IntelliTune® vs. Conventional Autotune

INTELLITUNE: INTELLIGENT AUTOTUNE

Wavelength's proprietary IntelliTune® algorithm characterizes the TE / Sensor system's response to the TC LAB temperature controller and then ***automatically adjusts the PID control values as setpoint, tuning mode, or bias current are changed***.

- Run IntelliTune easily just off ambient and watch the TC LAB instrument adapt the PID settings to a much higher or lower setpoint.
- After a single characterization scan, explore either optimized Setpoint Response or Disturbance Rejection performance to see what tuning mode works best with your load.
- Try the system with or without the D term to see if noise reduces stability around the setpoint.

With IntelliTune's ability to recalculate control values, the temperature controller becomes a tool for speeding up experimental studies. Questions like "What are the best PID control coefficients to use?" can now become "Which mode achieves best stability fastest?" or "Should I use the D term or leave it out?". These are quickly and easily answered.

INTELLITUNE VS. CONVENTIONAL AUTOTUNE

We ran a series of tests that highlighted the differences between the TC10 LAB instrument with IntelliTune and three competing instruments that use various conventional autotune algorithms. With a single scan, IntelliTune was able to characterize a load and automatically adjust the PID coefficients for changes in mode, setpoint, or control parameters (such as turning the D term OFF). The instruments using the traditional autotune algorithm required recalibration for each scenario to achieve optimum performance.

Our first test was to establish a baseline by running a time-to-temperature test on the TC10 LAB instrument using the factory default settings. We then ran an IntelliTune scan to characterize the load. Next, a series of tests were run to demonstrate how the tuned TC10 LAB adjusted automatically to each change in mode, setpoint, and D coefficient. Performance criteria with Setpoint Response mode, Disturbance Rejection mode, and overdamped control loop were examined. Finally, we ran similar tests on the competing instruments.

TEST EQUIPMENT AND SET UP

The equipment we used includes:

- TC10 LAB instrument, firmware v. 1.5
- Thermoelectric load comprised of a 3 A thermoelectric (1" x 1"), a coldplate, a heatsink, and a 10kΩ thermistor embedded in the coldplate.
- Fan to cool the load heatsink
- Remote computer with a data logging program and the free LabVIEW® interface installed.

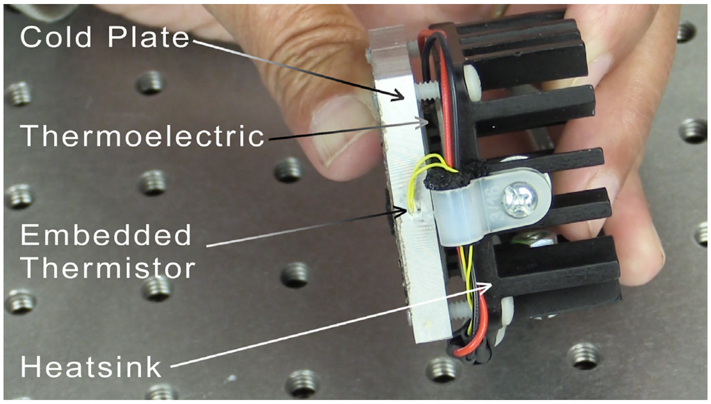

Figure 1. 3 A thermoelectric load with thermistor

We used the LabVIEW software to read the voltage limit and bias current settings, and the data logger program to record the test data.

Current limits were set to ±3 A, tolerance to ± 0.05ºC , and Power Supply voltage limit to 18 V. Temperature limits were set to -10°C and 55°C.

UNTUNED SYSTEM RESPONSE

Using factory default PID settings, and no active IntelliTune data stored (tune mode was set to Manual Tuning), we ran a time-to-temperature scan from just above ambient (19°C) to 15°C. We started with a setpoint of 23.5°C then changed the setpoint to 15°C. We measured the time from when the setpoint was changed to when the controller maintained the load temperature at 15°C ±0.05°C.

By setting the tolerance to 0.05°C, we could tell when the load had stabilized by looking for the STABLE (target) icon on the front panel of the TC10 LAB. We also determined the first crossing, when the actual temperature reached setpoint for the first time.

The following data was recorded:

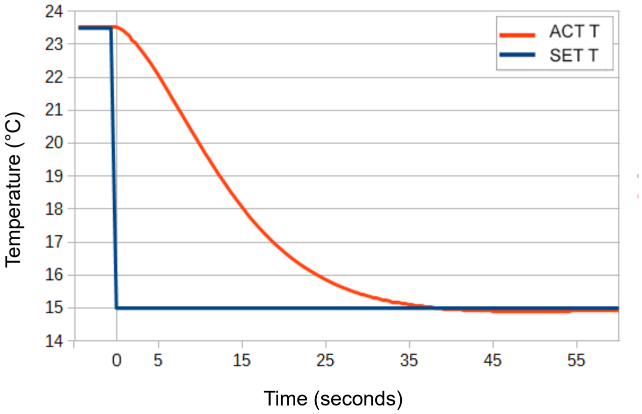

**Figure 2. Untuned system;
66.4 seconds to stable temperature
First crossing of setpoint: 38.4 seconds
P=12; I=0.10; D=OFF**

INTELLITUNE CHARACTERIZATION SCAN

To run a scan, the setpoint needs to be about 5°C off ambient and in a range where the sensor voltage will not trigger a bias current change. We chose 15°C because ambient was 19°C. At 15°C a 10kΩ thermistor is 15710 Ω, and with a 100 µA bias current produces 1.571 V. The scan raises the temperature setpoint a few degrees, so the sensor voltage will decrease, but stay above the 0.625 V minimum where a bias current change will be triggered.

We entered a setpoint of 15°C, and changed the Tune mode to Disturbance Rejection. The characterization results are independent of Tune mode, although IntelliTune cannot be run with Tune mode set to Manual. We left the D term OFF deliberately. We disabled output current, then pressed the note icon on the front panel, and the characterization started. It took about two minutes. The characterization would fail if we started the scan too close to the setpoint. The sensor temperature had to be 16.5ºC or higher to complete a scan.

After running IntelliTune, the PID coefficients changed to P = 14.081, I = 0.352, D = OFF. The Power Supply Voltage Limit was changed to 9V.

