Laboratory 7: Discrete control in LabView of a hoist.

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Abstract--- For this practice, a digital controller is designed using the national instruments DAQ acquisition card, NI USB 6009. The plant to be controlled will be a system of the control of a mass, using a motor and coupled to a hoist system. A PID is designed and then discretized, different discretization methods are used, such as Euler in advance and delay, as well as the Tustin method, the sampling time and the constants are found, and then they are implemented in a LaBView diagram.

Abstract--- For this practice, it is designed with a digital acquisition controller of national instruments DAQ, NI USB 6009. The plant to be controlled will be a control system of a mass, using a motor and coupling a hoist system. A PID is designed and then discrete, various methods of discretization are used as Euler in advance and delay, just as the method of Tustin is the sampling time and the constants and then executed in a diagram of LaBView.

Keywords--- Discretization, discrete control.

General Objective--- Design and build a system that ensures the position of a mass of a hoist system, using Labview.

Specific objectives--

* Design a hoist system that allows the ascent and descent of a mass, this must have a DC motor as actuator.

* Identify the mathematical model that represents the functioning of the prototype.

* Design a discrete PID that ensures the position of the mass.

*Implement the discrete controller through the use of acquisition cards (DAQ) and the use of Labview.

1. INTRODUCTION

Theoretical framework:

Within control processes, most of the time, their integration into the real world is done through digital systems. The current advance of low-cost processing systems has made it possible to have a discrete control system in almost any process.

The progress in the miniaturization of processing systems, the improvement of their speed in executing instructions, today allow the implementation of controls in most of the systems that interact in our environment. When seeking to program a discrete control in microcontrollers, computers, PLC's, it is necessary to proceed from an analysis and interpretation of the behavior of the system to be controlled.

For the approach of the difference equation (the one that allows integrating the discrete control to a processing system), one can start from a continuous design and apply some discretization technique for the control found, or discretize the system model and design in the discreet world control.

For the first method, any of the steps that have been discussed in prior practices or known continuous control theories are followed. With the continuous control fulfilling the design criteria, its discretization is carried out and from this discrete equation (in Z), the difference equation is proposed. In this procedure, it is desirable that the method used for discretization maintains most of the temporal and frequency characteristics.

There are several theories that allow finding the discrete representation. One can be that s transforms to $\frac{1-z^{-1}}{t_m}$, where t_m is the sampling time. It is important for the above equation to select a good sampling time. In the literature it is found that *tm* is related to the kind of system to be controlled, with the response time or its bandwidth.

For the second method, the first step is to find a discrete model of the system and from this, apply one of the many ways that exist to calculate the coefficients of a discrete regulator. The design of a discrete PID regulator, whose equation is represented by $\frac{q0+q1Z^{-1}+q2Z^{-1}}{1-z^{-1}}$, can be faced by the pole assignment technique [1].

Fast stabilization systems require fast response control systems and, in turn, require electronics or mechanical actuators suitable for this dynamic. Within the theory necessary for the design of this type of control, there is an adequate selection of the sampling time *tm*. The generation of the control signal involves several steps: the acquisition of the output variable (sensed signal), conditioning or filtering of it, calculation of the control signal and its output (conversion from digital to analog) must be done. . The driver or actuator is an important element in the integration of the control signal and the system.

What is data acquisition?

Data Acquisition (DAQ) is the process of using a PC to measure an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. A DAQ system consists of sensors, DAQ measurement hardware, and a PC with programmable software. Compared to traditional measurement systems, PC-based DAQ systems harness the processing power, productivity, visualization, and connectivity capabilities of industry-standard PCs, providing a more powerful, flexible, and cost-effective measurement solution. [2]

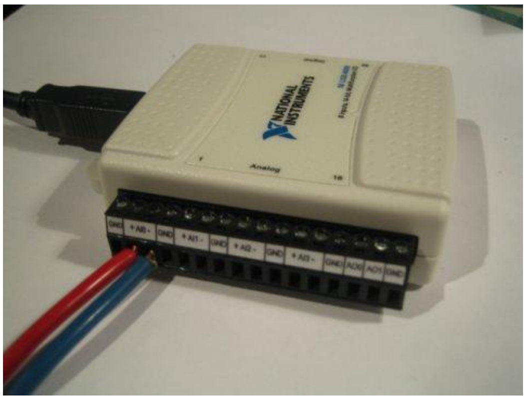


Figure 1: DAQ acquisition card

2. MATERIALS

* White coat.

