Bit Resolution Enhancement

REV: 01
May. 18, 2013

The objective of this article is to illustrate the advantages of the hardware DSP based bit resolution enhancement function of the second-generation VT DSOs, a unique feature not found in any other USB DSOs at the time of this article.

TABLE OF CONTENTS

1. Introduction

Hardware DSP based bit resolution enhancement is a unique feature that is only found in the second-generation VT DSOs. 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.

The second-generation VT DSOs have three modes regarding bit resolution: 16-Bit Mode, Enhanced 8-Bit Mode and 8-Bit Mode.

(1) 16-Bit Mode

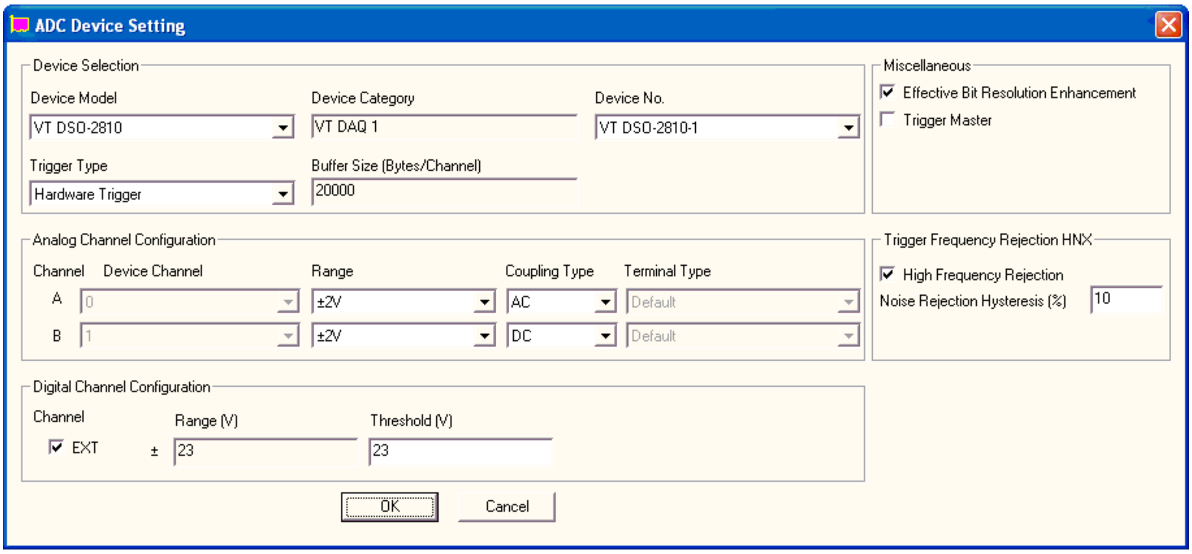
To use the bit resolution enhancement feature, select “16Bit” in the Sampling Bit Resolution combo box in the Sampling Parameter Toolbar of the Multi-Instrument software (a powerful multi-function virtual instrument software, downloadable at: www.virtins.com/Misetup.exe). The actual effective bit resolution achieved depends on the sampling frequency used and the nature of the background noise, and can go up 16 bits. We take VT DSO-2810 as an example. It has a maximum sampling rate of 1 × 100 MHz or 2 × 50 MHz. The following table shows its effective bit resolutions at different sampling rates.

(VT DSO-2810, assuming white background noise)

Sampling Frequency	Effective Bit Resolution	Sampling Frequency	Effective Bit Resolution
≥ 40 MHz	8 Bits	≤ 10 MHz	9 Bits
≤ 2.5 MHz	10 Bits	≤ 625 kHz	11 Bits
≤ 156 kHz	12 Bits	≤ 39 kHz	13 Bits
≤ 9.8 kHz	14 Bits	≤ 2.4 kHz	15 Bits
≤ 610 Hz	16 bits		

(2) Enhanced 8-Bit Mode

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.



(3) 8-Bit Mode
If "8Bit" is selected and [Setting]>[ADC Device] > "Effective Bit Resolution Enhancement" is not enabled, then the oscilloscope is in 8-Bit Mode.

Oscilloscopes are generally not considered as accurate voltage measurement devices when compared with multimeters. This is especially true as most of the digital storage oscilloscopes in the market are 8-bit ADC devices. With the bit resolution enhancement feature in the second-generation VT DSOs, together with the user-adjustable gain and offset for each voltage measuring range, it is possible for the second-generation VT DSOs to achieve a DC measurement accuracy comparable to that of 3 ½ multimeters.

In the following sections, we will use VT DSO-2810, a second-generation 8~16bit USB DSO, as an example to compare the noise level, THD, IMD, SFDR among the three modes: 8-bit, Enhanced 8-bit, 16-bit. The results will also be compared with those from VT DSO-2810H, a first-generation 8-bit USB DSO. As one of the major USB oscilloscope manufacturers in the market uses software DSP based bit resolution enhancement in most of its products, we will also show how to implement the same feature in Multi-Instrument and its drawbacks as compared with the hardware DSP based method featured in our second-generation USB DSOs.

2. Noise Level and Effective Resolution Measurements

Noise Level is defined as:

[Noise Level] = 20 × log([RMS voltage of noise]/[Full-scale voltage]).

It was measured from 0Hz to ½ of the sampling rate with the input of the DSO grounded.

Effective Resolution can be derived from Noise Level via:

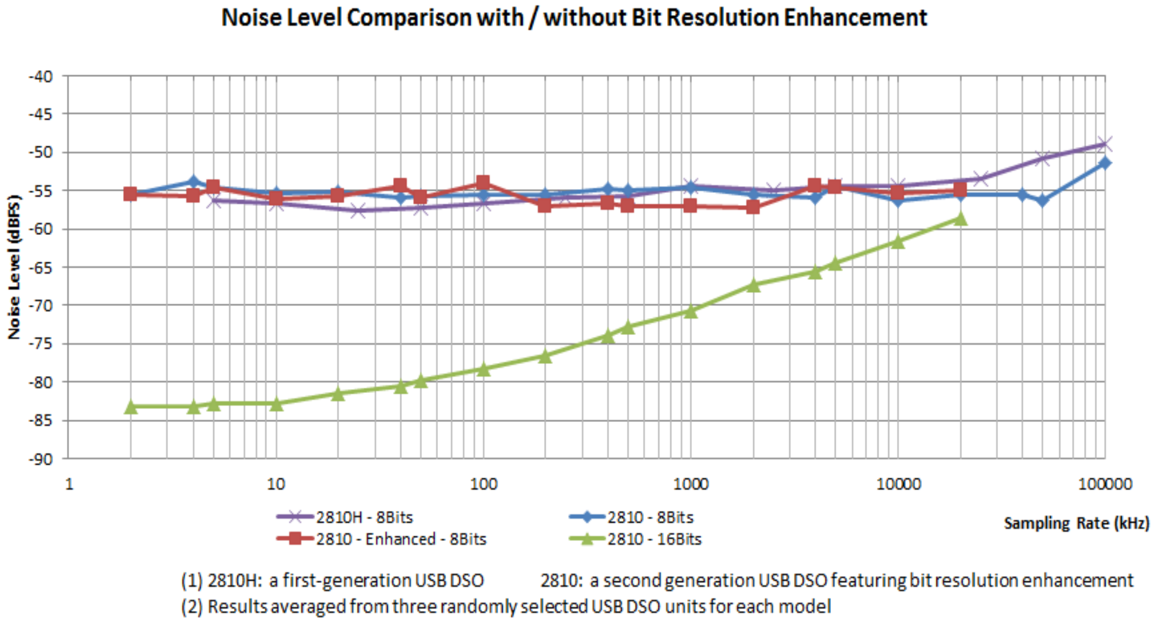
[Effective Resolution] = -[Noise Level] / (20 × log2) = -0.1661 × [Noise Level]

The following table lists some Effective Resolutions and their corresponding Noise Levels.

