USING DIGITAL ELECTROHYDRAULIC SERVO VALVES IN FLUID CONTROL SYSTEMS

Alexandru GANZIUC[1], Nicolae VASILIU[2], Radu PUHALSCHI[3], Szilard FEHER[4]

The authors present the structure and the performance of an original test bench designed in order to point out the accuracy, flexibility and stability of the digital control solution. The digital assembly is tested in parallel with an analog one in a harsh electromagnetic environment. This new type of controller area network is best suited for multipoint, long range cabling in high electromagnetic interferences areas where analog feedback signals may fail. This new type of control is already used in military, automotive and aerospace simulating platforms or other systems where precision is very important.

Keywords: digital servo valves, field bus distributed hydraulic axis controllers

1. Introduction

The modern applications of the electro hydraulic control systems become more and more dependent of the digital communications between the system components. The step ahead to the new digital network control systems needs the compatibility of all the components with the same bus. The key of the problem stays in the digital servovalves full compatibility with the common digital network. The highest level in this respect seems to be the EtherCAT bus, used in 2011 for testing the fly control systems of the new aircraft Airbus 350 [1]. The main problem raised by this new concept is the electromagnetic compatibility. This problem can be solved by the aid of the optical communication systems. Other problems are: the time response, phase lag and attenuation of the whole system. The extended temperature range, vibration insensitivity and EMI compatibility of microcontrollers, the digital on-board electronics (OBE) of the directional flow control valves can be fitted in a robust metal housing and can be used in rough environments, mounted on the actuator itself. This arrangement improves the overall system response time and performance in close loop control. The most important aspects of digital controlled high response valves are: flexibility, EMI susceptibility, distributed control / field bus integration and

[1] PhDs, Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania
[2] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania, e-mail: vasiliu@fluid-power.pub.ro
[3] PhDs, Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania
[4] PhDs, Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania

advanced diagnostics. This paper tries to offer responses to the above problems by the aid of an original test bench built in the Fluid Power Laboratory of U.P.B. [2].

2. Digital electrohydraulic servovalves peculiarities

According Figure 1, a common digitally controlled servo valves basically consist of: housing (1) with connection surface; LVDT position transducer (2); actuation solenoid (3); flow control spool (4) with centering springs.

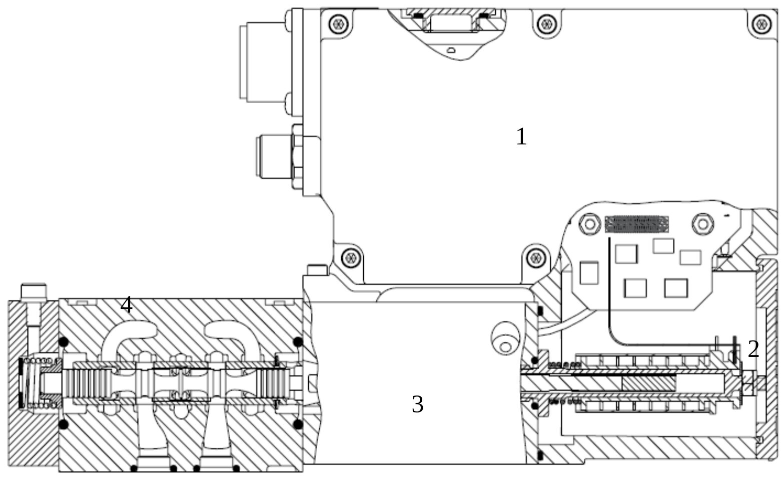


Fig. 1. Vickers digital servo-valve KBS1DG4V-3.

Inside the housing (1) there is the on-board electronics with the logic unit. This unit is responsible for all communication, analog to digital converting, demodulating of the LVDT signal, control algorithms and current output control to the solenoid (3).

