Measurement of CMOS Inverter Electrical Parameters in LabVIEW Software Environment

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Abstract – **Possibility of using virtual instrumentation software LabVIEW in procedure for recording of transfer characteristics and measurement of CMOS inverter parameters, is presented in this paper. Measurements are performed on integrated circuit HCF 4007 UB, which is consisting of three independent inverters. Presented solution for laboratory measurement and acquisition system includes the PCI data acquisition card NI 6251 and model of checked integrated circuit. Functional basis of given solution is provided using the software application developed in LabVIEW programming environment. Developed application performs the graphical presentation and recording of inverter characteristics concerning linear input voltage waveforms. Also, programming application provides the comparative presentation and software analysis of the circuit transfer characteristics for different supply voltages, with measurement of electrical parameters regarding to input and output voltage waveforms of CMOS inverters circuit.**

Keywords – **CMOS inverter circuits, Virtual instrumentation, LabVIEW programming application.**

I. Introduction

Appearing of the CMOS technology and integrated circuits presents huge step in the development of semiconductor based technologies and microelectronics. Integrated circuit designed and manufactured in CMOS technology are today widespread used in microprocessors, microcontrollers, memory modules and digital logical circuits. Besides that, these components are applied in different types of analogue electronic circuits, such as the measurement transducers, data converters, transmitters and signal receivers. Two most important advantages of these integrated circuits are large noise signals immunity and small power dissipation in stationary operational mode. Significant increasing of power dissipation only occurs during transitions periods between on and off circuit conditions, providing much smaller component heating comparatively to circuits produced in TTL or NMOS technology. CMOS technology in integrated circuits production gives possibility for significant increasing of the component packaging density on integrated chip, which represents one of the basic reasons for widespread applying of this technology in the semiconductors production industry [1].

Simplest logical circuit manufactured in CMOS technology is inverter, which performs primary logical operation of signal inversion. Also, inverter circuit represents basic for designing of complex semiconductor components. The inverter contains two complementary MOS transistors with induced channels of n and p types. As typical represent of CMOS inverters family, the object of measurement and analysis described in this paper is inverter integrated circuit HCF 4007 UB. This is monolithic integrated circuit, present on the market in couple of different packaging variations inside the plastic or ceramic housing. For this specific analysis is used inverter integrated circuit having packaging variation EY DIP 14, inside the plastic housing [2].

Integrated circuit HCF 4007 UB is consisting of the three n channels and three p channels enhancement MOS transistors. Transistors elements are accessible using packaging terminals, which enables designing of the typical functioning variations. Accepted values of circuit supply voltages are inside the range from -0.5V to 18V. Supply voltage recommended from circuit manufacturer Thompson Microelectronics Group is within the range 3V to 15V. Possible input voltage values are from -0.5V to 18V, while permissible input current values are in the range ±10mA. Maximum acceptable power dissipation for an entire circuit is 200mW, regarding to the working temperatures from -45 to 85°C. Long time exposure of inverter circuit to working conditions outside the specified limitation values may to cause decreasing of circuit reliability or its permanent damaging [2].

Solution for recording of integrated circuit HCF 4007 UB transfer characteristic, including and measurement of the basic parameters of input and output inverter voltage signals, which is described in this paper, functionally is based on the virtual instrument program tool LabVIEW [3] in the PC environment. Designed programming application combined with acquisition card NI 6251 [4], with possibility for D/A and A/D conversion of signals, provides generation of voltage signals for checking of CMOS inverter integrated circuit and performs acquisition of the voltage signals obtained from integrated circuit outputs. At the final process stage, realized virtual instruments provide the graphical presentation and chronological recordings of the obtained measuring results and circuit transfer characteristics.

II. Hardware Configuration of Laboratory Measurement System

Hardware block configuration of the solution for laboratory measurement and acquisition system designed for the purpose of input and output characteristics recording and measurement of CMOS inverter basic parameters, is presented on the Fig. 1. This system includes the standard PC configuration, supported with LabVIEW software package, multifunctional 16-channel card for data acquisition PCI NI 6251 and practical realization of the model with implemented inverter circuit HCF 4007 UB. Parameters of input voltage signals for checking of integrated circuit, generated on the data acquisition card analog outputs, are defined in LabVIEW programming environment. Voltage signals generated on acquisition card outputs, within the range

