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Virtual Instrumentation Based Acquisition and Synthesis Module for Communication Signals

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Abstract **– This paper presents a versatile implementation of a reconfigurable module for acquisition and synthesis of modulated signals that are specific to the modern communication equipments. The hardware structure of the system is elaborated mainly around the TDA 8702 high speed video digital-to-analog converter and ADC 0820 analog-to-digital converter, both connected in a configuration that is controlled by a dedicated virtual instrumentation application realized in LabVIEW. The external module of the system is connected to a PC through the parallel port. The designed structure can operate with a wide range of modulation techniques including double-sideband with suppressed or conserved carrier, frequency and phase modulations. In addition, the proposed module offers the possibility to acquire and study complex waveforms that are specific to various communications systems and also to test different circuits and configurations using the synthesized signals as input stimuli. Besides the intrinsic advantages resulting from the usage of virtual instrumentation based on LabVIEW graphical programming, the conversion hardware of the proposed module is relatively simple and can be implemented with low costs.**

Keywords - acquisition; synthesis; modulation; virtual instrumentation.

I. INTRODUCTION

Due to its intuitively and easy to use programming technique based on graphical elements but also because of it versatility, the virtual instrumentation has become an preferred solution in the field of data acquisition and measurement systems but also in general purpose or specialized applications such as signal processing for communications. This evolution was generated by the accelerated development of the microprocessors and computers that was also correlated with the continuously increasing demands for improved hardware and software components that are necessary in the realization of complex applications. The LabVIEW graphical programming environment, with its complex and powerful library of functions is the most prominent representative from the class of software tools dedicated for the implementation of virtual instrumentation applications. This was one of the motivations for selecting the LabVIEW for realization of the module proposed in this paper. In this case, based on this new approach, it was designed a laboratory equipment for didactical purposes, characterized by an extended and improved set of features and capable to realize simulation, synthesis and acquisition of various communication signals. The module presented in this paper is intended for testing and verifying the correct operation of various communication configurations, especially those which are designed for experiments regarding the fundamental modulation techniques used in modern transmission systems [1], [2]. The paper is organized in four sections and the conclusions. After a short introduction in the paper's domain, the second section describes the structure of the acquisition and synthesis module. The third part of the paper contains the architecture of the virtual instrumentation application. In the forth section are revealed some implementation details and few sample results regarding the operation of the proposed system.

II. THE STRUCTURE OF THE ACQUISITION AND SYNTHESIS MODULE

The general structure of the acquisition and synthesis module for communication signals is detailed in Fig. 1. The design is characterized by two processing channels, one for acquisition and analysis of input signals and the other channel for synthesizing and visualizing complex waveforms specific to various communication systems. Both channels are controlled by the LabVIEW application that runs on PC. The communication with the external module is realized through a set of buffers that are connected to the standard parallel interface of the PC [3].

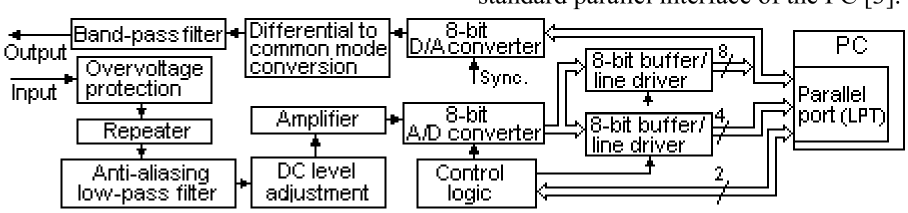

Figure 1. The simplified structure of the acquisition and synthesis module for communication signals.

