SIGNAL ANALYSIS OF A FUNCTION MICROCONTROLLED GENERATOR

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Key Words: function generator, microcontroller, signal analysis, measurement results.
Abstract: The general purpose microprocessor controlled function generator developed in our laboratory is a low cost and easy to use instrument for engineers of all levels: electronics, education, specific research. It is based on the Analogue Devices AD9832 Direct Digital Synthesis (DDS) Generator chip. The controller chip is a Microchip PIC16F877A. After the prototype for this design was built, some measurement results and evaluation of generated signals were necessary. The output sine/square signals were analyzed using Analogue-Digital-Oscilloscope HM1507-2.

1. DESCRIPTION OF ELECTRONIC DEVICES USED IN THE TEST OF THE FUNCTION GENERATOR

The functions generator in Figure 1 was developed based on the PIC 16F877A microcontroller. It was connected to the oscilloscope HM1507-2. Oscilloscope 2, which are user selectable between the analogue and the digital mode, is undoubtedly the most versatile displaying instrument and meet this requirement. Despite of additional functions, SP107 virtual instrument enables the PC to control and receive instrument settings in analogue and digital mode, allowing visualization of signals 4 and sine/square signals checking , data tabulated as seen in 3, Figure 1.

An image of the test stand is shown in Figure 1.

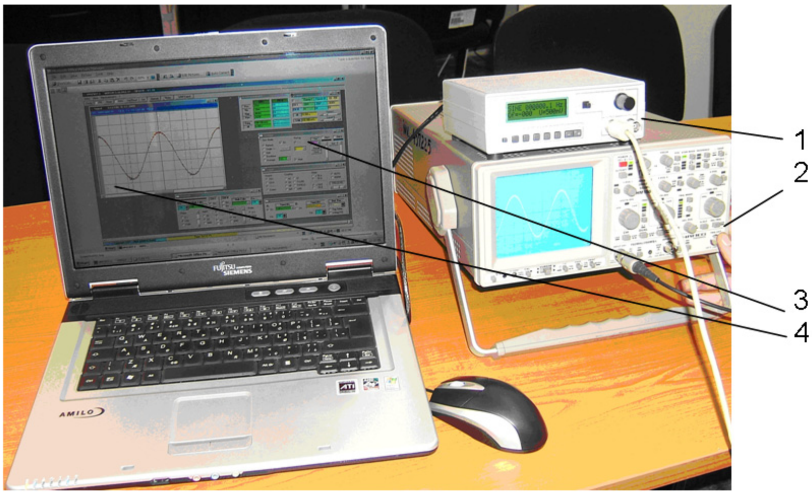

Fig. 1: General Description of the Test Rig
1 –Function Generator, 2 – Oscilloscope HM1507-2, 3 – SP107 Virtual Instrument,
4 – Sinusoidal signal acquired image

Experimental determinations have concerned the use of different frequencies from 0.1 Hz to 990 kHz and voltages between 500 mV and 10 V. Measurements were made using sine/square signals.

2. EXPERIMENTAL RESULTS

The figures below are images of signals obtained for two types of sinusoidal and square signal. Every figure has specified the frequency and voltage applied.

