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# Signal Analysis and Processing Platform Based on LabVIEW

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**Abstract:** A signal analysis and processing platform was developed in this paper. The platform was designed by LabVIEW 2012 which covered many signal analysis and processing functions, such as Filter, Spectrum analysis and so on. After testing and practical application, the interface of the platform is flexible, vivid and easy to operate which can meet the needs of universities and research laboratories. *Copyright © 2014 IFSA Publishing, S. L.*

**Keywords:** Signal analysis and processing, Time domain analysis, Frequency domain analysis.

## 1. Introduction

With the development of microelectronics, computer, and software technology, some traditional instruments began to develop in the direction of computerization. Virtual Instrument (VI) arises at the historic moment. VI is a kind of instrument with extended and user defined functions which is widely application in many fields, such as noise testing in [3], simulation of robotic systems dynamic model in [4], bio-signal acquisition in [5], signal process in [6-8], DAQ system in [9-11], digital image enhancement in [12].

Radio and electronic professional requires knowledge of signal processing and analysis. LabVIEW is the most popular development tools of VI software. With the capabilities of strong signal processing and analysis in LabVIEW; we designed a signal analyzer platform. The platform can make users feel more visual in image impression of signal analysis and processing for the environment of LabVIEW graphic programming.

Altogether, this platform has designed five big modules [1], including several small modules. The detail models of this platform are shown in Fig. 1.

## 2. The Design and Implementation of Signal Analysis and Processing

Signal analysis and processing platform included five big modules: primary signal processing, signal analysis of time domain, signal analysis of frequency domain, filter and comprehensive use. Every big module contained several sub modules to explain the key points of them. We took several signal analyses function as example to introduce the composition of the platform.

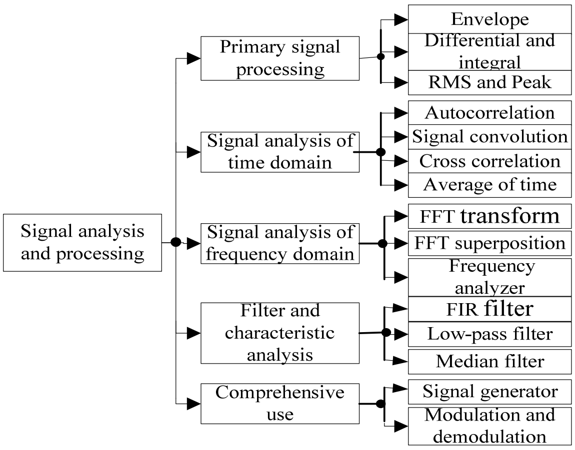


**Fig. 1.** The modules of the platform.

## 2.1. Signal Analysis of Time Domain – Envelope Detection

If we links the peaks of the high frequency signal wires for a period of time, we can get a line above and below the (negative) of a line, the two lines is called the envelope. Envelope curve reflects the high frequency signal amplitude changes.

a) The front panel of envelope detection function.

- Create a new VI, and then place one "Waveform Graph" in the front panel to show the result of signal envelope [2].
- Place several Numeric controls to set the "frequency", "amplitude" and "samples", etc. The panel is shown in Fig. 2.

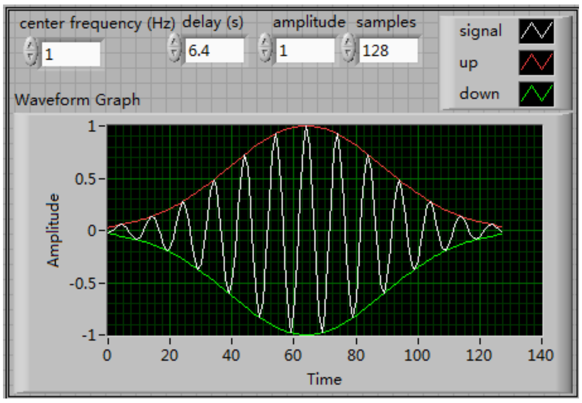


**Fig. 2.** The front panel of envelope.

b) The function panel of envelope detection.

- Place Gaussian Modulated Sine Pattern.vi in a while loop from the path of "Signal Processing\Signal Generation".