The PID values automatically change with setpoint and mode. The following are values IntelliTune generated at various setpoints during the testing:

Setpoint	P	I	D	Mode*
15ºC	8.214	0.685	OFF	SR
15ºC	14.081	0.352	OFF	DR
23.5º	12.287	1.024	OFF	SR
23.5º	21.064	0.527	OFF	DR
15ºC	14.081	1.408	1.594	SR
15ºC	22.295	0.929	2.120	DR
23.5º	21.064	2.107	2.385	SR
23.5º	33.352	1.390	3.172	DR
35ºC	35.187	3.519	3.984	SR
35ºC	55.713	2.322	5.299	DR

* SR = Setpoint Response, DR = Disturbance Rejection

Table 1. IntelliTune generated PID coefficients

For IntelliTune to use a D term, we changed the D value to anything non-zero and pressed the Tune mode to cycle through the modes and force IntelliTune to recalculate the best coefficients with a non-zero D term.


23.500 °C
Setpoint: 23.500 °C
P: 33.352 I: 1.390 D: 3.172
Tune mode: Disturbance Rejection

Figure 3. PID coefficients after D is turned on, IntelliTune automatically recalculates the optimal coefficients when tune mode is cycled

STEP RESPONSE OR TIME-TO-TEMPERATURE TESTS

When a system is scanned across temperature, fastest time to temperature is often desired. For example, scanning a laser in temperature to change the center wavelength allows laser diode manufacturers to characterize the laser quickly. Setpoint Response mode calculates PID coefficients to drive the system fastest to the first crossing of the setpoint. Disturbance Rejection mode PID coefficients force less overshoot, and the system achieves stable temperature more quickly.

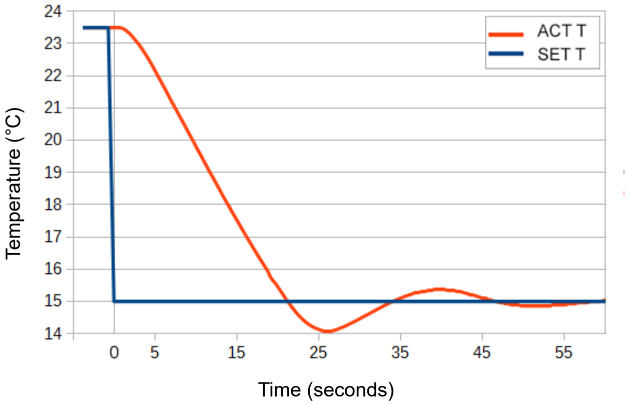

Figure 4. Tuned; 57.1 seconds to stable temperature
First crossing of setpoint: 21.3 seconds
P=8.214; I= 0.685; D=OFF
Setpoint Response

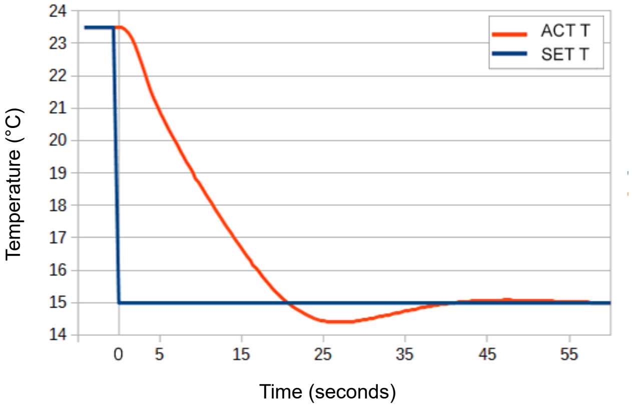

Figure 5. Tuned, 52.2 seconds to stable temperature
First crossing of setpoint: 20.7 seconds
P = 14.081; I = 0.352; D = OFF
Disturbance Rejection

The D term can amplify system noise, so we wanted to see its affect on time to temperature. To demonstrate the differences, we varied the tuning mode, turned the D term on and off, and repeated the 23.5°C to 15°C step response tests.

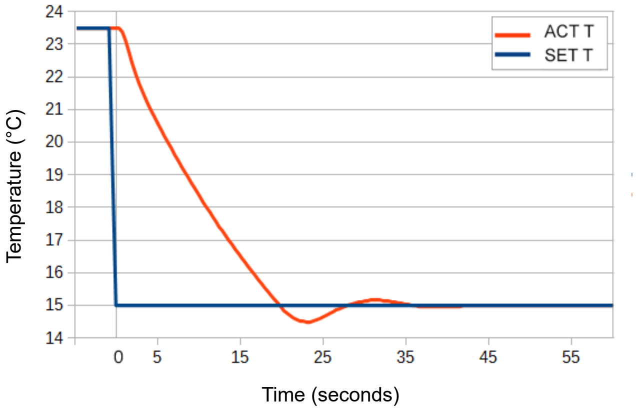

Figure 6. Tuned, 39.9 seconds to stable temperature
First crossing of setpoint: 19.9 seconds
P = 14.081; I = 1.408; D = 1.594
Setpoint Response

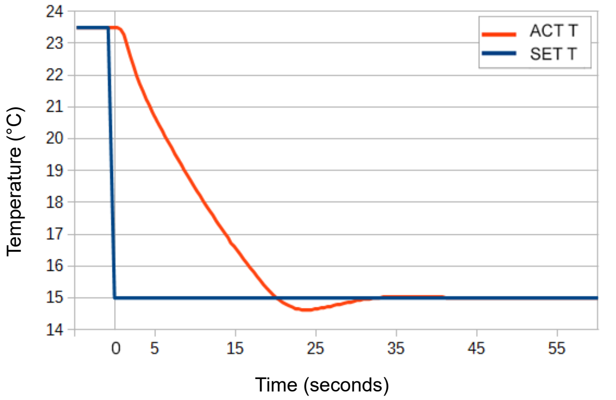

Figure 7. Tuned, 32.0 seconds to stable temperature
First crossing of setpoint: 20.9 seconds
P = 22.295; I = 0.929; D = 2.120
Disturbance Rejection

The first crossing times were around 20-21 seconds. The fastest time to first crossing was 19.9 seconds in Setpoint Response mode with all PID terms used, as shown in Figure 6. The time to setpoint ±0.05°C varied from 32.0 to 57.1 seconds. The fastest time to stable temperature was 32.0 seconds with Disturbance Rejection and all PID terms used, as shown in Figure 7. For this load, a Setpoint Response tuned system causes a second overshoot out of tolerance, delaying arrival at stable temperature.

Eliminating the D term significantly increased overshoot and extended time to temperature. The D term roughly acts as a brake to offset the accelerator (PGAIN).

There are other strategies Wavelength often suggests to reduce time to temperature. The first strategy is to reduce the current limit. Sometimes this reduces the initial overshoot and shortens time to temperature. For this test, we set limits to ±2A.

