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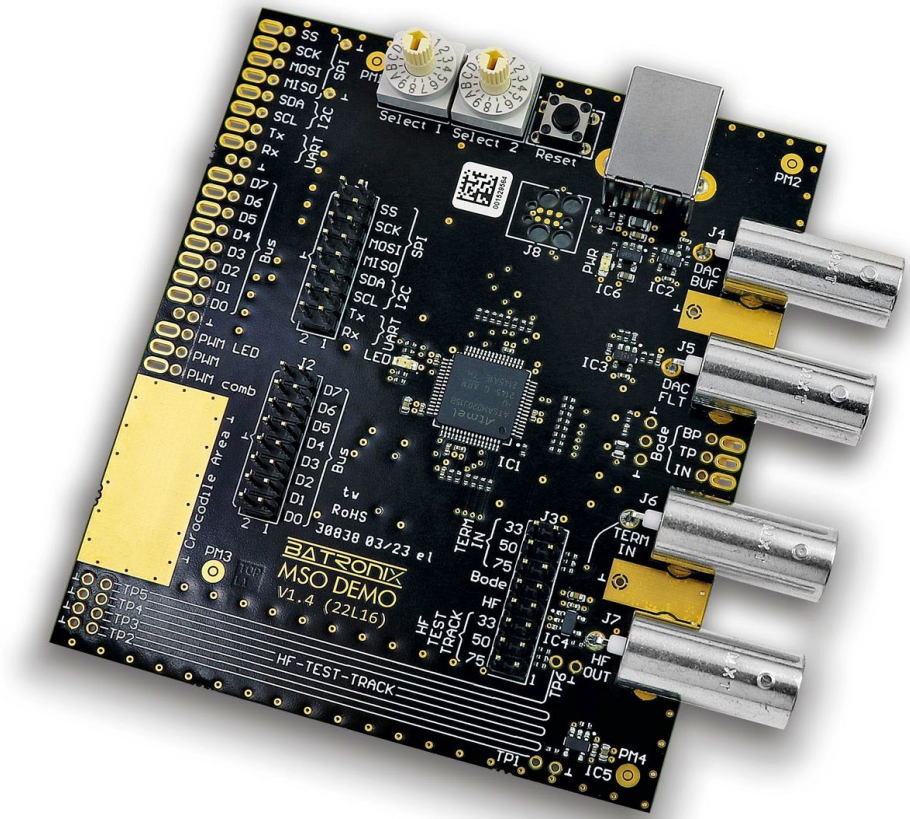

MSO Demo Board Guide

Version 1.01 (2 June 2023)

www.batronix.com

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Introduction

The Batronix MSO demo board offers various signals and experiments for demonstrating the functions of your oscilloscope or logic analyzer collected on a compact board. It is thus ideally suited for training and education from beginner to advanced user.

Chapter 1 of this manual provides you with an overview and general information about the demo board. The training section begins with Chapter 2, which covers you will get to know the functions of your oscilloscope step by step with the help of the demo board. Chapter 3 is about decoding interfaces and chapter 4 deals with high frequency effects (RF effects). In the training section there is always room for your own experimentation, while at the same time a possible solution for the experiment is presented. Due to the versatile variation possibilities, an individual measuring experience is made possible.

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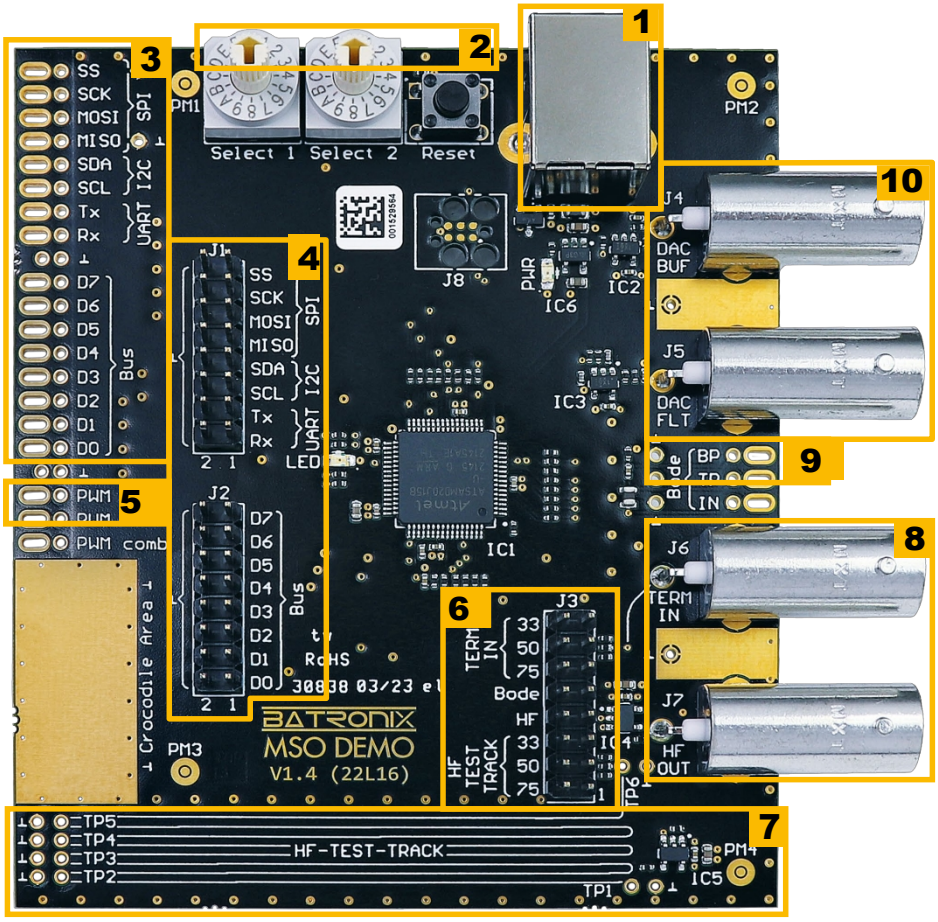
1 Overview demo areas



