Figure 1: The Oscilloscope Watch

Description:

The Oscilloscope Watch (OW) is a digital watch with three electronic instruments integrated: a Mixed Signal Oscilloscope, an Arbitrary Waveform Generator, and a Protocol Sniffer; all housed in a very small enclosure. Additional digital watch features include: Time, Alarms, Calendar, Stopwatch, Countdown timer and Moon phase.

Main Features:

- **Mixed Signal Oscilloscope**: Simultaneous sampling of 2 analog and 8 digital signals.
- **Arbitrary Waveform Generator** with advanced sweep options on all the wave parameters.
- **Protocol Sniffer:** SPI, I²C, UART
- **Advanced Triggering System**: Normal / Single / Auto / Free, with many trigger modes; adjustable trigger level, and ability to view signals prior to the trigger.
- **Meter Mode**: VDC, VPP and Frequency readout.
- **XY Mode:** For plotting Lissajous figures, V/I curves or checking the phase difference between two waveforms.
- **Spectrum Analyzer** with different windowing options and selectable vertical log and IQ visualization.
- **Channel Math**: add, multiply, invert, and average.
- **Horizontal and Vertical Cursors** with automatic waveform measurements, and waveform references.

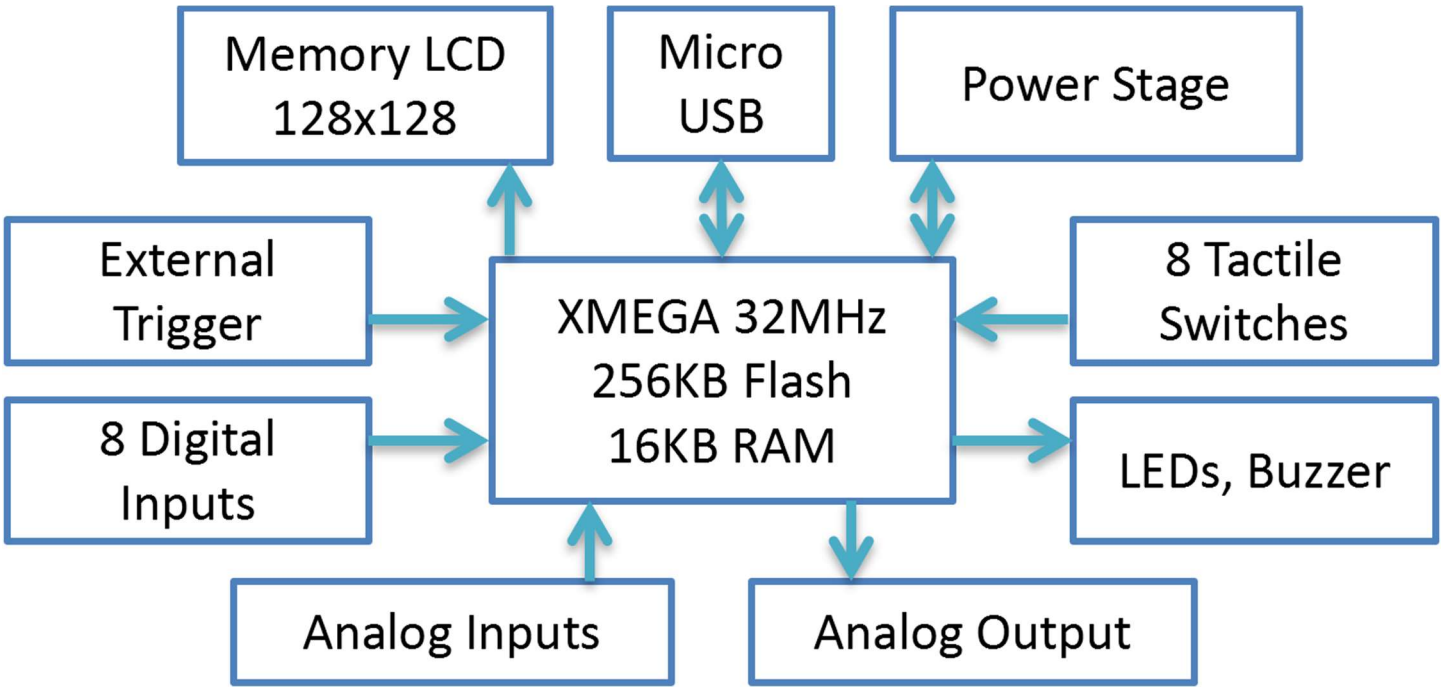

Figure 2: Oscilloscope Watch Block Diagram

About this manual

This manual targets both novice and advanced users, providing a full resource for everyone. However, for a full understanding of the operation of the Oscilloscope Watch, the user should be familiar with the operation of a regular oscilloscope.

The features documented in this manual are for units with firmware version 2.95+.

Conventions

OW: Oscilloscope Watch
CH1: Analog Channel 1
CH2: Analog Channel 2
CHD: Logic Inputs
Fast Sampling: 10ms/div or faster time base
Slow Sampling: 20ms/div or slower time base

Helpful tip

Warning

Technical Detail

Manual Revision History

Version	Date	Notes
3.0	December 2013	Updated protocol interface information
3.1	February 2014	Minor error corrections
3.2	May 2014	Firmware update on Linux
3.3	October 2014	Updated interface protocol
3.4	November 2014	Counter mode
3.5	December 2014	New Sniffer ASCII mode
3.6	August 2023	Oscilloscope Watch features
3.7	January 2026	Documenting new features
3.8	July 2026	Documenting last round of features

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1. General Overview

1.1 Oscilloscope Watch Pin Description

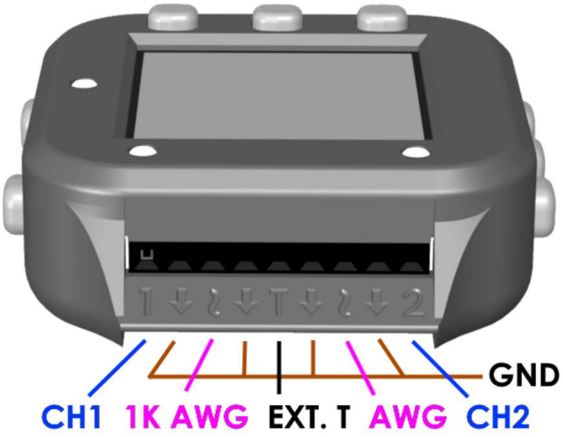


Figure 3: Top Signals

Figure 4: Bottom Signals

Name	Description	Comment
GND	Ground	To reduce voltage offset errors, use multiple GND connections with short lengths.
Logic 0	Digital Channel 0	I2C Sniffer signal: SDA
Logic 1	Digital Channel 1	I2C Sniffer signal: SCL
Logic 2	Digital Channel 2	UART Sniffer signal: RX
Logic 3	Digital Channel 3	UART Sniffer signal: TX
Logic 4	Digital Channel 4	SPI Sniffer signal: /SS
Logic 5	Digital Channel 5	SPI Sniffer signal: MOSI
Logic 6	Digital Channel 6	SPI Sniffer signal: MISO
Logic 7	Digital Channel 7	SPI Sniffer signal: SCK
EXT. T	External Trigger	Digital input, max 5.5V
AWG	Arbitrary Waveform Generator	Output range: +/- 4V
1K AWG	Arbitrary Waveform Generator thru 1K resistor	Output range: +/- 4V
CH2	Analog Channel 2	Input range: -14V to +20V
CH1	Analog Channel 1	Input range: -14V to +20V

Table 1: Pin description

TIP The 1K AWG signal is useful to generate component V/I curves. See the Example section for more information

1.2 Oscilloscope Watch Overview

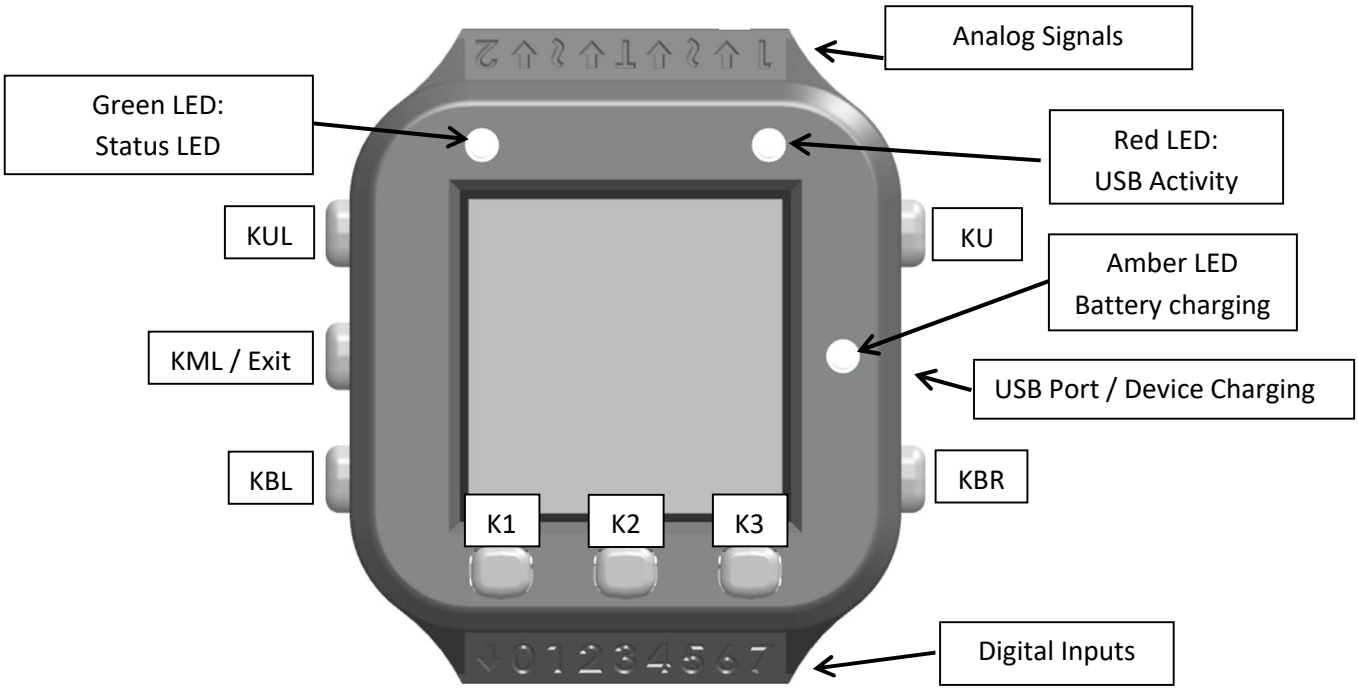


Figure 5: Oscilloscope Watch Overview

1.2.1 USB Port / Device Charging

The USB port is used to charge the battery; the battery can be fully charged in about 9 hours. When in Oscilloscope mode, the device can communicate with a host such as a Windows PC.

1.2.2 Quick Start Guide

- Take the device out of the packaging. There is a protective film on the display which can be removed.
- Exit the Watch mode, browse the menus and enter Oscilloscope mode.
- Connect the AWG pin to CH1 using one of the provided jumper wires.
- Press and hold the K1 key (auto setup). The screen should look like figure 6.
- Pressing K2 or K3 will change the sampling rate.

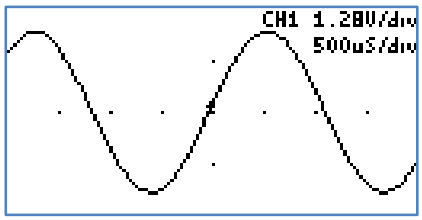


Figure 6: Quick start

TIP

Always exit Oscilloscope mode when not using it as it discharges the battery faster.

1.3 Specifications

General	Variant	**Standard Size**	**Slim Size**
	Device size	43.20 x 48.50 x 15.85 mm^3	42.96 x 41.52 x 11.22 mm^3
	Weight	46 grams	35 grams
	Battery	Li-Ion 3.7V 450mAh	Li-Ion 3.7V 120mAh
	Operation time	7.5 Hrs. Scope Mode, 12 Months Watch	2 Hrs. Scope Mode, 3 Months Watch
	Microcontroller	ATXMEGA256A3U 256KB+8KB Flash, 16KB SRAM, 4KB EEPROM	
	Display Type	Memory LCD, 128x128 pixels, max. refresh rate 60Hz	
	Display Size	1.28"	
	Interfaces	8 Tactile Switches, USB (Micro USB connector), PDI for debugging	
	Active current	60mA average	
	Sleep current	3uA	
Logic Analyzer	Logic Inputs	8 Digital Inputs	
	Logic Input levels	3.3V, 5V tolerant	
	Input Pull	820kΩ Pull Down	
	Max. Sampling rate	2Msps	
	Buffer Size	4096	
	Frequency Counter	16MHz, 1Hz resolution, +/- 100ppm accuracy	
	Sniffer Protocols	UART, I2C, SPI	
Oscilloscope	Analog Inputs	2 Analog Inputs	
	Max. Sampling rate	2Msps per channel	
	Analog Bandwidth	200kHz	
	Resolution	8 bits	
	Input Impedance	1MΩ	
	Buffer size	256 samples on each channel	
	Input Voltage Range	-14V to +20V	
	Vertical Sensitivity	80mV/div to 5.12V/div	
AWG	Analog Outputs	1 Analog Output	
	Max. Conversion rate	1Msps	
	Resolution	8bits	
	Buffer Size	256	
	Output current	> +/- 7mA	
	Output Voltage	+/- 4V	
	Low Pass Filter	53kHz	

Table 2: Oscilloscope Watch Specifications

1.4 Absolute Maximum Ratings

Parameter	Minimum	Maximum	Unit
Analog Inputs[1]	-180	180	V
Digital Inputs	-0.5	5.5	V
External Trigger	-3.5	6.8	V
Operating Temperature	0	45	°C
Storage Temperature	-10	60	°C

Table 3: Absolute Maximum Ratings

1. The maximum voltage on the analog inputs has only been tested to these limits. The device may tolerate higher voltages, but it is not recommended for safety.

