AUTOMATIC CONTROL TECHNOLOGY

INTRODUCTION

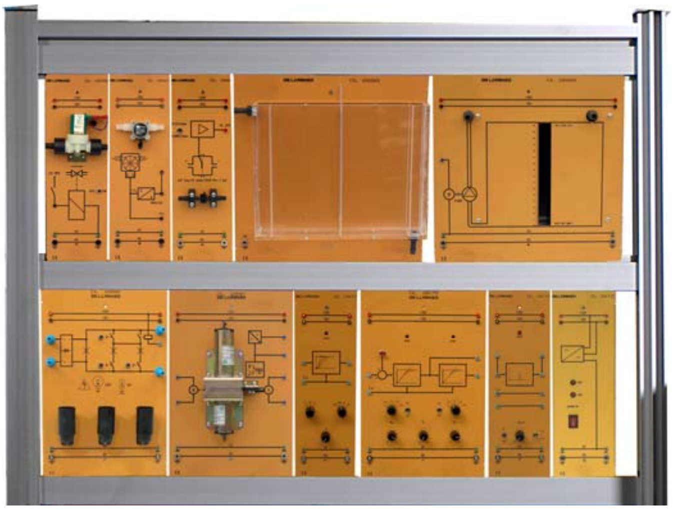
This laboratory has been designed to introduce the fundamentals of automatic control technology. The main functions of processes, controllers and controlled systems are shown on a simulated controlled system, as well as the interactions between the transfer elements of a control loop.
The individual components are represented on the panels together with the standard block circuit diagrams. The laboratory has been functionally divided in a number of sections, so that the student can follow a proper educational path, with increasing difficulties from theory to practical applications. The sections have been set up as follows:

Fundamentals of Automatic Control Technology

Automatic Control Theory	*TEO*
Processes	*PRO*
Controllers	*PID*
Continuous Automatic Control	*CAC*
Discontinuous Automatic Control	*DAC*

APPLICATIONS

Control of a DC motor	*MOT*
Temperature control	*TEM*
Light control	*LUM*
Level control	*LEV*
Flow control	*FLO*



FUNDAMENTALS OF AUTOMATIC CONTROL TECHNOLOGY

TEO

Automatic Control Theory

Before facing the experimental development relevant to Processes, Controllers, the Continuous and Discontinuous Automatic Regulation technique, up to the analysis of specific Process Controls, it is useful to provide a synthesis of the basic concepts relevant to the "Automatic Control Theory", that are necessary for a correct understanding of what will be stated afterwards:

- *General Definitions*
- *Graphical representation of control systems*
- *Subdivision of control systems*
- *Canonical form of systems driven back*
- *Canonical functions and characteristics of control systems*
- *Analysis and design of control systems*
- *Proportional action (P)*
- *Integral action (I)*
- *Derivative action (D)*
- *PID combined action*
- *Preparing the Controller*

PRO

Processes

In this experimental chapter the student can analyze the typical behaviours of the processes: the transfer characteristics, the behaviour in transitory conditions, the time constants, the 1st and 2nd order processes, the higher order processes, the dead time, etc.

The knowledge of the typical characteristics of the process is extremely important for a correct approach to the design of a control system.
For such reason, before studying the typical behaviours of the controllers, it is necessary to analyze all the possible characteristics that the process to be controlled can practically have.
The processes that are analyzed in this chapter are the following:
- P type process
- I type process
- I^2 type process
- 1st order processes
- Processes of order highest than the 1st

PID
Controllers
In this experimental chapter the student can analyze the characteristics and the typical behaviours of the controllers: linearity, proportionality, dynamic behaviour, gain, conventional values, critical frequency, phase, etc.
After having analyzed the single P, I and D elements, he can study their PI, PD and PID combinations and he can set up both series and parallel configurations.
The knowledge of the typical characteristics of the controllers is extremely important for a correct approach to the design of the control systems.
The controllers that are analyzed in this chapter are the following:
- *P Controller*
- *I Controller*
- *D Controller*
- *PI Controller*
- *PD Controller*
- *PID Controller*