The typical block structure of the on-board electronics (OBE) can be seen in Fig. 2 and consists of: DC-DC power supply, level shift converters, analog to digital converters, a communication controller for fieldbuses (PROFIBUS, CANopen, EtherCAT etc.), oscillator demodulator for spool position tracking and PWM current control, all linked to a logic unit – the microcontroller.

The DC to DC power supply (pin 9) converts the main supply voltage, 24Vcc or 12Vcc, to acceptable TTL or CMOS logic level voltages for integrated circuits, and to +/- 12V/15V for the analog to digital converters inputs.

To maintain compatibility, analog command and feedback signals can be used because of ADC implementation in the OBE. In a closed-loop position system, a 16bit ADC resolution is recommended but most manufactures use the integrated ADC in microcontrollers that usually have 10 bit to 12 bit resolution. A 12 bit resolution means 1024 increments in the physical measured system which is good for pressure/force applications but not for accuracy positioning. In digital servovalves, digital output sensors can be fieldbus connected or direct connected through differential signals to improve EMI resistance [3...6]. Such sensors use standard protocols like Synchronous Serial Interface (SSI) for communication.

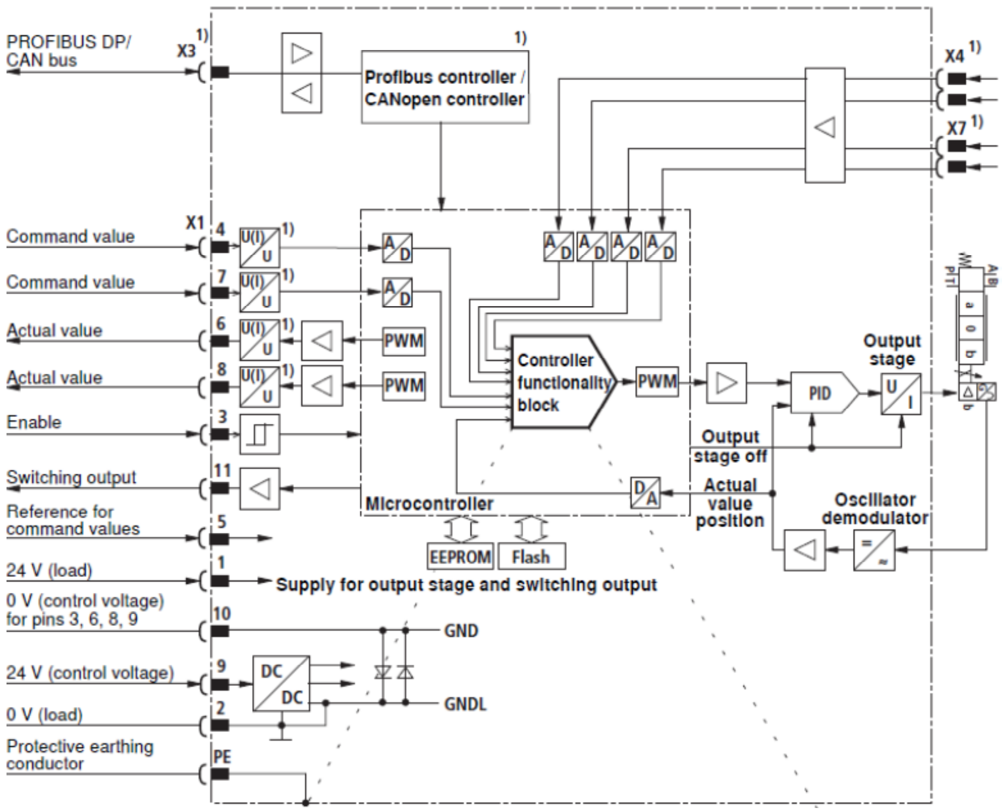


Fig. 2. Block diagram of a Rexroth digital servovalve

The interface has a very simple design as illustrated in fig. 3. Two pairs of twisted wires are used for communication: one for transmitting the clock signals from the master (digital servo-valve) and the other for transmitting the data from the slave (transducer). The clock sequences are triggered by the master when need arises. Different clock frequencies can be used ranging from 100 kHz to 2 MHz. The number of clock pulses depends on the number of data bits to be transmitted. For every clock pulse the transducer sends one bit from the binary value of its physical measurement.

