POWER ANALYSIS & EMI DEBUGGING WITH R&S OSCILLOSCOPE

ROHDE & SCHWARZ

Make ideas real

TOPICS

- Power Integrity
  - Choosing the Right Probes
  - Floating Measurement
  - Power Rail Probe
  - Current Probe
- Use Cases
- EMI Debugging
- Q&A

WHY POWER INTEGRITY MATTERS?

POWER ELECTRONICS DESIGN

Design Flow

A. Check sub-circuits and (gate) timing without DC-Link voltage

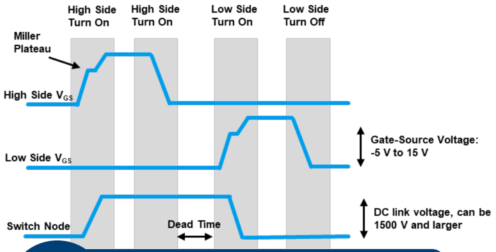
B. Check for FET ratings at nominal DC-Link voltage

C. Analyze passive components (L,C)

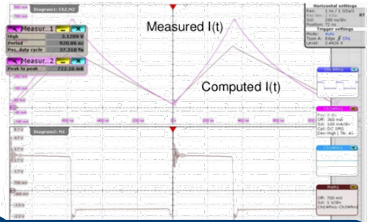
D. Analyze Start-up and load variations, efficiency, stability

E. Check environmental – thermal and DC-link variations

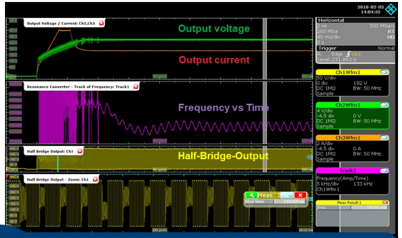
F. EMI analysis (conducted, radiated)



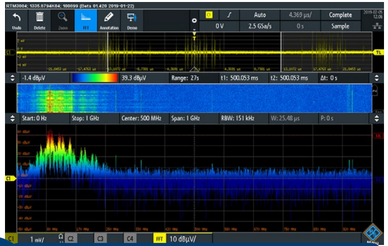
1 Probing



2 Math functionality



3 Analysis capabilities

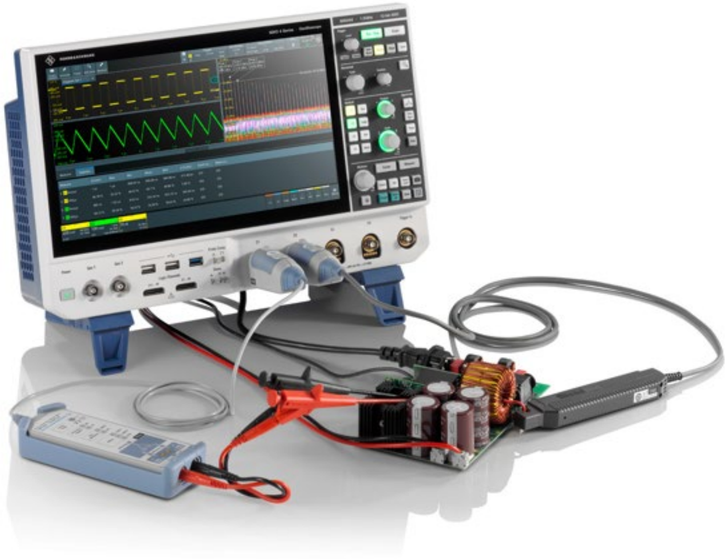


4 FFT performance

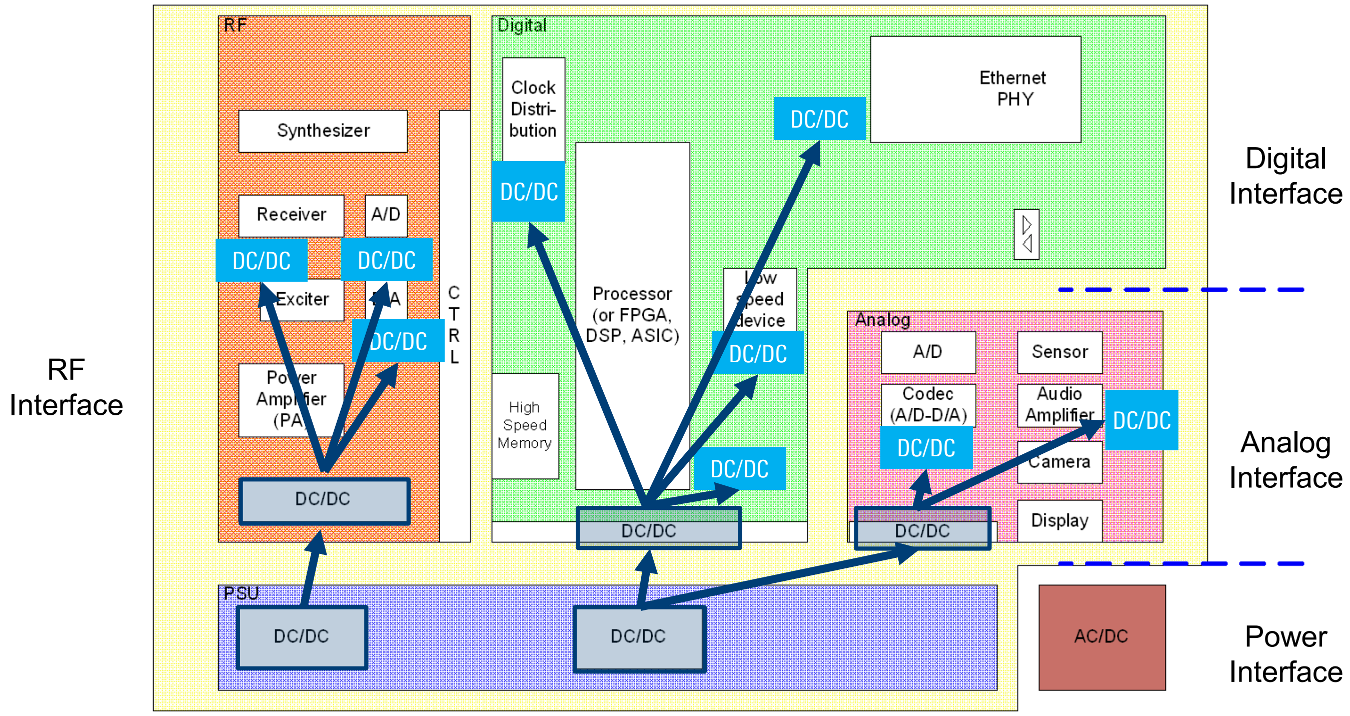
MEASURING SIGNALS IN THE CIRCUIT IS NOT EASY

- Signal is not easy to reach
- There is a lot of noise around
- Safety is a concern
- Current and voltage signals have different propagation delay

- **Voltage probing**
  - Floating measurements
  - Understanding common-mode rejection ratio
  - Other important probe parameters
- **Current probing options**
- **Other things to consider**

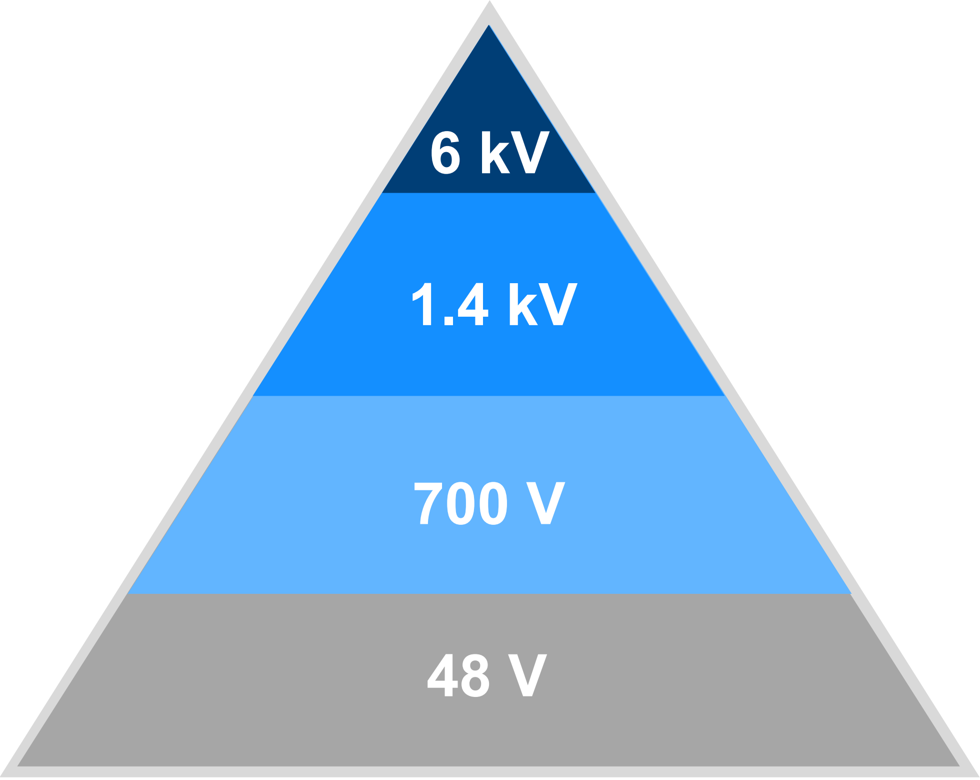


POWER INTEGRITY ACROSS ALL INTERFACES



- Most circuit chipsets and design are based on DC supplies
- They rely on the source stability and expect them to be steady and quiet

MEASURING VOLTAGE



High-Voltage differential probes (e.g. RT-ZHD07/15/16/60)

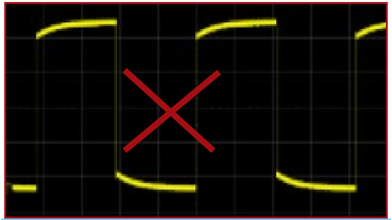
Isolated channel oscilloscopes

High-Voltage Passive Probes

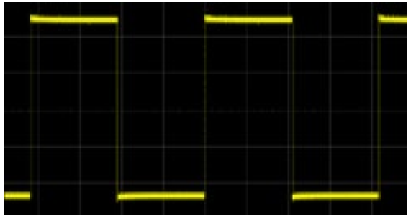
Broadband differential pro

Standard Passive Probes

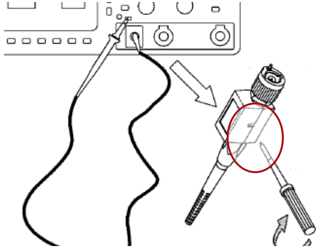
COMPENSATE YOUR PASSIVE PROBE BEFORE USE

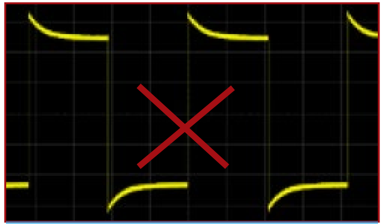


Under-Compensated Signal

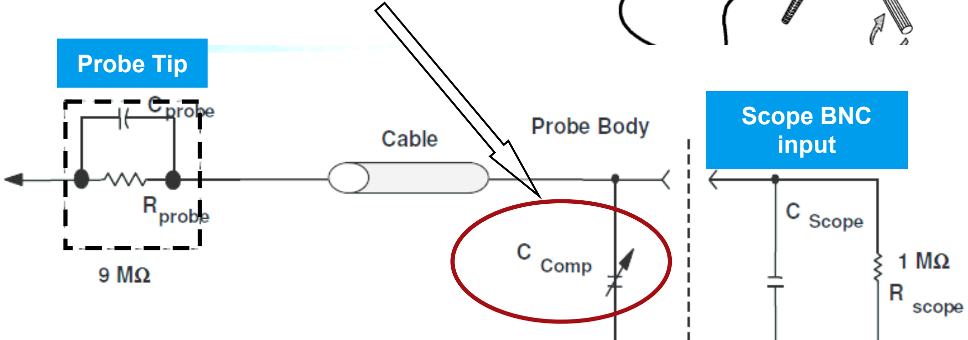


Properly Compensated Signal



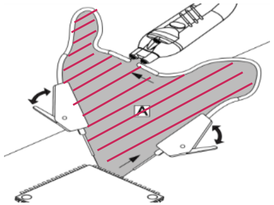


Over-Compensated Signal

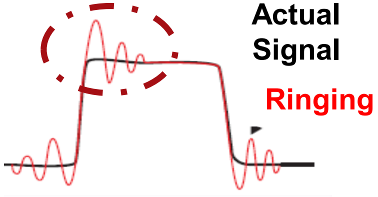


To maintain probe attenuation ratio over its rated bandwidth

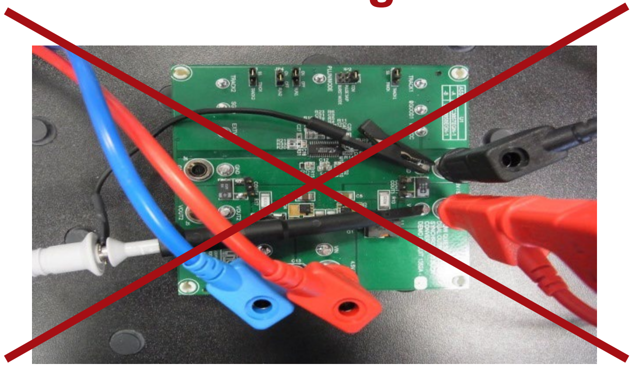
WHAT ELSE IS IMPORTANT



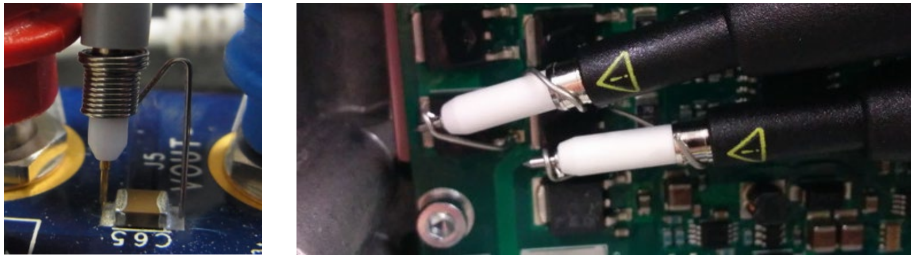
$$f_{Resonant} = \frac{1}{2\pi\sqrt{L \cdot C}}$$



Wrong



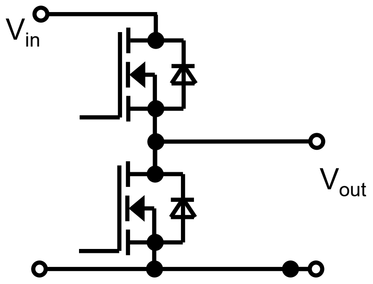
Right



Keep Connections short

MEASURING VOLTAGE

► Basic sub-circuit for inverter, sync buck converter/resonant (LLC) converter, sync boost converter consists of a so called **high-side** and **low-side switch**



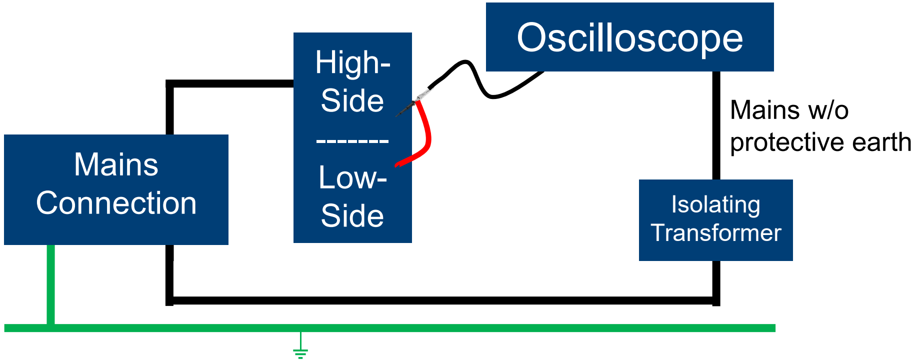
High-side switch: referenced to output voltage

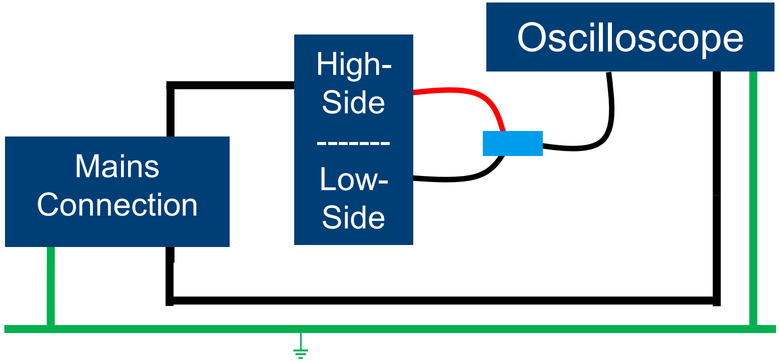
Low-side switch: ground referenced

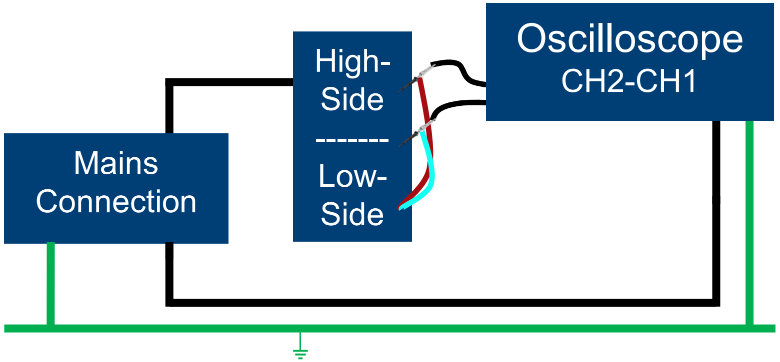
► DC-Offset of high-side switch has to be considered by design of measurement setup

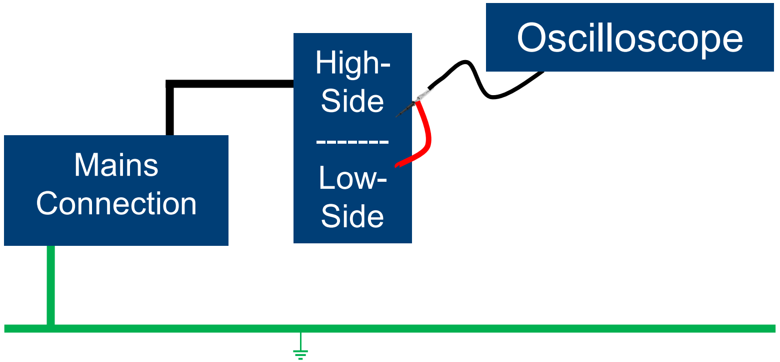
► Floating measurement on high-side switch is necessary

