

VT DSO-2820E Manual



This product is designed to be used by those who have some basic electronics and electrical knowledge. It is absolutely dangerous to connect an unknown external voltage to the VT DSO unit. Be sure that the voltage to be measured is less than the maximum allowed input voltage.

Note: VIRTINS TECHNOLOGY reserves the right to make modifications to this manual at any time without notice. This manual may contain typographical errors.

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1 Installation and Quick Start Guide

This is one of the second-generation USB DSOs designed and developed by Virtins Technology. This generation of USB DSOs features Virtins Technology's unique hardware-based DSP algorithm which enhances the performance and functionality dramatically without adding extra hardware cost. When used in conjunction with Multi-Instrument[®] software, the USB DSO converts any desktop, laptop, or tablet PC into a powerful oscilloscope, spectrum analyzer, multimeter, data logger, signal generator and so forth, all of which work simultaneously.

1.1 Package Contents

A standard VT DSO-2820E Package contains the following items:

- 1) VT DSO unit with a hardware bundled Multi-Instrument Standard software license



- 2) 2 × 100 MHz Oscilloscope Probe P2100 (Old Tag: P6100) with two switchable positions: ×1, ×10



- 3) Signal Generator Test Lead (1 m)



- 4) USB cable (1.5 m)



- 5) CD (contains the copy-protected Multi-Instrument software and VT DSO driver)



1.2 Multi-Instrument Software Installation

Insert the installation CD into your computer's CD-ROM drive and follow the instruction on the screen to install the Multi-Instrument software.

1.3 Hardware Driver Installation

1.3.1 Installation Procedure

The USB cable has one USB A-type connector at one end and one USB B-Type connector at the other end. The A-type connector should be connected to a USB port of your computer while the B-type connector should be connected to the DSO.

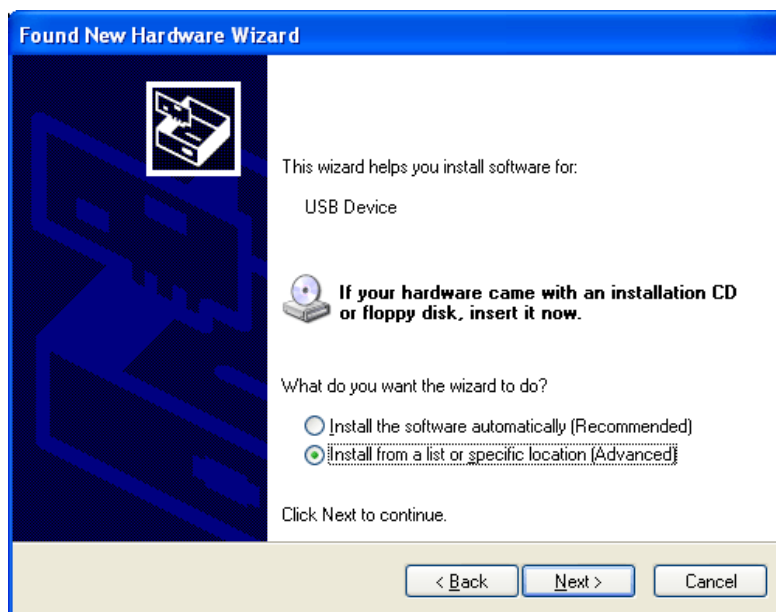
Starting from Multi-Instrument 3.6, the VT DSO hardware driver will be installed automatically during software installation, even without the connection of the DSO. Therefore, the following driver installation procedures are more for manual installation and troubleshooting purpose.

For Windows XP (and similarly Windows Vista):

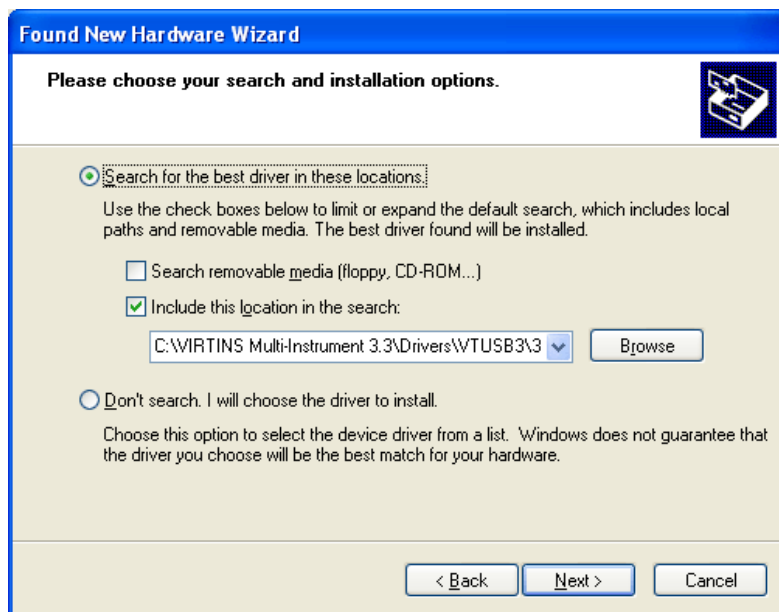
- 1) Wait for the "Found New Hardware Wizard" dialog to pop up. And then select "No, not this time" and click "Next".



- 2) Select “Install from a list or specific location (Advanced)” and click “Next”.



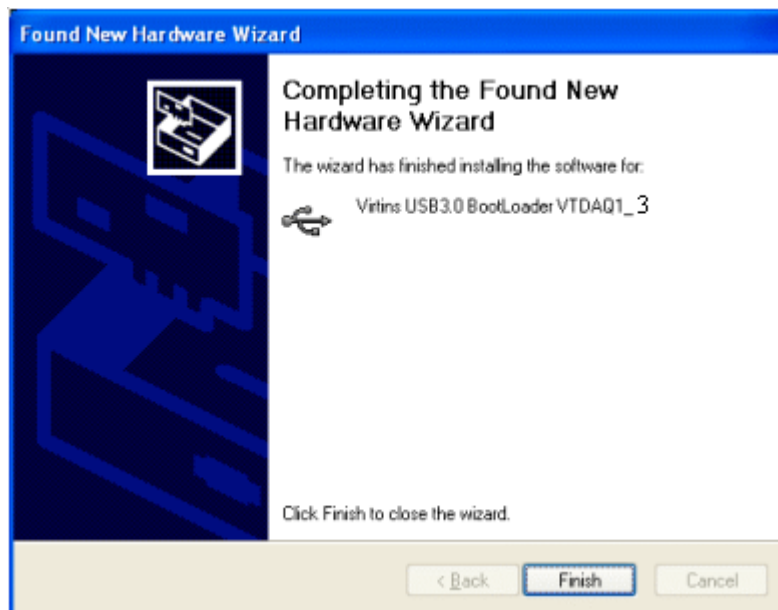
- 3) Choose “Search for the best driver in these locations” and “Browse...”, and then locate the driver. The driver can be found at Multi-Instrument’s installation directory\Drivers\VTUSB3\32bit or 64bit. Choose 32-bit or 64-driver according to your Windows version. After that, press “Next”.



4) The following dialog box will pop up. Click “Continue Anyway”.



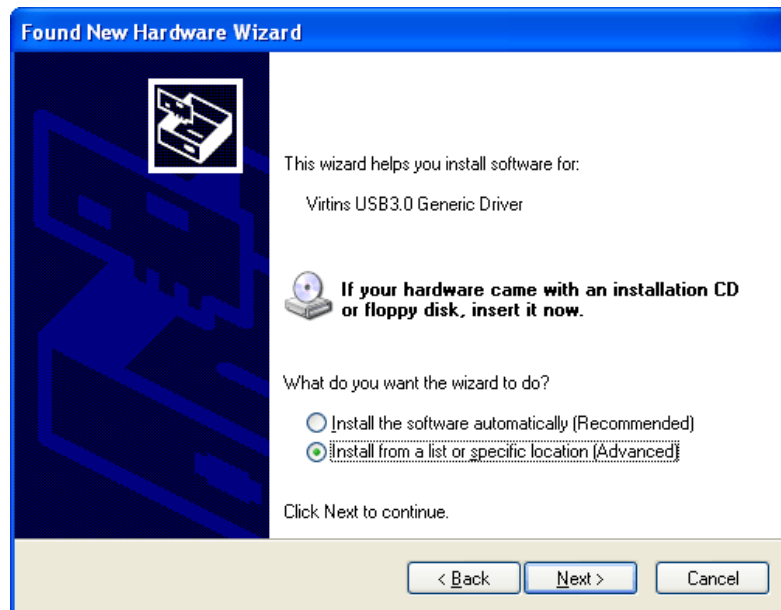
5) Click “Finish”.



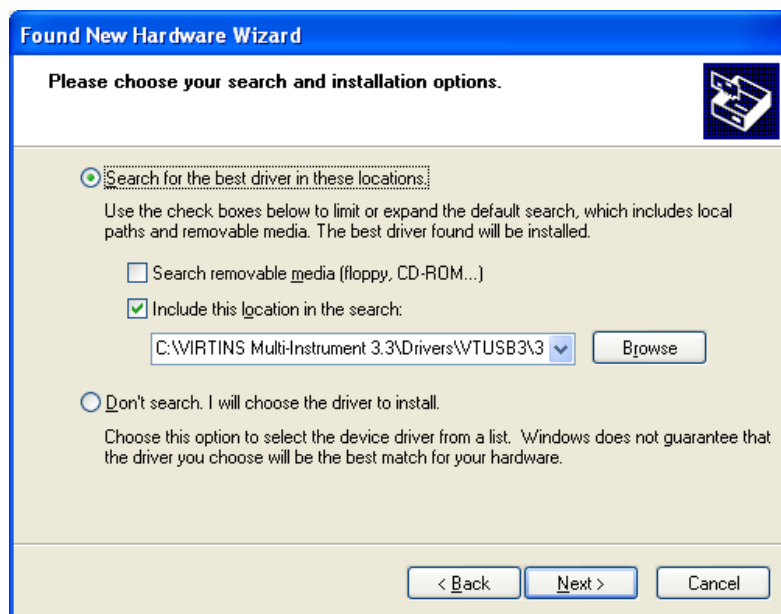
6) Select “No, not this time” and click “Next”.



7) Select “Install from a list or specific location (Advanced)” and click “Next”.



- 8) Choose “Search for the best driver in these locations” and “Browse...”, and then locate the driver. The driver can be found at Multi-Instrument’s installation directory\Drivers\VTUSB3\32bit or 64bit. Choose 32-bit or 64-driver according to your Windows version. After that, press “Next”.



- 9) The following dialog box will pop up. Click “Continue Anyway”.

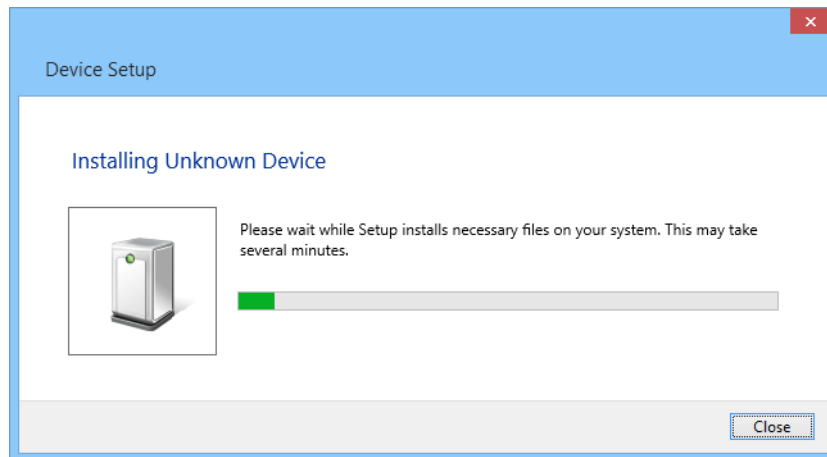


10) Click “Finish”.

