Fully Electric from 0 to 100 in less than 3 seconds!

Remi Jonkman | Electric Superbike Twente

Marcel Wezenberg | CB Distribution

Agenda

- CB Distribution
- Electric Superbike Twente
- Design challenges
- Use of EDA Tools
- Results

CB Distribution

- Cadence Channel Partner for the Benelux, Spain and Portugal
- Focused on System, IC, Package and PCB solutions
  - OrCAD
  - Allegro
  - Virtuoso
- Training
  - Tool and methodology
- CAD Support
  - Environment setup
  - Setup and maintenance of data transfer
  - Conversions

Electric Superbike Twente

- 15 students
- Goals:
  - Show how epic electric motorcycles are!
  - Winning the MotoE competition.
    - Thus beating TUDelft
  - Collaborate in a large multidisciplinary team.

Challenges

- Electrical System
- Mechanical System
- Finance
- Planning
- Short Development Phase

Planning

September 2017 | **Design**

December 2017 | **Production**

March 2018 | *Official Release*

May 2018 | **Testing**

July 2018 | **First Race**

Top Level Requirements

- Power: 150 kW
- Maximum Voltage: 700 VDC
- Top speed: 250 km/h
- Torque: 500 Nm
- Capacity: 8-12 laps
- Maximum weight: 200 kg
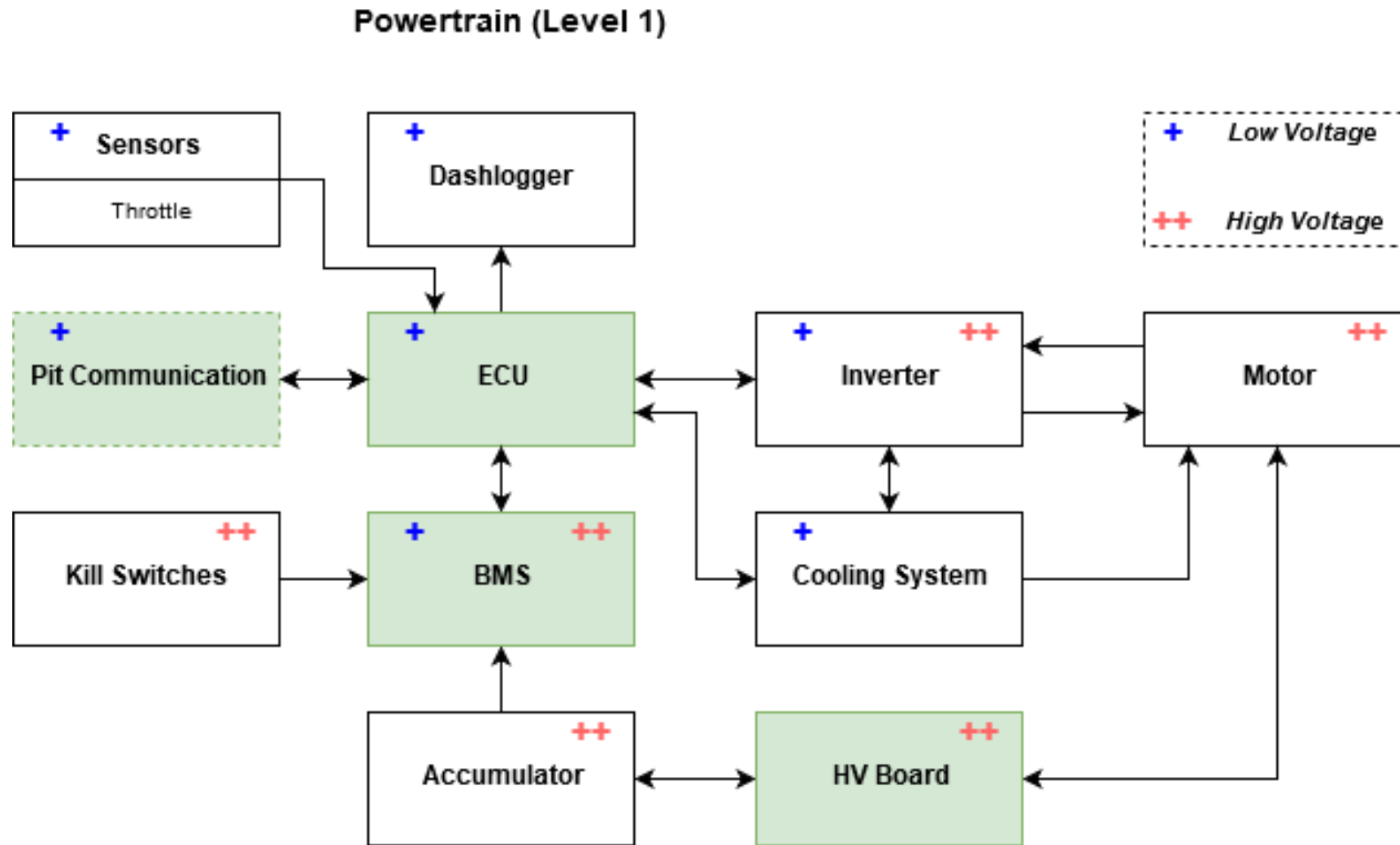- Water and Dust Proof

