

LABVIEW-BASED LABORATORY ENVIRONMENT FOR LEARNING OF FILTERING CONCEPTS

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Abstract—Better understanding of the acquired theoretical knowledge in the field of digital signal processing, for their successful use in future engineering practice, is achieved by introducing interactive laboratory experiments in the classroom. In this paper we present realization of LabVIEW virtual interactive DSP experiments and hardware DSP laboratory experiments on the NI-ELVIS II + development platform. These experiments can be used in the DSP lab for "visualization" of filtering concepts. For the purpose of "visualization", LabVIEW filter palette has been used for the procedure of band pass digital filter design and active band pass filter has been realized on the NI-ELVIS II+ developing platform. Theoretical characteristics of active band pass filter validated by measurements on realized hardware model.

Keywords – band pass filter, filter characteristics, virtual experiments, hardware development platform, visualization of DSP theory

I. INTRODUCTION

As a rule, learning basic theoretical concepts of signal and system analysis and synthesis is difficult for the students of engineering. This difficulty is a result of the gap between understanding mathematical formalisms of these concepts and student's abilities to connect these theoretical concepts with practical engineering applications. In the aim of solving this problem many "recipes" suggest "visualization" of digital signal processing theory [1].

MATLAB software package has become standardized and inevitable way of "visualization" of DSP theory for a long time. Many MATLAB based DSP "visual experiments" are constituent parts of lectures and practical exercises at the courses of system and signal theory and digital signal processing [2], [3], [4]. Ability of programming in MATLAB is the skill which is acquired by students at the beginning of their Electrical Engineering studies.

However, all that can be done with MATLAB based DSP "virtual experiments", in simpler way, without writing lines of program code, and it can also be done with using software package LabVIEW (Laboratory Virtual Instrument Engineering Workbench). LabVIEW is

graphic developing environment with built-in functionality for simulation, data acquisition, instrumentation, measurement analysis and data presenting. User's interface for some application is created without any code line, with simple "drag-and-drop" of pre-defined objects [5]. Graphic applications created in LabVIEW are called virtual instruments (VI), as their look and functions "imitate" real instruments: oscilloscopes, voltmeters, ammeters, function generators, etc. [6]. LabVIEW contains a great number of library functions which are used for creating applications for solving set of standard tasks from the field of digital signal processing, such as: DFT and FFT transform, presentation and analysis of signals in spectral and time domain, analogue and digital FIR and IIR filters, multirate filters, etc. LabVIEW filter palette possesses range of tools for synthesis and analysis of filters [5] (Fig.1).

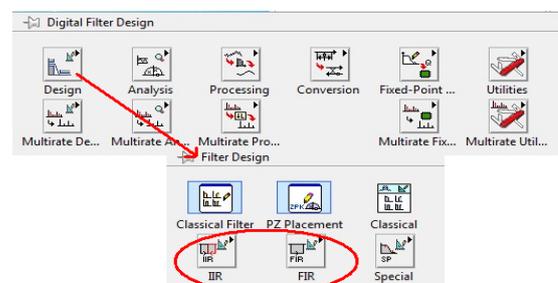


Figure 1. LabVIEW filter palette

However, virtual laboratory environment of MATLAB and LabVIEW cannot completely prepare students of Electrical Engineering for work with hardware equipment and real instruments needed for designing, testing and running of practical engineering applications. So, experiments with hardware equipment and real instruments are necessary at studies. The aim of hardware laboratory experiments in education of engineers through "physical contact with hardware" also means better understanding of acquired theoretical knowledge in order to apply it more successfully in future engineering practice. Hardware lab experiments for "visualization" of DSP theory is possible to realize even without a laboratory which often demands expensive hardware for

digital signal processing. Instead of expensive and “bulky” lab equipment in DSP lab it is more appropriate to use National Instruments (NI) LabVIEW software package in combination with NI-ELVIS II+ hardware developing platform and PC.

National Instrument Educational Laboratory Virtual Instrumentation Suite NI-ELVIS II+ is a hardware developing platform, completely adjusted for software package LabVIEW, by which its usage is easier significantly, on the other hand, it is yet limited to this software package. NI-ELVIS developing platform has numerous abilities which can be applied both in labs at the faculties and in designing professional devices.