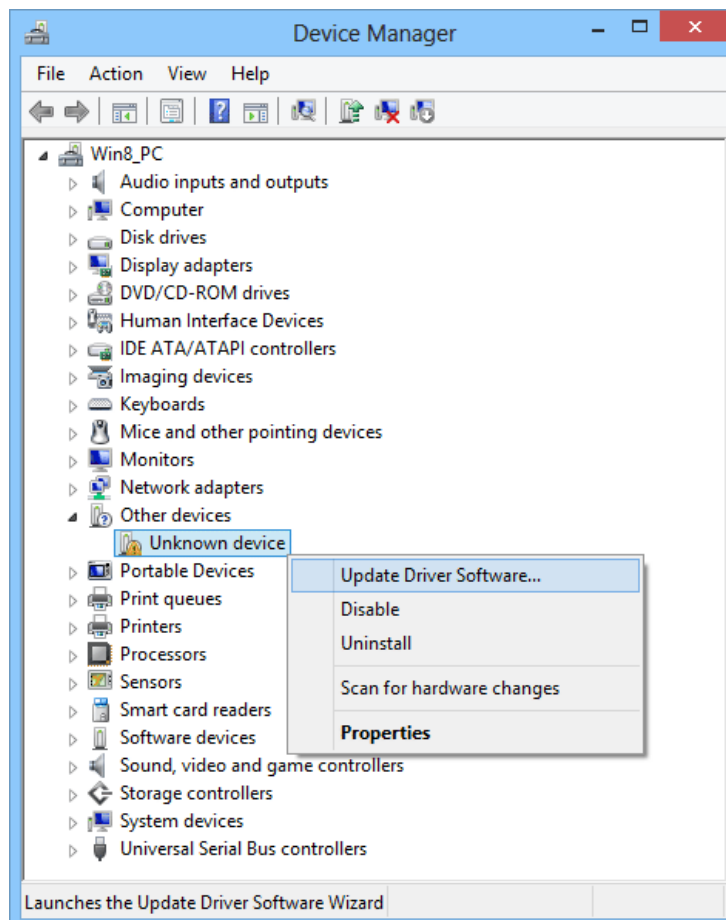


For Windows 8 (and similarly Windows 7) :

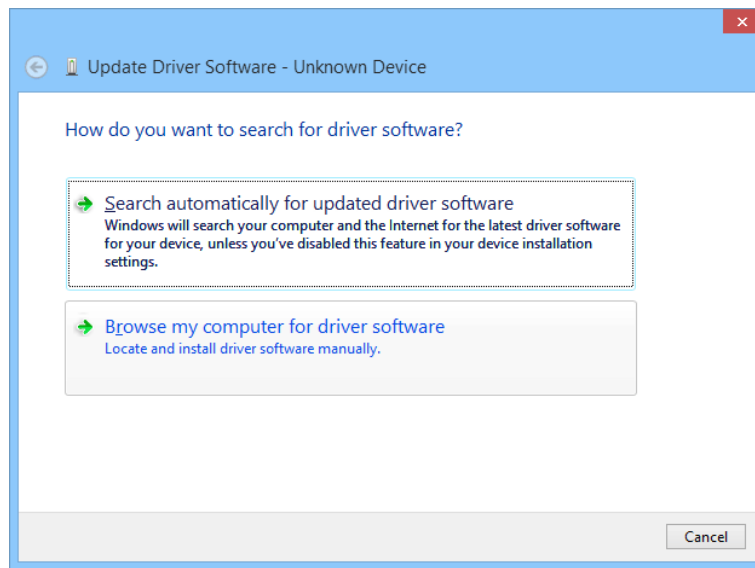
- 1) If there is an available internet connection, Windows 8 will silently connect to the Windows Update website and search for the driver. The following dialog box will pop up. Click “Close” or let it close automatically after failing to find the driver.



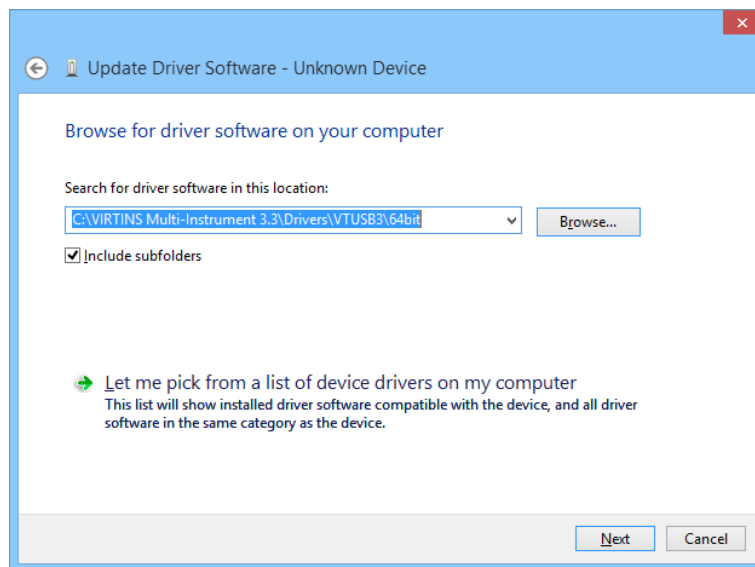
- 2) The DSO driver has to be installed manually via Device Manager under Windows Control Panel. The Device Manager can be accessed from Windows 8 Metro Start Screen via [Charm Bar]>[Settings]>[Control Panel]>[Hardware and Sound]>[Device Manager]. In the Device Manager window, there will be an Unknown device under Other Device with a yellow warning symbol to indicate that the driver for the device has not been installed. Right click on the Unknown device and choose “Update Driver Software...” on the pop-up menu.



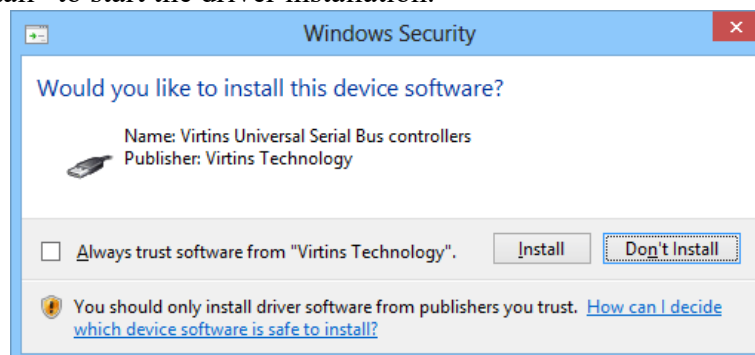
3) Choose “Browse my computer for driver software”.



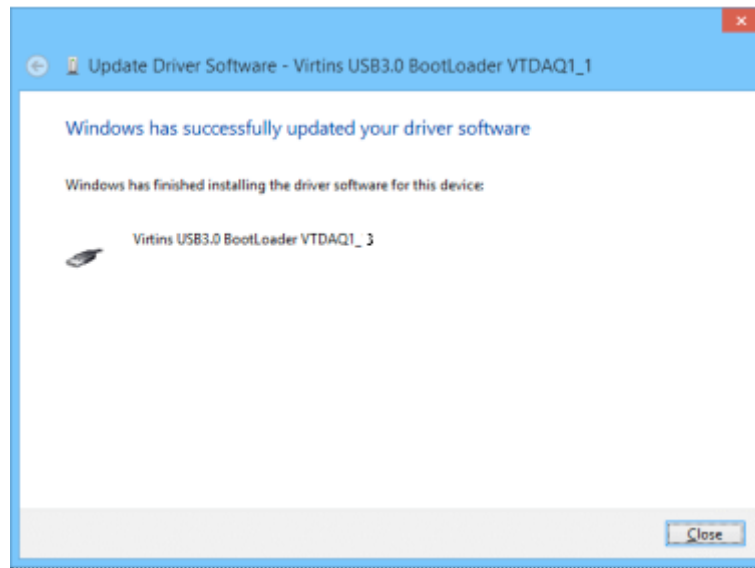
4) Choose “Search for driver software in this location” and “Browse...”, and then locate the driver. The driver can be found at Multi-Instrument’s installation directory\Drivers\VTUSB3\32bit or 64bit. Choose 32-bit or 64-driver according to your Windows version. After that, press “Next”.



5) Choose “Install” to start the driver installation.



6) Press “Close” after the installation has been completed.



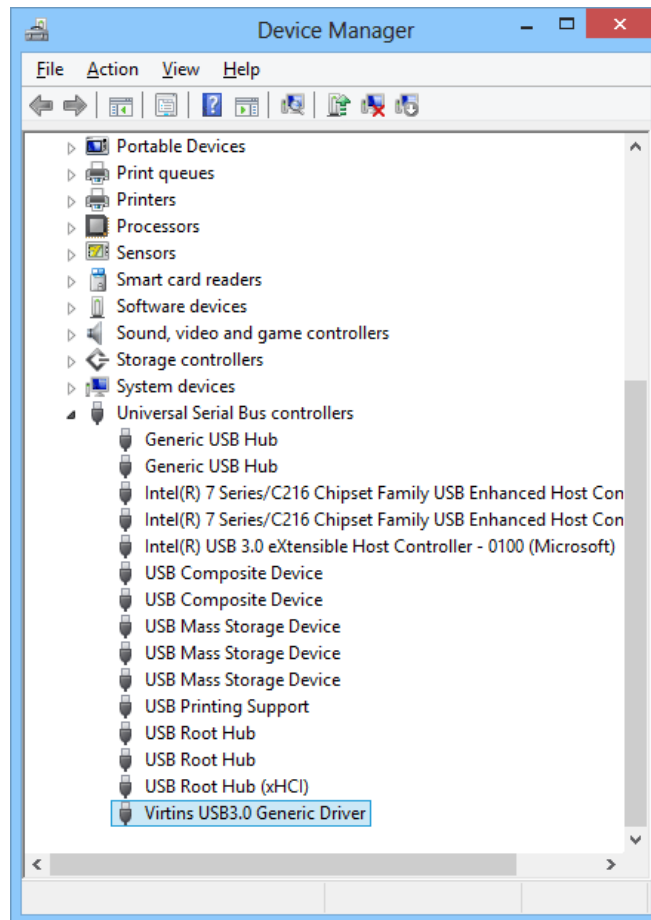
The driver is located in the Drivers\VTUSB3 directory in the CD. When you install the Multi-Instrument software, a copy of the respective driver will also be installed in the software installation directory \Drivers\VTUSB3.

Once the driver has been installed successfully, the LED on the DSO’s front panel will blink red once.

Note: you may need to re-install the driver if you change to use another USB port of your computer for the VT DSO unit. However, the installation CD is not required during driver re-installation. To avoid driver re-installation, stick to a fixed USB port of your computer for the VT DSO unit.

1.3.2 Installation Verification

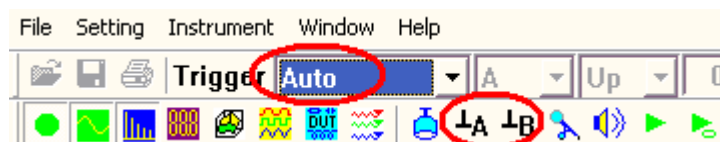
If the hardware driver has already been installed, the LED on the DSO’s front panel will blink red once whenever you attach the DSO to the computer. You can follow the steps in the next section to start the Multi-Instrument software. If the software starts in licensed mode (do not plug out the DSO), that means that the driver has been installed successfully. Otherwise, please open the Windows Device Manager via [Start]>[Control Panel]>[System]>[Hardware]>[Device Manager] (for Windows XP, and similarly for other Windows versions), you should see “Virtins USB3.0 Generic Driver” under “Universal Serial Bus controllers” category. If not, then re-installation of the hardware driver is required.



1.4 Start Multi-Instrument Software

To start the Multi-Instrument software, on Windows desktop, click the MI icon directly, or select [Start]>[All Programs]>[Multi-Instrument]>[VIRTINS Multi-Instrument] (for Windows XP, and similarly for other Windows versions). The LED on the DSO panel will keep blinking green very fast for a little while during the software startup. If the oscilloscope is running, the LED will be steady green. If the signal generator is running, it will be steady red. If both are running, it will be steady orange. If some error occurs, it will blink red at a slow speed.

1.5 Zeroing



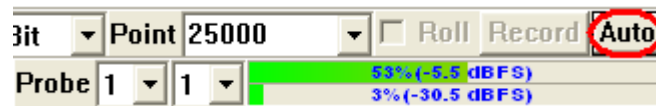
Connect the oscilloscope probe tip to its ground lead for both channels, and switch the Trigger Mode to “Auto” (see the figure above). With the oscilloscope running, you should see a horizontal line at 0V in the oscilloscope. If not, you should click “**LA**” and “**LB**” in the toolbar and choose “Yes” to compensate the ground levels of both channels to zero. You may

need to do this every time after you change the sampling parameters. If “No” is chosen instead, the software DC compensation will have no effect.

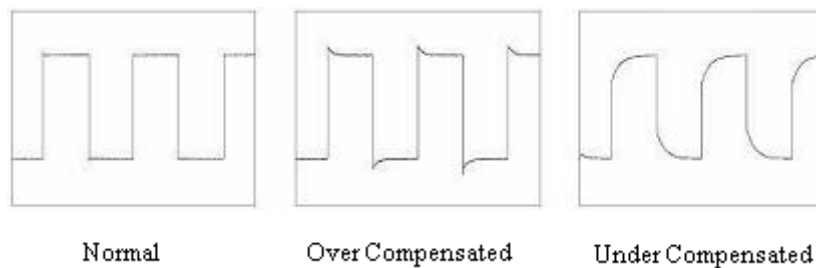
For VT DSOs that support hardware offset adjustment, it is recommended to use that function for zeroing instead (described in the following sections). To make sure that the software DC compensation is inactive, go to [Setting]>[Calibration] and check the “Input DC Offset”, make sure that the values are zero for both channels.

1.6 Probe Calibration

Connect the probe (at $\times 10$ position) to the 1 kHz square wave output of the DSO, and then adjust the sampling parameters such that the waveform displayed on the screen can be clearly seen. You can also do this by simply clicking the “Auto” button at the upper right corner of the screen.



Adjust the probe compensate capacitor at the end of the probe cable such that the square wave looks normal, as shown below.

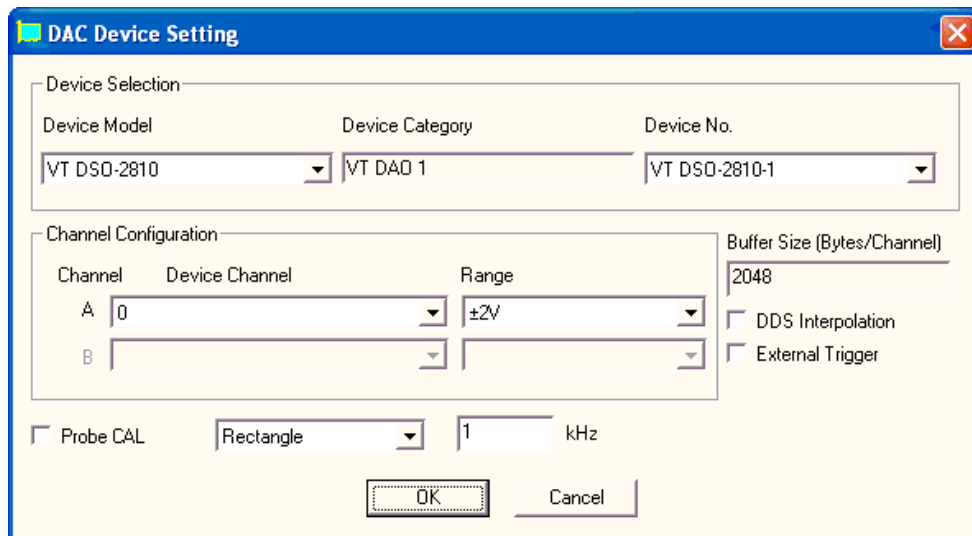


For VT DSOs (such as VT DSO-2810R and VT DSO-2820R) that do not have a built-in analog signal generator, the probe calibration signal is generated digitally and output via a dedicated pin.

