Accurate Measurement by DSO

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Outline

- Basic DSO block diagram
- Key Parameters of DSO measurement
- Advanced parameters
- Advanced functions (Trigger, Roll mode, Search, Segmented memory)
- Probe

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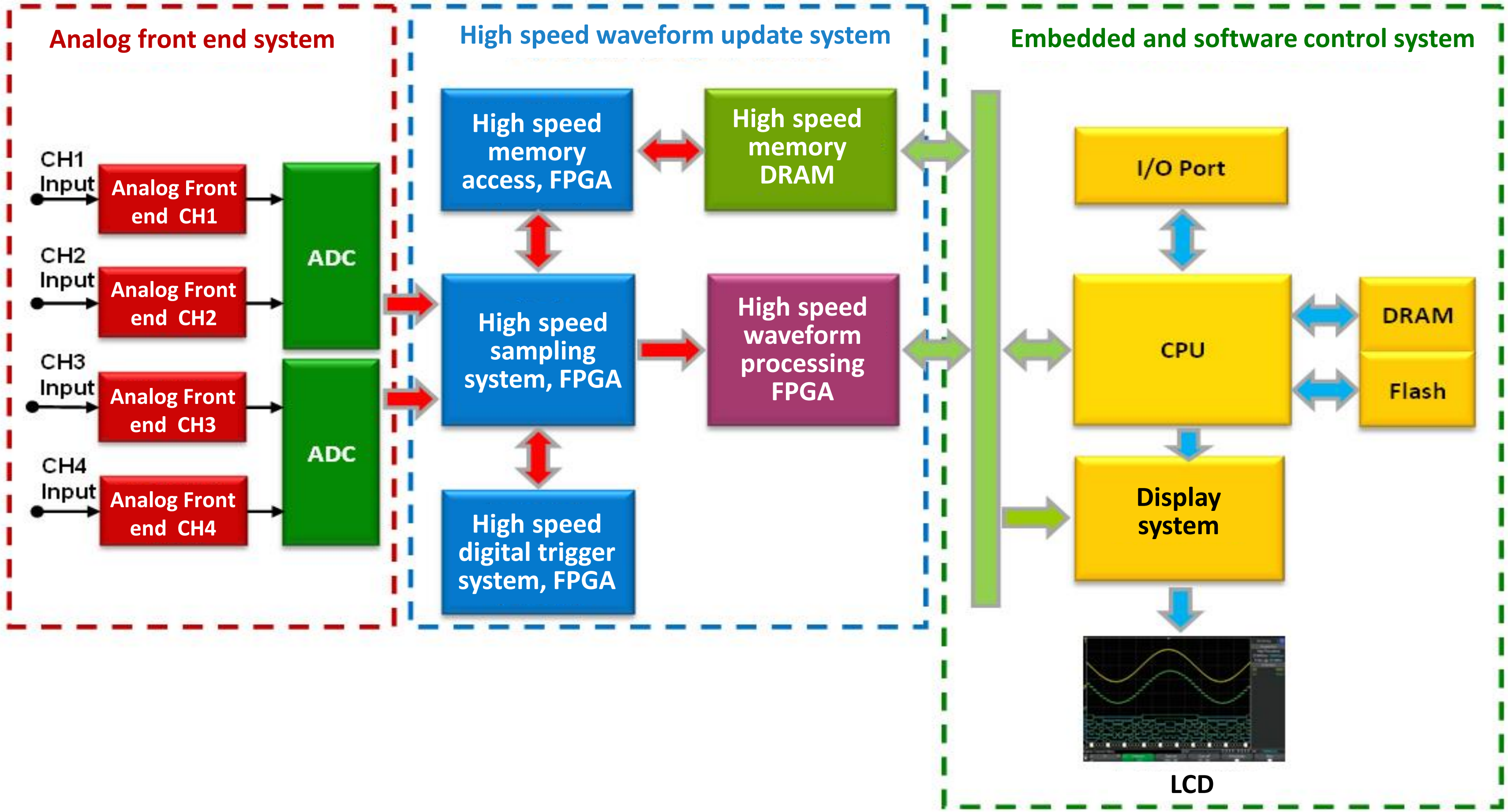
Oscilloscope Evolution

- **ARO** (Analog Real Time Oscilloscope)
  FAST update rate – See the real time waveform
- **RSO** (Real-Time and Digital Storage Oscilloscope)
  Combination of both features
- **DSO** (Digital Storage Oscilloscope)
  Waveform storage & analysis

DSO system block diagram



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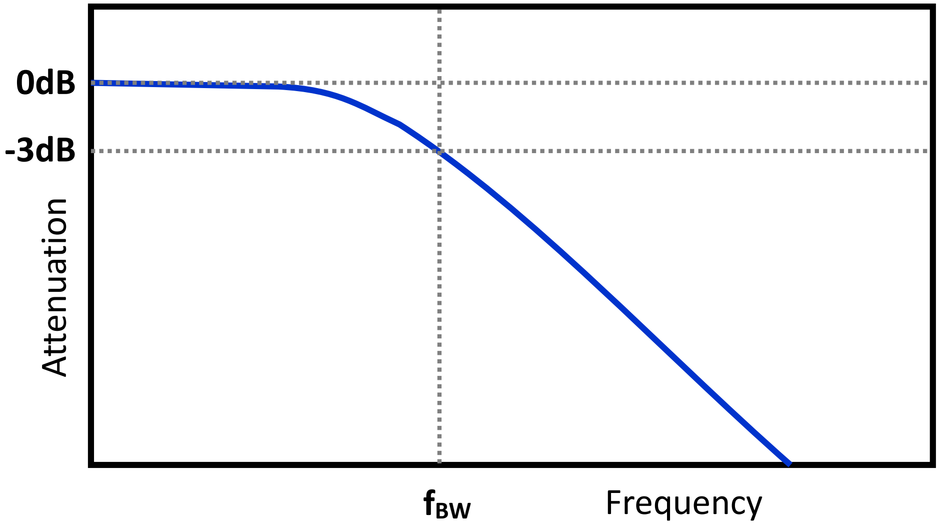
Three major parameters

Three major parameters contribute to the selection of a digital oscilloscope. Including

- Bandwidth,
- Sample rate,
- Memory depth,

Bandwidth

- All oscilloscopes exhibit a low-pass frequency response that rolls-off at higher frequencies.
- Bandwidth of an DSO is defined as the signal attenuation at the –3 dB frequency which is about -30% amplitude error.
- The rule of thumb is the scope's bandwidth should be at least five times higher than the fastest signal in the system under test.



