Validating Banner Specifications:

Digitzer Specifications and what they mean to measurments

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Agenda

- Bandwidth/Frequency Response
- ENOB

Bandwidth & Frequency Response

An oscilloscope typically will have two frequency responses (flat or Gaussian).

The frequency response impacts measurements in the following ways:

- Can cause amplitude measurement inconsistencies
- Can increase ISI
- Can increase noise
- Can change wave shape

Frequency Response

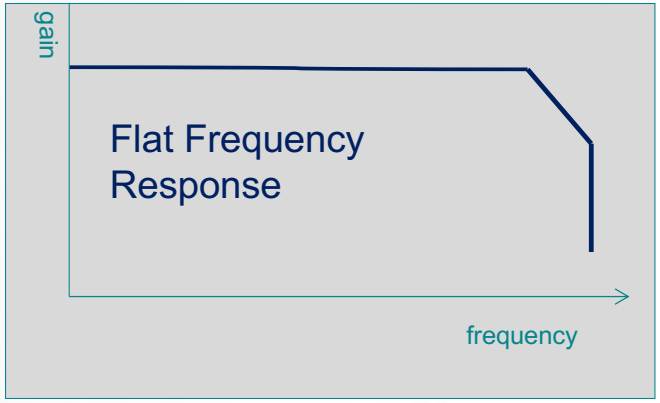
WHY WILL TWO SCOPES HAVE DIFFERENT BANDWIDTHS?

