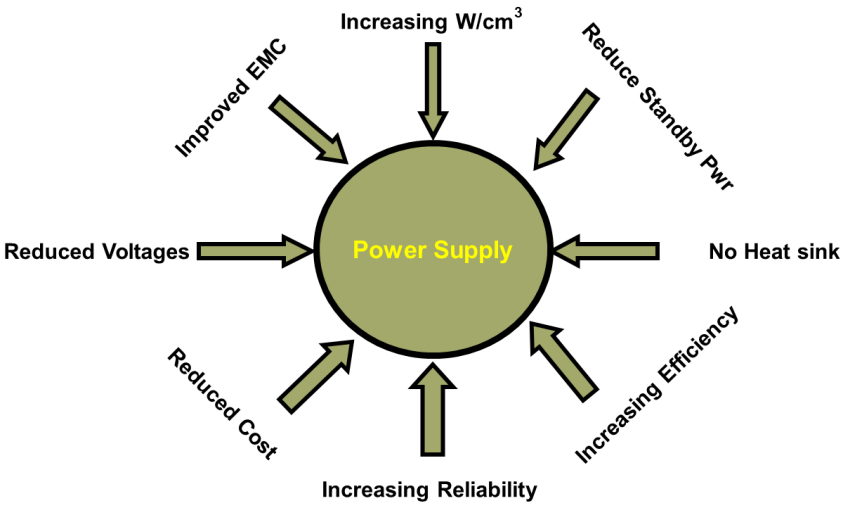
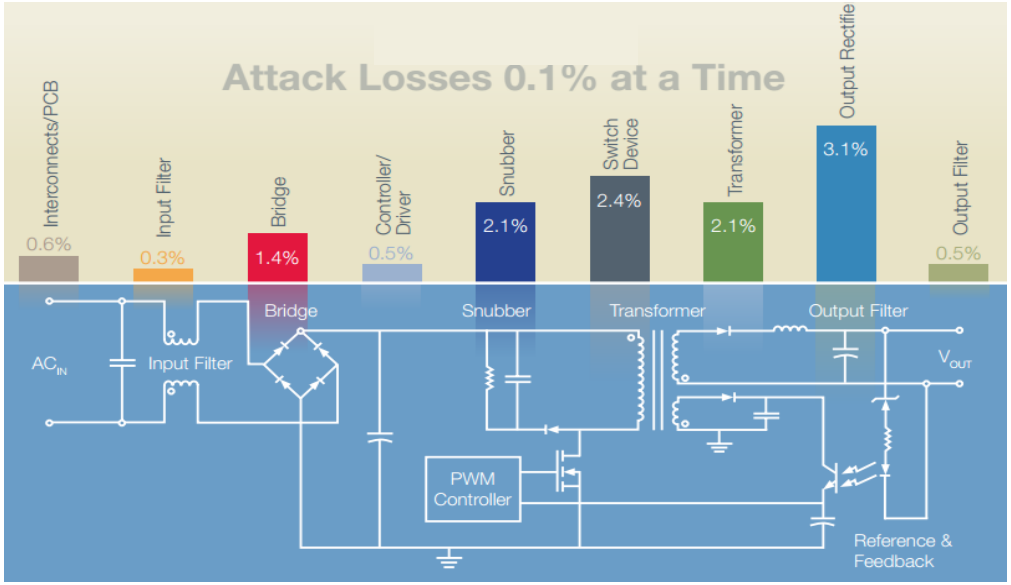
Tektronix

Safe and reliable measurements on Switch Mode Power Supplies

Power Supply Design Test

DESIGN GOALS AND POINTS OF OPTIMISATION





Technology trends

- Worldwide research on power conversion in automotive (electrical cars!) and green energy - main focus is efficiency and power density
- Faster switching speeds for higher efficiency and smaller packaging -> capacitors and inductors can be selected much smaller
- Half bridge switching is among the most popular switching topologies currently being used in power conversion
- Wide bandgap semiconductors GaN, SiC are being used to accomodate higher power at higher switching speeds and higher temperatures