For VT DSOs (such as VT DSO-2810 and VT DSO-2820) that have a built-in band-limited (<5MHz) analog signal generator, the probe calibration signal is generated digitally and output via the signal generator output BNC when the analog signal generator is not running.

For VT DSOs (such as VT DSO-2810E and VT DSO-2820E) that have a built-in wide-band analog signal generator, the probe calibration signal is generated analogously and output via the signal generator output BNC when the signal generator is not running. You can also generate it using the signal generator.

The probe calibration output can be configured via [Setting]>[DAC Device] (see figure below).



You can choose to output either Rectangle or MLS signal. When MLS is selected, the frequency value here refers to the clock frequency of the MLS generator rather than the output signal frequency. By default, the Probe CAL signal output is enabled. You can disable the signal output by un-ticking the “Probe CAL” checkbox. This will help to improve the Signal-to-Noise ratio in the oscilloscope, especially when the measuring range is lower than 100 mV.

1.7 Hard Reset

A hard reset can be done via disconnecting the DSO from your computer and then re-connect it to the computer again. You can only do this with the Multi-Instrument software closed.

1.8 Feature Highlights

The following sections highlight some unique features of the second-generation VT DSOs. Most of these features are not available in other USB DSOs in the market. For a complete description of functions, please refer to the Multi-Instrument software manual.

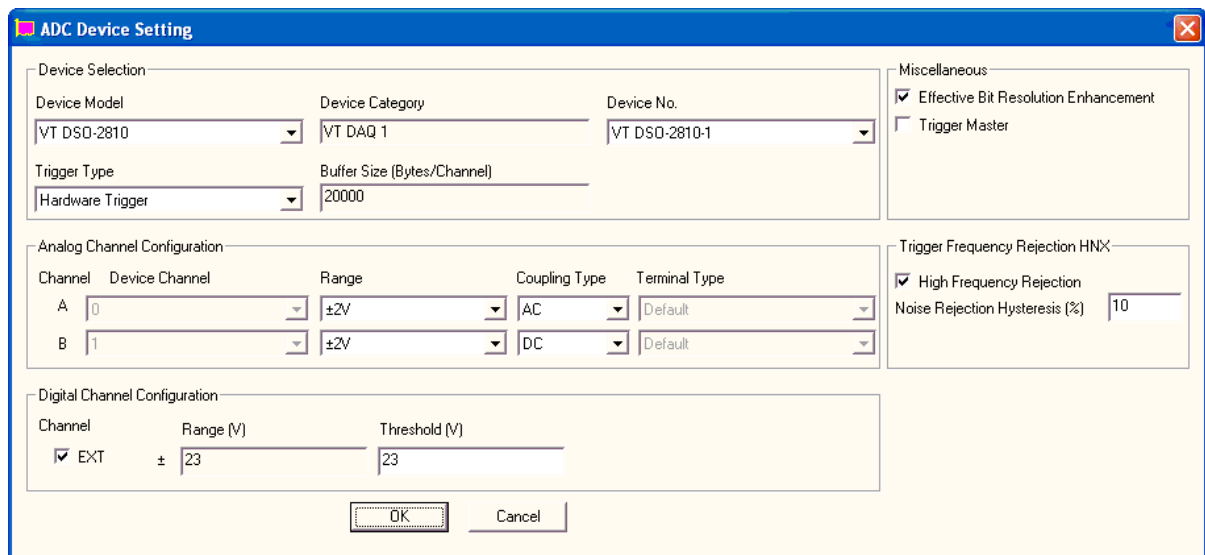
1.8.1 Hardware DSP based Bit Resolution Enhancement for Oscilloscope

Hardware DSP based bit resolution enhancement is a unique feature that is only found in the second-generation VT DSOs. Virtins Technology is the first and currently the only company to implement this feature in USB oscilloscopes. With this feature, an 8-bit ADC device would be able to produce samples with an increased effective bit resolution as the sampling frequency (defined here as its sample output rate) goes down. Theoretically, additional ½ bit of resolution could be gained through some algorithm whenever the sampling frequency decreases by a factor of 2. Therefore, an 8-bit ADC device could output samples with a 16-bit effective bit resolution if the sampling frequency is $1/2^{16}$ of its maximum sampling frequency.



To use the bit resolution enhancement feature, select “16Bit” in the Sampling Bit Resolution combo box in the Sampling Parameter Toolbar. The actual effective bit resolution achieved depends on the sampling frequency used and can go up to 16 bits. Please refer to the hardware specifications in the following chapter.

If “8Bit” is selected instead, it is still possible to partially utilize the bit resolution enhancement feature. To enable this feature, go to [Setting]>[ADC Device] and select “Effective Bit Resolution Enhancement” under Miscellaneous section (see figure below). The effective number of bits (ENOB) of an 8-bit ADC device (when “8Bit” is selected in the above figure) is always less than 8 bits due to noise and distortion. Enabling this feature will make the ENOB of the device closer to 8 bits.



The above bit resolution enhancement is realized through hardware. It is also possible to implement this feature through software. After the acquired data have been transferred from the DSO into the computer, one can apply a moving average digital filter (a FIR filter with equal filter coefficients) to them. A 2-tap moving average filter would increase the effective bit resolution by ½ bit. A 2¹⁶-tap moving average filter would turn an 8-bit ADC device into a 16-bit one. However, software DSP based bit resolution enhancement has significant side effects as compared to its hardware counterpart. (see table below)

Side Effects	Hardware DSP based bit resolution enhancement	Software DSP based bit resolution enhancement
Reduces the signal bandwidth (normally from 0 to ½ of the sampling frequency) roughly by a factor equal to the number of taps used in the moving average. As a result, high-frequency details of the signal, which should have shown up, are lost. For instance, spikes will be widened and flattened, vertical edges will become straight-line slopes, etc.	No	Yes
Reduces the number of independent samples per frame by a factor equal to the number of taps used in the moving average, as the adjacent samples are correlated after moving average.	No	Yes
Non-uniform behavior at the starting and/or the ending parts of the data frame due to the fact that it is not possible to apply exactly the same moving average filter there as the one applied to the middle part of the data frame.	No	Yes

To use software DSP based bit resolution enhancement, right click anywhere within the oscilloscope window and choose [Oscilloscope Processing]>“Digital Filtering”> “Arbitrary”> “IIR Coefficients”. Then select an appropriate moving average filter file from the IIR subdirectory. Software DSP based bit resolution enhancement is generally not recommended when hardware DSP based bit resolution enhancement is available.

1.8.2 Oscilloscope Normal Frame Mode, Record Mode and Roll Mode

The second-generation VT DSOs support both normal frame and streaming modes. There are two streaming modes: Record Mode and Roll Mode. The following is a comparison table of these three modes.

	Normal Frame Mode	Record Mode	Roll Mode
Max. Sampling Frequency	High	Medium	Low
Record Length	Low (limited by DSO hardware buffer size)	High (limited by hard disk space)	Medium (limited by computer memory size)
Trigger	Trigger per frame	Trigger required at startup (first frame) only	Trigger required at startup (first segment) only
Discontinuity within each data frame	Absolutely no	Normally no	Normally no
Discontinuity between adjacent data frames	Most likely	Normally no	Normally no
Usage	General purpose	Used when Record Length exceeds the limit determined by the DSO hardware buffer	Generally used to provide instant display response at very slow sweep speed. Without it, the entire frame of data must be acquired first before the display can be updated. Also used when Record Length exceeds the limit determined by the DSO hardware buffer

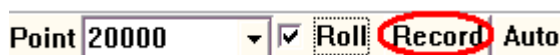
1.8.2.1 Normal Frame Mode

Normal frame mode is the most commonly used oscilloscope mode. Each data frame is triggered and acquired individually. There may be discontinuity between two adjacent data frames. The length of the data frame is limited by the DSO hardware buffer size. One major advantage of this mode is that it supports the highest sampling frequency of the ADC device.

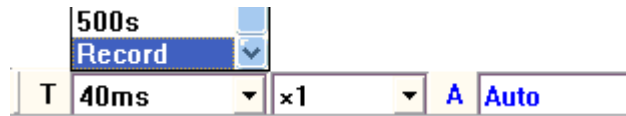
1.8.2.2 Record Mode

Record Mode can be activated using either of the following methods:

- Clicking the Record button in the Sampling Parameter Toolbar

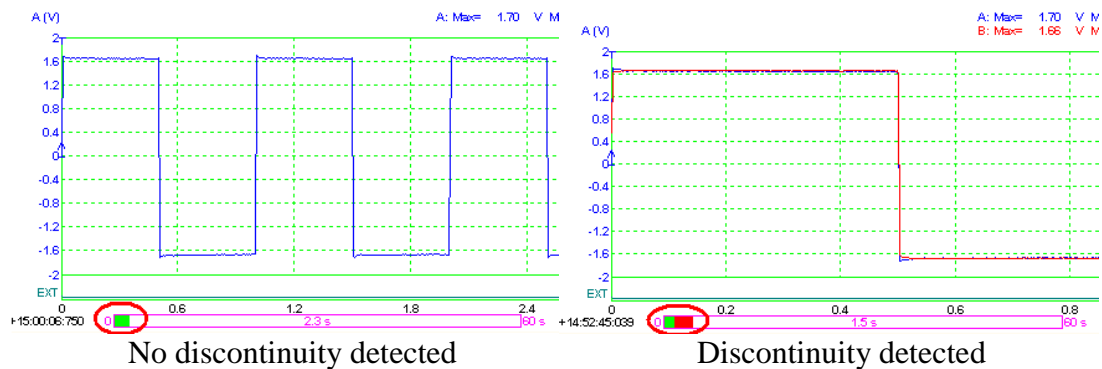


- Selecting “Record” in the Sweep Time combo box (at the bottom left corner of the screen after clicking anywhere in the oscilloscope window) and then clicking the Run button of the oscilloscope (at the upper left corner of the screen).



Click the Record button or oscilloscope Run button again to stop recording. When the sampling frequency is high, the hard disk file used for recording will be filled up very quickly, remember to click either of the above buttons to stop recording in time. To exit the Record Mode, select an oscilloscope sweep time other than “Record” in the above Sweep Time combo box.

Under Record Mode, raw ADC data will be written into the hard disk continuously in WAV file format. Meanwhile, data analysis and display will still be performed in order to keep the screen updated in real time. Priority is given to the former process in order to try the best to ensure uninterrupted data recording. Whether the recorded data are continuous (i.e. the adjacent frames of data are connected smoothly without missing any data in between) or not depends on the system throughput, sampling frequency, bit resolution, number of sampling channels, etc. The DAQ progress bar under the oscilloscope graph shows the recording progress. The progress bar will be filled with some red color if the recorded data are not continuous (see figures below). You can lower the sampling frequency and bit resolution, and use single channel if possible, to get continuous data stream.

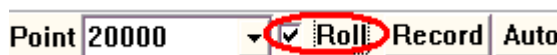


During the recording process, the screen will still be updated. The oscilloscope frame width can be adjusted via [Setting]>[Display]> “Record Mode”> “Frame Width” (in points).

When the recording process is stopped, the recorded file will be opened automatically. If it is too big, it will be opened frame by frame. In this case, the Long Wave File Navigation Toolbar (as shown below) will pop up to allow you to navigate through the file.



1.8.2.3 Roll Mode



Roll Mode is activated by ticking the above “Roll” button in the Sampling Parameter Toolbar. Under this mode, the oscilloscope frame is split into many segments with the length of each segment equal to the Roll Width, which is set via [Setting]>[Display]>“Roll Mode”> “Roll Width” (in points). The data displayed in the oscilloscope window will shift left by a step of one Roll Width each time when a new segment of data arrives. The newly arrived

data will be shown in the right most portion of the graph. You can consider using Roll Mode if the sweep time is too long (e.g. greater than 1 s) to avoid long time waiting for screen update. The Roll Mode button is enabled when the Record Length per sweep is four times or more of the Roll Width. Under the Roll Mode, whether the acquired data are continuous (i.e. the adjacent segments of data are connected smoothly without missing any data in between) or not depends on the system throughput, sampling frequency, bit resolution, number of sampling channels, etc.

1.8.3 Oscilloscope Digital Trigger and Trigger Frequency Rejection

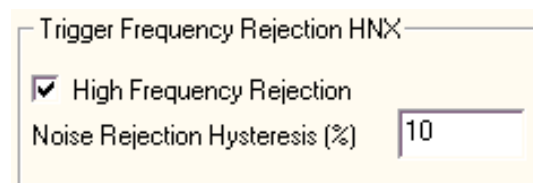
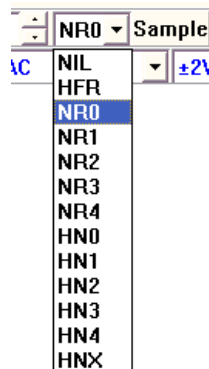
The second-generation VT DSOs use hardware based DSP algorithm for triggering and trigger frequency rejection. This greatly improves the trigger stability and accuracy, even with noisy signals.