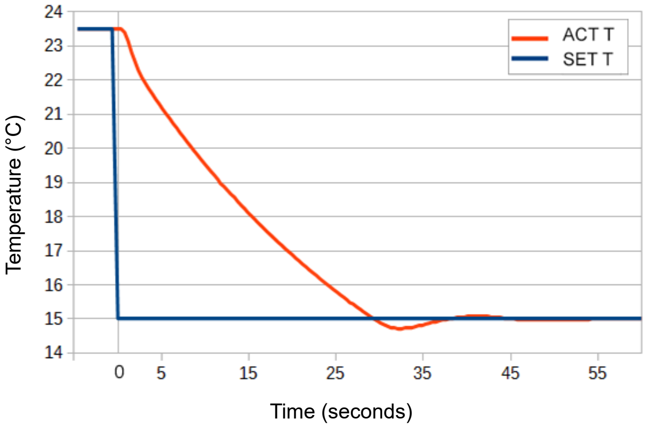

Figure 8. Tuned, 43.6 seconds
First crossing of setpoint: 29.7 seconds
P = 14.081; I = 1.408; D = 1.594
Setpoint Response

Using the PID coefficients in Step Resonse mode, the overshoot was almost a quarter degree less, first crossing was 10 seconds later, and time to stability was 3.7 seconds longer.

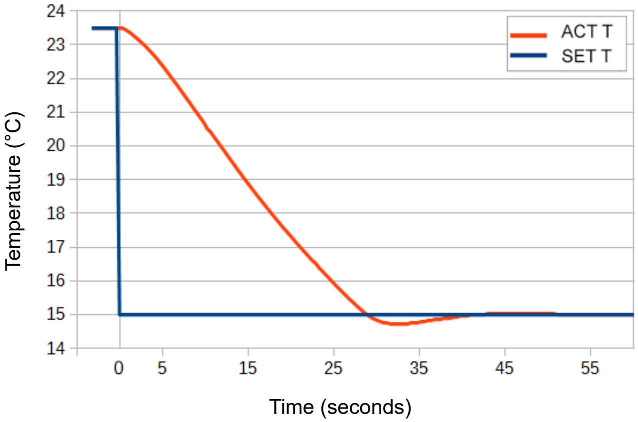

Figure 9. Tuned, 40.2 seconds
First crossing of setpoint: 29.2 seconds
P = 22.295; I = 0.929; D = 2.120
Disturbance Rejection

Using the PID coefficients calculated in Disturbance Rejection mode, the overshoot was decreased by about 0.1°C. First crossing and time to stable temperature were extended about 9 seconds each.

For this load, decreasing the current limit extended both the first crossing and the time to stable temperature marks. It is a strategy to consider for larger loads or larger temperature differentials. We returned the current limits to ±3A for the remainder of the testing.

A second strategy to consider is to push the control system to a point where it is over-damped, where any overshoot is within the tolerance parameter. We manually iterated the P and D terms by factors ranging from 1.89 to 2.1 to find this point. We put the TC10 LAB into Manual Tuning mode and forced PID coefficients of 46.820, 0.929, and 4.452 (2.1 times the P and D coefficients in Disturbance Rejection mode at 15ºC). The following response was observed.

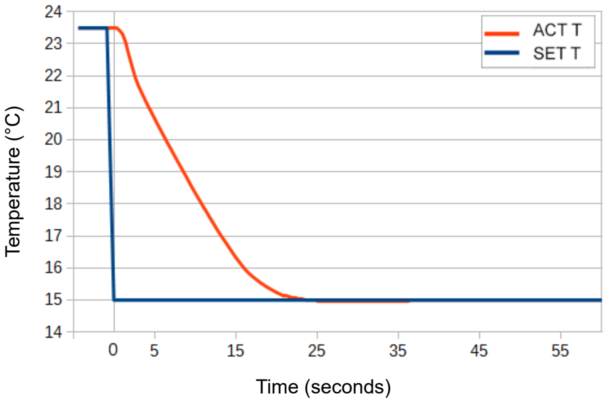

Figure 10. Manual Tuning, 22.8 seconds
First crossing of setpoint: 24.0 seconds
P = 46.820; I = 0.929; D = 4.452

The time to first crossing increased from 19.9 seconds (Fig. 6) to 24.0 seconds (Fig. 10). Because there was no overshoot, the temperature was in tolerance at 22.8 seconds, instead of 32.0 seconds (Fig. 7).

In some instances, overdamping the system sacrifices steady state performance and stability is not as good. For the TC10 LAB and this load, stability in Disturbance Rejection mode or overdamped mode was comparable.

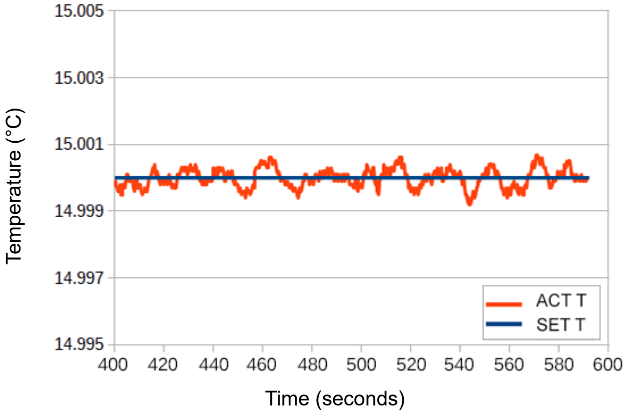

Figure 11. Disturbance Rejection mode: Stability was 1.27mK (Three standard deviations over 1500 seconds).

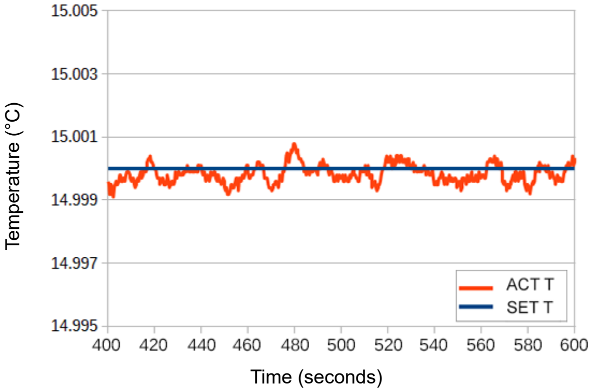

Figure 12. Overdamped: Stability was 1.24mK (Three standard deviations over 1500 seconds).

DISTURBANCE REJECTION TESTS

When a temperature controlled system includes a variable active load (like a pulsing laser diode) or experiences ambient temperature fluctuations (like an opening and closing door), keeping the system at stable temperature can be challenging. Under these conditions, Disturbance Rejection mode is usually recommended. We compared the response of Disturbance Rejection and Setpoint Response modes with or without a D term, and we demonstrated the response of an overdamped system.

