# A HIGH-PERFORMANCE LINEAR ACTUATOR LABORATORY SET-UP AS AN EDUCATIVE TOOL IN CONTROL AND ELECTRONIC INSTRUMENTATION SUBJECTS

M. R. ARAHAL[1], S. TORAL[2], F. BARRERO[2]
[1]Dpto. de Ingeniería de Sistemas y Automática - Universidad de Sevilla. España.
[2]Dpto. de Ingeniería Electrónica - Universidad de Sevilla. España.

Learning systems based on student project oriented to the solution of real problems have proved to be efficient in the different educational levels. The use of electronic devices, as sensors and actuators, for automatic control is an important field in the electrical engineering curricula that involves many aspects. In particular, the interplay of automatic control issues within the enclosing application. The subject of automatic control is often presented to the student as a rather theoretical discipline. Novel laboratory applications have been proposed as a means to grasp the interest of students. This paper presents a high-performance linear actuator for positioning control experiments to be used in control and electronic instrumentation subjects. The laboratory set-up and the educative experiments are described with some detail showing its possibilities for different engineering courses.

## 1. Introduction

Automatic control is a field were electronic devices find widespread use. The applications of electronics range from sensors to actuators covering the whole feedback loop. The introductory control courses for electrical and electronic engineers often have a marked theoretical character that makes it appear far from real applications and subtracts interest from the student.

The use of laboratory experimentation is not new and many commercial as well as special purpose plants do exist in most universities. The recent trend is to incorporate remote operation capabilities in these laboratory set-ups to provide a more accessible means of experimentation as well to encapsulate the experiment in the well known and attractive (for the students) environment of internet browsers. There is a large wealth of remote laboratories available in the web and many more appear every year. Most of them, however, include simple plants (although with a rich potential for the control course) like water level control in deposits or temperature control in an air-blowing device.

Another trend is to provide the student the opportunity to interact with novel technologies such as the high-performance linear actuator that forms the core of the educative tool proposed in this paper. Motivation being an important ingredient for successful learning [1,2,3,4] the linear actuator provides a powerful visualization of what control means. Since students typically admit goal-oriented training, their motivation can be enhanced by the use of novel equipment and by organizing challenging activities. Both equipment and activities must be chosen adequately to balance the time spent in the laboratory with the expected benefits of the sessions.

Apart from the motivation considerations, the laboratory plant should help the student to grasp the fundamental concepts of automatic control and the part played by the electronic equipment and at the same time being able to illustrate the key features of state-of-the-art electronic applications for control.

This paper presents a high-performance linear actuator for positioning control experiments to be used in control and electronic instrumentation subjects.

## 2. The linear actuator

The linear actuator consists of a SIEMENS 1FN3 050-2W00-0AA linear motor with 550N of maximum force, mounted in a 3m long rack with a sensor grid capable of producing position measurements within a +5 µm accuracy range. Figure 1 shows clockwise: A) a diagram of the laboratory set-up containing the linear actuator, a control panel and a PC. The control panel holds a SIEMENS SimoDrive 611 controller whereas the PC is capable of producing control signals using a DSpace card for high-performance digital control. B) a diagram of the LC181 Heidenhein's micro-positioning optical sensor system that the linear actuator uses to measure its position, C) a photograph of the linear actuator and D) a photograph of the control panel showing the SimoDrive controller.

