90 YEARS OF ENSURING A SAFER AND CONNECTED WORLD

DC POWER MEASUREMENT & EMI DEBUGGING WITH R&S OSCILLOSCOPE

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Application Engineer Oscilloscopes

ROHDE&SCHWARZ

Make ideas real

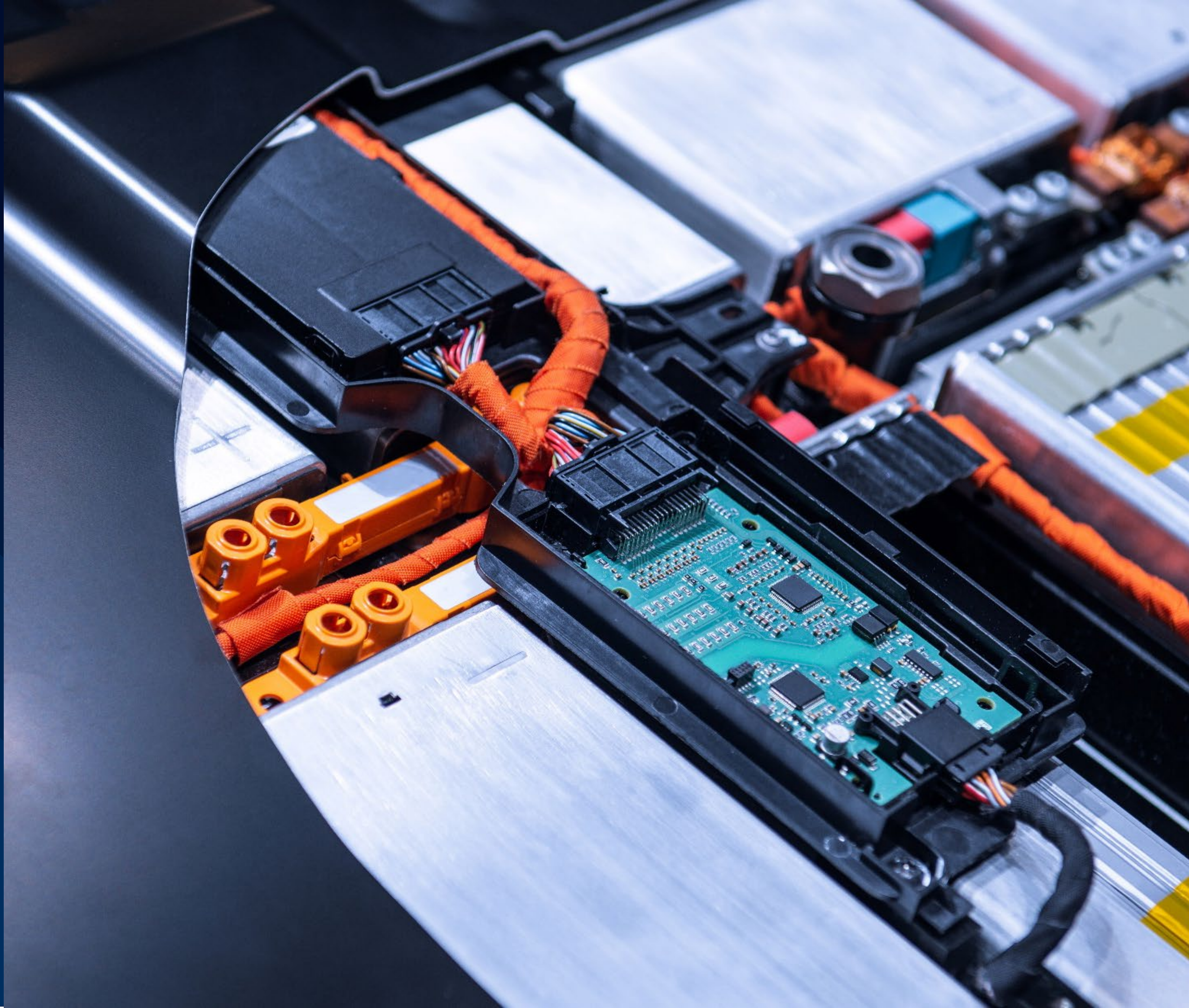
CONTENT

1. DC Measurement
   - Choosing the right probes
   - Power rail probe

2. EMI Debugging

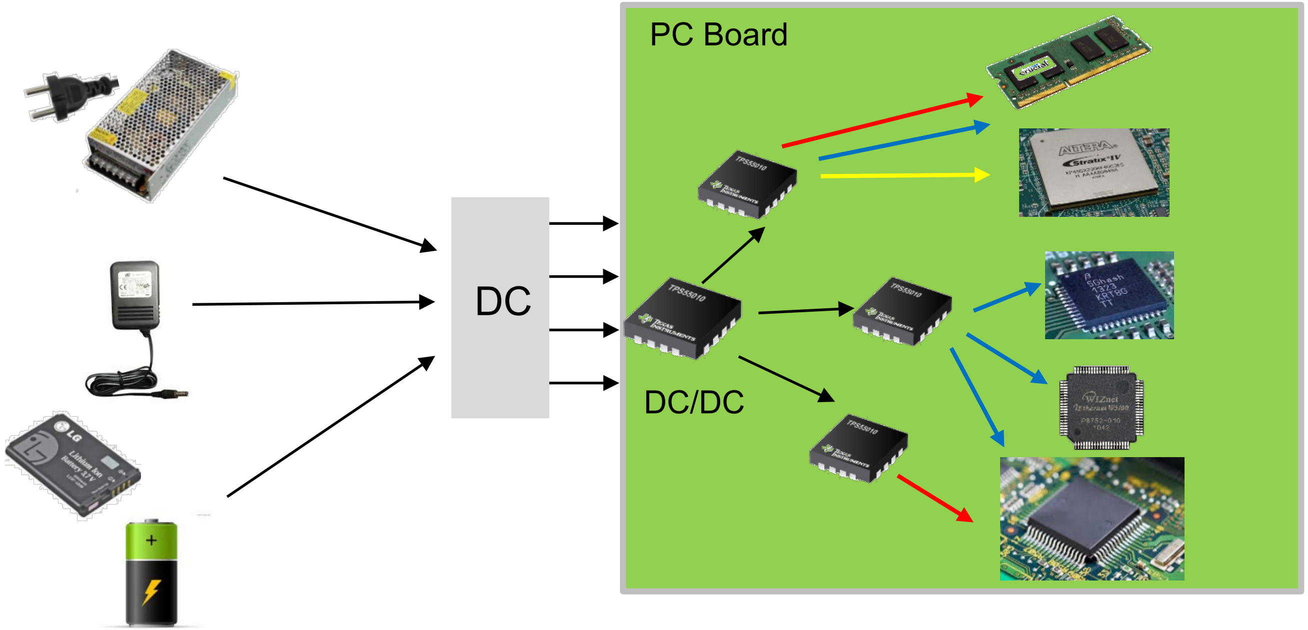
3. R&S Oscilloscope Portfolio

4. Q&A

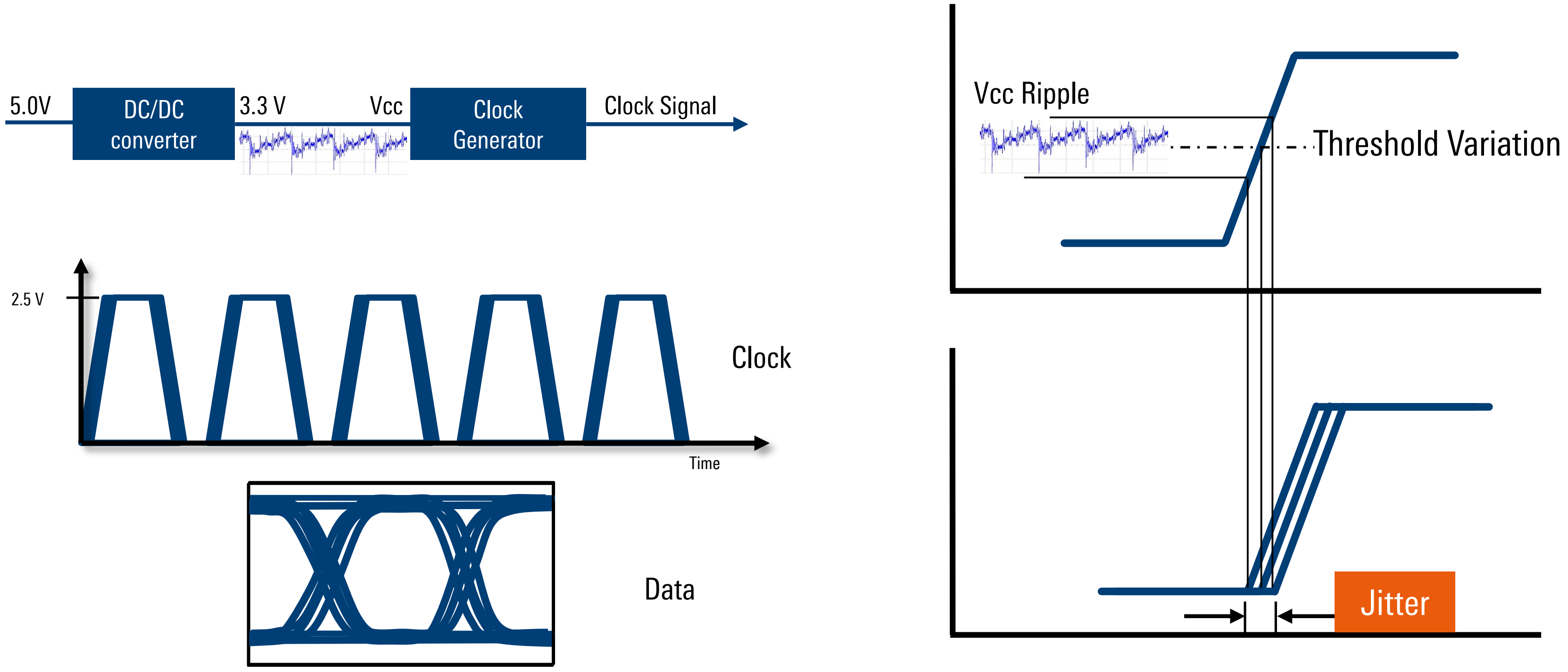


DC MEASUREMENT

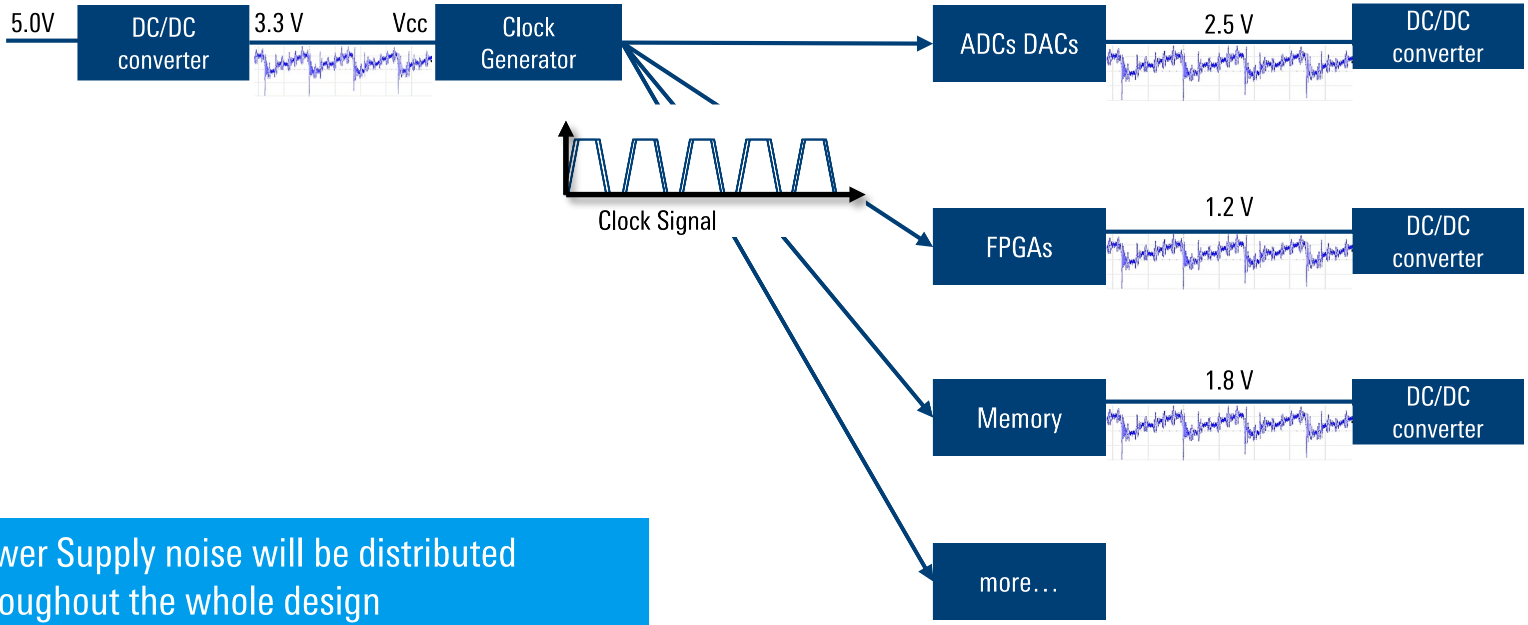
TYPICALLY LOTS OF POWER RAILS



NOISY POWER INFLUENCE SIGNAL INTEGRITY



POWER NOISE PROPAGATE TO OTHER CIRCUITS

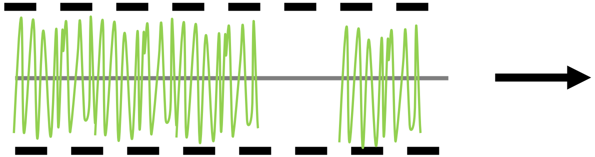


Power Supply noise will be distributed throughout the whole design

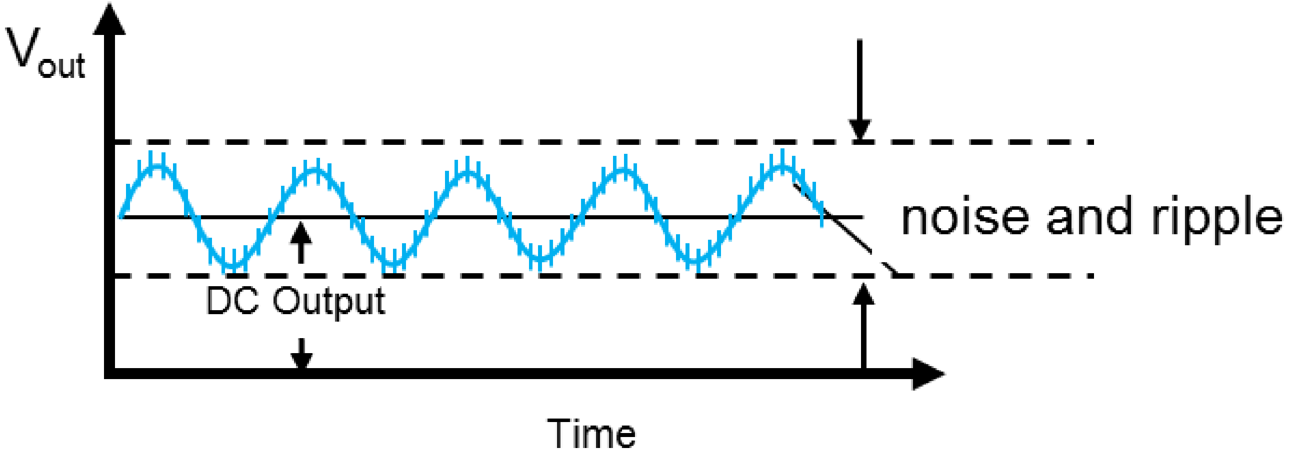
POWER RAIL TESTING

- IC suppliers specify # of power rails, voltage for each, and tolerance for each.
  - FPGAs, ASICs, CPUs, DDR memory…
- Measurements: sequencing, noise / ripple, drift, load/step response, EMI

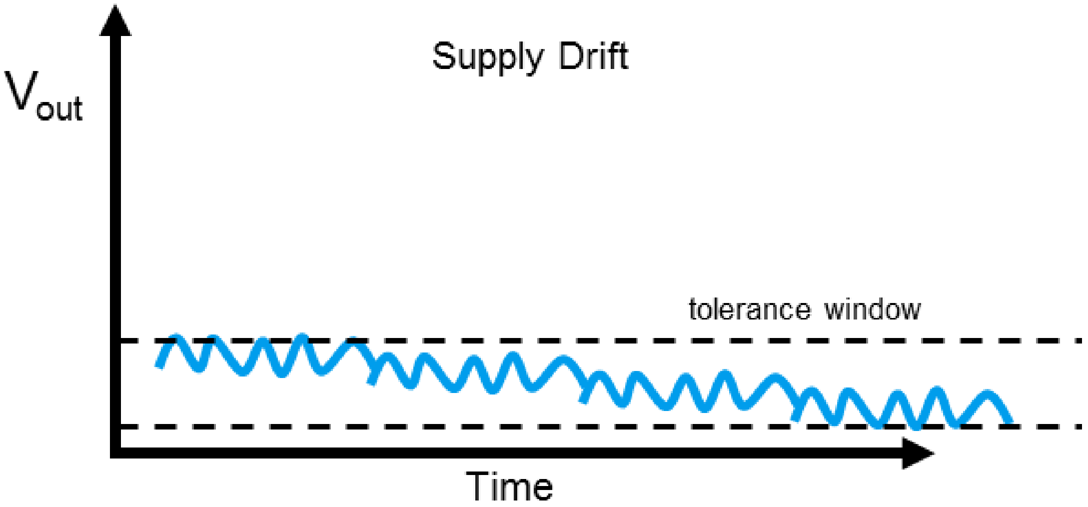
Power voltage



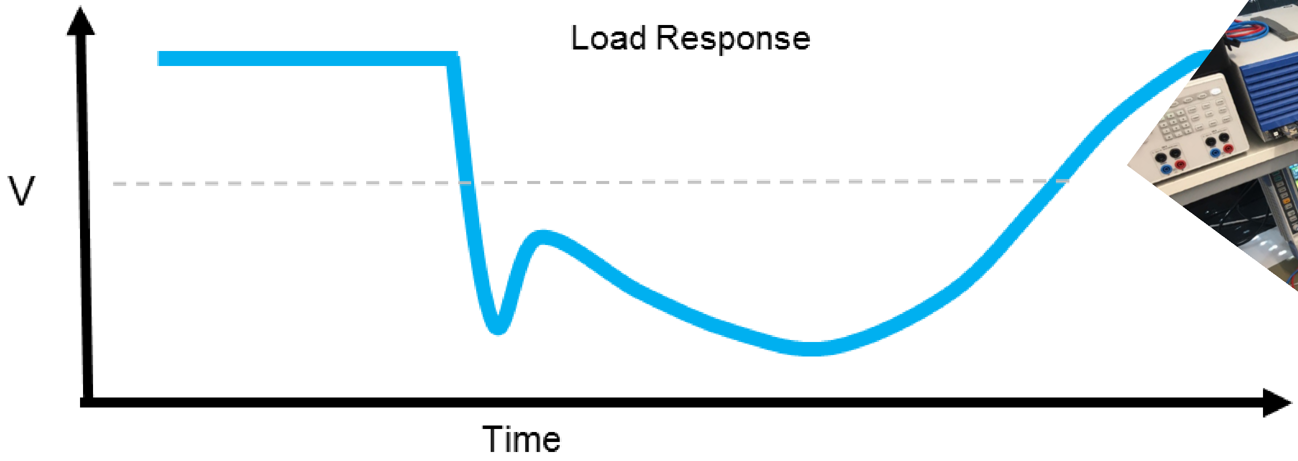
POWER RAIL MEASUREMENTS: NOISE / RIPPLE (VPP)