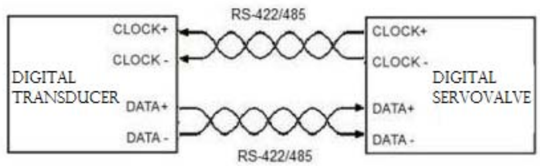


Fig. 3. Standard SSI sensor-valve communication

For spool position tracking, a LVDT transducer is mounted inside the solenoid or in-line with it as seen in figure 1. LVDT stands for Linear Variable Differential Transformer and they are well-established transducers which have been used throughout all proportional valves, analog and digital alike. A distinct advantage of using an LVDT position transducer is that the moving core does not make contact with other electrical or assembly components, as with resistive types, offering high reliability and long life.

Safety regulations require incorporating an "Enable" function from fig.3, pin 3. This safety feature requires a specific voltage to be present at the enable connection before the output of the controller will operate. Enable can be used for an emergency stop switch or other safety interlock device. While it is possible to place an emergency stop switch in the power supply, this is not recommended because stored charges in capacitors can maintain the valve signal for a period of time after the switch is opened.

The main difference between analog and digital servovalves is the way the control function is made. In analog servovalves the control algorithm, usually PID or PI, is made with active and passive electronic components. The adjustment of the variable parameters is made with switches and potentiometers giving users a hard time setting the values. In digital control valves the algorithm is made inside the logic unit, either in a microcontroller or a FPGA. Some types of microcontrollers also incorporate the acquisition process, digital data filters, spool characteristics for linearization and dead band compensation, as well as communication interface with the user.

To control a digital servovalve you have to configure it to your application requirements; either you download a motion profile or you control it though fieldbus communication. Some standard protocols used in automation processes are: Profibus DP and CANopen over RS-485 standard or EtherCAT and PROFInet over IEEE 802.3 (Ethernet) standard. The use of the a decentralized bus communication takes substantially less wiring which speeds commissioning and startup; you can use digital transducers to maximize EMI immunity; monitor and modify process variables; simplify SCADA implementation; quick fault detection.

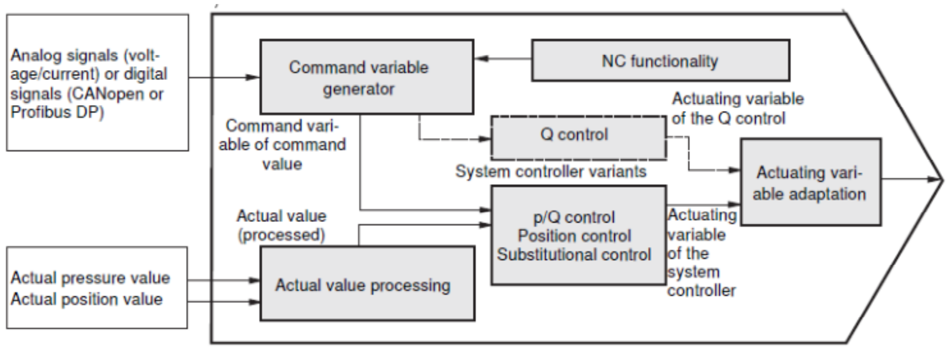


Fig. 4. Controller functionality block

3. Integrated digital electrohydraulic linear actuators

Developments in mechatronics allowed manufactures to incorporate the hydraulic linear actuator with high speed digital servovalves and high precision transducers to create compact electrohydraulic axes with numerous functions, available as integrated algorithms for: position control of a cylinder or rotary drive, pressure control in open or closed volumes, p/Q functions, alternating position/pressure and position/power controls with smooth transitions between the control modes, and power control using a differential pressure sensor, taking into consideration area ratios of the cylinders.