Area	Description
1	USB-B Power supply (5 V DC)
2	Selector switch for configuration • Select 1: Signal form of the function generator / configuration of the serial interfaces • Select 2: Speed or other characteristic quantity of the signal (e.g. Duty Cycle, ...) Reset button (e.g. to restart the counter values used in some serial messages).
3	Slotted holes for tapping the digital signals, e.g. with probe clamping hooks
4	Pin header (2.54 mm) for tapping the digital signals, e.g. for logic analyzer Dupont connector. • J1: Serial interfaces (SPI, I2C, UART) • J2: 7-bit bus or CAN-/CAN-FD-/LIN-/Manchester communication
5	PWM signal output • "PWM LED": PWM signal that also drives the LED • "PWM": Further PWM signal • "PWM comb": PWM signal applied with slower square wave signal
6	• Selection of the termination resistor for areas 7 and 8 • Connection of the Bode Plot Demo Filter with the BNC socket J6 • Activation of the RF test signals
7	RF test track for demonstration of RF effects and terminations
8	• "TERM IN" (J6): BNC input socket with adjustable termination (33/50/75/open). Furthermore, input for the Bode Plot demo filter. • "HF OUT" (J7): BNC output socket for the HF signal
9	Signal taps of the Bode Plot Demo Filter • IN: Tapping per probe for the measurement of the filter input signal • TP: Low pass filter • BP: Bandpass filter The signal from the oscilloscope generator is connected to "TERM IN" (J6) and at J3 the jumper "Bode" must be set.
10	Signal output of the function generator • "DAC-BUF" (J4): Amplified but largely unfiltered output of the DAC output. • "DAC-FLT" (J5): Amplified and low-pass filtered output of the DAC-. Output

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1.1 Power supply (range 1)

The demoboard is supplied with 5 V DC via a USB socket. For this purpose, please connect the supplied USB cable to the demoboard and the opposite side of the cable to the USB port of your oscilloscope, your PC or to a suitable USB power supply. The green LED (PWR) located close to the USB socket should light up clearly visible.

1.2 Input elements (area 2)

There are two selector switches on the demoboard that can be used to comprehensively configure many areas of the demoboard. For example, the Select 1 switch is used to select the waveform of the function generator, while Select 2 is used to vary the frequency. The possible settings are described in the following sections. Long-life selector switches from the Würth company were used, which are not very easy to turn. If necessary, you can use a probe adjustment tool or a small screwdriver as an aid for turning the selector switches.

The reset button can be used to restart the counter values used in some serial messages.

1.3 Digital signals (range 3 and 4)

On the left side of the demoboard there are taps for different standard interfaces (SPI, I2C, UART) with bidirectional communication as well as a 7-bit digital bus, which also runs CAN, CAN-FD, LIN and Manchester communications.
Details with regard to the various setting options of these interfaces are explained in chapter 3 and shown there in tabular form for the individual interfaces.

1.4 PWM signals (range 5)

The PWM signals "PWM LED", "PWM" and "PWM comb" can be found on the left above the large golden ground plane.

- The "PWM LED" signal also drives the LED you see centrally on the board. The "Duty Cycle" and thus the luminosity of the LED changes with the setting of the Select 2 switch, the frequency is 100 kHz.
- With the "PWM" signal, the frequency can be set via the Select 1 switch and the "Duty Cycle" via the Select 2 switch. The duty cycle setting of the PWM fits up to 100 kHz and is only roughly or not at all maintained at higher frequencies.
- The "PWM comb" signal shows the PWM signal, applied with a square wave signal slower by a factor of 128.

