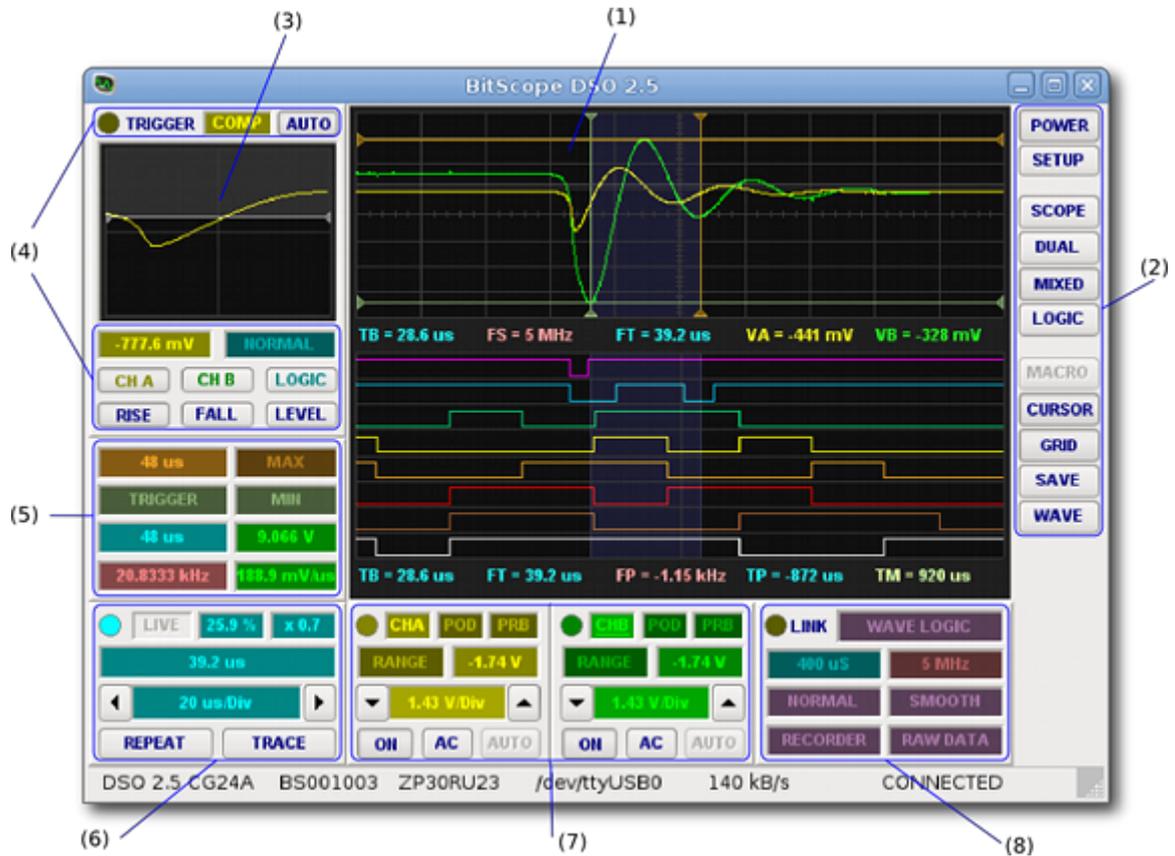


# BitScope DSO User Guide

BitScope DSO is the premier software for all [BitScopes](http://bitscope.com).



ID	FEATURE	DESCRIPTION
(1)	Main Display	Waveform, logic and spectrum displays, measurements and cursors.
(2)	Scope Selectors	Virtual instruments, scope tools, presets, cursors, graticule etc.
(3)	Trigger Windows	Shows trigger levels, analog and logic waveforms at the trigger.
(4)	Trigger Controls	Controls trigger setup and displays trigger waveform and data.
(5)	Cursor Measurements	X and Y cursor values, voltage, time and rate measurements.
(6)	Timebase Control	Timebase, Zoom and Time Focus control parameters.
(7)	Channel Controls	Controls input source, range, vertical position and scaling.
(8)	Capture Control	Capture sample rate, duration, frame rate and display modes.

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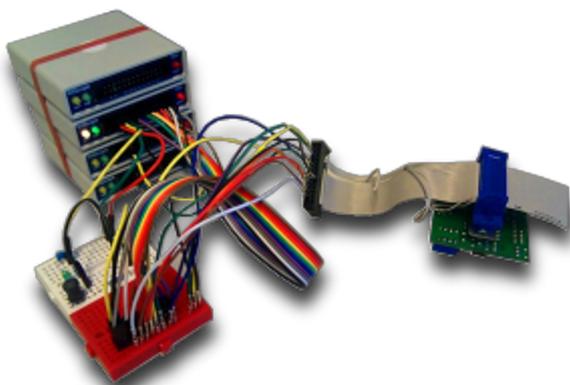
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## 1.1 A quick example demonstrates what DSO can do...

The latest DSO version supports all current model BitScopes and configures itself according the connected BitScope. The screenshot on the first page shows DSO connected to the BS10 and below is a photo of the setup we used to generate this screenshot.



This little circuit models a logic controller driving an electro-mechanical relay. It generates multiple time related analog and logic signals similar to any mixed signal system (in this case a PLC).

At a glance, BitScope DSO can provide huge amount of information about this circuit. Logic channels D0 to D5 (white through to green in the screenshot) show six channels of logic data from which numerous timing measurements can be made.

The controller uses the AND combination of D0 to D3 to drive a tiny switch which when activated disconnects the current flowing through the relay's inductor.

This circuit responds with "ringing" which is an undesirable artefact we wish to measure.

The ringing is captured simultaneously using BitScope's analog channels; CH-A (yellow) shows the impulse response in the driver current during the transition and CH-B (green) shows the voltage across the relay's inductor.

This is a 3.3V system and the voltage cursors are set to track the MIN and MAX voltages on CH-B which reports a peak-to-peak voltage across the inductor 9.066V. In a real PLC circuit this amount of over-voltage relative to the supply voltage may be a significant problem!

The time cursors report the first cycle of the oscillation starting at the trigger and ending one period later. This shows a period of 48us or an oscillation frequency of 20.83' kHz.

The blue "time band" on the analog and logic displays highlights this region of interest and channels D6 and D7 are configured to show the points at which the analog voltage crosses the trigger level.

## 1.2 This is just the beginning.

All the information in this example was derived from a single screenshot of a mixed signal system captured using BitScope Pocket Analyzer and BitScope DSO. When used interactively there are a huge range of other measurements that are possible.

DSO captures, displays and records analog waveforms, logic traces, frequency spectra, X/Y plots and timing diagrams. It can perform all sort of signal measurements real-time as you adjust its parameters using its intuitive Act On Touch user interface.

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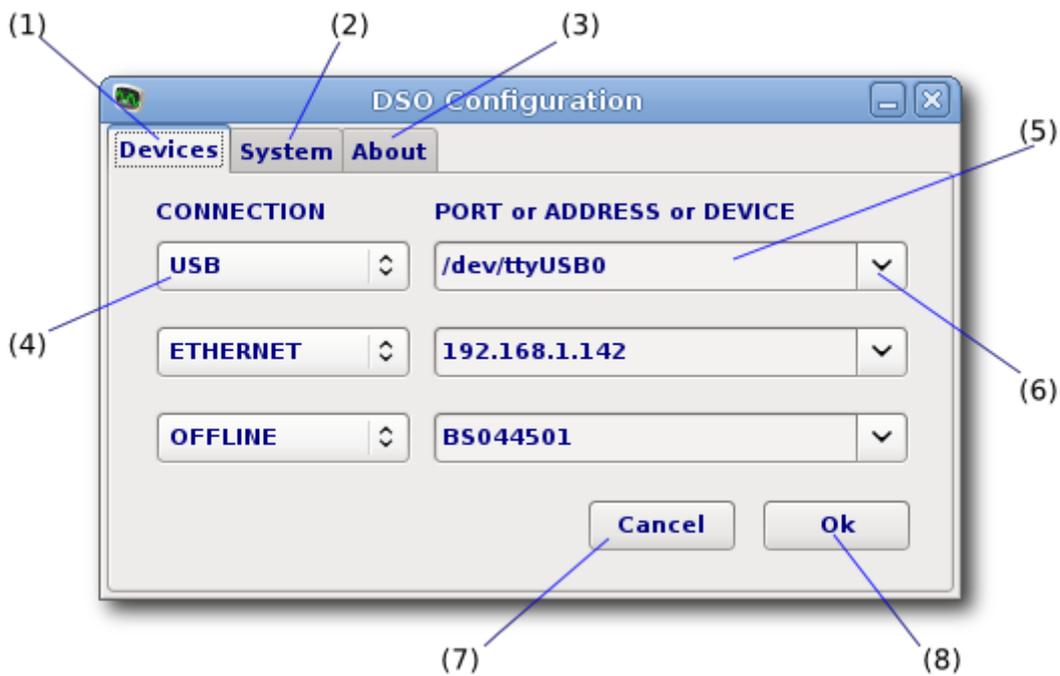
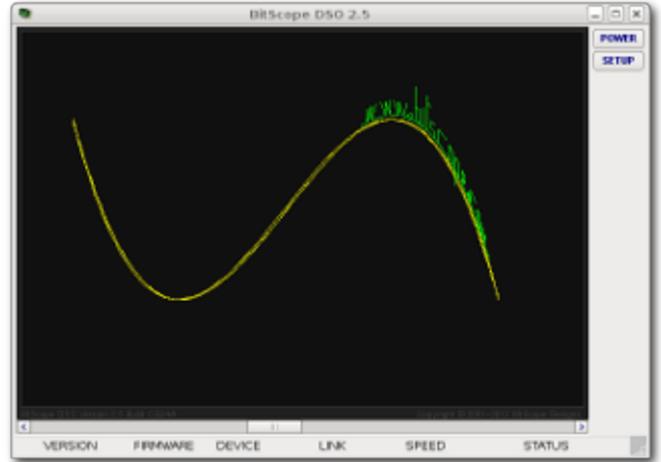
## 2. Setup Dialog

When the DSO first runs it displays an animated lissajous figure and two buttons.

Click POWER to open the connection to BitScope and start using the DSO. If only one BitScope is plugged into the PC there is no need to click SETUP.

If the BitScope is not locally connected (via USB or a local LAN) or if more than one BitScope is available, DSO SETUP is required tell DSO which BitScope to use.

Clicking SETUP opens the setup dialog box:



ID	FEATURE	DESCRIPTION
(1)	Devices Page	Selects BitScope connection preferences.
(2)	System Page	Configures various system defaults for BitScope DSO.
(3)	About Page	Some information about the DSO and its authors.
(4)	Connection Method	Specifies how to connect with BitScope.
(5)	Device Selection	Specifies the port, address or ID of BitScope.
(6)	Device Menu	Shows a menu of possible alternative connections.
(7)	Cancel Changes	Close SETUP without making any changes.
(8)	Accept Changes	Close SETUP saving any changes.

The dialog works the same way regardless of whether DSO is running on Windows, Mac OSX or Linux systems but the names of the devices listed may be different.

## 2.1 Specifying device connection

Four connection methods are supported and up to three connections may be specified in descending priority order via the SETUP.

NAME	DESCRIPTION
USB	Local, connected via USB.
SERIAL	Local, connected via a Serial Port.
ETHERNET	Local or remote, connected via LAN.
OFFLINE	Emulated device, no connection.

A USB BitScope will automatically appear as the first device (i.e. /dev/ttyUSB0 in the example above). If more than one BitScope is plugged into the PC, choose which one you want (6) or type in the device name (5) directly.

If you have a Network BitScope, choose the ETHERNET connection method and select from the menu or type in the IP address or its host name (on your LAN). If you don't have a BitScope you can still run DSO by choosing OFFLINE and specifying the BitScope model you want to emulate.

This is useful to replay previously recorded waveform data for offline analysis.

## 2.2 How device discovery and connection works

When the POWER button is pressed the device connections specified via SETUP are opened in descending order until a BitScope device is found or all connections have been attempted. If a device is already open and connected (e.g. by another DSO instance) it is skipped and the next one used. In this way two or three BitScopes may be used at once from a single PC. If no devices can be found the DSO defaults to OFFLINE REPLAY MODE which means the DSO is running but is not connected. A file dialog appears asking for a DDR file to play.

## 2.3 BitScope Probe File

The connection setup described above is managed using BitScope Probe Files.

For more information about probe files and how to modify them see the [BitScope Probe File Guide](#).

### 3. Act On Touch Parameter Widgets

DSO 2.5 and later use a simple gesture based user interface called Act On Touch.

Act On Touch makes mouse, track-pad and touch-screen use easy. Whether you use a PC or Mac, netbook or tablet running Windows Touch, Android or iOS, DSO works the same way\*. Act On Touch simply means you can click, drag or select to adjust almost any DSO parameter using your finger or stylus (on a touch-screen device) or a mouse or track-pad (on a PC or Mac) to change its value or select related functions.

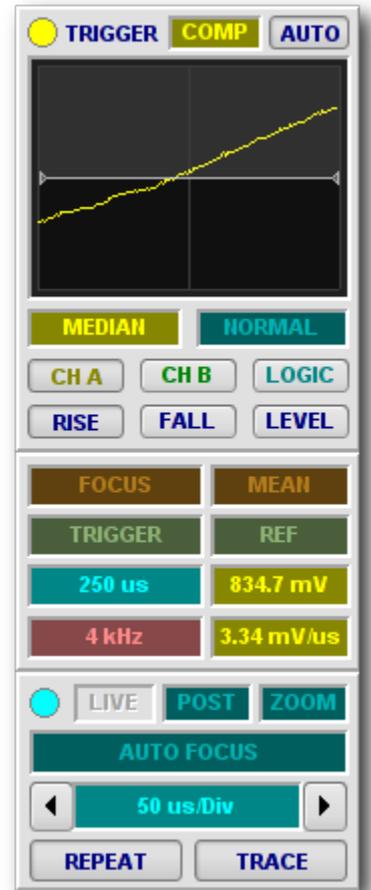
Shown here are three panels that use Act On Touch.

- Dynamic Trigger Control (top)
- Cursor Measurement Control (middle)
- Zoom Timebase Control (bottom)

Using Act On Touch is easy; click and drag up and down or left and right on a parameter to adjust its value. Click on the left or right edge of the parameter to select a previous or next value.

Right-click (or control-click on a Mac or press-and-hold on a tablet) to pop up a context menu and double-click to open an editor to type in a value or select a default value. We call these UI interactions Act On Touch Gestures.

Objects on the display can also be clicked and/or dragged to change location or value. For example, the trigger level can be adjusted by moving the trigger cursor and measurement cursors or waveform feature bands on the main display can be moved to make various measurements. Act On Touch means DSO is more compact and informative because parameter can report a value and accept user input to change that value without unnecessary scrollbars or other UI widgets. The channel control panel shown above provides a good example; using this panel you can choose the source and signal coupling, adjust voltage scaling, input range, probe scaling and signal offsets and perform channel calibration, all using simple Act On Touch Gestures on parameter widgets.



#### 3.1 Act On Touch Gestures

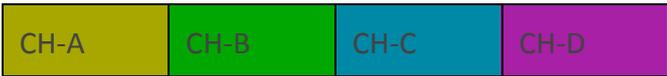
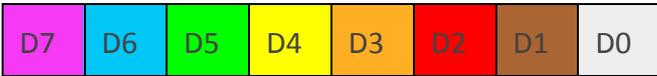
Up to seven single-touch Act On Touch Gestures are supported for each parameter:

NAME	GESTURE	WHERE	DESCRIPTION
Click	Click	Center	Perform primary parameter action.
Select	Double-Click	Anywhere	Perform secondary parameter action.
Choose	Menu-Click^	Anywhere	Pop-up a context menu for the parameter.
More	Click	Right Side	Choose the next (or higher) value.
Less	Click	Left Side	Choose the previous (or lower) value.
Change X	Click-Drag+	Left/Right	Adjust a parameter value continuously (X-axis).
Change Y	Click-Drag+	Up/Down	Adjust a parameter value continuously (Y-axis).

Not all parameters respond to all gestures and some respond in different ways. Some gestures apply to non-parameters (e.g. pop-up menus on buttons or lights) and multi-touch gestures apply to other objects such as waveforms and displays. These differences are explained elsewhere.

### 3.2 Parameter Widget Colours

DSO uses colour to classify all parameter types according to their purpose or usage:

COLOURS	DESCRIPTION
	Analog Channel Colours (CH-A to CH-D)
	Logic Channel Colours (D7 to D0)
	Cursors and related parameters and measurements.
TIME DOMAIN	Time measurements, parameters and values.
FREQUENCY DOMAIN	Frequency measurements, parameters and values.
GENERAL PARAMETERS	All other measurements, parameters and values.

The colour of each parameter identifies it as belonging to an analog or logic channel or a cursor, time or frequency measurement. All others are general parameters which control the operation of DSO or selection various options. Logic channels use standard [electronic colour codes](#) (except D0 which is white not black) and analog channels use defaults from across the BitScope product range. Colours may be changed if necessary but this table shows the defaults.

### 3.3 Parameter Types and Values

Parameter widgets report alpha-numeric values associated with controls and/or measurements and appear in appropriate colours with or without highlights. There are four types of parameter:

TYPE	VALUES	DESCRIPTION
Option	Alpha	A set of non-numeric values, e.g. Display Mode which selects from values NORMAL, DECAY or OVERLAY.
Selector	Alpha Numeric	A discrete set of numeric values, e.g. Input Range which selects from a fixed and finite set of voltage ranges supported by the device.
Vernier	Alpha Numeric	A real parameter with calibrated and vernier values, e.g. Input Scale which selects from set of voltages but which also allows arbitrary scaling.
Real	Alpha Numeric	A real parameter with arbitrary value, e.g. Focus Time which specifies the time (relative to the trigger point) of the center of the display.

Option parameters show text reporting the selected option (i.e. they are not numeric) but the other parameters may report alpha-numeric values.

Usually, alpha-numeric parameters report a numeric value. However, if the parameter is set to its default value (e.g. the input offset is zero volts) it reports the parameter name, not the value. This makes it easy to identify parameters by name (as most are set to their default at startup).

Some parameters can be set to track others. When a parameter is tracking another it reports the name of the parameter it is tracking, not the value (e.g. the MARK cursor reports "MAX" when tracking waveform maxima). The value itself can often be seen via the tracked parameter widget or via a derived measurement elsewhere in the UI (e.g. Vpp).

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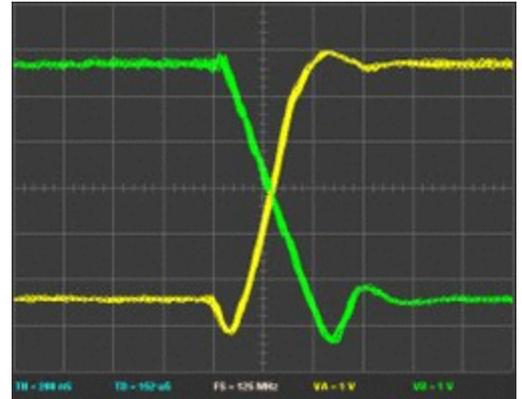
^ Menu-Click on a Windows or Linux PC means clicking with the right mouse or track-pad button. On Mac OS X the equivalent is a Control-Click (hold the control key and click the mouse button or track-pad) and on touch-screen devices simply Press-and-Hold until the menu appears.

+ Click-Drag on a PC or Mac means to click the (left) mouse or track-pad button and then drag the mouse pointer left or right or up and down (or both). On a touch-screen device it means to double tap and immediate drag left and right or up and down (or both).

## 4. Virtual Instruments

Using Virtual Instruments, DSO offers much more than just an oscilloscope. The current version supports the following test, measurement and data acquisition functions:

- Digital Storage Oscilloscope
- Mixed Signal Oscilloscope
- Logic State Analyzer
- Waveform Generator
- Spectrum Analyzer
- Data Recorder



Each function is implemented by a user selectable virtual instrument (VI). VIs program BitScope to perform appropriate waveform acquisition, generation and/or signal processing.

They are all tightly integrated making comparative measurements between them possible. For example, high speed logic capture can be compared with high resolution analog waveforms and their spectra captured at a different time scale.

