DATA LOGGING SYSTEM FOR PRESSURE MONITORING

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In this paper the desktop data logging system for pressure measurement and monitoring is presented. Desktop systems use measurement hardware designed to work with standard desktop PCs. They are ideal for a wide range of laboratory-based data logging applications, such as pressure monitoring. As software part of the presented system the graphical application development environment LabVIEW is chosen. The acquisition hardware is based on the multifunction DAQ, manufactured by National Instruments The device converting pressure into voltage is the MEMS silicon pressure sensor such as the Freescale's MPX41XX series of integrated silicon sensors. This monolithic sensor systems are generally based on piezoresistivity, i.e. on the change of the electrical resistivity under application of uniaxial stress or hydrostatic pressure. To achieve more accuracy, stability and flexibility the mathematical capability of software is considered and implemented in the presentation.

Keywords: Data Logging System, Multifunction DAQ, Graphical Programming, Virtual Instrumentation.

1. INTRODUCTION

Data collecting and recording is a very common measurement application. In its most basic form, data logging is the measurement and recording of physical or electrical parameters over a period of time. The data can be temperature, strain, displacement, flow, pressure, voltage, current, resistance, power, or any of a wide range of other parameters. Three types of instruments are commonly used for collecting and storing data. They are Real-Time Data Acquisition Systems, Chart Recorders and Data Loggers. Real time data acquisition is when data acquired from sensors is used either immediately or within a short period of time, such as when controlling a process. Chart recorders are analog instruments that translate electrical impulses from sensors into mechanical movement of an arm. A pen is attached to the arm, and long rolls of paper are moved at a constant rate under the pen. The result is a paper chart displaying the parameters measured over the course of time. Data logging on the other hand is when data acquired from sensors is stored for later use. In reality, there is a continuum of devices between real time data acquisition and data logging that share the attributes of both of these classifications.

The major difference between a data logger and a recorder, however, is the way the data itself is stored, analyzed and recorded. A common recorder accepts an input, and compares it to a full scale value. The pen arm is then deflected across the recording width, to produce the appropriate ratio of the actual input to the full scale input. Data loggers are normally more economical than chart recorders. They offer more flexibility and are available with a greater variety of input types. Most data loggers collect data which may be directly transferred to a computer. Using data logging, scientists and engineers can evaluate a variety of phenomena, from weather patterns to factory performance.

PC-based data logging systems combine the acquisition and storage capabilities of stand-alone data loggers with the archiving, analysis, reporting, and display capabilities of modern PCs. PC-based data logging systems provide the most flexibility, customization, and integration and finally brought about full automation of the data logging process. The move to PC-based data logging systems was enabled by three technological enhancements:

1. Increasing reliability of PCs.
2. Steadily decreasing cost of hard drive space on PCs.
3. PC-based measurement hardware that could meet or exceed measurement capabilities of stand-alone data loggers.

In order to define a data logging system, the engineer must evaluate the requirements for acquisition, online analysis, logging, offline analysis, display, report generation, and data sharing. Based on these requirements, he can choose data logging software and hardware.

Every data logging application can be broken down into a set of five common functional requirements [1], illustrated in Figure 1. Acquiring is the process of actually measuring the physical parameters and bringing them into your logging system. Online analysis consists of any processing done to the data while you are acquiring. It includes alarms, data scaling, and sometimes control, among others. Logging, or storing, the data is an obvious requirement of every data logging system. Offline analysis is everything done with the data after it has been acquired in order to extract useful information from it. The final functional block is made up display, reporting, and data sharing. These are all the "miscellaneous" requirements that fill out the functionality of a data logging system.

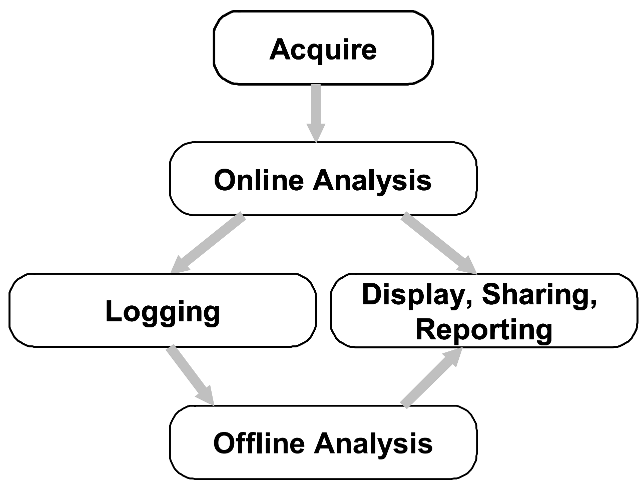

Fig. 1. Basic Elements of a Data Logging System

2. Data Acquisition Hardware

The acquisition function is one of the most critical components of every data logging system. In a PC-based system, the acquisition is accomplished by the measurement hardware, which can be further broken down into sensors, signal connectivity, signal conditioning, and analog-to-digital conversion.