The Gaussian Modulated Sine Pattern VI generates the pattern according to the following equations [6].

$$y_i = Ae^{-k(i*\Delta t-d)^2}\cos(2\pi f_c(i*\Delta t-d)), \quad (1)$$

and

$$k=\frac{5\pi^2 b^2 f_c^2}{q*\ln(10)} \quad for \quad i=0,1,2,\cdots,N-1, \quad (2)$$

where $A$ is the amplitude, $b$ is the normalized bandwidth, $q$ is the attenuation, $fc$ is the center frequency (Hz), $d$ is the delay, and $N$ is the samples.

- Place Fast Hilbert transform.vi from the path of "Signal Processing\Transform". The connection method is shown in Fig. 3.

The Hilbert transform of a function x (t) is defined as

$$h(t)=H\{x(t)\}=\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{x(\tau)}{t-\tau}d\tau, \quad (3)$$

Using Fourier identities, we can show the Fourier transform of the Hilbert transform of $x(t)$ is $h(t)\cdot H(f)=-j\,\mathrm{sgn}(f)X(f)$, where $x(t)$ and $X(f)$ is a Fourier transform pair and

$$\mathrm{sgn}(f)=\begin{cases}1 & f>0\\ 0 & f=0,\\ -1 & f<0\end{cases} \quad (4)$$

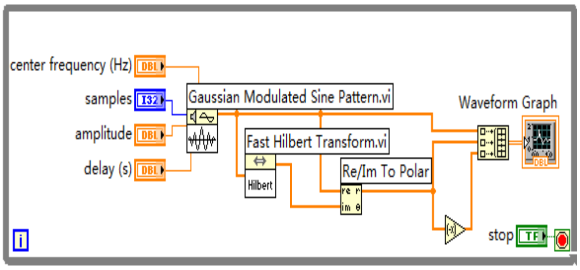


**Fig. 3.** The function panel of the envelope.

## 2.2. Signal Analysis of Time Domain – Cross Correlation

The cross-correlation function compares two different signals calculating a correlation value for every point of one signal compared with the other. As shown in Fig. 4, two functions are being compared, one is the input signal $X(t)$, the other is $Y(t)$.Waveform of $X(t)$ and $Y(t)$ can be a sine wave, triangle wave, saw tooth wave and so on. We can test different signal correlation at different time through changing the time and the signal amplitude size.

In the match position 15 two functions are very similar to each other and the correlation value is closer to 1. A different case occurs in the match position 35 where the functions differ from each other. In this case the correlation plot indicates a value closer to zero.

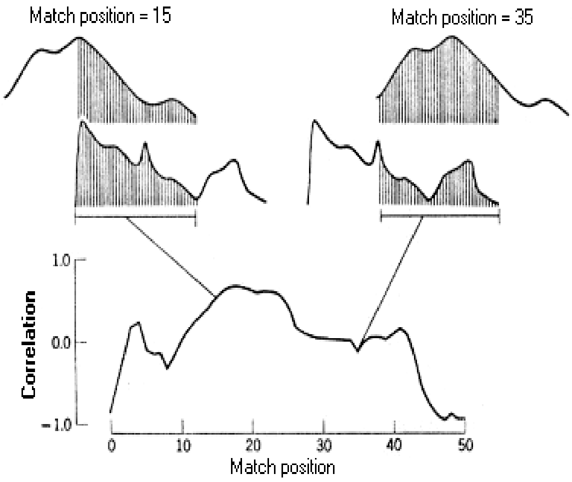


**Fig. 4.** Cross correlation between two functions.

a) The front panel of cross correlation.

We placed three waveform graphs in the front panel: the first two were to display the input signal, In order to show the changes of visual signals, we placed another waveform graph respectively to show the correlation result of correlation of the two inputs. We also used the Express VI to computing the correlation, with the path of "Express \signal analysis \ Convolution and related". Configuration interface will pop-up automatically after we put the module in the block programmer panel. Then we chose correlation in the option of signal processing.

