Development of a data acquisition system using LabVIEW and Arduino microcontroller for a centrifugal pump test bench connected in series and parallel

D A Quintero1, H Claro1, F Regino2, and J A Gómez2

1 Grupo de Investigación en Tecnología y Desarrollo en Ingeniería, Universidad Francisco de Paula Santander, Ocaña, Colombia
2 Grupo de Investigación en Ingenierias Aplicadas para la Innovación, la Gestión y el Desarrollo, Universidad Francisco de Paula Santander, Ocaña, Colombia

E-mail: daquinteroc@ufpsou.edu.co

Abstract. A data acquisition system using LabVIEW software and the Arduino microcontroller for a test bench of centrifugal pumps connected in series and parallel has been developed. The acquisition system allows real-time display of centrifugal pump discharge pressure values, voltage, current and volumetric flow of the test bench. A description of the system operation (front panel and block diagram) as well as the elements (actuators, instruments, controller and software) used in the system is given. From the front panel it became possible to operate the test bench for three modes of operation (Individual, Series and Parallel). Pressure, voltage, current and volumetric flow values were recorded over time and stored in a text file generated by the acquisition system.

1. Introduction
In industrial processes of any kind, data acquisition systems are used, which, by means of computers, controllers, instruments, actuators and interfaces, allow the control and recording of process data. These systems allow observing in real time, variables of interest in an activity, which in turn leads to make decisions about the process, readjust values, among others.

Data acquisition systems require for their operation a series of elements to operate properly, which, depending on the activities or processes that are developed, will have an economic cost proportional to the system to monitor, that is why, in some cases, mainly in processes of low or poor industrial application, the monitoring of the variables is done manually by working personnel.

Regardless of how the data acquisition system is executed, this is necessary in any process. However, the work developed here, aims to show the design and implementation of a data acquisition system using LabVIEW software together with the Arduino microcontroller, for a test bench of centrifugal pumps in series and parallel operation belonging to Francisco de Paula Santander University Ocaña, which is used by Mechanical Engineering students. The test bench works properly in a manual way, that is to say, the starting up of the pumps and the opening and closing of the valves is carried out by the students by means of the direct operation on the bench, likewise, the collection of values of suction and discharge pressure, flow, voltage, current, among others, necessary to obtain the characteristic curves of the pumps is carried out manually, which brings with it the component of human error in the reading and collection of data.
In this way, several works have been developed whose common operator is the automation of the processes, which brings with it the monitoring or development of data acquisition systems. At the academic level, the work developed by Moyano et al. [1] who studied the measurement of variations of flow and pressure in suction, discharge of a centrifugal pump, whose values were decisive for the selection and purchase of pressure transducers and flow sensor system is emphasized, the data acquisition is carried out with the card DAQ NI USB 6009 and LabVIEW software which introduced equations governing each sensor obtained after their respective calibration. Thus, Vera [2] built a hydrodynamic test bench equipped with two centrifugal pumps for series and parallel practices, the main purpose being to incorporate equipment to the Unit Operations Laboratory of the Faculty of Engineering Sciences, the test bench is equipped with two centrifugal pumps of 1/2 Hp each, by Paolo; in addition, it is equipped with accessories such as pressure gauges, ball valves, globe valves, inclined-seat valves and gate valves. A control panel containing voltmeters and pilot bulbs allow observing in a safe way the conditions in which the pump is working. On the other hand, a test bench to study the flow through a regulated loop was built by MORA [3], in order to familiarize the students of the career of electromechanical engineering at the University of Loja in Ecuador. The author built the prototype of the plant, once ready, data was acquired with the DAQ6008 card of National Instruments and LabVIEW. Subsequently, with the model of the plant, a PID controller was developed with Matlab and Simulink. The author verified that the functioning of the controller is adequate through its implementation together with LabVIEW, with the same software, Pillapa [4] developed a data acquisition program for a centrifugal pump test bench of the Technical University of Ambato located in Ecuador. The purpose of the project was to evaluate the performance of the pump characteristic curves by comparing the data reported by the manufacturer with those obtained by the acquisition system. Similar works to the previous ones have been developed by Poveda et al. [5-7].

