Basic Oscilloscope, Spectrum Analyzer, Multimeter and Signal Generator Functional Tests using Multi-Instrument and Pocket Multi-Instrument with Sound Cards

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1. Introduction of a sound card based system

Almost every PC or Pocket PC has a built-in sound card (or sound chip for the case of a Pocket PC). A sound card is usually treated as an audio input and output device for recording, synthesizing, and replaying speech, music and songs. However, a sound card can do more than that.

From instrumentation point of view, a sound card is a dual-channel ADC and dual-channel DAC device, which has a flat frequency response in audio frequency range and has a sampling rate of up to 192kHz, sampling depth of up to 24 bits. Even without any external amplification / attenuation circuit, it is able to measure a signal from as low as 1 µV to about 1V, thanks to its built-in gain controls (e.g. Mic Boost, Mic Volume and Line In Volume). As the sound card can work in data streaming mode, thus it is possible to use almost all the computer memory as well as the hard disk for continuous data storing. In other words, the storage buffer for a sound card based system is huge as compared with an ordinary standalone digital storage oscilloscope.

With Multi-Instrument / Pocket Multi-Instrument software, you can turn your PC / Pocket PC into a multi-function test and measurement instrument. The software has a wealth of features normally only found in much more expensive instruments. Generally, the on-board sound card / sound chip supplied with a PC / Pocket PC is sufficient to allow measurement in audio frequency range. Perfect measurement quality can be archived by using a professional grade sound card, which may has a Total Harmonic Distortion plus Noise (THD+N) <0.001% (-100dB), Signal-to-Noise Ratio (SNR) > 110 dB and upper frequency bandwidth limit up to 96 kHz. Together with the VIRTINS Sound Card Oscilloscope Probe P601, the instrument is able to measure a signal with a magnitude from as low as 1 µV to 24 V.

Measurement accuracy depends on the sound card/chip hardware used. Typically, an internal standalone sound card is better than an on-board sound card (chip), and an external sound card is the best. Using an external sound card can avoid the interference within the enclosure of the computer casing. A professional grade sound card is better than a consumer grade sound card. In terms of price, even the professional grade sound card is much cheaper (a few times typically) than its peers in professional ADC and DAC cards.

A professional sound card can be as good as a professional ADC or DAC card for test and measurement in audio frequency range. A good article in *Test & Measurement World* (http://www.tmworld.com/article/CA187380.html) had conducted a comparison test between an old 16-bit Creative Labs Sound Blaster AWE-32 and a 16-bit ADC National Instruments PCI MIO-16XE-10, the result showed that in THD measurement, which requires high precision and accuracy, the results measured by both cards were comparable. Compared with a professional ADC card, one limitation of a sound card is that it cannot measure DC signal due to the fact that its input is AC coupled. Similarly it cannot output DC signal due to the fact that its output is also AC coupled. Another limitation of a sound card is that it requires calibration if absolute magnitude values need to be measured, which is not necessary in many cases whereby only relative magnitude values and absolute frequency values are of interest.

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The accuracy of the clock reference is typically 0.00x% for an ordinary sound card. For example, a 0.002%'s inaccuracy in a sampling rate of 48000 Hz means an error of only 0.96Hz.

So, what can be measured by a sound card. Well, it can measure any signals perfectly within audio frequency range, such as sound, vibration signal, heart and lung sound, EEG (Electroencephalogram) signal..., depending on the sensors used.

In the following parts of this document, we will demonstrate some basic oscilloscope, spectrum analyzer, multimeter and signal generator functions of the Multi-Instrument and Pocket Multi-Instrument software using sound cards. Although each software can perform the oscilloscope, spectrum analyzer, multimeter and signal generator functions simultaneously on its own, we use one of them as the oscilloscope, spectrum analyzer and multimeter, and the other as the signal generator, for cross checking and easy understanding purpose.

Advanced functional tests with Multi-Instrument software will be documented separately.

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2. Test Setups

2.1 Description of Setup 1

Setup 1 (as shown above), consisted of a laptop PC with Multi-Instrument software and a Pocket PC with Pocket Multi-Instrument software. The former one was used as an oscilloscope, spectrum analyzer and multimeter while the latter one was used as a signal generator. The laptop PC was IBM ThinkPad R51 with 1.60GHz Intel Pentium M processor, 248MB RAM and Windows XP SP2. The Pocket PC was Dell Axim X50v with 624MHz Intel PXA270 processor, 64MB RAM, 128MB ROM and Windows Mobile 2003 SE. The input impedance of the laptop sound card's microphone jack was about 50kΩ while the input impedance of the Pocket PC's microphone jack was about 660Ω. The connection from the Pocket PC to the Laptop PC was made via:

(1) a 3.5mm 4-pole headset jack to 3 RCA converter (only the channel for Left Out was used)
(2) a VIRTINS Sound Card Oscilloscope Probe P601 (with attenuation switch at Position 2, i.e. impedance = 201kΩ)
(3) a VIRTINS Sound Card Oscilloscope Probe P601 (with attenuation switch at Position 1, i.e. impedance = 1kΩ)
(4) a 3.5 mm mono to 1 RCA converter (connected to the microphone input of the laptop soundcard)

The tips and ground leads of the two probes were connected respectively. The signal from the Pocket PC was attenuated by the voltage divider formed by the two probes' impedance (201+1=202 kΩ) and the laptop sound card's input impedance (50 kΩ). The attenuation ratio was 5.04 :1.

The laptop's microphone input was mono, and the same signal was fed to the two channels of the sound cards. Windows Recording Control was used to adjust the gain of the microphone input.

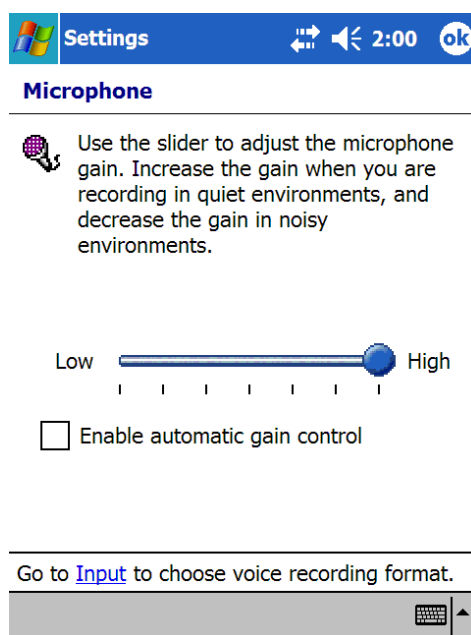## 2.2 Description of Setup 2

Setup 2 (as shown above) consisted of the same hardware as Setup 1. Unlike Setup 1, in Setup 2, the laptop was used as a signal generator and the Pocket PC was used as an oscilloscope and spectrum analyzer. The connection from the PC to the Pocket PC was made via:

(1) a 3.5 mm mono to 1 RCA converter (connected to the earphone output of the laptop soundcard)
(2) a VIRTINS Sound Card Oscilloscope Probe P601 (with attenuation switch at Position 1, i.e. impedance = 1kΩ)
(3) a VIRTINS Sound Card Oscilloscope Probe P601 (with attenuation switch at Position 1, i.e. impedance = 1kΩ)

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(4) a 3.5mm 4-pole headset jack to 3 RCA converter (only the micrphone input is used)

The tips and ground leads of the two probes were connected respectively. The signal from the PC was attenuated by the voltage divider formed by the two probes' impedance (1+1=2 kΩ) and the Pocket PC microphone jack's input impedance (660 Ω). The attenuation ratio was 4.03 :1.

The Pocket PC's microphone input was mono, the same signal was fed to the two channels of its built-in sound chip. The Microphone Setting (see figure below) under Windows Mobile was used to set the gain of the microphone input, and the automatic gain control was disabled in order to avoid any artificial modification on the original signal.

On the PC side, Windows Volume Control was used to adjust the volume of the signal generator in Multi-Instrument.

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3. Basic Functional Tests with Setup 1

3.1 1kHz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate that the peak frequency detection function in Multi-Instrument can achieve sub-FFT- bin-size accuracy
(4) To demonstrate the frequency counter function of the Multimeter in Multi-Instrument
(5) To demonstrate the signal generator function of Pocket Multi-Instrument
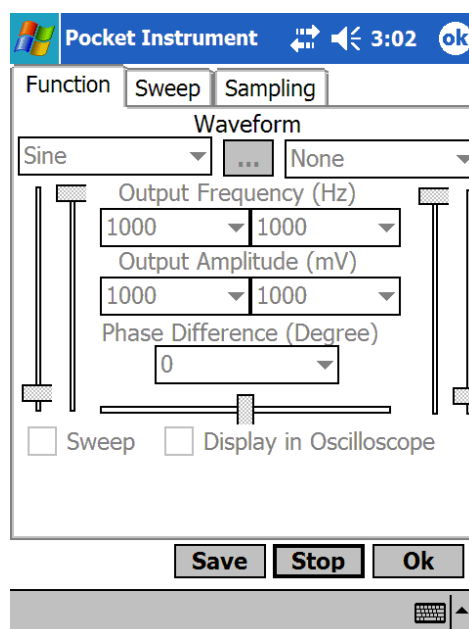
Background

A sound card is not built with hardware trigger capacity. However, one good feature of the sound card is that it supports continuous data streaming, which makes the software trigger possible.

Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Sine   Frequency: 1kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
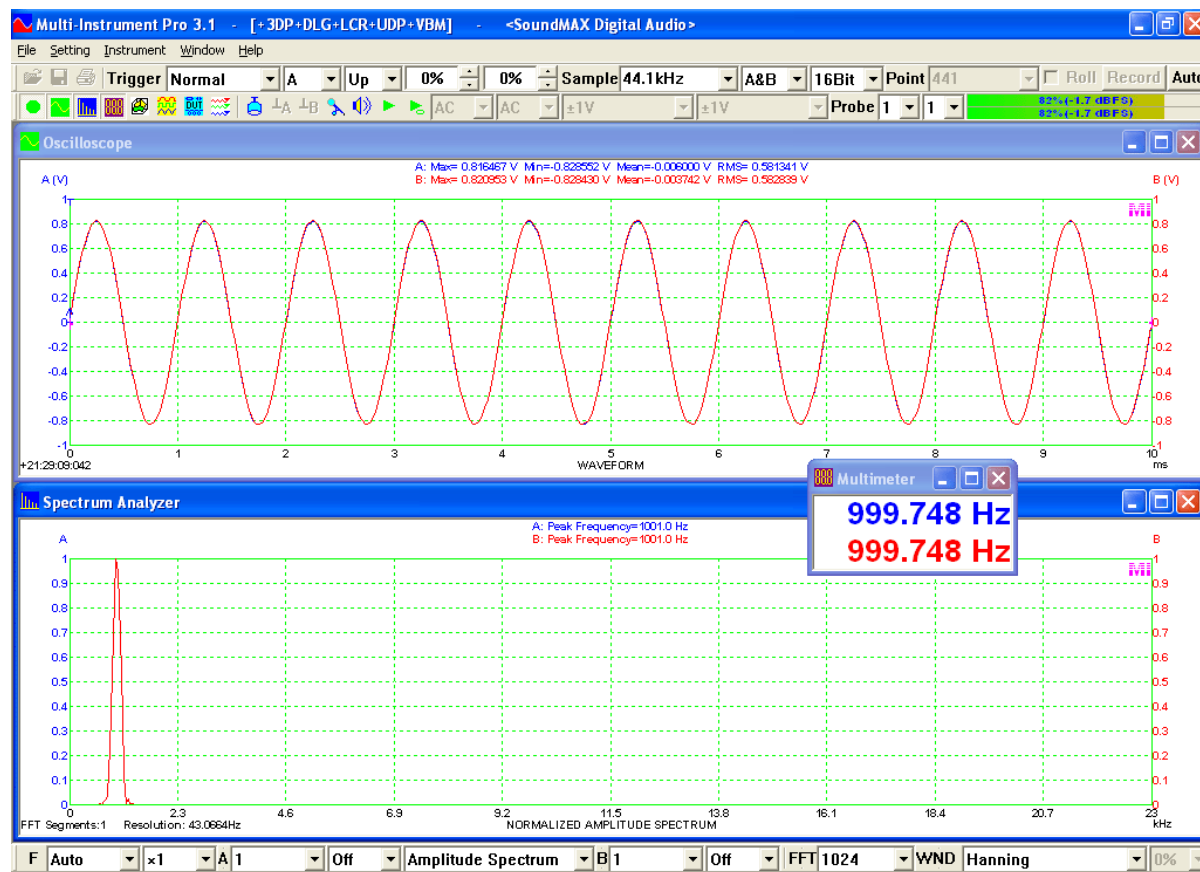Trigger Level: 0%   Trigger Delay: 0%

Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0V (Trigger Level = 0%) upward (Trigger Edge = Up). The stability of the triggered waveform display was excellent and no shaking left and right or up and down was seen, thanks to the unique algorithm used in the Multi-Instrument software, which is specially designed to overcome the small shaking left and right problem inherent in common software trigger algorithms.

The spectrum analyzer uses FFT to detect the peak frequency. The FFT frequency resolution is determined by the equation:

$$[\text{FFT frequency resolution}] = [\text{Sampling Frequency}] / [\text{FFT Size}]$$

In the above test, the FFT frequency resolution is 44100 / 1024 = 43.0664 (Hz). Thus the FFT spectral lines are located at discrete frequencies: 0Hz, 43.0664Hz, 86.1328Hz, 129.1992Hz, …947.4609Hz, 990.5273Hz, 1033.594Hz, 1076.66Hz…22006.93Hz, 22050Hz. The closest spectral lines around 1kHz are 990.5273Hz and 1033.594Hz. This implies that the peak frequency would have been detected at either 990.5273Hz or 1033.594Hz if the ordinary FFT method had been used for frequency peak detection. In contrast, the peak frequency measured in the spectrum analyzer in the above screenshot was 1001.0Hz, which

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is very close to 1000Hz generated by the signal generator. This is because Multi-Instrument has a unqiue built-in algorithm which is able to detected peak frequency at much higher resolution (referred to as sub-FFT-bin-size resolution) than the FFT frequency resultion dictated by the above equation. In fact, the above 1Hz's measurement error is more attributed to the fact that the signal generator and the spectrum analyzer do not share the same sampling clock (one in the Pocket PC, the other in the laptop).

To increase the FFT frequency resolution, one must either increase the FFT size or decrease the sampling frequency. Note that although decreasing the sampling frequency can improve the FFT frequency resolution, the highest frequency that can be measured will also be decreased which in turn may cause the spectral aliasing problem. Decreasing sampling frequency can be used only if you are very sure that the highest frequency in the signal under test is below half of the sampling frequency (Nyquist Sampling Theorem).

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 999.748 Hz, which is very closed to 1000Hz generated by the signal generator.

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3.2 20Hz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate that the peak frequency detection function in Multi-Instrument can achieve sub-FFT- bin-size accuracy
(4) To demonstrate the frequency counter function of the Multimeter in Multi-Instrument
(5) To demonstrate the signal generator function of Pocket Multi-Instrument

Background

A sound card is not built with hardware trigger capacity. However, one good feature of the sound card is that it supports continuous data streaming, which makes the software trigger possible.
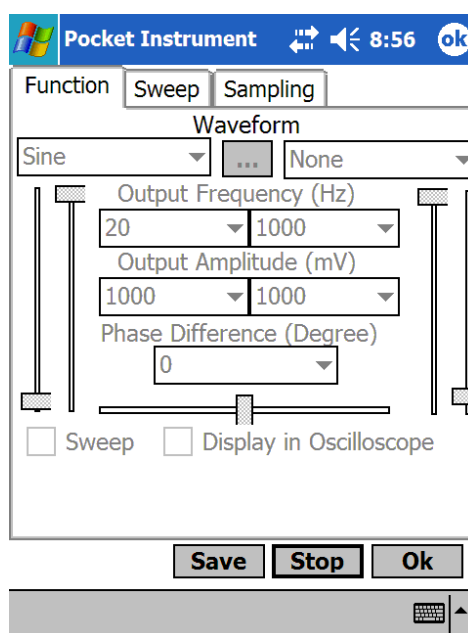
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Sine   Frequency: 20Hz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
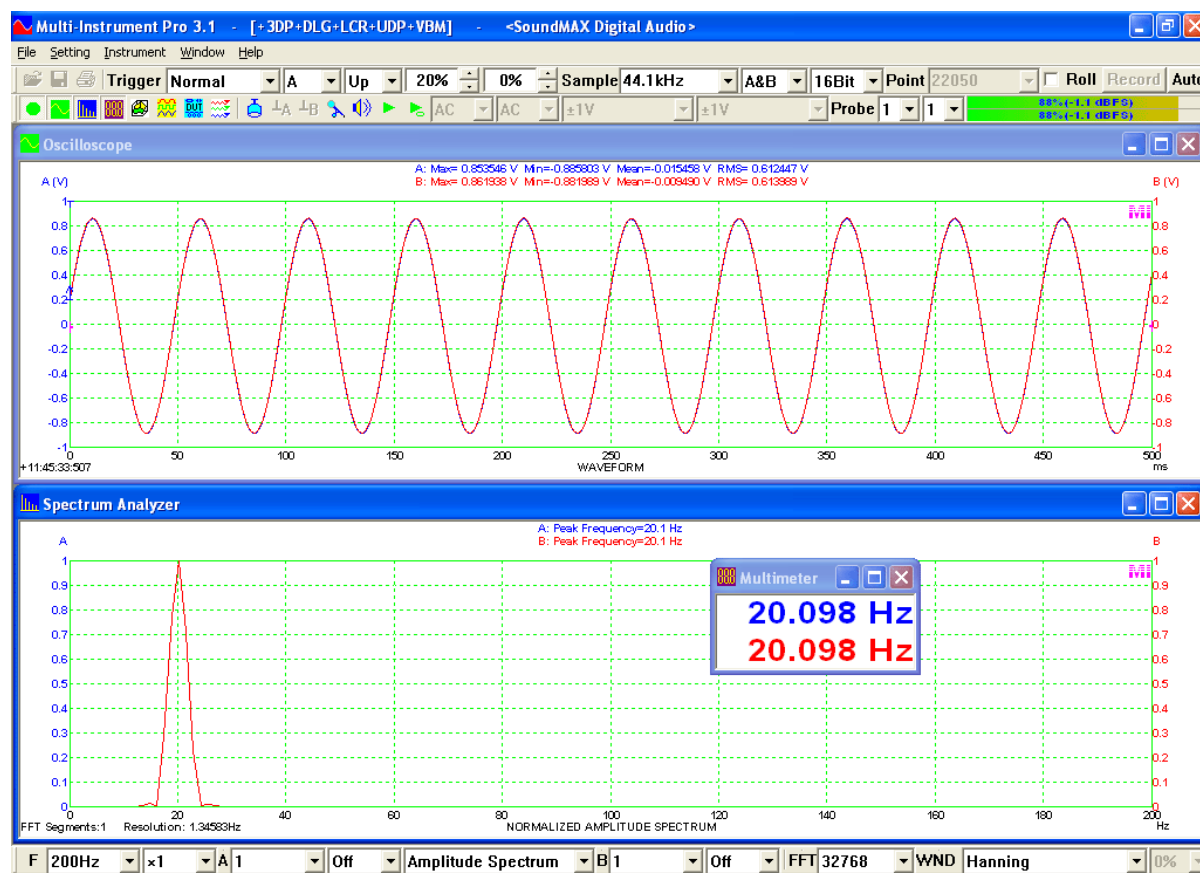Trigger Level: 20%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0.2V (Trigger Level = 20%) upward (Trigger Edge = Up). The stability of the triggered waveform display was excellent and no shaking left and right or up and down was seen.

