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Chapter 1 Introduction

*LOOP-PRO TUNER* is an optional online PID diagnostic and optimization solution that integrates seamlessly with the Control Platforms. *LOOP-PRO TUNER* is configurable to support access to real-time process data in addition to Historical Data Files.

Analysis performed by *LOOP-PRO TUNER* can be used to better understand business-critical process dynamics and to improve overall production performance.

The manual provides instructions for using authorized licenses of *LOOP-PRO TUNER*. The primary audience for this document includes staff charged with the deployment, maintenance and tuning of PID controllers on the ControlLogix platform.

1.1 Prerequisites

The *LOOP-PRO TUNER* License must be activated with a valid License supplied by Control Station, Inc.. If properly licensed, the software will execute when selected and clicked from the main screen.

1.2 Definitions

<table>
<thead>
<tr>
<th>License</th>
<th>An authorized copy of <em>LOOP-PRO TUNER</em> for installation and operation on either an individual computer workstation or an individual laptop computer. Licenses are not intended for shared use across an end-user’s computer network.</th>
</tr>
</thead>
<tbody>
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Chapter 1 Launching *LOOP-PRO TUNER*

**Launching *LOOP-PRO TUNER***

- After installation and license activation, *LOOP-PRO TUNER* can be launched from either the Start Menu or from a command line. The application is launched from the Start Menu → LoopPro Tuner → LoopPro Tuner
Loop-Pro Tuner will then launch on the engineering workstation as shown below.

When launching *Loop-Pro Tuner* from the Start Menu, the user must decide which type of tuning session wishes to create. The choices are:

- **Online**: *Loop-Pro Tuner* will connect to via an OPC Connection, and gather real-time process data. The user can also (if the user has the correct “write-to” permission set) make adjustments to the controller.

- **Offline**: *Loop-Pro Tuner* has the ability to import Achieved Data Files from either Text, Comma-Separated-Value or .DBF formatted flat-text files.
Chapter 2 The *Loop-Pro Tuner ONLINE* Ribbon

- To Start an ONLINE Tuning Session, select the “Connect to Network” Icon

The *Loop-Pro Tuner ONLINE* Ribbon Toolbar

- *Loop-Pro Tuner* software is a Windows-based application that provides the users a step-by-step approach to the PID controller loop tuning process using a Tab-based Windows ribbon toolbar. These Tab steps are used to step through and select from the various options as the PID control loop data collection, modeling and analysis, control tuning and refinement, implementation and testing, and reporting steps are performed.

- The ribbon is located on the top of window.

The Ribbon Tabs

- The Tabs across the top of the ribbon toolbar show the steps required for tuning and reporting. The color that the Tabs are displayed in indicates whether they are enabled for use at the current moment.

- Tabs that are disabled are shown in a very light gray, indicating that they require the completion of a previous step before they are available. In the example below, the Implement Tunings tab is disabled because proper tuning values have not yet been determined using the Tune tab.
To move forward or backward through the Tab steps, use the blue arrows in the lower right of the Ribbon, or directly select an enabled Tab. The Enabled Tabs are displayed in black as shown below.
**Enabled and Disabled Tabs**

- **Enabled Tabs** can be selected by clicking on them with the mouse. Selecting (clicking) Tabs enables you to move to the next step or back to a previous step.

- **Disabled Tabs**, displayed in light gray, are not available for use because *LOOP-PRO TUNER* recognizes that a required previous step has not been completed.

**Exiting LOOP-PRO TUNER**

- Click the CS Icon to the upper left on the ribbon toolbar to open a menu that provides an “Exit TUNER” selection as highlighted below.

- Alternatively, click the Close Window button to the upper right to close and exit.
The About Button

- The About Button, highlight below on the upper left of the Ribbon Toolbar, provides Loop-Pro Tuner version information and license information.
Chapter 3 The Six Tab Steps LOOP-PRO Tuner ONLINE

Tabs on the Loop-Pro Tuner Toolbar

There are six tabs across the ribbon toolbar, and these are used to perform the steps required for PID controller loop tuning and reporting.

- **Tab Step 1: Choose a Loop**
  - The Loop Specification Tab is used for find and connecting to the correct Control Loop. From this tab the can browse the tags available on the OPC Server using the familiar OPC Tag Tree Structure or simple search the entire database for all Loops matching the signatures.

