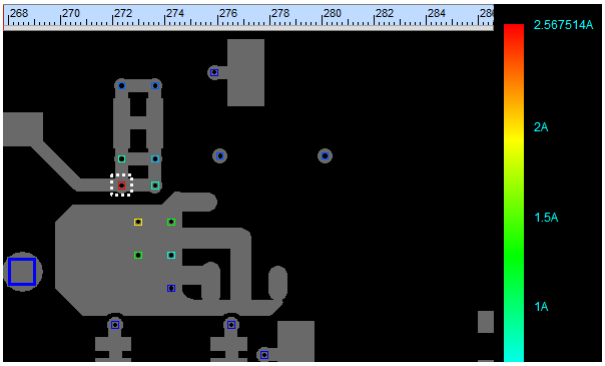
DC analysis

- With IR drop analysis you see
  - Voltage levels across the board
  - Current density
  - Via current and hotspot



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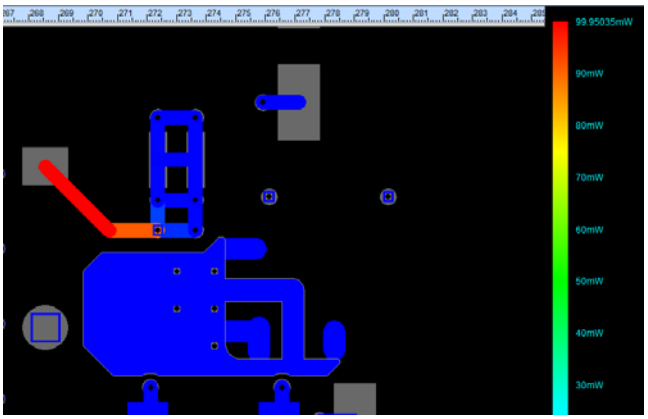
DC analysis

- With IR drop analysis you see
  - Voltage levels across the board
  - Current density
  - Via current and hotspot
  - Power loss



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What about Thermal effects ?

- Heating due to current changes resistance of copper
- Without Thermal effect IR drop estimates will be inaccurate.
- High temperature due to localized current density can cause smoke or fire hazard
- Cadence DC analysis includes effects of
  - Component heating (power dissipation), including heatsinks
  - Joule heating (PCB copper)

	Pure Heat Transfer Simulation (component heating only)	Electrical / Thermal Co-Simulation (component & Joule heating)	Effect of Joule Heating
Max Component Temperature	79 °C	85 °C	+6 °C
Max Board Temperature	72 °C	82 °C	+ 10 °C

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Why AC power analysis?

- Switching circuit requires current to charge the load. VRM needs to supply this power
- VRM is unable to respond if output impedance exceeds target impedance.
  - Introduces switching noise: $Z_t = \frac{Vdd * ripple}{50\% * I_{max}}$
- Impedance should be smaller than Z_t at broad frequency range to lower switching noise.
- AC analysis calculates PDN impedance

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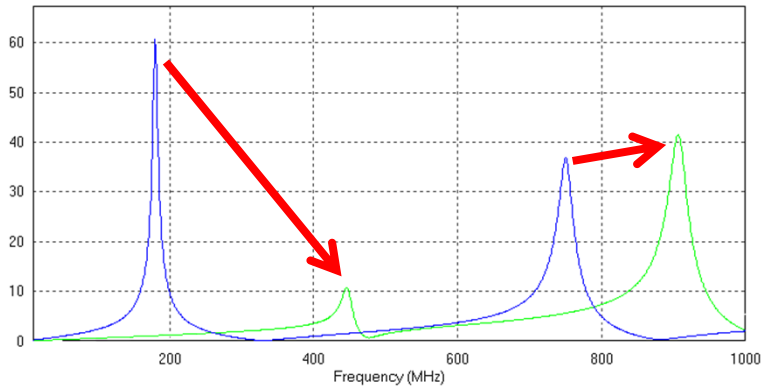
How to lower impedance?

