Agilent Technologies

12 Tips on How to Select Your Next Oscilloscope

Test & Measurement Specialist

Jays

Solution Provider, Distributor, Reseller.

12 Tips on How to Select Your Next Scope

"Banner" Specifications to Consider

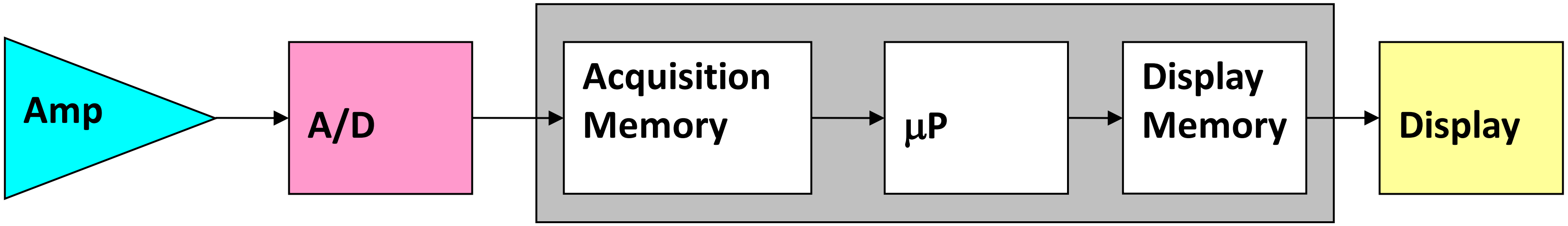
1. Bandwidth
2. Sample Rate
3. Memory Depth
4. Number of Channels
5. Waveform Update Rate
6. Triggering

Other Important Factors to Consider

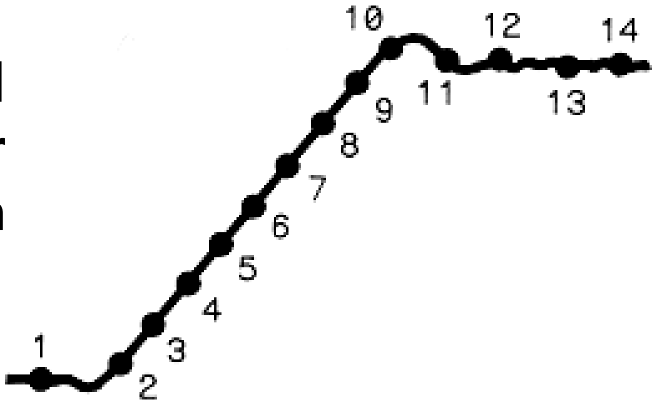
7. Display Quality
8. Serial Bus Applications
9. Measurements & Analysis
10. Connectivity & Documentation
11. Probing
12. Ease-of-use

Introduction

- **Processing overview**

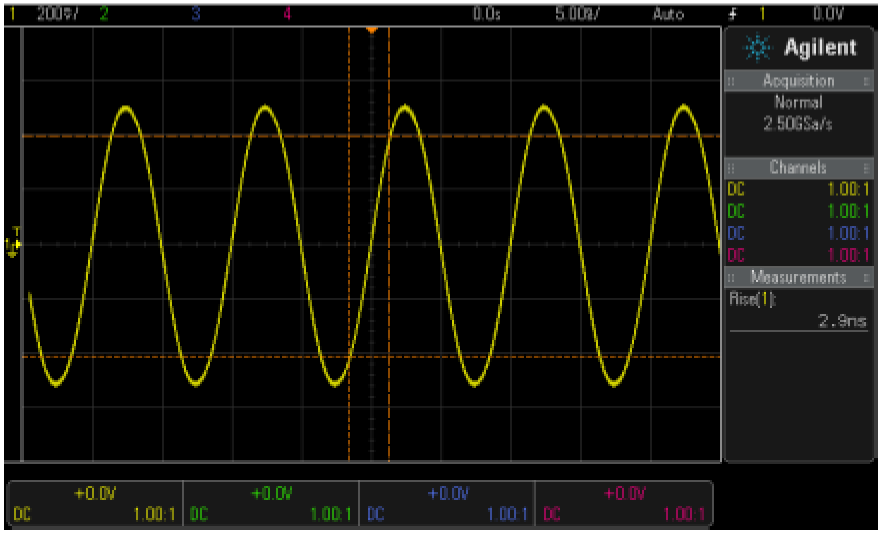


- **The input electrical signal is digitized by an A/D converter (usually 8 bits or 256 levels) and the output digital data is saved in Memory.**

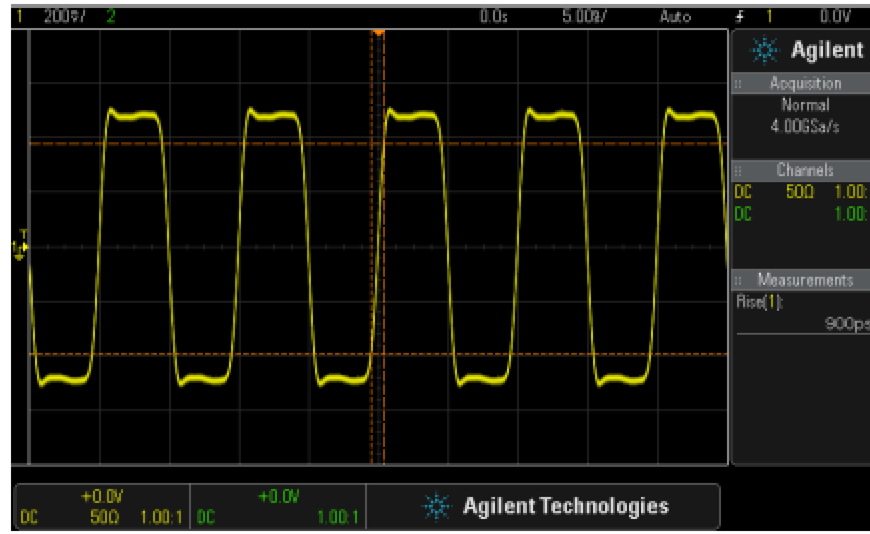


Tip #1 - Bandwidth

What does a 100-MHz clock signal really look like?



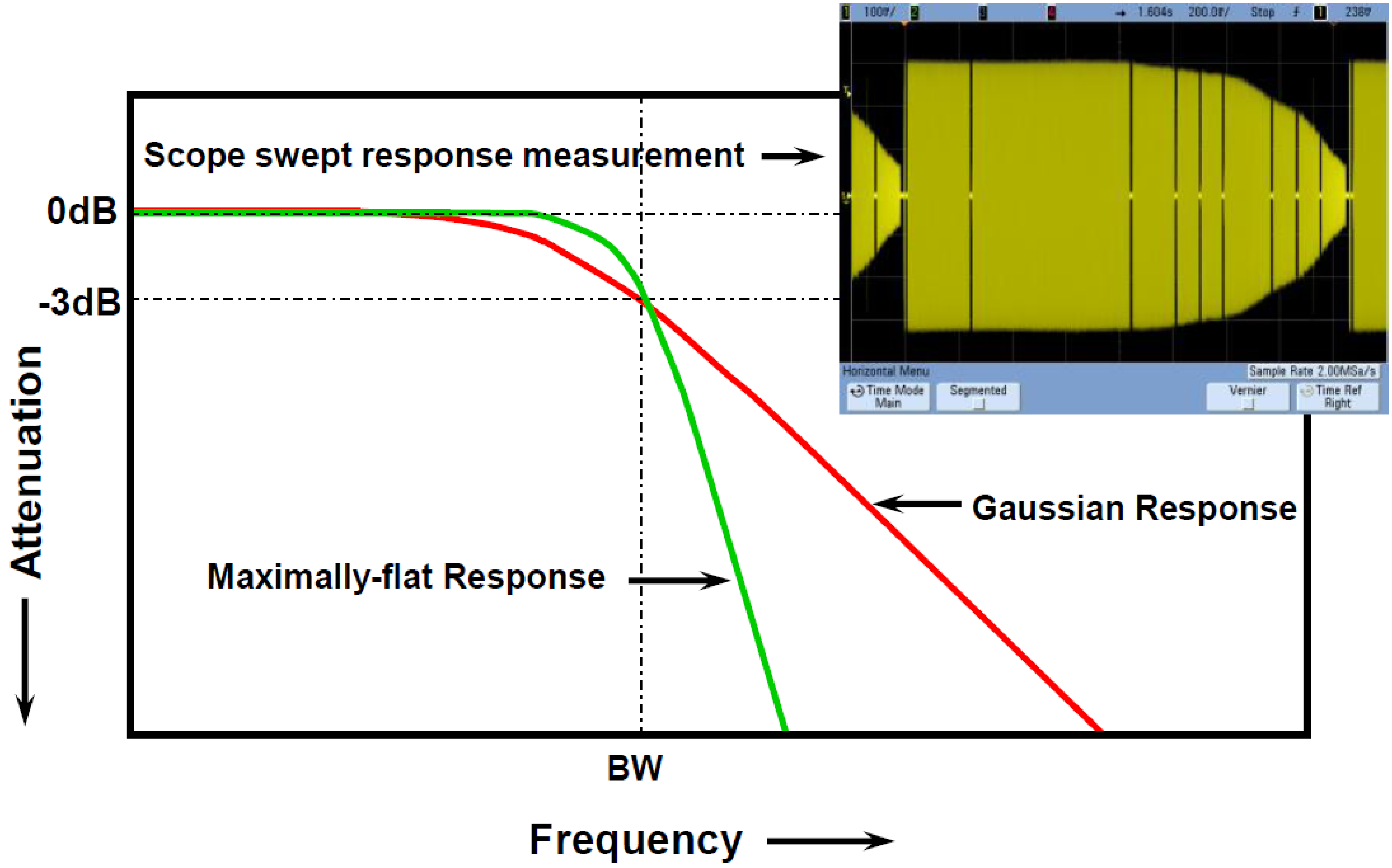
Response using a 100-MHz BW scope



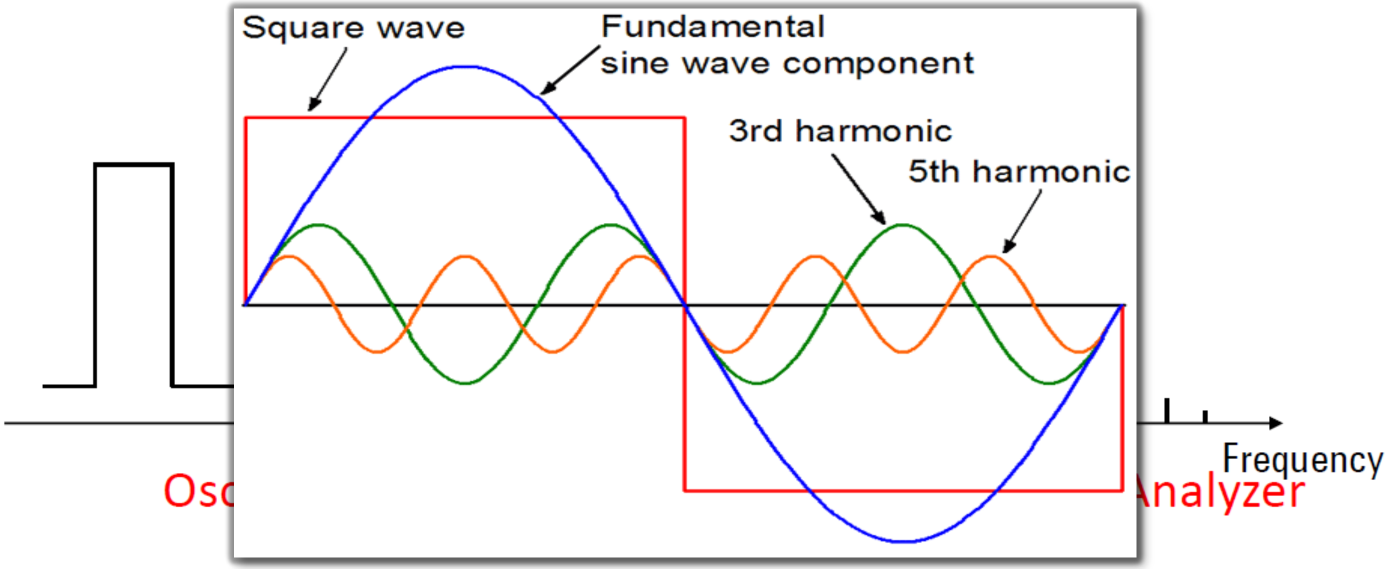
Response using a 500-MHz BW scope

- Required BW for analog applications: ≥ 3X highest sine wave frequency.
- Required BW for digital applications: ≥ 5X highest digital clock rate.
- More accurate BW determination based on signal edge speeds

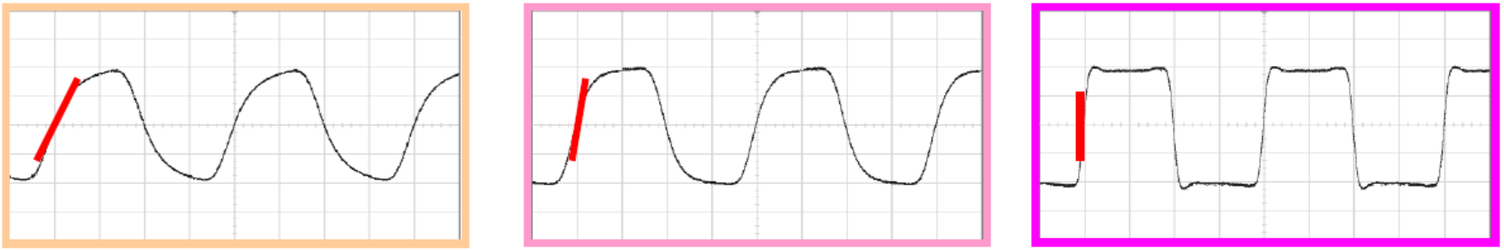
Oscilloscope Frequency Response



Square Wave and Harmonics

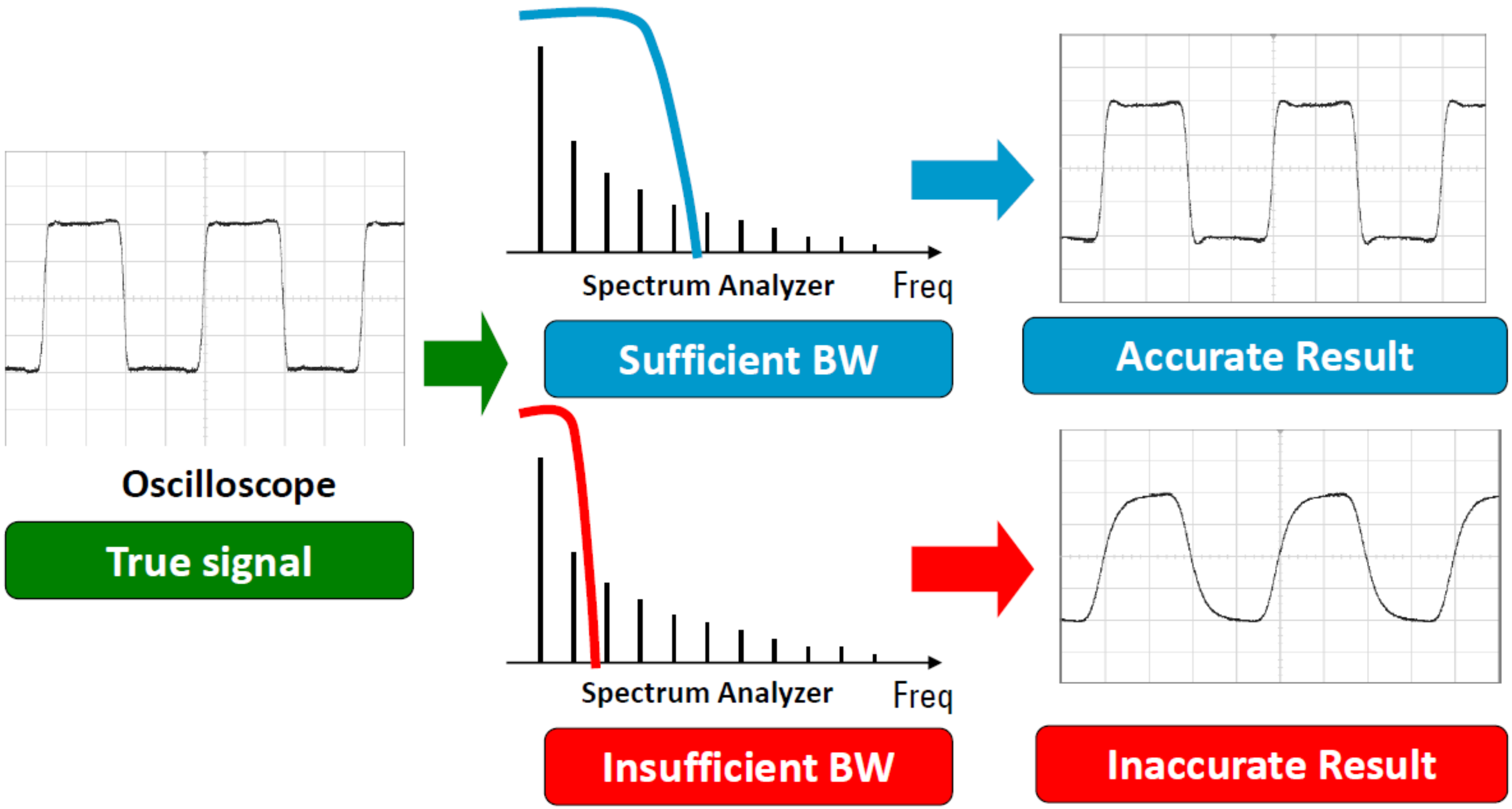


$$y(x) = A + \sin x + 1/3 \sin 3x + 1/5 \sin 5x + \cdots \quad (x = 2\pi t/T)$$



Square wave consists of the fundamental frequency and its add number harmonics. With faster rise time, more harmonics it contains.

