# CONSIDERATIONS ON USING THE VIRTUAL INSTRUMENTS FOR THE ACQUISITION AND ANALYSIS OF EXPERIMENTAL DATA FROM DYNAMIC SYSTEMS

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## ABSTRACT

*The new slogan "The software is the tool" takes into consideration a new construction principle for the measuring tools and systems, with a brand new architecture. These systems and tools are assembled into a "virtual space" computer programming environment which provides such basic elements of construction. There is a big advantage of this type of measuring system: each human user can build himself an unlimited number of instruments intended to process and to analyze experimental data; these virtual instruments on the basis of dedicated computer applications can meet individual requirements designated to cover an extended domain of analysis. The function of data acquiring of the equivalent real instrument is now taken by a new PC peripheral (DAQ - data acquisition interface). The functions of data conditioning, data analysis and control are completely taken by the existing hardware in the computer and the software package in question. The current instrument system, as a whole, is designed and developed as a part of the computer, making possible the direct use of the computing power and the facilities of the PC. The article presents the virtual instrument developed on ICECON S.A. Bucharest on the basis of LabView® ver. 8.5 from National Instruments. The virtual instrument was used to acquire and to process some experimental data from the dynamic tests of the Bechtel viaduct at KM 29+602,75↔KM 29+801,25 on the Romanian Highway A3 ("Transilvania" highway).*

KEYWORDS: virtual instrumentation, dynamic parameters, vibration measurement, FFT analysis

## 1. INTRODUCTION

A virtual instrument can be defined as a complex software and hardware interface that is implemented in PCs, so theat the user can interact with traditional analysis tools [1], [2].

The virtual instrument can perform the following functions:
- the function of data collection, executed by acquisition card DAQ connected directly to the processor bus; memory registers are accessible directly on the PC's motherboard to address the cells I/O on computer memory;
- the function of data control and analysis, which is completely taken up by the existing hardware and software in the PC;
- the function to display the results; the existence of a graphical unit interface (GUI) driver permits a much easier handle and control of any application of virtual instrument.

The virtual instrument panel is displayed on the computer monitor, which can look just like traditional instrument panel. Virtual instrument panel has a background program

which simulates the controls of the real instruments, allowing the working routines of acquisition, data analysis, graphic presentation and storage of data or results files. Virtual instrument construction is done in accordance with the user's „specifications". In order to do that, the programme uses standard hardware architectures, proper drivers, specific software packages and special libraries. The virtual instrument uses digital tools like traditional software modules from a large package, difference being that while traditional instruments include the software in its ROM memory, the virtual instrumet uses the computer HDD to do it.
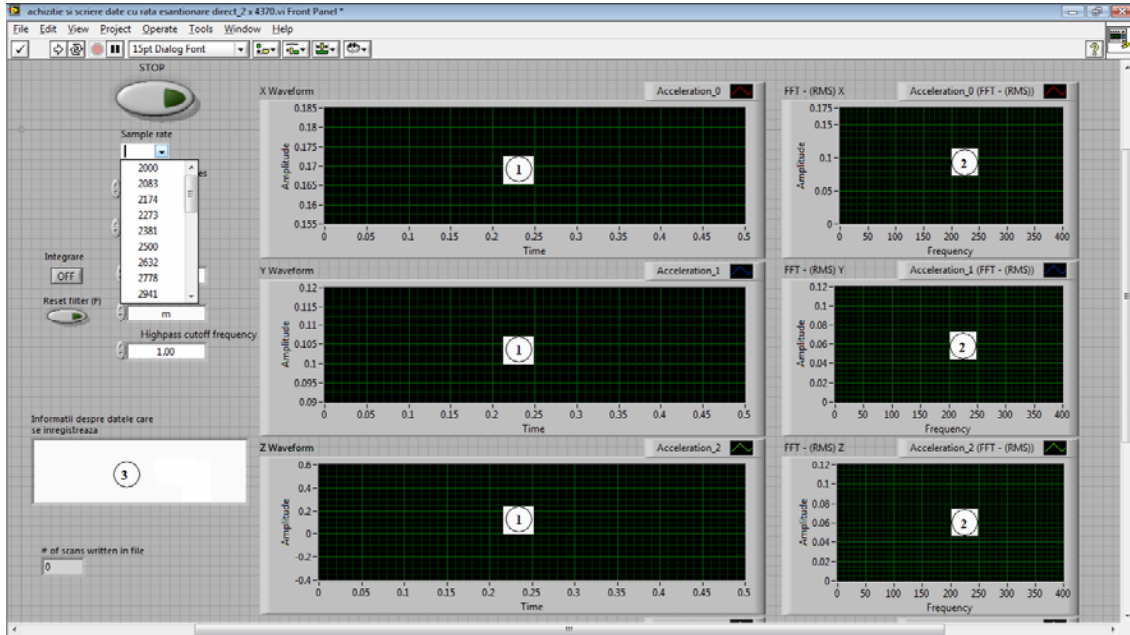


