GaN Power Module for high power BEV Inverter Applications

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VisIC Technologies Ltd.

Bodo's Wide Bandgap Event 2025

Making WBG Designs Happen

GaN

Agenda

- D^3GaN (Direct Drive D-mode technology)
- Power Module VM030-EVB
- Short circuit behavior
- Cooler System & Module
- Paralleling of Modules
- System & Bench Testing
- Q & A

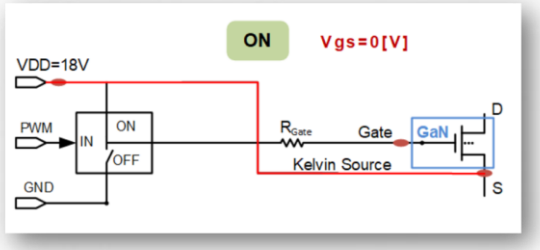
Why Direct Drive – D3GAN

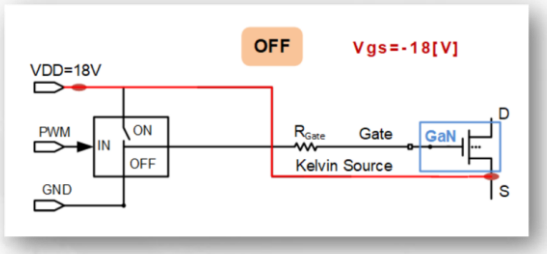
D3GaN : Why Direct drive?

GaN switching losses

V_T > +7V

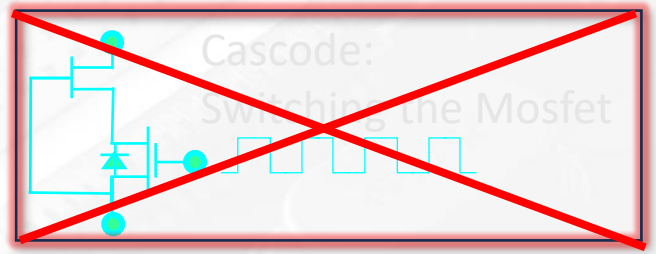
$VB_{GATE-SOURCE}$ +35V

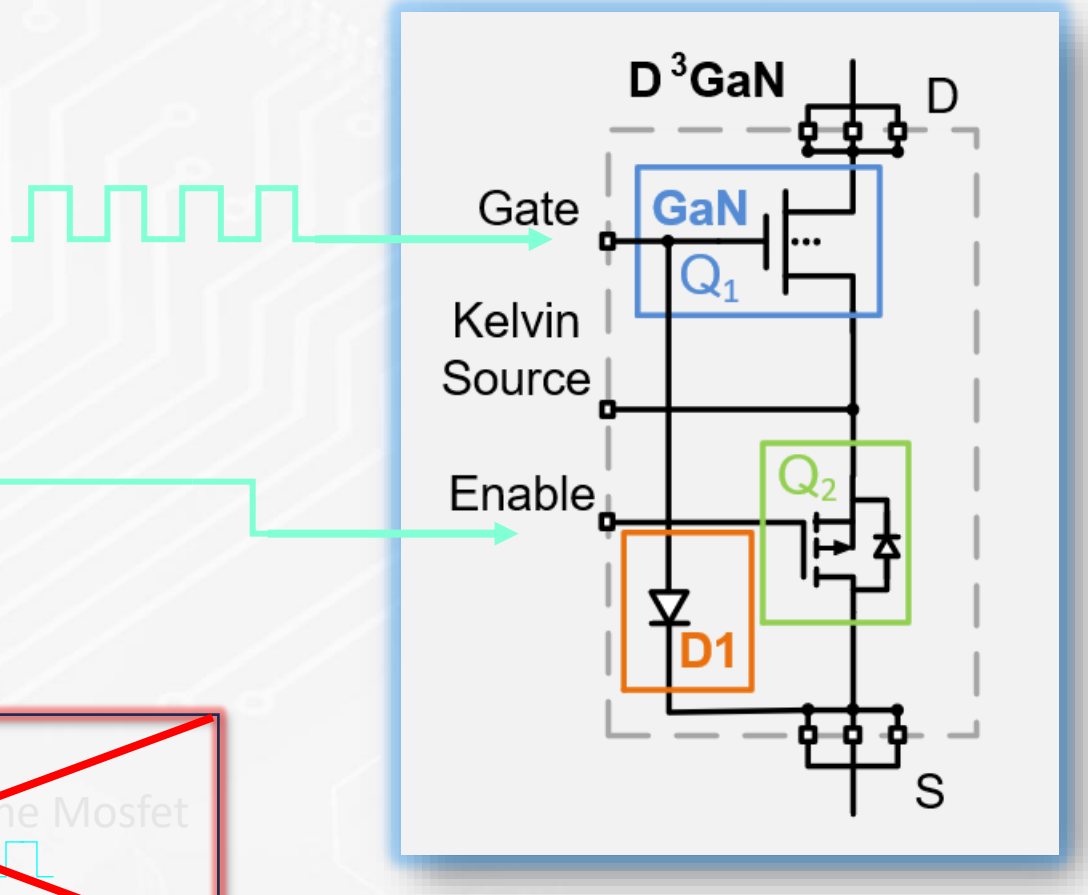




Driver switches GaN directly 0V and +15V

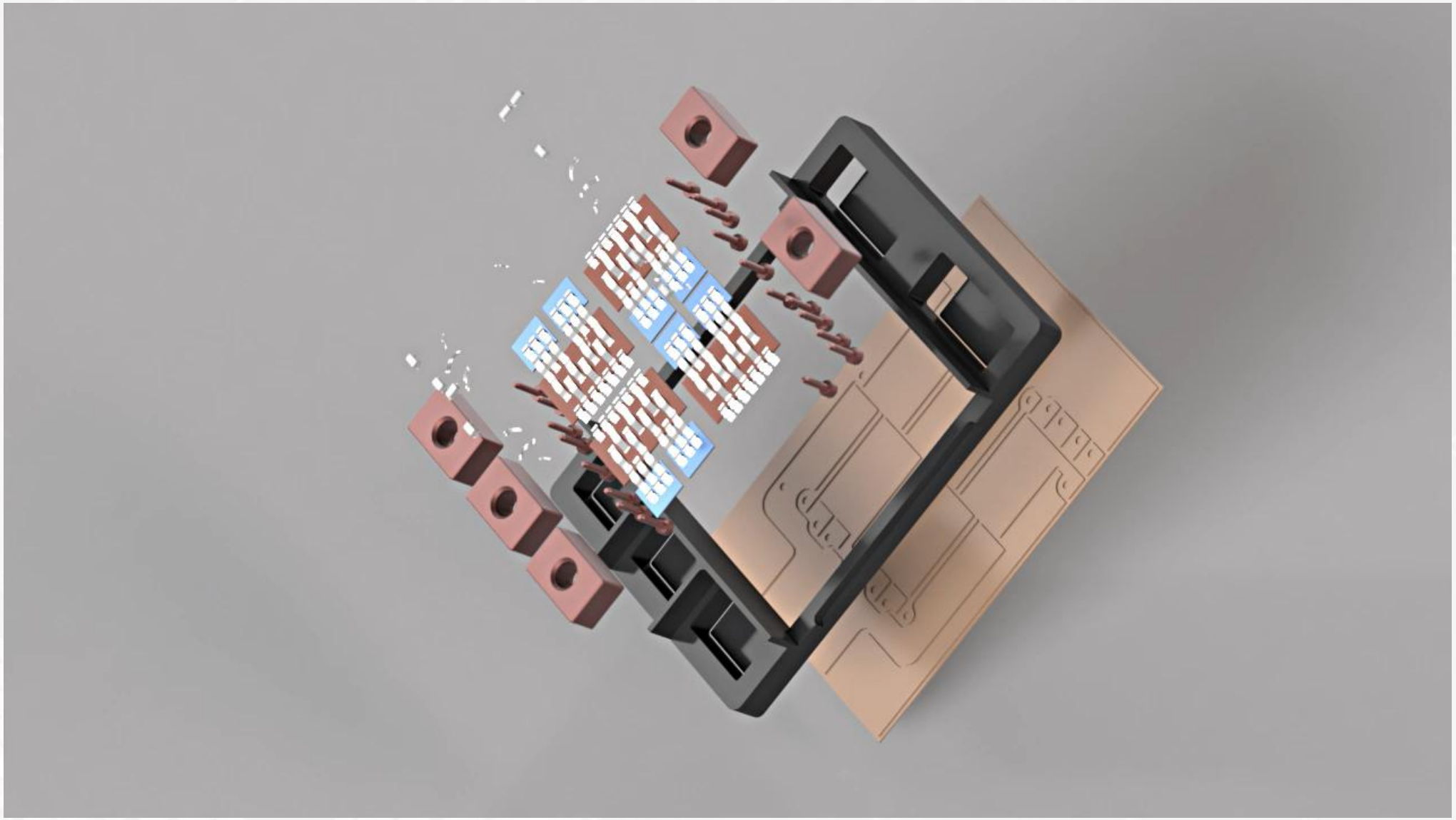
Silicon p-MOSFET is conducting continuously



