# Temperature Controllers:  Setting PID Gains for the 6100 and 3700

One of the most difficult to understand and confusing processes when working with temperature control of laser diode systems is the choice of the PID gains to be used.  The goal of this paper is to help clarify this process with respect to Newport Corporation's temperature controllers.  For a more detailed presentation on the theory of determining PID settings please see the ILX Lightwave Group's Application Note #20.

## What is PID?

Temperature control in laser diode applications can be as simple as maintaining an approximately constant temperature to within several degrees of room temperature when tight control of laser diode parameters, such as wavelength is not critical.  Or, to within fractions of a degree when much tighter control is required.

Tighter control of the temperature requires the ability to adjust the PID gains.

The term PID comes from the proportional (P), integral (I), and derivative (D) gain factors that are the basis of the control loop calculation.

$$(K_p \cdot e) + K_i \int (e\,dt) + K_d \; de/dt$$

where,

$K_p$ = proportional gain factor
$K_i$ =  integral gain factor
$K_d$ = derivative gain factor
$e$ = instantaneous following error

Tuning the PID means to change these three gain factors to obtain a certain system response.  This is a difficult task to achieve without some understanding of the behavior of a closed loop system.

## The Proportional Term

The proportional term, $K_p \cdot e$, is proportional to the temperature error.  For a temperature controller that has only the ability to set $K_p$ (where $K_d = K_i = 0$), the resulting temperature will not always settle at the target (set point) temperature, but will have a tendency to oscillate around the set point.

If the gain value is set too high, the oscillation will have a long damping time constant.  If the gain is set too low, it will take a long time for the temperature to reach the set point.

Proportional control with constant gain will cause the temperature to settle to a point offset from the actual set point, leaving a non-zero error known as the steady state error.

If the steady state error, or oscillations about the set point fall within an acceptable tolerance range for the user's application, adjustment of the proportional gain factor may be all that is needed. The integral and derivative terms can remain set to zero.


## The Integral Term

The contribution from the integral term, $K_i \int (e\,dt)$, is proportional to both the duration and magnitude of the error. The integral term is the sum of the instantaneous error over time and gives the accumulated error that should have been corrected for in the proportional term. It allows for the offset correction after the proportional effort has decayed and settled.

The integral term accelerates the movement of the temperature toward the set point, and decreases or eliminates the steady state error introduced from the proportional term.


## The Derivative Term

The derivative term contribution, $K_d\ de/dt$, is proportional to the change in error per unit time. This term provides one large, not necessarily precise, correction immediately after a change, in setpoint or load, in order to start reducing the error as quickly as possible.


## General Procedure for Manual Determination of PID Settings

Regardless of whether you are using one of Newport Corporation's 350B, 6100, or 3700 Temperature Controllers, an ILX model, or a third party system, the general procedure for manually tuning the PID settings will be the same. The procedure appears deceptively simple, but in reality it can take anywhere from a few minutes to several hours to find a setting that will work for a given system and temperature. Any changes to the system, or a change in the required temperature or temperature tolerance may require retuning the PID settings. For any one system or set of specifications there may be more than one combination of PID settings that will produce the required results. These settings are determined predominantly by trial and error. Ideally, multiple identical systems will operate at the same PID settings, however, since no two systems are exactly identical variations from one system to another are not uncommon.

One method for determining the values of the Proportional, Integral, and Differential terms is –

1.  Begin with the Proportional (P), Integral (I), and Derivative (D) terms all set to 0.

2.  Increase the Proportional term contribution slowly until the temperature contribution setting becomes unstable or begins to oscillate. The equilibrium temperature may not reach the chosen set point, but it may come close.

    If the $K_p$ contribution is too low, try increasing the Ite (output current). This will cause the Proportional contribution to rise more quickly and approach the temperature set point. If the Kp contribution rises too quickly and overshoots the temperature set point, consider decreasing the Ite supplied by the temperature controller.

    In some cases, depending upon the amount of temperature deviation acceptable for your application, the Proportional term setting may be all that is required.

    Be certain to take note of the Proportional setting for future reference.