Square Wave and Required Bandwidth



Requires sufficient bandwidth to cover most of the frequency components.

More Accurate Bandwidth Determination

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.

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}

Step #4: Calculate required bandwidth.

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

Scope System Bandwidth Calculation

Example (using the more accurate method)

Determine the minimum required bandwidth of an oscilloscope (assume Gaussian frequency response) to accurately measure digital signals that have rise times as fast as 1 ns (10-90%):

$$f_{knee} = (0.5/1 \text{ ns}) = 500 \text{ MHz}$$

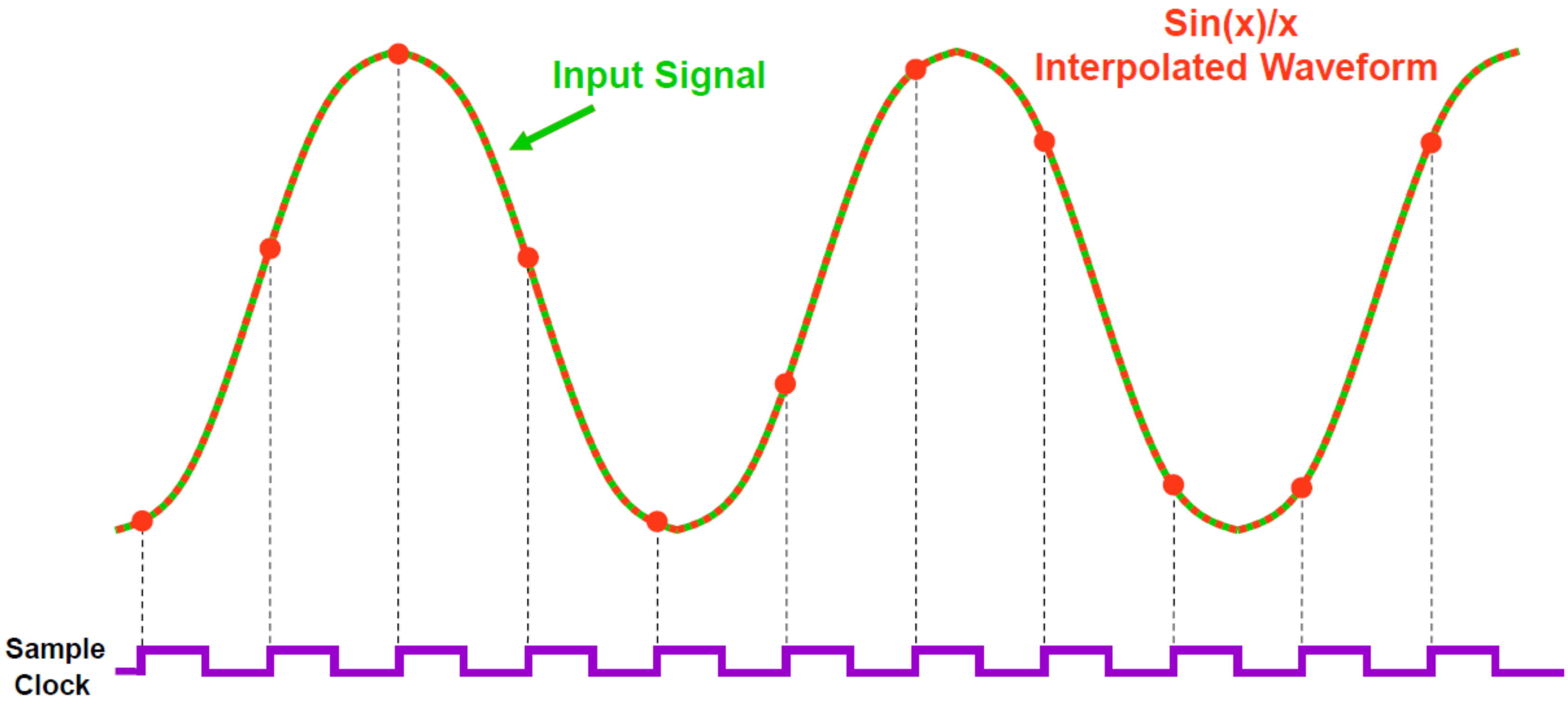
3% Accuracy: Scope Bandwidth = 1.9 x 500 MHz = 950 MHz

20% Accuracy: Scope Bandwidth = 1.0 x 500 MHz = 500 MHz

Agilent's Recommendation:

Select a scope that has sufficient bandwidth to accurately capture the highest frequency content of your signals.

Tip #2 – Sample Rate



= Input Signal
= Sample Clock
= Sin(x)/x Interpolated Waveform
= Real-time Digitized Point

How Much Sample Rate is Required?

Professor Smart has total trust in Dr. Nyquist and says:

"2X over the scope's bandwidth."

Professor Wise doesn't trust Dr. Nyquist and says:

"10X to 20X over the scope's bandwidth."

The truth lies somewhere in between!

Nyquist's Sampling Theorem

Dr. Harry Nyquist

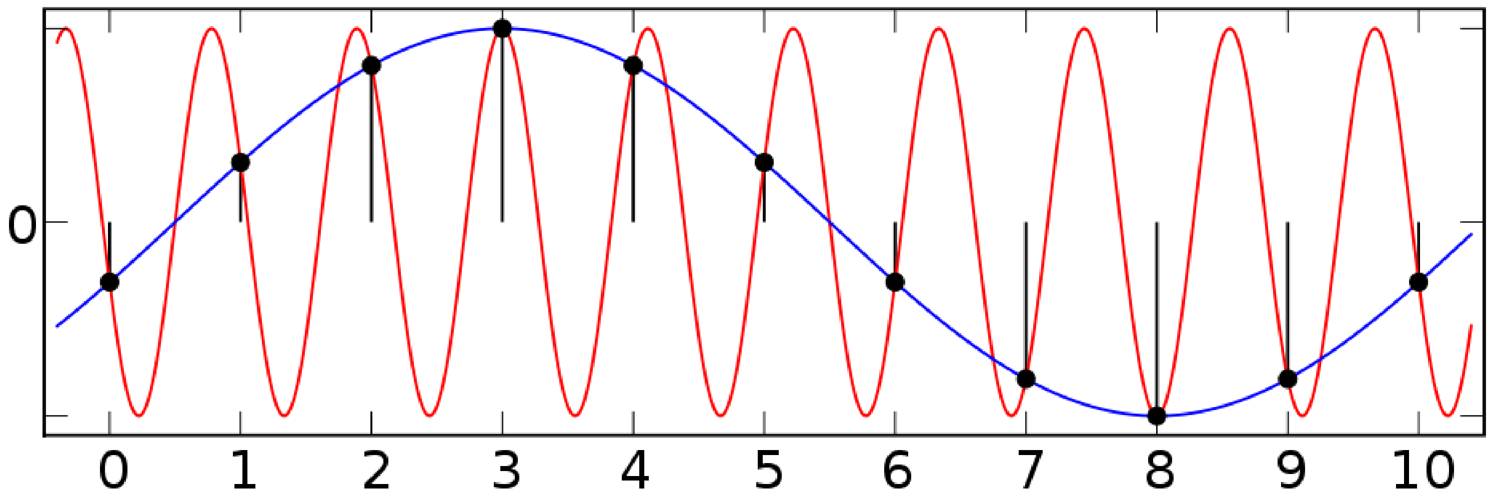
Nyquist's sampling theorem states that for a limited bandwidth (band-limited) signal with maximum frequency f_{max}, the equally spaced sampling frequency f_s must be greater than twice of the maximum frequency f_{max}, i.e.,

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

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

The frequency **2·fmax** is called the Nyquist sampling frequency (f_S). Half of this value, $\mathbf{f_{max}}$, is sometimes called the Nyquist frequency (f_N).