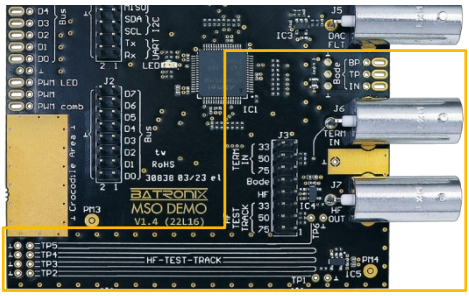
Select 1	"PWM" Frequency [kHz]
0	50
1	80
2	99,2
3	100
4	100,8
5	200
6	300
7	400
8	500
9	800
A	1000
B	1200
C	1500
D	2000
E	3000
F	4000

Select 2	"PWM" (up to 100 kHz) and "PWM LED Duty Cycle [%]
0	0,8
1	5,8
2	12,5
3	14,1
4	25,8
5	32,5
6	39,1
7	45,8
8	52,5
9	59,2
A	65,8
B	71,6
C	78,3
D	85,0
E	91,7
F	98,3

1.5 RF test track, RF out and Bode plot (range 6 to 9)

There are two fast logic gates on the demoboard which can be used to demonstrate a number of RF effects, the need for good probe ground connections and suitable termination. The assignment of the jumpers can be found in chapter 4.

For Bode plot demonstrations the jumper "Bode" must be set at J3 and the generator signal of the oscilloscope must be applied to "TERM IN" (J6).



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1.6 Function generator (range 10)

On the demoboard there is a function generator that can generate a number of different waveforms via a 10-bit DAC (analog-to-digital converter). The signals are low-pass filtered via operational amplifiers on one BNC socket and output unfiltered on another BNC socket. 16 frequencies from 0.2 Hz to 10000 Hz can be set.

With the selector switch Select 1 a signal mode (signal form and if necessary modification) can be selected:

Position	Select 1 Signal	Select 2 parameter s
0	Sine	Frequency
1	Rectangle	Frequency
2	Triangle	Frequency
3	Ramp	Frequency
4	Direct voltage (DC)	Voltage
5	Pulse with increasing amplitude	Frequency
6	Sweep 200 Hz - 10 kHz sine	Sweep time
7	Burst with 10 kHz sine	Number of periods
8	AM modulated sine wave (400 Hz / 6 kHz)	-
9	1 kHz PWM with adjustable duty cycle	Duty Cycle
A	1 kHz sine with noise	Noise component
B	10 kHz sine with pseudorandom errors	Error/Cycle
C	10 kHz sine with peak after x periods	Events/s
D	1 kHz square wave with noise	Noise component
E	10 kHz square wave with pseudorandom errors	Error/Cycle
F	Various test signals, e.g. for trigger experiments. The selection can be seen in the table after next.	Signal

The Select 2 switch can be used to set the frequency, voltage, duty cycle or other parameter depending on the signal mode.

Select 2	Frequency [Hz]	Voltage [V]	Sweep time [ms]	Number of periods	Duty Cycle	Events [1/s]	Error Err/Wfms
0	0,2	0,2	1	1	1 %	0,1	~11 ppm
1	0,4	0,4	2	2	2 %	0,2	~22 ppm
2	1	0,6	3	3	5 %	0,5	~55 ppm
3	5	0,8	4	4	10 %	1	~110 ppm
4	10	1,0	5	5	20 %	2	~220 ppm
5	20	1,2	6	6	30 %	5	~550 ppm
6	50	1,4	7	7	40 %	10	~0,11%
7	100	1,6	8	8	50 %	20	~0,22%
8	200	1,8	9	9	50 %	50	~0,55%
9	500	2,0	10	10	60 %	100	~1,1%
A	800	2,2	15	11	70 %	200	~2,2%
B	1000	2,4	20	12	80 %	500	~5,5%
C	2000	2,6	25	13	90 %	1000	~11,5%
D	5000	2,8	50	14	95 %	2000	~21%
E	8000	3,0	125	15	98 %	4000	~55%
F	10000	3,2	250	16	99 %	6000	~94%

If the selector switch Select 1 is set to "F", some more special signals can be output with the selector switch Select 2:

Select 2	Test signal
0	100 kHz clock
1	100 kHz clock with occasional dropouts
2	50 kHz clock
3	50 kHz clock with occasional shorter or longer pulses / pauses
4	50 kHz clock (low level 1 V, high level 2 V)
5	Pulse with 160 µs rise and fall times
6	Pulse with varying rise and fall times (80 µs/160 µs/320 µs)
7	1 V DC voltage with noise and occasional peaks
8	1 V DC voltage with strong noise