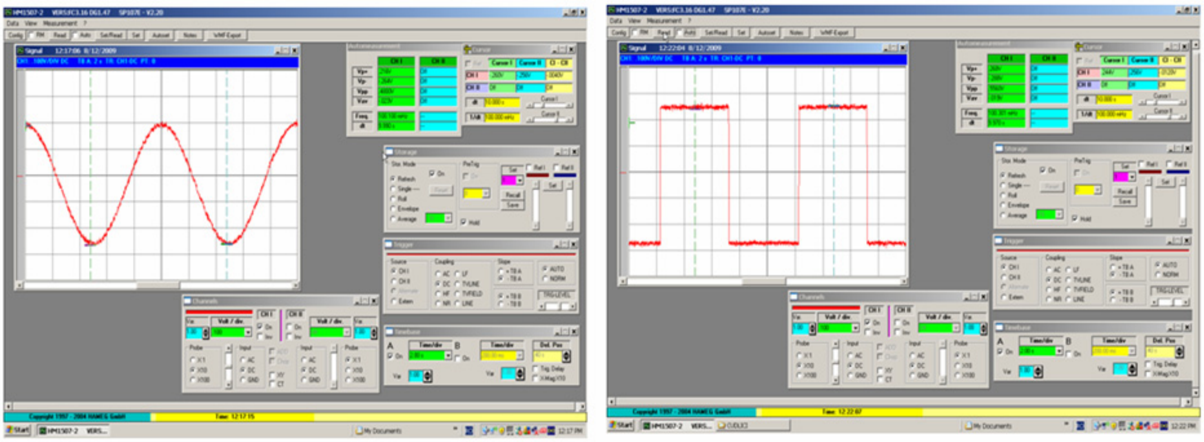

Fig. 2: Sine and square wave 0,1 Hz – 500 mV at 0,1 V/div.

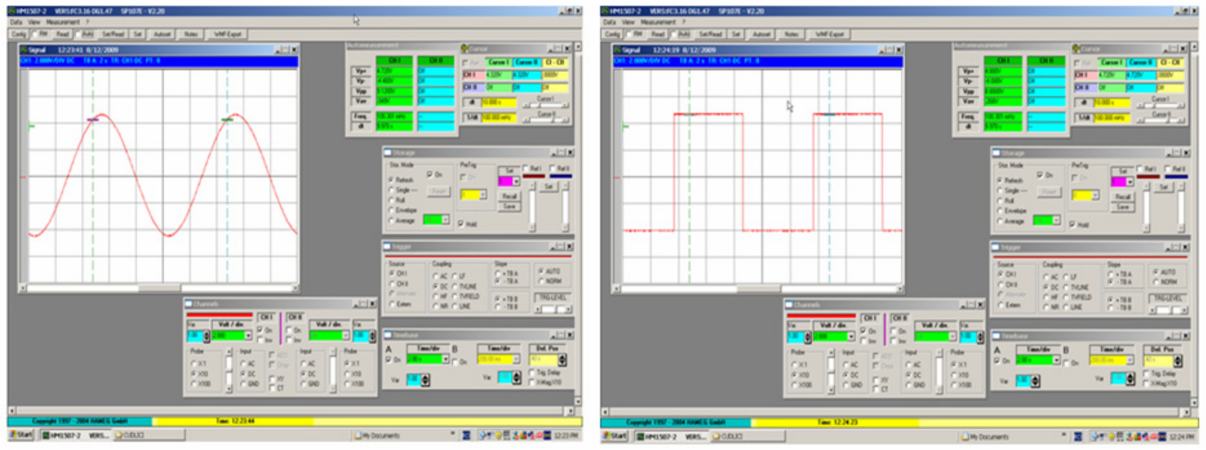

Fig. 3: Sine and square wave 0,1 Hz – 10 V at 2 V/div.

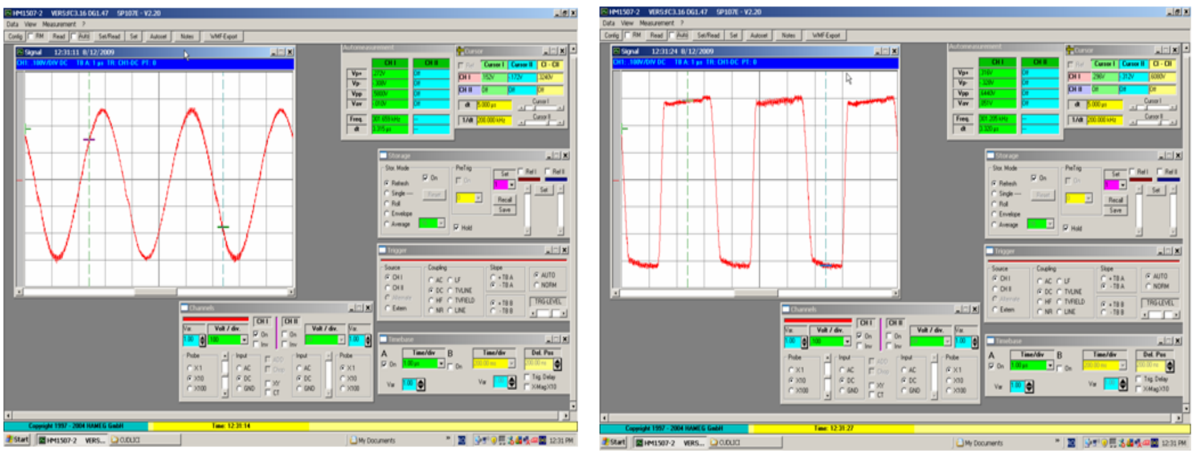

Fig. 4: Sine and square wave 300 kHz – 500 mV at 0,1 V/div.