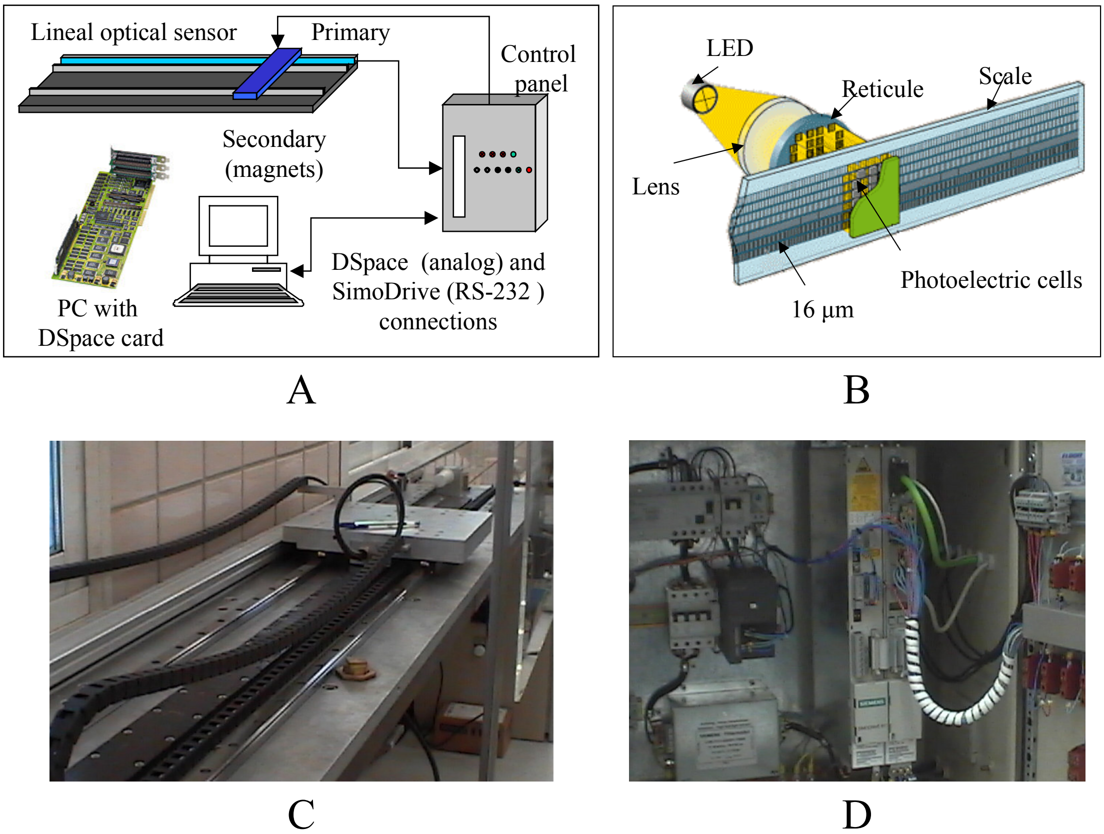


**Figure 1.** Diagrams and photographs of the linear actuator laboratory set-up.

The control, power electronics modules and electrical installation including protections are placed near the linear actuator in a rack as shown in Figure 1.D. In the front door the control module connections are accessible to facilitate the measurement of signals with an oscilloscope or with a PC analogue to digital connection.

The control experiments are more easily carried out using a graphics environment created for the DSpace card with Simulink RTI as shown in Figure 2.

The PC has a double use: in one hand and thanks to the SimoCom U software it is very easy to use the control module. The visualization of signals and desired positioning sequences are easy to perform. On the other hand, and using a A/D card it is possible to obtain/send signals coming from and going to the control module. In this way it is possible to perform digital control using any control scheme that the PC can compute.