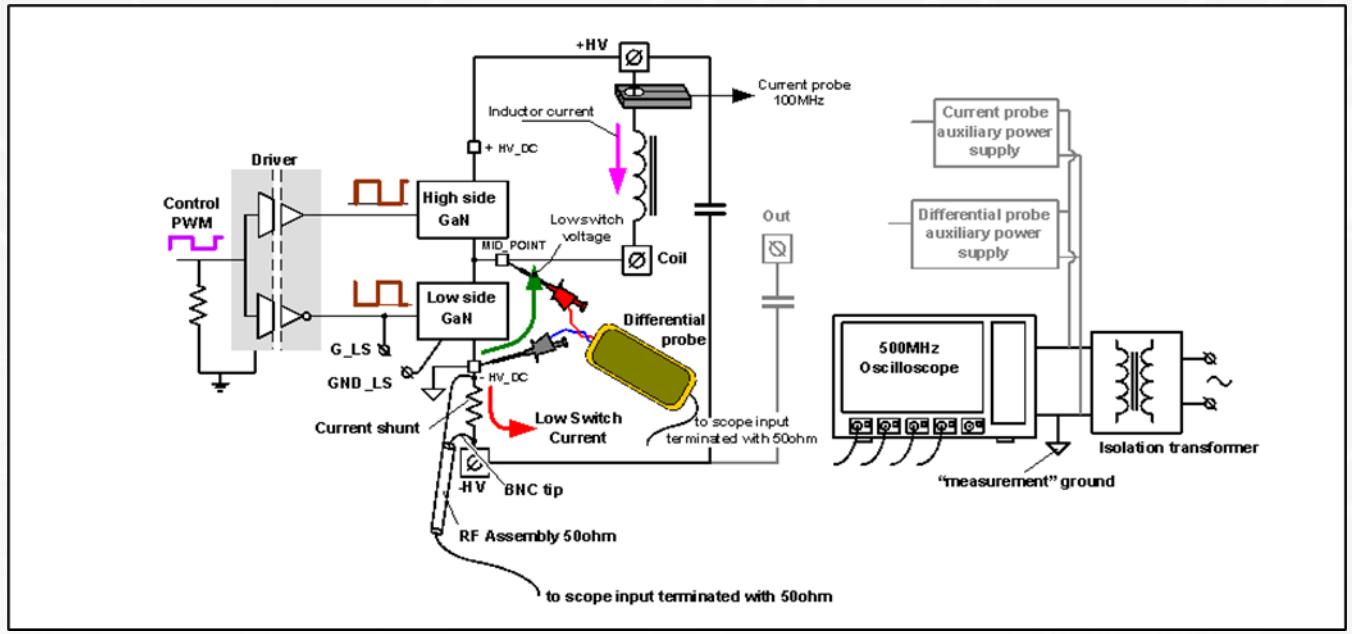


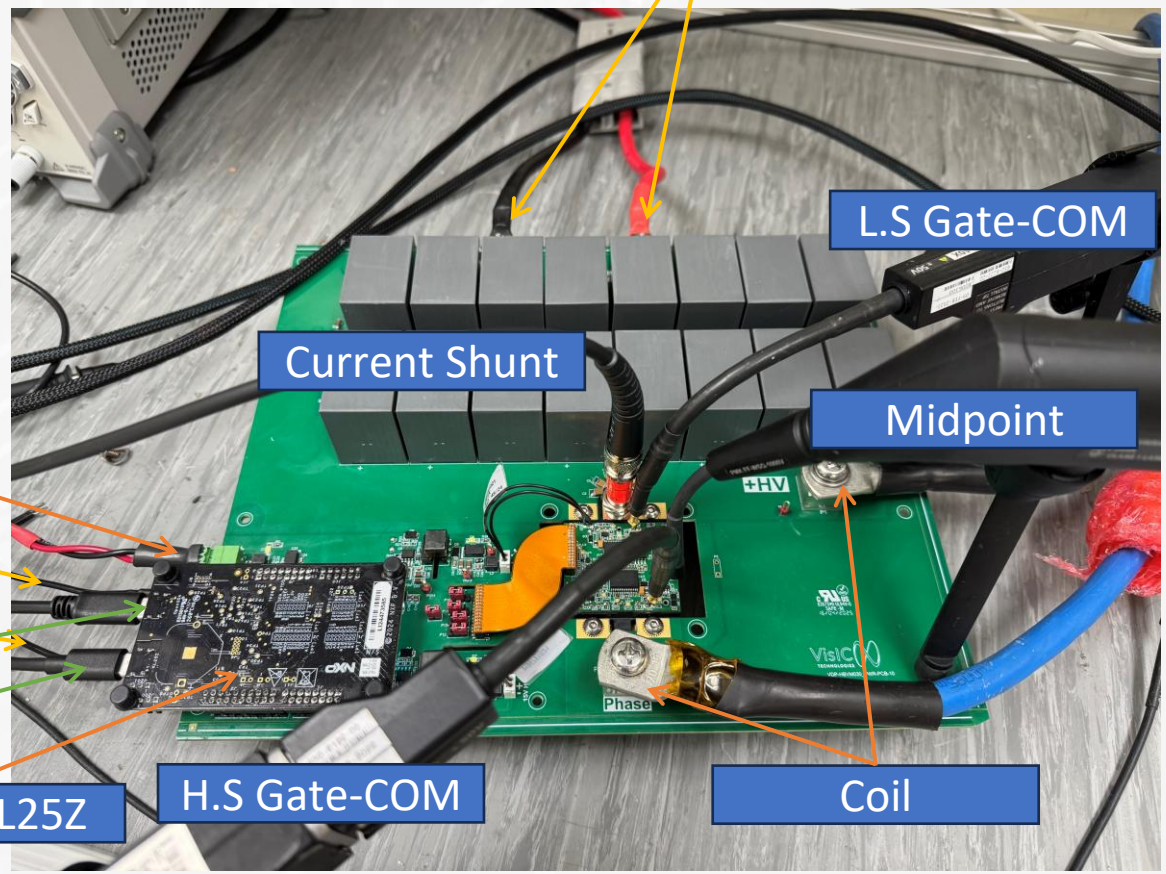
Power Module VM030 – 650V/350A

MPM2 – VM030 D³GANPower Module



VM030 EVB – available for customer testing





Auxiliary 12V power Supply

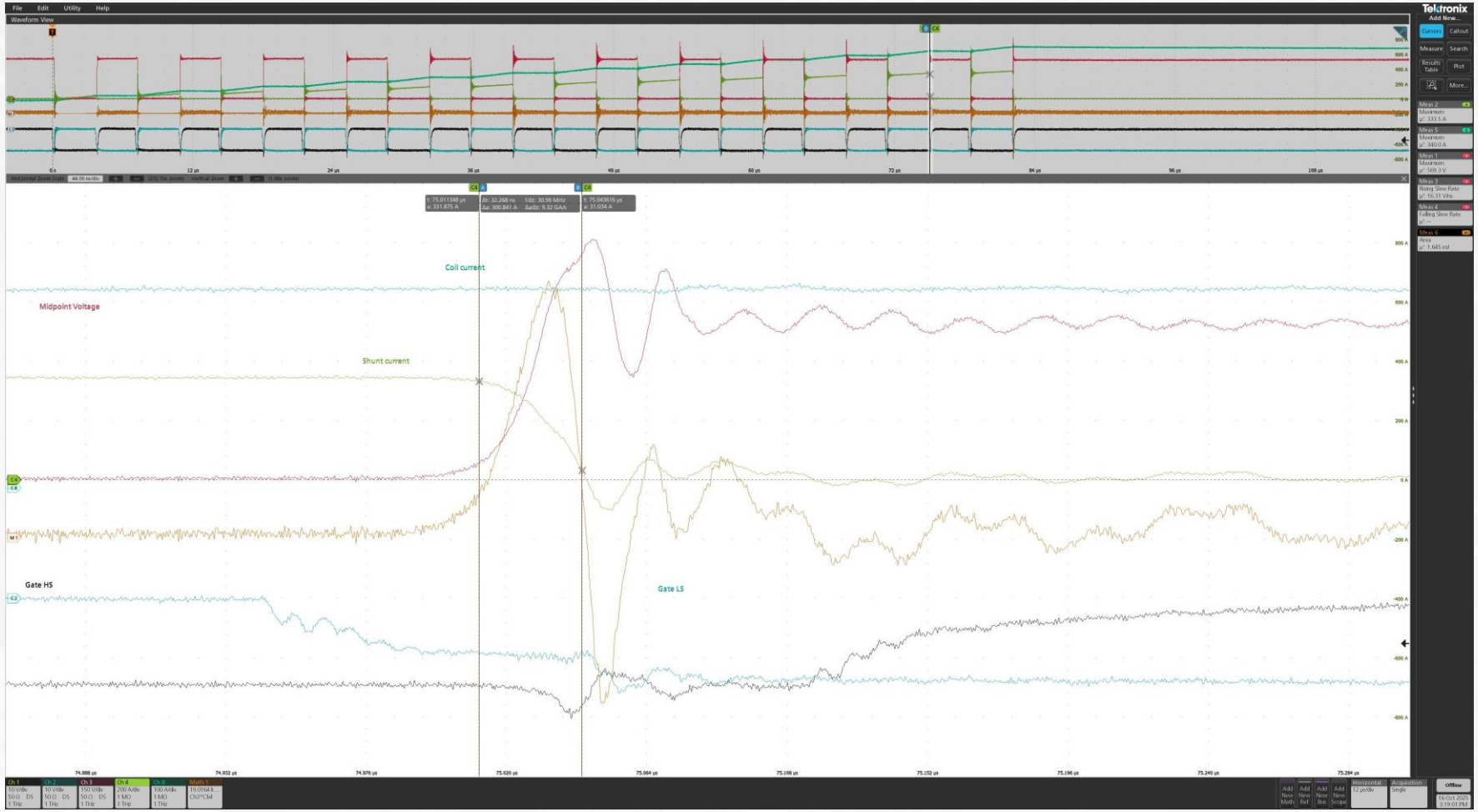
PWM H.S.