Design Choices

Stock components
- ✓Plug and play
- ✓Support
- ✓Availability
- ✓Cost

Self-made components
- ✓Flexibility
- ✓Cost
- ✘Time expensive
- ✘Potentially buggy

Electrical System – High Level

Powertrain (Level 1)

Safety

- What if throttle cable malfunctions at 200 km/h?
- What if there's an under voltage in the high voltage battery pack?
- Fail Scenario's
  - Driver safety first
- Automotive Grade ECU
  - Component selection

Subsystems

- Analog
- Digital In/Out
- 12V Digital In/Out
- Communication
  - JTAG (Debugging)
  - CAN
  - SPI
  - UART (RS232)

- Bluetooth
- Power Supplies
  - 1.9 V
  - 3.3 V
  - 5.0 V
- Overvoltage Protection
- Reverse Polarity Protection
- Microprocessor

Subsystems – Block Diagram
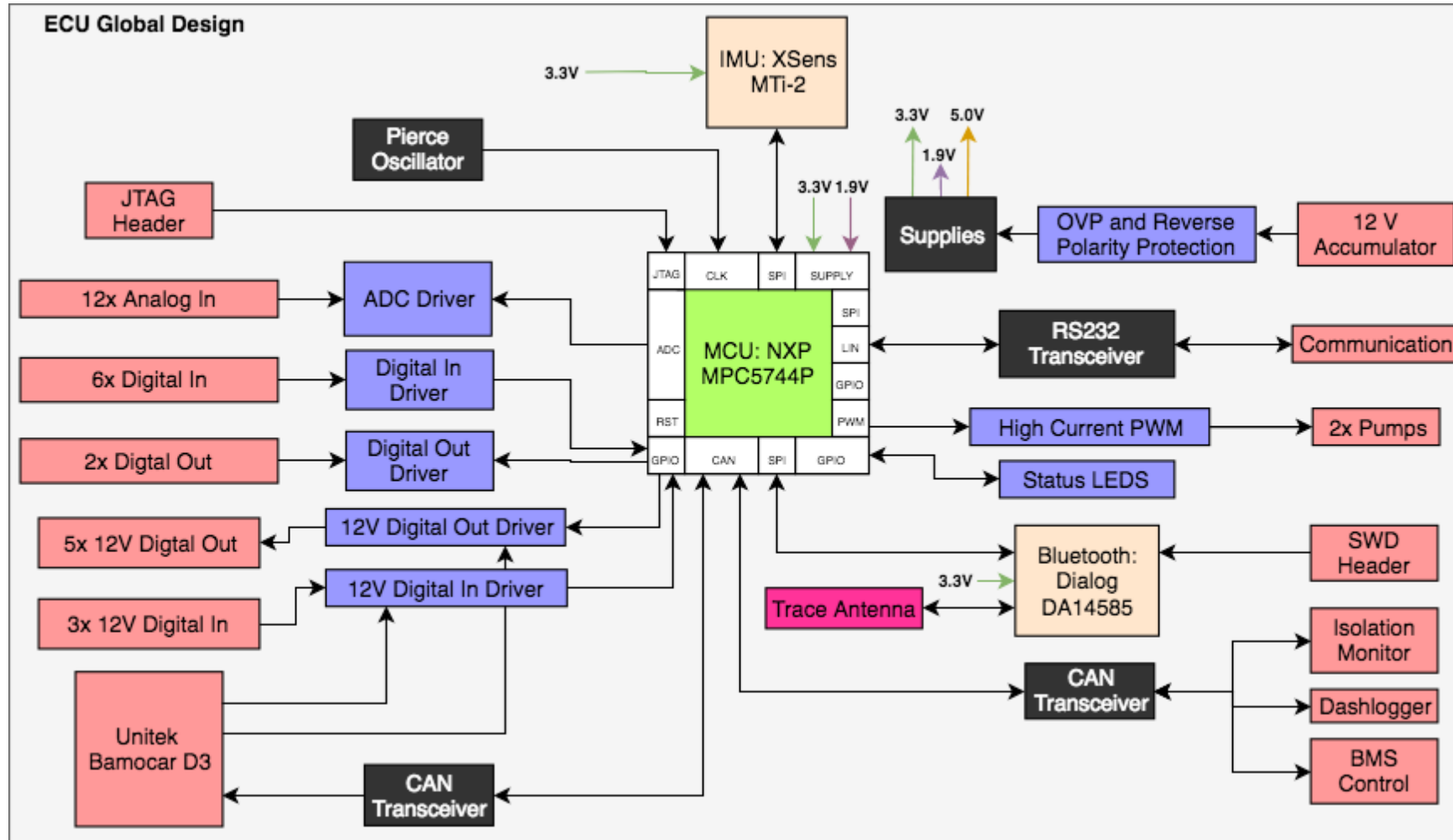
Mixed Signal Circuit Simulation