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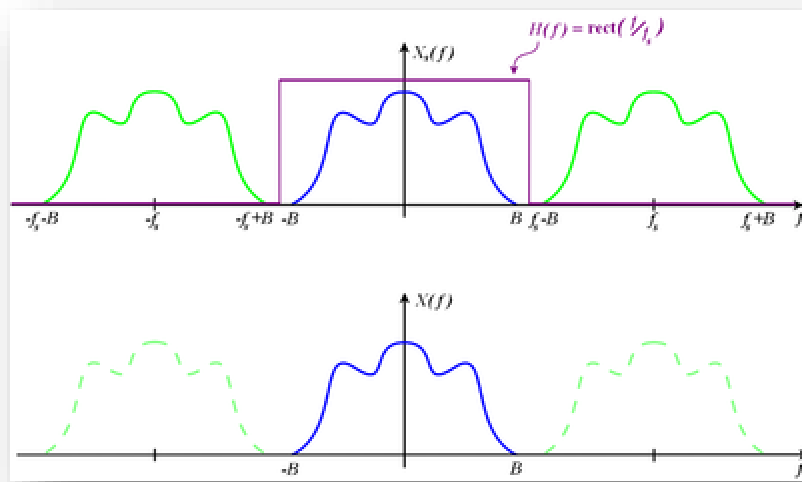
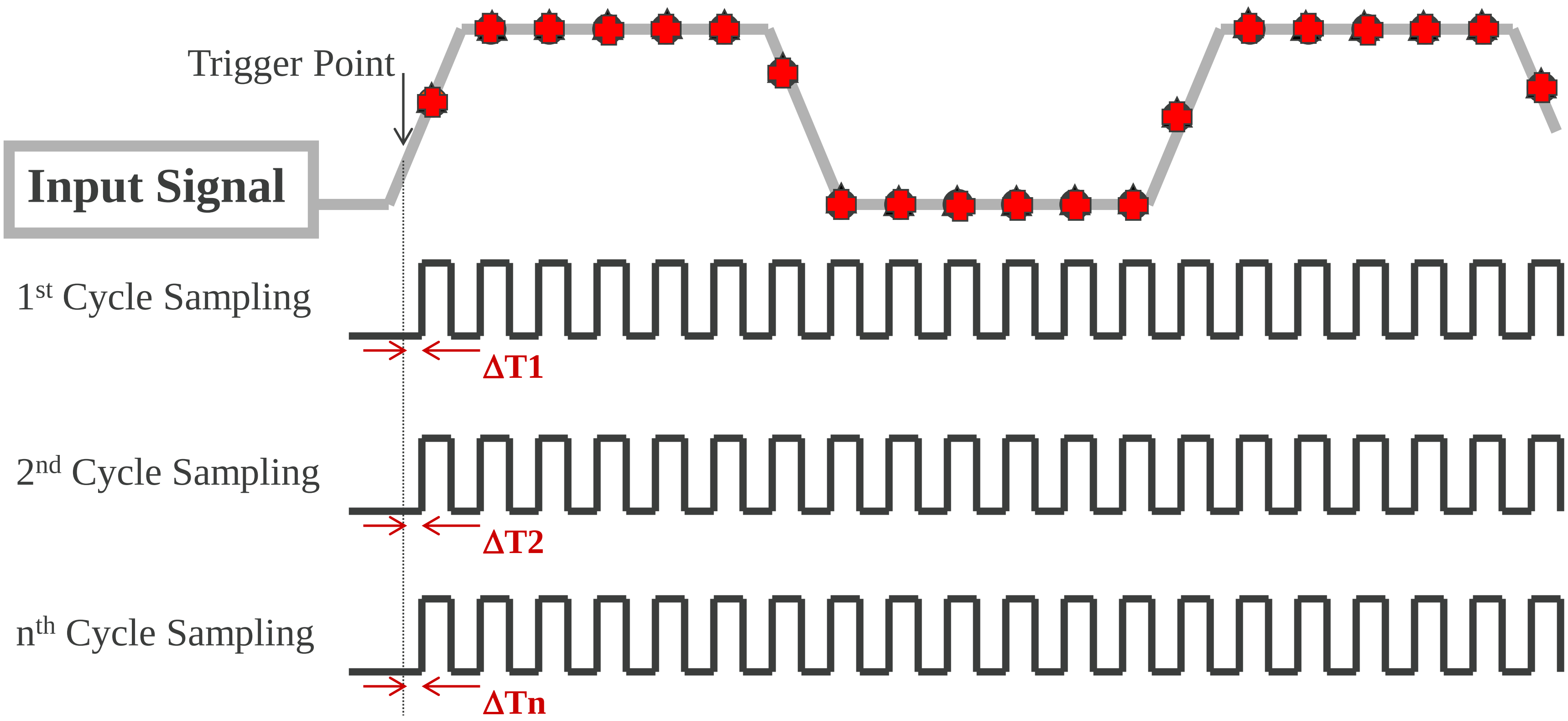
The Fact about Sampling Rate

- The most important specification that the DSO user should understand :
- Sampling Rate specification actually means the Maximum Sampling Rate.
- The DSO is running under a far slower sampling rate than the Maximum Sampling Rate under most of the test conditions.



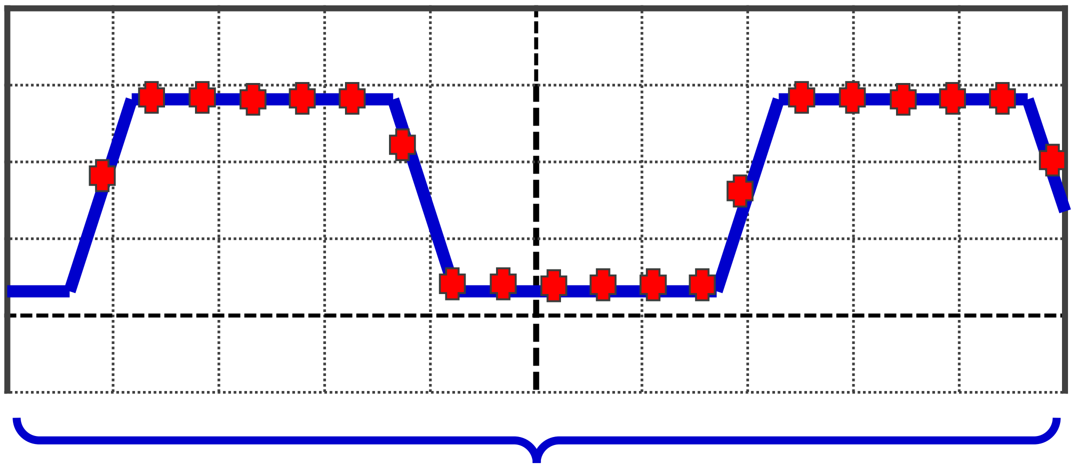
Real Time Sampling

Real-Time Sampling



Sampling Rate & Memory Length

Sample Rate= Samples taken per second, Sa/s



Total time of waveform process
= time/ Div x 10, s

Memory Length requested to record waveform data in total time =
Sample Rate x Time

Sampling Rate & Memory Length

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$$\text{Sample Rate} = \frac{\text{Memory}}{\text{Time/DIV} * 10}$$

Actual Sample Rate is constrained by <u>Memory Length</u> and <u>Time/DIV</u>

Actual Sample Rate

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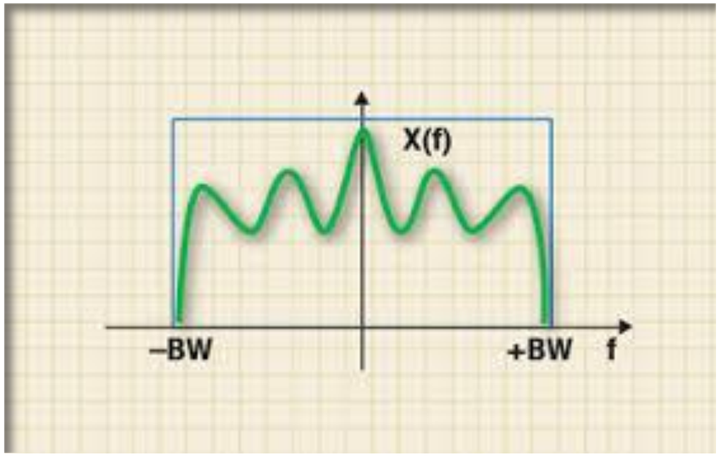
Time Base	Tek TBS-1000B-EDU	GW GDS-1000B	Time Base	Tek TBS-1000B-EDU	GW GDS-1000B	Time Base	Tek TBS-1000B-EDU	GW GDS-1000B
50s	5	20k	10ms	25k	100M	2.5us	100M	1G
25s	10	50k	5ms	50k	200M	1us	250M	1G
10s	25	100k	2.5ms	100k	500M	500ns	500M	1G
5s	50	200k	1ms	250k	1G	250ns~5ns	1G	1G
2.5s	100	500k	500us	500k	1G	250ns~5ns	1G	1G
1s	250	1M	250us	1M	1G	250ns~5ns	1G	1G
500ms	500	2M	100us	2.5M	1G	250ns~5ns	1G	1G
250ms	1k	5M	50us	5M	1G	250ns~5ns	1G	1G
100ms	2.5k	10M	25us	10M	1G	250ns~5ns	1G	1G
50ms	5k	20M	10us	25M	1G			
25ms	10k	50M	5us	50M	1G			

