Redesign of the Control Stage for an Obsolete Hydraulic Robot

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Abstract: *The Mechatronics Department holds in its robots park a hydraulic robot. The robot has been well preserved but now the control electronics is obsolete. A new method of control must be implemented so that the robot could work again, by replacing old digital electronics with a PC computer.*

Keywords: *Hydraulic robot, Control electronics, Didactical activities*

I INTRODUCTION

A large Bulgarian hydraulic industrial robot, the RB231 is in the Mechatronics Department's possession for almost 25 years now. Due to the fact that it has been well preserved, it is partially operational. Taking a closer look, one could observe that the mechanics and the hydraulics of the robot are in excellent condition despite their age. Problems appear in the digital control area making the robot to act heretically on the axes that can be controlled and to make it hazardous for safety. Hence, a decision has been made to operate a "brain transplant" in order for the robot to be fully operational again.

II CONSTRUCTION AND ACTUAL STATUS OF THE ROBOT

By mechanical structure this is a TRTT robot, hydraulically actuated as follows [1]:
- Horizontal, realized as a sledge moving the robot along its base. It is actuated with a rack-pinion by a double sense hydraulic rotary motor controlled by a proportional servovalve. Position feedback is made with a multiturn rotary potentiometer geared to the same.
- Swing, built around a central pivot, rotates the entire robot and it is actuated by chain and sprocket. The two ends of the chain are linked to the ends of two hydraulic cylinders working in tandem. Control is made with a proportional servovalve and position feedback with a multiturn rotary pot and a DC generator, both geared to the main pivot (Bourns 3550S, ServoTek Sa-740A) [6], [7].
- Traverse, actuated by a long single-ended cylinder extends and retracts the robot's arm, which is made of a hollow shaft sliding in a ball-nut. It is controlled by a proportional servovalve and position feedback is made by a multiturn rotary pot, geared to a rack on the shaft.
- Vertical, rises and lowers the robot's arm along two structural columns and

is actuated by a cylinder controlled with a proportional servovalve and feed backed by a multiturn rotary potentiometer, geared to a rack on one column.

- Sweep, rotates the gripper around it's vertical axis, actuated by a small hydraulic cylinder controlled by a two-way distributor. It has adjustable mechanical limiters and no position feedback.
- Rotate, rotates the robot's gripper and is actuated by a small hydraulic cylinder in the back end of the arm. Mechanical link is made by a smaller shaft inside of the main arm shaft. Control is done with a two-way (4/2) distributor and no position feedback. The gripper has an adjustable mechanical limiter allowing rotation from 45 to 180 degrees.
- Jaw, represents the robot's gripper and is actuated by a oscillator hydraulic motor placed on the back end of the gripper. It is controlled by a two-way distributor has no feedback and is not adjustable; it can be fully open or fully closed.

Hydraulic power for the robot is built by a axial pistons pump, actuated by a tri-phased electrical motor. The hydraulic power plant also has a oil reservoir, filters, oil intercooler, safety valves and mains distributor.

Figure 1 shows the RB231 robot with the electronic control unit in the background and figure 2 the hydraulic power source.

The electronics is built around a digital core, the Motorola M6800 8-bit, 4 MHz processor [2]. It has 4KB ROM memory for the OS and 1KB battery backed-up RAM for program and position computing. The interface to the analogic power electronics (the servoamplifiers that drive the hydraulic servovalves) is made by a 12 bit buffered bus. Programming possibilities are limited for this robot and a lot of memory cells degradation has been observed, making the control of the robot almost impossible; it can only be moved by operating the teaching pendant and not on all axes.