- Why simulation?
  - Verify our design choices
    - Functionality
    - Reliability
  - Quick compared to hardware production process
    - A lot of PSpice models available

Tools Used

- OrCAD Capture

- PSpice

- OrCAD PCB Editor
  - Padstack Editor
  - Constraint Areas

Use of EDA Tools

- Mixed Signal Circuit Simulation
    - Simulation models
    - Reliability Analysis

- PCB Design
    - Constraints
    - 3D View
    - Multi board verification

Use of EDA Tools
Simulation models

- There   grate them
  - Cr   ns
- Differ
  - Ve
  - Nc   ls
  - M

- Spice
  - Te

  - Re

SPICE Model of Polyswitch Device

Hanbin Hu, Guoyong Shi and Qin Wang
Dept. of Micro/Nano-electronics,
Shanghai Jiao Tong University, Shanghai 200240, China
huhanbinnew@hotmail.com,{shiguoyong,qinqinwang}@sjtu.edu.cn

Taichu Dai and Hongye Xia
TE Connectivity,
Menlo Park, CA 94025, USA
{leo.dai,henry.xia}@te.com

Abstract—Polymer Positive Temperature Coefficient thermistor (PPTC) as a polyswitch for circuit protection is not a standard circuit element for SPICE simulation, which hinders circuit performance evaluation and prediction. Physics-based model written in SPICE engine is of advantage in speed and accuracy, however, it is impractical for every device engineers to build a physical theory and rewrite a SPICE engine to simulate a new device. This report illustrates a novel circuit architecture with pre-existing SPICE elements for PPTC simulation. Three types of PPTCs, miniSMDC014F, miniSMDC050F, miniSMDC150F-24, offered by TE Connectivity, are verified for this method. The related data and netlist, including library usage, are provided.

Index Terms—SPICE model, polyswitch, curve fitting, positive temperature coefficient thermistor (PTC).

however, the proposed netlist can't adapt itself to different ambient temperature and fault current, limiting the simulation flexibility of the SPICE model.

This report demonstrates a novel circuit structure for PPTC SPICE model with switching and tripping behaviour, suitable for various ambient temperature and fault current. The article is organized as follows. Section II reviews some fundamental parameters and related definitions of PPTC, and also discusses the curve fitting procedure for parameter extraction. The entire circuit system for PPTC model is illustrated and analyzed in Section III. Several experimental examples are given in Section IV to validate the effectiveness of the SPICE model in OrCAD PSPICE. Section V concludes the paper.

