Using LVProSim

Version 1

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About LVProSim

The latest iteration of the LVProSim software has modern features such as a web interface and an intuitive design. This appendix summarizes the essential features of LVProSim. You can use this software in conjunction with the I/O interface, Model 9065-B, as a data acquisition device to monitor and control a real process. You can also run LVProSim in simulation mode to model the characteristics of a process and try different process control schemes. The sections below describe both the data acquisition and the simulation modes.

Connecting LVProSim for data acquisition

Figure 1 shows how to connect a computer running LVProSim to a transmitter and a control element through the I/O interface. The connections shown in this figure are typical of a process controlled via LVProSim running in data acquisition mode.

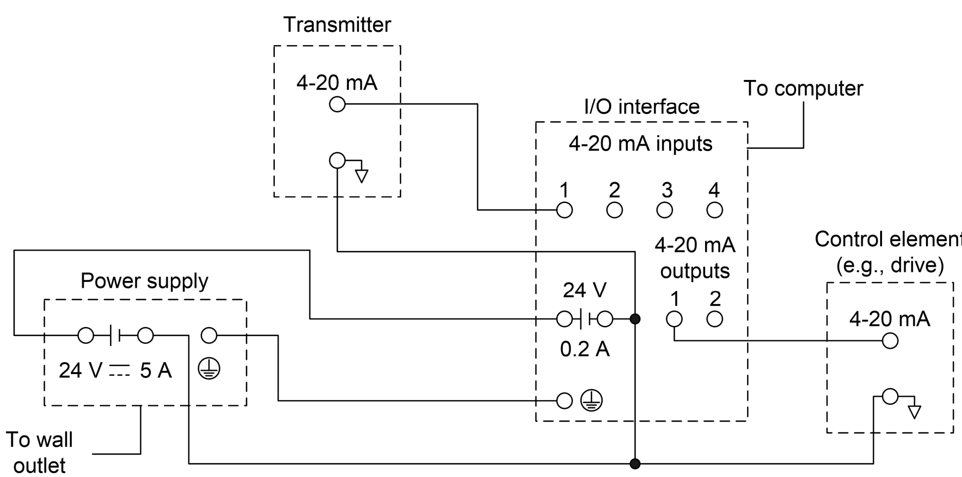


Figure 1. Typical connections to control a process using LVProSim.

Data acquisition mode

LVProSim runs in your favorite web browser. When you click on the LVProSim icon, a new browser tab opens and LVProSim prompts you to select the mode in which you want to run the application. The mode is determined by the input source LVProSim uses to acquire data. First, we describe the data acquisition mode, which uses the I/O interface connected to a USB port (USB-IO) as its primary data source. The simulation mode is covered later.

To select the data acquisition mode, choose USB-IO from the drop-down menu and click *Confirm* (Figure 2).

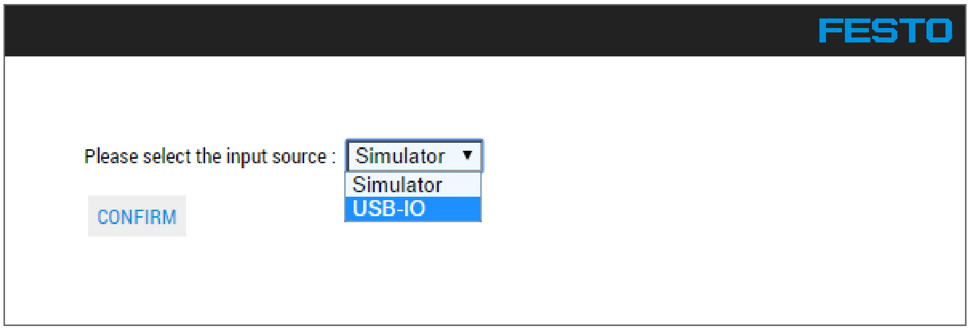


Figure 2. Select the input/output mode.

User interface

In the data acquisition mode, the software interface divides in the different sections shown in Figure 3. We will refer to these sections throughout this appendix.

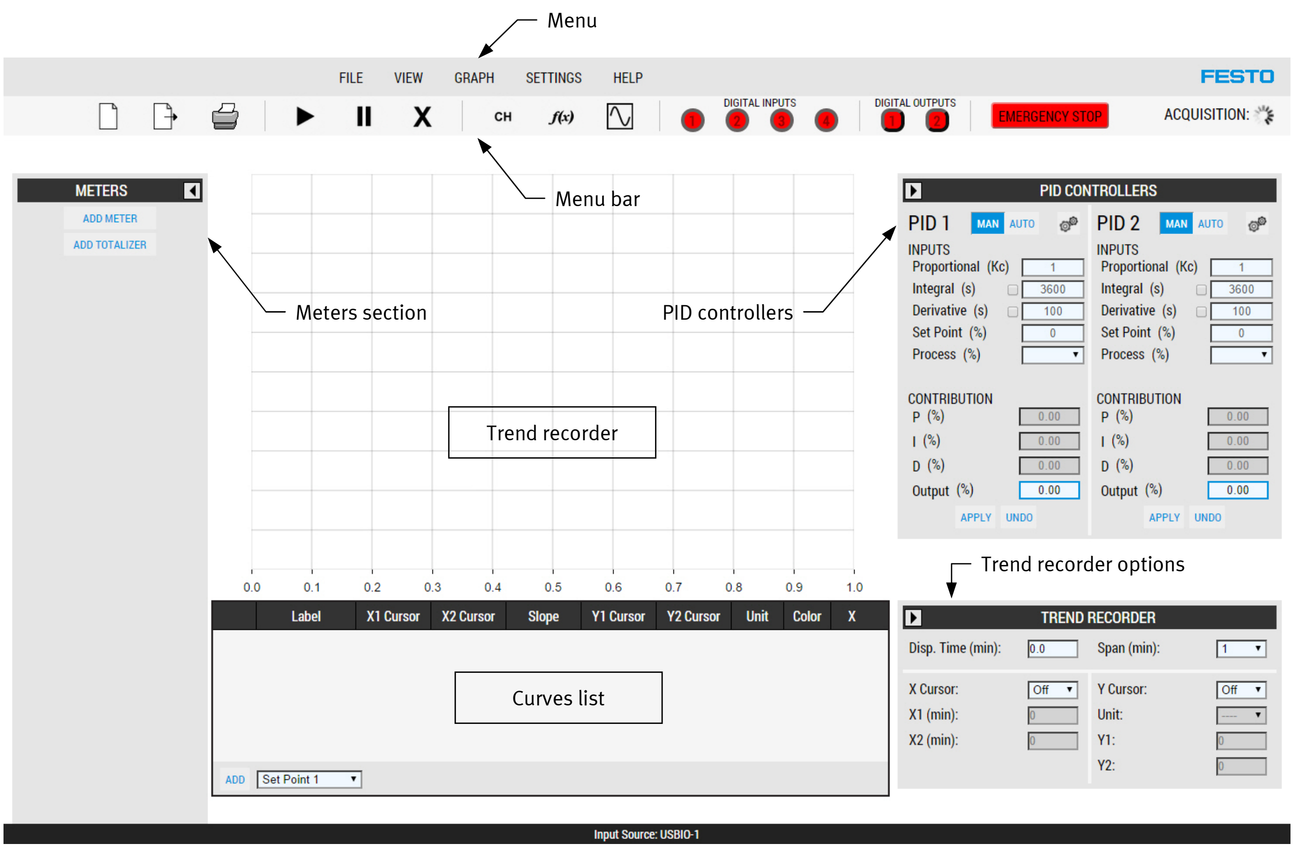


Figure 3. User interface.