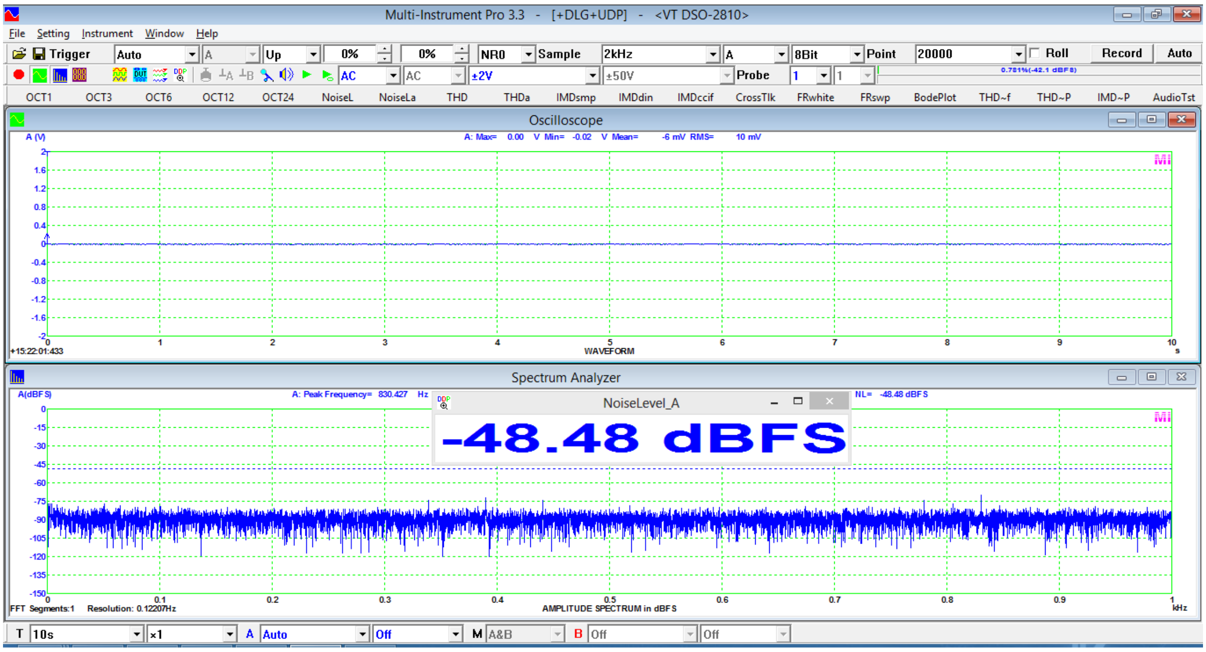
Effective Resolution	Noise Level
6 bits	-36.1 dBFS
7 bits	-42.1 dBFS
8 bits	-48.2 dBFS
9 bits	-54.2 dBFS
10 bits	-60.2 dBFS
11 bits	-66.2 dBFS
12 bits	-72.2 dBFS
13 bits	-78.3 dBFS
14 bits	-84.3 dBFS
15 bits	-90.3 dBFS
16 bits	-96.3 dBFS

Effective Resolution vs Noise Level

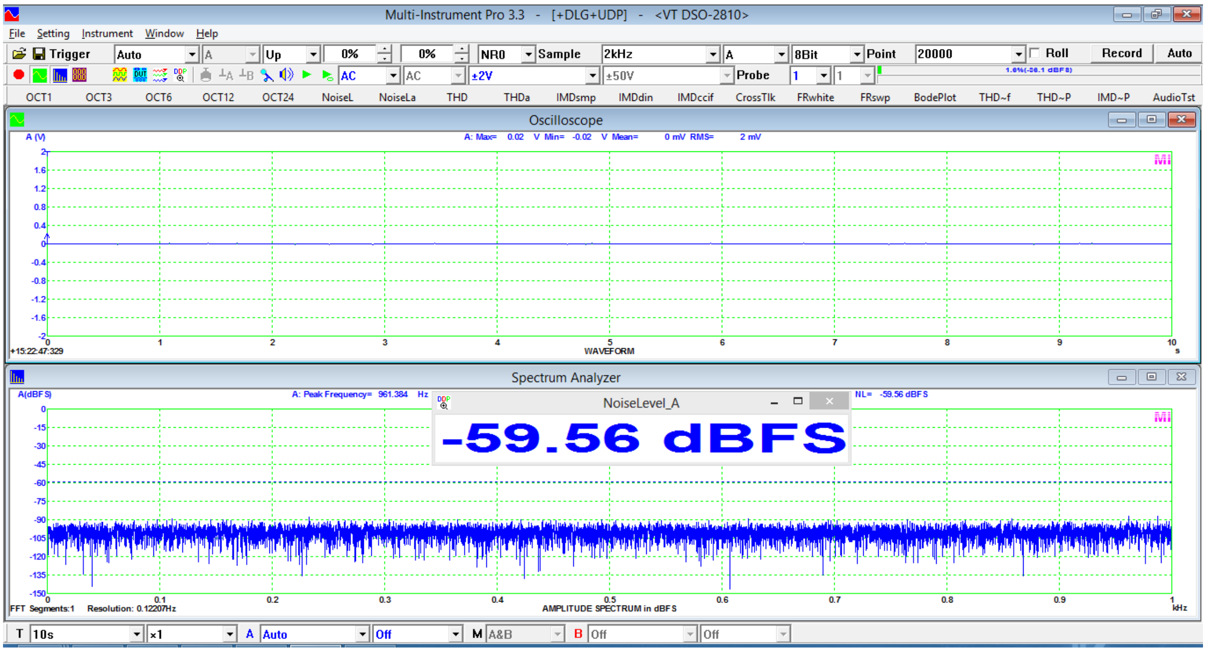
The following figure summarizes the noise level measured under 8-Bit, Enhanced 8-Bit and 16-Bit modes of VT DSO-2810 for different sampling rates. The noise level from VT DSO-2810H is also shown for comparison. The figure shows that, while for the cases of 2810-8Bits, 2810-Enhanced-8Bits and 2810H-8Bits, the Noise Levels are more or less the same and do not change with the sampling rate, it improves substantially for the case of 2810-16Bits: the lower the sampling rate, the lower the noise level.



