POWER INTEGRITY MEASUREMENTS

TECHNIQUES FOR MORE ACCURATE POWER RAIL MEASUREMENTS

Jithu Abraham
RSUK Product Manager

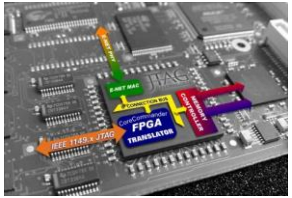
ROHDE&SCHWARZ

Make ideas real

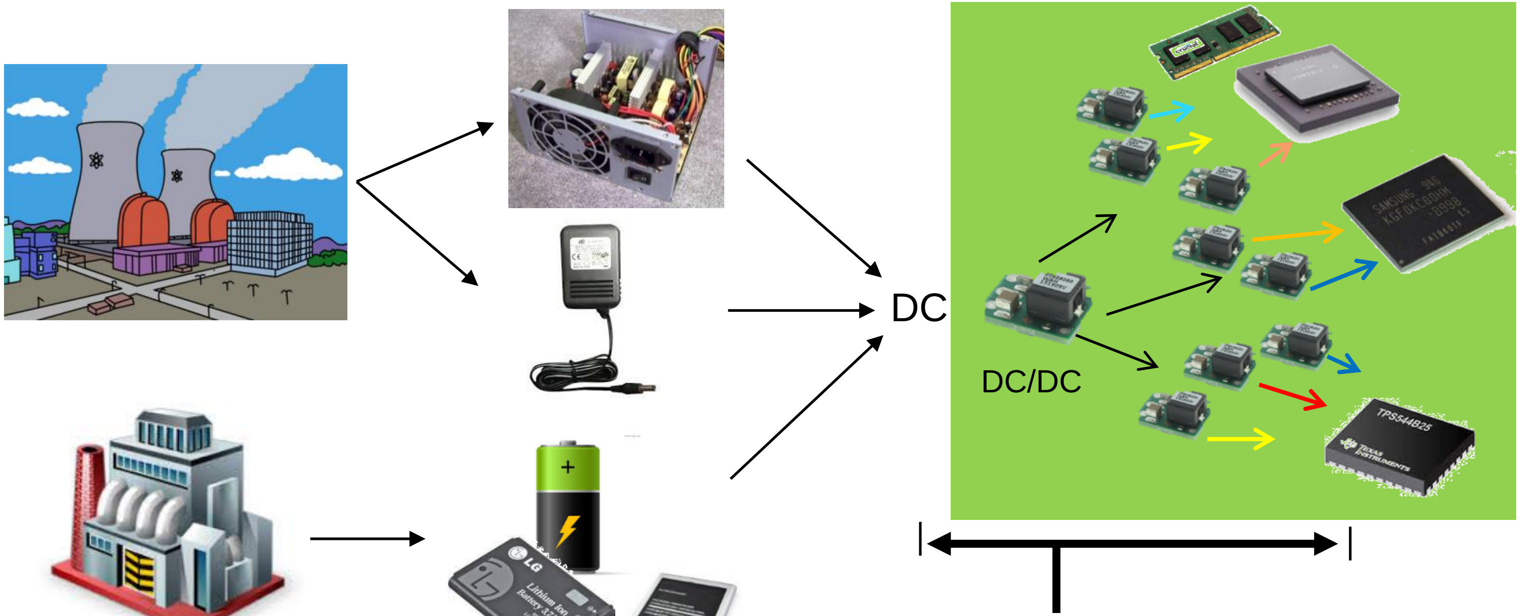
POWER ELECTRONICS – OVERVIEW

► DC Power distribution networks are everywhere

DC Power Distribution Network



POWER ELECTRONICS – OVERVIEW

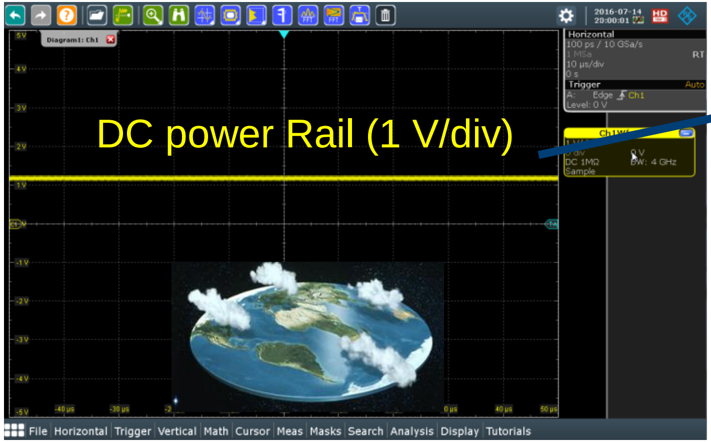


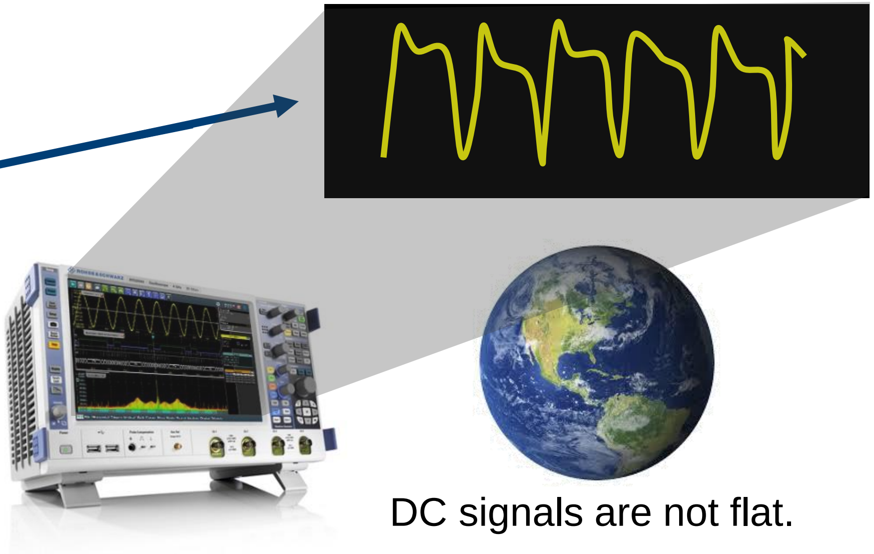
Typical Power Rail Quantities
- SSD: 12+
- RTO2K: 20+
- Tablet: 24+
- Network switch: ~56
- Next gen mobile: ~100

Power Integrity:

Analysis to determine quality of DC power from the output of the DC converter to ICs. Includes chip, board, & system.

OSCILLOSCOPES –
PRIMARY TOOL FOR POWER RAIL ANALYSIS



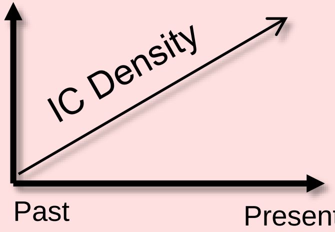


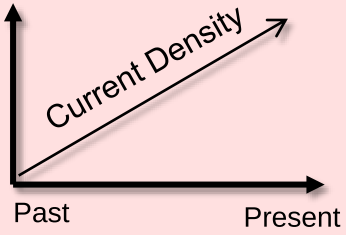
DC signals are not flat.

POWER ELECTRONICS – OVERVIEW

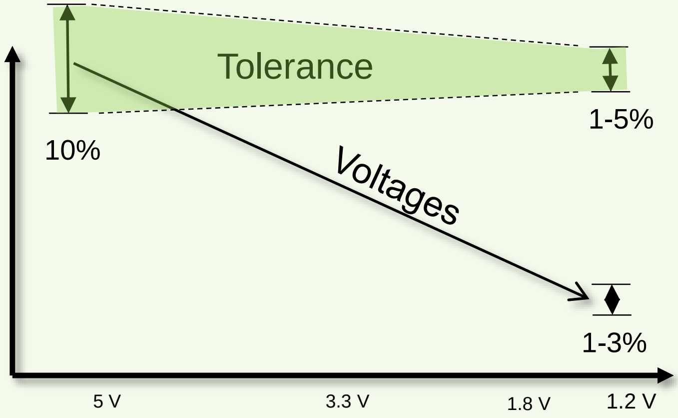
► Why is Power Integrity becoming more important?

Goal: less power consumption with each generation



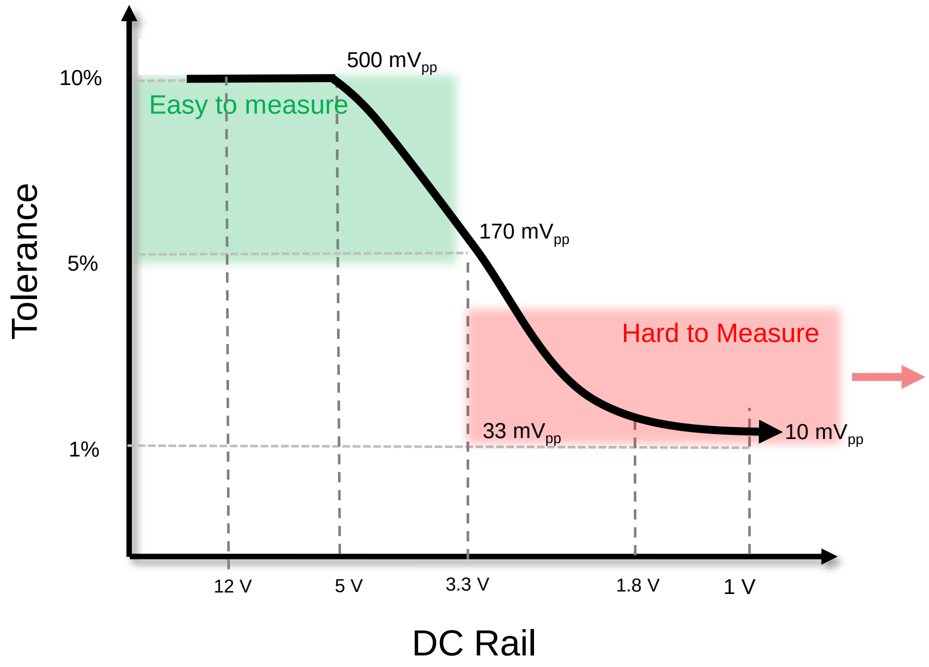


Increasing current



Requires smaller voltages (power, heat, quality)