To sum up, with the work developed, it is expected to automate the test bench of series and parallel pumps of the Francisco de Paula Santander University Ocaña, by incorporating a microcontroller, actuators, instruments and other elements that ensure its proper functioning. Through the test performed, the students can observe the behavior of the process through direct visualization in a graphical interface developed in LabVIEW, this work facilitates the laboratory practices carried out by the students, since it decreases the time of the tests, as well as the collection and recording of data, similar works to the one developed here were performed by the authors [8-10], for which the software used was LabVIEW [11-13].

2. Methodology

In the development of this work, a series of stages shown in Figure 1, were carried out. It starts with a review of the state of the art of the subject matter to be developed, then it deals with the analysis and understanding of the operation of the test bench of series and parallel pumps, the identification of elements necessary for the development of the acquisition system, finally, it deals with the design and implementation of the system developed.

![Figure 1. Methodology developed.](image)

2.1. Operation description of the centrifugal pump test bench in series and parallel

The series and parallel centrifugal pump test bench shown in Figure 2 is located in the Francisco de Paula Santander University facilities. It consists of two centrifugal pumps of the same denomination.
that are in charge of driving the fluid through the pipe. It is equipped with valves, pressure gauges, vacuum gauges and a rotameter. The system allows the configuration of the test bench for three modes of operation: Operation mode for a single pump and operation modes in series and/or parallel according to the opening and closing of the valves.

![Test bench for centrifugal pumps in series and parallel.](image)

The development of laboratory practices with the test bench of centrifugal pumps in series and parallel has as its ultimate aim to evaluate the performance of the system, i.e. to determine the operation of the pumps from the calculation of their characteristic curves and their comparison with theoretical data.

In this way, the first mode of operation evaluates the performance of a single pump, for which it is necessary to adjust the bench in the following way:

- Close the valve 1 (Valve 1).
- Close the valve 2 (Valve 2).
- Close the valve 4 (Valve 4).
- Put pump 1 into operation only (Pum.1).

The laboratory guide for this mode specifies the parameters that will be taken under this arrangement when the students are going to perform the tests.

The configuration of the bench to operate with the series pumps is used to increase the pressure of the fluid obtaining a greater dynamic head keeping the flow constant. The series system for the test stand is achieved by making the following adjustments:

- Close the valve 2 (Valve 2).
- Close the valve 3 (Valve 3).
- Open the valve 4 (Valve 4).
- Put pumps 1 and 2 into operation

Two pumps are connected in parallel when it becomes necessary to increase the flow at the expense of maintaining constant pressure, i.e. the flow is increased, but the same head is obtained. To configure the test bench for parallel operation, the following settings are necessary:

- Close the valve 2 (Valve 2).
- Open the valve 1 (Valve 1).
- Open the valve 3 (Valve 3).
- Open the valve 4 (Valve 4).
- Put pumps 1 and 2 into operation
As can be observed in the previous description, the different modes of operation of the test bench involve opening and closing valves manually, so it can be a rather tedious and erroneous process if the proper functioning of the bench is not taken into account, associated with this, the reading and collection of data is performed manually, which brings an associated component of human error that can be harmful when developing the laboratory guide of the test bench.

This opens up the possibility of automating the test bench through the use of solenoid valves and sensors to measure variables such as flow, pressure, voltage and current that will be necessary for the corresponding calculations in determining the operation curves of the pumps.

2.2. **Elements required for the data acquisition system**

The previous stage, in addition to allowing the analysis and understanding of the test bench, leads to the identification of the elements necessary for the data acquisition system to be developed. Table 1 shows these elements.

| Table 1. Elements for the data acquisition system. |
|-----------------------------------------------|
| **Type** | **Number** | **Description** |
| Flow | 2 | 1/2”- Maximum capacity 30l/min; V output 0.5-4.6V |
| Pressure | 3 | 0-1.2Mpa; G1/4” Thread; output V of 0.5-4.6VDC; Operating V of 5V |
| Electro valves | 3 | Pressure 0.02-0.8Mpa; normally closed; 0.6A, supply V 12VDC |
| Microcontroller | 1 | ATmega328; Operating V of 5V; Input V 7-12V; digital pins 14; Analog pins 6 |
| Relay | 2 | 1 channel; Operating V of 250VAC/30VDC; Operating current 10A, Trigger current 15-20mA |
| Voltage sensor | 1 | Operating current 2A; supply V of 5-30VDC; V output 1-2VDC |
| Current sensor | 1 | ACS712ELC-30A; V supply V of 5VDC |
| Dimmer | 1 | Operating V up to 1200V; Voltage regulation: 50-220VAC; 2000 watts |
| Voltage source | 1 | 24 pins; 250watts |