1.8.3.1 Digital Triggering

The second-generation VT DSOs use a digital trigger instead of the conventional analog trigger. The digital trigger is implemented through hardware. It is able to search for the trigger event in the digitized samples in real time. Trigger jitter is a significant problem in conventional analog trigger. It is caused by the disparity between the acquisition and trigger circuits. Trigger jitter causes the waveform displayed on the screen to shift left and right as the display is updated. A digital trigger, on the other hand, does not have this kind of jitter as it shares the same physical path with the acquisition.

The Multi-Instrument software also features a specially designed algorithm which effectively eliminates the lateral shaking of waveform display due to limited sampling rate compared with the signal frequency (i.e. very few samples acquired per signal cycle).

1.8.3.2 Trigger Noise Rejection



Trigger Frequency Rejection can be used to filter out noises from the trigger signal to prevent false triggering. The available options are: NIL (All-Pass), HFR (High Frequency Rejection), NR0~NR4 (Noise Rejection), HN0~HNX (High Frequency Rejection + Noise Rejection). There are different levels of noise rejection. For Levels 0~4, the hysteresis values are fixed while for Level X, it is user-configurable via [Setting]>[ADC Device]> “Trigger Frequency Rejection HNX”. You can configure whether to include high frequency rejection and specify the noise rejection hysteresis (in percentage) for HNX option. Please refer to the hardware specifications in the next chapter for the detailed specification of the rest of options.

1.8.4 Oscilloscope Persistence Mode

Under persistence mode, up to 200 most recent waveforms are kept in the computer memory. These waveforms can be superimposed/drawn in the oscilloscope window in three ways: Phosphorescent, Rainbow, Equivalent Time Sampling. Persistence Mode can be activated by right clicking anywhere within the oscilloscope window and select [Oscilloscope Chart Option]> “Persistence”. Please refer to Multi-Instrument software manual for details.

1.8.5 External Trigger Input Channel as a Digital Input Channel

The external trigger input channel of a second-generation VT DSOs can be used as a digital input channel. It is actually a 1-bit ADC with the threshold for digitization adjustable. This channel can be configured via [Setting]>[ADC Device]> “Digital Channel Configuration”. If the external trigger is selected as the trigger source, then the threshold for digitization can also be adjusted by adjusting the trigger level in the main window. With two analog input channels and one digital input channel, the oscilloscope can be used for mixed signal measurements. It can also be used as a protocol analyzer for serial communications.

1.8.6 Anti-aliasing filter for Spectrum Analyzer

The USB DSOs in the market are generally equipped with only one fixed anti-aliasing filter for the highest sampling frequency. Aliasing will still occur when the sampling frequency goes down. This will cause wrong measurements in both the oscilloscope and the spectrum analyzer. The second-generation VT DSOs solve this problem using anti-aliasing filters that can adapt to the sampling frequency. 16-bit resolution should be used to fully utilize this feature. Please refer to the hardware specifications for details.

1.8.7 Signal Generator DDS and Streaming Modes

The signal generator of the second-generation VT DSOs features advanced hardware based DSP algorithm which supports both streaming and DDS (Direct Digital Synthesis) modes. Complicated signals such as white noise, MLS, frequency sweep and amplitude sweep, which generally are not found in other USB signal generators in the market, can be generated using the second-generation VT DSOs, for both streaming and DDS modes.

Under streaming mode, the output data are computed, continuously if necessary, by the Multi-Instrument software in the computer and then streamed continuously to the DAC device for output. One advantage of using streaming mode is that you can fully utilize the power of the Multi-Instrument software to generate very complicated signal at minimum hardware cost. However, limited by the software computing and the streaming speed, this mode is not able to provide high frequency output. Also, it may consume a lot of CPU time when the output sampling frequency is high or the output signal is complicated. Whether the output signal is continuous or not depends on the system throughput, sampling frequency, bit resolution, number of sampling channels, etc.

Under DDS mode, the computer only needs to send the output signal parameters (such as signal frequency, amplitude, waveform type or shape data, etc.) to the DAC device and the DAC device will take care of the rest. No actual output data will be sent from the computer to the DAC device. This greatly reduces the CPU work load and communication traffic between the computer and the DAC device. Very high signal frequencies can be generated if the DAC device is capable. One drawback is that not all functions supported by the streaming mode are supported by the DDS mode.

The following table compares these two modes.

	Streaming Mode	DDS Mode
Max. Sampling Frequency	Medium	High
Load to computer CPU	High	Very Low, only when Start/Stop button is pressed
Functionality	Virtually no limit, fully determined by the computer software	Limited by the hardware and the nature of DDS
Discontinuity in output signal	Normally no	Absolutely no
Sweep speed accuracy	High	Medium
Usage	To generate those waveforms that cannot be generated by DDS	Generally DDS mode should be used in order to utilize high sampling frequency and reduce the computer CPU load



Tick / Untick the DDS checkbox on the signal generator panel to select the DDS / Streaming mode.

Unlike the DDS function provided by some DDS IC chips, which has only a few fixed waveform options, the DDS function here is fully user-configurable. Beside some pre-configured waveforms (sine, rectangle, triangle, etc.), you can configure your own waveform via a waveform library file. This file will be downloaded to the DDS buffer when you choose “WFLibrary” in the waveform combo box on the signal generator panel. Please refer to the Multi-Instrument software manual for details.

1.8.8 Signal Generator DDS Interpolation

A DDS DAC device uses a lookup table (i.e. DDS buffer) to hold the shape of the signal to be generated. The DDS output suffers from the limited number of entries in the lookup table. The output value “jumps” when going from one entry to the next, introducing unwanted high frequencies in the output signal. This adverse effect may not be discernible when the output signal frequency is high, but becomes sensible as the output signal frequency goes down. DDS interpolation can be used to fix or alleviate this problem. Instead of using the value stored in the lookup table directly, it dynamically computes the output value through linear interpolation between two successive lookup table values. This effectively enlarges many times the DDS lookup table.

To enable the DDS interpolation, go to [Setting]>[DAC Device] and tick the “DDS Interpolation” checkbox.

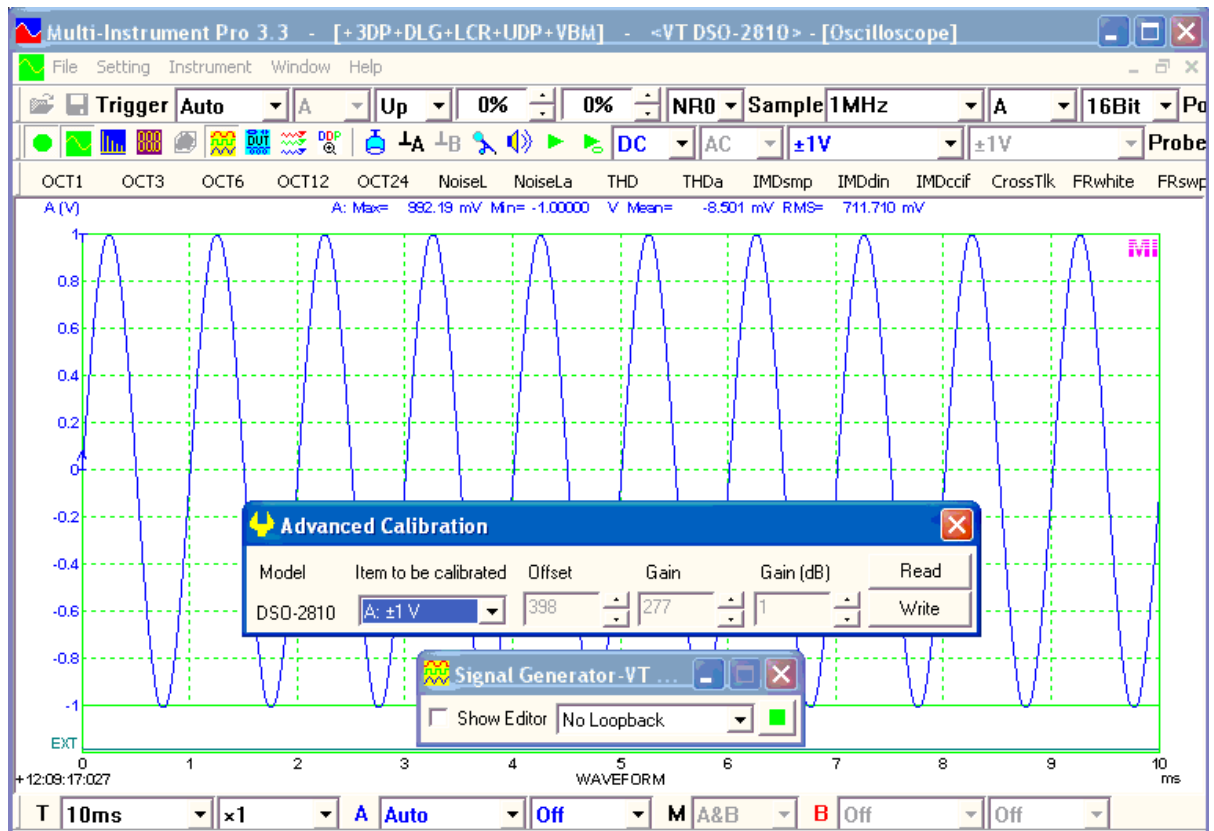
1.8.9 Simultaneous Data Acquisition and Data Output

The oscilloscope and signal generator of the second-generation VT DSOs can work simultaneously. You can generate a stimulus to the Device Under Test (DUT) and acquire the response from that device at the same time. You can even configure a sequence of steps to generate different stimuli to the DUT and analyze the different responses from it. Please refer to the chapter for Device Test Plan in the Multi-Instrument software manual for details.

1.8.10 Calibration and Re-Calibration

All the second-generation VT DSOs are individually calibrated to the specifications. Some models allow the user to re-calibrate them. To do the re-calibration, go to

[Setting]>[Calibration]> “Advanced”. The following “Advanced Calibration” dialog will pop up.



You can calibrate the offset and gain settings for each voltage measuring range and for each channel. The following are the steps to calibrate Channel A at $\pm 1V$.

- (1) Write down the current Offset, Gain (linear) and Gain (dB) values. This is important for system restoration in case all the settings are messed up.
- (2) Put Channel A to DC, $\pm 1V$, 16Bits, 1MHz (or lower, 100kHz recommended).
- (3) Short the probe tip to its ground lead.
- (4) Adjust the Offset spin box in the Advanced Calibration dialog such that the mean value of Channel A is zero.
- (5) Inject a DC or low-frequency signal with known amplitude to channel A. For better accuracy, the amplitude should approach the limit of the voltage measuring range to be calibrated. For the calibration of some voltage measuring ranges, you may use the DSO’s signal generator to generate the test signal.
- (6) Adjust the Gain or Gain (dB) spin box in the Advanced Calibration dialog such that the maximum/minimum value (when the test signal is AC) or mean value (when the test signal is DC) of Channel A is equal to the amplitude of the test signal.
- (7) Click the Write button in the Advanced Calibration dialog to save the changed settings into the DSO hardware. Note that if you click the Read button before you click the Write button, the changed settings will be overwritten by the settings previously stored in the DSO hardware.

Hardware based offset and gain adjustment is superior to software based methods in that it does not reduce the precious dynamic range offered by the ADC devices.

1.8.11 Upgradable software, firmware, and hardware based DSP algorithm

The computer software as well as its license level, the firmware in the DSO, and the hardware based DSP algorithm in the DSO are all remotely upgradable. What you need to do is to check our website frequently to see if there is a free upgrade available for download.

1.9 Non-routine Applications

The non-routine applications refer to those applications that are not considered as routine tasks of an ordinary oscilloscope. With VT DSO's capability of simultaneous input and output, you can generate a stimulus to a Device Under Test (DUT) and acquire the response from it at the same time. Different stimuli can be generated and the responses can be analyzed in different ways. The characteristics of the DUT, such as frequency response and distortion, can then be obtained. You can even configure and then perform a sequence of automated test steps to evaluate a DUT using the Device Test Plan software module.

The following sections provide information and guidelines to help you to configure your own measurement settings for your specific applications.

1.9.1 Frequency Response Measurement

Frequency response includes magnitude frequency response and phase frequency response. Most of the time you may be only interested in the magnitude frequency response. However, if you need to measure both, i.e. Bode Plot (also called Gain & Phase Plot, or Transfer Function), then Multi-Instrument Pro is required. For Bode plot measurement, the stimulus should be fed to the DUT as well as Channel B while the response from the DUT should be fed to Channel A.

There are quite a few methods to measure the frequency response of a DUT.

- (1) Stimulus with an equal amount of energy per Hz of bandwidth in the frequency range of interest together with FFT spectrum analysis

The stimulus can be a white noise or MLS (Maximum Length Sequence) signal. No synchronization between the signal generator and oscilloscope is required. Just start the signal generator first and then start the oscilloscope. Inter-frame averaging should be used to get better results. You can set the number of frames to be averaged by right clicking anywhere within the spectrum analyzer window, selecting [Spectrum Analyzer Processing]> "Inter-Frame Processing"> "Linear Average" and choosing a number in the "Frames" field. Rectangle Window should be used in the spectrum analyzer. FFT size of the spectrum analyzer should be equal to or greater than the Record Length of the oscilloscope. If MLS is used, its length should be greater than the FFT size. Stop the oscilloscope first before stopping the signal generator.

