14/10/2022 - Undersampling of microwave AWG

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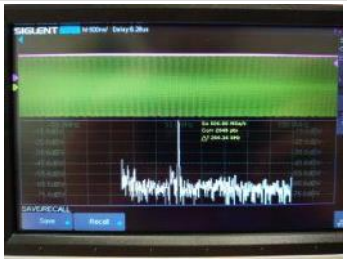
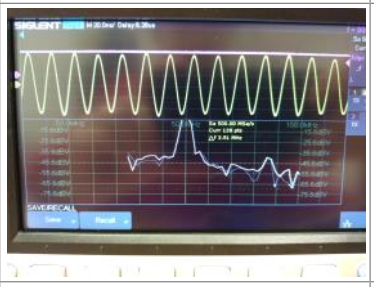
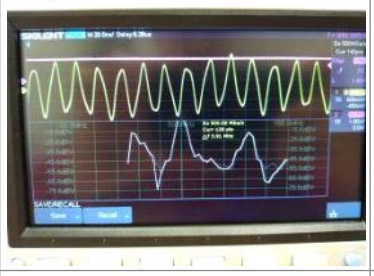
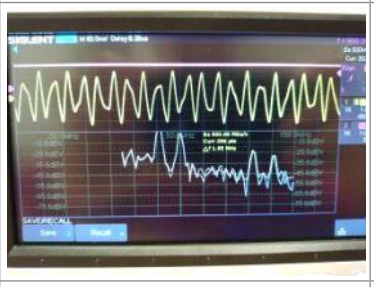
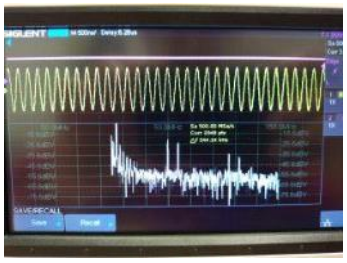
Today I want to debug the strange sampling issues of the Siglent AWG, more particularly the fact that the waveform sent by the AWG looks shitty for some values of the waveform duration (t_max).

For this I test a simple sine waveform on a spare Siglent AWG (model: SDG6022X).
The AWG is triggered externally and I visualize the output of CH1 on a scope. The waveform is a single square pulse with duration t_max and fixed frequency 50MHz.

We observe that when t_max is increased, the purity of the signal gets worse (the amplitude plays no role here). Here are some photos of the screen of the oscilloscope for various values of the pulse duration:

Pulse duration t_{max}	**Number of desired points in the wavefunction**	**Measured time and frequency signals on the scope**	**Measured time signal on the scope (zoom)**	**Time step δt (if visible)**	**$t_{max}/\delta t$**
10 ns	24e3			No visible time step, the signal looks smooth and sinusoidal	
100 ns	240e3			Quite smooth, but the spectral purity of the signal is worse around 50 MHz.	
200 ns	480e3			6 ns	33e3
400 ns	960e3			12 ns	33e3

600 ns	1440e3			18 ns	33e3
1000 ns	2400e3			30 ns	33e3

Parameters: frequency=50MHz, DDS mode, amplitude = 4 Vpp. Program for communicating with the AWG: C:\Users\Gabriel Emperauger\Dropbox \CHADOQ\CondeTrol\2020\test_AWG_control_siglent.py.

This shows that the AWG undersamples the waveform when the number of points gets too high. From the calculation of $t_{max}/\delta t$, it looks like the **number of points in the waveform saturates at about 33e3** (which is more or less 2^15=32 768). I think this comes from the fact that in DDS mode (Direct Digital Synthesis), the AWG recalculates the number of points in the waveform depending on the duration of the waveform.

Interestingly, **this phenomenon disappears when the mode of the AWG is set to TrueArb**. However this mode has the drawback that the sampling rate cannot go higher than 300MSa/s (VS 2400 Msa/s in DDS mode).
Comparison of DDS and TrueArb modes:

AWG mode	DDS	TrueArb
Principle	Uses a fixed clock frequency and a phase accumulator to generate the waveform The sampling rate is decided by the program.	Uses a variable-frequency clock followed by a Digital-analog converter. The sampling rate is the one decided by the user.
Sampling rate	<2400 MSa/s Typically 1200 MSa/s	< 300 MSa/s
Number of points in the waveform	< 33 000	< 20 000 000
Limiting factors	Given a duration t_{max}, the smallest achievable time step is $\delta t = \frac{t_{max}}{33\,000}$ which corresponds to a maximum frequency of $f_{Nyquist} = \frac{1}{2\delta t} = \frac{16\,000}{t_{max}}$ which is 1.6 GHz for $t_{max} = 10\mu s$. + Risk of bad sampling due to the fact that the program decides the sampling rate. + Bad response to phase and frequency discontinuities.	The smallest achievable time step is $\delta t = \frac{1}{300\,000\,000} = 3$ ns which corresponds to a maximum frequency of $f_{Nyquist} = \frac{1}{2\delta t} = 150$ MHz. In principle we want more than 2 points per period, so it is probably not good to use TrueArb for frequencies higher than 100MHz.

More documentation about DDS mode and TruArb mode can be found here:

Choosing a waveform...