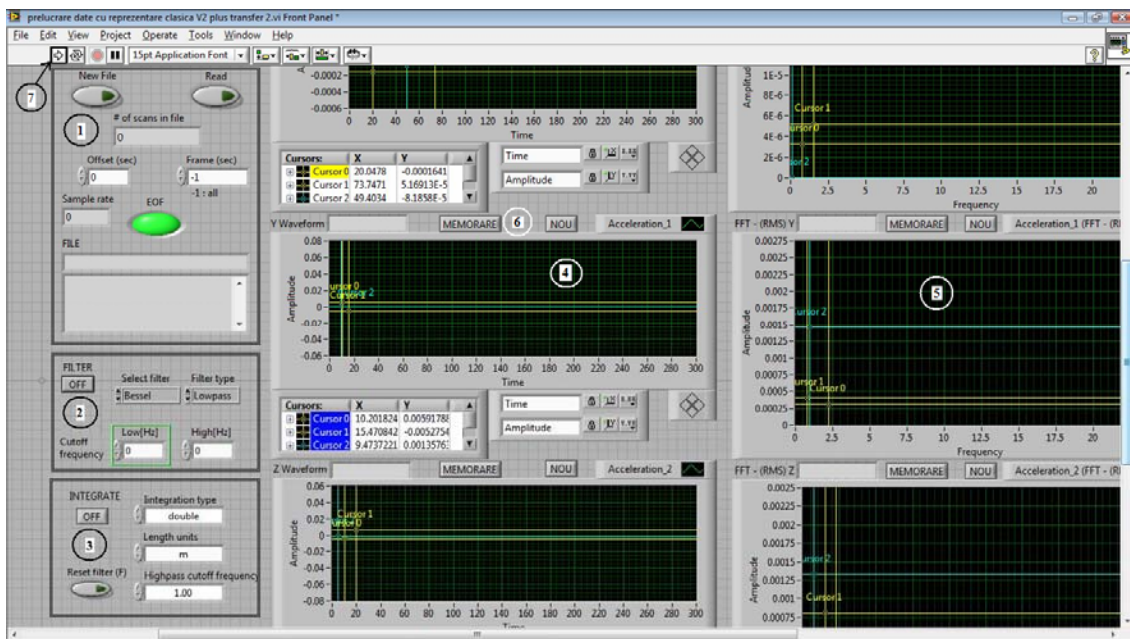Figure 1 Front panel instrument reading acceleration values on three channels