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The input and output channels are preceded by proper conditioning circuitry comprising: filters, adjustable amplification circuits with DC level adjustment, repeaters and also overvoltage protection, as can be observed in Fig. 1. The implementation schematics for those circuits can be viewed in Fig. 2, which contains the complete electronic diagram of the hardware module. The proposed module is based on a simple and efficient approach and contains general purpose circuits. The signal acquisition channel is realized around the 8-bit analog-to-digital converter ADC 0820 that has half-flash high-speed architecture and is capable to process an input sample in a time interval of approximately 1.4μs. The minimum value of the conversion time ensured by the ADC 0820 is acceptable for acquiring and analyzing the modulated signals of lower frequencies, which are specific to the practical modules and circuits encountered in standard didactical laboratories used for teaching activities. Anyway, the speed limitation is mostly imposed not by the analog-to-digital converter but by the parallel interface that was used for transferring the data to the PC. In applications that require a higher acquisition speed, the hardware and software components of the proposed module can be easily adapted to operate with a more rapid interface like USB [4]. For overcoming the limitations imposed by the data bus width of some types of standard parallel interfaces that cannot operate in bidirectional mode, in our implementation was used a set of two 74LS244 tri-state buffers. The inputs of these buffers are connected in parallel to the output of the ADC 0820 and are activated at a time, periodically, by the control logic, which is also triggered by the LabVIEW application that runs on the PC. If the external module is coupled to a PC having a standard parallel port that can operate in full bidirectional mode, then only one 74LS244 buffer is sufficient for transferring the complete octet generated at the output of the analog-to-digital converter. However, the transfer of the 8 bits data in two steps is not desired because this operation mode will introduce an inherently delay and a significant reduction of the acquisition speed [5]. The module presented in this paper is also capable to synthesize communication signals based on linear and exponential modulation techniques such as: amplitude modulations with double-sideband and suppressed carrier (DSB-SC) or with conserved carrier (DSB-CC), frequency modulation (FM) and phase modulation (PM). The DSB-CC and FM signals can be expressed as:

$$s_{DSB\text{-}CC}(t) = [1 + m_a \cdot u_m(t)] \cdot \cos(\omega_c \cdot t + \varphi_c) \quad (1)$$

$$s_{MF}(t) = A_0 \cdot \cos\left[\omega_c \cdot t + k_\omega \cdot \int_0^t u_m(t) \cdot dt + \varphi_c\right] \quad (2)$$

where ω_c is the angular frequency, φ_c is the initial phase and A_0 is the amplitude of the harmonic charier, $u_m(t)$ is the modulation waveform and m_a, k_ω represents the modulation indexes.

In addition the proposed system is also suitable for synthesizing digital modulated signals using techniques like amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK). These waveforms are obtained at the output of the digital-to-analog converter TDA 8702, connected in a standalone configuration. The circuit achieves a high conversion rate of 30 MHz at a resolution of 8 bits [6].

