

# Experimental Electronic Instrument for an Hydraulic Towing Winch

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**Abstract** - The objective of this work is the design and implementation of an experimental electronic instrument that will be used for the automation control of an hydraulic towing winch, for a Spanish manufacturer of naval deck machinery (fishing, merchant, towing and oceanography). This electronic instrumentation system integrates the controller and the human machine interface. For this reason, an experimental programmable automation controller has been developed. This paper makes an introduction to the machine control architectures and the main solutions for application developing; provides an overview to the machine control architecture running on a National Instruments CompactRIO programmable automation controller using the LabVIEW Statechart and Real-Time modules as development tools; presents the structure of the designed electronic instrument; and finally summarizes the main conclusions.

**Keywords** - Tug winches, electronic instrumentation, data acquisition, electronic sensors, control system

## I. INTRODUCTION

The heart of most machine control applications is an electronic controller such as a programmable automation controller (PAC) or programmable logic controller (PLC) [1]. The controller is used to receive sensor data and to control the machine using analog and digital I/O signals, and mathematical algorithms like PIDs [2]. Traditionally PLCs have been used in machine control and they are programmed using tools such as ladder diagrams or sequential function charts. One of the biggest benefits of using a PAC is the ability to add other tasks to the control application, which could not be handled by a traditional PLC [3]. For this reason, increasingly machine control is moving to PACs because they offer higher performance and more functionality, allowing operations such as high-speed data acquisition and processing, as well as motion control and vision which are not supported in traditional PLCs [1, 4, 5].

The designed electronic instrument must accomplish the control requirements for a naval deck machinery, composed by a tug winch with an hydraulic pump feeding four hydraulic motors, linked together to a towing drum (Fig. 1) [6]. Basically, the functional requirements for the electronic instrument are: capture of relevant parameters from hydraulic motors by appropriate industrial sensors; conditioning of that parameters in terms of voltage, current, impedance, etc. for their acquisition [7]; analog-to-digital conversion of signals from sensors for transmitting them to the processor; designing of algorithms to fulfill all functioning modes of tug winch; digital-to-analog

conversions for convenient actuators; storing of all relevant events for different working conditions; programming of warnings to an operator/supervisor for given manual operations, alarms, maintaining tasks, etc.; designing of a human machine interface (HMI) for on-board operations; and programming of that man-machine interface for on-line or remote operation.

## II. ELECTRONIC INSTRUMENT ARCHITECTURE

The electronic instrument architecture, including the machine controller hardware and software, has been defined considering the following characteristics: (i) combination of HMI and real-time control in the machine control system; (ii) ruggedness, flexibility and modularity; and (iii) the availability of common intuitive development software for programming all the elements of the system [4, 8].

From the previous considerations, the adopted solution was based on a NI CompactRIO PAC, a modular low-cost reconfigurable control and acquisition system designed for applications that require high performance and reliability. The system combines an open embedded architecture with small size, extreme ruggedness, and hot-swappable industrial I/O modules. NI CompactRIO is powered by reconfigurable I/O (RIO) field-programmable gate array (FPGA) technology. This solution comprises a CompactRIO chassis and real-time embedded controller (NI cRIO-9014) and several I/O modules. The I/O modules were selected in order to meet the I/O signal handling capabilities, keeping some extra ports available for providing flexibility and possible future expansion. Therefore, the following I/O modules were added to the CompactRIO chassis:

- NI 9205 (32 Channel +-200mV to +-10V, 16 bit, 250KS/s Analog Input Module).
- NI 9203 (8 Channel +-20mA, 16 bit, 200 KS/s Analog Current Input Module).
- NI 9265 (4 Channel, 0 to 20mA, 16 bit, 100KS/s Analog Current Output Module).
- NI 9425 (32 Channel, 24V, 16 bit, 7 $\mu$ s, Sinking Digital Input Module).
- NI 9477 (32 Channel, 5 to 60 V, 8 $\mu$ s, Sinking Digital Output Module).

Figure 1 illustrates the architecture of the electronic instrument and software tasks running in HMI and Real-time Controller.

