Oscilloscope Measurement Fundamentals

Keysight	***2025.05.14***
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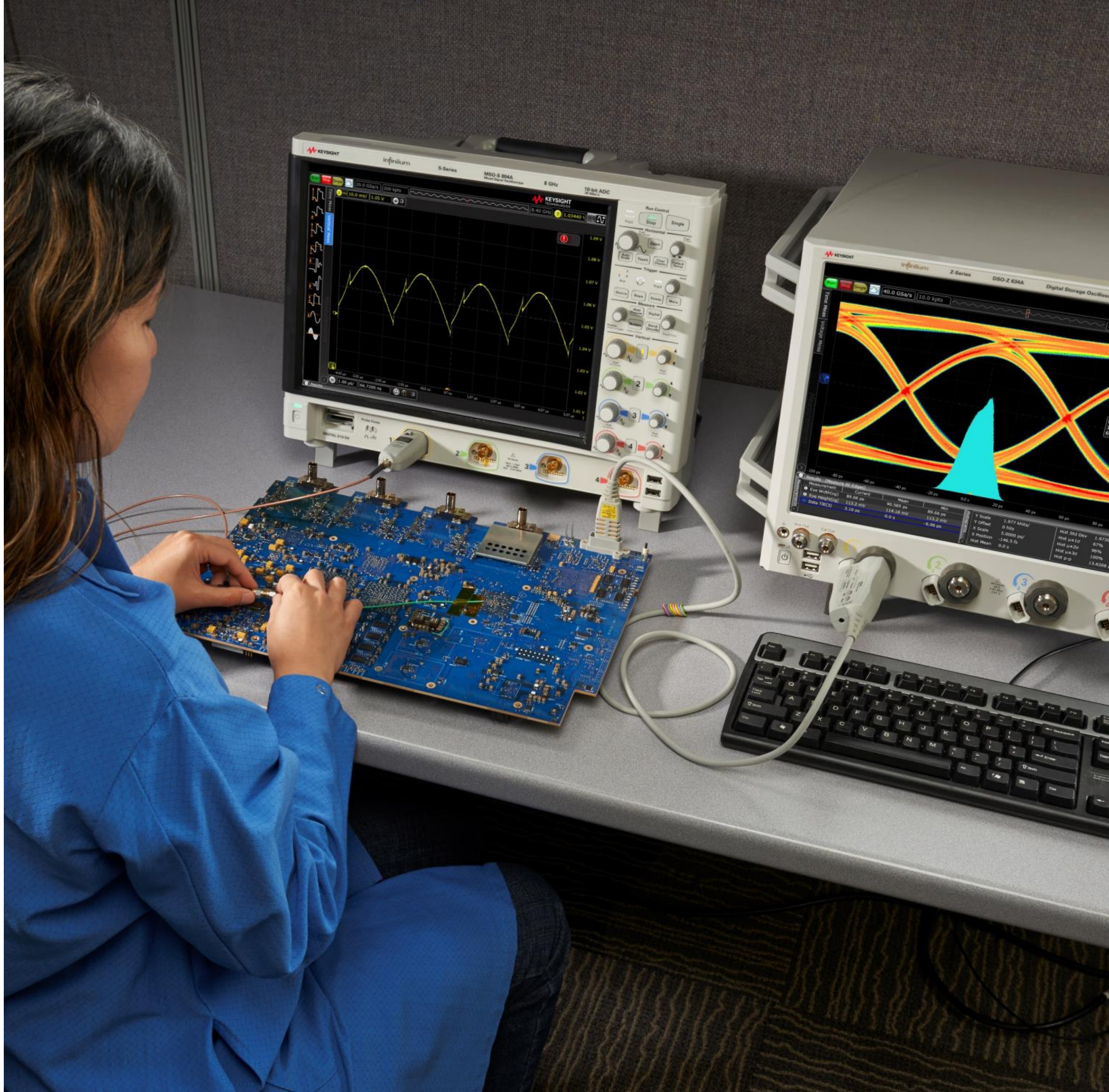
KEYSIGHT
TECHNOLOGIES

Oscilloscope Fundamentals

AGENDA SLIDE

- Time vs. Frequency Domain
- Sampling Rate and Modes
- Bandwidth and Aliasing
- Oscilloscope Architectures
- Triggering: Basics and Advanced
- Memory Depth and Methods
- Waveform Visualization Tools
- Probing Architecture, Tips and Tricks



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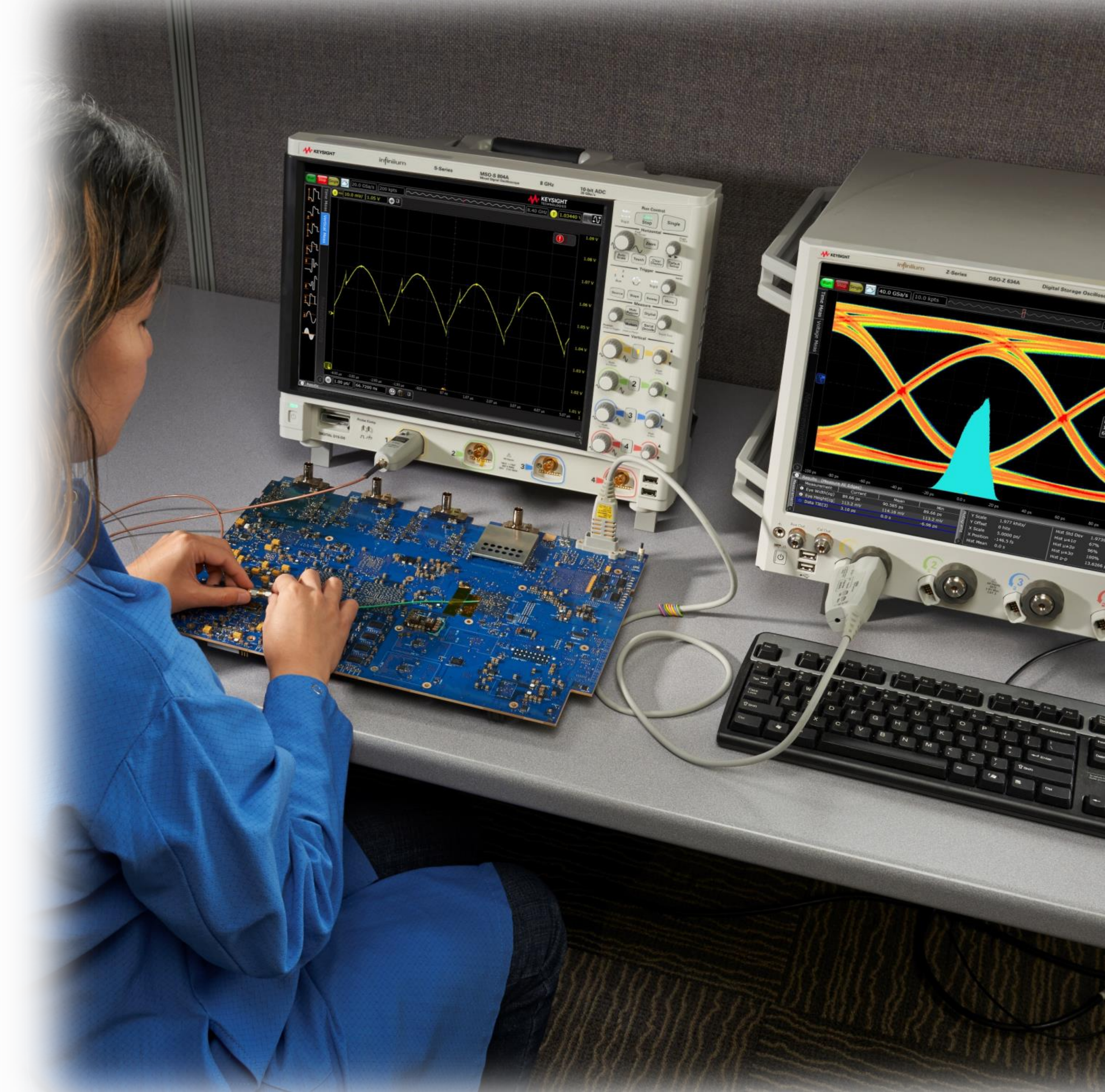
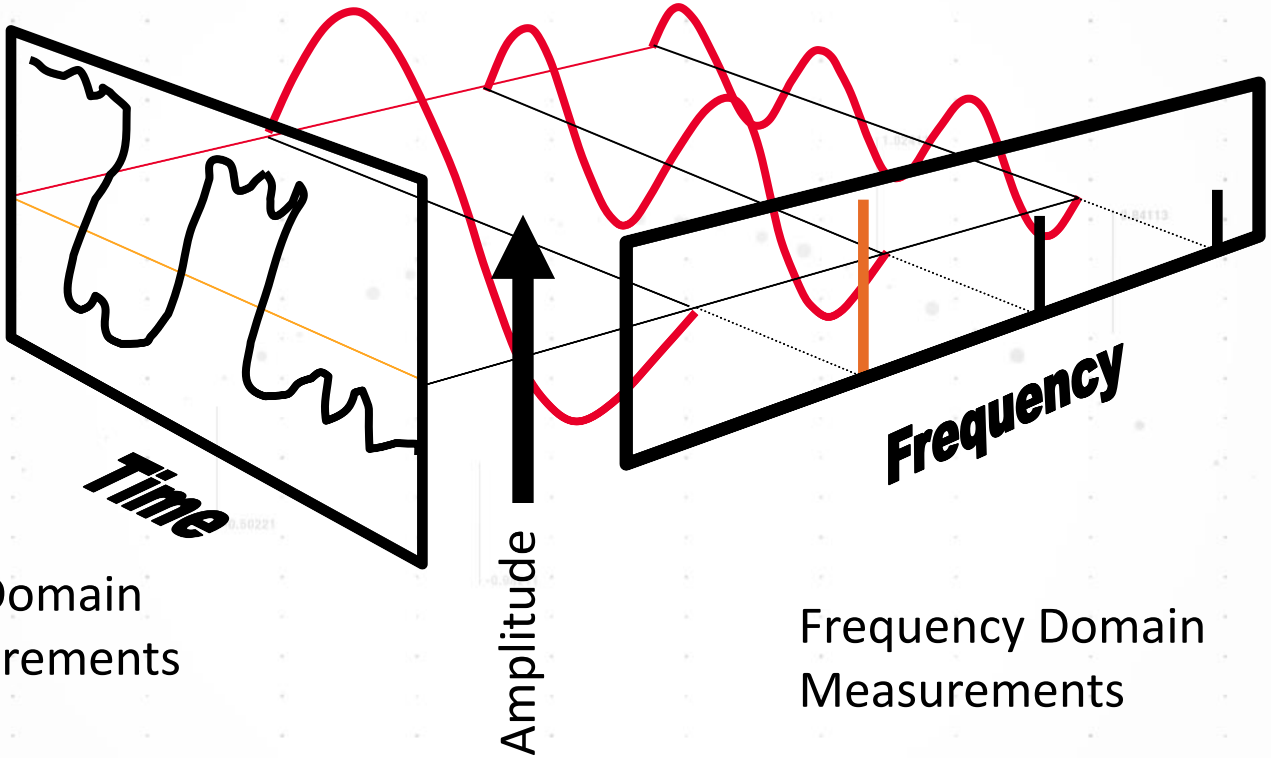


Time Domain vs. Frequency Domain

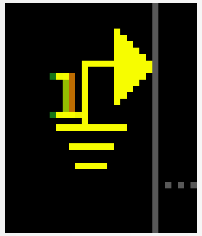


Time Domain
Measurements

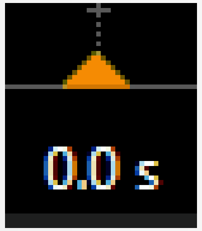
Frequency Domain
Measurements

Time Domain vs. Frequency Domain

HOW TO UNDERSTAND WHAT IS ON A SCOPE SCREEN (TIME DOMAIN)

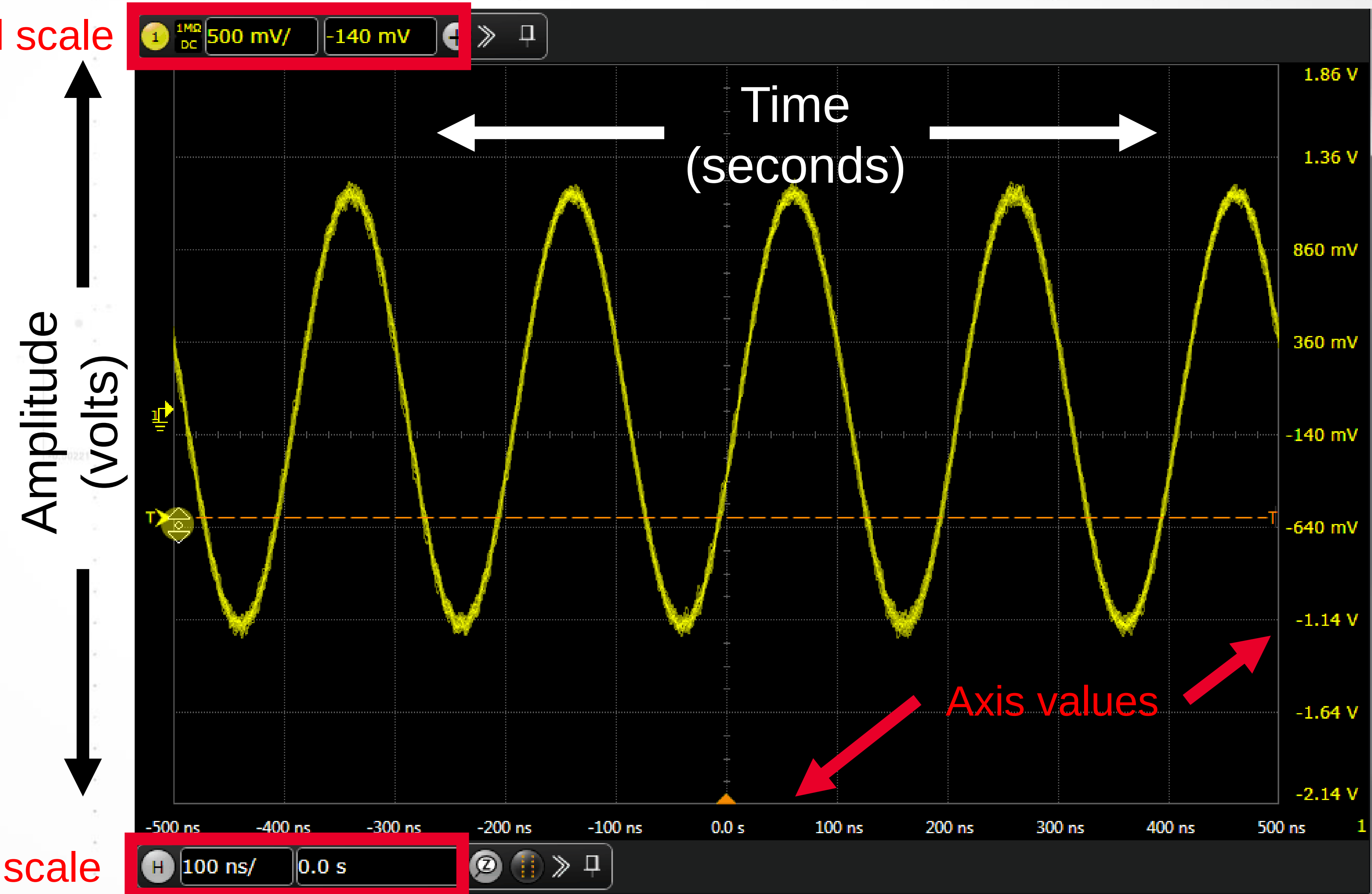


0 volts (or amps) is shown with a ground symbol to the left edge of the screen, and can be adjusted up and down.



0 seconds (trigger point) is shown with an orange triangle, and can be adjusted left and right.

Vertical scale



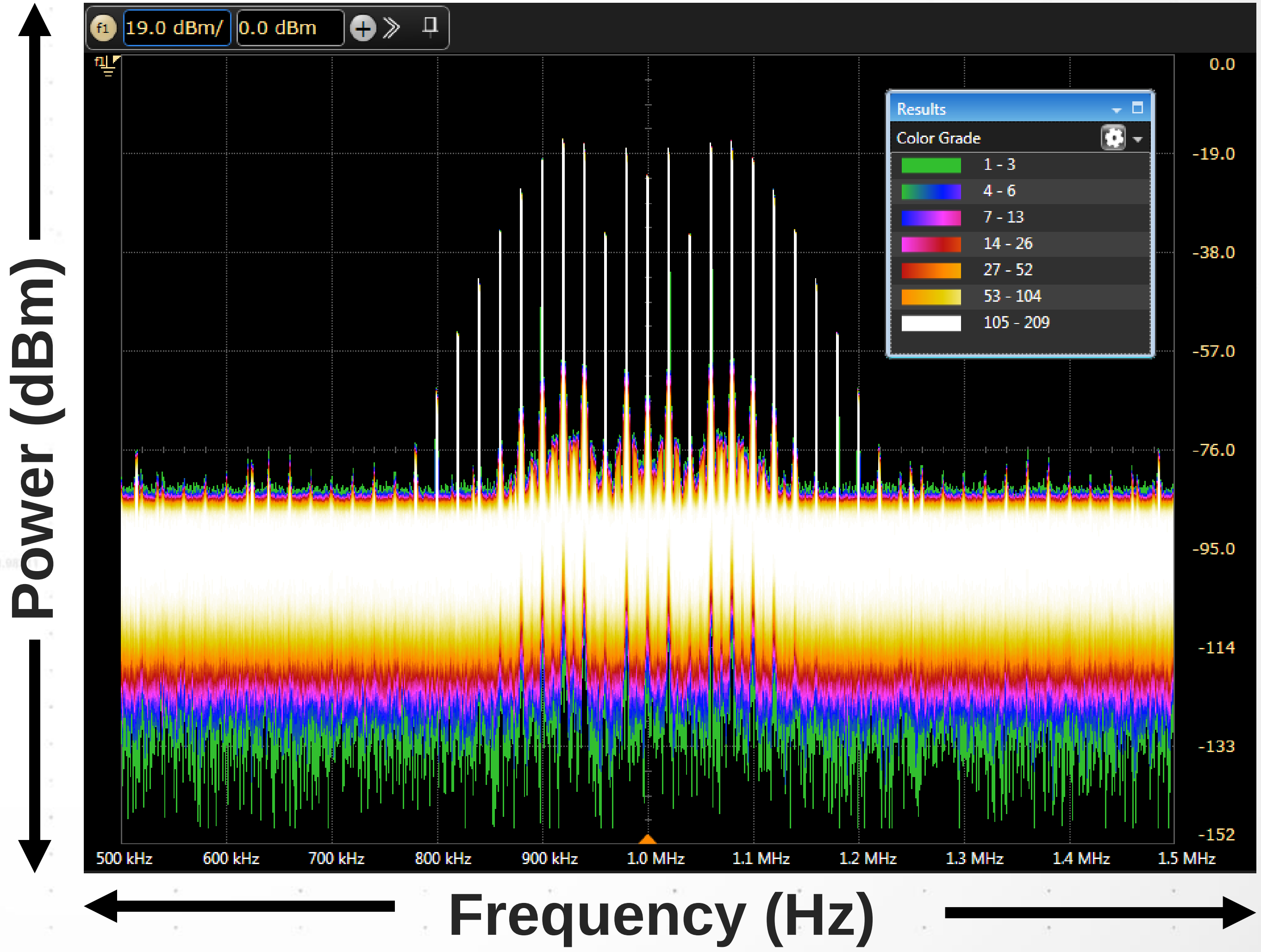
time scale

KEYSIGHT TECHNOLOGIES

Time Domain vs. Frequency Domain

HOW TO CONVERT BETWEEN THE TWO – OR HAVE BOTH!

- A mathematical conversion between time and frequency domain can always be performed
- Fast Fourier Transform (FFT) – less calculations
- FFT - easily processed by a computer
- Alternative ways of representing the same signal
- Some behavior is seen easier in one domain



Time Domain vs. Frequency Domain

MEASUREMENT DEVICES

Time Domain Equipment

Oscilloscope

Signal Analyzer (within RBW)

Network Analyzer (within RBW)

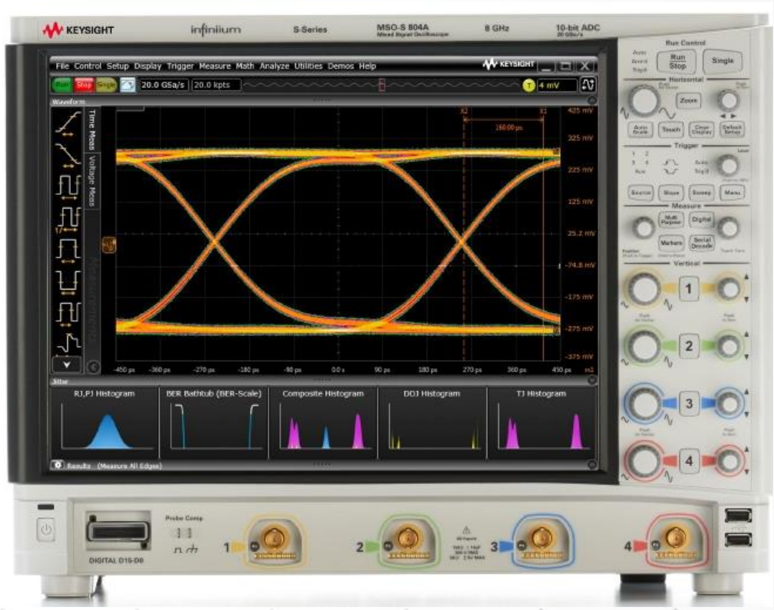
Frequency Domain Equipment

Spectrum Analyzer

Network Analyzer

FFT Analyzer

FFT function on an Oscilloscope



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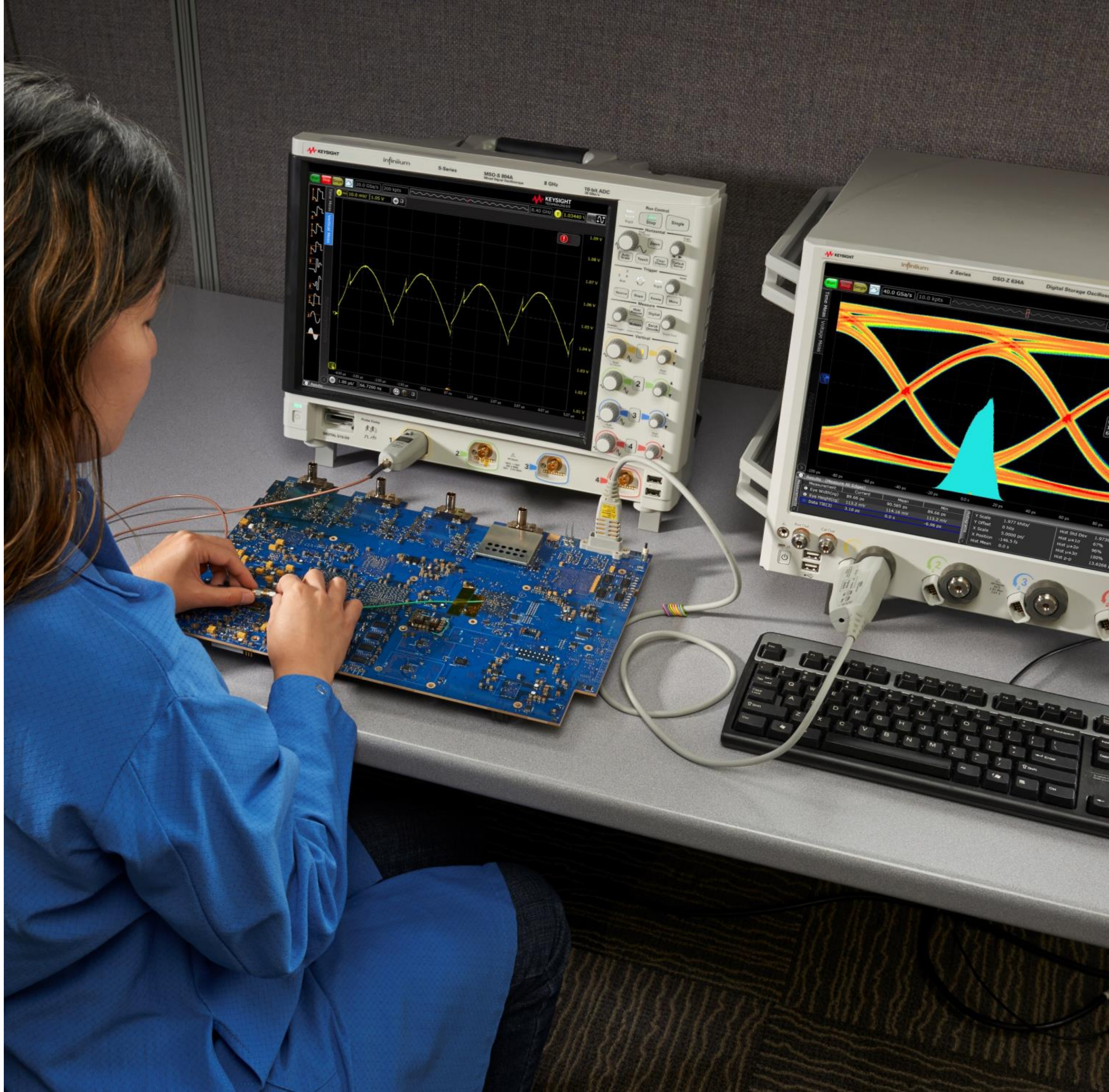


Sampling Basics

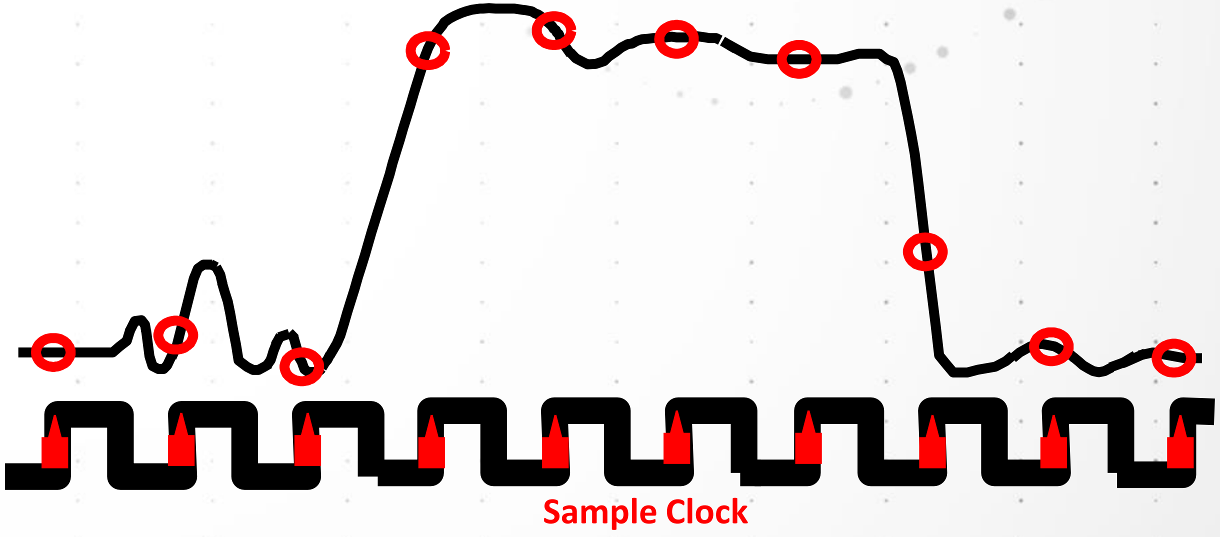
HOW OFTEN THE OSCILLOSCOPE MEASURES VOLTAGE

- The speed which the oscilloscope samples the voltage of the input signal. Measured in samples per second (Sa/s)
- The signal you see on screen is actually a “connect the dots” image of up to billions of samples to create a continuous shape over time.
- The minimum requirement is generally 2.5x the bandwidth, e.g. 8 GHz needs 20 GSa/s

