Multi-Instrument System for Education

in Middle Schools, High Schools, Vocational Schools, Colleges and Universities

-A PC Based All-in-One Test and Measurement Solution

Version 1.0

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1. Introduction

Multi-Instrument System for Education is designed specially for educational use. It is easy enough for middle school students to use, yet powerful enough to be used by college and university students. It is versatile and comes with all you need to perform a variety of experiments for different topics and subjects in labs. It also supports experimenting with simulated data and thus is a good tool for the teachers to perform demonstration using a projector in classes.

1.1 What is Multi-Instrument?

Multi-Instrument is a powerful PC based 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, Virtins Technology's Digital Storage Oscilloscopes (VT DSO), Virtins Technology's Real Time Analyzers (RTA) and so on. It consists of an oscilloscope, spectrum analyzer, signal generator, multimeter and five add-on software modules: data logger, spectrum 3D Plot, vibrometer, LCR meter and device test plan, all of which can run simultaneously and in real time. It has been widely used in education and training, scientific research, audio and acoustic engineering, electronic engineering, vibration analysis, medical diagnosis, musical instrument inspection, etc. The software can be downloaded from: www.virtins.com/MIsetup.exe for a 21-day fully functional FREE trial, using your computer sound card as the ADC and DAC devices.

1.2 What is a Multi-Instrument System?

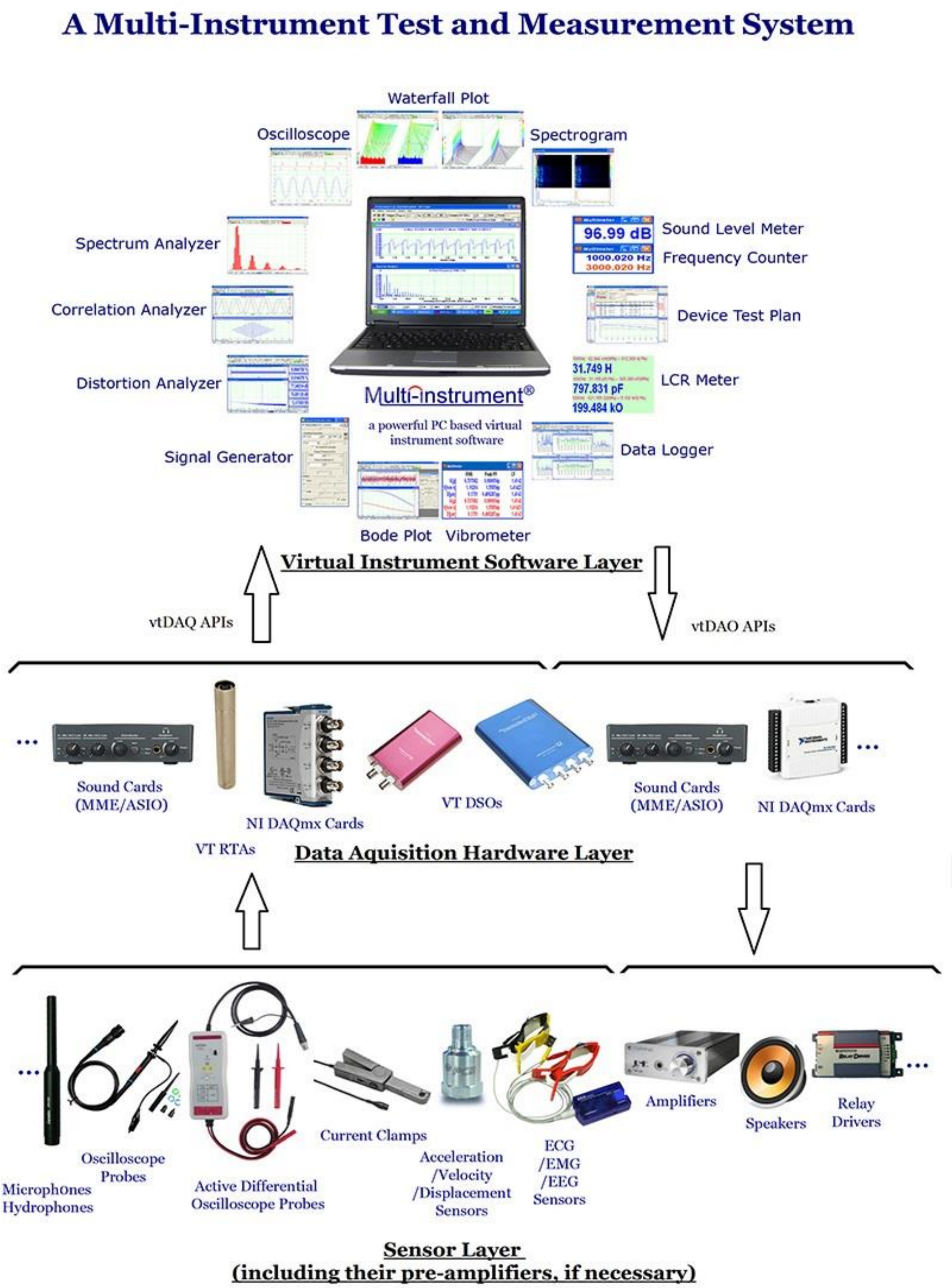
A Multi-Instrument system consists of three layers of components (from front end to back end, as shown in the figure below): sensor layer, data acquisition hardware layer and virtual instrument software layer (i.e. Multi-Instrument software).

The sensor layer is made up of sensors and their pre-amplifiers (if necessary). It converts physical quantities to electronic signals which can then be quantized by the data acquisition layer. It defines the field of application of the Multi-Instrument system. For example, a passive oscilloscope probe or active differential oscilloscope probe can be used to measure electronic or electrical voltage signals; a current clamp can be used to measure electronic or electrical current signals; a microphone can be used to sense sounds, an acceleration sensor can be used to sense vibration; an ECG sensor can be used to sense the electrical activity of the heart, etc..

The data acquisition hardware layer contains the data acquisition hardware such as Virtins Technology's PC based USB Oscilloscopes, Spectrum Analyzers and Signal Generators, Virtins Technology's Real Time Analyzers, NI DAQmx cards, sound cards, etc. It scales, conditions and quantizes the electronic or electrical signals passed on by the sensor layer. Together with the sensor layer, it defines the measurement accuracy and precision of the Multi-Instrument system.

The virtual instrument software layer is dominated by the Multi-Instrument software. It defines the functions and Graphical User Interfaces (GUI) of the Multi-Instrument system.

In general, the Multi-Instrument system is extremely powerful, flexible, customizable, yet cost-effective. Simply through software configuration without any coding, it is possible to achieve custom functions that can only be realized through custom software development using programming tools such as Labview, Matlab, C++, etc. A properly configured Multi-Instrument system will meet your every need in test, measurement, monitoring and control.


A Multi-Instrument Test and Measurement System
Waterfall Plot
Oscilloscope
Spectrogram
Spectrum Analyzer
Sound Level Meter
Frequency Counter
96.99 dB
1000.020 Hz
3000.020 Hz
Correlation Analyzer
Device Test Plan
Distortion Analyzer
31.749 H
797.831 pF
199.484 kΩ
LCR Meter
Multi-Instrument®
a powerful PC based virtual instrument software
Signal Generator
Data Logger
Bode Plot
Vibrometer
Virtual Instrument Software Layer
vtDAQ APIs
vtDAO APIs
Sound Cards (MME/ASIO)
NI DAQmx Cards
VT DSOs
Sound Cards (MME/ASIO)
NI DAQmx Cards
VT RTAs
Data Aquisition Hardware Layer
Microphones Hydrophones
Oscilloscope Probes
Active Differential Oscilloscope Probes
Current Clamps
Acceleration /Velocity /Displacement Sensors
ECG /EMG /EEG Sensors
Amplifiers
Speakers
Relay Drivers
Sensor Layer
(including their pre-amplifiers, if necessary)

2. System Components

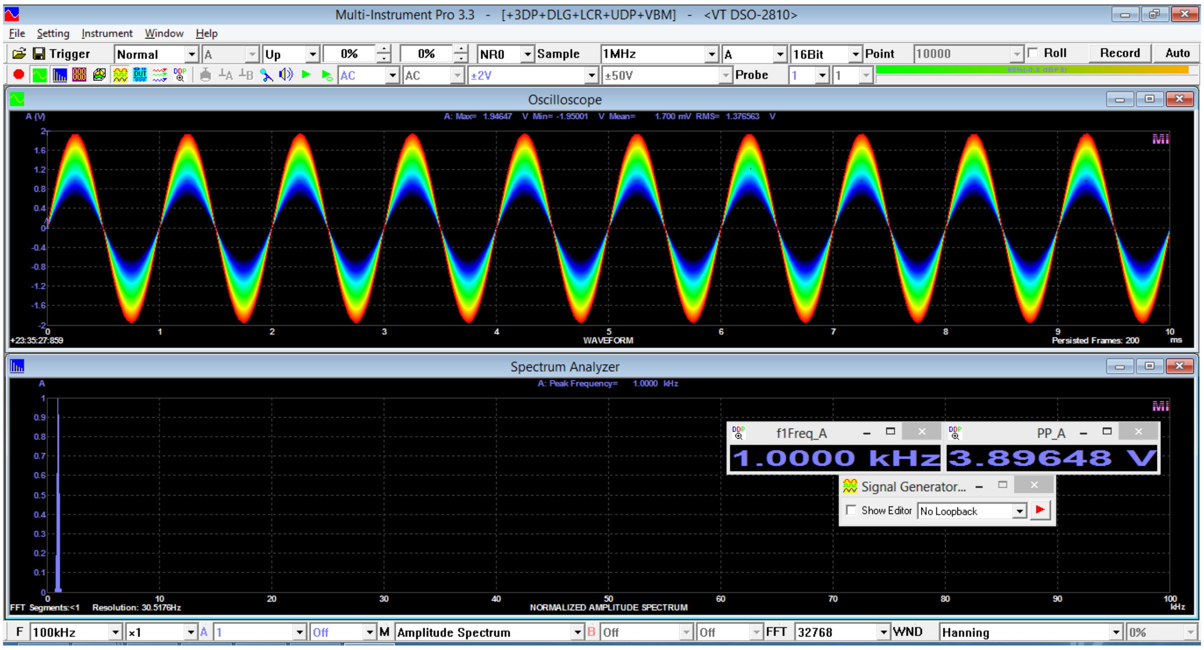
2.1 Virtual Instrument Software Layer - Multi-Instrument

Multi-Instrument is a powerful PC based multi-function virtual instrument software. It consists of an oscilloscope, a spectrum analyzer, a signal generator, a multimeter, a vibrometer, a spectrum 3D plot, a data logger, a LCR meter, a device test plan and 16 derived data point viewers, all of which can run simultaneously.

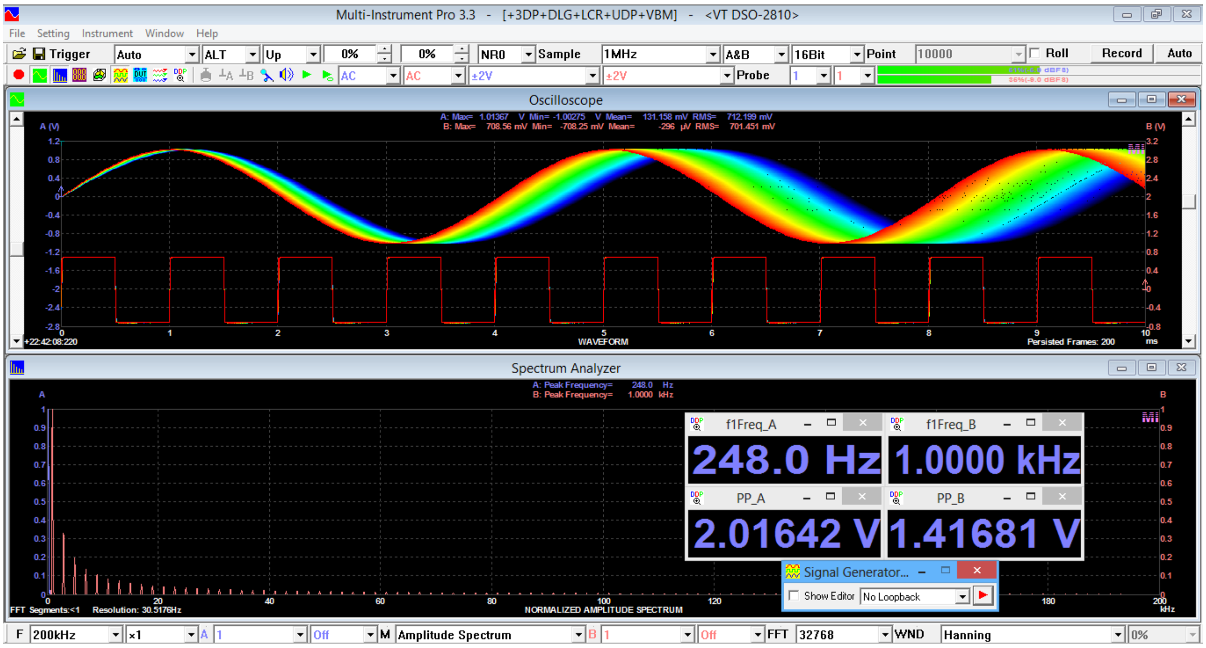
2.1.1 Oscilloscope

separate waveforms, waveform addition, subtraction and multiplication, Lissajous Pattern, mixed signal display, long-time signal recording (streaming mode), pre-configured or arbitrary digital filters (FFT, FIR, IIR), digital persistence display, equivalent time sampling, roll mode, etc..