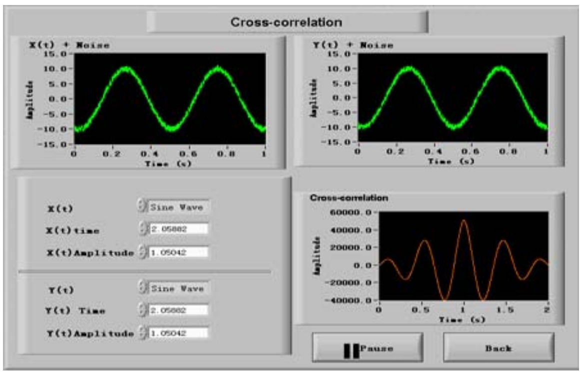


**Fig. 5.** The front panel of cross correlation.

By changing the amplitude and the time of the input signal in the front panel, we can see different results of cross correlation. It is convenient for the users to understand the idea of cross correlation.

b) The function panel of cross correlation.

We placed case structure and while loop to the block diagram, then found two express VI of "Simulate signal" which configuration to "Saw tooth with noise signal" and "Sine with Uniform signal". Both of the two signals were the input of the "correlation function". The output is the result of correlation.

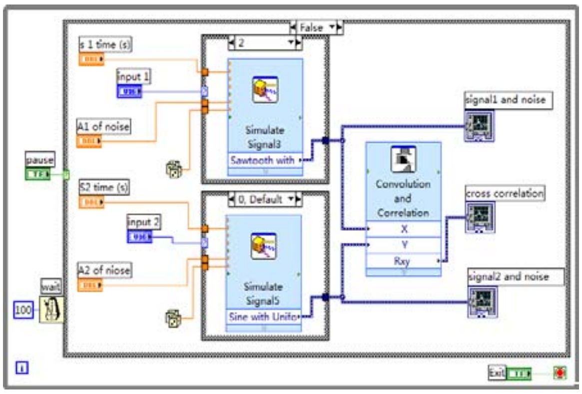


**Fig. 6.** The function panel of the autocorrelation.

## 2.3. Filter – Median Filter

The Median Filter VI obtains the elements of **Filtered X** using the following equation [8].

$$y_i = Median(J_i) \quad for \quad i = 0,1,2,\cdots,n-1, \quad (5)$$

where *Y* represents the output sequence **filtered X**, *n* is the number of elements in the input sequence **X**, *Ji* is a subset of the input sequence **X** centered about the $i^{th}$ element of **X**, and the indexed elements outside the range of **X** equal zero. The following equation describes *Ji*.

$$Ji=\{xi-rl, xi-rl+1, K, xi-1, xi, xi+1, K, xi+rr-1, xi+rr\},$$

where *rl* is the filter **left rank**, and *rr* is the filter **right rank**.

a) The front panel of Median filter.

- Create a new VI ,and then place one "Waveform Graph" in the front panel, In the simulator one can identify the Noise Pulse signal (yellow signal), and the Median filtered signal (blue signal).
- Place several Numeric controls to set the "samples", here is "128"; "Amplitude", here is "5" and "Width", here is "32". etc.
- Place three Numeric indicators to show the result of "Amplitude", "Width" and "Delay". The panel is shown in Fig. 2.

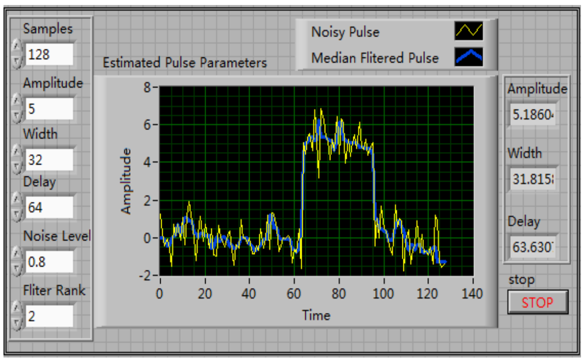


**Fig. 7.** The front panel of cross correlation.

b) The function panel of Median filter.

- Place “Median filter.vi” in a while loop with the path of “Signal processing \Filters”.
- Place “Pulse Pattern.vi” and “Gaussian white noise.vi” with the path of “Signal Generator” to generate the signal.
- Place “Pulse parameters.vi” to calculate the Amplitude, width and delay. The filter rank must be less than the width of the pulse, otherwise the filtered signal misses the pulse. The panel is shown in Fig. 8.