Table 1 makes the correspondence between the icons of the menu bar (Figure 4) and their descriptions. Note that the menu bar is slightly different in the simulation mode.

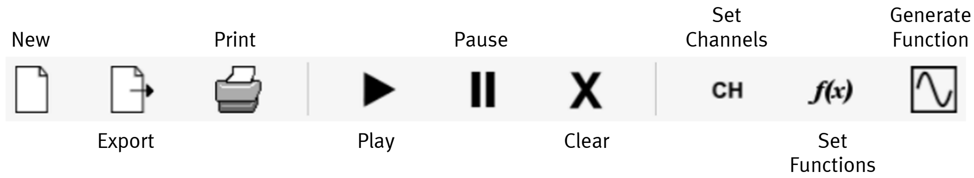


Figure 4. Menu bar in data acquisition mode.

Table 1. Description of the menu bar in data acquisition mode.

Icon name	Icon description
New	Closes the current window and allows opening a new window for either data acquisition or simulation
Export	Allows exporting the current recorded data and saving it to a file in comma-separated values (CSV) format
Print	Prints the current graph
Play	Starts recording the data from the different sources listed in the curves list
Pause	Pauses the trend recorder. This does not pause data recording. No data is lost while in pause mode. When the trend recorder display is resumed, the curves are immediately updated with the missed data
Clear	Clears all recorded data
Set Channels	Allows setting the four input channels from the I/O interface
Set Functions	Allows manipulating data sources using simple functions
Generate Function	Allows the creation of a data source from one of the mathematical functions available, such as a sine function

In addition to those icons, four indicators give the status of the digital inputs of the I/O interface and two indicators give the status of the digital outputs. A green indicator represents an actuated output, while a red indicator shows that the output is not actuated. At the right of these indicators is an emergency stop button. Pressing this button deactivates all digital and analog outputs of the I/O interface. The indicators and emergency stop button are shown in Figure 5.

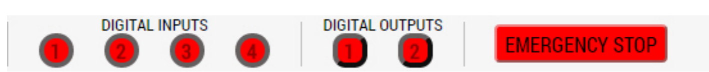


Figure 5. Indicators and emergency stop button.

Recording a signal from a transmitter

LVProSim can record the 4-20 mA signals from up to four devices via the I/O interface. To record the signal from a transmitter, first connect the device properly to the I/O interface (see Figure 1). Then, click on the channel icon in the menu bar to display the Set Channels window.

In the Set Channels window, select the number corresponding to the input to which the transmitter is connected on the I/O interface. Then:

- Enter the name you want to give to this channel in the Label section.
- Select the type of variable (e.g., pressure, temperature, volume, etc.).
- Select the unit of measurement.
- Select the minimum value, which will correspond to a 4 mA signal.
- Select the maximum value, which will correspond to a 20 mA signal.

Figure 6 shows an example where channel 1 is configured to receive a temperature measurement from a transmitter. With those settings, the temperature is displayed in degrees Celsius within a range from 25°C to 55°C (corresponding to an input signal that can vary from 4 mA to 20 mA).

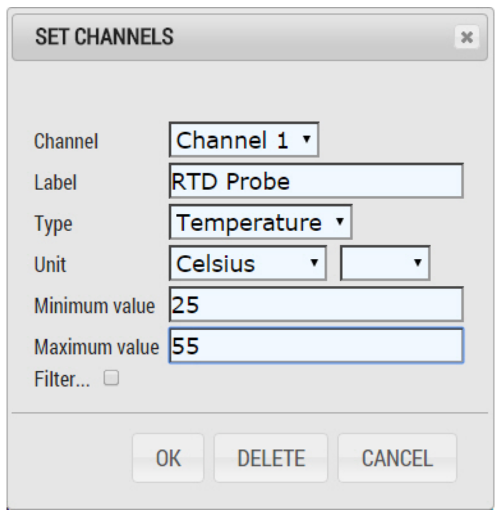


Figure 6. Channel configuration.

Once an input channel is configured, you must add it to the curves list to display the data on the trend recorder. To add a channel to the curves list located at the bottom of the trend recorder, select (in the drop-down list) the label that corresponds to the channel you want to record and press *ADD* (see Figure 8).

To start recording data from the channel added to the curves list, press the play button in the menu bar. Only the signal sources listed in the curves list are recorded. Adding a meter to display a signal value does not allow recording of this signal.

Configuring and using the trend recorder

Before recording signals, you can set the sampling interval. The sampling interval is the time between each reading at the input channels. It can be set to 100 ms, 200 ms, 500 ms, or 1000 ms in the *Settings ▶ Sampling Interval* menu (Figure 7).

Note that modifying the sampling interval resets the trend recorder; all previously recorded data will be lost.

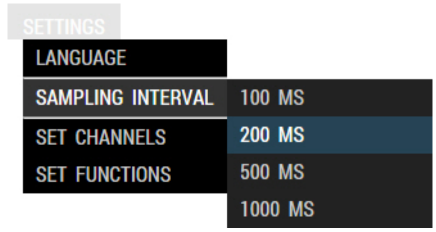


Figure 7. Setting the sampling interval in the Settings menu.

To plot a curve on the trend recorder, select an item from the *Label* drop-down list and click *ADD* (Figure 8). Once you have added one or more curve(s) to the list, press the play button in the menu bar to start recording. You can plot up to 8 different curves at the same time.

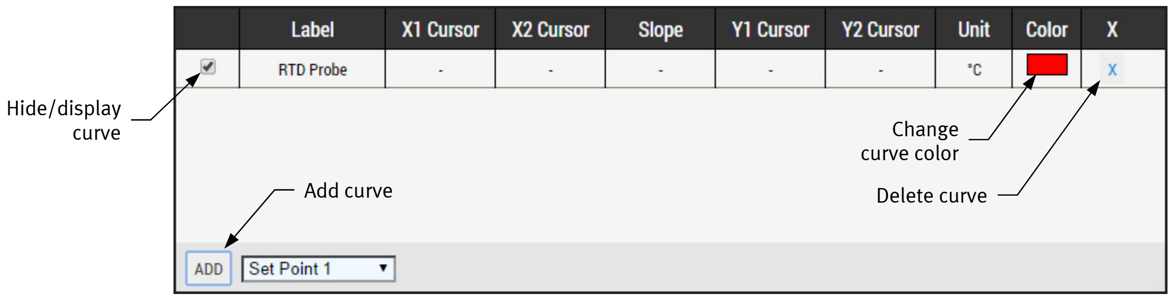


Figure 8. Adding a curve to the curves list.

At any time, you can pause the recording using the pause button or clear all recorded data using the X button. Figure 9 shows an example where four different curves are recorded.

The trend recorder is not limited to input channels; it can also display signals from digital inputs, digital outputs, and PID outputs as well as the proportional, integral, and derivative contributions to the PID outputs.

You can hide a curve by removing the check mark at the left of the curve name. You can delete a curve by clicking on the X at the right of the curve entry. Clicking on the color allows you to change the curve color using a color picker tool.