There is some debate on whether the Integral (I) or Derivative (D) term should be adjusted next. All current Newport Corporation temperature controllers have three parameters, $K_p$, $K_i$, and $K_d$ available for PID adjustment. Older model 300-series controllers had only PI capability.

3.   Once the Proportional term has settled out there will be a difference between the set point temperature and the temperature achieved by the Proportional term. This is the steady state error. Increase the Integral (I) term contribution to decrease the steady state error and bring the achieved temperature to within acceptable tolerance for your requirements.

     If you are not able to reduce the steady state error to within your required tolerance, you may need to choose a different Proportional term and begin again.

4.   If reduction of the time required for the oscillations to damp and the temperature to settle is required, adjust the Derivative (D) contribution.

**Setting the PID**

**Manual Interface for 6100 and 3700**

Both the 6100 and 3700 temperature controller systems have the ability to set the PID manually through the front panel interface as well as remotely using the supplied software interface. We strongly recommend using the remote interface whenever possible, as the graphical interface can be very useful in selection of the PID parameters. The procedure for both controllers is similar.

To set the PID parameters through the front panel interface on the 6100 when the instrument is displaying the Measurement Screen, you will need to press the SETUP/ENTER button on the front panel.
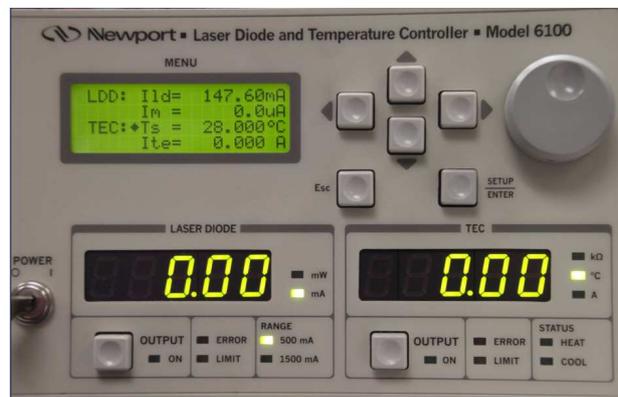
In the Menu window that appears select the Set TEC Params option using the up and down arrows on the front panel. Press the SETUP/ENTER button. This will take you to the Set Limits window.
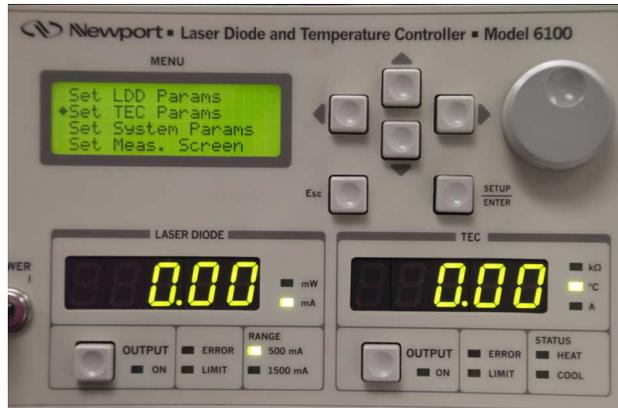


Use the arrow keys to select the Set PID Gains. Press the SETUP/ENTER button.



In the next window, use the arrow keys to select Customize Gain, and press the SETUP/ENTER button again.

Now you will see the $K_p$, $K_i$, $K_d$, and $I_l$ settings. Use the arrow keys to select the setting you wish to change.



Make changes using the arrow keys and dial as needed, by pressing the right or left arrow keys to get to the digit you wish to change, then use the up or down arrow (or dial) to make the change.

Press the ESC (Escape) button, followed by the up or down arrow keys to finish to finish with one parameter and move on to the next.

Press the SETUP/ENTER button to save the new settings. When completely finished setting parameters, press the ESC button as many times as needed to get back to the top level menu (Measurement Menu).

## Remote Interface for 6100 and 3700

The 6100 and 3700 temperature controllers use the same TEC Tuning software interface. The instructions for installation of the software are included with the controller. For this explanation we assume that the software has already been installed on your computer. Make certain that the controller is not connected to the computer when installing the software.

