Do your measurements match your expected results?

CN Rood – Sven De Coster

19 juni 2019
1931 Congrescentrum 's-Hertogenbosch

POWER ELECTRONICS 2019

Driven By Technology

Dependable.
Reliable.
Knowledge Partner.

Since the day we were founded in 1938 CN Rood has been on the cutting edge of technology. Enabling us to help you solve the challenges you encounter using the latest technological developments and insights.

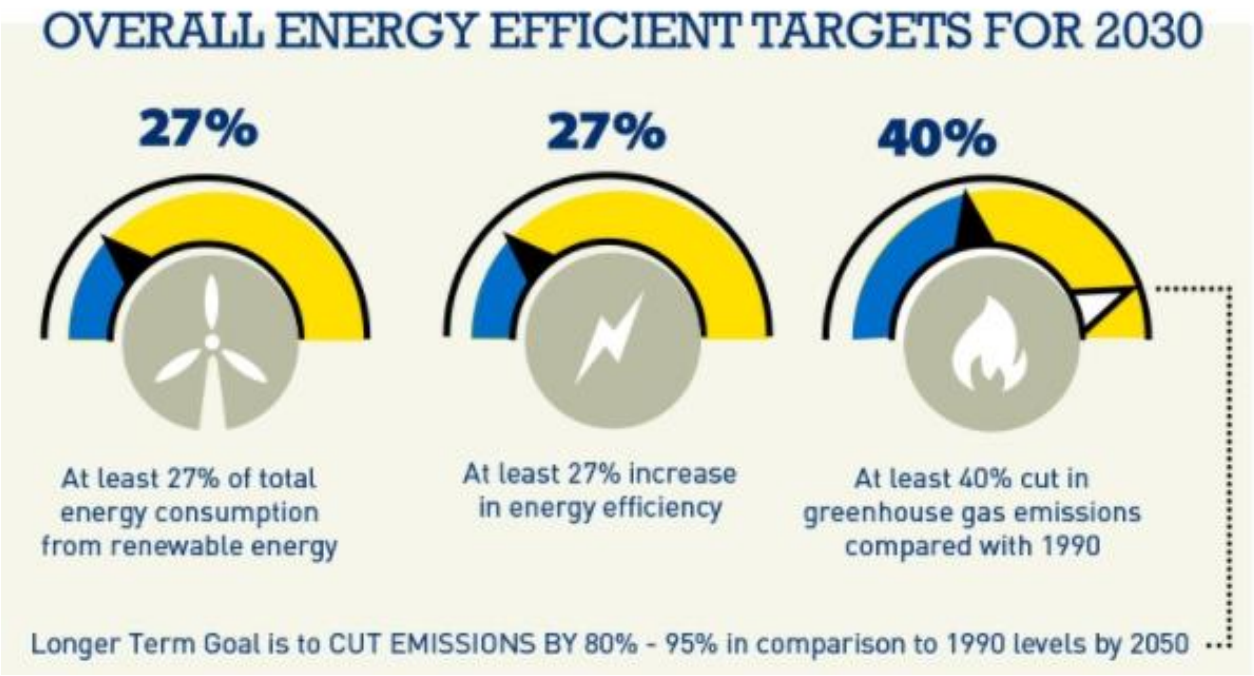
- instrumentation
- biomedical test equipment
- auto-id
- communication
- automatic test equipment
- services
- video broadcast
- data acquisition
- rental and leasing

Agenda

- Do we have a problem?
- Technology that helps: SiC and GaN
- Measurement challenges
- Solution and conclusion

We share a common problem

The “green” economy and why we care

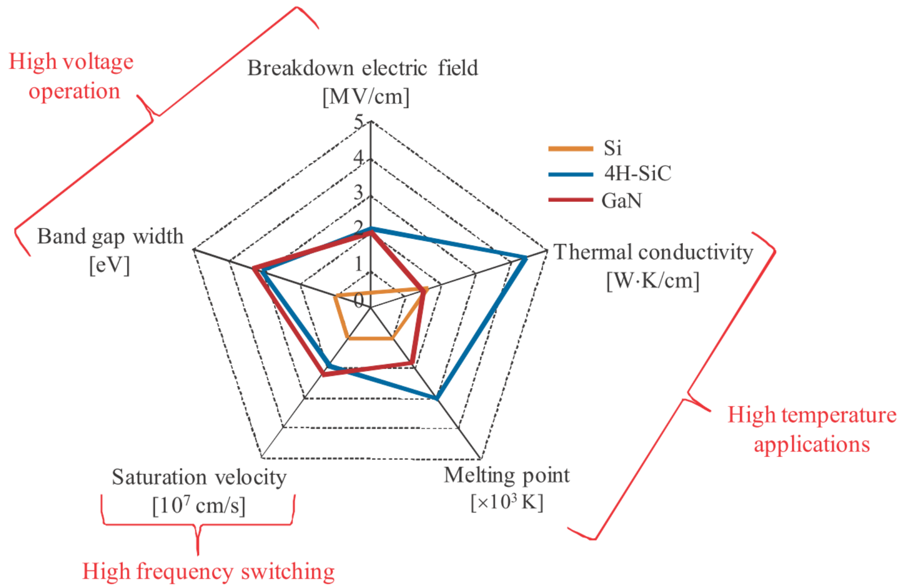


- Source:EEA Europe

Introduction

Why #widebandgap

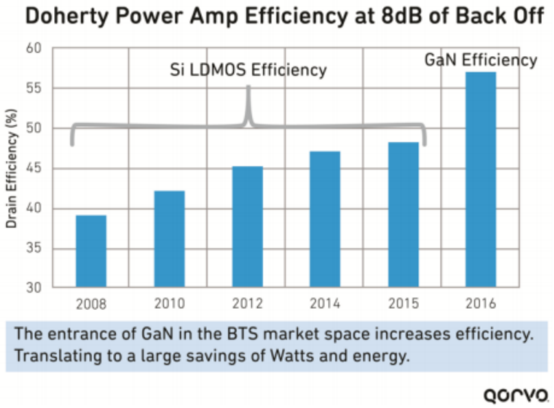
- Wide band gap power devices are dictating the pace of development of power electronics today
- Power modules developed with silicon carbide (SiC) and gallium nitride (GaN) technologies
- Higher : output power + efficiency + power density
- Size of the passive components and thermal management dictating the overall size of modules