* Plant: DC motor, support, pulleys, rope, mass, linear potentiometer.

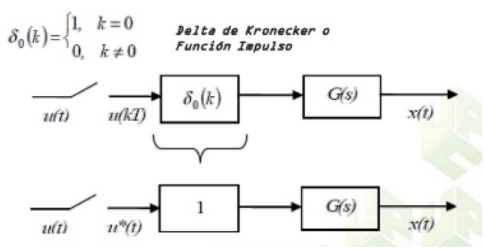
* Digital control: National Instruments DAQ acquisition card, Labview 2015.

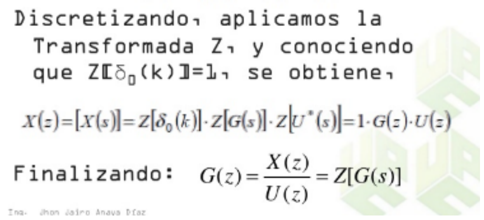
3. PROCEDURE

solution **Questionnaire**:

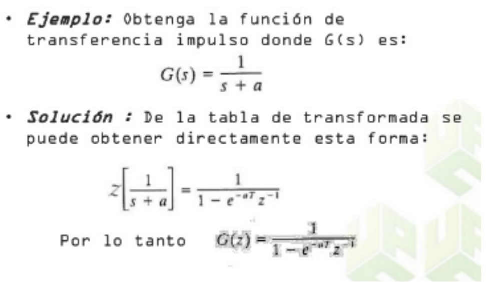
How many discretization methods are found in the literature? Give an example of each of them (at least 4), applied to real systems.

-Direct discretization or invariant impulse response.

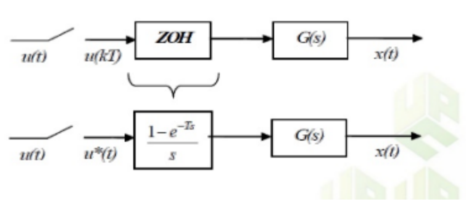




Example:



-Zero order retainer or invariant step response.



-First order

retainer -Triangular retainer or invariant response to the ramp.

Backward finite difference transformation. (backward Euler)

-Forward finite difference transformation (forward Euler)

-Trapezoidal, bilinear, tustin, or bilinear z transformation.

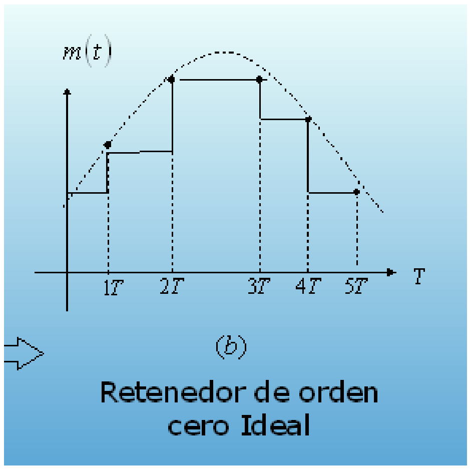
What is a difference equation? How is it programmed in a processing system such as acquisition cards or microcontrollers?

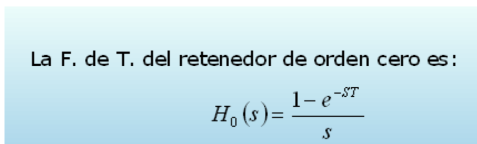
In an acquisition card or in a microcontroller, a processing system is designed as follows:

First, a reference is defined that will be a variable within the microcontroller program. The card must have as input the value of the sensor that measures the output, to achieve feedback, for this case an analog reading is used as an ADC or a DAC if desired, depending on the application. And the output that the card must have, must be the control signal that will be able to control the plant with any of the three necessary constants P,PI,PD p PID among others.

