Pulses. Triggering.

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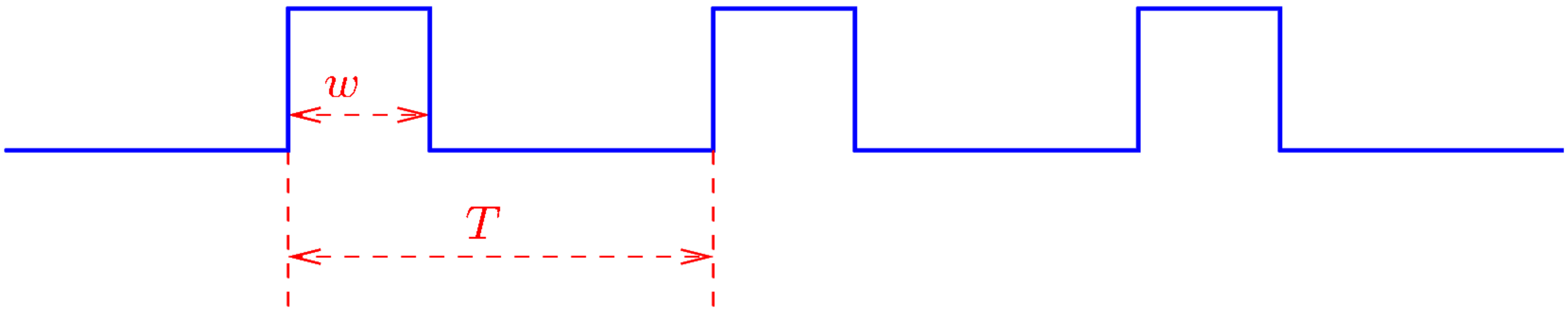
See https://mviordache.name/EEGR2051 for more information.

Rectangular Waveforms



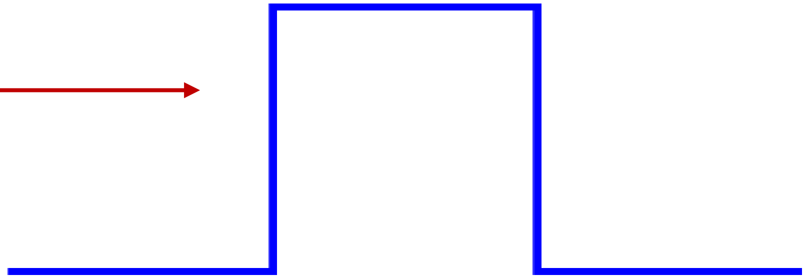
- The ***duty cycle*** of a periodic rectangular waveform is the ratio of the pulse width and the period:

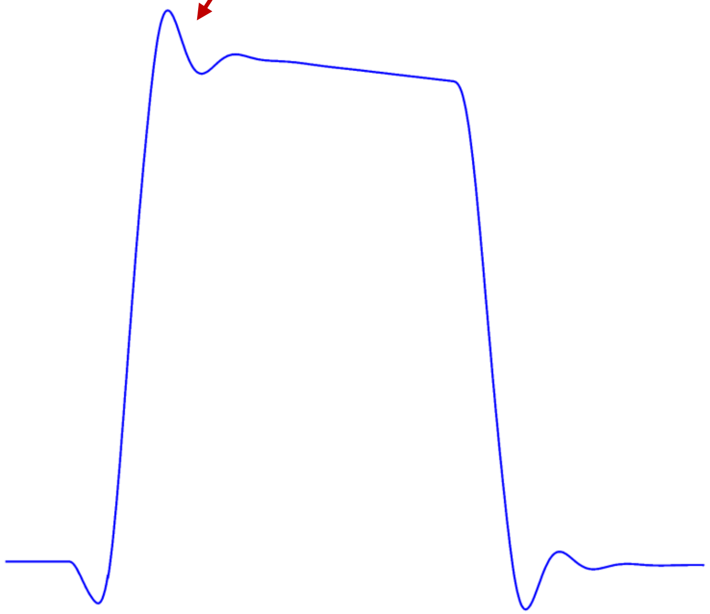
$$duty = \frac{w}{T}$$

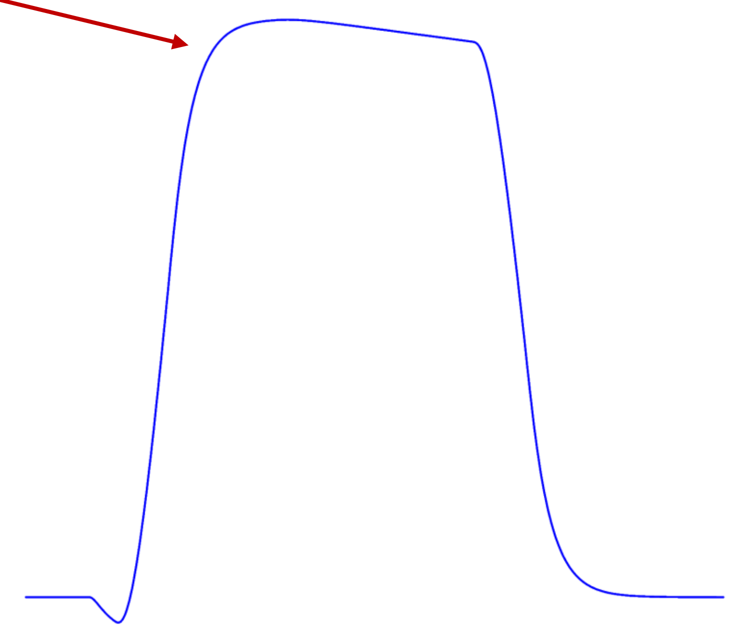
- A ***square wave*** is a rectangular wave with 50% duty cycle.