CAC
Continuous Automatic Control
After the experimental chapters where the characteristics and the typical behaviours of processes and controllers have been deeply analyzed, we open here a new chapter where processes and controllers are suitably combined to simulate and to study the most common problems related to the Continuous Automatic Control.
The analysis of the interactions between controllers and processes is complicated by the possible presence of noise; sometimes, the latter can trigger a series of oscillations with consequences, potentially serious, for the process. In this chapter, in addition to the analysis of the interactions between controllers and processes, the student can study the causes of the above mentioned instabilities, in order to find possible solutions.
The topics that are covered in this chapter are the following:
- *P control of a P type process*
- *P control of 1st, 2nd, 3rd and 4th order processes*
- *I control of 2nd order and I type processes*
- *P, PD, PI and PID controls of a high order process: stability and optimization*
- *P, PD, PI and PID controls of a high order process: presetting of the parameters according to Ziegler-Nichols (dynamic method)*
- *P, PD, PI and PID controls of a high order process: presetting of the parameters according to Chien-Hrones-Reswick (static method)*
- *P, PD, PI and PID controls of a high order process: parallel and series configuration*

DAC

Discontinuous Automatic Control

After the experimental chapters where the characteristics and the typical behaviours of processes, controllers and continuous automatic control systems have been deeply analyzed, we open here a new chapter where the Discontinuous Automatic Control systems are simulated and analyzed; in these systems the controller is composed of a an element with discontinuous intervention.

A discontinuous controller is characterized by an output having two or more fixed states and its value is switched among these states according to the input value.

The topics that are covered in this chapter are the following:

-Two position controllers, three range controllers

-Sampling acquisition techniques

-The two position controller in a 1st order process

-The three range controller in a 2nd order process

-The two position controller with delayed feedback in a 2nd order process

-The two position controller with elastic feedback in a 2nd order process

-The sampling control in a 4th order process

APPLICATIONS

At the end of the experimental chapters dedicated to the analysis and testing on: Processes, Controllers, Continuous Automatic Control, Discontinuous Automatic Control, we can consider as completed the theoretical-experimental knowledge acquisition which is necessary for the practical application to be performed on real processes.

The Laboratory Experiments that are proposed in this section form a working path purposely structured in order to stimulate students to the application of what has been learned in the previous chapters.

In this way we want to educationally involve the students in the search for the most suitable solution for that particular type of control of the real process under evaluation.

MOT

Control of a DC motor

- *P, PI and PID controls of the speed of a DC motor using the CHR method*

TEM

Temperature control

- The two position controller in the temperature process

- The two position controller with delayed feedback in the temperature process

- The two position controller with elastic feedback in the temperature process

- The three range controller in the temperature process

- P, PI and PID controls of the temperature process using the CHR method

LUM

Light control

- P, PI and PID light controls using the CHR method

LEV

Level control

- P, PI and PID level controls

FLO

Flow control

- P, PI and PID flow controls

THE MODULES

DC Power Supply

DL 2613

Laboratory power supply with two fixed voltage outputs and protected against short-circuit.

Technical features:

Output voltages: +15 V ; 0 V ; -15 V
Output current: 2,4 A (3 A for a short period).
Power supply: single-phase from mains (see the identification plate)
Two led (+15 V ; -15 V) for the indication of the nominal voltage.
Mains switch with pilot lamp

Voltage Reference Generator

DL 2614

It allows the realization of a voltmetric reference signal through a potentiometer mounted on the same panel or by transferring an external reference signal. Moreover, there is the possibility to generate volt metric step reference signals.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Range of the continuous regulation reference signal:
from - 10 V to + 10 V
from 0 to + 10 V
Range of the step reference signal:
from - 10 V to + 10 V
from 0 to + 10 V
Switch for selecting between internal potentiometer reference signal and external reference signal
Switch for selecting between the 0 / ±10 V range and the 0 / +10 V range

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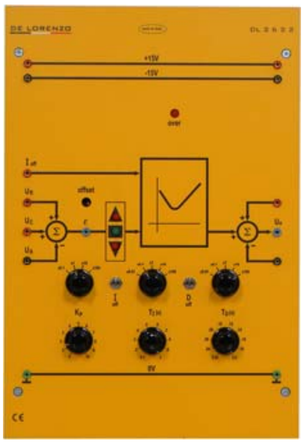
PID Controller