What is a zero order retainer?

The function of a latch is to keep the signal latched until a new value arrives, the zero-order latch is an ideal latch.





Practice

It is then that the transfer function of the plant of the hoist system is as follows:

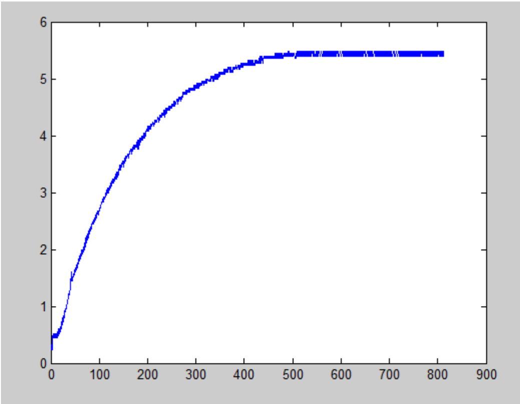


Figure 2: Response of the plant.

Response of the transfer function

This is how the graph of the response of the data obtained by the excel file of the oscilloscope is obtained.

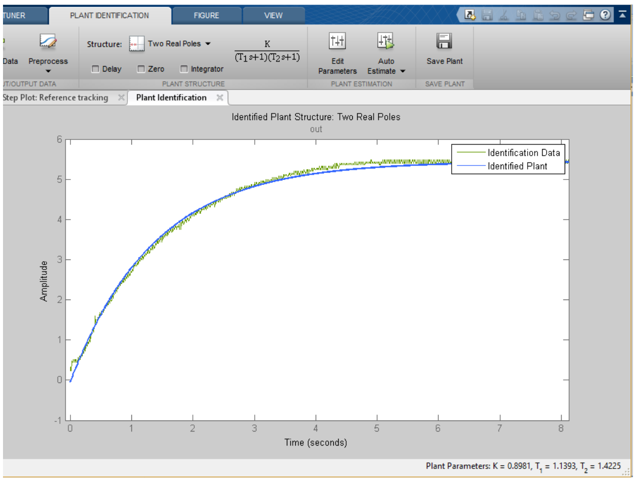


Figure 3: Approximation of the value of the plant.

It was obtained using the "identify new plant" tool of the Matlab command window tool "pidtool".

Approximate the result obtained from the oscilloscope, to a transfer function of a plant that behaves the same, for this case

Transfer function = $\frac{0.8981}{(1.1393s+1)(1.4225s+1)}$ = $\frac{0.5541}{s^2+1.5807s+0.6170}$

For a ts=5s and e1=0.8 -> Wn=1.125

$Wd = 1.125\sqrt{1-0.8^2}$

$Wd = 0.675$

$tr = \frac{\pi - cos^{-1}(0.8)}{0.675}$

$tr = 3.7$

And the PID constants

$kp = 23.8$

$ki = 14.44$

$kd = 14.47$

Backward Euler

$$tf(z) = \frac{0.5541}{\left(\frac{1-z^{-1}}{tm}\right)^2 + 1.5807\left(\frac{1-z^{-1}}{tm}\right) + 0.617}$$

$$= \frac{0.5541*tm^2}{1-2z^{-1}+z^{-2}+1.5807tm - 1.5807z^{-1}+0.617mt^2}$$

$$= \frac{0.5541*mt^2}{z^{-2}+(-2-1.5807\,mt)z^{-1}+1.5807\,mt+1+0.617mt^2}$$

$$PID = \frac{Kps+Ki+Kds^2}{s}$$

$$PID = \frac{Kp\left(\frac{1-z^{-1}}{tm}\right)+Ki+Kd\left(\frac{1-2z^{-1}+z^{-2}}{tm^2}\right)}{\frac{1-z^{-1}}{tm}} * \frac{tm^2}{tm^2}$$

$$PID = \frac{Kp*tm(1-z^{-1})+Ki*tm^2+Kd(1-2z^{-1}+z^{-2})}{tm-tmz^{-1}}$$

$$= \frac{(Kp*tm+Ki*tm^2+Kd)+(-Kp*tm-2Kd)z^{-1}+(Kd)z^{-2})}{tm-tmz^{-1}}$$

$$= \frac{(Kp+Ki*tm+\frac{kd}{tm})+(-Kp-2\frac{Kd}{tm})z^{-1}+(\frac{kd}{tm})z^{-2})}{1-z^{-1}}$$