Sampling Basics

REAL TIME SAMPLING

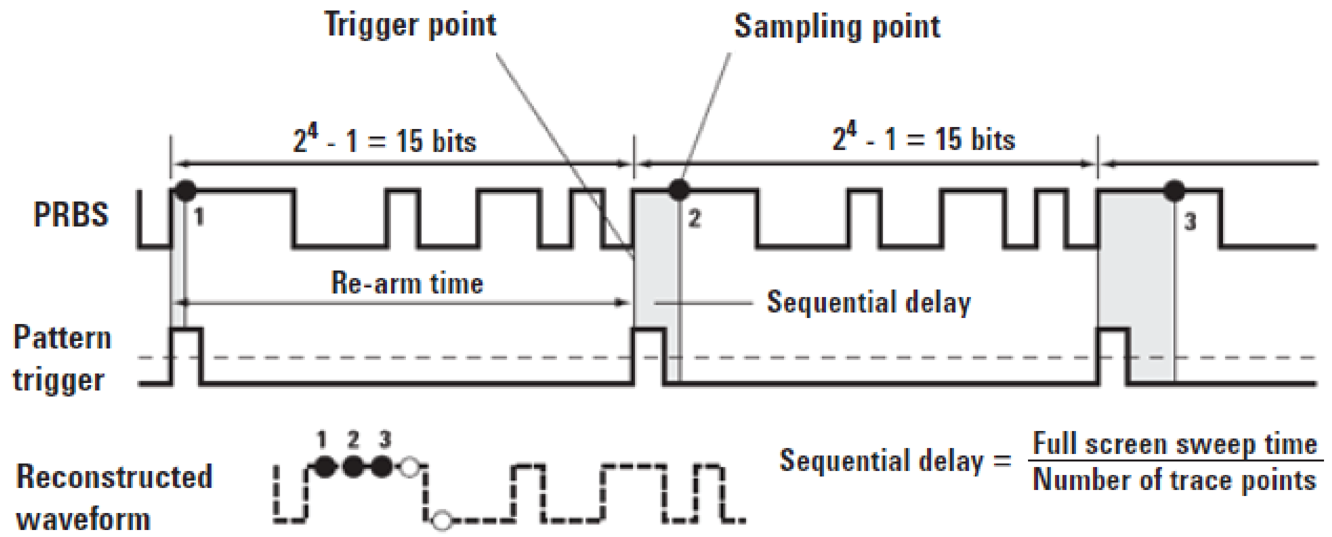
- All samples are taken on a single trigger event
- Pre-trigger acquisition is possible (data before trigger)
- Bandwidth depends on sampling frequency
- Sampling frequency is also called the digitizing rate
- Resolution of points on screen is 1/sample rate



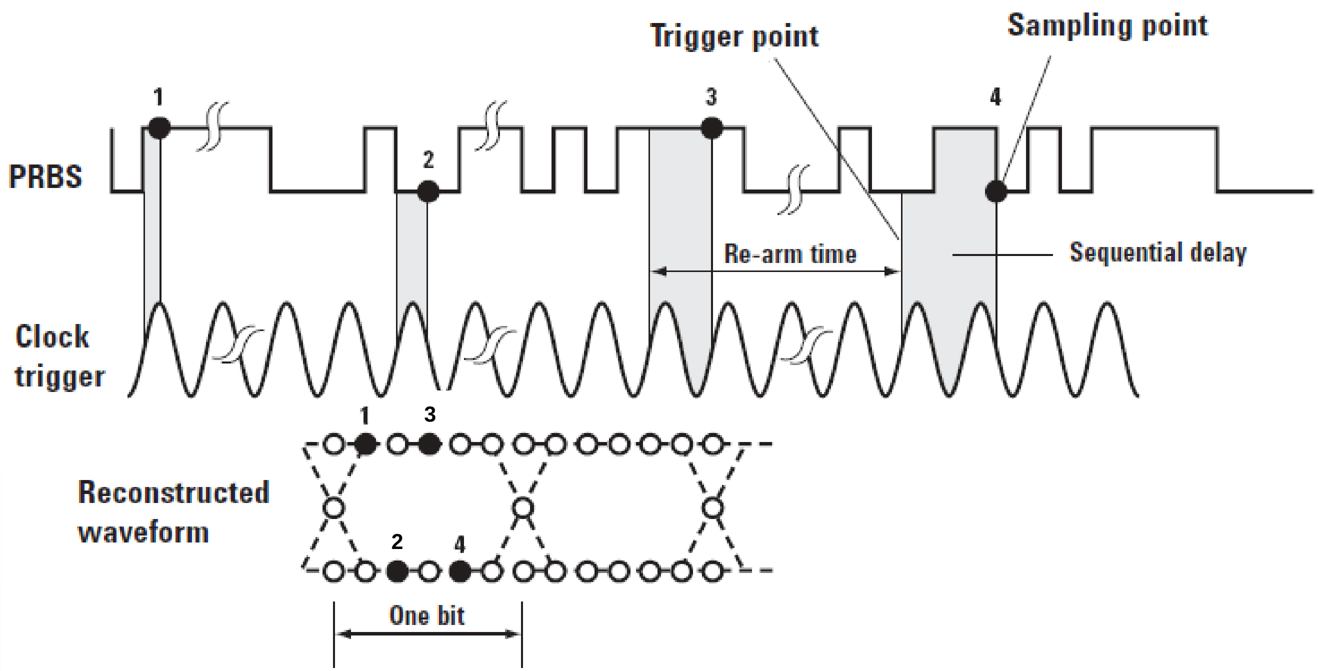
Sampling Basics

EQUIVALENT TIME SAMPLING

- Bandwidth / sample density is not limited by sample rate!
- Sample clock is synchronous to trigger (waveform) or bit period (eye diagram)
- Pre-trigger acquisition is possible (data before trigger)
- Waveform "BUILDS-UP" with repetitive input.



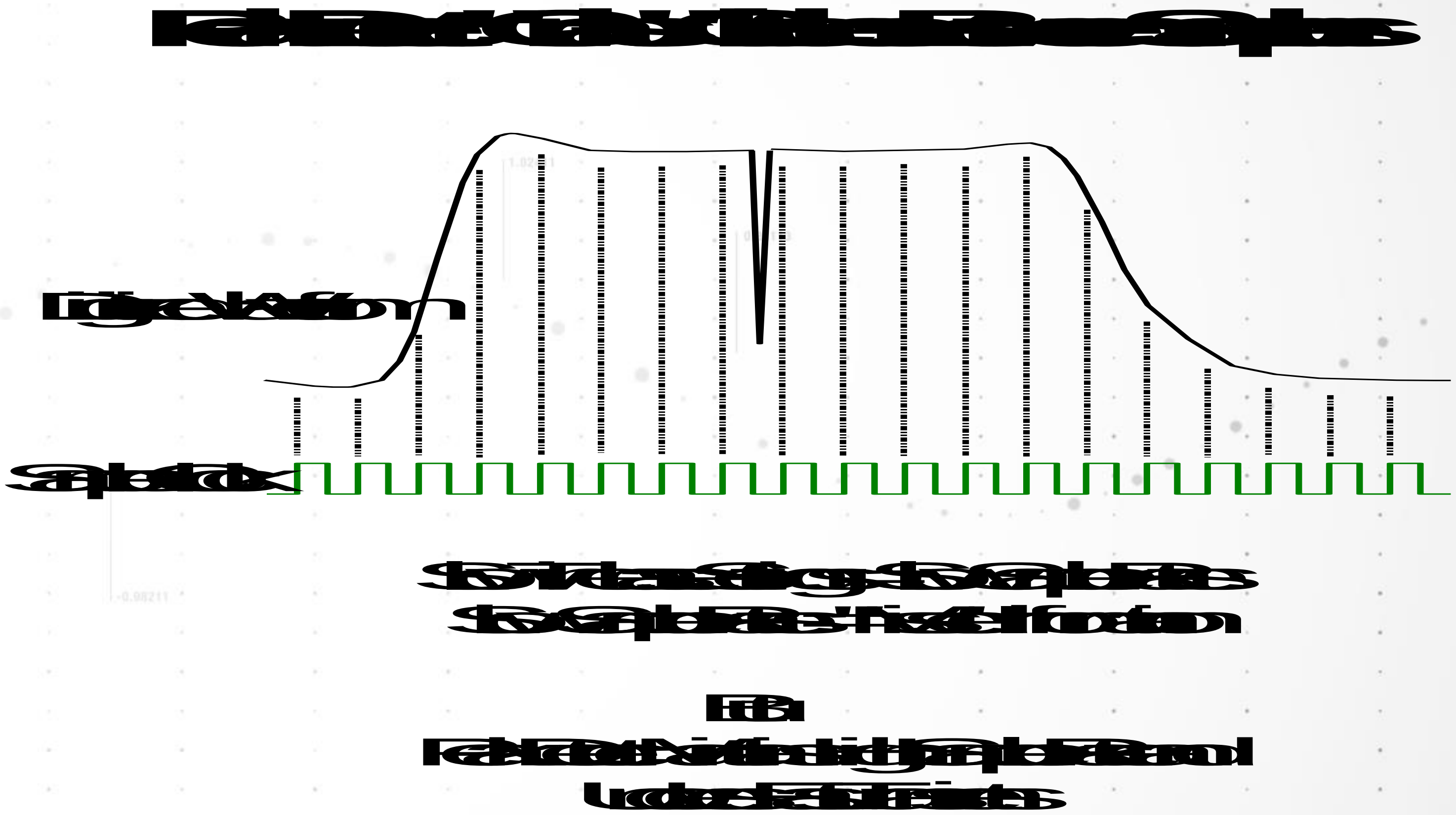
Reconstruct a waveform ↑ or an eye diagram ↓



Sampling Basics

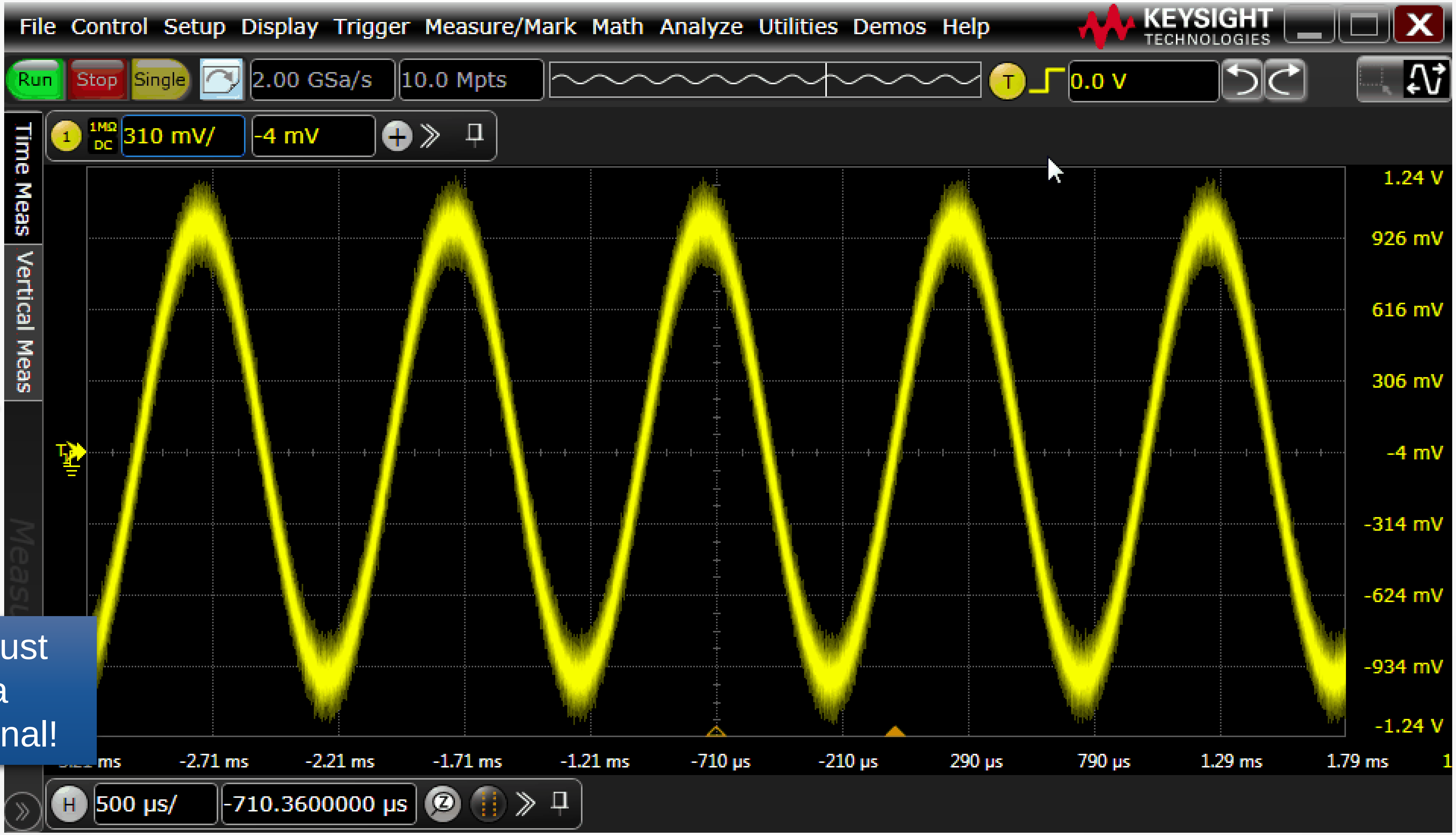
PEAK DETECT MODE

- Helps find high frequency spikes when running the scope at a lower sample rate.
- Oversamples in the background, then stores maximum and minimum voltages for display.
- Will make signal look “noisier” since it’s capturing and saving the extremes; only useful for finding high speed information in a low sample rate setting



Sampling Basics

AVERAGING

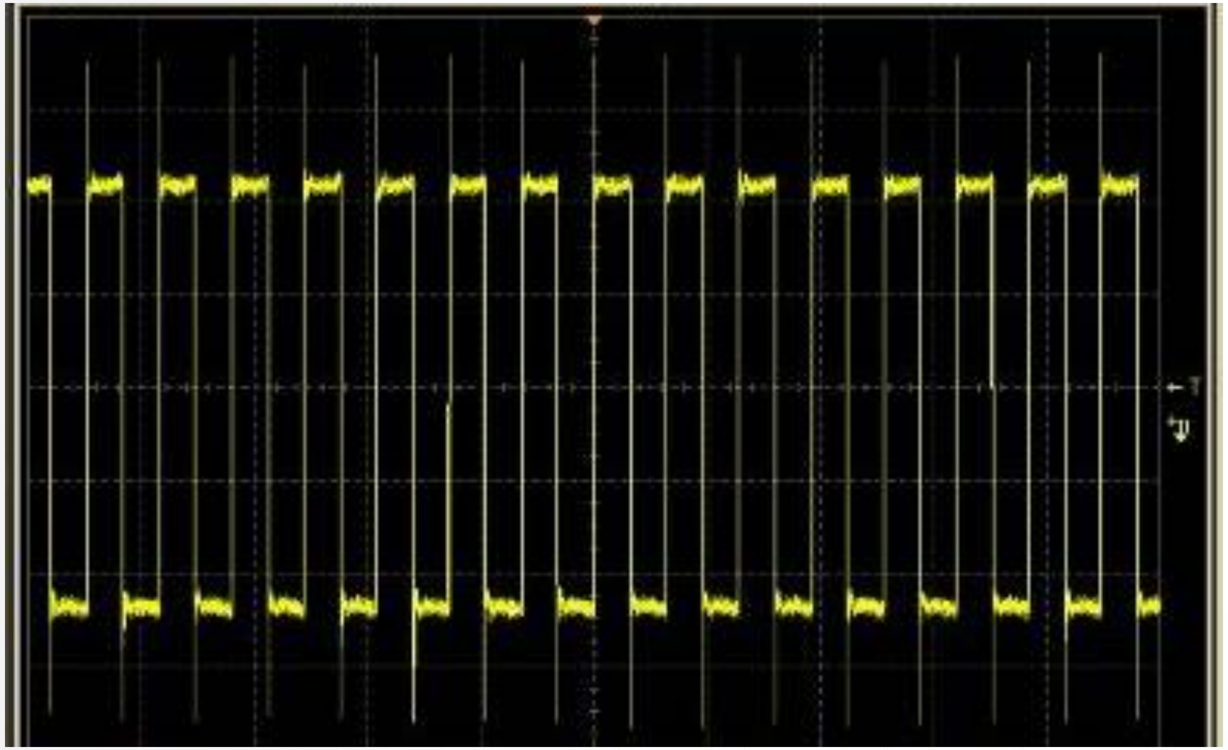


Averaging must be done on a repetitive signal!

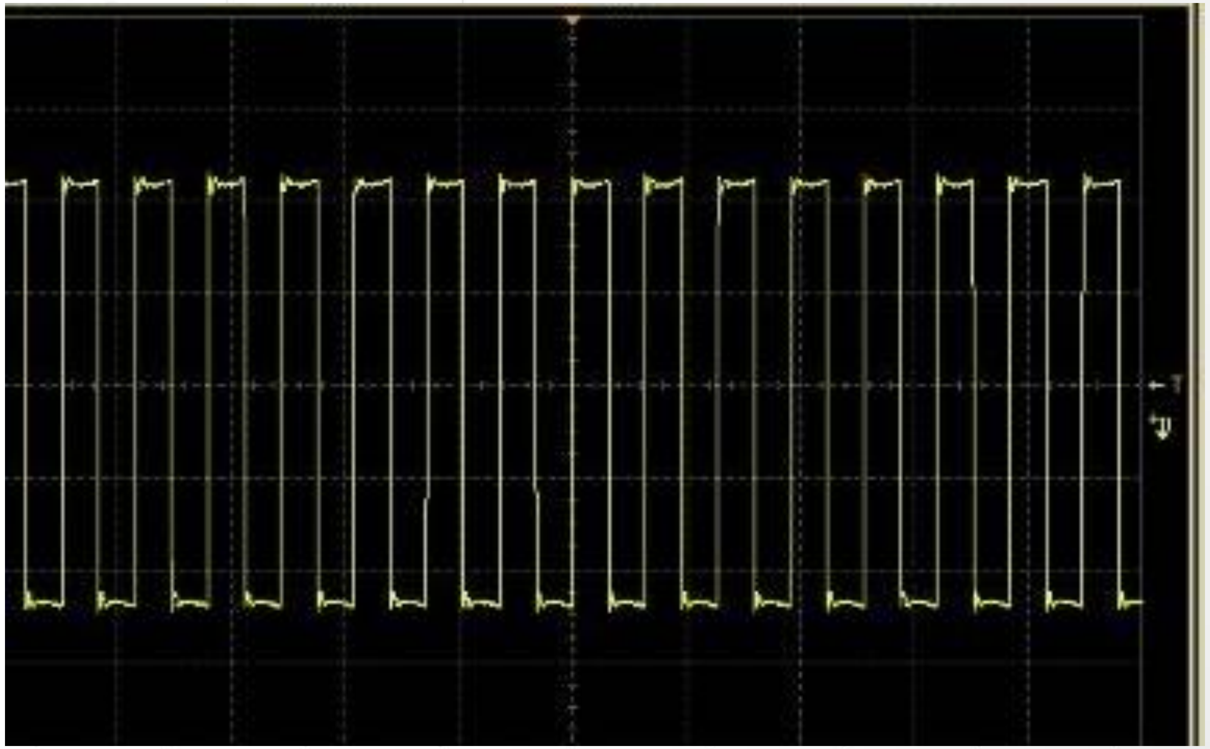
Sampling Basics

HIGH RESOLUTION MODE

- Waveform is sampled faster than required
- Sequential samples are averaged
- Reduces noise at the expense of bandwidth



1.5MHz clock with Real-Time sampling



1.5MHz clock with High Resolution sampling

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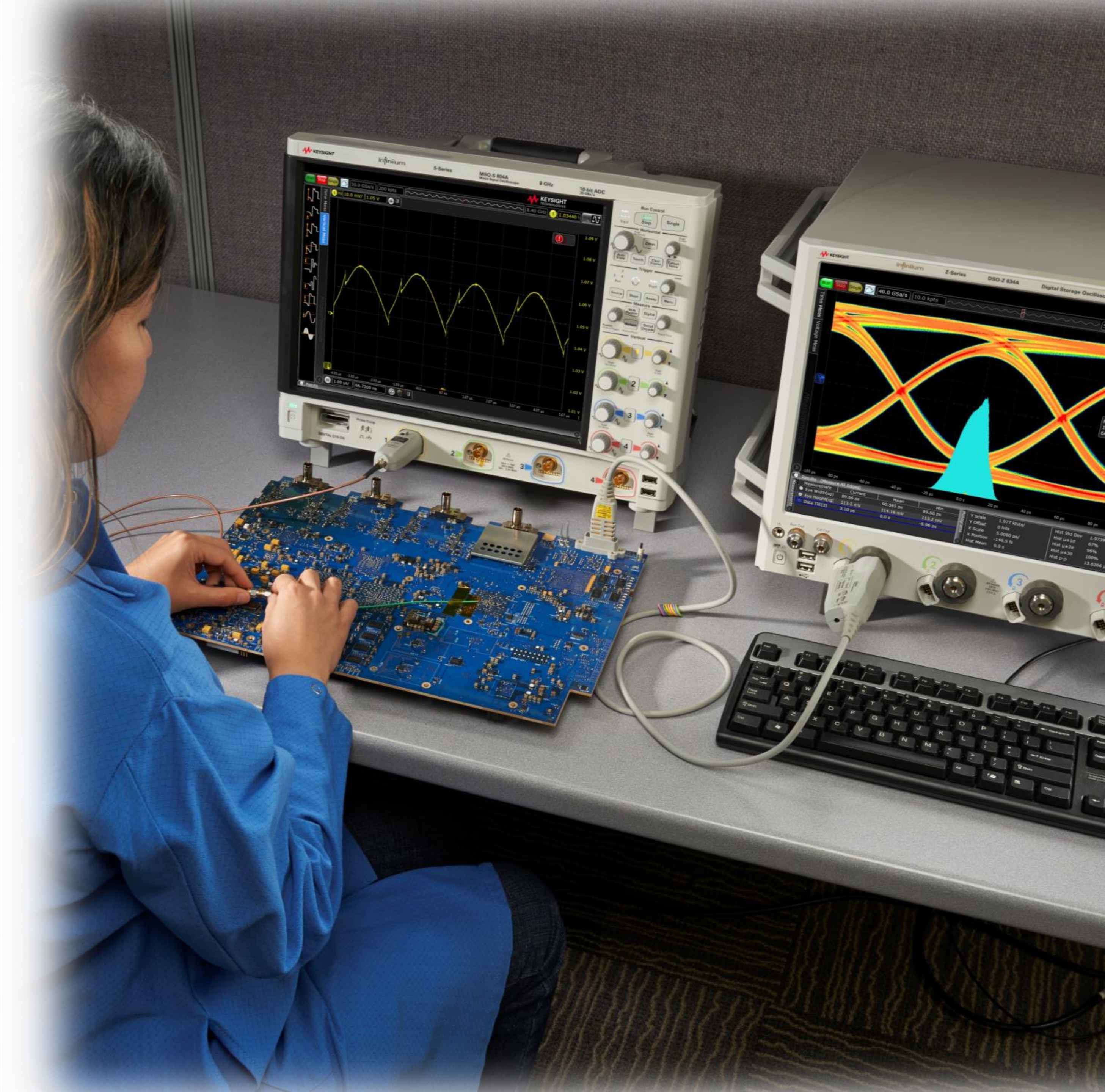


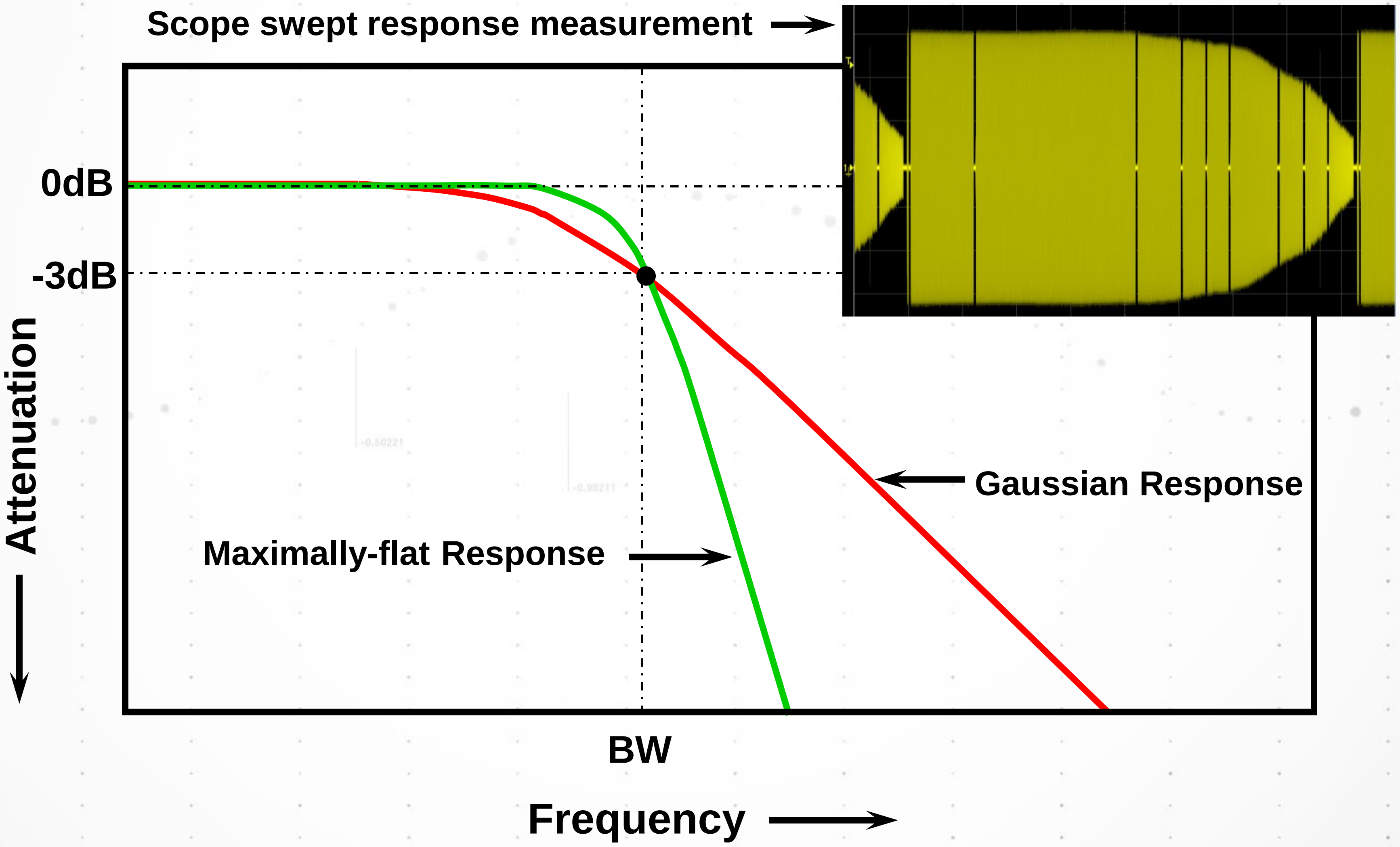
Bandwidth Basics

THE DEFINING CHARACTERISTIC OF AN OSCILLOSCOPE

- Defines the fastest signal the oscilloscope can capture. Any signals faster than the bandwidth of the scope will not be accurate, or even shown at all.
- In datasheets, defined along with “rise time”.

Bandwidth Basics

ALSO CALLED THE "3DB DOWN POINT"



Bandwidth Basics

NYQUIST'S THEOREM: REMEMBERING THE COLLEGE DAYS

- **Nyquist's sampling theorem** states that for a limited bandwidth (band-limited) signal with maximum frequency f_{max}, the equally spaced sampling frequency f_s must be greater than twice of the maximum frequency f_{max}, i.e.,

$$\mathbf{f_s > 2 \cdot f_{max}} \quad \textbf{[[sample twice the frequency of the signal!]]}$$

in order to have the signal be uniquely reconstructed without aliasing.