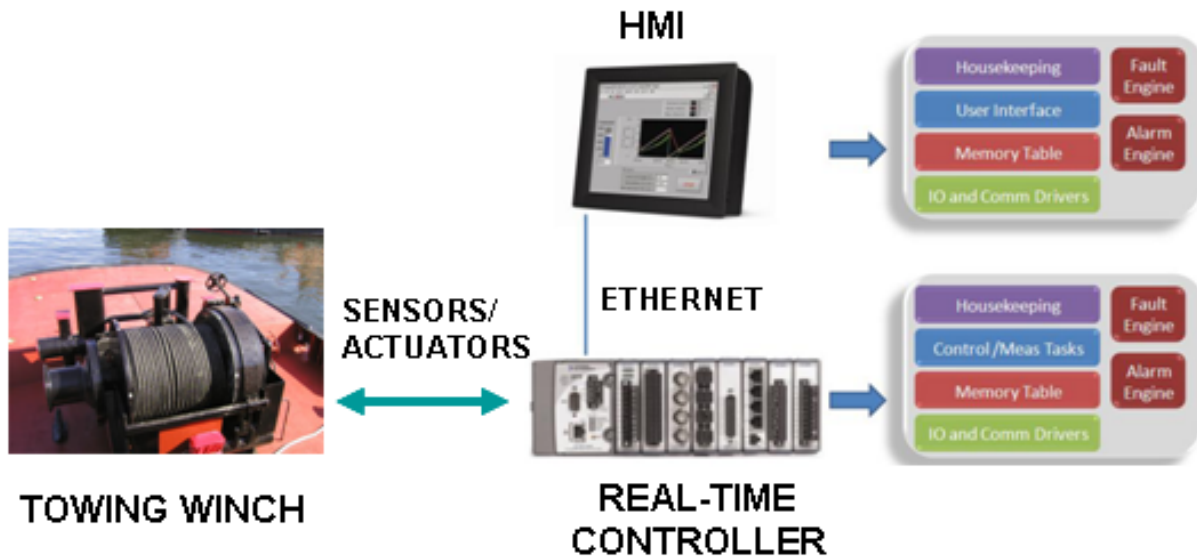


Figure 1. Architecture of the electronic instrument and running tasks.

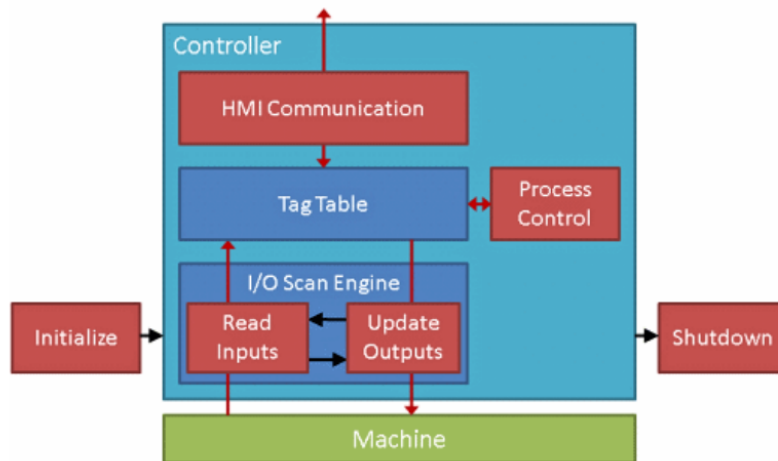


Figure 2. Controller components and operations

Nevertheless, to take advantage of all the features and capabilities of a PAC, it is fundamental that the application code was well designed, coordinating various controller processes such as I/O, process control logic, communication to a HMI and other tasks [1, 5]. The LabVIEW Real-Time Module 8.6 introduces powerful new features for programming CompactRIO hardware that reduce development time and complexity as well as provide tools for monitoring and maintaining CompactRIO applications [9]. The basis of the CompactRIO PAC is the FPGA which performs the interconnection of the I/O modules and offers performance maintaining the flexibility. CompactRIO is entirely programmable with LabVIEW, including the FPGA, real-time processor, and human machine interface.

### III. PROGRAMMING OF MACHINE FUNCTIONS

The generic core operations of a machine controller include I/O scans and process control. After the initialization, the controller continuously reads inputs,

calculates control parameters for the machine process using application-specific logic based on the input data, and then updates outputs to the machine. Finally, some shutdown process may be completed before the controller is turned off (Fig. 2) [1].

The implementation of the control software has been developed using the CompactRIO Scan Mode, which automatically detects the I/O modules and adds them to the LabVIEW project [4, 9]. Thus, the I/O variables can be dragged and dropped in the LabVIEW Real-Time block diagrams or machine control or in a host PC or Touch panel, for monitoring and alarm display (HMI), and then can be used without any FPGA programming (Fig. 3). The development of faster algorithms is also possible, with a greater programming effort, by using the LabVIEW FPGA module.