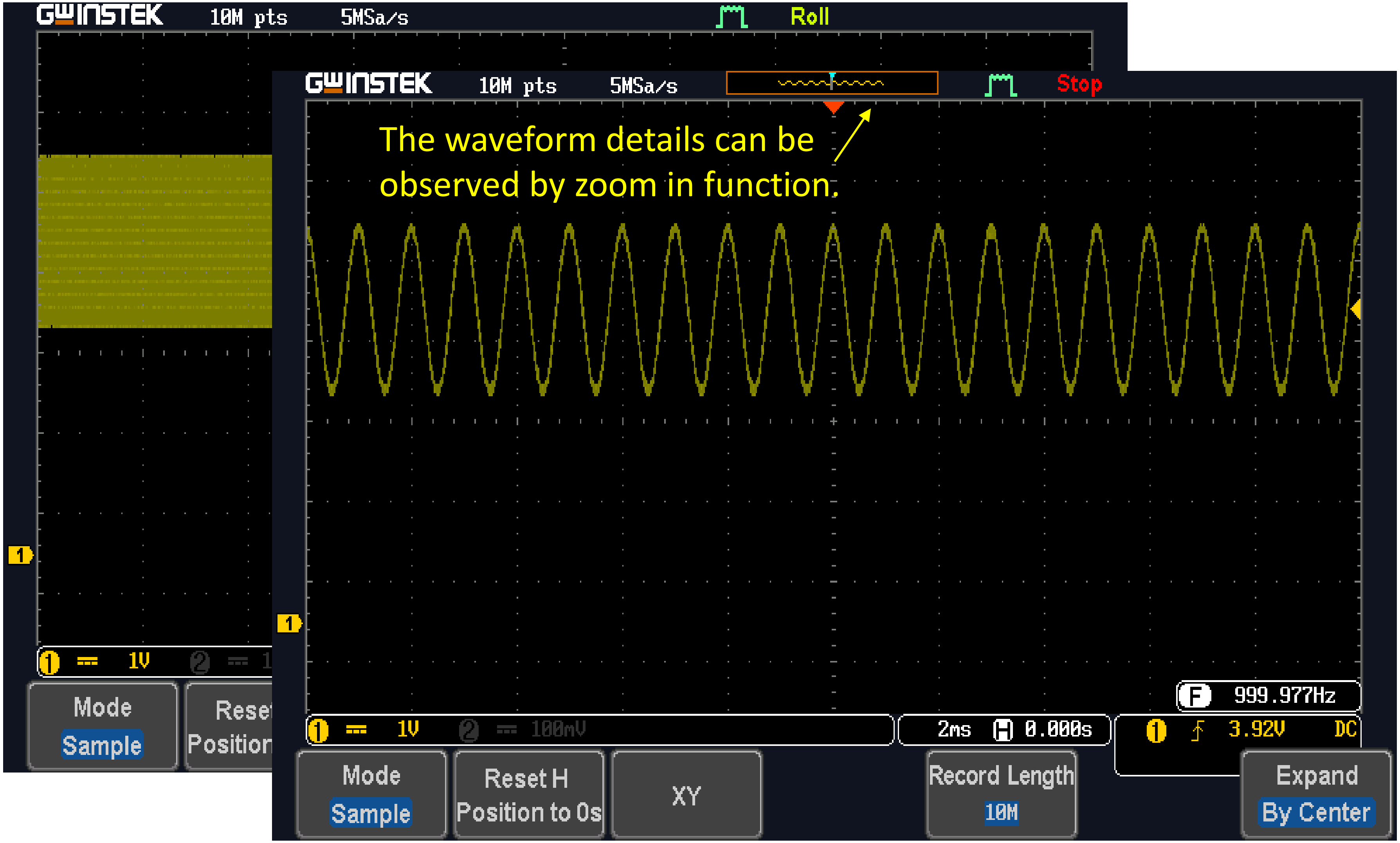
TBS-1000B-EDU has 2.5k memory depth, GDS-1000B has 10M memory depth per ch.

Nyquist–Shannon sampling theorem

- If a signal contains no frequencies higher than bandwidth B, a sufficient sample-rate is therefore $2B$ samples/second, or anything larger.
- Equivalently, for a given sample rate f_s, perfect reconstruction is guaranteed possible for a band limit $B < f_s/2$.
- The insufficient sample rate distorts the reconstructed waveform because of Aliasing.



Sufficient sampling of waveform



Sample rate declined by memory shortage

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- Advanced parameters: Update Rate, FFT
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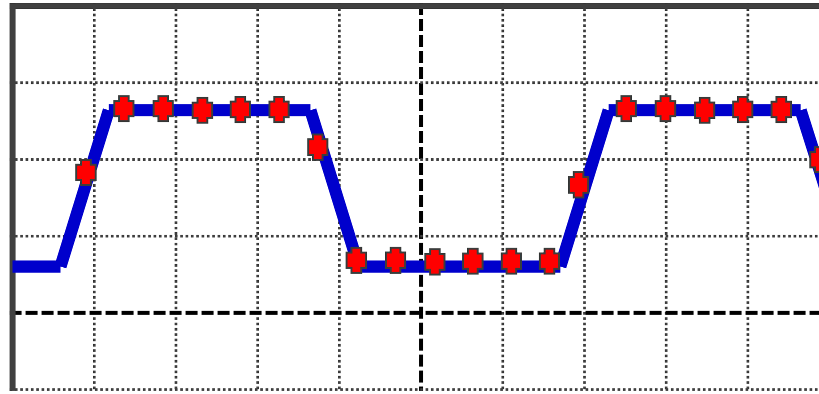
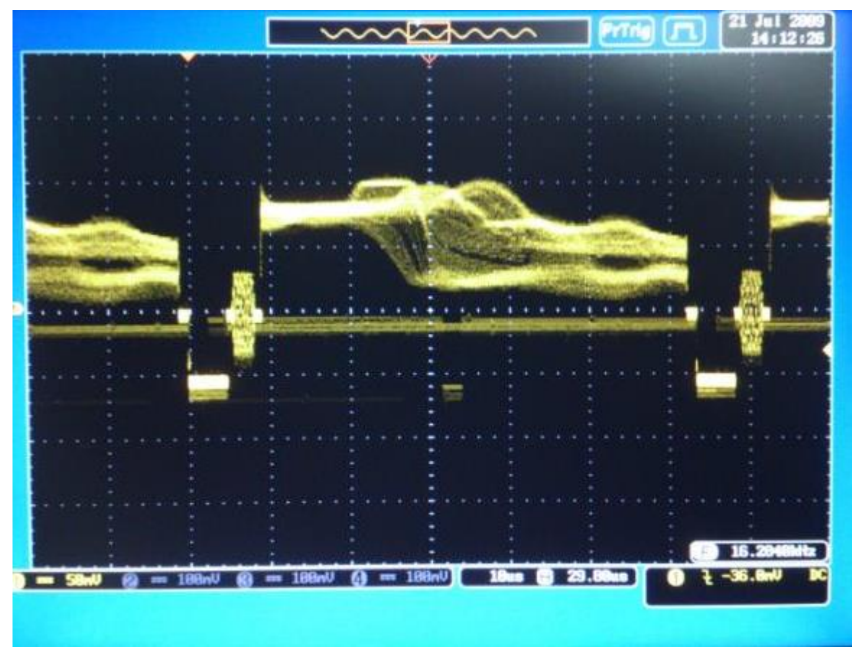
Waveform Display Update Rate

- Sample rate is getting higher which allows to measure signal within a short period.
- It requests the faster waveform display update rate to reveal the waveform from the acquired data.
- Faster update rate enables to reconstruct fast jitter or glitch signal without a miss.