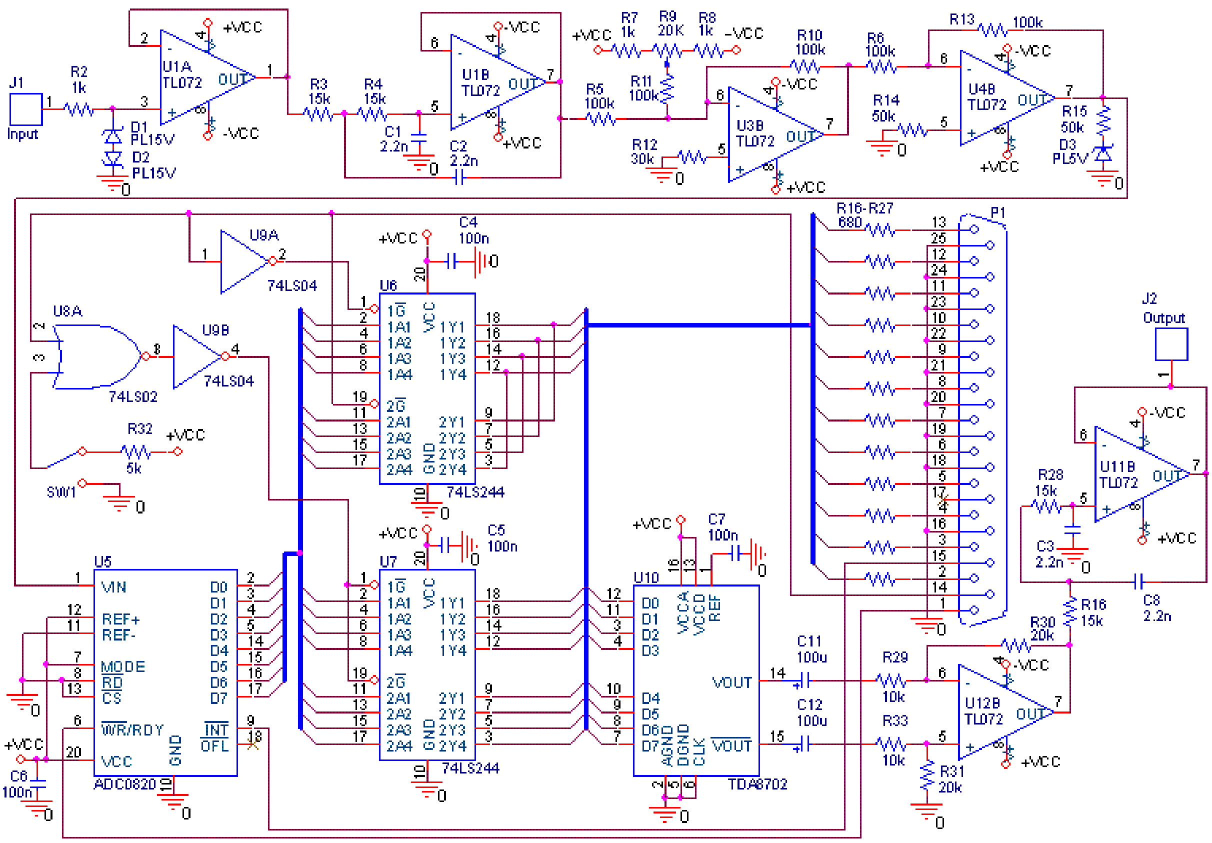

Figure 2. The electronic schematic of the acquisition and synthesis module for communication signals.

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III. The Virtual Instrumentation Application

The virtual instrumentation application that controls the operation of the acquisition and synthesis module presented in this paper was realized in LabVIEW. The advantages of this approach are closely bounded to the facilities offered by this software environment that allows a rapid development of complex programs with attractive and easy to use interfaces. The front panel of the proposed software platform is presented in the Fig. 4. From this diagram it can be seen that the user can modify almost all parameters that are significant for the acquisition and synthesis process. Some very important controls which must be very carefully adjusted are the sampling frequency and the number of samples per second. This is mainly because these parameters affect the internal representation of signals that are displayed. Also an improper selection of the values for these two parameters can lead to the exceeding of the transfer capacity of interface used for communication with the external hardware module, with the consequence of an erroneous operation of the external data converters [7].

In Fig. 3 is presented a detail from the diagram of the realized instrumentation application showing the routine that is responsible with the transmission of the samples to the parallel port for synthesizing various modulated waveform. Overall, the application allows the simultaneous visualization on the PC's display of three waveforms: the modulation signal, which simulates the usual information signal, the obtained signal after modulation process and its spectrum.

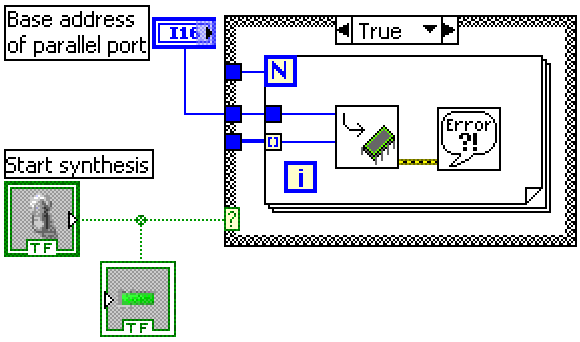

Figure 3. The routine used for transmission of the samples to the parallel port for synthesizing various communication signals.

