

INTERCONNECTION BETWEEN INDUSTRIAL SMALL/MICRO LINEAR ACTUATOR AND MATLAB – REPLACEMENT OF PLC CONTROLLER FOR INTELLIGENT ROBOTIC SYSTEMS

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Abstract

In this paper the new approach is presented where industrial version of small linear actuator (from PC are possible to only main settings) is controlled from computer by utilization of MATLAB. The article is focused on description of particular elements which support connection between higher control system – computer and controller of linear actuator.

Key words: compact compliant mechanism, small linear actuator, MATLAB, control system

INTRODUCTION

The modern trends in the field of robotics are closely connected with minimization of classical kinematical structures. The one kinds of minimization in robotics are compact compliant mechanisms [1, 2]. Such devices work on principle of elastic deformation and are use to the applications where specific requirements to small workspaces are put. For instance manipulation tasks with objects smaller than 1mm a high positioning accuracy are required. In real could be such devices in size of some nanometers to number of millimeters. Compact compliant devices have one disadvantage that usually only small linear actuators could be utilized for produce of mechanism movement.

In design process is demanded verification of device behavior on prototype, of course such stage of design process is executed after careful analysis of results from mathematical modeling and simulations, and more complex design analysis of mechatronics devices is described in [3]. The ideal case of device behavior verification is use of these same components which will be used in really. But some industrial components could not have possibility to direct control with computer, which is very often used as higher control system, mainly in process of tests on prototype.

The approach of connection between industrial controller of small linear actuator and

computer as higher control unit will be described in this paper. This approach is based on utilization of possibility to send main control instruction throughout PLC (Programmable Logic Controller) and their digital inputs or outputs. The aim is find robust and flexible tool which on site of input support connection between computer and mainly MATLAB, and in other site (output) provide needed number of digital inputs and outputs with 24V logic, which is standard type of logic used in industrial application because support high noise threshold value. Of course designed approach must have minimal time delay and in the ideal case had minimal costs.

LINEAR ACTUATOR

As was mentioned usually only small/micro linear actuators could be utilized for producing desired moving of compact compliant devices. We can divide actuators in accordance with various criterions. For basic and the most often mentioned is dividing which takes into the consideration creation of action power on physical principle basis [4].

- Pneumatic actuators
- Hydraulic actuators
- Thermal actuators
- SMA actuators
- Piezoelectric actuators
- Magnetic actuators
- Mechanical actuators (resonators)

Some actuators use transformation of the one energy to other when creating required force. From the basic classification is obvious that various systems and actuators used in micro-gripper are using actuator properties in classical robotics (mechanisms build from discrete parts as joints, links etc.). Part of mentioned drives is unusable in classical robotics because of the force and movement, which are created by them, are inadequate. Surely, drives working on principle SMA actuators are difficult to use in classical robotics due to using shape material memory. Contrasts of single forces actuating on system of length 1mm and 100mm are in tab. 1.

Tab.1 Types and intensity of single forces for length, L=1mm and L=100mm [4]

Type of force	Intensity of force for L= 1mm	Intensity of force for L= 100mm
Van der Waals	0.119	1.19e-9
Electrostatic	0.014	1.36e-6
Gravity	3.00e-5	30.0
Inertia	3.06e-9	0.306

Magnetic	1e-6	0.1
Capillarity	0.458	0.229
Grasping	1	300

* $1e-3 = 1 \cdot 10^{-3}$

In our case, the linear actuator (LAT3) work on principle of magnetic linear motor, in one “package” is integrates a magnetic linear motor, a recirculating ball guide, and a high resolution position sensor. Its main characteristics are: stroke 10mm, resolution $30\mu\text{m}$, maximum instantaneous thrust 5.2N and in case of positioning repeatability and pushing tasks is accuracy on value of $100\mu\text{m}$. Because in our case such linear actuator is used for tests and verifying prototypes in scale (for instance 1:5 or 1:10) to original compliant device, the lower accuracy of whole linear actuator have not impact to final accuracy of designed precise compliant structure (positioning mechanism). On the Fig. 1 is drawn structure of our linear actuator [5].

