Keysight Measurement Forum 2016

Kim, Do-Ho

Key Solution to Power Integrity Measurements

KEYSIGHT TECHNOLOGIES

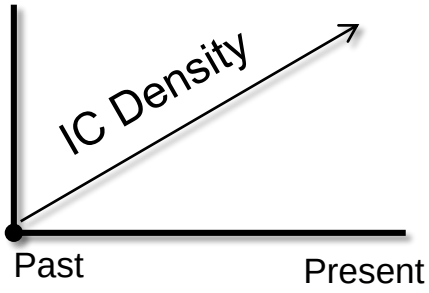
HARDWARE+SOFTWARE+PEOPLE=INSIGHTS

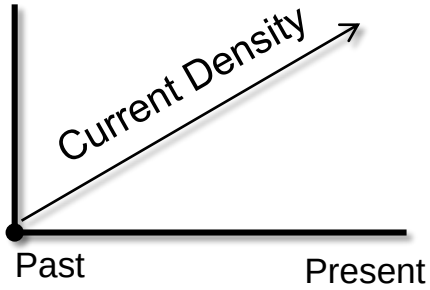
Agenda

- Needs for Power Integrity Measurements
- Utilizing Oscilloscope
  - Infiniium S-Series with N7020A
- DC Power Analyzer
  - N6705B
- Current Waveform Analyzer
  - CX3300

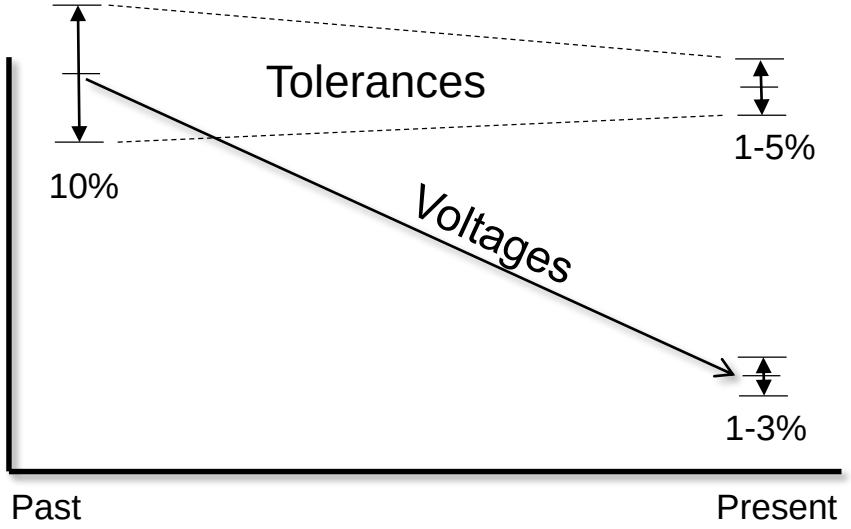
The Case For Power Integrity

Moore's Law: transistors on an integrated circuit will double every two years.





Goal: improve power consumption with each generation

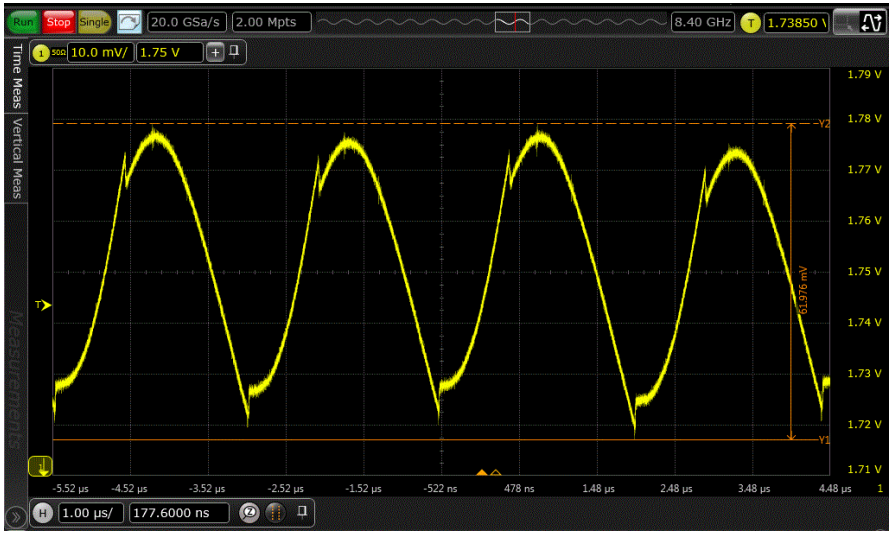


Power Integrity Measurements

The Need for Power Integrity Measurements

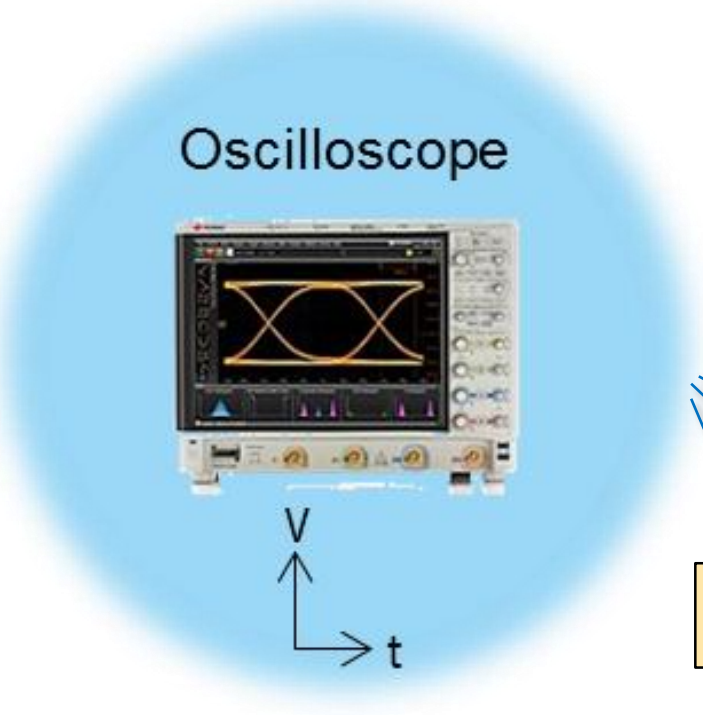
- Increased functionality, higher power density and higher frequency operation drives need for lower supply voltages
- Power rail tolerances are much tighter (from +/- 5% down to +/- 1%)
- Ripple, noise and transients riding on these lower DC supplies can adversely affect clocks and digital data—Power Supply Induced Jitter (PSIJ)

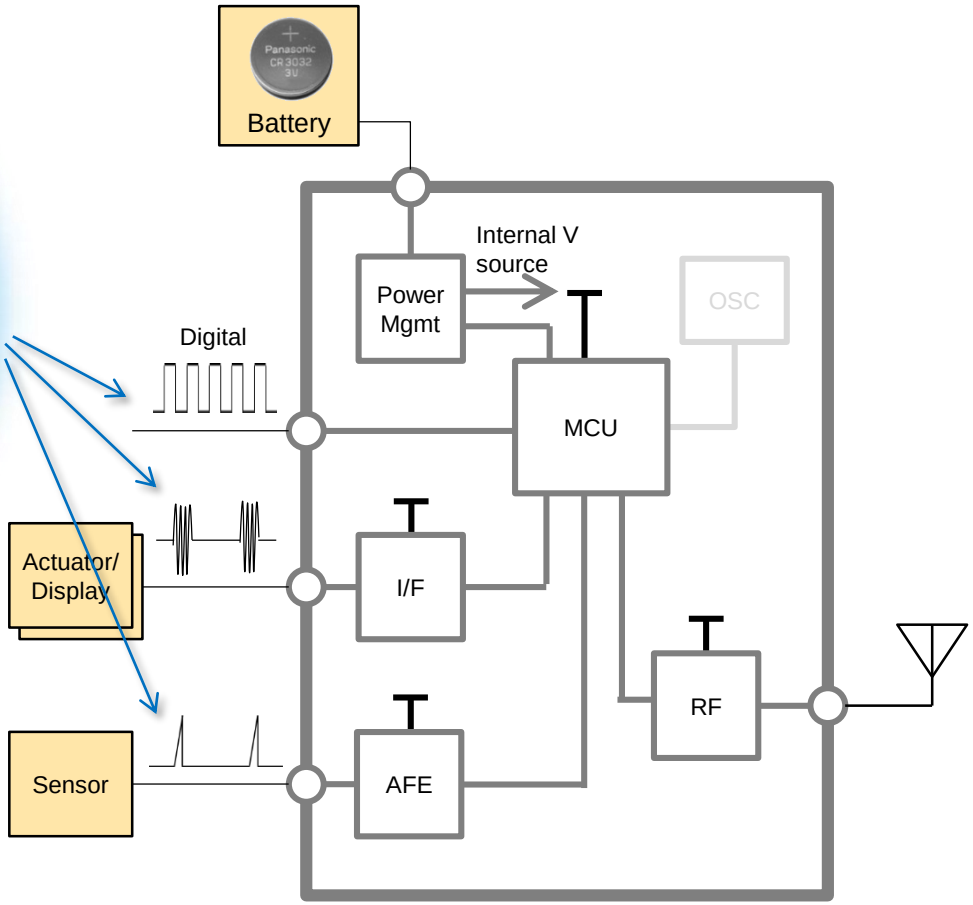
Believe it or not, this is what a typical1.8V DC supply looks like if you zoom-in on the top of it.



Power Integrity Measurements

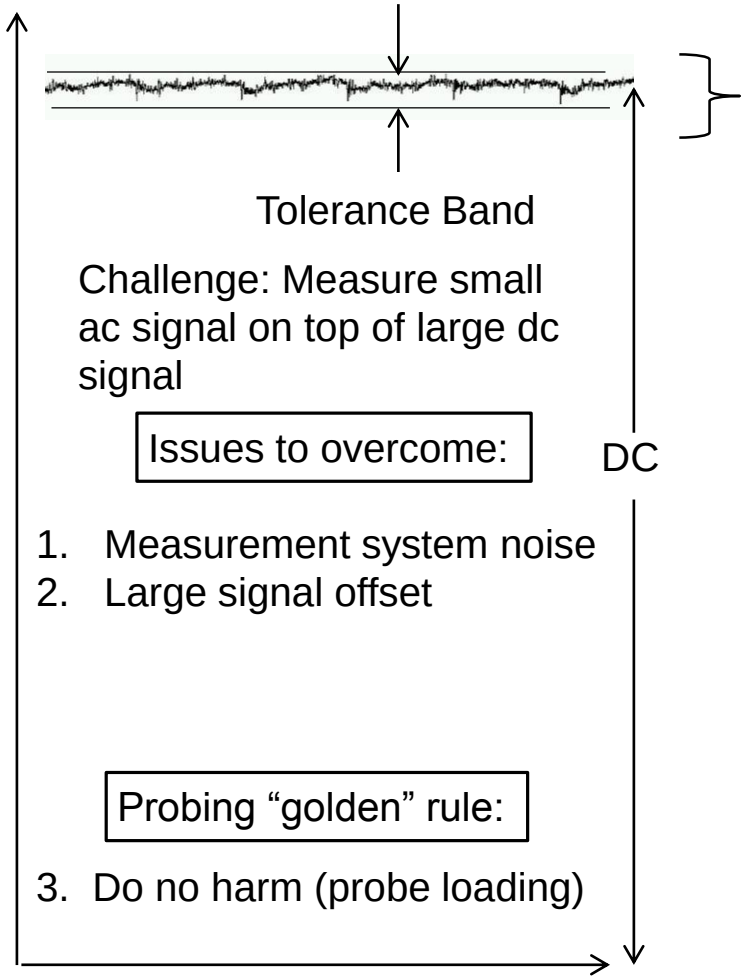
Utilizing Oscilloscope

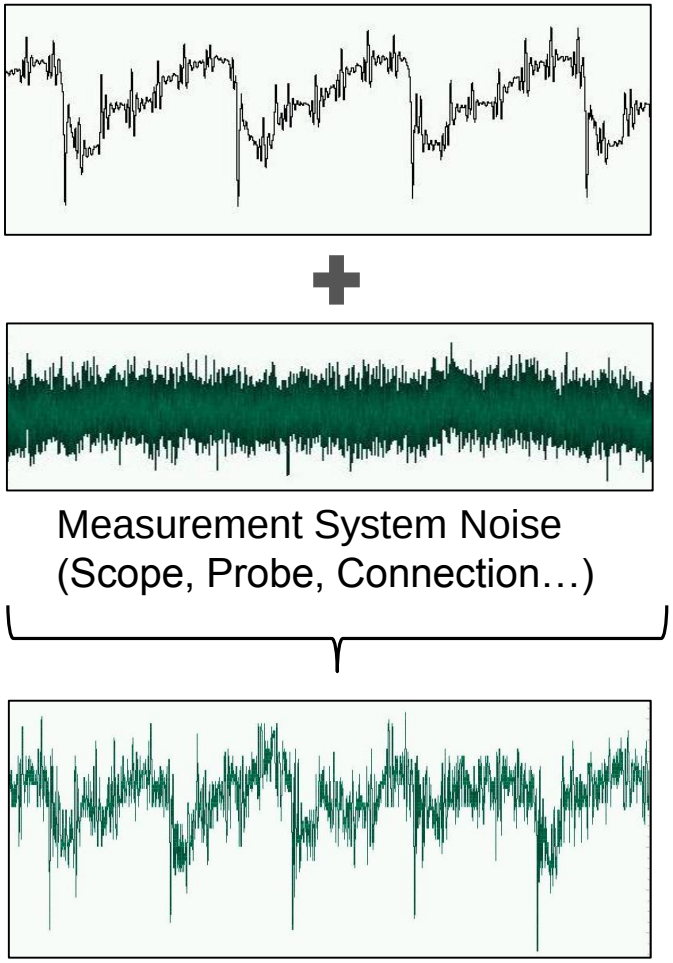




Power Integrity Measurements

Fundamental Challenge

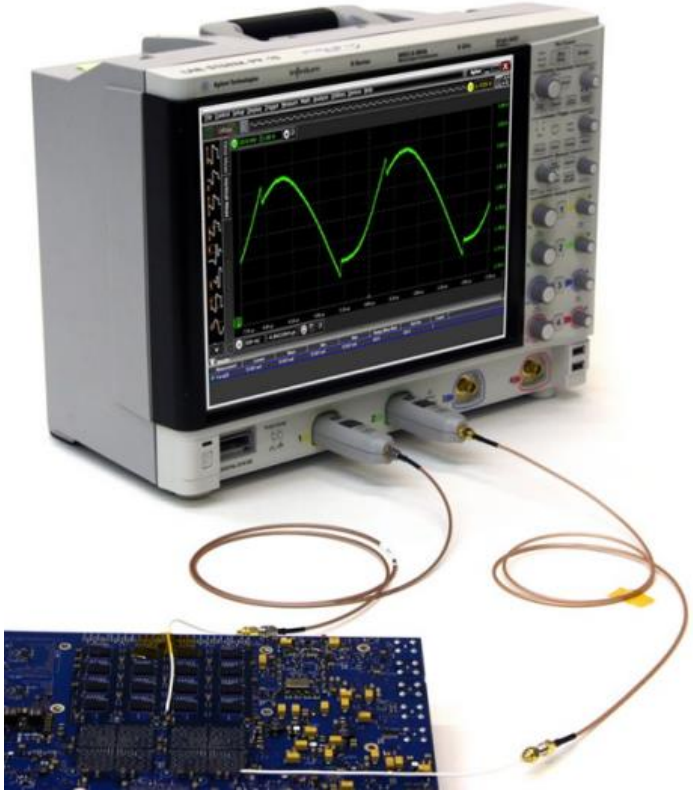




Power Integrity Measurements

Infiniium S-Series High-Definition Oscilloscope

- Low noise front end at small vertical settings
- Full 10-bit ADC support with full BW down to 16 mV full screen
- Analog and DSP-based bandwidth limit filters
- Measurement capability including FFTs, axis annotation, dynamic delta markers