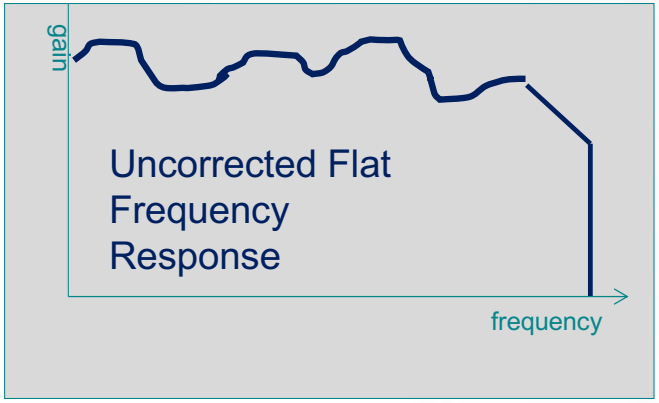
Vpp = 611mV

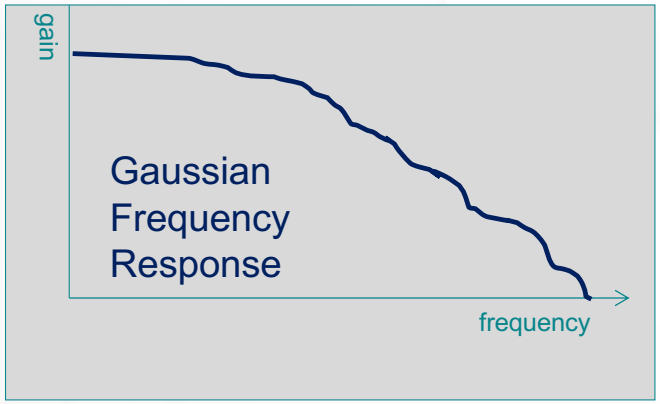
Vpp = 242mV

The two scopes will report different Vpp and risetime values

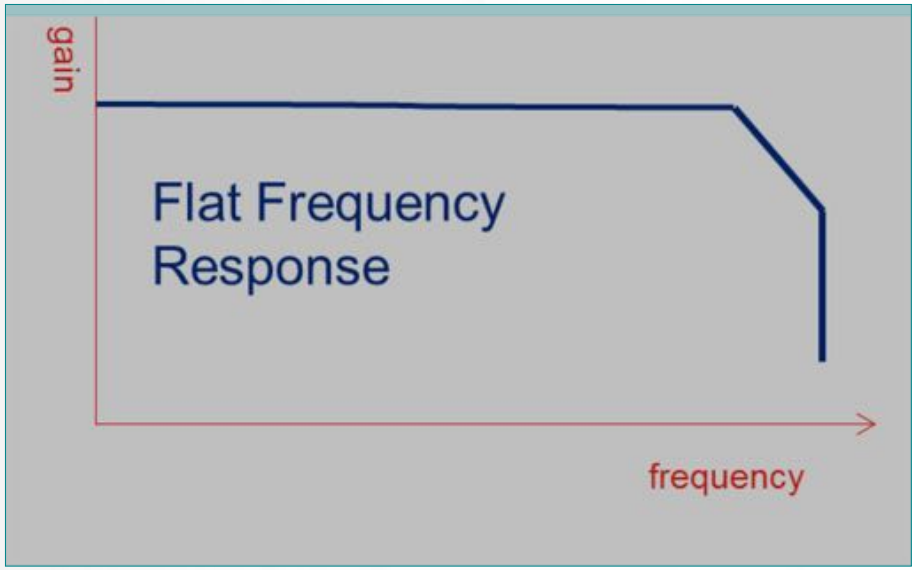
What are the 3 frequency responses







Flat Frequency Resposne



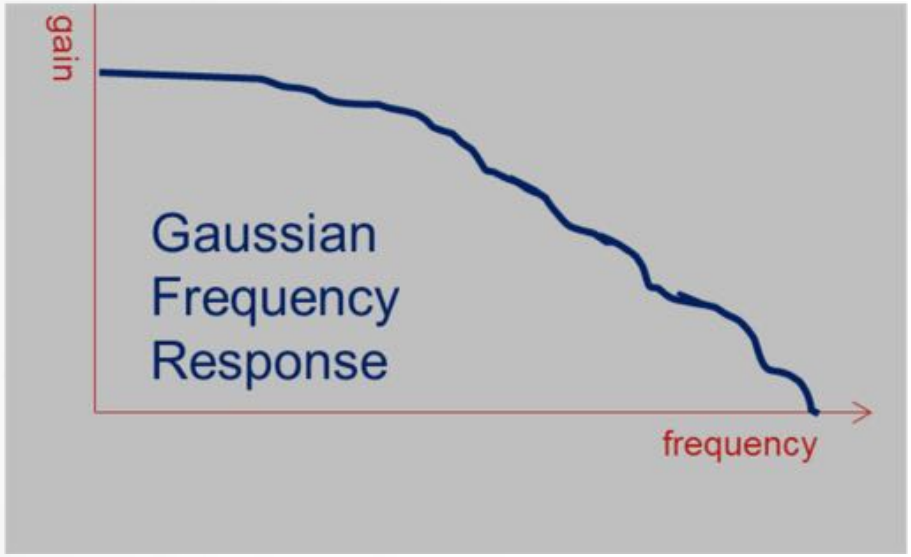
Positives:

1. Measures correct signal amplitude at all pass-band frequencies
2. Will not increase the noise of the system
3. Gives equal weight to all frequencies

Negative:

1. If you drive the rise time faster than the scope, can see ringing

Gaussian Response



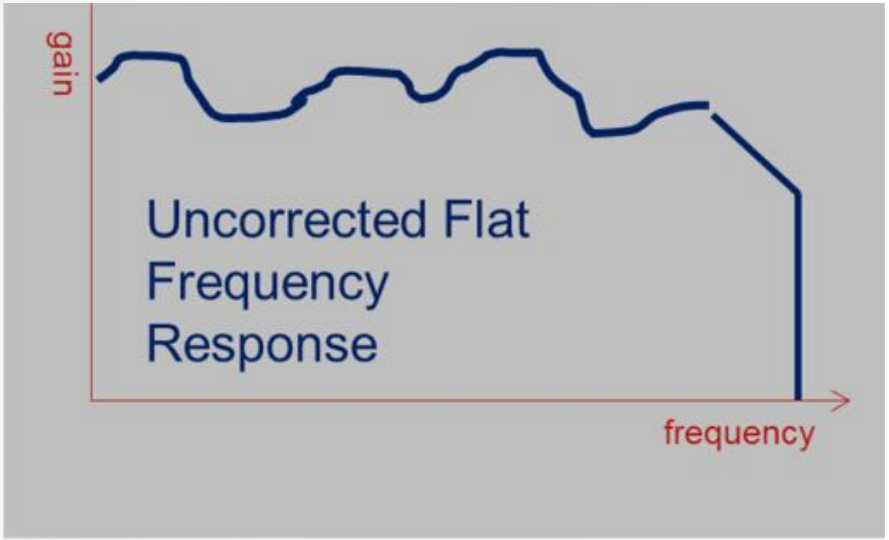
Positives:

1. Will not cause ringing on fast rise times
2. Has bandwidth outside of the pass-band

Negative:

1. As frequencies increase on the device, amplitude measurements decrease
2. Does not give equal weight to all frequencies.
3. Superficially decreases noise on the system

Uncorrected



Positives:

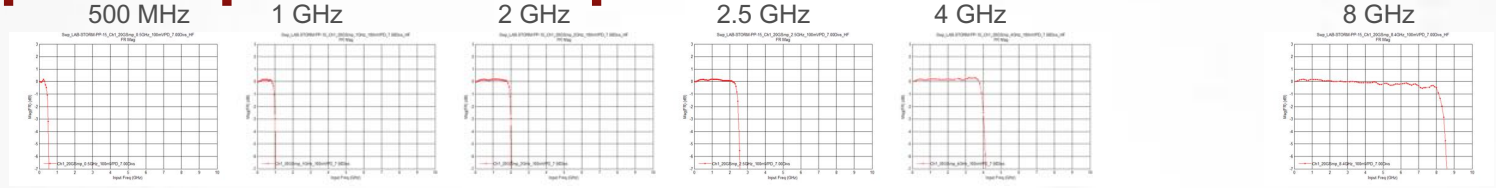
1. Runs quickly

Negative:

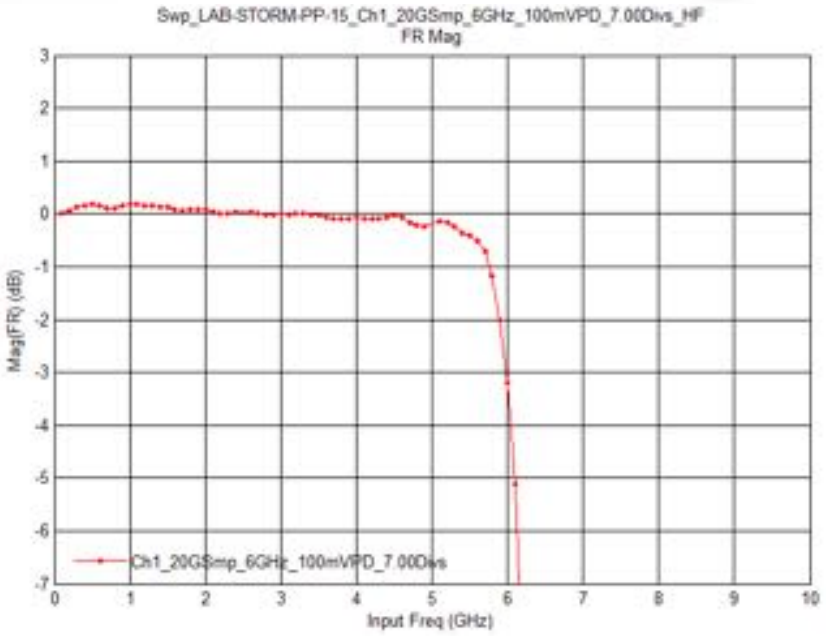
1. Can measure incorrect signal amplitude at all pass-band frequencies
2. Unknown weight of different frequency tones.
3. Can increase the noise of the system

Digitzer manufacturers will typically provide frequency response plots on request.