Pulses

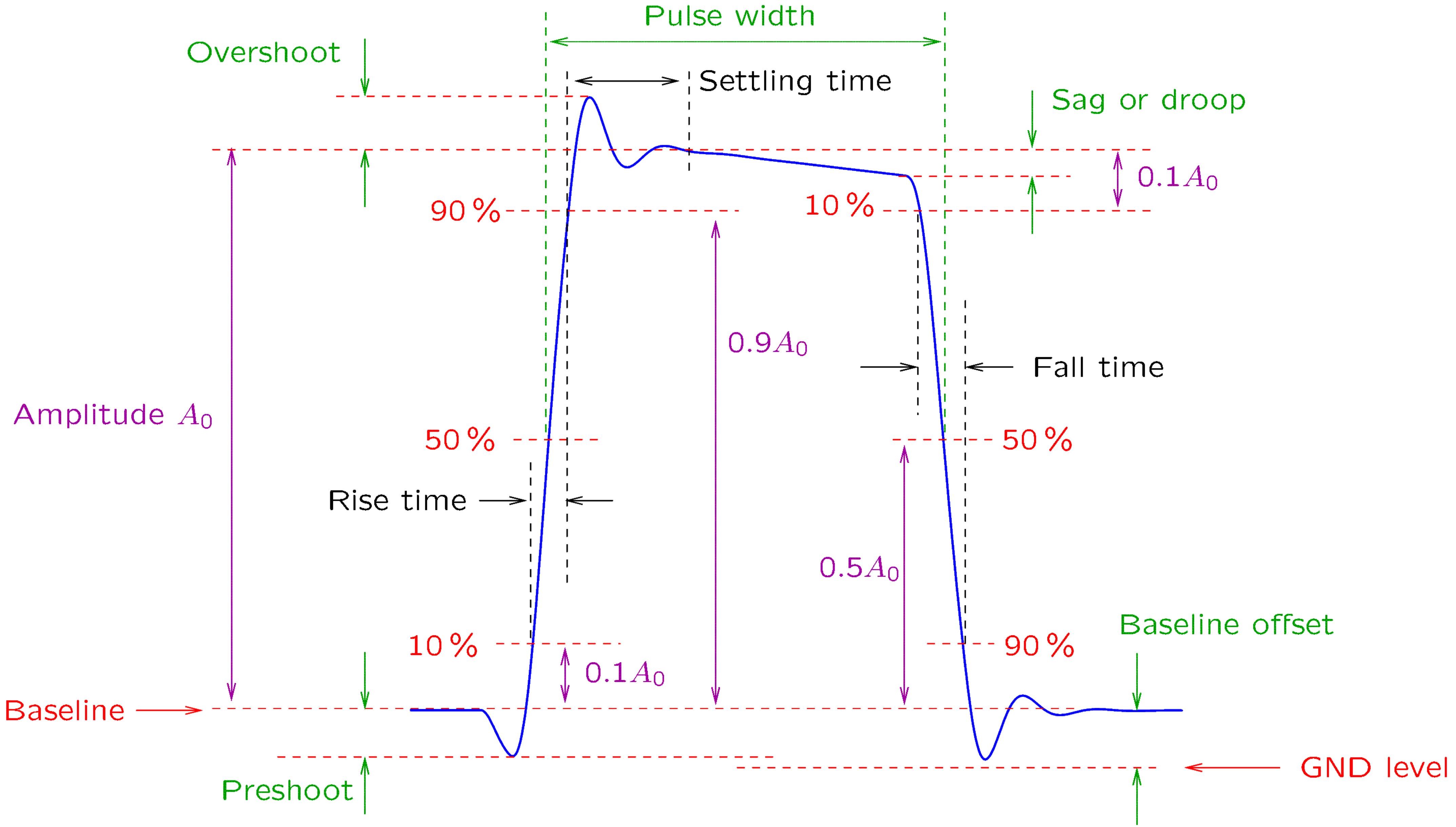
- Ideally, pulses have vertical edges.
- In practice:
  - Edges are not vertical.
  - Pulses exhibit ringing or rounding.







Pulse Parameters



Pulse Parameters

Note that:

- *Amplitude* is measured between the baseline and the level at which the signal settles (before the droop).
- *Pulse width* is measured between the 50% points of the rising and falling edges.
- *Rise time* and *fall time* are measured between the 10% and 90% levels of the signal.

Waveform Generators

- Waveform generators have an ***internal resistance*** R_{in}.
  - Therefore, the output voltage depends on the load connected to the source.
  - The internal resistance could be seen as the resistance of the *Thevenin equivalent* of the generator.

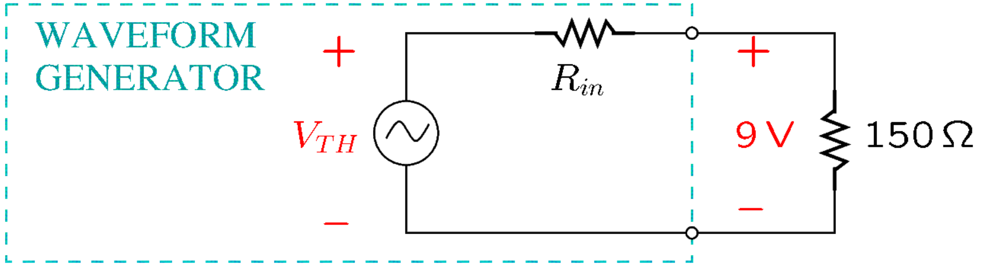
Example: A waveform generator was programmed to output 9 V on a $150\ \Omega$ *load. Assuming* $R_{in} = 50\ \Omega$*, find the voltage of the waveform generator when used with a* $100\ \Omega$ *load.*