Half bridge switching circuit

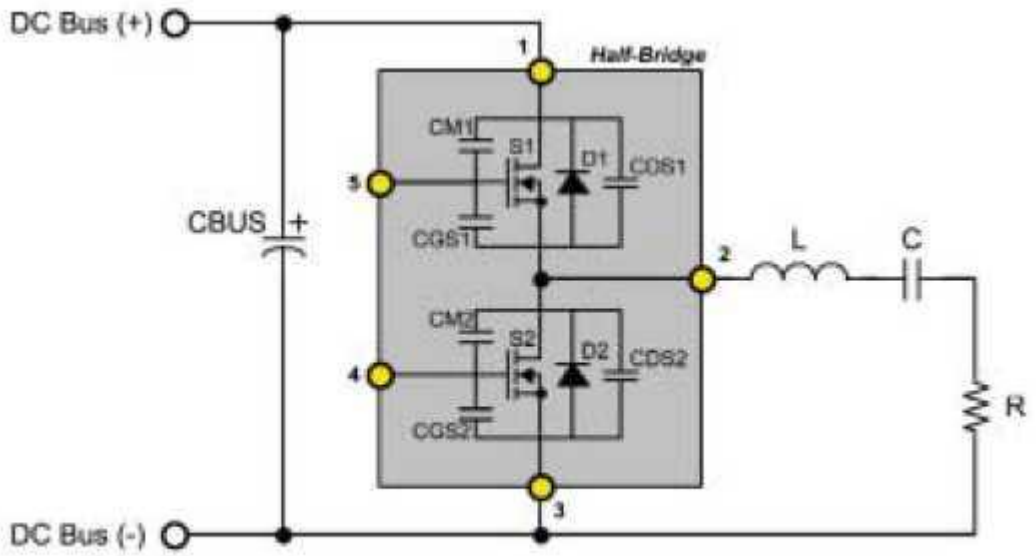


Figure 1: Half-bridge circuit and R-C-L load

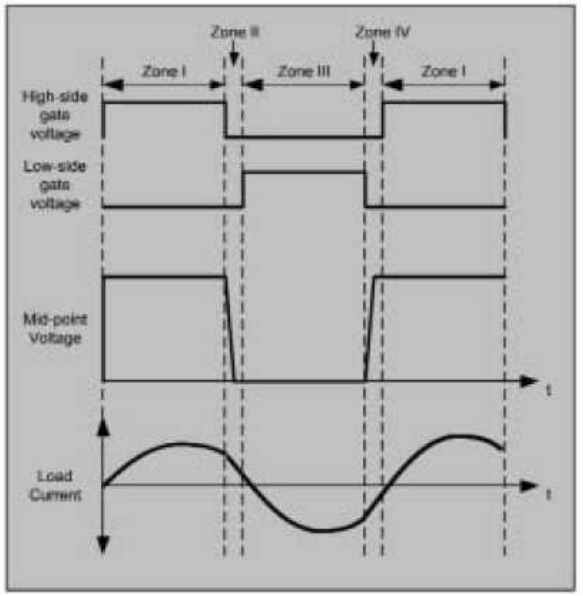


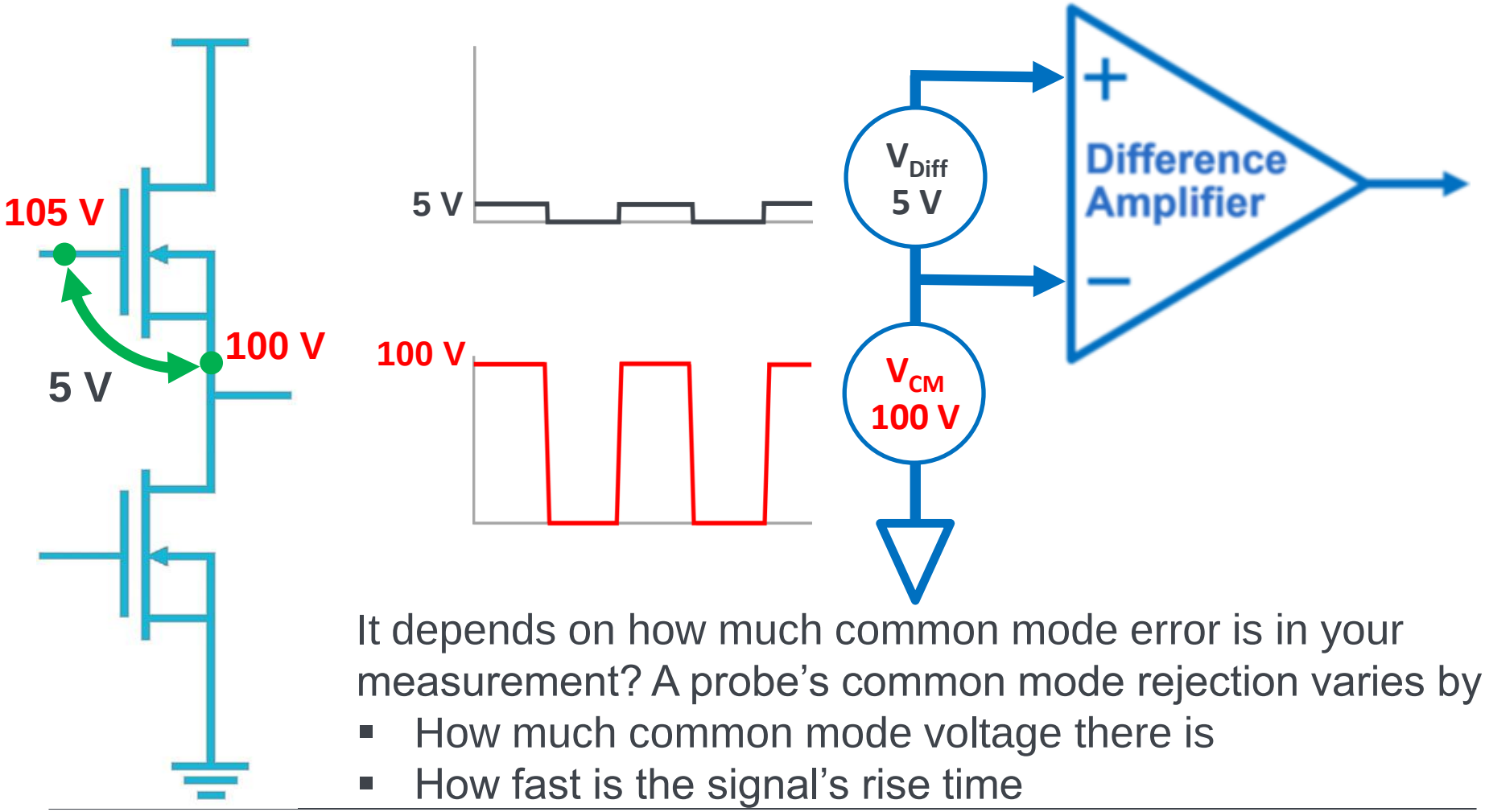
Figure 2: Half-bridge switching waveforms

- Very fast switching, harmonics into hundreds of MHz
- Fast ringing caused by different capacitances in the circuit
- Large spikes caused parasitic inductances or hard switching in the circuit
- High CMRR for the entire frequency band required, sometimes mV to measure riding on hundreds of Volts common mode signals

The Measurement Problem

CMRR IS A CRITICAL BUT OFTEN OVERLOOKED SPECIFICATION

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

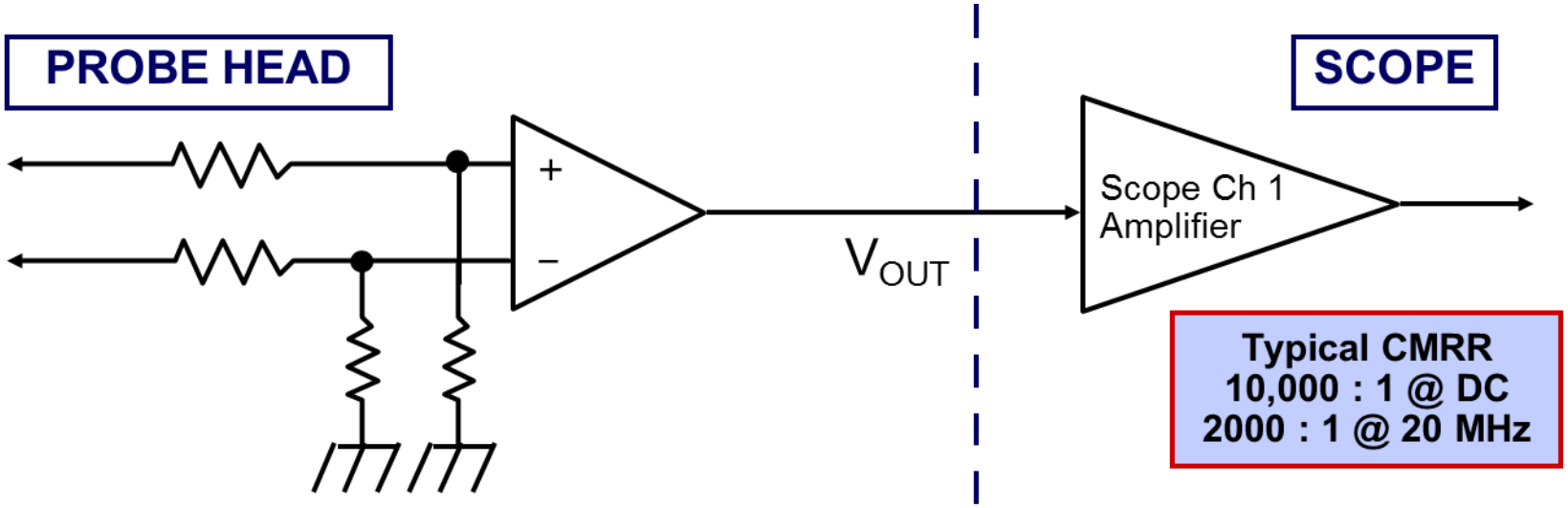


It depends on how much common mode error is in your measurement? A probe's common mode rejection varies by:

- How much common mode voltage there is
- How fast is the signal's rise time

Why aren´t traditional floating measurements adequate?

DIFFERENTIAL PROBES



Advantages:

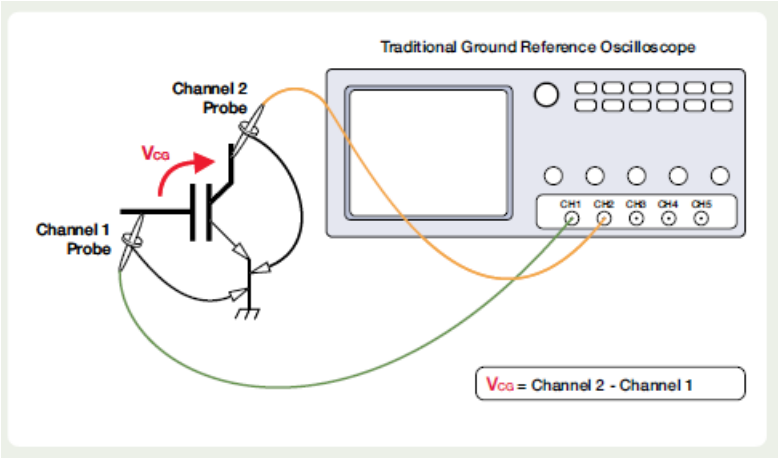
- Lower Input Capacitance
- Higher CMRR vs Frequency Than Passive Differential Pair

Disadvantages:

- Strong degradation of CMRR for higher frequencies
- Limited Dynamic Range

Why aren´t traditional floating measurements adequate?