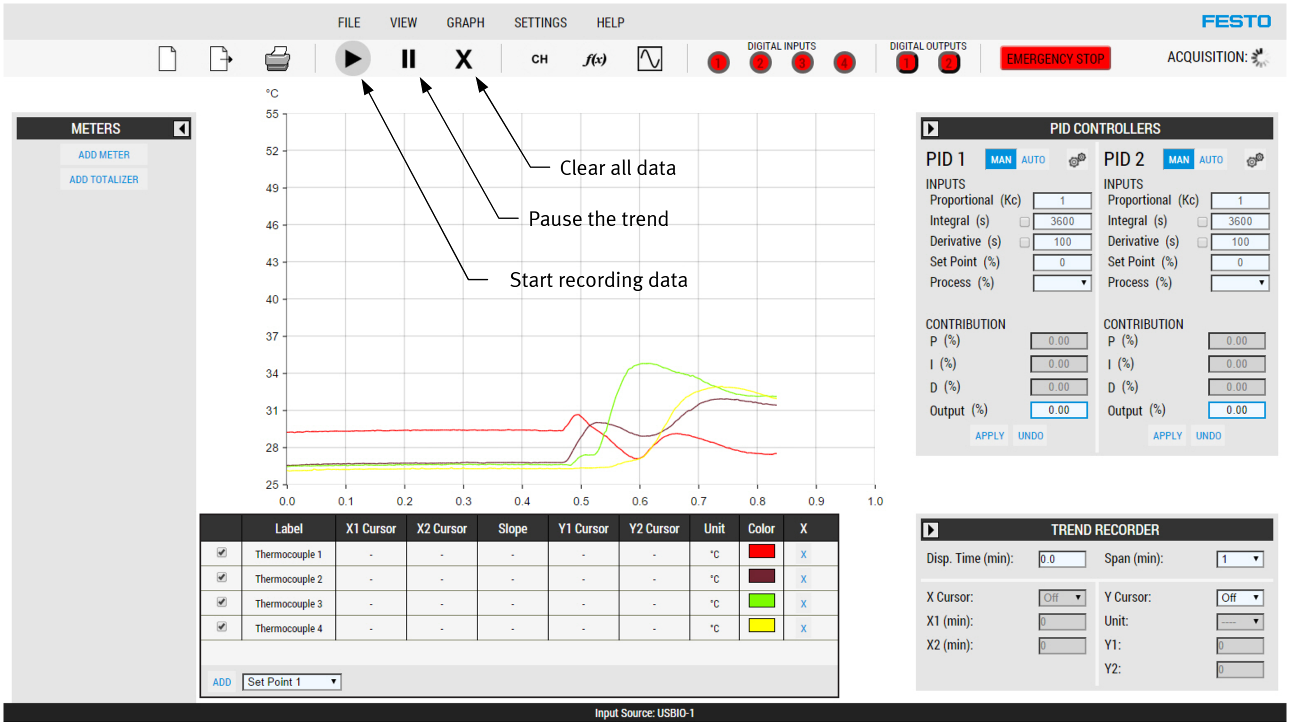


Figure 9. Plotting curves on the trend recorder.

The trend recorder menu (Figure 10) provides two interesting features. In the top section, you can change the time for which the curves are displayed. For example, if LVProSim has been recording data for 20 minutes, you can set the *Disp. Time* parameter to 5 minutes so that the data points are plotted for an acquisition time greater than 5 minutes. In this section, you can also set the *Span* parameter, which determines the time lapse displayed. Figure 11 shows a trend where the display time starts at 2 minutes and the span is 5 minutes.

Figure 10. Trend recorder menu.

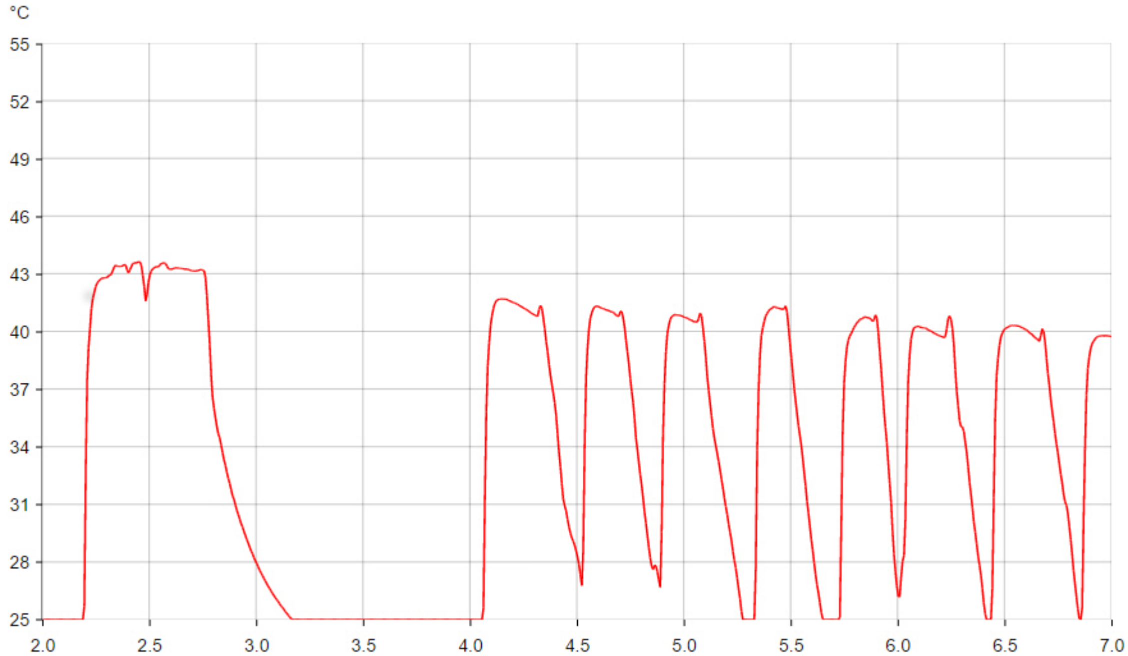


Figure 11. Modified display time and span.

In the bottom section (Figure 12), you can add horizontal or vertical cursors. Cursors are visual help that allow precise reading on a curve for a given horizontal or vertical value.

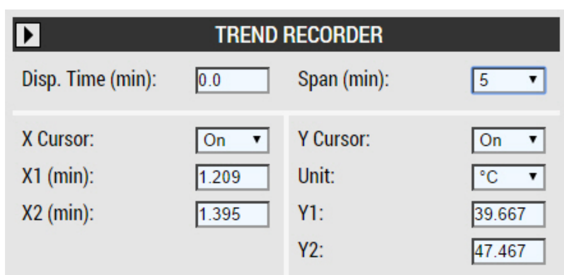


Figure 12. Trend recorder cursor sections.

To activate the X-axis or Y-axis cursor, select *On* in the X Cursor or Y Cursor menu[1]. This displays two horizontal or vertical lines. The point at which a cursor line intersects a curve is displayed in the curves list below the graph (see Figure 8). Additionally, for the X-axis cursors, the slope between the two cursors is computed. The point at which a cursor intersects the axis is also displayed below the X Cursor or Y Cursor menu. Figure 13 shows an example of using both types of cursor. The numerical values of the cursors are displayed in Figure 12.

[1] The X cursor cannot be turned on unless the graph is paused.