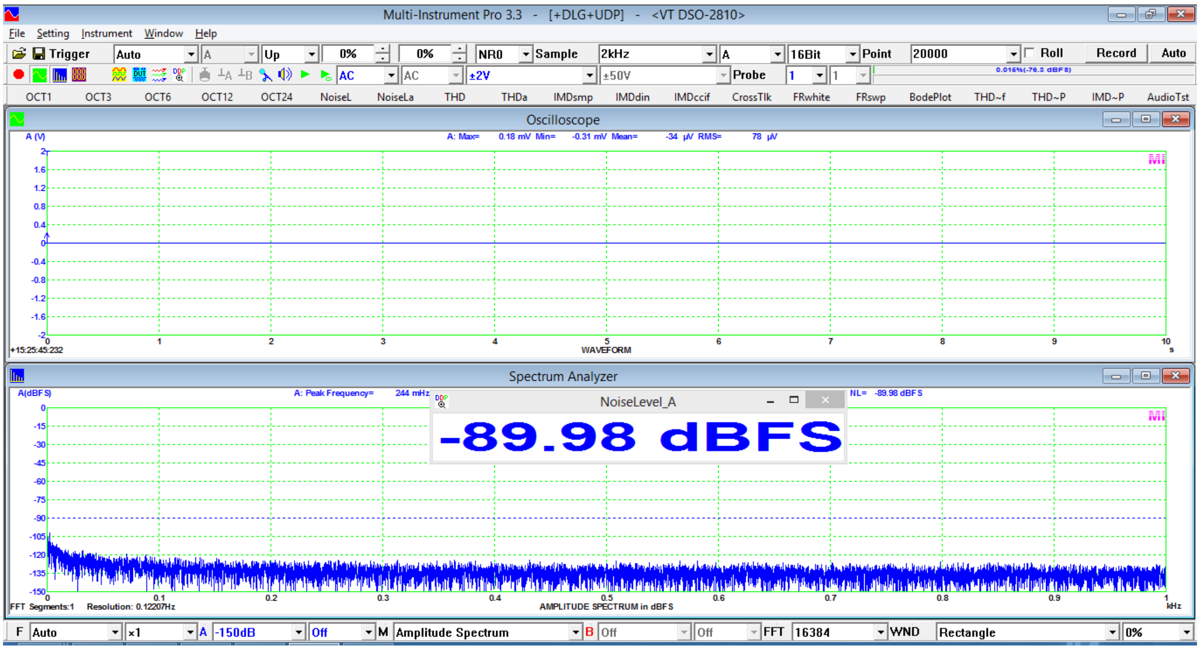
The following figure shows the noise level measurements of a VT DSO-2810 under 8-Bit, enhanced 8-Bit and 16-Bit modes respectively, with a sampling rate of 2kHz. The measured noise level under 16-Bit Mode at the sampling rate of 2kHz is equivalent to an effective resolution of 15 bits while that under 8-bit Mode is equivalent to an effective resolution of 8 bits.