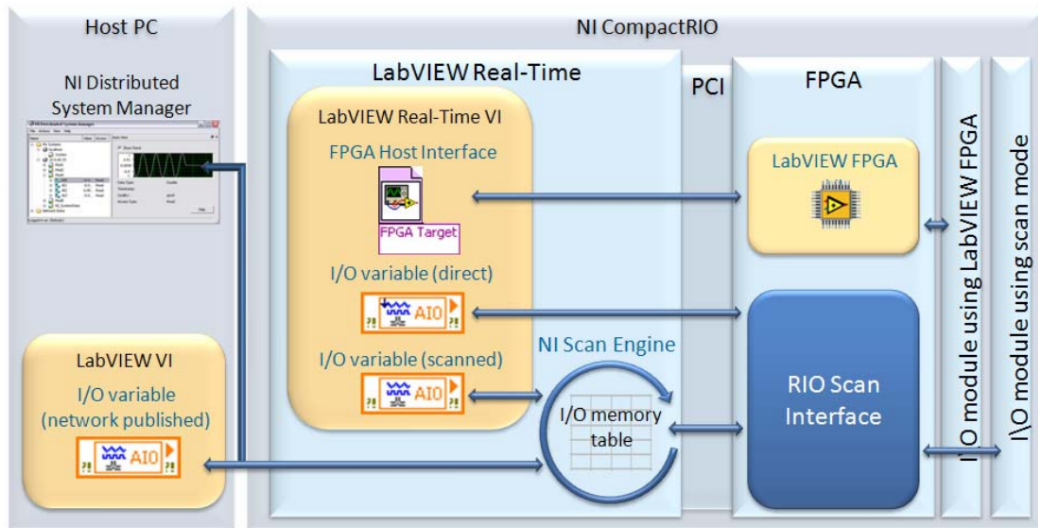


Figure 3. CompactRIO Scan Mode.

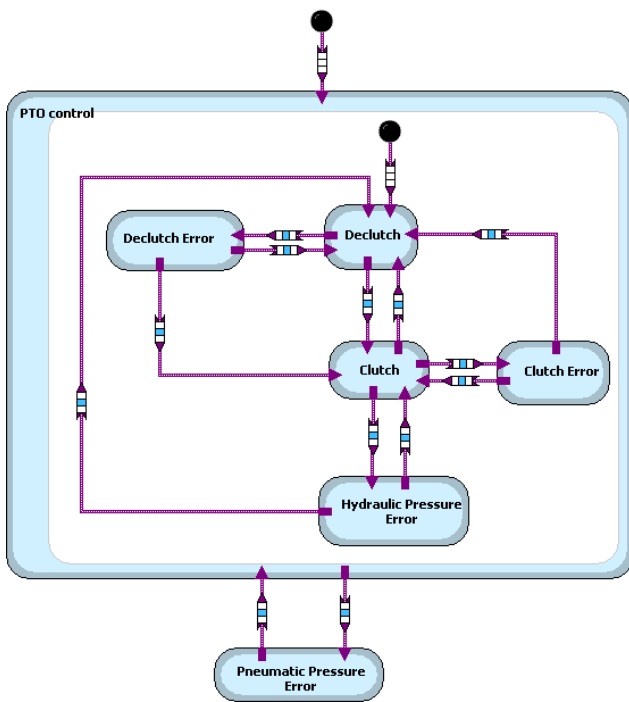


Figure 4. PTO state chart diagram.

With these considerations, the design of the PAC software was divided in several independent functional modules, in order to achieve the characteristics of flexibility and modularity defined in Section 2. Each module performs the control of a defined element of the system like hydraulic pump, hydraulic motors, drum clutching-declutching, etc. [3, 6]. So, the modules can be interconnected, considering the different elements of the system, their function and their interconnection. Each functional module was characterized with its classic state diagram, which consists of two main constructs: states and transitions. The LabVIEW Statechart module provides a graphical implementation of state

diagrams (state charts) for developing event-based control and test systems [10]. The Statechart module adds the notions of hierarchy, concurrency and events to the classic state diagram structure, allowing the reduction of the number of states and transitions. Figure 4 shows the state chart resulting of the functional definition for the power take off (PTO) control, which handles the operation of the hydraulic pump.

Using LabVIEW statecharts for system design provides a system-level view that describes the complete function of a system or application, because a statechart diagram captures each possible state of the system. Therefore, the use of statecharts helps to reduce the possibility of software “hangs” and other unexpected behavior, because the designer is forced to consider every alternative to which the software needs to respond.