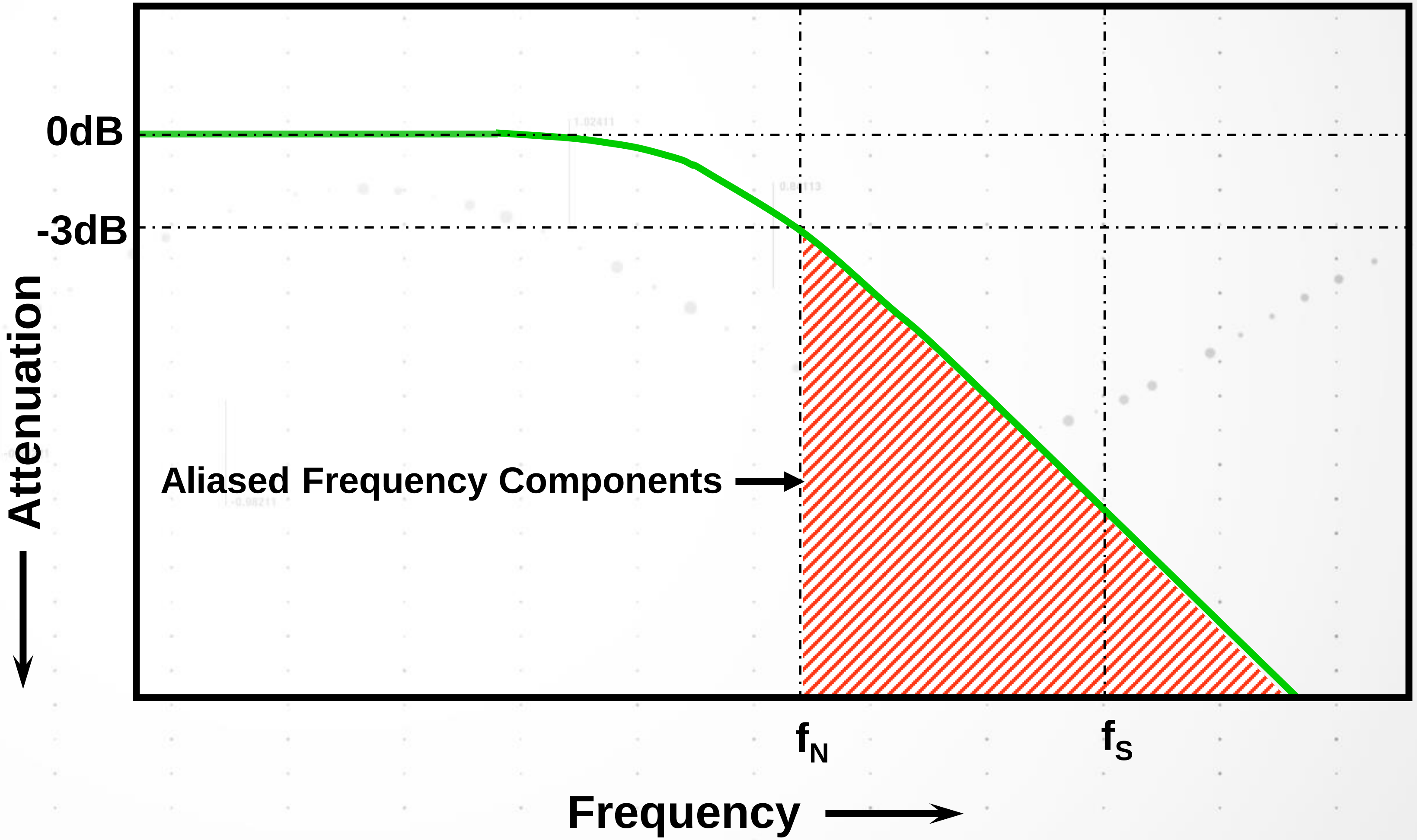
- $\mathbf{f_s}$ is called the Nyquist sampling frequency.
- $\mathbf{f_{max}}$ is sometimes called the Nyquist frequency (f_N).

Dr. Harry Nyquist, 1889-1976, articulated his sampling theorem in 1928

KEYSIGHT TECHNOLOGIES

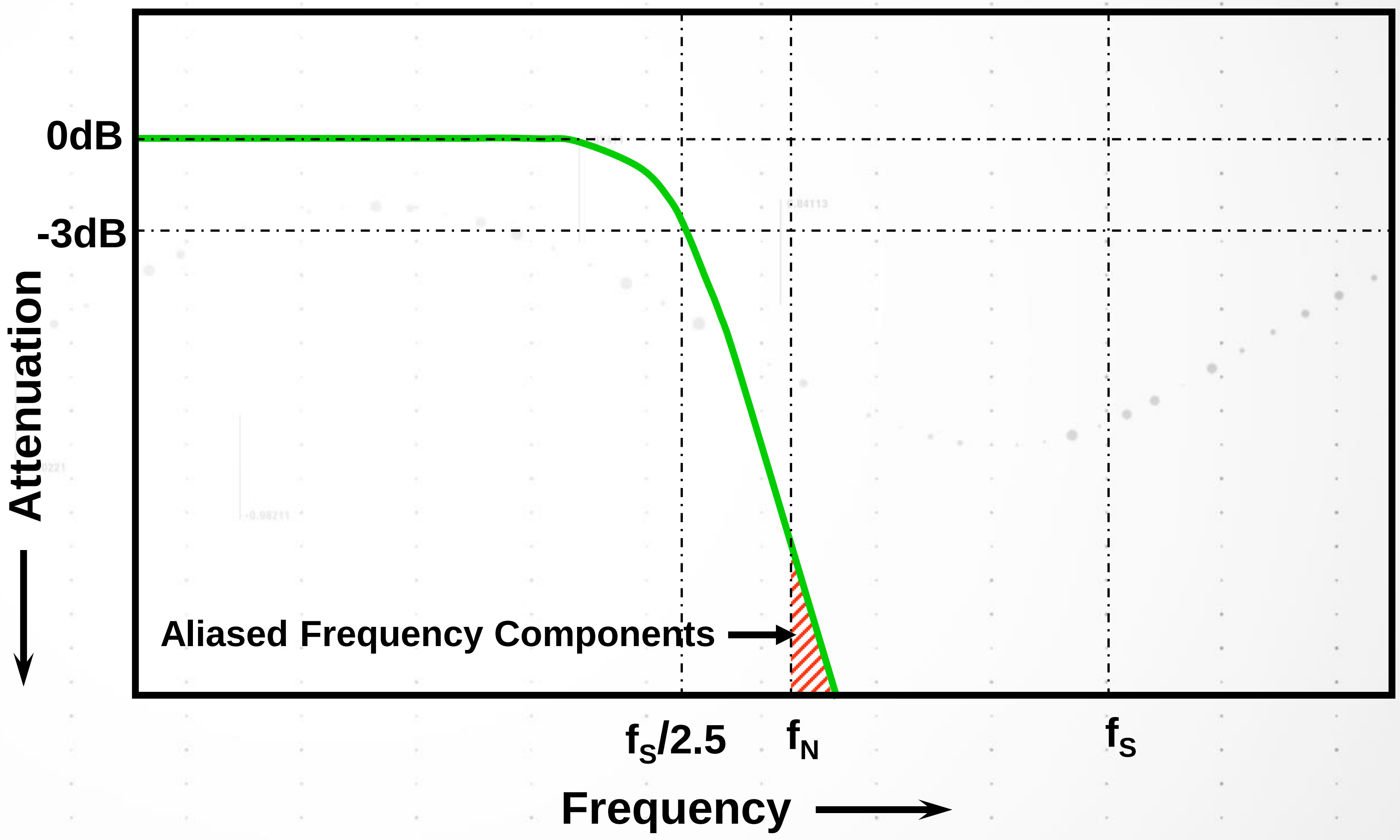
Gaussian Response w/ BW @ fs/2 (fN)

"Gaussian front end" has a typical 20 db/decade low pass filter response, and we're at the limits of Nyquist's theorem, meaning that content higher than f_N gets through easier. This causes aliasing.



Maximally-Flat Response w/ BW @ fs/2.5 (fN/1.25)

"Maximally flat front end" has a steeper low pass filter response, and we are sampling 2.5x of f_N, preventing most aliasing.

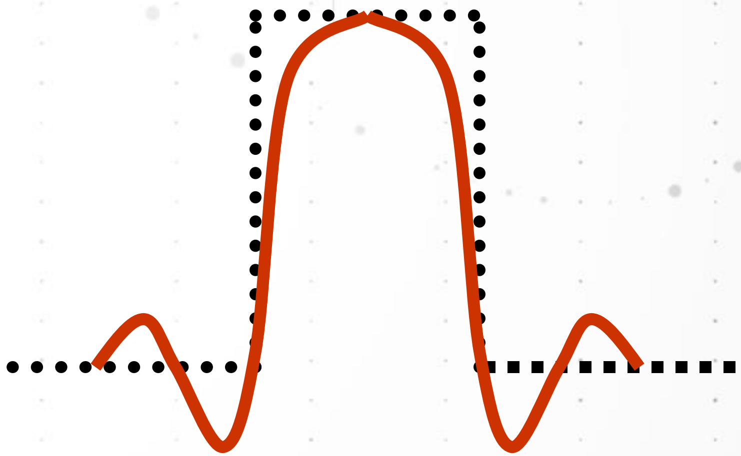


Bandwidth Basics

DISTORTION DUE TO ALIASING AND BANDWIDTH LIMITING

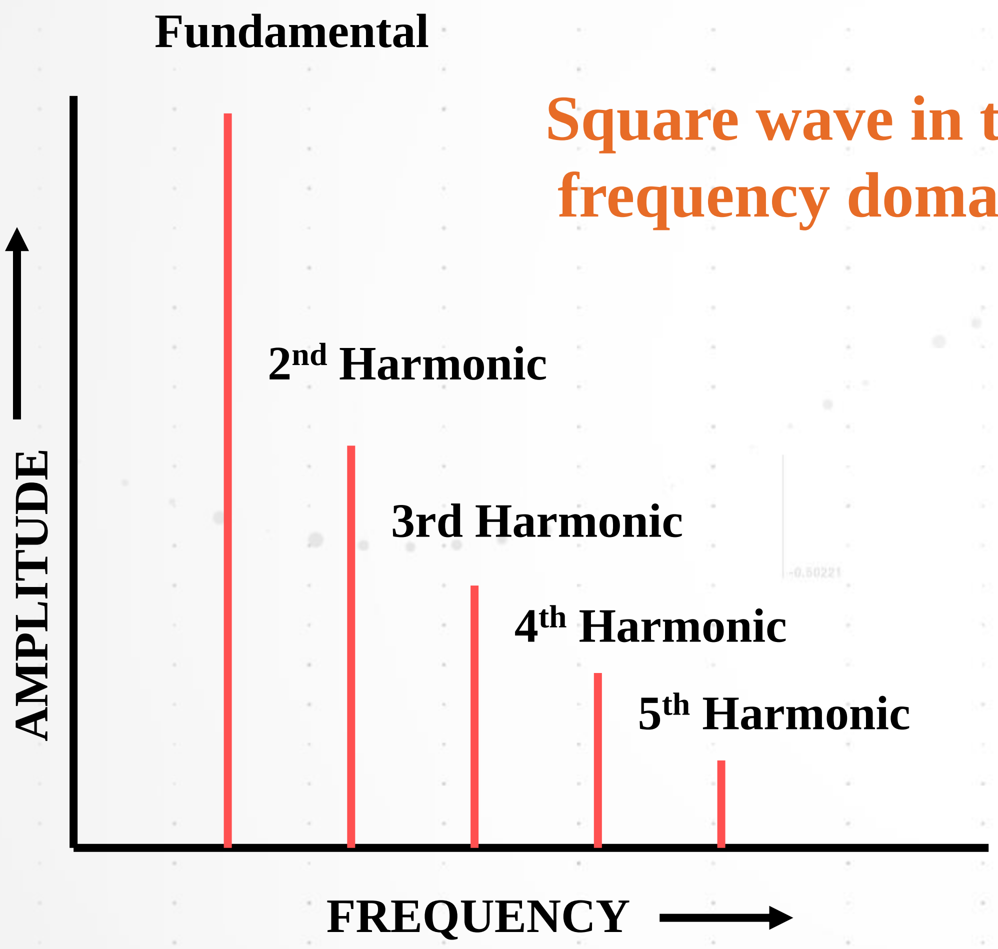
ACTUAL PULSE

DISPLAYED PULSE



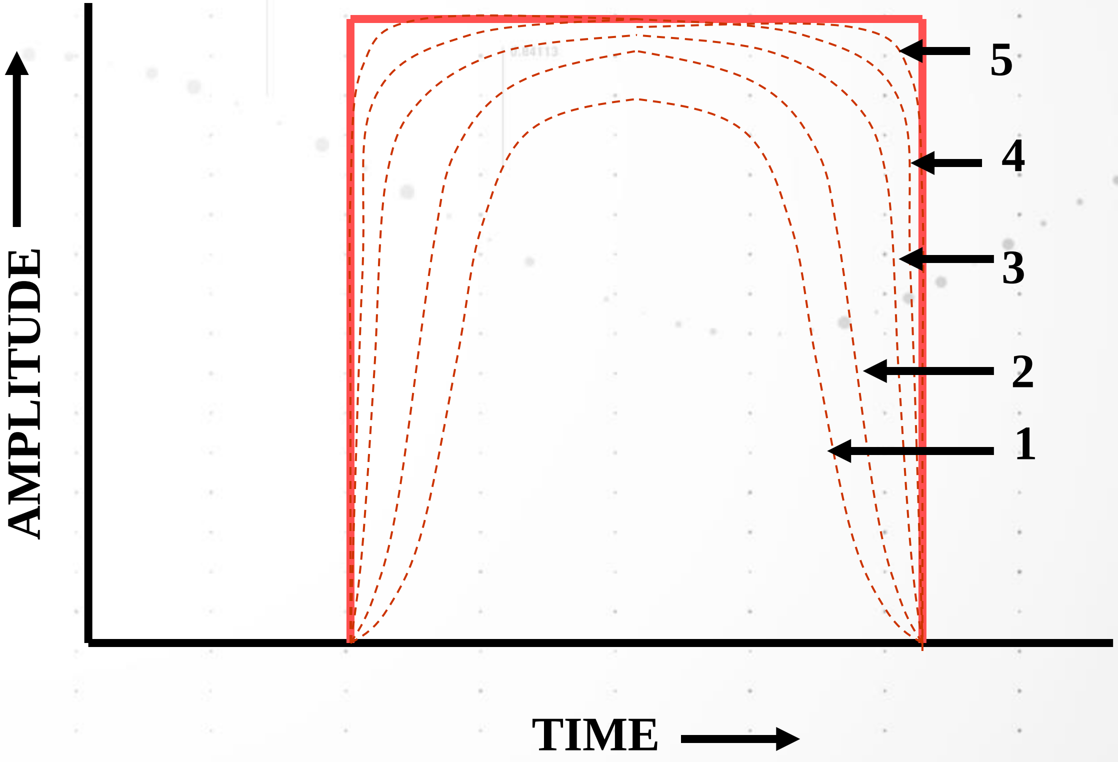
Bandwidth Basics

EVERY SIGNAL CONSISTS OF A FUNDAMENTAL AND ITS HARMONICS



Square wave in the frequency domain

Square wave in the time domain, as we add more harmonics (bandwidth)



Bandwidth Basics

HOW MUCH BANDWIDTH DO YOU NEED?

Step #1: Determine fastest rise/fall times of device-under-test.

Step #2: Determine highest signal frequency content (f_{knee}).

$$f_{knee} = 0.5/RT\ (10\% - 90\%);\ f_{knee} = 0.4/RT\ (20\% - 80\%)$$

Step #3: Determine degree of required measurement accuracy.

Accuracy	Gaussian	Maximally-flat
20%	BW = 1.0 x f_{knee}	BW = 1.0 x f_{knee}
10%	BW = 1.3 x f_{knee}	BW = 1.2 x f_{knee}
3%	BW = 1.9 x f_{knee}	BW = 1.4 x f_{knee}

Step #4: Calculate required bandwidth.

Source: Dr. Howard W. Johnson, "High-speed Digital Design – A Handbook of Black Magic"

Example:

Determine the minimum bandwidth of an oscilloscope with Gaussian frequency response to measure signals that have rise times as fast as 500 ps (10-90%) to 3%.

1. **Fastest edges = 500 ps**

2. **f_{knee} (10-90%)= (0.5/RT) = (0.5/0.5 ns) = 1 GHz**

3. **3% desired.**

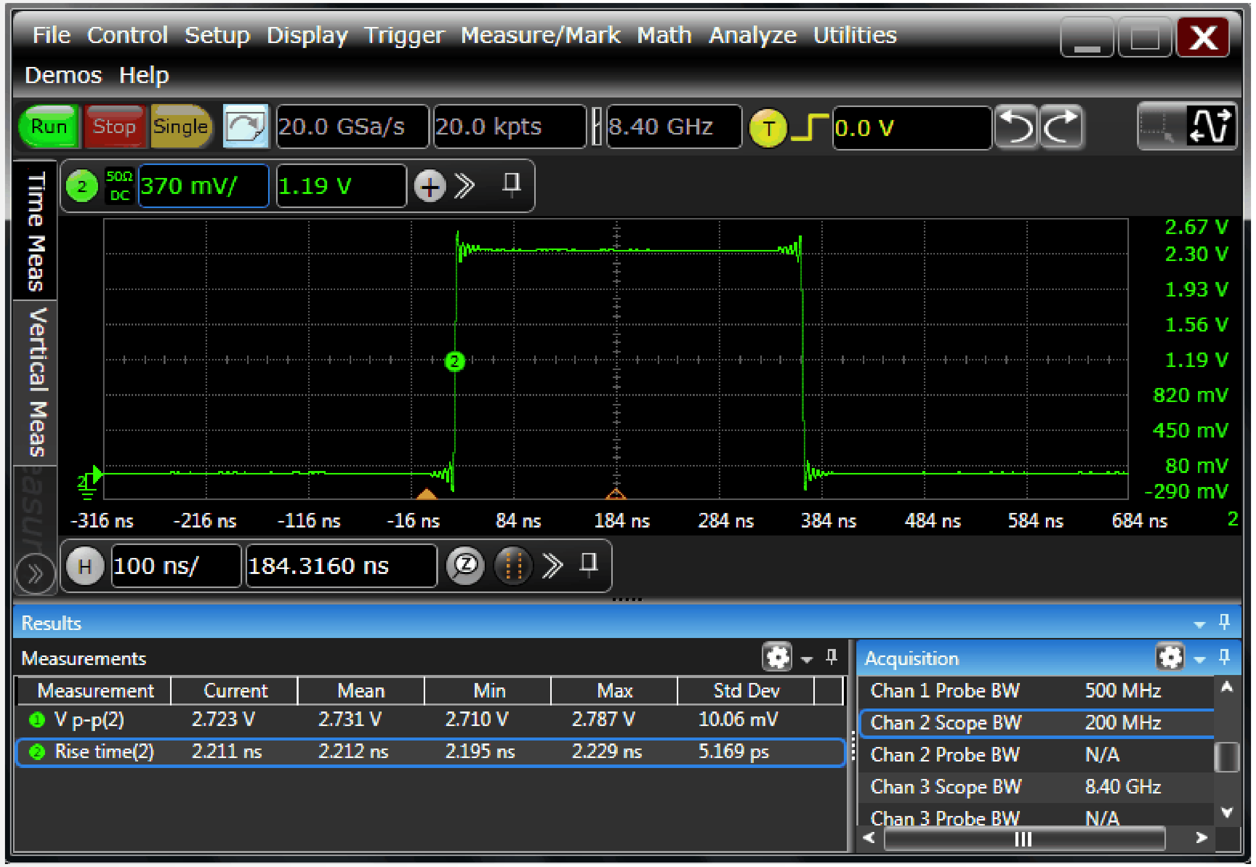
4. **BW = 1.0 x f_{knee} = 1.9 x 1 GHz = 1.9 GHz**

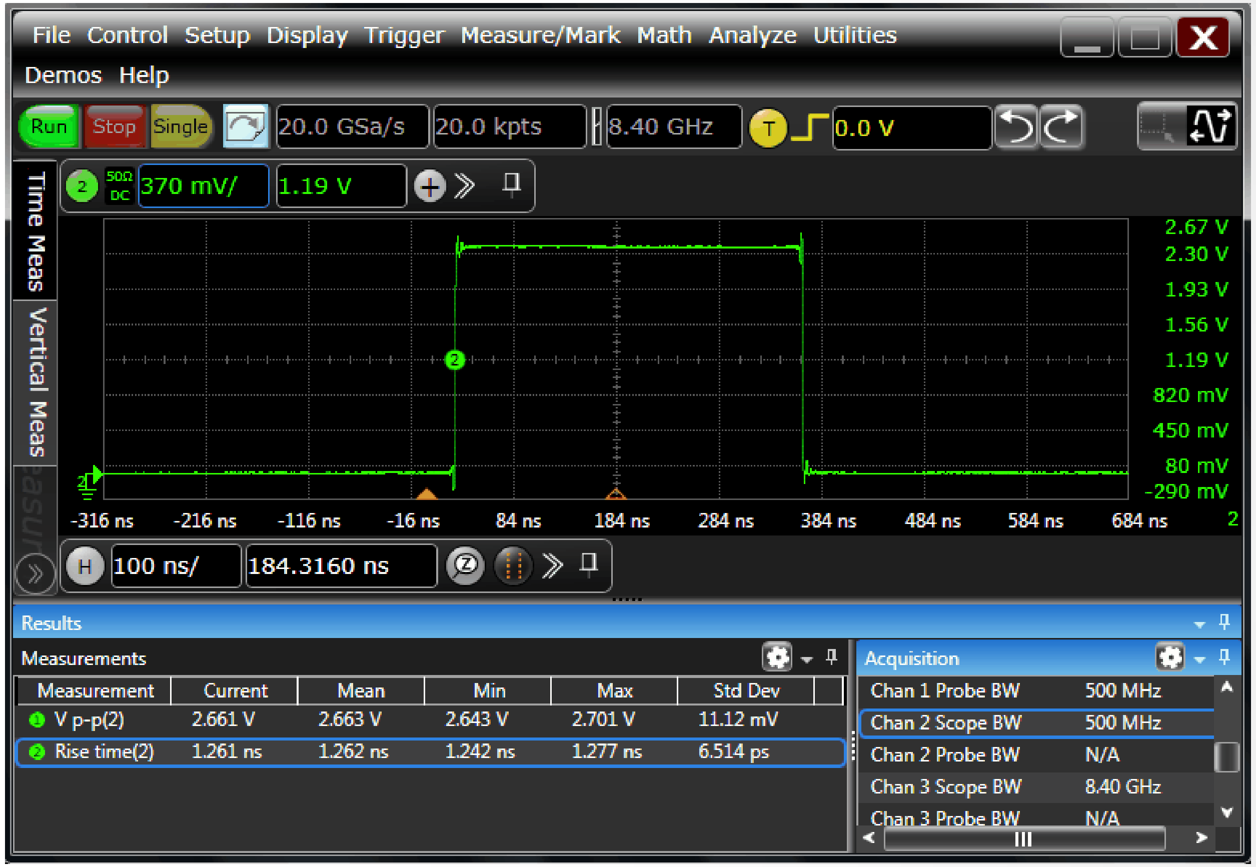
Bandwidth Basics

WHAT HAPPENS IF MY OSCILLOSCOPE IS TOO SLOW?