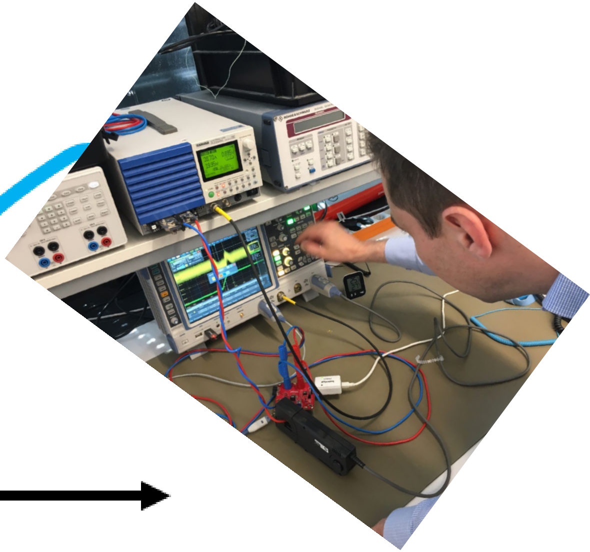


POWER RAIL MEASUREMENTS: SUPPLY DRIFT

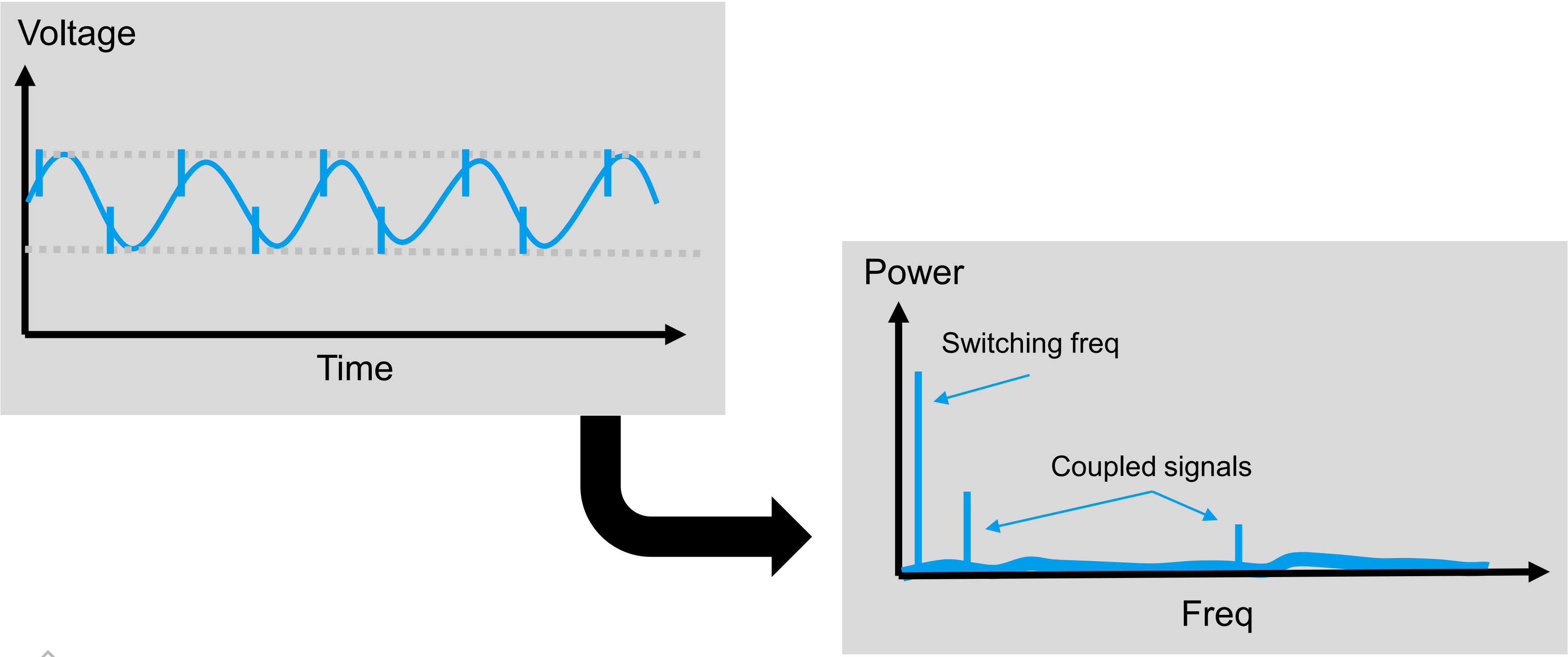


POWER RAIL MEASUREMENTS: LOAD/STEP RESPONSE





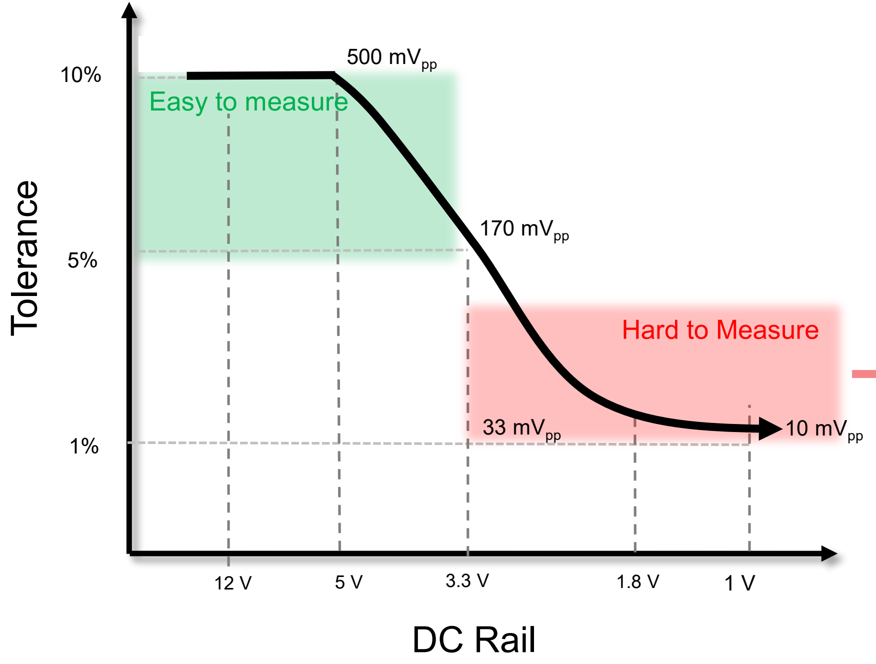
POWER RAIL MEASUREMENTS: COUPLED SIGNALS (EMI)

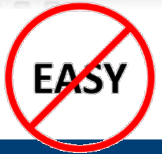


DC OR AC?

POWER RAIL MEASUREMENT CHALLENGES

Lower rail voltages and smaller tolerances





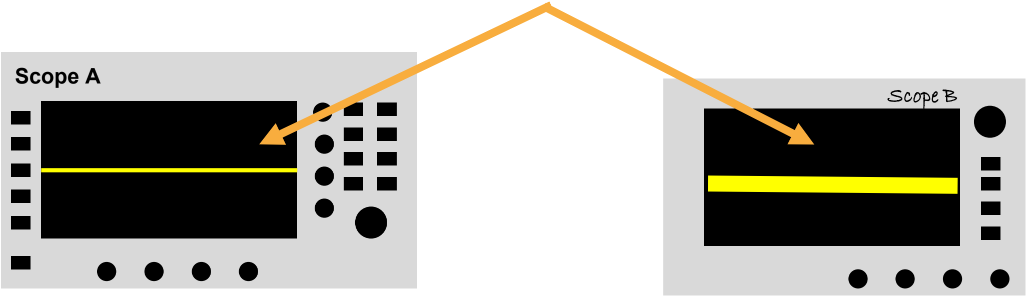
Examples

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$_{pp}$

Scope measurement noise can approach or exceed needed signal measurement values

MEASUREMENT NOISE…
IS A FUNCTION OF WHAT SCOPE YOU USE

You will never be able to measure signal attributes smaller than the intrinsic noise of the scope.



Less noise

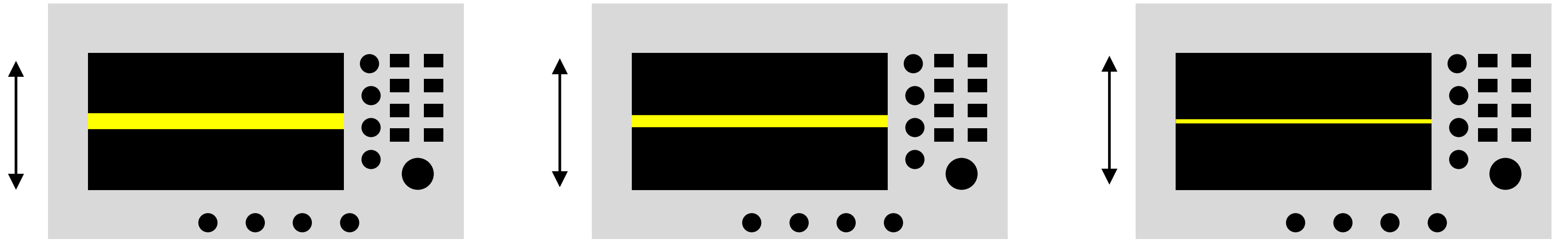
More noise

Intrinsic measurement noise with all input signals disconnected.

MEASUREMENT NOISE...

IS A FUNCTION OF FULL-SCALE VERTICAL SCALING (% OF FULL VERTICAL)