POWER RAIL MEASUREMENT CHALLENGES

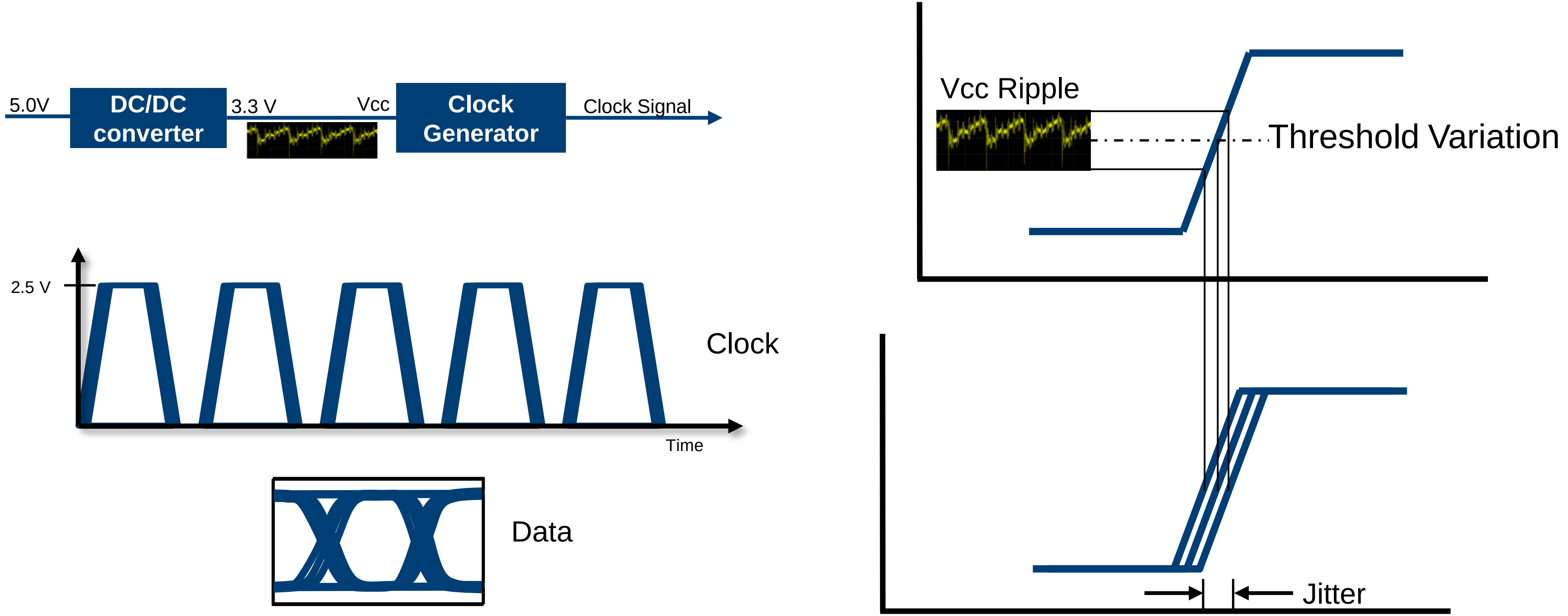


Examples

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}

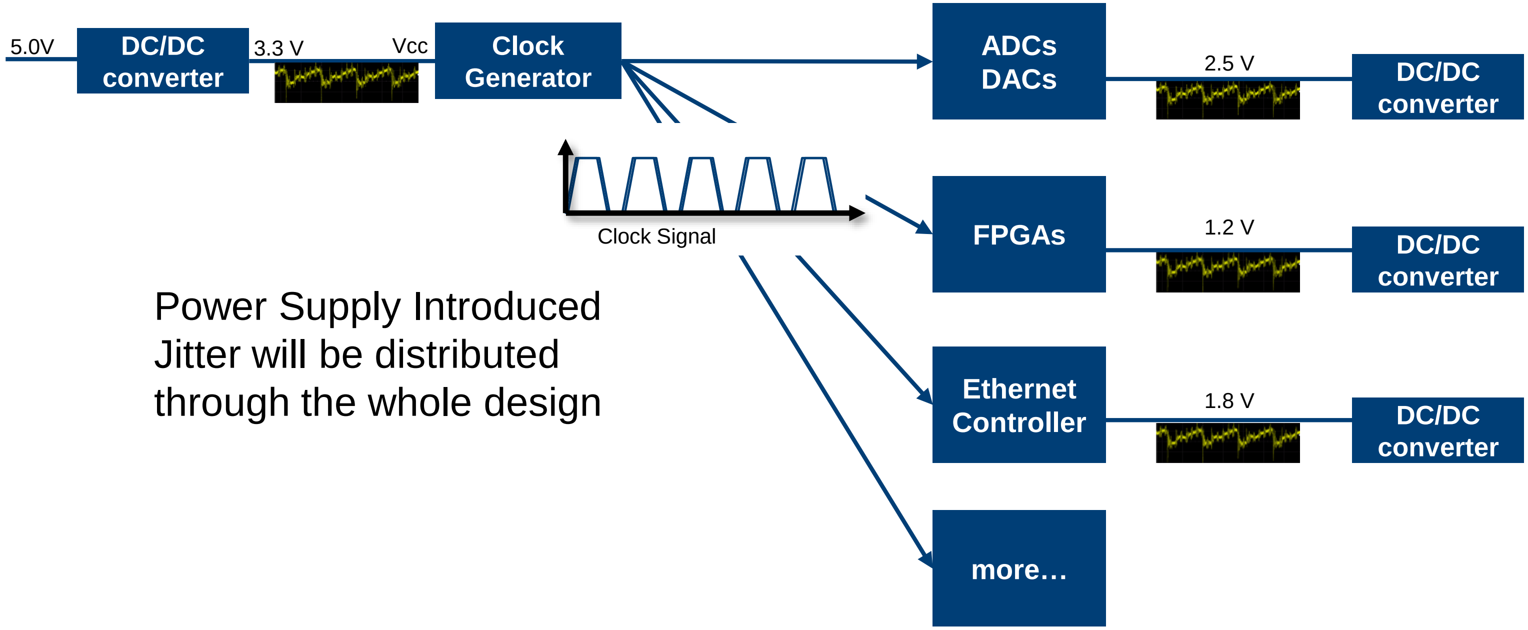
WHY POWER INTEGRITY MATTERS?

► Signal Integrity degrading and Influence on functionality



WHY POWER INTEGRITY MATTERS?

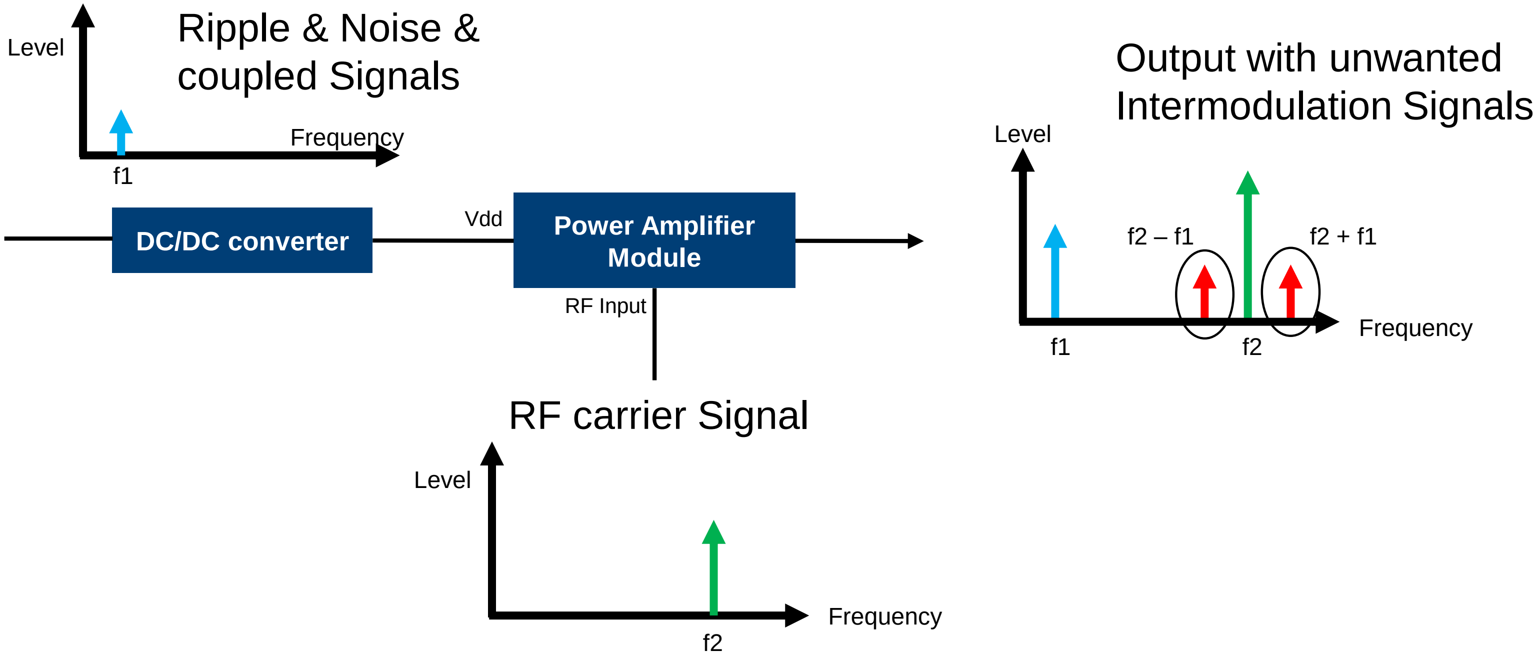
- Signal Integrity degrading and Influence on functionality



Power Supply Introduced Jitter will be distributed through the whole design

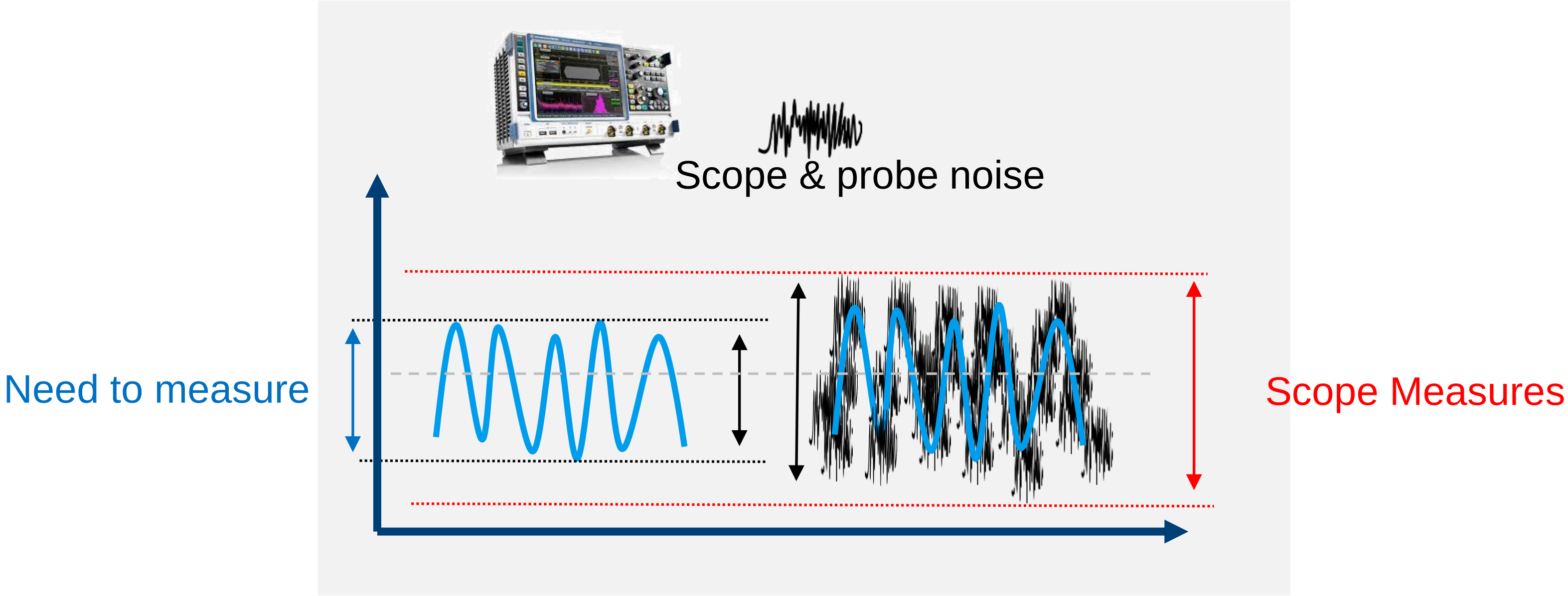
WHY POWER INTEGRITY MATTERS?

