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XScopes | User's Manual

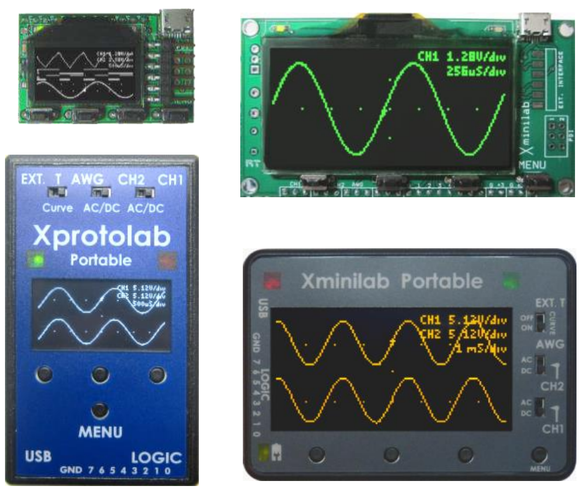

Figure 1: Xprotolab, Xminilab, and the Portable models

Description:

The XScopes (Xminilab and Xprotolab) are a combination of three electronic instruments: a mixed signal oscilloscope, an arbitrary waveform generator, and a protocol sniffer; all housed in a small breadboard friendly module. The XScopes can also be used as development boards for the AVR XMEGA microcontroller.

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, I^2C, 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.

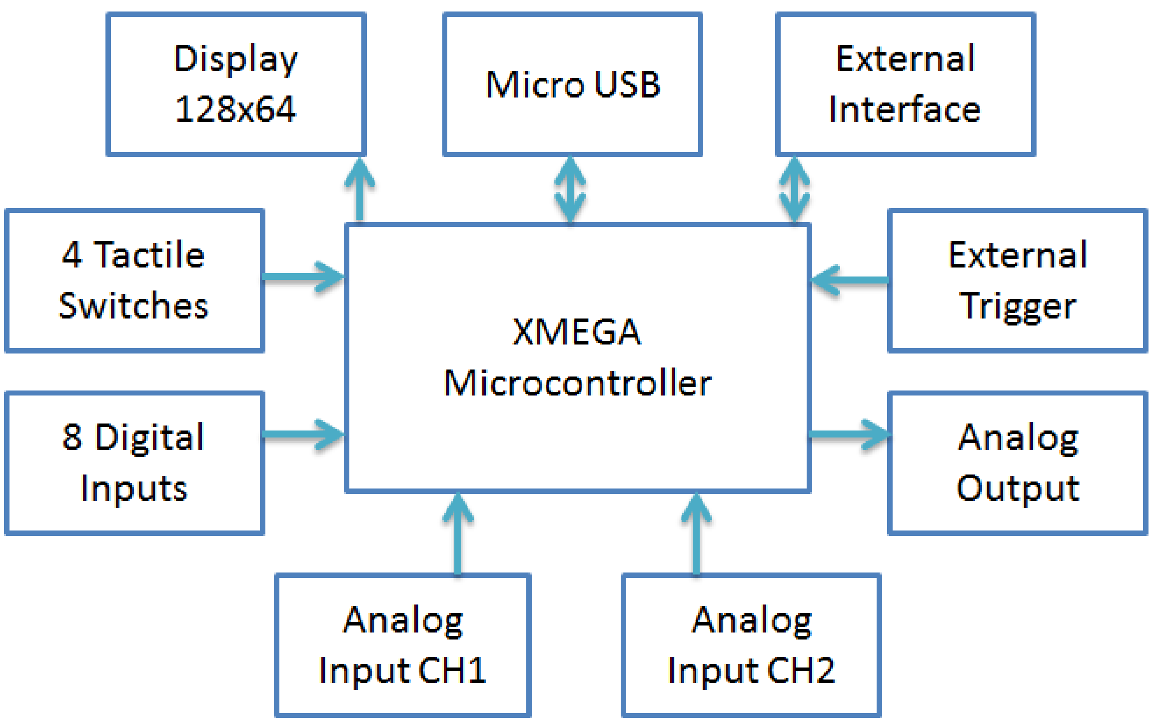

Figure 2: XScopes Block Diagram

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 XScopes, the user should be familiar with the operation of a regular oscilloscope.

The features documented in this manual are for units with firmware version 2.40+.

Conventions

XScope: Xprotolab, Xminilab, Xprotolab Portable or Xminilab Portable.
Portables: Xprotolab Portable or Xminilab Portable
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