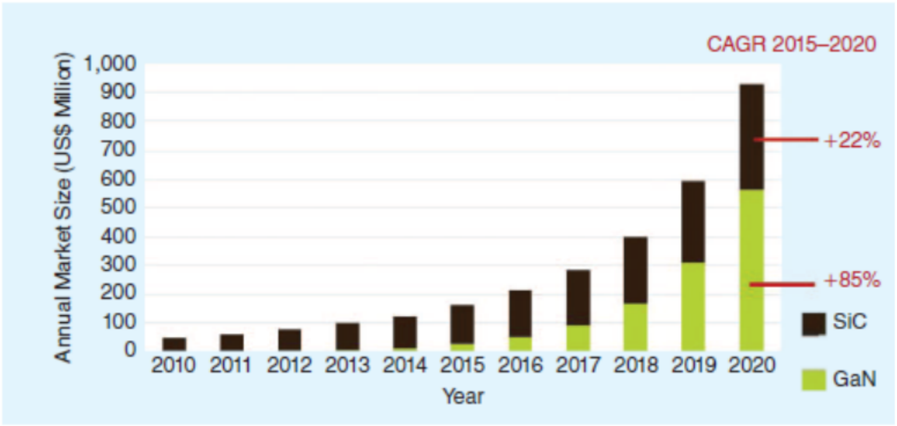


Power conversion markets and their interest

Decrease cost, reduce energy loss in power conversion

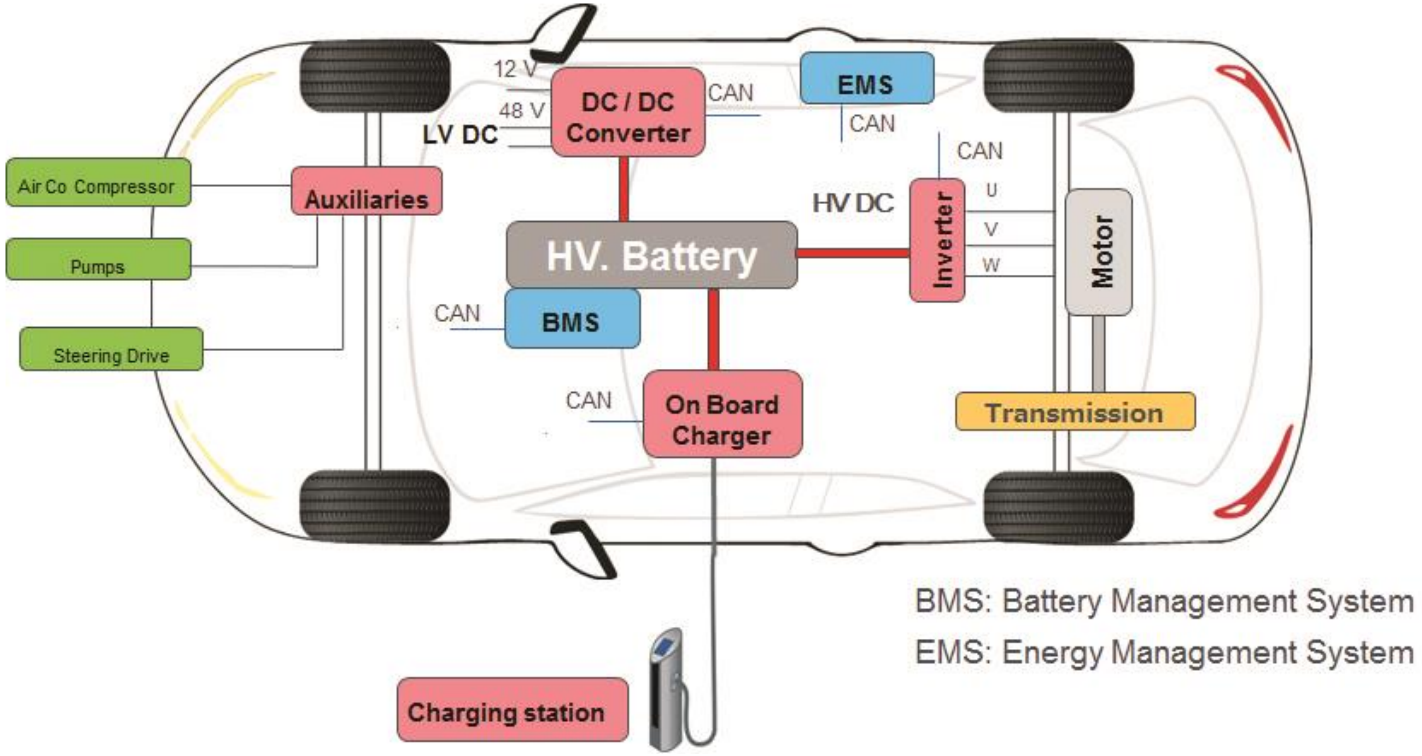
- Consumer
- Server (Datacenter)
- Servo motors and driver (Industrial)
- Electric mobility
- Solar
- Telecom





Example: SiC and GaN for Automotive

Electric mobility

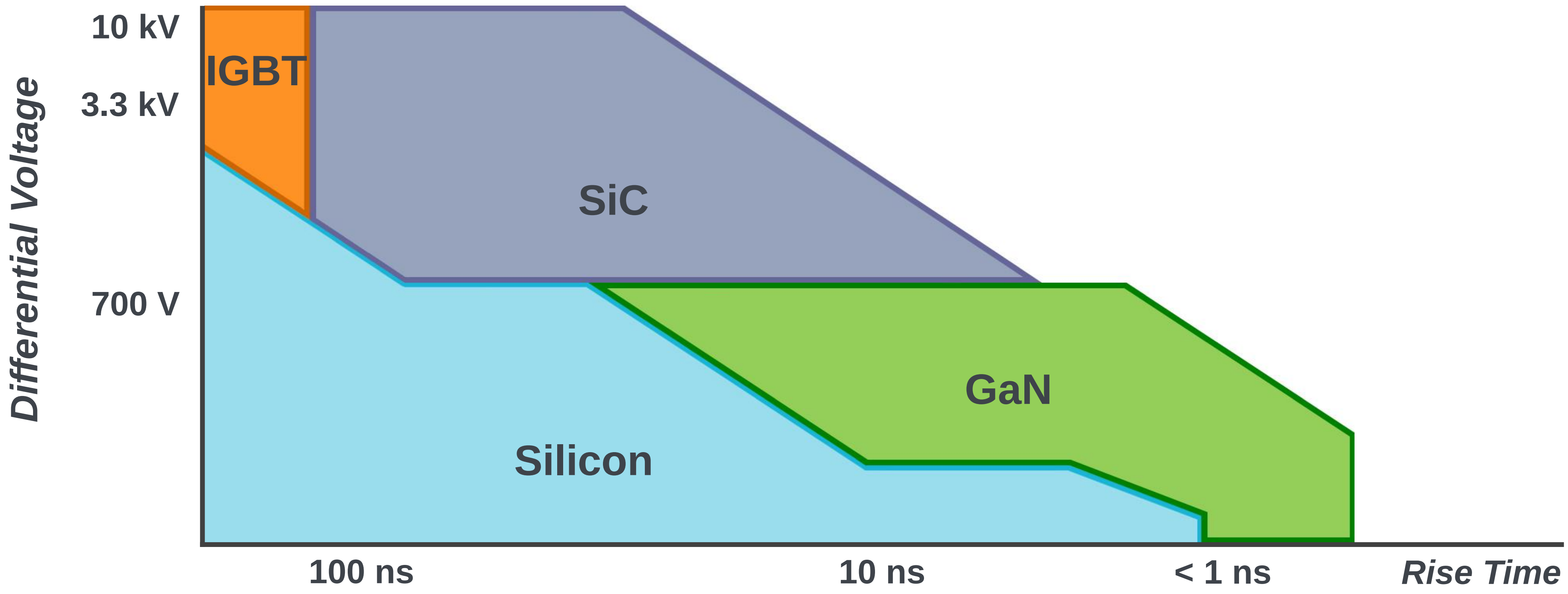


Toyota PCU resize using SiC

Switching loss characterization

Measurement challenges with widebandgap

- What do we use to measure these?