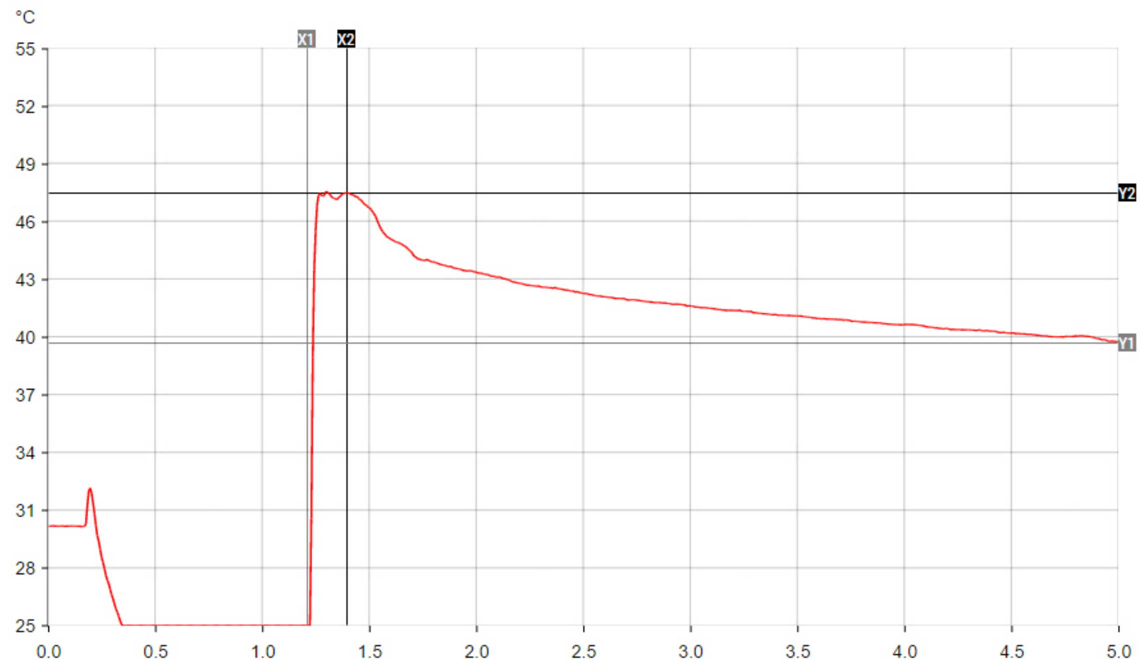


Figure 13. Using the cursors.

Meters and totalizers

At the left of the trend recorder, you can add meters to display the values of different data sources in real time. To add a meter, click *ADD METER*, enter a label name, select the data source, and press *OK*. Once a meter is added, you can display the source value as a percentage, edit the meter parameters, or delete the meter as shown in Figure 14.

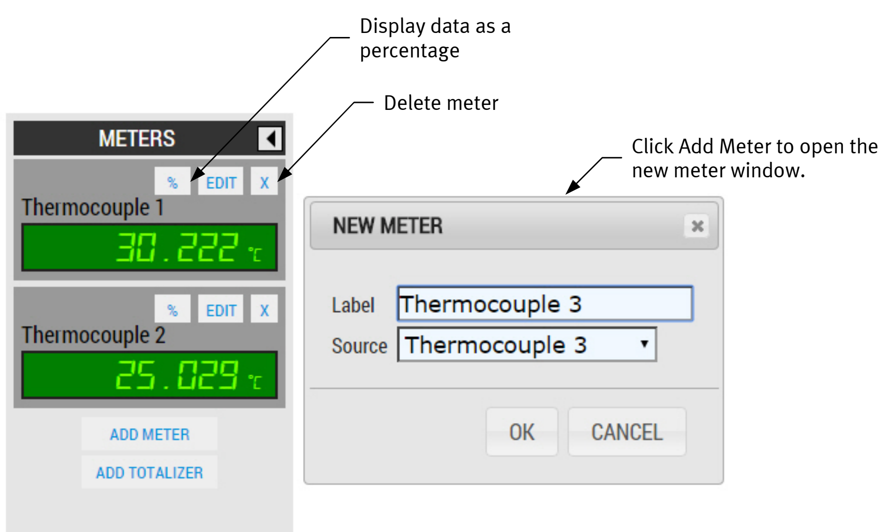


Figure 14. Adding and using meters.

If one of the channels measures a quantity per unit of time (e.g., L/s or L/h), you can add a totalizer that will compute the total quantity measured since the beginning of the recording. The *Reset* button clears the totalizer without restarting the recording.

Figure 15 shows a totalizer that computes the total number of liters from a flow rate in liters per minute.

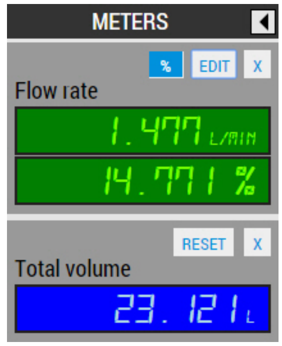


Figure 15. Using a totalizer to record the total number of liters.

Using and configuring the PID controllers

There are two configurable controllers (PID1 and PID2), at the right, in the PID Controllers section (Figure 16). For each controller, you can set the tuning constants, the set point, and select a controlled variable (Process %).

Each controller can be used in automatic or manual mode. By default, the controller is in manual mode. In the manual mode, you can only change the controller output by entering a new value in the *Output* parameter field and clicking *Apply*. Using the controller in manual mode allows manual control of a manipulated variable, such as a pump speed.

The second mode available is the automatic mode. To switch to the automatic mode, click *Auto* in the controller section. In this mode, LVProSim uses a non-interacting ideal algorithm to compute the controller output. The equation describing the output signal at any given time is:

$$m(t) = K_c\left(e(t) + \frac{1}{T_i}\int e(t)\,dt + T_d\frac{d}{dt}e(t)\right) + b \tag{1}$$

where $m(t)$ is the output of the controller (i.e., the manipulated variable)
K_c is the controller gain
$e(t)$ is the error
T_i is the integral time constant
T_d is the derivative time constant
b is the bias

Figure 16 shows the PID Controllers section. At the top, you can set the controller gain, integral time, and derivative time. Those parameters correspond to K_c, T_i, and T_d in Equation (1). Below those parameters, you can adjust the set point and select the controlled variable from the drop-down list. The controller gain, set point, and controlled variable are mandatory to achieve at least proportional control. Integral action and derivative action are not enabled by default. To enable them, check the box beside the name of the parameter. Each time you modify a parameter you must click the *Apply* button to apply changes; until you click this button all modified parameters are shown with a yellow background.

When the automatic mode is enabled, the proportional, integral, and derivative contributions to the controller output are shown in the bottom section of the controller zone. The controller output is also shown in this section. These four values are continuously updated as long as the automatic mode is running.

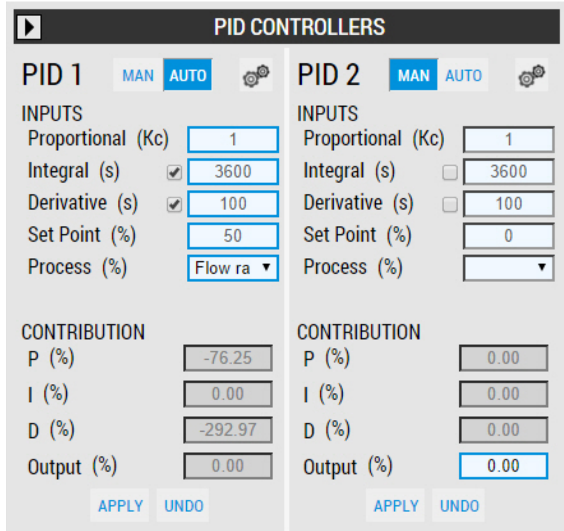


Figure 16. PID Controllers section.

Figure 17, Figure 18, and Figure 19 show typical settings for P control, PI control, and PID control respectively. For these examples, a temperature is recorded from channel 1 and it is used as the controlled variable. The set point is 50%.

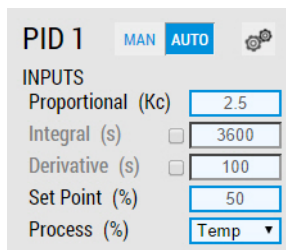


Figure 17. Setting P control.

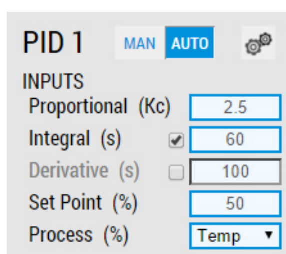


Figure 18. Setting PI control.