Aliasing



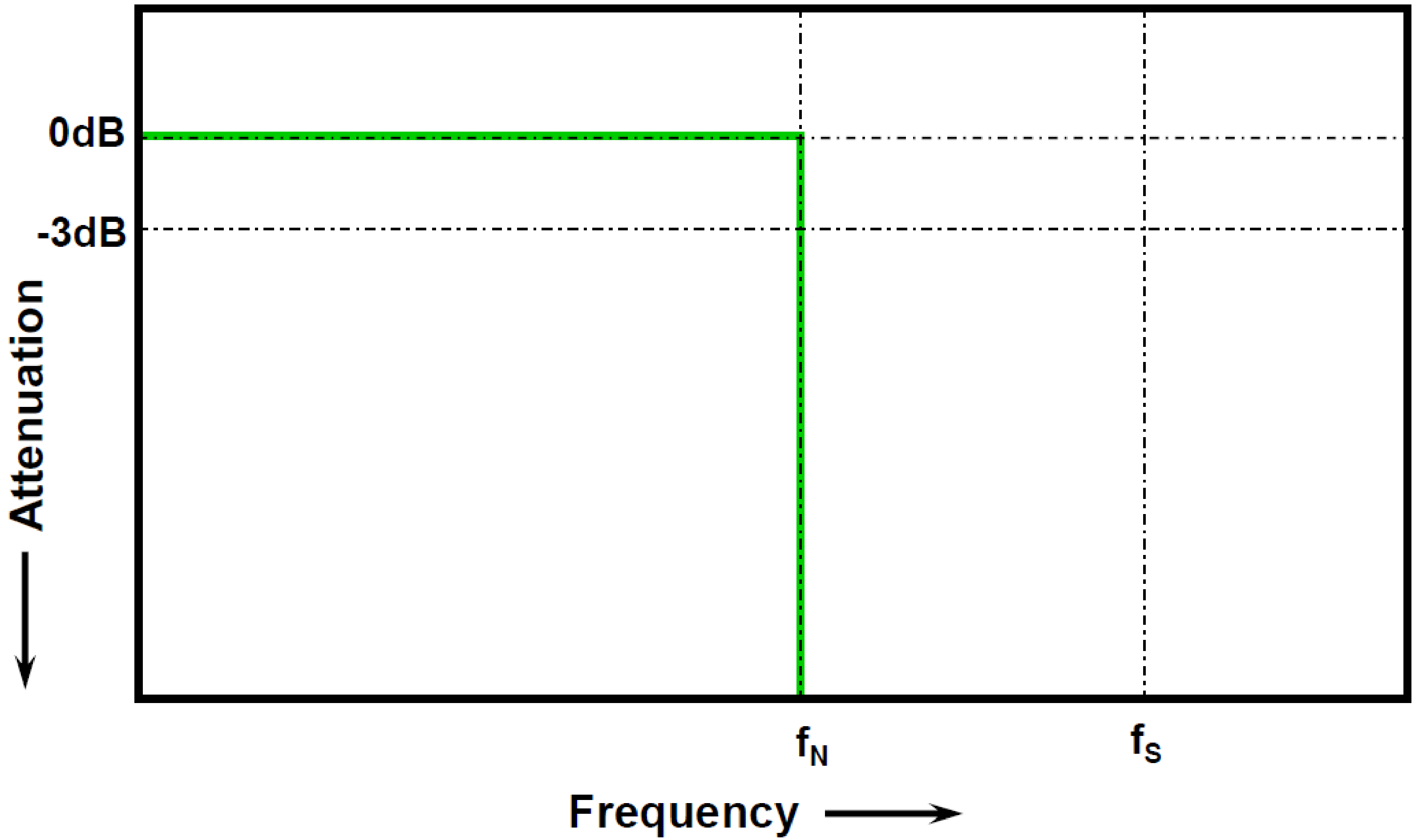
$F_{Red(Original)} = 9Hz$

@ $F_{S(Sample\ Freq)} = 10Hz$

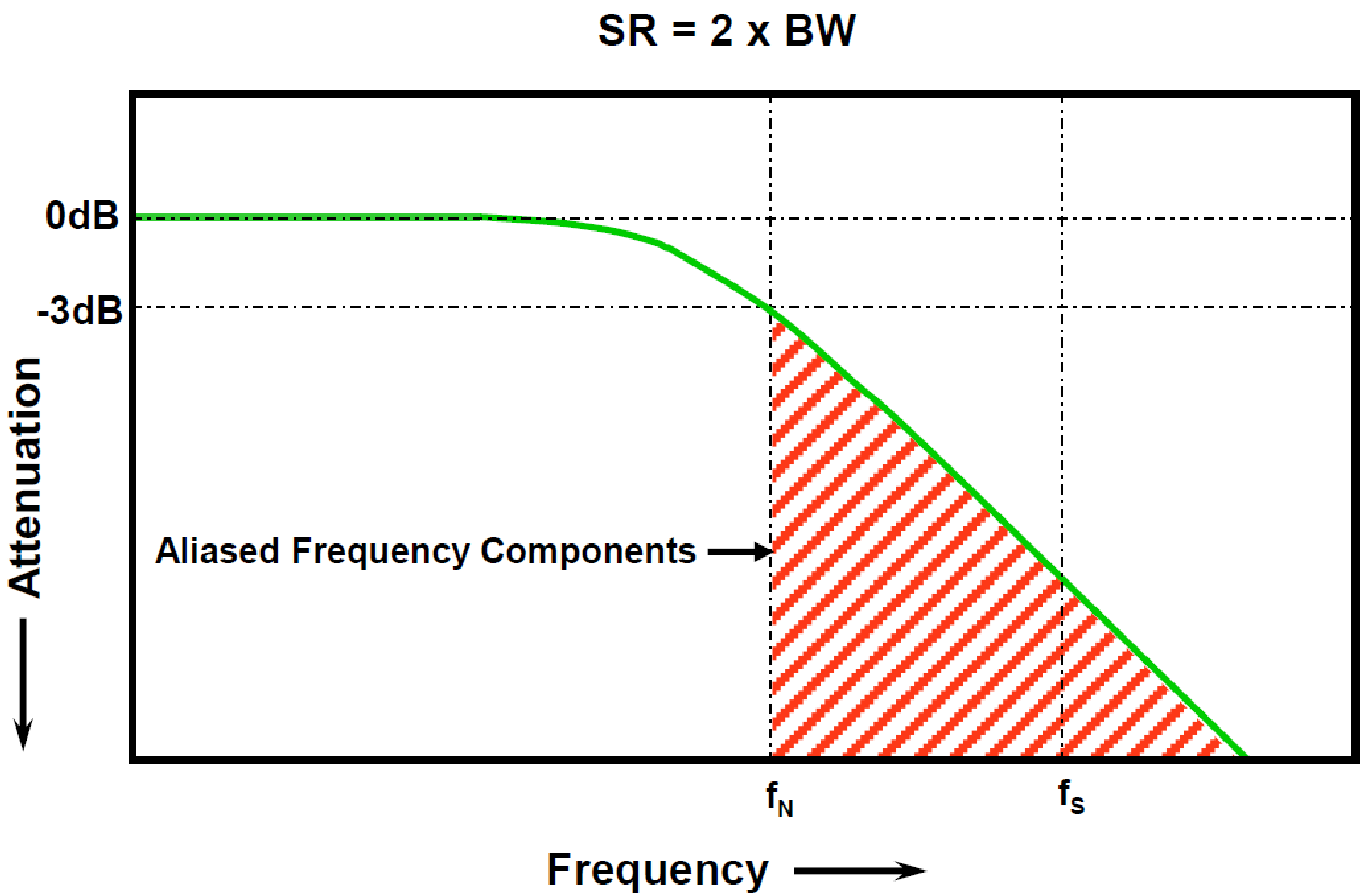
$F_{Blue(Aliased)} = 1Hz$

$$F_{aliased} = abs(N * F_s - F_{original})$$

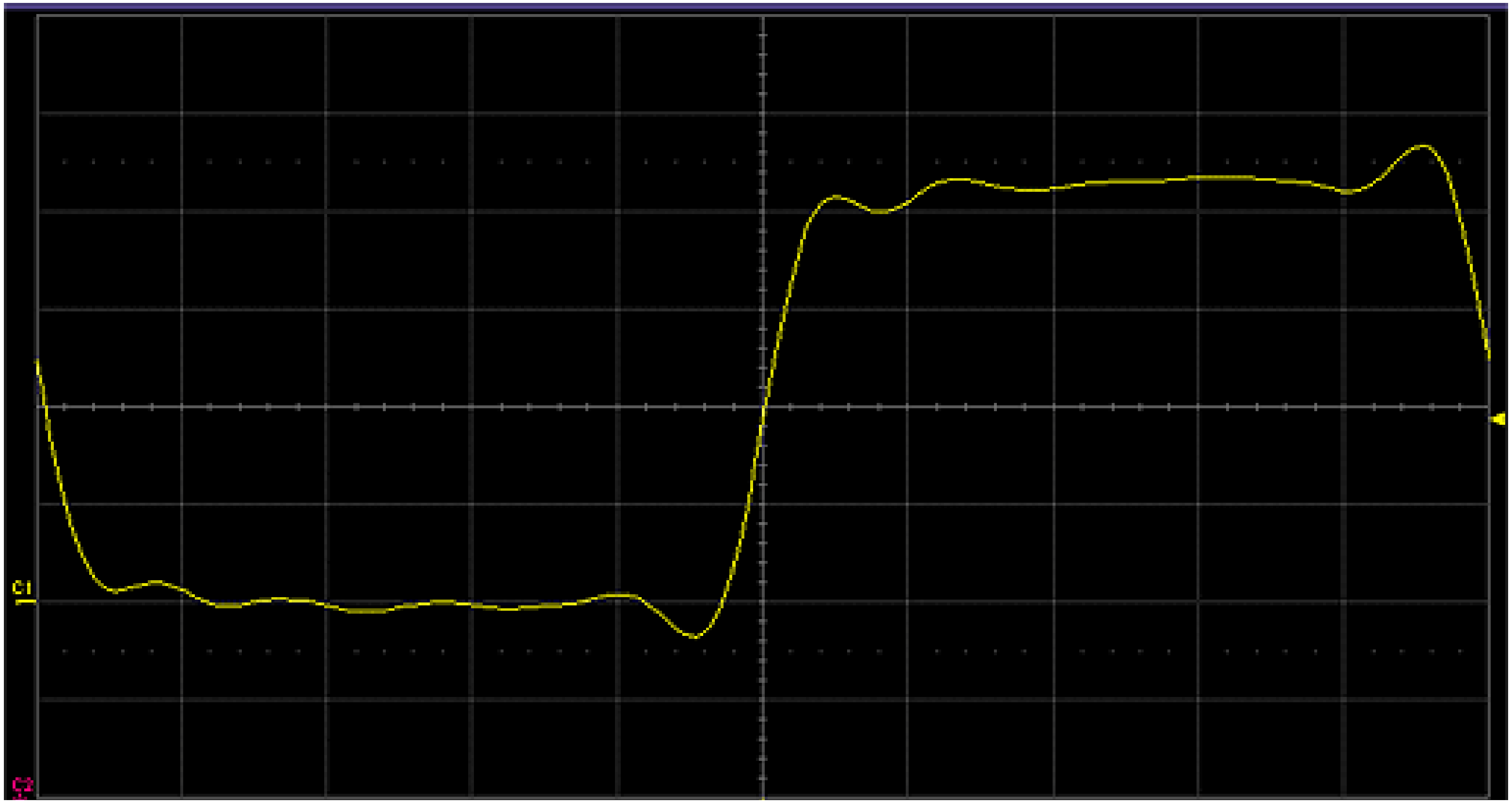
Ideal Brick-wall Response w/BW @Nyquist (f_N)



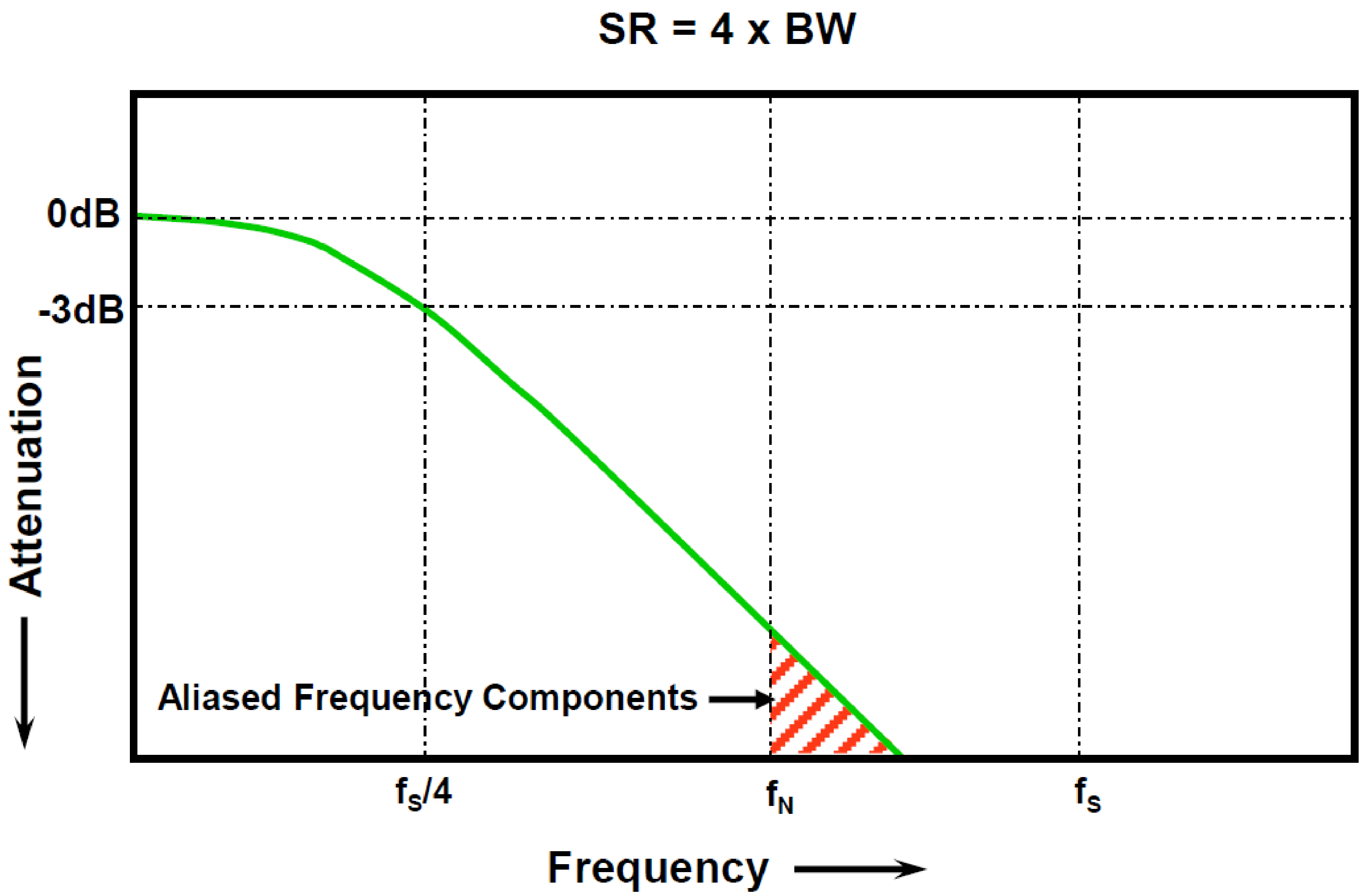
Gaussian Response w/BW @$f_S/2$ (f_N)



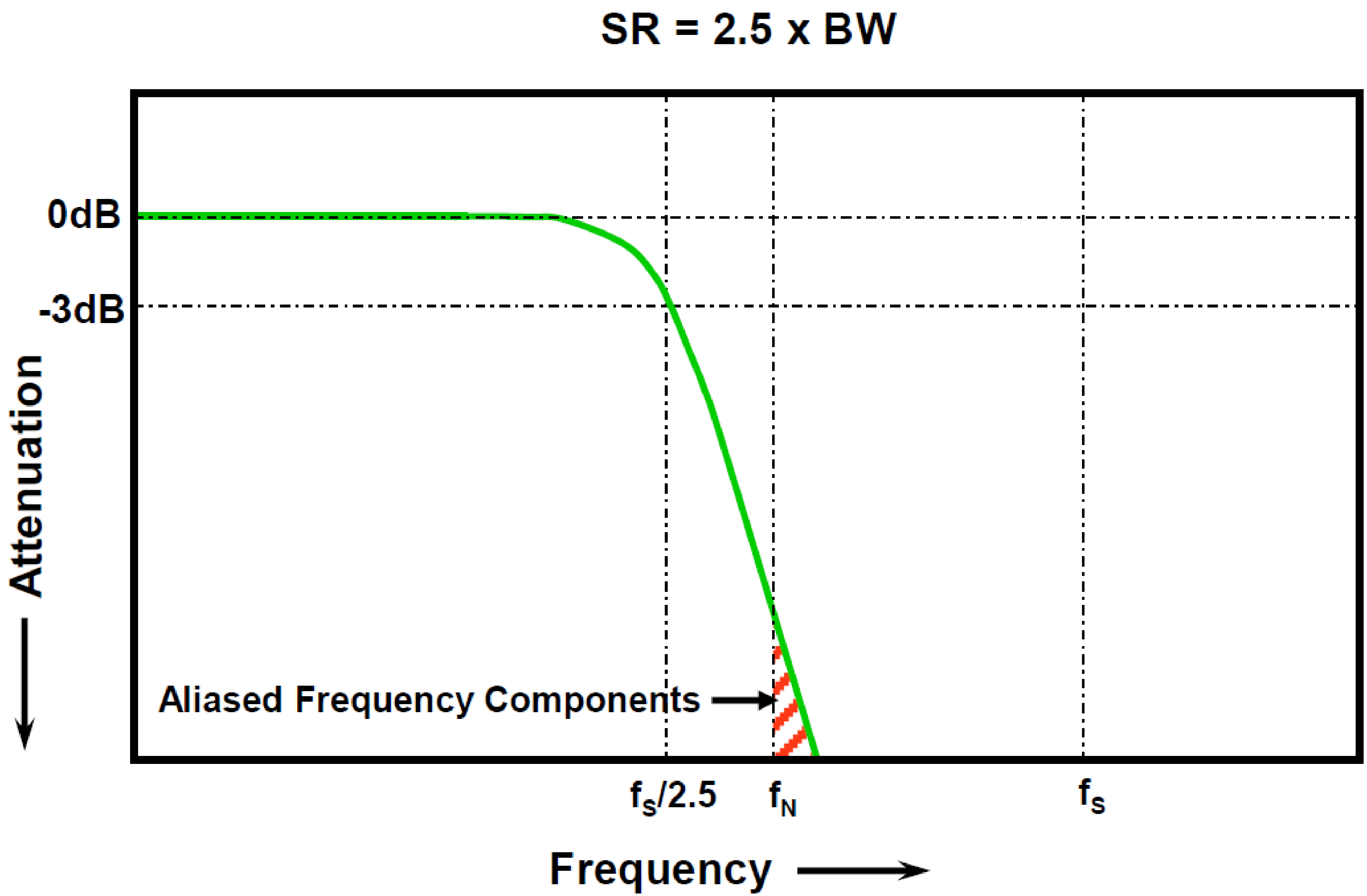
500MHz Scope @1GSa/s (BW=f_S/2=f_N)



Gaussian Response w/BW @ $f_S/4(f_N/2)$



Maximally-Flat Response w/BW @ $f_S/2.5(f_N/1.25)$



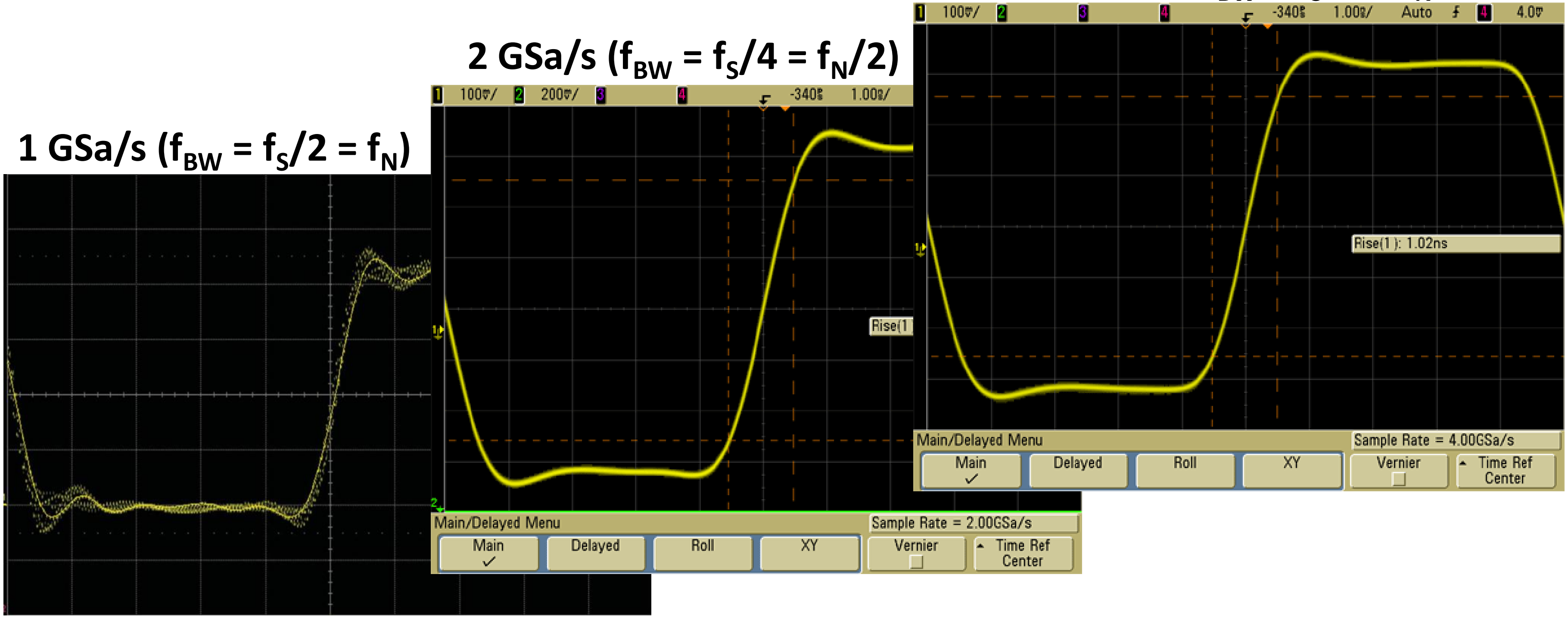
500MHz Scope (@1GSa/s vs. 2GSa/s vs. 4GSa/s)