Keysight N7020A Power Rail Probe:
www.keysight.com/find/N7020A

Power Integrity Measurements

Both Ends of The Spectrum

Specialized

General Purpose

N7020A Power Rail Probe

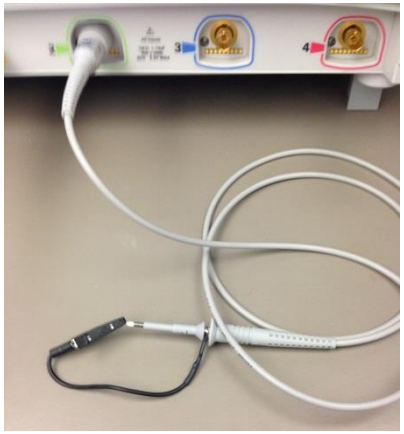
10:1 Passive Probe

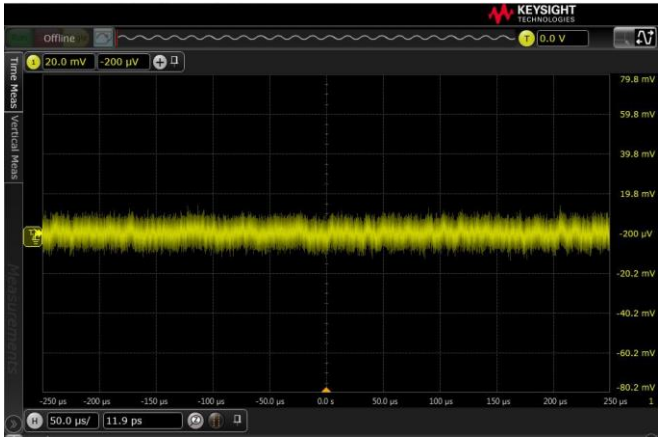
Power Integrity Measurements

First things first—Null Measurement (Sanity Check)

– Null measurement: Baseline noise of the oscilloscope measurement system to verify that the tools being used are appropriate for the task at hand.

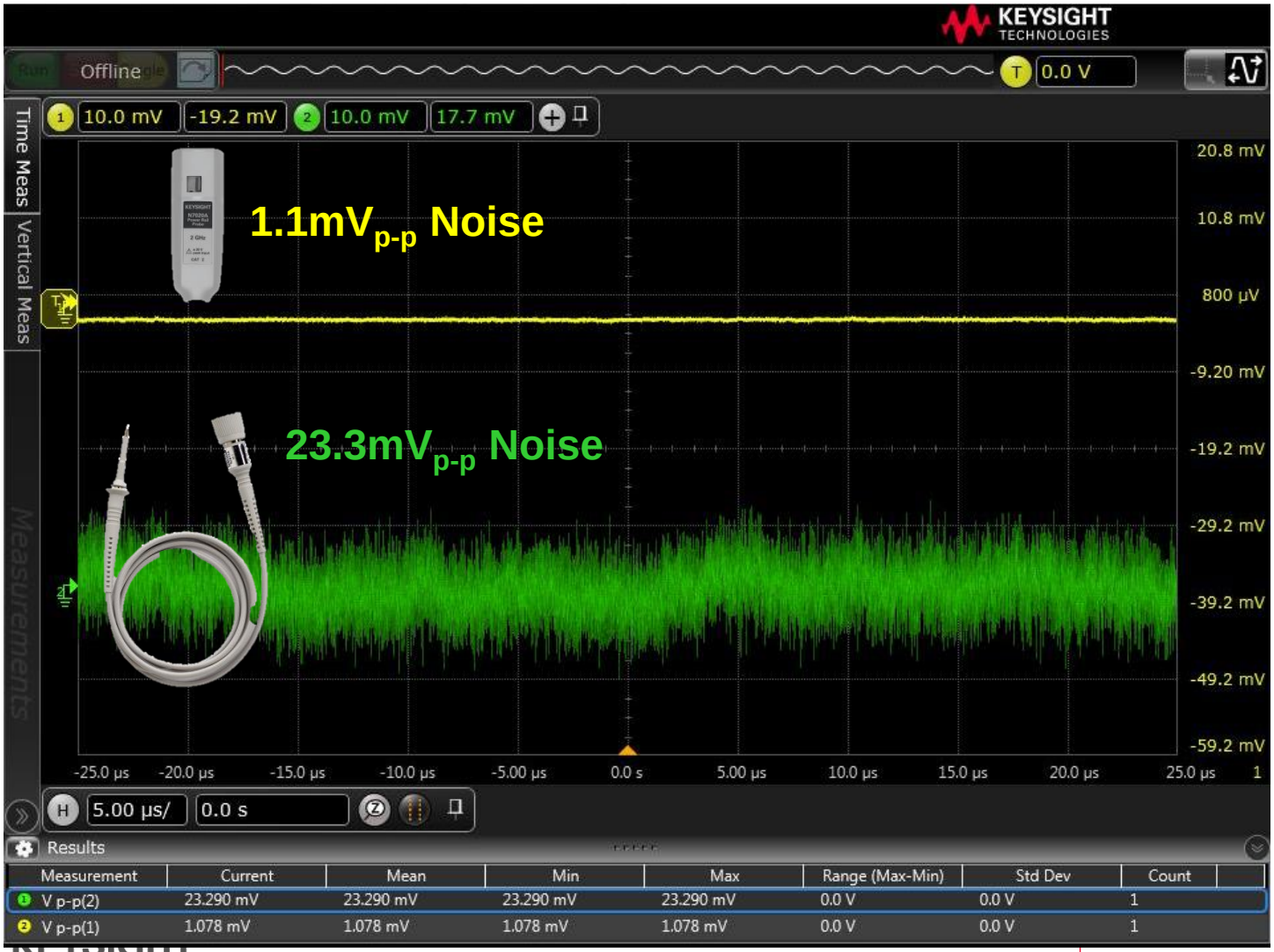
  - Set-up you scope and probe as they will be used—V/div, connection accessories…
  - Short the input and measure the baseline noise.





Power Integrity Measurements

Null Measurement Compare—Ends of The Spectrum



Power Integrity Measurements

Both Ends of The Spectrum

Specialized ⟷ General Purpose

N7020A Power Rail Probe
Termination: 50Ω
Attenuation: 1:1
Bandwidth: 2GHz
Probe offset: Yes(+/-24V)

Passive Probe
Termination: 1MΩ
Attenuation: 10:1
Bandwidth: 500MHz
Probe offset: No

Good for quantitative measurements

Good for qualitative measurements

KEYSIGHT TECHNOLOGIES

Power Integrity Measurements

Both Ends of The Spectrum

Specialized ⟷ General Purpose

N7020A Power Rail Probe
Termination: 50Ω
Attenuation: 1:1
Bandwidth: 2GHz
Probe offset: Yes(+/-24V)

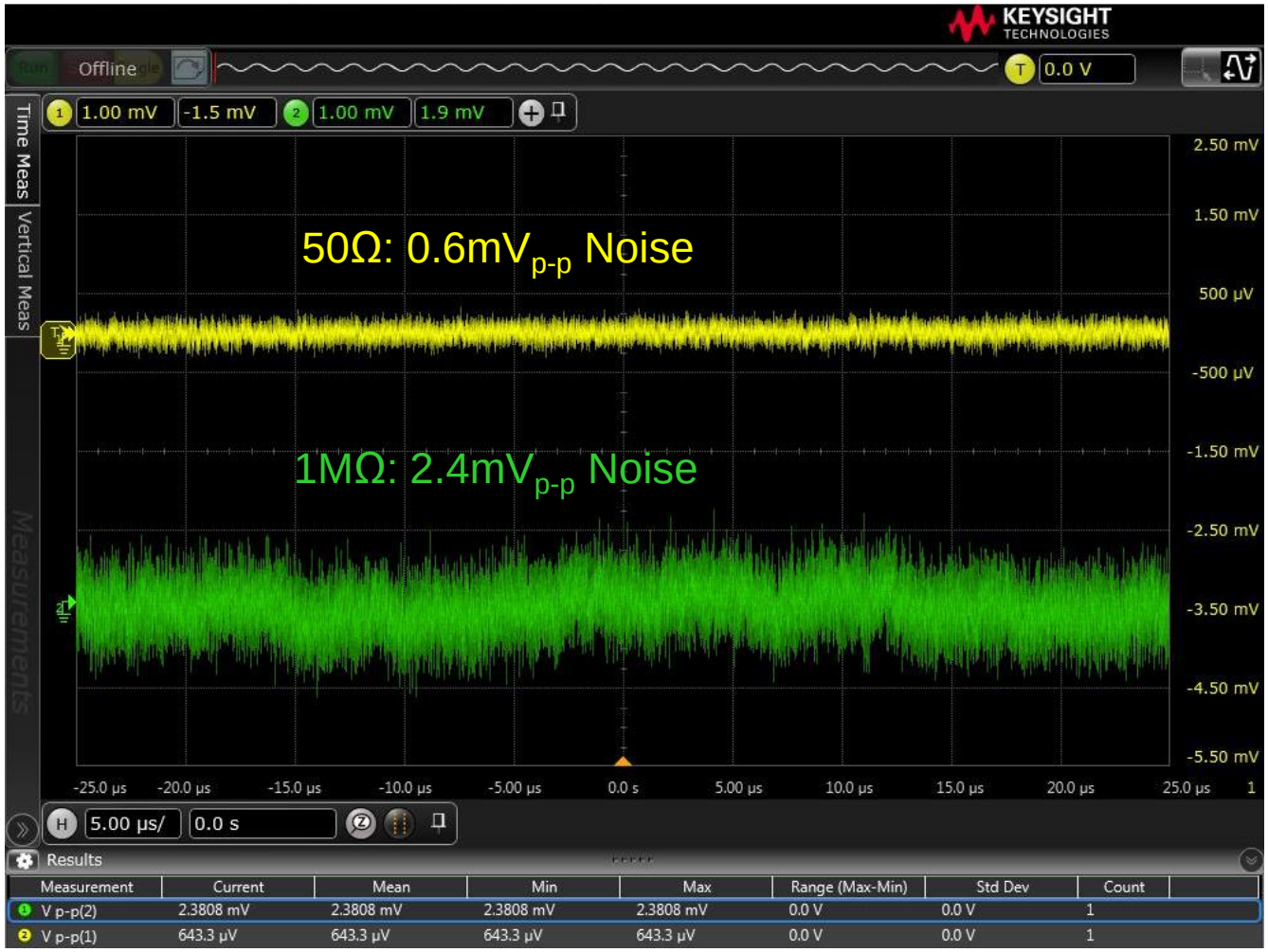
Passive Probe
Termination: 1MΩ
Attenuation: 10:1
Bandwidth: 500MHz
Probe offset: No

Good for quantitative measurements

Good for qualitative measurements

Power Integrity Measurements

Scope Input Termination—Lowest Noise Path



Power Integrity Measurements

Both Ends of The Spectrum

Specialized ⟷ General Purpose

N7020A Power Rail Probe
Termination: 50Ω
Attenuation: 1:1
Bandwidth: 2GHz
Probe offset: Yes(+/-24V)

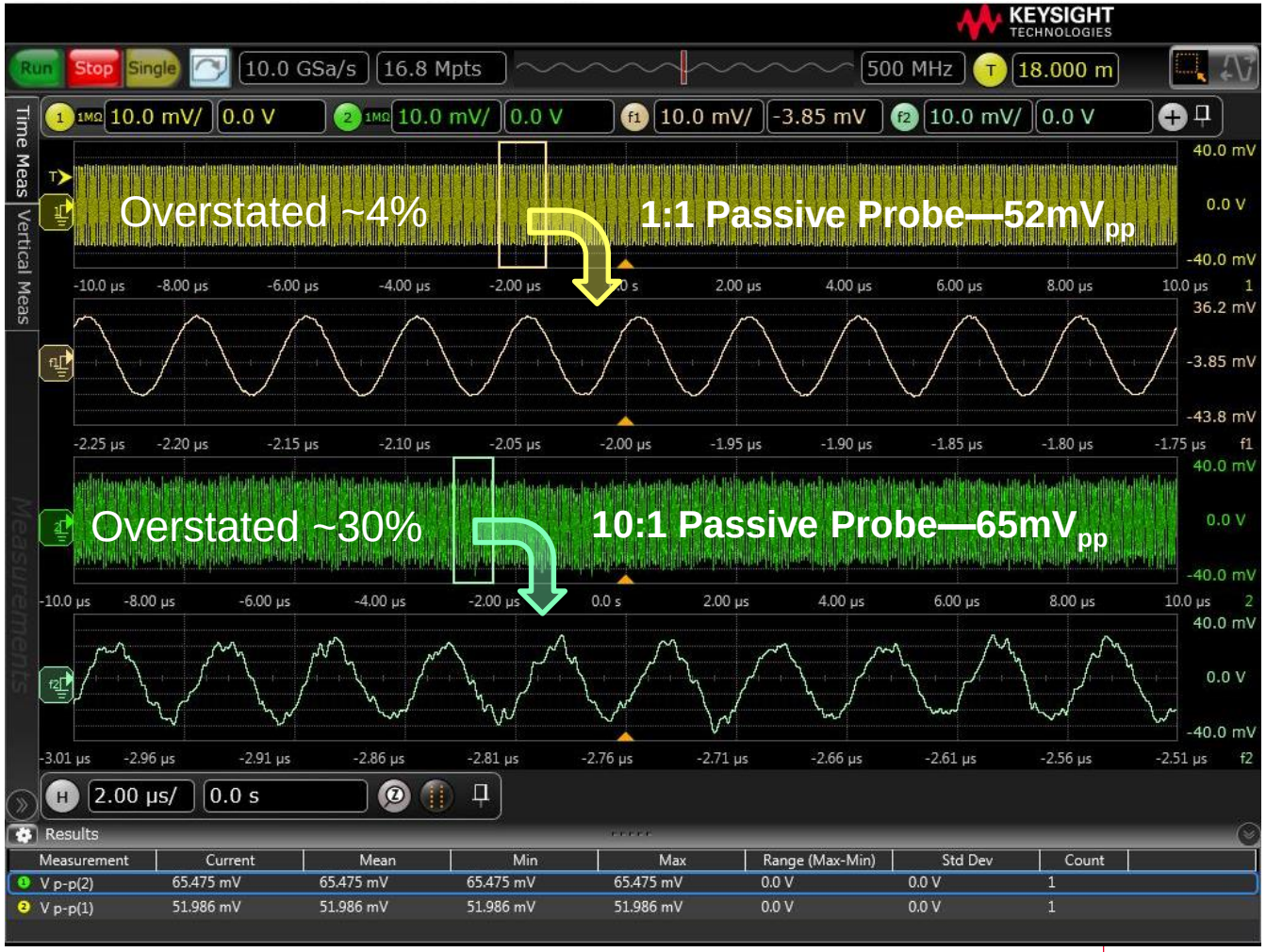
Passive Probe
Termination: 1MΩ
Attenuation: 10:1
Bandwidth: 500MHz
Probe offset: No