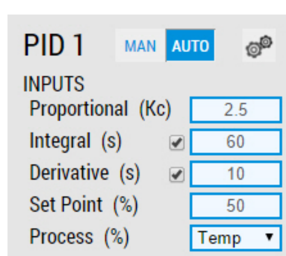


Figure 19. Setting PID control.

Other configuration options are available by clicking on the gears icon. The available options are shown in Figure 20. Enabling the *Dynamic Set Point* transforms the set point input field into a drop-down list that allows selection of a signal. This signal will be used by the controller as a set point. This allows more sophisticated control schemes such as cascade control. The other two options available are *Reverse Action* and *Derivative on Error*. Both of these options are enabled by default. Disabling the *Reverse Action* option puts the controller in direct action mode. In direct action mode, an increase in the error results in an increase in the controller output. Disabling the *Derivative on Error* changes the controller algorithm such that the derivative action uses the controlled variable (i.e., the process variable) instead of the error in its algorithm.

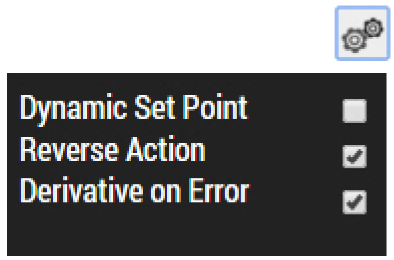
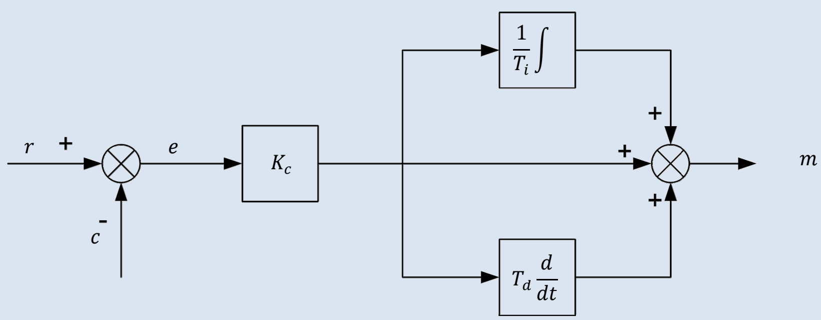


Figure 20. Controller configuration options.

Tuning parameters (a very short review)

The **controller gain**, K_c, determines the magnitude of the proportional action; the higher the controller gain, the greater the proportional action. For a non-interacting controller, changing the controller gain also influences the integral action and derivative action as illustrated in the figure below.



Non-interacting controller.

The **integral time**, T_i, determines the magnitude of the integral action. It corresponds to the time necessary for the integral action to repeat the action of proportional control, assuming that the error is constant. The shorter the integral time, the greater the integral action.

The controller algorithm of LVProSim contains an anti-reset windup function. This function turns off the integral action as soon as the controller output reaches its output limit (either 0% or 100%), which minimizes the overshooting of the controlled variable following a step change in the error signal.

Finally, the **derivative time**, T_d, determines the magnitude of the derivative action. It corresponds to the time by which the derivative action advances the effect of proportional action. The longer the derivative time, the greater the derivative action.

The derivative action can be implemented on either the error or the process (the controller variable). In LVProSim, the default setting is *Derivative on Error*. When derivative action is implemented on the error, changes in set point cause the derivative action to produce an output. This could lead to erratic swings in controller output with subsequent oscillations of the process. By implementing the derivative action on the process, the derivative action produces an output only when the process is changing, so no derivative action occurs immediately after a change in the set point.

User defined functions

Sometimes the signal from an input or output must be treated before being plotted or used as a controlled variable. The SET FUNCTIONS dialog box offers several options to combine or apply a treatment to a signal (Figure 21).

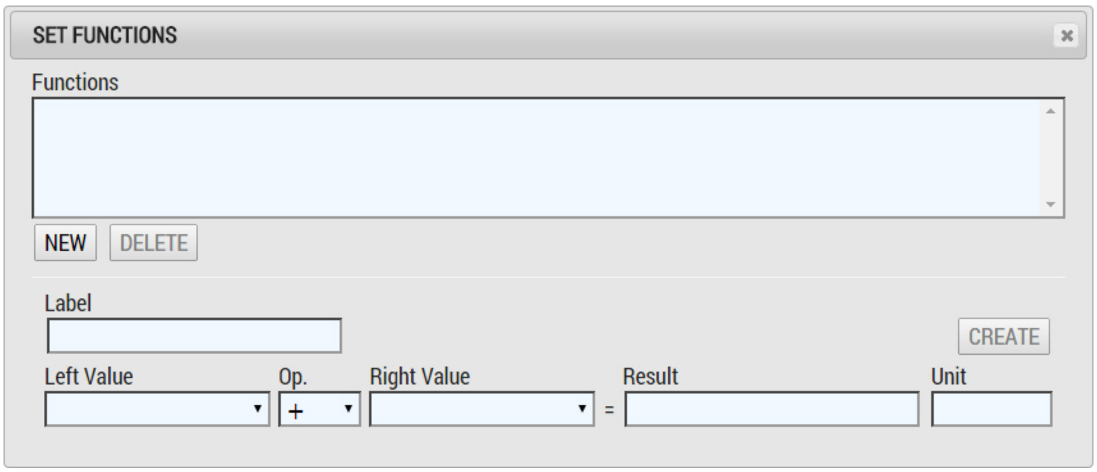


Figure 21. SET FUCTIONS dialog box.

Using the SET FUNCTIONS dialog box, you can combine two signals using operators. Basically anything that can be plotted on the trend is a signal. You can even use the result of another function as an operand for a new function. Figure 22 shows an example of a user-defined function that returns the sum of two pressure signals.

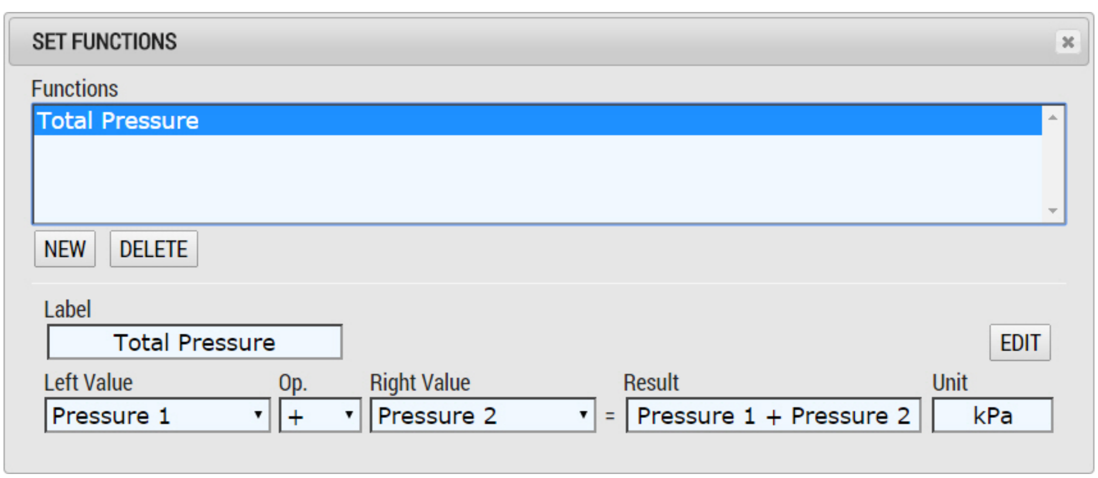


Figure 22. User-defined function.

The left operand is optional, which allows you to apply operators such as a square root or a filter to a single signal. Figure 23 shows how this can be used to obtain a signal proportional to the flow rate from a pressure differential reading by taking the square root of this signal.