DL 2622

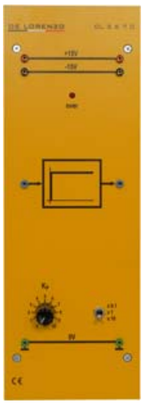
Standard industrial controller that can be used as P, PI, PD or PID controller in the closed loop automatic control systems.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Input summing node for two different reference variables UR and UC and for one controlled variable UA.
Signal voltage range: -10V .... +10V
Parameters of the controller continuously adjustable
Proportional gain: Kp = 0 ... 1000
Time of the integral action: TI = 1ms ... 100s
Time of the derivative action: TD = 0.2ms ... 20s
Reset input of the integral controller.
Output summing node to add or subtract noise variables.
Measurement terminal for the error signal.
Adjustment screw for the output offset.
Three led indicator of the sense of deviation.
Coarse and fine adjustment of the proportional gain Kp, of the time of the integral action TI and of the time of the derivative action TD.
Indicator of over-range: led "over" on when the output voltage is higher than 10 V or lower than -10 V.
Input I_{off} for resetting the I controller.

AUTOMATIC CONTROL TECHNOLOGY

P Controller



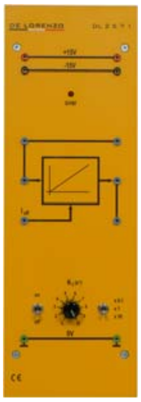
DL 2670

Proportional action controller suitable for the closed loop continuous control systems.

Technical features:

Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ... , +10V
Proportional gain Kp = 0 ... 100
Three position switch coarse setting.
Potentiometer fine setting.
Led indicator of over-range.

Integral-Action Element



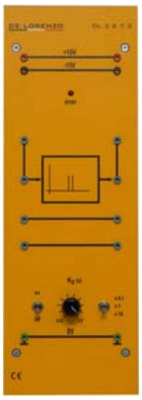
DL 2671

Integral action controller suitable for closed loop continuous control systems.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Coefficient of the integral action KI = 0.1 .... 100 s-1
Three position switch coarse setting.
Potentiometer fine setting.
Integral action reset input.
Switch for inclusion/exclusion of the integral action.
Led indicator of over-range.

Derivative-Action Element



DL 2672

Derivative action controller suitable for closed loop continuous control systems.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Coefficient of the derivative action KD = 2 ms .... 2 s
Three position switch coarse setting.
Potentiometer fine setting.
Switch for inclusion/exclusion of the derivative action.
Led indicator of over-range.

AUTOMATIC CONTROL TECHNOLOGY

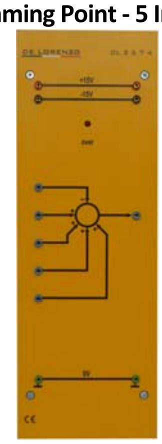
Summing Point - 2 Inputs

DL 2673

Two input summing point, one non inverting input and one inverting input.

Technical features:
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Gain factor = 1
Led indicator of over-range.

Summing Point - 5 Inputs

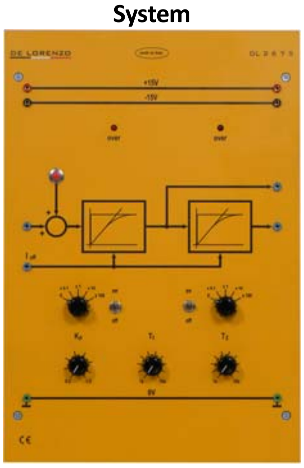


DL 2674

Five input summing point; three of them, non inverting, can be used in the realization of particular configurations of the controller, using separately the elements P, I and D; the remaining inputs, one inverting and one non inverting, can be used to add the noise variables.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Gain factor = 1
Led indicator of over-range.