Good for quantitative measurements

Good for qualitative measurements

Power Integrity Measurements

Attenuation Ratio Effects Noise—Ex. 50mV$_{pp}$ Sine Wave



Power Integrity Measurements

Both Ends of The Spectrum

Specialized ⟷ General Purpose

N7020A Power Rail Probe
Termination: 50Ω
Attenuation: 1:1
Bandwidth: 2GHz
Probe offset: Yes(+/-24V)

Passive Probe
Termination: 1MΩ
Attenuation: 10:1
Bandwidth: 500MHz
Probe offset: No

Good for quantitative measurements

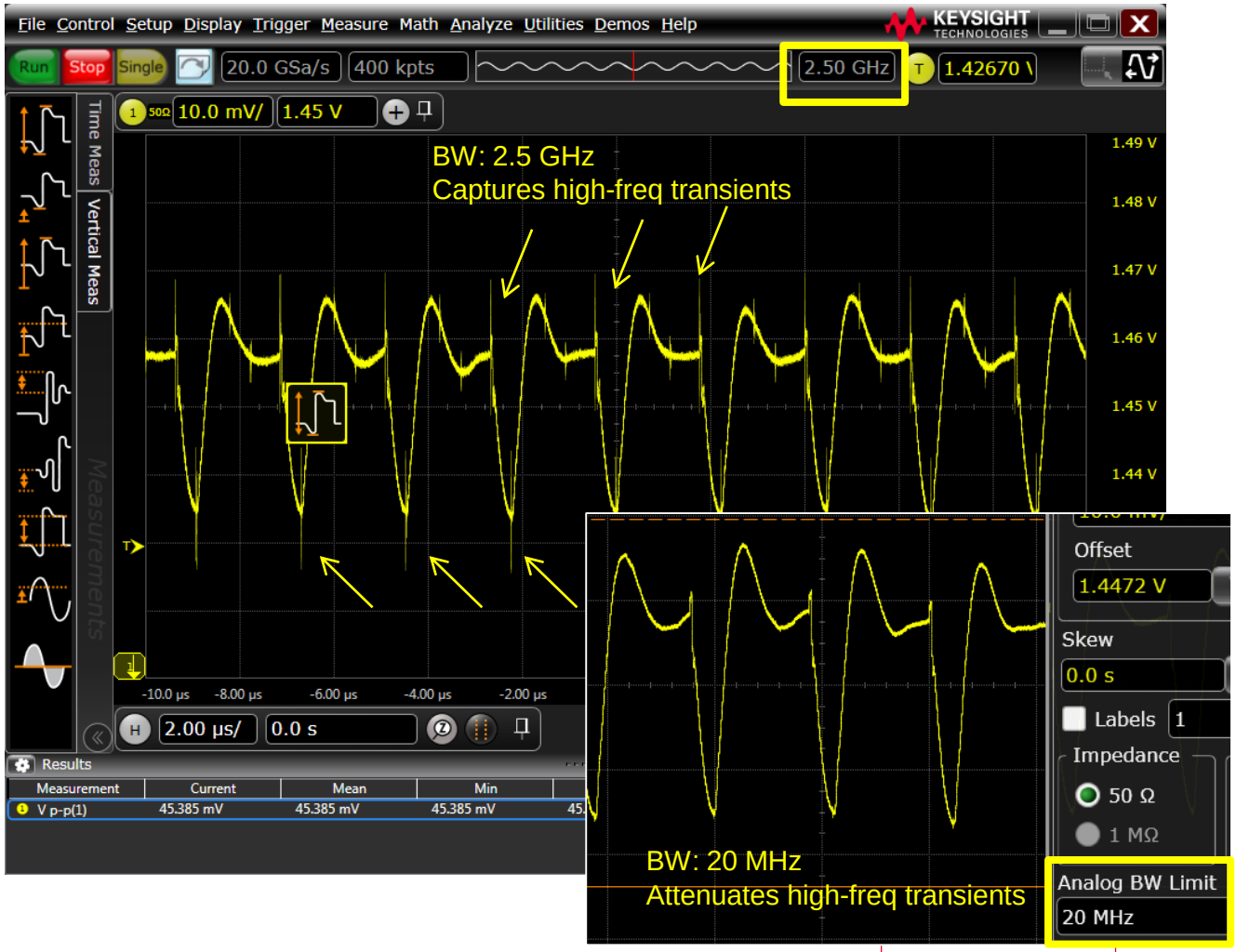
Good for qualitative measurements

Power Integrity Measurements

Tradeoff with BW limiting—Use What is Needed

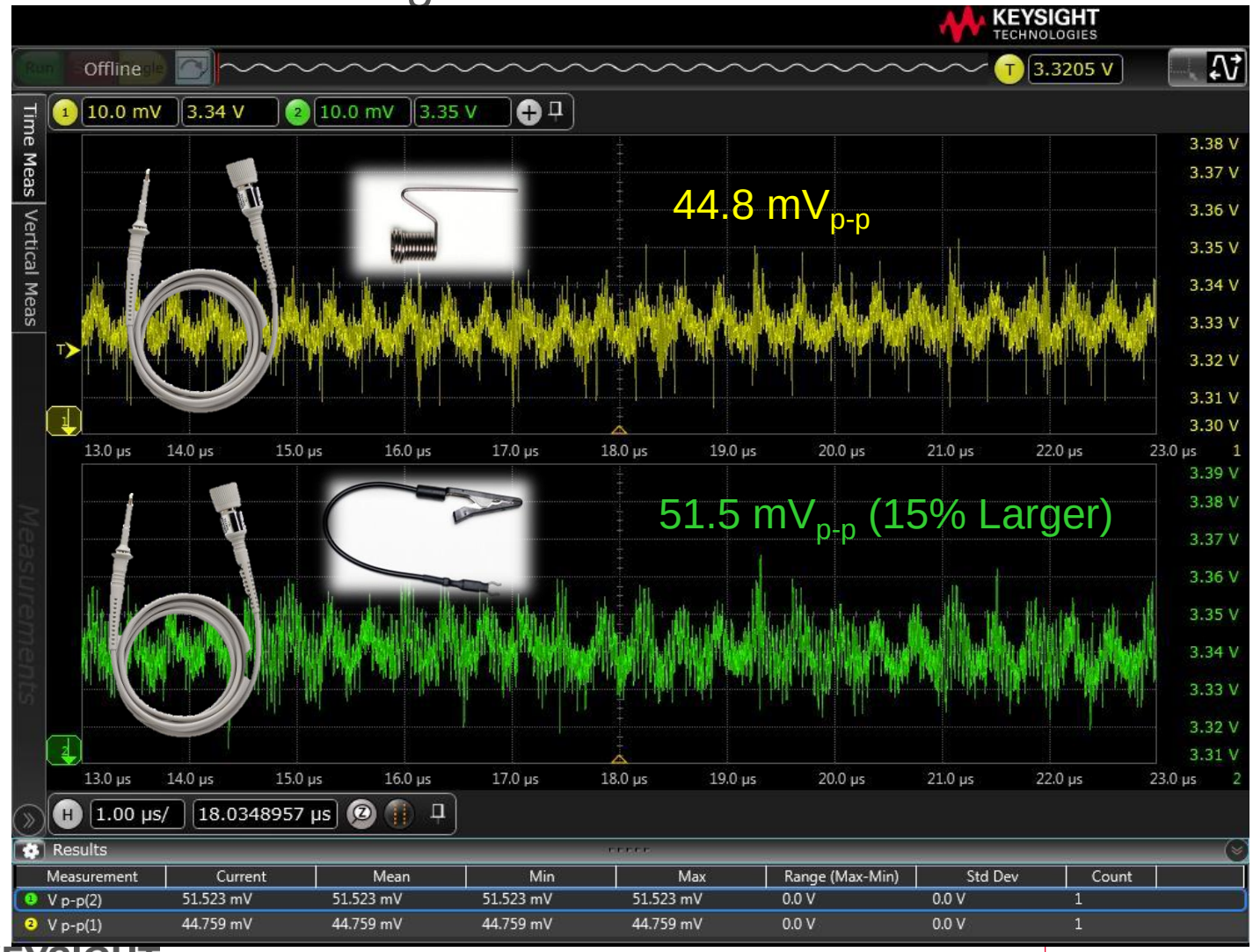
Switching currents cause transients that can easily exceed 1GHz.

Supply noise is a leading cause of clock/data jitter.



Power Integrity Measurements

Gnd Connection Length Effects Noise: Ex. Passive Probe



Power Integrity Measurements

Both Ends of The Spectrum

Specialized ⟷ General Purpose

N7020A Power Rail Probe
Termination: 50Ω
Attenuation: 1:1
Bandwidth: 2GHz
Probe offset: Yes(+/-24V)

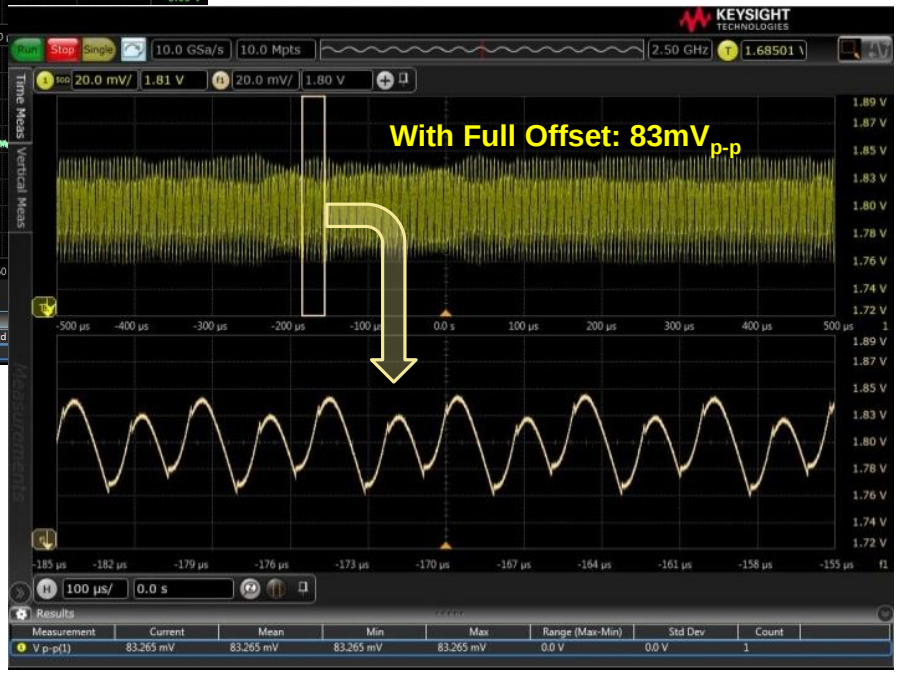
Passive Probe
Termination: 1MΩ
Attenuation: 10:1
Bandwidth: 500MHz
Probe offset: No