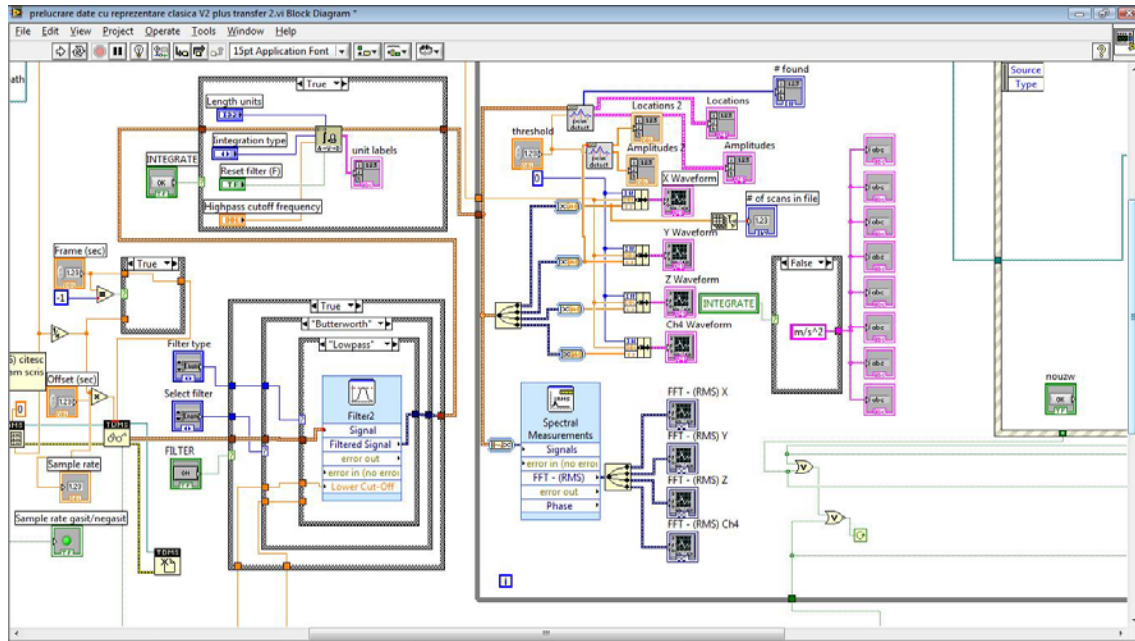Figure 2 Partial view of the front panel of instrument analysis

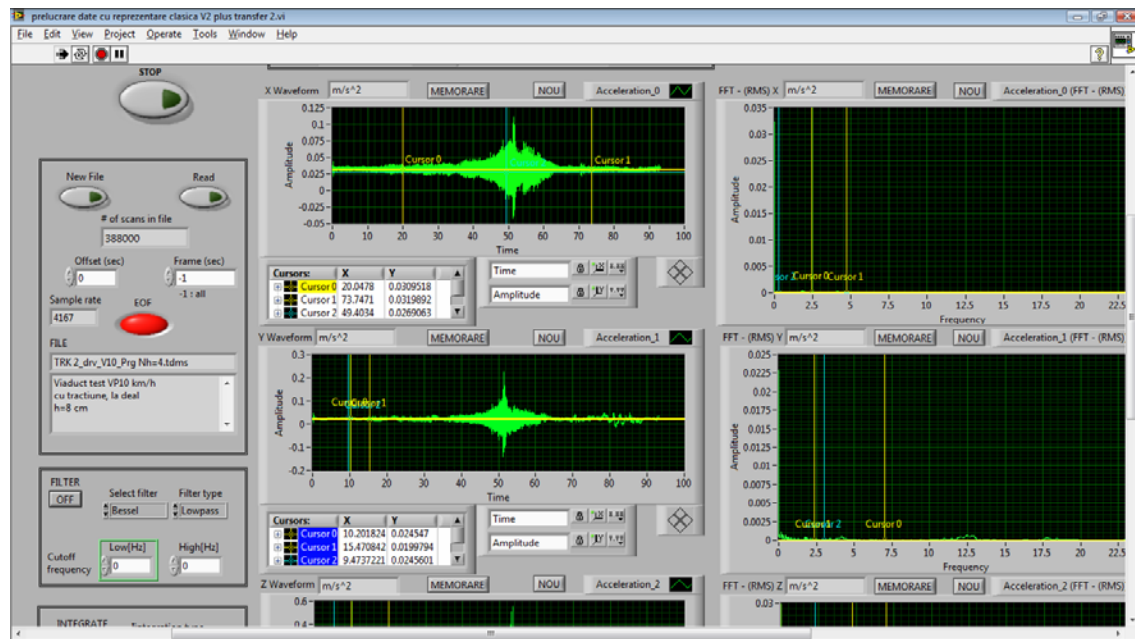Figure 3 Partial view of the virtual instrument block diagram analysis



Figure 4 Front panel display for a data file

## 2. THE STRUCTURE OF THE VIRTUAL INSTRUMENT

In order to analyze the dynamic parameters of vibration, there were designed and built two virtual tools:

- one for acquiring and saving acceleration values taken during experiments;
- the second to analyze the acceleration parameters.