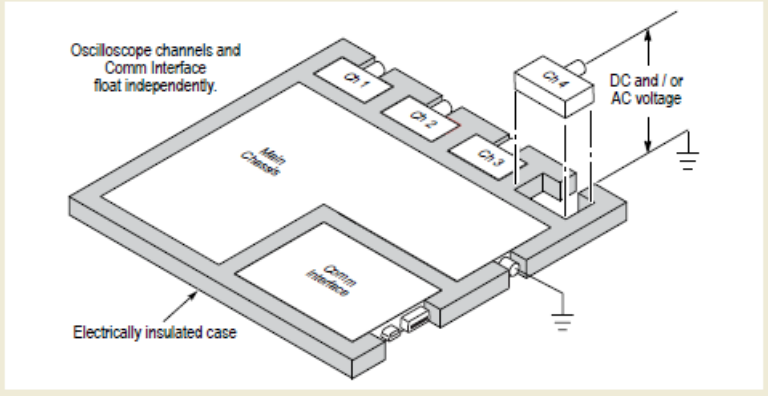
TWO SINGLE-ENDED PROBES PLUS SCOPES MATH



- Cheap
- Requires deskew
- Requires 2 channels
- Very poor CMRR

Why aren´t traditional floating measurements adequate?

ISOLATED CHANNEL OSCILOSCOPES

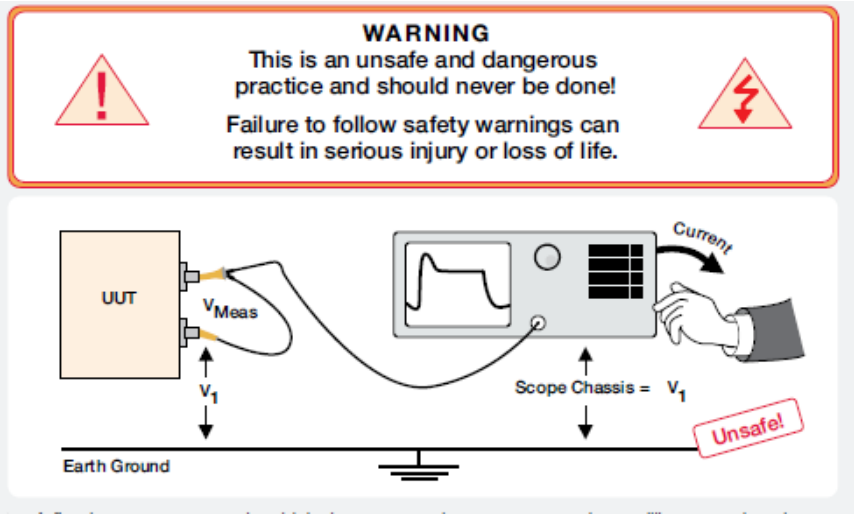


- Battery operated
- Isolated channels up to 1000Vrms
- Special passive probes

- Scope performance not adequate
- <200MHz bandwidth
- < 60dB CMRR derating over frequency
- Relatively high input capacitance

Why aren´t traditional floating measurements adequate?

FLOATED OSCILLOSCOPES



- Unfortunately quite common
- Scope chassis to earth connection interrupted
- Cheap but very dangerous
- Scope chassis can be floated thru the probes ground lead to potentially lethal voltages

What is IsoVu Technology?

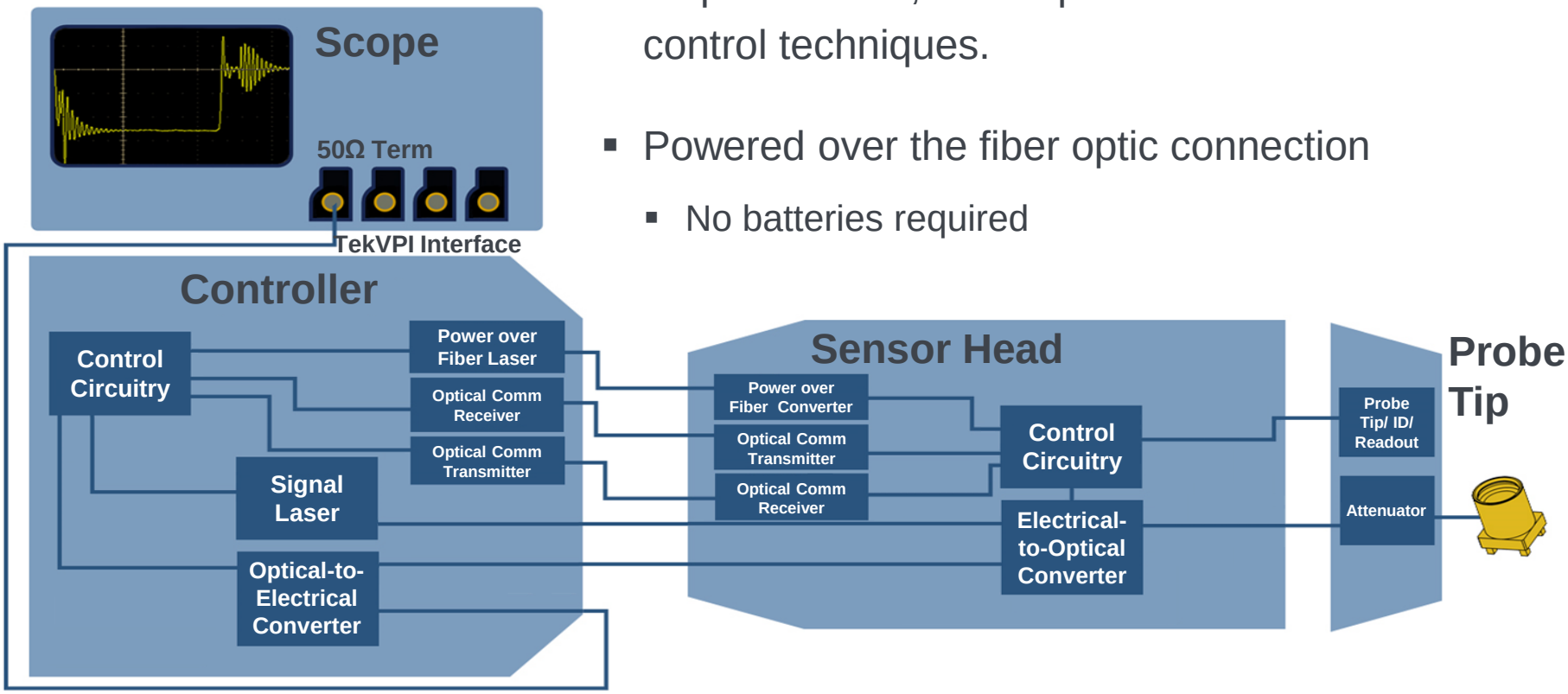
IsoVu™ technology is a radically new high voltage isolated differential probing solution that gives **Accurate** and **Repeatable** results

- Galvanically isolates the device-under-test from the oscilloscope.
- **1 GHz** bandwidth
- Impressive Common Mode Rejection
  - Up to **160 dB** (100 Million to 1)
- **> 1000 V differential** voltage range
- **60 kV** common Mode voltage range
- Up to **40 MΩ** input resistance

What is IsoVu Technology?