Good for quantitative measurements

Good for qualitative measurements

Power Integrity Measurements

Large DC Signal Offset



At larger V/div

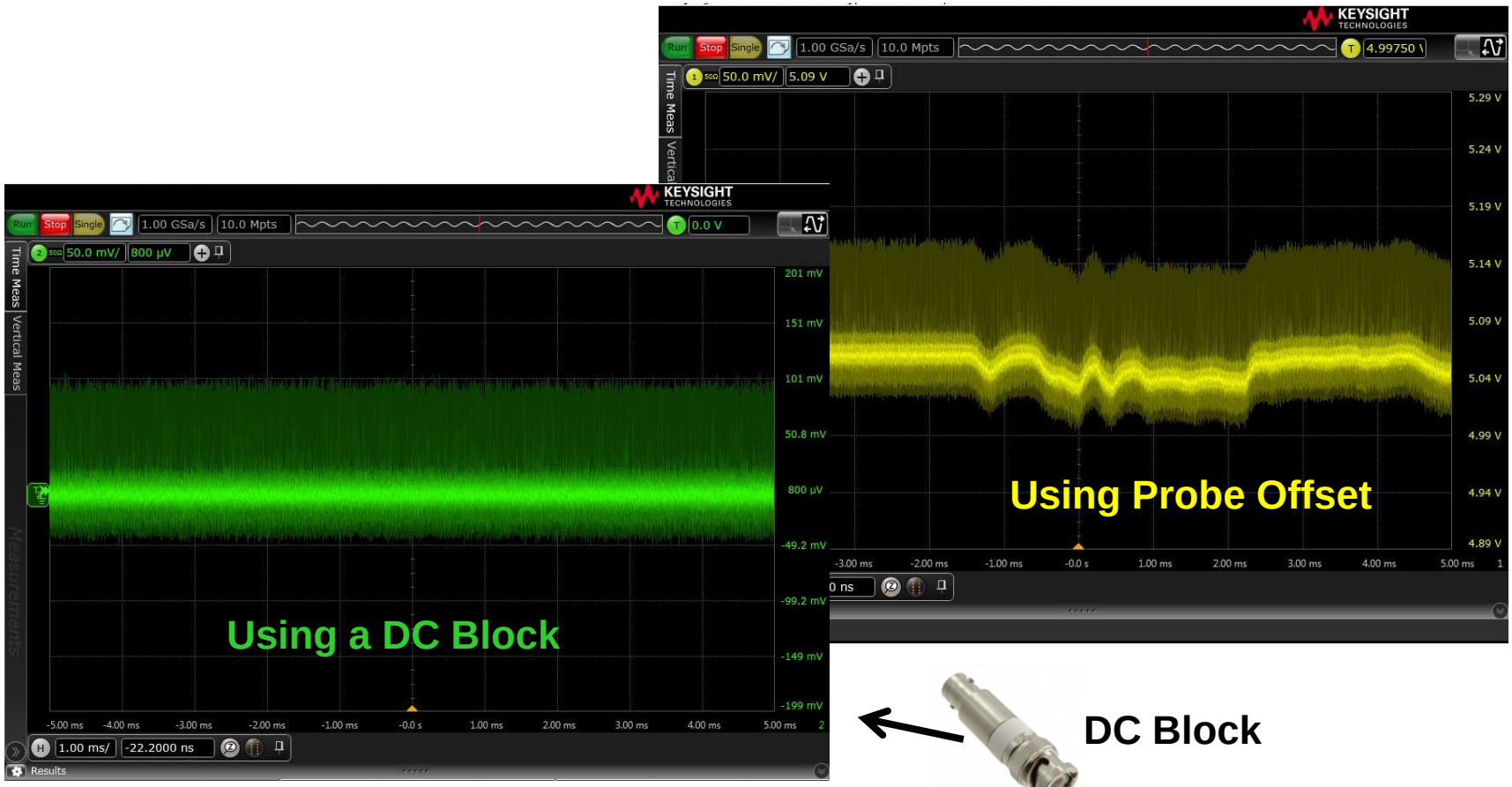
- Sensitivity is decreased
- Scope noise relative to small ac signal is increased.

Remove DC Signal Offset

- Probe Offset
- DC Block

Power Integrity Measurements

Removing Large DC Signal—Probe Offset or DC Block



Power Integrity Measurements

Summary

Specialized

General Purpose

1. Begin with a Null measurement.
2. Choose the low noise path.
3. Reduce attenuation ratio.
4. BW—use what is needed.
5. Minimize ground loop area.
6. Use probe offset.
7. Minimize loading.

Bonus Tip: Use a specialized tool

Good for <u>quantitative</u> measurements

Good for <u>qualitative</u> measurements

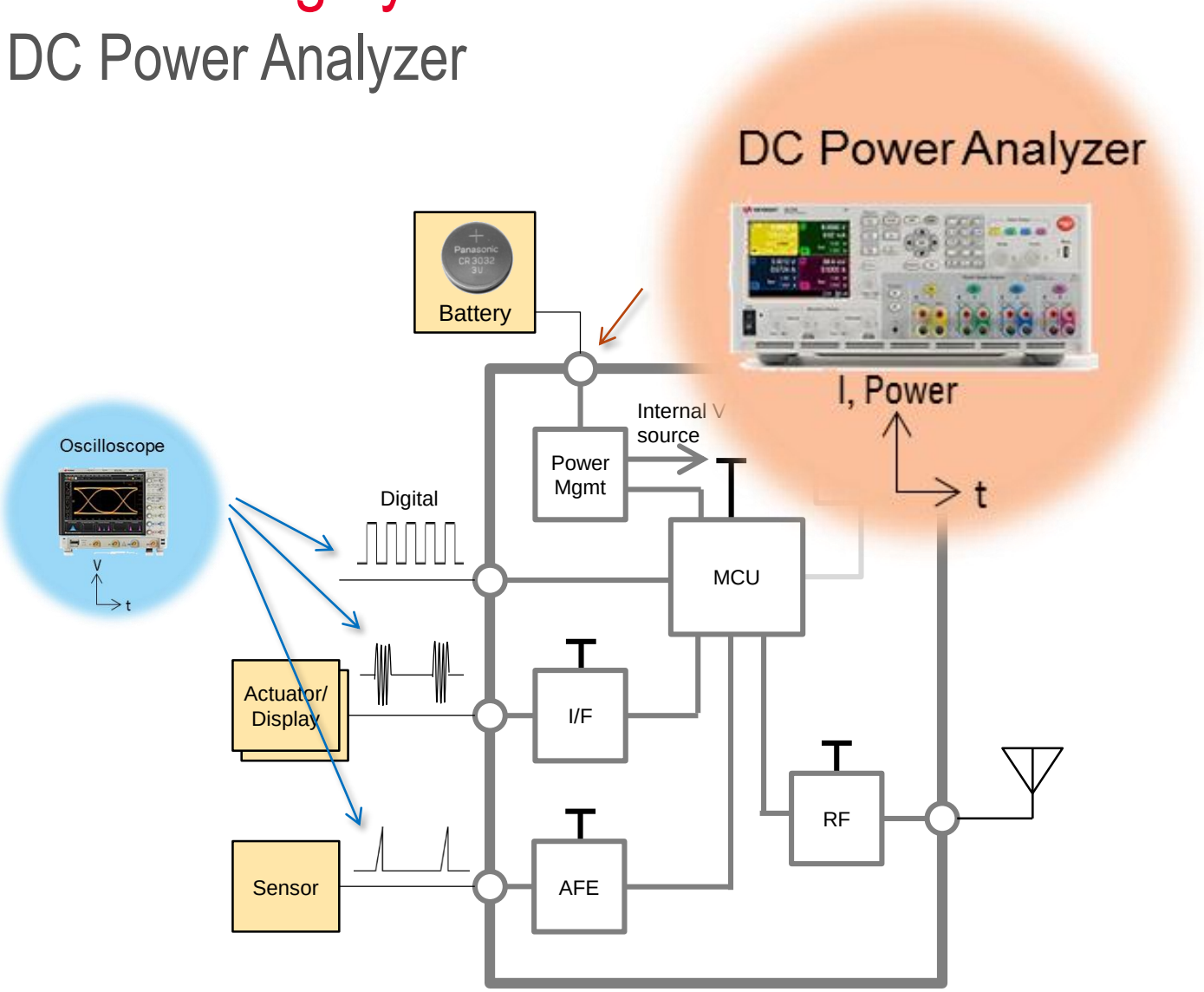
KEYSIGHT TECHNOLOGIES

N7020A Specifications

Specification	Pigtail / Browser
Probe Bandwidth	2 GHz / 350MHz
Attenuation ratio	1:1
Risetime(10% to 90%)	175ps / 1ns
Offset range	+-24V
Input impedance @ DC	50kΩ
Probe type	Single-ended

Power Integrity Measurements

DC Power Analyzer



N6705B DC Power Analyzer
Award Winning Solution

The N6705 boosts the productivity of the R&D Engineer

Multiple instrument functionality in a single box

- 1 to 4 advanced power supplies
- Digital voltmeter and ammeter
- Arbitrary waveform generator
- Oscilloscope
- Datalogger

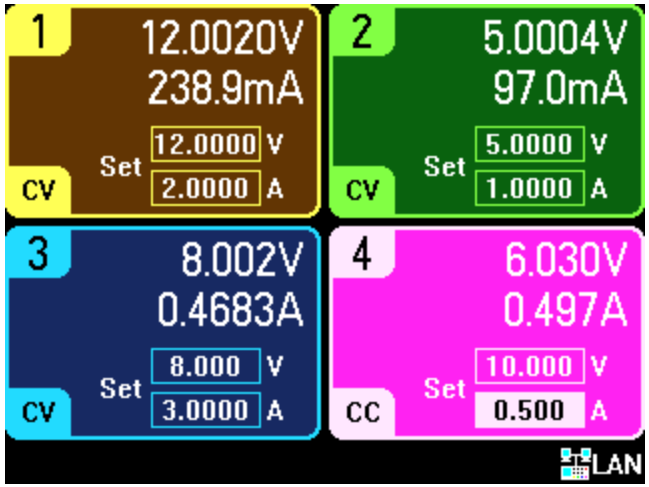
- All functions and measurements available from the front panel
- Utilizes the same modules in the N6700 family
- 600W total output power

Gain insights into a DUT's power consumption – in minutes, not hours – without writing a single line of code!

KEYSIGHT TECHNOLOGIES

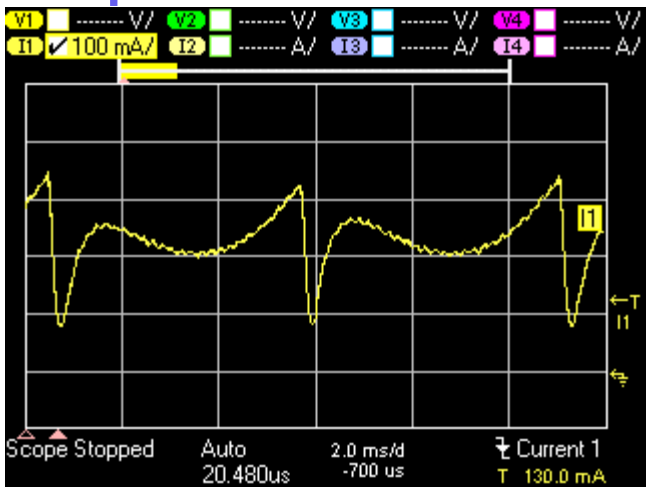
N6705B Front Panel Measure Screen

Meter View

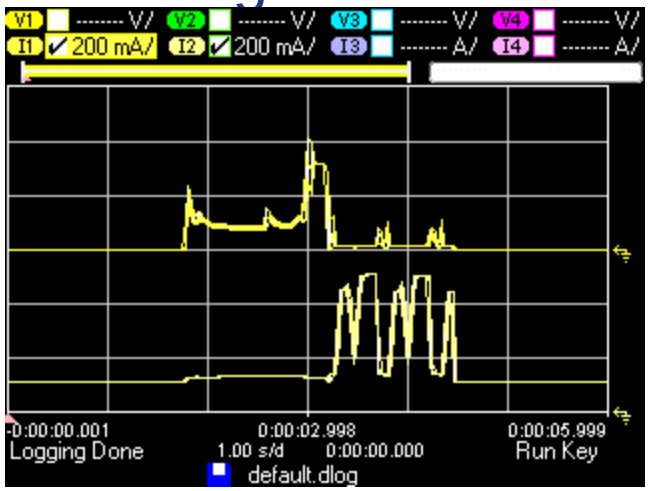


All Free from Programming

Scope View



Data Log View

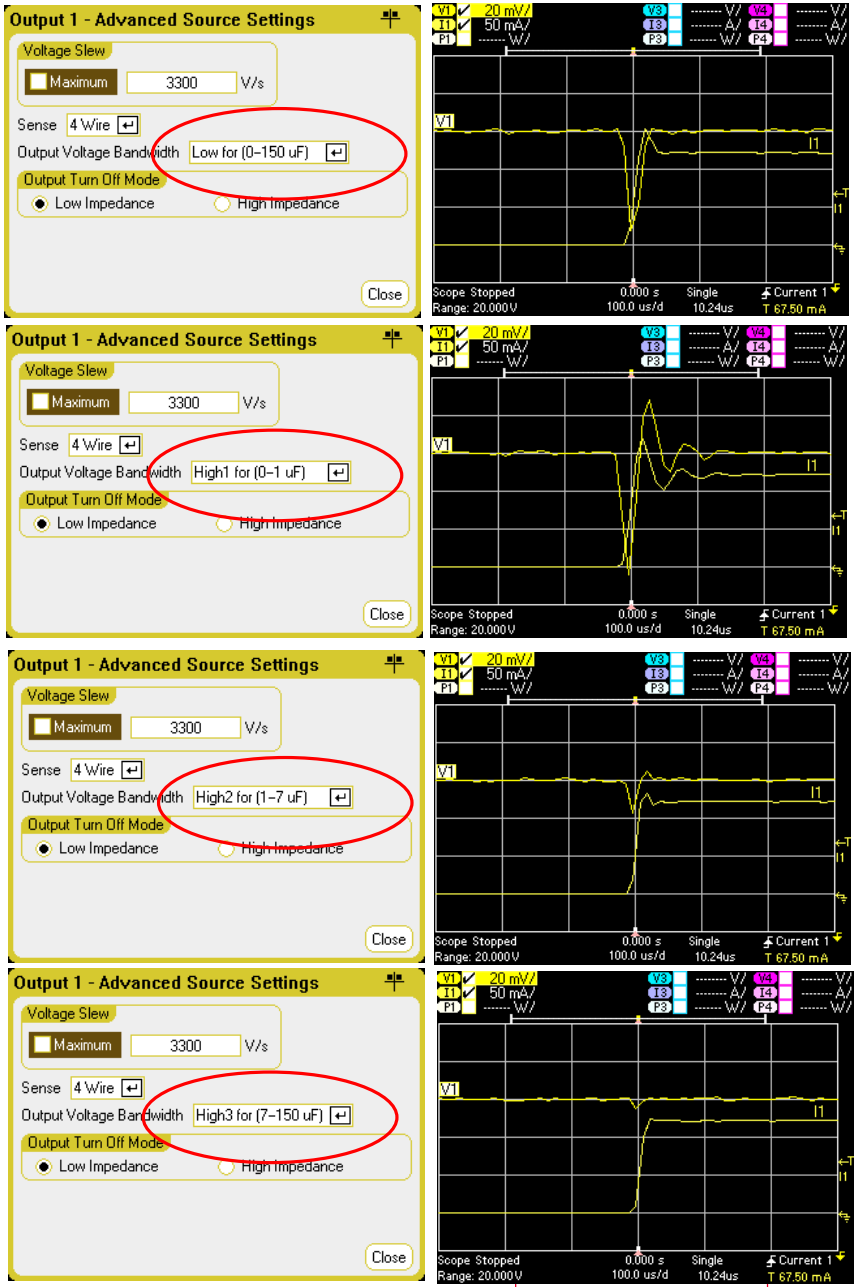


Output Bandwidth Control

APPLICATION: Optimize the output voltage response due to different capacitive loading conditions

This example was using the Pulse Load Demo Board that has 10 uF of DUT capacitance