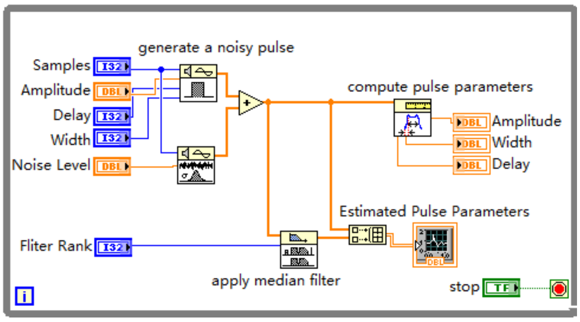


**Fig. 8.** The function panel of the autocorrelation.

## 2.4. Frequency Domain Analysis – Spectrum Analyzer

a) The front panel of signal generator.

- Create a new VI ,and then place two “Waveform Graph” in the front panel, one is to show the signal the other is to illustrate the Spectrum of the signal
- Place a “Tab” in the front panel, one is to select the channels A or B or AB, the other is to control the input signal. The front panel is shown in Fig. 9.

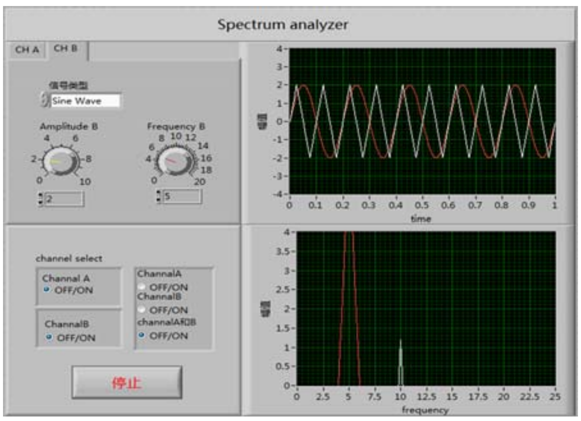


**Fig. 9.** The front panel of cross correlation.

- b) The function panel of cross correlation.
- Place two “Sine Wave.vi” in a while loop, then connect all the input.

- An express VI was utilized in this function, which is “Spectral Measurement”, the function can be configured with the configuration window, as shown in Fig. 10. From the configuration interface we can see that the function can calculate the Peak value, RMS value and the power spectrum, etc.

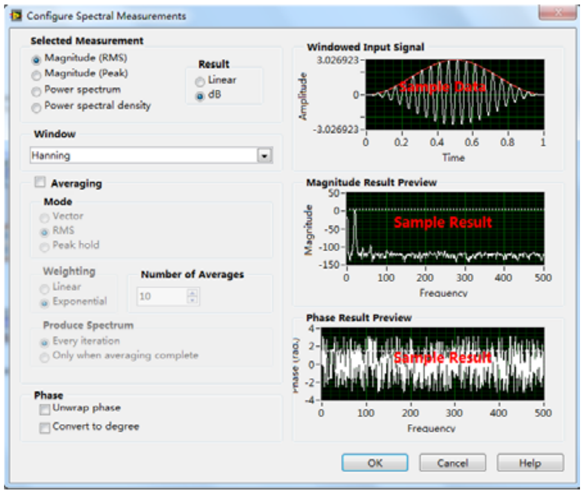


**Fig. 10.** The function panel of the autocorrelation.

- Place two “case structure” to select the channels then connect all the module as shown in Fig. 11.

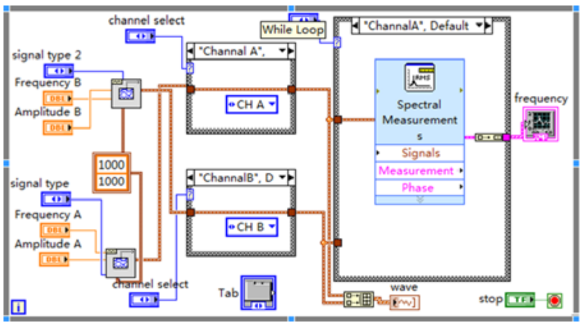


**Fig. 11.** The function panel of the autocorrelation.

## 2.5. Comprehensive Use – Signal Generator

a) The panel of signal generator.