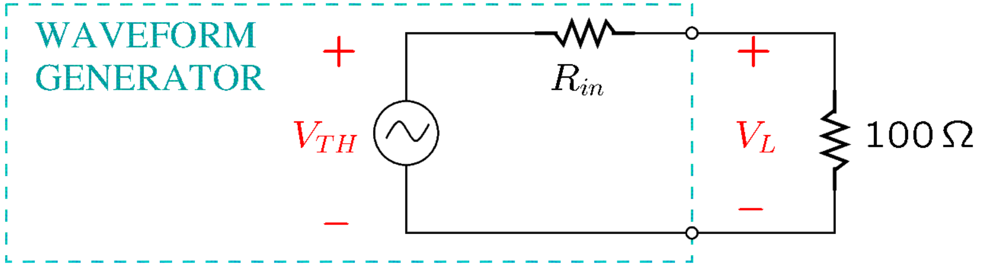
- *By voltage division:*

$$9 = V_{TH} \cdot \frac{150}{R_{in}+150} \Rightarrow V_{TH} = 12\ V.$$

- *With a load of* $100\ \Omega$

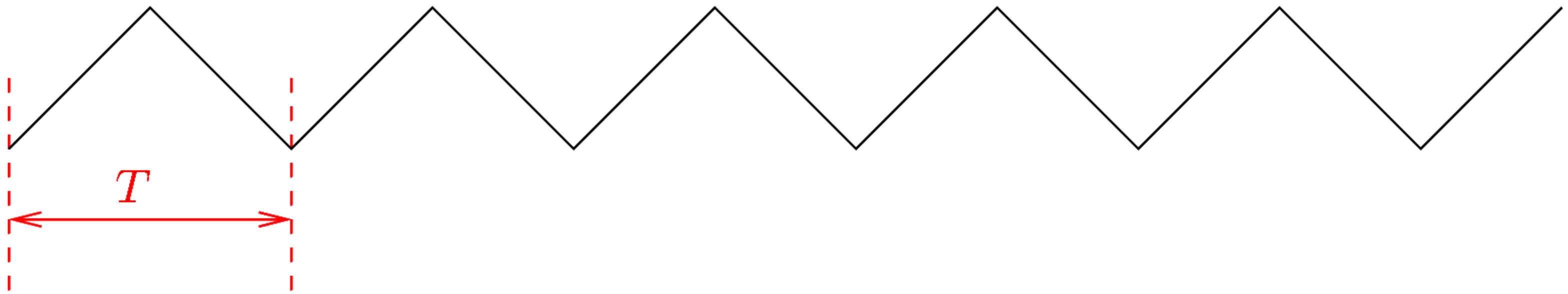
$$V_L = V_{TH} \cdot \frac{100}{R_{in}+100} \Rightarrow V_L = 8\ V.$$



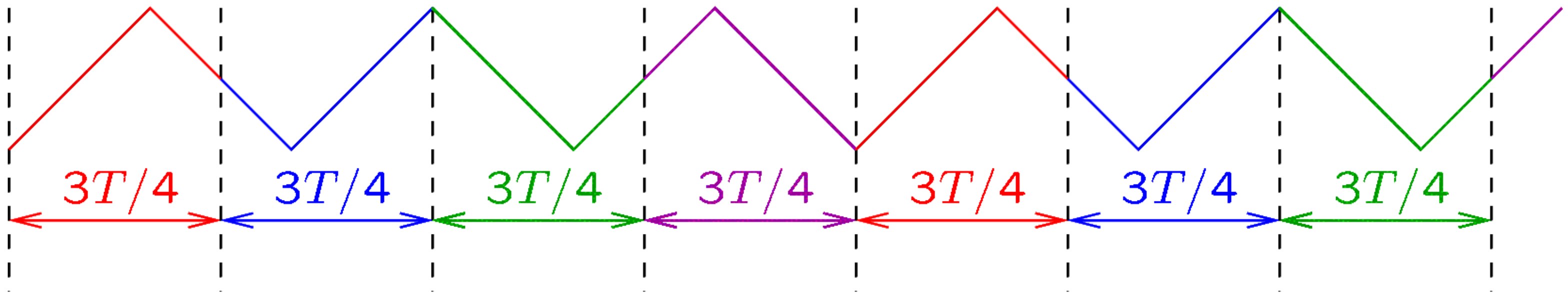


Triggering

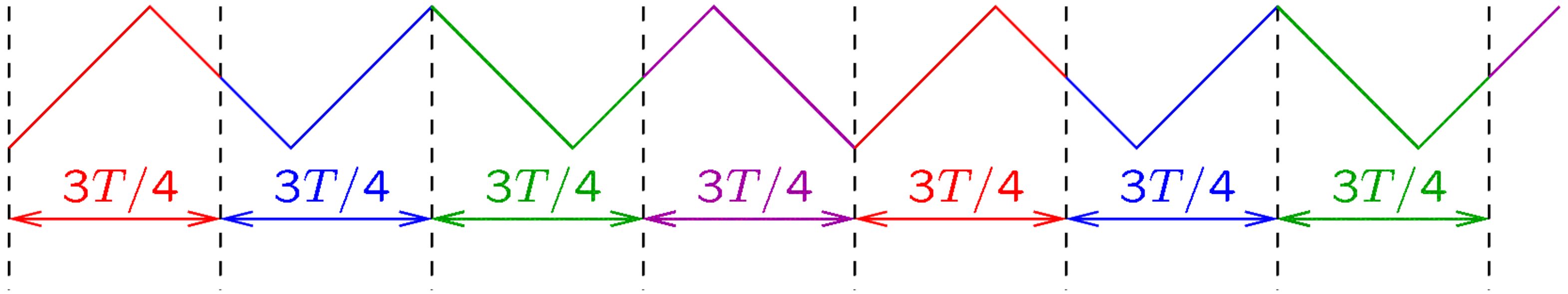
- Suppose that an oscilloscope should display the following signal of period T.