For stable operation the maximum capacitance loading is 150 uF

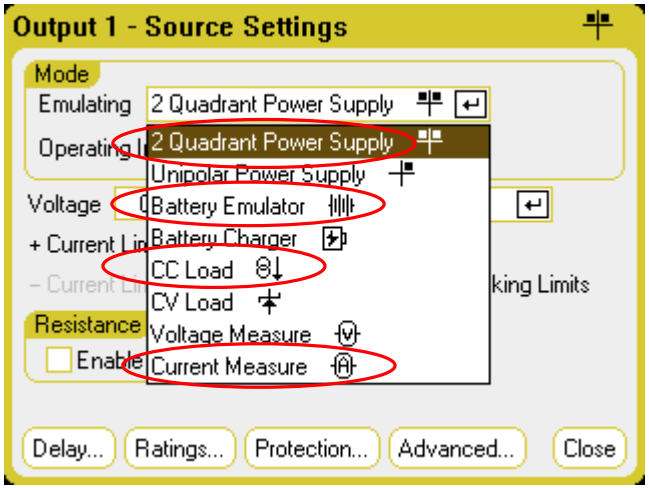


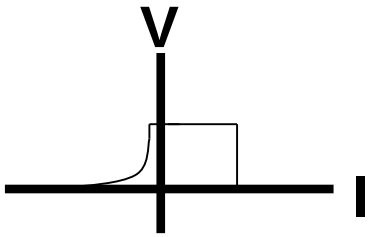
Emulation Modes

APPLICATION: To simplify using the new SMU modules select one of the emulating modes, keeps operation in quadrant and behavior that is best fit for the application

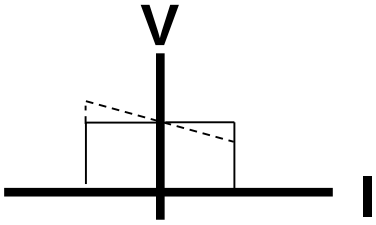
Most commonly used are:

- 2-Quadrant
- Battery Emulator
- CC Load
- Current Measure

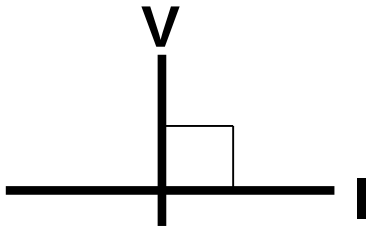




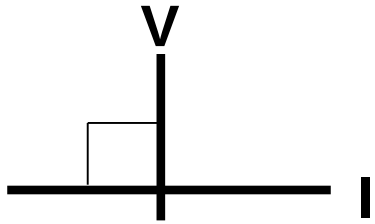
Standard DC Supply



Battery Emulator with programmable Rout



Battery Charger



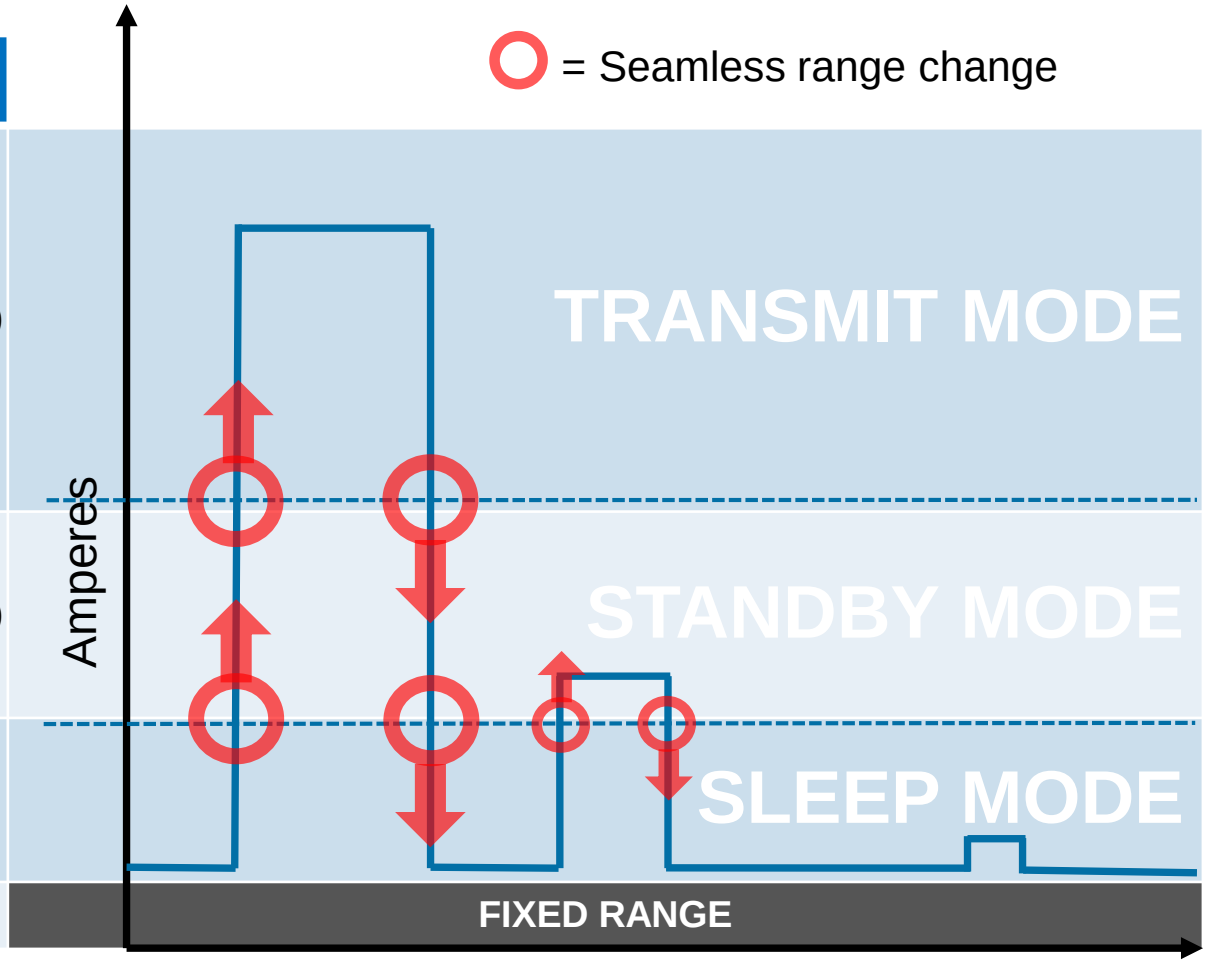
CC or CV Load (Electronic Load)

Seamless Current Measurement

Range	Measurement Accuracy
3 A	±(0.03% + 250 µA)
100 mA	±(0.025% + 10 µA)
1 mA	±(0.025% + 100 nA)
10 µA	±(0.025% + 8 nA)

Seamless Range Changes

Think: Vertical Mega-Zoom



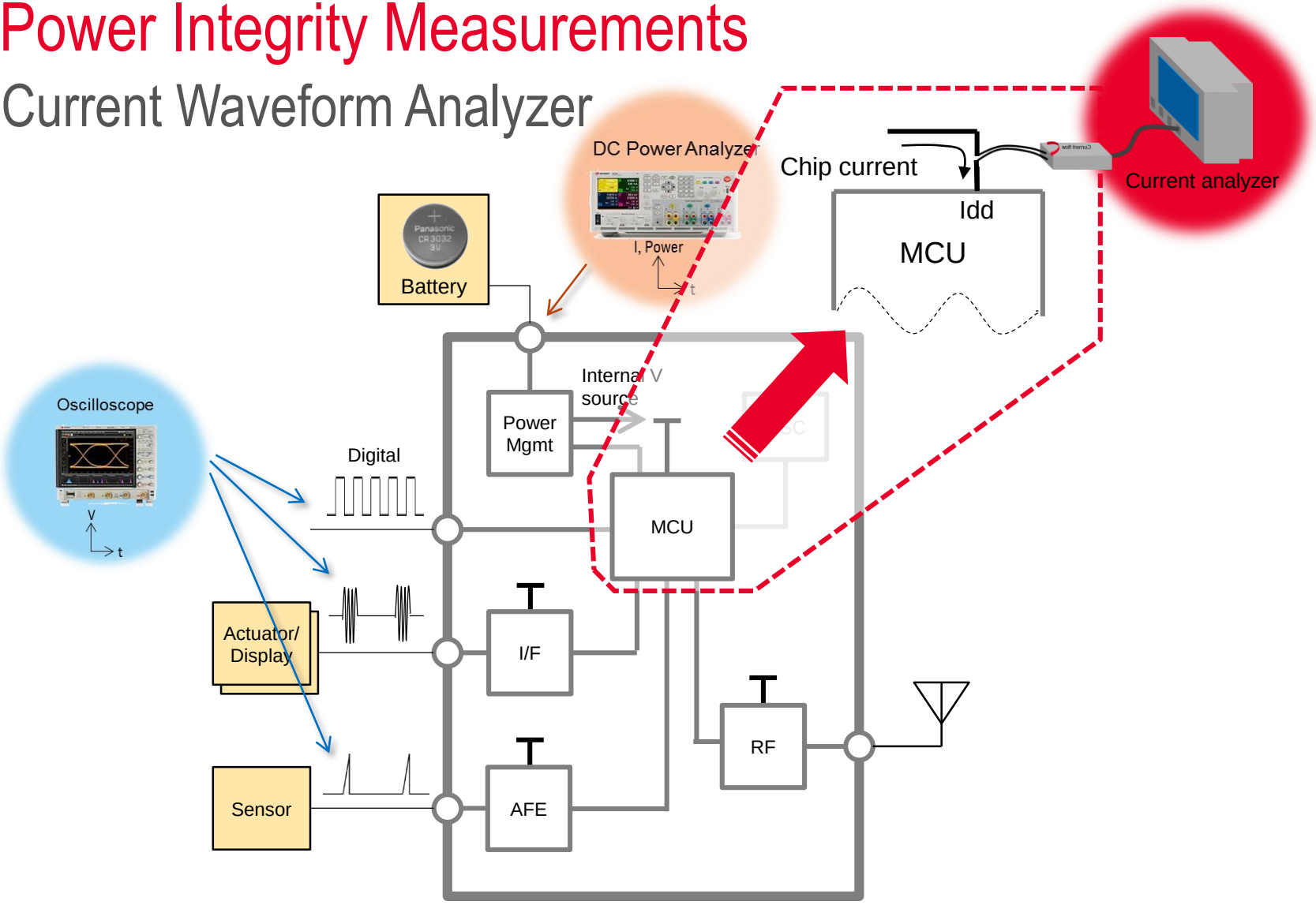
See the complete current waveform you've never seen before
– from nA to A –
in one pass and one picture

N6705B Mainframe Specifications

Specification	
Max Slot No. for modules	4
Max power of total modules	600W
AWG function	BW 100kHz / 500W
Scope function	BW 200kHz, ADC 18bits
Module type	Basic : N6730/40/70 High-performance : N6750 Precision : N6760 SMU : N6780

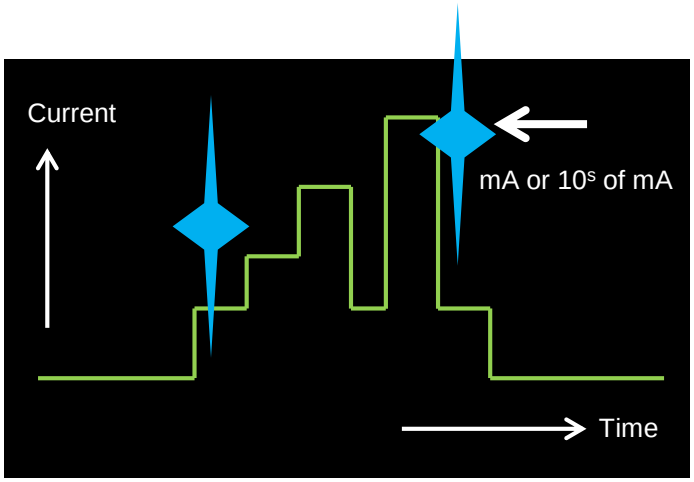
Power Integrity Measurements

Current Waveform Analyzer

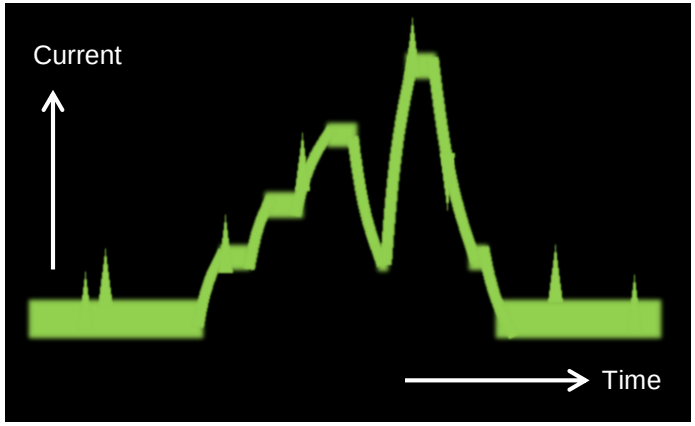


Challenges to measure low-level current waveforms?