2. Home Menu

The user can access the different operation modes from the Home menu. Regardless of the active mode or operation being performed, the Home menu can be reached by pressing the exit button (KML) repeatedly.

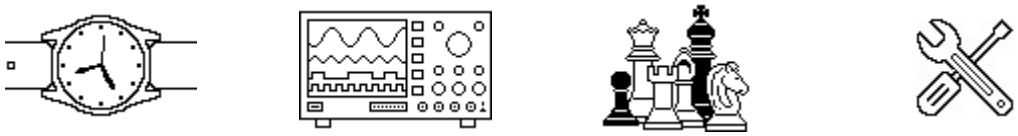


Figure 7: Home Menus: Watch, Oscilloscope, Games, Settings

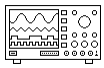
2.1 Watch Menu

This menu has three items:

- **Time**: Enters the Watch mode. More information is on Chapter 3.
- **Calendar**: Enters the Calendar Mode. The user can navigate dates by pressing the buttons:

  KUL: Increase Year KUR: Increase Month
  KBL: Decrease Year KBR: Decrease Month
  K1: Decrease Day K2: Today K3: Increase Day
- **Moon**: Shows an estimation on the Moon phase for today or any date.

2.2 Oscilloscope Menu



This menu has three items:

- **Profile**: A profile is a set of all the Oscilloscope settings. Up to 8 custom profiles can be saved in EEPROM. The K1 button restores the factory settings. If the oscilloscope is in an unknown or undesired state, this function is useful to set the device to a known state.
- **Image**: This setting shows the screenshot taken in Oscilloscope mode. To take a new screenshot during Oscilloscope mode, press the KUL and KUR buttons simultaneously. Only one screenshot can be saved.
- **Start**: Enters the Oscilloscope mode, more information is on Chapter 4.

2.3 Games Menu

This menu launches different games:

- **Snake**: The typical snake game where the snake grows as it eats the fruit.
- **Qix**: Avoid the Qix that is moving on the screen and the traps that are traveling on the walls. To pass to the next level, fill 75% of the screen by drawing walls. These are the player's controls:

  KUL: Draw wall / turn left KUR: Draw wall / turn right
  KUR: Perimeter walk clockwise KBR: Perimeter walk counter-clockwise

  The Qix can only kill the player when it is drawing a wall. The player will die if it collides with a wall that is being drawn.
- **Chess**: Classic chess game with Human vs Human, CPU vs Human, and CPU vs CPU options. The controls:

  KUR: Move cursor up KBR: Move cursor down
  K1: Move cursor left K2: Select K3: Move cursor right

2.4 Settings Menu

The Settings menu has 3 items:

- **Config**: Settings for the watch and the device in general**:**
  - Hourly Beep
  - 24 Hour Format
  - Year at the end: Date format.
  - Month after day: Date format.
  - Show moon icon: Shows an icon in Watch mode representing today's moon phase.
- **Diagnose**: This page shows diagnostic information such as voltages and port values.
  The offset calibration function is available from this page:
  - **Offset calibration**: The unit is calibrated before being shipped, but calibration is required again if the firmware is updated without saving the EEPROM. During calibration, two graphs are shown that represent the calibration offsets from each analog channel.
- **About**: Shows information about the device and the firmware version.

3. Digital Watch

The Watch mode shows all the typical information of a digital watch:

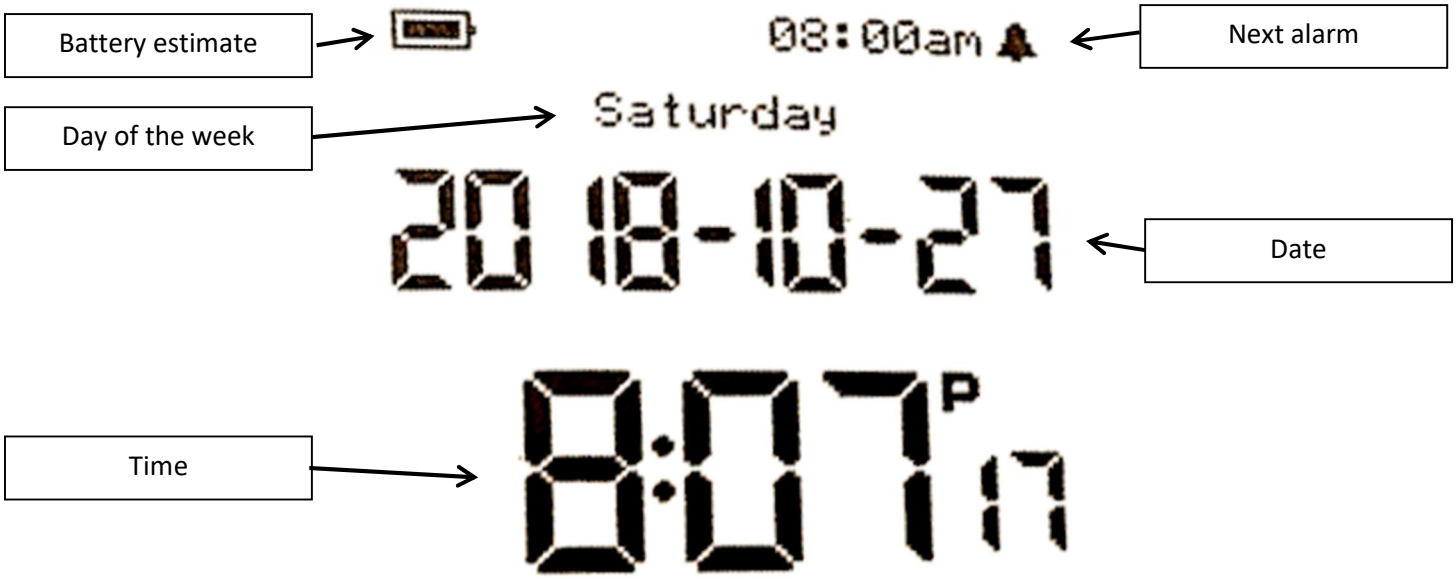


Figure 8: Watch mode

The date and time formats can be changed in the Configuration in the Home menu.
The screen backlight can be activated with the KUL button.

3.1 Watch Faces

The watch has 4 different faces that can be changed with the buttons on the right:
- KUR: Toggles between the full or simplistic digital watch faces.
- KBR: Toggles between the full or simplistic analog faces.

3.2 Time and Date Adjusting

To change the date and time, long press the KBL button, a blinking cursor will initially appear under the seconds. From here, use these buttons to adjust the date and time:

- KUR: Increase the selected item
- KBR: Decrease the selected item
- KBL: Moves the cursor to the next item
- KML: Exit

3.3 Stopwatch

Press K1 to enter the Stopwatch. Once in Stopwatch, use these buttons to control the operation:

- KUR: Start and stop
- KBR: Laps and reset

3.4 Countdown Timer

Press K2 to enter the Countdown timer. Once in Countdown mode, use these buttons to control the operation:

- K1: Add 1 hour
- K2: Add 1 minute
- K3: Add 1 second
- KUR: Start and stop
- KBR: Laps and reset

Beeps will sound when the countdown expires.

3.5 Alarms

There are 4 alarms in the watch. Each alarm can be configured to be active on any day of the week. There are 10 melodies that can be used for each alarm. To configure the alarms, press K3 to enter the Alarm Editor. Once in the Alarm Editor mode, use these buttons to configure the alarms:

- KUR: Increase selected item.
- KBR: Decrease selected item.
- K1: Go to previous item.
- K3: Go to next item.
- K2: Edit next alarm.

4. Mixed Signal Oscilloscope

The XScope is a mixed signal oscilloscope; it has 2 analog channels and 8 digital channels. This chapter will focus on the analog signals. More information about the digital channels is presented in chapter 5.

4.1 Oscilloscope User Interface

The KBR button is the Next Menu button and KBL is the Previous Menu button, they are used to navigate the menus. The K1 - K3 buttons action depend on the current menu. The green arrows represent the flow when pressing the KBR button. When the KBR button is pressed on the last menu, the device settings are saved and the menu goes back to the default. Figure 9 shows the main and some secondary menus. Further ramifications are shown on the respective chapters.

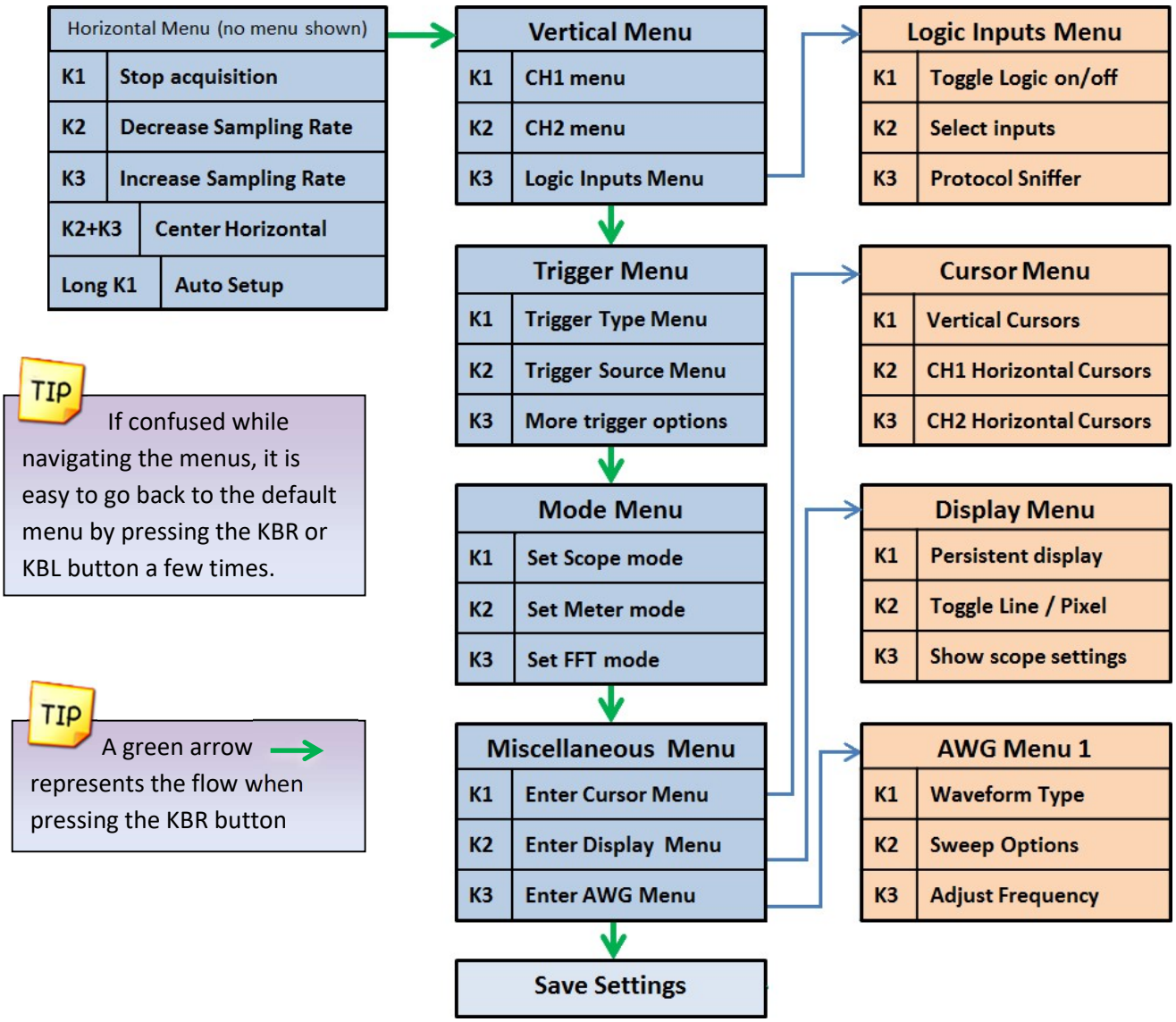


Figure 9: Main Menus

4.2 Saving the settings

All settings are stored to non-volatile memory only when exiting from the last menu. This method is used to reduce the number of write cycles to the microcontroller's EEPROM. The settings are not saved if the VCC voltage is under 3.15V.

4.3 Horizontal Settings

The horizontal settings are controlled on the default menu. The menu is shown on figure 10.

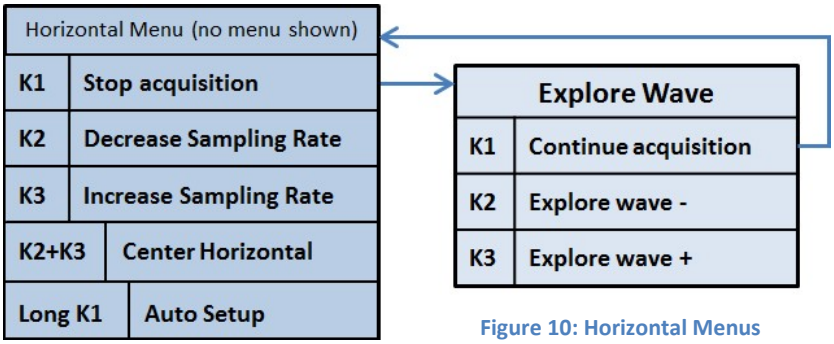


Figure 10: Horizontal Menus

4.3.1 Time Base

The time base can be varied from 8µs/div to 50s/div. Table 4 shows all the possible time bases. One time division consists of 16 pixels. Example: 8µs / division = 8µs / 16 pixels → 500ns / pixel.