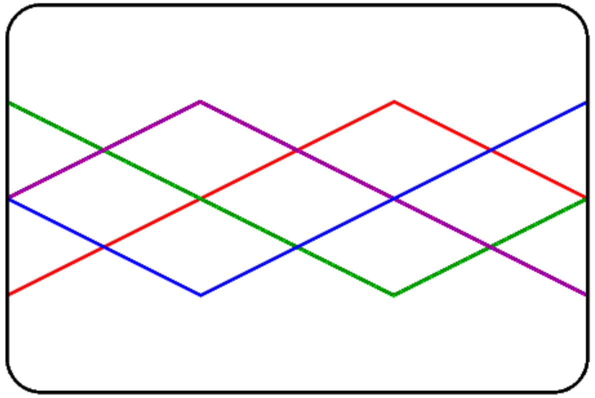
- Suppose that the oscilloscope refreshes the screen periodically, once for every time interval of length $3T/4$.



Triggering



- Suppose that the oscilloscope displays each $3T/4$ segment as it is, from the left end of the screen to its right end.



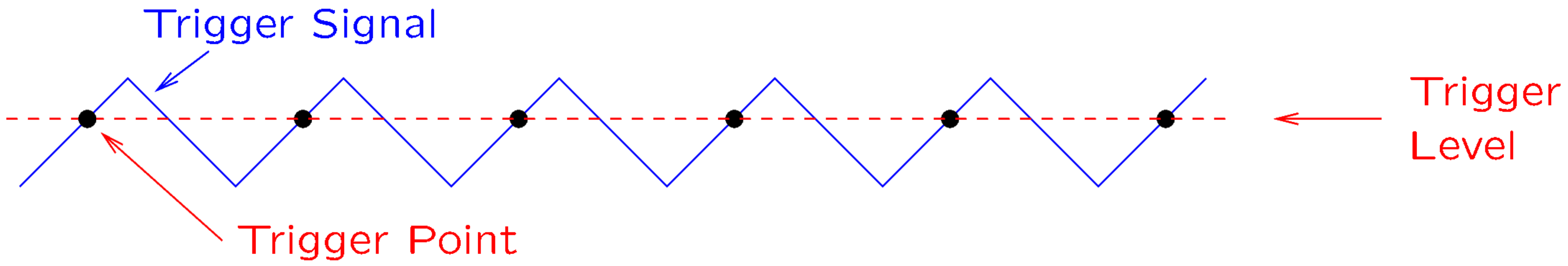
- The screen will appear to display several overlapping signals, though only one signal is actually present at the input!

Triggering

- To obtain the correct image, the oscilloscope should refresh the screen by starting always with the same point of the signal.
- This can be achieved by means of ***triggering***.
- The oscilloscope uses a ***trigger signal*** in order to display signals consistently on the screen.
- The trigger signal may be:
  - One of the signals that is to be displayed (such as the signal of channel 1 or 2).
  - Some other external signal that is synchronous with the signals to be displayed.
- ***Edge triggering*** is one of the most common triggering methods.
- In edge triggering, the oscilloscope uses an internal DC voltage, called ***trigger level***, and monitors the instances in which the trigger signal intersects the trigger level.

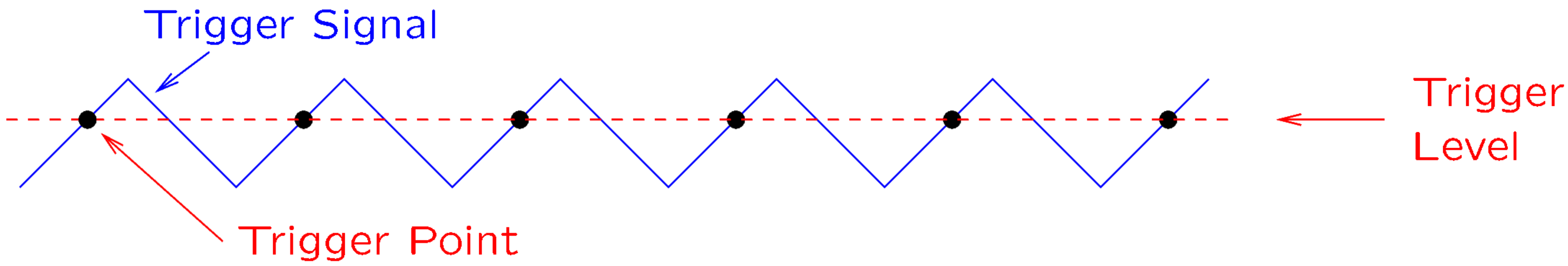
Edge Triggering

- In edge triggering, the user must select the kind of edges used for triggering.
- The options are:
  - Rising edges (*positive slope*).
  - Falling edges (negative slope)
  - Any edges (both rising and falling).
- A trigger point is an instance in which the selected edge of the trigger signal intersects the trigger level.
- For example, note the intersection points when triggering on rising edges:

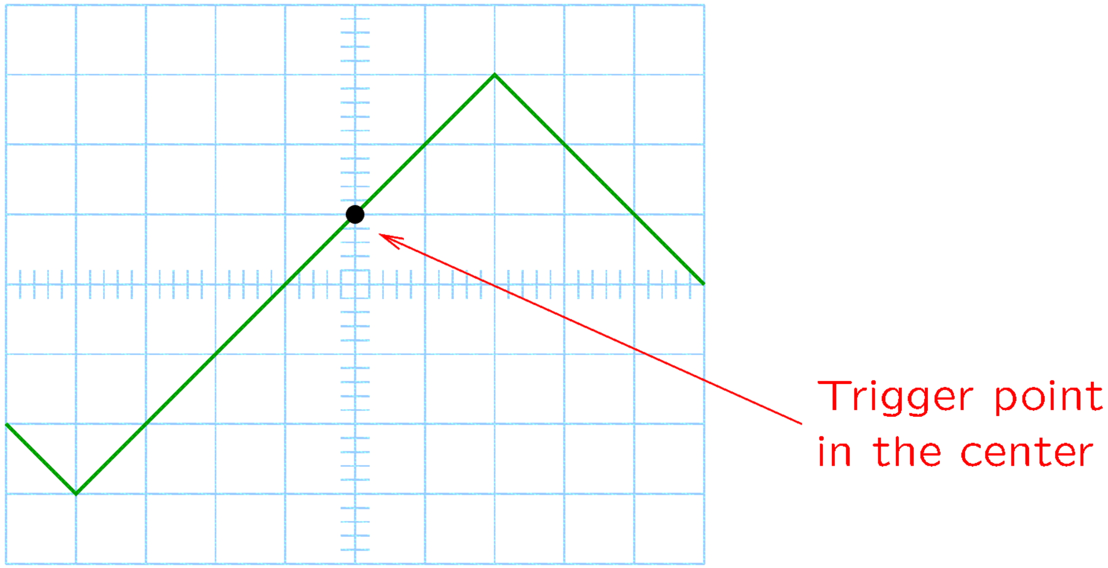


Edge Triggering

- By default, the oscilloscope centers horizontally the image so that the trigger point is in the center.

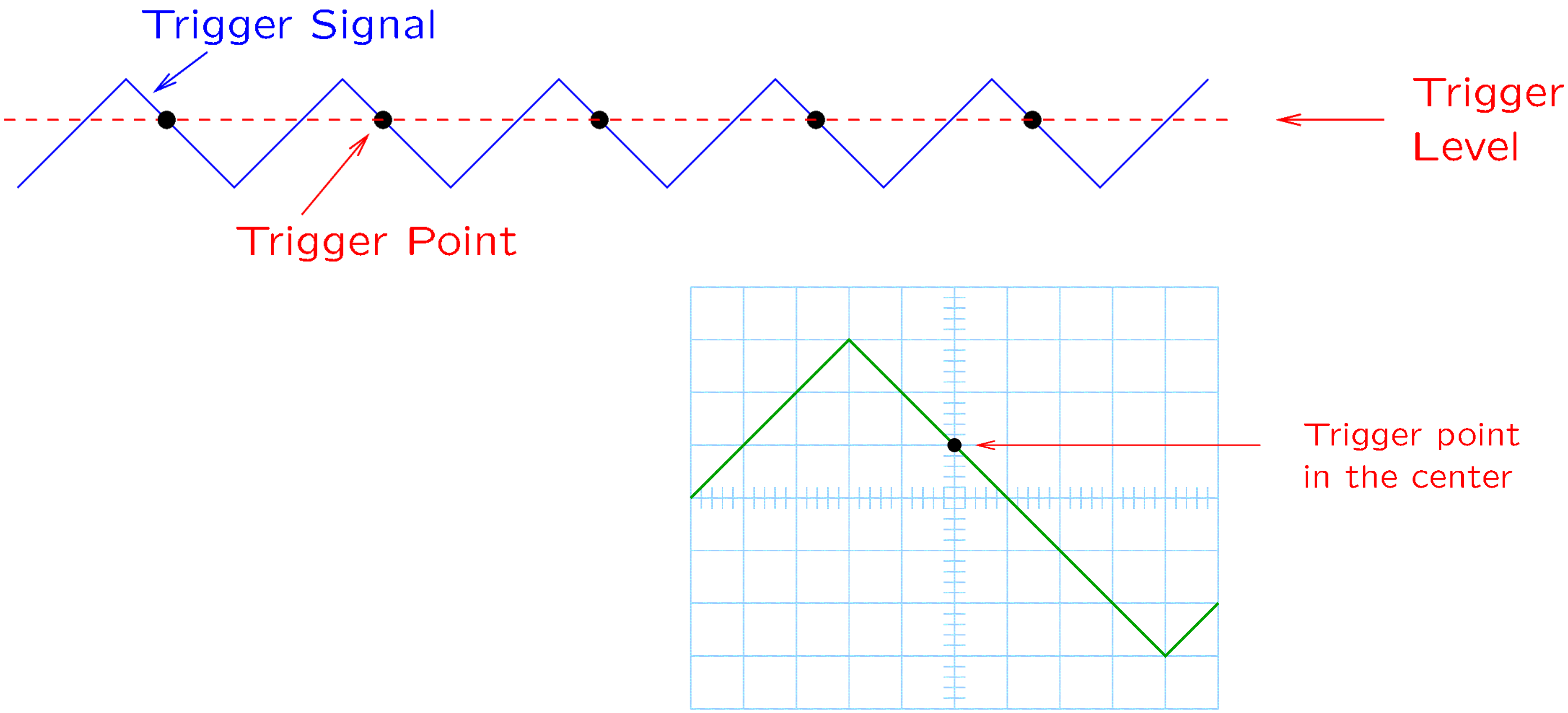


- If the trigger signal is displayed, the trigger point will be in the center:



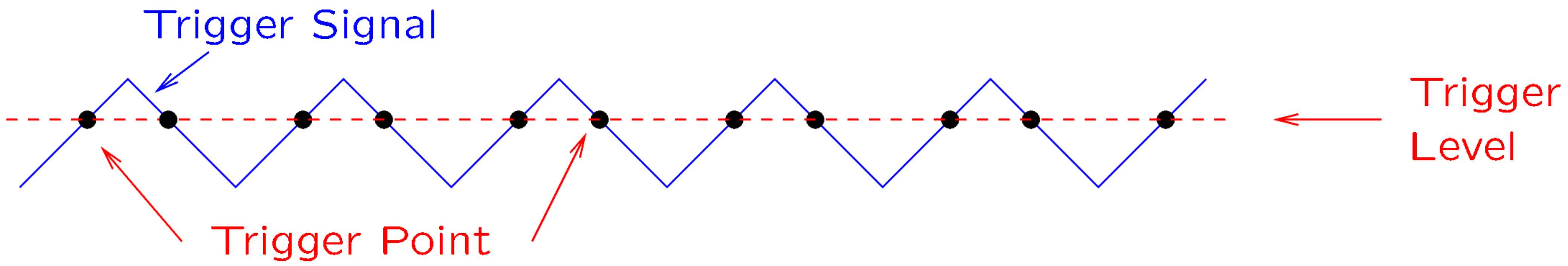
Edge Triggering

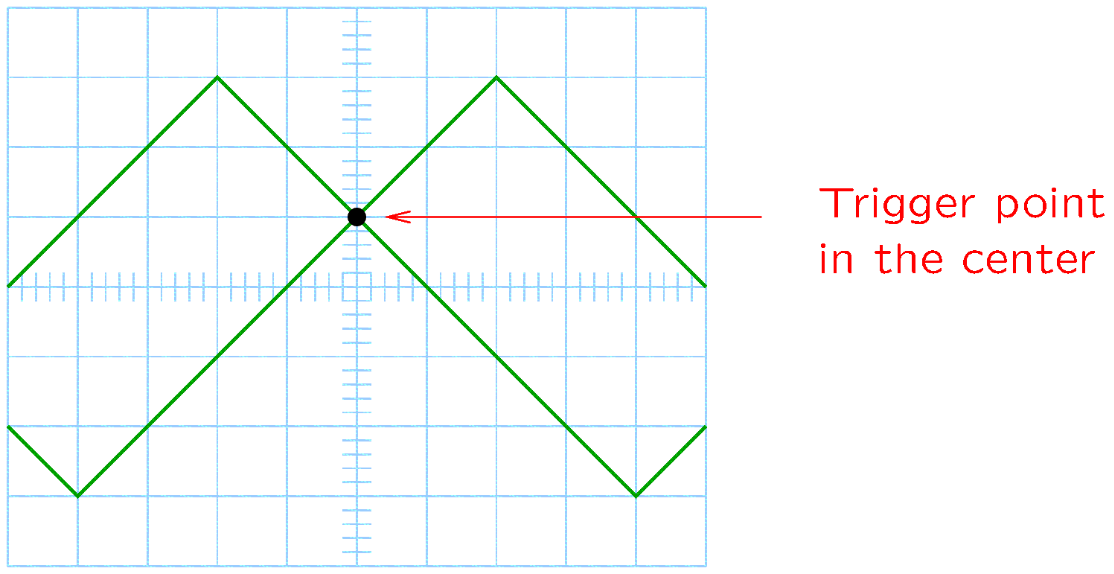
- Assuming now triggering on falling edges:



Edge Triggering

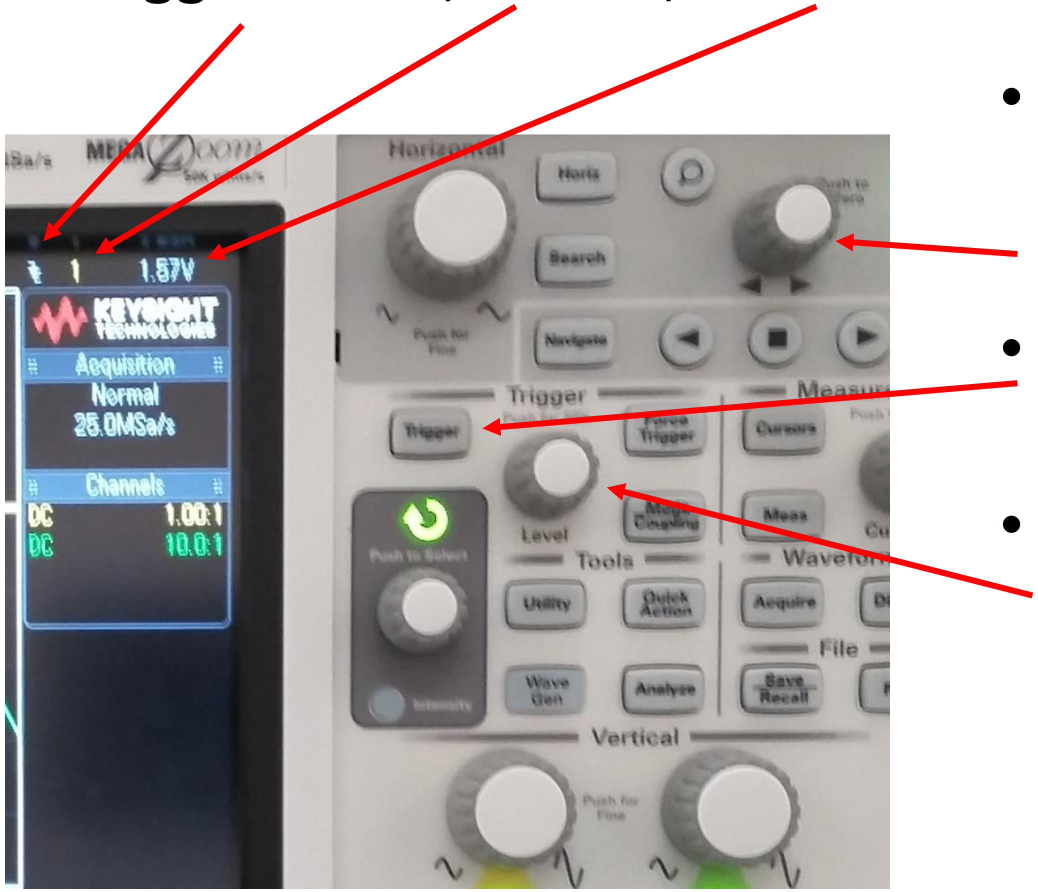
- If both rising and falling edges are selected, the oscilloscope will trigger on either edge and both curves may be displayed at the same time.