PWM L.S.

FRDM-KL25Z DC 5V

FRDM-KL25Z Control Interface to PC

Test Results – Turn–off Switching Energy Test-Coil Up



Test Conditions:
Ambient temperature = 25 °C
HS gate strength:
- Turn-on: Low
- Turn-on: Med

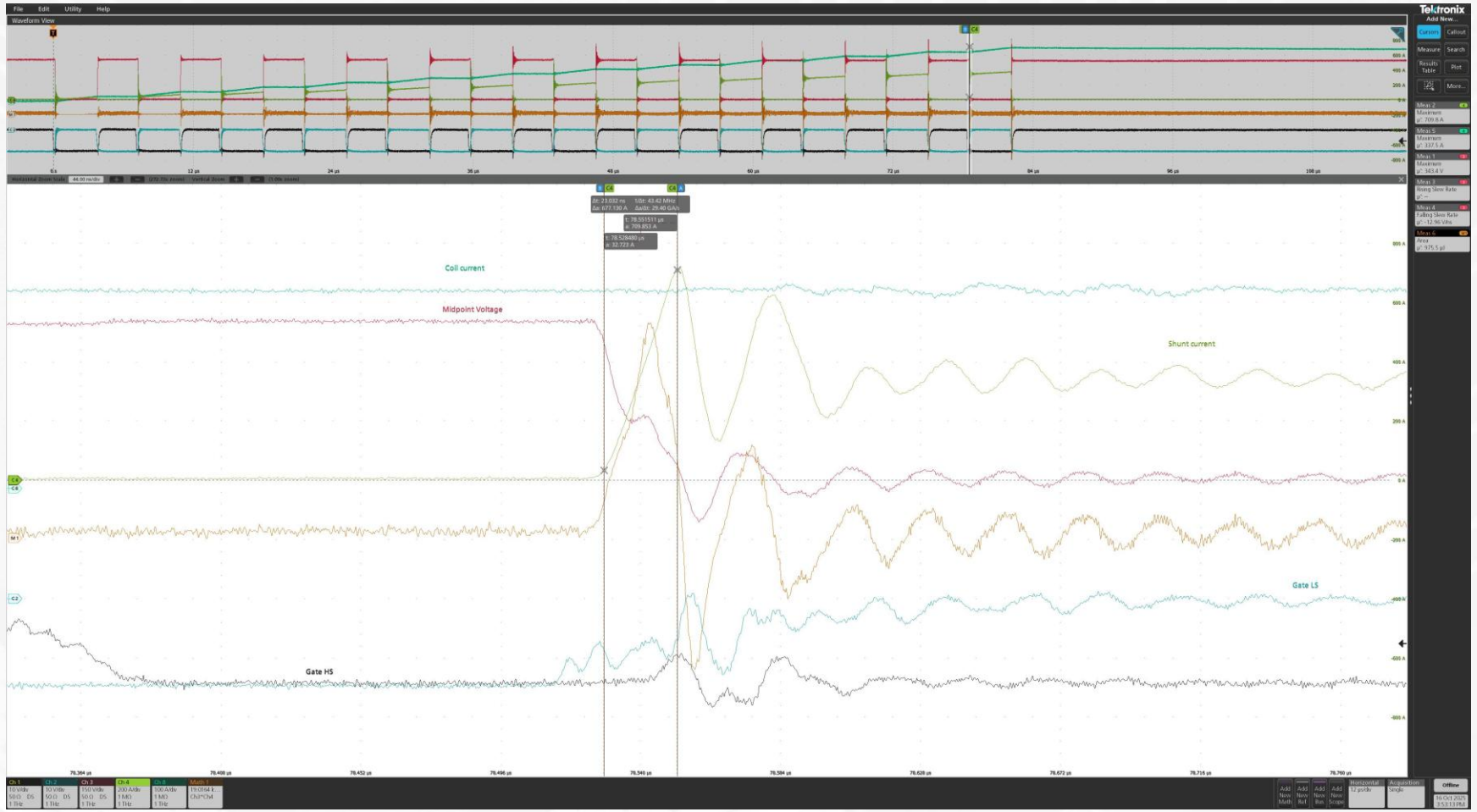
LS gate strength:
- Turn-on: Med
- Turn-on: Med

Coil inductance = 45uH

Test Results:
$VDS_{\_MAX}$ = 617.2V
I_{COIL_PK} = 344A
Rising slew rate = 16.36V/ns
E_{SW_OFF} = 1.645 mJ
Test Verdict = Pass

TSS file: 1492_035.tss

Test Results – Turn-On Switching Energy Test-Coil Up



Test Conditions:
Ambient temperature = 25 °C
HS gate strength:
- Turn-on: Low
- Turn-on: Med

LS gate strength:
- Turn-on: Med
- Turn-on: Med

Coil inductance = 45uH

Test Results:
$VDS_{\_MAX}$ = 617.2V
I_{COIL_PK} = 333.6A
Falling slew rate = 13.74V/ns
E_{SW_ON} = 0.9755 mJ
Test Verdict = Pass

TSS file: 1492_035.tss

Summary and Conclusions

Summary:

- The multi-pulse test was conducted in two configurations: coil-up and coil-down.
- Switching energy was measured in coil-up configuration with the following results: E_{SW_OFF} = 1.645 mJ and E_{SW_ON} = 0.9755 mJ.
- All tests passed successfully.

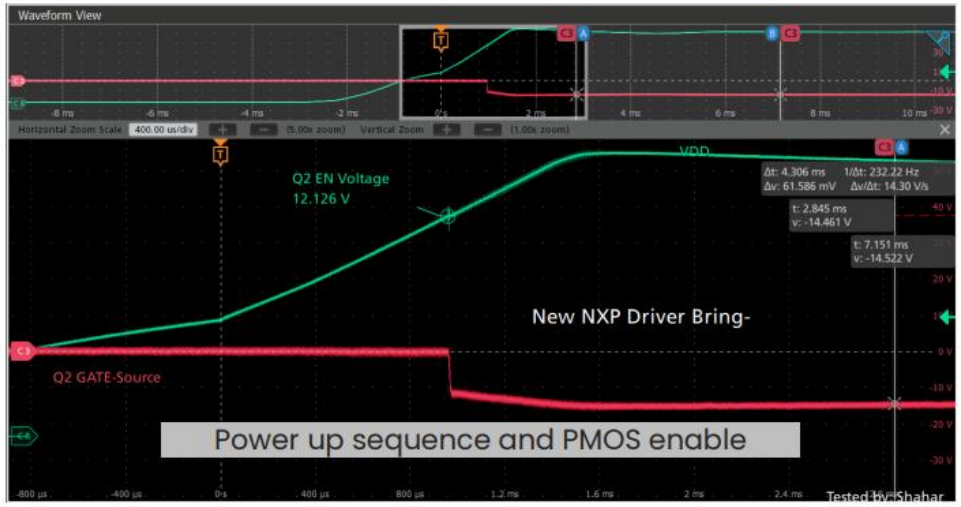
Conclusions:

- The VM030 Evaluation Kit is ready for shipping to the customer.