Bandwidth Basics

HOW MEASUREMENT QUALITY CHANGES





200 MHz Bandwidth

V_{PP} **= 2.73V**

T_{RISE} **= 2.21 ns**

500 MHz Bandwidth

V_{PP} **= 2.66V**

T_{RISE} **= 1.26 ns**

KEYSIGHT TECHNOLOGIES

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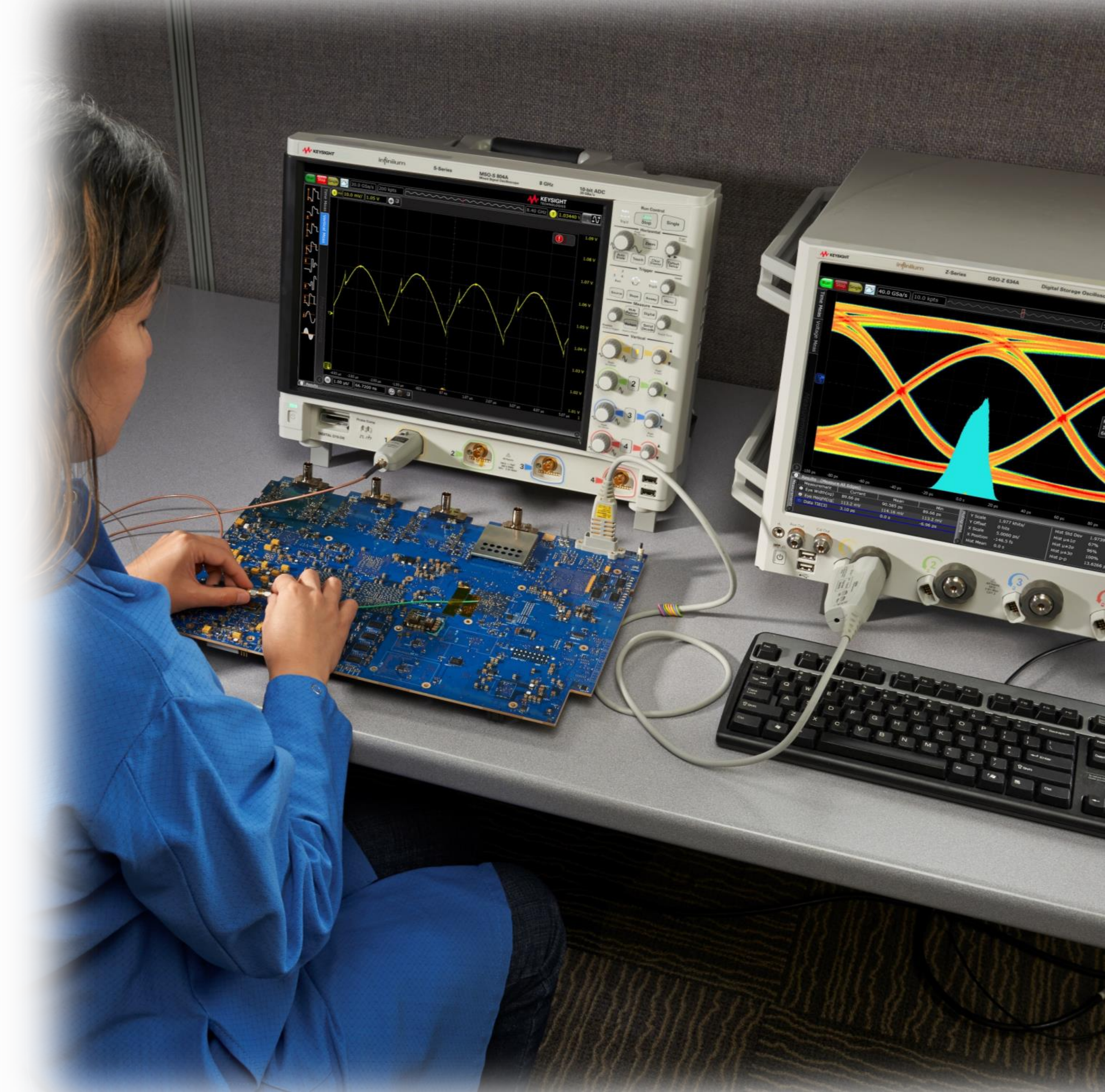
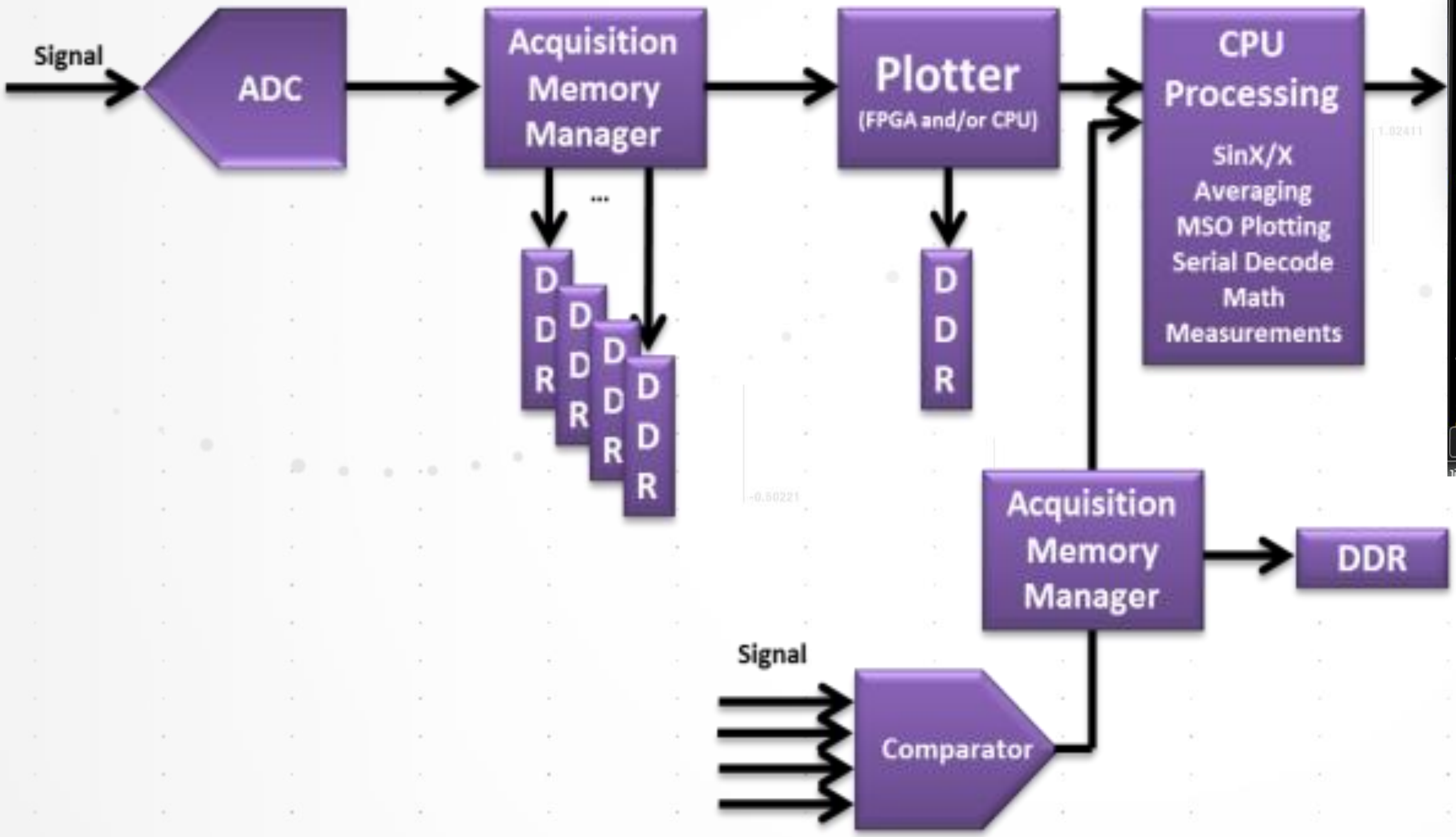
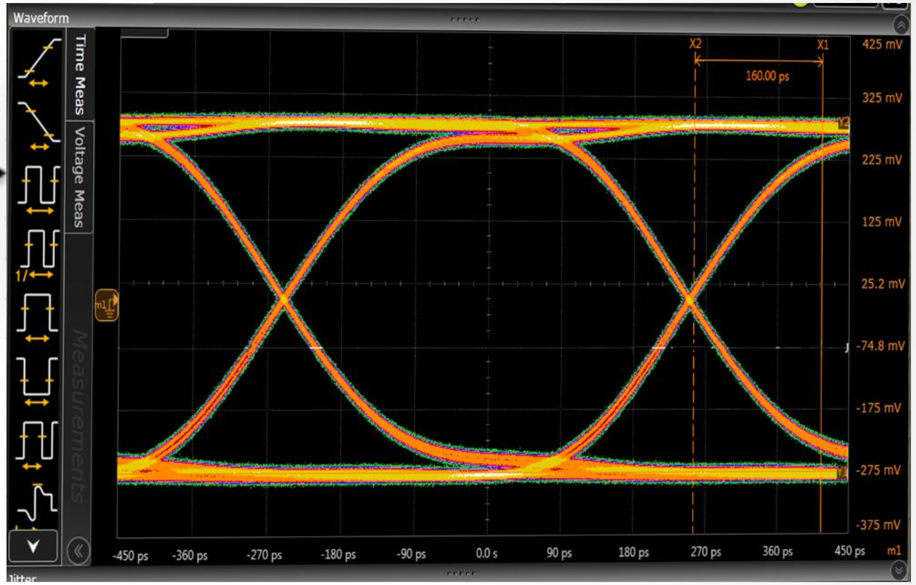


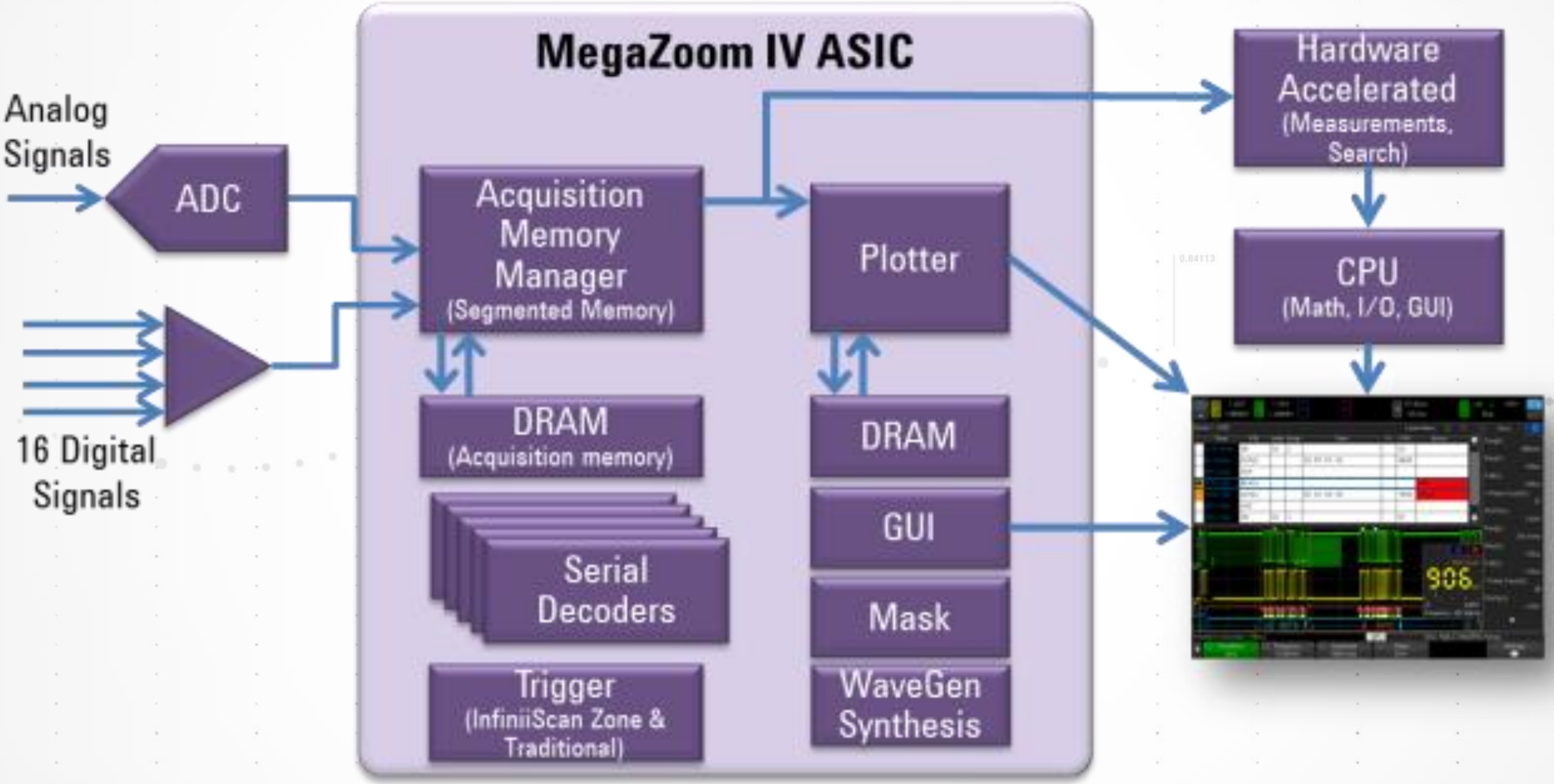
KEYSIGHT
TECHNOLOGIES

Infiniium Oscilloscope Architecture





InfiniiVision Oscilloscope Architecture



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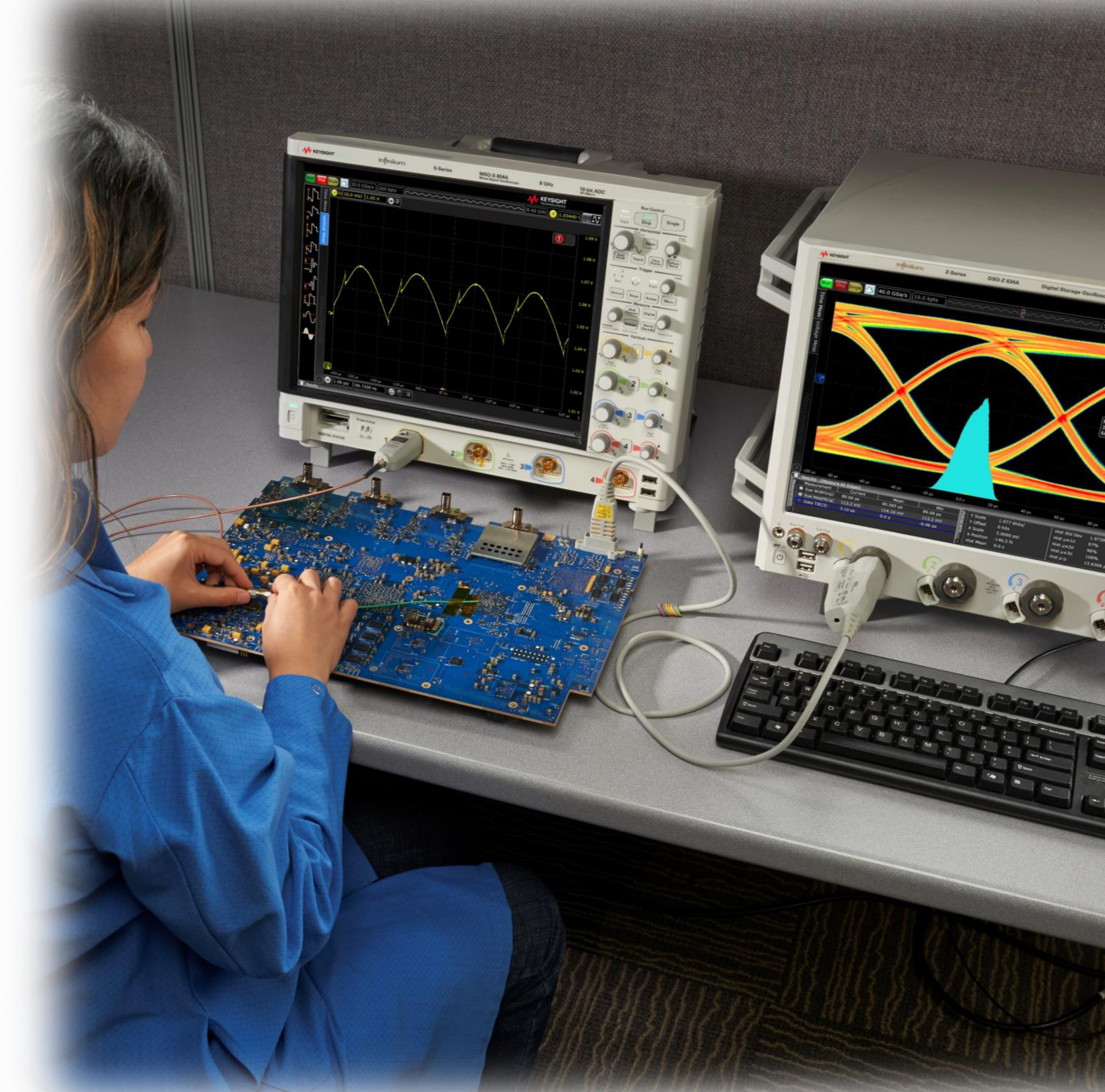
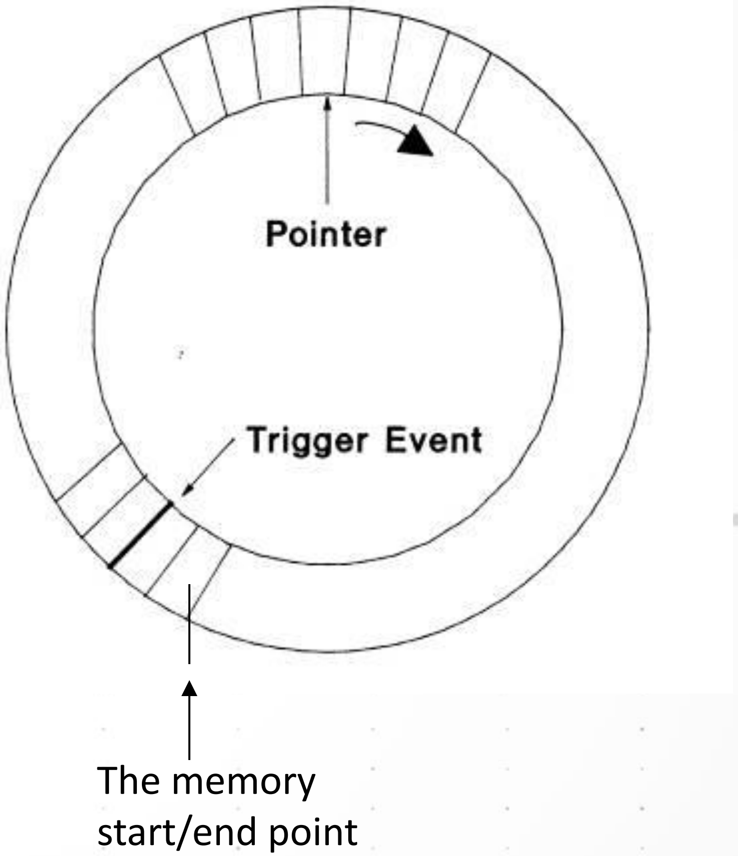


KEYSIGHT TECHNOLOGIES

Triggering

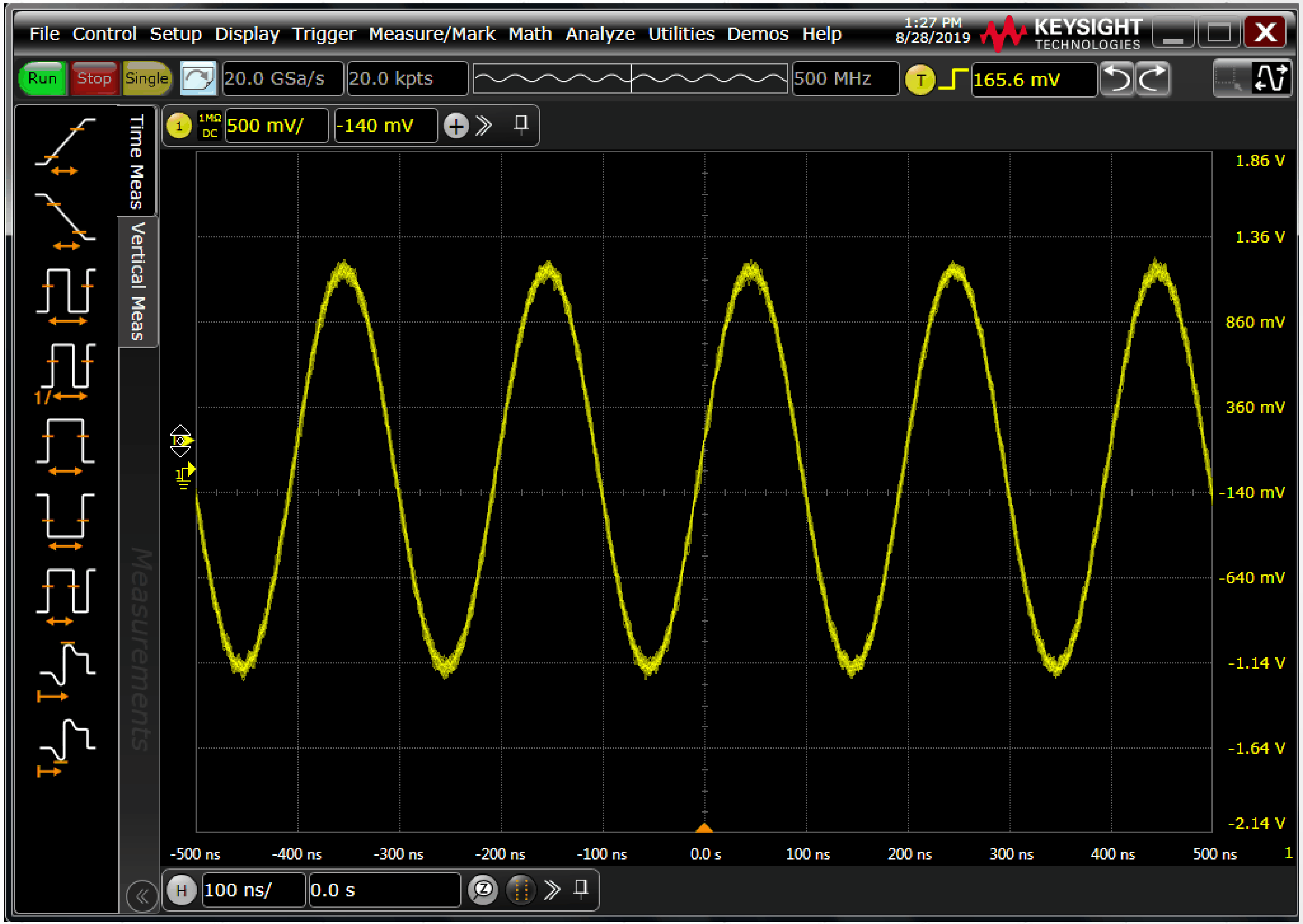
RING ACQUISITION MEMORY

- Digital scopes allow for “pre trigger” data to be saved, unlike older analog scopes. How can the scope do this? With a unique memory structure!
- This allows you to define how much time and data you want to see before and/or after the trigger event.



Triggering

EDGE TRIGGER (DEFAULT)

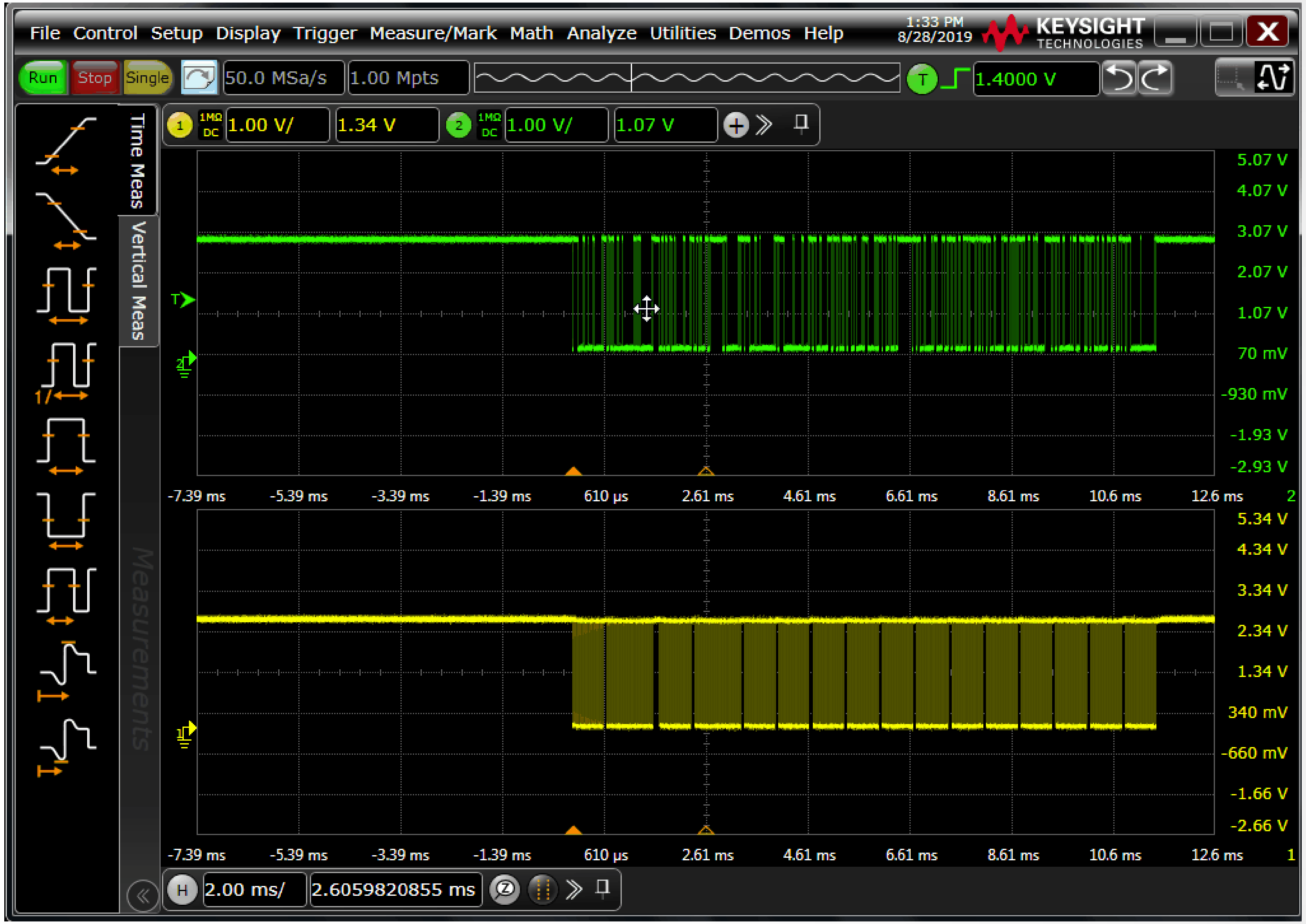


Triggering

ADVANCED OSCILLOSCOPE TRIGGERING

Much of your oscilloscope use will only require standard “edge” triggering. Sometimes your signal is more complex, like this serial bus.

Triggering on more complex signals requires advanced triggering options.



Example: Triggering on an I²C serial bus

Triggering

ADVANCED TRIGGERS

Advanced triggers are just more complex ways to describe the shape of a waveform, such as the pulse width trigger described in the video here.

Triggering

VISUAL TRIGGERING MAKES LIFE EASY

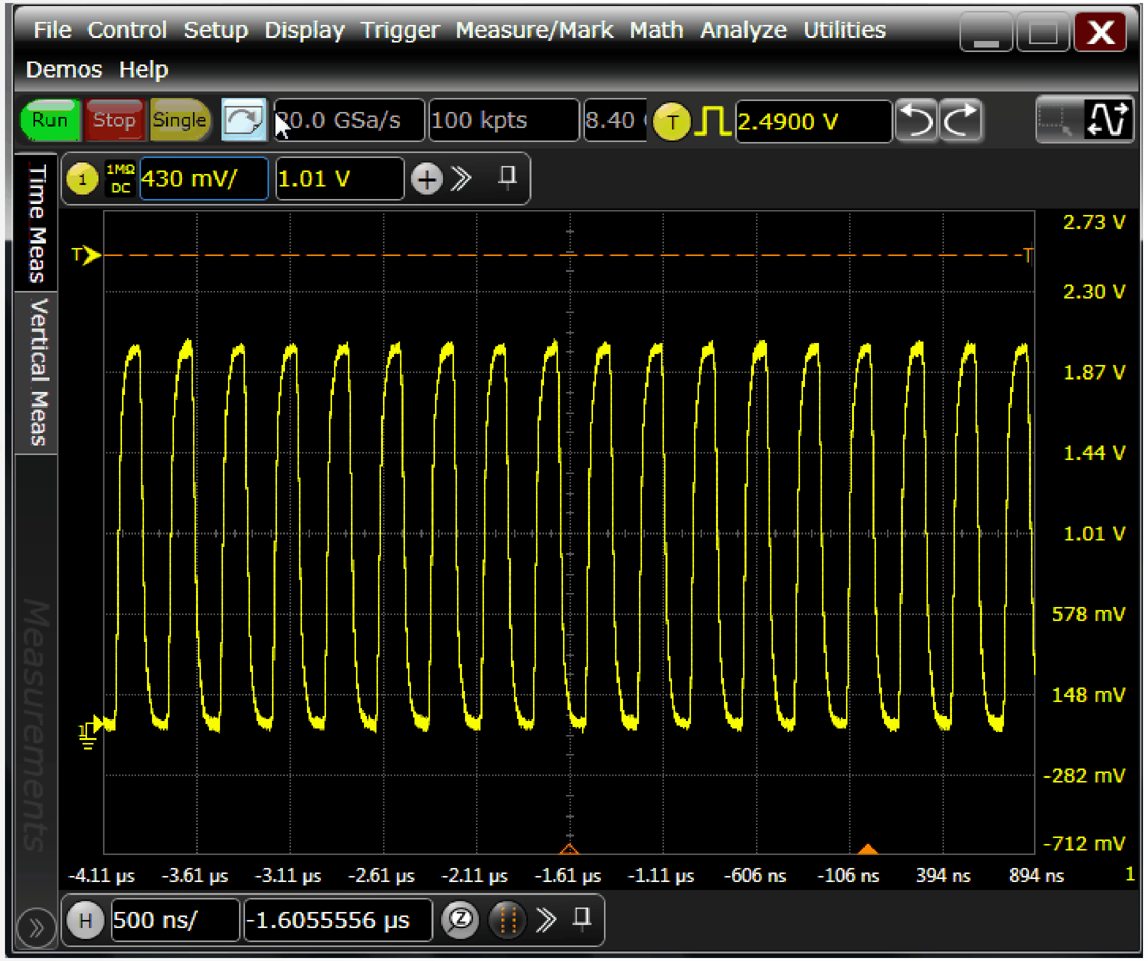
InfiniiScan trigger allows you to use a simple edge trigger and still trigger on complex waveform shapes.

It can be used to create up to a three stage trigger: Use A→B trigger, plus InfiniiScan, for two hardware triggers and the additional software InfiniiScan trigger for ultimate triggering control.

KEYSIGHT TECHNOLOGIES

Triggering

AUTO VS. NORMAL: WHAT IF THE SCOPE SEES NO TRIGGER?



Auto trigger: “I don’t see a trigger; I’ll trigger on my own”

Normal trigger: “I don’t see a trigger; I’ll do nothing at all”

Triggering Basics

HOW TO DEAL WITH NOISY SIGNALS

Noisy signals often “double trigger” as the noise is so large, there are large enough rising edges on the falling edge to trigger. Two solutions:

High Frequency Reject

A low pass filter is put into the trigger circuit. Signal display unchanged, but high frequency noise is ignored for triggering.

Pros: high frequency signals won’t accidentally trigger the scope.

