Measuring accurately and safely on fast WBG Testing Environment

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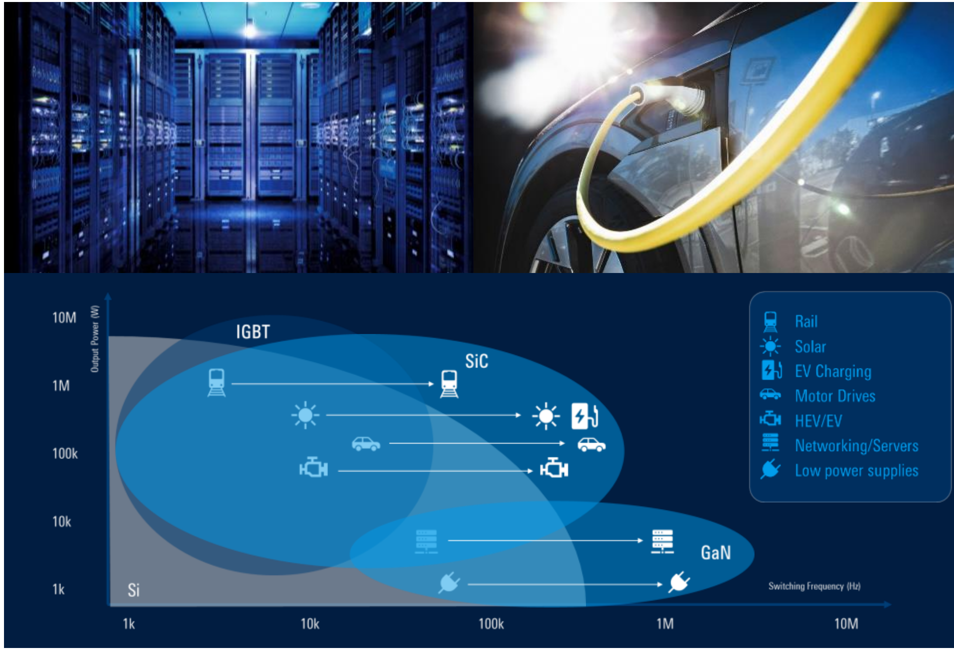
Bodo‘s Wide Bandgap Event 2024

Making WBG Designs Happen

SiC

THE GROWING COMPLEXITY OF MODERN ELECTRONICS

- Higher integration density
- Efficiency has to be increased:
  - Fast switching
  - Smaller internal Capacitances → Miniaturization and higher integration on IC Level
  - Usage of new materials like SiC, GaN, …
- New Semiconductors typically lead to new boundary conditions like e.g. isolated gate drivers
- Wide range of power applications served (from mW to GW)
- Measurement equipment has to ensure that measurements can be made Safe, accurate and repeatable to find all anomalies of interest.



MEASUREMENT CHALLENGES IN WBG TESTING

DUT

- Fast switching needed to increase efficiency
- Voltage Levels:
  - Offset Voltage up to several kV
  - Gate Voltages up to several 10 V
- Current measurement:
  - Only indirect measurement
  - Current probes have insufficient BW
  - Shunts introduce a burden voltage
- EMC has to be fulfilled

Measurement equipment

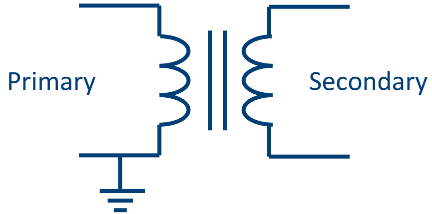
- High Offset Voltage:
  - High CMRR needed
- Noise and Thermal drift:
  - Noise reduces signal fidelity
  - Drift affects longterm stability
  - Both reduce accuracy and reliability of the measurement result.
- Fast switching leads to high frequency excitation
  - CMRR and isolation are stronlgy frequency dependent.

Safety

- Isolation concept has to consider the derating over frequency
- Breakdown of insulation can cause hazard to equipment, DUT and possibly personnel.

WHAT TOOL TO USE?