- **Tab Step 2: Collect Loop Data**
  - The Grab Loop Data Tab is used to collect in real-time the user-selected control loop process data. Data is collected at the same frequency as the controller sample time (up to 100ms) and displayed in a trend plot to provide a visual representation of the behavior of the selected controller loop during the data collection process.

- **Tab Step 3: Fit Model**
  - The Fit Model Tab is used to fit a process model to the data collected in Step 2. In just a few clicks, a visual comparison of model and data is displayed in a trend plot to provide confidence that the data is meaningful and the model representation is valid. The model is then used in the Tune step 4.

- **Tab Step 4: Tune**
  - The Tune Tab provides the user with the tools to compute and adjust the PID controller tuning values for the selected control loop. Plots show before-and-after response behavior. Tools and options are provided to fine-tune the predicted performance if customized controller loop behaviors are desired.

- **Tab Step 5: Implement Tunings**
  - The Implement Tunings Tab enables the user to apply the tuning values from Step 4 or to restore the original tunings to the actual controller of the selected loop.

- **Tab Step 6: Report**
  - The Report Tab creates a PDF document to provide a permanent record detailing the tuning session, including the process data collected, the data displayed as trend plots, and the before-and-after PID control loop tuning values with expected performance.
Chapter 4 Tab Step 1: The Loop Specification Tab

The Choose a Loop Tab is the first tab the user is presented with after they select ONLINE mode from the Welcome Screen. This ONLINE version of the LOOP-PRO TUNER product is restricted to accessing process data from OPC Servers. From this Tab the user can connect to the OPC server by selecting the server listed in the left portion of the window. Once connected, the user can browse the tree structure on the left to locate the controller of interest. The empty white box on the right of the screen will list the “Found” Control Loops. Once the user has located the control loop of interest, they can simply select that loop, and hit the “Right Arrow”.

Loop-Pro Tuner has the ability to automatically search the entire tag database to locate Controllers, simply select the “Deep-Scan for PID Controllers” button. The Scan Function will start the scan process from the currently selected on the Tree. In the example above, the search will begin from the “Online” point in the tree-structure. Selecting a folder closer to where you think your loops are located can greatly speed in the search for the control loop. This search can take anywhere from 10 seconds to 10 minutes depending on the complexity and length of the database. Once the loop of interest appears on the right, you can select it and hit next, you do not have to wait for the Scan to complete, it will automatically stop searching when you move to the next step.
Chapter 5 Tab Step 2: Collect Loop Data

The Collect Loop Data Tab is the first, and perhaps most critical, step in controller loop tuning. Collect Loop Data is used to select, collect and trend in real-time the control loop process data from the user-selected control loop faceplate.

Data is collected to provide a visual display of the behavior of the selected controller loop during the data collection process.

When a control loop is selected, the Process Variable, Set Point, and Controller Output data will be displayed in a real-time trend plot as shown below.

While tracking data with the Grab Loop Data Tab, feature options available to the user include:

- Export Data
- Track Values
- Change Display History of Trend Plot
- Zoom & Undo Zoom
- Customize, Copy and Print the Plot
- Faceplate Control of the Loop (Adjust Set Point, Controller Output, Mode and Commands)
**NOTE: Data Must Be Rich in Dynamic Information**

Data used for controller tuning must be rich in dynamic information. Data rich in dynamic information is typically generated using bump tests. Bump tests can be performed in manual mode using a step, pulse, doublet or similar bump of the Output, or in automatic mode using a step, pulse, doublet or similar bump of the Set Point.

The bump tests should be performed near where the Set Point will be during normal operation. The bump test should force the Measured Variable far enough and fast enough such that the bump response event dominates the random noise evident in the Measured Variable signal.

If these ideas are not familiar, users are strongly encouraged to take refresher training, either as self-study or in an instructor-led workshop, so they understand what constitutes “good” data before using LOOP-PRO TUNER or any other controller tuning package.

*Self-help information is available at: http://www.controlguru.com/*
Export Data

With data collection in progress, Export Data enables the user to select a portion of the trended process data with the mouse cursor and export it to a text file.