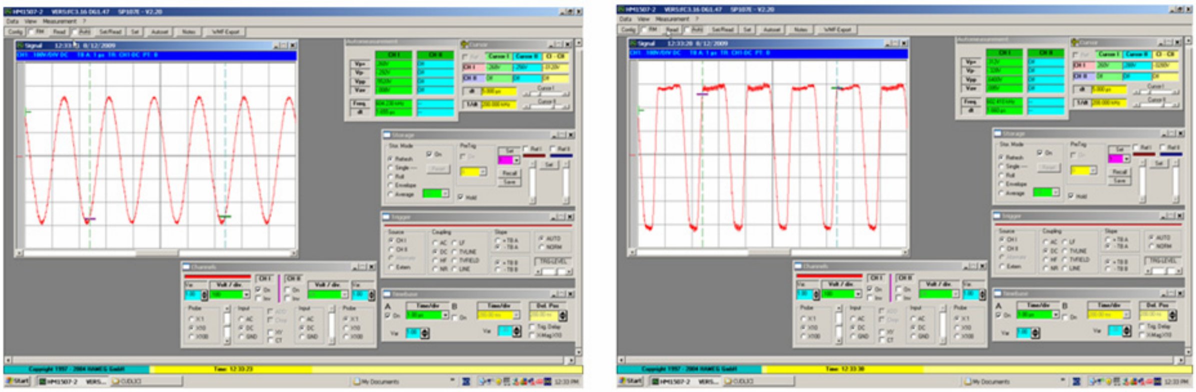

Fig. 5: Sine and square wave 300 kHz – 10 V at 2 V/div.

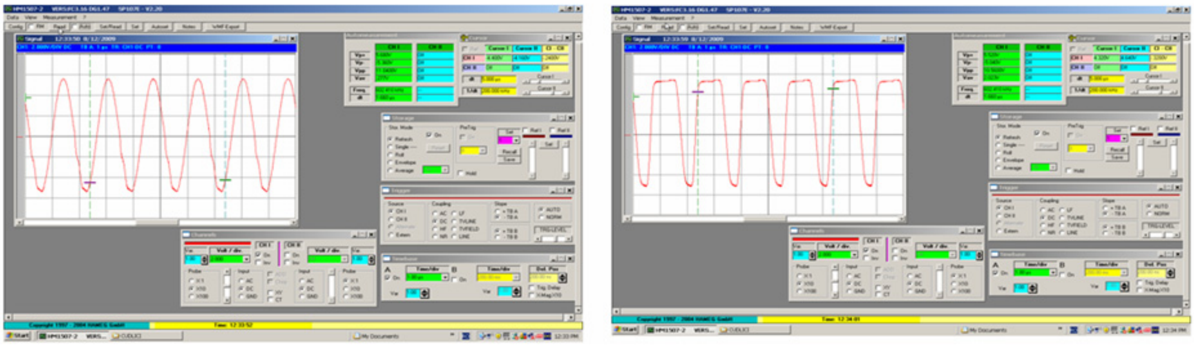

Fig. 6: Sine and square wave 600 kHz – 500 mV at 0,1 V/div.

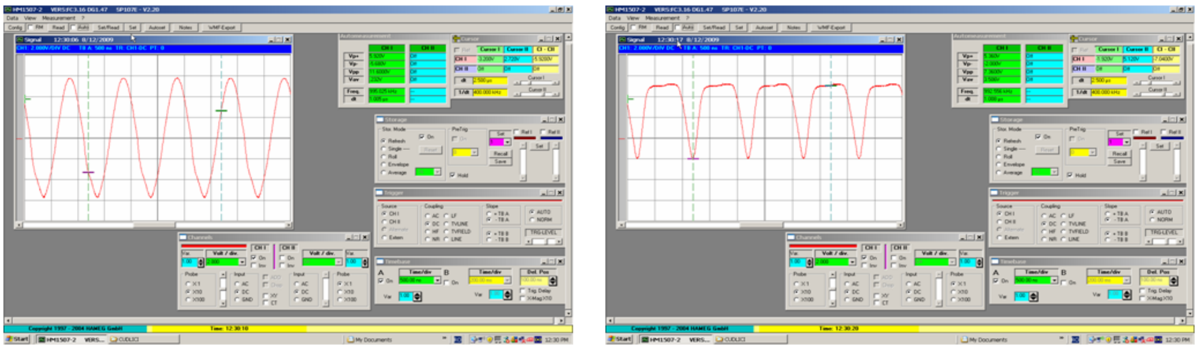

Fig. 7: Sine wave 990 kHz – 10 V and square wave 2 V/div.