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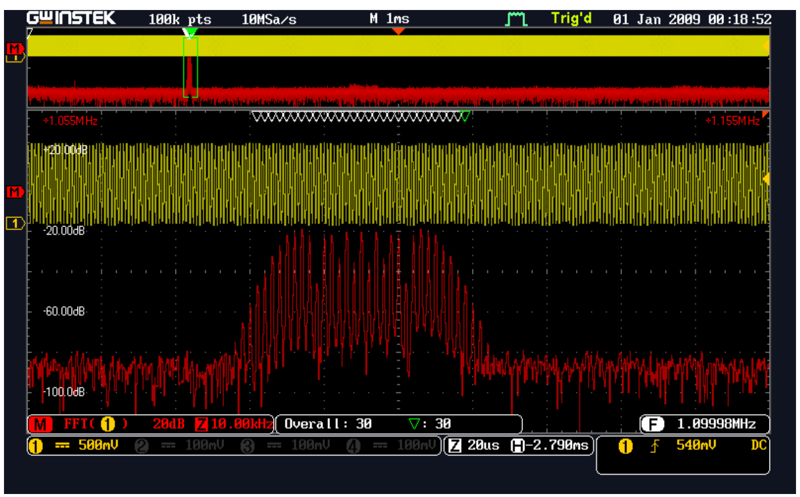
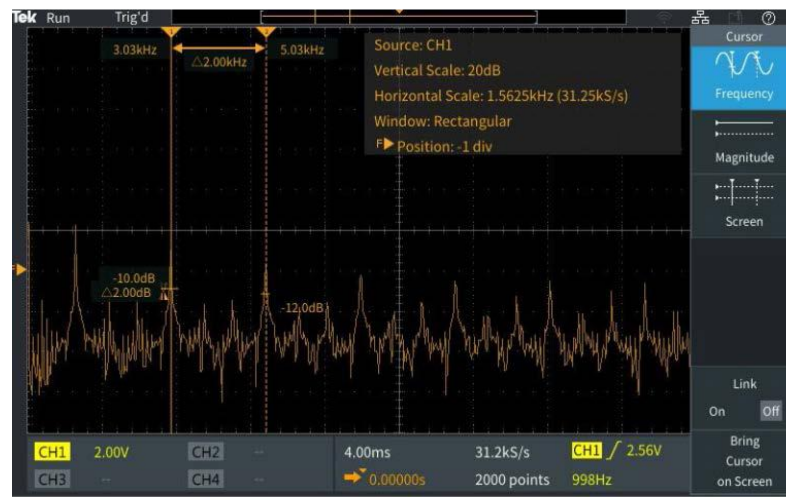
Fast Fourier Transformation (FFT)

- FFT provides the capacities to reveal the signal under test in frequency domain.
- Again the high sampling rate and long FFT memory length provide the capacity of accurate frequency domain measurement.
- Taking FM signal as an example, the FM deviation and envelope can be correctly measured only by sufficient sample rate and FFT memory.





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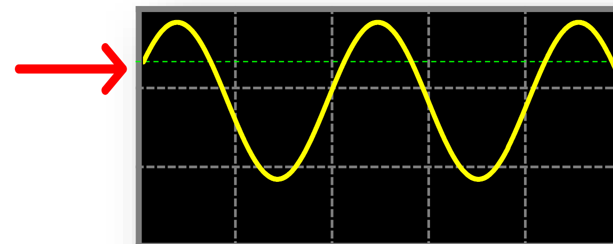
Trigger Control

- Trigger Control establishes the condition enabling the waveform capture, reconstruct and display.
- Effective trigger control setup assures or accelerates the targeted waveform capture.
- Not only the analog waveform but also the data can enable the trigger.
- Trigger source setup allows the waveform capture and display to be synchronized with specified channel or external signal.



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Trigger Control

Trigger Control is important for DSO to accurately measure the waveform. The control is categorized by type, mode and source.

Trigger Control	Description
Trigger Type	Edge, Pulse Width, Video, Pulse Runt, Rise & Fall, Timeout, Alternate, Event-Delay(1~65535 events), Time-Delay(Duration, 4nS~10S), Pre-trigger, Post-trigger, Bus
Trigger Mode	Auto (Roll Mode for slower time/div), Normal, Single
Trigger Source	CH1, CH2, CH3*, CH4*, Line, EXT** , Alternate

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Trigger Control: Trigger Type

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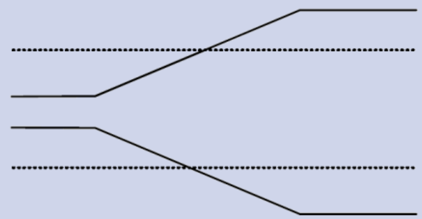
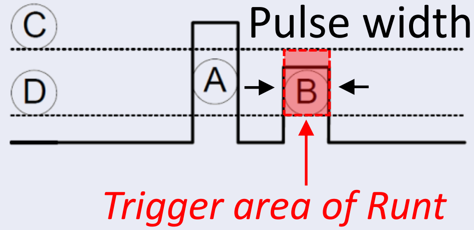
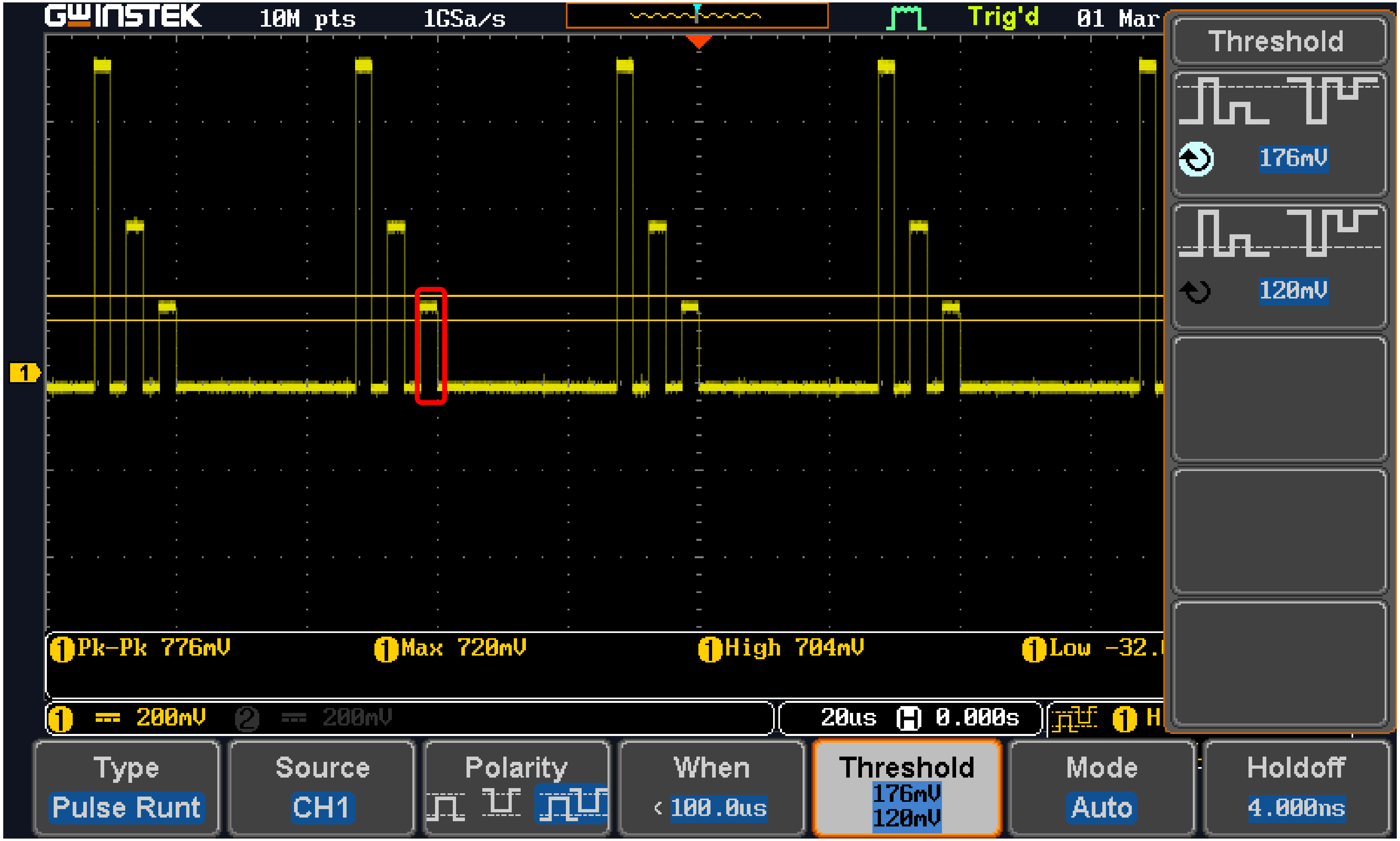
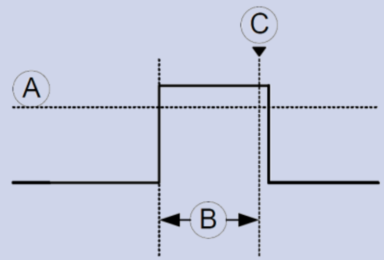
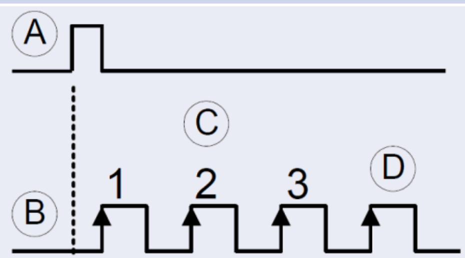
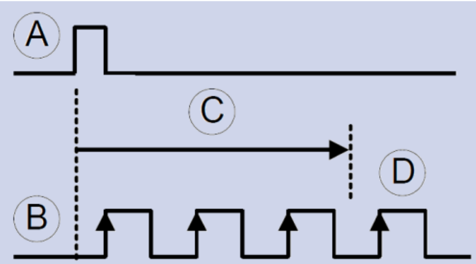
Trigger Type	Description
Trigger edge: Rising edge and falling edge trigger	 Rising edge trigger Falling edge trigger
Pulse width	 Trigger occurs when the pulse width of the signal is <, =, ≠,> than the specified pulse width.
Video	Extracts a sync pulse from a video format signal, and triggers on a specific line or field.
Runt with Pulse *Runt (smaller pulse) can't be trigger source by normal trigger mean*	 A Pulse B Runt C High threshold D Low threshold