Measure the low current waveform are always noisy and slow



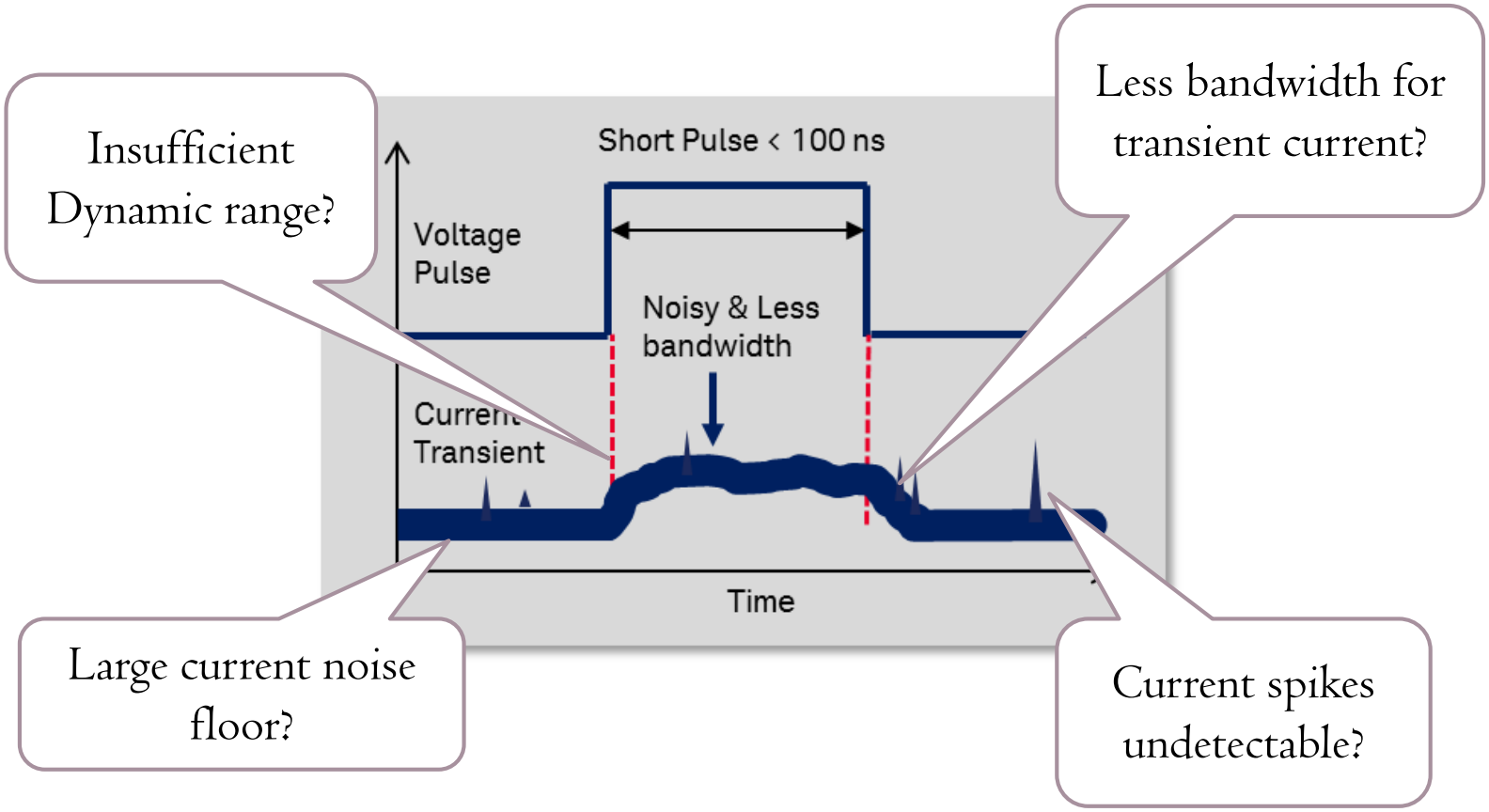
Expected waveforms



Always like this !

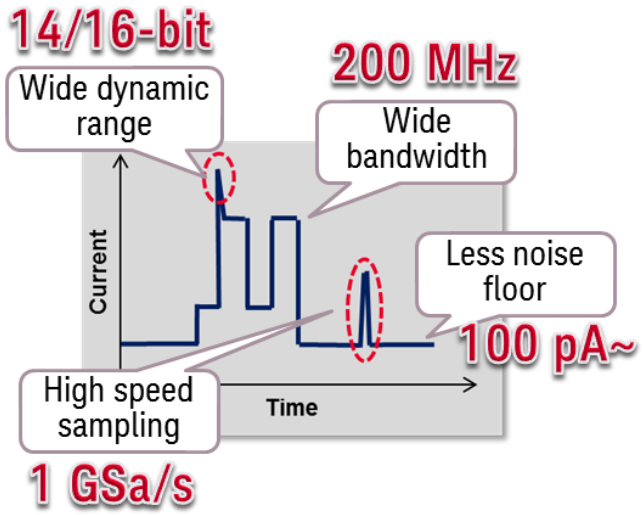
As a result, it is quite difficult to analyze the current profile in detail.

No Perfect Solutions to Capture Complete Low-level Current Waveform

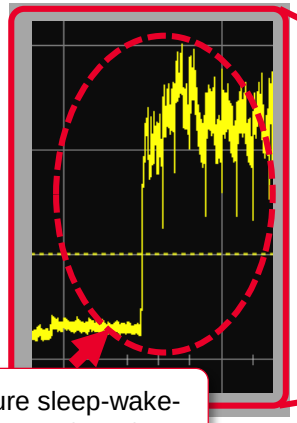


Keysight is now developing a new analyzer enabling clear and precise current waveform measurements

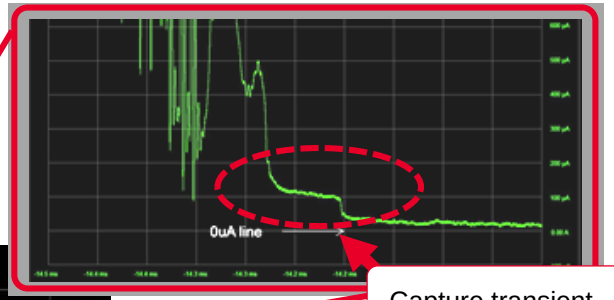
The new analyzer provides enough capabilities to clearly and easily visualize the low-level current waveforms as you expected !



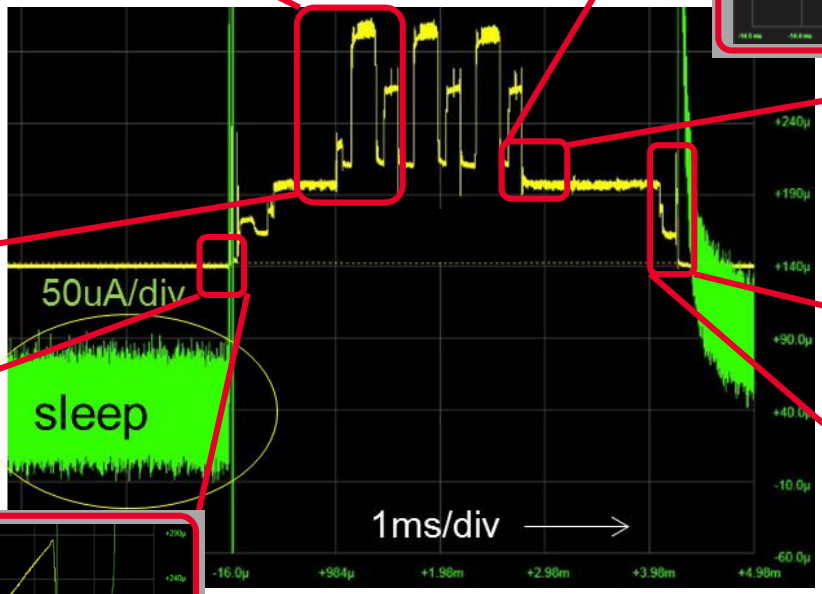
New analyzer let you see the current waveform that you've never seen before!!

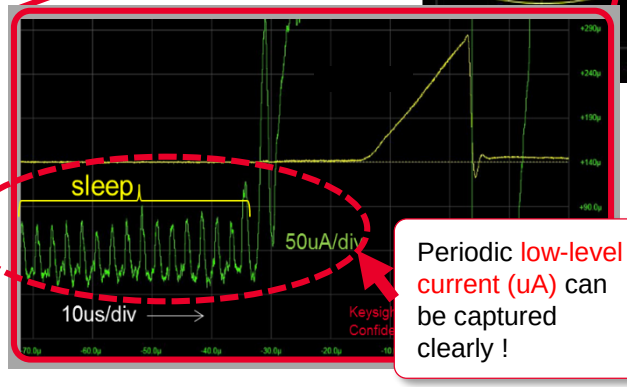


Capture sleep-wake-sleep waveform for power consumption optimization

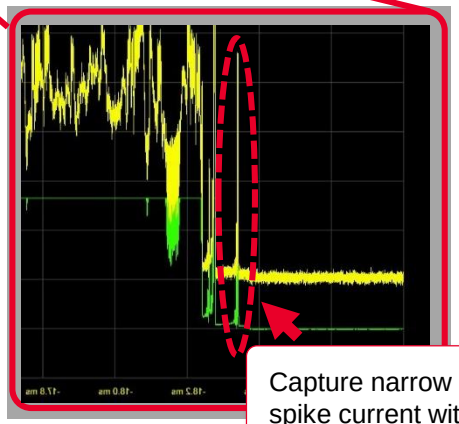


Capture transient current with high speed sampling





Periodic low-level current (uA) can be captured clearly !

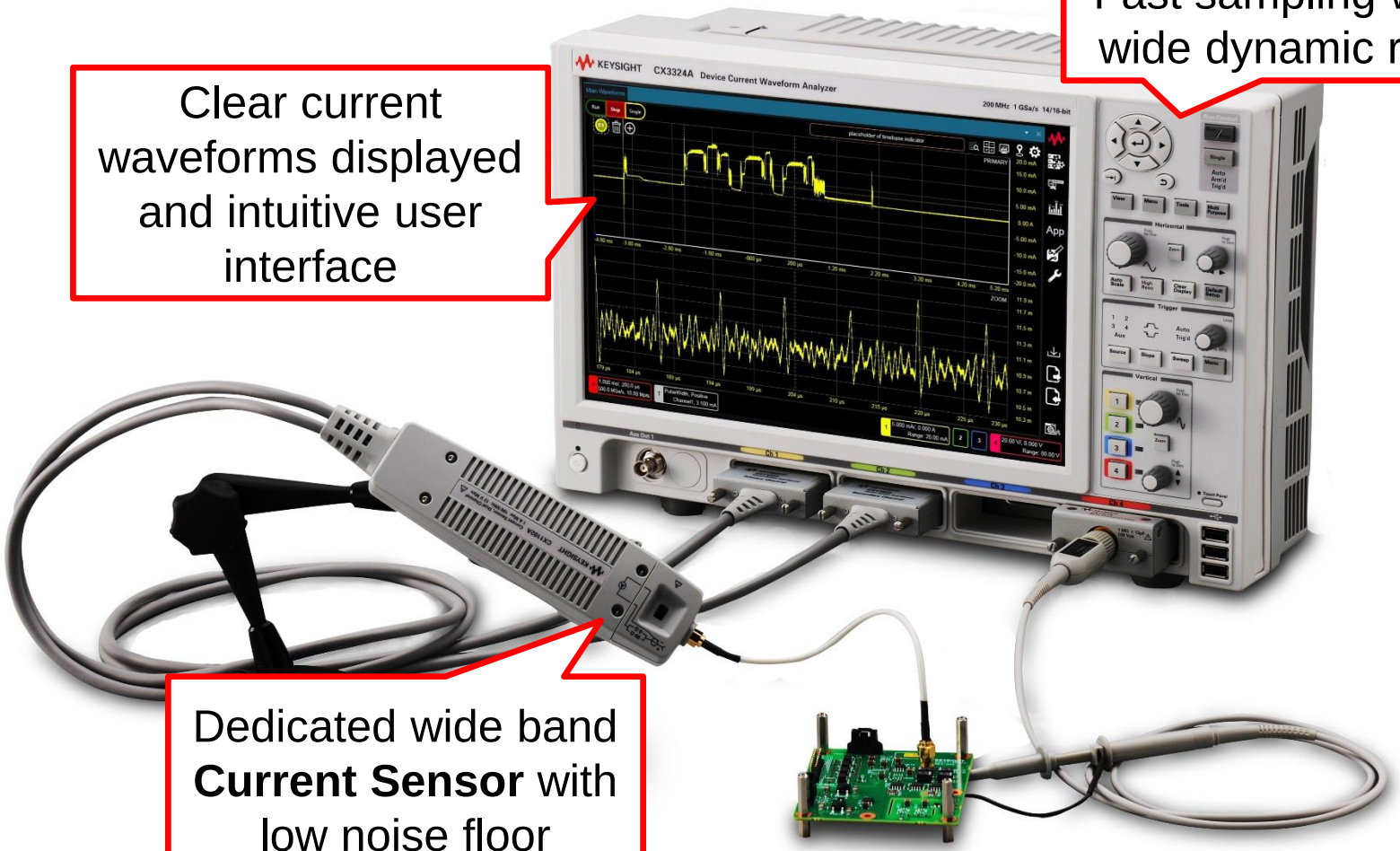


Capture narrow spike current with sufficient bandwidth

New Analyzer for Current Waveform Measurement

Fast sampling with a wide dynamic range

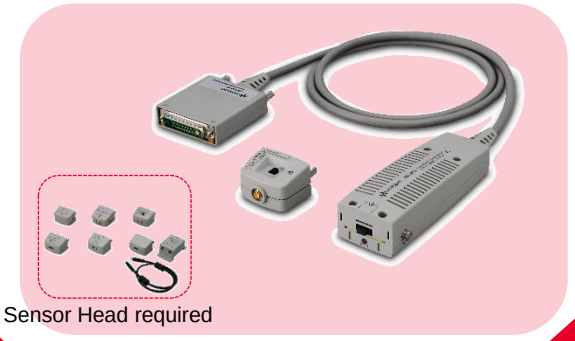
Clear current waveforms displayed and intuitive user interface



Dedicated wide band **Current Sensor** with low noise floor

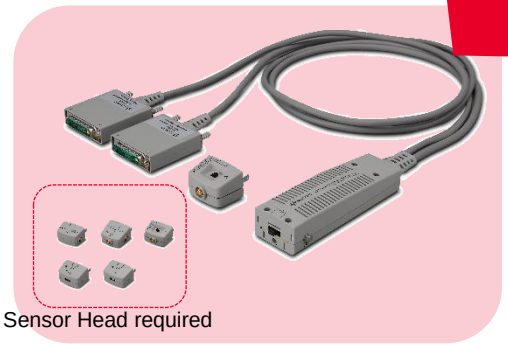
Current Sensors

High-frequency noise suppressed low-burden current sensing



Current Sensor, Single Channel
- ✓100 MHz max bandwidth
- ✓40 nA to 10 A
- ✓+/- 40 V Common mode voltage
- ✓Changeable Sensor head along with DUT type

Basic Current Sensor



Current Sensor, Dual Channel
- ✓100 MHz max bandwidth
- ✓40 nA to 1 A
- ✓+/- 12 V Common mode voltage
- ✓Provide 100dB Dynamic Range by 2 channels
- ✓Changeable Sensor head along with DUT type