Important Metrics and Measurements

GATE DRIVERS

- Voltage Characteristics
  - High side and low side
  - Input, output, and supply voltages
  - Absolute maximum and threshold
  - Common mode transient immunity
- Current Characteristics
- Timing
  - Rise and fall times
  - Propagation delay
  - Dead time
  - Channel to channel delay
- CMTI

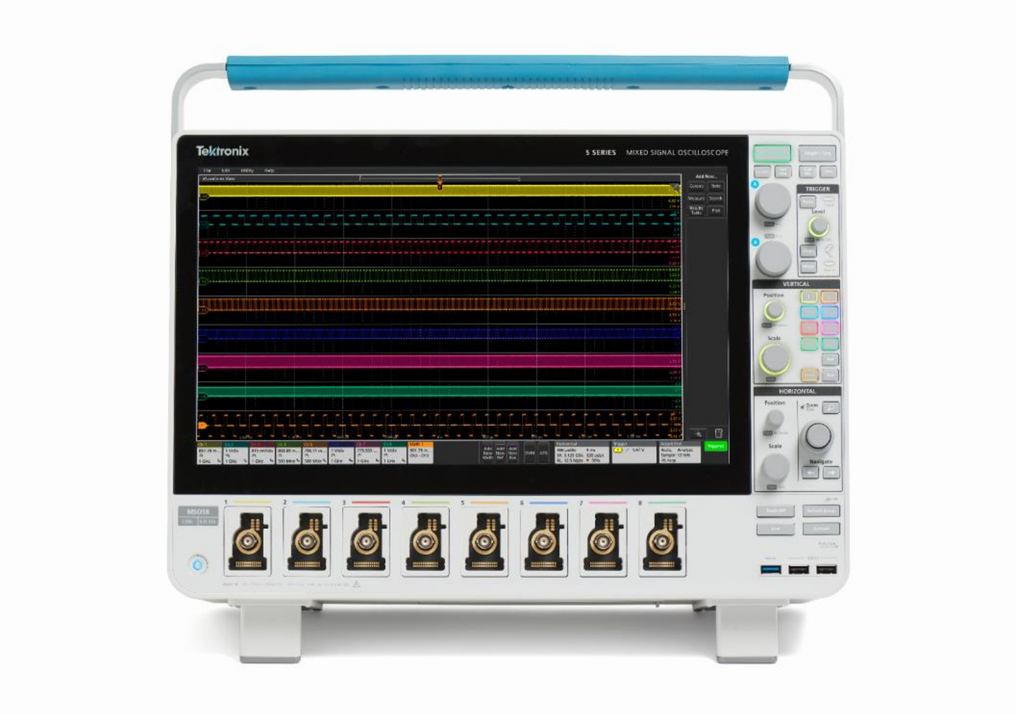
HALF BRIDGE

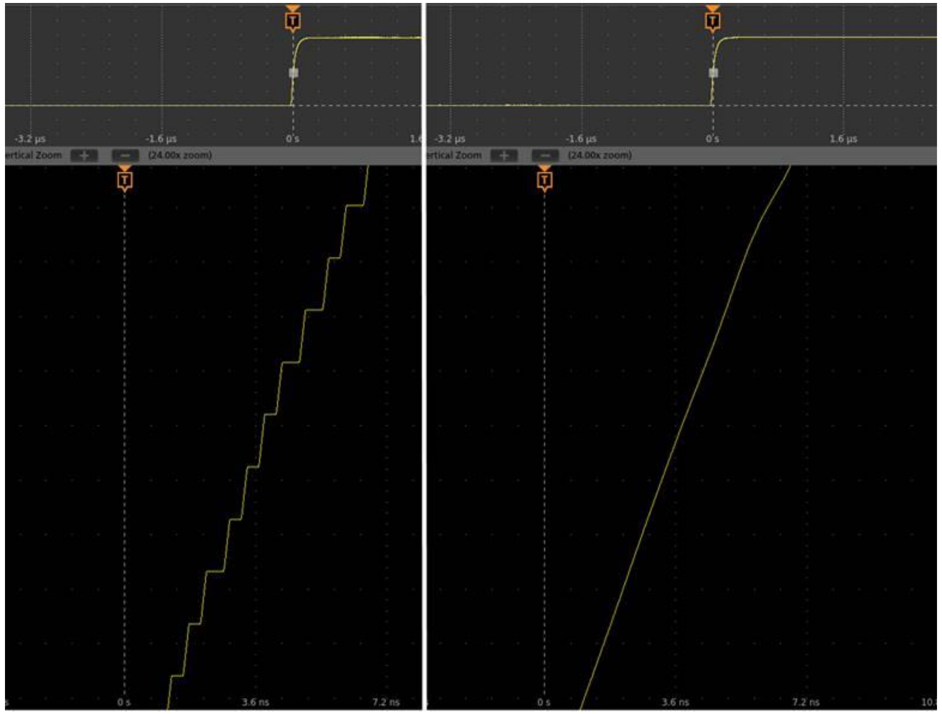
- Voltage Characteristics
  - Large dv/dt
  - High side and low side V_{GS} and V_{DS}
  - Absolute maximum and threshold
- Current Characteristics
- Timing
  - Rise and fall times
  - Propagation delay
  - Dead time
  - Channel to channel delay
- Double Pulse Testing

What Measurement Equipment?

Is the oscilloscope still a good tool?

- YES it is, better than ever





See 16x more digitizing levels on a 12-bit scope

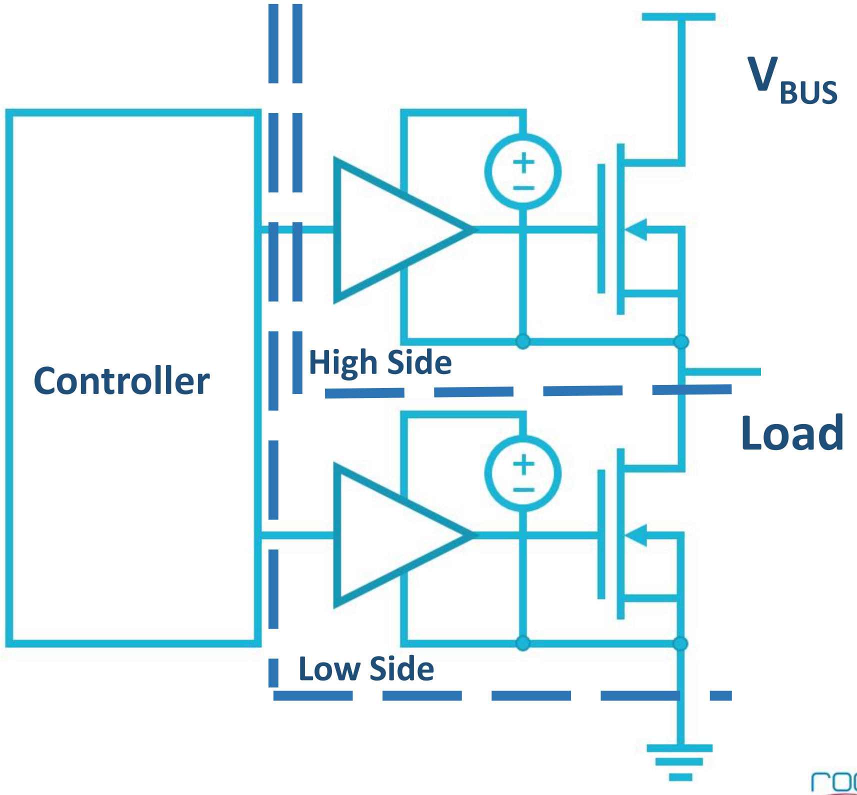
What Measurement Equipment?

Probes! But they have become the primary limiting factor…

- How do I get the signal from the test point to the oscilloscope?

- Probe Types
  - Single Ended Probes
  - Traditional High Voltage Differential Probes
  - Isolated Probes
  - Current Probes

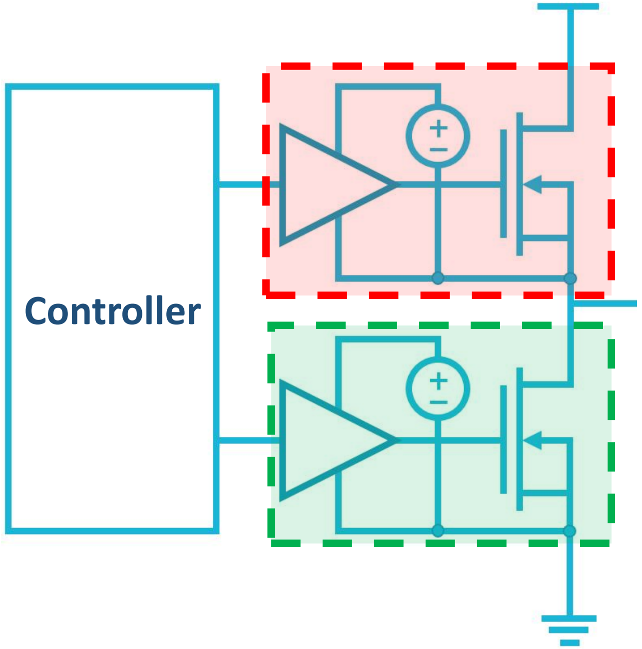
- Selecting the right probe for the job



Single Ended Probes?