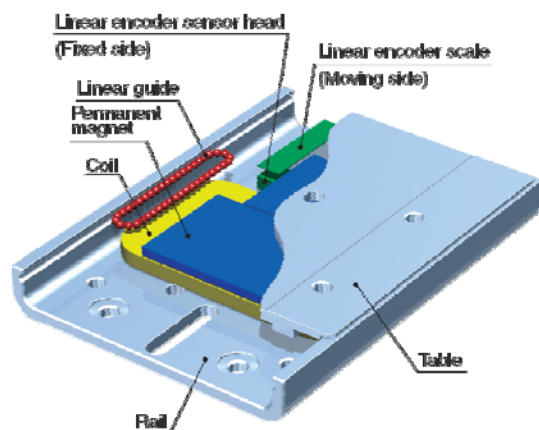


Fig. 1 Structure of own linear actuator LAT3 [5]

LATC4 Card Motor Controller is used as controller for our linear actuator. Such device support to set basic settings of linear actuator control by utilization of relatively easy software. Connection between computer and controller is based on USB communication protocol, where is used hardware convertor of signals suitable for controller. The basic settings of controller are connected with exactly definition of connected card motor and specification of two main modes of control. Both modes of linear actuator control are suitable for positioning tasks, but one mode need only time, target position and load mass. Input parameters for second mode are speed, target position, acceleration, deceleration and load mass. One disadvantage is, that only 15 values (step data) could be defined, where first value is reserved for “move to initial position”. Throughout setting software it is possible to control linear actuator only in test mode. The setting software and controller have not possibility use such communication protocol for connect it to the higher control system based on computer with USB. In other site

controller support send main control instruction throughout parallel I/O connector, where is prerequisite that PLC will be utilized by its digital inputs and outputs.

The controller has six digital inputs (four inputs for set one step data, DRIVE input which scan value of step data and run drive, and SVON input is an energizing command) and four digital outputs which signalize state that motor is moving, and alarm signal with inverse logic. Last two output signals are relative programmable.

POSSIBLE METHODS OF INTER-CONNECTION

According to specifications mentioned before we have to find solution of interconnection between industrial controller of card motor and computer. In other words, it is necessary expand computer by digital inputs and outputs. Sufficient condition but not necessary condition is support of MATLAB environment. Others conditions was mentioned before.

The first method of expanding computer by digital ports and support of MATLAB is utilize of known data acquisition cards. In this case, such cards are fully supported by MATLAB and its Real-Time toolboxes. Usually they need only one free PCI expansion slot in the computer. Cheapest cards have eight digital inputs and outputs, and some analog inputs and outputs with 12 or 14-bits converter. The cheapest card from Humusoft Company cost about 750 Euros [6].

Other method of interconnection between computer and industrial controller could by utilize of convertor (USB to Digital I/O) which have similar parameters as DAQ card but support only digital inputs and outputs. For instance “The USB-4700 series consists of true plug & play data acquisition devices. It’s easy and efficient. USB-4751/4751L is a 48/24-bit digital I/O module for the USB bus. Its 48/24 bits are divided into six/three 8-bit I/O ports and users can configure each port as input or output via software. USB-4751/USB-4751L also provides one event counter and three 16-bit timers, which can be cascaded to become a 32-bit timer.” [7]. Approximate price of this approach is around 300 Euros; it depends on produces of concrete convertor. In other site it is hard to say if such products are supported by MATLAB environment, and if it is possible to get own Real-Time application (if such device support own configuration software).

Other method how to make interconnection between computer and industrial controller is utilize microprocessor with sufficient amount of digital ports. Because microprocessors usually work with TTL logic it is necessary prepare some galvanic isolation which will be in this case fulfill task of galvanic isolation and convertor of

TTL logic to 24V logic. The block scheme of this solution is shown on the Fig. 2.