Input = 100 MHz clock with 1 ns edge speeds

4 GSa/s ($f_{BW} = f_S/8 = f_N/4$)

2 GSa/s ($f_{BW} = f_S/4 = f_N/2$)

1 GSa/s ($f_{BW} = f_S/2 = f_N$)

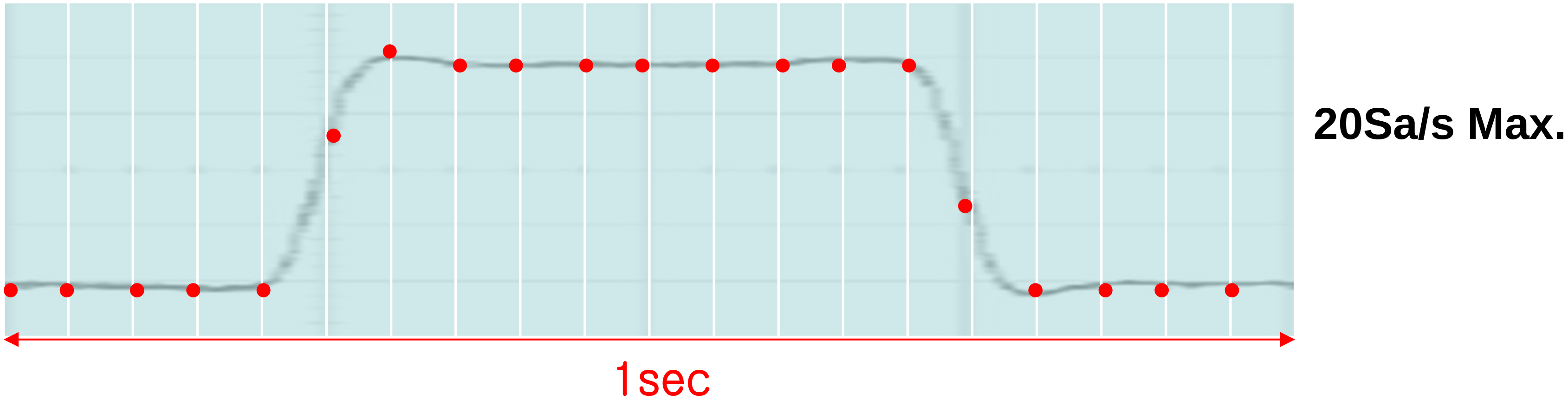


Agilent's Recommendation:

Select a scope that has a maximum specified sample rate fast enough to deliver the scope's specified real-time bandwidth (SR ≥ 4 x BW.)

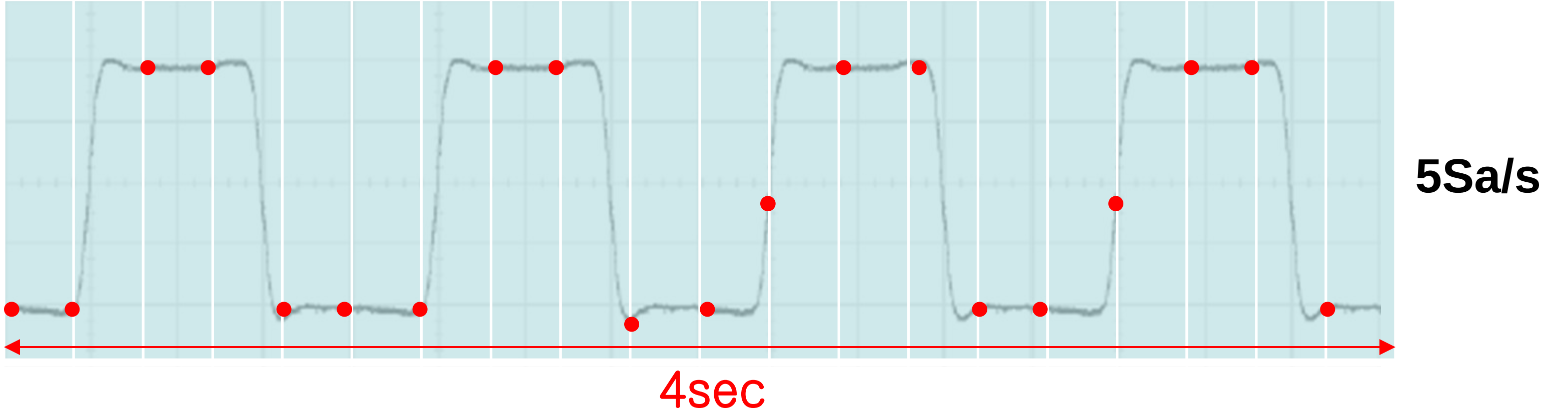
Tip #3 Memory Depth

@ Scope Memory=20points



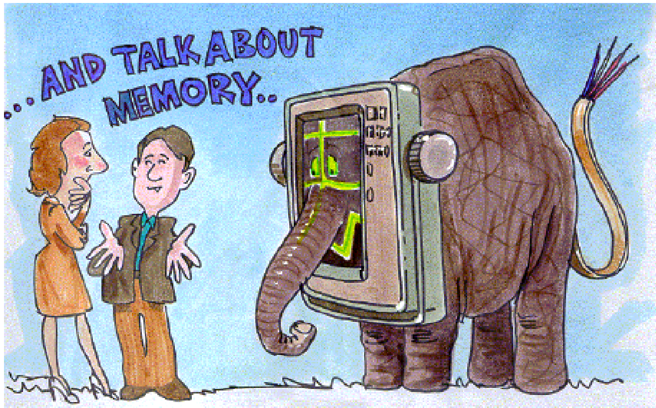
Time span = Memory depth / Sample Rate

Solution?
Deep Memory



Deep Momory

- Scopes with deep acquisition memory can capture longer time spans while also sampling at a higher rate.
- Scopes automatically adjust their sample rates based on the timebase setting and memory depth of the scope.
- Deep memory
  - ✓ Usually a manual selection
  - ✓ Usually slows update rates
  - ✓ Usually adds cost



MEGA Zoom 1M wfms/s

Agilent's MegaZoom Technology automatically turns on deeper memory when the scope is used on slower timebase settings in order to sustain faster sample rates, while also providing responsive waveform update rates.

How Much Memory Do I Need?

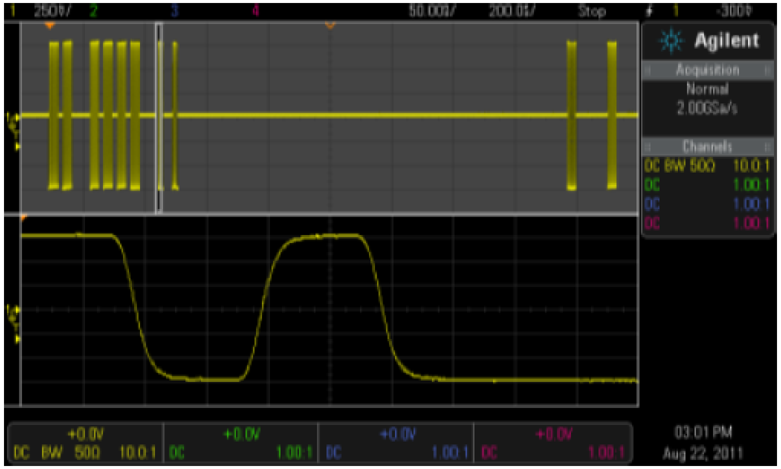
Step #1: Determine required sample rate

- ✓ Usually based on fastest clock rate

Step #2: Determine longest time-span to acquire

- ✓ Usually based on slowest analog signal or digital packets

Required Memory Depth = Time-span/Sample Interval



Example:
Required Sample Rate = 2 GSa/s
Sample Interval = 1/SR = 500 ps
Longest Time Span = 2 ms (200 µs/div)
Required Memory Depth
= 2 ms / 500 ps
= 4 MB

Agilent's Recommendation:

Select a scope that has sufficient acquisition memory to capture your most complex signals with high resolution.

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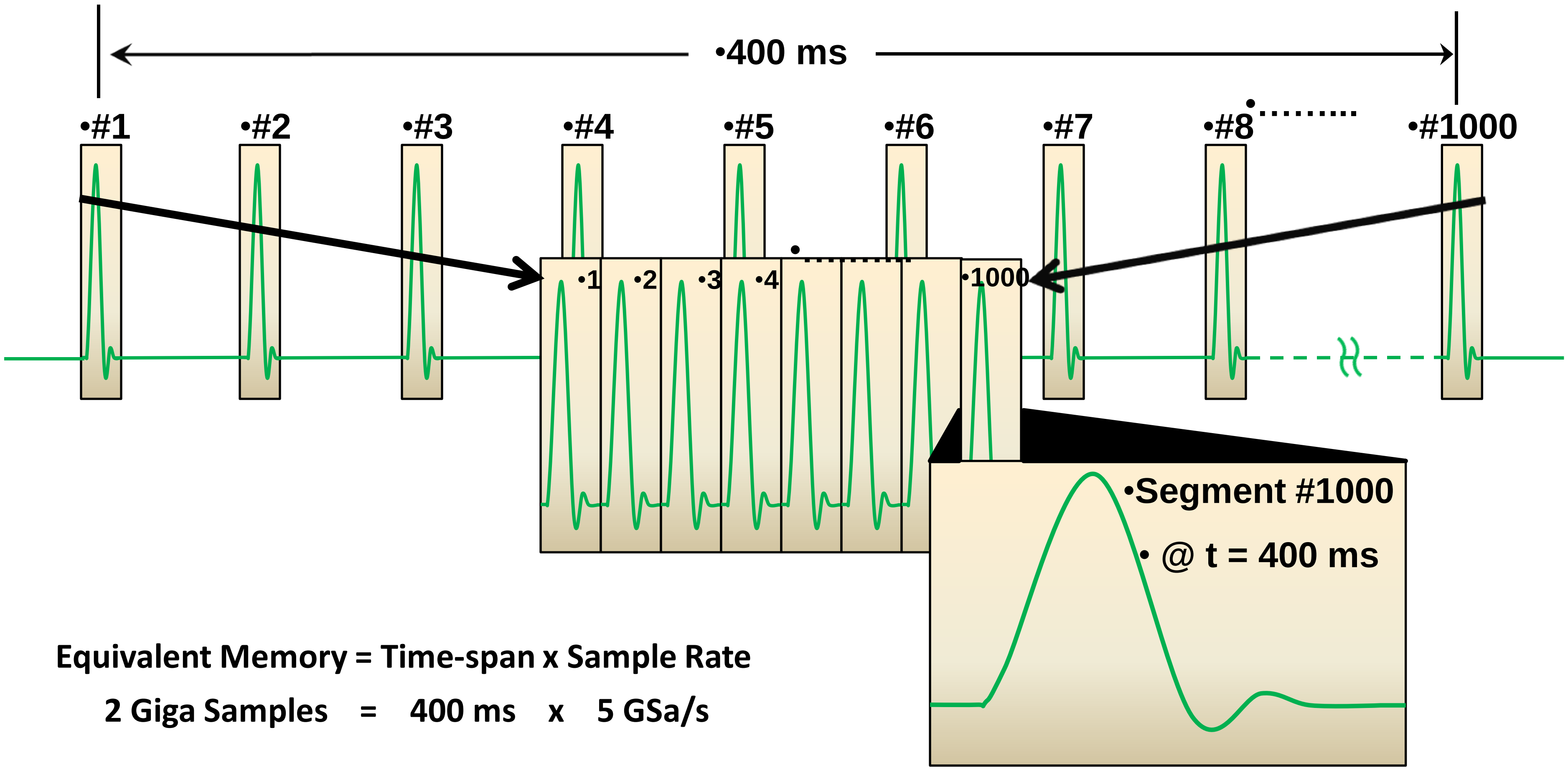
Segment Memory

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

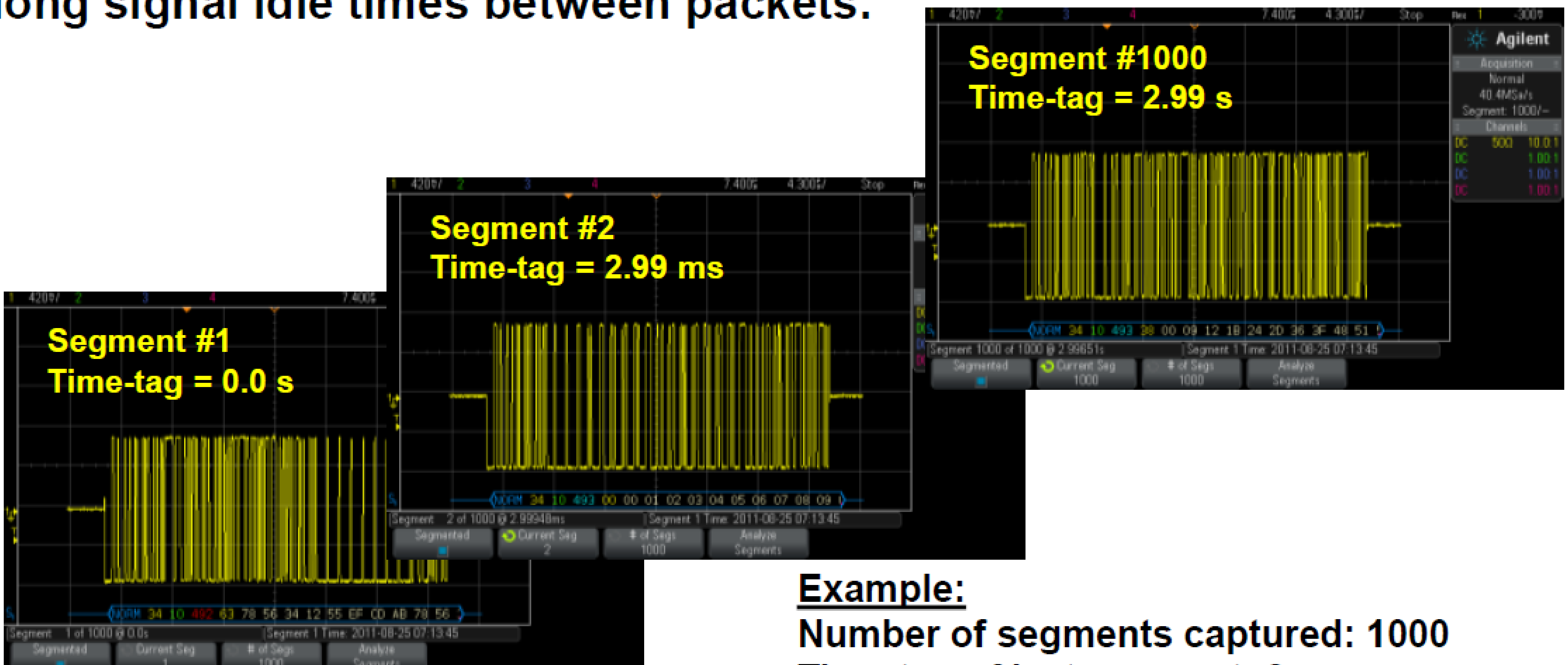


Equivalent Memory = Time-span x Sample Rate

2 Giga Samples = 400 ms x 5 GSa/s

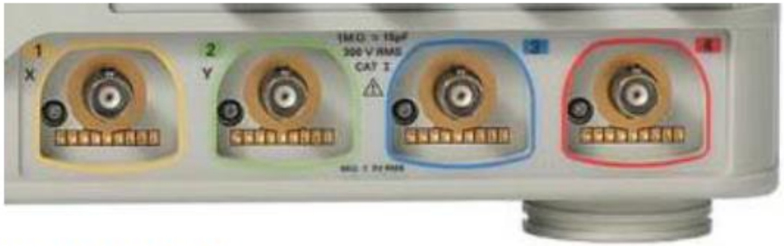
Segment Memory

Segmented Memory optimizes a scope's available acquisition memory by only capturing important segments of an input signal. It is ideal for capturing bursts of signals such as packetized serial data that have long signal idle times between packets.