### 4.1 Scope Selectors

The buttons that appear down the right side of the DSO app is where virtual instruments and their associated tools are selected.

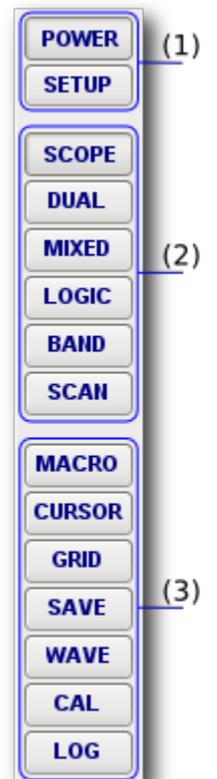
The selectors are arranged in three groups:

ID	GROUP	FUNCTION
1	Power and Setup	Setup and DSO application start up.
2	Virtual Instruments	Selects from available virtual instrument.
3	Scope Tools	Selects various tools and features.

Group 1 provides POWER and SETUP as described for setup.

These buttons are always available.

However, the buttons which appear in the groups 2 and 3 depend on what type of BitScope is connected. For example, the buttons shown on the left are those supported by BS10. Other models may offer different choices.



### 4.2 Virtual Instruments

When using DSO, the first step is to choose the virtual instrument required. Selection is mutually exclusive; choosing one instrument deselects another. Almost all DSO parameters (e.g. timebase, voltage scaling, display mode etc) depend on which instrument is selected and the parameter values are stored with each instrument. Switching between instruments restores parameters.

The exceptions are those parameters for which it does not make sense to have different values just because the instrument changed (e.g. probe scaling which depends on the probes used not the selected virtual instrument).

The virtual instruments that are available depend on features of the BitScope but the complete list of instruments that can be supported by the current DSO version is:

INSTRUMENT	DESCRIPTION
SCOPE	Independent multiple channel Digital Storage Oscilloscope.
DUAL	Sample linked dual channel Digital Storage Oscilloscope.
CHOP	Dual channel chopped capture Digital Sampling Oscilloscope.
ALT	Dual channel alternating capture Digital Sampling Oscilloscope.
MIXED	Multi-channel Mixed (Analog+Logic) Signal Storage Oscilloscope.
LOGIC	Direct capture high speed Logic State and/or Timing Analyzer.
WAVE	Combined Analog Waveform Generator and Sampling Oscilloscope.
BAND	Multi-band RF Spectrum Analyzer and Sub-Sampling Oscilloscope.
SCAN	Slow speed continuous sampling Digital Oscilloscope.

Some features such as the built-in base-band spectrum analyzer and data recorder in all BitScope models are available regardless of which instrument is selected. They do not appear as instruments themselves. Other model specific features such the DSP waveform generator are also available to all virtual instruments and do not appear as instruments themselves.

### 4.3 Scope Tools

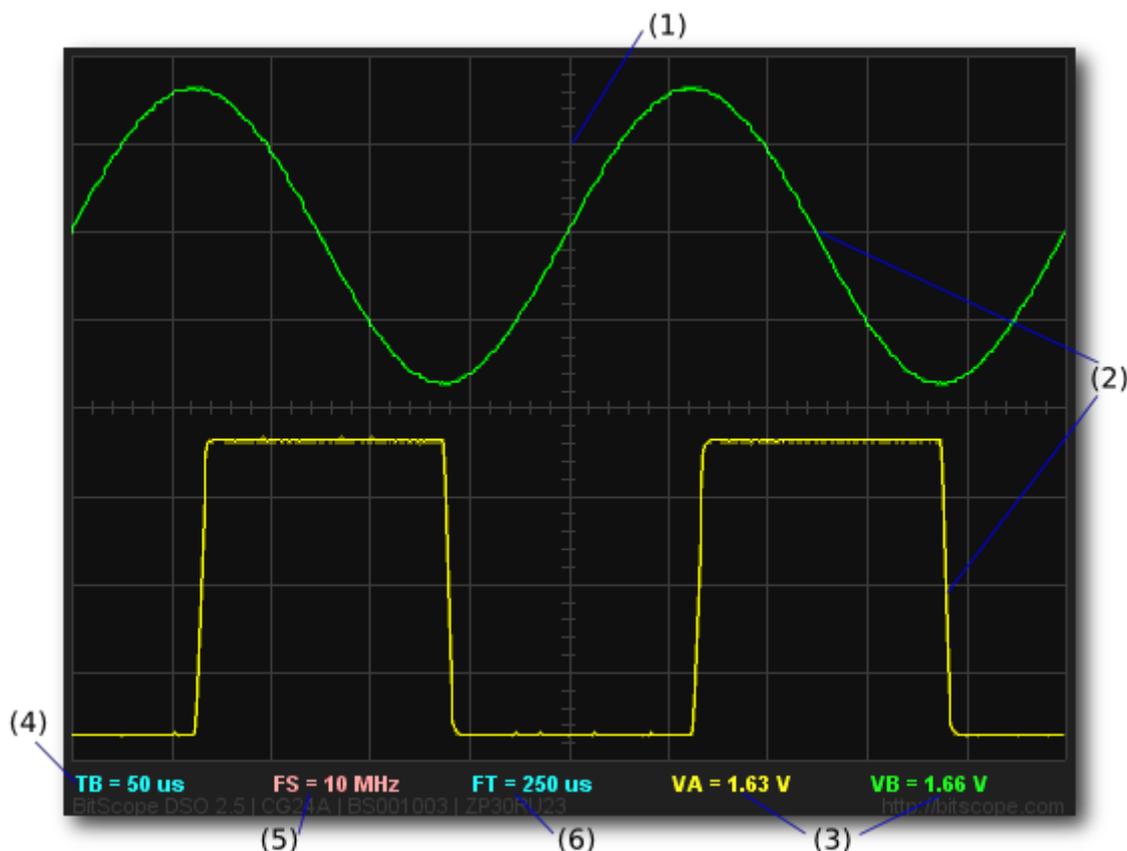
Scope Tools are additional features provided by the DSO which usually operate independently of the selected virtual instrument and provide a variety of test, measurement and related functions. This table enumerates the scope tools supported by the current DSO version:

TOOL	DESCRIPTION
GRID	Enables the display graticule and adjusts its brightness.
CURSOR	Enables measurement cursors (time, voltage and/or frequency).
MACRO	Enables high resolution data capture ("macro mode").
PRESET	Configuration presets (selectors for configuration memories).
SAVE	Saves the complete waveform display to an image file.
WAVE	Enables the DSP based waveform generator on supported devices.
CAL	Enables probe calibration and clock signal generation on supported devices.
HIDE	Hide parameter control panels (to maximize screen realstate).
HELP	Open online help (i.e. launches this user guide).

All BitScope models support GRID, CURSOR, SAVE, HIDE and HELP. Only some models support the other tools. Some buttons may appear disabled (unclickable) because the feature is supported but not currently available (e.g. a required hardware option is not installed).

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## 5. Main Display



The oscilloscope display above is selected when DSO is first powered on. It comprises:

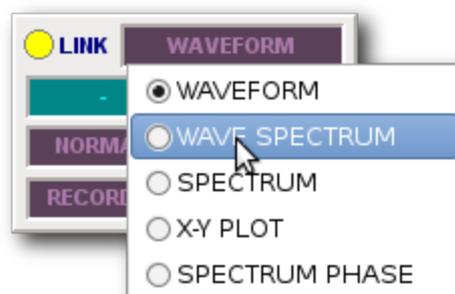
ID	FEATURE	DESCRIPTION
(1)	Graticule	Display graticule (X-Axis 10 Divisions, Y-Axis 8 Division).
(2)	Waveforms	Waveforms connected to CH-A and CH-B.
(3)	DC Voltages	Measured DC (or bias) voltages on CH-A and CH-B.
(4)	Zoom Timebase	The zoom timebase value (reported as time per division).
(5)	Sample Rate	The sample rate at which the waveforms were captured.
(6)	Focus Time	The time at the centre of the display (relative to the trigger).

This is BitScope DSO's standard dual channel oscilloscope display format. In this example, two 4kHz 3.3Vpp waveforms sampled at 10MHz are shown each with a 1.65V DC (bias) voltage.

### 5.1 Display Format Menu

There are many other display formats available. They are grouped by virtual instrument.

For example, logic capture offers timing diagrams and mixed signal displays whereas analog capture includes spectrum analyzer and X-Y plot displays.



Most displays support a range of other features including decay phosphors, time and frequency cursors, region bands and signal variables.

The active display is selected via Act On Gestures on the capture control display format widget.

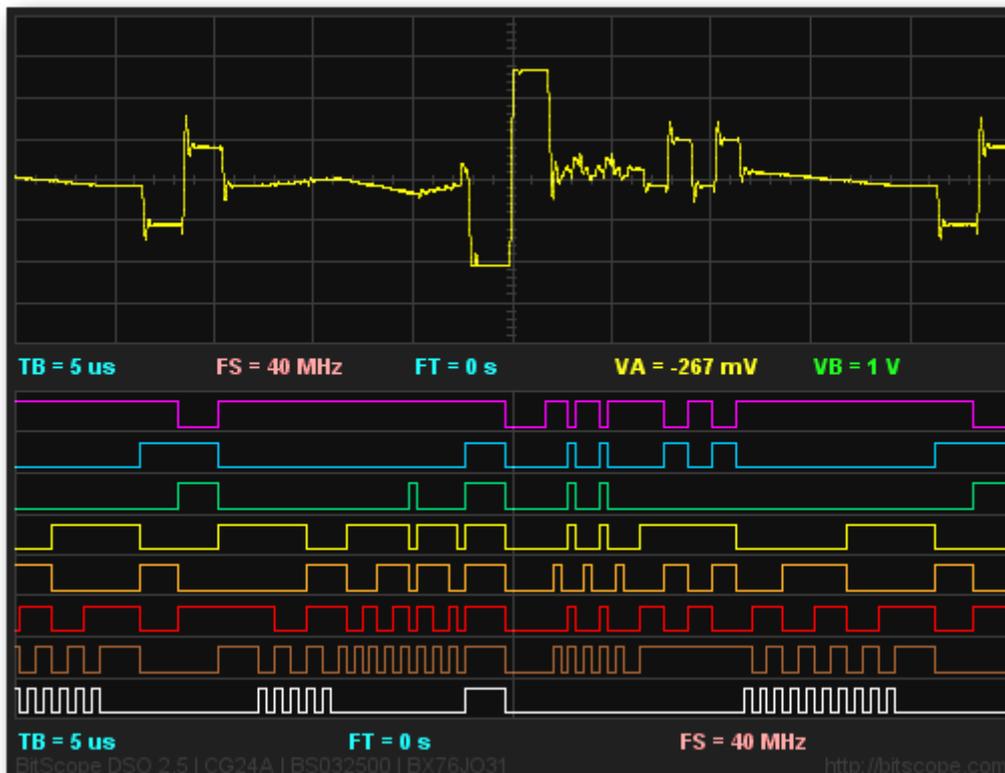
A Click or Select switches between the current format and the previous one and a Menu-Click pops up the format menu for other display formats. In this example (taken from the SCOPE virtual instrument running on a BS10) the options include WAVEFORM, WAVE SPECTRUM, SPECTRUM, X-Y PLOT and SPECTRUM PHASE. The display formats supported across all instruments in the current DSO version are:

FORMAT	DESCRIPTION
WAVEFORM	Time domain analog waveform (digital oscilloscope).
SPECTRUM	Frequency domain analog spectrum magnitude (spectrum analyzer).
WAVE SPECTRUM	Time and frequency domains combined in one display.
SPECTRUM PHASE	Frequency domain spectrum magnitude and phase (spectrum analyzer).
X-Y PLOT	X-Y plot (lissajous) of data on Channel A vs B, C and/or D.
LOGIC STATE	Logic state (timing) display (8 channels, logic analyzer).
WAVE LOGIC	Analog waveform and logic state (timing) display combined.
LOGIC VALUE	Logic value (decoded) data display (8 channels, logic analyzer).

Below are some screenshots of some of the more commonly used display formats.

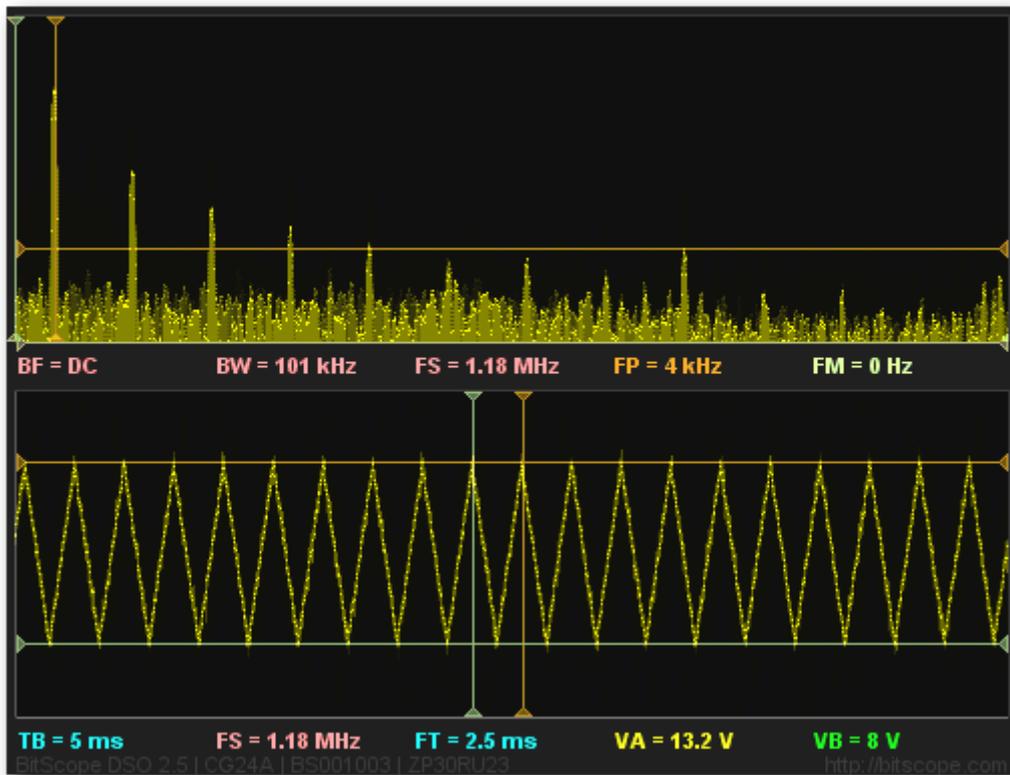
## 5.2 Mixed Signal (Analog+Logic) Display

When DSO captures analog and logic signals together, the default is a split analog and logic display.

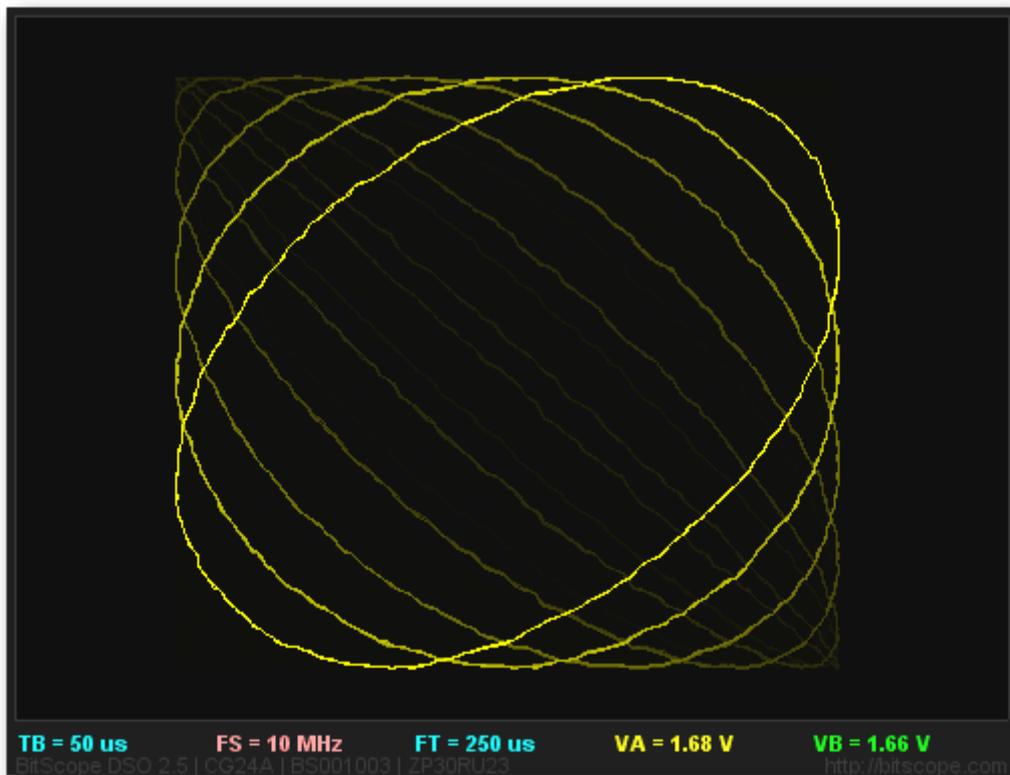


The timing of the analog and logic waveforms is synchronized so that time measurements can be made between any combination of analog and logic channels.

### 5.3 Mixed Domain (Time+Frequency) Display

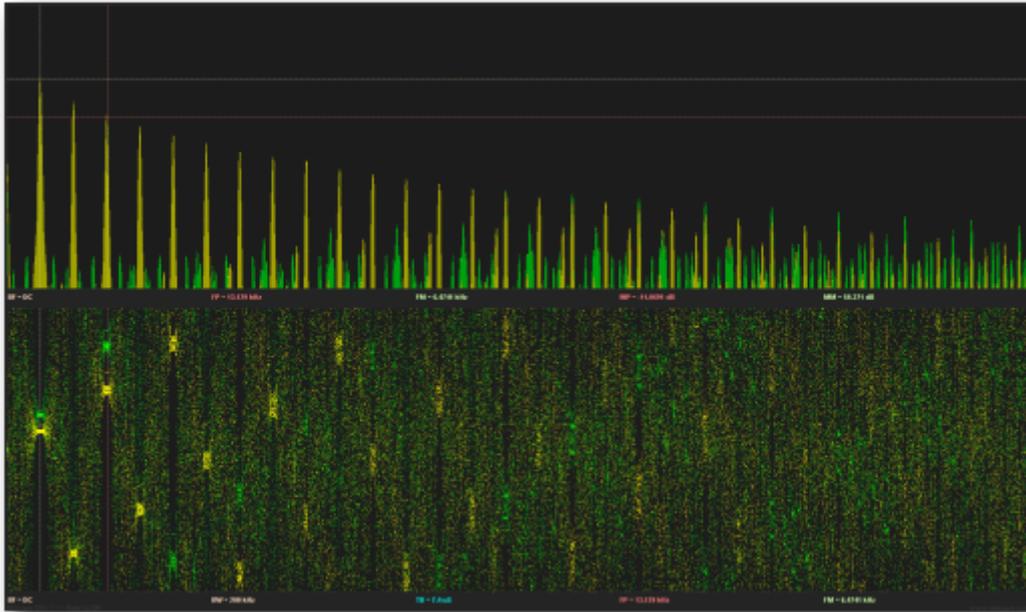


### 5.4 X-Y Phase Plot



## 5.5 Spectrum Magnitude and Phase

Several spectrum display formats are available. This one shows magnitude and phase.



This shows a phase density plot and magnitude spectrum of a pair of related signals. This screenshot looks a little different to the others because it was taken on a very high resolution display with the DSO maximized to full-screen.

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## 6. Channel Controls

The channel control panels appear below the display.



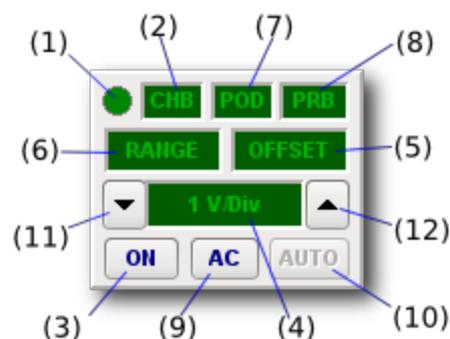
The number of control panels that appear depends on the type of BitScope connected.