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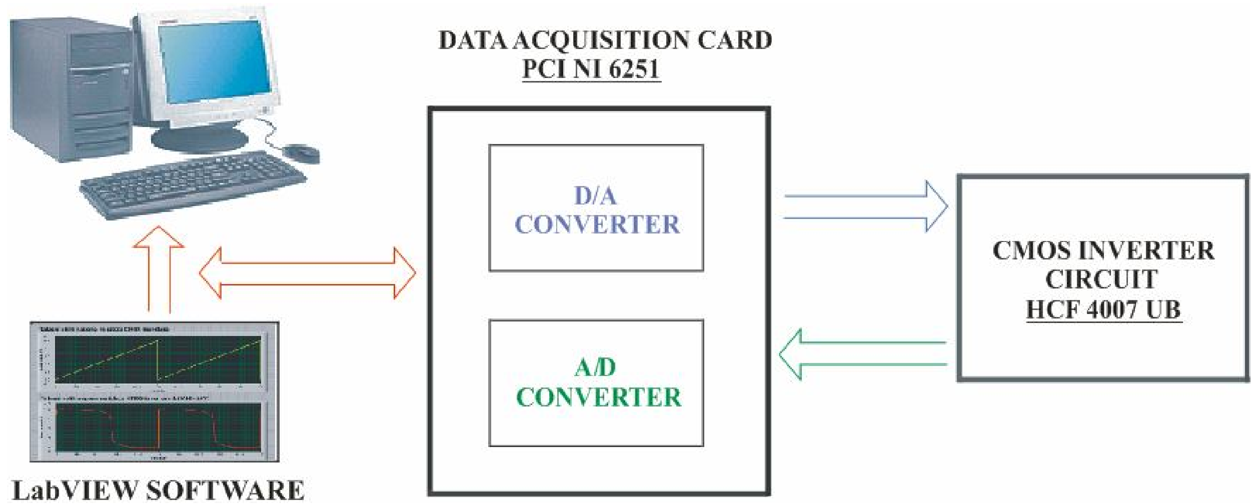

Fig. 1. Hardware block configuration of the experimental measurement and acquisition system

of ±10V, are sending directly to inputs of integrated circuit on the designed model. In the next process stage voltage signals obtained from inverters outputs are sending back to the inputs of acquisition card A/D converter having the 16-bit resolution. Data acquisition card PCI 6251 from American manufacturer, National Instruments Corporation, for this specific application uses two analog output channels which provide the continuous generation of by user defined voltage signals for three inverter inputs, together with six analog input channels, which receive the measurement signals from all inverter outputs. This card is inserted in one of currently available standard computer slots, with the internal communication and data exchange performed using PCI/PXI communication interface [4]. Integrated circuit HCF 4007 UB is implemented on the beneath side of designed model, which construction diagram is presented on the Fig. 2.

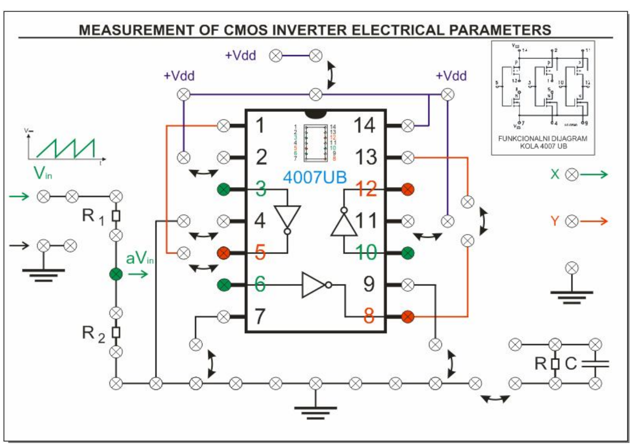

Fig. 2. Construction diagram of the model for CMOS inverter integrated circuit HCF 4007 UB

A part of experimental measurement and acquisition system for measurement of the CMOS inverter parameters, developed at the Department of Measurement on Faculty of Electronic Engineering in Niš, is presented on Fig. 3. This picture shows a model of CMOS inverter integrated circuit, including supply voltage source and number of connection wires attached to the connector block of applied data acquisition card PCI NI 6251.

