LabVIEW Modules in a Concept of a Portable Signal Analyzer (PSA)

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A Portable Signal Analyzer (PSA) is the target instrument to be designed. Its internal architecture is a pure composition made of standard National Instruments programmable automation controller (cRIO) and an advanced touch screen panel. The prominence of the design arises in the powerful software application which combines extremely rapid signal processing and beneficial rendering. Data acquisition is based on LabVIEW modules, including custom tailored functions, while the user interface is programmed in touch screen (Easy View) editor. Integrated design of the multichannel analyzer incorporates a set of four accelerometer input lines, as well as two common analog inputs (4 – 20 mA). A vast selection of assorted signal analysis functions is available with this device.

Keywords: *data acquisition, LabVIEW, multichannel signal analyzer.*

1. INTRODUCTION

Market researches on multifunctional multichannel signal analyzers show the lack of such equipment in the range of powerful jet affordable devices. This paper describes an engineering attempt to develop a novel vibro-diagnostic instrument, consisting of standard items but aimed for demanding technical applications. The multichannel signal analyzer is designed to monitor a cluster of accelerometer signals in order to determine: vibration severity (RMS value of vibration velocity), peak tones of the spectrum (FFT), time graph of signal trends, also to display and exchange data via conventional communication ports and protocols.

The concept of a novice portable data logger is based upon the idea of composing NI cRIO specialized PLC and sophisticated touch screen HMI.

The role of NI cRIO in this arrangement is to accept analog and digital signals, scan them fast enough, convert them into useful data and deliver comprehensible data packages to HMI.

On the other hand, the role of HMI is to receive data packages, adapt them for a specified application and make the information perceivable for the user.

A major difficulty arose regarding bidirectional communication of cRIO and touch screen via Modbus protocol. Synchronization between the Master device (T.S.) and the Slave device (cRIO) was a critical for a fluent operation. Therefore, both the data acquisition and the data analysis should be done in a strictly determined sequence. If any delay in task completion occurs, the bundles of data can be permanently lost, and the whole system might come into a halt. This difficulty is solved by the task priority definition. Timely data delivery is of the highest rank. More precisely, when a master unit requests a new data package the slave must shortly send some data package, whether it is a valid or a simulated one. Such a data exchange strategy enables smooth program development.

2. HARDWARE DESCRIPTION

The measuring system comprises: an NI Compact RIO device as a core unit, conditioning block for analog signals, touch screen as user interface, power supply unit and a set of connectors. The cRIO is an embedded controller for deterministic control, data logging and analysis (Fig. 1). Processing speed is 195 MHz, which is considerably high with the nonvolatile Compact Flash memory of 512 MB. Programming of cRIO is performed via Ethernet port in LabVIEW program code. The RS-232 port of cRIO is connected to Easy View touch screen. In the cRIO an analog input module NI 9201 is embedded. It has eight analog ports with ± 10 V input range. Overall sampling rate is 500 kS/s with a 12 bit resolution. For the analog signal pre-conditioning an originally developed module is used. It is necessary to provide a current pump for the SKF accelerometers (CMCP 1100) and gain sufficiently useful signal, as well suppress the interference. The sensitivity of the accelerometer is 100 mV/g, and the measuring range is ± 50g.

3. FUNCTIONS AND LAB VIEW MODULES

For the cRIO programming a LabVIEW graphical development environment is used, also referred to as G, a data flow programming language. Task execution is determined by the structure of a graphical block diagram (the LV-source code). These wires propagate the variables and any node would execute when all its input data become available. Since this might be the case for multiple nodes simultaneously, G is inherently capable of parallel execution. Multiprocessing and multithreading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

The LabVIEW concept can be explained by a simple example (Fig. 2). Two numbers “Number 1” and “Number 2” are numeric controls. An icon with the sign “+” makes a sum of these two inputs. Subsequently the sum is multiplied by two. Result appears in the “Result”

