

# MPC-ControLAB USER'S GUIDE

© 2004 Wade Associates, Inc.  
17522 Brushy River Court  
Houston, TX 77095  
281-304-9504 FAX: 281-256-3442  
e-mail: controlab@wadeco.com

## PROGRAM DESCRIPTION

**MPC-ControLAB** is a process and model predictive control simulation program. It permits demonstrating the behavior of multivariable model predictive control (MPC). The program displays on a scrolling strip chart recorder the behavior during the past 60 minutes (simulated time) of up to four process variables, two manipulated variables and two disturbance variables. In addition, it displays on a fixed graph the predicted future behavior over the next 30 minutes, based on past control moves and process disturbances, of the four process variables. The model predictive control calculation cycle can be either free running (that is, continuous calculation, as would occur in the real world), or the user can advance through the calculation cycle step-by-step. This permits a detailed examination of the results of the model predictive control algorithm following each step. A numerical listing of the predicted future PV values or control move values, following each step of the calculation cycle, is also available to reinforce the information presented on the graphical display.

This program is derived from **PC-ControLAB 3**, therefore many of the display and operational features are similar. Furthermore, the process model builder program, **BUILDER**, furnished as a companion to PC-ControLAB, can be used to configure process models for MPC-ControLAB.

The program executes under Windows 95, 98, ME, NT, 2000, or XP.

## PROGRAM INSTALLATION

The program is installed automatically by the PC-ControLAB 3 installation program. The default folder is

C:\Program Files\PC-ControLAB 3

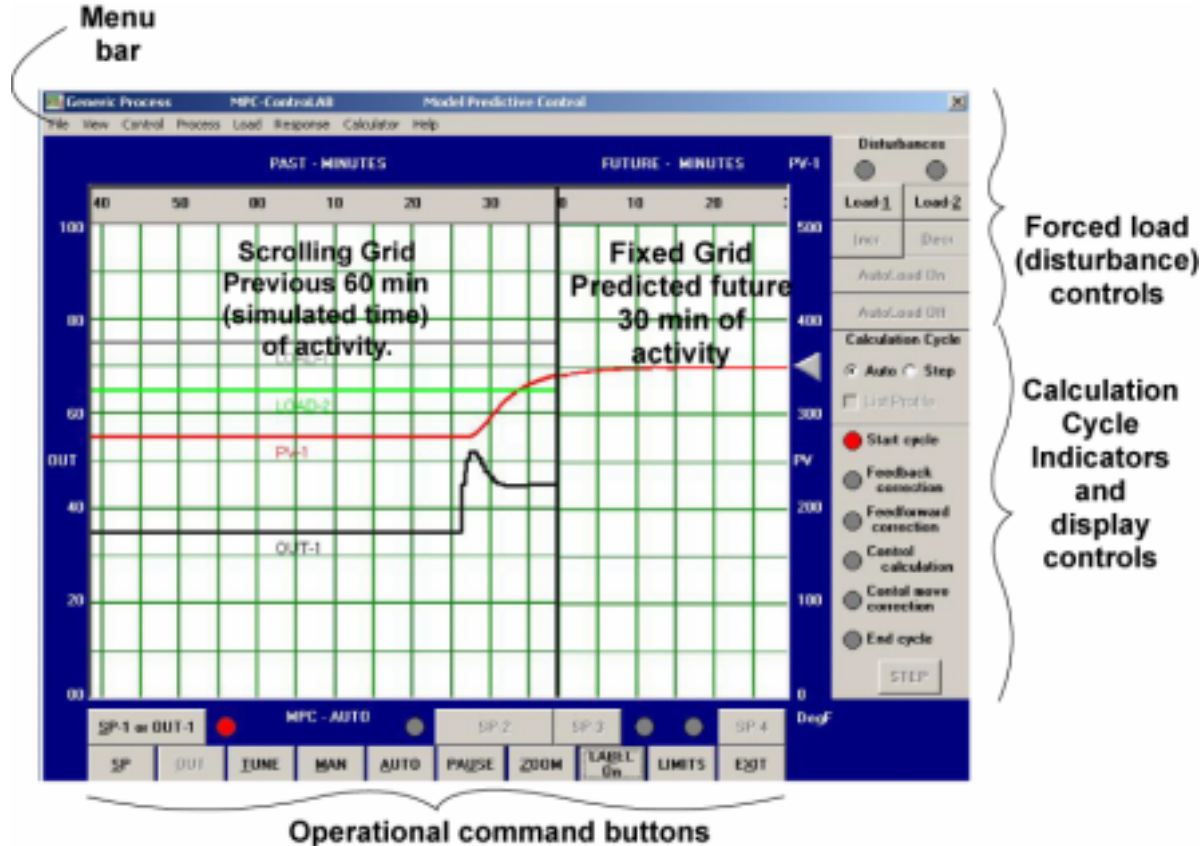
## STARTING THE PROGRAM

In the Windows START menu, issue the following command:

*RUN* C:\Program Files\PC-ControLAB 3\MPC-LAB

The Title Display will appear for a brief time, and then be replaced by the main operational display.