Example:
Number of segments captured: 1000
Time-tag of last segment: 3 sec
Equivalent memory depth: 120 MB

Tip #4 – Number of Channels



- 2 & 4 Channel DSOs are common
- > 4 Channel DSOs are less common and expensive

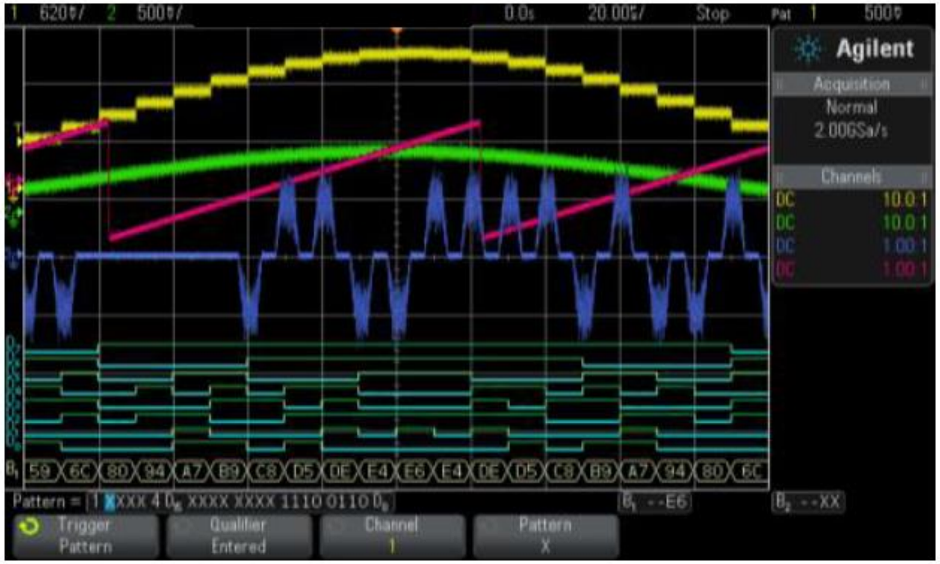
But many of today's complex digital systems require measurements on more than 4 channels simultaneously.

Solution: Mixed Signal Oscilloscope (MSO)

Mixed Signal Oscilloscope -- MSO

MSOs combine ALL the measurement capabilities of an oscilloscope, with SOME of the measurement capabilities of a logic analyzer.

- ***What is an MSO?***
- **Time-correlated display of scope and logic-timing waveforms**
- **Full scope functionality with ease-of-use**
- **Advanced logic triggering**

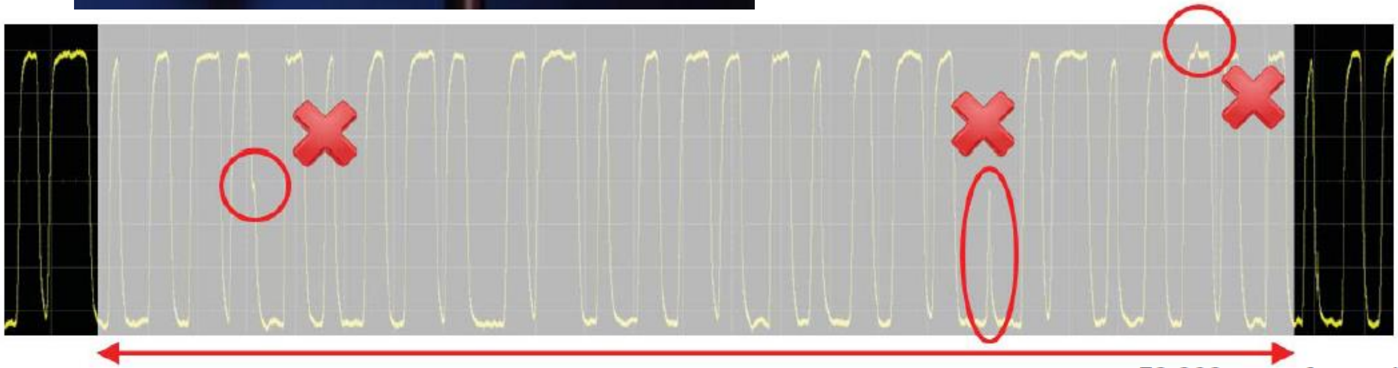


Agilent's Recommendation:

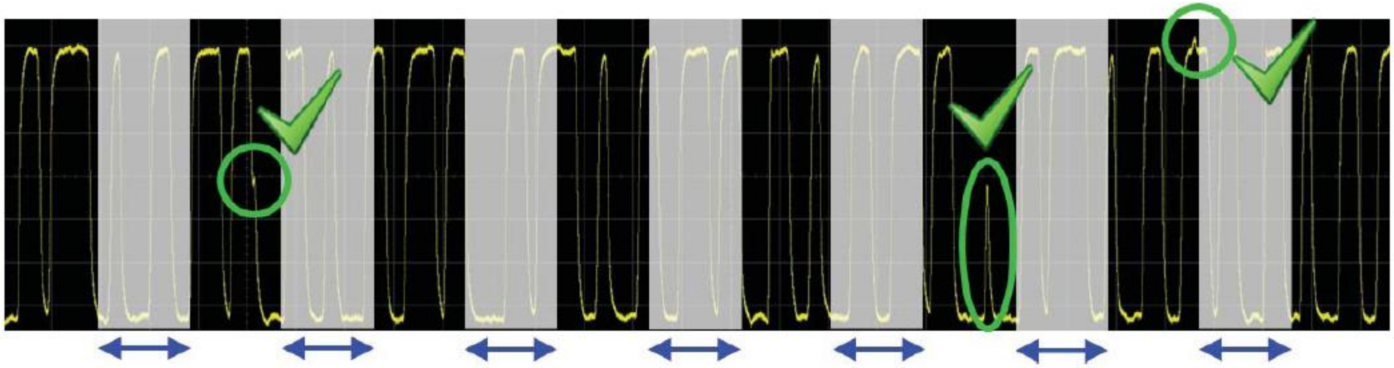
Select a scope that has a sufficient number of channels of acquisition so that you can perform critical time-correlated measurements.

Tip #5 – Waveform Update Rate

Frame(waveform) per Sec



50,000 waveforms/second. A long dead time

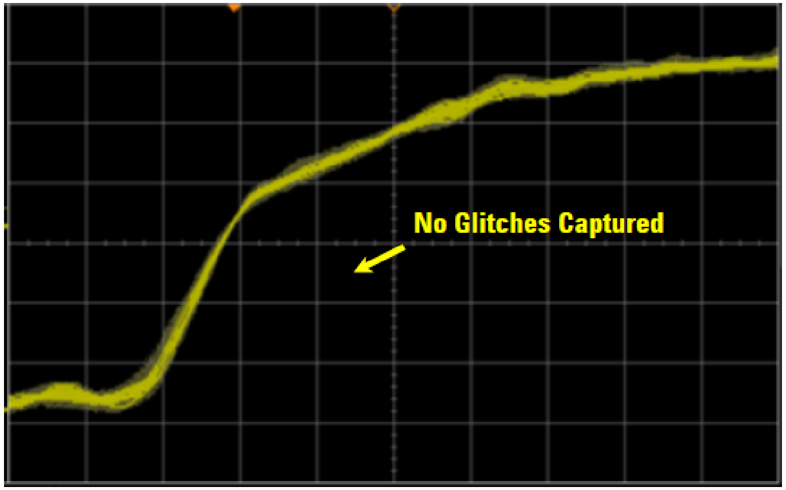


1,000,000 waveforms/second. A short dead time

Infrequent Glitch Capture Comparison

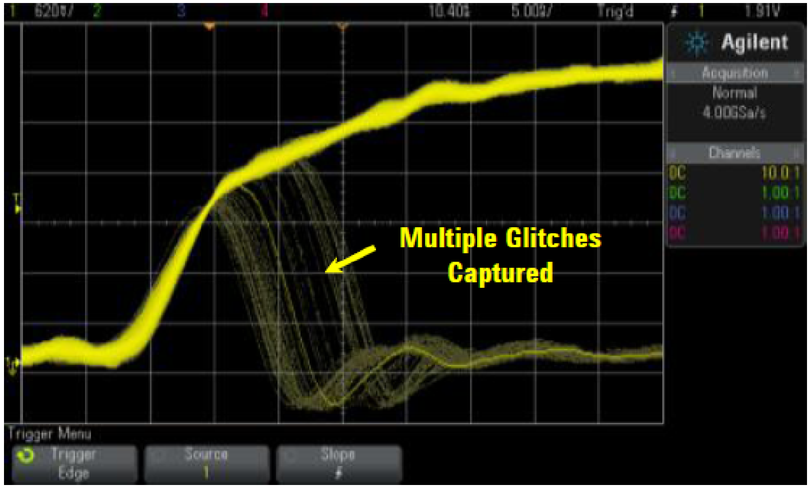
Glitch Rate = 10 occurrences/sec
Viewing Window = 50 ns (5 ns/div)
Observation Time = 5 seconds

Ex #1: Update Rate = 1000 waveforms/sec



% Dead-time = 99.995%
Glitch Capture Probability = 0.25%

Ex #2: Update Rate = 1,000,000 waveforms/sec



% Dead-time = 95%
Glitch Capture Probability = 91.8%

Agilent's Recommendation:

Select a scope that has a fast enough waveform update rate to capture random and infrequent events to help you debug your designs faster.

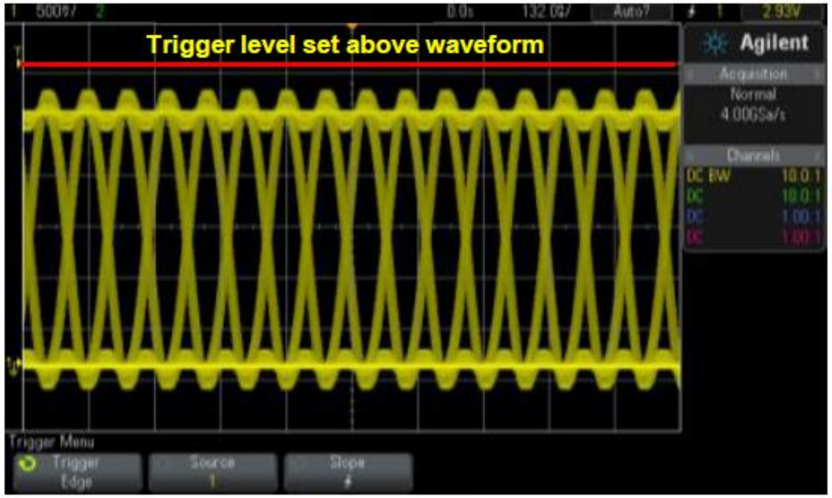
Tip #6 - Triggering

Triggering is often the least understood function of a scope, but is one of the most important capabilities that you should understand.

- **Think of oscilloscope "triggering" as "synchronized picture taking".**
- **One waveform "picture" consists of many consecutive digitized samples.**
- **"Picture Taking" must be synchronized to a unique point on the waveform that repeats.**
- **Most common oscilloscope triggering is based on synchronizing acquisitions (picture taking) on a rising or falling edge of a signal at a specific voltage level.**

A photo finish horse race is analogous to oscilloscope triggering

Edge Triggering Examples



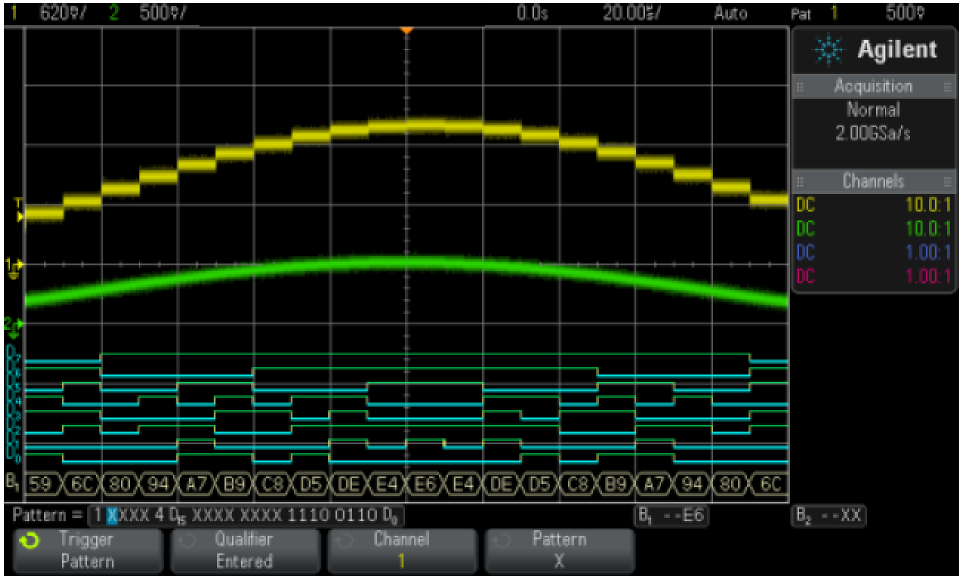
Untriggered
(unsynchronized picture taking)

Trigger = Rising edge @ +2.01 V

- Default trigger location (time zero) on DSOs = center-screen (horizontally)
- Only trigger location on older analog scopes = left side of screen