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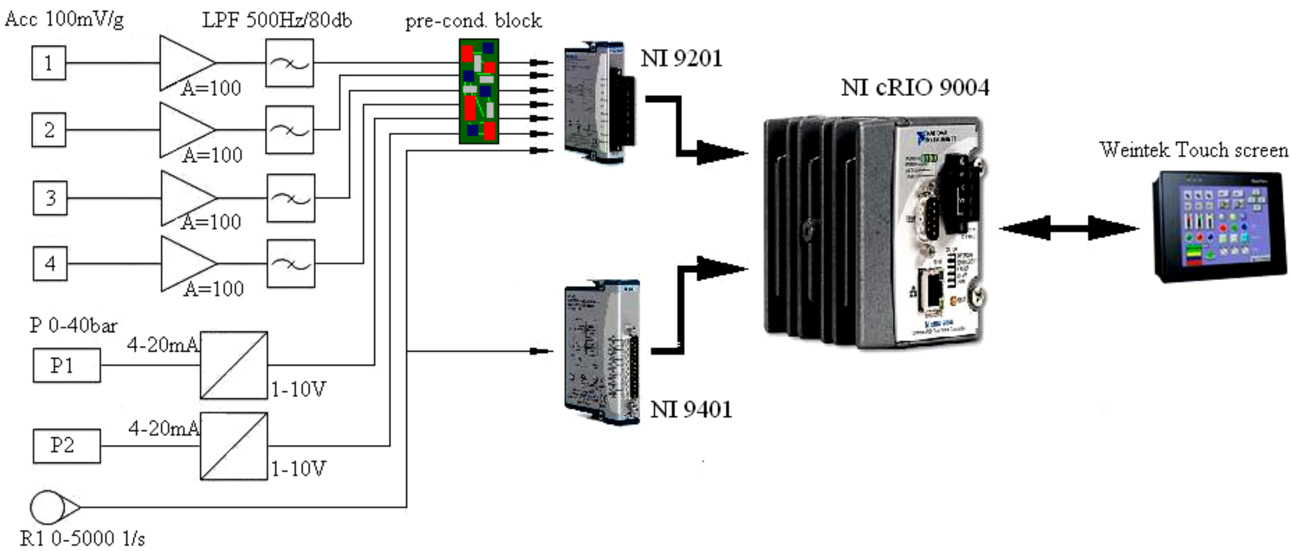

Figure 1. PSA architecture

box. This code block is within the “While loop”, which means the code runs until the “STOP” button is pressed. The code is written in the surrounding called “Block diagram”. “Number 1” and “Number 2” values can be set on the “Front Panel” while the program is running. The stop button could be also activated from this surrounding (Fig. 3).

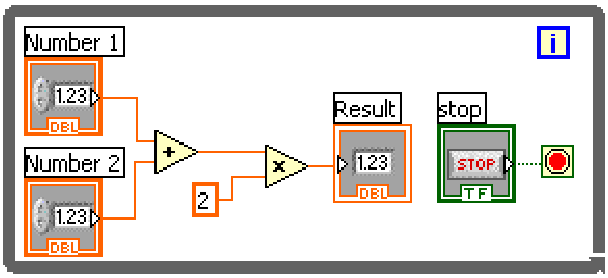

Figure 2. Simple Math loop in LabVIEW

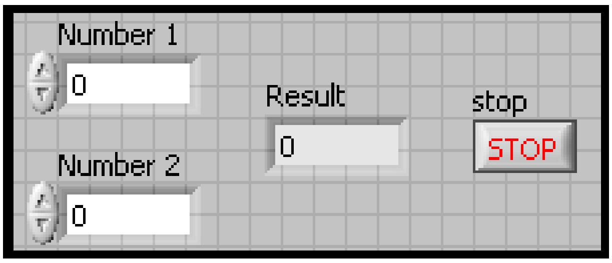

Figure 3. Front Panel

The LabVIEW has a large built-in mathematics library, particularly for matrix and array calculus which are substantially important in our case.

A vast number of libraries contain different functions for data acquisition, signal generation, mathematics, statistics, signal conditioning, analysis, etc. Also, the numerous graphical interface elements are provided in several LabVIEW package options. Mathematic blocks also involve integration, filtering, and other specialized data capture features. Besides, LabVIEW includes a text-based programming component called MathScript which uses syntax generally compatible with MATLAB [1].