10 mV full screen | 100 mV full screen | 5 V full screen

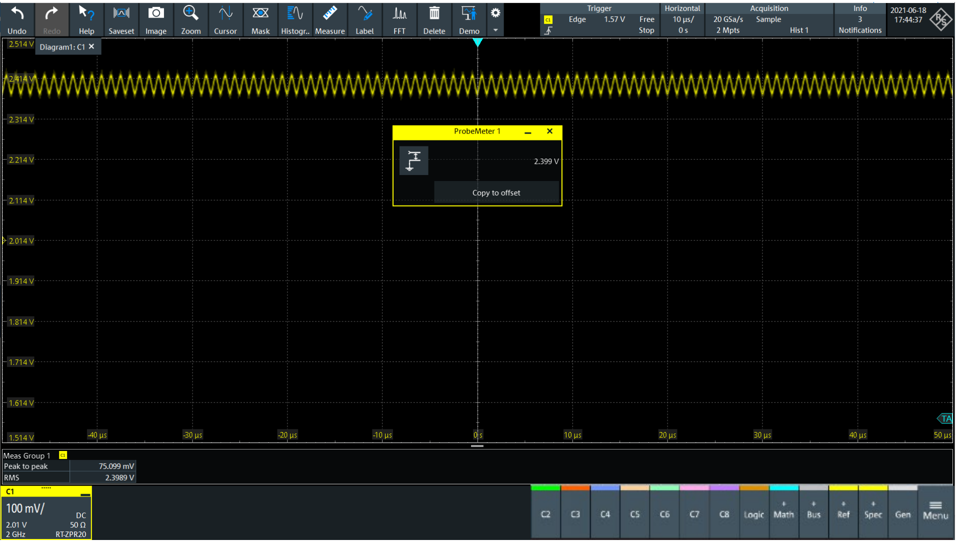


Least noise | More noise | Even more noise

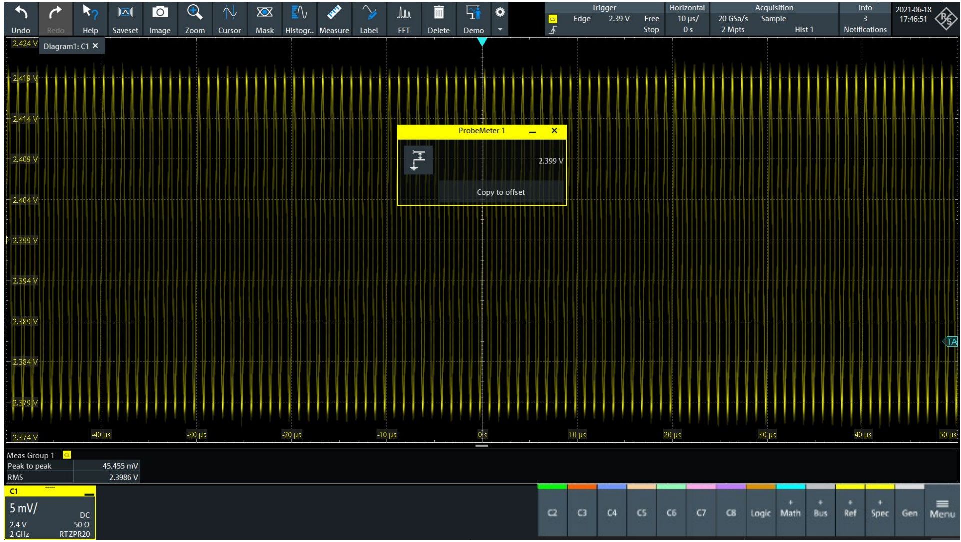
MEASUREMENT NOISE: INSUFFICIENT INTERNAL OFFSET IMPACTS

Requires using a higher vertical sensitivity → more noise

Using max built-in scope offset

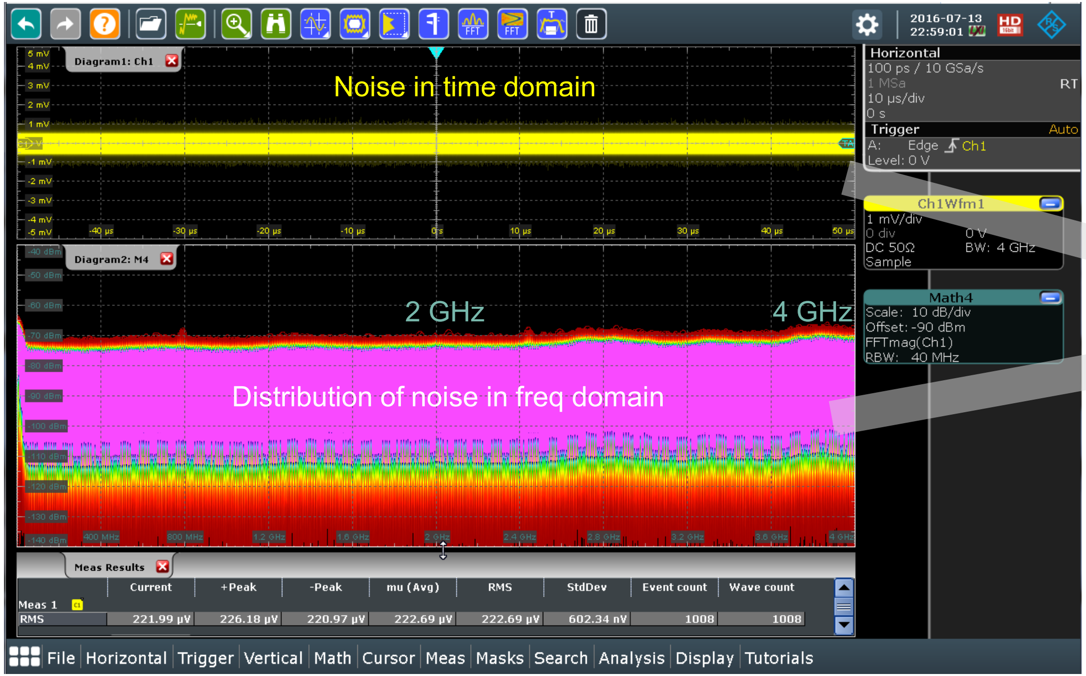


Using built-in probe offset



MEASUREMENT NOISE…

IS A FUNCTION OF MEASUREMENT BANDWIDTH



Noise in time domain

=

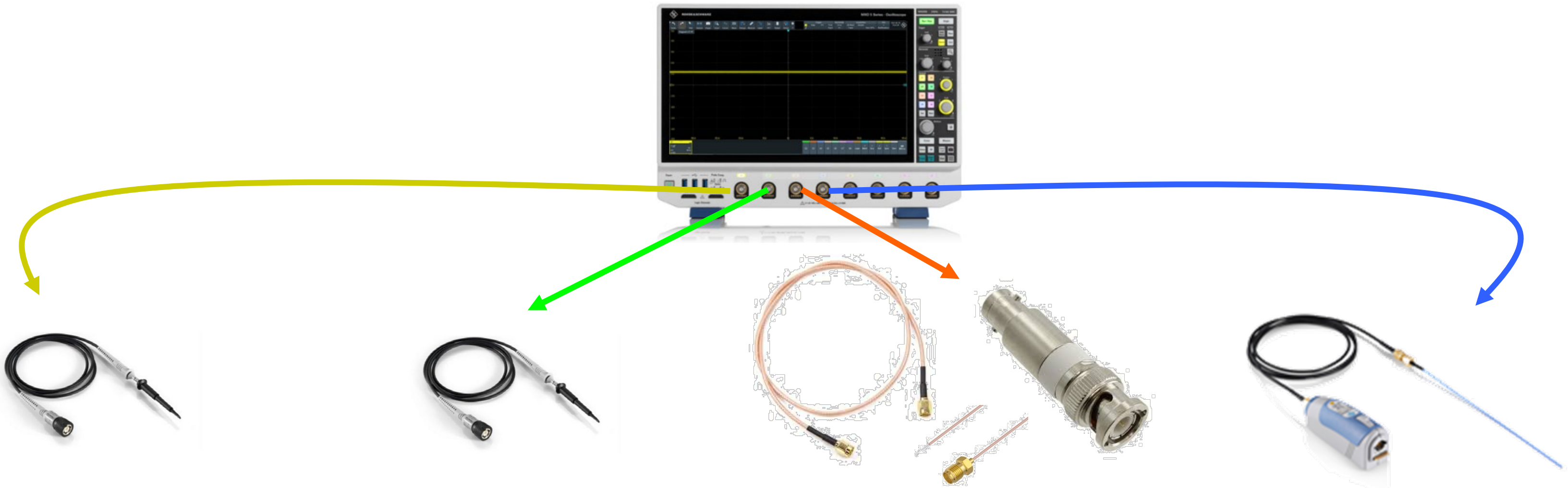
$\int$ freq domain form 0 to BW

More measurement bandwidth = more measurement noise

MEASUREMENT NOISE…

IS A FUNCTION OF MEASUREMENT SIGNAL PATH (50Ω / 1 MΩ) +PROBE + PROBE ACCESSORIES

FOUR MEASUREMENT APPROACHES

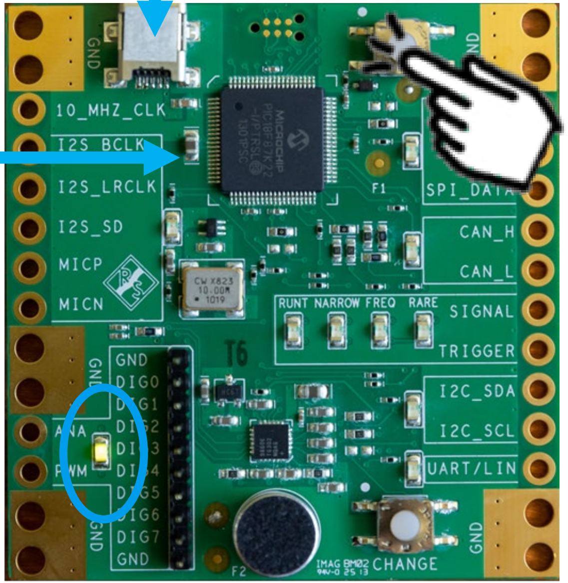


Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

DEVICE UNDER TEST – 3.2V POWER RAIL

USB power

3.2 V rail



10:1 Passive Probe

Standard
10:1
passive
probe

Low BW
1:1
passive
probe

50 Ω cable
(with blocking cap)

Specialized
power rail
probe

10:1 Passive Probe

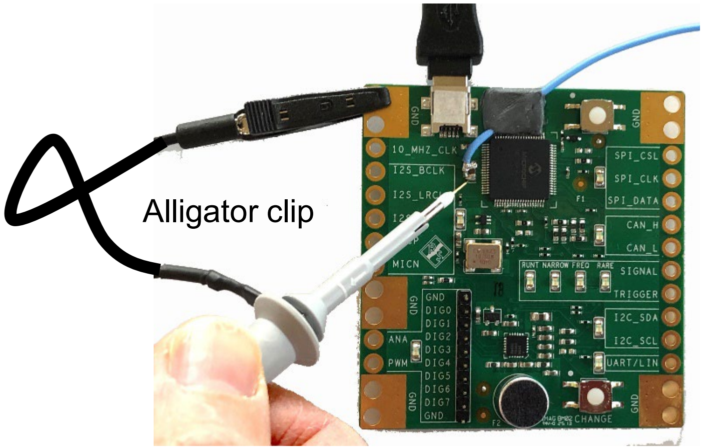
Advantages

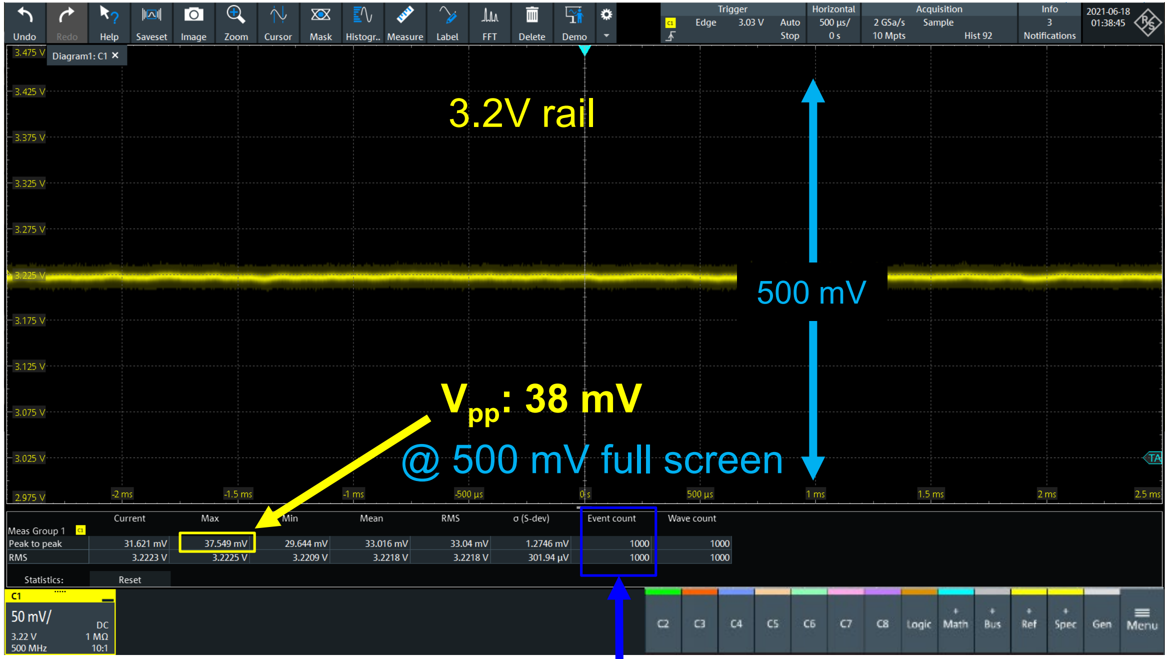
- Comes standard with most scopes
  - no extra expense
- 1 MΩ loading at DC
  - Preserves expected DC value
- Easy to connect using browser tip
  - Multiple ground alternatives

Disadvantages

- Significant noise
  - 10:1 attenuation
  - Minimum vertical setting of 10 mV/div
- Long grounds
- BW limited (700 MHz for ZP-11)
- No solder-in alternative

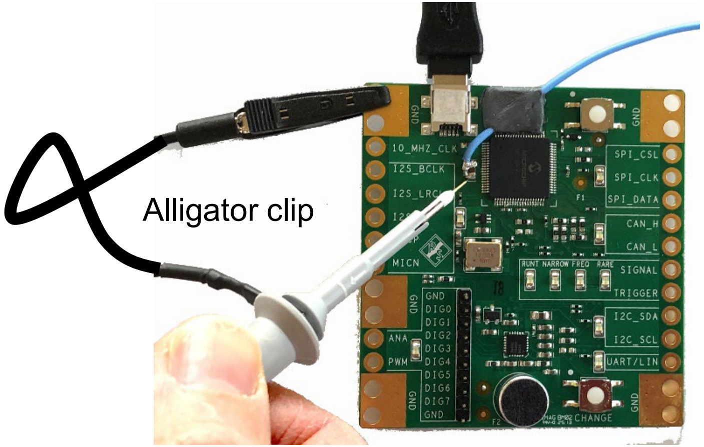
10:1 Passive Probe with Alligator Clip

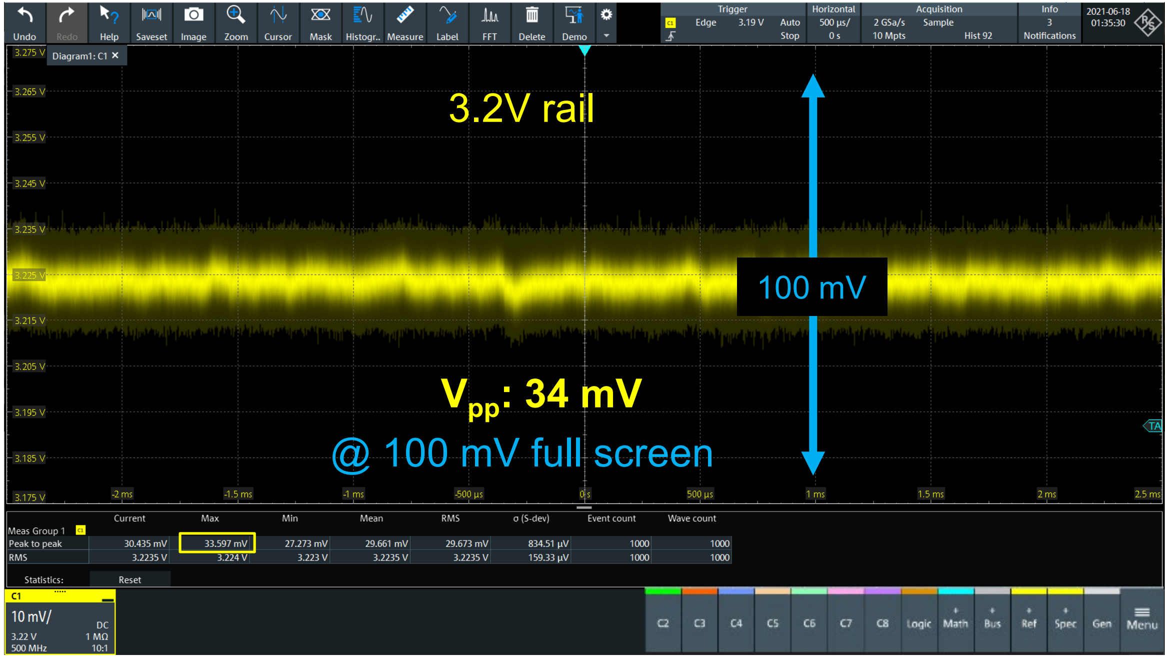




1000 Measurements

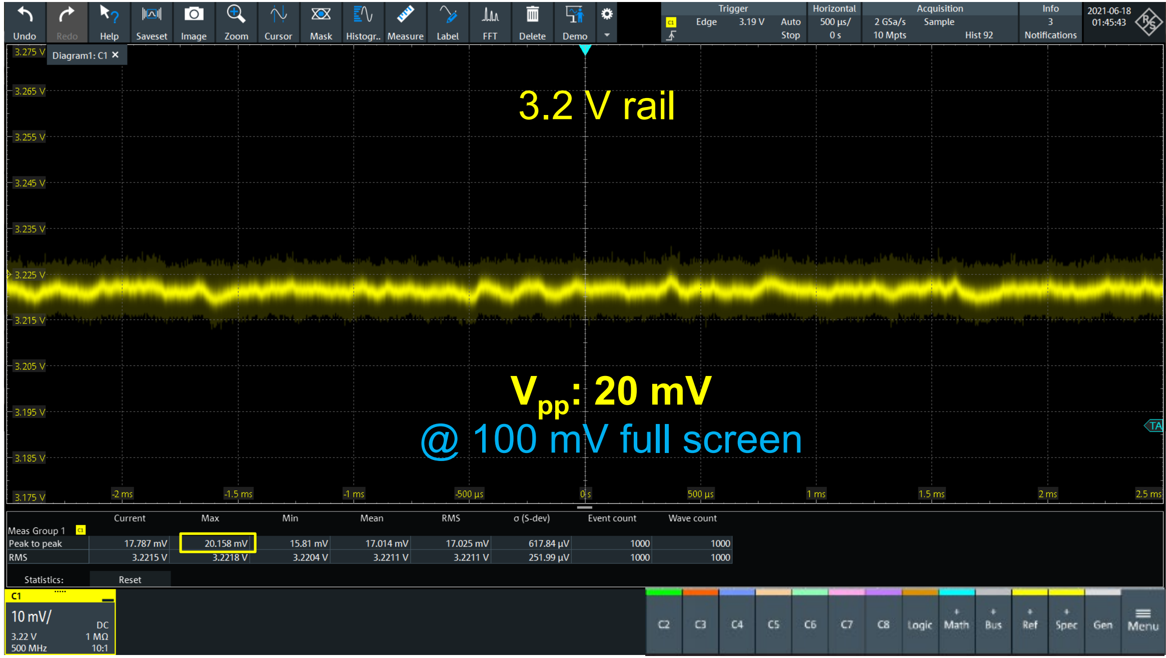
NOISE: FUNCTION OF VERTICAL FULL SCALE



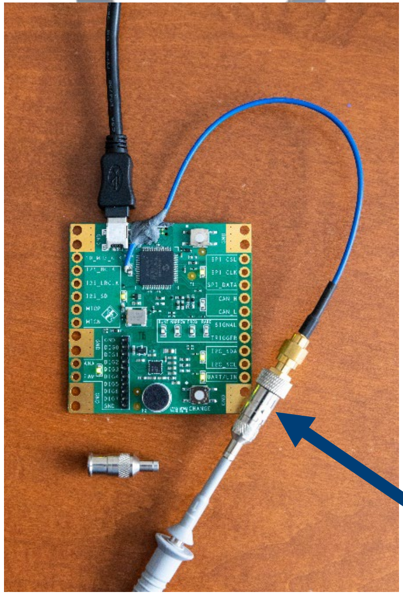


NOISE: FUNCTION OF PROBING ACCESSORIES

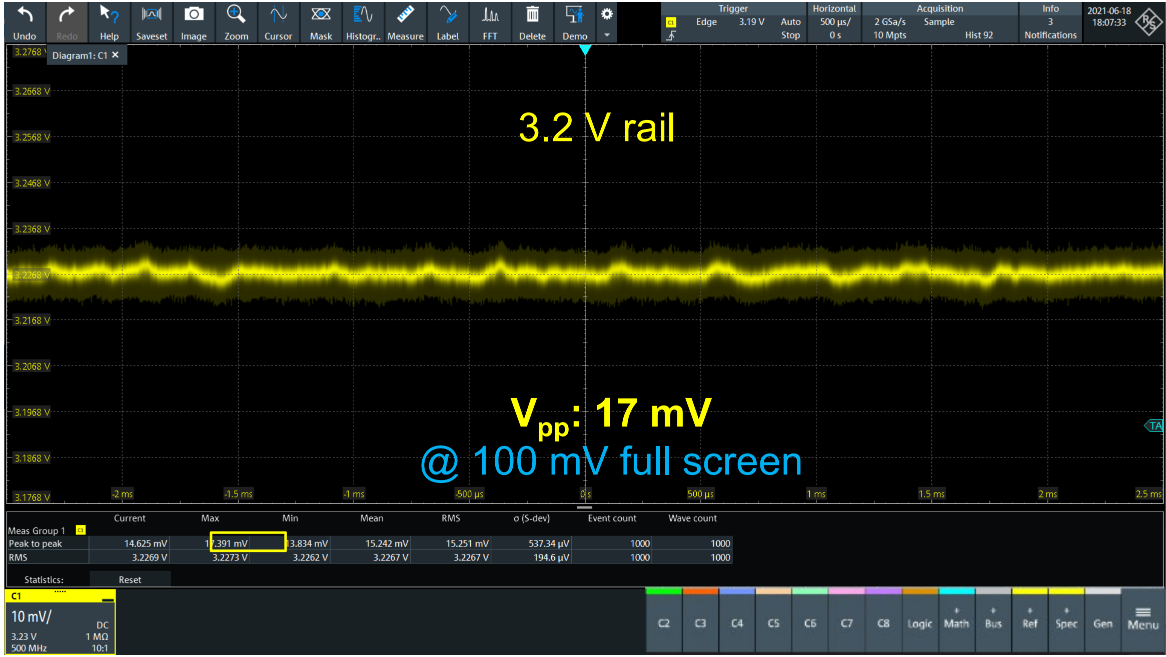
Ground spring



NOISE: FUNCTION OF PROBING ACCESSORIES



Passive probe to BNC adapter
(RT-ZA1 accessory)



ADD AN EXTRA HAND

2D Probe Positioner

3D Probe Positioner (RT-ZAP)