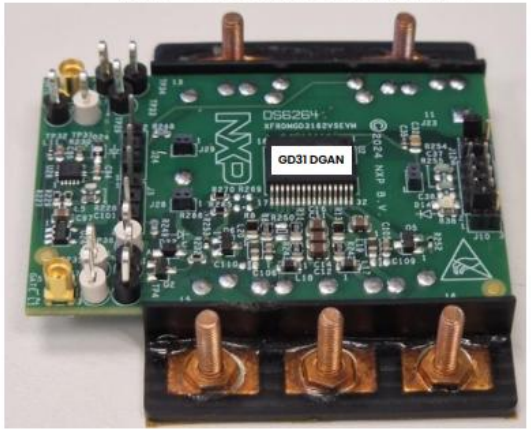
Short Circuit Behavior

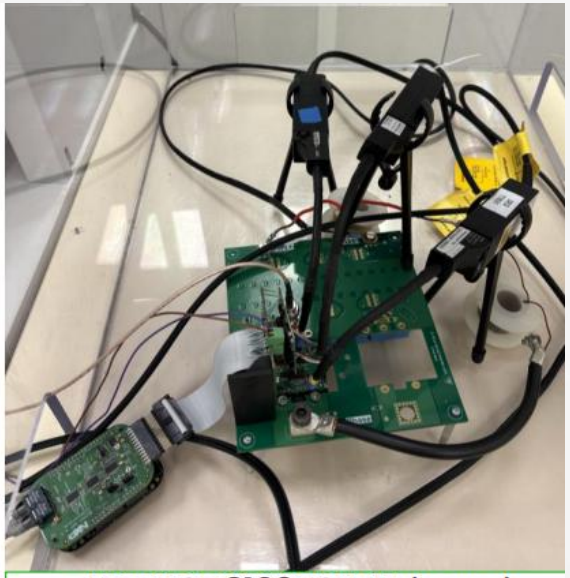
NXP test of GD3171 on VM030 EVB

Shuttle evaluation results (external AMC, PMOS control)