The FFT frequency resolution is 44100 / 32768 = 1.34583 (Hz). The measured peak frequency is 20.1Hz which is very close to 20Hz generated by the signal generator, thanks to the sub-FFT-bin-size peak frequency detection algorithm used in Multi-Instrument.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 20.098 Hz, which is very closed to 20Hz generated by the signal generator.

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3.3 10kHz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate that the peak frequency detection function in Multi-Instrument can achieve sub-FFT- bin-size accuracy
(4) To demonstrate the frequency counter function of the Multimeter in Multi-Instrument
(5) To demonstrate the signal generator function of Pocket Multi-Instrument

Background

A sound card is not built with hardware trigger capacity. However, one good feature of the sound card is that it supports continuous data streaming, which makes the software trigger possible.
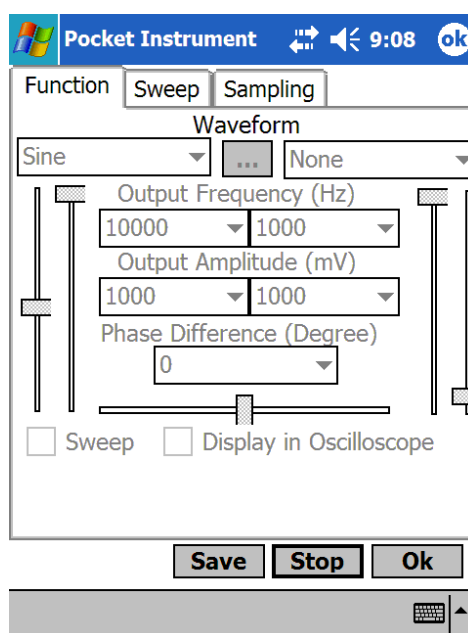
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Sine   Frequency: 10kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
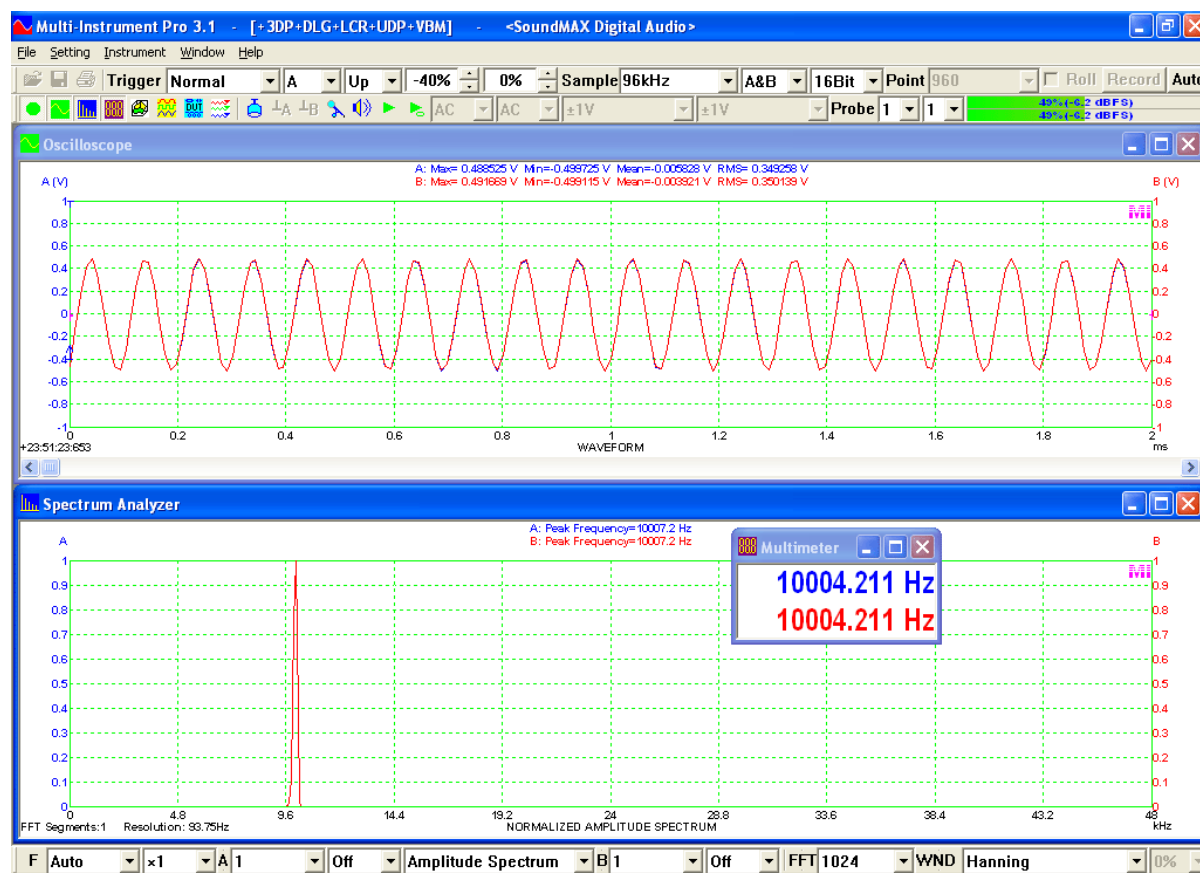Trigger Level: -40%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at -0.4V (Trigger Level = -40%) upward (Trigger Edge = Up). The stability of the triggered waveform display was excellent and no shaking left and right or up and down was seen. The sampling frequency was set to 96kHz which is 9.6 times of the signal frequency, in order to obtain sufficient data points in one signal cycle. Generally speaking, the oscilloscope requires the sampling frequency to be at least 5~10 times of the highest signal frequency in order to capture the signal's waveform shape. However, the spectrum analyzer only requires the sampling frequency to be at least 2 times of the highest signal frequency according to Nyquist Sampling Theorem.

The FFT frequency resolution is 96000 / 1024 = 93.75 (Hz). The measured peak frequency is 10007.2Hz which is very close to 10kHz generated by the signal generator, thanks to the sub-FFT-bin-size peak frequency detection algorithm used in Multi-Instrument.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 10004.211 Hz, which is very closed to 10kHz generated by the signal generator.

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3.4 1kHz + 2kHz + 4kHz sine wave generation and measurement

Purpose

(1) To demonstrate the importance of setting proper trigger level in order to get a stable waveform display for a periodic signal
(2) To demonstrate the multi-peak detection function of the spectrum analyzer in Multi-Instrument
(3) To demonstrate the importance of setting proper counter trigger level in the frequency counter of Multi-Instrument
(4) To demonstrate the multitone signal generation function of Pocket Multi-Instrument
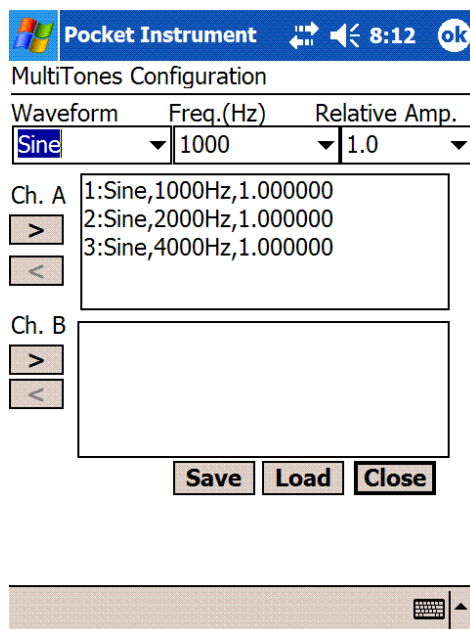
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Sine   Frequency: 1kHz + 2kHz + 4kHz with amplitude ratio 1:1:1