To simulate how the system responds to disturbances (e.g. active heating of a pulsing laser, ambient temperature fluctuations), we introduced freeze spray to cool the coldplate where the thermistor is embedded. We dropped the actual thermistor temperature about a degree and measured how quickly the temperature returned to the setpoint ± tolerance. The absolute times vary with the lowest temperature reached, but the data demonstrated the impact of a disturbance and the system response.

Without running another IntelliTune, we varied Tuning mode, turned the D term on and off, and did the test from a 23.5°C setpoint. We measured the time to return to temperature from the lowest temperature to when the controller maintained load temperature at 23.5°C, ± 0.05°C.

* Caption details data for this disturbance

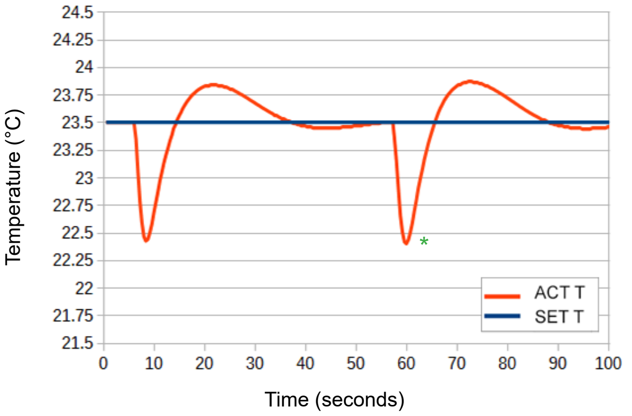

Figure 13. Tuned, 26.6 second recovery
First crossing of setpoint: 6.1 seconds
P = 21.064; I = 0.527; D = OFF
Lowest Temp: 22.43ºC
Disturbance Rejection

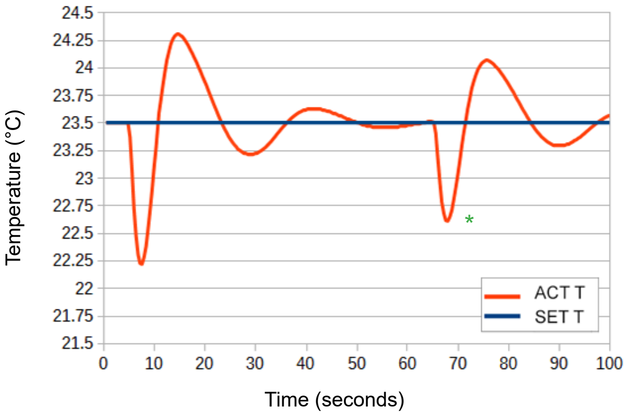

Figure 14. Tuned, 40.8 second recovery
First crossing of setpoint: 3.5 seconds
P=12.287; I= 1.024; D=OFF
Lowest Temp: 22.61ºC
Setpoint Response

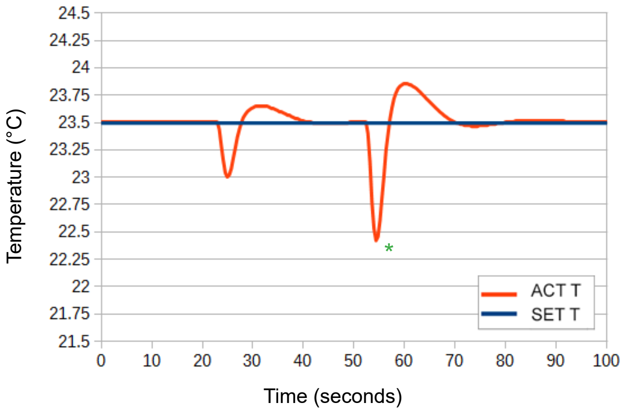

Figure 15. Tuned, 14.3 second recovery
First crossing of setpoint: 2.8 seconds
P = 33.352; I = 1.390; D = 3.172
Lowest Temp: 22.42ºC
Disturbance Rejection

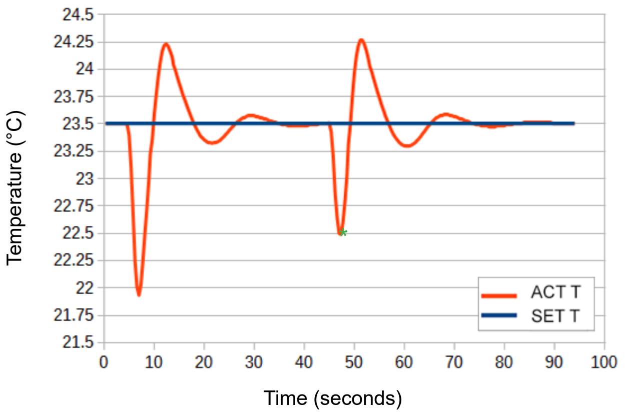

Figure 16. Tuned, 23.8 second recovery
First crossing of setpoint: 2.24 seconds
P = 21.064; I = 2.107; D = 2.385
Lowest Temp: 22.49ºC
Setpoint Response

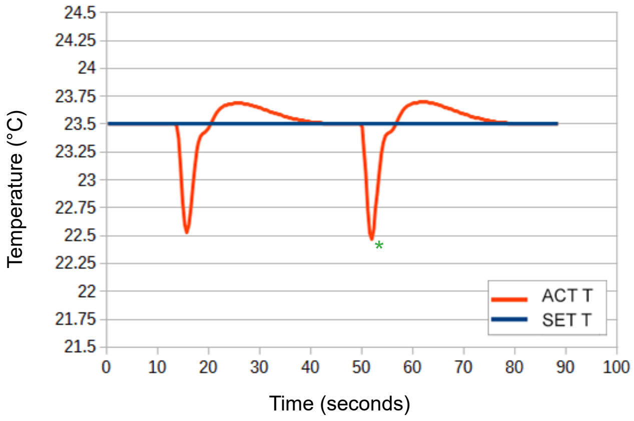

Figure 17. Forced overdamped at 15ºC
Manual Tune, 21.4 seconds
First crossing of setpoint: 4.9 seconds
P = 46.820; I = 0.929; D = 4.452
Lowest Temp: 22.47ºC

The system PID control values for the overdamped system at 15ºC are not optimized for operation at 23.5ºC, so the system overshoots and is not overdamped at the higher temperature.

The fastest return time to temperature was Disturbance Rejection mode with all PID terms used (Fig. 15). The overshoot in Setpoint Response mode is significantly larger and multiple overshoots are required before the system stays within tolerance. The overshoot and recovery time varies with minimum temperature reached. Adding the D term significantly decreased recovery time (17 seconds faster in Setpoint Response mode [Fig. 16 vs Fig. 14]; 12.3 seconds faster in Disturbance Rejection mode [Fig. 15 vs Fig. 13]).