Noise Level measurement of a VT DSO-2810, 8-Bit Mode, f_s = 2kHz

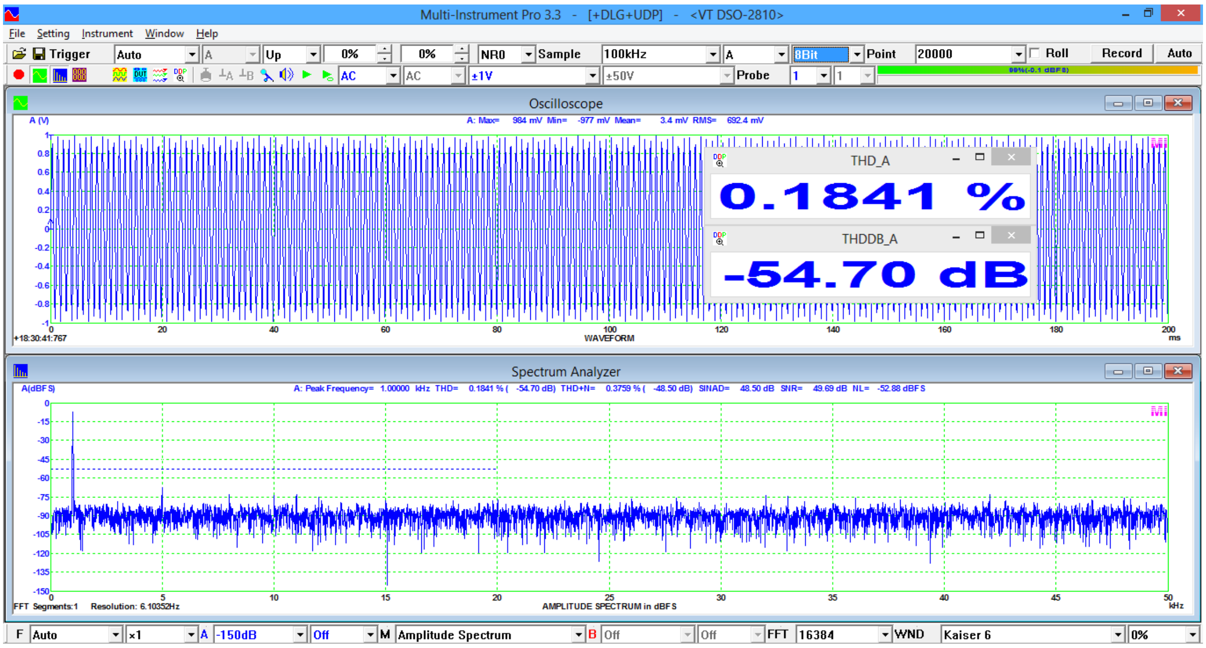


Noise Level measurement of a VT DSO-2810, Enhanced 8-Bit Mode, f_s = 2kHz

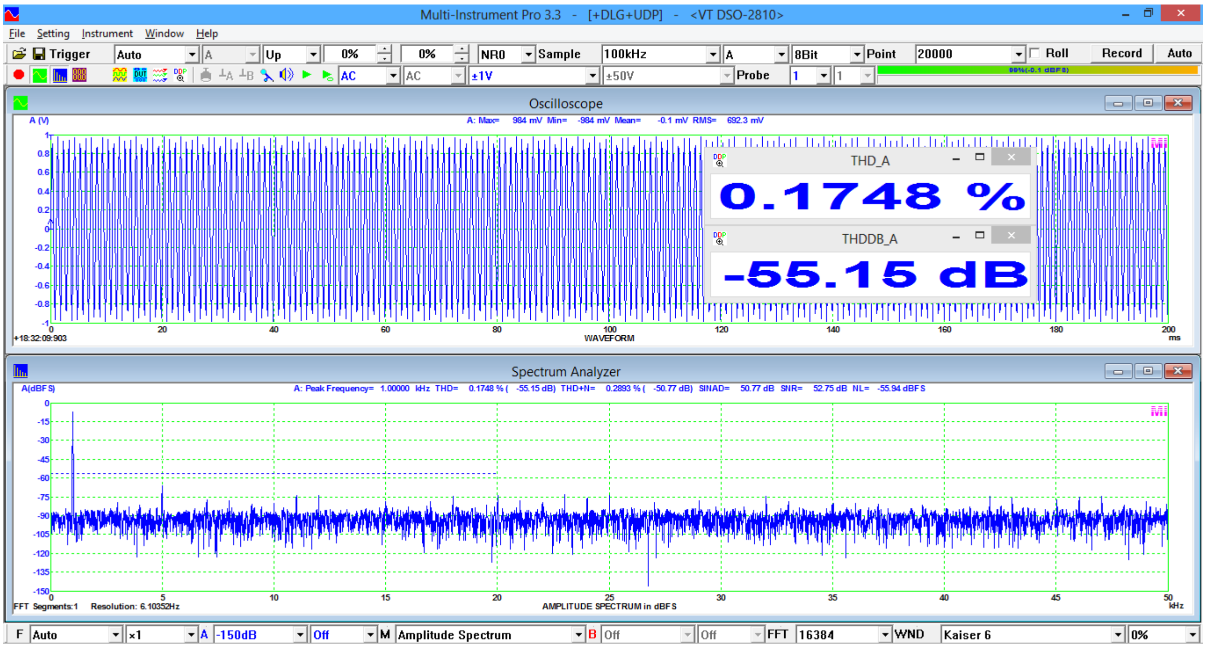


Noise Level measurement of a VT DSO-2810, 16-Bit Mode, f_s = 2kHz

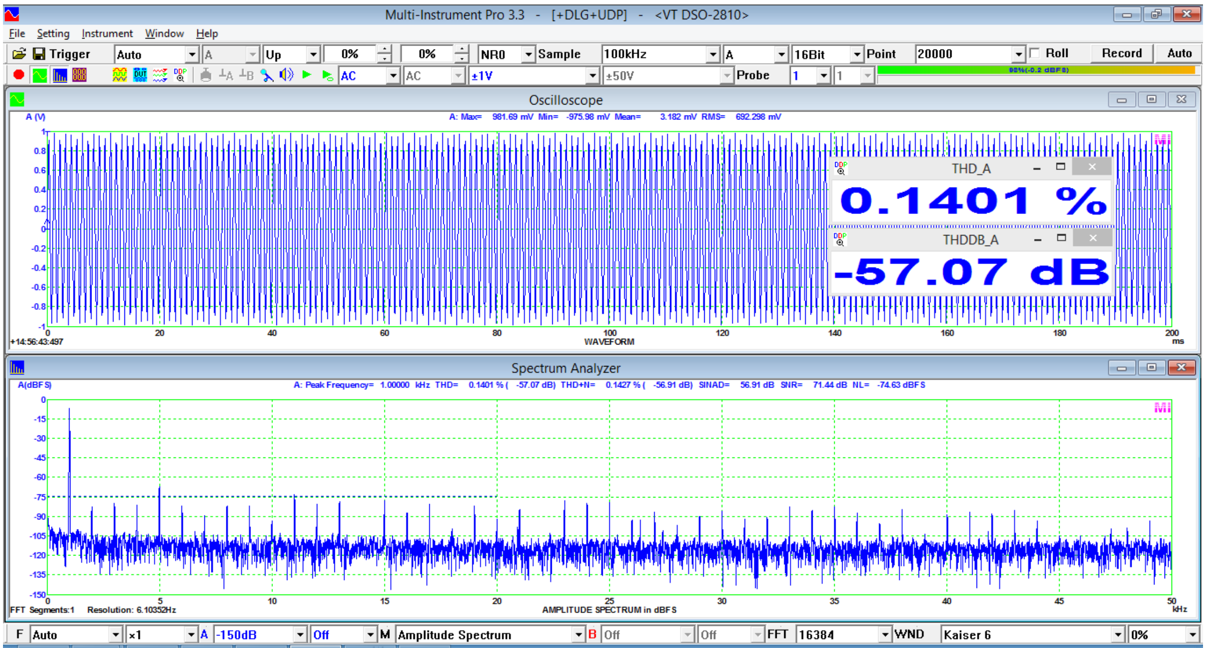
3. THD Measurements



THD Measurement of a VT DSO-2810, 8-Bit Mode
f_s=100kHz, f=1kHz, from 2nd to 20th order, full-scale input



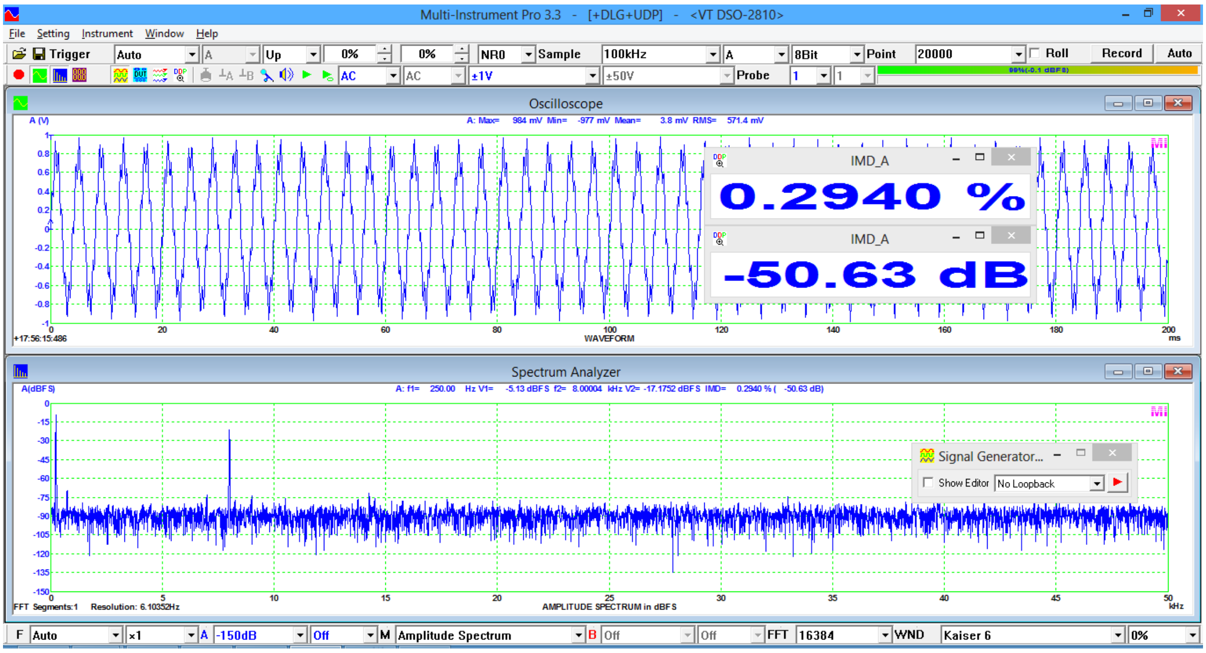
THD Measurement of a VT DSO-2810, Enhanced 8-Bit mode
f_s=100kHz, f=1kHz, from 2nd to 20th order, full-scale input