- Create a new VI, and then place one “Waveform Graph” in the front panel to show the signal we create [11].
- Place several “number controls” to control the phase, amplitude, frequency, etc.
- Place two “Enum controls”, one is to select the “original signal or Formula signal”, the other is to select the “Sine wave” or “Square Wave” or others. It can generate many kinds of signals by adjusting all the controls. The panel is shown in Fig. 12.

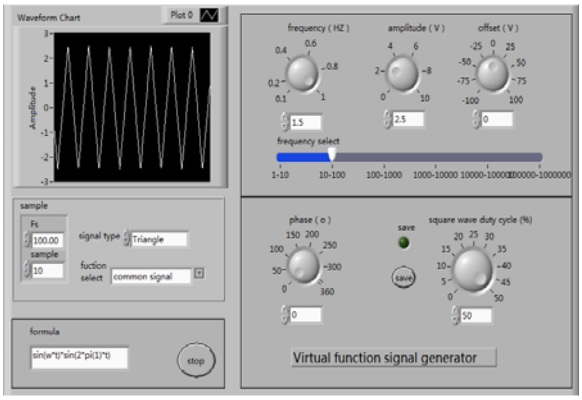

**Fig. 12.** The front panel of cross correlation.

b) The function panel of cross correlation.

- Place "Case Structure" and "Sequence Structure" in a while loop.
- Add three cases by "Add case after" in the case structure, each case place one "Sine wave.vi" or "Triangle Wave.vi" or "Square Wave.vi" or "Saw tooth Wave.vi" or "Formula" by the path of "Signal Process \Signal Generator".
- Connect all the numeric controls to each "* Wave .vi".
- Place an Express VI named "Write to Measurement file" to save the signal which generated by the "signal generator". The panel is shown in Fig. 13.

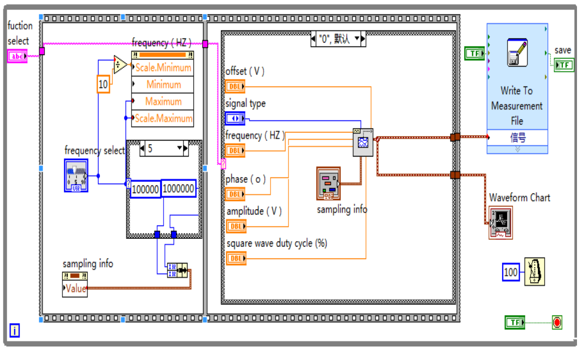

**Fig. 13.** The function panel of the autocorrelation.

## 3. The Design and Integration of the Main Interface

Create a new VI, add one "Enum control", through the way of editing menu we could integrate all the child interface modules into one main.vi. Next we put all the front panel of each child VI in the "Tab control" [14] one by one, for the meanwhile, all the function panel of them should be put into the function panel of the main.vi one after another. Part of the function panel of the main.vi is shown in Fig. 14. The menu of TAB must be the same as the menu of the Enum which names "function select", otherwise they can not connect in the block programme.

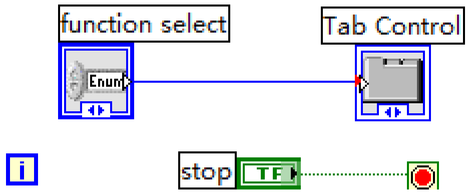


**Fig. 14.** Part of the function panel of main.vi.

One thing we should notice: we must copy the function panel of each sub VIs to the main.vi first not the front panel of them, otherwise the connection to the program diagram will be disorder. This design we chose a "Tab controls" because it was convenient for the management of the front panel. If not, we couldn't distinguish which module was belonging to which son VIs for the program modules was too much.