STEP RESPONSE & DISTURBANCE — SETPOINT 35ºC

Still using the same IntelliTune run at 15°C, we reversed the time-to-temperature experiment starting at 23.5°C and ending at a setpoint of 35°C. The PID coefficients automatically changed when the setpoint of 35°C was entered.

Figure 18. PID Coefficients automatically recalculated for setpoint change

Output current to the load was enabled and the data logged from the starting temperature to setpoint.

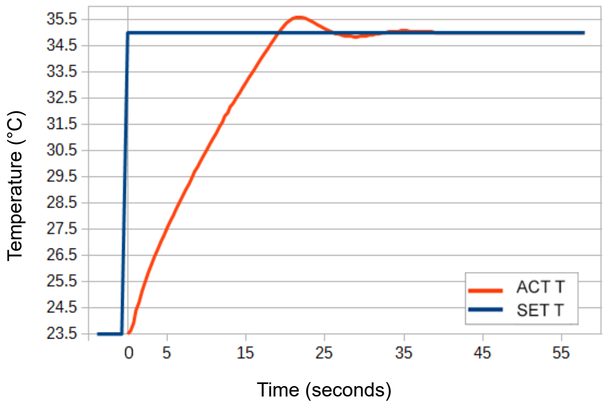

Figure 19. Tuned at 15°C, 36.2 seconds to stable at 35°C
First crossing of setpoint: 19.3 seconds
P = 35.187; I = 3.519; D = 3.984
Setpoint Response

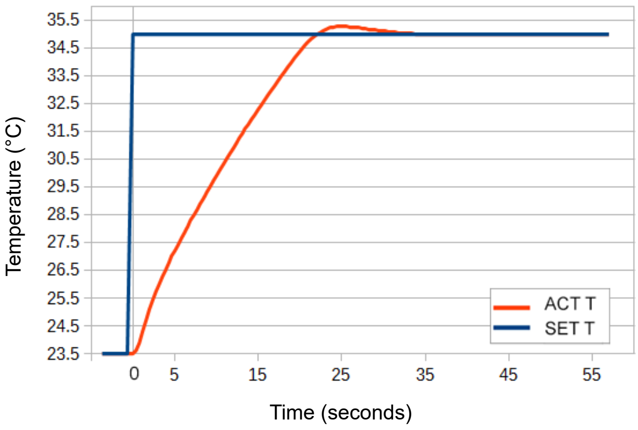

Figure 20. Tuned at 15°C, 31.8 seconds to stable at 35°C
First crossing of setpoint: 22.4
P = 55.713; I = 2.322; D = 5.299
Disturbance Rejection

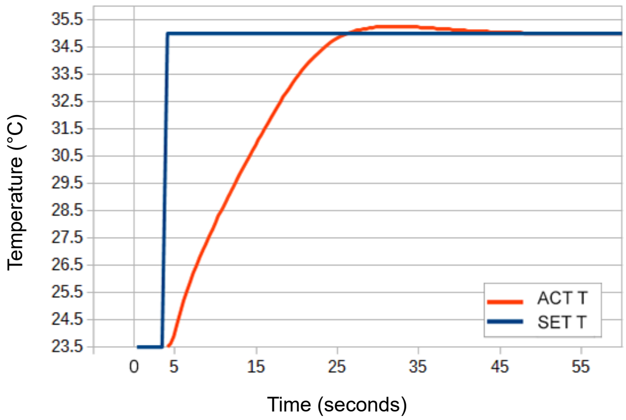

Figure 21. Forced overdamped at 15ºC, 39.8 seconds to stable at 35°C
First crossing of setpoint: 22.5 seconds
P = 46.820; I = 0.929; D = 4.452
Manual Tune

The manually tuned system overshoot goes out of the tolerance band. The PID coefficients optimal for overdamping at 15°C are not optimal for a 35°C setpoint.

The fastest time to first crossing was the system in Setpoint Response mode at 19.3 seconds. The fastest time to stable temperature was the system in Disturbance Rejection mode at 31.8 seconds.

We then repeated the Disturbance Rejection test around the 35ºC setpoint. The PID coefficients automatically changed when the mode was changed to Disturbance Rejection.

Figure 22. PID Coefficients automatically recalculated for Tune mode change

We used freeze spray to reduce the thermistor actual temperature by about two degrees. The system returned to temperature in 10 seconds.

* Caption details data for this disturbance

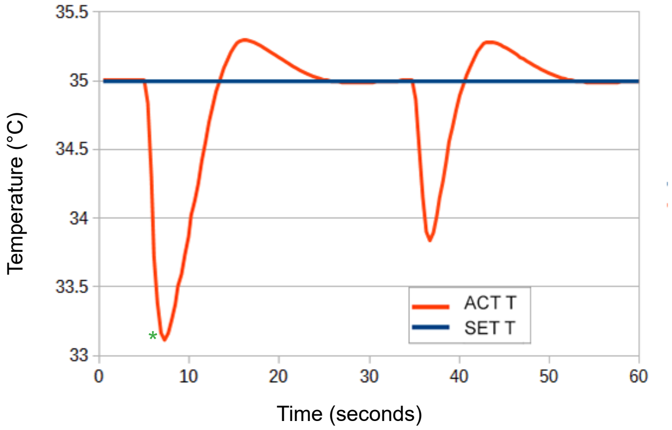

Figure 23. Tuned at 15°C, 16.3 seconds recovery at 35°C
First crossing of setpoint: 6.6 seconds
P = 55.713; I = 2.322; D = 5.299
Lowest Temperature: 33.1ºC
Disturbance Rejection

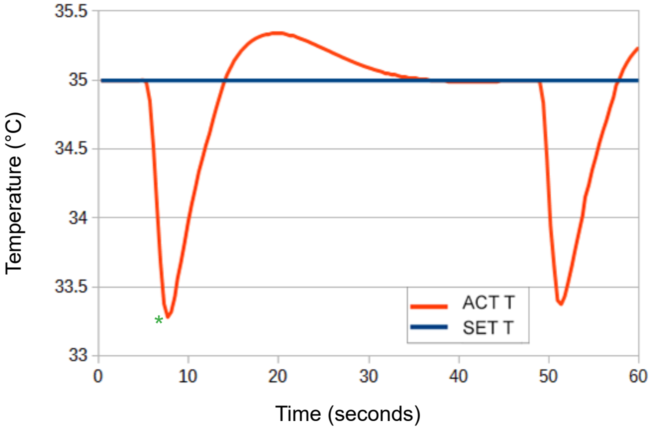

Figure 24. Forced overdamped at 15ºC, 24.5 seconds recovery at 35°C
First crossing of setpoint: 6.6 seconds
P = 46.820; I = 0.929; D = 4.452
Lowest Temp: 33.28ºC
Manual Tune

The fastest time to stable temperature was in Disturbance Rejection mode at 16.3 seconds, despite a slightly lower temperature minimum.