1:1 Passive Probe

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

1:1 Passive Probe

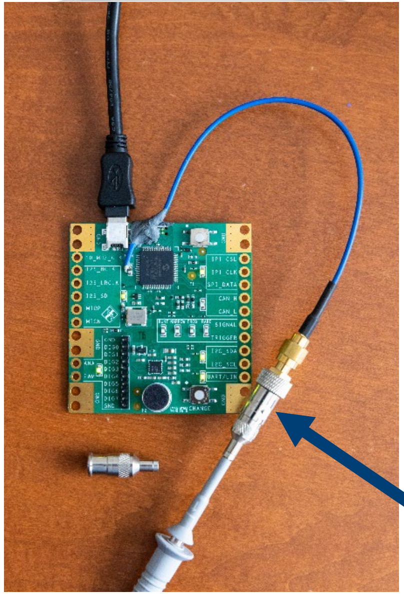
Advantages

- 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

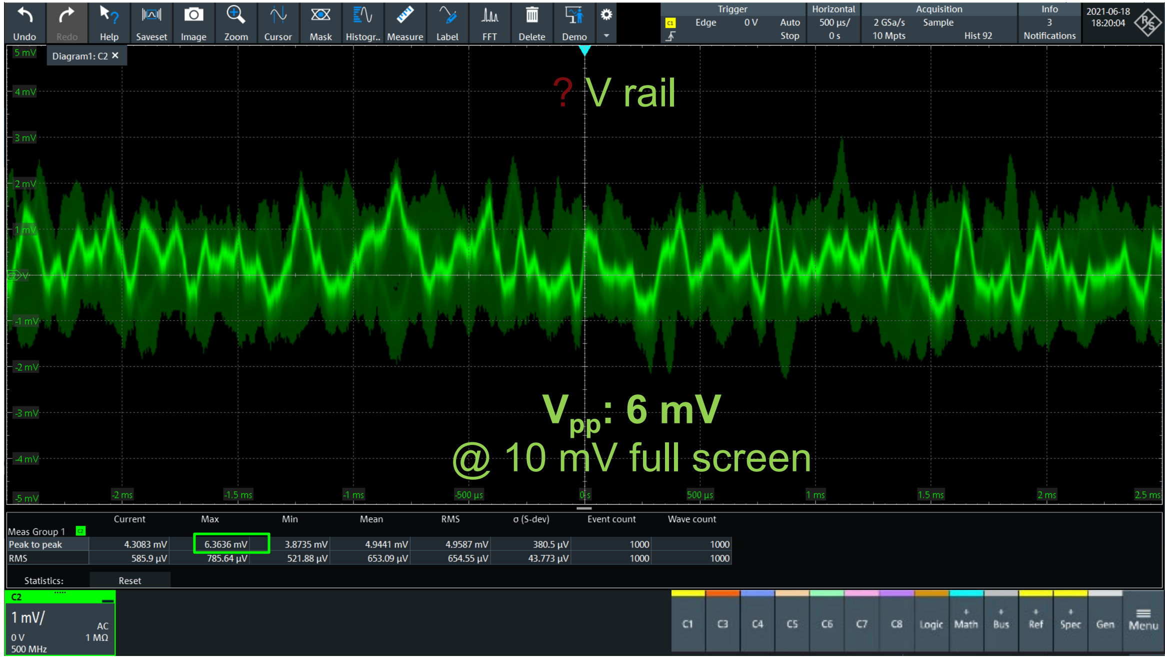
Disadvantages

- 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

38 MHZ 1:1 PASSIVE PROBE WITH GROUND SPRING

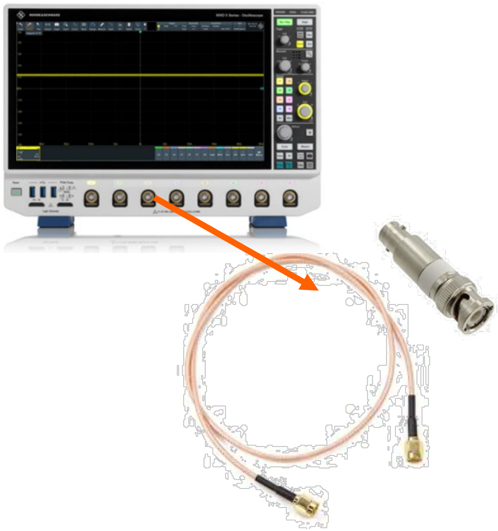


Not enough offset, required AC coupling



Passive probe to BNC adapter
(RT-ZA1 accessory)

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

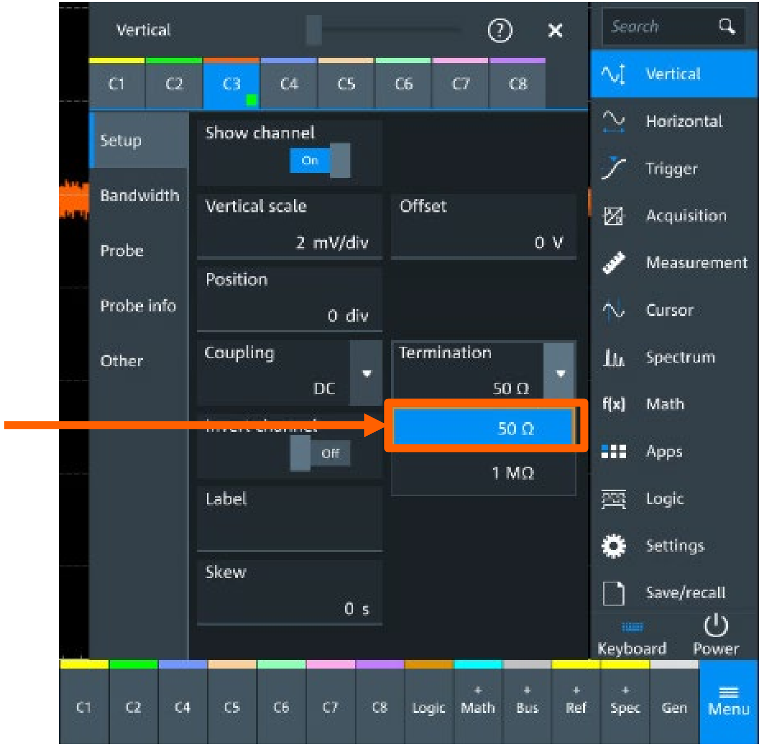
Advantages

- 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

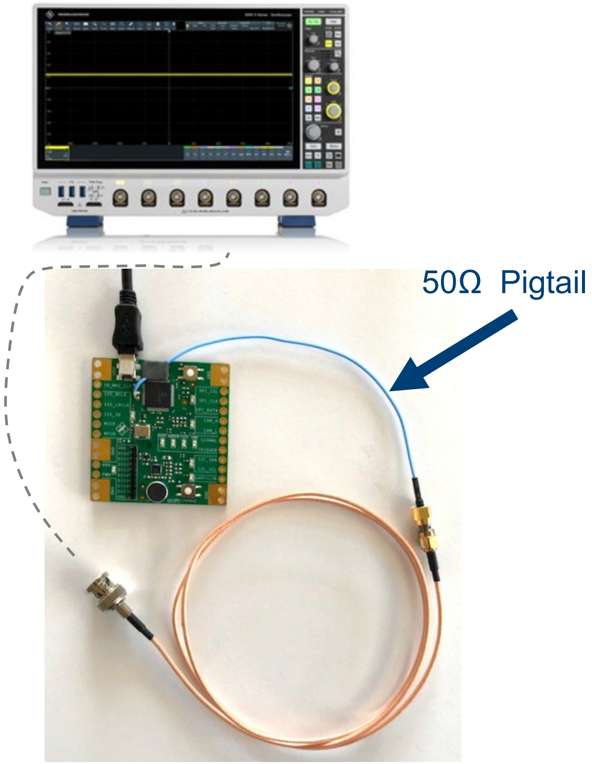
50Ω PATH: AC COUPLING

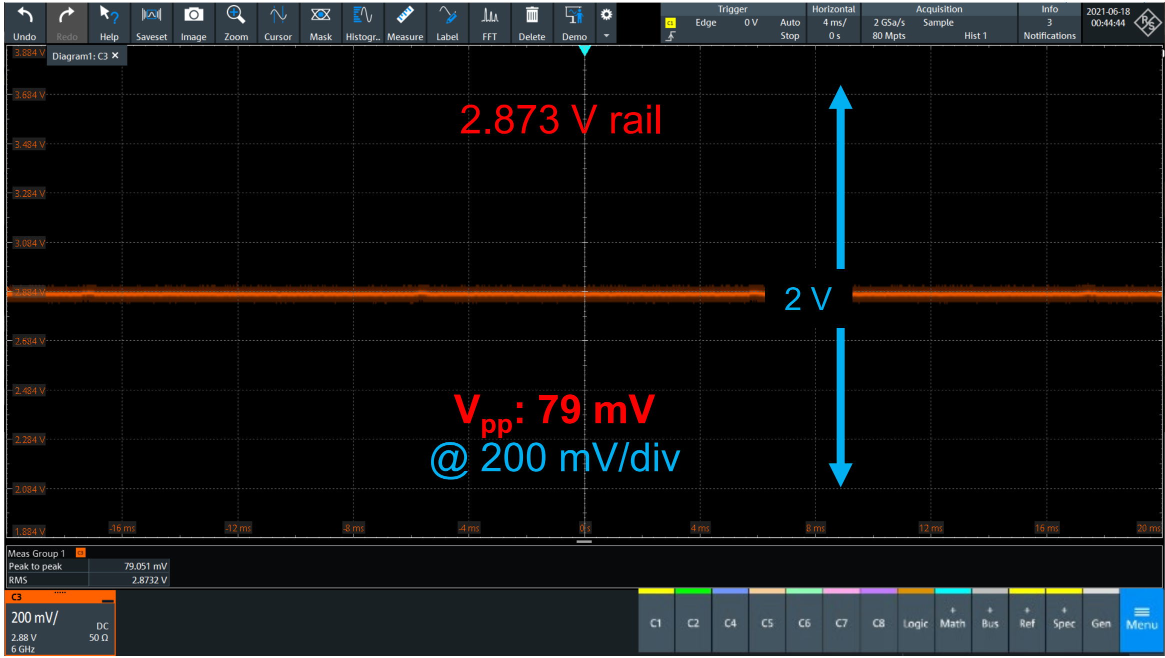


- Set to 50Ω path (channels setup)
- Attenuation to 1:1 (probe setup)
- 50Ω path (limited offset may require AC coupling)

50Ω PATH:

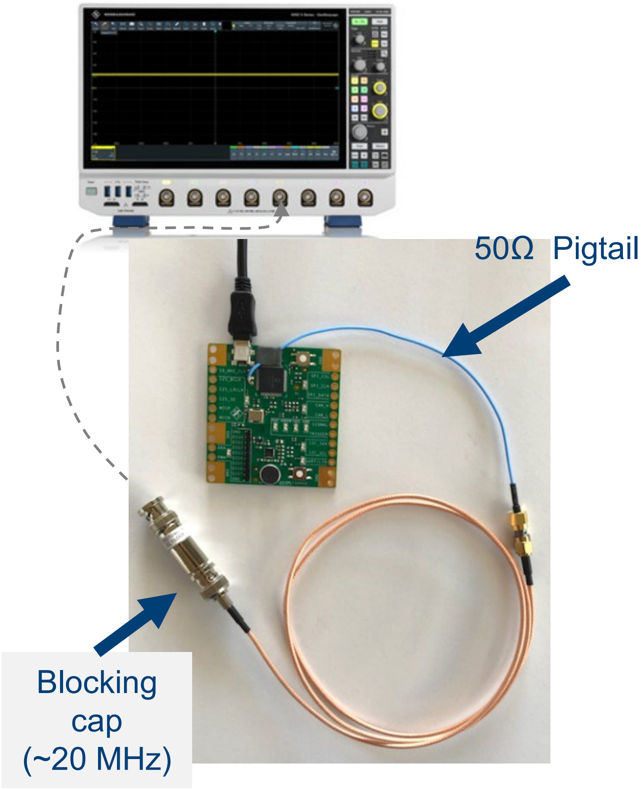
SUFFICIENT OFFSET NOT AVAILABLE: REQUIRES 200 MV/DIV SCALING.

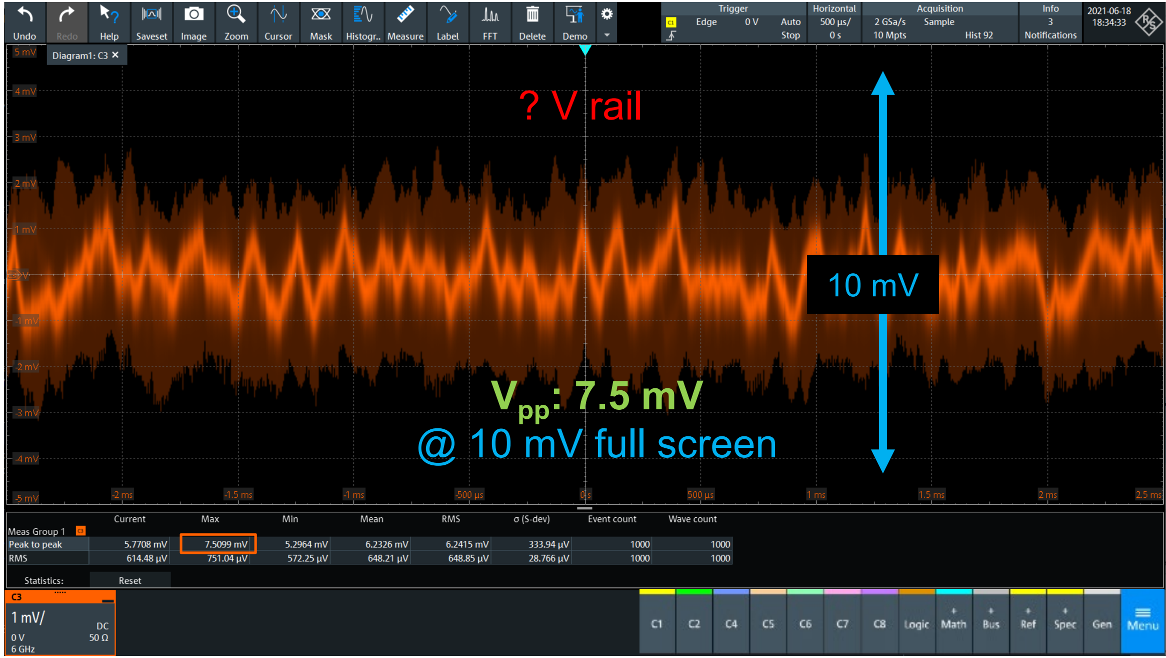




50Ω PATH WITH BLOCKING CAP (3DB BW = ~20 MHZ)

NO ABILITY TO MEASURE ABSOLUTE VERTICAL VALUES

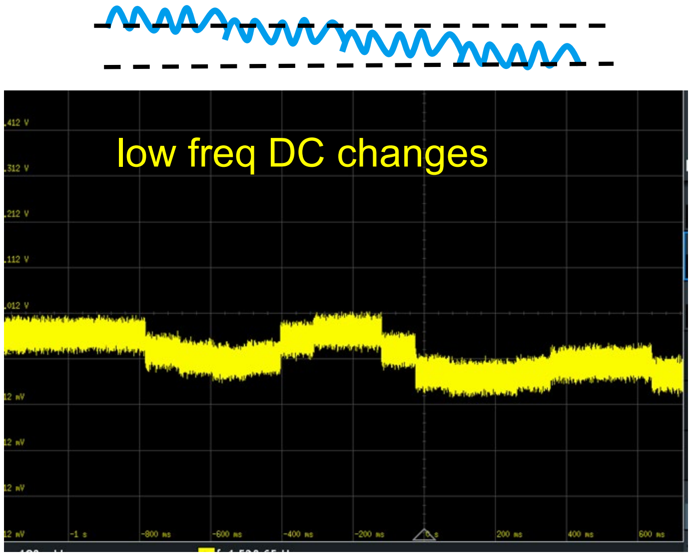


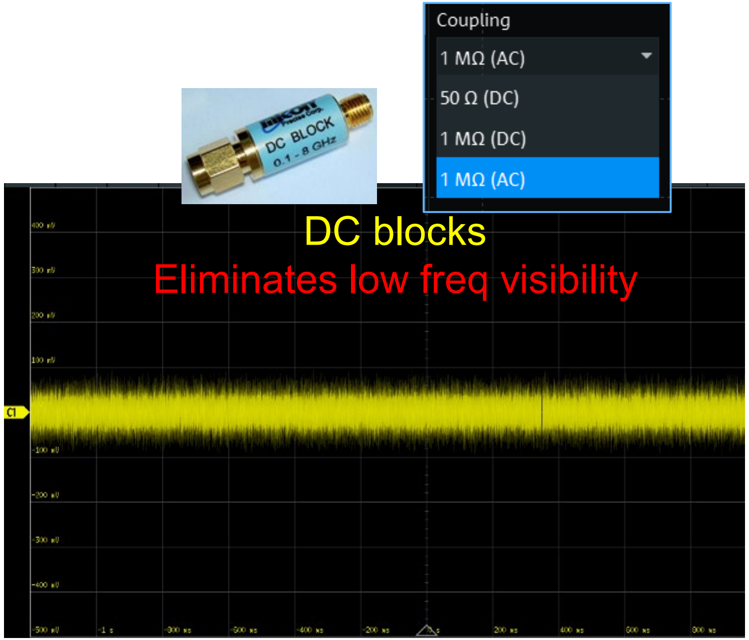


Blocking Caps (and AC coupling) Create Measurement Problems

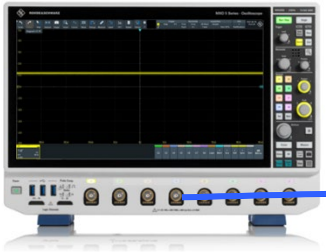
AC coupling mode and blocking caps eliminate ability to see DC changes