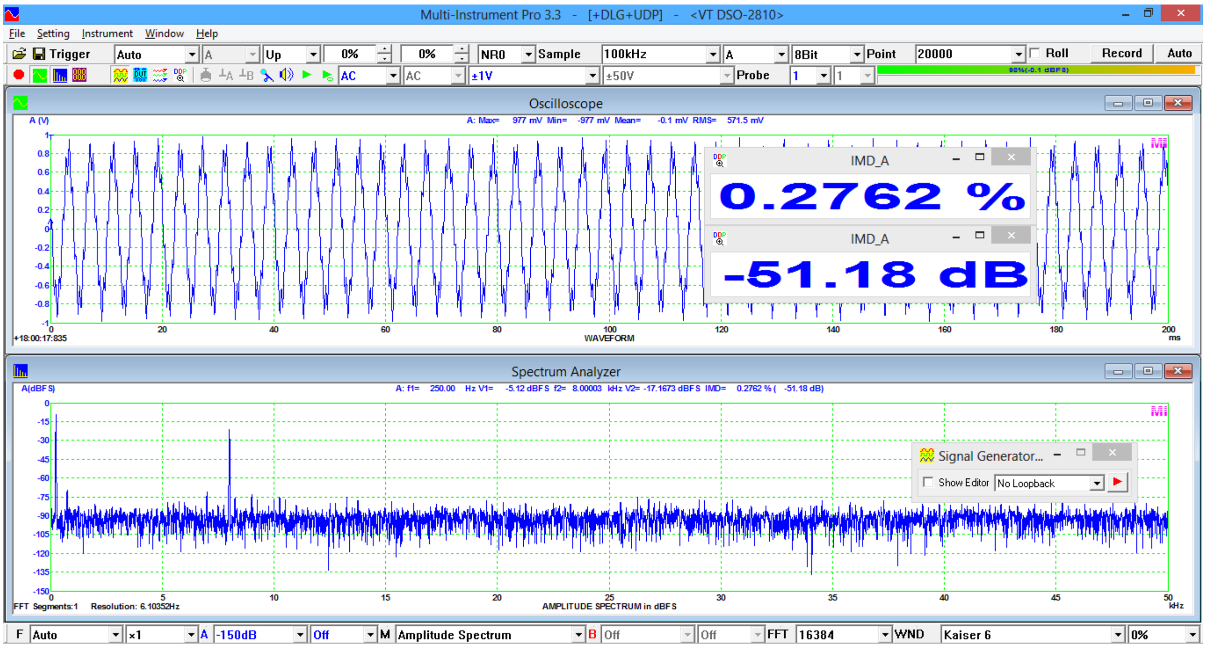
THD Measurement of a VT DSO-2810, 16-Bit mode
f_s=100kHz, f=1kHz, from 2nd to 20th order, full-scale input

The above figures show that only marginal improvement in THD is achieved under 16-Bit Mode. The improvement is due to the improved computing resolution rather than any improvement in analog aspect.

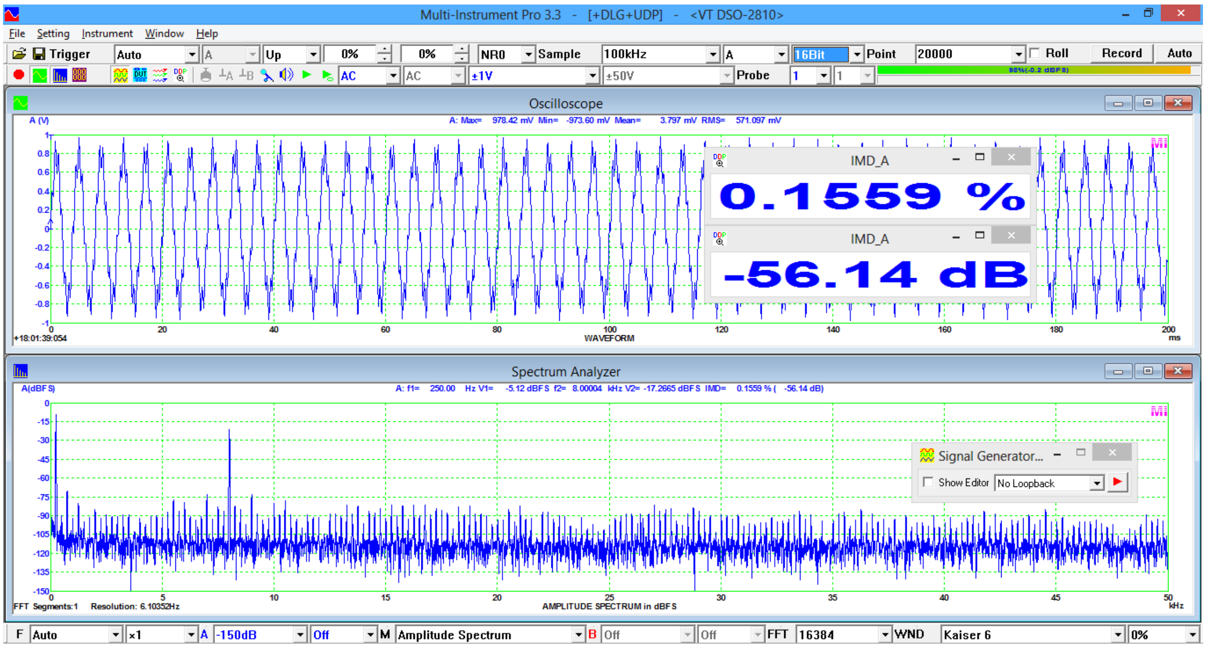
4. IMD DIN Measurements



IMD DIN Measurement of a VT DSO-2810, 8-Bit Mode
f_s=100kHz, (250Hz+8kHz, 4:1), full-scale input