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1. General Overview

1.1 Xprotolab & Xminilab Pin Description

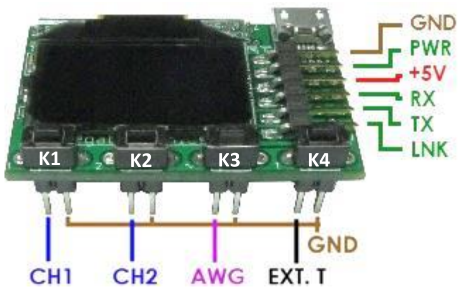


Figure 4: Front and Top Signals

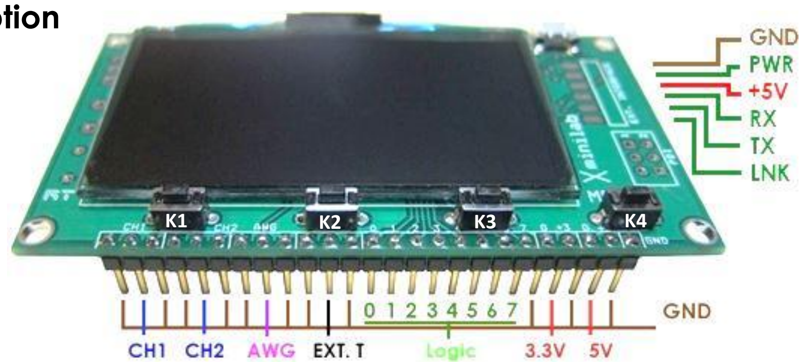


Figure 3: Xminilab HW 2.1 & 2.2 Front Signals

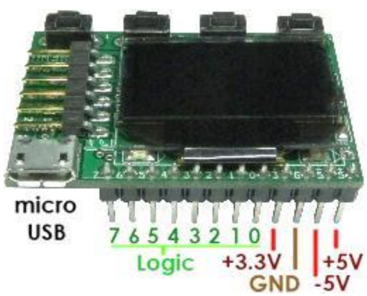


Figure 5: Back Signals

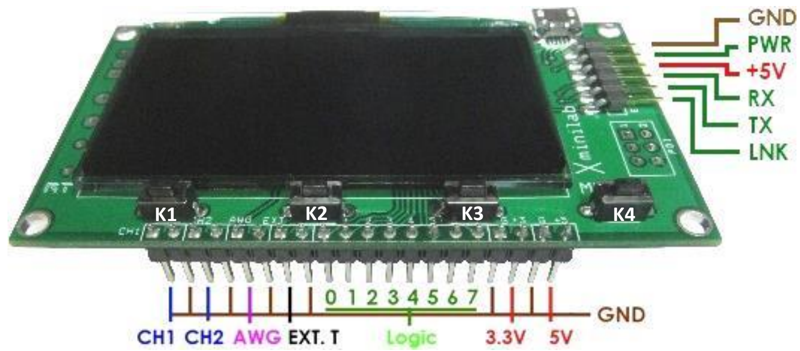


Figure 6: Xminilab HW 2.3 Front Signals

Name	Description	Comment
+5V	+5V Input voltage	Do not apply +5V if using the USB port
-5V	-5V Output voltage	50mA max output
GND	Ground	It is recommended use all ground pins to reduce voltage offset errors.
+3.3V	+3.3V Output voltage	200mA max output
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: +/- 2V
CH2	Analog Channel 2	Input range: -14V to +20V
CH1	Analog Channel 1	Input range: -14V to +20V
PWR	Power up output signal	3.3V signal, 10mA max output
RX	Interface RX input	Connect to host's TX
TX	Interface TX output	Connect to host's RX
LNK	Interface link input	3.3V level input, with internal pull up

Table 1: Pin description

1.2 Xprotolab Portable and Xminilab Portable Overview

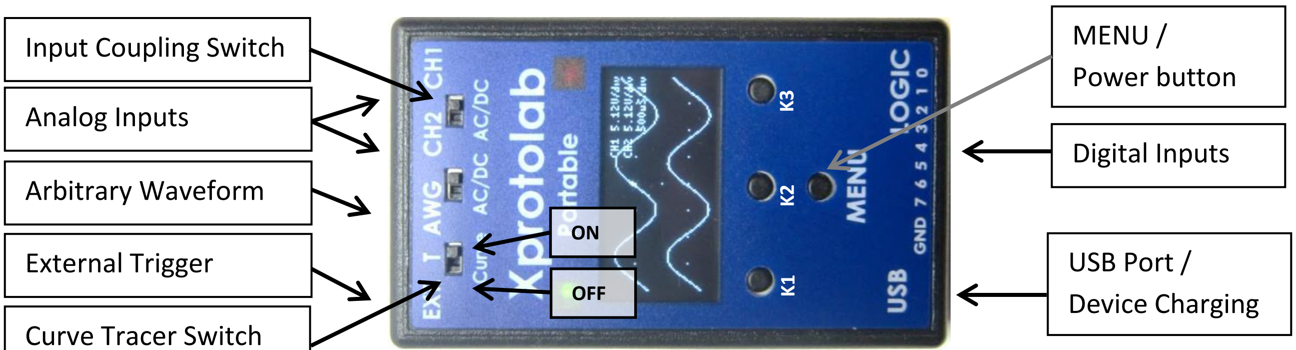


Figure 7: Xprotolab Portable

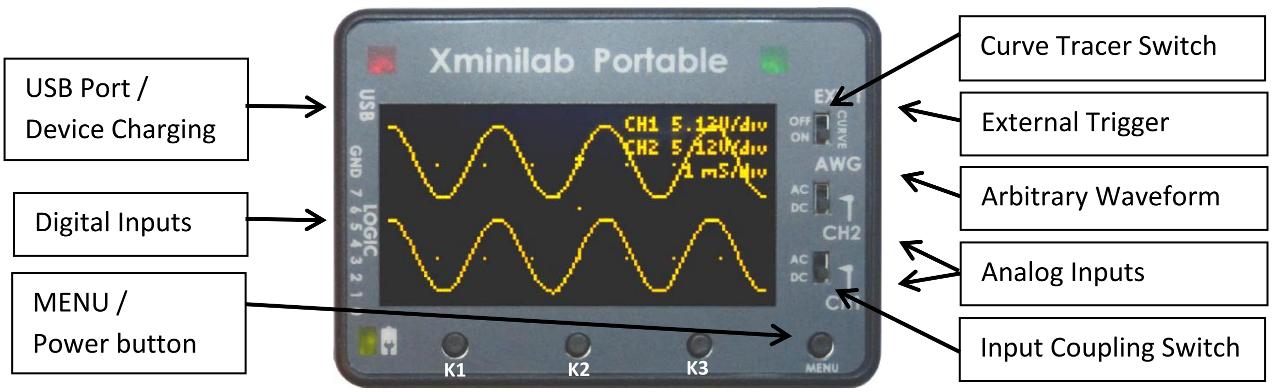


Figure 8: Xminilab Portable

1.2.1 Input Coupling Switch

The coupling switch is electrically placed between the input connector and the oscilloscope's input amplifier. The switch selects a direct path for DC or AC measurements, or a path thru a capacitor, for AC only measurements.

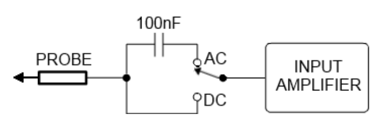


Figure 9: Input Coupling Switch

1.2.2 Curve Tracer Switch

This switch connects the AWG to the input channels, this is used in particular for creating V/I curve traces. An example of setting the device for curve tracing is showed in section 8.5.

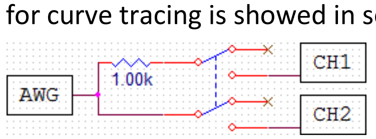


Figure 10: Curve Tracer Switch

Do not connect CH2 to a voltage source while the CURVE switch is on. Damage to the device will occur.

1.2.3 MENU / Power button

The device is powered on by pressing the MENU button. To power off, press the MENU button for 2 seconds. Some of the device modes disable this command, so to power off, set the device in Scope mode. The device is also powered off when the shutdown timer expires (regardless of the device mode).

1.2.4 USB Port / Device Charging

The USB port is also used to charge the device. The device can be charged either when the powered on or off. When the device is powered off, the battery can be fully charged in about 2 hours.