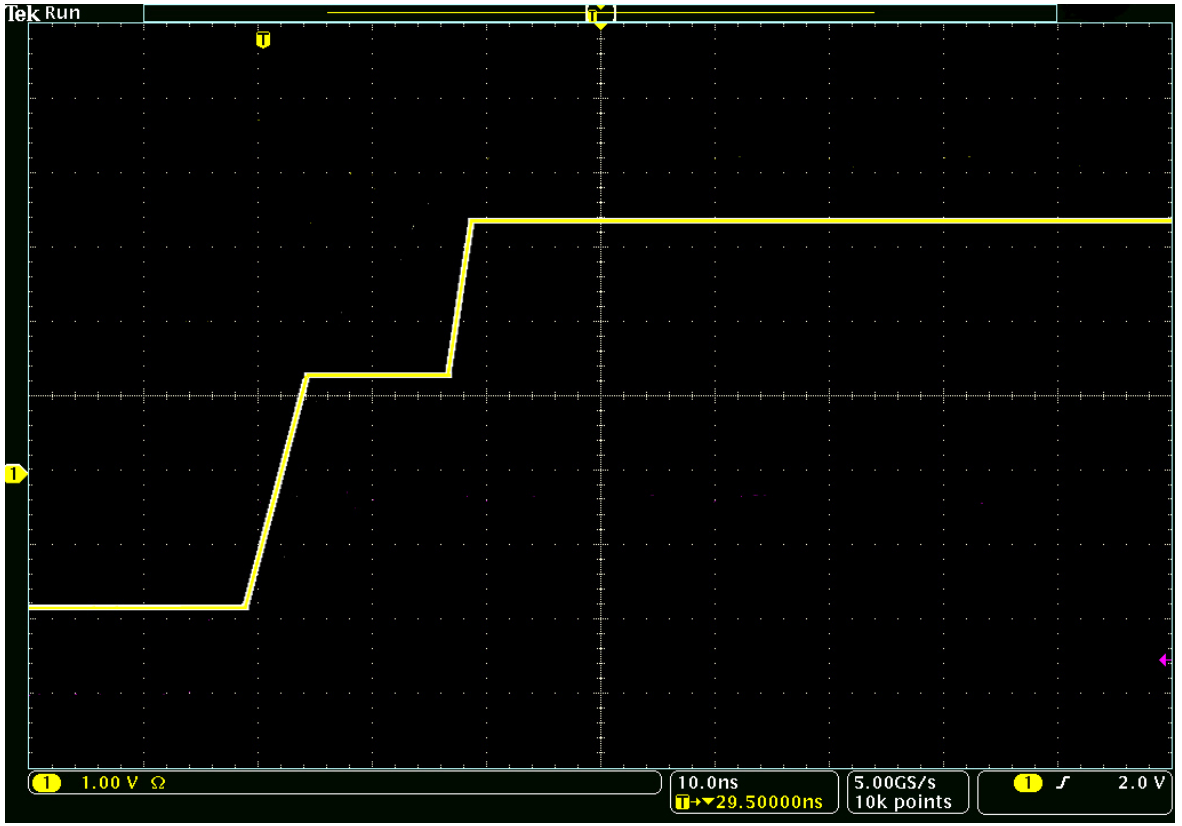
IsoVu™ utilizes an electro-optic sensor to convert the input signal to **optical modulation**

- Incorporates 4 separate lasers, an optical sensor, 5 optical fibers, and sophisticated feedback and control techniques.
- Powered over the fiber optic connection
  - No batteries required



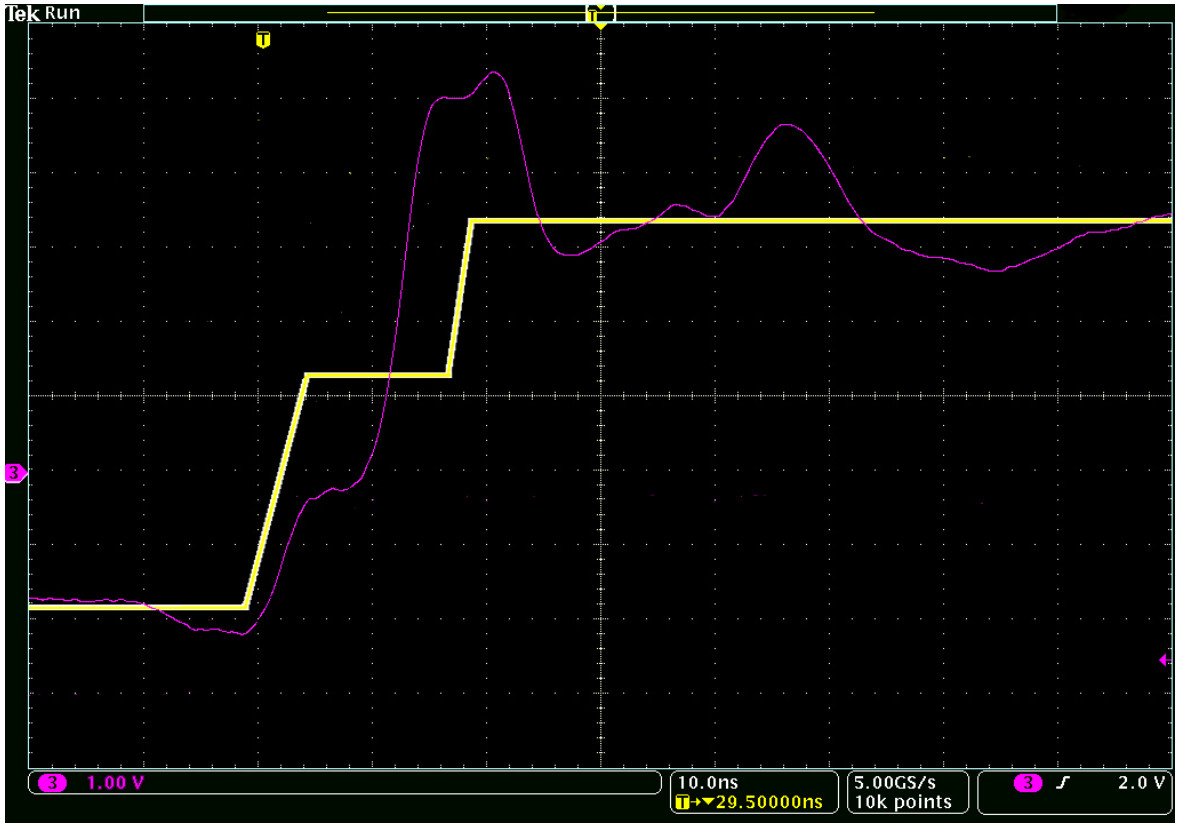
Do Your Measurements Match Your Expected Results

