Using FPGA reconfigurable integrated circuits for monitoring, controlling and managing industrial processes in potentially explosive atmospheres

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Abstract. The implementation of calculation architectures, data acquisition and processing systems, VLSI type integrated circuits within driving systems shows and increased trend in the industry, due to the advantages of such circuits compared to microcontrollers and ASIC's. In the first part of the paper is presented functional aspects of reconfigurable integrated circuits for monitoring, controlling and managing industrial processes. Compact RIO is a device developed by National Instruments and which is intended for monitoring and controlling industrial processes. This is also an "embedded" type system, which comprises a FPGA device, a processor with real-time operating system (RTOS) and various input-output modules which have to be attached by the user. Applications using such devices, usually also use an HMI (human machine interface) for creating a graphical interface with the user. The second part of the paper is allocated for establishing the requirements for using of such system in the explosive atmospheres. The practical achievement consists in the construction of a wirelessly PC-controlled robot and the analysis of measurements achieved, respectively data acquired from sensors and video recordings. Among conclusions is highlighted the opportunities brought by the use of the intrinsic safety and flame proof types of protection.

1 Introduction

The secure and safe operation of industrial equipment operating in a potentially explosive atmosphere, is ruled by specific regulations under the ATEx Directives which regulate both the technical conditions that the equipment used in such places must meet the safety measures that are required. [1]

Despite all these measures, there are still a lot of incidents either due to technical issues, human errors or even natural disasters, which lead to serious accidents such as explosions followed (or not) by fires.

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Technical expertise following such events due to technical installations (equipment) covered by the ATEx Directive 2014/34 / EU, establishing the necessary measures to remedy the damage caused, as well as developing measures to avoid future technical accidents that, could cause significant damage or even human casualties, require measurements, on-site sampling, technical inspections that might be activities with significant risks for designated personnel in assessing and determining the causes of accidents. [1]

In this order of words, it is proposed to create a robot that can be used in the exploration of places with high risk, or with difficult access for human personnel, to be safe and reliable in terms of operation. It must also be able to remotely transmit on-site images as well as the necessary parameters in assessing the existing situation such as temperature, humidity and concentration of toxic gases and / or explosion.

The technical requirements imposed on the prototype of an inspection robot for high risk places are:

- safety and reliability in operation;
- remote control;
- data transmission to a computer or mobile device from sensors of temperature, pressure, humidity, noxious concentration, volatile compounds or potential inflammable gases;
- the possibility of sending commands to the monitored system, the execution of certain operations by the robot;
- video transmission to the inspected location/area;
- the possibility of storing data in a data base for further inspection;
- compliance with explosion protection requirements.

2 Requirements for electrical equipment used in potentially explosive environments

The use of electricity in potentially explosive atmospheres has many peculiarities, for which the problems raised by the design, construction and operation of electrical equipment and installations present many difficulties, their approach requiring special attention in considering the multiple technical and economic aspects of labor safety. Thus, require special attention to aspects regarding the construction and marking of electrical equipment, cable inputs and Ex components, intended for use in explosive atmospheres generated by gases, vapors or flammable mists.

Taking into account the constructive and functional aspects of the electrical equipment, types of protection for the different electrical equipment have been developed and are presented in Table 1. [1-7]

Table 1. Suitable Ex types of protection identified for robotic components

Type of protection		Equipment type – Operational role
Symbol	**Name**	
Ex m	Encapsulation	parts of circuits; small components etc.
Ex p	Pressurized enclosures	control panels; analysers; rotary machines; electrical appliances etc.
Ex e	Increased safety	rotary machines; lighting objects; terminal / branch boxes etc.
Ex n	Non-sparking	rotary machines; lighting objects; terminal / branch boxes etc.

Type of protection		**Equipment type – Operational role**
Symbol	**Name**	
Ex d	Flameproof enclosures	rotary machines; lighting objects; terminal / branch boxes; on-off switches; electrical appliances etc.
Ex i	Intrinsic safety	monitoring - control – signalling system; generally low current equipment.