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
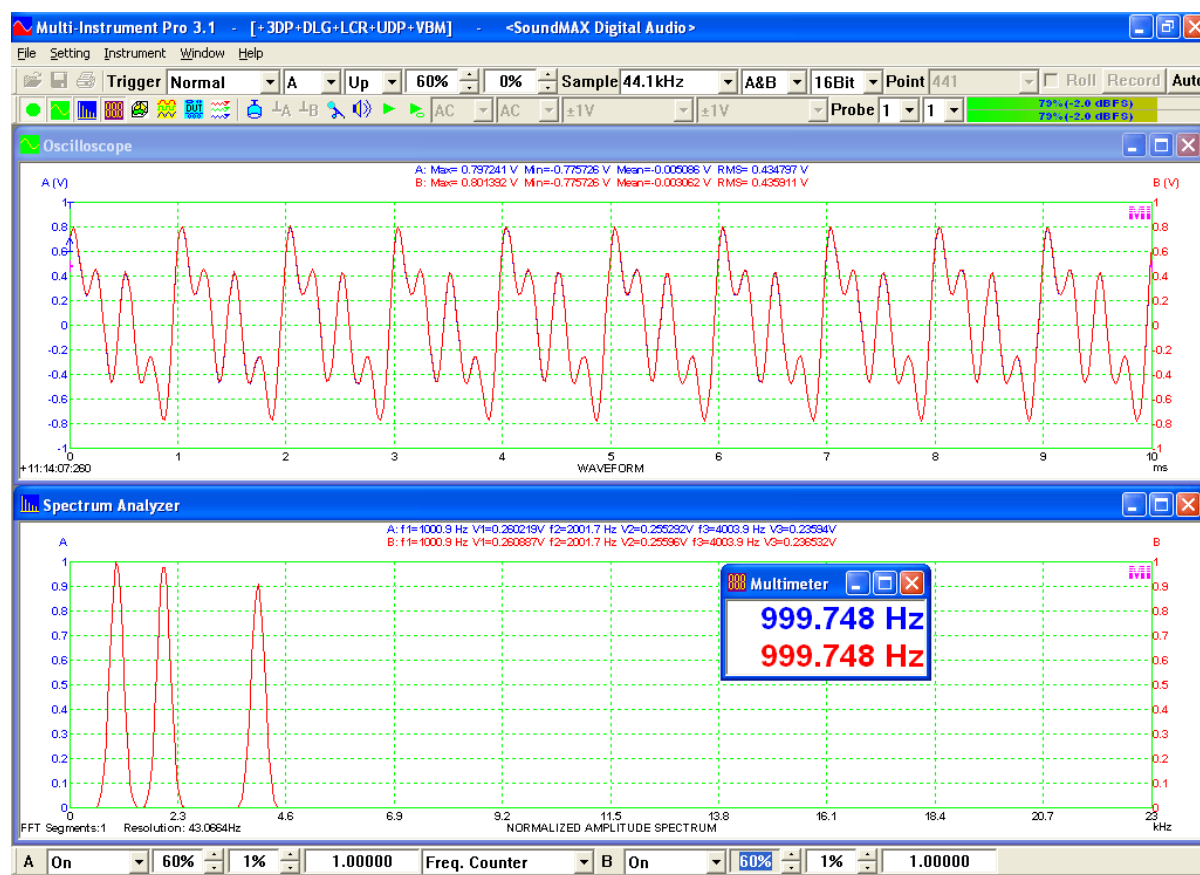Trigger Level: 60%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0.6V (Trigger Level = 60%) upward (Trigger Edge = Up). The signal has four peaks and four troughs in one cycle. If the trigger level is set to be within the band bounded by the second highest peak and the second lowest trough, then the real time waveform display on the screen will not be stable as there are multiple points that satisfy the trigger condition within one cycle. Therefore, to get a stable display, the trigger level must be set outside this band to ensure a single trigger point in a cycle.

The spectrum analyzer was set to multi-peak detection mode via [Setting]>[Spectrum Analyzer Processing]>[Parameter Measurement]>[Peaks] with Deadband = 50Hz and Number of Peaks = 3. The FFT frequency resolution is 44100 / 1024 = 43.0664 (Hz). The measured three peak frequencies are 1000.9Hz, 2001.7Hz and 4003.9Hz, which are very close to 1kHz, 2kHz, 4kHz generated by the signal generator, thanks to the sub-FFT-bin-size peak frequency detection algorithm used in Multi-Instrument.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 999.748 Hz, which is very close to the 1kHz fundamental frequency generated by the signal generator. Note that, similar to the sampling trigger level, the trigger level of the frequency counter has to be set to a value outside the band bounded by the second highest peak and the second lowest trough.

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3.5 1kHz square wave generation and measurement

Purpose

(1) To demonstrate the generation and measurement of a square wave using Pocket Multi-Instrument and Multi-Instrument respectively
(2) To show the fundamental and harmonic frequencies of a square wave
(3) To demonstrate the multi-peak detection function of the spectrum analyzer in Multi-Instrument
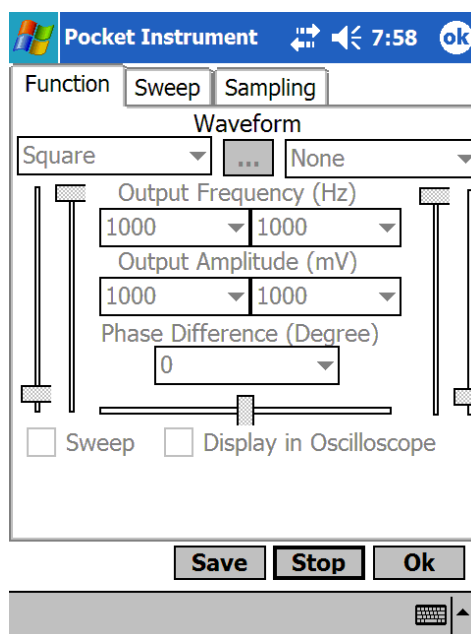
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Square   Frequency: 1kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
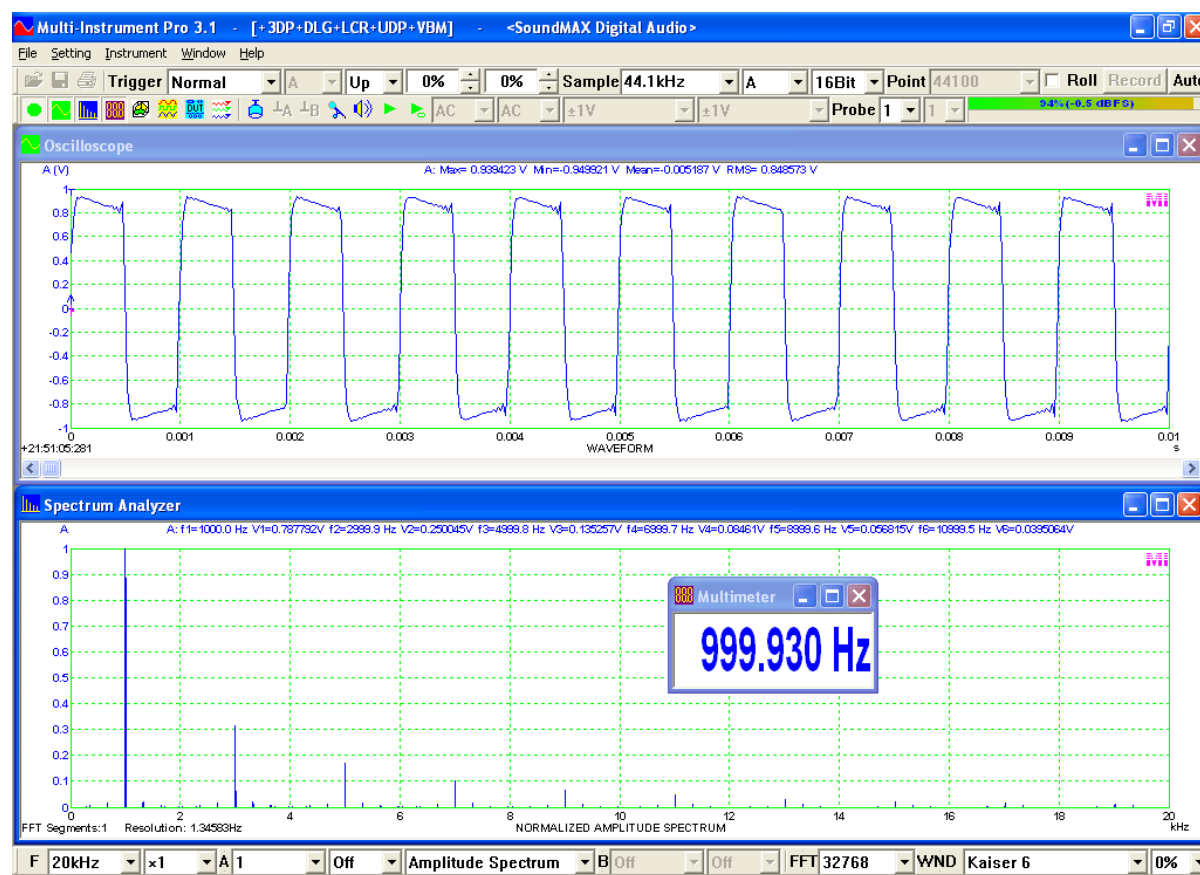Trigger Level: 0%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0V (Trigger Level = 0%) upward (Trigger Edge = Up). The square waveform measured is reasonably good in shape despite that the top and bottom of the waveform is not so flat as the ideal one, which can be attributed to the limited bandwith and phase distortion of both the output channel of the Pocket PC and the input channel of the laptop.

The spectrum analyzer was set to multi-peak detection mode via [Setting]>[Spectrum Analyzer Processing]>[Parameter Measurement]>[Peaks] with Deadband = 50Hz and Number of Peaks = 6. The FFT frequency resolution is 44100 / 32768 = 1.34583 (Hz). The measured six peaks are 1000.0Hz (0.787792Vrms), 2999.9Hz (0.250045Vrms), 4999.8Hz (0.135257Vrms), 6999.7Hz (0.08461Vrms), 8999.6Hz (0.056815Vrms), 10999.5Hz (0.0395064Vrms), which correspond to the 1kHz fundamental frequency and its odd order harmonics. Theoretically, a square wave contains only odd order harmonics in addition to the fundamental frequency. For example, a 1kHz square wave contains harmonics at: 3kHz, 5kHz, 7kHz, 9kHz, 11kHz, etc.. The amplitude of the harmonics decreases very fast as the frequency goes up. The theoretical decay rate is 1/N, where N is the order of the harmonic frequency.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 999.930 Hz, which is very close to the 1kHz fundamental frequency generated by the signal generator.

