KEYSIGHT

Welcome to the Keysight Technologies Students Workshop

Agenda

01 Introduction

02 Keysight Career Opportunities for Students and Graduates

03 Collaboration with Universität Stuttgart (Fachschaft Elektrotechnik und Informationstechnik) in 2022

04 Keysight Technologies in Germany

05 Workshop

01

Introduction

Every Day, New Technology Transforms the World Around Us

KEYSIGHT

To Accelerate Tomorrow’s Innovations, You Must

quickly solve design, test, and validation challenges in a dynamic environment.


When Engineers Face Complex Challenges, Their Most Important Question Isn’t “What’s the Solution?”
It’s “Where Do I Start?”
start here
KEYSIGHT

Ensure That Tomorrow's Technologies Perform in the Real World

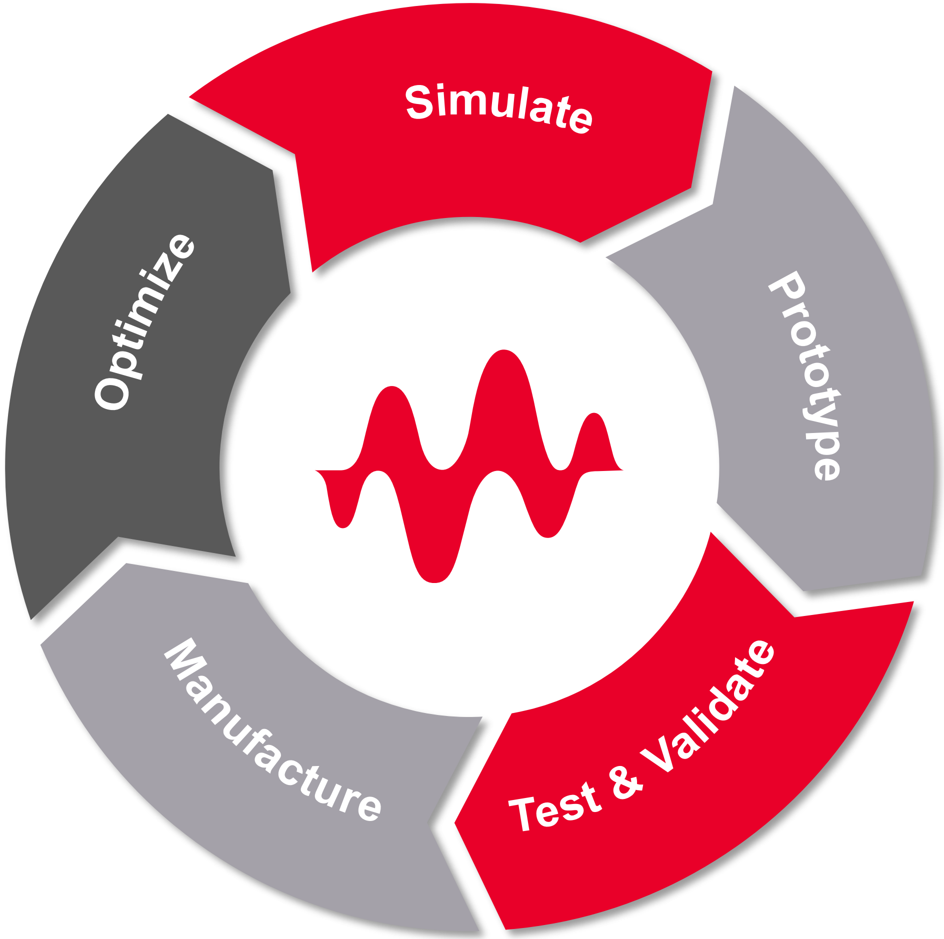
At Keysight, we help innovators:

- anticipate emerging technologies
- automate intelligence throughout the workflow
- measure what's never been measured before
- speed time-to-market and reduce risk

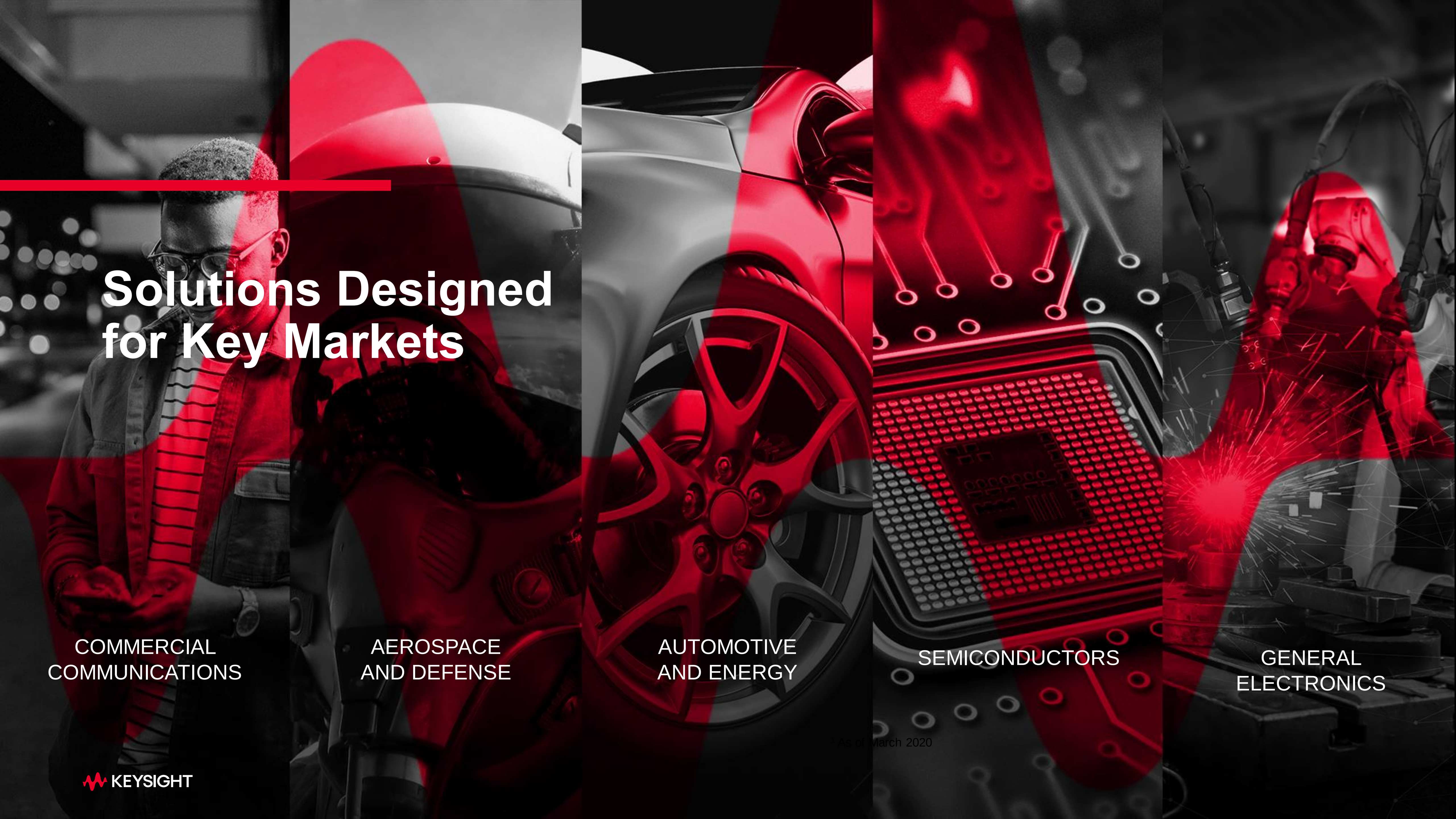
From conceptualization to commercialization, innovators start with Keysight.

Tailored End-to-End Solutions Across the Workflow

We integrate hardware, software, and services to create a customized solution that serves you across the development lifecycle.



Solutions Designed for Key Markets



[1] As of March 2020

KEYSIGHT

Why Keysight?

Work With a Market Leader[1] With Deep Customer Relationships

#1

Electronic Design and Test

Software

Commercial Communications

Aerospace & Defense

Electronic Industrial

Oscilloscopes

Network Analyzers

Signal/Spectrum Analyzers

Signal Sources

[1] Company estimates and external sources

Customer Success is at the Heart of Keysight

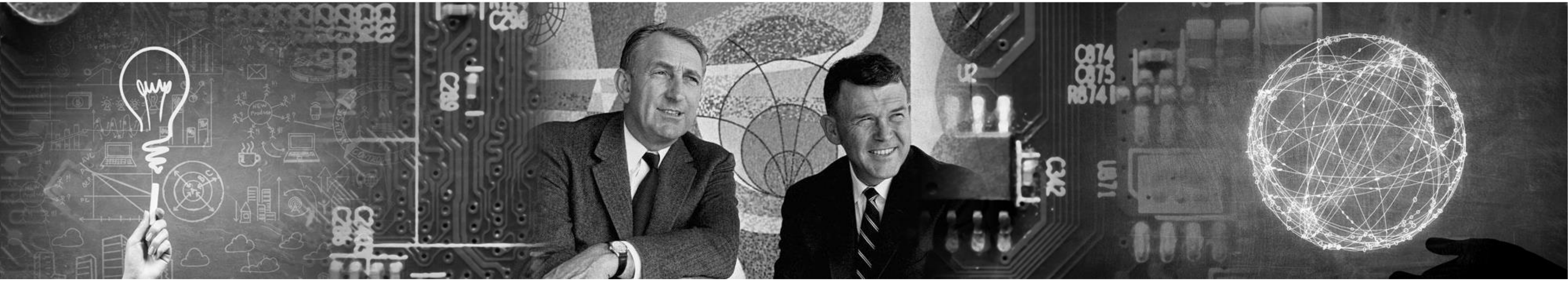
Keysight's Leadership Model

Is the company's enabler to continuously deliver greater value to customers, shareholders, and employees.

It is the philosophy that permeates every aspect of our operations – driving innovation, speed, and excellence in execution.

Keysight Helps Companies Get to Market Faster

We Help You Create. Innovate. And Deliver What's Next.



The innovation leader in electronic design and test for over 80 years

Founded in 1939 by Bill Hewlett and Dave Packard as HP with an ongoing mission to help create new markets

Trusted hardware, innovative software and a global network of experts

Recognized as an Industry Leader

- Sustainalytics ESG Industry Top Rated Company in 2021
- Continued Constituent of FTSE4Good Index Series
- Barron’s 100 Most Sustainable Companies in America
- Newsweek and Statista Inc. America’s Most Responsible Companies 2022


To Accelerate Innovation
to Connect and Secure the World,
start here
Keysight
KEYSIGHT

02

Keysight Career Opportunities for Students and Graduates

Keysight Career Opportunities for Students and Graduates

You can always apply for our open job requisitions at the Keysight Career Portal for Students for an internship, a working student job, or a full-time graduate position.

Keysight Career Opportunities for Students and Graduates

- Every year **we hire hundreds of the best students** around the world for internships and full-time employment in software and hardware engineering, sales, marketing, customer service and more.
- We're always looking for **smart, motivated and action-oriented people** to fill internships and full-time positions.
- Our goal is to identify and attract **top students with the diversity of viewpoint and experiences** that help Keysight remain a business leader.
- In our experience, **qualified students bring exceptional energy and enthusiasm, new perspectives and ideas, and technical savvy** based on the latest research and technology.

JOB MATRIX

	B Tec	HND	B Eng	M Eng	M Sc	IT	Business Admin	MBA	PhD
Solutions Engineer			●	●	●				●
Hardware Design Engineer			●	●					●
Software Design/ Development Engineer			●	●	●	●			●
Technical Consultant			●	●	●				●
Technical Support Engineer		●	●	●	●				
RF Engineer			●	●	●				
Repair / Calibration Engineer	●	●	●	●	●				
Project Manager			●	●	●			●	●
Field Engineer/ Sales Account Manager			●	●				●	
Inside Sales Engineer		●	●	●	●				
Product Marketing			●	●				●	
Business/Marketing Development	●	●	●				●	●	

For Example, Two Open Positions in the SEO in Boeblingen

JOB FLYER

Join Keysight Technologies Today!

Job ID: 47812 Werkstudent / Working Student
Quantum Engineering Solutions

Job Description

Keysight Technologies is **the world's premier electronic design & measurement company.** Through more than 80 years of our history, our strong product development and business processes created strong leadership **in most test & measurement product categories** like network analyzers, signal analyzers, oscilloscopes, signal generators, bit error ratio testers, optical instruments, and many others.

As one of the application examples, **quantum technology** provides the means to achieve breakthroughs in computing and communications. The unique properties of superposition and entanglement enable previously unimagined performance in **quantum applications like computing, communications, and sensing**. As quantum research enters this new phase in physics and mathematics, you can use engineering to build real systems to control experiments.

This job is the **working student position** in the **Solutions Engineering Organization (SEO)** at the EMEAI Sales Organization (ESO) of Keysight Global Sales (KGS) to support Keysight's **Quantum Engineering Solutions (QES)**.

Our Requirements

We're particularly interested in students from onw of the German universities with the following qualifications:

- Pursuing **a master's degree in electrical engineering** (preferred: any relation to optical communications, quantum computing, or quantum communications).
- Some experience with **test & measurement equipment** (preferred: arbitrary waveform generators, oscilloscopes, digitizers, photonic test instruments), strong interest in state-of-the-art electronic technologies, and intention to learn and use comprehensive measurement tools and methods.
- **Software development** experience (preferred: programming in C# and/or Python) and other **software expertise** (creating visually appealing documents in Microsoft Word, PowerPoint, Visio).
- ... **and presentation skills**.
- ... spoken/written forms.

Our Offering

- Paid part-time work (max 20 hours/week) in parallel with your study.
- Extensive technical mentorship.
- Comprehensive training program.
- Regular work on customer-facing projects in the area of quantum computing and communications.
- Open, international and cooperative working environment.
- Location in our headquarters in Böblingen, Germany.

JOB FLYER

Join Keysight Technologies Today!

Job ID: 46039 Praktikum / Internship – Technical & Application Support in Test & Measurements

Job Description

Keysight Technologies is **the world's premier electronic design & measurement company.** Through more than 80 years of our history, our strong product development and business processes created strong leadership **in most test & measurement product categories** like network analyzers, signal analyzers, oscilloscopes, signal generators, bit error ratio testers, optical instruments, and many others.

We are looking for **a student of one of the German universities to be our next intern** participating in delivering **post-sales customer support** directly to Keysight's key customers and strategic partners. The internship is associated with the **KeysightCare Technical Support Application (K-TAS)** team which is a key player in the customer value chain and in supporting our customer's technical problems.

You'll learn how to provide **timely and effective online technical support** by clarifying, analyzing, and resolving technical problems of varied scope and complexity. You will be required to **demonstrate a broad knowledge of instrumentation, applications, and technologies**, with the intent that over time as you build your knowledge and experience you become more specialized in a specific technology/industry area.

Our Requirements

We're particularly interested in students with the following qualifications:

- Pursuing **Masters's degree in Electrical Engineering**.
- Solid understanding of **RF/µW, digital signal processing, communications** fundamentals. Some experience with **test & measurement equipment**.
- Basic **programming skills** applied in the T&M environment using languages such as VEE, LabView, MATLAB ®, C/C#, and Python.
- **Native or high-proficient German** (min. B1) and **high-profici...** language skills in spoken and writt...

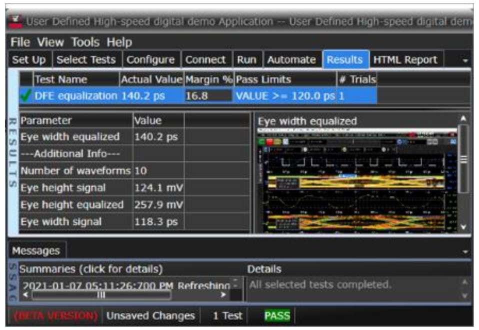
Our Offering

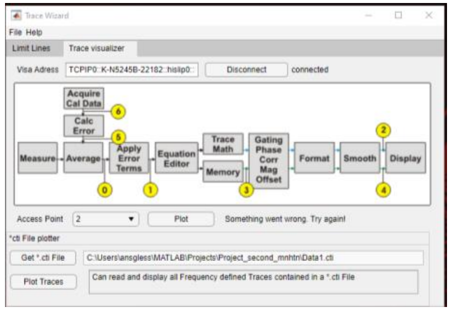
- Paid 6-month internship with demanding tasks in a high-skilled inclusive and diverse team of technical and application support engineers.
- Extensive technical mentorship.
- Comprehensive training program.
- Open, international and cooperative working environment.
- Location in our headquarters in Böblingen, Germany.

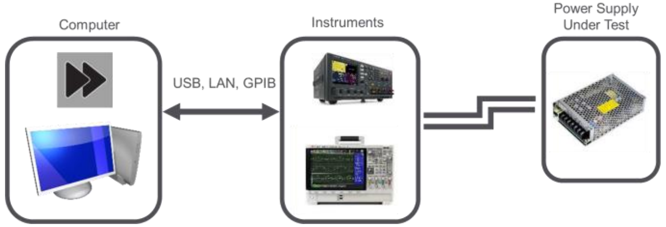
Project Examples

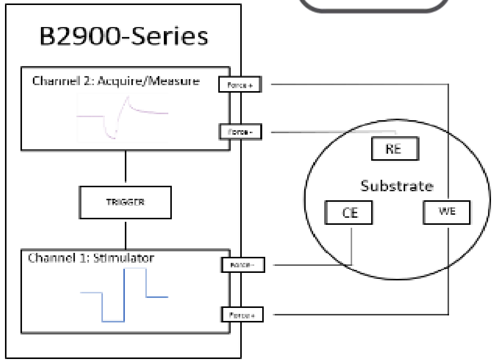
Students From All Over Germany

- High-speed digital measurements demonstrator + test automation
- Custom radar characterization for the integration in the Radar Scene Emulator solution
- Custom test automation for CAN, LIN, FlexRay, and proprietary standards (GMSL, APIX, FPD-Link, etc.)
- Plugin for characterization of power supplies
- Arduino controlled stacklight design
- Application note for a customer biomedical application – charge-injection-capacity measurement
- “VNA Trace Wizard” – Matlab automation for Keysight vector network analysers
- And many more...









03

Collaboration with Universität Stuttgart (Fachschaft Elektrotechnik und Informationstechnik) in 2022

Universität Stuttgart

Collaboration with Universität Stuttgart (FS-EI)

Calendar Year 2022

Universität Stuttgart

April 2022 — Workshop #1: RF Signal Generation and Analysis Fundamentals

May 2022 — Workshop #2: Vector Network Analysis Fundamentals

July 2022 — Open Doors Day at Keysight: Full-Day Plan

Oct 2022 — Workshop #3: High-Speed Oscilloscopes Fundamentals

Nov 2022 — Open Doors Day at Keysight: Full-Day Plan

Nov 2022 — Workshop #4: Fundamentals of Arbitrary Waveform Generation

Keysight Workshops 2022

Universität Stuttgart (Fachschaft Elektrotechnik und Informationstechnik)

- **Purpose:**
  - To promote Keysight internship/campus programs
  - To give students possibility to “touch” best-in-class equipment
  - To probe and increase students’ interest in test & measurements
- **Agenda:** 1.5h presentation, 30min break, 2.5h demo/hands-on, 30min conclusion = 5h in total
- **Dates:**

#	Topic	Date
~~1~~	~~RF Signal Generation and Analysis Fundamentals~~	~~19.04.2022, Tuesday~~
~~2~~	~~Vector Network Analysis Fundamentals~~	~~12.05.2022, Thursday~~
3	High-Speed Oscilloscopes Fundamentals	25.10.2022, Tuesday
4	Fundamentals of Arbitrary Waveform Generation	08.11.2022, Tuesday

Registration:

Keysight Open Doors Day 2022

Universität Stuttgart (Fachschaft Elektrotechnik und Informationstechnik)

- **Purpose:**
  - To promote Keysight internship/campus programs and Keysight as your future employer
  - To give students high-level overview on the technologies and industries where Keysight is involved & increase Keysight awareness
  - To show the whole perspectives area of Keysight in Böblingen
- **Agenda:** office tour, kick-off with high-level management, meeting R&D representatives, lunch, workshops, presentations
- **Dates:**
  - One full day:

Thursday, 24 November 2022

04

Keysight Technologies in Germany

Keysight Technologies in Germany

German Offices Locations

 # Employees: ~630

- **Sales & Support**
- **Research & Development**
- **Manufacturing**
- **Technical Support Center**
- **Service Center**

Hauptsitz
Geschäftsstelle

Keysight Technologies in Böblingen

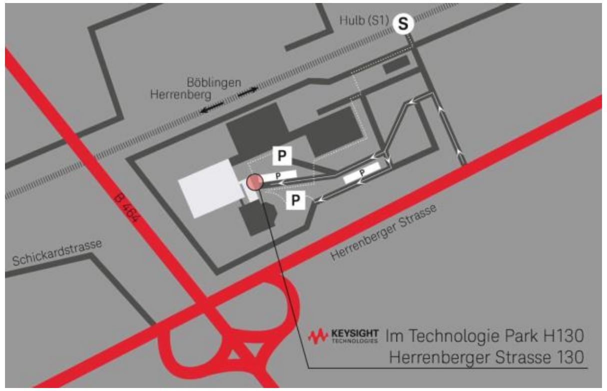
Modern Environment Enables Creativity

- Keysight Technologies Deutschland GmbH
- Address:

  Herrenberger Strasse 130

  71034 Böblingen

  Germany



Join Us. And Be First and Best. With Keysight.