DC Drift



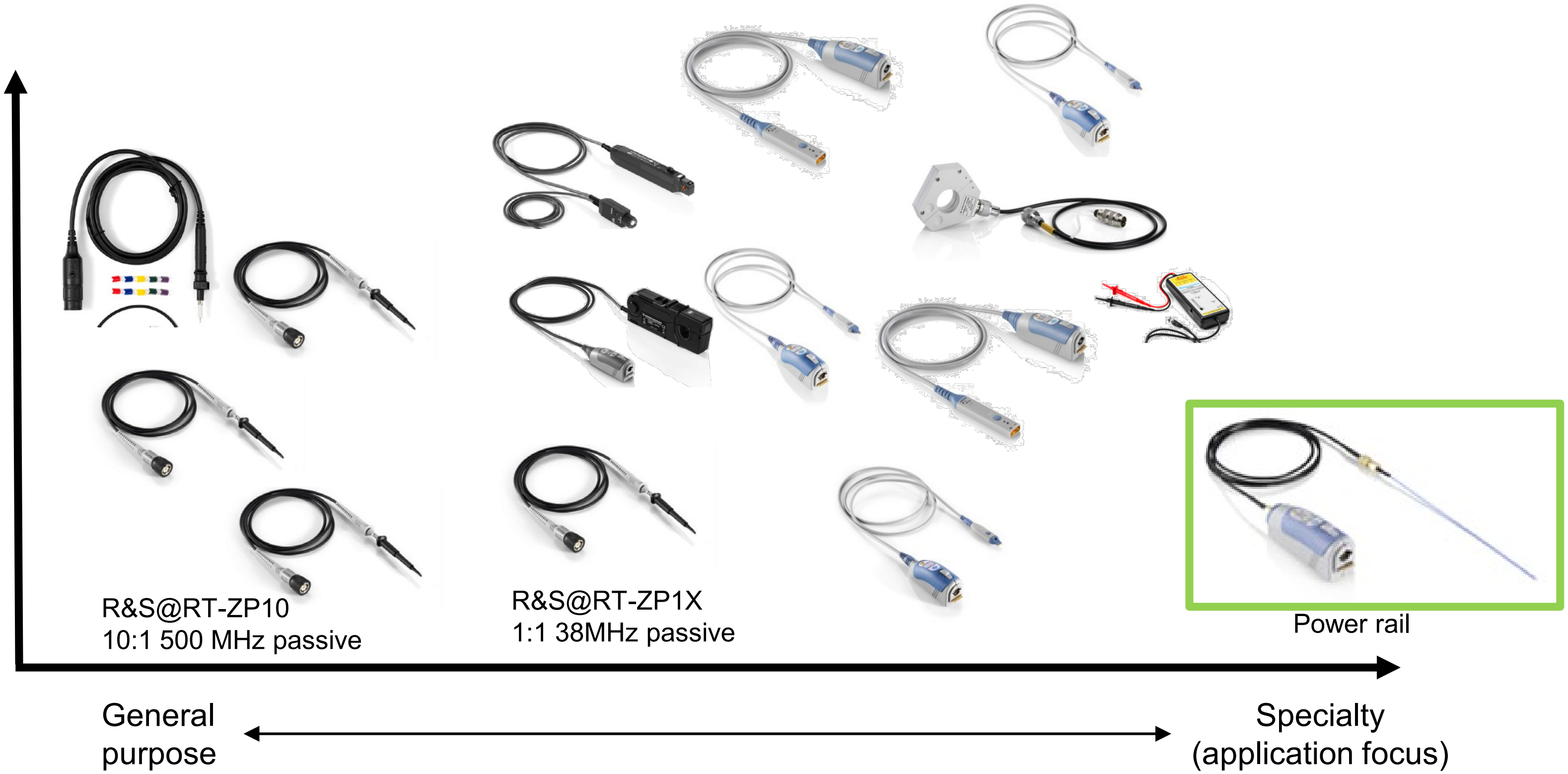


POWER RAIL PROBES



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

LOTS OF PROBES FOR DIFFERENT APPLICATIONS



POWER RAIL PROBE

Advantages

- Low noise (typically 1:1 attenuation ratio)
- Built-in offset (typically at least +/- 12V)
- Excelling loading at DC (typically 50 KOhms)
  - Power rail retains DC value
- Browser and solder-in connection

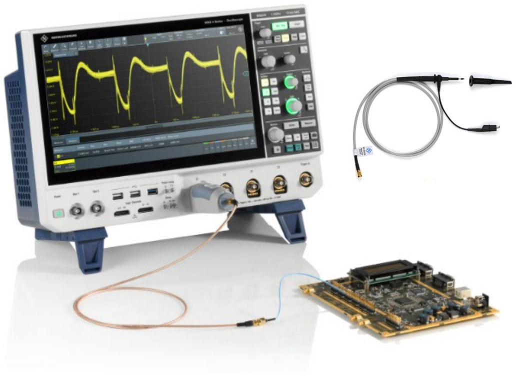
Disadvantages

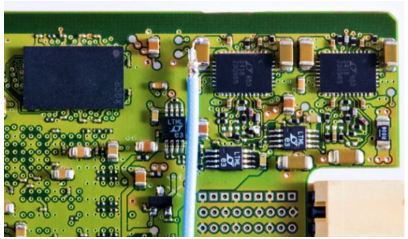
- Initial investment expense
- Requires solder-in/SMA for full BW

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

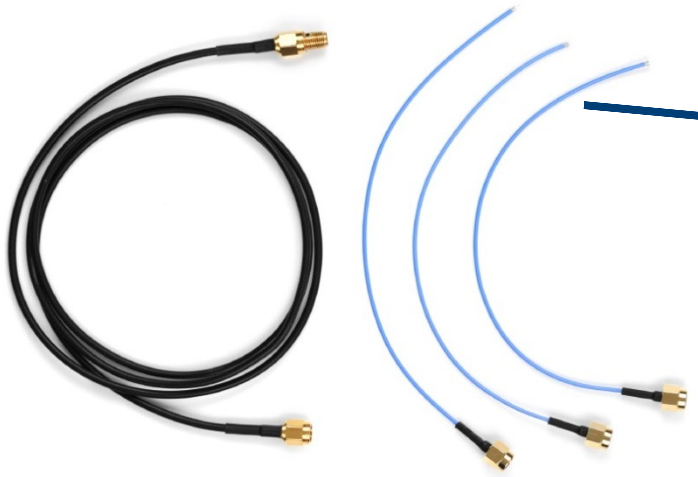
Key Specifications	
Attenuation	1:1
Probe BW	2 GHz / 4 GHz
Browser BW	350 MHz
Dynamic Range	±850 mV
Offset Range	> ±60 V
Noise Scope (RTO) standalone Scope + Probe Noise (at 1 GHz, 1mV/div)	 107 μV AC_{rms} 120 μV AC_{rms}
Input Resistance	50 kΩ @ DC
R&S ProbeMeter	Integrated
Coupling	DC or AC



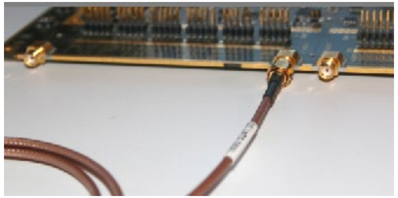


TYPICAL POWER RAIL PROBE SOLDER-IN TECHNIQUE

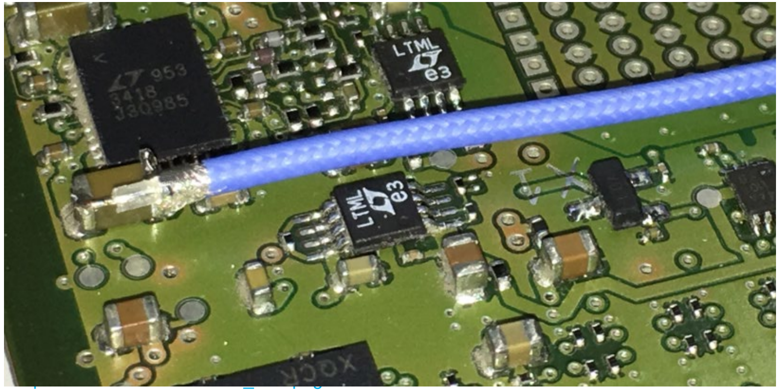
Active probe head, main cable and solder-in cables



Direct connect to SMA

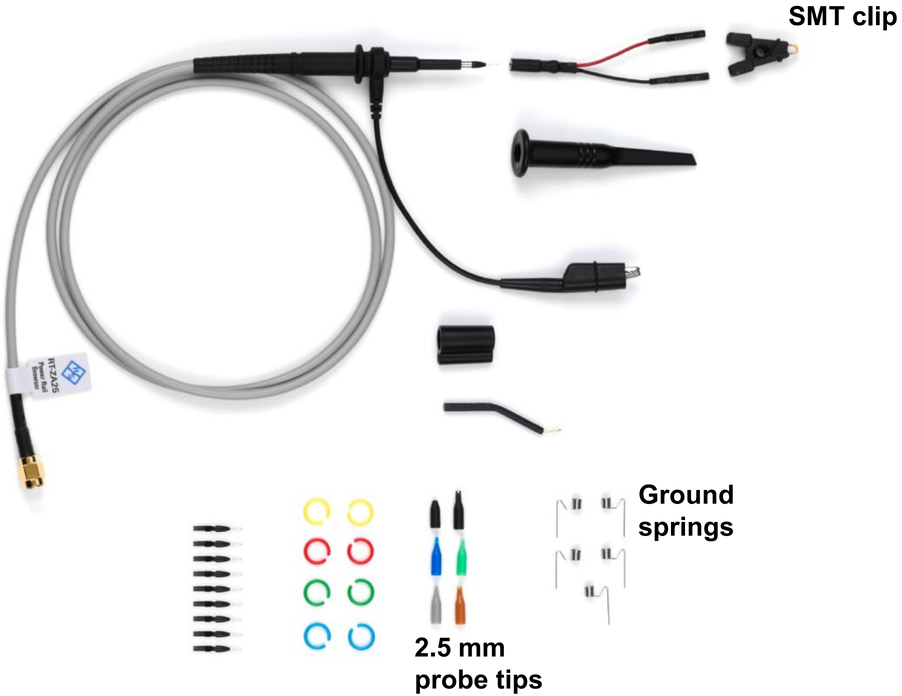


50 Ω SMA coaxial solder-in (2.5 GHz BW)

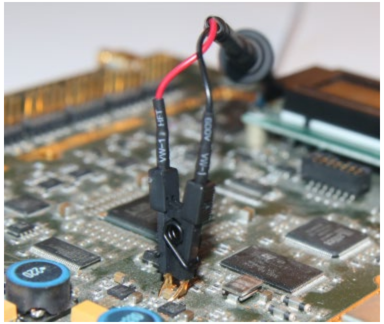


RT-ZPR POWER RAIL PROBE BROWSER

350 MHZ BW, 1:1 ACTIVE PROBE, USES PASSIVE PROBE ACCESSORIES (INCLUDED STANDARD)



Ground spring

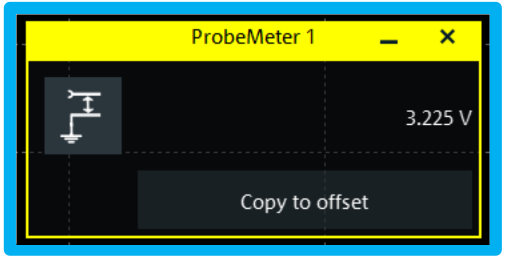


SMT clip

Some Power Rail Probes have an Integrated Voltmeter

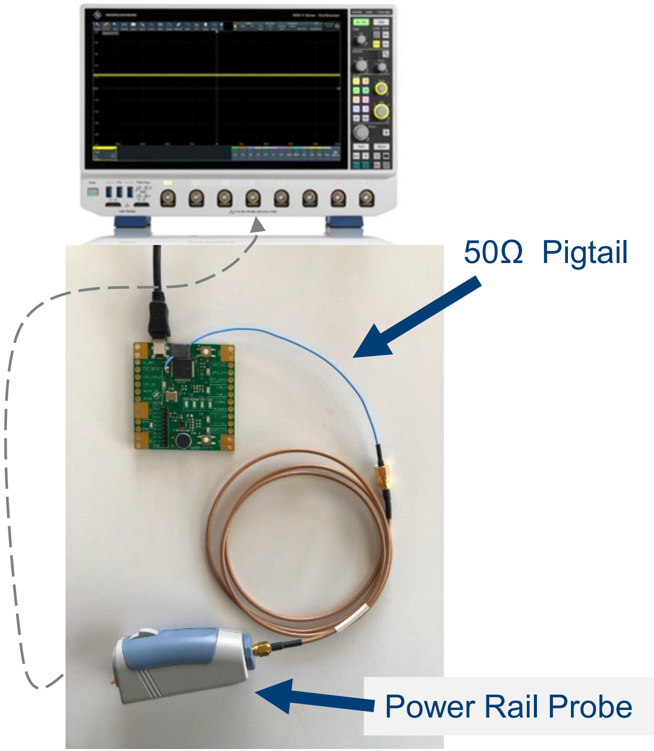
R&S probes call this a "ProbeMeter"

- Separate circuit with 18-bit ADC inside the probe
- Independent of scope ADC
- Measures DC value with 0.05% accuracy
  - > 10X more accurate than scope channel for DC measurement
- Eliminates need to attach a separate DVM in parallel to accurately measure DC

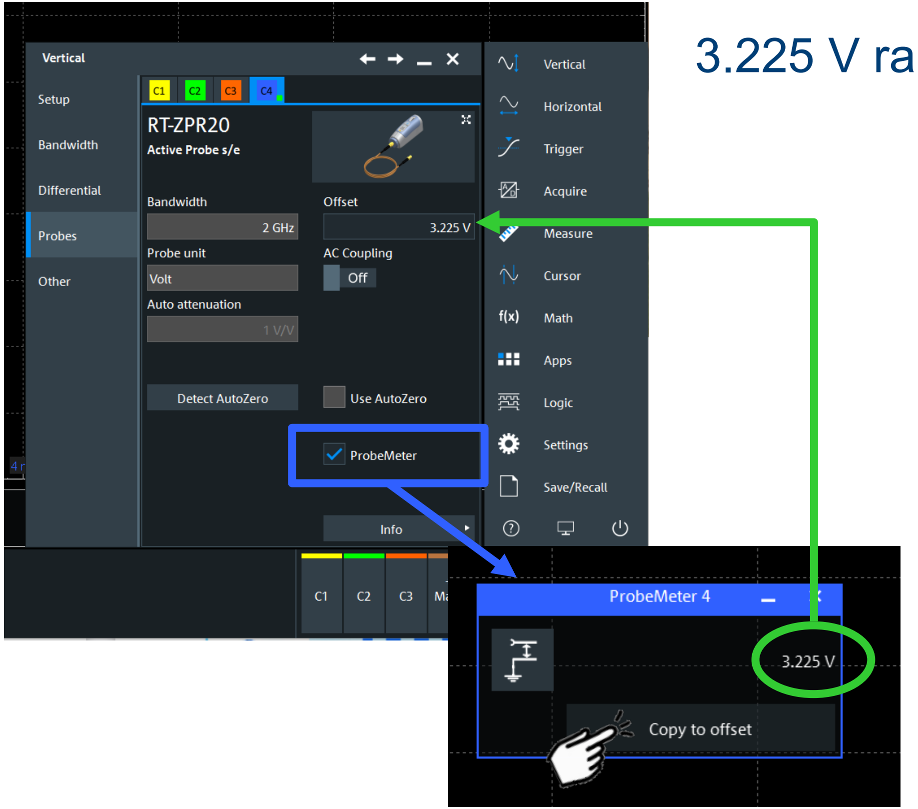


INTEGRATED VOLT METER

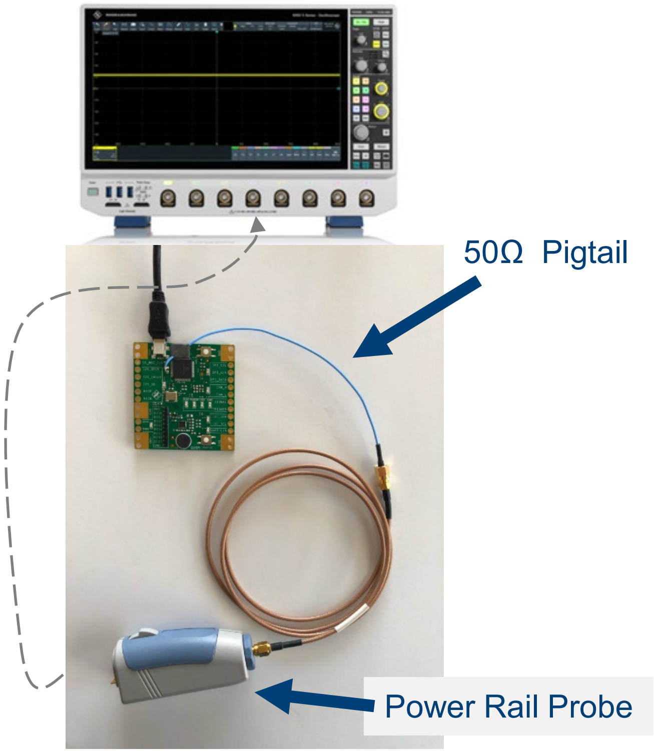
WITH CUT/PASTE DC OFFSET

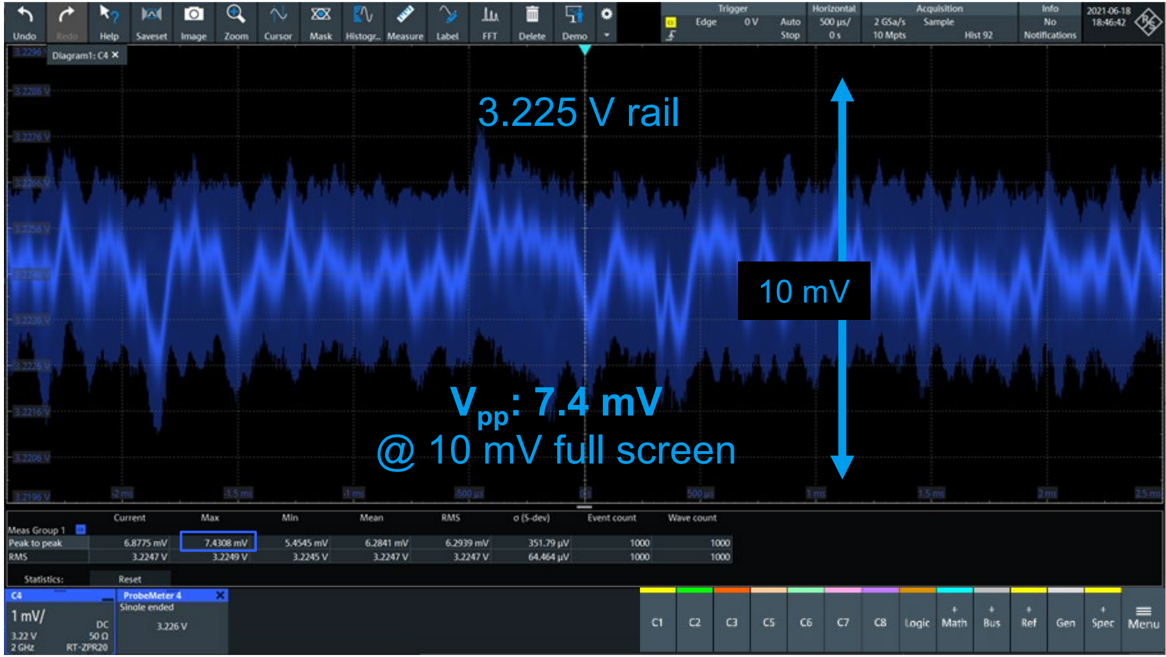


3.225 V rail



POWER RAIL PROBE





MEASUREMENT TECHNIQUE RESULTS COMPARISON

Noisy
10 MΩ DC loading
Limited BW
Limited scaling

Vpp: 17 mV

Standard
10:1
passive
probe

Low noise
1MΩ DC loading
Limited BW
Limited offset

Vpp: 6 mV

Low BW
1:1
passive
probe

Low noise
50 Ω loading
Inability to see drift
Inability to see DC value

Vpp: 7.5 mV

50 Ω cable
(with blocking cap
or AC coupling)