3 Hardware Implementation

For the creation of the experimental model, the performance of tests, measurements, and analysis of results, it is proposed to use a MyRio 1900 module, developed by the American company National Instruments and whose structure is presented in Figure 1.

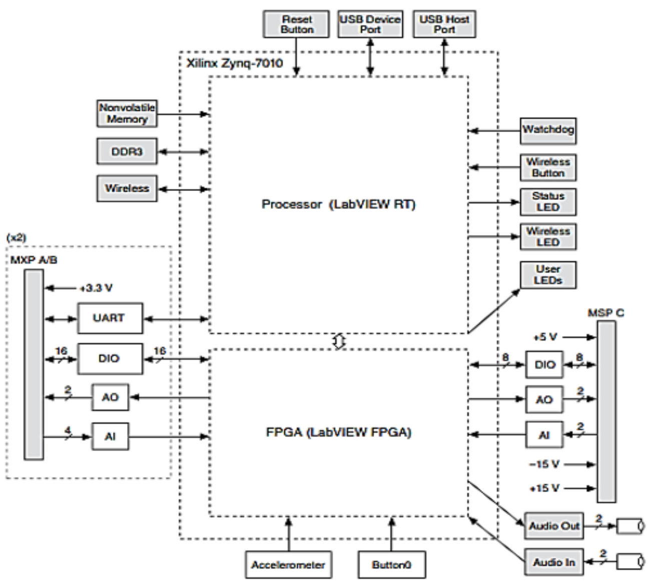

Fig. 1 Company structure National Instruments

Specification MyRio

- Xilinx Z-7010 processor 667 MHz (ARM Cortex A9 x2 cores 28 nm process NEON SIMD, VFPv3 Vector Float)
- Memory: NV: 256 MB, DDR3 512MB, 533 MHz, 16 bits
- FPGA type same as processor
- Wireless: IEEE 802.11 b,g,n ISM 2.4 GHz 20 MHz.
- USB 2.0 Hi-Speed
- Breakout Board support
- 2 ports of 16 Digital I/O lines
- 3 axis accelerometer
- Max power consumption : 14 W
- Typical idle : 2.6 W
- LED's

This device consists of analog and digital inputs and outputs, audio outputs that can supply 5V, 3.3V or 12V, indicator lights or reset button. Communication with a computer can be done via a USB cable or via WI-FI.

The MyRIO device has 3 ports, of which 2 identical ports (Figure 2), marked with A and B each with 34 pins and an additional port C with 20 pins (Figure 3). [8,13]

In general, the pins are for power, digital or analog inputs or outputs, as well as dedicated pins for various tasks, such as PWM (Pulse With Modulation), SPI (Serial Peripheral Interface) communication, I²C (Inter-Integrated Circuit) communication or pins ENC for encoder.