Fig. 5. An integrated electrohydraulic axis controller (PARKER).

Because control algorithms are made inside the logic unit of the OBE and control commands are transmitted over a fieldbus, the PLC power computation is greatly reduced. Instead of real-time position calculation, the PLC can be used in monitoring and decision making regarding the overall application process.

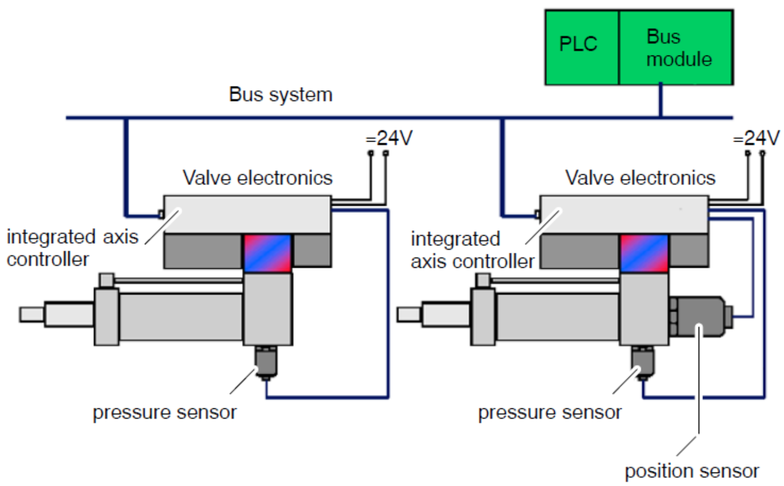


Fig. 6. Decentralized/distributed control of two servo cylinders

3. Integrated axis controller applications

In Fig. 8 is presented a multi-axis shaker table, a dynamic system designed to perform research and development tests. It requires an appropriate configuration, coupled with a dedicated controller and features a state-of-the-art digital architecture using the latest electro hydraulic integrated digital axis controller and monitoring software.

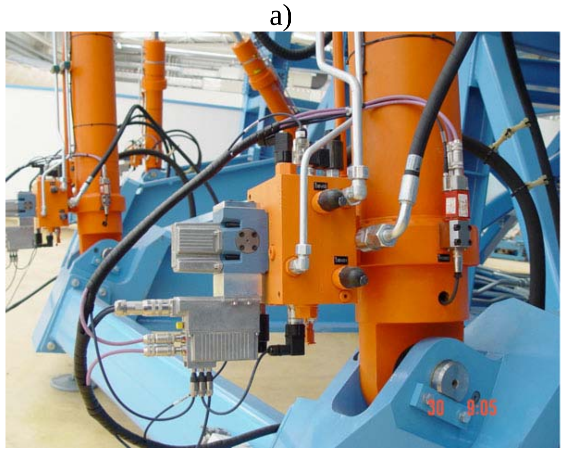
This dynamic simulation table is comprised of a platform that is as compact and light as possible and a base jig consisting of base plates on which stress resistant hydrostatic jacks are assembled with rods jutting from the jacks connected to the platform structure.

Both position and acceleration are controlled by the system through integrated control hardware and software. The simulation table can support heavy loads, while requiring only a minimum of space. This simulation table is used to perform various tests like: Vibration Durability Buzz, Squeak and Rattle Noise and Harshness Testing of vehicle components.

