Visión Electrónica Vol. 14 No. 2 (2020) • July • p.p. 222-227 • ISSN 1909-9746 • ISSN-E 2248-4728 • Bogotá (Colombia)

Universidad Distrital Francisco José de Caldas

Visión Electrónica
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https://doi.org/10.14483/issn.2248-4728

VISIÓN ELECTRÓNICA

A CASE-STUDY VISION

Virtual instrumentation for load cell signal processing

Instrumentación virtual para el procesamiento de la señal de una celda de carga

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INFORMACIÓN DEL ARTÍCULO

Historia del artículo:
Enviado: 12/11/2020
Recibido: 18/11/2020
Aceptado: 21/12/2020

Keywords:
Digital filter
Load cell
Moving average
Strain gauge
Virtual instrument

Palabras clave:
Celda de carga
Filtro digital
Galga extensiométrica
Instrumentación virtual
Media móvil

ABSTRACT

In different spheres of everyday life it is very important to determine the weight of substances, objects and peoples. Strain gauges are widely used in load cells for electronic scales. However, the signal from these transducers presents noise due to various factors. This work presents a virtual instrument developed in LabVIEW for acquisition and processing of the AC108B/BW load cell signal. A moving average digital filter was developed, in order to decrease the amplitude of the signal noise.

RESUMEN

En diferentes esferas de la vida cotidiana es muy importante determinar el peso de sustancias, objetos e incluso de personas. Las galgas extensiométricas son ampliamente utilizadas en la construcción de celdas de carga para balanzas electrónicas. Sin embargo, la señal de estos transductores presenta ruido debido a diversos factores. En este trabajo se presenta un instrumento virtual desarrollado en LabVIEW para la adquisición y procesamiento de la señal de una celda de carga AC108B/BW. Se desarrolló un filtro digital integrador de media móvil, configurable, para disminuir la amplitud del ruido de la señal.

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Cite this article as: L. C. Vega-Gómez, S. Pavoni-Oliver, D. Criado-Cruz, V. E. Escartín-Fernández, "Virtual Instrumentation for load cell signal processing", *Visión Electrónica*, vol. 14, no. 2, pp. 222-227, July 2020. https://doi.org/10.14483/22484728.17428

1. Introduction

In commercial industry, medicine, research work and practically in everyday life, it is of great importance to determine the weight of substances, objects, and even people. There are several methods to measure weight: comparison with other standard weights, the use of load cells based on strain gauges, hydraulic load cells and pneumatic load cells [1]. In the construction of electronic scales, it is usual to select load cells with strain gauges as transducer. These elements convert the state of deformation caused by a weight applied to the cell, into a voltage level that allows this weight to be measured [2].

The low voltage levels of the strain gauge load cell output signal are superimposed by noise added by the power supply and mechanical components of the system. As a consequence, the useful information of the cell signal can be significantly affected and required to perform a filtering process. Traditionally, signal filtering has been carried out with analog techniques implemented electronically with circuits based on operational amplifiers, resistors, capacitors and inductors. This type of filtering offers advantages such as the low cost of the components, the possibility of being carried out in real time and the possibility of designing integrated circuits that compact an entire electronic network. However, analog components add noise and are sensitive to changes in operating conditions. To solve this problem, alternatives of digital filters appear that, compared to analog systems, are more robust to disturbances, can be programmable, are more stable, do not require very precise components and do not vary their behavior with operating conditions [3, 4].

The digital signal processing and filtering can be performed on different technologies, for example, microcontrollers, DSP devices, FPGAs and computers [5, 6]. For the study of the output signals of sensors, the analysis of digital processing variants, as well as the conception of functionalities equivalent to those of traditional instruments, virtual instrumentation constitutes a very useful tool [7]. The virtual instrumentation is integrated for transducers, a personal computer (PC), application software, a data acquisition (DAQ) card and a signal conditioning module. The signal analysis and presentation processes are carried out in application software that can be graphic programming or using a text-based language. LabVIEW is an example of a graphical programming language and environment in which applications can be created quickly and easily. The objective of this work is to process the output signal of the load cell based on strain gauges AC108B / BW using a virtual instrument (VI) developed in LabVIEW. The AC108B/BW load cell, the National Instruments USB-6009 data acquisition card, a PC and the LabVIEW 2019 program were used.

In addition to the Introduction, the rest of this work has been structured into six other sections addressing the topics described below: Section 2 “Load cell” describes the operating principle of load cells based on strain gages and the main characteristics of the AC108B/BW cell. In Section 3 "Measurement system", the system developed for the acquisition stage and processing of the cell’s output signal, based on virtual instrumentation, is described. In Section 4 “Virtual Instrument”, fundamental theoretical aspects of the VI are presented, as well as the one developed in this work for the implementation of digital filtering. Sections 5 and 6, “Experimental work” and “Results and Discussion”, are dedicated to exposing the experiments carried out related to the digital measurement and processing of the load cell signal. Finally, the “Conclusions” Section is presented.