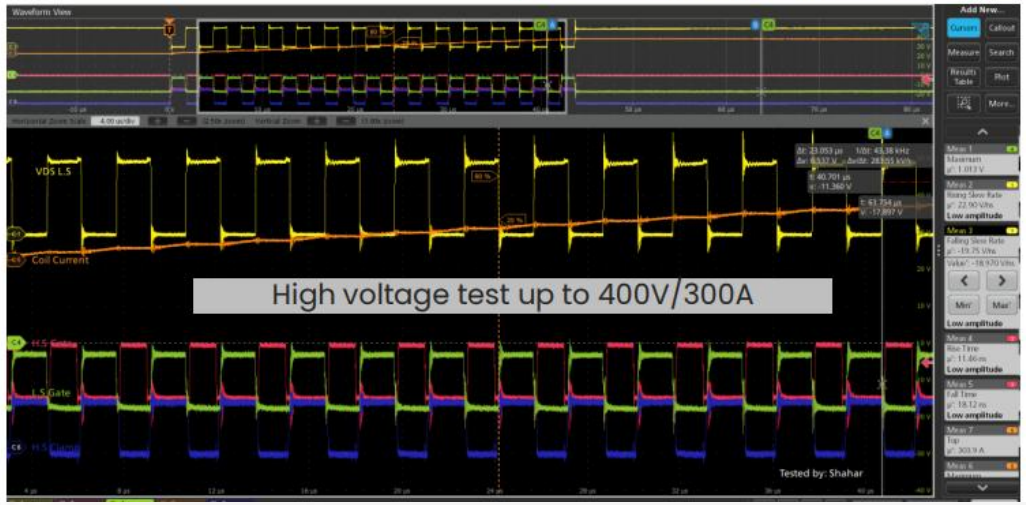


NXP GD31xx DGaN EVB



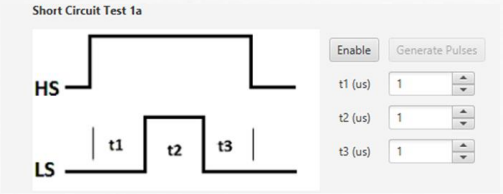


xFRDMGD3162VSEVM board
+ Visic Hazelnut Module

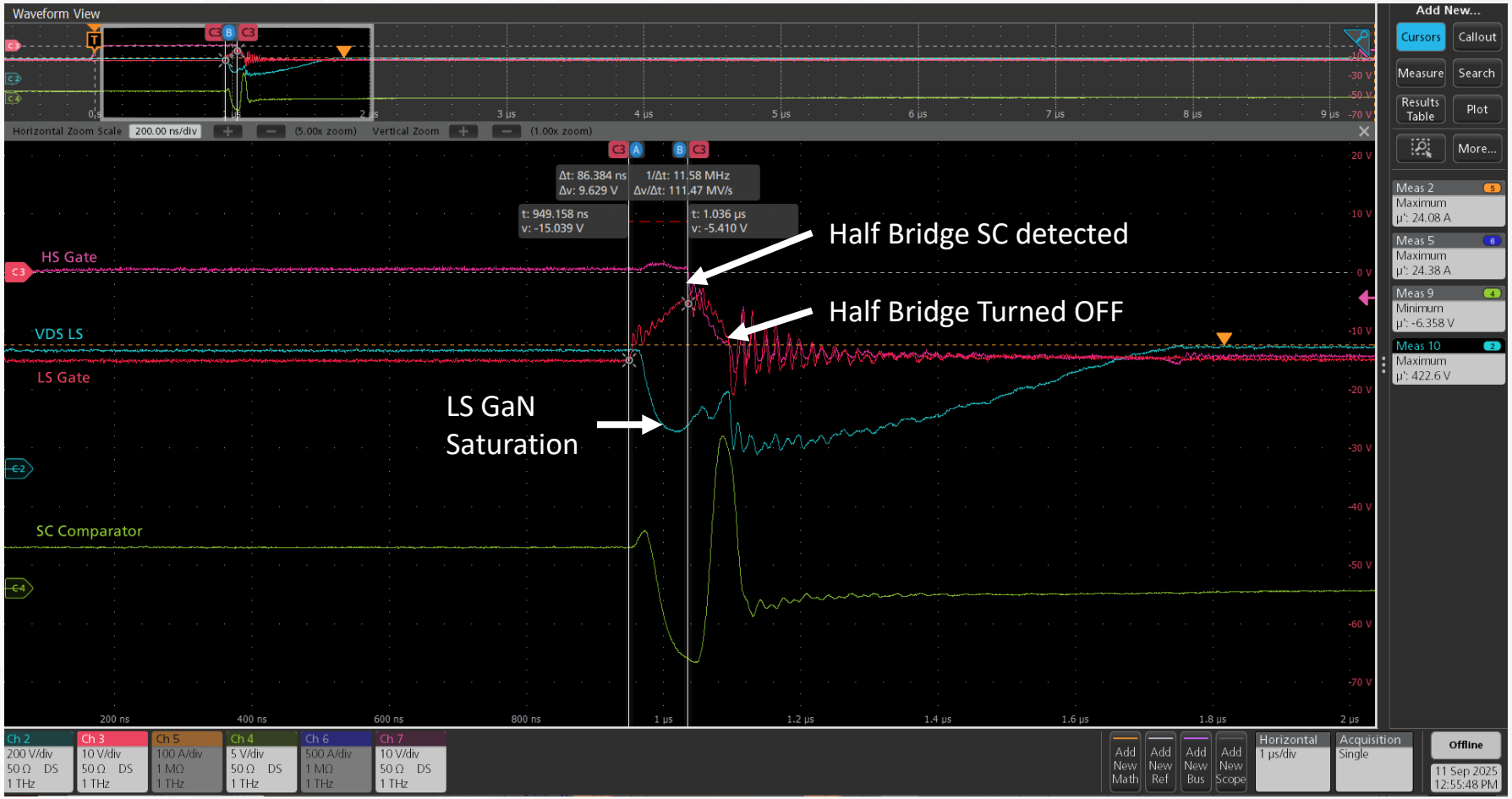


VM030 + GD3171 testing Short Circuit Type 1

Tested using NXP GUI at 400V

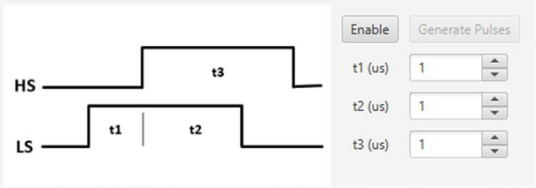


- Detection time < **100ns**
- Vgs OFF time < **150ns**
- Vds Overshoot < **0V**

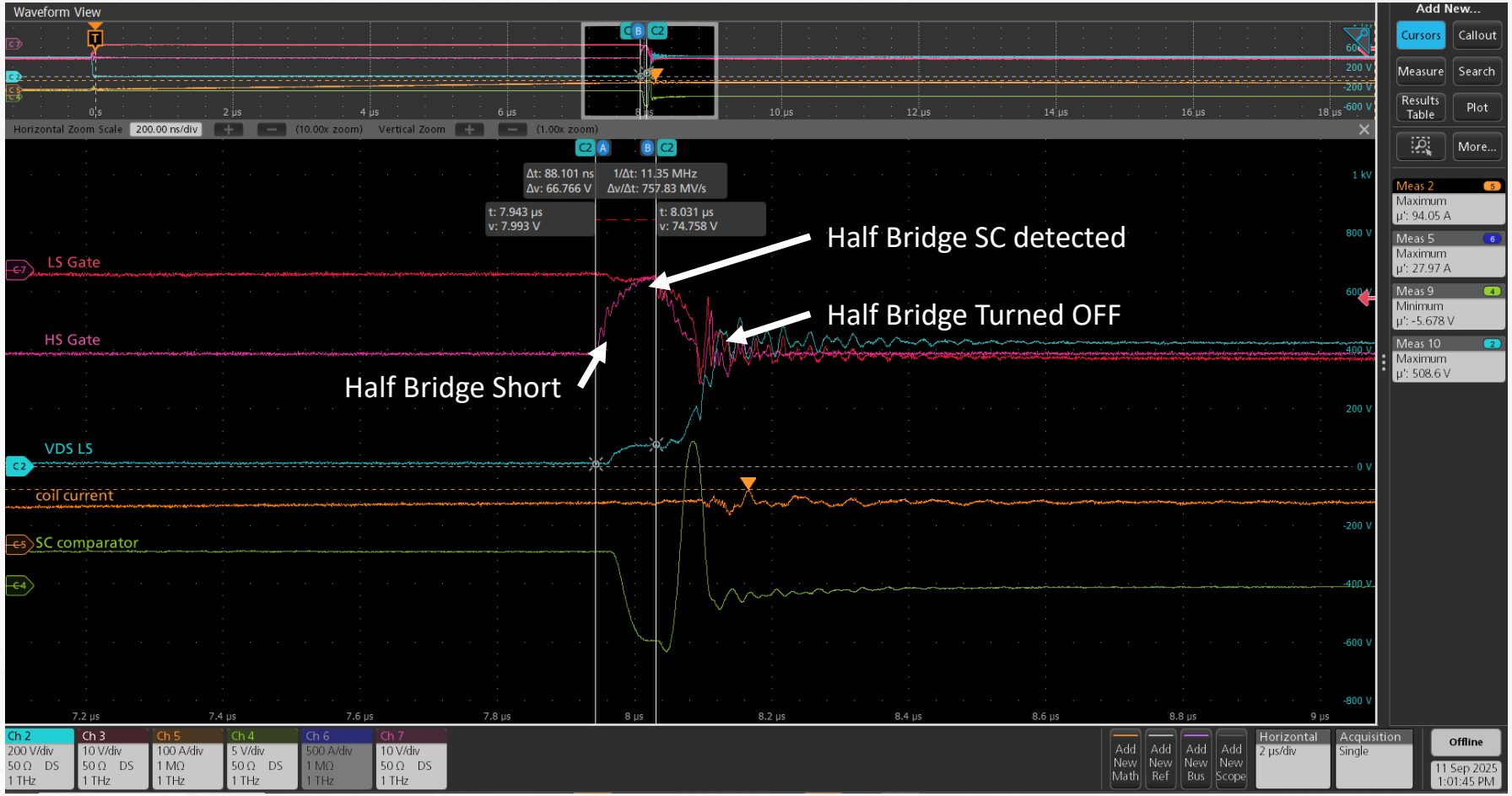


VM030 + GD3171 testing Short Circuit Type 2

Tested using NXP GUI at 400V



- Detection time < **100ns**
- Vgs OFF time < **150ns**
- Vds Overshoot < **100V**



D3GaN Safety Analysis

- VisIC together with NXP investigated the D3GaN + GD31 failure modes for inverter application and included safety mechanisms in the future GD3171 driver.

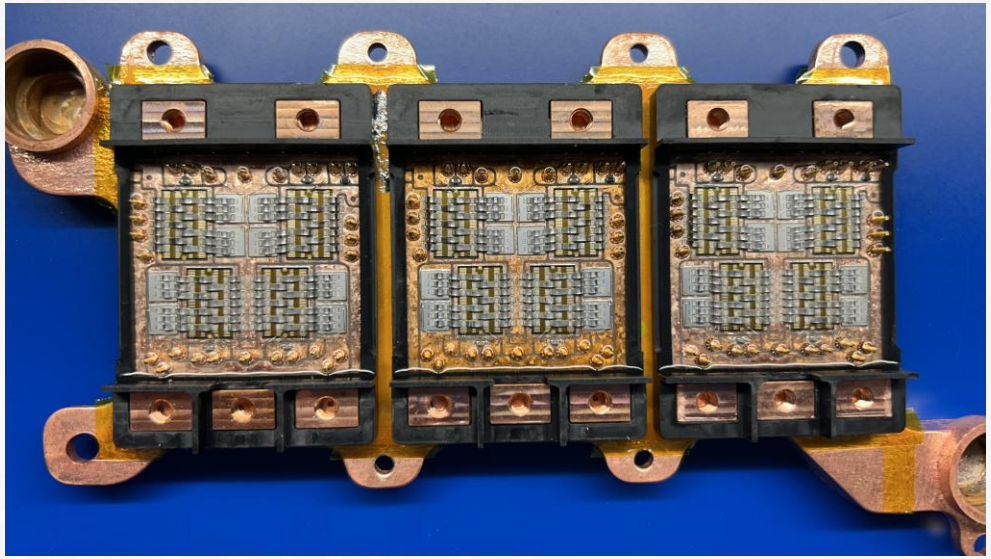
- Short Safety table summary is below:

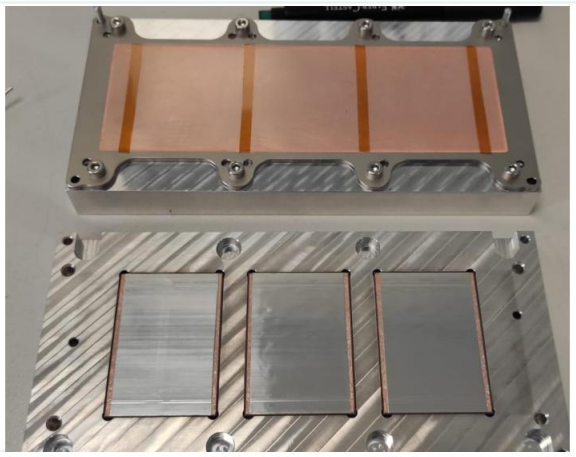
Failure Mode	Failure effects	Safety requirements	GD Safe state	System Safe state
AMC Pin Stuck Low (by external short to GND) AMC Mosfet Always OFF (internal logic stuck) AMC open GL pin stuck high GL pin open	AMC always OFF Discharge only through GL Lead to shoot through	**SC Protection** **AMC logic Vgs monitoring**	Stop PWM Turn Gate low ASAP	3 phase safe state
EN_LVP Pin Stuck High EN_LVP Pin Stuck Open after Rpu EN_LVP Pin Stuck Open before Rpu	LVPMOS always OFF Not safe if GaN ON	**PMOS enable monitor** **PMOS Vds monitor**	Stop PWM Turn Gate low ASAP	-
GaN shorted	Fatal failure Potential shoot through	**PMOS Vds monitor**	Stop PWM Turn Gate low ASAP	3 phase short Turn off complementary GaN
GaN open	Unproper function of system	**PMOS Vds monitor**	Stop PWM Turn Gate low ASAP	-
VCC_open on GaN	Unsafe gate control with slow commutations Critical currents at switching if PWMing	**PMOS Vds monitor**	Stop PWM Turn Gate low ASAP	-
EN_LVP Pin Stuck Low	LVPMOS always ON No shoot through thanks to opposite side open	**PMOS enable monitor** **PMOS Vds monitor**	Stop PWM	3 phase open

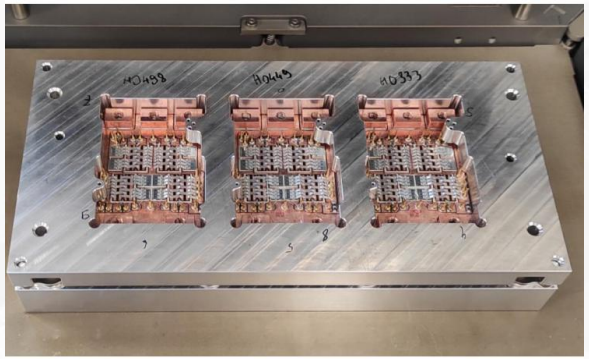
Cooler & Module

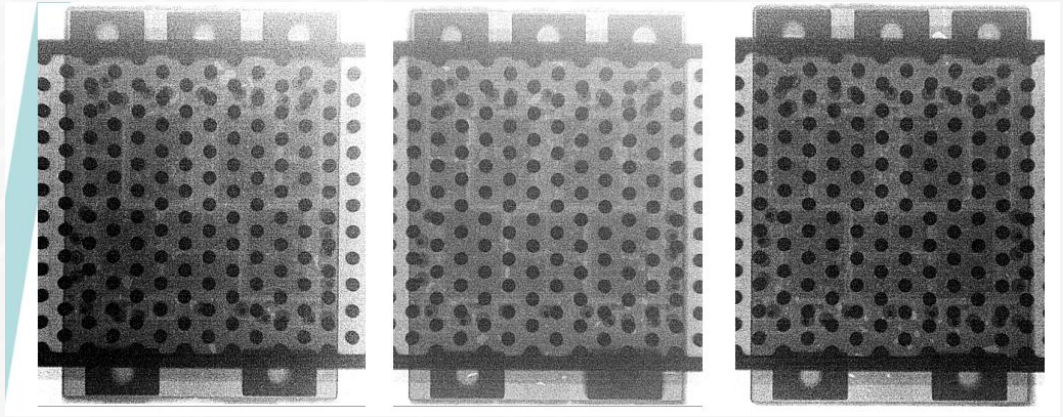
VM030 – Assembled Power Core

- Challenges:
  - Vacuum soldering to cooler with low temp solder
- Results:
  - Void free soldering
  - 1000h TC with no issues
  - X-Ray passed



