High-Resolution Oscilloscopes

1. Introduction

PicoScope 4262

Since 1991, Pico Technology has played a pioneering role in the development of PC oscilloscopes. These compact devices, along with traditional full-sized digital storage oscilloscopes (DSOs), account for most of the oscilloscopes sold today. The driving force behind all of these instruments has been digital electronics. As clock speeds in digital circuits increase, manufacturers have responded by designing scopes with faster sampling rates and higher bandwidths. Unfortunately, analogue designers have been left behind: the quest for higher speed has been at the expense of accuracy, dynamic range and precision.

2. What is a 'Precision' DSO?

The precision of an oscilloscope is determined by its resolution and its accuracy. Here are the characteristics of some of the resolutions available:

Oscilloscope resolution	Number of steps	Smallest change that can be detected	Ideal dynamic range
6 bits	64	1.6% (16 000 ppm)	36 dB
8 bits	256	0.39% (4 000 ppm)	48 dB
12 bits	4 096	0.024% (244 ppm)	72 dB
16 bits	65 536	0.0015% (15 ppm)	96 dB

Accuracy is not regarded as important for most oscilloscopes. You can make measurements within a few per cent (most DSOs quote 3% to 5% DC accuracy) but for accurate measurements you have to reach for a multimeter. With precision oscilloscopes, however, accurate measurements are possible at full speed. Most handheld meters have 12-bit resolution (equivalent to 3½ digits), while a 16-bit oscilloscope is equivalent in resolution to a 4½-digit bench-top meter.

As well as resolution and accuracy, noise is an issue. The amplifiers that make up the front end of a conventional DSO are designed to have a high bandwidth. Low noise is not a priority for most scopes, so 1% noise figures are typical. The designer of a 16-bit oscilloscope has a tougher job, as only 0.0015% of noise is enough to mask the least-significant bit.

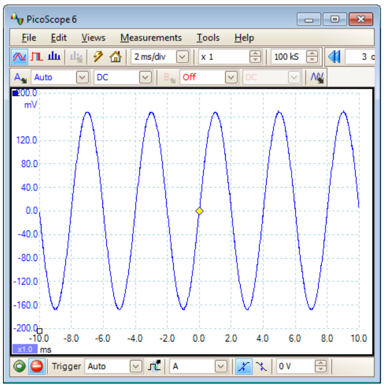
3. Test I: Low-cost signal generator

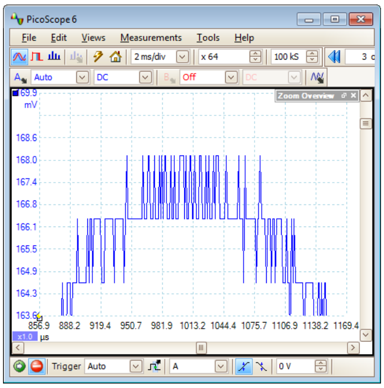
The pictures below show the time-domain and frequency–domain displays from typical 8-bit, 12-bit and 16-bit PicoScope oscilloscopes. The signal source is an Android smartphone running the FuncGen app, set to generate a 250 Hz sine wave with its maximum amplitude of about 170 mV.