*For a $tm = \frac{tr}{30} = 0.123s$

q0=143.22

q1=-259.1

q2=117.64

*For a $tm = \frac{tr}{10} = 0.37s$

q0=68.25

q1=-102.02

q2 =39.12

*For a $tm = \frac{tr}{50} = 0.074s$

q0=220.41

q1= -414.88

q2=195.54

The results are simulated in MATLAB from the block diagram shown below.

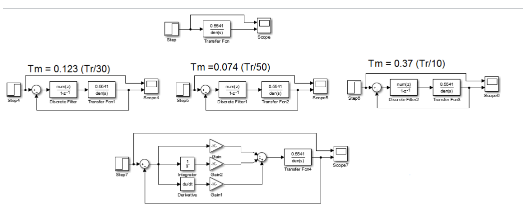


Figure 4: Simulated diagram in Matlab working.

As can be seen, there are 5 different diagrams, the continuous plant, the continuous PID design, and its discrete equivalent, implementing 3 different sampling times.

Now the recursive equation is performed on the LabView block diagram, as shown in the following figures.

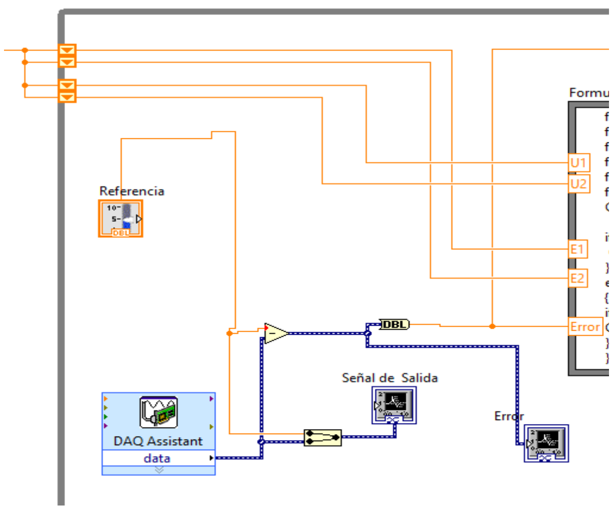


Figure 5: LabView block diagram, left side

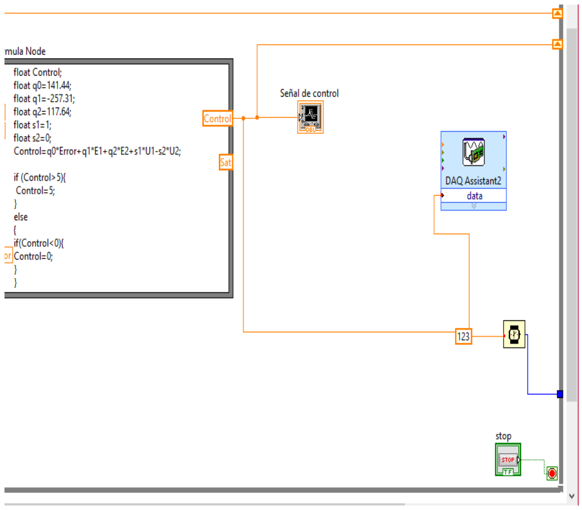


Figure 6: LabView block diagram, right side

As can be seen, from the input we have the analog values obtained by the DAQ (Potentiometer), and from the reference value given by the slider gives the value of the error that enters the formula node where, given the previously calculated constants, the value of the control is determined; Since it is possible to reach values greater than 5 volts, it saturates using a conditional. This occurs because the hardware does not allow higher output values.