3. SPECIFIED GENERATOR PARAMETERS AND INTERPRETATION OF RESULTS

Frequency Range: The quality metrics for a signal generator includes frequency stability, phase noise and spectral purity. The frequency range of the developed generator is characterized by minimum and maximum values f_{min} and f_{max} for the output frequency. The frequency range given by the difference f_{max} - f_{min} can be divided in multiple frequency sub-ranges. The frequency coverage ratio: $K'_f = f'_{max}/f'_{min}$, where f'_{max} and f'_{min} are extreme values of the considered range. The number of ranges was chosen so, that all sub-ranges have the same coverage ratio K'_f. So, the frequency range is 0,1 Hz to 1 MHz (f'_{min} = 0,1 Hz ÷ f'_{max} = 1000 kHz), number of sub ranges is 7 and coverage ratio is K'_f =10 (0,1 Hz - 1 Hz, 1 Hz I- 10 Hz, 10 Hz -100 Hz,100Hz -1000 Hz, 1KHz -10 KHz,10 kHz -100 kHz and 100 KHz - 1000 kHz). The number of sub-ranges is large enough to ensure good signal quality.

It was established experimentally that only the signals obtained in the last range may have errors.

Frequency stability: Stability is the measure of how far a generator's output frequency drifts with time, supply voltage and temperature. Stability is the ability of an oscillator to maintain a desired frequency and is usually expressed as percent deviation from the assigned frequency value. Frequency stability can be defined by the ratio $\Delta f'/f$, where $\Delta f'$ is the unwanted frequency variation produced by changes of a single parameter (electric or non-electric), and the other conditions remaining unchanged. The frequency f is the basic frequency on which the generator was initially tuned. A plot of the stability vs. some important disturbing factors (e.g., heat, supply voltage, output amplitude) is presented in Figure 8.

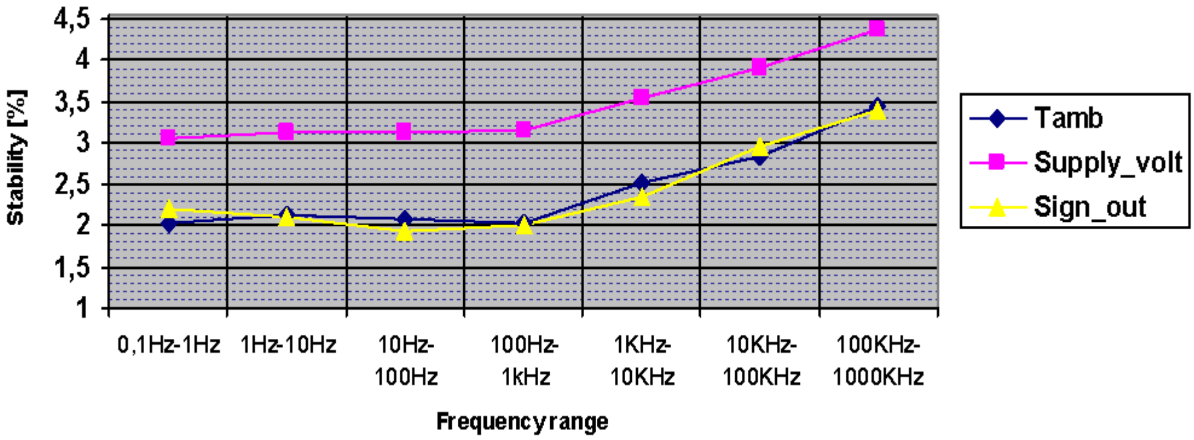

Fig. 8: Behaviour of the generator' stability vs. heat, supply voltage and signal output

Nonlinear distortions noise and ripple noise: As is known for a pure sine wave, only one signal is present, the fundamental frequency. The real generated sine signal will contains a frequency spectrum with virtually a limited number of low level harmonics. Harmonic distortion is a measure of the amount of power contained in the harmonics of a fundamental signal. Harmonic distortion is inherent to devices and systems that possess nonlinear characteristics – the more nonlinear the device, the greater its harmonic distortion.