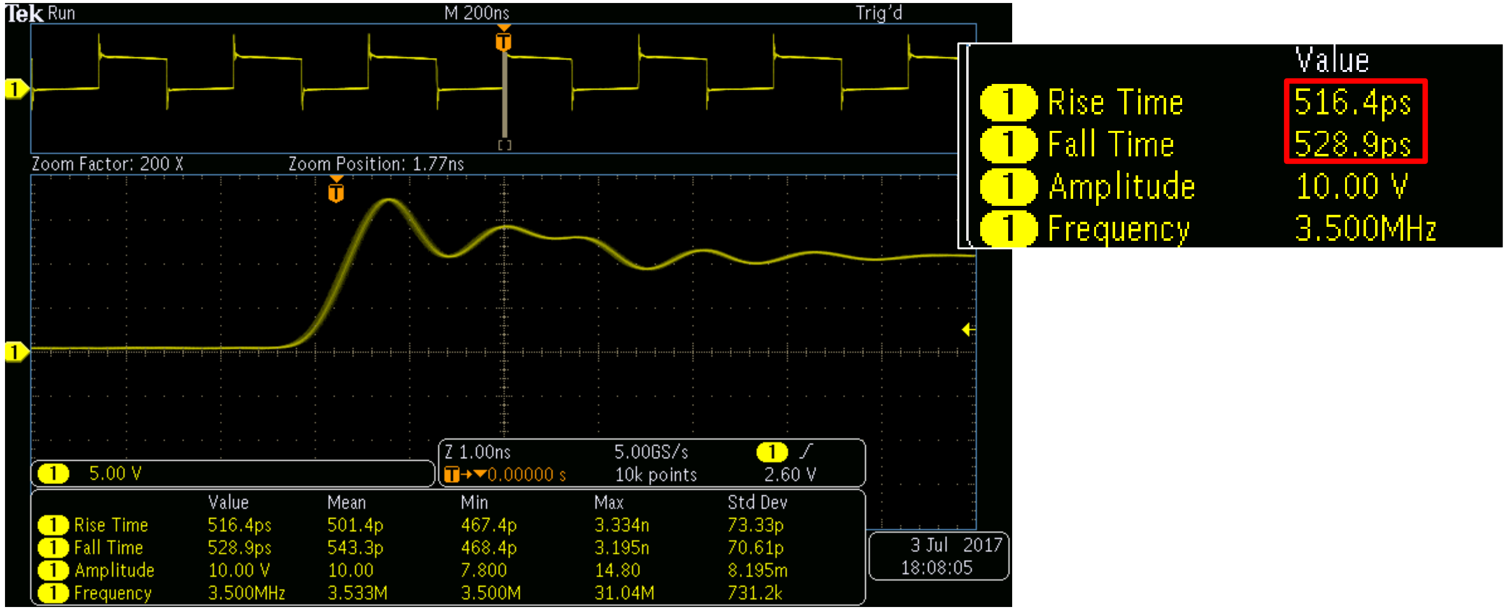
For low side this is still good

- Probe ground lead cannot be used directly on the high side because it is attached to scope ground
- Is the bandwidth sufficient, typical 500MHz?
  Do I need more? 800MHz? 1GHz?
- Ground lead is big… am I picking up noise? What about inductance?
- Input capacitance: 8-11pF typical? Can I get a lower value? 4pF is the best available on the market…



Bandwidth vs. Rise Time Considerations

- Do not confuse your circuit switching frequency with potential aberrations frequencies you are searching for



PE29100
High-speed FET Driver

Peregrine Semiconductor

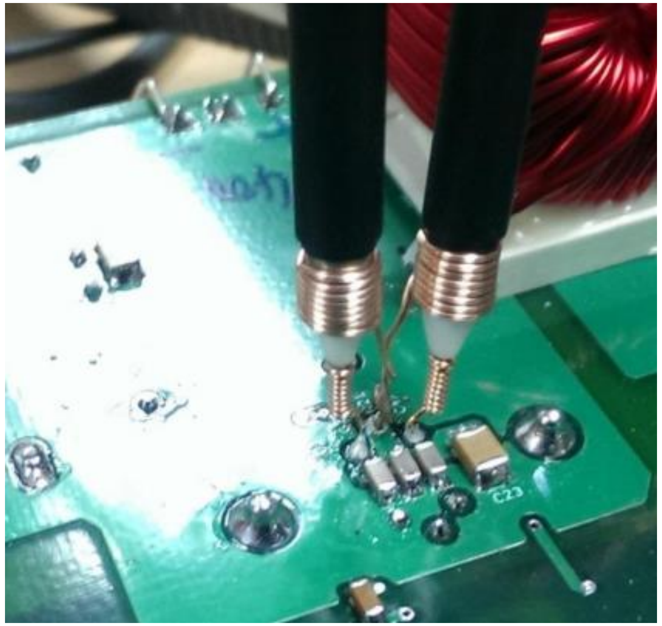
Table 3 • *DC Characteristics (Cont.)*

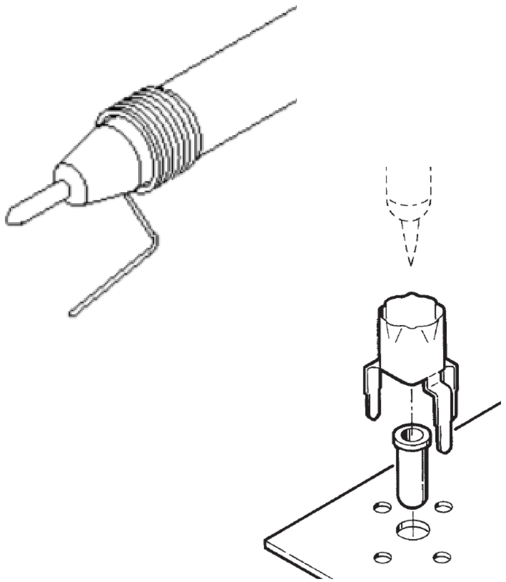
Parameter	Condition	Typ	Unit
Dead-time control voltages	30k to 80 kΩ resistor to GND	1.2	V
Dead-time from HSG going low to LSG going high	RDHL = 30 kΩ	0.8	ns
	RDHL = 80 kΩ	3.4	ns
Dead-time from LSG going low to HSG going high	RDLH = 30 kΩ	0.8	ns
	RDLH = 80 kΩ	3.2	ns
Switching Characteristics			
LSG turn-off propagation delay	At min dead time	8.4	ns
HSG rise time	10%–90%	1.0	ns
	10%–90% with 1000 pF load	2.5	
LSG rise time	10%–90%	1.0	ns
	10%–90% with 1000 pF load	1.8	
HSG fall time	10%–90%	0.9	ns
	10%–90% with 1000 pF load	2.5	
LSG fall time	10%–90%	0.9	ns
	10%–90% with 1000 pF load	1.8	
Max switching frequency @ 50% duty cycle	RDHL = RDLH = 80 kΩ	33	MHz

Pro-tip:Keep Your Ground Leads Short

Ground Springs and chassis Mounts

- Trade-off of convenience versus performance
- Smaller loop area = Lower inductance, lower noise, cleaner meas.