2. Load cell

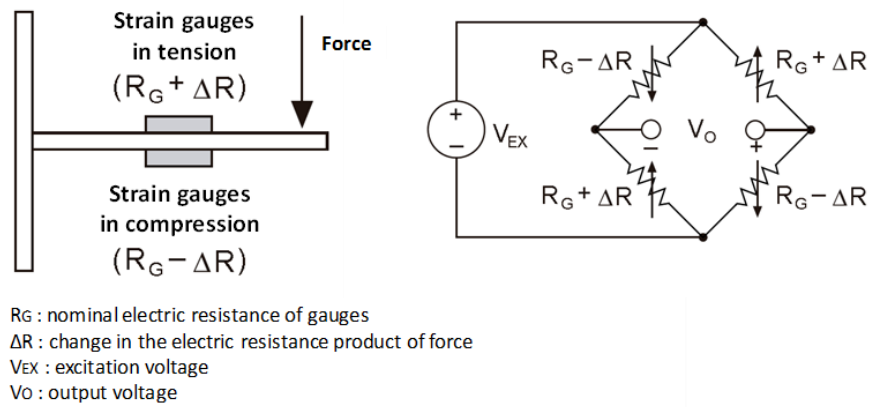
Strain gauges are devices used to measure strain. The most widely used gauge is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The electrical resistance of the strain gauge changes proportional to the amount of strain on the device [2, 8].

The load cell based on strain gauges has a beam with known elasticity; it should be capable of supporting the load without exceeding its elastic limit. The Wheatstone bridge and the strain gauges are sealed, encapsulated and mounted on beam (Figure 1). The Wheatstone bridge circuit converts small change in electrical resistance into a voltage and compensate for temperature [2, 9, 10, 11]. The load cell has two terminals to apply the excitation voltage (VEX) and two terminals for the output signal (VO); this voltage varies depending on the tension or compression applied to cell for weight load [1, 2, 12].

In this work an AC108B/BW load cell was used. Its accuracy is class C3 according to the OIML R60 [13] standard, which regulates the values of parameters such as linearity deviation, repeatability, hysteresis error and effect of temperature on sensitivity. The maximum capacity of this cell is 30 kg, the sensitivity is 2 mV / V ± 10%, it has an input resistance of 415 Ω ± 15

Ω, an output resistance of 350 Ω ± 3 Ω, and the nominal temperature range is from -10 ºC to +40 ºC. The load cell was excited with 5 V, which should generate an output voltage of 10 mV for maximum load (30 kg).

Figure 1. Circuit with full active bridge.



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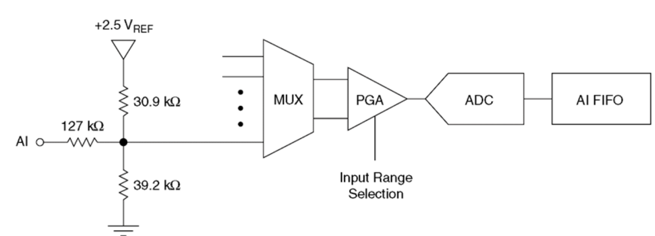
3. Measurement system

The main function of the acquisition stage is to convert the analog signal into a digital signal that can be processed by a computer. For this task, the use of DAQ card has achieved great acceptance in many applications. The data acquisition cards are connected to the computer bus and allow data acquisition and signal processing in real time. Each card has several functionalities, which provides a lot of flexibility and operability for the requirement of measurement. After the signal acquisition, the information of interest must be obtained. The information extraction is two procedures: signal filtering and signal processing.

In this work, a PC-based measurement system was designed. In order to acquire the cell's output signal the NI USB-6009 to the PC by USB bus were used. The NI USB-6009 provides connections to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels and a 32 bits counter for counting input / output. The analog inputs have 14 bits resolution in differential mode and 13 bits in single-ended mode. Its maximum sampling frequency is 48,000 samples per second per channel. Figure 2 illustrates the analog input circuitry of the NI USB-6009. The multiplexer (MUX) selects the analog input channel to be sampled. The programmable gain amplifier (PGA) provides specific gain values between 1 and 20 to the input signal, if the channel is configured in single-ended mode the gain is 1. The analog-digital converter (ADC) type is successive approximations. The NI USB-6009 can perform both single and multiple A/D conversions of a fixed or infinite number of samples. A first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost. The USB-6008/6009 also supplies a 5 V, 200 mA output. This source was used to excite the load cell [14].