The acquisition of vibration analog signals is made by accelerometers. The analog signals are transmitted to DAQ, which may be inside

(internal) or outside (external) the PC. The DAQ performs a signal conditioning and conversion in the digital format. Digital values are transmitted directly or through a cable into a USB port on the PC which is running the signals' acquisition program. The acquisition program has some features which provide the opportunity for memorizing information about the measurement conditions.

Figure 1 shows the front panel of the virtual instrument designed to acquire the experimental data from the accelerometers. The values of the vibration accelerations are shown as evolving over time (time representation) in the graphs numbered with 1; the graphs numbered with 2 show the results of FFT analysis of the acceleration signals from graphs 1. In the front panel of the virtual instrument, the buttons from area 3 permit the introduction of additional information.

Figure 2 shows the virtual instrument for signal processing. Area 1 can read all data, or only a portion of the signal, by specifying an offset, in seconds. Area 2 contains buttons that allow filtering the input signal indicating the type of filter and filtration method. Area 3 is the control area of the instrument which contains buttons that perform the numeric integration of the input signal of acceleration; in this way, the virtual instrument can offer the velocity and the displacement parameters of the vibration (time representation, frequency distribution). In the 4th area of the virtual instrument there are values for the signal (the „on-line" values of the accelerations). Area 5 shows the corresponding signal spectrogram (frequncy distibution) of the signal displayed in area 4. The panel of the virtual instrument contains such pairs of graphs for all the channels DAQ. The button numbered with 6 allows to store, in another file, the values corresponding to the cursor number 2 in the chart, for other data processing. The front panel cannot fully be displayed on the screen, because there are a lot of data to be displayed in the virtual instrument front panel; the window of the instrument front panel has vertical and horizontal scroll bars that allow displaying the desired area.

Figure 3 shows a block diagram for the virtual instrument analysis (partial view). We can see blocks that allow the filtering and the integration of the signal and the function to display the processing results. Block diagram is a WHILE-DO BLOCK with a stopping condition (by pressing the Stop button). In the scketch from fig. 3 there are all other functional blocks. Colored lines represent different data moved between functional blocks.

## 3. THE VIRTUAL INSTRUMENT OPERATION

The program is starting from the power button 7 in fig. 2. The "push" on this button opens a dialogue where the user selects the file containing the signal to analyze.

Figure 4 shows a part of the front panel after reading a data file. It is possible to modify the extremes of the x-axis for any graphic. The resulting image is automatically extended to the whole area of the graphic. In this way actually runs a zoom image.

Figure 5 shows a time representation of a signal between 0 and 100 seconds. Modifying the time limits, 40 seconds on the left and 65 seconds on the right, fig. 6 shows the appropriate time representation of the signal between these two moments in time.

Cursors can be moved to any point in the graphs; in this case, in the area under the time representation of the signal graph is shown the corresponding values of the two axes. Virtual instrument was designed to be able to save the coordinates of any point of view graphics in another Excel compatible file. By using the zoom function of the virtual instrument, we can view a desired area. By moving the cursor to the desired point we can read its details.
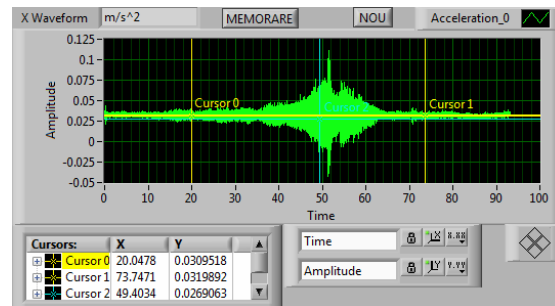