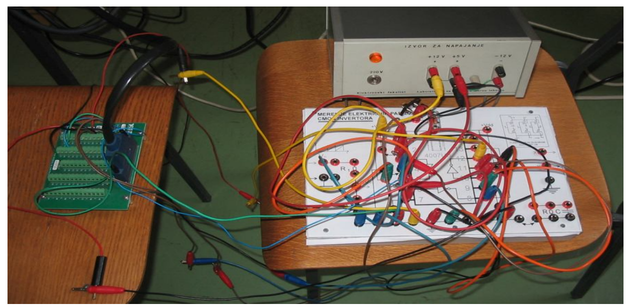

Fig. 3. A part of the developed laboratory measurement system

III. LabVIEW based software support

Procedure for recording of integrated circuit HCF 4007 UB transfer characteristics, which hardware block configuration is previously described, is controlled using software application developed in LabVIEW graphical programming environment. Concept of virtual instrumentation represents methodology for designing of measurement instruments, based on the standard PC computers and industrial operating stations, additional cost effective hardware components for measuring data acquisition and specialized software packages for analysis and graphical presentation of obtained measuring results. Hardware segment of the virtual instruments includes computer configuration and data acquisition card. Software segment of virtual instruments is programmed depending on current user request on the basis of predefined universal functional blocks, individual elements and measurement instruments front panels from program data base. A most important advantage of the virtual instruments is possibility for simple and fast correction of program algorithm which controls execution of specific measuring procedure [5].

Results from software based analysis presented in the paper are concerning to CMOS inverter input voltage signals having sawtooth shape linear waveforms. Basic parameters of signals

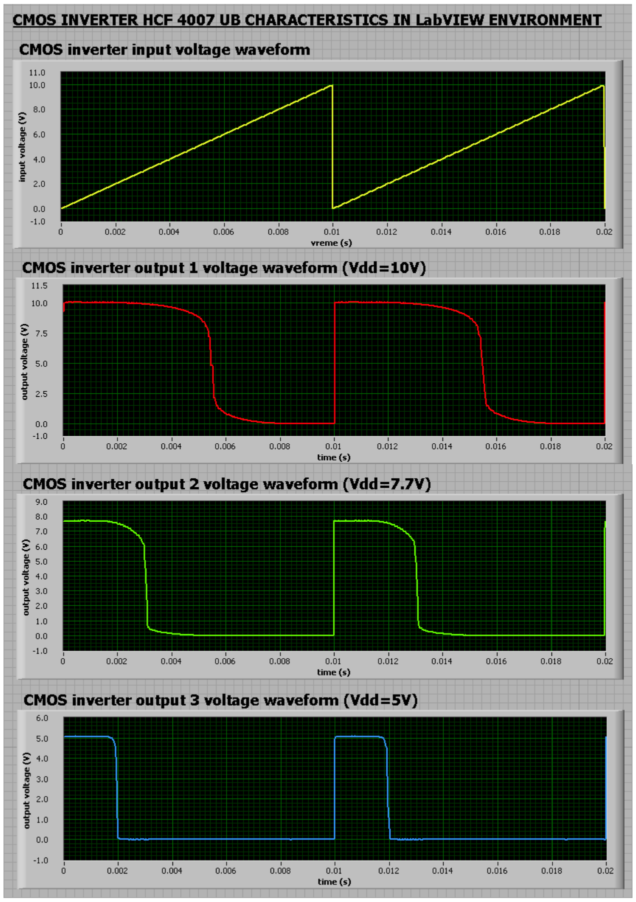

Fig. 4. LabVIEW virtual instrument for presentation of input and output CMOS inverter voltage signals

provided on acquisition card analog outputs, are defined in the developed programming sequence according to the actual user requirements. In this specific case the linear voltage signal put into the inverter inputs, is generated with 10V amplitude value and basic frequency value of 100Hz. Front panel of the virtual instrument developed in programming package LabVIEW 8.0, for graphical presentation of input and output inverter voltage waveforms, is presented on the Fig. 4. Voltage signal put into inputs of three CMOS inverters in the HCF 4007 UB circuit is presented on first above diagram. Next three diagrams present voltage waveforms obtained on the inverter outputs, regarding to different inverter circuit supply voltage values of 10V, 7.7V and 5V, as it indicated on diagrams shown on previous figure.