Once the software has been installed and your 6100 controller has been recognized you will see the TEC Tuning Utility window.
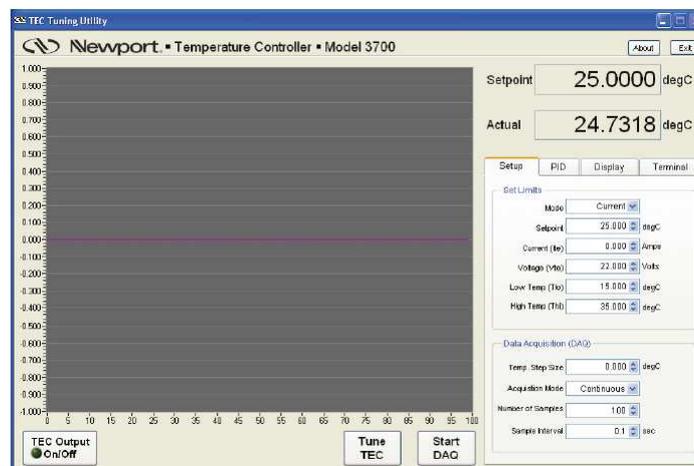
There are three menu tabs that must be configured before tuning your TEC. (Note, there is no auto tuning application available.) You will need to set your PID parameters by trial and error, but the visual graphical interface will make manual tuning through the remote interface much easier than attempting to tune without a visual interface.



Begin by setting up the Display tab. Here you can choose which parameters you would like to monitor. We suggest the Current, Voltage, Desired Temp (Set Point) and Actual Temp. The pre-assigned curve colors cannot be changed.

Then move on to the Setup Tab. This is where you will choose either constant Current or constant Power Mode, Setpoint (the temperature you would like to achieve), Ite (output current from the temperature controller to the TEC), compliance Voltage limit, High and Low temperature limits. You will also choose the Temperature step size, Continuous or Fixed Acquisition Mode, the number of samples to display on the screen, and the time interval between samples.

Next you will work with the PID tab. Here you will choose your $K_p$, $K_i$, and $K_d$ values. You can either type in the numbers you wish to use, or drag the lever up and down above each gain parameter.

Once you have entered your starting settings, click the "Save to Controller" button on the bottom of the PID tab. The current PID settings will be saved to bin 1 on the controller.

**Data Acquisition**

The software allows for two acquisition modes, as already stated—Continuous and Fixed. In Continuous mode, the software only keeps the latest samples in its data buffer. The data buffer is equal to the designated Number of Samples on the Setup Tab. The graphical interface display can only show a maximum number of data points that is equal to the Number of Samples. Once the buffer is full, the oldest point on the left of the graphical interface will be dropped and a new data point will be added on the right side of the screen on a rolling basis. Once a data point is dropped, it cannot be retrieved for later analysis. Data collection begins when the Start DAQ button is clicked (and then replaced by the Stop DAQ button). Data collection ends when the Stop DAQ button is pressed.

In Fixed Mode, the data buffer is limited to the specified Number of Samples on the Setup Tab. Once that number of samples is collected, and the graphical interface display is full, data collection will automatically cease. Again data collection starts by clicking on the Start DAQ button.

A progress bar below the graph is used to display the percentage of data acquisition completed.  If the number of samples and/or the sampling interval are changed while data acquisition is in progress, the software will clear all the previously acquired data and restart the DAQ process.

The TEC Output On/Off is used to toggle the TEC current output enable state.

The Tune TEC button commands the software to momentarily turn the TEC output off, setup the controller (mode, setpoint, limits, PID gains) based on the values specified in the Setup and PID Tabs, and also to turn the TEC output on.  The software will automatically start data acquisition if it has been previously stopped.