Sampling rate of 2 kHz per channel provides continually 14,000 samples each second. Data record is a sample compound from four accelerometers, two pressure gauges, and one pulse detector. These samples are dispatched into LabVIEW application for FFT analysis module. Then, “Peak Finder” application determines the frequencies of undesired perturbation. Afterwards, a special code forms an ascending array of frequencies and related amplitudes. Now, the packages of these arrays are ready to be sent towards the touch screen via Modbus Serial protocol. Each channel data block is represented by one array, and they consist of seven dominant tones. More than ninety individual values are sent in each communication transaction every second. Those values are used to form the charts, trend lines, and show the result fluctuation, on-line.

The PSA was originally designed for small hydropower plants condition monitoring. Water pressure is measured both on the inlet and discharge side of a turbine. Raw data samples are irrelevant because of the fast pressure fluctuations. Pressure peaks must be statistically treated. The experts in hydropower plant-design suggest taking into account just smooth 95 % of collected samples. These 95 % should not include peak values. Bundles of 2000 samples are collected each second and packed in an array. First icon “Sort 1D Array” (Fig. 4) sorts these samples into the ascending order. “Delete From Array” application truncates specific elements of an array.

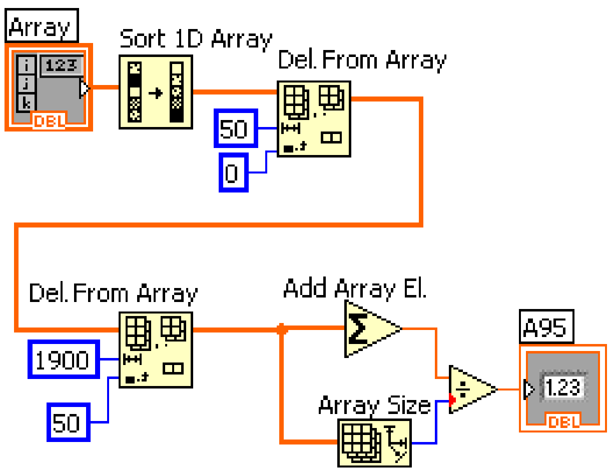

Figure 4. PSA statistical data processing

In this case the first and the greatest 50 elements of an array are deleted (index 0, length 50). Also, the last and the least 50 elements are cut off. Finally, the elements sum is divided by the number of elements (that are left in the array) in order to calculate average value (A95).

Signals obtained from the accelerometers are scanned with a sampling rate of 2 kS/s. One-second record contains 2000 elements. Such an array "undergoes" the "Power Spectrum" treatment, in other words Fast Fourier Transformation (Fig. 5).

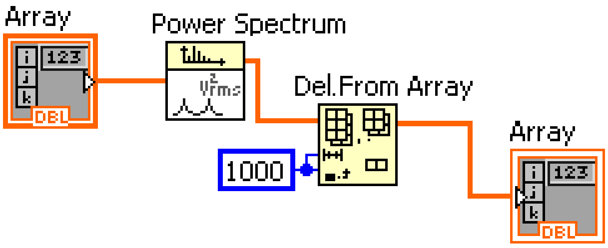

Figure 5. PSA module for FFT

The outcome of FFT is a new array of 2000 elements. Elements indexed 1000 to 1999 are identical with those indexed 0 to 999 (including the marginal elements). It is a pure nature of applied mathematics. Practically, the useless fraction of array is truncated (elements 1000 – 1999). Now, the Power spectrum is formatted and available. Essential task is to select the prominent peaks to be shown on Touch screen. For the purpose of pure engineering needs the seven peaks of highest amplitude should be expressed. Less than that number could be insufficient for the competent vibration. More than seven peaks would be confusing. In order to extract seven dominant peaks, the following code is applied. The already formed Power spectrum of 1000 elements is an input array. "Peak Detector" scans the whole array and finds the peaks. The output of "Peak Detector" is a dual array (Fig. 6).