Triggering

- Trigger mode, source, and level are displayed in the upper right corner.



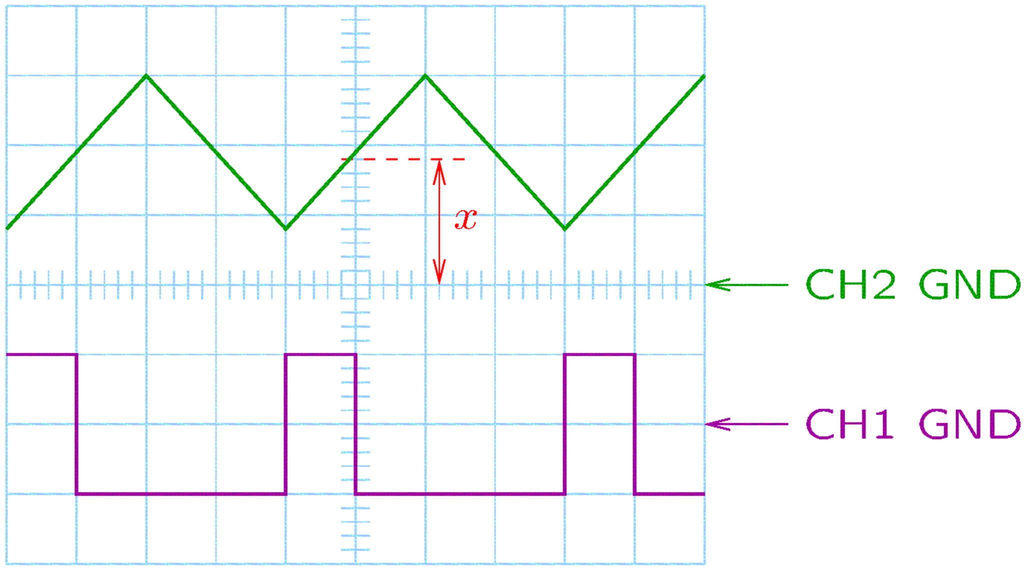
- The horizontal position of the trigger point can be adjusted with the horizontal position control.
- Use the trigger menu to change the trigger mode and the trigger source.
- The trigger level can be adjusted with the level control.

Example

CH1 has 200 mV/div and CH2 has 1 V/div. Indicate the trigger settings if:

(a) CH1 is the trigger source.

(b) CH2 is the trigger source.



- *Assuming the trigger point at the center, the oscilloscope triggers on*
  - *Falling edges (negative slope) in case (a).*
  - *Rising edges (positive slope) in case (b).*
- *In case (a), the trigger level could be anywhere between* $-1\ div \ldots +1\ div$, *that is, within the range* $-200 \ldots 200\ mV$.
- *In case (b), the trigger level is* $x = 2.8\ div = 2.8\ V$.

Example

The CH1 signal is $v(t) = 3 + 5\cos(900t)\ V$. What is an appropriate trigger level when CH1 is in

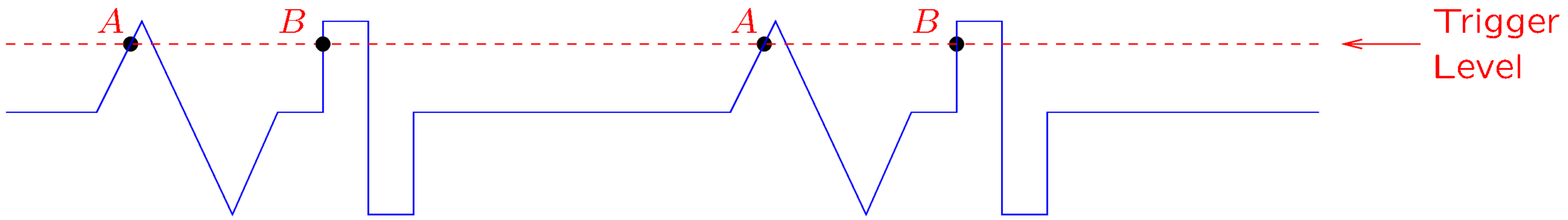
(a) DC mode.

(b) AC mode.

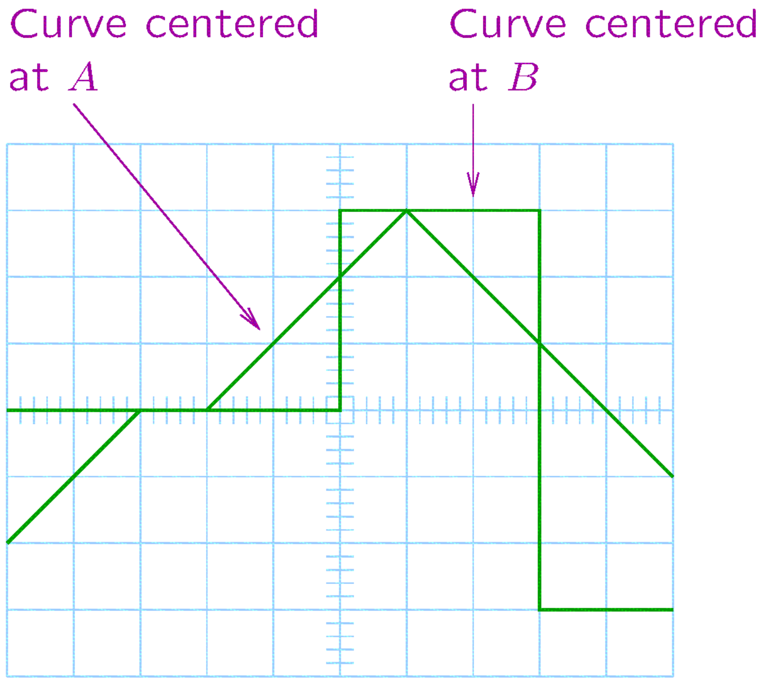
- *To obtain a stable image, the trigger level must intersect the signal.*
- *The range of $v(t)$ is $3 - 5 \ldots 3 + 5\ V$, that is, $-2 \ldots 8\ V$.*
- *At part (a), any value in the range $-2 \ldots 8\ V$ could be used, such as $1\ V$.*
- *In AC mode, the channel removes the DC component.*
- *The AC component is $v_a(t) = 5\cos(900t)\ V$.*
- *The range of $v_a(t)$ is $-5 \ldots 5\ V$.*
- *At part (b), any value in the range $-5 \ldots 5\ V$ could be used, such as $0\ V$.*

Triggering—The Holdoff Control

- Suppose that the triangular part of the signal should be displayed.