- To select the data of interest, Click Export Data, then click and hold down the left mouse key and drag a “box” around the portion of the trend data of interest.

- The data associated with the selected (or “boxed”) portion of the plot will be automatically copied to a text file. The user may then choose to rename the file, save the data to disk, or perform all other functions available for any Windows text file.

Track Values

With data collection in progress, Track Values enables the user to mouse over the process data displayed in the trend plot and read specific point-values of data.

- The trend plot below shows that as the pointer is moved across the trend plot, the complete set of Process Variable, Set Point and Controller Output values for a specific point in time is displayed at the bottom of the plot. The zoom display shown below is not an actual feature of the software, but is used to better show the values as they are displayed at the bottom of the trend plot.
Trend Plot Display History

- The History display selection enables users to choose how much history to show on the real-time trend plot.

- The Preset values will show the last 5, 15, 60 minutes of process data with a single click.

- The “Custom…” selection allows users to specify any amount between 1 minute and 48 hours.

- The Maximum amount of data that LOOP-PRO TUNER can store and display is 48 hours. After 48 hours has elapsed, LOOP-PRO TUNER will start to clear out the oldest data (First-In-First-Out).

Plot Options

- The Plot Options allows the user to change the titles, fonts, colors and related plot features of a trend display.

- Note that changes during a session will NOT be permanent and will return to the default settings upon exiting the LOOP-PRO TUNER session.
Chapter 6 Tab Step 3: Fit Model

Success in controller tuning depends on success in model fitting. Model fitting requires data rich in dynamic information as generated with bump tests. Bump tests can be performed in manual by bumping the Controller Output, or in automatic mode by bumping the Set Point.

The bump test should cause an Output change that drives the Measured Variable far enough and fast enough such that the response dominates the random noise in the Measured Variable signal.

When performing the model fitting step, it is best to zoom in on the sections of process data that include Measured Variable dynamics driven primarily by the Output.

Default Model Fitting

- By default, LOOP-PRO TUNER will fit a model to the entire data set moved forward upon completion of Step 1 - Collect Loop Data.
Change Model Type

- The two model forms supported by LOOP-PRO TUNER include the Non-Integrating (also called the self-regulating) form, and the Integrating (also called the non-self-regulating) form.

- Use the Toolbar Button as shown below to switch between the model types.

- The plots below show idealized trends of the Process Variable responding to a step bump of the Controller Output while in manual mode. Few real processes will match these ideal responses. The user must be knowledgeable enough to choose the correct model form for a particular application.

Non-Integrating

Flow, Pressure Temperature, Concentration, pH

Integrating

Level, Batch Temperature

A characteristic behavior of a non-integrating process is that the Process Variable will naturally self-regulate to a steady state balance point after the Controller Output step as shown in the trend plot to the left.

For an integrating process, the process does not have a natural balance point. As shown in the trend plot to the right, the Process Variable will move in one direction or the other when bumped and will continue until further actions correct the process excursion.
**Autofit Button**

- By default, the Autofit Button is enabled and this is the recommended setting. Click the icon to turn Autofit off and disable the function.

- If the Autofit button is enabled, a new model will be automatically calculated and displayed whenever the model cropping bars are moved.
Model Fit Status Icon

- The *LOOP-PRO TUNER* application will display one of three Status Icons after a model fit.

- The three possible Status Icons and the meaning associated with each include:

  - **Fit Terminated with an Error**
    - This icon will be shown if an error is detected during the model fit or if *LOOP-PRO TUNER* is unable to converge on a model. For example: If the Controller Output is Constant within the Data Range.

  - **Fit Model to Window Data**
    - This icon will appear if the "Autofit" icon is disabled, and the user has moved the windowing bars and *LOOP-PRO TUNER* is ready to fit a new model. To fit a new model, simply click this icon. This icon will also appear if the user enters or adjusts the model parameters from the parameters that *LOOP-PRO TUNER* calculated.

  - **Model was fit Successfully**
    - This icon appears after *LOOP-PRO TUNER* has successfully completed its model fitting process.
Plot Options

- The Plot Options allows the user to change the titles, fonts, colors and related plot features of a trend display.

- Note that changes during a session will NOT be permanent and will return to the default settings upon exiting the Loop-Pro Tuner session.