Simulated Controlled System

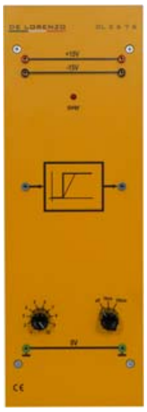


DL 2675

It allows the simulation of different processes, such as: 1st and 2nd order processes, proportional (P) action processes, integral (I) action processes, double integral (I2) action processes.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Input summing point for controlling variable (y) and noise variable (z).
Signal voltage range: -10V, ..., +10V
Coefficient of the proportional action of the process KP = 0.2 (attenuation) ....1.5 (amplification)
Time constant T1 = 0.1 .... 1000 s
Time constant T2 = 0.1 .... 1000 s
Reset input for the restoration of the initial conditions.
Coarse setting through rotary switches.
Potentiometer fine setting.
Led indicators of over-range.

Dead Time Element

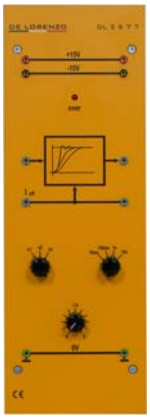


DL 2676

It allows the insertion of an adjustable real dead time in those processes which are characterized by it.

Technical features:
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Proportional coefficient of the module KS = 1
Dead time Tt = 10 ms .... 100 ms / 100 ms .... 1 s
Three position switch for coarse setting and exclusion of the dead time.
Potentiometer fine setting.
Led indicators of over-range.

Second Order Transfer Element



DL 2677

It allows analyzing the behaviour of an element with proportional transfer function able to oscillate, with a delay of the second order, both in the time domain and in the frequency domain.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Gain factor = 1
Time constant T = 10 ms .... 30 s, selectable through two rotary switches.
Damping coefficient d = 0 .... 3, with potentiometer setting.
Reset input for the restoration of the initial conditions.
Led indicators of over-range.

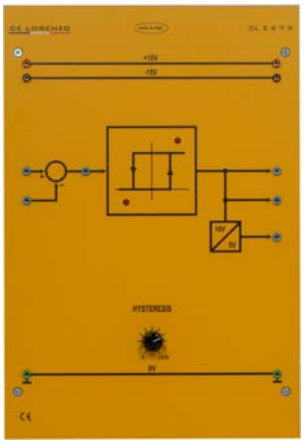
Manual/Automatic Switch

DL 2678

It allows to close the control loop, without oscillations, after a suitable setting of the system.
It is composed of a summing point to which the signal coming from a potentiometer (manual mode) and the signal coming from the controller (automatic mode), that can be inserted through switch, are connected.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Manual mode/Automatic mode switch
Manual mode potentiometer
Output summing point.

Two Position Controller



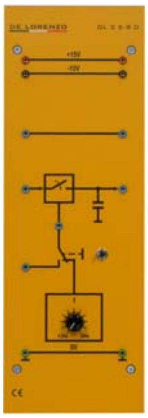
DL 2679

Two position controller for discontinuous closed loop control systems. It is provided with an input summing point to which the reference variable (non inverting input) and the controlled variable (inverting input) are connected. By means of two led the binary state of the controller, whose hysteresis can be changed, is visualized. The controller is provided with two binary outputs at different voltages.

Technical features:

Power supply: +15 V ; 0 V ; -15 V
Input summing point
Signal voltage range: -10V, ..., +10V
Output voltages: 0/+5 V ; 0/+10 V
Adjustable hysteresis: 0 .... ± 2.5 V.

Sample and Hold Element



DL 2680

Used to discontinuously sample the behaviour of a continuous control on a process.
The sampling frequency can be provided by the generator which is integrated in the module or by an external signal.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10 V, ..., +10 V
Sampling frequency: 0,2 .... 20 Hz

Motor-Generator Set

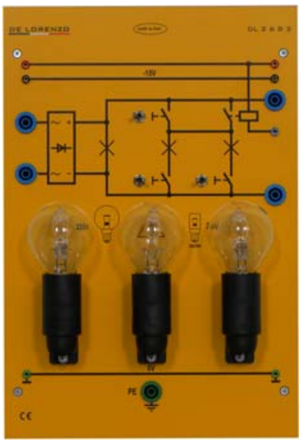
DL 2681

It represents a process for the control of the speed of a dc motor.
In this module an electric motor and a generator are coupled through a flywheel in order to increase the momentum of inertia of the whole system.
A motor speed transducer provides a feedback digital signal; through a D/A converter such signal is available also in analogue form.