Besides standard palette of virtual instruments from LabVIEW, NI-ELVIS enables usage a set of additional virtual instruments (Fig. 2).

Palette contains 12 most often used lab instruments such as oscilloscope, DMM (digital multi meter), generator of functions, Bode analyzer, spectral analyzer, etc. The mentioned VIs are suitable for simple measuring, while for more complex measuring, continual recording of measured data and signal processing it is possible to create new LabVIEW based VI (by using available SubVIs [6]) which would use potentials of hardware platform to the full extent.

Transmission of measured data from developing platform into the computer and vice versa is carried out over USB port which is, unfortunately, a bottleneck of the whole system and limits the speed of hardware’s part down to 1.25 MS/s (data refers to oscilloscope).



Figure 2. Ni-ELVIS palette of virtual instruments

II. LABVIEW DSP VIRTUAL LABORATORY EXPERIMENTS

The students need to see the results of processing – what they see is what they learn best. It is necessary that visual experiment is be highly interactive [7]. LabVIEW has easy-to-use and highly visual GUIs named virtual instruments that built powerfull DSP simulation environment.

Almost all common digital filters design tools are included in LabVIEW.

“Visualization” of the procedure of digital filter design using LabVIEW filter palette is given on the example of obtaining of frequency characteristics for FIR and IIR band pass filter with the following specifications: Lower Pass Band $f_{pass1} = 132\text{Hz}$, Upper Pass Band $f_{pass2} = 1561\text{Hz}$, Lower Stop band $f_{stop1} = 30\text{Hz}$, Upper Stop Band $f_{stop2} = 1800\text{Hz}$ (fig. 3), SB attenuation equal 30dB and PB Ripple equal 0,40.

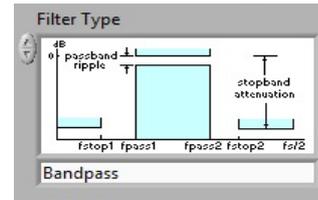


Figure 3. Band pass filter specifications

Filter input signal is sine wave with frequency 1000 Hz. Sampling frequency is 4000 Hz.

LabVIEW filter pallets are used to obtain phase and magnitude response of FIR and IIR band pass filter. Applied FIR filter design method is windowing (selected window is Kaiser-Bessel). Butterworth Approximation for IIR filter is used.

Obtained FIR band pass filter magnitude and phase response are shown in Fig. 4.

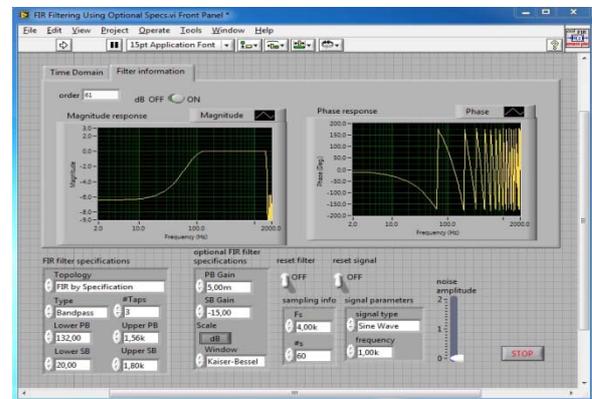


Figure 4. FIR band pass filter magnitude and phase response

Obtained IIR band pass filter magnitude and phase response are shown in Figure5.

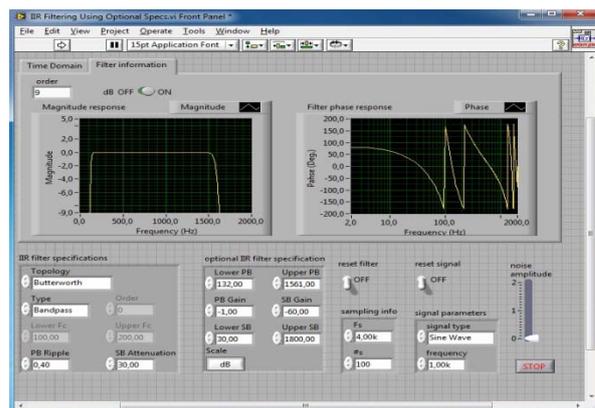


Figure 5. IIR band pass filter magnitude and phase response

Obtained frequency responses of FIR and IIR filters confirm the known fact that FIR filters require a much higher filter order than IIR filters to achieve a given specifications, but have exact linear phase.