Show Set Point

- Checking “Show Set Point” will add the Set Point data to the process trend plot.

- This can be helpful, for example, if the user seeks to locate where the SP moves take place when analyzing automatic mode (closed loop) data.
Update Trend

- If *Loop-Pro Tuner* is Online with the process, it will be constantly collecting process data in the background.

- If the user wishes to add additional data to the Model Fit Plot, click the “Update Trend” button. This will update the trend plot to contain all the data up to the current time.

Using the Cropping Bars

- The vertical Cropping Bars can be moved to “window in” on particular data.

- To move the Cropping Bars, click and drag them to a new location.

- If Autofit is enabled, *Loop-Pro Tuner* will automatically fit a new process model to the windowed data.
Combining Multiple Models

- When a model is fit to a window of data, the model parameters will be displayed right below the trend plot as shown below.

- By clicking the plus sign (“+”) on the next line, the user can move to a new window of data and add an additional model and parameters to a growing list.

- After clicking the plus sign (“+”), move the Cropping Bars to any section of process data and if Autofit is enabled, LOOP-PRO TUNER will automatically fit a new process model to the new window of data.
The Composite Model shown above the trend plot of the Fit Model Tab is the numerical average of each of the select models displayed below the trend plot.
The Model Parameters

- Each row below the model fit trend plot lists the model parameters associated with a window of data.
- To switch between models, click anywhere within the row of model parameters.

\[ R^2 \] measures the “Goodness of Fit”. 
\[ R^2 = 1.0 \text{ is a perfect model fit.} \]
Try to keep the \( R^2 > 0.8 \)
Adding/Removing a Model From the Composite

- To completely delete a model from the list, click the minus sign ("–") located on the left side of the row.
- To temporarily remove a model from the composite average, uncheck the box located on the left side of the row.

Model Magnifying Glass

- The magnifying glass to the left of the model parameters enables the user to zoom in on the portion of the trend plot associated with that particular model fit.
Model Parameter Warnings

- If LOOP-PRO TUNER detects a problem with the model fit, it will display an exclamation mark next to the parameter of concern.
- These errors will also cause the background color of the composite model to change color, depending on the severity of the problem.
  - RED – Major Problem, LOOP-PRO TUNER will not proceed to the next step (Tuning) until this problem is cleared
  - ORANGE – Minor Problem, LOOP-PRO TUNER will proceed to the next step, but you should beware of the model fit
  - YELLOW – Minor Warning, LOOP-PRO TUNER will proceed to the next step

- RED – Example Major Problem

<table>
<thead>
<tr>
<th>Composite Model</th>
<th>Gain, K</th>
<th>t (sec)</th>
<th>θ (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-10.15</td>
<td>10.11</td>
<td>351</td>
</tr>
</tbody>
</table>

**Sign of Gain does not match action of controller:**
The current controller action is "SP - PV". It is very unlikely that in this situation the Process Gain (-10.15) would be Negative.

**Solution:**
Please check the process data for a disturbance or choose a different section of data for analysis.
- ORANGE – Example Minor Problem

<table>
<thead>
<tr>
<th>τ (sec)</th>
<th>θ (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2307</td>
<td>1.421</td>
</tr>
</tbody>
</table>

**Time Constant is Suspiciously Small**

The time constant computed from the model fit is smaller than 1 second. This OPC Server is limited to a capture rate of 1 second.

This fit may be suspect. Please consider whether:

1. Data was collected long enough to allow the dynamics of the process to be properly captured
2. Make sure the step change made to the process was “sharp enough” to show a clear response on the controller output.
3. This data is for a very fast loop which may require special data acquisition to properly model its dynamics.
• YELLOW – Example Minor Warning

![Image](image_url)

Accepting the Model Fit

• After the user has compared the model(s) to the data and is comfortable that the model reasonably describes the data, then either click on the Tune Tab or use the Right Arrow to move to the Tune step.
Chapter 7 Tab Step 4: Tune

The Tune Tab provides tools to tune the user’s controller based on the model fit from Tab Step 3. As shown below has Tune screen function capabilities to:

- Adjust the controller response
- Interpret and use the robustness plot and the PID response statistics
- Switch to the different PID forms
- View a historical tuning log
New and Existing Tuning Values

- The *LOOP-PRO TUNER* computed tuning values are highlighted below. They are based on the Composite Model parameters from Tab Step 3 and the particular controller form selected by the user.