The plots shown on the graph can be turned on or off at any time without disrupting data collection by simply checking/unchecking the desired items on the Display Tab.
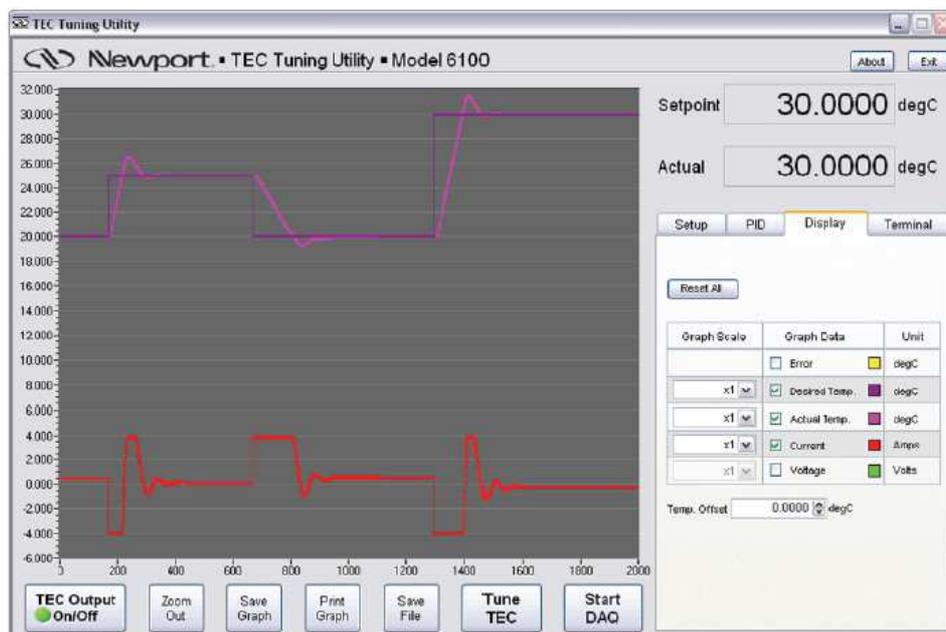


Once data acquisition has been completed, four new buttons will appear below the graphical display. These are the Zoom Out, Save Graph, Print Graph, and Save File buttons. Their functions are as follows.

**Zoom Out**

This button can be used to zoom into a portion of the graph by selecting a region around the desired portion.  Press the Zoom Out button to show the entire data collected.

## Save Graph

Press this button to save the graphical display as an image file.  The saved file will be in .jpg format and will contain the limit settings, DAQ settings, PID settings, as well as the graph.
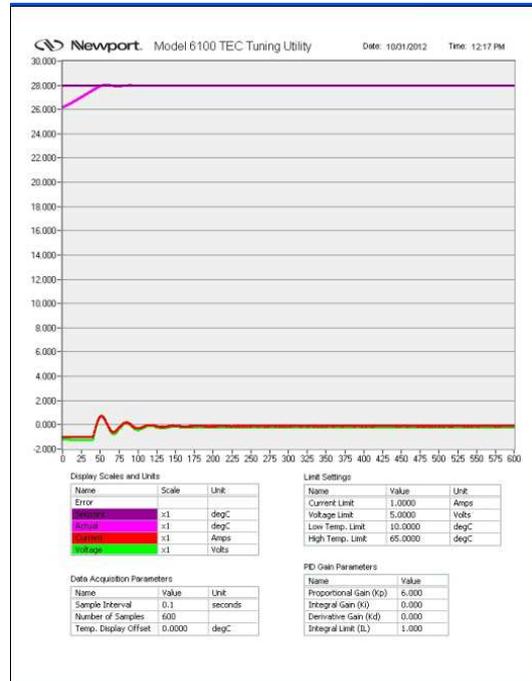


## Print Graph

This button is used to print the graph to your default printer.  The printed file will contain the same information as stated for the Save Graph button.

## Save File

Press this button to save the data collected to a text file. This file will contain the same information as stated for the Save Graph button as well.  All the information in this file is tab delimited.

In the upper right hand corner of the graphical interface window you will also find an **About** button. When this button is pressed you will see an image that contains the software and controller firmware versions.



For more information on configuring PID settings, or other questions on the 6100 and 3700 temperature controllers, please contact the Newport Technical Staff at tech@newport.com.