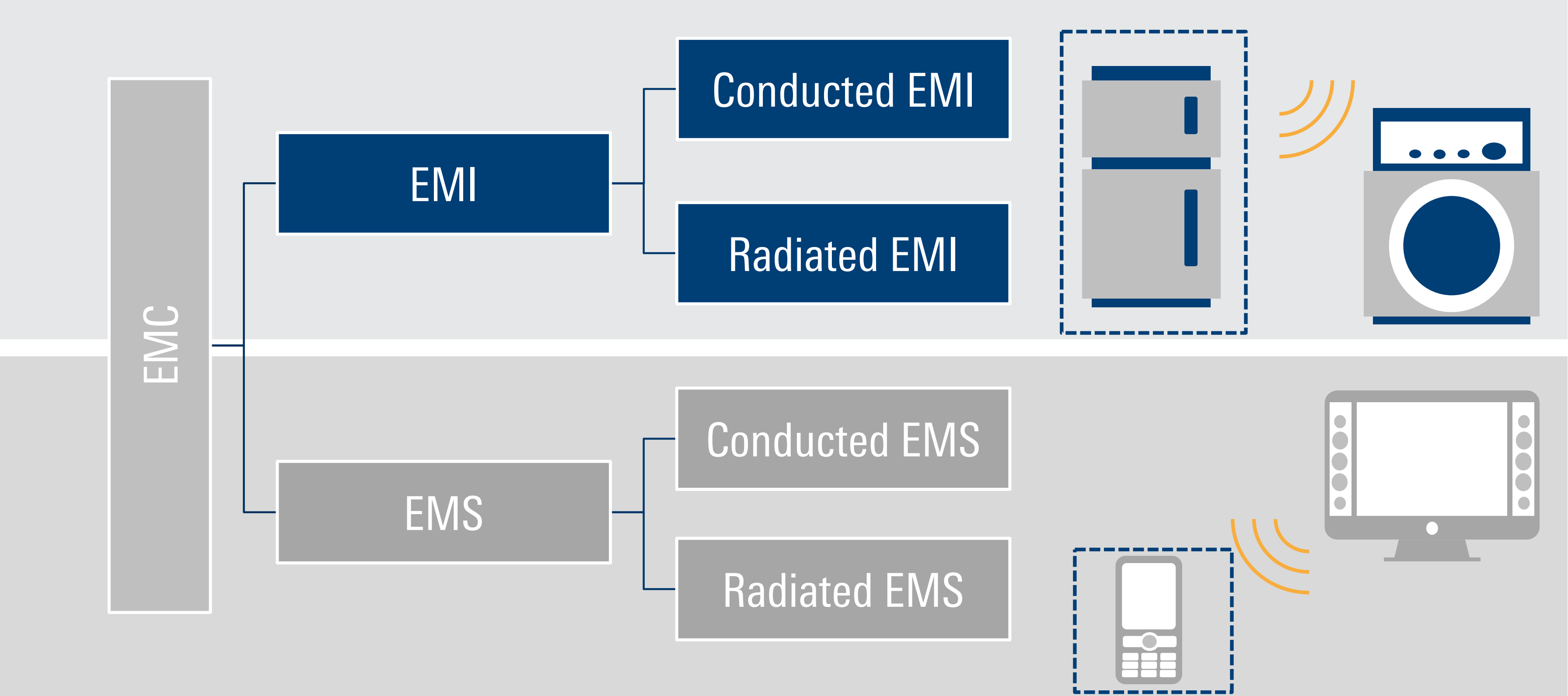
Low noise
50 KΩ loading
High BW
Built-in offset

Vpp: 7.4 mV

Specialized
power rail
probe

INSTRUMENT NOISE

WHAT IS EMC?

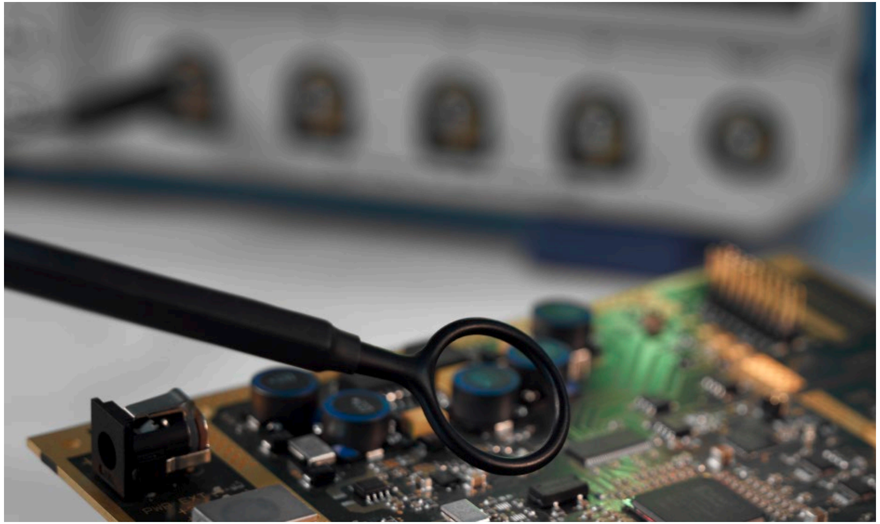


EMC
EMI
Conducted EMI
Radiated EMI
EMS
Conducted EMS
Radiated EMS

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		✓		

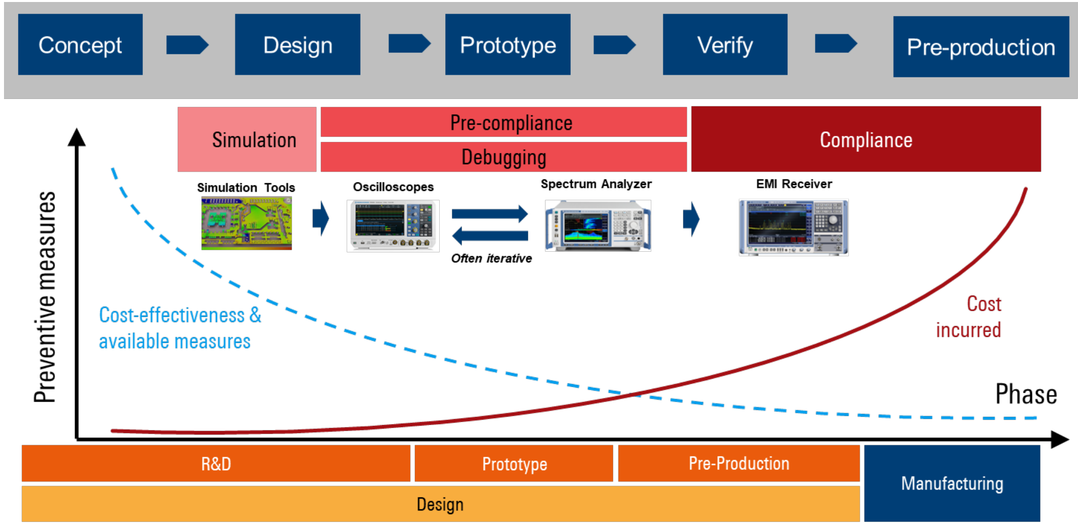
EMI DEBUGGING
PREVENTION IS BETTER THAN CURE



Similar to medical check-up for preventive health care, we diagnose early on circuit to avoid future issues

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



TEST RECEIVER VS OSCILLOSCOPE

- Scan spectral energy for fixed duration
- Using different band-limited detectors
- Log scale display with limit lines

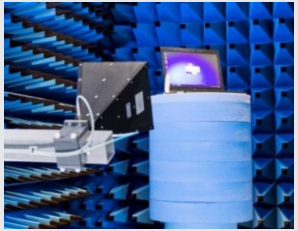
Right tool and compliant to standard

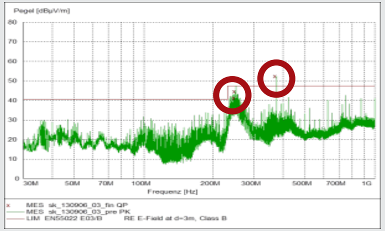
- Time domain captured calculated FFT spectrum
- Wideband capture with limited ADC sensitivity
- Typically linear spectrum display

Companion for early debug testing

COMMON EMI DEBUGGING PROCEDURE : ANALYSIS STEPS

A) Far-field measurement

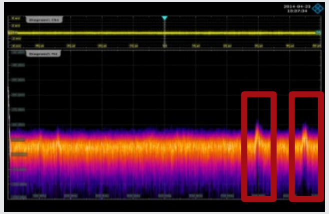




B) "Know your DUT":
List of potential interferer sources

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

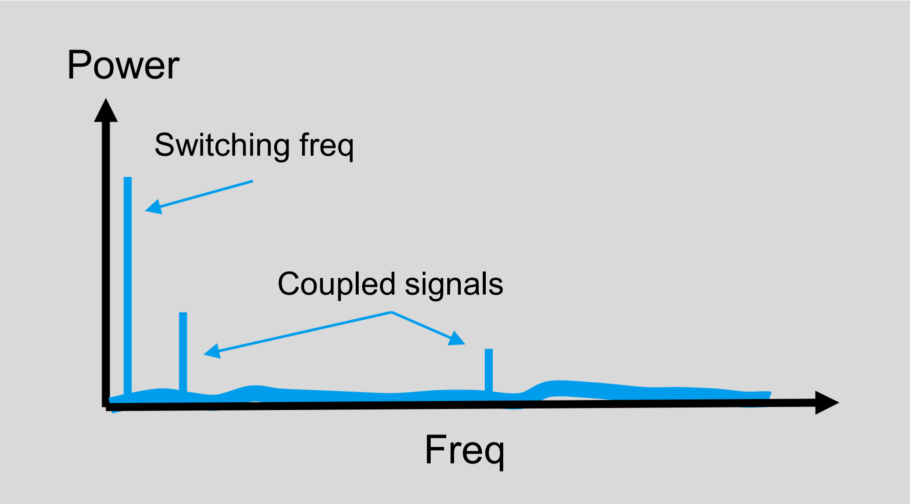


D) Interferer current measurement to find out the coupling type

E) Nearfield probe to localize the interferer source

F) Applying counter-measures and validation

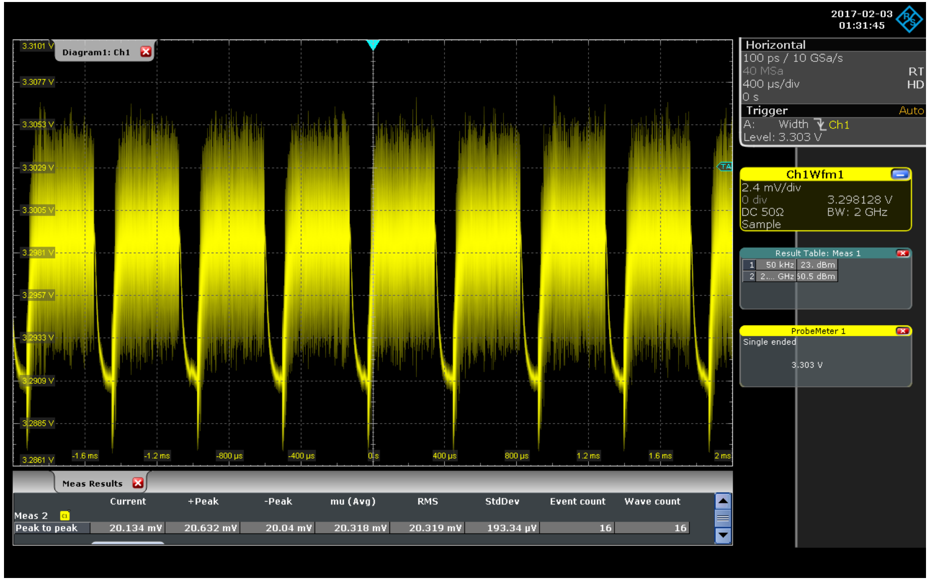
HOW MUCH BANDWIDTH OR PI MEASUREMENTS?



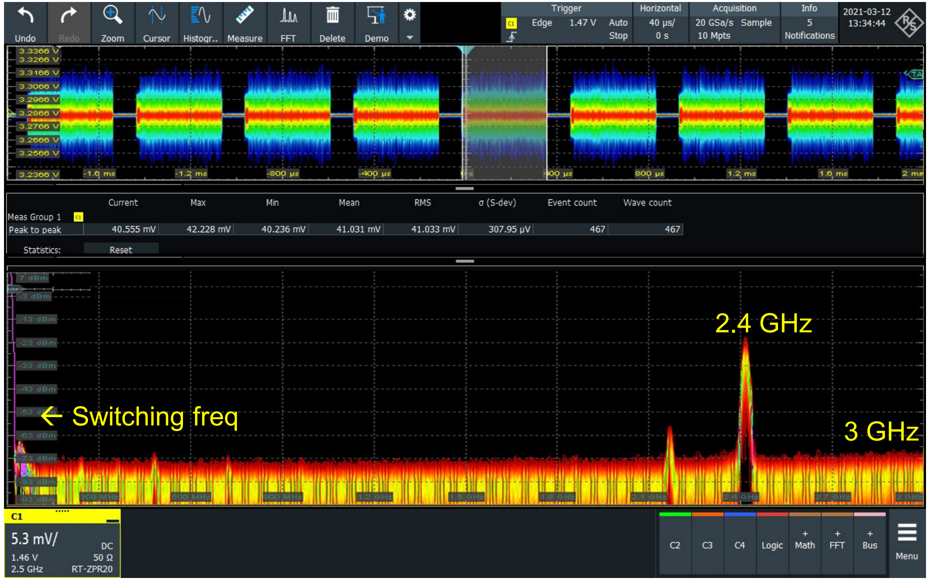
HOW MUCH BANDWIDTH DO YOU NEED?

USE THE FFT TO HELP YOU DETERMINE

How much is needed here?



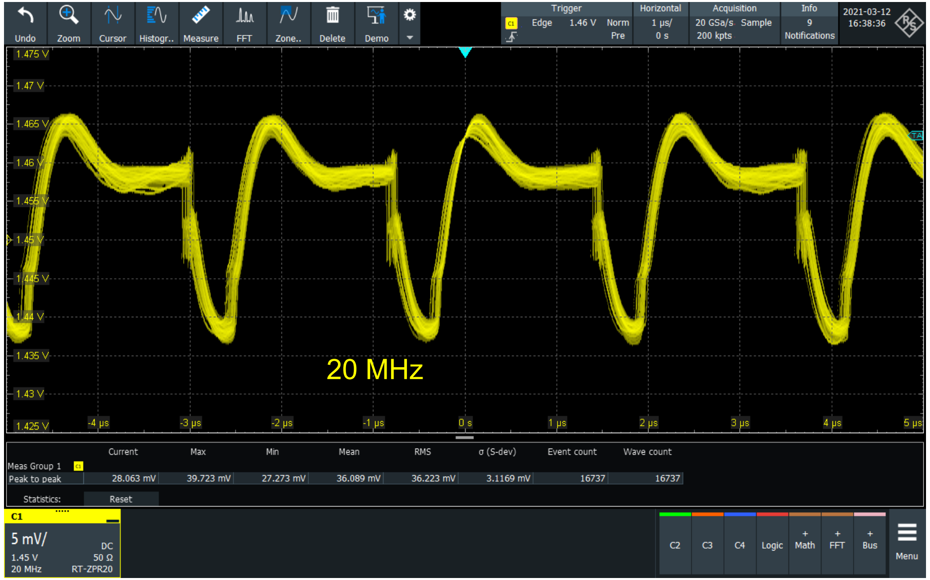
How much is needed here?