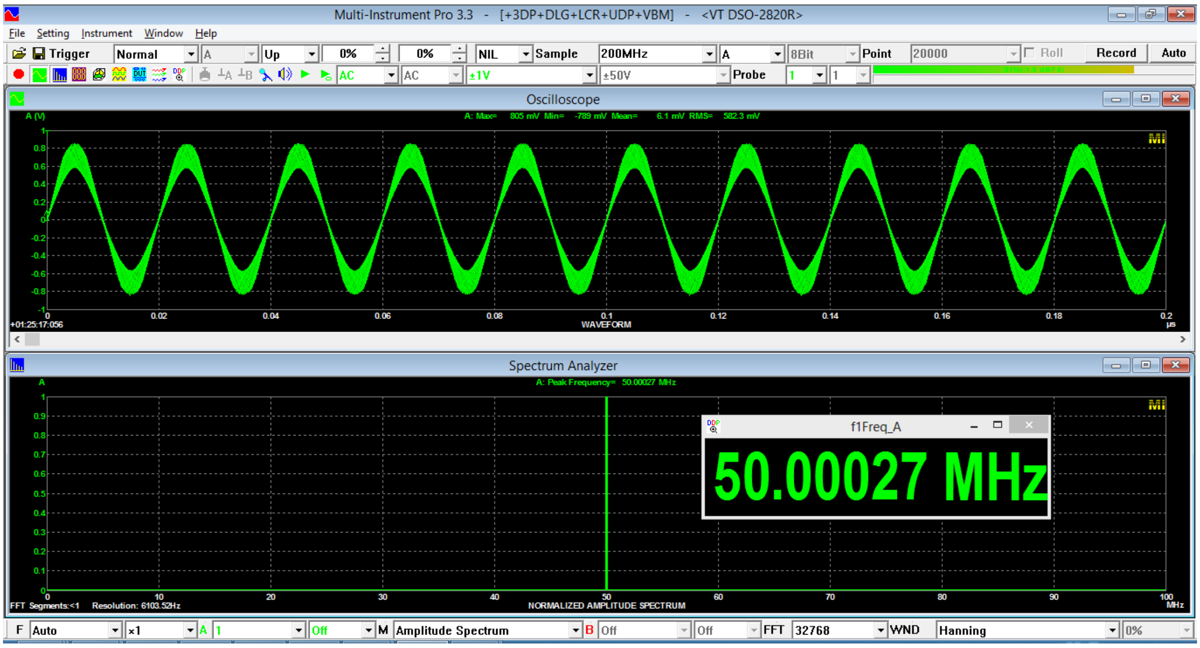
<u>Sine and square waves</u>



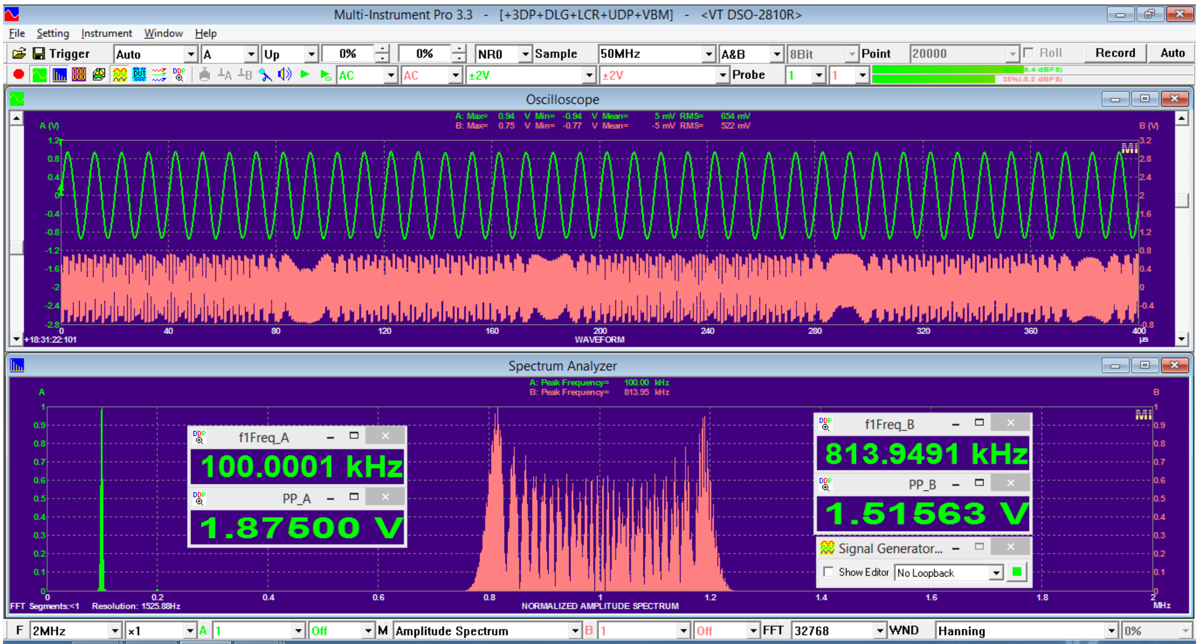
Amplitude sweep (sine) captured under oscilloscope persistence mode



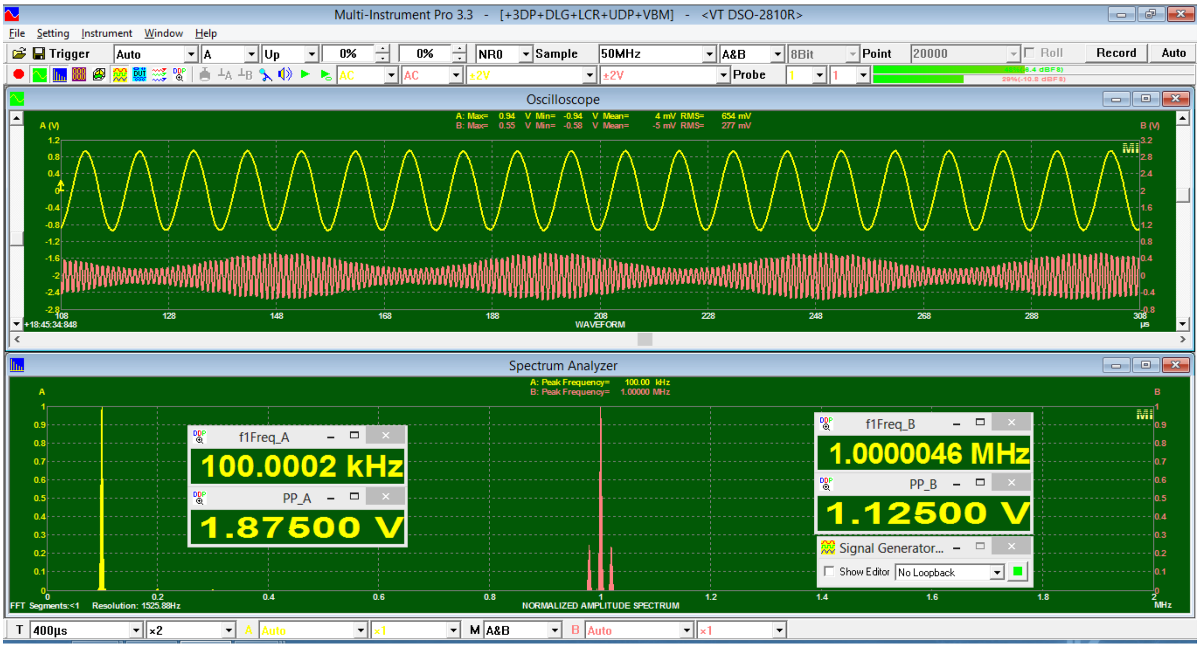
Frequency sweep captured under oscilloscope persistence mode



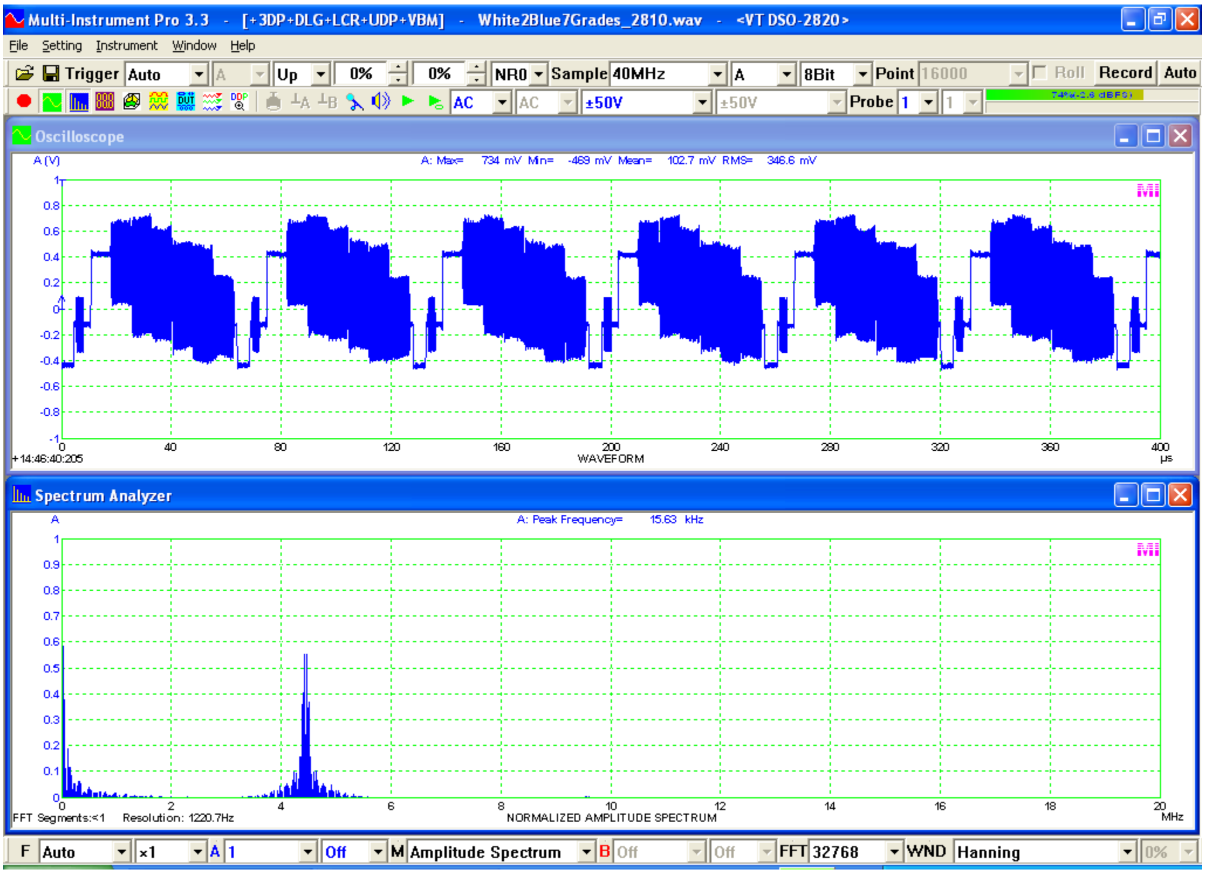
50MHz sinewave sampled at 200MHz with Oscilloscope in persistence mode