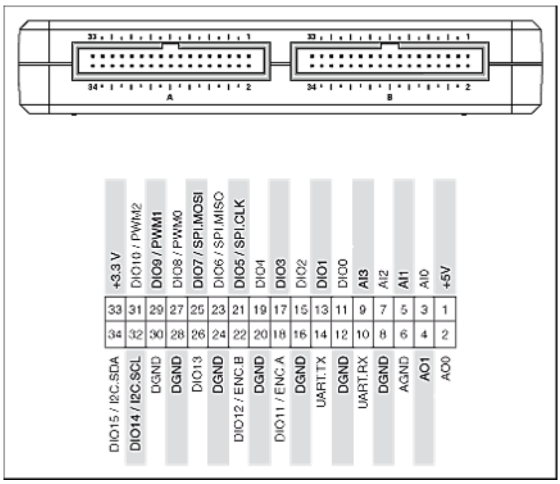

Fig. 2 Ports configuration A and B Ni-myRIO 1900

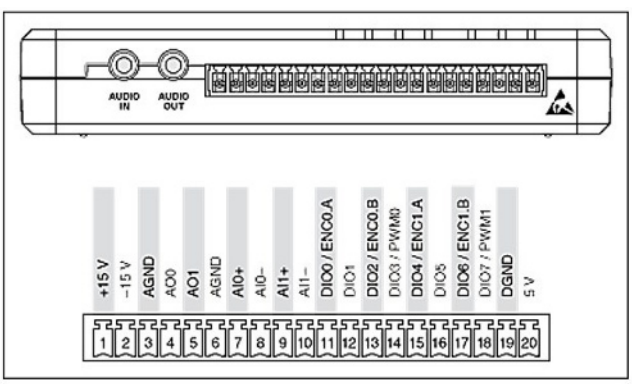

Fig. 3 Port C config.Ni-myRIO 1900

The power supply of the prototype was made with a 12V - 5Ah battery, which ensures an autonomy of at least 6 hours for a full charge. The propulsion system is provided by 2 tracks driven by 12Vdc powered motors, controlled by PWM and reversible drive. The prototype is also equipped with a robotic arm with 6 actuators, presented in Figure 4.

Fig. 4 Robotic arm

The 6DOF structural design makes the robotic arm move flexibly so that it can grab objects from any direction.

The accuracy of the servos is ensured by:

- LDX-218: 17 kg high torque, double ball bearing, connectable cable;
- LFD-06: resistance to high temperatures, prevents blocked rotor;
- LD-1501MG: large torque of 17 kg, for large bottom plate.

In the hardware implementation were also used digital ultrasound sensors, for the detection and avoidance of obstacles encountered, type HC-SR04, sensors for determining and transmitting temperature and humidity parameters, type DTH-11, methane concentration sensors MQ-5, a video camera for transmitting images on the spot, as well as an LED projector to ensure sufficient illumination so that images can be taken in conditions of satisfactory definition.

4 Software Implementation

The programming of the command, control and data acquisition device, was performed in the programming environment based on the graphic programming language G, LabVIEW of the company National Instruments. [9,10]

Unlike textual programming languages, in which the instructions are those who determine the execution of the program, LabVIEW uses, instead, the data flow highlighted by an appropriate graphical presentation. For programming, install the LabVIEW myRIO software package in the main program that provides the toolkit needed to configure and schedule your hard drive. Field Programmable Gate Arrays FPGAs, known in the literature as programmable logic gate arrays, are user-programmed, and the most common languages are VHDL and VERILOG.

Vhdl and Verilog are hardware description languages for describing the behavior and / or architecture of a number system, in other words, a combinatorial or sequential logic function.

The MyRio 1900 device has an integrated Xilinx Z-7010 FPGA, which in order to be programmed with the LabVIEW development environment, needs a compiler provided by Xilinx, namely the Vivado 2015.4 version, which adds to the package from National Instruments and also two more modules that make it possible to compile the program (Figure 5). [1,4,12]

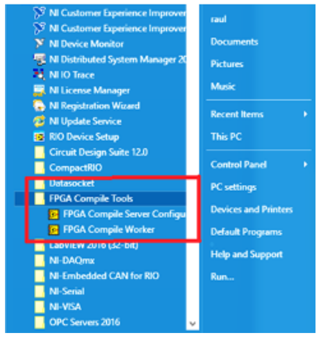

Fig. 5 Installing the Xilinx compiler

The programming of the MyRio 1900 device requires the creation of subprograms for each sensor and also subprograms for controlling the servomotors that must then be compiled into a main program.

Figure 6 shows a sequence of the main program from the block diagram of the LabVIEW programming environment.

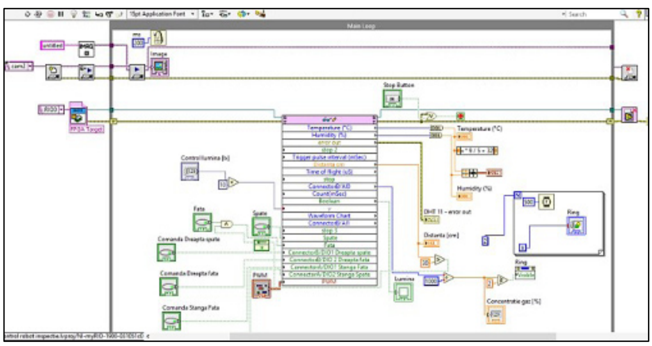

Fig. 6. Sequence from the block diagram of the program

The corresponding block diagram in LabView is the front panel, which is actually the user interface and where the parameters from the sensors programmed in the system, as well as video images, are displayed in real time.