- The existing controller form and tuning parameters as found from the PID Block when *LOOP-PRO TUNER* was launched at the start of this session are highlighted below.
Predicted Statistics and Report Notes

- Highlighted are the PID Response Statistics, including values for Stability, Settling Time, Overshoot, Decay, and Output Travel as predicted based on the existing and new controller forms and tuning values.

These are the predicted PID Response Statistics, including values for Stability, Settling Time, Overshoot, Decay, and CO Travel.

- The window at the bottom left is used to add user notes and comments during the loop tuning process. These notes will appear in the Tab Step 6 PDF report.

Use this area to add your own notes and comments to the loop tuning process. These will appear in the Tab Step 6 PDF report.
Predicted Response and Robust Stability

- The trend plot shows the predicted response to a “1% of span set point change.” Thus, the user can visually evaluate performance of the new controller and tuning values compared to the existing (as-found) controller and tuning values.

- The Stability Plot displays the robust stability of the existing vs. new controllers. When more area is covered in the Stability Plot, the controller will be stable under a broader range of process conditions. Experimentation will reveal that the trade-off for increased robustness is a more conservative (slowly responding) controller.
Switching Controller Form and Viewing Tuning Log

- The toolbar on the upper left of the screen enable the user to view a Historical Tuning Log of past controller and tuning changes, and to see which PID Block Type is selected.

Changing Controller Mode

- Use the Drop-Down Menu next to the Slide Bar to change the controller from a PI to a full-mode PID Controller or a simple P-Only Controller.
Exploring Tuning Options

- The default tuning values presented by Loop-Pro Tuner for any controller form are those that provide moderate control action.

- In certain applications, these default tuning values may be considered too conservative (or sluggish in taking corrective action), and in other applications, these default tunings may be considered too aggressive (or overly active in taking corrective action).

- The user can adjust the controller from the default moderate values by moving the slider bar highlighted below.

- The tuning values can be made more aggressive (more active or aggressive control action) by moving the slider bar to the left, or more conservative (more conservative or sluggish control action) by moving the slider bar to the right.

Moving the slider bar to the left will make the controller settings more aggressive.
Slider Bar and Response Trend Plot

- As the Slider Bar is moved left or right to make the controller more or less aggressive (or active), the response trend plot will automatically update with a new predicted set point response.

- The predicted response from the existing controller will also be displayed for a side-by-side comparison in the response trend plot.

- When The user is deciding on the “best tuning values,” keep it **SIMPLE:**
  
  - **Safety:** What is the worst thing that can happen if this control loop fails? When defining your control objective, the safety considerations are paramount to all others.
  
  - **Impact:** Where does this control loop fit in the overall process diagram. Where do the process disturbances come from? When this process changes, who gets impacted by it?
  
  - **Management:** If management desires a certain type of performance, it is your job to match that objective or explain in a logical manner why that type of control is not possible.
  
  - **Profit:** What are the primary economics factors associated with this loop?
  
  - **Longevity:** How often is this loop the ‘culprit’ when diagnosing process performance? Keep the control strategy simple, the more complicated the strategy, the more likely it will fail.
  
  - **Equipment:** Process equipment is expensive, its components are expensive, and as such, should be included when formulating your control objective.
The Stability Plot

- The Stability Factor is shown in the first column of the Response Statistic chart.
- The Stability Factor provides a measure for the likelihood that the controller, when implemented with the New or Existing tuning values, will remain stable even as the character and behavior of the process being controlled itself changes.