Product and Technology Leadership

Measure today's and tomorrow's most complex signals with leading-edge performance

A Strong Software Franchise

Accelerate development with end-to-end design simulation software and hundreds of measurement applications

A Comprehensive Set of Services and Solutions

Achieve remarkable results with industry and custom solutions, test process and operations optimization

Thank you

KEYSIGHT

Workshop

High-Speed Oscilloscopes Fundamentals

Vitaly MORARENKO
Marius LIPPKE

Solutions Engineering
Keysight Technologies

High-Speed Oscilloscope Fundamentals

Agenda

- Time vs. Frequency Domain
- Bandwidth and Frequency Response
- Sampling Rate and Modes, Aliasing
- Vertical Resolution, ENOB
- Memory Depth and Acquisition Methods
- Triggering: Basics and Advanced
- Waveform Visualization and Analysis Tools:
  - Eye Diagram
  - Jitter Analysis
  - Fault Hunter
  - Real-Time Spectrum Analysis
  - Bode Plots)

High-Speed Oscilloscope Fundamentals

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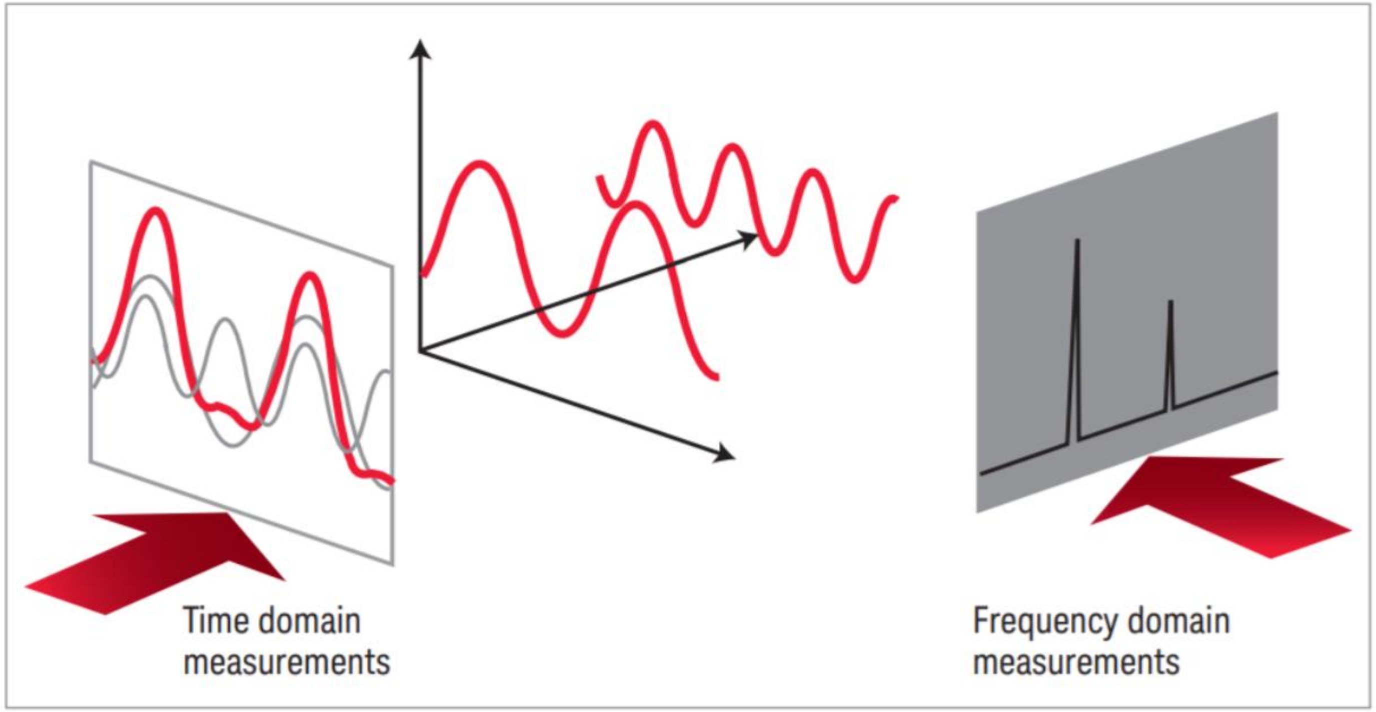
Time Domain vs. Frequency Domain Measurements

What is the difference between frequency domain and time domain?



- **Frequency domain analysis** is used in conditions where processes such as filtering, amplifying and mixing are required.
- **Time domain analysis** gives the behavior of the signal over time. This allows predictions and regression models for the signal.
- **Frequency domain analysis** is very useful in creating desired wave patterns such as binary bit patterns of a computer.
- **Time domain analysis** is used to understand data sent in such bit patterns over time.

Time Domain vs. Frequency Domain Measurements

Measurement Instruments

<u>**Time Domain Applications**</u>

Oscilloscope

Signal Analyzer

Network Analyzer

<u>**Frequency Domain Applications**</u>

Spectrum Analyzer

Network Analyzer

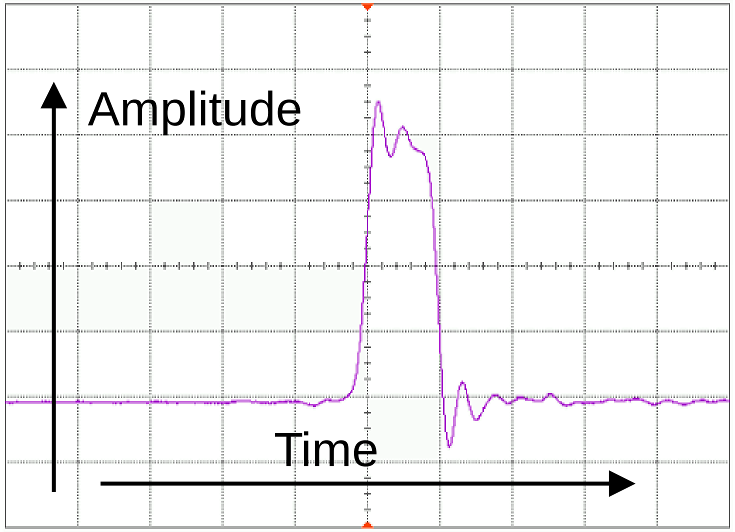
FFT Analyzer

Signal Analyzer

FFT function on Oscilloscope

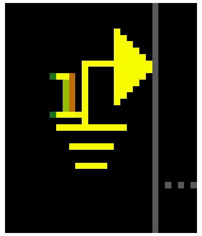
What is an Oscilloscope?

- An **oscilloscope** is an electronic measurement device that visualizes independent voltages in a two-dimensional coordinate system.
- Usually, the time axis is chosen as the horizontal x-axis and the vertical y-axis is used to plot the voltage over time.

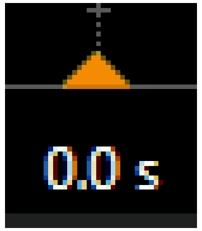


Oscillum – to oscillate (lat.)
Skopein – to examine (griech.)

Time Domain vs. Frequency Domain



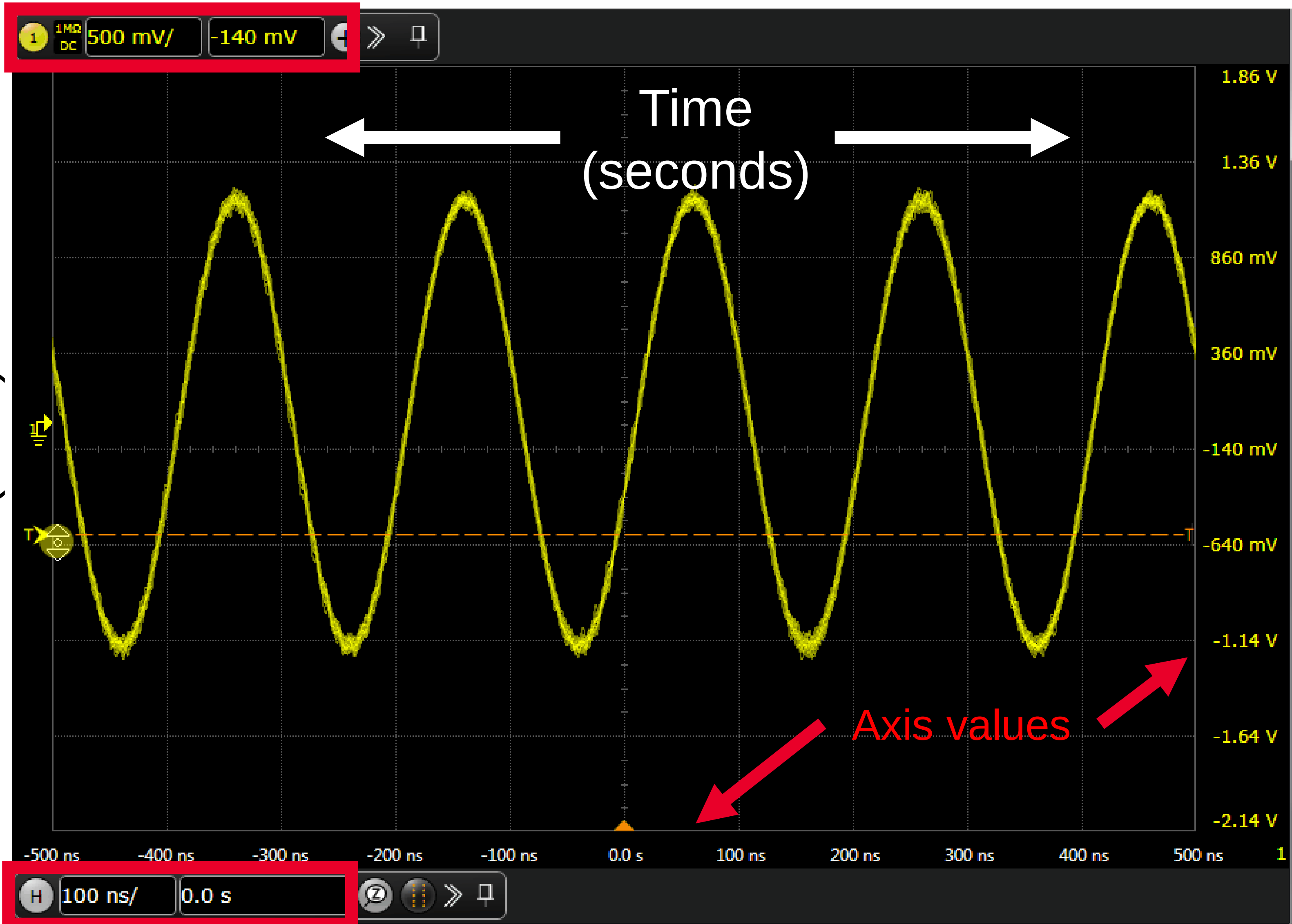
0 volts (or amps) is shown with a ground symbol to the left edge of the screen, and can be adjusted up and down.



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

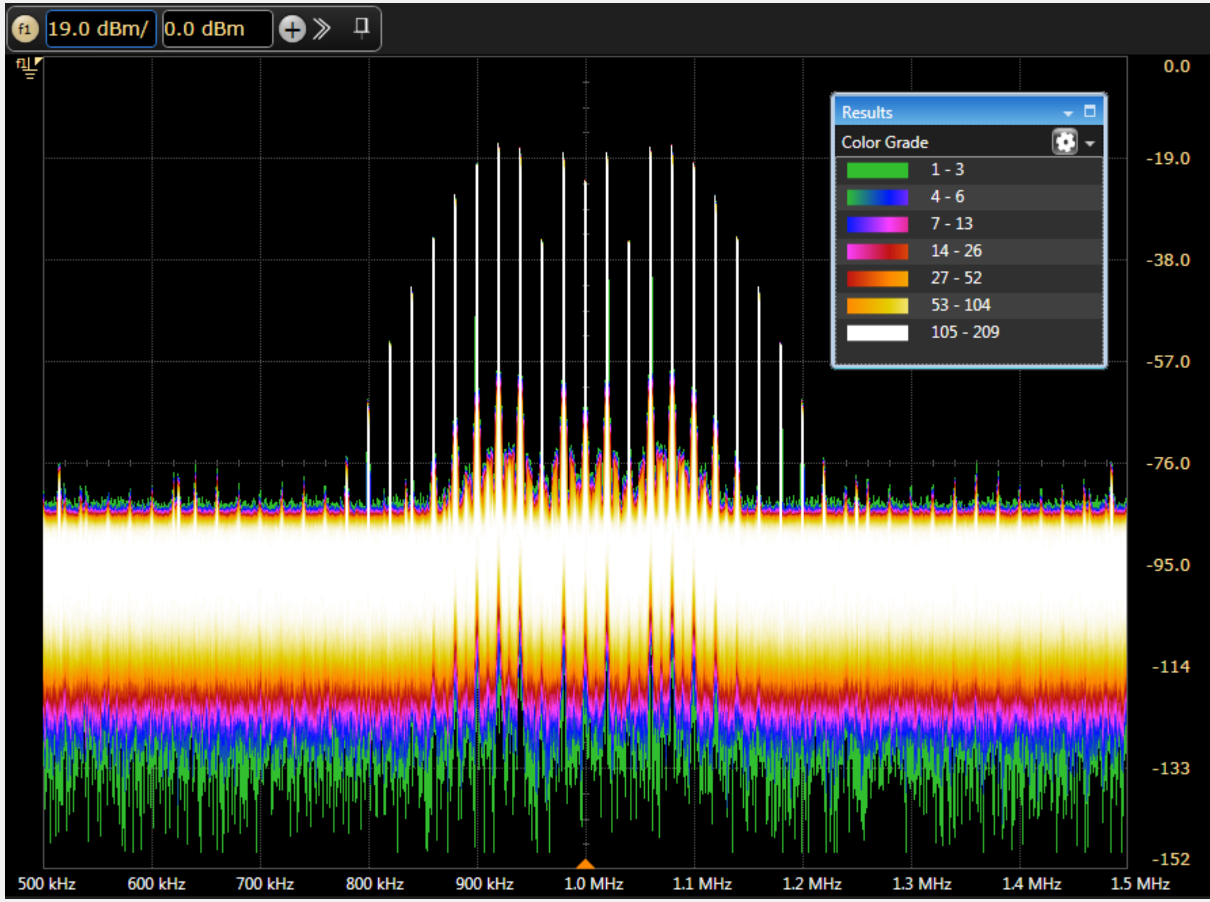
Vertical scale

Amplitude (volts)



Time Domain vs. Frequency Domain

- 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



Power (dBm)

Frequency (Hz)

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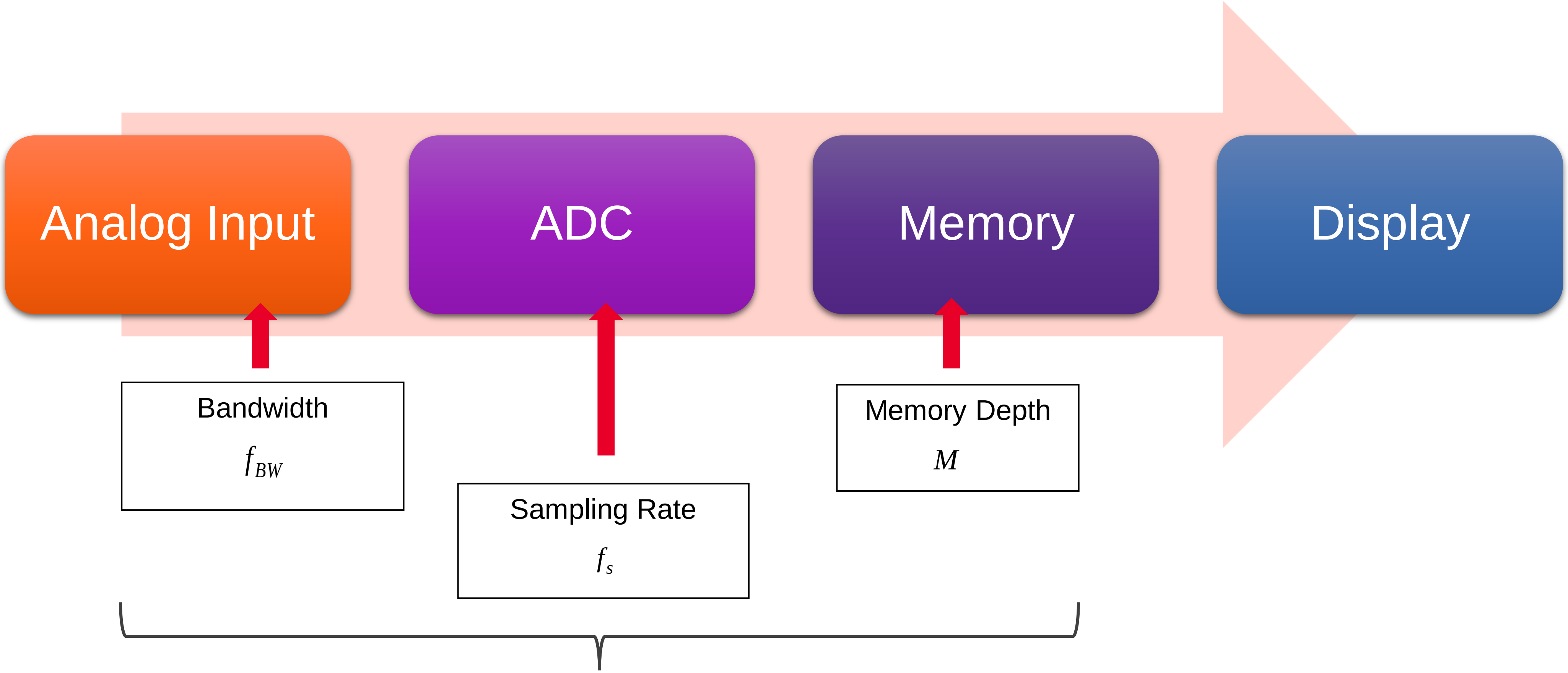
Simplified Block Diagram of a Digital Oscilloscope

Main building blocks and criteria



The most important criteria when buying a digital real-time oscilloscope

It’s time for some hands-on practise

High-Speed Oscilloscope Fundamentals

Agenda

- Time vs. Frequency Domain
- Bandwidth and Frequency Response
- Sampling Rate and Modes, Aliasing
- Vertical Resolution, ENOB
- Memory Depth and Acquisition Methods
- Triggering: Basics and Advanced
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  - Fault Hunter
  - Real-Time Spectrum Analysis
  - Bode Plots)

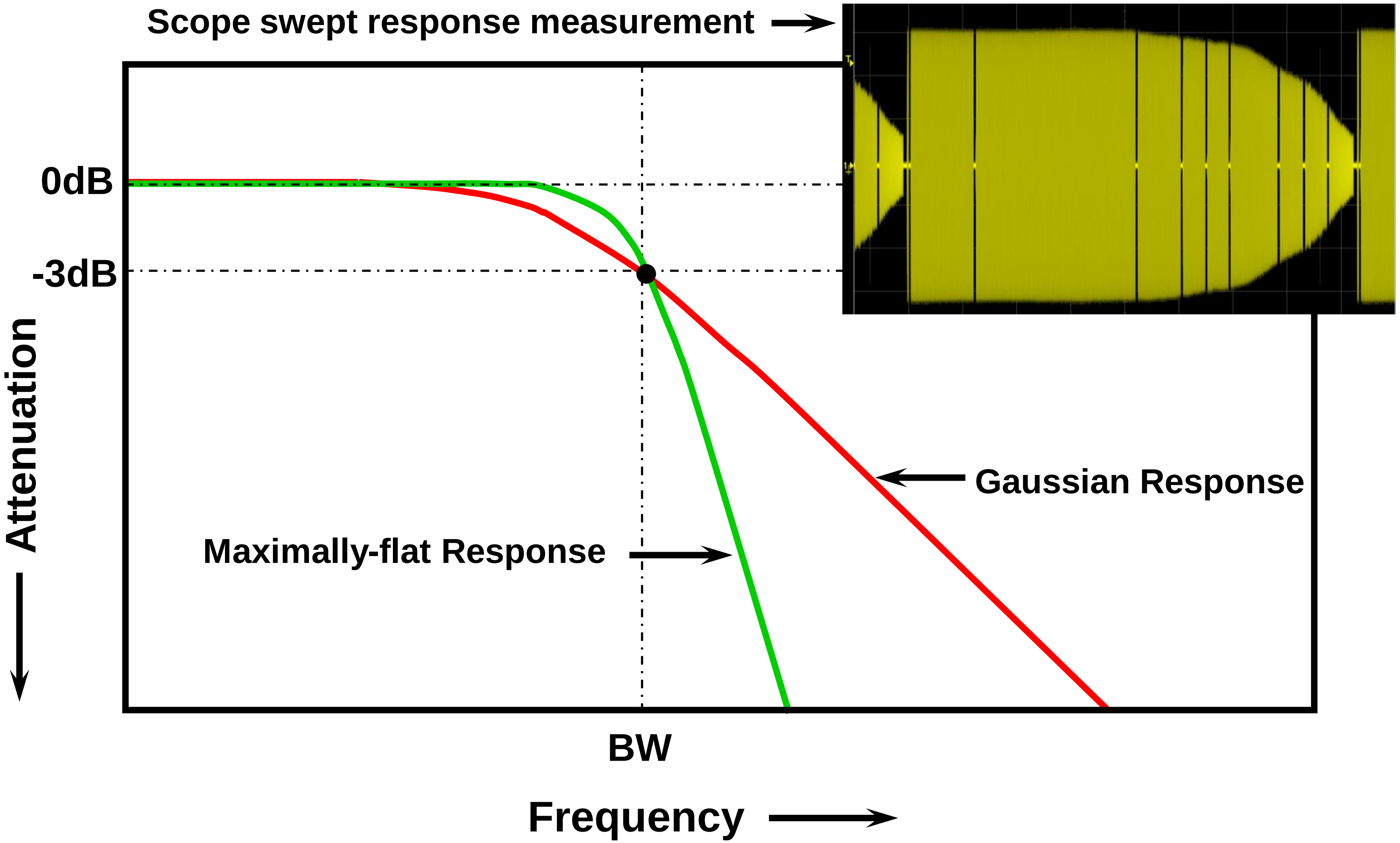
Bandwidth Basics

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/fall time” for two threshold definitions: 10-90% or/and 20-80%.