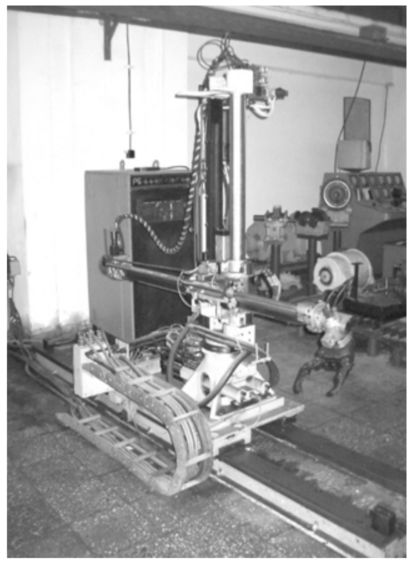

Figure 1
The RB231 robot with the electronic control unit in the back

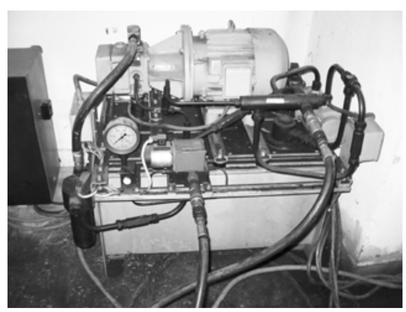

Figure 2
The RB231's hydraulic power source

III ELECTRONIC BLOCKS ANALYSIS

In order to determine the scale of modifications to be made a backtracking was applied from the servovalves to the processor. Following things were observed:

- all power electronics are in good condition including the power transistors, relay blocks and power source, the decision was to keep everything without modification;
- the servoamplifiers work well providing good position control and decision was to keep them to the level of the digital/analog converters, without any modifications;
- the multiturn rotary potentiometers used for position feedback and the DC generator were acting very well and decision was to keep them as they are, having good accuracy;
- the front panel (used for programming and monitoring) is heavily outdated and decision was to remove it in order to plant an AT keyboard which is similar in size;
- the teaching pendant is desired to be kept as long as an easy way to interface it to the PC will be found, but if this is not possible, the keyboard's numerical pad will take it's place (more likely);
- the digital core including the M6800 processor and memory modules were found faulty and decision was to replace the entire board to the level of servoamplifiers' DACs with something more flexible, that could offer better programmability and monitoring capabilities. After some research a AT-PC class machine was chosen to be interfaced via parallel port or an 8-bit ISA bus.

The actual configuration of the control blocks are given in Figure 3.

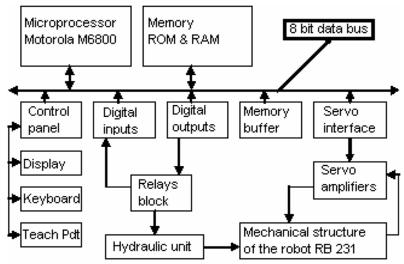

Figure 3
Actual configuration of the electronic unit

IV THE CLOSED LOOP SERVOAMPLIFIER

RB231's main axes are controlled by proportional servovalves [5]. This servovalves are driven with electrical current variations. Position feedback is given by a potentiometer. The block that makes use of the pot's position and drives the servovalve's torque motor is called a *servoamplifier* [3] and it's operating principle is given in Figure 4.

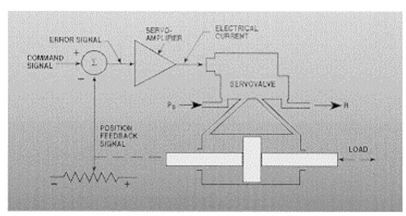

Figure 4
The principle of a closed-loop servoamplifier

Looking from the computer's parallel port point of view one must know the intrinsic operations that are made inside the servoamplifier and how it is internally organized (Figure 5).

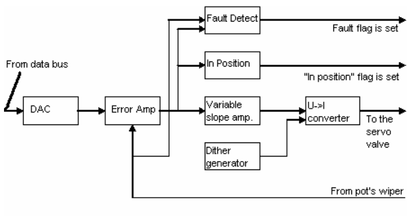

Figure 5
Internal blocks of the servoamplifier

In order to make some digital data become a current value the servoamplifier's blocks do the following operations:

- DAC – is the digital to analog converter. This converts 12 bits of digital data appearing on the data bus into a signed voltage value in the ±10V interval;
- Error amplifier – this amplifier takes on the non-inverting input the voltage generated by the DAC an on the inverting input the voltage collected from the position potentiometer's wiper;
- Fault detect – is a comparator that flips if the potentiometer's value deviates too much from the prescript value (loose wires or cogged wiper) and sets a flag indicating a fault has occurred;
- In position – is another comparator that flips when the value from the Error amplifier is as small as 0.1 V (low difference between prescript value and pot's reading) and sets an "In position" flag on the data bus, thus letting the computer know that the "move" command was successful;
- Variable slope amplifier – it's role is to amplify small signals with high gain and large signals with low gain in order to maintain linearity to the actuated cylinder;
- Dither generator – superimposes over the main signal another one having small amplitude (10% relative to main signal) and a frequency of 600 Hz. This signal vibrates the valve's slider making sure that it won't get stuck during operations;
- U->I converter – due to the fact that a servovalve is current-controlled a converter is needed to transform the voltage value of ±10 V into current value of ±10 mA (which is the rated current for the torque motor).

V THE PROPOSED CONTROL METHOD

Due to the fact that the main data bus is an 8-bit bus it is an easy way to interface to a PC's parallel port (Figure 6) [4]. By the intrinsic construction of the PC a CRT display and an AT keyboard will be available. This leads to the possibility of controlling the robot in real time, point-to-point strategy and also offline trajectory programming and remote programming (on a simulator machine).

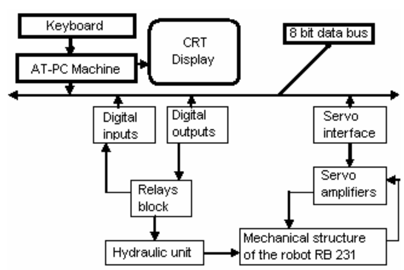

Figure 6
The proposed configuration

An excellent part in the control algorithm is that the position control is made by a closed-loop servoamplifier for each axis, so the PC does not have to monitor the actual moving of that axis, it only gives the desired position for that axis and receives the "in position" bit from the servoamplifier.

VI THE NEW CONTROL UNIT REQUIREMENTS

The PC is supposed to run in DOS environment to allow real time port access. The operating system for the robot should be programmed in C language and should implement at least all the commands found previously in the old ROMs.

Due to the fact that this PC will be transformed into a “process computer” it is desirable that the OS is not to be stored on a hard drive neither a floppy drive. It seems appealing to store it on a flash disk or a flash memory card but because of DOS and PC’s limitations (it is a Pentium class machine at the best), this is not a feasible solution.

Something even better is to compile the OS together with the machine’s BIOS ROM code and reflash it. This is possible by making use of the free ROMOS project found on the web. ‘The ROMOS is a stand-alone x86 code that allows loading and running binary code or 3rd-party code. ROMOS rely on BIOS functions only so it can be executed directly without any operating system. The main purpose of ROMOS is to be placed in a ROM, from where it can load/run other software. It can also load DOS-based operating systems (may be other OSes) such as FreeDOS stored in ROM together with ROMOS. This mean that any floppy/harddisk/CD-ROM drive is not needed. It may be very useful in various embedded diskless systems.’ [8]

Conclusion

The programming and monitoring capabilities of the robot are very well enhanced (to the limit of the mechanical construction) by applying the proposed method, and the robot could re-enter in the didactical circuit as an active, versatile hydraulic robot.

References

[1] RB231 – ‘Tehnical specs’ (Mechanical and hydraulical)

[2] RB231 – ‘PC501 Panka 1’ (Electronic and processing unit) – processor side

[3] RB231 – ‘PC501 Panka 2’ (Electronic and processing unit) – servoamplifier side

[4] Zhahai Stewart – ‘IBM Parallel Port Tutorial’ – http://www.lvr.com/files/ibmlpt.txt

[5] Moog servovalve and servo amplifier (obsolete and legacy sections – www.moog.com

[6] Bourns multiturn rotary pots (obsolete and legacy sections) – www.bourns.com

[7] Servo-Tek DC generators– http://www.servotek.com

[8] ROMOS project – http://hosting.modflex.com/rayer/romos/romose.htm