7 NOV ← BELGIË
8 NOV ← NEDERLAND
D&E event 2018

Use of EDA Tools
Reliability Analysis

- Sensitivity
- Monte Carlo
- Stress Analysis, "Smoke"

Use of EDA Tools
Reliability: Sensitivity Analysis

- Find parts with most impact on Specification
  - High impact => must use low tolerances => more expensive
  - Low impact => could use higher tolerances => cheaper
- Find worst case scenario and determine if this is within specification
- Verify each domain (Time, Frequency, DC)

Driver ADC input filter circuit
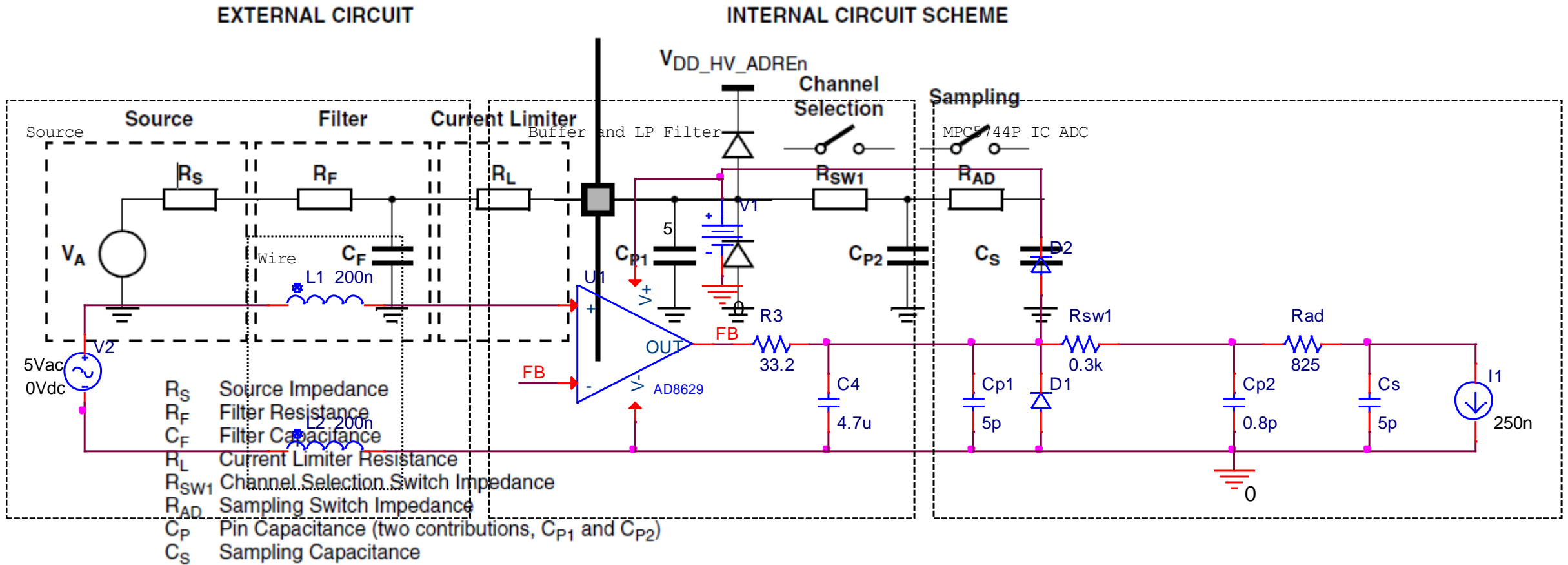
Sensitivity Analysis
Results

- Designed for 1k Bandwidth

- Calculated Min and Max Bandwidth: 841 and 1.25k
  (based on 10% tolerance)

- No Impact of Cs on Bandwidth

	Component	Parameter	Original	@Min	@Max	Rel Sensitivity	Linear
▶	C4	VALUE	4.7000u	5.1700u	4.2300u	-9.7833	99
	R3	VALUE	33.2000	36.5200	29.8800	-9.7834	99
	Cs	VALUE	3p	3.9000p	3p	-6.4936u	< MIN >

Sensitivity Component Filter = [*]

	On/Off	Profile	Measurement	Original	Min	Max	
♥	☑	ac.sim	Cutoff_Lowpass_3dB(V(C4:2))	1.0176k	841.0630	1.2563k	
			Click here to import a measurement created within PSpice...				