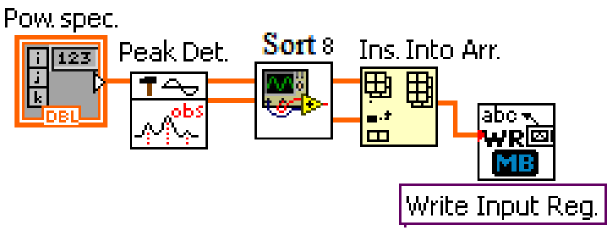

Figure 6. PSA prominent tones extraction

One array section contains prominent amplitudes of the founded peaks, and the other contains related frequencies. "Sort8" function sorts the amplitudes in ascending order, and accordingly corresponding frequencies. "Insert Into Array" merges these two sections into one array, so the first seven components are frequencies, and the following seven are amplitudes. Each channel array with its FFT array contributes the joint register, which is formed by "Write Input Registers". Due to seven monitored channels, and four operating modes, more than hundred values are dispatched towards the touch screen each second. These values have strictly assigned addresses, which guarantees proper unpacking, and interpreting.

A very specific part of a program code is aimed for sight balancing. For the unbalance vector calculus it is necessary to synchronize analog signal from the accelerometer and the phase tracking signal Unbalance occurs at the fundamental frequency generating more or less pure sinusoid. On the other hand, from the photocell comes a pulse signal (Fig. 7).

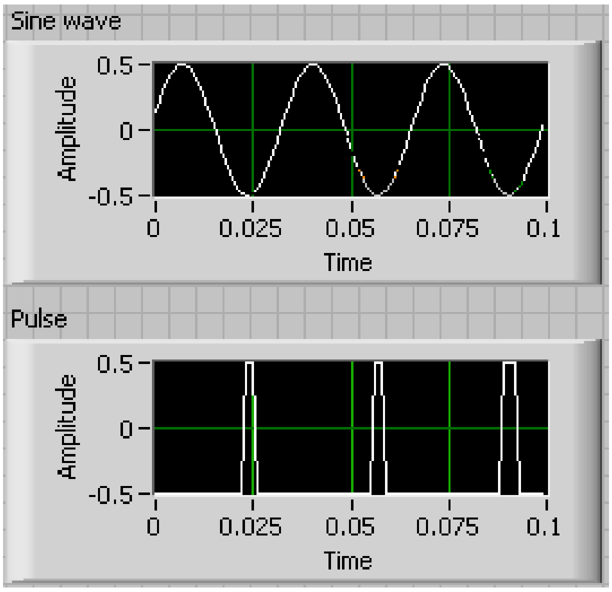

Figure 7. Sine wave and pulse reference of unbalance LabVIEW Front Panel

Phase reference of the sinusoidal signal is a moment of the transition 0 to 1, of the parallel observed pulse signal (Fig. 8). This point is the left margin of the sampled interval and the right margin is four full periods farther (Fig. 9). One full period counts N points.

$$N = \frac{\text{Sampling rate}}{\text{Fundamental frequency}} . \quad (1)$$

Magnitude averaging is applied on four full periods.

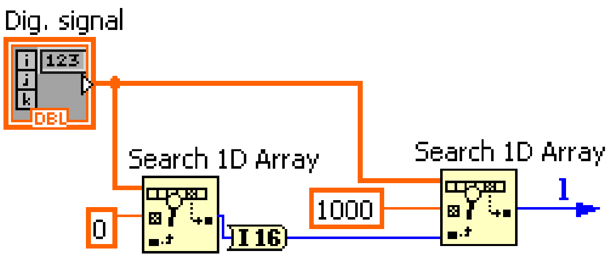

Figure 8. Pulse detection

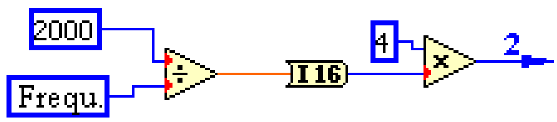

Figure 9. Extraction of four full periods

Now, all the relevant information to determine unbalance vector are prepared (Fig. 10). "Array Subset" extracts a specific segment of an array. A new array consists of four full periods, with a consistent phase reference.

Start is related to the pass of reflection marker near photocell. "Balance" module simply calculates amplitude and angle of unbalance vector. These two parameters are dispatched to the touch screen by the routine procedure (Fig. 11).