#### IV. CONCLUSIONS

The work presented in this paper was focused on the design of an experimental electronic instrument for automation control of an hydraulic towing winch. The experimental programmable automation controller was based on the NI CompactRIO Scan Mode architecture, and was developed using the LabVIEW Real-Time developing tool and its modules.

The system was divided in several independent basic functional blocks or modules. These functional blocks improved the modularity and the flexibility of the system. This structure facilitates the addition of new elements to the system or the design of whole new system, simply by the design and addition of new software modules, or by the reuse of the existing ones.

Since the state diagram considers each possible state of the system, the using of LabVIEW Statecharts provides a system-level view that describes the complete function of a module, a system or an application. Therefore, the use of Statecharts reduces the possibility of unexpected behavior

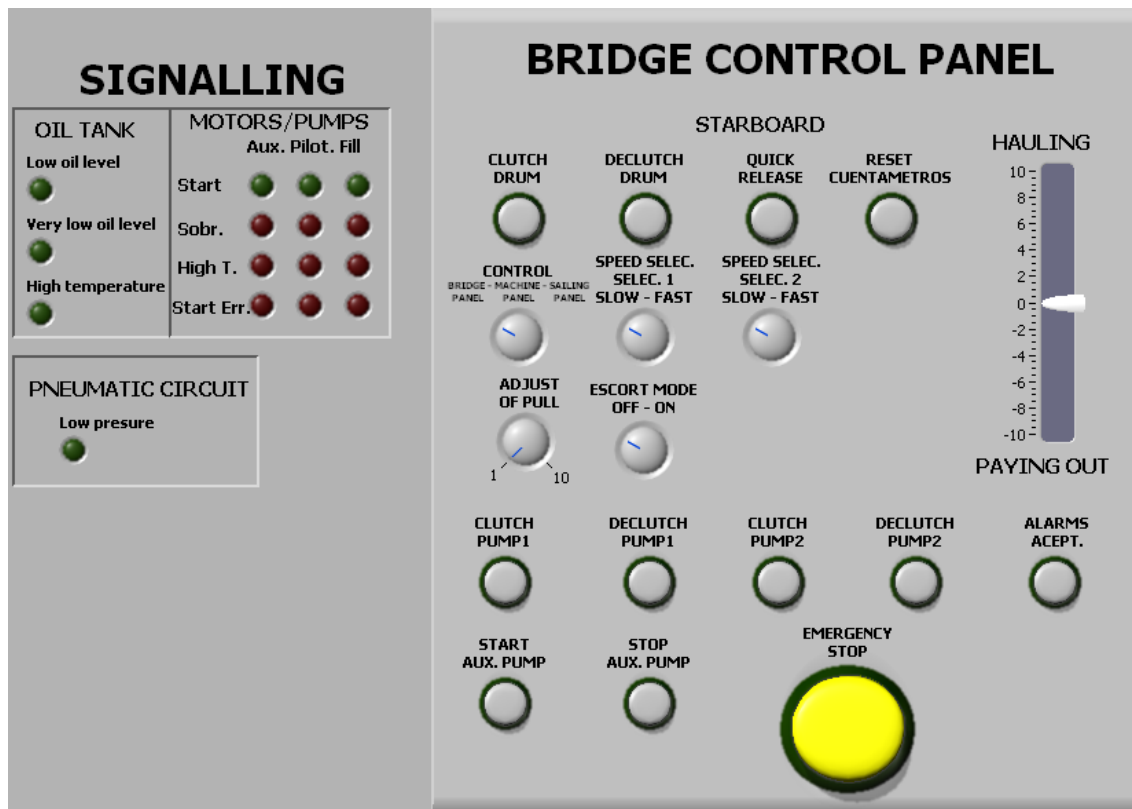


Figure 5. Example of the bridge control panel simulation.

because the state chart definition of a module forces to take into account the possible scenarios to which the software needs to respond. The LabVIEW development tool also provides a powerful debugging and testing platform, so each module was previously verified and simulated using virtual panels and virtual machines (inputs/outputs). These virtual panels and machines allow the functional verification of each module and the whole system (Fig. 5).

Currently, this experimental electronic instrument is being tested on the facilities of Ibercisa, a Spanish manufacturer of naval deck machinery for big trawlers and tugboats in the national and overseas markets [11, 12] from 1969 (<http://www.ibercisa.es>). The experimental prototype will be finally implemented for dynamic ship assist and escort towing.

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