FLOATING MEASUREMENT TECHNIQUES

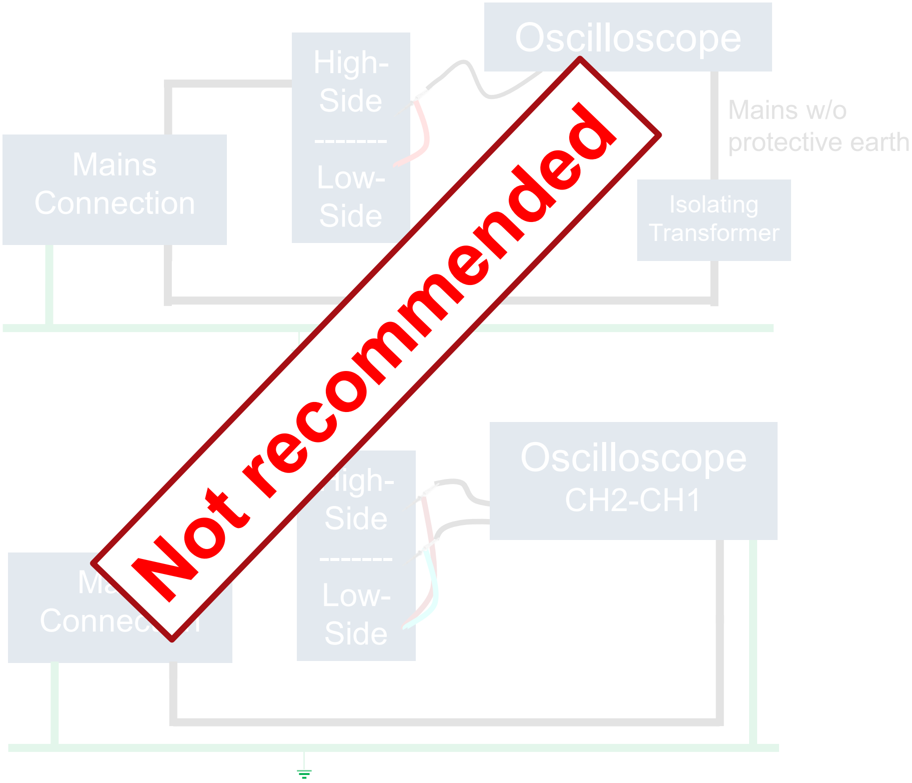


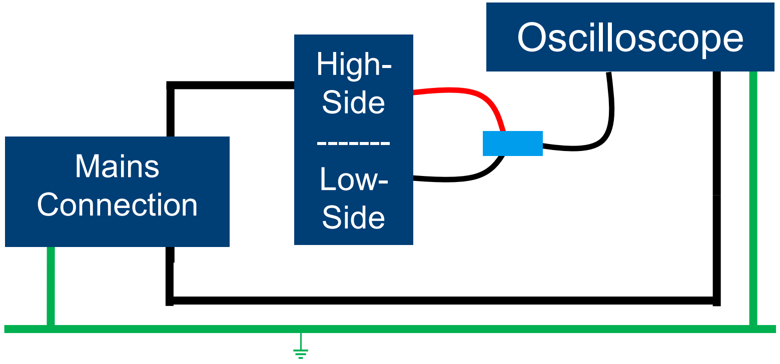


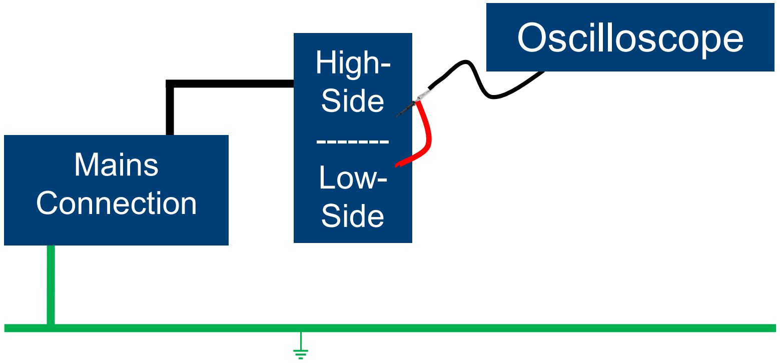




FLOATING MEASUREMENT TECHNIQUES







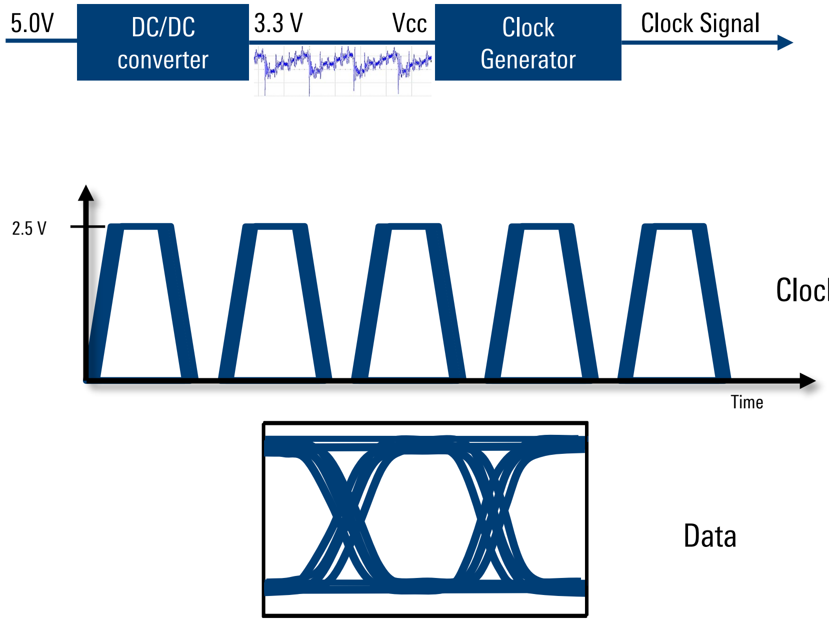
FLOATING MEASUREMENT TECHNIQUES

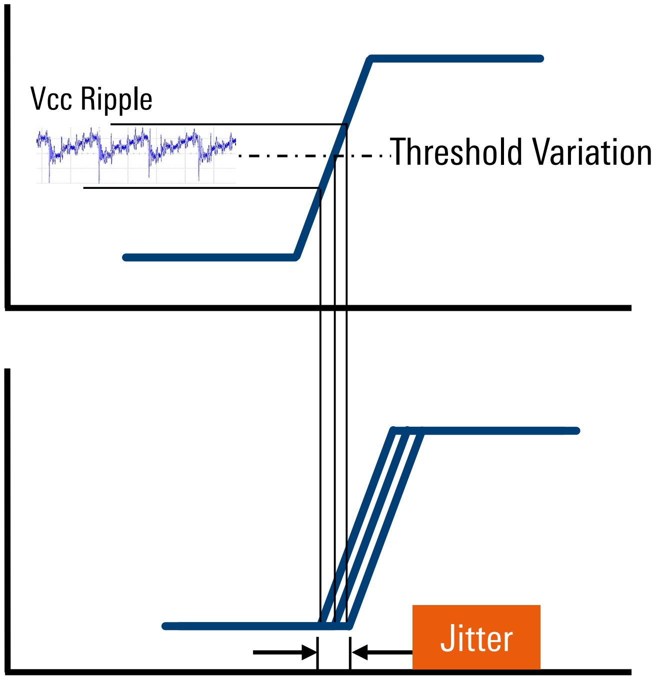
	Floating the Scope	A minus B	High-Voltage Differential Probes	Isolated Channel Oscilloscope
Safety	**Dangerous!**	Ok	**Very good**	**Very good**
Flexibility	Limited all channels have ground connected	Limited, needs two channels per signal	**Very good**	**Very good** (limited by max ground potential rating)
Sensitivity	**Very good**	**Very good**	Good (typ. 50:1 or 100:1)	**Very good** (10:1 attenuation)
Accuracy	**Very good**	**Not good**	**Very good**	**Very good**
Bandwidth	**Very good**	**Not good**	Good (typ. <=200 MHz)	**Very good** (up to 500 MHz)
CMRR	Not good	**Very bad**	**Very good**	Good
Conclusion	**Only recommended behind safety screen.**	**Not recommended!**	**Generally recommended**	**Recommended** (with limitations)

WHICH PROBE TO USE

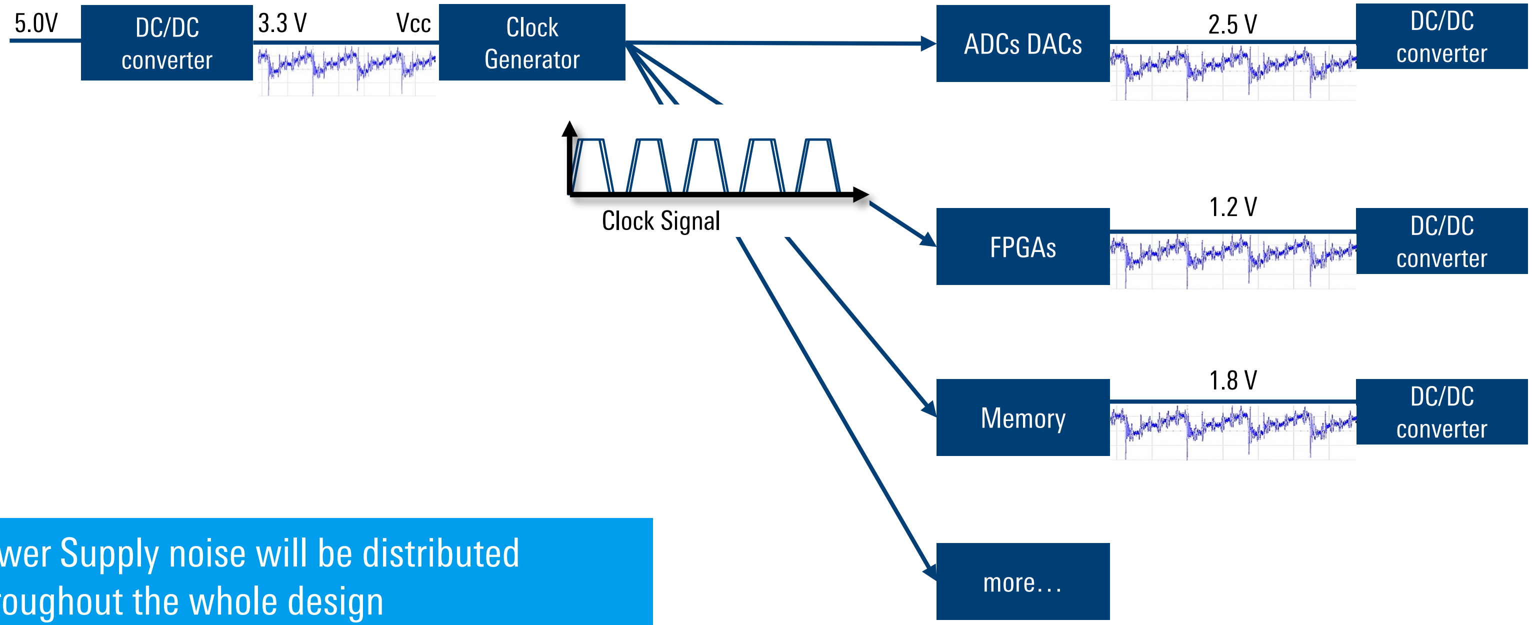
	RT-ZD10	RT-ZHD07/15/16/60	RT-ZH10/11	RT-ZI10/10C/11
				
Type / Interface	Active differential / **R&S**	Active differential / **R&S**	Passive / **BNC**	Passive / BNC only for R&S®Scope Rider
Bandwidth	1 GHz	100 MHz / 200 MHz	400 MHz	500 MHz
Max. Input Signal	5 V (without RT-ZA15) 60 V (with RT-ZA15)	750 Vpeak to 6000 Vpeak	1000 Vrms 6000 Vpeak	1000 Vrms 5000 Vpeak
CMRR	80 dB @ 10 Hz 40 dB @ 10 kHz to 1 MHz 30 dB @ 1 MHz to 100 MHz 20 dB @ 100 MHz to 1 GHz	80 dB @ DC – 60 Hz 60 dB @ 1 MHz 30 dB @ 100 MHz	N/A	Depends on measurement scenario
Offset	Up to 50 V	Up to 2000 VDC	N/A	N/A
DC Voltmeter	R&S Probemeter	R&S Probemeter	N/A	N/A

NOISY POWER INFLUENCE SIGNAL INTEGRITY



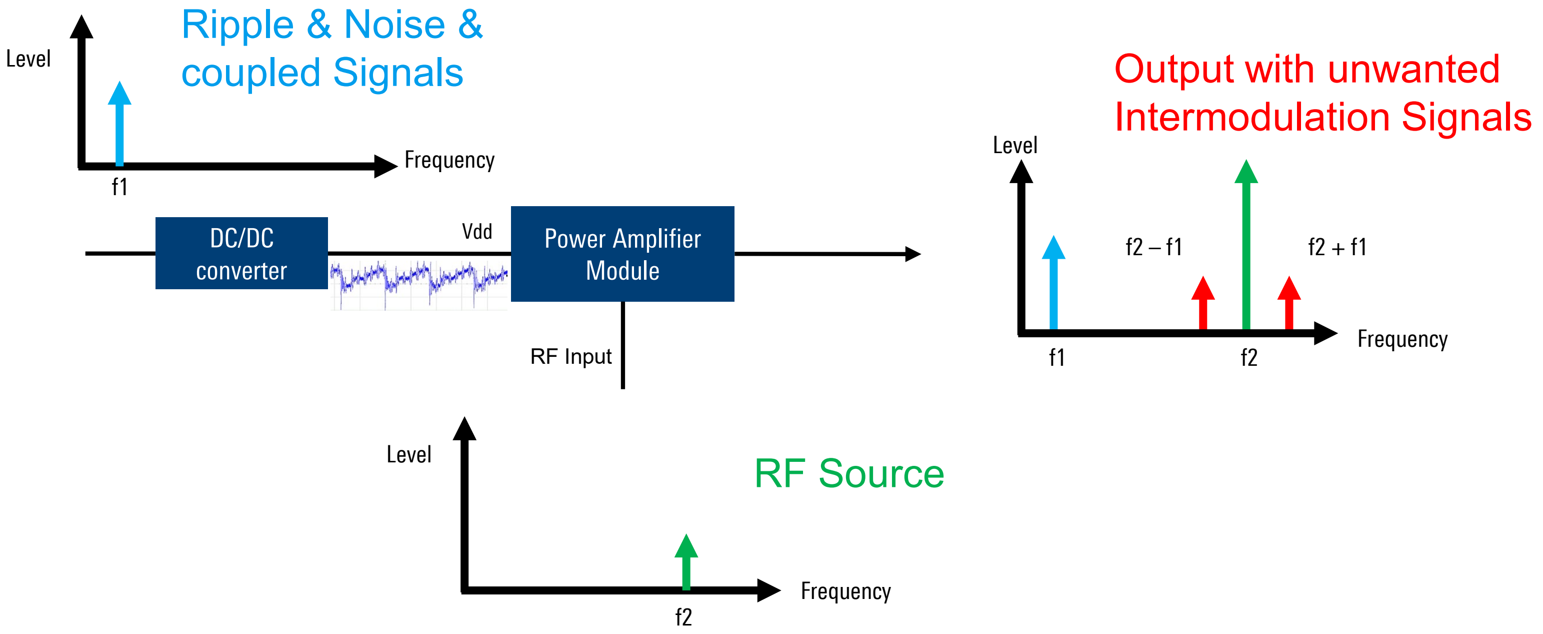


POWER NOISE PROPAGATE TO OTHER CIRCUITS



Power Supply noise will be distributed throughout the whole design

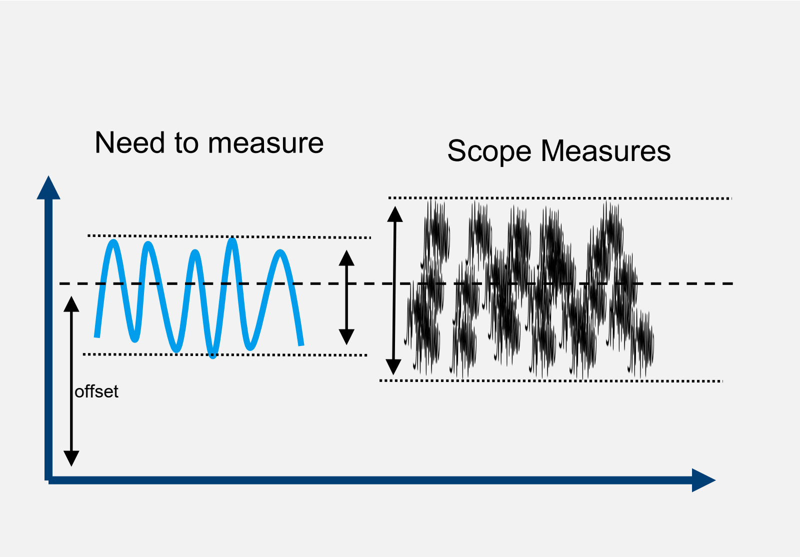
POWER NOISE AFFECTING RF PERFORMANCE



CHALLENGES ON MEASURING DC POWER

- Attenuation ratio increases displayed noise floor of the instrument.
- Limited offset capabilities:
  - Vertical resolution is reduced as Offset has to be measured too.
- Decreasing voltage and tolerance levels:

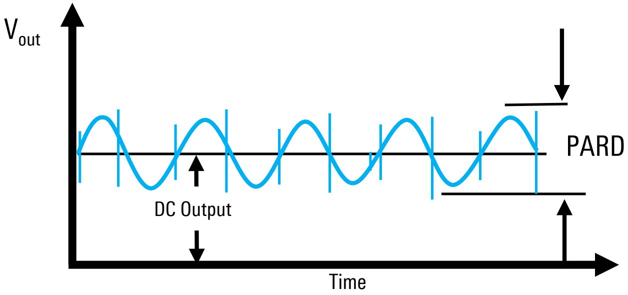
Rail Value	Tolerance	Need to measure
3.3 V	1%	33 mV_{pp}
1.8 V	2 %	36 mV_{pp}
1.2 V	2 %	24 mV_{pp}
1 V	1 %	10 mV_{pp}



DC OR AC?

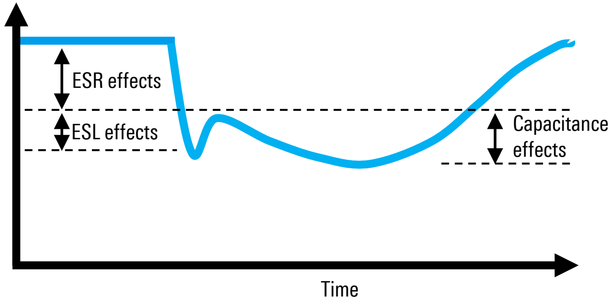
Screen Capture
Annotate
Preset
Add Zoom
Measure
Add Cursor
Delete
Clear
Run / Stop
Run Single
Edit Spectrum
Trigger
C1
Edge
1.2276 V
Auto
Trg'd
Horizontal
1 ms/div
0 s
Acquisition
1 GSa/s
10 Mpts
Sample
12 bit
Hist 213
Info
2022-10-21
09:26:08
Diagram Set 1
1.8 V
1.6 V
1.4 V
DC Voltage (200 mV/div)
1.2 V
TA
1 V
800 mV
600 mV
400 mV
200 mV
C1
-200 mV
-4 ms
-3 ms
-2 ms
-1 ms
0 s
1 ms
2 ms
3 ms
4 ms
5 ms
C1
200 mV/
1 GHz
DC 50Ω
800 mV
C2
C3
C4
Logic
Math
Bus
Ref
Spec
Gen
Menu

TYPES OF POWER NOISES

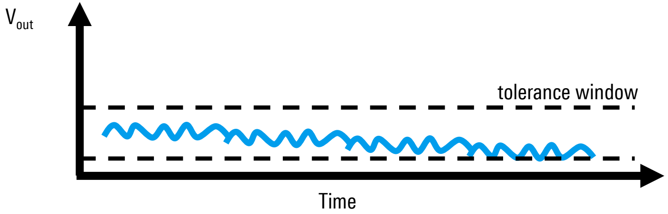


- PARD (Periodic and Random Disturbances):
  - Switching noise
  - Ripple
  - Transients
  - Random noise

- Load step response



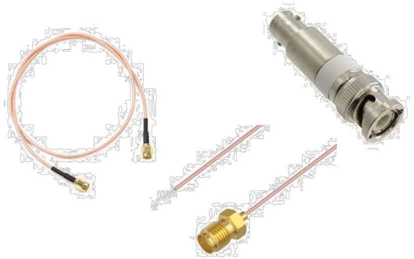
- Supply drift



LOW VOLTAGE APPROACHES ON DC POWER LINES

Standard
10:1
(passive)
probe

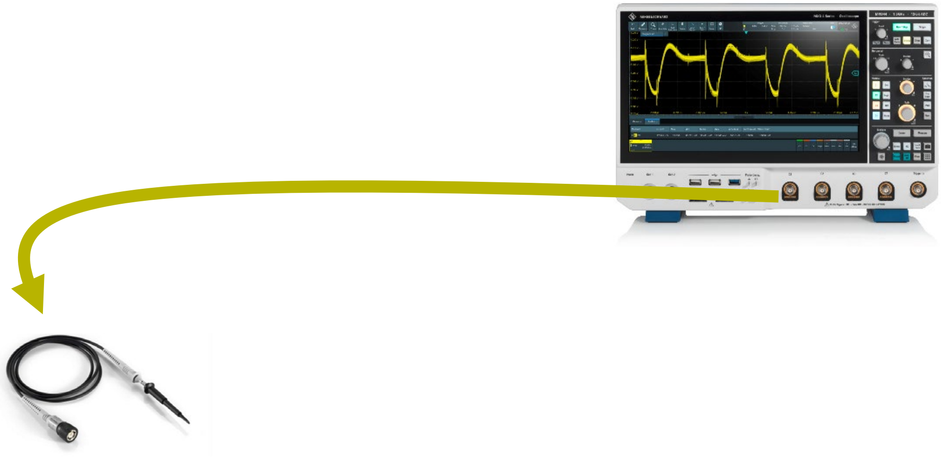
Low BW
1:1
passive
probe



50 Ω cable
(with blocking cap
or AC coupling)