4. RESULTS

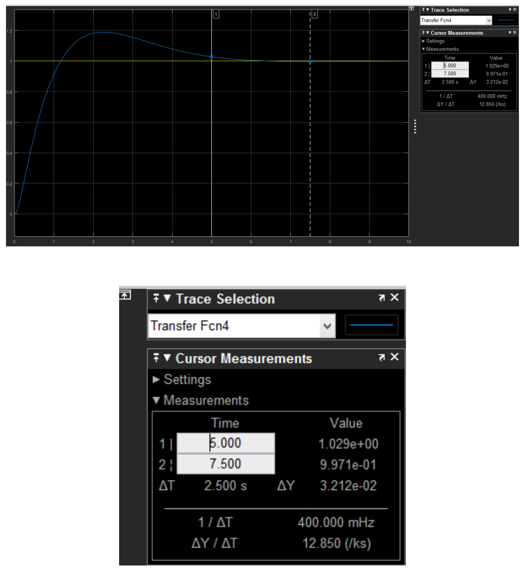


Figure 7: Continuous PID response

The continuous PID design is shown to be correct since it stabilizes at the chosen time and with an overshoot corresponding to the assigned damping factor

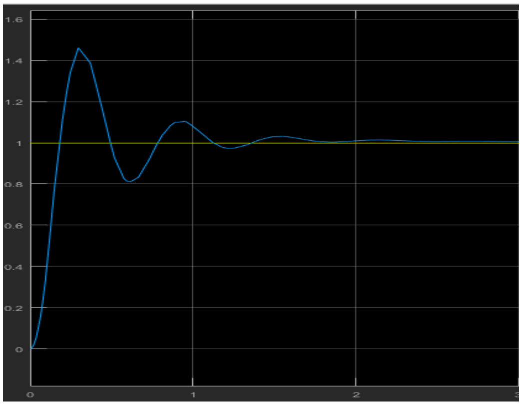


Figure 8: Discretized PID control with ™ of 0.123s

For thecontrol **discretized**, using the Euler method in delay and a sampling time of 0.123s, it is seen that the system presents an error in stable state of zero, although it shows greater oscillation in the transient

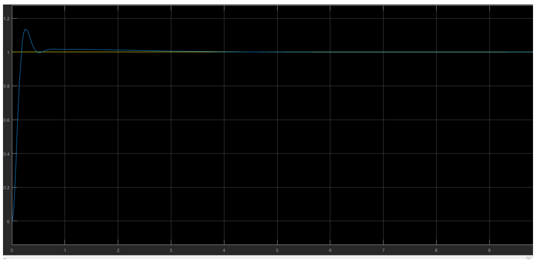


Figure 9: Discretized PID control with ™ of 0.074s

Now, implementing a sampling time of 0.074 s, it is observed that the system responds more quickly, which would be expected to be reflected in a greater control action, respectively.