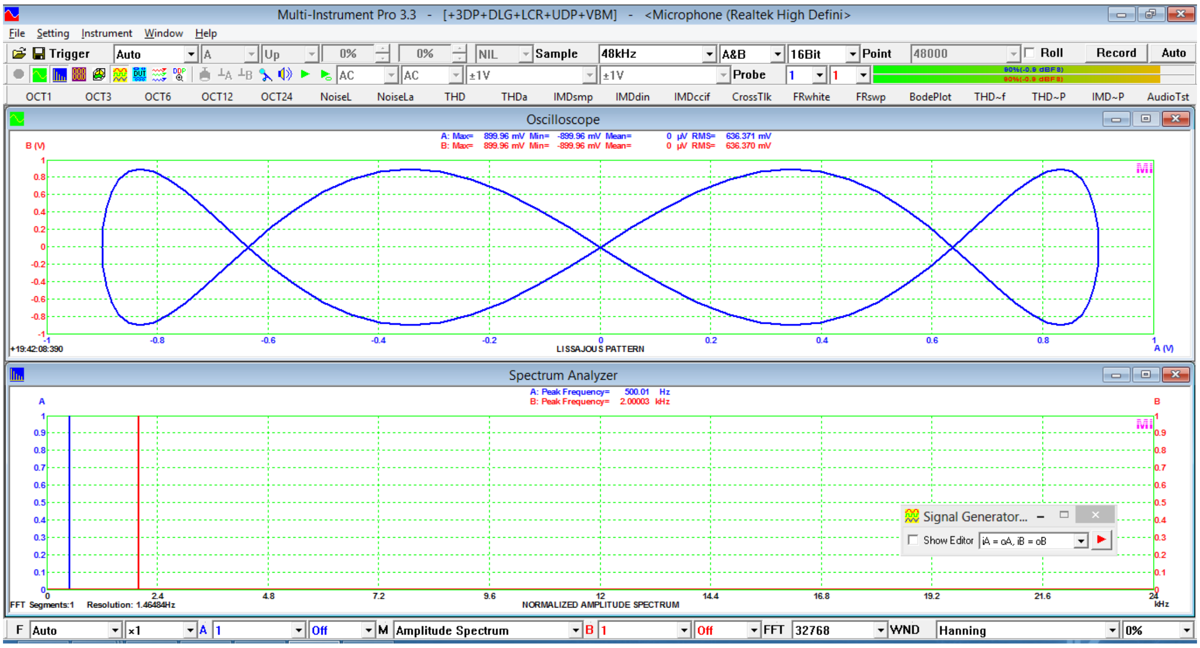
Frequency Modulation measurement



Amplitude Modulation measurement



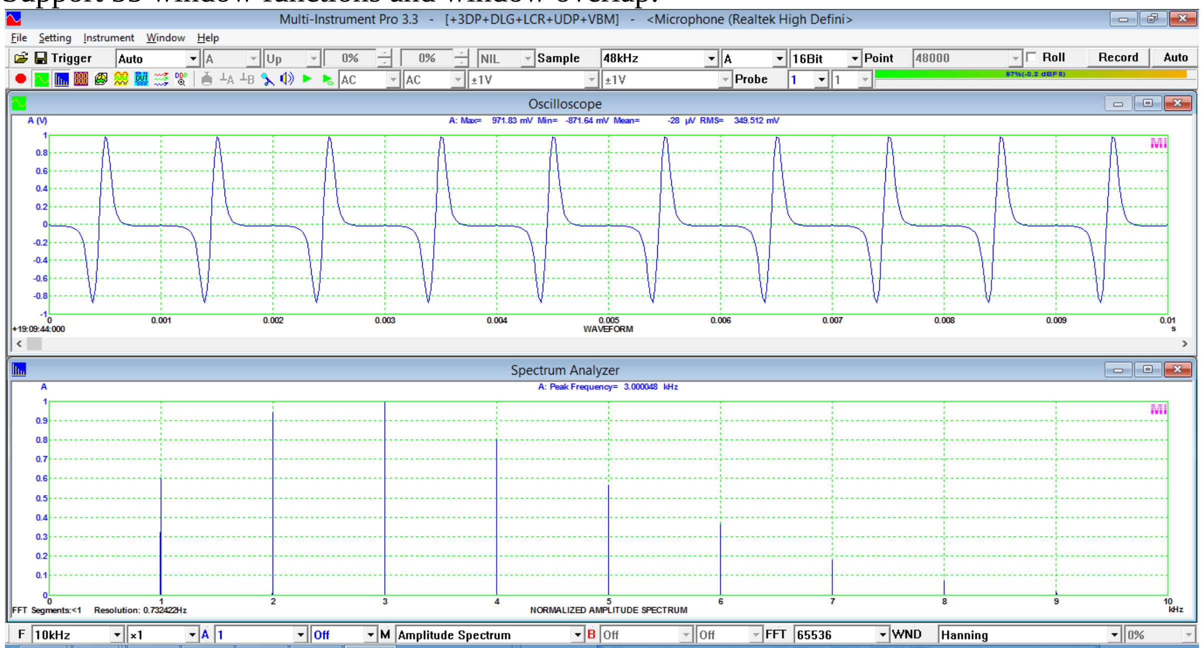
PAL composite video signal



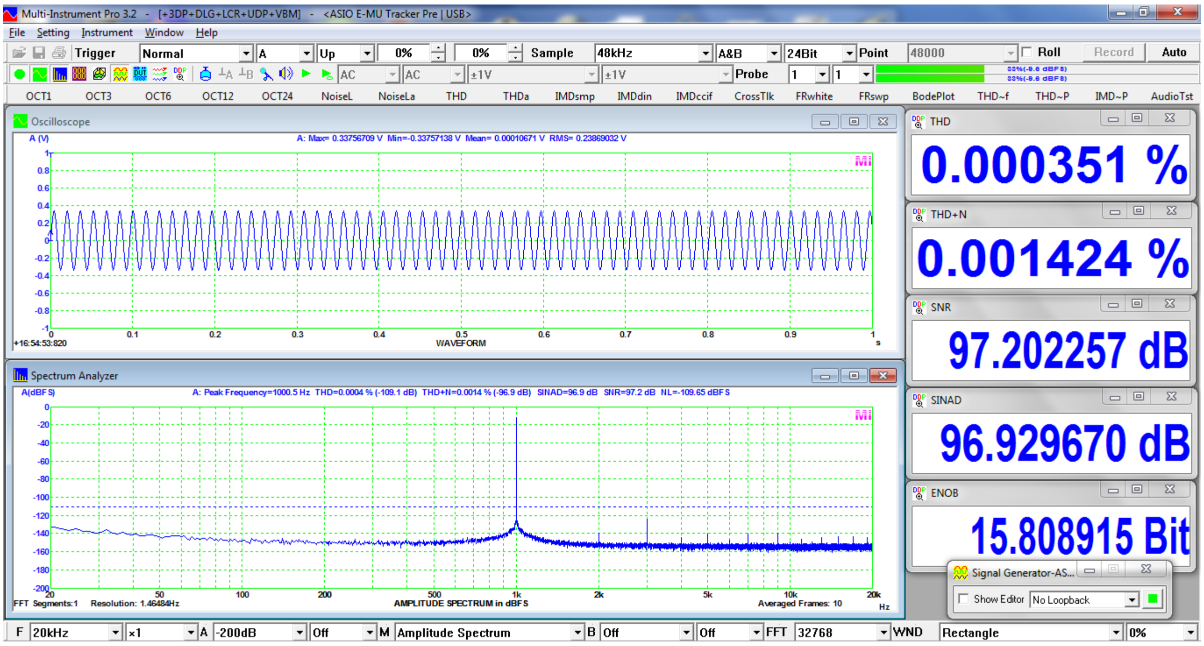
Lissajous Pattern

2.1.2 Spectrum Analyzer

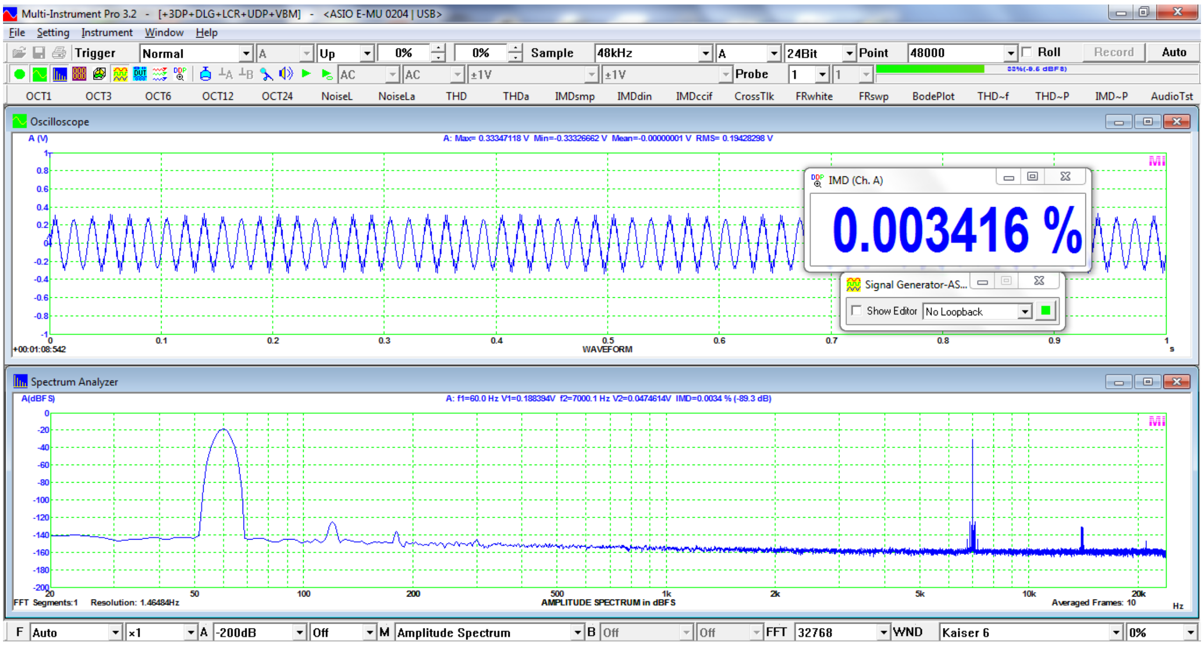
amplitude spectrum, octave analysis (1/1, 1/3, 1/6, 1/12, 1/24, 1/48, 1/96), frequency compensation, frequency weighting (A, B, C, ITU-R 468), peak hold, linear / exponential average, measurement of THD, THD+N, SNR, SINAD, Noise Level, IMD, Bandwidth, Crosstalk, peaks, harmonics, phase spectrum, auto / cross correlation, coherence function, transfer function (Bode plot, gain and phase plot, or frequency response), impulse response. Support 55 window functions and window overlap.



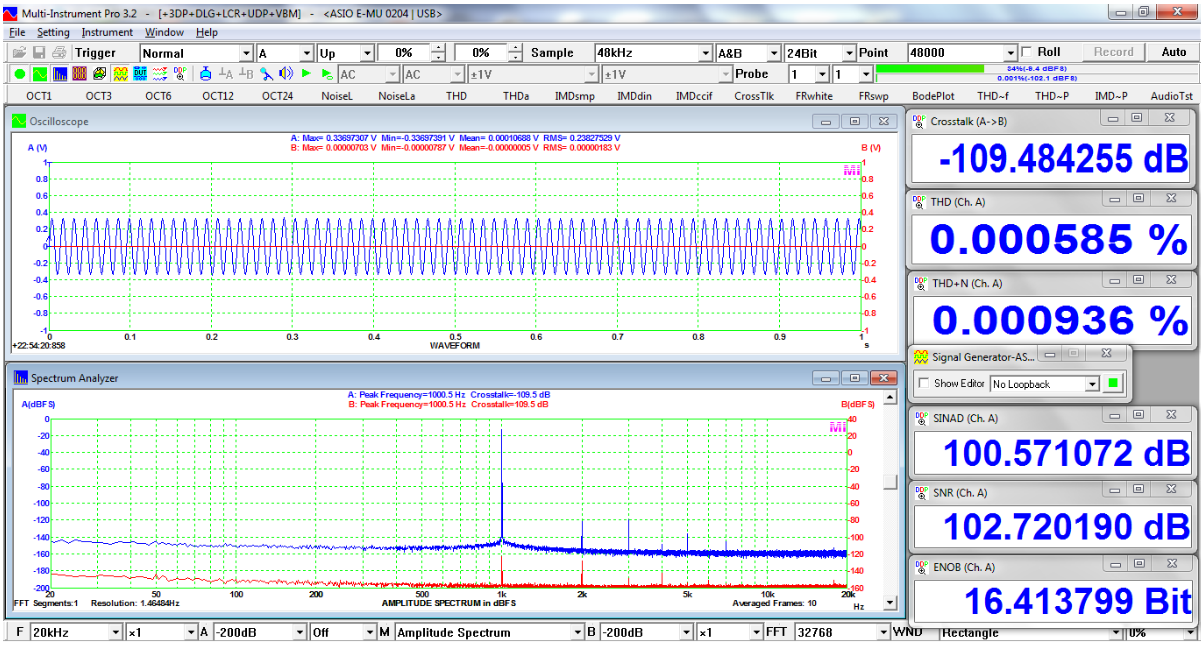
Normalized amplitude spectrum of a signal



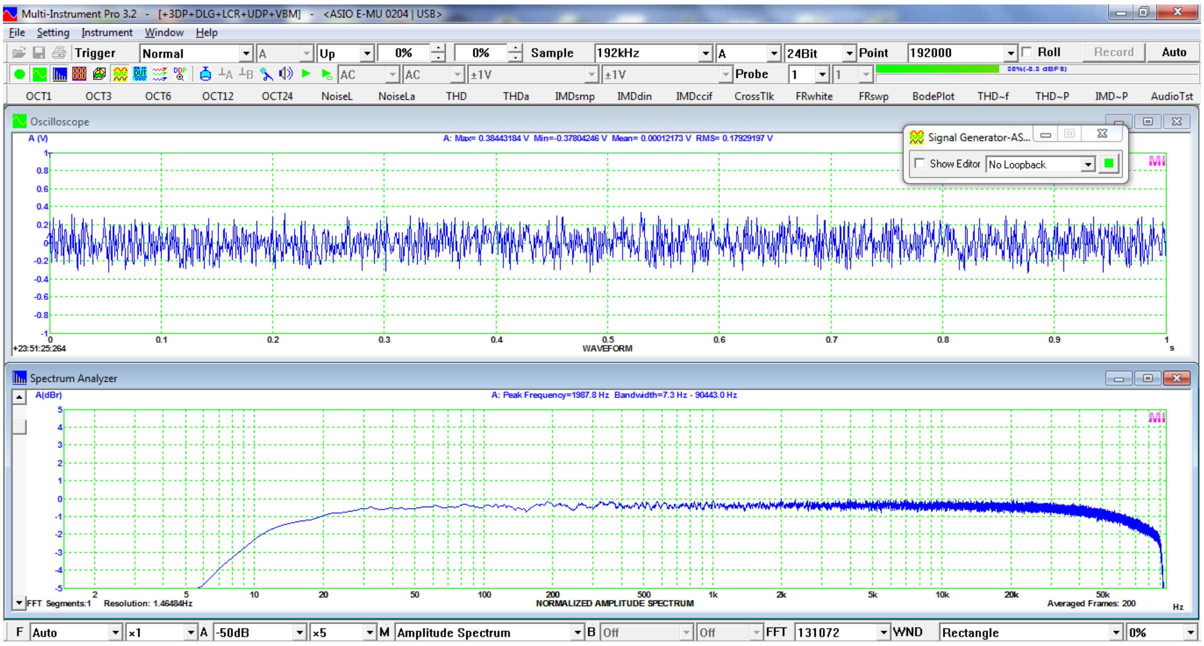
Measurement of THD, THD+N, SNR, SINAD, ENOB…



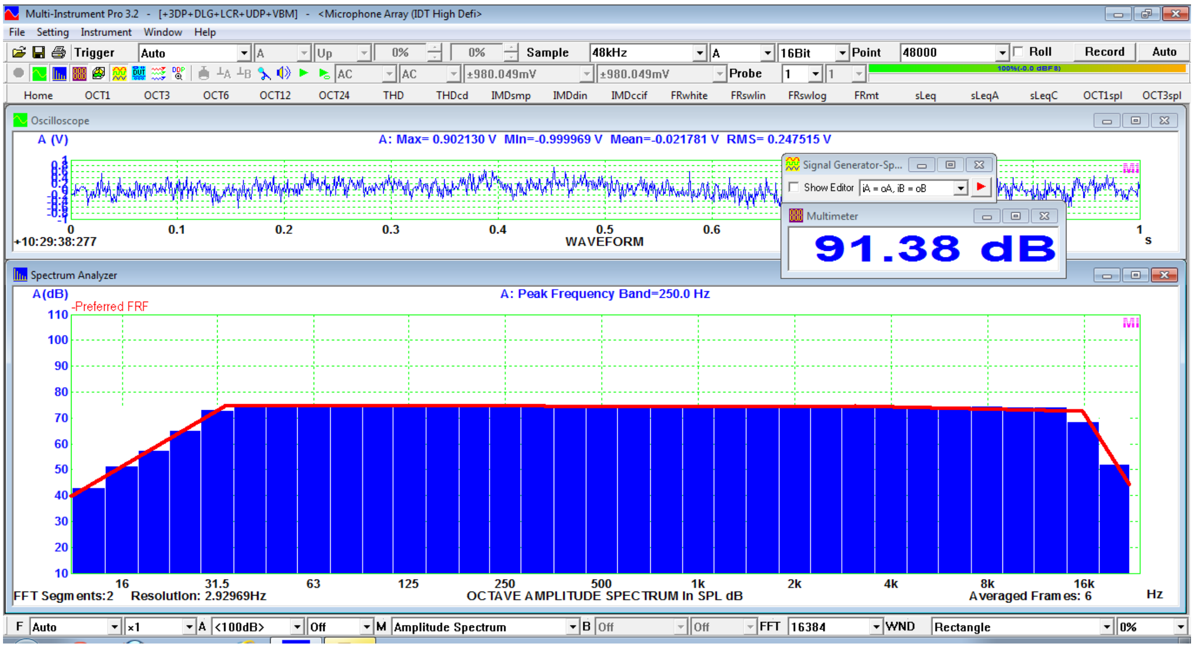
Measurement of IMD (SMPTE)