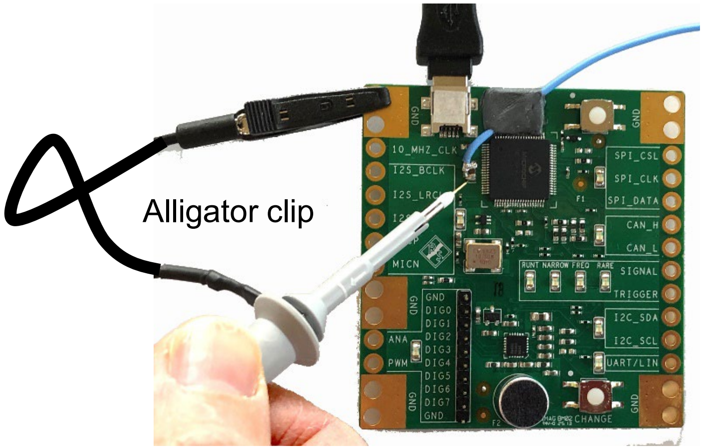
Specialized
power rail
probe

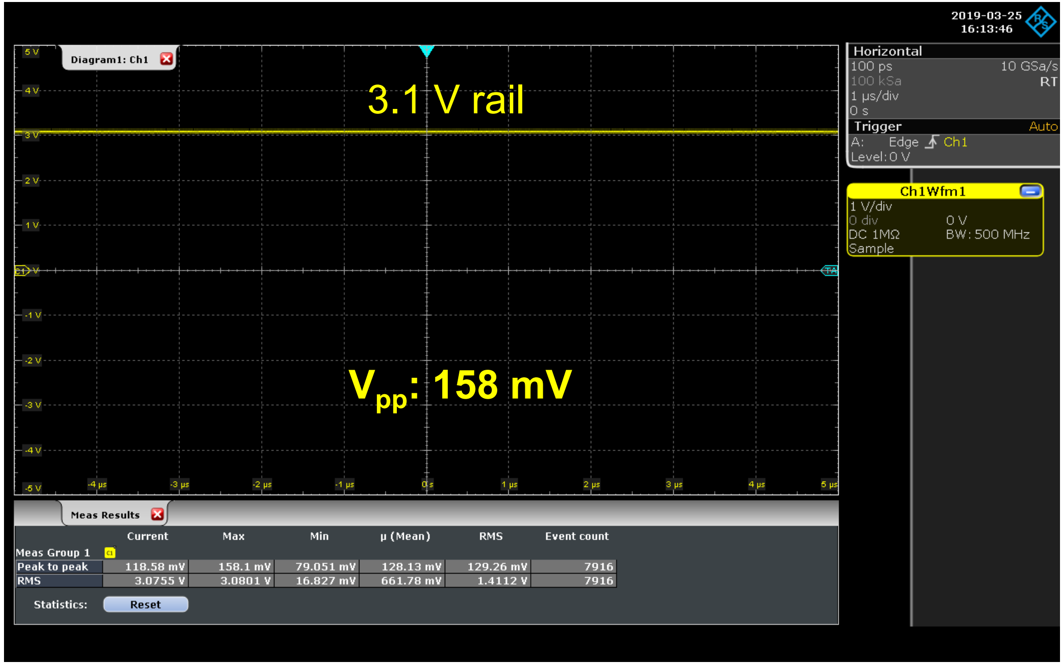
MEASUREMENT APPROACH: 10:1 Passive Probe (ZP-10)



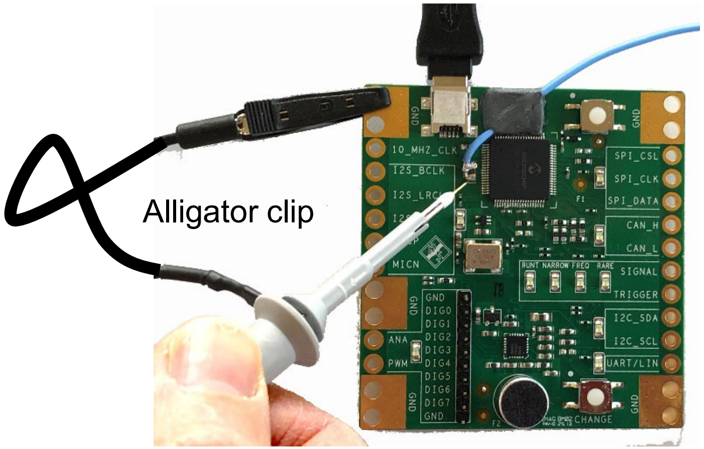
Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

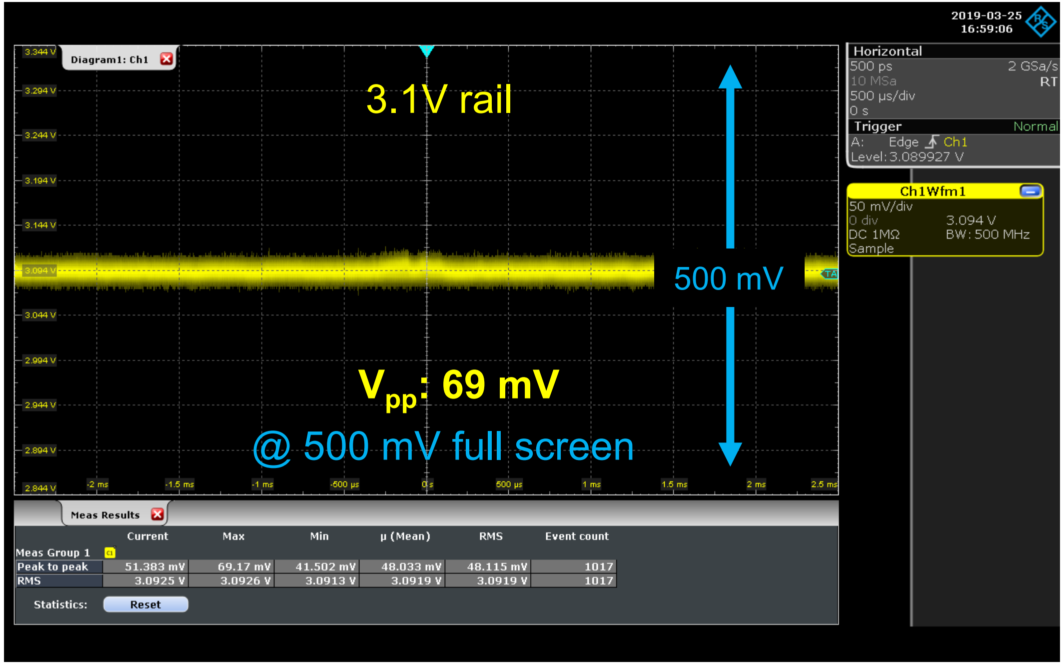
STANDARD 10:1 PASSIVE PROBE WITH ALLIGATOR CLIP



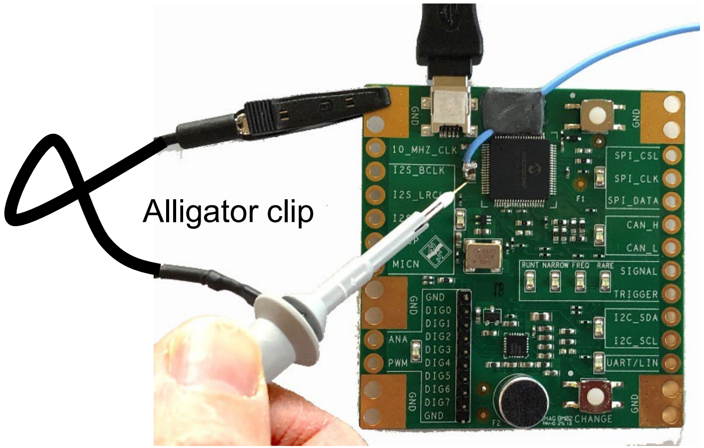


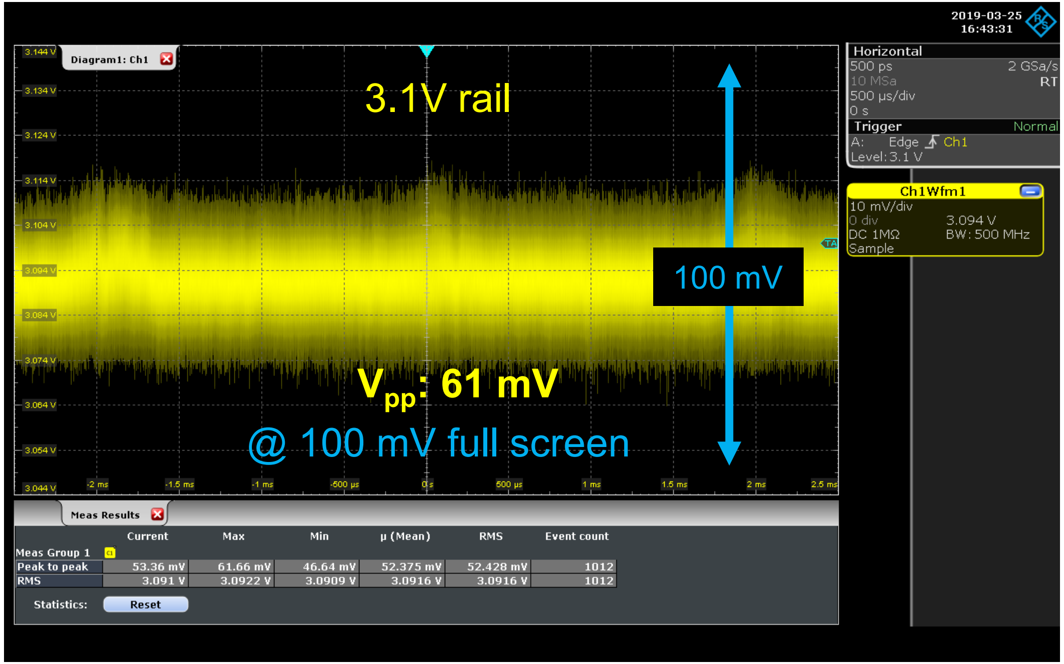
STANDARD 10:1 PASSIVE PROBE WITH ALLIGATOR CLIP





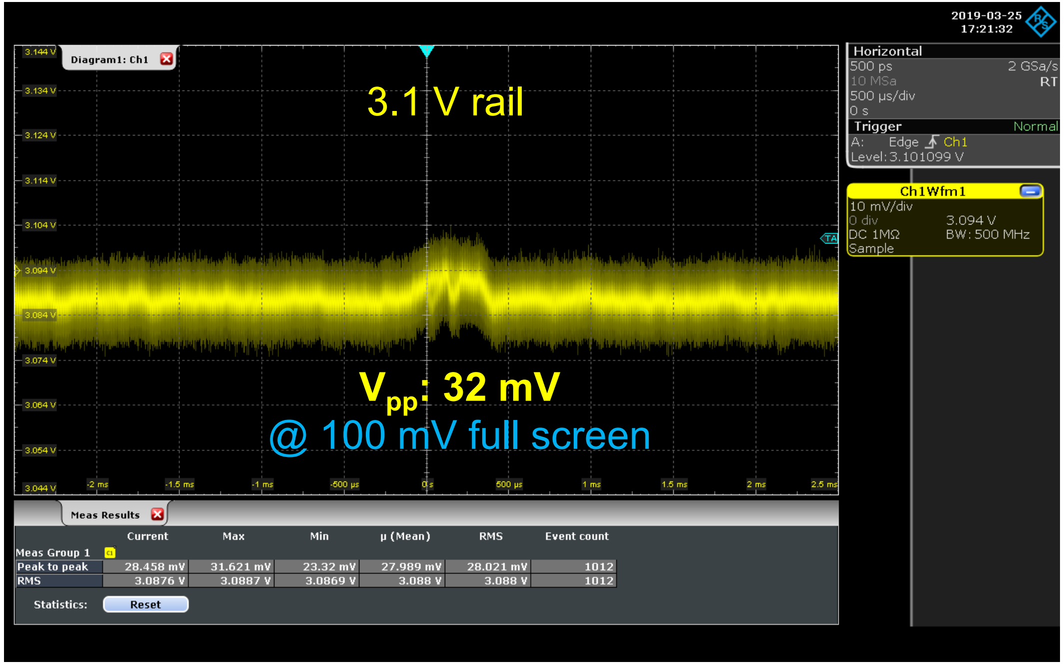
NOISE IS A FUNCTION OF FULL SCREEN VERTICAL





STANDARD 10:1 PASSIVE PROBE WITH GROUND SPRING

Ground spring



10:1 PASSIVE PROBE

Advantages

- Comes standard with most scopes
  - no extra expense
- 1 MΩ loading at DC
  - Preserves expected DC value
- Easy to connect using browser tip
  - Multiple ground alternatives

Disadvantages

- Significant noise
  - 10:1 attenuation
  - Minimum vertical setting of 10 mV/div
- Long grounds
- BW limited (500 MHz for ZP-10)
- No solder-in alternative

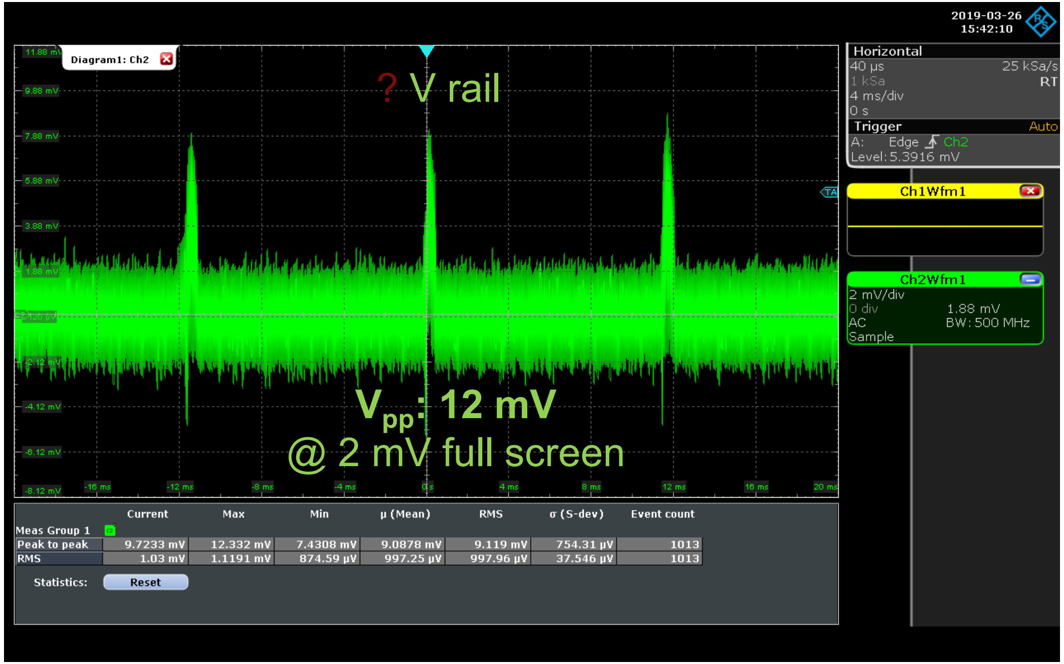
MEASUREMENT APPROACH: 1:1 Passive Probe (ZP-1X)

Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

38 MHZ 1:1 PASSIVE PROBE WITH GROUND SPRING (ZP-1X)

Ground spring

Not enough offset, required AC coupling



1:1 PASSIVE PROBE

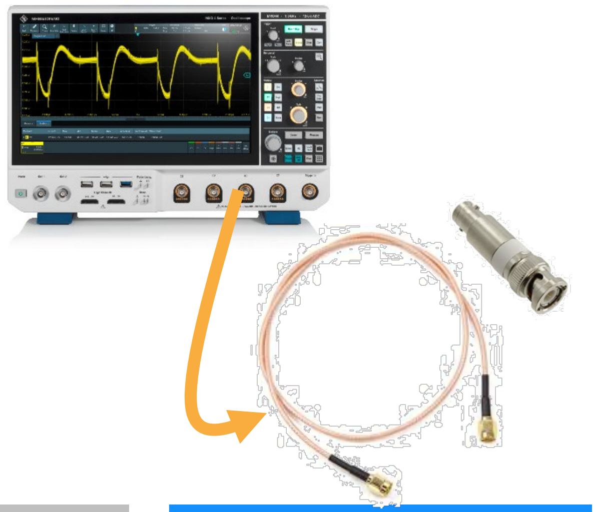
Advantages

- Low cost
- Excellent 1 MΩ loading at DC
  - preserves expected DC value
- Ability to scale to 1 mV/div
- Easy to connect using browser tip
  - Ground spring ground alternative

Disadvantages

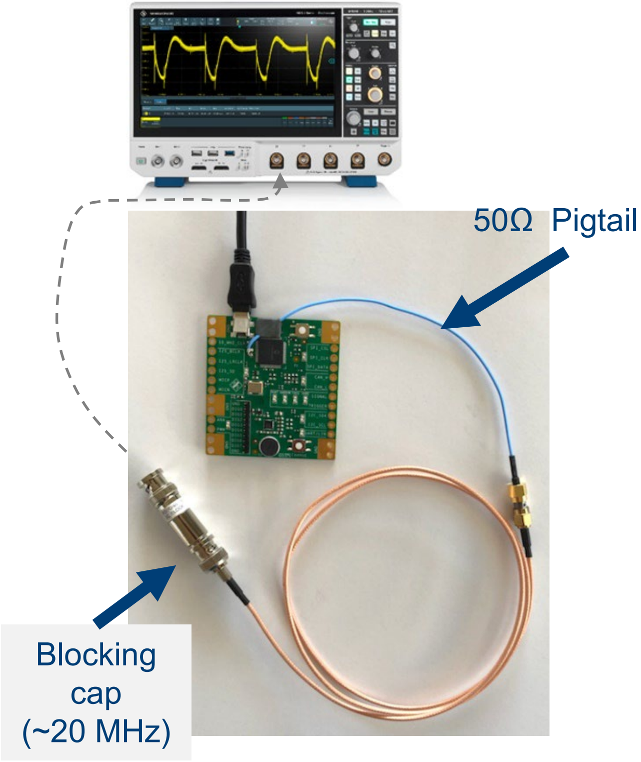
- Limited BW
  - 38 MHz for ZP-1X
  - under reports V_{pp} measurements
  - masks high freq signal coupling
- Limited offset – may require AC coupling
- No solder-in alternative

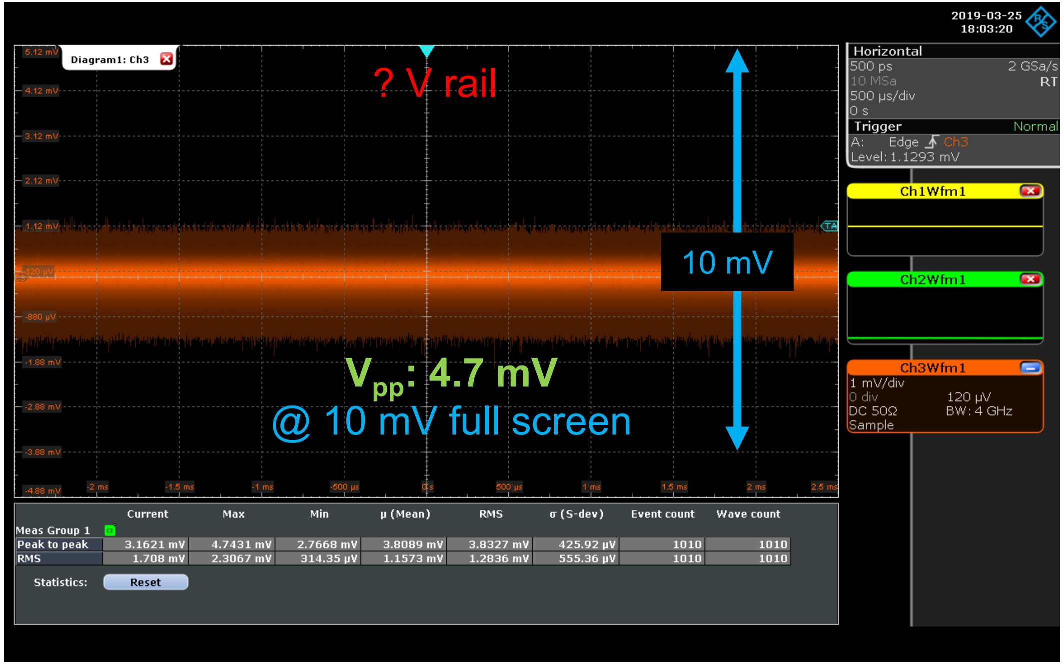
MEASUREMENT APPROACH: 50Ω PATH



Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

50Ω PATH WITH BLOCKING CAP (3DB BW = ~20 MHZ)





50Ω PATH

Advantages

▶ 50 Ω scope path typically has less noise than 1M Ω scope path
▶ SMA connector or solder-in pigtail allows for measurement consistency and ease of access

Disadvantages

▶ 50 Ω loading at DC reduces power rail voltage
▶ Insufficient offset (requires blocking cap or AC coupling)
  – Masks DC drift
  – Eliminates ability to see true DC voltage