Isolation transformer



- Good DC Isolation
- Parasitic internal and external coupling limits usable frequency range
- Shows resonant behavior for faster switching devices

High voltage differential probe

- Bandwidth few 100 MHz
- Medium CMRR
- Limited Isolation to Ref-GND
- Best price-value proposition

Optical isolation

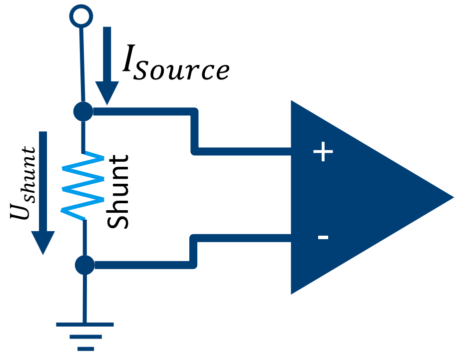
- BW up to 1 GHz
- Highest CMRR
- No disruption of isolation
- Lowest noise
- Thermal drift compensation
- Best choice for high isolated or high offset applications e.g. high-side gate or shunt measurement.

HOW TO MEASURE CURRENT USING A SHUNT

- Ohm‘s law:

$$R_{Shunt} = \frac{U_{Shunt}}{I_{Source}} \rightarrow U_{Shunt} = R_{Shunt} * I_{Source}$$

- 2 possible configurations for the shunt:
  - High-side: Between Source and DUT
  - Low-side: Between DUT and GND



HOW TO MEASURE CURRENT USING A SHUNT LOW-SIDE SENSE CONFIGURATION

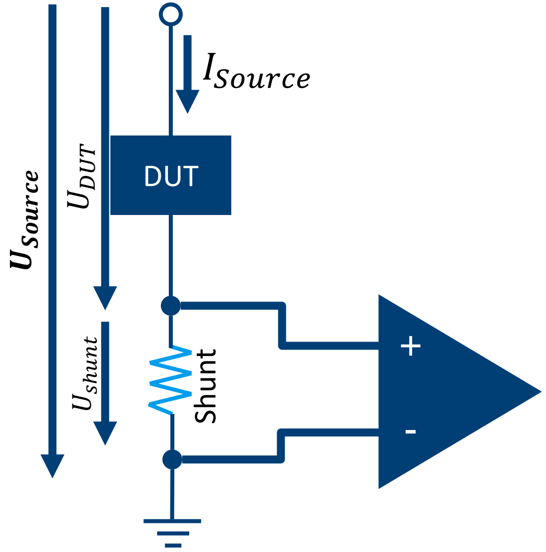
- Ohm‘s law:

$$R_{Shunt} = \frac{U_{Shunt}}{I_{Source}} \rightarrow I_{Source} = \frac{U_{Shunt}}{R_{Shunt}}$$

- U_{Source} is affected by U_{Shunt}

$$U_{Source} = U_{Shunt} + U_{DUT}$$

- To reduce effect of burden voltage, shunt has to be as small as possible.
- Low-side sense configuration:
  - U_{Shunt} is ground referenced.
  - DUT is decoupled from GND by shunt
  - Short circuit detection might be affected



HOW TO MEASURE CURRENT USING A SHUNT HIGH-SIDE SENSE CONFIGURATION

- Ohm‘s law:

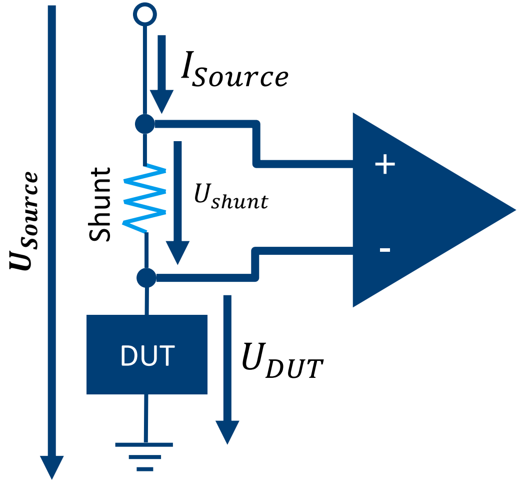
$$R_{Shunt} = \frac{U_{Shunt}}{I_{Source}} \rightarrow I_{Source} = \frac{U_{Shunt}}{R_{Shunt}}$$

- U_{Source} is affected by U_{Shunt}

$$U_{Source} = U_{Shunt} + U_{DUT}$$

- To reduce effect of burden voltage, shunt has to be as small as possible.
- High-side sense configuration:
  - U_{Shunt} is referenced on U_{DUT}
  - Measurement needs to be real floating to minimize errors.