500 MHz 1 GHz 2 GHz 2.5 GHz 4 GHz 8 GHz



6 GHz →



Measuring a frequency response

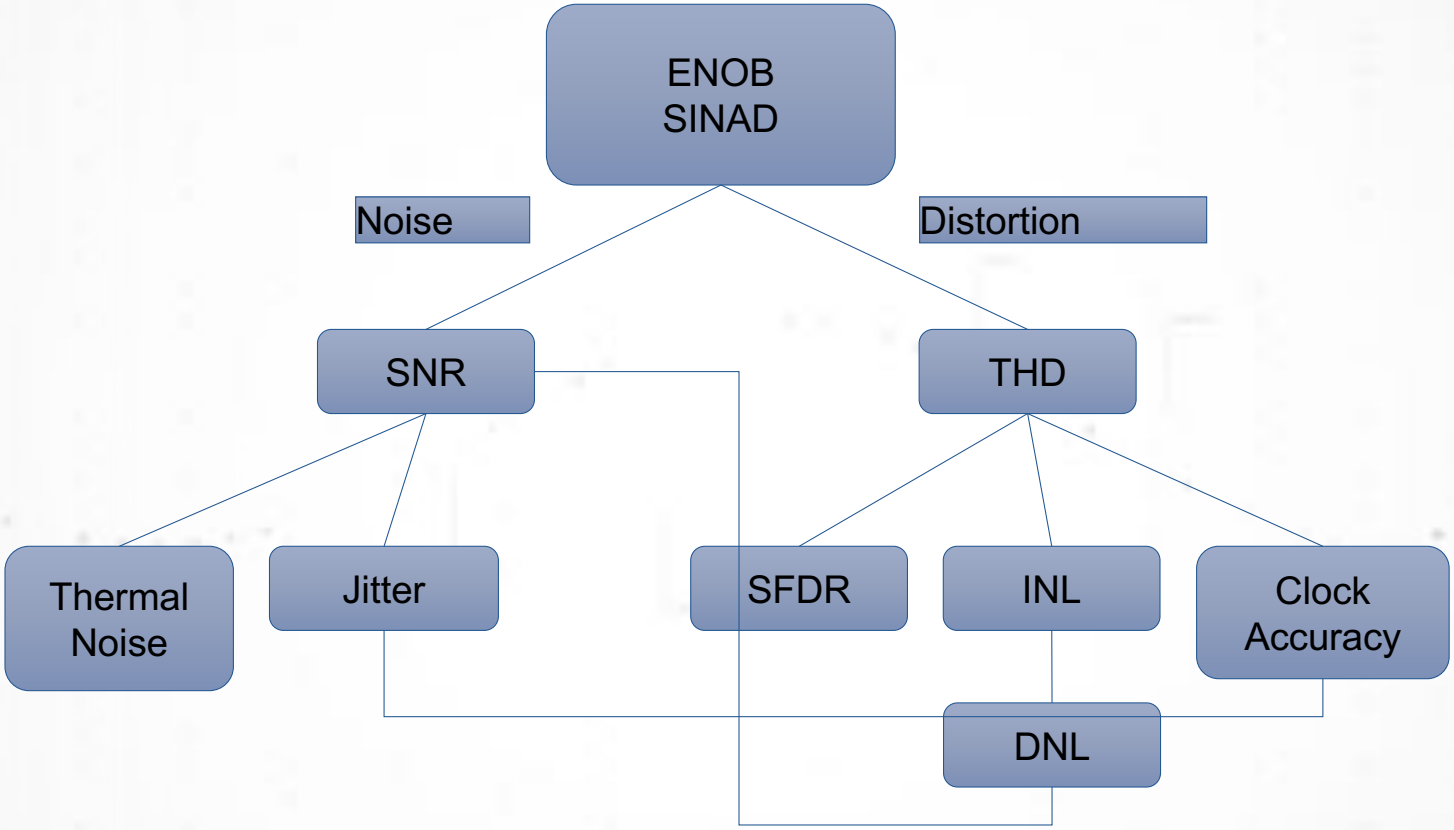
Procedure:

1. Input a fast edge into the oscilloscope.
2. Turn on averaging
3. Turn on the differential function of the fast edge (this creates a pulse)
4. Turn on the FFT of the pulse
5. You now will see the scope frequency response

ENOB

- Was established in 1993 as a measurement of a digitizer's "goodness" and is an IEEE standard measurement
- Directly correlates with a digitizer's signal to noise ratio
- Does not take into account frequency response
- ENOB can impact:
  - Amplitude measurements
  - Frequency measurements
  - Repeatability of measurements

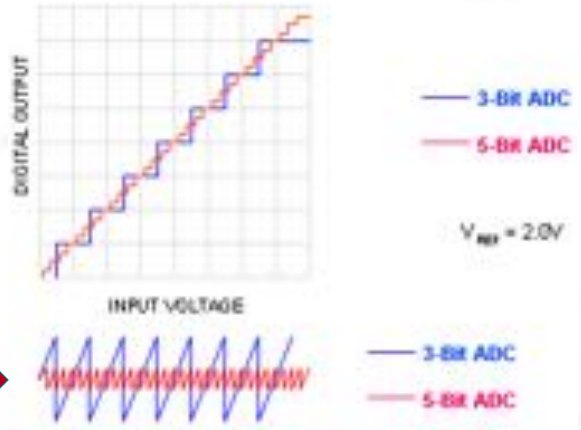
ENOB


ENOB
SINAD
Noise
Distortion
SNR
THD
Thermal Noise
Jitter
SFDR
INL
Clock Accuracy
DNL