The inspection robot can be ordered back and forth, rotated to 1800 and the recorded data and downloaded images are stored in a database that can be accessed later to allow their analysis and processing.

Figure 7 shows the monitoring and command interface of the LabVIEW programming environment. [9,10,11]

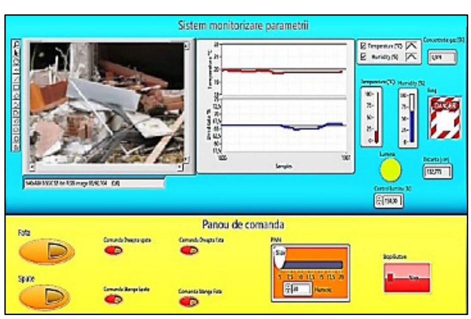

Fig. 7 The front panel of the program

5 Realization of the experimental model

The realization of the experimental model consists in the construction of a robot controlled wirelessly from the computer and the analysis of the received measurements, respectively of the data received from the sensors as well as video footages.

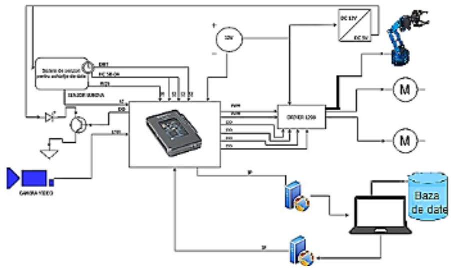

Fig. 8. Inspection robot block diagram

In the middle of the block diagram, the control device equipped with myRIO-1900 FPGA, powered by a 12V and 5A battery, a battery that allows the robot to operate between 6 and 8 hours because the consumption differs depending on the conditions to which the robot is subjected.

The experimental model is presented in Figure 9.

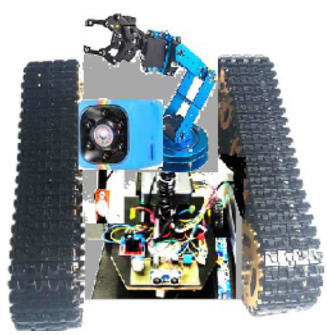

Fig. 9. Experimental inspection robot model

Saving the monitored data through the sensor systems is done through a subprogram written in LabVIEW, and their reading will be done in Excel and will also be presented graphically. [9,10,11]

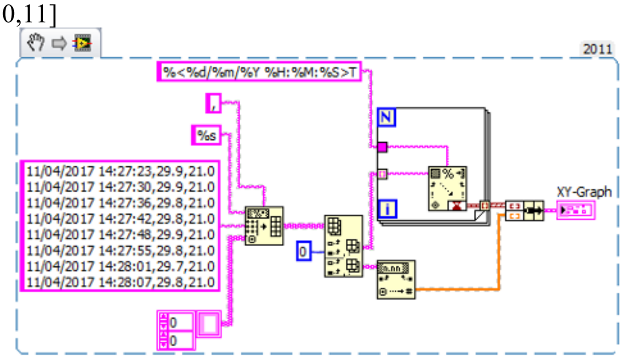

Fig. 10 Data storage subprogram

6 Conclusions

The realization of the experimental model made it possible to test the equipment primarily at the stability of the WI-FI connection and maneuver the equipment in the field with different degrees of difficulty. It was found a good maneuverability for both the march drive and the robotic arm, each being operated with variable speed, depending on the nature of the terrain and the operations it has to perform.

The ultrasonic obstacle detection sensors, as well as the fact that the MyRIO device has an integrated 3-axis accelerometer, which gives it a good stability and rollover protection. In order to expand the use of such equipment in the inspection of places with a high degree of danger, it is intended to continue the research and development of a stepping robot that can more easily access the rugged terrain and meet the requirements of explosion protection.

The robotic arm was tested to remove obstacles and take certain samples to be brought to the base for further analysis.

The signals from the embedded sensors have been transmitted with great accuracy at a user-prescribable sampling rate and have also been successfully saved in the database.

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