A linear frequency swept sine signal can also be used as the stimulus. Trigger level should be set properly such that the oscilloscope only gets triggered right after the frequency sweep starts. Start the oscilloscope first and then start the signal generator. If the VT DSO outputs the probe calibration signal when the signal generator is not running, disable it first via [Setting]>[DAC Device]>"Probe CAL" to avoid false trigger. The record length of the oscilloscope should be equal to the frequency sweep duration of

the signal generator. This is to ensure that an oscilloscope frame captures exactly the entire frequency sweep process from start to end. The oscilloscope should be set to single trigger mode and inter-frame averaging is not required. Rectangle Window should be used in the spectrum analyzer. FFT size of the spectrum analyzer should be equal to or greater than the Record Length of the oscilloscope. Stop the oscilloscope first before stopping the signal generator.

Theoretically, unit impulse is an option for the stimulus as well. But it has much less excitation energy than those mentioned above, resulting in poor signal-to-noise ratio in the measurement. It is thus not recommended.

- (2) Stimulus with an equal amount of energy per octave of bandwidth in the frequency range of interest together with octave spectrum analysis

Pink noise can be used as the stimulus. No synchronization between the signal generator and oscilloscope is required. Just start the signal generator first and then start the oscilloscope. Inter-frame averaging should be used to get better results. You can set the number of frames to be averaged by right clicking anywhere within the spectrum analyzer window, selecting [Spectrum Analyzer Processing]> “Inter-Frame Processing”> “Linear Average” and choosing a number in the “Frames” field. Rectangle Window should be used in the spectrum analyzer. FFT size of the spectrum analyzer should be equal to or greater than the Record Length of the oscilloscope. Stop the oscilloscope first before stopping the signal generator.

A logarithmic frequency swept sine signal can also be used as the stimulus. Trigger level should be set properly such that the oscilloscope only gets triggered right after the frequency sweep starts. Start the oscilloscope first and then start the signal generator. If the VT DSO outputs the probe calibration signal when the signal generator is not running, disable it first via [Setting]>[DAC Device]>“Probe CAL” to avoid false trigger. The record length of the oscilloscope should be equal to the frequency sweep duration of the signal generator. This is to ensure that an oscilloscope frame captures exactly the entire frequency sweep process from start to end. The oscilloscope should be set to single trigger mode and inter-frame averaging is not required. Rectangle Window should be used in the spectrum analyzer. FFT size of the spectrum analyzer should be equal to or greater than the Record Length of the oscilloscope. Stop the oscilloscope first before stopping the signal generator.

- (3) Stimulus with an equal amount of energy in each frequency band resolved in the frequency range of interest in spectrum analysis

Multi-tones with each tone frequency corresponding to the center frequency of each frequency band resolved in the spectrum analyzer and an equal amplitude mixing ratio can be used. For example, in 1/3 octave analysis, the center frequencies of the resolved octave bands are 16Hz, 20Hz, 25Hz, ..., 20kHz. Thus, a multi-tone signal consisting of an equal amount of energy from each of these frequencies should be used as the stimulus. No synchronization between the signal generator and oscilloscope is required. Just start the signal generator first and then start the oscilloscope. Rectangle Window should be used in the spectrum analyzer. FFT size of the spectrum analyzer should be equal to or greater than the Record Length of the oscilloscope. Stop the oscilloscope first before stopping the signal generator.

- (4) Signal generator excites a single frequency or a narrow frequency band one at a time across the frequency range of interest and the response is analyzed one at a time and assembled together in the end.

A linear frequency swept sine signal can be used as the stimulus and peak hold function of the spectrum analyzer can be used to assemble the result. No synchronization between the signal generator and oscilloscope is required. Just start the signal generator first and then start the oscilloscope. You can set the number of frames to be peak-held by right clicking anywhere within the spectrum analyzer window, selecting [Spectrum Analyzer Processing]> “Inter-Frame Processing”> “Peak Hold”, and choosing a number in the “Frames” field. Hanning Window is recommended in the spectrum analyzer. If the assembled curve shows some unresolved “gaps”, then lengthen the sweep time of the signal generator and / or reduce the FFT size of the spectrum analyzer to ensure that each resolved frequency band in the spectrum analyzer is excited and analyzed as the sweep goes.

Frequency stepped sine can also be used as the stimulus. Device Test Plan software module is required in order to perform automated test to step through the frequency band of interest.

Notes:

- (1) To measure the frequency response of a DUT accurately, the overall frequency response of the setup itself should be flat enough in the frequency range of interest. The bandwidth of a VT DSO under 16-bit mode is about 0.443 of the sampling frequency selected. Thus select a sampling rate such that the bandwidth of the oscilloscope is wider than the frequency range of interest of the frequency response measurement. The wide-band noise generated by the signal generator can be considered to span from 0 Hz to $\frac{1}{2}$ of the sampling frequency of the signal generator. The frequency range of the stimulus should be equal to or a bit wider than the frequency range of interest of the measurement. If the frequency range of the stimulus is too wide, then the excitation energy in the frequency range of interest will be reduced, resulting in reduced signal-to-noise ratio in the measurement. Thus select a sampling rate of the signal generator such that the frequency range of the generated noise is just enough to cover the frequency of interest of the measurement. However, if a sine wave is used instead, the highest sampling rate of the signal generator is recommended. Any signal generated by the signal generator is further limited by the analog bandwidth of the signal generator.
- (2) It is possible to compensate the frequency response of the setup if only magnitude frequency response is to be measured. Connect the output of the signal generator to the input of the oscilloscope using the same cabling to be used with the DUT, and then measure the frequency response using the same measurement setting to be used with the DUT. After the magnitude frequency response of the setup itself is obtained, right click anywhere within the spectrum analyzer window and select [Spectrum Analyzer Generate Frequency Compensation File (Flat)], then provide a file name and save it. Right click anywhere within the spectrum analyzer window again and select [Spectrum Analyzer Processing], tick “Compensation1” and select the frequency compensation file saved previously.

- (3) The streaming mode of the signal generator provides more functions (e.g. pink noise, multitones) but consumes more computing power of the computer. DDS mode is thus recommended if possible.
- (4) Some VT DSOs such as VT DSO-2810R and VT DSO-2820R are not equipped with a built-in signal generator. You can use the computer sound card as the DAC device for the signal generator instead. The probe calibration signal output is also able to generate MLS signal. To configure it, go to [Setting]>[DAC Device], enable “Probe CAL” and select “MLS”, please note that the frequency value beside “MLS” refers to the sampling frequency rather than the signal frequency of the MLS signal.

1.9.2 Distortion, Noise Level, and Crosstalk Measurements

VT DSOs can be used to measure the distortion, noise level and crosstalk of a DUT whose respective parameter is substantially inferior to the VT DSO used. Please refer to Multi-Instrument software manual for a detailed description of these parameter measurements.

The measurement of THD, THD+N, SINAD, SNR, Noise Level, ENOB, Crosstalk, SFDR requires a pure sine wave excitation while IMD measurement requires multitone excitation. To avoid spectral leakage, which is critical in these tests, Kaiser 6 Window is recommended and FFT size of the spectrum analyzer should be equal to or less than the Record Length of the oscilloscope. Device Test Plan is required for automated test at multiple frequency points.

Note:

- (1) Unlike the magnitude frequency response measurement, the distortion, noise level and crosstalk of the VT DSO itself cannot be compensated. Thus the setup can only be used to test those DUTs that have a substantially inferior performance in the respective aspects to the setup itself. Please refer to the hardware specifications of the VT DSO for information.
- (2) The distortion, noise level and crosstalk of the setup itself can be measured by looping the output of the signal generator back to the input of the oscilloscope. You may need to adjust the amplitude of the test tone, voltage range of the oscilloscope, etc. to optimize the settings.

1.9.3 Measurement of Derived Quantities

Multi-Instrument comes with nearly 200 pre-defined quantities called Derived Data Points which are derived from the raw DAQ data, such as RMS values, Mean values, Peak Frequency, etc. You can also define your own set of derived quantities using mathematical expressions. This requires Multi-Instrument Pro. If you are measuring a physical quantity other than voltage, you can enter the sensor sensitivity via [Setting]>[Calibration]>“Sensor”> “Sensitivity” and “Unit”.

1.9.4 Some Pre-configured Measurement Settings

The pre-configured panel setting files for VT DSOs are stored in the directory: psf\VTDSO. You may use them directly in your tests, or use them as templates to configure your own test settings. You can load these panel setting files via [Setting]>[Load Panel Setting]. Furthermore, some frequently used panel setting files are pre-configured in the Hot Panel Setting Toolbar (The third toolbar from the top. If it is not shown, select [Setting]>[Show

Hot Panel Setting Toolbar]) and you can load one of them by a single mouse click. These measurement settings are:

(1) Home: Default Setting

The factory default panel setting. It is equivalent to the [File]>[New] command.

(2) OCT1: 1/1 Octave Analysis with Pink Noise Stimulation (Avg. 10)

Pink noise will be generated by pressing the start button of the signal generator. The pink noise will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. A flat curve in the spectrum analyzer would indicate a flat magnitude frequency response of the DUT.

(3) OCT3: 1/3 Octave Analysis (Avg. 10)

Same as OCT1, but with finer frequency resolution.

(4) OCT6: 1/6 Octave Analysis (Avg. 10)

Same as OCT3, but with finer frequency resolution.

(5) NoiseL: Noise Level when there is no input signal (Avg. 10)

(6) NoiseLa: Noise Level (A-Weighted) when there is no input signal (Avg. 10)

(7) THD: THD, THD+N, SNR, SINAD, Noise Level, ENOB (Avg. 10)

A 1 kHz sine wave will be generated by pressing the start button of the signal generator. The sine wave will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. All the above parameters of the DUT will be measured and displayed.

(8) CrossTlk: Crosstalk A->B, THD, THD+N, SNR, SINAD, ENOB (Avg. 10)

A 1 kHz sine wave will be generated by pressing the start button of the signal generator. The sine wave will be injected into Channel A of the DUT (Device Under Test) while the input of Channel B is connected to Ground. The response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. All the above parameters of the DUT will be measured and displayed.

(9) IMDsmp: IMD SMPTE (60 Hz + 7 kHz, 4:1) (Avg. 10)

A 60 Hz and a 7 kHz sine waves mixed at an amplitude ratio of 4:1 will be generated by pressing the start button of the signal generator. The mixed signals will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The SMPTE IMD value of the DUT will be measured and displayed.

(10)IMDdin: IMD DIN (250 Hz + 8 kHz, 4:1) (Avg. 10)

A 250 Hz and a 8 kHz sine waves mixed at an amplitude ratio of 4:1 will be generated by pressing the start button of the signal generator. The mixed signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The DIN IMD value of the DUT will be measured and displayed.

(11)IMDccif: IMD CCIF2 (19 kHz + 20 kHz, 1:1) (Avg. 10)

A 19 kHz and a 20 kHz sine waves mixed at an amplitude ratio of 1:1 will be generated by pressing the start button of the signal generator. The mixed signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The CCIF2 IMD value of the DUT will be measured and displayed.

(12)FRwns: Magnitude Frequency Response (White Noise, Streaming Mode, Avg. 30)

White noise will be generated by pressing the start button of the signal generator. The white noise will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(13)FRwnd: Magnitude Frequency Response (White Noise, DDS Mode, Avg. 30)

White noise will be generated by pressing the start button of the signal generator. The white noise will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(14)FRmls: Magnitude Frequency Response (MLS, Streaming Mode, Avg. 30)

MLS (Maximum Length Sequence) will be generated by pressing the start button of the signal generator. The MLS signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(15)FRmld: Magnitude Frequency Response (MLS, DDS Mode, Avg. 30)

MLS (Maximum Length Sequence) will be generated by pressing the start button of the signal generator. The MLS signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured and analyzed by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(16)FRswLin: Magnitude Frequency Response (Frequency Sweep, Linear)

A 0.4-second 10Hz-to-25kHz linear frequency swept sine wave will be generated once by pressing the start button of the signal generator. The signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT. Note that you may have to adjust the trigger level so that the oscilloscope will be triggered just upon the start of the sweep.

(17)FRswLog: Magnitude Frequency Response (Frequency Sweep, Log)

A 0.4-second 10Hz-to-25kHz logarithmic frequency swept sine wave will be generated once by pressing the start button of the signal generator. The signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT. Note that you may have to adjust the trigger level so that the oscilloscope will be triggered just upon the start of the sweep.

(18)FRmt: Magnitude Frequency Response (MultiTones, 32 1/3 Octave Bands)

A multitone signal consists of 32 single frequency tones corresponds to the center frequencies of 32 1/3 octave bands will be generated by pressing the start button of the signal generator. The signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(19)FRph: Magnitude Frequency Response (Frequency Sweep, Linear, Peak Hold)

A 60-second 10Hz-to-25kHz linear frequency swept sine wave will be generated repeatedly by pressing the start button of the signal generator. The signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT.

(20)FR2M: Magnitude Frequency Response (0~2MHz, White Noise, DDS Mode, Avg. 30)

White noise will be generated by pressing the start button of the signal generator. The signal will be injected into the DUT (Device Under Test), and the response of the DUT will be captured by the oscilloscope and spectrum analyzer. The curve in the spectrum analyzer indicates the magnitude frequency response of the DUT. Unlike the settings from (2) to (19), which deal mainly with audio frequency, the setting here can be used to measure frequency response from 0 to 2MHz.

