Electronic Control Module for Test Stand on the Production Line of Hydraulic Cylinders and Rotary Hydraulic Motors

PhD. Eng. **Radu RĂDOI**[1], Dipl. Eng. **Alexandru HRISTEA**[1],
Dipl. Eng. **Bogdan TUDOR**[1], PhD. Stud. Eng. **Mihai ALEXE**[1]

[1] INOE 2000 – IHP Bucharest, radoi.ihp@fluidas.ro

Abstract: *In order to ensure the quality of the products delivered at the exit from the production lines there are used functionality testing stands which are located at the exit of the line. The functionality of the products is verified with the help of specialized stands. The testing stand can be controlled with dedicated electronic modules which ensure the logic of operation, or with PLC's. This paper will present an electronic module from a hydraulic motor testing stand, also provided with an operating console, which communicates serially with the control module.*

Keywords: *Test stand, electronic module, microcontroller, sensors*

1. Introduction

The electronic command module is intended for monitoring and controlling the installation of a test stand [1] which is intended for testing hydraulic cylinders and hydraulic motors. The module is capable of data acquisition from the transducers and detectors located on the installation and the control of the hydraulic installation and electro pump based on the operating graph – finite state machine (FSM) that describes the operation of the testing installation – according to the operating mode selected by the operator. In this paper is presented the description of the module, components and the operating program written in the microcontroller, based on which the electronic module for the test stand was made.

2. Electronic module description

The electronic module located on the device communicates with the operator console located next to the stand. Communication is physically implemented through a serial data line that complies with RS-232C specifications standard; the communication protocol used is a master protocol developed by the designer, master/slave type which uses a 7-bit ASCII coding.
The operator console contains controls and signaling to control the hydraulic installation of the test stand. The operating mode can be selected by means of two push-button controls with operation confirmation by illuminating the buttons. This makes possible the use of the "Move right" and "Left shift" or no mode is selected, the working pressure is disconnected. Hydraulic cylinder movement and hydraulic motor rotation are displayed on the console via two groups of signaling, each group having two optical signals: hydraulic cylinder movement, left/right signaling and hydraulic motor rotating group, left/right signaling. Specialized buttons are provided on the console in order to control the movement on left/right and to turn left/right. Another signaling group is located on the operator panel which allows checking the stats of the stand that are monitored: the minimum level of oil in the tank, connected pressure, maximum oil temperature and a signaling which indicates the state of communications between the console and the control module.
The module is built around a microcontroller of general use PIC16F876A manufactured by Microchip. Some of the important features of this microcontroller are:

- RISC architecture with 35 instructions with the length of one word (14 bits);
- Maximum operating speed is 200 ns on an instruction cycle;
- The program memory is a flash memory containing 8096 instructions;
- Data memory (RAM) is 368 bytes;
- EEPROM data memory is 256 bytes;

The PIC16F876A microcontroller features a wide variety of integrated peripheral devices such as:

- An 8-bit timer and two 16-bit timers;
- Two Capture/Compare/PWM modules with resolution of 12.5 ns in Capture mode, 200 ns in Compare mode and 10 bit maximum PWM resolution;
- Synchronous serial communication port that supports SPI) Master mode) and I2C;
- USART communication port with address detection;
- 10-bit analogue-to-five-channel digital converter;
- Two analog comparators;
- Programmable voltage reference.