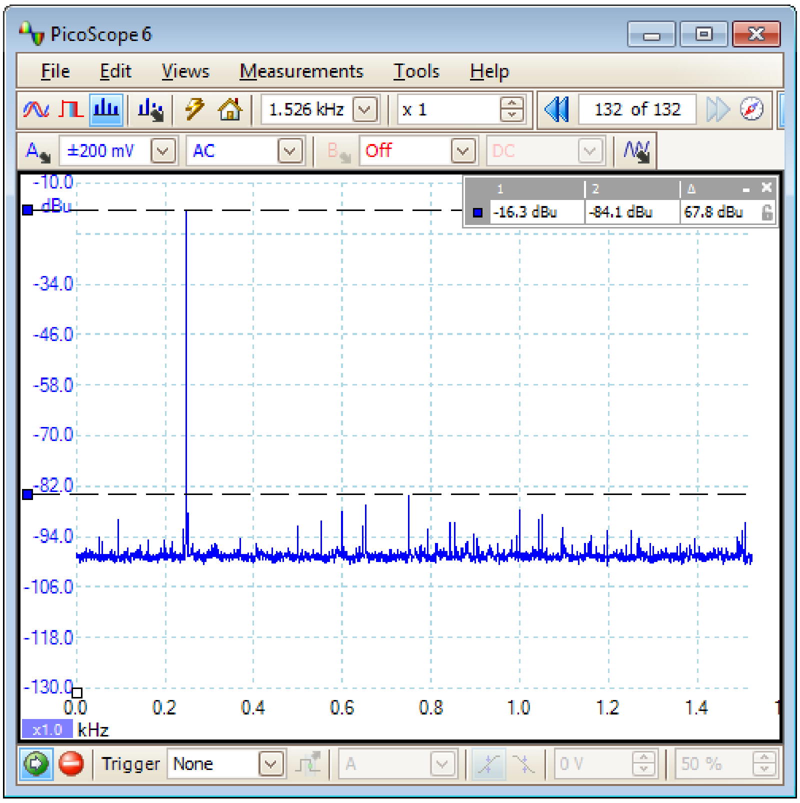
3.1 8-bit oscilloscope example

An 8-bit oscilloscope such as the PicoScope 2205 gives a good enough visual representation of the wave, as the upper-left picture shows. The frequency and amplitude of the wave can be measured with reasonable accuracy. Zooming in by 64x (lower-left picture), however, shows up the limitations of 8-bit resolution.

The right-hand picture shows a spectrum analyzer plot (FFT) of the signal. The peak at 250 Hz is the fundamental frequency of the input signal. The SFDR, shown as the delta between the rulers, is about 68 dB. The noise floor masks the true characteristics of the input signal.