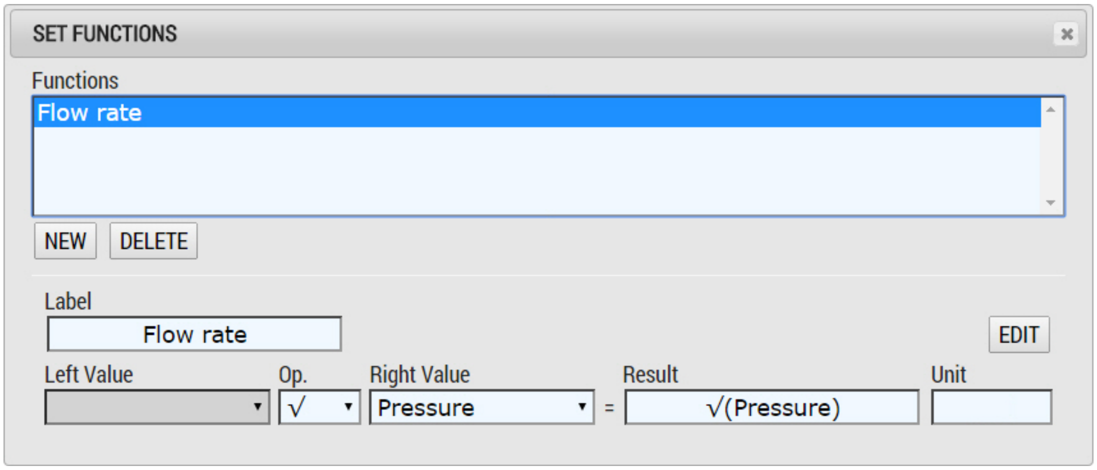


Figure 23. Obtaining a signal proportional to the flow rate from a pressure differential.

Simulation mode

In the simulation mode, you do not need (nor can use) the I/O interface. The process signals are generated from the dynamic constants of your choice.

User interface

In the simulation mode, the software interface is almost the same as in the data acquisition mode. Since LVProSim cannot access the I/O interface in this mode, no functions pertaining to this mode are available. Almost all features of the simulation mode are similar to the features of the data acquisition mode; only the instructions on how to use and configure the simulator are presented below. For details on any other function, refer to the Data acquisition mode section above.

Table 2 makes the correspondence between the icons of the menu bar (Figure 24) available in the simulation mode and their descriptions.

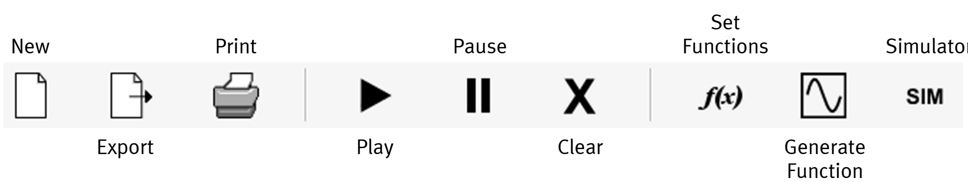


Figure 24. Menu bar in simulation mode.

Table 2. Description of the menu bar in simulation mode.

Icon name	Icon description
New	Closes the current window and allows opening a new window for either data acquisition or simulation
Export	Allows exporting the current recorded data and saving it to a file in comma-separated values (CSV) format

Icon name	Icon description
Print	Prints the current graph
Play	Starts recording the data from the different sources listed in the curves list
Pause	Pauses the trend recorder. This does not pause data recording. No data is lost while in pause mode. When the trend recorder display is resumed, the curves are immediately updated with the missed data
Clear	Clears all recorded data
Set Functions	Allows manipulating data sources using simples functions
Generate Function	Allows the creation of a data source from one of the mathematical functions available such as a sine function
Simulator	Opens the simulator setting pop-up window

Running a process simulation

The simulator is a powerful tool that allows you to simulate a first-order or a second-order process and test different controller configurations. You can also add a disturbance to the process simulation.

Setting a simulation requires some simple steps. First you must decide which type of simulation, among the four available, you want to run. The four simulation types available are:

- Simulating a process controlled using the PID 1 controller
- Simulating a process controlled using the PID 2 controller
- Simulating a process with a cascade control scheme using PID 1 as primary controller (master) and PID 2 as secondary controller (slave)
- Simulating a process with a cascade control scheme using PID 2 as primary controller (master) and PID 1 as secondary controller (slave)

Once you have chosen the type of process you want to simulate, click the simulator button to open the simulator settings window. To select a single-loop process control, click either on PID1 or PID2 in the menu bar, depending on which controller you want to use (Figure 25). To select a cascade simulation, first select CAS in the menu bar, and then, click either on PID1 or PID2 to select which controller will act as the primary controller (Figure 26).

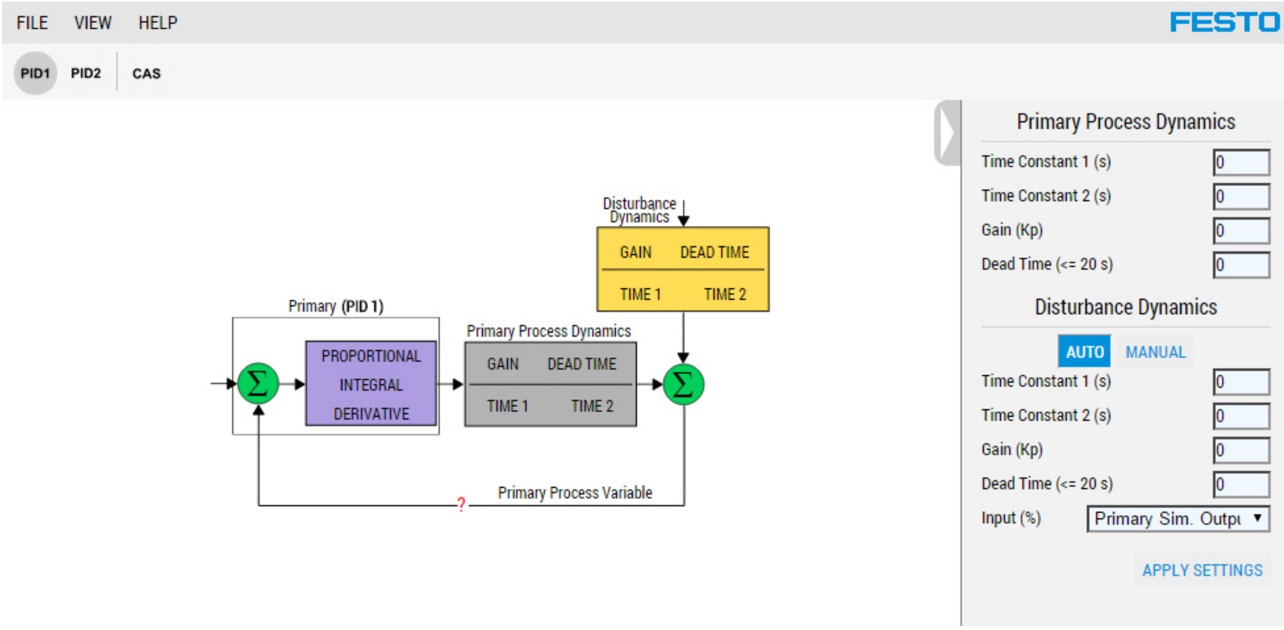


Figure 25. Selecting a single loop simulation.