CONVENTIONAL AUTOTUNE COMPARISON

We ran the same tests with the same load on three different temperature control instruments that use conventional Autotune systems.

COMPETITOR A

The Autotune was performed at 15°C and took about two minutes. The step response from 23.5°C to 15°C took 29.3 seconds with virtually no overshoot instead of 32.0 seconds for IntelliTune, and the first crossing was at 43.9 seconds compared with 20.9 seconds for IntelliTune (Fig. 25 vs Fig. 7). This instrument Autotune avoids overshoot.

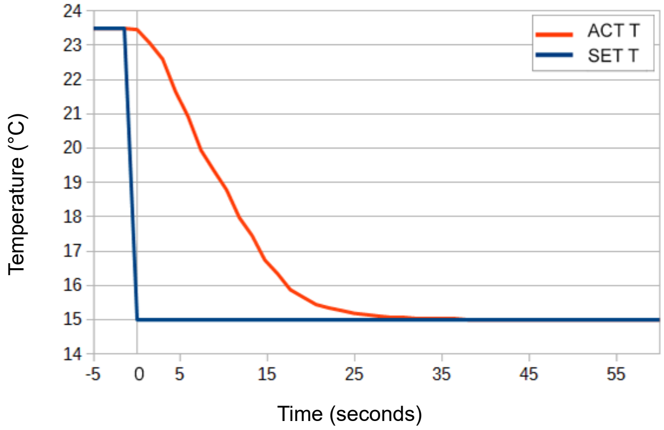

Figure 25. Conventional Autotune, Instrument A
Tuned, 29.25 seconds
First crossing of setpoint: 43.9 seconds
P = 37; I = 0.4; D = 19

The step response at 35ºC also took longer with the fixed PID coefficients compared to the adaptive response with IntelliTune.

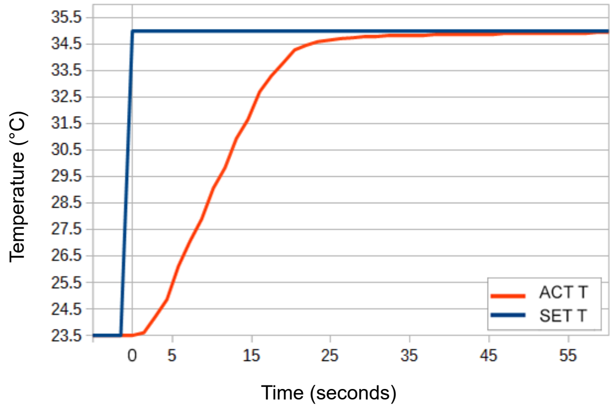

Figure 26. Conventional Autotune, Instrument A
Tuned, 67.3 seconds
First crossing of setpoint: 112.7 seconds
P = 37; I = 0.4; D = 19

First crossing was 112.7 seconds, so the controller displays an offset, asymptotically approaching the setpoint. IntelliTune first crossing was 22.4 seconds (Fig. 26 vs Fig. 20).

The Disturbance Rejection test was also repeated at 23.5ºC and 35ºC.

* Caption details data for this disturbance

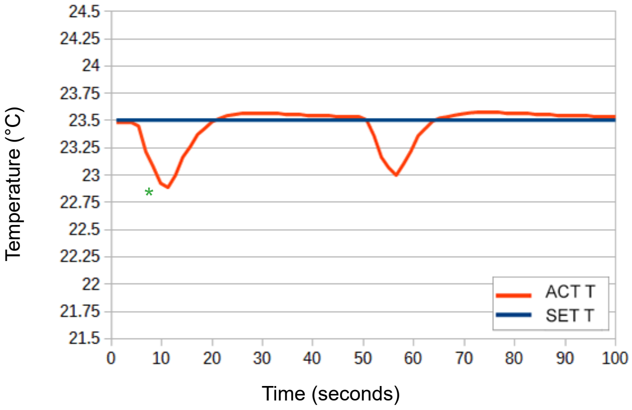

Figure 27. Conventional Autotune, Instrument A
Tuned, 27.7 seconds
First crossing of setpoint: 10.2 seconds
P = 37; I = 0.4; D = 19
Lowest Temp: 22.9ºC

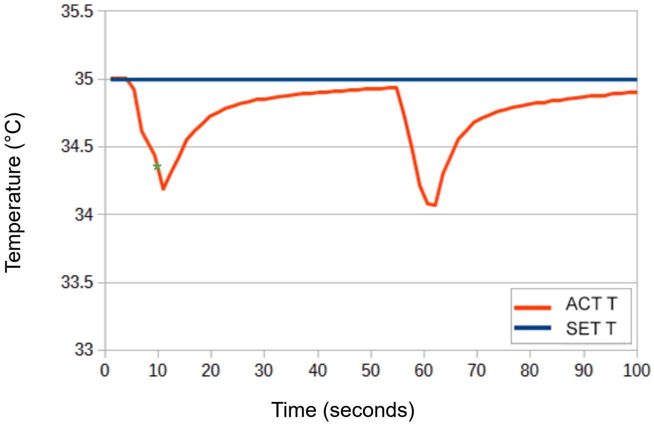

Figure 28. Conventional Autotune, Instrument A
Tuned at 15ºC, 44+ seconds
First crossing of setpoint: N/A
P = 37; I = 0.4; D = 19
Lowest Temperature: 34.2ºC

The PID coefficients are not automatically changed with conventional Autotune, so when we ran a disturbance test at 23.5ºC, the time to return to temperature was 27.7 seconds vs. 14.3 seconds with IntelliTune (Fig. 27 vs Fig. 15), even though the lowest temperature was 0.5ºC higher for Competitor A. The time to return to temperature at 35ºC exceeded 44 seconds - compared to 16.3 seconds with IntelliTune - even though the lowest temperature was 34ºC vs. 33.1ºC (Fig. 28 vs Fig. 23).

COMPETITOR B

This instrument took about 2 minutes to complete the tune. This instrument Autotune finds coefficients with behavior similar to an overdamped system, Initial overshoot is within the tolerance band.