The figure above shows the layout for BS445N.

The one on the right shows CH-B for BS10.

Other models may be slightly different.

Each parameter is shown in channel colours and the brightness indicates whether the parameter is active or not. In this case it's CH-B and it is disabled so all the parameters are shown dimmed. Compare this with the enabled channels at the top of the page.



There are parameters of all four types in a channel control. For example OFFSET (5) is a Real parameter, SCALE (4) is a Vernier, RANGE (6) is a Selector and SOURCE (7) is an Option list.

All channel parameters and widgets respond to Act On Touch Gestures as listed here:

ID	WIDGET	DESCRIPTION
(1)	LED	Channel mode, activity and calibration (Click, Choose)
(2)	FOCUS	Channel identifier and Channel Focus selection (Click).
(3)	ENABLE	Turn channel on and off (Click)
(4)	SCALE	Set or adjust channel scaling in V/Div (Click, Choose, Change Y)
(5)	OFFSET	Adjust (or track) input offset (Click, Choose, Select, More, Less, Change Y)
(6)	RANGE	Choose (or track) input (analog) range (Click, Choose, More, Less)
(7)	SOURCE	Choose input source (POD or BNC) and prescale factor (Click, Choose)
(8)	PROBE	Choose probe attenuation (Click, Choose)
(9)	COUPLING	Choose input AC/DC coupling or RF mode (Click)
(10)	AUTOSET	Automatically set all channel parameters to see a waveform (Click)
(11)	SMALLER	Make the waveform on the display smaller (Click)
(12)	LARGER	Make the waveform on the display larger (Click)

Note that some numeric parameters (e.g. RANGE and OFFSET) may report non-numeric values (e.g. MEAN, MEDIAN, REF etc). This means the parameter is set to its default value (e.g. REF for "zero offset") or is tracking something else (e.g. MEAN for "tracking the waveform mean voltage").

## 6.1 Channel Enable and Waveform

Each analog channel may be individually enabled or disabled. When disabled, the channel control panel's widgets are shown dimmed indicating their "disabled" status. Disabling a channel turns off data capture (on that channel) but capture may still be active if the channel is a trigger source.



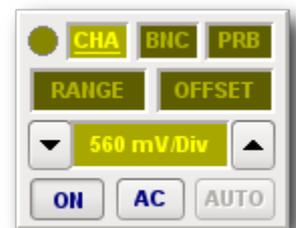
It is a good idea to turn off channels you are not using because it may free up some buffer memory and increase the frame rate. When disabled, most of the channel's controls can still be modified and the changes are applied next time the channel is enabled.

## 6.2 Input Range and Voltage Scale

Analog waveform capture and display depends on the input range and voltage scale. The scale is the most important channel parameter and may be changed using the larger and smaller buttons or other Act On Touch Gestures the scale parameter itself.

### 6.2.1 Voltage Scale

Voltage scale adjusts the vertical size of the waveform. Defined in "Volts per Division" (V/Div) it changes in a 1, 2, 5, 10 sequence each time the larger and smaller buttons are Clicked.



Choose the scale parameter to pop-up a menu to change the scale directly and Change Y to make vernier changes. In this example, CH-A has a vernier value of 560 mV/Div.

### 6.2.2 Input Range

Input range defines the maximum peak-to-peak signal the channel can capture without clipping.

Normally this parameter shows the word RANGE which means it tracks the other parameters automatically (auto range mode).

It may be manually adjusted using Choose to pop-up a menu or via More or Less to increase or decrease it. When adjusted this way the range highlights and reports a numerical value to indicate that it has been changed (manual mode).



A Click on the range selects normalized mode which forces the scale to track the range. The scale parameter dims to indicate this.

To switch back to auto range mode simply Click the scale.

In this example, CH-A is shown with a 23.6V input range in normalized mode where voltage scaling (shown dimmed) tracks the range to scale the waveform display to 2.95 V/Div.

These three modes are useful for different purposes:

MODE	DESCRIPTION
AUTO	The default and most useful for mode general measurement. The range parameter reports the wordRANGE and tracks voltage scale, probe scaling, input source and channel prescaling (if any) to ensure that the waveform on the display never clips.
MANUAL	A specialised mode that ensures a specific input range is used regardless of the other parameter settings. Some BitScopes offer different analog signal bandwidth in different ranges which can help with spectrum analysis or when using specific signal levels but waveforms can be shown clipped on the display in this mode.
NORMALIZE	This is the inverse of auto range mode. In this mode the scale tracks the range so as to ensure that the full scale of the display matches the full scale of the A/D convertor for the selected range, probe and prescale. Waveform clipping on the display is impossible and the signal is always captured to the highest resolution.

### 6.3 Attenuation, Prescale & Source

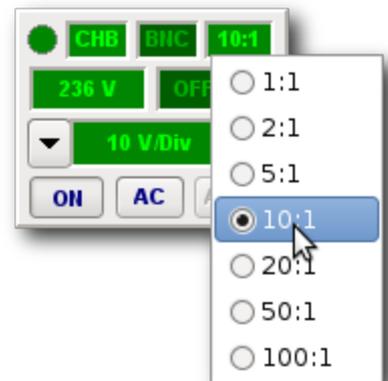
Some probes used with BitScope may attenuate the signal. This attenuation may be specified via the probe attenuation parameter. Other probes may amplify the analog signal and some BitScopes have built-in prescalers which do the same thing. This gain is specified via the prescale parameter.

#### 6.3.1 Probe Attenuation

Channel inputs inputs may need to be scaled for the attenuation applied by a connected probe. Shown here is CH-B with 1V/Div scale and 23.6V range originally selected but with 10:1 probe attenuation also applied so the channel has a 236V range scaled to 10V/Div (at the probe tip).

Using attenuating probes extends the measureable range.

In this example, a switchable 1:1/10:1 probe ([PRB-01](#)) is set to 10:1 can measure signals up to 236Vpp.



Similarly a 100:1 probe can measure more than 2.3kVpp.

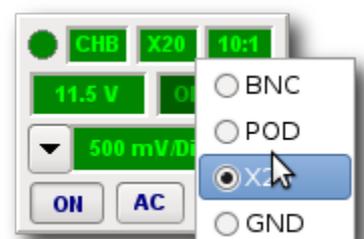
In practice we highly recommend the use of a fully isolated differential probe such as the one pictured here when working at high voltages.

Isolation is also very important when measuring high voltages which is why many BitScope models are electrically isolated from the PC. This means they can be ground referenced independently.

#### 6.3.2 Prescale Gain and Source Selection

The BNC inputs (on most models) may be prescaled for measurement of very low level signals.

The set of available prescale values depends on the connected model.



Prescale may also be used to compensate for the attenuation of the probe in which case the channel sensitivity may be similar to a 1:1 probe but the input impedance will be much higher.

For example, shown here is a 10:1 probe combined in the X20 prescale gain which results in a measurement range of 11.5V and a display scale of 500mV/Div.

The input impedance in this configuration is 10MΩ (which is 10 times higher than a 1:1 probe). This is important for high impedance circuits or working at very high frequencies.

This parameter also selects from the available input sources which depend on the BitScope model used. DSO supports these sources and prescale values.

SOURCE	DESCRIPTION
BNC	The BNC terminated input for the channel (not available on Pocket Analyzer models).
POD	The POD connector input for the channel (supported by all BitScopes).
ALT	An alternate input (used for low impedance data acquisition on some models).
GND	A ground reference input (used for input calibration).
X10	The BNC input prescaled by a factor of 10.
X20	The BNC input prescaled by a factor of 20.
X50	The BNC input prescaled by a factor of 50.

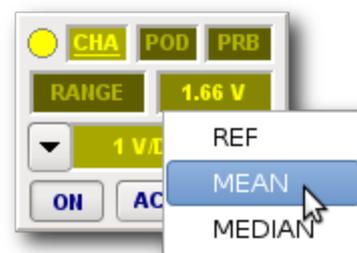
### 6.4 Input Offsets and Offset Tracking

Most BitScopes also support input offsets which may be changed using Click, Select, Choose, More, Less and Change Y on the OFFSET parameter.

Input offset may be manually set (Select, More, Less and Change Y) or assigned automatically (Choose).

When automatically assigned there are three options:

OFFSET	DESCRIPTION
REF	Zero reference voltage (i.e. no input offset)
MEAN	Waveform mean (average) value.
MEDIAN	Waveform median value.



Assigning REF removes the input offset (assigns it to zero volts). This is the default.

The other two options (MEAN and MEDIAN) operate similarly to AC coupling; they dynamically adjust the input offsets so as to "zero out" bias voltages from the waveform. Both locate the waveform towards the middle of the display and both optimize waveform capture resolution.

Choosing between manual, AC, REF, MEAN or MEDIAN offsets depends on what you're doing.

- Use REF when performing ground referenced (i.e. DC) measurements. Waveforms appear on the display located relative to ground. Any DC bias moves the waveform up or down.

- Use [AC Coupling](#) to eliminate DC bias from the input signal. Use it if the bias is beyond the reach of the offset control or if you have a BitScope that does not support input offset.
- Use MEAN offset tracking to eliminate DC bias from the captured waveform. Very similar to AC Coupling but is instantaneous and applies to one-shot waveform capture as well.
- Use MEDIAN offset tracking if the waveform has a variable mean. Useful for pulse-width modulating or other dynamically changing waveforms that have consistent peak values.
- Use manual offsets to remove a known bias from a waveform. Useful to see a waveform relative to a known or expected DC bias (e.g. ripple on a power rail).

Clicking the offset parameter at any time freezes and reports its numeric value. For example, the 1.66V offset shown above was frozen from MEDIAN tracking a 3.3V logic signal. More and Less apply one division more or less offset and aChange Y allows continuous adjustment of the offset.

Important: do not confuse input offset with vertical position. The former applies an true analog offset to the signal. The latter simply relocates the vertical position of the waveform on the display.

## 6.5 AC/DC Coupling and RF Mode

The BNC inputs on most BitScope models may be AC or DC coupled.

This is selected by Clicking the AC button. The other input sources (POD, GND) are DC coupled.

Models that don't have BNC inputs do not support AC coupling. Instead they use mean tracking to simulate AC coupling (if required). On these models the AC button is replaced by an RF button.

Clicking the RF button disables the baseband input filters that otherwise apply on these channels.

This opens the channel bandwidth for use with RF signals. It also means that RF noise (if present) will be captured so when working with baseband signals it is recommended that RF turned off.

Turning on Macro Mode can also dramatically improve small signal baseband resolution.

## 6.6 Level Sensing Inputs

Some BitScopes (e.g. BS10) offer level sensing inputs.

Sensing inputs are electrically compatible a traditional scope (1M $\Omega$ /10pF) but they also include a sensing bias which redefines scope inputs to suit the modern world of mixed signal electronics.

Sensing inputs can detect low, high and tri-state or open circuit conditions. Traditional scope inputs cannot distinguish between open/tri-state and low states. It is also possible to perform impedance measurements without the need for any other test equipment.

For normal waveform display, a low impedance source (by far the most common type) overrides the sensing bias and operates like a traditional scope input. For high impedance sources the issues are the same as a standard scope\* but the sensing bias may also be visible (as a variable offset).

DSO compensates for this automatically when used with MEAN or MEDIAN tracking for situations where one is not interested in the source impedance or the (logic) state of the circuit.

## 6.7 Probe Impedance and Waveform Measurement

A common mistake when using any oscilloscope is to assume connecting the probe to the circuit does not affect the measurement. This is only true for low impedance circuits (i.e.  $<10\text{k}\Omega$ ).

For example, probing a circuit to look at high impedance inputs (CMOS inputs, FET inputs, floating transistor base nodes) but relying on the probe itself to reference the input to ground (via its  $1\text{M}\Omega$  impedance) can be very misleading, especially at higher frequencies.

In these cases a better solution is to use a low value resistor to ground as a shorting link and use the analog channel to monitor signals of interest. Similarly, relying on the scope input to bias the signal to ground can be misleading if the scope input has been switched to AC. Looking at an input such as a FET gate with high value bias resistors can be seriously affected by any  $1\text{M}\Omega$  probe.

For most high impedance measurements a probe offering  $10\text{M}\Omega$  or higher impedance (e.g. PRB-01 in 10:1 mode) is a better choice. However, even this traditional solution has problems:

1. Physically large probes with long coax cables terminated in a BNC. This type of probe was designed more than 50 years ago to suit rack mounted vacuum tube oscilloscopes.
2. 10:1 attenuation reduces the signal by 10 at the scope input. This requires extra (prescale) gain and noise reduction in the scope to compensate.
3. Single ended design requires 2 channels to measure differential signals.

Most BitScopes address these issues by offering BNC input termination (1), analog prescalers (2) and at least 2 analog channels (3) but Pocket Analyzer adopts a different solution.

For this model the POD connector provides sufficient power to use a dual channel differential probe with active gain of X2 and X20 and high input impedance ( $10\text{M}\Omega$ ). These probes offer much greater input sensitivity, negligible circuit loading and the ability to directly measure signals across any component in the circuit without requiring the use of two scope channels.

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## 7. Timebase Control

The timebase control panel appears at the bottom left.

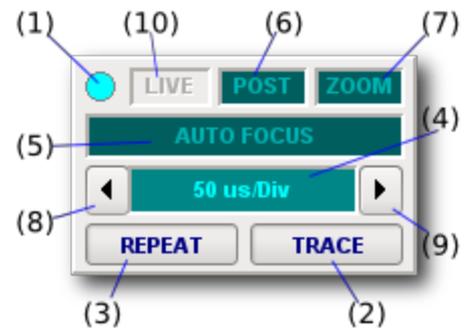
It provides the TIMEBASE (4), ZOOM (7) and FOCUS (5) parameters.

TIMEBASE and ZOOM combined set the time scale in seconds per division at which to display the waveform. FOCUS chooses which part of the waveform (specified as a time offset relative to the trigger) to display.

All channels use the same timebase parameters so they remain time synchronised. FOCUS may be arbitrarily set subject to available pre-trigger buffers and post-trigger delays supported by the connected BitScope.

The timebase control also provides the TRACE (2) and REPEAT (3) capture controls and other parameters which manage buffers (6) and display refresh (3).

All timebase parameters and widgets respond to Act On Gestures as listed here:



ID	WIDGET	DESCRIPTION
(1)	LED	Highlights to indicate activity.
(2)	TRACE	Start and Stop waveform capture and display (Click).
(3)	REPEAT	Selects one-shot or repeat capture and sets frame rates (Click, Choose)
(4)	TIMEBASE	Set or adjust the time scale in S/Div (Select, Choose, Change X)
(5)	FOCUS	Set (or track) the focus time (Click, Choose, Select, More, Less, Change X)
(6)	BUFFER	Selects how much buffer to use pre and post trigger (Click, Choose)
(7)	ZOOM	Adjust time scale post capture (Select, Choose, More, Less, Change X)
(8)	SLOWER	Make the timebase slower in 1, 2, 5 steps (Click)
(9)	FASTER	Make the timebase faster in 1, 2, 5 steps (Click)
(10)	SOURCE	Selects between live waveforms, presets and recorded waveform data.

The SOURCE parameter is not (yet) active as of the current version but some of its functions are available via the built-in DSO Data Recorder.

### 7.1 Waveform Capture and Display

TRACE and REPEAT control waveform capture and replay for all virtual instruments.



Clicking TRACE initiates a single (i.e. one-shot) waveform capture on all enabled channels and displays the result.

Clicking REPEAT does the same thing but capture continues indefinitely, updating the display in real-time until stopped. Choosing the REPEAT button pops up a frame rate menu to adjust the capture rate.

## 7.2 Using Auto Trigger

Is it important to understand that TRACE and REPEAT on their own are not enough to guarantee capture proceeds; the trigger condition must be satisfied or [auto trigger](#) must be enabled.

By default, repeat trace, auto trigger and CH-A are all enabled which ensures something appears on the display as soon as DSO starts. However when doing one-shot capture or when looking at intermittent signals it may be better to turn off auto trigger after a trigger condition as been set.

## 7.3 Terminating Waveform Capture

Waveform capture can be terminated by Clicking up the REPEAT or TRACE button.

However there is an important difference between these two options:

- Clicking REPEAT causes capture to stop after the capture frame completes. However, the frame may never complete if auto trigger is not selected and no trigger event is seen.
- Clicking TRACE aborts capture immediately. Use this option if clicking REPEAT does not terminate or just to terminate immediately. In this case the waveform displayed may be stale (you cannot rely on its validity) because capture may have been aborted after the previous waveform has been overwritten but before new waveform has been captured.

In general Clicking up REPEAT is the recommended way to terminate repeating capture.

## 7.4 Waveform Capture and Data Recording

It is also important to understand that as soon as TRACE or REPEAT is clicked to commence a new capture, any waveform previously displayed will be overwritten immediately. If you don't want to lose previously captured waveforms the data recorder can be enabled prior to capture.

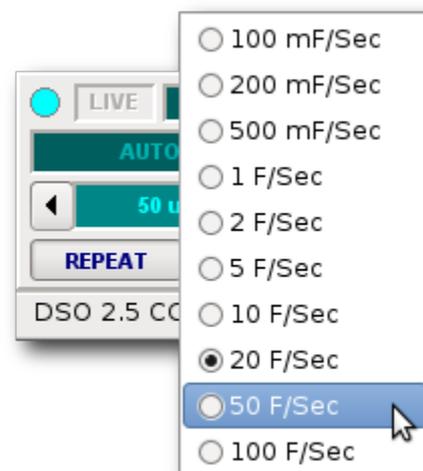
The reason waveforms are overwritten (unless the recorder enabled) is that as soon as a new trace is commenced the capture buffer is filled with new data even if no trigger is seen i.e. BitScope does not wait for a trigger to start capture. If it did, signals before the trigger could not be captured.

When replaying previously recorded waveforms (SOURCE is set to REPLAY) TRACE and REPEAT control the replay of the recorded waveforms instead of the capture of new waveforms.

## 7.5 Display Frame Rate

The rate at which repeat capture display refresh occurs is called the frame rate. Choose the REPEAT button to pop up the menu to change the frame rate. Whether DSO refreshes at the requested rate depends on a number of factors:

1. CPU, GPU, USB and/or LAN speed.
2. USB driver configuration and setup.
3. Timebase, auto trigger and buffer size.
4. The instrument and enabled channels.



## 5. The data, phosphor and display modes.

When run on a computer with a 1GHz or greater speed CPU, even with modest graphics cards, the maximum display refresh rate can typically reach 50Hz or beyond.

Even low cost Netbooks are usually capable of this. On older PCs or where the link speed is slow (eg, connected to a Network BitScope via a limited bandwidth Internet connection) or when run on a very high resolution displays, the frame rate may be lower (for example connecting to SYDNEY).

## 7.6 Timebase Parameter

The TIMEBASE parameter sets the primary time per division at which to capture and display.

Click on the FASTER and SLOWER buttons on the left and right of the timebase parameter to change it in a 1, 2, 5 sequence. Choose the timebase parameter to pop-up a menu of values or Change X to adjust it arbitrarily and in real-time. Select the timebase to toggle between the two most recently used values and make comparisons between two different timebase values.



Timebase implicitly sets the capture sample rate; for a given timebase DSO always uses the highest sample rate it can based on the selected buffer size to maximize the non-interpolating timebase zoom range and capture waveforms with the highest possible resolution.

## 7.7 Timebase Zoom

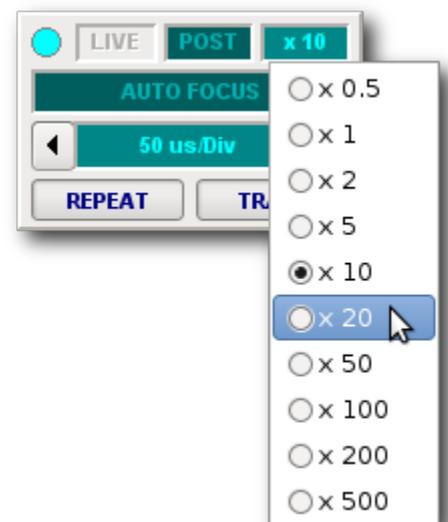
All BitScopes can capture far more data than is usually shown on the display at once.