→High CMRR and isolation is needed

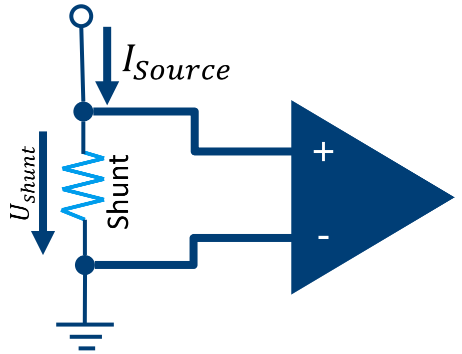


HOW TO MEASURE CURRENT USING A SHUNT

- Ohm‘s law:

$$R_{Shunt} = \frac{U_{Shunt}}{I_{Source}} \rightarrow U_{Shunt} = R_{Shunt} * I_{Source}$$

- 2 possible configurations for the shunt:
  - High-side: Between Source and DUT
  - Low-side: Between DUT and GND
- How to minimize U_{shunt} while maintaining good SNR?
  - Reduce the Shunt value.
  - Typically value of shunt is limited by the smallest sensitivity of the differential probe connected to the shunt.

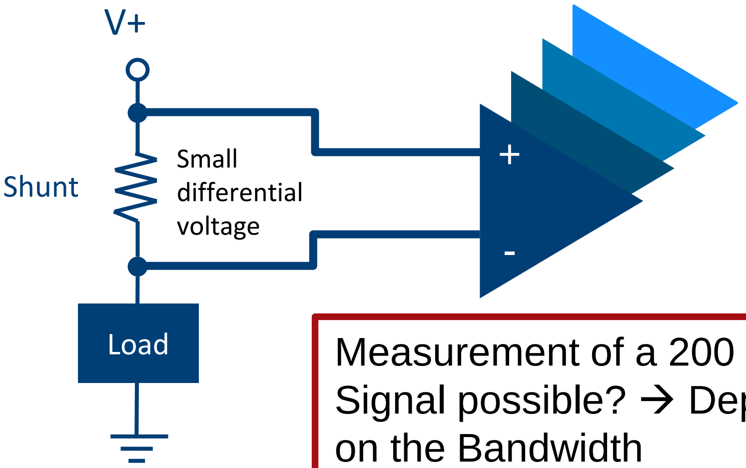


R_{Shunt}	I_{Source}	U_{Shunt}
1Ω	10A	10V
1mΩ	10A	10mV
20µΩ	10A	200µV

Is this possible?

FRONT-END AMPLIFIER ON PROBE HEAD

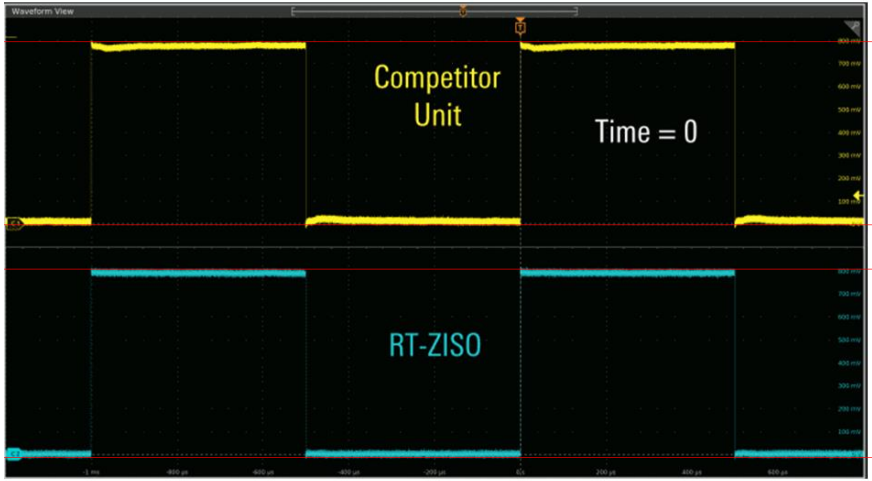
- Input Voltage range is limited by 2 Points:
  - Static divider ratio of the Probe tip e.g. 1:1, 1:10 or 1:100
  - Vertical input scaling selected by the frontend.
- What if we include a Frontend in an isolated Probe?
  - Input voltage range can be varied between $\pm 10\,mV$ up to $\pm 30\,V$
  - Using a 1:1 probe tip gives superior resolution for measuring small signals in presence of a huge CM Offset.
  - Offset compensation like for an oscilloscope input is possible.