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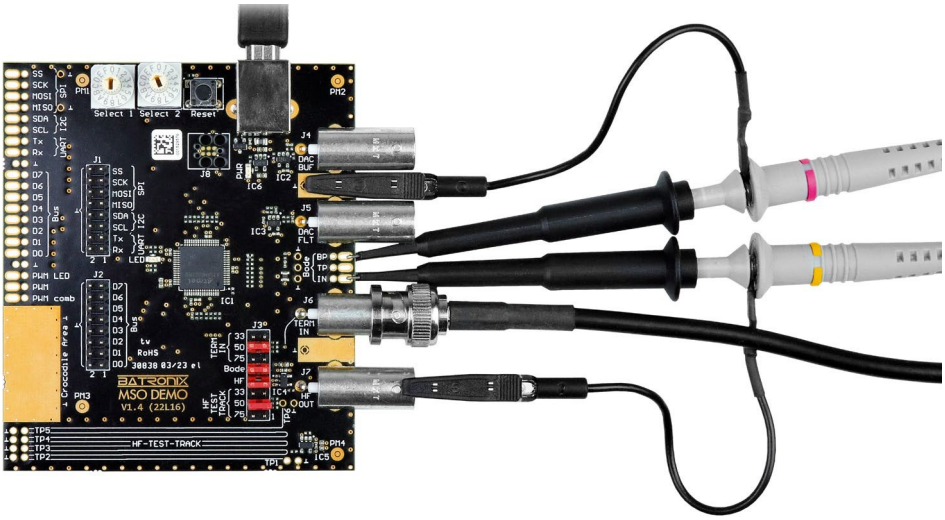
2 Oscilloscope training area

2.1 General notes

- Supply the demo board via the USB cable (see 1.1).
- When using probes, a probe compensation should be performed beforehand. You will find notes on this in your oscilloscope manual.
- Make sure to connect the ground crocodile clip of the probes to the ground of the demoboard. The golden areas with the ground symbol or also the outer area of unused BNC sockets are well suited for this.
- In many cases oscilloscope probes can be equipped with clamping hooks. Their use here is convenient, since they can be hooked well into the slotted holes on the board edges or on the leads of the BNC sockets.
- When using probes with a divider factor (e.g. 10:1), make sure that you also set this divider factor on your oscilloscope for the corresponding channel.
- Please make sure to use BNC cables with a characteristic impedance of 50 ohms.
- If you have a "Default" or "Preset" button on your oscilloscope, you can use it to reset specific settings of previous measurements and continue with the default settings.
- There may be differences between individual manufacturers when naming oscilloscope functions. We use a manufacturer-independent description as far as possible here. If necessary, take a look at the manual of your oscilloscope.



Screenshot: Demoboard with connected probes and BNC cable for a Bode Plot measurement.

2.2 Introduction horizontal and vertical system

In today's common digital oscilloscopes, an analog-to-digital converter (ADC) converts analog signal voltages into digital quantization levels. Depending on the oscilloscope, ADC resolutions of 8, 10 and 12 bits are common and the analog signal is thus converted into 256, 1024 or 4096 quantization stages. These steps are distributed over the complete input voltage range of the ADC and are displayed on the screen over the entire vertical display range.

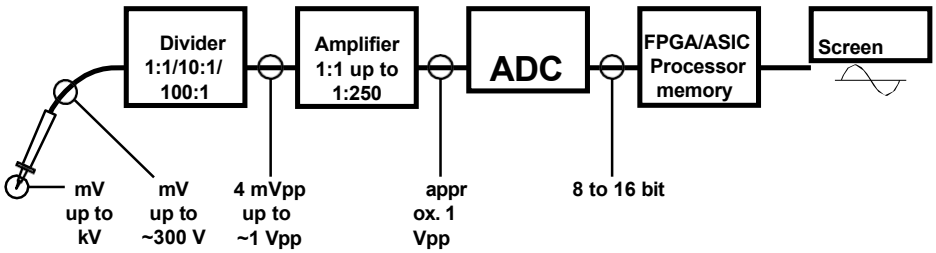
Oscilloscopes can amplify or attenuate signal voltages in their front end (the input range up to the ADCs) to match various voltage levels from a few millivolts to hundreds of volts to the input voltage range of the built-in ADC.

To make the most of the ADC's limited accuracy, scale signals to occupy a large portion of the screen vertical (and thus a large portion of the ADC's input voltage range).

In the oscilloscope front-end, the signal can also be assigned an offset voltage, e.g. to bring negative signal voltages into the input voltage range of the ADC.
to move. On the screen, the measurement signal moves vertically when the offset voltage is set.