► Power Integrity influences RF Signal Integrity



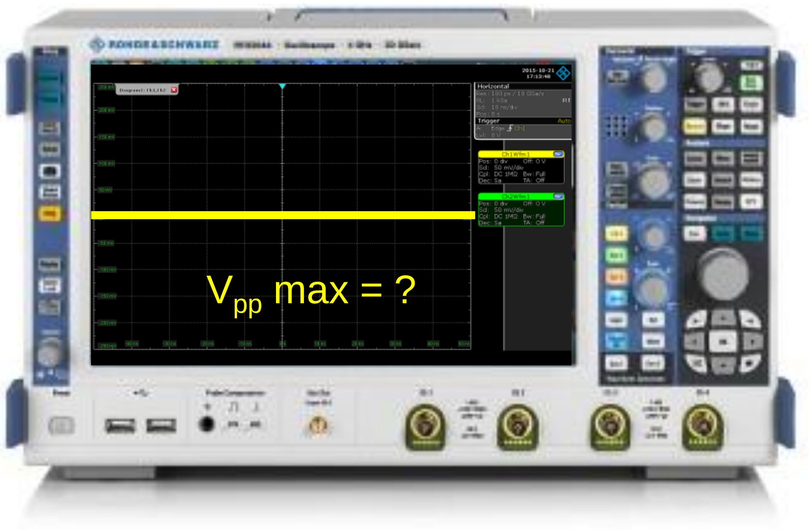
POWER RAIL MEASUREMENTS – OSCILLOSCOPE

► Several factors make it difficult to measure small signals



POWER RAIL MEASUREMENTS TIPS & TECHNIQUES

► Characterising your Scope's Peak-to-Peak Noise in 5 minutes

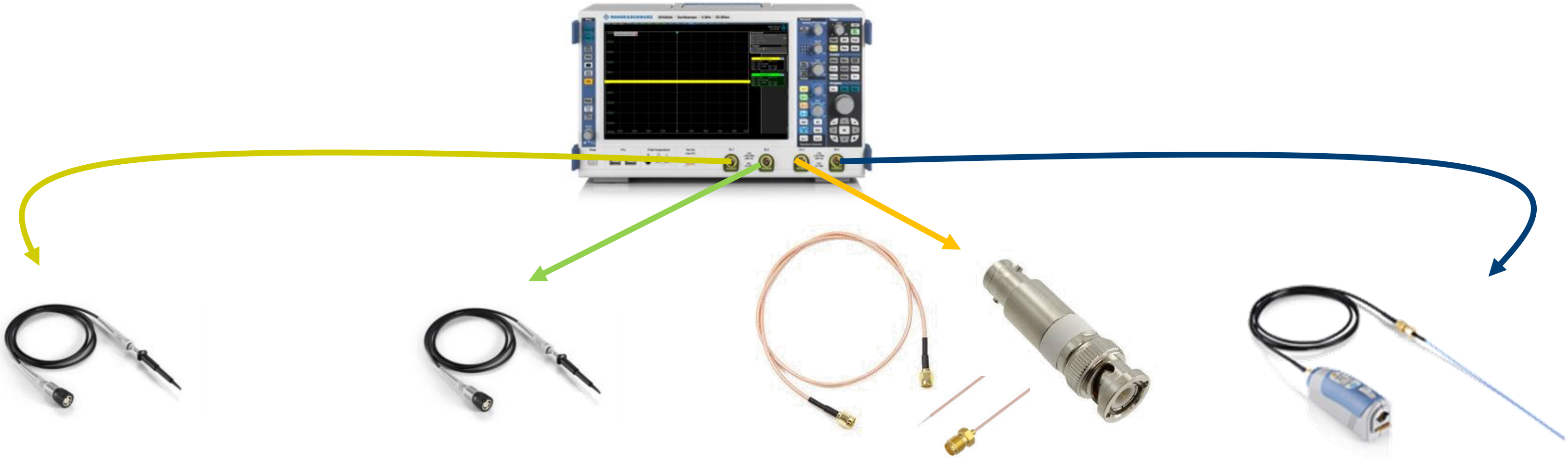


1. Disconnect all inputs
2. Set sample rate (e.g.10 Gsa/s), memory depth, (e.g.1 Mpts), path, and BW to mirror your requirements
3. Turn on Vpp measurement with stats for channel 1
4. Adjust vertical setting to cover the smallest vertical setting you will use
5. Record V_{pp} value
6. Repeat for all other vertical scales that you may use.
7. Repeat for all channels that may be used (will have variation from channel to channel)

(Can perform with probe attached.)

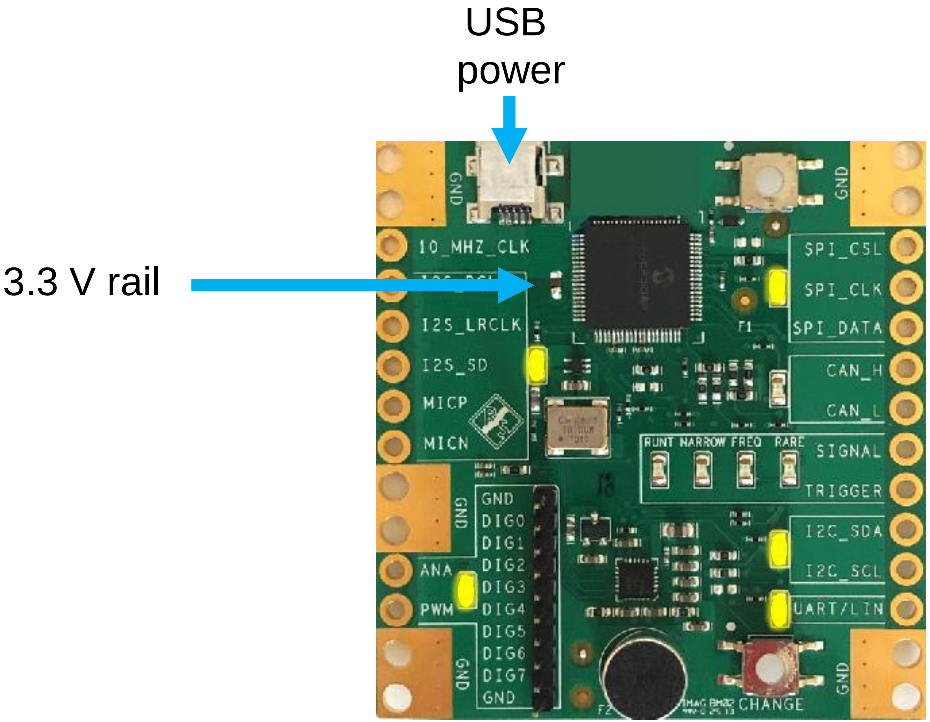
POWER RAIL MEASUREMENTS
TIPS & TECHNIQUES