III. DSP LAB EXPERIMENTS BASED ON NI ELVIS II+ DEVELOPING PLATFORM

A simple hardware lab exercise for measuring characteristics of active band pass filter has been realized on a NI-ELVIS II+ developing platform.

By cascade connection of high pass filter (HP filter) and low pass filter (LP filter) it is possible to realize band pass filter (BP filter) and by parallel connection of high pass filter (HP filter) and low pass filter (LP filter) it is possible to realize band reject filter (BR filter). Impulse response of BP filter is obtained by convolution integral of impulse responses of HP filter and LP filter which are cascade connected [8].

Active band pass filter whose electrical scheme is shown in Fig. 6 is realized by cascade of three levels [9]: HP filter, amplifier and LP filter. Each level contains an operational amplifier LM741 which is an active component and resistors as well as condensers which are passive components.

Excitation of filters is carried out by LabVIEW function generator (FGEN).

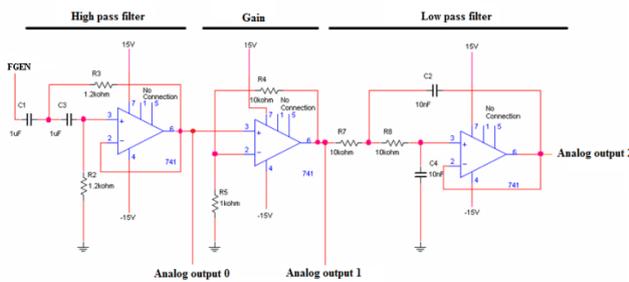


Figure 6. The active bandpass filter electrical scheme

The first level in the Fig. 6 is high pass filter. Its cutoff frequency is $f_{cvf} = 132.6\text{Hz}$. The second level is amplifier whose gain is $A=11$. The last level is lowpass filter whose cutoff frequency is $f_{cnf} = 1591.5\text{Hz}$.

Electrical scheme in the Fig. 6 is realized on NI-ELVIS II+ hardware developing platform (Fig.7).

In the aim of illustrating basic filter function - passing signals without attenuation in certain frequency range, using generator of functions at input of FGEN circuit from Fig. 6 signals of different frequencies were brought to.

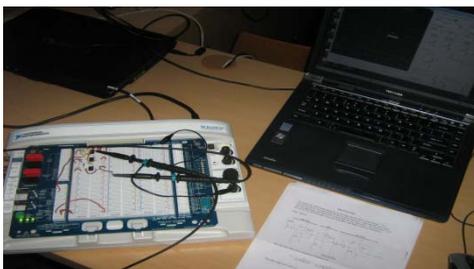


Figure 7. Realization of BP filter on Ni ELVIS II+ hardware developing platform

The waveform of the signals at input (green curve) and output (blue curve) – analogue output 2 of BP filter are shown on the Fig. 8. Expectedly that high pass filter passes signals whose frequency is lower than its cutoff frequency 136.2Hz with significant attenuation while signals with frequencies higher than the cutoff one are passed without attenuation (Fig. 9). It should be pointed out that the amplitude of the output signal is increased as signal passes through amplifying level.

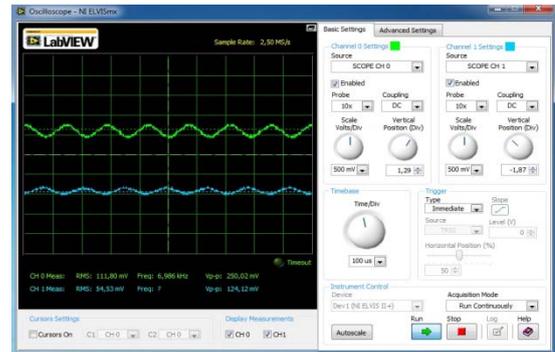


Figure 8. Waveforms of the signals at input and output of BP filter – frequency of the input signal is lower than