Time Base (s / div)												
	Fast	8µ	16µ	32µ	64µ	128µ	256µ	500µ	1m	2m	5m	10m
	Slow	20m	50m	0.1	0.2	0.5	1	2	5	10	20	50

Table 4: Time divisions

4.3.2 Technical Details

There are two distinct sampling methods: Fast Sampling and Slow Sampling.

- **Fast Sampling** (10ms/div or faster): All samples are acquired to fill the buffer, and then they are displayed on the screen.
  - Pre-trigger sampling (ability to show samples before the trigger) is available only with fast sampling.
  - Only 128 samples are visible at a time, varying the horizontal position allows exploring the full buffer.

- **Slow Sampling** (20ms/div or slower): Single samples are acquired and simultaneously displayed on the display.
  - The ROLL mode (waveform scrolls to the left during acquisition) is only available with the slow sampling.
  - All 256 samples are visible on the display (each vertical line will have at least two samples)

4.3.3 Explore Wave

The horizontal position can be varied on the Fast Sampling time bases. There are 256 samples for each channel, but only 128 are displayed on the screen. When the acquisition is stopped, the full sample buffer can be explored with the K2 and K3 buttons. Pressing K2 and K3 simultaneously on the default menu will center the horizontal position.

When setting the XY mode, the graph can be moved vertically (Section 2.4.1.3).

4.3.4 Auto Setup

The Auto Setup feature will try to find the optimum gain and time base for the signals being applied on CH1 and CH2.

4.4 Vertical Settings

The analog channel controls are discussed in this section. Figure 11 shows the Vertical menu flow.

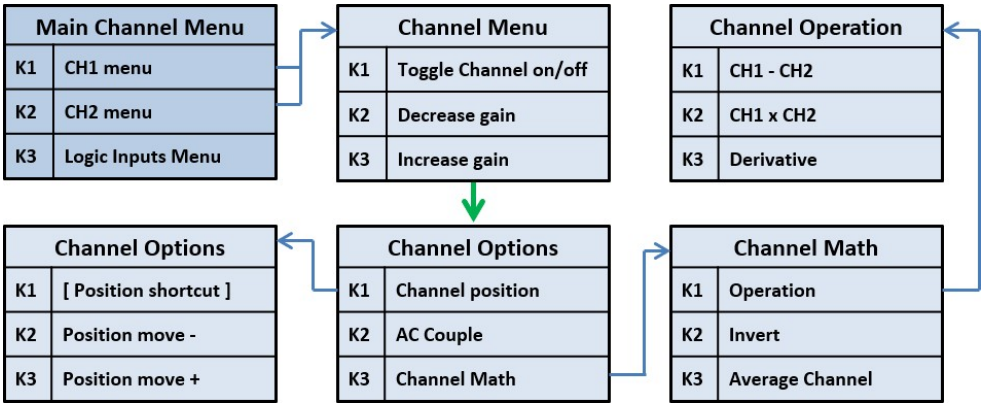


Figure 11: Vertical menus

TIP

CH1 and CH2 have identical settings.

4.4.1 Channel Gain

Table 5 shows the possible gain settings for the analog channels. One gain division consists of 16 pixels. The current gain settings for the analog channels are shown in the top right part of the display (If the SHOW setting of the display is enabled).

Gain Settings (Volts / Division)
5.12
2.56
1.28
0.64
0.32
0.16
80m

Table 5: Gain Settings

4.4.2 Channel Options

- **Position**: the waveform can be moved up or down.
- **AC Couple**: AC Couple the input (capacitive coupling).
- **Channel Math**: Math operations on the channel data.

4.4.3 Channel Math

- **Math Operations**:
  - **Subtract**: The channel trace will be replaced with the difference.
  - **Multiply**: The channel trace will be replaced with the product.
  - **Derivative**: Calculates the discrete derivative.
- **Channel Invert**: The channel data is inverted.
- **Average**: The channel samples will be averaged to reduce aliasing. (See Figure 12).

```
  8 µs/div:   1 sample  (no average)
 16 us/div:   1 sample  (no average)
 32 µs/div to
 10 ms/div:   2 samples are averaged
 20 ms/div:   1 sample  (no average)
 50 ms/div:   2 samples are averaged
100 ms/div:   4 samples are averaged
200 ms/div:   8 samples are averaged
500 ms/div:  20 samples are averaged
  1  s/div:  40 samples are averaged
  2  s/div:  80 samples are averaged
  5  s/div: 200 samples are averaged
 10  s/div: 400 samples are averaged
 20  s/div: 800 samples are averaged
 50  s/div:2000 samples are averaged
```

Figure 12: Number of samples averaged when enabling the channel AVERAGE option. The device's sampling rate is normally faster than needed to be able to average samples

Channel Math Examples:

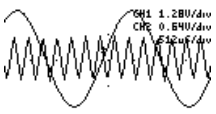


Figure 14: Two signals

Figure 13: CH1+CH2

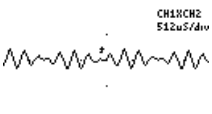


Figure 15: CH1xCH2

TIP

To display CH1+CH2, first invert CH2 and then select the SUBTRACT

4.5 Trigger Settings

The Oscilloscope Watch has an advance triggering system, it has most of the trigger controls of a professional oscilloscope. Figure 16 shows the trigger menus.

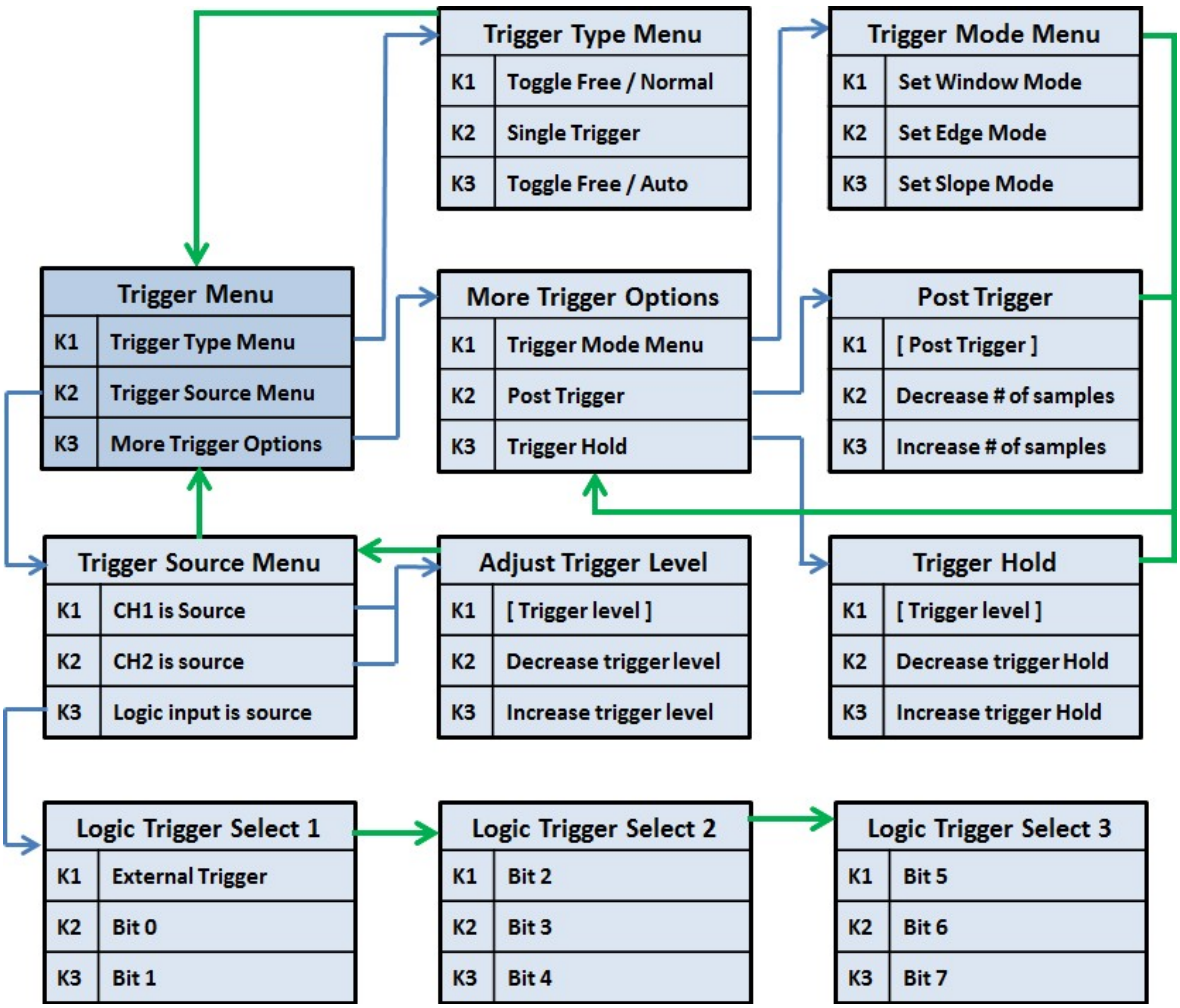


Figure 16: Trigger menus

4.5.1 Trigger Types

There are four different trigger types, which determine when to display the trace on the screen:

- **Normal**: Trace only when the trigger event occurs.
- **Single**: Only one trace is displayed when the trigger event occurs.
- **Auto**: Trace when the trigger event occurs, or after a timeout.
- **Free**: Trace continuously ignoring the trigger.

4.5.2 Trigger Modes

Three triggering modes are available: Edge, Window, and Slope. The Edge and Slope have selectable direction. When selecting an analog trigger source, the trigger direction is changed in the "Adjust Trigger Level" menu, by moving up or down the trigger level. When selecting a digital trigger source, the trigger direction is toggled on every button press.

- **Edge Trigger**: The trigger occurs when the signal crosses the trigger level in a certain direction. The trigger level is represented on the display as a rising (↑), falling (↓) or dual arrow (↕).
  - **Rising edge**: The trigger occurs when the signal crosses the level from below to above.
  - **Falling Edge**: The trigger occurs when the signal crosses the level from above to below.
  - **Dual Edge**: The trigger occurs when the signal crosses the trigger level in any direction.
    To select the Dual Edge mode, deselect Window, Edge, and Slope in the "Trigger Mode Menu", the trigger mark will change to a dual arrow: ↕

TIP **Edge Trigger**:
The signal crosses a level.

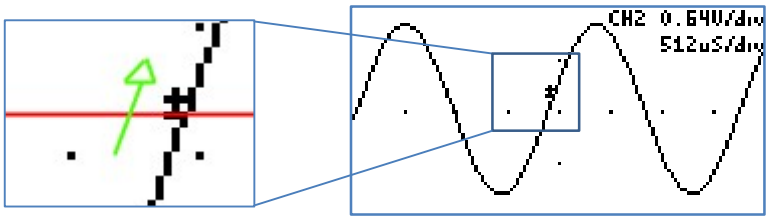


Figure 17: Edge Trigger

- **Window Trigger**: The trigger occurs when the signal leaves a voltage range. This mode is useful for detecting overvoltages or undervoltages. Two arrow trigger marks represent the window levels.

TIP **Window Trigger**:
The signal is outside a range.

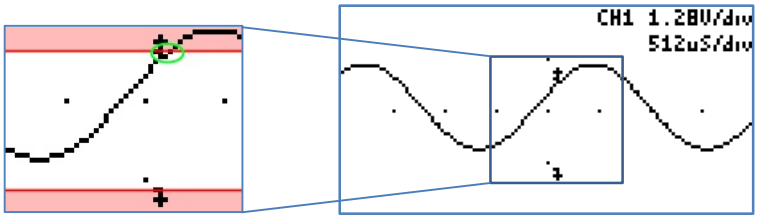


Figure 18: Window Trigger

- **Slope Trigger**: The trigger occurs when the difference between two consecutive samples is greater or lower than a predefined value. This is useful for detecting spikes or for detecting high frequency signals. The trigger mark is represented on the screen as two small lines, with a separation proportional to the trigger value.

TIP **Slope Trigger**:
The difference of two points in the signal is above a value.

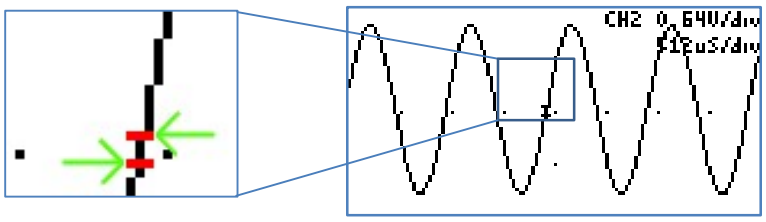


Figure 19: Slope trigger

4.5.3 Trigger Hold

The trigger hold specifies a time to wait before detecting the next trigger. It is useful when the signal can have multiple trigger events occurring close to each other, but you only want to trigger on the first one.

4.5.4 Post Trigger

The oscilloscope is continuously acquiring samples in a circular buffer. Once the trigger event occurs, the oscilloscope will acquire more samples, specified by the Post Trigger value. The ability to show samples before or after the trigger is one of the most powerful features of a digital sampling oscilloscope. The post trigger is only available on the fast sampling rates.

Depending on the post trigger settings, different parts of a signal can be displayed. Consider the signal on figure 20:

Figure 20: Sample signal

Even though the buffer sample is relatively small, any section of the shown figure can be analyzed by varying the post trigger value. Examples:

- Post trigger = 0 (don't acquire more signals after the trigger).
  Only the signals that occurred before the trigger event are shown.