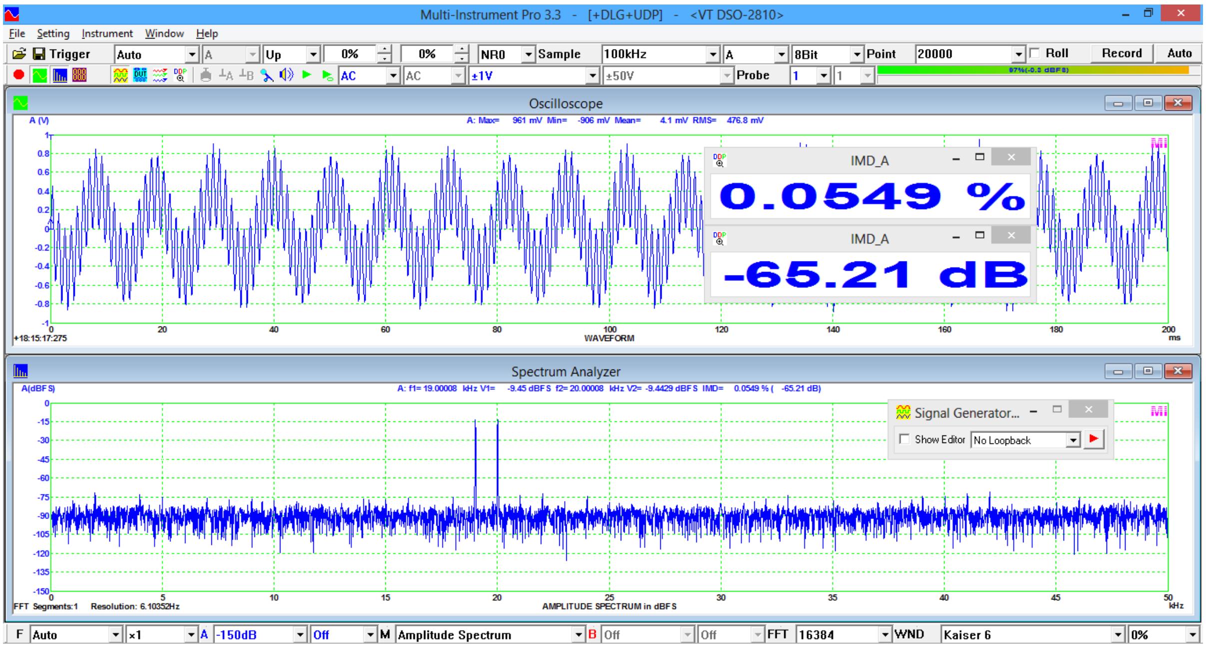
IMD DIN Measurement of a VT DSO-2810, Enhanced 8-Bit Mode
f_s=100kHz, (250Hz+8kHz, 4:1), full-scale input



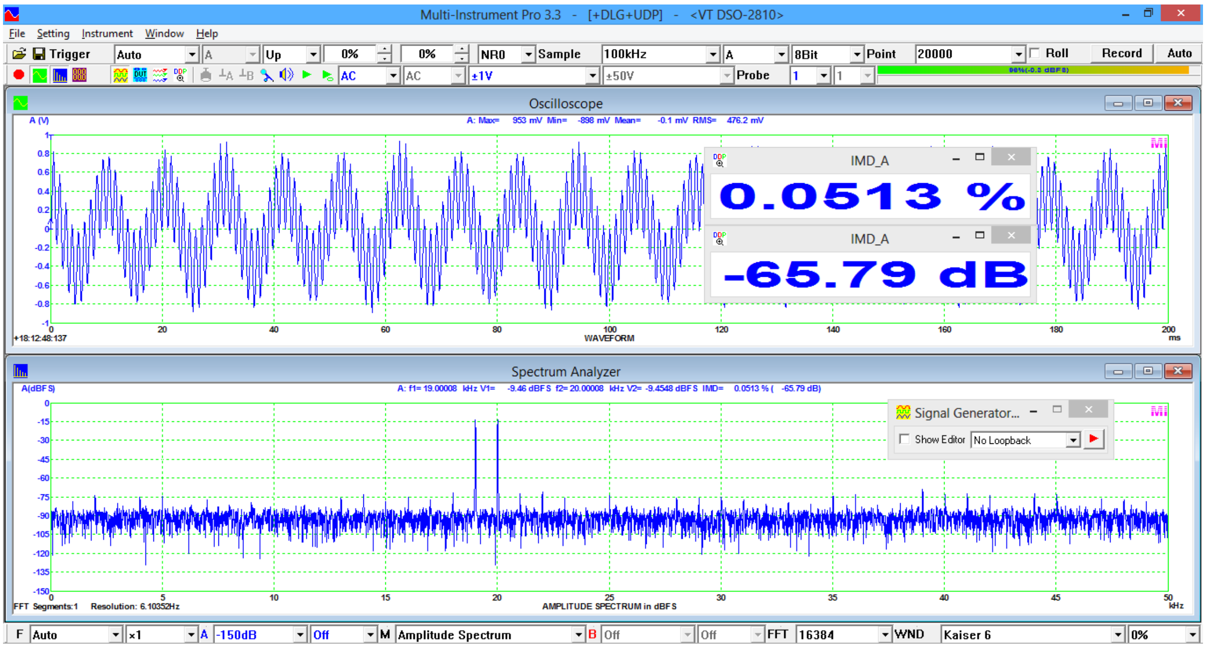
IMD DIN Measurement of a VT DSO-2810, 16-Bit Mode
f_s=100kHz, (250Hz+8kHz, 4:1), full-scale input

The above figures show that some improvement is achieved in IMD DIN under 16-bit Mode. The improvement is due to the improved computing resolution rather than any improvement in analog aspect.

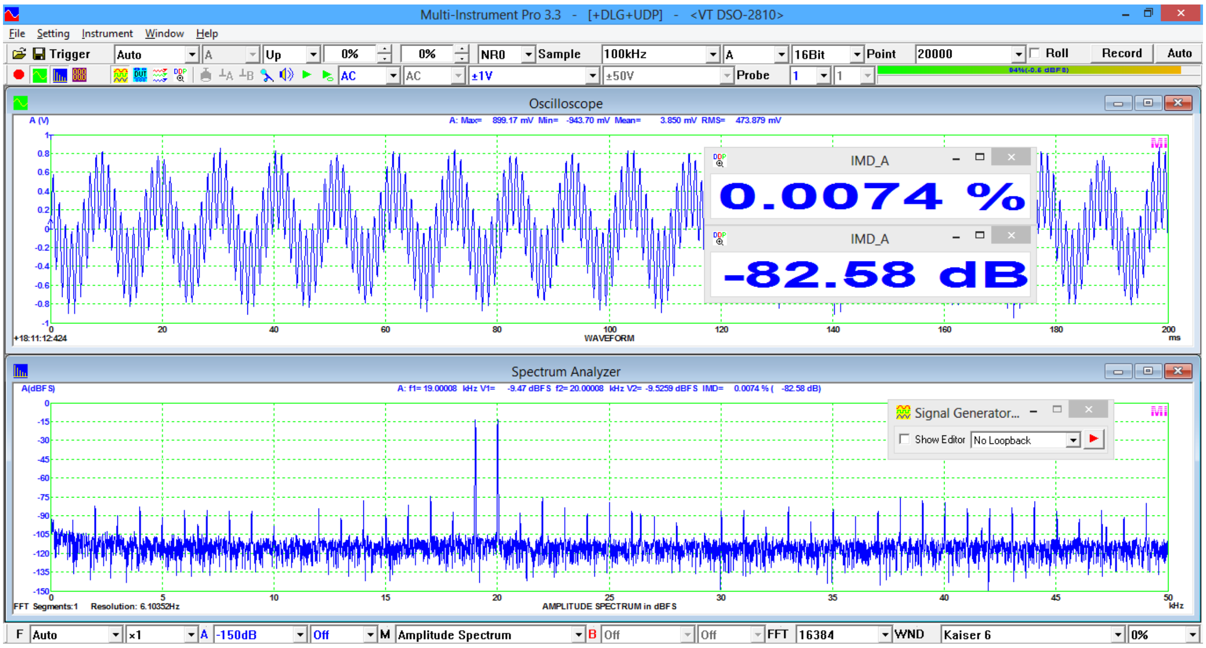
5. IMD CCIF Measurements



IMD CCIF Measurement of a VT DSO-2810, 8-Bit Mode
f_s=100kHz, (19kHz+20kHz, 1:1), full-scale input