For example, Fig. 15 showed the "RMS and Peak" function when we choose the menu "RMS" in "Tab control". The peak of a waveform is the absolute value from zero to the maximum value the waveform reaches. The peak to peak value is the absolute value from the maximum negative excursion to the maximum positive excursion and it is called amplitude, as shown in Fig. 16. The RMS value, peak, the max value and the min one will be shown when we change the type of the input signal.

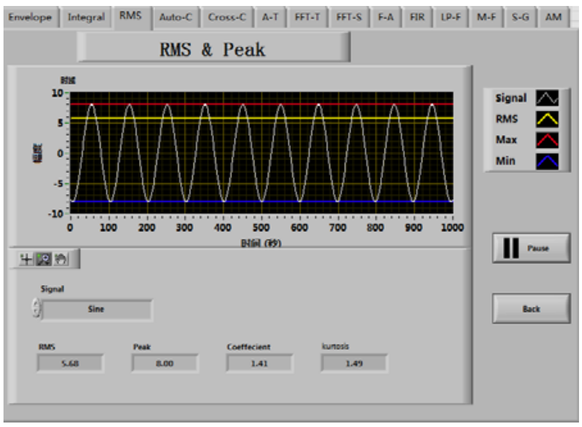


**Fig. 15.** RMS and Peak of signal.

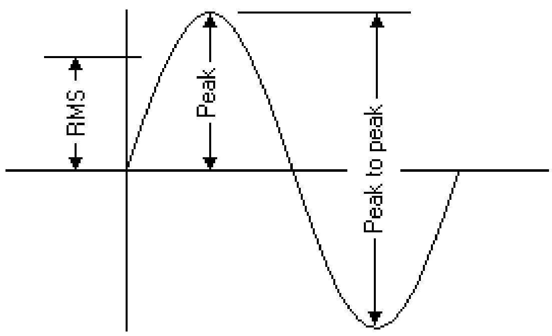


**Fig. 16.** The parameters of a waveform.

The root mean square value (RMS) is used to measure the energy in a waveform. For sine waveforms it is 0.707 times to the peak. The energy contained in a waveform is the same as the energy contained in a continuous DC signal with a value equal to RMS.

The kurtosis is a measurement of the peak value of a signal. The coefficient is a measurement of the peak value of the signal and it is obtained dividing the peak value by the RMS value. For the convenience of users, we made different color markers for the different values of the output signals. LabVIEW has the powerful function of processing signal at a very fast speed [15].

Another example is the Amplitude Module (AM) function. When we click the module of " AM wave" in the "Tab control", the interface will show in Fig. 17. In the AM wave signal design, we put the signal modulation and demodulation program diagram in one VI by another "Tab control". Parameters settings of the AM wave is as follow: signal and modulation amplitude is 1, the frequency of signal is 10 Hz, the frequency of modulation is 50 Hz. Change the frequency of the signal and the modulation, the program will display the modulated signal form in real-time. Transform operation types from modulation to demodulation, then show the interface of demodulation of signal, fully reflects the advantages of LabVIEW interface.

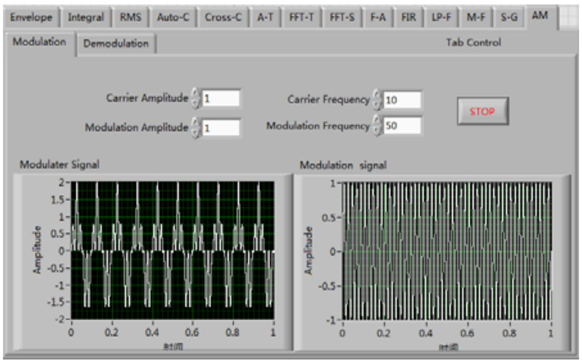


**Fig. 17.** Modulation and demodulation of AM wave.

## 4. Conclusions

The virtual experimental platform of signal analysis and processing was designed by LabVIEW. Compared with the traditional instruments, the virtual instruments have obvious advantages in the level of intelligence, processing power, ratio to price and operability etc. Optimization of the platform can be done by the experimental teachers according to experimental requirements; it has the advantage of flexible operation.