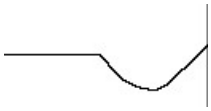


Figure 21: Post trigger value equal zero

- Post trigger = 50% of the sample buffer (default setting).
  Half of the buffer contains samples before the trigger,
  and half contains the samples after the trigger.

Figure 22: Post trigger = 50% of sample buffer

- Post trigger = 100% of the sample buffer
  Only signals immediately after the trigger event are shown.

Figure 23: Post trigger = 100% of buffer

The actual post trigger value can vary between 0 and 32768 samples, so you can explore the signal after a very long time after the trigger event has occurred, but with a high post trigger value, the refresh rate of the scope will be reduced.

4.5.5 Trigger Source

Any analog or digital channel can be the trigger source. If selecting a digital channel as trigger source, the slope and window modes are not applicable; the device will use edge triggering. The external trigger input is an additional digital trigger source which tolerates voltages up to 5.5V.

4.6 Device Modes

There are multiple device modes that can be selected; the menus shown on figure 24 allow selecting the Scope Mode, the Meter Mode or the Spectrum Analyzer Mode (FFT). Another device mode is the Protocol Sniffer, which is discussed in section 3.8.

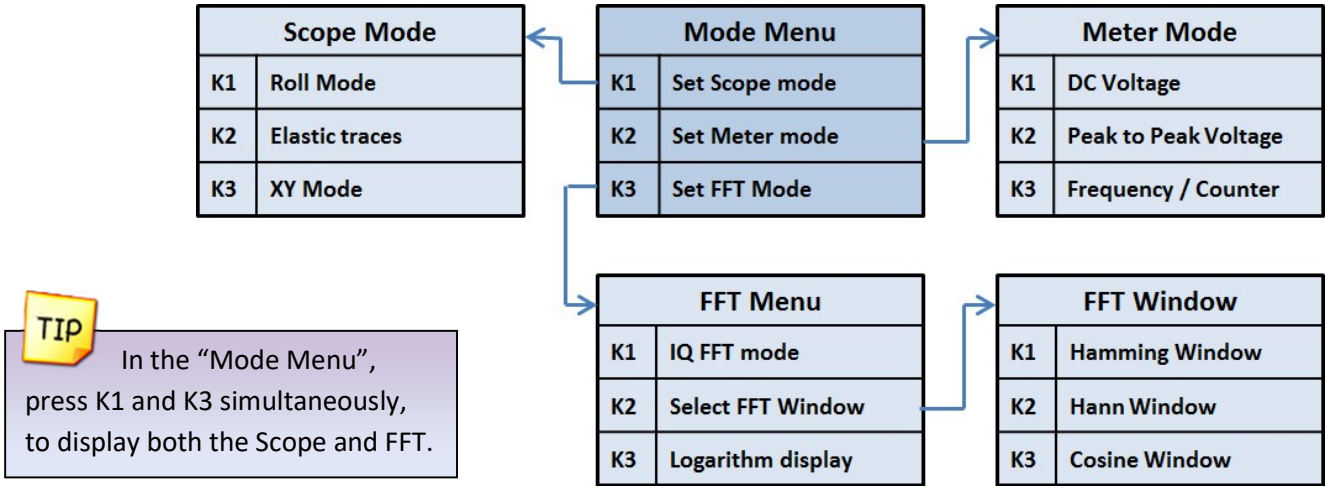


Figure 24: Device mode menus

4.6.1 Oscilloscope Mode

This is the default mode of the XScope. The 2 analog and 8 digital channels are sampled simultaneously. Any of these 10 channels can be shown on the display. Figure 25 shows the oscilloscope mode and the various sections of the display are detailed.

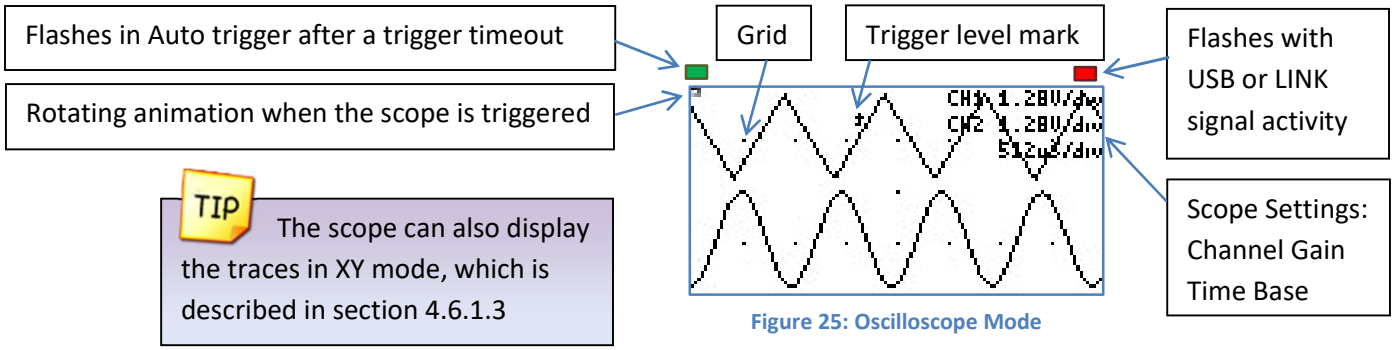


Figure 25: Oscilloscope Mode

4.6.1.1 Roll Mode

The data on the display is scrolled to the left as new data comes in. This is only available on the Slow Sampling rates. The Roll mode and Elastic mode cannot be selected simultaneously. The Roll mode disables the triggering.

4.6.1.2 Elastic Traces

This is also called "Display average" on other digital oscilloscopes. It works by averaging the trace data with the new data. The result is a more stable waveform displayed on the screen. However, using this setting only makes sense when the scope is properly triggered on a periodic signal. The Elastic trace computes this equation for every point in the trace:

$$NewTrace = \frac{OldTrace + NewData}{2}$$

4.6.1.3 XY Mode

The XY mode changes the display from volts vs. time, to volts vs. volts. You can use XY mode to compare frequency and phase relationships between two signals. The XY mode can also be used with transducers to display strain versus displacement, flow versus pressure, volts versus current, or voltage versus frequency. Lissajous figures can be plotted using the XY Mode. Component V/I curves can also be plotted, see section 9.5.

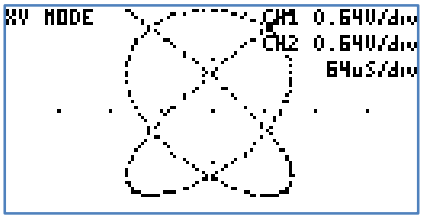


Figure 26: XY Mode

TIP When using the XY modes with a Slow Sampling rate, activating the ROLL mode will display a continuous "beam".

TIP You can use the "Explore Wave" menu to move the graph vertically.

4.6.2 Meter Mode

The XScope can function as a dual digital voltmeter. The font used is bigger in meter mode to facilitate reading. The available measurements in meter mode are: Average Voltage (DC), Peak to Peak Voltage, Frequency, and Pulse counting. A small trace of the analog signals is displayed below the voltage measurements.

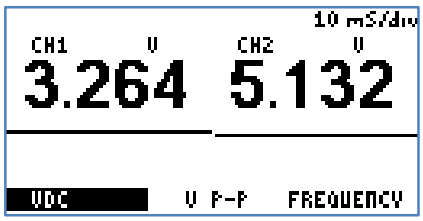


Figure 27: Meter Mode

4.6.2.1 Frequency Measurements

The device can measure frequencies on any channel (analog or digital). The measurements on the analog channels are always shown, and the trigger source (see section 4.5.5) selects which digital channel to measure.

Frequency measurements on the analog channels are done using the FFT of the acquired data, so measured frequencies have discrete steps. The frequency range is determined by the highest frequency of the analog channels. If there is a high frequency on one channel and a low frequency on the other, the channel with the lowest frequency will have low resolution. Frequency measurements with the FFT are best suited for analog signals. Frequency measurements on the digital inputs are done counting the pulses on the pin over one second. The resolution of the measurement is 1Hz. Frequency measurements with the Frequency counter are best suited for digital signals.

	FFT (Analog channels)	Frequency Counter (Digital channels)
Maximum voltage range	-14V to 20V	Logic level range (or Ext. Trig -2.2V to 5.5V)
Maximum Frequency	500kHz	16MHz (or 12MHz on the Ext. Trig)
Resolution	Variable, depending on frequency range. From 6.25Hz to 7.812kHz	1Hz
Signal is noisy, or is mixed with other signals	Finds the fundamental frequency	Not suitable
Signal has a high offset	Still works	Stops working when the offset is above the logic threshold.

Table 6: FFT vs. Frequency Counter

4.6.2.2 Pulse Counter

The device can count the number of pulses on a digital input. The counter will roll over after reaching 99,942,399. The counting can be stopped by stopping the acquisition (K1 button on the main menu). Pressing any button will reset the counter. A stopwatch displays the time since the Pulse Counter started, and can reach 255 hours, 59 minutes, 59 seconds.

4.6.3 Spectrum Analyzer

The spectrum analyzer is done by calculating the Fast Fourier Transform (FFT) of the selected analog channels (or the channel math functions if enabled). When the FFT is enabled, the spectrum is plotted as frequency vs. magnitude. The horizontal axis represents the frequency (Hertz), and the vertical axis represents the magnitude. Figure 28 shows the XScope in Spectrum Analyzer Mode. The Nyquist frequency is shown on the top right corner of the display.

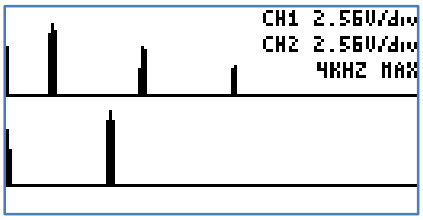


Figure 28: Spectrum Analyzer Mode

TIP

If only interested in one channel, turn off the other channel to maximize the vertical display.

4.6.3.1 IQ FFT Mode

When the IQ FFT is disabled, the XScope calculates two independent 256 point FFTs of the analog channels, the Real and Imaginary components of the FFT have the same data. The output of the FFT is symmetrical, but only half of the result is shown on the display. When the IQ FFT is enabled, only one FFT is calculated, the Real component is filled with the CH1 data, and the Imaginary component is filled with the CH2 data. The result is a 256 point FFT, you can use the horizontal controls described in section 4.3.3 to explore all the data (since only 128 points can be shown on the display). The IQ FFT is useful to monitor RF Spectrums with the proper hardware mixer.

4.6.3.2 Logarithm display

The log is useful when analyzing low level components on the signal. When analyzing audio, it is also very useful as it maps more directly to how humans perceive sound. The actual function performed is: $y = 16 * \log_2(x)$.

Example:

Figure 29: Triangle Wave

Figure 31: FFT without Log

Figure 30: FFT with Log

4.6.3.3 FFT Windows

To reduce the spectral leakage, an FFT window function can be applied. Four FFT window types are available:

- **Rectangular**: No window applied
- **Hamming**: $0.53836 - 0.46164 * COS\left(\frac{2*\pi*n}{FF_N - 1}\right)$
- **Hann**: $0.5 * \left(1 - COS\left(\frac{2*\pi*n}{FF_N - 1}\right)\right)$
- **Blackman**: $0.42 - 0.5 * COS\left(\frac{2*\pi*n}{FFT_N - 1}\right) + 0.08 * COS\left(\frac{4*\pi*n}{FFT_N - 1}\right)$

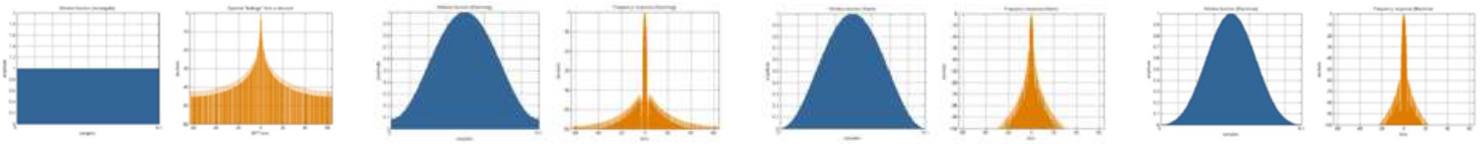


Figure 32: Window and sine frequency response, from left to right: Rectangular, Hamming, Hann and Blackman

4.7 Cursors

You can measure waveform data using cursors. Cursors are horizontal and vertical markers that indicate X-axis values (usually time) and Y-axis values (usually voltage) on a selected waveform source. The position of the cursors can be moved on the respective menu. Figure 33 shows the cursor menus.

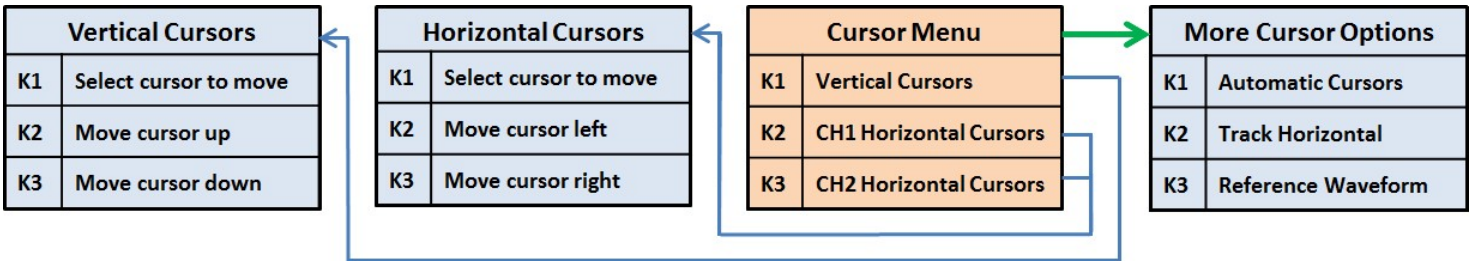


Figure 33: Cursor menus

4.7.1 Vertical Cursors

Time interval measurements are made with a pair of time markers. The oscilloscope automatically calculates the time difference between the two markers and displays the difference as a delta time. Additionally, the oscilloscope calculates the inverse of the delta time, which is the frequency of the selected period.