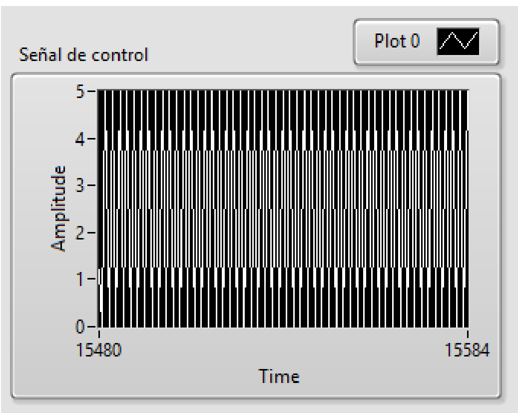


Figure 10: System control signal

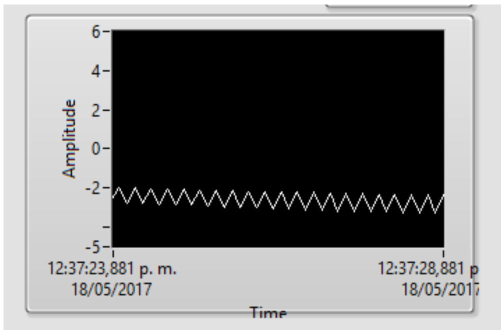


Figure 11: System error signal

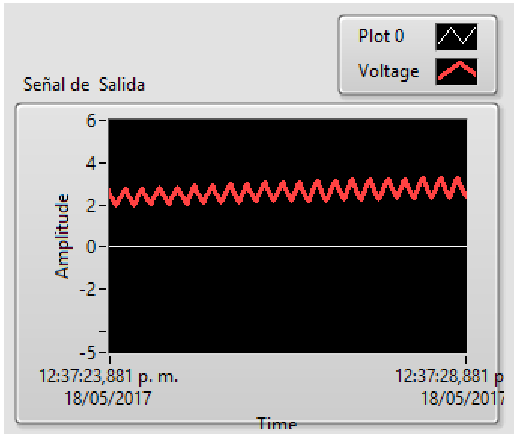


Figure 12: System output signal, oscillating at 2.4v, the reference is 2.2v.

The system with the integrated designed control presents a small difference with the simulated model, the output of the complete system keeps oscillating at an average value of 2.4v for an input that is 2.2v which is the reference; an attempt was made to correct it by implementing a control with a greater integral control, performed in discrete with what the constants and the recursive equation change, the system is controlled at the point where it is wanted but an unstable response is obtained, with an error of 10%

NOTE : When doing the latter, ***Measurement & Automation Explorer*** was used where voltage values were "forced" on the pin corresponding to the control signal. (**See figure 14).** With the unmodified physical system, an adequate response was obtained.

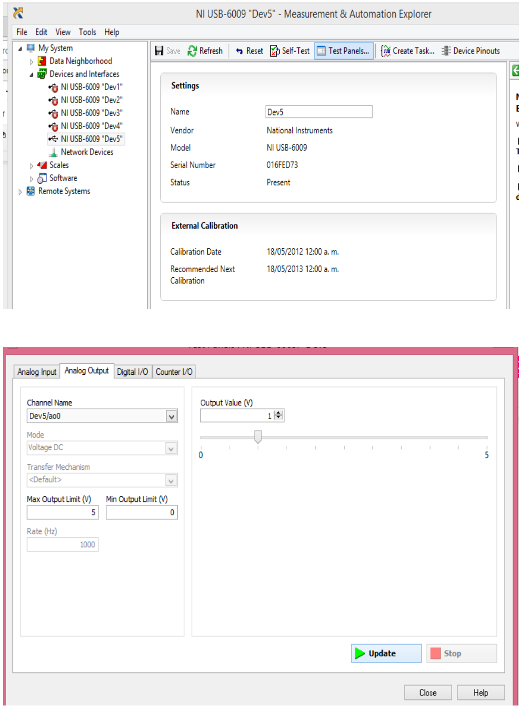


Figure 13-14: Measurement & Automation Explorer

After this, the control signal is observed and performed although it has limited voltage for certain inputs.

5. CONCLUSIONS

- Adding the other mobile pulley to the system, it is possible to have a controlled mass reduction, making the motor not exert the torque exerted as in the last plant.
- In Euler lag, the control simulated in Matlab performs better than with the other discretization methods.
- At the moment of discretization of the PID controller, there are differences between the responses of the system, regarding settling times, oscillations and overshoots.
- The implementation of the LabView software, together with the DAQ, are very useful when obtaining the response values of the system for their due processing; this every time interval, that is, it is very useful to generate a **DISCRETE control system.**

6. REFERENCES

[1] K. Ogata, Discrete-Time Control Systems, Prentice Hall International, 1996.

[2] N. Instruments, "National Instruments," [Online]. Available: http://www.ni.com/data-acquisition/what-is/esa/. [Last access: 06 15 2016].

[3] Discretization of transfer functions. [Online]. Available at: https://es.slideshare.net/davinso1/unidad-3-c2control2-1