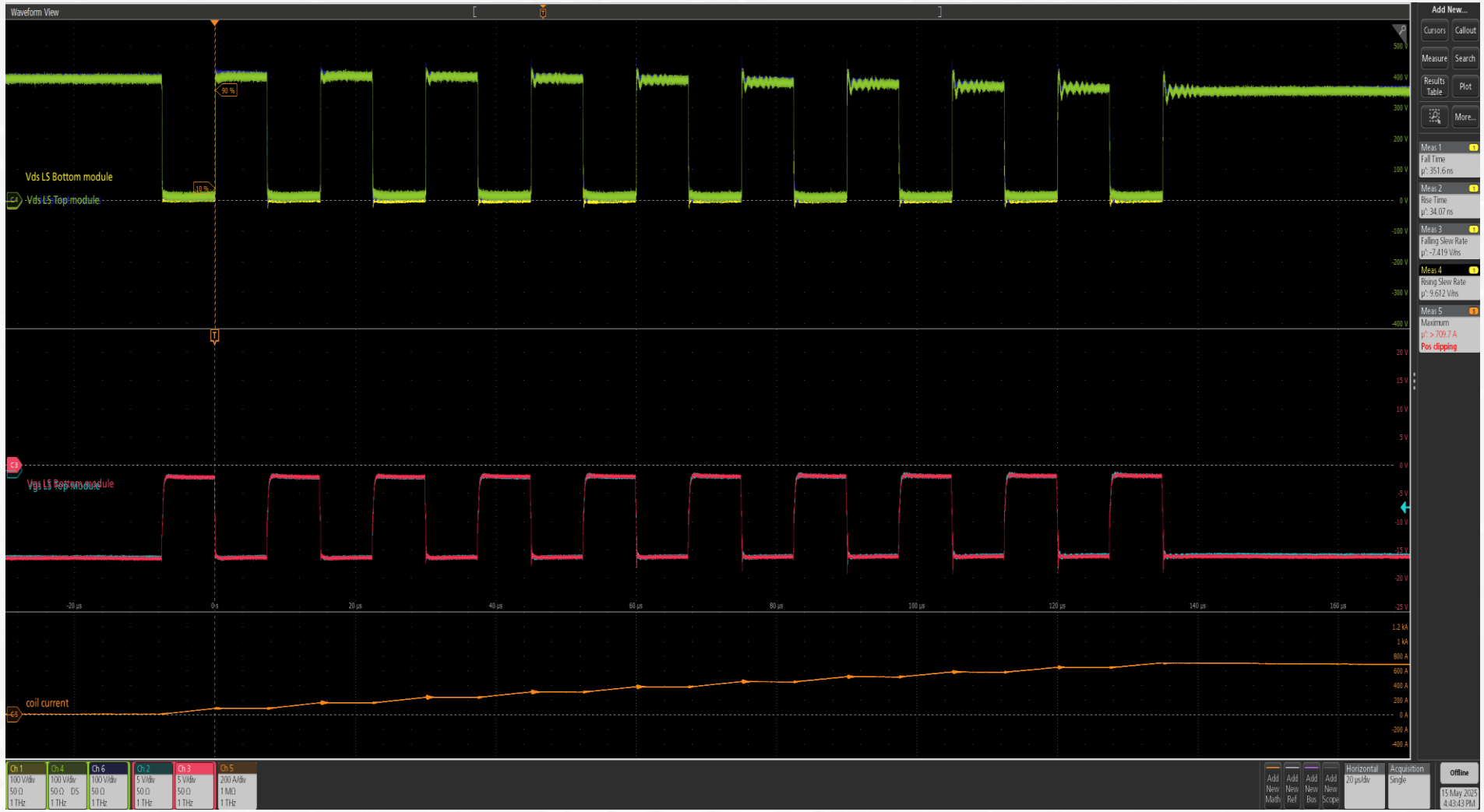






Paralleling of Modules – 2 x VM030 700A

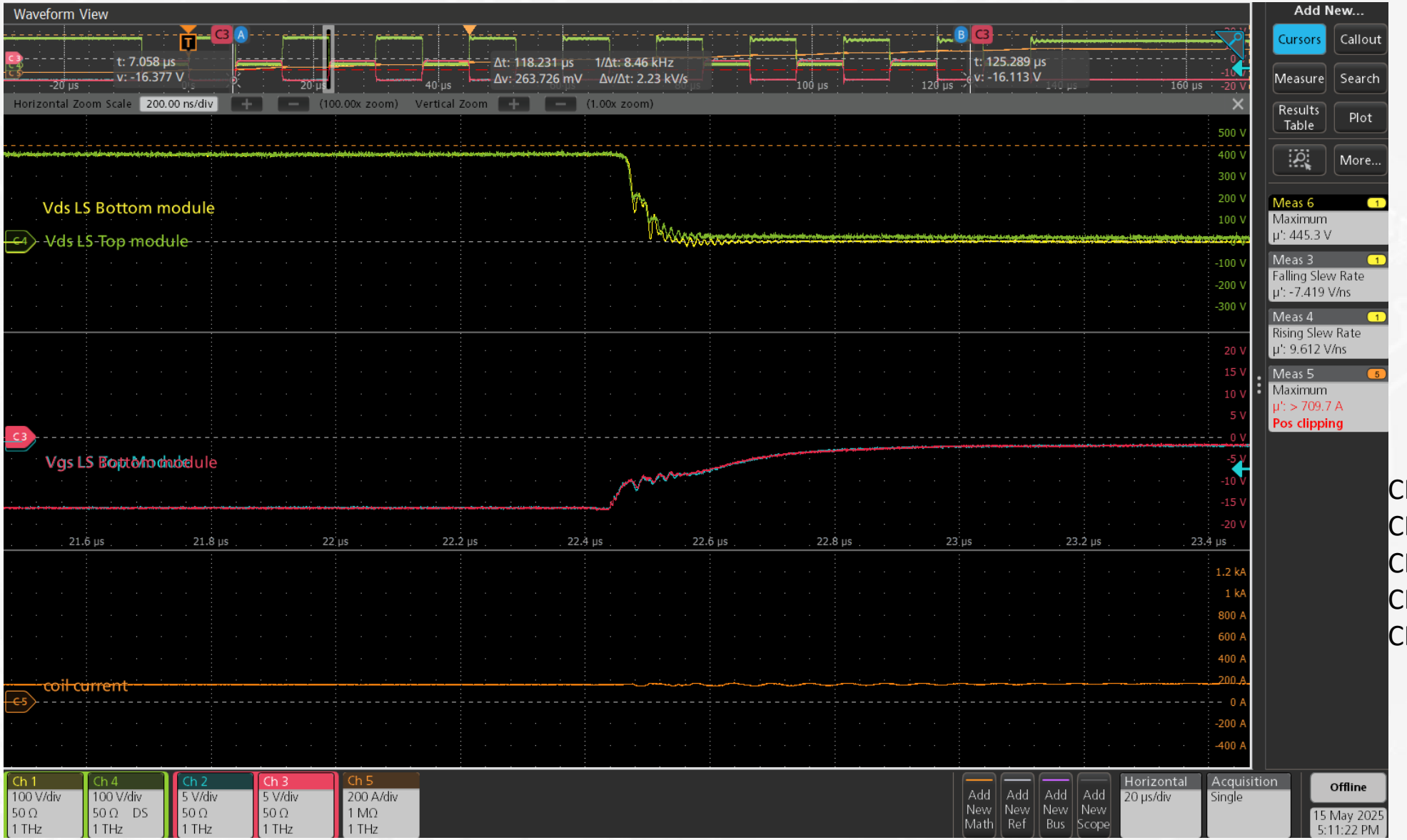
Switching of parallel 2 x VM030 Modules – 700A