Technical features

Power supply: +15 V ; 0 V ; -15 V
Electric power of the motor: about 10 W
Maximum speed of the motor: 3000 min-1
Output power from the generator: about 4 W
Output voltage from the generator: 0 .... 20 V cc
Digital output from the speed transducer:
60 pulses/rotation
Analogue output from the speed transducer: 1V/1000 rpm.

Load Switch



DL 2682

It has been developed to apply a load to the two pole output electric machines and it can be controlled both manually and automatically.

Technical features:
Power supply: +15 V ; 0 V ; -15 V
Input voltage: max. 220 V ac
Load: 3 incandescent lamps.
Three switches for the manual control of the load.
Electronic control relay for the automatic control of the load.
Safety junctions both for the connection of the input. voltage and for the connection of the rectified output voltage.

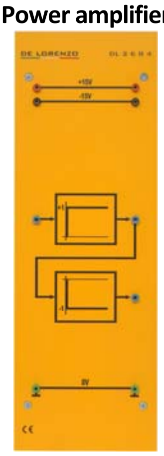
Gain and Offset Adjust

DL 2625

It allows the proportional adaptation of the external signals to the normal voltages used in the automatic control systems.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Voltage interval of the input signal: -50 V, ..., +50 V
Adjustable level through the setting of the gain: 0 ....1, 0 .... 10, 0 100
Attenuation of the pulse signals.
Time constants: 0,1 .... 10 ms ; 10 .... 100 ms
Offset voltages that can be connected: -10 V .... +10 V
Coarse setting through rotary switches.
Potentiometer fine setting.

Power amplifier



DL 2684

It is composed of two amplifiers, one non inverting and one inverting, with voltage gain +1 and -1 respectively.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: -10V, ..., +10V
Output voltage:
-10 V .... +10 V to ground
0 .... ±20 V symmetrically
Max. output power: 30 W, with protection against short-circuit.

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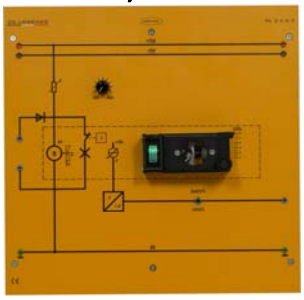
Temperature control system



DL 2685

It represents a process for the control of the temperature, suitable for analysing continuous and discontinuous closed loop control systems.
A halogen lamp represents the heating element; a PTC sensor provides the feedback signal; a fan and a shutter valve allow, besides the reaching of a uniform temperature within given safety limits, also the insertion of noise variable.

Technical features:
Power supply: +15 V ; 0 V ; -15 V
Max. temperature: 100 °C
Temperature for the intervention of the bimetallic safety switch: 90 ....100 °C
Feedback signal:
2 mA / 10 °C
1 V / 10 °C
Apparent dead time TU: about 10 s
Compensation time TG: about 120 s

Light control system

DL 2686

It represents a process for the control of the light.
In this module an incandescent lamp represents the opto-transmitter element, while a phototransistor is the opt-receiver element.
There are different possibilities for generating noise variables.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Signal voltage range: 0 ... 20 V
Output signal: 0 .... 10 V
Maximum power: 10 W

Test function generator

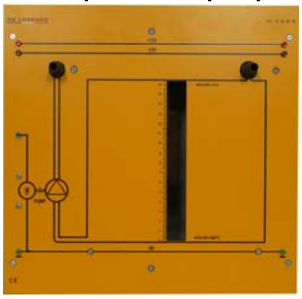
DL 2687

It is a generator of functions such as: Dirac pulse, square wave and triangular wave selectable through selection switch.
At some terminals the output signal has a fixed amplitude; at other terminals the amplitude can be continuously adjusted, from 0 V to 10 V, through a potentiometer.
The frequency can be continuously adjusted, from 0.02 Hz to 10 Hz, through a potentiometer.
For what concerns the square wave, it is possible to set the ratio between high signal and period, by choosing between 1/2 and 9/10.