2.3. **Design and implementation of the data acquisition system**

The LabVIEW software from National Instruments is used to make the graphical interface of the data acquisition system. This selection is due to the fact that the Francisco de Paula Santander University Ocaña has the license, in addition to teaching this software in the Mechanical Engineering program.

LabVIEW is a fast learning graphical programming environment, which allows to interact between a front panel and a block diagram where the connection is made through “wires”. This environment allows the execution and development of diverse applications [14].

Now, LabVIEW has within its libraries a tool to make the connection with Arduino, which is decisive in the development of the acquisition system.

The LabVIEW Interface for Arduino (LIFA) is a free tool that can be downloaded from the NI (National Instruments) server that allows Arduino users to acquire data from the microcontroller and process it in the LabVIEW graphical programming environment. [15].

Thus, the first step corresponds to the installation of LabVIEW and the Arduino integrated development environment (IDE); subsequently, to install the LIFA tool, as well as the LabVIEW serial port recognition tool (NI Serial); finally, it is necessary to upload the LIFA Base program to the Arduino board, once loaded it allows communication between LabVIEW and Arduino. The versions of the software used in this work correspond to the year 2015 for LabVIEW and version 1.8.5 for Arduino.
Finally, with the programming and control elements working correctly, the instruments and actuators are assembled on the test bench as shown in Figure 3.

![Figure 3. Test bench for centrifugal pumps in series and parallel with actuators and instruments.](image)

### 3. Results

In this part, a general description of the block diagram and the developed graphical interface is made, Figure 4 and Figure 5 show the front panel (display of variables) and the block diagram respectively, while Table 2 allows to visualize the text file where the values of voltage, current, pressure and volumetric flow are stored.

As can be observed, Figure 4 shows the graphical interface developed, which consists of the main indicators, voltage, current, flow, pressure, necessary to calculate the characteristic curves of the pumps in order to compare them with those provided by the manufacturers, in addition to interpreting and finding the different operating points of the pumps, whose purpose is to familiarize students of mechanical engineering in the field of fluid mechanics. It also presents a diagram of the flow of the fluid through the pipes, the main advantage of which is to visualize the flow of the fluid when the system is operated in series and parallel, it also allows observing the elements that are active at the moment of passing from one configuration to another.

![Figure 4. Graphical interface developed.](image)
On the other hand, Figure 5 shows the block diagram for the acquisition system developed. Like any programming language, it is this panel that develops the code that allows executing the actions of the system. Figure 5 shows an extract of the developed code.

**Table 2.** Extracted values stored by the data acquisition system.

| Voltage (V) | Current (A) | Pressure (bar) 1 | Pressure (bar) 2 | Pressure aux (bar) | Flow (l/min) |
|------------|------------|------------------|------------------|-------------------|--------------|
| 125.1841   | 3.1237     | 0.1243           | 0.8025           | 0.1316            | 18.6667      |
| 125.2165   | 3.1255     | 0.1242           | 0.8030           | 0.1301            | 18.6667      |
| 125.2274   | 3.1237     | 0.1233           | 0.8016           | 0.1303            | 17.3333      |
| 125.2254   | 3.1194     | 0.1213           | 0.7942           | 0.1173            | 18.6667      |
| 125.2550   | 3.1257     | 0.1108           | 0.7926           | 0.1147            | 17.8667      |
| 125.2918   | 3.1288     | 0.1084           | 0.7926           | 0.1147            | 17.8667      |

The block diagram starts with the initialization block for Arduino, then it is necessary to declare the pins that will be used as inputs and outputs respectively, then it is necessary to have a while cycle that will execute the developed code until it is stopped by means of a control.

The digital pins have been used for the activation of the electro valves, the centrifugal pumps, and the reading of the flow sensors. Analog pins are also used to read pressure, current and voltage sensors.