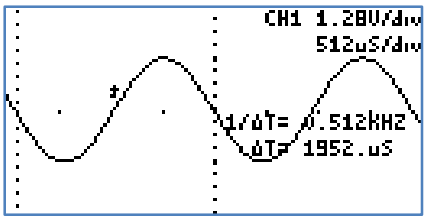


Figure 34: Vertical Cursors

4.7.2 Horizontal Cursors

Voltage measurements are made with a pair of voltage markers to determine 1 or 2 specific voltage points on a waveform. The oscilloscope automatically calculates the voltage difference between the two markers and displays the difference as a delta voltage value.

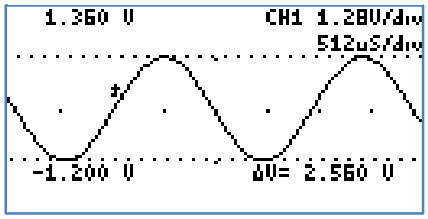


Figure 35: Horizontal Cursors

4.7.3 Automatic Cursors

When the automatic cursors are enabled, the device will try to automatically make measurements on the waveform.

- **Vertical Cursors**: The device will try find a full or half cycle of the selected waveform. If both CH1 and CH2 are enabled, the channel with the most amplitude will be used.
- **Horizontal Cursor**: The selected horizontal cursor will be set with the maximum and minimum points of the waveform.

4.7.4 Track Horizontal Cursors

When Track is enabled, the location of the horizontal cursor will track the signal located on the vertical cursor.

4.7.5 Reference Waveform

A snapshot is taken of the analog waveforms to be used as reference waveforms (the captured waveforms stay on the screen). The reference waveforms are stored in non-volatile memory.

4.7.6 Cursors in XY Mode

When the XY mode is active, the vertical cursors are disabled, and the pair of horizontal cursors represent the X and Y position.

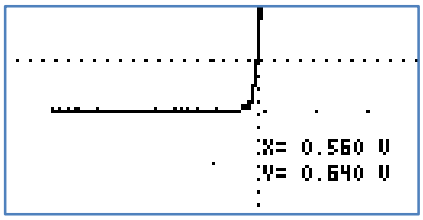


Figure 36: Cursors in XY Mode

4.8 Display Settings

These menus control various characteristics of the display. Figure 37 shows the display menus.

Display Menu	
K1	Persistent display
K2	Toggle Line / Pixel
K3	Show scope settings

More Display Options	
K1	Select Grid Type
K2	Flip Display
K3	Invert Display

Figure 37: Display menus

4.8.1 Persistent Display

When the persistent display is enabled, the waveform traces are not erased. The persistent display is useful as a simple data logger or to catch glitches in the waveform. The persistent mode can also be used to make frequency plots in combination with the AWG frequency sweep.

4.8.2 Line / Pixel Display

This menu item selects the drawing method.

- **Line**: A line is drawn from one sample to the next.
- **Pixel**: A single pixel represents a sample. The pixel display is useful at slow sampling rates or when used in combination with the persistent mode. Figure 38 shows the pixel display.

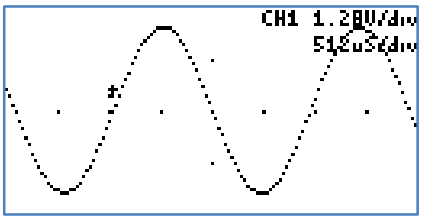


Figure 38: Pixel Display

4.8.3 Show scope settings

Toggles the display of the scope settings (Channel gain and time base).

4.8.4 Grid Type

There are 4 different grid types:

- **No grid**.
- **Dots for each division**: Vertical dots represent the scale divisions. Horizontal dots represent the time base setting and the ground level of each channel.
- **Vertical grid line follow trigger**: Vertical dots represent the position of the trigger, the location of the vertical dots follow the trigger position. Horizontal dots represent the time base setting and the ground level of each channel.
- **Dot graticule**: The screen is filled with dots that represent the vertical and horizontal divisions.

4.8.5 Flip Display

Not applicable in the Oscilloscope Watch.

4.8.6 Invert Display

Not applicable in the Oscilloscope Watch.

5. Logic Analyzer and Protocol Sniffer

The XScope has an 8 bit logic analyzer and can do sniffing on standard protocols: I2C, UART and SPI. The logic inputs are 3.3V level, only the Portable devices are 5V tolerant. If you need to connect 5V signals to the logic analyzer, you could add a 3K resistor in series with the signal, or use a 5V to 3.3V level converter chip. Figure 39 shows the logic menus.

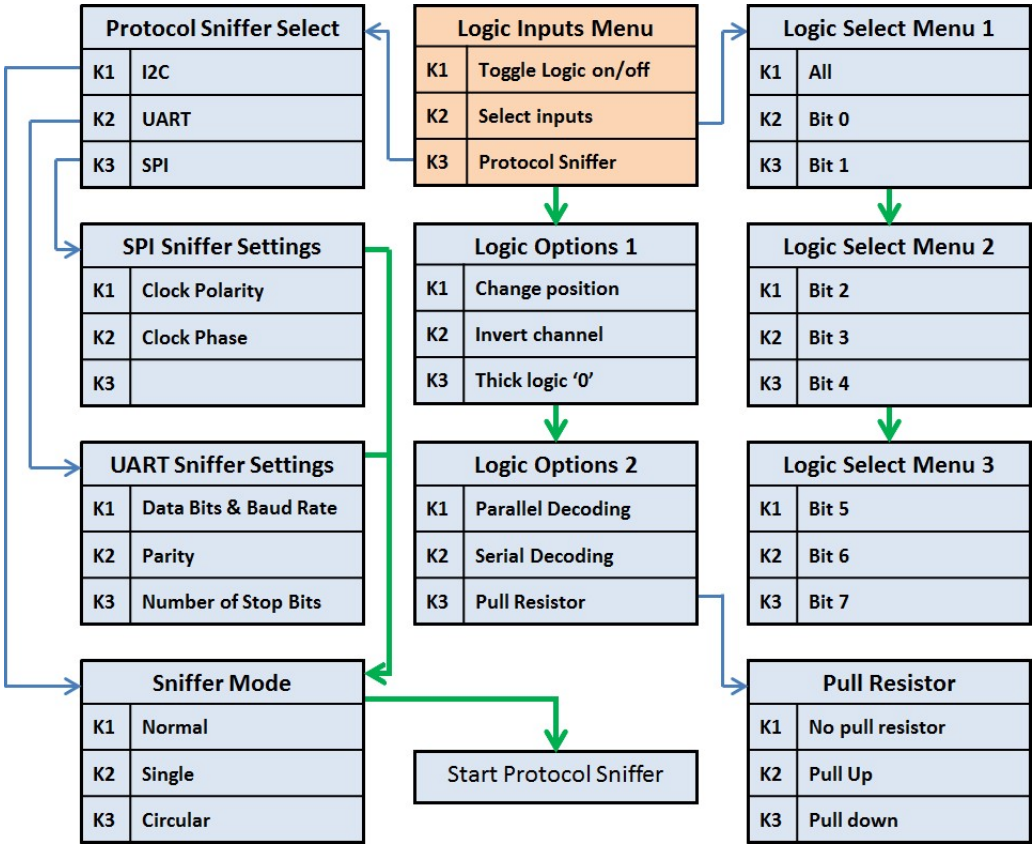


Figure 39: Logic Analyzer Menus

5.1 Input Selection

A subset of the 8 digital signals can be selected. Any digital signal can be enabled or disabled.

5.2 Channel Position

The selected digital channels can be moved up or down. Only applicable if less than 8 digital signals are selected.

5.3 Invert Channel

All digital channels are inverted. This setting also affects the protocol sniffer!

5.4 Thick Logic '0'

A thick line is drawn when the signal is at logic '0'. This is useful to quickly differentiate a '0' from a '1'.

5.5 Parallel Decoding

Shows the hexadecimal value of the 8 bit digital input lines. The hexadecimal number is shown below the last digital trace. If all the 8 digital traces are enabled, then there is no space to show the parallel decoding. Figure 40 shows an example of the parallel decoding with 4 logic lines enabled.

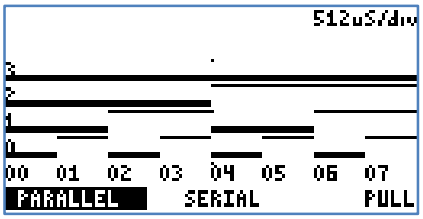


Figure 40: Parallel Decoding

5.6 Serial Decoding

Shows the hexadecimal value of the stream of bits on each channel. The decoding starts at the first vertical cursor and ends at the second vertical cursor, 8 bits are decoded. If the cursors are disabled, then the decoding is done from the start of the screen, to the end. The data can be decoded MSB first or LSB first, depending on the position of the first vertical cursor.

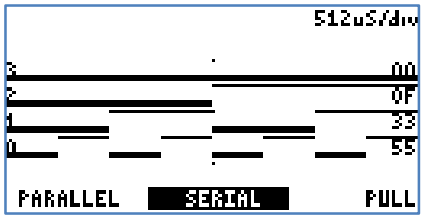


Figure 41: Serial Decoding

5.7 Protocol Sniffer

When the XScope is in Sniffer mode and before any data is received, a brief text appears on the screen to indicate where to hook up the signals. As soon as data is received, the data is displayed in "pages". There are 16 pages of data.
To browse thru the pages, use the buttons K2 and K3. To stop and start the sniffer, press the K1 button. Figure 42 shows the device in sniffer mode.

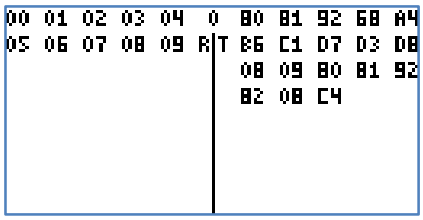


Figure 42: Sniffer

In the UART and SPI sniffers, the data can be displayed in HEX or ASCII, press K2 and K3 simultaneously to toggle between them.

When the ASCII mode is enabled:

- Only codes 0x0A, 0x0D and 0x20 thru 0x7A will show valid characters.
- More information fits the screen but the size of the buffer is the same: The data on each page will double and the number of pages is halved.

Figure 43 shows the 3x6 font.

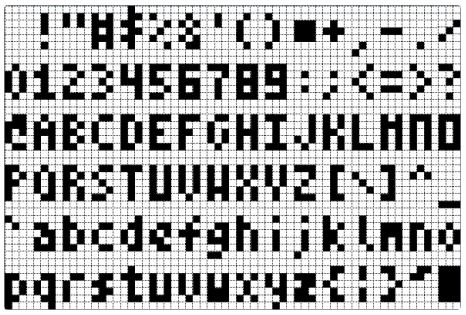


Figure 43: Small 3x6 font (characters 0x20 thru 0x7A)

5.8 Sniffers Modes

- **Normal** mode: Continuous operation, when the buffer is filled, all pages are erased, the index goes back to page 1
- **Single** mode: The sniffer will stop when the buffer is filled.
- **Circular** mode: New data will be placed at the end of the last page, older data will be shifted towards the first page. At the beginning, the device will show 0x00 an all pages, and the last page will be set. The circular mode is useful if you are only interested in the most recent data received.

5.9 I2C Sniffer

Connect SDA to Bit 0, SCL to Bit 1

The XScope implements the I2C sniffing in a bit-bang fashion. The maximum tested clock frequency is 400kHz (Standard I2C Fast Speed). As the data is decoded, the data in HEX will appear on the screen, accompanied by a symbol:

When the Master initiates a read, **<** is an ACK and **(** is a NACK

When the Master initiates a write, **>** is an ACK and **)** is a NACK

Subsequent data in the frame will be accompanied by **+** for ACK or a **–** for NACK.

There are 16 pages of data, each page shows 64 bytes => the total memory for the I2C sniffer is 1024 bytes.

Example communicating to a Si570 Programmable oscillator:

```
55> 07+                    (Master initiates Write to slave 55, byte address 7)
55< 05+ 42+ B6+ 04+ 79+ 9A- (Master initiates Read to slave 55, then reads 6 bytes)
```

5.10 UART Sniffer

Connect RX to Bit 2, TX to Bit 3

The XScope can decode both the TX and RX lines of the UART at the standard baud rates, and with selectable data bits:

5,6,7,8 Data bits / 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200 bps

When the sniffer begins, the screen is split in two, the left side is used for the RX line, and the right side is used for the TX line. Each side can show 40 bytes per page. With 16 pages, a total of 640 bytes can be stored for each decoded line.

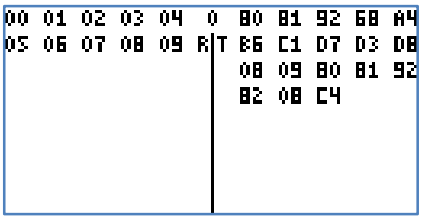


Figure 44: UART Sniffer screen

5.11 SPI Sniffer

Connect the Slave Select to Bit 4, MOSI to Bit 5, MISO to Bit 6, SCK to Bit 7

The XScope can decode both the MOSI and MISO lines of an SPI bus. The SPI's MOSI pin decoding is done in hardware, so it can decode data at high speed (up to 8MHz), but the SPI's MISO pin decoding is implemented in software using bit-banging, the maximum clock is 439kHz. Decoding starts when a falling edge on the SS pin is detected.