- You run your simulations and this is the waveform you expect



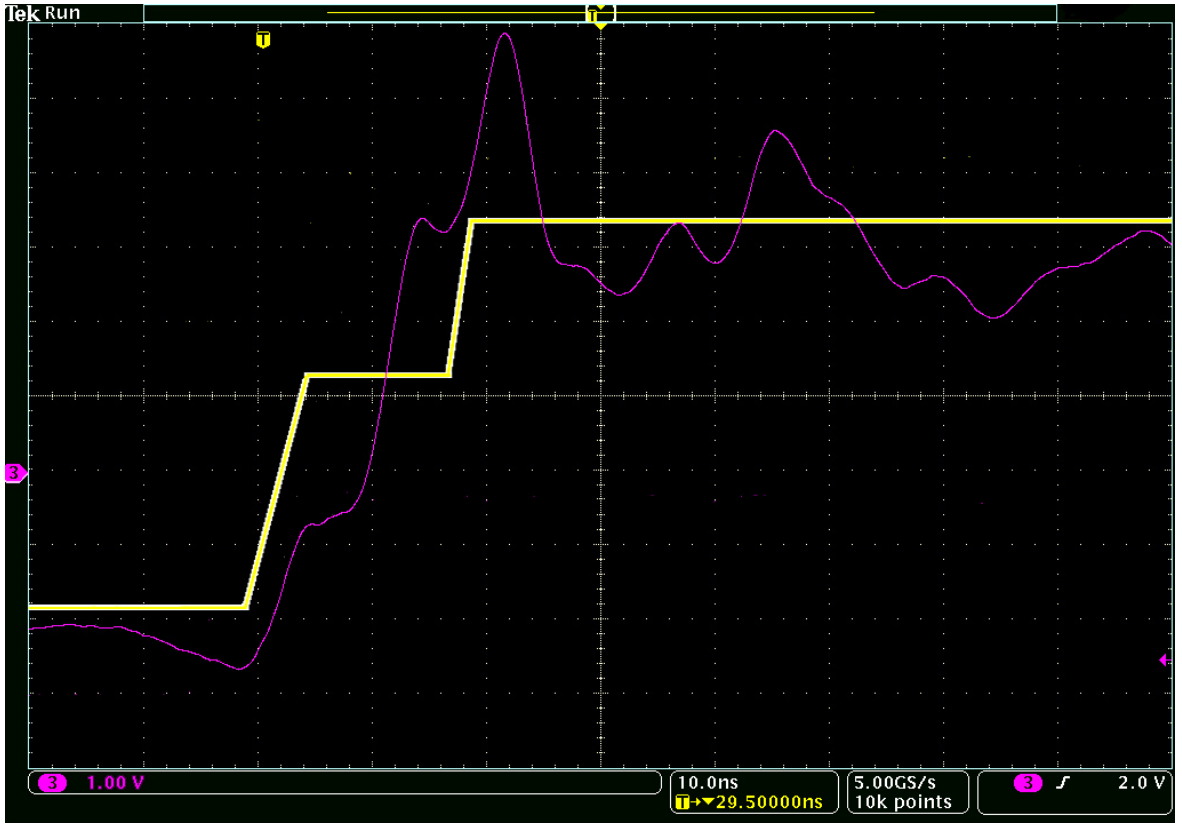
Do Your Measurements Match Your Expected Results

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



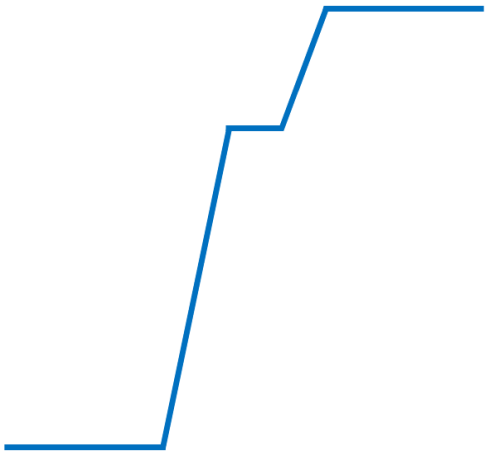
Do Your Measurements Match Your Expected Results

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

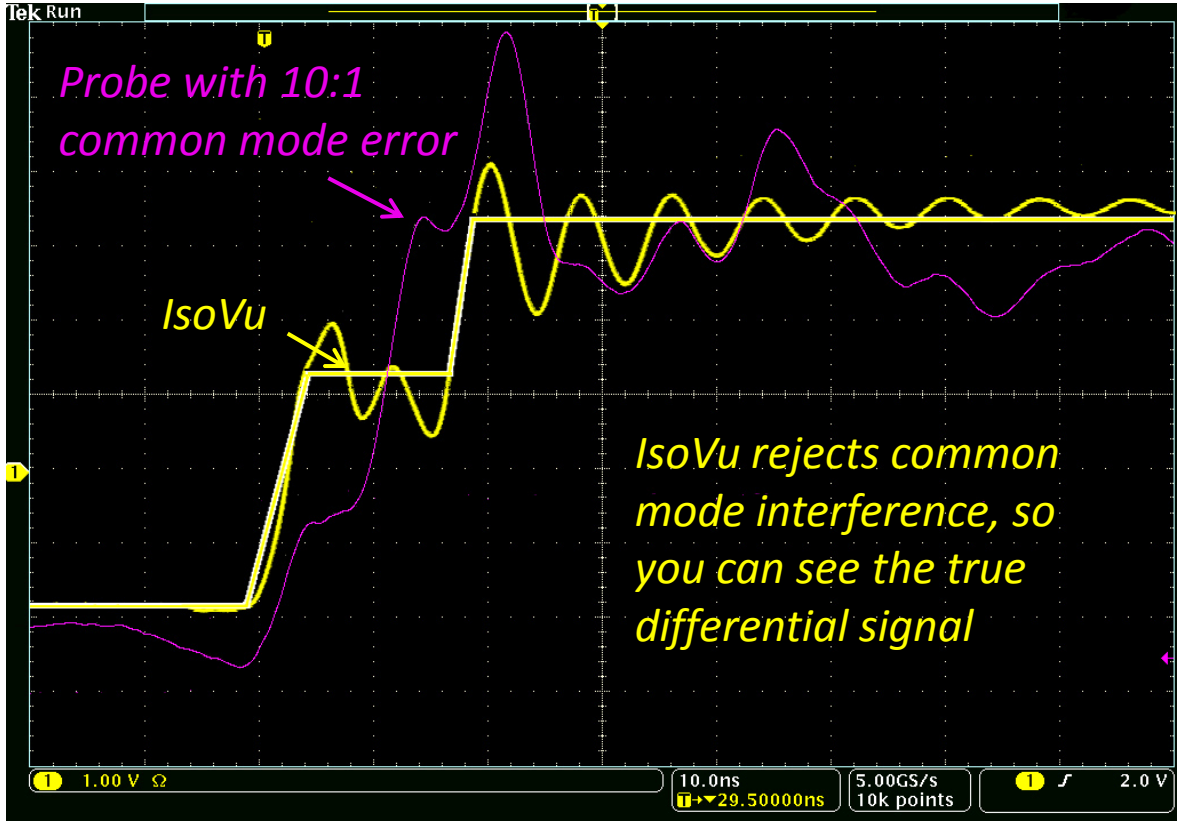


Do Your Measurements Match Your Expected Results

- IsoVu gives you an accurate, repeatable measurement providing meaningful correlation with expected performance

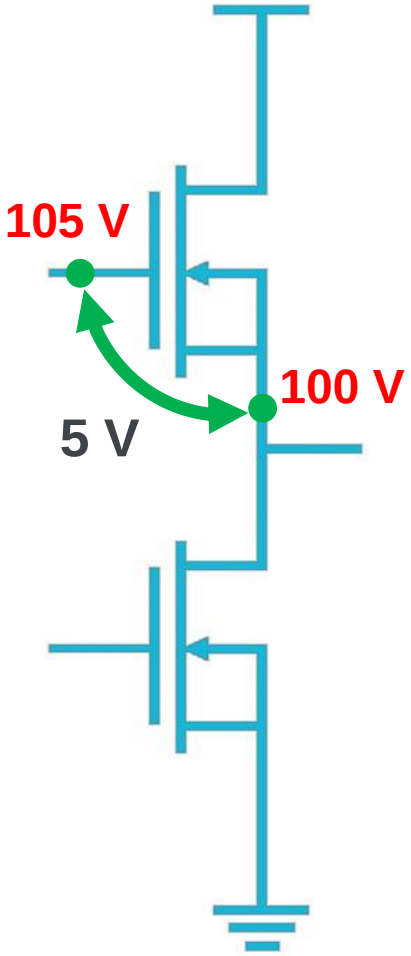


Expected Simulation Results



IsoVu Solves the Common Mode Problem

MOST PROBES HAVE VERY POOR CMRR ABOVE A FEW MHZ



At 100 MHz, most probes have 20 dB or 10:1 common mode rejection

The common mode error with 100 V common mode voltage using a probe with 20 dB (10:1) common mode rejection is: **100 V** divided by **10** → **10 V error**