1.3 Specifications

		Xprotolab	Xminilab	Xprotolab Portable	Xminilab Portable
					
General	Microcontroller	ATXMEGA32A4U 32KB+4KB Flash, 4KB SRAM, 1KB EEPROM			
	Display Type	Graphic OLED, 128x64 pixels, max. refresh rate 122Hz			
	Display Size	0.96 inches	2.42 inches	1.3 inches	2.42 inches
	Display Life Time	10,000 hours min.	40,000 hours min.	10,000 hours min.	40,000 hours min.
	Device size	1.615" x 1.01"	3.3" x 1.75"	1.83" x 3.13" x 0.7"	3.17" x 2.22" x 0.7"
	Weight	8.6 grams	25 grams	60 grams	75 grams
	Interfaces	4 Tactile Switches, USB (Micro USB connector), UART, PDI for debugging			
	Battery	N/A		Li-Ion 3.7V 600mAh	Li-Ion 3.7V 750mAh
	Active current[1]	40mA to 60mA	45mA to 75mA	40mA to 60mA	45mA to 75mA
	Sleep current	3.6mA		1uA	
Logic Analyzer	Logic Inputs	8 Digital Inputs			
	Logic Input levels	3.3V only		3.3V, 5V tolerant	
	Input Pull	None, 24kΩ Pull Up, or 24kΩ Pull Down		820kΩ Pull Down	
	Max. Sampling rate	2Msps			
	Buffer Size	256			
	Frequency Counter	16MHz, 1Hz resolution, +/- 100ppm accuracy			
	Sniffer Protocols	UART, I2C, SPI			
Oscilloscope	Analog Inputs	2 Analog Inputs			
	Max. Sampling rate	2Msps			
	Analog Bandwidth	200kHz			
	Resolution	8 bits			
	Input Impedance	1MΩ			
	Buffer size	256 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	+/- 2V		+/- 4V	
	Low Pass Filter	44.1kHz		53kHz	

Table 2: XScopes Specifications

Notes: 1. The Active current varies depending on the number of pixels lit on the display.