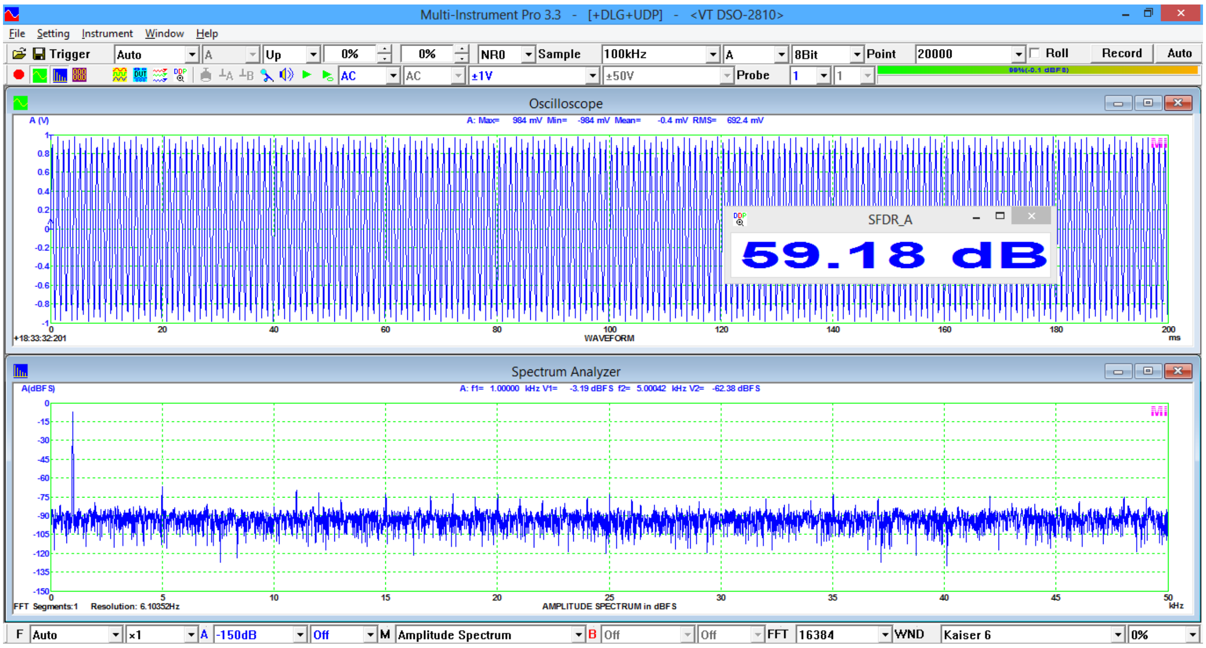
IMD DIN Measurement of a VT DSO-2810, Enhanced 8-Bit Mode
f_s=100kHz, (19kHz+20kHz, 1:1), full-scale input



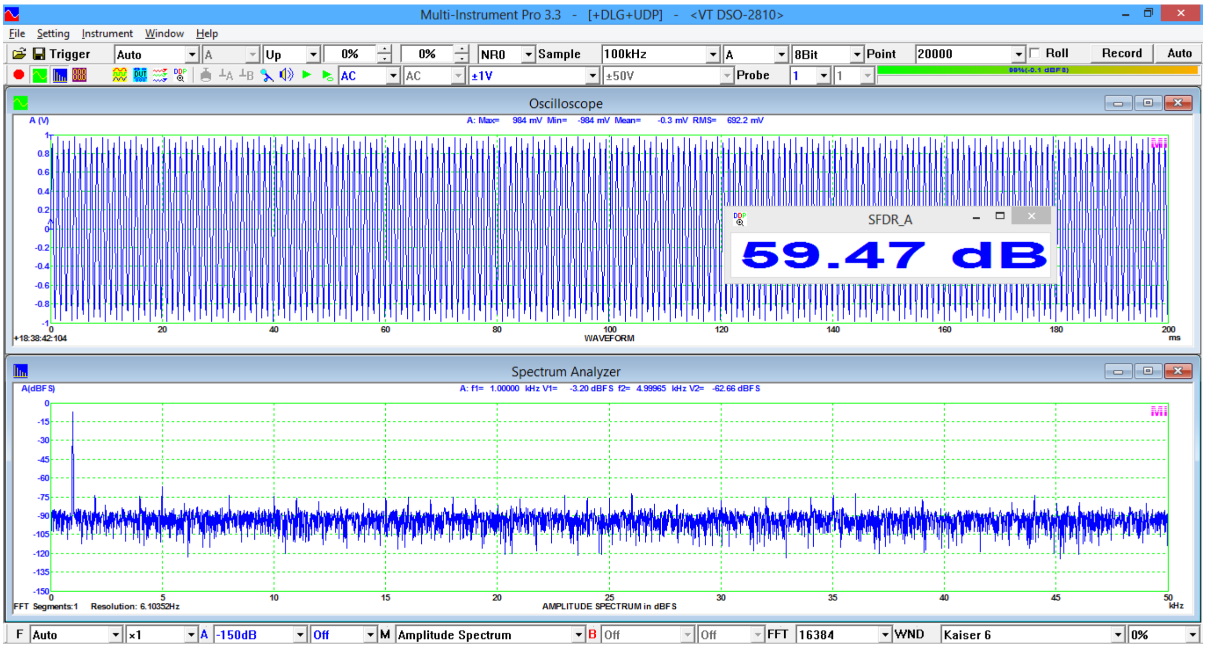
IMD DIN Measurement of a VT DSO-2810, 16-Bit Mode
f_s=100kHz, (19kHz+20kHz, 1:1), full-scale input

The above figures show that some improvement is achieved in IMD CCIF2 under 16-bit Mode. The improvement is due to the improved computing resolution rather than any improvement in analog aspect.