Fig. 7. Electrohydraulic simulation table with hydrostatic bearings (MOOG)

Another interesting application is the motion control system for testing the landing flaps of the new Airbus A350 airplane. The new Airbus A350 has two landing flaps at each wing that are stressed by high aerodynamic forces. These forces needed to be simulated during the test so digital controlled hydraulic linear actuators were used.

a)



b)

Fig. 8. Wing stress test for A350 leading edge aerodynamic forces (MOOG)

4. Test bench structure and performance

The new bench is a compact elastic force simulator adapted to test digital and analog controlled servo valves in a close loop position systems with force limitation [2]. All the devices will be disturbed by controlled electromagnetic radiations taking as reference an analog electrohydraulic positioning servomechanism [7...9]. The hydraulic diagram of the whole test bench is presented in figure 9. A partial view of the digital table is shown in Fig. 10, and a sequence of the LabVIEW data acquisition system is presented in Fig. 11.

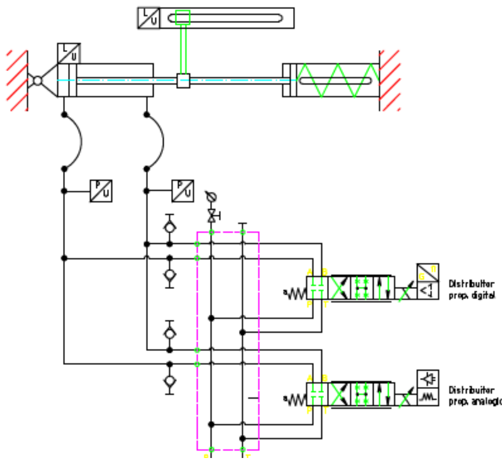


Fig.9. Hydraulic diagram of the new test bench

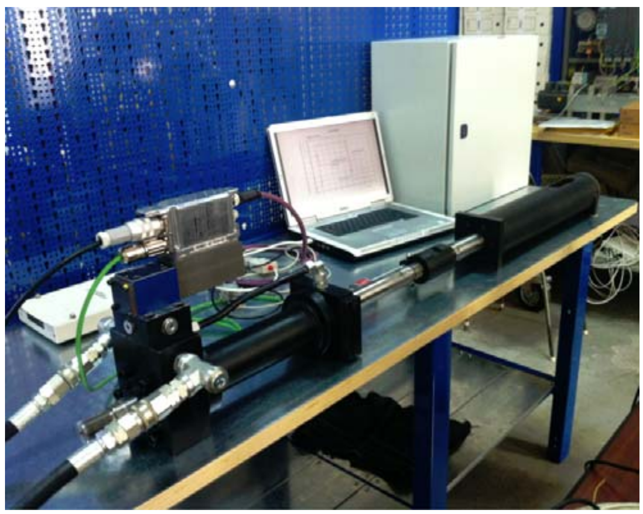


Fig. 10. Partial view of the new test bench for testing digital control servomechanism

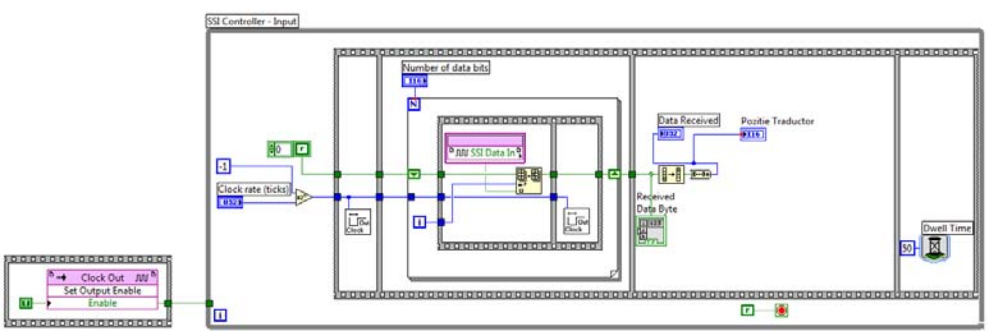


Fig. 11. Labview program of a SSI data aqusiton

To test the analog controlled servovalves analog resistive displacement transducers are used as feedback and unified voltage signals as position reference. The control PI algorithm is made with VT-MACAS analog position controller from Rexroth. To test the digital controlled servovalve magnetostrictive digital displacement transducers with SSI interface were used. Position reference is given though CANopen bus, and the algorithm is PID made with the OBE of the digital servo valve. The reference value for the digital test was generated with the application provided by the manufacturer and sent with a USB<->CANopen adapter. Fig. 12 shows a typical response of a servomechanism with P controller, and figure 13 indicates the influence of K_P on system response.