Analog to Digital Chip (ADC) Resolution

Bits of Resolution	Quantizing Levels	At 1V Full Scale 1 LSB =
8-bit	256	3900 uV
10-bit	1,024	976 uV
12-bit	4,096	244 uV
14-bit	16,384	61 uV

- Adding more bits makes each step size smaller, so the maximum error is smaller
- See the comparison to the right of a 3 bit ADC versus a 5 bit ADC

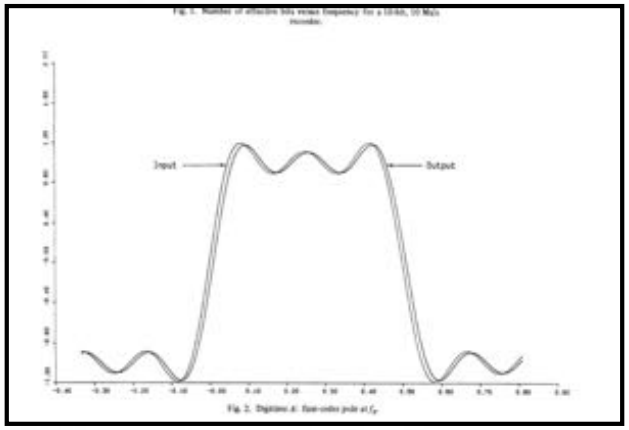


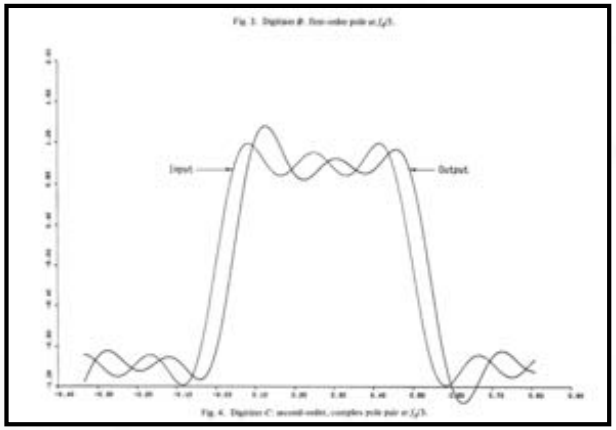
3 bit versus 5 bit error difference

Caution around ENOB

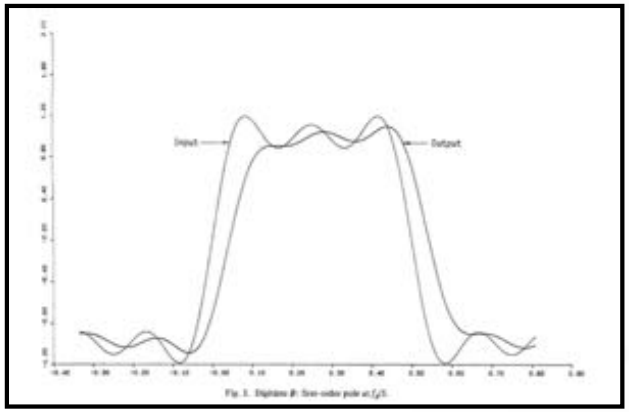
- Effective bits and signal to noise ratio tend to be closely tied, but only under very ***specific*** conditions.
- Effective bits ***neglect*** key sources of error:
  - Amplitude Flatness
  - Phase Linearity
  - Gain Accuracy
  - Offset Accuracy
- Effective bits ***over-emphasize*** the effect of several measurements including harmonic distortion and high frequency timing jitter
- Effective bits ***under-emphasize*** the importance of noise floor in a system
- Effective bits ***won't*** tell you which is degrading the effective bits