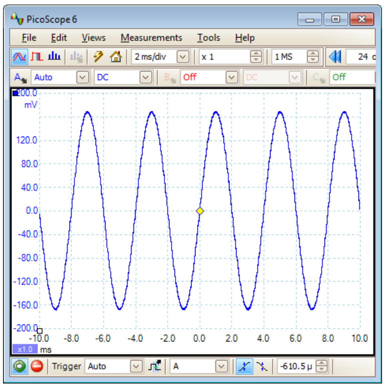


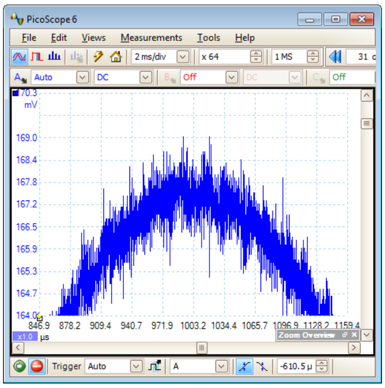


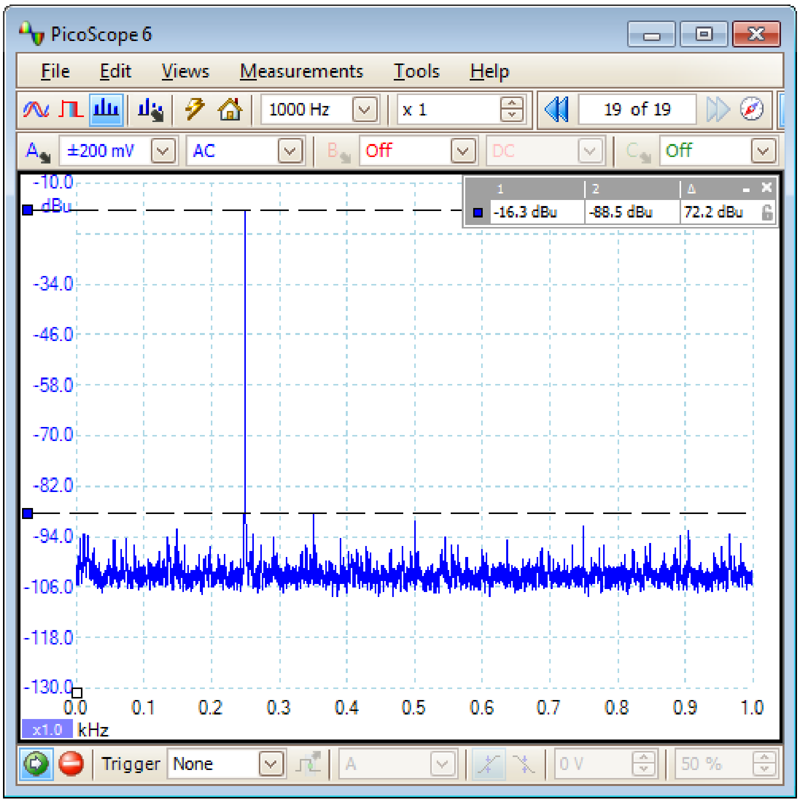


3.2 12-bit oscilloscope example

The same signal captured with a PicoScope 4423 12-bit oscilloscope looks the same in the normal scope view. The x64 view now shows no digitization steps, but with 12-bit resolution we can see noise that was invisible with the 8-bit scope. The spectrum analyzer shows the SFDR to be about 72 dB, and distortion peaks at the second (500 Hz) and third (750 Hz) harmonics are just visible.



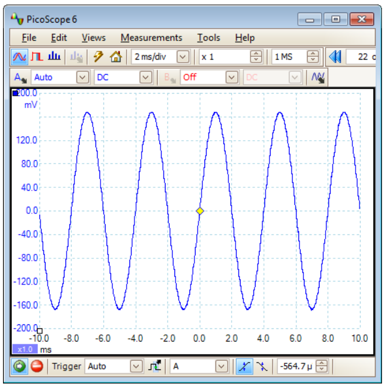


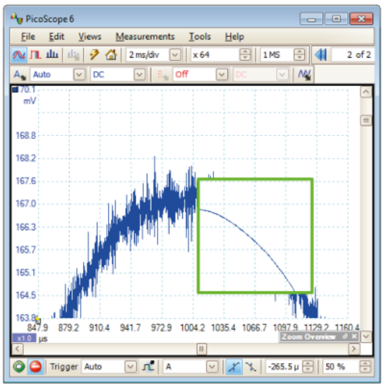


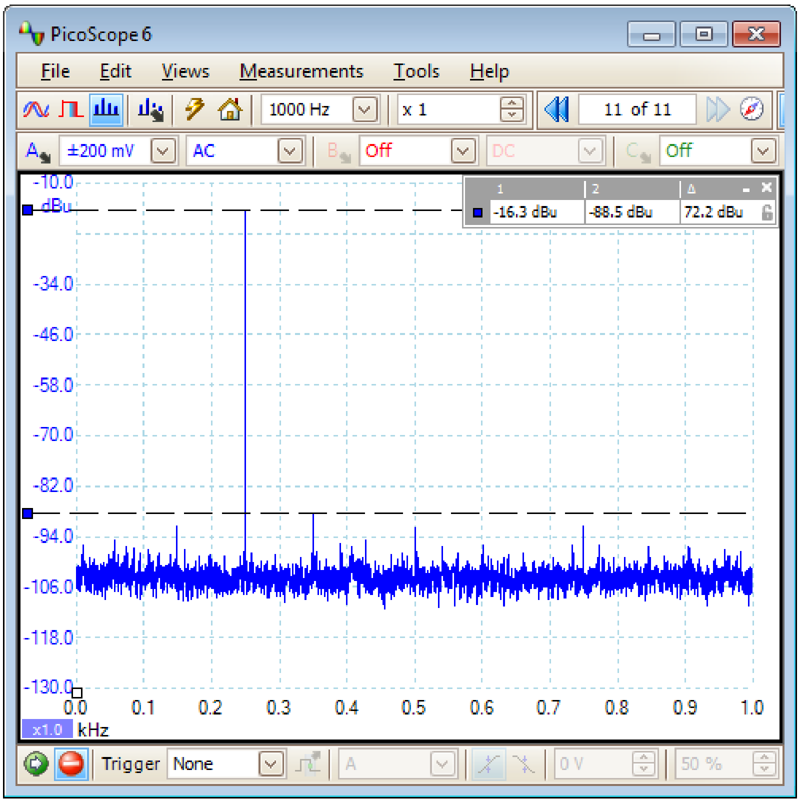
3.3 16-bit oscilloscope example

With a 16-bit PicoScope 4262 oscilloscope, the x64 trace is cleaner, although of course the noise due to the signal source is still visible. (The inset picture shows the effect of a 10 kHz digital filter applied by PicoScope.)