Analog channel specifications							
		MXR05xA	MXR10xA	MXR20xA	MXR25xA	MXR40xA	MXR60xA
Bandwidth (-3 db)	50 Ω [1]	500 MHz	1 GHz	2 GHz	2.5 GHz	4 GHz	6 GHz
	1 MΩ	500 MHz	500 MHz	500 MHz	500 MHz	500 MHz	500 MHz
Typical rise/fall time [4]	10/90%	860 ps	430 ps	215 ps	172 ps	107.5 ps	71.7 ps
	20/80%	620 ps	310 ps	155 ps	124 ps	77.5 ps	51.7 ps

Bandwidth Basics

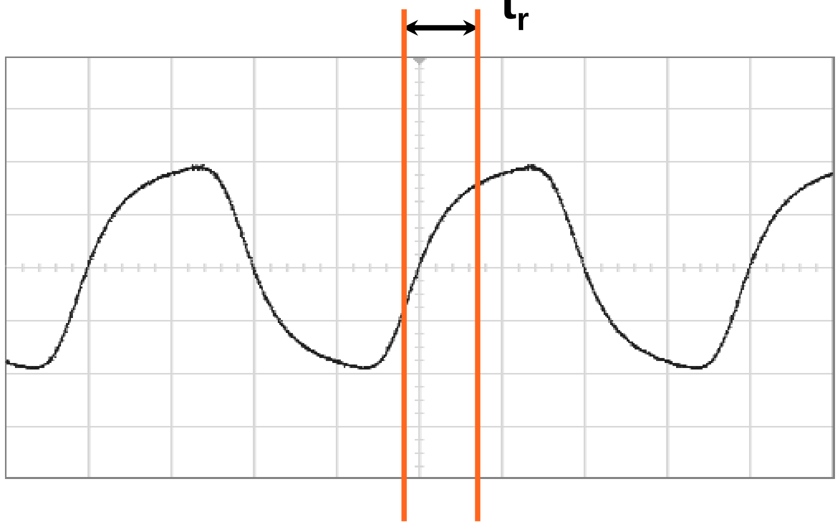


Influence of Bandwidth on Measurement Results

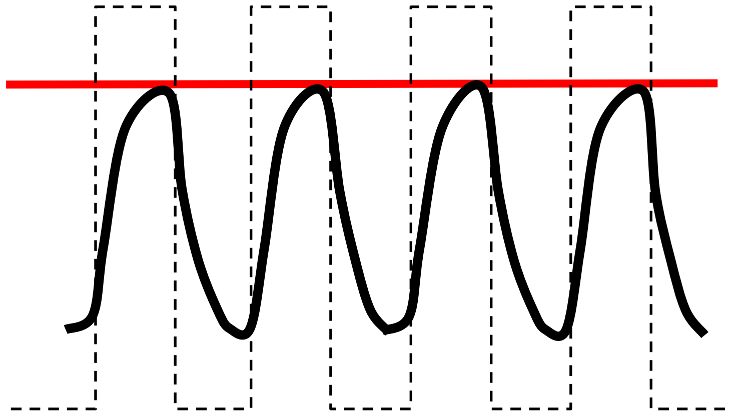
BW Of Oscilloscopes Will Affect Digitized Signal

Affects Signal by:

- **Slowing Rise Time**
- **Attenuating Amplitude**



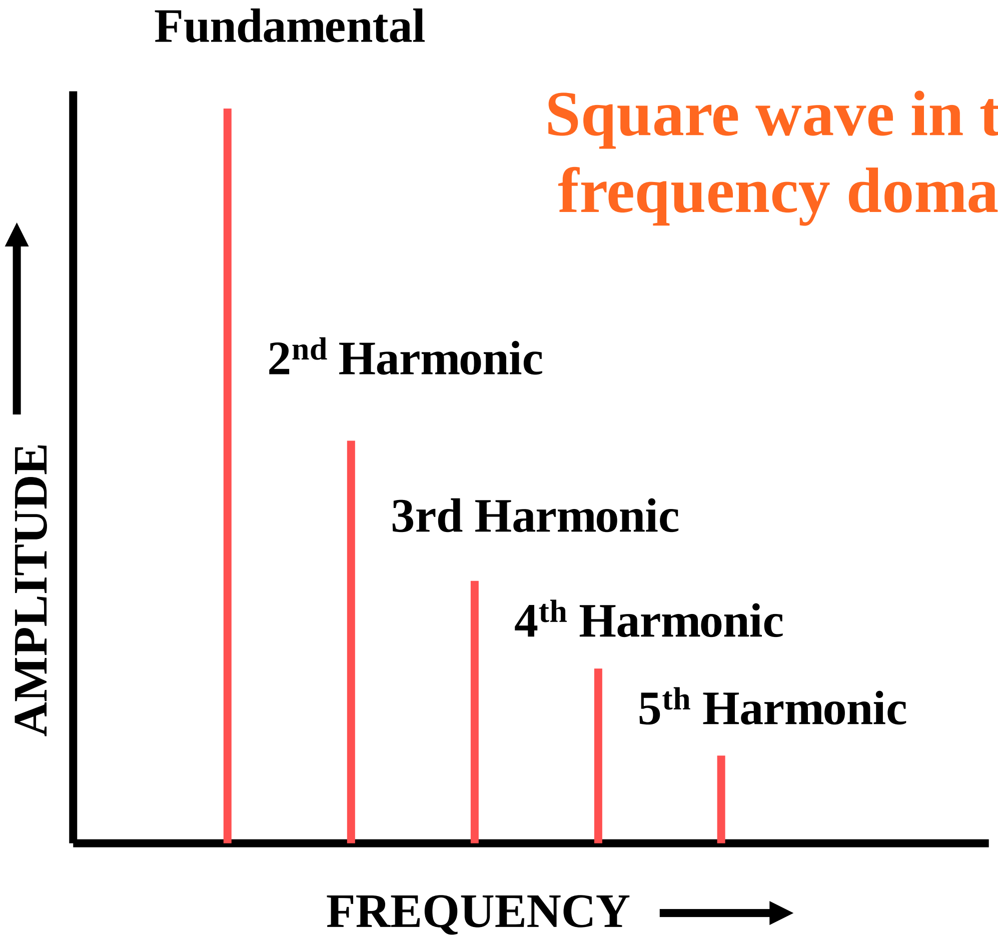
Amplitude



Caused by:

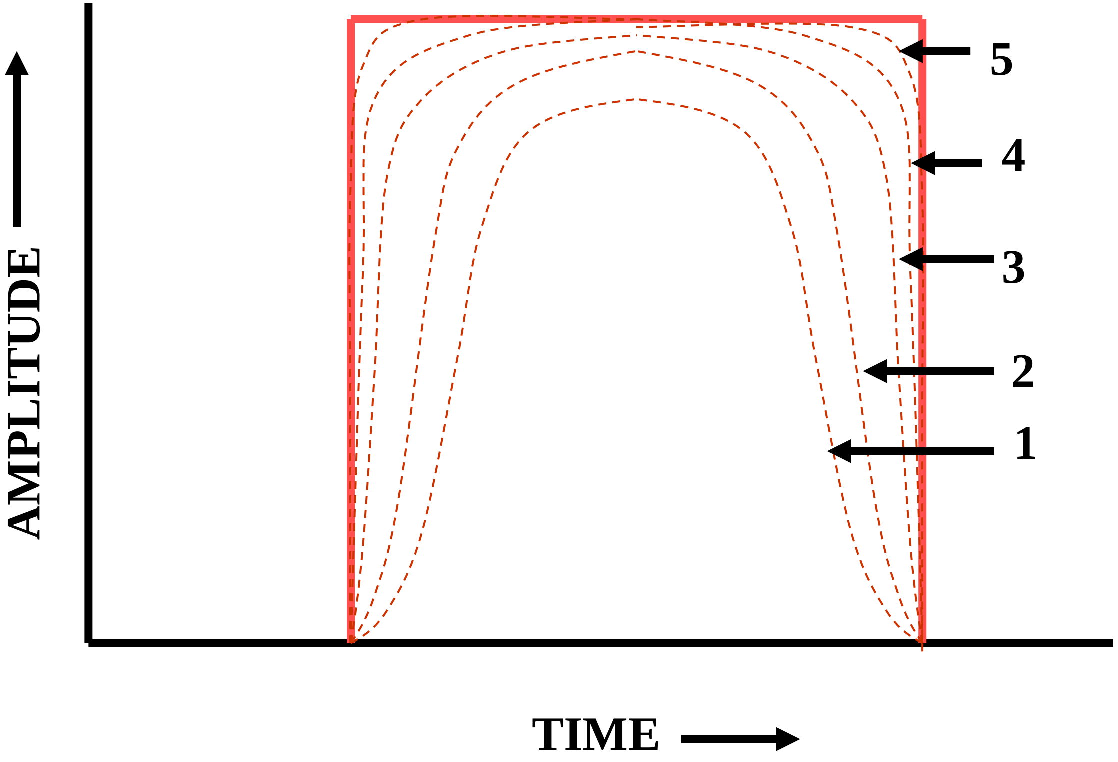
- **Attenuator/Amplifier**
- **Other Front-End Acquisition Hardware**

Bandwidth Basics

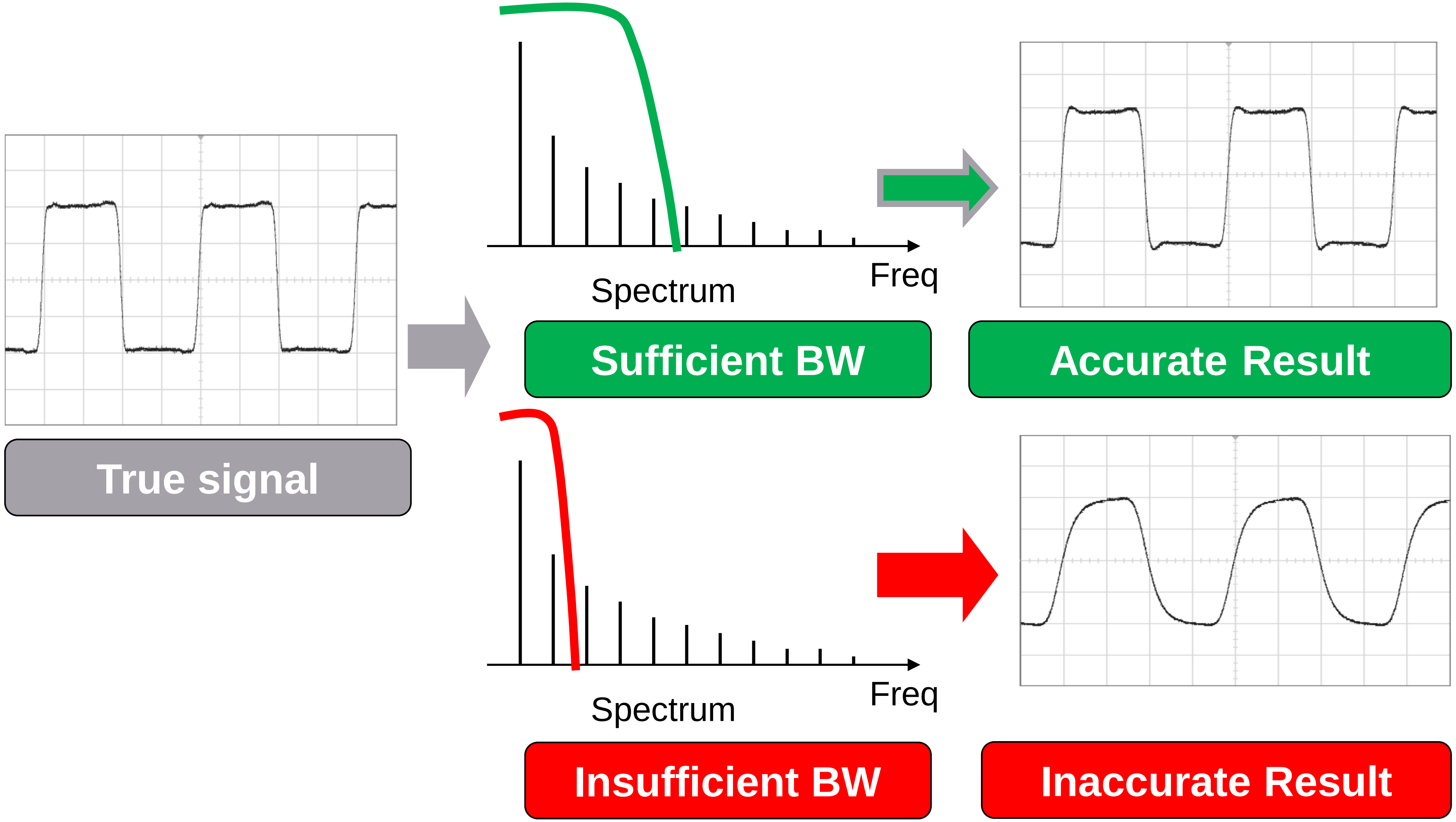


Square wave in the frequency domain

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

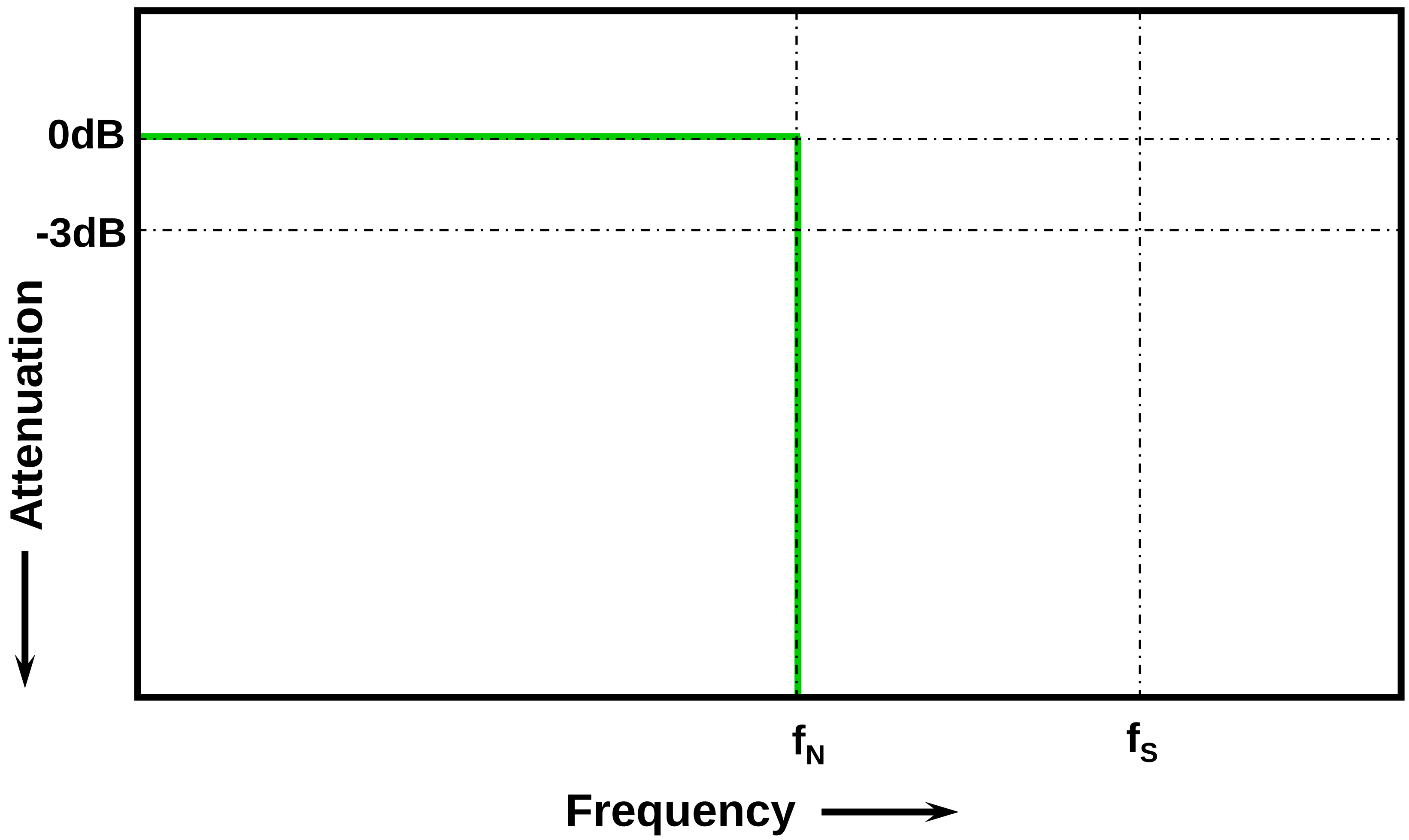


Accurate Measurement Requires Sufficient Bandwidth



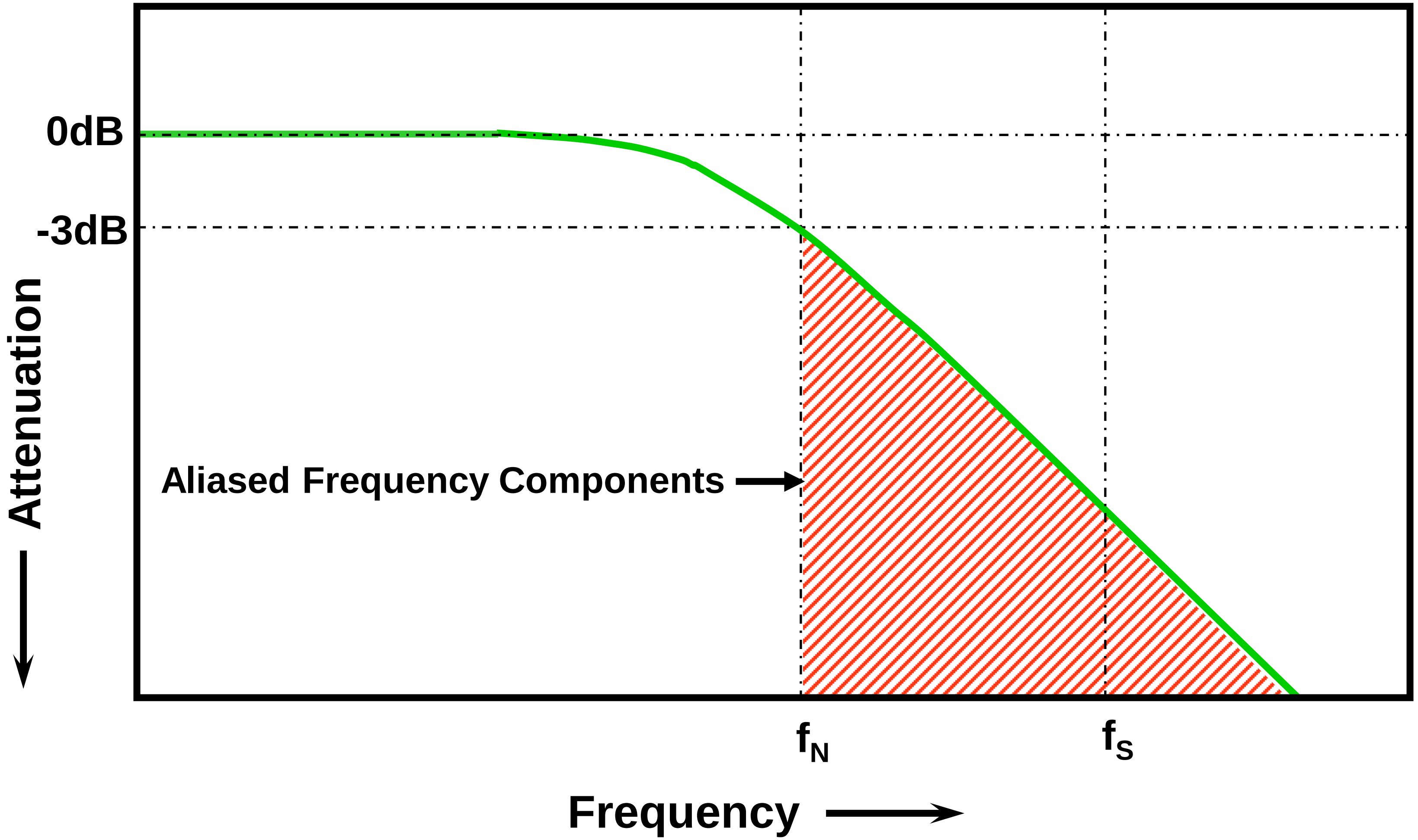
Ideal Brickwall Response w/ BW @ Nyquist (fN)

Not feasible in the real world



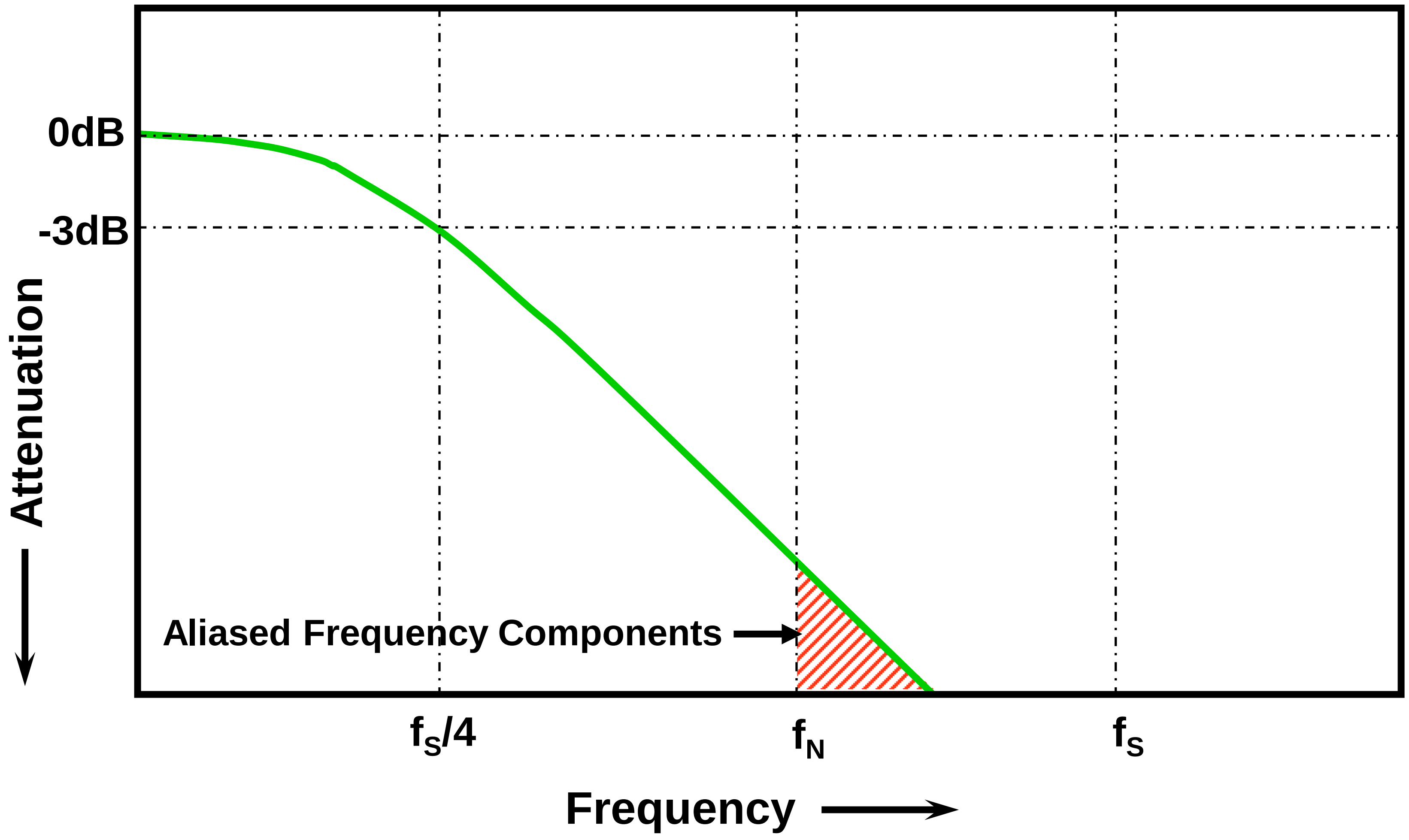
Gaussian Response w/ BW @ fs/2 (fN)

"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.