The timebase zoom takes advantage of this by allowing one to zoom in on fine waveform details or zoom out to see an overview of the entire waveform on the display.

Unlike the timebase, zoom operates on previously captured waveforms and is instantaneous. Its range depends on the available buffers (device dependent).

The zoom menu shown here is for BS325.

Use More, Less or Choose to increase, decrease or select a timebase zoom directly. Select to toggle between the two most recently used values.



The timebase and zoom parameters combined define the time scale used to display captured waveforms. This time scale is also reported in seconds per division but at the bottom of the display not on the timebase itself.

In this example x 10 timebase zoom results in a timebase of TB = 5uS/Div being reported on the display.

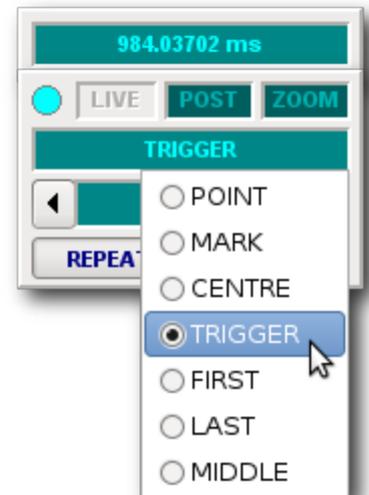
**TB = 5uS**

Whatever combination of timebase and zoom is used, the resulting time scale is always shown at the bottom of the display. If the graticule is disabled (ie. there are no divisions on the display) the time scale is reported as time per display instead of time per division.

## 7.8 Focus Time Parameter

The focus parameter specifies the time (relative to the trigger) at the middle of the display.

It is specified in seconds where positive values locate the display after the trigger and negative values before it. A value zero means the trigger is at the center of the display. In this example the center of the display (and any waveform appearing there) is located precisely 984 ms and 37.02 us after the trigger point. Use More and Less to increase or decrease the focus time by one display division, Choose to assign it directly, Change X to adjust it continuously or Select to toggle Auto Focus mode.



### 7.8.1 Auto Focus and Cue Points

Focus time may be automatically updated and/or assigned. Select the focus parameter to toggle auto focus on and off. When enabled, AUTO FOCUS appears (instead of a numeric value) and the focus is automatically updated to ensure the trigger point is visible, either in the middle of the display (if pre-trigger is enabled) or at the left (if post-trigger only). In addition to manual adjustment, there are seven other cue points which may be assigned to the focus.

CUE POINT	DESCRIPTION
TRIGGER	Locate the focus to trigger point. If capture is post-trigger only, no waveform will appear on the left half of the display (because there is no data before the trigger)
FIRST	Locate the focus to the first sample in the capture buffer. If viewing one-shot capture, no waveform will appear on the left half of the display. If viewing a repeating capture the buffer will relocate to show waveform on the left too.
LAST	Locate the focus to the last sample in the capture buffer. If viewing one-shot capture, no waveform will appear on the right half of the display. If viewing a repeating capture the buffer will relocate to show waveform on the right too.
MIDDLE	Locate the focus to the sample in the middle of the capture buffer. If viewing one-shot capture, locating to the middle offers the same amount of capture waveform on either side of the display.
POINT	Locate the focus to the point cursor. This shows the point cursor in the middle of the display but it may result in no visible waveform when looking at a one-shot capture (it depends what the focus was when it was captured).
MARK	Locate the focus to the mark cursor. This shows the mark cursor in the middle of the display but it may result in no visible waveform when looking at a one-shot capture (it depends what the focus was when it was captured).
CENTER	Locate the focus to the midpoint between and point and mark cursors. This aligns the display such that the cursors are located equidistant from the center of the display and may result in no visible waveform when looking at one-shot capture (it depends what the focus was when it was captured).

When a cue point is assigned to the focus, the widget reports the cue name (not the numeric value of the time at that cue point). Click the focus to see what the numeric value is (if necessary).

### 7.8.2 How Display Focus Works

The focus time parameter effectively scrolls waveforms on the display. It does this by combining two time related functions, waveform offset and post-trigger delay.

DSO automatically assigns the offset and (depending on its value) any post-trigger delay to ensure that waveforms that should appear on the display will appear upon completion of the next trace. There are no complicated delay timebase setup or waveform offset calculations are required.

When viewing a one-shot capture, the duration of the buffered waveform is finite and it is possible to locate the focus such that no waveform will appear on the display (i.e. because the display has been located beyond an edge of the buffer). When viewing repeating capture, DSO continuously adjusts the waveform offset and post-trigger delay to ensure that waveform appears on the display at the specified time. This means one can update the focus and waveform will always be displayed at and around the focus point.

The focus can be changed without (practical) limit in the post-trigger (positive) direction because the post-trigger delay can become very large but there is a hard limit in the pre-trigger (negative) direction which depends on the available capture buffer in the BitScope itself.

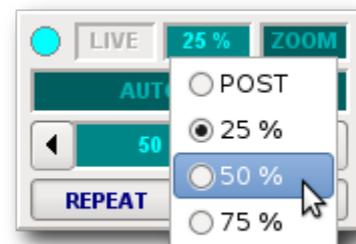
Tip: when using More, Less and Change X to adjust the focus time manually, the rate of change depends on the selected timebase. To make large changes (e.g. in seconds) choose a very slow timebase first and use a faster timebase to make finer changes.

### 7.9 Pre-Trigger Buffer Parameter

By default DSO captures analog waveforms and logic that occur after the trigger.

The pre-trigger buffer parameter reports POST to indicate this. However full waveform and logic capture before the trigger is also possible. Choosing this parameter allows the selection of how much buffer to dedicate to pre-trigger waveform capture.

Important: this parameter provides guidance only as to how much buffer DSO should use for pre-trigger capture. The actual amount used may be different and depends on the chosen focus time. If the focus time is set high enough such that the BitScope buffer is not large enough to capture before the trigger as well, it will reduce the pre-trigger buffer size.



Likewise if only 25% is requested but the focus time is set to sufficiently large negative value that waveform cannot be displayed without increasing the pre-trigger buffer it will be increased. The only exception is post trigger only (i.e. POST). In this case no pre-trigger capture will be done regardless of the focus time (caveat emptor). If the BitScope used does not support pre-trigger it will also be disabled (applies to early BitScope models only). When pre-trigger capture is disabled for any reason, the parameter widget is "dimmed" it indicate this.

## 8. Trigger Control

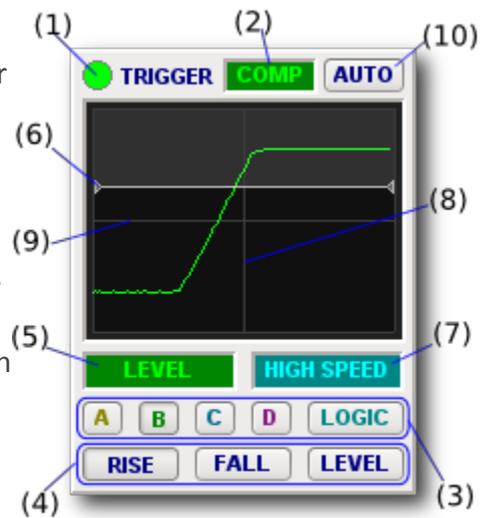
The trigger control panel appear at the top left.

It establishes the time reference for waveform display and measurement.

It specifies the logical condition or waveform feature which defines the origin of the display's time axis. This time origin is called the Trigger Point and is often just referred to as the trigger. Time related parameters (e.g. Focus Time) are defined by reference to it.

Oscilloscopes normally define the trigger as the point at which the waveform transitions a specified voltage called the trigger level. BitScope does this too but because it's mixed signal it needs to do a lot more. The control implements analog and logic triggers individually or in combination and supports auto triggers, glitch, hold-off and post-trigger filters, cross-triggers and parameter and signal condition tracking.

The layout of the trigger control varies by BitScope model, trigger type and mode. Shown here is an analog comparator rising edge trigger. All trigger parameters and widgets respond to Act On Gestures as listed:

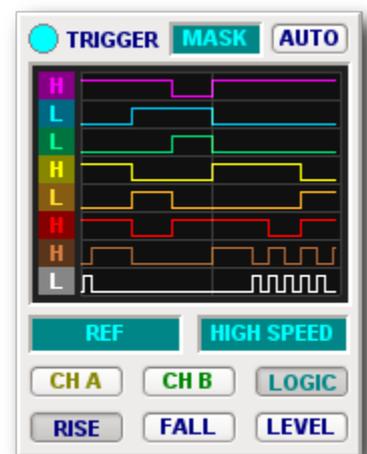


ID	WIDGET	DESCRIPTION
(1)	LED	Lights RED while waiting. Switches to trigger source colour when fired.
(2)	TYPE	Specifies trigger type from those provided by the BitScope (Choose)
(3)	SOURCE	Selects the analog channel or logic channels as the trigger source (Click)
(4)	EDGE	Selects rising or falling edge or level/state trigger mechanism (Click)
(5)	LEVEL	Trigger (voltage) level (Click, Select, Choose, More, Less and Change Y)
(6)	CURSOR	Adjustable and/or trackable trigger level cursor (Change Y)
(7)	FILTER	Adjustable trigger filter and hold-off (Choose, Change X)
(8)	POINT	The Trigger Point (aka time origin).
(9)	REF	The trigger level reference voltage (nominally zero).
(10)	AUTO	Auto trigger enable (Click).

The TYPE (2) and SOURCE (3) determine trigger operation.

For example this what the trigger control looks like when the MASK trigger is used with the logic channels selected as the trigger source. In this case the trigger point is set 1uS after all logic channel have transitioned to the low (aka zero) state.

For any type of trigger this display will always show the source signal(s) at the trigger point regardless of which channels are enabled for capture or how the main display is set up.



## 8.1 Trigger Type

DSO supports a range of different trigger types.

Not all types are supported by all BitScopes and some triggers are meaningful only for some types of source (analog or logic).

The set of trigger types supported by the latest DSO release are:

TYPE	DESCRIPTION
COMP	Analog COMPArator trigger. An analog comparator applied to an analog channel. This is the most often used trigger for analog signals. The trigger is applied to the analog signal before it is sampled and it does not require the channel to be enabled. The comparator outputs for each analog channel can also be routed to logic channels on some models to be used as part of a variable level mask trigger (see MASK below).
SALT	Sample Analog Level Trigger. A digital comparator applied to an analog channel. This is an alternative to the COMP trigger. Very useful for RF or sub-sampled capture. It applies the trigger condition to the sampled analog signal. It can take advantage of pre-scalers (for low level signals) and it can trigger on frequency shifted RF including AM, FM and other modulated or complex signals such as video. It requires the source channel is enabled for capture and it precludes pre-trigger capture on other analog channels on some models.
MASK	Logic Bit MASK trigger. Applies AND combinatorial conditions to the logic channels. This is the most often used trigger for logic signals. Any combination of logic channels may be assigned to participate in the trigger logic. Some channels may also be derived from the comparator outputs of the associated analog channels.
BAND	Logic BAND trigger. Applies level constrained logic condition to an analog channel. This is similar to the SALT trigger in that it works with the sampled analog signal but it applies combinatorial logic instead of level comparison to the digitally encoded analog signal. It is also useful for RF work but can be used to set up trigger conditions for complex digitally derived analog signals too.

Choose the TYPE parameter to select the trigger type from those available for your BitScope.

## 8.2 Trigger Source

Any analog channel or combination of logic channels can be selected as the trigger source.

The top row of buttons selects the trigger source. The number of buttons depends on the BitScope (i.e. how many channels it has). Shown here are the BS445 trigger sources.



Some virtual instruments, trigger types or BitScope models may not allow all sources to be selected. For example the BS10 LOGIC VI does not allow analog sources although it can use the comparator signals derived from the analog channels.

Disallowed sources are shown greyed out (i.e. they cannot be selected).

## 8.3 Trigger Edge

This parameter specifies more than just which edge of an analog waveform will fire the trigger. It controls how the output of the trigger logic is applied for all trigger types. It is selected using the second row of buttons and offers three choices:



VALUE	DESCRIPTION
RISE	Fires upon transition from FALSE to TRUE of trigger condition logic, i.e. the condition must be seen to be FALSE at least once after the trace starts or the trigger will not fire.
FALL	Fires upon transition from TRUE to FALSE of trigger condition logic, i.e. the condition must be seen to be TRUE at least once after the trace starts or the trigger will not fire.
LEVEL	Fires as soon as the trigger condition logic is seen to be TRUE even if it is always true.

It's important to understand that it's not signal transitions that matter but rather the output of the trigger logic.

For some trigger types (COMP, SALT) they are the same but for others they are not.

For example, a falling MASK trigger of XXXXXX10 fires when:

- D0 transitions from low to high while D1 is high, or
- D1 transitions from high to low while D0 is low

The trigger fires when the trigger logic output transitions regardless of which signal produced that transition. The sign of the transition we're interested in is specified by this parameter.

In most (repeating capture) applications, RISE or FALL will produce the best results. The LEVEL trigger is best used for one-shot capture when manually controlling the trigger signal.

## 8.4 The Trigger Level and Cursor

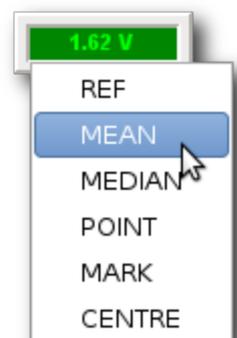
The trigger level specifies the voltage at which an analog signal may fire the trigger.

A cursor (6) appears on the display at this level, the display region where the trigger condition is true is highlighted and the trigger voltage reported via the level parameter (1.62V in this example).

The level may be changed with More, Less or Change Y on the parameter or by moving the cursor directly on the display. If using the parameter the rate of change depends on the source voltage scale.

For this reason the parameter may be more convenient to use, especially for small signals or when offset tracking is enabled because the required cursor movement may be very small or the cursor may be moving around on the display making it hard to "pick up".

The trigger level may also be set to track other parameters, cursors or measured waveform values instead of being manually set. By default the level is set to track the signal mean (DC bias) because this level will trigger almost any AC signal automatically.



The complete set of available tracking and assignment options are:

SOURCE	DESCRIPTION
REF	Assign the reference voltage. Normally this is signal ground or zero volts and will trigger most pure AC signals unless <a href="#">input sensing</a> is active.
MEAN	Track the signal mean. Similar to REF but works with AC signals regardless of the DC bias that may be present. The best choice when <a href="#">input sensing</a> is active.
MEDIAN	Track the signal mid-point. Similar to MEAN but preferred if the signal mean varies or is highly asymmetric. Useful for pulse-width modulating or other dynamically changing waveforms that have consistent peak values.
POINT	Track the voltage POINT cursor from the main display. Makes it easy to adjust the trigger level from the (much larger) main display using the point cursor.
MARK	Track the voltage MARK cursor from the main display. Makes it easy to adjust the trigger level from the (much larger) main display using the mark cursor.
CENTRE	Track the mid-point between the POINT and MARK cursors. This allows an automated trigger level to be assigned using both cursors which may themselves be set to track other waveform features (e.g. the RMS value of the signal).

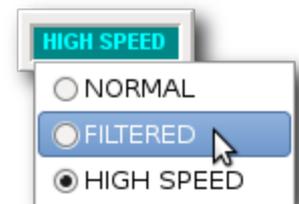
Clicking the level parameter at any time freezes and reports its numeric value. For example, the 1.62V level shown above was frozen from MEAN tracking a 3.3V waveform. This makes it easy to set a trigger level by (say) tracking the MEAN and once it's working clicking to fix its value.

## 8.5 Trigger Filter

Trigger filters may be enabled on any type of trigger and apply to trigger logic output.

The trigger is normally very fast. Sometimes it's too fast.

In these situations the filter offers a number of ways to slow it down and avoid false triggers on noise or glitches or to trigger on specific features of an analog waveform or set of logic signals.



For example one may wish to trigger only on pulses of a certain duration (e.g. video frame sync) or only when an analog waveform has been beyond a specified level for a period of time.

For these purposes the trigger filter parameter offers three choices:

FILTER	DESCRIPTION
NORMAL	Simple noise and glitch rejecting filter. This is the default and most useful for analog triggers (COMP and SALT) and typical oscilloscope applications.
FILTERED	User adjustable hold-off filter. When selected the filter parameter reports the filter hold-off in seconds which may be continuously adjusted using Change X.
HIGH SPEED	Fastest trigger mode. Recommended for high speed logic analysis applications.

Filters prevent triggers on high frequency noise that is often present in waveforms or on glitches that may appear between logic channels. Usually the NORMAL filter will eliminate these artefacts.

For slower signals it may be necessary to use FILTERED and increase the hold-off until a stable waveform display is achieved but for high speed logic it may be preferable to HIGH SPEED and allow the trigger to see very fast logic transitions.

## 8.6 Auto Trigger

Auto Trigger button modifies the trigger to guarantee that it fires after a finite period of time.



It is enabled by default and makes repeat capture easier.

It works by causing the trigger to fire even if the trigger condition is not met. In general this may not be what you want for one-shot capture but it is not disabled automatically (caveat emptor).

Auto Trigger makes it easy to see waveforms before one has established the trigger condition or when triggering is unreliable or impossible (eg, an edge trigger on a DC signal).

Auto ensures that within a short time a trace will appear on the display and is most useful for high display refresh rate repeat capture with a fast timebase. If the timebase or refresh rate is too low, auto traces can become difficult to distinguish from normal ones.

In these cases it is a good idea to disable auto trigger after setting up a suitable trigger condition.

## 8.7 Cross-triggering on Analog or Logic Signals

One of the most powerful and useful features of BitScope is its mixed signal capture capabilities.

At its heart is the cross-trigger; the ability to trigger analog waveforms on logic and vice versa.

At its simplest it means you can use any logic input as an external trigger source for analog waveforms. In more sophisticated setups it means you can trigger a logic capture when a related analog signal reaches a certain level or crosses a defined threshold.

In essence the cross-trigger is simply one of the previously described analog or logic triggers but used to trigger the capture of the other (or both) types of data.

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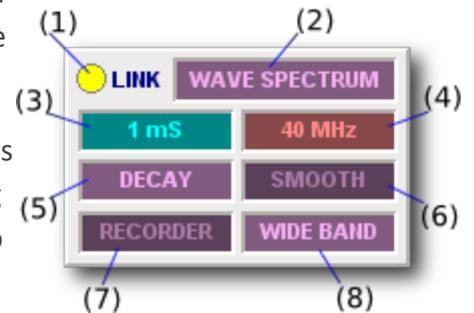
## 9. Capture Control

The capture control panel appears at the bottom right.

It manages how analog and logic signals are sampled, stored and displayed. BitScope's inputs are always sampled at the highest rate available to maximize bandwidth and minimize aliasing.

However the sample rate used for display is typically lower which allows timebase zoom, noise reduction and wide band or other data processing modes. The capture control establishes all the parameter values used to manage these features.

It is also home to the DSO Data Recorder, buffer and sample rate controls and the display format menu. All these parameters and widgets respond to Act On Touch Gestures as listed here:



ID	WIDGET	DESCRIPTION
(1)	LED	Highlights in focus channel colour to indicate activity.
(2)	FORMAT	Virtual instrument display format menu (Select, Choose).
(3)	BUFFER	Set or adjust the buffer size and capture duration (Select, Choose)
(4)	SAMPLE RATE	Set or adjust the sample rate (Select, Choose, More, Less)
(5)	PHOSPOR	Set display decay or overlay phosphor mode (Click Choose)
(6)	DISPLAY	Set the display rendering mode (Click, Choose)
(7)	RECORDER	Control integrated data recorder (Click, Choose)
(8)	DATA MODE	Choose the preferred data processing mode (Click, Choose)

### 9.1 Capture and Display Sample Rates

There are two sample rates managed by BitScope DSO.



RATE	DESCRIPTION
CAPTURE	signal acquisition sample rate
DISPLAY	waveform display sample rate

The capture sample rate is shown at (4) and the display rate is shown on the display (as FS =).

The ratio between them depends on the buffer size, timebase and timebase zoom.

In this example the capture rate (40 MHz) is much higher than the display rate (250 kHz). In some data modes they may be the same but when they're different bandlimited filtering and decimation is applied to maximize the display resolution.