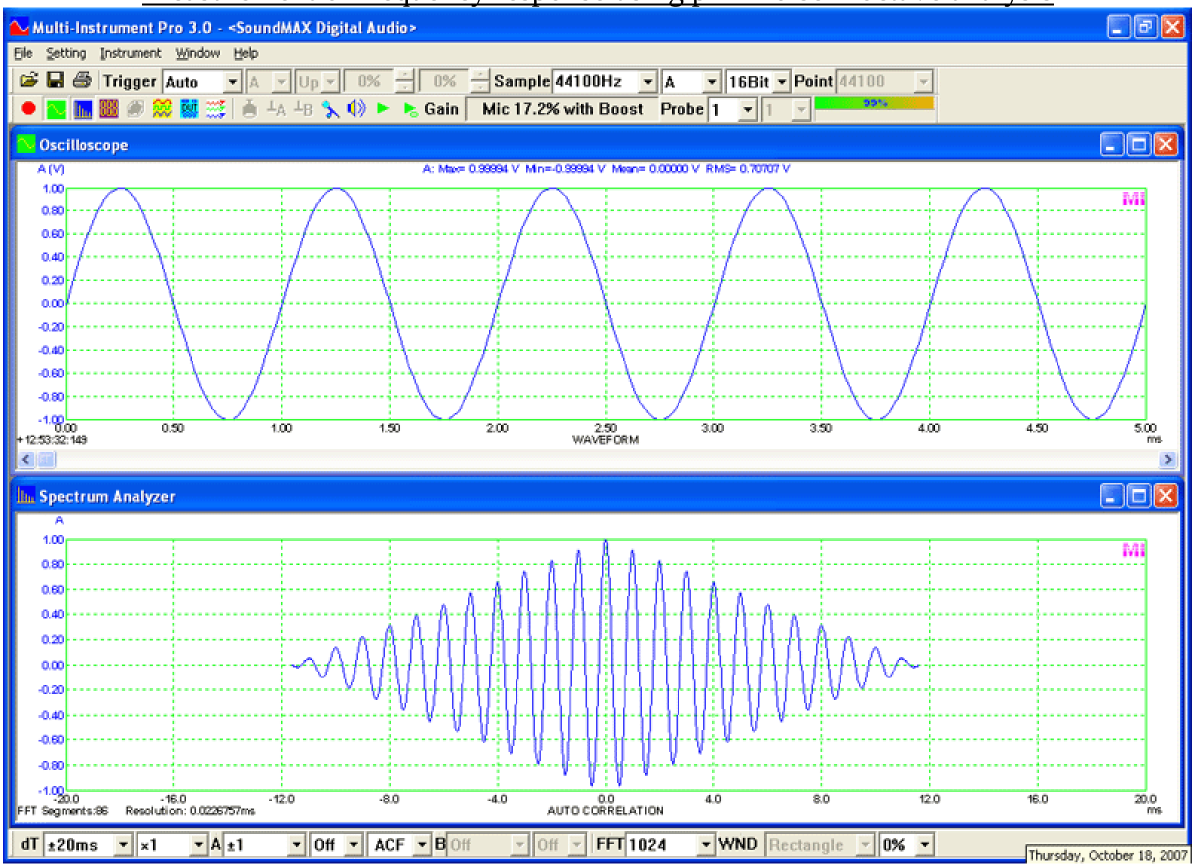
Measurement of crosstalk



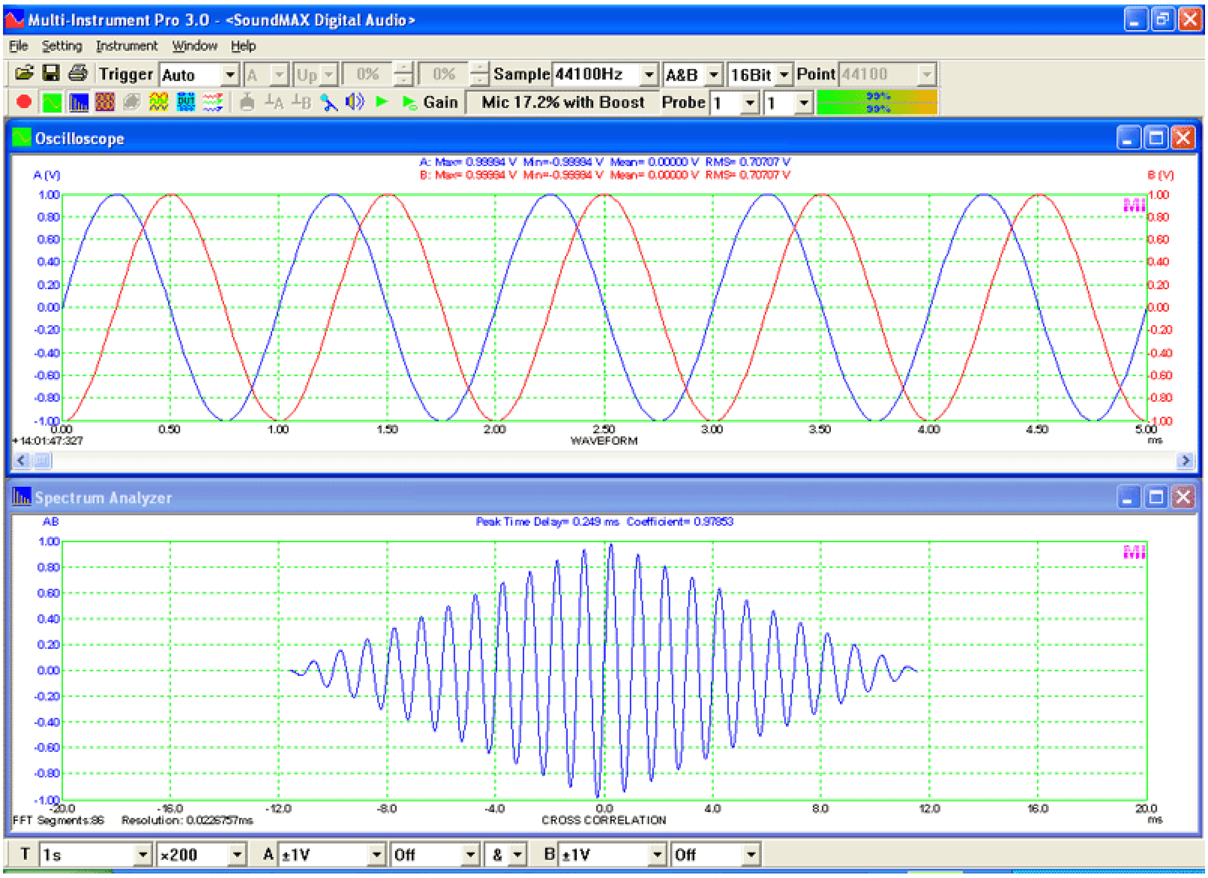
Measurement of frequency response using white noise



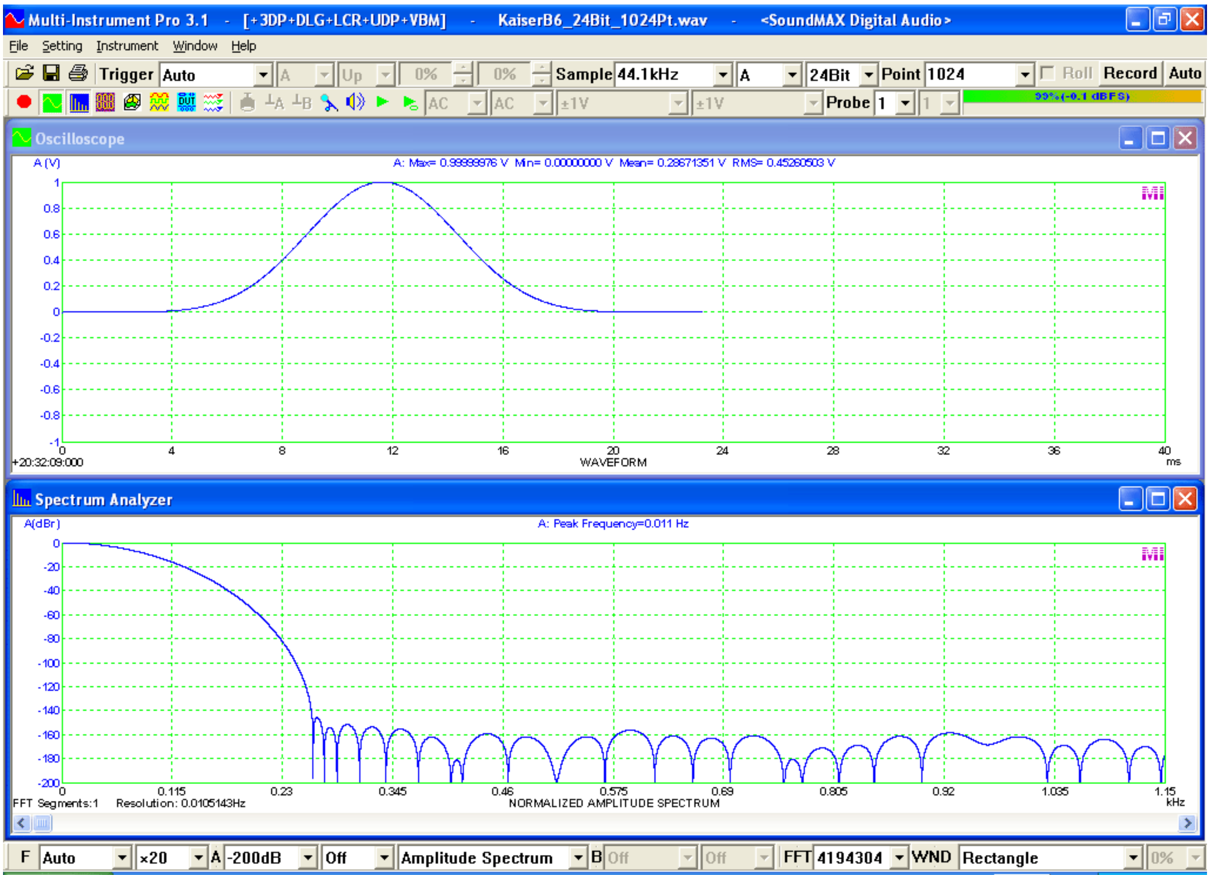
Measurement of frequency response using pink noise + octave analysis



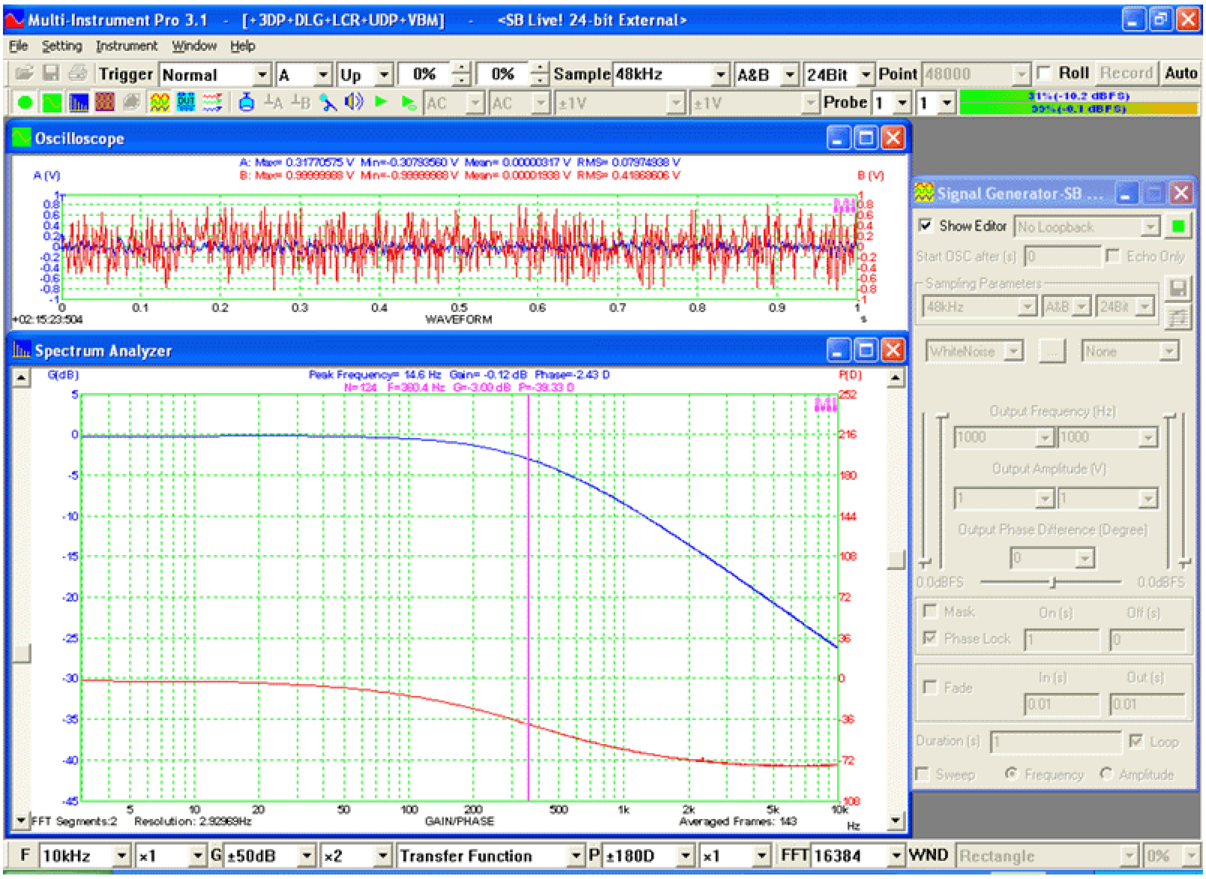
Auto correlation



Cross correlation



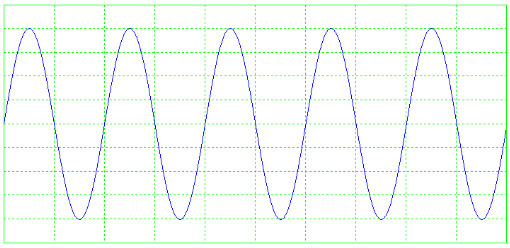
Spectra of Kaiser 6 Window Function



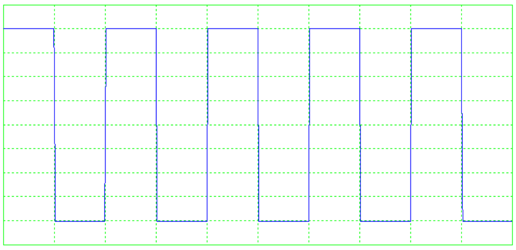
Bode Plot

2.1.3 Signal Generator

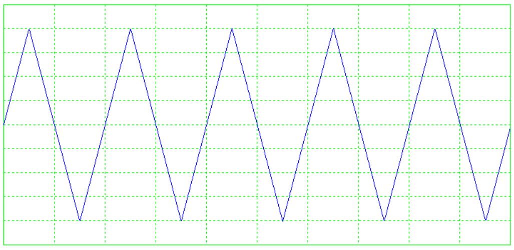
function / multitone / arbitrary waveform / burst tone / MLS / DTMF / musical scale / white noise / pink noise generation, frequency/amplitude sweep, fade in/out, wave file replaying. Support both streaming mode and DDS mode.