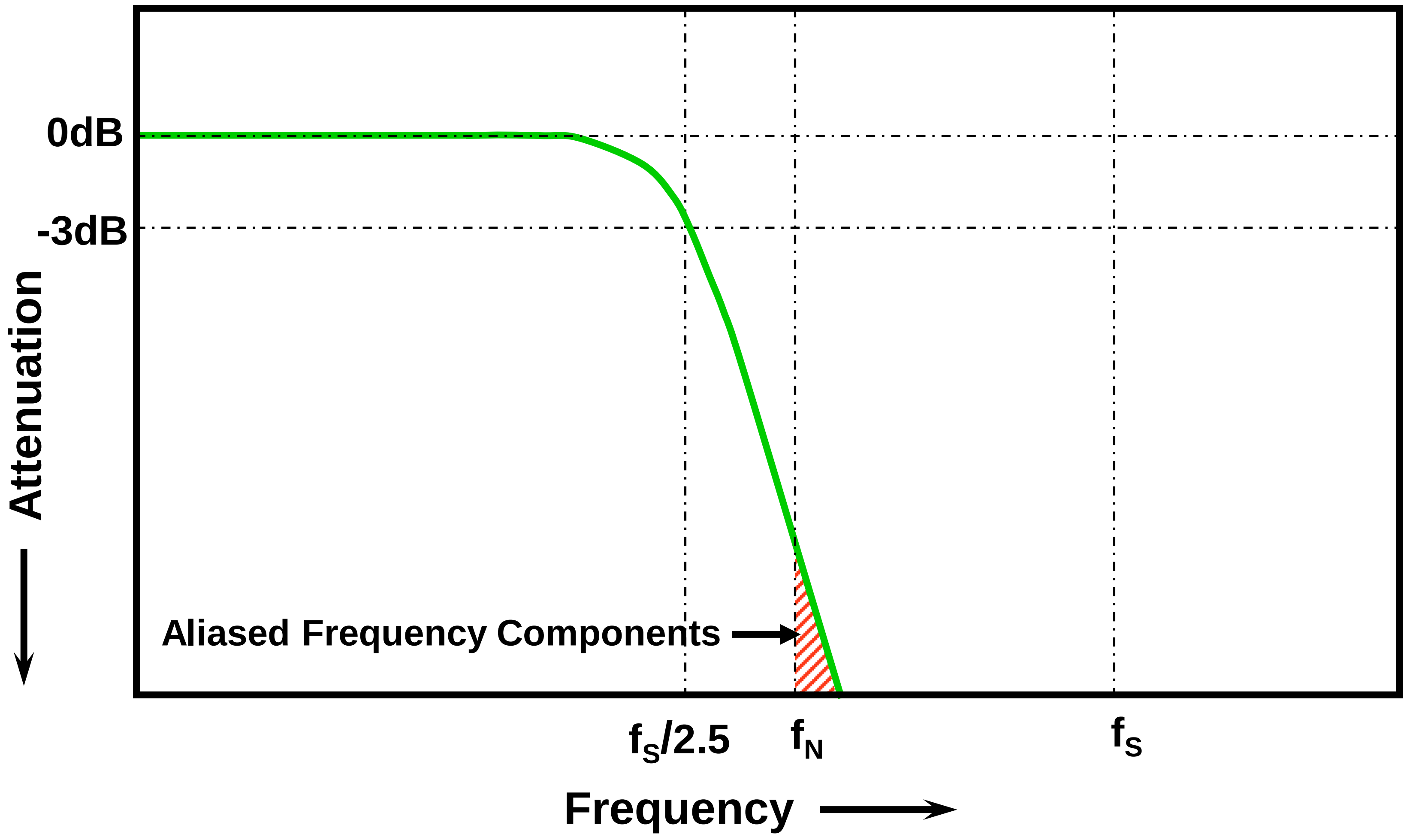
Gaussian Response w/ BW @ fs/4 (fN/2)

Sample rate is four times bandwidth



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 Calculation

How Much Bandwidth Do You Need?

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

Step #2: Determine the 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 the required measurement accuracy and calculate the required oscilloscope bandwidth:

Required Accuracy	Gaussian Response	Maximally-flat Response
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}

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

Bandwidth Calculation

Calculation Example

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

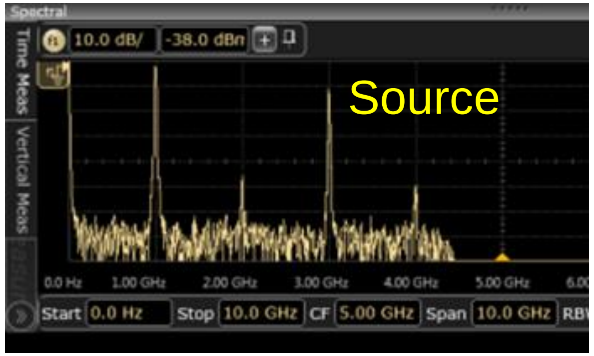
f_{knee} (10-90%) = (0.5/RT) = (0.5/0.5 ns) = 1 GHz

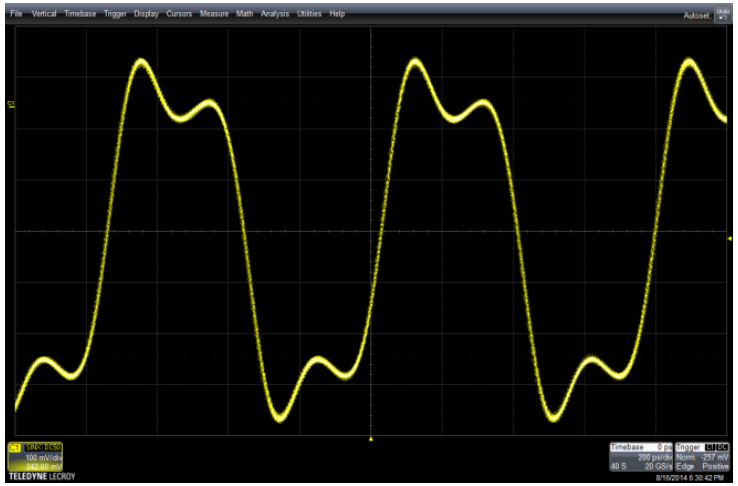
20% Accuracy: BW = 1.0 x f_{knee} = 1.0 x 1 GHz = 1.0 GHz

3% Accuracy: BW = 1.9 x f_{knee} = 1.9 x 1 GHz = 1.9 GHz

Why Do Scopes of Equal Bandwidths Show Different Waveform Shapes?

All Scope Settings Are Identical





The two scopes will report different Vpp and rise time measurement values

It’s time for some hands-on practise

High-Speed Oscilloscope Fundamentals

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  - Bode Plots)

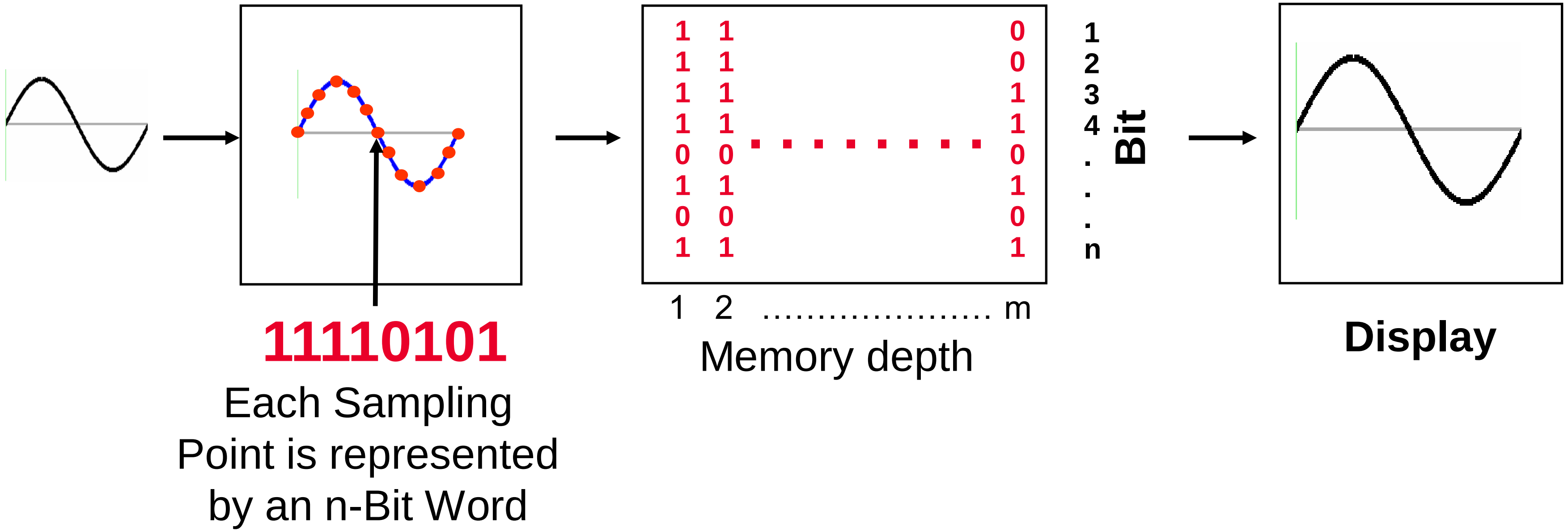
Sampling Basics

How often the oscilloscope measures voltage → sampling rate

- **Sampling Rate** is 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 sample rate varies from ~2.5x to 5x the oscilloscope bandwidth (depending on the frequency response type). E.g., 1 GHz needs 5 GSa/s

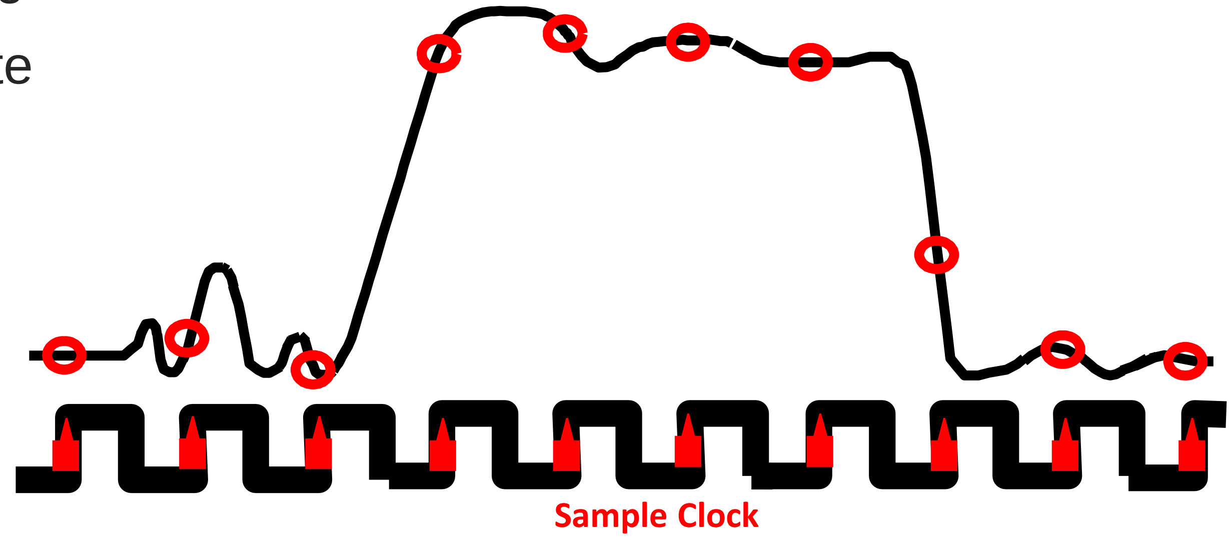
Sampling Basics

From Samples to a Displayed Trace



Sampling Basics

- 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

- **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.,

$$\mathbf{f_s > 2 \cdot f_{max}}$$

[sample twice the frequency of the signal!]

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

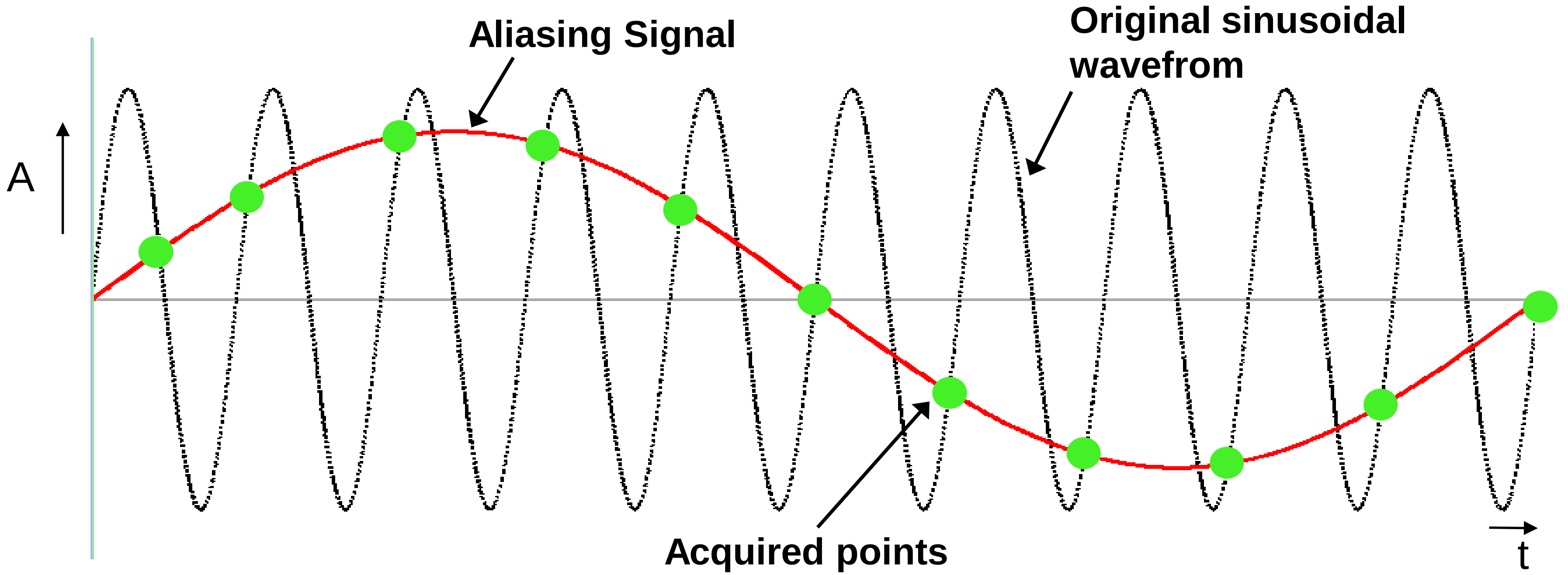
- $\mathbf{f_s}$ is called the Nyquist sampling frequency.
- $\mathbf{f_{max}}$ is sometimes called the Nyquist frequency (f_N).

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

What is Aliasing?

- **Aliasing** is caused by violation of Nyquist‘s theorem, when less than two sample points per period of a sinusoidal waveform are acquired.

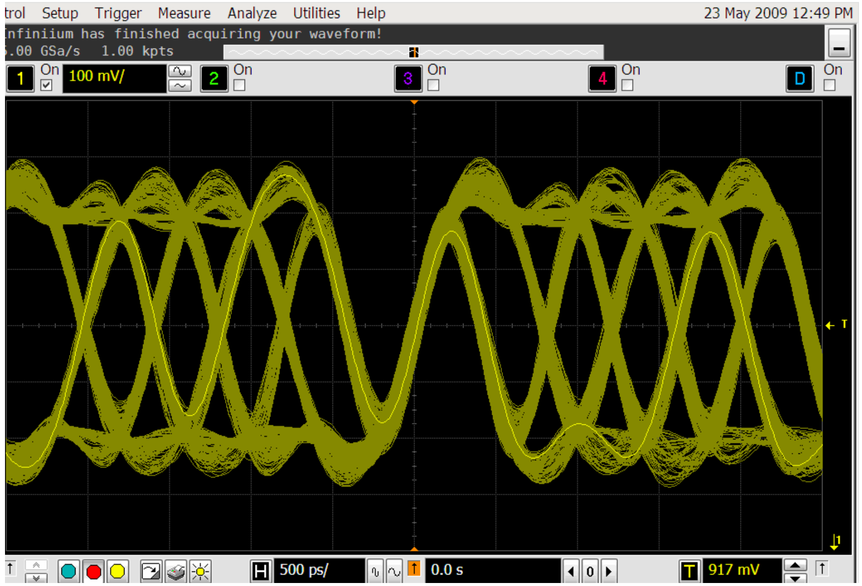
$$x(n) = \sin(2\pi f_0 n t_s) = \sin(2\pi (f_0 + k f_s) n t_s)$$



Aliasing Caused by Undersampling in Digital Applications

PRBS 2.5 Gbit/s with fmax ≈ 5 GHz

10 GSa/s



5 GSa/s

It’s time for some hands-on practise

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  - Fault Hunter
  - Real-Time Spectrum Analysis
  - Bode Plots)

Waveform Reconstruction

Vertical and Horizontal Resolution

<ins>Vertical resolution:</ins>

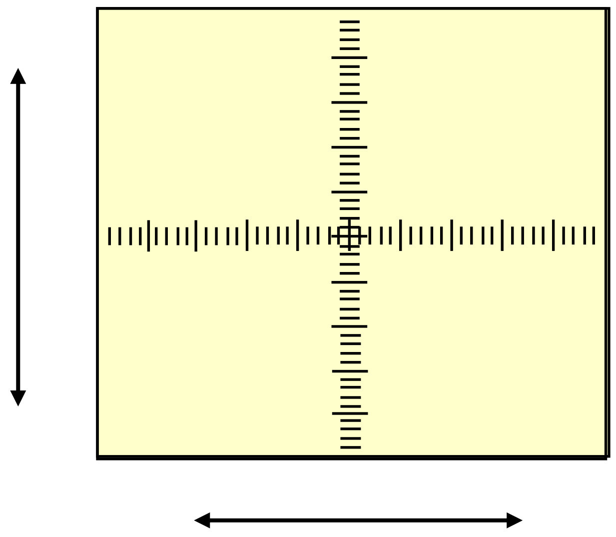
- Given in Bits
- Quantisation steps = 2^N ,

where N = Number of bits

Examples:

8 Bit → 256 levels

10 Bit → 1024 levels



<ins>Horizontal resolution:</ins>

Time resolution = ${}^{1}/_{Sample\ rate}$

Examples: $\frac{1}{10\ GSa/s} = 100\ ps$

Waveform Reconstruction

Quantisation and Quantisation Error

- A N-bit ADC has quantisation steps of $n = 2^N$.
- The Quantisation Error q of a signal with an Amplitude A is calculated using $q = \frac{A}{2^N - 1}$.

Examples for a signal with an amplitude of 1V at full scale:

✓ Vertical resolution for an 8-bit ADC is $n = 2^8 = 256$ steps.
✓ The quantisation Error is then calculated to $q = \frac{1V}{2^8 - 1} = 3.9\, mV$

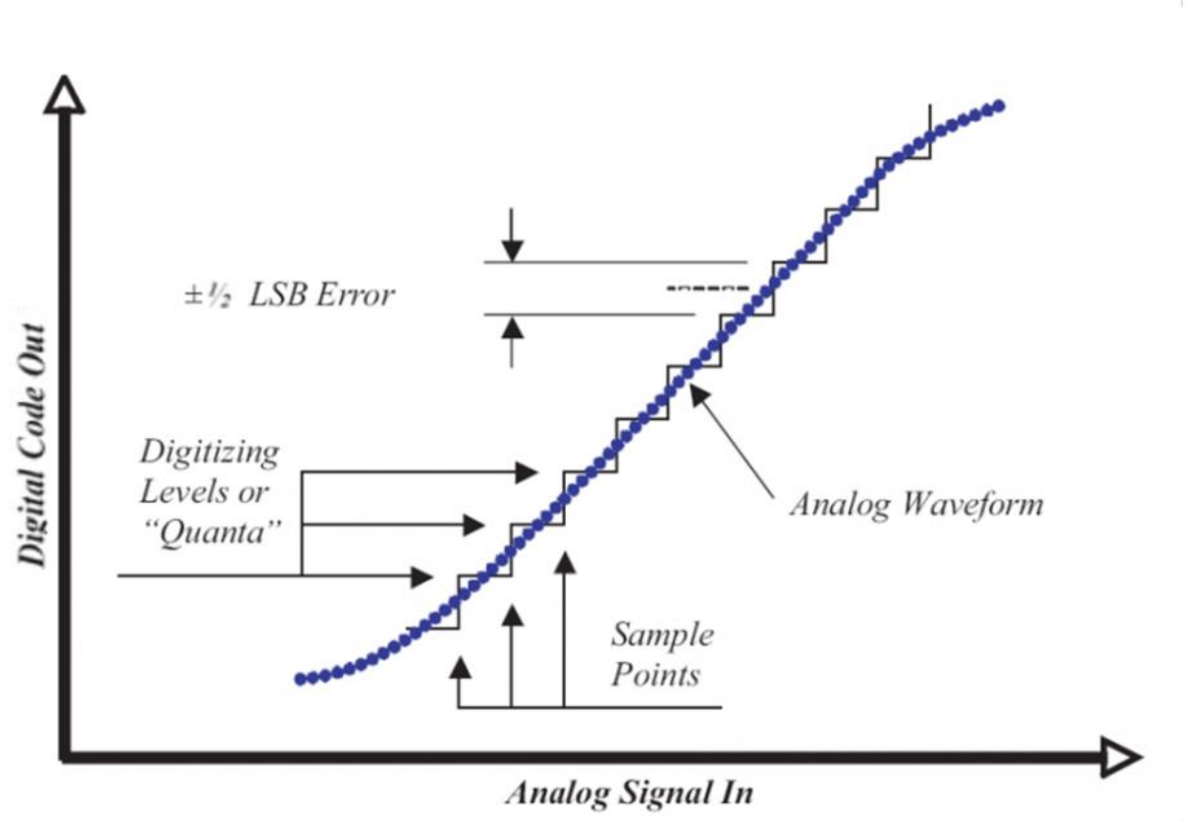
✓ Vertical resolution for a 10-bit ADC is $n = 2^{10} = 1024$ steps.
✓ The quantisation Error is then calculated to $q = \frac{1V}{2^{10} - 1} = 0.98\, mV$

✓ Often q is also called „**quantisation noise**“ which can be analyzed easily within the frequency domain.