2 Specifications

2.1 VT DSO-2820E Hardware Specifications

Oscilloscope Horizontal (Time) Axis			
Real Time Sampling Frequency (f_s)		<u>Single Analog Channel</u> 200 MHz <u>Single or Dual Analog Channels with or without 1-bit Digital Channel</u> 100 MHz, 50 MHz, 25 MHz, 20 MHz, 10 MHz, 5 MHz, 4 MHz, 2 MHz, 1 MHz, 500 kHz, 400 kHz, 200 kHz, 100 kHz, 50 kHz, 40 kHz, 20 kHz, 10 kHz, 5 kHz, 4 kHz, 2 kHz, 1 kHz, 500 Hz, 400 Hz, 200 Hz, 100 Hz, 50 Hz, 40 Hz, 20 Hz, 10 Hz, 5 Hz, 4 Hz, 2 Hz, 1 Hz	
Equivalent Sampling Frequency		= [Real Time Sampling Frequency] × [Number of Frames Persisted]. Maximum 40 GHz, for repetitive signals whose maximum frequency is less than ¼ of the real time sampling frequency. Not valid for the case of post-trigger.	
Buffer Size	Normal Frame Mode	Analog	Single Channel 40000 samples (8 bits) 20000 samples (16 bits) Dual Channels 20000 samples / channel (8 bits, Non-ALT mode) 10000 samples / channel (16 bits, Non-ALT mode) 40000 samples / channel (8 bits, ALT mode) 20000 samples / channel (16 bits, ALT mode)
		Digital	20000 samples (1 bit)
	Record Mode (Streaming Mode)	Limited only by hard disk space available and maximum file size allowed by the operating system. Maximum sampling frequency for continuous streaming is computer speed and software setting dependent and typically 10 MHz (single channel, 8 bit) in Multi-Instrument.	
Roll Mode (Streaming Mode for Low Frequency Signals)	Limited only by the computer memory available. Roll Mode is allowed when $f_s \leq 1\text{MHz}$ and $[\text{Record Length}] \geq 4 \times [\text{Roll Width}]$. Maximum sampling frequency for continuous streaming is computer speed and software setting dependent.		
Sweep Time		5 ns ~ 500 s (Non-Streaming Mode)	
Sampling Frequency Accuracy		±50 ppm	

Oscilloscope Vertical (Analog) Axes	
Number of Channels	2 (i.e. Ch. A and Ch. B)

ADC Bit Resolution		8 Bits			
Enhanced ADC Bit Resolution (available only when Sampling Frequency is less than 100 MHz)		16 Bits If this option is selected, the effective bit resolution increases from 8 bits to up to 16 bits as the sampling frequency goes down. (Assuming white noise in the signal)			
		Sampling Frequency	Effective Bit Resolution	Sampling Frequency	Effective Bit Resolution
		≥ 100 MHz	8 Bits	≤ 25 MHz	9 Bits
		≤ 6.25 MHz	10 Bits	≤ 1.563 MHz	11 Bits
		≤ 391 kHz	12 Bits	≤ 97.7 kHz	13 Bits
		≤ 24.4 kHz	14 Bits	≤ 6.10 kHz	15 Bits
		≤ 1.526 kHz	16 bits		
Bandwidth	$f_s > 50$ MHz	80 MHz			
	$f_s \leq 50$ MHz	8 Bits	No Effective Bit Resolution Enhancement	80 MHz	
		16 Bits	Effective Bit Resolution Enhancement	15 ~ 25 MHz	
		16 Bits	Effective Bit Resolution Enhancement	about $0.443 f_s$	
Voltage Measuring Range (Full Scale)		± 10 mV, ± 20 mV, ± 50 mV, ± 100 mV, ± 200 mV, ± 500 mV, ± 1 V, ± 2 V, ± 5 V, ± 10 V, ± 20 V, ± 50 V			
Max. Allowed Voltage		± 100 V (DC + AC peak), derated above 100kHz			
DC Accuracy		$\pm 1\%$			
Coupling Type		AC / DC			
Input Isolation		No (Isolation can be achieved through a USB isolator)			
Terminal Type		Referenced Single-Ended, BNC			
Input Impedance		1 M Ω , 15 pF			
Zero Calibration		Through hardware. Individually done at factory, user adjustable			
Gain Calibration		Through hardware. Individually done at factory, user adjustable			

Oscilloscope Vertical (Digital) Axis

Number of Channels	1 (i.e. External Trigger Channel, 1-bit ADC)
Bandwidth	140 MHz
Threshold Resolution	45 mV
Threshold Hysteresis	225 mV
Threshold Range	± 20 V
Max. Allowed Voltage	± 100 V (DC + AC peak), derated above 100kHz
Threshold DC Accuracy	$\pm 1\%$
Coupling Type	DC
Input Isolation	No (Isolation can be achieved through a USB isolator)
Terminal Type	Referenced Single-Ended, BNC
Input Impedance	1 M Ω , 15 pF
Zero Calibration	Through software. Individually done at factory.

Gain Calibration	Through software. Individually done at factory.
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Oscilloscope Trigger	
Trigger Detection Method	Digital
Trigger Source	Ch. A, Ch. B, EXT, ALT
Trigger Mode	Auto, Normal, Single, Slow
Trigger Edge	Rising, Falling
Trigger Level	Adjustable within full scale
Pre-Trigger	-100% ~ 0% of Record Length
Post-Trigger	0 ~ 100% of Record Length
Trigger Frequency Rejection	<p>Nil: No Rejection</p> <p>HFR: High Frequency Rejection, cut off at $0.11f_s$</p> <p>NR0: Noise Rejection, hysteresis = 1% of half of full scale</p> <p>NR1: Noise Rejection, hysteresis = 2% of half of full scale</p> <p>NR2: Noise Rejection, hysteresis = 4% of half of full scale</p> <p>NR3: Noise Rejection, hysteresis = 8% of half of full scale</p> <p>NR4: Noise Rejection, hysteresis = 16% of half of full scale</p> <p>HN0: HFR + NR0</p> <p>HN1: HFR + NR1</p> <p>HN2: HFR + NR2</p> <p>HN3: HFR + NR3</p> <p>HN4: HFR + NR4</p> <p>HNX: selectable HFR + adjustable hysteresis = 0% ~ 25% of half of full scale</p> <p>Note: The specified hysteresis may be modified internally to ensure [Trigger Level (%)] – [Hysteresis (%)] \geq -100% at rising edge, or [Trigger Level (%)] + [Hysteresis (%)] \leq 100% at falling edge.</p>

Oscilloscope Dynamic Performance (Typical)	
THD	$f_s=100$ kHz, $f=1$ kHz, from 2 nd to 20 th order, full-scale input: 8 bits (without bit resolution enhancement): \leq -55 dB 8 bits (with bit resolution enhancement): \leq -56 dB 16 bits: \leq -59 dB
IMD (250 Hz + 8 kHz, 4:1)	$f_s=100$ kHz, from 2 nd to 3 rd order, full-scale input: 8 bits (without bit resolution enhancement): \leq -51 dB 8 bits (with bit resolution enhancement): \leq -52 dB 16 bits: \leq -57 dB
IMD (19 kHz +20 kHz, 1:1)	$f_s=100$ kHz, 2 nd order only, full-scale input: 8 bits (without bit resolution enhancement): \leq -65 dB 8 bits (with bit resolution enhancement): \leq -65 dB 16 bits: \leq -78 dB
SFDR	$f_s=100$ kHz, $f=1$ kHz, full-scale input: 8 bits (without bit resolution enhancement): \geq 61 dB 8 bits (with bit resolution enhancement): \geq 61 dB 16 bits: \geq 62 dB

Crosstalk	≤ -45 dB (at the same voltage measuring range for full bandwidth)
Noise	<p>For voltage measuring ranges ± 50 mV and above:</p> <p>8 bits (without bit resolution enhancement): $\leq \pm 3$ counts ($\pm 1\%$)</p> <p>8 bits (with bit resolution enhancement, $f_s = 100$ kHz): $\leq \pm 2$ counts ($\pm 0.8\%$)</p> <p>16 bits ($f_s = 100$ kHz): $\leq \pm 0.3$ 8-bit count ($\pm 0.1\%$)</p> <p>For voltage measuring ranges ± 10 mV and ± 20 mV:</p> <p>8 bits (without bit resolution enhancement): $\leq \pm 15$ counts ($\pm 6\%$)</p> <p>8 bits (with bit resolution enhancement, $f_s = 100$ kHz): $\leq \pm 9$ counts ($\pm 4\%$)</p> <p>16 bits ($f_s = 100$ kHz): $\leq \pm 1$ 8-bit count ($\pm 0.4\%$)</p>

Signal Generator General

Number of Channels	1
Coupling Type	DC
Output Isolation	No
Terminal Type	Referenced Single-Ended, BNC
Output Impedance	50 Ω
Overvoltage Protection	± 35 V

Signal Generator -Analog (when Signal Generator is running)

Output Voltage Range	± 2 V, adjustable				
DAC Bit Resolution	10 Bits				
Output Sampling Frequency (f_s)	<p><u>DDS Mode</u></p> <p>200 MHz, 100 MHz, 50 MHz</p> <p><u>DDS Mode or Streaming Mode</u></p> <p>20 MHz, 10 MHz, 5 MHz, 2 MHz, 1 MHz, 500 kHz, 200 kHz, 100 kHz, 50 kHz, 20 kHz, 10 kHz, 5 kHz</p>				
Output Sampling Frequency Accuracy	± 50 ppm				
Bandwidth	DC ~ 60 MHz				
Output Signal Frequency	0 ~ $\frac{1}{2}$ of output sampling frequency				
Rise Time (10% ~ 90%)	< 5.8 ns				
DC Offset Range	Full output voltage range				
DC Accuracy	$\pm 0.5\%$ of full scale				
Waveform	<table border="1"> <tr> <td>DDS Mode*</td> <td>Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, MLS (length = $2^{63}-1$), User Configurable Waveform Library (Arbitrary), Musical Scale</td> </tr> <tr> <td>Streaming* Mode</td> <td>Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, Pink Noise, MultiTones, MLS (127~16777215), DTMF, User Configurable Waveform Library (Arbitrary), Musical Scale</td> </tr> </table>	DDS Mode*	Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, MLS (length = $2^{63}-1$), User Configurable Waveform Library (Arbitrary), Musical Scale	Streaming* Mode	Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, Pink Noise, MultiTones, MLS (127~16777215), DTMF, User Configurable Waveform Library (Arbitrary), Musical Scale
DDS Mode*	Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, MLS (length = $2^{63}-1$), User Configurable Waveform Library (Arbitrary), Musical Scale				
Streaming* Mode	Sine, Rectangle (duty cycle adjustable), Triangle, Saw Tooth, White Noise, Pink Noise, MultiTones, MLS (127~16777215), DTMF, User Configurable Waveform Library (Arbitrary), Musical Scale				

Signal Frequency Resolution	DDS Mode	<0.05 Hz ($f_s = 200$ MHz) <0.000001 Hz ($f_s = 5$ kHz)
	Streaming Mode	Virtually infinitesimal
Buffer Size	DDS Mode	Without interpolation: 1024 samples With interpolation: $1024 \times 65536 = 67108864$ samples (Note: interpolation is only available when $f_s \leq 100$ MHz)
	Streaming Mode	Virtually unlimited
Frequency Sweep	DDS Mode	Supports linear sweep of all types of repetitive waveforms. Sweep speed range: $1/32768 \times f_s^2 / 2^{32} \sim 65535 \times f_s^2 / 2^{32}$ (e.g. 284 Hz/s \sim 610 GHz/s when $f_s = 200$ MHz)
	Streaming Mode	Supports linear and logarithmic sweep of all types of repetitive waveforms. Sweep speed range: unlimited
Amplitude Sweep	DDS Mode	Supports linear sweep of all types of waveforms. Sweep speed range: $1/32768 \times f_s / (2^{32} - 1) \sim 65535 \times f_s / (2^{32} - 1)$ (e.g. 0.000142 %/s \sim 305171 %/s when $f_s = 200$ MHz)
	Streaming Mode	Supports linear and logarithmic sweep of all types of waveforms. Sweep speed range: unlimited
Duration (Signal Length) Resolution	DDS Mode	$1/f_s$ or $1 \mu\text{s}$, whichever is greater
	Streaming Mode	$1/f_s$
THD	≤ -60 dB ($f_s = 2$ MHz, $f = 1$ kHz, from 2 nd to 20 th order, full-scale output)	
SFDR	≥ 65 dB ($f_s = 2$ MHz, $f = 1$ kHz, full-scale output)	
Zero Calibration	Through software. Individually done at factory.	
Gain Calibration	Through software. Individually done at factory.	

*DDS mode consumes almost no computer CPU time while streaming mode consumes a lot. Maximum sampling frequency for continuous streaming is computer speed and software setting dependent and typically 10 MHz in Multi-Instrument. More advanced functions are provided via Multi-Instrument software under streaming mode. Please refer to Multi-Instrument software manual for details.

Signal Generator - Digital (when Signal Generator is not running)

Voltage Range	-1.65 ~ 1.65 V, not adjustable		
Output Signal Frequency Accuracy	± 50 ppm		
Bandwidth	60 MHz		
Rise Time (10% ~ 90%)	< 5.8 ns		
Waveform	Square	Signal Frequency	25 MHz / N, (N=1, 2, 3,25000)
	MLS	Sampling Frequency	25 MHz / N, (N=1, 2, 3,25000)

General

Interface	USB 2.0 High Speed / USB 1.1 Full Speed / USB Isolator	
Device Category in Multi-Instrument	ADC Device	VT DAQ 1
	DAC Device	VT DAO 1
Firmware Upgradable	Yes	
Power	Bus powered by USB port, no external power source required.	
Power Consumption	Max. 2.5W	
Dimensions	145 mm (L) × 108 mm (W) × 26 mm (H)	
System Requirement	Windows XP, Vista, 7, 8 or above, 32 bit or 64 bit	
Operating Temperature	0°C ~50°C	

2.2 P2100 Oscilloscope Probe Hardware Specifications

Attenuation Ratio	×1, ×10
Bandwidth	DC ~ 100 MHz (×10), DC ~ 6 MHz (×1)
Input Impedance	1 MΩ (×1, with VT DSO connected) 10 MΩ (×10, with VT DSO connected)
Input Capacitance	14 pF~18 pF (×10), 70 pF~120 pF (×1)
Input Capacitance Compensation Range	15~45 pF
Length	1.2 m

Accessories include: a 12 cm snap-on rotating ground lead, a sprung hook, two marker rings, a probe compensation adjustment tool, two probe tip caps.