For this reason most virtual instruments use the fastest sample rate available but there are times one might want to choose a particular sample rate or limit the rate. In these cases Choose the sample rate (4) required or Click to toggle between the two most recently used rates.

## 9.2 Capture Duration and Buffer Size

The buffer (3) parameter reports the total capture duration or the associated buffer size.

When capturing data it reports the duration (in seconds).

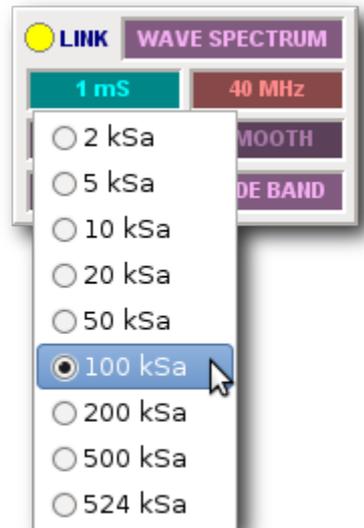
When selected it reports the buffer size (in samples) which size is also indicated via the Choose menu. In this example the capture duration is 1ms with a 100kS buffer.

Choose the parameter to view this menu or Select to toggle between the two most recent values. The list of values available depends on the BitScope itself. The chosen buffer size is maintained per virtual instrument so selecting a different instrument may change the buffer size.

Which size to use depends on what you want to achieve.

Small sizes are best suited when high speed display refresh rates or persistent phosphor displays are desired. Larger sizes are better suited to one-shot storage and mixed signal oscilloscope or logic analyzer applications.

A typical logic analyzer works best when the capture buffer is set as large as possible so as much information as possible is captured in a single frame. Another reason to use a larger buffer is to look at very low level or high bandwidth analog signals. In this case ENHANCED or WIDE BAND data mode afford the highest sample precision possible.



## 9.3 Display Phosphor Mode

The phosphor mode defines how to accumulate waveforms and logic on the display phosphor.

It is changed by Clicking the parameter to toggle between values or Choosing a value from the menu. There are three phosphor modes:

MODE	DESCRIPTION
NORMAL	live display with periodic refresh
OVERLAY	persistent accumulating display
DECAY	semi-persistent accumulating display

In most cases NORMAL mode is used. The waveform is redrawn every frame and is best suited to one-shot captures or repeating capture when the highest possible frame rates are desired.

Accumulating modes are better suited to waveform or spectrum displays that have with features that may occur infrequently or intermittently or for which persistence is beneficial. Examples may include X-Y density plots, clock timing jitter, ISI eye patterns or spectral plots.

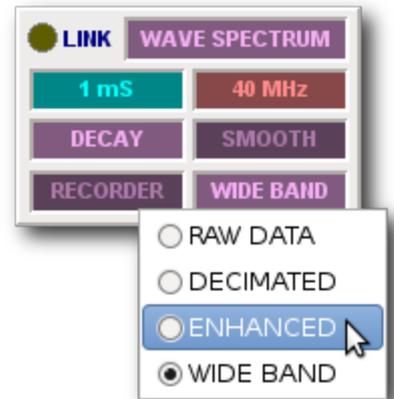


## 9.4 Data Processing Mode

The data processing mode defines how waveform data is (pre)processed by BitScope (if at all). It is changed by Clicking the parameter to toggle between two values or Choosing a value from the menu.

Not all BitScopes support all data modes but those that don't delegate mode processing to the host. The modes still work but they may slow the [frame rate](#). There are four modes:

MODE	DESCRIPTION
RAW DATA	no signal processing, just the data
DECIMATED	sub-sampled data processing
ENHANCED	decimated with improved resolution
WIDE BAND	enhanced plus wide bandwidth data



### 9.4.1 RAW DATA Mode

To see all the waveform or logic data as actually captured by BitScope, choose RAW DATA.

No signal processing applied. If the buffer size is very large this mode may be a little slower than the others because all of raw capture data is sent by BitScope for every frame.

When capturing waveforms for export to a file or for processing by other software, RAW DATA is usually preferred because it saves the data as originally captured by BitScope. It can also be useful when looking for analog glitches or very short duration logic events in one-shot data because every sample captured is shown on the display.

### 9.4.2 DECIMATED Mode

For the fastest repeating display refresh rates choose DECIMATED but beware of aliases!

BitScope usually captures at sample rates much higher the display's sample rate. As a consequence decimating the data in BitScope before sending it reduces the required data link bandwidth. This can speed up the refresh rate or improve operation via very slow links.

As with any digital sampling oscilloscope, decimation can produce aliases and images of the waveform can appear at the wrong frequency. This may or may not be what is expected and it occurs when frequencies in the signal are higher than 1/2 of the display rate.

#### Aliases and Decimated Waveforms

When looking at low bandwidth analog waveforms and certainly when viewing logic data aliases are usually undesirable. It's easy to tell whether the waveform is an alias; select ENHANCED or WIDE BAND mode. If the waveform changes shape or frequency, DECIMATED is showing an alias in which case use either of these other two modes to avoid this.

However, aliases are something very useful such as when sub-sampling or accumulating X-Y plots or dot displays on persistent phosphor. Using these techniques one can view periodic waveforms of frequencies up to the full analog bandwidth of BitScope.

### 9.4.3 ENHANCED Mode

For the highest bit-resolution capture with minimal chance of aliases choose ENHANCED mode.

Depending on the ratio between the capture and display sample rate, Enhanced mode can improve the bit resolution of captured data (at the display sample rate) by up to 4 bits (for 12 ENOB resolution from an 8 bit BitScope). Like Decimated mode, Enhanced mode is also fast.

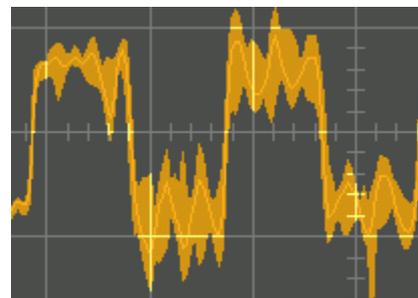
Due to the higher bit resolution, Enhanced mode can be very effective when viewing low level signals. It can also significantly enhance spectrum displays, particularly when low level periodic signals are buried in wide band noise (a common situation).

See the quantization noise example below for what ENHANCED mode can do and to maximize the potential benefit of ENHANCED, choose a larger buffer size.

### 9.4.4 WIDE BAND Mode

To see the full picture Choose WIDE BAND mode.

Like ENHANCED, WIDE BAND offers high bit-resolution analog waveform display but simultaneously shows high frequency components (e.g. noise or harmonics) that may also be present on the waveform.



For example this WIDE BAND display shows a square wave in the presence of a higher frequency tone burst and a lot of noise. Without this mode aliasing effects would distort the displayed waveform beyond recognition.

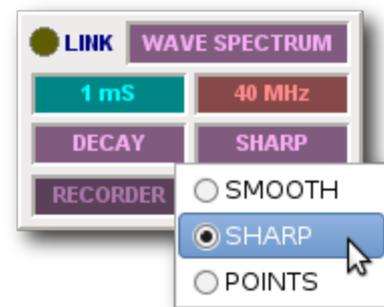
WIDE BAND is the most useful mode for most type of analog signal so it is the default for analog virtual instruments. For those with experience of high performance analog scope, WIDE BAND should look quite familiar as it shows almost the same thing as an analog oscilloscope trace.

## 9.5 Display Rendering Mode

The display mode selects how the DSO renders waveforms and logic on the display.

It is changed by Clicking the parameter to toggle between two values or Choosing a value from the menu. There are three display modes:

MODE	DESCRIPTION
SMOOTH	lower resolution interpolated waveforms
SHARP	high resolution non-interpolated waveforms
POINTS	sample points only, useful for sub-sampling



Which is best depends on which features of a trace one wants to see and the [data mode](#).

### 9.5.1 SMOOTH Display Mode

This is the default and most familiar looking display mode. Analog waveforms are drawn as curves that fit the sampled analog data and logic traces are drawn as standard high/low line segments. Implicit in smooth mode is the assumption that the waveform data is sampled real-time (i.e. it's not sub-sampled or equivalent time sampled). It uses bandlimited interpolation to render waveforms, which means that very high frequency real-time waveforms will be shown as approximations. If higher resolution rendering of high frequencies is required, equivalent time sampling (periodic sub-sampling) should be used. Smooth display mode can accommodate this but points on a persistent phosphor will produce higher resolution results.

### 9.5.2 SHARP Display Mode

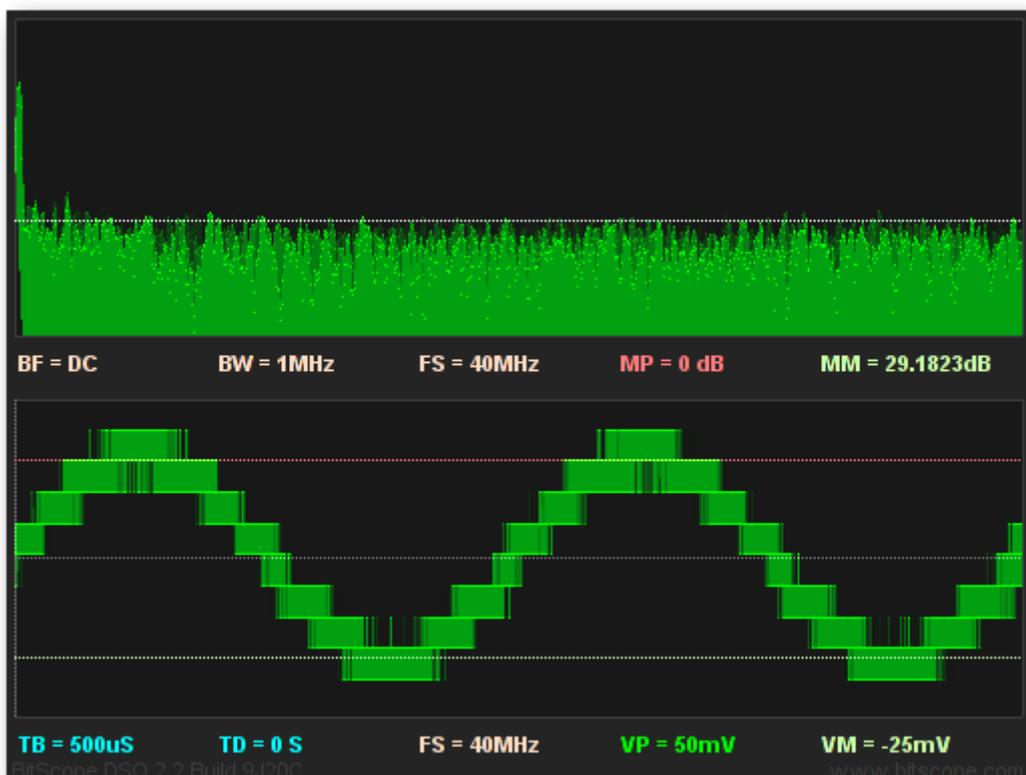
Similar to smooth but drawn without bandlimited interpolation and showing individual samples. Sharp is a finer display mode (it doubles the display sample rate) and makes precise sample values visible with line segment transitions between them. Sharp spectrum displays are also double the resolution of smooth. This can be quite useful when more display bandwidth is needed to help identify aliased spectrum components or make more precise frequency or bandwidth [measurements](#).

### 9.5.3 POINTS Display Mode

Points mode plots only the sample points and assumes nothing about the mode of capture. It is ideal for accumulating X-Y plots or sub-sampled waveform displays and is most useful when used with [persistent phosphor](#). Spectra and logic are rendered the same as sharp mode.

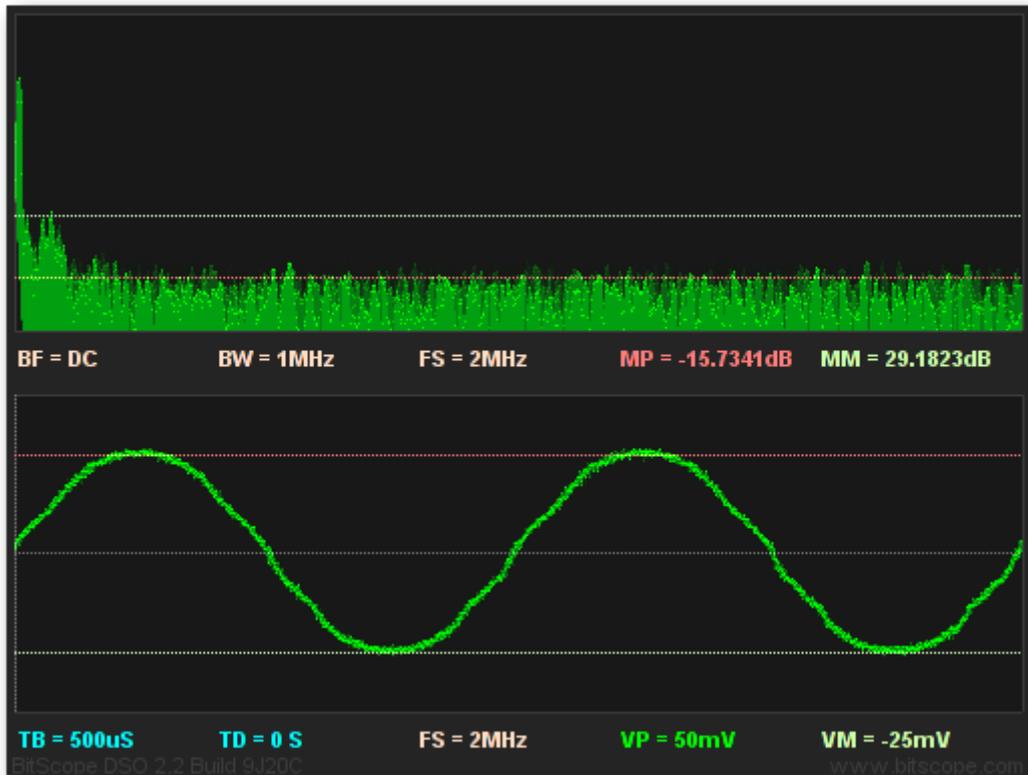
## 9.6 Quantization Noise and Resolution Enhancement

As with any digital oscilloscope, quantization noise is produced when converting analog signals.



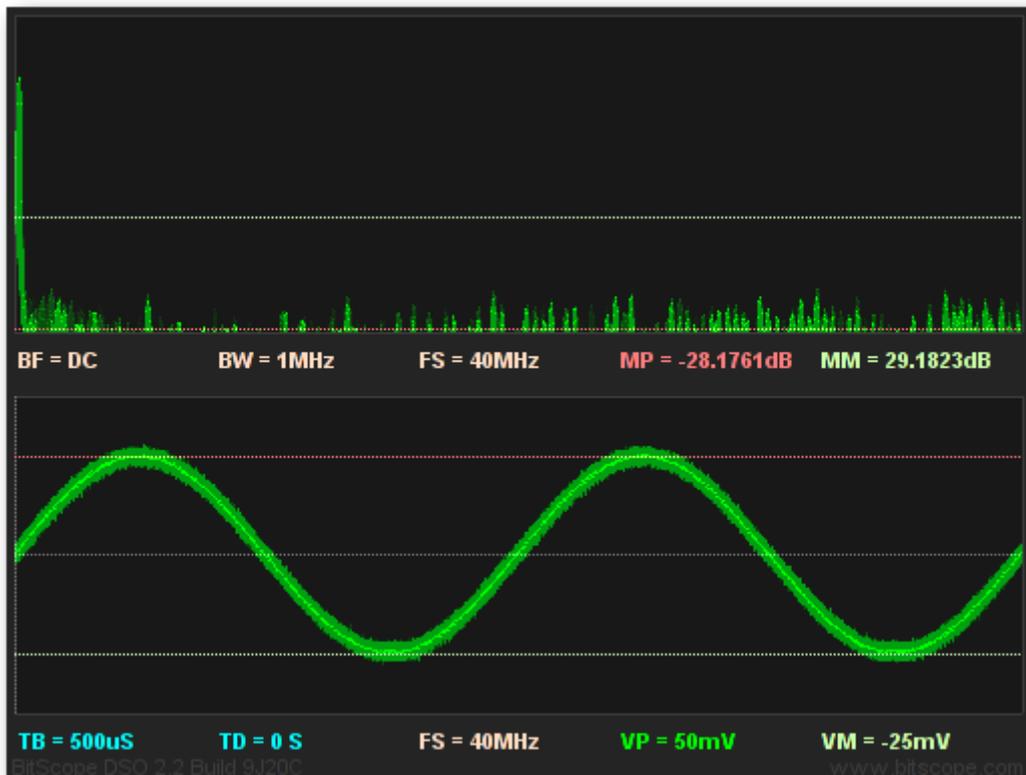
This is a 4 kHz sinusoid at very low level (50mV peak-to-peak).

Normally this is not a problem because the quantization noise level is very low compared to the signal itself and can not be seen on the display. However when measuring very low level signals, quantization noise can become significant. In this case it is about 8mV/quantum and is clearly visible on this Raw Data waveform display because at 50mVp-p this signal uses only the bottom 3 bits of the A/D range. Next we have same 4 kHz sinusoidal waveform but with Enhanced Data Mode selected and then with prescaling:



The huge resolution improvement in the first instance is done entirely in the digital domain by exploiting the oversampling inherent in the high capture sample rate used to acquire the waveform. Using bandlimited filtering and decimation, BitScope is able to extract more than 3 extra bits of resolution from the same 8 bit raw waveform data but we can do better. In the second instance we have both the prescaler and enhanced data mode enabled we can now really see the signal for what it is, a pure sinusoidal waveform with very low noise, even though it's just 50mVp-p. We have reduced quantization noise a massive 28dB compared the original raw waveform data.

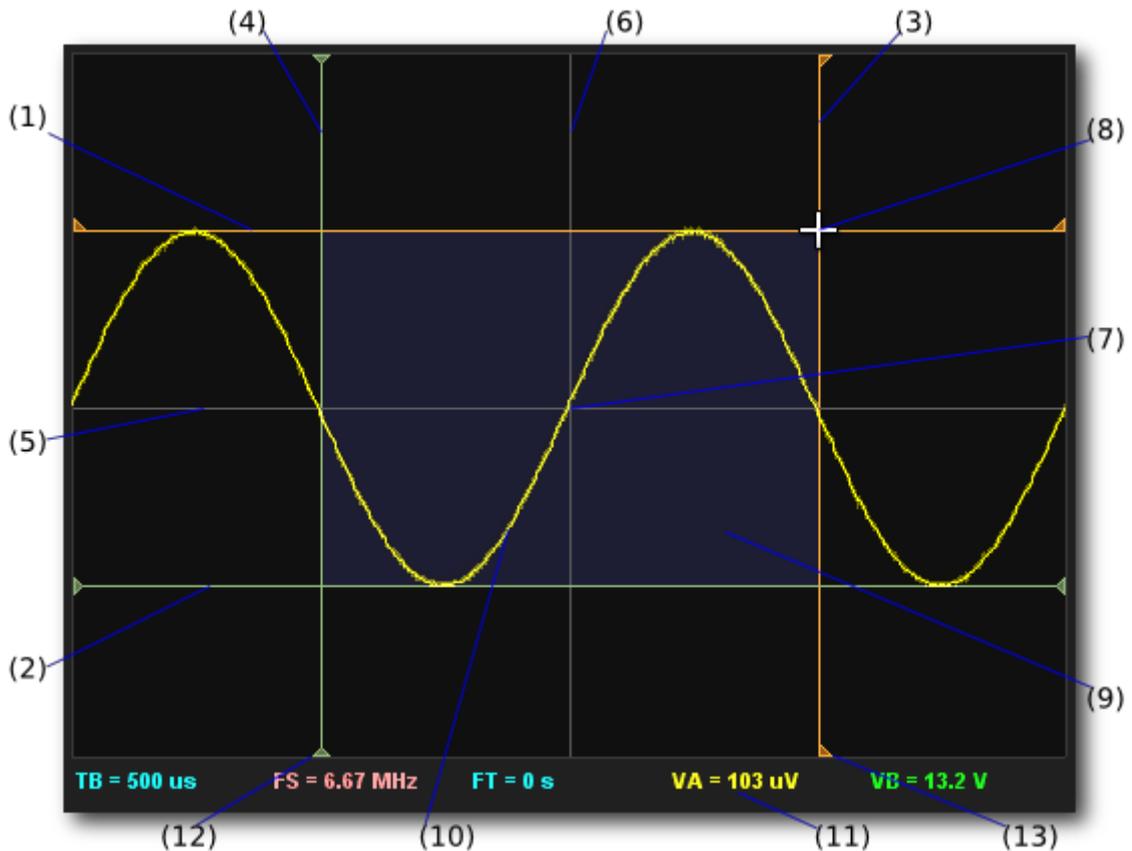
Enhanced data mode filters broadband noise (of which quantization noise is a common source), but it may be desirable to see whether any noise exists in the signal, even though one may also want to see a high quality image of the waveform itself. In this case, use WideBand Data Mode, here showing the same waveform in rendered WideBand:



Here it is possible to see both the resolution enhanced sinusoidal waveform and the broadband noise at the same time. In practice, if the primary source of noise is quantization, it's probably more useful to use Enhanced mode. Where the noise comes from other sources (details of which you may need to know), WideBand makes it easy to see.