The nonlinear distortion factor of the tested signal can be represented as:

$$\delta = \frac{\left(\sum_{k=1}^{\infty} U_k^2\right)^{\frac{1}{2}}}{U_1} \tag{1}$$

where Uk (k = 1,2, …) represents actual values (effective) of sine voltages f_k (k order harmonics). They are obtained by Fourier series decomposition of the output voltage $u_{0(t+kT1)}$, having the frequency f_1. In reality, the output voltage $u_{0(t)}$ has always small deviations from a perfect sinusoidal waveform.

For low frequencies, it is usual to define a stray voltage, arising from electronic noise floors and hum brought by the mains. This voltage is denoted u_{zg+br} and is superimposed over the useful voltage u_0. Therefore it is defined the voltage U_{zg+br} for $U_{0max.}$ The overall coefficient for distortion, noise and hum is defined as:

$$\delta' = \frac{\left(\sum_{k=2}^{\infty} U_k^2 + U_{zg+br}^2\right)^{\frac{1}{2}}}{\left(\sum_{k=2}^{\infty} U_k^2 + U_{zg+br}\right)^{\frac{1}{2}}} \quad (2)$$

The coefficient δ' shows the deviation of the generated wave from a perfect sinusoidal wave and can be measured with a selective distortion meter.

For high frequency generators, instead δ and δ' coefficients, it is specified the frequency spectrum of the harmonics, measuring their amplitude reported to their fundamental (20 lg(U_k/U_1), measured in dB with a frequency selective voltmeter or a frequency analyzer.

Typical performance curves of function generator are plotted below.

The Phase noise curves are presented in Figure 9.

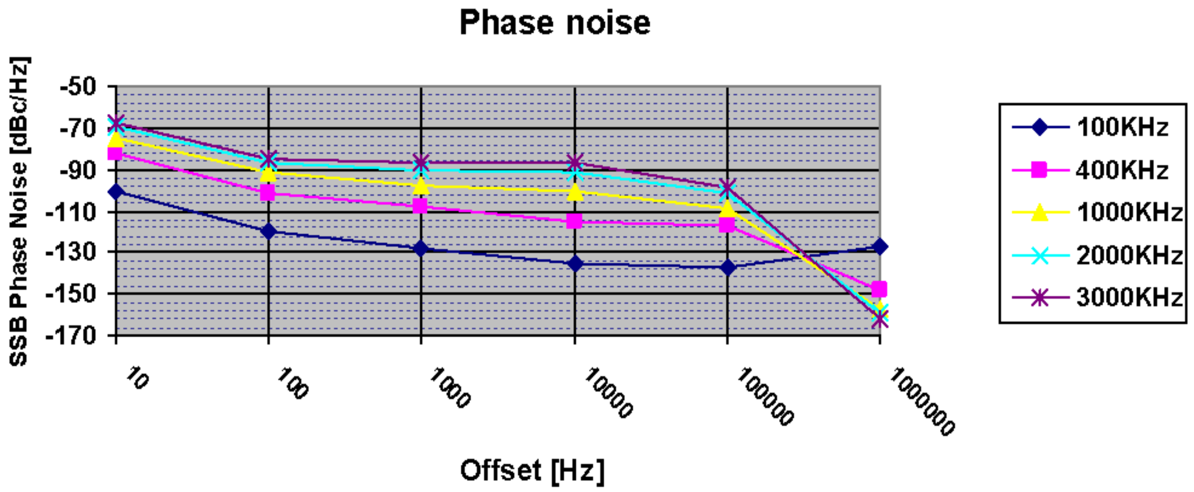

Fig. 9: SSB Noise offset representation function

Evolution of maximum output power vs. Frequency is presented in Figure 10.