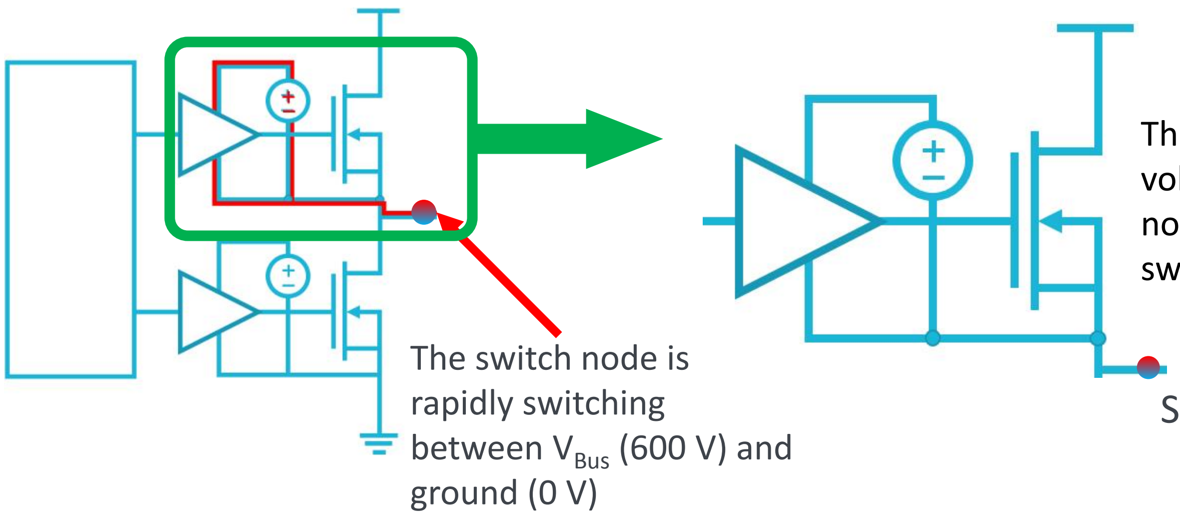




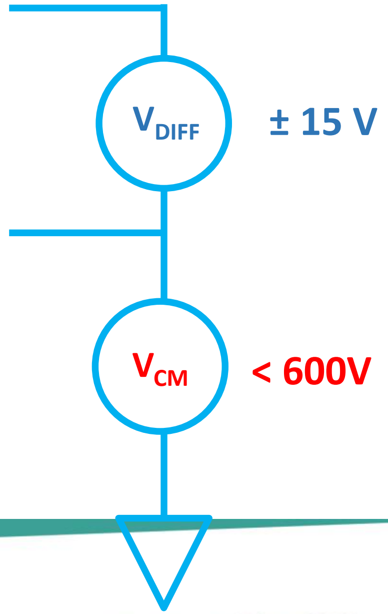
High Side Voltage Measurements

High side gate driver

- Measurement Conditions
  - The boost supply voltage is a relatively low voltage referenced to the switch node
  - Gate driver output is also referenced to the switch node
- Measurement Challenge Example: Measure a small differential voltage (± 15 V) in the presence of a large common mode voltage (600 V) when the switch node transitions very quickly (20 ns)



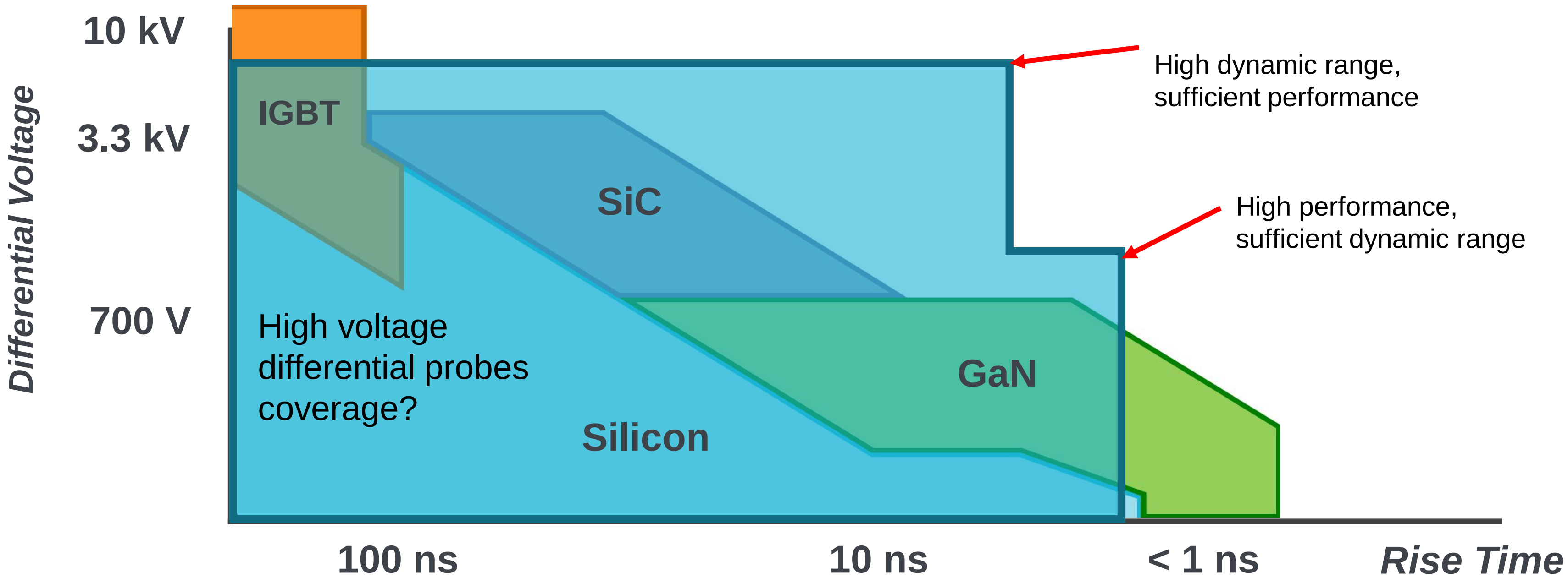
The driver's high side output or boost supply voltage and local GND are tied to the switch node and will float up and down with the switch node



High Side Voltage Measurements

At first glance, it appears existing differential probes have coverage

- A probe with the highest differential voltage is 7 kV with ~ 5 ns rise time
- A high performance differential probe offers ~ 1.5 ns rise time at 1.5 kV