The horizontal axis represents the time course. The time scaling can also be set over a wide range. Depending on the oscilloscope, a few picoseconds up to thousands of seconds can be displayed over the screen width.

The display is usually divided into a grid of "Divisions" (short form: Divs). Depending on the oscilloscope, there are usually 8 or 10 divs in the vertical and 12 to 16 divs in the horizontal. The vertical and horizontal scalings refer to these divs, the setting is then made e.g. as 2 V/div and 1 ms/div.



Screenshot: From the probe through the oscilloscope front end to the screen

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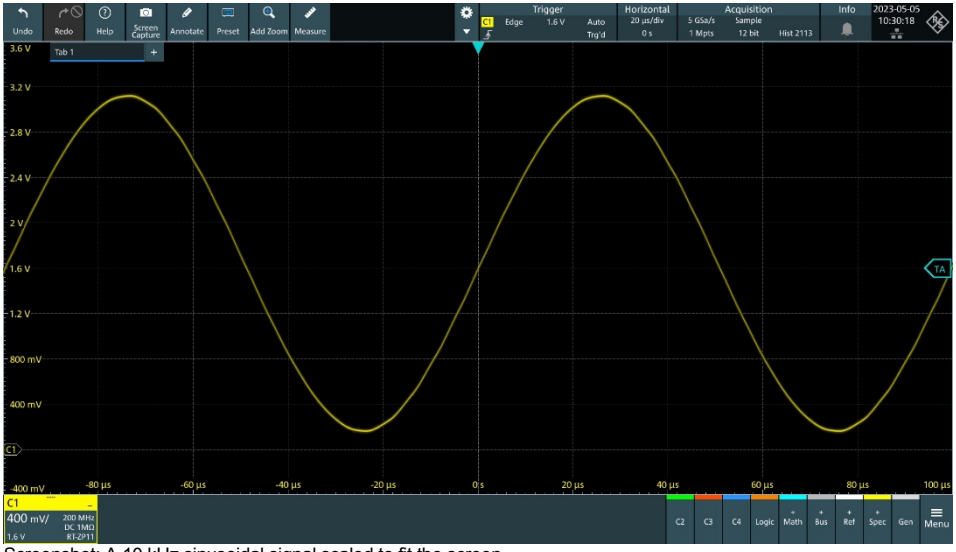
2.3 First experiments with signal scaling and positioning

Please perform the following steps:

- Set the demo board selector switch Select 1 to "0" and Select 2 to "F".
- Measure the "DAC-FLT" signal (J5) with a probe or connect it to an oscilloscope channel with a BNC cable. If this channel is not already switched on with your oscilloscope, switch it on now.
- Depending on the settings of your oscilloscope, you may already see the signal, parts of the signal or nothing at all. If the signal or parts of it are already visible, these can still run through the image or flicker.
- First of all, the horizontal and vertical settings of your oscilloscope must now be adjusted so that the signal is displayed on the screen clearly visible and standing still. After some practice you will succeed well and fast in displaying new and unknown signals on the screen.
- For this first signal, initially set the horizontal scaling to 50 µs/div and the vertical scaling to 1 V/div.
- Set the trigger to "Edge", set the trigger channel to the used channel and the trigger level to the center of the signal.
- The signal should now be displayed on the screen standing still.
- Now some fine tuning follows: Use the vertical scaling (position setting) and the offset setting of your oscilloscope to display the signal on the largest possible vertical area of the screen. The edges of the screen or the display should not be touched in the vertical direction or some distance should be kept.
- Now adjust the horizontal scaling so that you can see one to two complete periods of the signal on the screen.
- It should now look something like the screenshot below:



Screenshot: A 10 kHz sinusoidal signal scaled to fit the screen.

2.4 Trigger

2.4.1 Introduction trigger system

The oscilloscope continuously measures the input signal in "run mode" and displays it on the screen. With the trigger system, signals of subsequent signal courses are displayed on the same horizontal position (the time axis) as far as possible. The signal thus "stands" on the screen with a fixed time reference and can be easily viewed and evaluated.

The trigger system of an oscilloscope allows various settings of the trigger condition. If this trigger condition is detected, the measured signal is displayed on the screen aligned on the horizontal axis. The horizontal position (at which the trigger condition was detected) can be shifted to the left and right, even far outside the screen.

In order to be able to view and assess the signal before the correct setting of the trigger system, there is the auto-trigger option. If this is activated, signals are displayed several times per second even without triggering. These usually have no time reference and appear at different horizontal positions.
positions. However, they help to estimate and find the correct trigger setting.

Modern oscilloscopes offer a whole range of special triggers to trigger on different signal shapes. For example, there are edge, pulse width, interval, dropout, slope, window, run and pattern triggers as well as other triggers, for example for triggering on decoded data of serial interfaces.

