Watlow TRU-TUNE+™

Adaptive Tuning and Control of PID Loops

SCOPE

This white paper provides insight and guidance on the use of Watlow's TRU-TUNE+™ adaptive control algorithm and is intended as a supplement to the information found in the *CPC400 User's Guide*.

ADAPTIVE TUNING

Watlow's TRU-TUNE+™ adaptive tuning and control algorithm:

- Makes the optimizing of PID control loops virtually effortless.
- Is out-of-the-box capable of providing excellent tuning results with little operator setup. Typically only sensor type, output signal type, and set point parameters must be set by the operator prior to commissioning the loop.
- Tunes both heating and cooling PID control parameters to highly precise values.
- Is self-correcting and will not over-tune the PID parameters.
- Is capable of tuning temperature control systems to a control width of ±0.1° F depending on the actual process' capacity for control.
- Works well with processes over a broad range of response speeds. The algorithm can detect and automatically adjust to any process speed that is required. In the CPC408 controller with a scan rate of 333 milliseconds, it has worked well on processes with response speeds from 5° F/minute to 300° F/second.
- Provides overshoot reduction of the process variable when going to set point.

CPC400 CONTROL MODES

The mode setting in a controller such as the CPC400 determines the output's response to a change in the process variable relative to the set point. The CPC400 with TRU-TUNE+™ has four control modes: *Manual Mode*, *Auto Mode*, *Tune Mode*, and *Adaptive Mode.*

MANUAL MODE—In this mode the controller's heat and/or cool output levels are manually set by the operator. This mode is used to turn the controller off (manual 0%), or to provide a fixed output level when the sensor is defective, or to check final control element devices. This mode is indicated as, "man" on the CPC400's display.

AUTO MODE—In this mode the controller's heat and/or cool output levels are automatically adjusted by the controller's PID algorithm. The PID parameters are fixed having been manually entered or set by tuning in one of the other modes. Auto mode is indicated as, "auto", "heat" or "cool" on the CPC400's display depending on which outputs are enabled.

TUNE MODE—This mode is used when first tuning a controller in an application. It may also be used whenever re-tuning is required such as when installing the controller in a new process. Sometimes it may be desirable to re-tune a loop to reduce the amount of time to reach set point after a controller or process hardware change is made during maintenance or repair. The Tune mode is indicated by the blinking word, "tune" on the CPC400's display.

ADAPTIVE MODE—This is the TRU-TUNE+™ mode for continuous tuning of heating and/or cooling PID parameters in order to achieve and maintain the tightest control possible. This mode is indicated by "adpt", "HtAd" (when heating in an application with both heat and cool) or "ClAd" (when cooling in a heat-cool application) on the CPC400's display depending on which outputs are enabled. The mode indication may or may not blink. It blinks when the process variable is outside the *tuning band* (see below).

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TUNING A LOOP

The preferred and quickest method for tuning a loop is to use the Tune mode to establish initial control settings and continue with the Adaptive mode to fine tune the settings. Setting a loop's control mode to Tune starts this two-step tuning function. First a predictive tune determines initial, rough settings for the PID parameters. Second the loop automatically switches to the Adaptive mode which fine tunes the PID parameters. This function can be used for heat-only, heat and cool, and cool-only PID control systems. Even if the first step does not complete successfully, default PID values are loaded and the process continues to the second step. After completing the two-step tuning, the controller may be started from an off state by selecting the Adaptive mode directly.

Helpful Hint #1: The rough PID parameters set in the first step assist the TRU-TUNE+™ adaptive control algorithm in tuning to set point as quickly as possible. With a new controller starting TRU-TUNE+™ by setting the control mode directly to Adaptive mode uses the factory default values for the PID starting point. This method may take longer to get good PID parameters with a slow process than the two-step tuning procedure described above.

Helpful Hint #2: Set the *Power up loop mode* parameter on the *Global* menu to "from memory" so that upon power up the CPC400 will resume control of each loop in the control mode that was active at the time the power was turned off.

Helpful Hint #3: It may be desirable to stop tuning the PID parameters in some applications such as batch processes where the load changes, but the controller needs to be tuned for only one load condition. Once the process variable has been at set point for a suitable period of time (30 minutes for a fast process or 2 hours for a slower process) and if no further tuning of the PID parameters is desired or needed, the control mode may be switched to the Auto mode. The tuned PID parameters are retained unless changed by the operator or the controller is put back in the Tune or Adaptive mode.

Watch Out #1: Only operating the controller in the adaptive mode allows it to automatically adjust to load changes and compensate for differing control characteristics at various set points for processes that are not entirely linear.

TRU-TUNE+™ PARAMETERS

Parameters for adjusting the TRU-TUNE+™ adaptive algorithm are located on the CPC400's Control Menu. While the majority of processes will tune automatically with no operator intervention required, some processes may not control as desired with the automatically calculated or default values. In such cases it is possible to adjust these parameters.