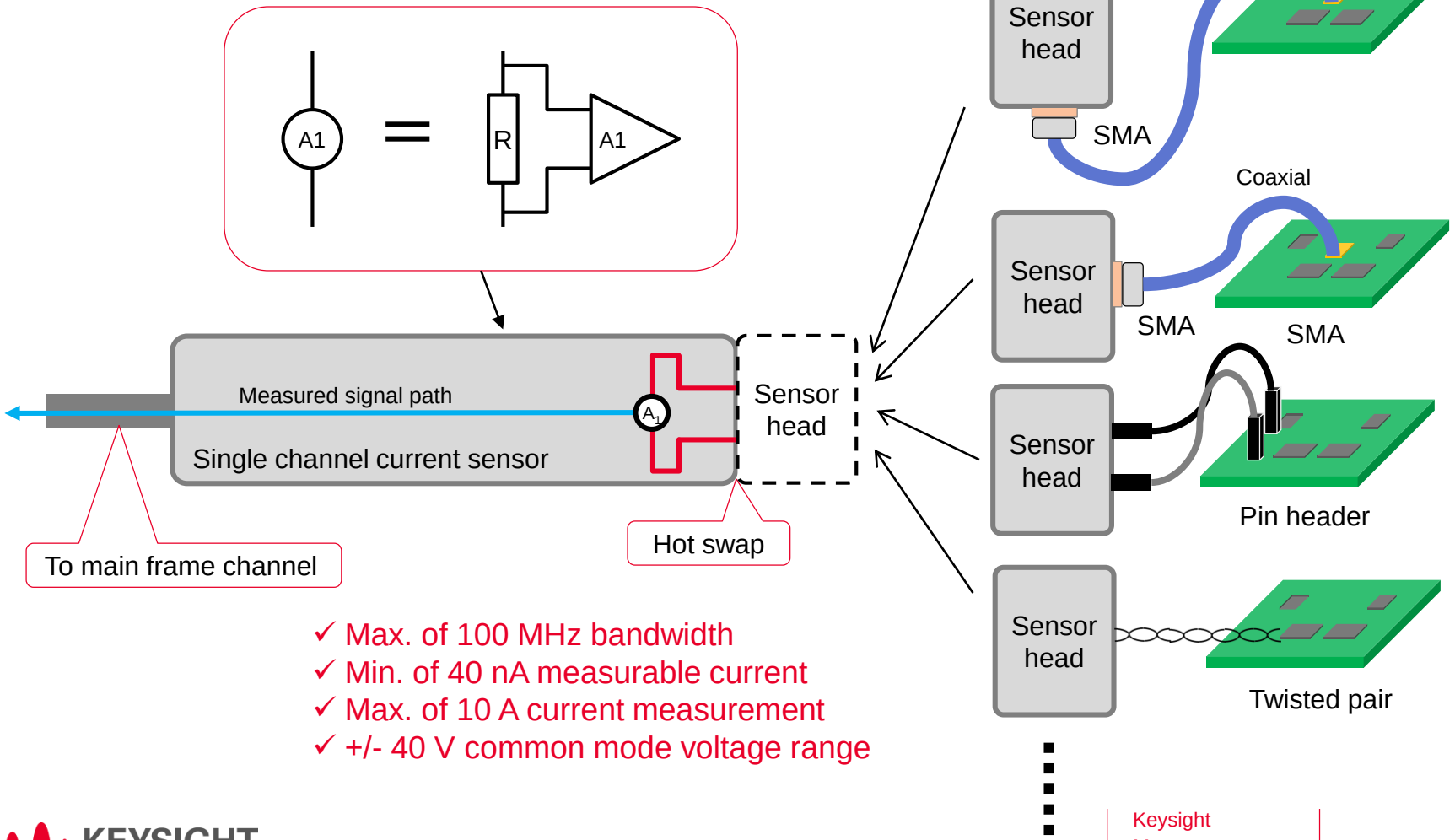
Wider Dynamic Range(100dB)

Current Sensor, Low Side
- ✓200 MHz max bandwidth
- ✓150 pA to 20 mA
- ✓+/- 0.5 V Common mode voltage
- ✓Input : SMA Connector

Low Noise Floor(sub nA)
&
Wider Bandwidth(200MHz)

How to measure current

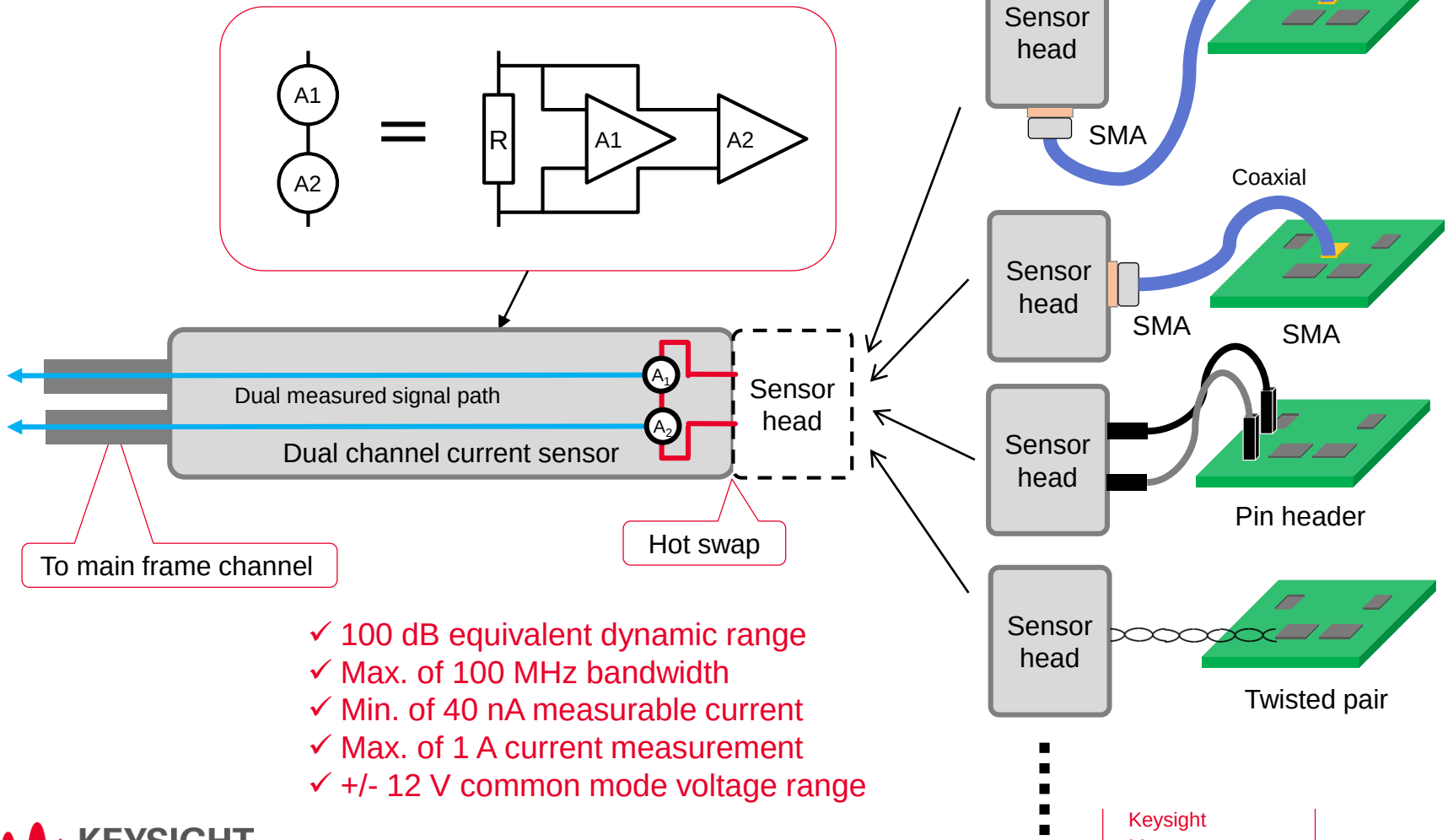
Current Sensor, Single Channel



- ✓ Max. of 100 MHz bandwidth
- ✓ Min. of 40 nA measurable current
- ✓ Max. of 10 A current measurement
- ✓ +/- 40 V common mode voltage range

How to measure current

Current Sensor, Dual Channel

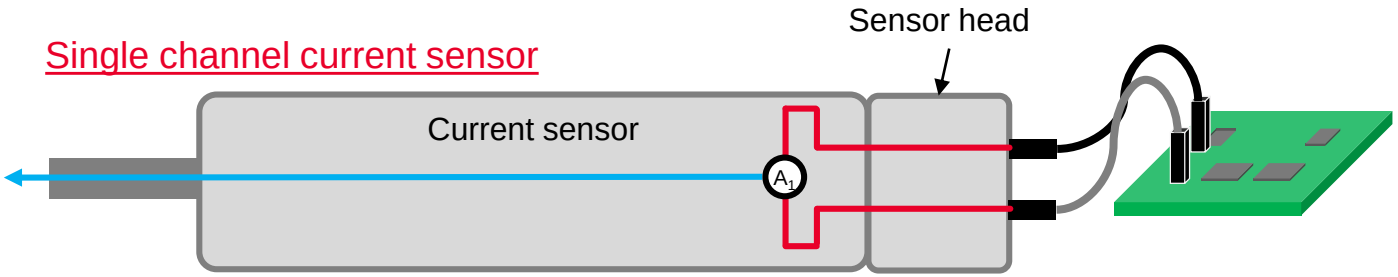


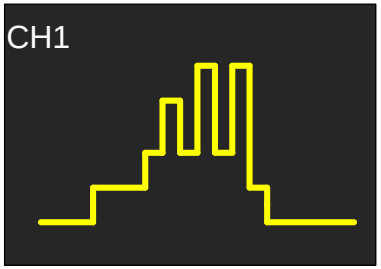
- ✓ 100 dB equivalent dynamic range
- ✓ Max. of 100 MHz bandwidth
- ✓ Min. of 40 nA measurable current
- ✓ Max. of 1 A current measurement
- ✓ +/- 12 V common mode voltage range

Dual channel current sensor

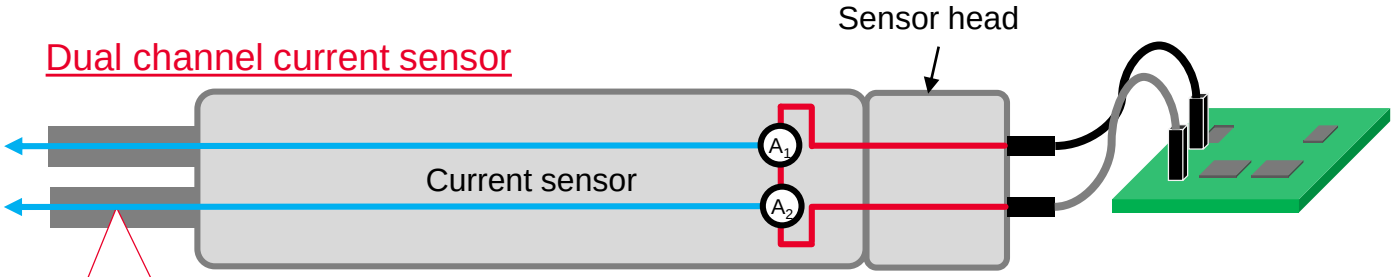
Almost 100 dB dynamic range is available

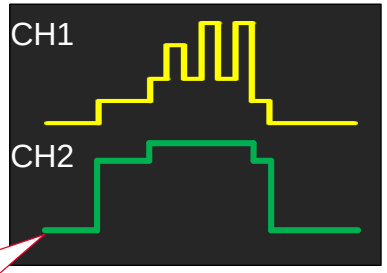
Single channel current sensor





Dual channel current sensor



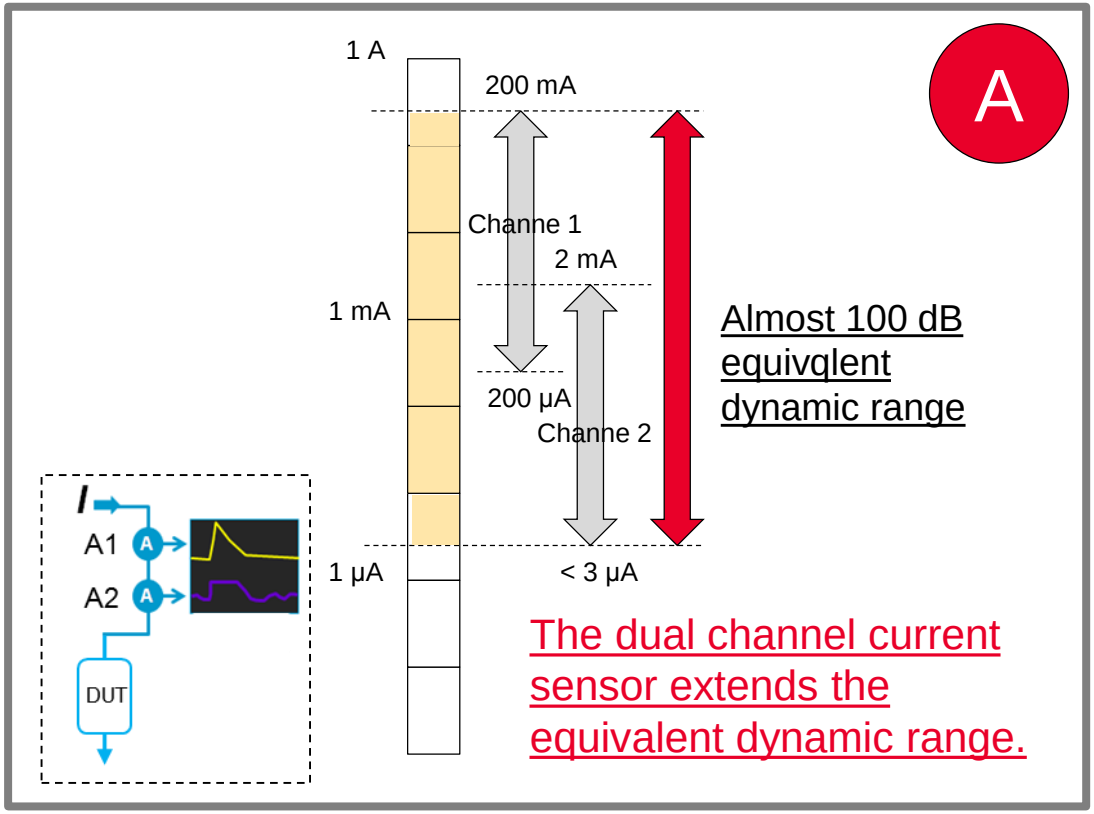


Two channels are required.

The range of CH1 is x100 larger than that of CH2.
→ Enabling a wide range of current measurement from min of CH2 to max of CH2.