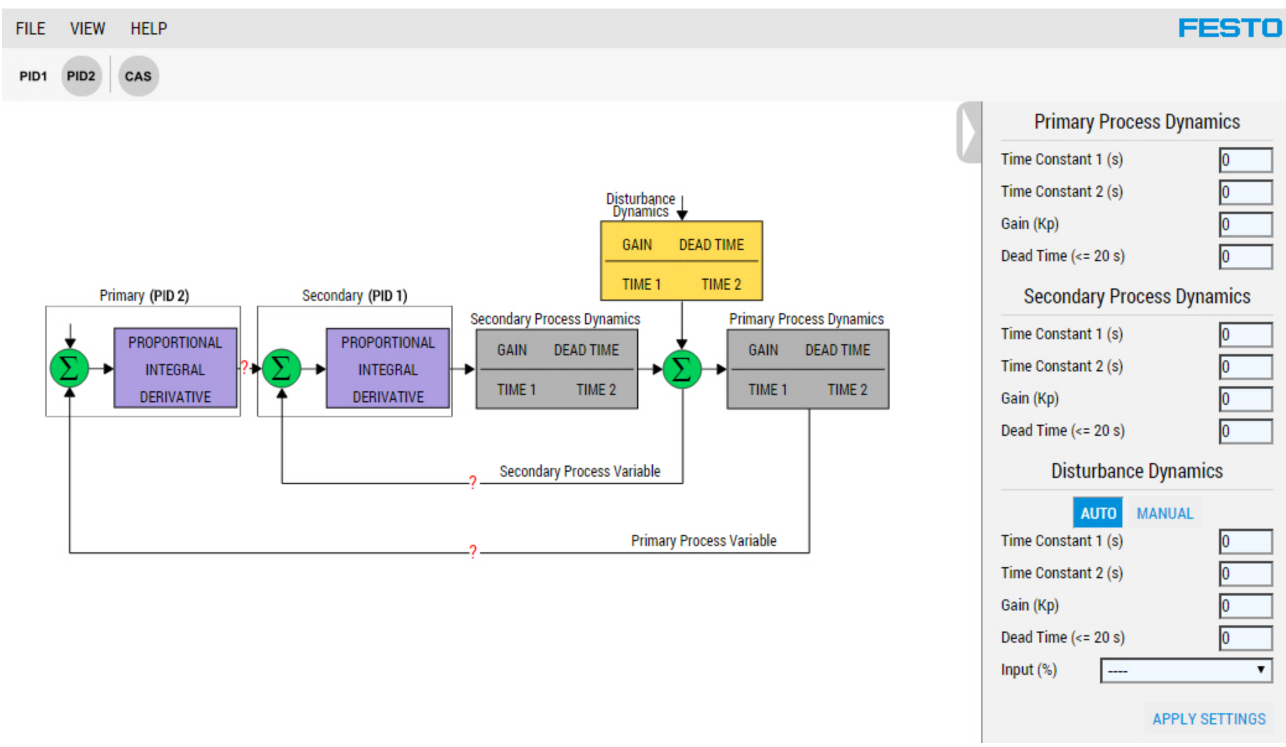


Figure 26. Selecting a cascade simulation.

Note that, at first, there is one or more red question mark(s) on the process drawing. This indicates that the feedback loop is not closed because one (or more) element is not selected yet. For example, the software displays a red question mark on the primary process variable line if no source is selected for the process signal. In this case, to close the simulation loop you have to switch to the main window and select *Primary Sim. Output* in the *Process* drop-down list of the controller section as shown in Figure 27.

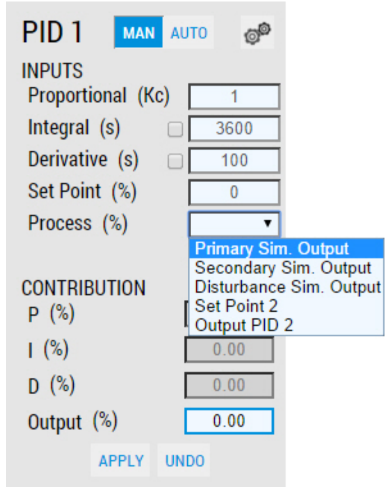


Figure 27. Closing the simulation feedback loop of a single loop simulation.

Once the simulation loop is closed, you can set the dynamic characteristics of the simulated process at the right of the simulation window. Figure 28 shows an example of a second-order process loop with the first time constant set to 10 s, the second time constant set to 3 s, a gain set to 2, and a dead time of 1 s. To simulate a first-order process, simply set the second time constant to 0 s. With the dynamic characteristics set, click on the process drawing to display the process equations in the Laplace domain (Figure 29).

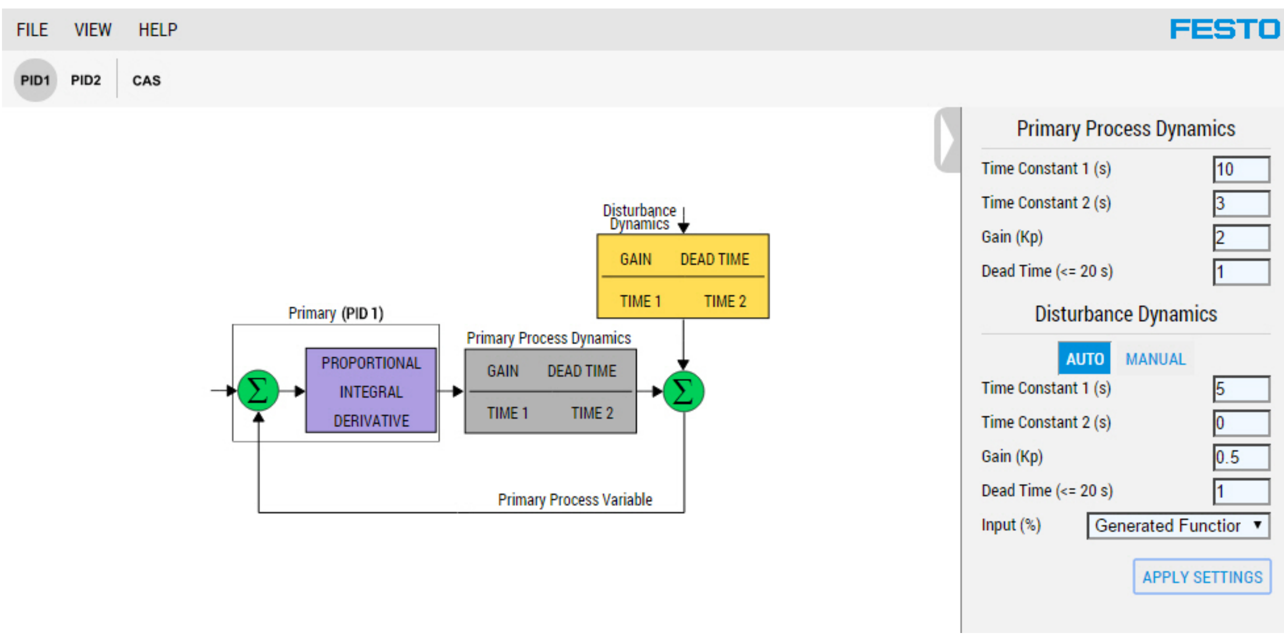


Figure 28. Setting the dynamic characteristics of the simulated process.