TUNE BAND—When the process variable is within this band around the set point, TRU-TUNE+™ adaptively tunes the PID parameters. When the process variable is outside this band, no tuning is performed. This prevents undesirable de-tuning of the PID parameters when, for example, the heaters are turned off but the controller is still on. The Tune Band is set automatically by the TRU-TUNE+™ algorithm and normally should not need to be manually adjusted.

A very fast process, one with a response time, for example, faster then 300° F per second, might need a manual adjustment to the Tune Band. This problem may be indicated by continuous flashing of the "adpt" control mode indicator on the CPC400's front panel display. In this case the process variable and control output would most likely cycle widely. The solution would be to set the Tune Band parameter to 300. The process variable should settle down and come into stable control at set point. Slower processes should not need any manual adjustment of this parameter.

Caution! An incorrect manual setting of the Tune Band in slower processes will cause incorrect tuning of the PID parameters. Use of automatic setting by TRU-TUNE+™ is highly recommended.

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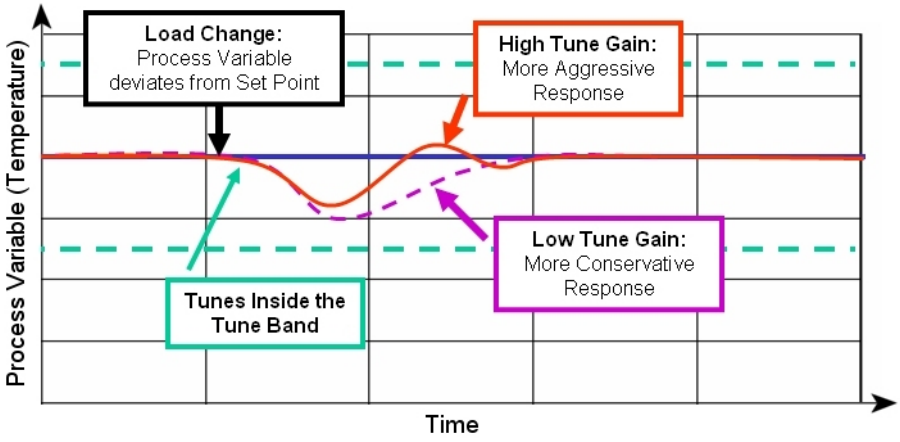
TUNE GAIN—This parameter determines how responsive the TRU-TUNE+™ algorithm will be to deviations from set point and set point changes. As this responsiveness is actually a user preference dependant upon the relative importance of preventing overshoot and minimizing time-to-set-point, this parameter is not set automatically and may be changed by the operator. There are six settings ranging from 1 with the least aggressive response and least potential overshoot (lowest gain) to 6 with the most aggressive response and most potential for overshoot (highest gain). The default setting, 3, is recommended for loops with thermocouple feedback and moderate response and overshoot potential.

Table 1. Recommended settings for Tune Gain by application

Setting	System or Process Type	Gain
1	Process Signal (4-20ma, 0-10V)	Low
2	Process Signal/RTD	↑
3	Thermocouple	Moderate
4	Radiant Heaters	
5	TC with AC noise	↓
6	TC with high AC noise	High

The settings in the table are suggested for particular types of processes. An operator may try other settings to achieve the desired process response. High gain yields a fast response, but may have some cycling after a set point change. Low gain yields a smoother response, but may take longer to return to the set point. Careful selection of this parameter setting will provide the most appropriate response for the process. Use of the recommended gain setting for the input type will normally provide excellent control in most processes. The figure illustrates the effects of adjusting the Tune Gain.

Figure 1. The effect of Tune Gain on recovery from a load change



OVERSHOOT REDUCTION

Other PID controllers depend upon the derivative part of PID control to provide for reducing the amount the process variable overshoots the set point upon start up or a large set point change. This works to a limited degree but introduces instability into the controller output signal. This instability increases as an operator attempts to suppress overshoot by increasing the derivative setting.

The TRU-TUNE+™ advanced PID control algorithm provides an overshoot reduction feature distinct from the derivative part of PID control. This allows for overshoot reduction without introducing the instability inevitable with

over-active derivative control. With TRU-TUNE+™ control the output level is smoothly reduced as the process variable reaches set point.

The amount of overshoot reduction may be adjusted by the operator. The range of reduction is from 0% (no overshoot reduction) to 100% (maximum overshoot reduction). The default value is 50%. As this is process and preference dependent the parameter may and most likely will need to be set by the operator.

If upon startup the process variable overshoots the set point, the Overshoot Reduction setting should be increased to at least 75%. A setting of 100% allows the full reduction to be applied. If upon startup the process variable undershoots the set point, Overshoot Reduction setting should be decreased. A suggested value to try would be 25%. Most likely a value of 0% would never be used nor would it be recommended. The value of the overshoot reduction can be adjusted until the response obtained, i.e. small over or under shoot of the set point.

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