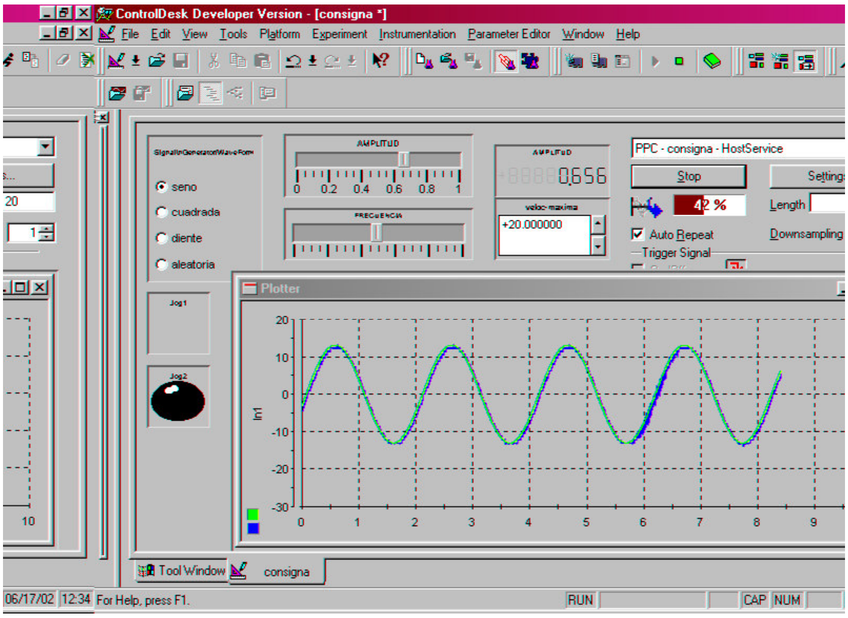


**Figure 2.** Screen capture of the DSpace environment to perform control experiments with the linear actuator

## 3. Laboratory experiences

The linear actuator allows to perform several educative activities at the laboratory. In the following a brief description of the ongoing experiences is given.

### 3.1 Sensor characterisation and calibration

The signal yielded by the position optical sensor can be accessed and used to characterise its properties: dead time, bandwidth, etc. It should be noted that most engineering trainees have a natural understanding of data acquisition. In many engineering domains people have a day-to-day contact with physical instruments (scopes, analysers, signal generators, etc.) or virtual ones (software based). However, most of the time, these instruments are used to collect a large amount of data that is then processed and analysed off-line. The focus is more on introducing the peculiarity of data acquisition in the context of real time control [5].

### 3.2 Position control

The aim is to introduce the student to the problem of position control using the included SIMODRIVE controller. The environment allows to change the control algorithm and parameters from one experiment to another.

The SimoDrive controller uses an internal speed control loop to provide position control as shown in Figure 3. In this diagram setpoint stands for the desired position or reference. The measured position is used to compute a reference signal that feeds the speed controller. The velocity or speed control is treated in the next subsection.

A typical position trajectory after a step in the reference is characterized by a dead time or pure delay followed by an underdamped transient. The comparison of the measured position after a step in the reference position with different control settings allows to verify the importance of each parameter for instance in a classical PID configuration.

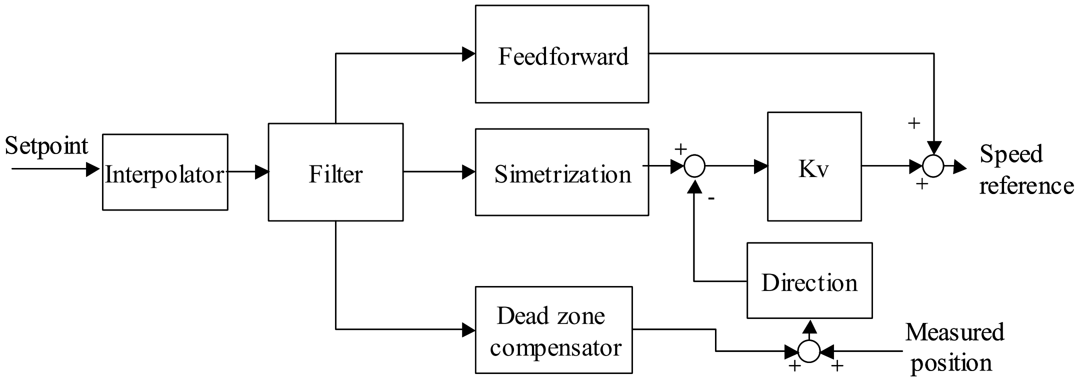


**Figure 3.** Operational block diagram of the control module for position control

## 3.3 Velocity control

In this case the task is to follow a pre-determined velocity profile. Again the influence of the control parameters can be easily checked experimentally. The absence of an integrator in the control loop with respect to the previous case can make the step response quite different (overdamped case) to the position control.