MEASUREMENT APPROACH: 50Ω PATH

Standard
10:1
passive
probe

Low BW
1:1
passive
probe

50 Ω cable
(with blocking cap)

Specialized
power rail
probe

POWER RAIL PROBE (RT-ZPR20, RT-ZPR40)

Advantages

- Low noise (1:1 attenuation ratio)
- Built-in offset
- Excelling loading at DC
  - Power rail retains DC value
- Browser and solder-in connection

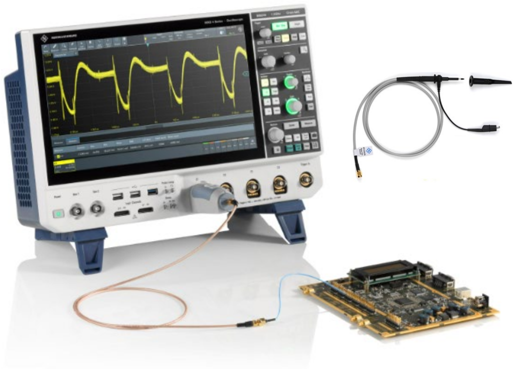
Disadvantages

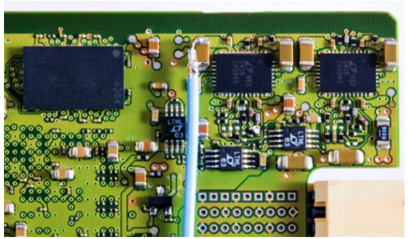
- Initial investment expense
- Requires solder-in/SMA for full BW

LOW VOLTAGE RT-ZPR20/40 POWER RAIL PROBES

- Designed uniquely for measuring small perturbations on power rails
- Active, single-ended probe
- Low noise with 1:1 attenuation
- Best in class offset compensation capability

Key Specifications	
Attenuation	1:1
Probe BW	2 GHz / 4 GHz
Browser BW	350 MHz
Dynamic Range	±850 mV
Offset Range	> ±60 V
Noise Scope (RTO) standalone Scope + Probe Noise (at 1 GHz, 1mV/div)	 107 µV AC_{rms} 120 µV AC_{rms}
Input Resistance	50 kΩ @ DC
R&S ProbeMeter	Integrated
Coupling	DC or AC





MAKING ACCURATE POWER RAIL MEASUREMENTS

1. Measurement accuracy
   - Minimizing measurement noise
   - Sufficient offset (zoom to utilize full scope ADC, seeing DC drift)
   - Sufficient BW to capture transients
   - Minimal DC loading
2. Frequency domain evaluation of coupling/switching
3. Time required to find worst-case violations

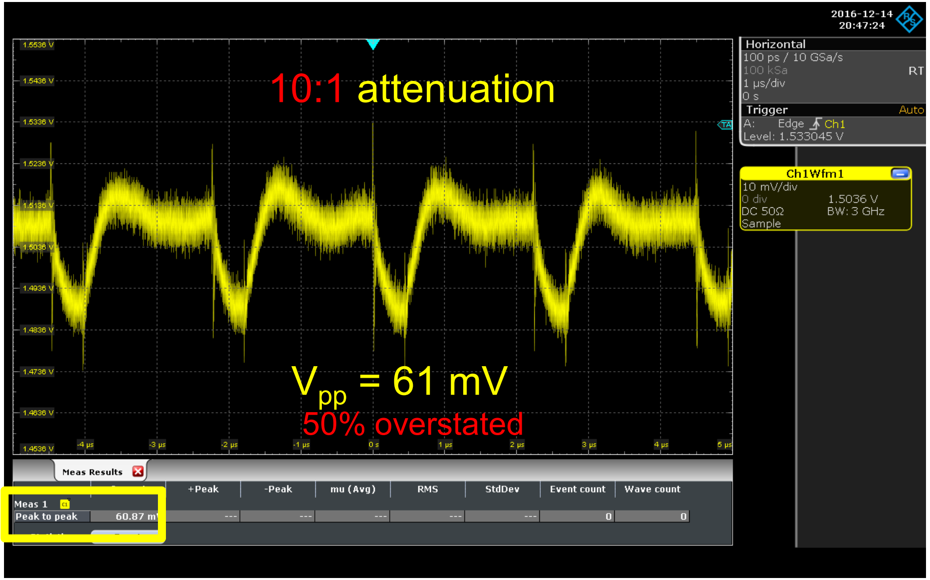
RT-ZPR:

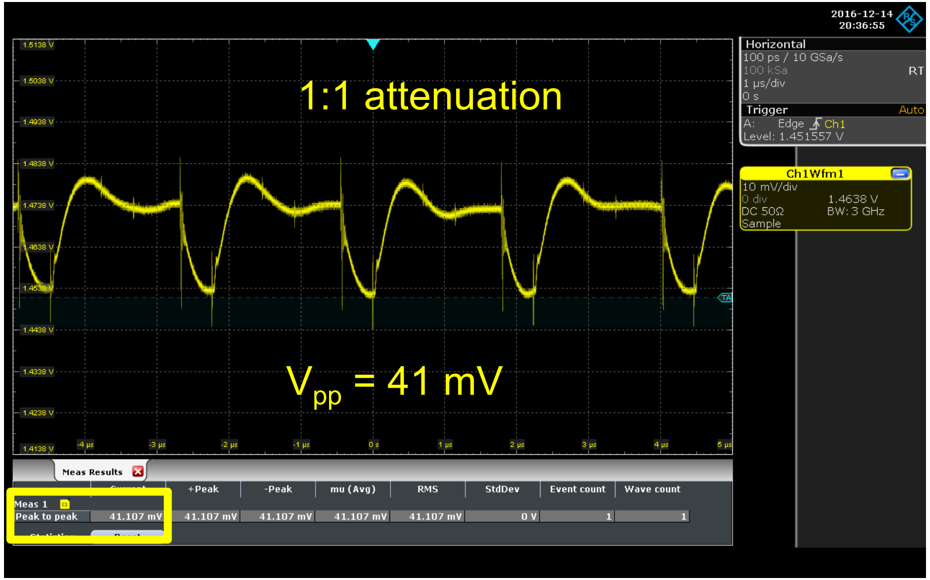
Adds ~10% more noise to RTO/MXO scope measurements)
+/- 60V offset
Up to 4 GHz BW to capture high-frequency transients
Input impedance of 50 KΩ @ DC

MEASUREMENT ACCURACY:

10:1

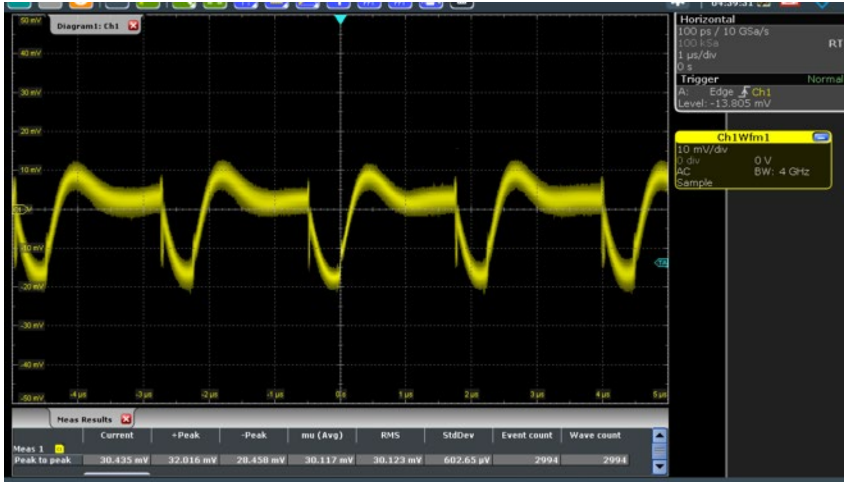
1:1





Noise Due to Probe Attenuation Ratio

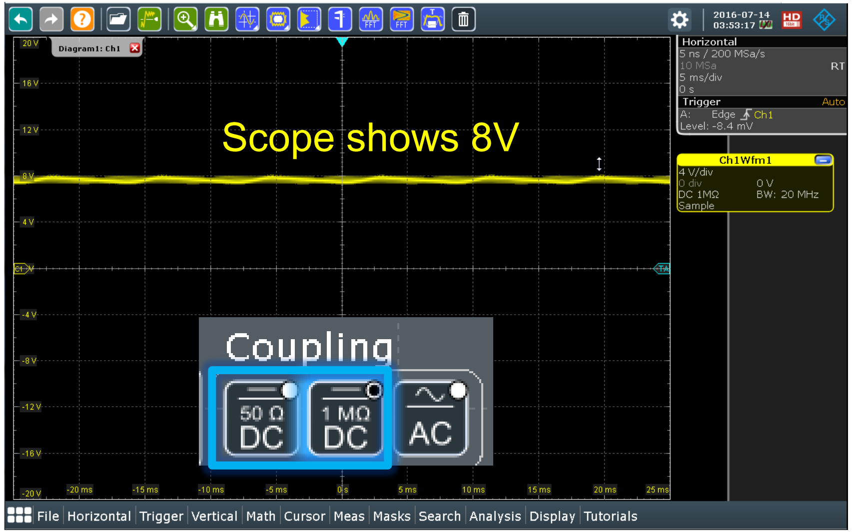
MEASUREMENT ACCURACY: HIGH BW NEEDED



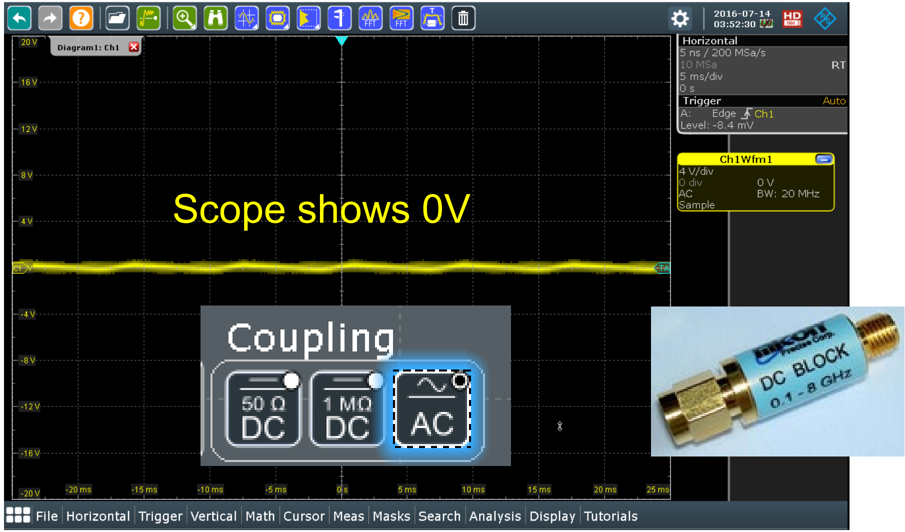
1:1 ZP1X passive 38 MHz BW

1:1 ZPR20 active 2 GHz BW
Captures high-freq transients

CHALLENGES WITH INSUFFICIENT SCOPE OFFSET



Can't zoom in (1V offset on RTO @ 20 mV/div) →



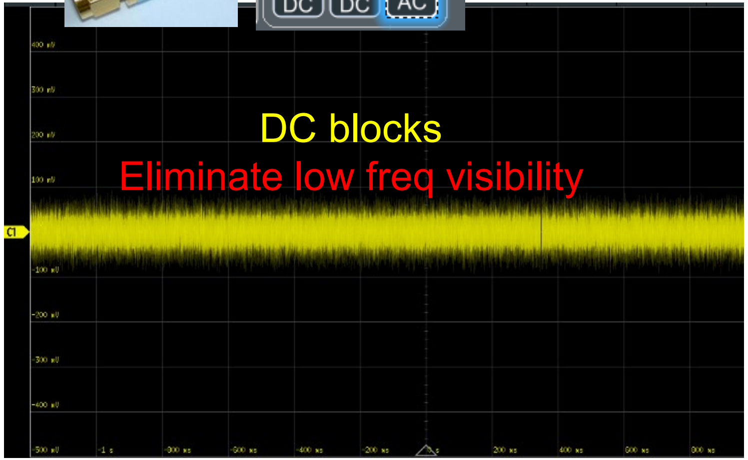
Can bring to center screen and zoom in

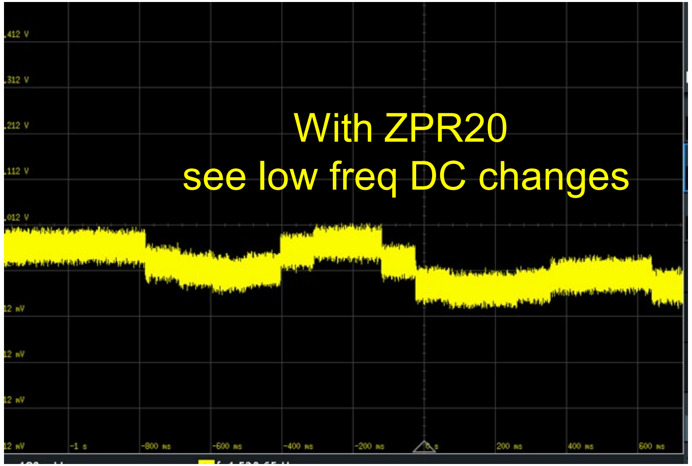
User can't tell absolute vertical value

User can't see DC offset issues

CHALLENGES WITH INSUFFICIENT SCOPE OFFSET

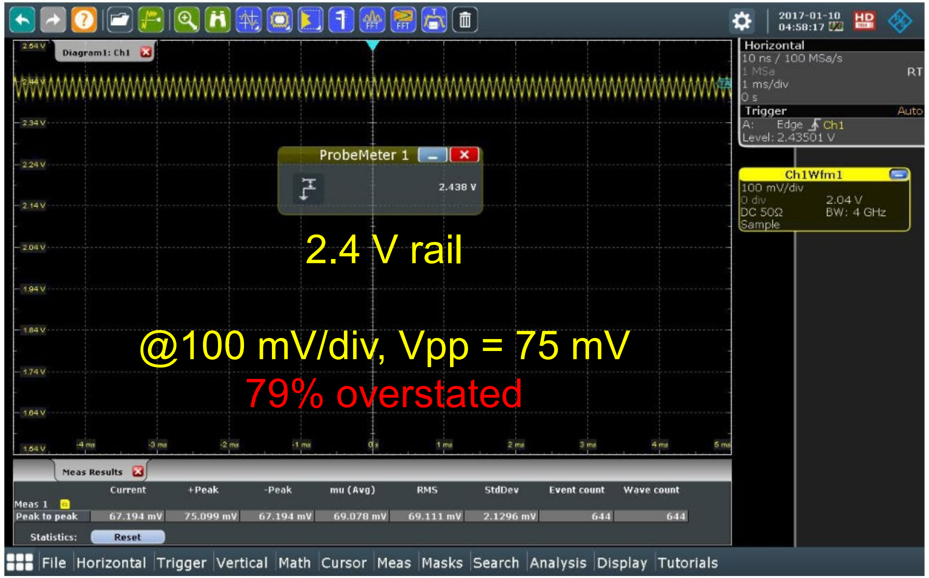
DC Drift



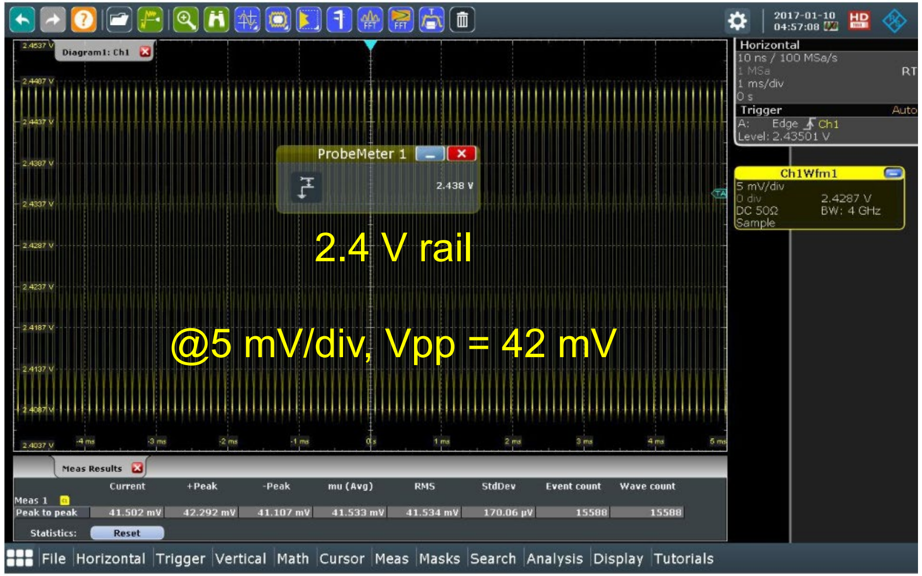


USING OFFSET TO USE MOST SENSITIVE VERTICAL SETTING

Using max built-in scope offset



Using built-in probe offset



MAKING MOST ACCURATE POWER RAIL MEASUREMENTS

1. Measurement accuracy
2. Frequency domain evaluation of coupling/switching
3. Time required to find worst-case violations

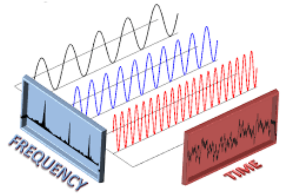
RT-ZPR + RTO:

- 4 GHz BW to capture high-frequency transients
- HW-accelerated FFT
- Color graded FFTs

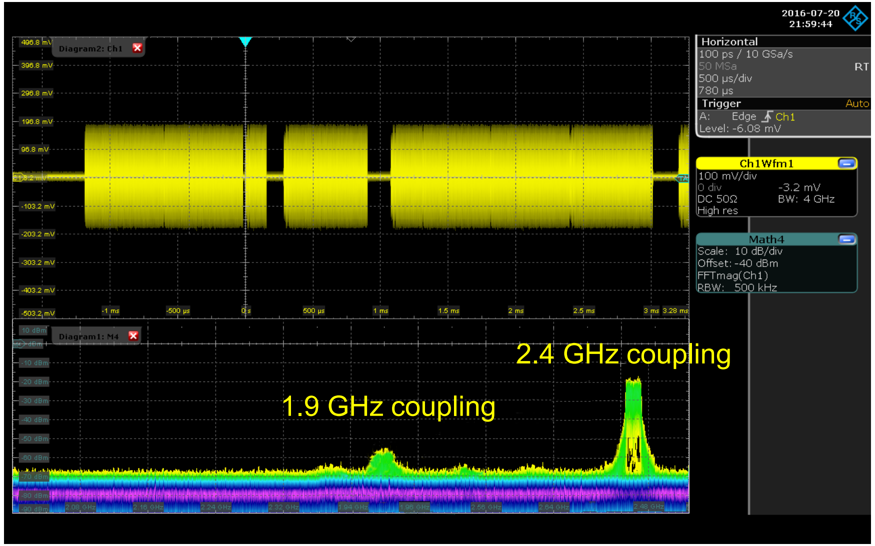
RT-ZPR + MXO:

- 1.5 GHz BW to capture high-frequency transients

FINDING COUPLED SIGNALS



Switching (low freq FFT)



EMI/coupling (high freq FFT)

MAKING MOST ACCURATE POWER RAIL MEASUREMENTS

1. Measurement accuracy
2. Frequency domain evaluation of coupling/switching
3. Time required to find worst-case violations

RT-ZPR + RTO:

Up to 1 Mio wfms/s

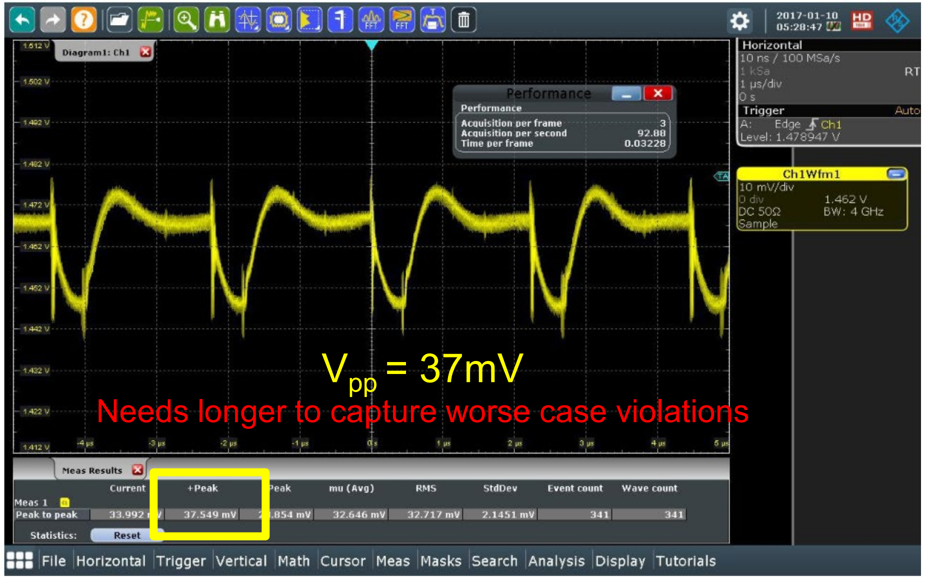
Measurements with statistics

RT-ZPR + MXO:

Up to 4.5 Mio wfms/s

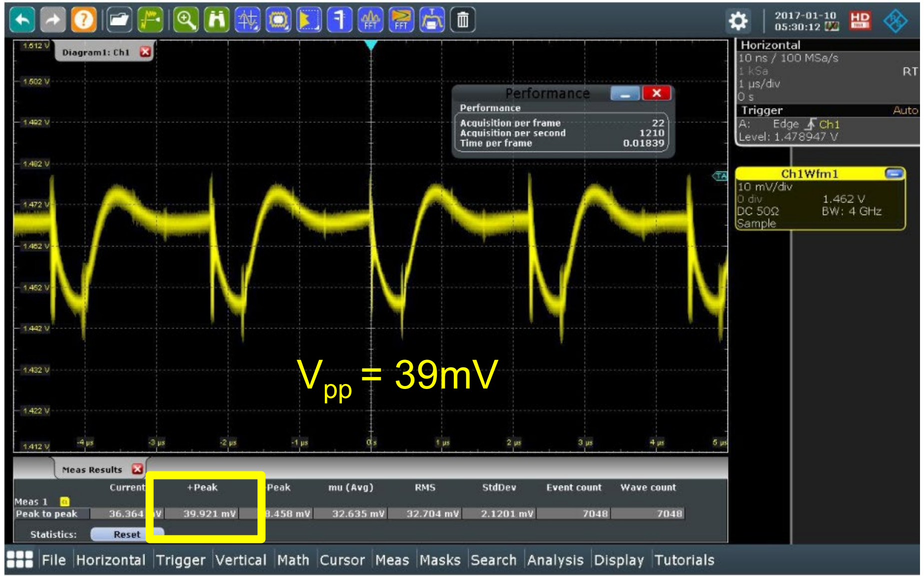
Measurements with statistics

FIND WORSE-CASE VIOLATIONS FASTER



Emulating competitive update rate of 100 wf/s

< 500 Vpp measurements in 5 seconds

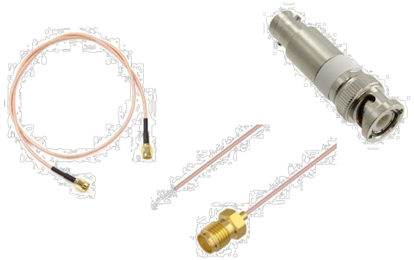


>5000 Vpp measurements in 5 seconds

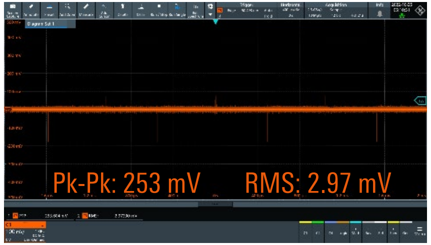
DIFFERENT SETUP COULD HAVE DISTINCTIVE RESULTS

Standard
10:1
(passive)
probe

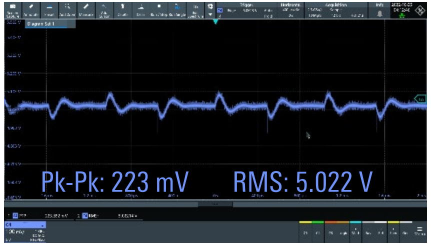
Low BW
1:1
passive
probe



50 Ω cable
(with blocking cap
or AC coupling)

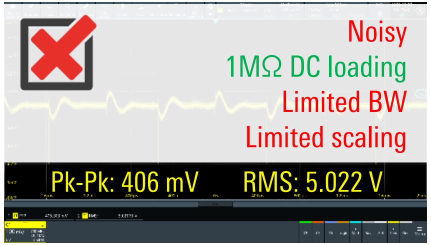


Specialized
power rail
probe

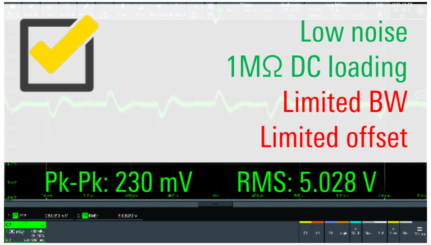


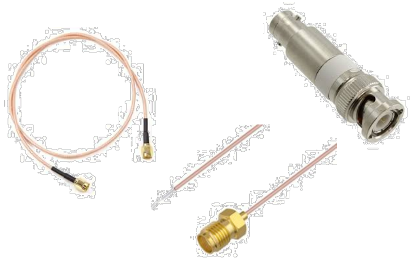
UNDERSTANDING THE DIFFERENCES

Standard
10:1
(passive)
probe

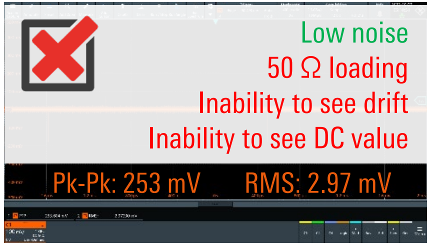


Low BW
1:1
passive
probe





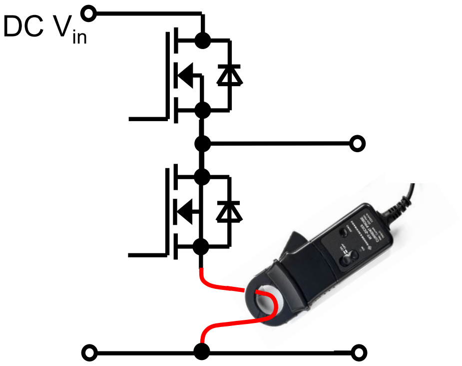
50 Ω cable
(with blocking cap
or AC coupling)



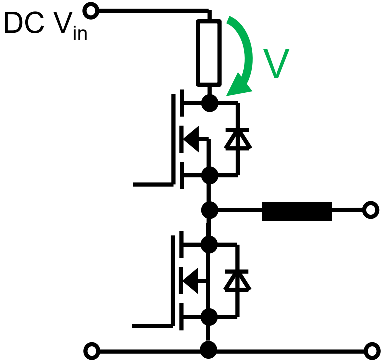
Specialized
power rail
probe

CURRENT MEASUREMENT

Clamp-on probes



Shunt resistors



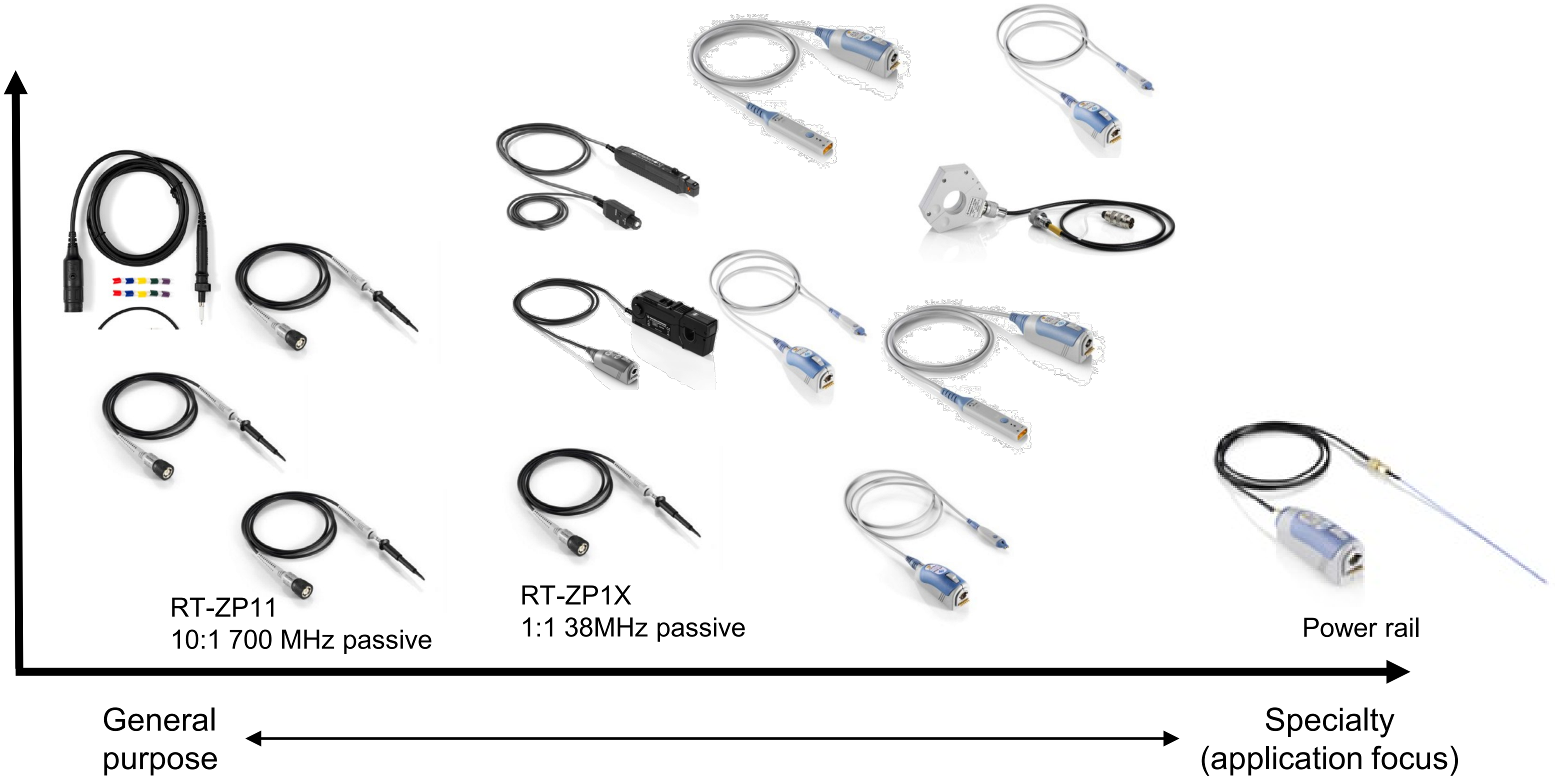
Rogowski probes

Photo: Curtesy PEM UK Ltd.

CURRENT MEASUREMENTS PROBE TYPES

	Clamp-on probes	Shunt resistors	Rogowski Probes
Bandwidth	**~120 MHz** (5 A range) … **~20 kHz** (~1000 A range) (depends on current range)	**Up to ~GHz**	**~50 MHz**
Current range	**~5 A** (120 MHz) … **~1000 A** (20 kHz) (depends on bandwidth)	**Depends on shunt-value** (typically limited by max. Energy per current pulse)	**~A to ~kA**
DC measurement	**Yes**	**Yes**	**No**
Important advantages	• DC measurement capability • Easy “clamp-on” measurement	• Very high bandwidth	• High bandwidth at high current • Easy “wrap-around” measurement (little space needed)
Important drawbacks	• Extra space needed, adds loop-inductance • Derating of maximum current with measurement frequency	• Design-in needed • Fixed measurement range • Limited maximum thermal load	• No DC measurement • Noise sensitivity • Accuracy depends on position of conductor in loop
Typ. applications	• All kind of general purpose current measurement	• Switching analysis (double-pulse test)	• Switching analysis • Motor drives

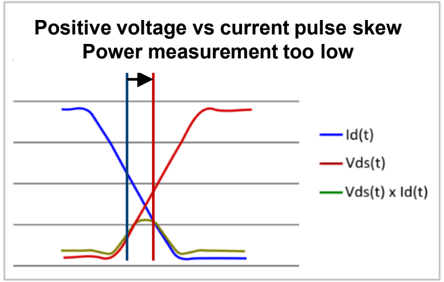
LOTS OF PROBES FOR DIFFERENT APPLICATIONS

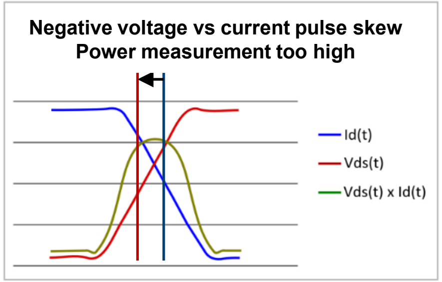


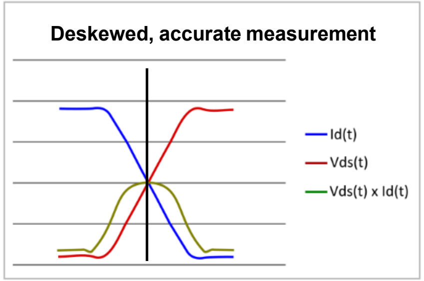
MATH FUNCTIONALITY

PROBING TECHNIQUES: WHY DESKEWING?

► Measuring Switching Loss

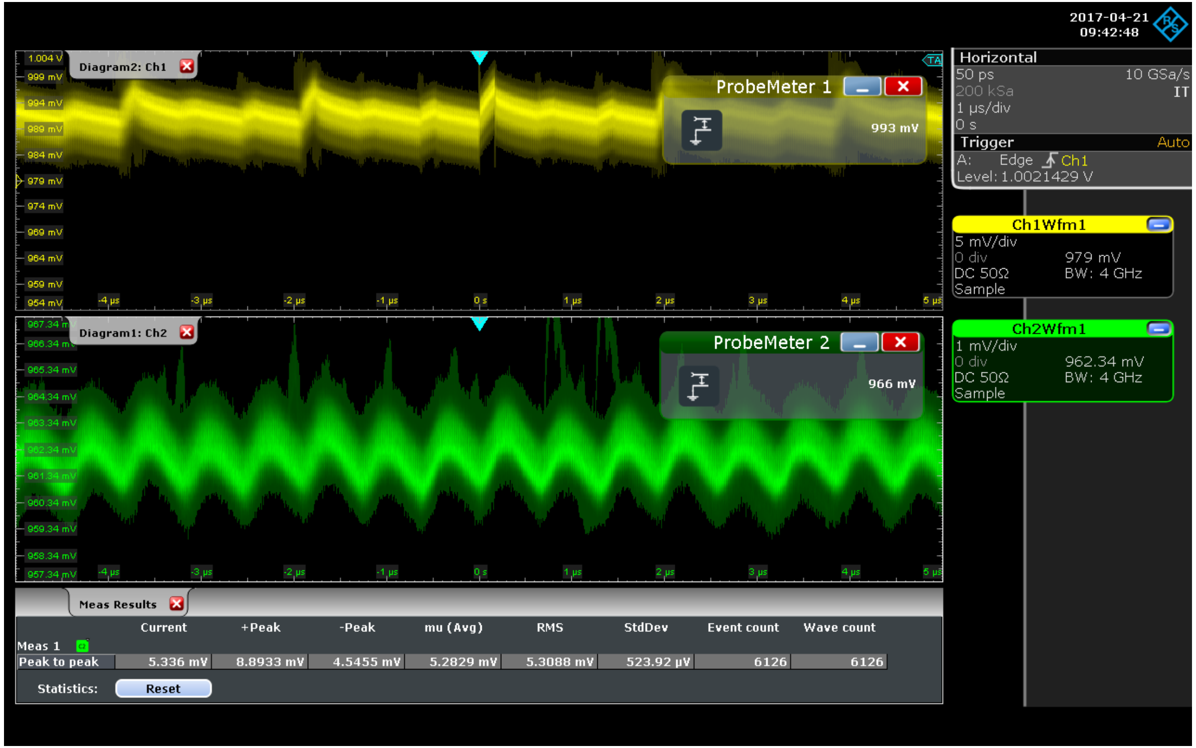






➡ Deskewing with reference voltage and current pulses is essential for accurate power measurements

USE CASE: RIPPLE MEASUREMENT



60A Load

>6000 waveforms captured in a few seconds

We can easily measure a 9 mV pp Ripple sitting on the FPGA power supply

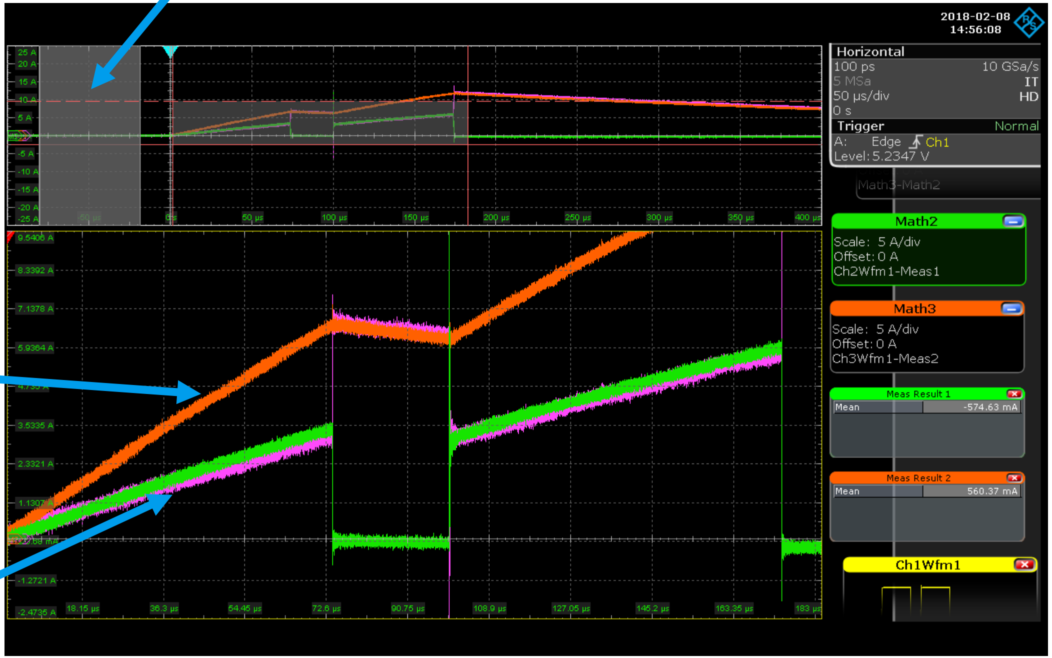
USE CASE: CURRENT IN PARALLELED MOSFETS

- **Advanced Math** capabilities:
  - Gates measurement used to „calibrate“ DC value of measurement results with Rogowski probe