IsoVu has 160 dB or 100 Million to 1 common mode rejection at 100 MHz

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

How is Common Mode Rejection Specified

Typically Only Specified at DC and Low Frequencies

This probe specifies a bandwidth of ≥100 MHz

Performance characteristics

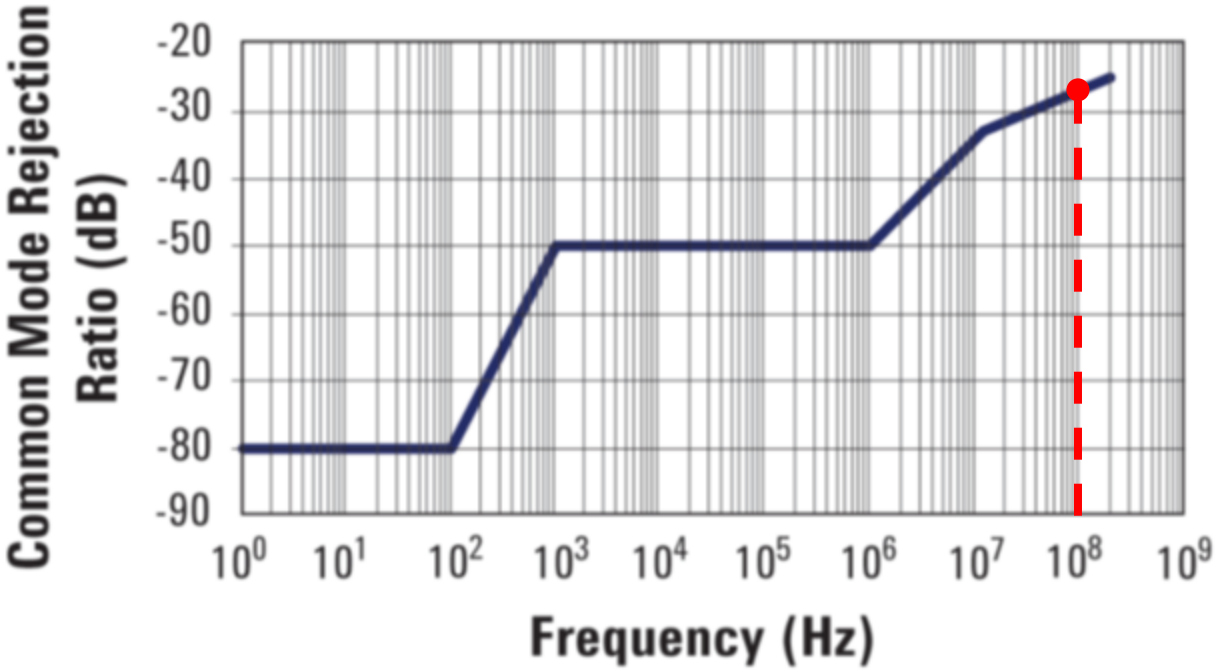
Product number	
Bandwidth (-3dB)	≥100 MHz probe bandwidth
DC CMRR	–70 dB at 500 VDC
AC CMRR	–80 dB at 50/60 Hz –50 dB at 1 kHz –50 dB at 1 MHz ←

but the data sheet only specifies CMRR to 1 MHz

WHY?

How is Common Mode Rejection Specified

Only at DC and Low Frequencies



At 100 MHz, this probe has -27 dB CMRR

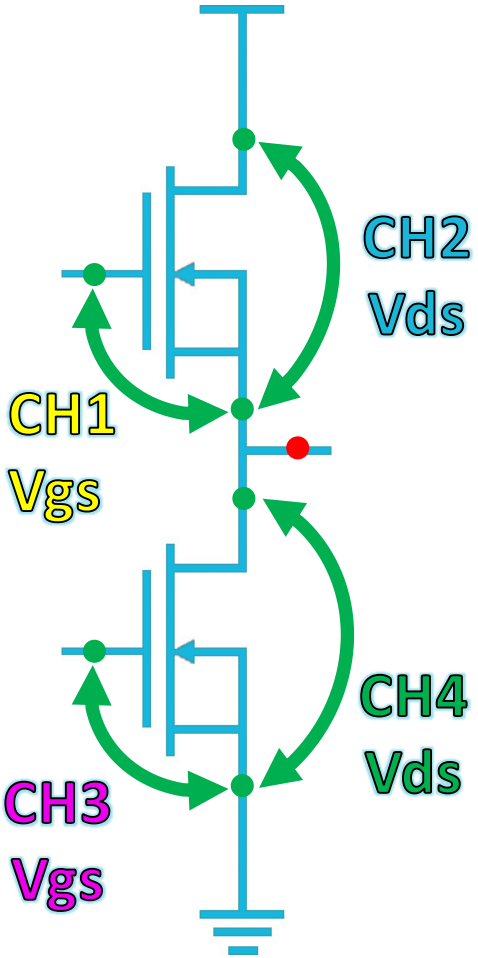
-27 dB CMRR? That's 22:1.