1.4 Dimensions

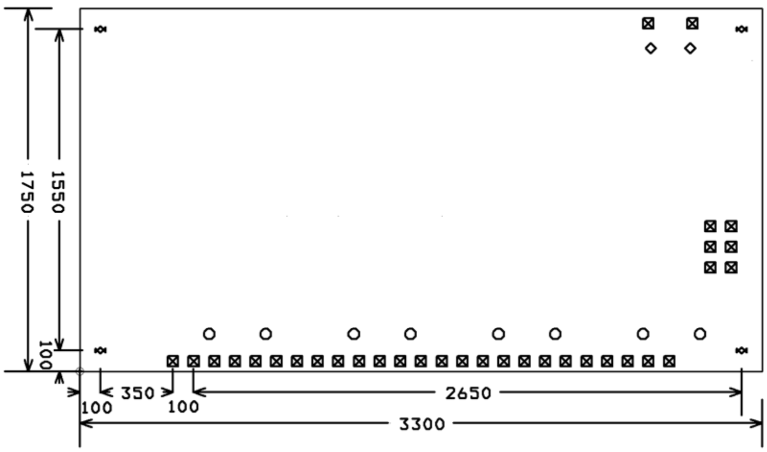


Figure 12: Xminilab 2.1 & 2.2 Dimensions

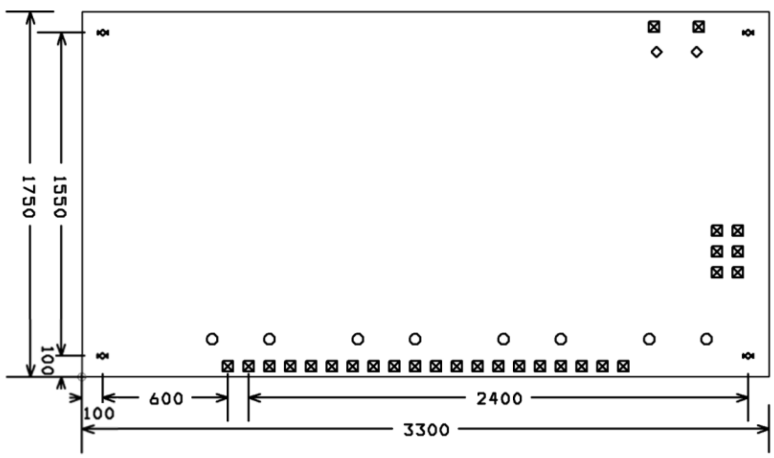


Figure 13: Xminilab 2.3 Dimensions

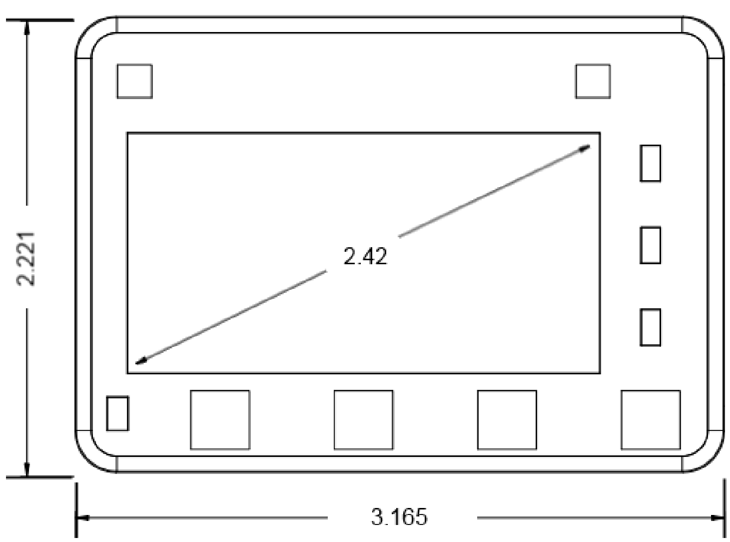


Figure 15: Xminilab-Portable Dimensions

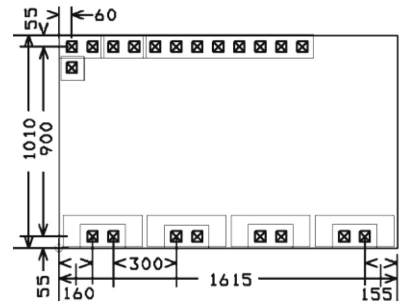


Figure 11: Xprotolab Dimensions

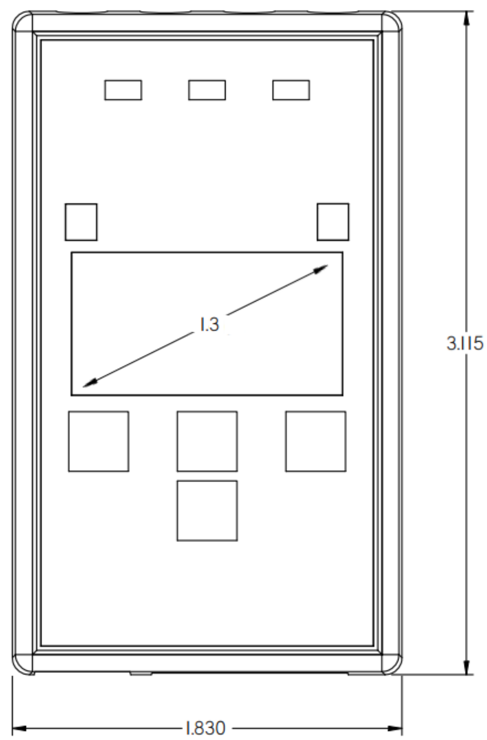


Figure 14: Xprotolab-Portable Dimensions

1.5 Absolute Maximum Ratings

	Xprotolab & Xminilab		Portable Variants		
Parameter	Minimum	Maximum	Minimum	Maximum	Unit
Supply Voltage (+5V)	-0.5	5.5	N/A (Battery Powered)		V
Analog Inputs[1]	-30	30	-180	180	V
Digital Inputs	-0.5	3.8	-0.5	5.5	V
External Trigger	-3.5	6.8	-3.5	6.8	V
Operating Temperature	-40	70	-40	70	°C
Storage Temperature	-40	80	-40	80	°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.

1.6 Factory Setup

The device can enter factory options if the MENU key is pressed during power up. The following options are available:

1) Offset calibration: The unit is calibrated before being shipped, but calibration is required again if the firmware is updated. During calibration, two graphs are shown that represent the calibration on each channel.
2) Shut off timeout: Sets the time to shut down the device after the last key has been pressed. On the non-portable devices, it will only shut off the display and put the microcontroller to sleep.
3) Restore defaults: Select this function to restore to the default the settings. There are many settings on the device, if you are not familiar with them, this function is useful to set the device to a known state.

1.7 Quick Start Guide

- Take the device out of the packaging. There is a protective film on the display which can be removed.
- Power on the device. The non-portable devices can be powered with either the USB or with an external power supply, by applying +5V on the corresponding pin. Double check your connections because the device WILL get damaged if applying power on the wrong pin. The portable variants are powered with the MENU button.
- Connect the AWG pin to CH1. On the portable variants, you can flip the Curve switch instead.
- The tactile switches are named (from left to right) K1, K2, K3 and K4. The K4 is the Menu button.
- Press and hold the K1 key (auto setup). The screen should look like figure 16.
- Pressing K2 or K3 will change the sampling rate.

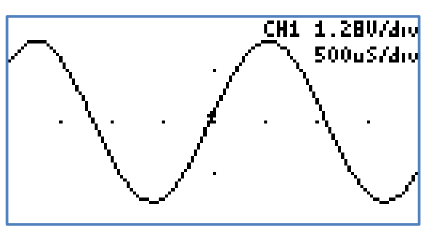
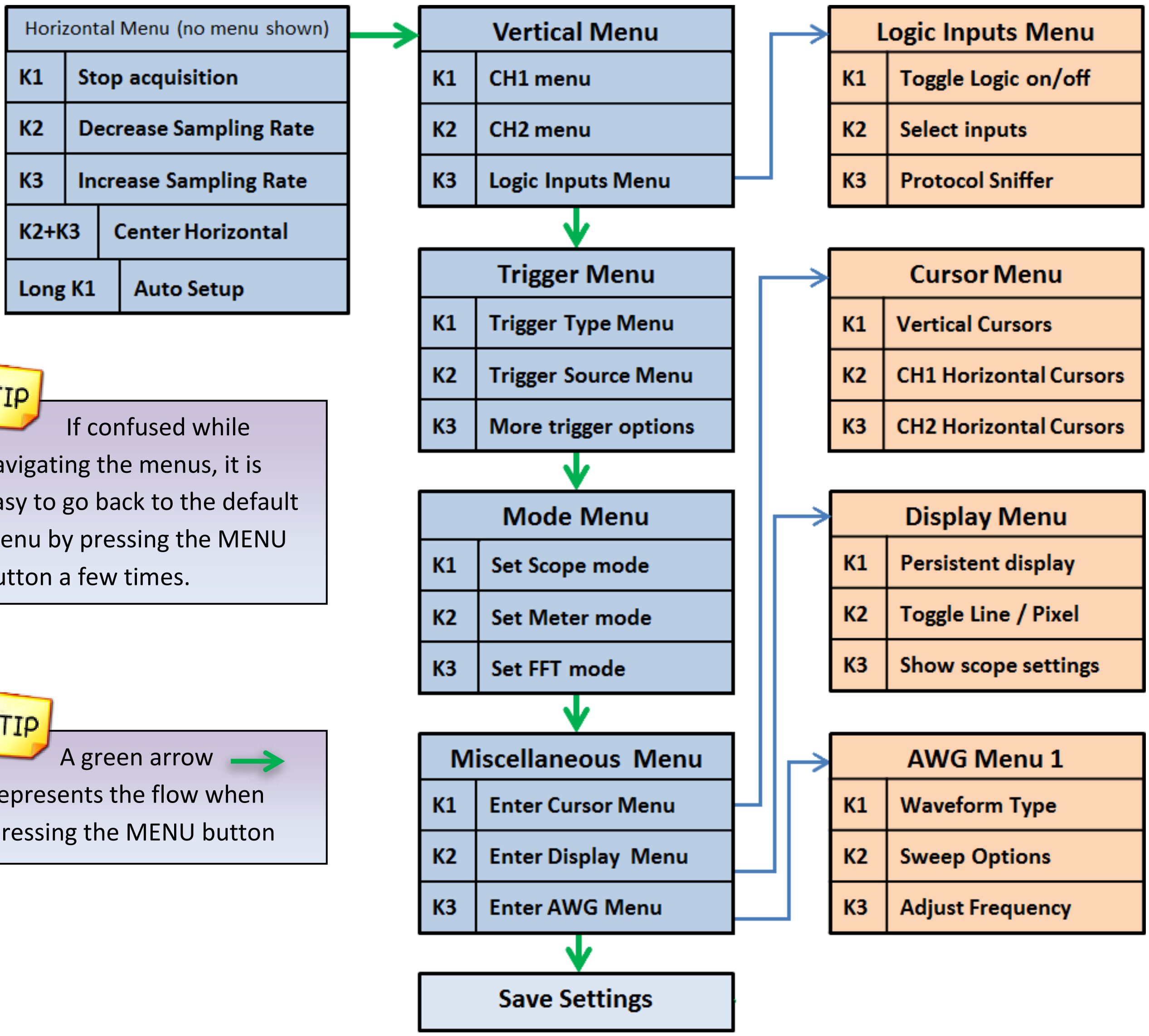


Figure 16: Quick start

TIP Additional examples on how to use the device are presented in chapter 8.