## 10. Cursor Measurement

Cursors facilitate waveform voltage, time and frequency measurement.



The display cursors are the primary means by which DSO performs and reports waveform measurements. This screenshot shows a sine wave with cursors enabled. The cursor panel shows the associated measurements. Many different measurements that are possible. This example highlights some common ones to explain how cursors work and how to use them effectively.



Cursors report absolute and relative values in the X and Y axes of the main display. They may be manually adjusted to measure features of interest or set to track automatic measurements such as peak or RMS voltages, triggers, time periods and more.

ID	CURSOR	AXIS	DESCRIPTION
(1)	POINT	Y	Voltage or Level Cursor (Click, Choose, More, Less and Change Y).
(2)	MARK	Y	Voltage or Level Cursor (Click, Choose, More, Less and Change Y).
(3)	POINT	X	Time or Frequency Cursor (Click, Choose, More, Less and Change X).
(4)	MARK	X	Time or Frequency Cursor (Click, Choose, More, Less and Change X).
(5)	ORIGIN	Y	Voltage or Level Origin (fixed, signal ground or 0dB).
(6)	ORIGIN	X	Time or Frequency Origin (fixed, time zero aka trigger point or 0Hz).

Other features on the display which are associated with the cursors are:

ID	FEATURE	DESCRIPTION
(7)	ORIGIN	Display origin (the intersection of each axis origin).
(8)	FOCUS	Cursor focus (where the mouse, stylus or your finger is on the display).
(9)	REGION	Measurement region (the highlighted region of the current measurement).
(10)	SIGNAL	Measurement waveform, logic or spectrum (on the focus channel).
(11)	BIAS	Bias DC or mean waveform voltage (on the focus channel).
(12)	BASE	Isosceles-triangular cursor base indicating the cursor has been assigned.
(13)	FLAG	Right-triangular cursor base indicating the cursor is being assigned.

The measurements made with cursors are reported via additional [colour coded](#) parameters:

ID	VALUE	AXIS	DESCRIPTION
(14)	DY	Y	Delta Voltage or Level (difference between POINT and MARK).
(15)	DX	X	Delta Time and Frequency (difference between POINT and MARK).
(16)	1/DX	X	Delta Frequency or Time (the inverse of DX).
(17)	DY/DX	XY	Delta Y on Delta X (nomially measures the slew rate).

With reference to the sine wave example above, cursors measure the waveform period as 250us with the pre-trigger zero crossing at -125us and the post-trigger crossing at 125us. The frequency is 4kHz. The waveform has a peak-to-peak voltage of 4V and DC bias of 103uV (calculated from the signal itself). The signal reaches a maxima of +2.02V and minima of -1.98V. While not directly relevant in this case, the slew rate of the voltage & time range of the cursor region is 16mV/us.

Other information available on the display tells us that the waveform is sampled at 6.67MHz, the total duration across the x-axis is 500us and the trigger is in the middle of the display (FT = 0s). Other [display formats](#) may measure in different domains (e.g. level vs frequency for spectrum analyzer displays) but cursor operation is the same from an operational point of view.

## 10.1 Cursor Types and Movement

On each display there are two movable and one fixed cursor per axis:

CURSOR	DESCRIPTION
POINT	Primary (relative or absolute) measurement cursor. Used on its own to make absolute measurements or together with MARK to make relative measurements. Is the first cursor picked up when more than one is located at the same point on the display.
MARK	Secondary (absolute) measurement cursor. Not used (i.e sits at the ORIGIN) when making absolute measurements with POINT, otherwise it works the same way as the POINT and is used as "the other side" of relative measurements.
ORIGIN	Origin (fixed location) cursor. Appears as a grey line which indicates the axis origin. It is not relocatable other via certain channel <a href="#">calibration operations</a> .

Click the CURSOR Scope Tool Button on the DSO selector bar to enable cursors on the display and show cursor measurement panel. Usually it is also desirable to turn off the graticule (the GRID Scope Tool Button) when performing cursor measurements to de-clutter the display.

### 10.1.1 Moving Cursors Manually

Change X a X-Axis cursor or Change Y a Y-Axis cursor directly on the display to move it. If both POINT and MARK are at the same location, POINT will move first. Both cursors in each axis may also be moved using the sameChange gestures on their respective parameters.

The cursor parameters also accept Select, More and Less gestures. These move a cursor to a specified location or move it in either direction by one display division per More/Less action.

### 10.1.2 Cursor Movement Indication and Regions

When a cursor is moved its end-points switch from isosceles triangles (12) to right-angles (13).

The direction the right-triangle points shows the preferred direction of the cursor.

The preferred direction is one which results in positive (relative) measurement (i.e POINT > MARK) and the region (9) is shown in blue. If the cursors are reversed (i.e. MARK > POINT) measurement will be negative and the region is shown in red.

Cursor never disappear from the display. If located beyond the edge of the display (or the display focus is moved) a cursor will appear stuck at the edge of the display so it may still be picked up.

### 10.1.3 Measurements Shared between Virtual Instruments

DSO has many virtual instruments but only one set of cursors for each measurement domain (i.e. one set for time, frequency, voltage and level). This makes it possible to perform comparative measurements between different virtual instruments and input channels.

For example, cursor positions referenced to a logic transition in the LOGIC instrument can be seen on an analog waveform in the SCOPE (assuming one the same trigger) or measurements made on one analog channel may be compared with measurements on another.

Of course MIXED mode provides similar capabilities all on the one display but one may prefer the SCOPE's more powerful waveform analysis tools or to use it to establish a "zoomed in" view.

In all cases the cursor positions are reported the same way making measurements on waveforms captured with in different instruments possible.

## 10.2 Cursor Tracking and Cue Points

A powerful cursor feature is that they can be set to track various signal measurements.

They may also be assigned to parameter cue points such as the [trigger](#), ground reference or even another cursor value.

When tracking or assigned the cursor reports the tracked or assigned measurement or parameter, not the value.

FOCUS	MAX
TRIGGER	MIN
250 us	4.006 V
4 kHz	16 mV/us

Shown here is a similar set of measurements but this time voltage cursors are set to track the waveform maxima and minima (MAX/MIN) and time cursors are assigned to the display focus time and trigger point.

Click a tracking cursor parameter at any time to terminate tracking and see the numeric value.

### 10.2.1 Voltage Cursor Cue Points

Choose either voltage cursor to select a cue point.

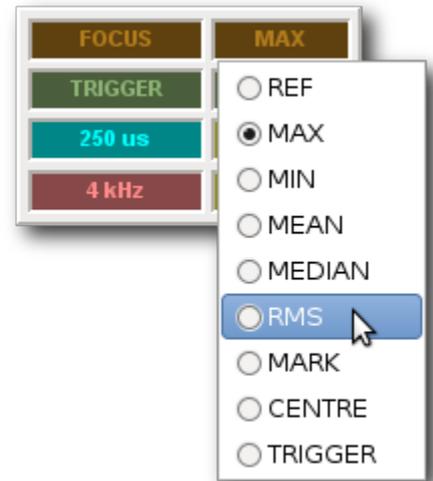
When selected the cursor immediately relocates to the cue point's value on the display.

For example assigning MAX and MIN to POINT and MARK respectively relocates the cursor to show the waveform (voltage) limits and reports values via the parameters.

These points are tracking which means as the waveform changes the cursors remain locked to these points on the waveform and continually report the maximum, minimum and peak-to-peak voltages as the waveform scrolled or as new signals are captured and displayed.

Other cue points such as REF or MARK may be assigned but they do not track.

The full set of voltage cues are:

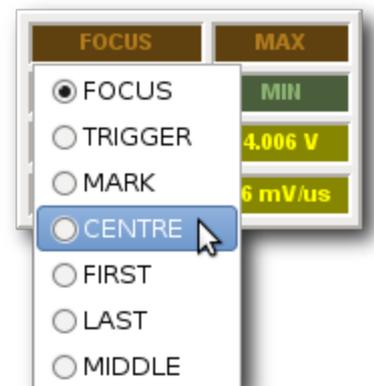


CUE POINT	TRACKING	DESCRIPTION
REF	NO	Zero reference voltage (aka signal ground).
MAX	YES	Waveform maximum voltage.
MIN	YES	Waveform minimum voltage.
MEAN	YES	Waveform average voltage.
MEDIAN	YES	Mid-point between MAX and MIN.
RMS	YES	Waveform RMS voltage.
MARK	NO	Current MARK cursor value (appears in POINT menu only).
POINT	NO	Current POINT cursor value (appears in MARK menu only).
CENTRE	NO	Mid-point between POINT and MARK.
TRIGGER	YES	Trigger Level (the trigger level shown on the main display).

### 10.2.2 Time Cursor Cue Points

Choose either time cursor to select a cue point. When selected the cursor immediately relocates to the cue point's value on the display. For example assigning FOCUS and TRIGGER to POINT and MARK respectively relocates the cursor to show the trigger and display mid-point and reports these values via the parameters.

As with voltage cursors, some cue points are tracking which means as the tracked value changes the cursor remains locked to that value and moves on



the display as necessary. Other cue points are assigned (the cursor moves to that point once). The cursor reports the parameter name (e.g. FOCUS) unless the parameter changes in which case it reports a numeric value.

CUE POINT	TRACKING	DESCRIPTION
FOCUS	YES	Mid-point on the display (i.e. the prevailing <a href="#">time focus</a> ).
TRIGGER	YES	Assigns the location of the <a href="#">trigger point</a> to the cursor.
MARK	NO	Current MARK cursor value (appears in POINT menu only).
POINT	NO	Current POINT cursor value (appears in MARK menu only).
CENTRE	NO	Mid-point between POINT and MARK. This of course changes both the cursor value and updates the CENTRE value.
CYCLE	YES	The trigger cycle point (i.e. the point after the trigger where the trigger condition again becomes true, if found).
PERIOD	YES	The waveform period (i.e. points delimiting one period of the waveform centered about the focus time, if a period can be found). This function requires the timebase to be set such that at 3 to 4 periods are visible on the display. The MARK cursor locates one half period to the left and the POINT one half period to the right.
FIRST	NO	Locate cursor to the first sample in the capture buffer.
LAST	NO	Locate cursor to the last sample in the capture buffer.
MIDDLE	NO	Locate cursor to the sample in the middle of the capture buffer.

In all cases of tracking or assignment it is possible that the cursor's location when assigned a new value may be beyond the limits of the display. In this case the cursor will remain stuck to the display edge beyond which its value has located it.

For time domain cursors it is always possible to locate the display to position that cursor in the middle by choosing POINT or MARK from the focus time menu.

## 11. Spectrum Analyzer

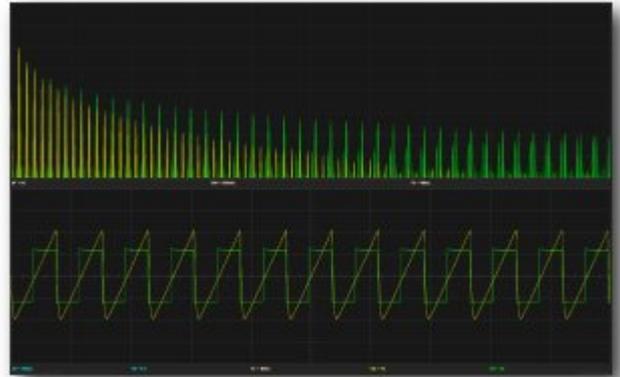
*This spectrum analyzer shows baseband spectra.*

A baseband real-time spectrum analyzer is included as part of the core DSO engine. Its output is available in most [instruments](#) that deal with analog waveform data.

The baseband analyzer is integrated with the instruments it serves, so there are no additional settings to adjust.

Instead the analyzer adapts automatically to the prevailing timebase, scale, volts/div and screen size to display the optimum resolution magnitude (or phase) spectrum of the waveform.

Fig [1] shows the spectra of the signals connected to the [Sydney](#)BitScope as well as the waveforms themselves.



Unlike most swept spectrum analyzers the BitScope spectrum analyzers are fourier transform based and update live at the same high speed refresh rate as the waveform display.

This means it is possible to observe fast moving dynamic features in the spectrum or catch transient spectral events not otherwise visible with a swept spectrum analyzer.

It also means it is possible to zoom and scroll through one-shot waveform captures to view and analyzer the spectrum dynamically at different points in the buffer.

### 11.1 Spectrum parameters

Located at the bottom of the spectrum display is a set of spectrum measurement parameters:

ID	NAME	DESCRIPTION
BF	Frequency	The frequency at the left edge of the spectrum display. In baseband this is always "DC". In multiband it's the lowest displayed frequency.
BW	Bandwidth	Spectrum bandwidth (aka "Nyquist frequency"). In baseband it is also the highest displayed frequency.
FS	Sample Rate	This reports the capture or display sample rate depending on the prevailing <a href="#">data mode</a> ; WideBand and Raw Data report the capture rate, Enhanced and Decimated report decimated display rate.
FM	Frequency Mark	The value of the mark frequency <a href="#">cursor</a> .
FP	Frequency Point	The difference between the point and mark cursor frequencies.
M M	Magnitude Mark	The value of the mark level cursor reported in Decibel Relative units.
MP	Magnitude Point	The difference between the point and mark levels cursors.

## 11.2 Magnitude Scaling

The normal vertical (i.e. magnitude) resolution of the spectrum analyzer is 10 dB per grid line and precise dB levels can be measured using the spectrum level cursors.

The spectrum magnitude display is unreferenced; all measurements are relative to the prevailing V/Div value on each channel. If you wish to shift the spectrum up to see low level signals simply increase the vertical scale of the associated channel.

However, if you wish to make measurements relative to a standard Decibel scale you can reference the display to show dBu, dBV or dBm values as follows:

SCALE	REFERENCE	CALIBRATION
dBu	0.775V (RMS)	Apply a 1 kHz 0.775V (RMS) voltage to any channel via a 1M Ohm (or greater) probe. Mark the peak of the spectral line for 0 dBu.
dBV	1.0V (RMS)	Apply a 1 kHz 1.0V (RMS) voltage to any channel via a 1M Ohm (or greater) probe. Mark the peak of the spectral line for 0 dBV.
dBm	0.224V (RMS)	Apply a 1 kHz 0.224V (RMS) voltage to channel B with 50 Ohm termination enabled. Mark the peak of the spectral line for 0 dBm.

## 11.3 Frequency Resolution and Sensitivity | EMC Example

The frequency resolution of the spectrum analyzer depends on the bandwidth (i.e. the prevailing timebase settings) and display sample rate (which depends on display size and mode).

Specifically, choose the SHARP display mode to maximize the frequency resolution for a given display size and maximize the display size. For example the screenshot below was taken from a widened display with a frequency resolution of 2000 bins over 1MHz bandwidth (i.e. 500Hz/bin).



This recording was created by connecting the flying ground lead of a standard oscilloscope probe to the probe tip, increasing the gain of the BitScope channel and then moving the "loop antenna" thus created near a standard desktop PC.

The signals that can be seen are EMI produced by this equipment. This example demonstrates just how easy it is to use BitScope to check for EMI (e.g. for preliminary [EMC](#) testing purposes) even using a simple low gain "antenna" as this. The bandwidth is reported via the BW parameter and the graticule has 10 vertical divisions, allowing quick frequency measurement to be made in much the same way as time measurements may be made with waveform displays. More precise measurements of spectral features can be made using frequency cursors.



## 12. Waveform Generator

Some BitScopes (eg BS3xx) have a built-in waveform generator. It is enabled by selecting the WAVE Instrument or on models that support [BitGen](#) (eg, [BS10](#)) via the WAVE Tool.

When selected this panel appears with parameters that control how (1) the waveforms are generated.

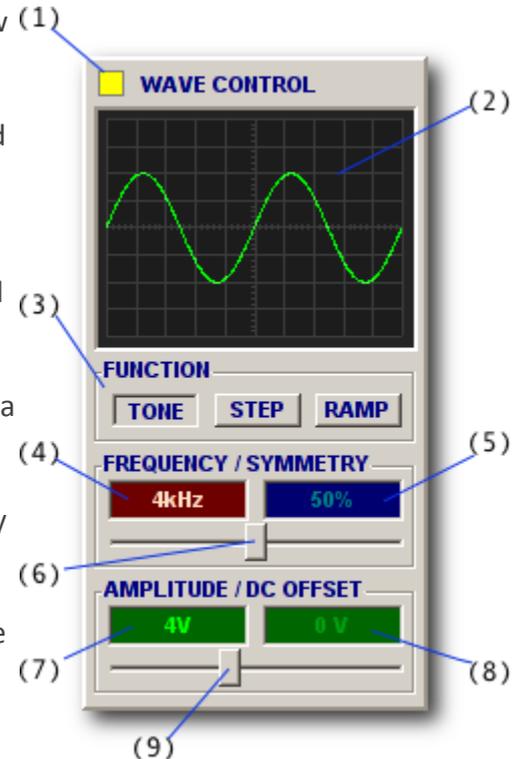
The generator LED (1) lights up when the generator is active and waveform preview (2) shows an image of the generated waveform.

Wave function buttons (3) select the basis function used to synthesize the waveform and four generator parameters control how the waveform is generated.

These parameters are divided into two pairs, each of which share a parameter control (6) and (9).

Frequency (4) specifies the fundamental frequency and symmetry (5) applies (an optional) symmetry modification to the waveform.

The second pair comprise the amplitude (7) which adjusts the output level and the the offset (8) which adjusts DC offset of the waveform.



### 12.1 Waveform Generator Implementation

How the waveform generator works in detail depends on the BitScope model, but from the perspective of this control panel, most differences are not significant.

The key functional difference is that the waveform generator built into the [BS3xx](#) models is a truly arbitrary sample recording and playback engine, whereas the [DSP based waveform generator](#) in [BS1xx](#) synthesises the waveforms directly.

That is, the generators themselves are capable of very different types of waveform synthesis but for the purposes of this discussion they work the same with two exceptions:

- The BS3xx generator can generate waveform only while the BitScope captures data. It also (re)uses the logic buffer (to store the waveform) so concurrent logic capture is not possible.
- The BS1xx generator is independent of waveform capture and can operate continuously, even when the BitScope is idle, but it cannot generate completely arbitrary waveforms.

There are other applications which can be used with either type to access the special features unique to each but for the purposes of this virtual instrument, waveform generation is automatically synchronized with waveform capture.

This makes transfer function analysis among other things very easy.

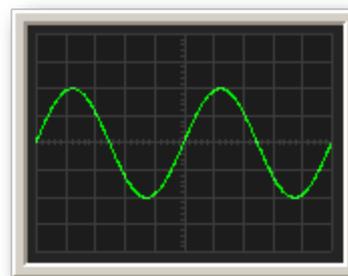


All BitScopes send the generator output to the WavePort (pin 26 on the POD connector) and some can also send it via BNC B (under software control). Some older models have a front panel generator switch to connect the waveform generator output to BNC B as shown here. On these models one must also turn this switch ON for the waveform output to be available via B BNC. In all models the waveform generator output is terminated in 50 ohms.

## 12.2 Waveform Preview

The waveform generator includes a mini-scope display for waveform preview.

