Reconfigurable Signal Generator and Simulator for Testing the Digital Transmission Circuits

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***Abstract**: In this article is presented the implementation of a new type of reconfigurable signal generator and simulator used for testing digital transmission circuits that requires complex modulated waveforms. In our experiments we choose as an example the quadrature amplitude modulation or quadrature phase shift keying (QAM/QPSK) signals. The proposed solution is based on a high-speed NI-USB-6251M data acquisition board connected to a computer running a LabVIEW application. The analog outputs of the board are used for applying the predefined test signals to the circuits that are under test. The response of the tested circuit is monitored using the inputs of the data acquisition board. The novelty of the proposed system is given by the association between a very flexible and user friendly graphical programming environment such as LabVIEW and a general purpose data acquisition board which lead to an attractive implementation solution for a virtual instrument capable to simulate, generate, and also test a multitude of circuits using various signals. Compared with the classical approaches, the system presented in this paper represents a versatile platform, with large spectrum of applications because, with proper configuration of the software application, can be generated a broad range of modulated signals, including arbitrary waveforms, the only limitation being the speed of the data acquisition/generation module.*

1. INTRODUCTION

The software simulation represents an important step in any design process of a complex electronic circuit. In the case of the advanced digital transmission circuits the simulation can take a relatively long time and the obtained results could have important errors compared with the measurements. A method to improve the accuracy and the speed of the simulation for a complex design is to implement a part of the simulator in hardware [1], [2].

This approach is also useful when it is necessary to ensure input test signals for circuits that operate with complex waveforms that require dedicated equipments. These equipments can be replaced, in conditions of good accuracy, by the reconfigurable signal generators. From the didactical point of view a reconfigurable signal generator and simulator is also very useful because it allows obtaining a broad range of complex waveforms including modulated signals that can be analyzed in a realistic manner.

2. THE PRINCIPLE OF GENERATING DIGITAL MODULATED SIGNALS

The basis for obtaining digital modulated signals is represented by the quadrature modulator known also as I/Q (in phase/quadrature) modulator. This type of circuit realizes an essential signal processing that is necessary in a wide variety of digital communications applications.

The basic diagram of the cuadrature modulator contains a set of two mixers that receive the carrier signals from the same local oscillator. The mixers operates with phase shifted carriers signals for generating the corresponding in phase (I) and quadrature (Q) channels.

The mixers realize the modulation of digital input data on the phase shifted carriers and the resulted I and Q signals are added for obtaining the output signal. In this way the quadrature modulator can be used for generating a pure phase modulation or a pure amplitude modulation or even a combination of this two modulation techniques. This last case is the most used in practice because allows an increased transmission speed [3].

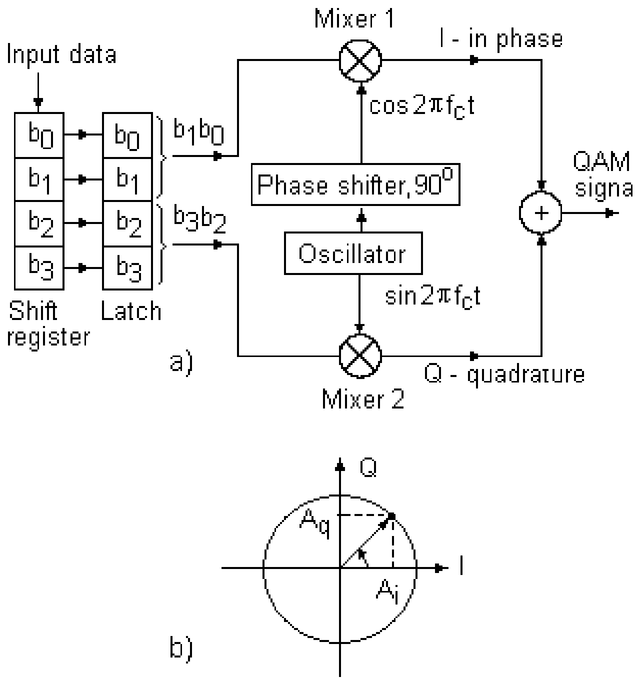

Fig. 1. a) The principle of quadrature modulator; b) Polar representation of output signal of a quadrature modulator.