The dominant design for pressure sensors is the micromachined silicon piezoresistive pressure sensor. Monolithic silicon pressure sensors are generally based on piezoresistivity, i.e. on the change of the electrical resistivity under application of uniaxial stress or hydrostatic pressure. The most common version uses gauges diffused or implanted into an Si substrate and operating in a Wheatstone bridge configuration on a diaphragm acting as mechanical amplifier of the strain. Using IC microfabrication techniques, manufacturers can create hundreds or thousands of sensor chips on one silicon wafer. The manufacturing technology used to build MEMS sensors also allows additional components (e.g., onchip signal conditioning) to be incorporated with the sensing devices [2, 3].

In bulk micromachining, the single crystal silicon is etched to form three-dimensional MEMS devices. This is a subtractive process in which the silicon in the wafer is specifically removed using anisotropic chemistries. Using this bulk micromachining method, sensors such as piezoresistive pressure sensors have been manufactured in high volume. In the simplest implementation, the silicon is selectively etched in certain areas to form a diaphragm. In an absolute pressure sensor, the silicon wafer is then bonded with another wafer (either of silicon or glass) to form a vacuum-sealed cavity below the diaphragm. The diaphragm then deflects in response to the applied pressure. The transduction mechanism that has been widely used is the piezoresistive effect. In piezoresistive materials, the change in the stress causes a strain and a corresponding change in the resistance. Thus, when implanted piezoresistors are formed at the maximum stress points of the diaphragm, the deflection under the applied pressure causes a change in the resistance. Typically, these piezoresistors are formed as a bridge network and the voltage applied between two terminals cause an output voltage to be measured between the other two terminals.

Due to mentioned benefits and capabilities of the integrated pressure sensor the connectivity between sensor and acquisition hardware can be accomplished without additional signal conditioning. The hardware configuration of the pressure monitoring system is shown in figure 2. As can be seen, after physical parameters have been converted into electrical signals, the signal connectivity, signal conditioning, and analog-to-digital conversion are accomplished with a plug-in data acquisition (DAQ) board.

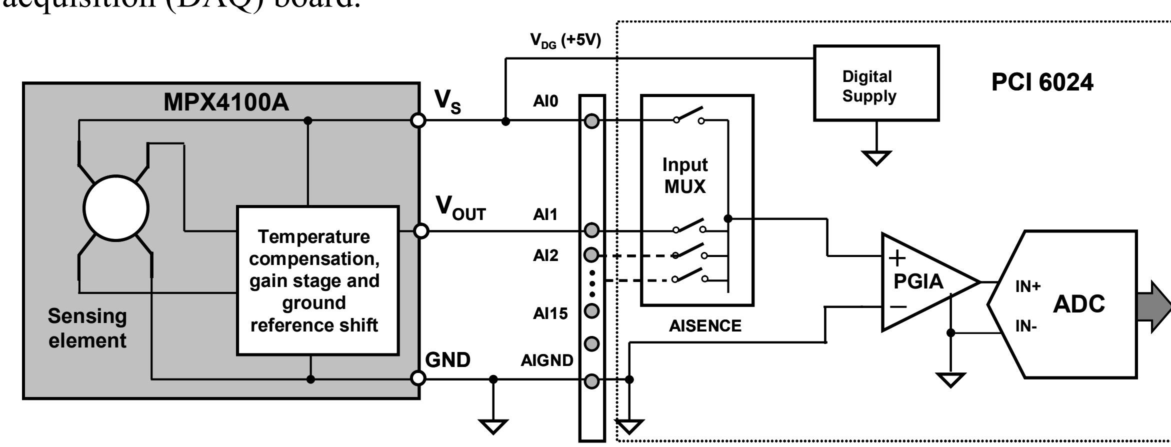

Fig. 2. The hardware configuration of the pressure monitoring system

National Instruments E Series DAQ devices [4] deliver accurate, reliable measurements for a wide variety of desktop, portable, and networked applications. Additionally this multifunction devices come with NI-DAQ driver software. This easy-to-use software tightly integrates the full functionality of the hardware to LabVIEW. In his turn the LabVIEW includes a configuration utility that simplifies the design and implementation of the measurement system [5].

For signal conditioning of the pressure sensors the DAQ's digital supply voltage $V_S = V_{DG} = 5$ V is used. The DAQ sequentially scans the sensor supply V_S voltage and the sensor output voltage V_{OUT}. When this voltages are measured the software divide them and as a result the pressure P is given by the equation:

$$P = \frac{1}{A} \cdot \left(\frac{V_{OUT}}{V_S} - B \right), \tag{1}$$

where A and B are coefficients according sensor type. This approach eliminate the errors due supply voltage uncertainties.