Figure 2. Circuit for analog inputs. [14]



A virtual instrument was designed in LabVIEW 2019 for the processing the acquired signal. The NI-DAQmx driver was used to communicate with DAQ card. This low-level software allows bidirectional communication between NI software products and data acquisition items. Configuration and diagnosis of the NI USB-6009 was performed using Measurement & Automation Explorer software. Signal acquisition and graphical interface were performed with DAQ Assistant Express VI.

4. Virtual Instrument

The use of computers is essential in any technological discipline. In fact, different branches of industry such as production lines and measurement systems depend on computers [3].

A virtual instrument is a software module that simulates the functional aspects of the real instrument, based on the physical devices that can be accessible to the computer (DAQ cards, DSP cards, instruments accessible via GPIB, VXI, RS-232, etc.) [3, 15].

Virtual instrumentation systems are widely used for their low cost, great flexibility and configurability, as well as its high performance and considerable savings in development time; for this reason they constitute a natural evolution with respect to traditional instrumentation systems. Historically, traditional instrumentation systems have been based on the use of individual measuring devices or instruments, including sensors or transducers to acquire physical variables and to translate into electrical signals that can be processed. The instrumentation technologies have been characterized by a continuous increase in terms of flexibility and scalability of measuring equipment, as well as interfaces that allow high-speed data acquisition into the computer for subsequent analysis and processing. All this has contributed to the emergence of virtual instrumentation that is associated with virtual instruments.

A virtual instrument consists of three main parts: acquisition, analysis and presentation. Through the acquisition process the analog signal is converted into digital format and delivered to the computer. The analysis stage allows characterizing and processing the acquired signal, that are carried out by software routines available in development environments. The data presentation can be done in different ways, such as using the PC monitor, by means of a printed hard copy, through files or published on the Internet web sites.

One of the digital filtering techniques is the moving average [15]. This is a low-pass filter that takes N samples of input at in a certain time interval (window), calculates the average of those N-samples and produces a single output point. In a discrete system the window size will be the input sequence samples that are averaged. This window is mobile, that is, it advances in each step of the algorithm one position in the input sequence to perform the average. The width of the window is determined empirically. It is important to observe that the number of operations carried out by the computer is proportional to the window size. Equation (1) corresponds to the moving average filter, where N corresponds to the number of samples in the window.

$$y(n) = \frac{1}{N} \Sigma_{k=0}^{N-1} x(n-k) \quad (1)$$

The Front Panel of the virtual instrument designed in LabVIEW to process the load cell signal is showed in Figure 3. Two graphs respectively show the signal acquired and the data resulting from the signal processing. LabVIEW controls were used to configure the number of samples in the filter window (N) and to establish the ranges for the graph axes. In the acquisition stage, this VI controls de signal reception and digitalization using the express DAQ Assistant VI. A moving window integrator filter was also developed; its programming diagram is shown in Figure 4. Input parameters of this function are the vector containing the filter samples and the size of the window (N). The output consists of a vector contained filtered data.

Figure 3. Front Panel of the virtual instrument for the load cell signal processing.