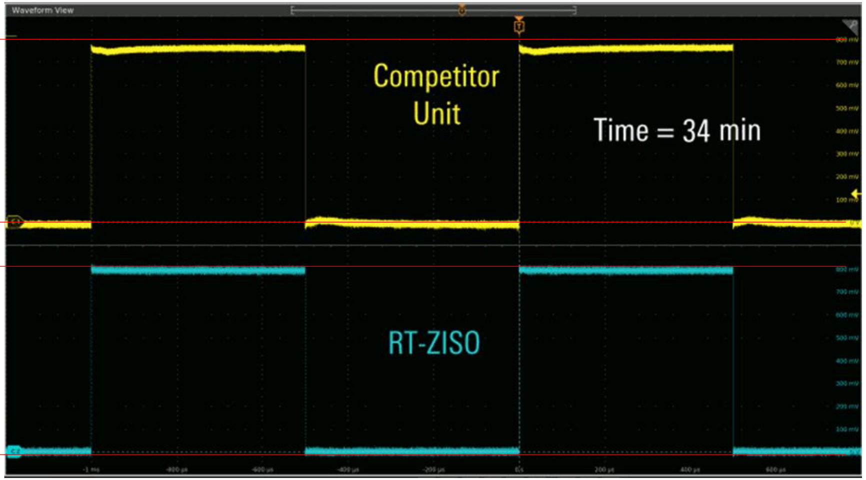


Measurement of a 200 µV Signal possible? → Depends on the Bandwidth

System noise voltage (meas.)	measured with compatible Rohde & Schwarz oscilloscope [illegible]					
	input voltage range	ZISO-B901 (100 MHz)	ZISO-B902 (200 MHz)	ZISO-B903 (350 MHz)	ZISO-B905 (500 MHz)	ZISO-B910 (1 GHz)
	±0.01 V	107 µV	121 µV	153 µV	172 µV	245 µV
	±0.025 V	140 µV	161 µV	220 µV	252 µV	383 µV
	±0.05 V	211 µV	255 µV	363 µV	417 µV	623 µV
	±0.1 V	382 µV	465 µV	683 µV	780 µV	1.16 mV
	±0.5 V	1.84 mV	2.26 mV	3.35 mV	3.81 mV	5.65 mV
	±1 V	5.90 mV	7.27 mV	9.49 mV	10.9 mV	16.0 mV
	±5 V	18.9 mV	23.5 mV	34.3 mV	39.0 mV	58.5 mV
	±10 V	37.0 mV	45.7 mV	67.4 mV	77.1 mV	115 mV
	±30 V	110 mV	134 mV	201 mV	229 mV	342 mV

THERMAL DRIFT PERFORMANCE



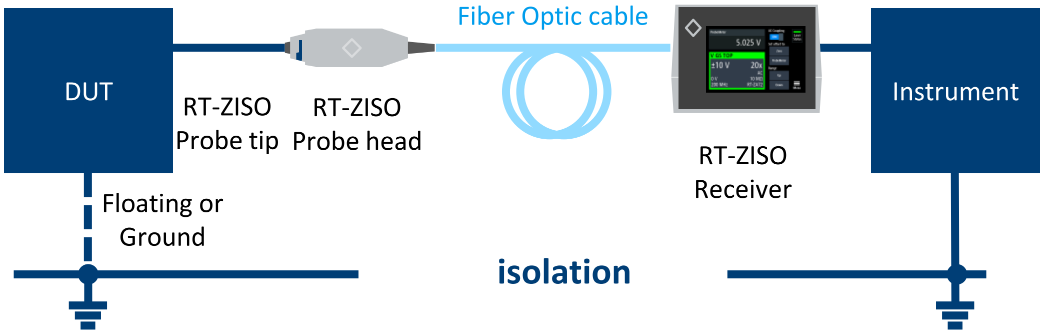


RT-ZISO Temperature drift:
attenuation ±0.15%/°C (meas.)

Dedicated front-end processing and receiver control help keep a stable thermal performance

DIFFERENCE IN DETAIL DUE TO CMRR

RT-ZISO SOLUTION OVERVIEW



1 GHz	Bandwidth
> 90 dB	CMRR @ 1 GHz
60 kV	Max. Common Mode Voltage
± 3000 V	Input | Offset range
± 10 mV	Highest sensitivity range
Dual	Connectivity modes


MMCX tips


Square pins


Wide Square pins

SUMMARY

- **Offset Voltages** in HVDC systems cause distorted measurements and make capturing true signal behavior difficult.
- **Noise and Drift** can couple into measurements, leading to mischaracterization of fast-switching behaviors, common in WBG devices.
- **Common-Mode Voltage** challenges arise, where **CMRR** performance deteriorates at high frequencies, making it harder to reject noise effectively.
- **Thermal Drift** caused by high temperatures in HVDC systems leads to inconsistent measurements over time.
- **Safety Risks** from isolation breakdown in high-voltage systems can lead to equipment damage and safety hazards.