Vertical Resolution: Effective Number of Bits *or* ENOB

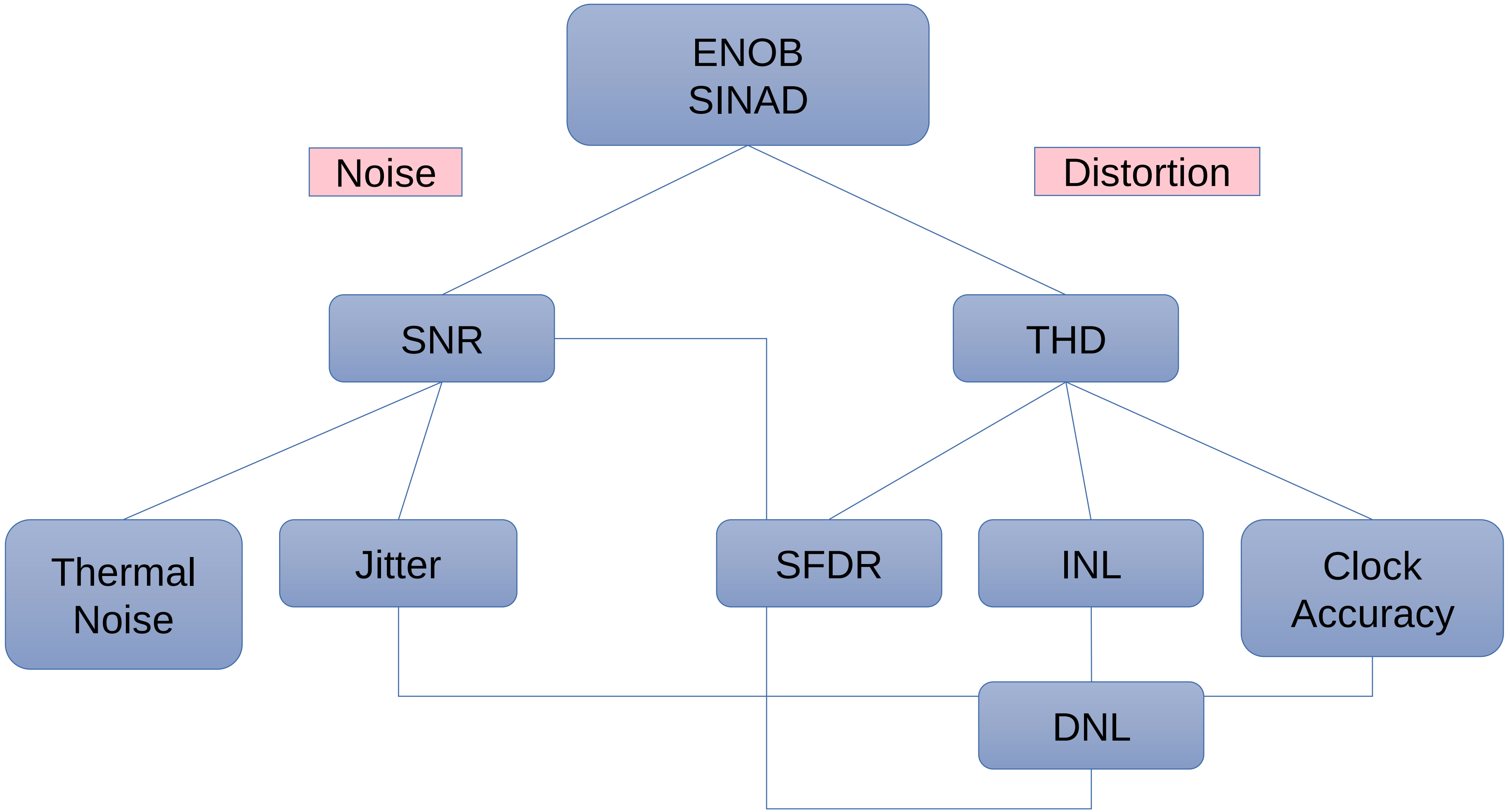
Effective Number of Bits

1. Capture perfect sine wave
2. Measure deviation of result vs input to determine how many “effective bits” the scope system has.
3. ENOB takes into consideration both vertical and horizontal systems of the scope (noise, ADC resolution, interleaving errors, etc.)



Vertical Resolution: Effective Number of Bits *or* ENOB

What Sources are Included in the Calculation?



Vertical Resolution: Effective Number of Bits *or* ENOB

Keep Your Attention to the ENOB Specifications in the Datasheet

- All Infiniium MXR-Series scopes come from the factory calibrated to 6 GHz, and leverage brickwall filters to achieve each model bandwidth. Thus, the noise and ENOB data below is applicable from 20 MHz up to the bandwidth of your oscilloscope model when using the built-in global bandwidth limit feature

ENOB on 50 Ω inputs, 50 mV/div											
20 MHz	200 MHz	250 MHz	350 MHz	500 MHz	1 GHz	2 GHz	2.5 GHz	3 GHz	4 GHz	5 GHz	6 GHz
9.0	8.5	8.4	8.3	8.2	8.0	7.6	7.5	7.4	7.2	7.1	6.8

Vertical Resolution

Noise Sources

- Noise added by the input amplifier and dependend from the attenuator setting
- Quantisation noise
- Sampler noise
- Noise caused by the power supply
- Thermal noise

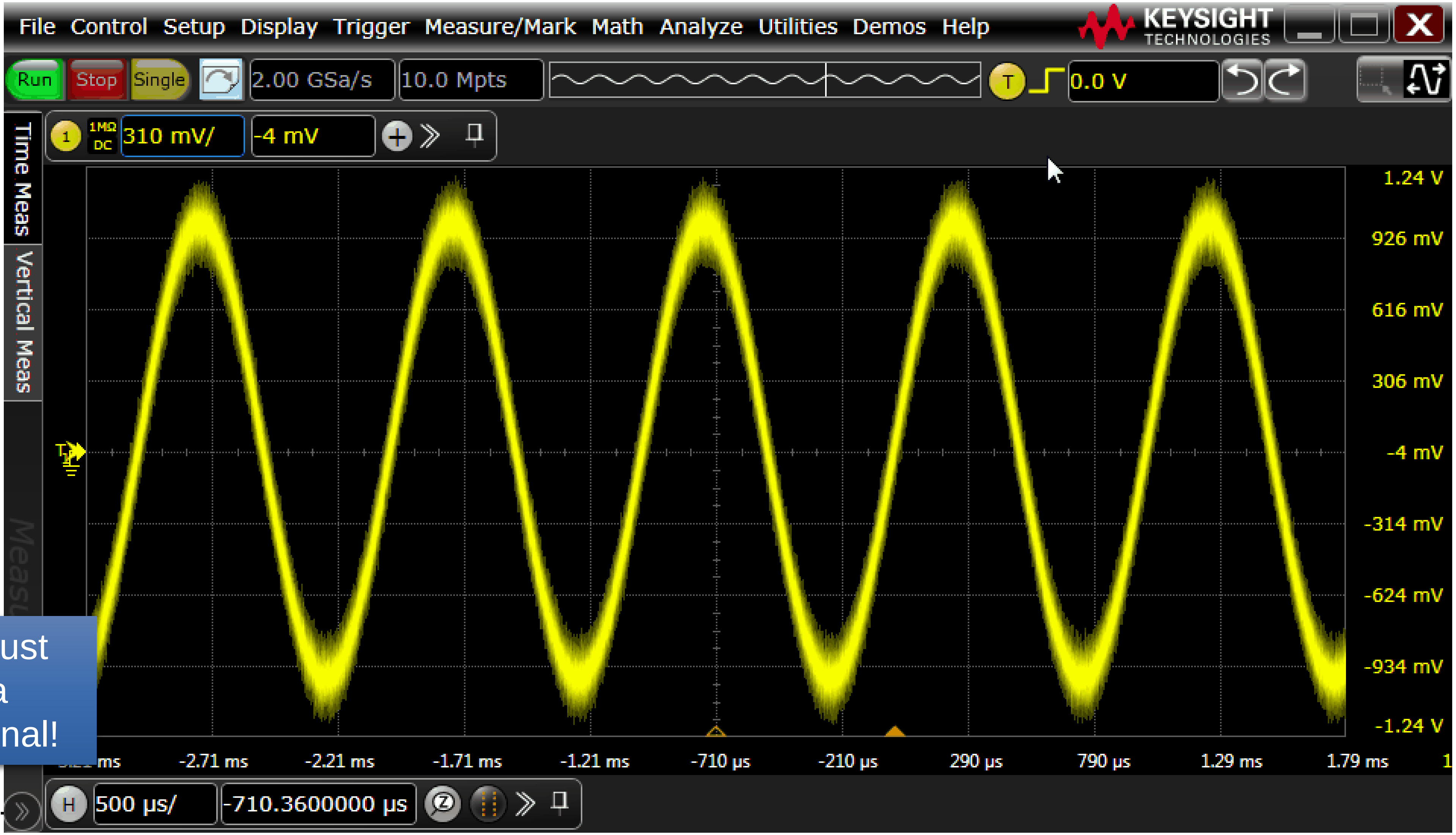
$$u_n = \sqrt{4k_B T R \Delta f}$$

Noise is directly linked to the analog bandwidth of the oscilloscope!

ENOB Improvements Techniques

Bandwidth Limitation

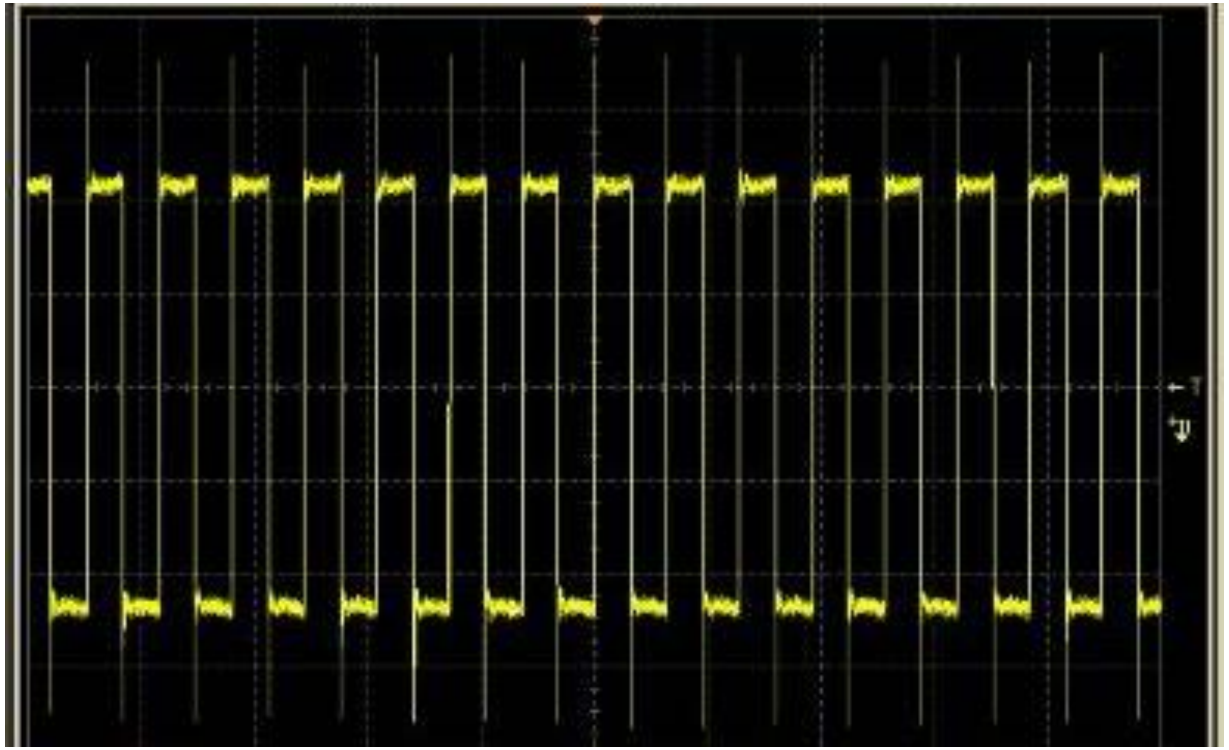
ENOB Improvements Techniques



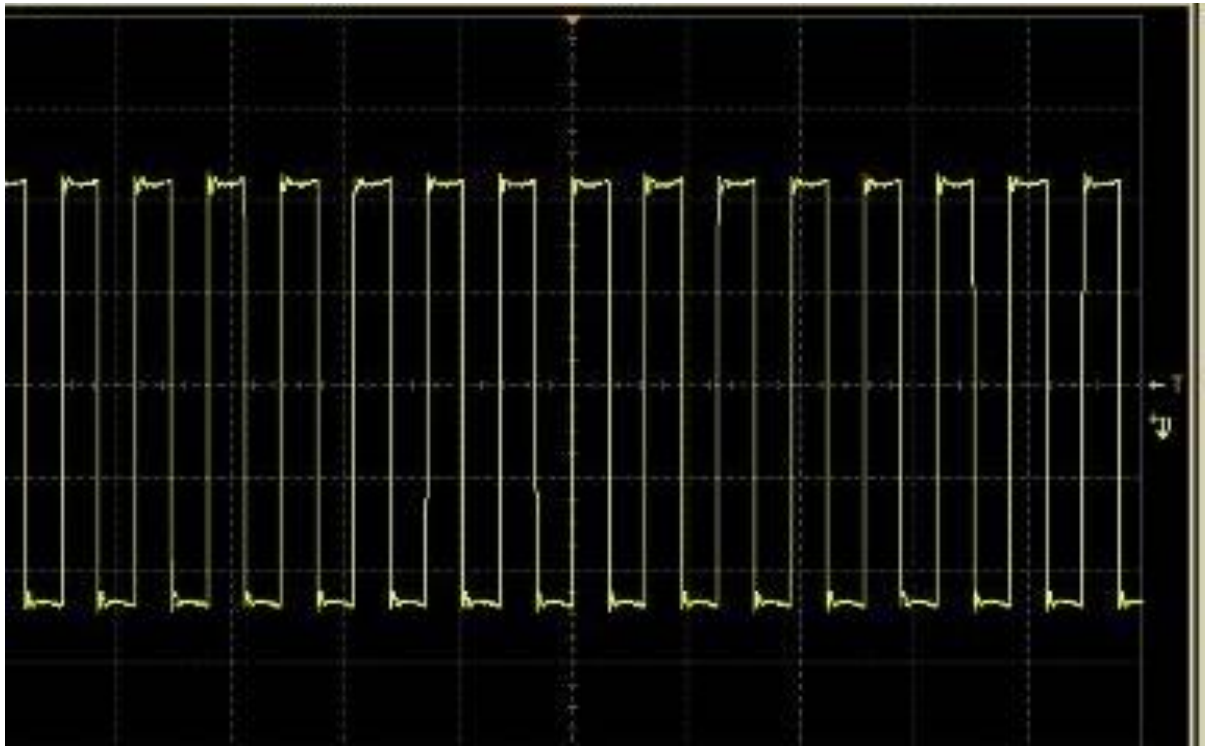
Averaging must be done on a repetitive signal!

ENOB Improvements Techniques

- 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

It’s time for some hands-on practise

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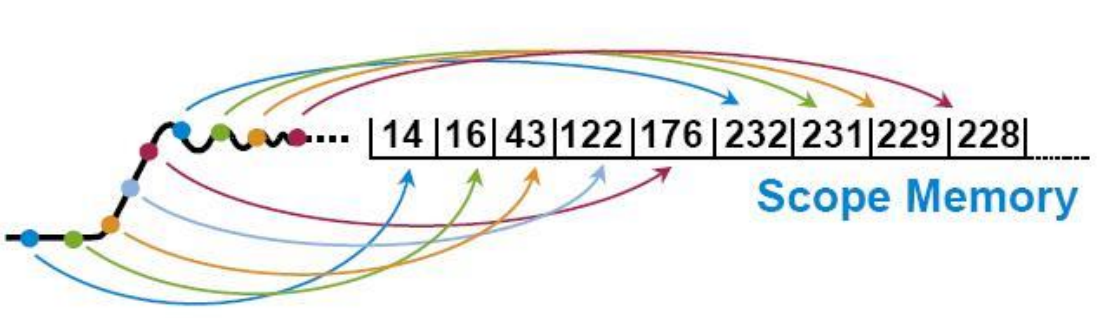
  - Bode Plots)

Memory Depth

- 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!



Memory Depth

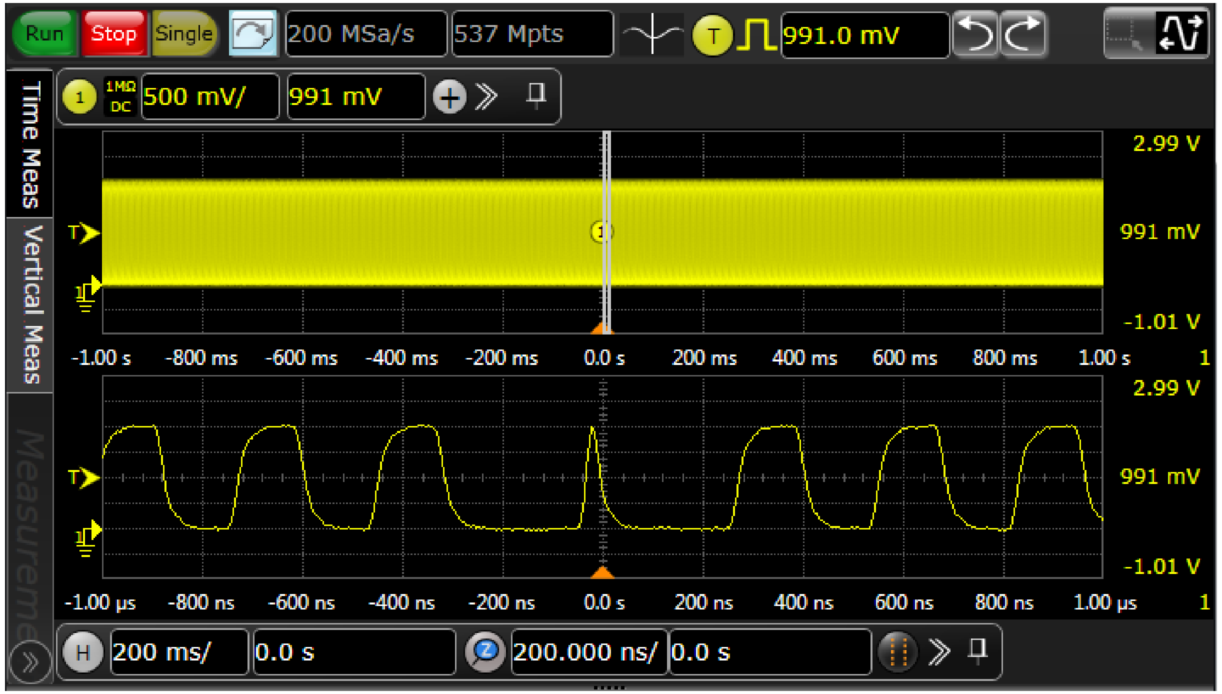
Determine required sample rate

- *See first section about determining sample rate*

Determine longest time-span to acquire

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

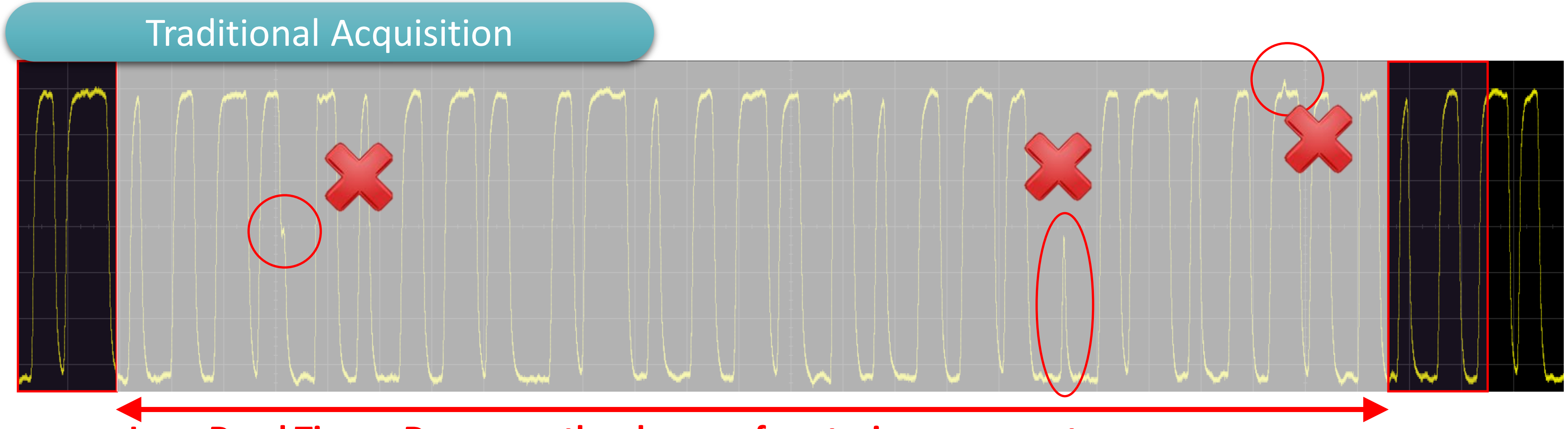
$$Memory\ Depth\ (Sa) = Sample\ Rate\ \left(\frac{Sa}{s}\right) * Time\ (s)$$



<u>Example:</u>
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

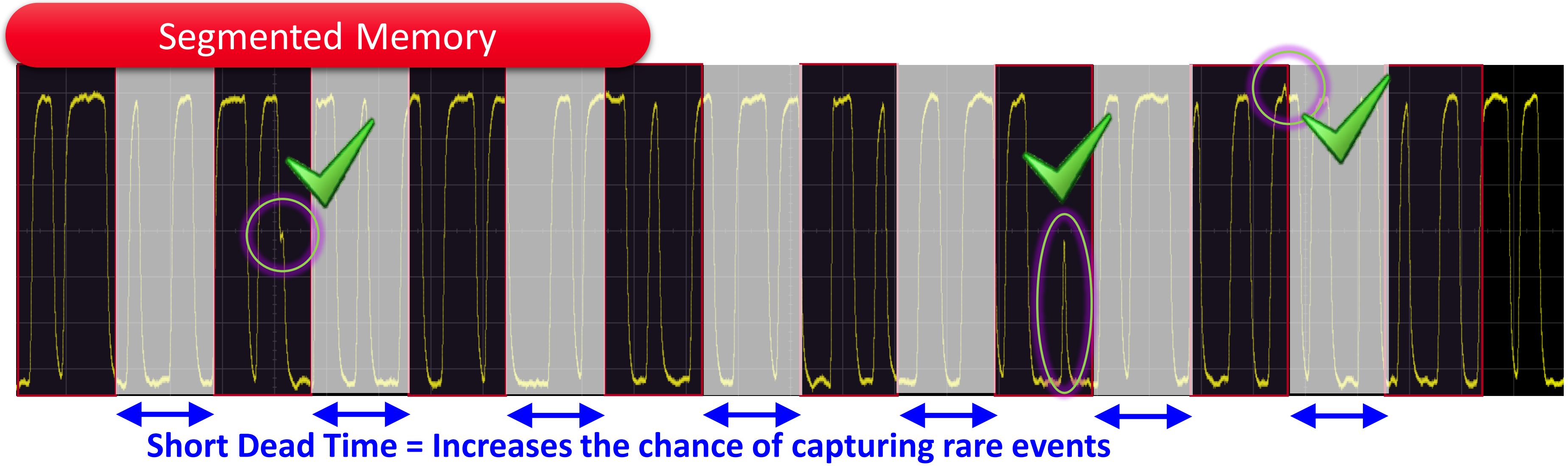
- Slower update rate: more time to process each waveform.
- Time between waveform updates is called “dead time”; the scope is not digitizing.
- Glitches or anomalies can be missed during this dead time.