► Four measurement approaches – Let's walk through each and compare

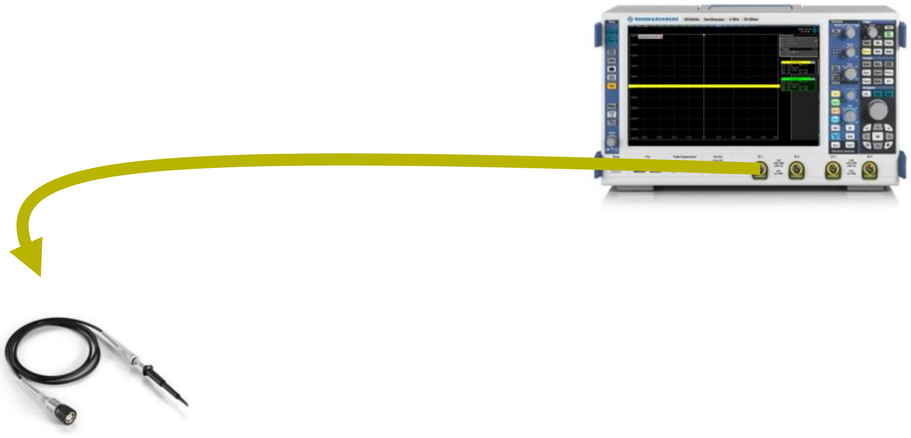


Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

POWER RAIL MEASUREMENTS
TIPS & TECHNIQUES



POWER RAIL MEASUREMENTS
APPROACH #1



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

POWER RAIL MEASUREMENTS APPROACH #1 – 10:1 PASSIVE PROBE

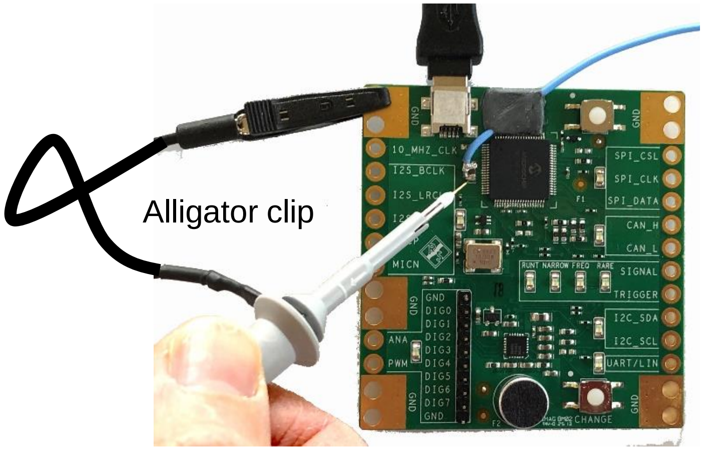
- Advantages

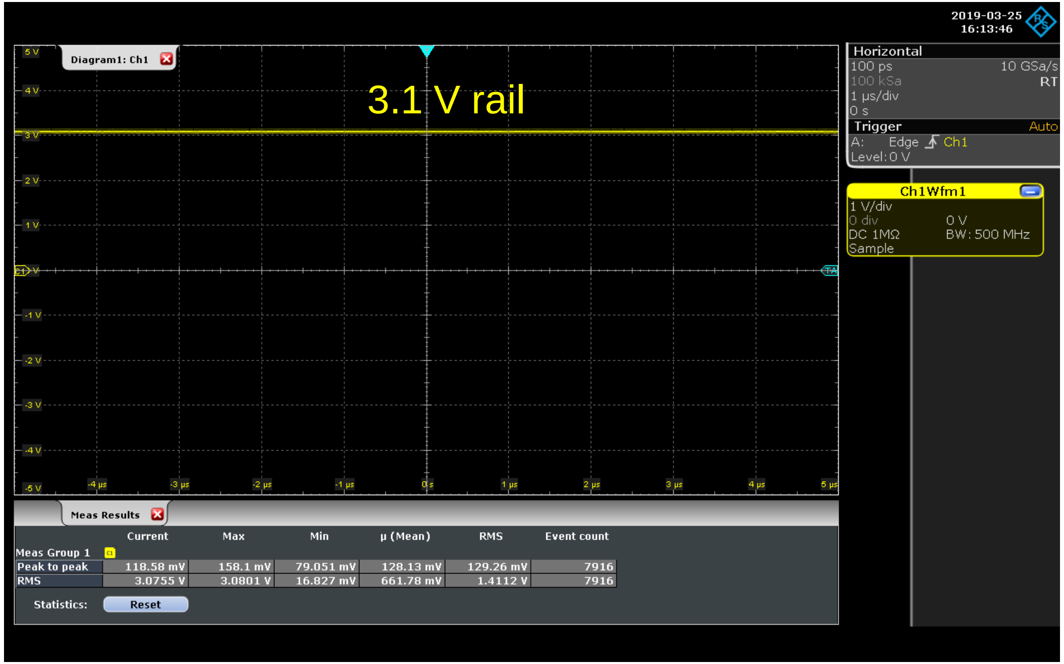
- Comes standard with most scopes
  - no extra expense
- 1 MΩ loading at DC
  - Preserves expected DC value
- Easy to connect using browser tip
  - Multiple ground alternatives

- Disadvantages

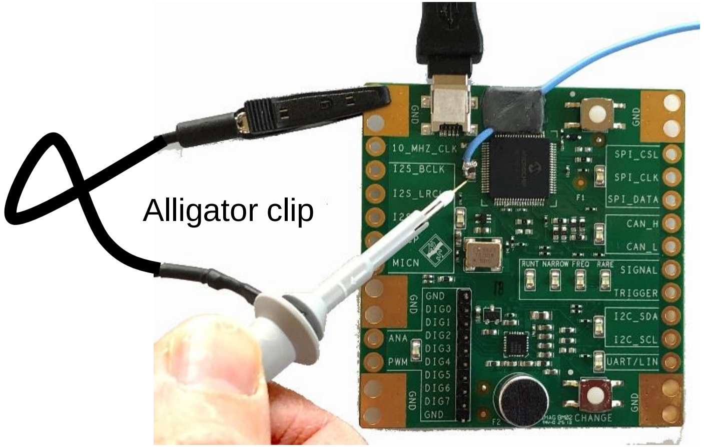
- Significant noise
  - 10:1 attenuation
  - Minimum vertical setting of 10 mV/div
- Long grounds
- BW limited (500 MHz for ZP-10)
- No solder-in alternative

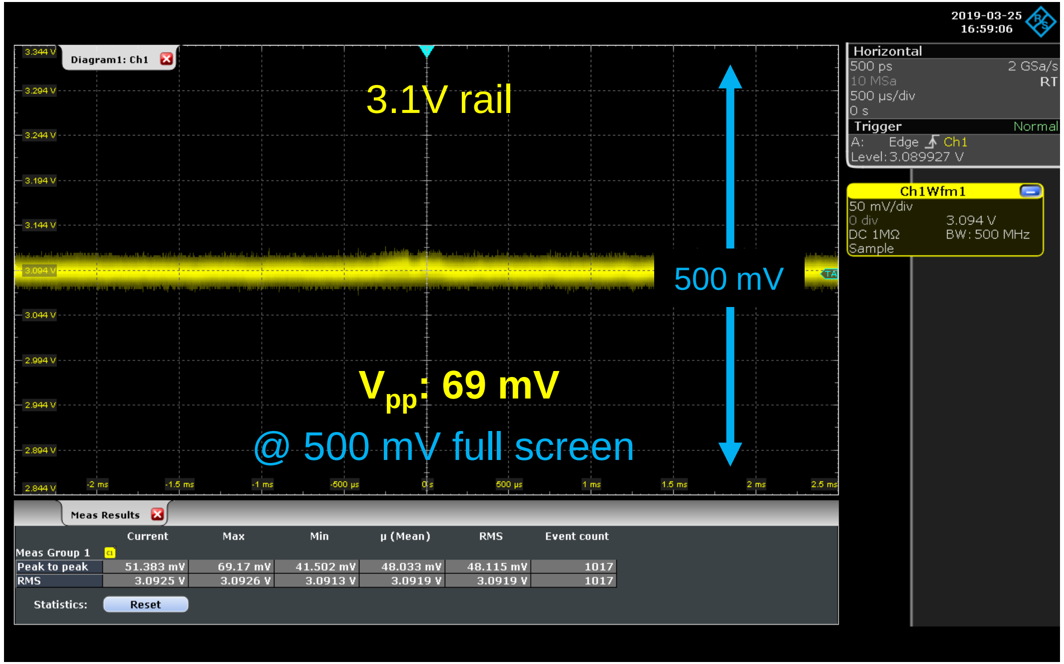
Standard 10:1 Passive Probe with Alligator Clip (ZP-10)



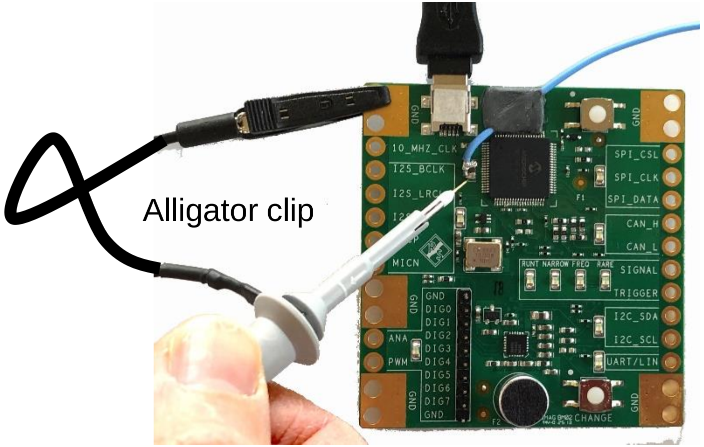


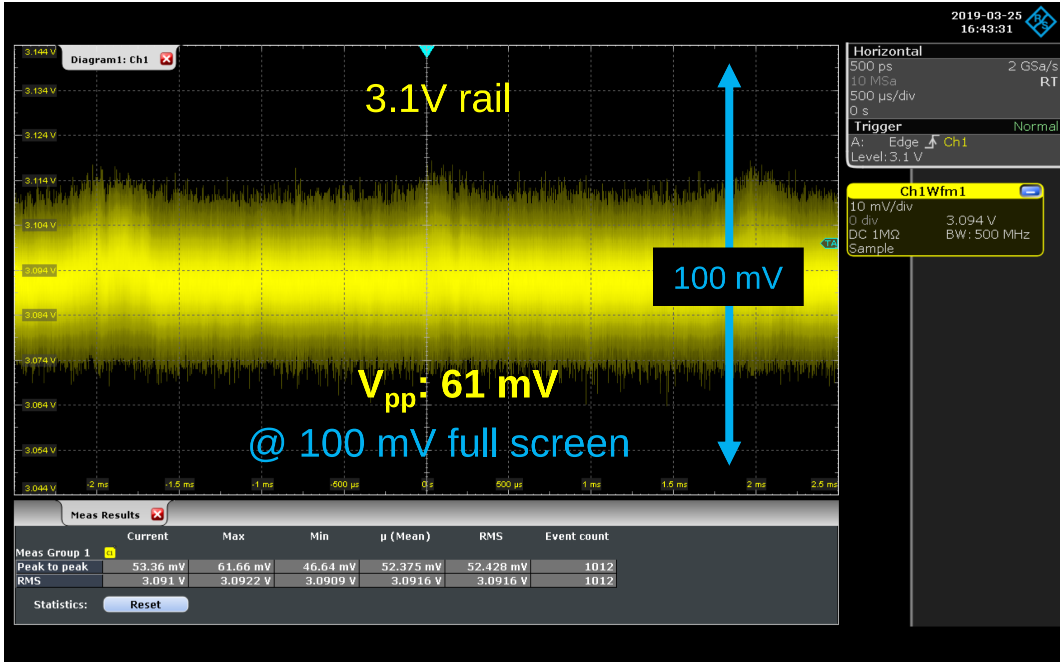
Standard 10:1 Passive Probe with Alligator Clip (ZP-10)





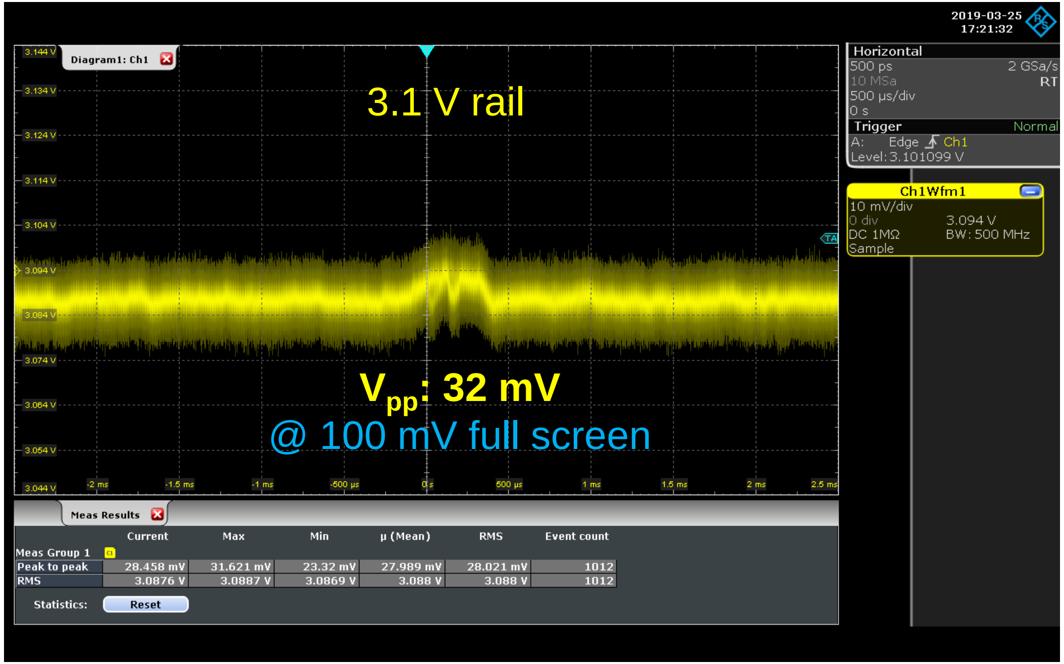
NOISE IS A FUNCTION OF FULL SCREEN VERTICAL