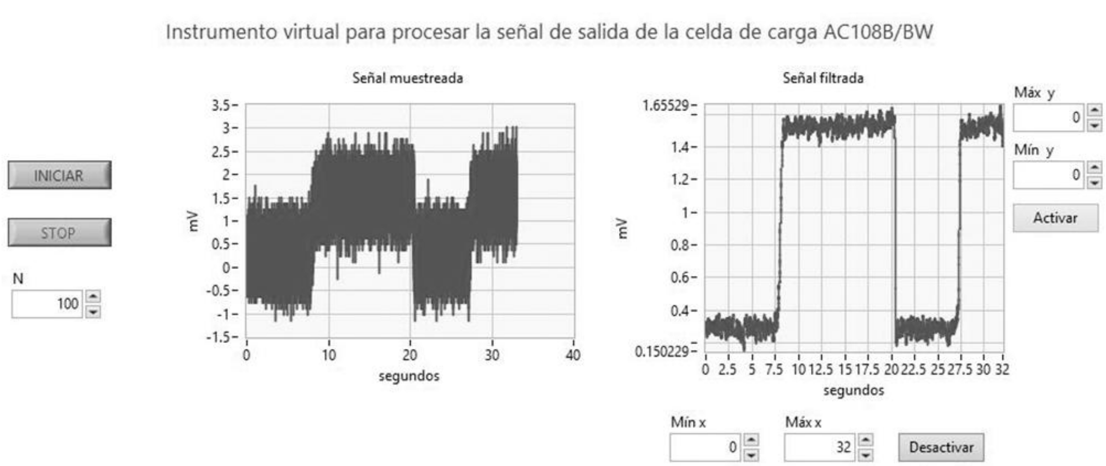


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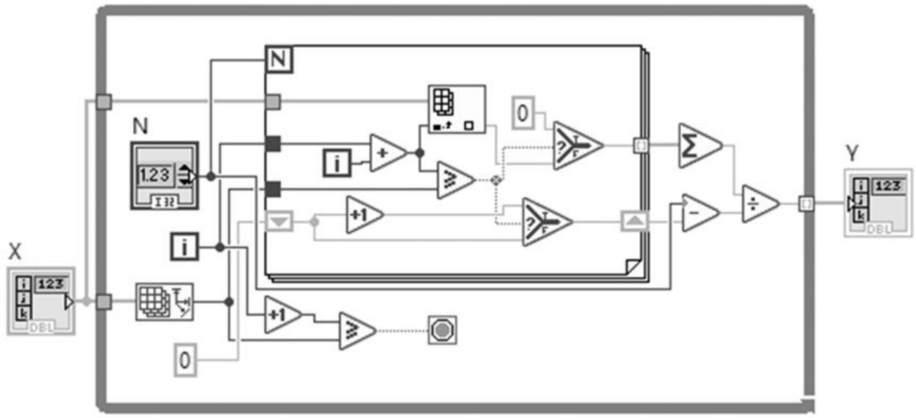
Figure 4. Block Diagram of the moving average filter.



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5. Experimental work

The load cell, the measurement system and the virtual instrument presented in the previous topics were used in the experimental work. Load cell output signal was acquired without weight on it and with a weight of 5 kg. The signals were processed without a digital filter and using the integrating filter with a moving window with windows of 100 and 1000 samples. The NI USB-6009 was set to "N Samples" acquisition mode to take a thousand samples at 1 kHz. The output of the load cell was connected to the analog input channel 0 (ai0) configured to measure voltage in single-ended mode in range of 0 V to +5 V.

Measurements started with the cell without load and then were alternate between placing a 5 kg weight for a few seconds and removing it.

6. Results and discussion

Figure 5 shows the measured cell output signals, without filter and filtered using the moving average filter developed in LabVIEW, for windows of 100 and 1000 samples, respectively. Table 1 shows quantitative results of these experiments.

Table 1. Experimental results.

Window Size (N)	Noise amplitude (mV)	Response time (s)
Without filter	2	-
100	0.2	0.8
1000	0.05	1.3

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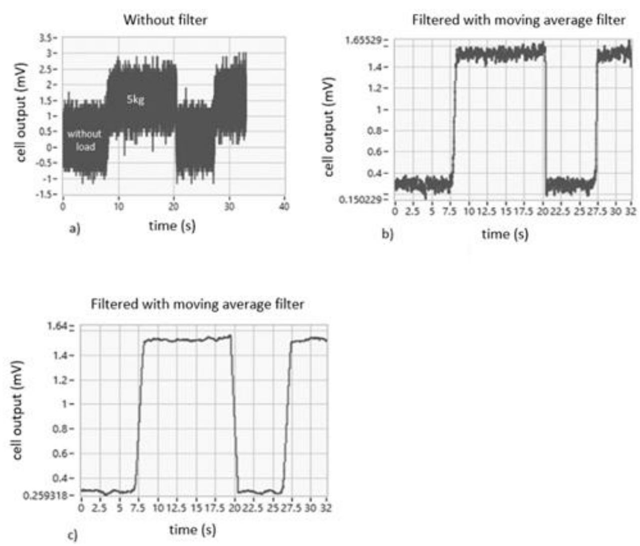
Figure 5. Cell output signal: a) without filter; filtered using moving average filter b) N = 100 and c) N = 1000.



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As can be seen, in the unfiltered signal the added noise significantly affects the useful information. The signal / noise ratio increased with the increase in the number of samples in the window. A weight of 5 kg on the cell generated an average voltage of 1.53 mV at the output of the cell; however, the peak-to-peak amplitude of the oscillations of the sampled signal is 2 mV.

By applying the integrating filter, the signal quality was improved since the noise amplitude was attenuated 10 times for the 100-sample window and 40 times for the 1000-sample window. As the number of samples in the window increased, the signal-to-noise ratio increased, however, the signal response time also increased.

7. Conclusions

In this work, the acquisition and processing of the signal of an AC108B / BW load cell was carried out using virtual instrumentation. An integrating moving average filter with a configurable window was developed in LabVIEW. The use of the digital moving average filter was able to reduce the amplitude of the noise added to the cell signal from 2 mV to 0.05 mV.

Increasing the size of the window in the filter markedly decreased the amplitude of the noise added to the load cell signal, however, the response time increased.

The signals analysis from sensors, using virtual instrumentation tool constitutes a practical tool for the study of digital filtering variants. For future work, it is recommended to identify the optimal size of the window, so that a compromise relationship is established between the signal / noise ratio and the response time of the filter.

Acknowledgments

We acknowledge the Cuban company PEXAC for providing us with the AC108B/BW load cell for carrying out the experimental work.

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