The block diagram of the control module for speed control is shown in Figure 4. The different components of a classic PID controller are present together with other elements such as limiters that act to protect the hardware during operation. In Figure 5 a SimoCom screen capture is shown illustrating the use of programmed velocity profiles in the experiments. It can be seen that various parameters can be defined such as maximum acceleration  and deceleration, maximum speed and other.

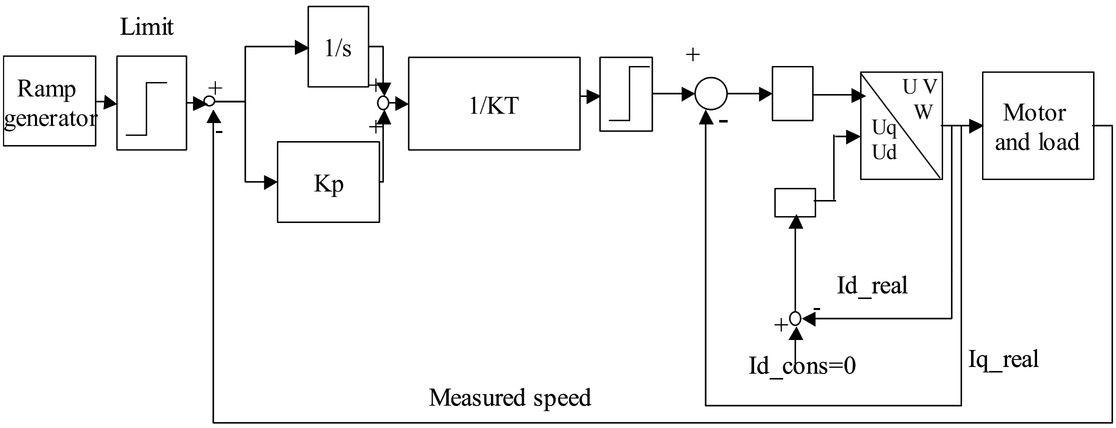


**Figure 4.** Operational block diagram of the control module for speed control

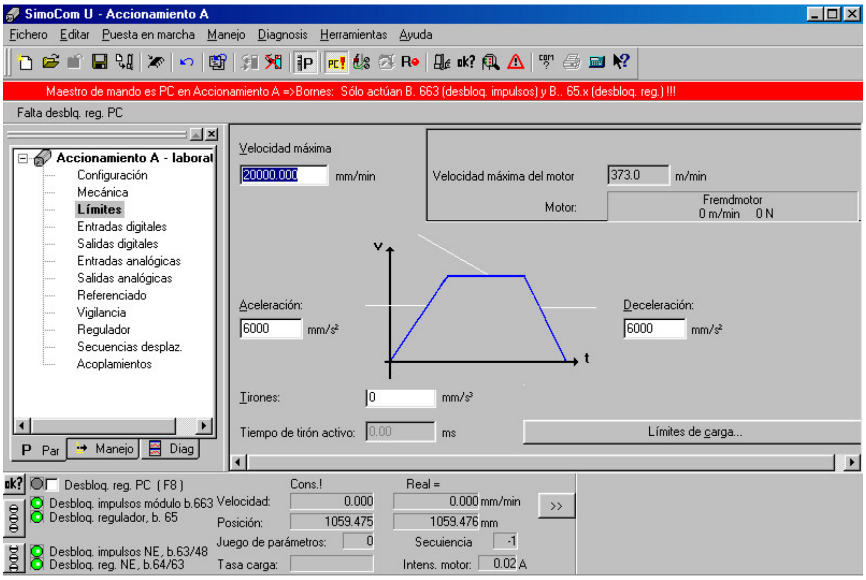


**Figure 5.** Screen capture of the SimoCom environment to perform speed control experiments with the linear actuator

## 3.4 Inverted pendulum

For these experiences An inverted pendulum is attached to the linear actuator. The angle of the pendulum is measured with a potentiometer. The aim of the control is now shifted to maintaining a zero angle (vertical upright position) and a position close to the center of the rack. The controller must cope with disturbances and with the intrinsic instability of the system. The disturbances can be provided in two ways: movements of the base of the pendulum that shift its position away from the desired one at the center of the rack, and movements of the pole produced externally (touching the pole with the hand is enough to tilt it).