For 100 V Common Mode, Divide by 22

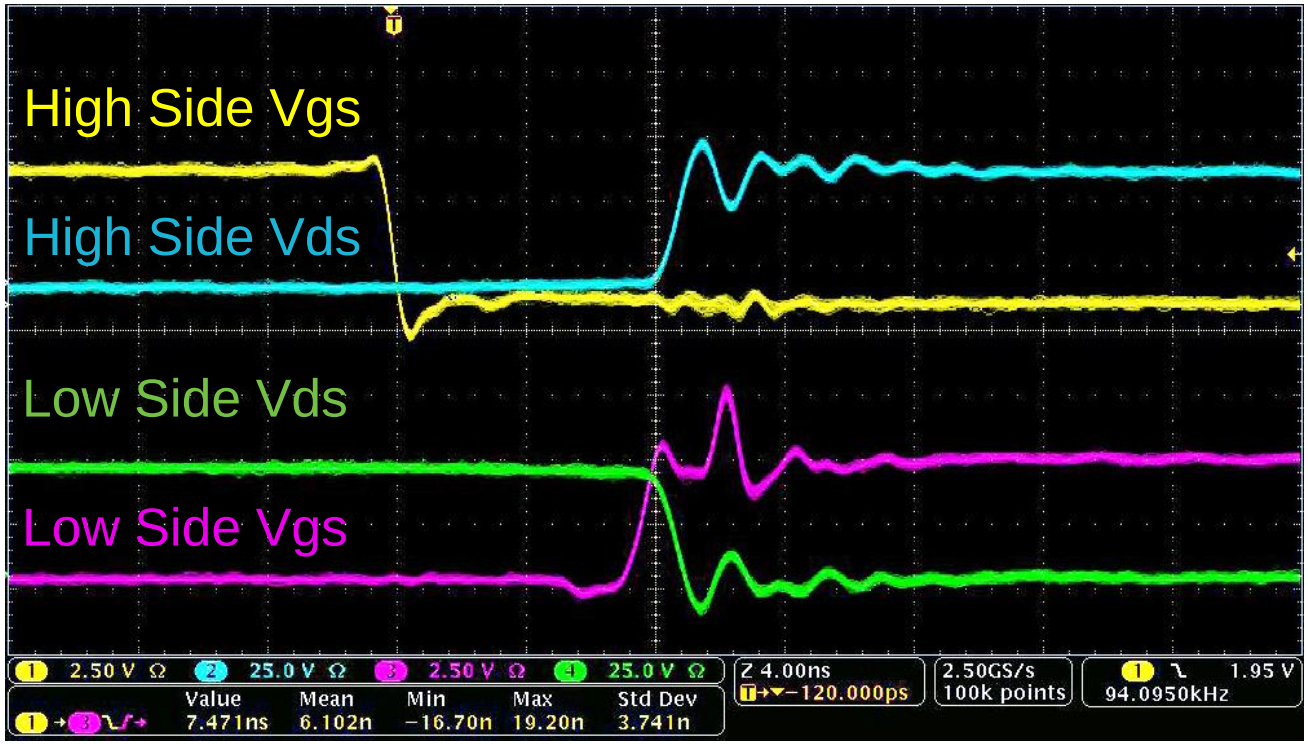
→ ~5 V Common Mode Error

Characterize the Entire Switching Circuit

BUT ISOVU MAKES THE HIDDEN VISIBLE



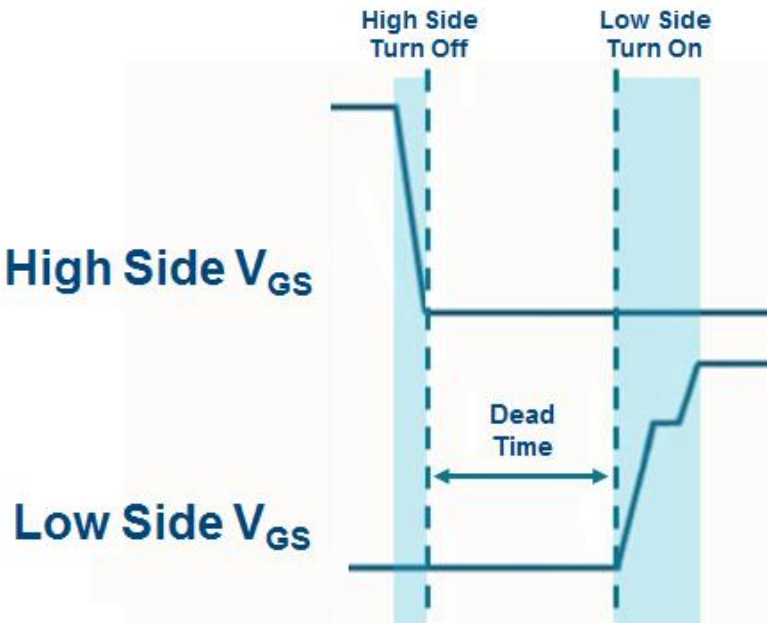
- Characterize the gate voltages, Vds, and Is
- Characterize the time alignment of high and low side events
- Optimize and tune switching characteristics (edge rates, overshoot, ringing and dead time)

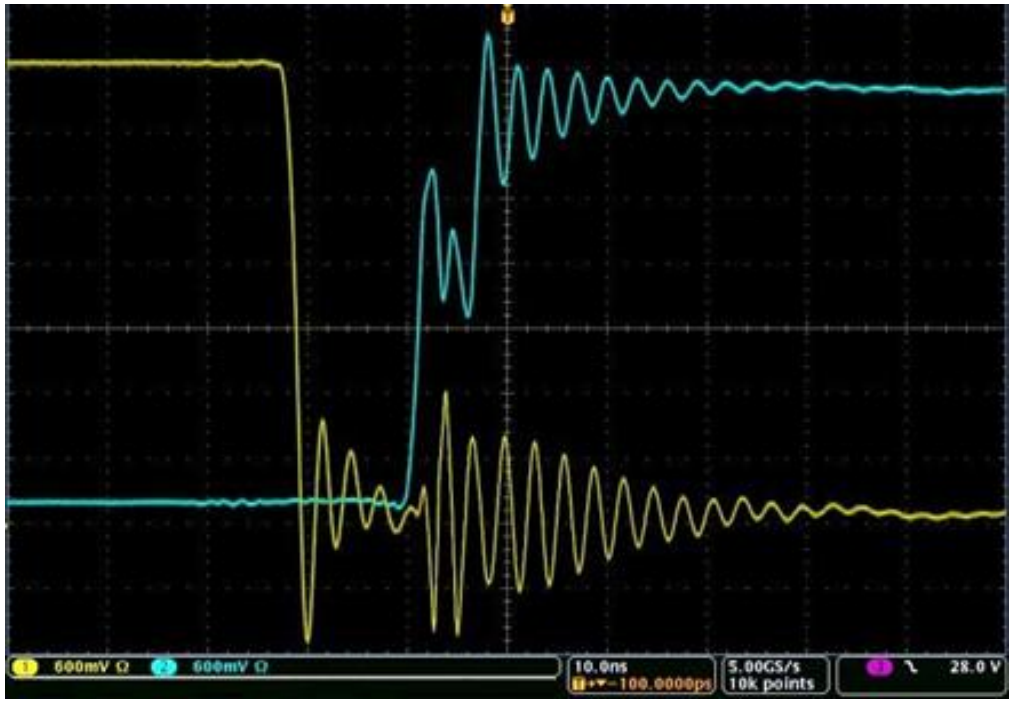


High-Side Gate Measurements

INTERACTION BETWEEN THE HIGH AND LOW SIDE

- Violation of specifications can lead to simultaneous conduction (it blows up), switch loss, loss of efficiency, and device degradation
- Parasitic coupling between switch node and both FETs