Current is known to be zero in this interval

Sum current through two parallel MOSFETS

Individual currents through each MOSFET

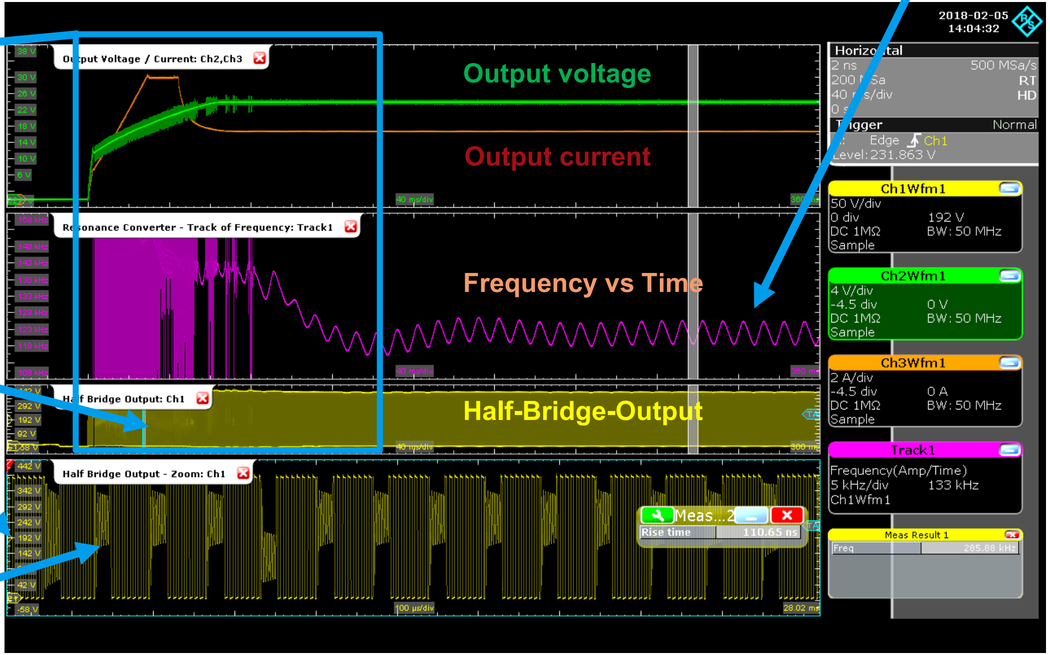


USE CASE: START-UP BEHAVIOR ANALYSIS

Example: Resonant Converter

Startup-Phase with non-continuous operation

100 Hz Ripple from DC-Link

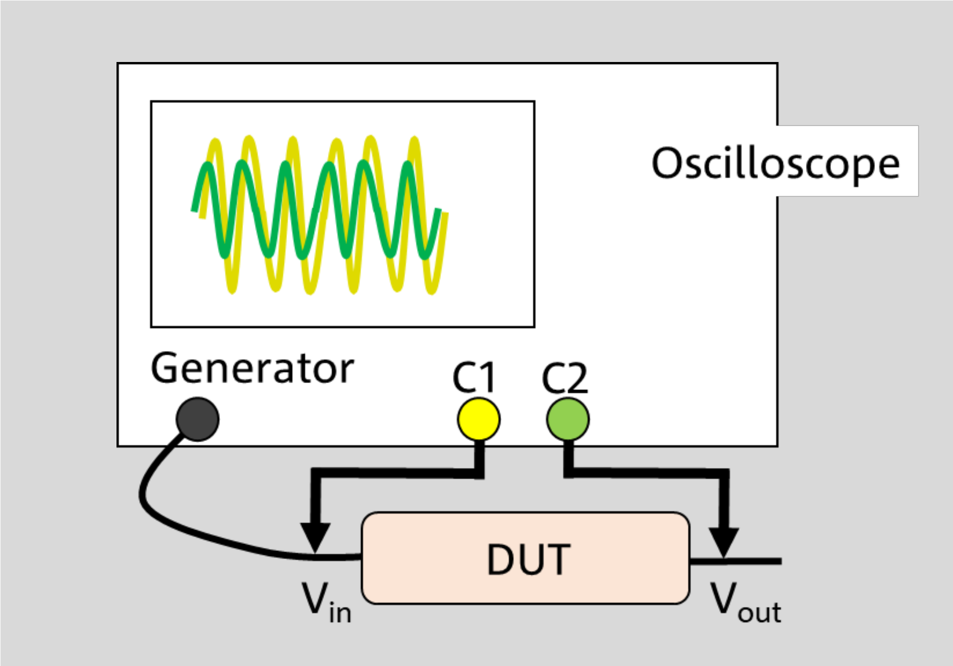


Zoom

Inactivity phases during startup

- **Deep memory:**
  - 160 ms Startup-Phase in this Example
- **High sampling rate:**
  - Rise time ~100ns
- **Advanced analysis capabilities:**
  - Track functionality

BODE PLOTS WITH OSCILLOSCOPES

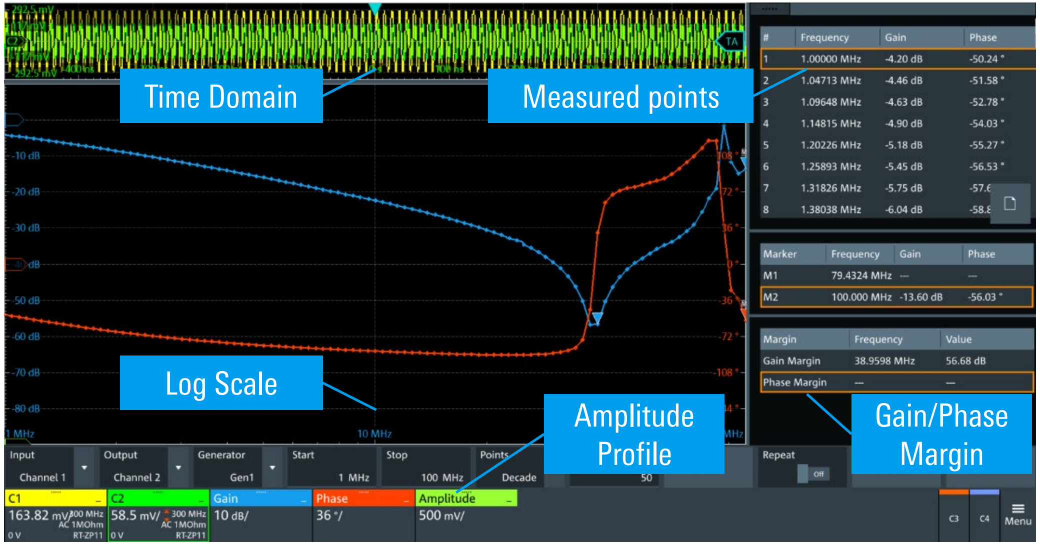


1. Internal signal generator provides swept stimulus (enables generator even is user hasn't purchased generator license)
2. Scope measures V_{in} and V_{out} amplitudes and phase at each frequency
3. Scope calculates and plots gain (logarithmically) and phase (linearly)

Supported oscilloscopes

MXO 4 **RTM3000** **RTB2000**

USE CASE: CONTROL LOOP STABILITY

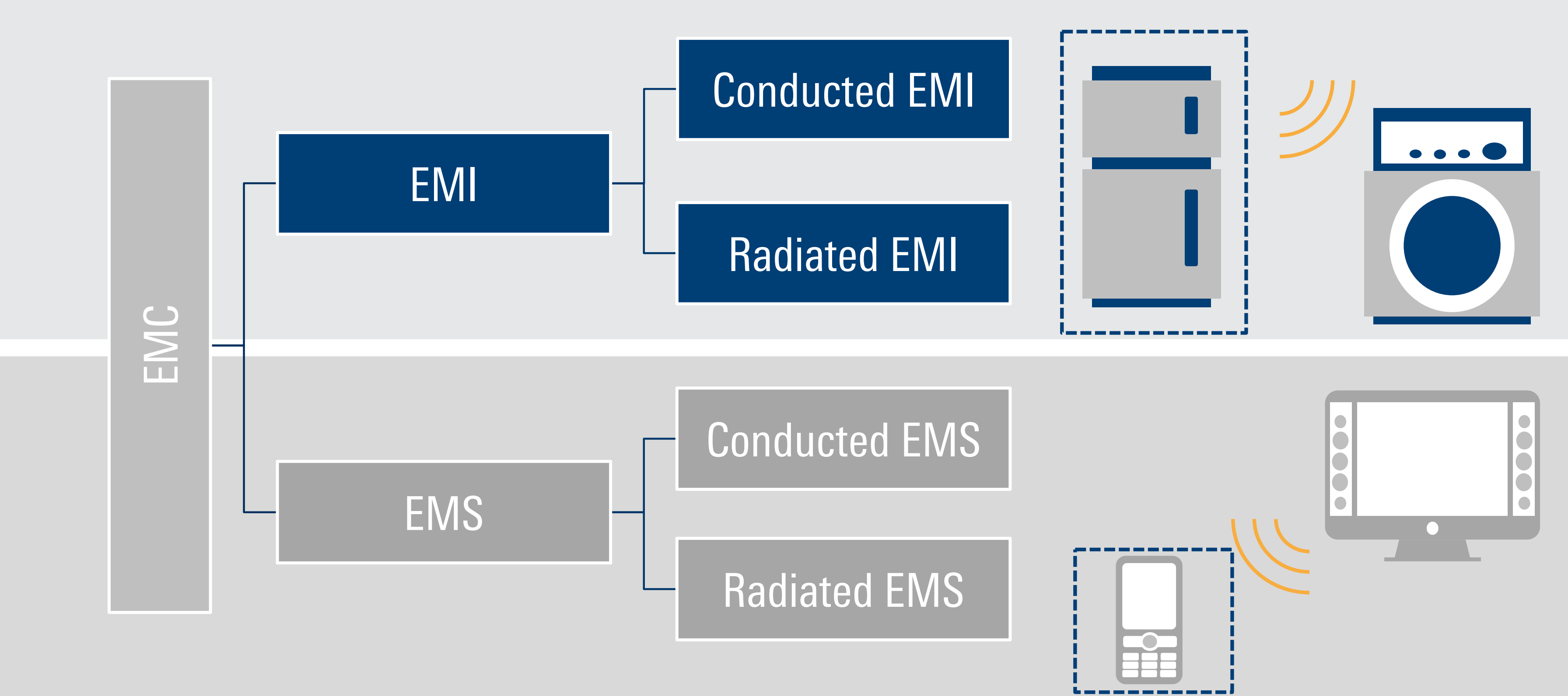


- Flexible tools for:
  - Frequency response, S21
  - Control loop response
  - Power supply rejection ratio

All-in-one tool analytic tool and future enhancements for impedance & lower start frequency

INSTRUMENT NOISE

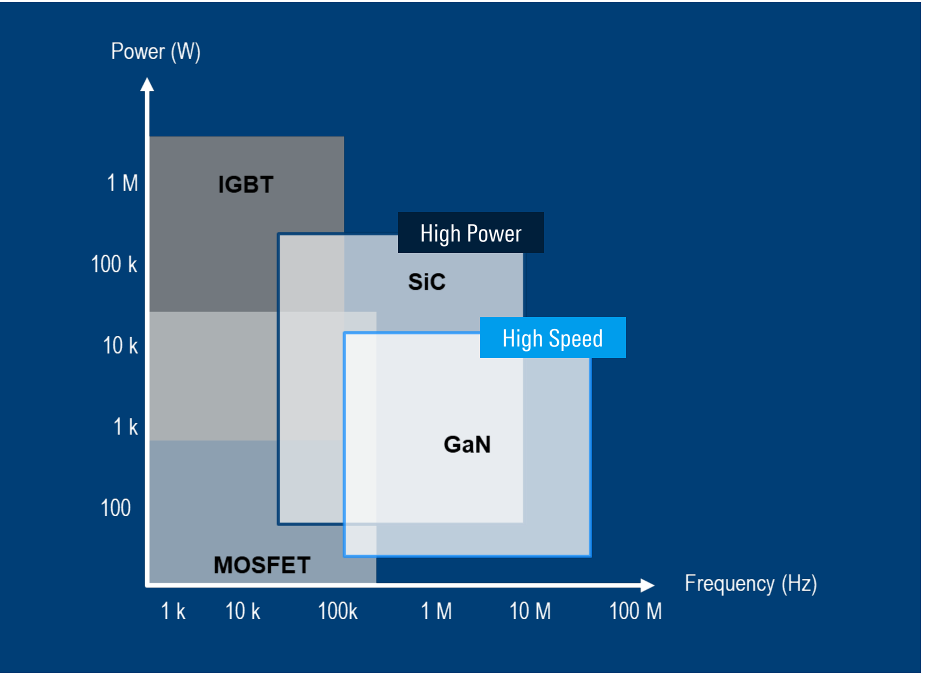
WHAT IS EMC?


EMC
EMI
Conducted EMI
Radiated EMI
EMS
Conducted EMS
Radiated EMS

EMI TESTS IN SUMMARY

	CISPR 11 ISM	CISPR 14 HOUSEHOLD EQUIPMENT	CISPR 15 LIGHTINGS	CISPR 32 MUTLIMEDIA EMC
CONDUCTED EMI (MAINS PORTS)	✓	✓	✓	✓
CONDUCTED EMI (TELECOM PORTS)				✓
RADIATED EMI (MAGNETIC FIELD)	✓	✓	✓	
RADIATED EMI (ELECTRIC FIELD)	✓	✓	✓	✓
POWER DISTURBANCE		✓		

THE DRIVE FOR WIDE BAND-GAP MATERIAL



Silicon Carbide

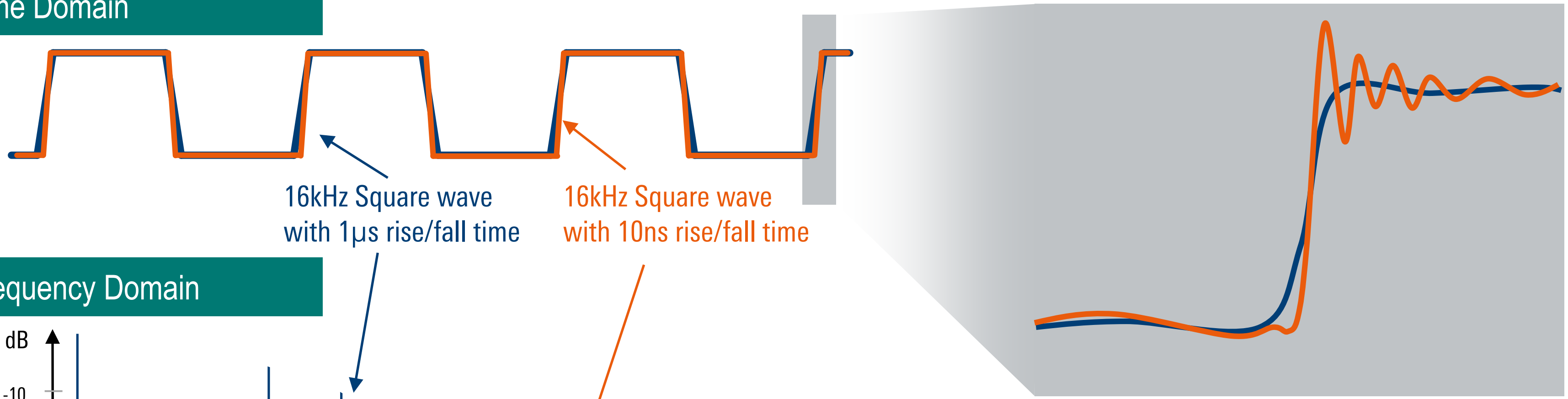
- High power voltages (>1kV)
- Industrial applications

Gallium Nitrite

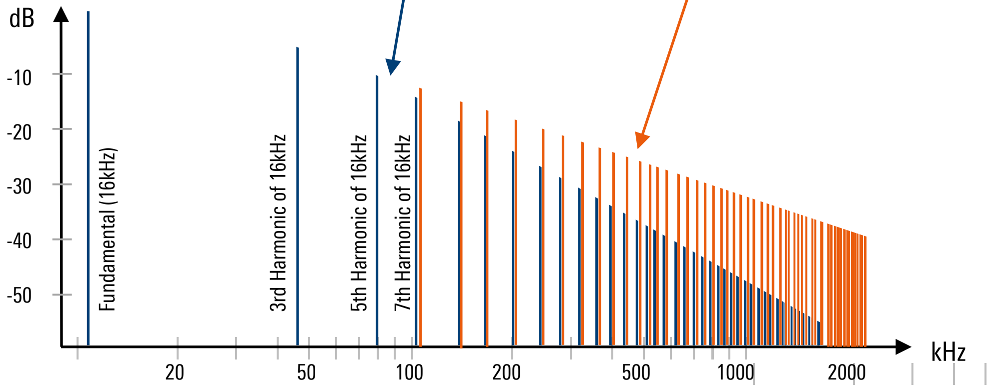
- Mid-range power (<1kV), high current (>100A)
- Limited form-factor

IMPACT OF FASTER SWITCHING AND STEEP EDGES ON EMI

Time Domain



Frequency Domain



High frequency Harmonics come with higher levels

EMI DEBUGGING WITH SCOPE IS NOT NEW?!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Path: EDN Asia >> Design Centre >> Test & Measurement >> Oscilloscope for EMI debugging? Really? (Part 1)

Test & Measurement

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Oscilloscope for EMI debugging? Really? (Part 1)

31 May 2013 | Alvin Ding, Markus Herdin

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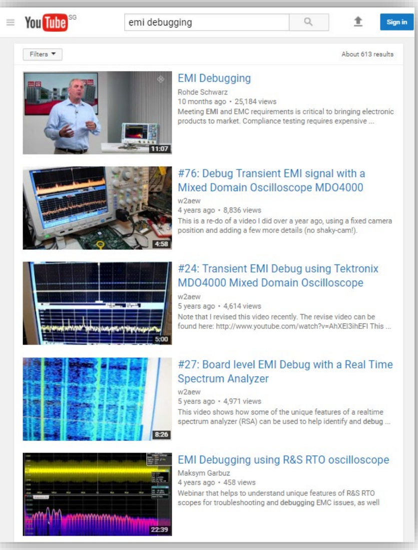
With the availability of high-performance oscilloscopes providing powerful FFT analysis and excellent noise performance, a new tool exists for debugging EMI problems. Based on the results from compliance testing, the oscilloscope proves to be a valuable tool to quickly understand unwanted emissions and identify their root cause. Having access to both time-domain and frequency-domain, in the same instrument, allows for faster analysis of unwanted emissions. Since the oscilloscope is usually available at the desk of the design engineer, it enables debugging of EMI problems in R&D and allows tests before going to the EMC lab, thereby significantly increasing the likelihood of a successful compliance test.

This is the first in a series that discusses various use cases and highlights limitations of high-performance oscilloscopes with powerful FFT implementations for EMI applications.

New digital oscilloscopes, such as the Rohde & Schwarz RTO, which we will use in this use-case analysis, bring EMI debugging capabilities directly onto the desk of the design engineer. This model offers front-end sensitivity that compares with spectrum analysers and allows simultaneous access to both the time domain and the frequency domain.


YouTube SG

emi debugging

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About 613 results

EMI Debugging

Rohde Schwarz

10 months ago • 25,184 views

Meeting EMI and EMC requirements is critical to bringing electronic products to market. Compliance testing requires expensive ...

11:07

#76: Debug Transient EMI signal with a Mixed Domain Oscilloscope MDO4000

w2aew

4 years ago • 8,836 views

This is a re-do of a video I did over a year ago, using a fixed camera position and adding a few more details (no shaky-cam!).

4:58

#24: Transient EMI Debug using Tektronix MDO4000 Mixed Domain Oscilloscope

w2aew

5 years ago • 4,614 views

Note that I revised this video recently. The revise video can be found here: http://www.youtube.com/watch?v=AhXEI3ihEFI This ...

5:00

#27: Board level EMI Debug with a Real Time Spectrum Analyzer

w2aew

5 years ago • 4,971 views

This video shows how some of the unique features of a realtime spectrum analyzer (RSA) can be used to help identify and debug ...

8:26

EMI Debugging using R&S RTO oscilloscope

Maksym Garbuz

4 years ago • 458 views

Webinar that helps to understand unique features of R&S RTO scopes for troubleshooting and debugging EMC issues, as well

22:39


embedded

cracking the code to systems development

DEVELOPMENT ▾ ESSENTIALS & EDUCATION ▾ COMMUNITY ▾ ARCHIVES

Home > Debug & Optimization Development Centers > Design How-To

Practical EMI troubleshooting with a mixed domain oscilloscope

DECEMBER 29, 2013

Share 1 G+ Tweet Like 1

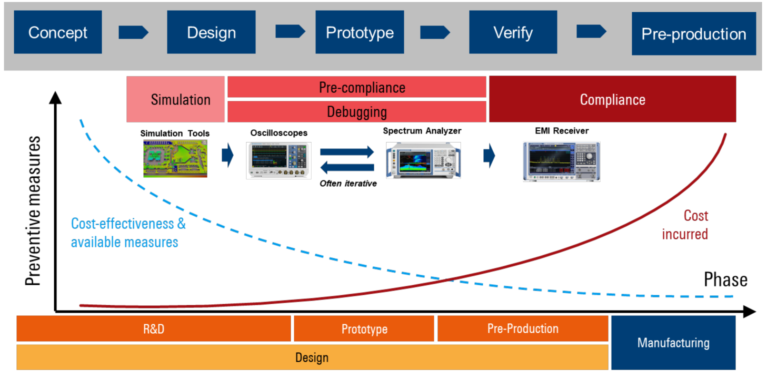
Modern embedded system designs present challenges for EMI testing and troubleshooting that didn't exist years ago. These challenges include switching power supplies, high speed system clocks and data buses, bursty information transfers, transmission line and termination issues, and spread spectrum clocking, as well as the integration of wireless interfaces and connectivity. Adding to the challenge is that most of these technologies can lead to issues that are transient, load dependent, and highly variable over time.

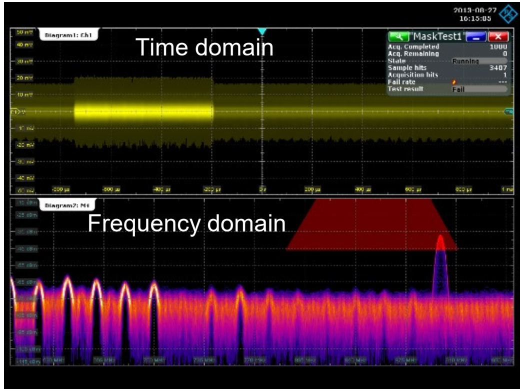
With budgets and time pressures greater than ever, it's critical that designers working on embedded systems test for potential EMI issues and head them off as early in the design process as possible. Traditional tools often are not adequate to identify the source of EMI problems in today's electronics. Fortunately, the combination of a practical approach to testing and new tools like the mixed domain oscilloscope (MDO) help eliminate guesswork. An MDO incorporates a wideband spectrum analyzer along with a traditional mixed signal oscilloscope, helping to make troubleshooting transient RF and EMI signals faster and more efficient.