2.3 Multi-Instrument Software Specifications

Please refer to Multi-Instrument software manual for detail. The following table shows the function allocation matrix for Multi-Instrument series. The Spectrum 3D Plot, Data Logger, LCR Meter, Device Test Plan, Vibrometer are add-on modules/functions and should be purchased separately, and they are only available for Multi-Instrument Lite, Standard, and Pro editions, except that the Vibrometer is only available for Multi-Instrument Standard and Pro editions.

Legend: √ - Function available √* - Function available in Full version only

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
General Functions							
ADC / DAC Hardware	Sound Card MME	√	√	√	√	√	√
	Sound Card ASIO						√
	Other Hardware				√	√	√
	vtDAQ, vtDAO software development kit	License automatically activated with the presence of the corresponding hardware, e.g. a USB hardkey or a VT DSO.					
File	Load WAV File	√	√	√	√	√	√
	Load TXT File					√	√

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
	Load WAV File Frame by Frame (fore Long WAV File)					√	√
	Combine WAV Files	√	√	√	√	√	√
	Extract Data and save them into a new WAV File	√	√	√	√	√	√
	Save/Load Panel Setting	√	√	√	√	√	√
Data Export	Copy Text to Clipboard	√	√	√	√	√	√
	Copy BMP to Clipboard	√	√	√	√	√	√
	Print Preview	√	√	√	√	√	√
	Print	√	√	√	√	√	√
	Export as TXT File	√	√	√	√	√	√
	Export as BMP File	√	√	√	√	√	√
Trigger Settings	Trigger Mode	√	√		√	√	√
	Trigger Source	√	√		√	√	√
	Trigger Edge	√	√		√	√	√
	Trigger Level	√	√		√	√	√
	Trigger Delay	√	√		√	√	√
	High Frequency Rejection				√	√	√
Sampling Settings	Noise Rejection				√	√	√
	Sampling Rate	√	√	√	√	√	√
	Sampling Channels	√	√	√	√	√	√
	Sampling Bit Resolution	√	√	√	√	√	√
Calibration	Record Length	√	√		√	√	√
	Input	√	√		√	√	√
	Output			√	√	√	√
	Probe	√	√		√	√	√
	Sound Pressure Level	√	√		√	√	√
	F/V Conversion					√	√
	Latency for Sync. Output/Input						√
	Sensor Sensitivity	√	√		√	√	√
Graph Operation	Load Factor for Power Calculation	√	√		√	√	√
	Zoom	√	√	√	√	√	√
	Scroll	√	√	√	√	√	√
	Cursor Reader	√	√	√	√	√	√
	Marker	√	√	√	√	√	√
	Chart Type	√	√	√	√	√	√
	Line Width	√	√	√	√	√	√
	Color	√	√	√	√	√	√
	Fast/Slow Display Mode	√	√	√	√	√	√
	Refresh Delay	√	√	√	√	√	√
	Font Size	√	√	√	√	√	√
	Roll Mode					√	√
	Reference Curves & Limits					√	√
Other	Gain Adjustment	√	√	√	√	√	√
	Input Peak Indicator	√	√	√	√	√	√

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
	Sound Card Selection	√	√	√	√	√	√
	Sampling Parameter Auto Setting	√	√	√	√	√	√
	Multilingual GUIs	√	√	√	√	√	√
	Show/Hide Toolbar	√	√	√	√	√	√
	Lock/Unlock Panel Setting	√	√	√	√	√	√
	Hot Panel Setting Toolbar	√	√	√	√	√	√
	ActiveX Automation Server	√	√	√	√	√	√
Oscilloscope							
Type	Individual Waveform	√	√	√ (offline)	√	√	√
	Waveform Addition	√	√	√ (offline)	√	√	√
	Waveform Subtraction	√	√	√ (offline)	√	√	√
	Waveform Multiplication	√	√	√ (offline)	√	√	√
	Lissajous Pattern	√	√	√ (offline)	√	√	√
Inter-Frame Processing	Linear Average					√	√
	Exponential Average					√	√
Demodulation (Intra-Frame)	AM					√	√
	FM					√	√
	PM						
Digital Filtering (Intra-Frame Processing)	Remove DC					√	√
	Rectification					√	√
	FFT Low Pass					√	√
	FFT High Pass					√	√
	FFT Band Pass					√	√
	FFT Band Stop					√	√
	FFT Frequency Response					√	√
	FIR Low Pass					√	√
	FIR High Pass					√	√
	FIR Band Pass					√	√
	FIR Band Stop					√	√
	FIR Frequency Response					√	√
	IIR Coefficients					√	√
	Others	Max, Min, Mean, RMS	√	√	√ (offline)	√	√
Record Mode						√	√
Persistence Display Mode		√	√		√	√	√
Equivalent Time Sampling Mode		√	√		√	√	√
	Analog & Digital Signal Mixed Display				√	√	√

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
	SINC Interpolation	√	√	√	√	√	√
Spectrum Analyzer							
Type	Amplitude Spectrum		√		√	√	√
	Phase Spectrum		√		√	√	√
	Auto-correlation		√		√	√	√
	Cross-correlation		√		√	√	√
	Coherence						√
	Transfer Function						√
	Impulse Response						√
Intra-Frame Processing	Frequency Compensation		√		√	√	√
	Frequency Weighting		√		√	√	√
	Remove DC		√		√	√	√
	Smoothing via Moving Average		√		√	√	√
Inter-Frame Processing	Peak Hold		√		√	√	√
	Linear Average		√		√	√	√
	Exponential Average		√		√	√	√
Parameter Measurement	THD, THD+N, SNR, SINAD, Noise Level, ENOB		√		√	√	√
	IMD		√		√	√	√
	Bandwidth		√		√	√	√
	Crosstalk		√		√	√	√
	Harmonics & Phase		√		√	√	√
	Energy in User Defined Frequency Band		√		√	√	√
	Peaks, SFDR		√		√	√	√
	Wow & Flutter						√*
	Sound Loudness						√
	Sound Loudness Level						√
FFT	FFT Size 128~32768		√		√	√	√
	FFT Size 65536~4194304						√
	Intra-Frame Average		√		√	√	√
	Window function		√		√	√	√
	Window Overlap		√		√	√	√
Others	Peak Frequency detection		√		√	√	√
	Cross Correlation Peak detection		√		√	√	√
	Octave Analysis (1/1, 1/3, 1/6, 1/12, 1/24, 1/48, 1/96)		√		√	√	√
	Linear/Log/Power Spectral Density Scale for X and Y		√		√	√	√
Signal Generator							

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
Waveform	Sine			√	√	√	√
	Rectangle			√	√	√	√
	Triangle			√	√	√	√
	Saw Tooth			√	√	√	√
	White Noise			√	√	√	√
	Pink Noise			√	√	√	√
	MultiTones			√	√	√	√
	Arbitrary Waveform			√	√	√	√
	MLS			√	√	√	√
	DTMF			√	√	√	√
	Musical Scale			√	√	√	√
	Wave File					√	√
	Play Waveform in Oscilloscope	√	√	√	√	√	√
	Cyclic Play Waveform in Oscilloscope	√	√	√	√	√	√
Sweep	Frequency Sweep (Linear/Log)			√	√	√	√
	Amplitude Sweep (Linear/Log)			√	√	√	√
Burst (Mask)	Normal			√	√	√	√
	Phase Locked			√	√	√	√
Fade	Fade In			√	√	√	√
	Fade Out			√	√	√	√
Modulation	AM			√	√	√	√
	FM			√	√	√	√
	PM			√	√	√	√
Others	Software Loopback (all channels)			√	√	√	√
	Software Loopback (1 channel)				√	√	√
	Sync. with Oscilloscope						√
	Save as WAV file			√	√	√	√
	Save as TXT file			√	√	√	√
	DDS				√	√	√
	DC Offset				√	√	√
Multimeter							
Type	RMS					√	√
	dBV					√	√
	dBu					√	√
	dB					√	√
	dB(A)					√	√
	dB(B)					√	√
	dB(C)					√	√
	Frequency Counter				√	√	√
	RPM					√	√
	Counter					√	√
	Duty Cycle					√	√
	Frequency/Voltage					√	√
	Cycle RMS					√	√
Cycle Mean					√	√	

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
Settings	Pulse Width					√	√
	Counter Trigger Hysteresis				√	√	√
	Counter Trigger Level				√	√	√
	Frequency Divider				√	√	√
DDP Viewer							
Function	DDP & UDDP display						√
	HH, H, L, LL Alarm						√
	Set Display Precision						√
	Define UDDP						√
	Alarm Sound						√
	Alarm Acknowledge						√

Legend: Blank - Function available if purchased Shaded Blank - Function NOT available for that version

		Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument Standard	Multi-Instrument Pro
Spectrum 3D Plot							
Type	Waterfall Plot						
	Spectrogram						
Settings	Spectrogram Color Palette						
	Waterfall Color Palette						
	Waterfall tilt Angle						
	Waterfall / Spectrogram Height						
	Linear / Log Scale for X and Y						
	Number of Spectral Profiles (10~200)						
Others	3D Cursor Reader						
Data Logger							
Real Time Logging							
Load Historical Log File							
Three logging methods							
201 derived data points available for logging							
Up to 8 × 8 = 64 variables can be logged simultaneously							
LCR Meter							
High Impedance Measurement							
Low Impedance Measurement							
Up to 8 X-Y Plots							

	Sound Card Oscilloscope	Sound Card Spectrum Analyzer	Sound Card Signal Generator	Multi-Instrument Lite	Multi-Instrument	Multi-Instrument Pro
(Linear/Log)						
Device Test Plan						
23 Instructions						
Create/Edit/Lock/Execute/Load/Save a Device Test Plan						
Up to 8 X-Y Plots (Linear/Log)						
Device Test Plan Log						
Vibrometer						
RMS, Peak/PP, Crest Factor for acceleration, velocity, displacement (in Multimeter)						
Waveform conversion among acceleration, velocity and displacement (in Oscilloscope)						
SI / English units						

2.4 Software Development Interface Specifications

Multi-Instrument provides the following secondary development features:

1. Multi-Instrument can work as an ActiveX automation server so that an external program can access the data and functions that Multi-Instrument exposes. You can integrate Multi-Instrument into your own software seamlessly via the ActiveX automation server interfaces exposed by Mutil-Instrument.

Please refer to: *Multi-Instrument Automation Server Interfaces*

Download link:

<http://www.virtins.com/Multi-Instrument-Automation-Server-Interfaces.pdf>

The above document and the sample automation client programs in Visual C++, Visual Basic and Visual C# can be found in the AutomationAPIs directory of the software.

2. You can use the vtDAQ and vtDAO interface DLLs supplied in this software to allow your own back-end software to interface to sound cards, NI DAQmx cards, VT DSOs, VT RTAs, etc.. You can also develop your own vtDAQ and vtDAO compatible DLLs to allow Multi-Instrument to interface to your own hardware.

Please refer to: *vtDAQ and vtDAO Interfaces*

Download link:

<http://www.virtins.com/vtDAQ-and-vtDAO-Interfaces.pdf>

The above document and the sample DAQ and DAO back-end programs and sample

vtDAQ compatible DLL in Visual C++, Visual C# and Labview can be found in the DAQDAOAPIs directory of the software.

3. Virtins Technology's Signal Processing and Analysis (vtSPA) Application Programming Interfaces (APIs) provides a suite of generic APIs for data processing and analysis. It contains some unique features / algorithms originated and only available from Virtins Technology.

Please refer to: *Signal Processing and Analysis (vtSPA) Interfaces*

Download link:

<http://www.virtins.com/Signal-Processing-and-Analysis-APIs.pdf>

The above document and the sample programs in Visual C++ can be found in the DAQDAOAPIs directory of the software.

Furthermore, Multi-Instrument is well prepared to be rebranded for OEM services. Its look and feel can be readily changed through configuration without even reprogramming. Contact Virtins Technology if interested.

3 Multi-Instrument Software License Information

3.1 License Types

The License of Multi-Instrument software has six levels and five add-on modules/functions. The six levels are: Sound Card Oscilloscope, Sound Card Spectrum Analyzer, Sound Card Signal Generator, Multi-Instrument Lite, Multi-Instrument Standard, Multi-Instrument Pro. The five add-on modules/functions are: Spectrum 3D Plot, Data Logger, LCR Meter, Device Test Plan, Vibrometer.

The license contained in the standard VT DSO package is a hardware bundled Multi-Instrument Standard license, without any add-on modules/functions. No softkey (activation code) and USB hardkey (USB dongle) are provided in this type of license. The software will run under the licensed mode as long as the VT DSO unit is connected to your computer before you start the Multi-Instrument software.

Note: If the software is started without the VT DSO unit connected to the computer, it will enter into 21-day fully functional trial mode, unless the software is activated by a softkey (activation code) or a hardkey (USB dongle), which are NOT included in the standard VT DSO package and should be purchased separately as a brand-new license if needed. In other words, the VT DSO hardware should always be connected to the computer in order for the Multi-Instrument software to work under the licensed mode, even though you might just want to use your computer sound card for ADC and DAC.

3.2 License Upgrade from one level to another

You can purchase an upgrade of the license, e.g. from Multi-instrument Standard to Multi-Instrument Pro + Data Logger, at any time if necessary. After you purchase the upgrade, a small upgrade package file will be sent to you via email. You can then use it to upgrade the license bundled within the VT DSO unit by selecting [Start]>[All Programs]>[Multi-Instrument]>[VIRTINS Hardware Upgrading Tool] on your Windows desktop.