$$f_{cvf} = 136.2\text{Hz}$$

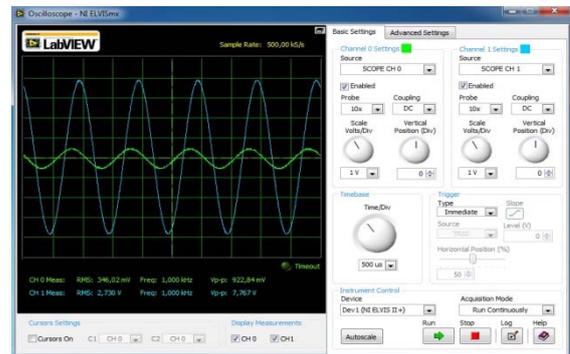


Figure 9. Waveforms of the signals at input and output of BP filter – frequency of input signal is higher than

$$f_{cvf} = 136.2\text{Hz}$$

By using of Bode analyzer from Ni ELVIS palette of virtual instruments Bode diagrams of realized BP filter were obtained. Bode diagrams for band pass filter with pointed cutoff frequencies are shown in Fig. 10.

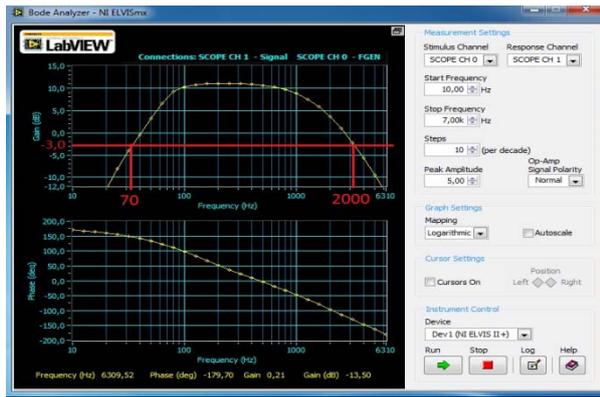


Figure 10. Bode diagrams for BP filter

By using Dynamic Signal Analyzer from NI-ELVIS palette of virtual instruments spectral characteristics at the output of BP filter were obtained. It is possible choose frequency display to be logarithmic [Magnitude (dB/ms)] or linear [Magnitude (/ms)]. Spectrum of output signal of realized band pass filter is shown in Fig. 11.

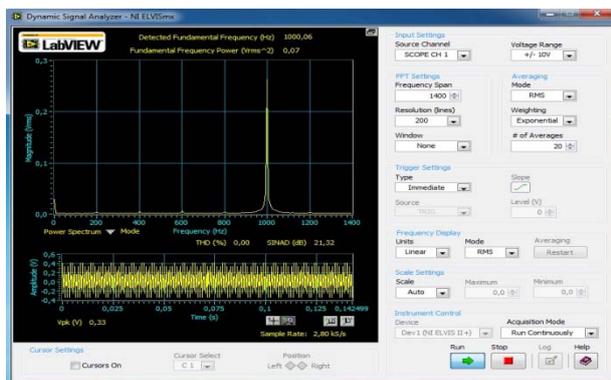


Figure 11. Spectrum of BP filter output signal

Obtained hardware experimental results validates the theoretical concepts of BP filters designing [8]

IV. CONCLUSION

Laboratory exercises realized with virtual interactive experiments and hardware components are very important in education of engineers. These exercises help them to understand better acquired theoretical concepts and apply them successfully in future engineering practice. Theory of signals and systems and signal processing is studied at Electrical Engineering studies through several courses which are mainly theoretical. With DSP lab experiments which can be realized on hardware developing platform NI-ELVIS II+ and with LabVIEW software which imitates realistically real

instruments, students can realize in hardware way and visualize mathematic concepts of filtering in an efficient way, as it is described in this paper. In this paper, in order to illustrate possibilities of application of LabVIEW and NI-ELVIS II+ developing platform for visualization of theoretical concepts of filtering, we have shown just some of the measuring which can be done by their usage. However, a whole range of characteristics is possible to be obtained by using LabVIEW and NI-ELVIS II+ palette of virtual instruments as well as by creating the new ones. It is also possible to record measured data in the form of data files for further processing. Similar DSP lab experiments can then be realized in MATLAB and then obtained results are compared and analyzed. DSP lab experiments are possible to realize with the help of FPGA developing platform which has been planned as one of the topics of future papers of the authors.

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