Example of Runt Trigger

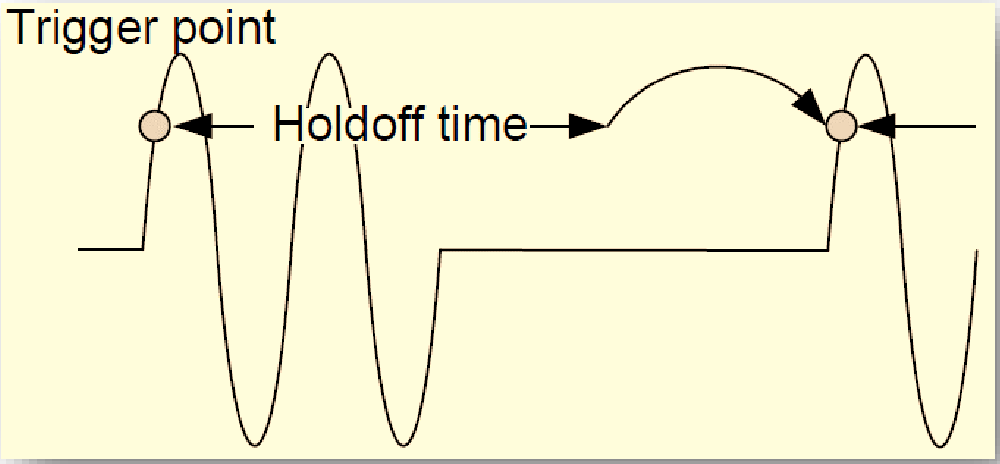


Trigger Control: Trigger Type

Trigger Control	Description
Timeout *Triggers when the signal stays high, low or either for a designated amount of time.*	 A Trigger level threshold B Timer designates the waiting time C Triggering point
Delay trigger: by event	 A Edge trigger B Delay Source C Delay event count (3) D First triggering point
Delay trigger: by time	 A Edge trigger B Delay Source C Delay time length D First triggering point

Trigger Control: Trigger Type

Trigger Control	Description
Holdoff	• Originally designed in ASO to cover retrace issue. • In DSO, it defines the waiting period before the DSO starts triggering again after a trigger point. The holdoff function ensures a stable display if some transient points need to be ignored after the triggering.



Trigger Control: Trigger Type

Trigger Control can be serial data. The bus types normally include the following options.

Bus type	Option
UART	Tx Start Bit, Rx Start Bit, Tx End of Packet, Rx End of Packet, Tx Data, Rx Data, Tx Parity Error, Rx Parity Error
I^2C	Start, Repeat Start, Stop, Missing Ack, Address, Data, Address/Data
SPI	SS Active, MOSI, MISO, MOSI&MISO
CAN	Start of Frame, Type of Frame, Identifier, Data, Id & Data, End of Frame, Missing Ack, Bit Stuffing Err
LIN	Sync, Identifier, Data, Id and Data, Wakeup Frame, Sleep Frame, Error