Better instruments progressively changes debug methodologies

EMI DEBUGGING WITH OSCILLOSCOPES?

- ► Available on every R&D engineers desk
- ► Oscilloscopes show both time and frequency domain
- ► Today's oscilloscopes provide excellent sensitivity and usability





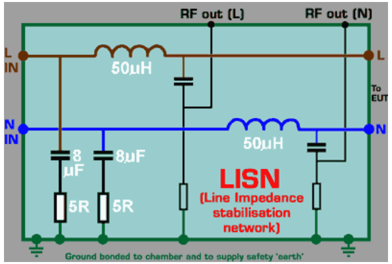
EMC APPLICATION FIELDS OF OSCILLOSCOPES

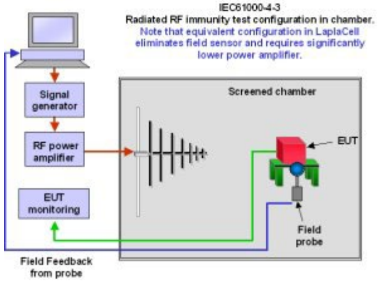
EMI

- Near-field probing
- Conducted Emissions Debugging

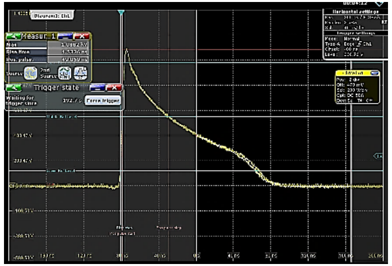
EMS

- EUT Monitoring
- ESD, EFT and Burst Calibration / ESD Tests





- ► EUT Monitoring



- ► Burst calibration
- ► ESD testing

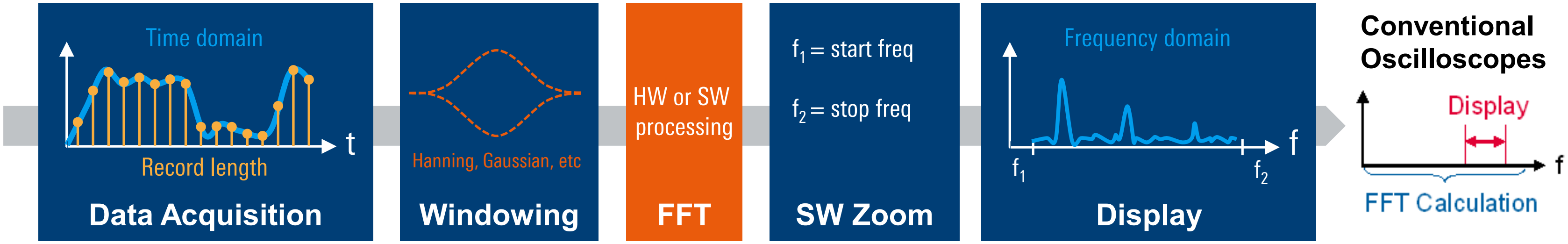
In R&D

In the test lab

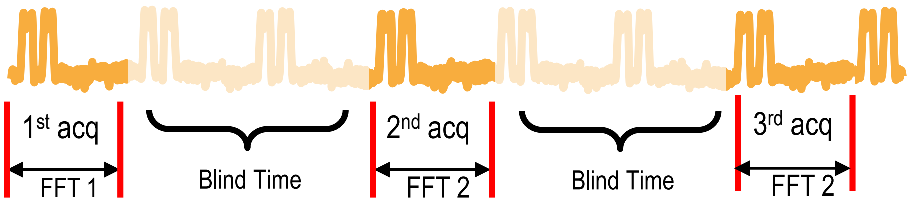
TEST RECEIVER VS OSCILLOSCOPE

Test receiver	Oscilloscope
Scan spectral energy for fixed duration	Time domain captured calculated FFT spectrum
Using different band-limited detectors	Wideband capture with limited ADC sensitivity
Log scale display with limit lines	Typically linear spectrum display
Right tool and compliant to standard	Companion for early debug testing

TRADITIONAL FFT CALCULATION IS SLOW



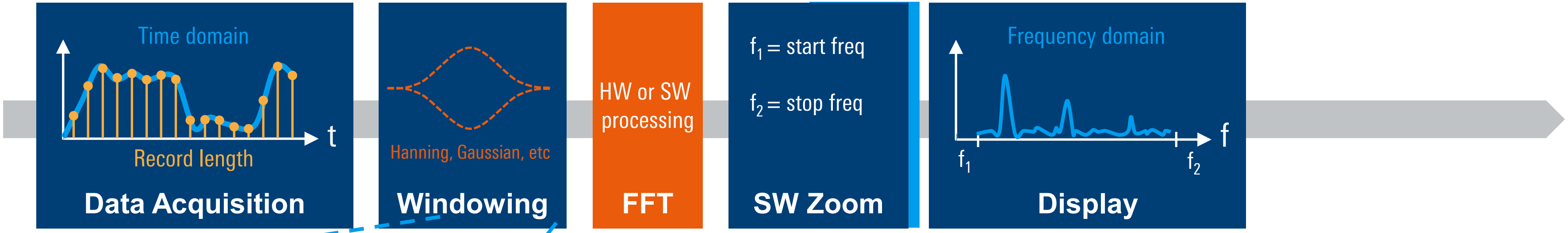
- ▶ Calculate FFT over entire acquisition
- ▶ Conventional Scope usually acquire one RL and reconstruct FFT then go on to acquire the next RL to compute the next FFT → Missing sporadic event

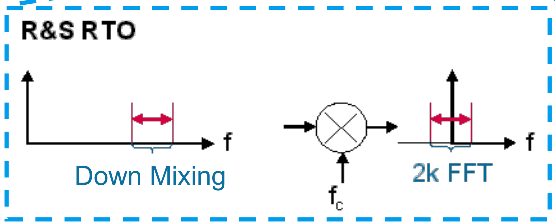


Disadvantages of conventional FFT :

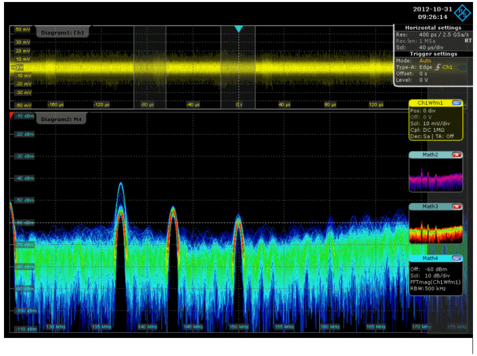
- ▶ Very slow speed / update rate
- ▶ Limited RBW due to insufficient RL
- ▶ Complex configuration (TD settings)

R&S MODERN OSCILLOSCOPE SPEEDING UP FFT





- Calculate only FFT over span of interest
- f_C = center frequency of FFT



Advantages of R&S approach:

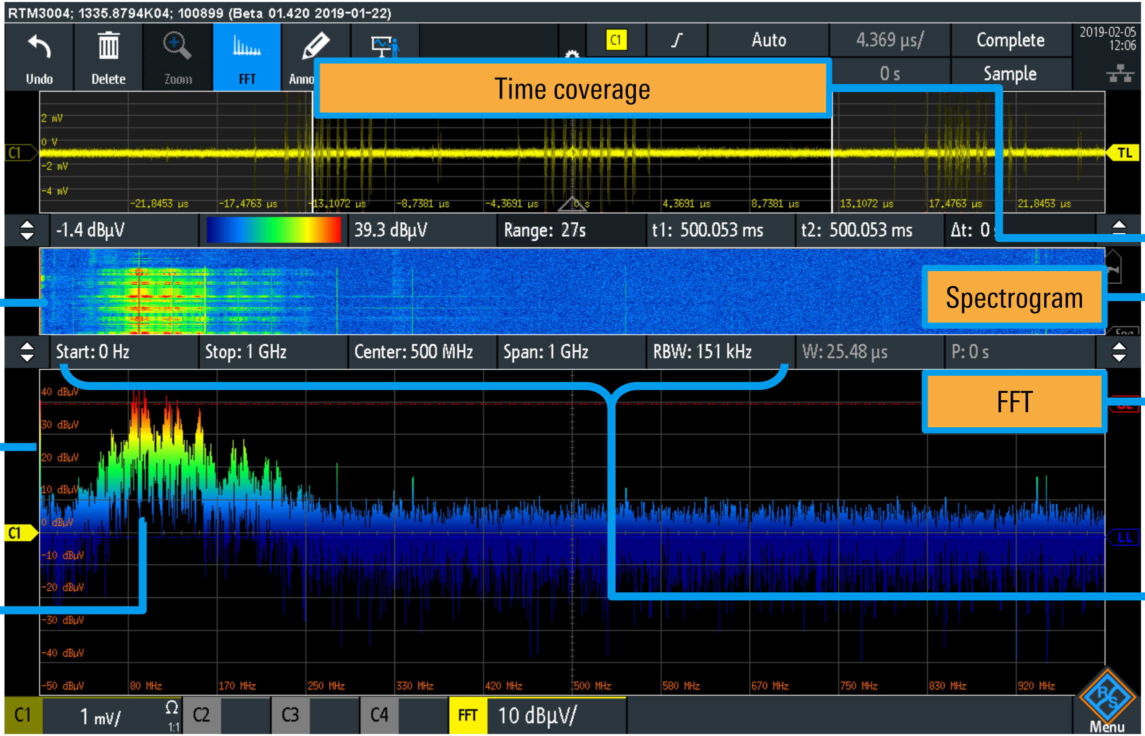
- Higher speed / update rate
- Good RBW without magnification
- Flexible configuration
- Multiple overlapping FFT able to find spurious faults

MODERN SCOPE FFT CAPABILITIES

Waterfall diagram helps to show short emissions

dBuV scaling like in EMI measurements

Color coding display for better visibility



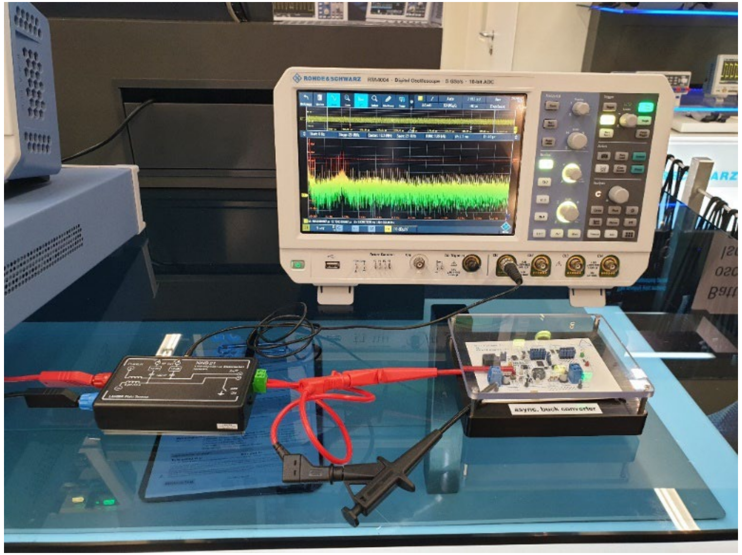
Time-frequency correlation of emissions

Directly set start, stop and resolution bandwidth

EMI DEBUGGING WITH OSCILLOSCOPES

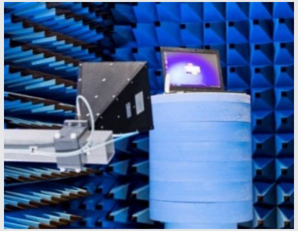
Radiated Emission
Debugging after failed Pre-Compliance or Compliance

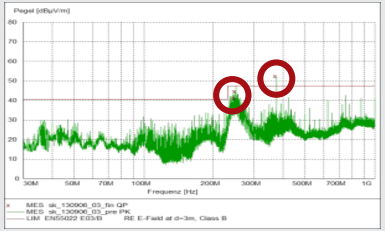
Conducted Emission
Pre-test and debugging in the R&D lab



COMMON EMI DEBUGGING PROCEDURE : ANALYSIS STEPS

A) Far-field measurement



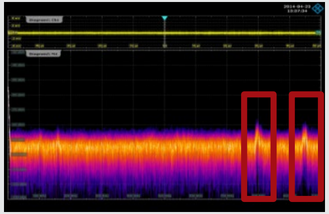


B) "Know your DUT":

List of potential interferer sources

Source	Frequency
Clock frequency	e.g. 25 MHz + Multiples
Ethernet PHY	e.g. 125 MHz + Multiples
Voltage converter / power adapter	broadband
…	

C) Reference measurement without DUT



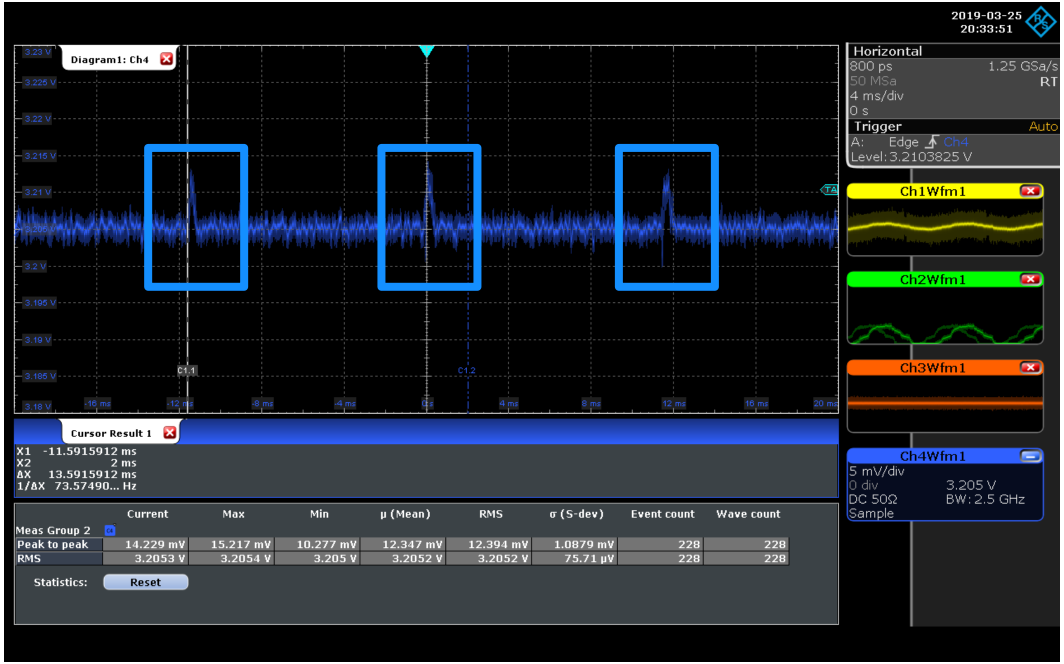
D) Interferer current measurement to find out the coupling type

E) Nearfield probe to localize the interferer source

F) Applying counter-measures and validation

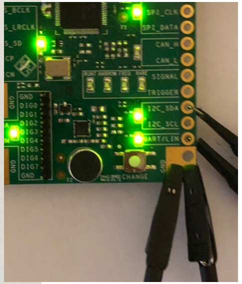
EXTRA CREDIT: WHAT'S CAUSING PERIODIC RAIL SPIKES?

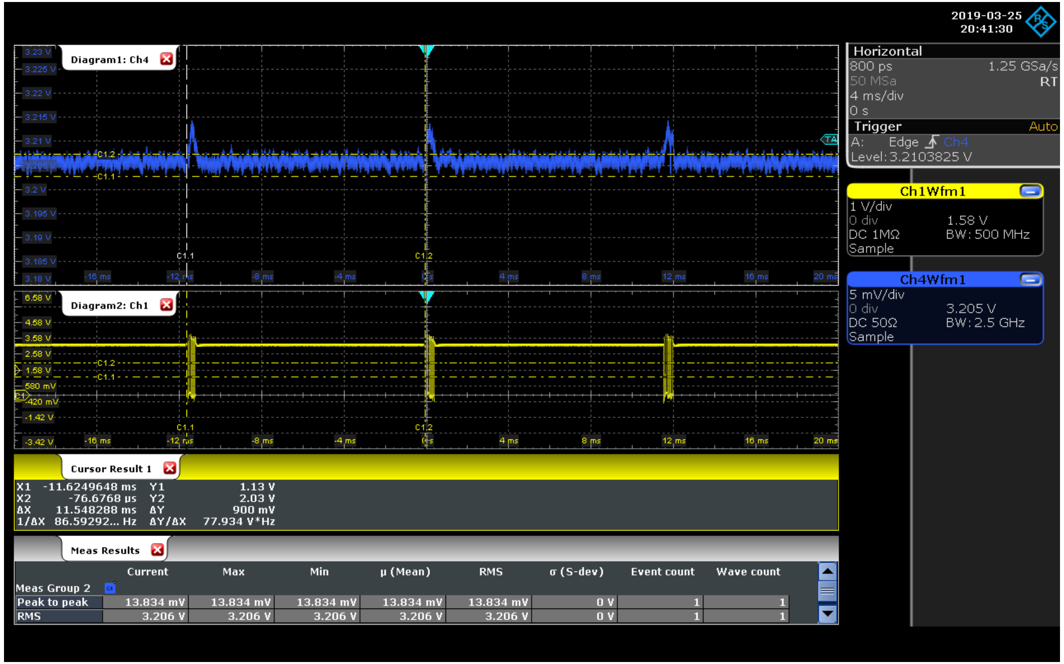
Adjust timebase to 4 ms / div



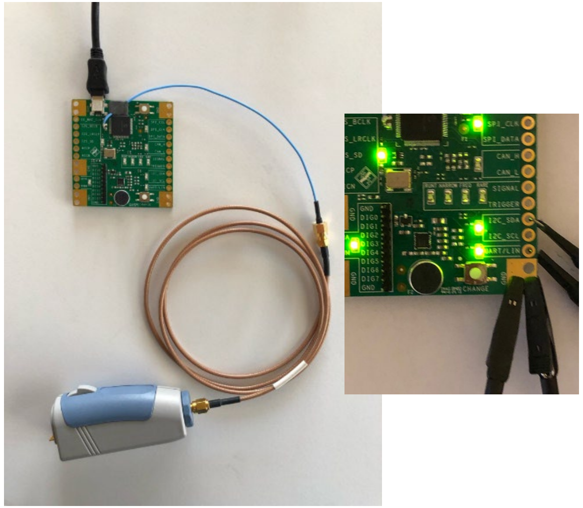
POWER RAIL PEAKING CORRESPONDS TO I²C PACKETS