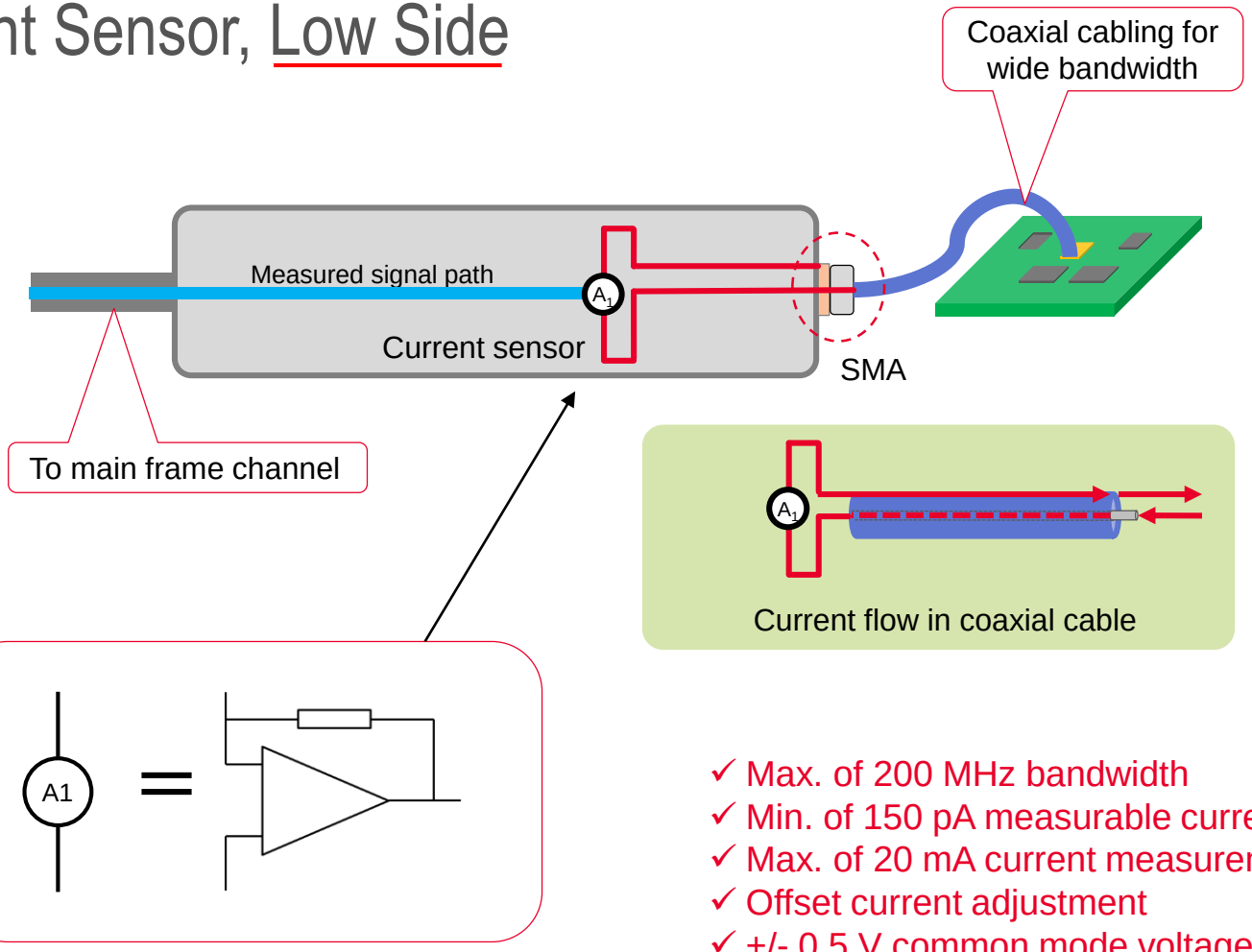
How to cover such a wide dynamic range?

The dual channel current sensor covers more than required



How to measure current

Current Sensor, Low Side



- ✓ Max. of 200 MHz bandwidth
- ✓ Min. of 150 pA measurable current
- ✓ Max. of 20 mA current measurement
- ✓ Offset current adjustment
- ✓ +/- 0.5 V common mode voltage range

CX3300 series Specifications

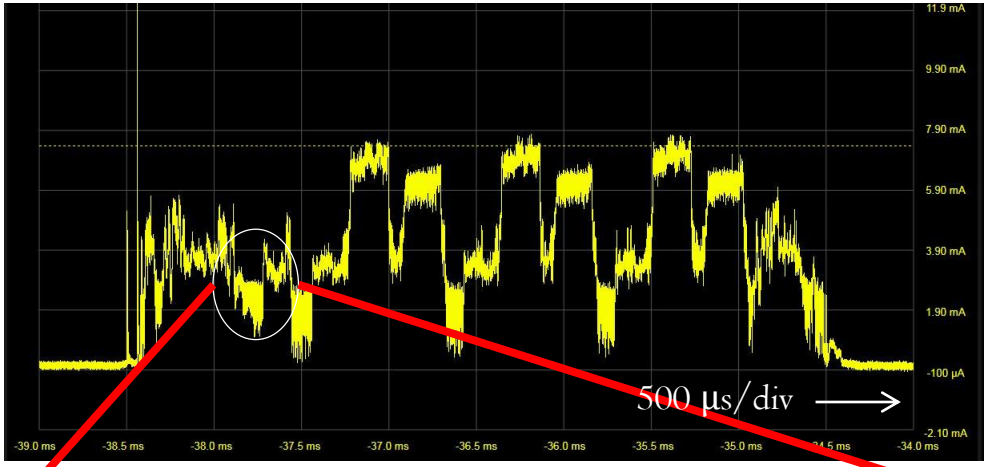
Specification	
Current measurement range	150 pA to 10 A
Power measurement range	10 pW to 400 W
Maximum measurement bandwidth	200 MHz
Maximum sampling rate	1 GSa/s
Measurement dynamic range	14-bit (Normal Mode) 16-bit (High-Res. mode)
Maximum memory size	256 Mpts/ch
Number of channels	2 or 4

Current waveform Measurement Example

In the active period of BLE(Bluetooth Low Energy) module
Measured by Current Sensor, Single Channel

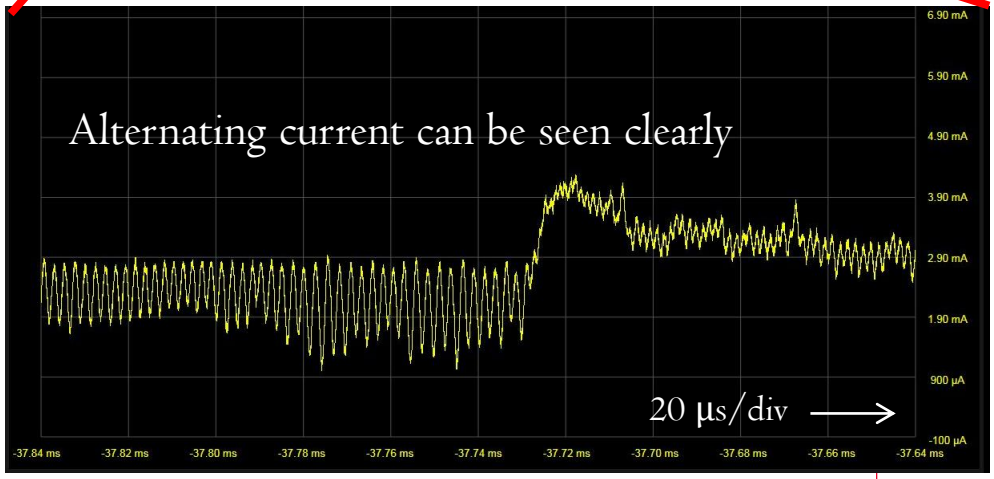
@200MPSPS, 20Mpts
Bandwidth 10MHz

Current profile



200 mA range
2 mA/div

Zoomed waveform



200 mA range
I mA/div

KEYSIGHT TECHNOLOGIES

“Anywhere” Zoom example

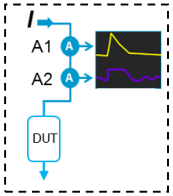
MCU with LED

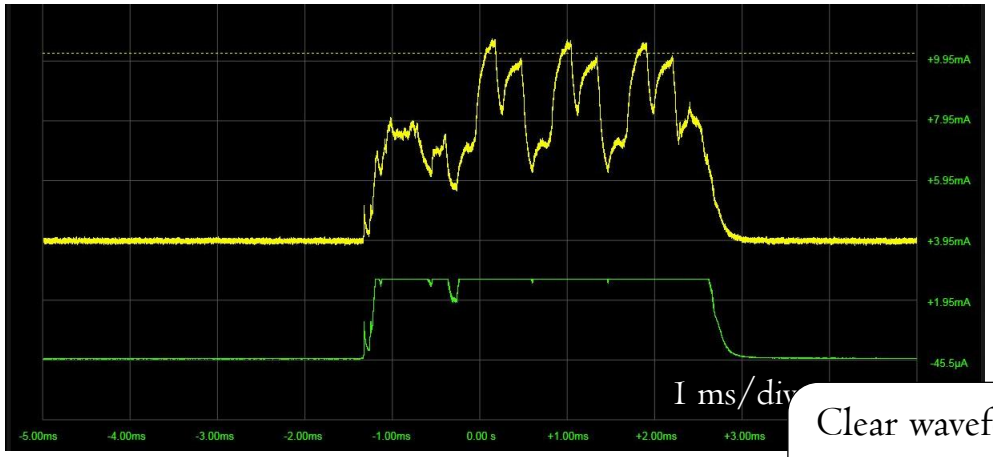
Current Profile measurement Example

Bluetooth Low Energy Chip
Measured by Current Sensor, Dual Channel

@200MPSPS, 20Mpts
Bandwidth 10MHz

With Decoupling Capacitor (47 uF)

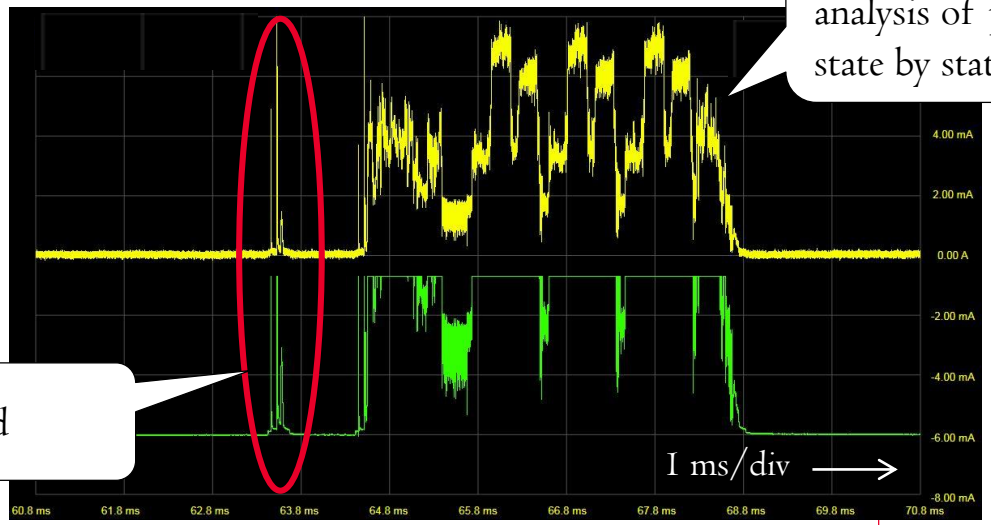




200 mA range
2 mA/div

2 mA range
I mA/div

Clear waveform allows detailed analysis of power consumption state by state



200 mA range
2 mA/div

2 mA range
I mA/div

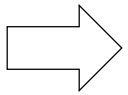
Without Decoupling Capacitor

Peak current is detected

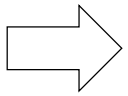
KEYSIGHT TECHNOLOGIES

This analyzer solves the issues

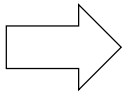
1. Transient current in Sleep mode is not visible due to large noise floor.
2. Multiple instruments are required to estimate the total current consumptions.
3. Measuring state transition current such as Sleep to Wake-up is very difficult due to less dynamic range.
4. Capturing narrow and sharp peak / spike current is very difficult due to less bandwidth.
5. Extra time is required to support your customers on the current and power consumption issues.



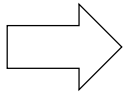
✓ Sleep mode current is now visible.



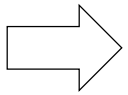
✓ One-time measurement covers from sleep to active current.



✓ The wide dynamic range visualizes the transition.



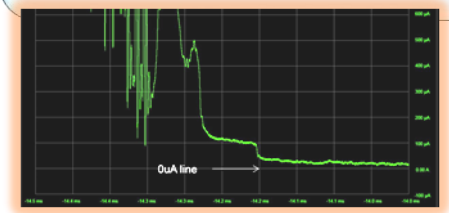
✓ The wideband measurement captures high speed phenomena.



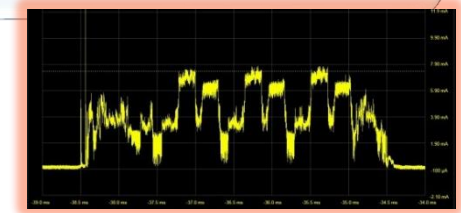
✓ It can be the Golden Instrument for current measurement.

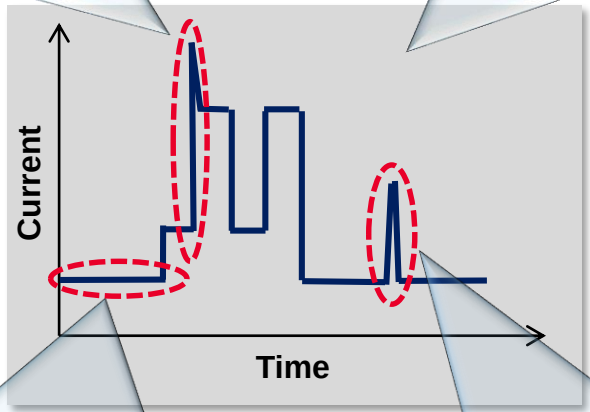
Your benefits from this analyzer

You can minimize extra current consumption by monitoring actual transition current waveforms.

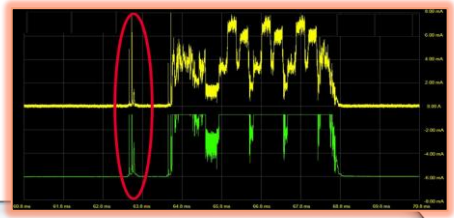


You can optimize and debug current profile by monitoring detailed waveforms in active period.





You can reduce sleep current consumption by monitoring actual waveforms.



You don't miss undesirable spike current or tell how much current it reaches.


Thanks!