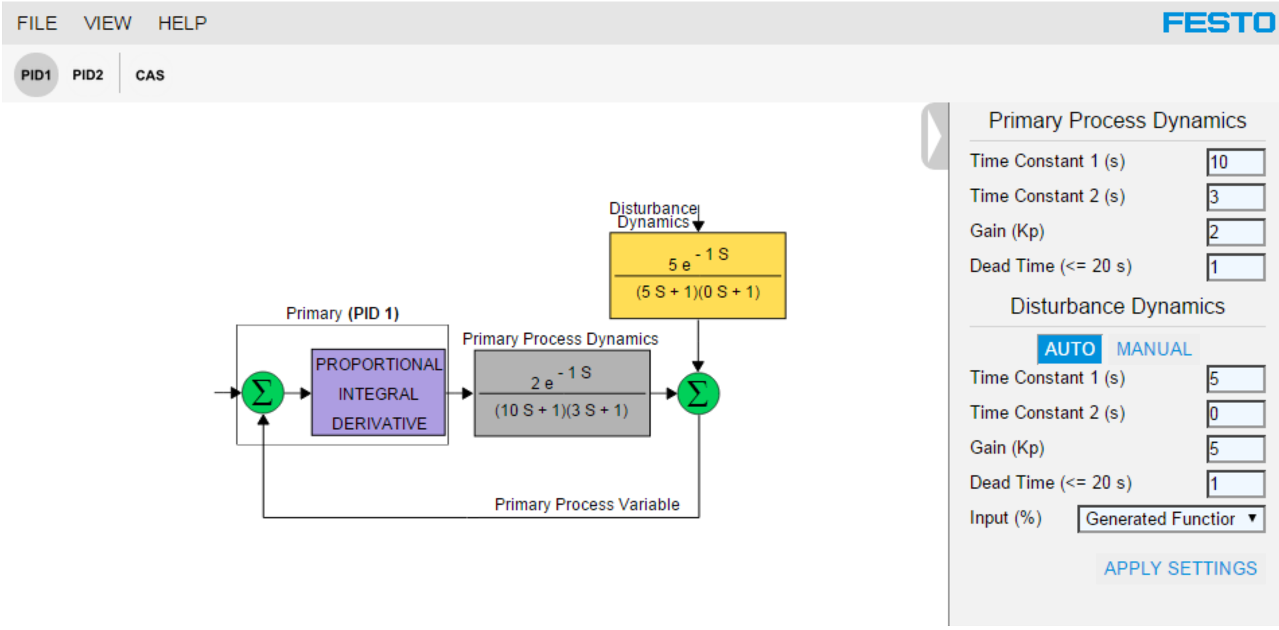


Figure 29. Display the process equation in the Laplace domain.

The procedure to set a simulation for a cascade process is similar except that there are two process loops instead of a single one. The most important aspect is closing the two loops correctly by selecting the appropriate sources in both controllers. For example, if you chose to use controller PID2 as the primary controller as shown in Figure 26, select *Secondary Sim. Output* in the *Process* drop-down list of the controller PID1 and *Primary Sim. Output* for controller PID2, as shown in Figure 30. Once the source for the process signal is set, the two red question marks on the feedback signal lines of both loops are replaced with a straight line.

However, there is still one red question mark in the process drawing between the primary and secondary controller. This question mark indicates that the set point of the secondary controller is not correctly configured. Indeed, in a cascade control scheme, the secondary controller uses a dynamic set point. To set a dynamic set point for the secondary controller, click on the gears icon of this controller, check *Dynamic Set Point*, and select the output of the primary controller in the *Set Point* drop-down list, as shown in Figure 31. Once all the red question marks are gone, you can set the dynamic characteristics of the simulated process as desired.

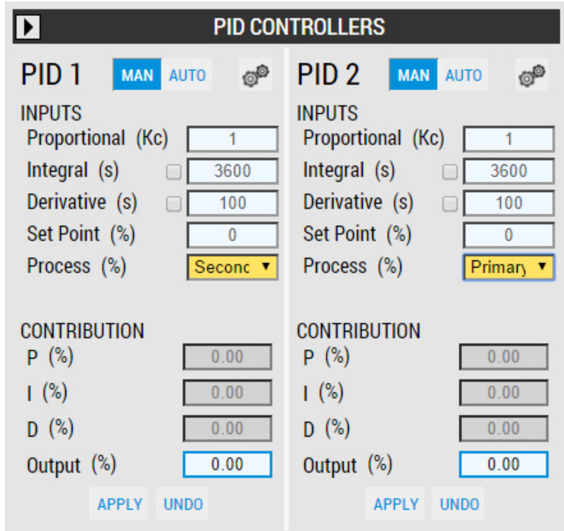


Figure 30. Closing the simulation feedback loop of a cascade simulation.

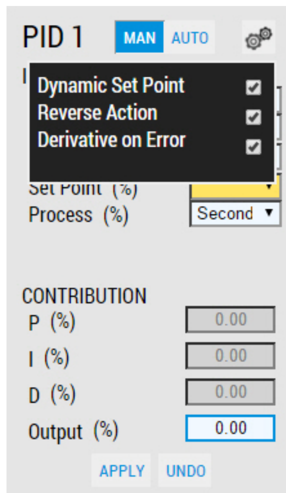


Figure 31. Configuring a dynamic set point.

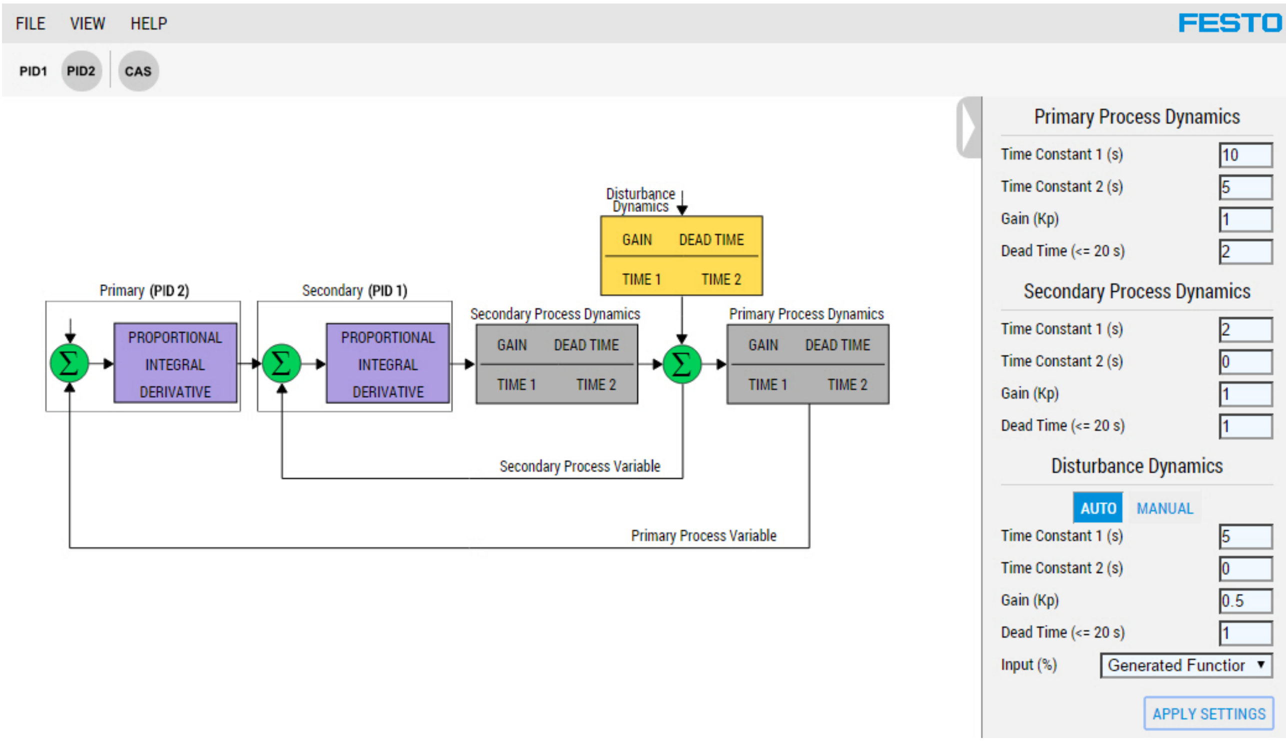


Figure 32. Setting the dynamic characteristics of the simulated cascade process.