The base address of the port used for communication with the external hardware module is selectable by the user. Also, the file path for saving the acquired and visualized data can be easily chosen in the front panel of the application. In the example presented in Fig. 4 is shown a capture of the application's interface considering the situation when it is synthesized a signal having dual sideband spectrum with suppressed carrier (DSB-SC). This signal is obtained by modulating a 100kHz carrier signal with a sinusoidal tone having a frequency of 2kHz and an amplitude of 2V.

The corresponding spectrum of output signal is also displayed. The samples of the synthesized signal are sent to the inputs of the TDA 8702, which produce a similar waveform, which can serve for further analysis and tests of various communication circuits.

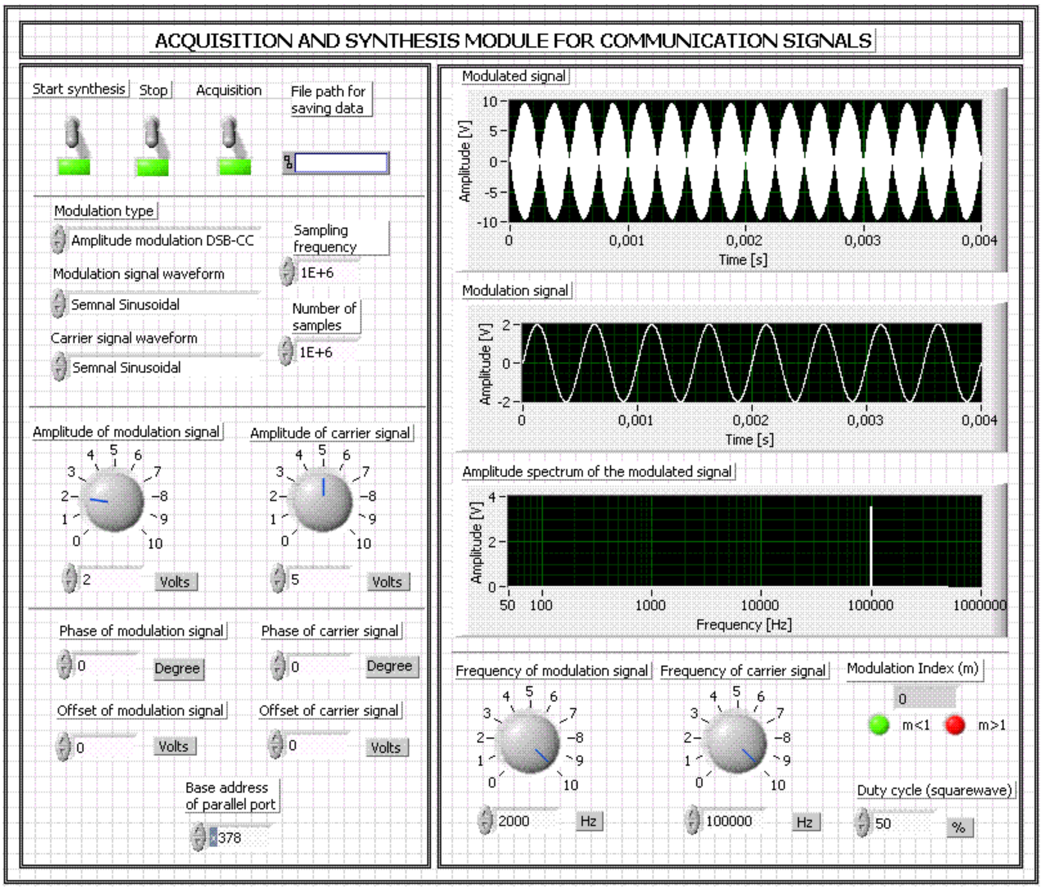

Figure 4. The front panel of the virtual instrumentation application used for controlling the acquisition and synthesis module.