More words of caution





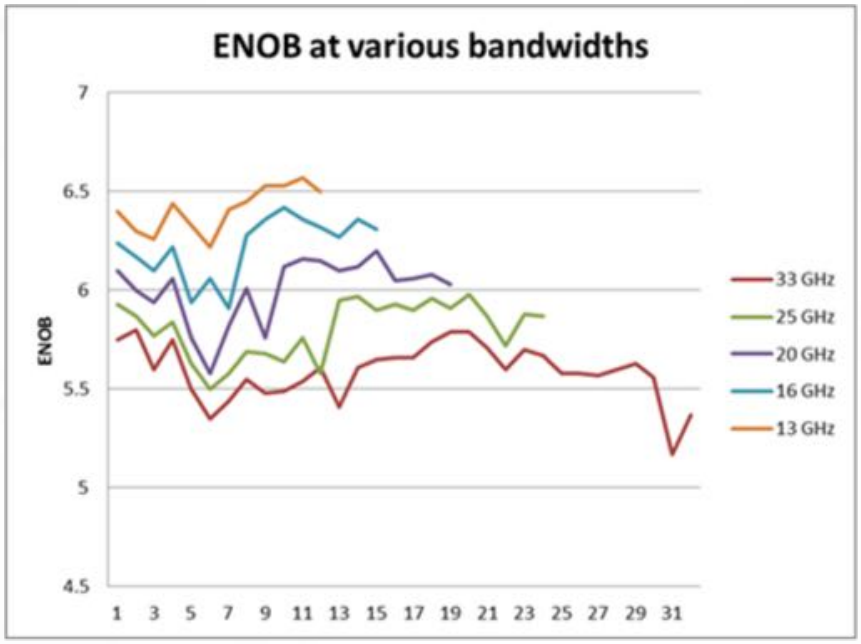
Three Oscilloscopes: All Have Same Effective Bits



Notice the effect of magnitude and phase flatness, when only considering effective bits, you could have any of the three

Other challenges with ENOB

- A single number for ENOB ***ONLY*** describes the ENOB value at one specific frequency:

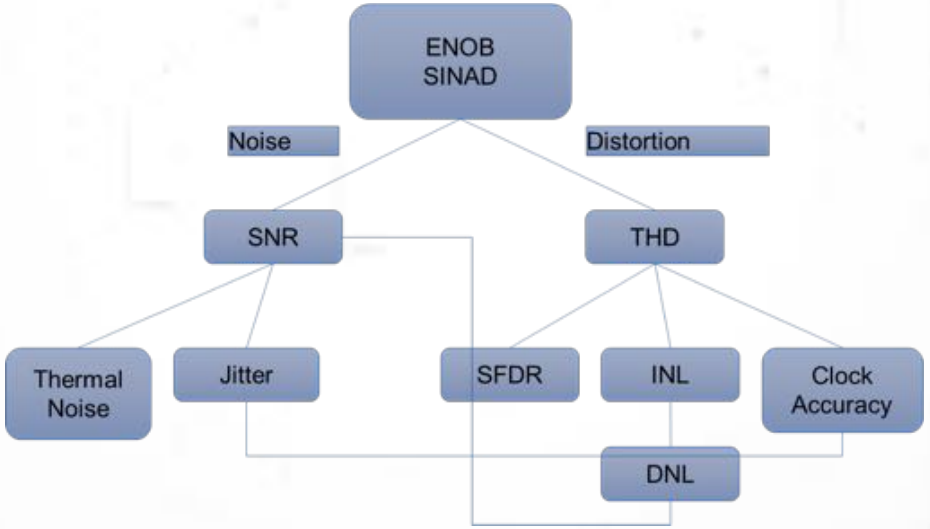


Other Challenges with ENOB

- ENOB is strongly affected by Volts per division setting
- ENOB is strongly affected by input signal amplitude

Why use ENOB then?

- There isn’t another easy to compare specification that sums up the many errors the digitizer can be adding to your measurements.
- If you can determine the ENOB in the environment you are doing your measurements (bandwidth, volts/div setting, and input signal size), it is a valid way of comparing two different digitizers.



How to measure ENOB

PROCEDURE:

- A sine wave signal is digitized by n-bit ADC under test;
- a sine wave fit to the measured data using least-mean-square algorithm is assumed to represent the actual input signal;
- differences between the data record and best fit sine wave are assumed to be errors

Sine Wave Curve Fit

Any imperfection erodes ENOBc

Other specifications

Phase Linearity

Oscilloscope phase impacts waveform shape. The less linear the phase the less square a square wave will look.

Offload Speed

If you do a lot of work on a PC for post processing, it is important to pull data off the scope quickly. Offload speed shows how fast the scope does this.

Spurious Free Dynamic Range

SFDR is the strength ratio of the fundamental signal to the strongest spurious signal in the output.

Error Vector Magnitude (EVM)

Similar to ENOB, EVM takes into account noise, phase noise and distortions, the lower the EVM, the better the scope measurement.

KEYSIGHT
TECHNOLOGIES