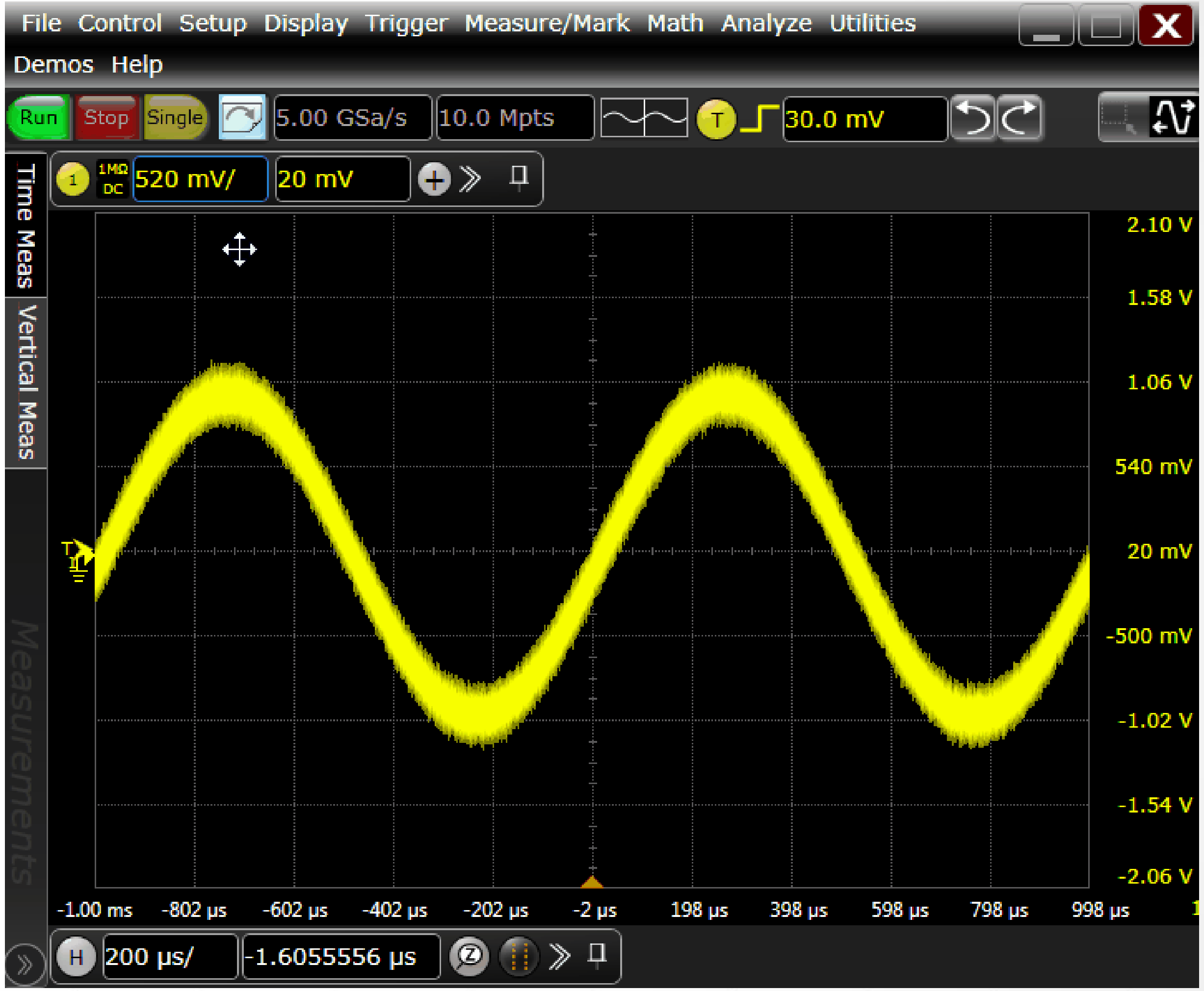
Cons: This won’t work at all for high frequency signals (generally >50 kHz)

Noise Reject

A larger “hysteresis” is put into the trigger circuit. This requires a larger “swing” to validate as a rising/falling edge.

Pros: will work for any frequency signal.

Cons: If you are working with small voltages/currents, the hysteresis required may be too large compared to your signal.



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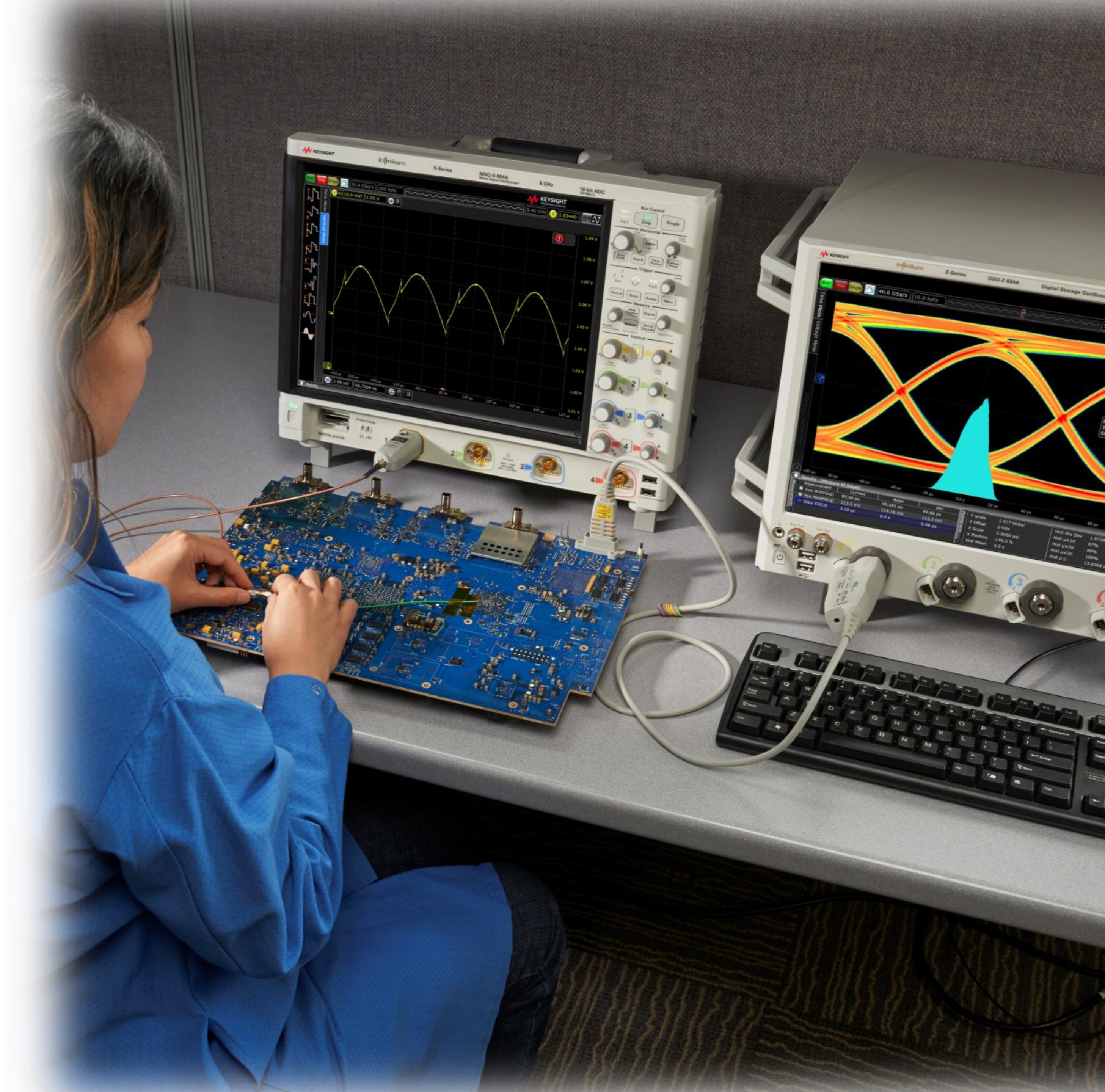


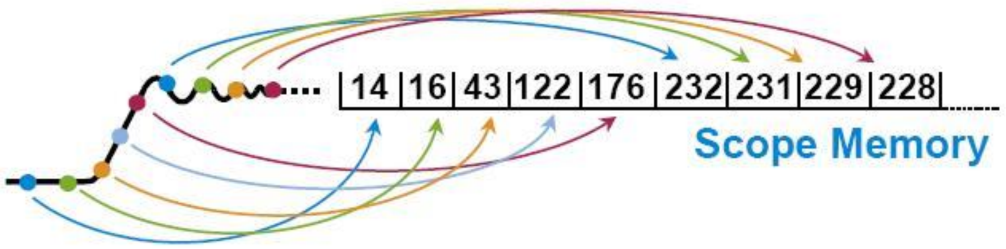
Memory Depth

HOW MANY SAMPLES CAN THE OSCILLOSCOPE TAKE AT ONCE?

- Measured in samples or points. Modern scopes have millions or billions of samples in memory.
- Longer periods of time means more samples to store in order to maintain sample rate.
- Maintaining a higher sample rate means:
  - more accurate reproduction of signal
  - Better resolution between points
  - Better chance of catching glitches or anomalies

Takeaway: more memory is often better: better measurements, better at finding anomolies!

In this image, we see a waveform being sampled into memory as a value from 0 to 255 (8 bit ADC).



Memory Depth

HOW MUCH MEMORY DO I NEED?

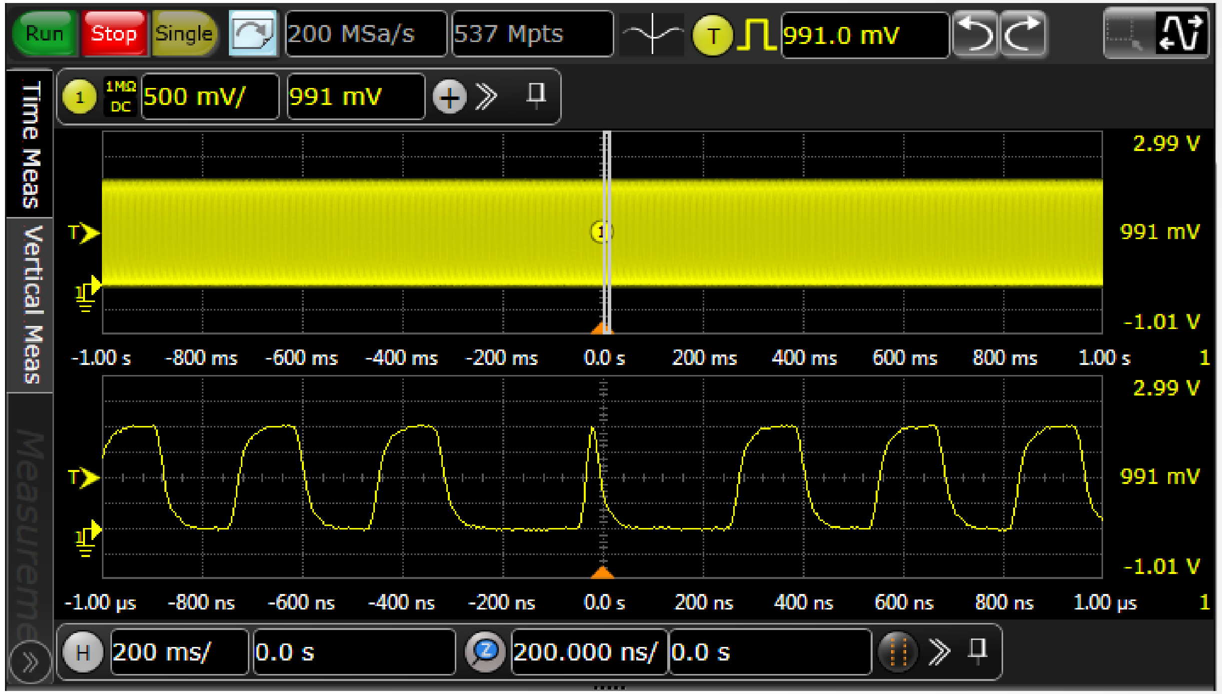
Determine required sample rate

- *See first section about determining sample rate*

Determine longest time-span to acquire

- *Usually based on slowest analog signal or digital packets*

$$Memory\ Depth\ (Sa) = Sample\ Rate\ \left(\frac{Sa}{s}\right) * Time\ (s)$$

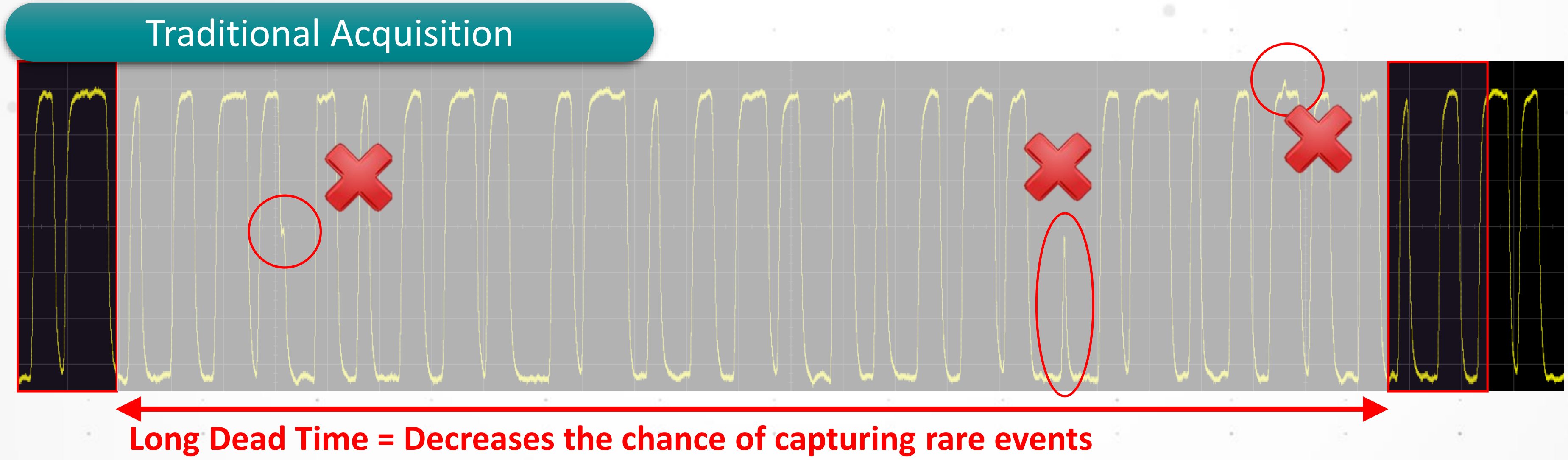


Example:
Required Sample Rate = 200 MSa/s
Longest Time Span = 2 s (200 ms/div)
Required Memory Depth = 2 s * 200 Msa = 400 MSa

Memory Depth

POSSIBLE NEGATIVE IMPLICATIONS OF DEEP MEMORY

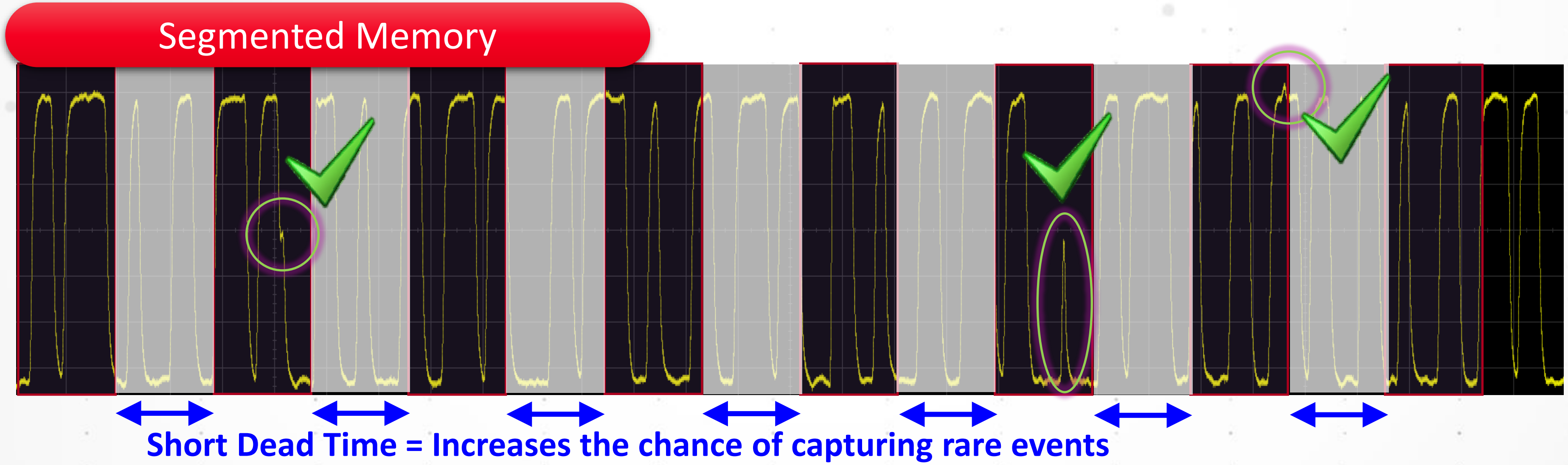
- Slower update rate: more time to process each waveform.
- Time between waveform updates is called “dead time”; the scope is not digitizing.
- Glitches or anomalies can be missed during this dead time.



Memory Depth

POSSIBLE NEGATIVE IMPLICATIONS OF DEEP MEMORY

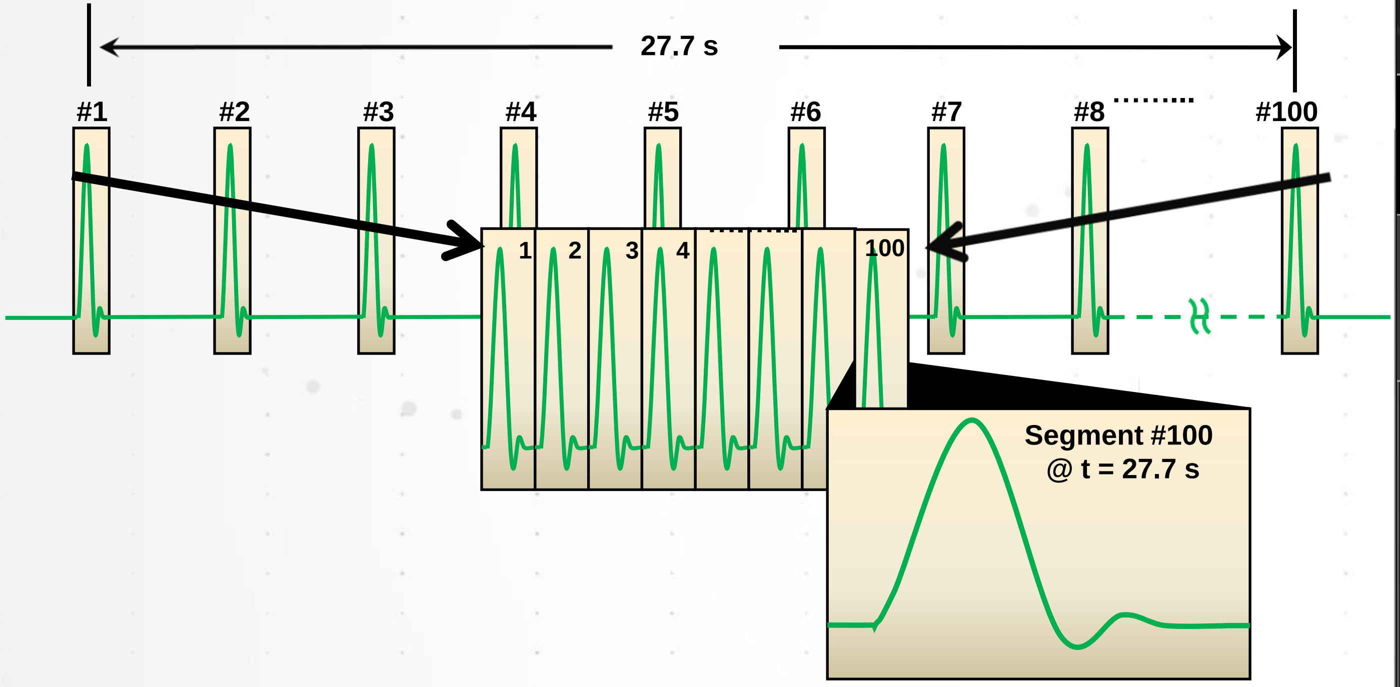
- Segmented memory decreases the dead time significantly
- Limitation: measurements can't be done in real time, only after a number of segments have been acquired.

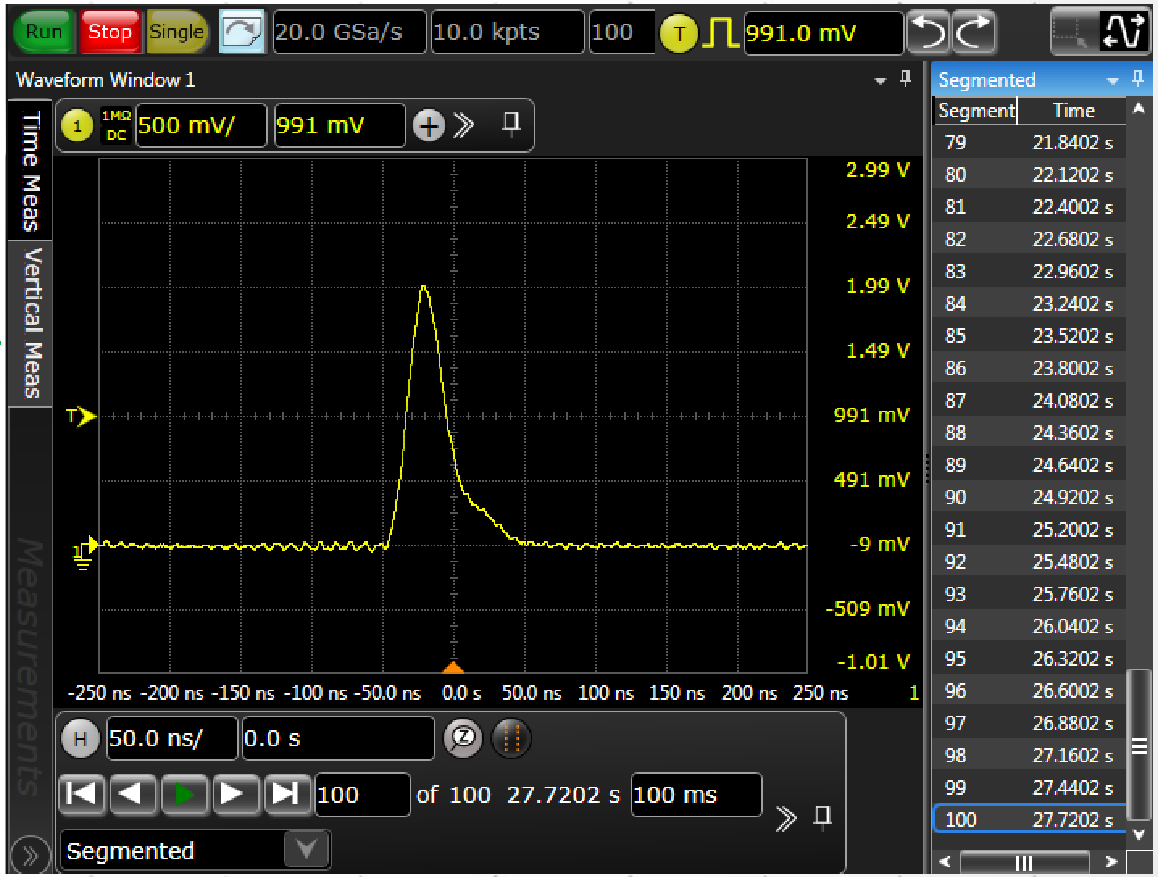


Memory Depth

SEGMENTED MEMORY ACQUISITION

Selectively captures more waveform data with precise time-stamps for each segment





Equivalent Memory = Time-span x Sample Rate

554 Gigasamples = 27.7 s x 20 GSa/s

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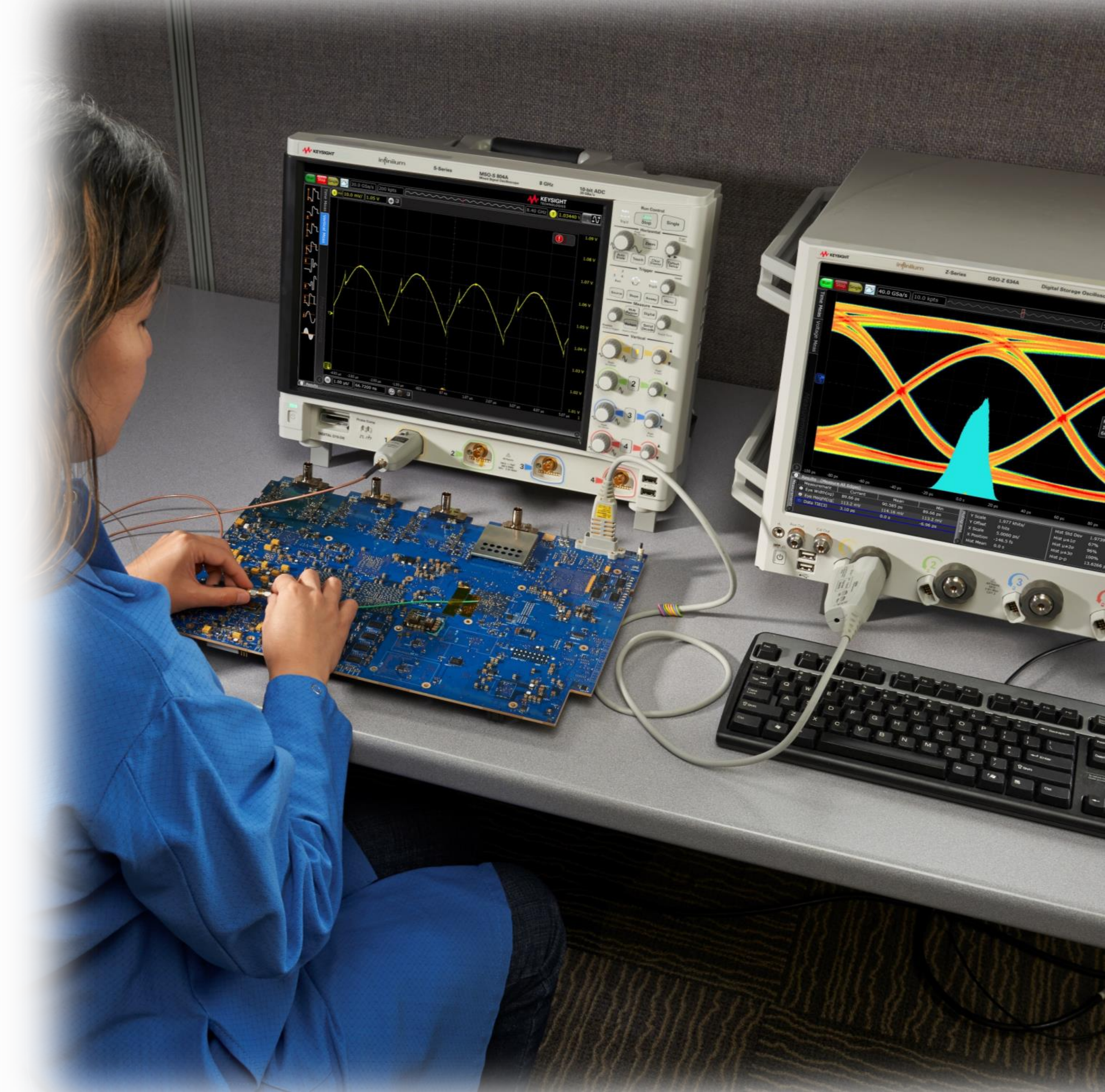