The preview is the same as the main display except it shows the waveform that will be generated, not the actual output. It adjusts according to the timebase and voltage scale used on the main display, so synthesized waveforms appear as they do on the main display.



The purpose of the preview is to provide instantaneous visual feedback about what the waveform will look like as waveform generator parameters are changed. It does this even when the waveform generator is not enabled. Of course the generated waveform can be recaptured and shown on the main display using one of the analog channels, but if one is using both analog channels to show other signals, the preview allows one to see the generator at the same time.

## 12.3 Wave Function

The first step when programming the waveform generator is to choose a wave function.

1. **TONE** sinusoidal waveforms (pure tones).
2. **STEP** square, pulse and impulse waveforms.
3. **RAMP** triangle, ramp and inverse ramp waveforms.



The wave function is not the waveform itself. It is instead the mathematical function used to synthesize the waveform according to the specified waveform generator parameters.

### 12.3.1 TONE Function

Synthesizes a standard sinusoidal waveform (assuming symmetry of 50%).

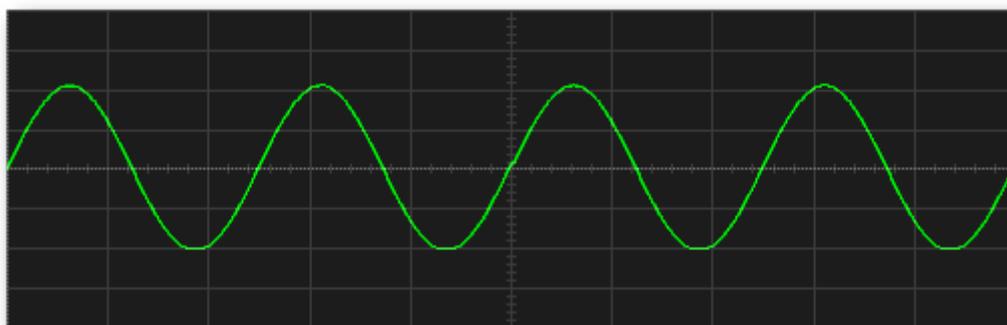
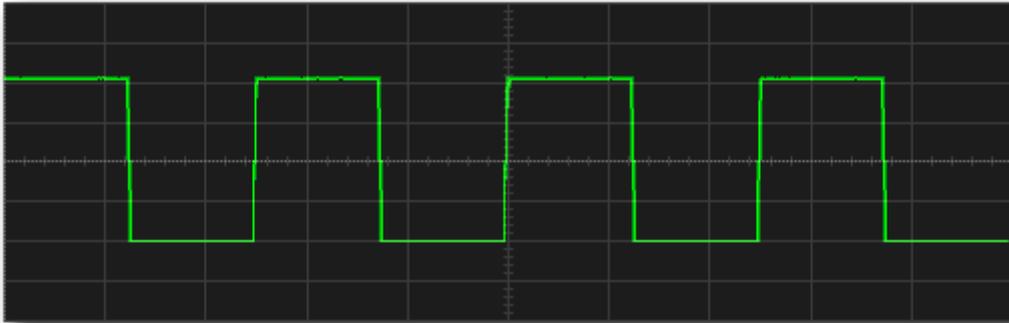


Fig [1] TONE Wave Function (50%)

TONE function waveforms are used for tone based circuit analyses including phase response and any other application that requires a single pure frequency. If the symmetry is set to other than 50%, the sinusoid is progressively phase distorted.

### 12.3.2 STEP Function

Synthesizes a standard square wave (assuming symmetry of 50%).

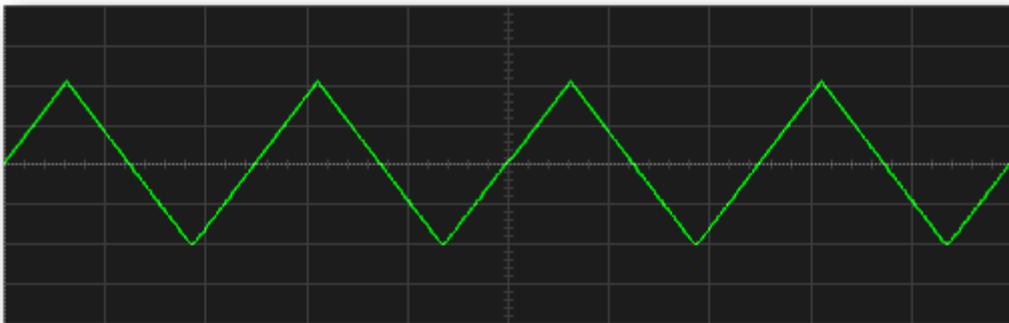


*Fig [2] STEP Wave Function (50%)*

STEP function waveforms are used for step and impulse response analysis and general transfer function analysis. If the symmetry is adjusted to other than 50%, the mark-space ratio of the square wave can be adjusted. In the extreme case one can synthesize a pulse train in this way.

### 12.3.3 RAMP Function

Synthesizes a standard triangle waveform (assuming symmetry of 50%).



*Fig [3] RAMP Wave Function (50%)*

RAMP function waveforms are useful to test system linearity, slew rate measurements or for their unique spectral characteristics. If the symmetry is adjusted to other than 50%, the triangle waveform can be transformed into a ramp or inverse ramp (aka sawtooth) waveform.

## 12.4 Parameter Controls

In addition to the wave function, the waveform generator divides the four other parameters (frequency, symmetry, [amplitude](#) and [offset](#)) into two parameter groups.

Each group displays the parameter pair and has a shared parameter slider positioned below them. To change a parameter, click on its value to highlight the parameter and adjust the slider to change the parameter. As the parameter is changed, the waveform preview adjusts immediately to reflect the change.

## 12.5 Keyed Parameter Entry

It is possible type in a new value for each parameter. Click on the parameter to be changed and type in a new value pressing enter to finish. The value typed may be followed by an optional range character (e.g. m, k, M). For example, the value 23.4k entered into the frequency parameter box will change the frequency to 23.4kHz. If no range is entered, units are assumed. It is also possible to enter a new value with a postfix operator to apply to the parameter value. For example, if the frequency is 4kHz and 3k+ is entered, the new frequency will be 7kHz. Likewise entering 2/ will produced 2kHz and entering 10\* will produce 40kHz.

As new parameter values are entered, the [waveform preview](#) updates immediately to show what the new waveform will look like. If the previewed waveform appears too small or the timebase is inappropriate, simply adjust the associated DSO contols ([timebase](#) and/or [voltage scale](#)).

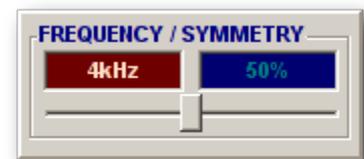
## 12.6 Frequency and Symmetry

The frequency and symmetry are the primary waveform generation parameters. The frequency is arguably the most important because it sets the fundamental waveform frequency.

### 12.6.1 Waveform Frequency

Frequency can be specified to 8 digits precision but when choosing the frequency it is important to understand how it relates to the generator sample rate. The frequency will always be accurate in the mean, but if the sample rate is too low the waveform shape may be somewhat distorted.

If the frequency is high (relative to the sample rate) low levels of short-term phase jitter may be produced, especially if it's not an integral fraction of the sample rate. The simplest way to ensure an optimal sample rate for high fidelity waveform synthesis is to choose a timebase that results in just a few periods of the waveform being displayed, or to maximize the waveform buffer size (for BS3xx, it does not affect BitGen).



### 12.6.2 Waveform Symmetry

The symmetry control adjusts the mark-space of STEP functions, the rise/fall ramp rate of STEP functions and the relative time span of each half of TONE functions.

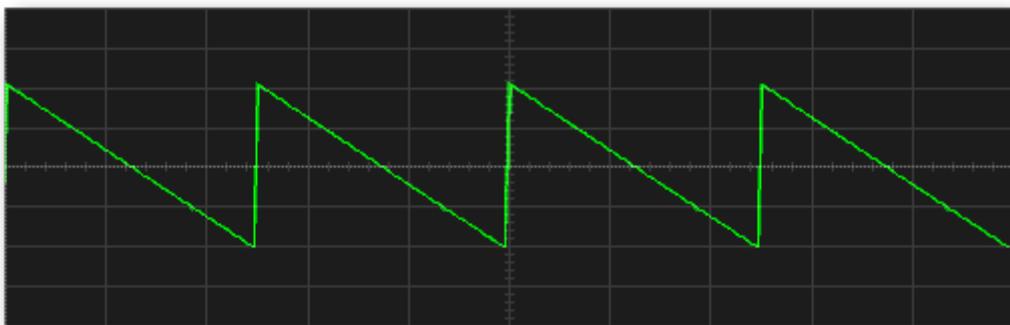


Fig [4] RAMP Wave Function (1%)

Fig [4] shows the RAMP function with 1% symmetry; the triangle waveform has been transformed into a sawtooth. Similarly a 1% STEP function (a pulse train) is shown Fig [7].

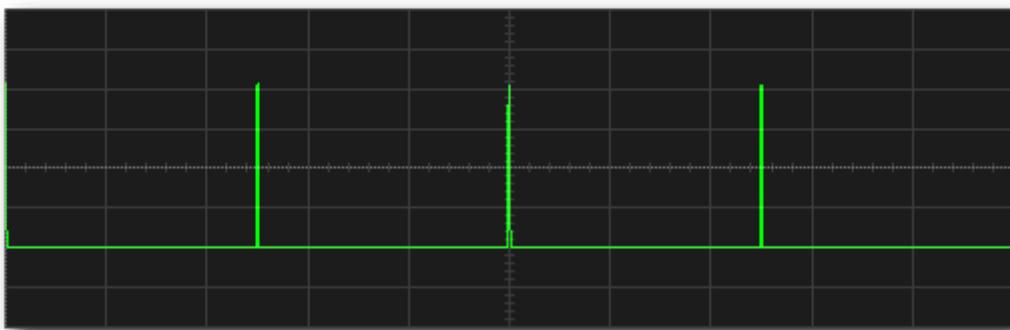


Fig [5] STEP Wave Function (1%)

Any variation between these extremes is possible. Likewise TONE can be made asymmetric:

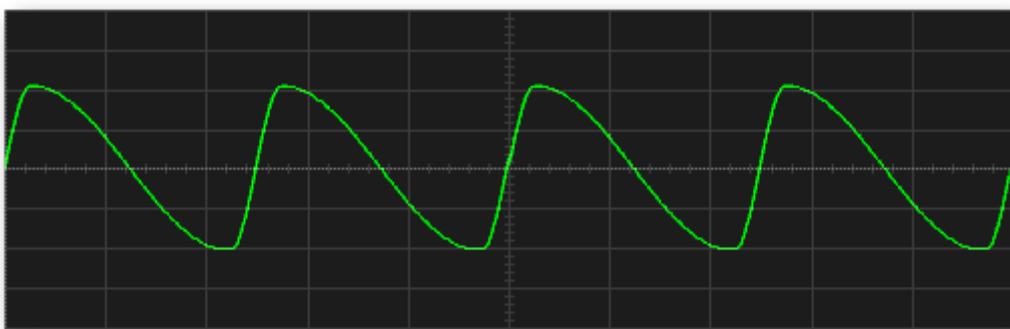
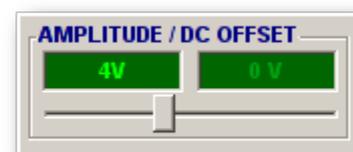


Fig [6] TONE Wave Function (20%)

In this example the rising phase is shortened to 20% of the cycle.

## 12.7 Amplitude and Offset

The amplitude and offset are the secondary waveform generator parameters. Neither of these controls affects the waveform shape or how it is encoded for replay, but they are both very important.



The amplitude controls the waveform generator's peak-to-peak output voltage swing. The largest amplitude possible depends on the BitScope model, and to some extent the prevailing offset.

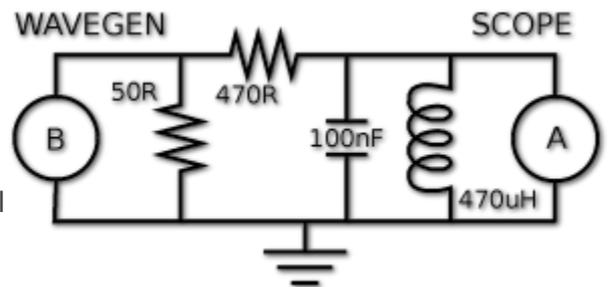
The offset controls the DC offset (if any) applied to the waveform. By default generated waveforms are bipolar; that is they oscillate between negative and positive voltages. In many situations a unipolar waveform is required, for example a 0 to 5V square wave in which case the offset and amplitude controls together can be used to adjust the output accordingly. These parameters are applied to the waveform generator output so that even at very low levels the resolution of the synthesized waveform is not compromised.

## 12.8 Transfer Function Analysis Example

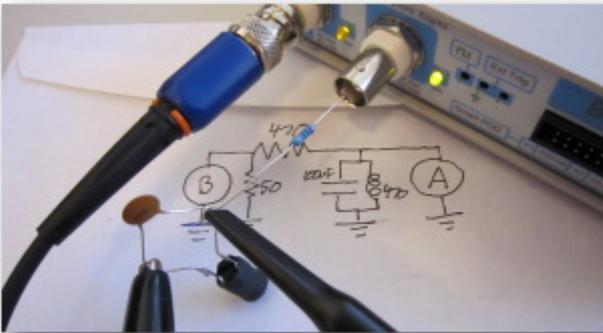
Simultaneous waveform generation and capture facilitates transfer function analysis. By using waveforms of appropriate shape, frequency and/or spectral characteristics, BitScope can be used to characterize electronic circuits without the need for additional test equipment. For example, one can test impulse, step, amplitude and phase responses directly and using the spectrum analyzer view approximations of the associated transfer functions simultaneously.

## 12.9 Tank Circuit Example

Back in Electronics 101 most of us learnt about the LC or [tank circuit](#). We'll use this simple circuit to demonstrate how to characterize the transfer function. The figure shows a tank circuit driven by the waveform generator (via Channel B) and the circuit response captured (via Channel A).



With an inductor, capacitor and resistor one can build this "back of an envelope" linear circuit as shown Fig [8] (hacked together with no soldering required :-).



It comprises a 470 uH inductor and 100 nF capacitor forming the tank circuit and driven directly from the waveform generator via a 470R.

The generator itself adds 50R to ground (i.e. its internal termination impedance).

When a step is applied to this circuit it will oscillate at its resonant frequency.

Due to the resistance in parallel with the tank (470R+50R) this is actually an [RLC circuit](#) so we expect it to decay.

Therefore if we set up the waveform generator to produce a square wave and plot the signal after an edge in the waveform, we would expect to see a damped sinusoidal waveform, i.e. "ringing", the frequency of which can be calculated using a standard formula.

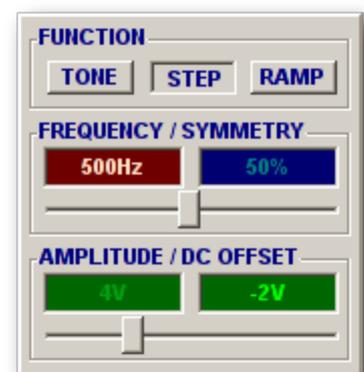
$$f_{\text{resonant}} = \frac{1}{2\pi \sqrt{LC}}$$

In this case, we expect a resonant frequency of 23.2 kHz so we'll set up the waveform generator to produce a square wave about an order of magnitude or two slower so we can observe a reasonable number of ringing oscillations.

Here the generator is set up to produce a 4V square wave at 500 Hz.

We've left symmetry at 50% in this case because we're looking at the step response.

If we were interested in the impulse response we could set symmetry to a small value to synthesize an impulse instead.

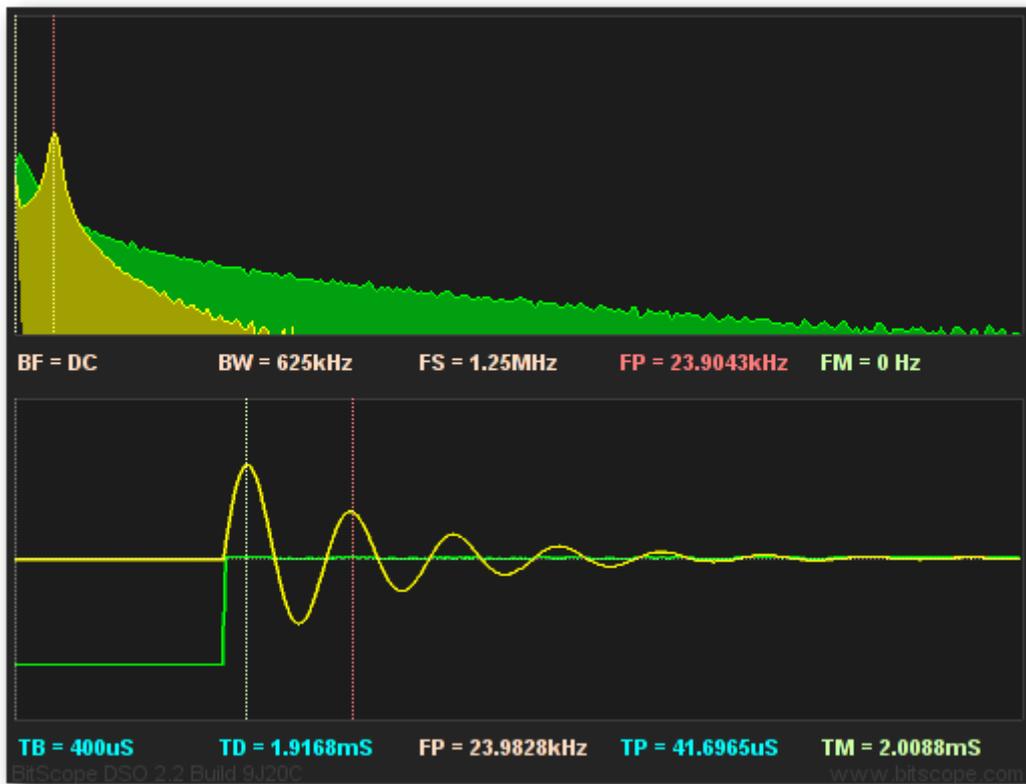


When the waveform generator is enabled, both analog channels and the spectrum analyzer should appear on the display similar to Fig [11].

In this screenshot we've disabled the graticule and enabled the time and frequency cursors to enable period and frequency measurements.

The green waveform and spectrum show the generator output (CHB) and the yellow waveform and spectrum show the tank circuit response (CHA).

This produces the response shown on the following page.



Some features of note are:

- The generator drives the tank circuit with a low frequency square wave.
- The display is offset and zoomed in on one edge switching from -4V to 0V.
- The tank circuit response shows the classic damped sinusoidal shape we expect.
- The [time cursors](#) measure a ringing period of 41.7 uS; a frequency of 24 kHz.
- The [frequency cursor](#) measures a peak at 23.9 kHz which agrees with the time domain.
- Above the resonant frequency the spectrum rolls off due to the effect of the capacitor.

The measured results match the theory to within the tolerance of the components used. This is just one example of using BitScope's waveform generator for transfer function analysis.

## 13. DSO Data Recorder (DDR)

BitScope DSO includes an integrated "DSO Data Recorder" (DDR). DDR records selected analog and logic channels to an internal buffer for immediate playback, review and comparison with newly captured data. Most importantly it also allows captured data to be recorded to [DDR Files](#) which may be reopened by the DSO for replay or analyzed with third party numerical analysis tools such as a spreadsheet or software such as MatLab.

DDR operation is integrated with the main DSO controls, so other than choosing when to record and which file to record to, you should not need to pay it much attention. The DDR commands are available via a pop-up menu selected by right-clicking the DDR status.

The example to the left shows DDR commands available when reviewing recorded data from the internal buffer. Other commands are available in other modes such as when recording to a file or replaying captured data.



The selection of which channels to record is automatic; if the channels are visible on the main display they will be recorded by DDR when Record or Listen commands are selected and capture is commenced.

Likewise for replay; if the DDR file or buffer has data available for the channels selected for the main display they will be replayed when Replay or Review commands are selected. The recorder's "transport controls", that is the controls that start DDR actually recording or replaying, are the same as those used by the DSO itself; the timebase TRACE and REPEAT.