In the Fig. 1 is presented an example of quadrature modulator and the polar coordinates representation of the modulated output signal. More often in practical applications the principle of quadrature modulator is used for generating complex signals with a large number of points in the polar diagram representation, which in such cases is named the signal constellation.

3. The Structure of the Reconfigurable Signal Generator and Simulator

The proposed solution for implementation of a reconfigurable signal generator and simulator used for testing digital transmission circuits is based on a versatile software application developed in LabVIEW and a data acquisition/generation board with multiple inputs/outputs that allows simulating various waveforms and various conditions for the tested circuit. In the block diagram presented in Fig. 2 we can observe that the proposed experimental implementation of the reconfigurable signal generator was realized with an NI-USB-6251M data acquisition board. The internal digital to analog converters of this versatile data acquisition board operates with a resolution of 16 bit and a maximum acquisition speed of 1,25MS/s. This is the main parameter that limits the speed of operation for the proposed system [4].

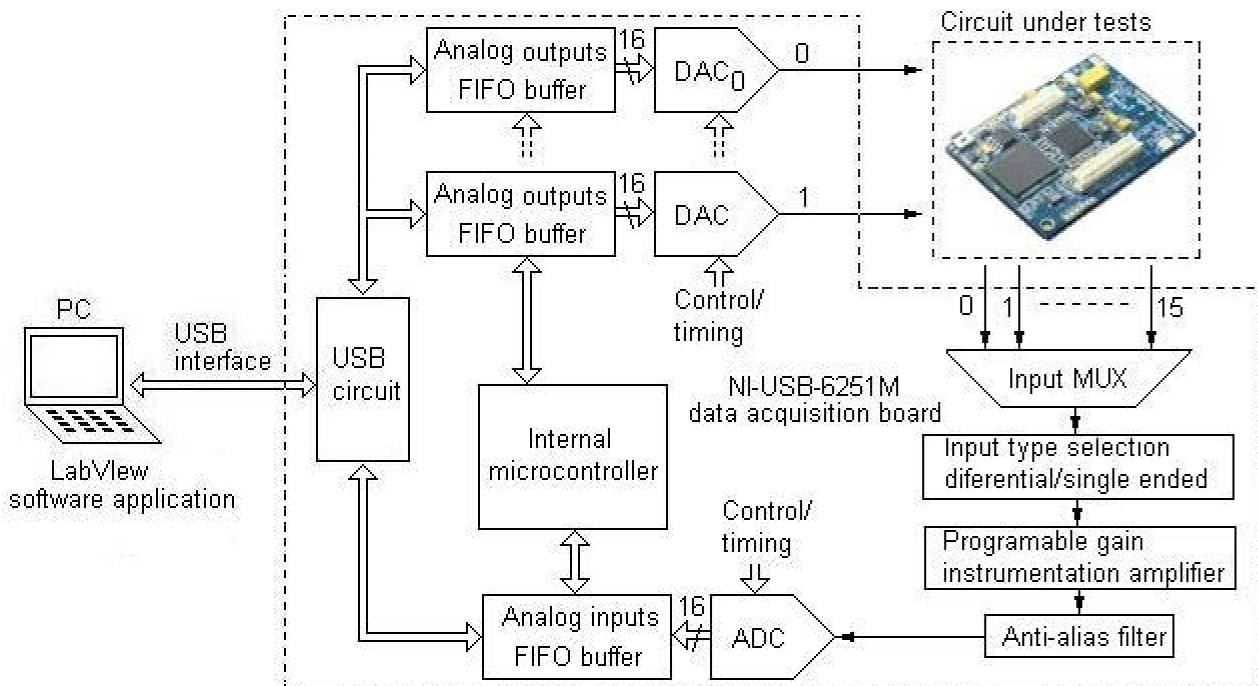

Fig. 2. The block diagram of the reconfigurable signal generator.