1.8 User Interface

The K4 button is the MENU button, used to navigate thru all the menus. The K1 - K3 buttons action depend on the current menu. The green arrows represent the flow when pressing the MENU button. When the MENU button is pressed on the last menu, the device settings are saved and the menu goes back to the default. Figure 17 shows the main menus in blue and some secondary menus in yellow. Further ramifications are shown on the respective chapters.



> **TIP** If confused while navigating the menus, it is easy to go back to the default menu by pressing the MENU button a few times.

> **TIP** A green arrow → represents the flow when pressing the MENU button

Figure 17: Main Menus

1.9 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.

2. 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 3.

2.1 Horizontal Settings

The horizontal settings are controlled on the default menu. The menu is shown on figure 18.

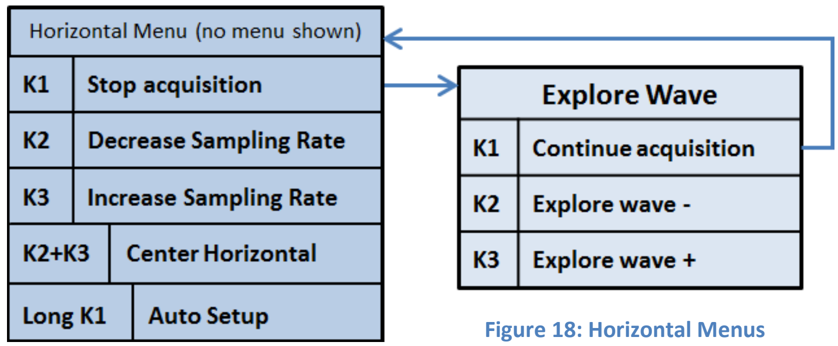


Figure 18: Horizontal Menus

2.1.1 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 *At 8µs/div, CH2 is not displayed.

2.1.2 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)

2.1.3 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).

2.1.4 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.

2.2 Vertical Settings

The analog channel controls are discussed in this section. Figure 19 shows the Vertical menu flow.

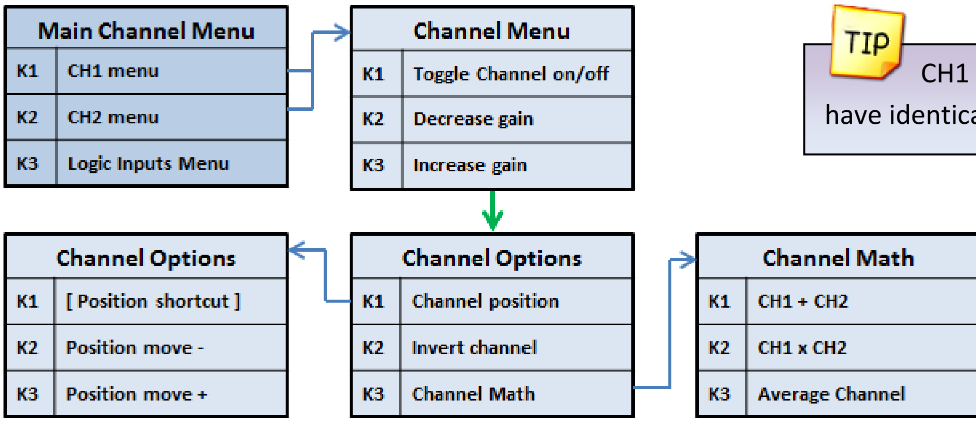


Figure 19: Vertical menus

TIP: CH1 and CH2 have identical settings.

2.2.1 Disable Channel

Any channel can be disabled; this is useful to reduce clutter on the display.

2.2.2 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

2.2.3 Channel Position

The position of the waveform can be moved up or down in the Channel Position menu.

2.2.4 Channel Invert

The channel can be inverted. The displayed waveform and channel calculations will be affected.

2.2.5 Channel Math

- Subtract: The channel trace will be replaced with the difference.
- Multiply: The channel trace will be replaced with the product.
- Average: The channel samples will be averaged to reduce aliasing. (See Figure 20).

Channel Math Examples:

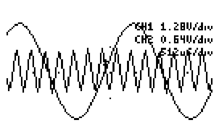


Figure 22: Two signals

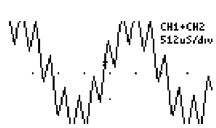


Figure 21: CH1+CH2

Figure 23: CH1xCH2

```
  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 20: 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

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

2.3 Trigger Settings

The XScope has an advance triggering system, it has most of the trigger controls of a professional oscilloscope. Figure 24 shows the trigger menus.

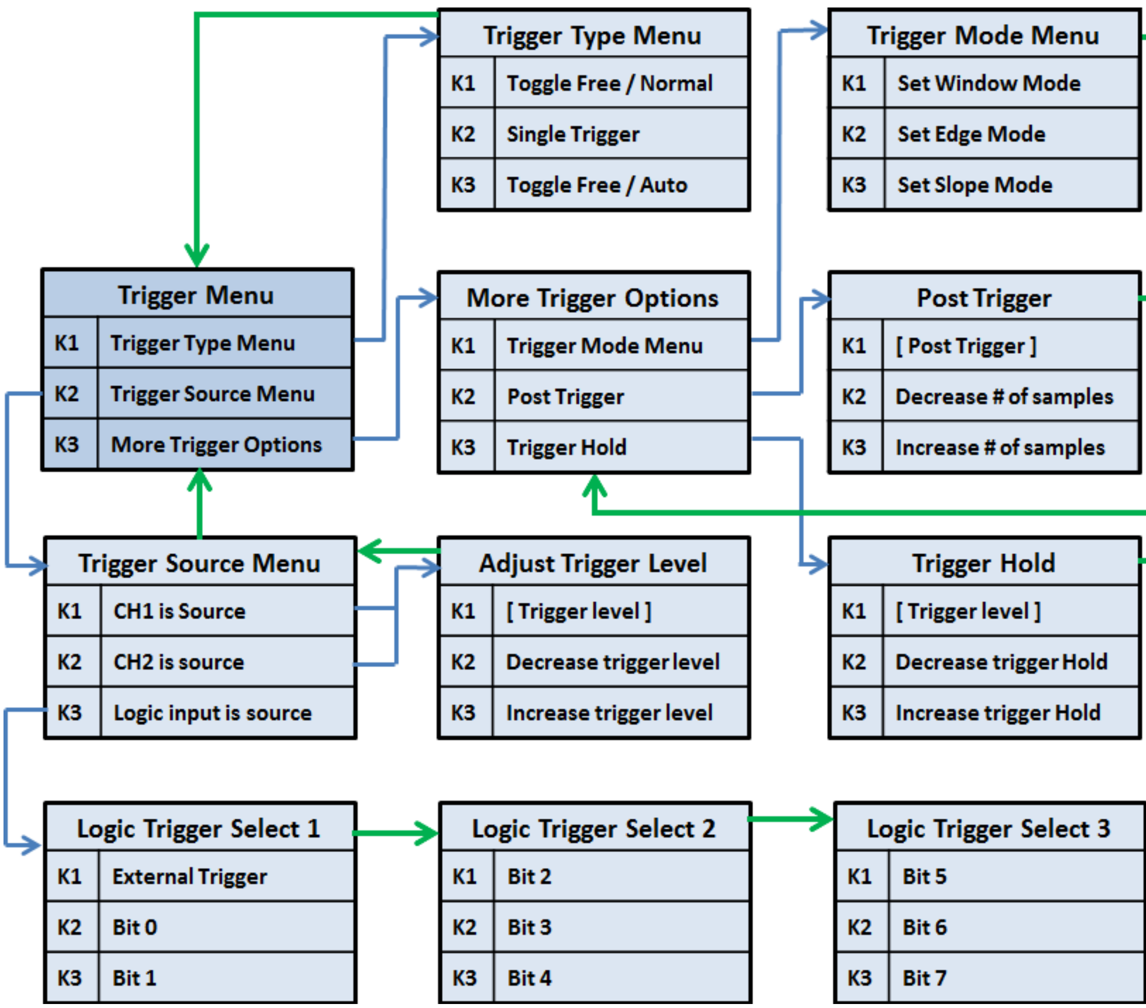


Figure 24: Trigger menus

2.3.1 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.

2.3.2 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.

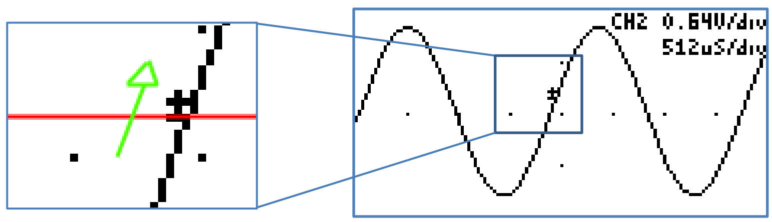


Figure 25: Edge Trigger

- **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.

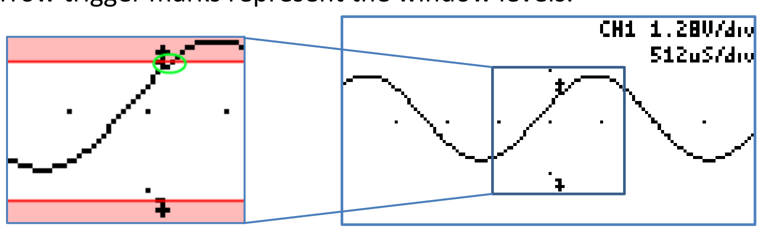


Figure 26: Window Trigger

- **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.

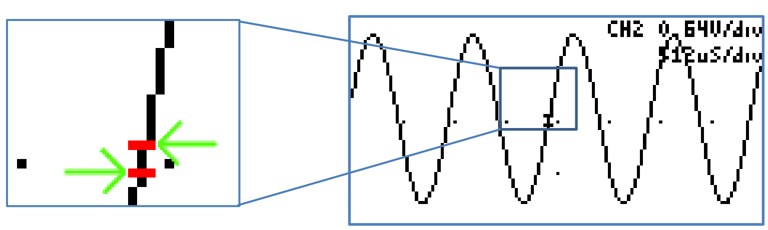


Figure 27: Slope trigger

2.3.3 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.

2.3.4 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 28:

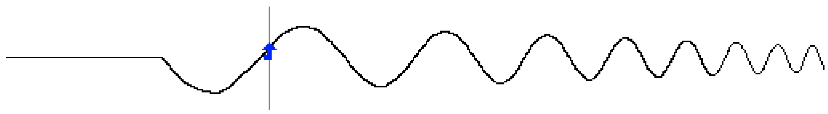


Figure 28: Sample signal

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.

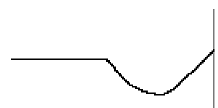


Figure 29: Post trigger value equal zero

- 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.

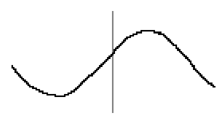


Figure 30: Post trigger = 50% of sample buffer

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

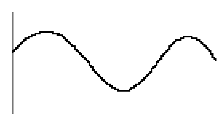


Figure 31: Post trigger = 100% of buffer

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.

2.3.5 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.

2.4 Device Modes

There are multiple device modes that can be selected; the menus shown on figure 32 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.

Scope Mode	
K1	Roll Mode
K2	Elastic traces
K3	XY Mode

Mode Menu	
K1	Set Scope mode
K2	Set Meter mode
K3	Set FFT Mode

Meter Mode	
K1	DC Voltage
K2	Peak to Peak Voltage
K3	Frequency / Counter

FFT Menu	
K1	IQ FFT mode
K2	Select FFT Window
K3	Logarithm display

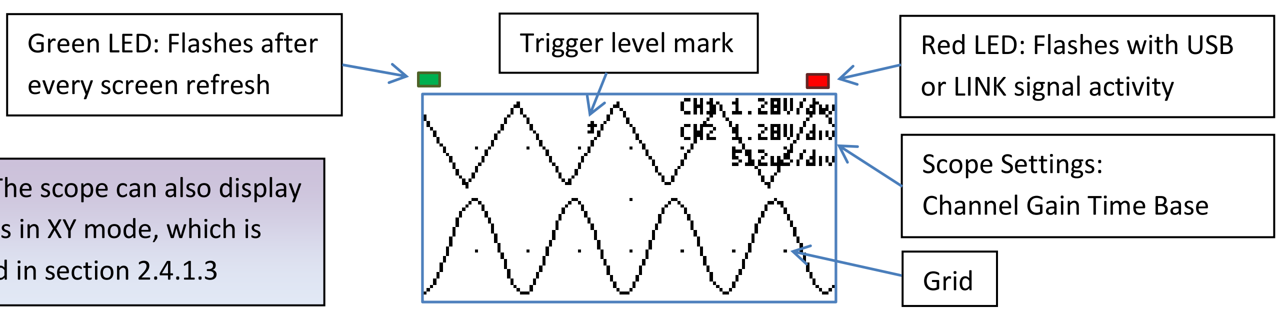
FFT Window	
K1	Hamming Window
K2	Hann Window
K3	Cosine Window

> TIP
> In the "Mode Menu", press K1 and K3 simultaneously, to display both the Scope and FFT.

Figure 32: Device mode menus

2.4.1 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 33 shows the oscilloscope mode and the various sections of the display are detailed.