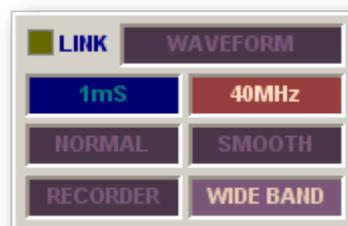
### 13.1 Basic Operation

DDR exists in one of four states: RECORDER (reset), PAUSED, RECORDING or REPLAYING.

The RECORDING and REPLAYING states have two "alter egos" called LISTENING and REVIEWING. These are the same as RECORDING and REPLAYING except no DDR file is specified and one can flip between them at will to compare new data with previously captured data.



When the DSO is first started, DDR reports RECORDER, meaning "reset". This is indicated with the word RECORDER appearing in the DDR status (as shown on the right). In this state, three DDR commands are available; Listen, New and Open, as shown on the left.

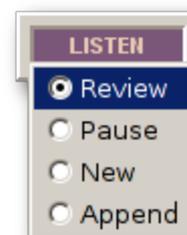


Listen is the default and will be selected automatically if you click the DDR status.

#### 13.1.1 Listen mode

Clicking the DDR status or selecting Listen from the menu puts DDR into listening mode as indicated by the word Listen which replaces RECORDER in the DDR status.

The next time TRACE or REPEAT is selected, the captured waveform and logic data recorded to a buffer as well as displayed and the DDR status shows the word LISTEN (i.e. upper case) showing data has been recorded. Listening mode records



is

selected waveform and logic data to an internal circular buffer. It does not require a DDR file and is a convenient mode to have enabled just in case "something interesting" happens. If it does, the recorded data can then be saved to a file. Because the listen buffer is finite and circular, previously captured data frames will eventually be overwritten with new ones unless you save them to a DDR file.

### 13.1.2 Pause mode

While listening (or recording, reviewing or replaying) clicking the DDR status or selecting Pause from the menu puts DDR into pause mode. Pause mode stops DDR from listening (or recording, reviewing or replaying). Clicking TRACE (or REPEAT) operates the DSO as usual, but has no effect on DDR which remains idle but data previously recorded (or loaded from a file) remains loaded and available. When paused, you can continue to listen to more data by selecting Listen from the menu or review what you have already recorded by selecting Review.

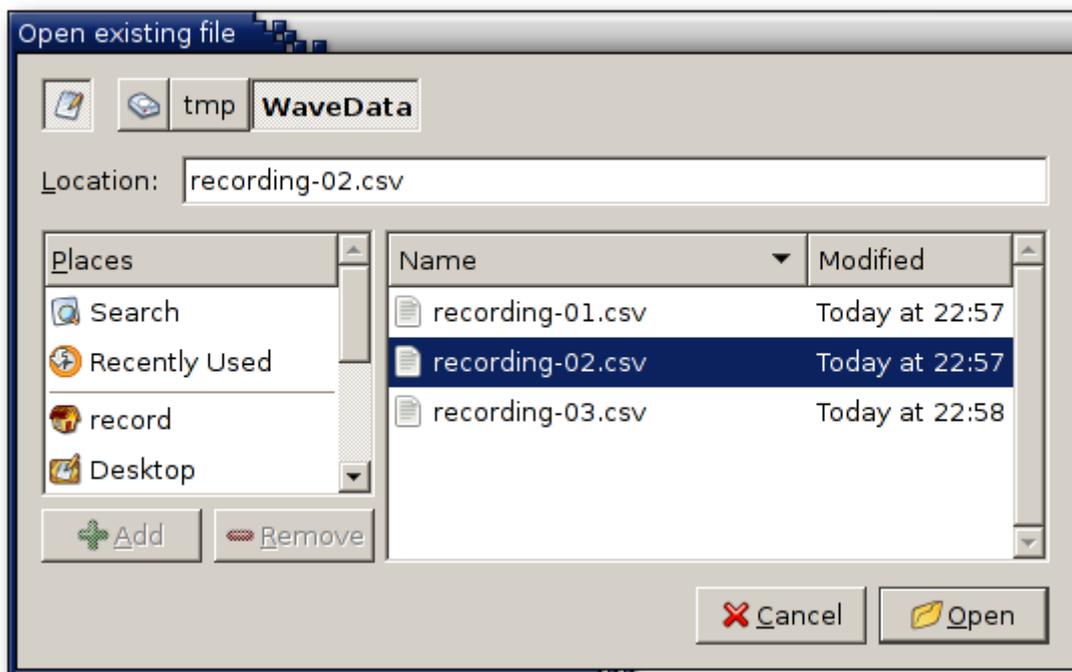
### 13.1.3 Review mode

Review means to replay previously recorded data from the DDR frame buffer. When paused, clicking the DDR status selects Review mode (indicated by the word REVIEW). Clicking it again reselects PAUSE. In this way it is simply a matter of repeatedly clicking the DDR status to toggle between viewing previously recorded data replayed by DDR and live data newly captured by the DSO.



## 13.2 File Operations

Listening and reviewing analog waveforms and logic data is very useful in its own right but the main purpose of DDR is to record captured waveforms to data files for export to other analysis tools or for replay via another BitScope DSO. When DDR is PAUSED, REVIEWING or LISTENING and has buffered data available, these data may be saved to a new file by selecting New from the menu. This opens a dialog:



By default the data is saved in the BitScope WaveData directory to a file named as you choose. If a file of that name already exists DDR will ask if you want to overwrite it.

Alternatively, if you want to append the captured data to an existing file, choose Append from the DDR menu instead of New. If an existing file is selected, the new data will not overwrite data already existing in that file. If no file of that name exists one will be created.

The standard file name extension for DDR files is .CSV but you can choose a different extension if you prefer. Note that CSV is used for a reason; DDR files are ASCII encoded as CSV formatted data files so they are (with some care) suitable for direct import into spreadsheets, databases and any other software tool capable of importing CSV files.

To open a previously recorded DDR file for replay, choose Open from the menu. The file must exist and be a suitable DDR formatted CSV file, otherwise DDR will ignore the file.

## 12.3 Data Recording (Data Logging)

In addition to saving a finite duration of previously captured data stored in the buffer to a file, it is also possible to stream captured frames continuously to an open DDR file for as long as you have disk space available for the file as it grows in size.



### 12.3.1 Record mode

Record mode is effectively "listening directly to a DDR file" except that it is not possible to review recorded data until the file is closed and reopened for replay. It is however possible to pause a recording (by clicking status or selecting Stop from the menu) and restart it without closing the file so you can make DSO setup changes without recording the interim junk data.



### 12.3.2 Record Pause mode

Record pause mode is similar to Pause mode but allows only the resumption of recording or closing of the DDR file. The default is to resume recording so toggling between recording and paused modes is simply a matter of clicking DDR status. When a recording is closed, all remaining data in the buffer is flushed to disk to ensure no data is lost.

## 12.4 Data Replay

One of the most useful features of DDR in collaborative or educational environments is its ability to replay previously recorded data to the display, even if no BitScope is connected to the PC.

With this feature it is possible to record reference waveforms and/or logic traces and distribute them to colleagues to compare with live data collected with other BitScopes. It is also possible to synthesize DDR files directly with a spreadsheet for replay via the DSO.



### 12.4.1 Replay mode

Replay mode is effectively "reviewing data directly from a DDR file" except that it is not possible to record more data until the replay file is closed and a new file opened for recording. It is however possible to pause replay (by clicking status or selecting Pause from the menu).

## 12.4.2 Replay Pause mode

Replay pause mode is similar to Pause mode but allows only the resumption of replay or closing of the DDR file. The default is to resume replay, so toggling between the replay of a data file and display of live capture data is simply a matter of clicking DDR status.

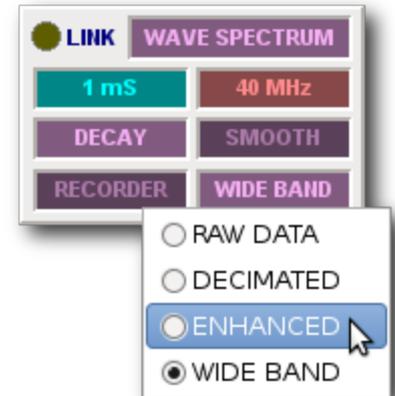


## 12.5 Data Format and Size

DDR records whatever channels and data formats you select for display.

This ensures it can open and display a file without information loss.

If your intention is to export data to another application you may wish to record the raw data (as captured by BitScope itself) or you may need to limit the amount data recorded per frame so it can be imported to Excel.



Use the data mode to choose the format of the data captured (and displayed). In particular choose Raw Data to record the raw data captured by BitScope but choose Decimated or Enhanced if you need a more compact encoding format.

Similarly, to maximize the amount of data recorded per frame in data modes other than Raw Data, choose the Dot/Vector or Dots display mode.

These modes have twice the display (and recording) resolution of the alternative Vector display mode.

## 12.6 File Format and Encoding

DDR files are simply lists of data records encoded as ASCII values recorded to files in CSV format suitable for import into a spreadsheet or database (so long as certain conditions are met). When recording, each data frame for every selected channel (both analog and logic) is appended the DDR file as a discrete CSV data record. This makes continuous data logging possible.

### 12.6.1 Metadata definitions

In addition to the capture data itself each record includes the following meta data:

- Trigger: a sequence number identifying the trigger event that produced the record.
- Stamp: a "time of day" time stamp recording when the record was captured.
- Channel: the index of the channel that captured the data.
- Index: an index identifying all records belonging to the same frame.
- Type: the capture data type (analog, logic, decimated, filtered etc).
- Delay: the post trigger delay applied to the capture (if any).
- Factor: the decimation/oversample factor applied to the capture (if any).
- Rate: the sample rate at which the data was captured.
- Count: the number of samples captured in this record.

As all fields are ASCII encoded, it is possible to open a DDR file with a simple text editor, word processor or spreadsheet to examine it.

### 12.6.2 Using a Spreadsheet

While CSV files are standard for spreadsheets, many (including Microsoft Excel) do not take kindly to being given too much data to load, and when using DDR it is very easy to produce vast quantities of data so there's a potential problem.

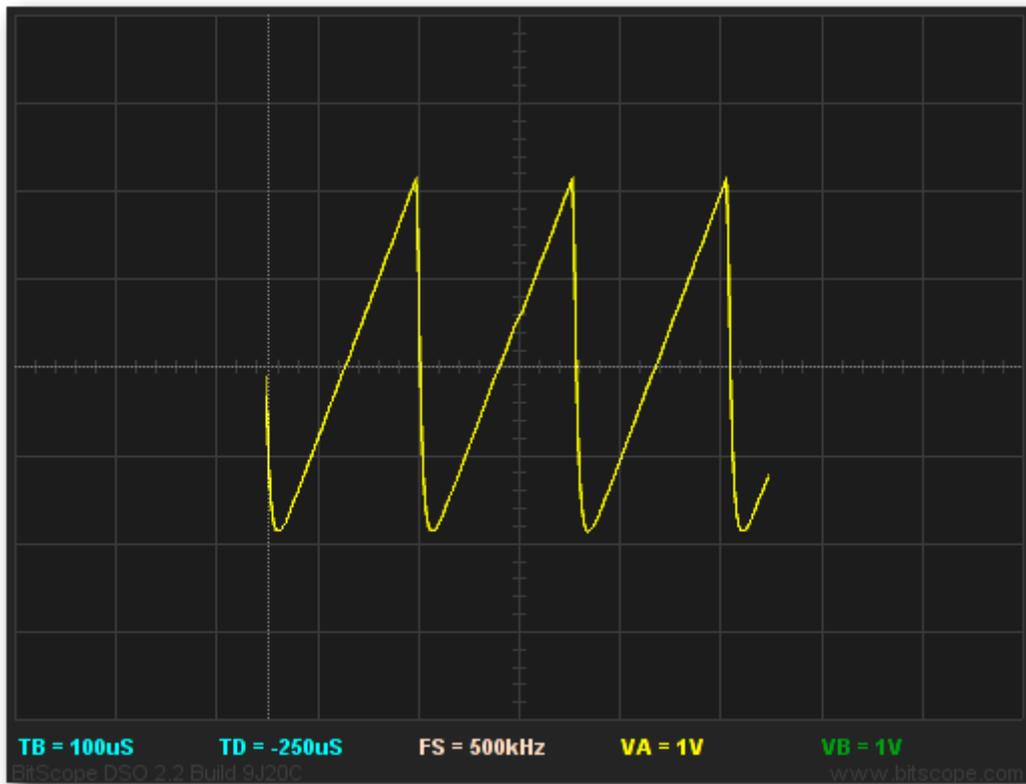
Specifically, if a CSV row contains more than 256 fields (i.e. columns) Excel will refuse to load it. Similarly if it has more than 65k rows it will truncate it.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	712311	stamp	channel	index	type	delay	factor	rate	count	data						
2	439	30.03.0	0	439	0	0	8	5.00E+05	250	2.5005	2.743	2.6936	2.6111	2.5177	2.4627	2.3957
3	439	30.03.0	0	439	1	0	8	5.00E+05	250	2.5464	2.7705	2.7705	2.6826	2.5506	2.5506	2.5067
4	439	30.03.0	0	439	2	0	8	5.00E+05	250	2.5946	2.7265	2.6396	2.5906	2.4627	2.3747	2.3308
5	440	30.03.1	0	440	0	0	8	5.00E+05	250	2.6915	2.7375	2.6826	2.5946	2.5230	2.4627	2.3902
6	440	30.03.1	0	440	1	0	8	5.00E+05	250	3.9579	2.7705	2.7365	2.6386	2.5506	2.5057	2.4187
7	440	30.03.1	0	440	2	0	8	5.00E+05	250	2.4167	2.6826	2.6396	2.5906	2.4627	2.4167	2.3747
8	441	30.03.1	0	441	0	0	8	5.00E+05	250	2.9134	2.765	2.6891	2.6331	2.5506	2.4662	2.3967

If you're using DDR to produce files for import into Excel and similar spreadsheets you will need to ensure that the data records you produce are shorter than 256 fields and that you don't attempt to load more than 65k of them. Because DDR is designed to avoid information loss (so you can reload a file and play it), it records as many samples per frame as the display requires to display the waveforms correctly. Further, if you record raw data you potentially get every sample captured by BitScope (which can be more than 130k samples per frame per channel).

Clearly most raw data DDR files will be big and completely overwhelm most spreadsheets! To use DDR files with Excel you must configure DDR to record fewer samples per frame. This will produce files which may be replayed via DDR but there will be some information loss so replayed waveforms will not be as precise as the originals and spectra produced from replayed data may be lower resolution.

## 12.7 Waveform Intuitive Display Engine (WIDE)



DDR was added to the DSO with another enhancement called Waveform Intuitive Display Engine (WIDE). WIDE replaces the old display engine to enable replay of DDR waveforms. Unlike live capture, replaying previously recorded waveforms means you do not control how the waveform is triggered; instead this information is embedded in the recording.

Consequently, if you are comparing new waveforms with previously recorded ones the trigger setup, waveform offset and delay may be different. However, in most cases you will be interested to see both waveforms referenced to the same relative time (i.e. a common trigger point).

This is what WIDE does. It displays waveforms relative to the trigger, timebase, zoom and offset, given the waveform data that is actually available for replay.

### 12.7.1 Truncated Display

In practice, this means is that replayed waveforms may be longer or shorter than the current display duration, or they may be offset to one side or the other (or not shown at all). This screenshot on the previous page shows one example. In this case the waveform was recorded at 50uS/Div but replayed at 100uS/Div.

As a consequence, data before the left edge and after the right edge of the display as recorded is not shown upon replay. This is because it was not recorded in the first place. DDR records whatever is displayed on screen at the time of the recording only.

### 12.7.2 Full Capture Recording

It is, however, easy to have DDR record as much data as BitScope can capture, regardless of the displayed time duration to be used upon replay; simply choose the widest zoom and slowest timebase required to capture all the data of interest when recording.

If you need to maintain the highest time resolution (i.e. sample rate) as well, choose the largest buffer size you can and capture Raw Data. Be warned though; doing this can produce very large DDR files and they will certainly not be suitable for import into a spreadsheet.

### 12.7.3 Variable Frame Rates

Another benefit of the WIDE engine, especially when used with DDR recordings is that you can change the rate at which multi-frame captures are replayed. If for example, you recorded 200 frames over 24 hours you can replay them at whatever frame rate you like to make looking at frame-to-frame differences or transient features easier.

A related feature is that if you are using a BitScope via a slow link (e.g. a remote Network BitScope via a dial-up link) but choose a fast frame rate, WIDE ensures that already displayed (i.e. cached) waveform data is redisplayed immediately upon a relevant parameter change (such as timebase or waveform offset) and new data is then appended dynamically when it finally arrives.

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## 13. Offset Calibration

All internal analog channel offsets in BitScope are factory calibrated.

This means that when the inputs are ground referenced (i.e. connected to ground) and the offset control is reset, the trace will appear in the center of display (i.e. at exactly zero volts).

However, there are circumstances where you may wish to make changes to this offset calibration; temporarily to eliminate offsets appearing in the signal under specific circumstances and permanently to recalibrate the channel if temperature or time make it necessary.

### 13.1 Offset Assignment

Sometimes a DC offset may appear in a signal which you want to ignore.

Alternatively you may find that for precise measurement you wish to finesse the calibration of a given range or prescale. Offset calibration is available via the menu shown in Fig [10] that appears upon right-clicking the zero offset button (12).



For a given source, range, prescale and the input referenced, offset controls can relocate the trace to the center of the display. With the trace centered, selecting Assign Input Offset recalibrates the channel offset for that channel setup.

That is, it assigns a temporary calibration offset to the channel which ensures that the reference signal appears exactly at the center of the display. All subsequent measurements will be made referenced to the assigned offset, not zero volts.

### 13.2 Offset Calibration

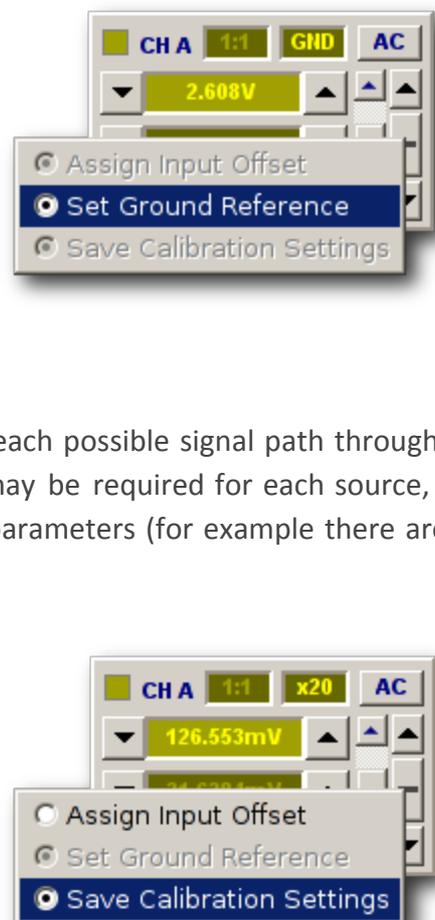
If offsets appear on a channel on a particular source, range or prescale when the input is properly ground referenced, the internal channel offsets may require persistent recalibration.

This is achieved the same way as offset assignment described above but there is a specific [procedure](#) that must then be followed to calibrate all the channel offsets correctly.

It is important to understand that an internal offset can appear in each possible signal path through the analog channel circuitry. That is, a different calibration parameter may be required for each source, range and prescale value. In some BitScopes this adds up to quite a few parameters (for example there are 20 possible parameters for each channel in [BS310](#)).

In practice the number of different parameters is much smaller (5 per channel in [BS310](#)) so in relatively few steps it is possible to recalibrate all channel offsets. The first step in all cases is assignment of the channel's global ground reference.

When a specific channel source, range and prescale is selected, the channel's global ground reference may be assigned as shown.



Next a small set of input offsets for other source, range and prescale values are assigned. At this point they may be saved to BitScope.

When this is done, all the channel calibration parameters are recalculated based on the assigned input offsets and saved to flash memory to be reused automatically in future. The set of channel settings for which the input offset must be (re)assigned to enable this complete recalibration of the channel depends on the BitScope model concerned.

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