Considering the proposed model of data acquisition board there are available 16 analog inputs and 2 analog outputs for testing the circuits. On the output side, the maximum operation speed is of 2,8MS/s. Because the board operates with one high speed analog-to-digital converter, it was necessary to be used an input multiplexer for reading the 16 analog inputs. The multiplexer route one input signal at a time to the ADC through an internal programmable gain instrumentation amplifier. The full range of the input and output signals at the data acquisition board that was used in out experiments is in [-10V to 10V] range which is acceptable for our application.

4. The Software Application

The reconfiguration characteristics of the signal generator and simulator used for testing digital transmission circuits is obtained due to the use of the software application programmed in LabVIEW for controlling the entire operation of the signal generator [3], [4]. As can be seen in Fig. 3 and Fig. 4, the software application that controls the generator is realized in a modular structure. The software routine responsible with configuration of input parameters of the QAM section of the generator is detailed in Fig. 3. From there sample parts of the generator's diagram can be remarked that the application uses dedicated programming routines from the "LabVIEW modulation toolkit" but also general blocks from the standard libraries of LabVIEW. All instructions are executed in a while loop for ensuring the continuous update of the application state, when the user realizes changes of input parameters or other configurations. For increasing the accuracy of the tests realized with the proposed reconfigurable generator, a channel modeling routine was introduced in the LabVIEW application. In addition, the generated signal can be affected by an adjustable level of noise, in order to evaluate these influences on the tested circuit. These characteristics are also useful if the reconfigurable generator is used for didactical purposed in teaching communications techniques based on digital modulations [5].

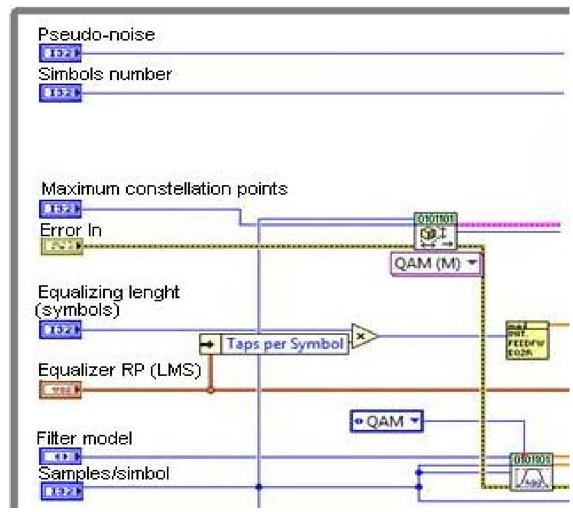

Fig. 3. The software routine responsible with the configuration of input parameters of the QAM generator.

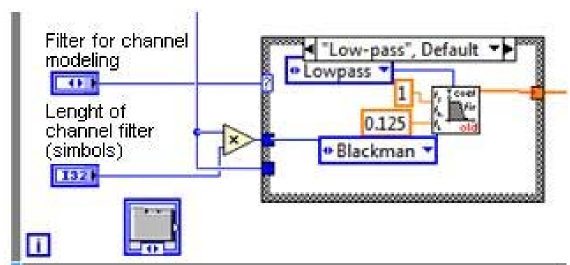

Fig. 4. Channel modeling using a filter structure implemented in LabVIEW.

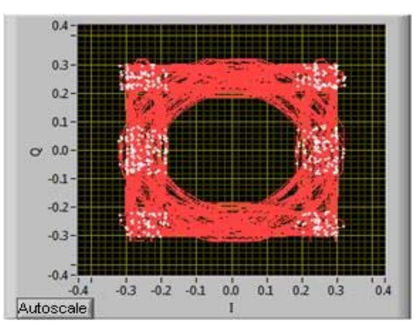

Fig. 5. An example of QPSK signal simulated with the proposed application - the constellation is obtained without data equalization (signal affected by distortions).