Technical features
Power supply: +15 V ; 0 V ; -15 V
Output wave forms:
Dirac pulse function: 0 .... +10 VP
Triangular wave function: 0 .... 20 VPP balanced with respect to ground
Square wave function: 0 .... 20 VPP with "high signal/period" ratio = 1/2
Square wave function: 0 .... +10 VP with "high signal/period" ratio = 9/10
Frequency of the output signal: 0.02 .... 10 Hz
Signal Ioff for resetting the integral controllers.

AUTOMATIC CONTROL TECHNOLOGY

Receptacle with pump



DL 2688

It is used in conjunction with the filling tank.

Technical features:
Vessel capacity: 1.5 l approx.
Signal voltage range: 0 . . . +10 V
Power consumption of the pump: 10 W max.

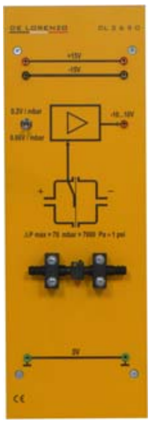
Filling tank

DL 2689

Used to demonstrate the characteristics of the controller system. Slide valves allow you to change the configuration of the controlled system. Includes plug-in devices for the sensors used to measure the level of the liquid.
Also includes a set of 10 transparent sheets, with a graduated horizontal scale and with a vertical one, for a manual recording of the characteristics of the controlled system, suitable to the use of markers soluble in water.

Technical features
Tank capacity: 1 l

Differential Pressure Transducer



DL 2690

It is used for connecting to the immersion tube for measuring the liquid level and to the measurement orifice gauge for flow measurement.

Technical features
Power supply: ± 15 V
Signal voltage range: O . . . +10 V
Differential pressure: ± 70 mbar
2 hose connections
Complete with immersion tube.

AUTOMATIC CONTROL TECHNOLOGY

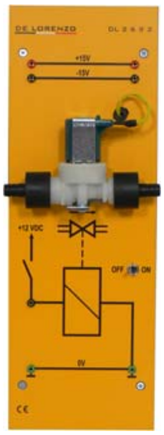
Turbine Flow Meter

DL 2691

It is used for measuring the flow according to the volumetric principle.

Technical features:
Power supply: ± 15 V
Measurement range: 10 ... 100 l/h
Measurement temperature: 20°C
Measurement medium: water

Solenoid valve



DL 2692

2-way valve with switching amplifier.

Technical features
Power supply: + 15V
Control voltage: > 1

Single Pole Switch

Plug-in element, normally open, switch load 2 A, 250 V.

DL PS-MOD

Single Pole Pushbutton

Plug-in element, switch load 2 A, 250 V.

DL PP-MOD

AUTOMATIC CONTROL TECHNOLOGY

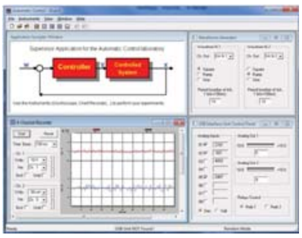
Computer Interface

DL 1893

Interface unit: used to interconnect real world signals to a data acquisition system.

Technical features:
16 analog inputs: 0-10 Vdc
2 analog outputs: 0-10 Vdc
8 TTL inputs
8 relay outputs
Power Supply: 220 V, 50 60 Hz
Input/output: 2 mm terminals
USB connection

Software



DL ACTSW

This software provides the tools to generate the control signals for the modules and to acquire and visualize the signals and the wave forms to be analyzed.

Technical features:
Input/Output Control window.
Signal Generator window (continuous, square wave, ramp, triangular, sinusoidal, pulse).
3 trace Oscilloscope window with continuous, single and trigger control operation.
4 channel Chart Recorder window.
Window with the diagram of the system under evaluation with I/O controls for setting and visualizing the signals.

Leads

DL 1155-ACT

Set of leads for connecting the terminals of the modules.

Frame

DL 2100-3M

Metal frame for assembling the modules of the laboratory.