Specifications

Use of EDA Tools
Reliability: Maximum Operation Conditions

- Check Against Maximum Operation Conditions
  - Stress Analysis, or also called 'Smoke'
- Based on Transient simulation of a real-life scenario
- Automation of many measurements
  - Peak Voltage/Currents
  - Max breakdown voltage
  - C-E voltages
  - Max Power dissipation
  - Junction temperatures

Use of EDA Tools
Reliability: Maximum Operation Conditions

- PSpice is the only spice simulator that supports smoke analysis

- PSpice models have Smoke parameters built-in

- It's customizable
  - Take datasheet values

Absolute Maximum Ratings T_A = 25°C unless otherwise noted

Symbol	Parameter		FQT7N10L	Unit
V_{DSS}	Drain-Source Voltage		100	V
I_D	Drain Current	- Continuous (T_A = 25°C)	1.7	A
		- Continuous (T_A = 70°C)	1.36	A
I_{DM}	Drain Current	- Pulsed	6.8	A
V_{GSS}	Gate-Source Voltage		± 20	V
E_{AS}	Single Pulsed Avalanche Energy	(Note 2)	50	mJ
I_{AR}	Avalanche Current	(Note 1)	1.7	A
E_{AR}	Repetitive Avalanche Energy	(Note 1)	0.2	mJ
dv/dt	Peak Diode Recovery dv/dt	(Note 3)	6.0	V/ns
P_D	Power Dissipation (T_A = 25°C)		2.0	W
		- Derate above 25°C	0.016	W/°C
T_J, T_{STG}	Operating and Storage Temperature Range		-55 to +150	°C
T_L	Maximum lead temperature for soldering purposes, 1/8" from case for 5 seconds		300	°C

Smoke Parameters

These are Device Maximum Operating condition parameters required for Smoke Analysis

Device Max Ops	Description	Value	Unit
IG	Max gate current		A
ID	Max drain current	1.7	A
VDG	Max D-G voltage		V
VDS	Max D-S voltage	100	V
VGSF	Max forward VGS	20	V
VGSR	Max reverse VGS		V
PDM	Max pwr dissipation	2	W
TJ	Max junction temp.	150	C
RJC	J-C thermal resist.		C/W
RCA	C-A thermal resist.		C/W

Use of EDA Tools
Reliability: Smoke results

	Component	Parameter	Type	Rated Value	% Derating	Max Derati...	Measured...	% Max
▼	X1	Maximum power dissipation	Average	1.4000	0	0	3.2036	< MAX >
▼	X1	Maximum junction temperature	Peak	125	100	125	7.1623k	5730
▼	X1	Maximum junction temperature	Average	125	100	125	251.2487	201
▼	X1	Max G-C voltage	Peak	6	100	6	6.2755	105
▼	X1	Max anode current	Peak	15	100	15	12.6227	85
▼	U2	Max forward VGS	Peak	20	100	20	14.8416	75
▼	U4	Rated Switch Contact Voltage	Peak	24	100	24	16.3930	69
▼	U2	Max drain current	Peak	1.7000	100	1.7000	738.6560m	44
▼	R4	Maximum breakdown temperature	Peak	200	100	200	72.2392	37
▼	U4	Rated Switch Contact Voltage	Average	24	100	24	7.8788	33
▼	U4	Rated Switch Current	Peak	40	100	40	12.6962	32
▼	R3	Maximum breakdown temperature	Peak	200	100	200	63.8574	32
▼	X1	Max A-C voltage	Peak	50	100	50	15.1776	31
▼	U3	Max anode current	Peak	20m	100	20m	5.1242m	26
▼	R5	Maximum breakdown temperature	Peak	200	100	200	42.7828	22
▼	U3	Max G-C voltage	Peak	6	100	6	1.2611	22
▼	U3	Maximum junction temperature	Peak	150	100	150	29.0662	20
▼	R3	Maximum breakdown temperature	Average	200	100	200	38.7861	20