The spectrum view shows the same harmonic spurs and SFDR as obtained with the 12-bit scope, indicating that the distortion is due to the signal source and not the scope.







3.4 Spectrum analyzer settings

The spectrum analyzer views above were created using, as closely as possible, the following settings:

- Frequency range: 0 to 1 kHz
- Spectrum bins: ≥ 8k
- Display mode: Average
- Window function: Blackman-Harris

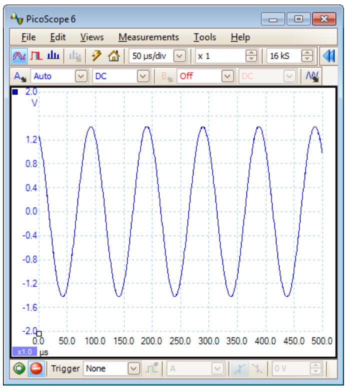
4. Test II: Low-distortion signal generator

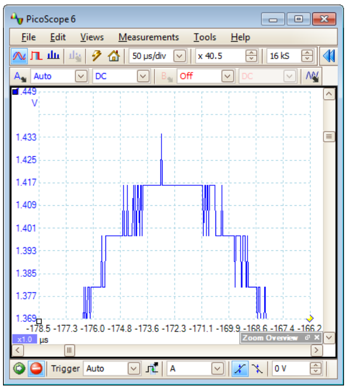
In this test we have replaced the low-cost signal generator with the PicoScope 4262's built-in low-distortion signal generator. This allows us to show the benefits of the very low distortion in the PicoScope 4264's front end. The generator was set to produce a 10 kHz sine wave with 990 mV amplitude.

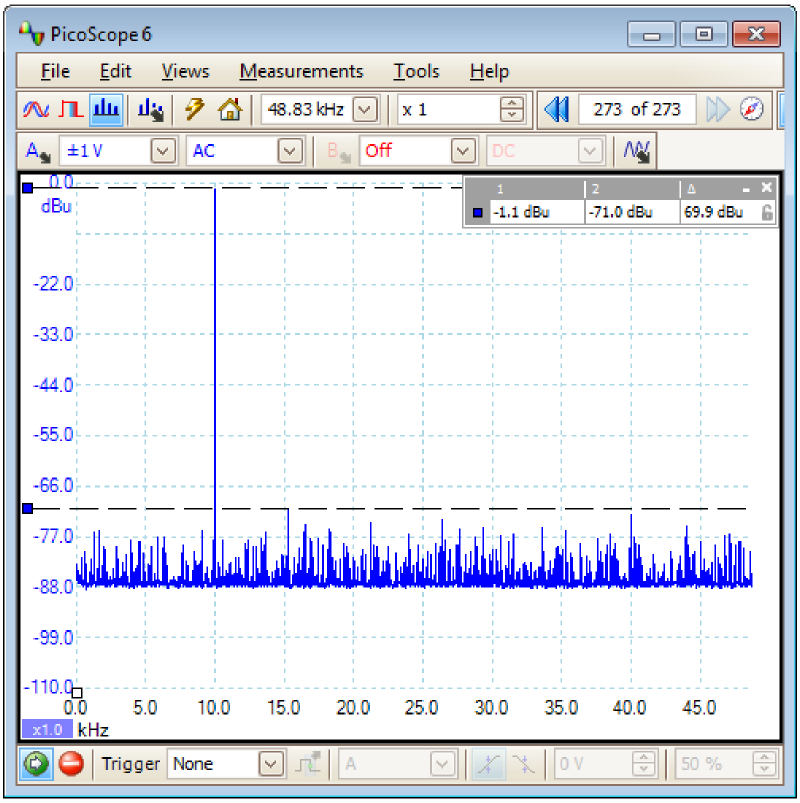
4.1 8-bit oscilloscope example

As in the previous test, the 8-bit scope is adequate for viewing the overall shape of the waveform (upper left) but shows its limitations when the display is zoomed in 64 times (lower left).