Advanced Scope Triggering

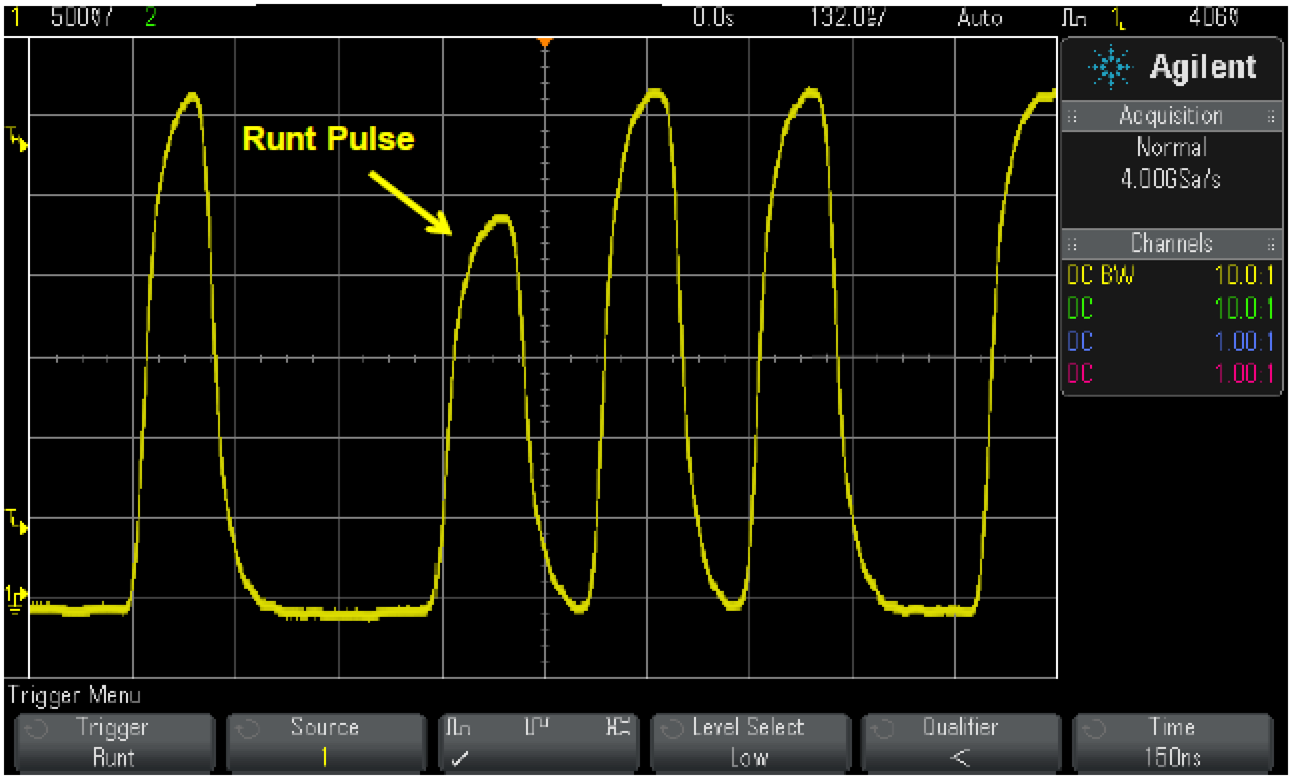
Some oscilloscopes can trigger on complex parallel bus conditions using <u>Pattern triggering</u> (especially useful on MSOs)



Example: Trigger on 1110 0110 ($E6_{HEX}$)

Advanced Scope Triggering

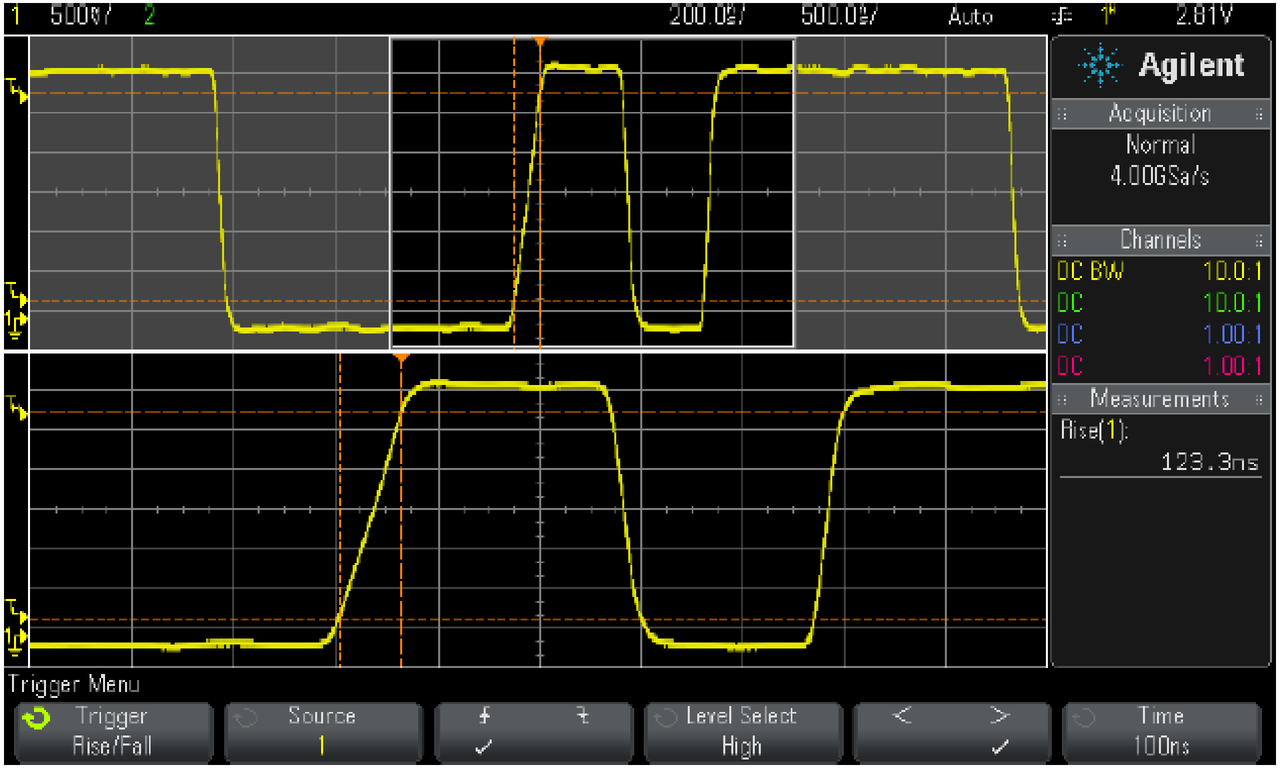
Some oscilloscopes can trigger on signal parametric violation conditions such as invalid pulse heights using <u>Runt triggering</u>



Example: Trigger on positive runt if < 150 ns wide

Advanced Scope Triggering

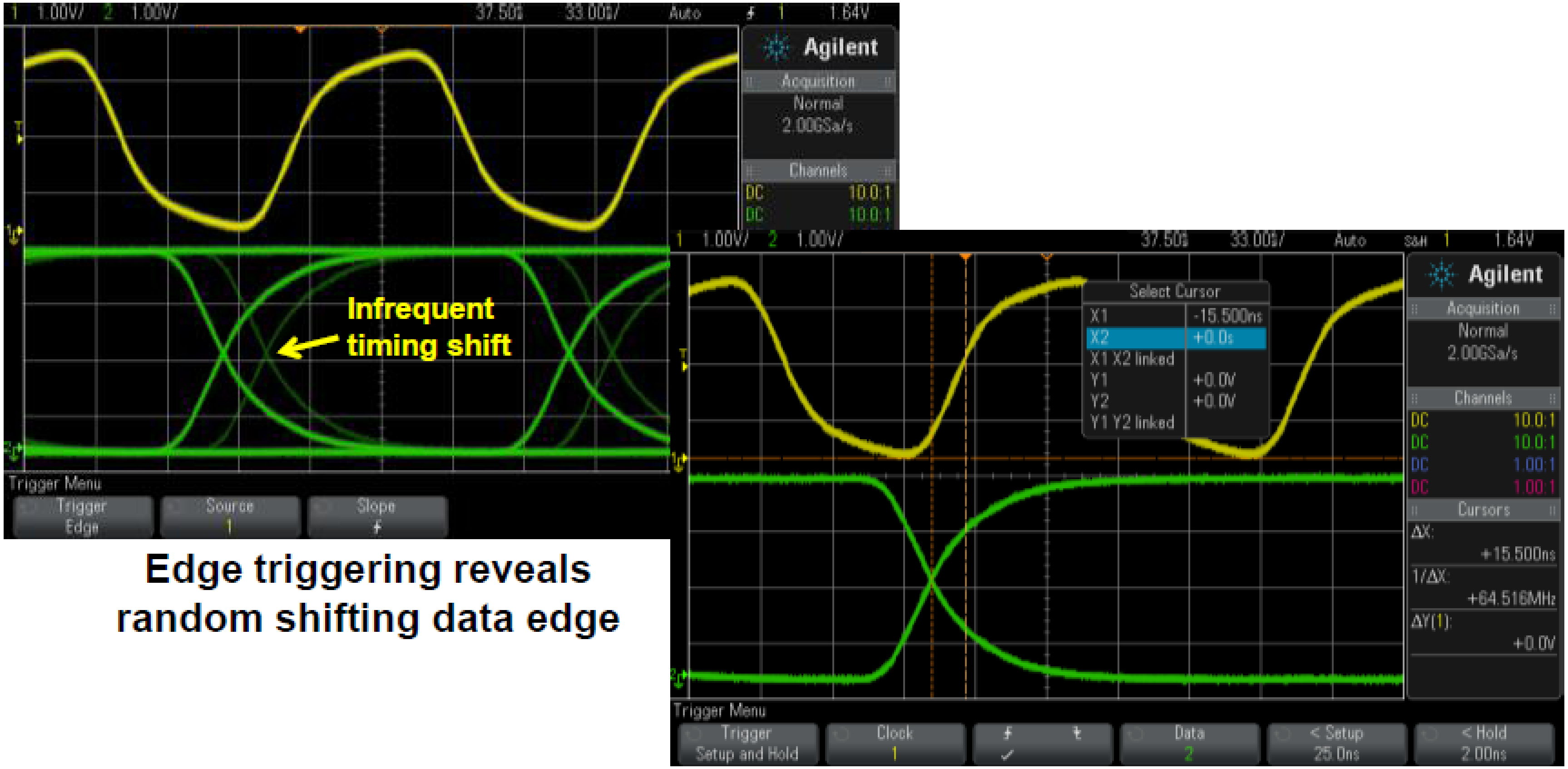
Some oscilloscopes can trigger on edge speed violation conditions using <u>Rise/Fall Time triggering</u>



Example: Triggering on rising edges if slower than 100 ns

Advanced Scope Triggering

Some oscilloscopes can trigger on clock-to-data timing violations using <u>Setup & Hold Time triggering</u>



Edge triggering reveals random shifting data edge

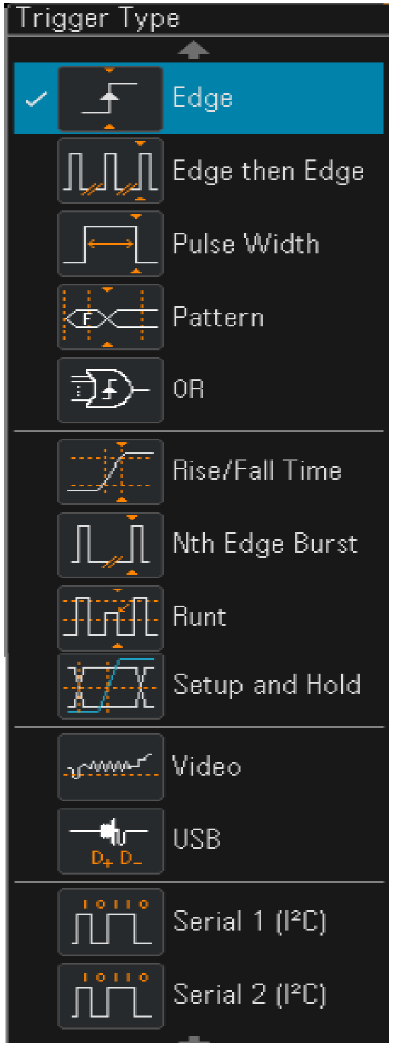
Example: Trigger if setup time < 25 ns

Advanced Scope Triggering

<u>Infiniscan Zone Touch Trigger</u>

Some Oscilloscopes set up an advanced trigger by drawing a Zone(box) around a signal of interest.

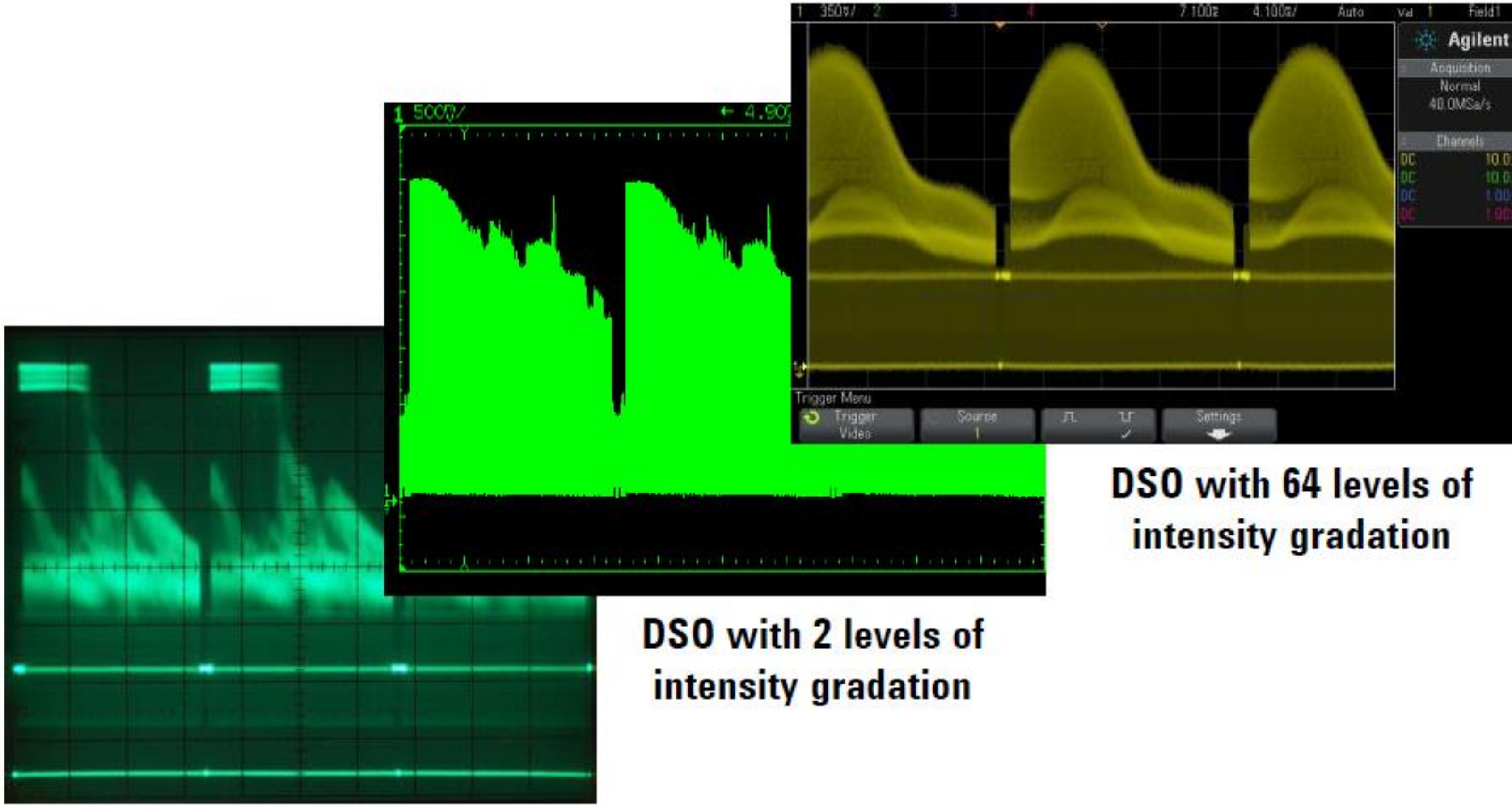
Advanced Scope Triggering



Agilent's Recommendation:

Select a scope that has the types of advanced triggering that you may need to help you isolate waveform acquisitions on your most complex signals.