The control scheme is in this case a bit more elaborate and must be implemented in the DSP using the linear actuator as a local controller to achieve a desired velocity calculated for instance using a state-space controller.

Figure 6 shows the experimental setup consisting on the linear actuator over with a pole is installed. The potentiometer is placed at the hinge of the pole producing a voltage proportional to the tilting angle. In the same figure the trajectories of the pendulum angle and position during a typical experiment are shown.

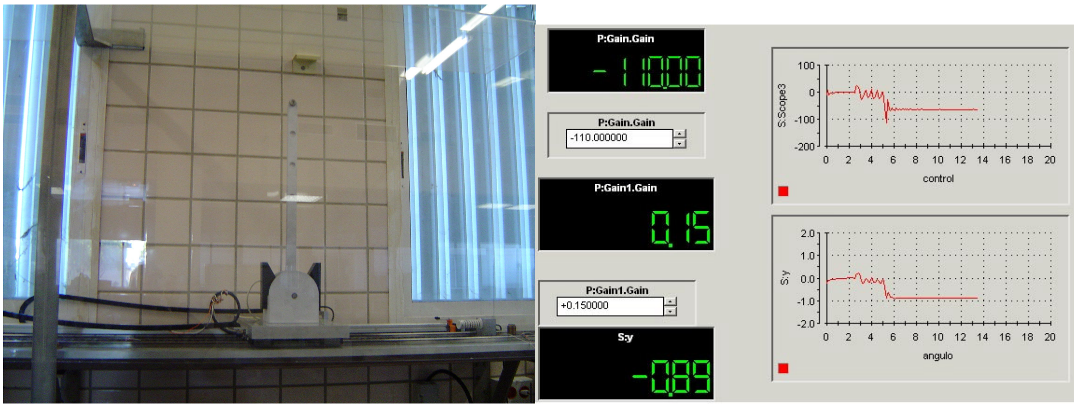


**Figure 6.** The linear actuator used as a base for the inverted pendulum (left) and a screen capture of the DSpace environment to perform control experiments using the linear actuator as a base for the inverted pendulum (right).

## 4. Conclusions

This paper presents a high-performance linear actuator for positioning control experiments to be used in control and electronic instrumentation subjects. The idea is to present an experiment based on an appealing and challenging system using state-of-the-art instrumentation technology, reinforcing the motivation of the students by exciting their curiosity and interest.

The laboratory set-up and the educative experiments have been shown with some detail putting emphasis in the capabilities for the pursued objectives. The proposed approach is currently implemented and its pedagogical value has been assessed with the cooperation of some final dissertation projects and doctorate courses activities.

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## References

[1] N.S. Edward and E. Middleton *Activity-Based Student Induction, Motivation, Performance, and Professional Socialisation: A Case Study*. Int. Conf. on Engineering Education, Norway (2001).

[2] Antsaklis, P., T. Basar, R. DeCarlo, N.H. McClamroch, M. Spong and S. Yurkovich. *Report on the NSF/CSS Workshop on New Directions in Control Engineering Education. IEEE Control Systems Magazine*, Vol. 19, No. 5, Oct. 1999, pp. 53 - 58 (1999).

[3] Edward, N. S. and E. Middleton (2001). *Activity-Based Student Induction, Motivation, Performance, and Professional Socialisation: A Case Study. Int. Conf. on Engineering Education*, Norway. Felder, R.M. and L.K. Silverman (1988).

[4] Felder, R.M. and L.K. Silverman *Learning and teaching styles in engineering education. Journal of Engineering Education*, 78(7), 674-681 (1988).

[5] Swain, N.K., J.A. Anderson, A. Singh, M. Swain, M. Fulton, J. Garrett and O. *Remote data acquisition, control and analysis using LabVIEW front panel and real time engine. Proceedings IEEE SoutheastCon*, April 4-6, pp. 1-6 (2003).