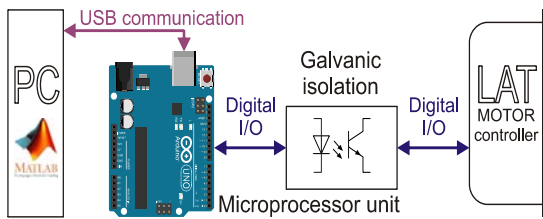


Fig. 2 Block scheme of interconnection between industrial motor controller and computer

Utilization of microprocessor is seemed as not very suitable solution, because many of them have not comfortable solved communication with computer throughout serial communication protocol (USB or RS232). In other site the requirement of microprocessor programmer is needed. But if we accept such approach we can get relatively chipset solution of our problem, because price of all electronic components is in number of Euros.

From this reason such approach will be in the next part of this paper analyzed.

UTILIZATION OF MICROPROCESSOR UNIT FOR INTERCONNECTION

According to review of possible approaches how to replace PLC by computer we get to the result that utilization of microprocessor unit with needed electronic is seemed as the best and cheapest solution of this problem.

The main block scheme of solved conception was shown on the Fig. 2; such configuration is composed from two main parts. First part is block of galvanic isolation, and as was mentioned fulfill two main tasks and it is separate galvanic isolation of signals between computer and motor controller. Second task is function of convertor, because microprocessor unit work with TTL logic what mean maximal value of voltage 5V, and logic values used by controller are in range to 24V.

Galvanic isolation is based on application of optocouplers. In case of controller digital input galvanic isolation (see Fig. 3a) is used classical circuit similar with test circuit from no matter which optocoupler datasheet. In our application is digital output from microprocessor unit connect to a digital input of controller unit. In case of controller digital output galvanic isolation (see Fig. 3b) was utilized resistance voltage divider for input voltage adjustment. In both cases of galvanic isolation was utilized pull down resistance for exactly setting of logical value at beginning.

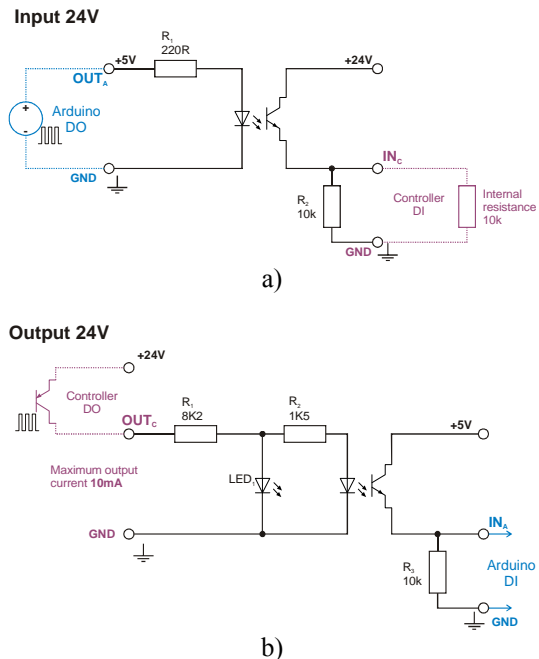


Fig. 3 a) controller digital input galvanic isolation circuit, b) controller digital output galvanic isolation circuit

Second part of chosen approach is microprocessor unit, as was mentioned; the some requirements must be satisfied. As suitable microprocessor unit was chosen Arduino board, which have included programmer and communication throughout serial communication protocol in one package.

Arduino is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on your computer (e.g. Flash, Processing, MaxMSP., MATLAB)[8].

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. But Arduino offers some advantage [8]:

- Inexpensive - The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than 50 Euros
- Cross-platform - the main software runs on all standard operating systems
- Simple, clear programming environment

- Open source and extensible software - the Arduino is based on Atmel's ATMEGA8 and ATMEGA168 microcontrollers

According to enumerated advantages of Arduino platform it is clear that number of people use such device for their own projects. For instance, one of this is application of quad-rotor UAV platform, which was applied for control strategy for a group of multi-rotor unmanned aerial vehicles (UAV) based on biologically inspired methods [9]. Other application is connect with robotic, where Arduino platform was utilized for control of robot arm in robotics-assisted mass spectrometry assay platform [10]. Other applications of researcher could be find in [11 - 12].