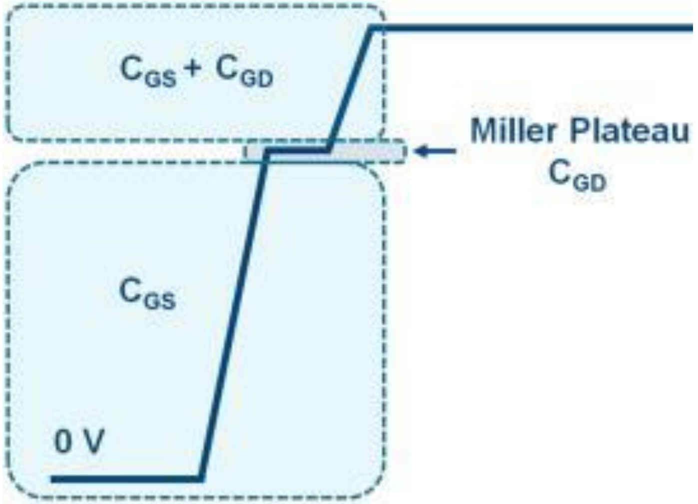


High Side Voltage Measurements

Seeing the 'Miller Plateau' – ideal representation

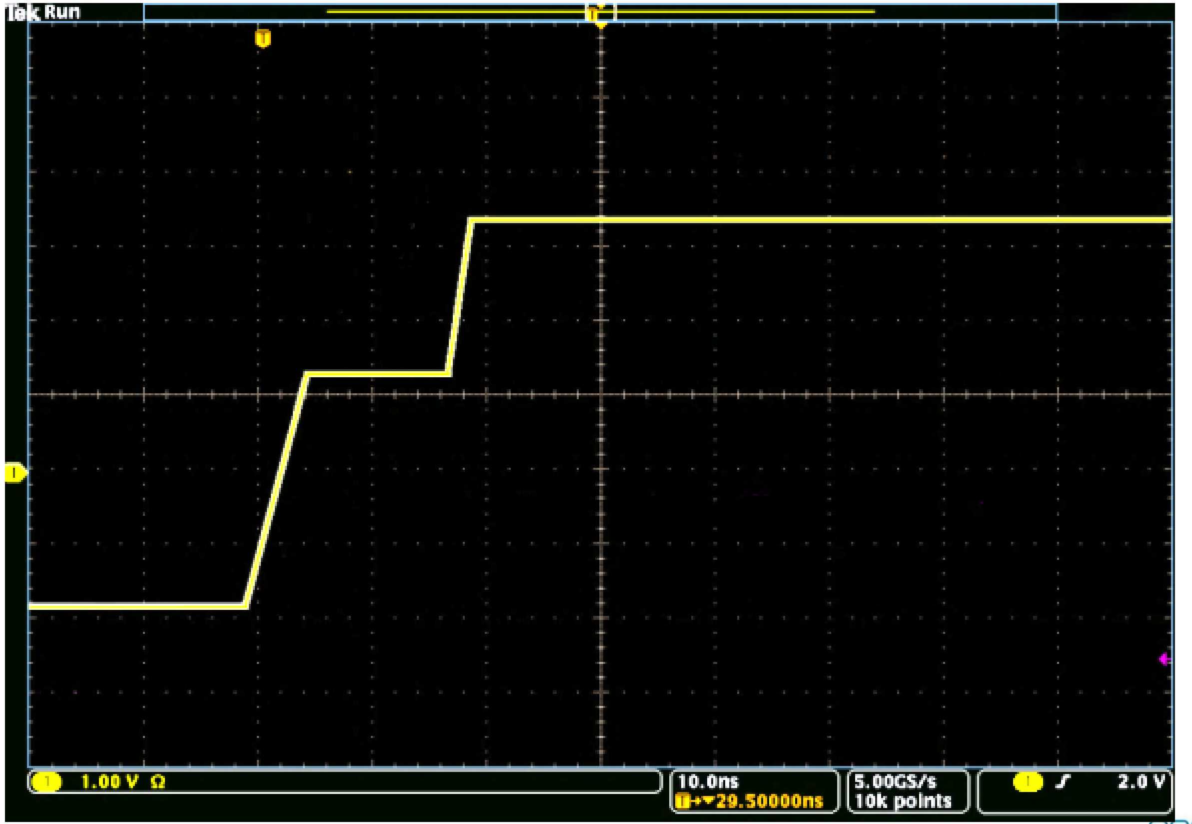
- high side Vgs turn on shows the first region being the C_{GS} charge time
- the Miller Plateau is the time required to charge the gate-drain Miller capacitance (C_{GD})
- Once the channel is in conduction, the gate will charge up to its final value.
- High Side V_{GS} requires a probe with:
  - Fast rise time capability
  - Large common mode range
  - High common mode rejection

ALL AT THE SAME TIME



High Side Voltage Measurements

Expectations from the simulation



High Side Voltage Measurements

Reality

- When the measurement doesn't match your simulation, is it your design or is it measurement error?

High Side Voltage Measurements

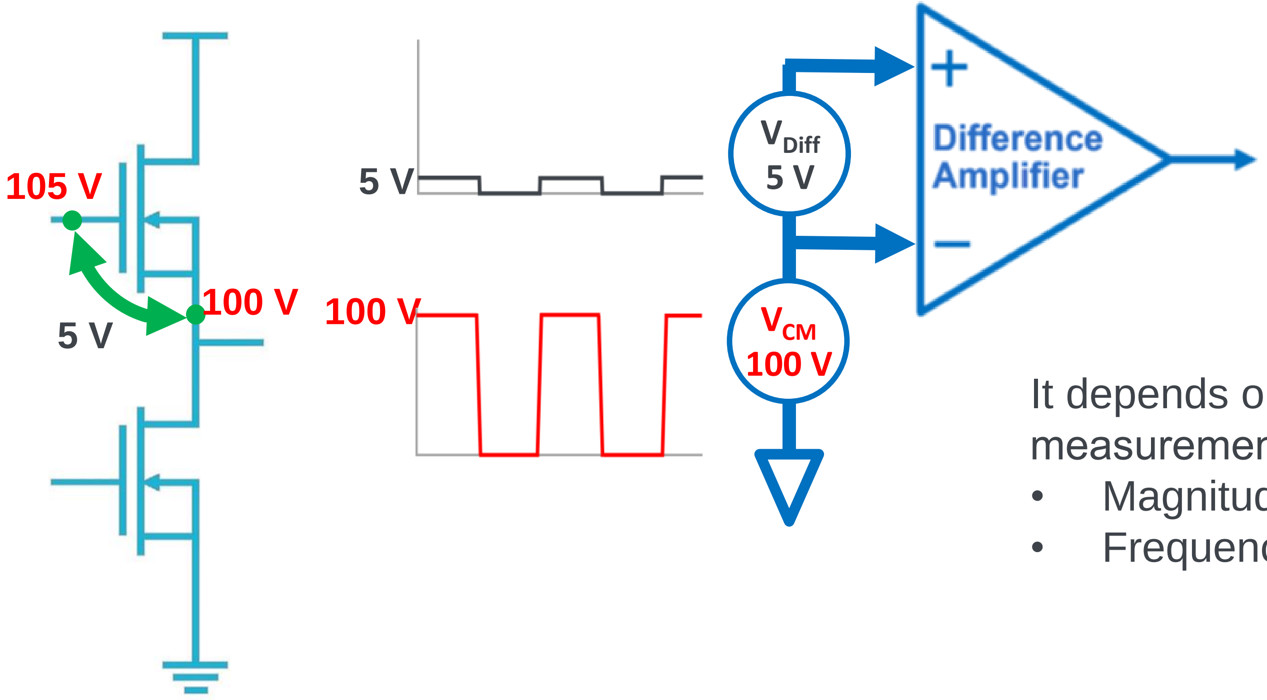
Reality

- And when you move the probe leads, the measurement result seems to change.

The Measurement Problem

CMRR is a critical but often overlooked specification

- Can a 5V differential signal be measured in the presence of 100V common mode signal?



It depends on how much common mode error is in your measurement? A probe's common mode rejection varies by:

- Magnitude of the common mode signal.
- Frequency content of the common mode signal.

How is Common Mode Rejection Specified?