2.4.2 Edge trigger (edge trigger)

Please perform the following steps:

- Perform the steps according to section 2.3 if not already done.
- Adjust the trigger level and observe which signal part is displayed at the trigger point.
- Adjust the horizontal position and view the temporal (horizontal) shift of the display.
- Press the "Stop" or "Run/Stop" key to stop further measurements and to continue displaying the measured signal.
- Press the "Single" key to perform a single measurement.
- You can move the signal stopped in this way with the vertical offset setting and the horizontal position on the screen.
- Press the "Run" or "Run/Stop" key to start the continuous measurements again.

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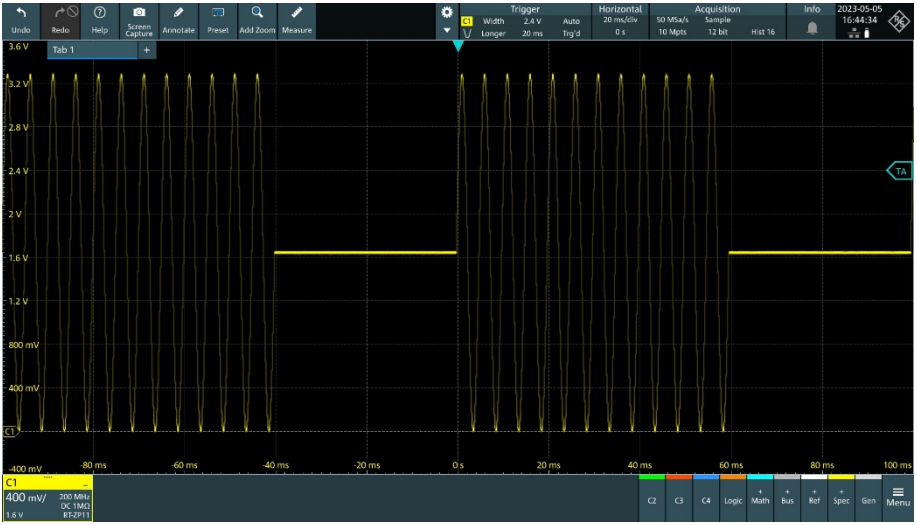
2.4.3 Pulse width trigger (pulse width trigger)

The Pulse Width Trigger triggers on positive or negative pulses that are shorter or longer than a preset time. This can be used, for example, to trigger on periodic or repeating patterns.

Depending on the oscilloscope manufacturer, this trigger is also just called pulse or width trigger.

Please perform the following steps:

- Set Select 1 to "7" and Select 2 to "B" (burst with 12 pulses).
- Measure the "DAC-FLT" signal (J5) with a probe or connect it to an oscilloscope channel with a BNC cable.
- Set the vertical scaling to 500 mV/div and the horizontal scaling to 500 µs/div.
- If you trigger on this signal with the edge trigger, different pulses will trigger the trigger and you will see an alternating non-standing display.
- Enter the Trigger menu and set the trigger type to Pulse Width Trigger.
- Set the trigger level slightly below the "pause voltage", here e.g. to 0.8 V and the polarity of the trigger to positive. The pause time in the signal is approx. 800 µs, therefore set the trigger time > 400 µs.



Screenshot: Triggering with the Pulse Width Trigger on a Burst

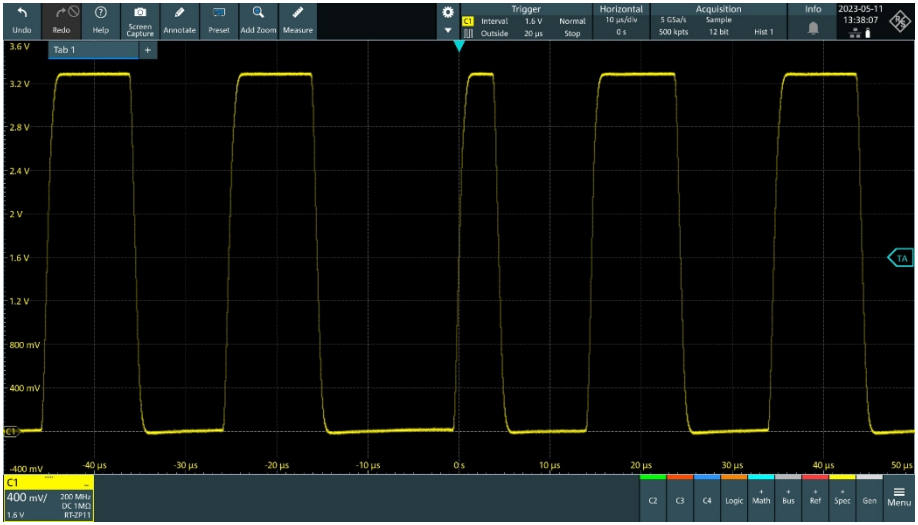
2.4.4 Interval trigger (period trigger)

The interval trigger is similar to the pulse width trigger, but triggers on period times instead of pulse times. It can be triggered on exceeding or falling below a time or also on a time range.