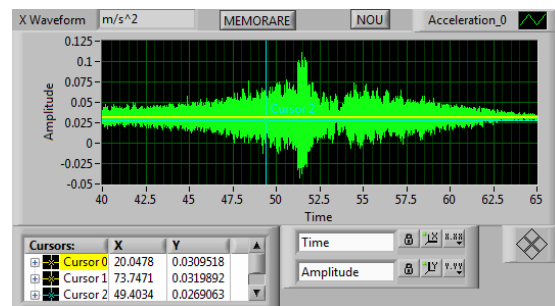Figure 5 Zoom in a graphic display
(time: 0 to 100 seconds)



Figure 6 Zoom in a graphic display
(time: 40 to 65 seconds)

## 4. CASE STUDY – FFT ANALYSIS OF THE EXPERIMENTAL DATA OF THE VIADUCT WITH COMPOSITE NEOPRENE BEARINGS

The virtual instrument developed on the basis of LabView® ver. 8.5 was used to perform the dynamic tests in site on the viaduct situated on km 29+602,75 - km 29+801,25 on the A3 Romanian highway; the dynamic actions were generated by running a four axle 41 ton truck over standardized height h=4 cm obstacles fixed on the viaduct surface with chemical anchors; running speeds were 10km/h, 20km/h, 30km/h and 50 km/h. The experimental data were obtained on three channels (accelerations on the axis x, y and z) by a fourth channel DAQ from National Instrument (NI 9233) through the USB port of a PC workstation.
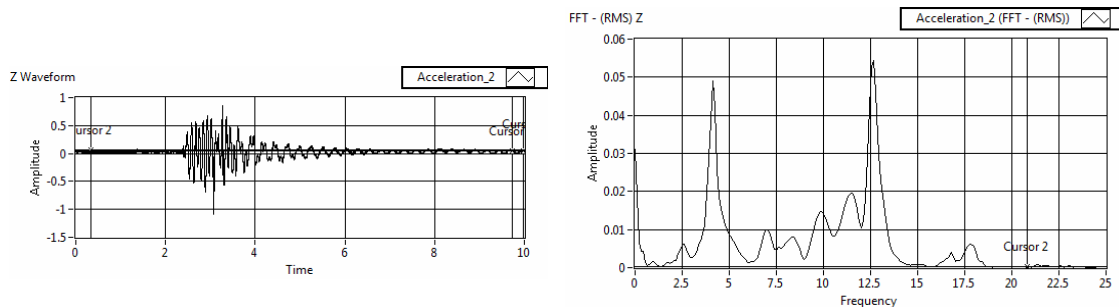
a)                  b)

Figure 7 Vertical acceleration ($v_0 = 30km / h$ with traction)
**a)** time representation; **b)** frequency representation
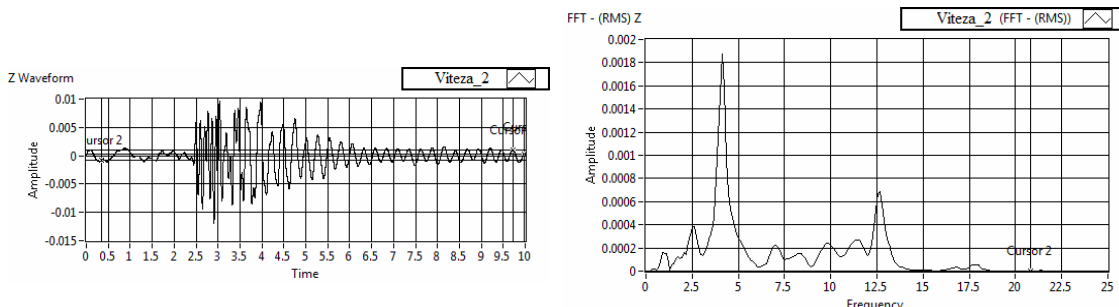
a)                  b)