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3.6 500Hz triangle wave generation and measurement

Purpose

(1) To demonstrate the generation and measurement of a triangle wave using Pocket Multi-Instrument and Multi-Instrument respectively
(2) To show the fundamental and harmonic frequencies of a triangle wave
(3) To demonstrate the multi-peak detection function of the spectrum analyzer in Multi-Instrument
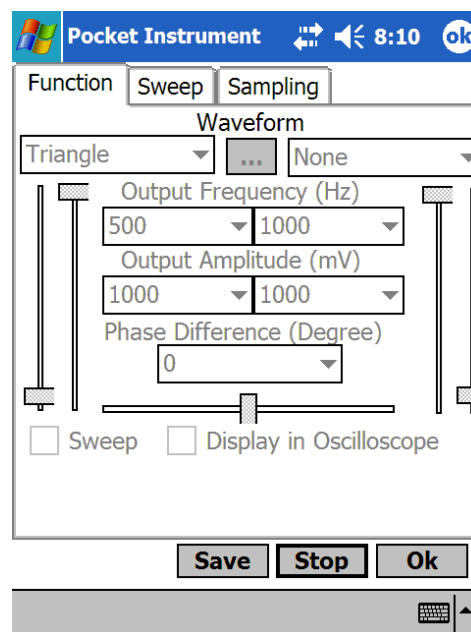
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Triangle   Frequency: 500Hz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Down
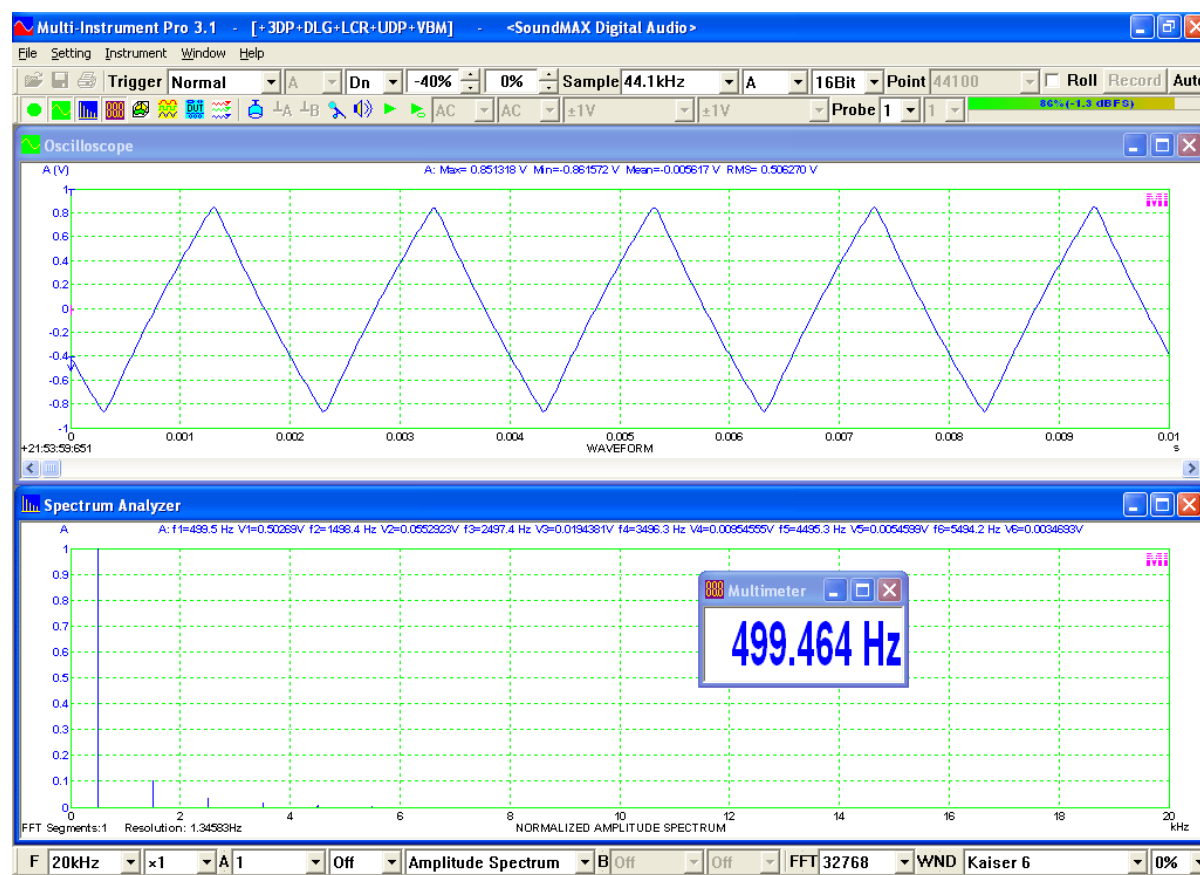Trigger Level: -40%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at -0.4V (Trigger Level = -40%) downward (Trigger Edge = Down). The triangle waveform measured is very good in shape.

The spectrum analyzer was set to multi-peak detection mode via [Setting]>[Spectrum Analyzer Processing]>[Parameter Measurement]>[Peaks] with Deadband = 50Hz and Number of Peaks = 6. The FFT frequency resolution is 44100 / 32768 = 1.34583 (Hz). The measured six peaks are 499.5Hz (0.50269Vrms), 1498.4Hz (0.0552923Vrms), 2497.4Hz (0.0194381Vrms), 3496.3Hz (0.00954555Vrms), 4495.3Hz (0.0054599Vrms), 5494.2Hz (0.0034693Vrms), which correspond to the 500Hz fundamental frequency and its odd order harmonics. Theoretically, a triangle wave contains only odd order harmonics in addition to the fundamental frequency. For example, a 500Hz triangle wave contains harmonics at: 1.5kHz, 2.5kHz, 3.5kHz, 4.5kHz, 5.5kHz, etc.. The amplitude of the harmonics decreases very fast as the frequency goes up. The theoretical decay rate is $1/N^2$, where N is the order of the harmonic frequency.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 499.464 Hz, which is very close to the 500Hz fundamental frequency generated by the signal generator.

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3.7 2kHz saw tooth wave generation and measurement

Purpose

(1) To demonstrate the generation and measurement of a saw tooth wave using Pocket Multi-Instrument and Multi-Instrument respectively
(2) To show the fundamental and harmonic frequencies of a saw tooth wave
(3) To demonstrate the harmonics function of the spectrum analyzer in Multi-Instrument
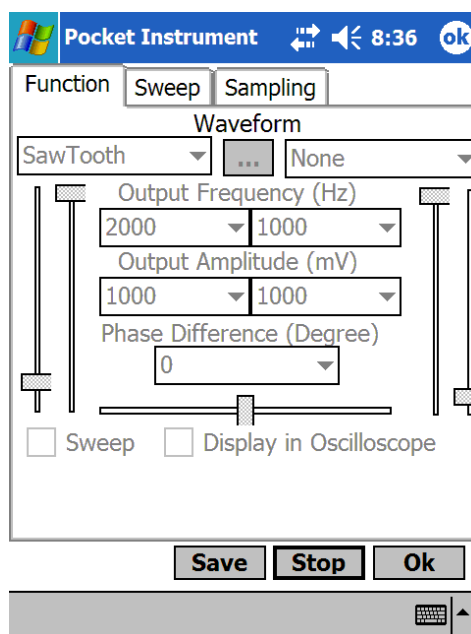
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: Saw Tooth   Frequency: 2kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
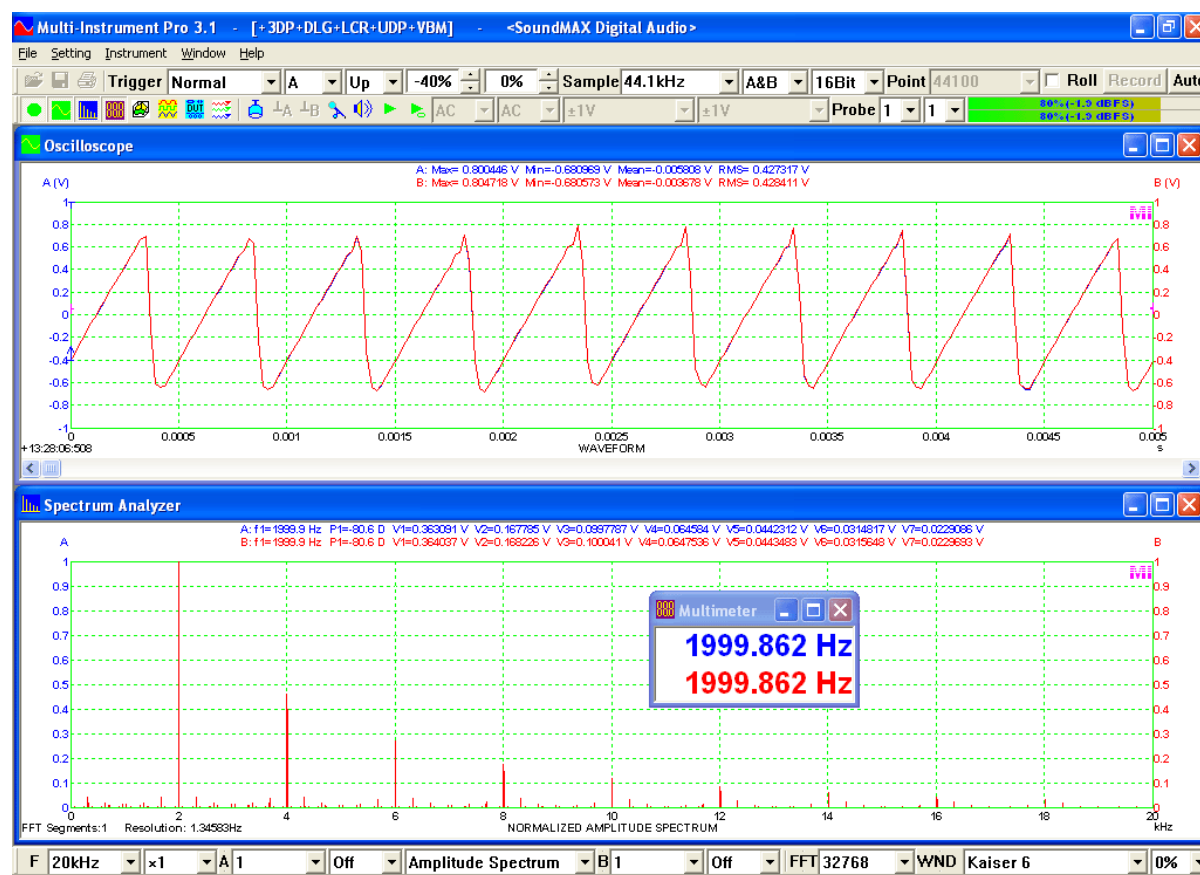Trigger Level: -40%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at -0.4V (Trigger Level = -40%) upward (Trigger Edge = Up). The sawtooth waveform measured is good in shape.