To read the data communication of the digital displacement transducer at our test bench the Clock+ and Data+ cable of the position transducer was connected to a National Instruments sbRIO-9642 embedded control and acquisition board that integrates a real-time processor and a FPGA. This way is possible to read the data in parallel with the digital servovalve.

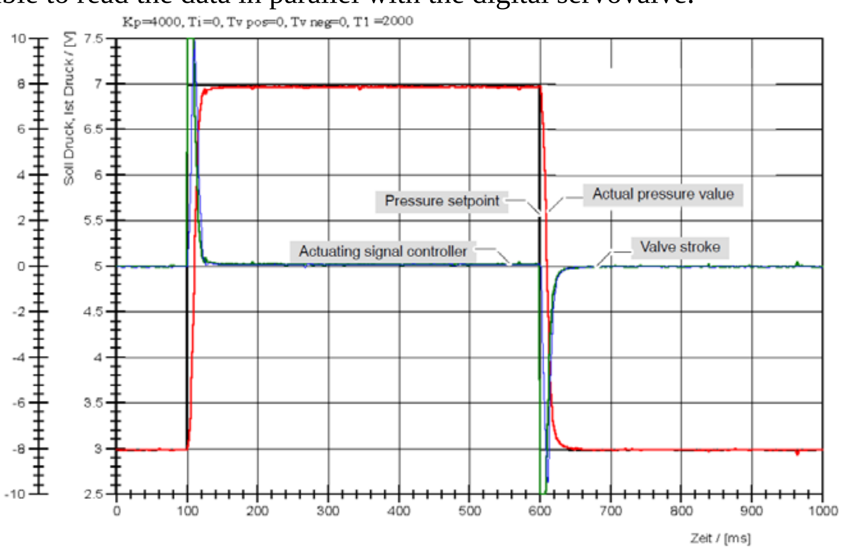


Fig. 12. Typical response of the servomechanism for a P controller

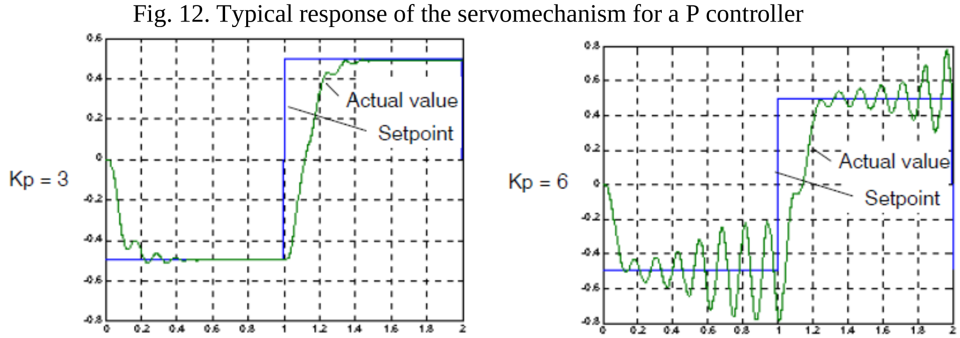


Fig. 13. The influence of K_P on the system step response (stroke [m] versus time [s]).

6. Conclusions

The new test bench can offer a better understanding of the digital servo valves characteristics, response times and EMI susceptibility. Future projects and modern applications where flexibility and accuracy is needed will be supported by the knowledge gained by developing redundant and more EMI resistant digital servo valves with FPGA logic control unit and optical communications [10, 11].

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