Configuration	Leading edge	Trailing edge
CPOL CPHA	Rising, sample	Falling, setup
CPOL CPHA	Rising, setup	Falling, sample
CPOL CPHA	Falling, sample	Rising, setup
CPOL CPHA	Falling, setup	Rising, sample

Table 7: SPI Configuration

The screen is split in two, the left side is used for the MOSI line, and the right side is used for the MISO line. Each side can show 40 bytes per page. With 16 pages, a total of 640 bytes can be stored for each decoded line. Table 7 shows the SPI configuration.

6. Arbitrary Waveform Generator

The XScope has an embedded arbitrary waveform generator. The waveform generator output is independent from the data acquisition and is always running in the background. You can adjust all the parameters of the waveform: frequency, amplitude, offset and duty cycle. You can sweep the frequency, amplitude and duty cycle. Figure 45 shows the AWG Menus.

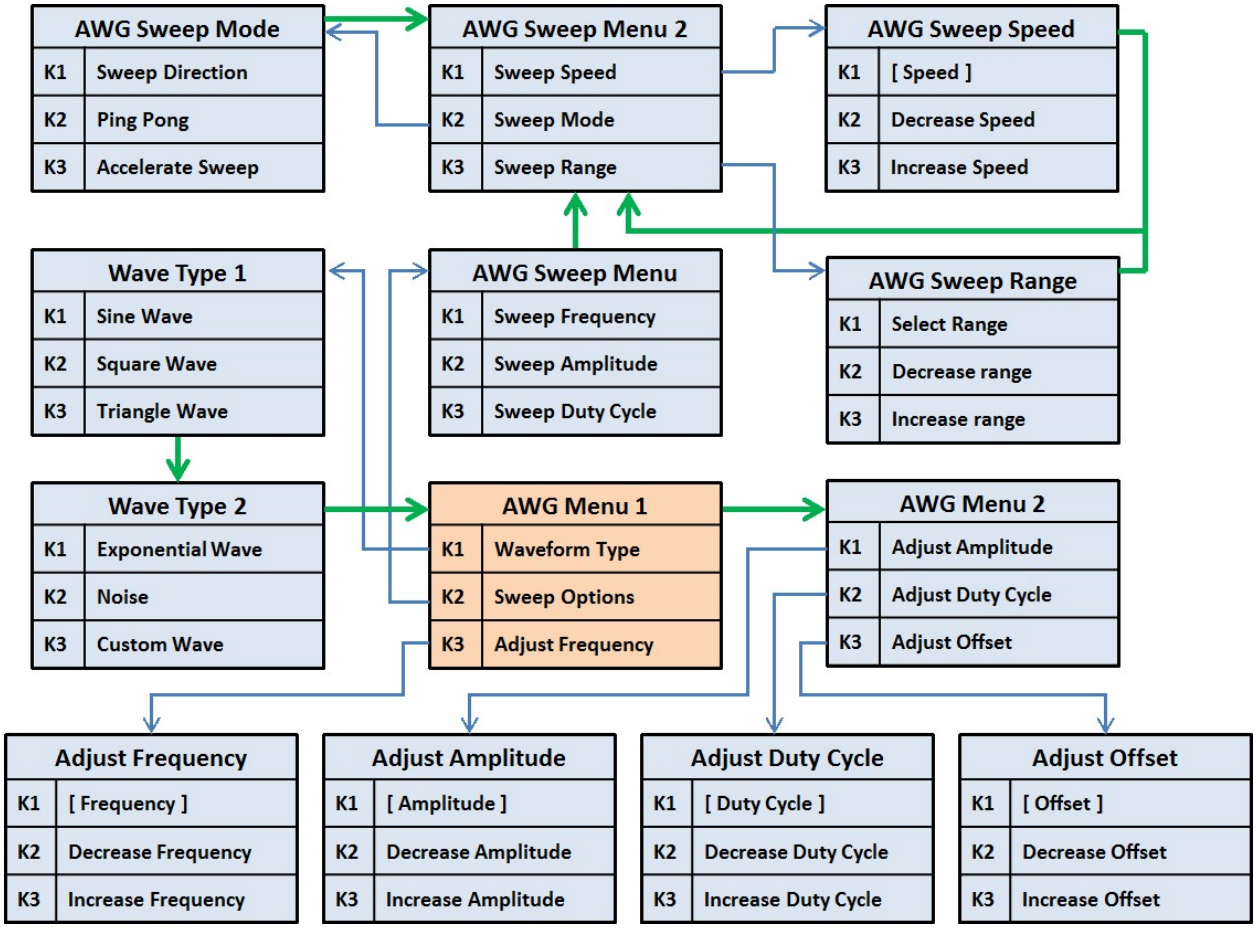
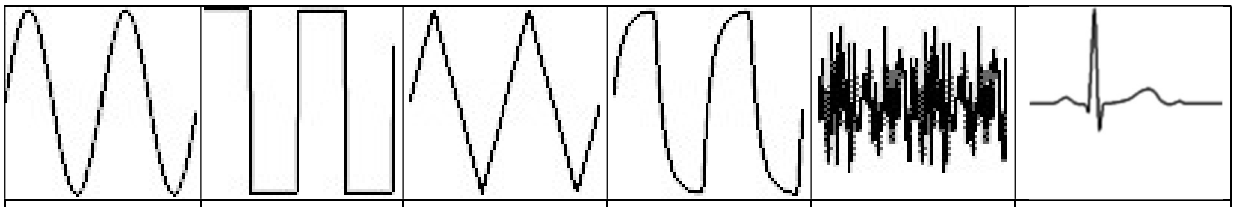


Figure 45: AWG Menus

TIP When adjusting the parameters, the K1 button serves as a shortcut key, which sets predefined values.

TIP When enabling the Sweep, the waveform will be updated only on a screen refresh. For a smooth sweep, set the scope with a high speed sampling, or stop the oscilloscope.

6.1 Predefined Waveforms



Sine Wave	Square Wave	Triangle Wave	Exponential	Periodic Noise	Custom Wave *

Table 8: AWG Preprogrammed Waveforms

The Oscilloscope Watch can output the following waveforms: Sine, Square, Triangle and Exponential. There is a "Periodic Noise" option that fills the AWG buffer with random data, it is periodic because the same data is output over and over, but each time the Noise wave is selected, new random data will be generated. There is also a custom waveform which is initially set with an ECG wave, but can be changed with the PC interface (see section 7.2).

6.2 Parameter Sweep

The XScope has a SWEEP feature, which increases one or more parameter values automatically **on each screen refresh of the oscilloscope**. When the sweep is enabled, three dots will appear at the bottom of the screen, representing the start, end, and current sweep value. When doing a Frequency sweep, the frequency range is determined by the current time base. Since the frequency sweep is synchronized with the oscilloscope, displaying perfect frequency plots is easy. To make a frequency plot, set the mode to FFT, and set the display to persistent. See section 9.6 for an example.

6.2.1 Sweep Modes

In the Sweep Mode menu, the sweep direction can be changed. Automatic change of the direction is done by enabling the Ping Pong mode. The sweep acceleration increases or decreases the sweep speed, the sweep speed is reset when reaching the start or end of the sweep.

6.3 Technical Details

The waveform is stored in a 256 byte long buffer, this buffer is fed to the XMEGA's DAC thru the DMA. Once the waveform is set, the waveform will be generated without any CPU intervention. The maximum conversion rate of the DAC is 1Msps, this limits the maximum output frequency of the AWG as a system. For example, if the AWG is generating a sinewave with 256 points, the maximum frequency is 3906.25Hz. If generating a sinewave with only 32 points, the maximum frequency is 31.25KHz. The AWG amplifier has a low pass filter of 44.1KHz. The predefined AWG Frequency range is: 1Hz thru 125 kHz

The resolution of the waveform generator varies depending on the frequency range: the lower the frequency, the higher the resolution. Note that the possible frequencies are discrete:

$$Frequency = Cycles * \frac{125000}{Period}$$

Cycles: Integer number, with these possible values: 1, 2, 4, 8, 16, 32
Period: Integer number, with values between 32 and 65535

7. PC Interface

The Oscilloscope Watch can interface with a PC (Linux, Mac, or Windows). Make sure to have the latest firmware on the device to properly communicate with the latest software. The device needs to be updated with the latest firmware. The Oscilloscope Watch only enables its USB interface when in Oscilloscope mode.

7.1 Connecting the device

The XScope can communicate to a PC thru the USB port. When the application starts, it will try to connect automatically.

7.1 Controlling the device

All of the functions described previously in this manual can be controlled with the PC interface. The main operating modes of the device can be selected by switching to the corresponding tab of the interface. Figure 46 shows a snapshot of the device in the Oscilloscope mode.

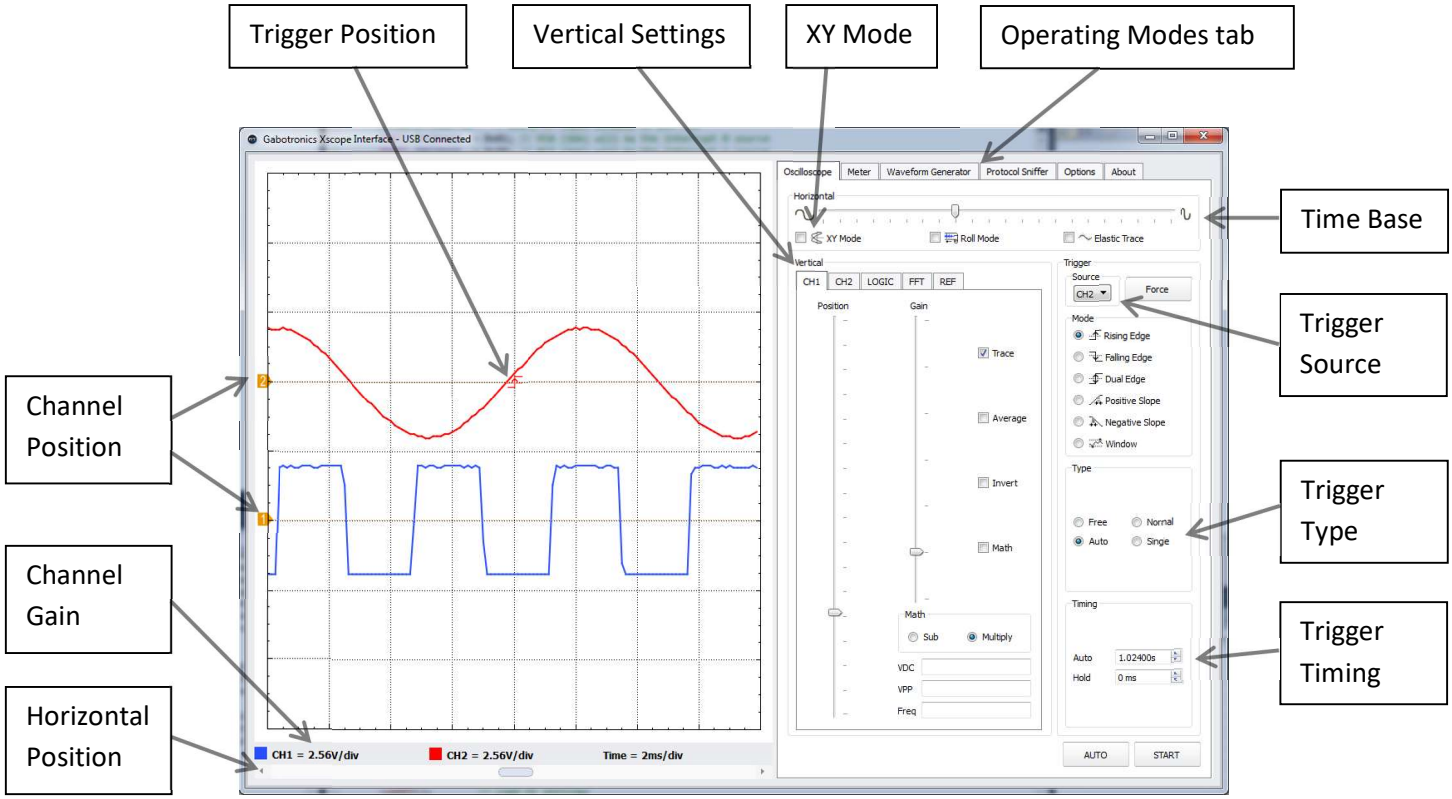


Figure 46: PC Interface

7.2 Custom AWG Waveform

You can define your own waveforms for the AWG. On the Waveform Generator tab, click "Open CSV" and select your CSV file, then click "Save as Custom", the waveform will be permanently saved in the device's EEPROM memory. When creating a CSV file, the range of the data must be [-127, 127], and there should be only 256 numbers.

7.3 Saving Waveforms and Screenshots

On the Options tab there are buttons to save and load waveforms, as well as saving screenshots of the graph area in PNG format. When saving a waveform or screenshot, the program will ask for a destination folder only once, and then use this folder for subsequent files. When opening a waveform, the "Clear" button must be pressed to continue normal operation.

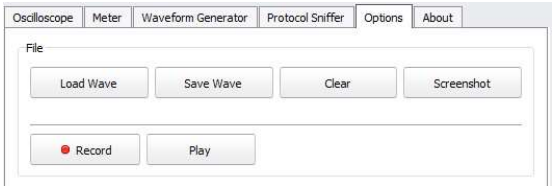


Figure 47: File operations

The Record button allows saving waveforms continuously. The Play button is used to playback a recording.