- The oscilloscope could trigger either at A or at B.
- Two curves may be displayed at the same time:
  - One with A at the center.
  - One with B at the center.



Triggering—The Holdoff Control

- The ***holdoff*** is the amount of time the oscilloscope waits after a trigger before looking for another trigger point.
- The holdoff control allows adjusting this amount of time.
- *In the previous example, the holdoff control could obtain the desired image.*
- *Using the horizontal position control in addition to the holdoff, the rectangular part of the signal can also be displayed.*

Image with appropriate holdoff.
Horizontal porsition control set to zero.

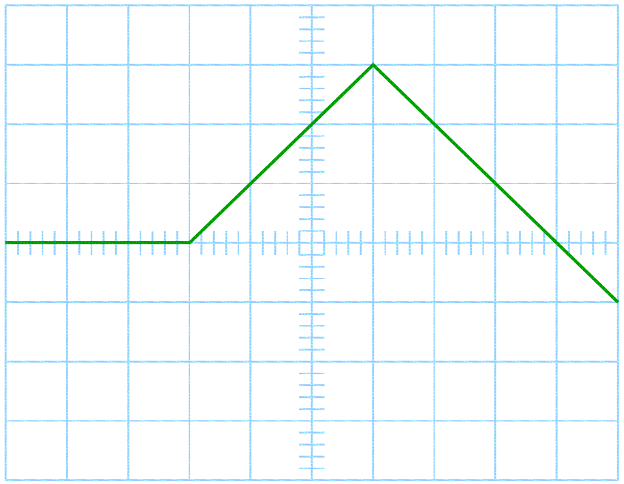
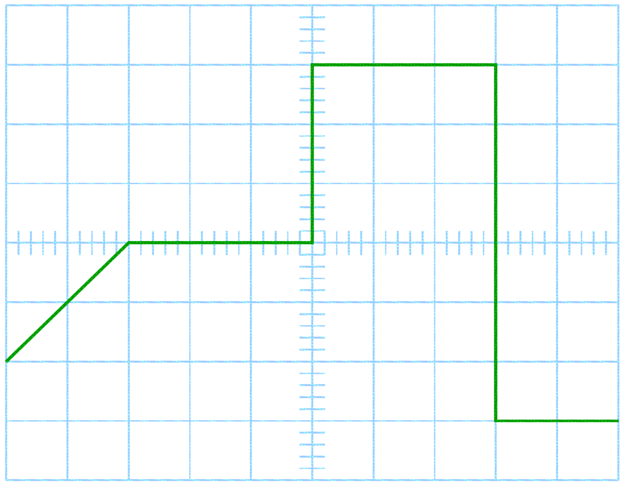
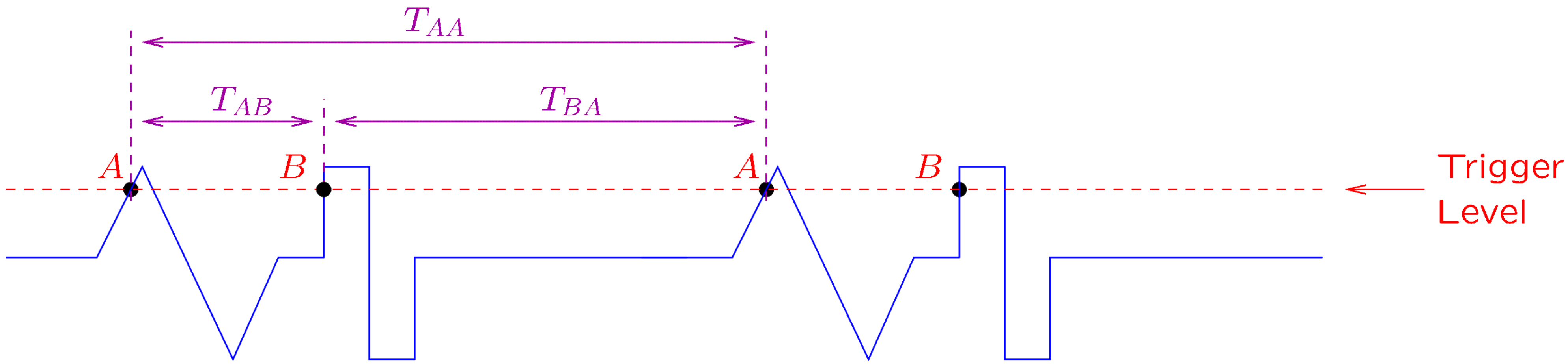


Image with appropriate holdoff and
horizontal porsition-control value.



Holdoff Example



- *Let t_h be the holdoff.*
- *If the oscilloscope triggers at A:*
  - *the next trigger point is A, not B, only if $t_h > T_{AB}$.*
  - *the next A is the next trigger point only if $t_h < T_{AA}$.*
- *If the oscilloscope triggers at B, the next trigger point is the next A only if $t_h < T_{BA}$.*
- *For a stable image, we could choose t_h so that $T_{AB} < t_h < T_{BA}$.*