Long Dead Time = Decreases the chance of capturing rare events

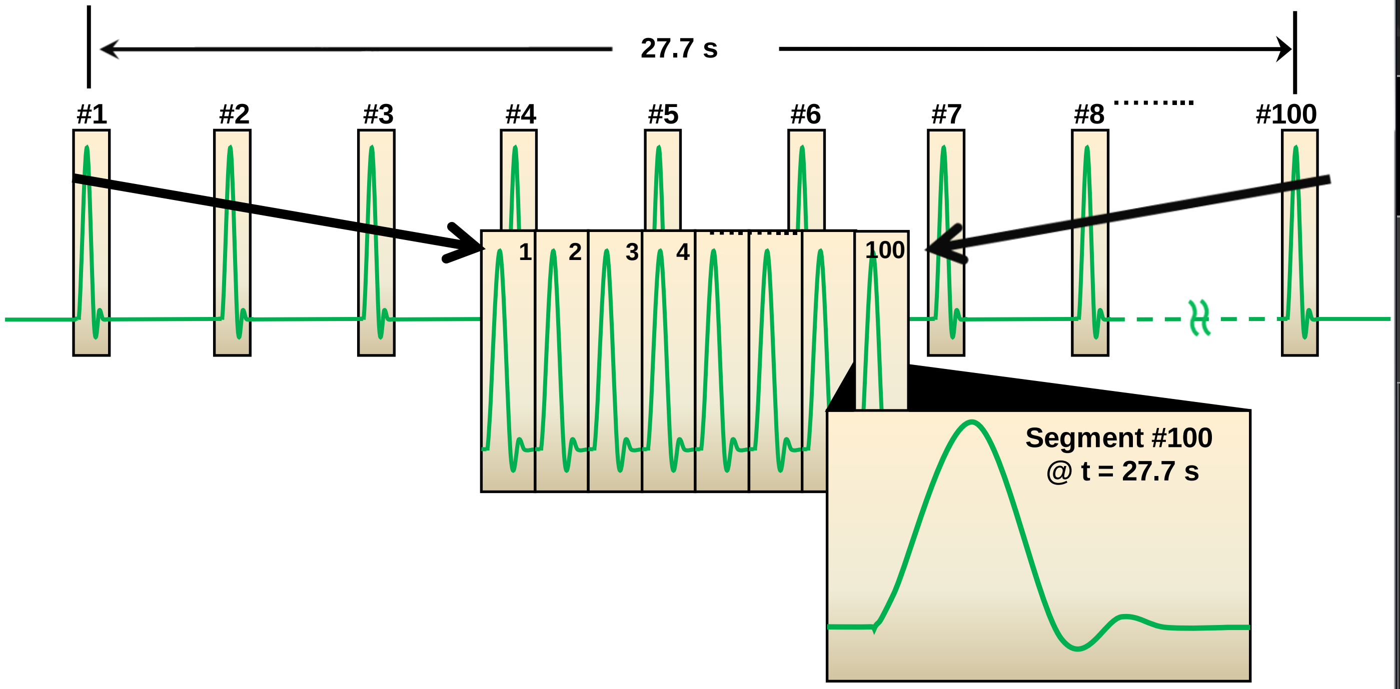
Memory Depth

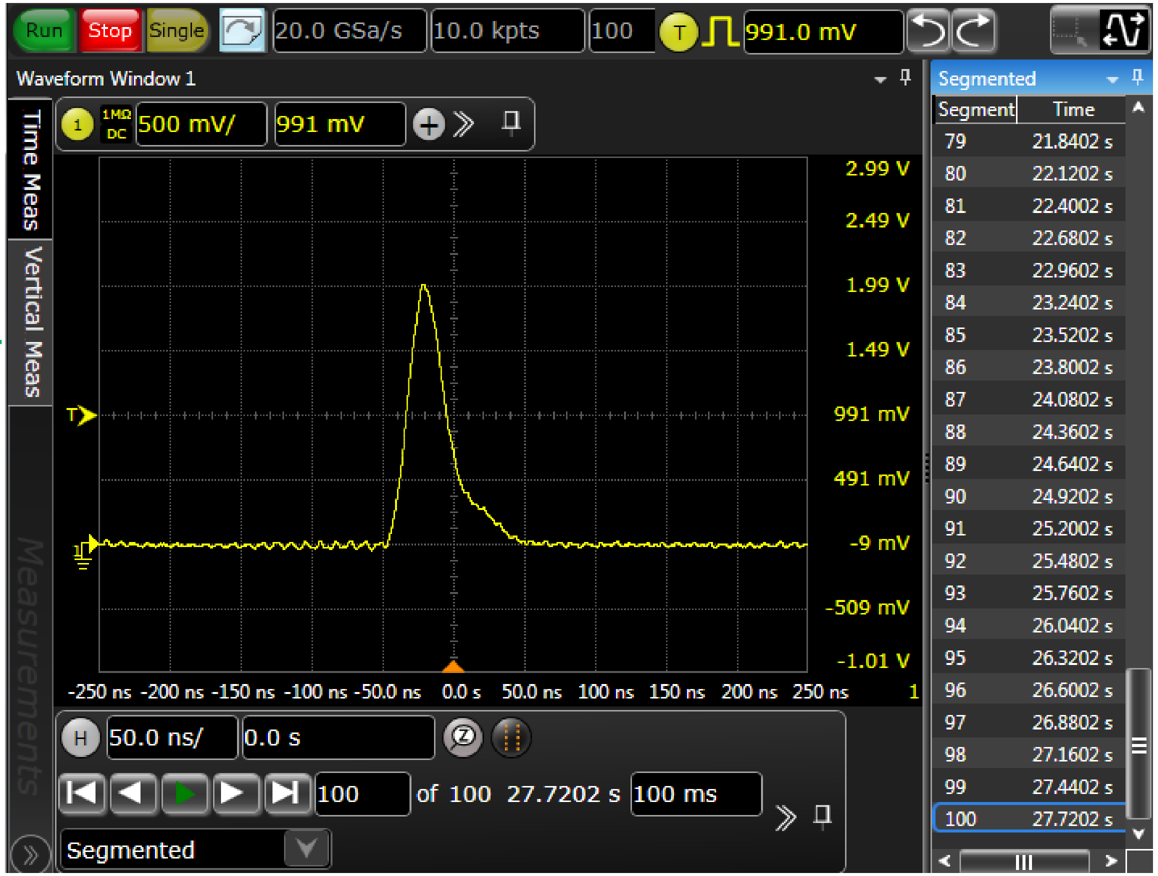
- Segmented memory decreases the dead time significantly
- Limitation: measurements can’t be done in real time, only after a number of segments have been acquired.



Memory Depth

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

Segmented Memory Acquisition on the MXR

- The maximum number of segments depends on the oscilloscope's memory option.
- Also, in the MXR/EXR-Series oscilloscopes, positive channel skew can limit the maximum number of segments to about 5k, depending on the amount of channel skew specified.
- The trigger time feature lets you determine time from the first segment's trigger point to the trigger point of the selected segment.
- The trigger time is displayed at the very bottom of the display along with the current segment number and the total number of segments acquired.

Standard History Mode & Segmented Memory

History mode to view previous trigger events

Segmented memory to capture future trigger events

- ✓ Stop the oscilloscope to look at the last 1,024 waveforms acquired.

- ✓ Arm the oscilloscope to capture the next 5,000+ waveforms and save them for your analysis.

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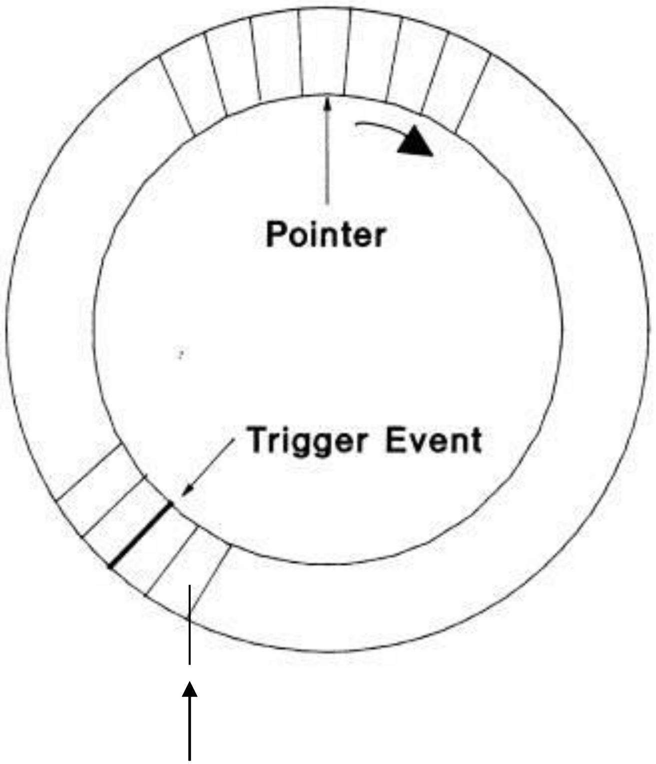
Triggering

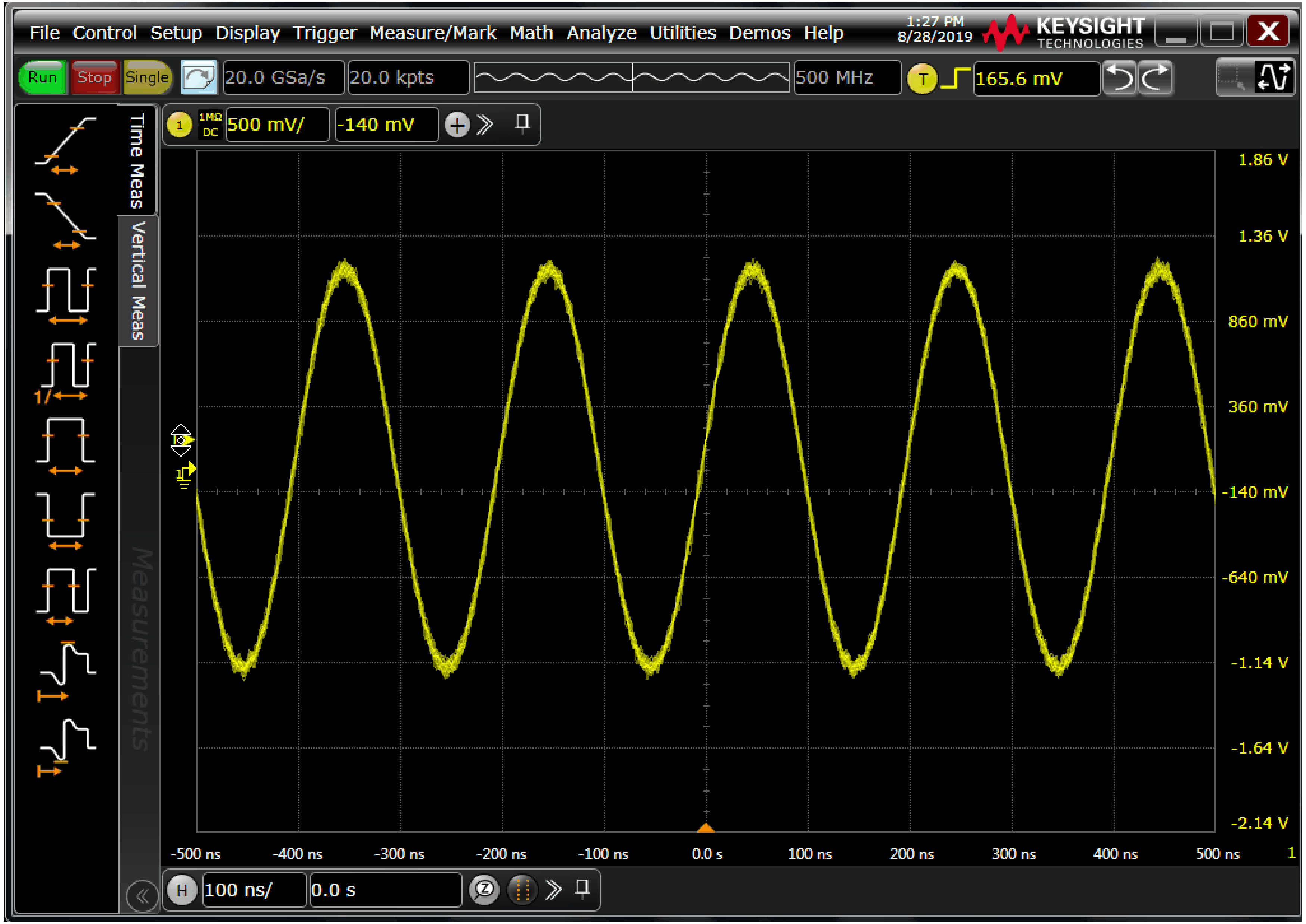
- Digital scopes allow for “pre trigger” data to b saved, unlike older analog scopes. How can the scope do this? With a unique memory structure!
- This allows you to define how much time and data you want to see before and/or after the trigger event.



The memory start/end point

Triggering

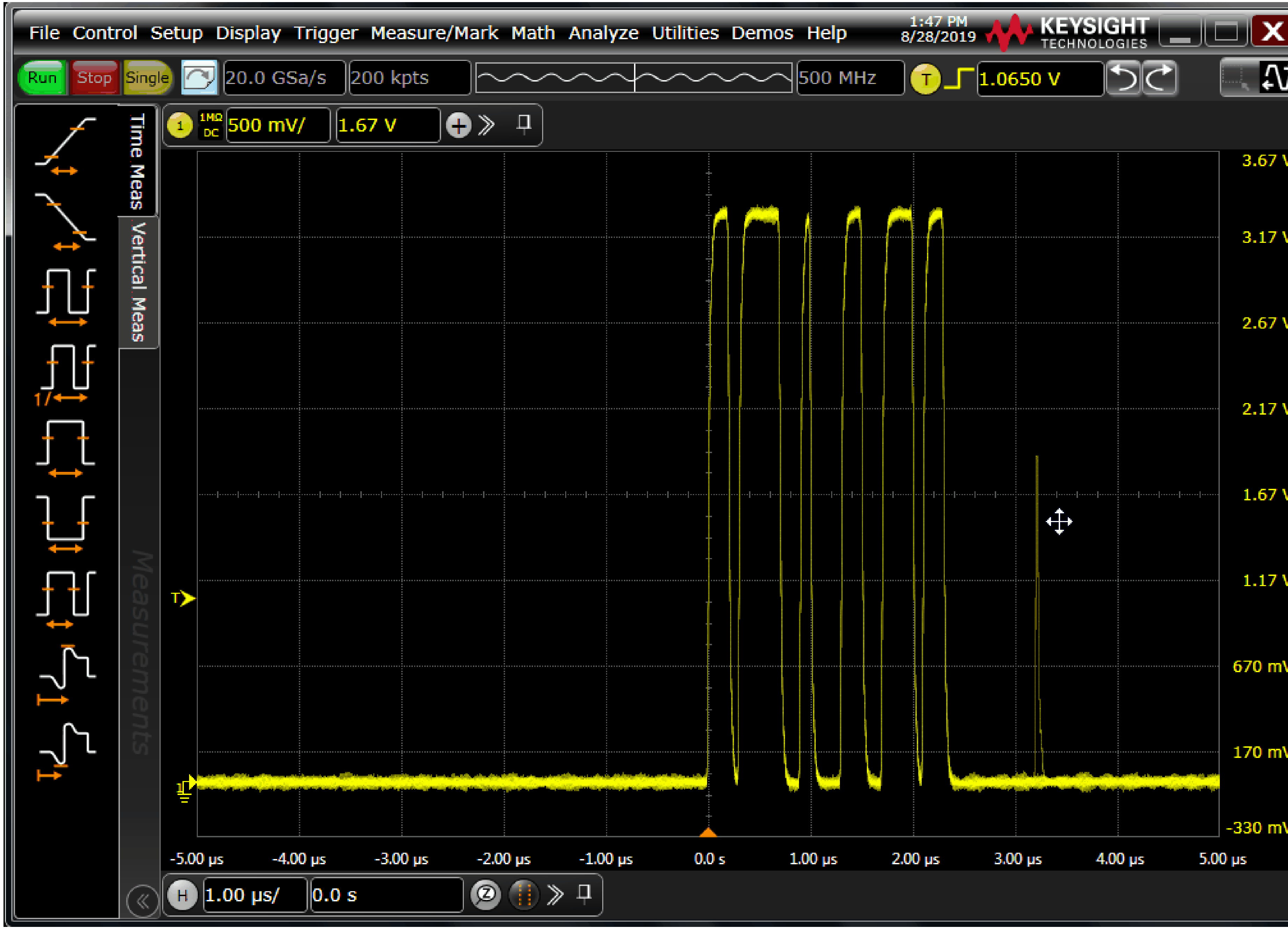
Trigger
Push for 50%
Level



File Control Setup Display Trigger Measure/Mark Math Analyze Utilities Demos Help
1:27 PM
8/28/2019
KEYSIGHT TECHNOLOGIES
Run
Stop
Single
20.0 GSa/s
20.0 kpts
500 MHz
165.6 mV
Time Meas
Vertical Meas
Measurements
500 mV/
-140 mV
1.86 V
1.36 V
860 mV
360 mV
-140 mV
-640 mV
-1.14 V
-1.64 V
-2.14 V
-500 ns
-400 ns
-300 ns
-200 ns
-100 ns
0.0 s
100 ns
200 ns
300 ns
400 ns
500 ns
100 ns/
0.0 s

Triggering

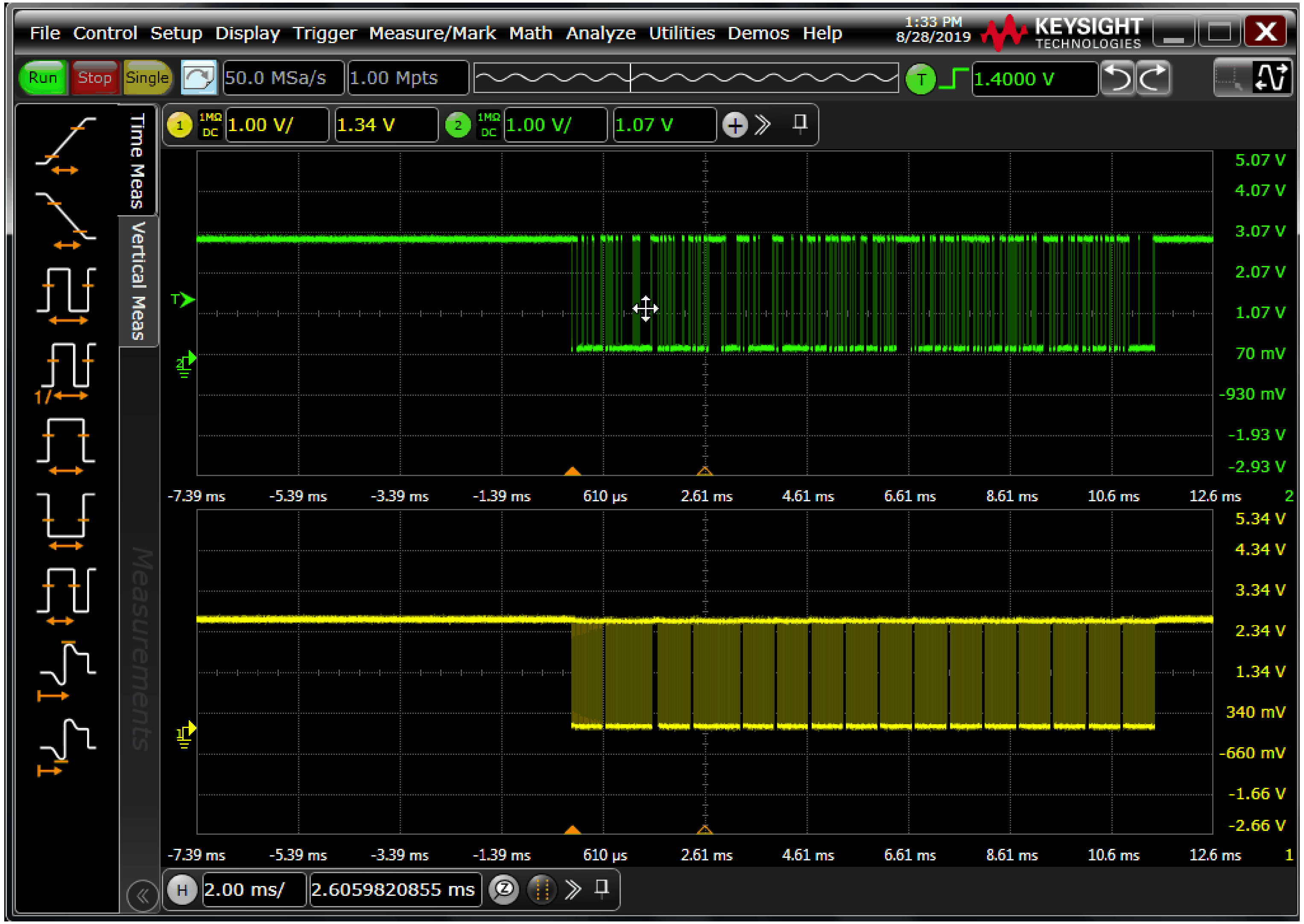
Advanced triggers are just more complex ways to describe the shape of a waveform, such as the pulse width trigger described in the video here.