The spectrum analyzer was set to harmonics mode via [Setting]>[Spectrum Analyzer Processing]>[Parameter Measurement]>[Harmonics]. The FFT frequency resolution is 44100 / 32768 = 1.34583 (Hz). The measured fundamental frequency is 1999.9Hz, which is very close to the 1kHz frequency generated by the signal generator. The measured starting phase angle of the fundamental frequency is –80.6 degree (Note: 1. A sine wave starting at 0 degree has a phase angle of 0 degree. 2. The starting phase angle will be displayed for the fundamental frequency when the FFT size is greater than ½ of the Record Length but less than or equal to the Record Length.). Theoretically, a saw tooth wave contains both even and odd order harmonics in addition to the fundamental frequency. For example, a 2kHz saw tooth wave contains harmonics at: 4kHz, 6kHz, 8kHz, 10kHz, 12kHz, 14kHz, etc.. The measured magnitude of the fundamental and harmonics frequencies (to the seventh order) are 0.363091Vrms, 0.167785Vrms, 0.0997787Vrms, 0.064584Vrms, 0.0442312Vrms, 0.0314817Vrms, and 0.0229086Vrms. The amplitude of harmonics decreases very fast as the frequency goes up. The theoretical decay rate is $1/N$, where N is the order of the harmonic frequency.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 1999.862 Hz, which is very close to the 2kHz fundamental frequency generated by the signal generator.

3.8 1kHz sine wave + white noise (1:0.4) generation and measurement

Purpose

(1) To demonstrate the generation and measurement of 1kHz sine wave + white noise (1:0.4) using Pocket Multi-Instrument and Multi-Instrument respectively
(2) To demonstrate the importance of setting proper counter trigger hysteresis in the frequency counter of Multi-Instrument
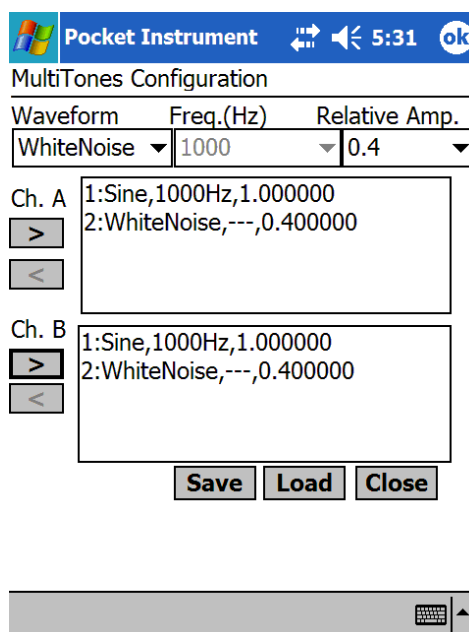
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: sine + white noise (amplitude ratio 1:0.4)   Frequency: 1kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
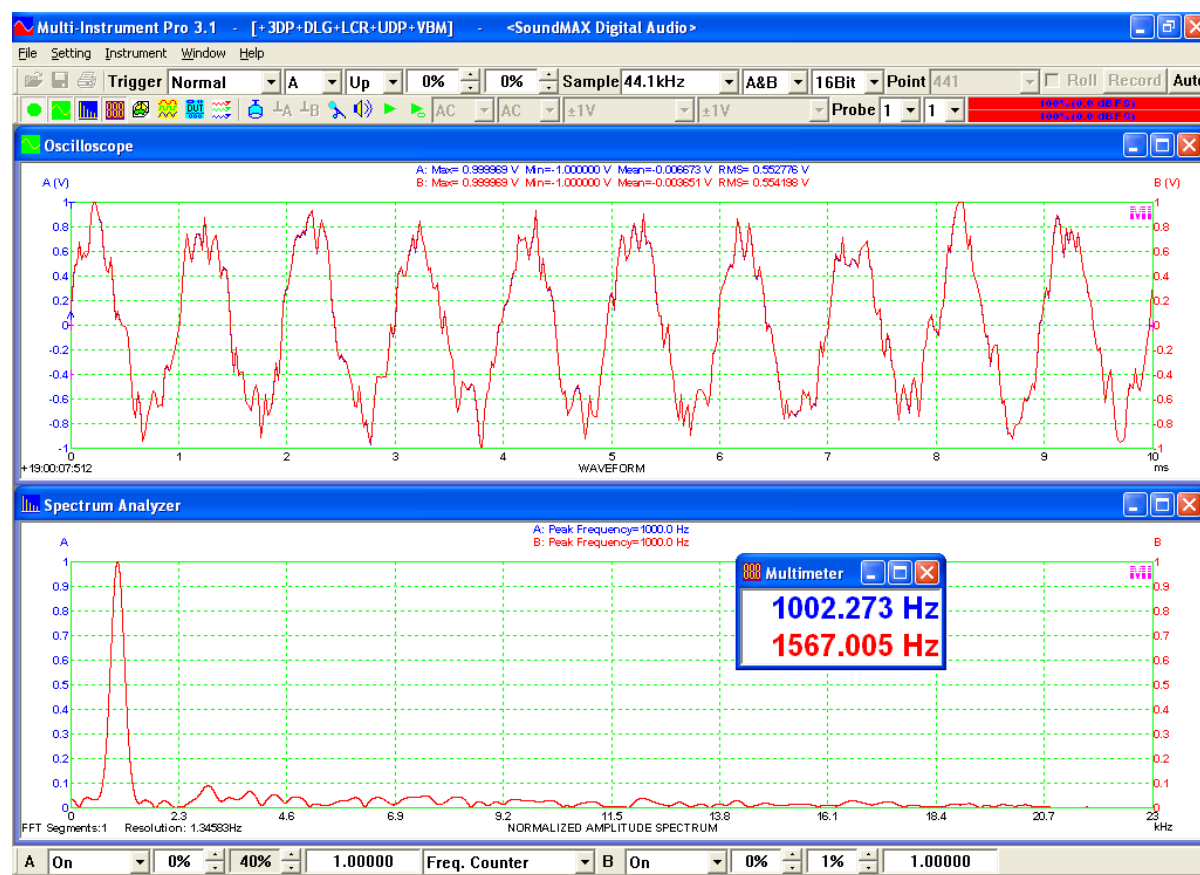Trigger Level: 0%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0V (Trigger Level = 0%) upward (Trigger Edge = Up).

The FFT frequency resolution is 44100 / 32768 = 1.34583 (Hz). The measured fundamental frequency is 1000.0Hz, which is very close to the 1kHz frequency generated by the signal generator.

The multimeter in the above screenshot was set to frequency counter mode with the counter trigger level = 0% and counter trigger hysteresis = 40% for Channel A and the counter trigger level = 0% and counter trigger hysteresis = 1% for Channel B. The signals in both channels were acquired from the mono microphone input and thus were the same. The counted frequency is 1002.273 Hz in Channel A and 1567.005Hz in Channel B. Obviously the frequency value measured in Channel A is correct as it is very close to the 1kHz fundamental frequency generated by the signal generator, and the frequency value measured in Channel B is wrong. This test shows that it is important to set the counter trigger hysteresis properly in order to suppress the noise interference during frequency counting process.
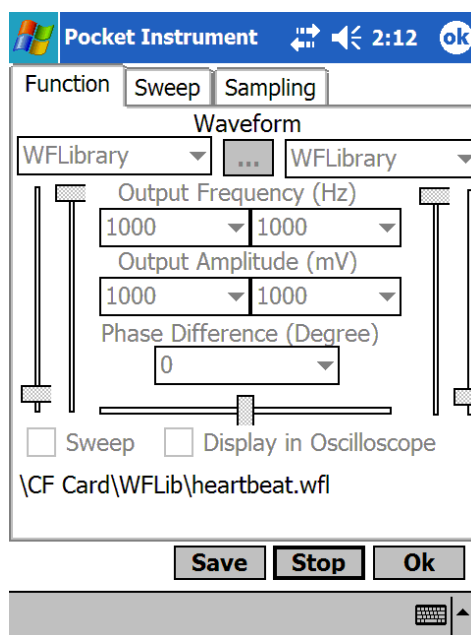
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3.9 Arbitrary waveform generation and measurement