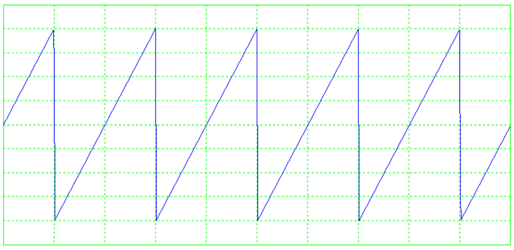
Sine wave



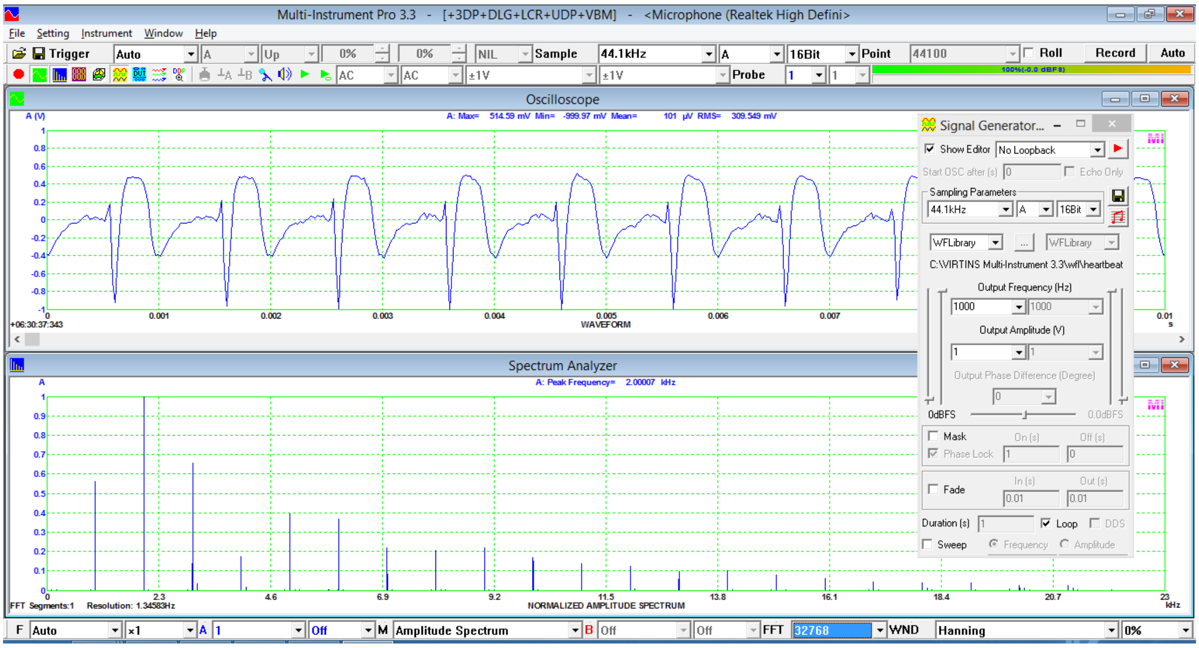
Square wave



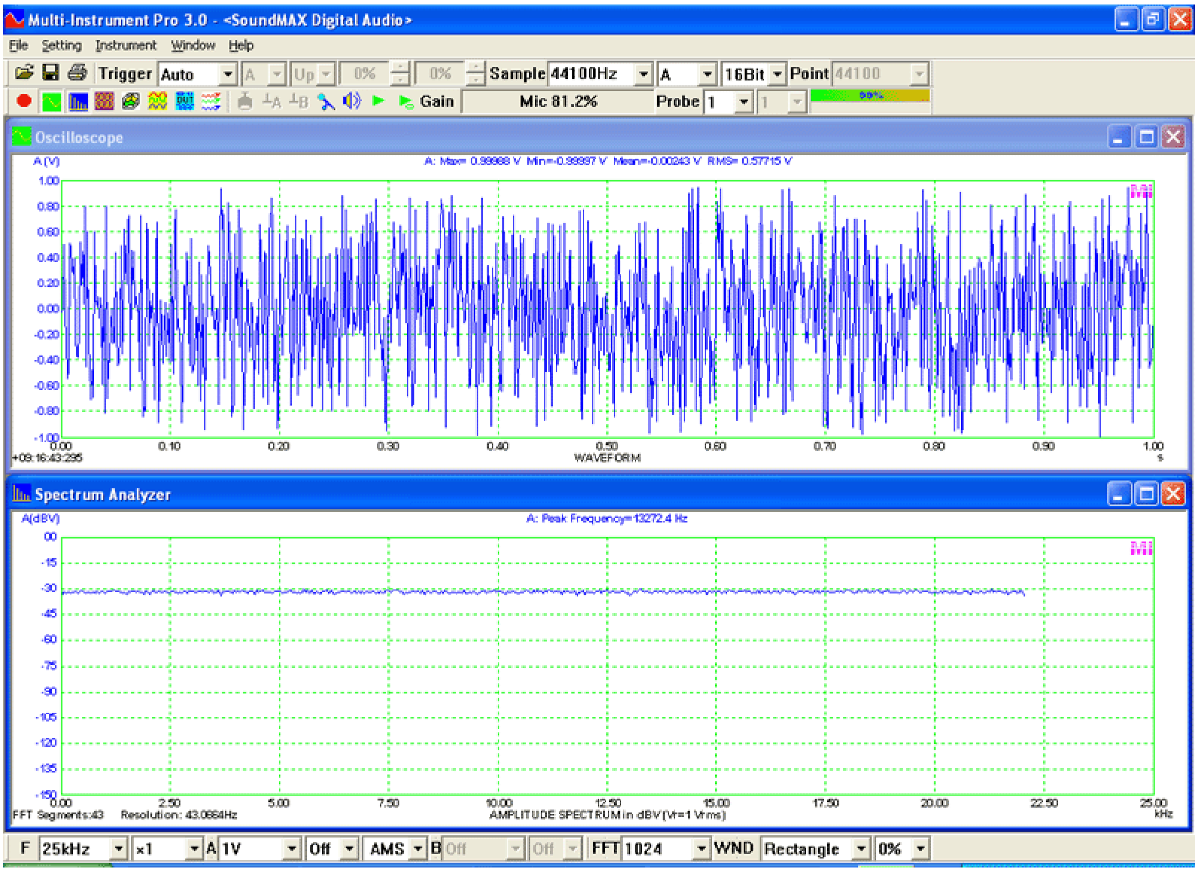
Triangle wave



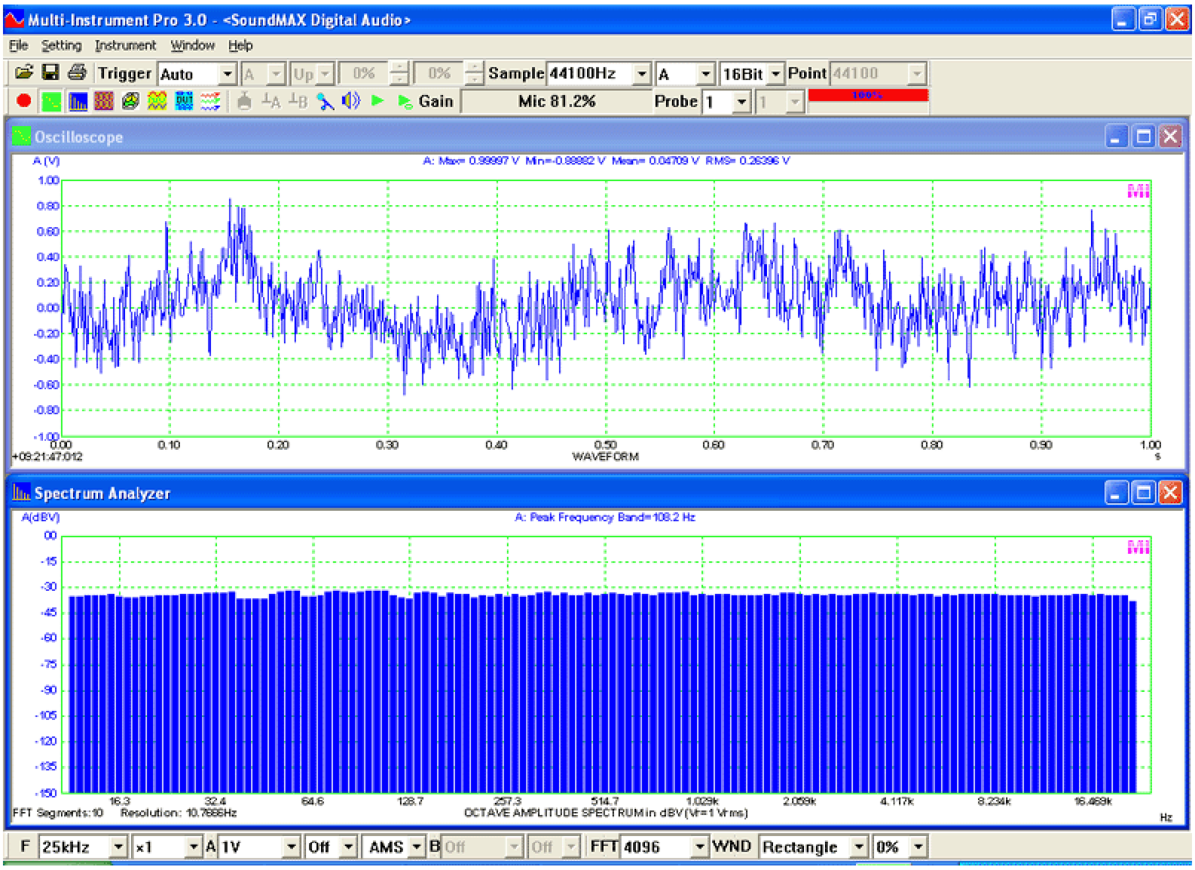
Saw tooth wave



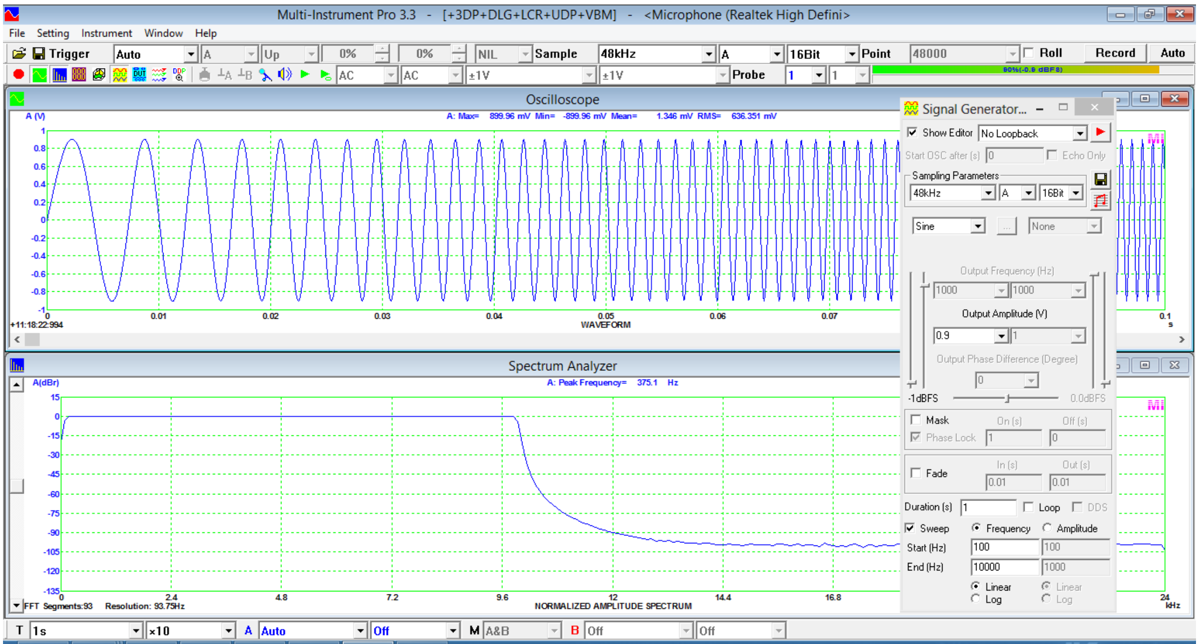
Arbitrary wave



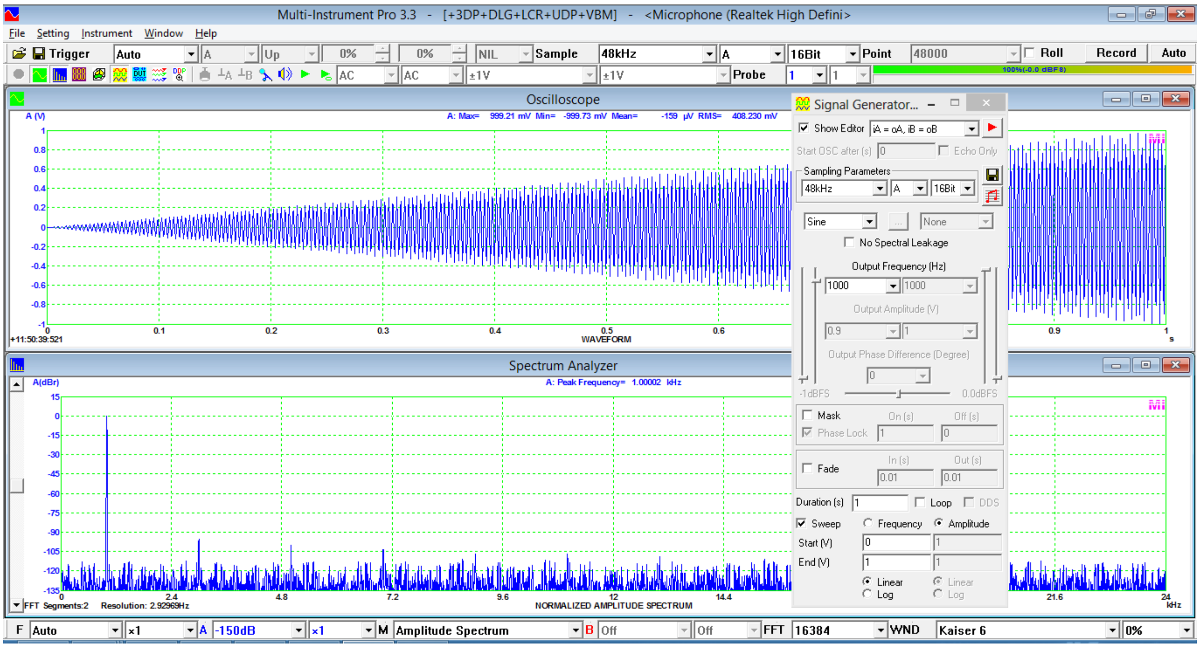
White Noise in narrow band analysis



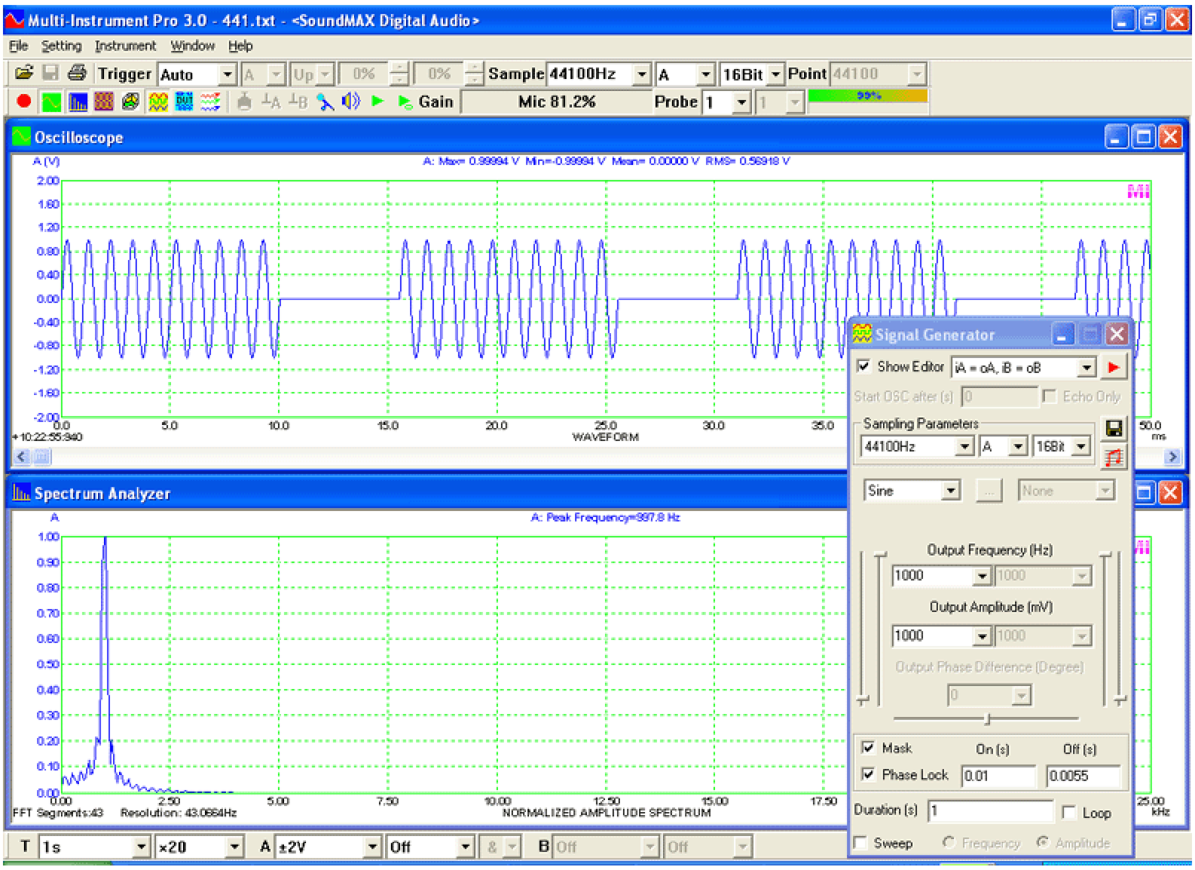
Pink Noise in octave band analysis



Frequency Sweep



Amplitude Sweep