Smoke - crowbar.sim [No Derating] Component Filter = [*]

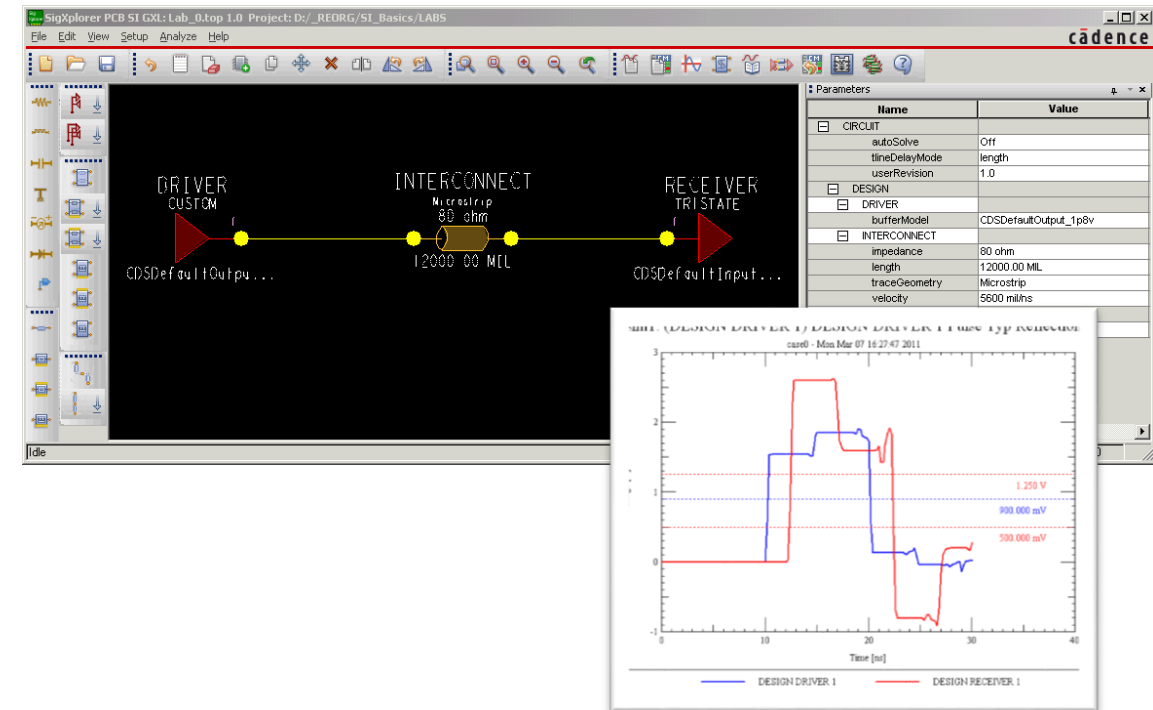# Use of EDA Tools

- Mixed Signal Circuit Simulation
  - Why simulation
  - Simulation models
  - Reliability Analysis
- PCB Design
  - Constraints
  - Multi board verification
 - 3D View

Use of EDA Tools
Create constraints

- With help of Simulation results
  - Currents -> Trace Width
  - Voltage levels -> Trace to Trace spacing
- With help of Signal topology study
  - Impedance mismatch -> Reflection
  - Highspeed -> Differential pair, matching length and phase.
- Start constraining at Schematic level