STANDARD 10:1 PASSIVE PROBE WITH GROUND SPRING

Ground spring



Probe Holders Greatly Help Measurement Repeatability

2D Probe Positioner

3D Probe Positioner (RT-ZAP)

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

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

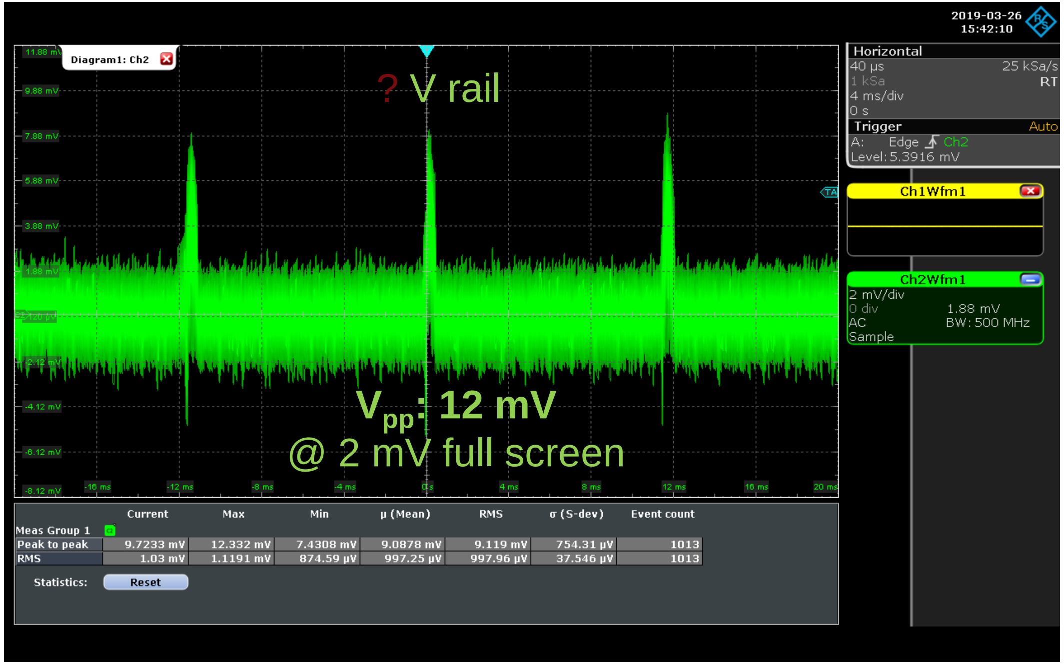
Disadvantages

- 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

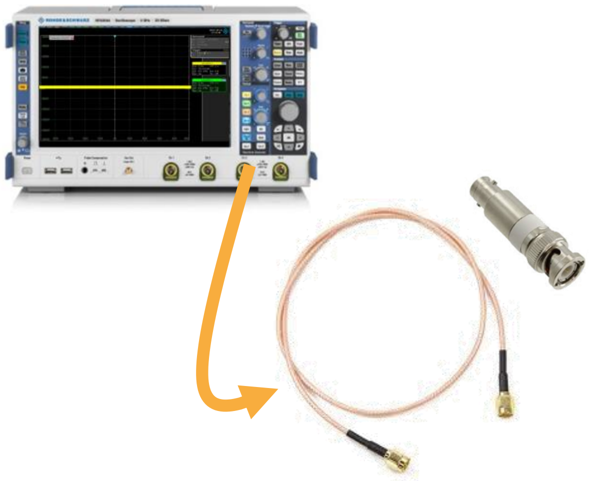
38 MHZ 1:1 PASSIVE PROBE WITH GROUND SPRING (ZP-1X)

Ground spring

Not enough offset, required AC coupling



MEASUREMENT APPROACH: 50Ω PATH

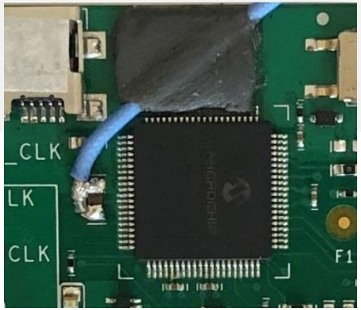


Standard **10:1** passive probe	Low BW **1:1** passive probe	50 Ω cable (with blocking cap)	Specialized **power rail** probe

50Ω PATH

Advantages

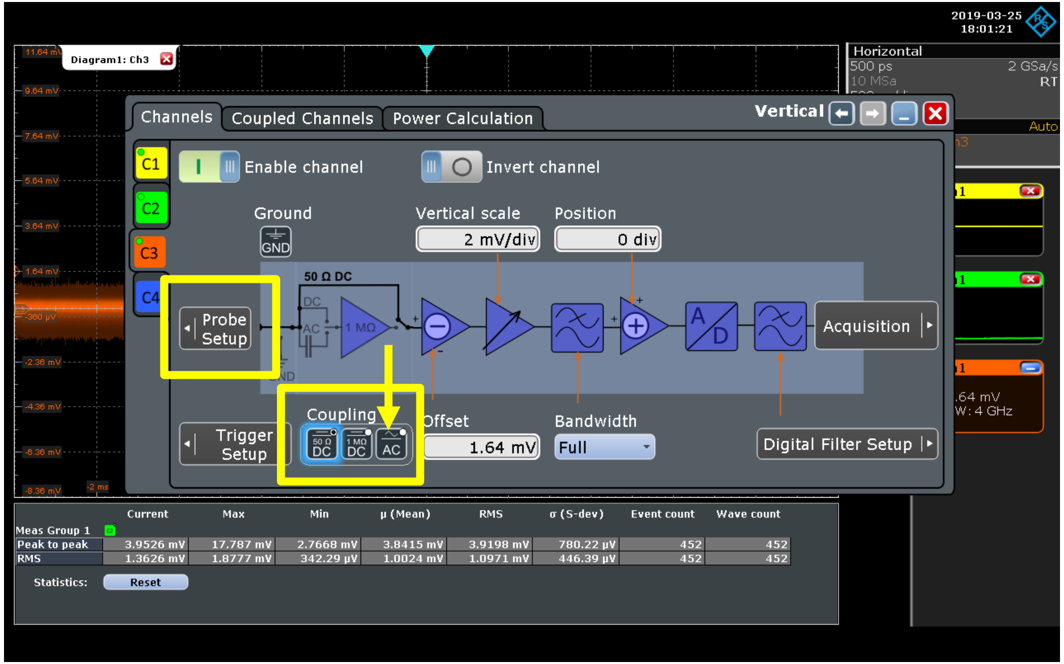
- ► 50 Ω scope path typically has less noise than 1M Ω scope path
- ► SMA connector or solder-in pigtail allows for measurement consistency and ease of access



Disadvantages

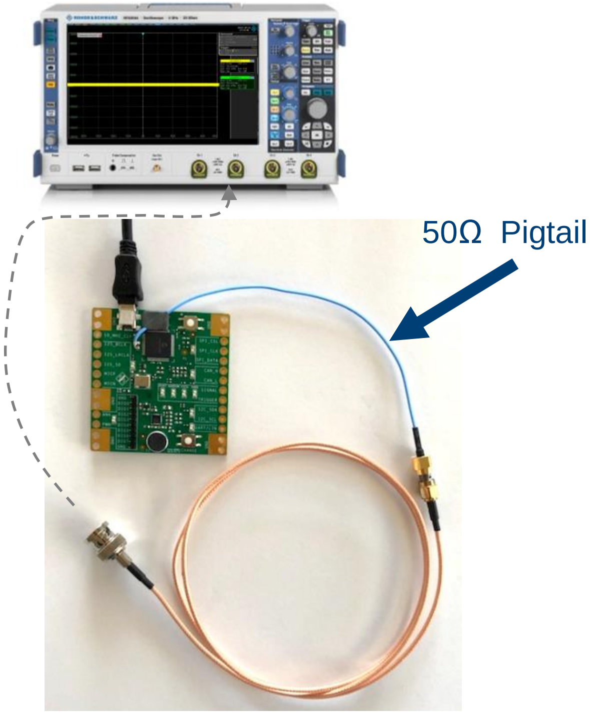
- ► 50 Ω loading at DC reduces power rail voltage
- ► Insufficient offset (requires blocking cap or AC coupling)
  - – Masks DC drift
  - – Eliminates ability to see true DC voltage