## MAIN DISPLAY



The Main Display consists of the following major sections:

A scrolling grid (strip chart recorder), displaying the past 60 minutes of behavior of up to 4 process variables, 2 disturbance variables and 2 controller outputs.

A fixed grid, displaying the predicted behavior 30 minutes into the future of the process variables.

A set of operational command buttons (bottom of the screen) which permit entry of set point and output values, selection of modes of operation and other features.

A control panel (upper right hand corner of the screen) which permits setting the mode of operation of two disturbance variables.

A control panel (right hand side of the screen) which controls the operation of the MPC calculation cycle and the display of the results.

A menu bar (top of the screen) which permits entry of certain set up information, such as selection of the process model, selection of the number of control variables (CV's) and controller outputs (manipulated variables – MV's).

## Display Size

At the start of execution, the program automatically detects the user's screen resolution, and adjusts the size of the display appropriately. In some cases the user may enlarge or decrease the size of the display. Press **View | Display Size Selection**. If **Bigger** or **Smaller** is not grayed out, select one of these to change the display size.

## Process Variable Display Range

The vertical scale for the process variable display can be either in engineering units (the default) or percent of span. To change the selection, press **View | Display Range**, and select either **Engineering Units** or **Percent of Span**. This selection affects the PV display on the grid, the units for set point entry, as well as the tabulation of the predicted profiles and the step responses.

## PROCESS MODEL SELECTION

MPC-ControLAB automatically reads in the process model "Generic4" at the start of execution. You can select a different process model, although some may not provide the number of PV's, MV's and load variables required by MPC-ControLAB.

To select a different process model:

- Select **Process | Select Model** from the menu bar.

- A dialog box appears which permits selection of a particular process model.

The menu bar selection **PROCESS** also permits:

- Saving a process model, if a model parameter has been changed;

- Saving a process model under a new name;

- Changing a process model parameter;

- Inspecting a designated process model function block's output value.

These operations are identical to similar operations in PC-ControLAB.

## CONTROL STRATEGY CONFIGURATION

The program contains of control configuration parameters. These can be changed, however

Select **Control | Control Options** from the menu bar.

The following configuration options may then be selected.

	Choices				Default
Number of samples (the “prediction horizon”)	30	60	90		60
Control sample interval, minutes:	0.2	0.5	1.0		0.5
Number of moves (the “control horizon”)	5	10			10
Number of controlled variables* (CV’s)	1	2	3	4	1
Number of auxiliary variables* (AV’s) (Number of CV’s + number of AV’s must be less than or equal to 4)	0	1	2	3	3
Number of manipulated variables (MV’s) (Number of MV’s must not exceed number of CV’s)	1	2			1

\*Controlled variables (CV’s) have a set point which the MPC algorithm attempts to maintain. Auxiliary variables (AV’s) are monitored, but have no part in the control strategy.

Note that the options may be changed only if MPC is in the *manual* mode of operation. If the MPC is in the *auto* mode, the options can be viewed, but not changed.

## PROCESS RESPONSE

A key element of model predictive control is the step (or pulse) response of the process variables to step (or pulse) changes in process inputs, both manipulated variables (MV’s) and disturbance variables. MPC-ControLAB permits testing the process to determine the step responses. Optionally, once the responses have been determined, they may be saved for retrieval in a subsequent session, thus avoiding the necessity of retesting the process.

The MPC algorithm must be in the *manual* mode for process response testing.

To perform a process response operation:

Select **Response** from the menu bar.

The drop-down menu provides four additional choices:

- **Capture.** Permits capturing the response of PV-1, PV-2, PV-3 and PV-4 to a step change in an MV or load variable. See below for detailed instructions on making a process test.
- **Retrieve.** Permits retrieval of a previously saved response file.
- **Save.** Permits designation of a directory, folder and file name for saving the captured responses of a process. Note that the **Save** option is only enabled if a full set of responses (4 PV’s, each to changes in both MV’s and both load variables) has been captured.