Roll mode

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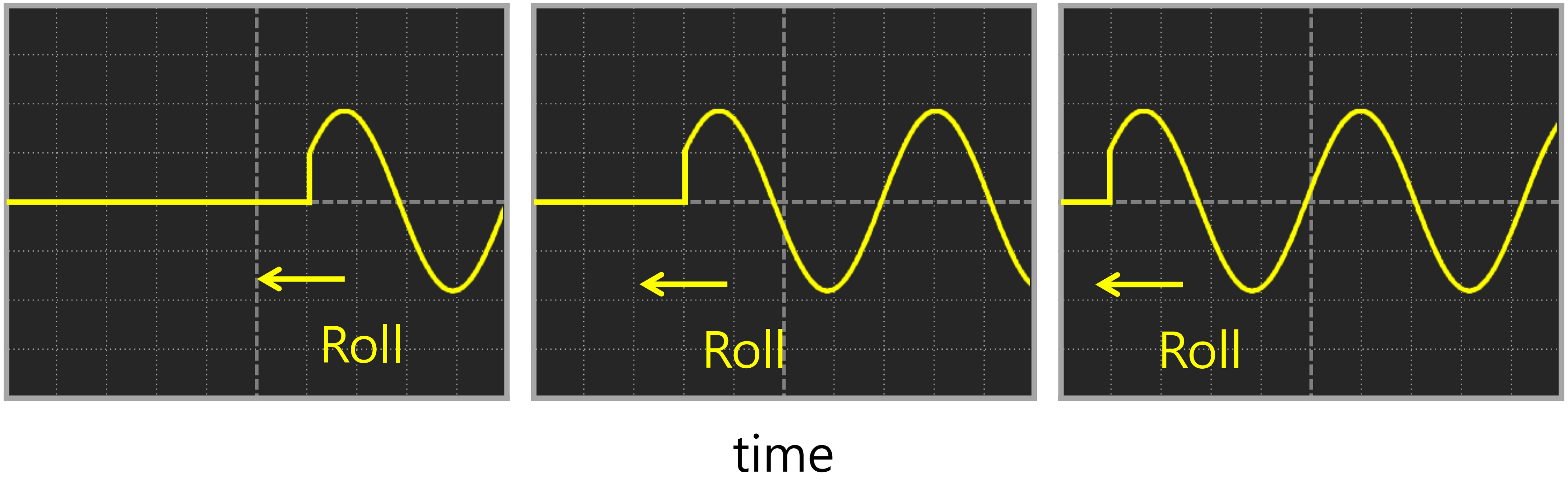
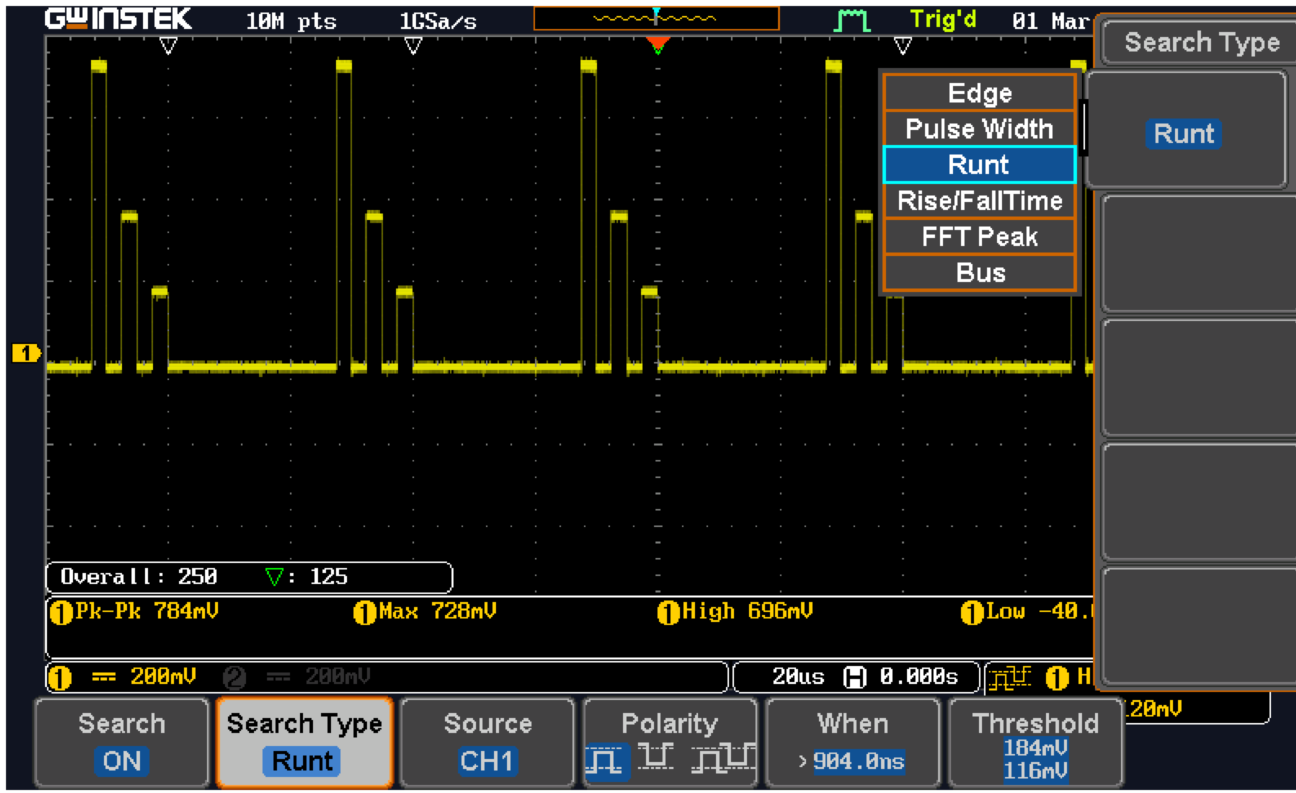
- Update and move the waveform gradually from the right side of the display to the left.
- Automatically selected when the time base (sampling rate) is slow. It is useful for low frequency waveforms.
- Roll mode needs massive data calculation and processing, some low performance DSO might stop auto-measurement functions.



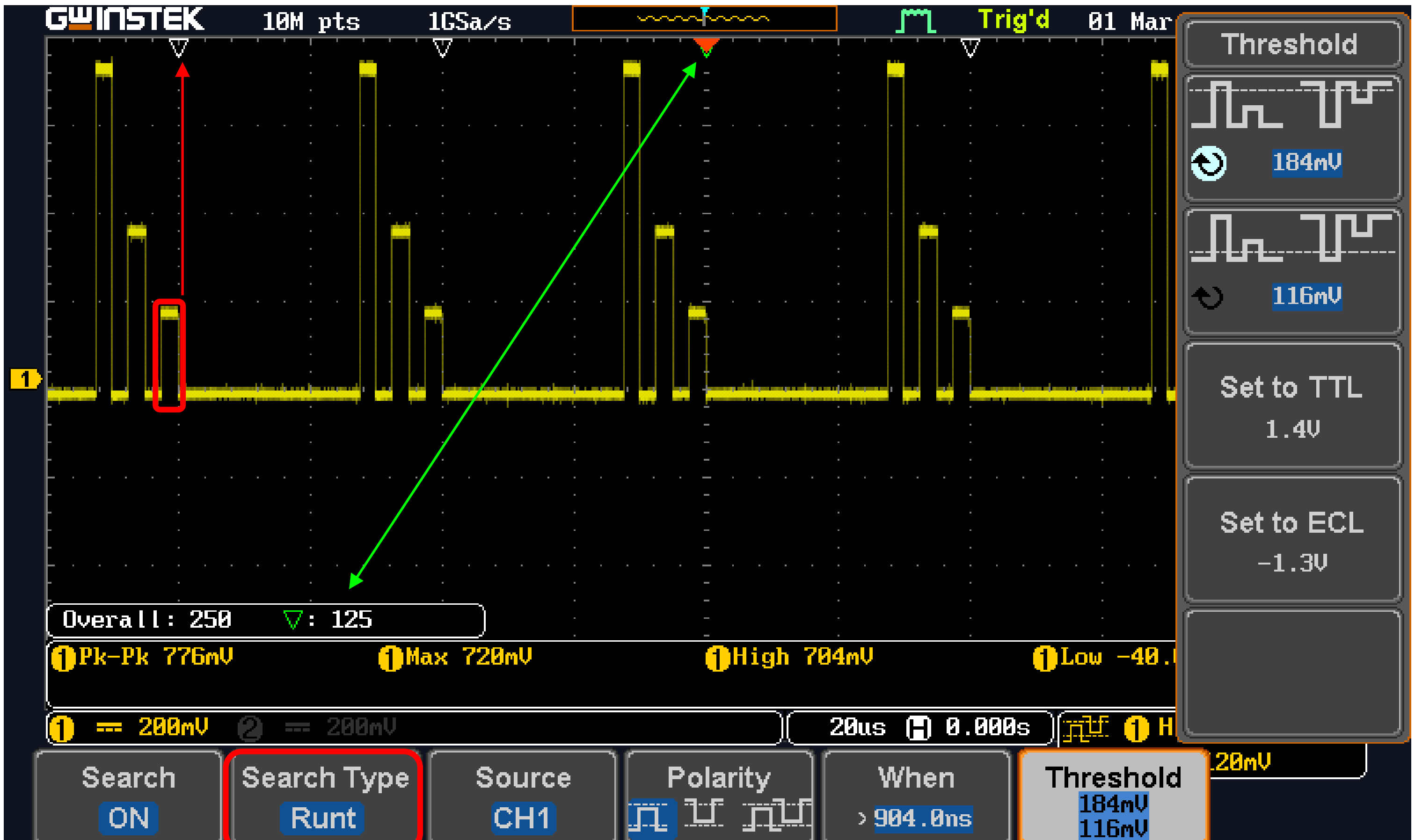
Waveform Search

- To search for events on the analog input channels in the memory.
- The events that can be searched for are similar to the events that are used for the trigger mode.