This can be used, for example, to trigger on temporal outliers of a clock line.

Please carry out the following steps:

- Set Select 1 to "F" and Select 2 to "3" (50 kHz clock with occasional shorter or longer pulses / pauses).
- Measure the "DAC-BUF" signal (J4) with a probe or connect it to an oscilloscope channel with a BNC cable.
- Set the horizontal scaling of your oscilloscope to 10 µs/div. Set the vertical system so that you see the signal as full as possible on the screen.
- First trigger on the square wave signal with the edge trigger. The square wave signal will mostly look correct. Possibly (depending on the oscilloscope) you will occasionally and briefly see incorrect representations "flashing".
- Now use the interval trigger of your oscilloscope. Set the trigger level to 1.6 V and the interval duration to < 18 µs or > 22 µs. Now you will see a number of erroneous signals which were not or hardly noticeable before with the normal edge trigger in the mass of correct signals.
- Switch from auto-trigger mode to normal trigger mode so that only the faulty waveforms are displayed. Set the auto-trigger mode again for subsequent measurements.



Screenshot: Triggering with the interval trigger on deviating period times

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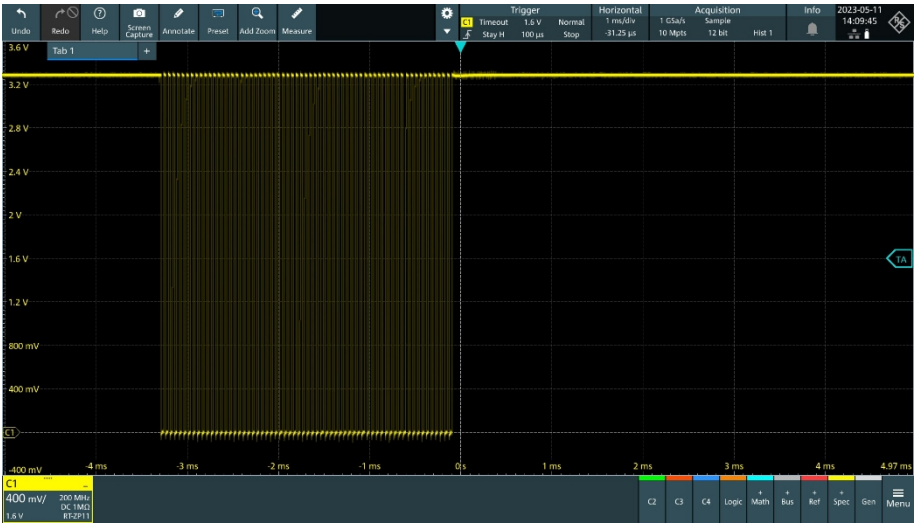
2.4.5 Dropout / Timeout Trigger

The dropout trigger allows triggering to an adjustable time without trigger edges.

This can be used, for example, to trigger on the end of a data transmission.

Please perform the following steps:

- Set Select 1 to "0" and Select 2 to "8".
- Measure the "I2C SCL" signal (range 3) with a probe.
- First set the vertical scaling to 500 mV/div and the horizontal scaling to 200 µs/div.
- First trigger the signal with the edge trigger.
- Now use the dropout trigger of your oscilloscope (also called timeout trigger depending on the oscilloscope). Set the trigger level to 1.6 V and the trigger time to 100 µs. If your oscilloscope offers a "Range" setting, this must be set to "Stays low" can be set.



Screenshot: Triggering with the dropout or timeout trigger on the end of a data transmission.

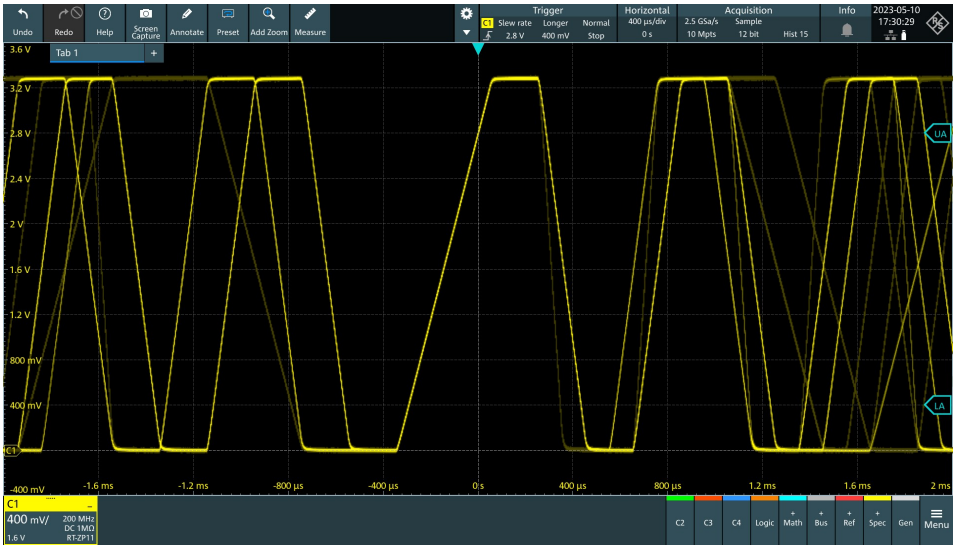
2.4.6 Slope / Slew Rate / Rise Time Trigger