8. Interface Protocol

The Oscilloscope Watch can communicate to external devices thru the USB. Each interface can access the Xscope's main settings. Follow the protocols to make your own applications, or to make devices that attach to the XScope.

8.1 Interface settings

If using the USB interface, you can use WinUSB or LibUSB libraries. The USB device's endpoints have a size of 64 bytes. The device uses BULK IN transfers on endpoint 1 for transferring data (770 bytes in SCOPE mode: CH1, CH2, CHD, FRAME and INDEX; 1289 bytes in SNIFFER mode), BULK OUT transfers on endpoint 1 to write to the AWG RAM buffer (256 bytes), and CONTROL READ transfers on endpoint 0 for changing and reading settings. The FRAME and INDEX are variables used to check the flow of the data. They are also needed if you want to implement the ROLL mode.

The **FRAME** will increase whenever a full buffer has been acquired. For the fast sampling rates, this will occur all the time. Ideally, when you read data, the FRAME will increment by 1 every time. If you see that the FRAME has incremented by more than 1, then you are not reading data fast enough and missing frames of data. In the slow sampling rates, since you can read faster than the acquisition, the FRAME will help you determine if you are reading from the same frame.

The **INDEX** is not used in the fast sampling rates. For the slow sampling rates, it indicates the current position in the buffer. For example, if you set the Xprotolab at 1S/div, you will see on the display that the samples start filling the screen from left to right. The index represents this position. So for the slow sampling rates, the FRAME and INDEX can help you determine if you need to erase the screen, and you are able to show more data on the screen (similar to the Xprotolab screen).

8.2 Control Data

All XScope's settings are stored in 44 bytes, table 10 shows these variables, table 11 describes the bitfield variables.

Index	Name	Data Type	Description	Notes
0	Srate	Unsigned 8bit	Sampling Rate	Range: [0, 21] 8 us/div to 50 s/div
1	CH1ctrl	Bit Field 8bit	Channel 1 controls	
2	CH2ctrl	Bit Field 8bit	Channel 2 controls	
3	CHDctrl	Bit Field 8bit	Logic Analyzer Options 1	
4	CHDmask	Bit Field 8bit	Logic enabled bits	Selects which logic channels are displayed
5	Trigger	Bit Field 8bit	Trigger control	
6	Mcursors	Bit Field 8bit	Cursor Options	
7	Display	Bit Field 8bit	Display Options	
8	MFFT	Bit Field 8bit	FFT Options	
9	Sweep	Bit Field 8bit	AWG Sweep Options	
10	Sniffer	Bit Field 8bit	Sniffer Controls	
11	MStatus	Bit Field 8bit	Scope Status	
12	CH1gain	Unsigned 8bit	Channel 1 gain	Range: [0,6] 5.12V/div to 80mV/div
13	CH2gain	Unsigned 8bit	Channel 2 gain	Range: [0,6] 5.12V/div to 80mV/div
14	HPos	Unsigned 8bit	Wave Position	Range: [0,127] pixels
15	VcursorA	Unsigned 8bit	Vertical Cursor A	Range: [0,127] pixels
16	VcursorB	Unsigned 8bit	Vertical Cursor B	Range: [0,127] pixels
17	Hcursor1A	Unsigned 8bit	CH1 Horizontal Cursor A	Range: [0,127] pixels
18	Hcursor1B	Unsigned 8bit	CH1 Horizontal Cursor B	Range: [0,127] pixels
19	Hcursor2A	Unsigned 8bit	CH2 Horizontal Cursor A	Range: [0,127] pixels
20	Hcursor2B	Unsigned 8bit	CH2 Horizontal Cursor B	Range: [0,127] pixels
21	Thold	Unsigned 8bit	Trigger Hold	Range: [0,255] 0 to 255 milliseconds
22	Tpost L	Unsigned 16bit	Post Trigger, default is 128	Range: [0, 32767] Indicates how many samples to wait after the trigger.
23	Tpost H			
24	Tsource	Unsigned 8bit	Trigger Source	0: CH1; 1: CH2; 2-9: CHD; 10: External Trigger
25	Tlevel	Unsigned 8bit	Trigger Level	Range: [3,252]
26	Window1	Unsigned 8bit	Windows Trigger Level 1	Range: [0,255]
27	Window2	Unsigned 8bit	Windows Trigger Level 2	Range: [0,255]
28	Ttimeout	Unsigned 8bit	Trigger Timeout	Range: [3,255] 0.16384s to 10.48576s
29	CH1pos	Signed 8bit	Channel 1 Position	Range: [-128,0] pixels
30	CH2pos	Signed 8bit	Channel 2 Position	Range: [-128,0] pixels
31	CHDpos	Unsigned 8bit	Logic Analyzer position	Range: [0,7]
32	CHDdecode	Unsigned 8bit	Selected Protocol	0: SPI; 1: I2C; 2: RS232
33	Sweep1	Unsigned 8bit	Sweep Start	Range: [0,255]
34	Sweep2	Unsigned 8bit	Sweep End	Range: [0,255]
35	SWSpeed	Unsigned 8bit	Sweep Speed	Range: [0,127]
36	AWGamp	Signed 8bit	AWG Amplitude	Range: [-128,0] 4V to 0V
37	AWGtype	Unsigned 8bit	AWG Wave Type	0: Noise; 1: Sine; 2: Square; 3: Triangle; 4: Custom
38	AWGduty	Unsigned 8bit	AWG Duty Cycle	Range: [1,255] 0.391% to 99.61%
39	AWGoffset	Signed 8bit	AWG Offset	Range: [-128,127] +2V to -1.985V
40	desiredF LLB	Unsigned 32bit	AWG Desired Frequency multiplied by 100	Range: [100, 12500000] 1Hz to 125kHz
41	desiredF LHB			
42	desiredF HLB			
43	desiredF HHB			

Table 9: Xscope's settings

8.2.1 Bitfield variables

Name	Bits	Notes
CH1ctrl and CH2ctrl Index 1 Index 2	Bit 0: Channel on	
	Bit 1: x10 probe	For future hardware
	Bit 2: Derivative	
	Bit 3: AC/DC select	
	Bit 4: Invert channel	
	Bit 5: Average samples	
	Bit 6: Math Active	Enables math (addition or multiplication)
	Bit 7: Math operation	Subtract (1) or Multiply (0)
CHDctrl Index 3	Bit 0: Channel on	
	Bit 1: Pull	Pull resistor enabled
	Bit 2: Pull Up	Pull up (1) or pull down (0)
	Bit 3: Low	Thick line when logic '0'
	Bit 4: Invert channel	
	Bit 5: Serial Decode	
	Bit 6: Parallel Decode	
	Bit 7: ASCII Sniffer display	
Trigger Index 5	Bit 0: Normal Trigger	
	Bit 1: Single Trigger	The Normal Trigger bit must also be enabled for Single Trigger
	Bit 2: Auto Trigger	
	Bit 3: Trigger Direction	
	Bit 4: Round Sniffer	
	Bit 5: Slope Trigger	
	Bit 6: Window Trigger	
	Bit 7: Edge Trigger	Dual Edge Trigger is enabled by clearing bits 5,6,7.
Mcursors Index 6	Bit 0: Roll Scope	
	Bit 1: Automatic Cursors	
	Bit 2: Track Cursors	
	Bit 3: CH1 Horizontal Cursors on	CH1 and CH2 Horizontal cursors are mutually exclusive
	Bit 4: CH2 Horizontal Cursors on	CH1 and CH2 Horizontal cursors are mutually exclusive
	Bit 5: Vertical Cursor on	
	Bit 6: Reference waveform on	
	Bit 7: Single Sniffer Capture	
Display Index 7	Bit 0: Grid 0	00: No Grid, 01: Dots per division 10: Follow trigger, 11: Graticule
	Bit 1: Grid 1	
	Bit 2: Elastic Display	
	Bit 3: Invert Display	
	Bit 4: Flip Display	
	Bit 5: Persistent Display	
	Bit 6: Line / Pixel Display	Line (1), Pixels (0)
	Bit 7: Show Settings	

Name	Bits	Notes	
MFFT Index 8	Bit 0: Hamming Window	Only one window must be selected, or none for No Window.	
	Bit 1: Hann Window		
	Bit 2: Blackman Window		
	Bit 3: Vertical Log		
	Bit 4: IQ FFT		
	Bit 5: Scope Mode	Multiple modes can be selected simultaneously. If no bits are set, the Meter mode is displayed.	
	Bit 6: XY Mode		
	Bit 7: FFT Mode		
Sweep Index 9	Bit 0: Acceleration Direction		
	Bit 1: Accelerate Sweep		
	Bit 2: Sweep Direction		
	Bit 3: Ping Pong Mode		
	Bit 4: Sweep Frequency		
	Bit 5: Sweep Amplitude		
	Bit 6: Sweep Offset		
	Bit 7: Sweep Duty Cycle		
Sniffer Index 10	Bit 0: Baud 0	UART Sniffer Baud Rates: 000: 1200 , 001: 2400, 010: 4800, 011: 9600, 100: 19200, 101: 38400, 110: 57600, 111: 115200	
	Bit 1: Baud 1		
	Bit 2: Baud 2		
	Bit 3: Uart 0	UART Data bits: 00: 5 Bits , 01: 6 Bits , 10: 7 Bits , 11: 8 Bits	
	Bit 4: Uart 1		
	Bit 5: Parity Mode / SS Invert	Enables UART parity check	SPI Invert Slave Select
	Bit 6: Parity / CPOL Clock Polarity	UART Parity Odd (1), Parity Even (0)	SPI Clock Polarity
	Bit 7: Stop Bit / CPOH Clock Phase	1 Stop bit (0), 2 Stop bits (1)	SPI Clock Phase
MStatus Index 11	Bit 0: Update	Exits triggering if the bit is set	
	Bit 1: Update AWG	The AWG parameters must be updated if the bit is set	
	Bit 2: Update MSO	The MSO parameters must be updated if the bit is set	
	Bit 3: Go Sniffer	Enters the Sniffer mode if the bit is set	
	Bit 4: Stop	Oscilloscope Stopped	
	Bit 5: Triggered	Oscilloscope Triggered	
	Bit 6: Meter VDC	If both bits are cleared, the Meter mode measures Frequency. If both bits are set, the Meter mode counts Pulses.	
	Bit 7: Meter VPP		

Table 10: Bitfield variable description

8.3 Vendor ID and Product ID

If you are using LibUSB to interface with the device, you need: VID=16D0 PID=06F9
If you are using WinUSB, you will need the GUID defined on the driver's .inf file:
GUID= 88BAE032-5A81-49f0-BC3D-A4FF138216D6

8.4 Command Set

When using the USB interface, the commands are sent as CONTROL READ requests, where the packet's request byte is the command, and the packet's Index and Value are additional parameters sent to the XScope. If the PC is requesting data, it will be returned in the endpoint 0 IN buffer. Table 12 shows the XScope Interface Protocol Commands.

Command	Description	Device Response / Notes
a	Request firmware version	The device returns 4 characters with the version.
b	Writes a byte to the XScope's Settings, at the specified index. If the Index is below 14, the updatemso bit is automatically set. If the Index is above 34, the updateawg is automatically set.	When using the USB interface, the setup packet's Index contains the index, and the setup packet's Value contains the data. When using the using the Serial interface, two additional bytes must be sent containing the index and data.
c	Sets the desired AWG Frequency (32bits).	When using the USB interface, the Index contains the lower 16bits, the Value contains the high 16bits. When using the Serial interface, 4 additional bytes must be sent in little endian format.
d	Save XScope's Settings in EEPROM	
e	Save AWG wave stored in RAM to EEPROM	
f	Stop Scope	
g	Start Scope	
h	Force Trigger	
i	Auto Setup	
j	Sets the desired Post Trigger value (16bits)	USB interface: the Value contains the 16bits. When using the Serial interface, 2 additional bytes must be sent in little endian format.
k	Restore factory settings	
m	Request METER measurement data	The device sends 4 bytes in little endian format. See the description in section 8.4.2 below.
p	Disable Auto send (Serial interface only)	Not implemented in the Oscilloscope Watch
q	Enable Auto send (Serial interface only)	Not implemented in the Oscilloscope Watch
u	Request settings	All the settings (44 bytes) are sent to the PC.
w	Request EE waveform (Serial interface only)	EE Wave data (256 bytes)
x	Send waveform data (Serial interface only)	'G' character, signals the PC that the device is ready, Then the PC sends the data (256 bytes), Then the device sends a 'T' character, which signals the PC that the data was received.
C	Request BMP (Serial interface only)	128x64 Monochrome BMP using the XModem protocol

Table 11: XScope Command Set

8.4.1 Auto Send

When the Auto send is active, the device will continuously send the channels data to the serial port. The "`Channels Sent`" byte is an ASCII number that represents which channels were sent, Channel 1 will add 1 to the number, Channel 2 will add 2, and the logic port will add 4. For example, if all channels are sent, the "`Channels Sent`" will be the character '7'.

Fast Sampling	0x0D	0x0A	'F'	Data	0x0A	0x0D	Channels sent
Slow Sampling	0x0D	0x0A	'S'	Data	0x0A	0x0D	Channels sent

Table 12: Auto Send Packet Format

8.4.2 METER measurement data

The METER mode must be enabled in order to receive valid data; the data sent will depend on which METER mode is selected. In the VDC mode, the Channel data is in 16bit signed format, the value represents the millivolts divided by 1.25. In the Frequency Counter mode, the data is in 32bit unsigned format, which represents the counter value.