For detailed software analysis concerning recorded inverters voltage transfer characteristics, are highly significant accurate measurements of propagation delay times for inverters output voltage waveforms. Generally speaking, delay times of output voltage impulses falling edge can be calculated on the basis of measured times correspondent to momentary voltage values of 0.9*V*max i 0.1*V*max [6]. Procedure for determination of delay times regarding to output voltages falling edges, performed in LabVIEW graphical programming environment, is described on Fig. 5. On presented virtual instrument are analyzed output voltage waveforms regarding to each of three CMOS inverters in applied integrated circuit. Two horizontal white markers are located on characteristic voltage levels of 0.9*V*max i 0.1*V*max, while two vertical yellow markers show times in milliseconds, corresponding to the mentioned voltage levels. By subtracting measured time values in the characteristic points of presented inverter output waveforms, for voltage signal falling times are obtained the measuring data: 1.088ms, 0.486ms and 0.115ms. From obtained measuring results can be made conclusion that decreasing of the supply voltage values for inverter integrated circuit causes decreasing of output voltage signal falling time.

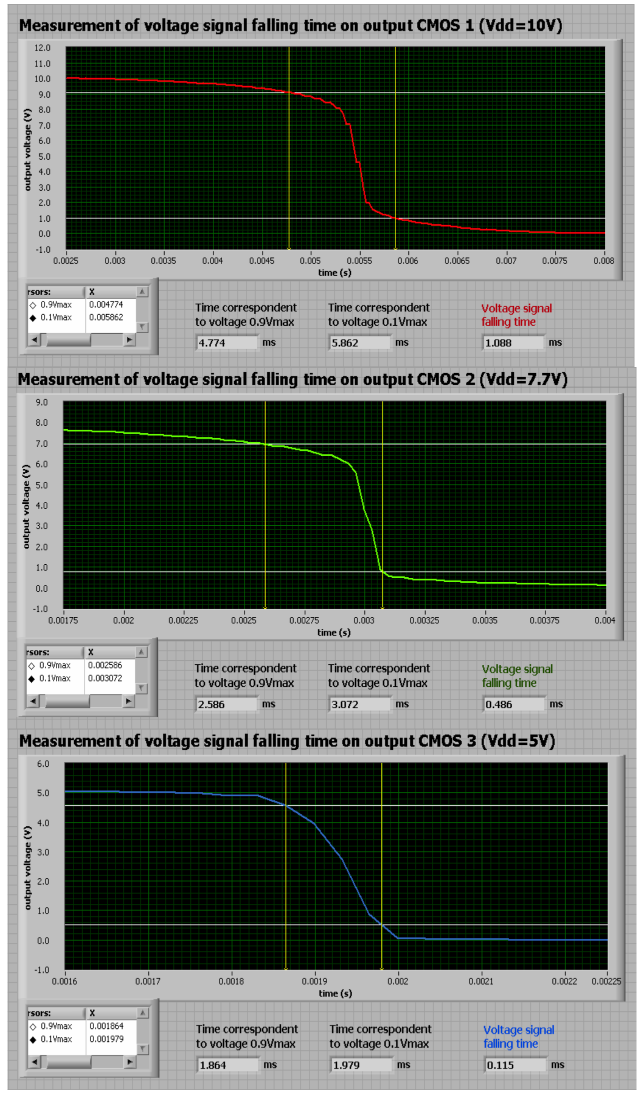

Fig. 5. Measurement of the falling edge delay times on CMOS inverter voltage outputs

Front panel of LabVIEW virtual instrument which performs comparative graphical presentation of the linear input voltage and corresponding voltage waveforms obtained on the CMOS inverter outputs, is presented on Fig. 6. Besides the presented input and output integrated circuit characteristics, recorded for three different values of inverter supply voltage, on the shown virtual instrument front panel are indicated measuring results, concerning the measured maximum output voltage values and time duration of voltage impulses on CMOS inverters outputs.