Type	Value
M.Point max	445 V
Falling SR Max.	9.7V/ns
Rising SR Max.	12.4V/ns
Peak Current	**700A**

CH1-Vds LS Module#1 (Yellow)
CH2-Vgs LS Module#2 (Light blue)
CH3-Vgs LS Module#1 (Red)
CH4-Vds LS Module#2 (Green)
CH5-Inductor current (Orange)

Turn ON - 2 x parallel VM030 Modules – 700A



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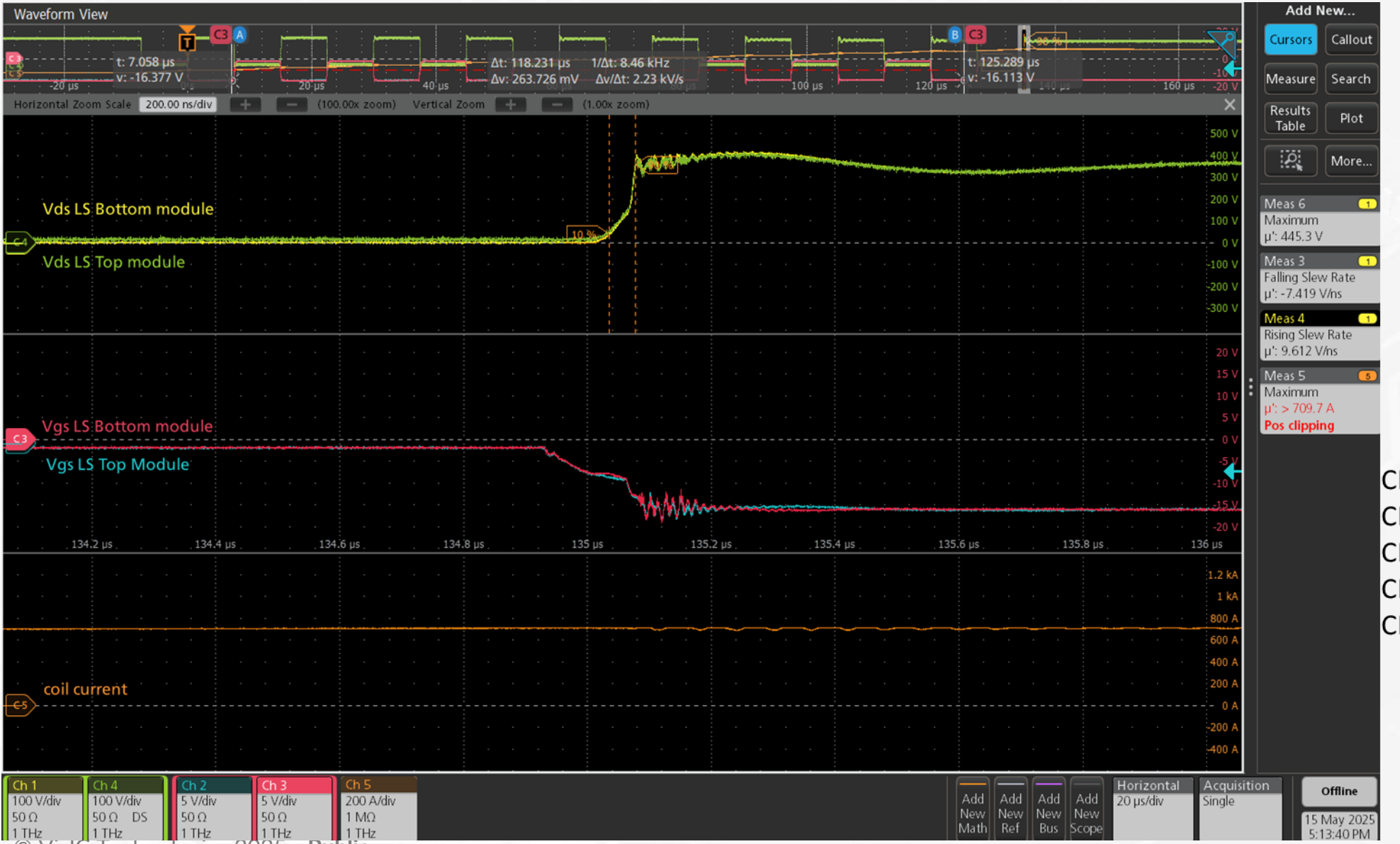
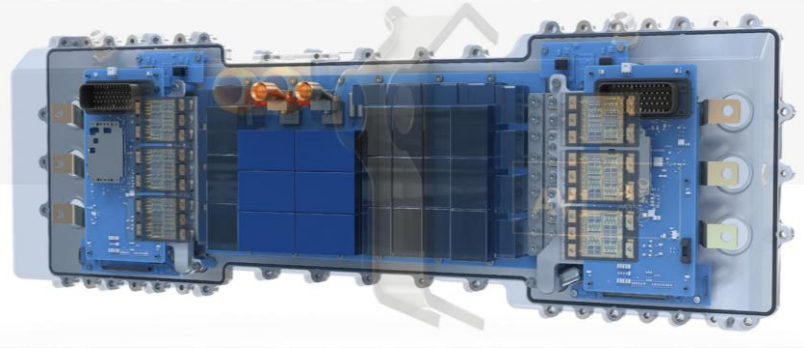


CH1-Vds LS Module#1 (Yellow)
CH2-Vgs LS Module#2 (Light blue)
CH3-Vgs LS Module#1 (Red)
CH4-Vds LS Module#2 (Green)
CH5-Inductor current (Orange)

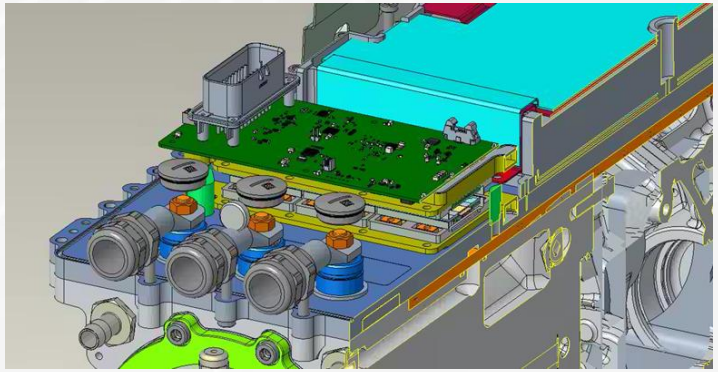
System integration

VM030 GaN Inverter – Demo Cars - AVL

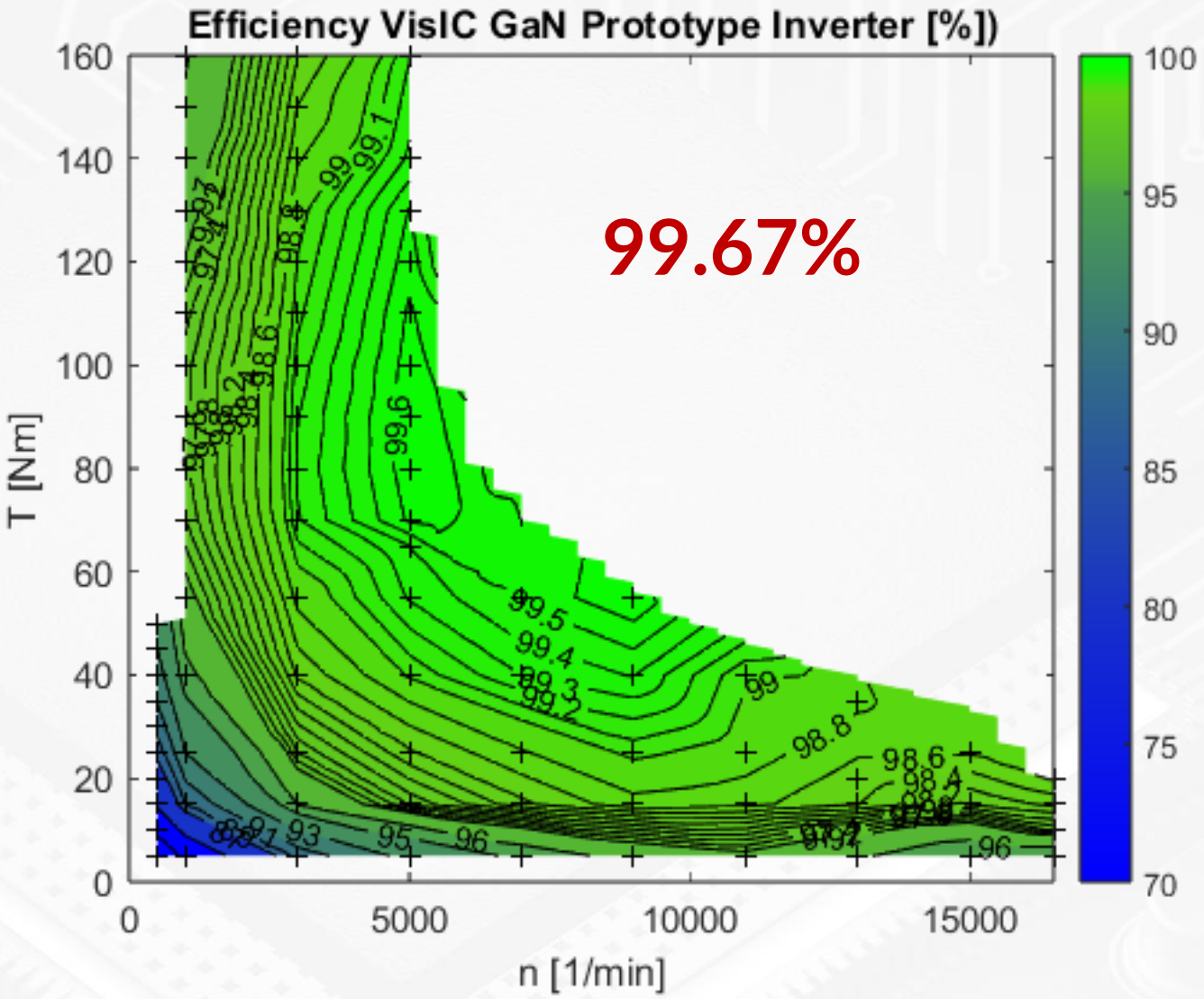
- **Performance Car – 500kW**
  - Dual Inverter with AVL/VisIC
  - TESLA Model S
  - 4 Modules in parallel – 1400A+
  - Q1 2026 system integration, Q2 2026 test drive