- **View.** Permits viewing the normalized step responses, once captured. (Normalized responses are responses to a one unit step change in the input, regardless of the size of the step at the time the test was made.)

### **MPC Matrix Formulation**

When the four PV responses to each of the four process inputs (2 MVs, 2 load variables) have been captured or retrieved from a file, the model predictive control matrices are formulated. The AUTO operational command button is also enabled, permitting *automatic* operation of the MPC algorithm. (Until the matrices are formulated, the AUTO button is disabled (grayed out), so that the MPC algorithm is in the *manual* mode.)

The MPC matrices are reformulated whenever:

- There is a configuration change which changes the number of CVs, the number of MVs or the number of moves;
- There is a change to a move suppression factor, through the TUNE command.

### **MPC AUTOMATIC OPERATION**

When all of the PV responses have been captured or a compatible response file retrieved, the model predictive control algorithm may be placed in automatic operation by pressing the AUTO button beneath the strip chart. The calculation cycle will be free running, with a simulated LED indicating the particular step of the calculation cycle just completed. Note that the scrolling strip chart recorder advances only at the end of a calculation cycle.

The following operations may now be performed:

- **Change set point.** Press **SP** and enter a new value in the dialog box.
- **Tune the controller.** Press **TUNE** and enter a new reference trajectory time constant for this PV, or a new move suppression factor for this MV. The default values are:

Ref Trajectory Time Constant	6 minutes
Move Suppression Factor	0.25

- If the control strategy is configured with more than one CV, you can select another CV for changing the set point or tuning. The selection buttons are labeled:

SP-1 or OUT-1  
 SP-2 or OUT-2  
 SP-3  
 SP-4

An LED beside each selection button indicates which selection is made.

- Make load changes. See “Load Changes” below.
- Return the MPC algorithm to the *manual* mode. Note that MPC operation will continue in the *automatic* mode until the end of the current calculation cycle. If the calculation cycle is under step control (see below), the **MAN** command will have no visual effect until you **STEP** to the end of the current calculation cycle.

## MPC CALCULATION CYCLE

The MPC calculation cycle can be either free running or stepped, under user command. LEDs on the Calculation Cycle control panel indicate the calculation cycle step just completed. These are:

- Beginning of cycle. Predicted PV profiles are advanced one sample period.
- Feedback correction. The currently predicted value of each PV is compared with the actual value, and the predicted profile is adjusted upward or downward so as to obtain agreement with the actual value.
- Feedforward correction. If there has been a load change since the last calculation cycle, the profile is adjusted by the magnitude of the load change times the normalized step response.
- Control move calculation. The MPC matrix is applied to the error vector, which incorporates the reference trajectory return to the set points from the current values of the PVs. Control moves for each of the MVs are calculated.
- Control move correction. Each PV profile is updated to reflect the influence of the control move on that PV, according to the step response data.
- End of calculation cycle. No action is taken. This is merely a visually displayed step.

To step through the calculation cycle, select the option “Step.” (The MPC algorithm must be in the *auto* mode.) Then press the command button **STEP** to go to the next calculation step.

To return to free running operation, select the option “Auto.”

To obtain a numerical listing of the predicted profile of the PVs, as well as the graphical display, click on the check box labeled “List Profile.” (The calculation cycle must be in the “step” mode.) This results in a tabular display of the predicted PV profile following each step except the Control Move Calculation step. For that step, the MV changes are displayed.

To discontinue numerical listing, click again in the check box labeled “List Profile.”

## LOAD CHANGES

One or two load changes (disturbances) may be introduced into the process (as configured in the process model), either under manual command or automatically. The load (disturbance) panel in the upper right hand corner of the screen controls the application of the load changes.

The top buttons, **LOAD-1** and **LOAD-2**, are selected to determine which disturbance the buttons below apply. LEDs indicate which load has been selected.

When a load is selected, you can make a one-time step increase (default of 5%) by pressing **INCR**, or a one-time step decrease (default of 5%) by pressing **DECR**. You can also cause the load to vary automatically and randomly by pressing **AutoLoadOn**. Discontinue automatic load changes by pressing **AutoLoadOff**.

The statistical characteristics of the automatically varying load, as well as the default value of the manually induced step load, are controlled through “Load” selection on the menu bar. These operations are identical to those found in PC-ControLAB.

## RESPONSE TESTING

Whenever you have read in a new process model, or have changed the number of samples or sample interval, the process must be tested to determine the step response to process input changes. If you change a process parameter to obtain different process characteristics, you must also obtain new process response data.