Use of EDA Tools
PCB Design, 3D view

- Footprint verification
- Height verification
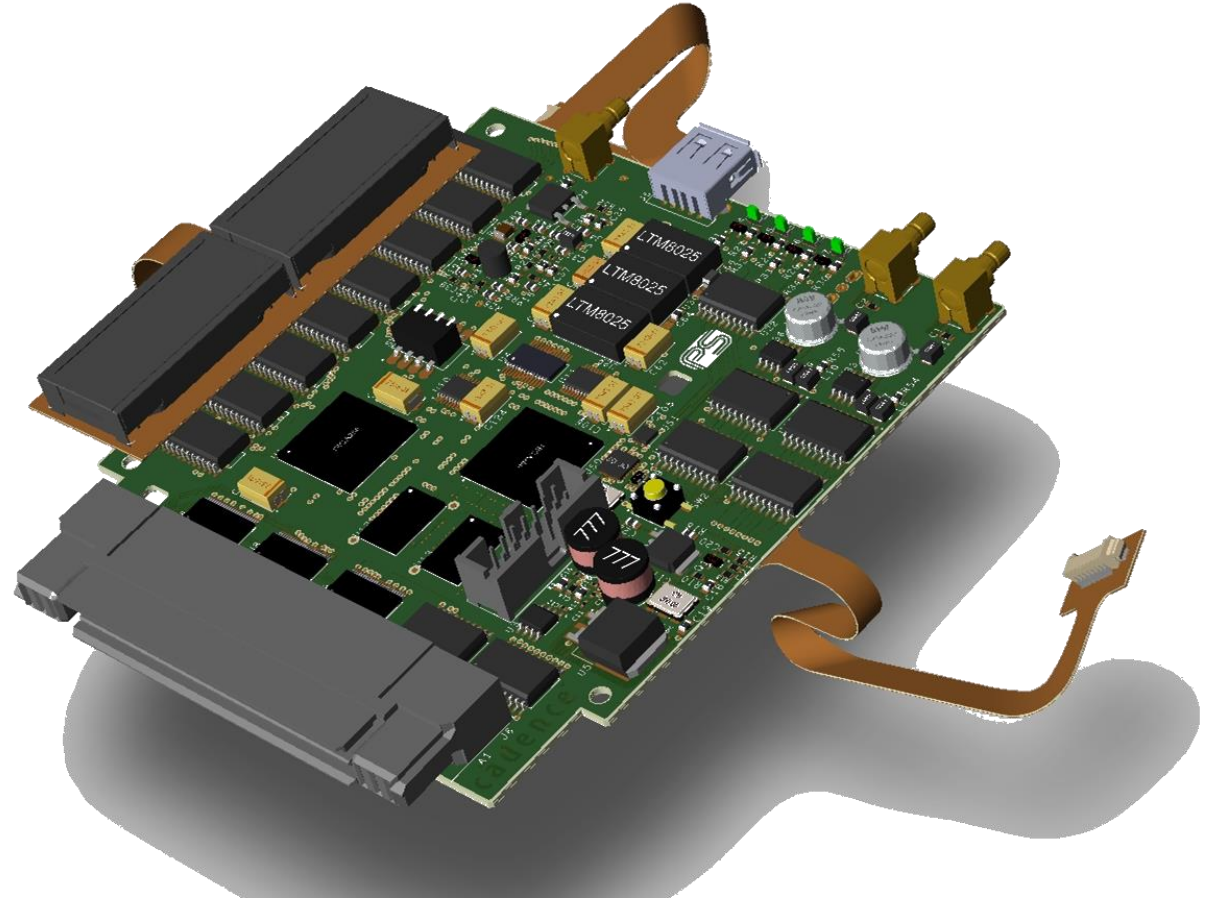
Use of EDA Tools
Multi board, interconnect verification