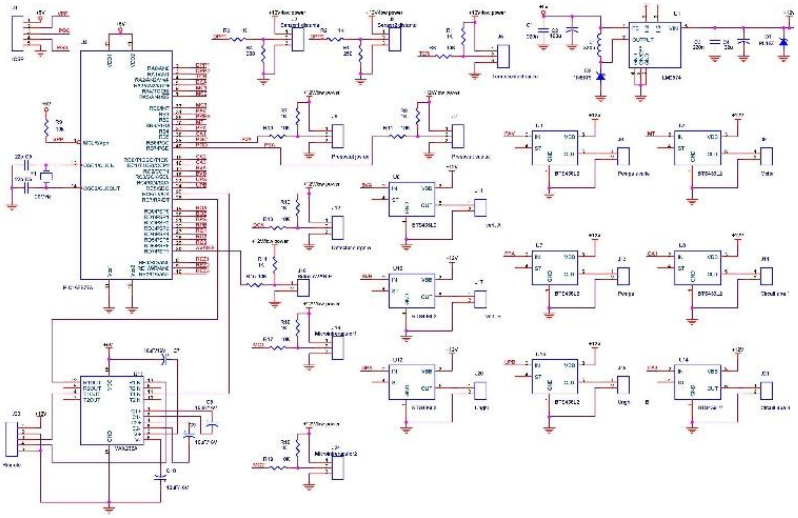

Fig. 1. Schematic of the electronic module

3. Elements of the electronic module

The electronic control module and operator console contain a stabilized voltage source, serial communication, analog and digital input circuits as well as digital outputs.
The stabilized voltage source receives at the input the supply voltage from the module, unstabilized continuous voltage in range of 9 to 36 V, providing a stabilized voltage at the output of 5 V with a current limitation of 0.5 A. The source is being built around the integrated circuit LM2574-05(LM2574-05 is a step-down switch/buck converter).
The chosen solution of a switching voltage source because it has advantages in terms of high efficiency, wide range of input voltage, low wiring dimensions, reliability, etc.
The analog input circuits allow the coupling of four transducers with output of 4 to 20 mA powered by 2-3 wires. Each input has a three-pin connector: power supply (+), power supply (-) and a current input signal entering the electronic module. The circuit's input signal provides a current/voltage converter that transforms the current range from 4 to 20 mA into a voltage range of 1 to 5 V. This voltage is applied to an analog input of the analog/digital converter with successive approximations integrated into the microcontroller. The voltage input signal is available in the microcontroller as a 10-bit numeric value. The digital analog converter is configured to operate with a reference voltage of 5V, so the range is 0 (5-5/1024=4.996) V and it will be converted to numeric values in the 0 to 1023 range. The current signal provided by the transducer will be converted to numerical values corresponding to the range of 1 to 5 V and 1024/5 respectively= 205 to 2023. The resolution obtained on the transducer's working range is 1023-205= 818 divisions. To improve the resolution of the signal read from the transducer, the "circular buffer" mediation technique uses the last 20 samples of the signal. In this way it is obtained a resolution of the analog input of 10,000 stable divisions on the transducer range.
The digital input circuits allow monitoring of the state of the contact type detectors such as thermocouples, limiters, and pressure switches [2]. The input circuit provides a current of 12 mA to "clean" the contact in the operating mode.

The digital output circuits allow the user to interface with the electronic module with the electromagnets of the hydraulic apparatus and the electropump. The output amplifier allows the control of an inductive DC load with a maximum of 10A being protected against overheating, voltage limits, overvoltage and reverse voltage resulting from the ON/OFF switching of the inductive load as well as from the short circuit at the load terminals.
With the right level of adaptors the serial communication enables communication with the electronic module using RS232, RS485, RS422 serial communication standards. The communication connector has a stabilized internal 5 Vcc source needed to power the communication adapter corresponding to the used standard like the TTL TX and RX level signals, transmission line(output module) and reception line(module input). For the multipoint communication lines is required a signal from the signal adapter and to switch between receive mode and the transmission mode. The signal for the operating mode selection is the TTL DIR level signal (direction).
The electronic module is provided with a ICSP header type connector *(In Circuit Serial Programming)*.
The microcontroller operates with a 20 MHz quad-core oscillator clock that corresponds to an execution time of an instruction and instruction clock of 200 ns.

4. The operating program in microcontroller memory

The operating program, written in the Flash memory of the microcontroller, was developed using ANSI C programming language. The program contains a sequence of initialization of microcontroller integrated circuits; the main operating loop contains a machine state that implements the electronic mode functionality and the interrupt handling routine, which performs the following: analogue acquisition, real time clock, display multiplexing, keypad reading and management of broadcast/ reception buffers for serial communication
The PIC16F877A microcontroller [3], with which the electronic module is build, treats the interruptions generated by various peripherals at the occurrence of specific events by saving the program counter's hardware stack and bypassing the execution of the instruction sequence to a fixed location in the program memory at 0x004 where the programmer inserts the interrupt handling code and as the last instruction, the instruction to return from the interrupt. The instruction restores to execution of the program from the point where it was interrupted by restoring the program counter to the stack. Note that the possibility of generating another interruption during the execution of the interrupt routine is deactivated upon entering the interrupt handling routine. Eventual interruption will be stored and treated later. A typical interrupt routine includes saving the context of the main program, identifying the source that generated the interrupt, determining the event that generated the interruption, treating the disruption, restoring the context to the existing situation at the time of the interruption, and returning from the interruption to the normal execution flow.