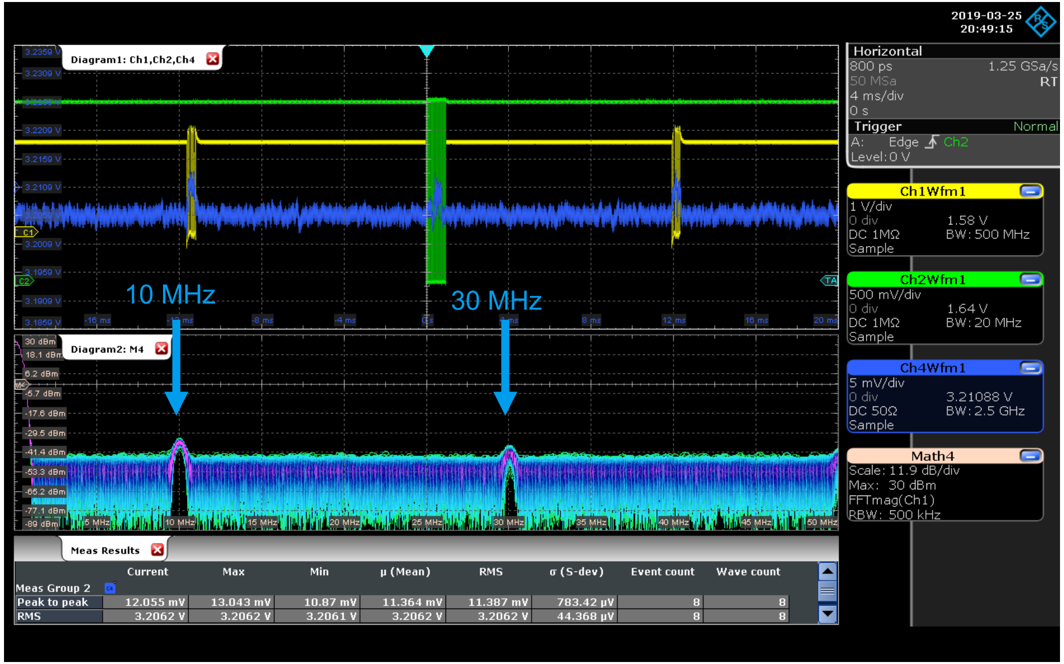
Attach to I²C signals



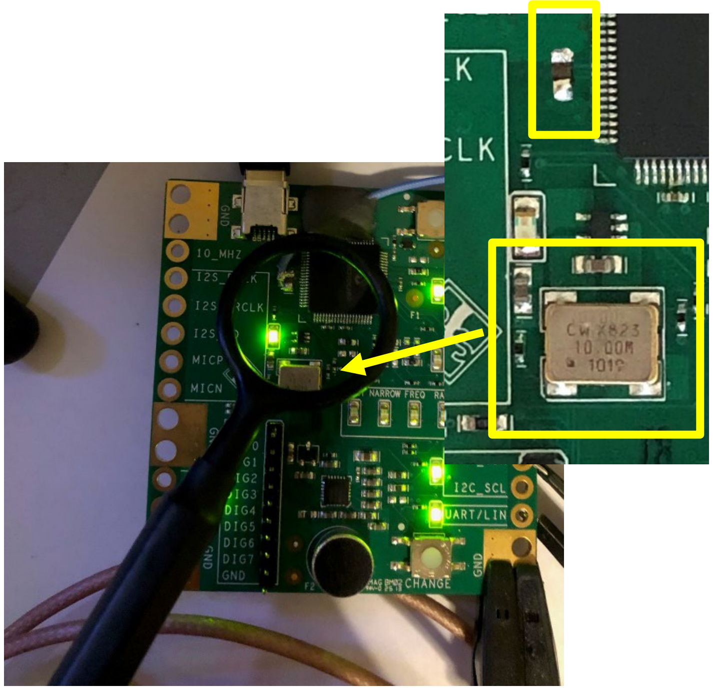


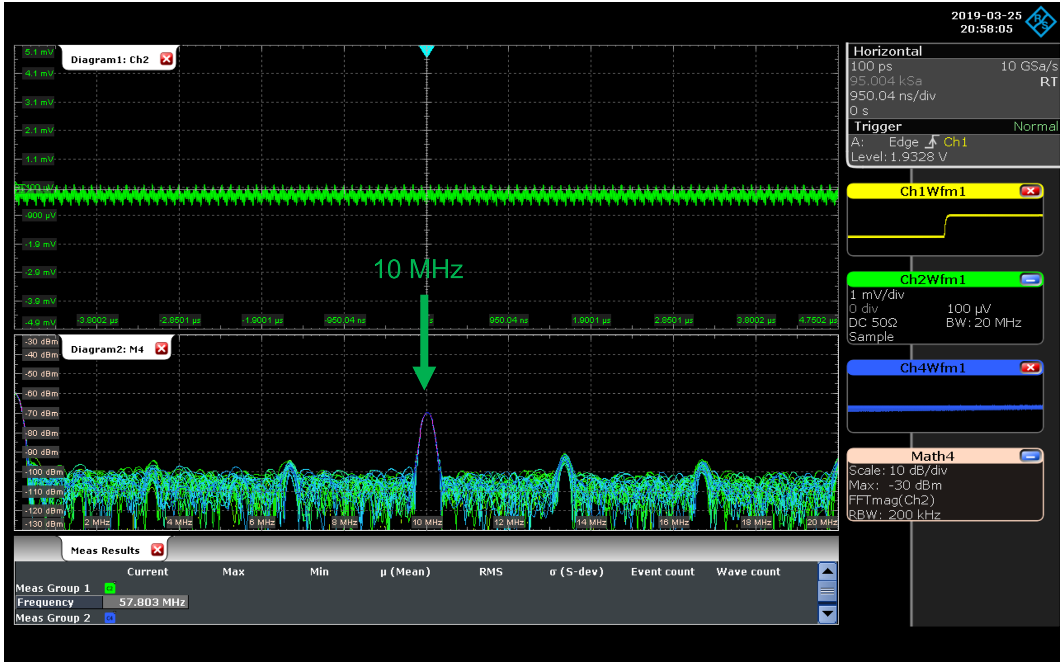
FFT ON POWER RAIL SHOW 10 MHZ AND HARMONIC TONES





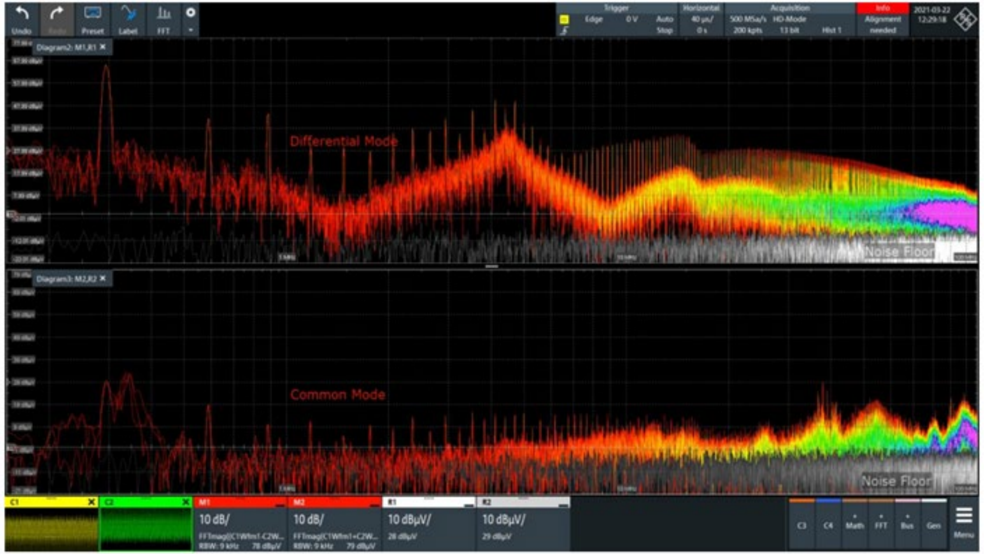
NEAR FIELD PROBE (HZ-15)

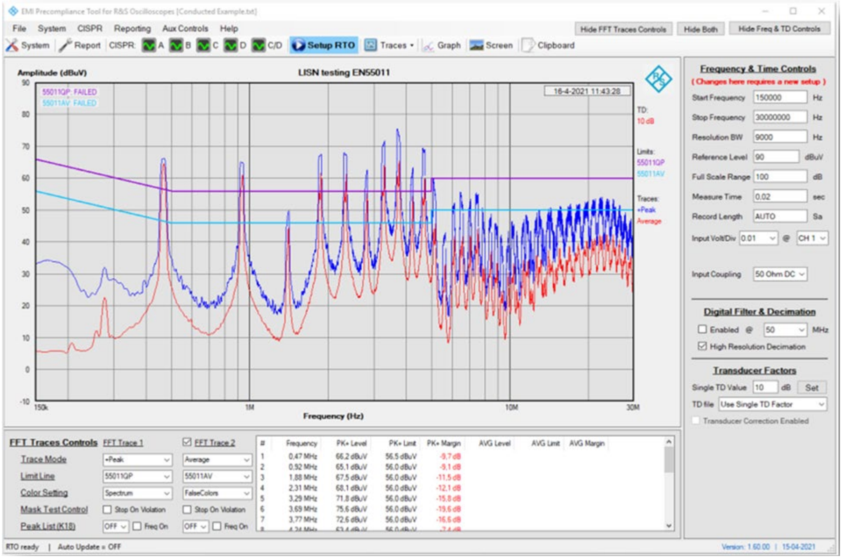




10 MHz EMI…. coming from 10 MHz oscillator

EMI PRECOMPLIANCE APPLICATION :

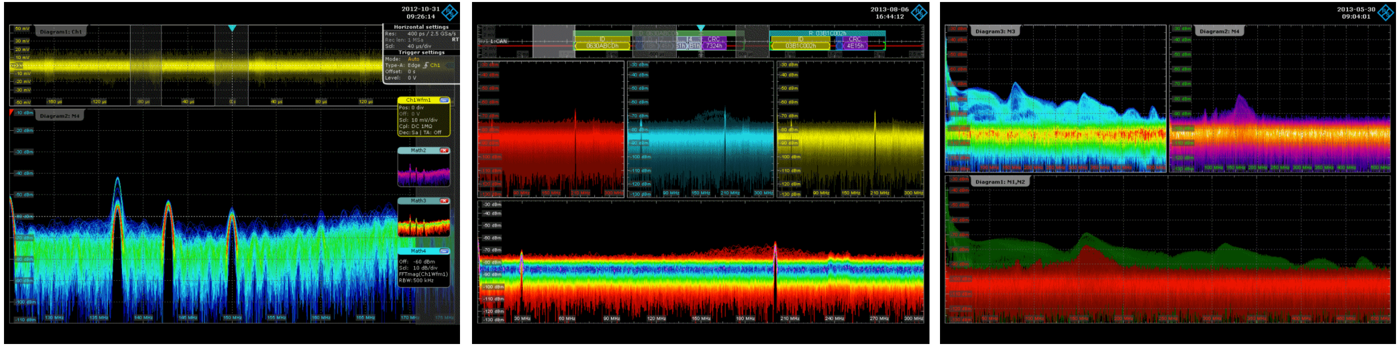




R&S OSCILLOSCOPE USP ON EMI DEBUGGING TECHNIQUES

Hardware Specifications	DDC, HW-based FFT, 1 mV/div at full BW, high ENOB, Acquisition bandwidth

Locate	Capture	Analyze



Locate	Capture	Analyze
High speed FFT Multi-channels FFT (Overlay of multi-channels FFT) Overlapped FFT Real time FFT Intensity grading display	**Time domain** Digital trigger system Serial and parallel bus trigger Mask violation **Frequency domain** Mask violation	Multi-traces Gated FFT Correlated time and freq. domain Sampled memory (Post analysis) History mode

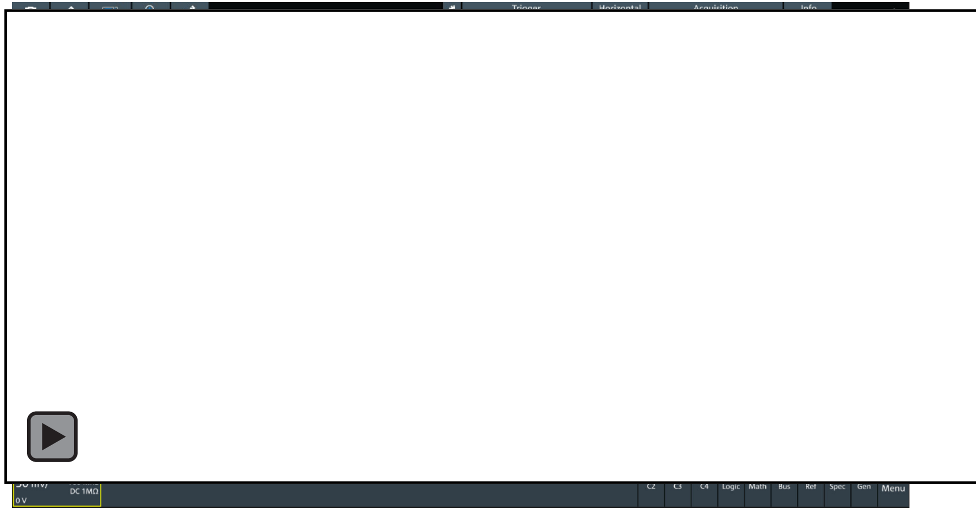
MXO4 SPECIFICATIONS AT A GLANCE

MXO 4 Series Key Specifications	
Channels	4
Bandwidth	200, 350 & 500 MHz, 1 & 1.5* GHz
Max. Sample Rate	5 GSa/s
Record Length	400 Mpts / channel (option: 800 Mpts on 2 ch)
Vertical resolution	12 bit ADC, up to 18 bit
Acquisition rate	4.5 Mwfm/s
HW options	• MSO 16 ch • 2 ch 100 MHz generator
Display	13.3“ Full HD
OS	Linux

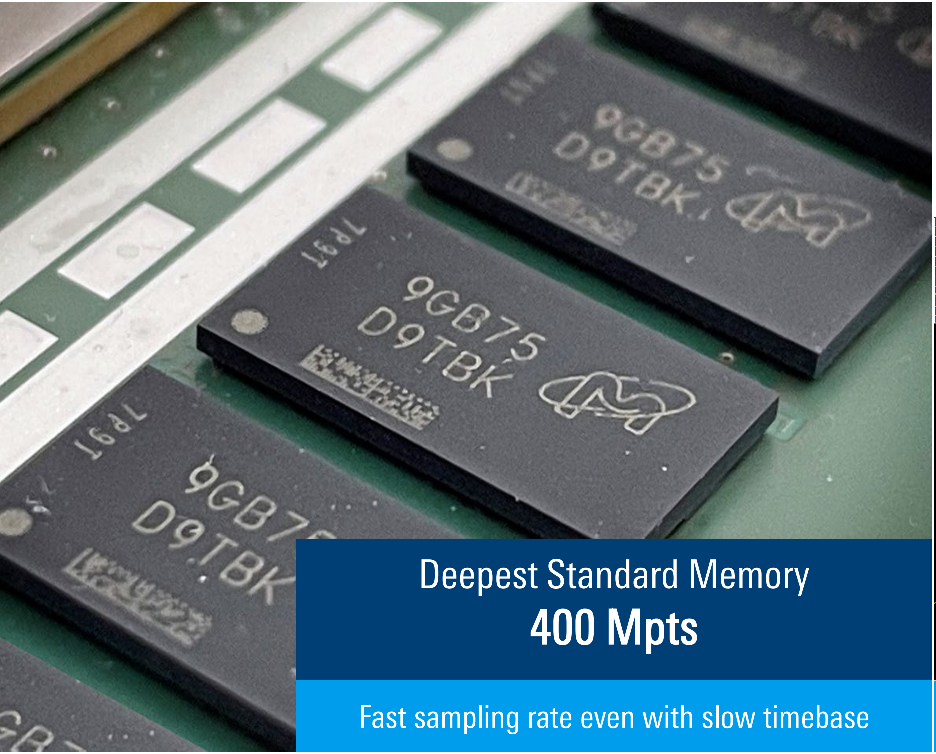
*interleaved

WORLD'S FASTEST UPDATE RATE & TRIGGER RATE

- New R&S ASIC technology
  - 4.5 M wfms/s (not a special mode)
  - 100% trigger captures up to 4.5 M events/sec
  - Trigger re-arm time < 21 ns



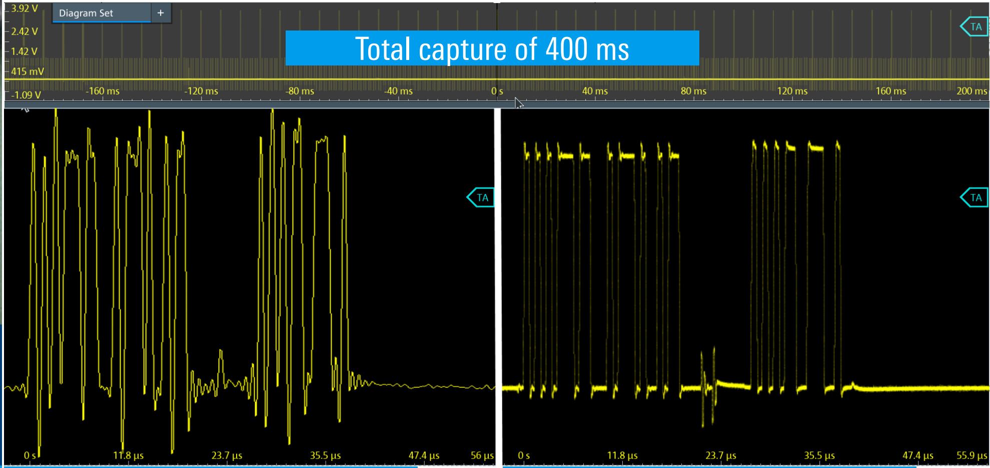
CAPTURE MORE TIME



Deepest Standard Memory
400 Mpts

Fast sampling rate even with slow timebase

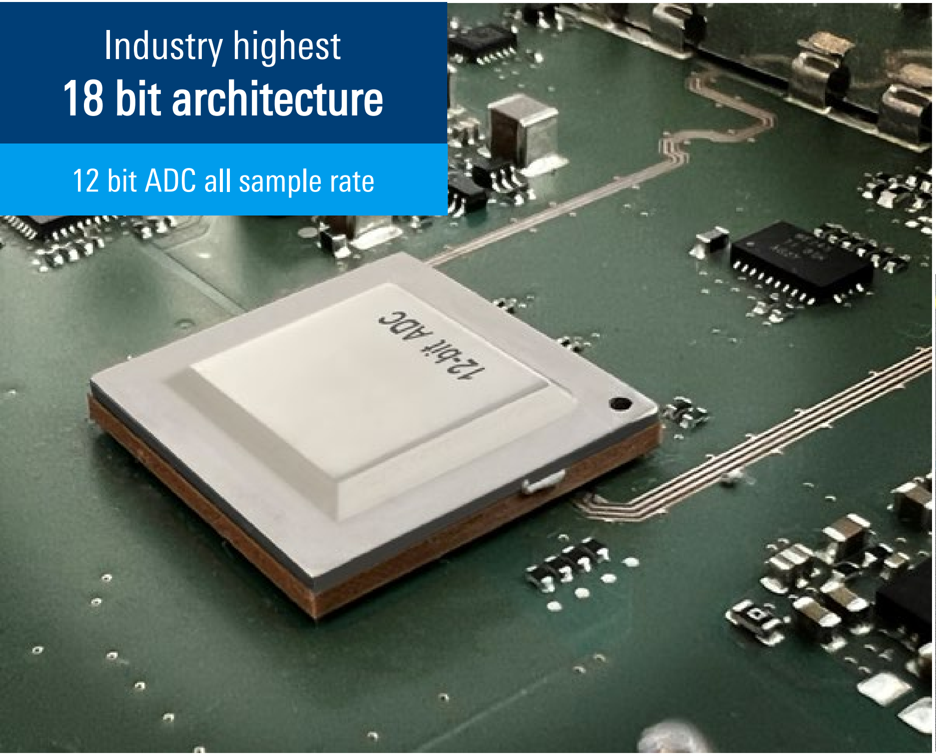
- 400 Mpts / ch
- Optional 800 Mpts (interleaved)



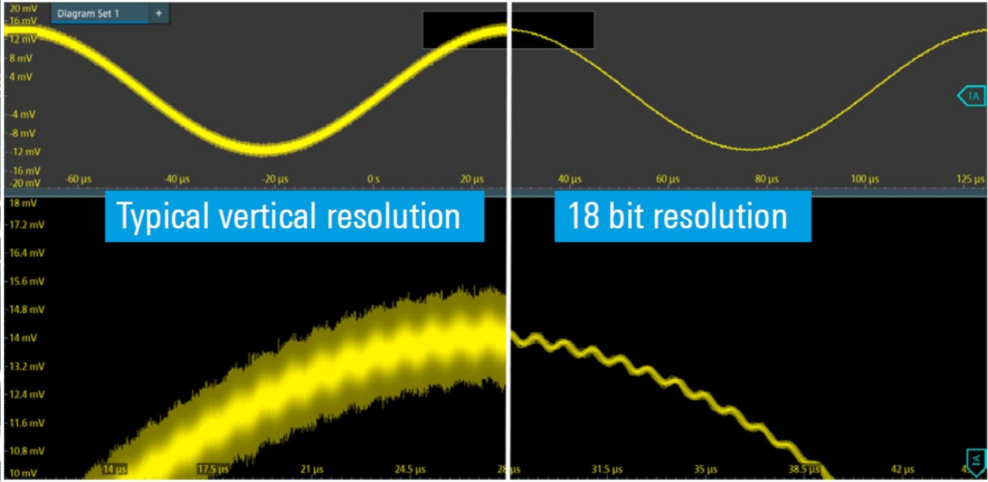
1 Mpoint memory

800 Mpoint memory

SEE YOUR SIGNALS ACCURATELY



- ► 12-bit ADC all the time
- ► 18-bit architecture (with HD mode)



OSCILLOSCOPES FOR POWER ELECTRONICS
WHICH R&S OSCILLOSCOPE TO USE

	Scope Rider	RTM	MXO 4	RTO
				
Bandwidth	• 60 MHz to 500 MHz	• 100 MHz to 1 GHz	• 100 MHz to 1.5 GHz	• 200 MHz to 6 GHz
Probes	• Passive • Battery operated or with external power supply	• Full probe portfolio available	• Full probe portfolio available	• Full probe portfolio available
Important Features	• **Isolated channels** • Harmonic analysis • Battery operated • 10 Bit ADC	• **Deep memory** • Power analysis • EMI debugging • 10 Bit ADC	• **Deep memory** • Power analysis • EMI debugging • 12 Bit ADC (18 Bit HD Mode)	• **Advanced measurement and analysis functions** • Very deep memory • EMI debugging • 16 Bit HD Mode • Excellent signal fidelity
Application	• **Performance & Efficiency**	• **General Purpose**	• **Performance & Efficiency**	• Performance & Efficiency **+ EMI Debugging**

Q & A