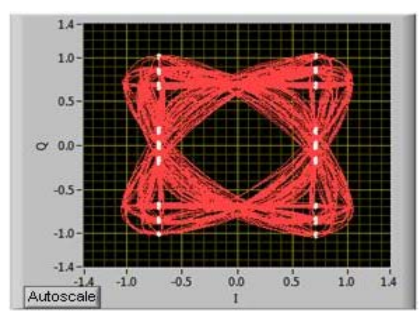

Fig. 6. QPSK constellation with equalization (reduced influence of noise and distorsions).

5. RESULTS

In the realized experiments a demodulator module for quadrature amplitude modulation or quadrature phase shift keying (QAM/QPSK) signals was used for testing the accuracy and the performances of the reconfigurable generator. The visualization of the test waveforms generated by the NI-USB-6251M data acquisition board and controlled by the LabVIEW application it was realized with a standard oscilloscope. In the Fig. 7 is presented an example of data pattern generated with the data acquisition board at maximum speed allowed by this device. Also, in Fig. 8 is depicted the quadrature phase shift keying (QPSK) signal modulated with the previously mentioned data pattern. This test signal was applied to the tested demodulator. Both initial data pattern waveform and resulted demodulated waveform were compared in different conditions (with or without noise and equalization) for a complete performances evaluation of the tested demodulator. The reconfigurable generator proven a good stability and accuracy, but the operation speed was a limiting factor. This disadvantage can be overcome by using a data acquisition board with higher conversion speed.

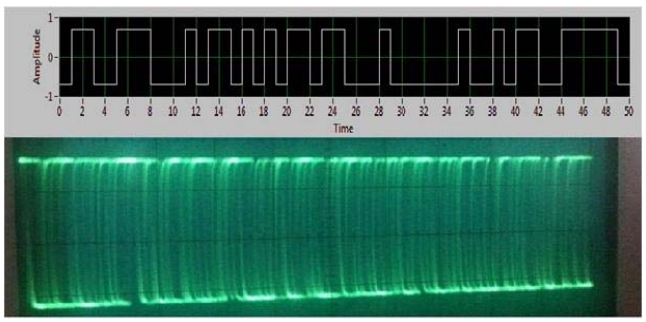

Fig. 7. Test waveform (data pattern) generated with NI-USB-6251M and visualized with an oscilloscope.

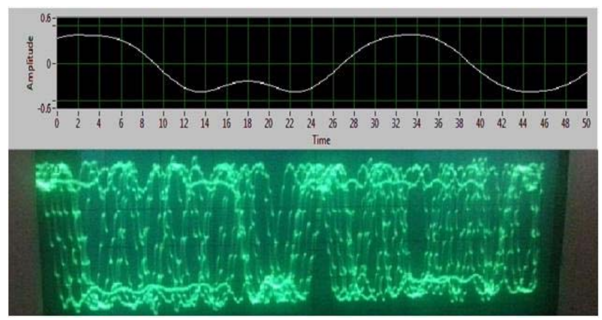

Fig. 8. An example of QPSK signal generated with the proposed application.

6. CONCLUSIONS

By combining a graphical programming environment such as LabVIEW and a versatile data acquisition board resulted an attractive implementation of a reconfigurable signal generator useful in simulation and testing of a multitude of circuits using various signal waveforms.

This approach allows replacing expensive and dedicated equipments whose function can be simulated by the proposed reconfigurable generator.

Because of it's reconfigurability, the generator described in this paper can be used also for didactical purposed in teaching communications techniques based on digital modulations.

The maximum frequency of the broad range of signals that can be obtained with the proposed system is limited by the hardware constrains, because this parameter is depended of the speed of the used data acquisition.

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