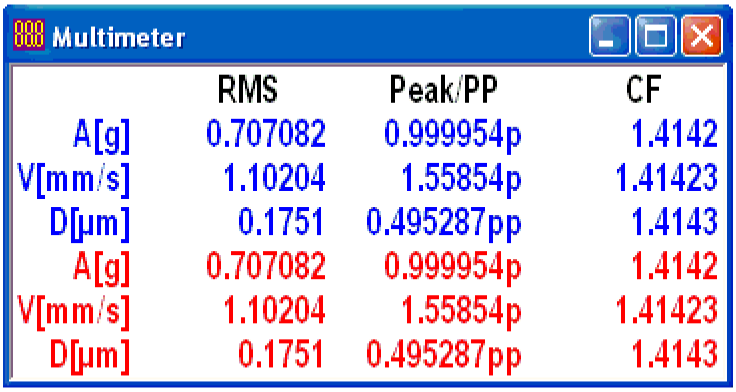
Burst Signal

2.1.4 Multimeter

voltmeter, sound pressure level meter(dB, dBA, dBB, dBC), frequency counter, RPM meter, counter, duty cycle meter, F/V converter, cycle mean/RMS

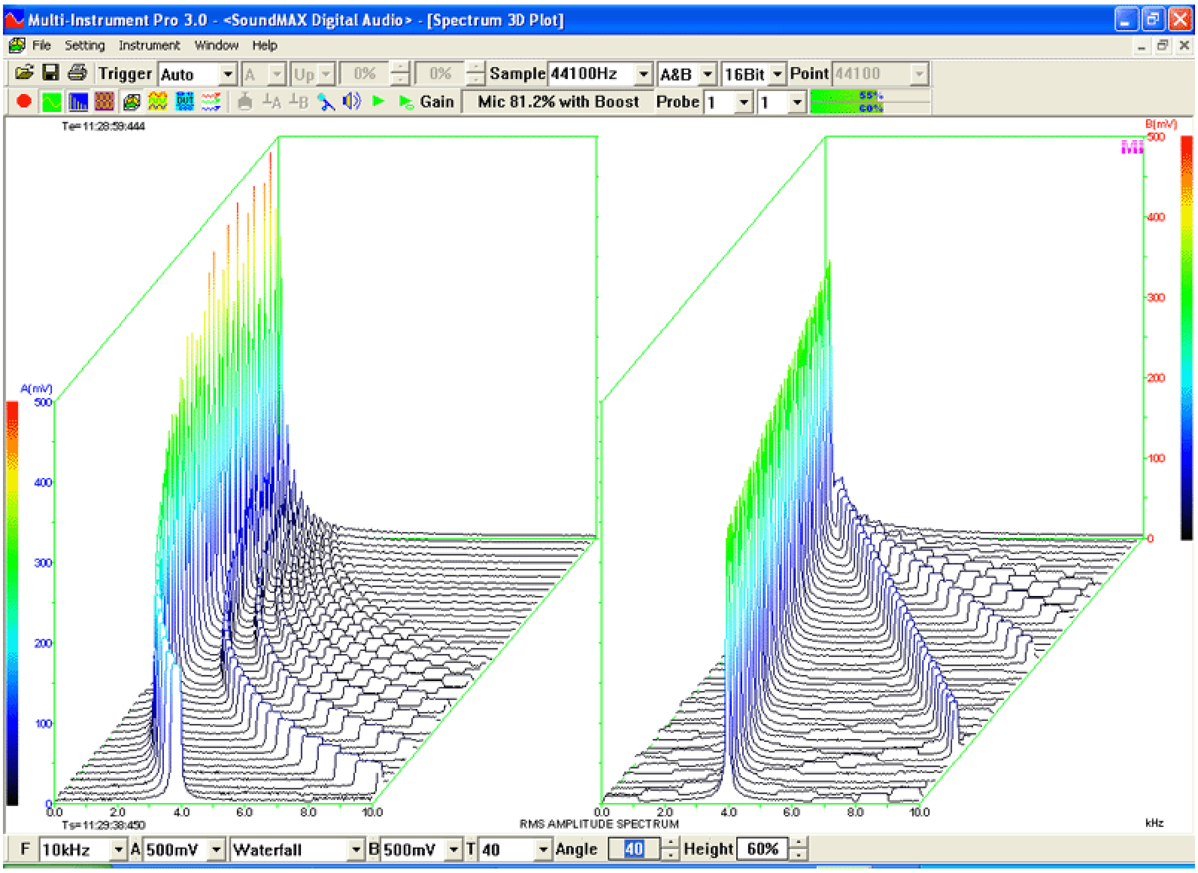
2.1.5 Vibrometer

waveform conversion among acceleration, velocity and displacement, when the raw data are acquired from acceleration, velocity or displacement sensors. This function is designed specially for vibration analysis.