Waveform Visualization Tools

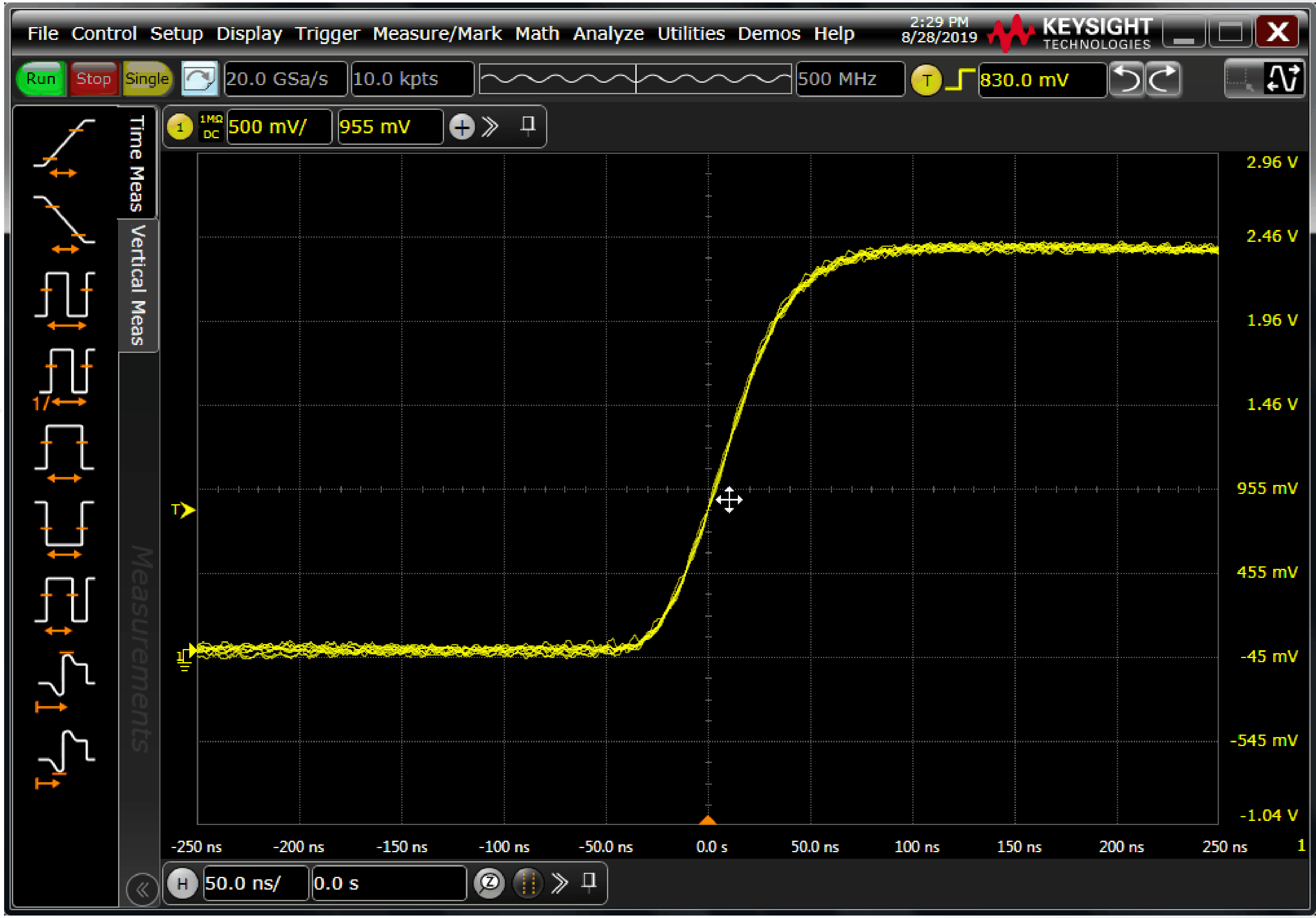
GETTING MORE INFO FROM DATA

- Persistence mode
- Triggering on noisy signals
- Average mode
- Real time eye diagrams
- Color grading / histograms

Waveform Visualization Tools

PERSISTENCE / COLOR GRADE

Lets you view infrequent signals that may pop on/off screen quickly, as well as the probability of that signal’s occurrence



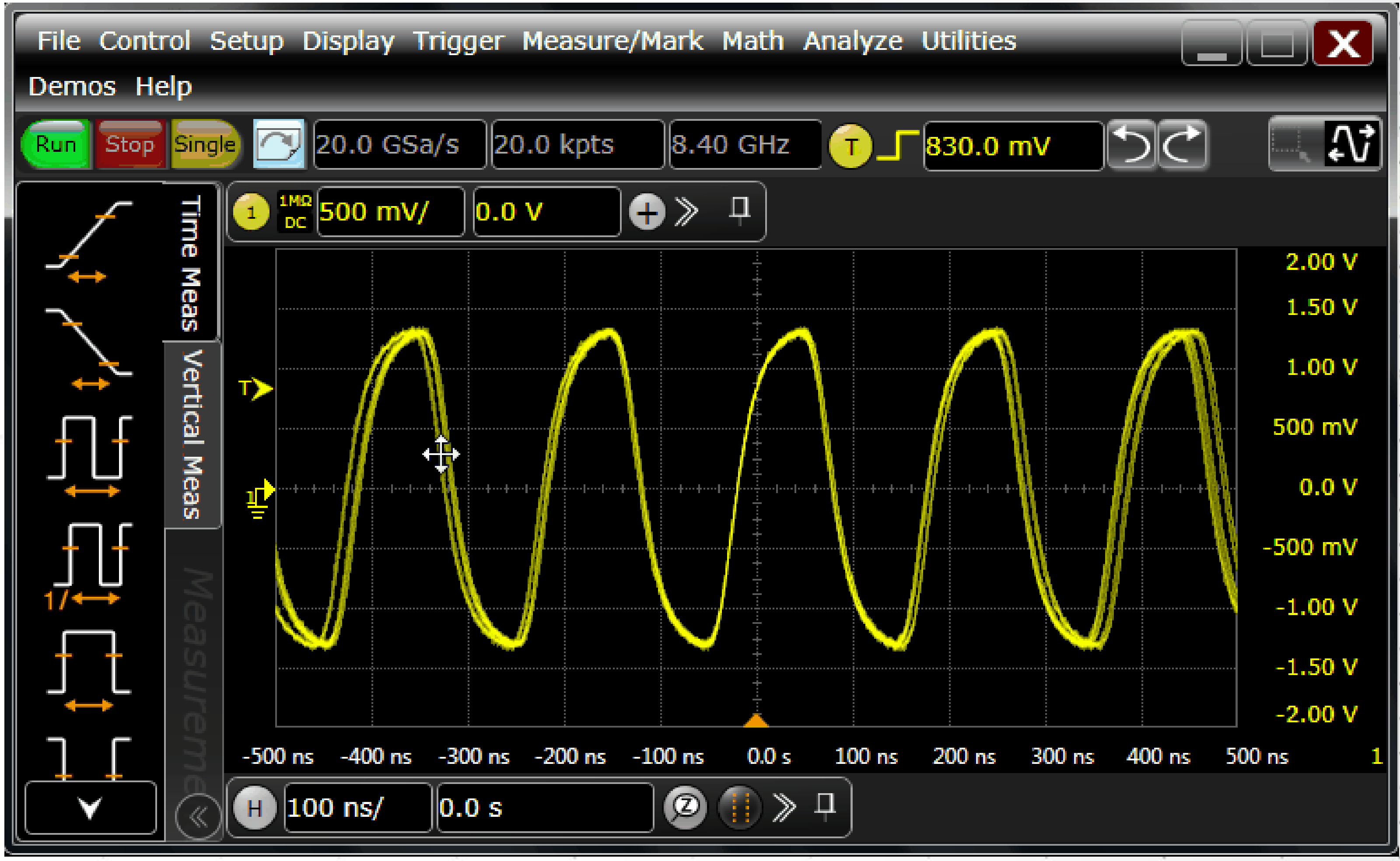
Waveform Visualization Tools

HISTOGRAM

Distribution of a *signal* within a region on screen

OR…

Distribution of *measurement results* (as exemplified)



Waveform Visualization Tools

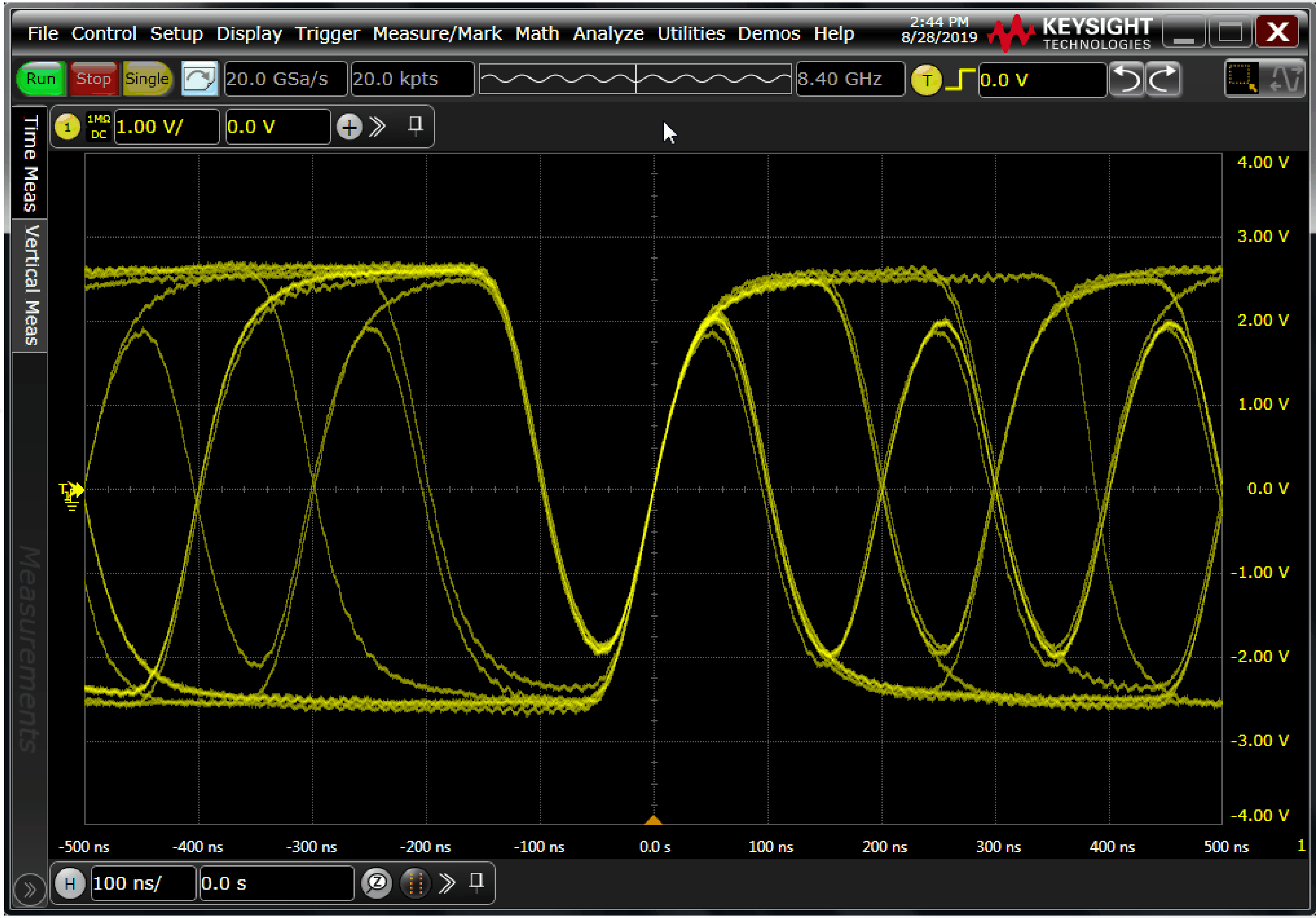
MEASUREMENT TRENDS

Show how a signal changes with time in respect to a particular measurement, such as frequency (pictured)

Waveform Visualization Tools

REAL TIME EYE DIAGRAMS

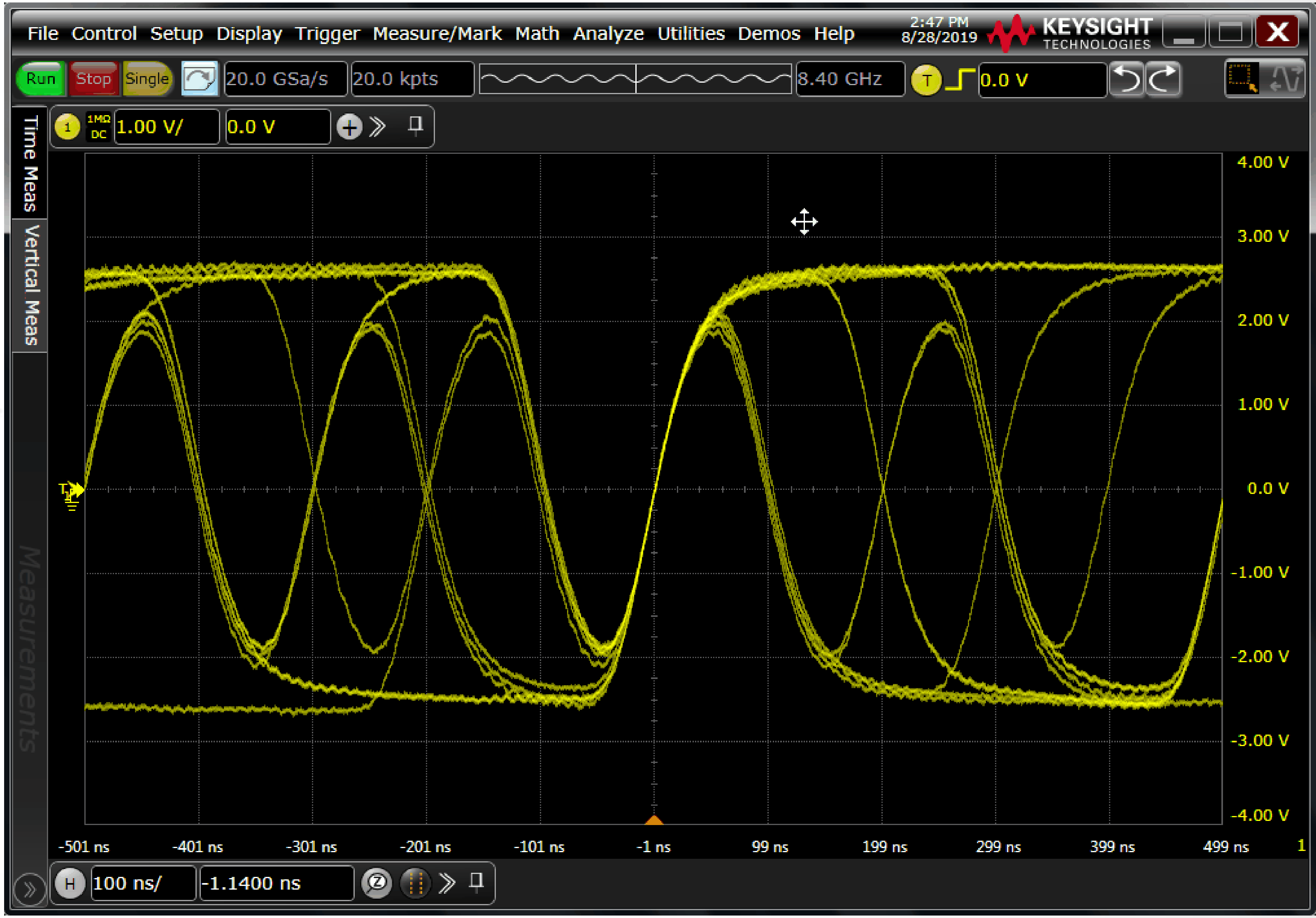
Overlay of millions of bits on top of each other to detect physical layer issues in a serial data stream.



Waveform Visualization Tools

JITTER ANALYSIS

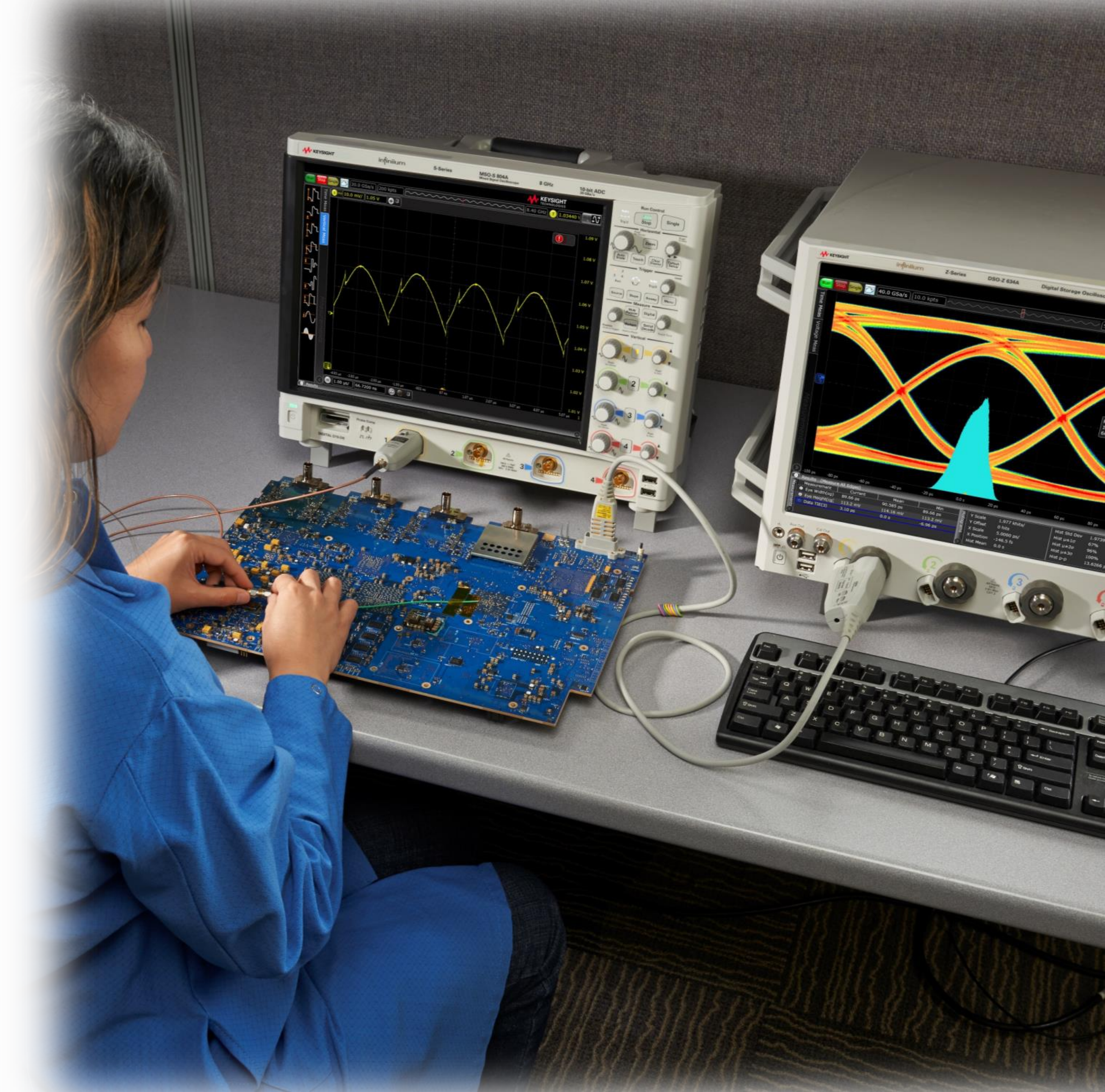
Let the scope run dozens of automatic measurements and build plots, dissecting the details of your real time eye diagram, giving you information on where jitter is coming from in your design.



Oscilloscope Fundamentals

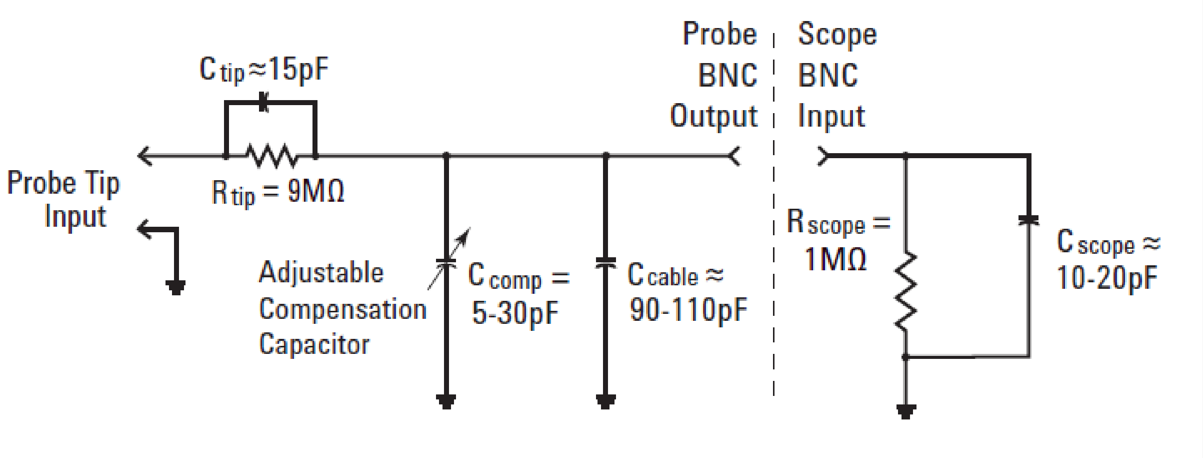
AGENDA SLIDE

- Time vs. Frequency Domain
- Sampling Rate and Modes
- Bandwidth and Aliasing
- Oscilloscope Architectures
- Triggering: Basics and Advanced
- Memory Depth and Methods
- Waveform Visualization Tools
- Probing Architecture, Tips and Tricks



Probing Architecture, Tips, and Tricks

RESISTOR DIVIDER PROBES – BLOCK DIAGRAM

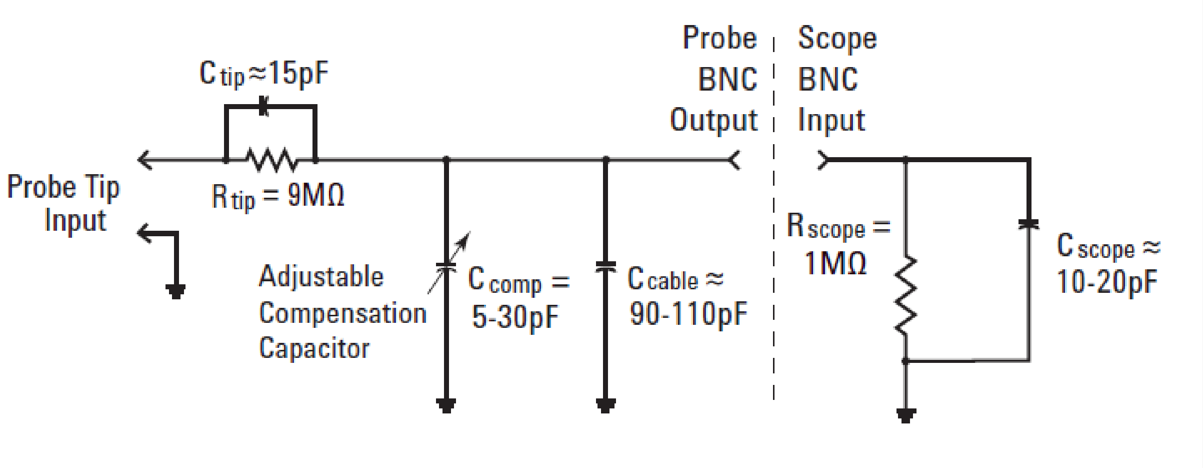


Passive 10:1 Probe Model

- Capacitors act as open circuits at low frequency.
- Inductors act as short circuits at low frequency.
- Simplifies to a 9-MΩ resistor in series with the scope’s 1-MΩ input termination.

Probing Architecture, Tips, and Tricks

RESISTOR DIVIDER PROBES – BLOCK DIAGRAM

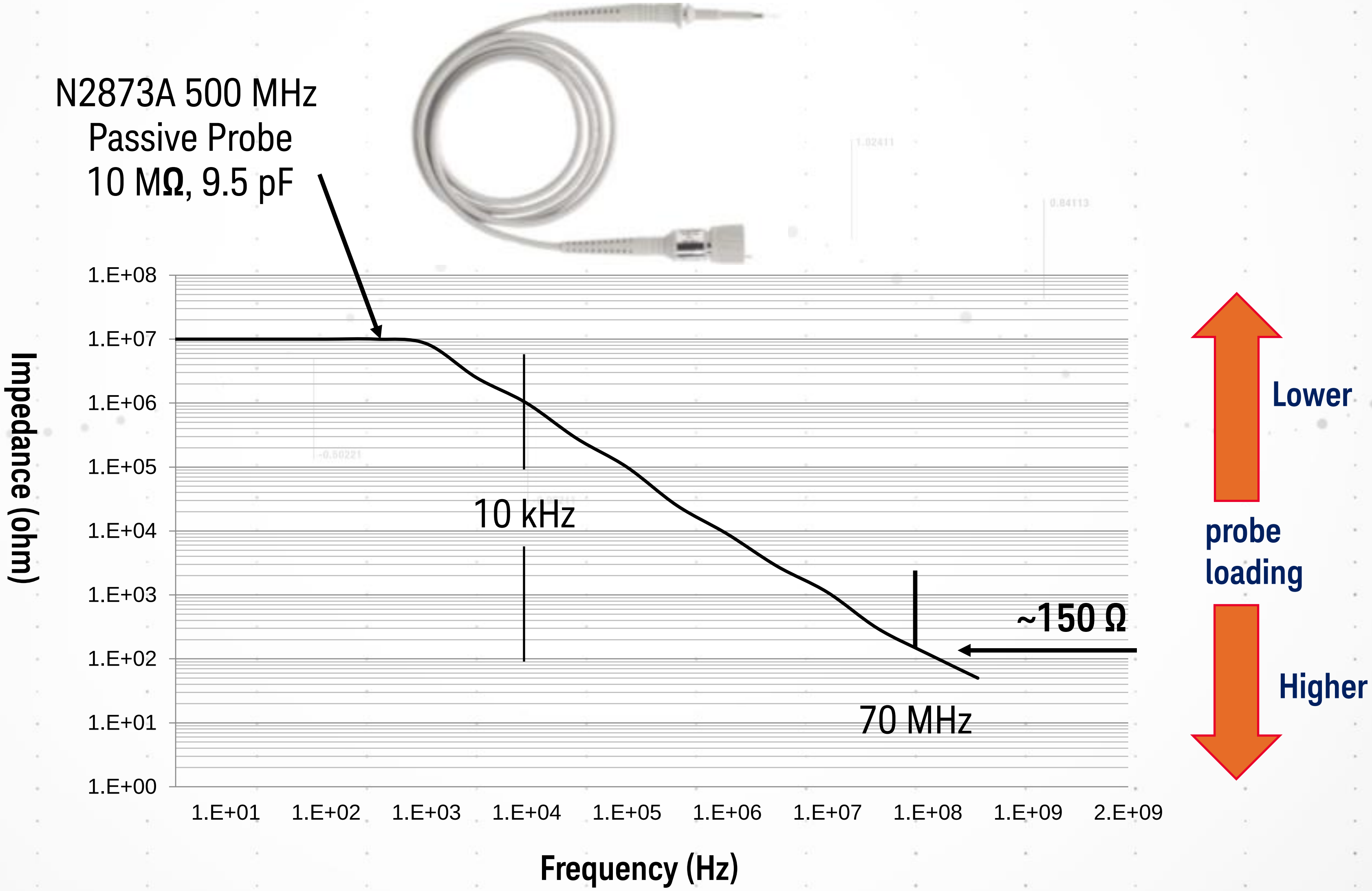


Where $C_{parallel}$ = C_{comp} + C_{cable} + C_{scope}

- At high frequency, we get an impedance divider, because capacitors will begin to express non-real resistances on our circuit.
- C_{comp} is adjusted by the user to create a 10:1 divider of capacitive elements using the following formula: $9\,C_{tip} = C_{parallel}$

Probing Architecture, Tips, and Tricks

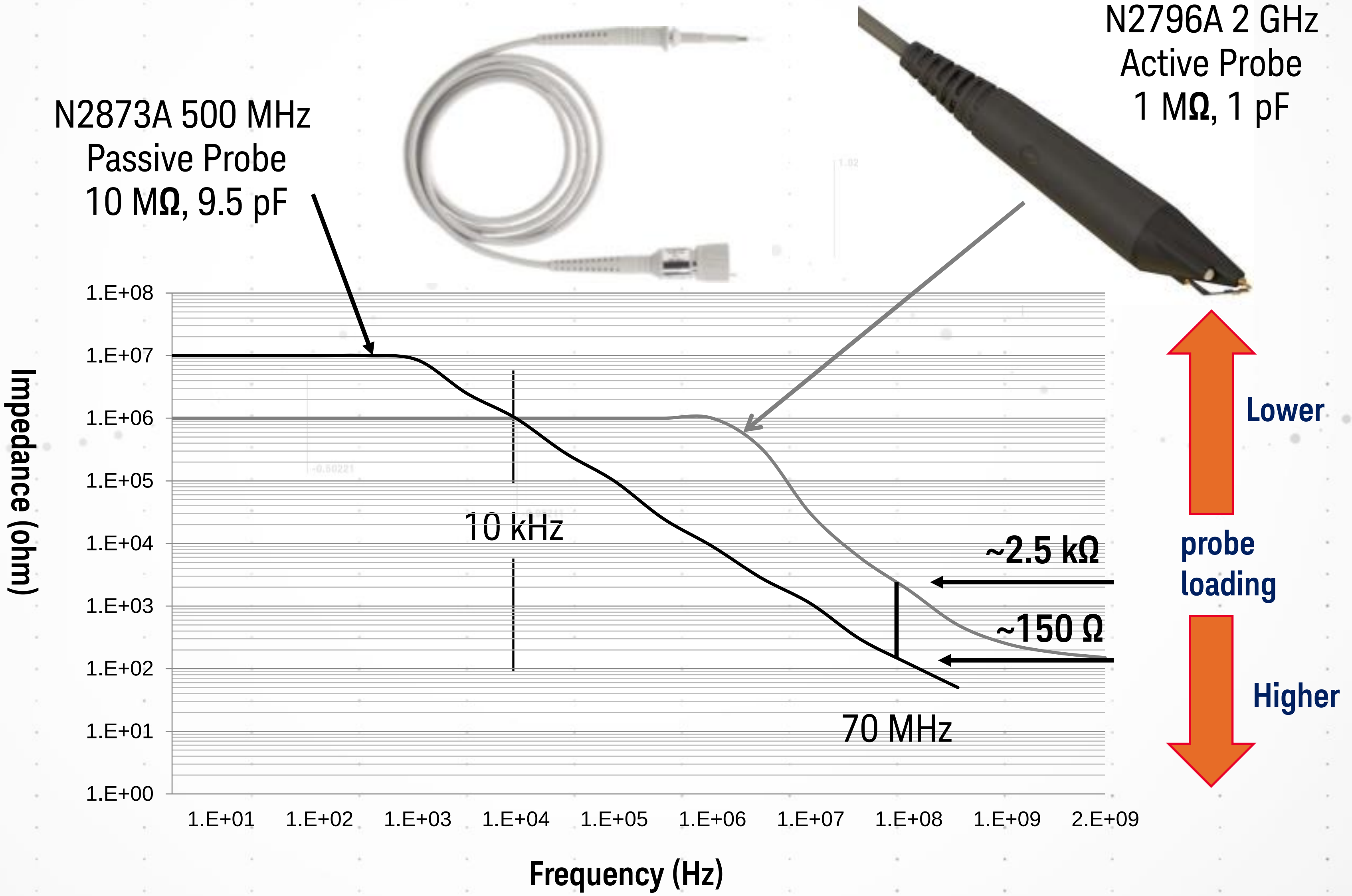
RESISTOR DIVIDER PROBES – LOADING CHARACTERISTICS



KEYSIGHT TECHNOLOGIES

Probing Architecture, Tips, and Tricks

ACTIVE PROBE LOADING IS SUPERIOR TO PASSIVE



So what's the point?