Typically Only Specified at DC and Low Frequencies

This high voltage differential probe specifies a bandwidth of ≥100 MHz

Performance characteristics

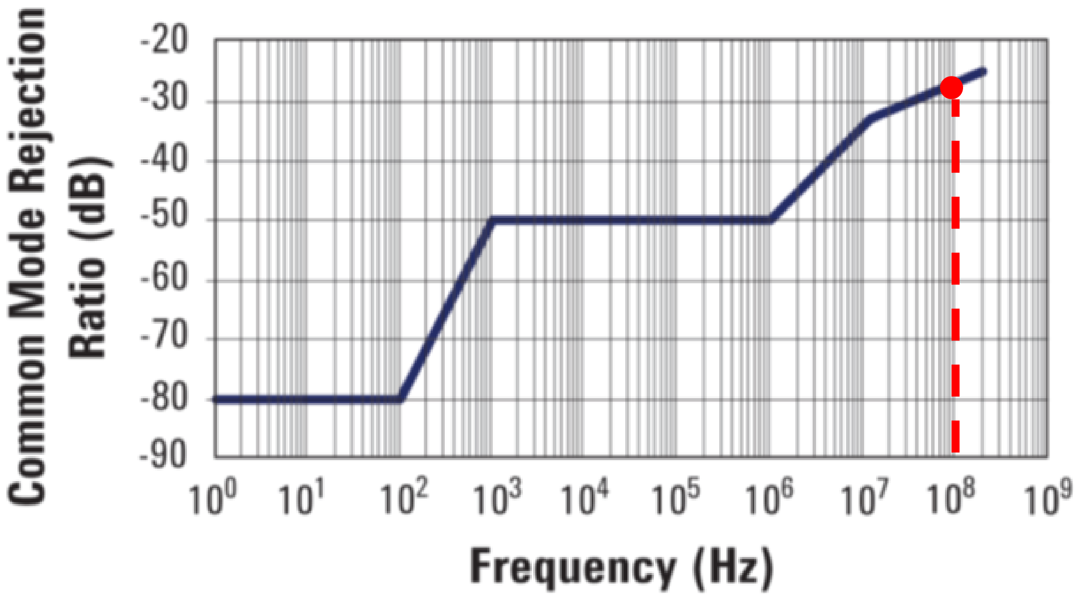
Product number	
Bandwidth (-3dB)	≥100 MHz probe bandwidth
DC CMRR	–70 dB at 500 VDC
AC CMRR	–80 dB at 50/60 Hz –50 dB at 1 kHz –50 dB at 1 MHz ←

but the data sheet only specifies CMRR to 1 MHz

WHY?

How is Common Mode Rejection Specified?

Typically Only Specified at DC and Low Frequencies

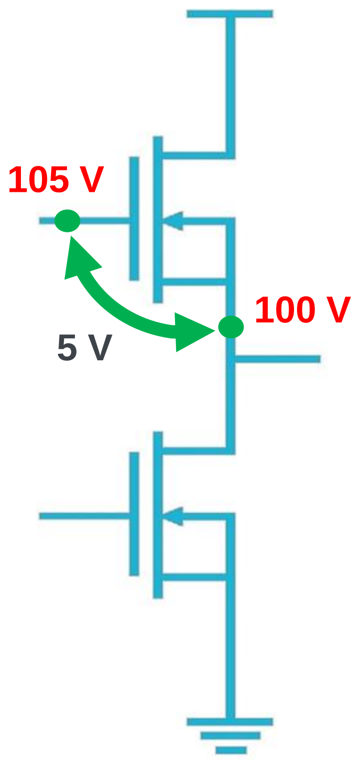


At 100 MHz, this probe has -27 dB CMRR

-27 dB CMRR? That's 22:1.
For 100 V Common Mode, Divide by 22 → ~5 V Common Mode Error

The Measurement Problem

Most probes have very poor CMRR above a few MHz



At 100 MHz, most probes have 20 dB or less common mode rejection.

This is 10:1 common mode rejection.

- With 100 V common mode voltage, 20 dB or (10:1) common mode rejection is:

  100 V divided by **10** → **10 V error**

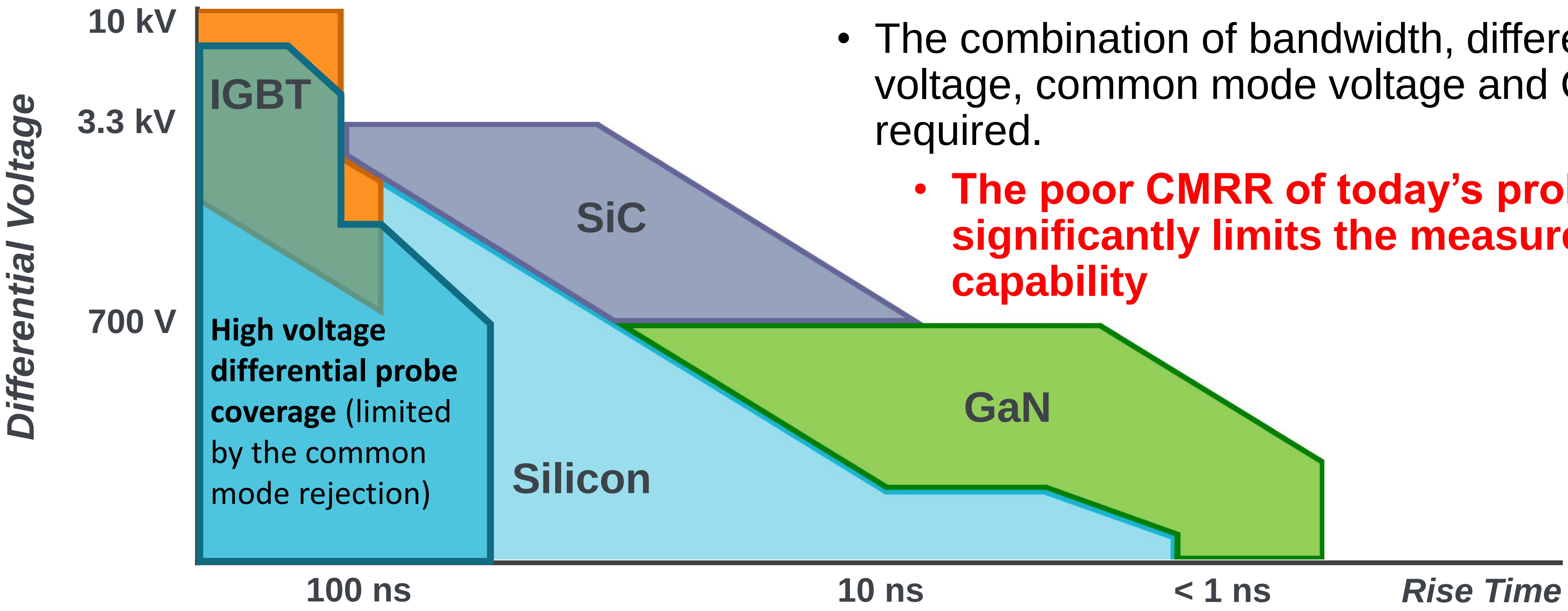
You can’t resolve 5V with 10V of error

IsoVu has 120 dB or 1 Million to 1 common mode rejection at 100 MHz

100 V divided by **1 Million** → **100 µV error**

The Measurement Problem

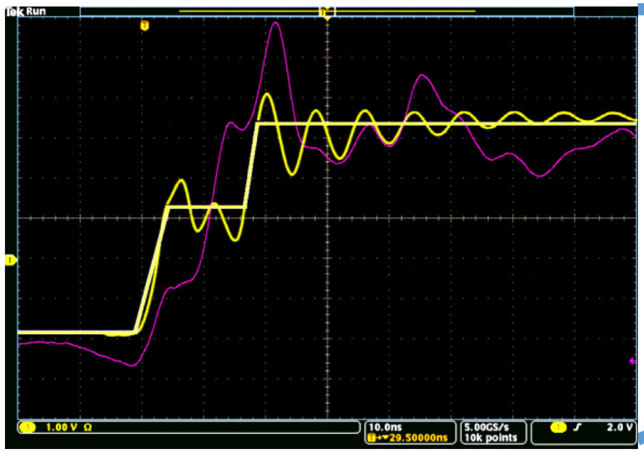
Poor common mode rejection limits the coverage