On the other hand, given the series and parallel configuration with which the test bench must operate, the “case” structure has been used, which has been configured to allow the activation of the solenoid valves (closing or opening) from a selector button on the front panel.
Table 2 shows the text file generated by the system, through which it is possible to visualize the values of voltage, current for pump 1, current for pump 2, pressure for pump 1, pressure for pump 2, auxiliary pressure and volumetric flow.

4. Conclusions
A data acquisition system using a LabVIEW-Arduino interface has been developed in order to facilitate the development of laboratory practices for students of the mechanical engineering degree at the Francisco de Paula Santander University. The development of the data acquisition system allowed the automation of the centrifugal pump test bench in series and parallel which operated manually. The automation also made it possible to configure directly from a computer the type of operation of the test bench, that is to say, to use it in series or parallel. The reading and collection of data is obtained directly by means of a text file in which the main variables are visualized for the calculation of the characteristic curves of the pumps, which allows diminishing the time with which the tests are developed, since the manual operation requires the collection and recording of data manually.

References
[1] J. Moyano and E. Naranjo 2015 Automatización de la adquisición de datos en un banco de pruebas de bombas centrífugas instaladas en serie y paralelo (Riobamba: Escuela Superior Politécnica De Chimbarrazo)
[2] Vera J 2015 Construcción de un banco de pruebas hidrodinámico de carácter didáctico para el laboratorio de operaciones unitarias de la U.T.E.Q. (Quevedo: Universidad Técnica Estatal de Quevedo)
[3] Ordoñez L Mora 2015 Diseño y construcción de un banco para el estudio y control de la variable caudal en un lazo de regulación de agua (Loja: Universidad Nacional de Loja)
[4] Guato A 2016 Adquisición de datos de parámetros hidráulicos y su efecto en el ajuste de las curvas de funcionamiento teóricas en el banco de bombas centrífugas del laboratorio de energía de la facultad de ingeniería civil y mecánica (Ambato: Universidad Técnica de Ambato)
[5] Peña F and Poveda O 2015 Diseño e implementación de un sistema de control de caudal e interfaz gráfica de usuario en planta didáctica del laboratorio de mecánica de la facultad tecnológica (Bogotá: Universidad distrital Francisco José de Caldas)
[6] Villarreal W 2008 Diseño de un banco para ensayo de bombas en serie y paralelo (Santiago de Cali: Universidad Autónoma de Occidente)
[7] García A, García L and Gaviria E 2009 Diseño y montaje del laboratorio de hidráulica de tuberías “Banco de pruebas tubo Venturi” (Girardot: Corporacion Universitaria Minuto De Dios)
[8] Osorio J, Pérez J and Rodríguez M 2010 Implementación de un sistema de adquisición de datos para monitorear una máquina de corriente directa Tecnura 14(27) 60–68
[9] Villanueva S 2015 Diseño de un sistema de captura y procesamiento de señales (Valencia: Universitat Politècnica de València)
[10] Medina A and Peñafiel C 2015 Diseño e implementación de un sistema de adquisición de datos en tiempo real para la captura, simulación y transformación de tramas de datos de sensores cinemáticos en trama TCP/IP para las corbetas misileras clase esmeraldas de la Armada del Ecuador (Guayaquil: Escuela Superior Politécnica del Litoral)
[11] Moreno F, Ramírez J and Ortiz O 2016 Sistema de supervisión y control para un banco experimental de refrigeración por compresión Respuestas 21(1) 97-107
[12] Machado-Mercado D, Herrera-Murgas G, Roldán-Mckinley J and Díaz-González J 2015 Una herramienta computacional didáctica para el análisis cinemático de mecanismos planos de cuatro barras Revista UIS Ingenierías 14(1) 59-69
[13] Simmonds-Mendoza A, Cabrera-Londoño N, Berdugo-Barandica N, Roldán-Mckinley J and Yime-Rodríguez E 2018 Implementación de control PID de nivel en laboratorio usando PLC Siemens S7-300 Revista UIS Ingenierías 17(2) 159-178
[14] LabVIEW-User Manual 2003 (Texas: National Instruments)
[15] Ruiz J 2012 Utilización de labview para la visualización y control de la plataforma open hardware Arduino (National Instruments LabVIEW)