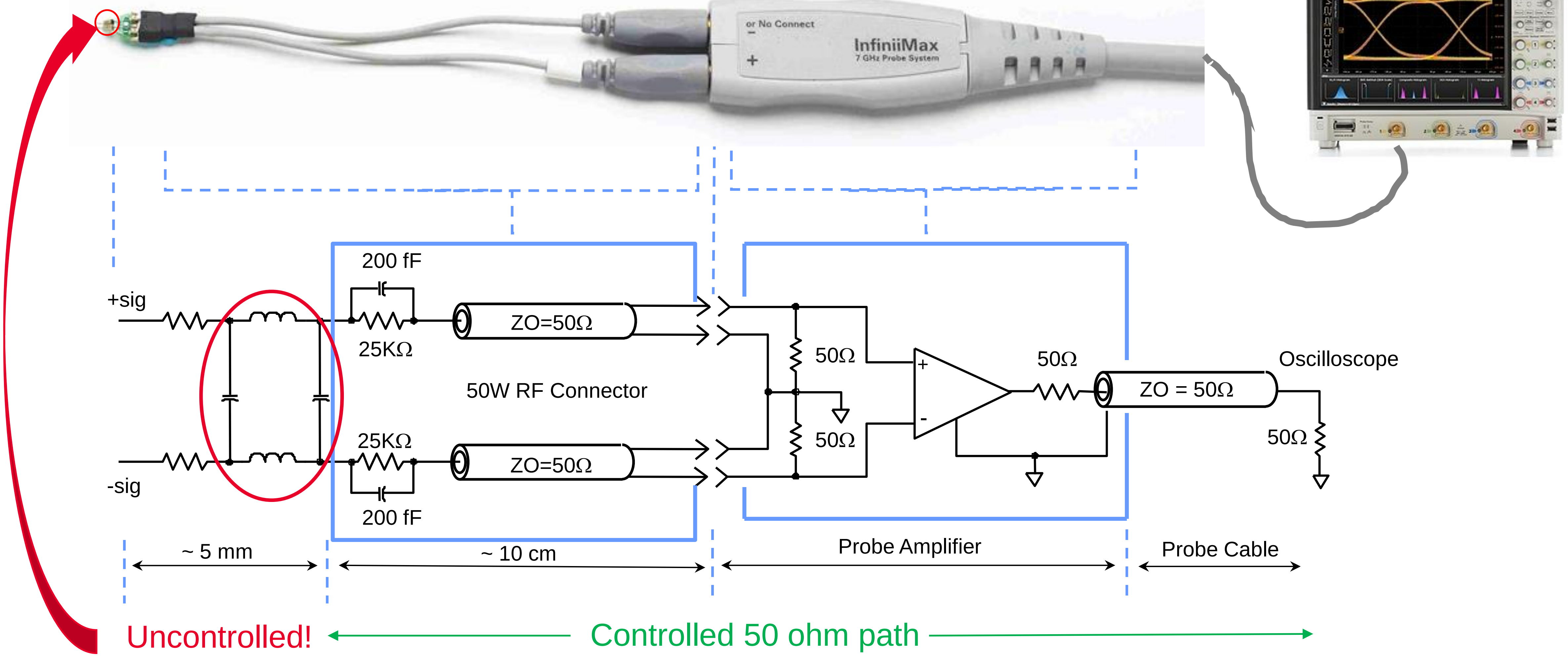
A probe can:

- Change the signal shape on screen
- Change the signal on the DUT itself (!!)

Let's take a look…

InfiniiMax I/II Probe Architecture

This uncontrolled ~4 mm tip leads may have a huge effect on the performance of your probe and the entire measurement system

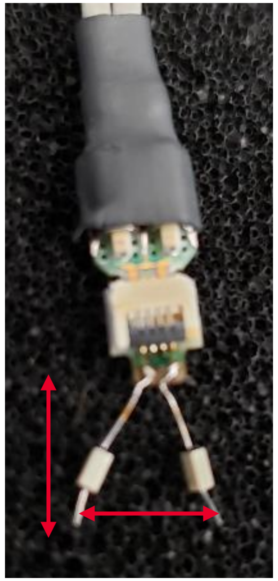


Varying Lead Length/Span Affects <u>Probe Bandwidth</u>

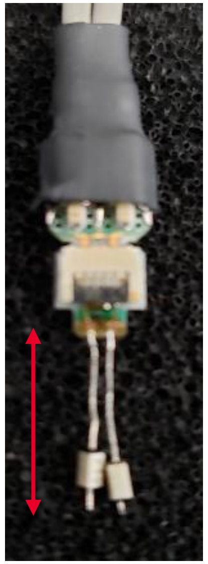
InfiniiMax II N5425B ZIF head + N5426A ZIF tips or N5451A Long-wire ZIF tips

2mm, 12.3 GHz

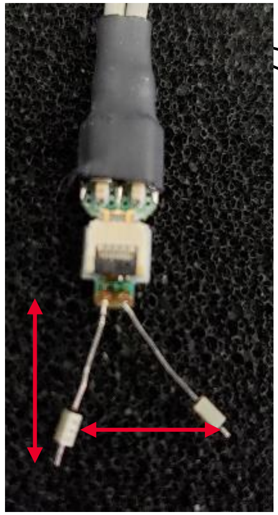
7mm, 9.9 GHz



7mm, 60 deg, 4.4 GHz



11mm, 0 deg, 5 GHz



11mm, 60 deg, 3.3 GHz

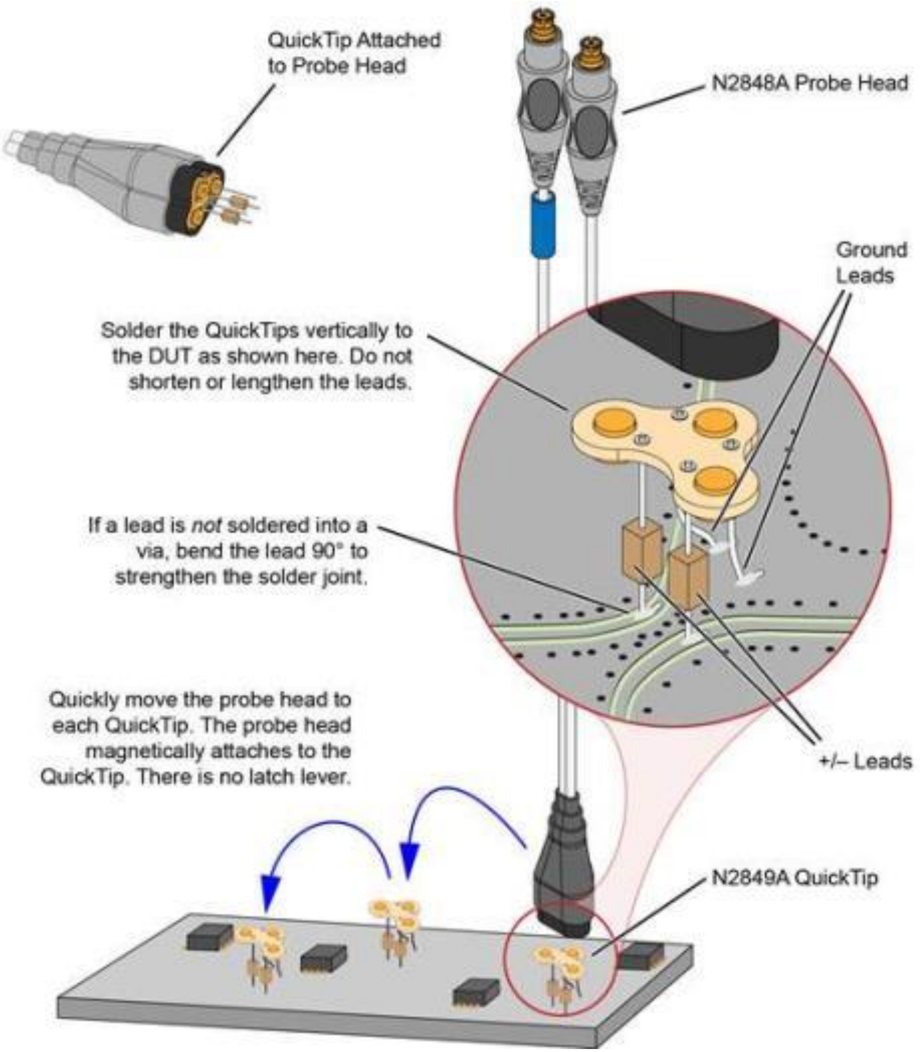
Longer lead wires

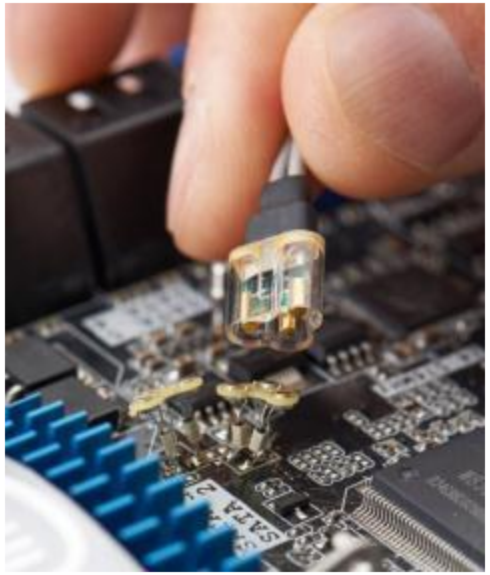
Wider pitch span

Lower bandwidth

Bandwidth is reduced with increased lead wire length and loop area created by two input leads. **Keep it short and a small loop area.**

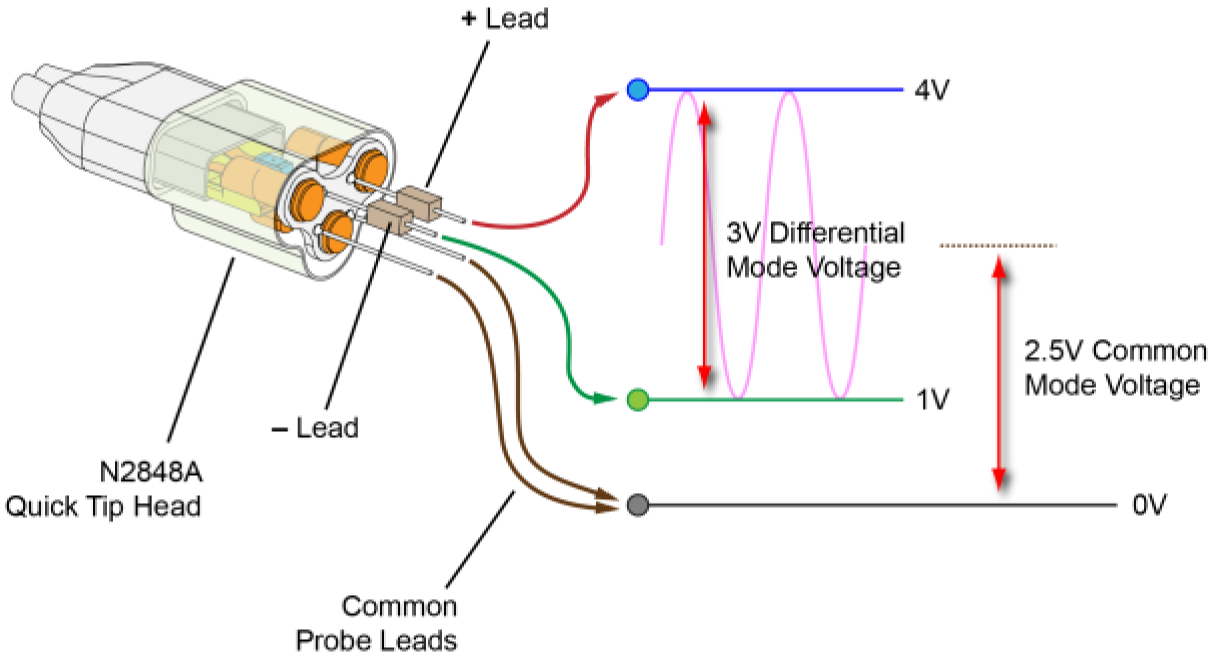
QuickTip probe head and tips





What is *InfiniiMode*?

InfiniiMode allows convenient measurement of differential, single-ended and common mode signals with a single probe tip without reconnecting the probe from its connection point.



Differential

$$A - B = 4V - 1V = 3V$$

Common Mode

$$\frac{A + B}{2} = \frac{4V + 1V}{2} = 2.5V$$

Single-Ended A

$$A - gnd = 4V - 0V = 4V$$

Single-Ended B

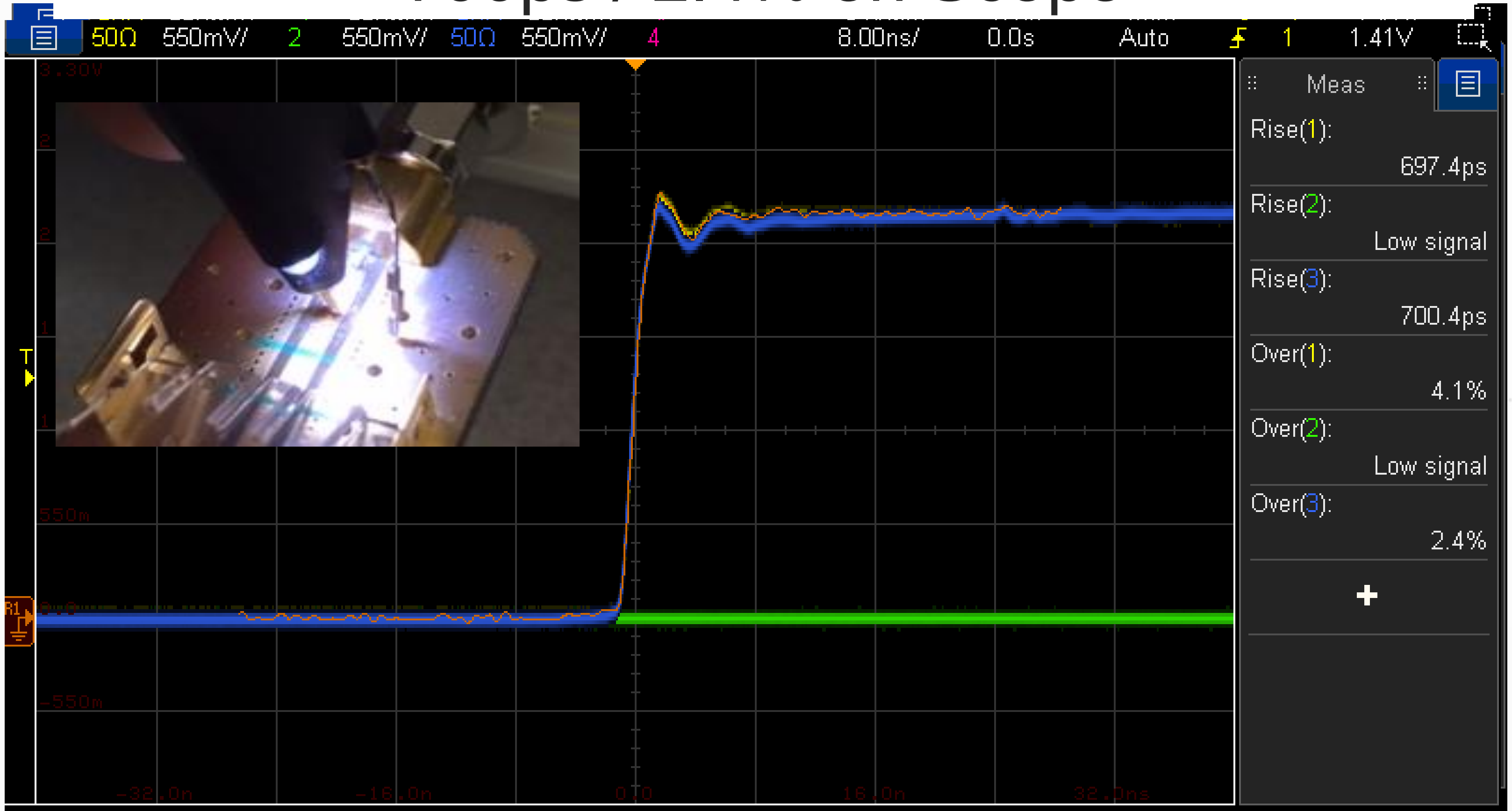
$$B - gnd = 1V - 0V = 1V$$

Probing Architecture, Tips, and Tricks

Yellow trace: signal going direct into channel 1 using pass through board
Green trace: signal probed with passive probe into channel 2
Blue trace: signal probed with active probe into channel 3

In images 2 and 3, yellow trace is the signal “on the DUT” via pass thru

With Active Probe:
697ps / 4.1% on DUT
700ps / 2.4% on Scope



BETTER LOADING + FLATTER RESPONSE = BETTER MEASUREMENTS

Probing Architecture, Tips, and Tricks

DIFFERENTIAL PROBES – CRITICAL FOR FLOATING MEASUREMENTS

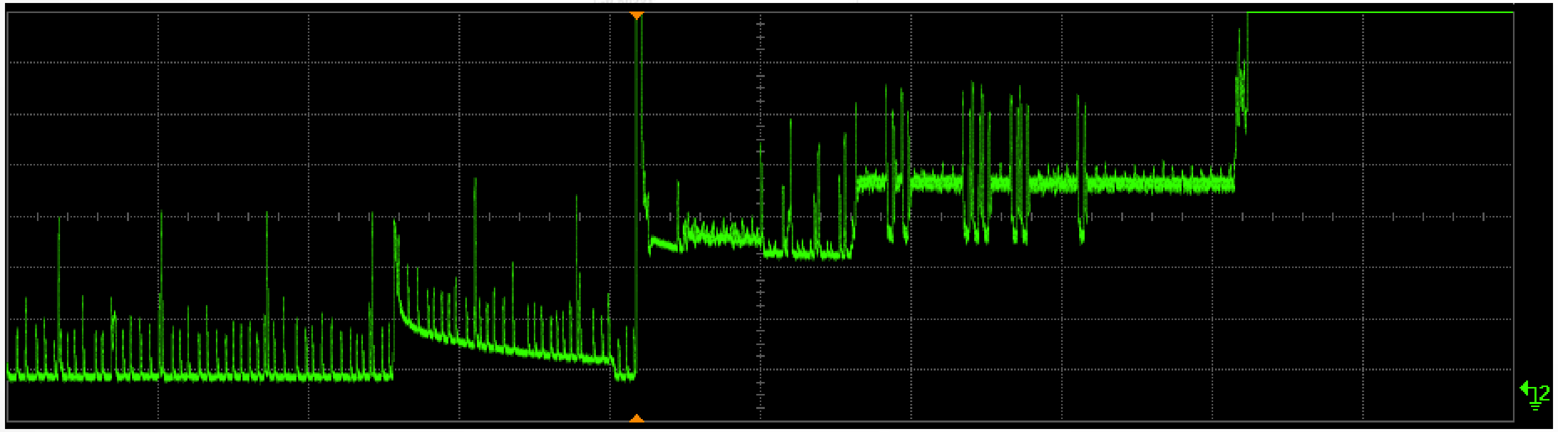
- Perfect for floating measurements, even up to many kilovolts
- Excellent common mode rejection even makes these a good all-purpose solution for single ended measurements (up to -70 dB)
- Much more accurate than using two single ended probes and waveform math to subtract
- Accurately depict what your DUT is receiving in differential serial buses

Probing Architecture, Tips, and Tricks

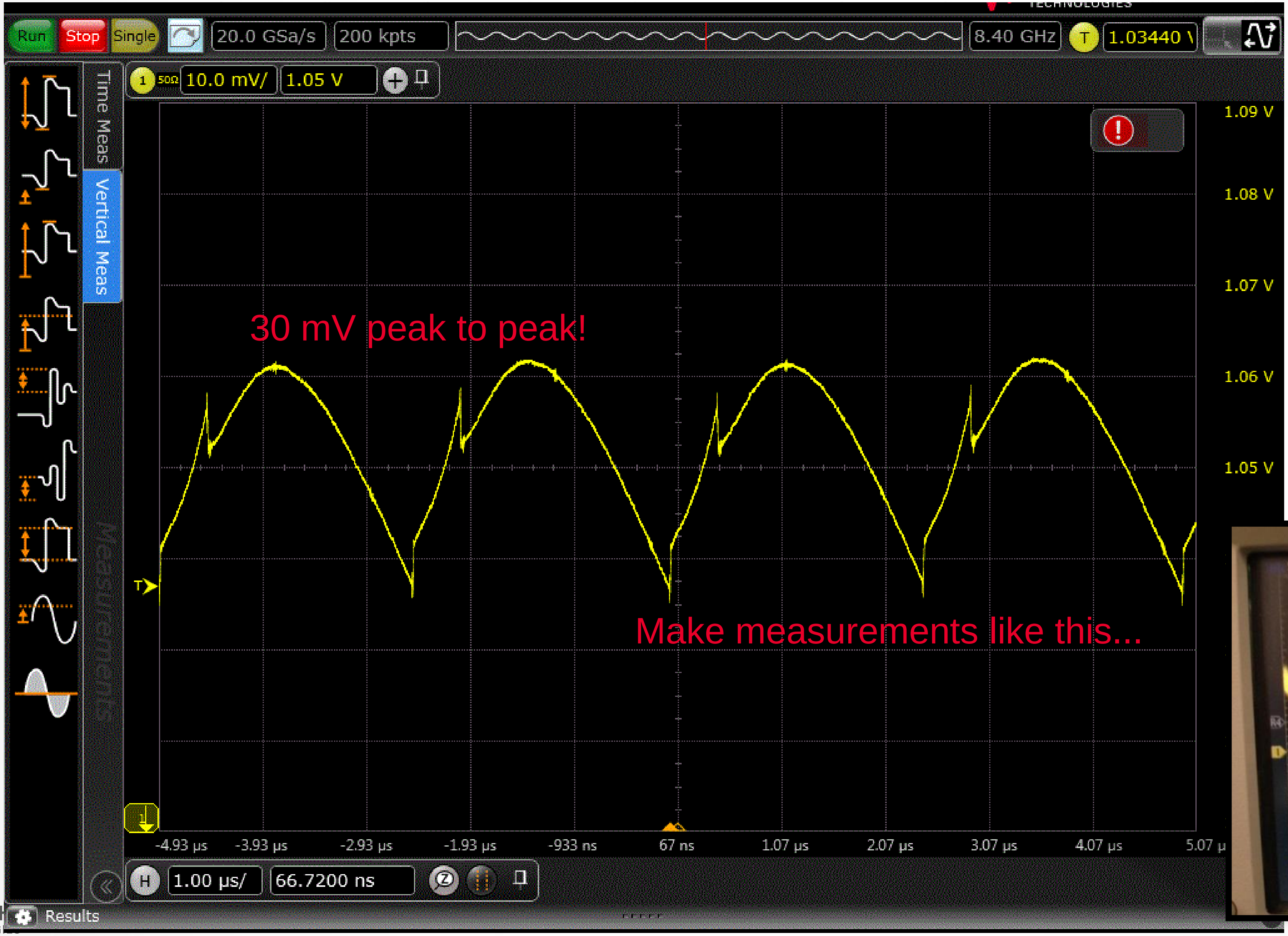
UNIQUE PROBING SOLUTIONS

Next: unique solutions for probing….

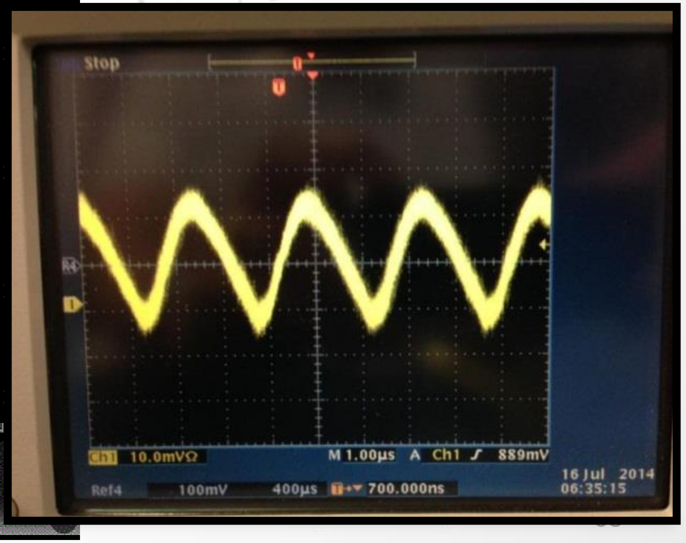
- Power rails (PMIC, power distribution, etc)
- inside an active temperature chamber



N7020/24A Power Rail Probe



Instead of like this.