The FFT spectrum analyzer plot (right) shows the 10 kHz fundamental. If there are any other components in the signal, they are masked by the noise floor about 70 dB below the peak.

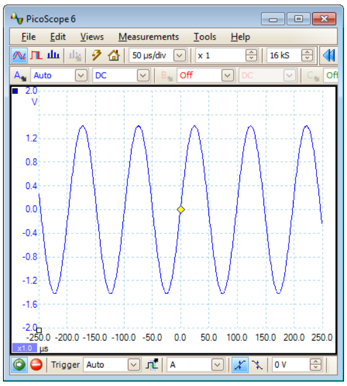


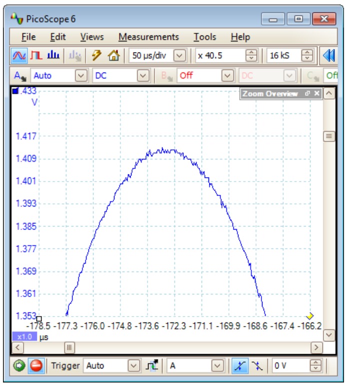


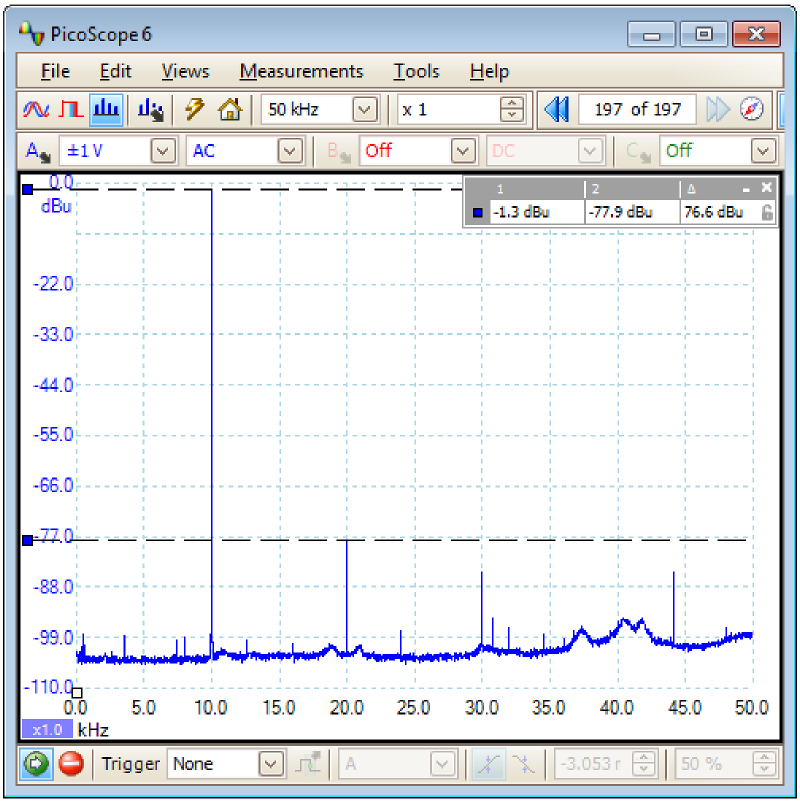


4.2 12-bit oscilloscope example

The same signal captured with a PicoScope 4423 12-bit oscilloscope looks the same in the normal scope view. The x64 view looks much cleaner, with very little noise and the digitization steps only just visible. In the spectrum view, the noise floor is now low enough to show some harmonics and other spurious signals reaching to about 76 dB below the 10 kHz peak. At this stage we do not know whether these are due to the scope or the signal generator.