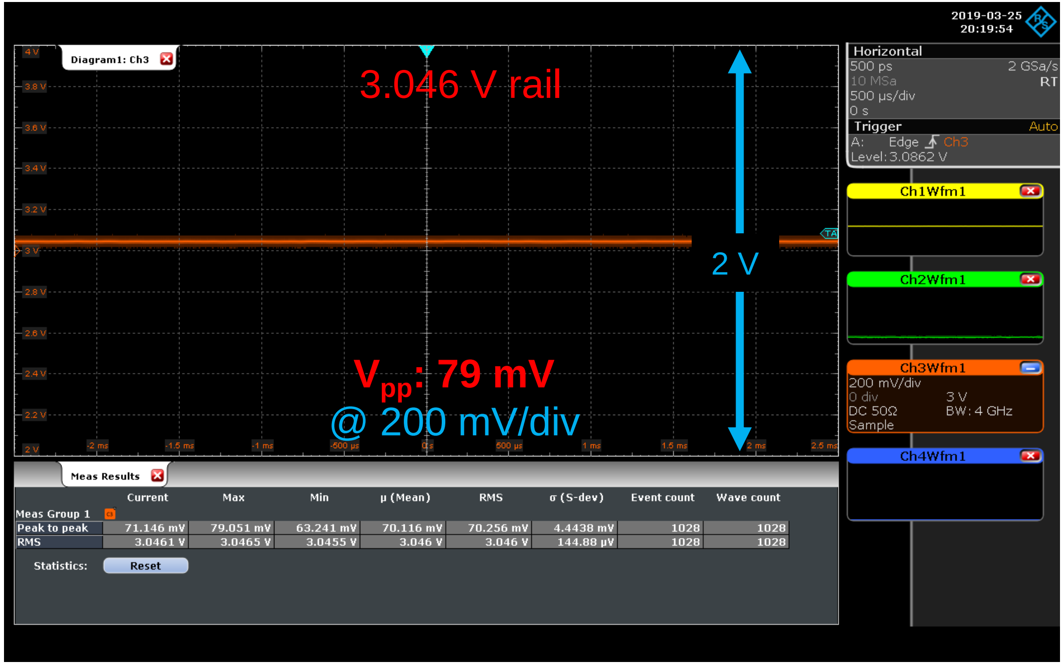
50Ω PATH: AC COUPLING



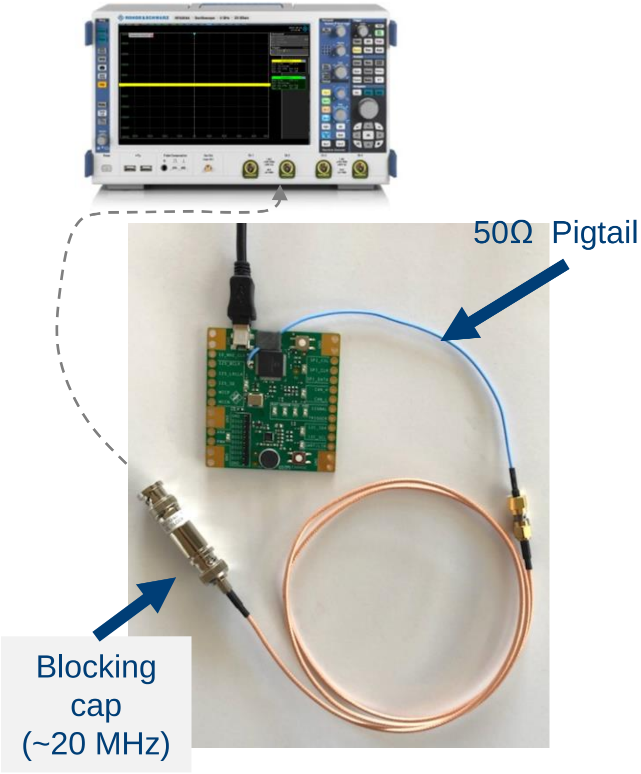
- Set to 50Ω path (channels setup)
- Attenuation to 1:1 (probe setup)
- 50Ω path (limited offset may require AC coupling)

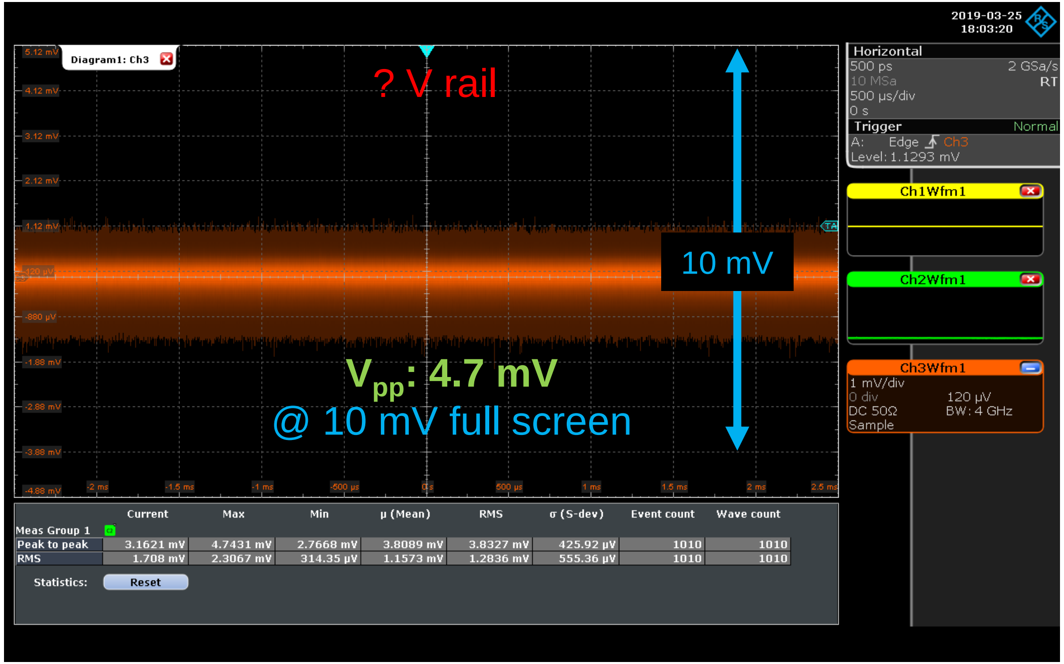
50Ω PATH (SUFFICIENT OFFSET NOT AVAILABLE)





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

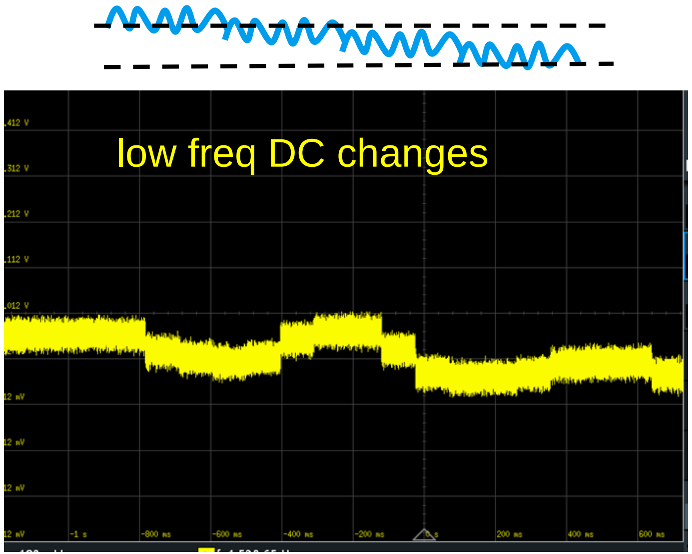


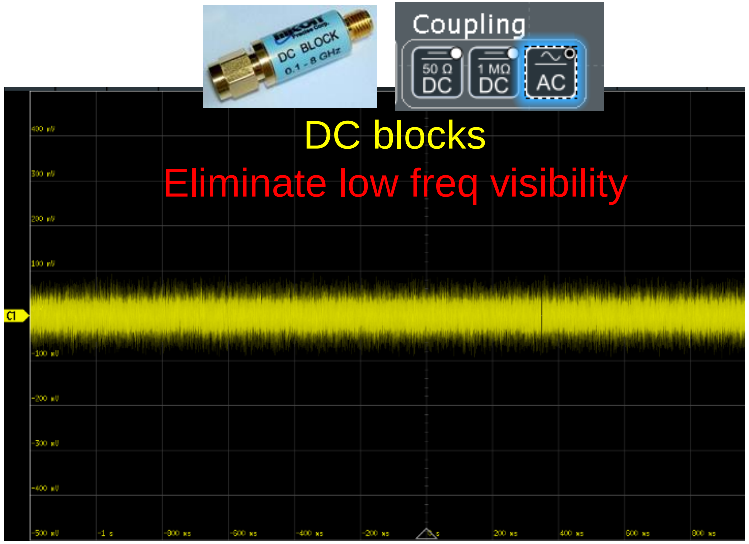


Blocking Caps (and AC coupling) Create Measurement Problems

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

DC Drift

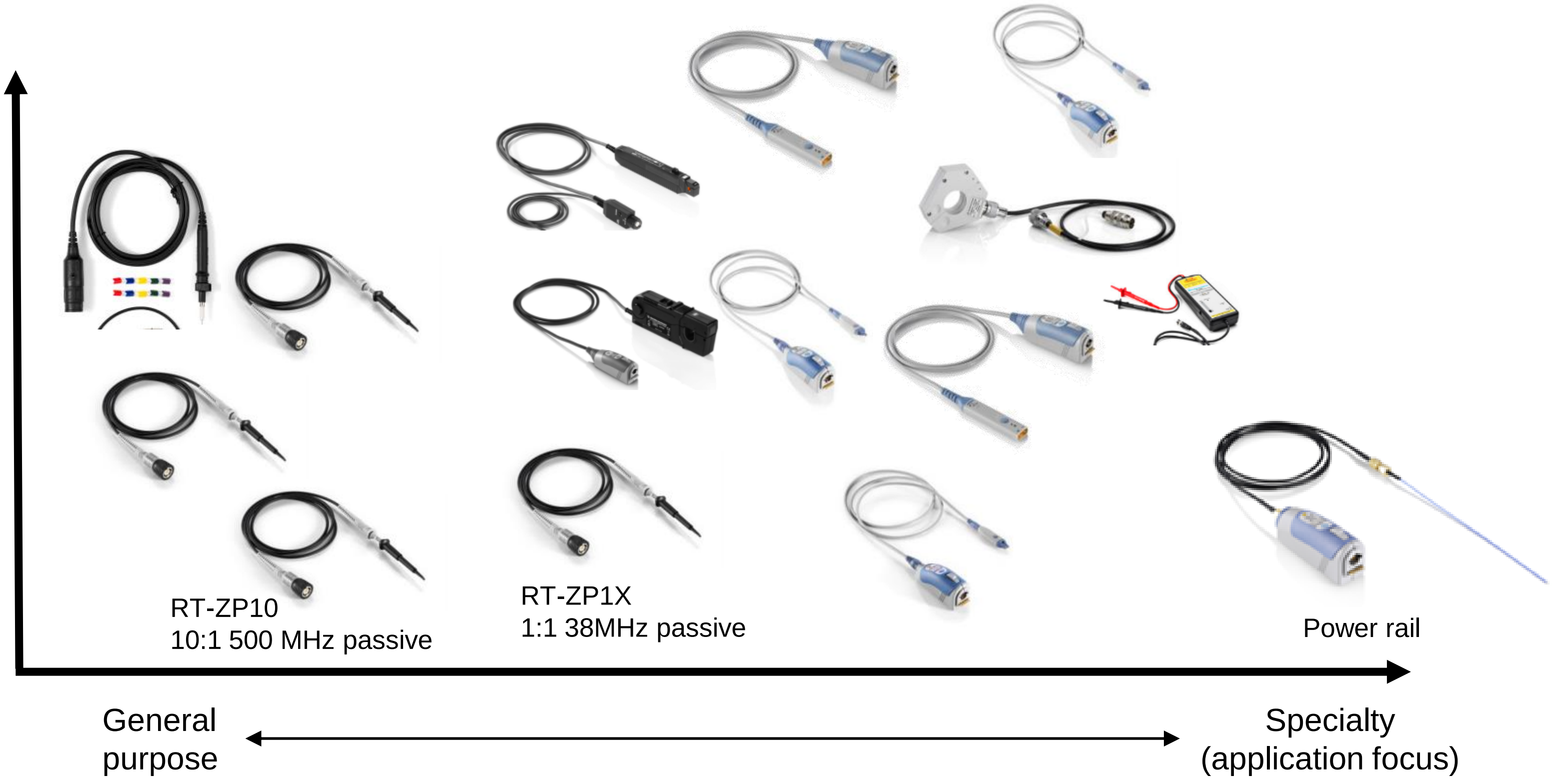




POWER RAIL PROBE (ZPR20, AND ZPR40)

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 PROBES…SPECIALTY TOOL

Circular saw
Great for a bunch of stuff.
Can’t cut door jambs.