LabVIEW has a graphic programming language which can represents many functions about signal analysis and processing such as mathematic expressions, formulas, algorithms, waveforms and frequency spectrums with friendly interface directly. Because of the openness' of LabVIEW, more virtual signal analysis and processing modules can be added, such as the wavelets transform, riding and beating and so on. In the future, more and more comprehensive application programs will be developed to meet the need of the user. With the technology of the web function, we can show the platform to the web which can provide a convenient for the users to view and the operating system at any time without constrains of time and space.

## References

[1]. Wang Zhijuan, Jin Xiuhui, Processing system of signal analysis based on LabVIEW, *Shanxi Electronic Technology*, Issue 5, 2006, pp. 68-73.

[2]. Hou Guoping, Wang Kun, Ye Qixin, LabVIEW 7.1 programming and design of virtual instrument, *Tsinghua University Press*, Beijing.

[3]. He Wenhai, Design of the noise testing system based on LabVIEW, in *Proceedings of the 4th International Conference on Computer Sciences and Convergence Information Technology*, 2009, pp. 95-98.

[4]. Aliriza Kaleli, Ahmet Dumlu, M. Fatih Corapsiz, et al, Detailed analysis of SCARA-type serial manipulator on a moving base with LabVIEW, *International Journal of Advanced Robotic Systems*, Vol. 10, 2013, pp. 1-11.

[5]. Patterson Casmir D'Mello, Sandra D'Souza, Design and development of a virtual instrument for bio-signal acquisition and processing using LabVIEW, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol.1, July 2012, pp. 1-9.

[6]. Han Ping, Kang Jian, Signal processing techniques application demo and experimental system design based on LabVIEW, *Experimental Technology and Management*, Vol. 27, No. 7, Ju1y 2010, pp. 99-103.

[7]. Wang Junfeng, Song Wen'ai, Liu Zhe, Virtual experimentation system of signal process based on LabVIEW, *Foreign Electronic Measurement Technology*, Vol. 25, No. 10, 2006, pp. 71-73.

[8]. Liang Fang, Yang Guang, Design of the virtual instrument of digital modulation and demodulation system on LabVIEW, *Electronic Test*, No. 2, February 2010, pp. 43-45.

[9]. Shujiao Ji, Ming Zhu, Ju Wang, Yanmin Lei, The design and implementation of temperature acquisition system based on PXI, in *Proceedings of the International Conference on Control Engineering and Communication Technology (ICCECT'12)*, Liaoning, 7-9 December 2012, pp. 267-269.

[10]. Ji Shujiao, Lei Yanmin, Zhang Wanli, The design of data acquisition system based on virtual instrument, in *Proceedings of the 2nd International Conference on Computer Science and Network Technology (ICCSNT)*, Changchun, 29-31 December 2012, pp. 594-597.

[11]. D. J. Kim and Z. Fisk, A LabVIEW based template for user created experiment automation, *Review of Science Instruments*, Vol. 83, Issue 12, 2012, pp. 123705.

[12]. Fakhraldeen H. Ali, Sura Nawfal Abd alrazaaq, Digital image enhancement using hybrid fuzzy

techniques based of LabVIEW, *Al-Rafidain Engineering*, Vol. 20, No. 4, August 2012, pp. 1-10.

[13]. Nie Chunyan, Xu Shanshan, Ji Shujiao, Data acquisition and realization of communication transmission based on LabVIEW, in *Proceedings of the International on Computer Science and Electronics Engineering (ICCSEE)*, Hangshou, 23-25 March 2012, pp. 215-218.

[14]. You Lihua, Zhou Yang, Building of "test technology" experimental teaching system based on virtual instrument, *Experimental Technology and Management*, Vol. 28, No. 2, February 2011, pp. 83-86.

[15]. Qu Qizhong, Research on network laboratory based on virtual instrument, in *Proceedings of the 8th International Conference on Electronic Measurement and Instrument (ICEMI'07)*, 2007, pp. 271-277.

[16]. Liu Yan, Data process and signal analysis based on LabVIEW, in *Proceedings of the 9th International Conference on Electronic Measurement and Instrument (ICEMI'09)*, Beijing, 16-19 August 2009, pp. 23-26.

[17]. LabVIEW Programmer Reference Manual, *National Instruments Co.*, 2013.

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