3.3 Software Upgrade for the same level

Software upgrade for the same level (if the hardware is still supported by the new version), e.g. from Multi-Instrument 3.0 Standard to Multi-Instrument 3.1 Standard, is always FREE. You just need to download the new version from our website and install it to any computer.

Thus, please do visit frequently our website to see if a new version or build is available.

4 Extended Use of Multi-Instrument Software

Multi-Instrument is a powerful multi-function virtual instrument software. It supports a variety of hardware ranging from sound cards which are available in almost all computers to proprietary ADC and DAC hardware such as NI DAQmx cards, VT DSO units, and so on. Furthermore, the ADC and DAC device can be chosen independently in Multi-Instrument. For example, you can use VT DSO for data acquisition and use your computer's sound card for signal generation simultaneously.

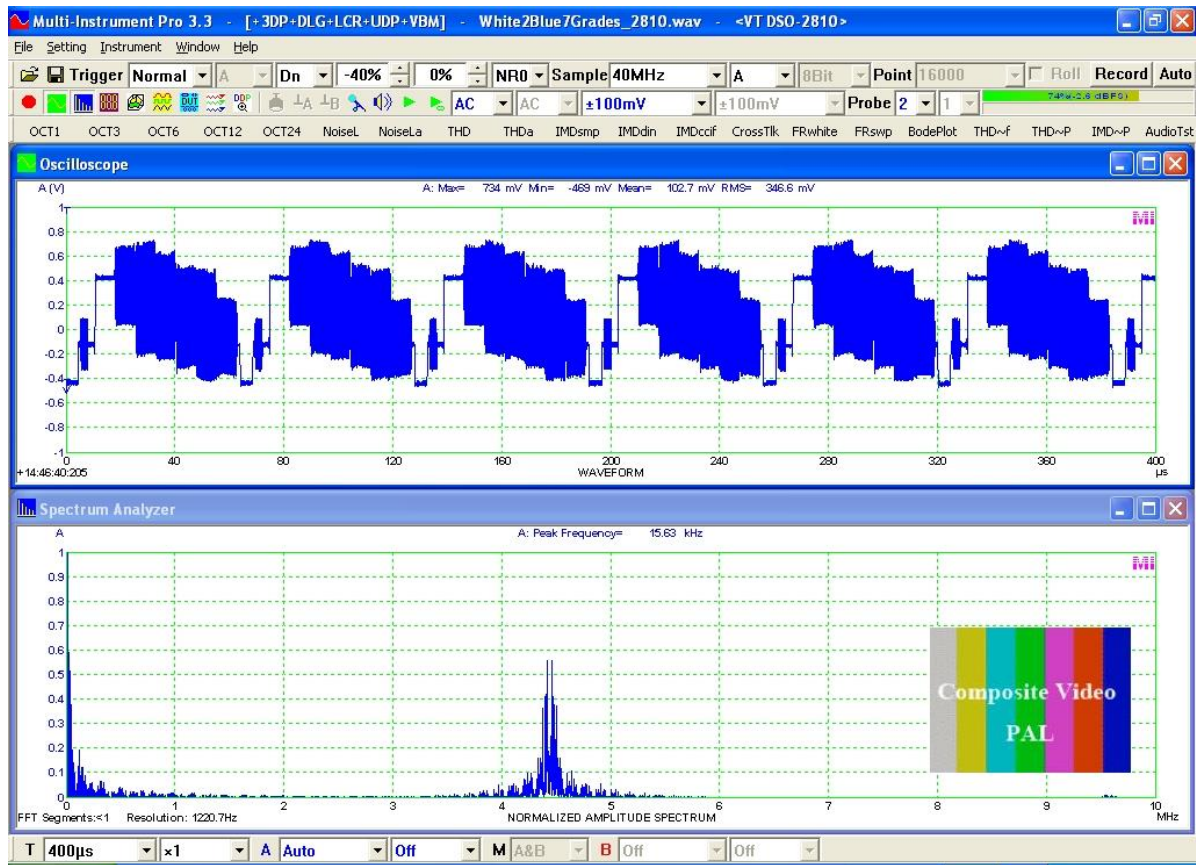
You can change the ADC device via [Setting]>[ADC Device]>[Device Model]. For example you can also use your computer's sound card as the ADC device.

If the VT DSO unit does not contain a built-in DAC, then no signal generator function is available within the hardware unit, except the digital signal output for probe calibration. However, you can choose other DAC device via [Setting]>[DAC Device]>[Device Model]. For example, you can use your computer's sound card as the DAC device and thus make full use of the signal generator function of Multi-Instrument.

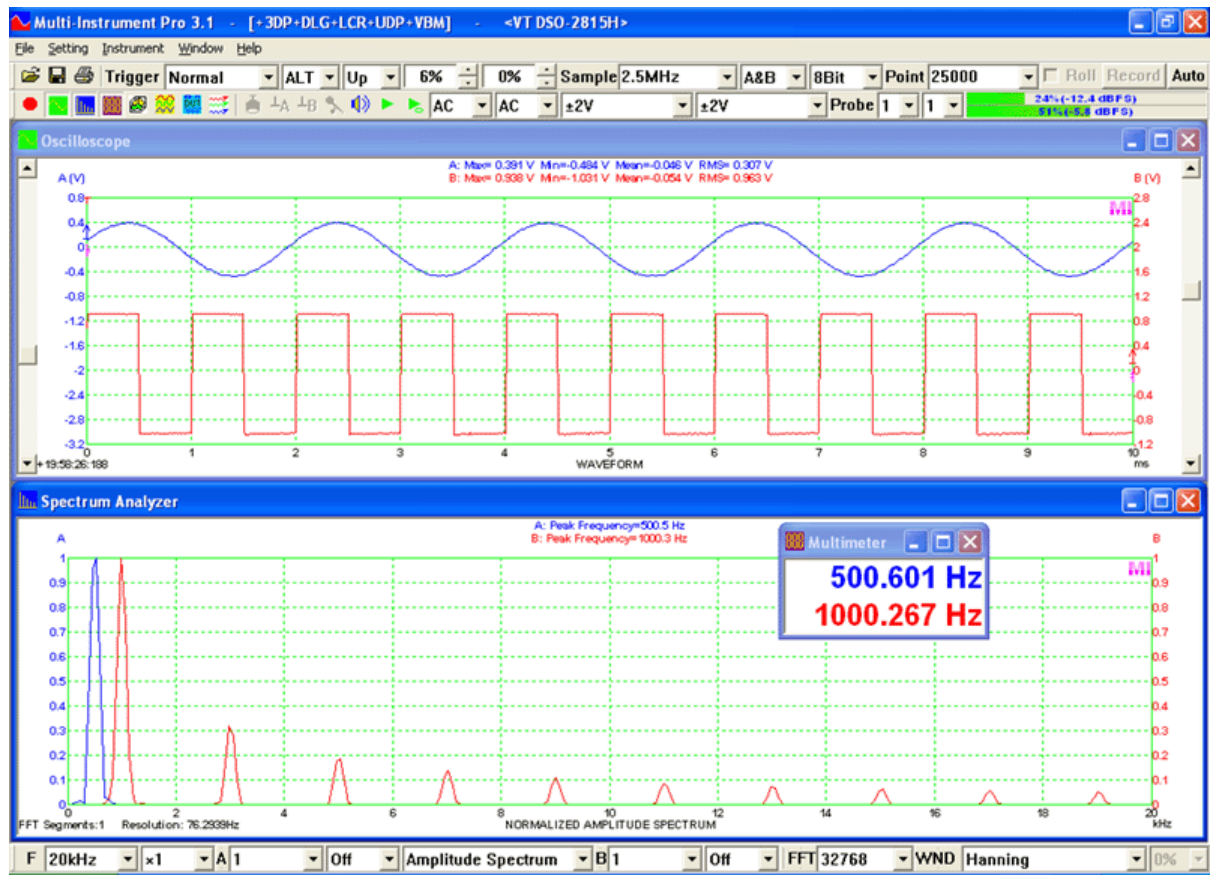
If you want to use the sound card as the ADC/DAC device, you may need to purchase the dedicated sound card oscilloscope probe kit from Virtins Technology separately, or you may make the connection by yourself.

5 Measurement Examples

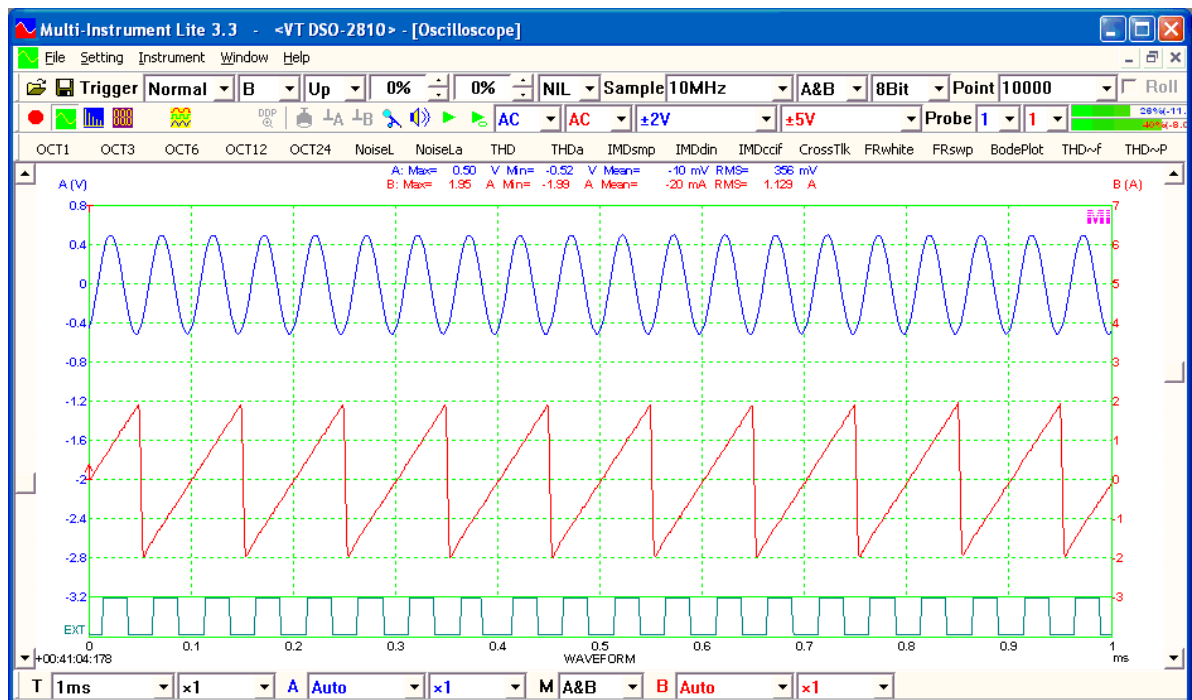
The following figure shows a measurement of a PAL composite video signal from a VCD player.



The following figure shows the measurement of a 500Hz sine wave and a 1kHz square wave under ALT trigger mode. The trigger level for both channels can be adjusted independently under this mode. The trigger level for Channel B can be adjusted by dragging the arrow on B axis in the oscilloscope window.



The following figure is a mixed signal display. Channels A & B are analog input channels while Channel EXT is used as a digital input channel.



6 Safety Instructions



- Always keep in mind that the input of the probe and the input of the VT DSO are NOT galvanically isolated from the computer connected.
- Never connect to a signal with unknown amplitude.
- Never connect to a signal with voltage greater than the measurement range.
- If you are not very sure about the exact voltage under test, always start measurement by putting the attenuation switch of the oscilloscope probe to $\times 10$ and selecting the highest measurement range of the VT DSO unit.
- When the input peak level indicator of the Multi-Instrument software turns full RED (100%, see the figure below), switch the probe to a higher attenuation ratio, switch the VT DSO unit to a higher measurement range, or disconnect the input signal immediately.

100% (0.0 dBFS)
 100% (0.0 dBFS)
- Be extremely careful when the voltage under test is greater than 5V.
- It should be noted that for many computers (typically desktop PCs or laptop PCs with a built-in AC power supply adapter), the ground line of the probe is connected to mains earth. This is not a problem if the circuit under test is floating (i.e. isolated from earth). Otherwise, you MUST make sure that the ground lead of the probe is connected to a point on the circuit that is also at earth potential.

7 Warranty

Virtins Technology guarantees this product against defective materials and manufacturing defects for a period of 12 months. During this period of warranty, a replacement of the faulty part will be shipped to the buyer's address free of charge upon receiving and verifying the returned faulty part. The Warranty is only applicable to the original buyer and shall not be transferable. The warranty shall exclude malfunctions or damages resulting from acts of God, fire, civil unrest and/or accidents, and defects from using wrong electrical supply/voltage and/or consequential damage by negligence and/or abuse, as well as use other than in accordance with the instructions for operation. The Warranty shall immediately cease and become void if the hardware is found to have been tampered, modified, repaired by any unauthorized person(s). Decisions by Virtins Technology on all questions relating to complaints as to defects either of workmanship or materials shall be deemed conclusive and the buyer shall agree to abide by such decisions.

8 Disclaimer

This document has been carefully prepared and checked. No responsibility can be assumed for inaccuracies. Virtins Technology reserves the right to make changes without prior notice to any products herein to improve functionality, reliability or other design aspects. Virtins Technology does not assume any liability for losses arising out of the use of any product described herein; neither does its use convey any license under its patent rights or the rights of others. Virtins Technology does not guarantee the compatibility or fitness for purpose of any

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