- Multi board project
  - Name of board
  - High level connections
- Connection Analysis
  - Number of pins
  - Net naming
- Color highlighting
  - Matching, Missing connections
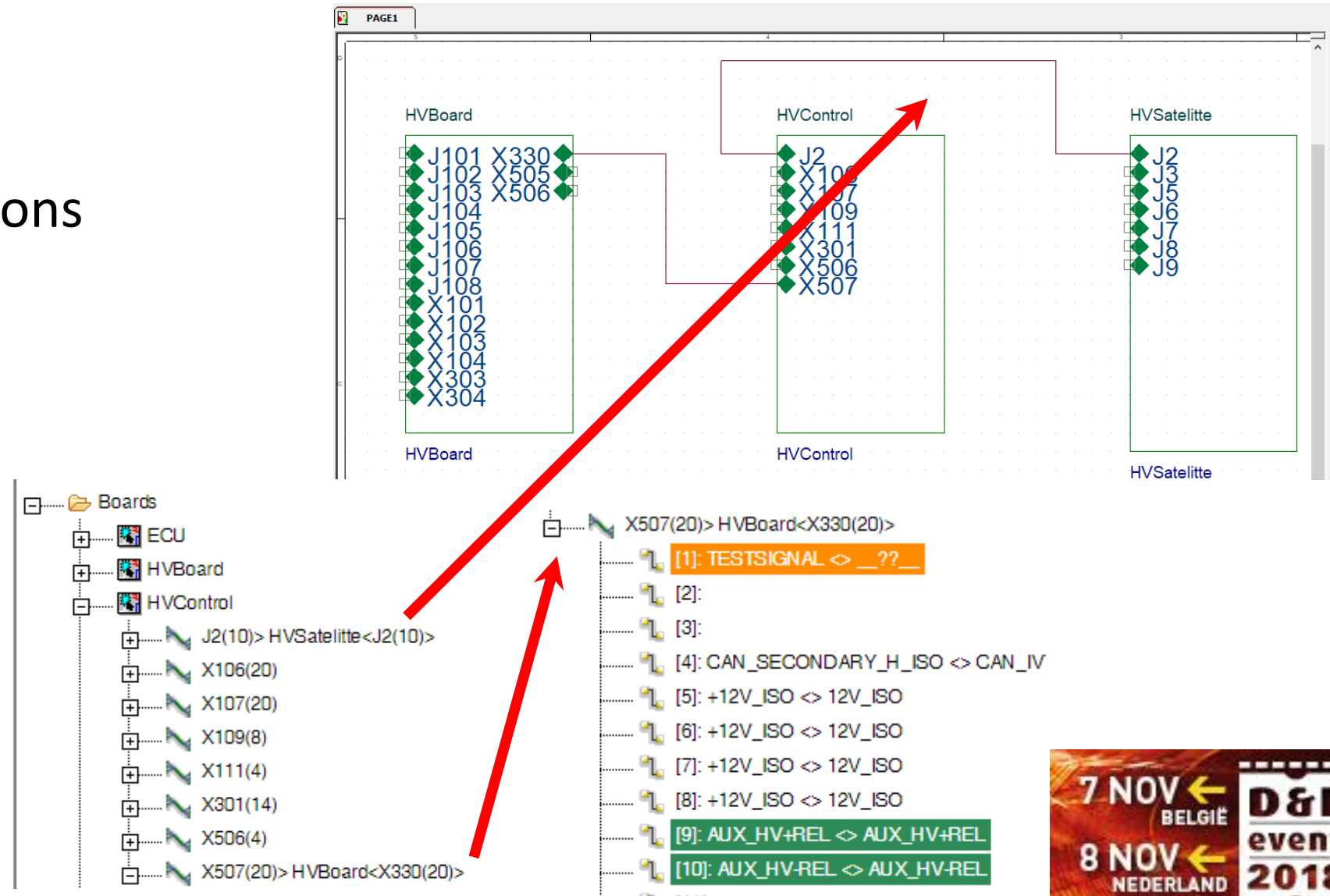
Use of EDA Tools
Summary

- One vendor
  - PSpice driven layout, set the right constraints
  - One schematic environment to drive both simulation and multi PCB-design
- Powerful simulation capabilities beyond regular spice simulation
  - Smoke
- PCB
  - Unique centralized constraint management
  - Integrated verification

Resulting PCB

- After simulation did we have any problems?
- Is it safe to drive the bike?

- Is the bike fast?

Race Results

11-12 augustus 2018	Donington Park	Verenigd Koninkrijk	P2
31-1 september 2018	**Assen**	**Nederland**	**P1**
5-6 oktober 2018	Anglesey	Verenigd Koninkrijk	P1

European Champions

More information

- Visit our booth: 22
- See the real thing, an electric superbike

- Thanks for your attention

OrCAD™
CADENCE PCB SOLUTIONS

More information

- Visit our booth: 19
- See the real thing, an electric superbike

- Thanks for your attention

OrCAD™

CADENCE PCB SOLUTIONS