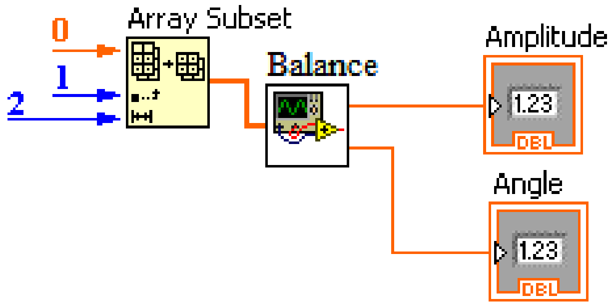

Figure 10. Unbalance vector calculus

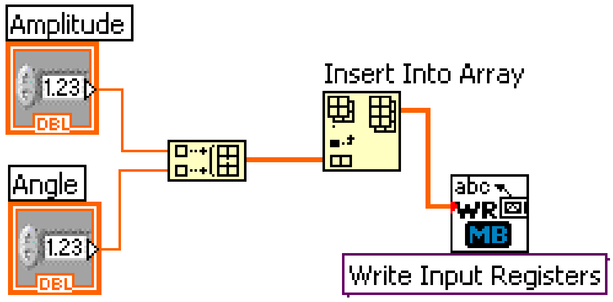

Figure 11. Unbalance data package (cRIO dispatches to Touch Screen)

4. PROGRAM INTEGRATION

Main menu of PSA comprises four operating modes.

In **Alarm mode** PSA observes 6 analog channels and compares measured values with prescribed alert levels. If any of the collected quantities exceeds alert level, it is promptly indicated on the screen.

Trend line mode recalls measured records of a value for the at most twelve months. For the selected channel, it is also possible to zoom any segment of the trend line. Refresh rate of the graph is two seconds. If anything odd is spotted on the graph, FFT analysis could be performed for that specific point. This feature supports post event analysis.

FFT analysis mode presents an off-line spectrum of seven dominant tones for the selected channel.

Balancing mode is conceived as a graphical composition of initial and final correction vector. A set of consecutive steps lead from initial magnitude measurement to apparent image of final, ISO acceptable correction vector.

5. CONCLUSION

The PSA is a multipurpose, multichannel data logger with a prominent feature of vibro-diagnosis and site balancing.

The distinctive design based on NI cRIO platform in the conjunction with a PC Touch Panel, promotes a flexible universal Data Acquisition device. When supplied with an adequate software application this system becomes a powerful handheld station.

Absence of a standard PC or a lap top in the measuring chain improves PSA immunity on numerous disturbances either in software or in hardware.

Compactness of the whole package reduces the vulnerability to the most of usual industrial threats: noise, impact, electricity surges, dust, contamination, moisture, etc.

The simplicity of the application reprogramming is incomparably unique. Both the great choice of different functions and redundancy of its libraries make the programming process a creative and effortless activity.

Experiences gained on this project will be extensively exploited in the forthcoming period, mostly for the design of similar site data acquisition systems as well for the development of new condition monitoring devices.

ACKNOWLEDGMENT

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NOMENCLATURE

NI	National Instruments
cRIO	compact reconfigurable input/output
RMS	root mean square value
FFT	fast Fourier transformation
PLC	programmable logic controller

LABVIEW ПРОГРАМСКИ МОДУЛИ ПРИМЕЊЕНИ У КОНЦЕПТУ ПРЕНОСНОГ СИГНАЛ АНАЛИЗАТОРА

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Преносни вишеканални сигнал анализатор је постављен за циљ иновационог развоја. Унутрашња архитектура уређаја усвојена је на бази стандардног *National Instruments* програмабилног контролера (*cRIO*) и усавршеног панела осетљивог на додир. Изузетност техничког решења огледа се у снази програма који успешно комбинује веома брзо процесирање сигнала и ефикасно графичко приказивање. Основна обрада података реализује се *LabVIEW* програмским модулима, укључујући и посебно развијене функције, док је корисничка комуникација решена помоћу панела осетљивог на додир (*Easy View*).