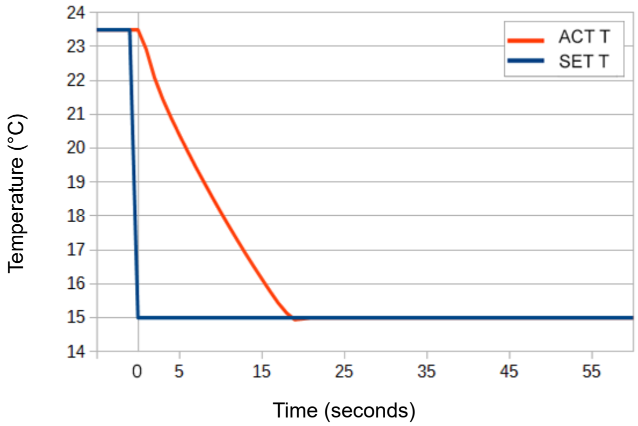

Figure 29. Conventional Autotune, Instrument B Tuned, 17 seconds First crossing of setpoint: 19 seconds P = 8.369; I = 10.243; D = 1.710

The TC10 LAB manually overdamped arrived at temperature in 22.8 seconds. The TC10 LAB using IntelliTune arrived at temperature in 31.8 seconds. However, the stability of Competitor B's unit was 5 times worse (Fig.30 vs Fig. 11).

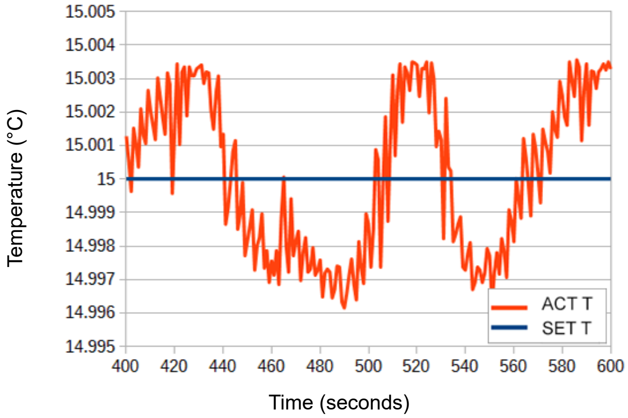

Figure 30. Instrument B Compromised Stability Three standard deviations over 600 seconds was 7.6 mK

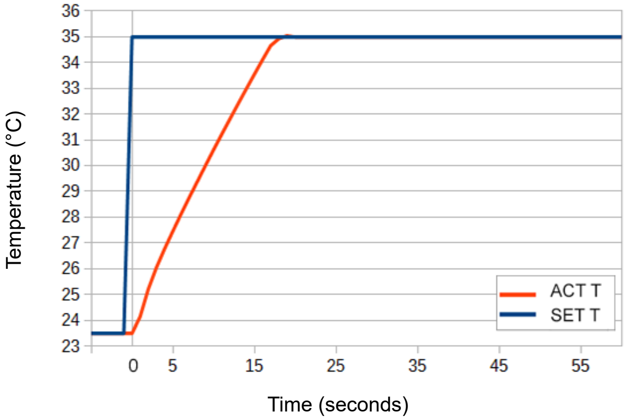

Figure 31. Conventional Autotune, Instrument B Tuned, 19 seconds First crossing of setpoint: 19 seconds P = 8.369; I = 10.243; D = 1.710

The time to temperature was faster - 19 seconds compared to 31.8 seconds (Fig. 31 vs Fig. 20).

Disturbance Rejection tests at 23.5ºC showed a faster return to temperature - 4 seconds compared to 14.3 seconds using IntelliTune - with similar stability problems. First crossing occurred at 3 seconds compared to 2.8 seconds (Fig. 32 vs Fig. 15).

* Caption details data for this disturbance

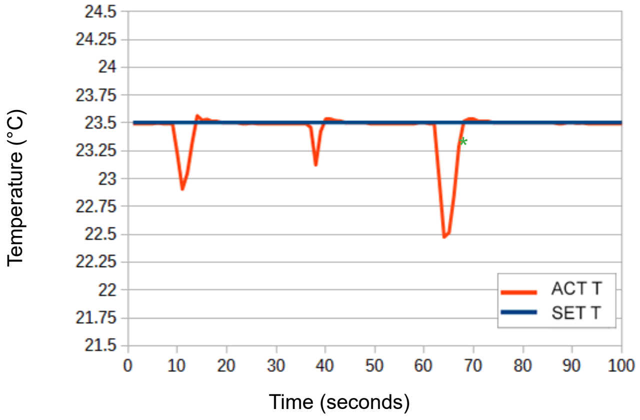

Figure 32. Conventional Autotune, Instrument B Tuned, 4 seconds
First crossing of setpoint: 3 seconds
P = 8.369; I = 10.243; D = 1.710
Lowest temperature: 22.5°C

Disturbance Rejection tests at 35ºC showed a faster return - 4 seconds compared to 16.3 seconds using IntelliTune (Fig. 33 vs Fig. 23) - with similar stability problems.

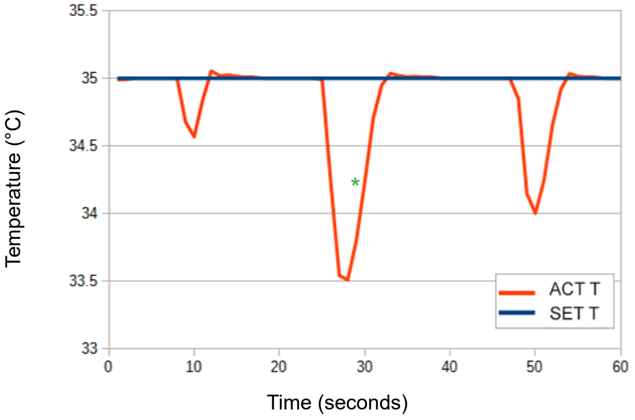

Figure 33. Conventional Autotune, Instrument B Tuned, 4 seconds
First crossing of setpoint: 4 seconds
P = 8.369; I = 10.243; D = 1.710
Lowest temperature: 33.5°C

COMPETITOR C

This instrument took 28 minutes to complete the tune. Data collection was truncated by this instrument at 2 decimal places, so stability data could not be calculated.

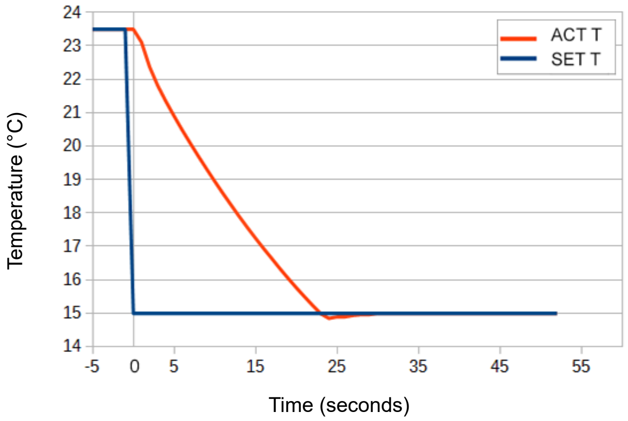

Figure 34. Conventional Autotune, Instrument C
Tuned, 28 seconds
First crossing of setpoint: 23 seconds
P = 5.2989; I = 0.2504; D = 15.4116

Once tuned, Competitor C's instrument reached temperature in 28 seconds compared to 32.0 seconds with IntelliTune, and first crossing came at 23 seconds compared to 20.1 seconds with IntelliTune (Fig. 34 vs Fig.7).