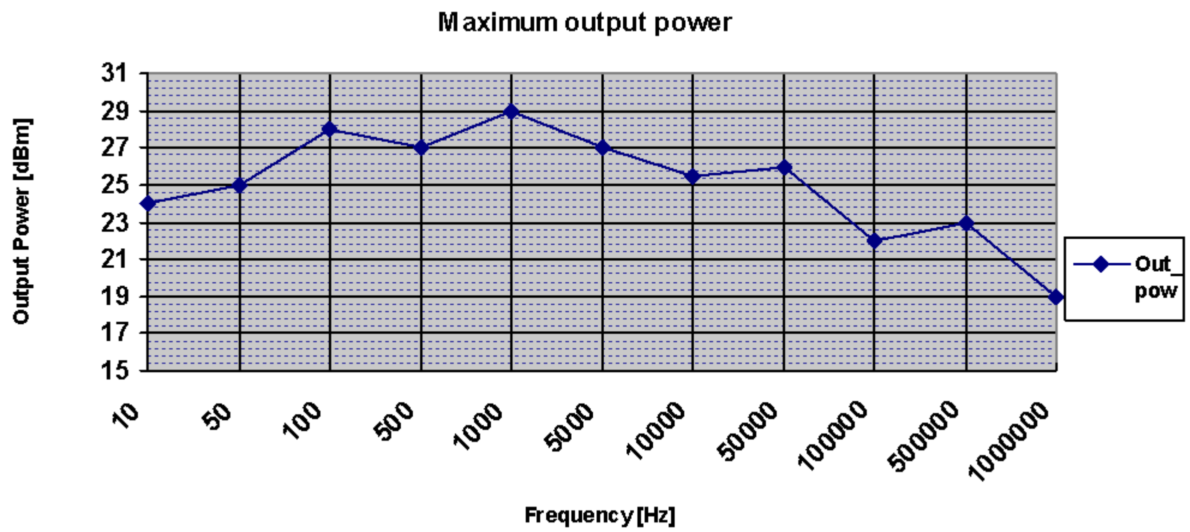

Fig. 10: Evolution of maximum output power vs. frequency

Figure 11 presents the changes of AM Noise performance vs. Offset frequency.

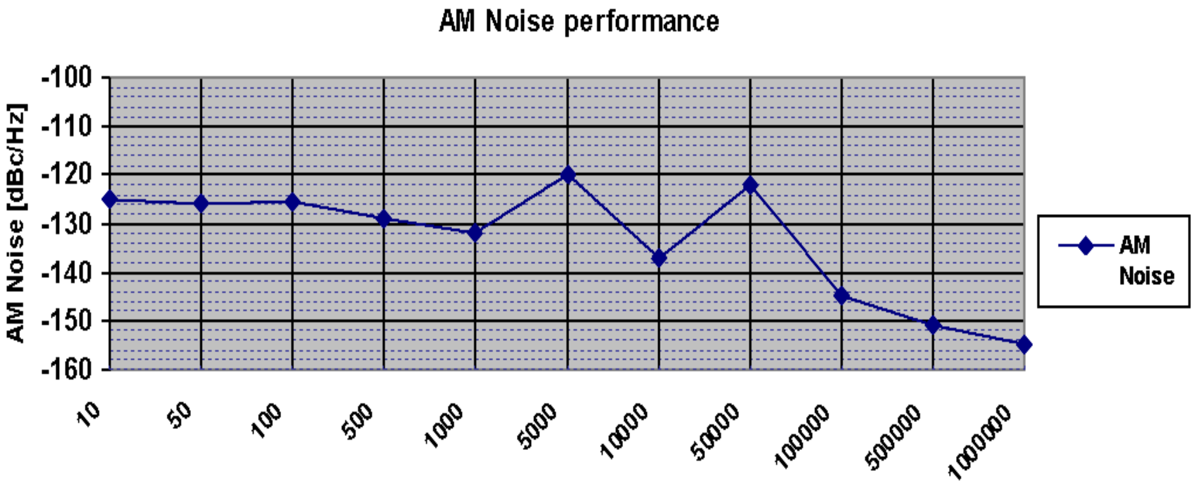

Fig. 11: AM Noise graph of function generator

4. CONCLUSIONS

At the beginning of the paper we present the results of a sine/square signal generator which is based on PIC 16F877A microcontroller. To analyze the generated signals we used a digital oscilloscope with analogue memory HAMEG HM1507-2 and SP107 software. Figures 2-9 show the deviating from standard for one signal of 500mV sine wave and another signal of 10V square wave depending on the frequency signals.

Finally, some typical performance curves are plotted, showing the behaviour of the function generator.

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