Waveform Search

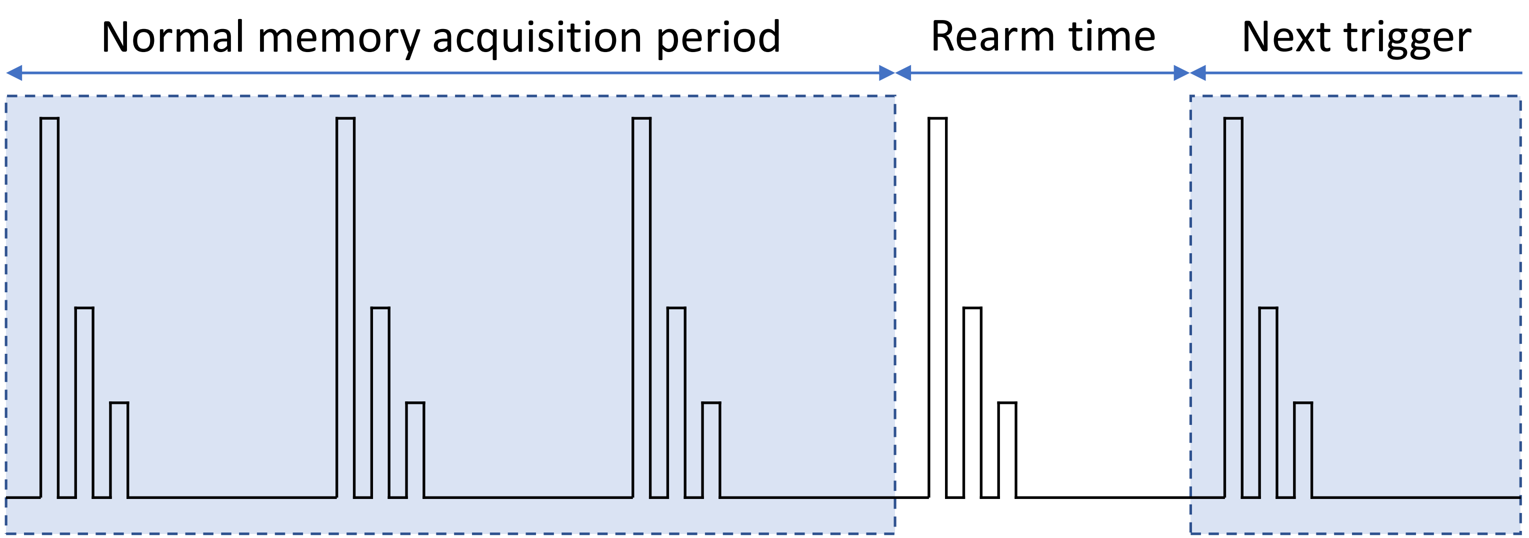
- Searched events are saved over the entire record length, with a maximum of 1000 marks.



Segmented Memory

Normal capture method

- DSO acquires the signal until the acquisition memory is filled up and then it will re-arm the trigger and then capture again.
- This could result in a number of events not being captured or captured at a less-than-desired resolution (depending on the horizontal scale and sampling rate).

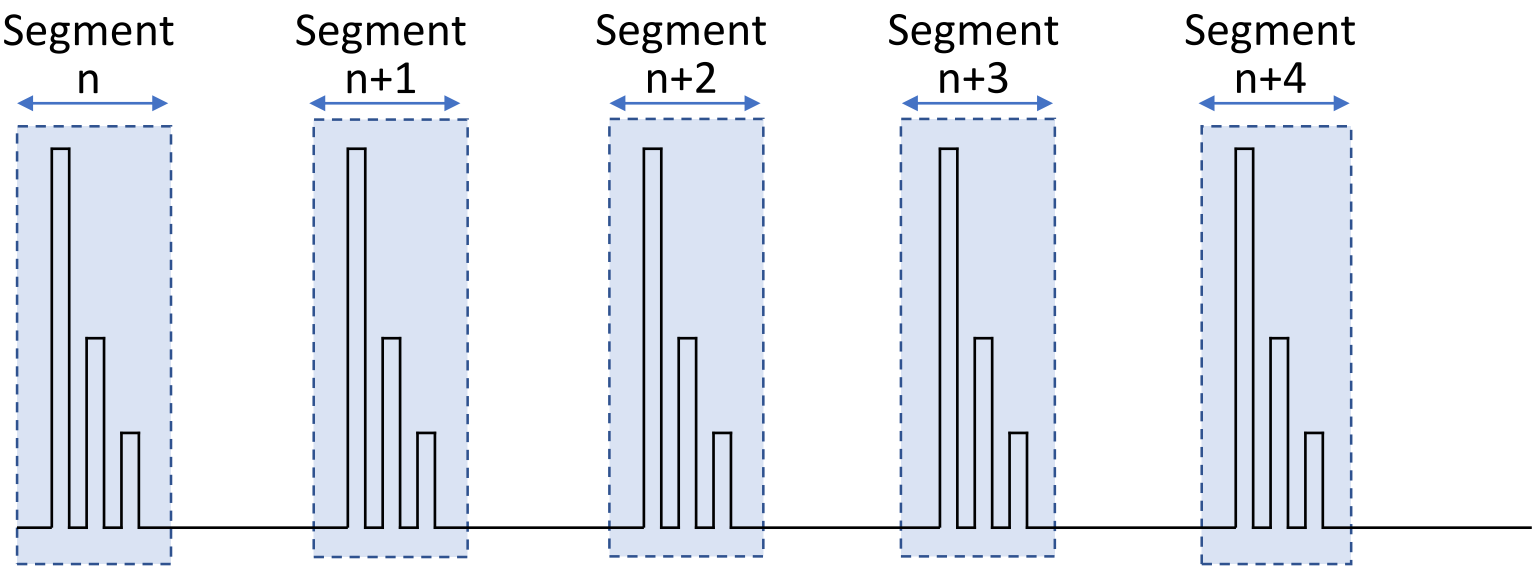


Normal acquisition mode example:

Segmented Memory

Segmented memory acquisition

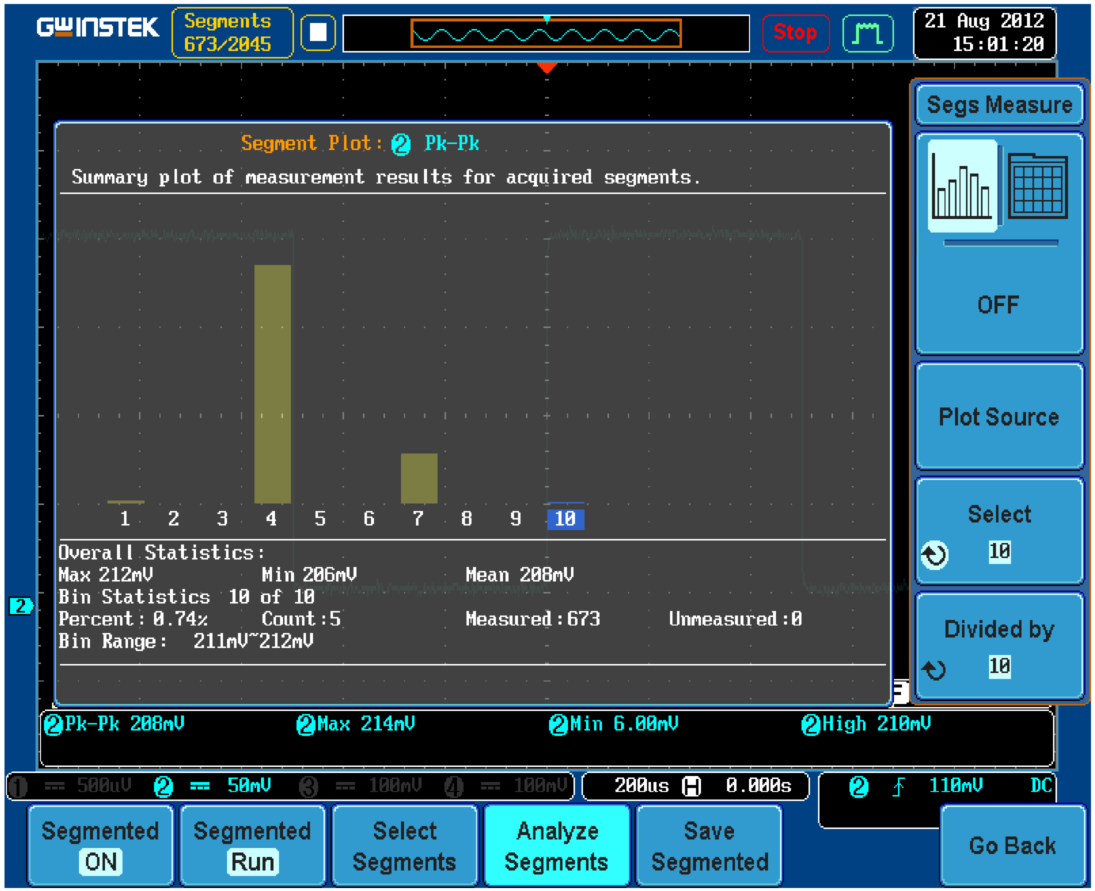
- The memory is divided into segments to increase the number of events that can be effectively captured.
- The scope doesn’t need to rearm the trigger between each segment. The time between each segment is also recorded so that accurate signal timing can also be measured.