> TIP
> The scope can also display the traces in XY mode, which is described in section 2.4.1.3

Figure 33: Oscilloscope Mode

2.4.1.1 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.

2.4.1.2 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:

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

2.4.1.3 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 8.5.

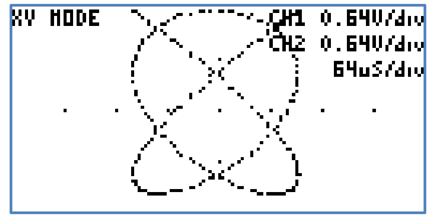


Figure 34: XY Mode

> **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.

2.4.2 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.

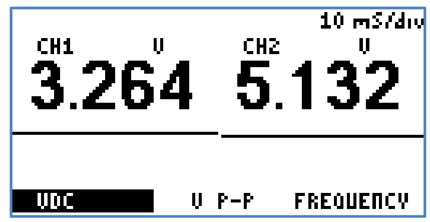


Figure 35: Meter Mode

2.4.2.1 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 2.3) 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

2.4.2.2 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.

2.4.3 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 36 shows the XScope in Spectrum Analyzer Mode. The Nyquist frequency is shown on the top right corner of the display.

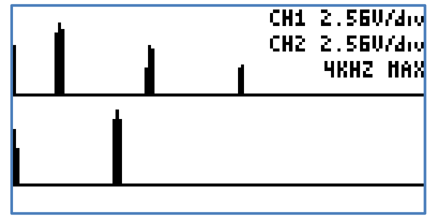


Figure 36: Spectrum Analyzer Mode

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

2.4.3.1 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 2.1.3 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.

2.4.3.2 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:

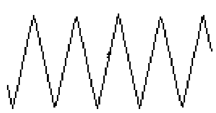


Figure 37: Triangle Wave

Figure 39: FFT without Log

Figure 38: FFT with Log

2.4.3.3 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**: $0.53836 - 0.46164 * COS\left(\frac{2*\pi*n}{FFT_N - 1}\right)$
- **Hann**: $0.5 * \left(1 - COS\left(\frac{2*\pi*n}{FFT_N - 1}\right)\right)$
- **Blackman**: $0.42 - 0.5 * COS\left(\frac{2*\pi*n}{FFT_N - 1}\right) + 0.08 * COS\left(\frac{4*\pi*n}{FFT_N - 1}\right)$

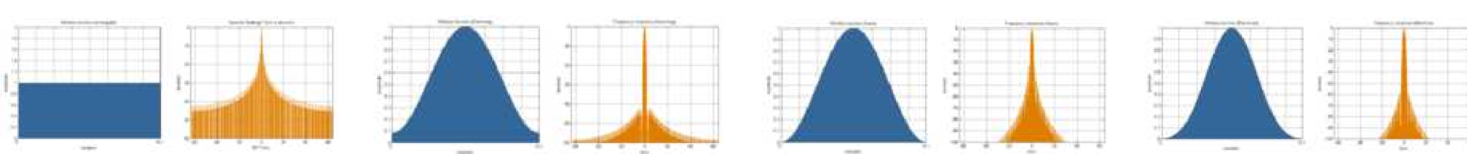


Figure 40: Window and sine frequency response, from left to right: Rectangular, Hamming, Hann and Blackman

2.5 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 41 shows the cursor menus.

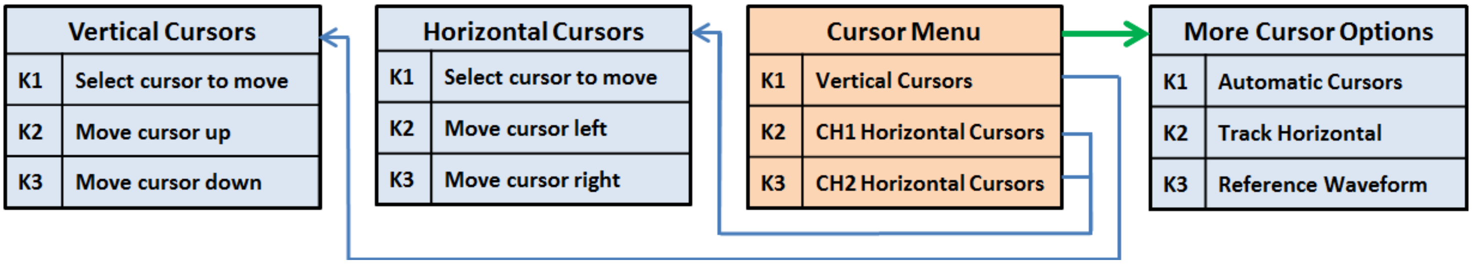


Figure 41: Cursor menus

2.5.1 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.

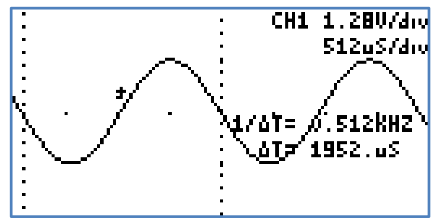


Figure 42: Vertical Cursors

2.5.2 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.

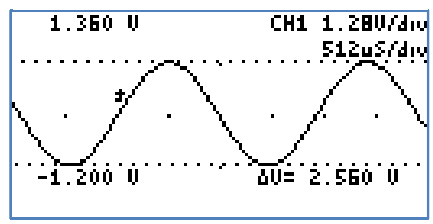


Figure 43: Horizontal Cursors

2.5.3 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.

2.5.4 Track Horizontal Cursors