The slope trigger enables triggering on an adjustable slope of the signal. Two voltage levels and a time period can be defined for this purpose.

This can be used, for example, to trigger on unexpectedly fast or slow signal slopes.

Please perform the following steps:

- Set Select 1 to "F" and Select 2 to "6".
- Measure the "DAC-FLT" signal (J5) with a probe or connect it to an oscilloscope channel with a BNC cable.
- Adjust the vertical and horizontal system so that 3 to 6 signal progressions are displayed almost full screen.
- First trigger the signal with the edge trigger. The signal will mostly look correct. Possibly (depending on the oscilloscope) you will occasionally and briefly see incorrect representations "flashing".
- Now use the slope trigger of your oscilloscope (also called slew rate or rise time depending on the oscilloscope). Set the trigger levels to 300 mV and 3 V and the trigger rise time to > 200 µs.
- Switch from auto-trigger mode to normal trigger mode so that only the faulty waveforms are displayed. Set the auto-trigger mode again for subsequent measurements.
- If your oscilloscope supports it, you can also set the slope trigger to "Outside" and set the time range to 140 µs to 180 µs and to rising and falling edges. With this you should be able to achieve triggering on all errors of this test signal.



Screenshot: Triggering with the dropout or timeout trigger on the end of a data transmission.

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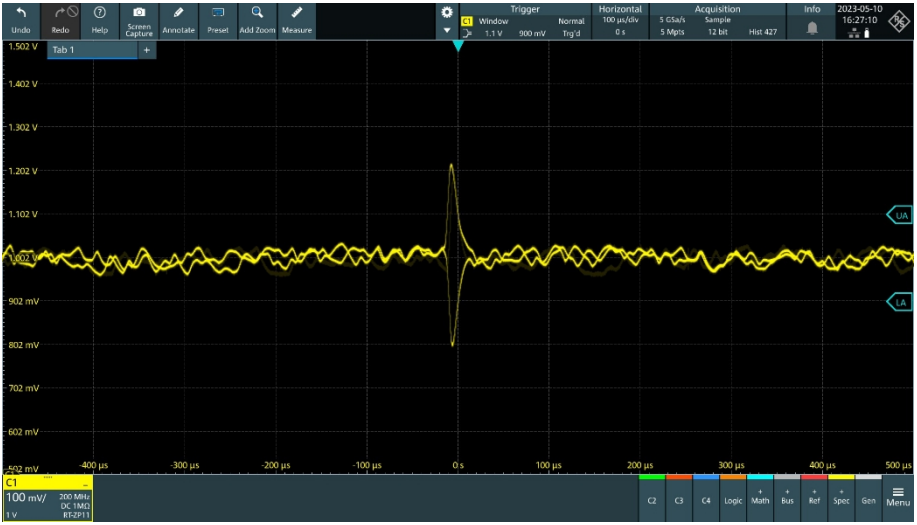
2.4.7 Window Trigger

The window trigger triggers on signals that enter or leave a voltage range. Depending on the oscilloscope, a time can be defined for the signal to remain within or outside the voltage range in order to trigger the trigger.

This allows, for example, a power supply to be monitored simultaneously for positive and negative voltage peaks.

Please perform the following steps:

- Set Select 1 to "F" and Select 2 to "7" (DC voltage 1 V with noise and occasional peaks).
- Measure the "DAC-FLT" signal (J5) with a probe or connect it to an oscilloscope channel with a BNC cable.
- Set the vertical scaling to 200 mV/div and the horizontal scaling to 100 µs/div. Set the vertical position (channel offset) to the bottom edge of the display area so that you can see the signal clearly.
- Now use the window trigger of your oscilloscope. Define the two trigger levels so that one is above and one is below the DC voltage (e.g. 0.9 V and 1.1 V).



Screenshot: Triggering with the window trigger on positive and negative peaks of a power supply line.