Segmented memory acquisition example

Segmented Memory Analysis

The data in segmented memory can be analyzed to obtain the values like Max ,Min ,Mean.



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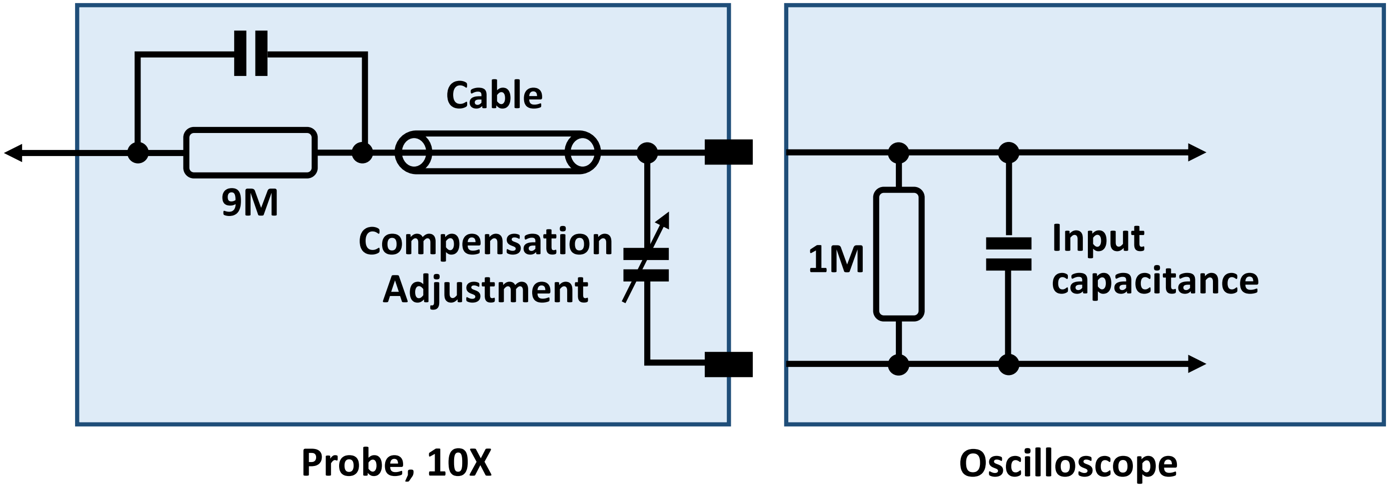
Probe Usage

Some basic concepts of using an oscilloscope probe:

- **Bandwidth.** Just like -3dB bandwidth of a scope, it needs to be taken into consideration when select a probe.
- **Load effect.** The equivalent circuit of a probe is as below. The capacitive effect affects the bandwidth most. Most of oscilloscope probes provide 10x attenuation which will perform better frequency response.



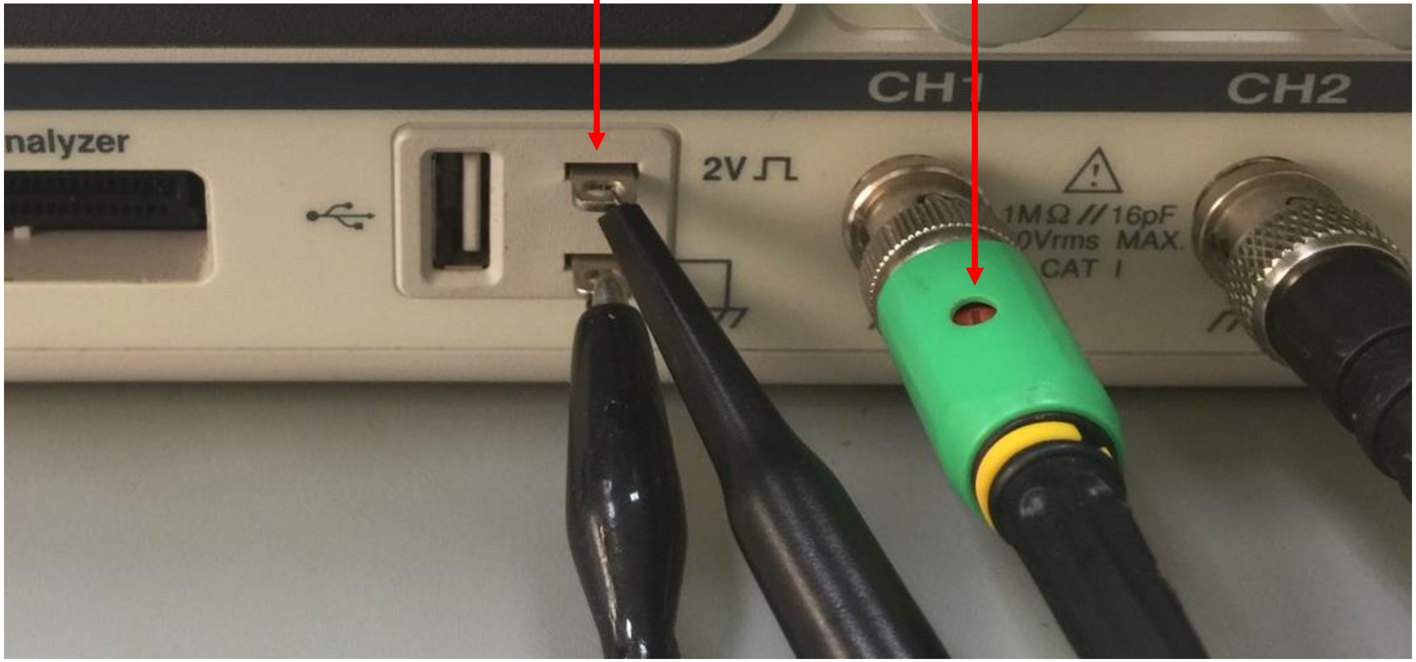
Probe Usage

Some basic concepts of using an oscilloscope probe:

- **Compensation.** A compensation output on scope generating square waveform can be used to compensate the probe frequency response.

Compensation output

Compensation Adjustment



Rise time/ Fall time measurement

- The oscilloscope's rise time is related to the oscilloscope's bandwidth* using the familiar formula:

$$T_r = \frac{0.35}{BW}$$

- The system bandwidth of oscilloscope and probe can be calculated with the formula:

$$BW_{system} = 1 \Big/ \sqrt{\left(\frac{1}{BW_{probe}}\right)^2 + \left(\frac{1}{BW_{oscilloscope}}\right)^2}$$

- From the formula, if the probe has sufficiently higher bandwidth than scope, the system bandwidth is dominated by scope.

* Assuming it is Gaussian-response oscilloscope.

Rise time/ Fall time measurement

- The measured rise time is commonly related to the system rise time and signal rise time, refer to the formula:

$$T_{r\_measured} = \sqrt{T_{r\_signal}^{2} + T_{r\_system}^{2}}$$

- The actual rise time of signal under test can be derived accordingly.

$$T_{r\_signal} = \sqrt{T_{r\_system}^{2} - T_{r\_measured}^{2}}$$

Review the topics

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Thank You

for

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