MPC-ControLAB captures the response to a step change by observing the response of the PVs as displayed on the visible strip chart recorder. After a change is made in a process input (MV or load variable), the response is captured when the user selects **Response | Capture** from the menu bar. The following requirements must be met, however:

- There must be no more than one process input change on the visible screen. When step testing for a MV change, key in a new output value through the dialog box. When step testing for a load change, use the **INCR** or **DECR** buttons, and click only **ONCE**.
- The PV data must completely fill the visible screen. Therefore do not issue the “capture” command if the program has been running less than 60 (simulated) minutes after startup.
- The “capture” command must be issued when the output of load step has moved at least 35 minutes across (right to left) the screen, but not more than 55 minutes. Reason: the program examines the five minutes of visible screen before the output or load change to see if the PVs were sufficiently stable at the beginning of the test. Furthermore, since the response can take 30 minutes (say, 60 samples at 0.5 minute sample intervals), then the program examines the 5 minutes following the allowed time for the response to see if the PVs were sufficiently stable at the end of the test. For convenience, whenever the “capture” command has been given, a red label appears to indicate the “capture zone.” To make this label disappear, simply click on the label.

### Example: Step Testing OUT-1 (MV-1):

The MPC operation must be in *manual*. (Press MAN beneath the strip chart.)

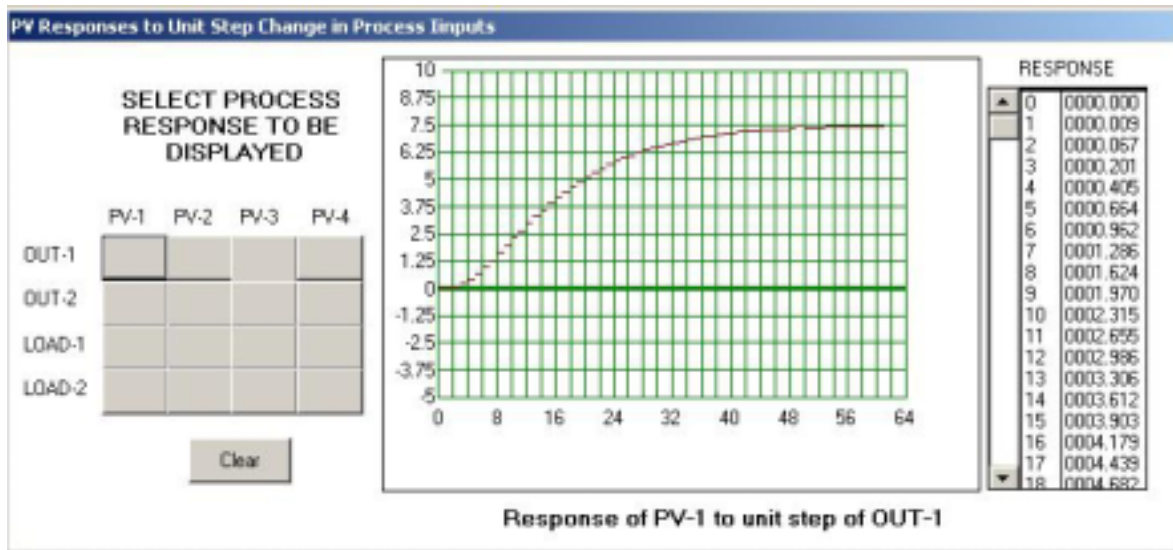
Be sure the control configuration (Control | Control Options) is set up for your desired number of samples and sample interval.

Press [SP-1 or OUT-1]. (If the current configuration calls for only one CV, this is not necessary, as it will be the default selection.)

Press OUT. In the dialog box, change the output by, say, 5%. (For example, from 35% to 40%). The captured response will be automatically normalized to be the response to a 1% change.)

When the displayed output change has moved into the “red zone,” select Response | Capture. (Hint: Select Response and move the cursor to highlight Capture well before the output change gets to the red zone. Then all you have to do is click the mouse when the output change does reach the red zone.) If no error message appears, then the response of the four PVs to this input change was successful.

To view the responses, select Response | View. A window appears with a 4X4 pushbutton matrix, relating each PV to each output and each load. Select any one of the buttons to view the normalized response.



### “VIEW RESPONSES” WINDOW

Continue in this manner until the responses to both MVs and both load variables have been captured. (The response to all four process inputs must be captured, even though only one MV is intended to be used in the subsequent control strategy.)

See “Save” under PROCESS RESPONSE above for saving the captured process responses.