3. Online analyse and logger

In modern data logging system the functions of analyzing and logging are performed by software. There are two general categories of software that can be used for PC-based data logging applications – turnkey software, also known as configuration-based software, and application development environments. A disadvantage of configuration-based applications is that, unless there is a method for customization, they are locked into the functionality provided by the manufacturer. On the other hand with the application development tools, it's possible to build customized data logging application, which does exactly meet the user needs. Application development tools can range from text-based programming languages to graphical programming environments such as LabVIEW.

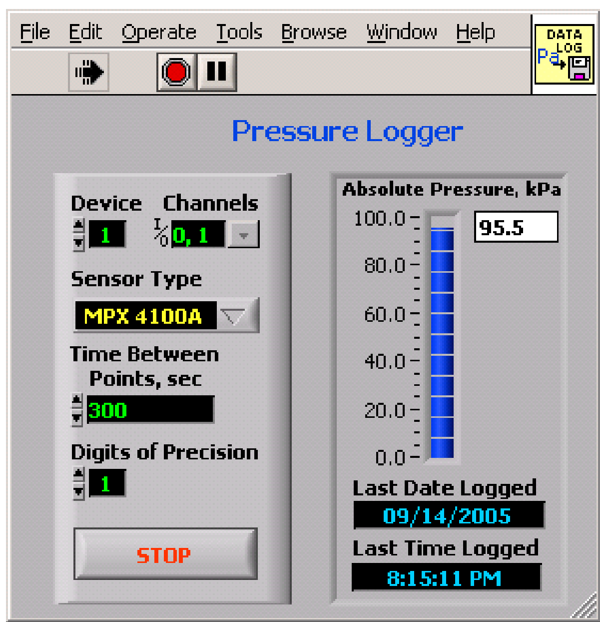

Fig. 3. The front panel the of pressure data logger

Such approach is used to create pressure monitoring system. The front panel of the virtual instrument called pressure data logger is shown in figure 3. This virtual instrument is dedicated to online analysis and to log the measured data according user defined time between measured points. On the left side of the figure can be seen the controls for a sensor type, for the time between two measurements and for the other DAQ's functions selections. The indicators for the moment value of the absolute pressure in kPa and the last data end time logged are placed on the right side of the panel. The created LabVIEW programming code or so called in realm of virtual instrumentation the block diagram is illustrated in figure 4.

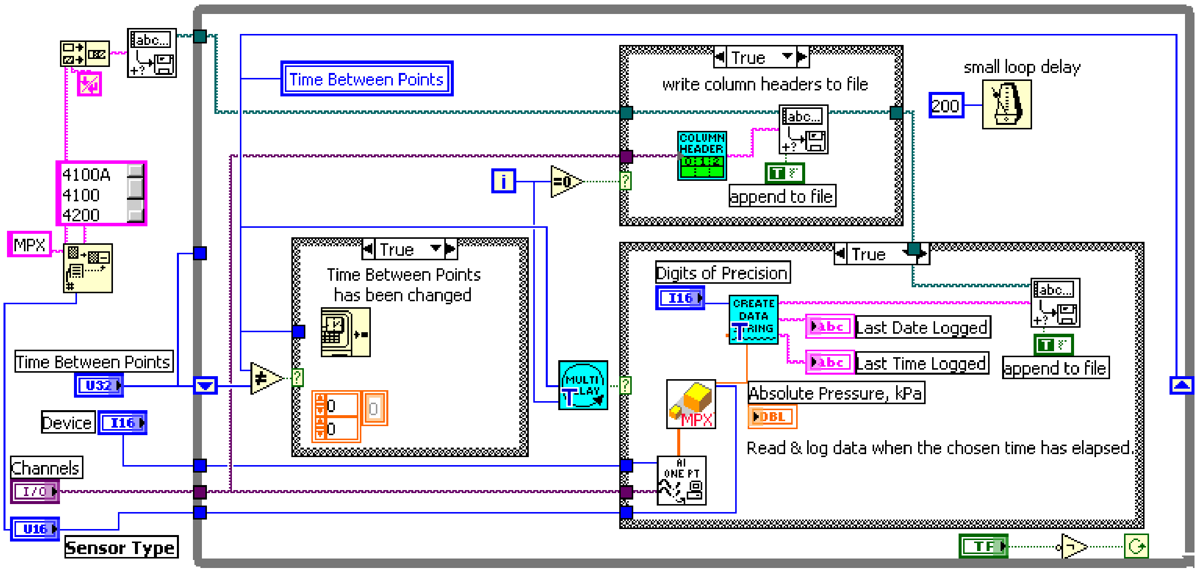

Fig. 4. Block diagram of the pressure logger

4. Offline analyse, report generation and sharing

Offline analysis is performing mathematical functions on data after it has been acquired in order to extract important information. Types of offline analysis can include computing basic statistics of measured parameters, as well as more advanced functions such as the frequency content of signals and order analysis. Offline analysis can be integrated with the rest of the data logging application, or it can occur separately through stand-alone analysis software packages. Often, offline analysis is combined with the report generation, historical display, and data sharing functions.