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

2.5.5 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.

2.5.6 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.

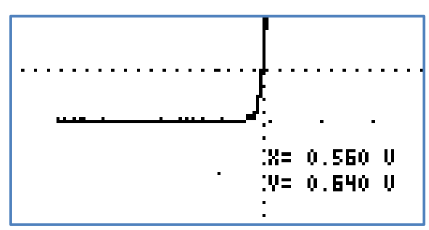


Figure 44: Cursors in XY Mode

2.6 Display Settings

These menus control various characteristics of the display. Figure 45 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 45: Display menus

2.6.1 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.

2.6.2 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 46 shows the pixel display.

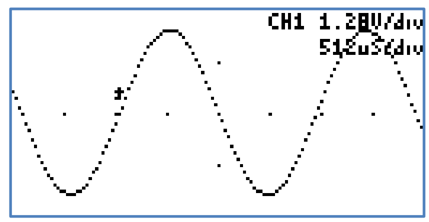


Figure 46: Pixel Display

2.6.3 Show scope settings

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

2.6.4 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.

2.6.5 Flip Display

The display orientation is flipped. This is useful when mounting the XScope on a panel, and the display's orientations is backwards.

2.6.6 Invert Display

When enabled, the display's pixels are inverted (the display will have a white background).

3. 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 47 shows the logic menus.

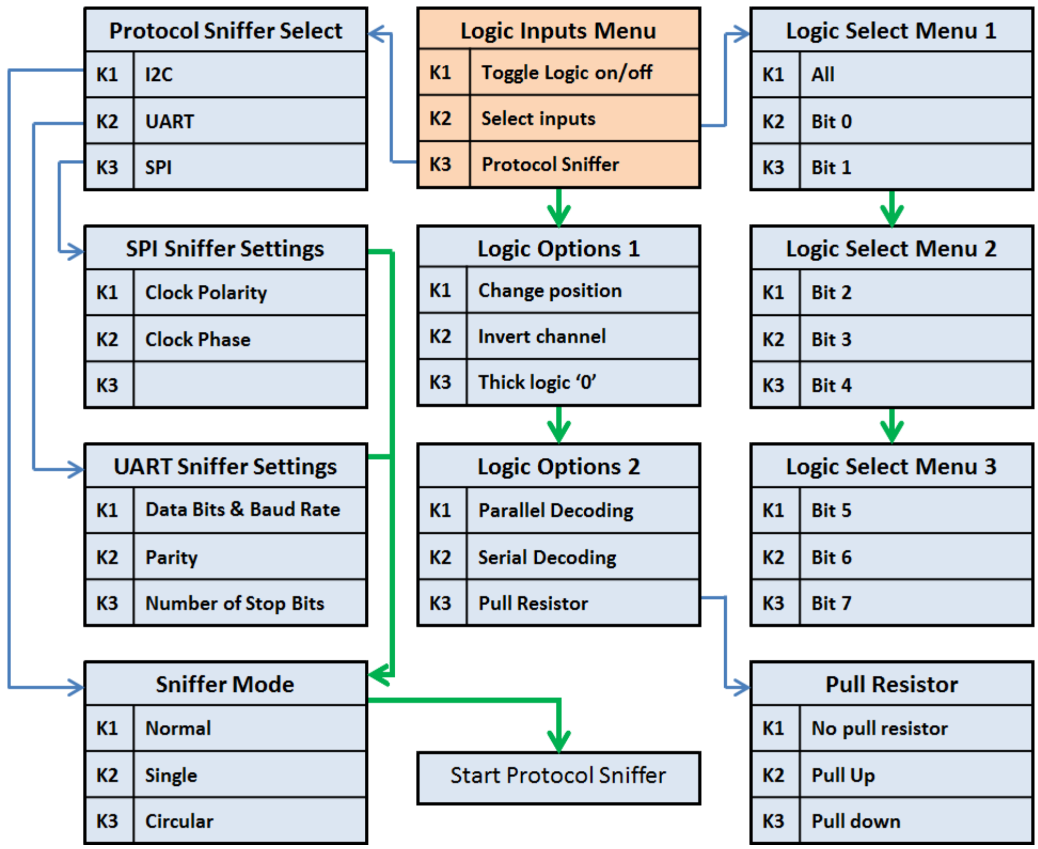


Figure 47: Logic Analyzer Menus

3.1 Input Selection

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

3.2 Channel Position

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

3.3 Invert Channel

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

3.4 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'.

3.5 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 48 shows an example of the parallel decoding with 4 logic lines enabled.

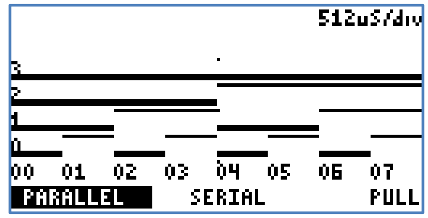


Figure 48: Parallel Decoding

3.6 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.

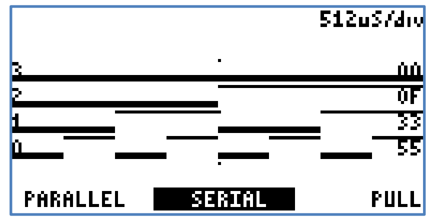


Figure 49: Serial Decoding

3.7 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 50 shows the device in sniffer mode.

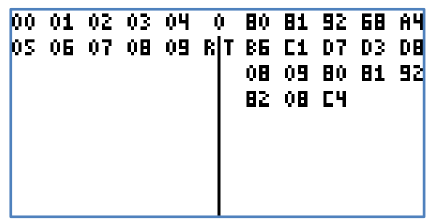


Figure 50: Sniffer

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 51 shows the 3x6 font.

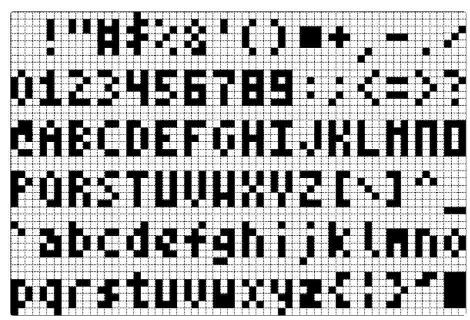


Figure 51: Small 3x6 font (characters 0x20 thru 0x7A)

3.8 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.

3.9 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)
```

3.10 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.

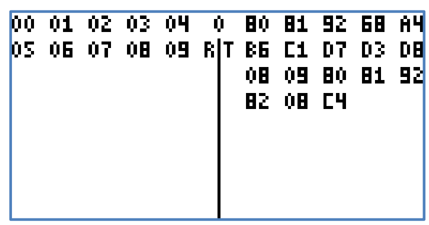


Figure 52: UART Sniffer screen

3.11 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.