The discontinuity routine dealt with interrupts generated by the following peripheral devices integrated into the microcontroller:

- The 16-bit TMR1 timer is used to generate the 1ms clock. In the initialization sequence, TMR1 is configured to increment at 200 ns (instruction clock) and interrupt generation at occurrence of the overflow event (TMR1 content goes from 0xFFFF to 0x0000); in the interrupt routine, the timer content is initialized with a t1ms value which allows the occurrence of the overflow event delayed by 1 ms respectively (0xFFFF – t1ms) x 200 ns = 1 ms;
- The analog to digital converter is configured to generate an interruption when the conversion result is available; then, after taking the conversion result, the next analog input to be read is chosen;
- The USART module is configured to generate interruptions if a character has been transmitted/received; the transmission of a character activates the switch to the next character to be transmitted from the transmission buzzer, while receiving a character involves updating the receiving buzzer with the received character. The termination of the transmission is signaled to the interrupt routine by presence of a character with ASCII 0

code in the transmission buffer; signaling to the main program of the end of the transmission is achieved by positioning the TXIE bit (transmission interrupt enable) to 0. At the reception, the appearance of the 0xa or 0xd characters requires, in accordance with the MODBUS ASCII specifications, the termination of the reception; the interrupt routine detects the reception of these characters and signals the event to the main program by inserting a character with the ASCII code 0 into the receiving bucket. Note that there are two pointers, one at the broadcast buffer and one at the receiving buzzer, which marks the current character received or to be transmitted.

The 1 ms interrupt routine performs the following tasks:

- Updates real time clocks used for time synchronization of processes;
- Updating the keyboard buttons
- The launch of analog-to-digital conversion
- Initiate the 1ms interrupt by loading TMR1 with the t1ms value and deleting the T1IF interrupt flag;

The analogue to digital converter interrupt routine performs the following tasks:

- Taking over the conversion result for the current analog input;
- Numerical filtering of the analogue signal from the current analogue input
- Establishing the analog input to be treated at the next interruption as the current analog input;
- The initialization of the interrupt of the analog to digital converter by deleting the ADIF interrupt flag;

The main execution loop contains a state machine that implements the operation of the electronic module.

5. Conclusions

Such an electronic module equipped with high side switches no longer requires intermediate relays as for PLCs to control the solenoids of the hydraulic devices.
Dedicated electronic modules may have the disadvantage that, in the event of a failure, there must necessarily be a backup module to avoid creating long interruptions of the installation.
If there is the wish to expand the functions of an electronic automation module, you must have spare input / output pins; otherwise the module must be redesigned.

Acknowledgments

This work has been funded by the national NUCLEU Programme, project PN16-40-03-01, 5N/2016 ad4/2017, Phase 3.1.2 - Development of electronic control blocks for hydraulic mechatronic systems.

References

[1] M. Blejan, A. Drumea, "Design, Implementation and Testing of an Electrohydraulic System for Automated Winding Machine for Aluminum Wire Rods", *2013 International Conference on Electronics, Computers and Artificial Intelligence (ECAI),* Jun. 27-29, 2013, Proceedings Paper, ISBN: 978-1-4673-4937-6, Accession Number: WOS:000343672500033;

[2] M. Blejan, P. Drumea, A. Mirea, I. Ilie, "Mechatronic module for monitoring the hydraulic parameters of the industrial production equipments", *ISSE 2007 - 30th International Spring Seminar on Electronics Technology*, Cluj-Napoca, 9-13 May 2007, Conference Proceedings, pp. 501 – 506, E-ISBN: 987-1-4244-1218-1, Print ISBN: 987-1-4244-1218-1, DOI: 10.1109/ISSE.2007.4432908;

[3] http://ww1.microchip.com/downloads/en/DeviceDoc/39582b.pdf.