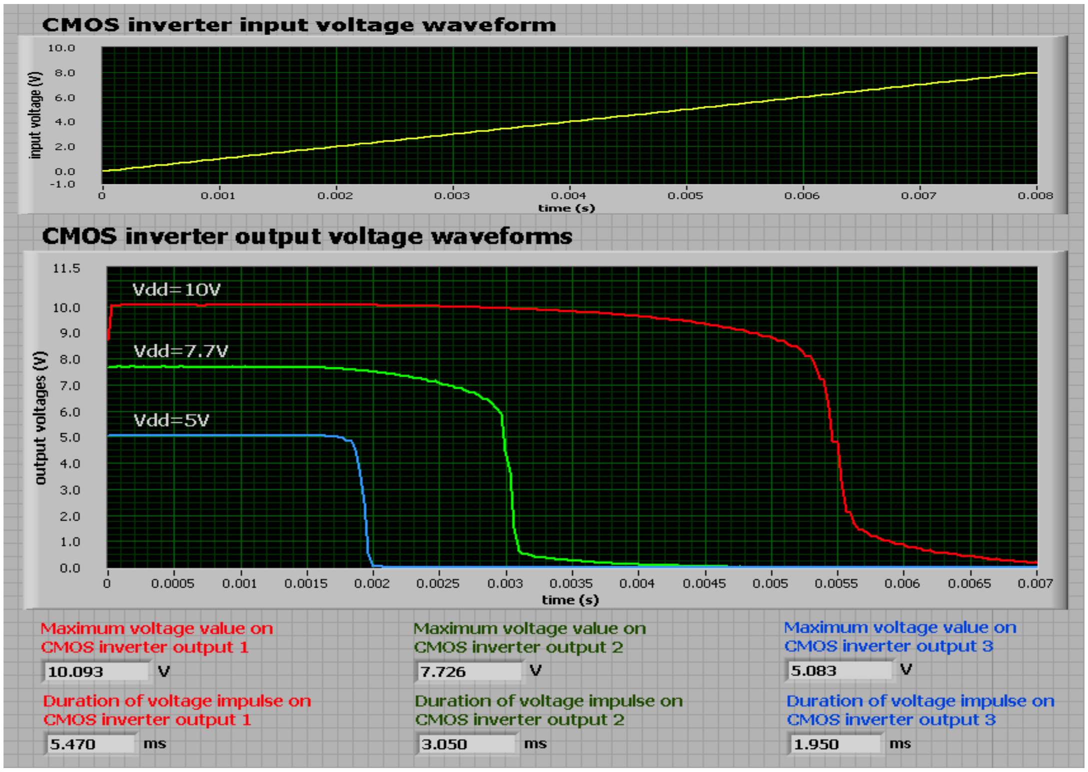

Fig. 6. LabVIEW comparative presentation of the CMOS integrated circuit HCF 4007 UB characteristics

These time intervals of output voltage impulse durations are defined as time values which are corresponding to momentary output voltage values 0.5*V*max [6]. For voltage characteristics presented on previous picture are measured maximum voltage values 10.093V, 7.726V and 5.083V. For duration intervals of voltage impulses on inverter circuit HCF 4007 UB outputs are obtained measurement results 5.470ms, 3.050ms and 1.950ms.

Programming block diagram of described LabVIEW virtual instrument for comparative presentation and software analysis of integrated circuit voltage waveforms is presented on Fig. 7.

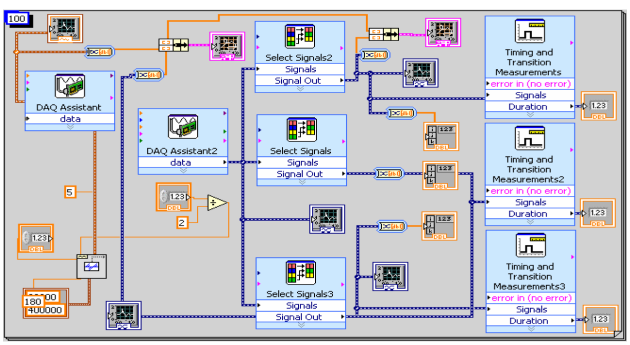

Fig. 7. Block diagram of the LabVIEW virtual instrument

IV. CONCLUSION

Developed solution for experimental measurement and data acquisition system used for the checking procedure of CMOS inverter integrated circuit HCF 4007 UB, is described in this paper. Presented laboratory system is based on the 16-channel data acquisition board PCI NI 6251 and developed model with implemented integrated circuit, controlled using programming application on PC configuration. Application support software is developed by means of the virtual instrumentation graphical programming package LabVIEW 8.0. Multifunctional card for data acquisition provides generation of the voltage test signals for CMOS inverter inputs and receives signals obtained on the inverter outputs. Presented virtual instrument in the LabVIEW environment enables software based processing, recording and graphical presentation of input and output inverter signals for various integrated circuit supply voltage values. Besides that, by designed application software is provided measurement of the inverter voltage signal parameters, including comparative representation and analysis of inverter transfer characteristics.

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