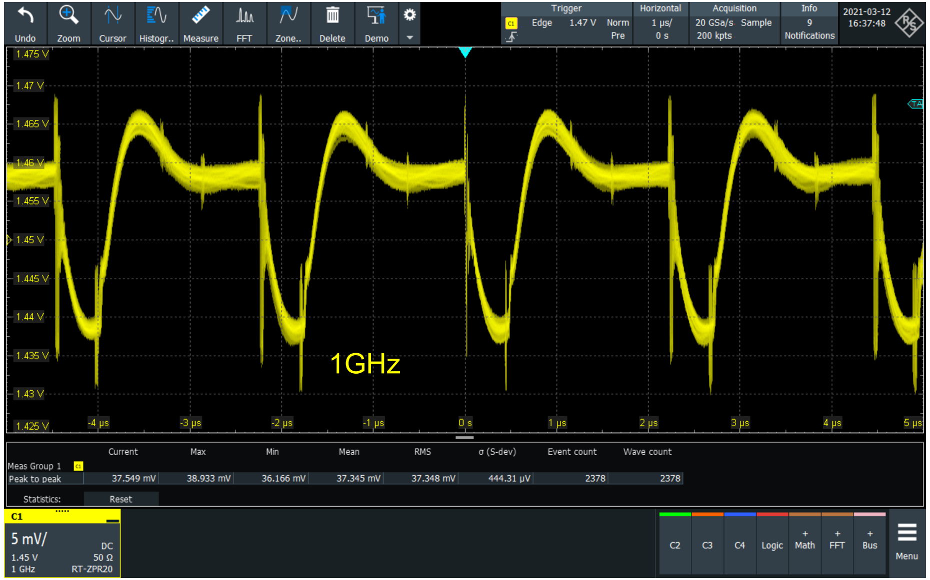
HOW MUCH BW DO YOU NEED?

START HIGH AND REDUCE. USE FFT TO HELP DETERMINE HOW MUCH.

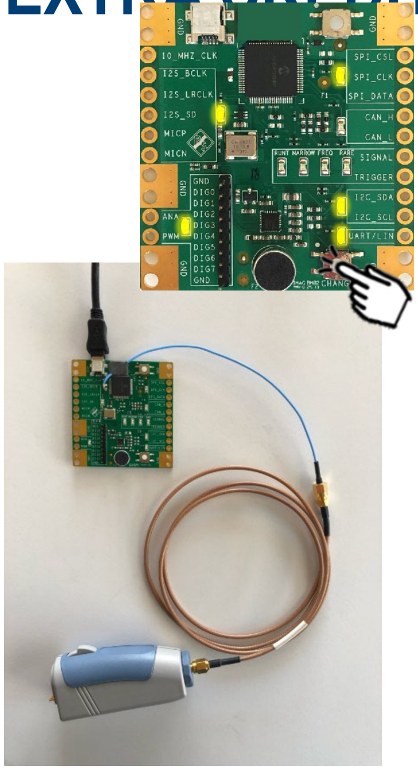
20 MHz



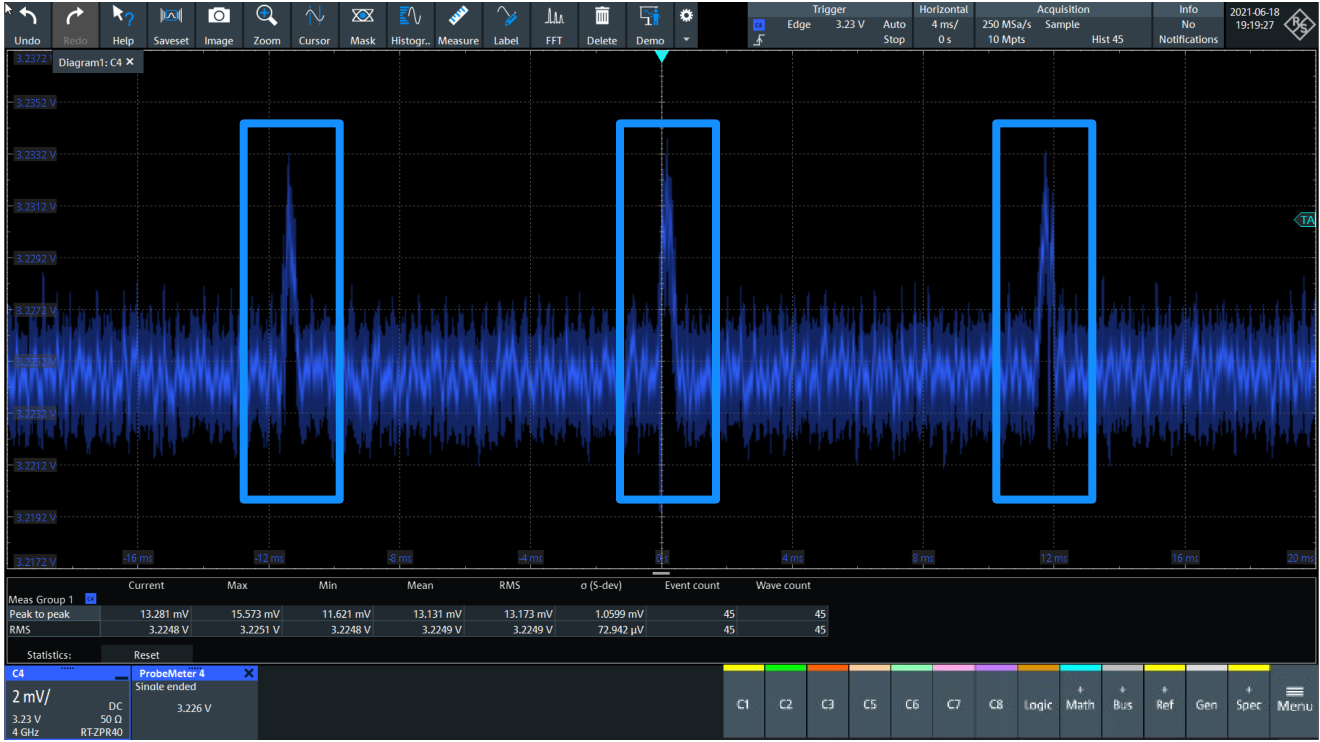
1 GHz



EXTRA CREDIT: WHAT'S CAUSING PERIODIC RAIL SPIKES?

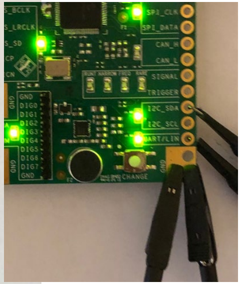


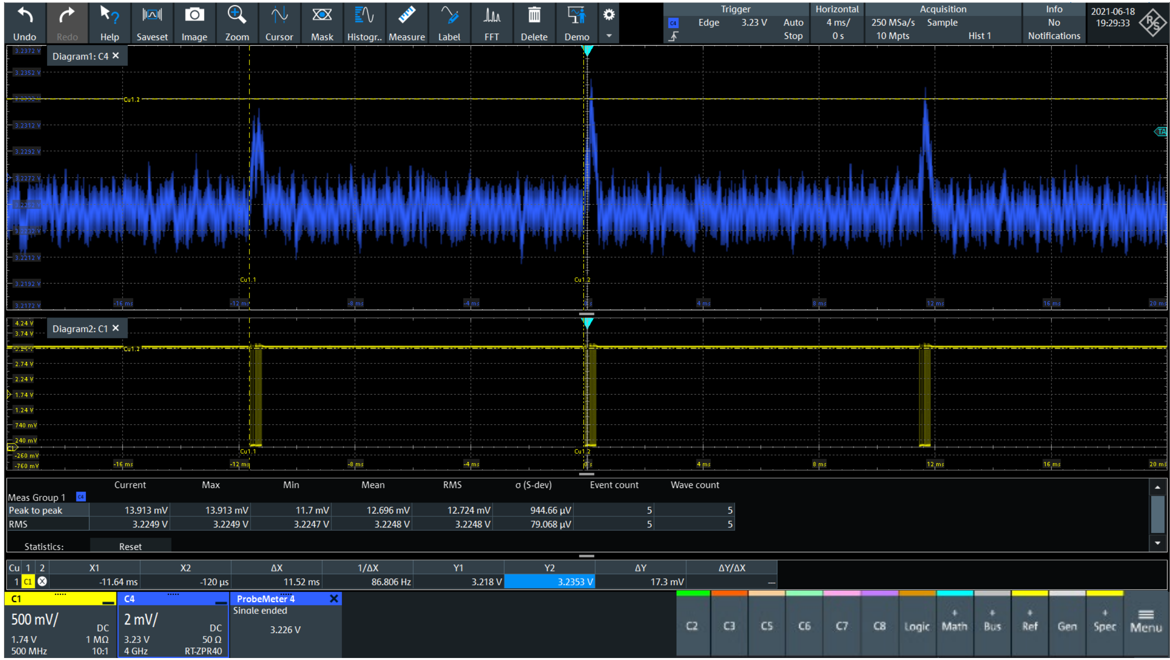
Timebase at 4 ms / div



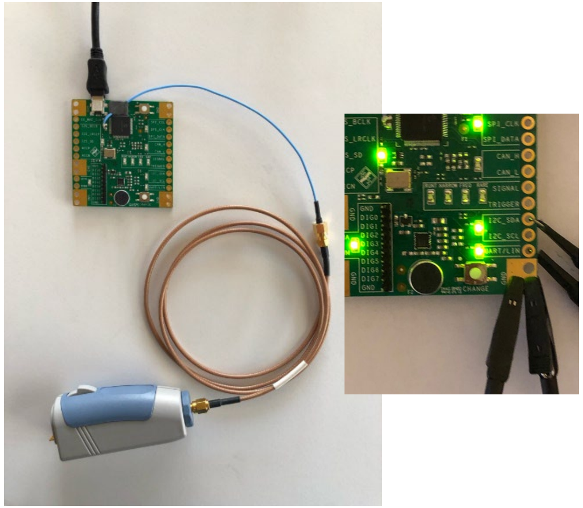
POWER RAIL PEAKING CORRESPONDS TO I²C PACKETS

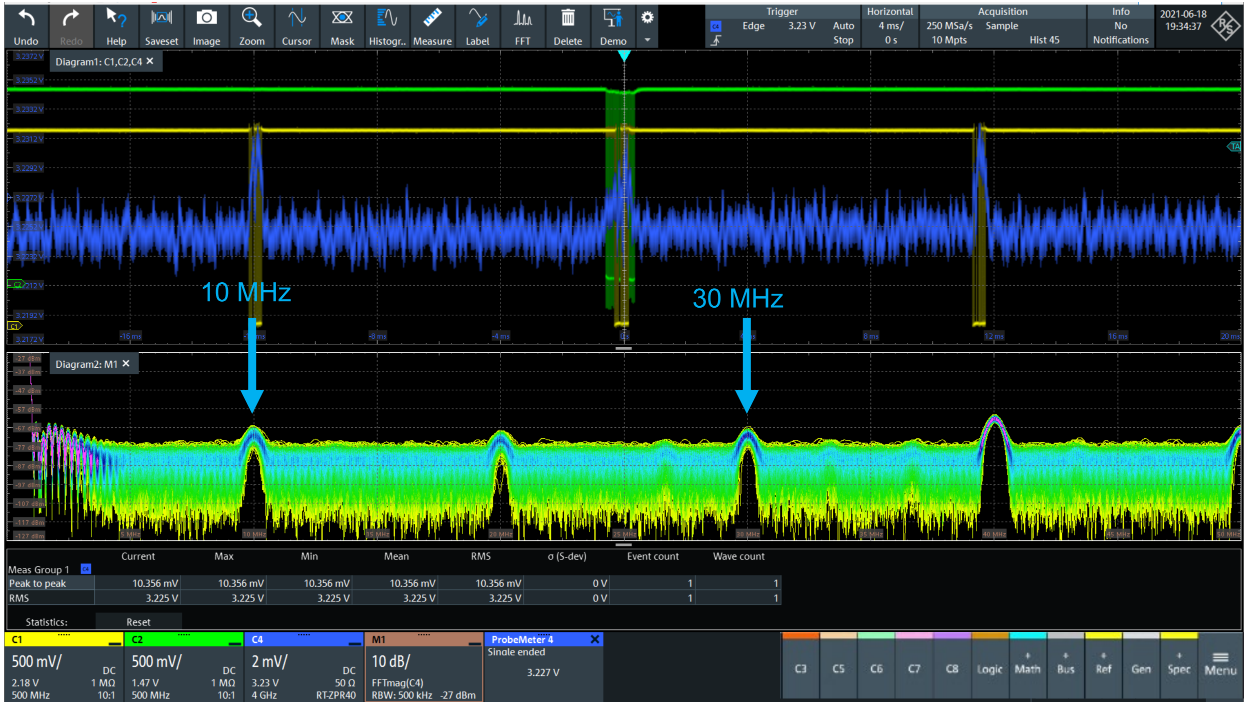
Attach to I²C signals





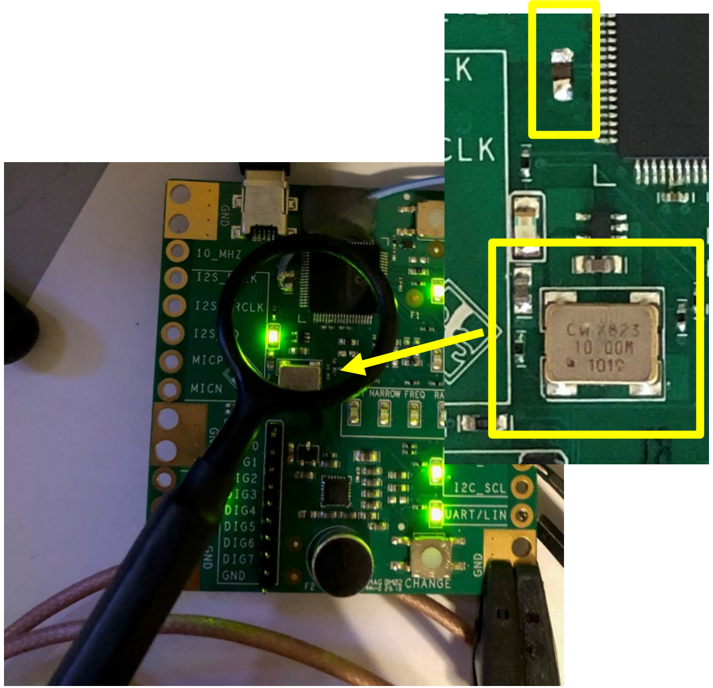
FFT ON POWER RAIL SHOW 10 MHZ AND HARMONIC TONES

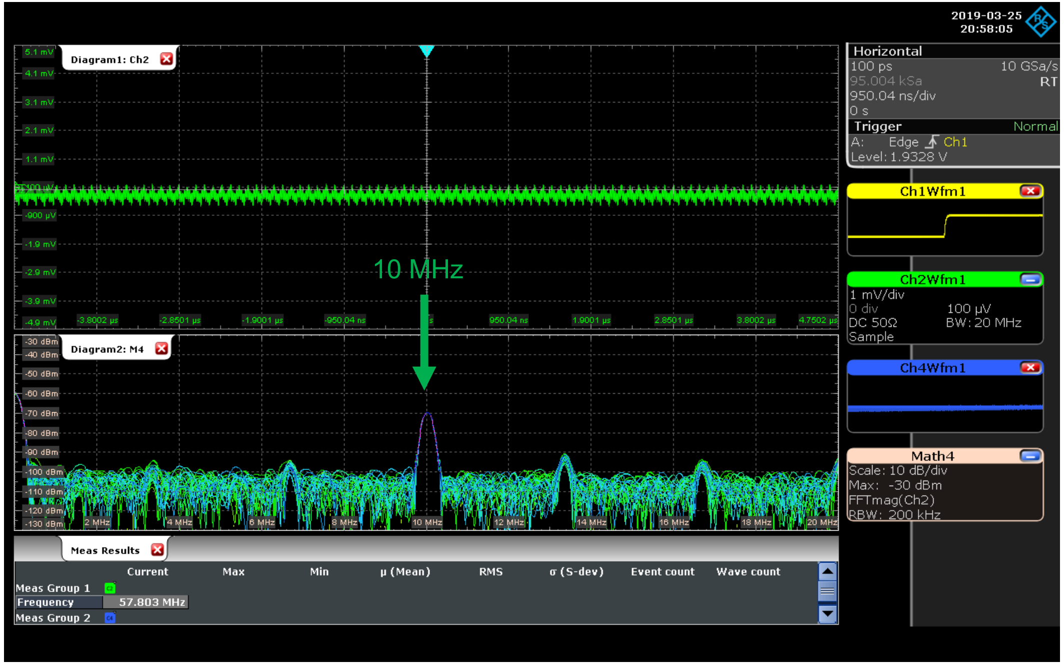




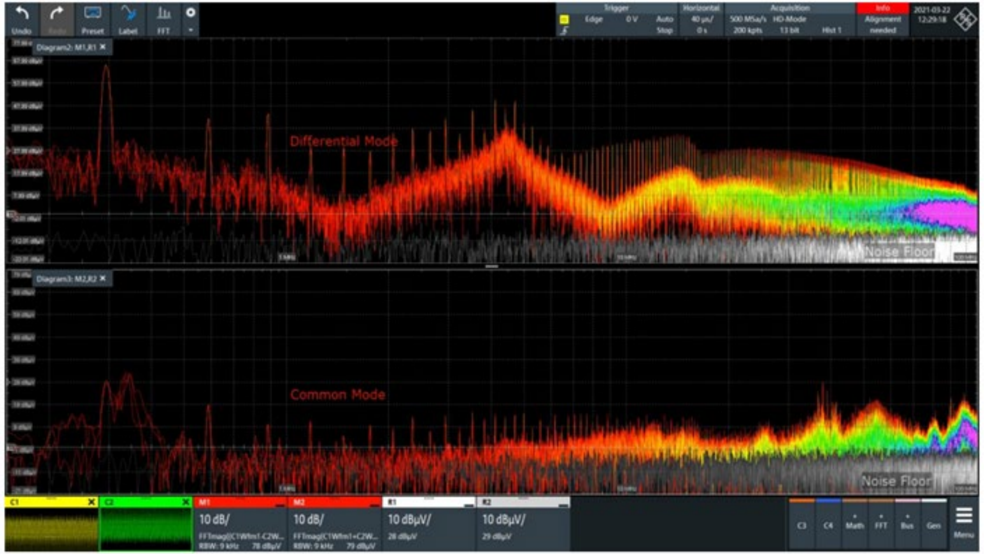
NEAR FIELD PROBE

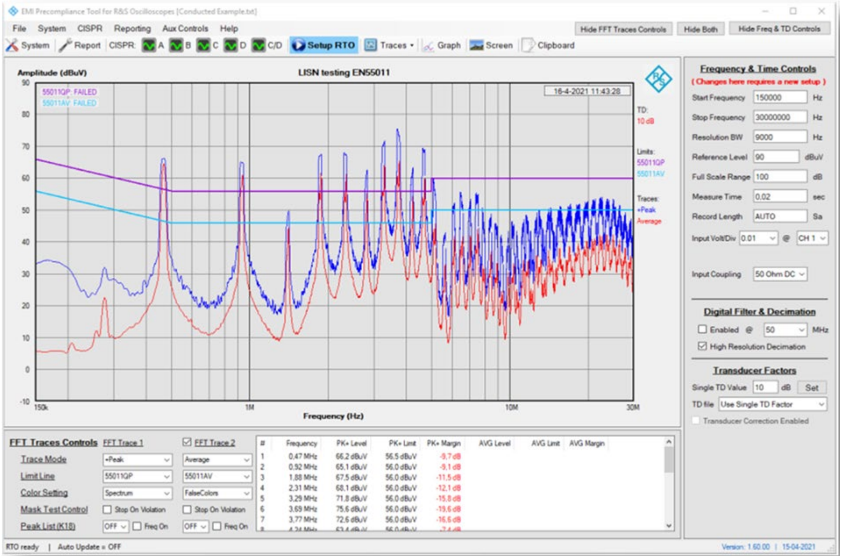
10 MHZ EMI…. COMING FROM 10 MHZ OSCILLATOR