Triggering

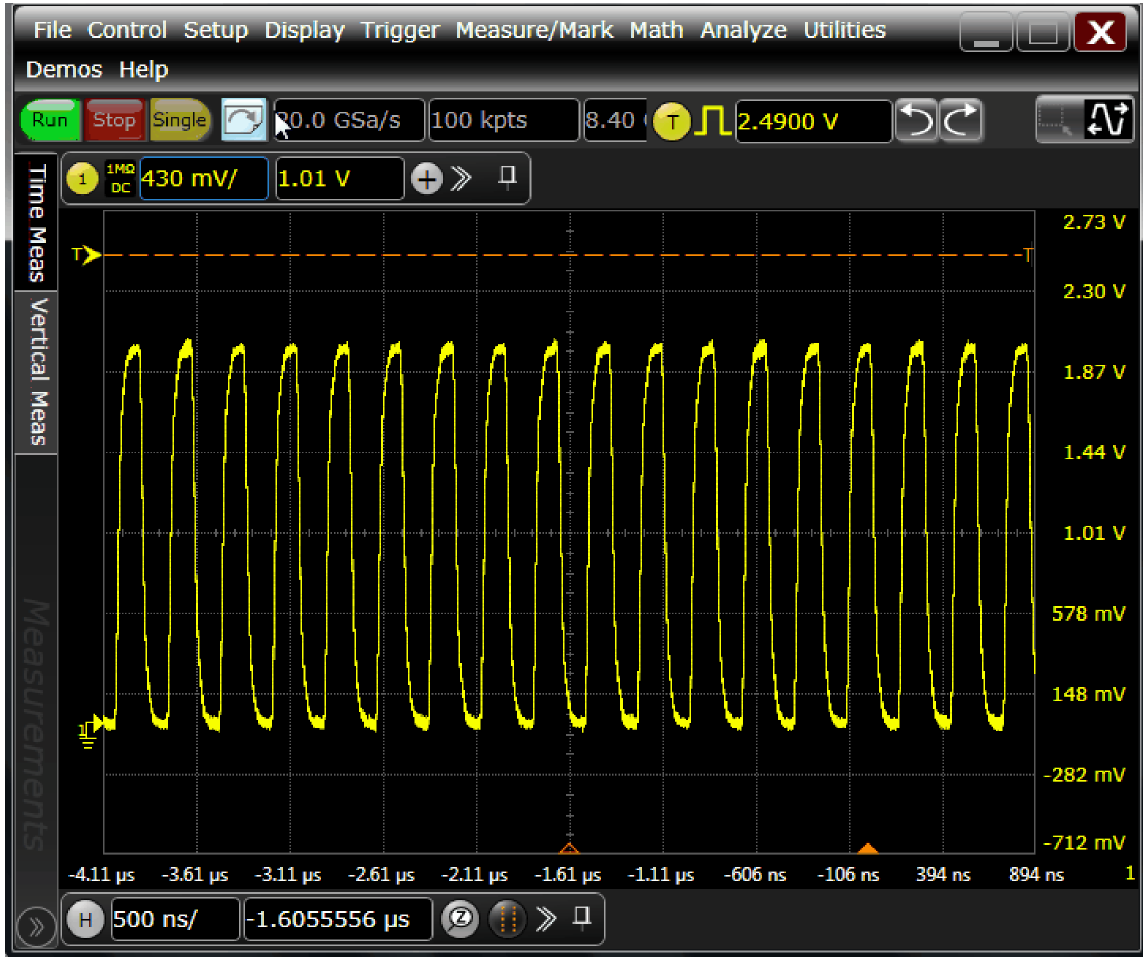
Much of your oscilloscope use will only require standard “edge” triggering. Sometimes your signal is more complex, like this serial bus.

Triggering on more complex signals requires advanced triggering options.



Example: Triggering on an I²C serial bus

Triggering



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

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.

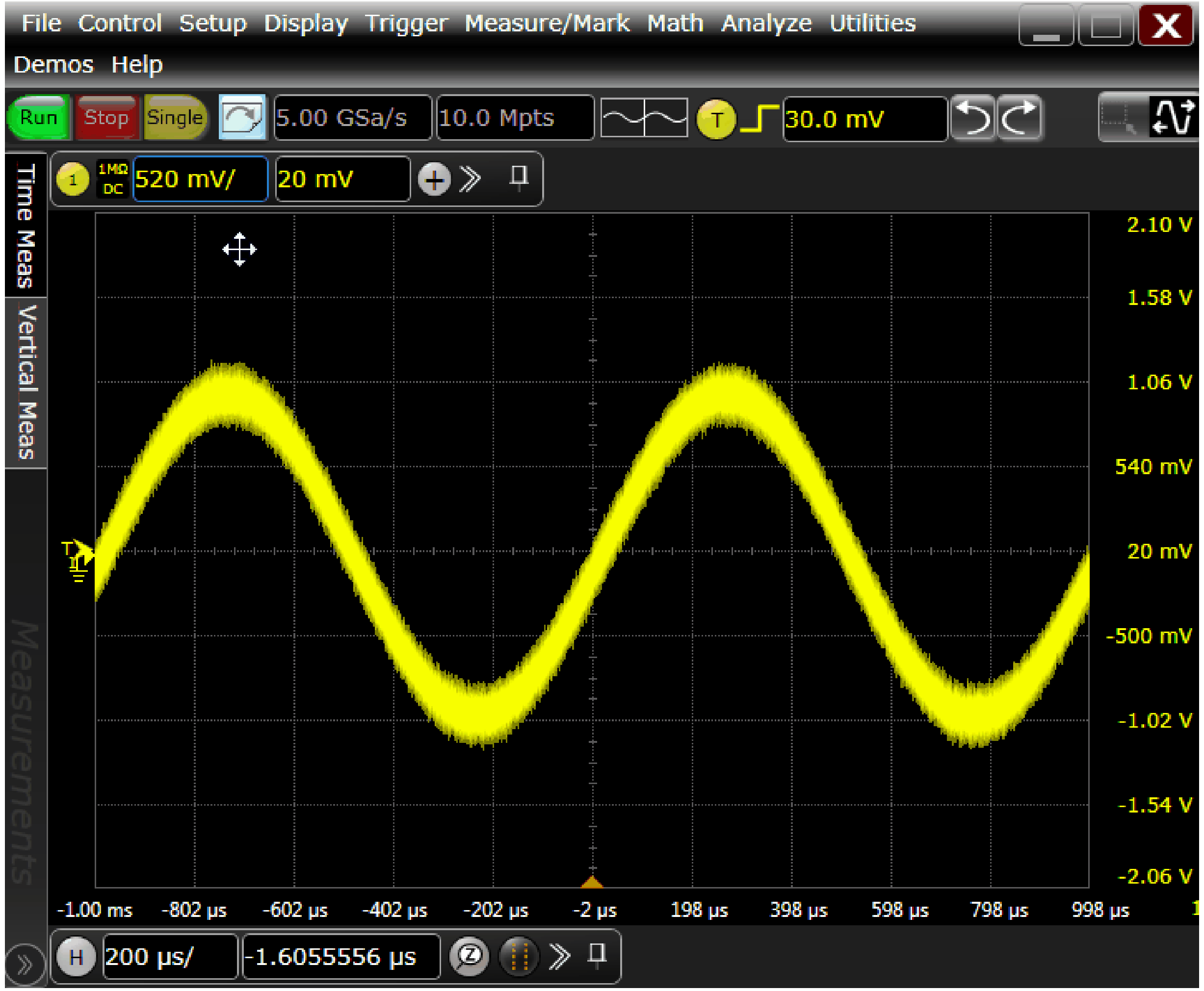
Pros: high frequency signals won’t accidentally trigger the scope.

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.

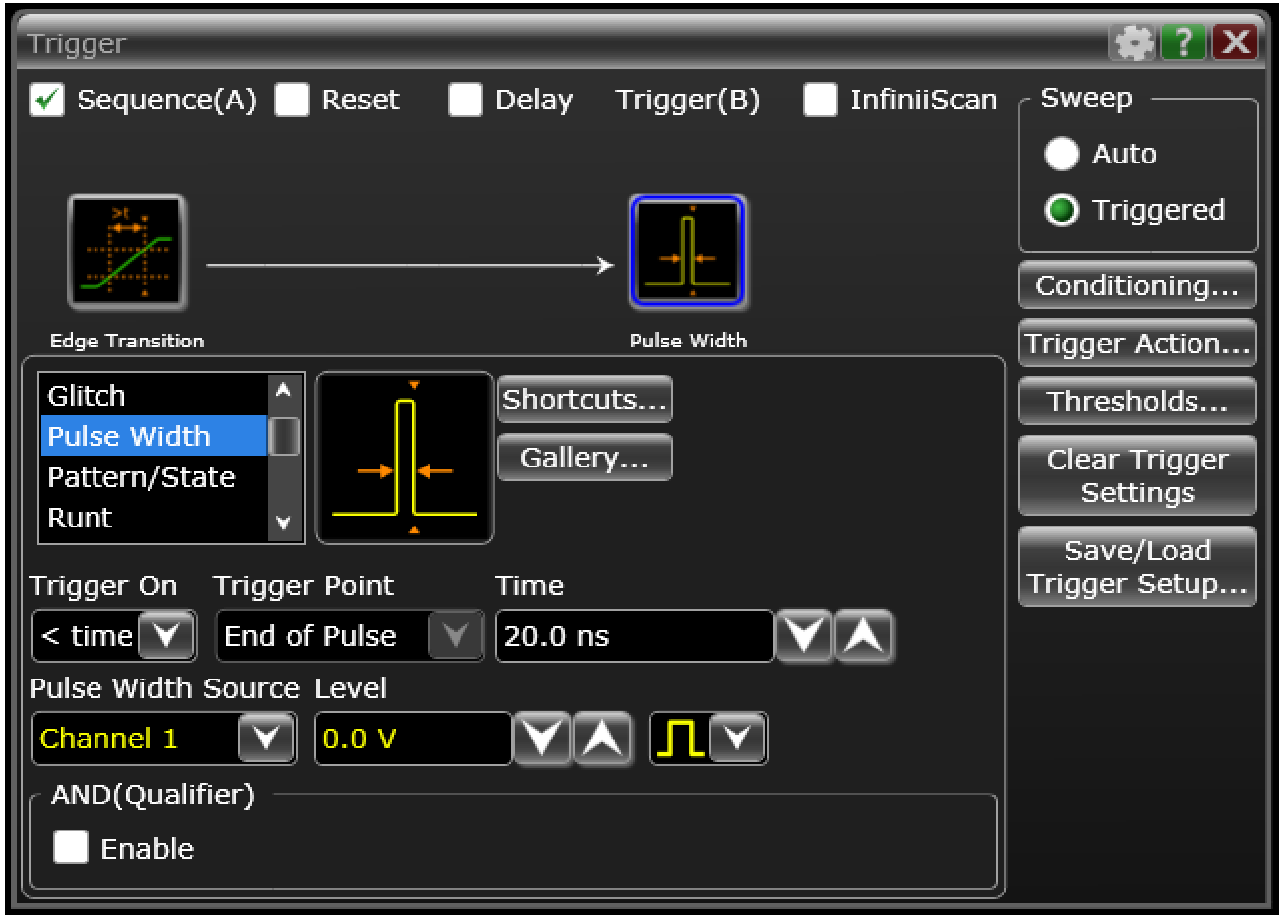


KEYSIGHT

Triggering on the Infiniium Oscilloscopes

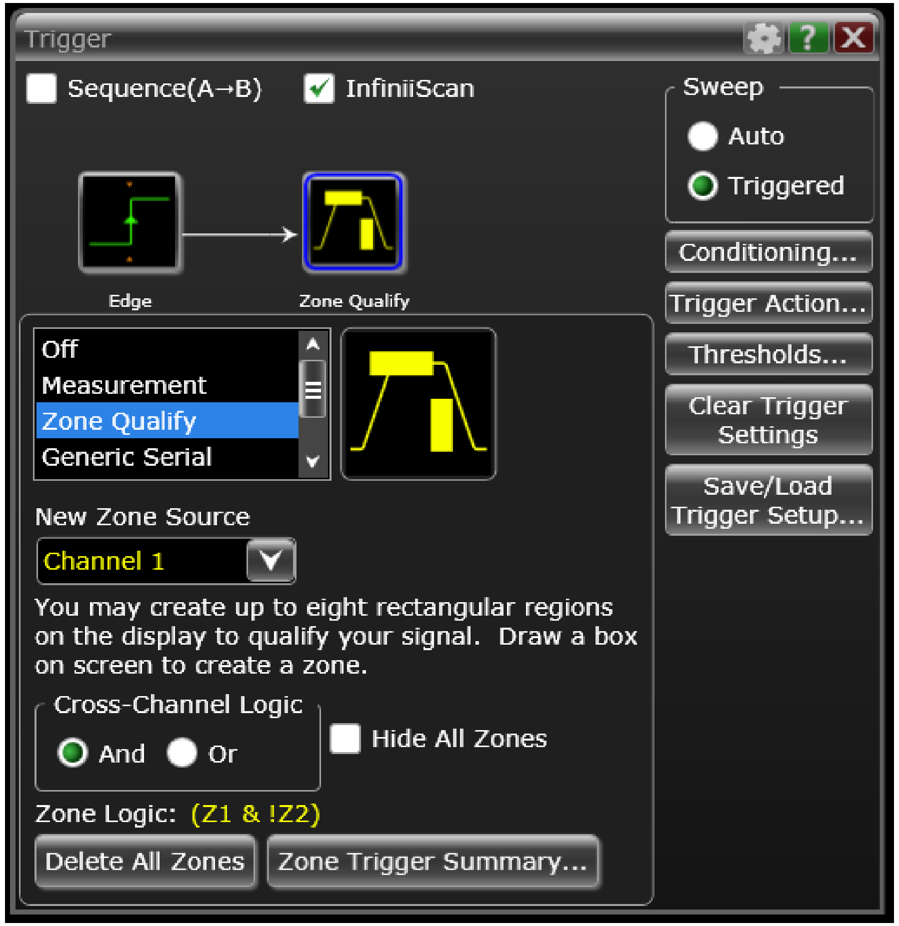
Trigger Sequencing

- First event arms the second event
- Second event generates scope trigger
- Totally asynchronous to scope data acquisition



Oscilloscope Software-Search Triggers

- Similar to trigger sequence in that an arm event starts the cycle (the Edge trigger configured for Channel 2 in the box on the right)
- Instead of arming an asynchronous hardware trigger event like in a sequence, the first event here triggers the scope to acquire data. That data is then analyzed in software to see if it qualifies as a trigger. If it does, it's displayed, if not it's discarded.
- Synchronous to scope data acquisition!
- D9010SCNA Option is required!



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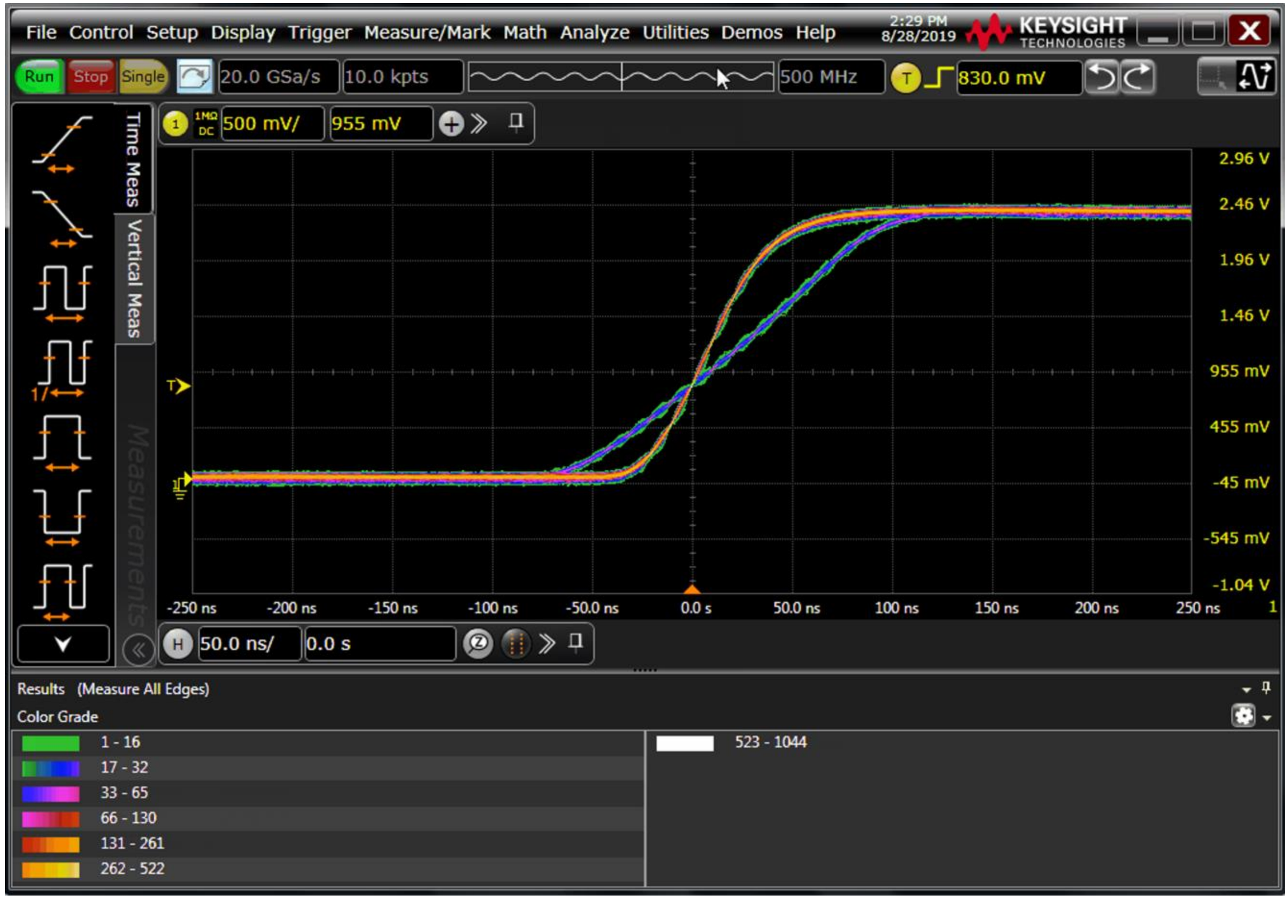
Waveform Visualization & Analysis Tools

Colour Grading

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



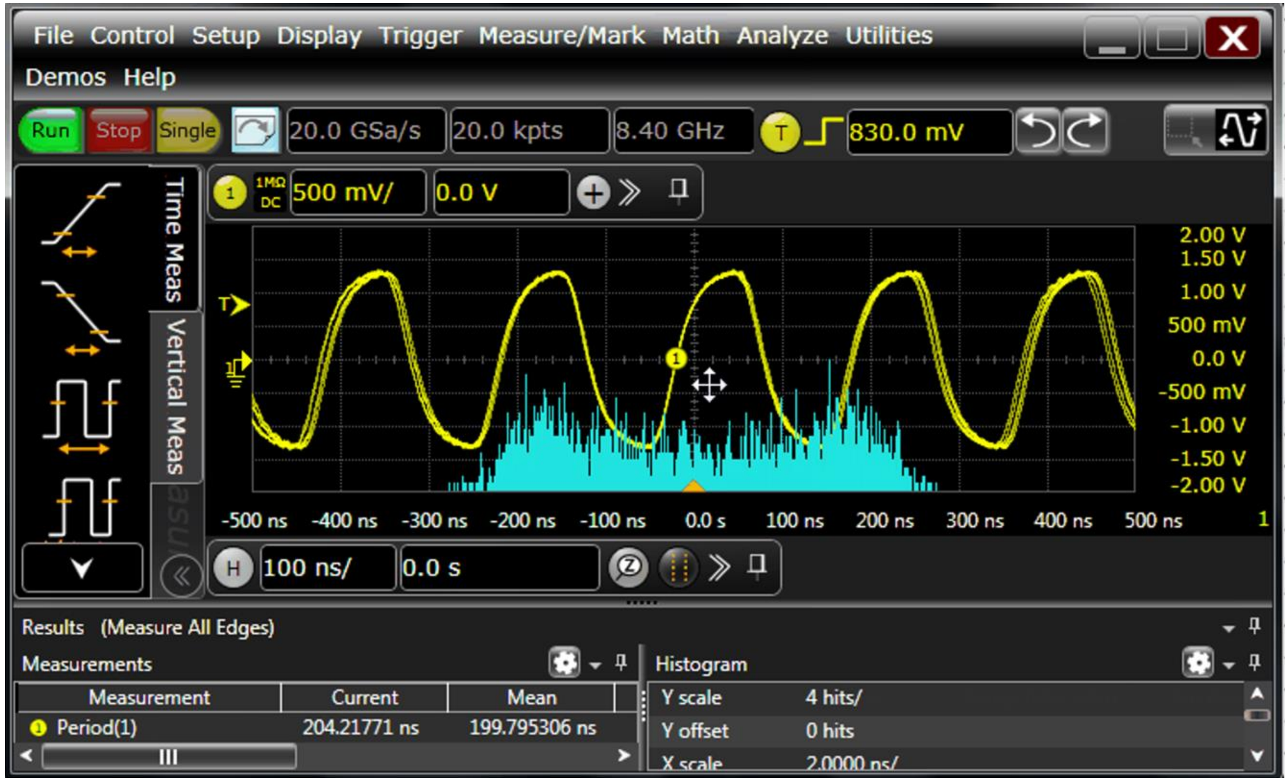
Waveform Visualization & Analysis Tools

Histograms

Distribution of a *signal* within a region on screen

OR…

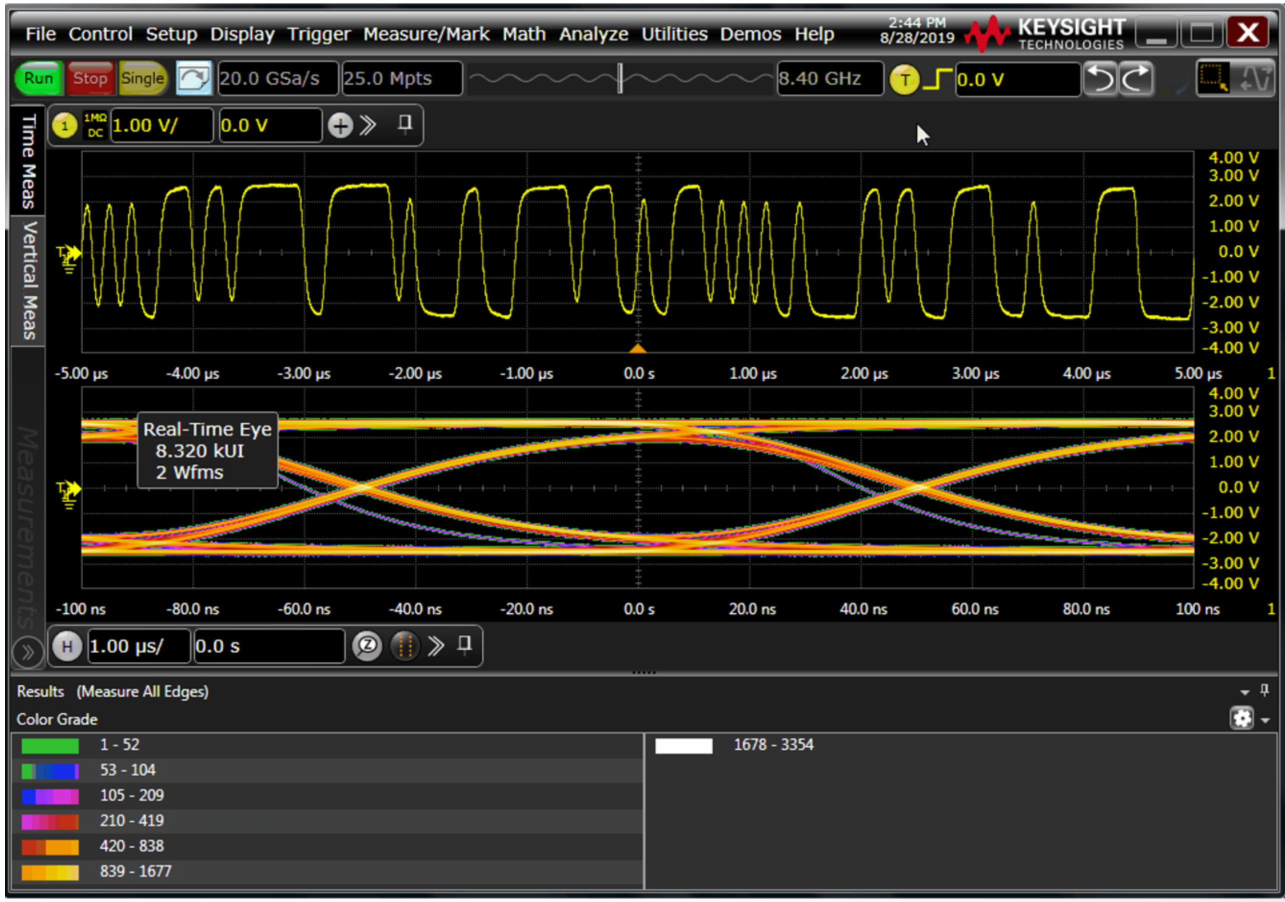
Distribution of *measurement results* (as exemplified)