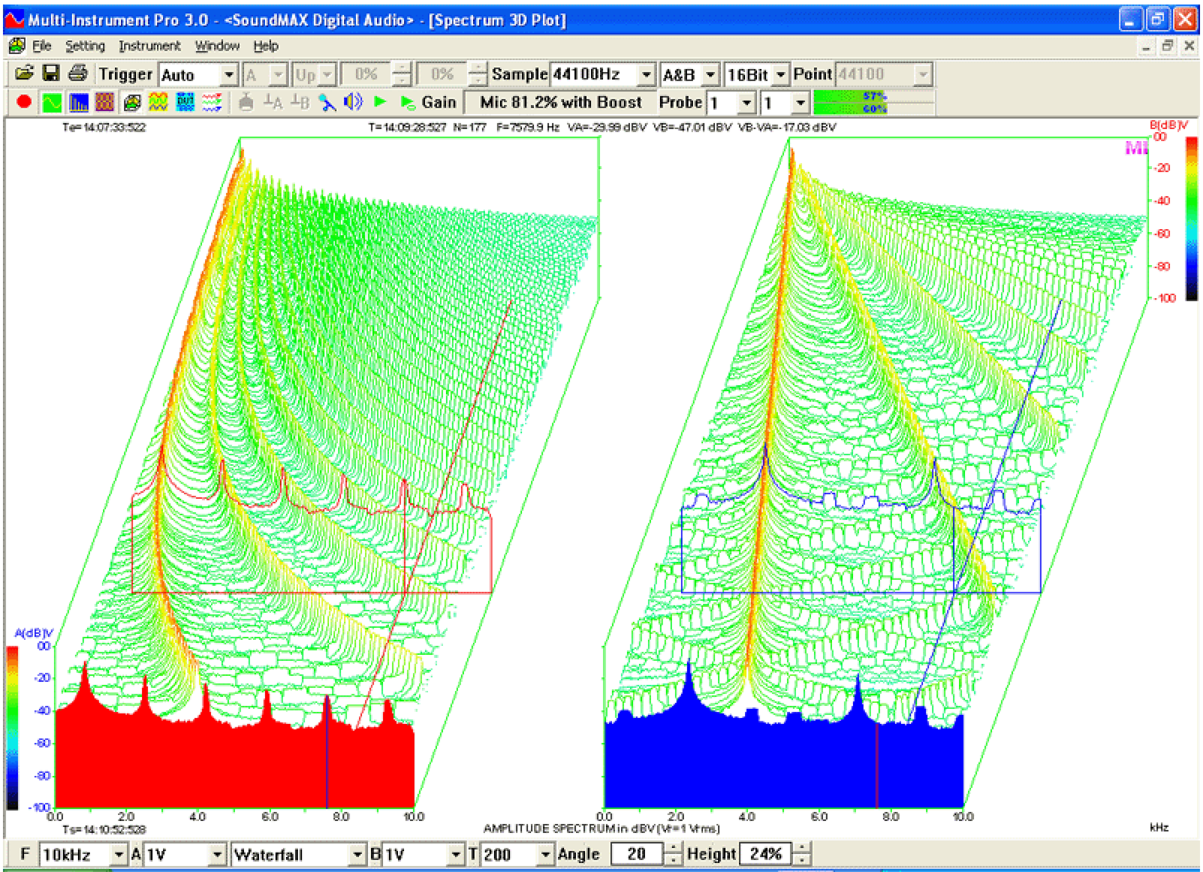


2.1.6 Spectrum 3D Plot

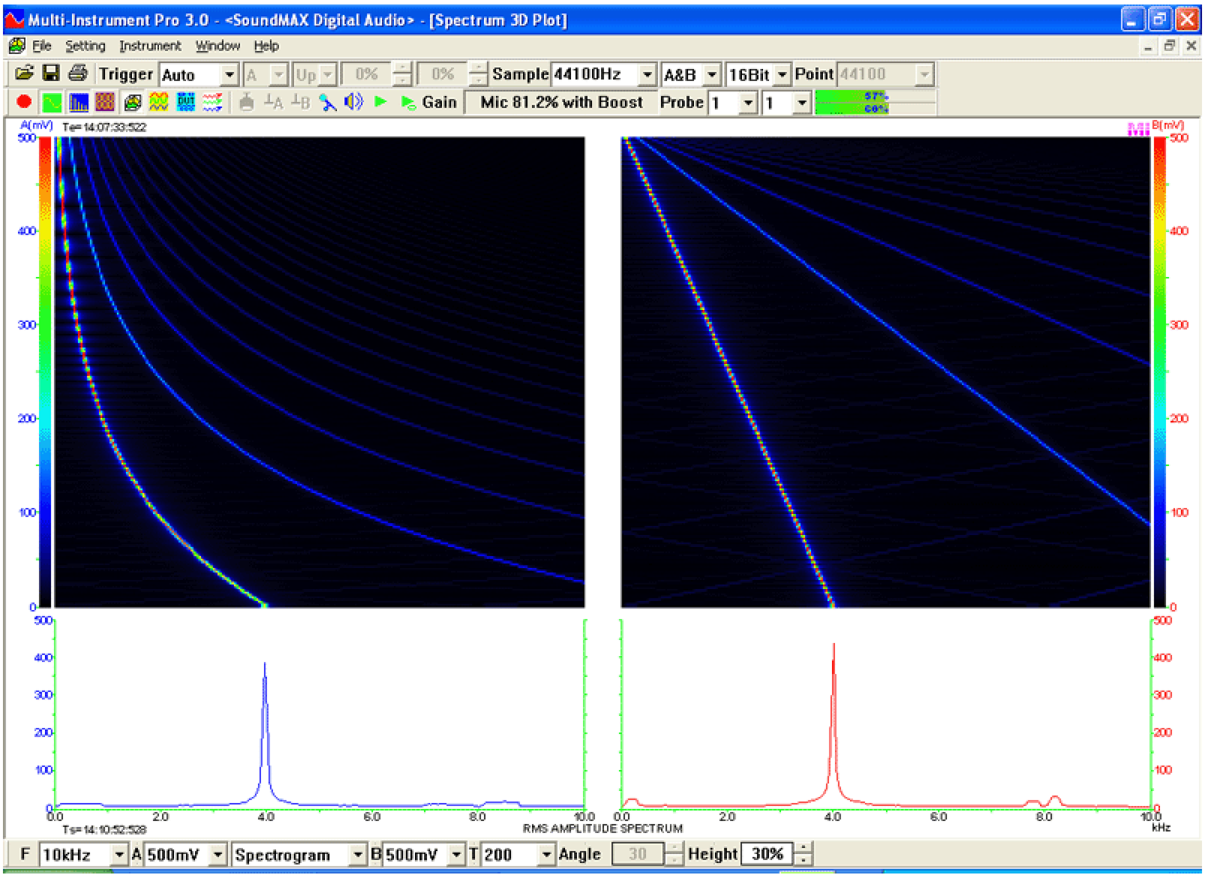
waterfall and spectrogram



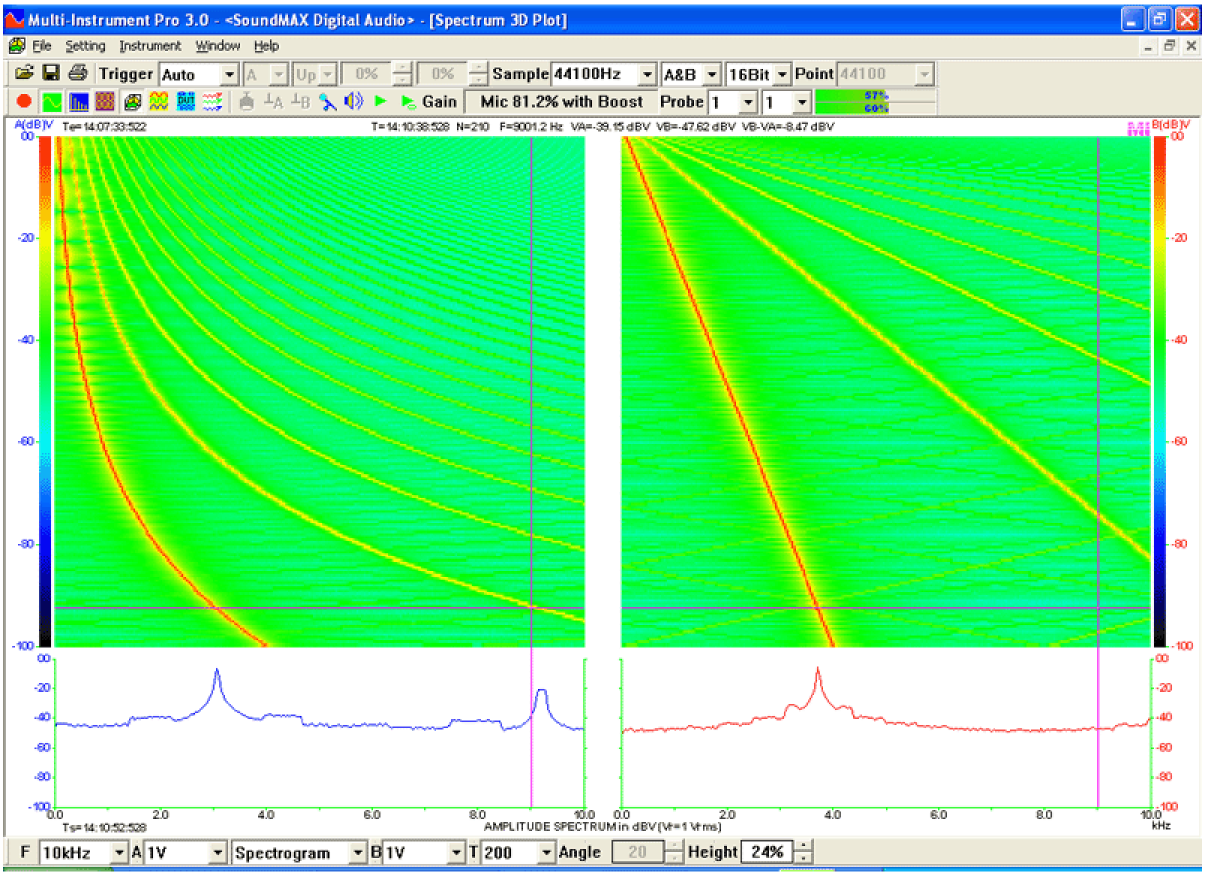
Waterfall Plot



Waterfall Plot with 3D cursor reader



Spectrogram



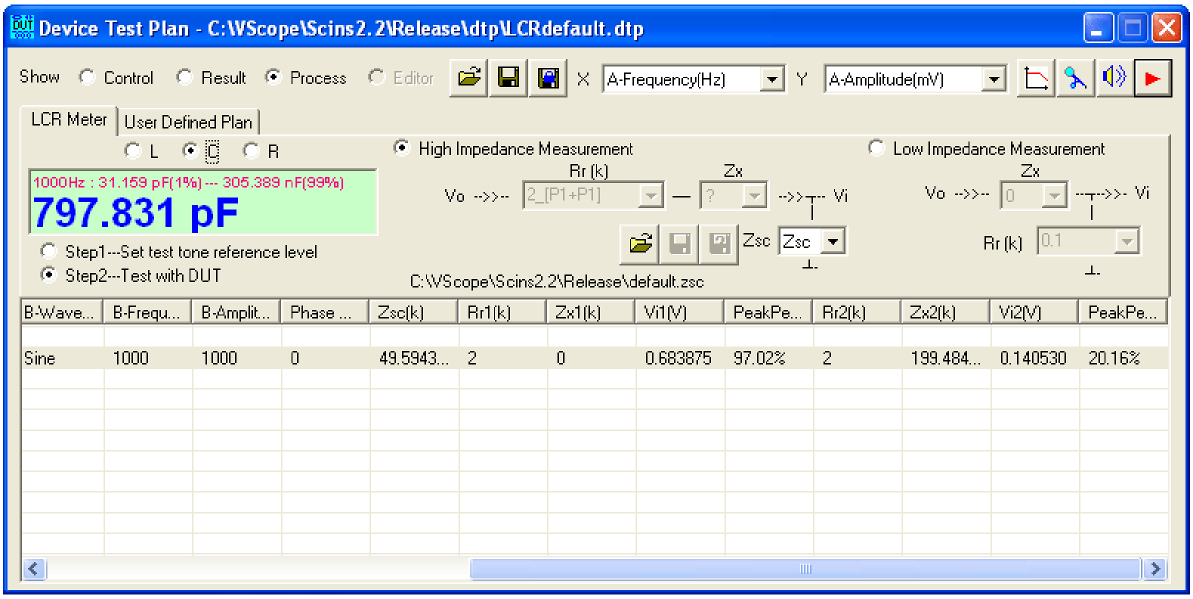
Spectrogram with 3D cursor reader

2.1.7 Data Logger

long time data logging for 151 derived data points (DDP) and 16 user defined data points (UDDP), including RMS values, peak frequencies, sound pressure levels, RPM, THD, etc. Up to eight data logger windows can be opened and each window can trace up to 8 variables.

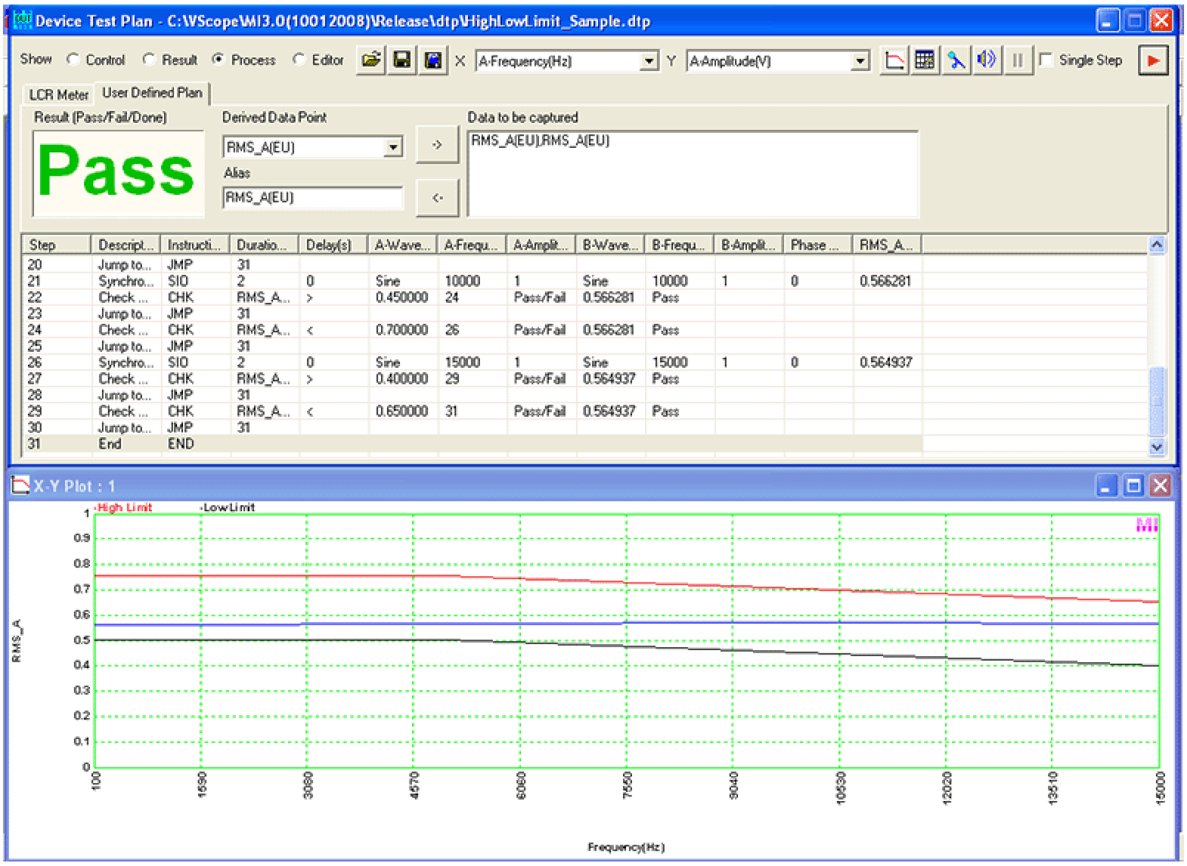
2.1.8 LCR Meter

measure the value of an inductor, capacitor or resistor, or the impedance of a network of them.