AUTOMATIC CONTROL TECHNOLOGY

DE LORENZO

	DL 2613	DL 2614	DL 2622	DL 2670	DL 2671	DL 2672	DL 2673	DL 2674	DL2675	DL 2676	DL 2677	DL 2678	DL 2679	DL 2680	DL 2681	DL 2682	DL 2625	DL 2684	DL 2685	DL 2686	DL 2687	DL 2688	DL 2689	DL 2690	DL 2691	DL 2692	DL PS-MOD	DL PP-MOD	OSCILLOSCOPE	DL 1155ACT	DL 2100-3M
PROCESSES																															
Type P	1								1												1								1	1	1
Type I	1								1												1								1	1	1
Type I^2	1								1												1								1	1	1
1st order	1								1												1								1	1	1
Higher than 1st	1								2												1								1	1	1
2nd order	1									1	1										1								1	1	1
CONTROLLERS																															
Controller P	1			1																	1								1	1	1
Controller I	1				1																1								1	1	1
Controller D	1					1															1								1	1	1
Controller PI	1			1	1			1													1								1	1	1
Controller PD	1			1		1		1				1									1						1		1	1	1
Controller PID	1			1	1	1		1													1								1	1	1
Controller PID with regulation of offset	1			1	1	1		1									1				1								1	1	1
CONTINUOUS AUTOMATIC CONTROL																															
Regulation P, process type P	1	1		1			1		1																				1	1	1
Regulation P, process of 1st order and superior	1	1	1						2																			1	1	1	1
Regulation I , process 2nd order	1	1			1		1		1																			1	1	1	1
Regulation P, PD, PI e PID, process of high order	1	1	1						2																		1	1	1	1	1
Ziegler-Nichols method	1	1	1						2																		1	1	1	1	1
Chien-Hrones-Reswick static method	1	1	1						2																		1	1	1	1	1
Parallel and series configuration	1	1		1	1	1	1	1	2																			1	1	1	1
DISCONTINUOUS AUTOMATIC CONTROL																															
Controllers with 2 positions, controllers with 3 ranges	1	1						1				1	2																1	1	1
Techniques of acquisition and sampling	1													1							1								1	1	1
Controller with 2 positions, process of 1st order	1	1							1				1															1	1	1	1
Controller with 3 range, process of 2nd order	1	1						1	1			1	2															1	1	1	1
Controller with 2 positions, process of 2nd order, delayed feedback	1	1						1	2				1														1	1	1	1	1
Controller a 2 positions, process of 2nd order, elastic feedback	1	1						1	2				1															1	1	1	1
Controller with sampling, process of 4th order	1	1	1						2					1														1	1	1	1
CONTROL OF A DC MOTOR																															
Regulation P, PI e PID of speed in a DC motor, CHR method	1	1	1	1											1			1										1	1	1	1
Control of a generator	1	1	1	1											1	1		1										1	1	1	1
TEMPERATURE CONTROL																															
Controller with 2 positions	1	1											1					1	1										1	1	1
Controller with 2 positions, delayed feedback	1	1						1	1				1					1	1								1	1	1	1	1
Controller with 2 positions, elastic feedback	1	1						1	1				1					1	1									1	1	1	1
Controller with 3 ranges	1	1						1				1	2					1	1									1	1	1	1
Regulation P, PI e PID of temperature, CHR method	1	1	1															1	1									1	1	1	1
LIGHT CONTROL																															
Regulation P, PI e PID of light, CHR method	1	1	1															1		1								1	1	1	1
LEVEL CONTROL																															
Pump's features	1	1																1				1	1							1	1
Measurement system's features	1	1																1				1	1	1						1	1
Level process features	1	1																1				1	1	1						1	1
Level control with adjuster P	1	1		1			1					1						1				1	1	1						1	1
Level control with adjuster PI	1	1		1	1		1	1				1						1				1	1	1						1	1
Level control with adjuster PID	1	1	1									1						1				1	1	1			1			1	1
Level control with a 2 position controller	1	1																1				1	1	1						1	1
FLOW CONTROL																															
Measurement system's features	1	1																1				1	1		1				1	1	1
Analysis of flow control features	1	1	1	1														1				1			1	1	1			1	1