Waveform Visualization & Analysis Tools

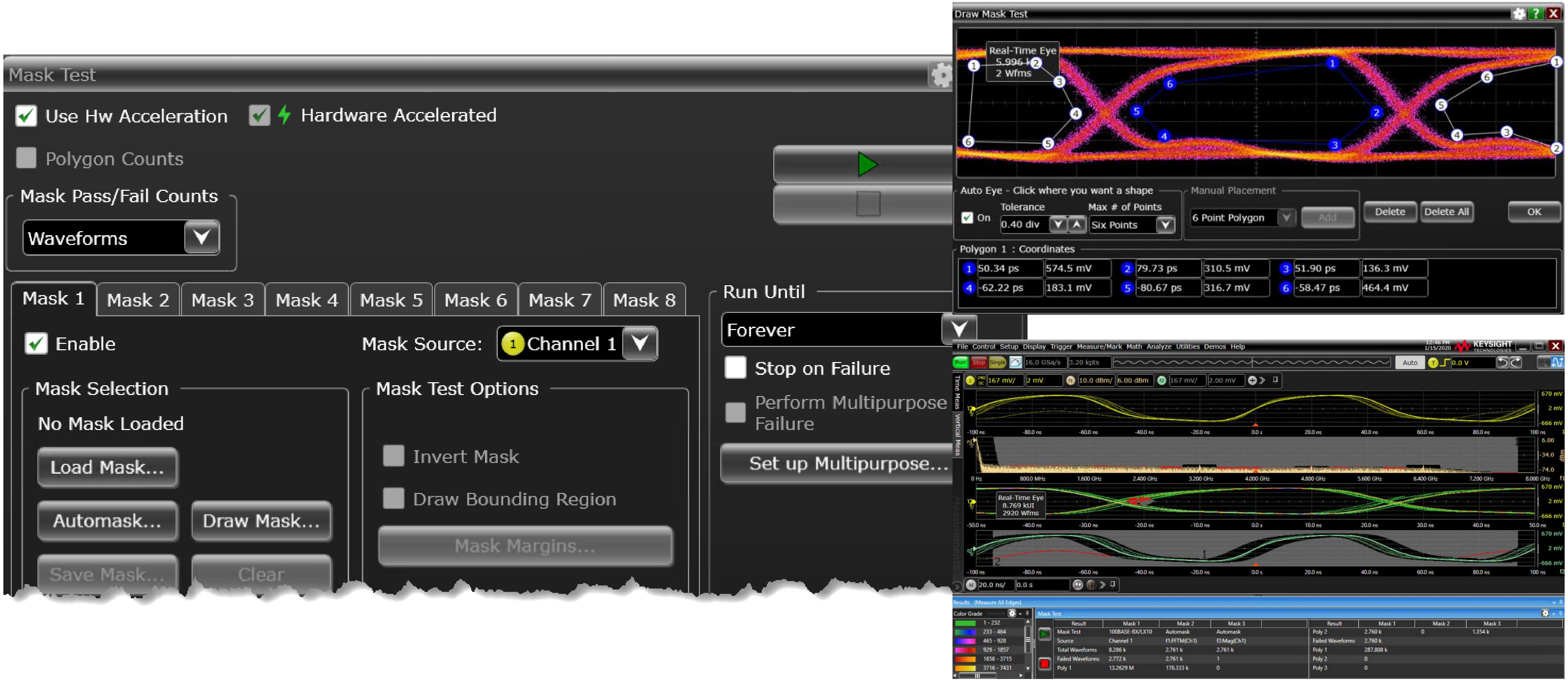
Eye Diagrams

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



Mask Test

Mask testing is much faster when using hardware acceleration than when it is done in software



Waveform Visualization & Analysis 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.

Waveform Visualization & Analysis Tools

Fault Hunter

- ✓ **ALL NEW Fault Hunter** automatically finds signal anomalies
- ✓ View button to **see waveform issues**
- ✓ **Analyze glitches**, slow edges, runts

Find signal faults faster than ever before!

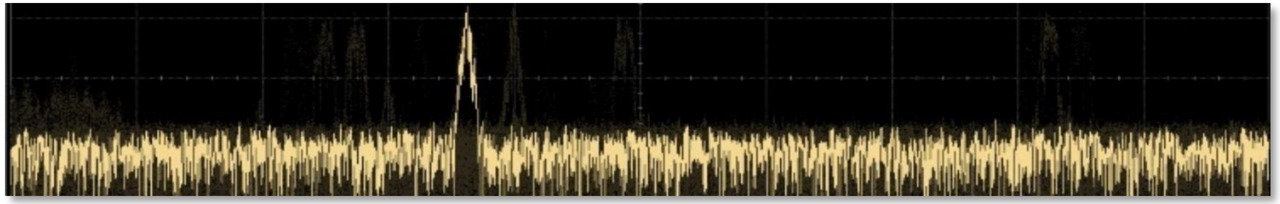
Waveform Visualization & Analysis Tools

First Ever RTSA on an Oscilloscope

- Perform powerful RF analysis with **up to 8 phase-coherent channels, all at once**. Digitally down-convert data on all 8 channels simultaneously with an analysis bandwidth up to 2 GHz.
- The RTSA view in the Infiniium MXR-Series provides **spans from 40 MHz to 320 MHz**.
- In this image, we're viewing (clockwise) local US radio stations (~100 MHz), 2.4 GHz WLAN channel 1, 5 GHz WLAN channel 157, and Bluetooth all at once. And since the data is from the analog channel inputs, they are **phase coherent by definition, with only a standard calibration required to ensure accuracy**.
- And with a maximum frequency range of 6 GHz, the Infiniium MXR-Series **easily supports applications from ZigBee to 5G FR1**.

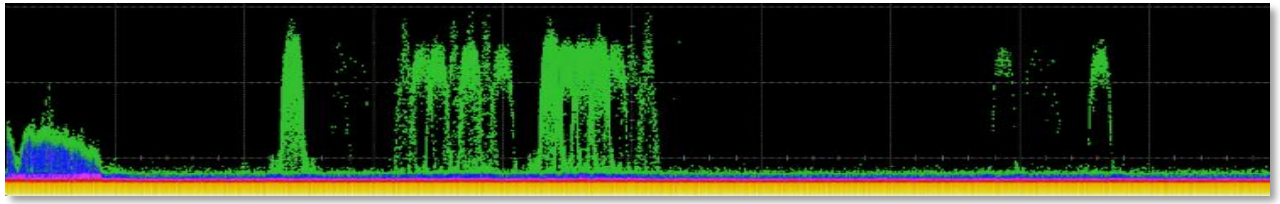
First Ever RTSA on an Oscilloscope

Same Bluetooth signal, but RTSA provides 400x more information!



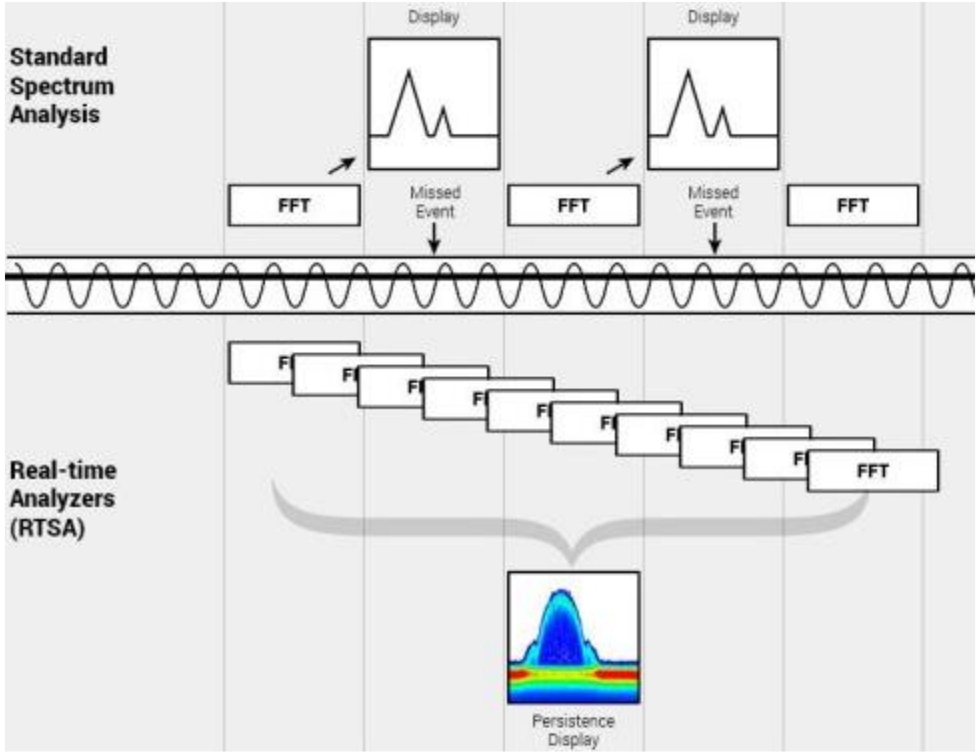
Fast Fourier Transform (FFT)

- ✓ ~1,000 per second; you may not capture every signal
- ✓ **Ideal for testing stable signals**
  - ➢ harmonics, carrier power, occupied channel, etc

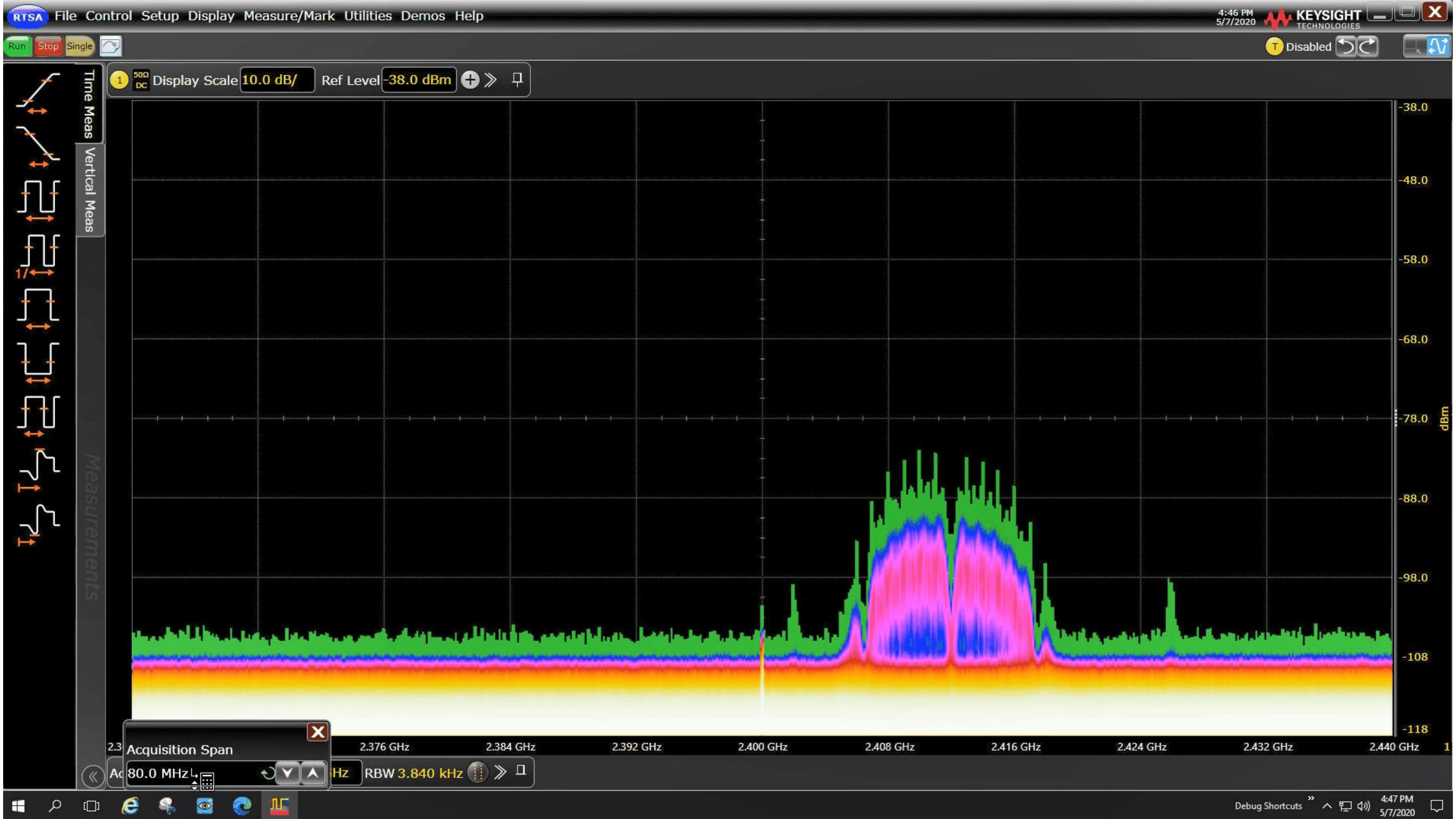


Real-time Spectrum Analysis (RTSA)

- ✓ Uses overlapping FFTs and high-speed memory
- ✓ ~400,000 per second, with 100% probability of intercept
- ✓ **Ideal for testing fast changing signals**
  - ➢ Radar, bursty packetized data, etc

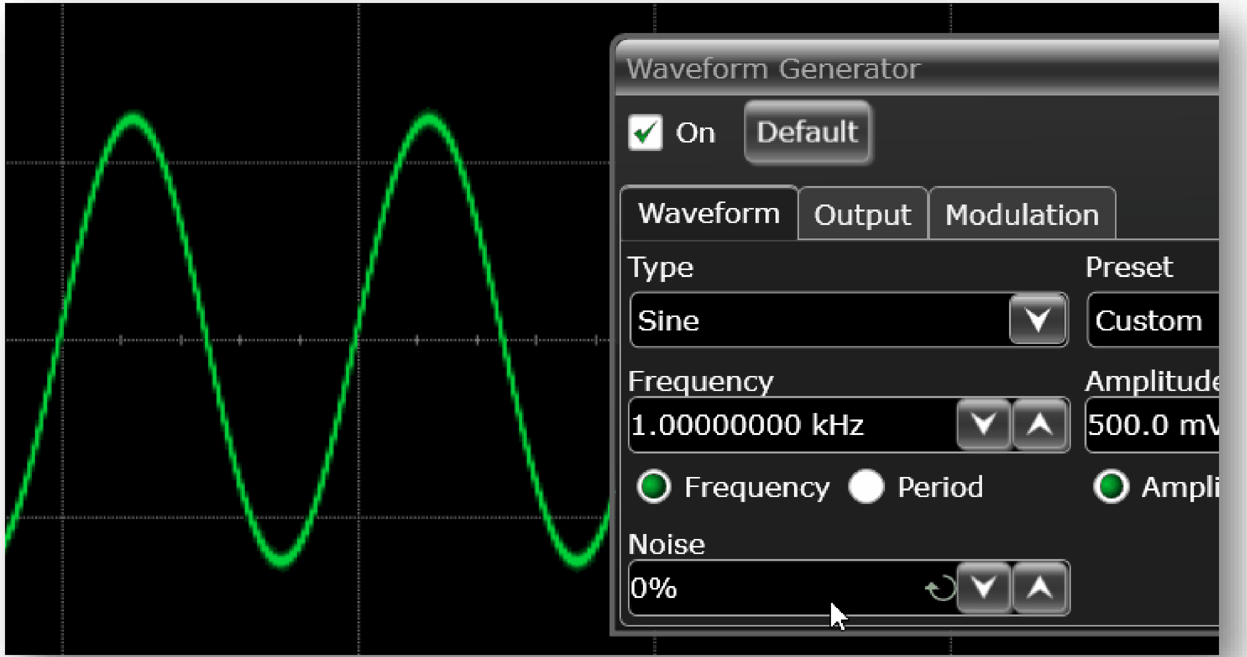


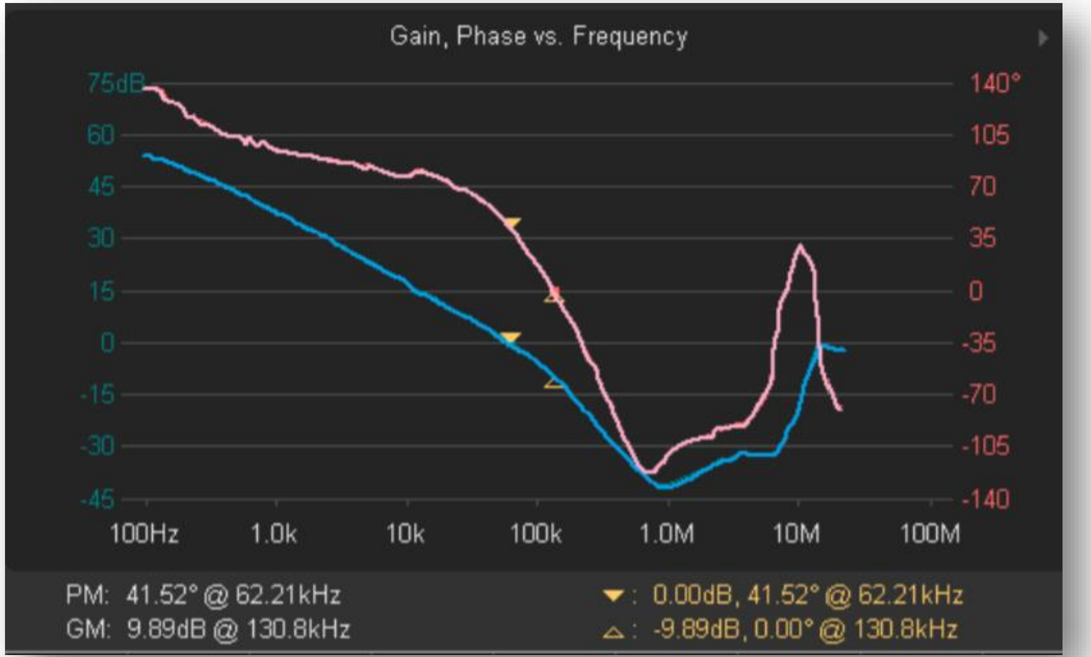
Present and future digital communications are challenging the usefulness of FFT with techniques such as frequency hopping, spread spectrum, pulsed, and cognitive radio.


RTSA File Control Setup Display Measure/Mark Utilities Demos Help
4:46 PM 5/7/2020
KEYSIGHT TECHNOLOGIES
Run Stop Single
Disabled
Display Scale 10.0 dB/
Ref Level -38.0 dBm
Time Meas
Vertical Meas
Measurements
-38.0
-48.0
-58.0
-68.0
-78.0
-88.0
-98.0
-108
-118
dBm
2.376 GHz
2.384 GHz
2.392 GHz
2.400 GHz
2.408 GHz
2.416 GHz
2.424 GHz
2.432 GHz
2.440 GHz
Acquisition Span
80.0 MHz
RBW 3.840 kHz
Debug Shortcuts
4:47 PM 5/7/2020

WaveGen / Bode Plotter

Use the WaveGen to send command signals, simulate added channel noise, see frequency response, and stress test your designs with ease!





WaveGen Specifications	
Output (Amplitude+Offset)	$\underline{+}10\ V_{PP}$ (1 MΩ), $\underline{+}5\ V_{PP}$ (50 Ω)
Frequency (sine)	50 MHz sine, 20 MHz square
Preconfigured Waveforms	Sine, Square, Pulse, Triangle, Ramp, Noise, DC, Cardiac, Sinc, Exponential Rise/Fall, Arbitrary
Arbitrary Waveform Memory	128 Kpts
Modulation	AM, FM, FSK

Bode Plot Specifications	
Frequency Mode	Single or Swept
Frequency Range	10 Hz to 50 MHz
Number of Test Points	1 to 1,000 points across test range
Test Results	Gain and phase plots, automatic gain/phase margin

The Oscilloscope That's Right For You

Measure Confidently with Keysight Oscilloscopes

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

InfiniiVision
50 MHz to 6 GHz

Infiniium Real-time
500 MHz to 110 GHz

DCA Sampling
18 GHz to 122 GHz

USB/Modular/Handheld
100 MHz to 1 GHz

Thank you