- Add decoupling capacitors, bulk/ceramic capacitors



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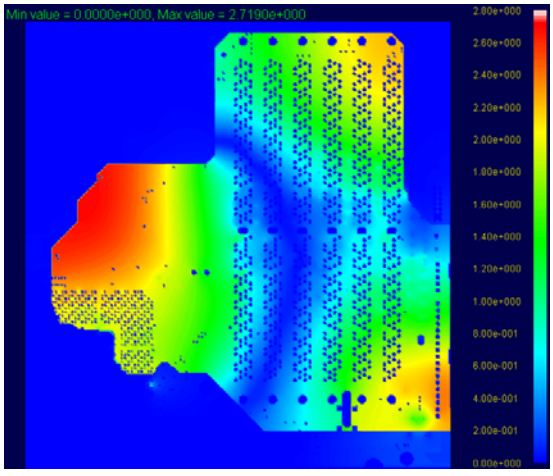
How to lower impedance?

- Add decoupling capacitors, bulk/ceramic capacitors
  - AC analysis will locate impedance hotspots and helps to get correct capacitor locations



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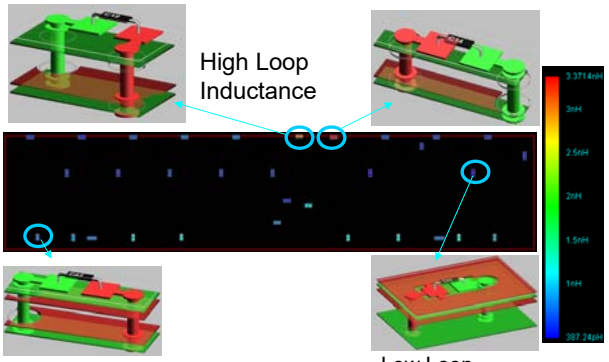
How to lower impedance?

- Add decoupling capacitors, bulk/ceramic capacitors
- Loop inductance' reduction, effect at higher frequencies
  - Different decoupling capacitors
  - Thinner dielectric
  - Location of capacitors
  - Change fanout



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Design Decisions depending on PDN Analysis

- To determine proper metal thickness for power/gnd planes
- To find out
  - If and where to add additional via or power/gnd shape to ease the overheat
  - Whether to add additional plane layers needed in the board stackup
  - Power dissipation and temperature profiles in PKG/PCB
  - If and where to add sense line compensation for VRM
- Decoupling capacitors
  - Quantity, type and location

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Prodrive Technologies

Bram Bruekers

Since 2003 working at Prodrive Technologies
Analogue / Mixed signal hardware design
PCB design
- 15+ years experience
- High current & voltage
- Low noise

PCB tooling support & maintenance

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Prodrive Technologies

- One of the fastest growing privately owned technology companies in Europe
- HQ located in Son, Netherlands
- International located: Germany, USA, Israel, China
- Design of electronics, software and mechanics
- Manufacturing
- Core competences
  - High end computing
  - Power conversion
  - Motion & mechatronics
  - Industrial automation
  - Vision & sensing
  - IoT
- Industries of main interest:
  - Industrial
  - Automotive
  - Infra & energy
  - Medical

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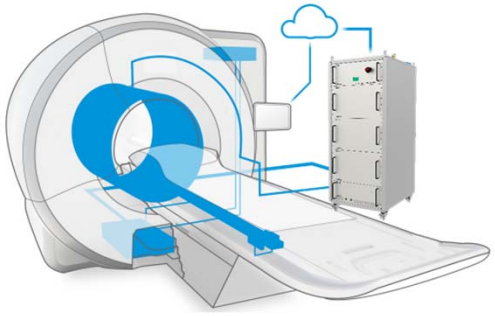
MRI Gradient Amplifier

- 3-axes gradient amplifier cabinet
- 2100V / ±1200A Patented end stage
- Maximum 45kW continuous output power for three axes
- Integrated high precision current sensors
- High reliability of >30,000 hours
- Lifetime: >10 years
- Multiple FRUs (Field Replaceable Units)