One of requirements of interconnection was support of MATLAB environment and real-time applications. Because Arduino platform is very commonly used therefore MathWorks company support it. Support in MATLAB is based on a server program running on the board, which listens to commands arriving via serial port, executes the commands, and, if needed, returns a result [13]. In other site real-time requirements could not be implemented because maximal value of control loops is 25Hz.

In our case does not need use MATLAB server application for Arduino board, because we use only selected digital ports. Therefore we have prepared source code for both platforms. One is for Arduino board where in setup part are defined used ports, and in loop part is continually reading/writing data to ports according to instructions from serial communication. On the Fig. 4, is extract of important source code for Arduino board and MATLAB m-file, it is an easy example of turn on/off of one LED, what shown work with digital port.

```

//Source code Arduino Uno rev. 3
int outPin=10;
int valueLED=0;
void setup() //inicialization
{
  Serial.begin(9600);
  Serial.println('a');
  char a = 'b';
  while (a != 'a') // check serial communication
  {
    a=Serial.read();
  }
  pinMode(outPin, OUTPUT); //set digital port mode
}

void loop()
{
  valueLED=Serial.read();//read data from serial
  digitalWrite(outPin, valueLED);//set DO
}

% Source code MATLAB
function ledka_on()
[out_flag]=setupSerial('COM8');
fprintf(out, 'LOW'); pause(5);
fprintf(out, 'HIGHT'); pause(5);
% close serial communication
if ~isempty(instrfind)
fclose(instrfind);
delete(instrfind);
end
disp('Serial Port Closed');
end

```

Fig. 4 Source code for Arduino board and MATLAB

From source code is clear method of programming of whole control application in MATLAB. In source code is used function

setupSerial(), this function is explain in [14]. In case of using digital input then the changes in source code will be small, concretely: in Arduino source code: change of PinMode to INPUT, and use two commands in loop part (value=digitalRead(pin); Serial.println(value);). In MATLAB source code is use function value=fscanf(out,%u).

According this approach was created in MATLAB Graphical User Interface (GUI) application for basic control of linear actuator (see Fig. 5). The GUI is composed from two main elements I/O Setup/Monitor Panel and Set Position Panel. In first panel the buttons are represented each digital input or output. Output buttons have only information function, they have not assigned any on click function. Second panel execute function of desired output position setting. In this case is in program defined table with step data loaded in motor controller, and according to easy algorithm will call particular step data to reach desired position.

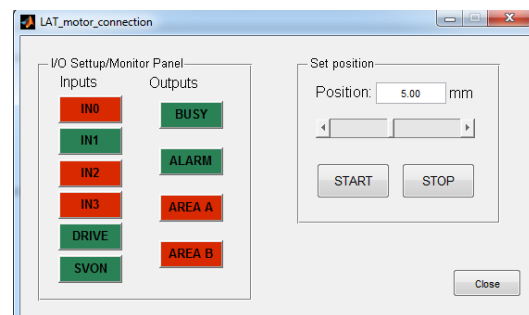


Fig. 5 Basic MATLAB GUI application for control of LAT3 card motor

CONCLUSION

Possibility of interconnection between computer and industrial controller had been discussed in this paper. Such possibility is very important in design process of mechatronic device, mainly in case when design process is in the stage of verifying device behavior on prototype.

Because our controller has not property take/accept control instruction throughout serial communication port (its mean instruction send by computer as higher control unit) was necessary create own connection between controller and computer with utilizing of parallel digital I/O connector, which expect control instructions from higher control unit in form of PLC.

The cheapest method of interconnection had been chosen and designed based on utilization of microcontroller unit based on Arduino platform, with galvanic isolation as convertor of TTL logic to 24V industrial logic.

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