Purpose

(1) To demonstrate the generation and measurement of an arbitrary waveform (using a predefined waveform library file named heartbeat.wfl as the example) using Pocket Multi-Instrument and Multi-Instrument respectively
(2) To show the fundamental and harmonic frequencies of the measured waveform
(3) To demonstrate the importance of setting proper counter trigger level in the frequency counter of Multi-Instrument
(4) To highlight the difference between the peak frequency detected in the spectrum analyzer and the frequency counted by the frequency counter in the multimeter
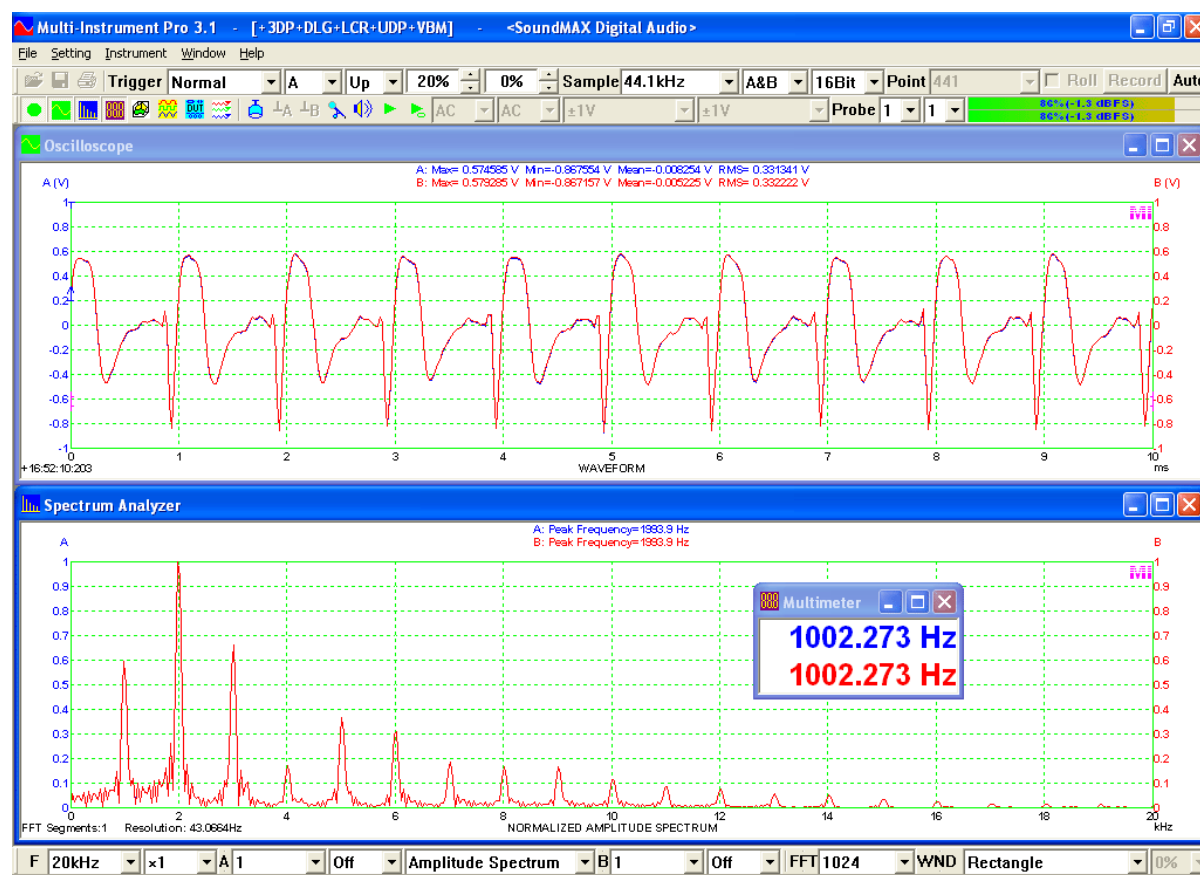
Signal Generator Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
Waveform: heatbeat.wfl   Frequency: 1kHz

Oscilloscope, Spectrum Analyzer and Multimeter Configuration
Software: Multi-Instrument Version: 3.1   Calibration: No
Trigger Mode: Normal   Trigger Source: Ch. A   Trigger Edge: Up
Trigger Level: 20%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum
Multimeter Display Mode: Frequency Counter

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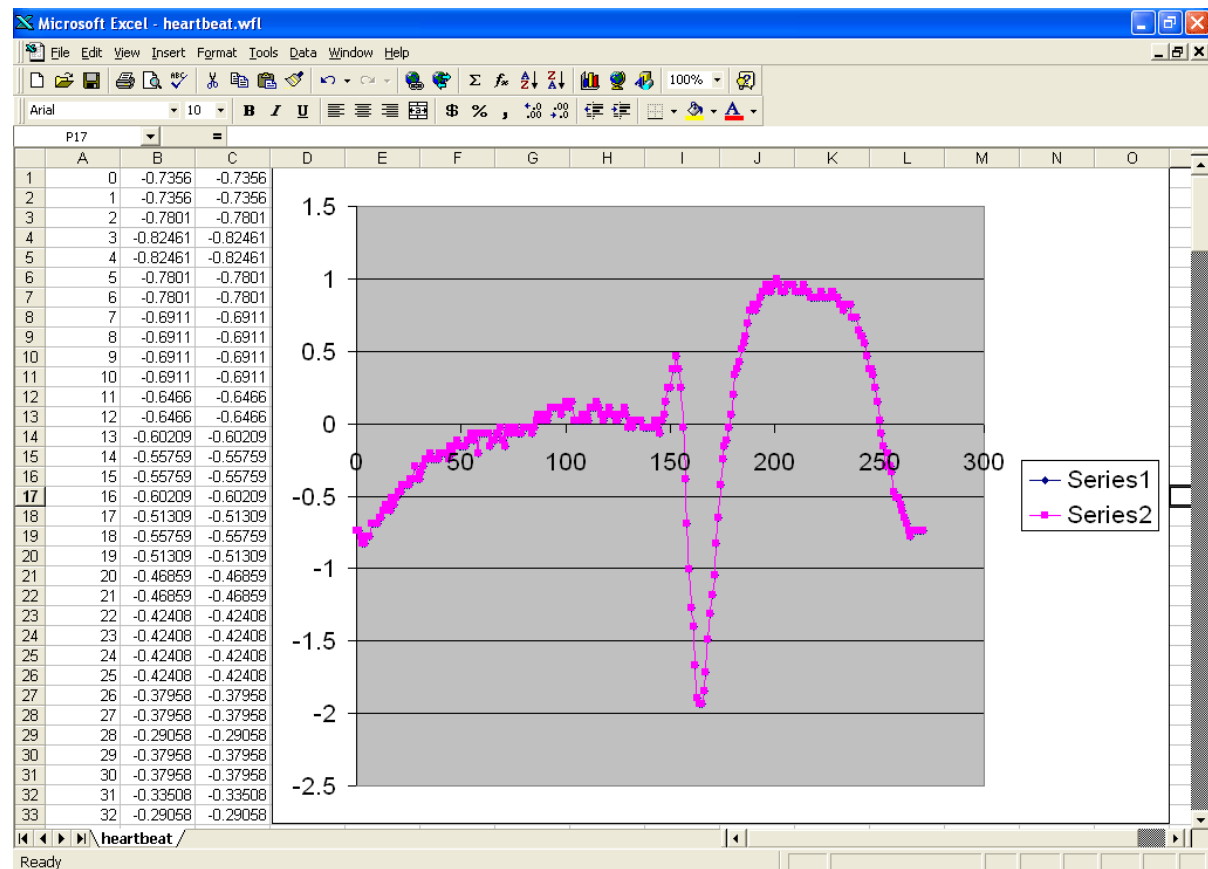**Vi Virtins Technology**

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0.2V (Trigger Level = 20%) upward (Trigger Edge = Up).

The FFT frequency resolution is 44100 / 1024 = 43.0664 (Hz). It indicates that a 1kHz "heartbeat" wave consists of a series of frequency peaks at 1kHz, 2kHz, 3kHz, 4kHz, 5kHz, etc., with the highest peak at 2kHz. The measured peak frequency is 1993.9Hz, which is very close to 2kHz, the second order harmonic frequency of the 1kHz "heartbeat" wave generated by the signal generator. It demonstates that the peak frequency detected in the spectrum analyzer corresponds to the highest peak in the frequency domain which is not necessarily the fundamental frequency.

The multimeter in the above screenshot was set to frequency counter mode and the counted frequency was 1002.273Hz, which is very close to the 1kHz fundamental frequency generated by the signal generator. The counter trigger level was set to -0.6V to ensure that each cycle of the signal would only trigger the frequency counter once.

The "heartbeat" wave was generated via the waveform library file "heartbeat.wfl" supplied with the software. It is simply a CSV (Comma Separated Variables) text file containing the coordinates of each data points in one cycle of the signal. The waveform library file can be easily created by users using any text editor such as Windows Notepad or Microsoft Excel. The following screenshot was obtained by loading the "heartbeat.wfl" file into Microsoft Excel and using the Chart function of Excel to plot the data. It can be seen that the data defines only one cycle of the "heartbeat" wave. It has no frequency defined in the file. The signal frequency (the repetition rate of the defined waveform) will be specified in the signal

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generator panel during signal generation. Note the "heartbeat" wave here does not represent any TRUE heartbeat wave, it is just a name of the file.

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4. Basic Functional Tests with Setup 2

4.1 1kHz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Pocket Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate the signal generator function of Multi-Instrument

Background

A Pocket PC sound chip is not built with hardware trigger capacity. However, one good feature of the sound chip is that it supports continuous data streaming, which makes the software trigger possible.
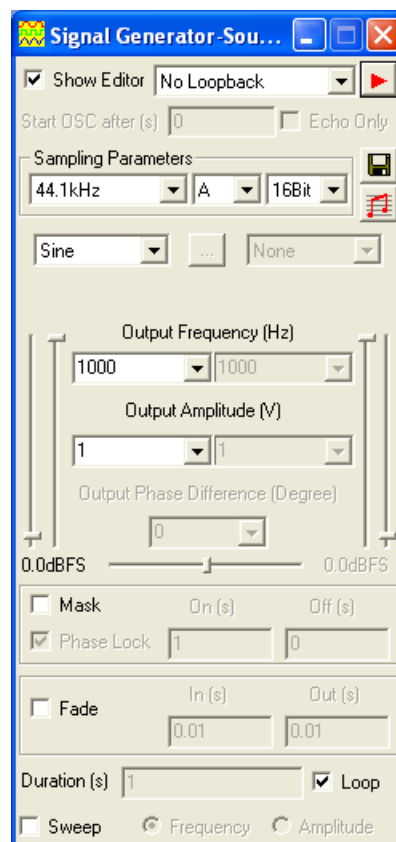
Signal Generator Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Waveform: Sine   Frequency: 1kHz

Oscilloscope, Spectrum Analyzer Configuration
Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
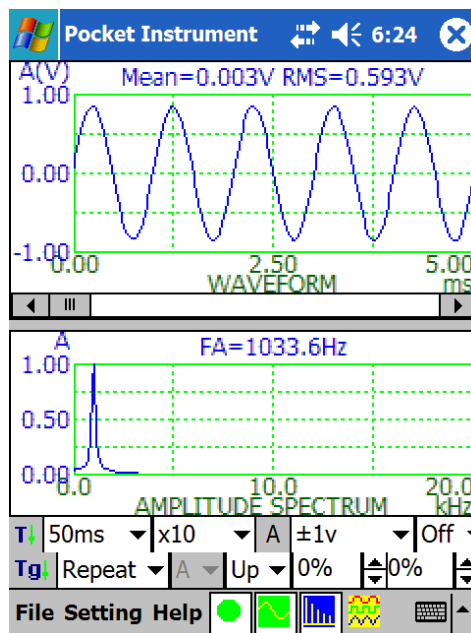Trigger Mode: Repeat (Normal)   Trigger Source: Ch. A   Trigger Edge: Up
Trigger Level: 0%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0V (Trigger Level = 0%) upward (Trigger Edge = Up). The stability of the triggered waveform display was very good. The scan time was set to 50ms. The multiplier of the horizontal axis was set to ×10 in order to see the individual cycles of the 1kHz sine wave signal. The scan time should be increased if instable triggering occurs.