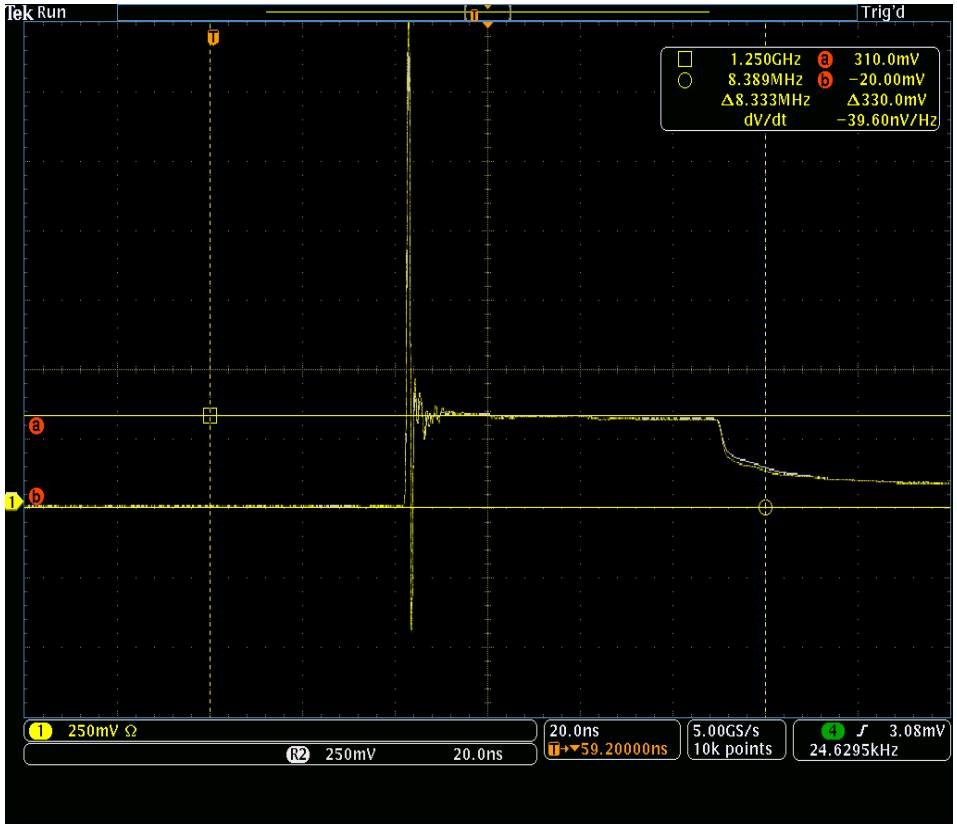




IsoVu Demo Video

Current measurements thru a shunt

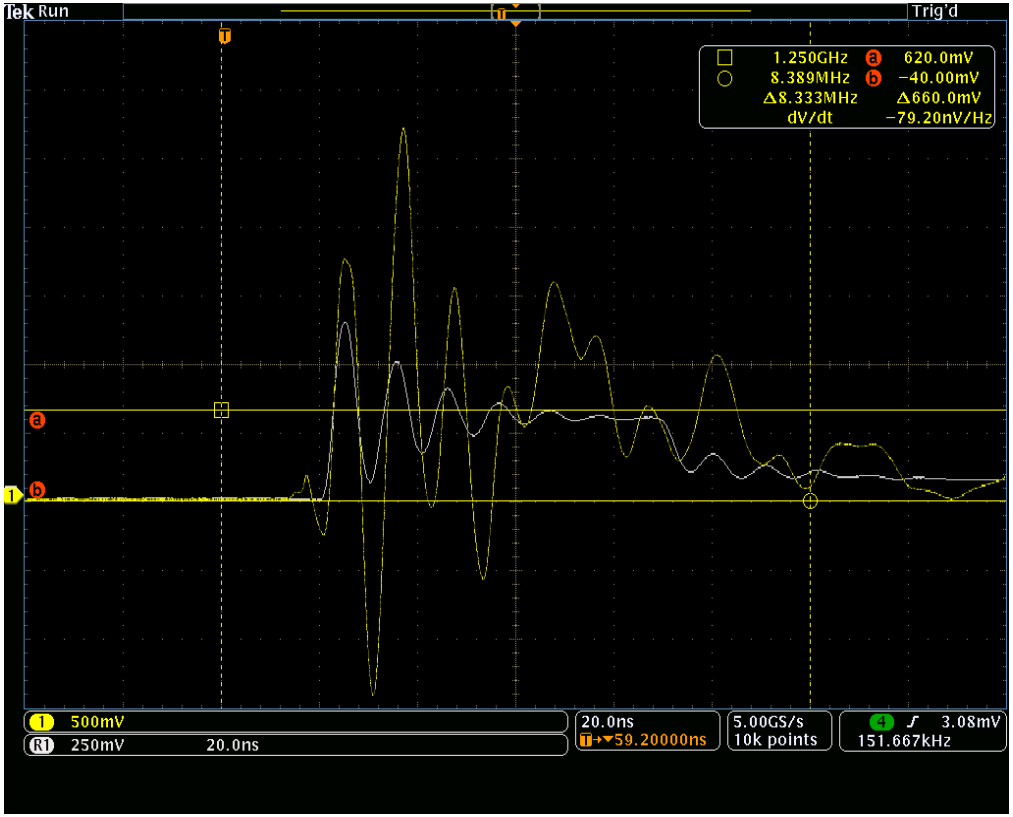
ISOVU PROBE



- Overshoot caused by shunt resisitor inductance
- Excellent CMRR allows for accurate current measurement
- This is showing 250mV diff on 50V common mode!

Current measurements thru a shunt

CONVENTIONAL DIFFERENTIAL PROBE



- High side vs low side current measured over shunt
- Measurements inaccurate and non repeatable due to bad CMRR

Different Tip Connectors

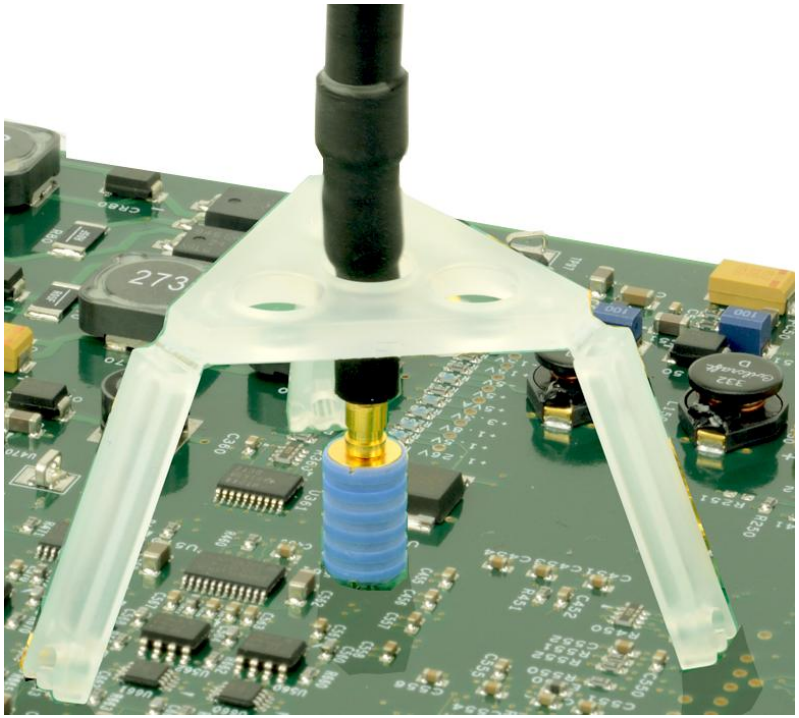
DESIGNED FOR OPTIMAL PERFORMANCE AND CONVENIENCE

- Planned test points (MMCX Connectors) → Best Performance
  - MMCX connectors are small, inexpensive test adapters that can be purchased from Digi-key or other vendors

Different Tip Connectors

UNPLANNED TEST POINTS

- Square Pin Adapter
  - High performance square pin adapter designed to minimize the performance impact of the square pins



IsoVu Technology Delivers

CHARACTERIZE THE ENTIRE CIRCUIT

- Simultaneously measure high-side V_{GS}, V_{DS}, and I_S
- Optimize and tune switching characteristics (edge rates, overshoot, ringing, dead time)
- Characterize time alignment of high and low side events

	ISOVU TIVM SERIES	ISOVU TIVH SERIES
Bandwidth	Up to 1 GHz	Up to 800 MHz
Rise Time	Down to 350 ps	Down to 450 ps
Differential Voltage Range	± 50 V	> 1000 V
Common Mode Voltage Range	60 kV	60 kV
Common Mode Rejection Ratio	DC – 1 MHz: 160 dB (100 Million to 1) 1 MHz – 100 MHz: 120 dB (1 Million to 1) 1 GHz: 80 dB (10,000 to 1)	DC – 1 MHz: 160 dB (100 Million to 1) 1 MHz – 100 MHz: 120 dB (1 Million to 1) 800 MHz: 80 dB (10,000 to 1)
Input Impedance	Up to 2.5 kΩ < 1 pF	Up to 40 MΩ As low as 2 pF
Fiber Cable Length	3 meters or 10 meters	3 meters or 10 meters
Power Over Fiber	Powered over the fiber connection – no batteries required	Powered over the fiber connection – no batteries required
Input Offset	± 100 V	Up to > 1000 V
AC Input Coupling	No	Yes

Note: Specifications are dependent on the probe tip cable

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