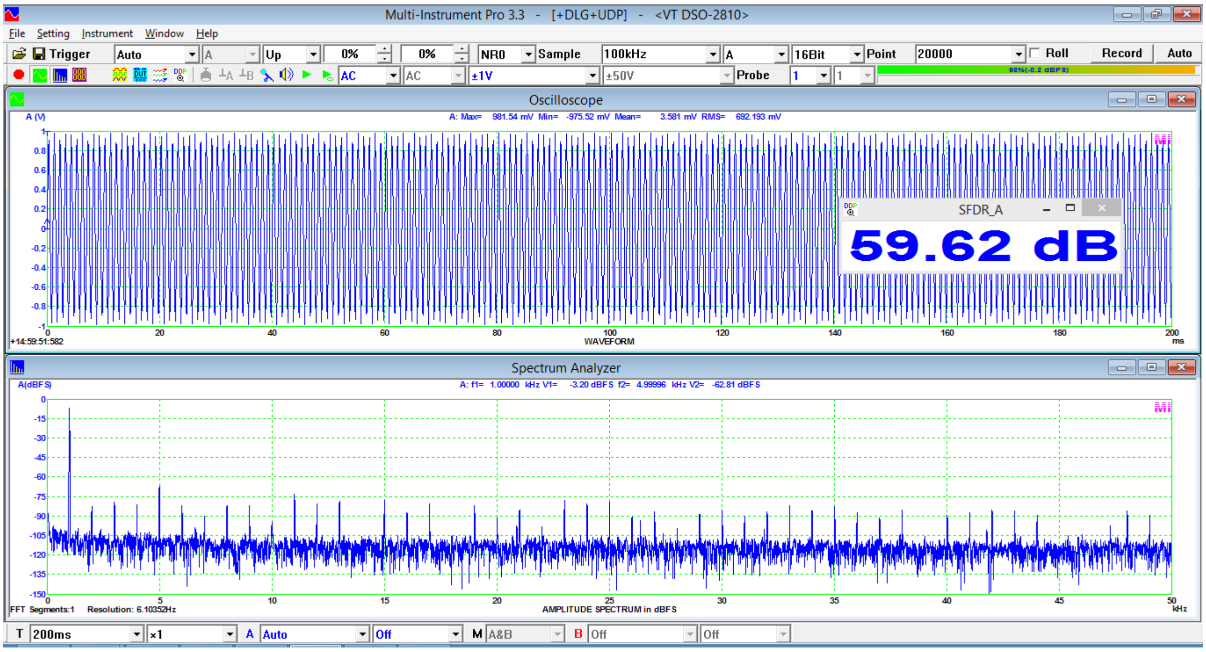
6. SFDR Measurements



SFDR Measurement of a VT DSO-2810, 8-Bit Mode
f_s=100kHz, f=1kHz, full-scale input



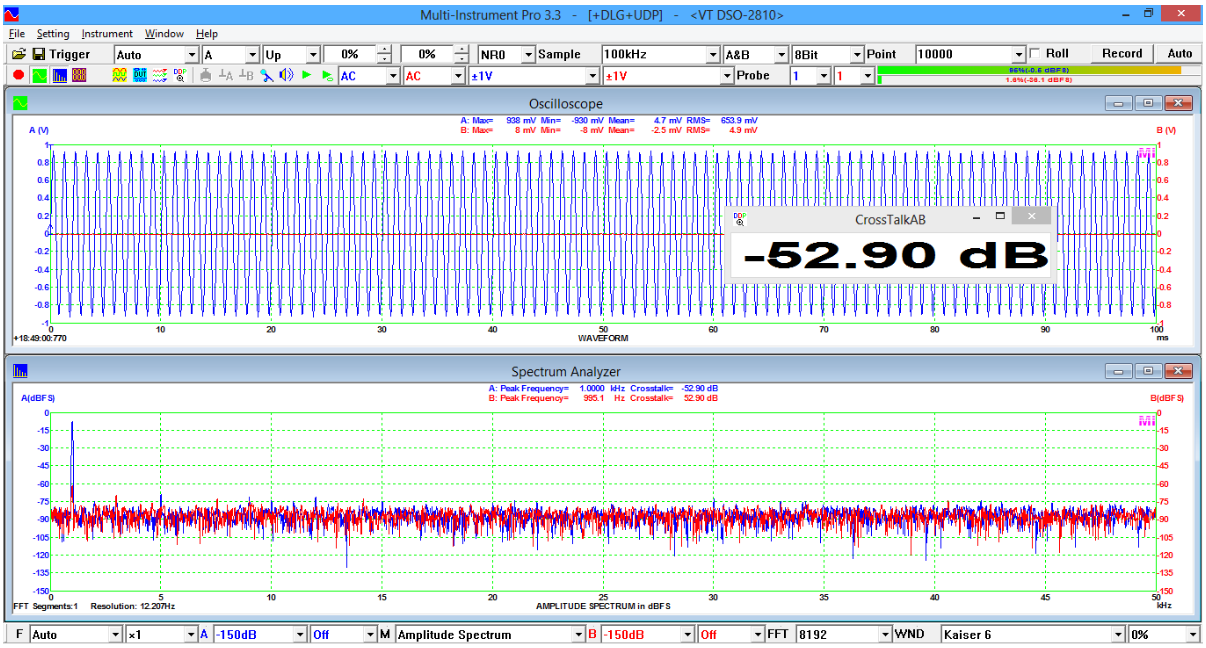
SFDR Measurement of a VT DSO-2810, Enhanced 8-Bit Mode
f_s=100kHz, f=1kHz, full-scale input



SFDR Measurement of a VT DSO-2810, 16-Bit Mode
f_s=100kHz, f=1kHz, full-scale input

The above figures show that little improvement is achieved in SFDR under 16-bit Mode.

7. Crosstalk Measurements



Crosstalk Measurement of a VT DSO-2810, 8-Bit Mode
f_s=100kHz, f=1kHz, full-scale input

Crosstalk Measurement of a VT DSO-2810, Enhanced 8-Bit Mode
f_s=100kHz, f=1kHz, full-scale input

Crosstalk Measurement of a VT DSO-2810, 16-Bit Mode
f_s=100kHz, f=1kHz, full-scale input

The above figures show that no improvement is achieved in Crosstalk under 16-bit Mode.

8. Hardware DSP based vs Software DSP based

In the second-generation VT DSOs, 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 2^{16}–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.

9. Conclusions

Hardware DSP based bit resolution enhancement is a unique feature in the second-generation VT DSOs. It allows an 8-bit ADC device to output samples with effective resolution up to 16 bits at the cost of sampling rate. The improved effective resolution is accompanied by substantially lower noise level. Some improvement in THD, IMD, SFDR and Crosstalk may be observed under 16-Bit Mode. However, the improvement is due to the improved computing resolution rather than any improvement in analog aspect.

Bit resolution enhancement can be achieved using either hardware or software method or both. Hardware DSP based method is superior than the software one as it does not cause any loss in high frequency detail allowed by the sampling rate.

Despite the lower effective resolution, as compared to 16-Bit Mode, both 8-Bit Enhancement Mode and 8-Bit Mode have a faster data transfer rate when streaming mode is used. This allows a faster sampling rate to be used for continuous streaming. When the background noise is low, there is almost no discernible improvement in Noise Level, THD, IMD, SFDR and Crosstalk under Enhanced 8-Bit Mode. Occasionally, some of these parameters may become even a little worse than those under 8-Bit Mode. The advance of Enhancement 8-Bit Mode becomes obvious as the background noise increases.