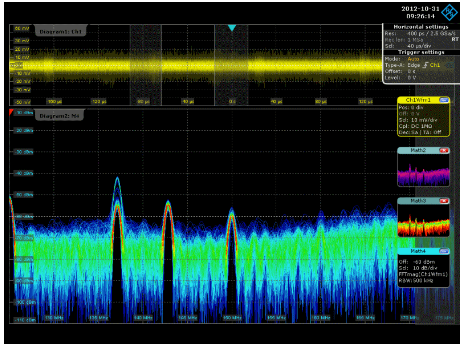
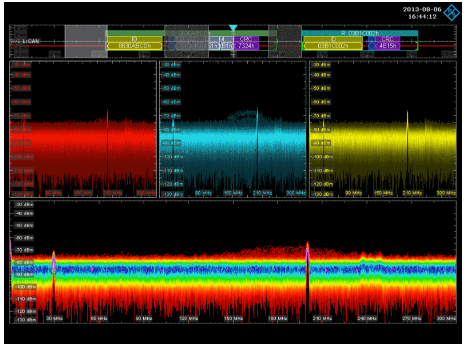
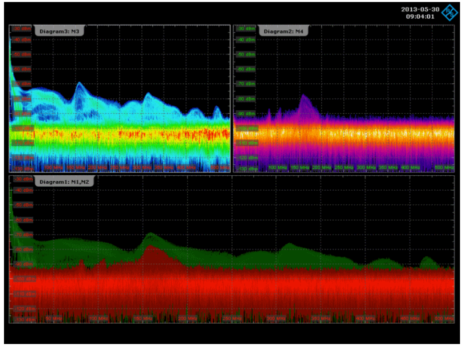
EMI PRECOMPLIANCE APPLICATION :





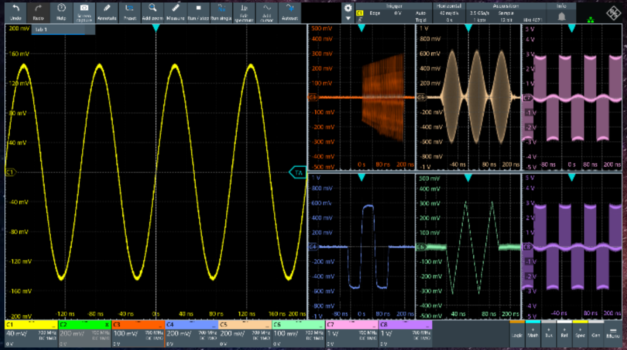
R&S OSCILLOSCOPE USP ON EMI DEBUGGING TECHNIQUES

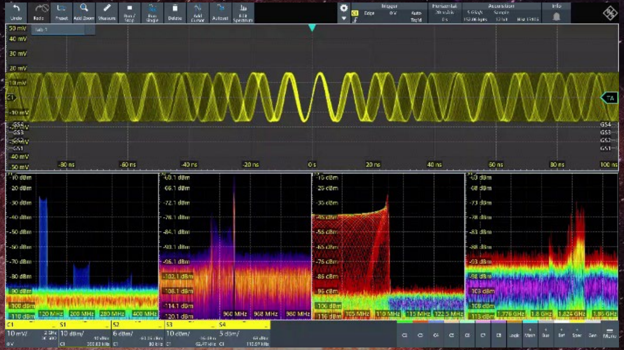
Hardware Specifications	DDC, HW-based FFT, 1 mV/div at full BW, high ENOB, Acquisition bandwidth

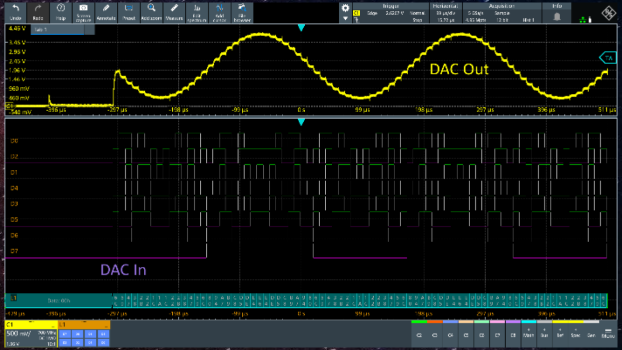
Locate	Capture	Analyze
		
High speed FFT Multi-channels FFT (Overlay of multi-channels FFT) Overlapped FFT Real time FFT Intensity grading display	**Time domain** Digital trigger system Serial and parallel bus trigger Mask violation **Frequency domain** Mask violation	Multi-traces Gated FFT Correlated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

R&S OSCILLOSCOPE PORTFOLIO

EVOLVED FOR MORE CHALLENGES







8 x analogue channels

4.5 Mil wfms per seconds
500 Mpoints per channels
18-bit HD resolution

4 x FFT spectrum analysis

45 kFFT per seconds
Time collated FFT with deep memory

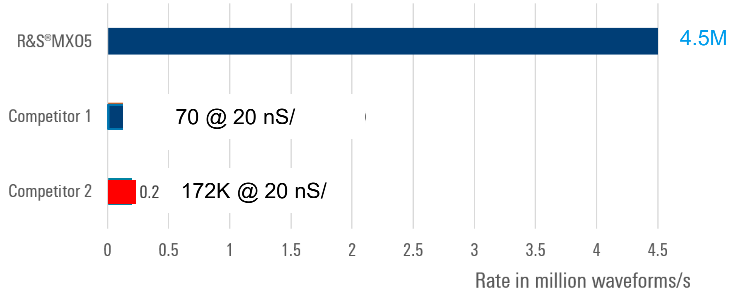
4 x protocol, 16 x logic channels

Dedicated logic channels
Simultaneous protocol decode

INSTANTLY SEE MORE SIGNAL DETAIL

Customer benefit

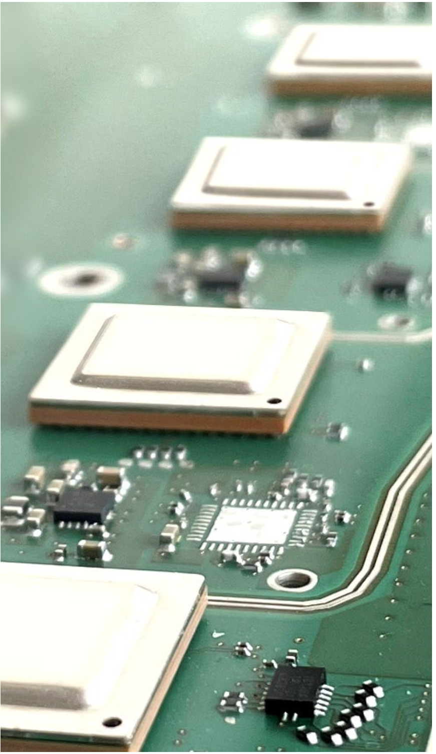
- ▶ 99% of realtime capture rate
- ▶ Detect signal faults & anomalies quickly
- ▶ Increase your statistical confidence



Signals with 1 error per second

Multiple channels with >4.5 Mwfm/sec

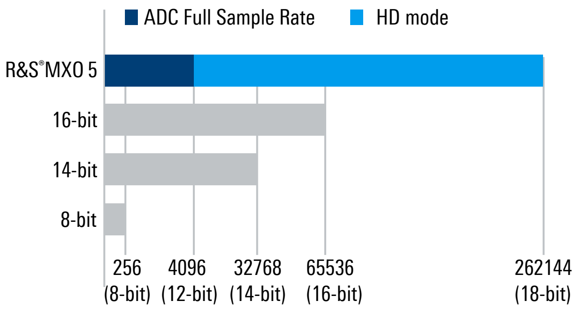
MORE RESOLUTION ON ALL SAMPLE RATE



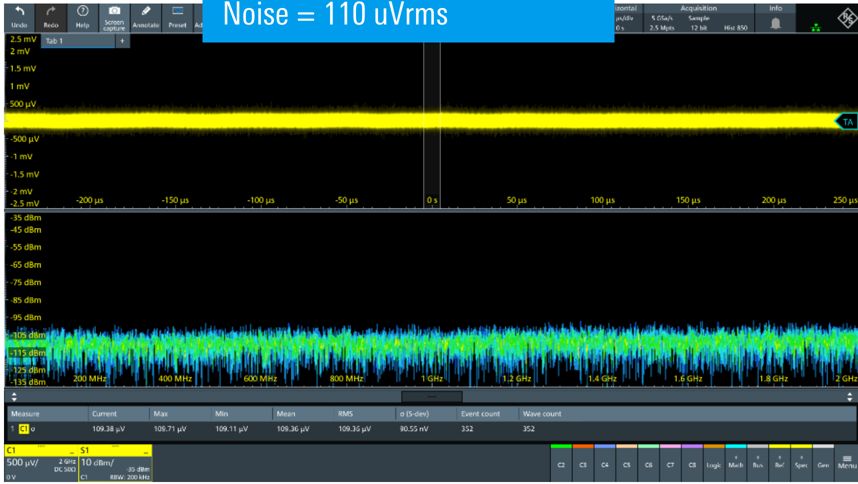
Customer benefit

- ▶ 12-bit ADC all the time (all sample rate)
- ▶ 18-bit HD mode for trigger and measurements

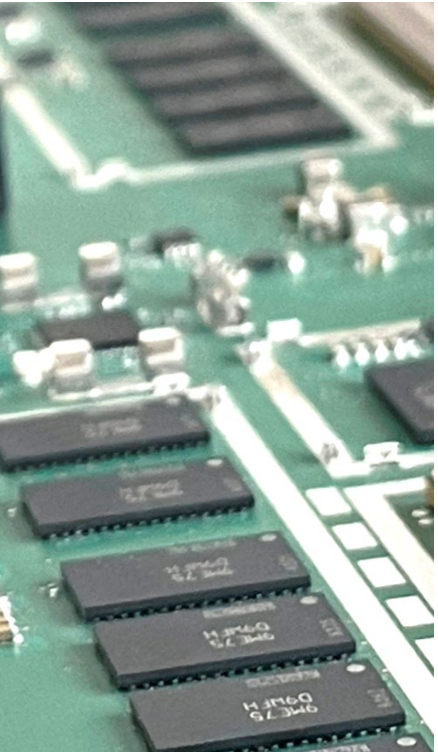
Vertical Quantization level (Resolution)



MXO 5 @ 2 GHz, 50 Ω, 500 uV/
Noise = 110 uVrms



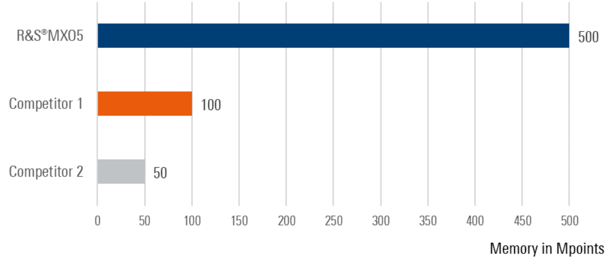
CAPTURE EVEN MORE TIME



Customer benefit

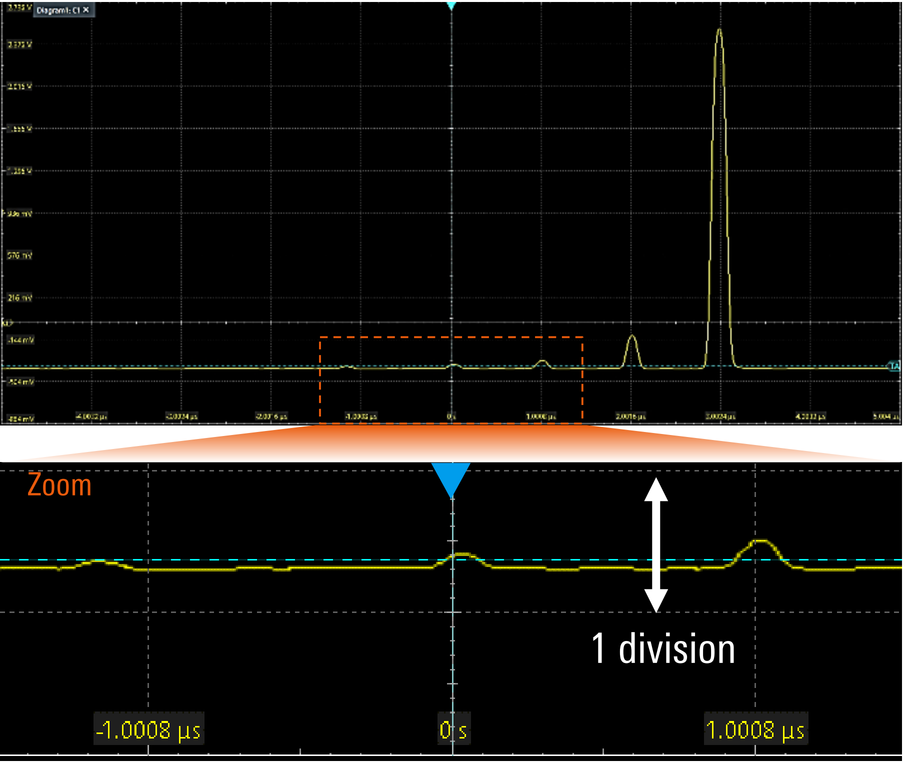
- 500 Mpts per channel (Standard)
- 1 Gpts (Option)
- Segmented memory 10 K (Std) ~ 1 M (Opt)

Standard memory per channel



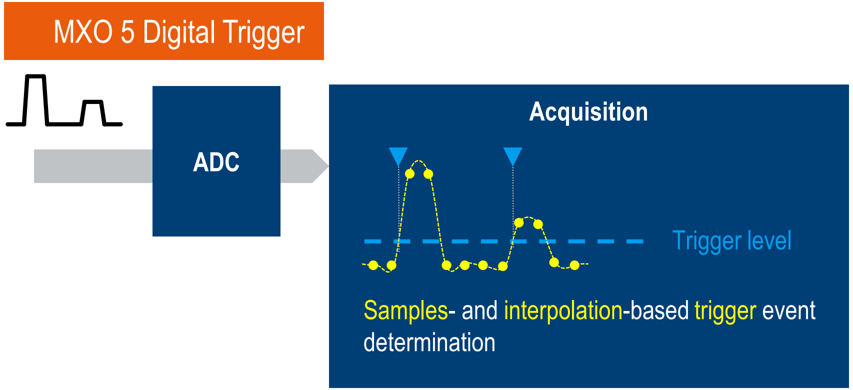
Total capture 1 second

TRIGGER WITH MORE RESOLUTION



Customer benefit

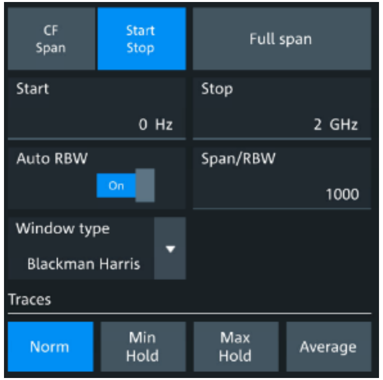
- Detect trigger event based on samples
- Adjustable trigger sensitivity
- Minimal trigger jitter < 1ps



MORE FFTS WITH UNMATCHED SPEED

Customer benefit

- ▶ Fastest RF insights >45 Kwfm/s
- ▶ Independent time vs spectrum control
- ▶ Standard spectrum features
- ▶ Log-scale and Future spectrogram



KEY USP

MXO 5

> 4.5 Million	wfms / sec
12 -bit	ADC 18-bit HD
500 Mpts	memory /ch
Digital	trigger
> 45 k	FFT / sec

Standard MSO

MXO 5

First 5000 class with VESA mount

Dual ARB Gen
100 MHz

MXO 5

25 dBA 1 meter from instrument

It is whisper quiet…

…class with …unt

MXO 5

9 KG 19.85 lbs

Performance meet portability…

MXO 5 HIGHLIGHT

MXO 5 Series Key Specifications		
Channels	4	8
Bandwidth	350, 500 MHz, 1 & 2 GHz	100, 200, 350, 500 MHz, 1 & 2 GHz
Max. Sample Rate	5 GSa/s (x 4ch)	5 GSa/s (x 4ch) 2.5 GSa/s (x 8ch)
Record Length	500 Mpts 1 Gpts (option)	
Vertical resolution	12 bit ADC, (up to 18 bit with HD mode)	
Acquisition rate	> 4.5 Mwfm/sec (x 4 ch) 180 K FFTs/sec (x 4 ch)	
HW options	▶ MSO (16 logic channel) ▶ 100 MHz generator (Dual Arb)	
Display	15.6“ Full HD	
OS	Linux	

Q & A