Figure 8 Vertical velocity ($v_0 = 30km / h$ with traction)
**a)** time representation; **b)** frequency representation
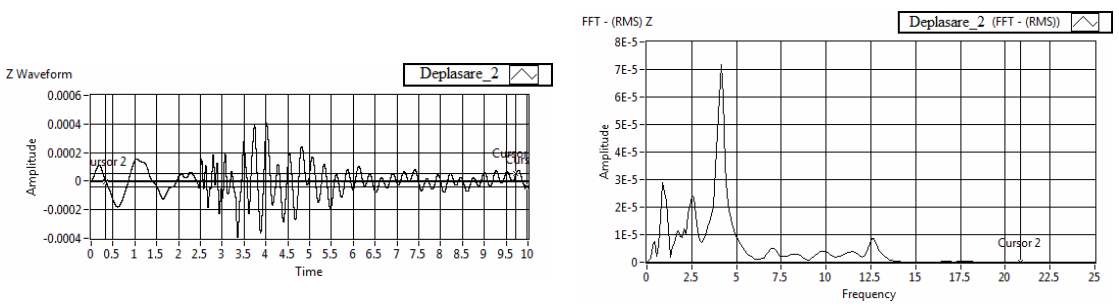
a)                  b)

Figure 9 Vertical displacement ($v_0 = 30km / h$ with traction)
**a)** time representation; **b)** frequency representation

Figure 7 shows the representations of the vertical acceleration [m/s$^2$] of the viaduct in the point where the transducer was mounted for a period of 10 seconds of signal analysis. In the time representation from fig. 7a, we can see the acceleration signal when the the tyres of the truck are passing over the obstacle (the moment time of the shock is about $t = 3\,sec.$) and the time duration of damping movement (between $t = 3\,sec.$ and $t = 10\,sec.$). In the representation of the signal from fig. 7b, we can see the frequency response of the viaduct; the significant natural frequencies resulting after FFT analysis are about $f = 4.1Hz$ and $f = 12.6Hz$.

Figure 8 shows the representations of the vertical velocity [m/s] of the viaduct for the same period of 10 seconds as in case of vertical acceleration. The signal of velocity was „calculated" by the virtual instrument through the integration block from the acceleration signal. As in the vertical acceleration representation from fig. 7, we can see in the two graphs of fig. 8 the moment of the shock, the damping of the vibration period and the natural frequencies.

After a second operation of numeric integration, the virtual instrument has obtained the displacement signal of the vibration of the viaduct. Figure 9 shows the representations of the displacement signal (in time and in frequency). In the graph from fig. 9a, we can see the evolution in time of the displacement of the bridge along the shock moment and the damping period. The diagram from fig. 9b shows the frequency distribution of the displacement signal for a 10 second-time of analysis.

## 5. CONCLUSIONS

In comparison with the real measurement apparatus and/or systems, the different virtual instrumentation softwares (LabView® from NI U.S. is not the only software dedicated to virtual instrumentation [4], [5], [6]) have the following advantages:
- they can "build" complex measuring instruments, which are not possible for physical instruments;
- they are "open systems": the achievement of virtual instruments may be realized by the sub-programs provided by the programming environment, but also by the human programmers' sequences (written in C++, MATHLAB, a.s.o.);
- processing results can be saved in different file types, allowing export of such data to other applications;
- graphic module of the instrument allows the viewer to enable zooms to display the contents of small details.

The greatest advantage of this type of measurement tools is that on the same PC can coexist more virtual instruments using the same monitor, independently or in relation to each other.

For the LabView® software from National Instruments U.S., we can say that in 2010 the producer has just developed the fourth generation of equipment (the version 8.6), which has the following advantages [3]:
- the executable code programming environment is optimized for performing computations in parallel processor cores and the user is able to program the kernel routing calculations;
- the substantial reduction of the number of devices required for data acquisition and processing;
- the improvement in the reliability of the virtual measuring system;
- the existence of rapid decision capabilities and error correction;
- the improvement of the possibilities of analysis, displaying and storage of results;
-the possibility of direct connection with performing numerical analysis programs;
-the reducing of the expenses with experimental research.

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