Jamb saw.
Does one task really well.
Not useful for anything else.

POWER RAIL PROBE (ZPR20, 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

RT-ZPR40 POWER RAIL PROBE
RT-ZPR20 POWER RAIL PROBE

- 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
- Built-in DC meter

Key Specifications	
Attenuation	**1:1**
ZPR20 BW ZPR40 BW	**2 GHz(*)** **4 GHz(**)**
Browser BW	350 MHz
Dynamic Range	±850 mV
Offset Range	**> ±60 V**
ZPR20 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

ZPR20

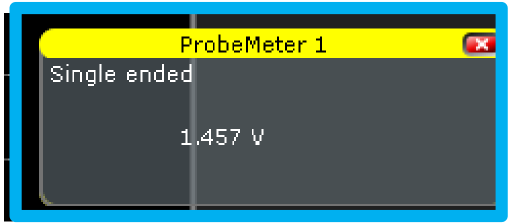
ZPR40

(*) 2.4 GHz typical 3 dB point
(**) 4.0 GHz typical 3dB point

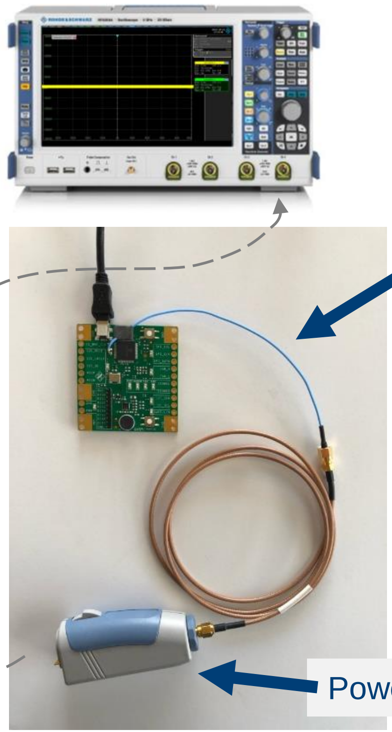
Some Power Rail Probes have an Integrated Voltmeter

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



POWER RAIL PROBE

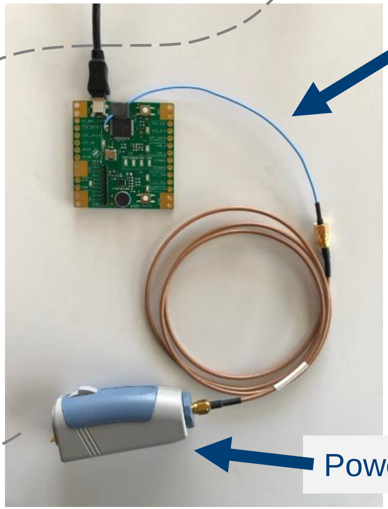


50Ω Pigtail

Power Rail Probe

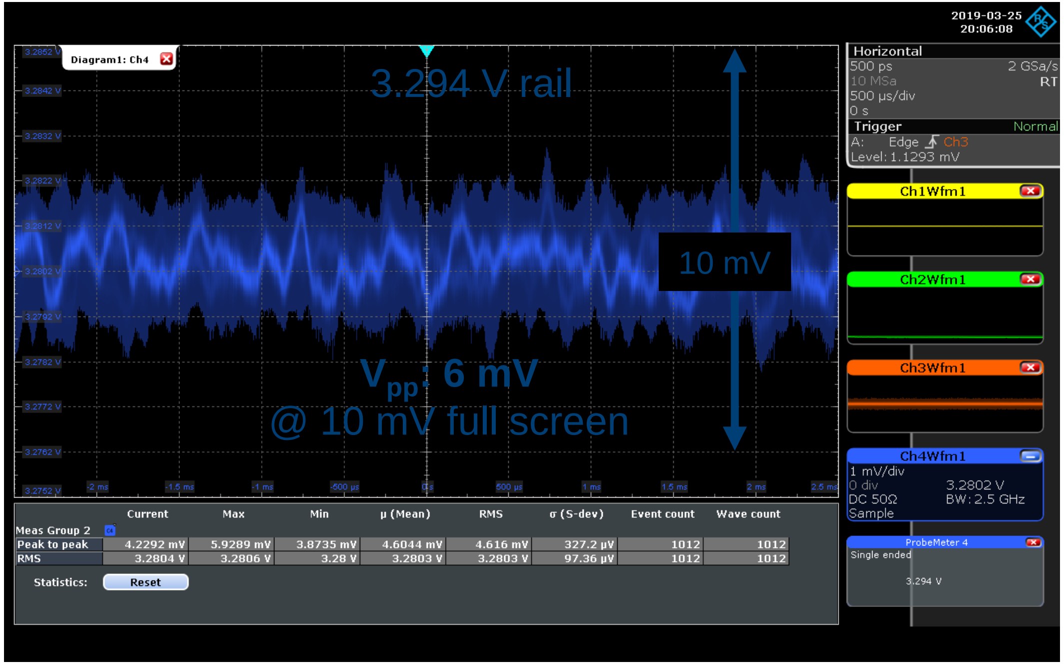
3.293 V rail

POWER RAIL PROBE (ZPR20: 3DB BW = 2.5 GHZ)



50Ω Pigtail

Power Rail Probe



MEASUREMENT TECHNIQUE RESULTS COMPARISON

Noisy
10 MΩ DC loading
Limited BW
Limited scaling

Vpp: 69 mV

Standard
10:1
passive
probe

Low noise
1MΩ DC loading
Limited BW
Limited offset

Vpp: 14 mV

Low BW
1:1
passive
probe

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

Vpp: 15 mV

50 Ω cable
(with blocking cap
or AC coupling)

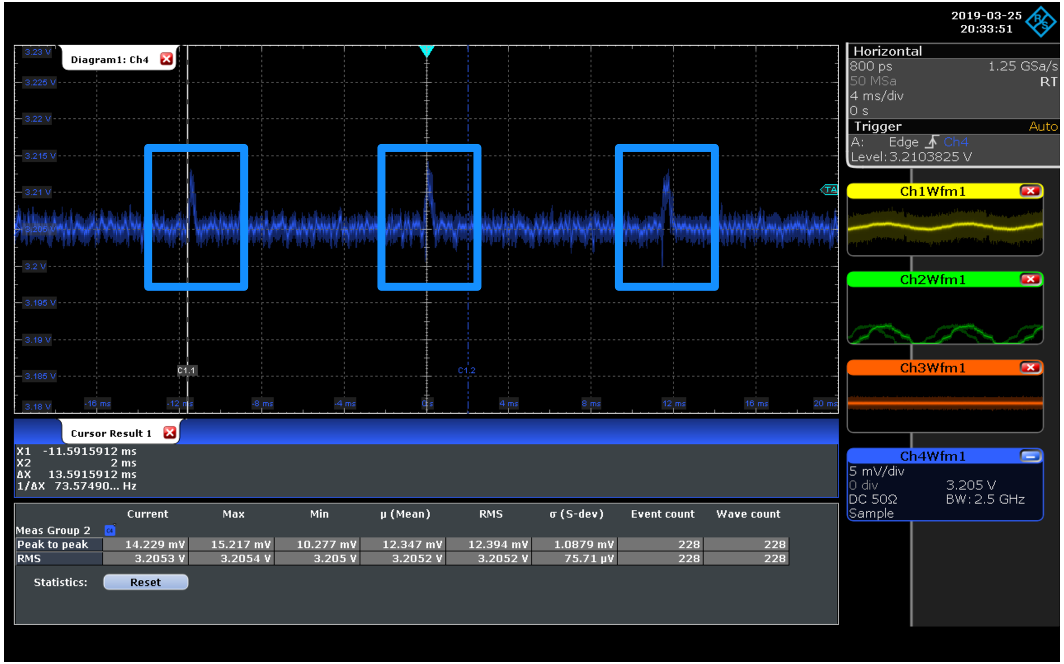
Low noise
50 KΩ loading
High BW
Built-in offset

Vpp: 6 mV

Specialized
power rail
probe

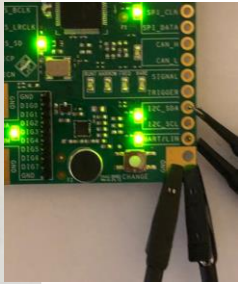
EXTRA CREDIT: WHAT'S CAUSING PERIODIC RAIL SPIKES?

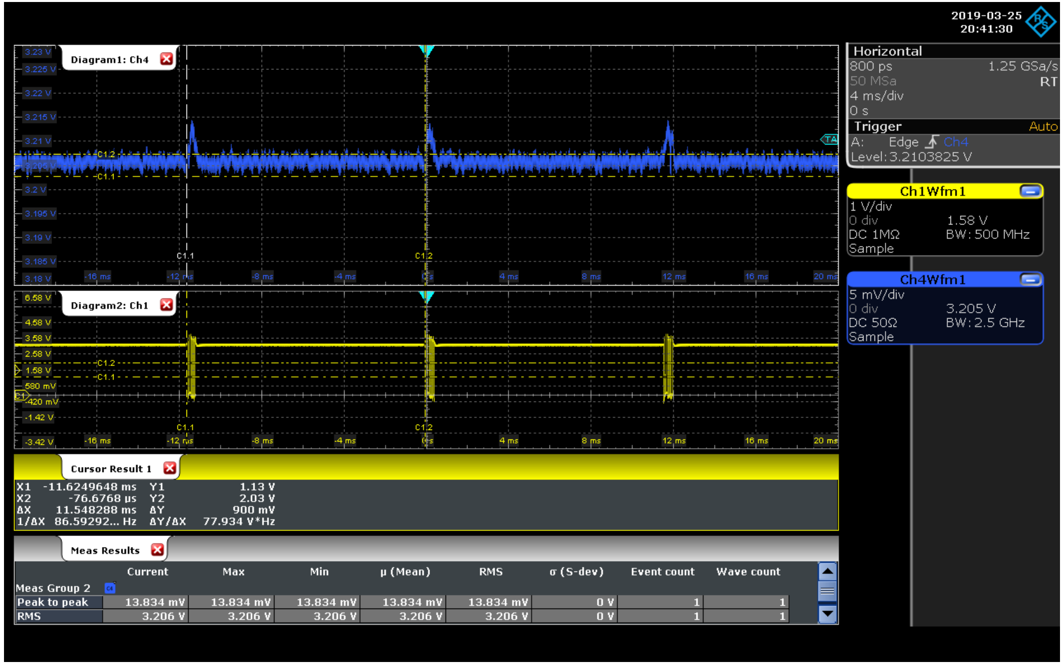
Adjust timebase to 4 ms / div



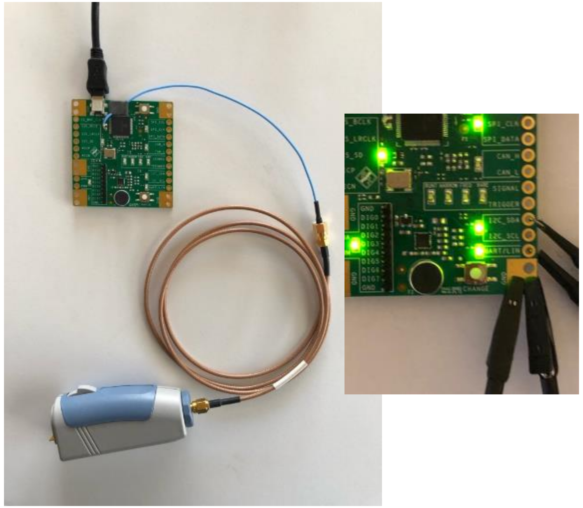
POWER RAIL PEAKING CORRESPONDS TO I²C PACKETS