The spectrum analyzer uses FFT to detect the peak frequency. The FFT frequency resolution is determined by the equation:

$$[FFT\ frequency\ resolution] = [Sampling\ Frequency] / [FFT\ Size]$$

In the above test, the FFT frequency resolution is 44100 / 1024 = 43.0664 (Hz). Thus the FFT spectral lines are located at discrete frequencies: 0Hz, 43.0664Hz, 86.1328Hz, 129.1992Hz, …947.4609Hz, 990.5273Hz, 1033.594Hz, 1076.66Hz…22006.93Hz, 22050Hz. The closest spectral lines around 1kHz are 990.5273Hz and 1033.594Hz. The latter one was corrected detected by the software as the peak frequency.

4.2 20Hz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Pocket Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate the signal generator function of Multi-Instrument
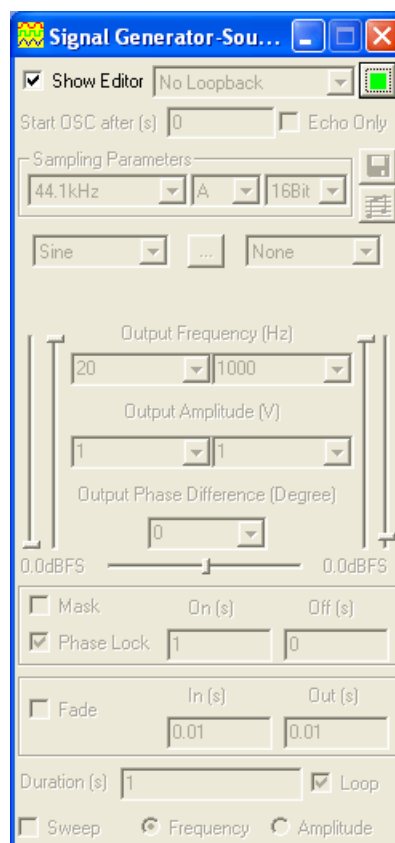
Background

A Pocket PC sound chip is not built with hardware trigger capacity. However, one good feature of the sound chip is that it supports continuous data streaming, which makes the software trigger possible.

Signal Generator Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Waveform: Sine   Frequency: 20Hz

Oscilloscope, Spectrum Analyzer Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
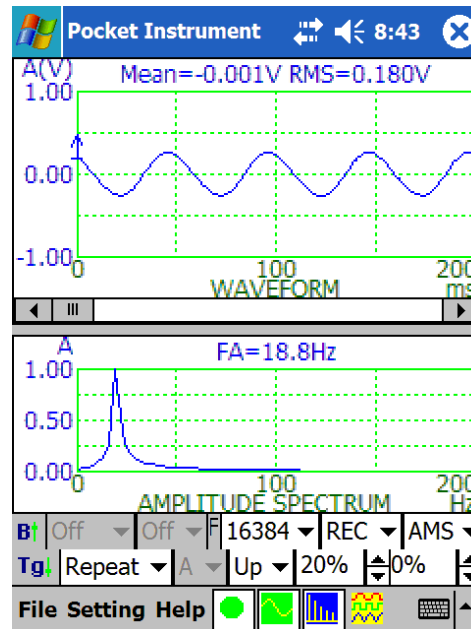Trigger Mode: Repeat (Normal)   Trigger Source: Ch. A   Trigger Edge: Up
Trigger Level: 20%   Trigger Delay: 0%

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Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at 0.2V (Trigger Level = 20%) upward (Trigger Edge = Up). The stability of the triggered waveform display was very good. The scan time was set to 1s. The multiplier of the horizontal axis was set to ×5 in order to see the individual cycles of the 20Hz sine wave signal. The scan time should be increased if instable triggering occurs.

The FFT frequency resolution is 44100 / 16384 = 2.69165 (Hz). The measured peak frequency is 18.8Hz which is very close to 20Hz generated by the signal generator. The peak frequency detection error is less than the FFT frequency resolution.

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4.3 5kHz sine wave generation and measurement

Purpose

(1) To demonstrate the software triggering function of Pocket Multi-Instrument
(2) To demonstrate the stability of the triggered waveform display
(3) To demonstrate the signal generator function of Multi-Instrument
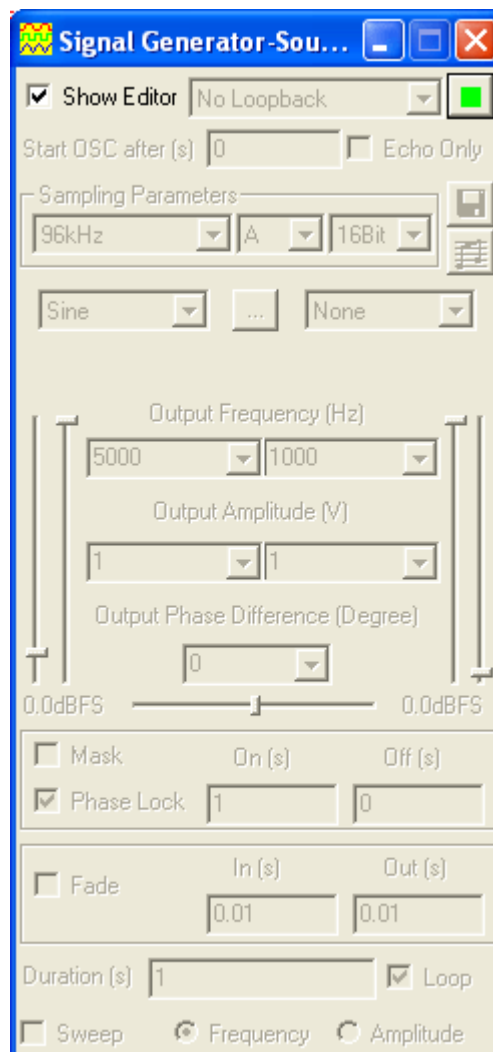
Background

A Pocket PC sound chip is not built with hardware trigger capacity. However, one good feature of the sound chip is that it supports continuous data streaming, which makes the software trigger possible.

Signal Generator Configuration

Software: Multi-Instrument Version: 3.1   Calibration: No
Waveform: Sine   Frequency: 5kHz

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Oscilloscope, Spectrum Analyzer Configuration

Software: Pocket Multi-Instrument Version: 1.0   Calibration: No
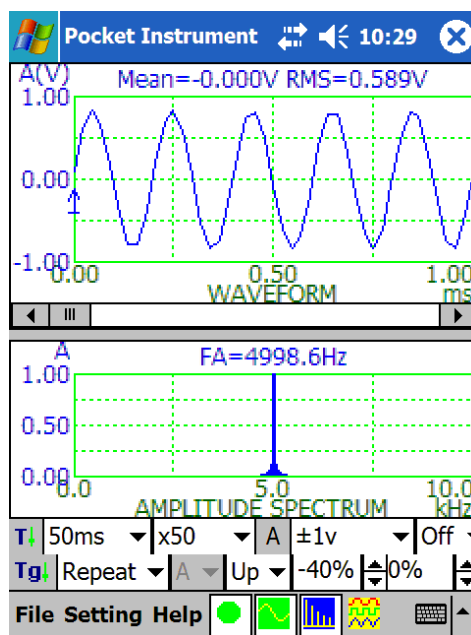Trigger Mode: Repeat (Normal)   Trigger Source: Ch. A   Trigger Edge: Up
Trigger Level: -40%   Trigger Delay: 0%
Oscilloscope Display Mode: A&B
Spectrum Analyzer Display Mode: Amplitude Spectrum

Result and Analysis

The oscilloscope in the above screenshot shows that the waveform was triggered right at –0.4V (Trigger Level = -40%) upward (Trigger Edge = Up). The stability of the triggered waveform display was very good. The scan time was set to 50ms. The multiplier of the horizontal axis was set to ×50 in order to see the individual cycles of the 5kHz sine wave signal. The scan time should be increased if instable triggering occurs. Generally speaking, the oscilloscope requires the sampling frequency to be at least 5~10 times of the highest signal frequency in order to capture the signal's waveform shape. However, the spectrum analyzer only requires the sampling frequency to be at least 2 times of the highest signal frequency according to Nyquist Sampling Theorem.

The FFT frequency resolution is 44100 / 16384 = 2.69165 (Hz). The measured peak frequency is 4998.6Hz which is very close to 5kHz generated by the signal generator. The peak frequency detection error is less than the FFT frequency resolution.