Tip #7 – Display Quality



DSO with 64 levels of intensity gradation

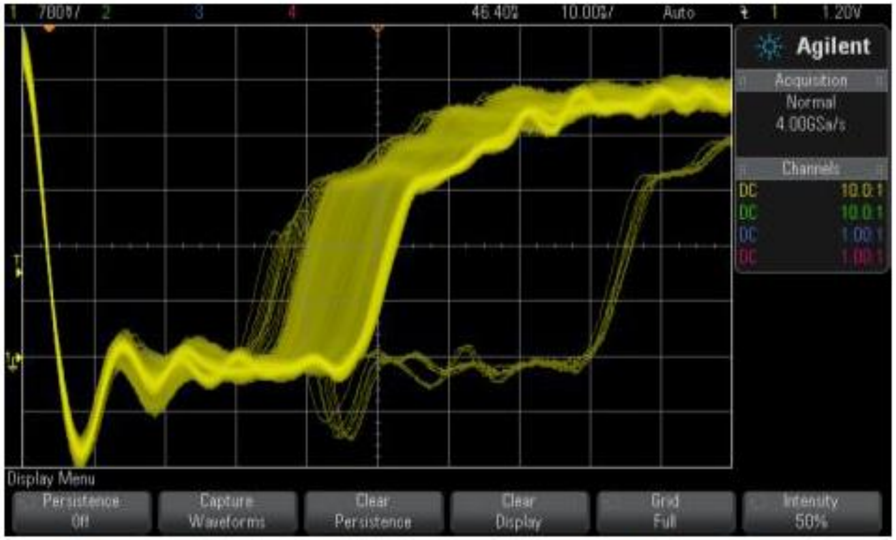
DSO with 2 levels of intensity gradation

Traditional analog scope

Oscilloscope Display Quality

Factors to consider…

- Number of levels of intensity modulation
- Display size
- Display resolution (VGA, XGA, etc.)
- Color or Monochrome



Intensity gradation can reveal relative jitter and noise distribution on digital signals

Agilent's Recommendation:

Select a scope that provides multiple levels of trace intensity gradation in order to display subtle waveform details and signal anomalies.

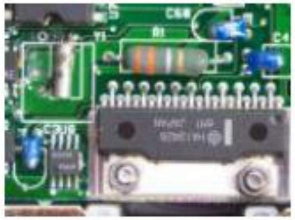
Tip #8 – Serial Bus Application

- I^2C
- SPI
- RS232/UART
- CAN
- LIN
- FlexRay
- MIL-STD 1553
- ARINC 429
- I^2S
- **USB**

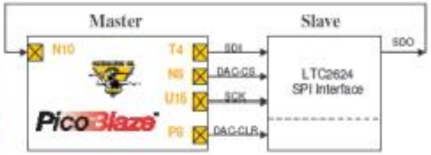
Serial buses are used pervasively in most of today's designs to communicate:

- Between functional blocks
- Chip to chip
- Board to IO
- Remote sensor to control

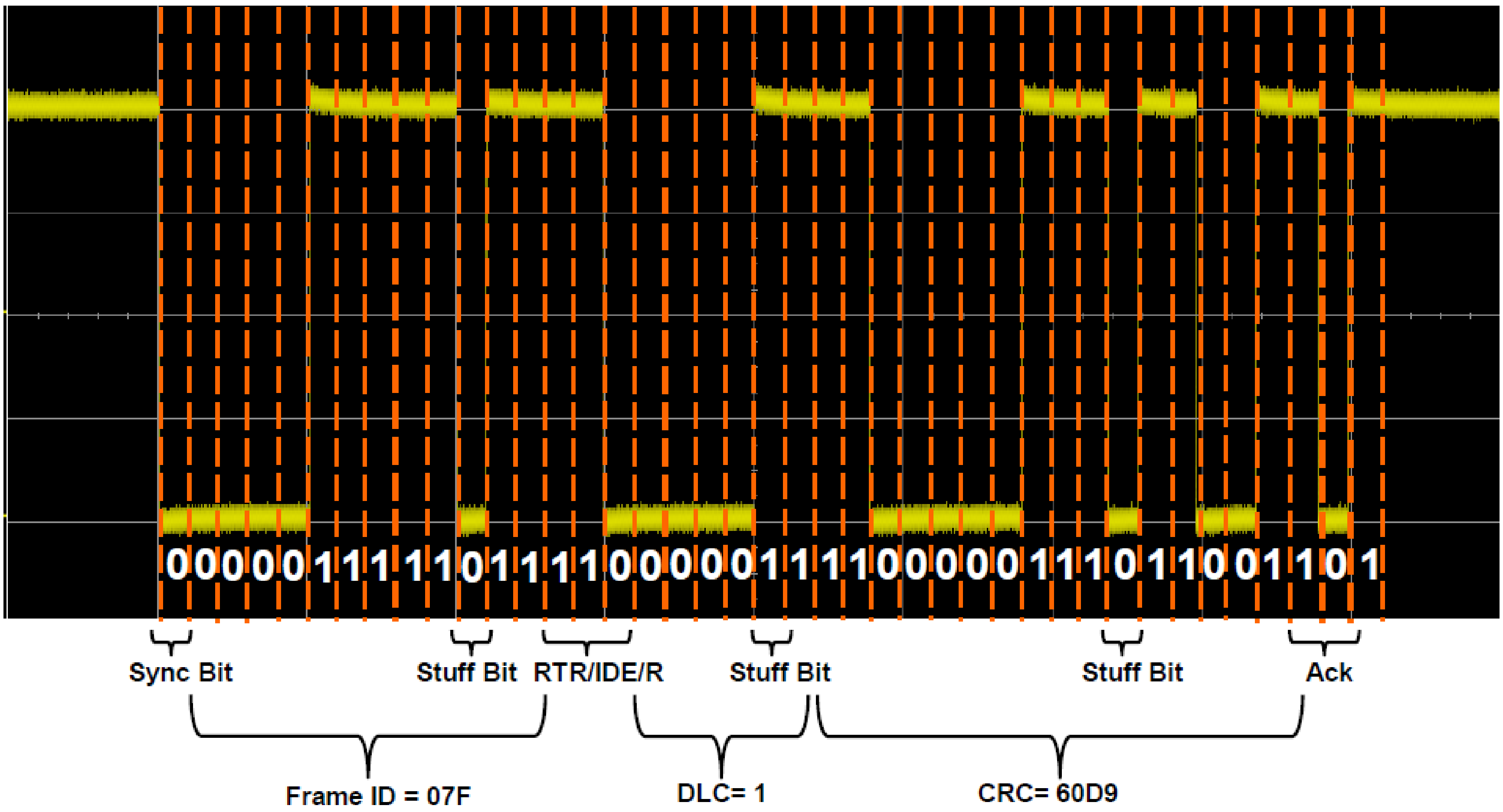








The “brute force” decoding method

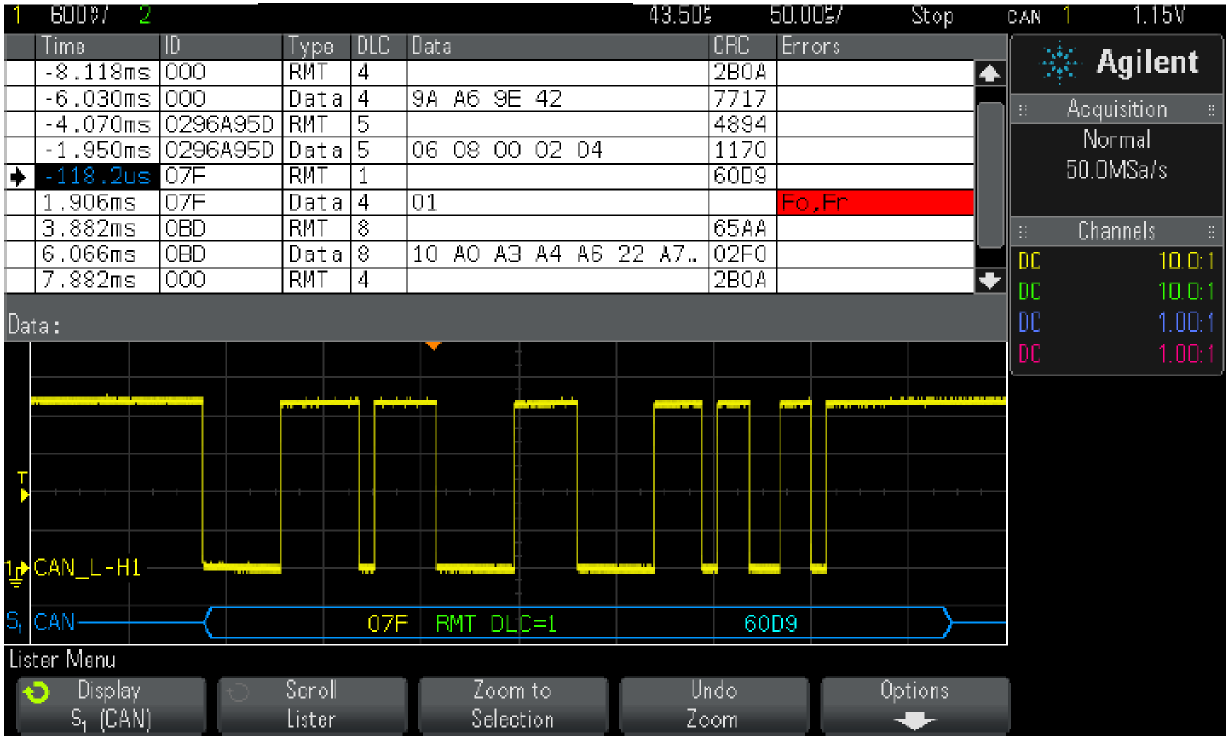


CAN Manual Decoding Example

Today's decoding method

Protocol Decode Lister/Event Table

Time-aligned Decode Trace



Frame ID = 07F

Frame Type = Remote Transfer Request (RMT)

Data Length Code = 1

Data = N/A

CRC = 60D9

Today's decoding method

Protocol Decode Lister/Event Table

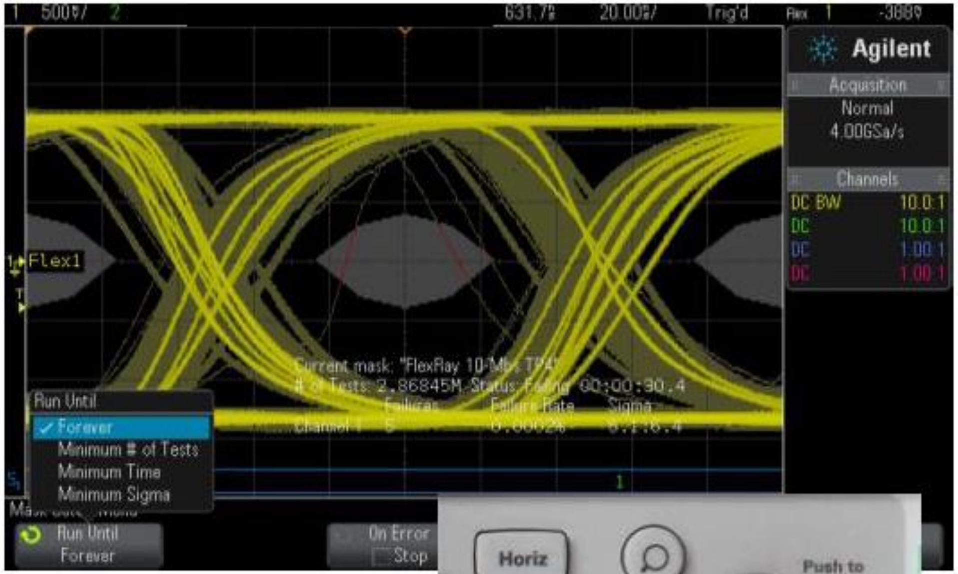
Time-aligned Decode Trace

Dual serial bus CAN and LIN decode

Serial Bus – Things to Consider

Things to consider…

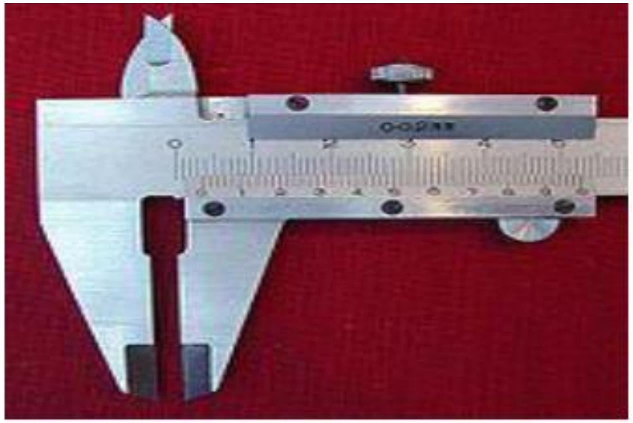
- **Protocols Supported?**
- **Decoding Method**
  - ✓ **Hardware-based?**
  - ✓ **Software-based?**
- **Serial Triggering**
  - ✓ **Address/Frame ID?**
  - ✓ **Data contents?**
  - ✓ **Errors?**
- **Post-acquisition Search & Navigation?**
- **Serial Eye-diagram Mask Testing?**



Agilent's Recommendation:

Select a scope that can trigger on and decode serial bus protocols to help you debug your designs faster.

Tip #9 – Measurement & Analysis



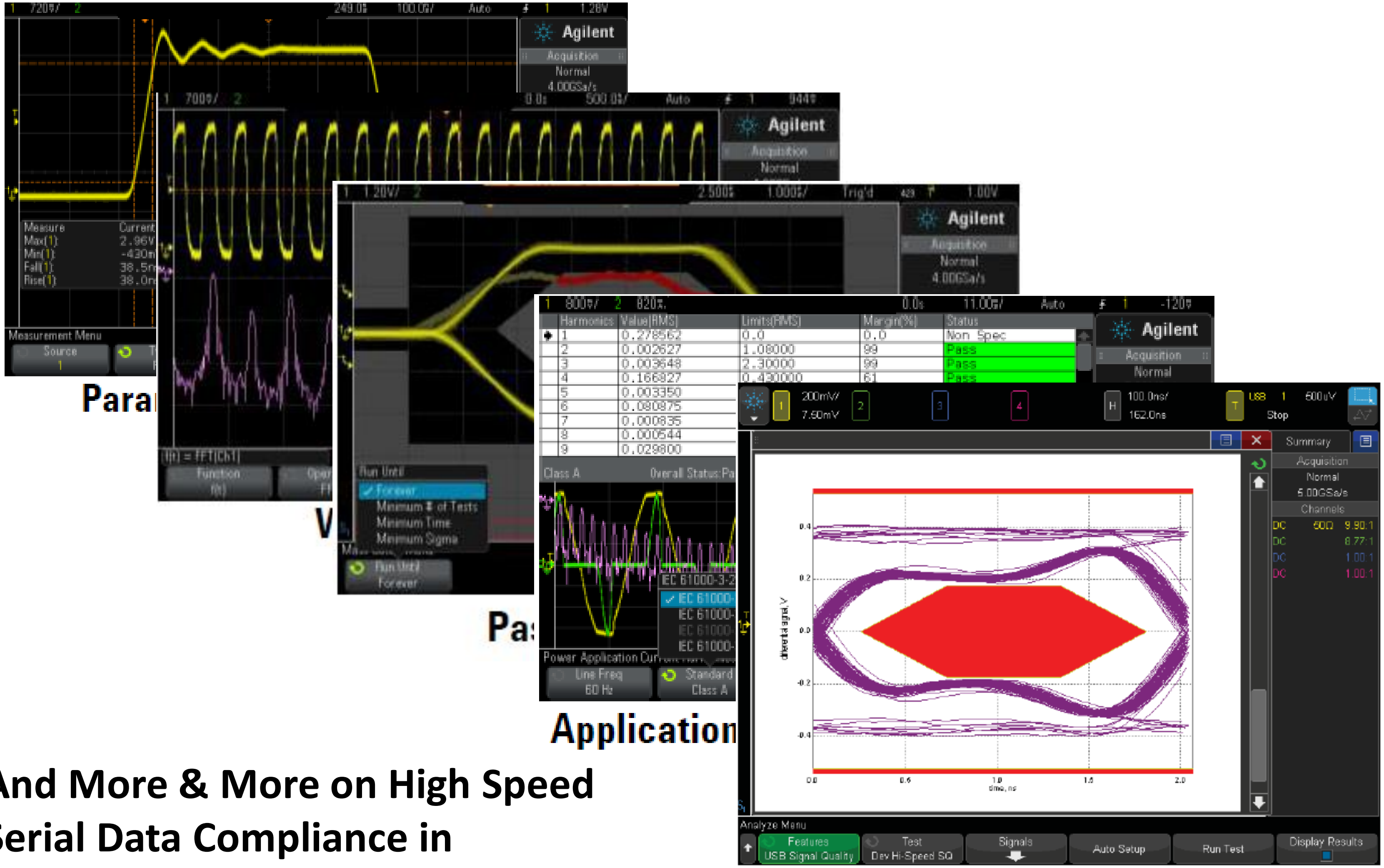
Things to consider…

- **Time & Voltage Cursors**
- **Parametric Measurements**
  - ✓ **Rise Time, Vpp, Pulse width, etc**
  - ✓ **Measurement statistics**
  - ✓ **User-selectable threshold settings**
- **Waveform Math**
  - ✓ **Sum, Subtract, Integrate, FFT, etc.**
- **Pass/Fail Mask Testing**
- **Application-specific Compliance Testing**

Agilent's Recommendation:

Select a scope that can automatically perform your required measurements and waveform analysis to help you characterize your designs faster.