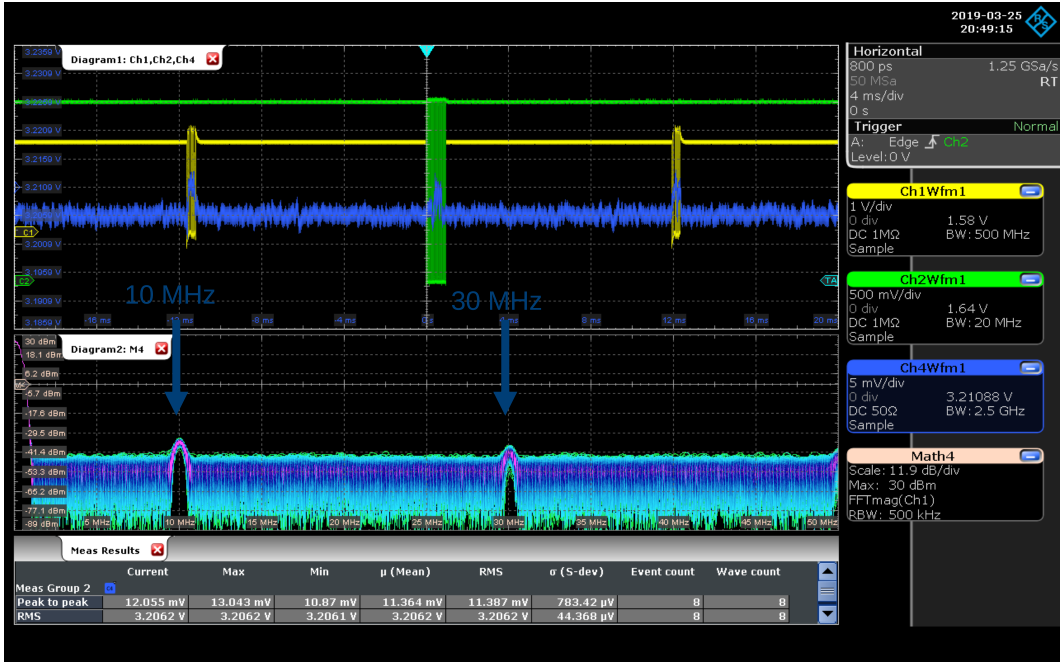
Attach to I²C signals





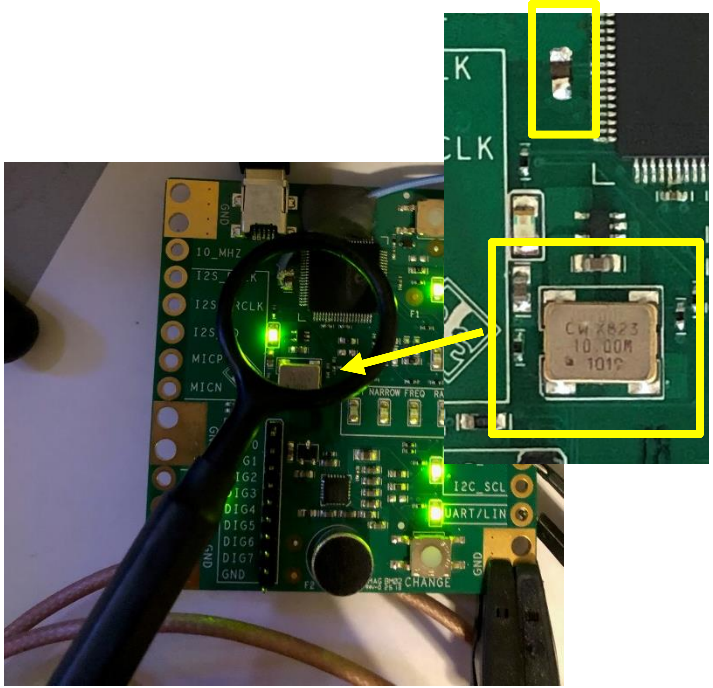
FFT ON POWER RAIL SHOW 10 MHZ AND HARMONIC TONES

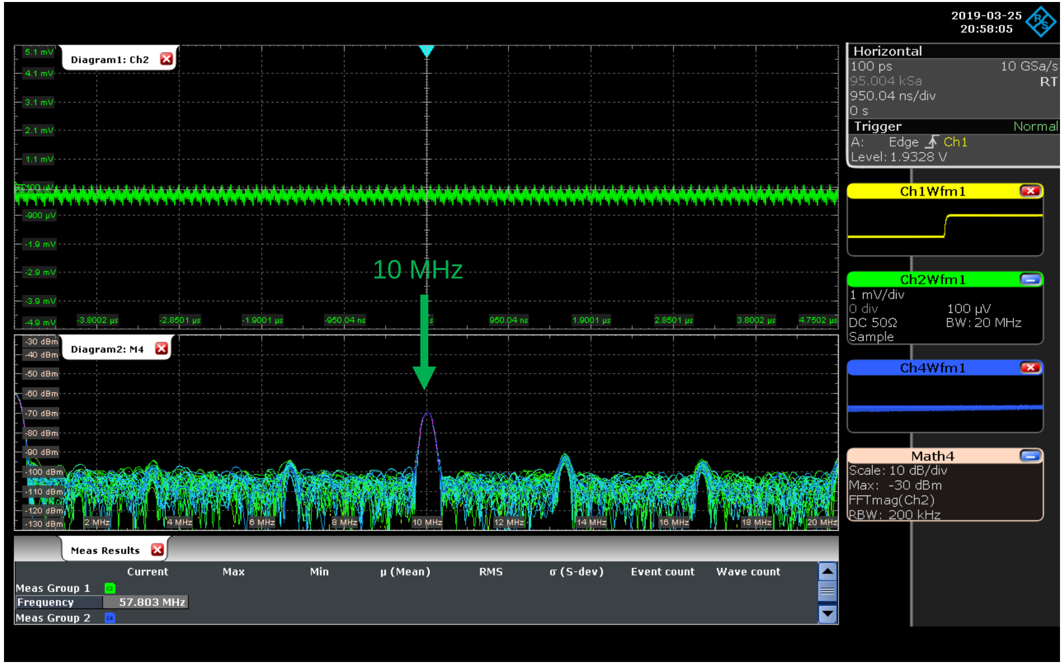




NEAR FIELD PROBE (HZ-15)

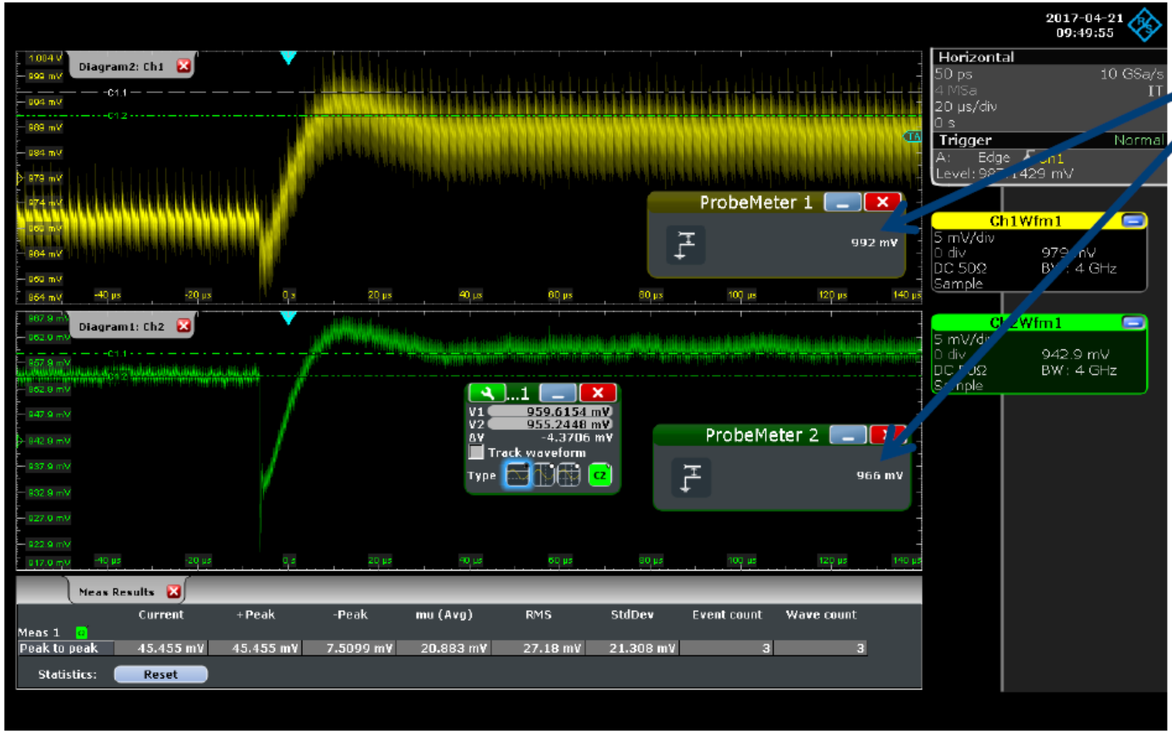
10 MHZ EMI…. COMING FROM 10 MHZ OSCILLATOR





EXAMPLES – FINDING COUPLED SIGNALS

EXAMPLE
30A TO 60A FPGA POWER SUPPLY LOAD STEP ANALYSIS



0.05% accurate measurement of DC voltage after load response
Difference shows voltage drop on board

DC voltage at output of DC-DC converter

DC voltage at FPGA

Statistics Window for Ripple measurement

Thank you