N7020/24A Power Rail Probe

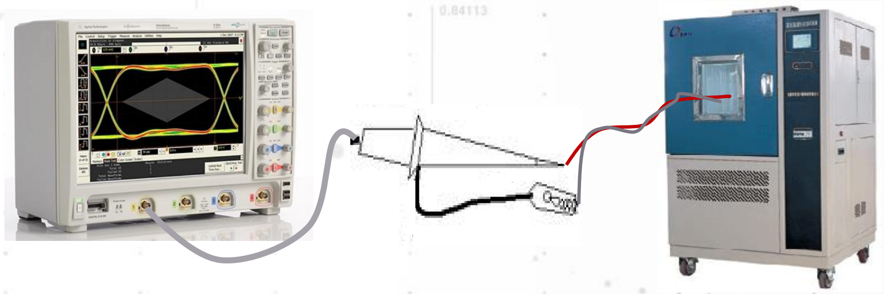
Specifications	N7020A	N7024A
Probe Bandwidth (-3dB)	2 GHz	6 GHz
Attenuation Ratio	1 : 1	1.3 : 1
Offset Range	± 24 V	± 15 V
* Input Impedance @ DC	50 kΩ +/- 2%	50 kΩ +/- 2%
Probe Noise	10% increase to the noise of the connected oscilloscope	30% increase to the noise of the connected oscilloscope
Probe Type	Single-ended	Single-ended
Maximum input voltage	±30 V (DC + peak AC)	±15 V (DC + peak AC)
Output impedance	50 Ω	50 Ω
Cable length	Main Cable: 48” Coaxial Probe Head: 8”	Main Cable: 48” Coaxial Probe Head: 8”
Ambient operating temperature	Probe head: -10 → +55 C Browser head: -10 → +55 C Main/Coax cable: -40 → +85 C	Probe head: -10 → +55 C Browser head: -10 → +55 C Main /Coax cable: -40 → +85 C

KEYSIGHT TECHNOLOGIES

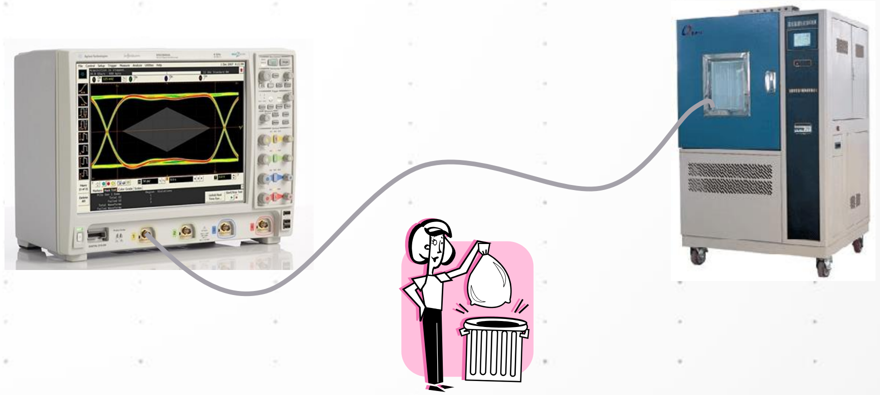
High Temperature Probe Solutions

How do you measure live signals in a chamber?
Most common method today—passive probes

- Probe connected to DUT via long extensions
  - Excessive probe loading on DUT
  - Noise couples onto wires



- Probe is placed directly into chamber
  - Cost of “disposable” probes
  - Failures create false readings



High Temperature Probe Solutions

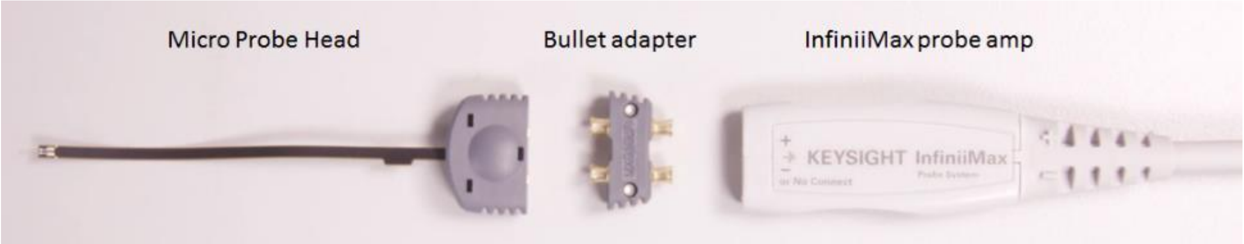
	N7007A passive	N2797A SE active	InfiniiMax w/ N5450B
Bandwidth	Up to 400 MHz	Up to 2 GHz	Up to 26 GHz
Temp Range	-40 °C - +85 °C	-40 °C - +85 °C	Up to -55 °C - +150 °C
Type	Single-ended	Single-ended	Single-ended or Differential
Max input	1 kV CAT II, 600V CAT III	-8V to +8V (dynamic range) ±12V (offset range)	3.3Vpp (w/ InfiniiMax II 1168A/69A) 5Vpp (w/ InfiniiMax I 1130A-34A)
Input loading	1 MΩ R (at DC)	1 MΩ R (at DC), 1 pF C	50 kΩ diff, <0.5 pF input C
Price range	US$500	US$2.5k	>US$5.5k (1130A + N5450B + E2677A)

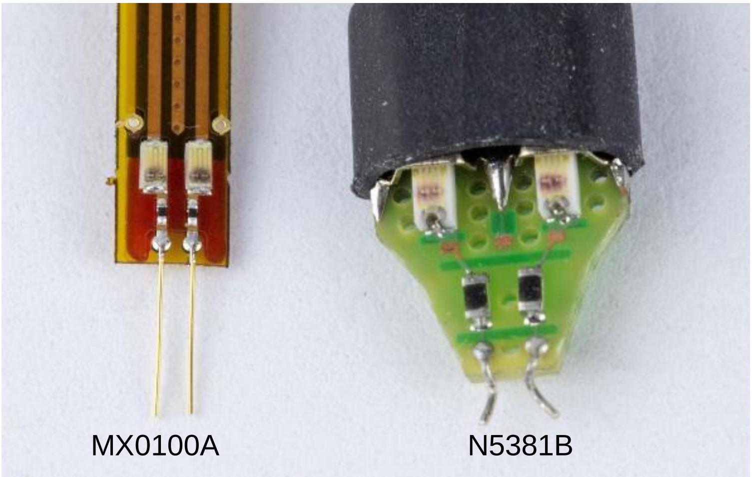
More info available on each! (See hidden slides)

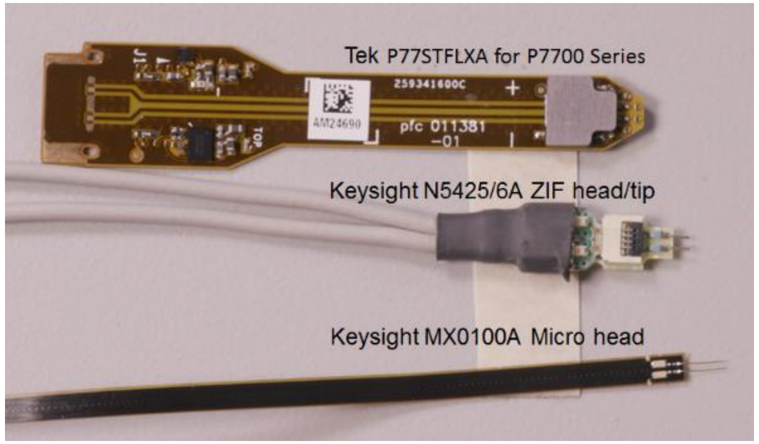
New MX0100A Micro Probe Head

Uncompromised access to your fine pitch devices

- < Half the size of existing solder-in probe heads
- **Small, flat and flexible** (using flex printed circuit)
- Full probe amp bandwidth (>12GHz with 1169B)
- **Excellent probe loading (0.17 pF)**
- Compatible with "RC" probe amps (InfiniiMax I/II and next generation RC probes)
- **Reusable**
- **Wider operating temp range : -55 to +150 degC** (per JEDEC JESD22-A104 revision E spec)
- Half the price of existing solder-in heads



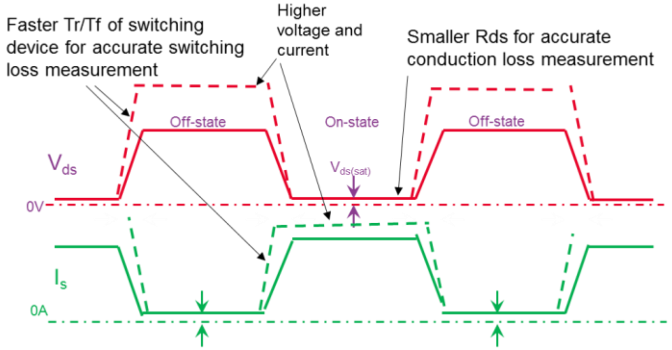


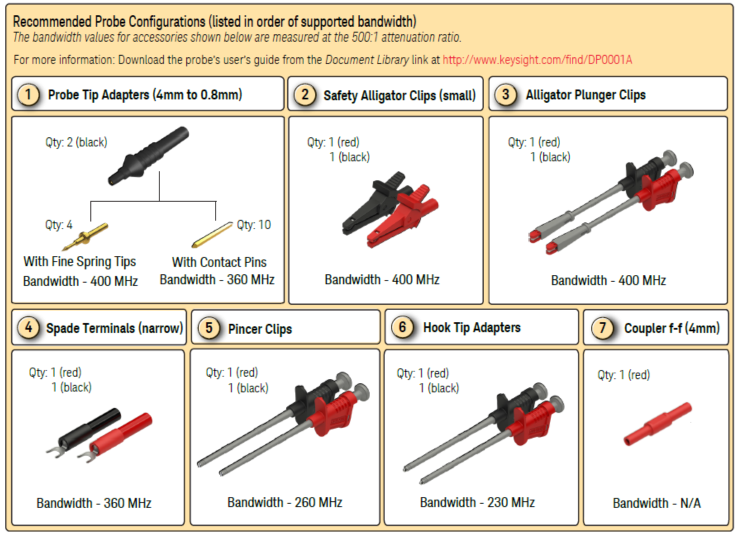


Really High Voltage? – DP0001A High-Voltage Differential Probe

- **High voltage differential probe**
  - **2kV CAT1, 1kV CAT III & 400 MHz**
  - 10 Mohm//2pF probe loading
  - AutoProbe interface (50 ohm termination)
- **Unlocks key general purpose power measurements**
  - 1.2kV IGBT
  - 1.7 kV SiC device characterization
- **Great for high speed, high voltage power supply design, debug and test**

Models:
- DP0001A Probe + Accessory kit
- DP0002A Std alone Accessory kit





Current Probing





	1146B Hall Element-based	1147B/N2893A Hall Element-based	N2780B/L Series (5 models) Hall Element-based	N7026A Hall Element-based	N2820A/21A High-Sensitivity Shunt-based	N7040A/41A/42A Rogowski Coil
Bandwidth	100kHz	50MHz/100MHz	2MHz/5MHz/50MHz/100MHz	150MHz	3 MHz (zoom-out ch) 500 kHz (zoom-in ch)	23/30/30MHz
Input range	DC-100A	DC-10A	DC-500A, 150A, 30A, 30A	DC- 30A	DC, 50uA – 5A	3kA/600A/300A
Minimum measurable current*		5 mA	N2780B/81B : 20 mA N2782B/83B/83L : 5 mA		50 uA (with supplied acc) 500 nA (with >10 ohm Rsense)	
Probe interface	BNC (1MΩ, requires battery)	AutoProbe (1MΩ)	BNC (1MΩ, requires N2779A power supply)	AutoProbe (1MΩ, requires power adapter for>5A)	AutoProbe (1MΩ)	BNC (1MΩ, requires battery or power supply, included)
Key benefits	Low cost	• AutoProbe • Auto degauss/offset (on N2893A)	• BNC interface for broad scope compatibility • N2783L (80MHz, 5m long cable) for long-reach apps	• High sensitivity (1mA/div) •150 MHz BW • 30A wide input • 4 per InfiniiVision	• High sensitivity down to 50 uA, MBB interface for convenient connections	• large current (kA) measurement • small flexible coil • non-intrusive
Limitations	• Sensitivity • Battery powered	• 15A peak max • 2 per InfiniiVision	• Ext power supply (N2779A) adds cost, limited low level sensitivity (~5mA)	• Price	• Limited BW (3MHz), max input range (1.2Vdiff, 12V CM)	• AC only

Keysight Probing Portfolio

ENGINEERED FOR SUPERIOR SIGNAL ACCESS AND MEASUREMENT ACCURACY

InfiniiMax

- Up to 30 GHz
- Probe amp / head topology
- Variety of connections – browser, solder-in, socketed, SMA, ZIF tip, QuickTip
- S-parameter correction

Optical

- 33 GHz O/E converter for up to 28 Gbps optical signals
- Optical measurement software

InfiniiMode

- 1.5 – 6 GHz
- Making differential, SE, and common mode measurements with a single probe
- Multi-function scope control

Power Rail

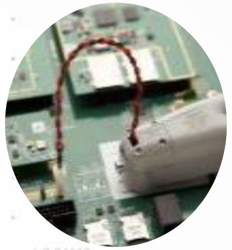
- Up to 6 GHz
- For making power integrity measurements
- Low noise
- Large offset range
- Low DC loading

SE Active

- Up to 2 GHz
- High input R and low C for low loading
- For high-speed ground referenced signal measurements

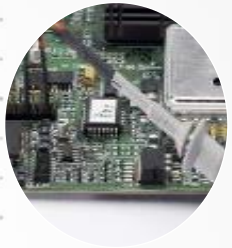
HV Diff

- Up to 800 MHz
- Up to 7 kV
- Ideal for power measurements
- High common mode rejection



Current

- DC to 100 MHz
- Clamp-on or high sensitivity
- 50 uA to 500 A



Passive

- Up to 6 GHz
- Low cost, rugged design
- Variety of accessories

Accessories

- InfiniiMax probe heads
- Compliance test fixtures
- TekProbe ® adapter
- BGA probe adapters
- Probe positioners
- Wedge adapters

The Oscilloscope That's Right For You

Whether you need high signal integrity, a portable form factor, or an affordable oscilloscope, we've got you covered. With our broad range of oscilloscopes, you are guaranteed to find the right scope, no matter where you are in the development cycle

MEASURE CONFIDENTLY WITH KEYSIGHT OSCILLOSCOPES

InfiniiVision
50 MHz to 6 GHz

Infiniium Real-time
500 MHz to 110 GHz

DCA Sampling
18 GHz to 122 GHz

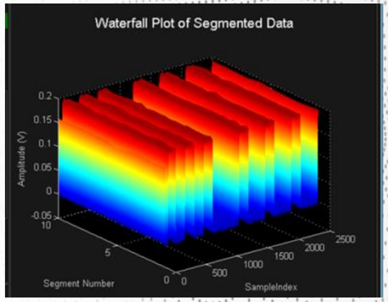
USB, Modular and Handheld
100 MHz to 1 GHz

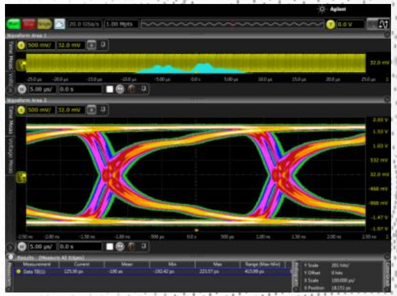
Infiniium Advanced Signal Analysis Tools

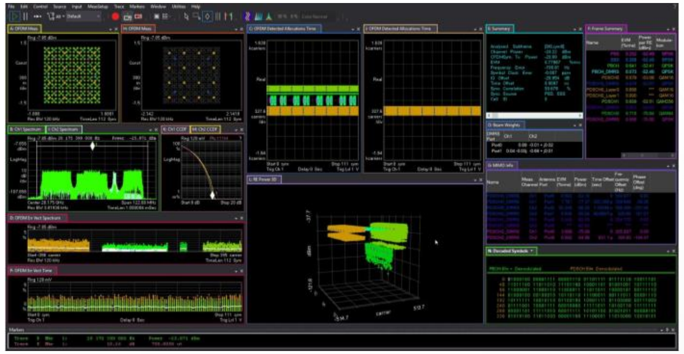
MOST COMPREHENSIVE APPLICATION-SPECIFIC MEASUREMENT SOFTWARE

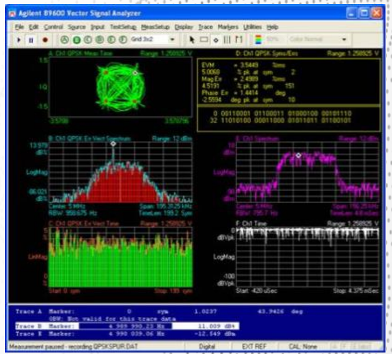
- Most Advanced Jitter Analysis:
  - RJ/DJ separation
  - Dual Dirac or Tailfit (BUJ crosstalk analysis)
  - Vertical noise separation
- Phase noise
- Equalization: FFE, CTLE and DFE
- Complex Triggering: including zone and serial bit streams
- Powerful embedding / de-embedding
- Create custom applications and integrations

- PAM-N
  - Jitter and amplitude analysis on JP03 patterns
- Power Integrity:
  - Analyze the adverse interactions between power supplies and digital lines
- Serial Data Analysis:
  - Clock recovery and eye-diagram analysis
- Seamless integration with MATLAB
- VSA: Vector signal analysis, spectral, EVM
- Infiniium Offline Software





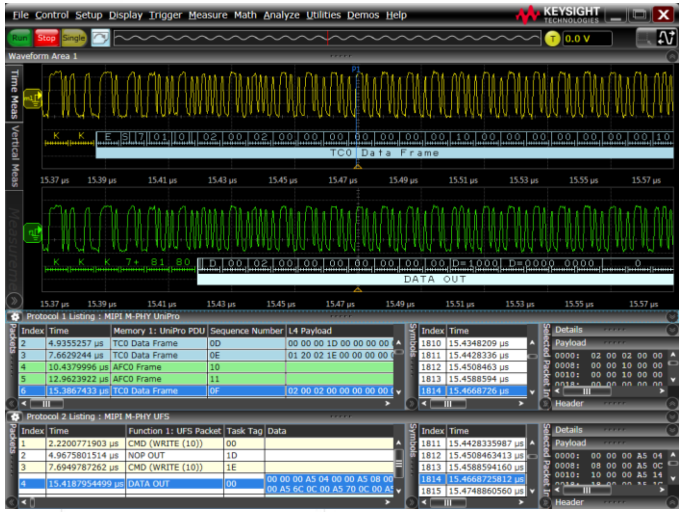


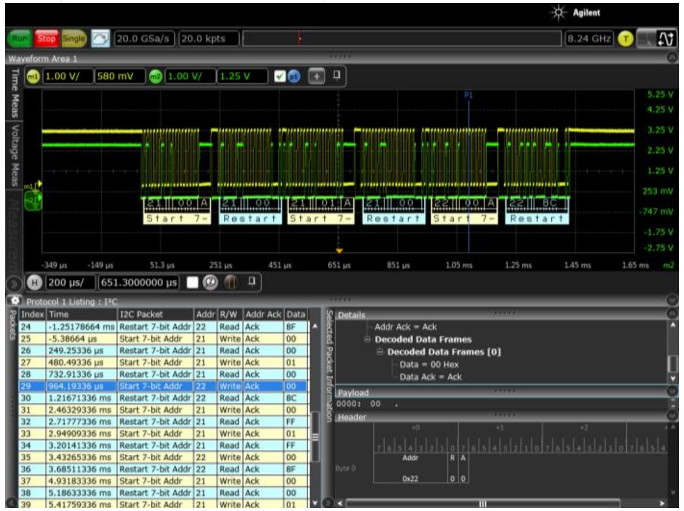


Over 50 Protocol Debug Tools

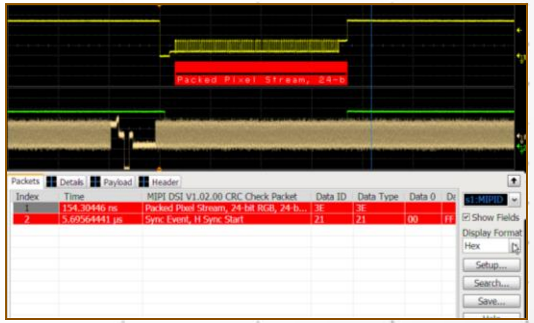
DECODE HIGHER LEVEL PROTOCOLS AND DEBUG CRC ERROR ROOT CAUSE

- SPI, eSPI, Quad eSPI
- RS232 / UART
- USB 2.0, 3.0, 3.1 Gen 1
- USB-PD, USB-HSIC
- USB 3.1, 3.2 (5 and 10 Gbps)
- Ethernet 10BaseT 8b/10b
- Ethernet 100Base-TX
- Ethernet 10GBase-KR 64b/66b
- Ethernet 100GBase-KR/CR 64b/66b
- CAN / CAN-FD / LIN / FlexRay / SENT
- SATA / SAS
- PCI Express Gen 1, 2, 3, 4
- I²C, I²S, JTAG (IEEE 1149.1)
- Manchester
- SVID
- ARINC 429, MIL-STD-1553, SpaceWire
- I3C / SPMI
- MIPI C-PHY, D-PHY, M-PHY
- MIPI DigRF v4, LLI, RFFE, UniPro
- UFS Universal Flash Storage
- Broad-R Reach / 100BASE-T1





- Run up to **4 protocol decoders** at the same time.
- Decoded packets are shown on the waveform as well as the **listing table**
- Show **payload and CRC** information.
- Quickly and **easily zoom** into waveforms
- Automatically warns when computed CRC and embedded CRC do not match, indicating a **CRC error**.
- Quickly **identify errors** related to signal integrity or protocol issues.

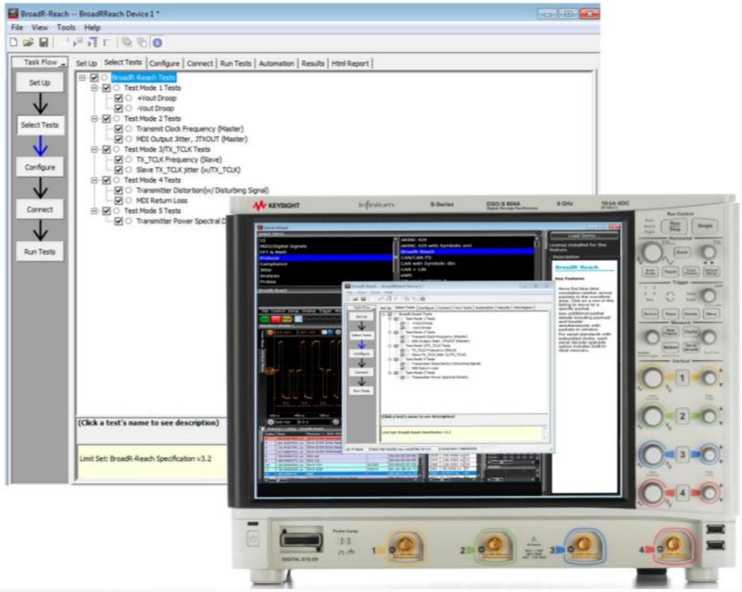


CRC error detected

Most Comprehensive Compliance Applications

ENSURE DESIGNS ARE COMPLIANT WITH INDUSTRY-LEADING STANDARDS

- Keysight experts help define compliance requirements
- Compliance applications are certified to test to the exact specifications of each technology standard
- Setup wizards combined with intelligent test filtering give you confidence you're running the right tests
- Comprehensive HTML reports with visual documentation and pass/fail results



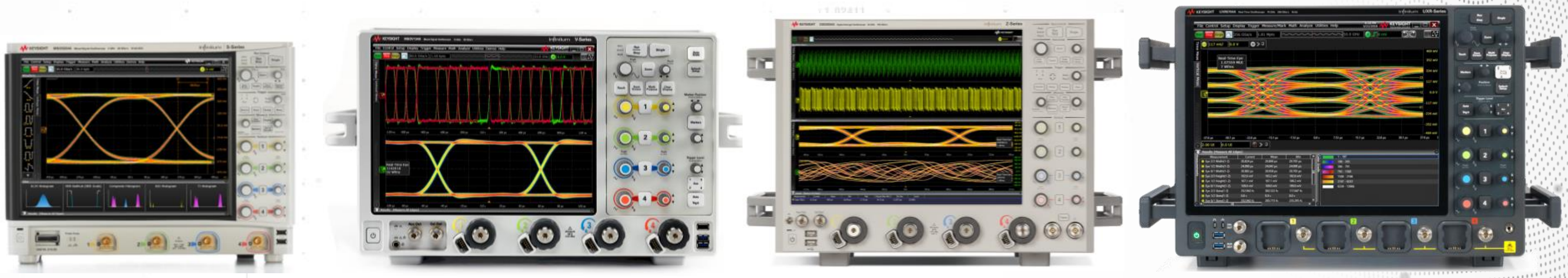
Supported Compliance Applications	
BroadR-Reach	MIPI M-PHY
CAUI-4	MOST
DDR1 and LPDDR1	OIF-CEI 4.0
DDR2 and LPDDR2	ONFI
DDR3 and LPDDR3	PCI Express 1.0a/1.1 2.5G
DDR4 and LPDDR4	PCI Express Gen 3
DDR5	PCI Express Gen 4
DisplayPort 1.4	PCI Express Gen 5
eDP 1.4	SAS-4 / SCSI-4
eMMC	SATA 1.5, 3.0 and 6.0Gbps
Ethernet + EEE 10/100/1000Base-T	SD UHS-II
Ethernet 10GBase-T and MGBase-T	SD UHS-I
Ethernet 10GBase-KR	SFP+
Ethernet 100GBase-CR10	OIF-CEI 4.0
Ethernet 100GBase-CR4	CAUI-4
Ethernet 100GBase-KR4	Thunderbolt / TBT3
Ethernet 1000Base-T1	UHS-I
GDDR5	UHS-II
HDMI 1.4, TMDS/2.0, 2.1	User-defined application
HMC	USB 2.0
IEEE802.3bs/cd	USB 3.1 5 Gbps and 10 Gbps
MHL 3.0	USB HSIC
MIPI C-PHY	XAUI with 10GBASE-CX4, CPRI, OBSAI, and Serial RapidIO
MIPI D-PHY	

KEYSIGHT TECHNOLOGIES

Infiniium High-Performance Real-Time Oscilloscopes

CONFIDENTLY SOLVE TODAY AND TOMORROW'S CHALLENGES

The highest signal integrity across the widest breadth of bandwidths available in the industry. Whether you need 500 MHz or 110 GHz, we've got you covered with the performance, accuracy and most comprehensive measurement software available to conquer even your most demanding engineering and research needs.



	S-Series	V-Series	Z-Series	UXR-Series
Bandwidth	500 MHz – 8 GHz	8 – 33 GHz	20 – 63 GHz	13 – 110 GHz
ADC Resolution	10 bits	8 bits	8 bits	10 bits
Intrinsic Jitter	100 fs	100 fs	75 fs	20 fs
Max Memory	800 Mpts	2 Gpts	2 Gpts	2 Gpts
MSO	16 ch. @ 2 GSa/s	16 ch. @ 20 GSa/s	N/A	N/A

Breadth – From Extreme Value to Extreme Performance

InfiniiVision - Real Time


InfiniiVision
1000 X-Series


M924XA PXI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2000 X-Series


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3000T X-Series


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4000 X-Series


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6000 X-Series

Infiniium - Real Time


Infiniium
9000A Series


Infiniium
S-Series


Infiniium
90000A Series


Infiniium
V-Series


Infiniium
Z-Series


Infiniium
UXR-Series

Digital Communication Analyzer – Sampling


N109x Optical Ref
Receiver and electrical
DCA-M series


N1000A DCA-
X Mainframe
Series


N1055A 50 GHz
TDR DCA
Plug-in Series


N1045A
60 GHz DCA
Plug-in
Series


N1060A >90 GHz
DCA Plug-in with
CDR Series


N1046A 122
GHz DCA
Plug-in Series


N107xA 64
GBd electrical
& optical CDR
Series

KEYSIGHT
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