<table>
<thead>
<tr>
<th>Stability Factor</th>
<th>Setting Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>1.91</td>
</tr>
<tr>
<td>Existing</td>
<td>3.44</td>
</tr>
</tbody>
</table>

- A larger Stability Factor indicates a controller that is more likely to remain stable as process conditions change. Thus, it might be considered a safer choice.
- The trade-off for achieving large Stability Factor values is that the controller performance becomes increasingly conservative (or sluggish in taking corrective action). A sluggish controller does not take corrective action quickly, sometimes permitting unacceptable drift, and this is a different but important problem in some applications.
- When tuning, it is good to seek a balance between having a sufficiently aggressive (or active) controller that will maintain the PV at the SV while also seeking tuning values that will permit the controller to remain stable if process conditions change.
- A “rule of thumb” is to design for a stability factor of 2 to 2.5 for Self-Regulating Processes when using the PI controller mode. Remember that every rule has exceptions. The user is challenged to know what those exceptions are for his or her process.
Settling Time

- The Settling Time is the amount of time it takes for the Process Variable to return to within ± 5% of the SP after a disturbance or set point change.

- A shorter settling time is generally considered better, as this means the controller has achieved its goal of having Process Variable equal the SP.

![Settling Time Diagram](image)

- As shown in the response plot below, the Measured Variable travels a path as before settles. This can be a crisp and responsive, highly oscillatory, or slow and sluggish pathway.

![Response Plot](image)

- The Settling Time is one of several important factors to consider when tuning a controller.
**Overshoot and Decay Ratio**

- Percent Overshoot and Decay Ratio quantify how quickly oscillations dampen out.

![PID Response Statistics Table](image)

- The metrics are computed as:

  \[
  \text{Percent Overshoot} = \frac{B}{A} \times 100\%
  \]

  \[
  \text{Decay Ratio} = \frac{C}{B}
  \]

- With *Loop-Pro Tuner*, it is often possible to tune the controller so it responds quickly but does not overshoot the set-point. In the chart above, this would correspond to a value of \( B=C=0 \). And in these cases, the Percent Overshoot = Decay Ratio = 0.

**Controller Output (CO) Travel**

- As the amount of movement in the Output increases or decreases during the predicted set point response, the amount of wear on the valve or other final control element will similarly increase or decrease, impacting its life.
View Tuning Log

- Clicking the “View Tuning Log” will bring up a window that displays final tuning changes made within *LOOP-PRO TUNER*

- **NOTE:** These tuning values are recalled based upon the “Saved Sessions” that are done at the end of the *LOOP-PRO TUNER* Tuning Session

Completing the Tuning Design

- Once you have design your controller and tuning values to give you your desired performance, click the “Right Arrow” to move to Tab Step 4 - Implement Tunings.
Chapter 8 Tab Step 5: Implement Tunings

With controller tuning values available from the Tune Tab, the user can choose to implement those values using the Implement Tunings Tab.

The Implement Tunings Tab can also be used to restore the original tuning values if the user decides not to proceed with the updated LOOP-PRO TUNER values.

- LOOP-PRO TUNER has the capability to write the tuning values directly to the PLC.
- Click on “Send Recommended Tunings” if the user chooses to proceed with implementation.
- Click on “Send Original Tunings” if the user chooses to maintain tuning at the current values.
To Implement Recommended tuning values, the user will be presented a confirmation screen.

- The user must specifically type in the word “Yes” to implement the new values. The tuning values will not otherwise move out to the PLC.
- This confirmation step ensures that tuning value updating is a deliberate and intentional act by the user and not an accident of software design.
- Even after clicking Implement Recommended, the user may click Cancel to halt the implementation process. At that point, the user may choose to retain or restore original tuning values, or after verification, again click Implement Recommended to move tuning values out to the PLC.
Chapter 9 Tab Step 6: Report

The user may use the Report Tab create a PDF Report that documents the complete tuning session as a hard copy document that can be printed and/or saved to disk.

- The “Save Report” button on the toolbar generates a PDF Report and automatically saves it to the “Save Sessions” Folder in a subfolder called “PDF”

NOTE: To Print a PDF Report, you must first Save the PDF and then print from Acrobat.
- The PDF report stores all the process data, relevant controller setting information and design plots that were collected during this particular *LOOP-PRO TUNER* session.

- You can save the session at any time using the Save Disk Icon located on the tool bar

- *LOOP-PRO TUNER* will ask if the user wishes to save the tuning session when the Right Arrow is clicked on the Final Step

![Image of Loop-Pro Tuner interface](image)

**NOTE:** You can also save the Session at anytime during the tuning process by clicking the “Save Disk” Icon located on the top of the Toolbar.