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IV. IMPLEMENTATION AND RESULTS

For verifying the correct operation of the proposed system, a prototype of the practical module was implemented. The structure of the experimental setup used for the initial tests can be observed in Fig. 5 and Fig. 6. In the presented cases the hardware module and the LabVIEW application was configured for synthesizing amplitude and frequency modulated waveforms, considering a 100kHz sinusoidal carrier and a sinusoidal modulating signal with a frequency of 2kHz and the amplitude of 2V. These values can be changed by the user and also the waveform type can be arbitrary selected. Also, the acquisition part of the module was experimentally tested and was found that the proposed module together with the virtual instrumentation application operates as expected until carrier frequency of about 1MHz. The limitation appears on both acquisition and synthesis channels due to the parallel port that was used for communication between the external hardware module and PC. By using a dedicated USB circuit and VISA blocks from the library of the LabVIEW this inconvenient can be alleviated. However, in our implementation the purpose was not to achieve very high speeds of operation but to demonstrate the principle of such kind of system, which founded many applications in didactical laboratories for teaching the principle of various communication techniques but also for testing the correct operation of some modulators and demodulators. In these cases various synthesized waveforms were supplied to the inputs of the tested circuits and the outputs were monitored using the acquisition channel. On this way it was possible to analyze and visualize the effects of various changes in the structure of the tested circuits, this facility being very valuable not only for didactical demonstration of communication circuits principles but also for research purposes, in order to validate new implementation solutions. A further improvement of the operation speed of the proposed module is by using a more complex buffering scheme based on local memories, but this method lead to an increased complexity and an more difficult control of the system.

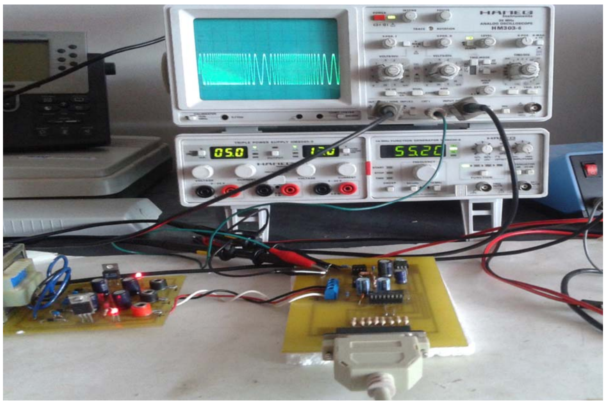

Figure 5. The experimental setup configured for synthesizing a frequency modulated signal that is visualized on a standard oscilloscope.

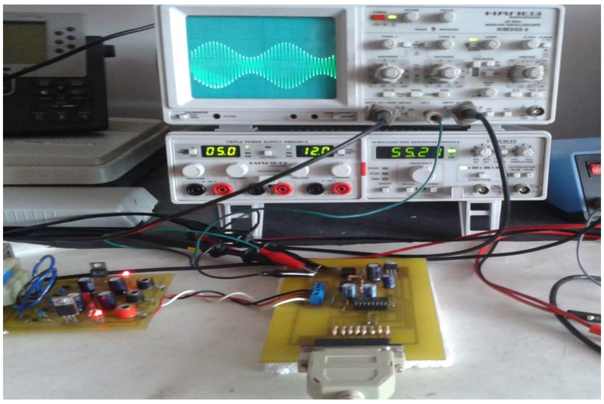

Figure 6. The experimental setup for testing the module in synthesis mode. In this case is synthesized an amplitude modulated waveform.

V. CONCLUSIONS

The implementation solution presented in this paper demonstrates the advantages of combining LabVIEW based virtual instrumentation with medium complexity hardware for achieving a reliable and versatile platform for studying various modulation techniques and also for testing different configurations of circuits that are frequently used in modern communications.

The proposed module has the advantage of being capable to operate not only as a simple digital oscilloscope but also as spectrum analyzer.

Also, by using a dedicated, high speed digital-to-analog conversion circuitry, the designed module can synthesize a large variety of modulated waveforms, the only limitation in this case being related to the data transfer rate for the communication interface used for realizing the connection between the hardware module and the instrumentation application that runs on PC. This problem can be solved by using a more rapid interface such USB or even PCI.

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