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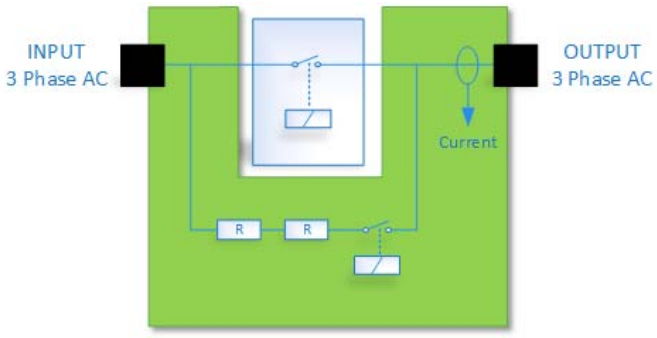
Mains Input Board

- Inrush current limiter
- Power distribution
- Integrated current measurements
- Designed for 3x 130A continuous



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Design Choices

- What type of interconnection to use?

	Pro	Con
Cable	Easy / flexible routing	Assembly issues, many connections Where to place electronic circuits?
Bus-bar	current carrying capability	Difficult to 'route' through complex product Where to place electronic circuits?
PCB	Electronic circuits possible Ease of assembly	Complex design Heating

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Design Choices

PCB

- Design complexity
  - How many layers ?
  - Copper weight ?
  - Total Thickness -> Limited by components !
- Thick copper
  - Lower temperature ?
    Not necessarily !
  - Higher costs + leadtime PCB FAB house
  - PCB Assembly issues

So, thicker is not always better

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Simulation to make design choices

- PCB heating most critical factor for this circuit
  - Absolute voltage drop not interesting
- Initial stackup : 6 layers 4oz (~140µm) copper
  - Creating hotspots due to stackup, routing and plane cuts.
  - Long leadtime for raw material
  - UL certification for 140µm+ copper in several PCB FABs not available
- Final stackup : 12x 2oz (~70µm) copper
  - Hotspots are more spread because of overlapping planes
  - 'Standard' available materials = short lead time !

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Comparison 2 PCB stack-ups

	Initial	Final design
# Layers	6	12
Copper weight	4oz	2oz
Material availability	-	+++
PCB costs	~~€€€€€~~	~~€€€~~
# PCB Fabs	-	+++

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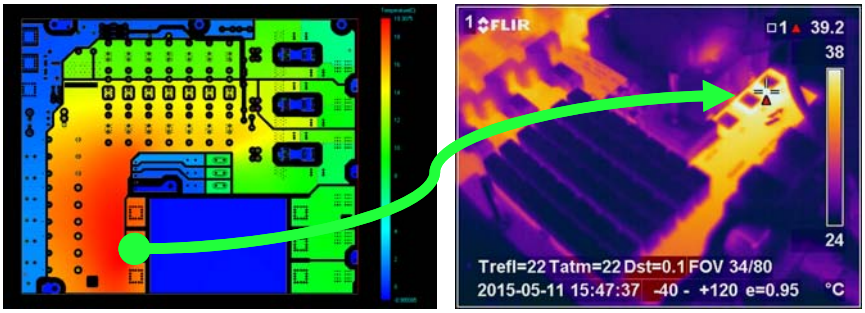
Simulated vs. Measured



ΔT simulated ~19˚C

ΔT measured ~16˚C

Total current of 390A
No airflow

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Other practical applications

- Feasibility check
- Debugging

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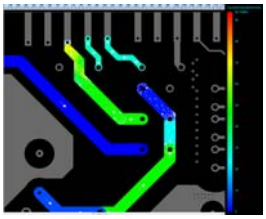
Feasibility

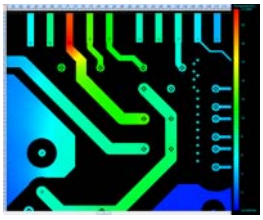
- Question from a customer:

  “Can the routing cope with a current of 7A?”