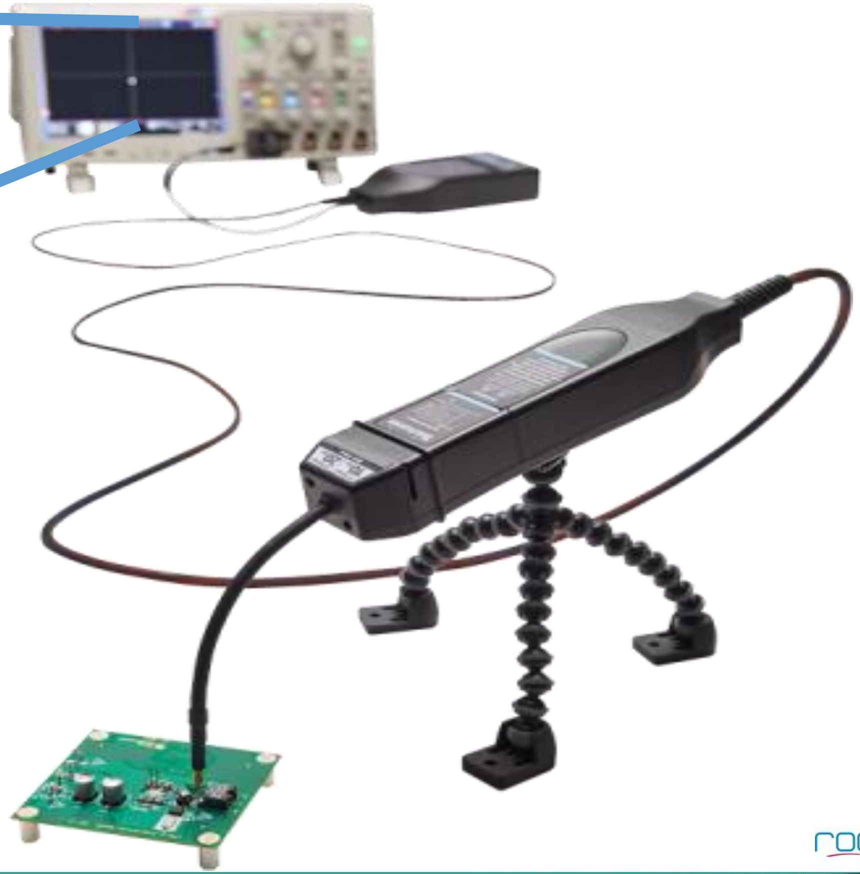


- The combination of bandwidth, differential voltage, common mode voltage and CMRR is required.
  - **The poor CMRR of today's probes significantly limits the measurement capability**

Solution

IsoVu™ technology (patented by Tektronix)

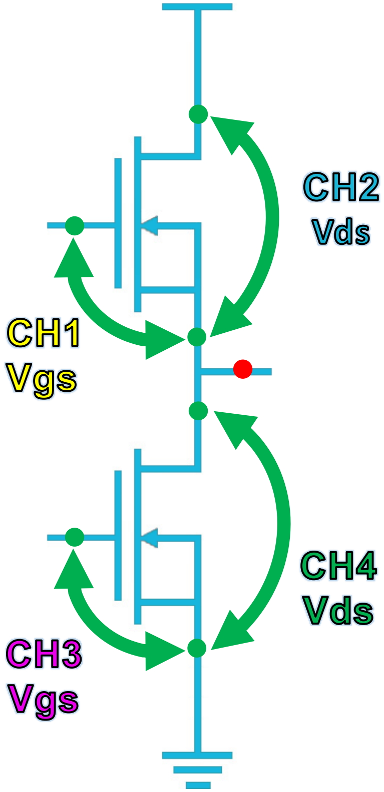




- up to **1 GHz** bandwidth (risetime <350ps)
- **World's best Common Mode Rejection**
- up to **2500 V differential** voltage range at **60 kV CM range**
- Up to **40 MΩ** input resistance

Characterize the Entire Switching Circuit

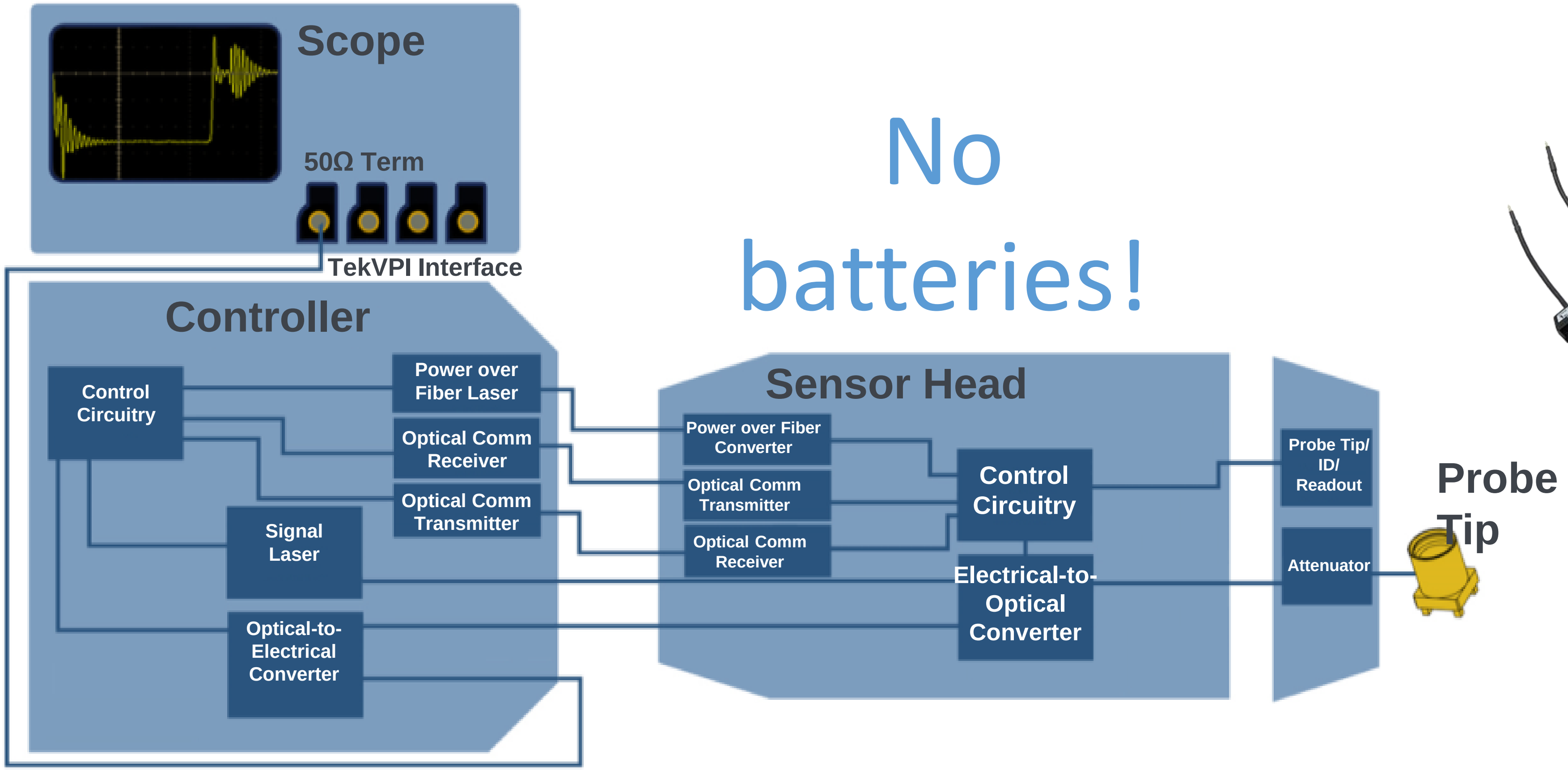
Isovu makes the hidden visible



What is IsoVu Technology?

Designed for increased sensitivity and convenience

No batteries!



Contactgegevens

- Company: CN Rood
- NL: Zoetermeer – BE: Zellik – SE: Stockholm
- E-mail: info@cnrood.com
- Standnummer: 8