Most data logging applications require some form of display to view the measurements that are being recorded. The display function can be further broken down to viewing live data and historical data. Live data display is necessary to view data as it is being acquired. Historical display views data that was previously acquired.

In order to create virtual instrument performing function of offline analysis and report generation the build-in LabVIEW library functions for data reading are used.

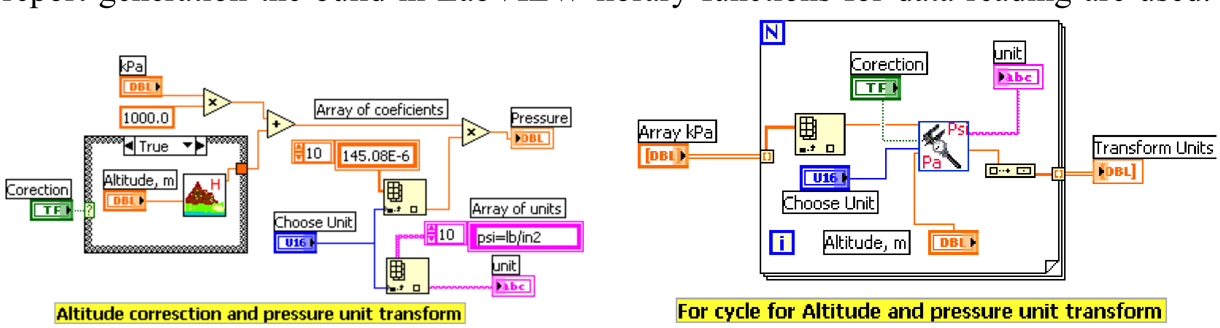

Fig. 5. Block diagrams of the subVIs for pressure unit conversion

In addition to calculate altitude correction of barometric pressure measuring and to facilitate user for unit conversion a LabVIEW subVIs are created which block diagrams are shown in figure 5. The design of front panel of virtual instrument for offline analysis and report generation is shown in figure 6. The controls for altitude correction of barometric pressure and for pressure unit conversion are placed in the left side of the panel. On the right side is shown the display of logged data. The pressure unit of measured data is defined by the user.

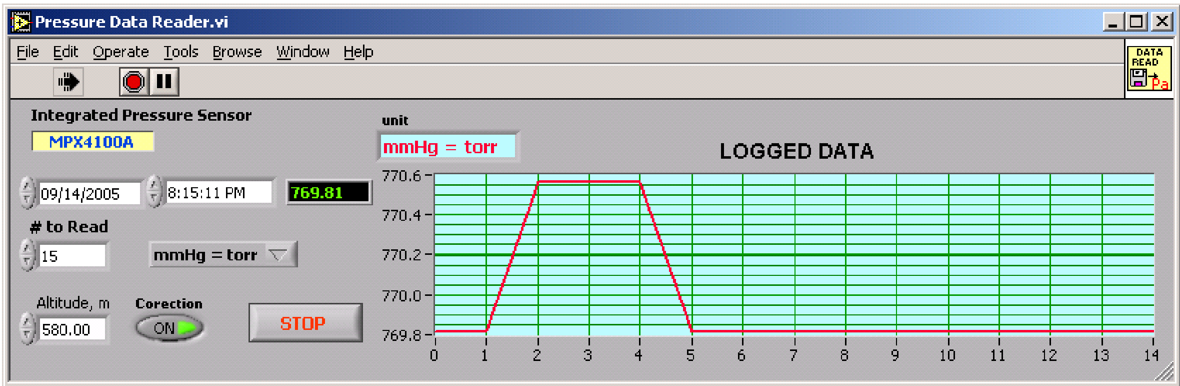

Fig. 6. Front panel of the Pressure Reader

The output data of measured and logged pressure is recorded in spreadsheet file. This format is appropriate for sharing with other programs like MS Exel.

5. Conclusion

Pressure is one of the most frequently measured quantity. Fully signal conditioned single chip pressure sensors are available in various ranges and offer several advantages over discrete sensors with interface electronics. System designers realize many advantages when using the monolithic fully signal conditioned pressure sensors for new applications. Such approach is implemented and considered in details in presented paper. The pressure logging and monitoring system based on integrated silicon sensor and multifunction DAQ is created. To develop software of the presented system the graphical application environment LabVIEW is used. The system is well suited as for educational laboratories as for weather stations and some manufactoring sections. The consideration for hardware and software design and development can be useful for engineers and designers of logging and monitoring systems of various physical quantities.

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