Measurement & Analysis Examples



USB 2.0 Signal Quality

And More & More on High Speed Serial Data Compliance in Performance Scopes

Tip #10 – Connectivity & Documentation

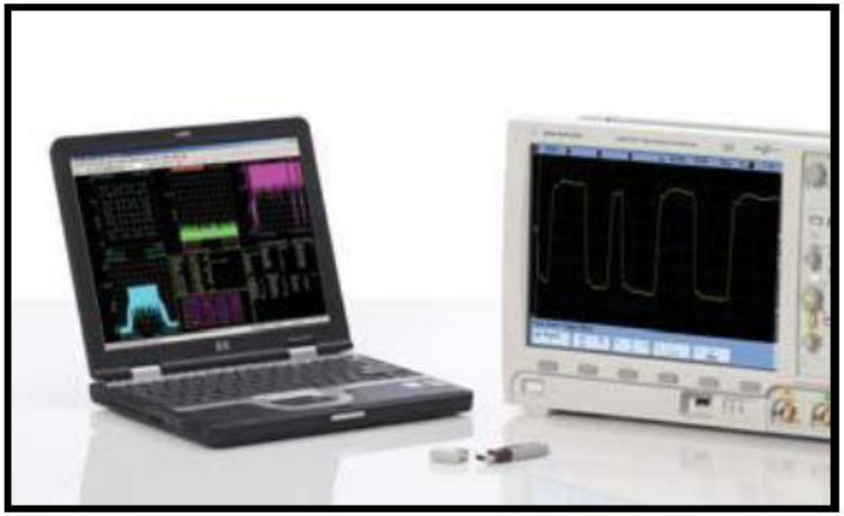
Automated testing requires that your scope be fully programmable and linked to a PC via:

- **GP-IB**
- **RS-232**

Supported on most older DSOs (sometimes optional)

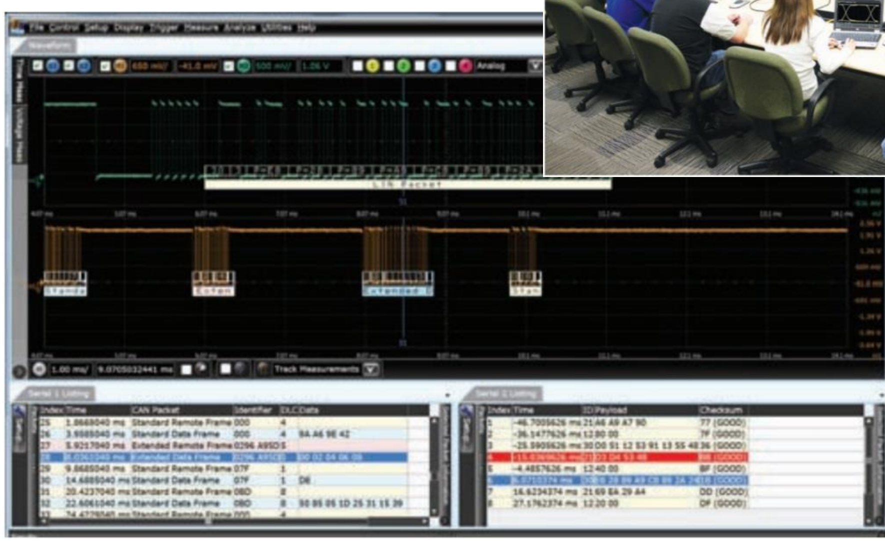
- **USB**
- **LAN**

Supported on most newer DSOs (sometimes optional)



All of Agilent's oscilloscopes come standard with USB and/or LAN connectivity.

Documentation & Analysis



N8900A InfiniiView Oscilloscope Analysis Software

View, analyze, share, and document, where, and how you want.

Agilent's Recommendation:

Select a scope that meets your particular connectivity and documentation requirements.

Tip #11 - Probing

Scope measurements are only as good as the what the probe can deliver to the scope's inputs.

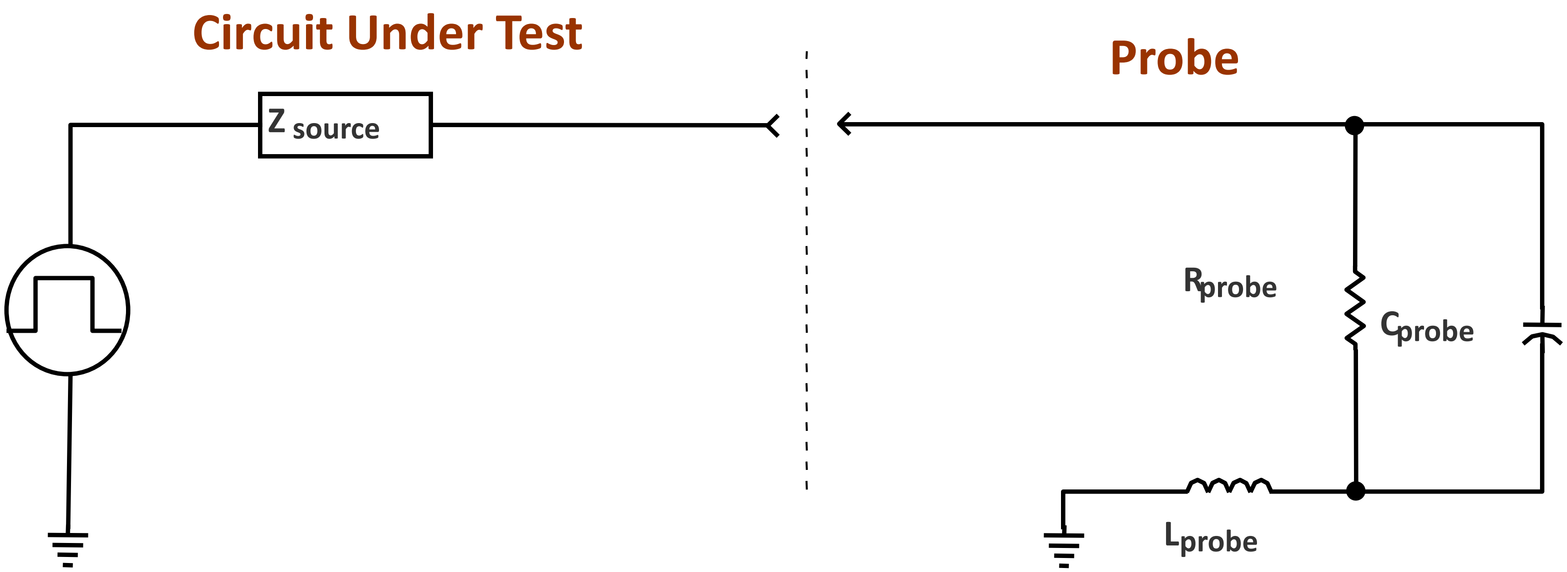
Types of Oscilloscope Probes:

- **Passive probes**
- **Active probes**
- **Single-end probes**
- **Differential probes**
- **Extreme Temperature probes**
- **High-Sensitivity Current Probes**

Agilent's Recommendation:

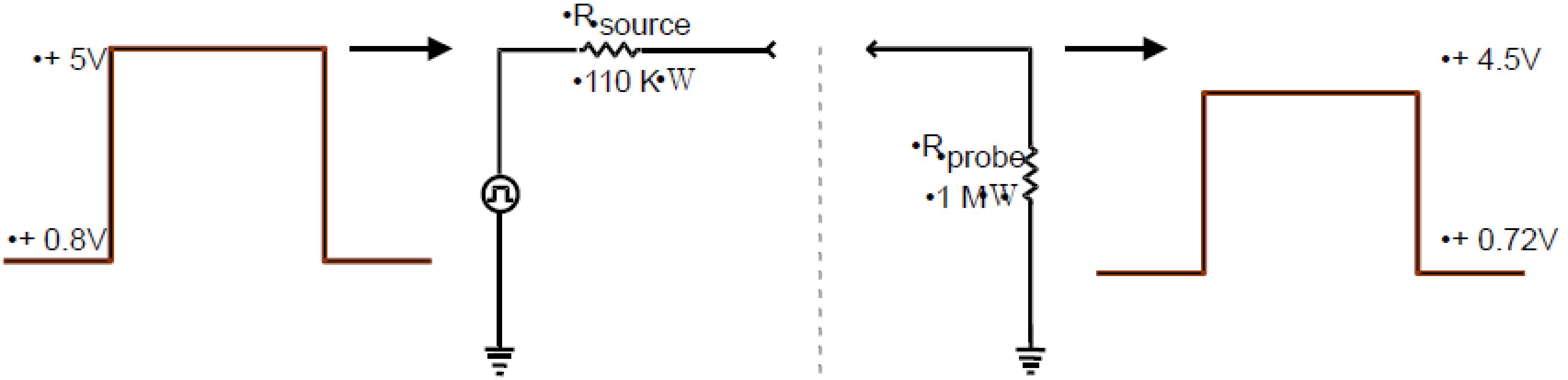
Select a scope from a vendor that can also provide the variety of specialty probes that you may require.

Probe and Loading Effects



- Resistive, Capacitive and Inductive loading effects must be considered!
- What are the effects of each type of loading?

Resistive Loading



•At Input: 5V

•Voltage Divider at Output: 5V x 1MΩ/(1MΩ + 110kΩ) = 4.5V

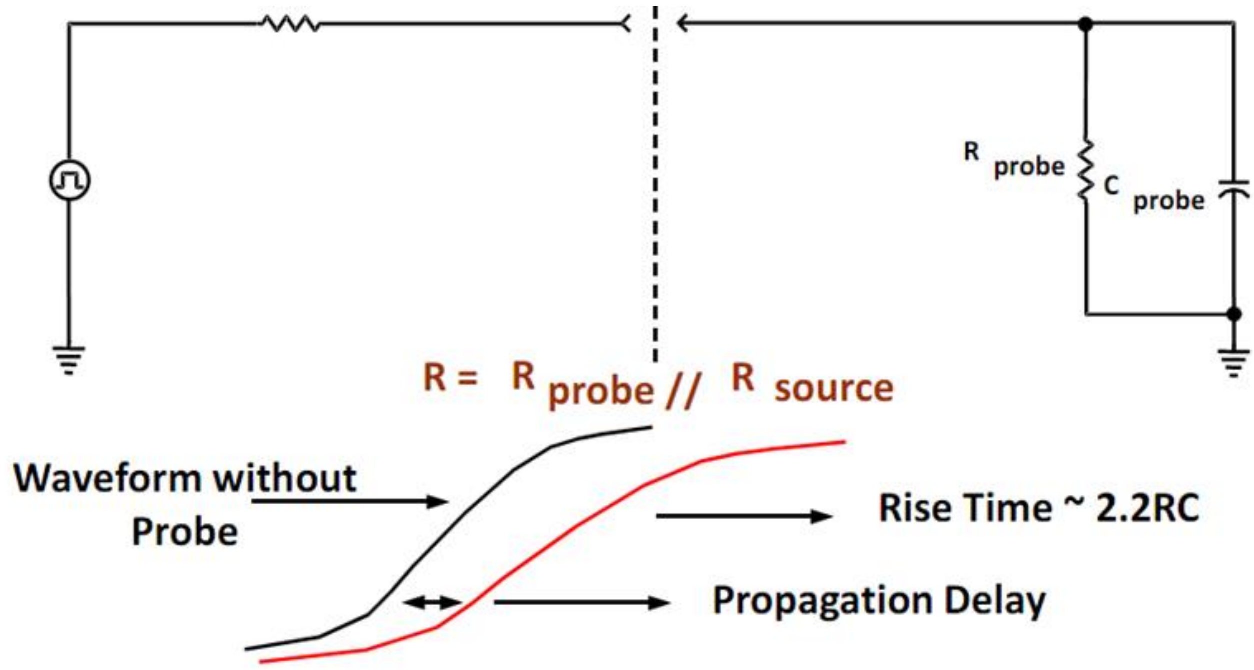
Effects

- The amplitude and DC offset at the node under test are reduced
- Circuit malfunctions but starts working when a probe is attached

Recommendation

- R_{probe} >10 R_{source} for less than 10% amplitude reduction

Capacitive Loading



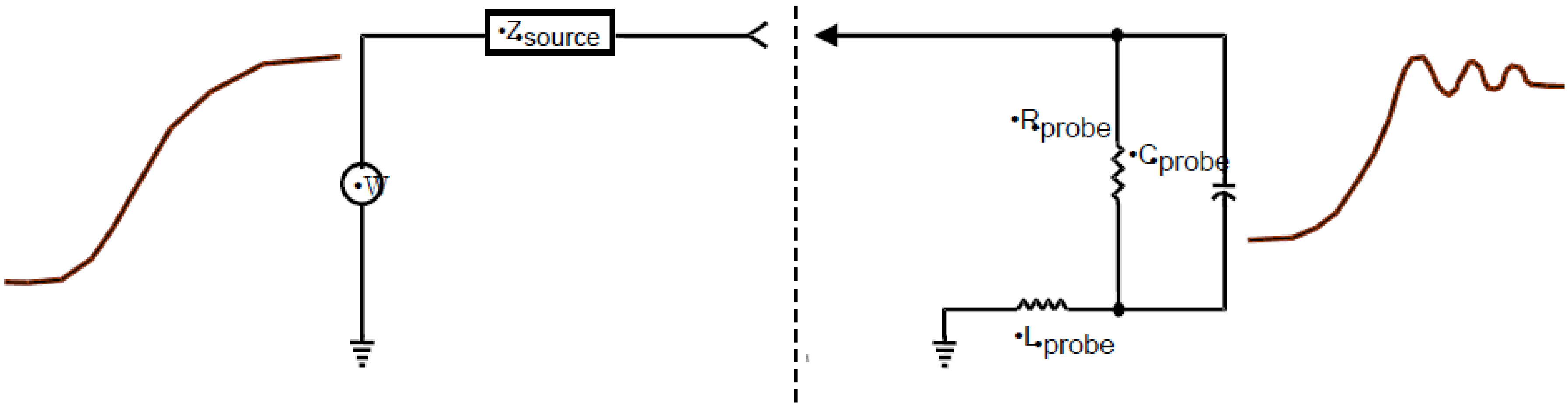
Effects

- Rise time slowed
- Bandwidth is reduced
- Propagation delay is increased

Recommendations

- Minimize probe tip capacitance
- Choose a probe that exceeds the signal bandwidth by 5

Inductive Loading



Effects

- Ringing is induced because of the inductive effects of the probe ground lead
- Measurement will be wrong due to ringing

Recommendations

- Use as short a ground lead as possible (ground wire inductance= 1nH/mm)

Tip #12 – Ease-of-use & Price

Ease-of-use

Ease-of-use is subjective.. but important. If a scope has advanced features, but if they can't be easily accessed and used, then they are effectively useless. Try before you buy.

Price

Scope prices are typically based on performance and features. Select a scope that meets your minimum measurement needs. But prioritize and be willing to make tradeoffs in order to meet budget requirements.

Test & Measurement Specialist

Jays

Solution Provider, Distributor, Reseller.

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(주)제이스 를 지켜봐 주십시오.

Thank you !!!