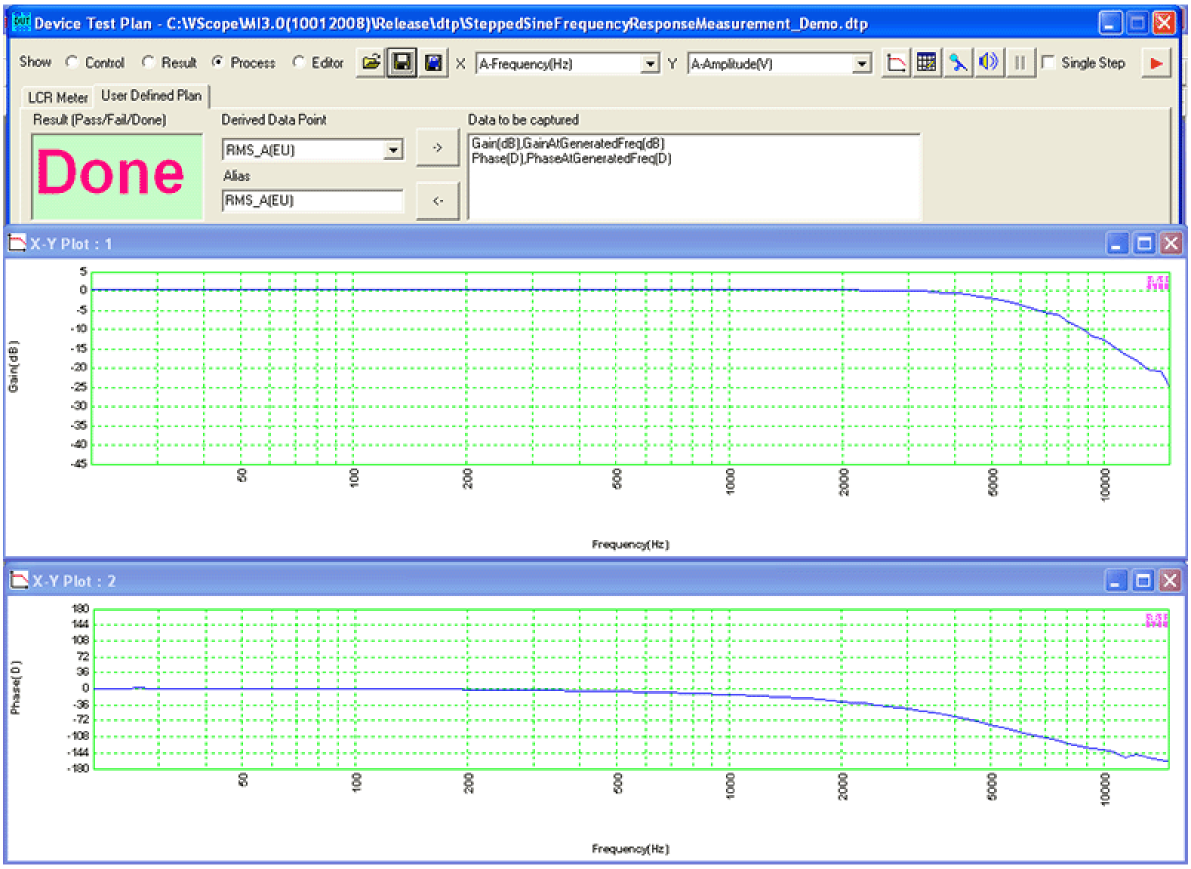


2.1.9 Device Test Plan

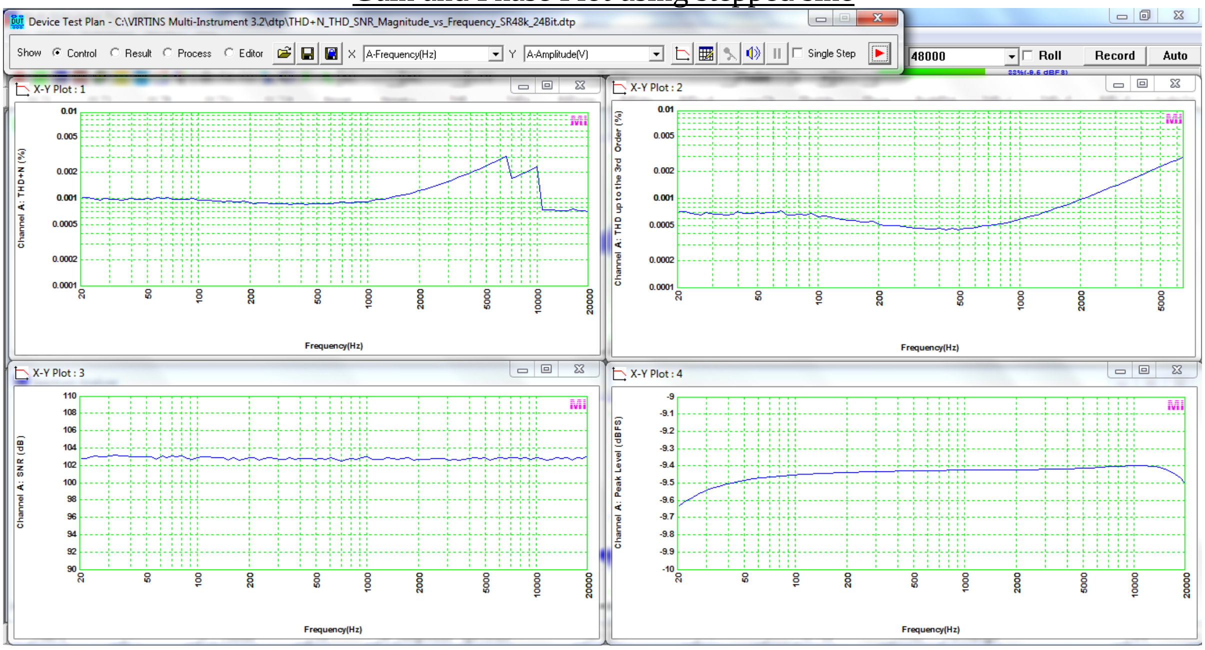
It provides a mechanism to configure and conduct the user's own device test steps. It takes the advantage of the sound card's (or other ADC/DAC device's) capability of simultaneous input and output, to generate a stimulus to the Device Under Test (DUT) and acquire the response from that device at the same time. Different stimuli can be generated and the response can be analyzed in different ways. The DUT can be marked as PASS or FAIL after a sequence of test steps.



Pass / Fail test



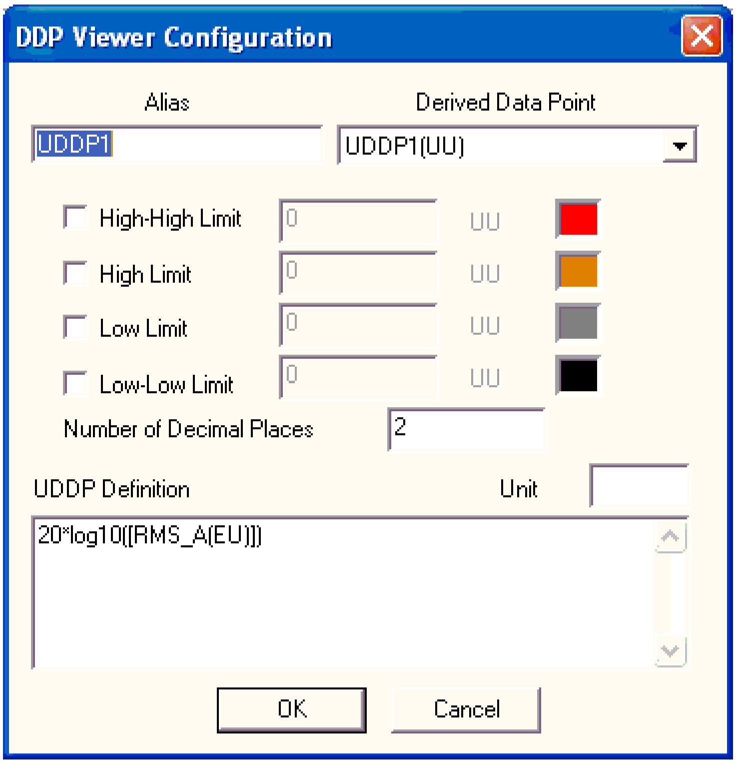
Gain and Phase Plot using stepped sine



THD, THD+N, SNR, Magnitude Response vs Frequency

2.1.10 DDP Viewer

It is used to display the value of a Derived Data Point (DDP) in a dedicated window with bigger font size. It is also possible to specify the DDP's high-hgih, high, low, low-low limits for alarming and the number of decimal places for display. Up to 16 DDP viewers can be opened. These DDP viewers can also be used to define and display User Defined Data Points (UDDP). A UDDP can be expressed as a function of DDPs and earlier-updated UDDPs. The mathematical expression may consist of constants, DDPs, UDDPs, mathematical operators, and mathematical functions.



2.1.11 General Functions

2.1.11.1 Sensor Sensitivity

The acquired data can be rescaled according to the sensor sensitivity configured by the user so that the displayed data are expressed in engineering unit corresponding to the physical quantity sensed by the sensors. This is very different from a conventional oscilloscope whereby only voltage can be displayed.

2.1.11.2 Graph Operation

Zooming and Scrolling is supported in all graphs, allowing you to investigate the fine details of the data. This is very important when a large amount of data are displayed in one screen. A cursor reader is provided in each graph to show the x and y readings of the actual measurement point. For Spectrum 3D Plot, the cursor reader supports the readout of x, y, t values of the actual measurement point. Two markers are provided in each graph to get the x and y readings of the actual measurement points nearest (in horizontal direction) to the points of the mouse clicks. Five chart types are supported: Line, Scatter, Column, Bar, Step. Line width and colors of the graph are configurable. Options are provided to either display all data points (slow) or only display one data points per vertical raster line (fast). The data in any graph can be copied into the clipboard as text and later paste into other software such as Microsoft Excel for further analysis. The image of the graph can be copied into the clipboard as Bitmap image and later paste into other software such as Microsoft Word.

2.1.11.3 Reference Curves

Up to five reference curves can be set for each channel in each graph. The reference curve can be configured by either copying the current curve, or loading a properly formatted text file or a previously saved reference file from the hard disk.

2.1.11.4 File Import and Export

The collected frame of data can be saved as a wave file (*.wav) or exported as a text file (*.txt). All analysis results can be exported as text files (*.txt). All graphs can be exported as bitmap files (*.bmp), copied & pasted into WORD, EXCEL, Windows Paint, Powerpoint, or printed out directly. A long wave file can be imported frame by frame either manually or automatically. Wave files with PCM format or properly formatted text file can be imported for analysis. The signal generated by the signal generator can be saved as a wave file or a text file for a given duration of up to 1000 seconds.

2.1.11.5 Data Merging and Extraction

Combining data from individual channels of different wave files, and extracting part of data from a wave file are supported.

2.1.11.6 Save and Load Panel Setting

You can save your preferred instrument panel setting either as default or as a customized panel setting for later use.

2.1.11.7 Controls/Options Enabling and Disabling

Graphical User Interface items such as menu items, button, combo box, edit box, radio box, check box are enabled/disabled based on context, so as to void any mis-understanding and mis-operation.

2.1.11.8 Multilingual User Interface

It supports Multilingual User Interface under Windows XP, Vista, 7 and 8. Supported languages are English, French, German, Italian, Portuguese, Spanish, Russian, Simplified Chinese, Traditional Chinese, Japanese and Korean.

2.1.11.9 Software Customization

Multi-Instrument provides the following user customizable features:

(1) You can save a frequently used panel setting as a Panel Setting File
(2) You can save your default pane setting so that it will be loaded right after software startup.
(3) You can configure your frequently used Panel Setting Files in the Hot Panel Setting Toolbar, so that they can be loaded at one single mouse click.

These features help you to set up your experiment with minimum amount of effort and time.

2.1.11.10 Software Development

(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.

(2) You can use the vtDAQ and vtDAO interface DLLs supplied in the software to allow your own back-end software to interface to sound cards, NI DAQmx cards, VT DSOs, VT RTAs, etc.. As all these devices conform to the same vtDAQ and vtDAO interface standard, you only need to write the interface codes in your program once and your program will support all these devices. You can also develop your own vtDAQ and vtDAO compatible DLLs to allow Multi-Instrument to interface to your own hardware.

(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.

2.2 Data Acquisition Hardware Layer – VT DSOs

The second-generation VT DSOs are the latest PC based USB oscilloscopes, spectrum analyzers and signal generators designed and developed by Virtins Technology. They feature 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, these VT DSOs convert 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.

Compared with the first-generation VT DSOs and those USB oscilloscopes from other manufacturers, this new generation has the following major advantages:

1) Hardware DSP Based Bit Resolution Enhancement for Oscilloscope
2) Streaming Mode in Oscilloscope
3) Oscilloscope Digital Trigger and Trigger Frequency Rejection
4) Oscilloscope Persistence Mode
5) External Trigger Input Channel as a Digital Input Channel
6) Adaptive Anti-aliasing Filter for Spectrum Analyzer
7) Signal Generator DDS and Streaming Modes
8) Signal Generator DDS Interpolation
9) Simultaneous Data Acquisition and Data Output
10) Calibration and Re-Calibration
11) Upgradable Software, Firmware, and Hardware Based DSP Algorithm

The following second-generation VT DSO models are recommended. Among them, VT DSO-2820E is highly recommended.

(1) VT DSO-2810
8~16Bit 100MSPS 40MHz Oscilloscope, Spectrum Analyzer, 10-bit 3.125MSPS 150kHz AWG Signal Generator

(2) VT DSO-2820
8~16Bit 200MSPS 80MHz Oscilloscope, Spectrum Analyzer, 10-bit 6.25MSPS 150kHz AWG Signal Generator

(3) VT DSO-2810E
8~16Bit 100MSPS 40MHz Oscilloscope, Spectrum Analyzer, 10-bit 200MSPS 60MHz AWG Signal Generator

(4) VT DSO-2820E
8~16Bit 200MSPS 80MHz Oscilloscope, Spectrum Analyzer, 10-bit 200MSPS 60MHz AWG Signal Generator

Note that with a VT DSO configured in the system, the Multi-Instrument software can still use the computer's sound card for ADC and DAC. This is very handy when doing sound and audio related experiments, and demonstrating Digital Signal Processing (DSP) concepts using simulated data.

2.3 Sensor Layer

The sensor layer is made up of sensors and their pre-amplifiers (if necessary). It converts physical quantities to electronic signals which can then be quantized by the data acquisition layer. The system is open to any kind of sensor as long as it outputs voltage. The connection is through hardwired BNC. The sensor layer defines the field of application of the Multi-Instrument system. With different sensors connected, the system allows you to conduct experiments for different topics and subjects in school labs.

2.3.1 Oscilloscope Probes

A passive oscilloscope probe or active differential oscilloscope probe can be used to measure electronic or electrical voltage signals.

2.3.2 Current Clamps
A current clamp is used to measure electronic or electrical current signals

2.3.3 Microphones
A microphone is used to sense sounds in air.

2.3.4 Hydrophones
A hydrophone is used to sense sounds in water.

2.3.5 Acceleration sensor
An acceleration sensor is used to sense the acceleration of an object.

2.3.6 Velocity sensor
A velocity sensor is used to sense the velocity of an object.

2.3.7 Displacement sensor
A displacement sensor is used to sense the displacement of an object.

2.3.8 Heart rate sensor
A heart rate sensor is used to sense the pulse rate of a heart.

2.3.9 ECG sensor
An ECG sensor is used to sense the electrical activity of a heart.

2.3.10 EEG sensor
An EEG sensor is used to sense the electrical activity along the scalp. It measures voltage fluctuations resulting from ionic current flows within the neurons of the brain.

2.3.11 EMG sensor
An EMG sensor is used to sense the electrical activity produced by skeletal muscles. It detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated.

2.3.12 Force sensor
A force sensor is used to sense the force. It converts an input mechanical force into an electrical output signal.

2.3.13 Light sensor
A force sensor is used to sense the light.

2.3.14 Temperature sensor
A temperature sensor is used to sense the temperature.

2.3.15 Humidity sensor
A humidity sensor is used to sense the humidity in air.

2.3.16 Magnetic field sensor
A magnetic field sensor is used to sense the magnetic field.

2.3.17 Air pressure sensor
An air pressure sensor is used to sense the air pressure.

2.3.18 Water pressure sensor
A water pressure sensor is used to sense the water pressure.

2.3.19 Thermal radiation sensor
A thermal radiation sensor is used to sense the thermal radiation.

2.3.20 Infrared sensor
An infrared sensor is used to sense the infrared light.

2.3.21 Ultrasonic sensor
An ultrasonic sensor is used to sense the ultrasonic sound.

2.3.22 Conductivity sensor
A conductivity sensor is used to sense the conductivity of a solution.

2.3.23 PH sensor
A PH sensor is used to sense the PH of a solution.

2.3.24 Dissolved oxygen probe
A dissolved oxygen probe is used to sense the DO in water.

2.3.25 Oxygen sensor
An oxygen sensor is used to sense the oxygen in air. It is an electronic device that measures the proportion of oxygen (O_2) in the gas being analyzed.

2.3.26 Carbon dioxide sensor
A carbon dioxide sensor is used to sense the carbon dioxide in air. It is an electronic device that measures the proportion of carbon dioxide (CO_2) in the gas being analyzed.

2.3.27 Colorimeter sensor
A colorimeter sensor is used for Beer's law experiments, determining the concentration of unknown solutions, or studying changes in concentration vs. time.

3. Experiment Examples

3.1 Speed of Sound in Air
This experiment uses two microphones to measure the speed of the sound.

3.2 Speed of Sound in Water
This experiment uses two hydrophones to measure the speed of the sound.

3.3 Faraday's law
The Faraday's law experiment demonstrates that the EMF induced in a conductor linked by a changing magnetic flux is proportional to the rate of change of the flux.

3.4 AC dynamo
The AC dynamo experiment builds on the results of the Faraday's law experiment. Repeated pulses of EMF are induced in a coil by a rotating magnet, resulting in an AC voltage output of change of the flux.

3.5 Fourier transform of a periodic signal
It demonstrates how a periodic signal of any waveform can be decomposed into the sum of a (possibly infinite) set of simple oscillating functions, namely sines and cosines (or, equivalently, complex exponentials).

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