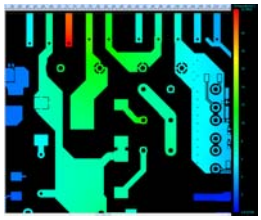
- Microcontroller board
  - Dense design, not much place for wide traces
- Used PowerDC to simulate the current through the specific part of the PCB
  - Result: Yes, routing can handle the specified current.
    Hotspot is caused by the connector.



Current density



Top



Bottom

ΔT simulated ~14˚C

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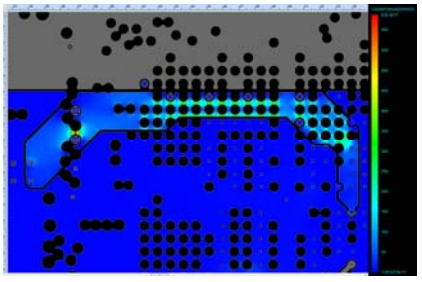
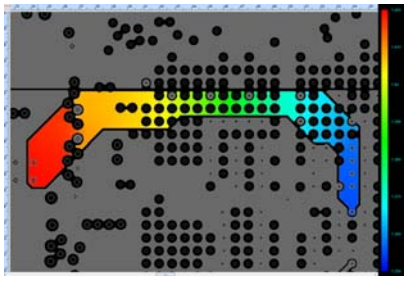
Debugging

- Issue with core supply of microcontroller
  - Stability issues during qualification
- IR drop simulation to simulate the voltage drop from the supply to the microcontroller





- Last minute PCB change, extra VIAs were added
- ΔV is about 65mV → only ~5mV supply voltage margin!

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Why we use PowerDC

- Initially usage:
  - High-current designs
    - IPC2221B / IPC2152 not possible to use on complex boards
  - Temperature rise of a PCB
- Now also for power distribution and voltage drop simulations

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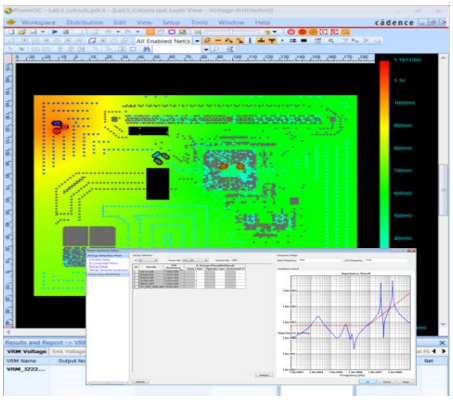
Integration with PCB tools

- Direct integration with OrCAD/Cadence PCB Editor
  - Use PI constraints during layout
  - DRC markers
- Capable to analyze designs from:
  - Altium
  - Mentor Graphics
  - ODB++
  - Zuken



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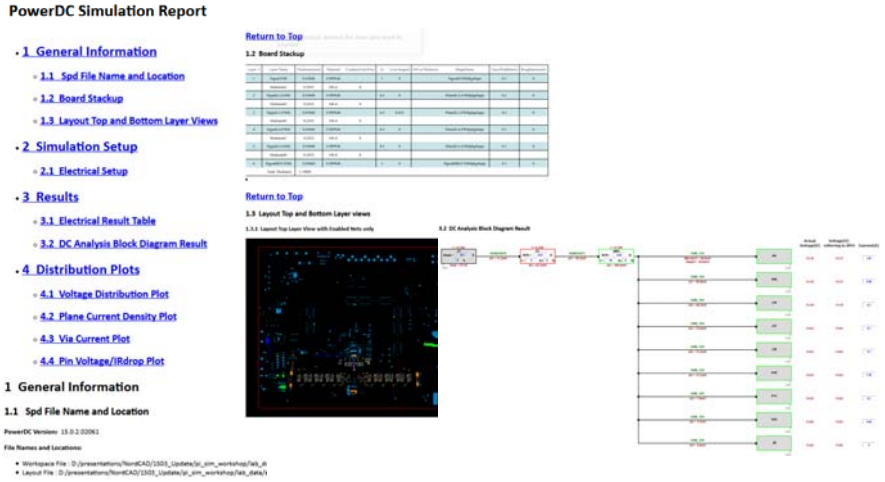
Automatic Report generation



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