	VDC	FREQUENCY
Byte 0	Channel 1 LB	Freq. Cnt. byte 3
Byte 1	Channel 1 HB	Freq. Cnt. byte 2
Byte 2	Channel 2 LB	Freq. Cnt. byte 1
Byte 3	Channel 2 HB	Freq. Cnt. byte 0

Table 13: METER data

9. XScope's Examples

9.1 Resistor Voltage Divider

1) Build the circuit shown on figure 48.
2) Set the device to Meter mode
3) You should see similar voltages as shown on figure 49.

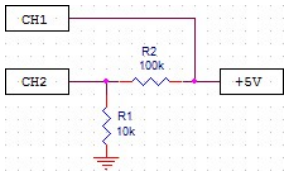


Figure 48: Resistor divider

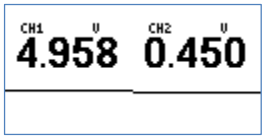


Figure 49: Meter mode

Theory of operation: The circuit is a voltage divider, where Vin is 5V, and Vout is the voltage at CH2: $\boldsymbol{Vout = \frac{Vin * R1}{R1 + R2}}$

9.2 Measurement of an RC time constant

1) Build the circuit shown on figure 51.
2) Set the time base to 500µs/div.
3) Set the AWG to Square wave, 500Hz, 4V.
4) Set the gain on both channels to 2.56V/div.
5) The display should look similar to figure 50.
6) Now set the time base to 16µs/div.
7) Turn off CH1, set the CH2 gain to 1.28V/div.
8) Adjust the horizontal and CH2 positions so that the rising wave takes most of the screen.
9) Turn on the vertical and CH2 horizontal cursors.
10) Enable the cursors TRACK option.
11) Set the first vertical cursor at the corner of the wave, and the second cursor where the voltage equals 0V.
12) The display should look like figure 53. The measured time $T_{1/2} = 69\mu s$, is the "half-life" time, so $RC = 99.95\mu s$

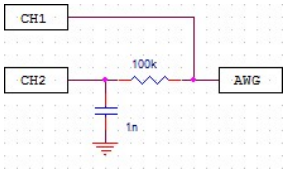


Figure 51: RC Circuit

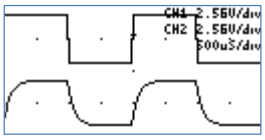


Figure 50: RC Measurements

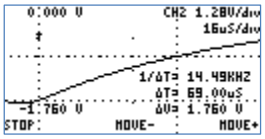


Figure 53: Half-life measurement

$$V_c = V_0(1 - e^{-\frac{t}{RC}})$$

$$RC = \frac{T_{1/2}}{\ln(2)}$$

Figure 52: RC Equations

Theory of operation: Circuit theory shows that if the RC circuit is fed with a step input, the output will approach a DC value exponentially; figure 52 shows the equation from which we can obtain RC when the half-life value is known.

9.3 Half Wave Rectifier with Smoothing Capacitor

1) Build the circuit shown on figure 55.
2) Set the time base to 2mS/div.
3) Set the AWG to Sine wave, 125Hz, 4V.
4) Set the gain on both channels to 1.28V/div.
5) The display should look like figure 54.
6) If the capacitor is removed, the display should look like figure 56.

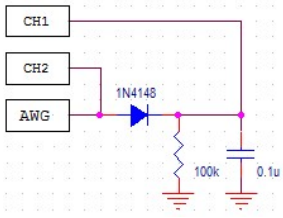


Figure 55: Half wave rectifier circuit

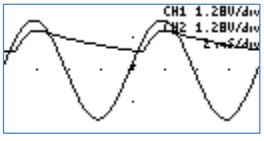


Figure 54: Half wave rectifier

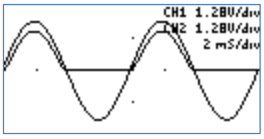


Figure 56: Removing the capacitor

Theory of operation: The diode will allow current to flow only during the positive half of the sine wave. The output voltage is a little bit lower because of the voltage drop of the diode. When the AWG voltage is negative, the diode acts like an open circuit and the capacitor discharges thru the resistor at an exponential rate.

9.4 BJT Amplifier

1) Build the circuit shown on figure 58.
2) Set the time base to 2ms/div
3) Move the position on both channels all the way down (GND reference grid is at the bottom of the screen).
4) Set CH1 to 0.32V/div, Set CH2 to 1.28V/div.
5) Set the AWG to Sine wave, 125Hz, 0.250V amplitude.
6) Increase the AWG offset until the CH2 wave is centered on the display. The display should look like figure 57.

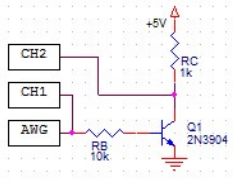


Figure 58: Amplifier circuit

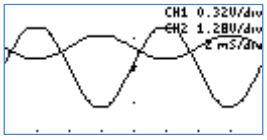


Figure 57: BJT Measurements

Theory of operation: The transistor needs to be biased in its forward active region; this is what the offset in the AWG is for. The output voltage will vary according to the BJT transfer curve: changes in the input make large changes in the output.

9.5 Component V/I Curves

1) Build the circuit shown in figure 61, or flip the CURVE switch on the Portables.
2) On the Portables, flip the input switches to the DC position.
3) Set the time base to 500µs/div.
4) Set the AWG to Sine wave, 125Hz, 4V.
5) Set the gain on both channels to:
   0.64V/div, or 1.28V/div on the Portables.
6) Enter the CH2 options and select SUBTRACT.
7) Set the device oscilloscope in XY mode.

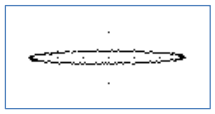


Figure 59: 100nF Capacitor curve

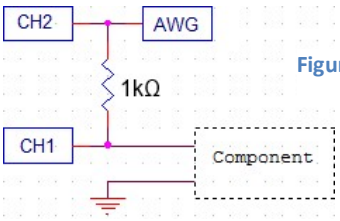


Figure 61: Component tester

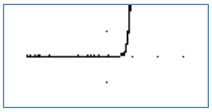


Figure 60: 1N4148 curve

Theory of operation: The goal is to plot the component's voltage, versus the component's current. Using the integrated waveform generator and a 1kΩ resistor, we can inject current into the component. The voltage is measured directly using CH1. The current thru the component is the same as the current thru the resistor, the voltage on the resistor is proportional to the current. The voltage on the resistor is equal to CH2-CH1. 1V on the scope will represent 1mA on the component. Figure 59 and figure 60 show examples of V/I curves on components.

9.6 Frequency Plots

The AWG sweep function can be used to plot the frequency response of a circuit. This method is not directly a BODE plot since the horizontal axis is linear, not logarithmic.

1) Connect the AWG to the input and CH1 to the output.
2) Set the device to FFT mode.
3) Change to the desired time base. The maximum frequency is shown on the top right of the display.
4) Set the AWG to Sine Wave.
5) Enable the Frequency Sweep.
6) Set the AWG Sweep range to 1:255
7) Set the display to persistent.

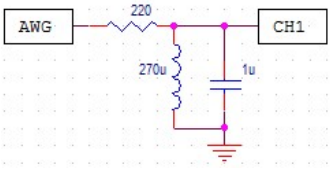


Figure 62: RLC Circuit

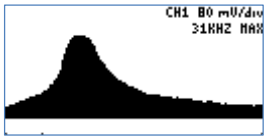


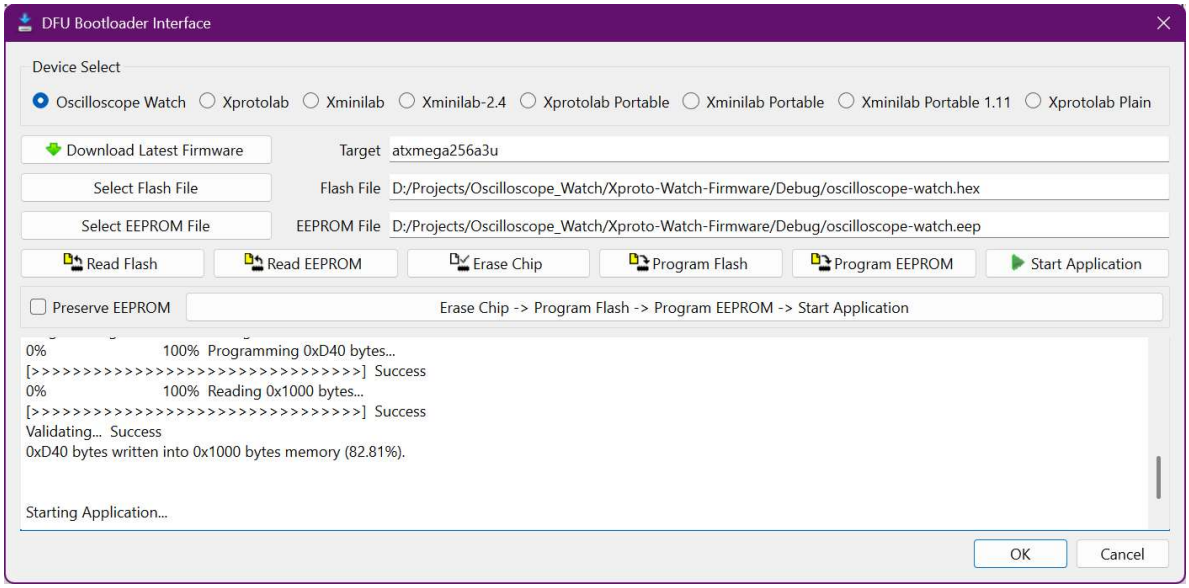
Figure 63: Frequency plot

Figure 62 shows an RLC circuit, and figure 63 shows the frequency response. This example shows the vertical scale with the LOG disabled.

10. Firmware Updating

The firmware can be upgraded thru the USB port. Download the XScope Qt6 software and follow these instructions:

- Connect the watch to the PC using a USB cable.
- Press the KUL, KUR and KML buttons simultaneously to enter Bootloader mode. You will see a message on the device's screen that says "OSCILLOSCOPE WATCH BOOTLOADER".
- The device's red LED will be lit when communicating to the PC.
- If you wish exit bootloader mode, press the KBL and KBR buttons simultaneously.
- Start the XScope Qt6 software and go to Tools -> Upgrade Firmware.
- Check the "Preserve EEPROM" if you wish to keep the device's settings (although a major firmware upgrade may change the EEPROM layout requiring to write its data again).
- Select "Oscilloscope Watch", press "Download Latest Firmware" and click the giant button "Erase -> Program Flash -> Program EEPROM -> Start Application".



10.1.1 Alternative programming methods

The firmware can also be programmed using these alternative software:

- Atmel's FLIP software: https://www.microchip.com/en-us/development-tool/flip
- AVRDude: https://github.com/avrdudes/avrdude
- Microchip Studio using the PDI interface. A PDI programmer is required, as well as physical access to the PDI pins, requiring disassembling the device.

HEX and EEP files for the device, found on the Oscilloscope Watch page (Look for the HEX icon).
https://www.gabotronics.com/categories/products/oscilloscope-watch.html

11. Frequently Asked Questions

1) What tools do I need to develop my own programs on the Oscilloscope Watch?
If you don't need debugging capabilities, only a regular cable is needed to program the device. If you want to be able to debug your code, you need an external debugger, such as the AVR JTAGICE mkII or the AVR ONE!.

Software Tools:

- Integrated Development Environment: Microchip Studio

2) Can the waveform generator and the oscilloscope run simultaneously?
Yes, the waveform generator runs on the background. (The AWG uses the DMA, so it doesn't need any CPU intervention).

3) Can I connect the Oscilloscope Watch to the computer to control the oscilloscope and get the data?
Yes, you can use the XScope PC Interface, but only in Oscilloscope mode.

4) Can I connect the Oscilloscope Watch to the computer using the USB for firmware updates?
Yes.

5) What is the maximum frequency that I can measure with the Oscilloscope Watch?
The analog bandwidth is set at 200kHz. However, you can still measure frequencies up to almost Nyquist/2, i.e. 1MHz. The FFT analysis will be particularly useful when measuring high frequencies. For digital signals, you can measure up to 16MHz.

6) Can I measure voltages above 20V?
The portable XScopes can use a 3.5mm to BNC adapter, and then you could use a standard 10:1 probe. On the non-portable devices, you can add a 9Mohm resistor in series to the input. Since the input impedance of the device is 1Mohm, the voltage will is divided by 10 (This is the equivalent of using a 10:1 probe).

7) Are the logic inputs 5V tolerant?
Yes.

8) Where can I find the source code for the Oscilloscope Watch?
The full source code can be found on GitHub: https://github.com/ganzziani/Xproto-Watch-Firmware

9) I tried updating the firmware using the USB bootloader. It didn't work and now the device does not start.
The bootloader should still be functional. Try resetting the computer and try the procedure again, step by step.

10) How does the XScope compare to other digital oscilloscopes?
You can check this comparison table: http://www.gabotronics.com/resources/hobbyists-oscilloscopes.htm

12. Troubleshooting

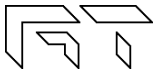
1) The Oscilloscope Watch does not power up!
Try to charge the device, if nothing appears on the display, try updating the firmware..

2) Something went wrong during the USB updating, now my portable device doesn't even get recognized by the PC.
Try entering bootloader mode again and reprogramming with the correct firmware.

3) The unit powers up but the MSO is not working.
Try restoring the default settings: From the Home menu, go to the Oscilloscope menu, then select Profile, then select "Restore".

4) The oscilloscope data seems incorrect.
The device may be low on battery, fully recharge the device.

5) My enclosure broke, can I 3D print one myself?
You can find the STL files at: https://makerworld.com/en/models/3091298-oscilloscope-watch-enclosure.



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