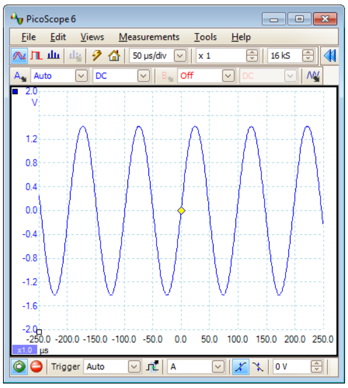


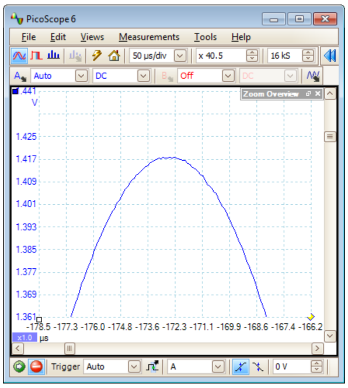


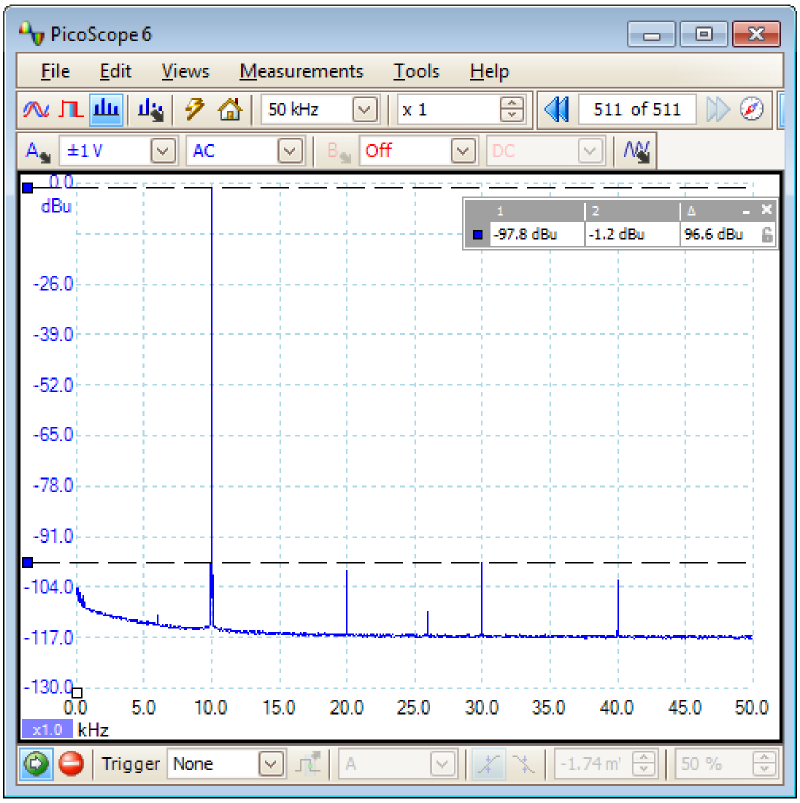


4.3 16-bit oscilloscope example

With a 16-bit PicoScope 4262 oscilloscope, the x64 trace is smooth and noise-free, with no sign of distortion caused by digitization. The spectrum trace shows an SFDR of about 96 dB, with a much lower noise floor than that of the 12-bit scope. The distortion peaks are 20 dB lower than those seen by the 12-bit scope, indicating that most of the distortion seen in the previous test was due to the limitations of the 12-bit scope and not the signal generator.







4.4 Spectrum analyzer settings

The spectrum analyzer views above were created using, as closely as possible, the following settings:

- Frequency range: 0 to 50 kHz
- Spectrum bins: ≥ 8k
- Display mode: Average
- Window function: Blackman-Harris

A suitable number of spectrum bins was chosen to place the FFT noise floor below the signals of interest for each oscilloscope.

Terminology

FFT	Fast Fourier Transform
SFDR	spurious-free dynamic range
DSO	digital storage oscilloscope
ppm	parts per million