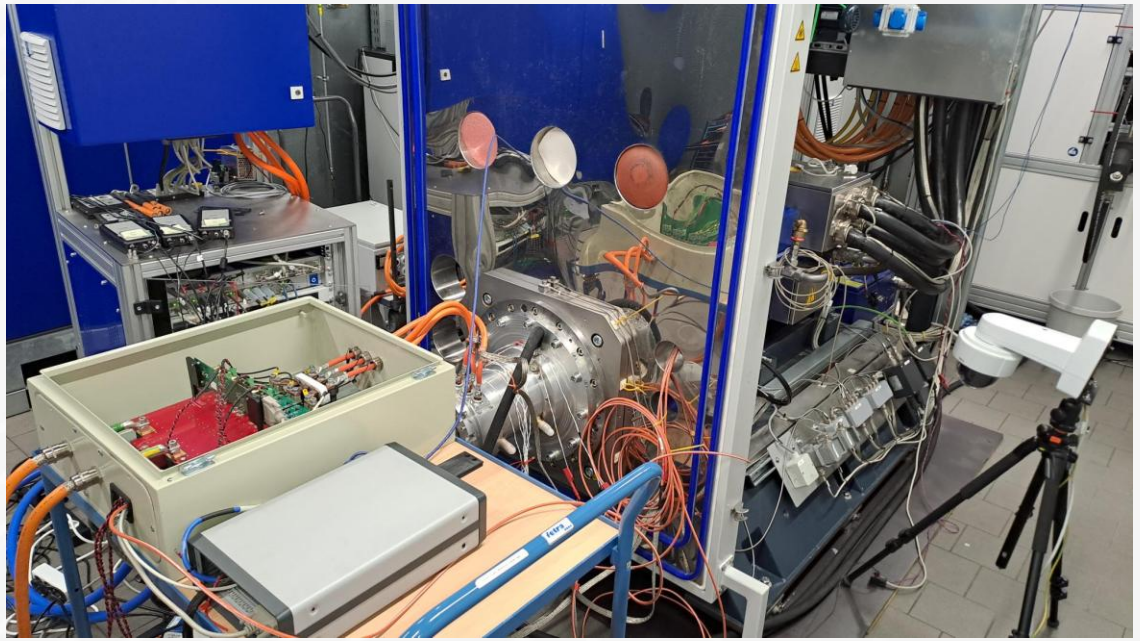


- **Urban Car – 100-125kW**
  - TBD with Partner
  - Q4 2026



Dyno Tests @ AVL Regensburg





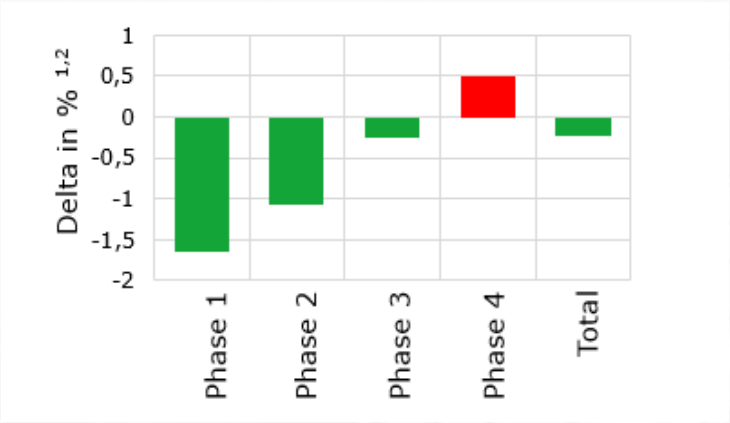
- Max. Efficiency: >99.5% (400V, 10kHz, 9kmin^{-1}, 55Nm)
- DUT Gen. 1 GaN: latest Generation will improve further Performance and Efficiency
- Max current: 330Arms
- Sensitivity of Switching Frequency (5 – 14 kHz) have been measured – analysis ongoing

WLTP Comparison- Measurement data

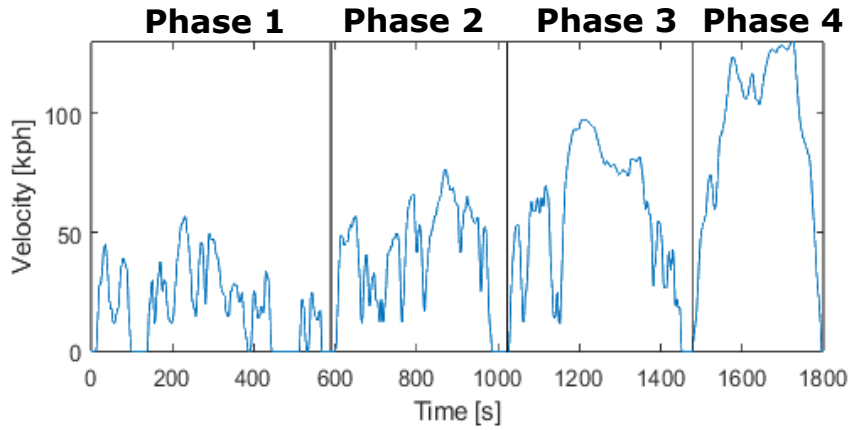
D³GaN 400V Gen 1 vs SiC 800V @ same e-machine and same speed & load

WLTP Results		GaN	SiC	Delta in %[2]
Energy Consumption Phase 1[1]	kWh	0.440	0.447	-1,65
Energy Consumption Phase 2[1]	kWh	0.715	0.723	-1,08
Energy Consumption Phase 3[1]	kWh	1.163	1.166	-0.25
Energy Consumption Phase 4[1]	kWh	1.738	1.729	+0.49
Energy Consumption Total[1]	**kWh**	**4.056**	**4.065**	**-0,23**
Specific Energy Consumption[1]	**kWh/100km**	**17.434**	**17.474**	**-0,23**

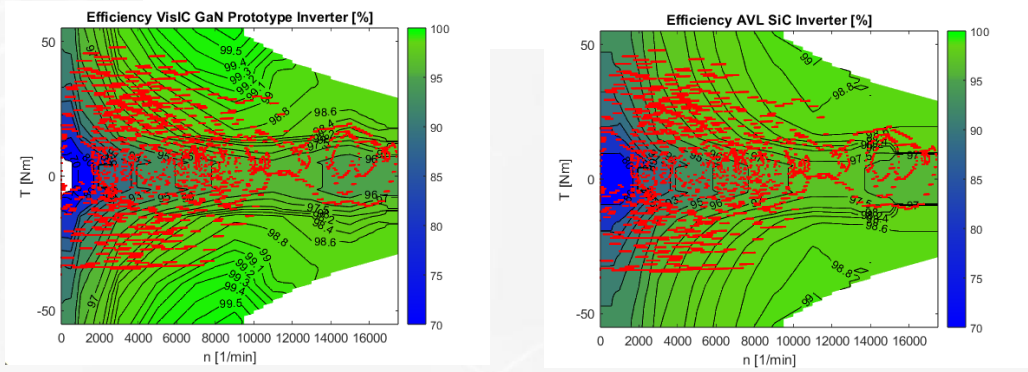
[1] *on one driving cycle*
[2] *delta calculated (GaN – SiC)/GaN*



● GaN outperforms SiC ● SiC outperforms GaN



GaN **SiC**



● WLTP load points

VisIC TECHNOLOGIES

THANK YOU