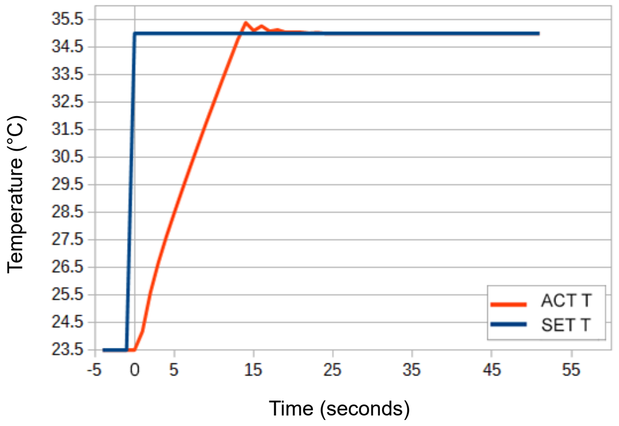

Figure 35. Conventional Autotune, Instrument C
Tuned, 19 seconds
First crossing of setpoint: 19 seconds
P = 5.2989; I = 0.2504; D = 15.4116

In the 35°C test, instrument C reached stable temperature in 19 seconds compared to 31.8 seconds with IntelliTune and first crossing came at 19 seconds compared to 22.4 seconds with IntelliTune (Fig. 35 vs. Fig. 20).

* Caption details data for this disturbance

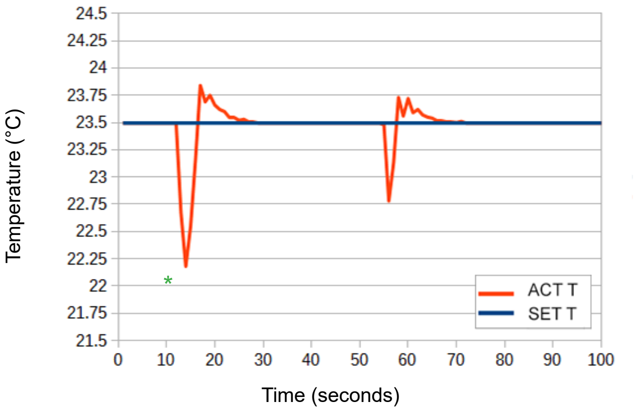

Figure 36. Conventional Autotune, Instrument C
Tuned at 15°C, 11 seconds recovery at 23.5°C
First crossing of setpoint: 2 seconds
P = 5.2989; I = 0.2504; D = 15.4116
Lowest Temperature: 22.18ºC

Instrument C recovered from a disturbance in 11 seconds compared to 14.3 seconds with IntelliTune (Fig. 36 vs. Fig. 15).

SUMMARY

Each temperature controller instrument uses a different Autotune algorithm. Most take about two minutes to complete. One took 28 minutes to choose the optimal PID coefficients.

Step response varied from underdamped to overdamped. Some algorithms drive the load to the edge of instability to choose PID coefficients. P, I, and D coefficients do not represent the same physical units across instruments.

IntelliTune goes beyond conventional Autotune by recalculating optimal PID coefficients for different setpoints or tuning modes without requiring multiple characterization scans. Control coefficients are chosen for best stability.

Setpoint Response mode drives more current to the thermoelectric at first, with the load crossing the setpoint temperature sooner than a system using Disturbance Rejection tuning mode. The system also experiences more overshoot in Setpoint Response mode.

Using the D term significantly shortens time to temperature. Decreasing current limit did not shorten time to temperature for this small load, but it has been shown to decrease overshoot and time to temperature for larger loads.

Overdamping a system can reduce time to temperature, sometimes at the expense of steady-state stability.

Here are some suggestions for using IntelliTune in your application:

- Try both Setpoint Response and Disturbance Rejection modes with your load. Their distinct signatures shown in this Application Note are thermoelectric and sensor dependent. When choosing a mode, determine which is more important, first crossing or time to temperature.
- Use Disturbance Rejection mode if overshoot is not tolerable in your application, if fast ambient temperature changes are expected (e.g. if the setup is near a door that opens frequently), or if an active load will intermittently increase the energy the thermoelectric needs to transfer.
- Use a non-zero D term if possible. The D control term was critical for our load in reaching temperature quickly. It can also amplify noise, however. If the noise around setpoint is too great (for example, the temperature stability is too low), then turn the D term off.
- Vary the current limit to see if time to temperature will improve with less overshoot.
- If your setpoint is far from ambient, run IntelliTune much closer to ambient (but about 5°C off) to characterize the load and let IntelliTune recalculate the PID coefficients for your actual setpoint. The tuning scan will be faster and still effective.
- Always set up temperature limits before running a scan.
- Use IntelliTune to improve your system’s thermal design. A high value I term means there is significant lag time between the thermoelectric and sensor. Put them closer, improve the thermal bond between components, or reduce the load mass and rerun IntelliTune to see if the I term has dropped.
- If you change setpoint and the PID coefficients do not change, IntelliTune is not active. Make sure Tune mode is not Manual Tuning.
- If you change the sensor choice on the sensor screen, IntelliTune will consider the last scan data invalid and you will need to perform another tuning scan - even if you don’t physically change out your sensor.
- The tests in this application note use thermistors, but IntelliTune works with RTDs, IC sensors, and the IR sensor.
- IntelliTune is sensitive to system variations. If the heatsink on the thermoelectric is undersized and heats up considerably, a tuning scan run when the heatsink is hot (e.g. at the end of the day) will produce slightly different PID coefficients than if the scan is run with the heatsink cool at the start of the day. Run IntelliTune on the system when it has reached equilibrium under typical conditions for best results.

DATA AT A GLANCE

STEP RESPONSE TESTS

TC10 LAB with all PID values derived from a single IntelliTune scan at 15ºC. Step response time to reach 15ºC ± 0.05°C setpoint from 23.5ºC

Mode/settings	P	I	D	Setpoint (ºC)	1st Crossing (sec)	Time to Stability (sec)
Setpoint Response, without D term, 3A	8.214	0.685	OFF	15	21.3	57
Setpoint Response, with D term, 3A	14.081	1.408	1.594	15	19.9	39.9
Disturbance Rejection, without D term, 3A	14.081	0.352	OFF	15	20.7	52
Disturbance Rejection, with D term, 3A	22.295	0.929	2.120	15	20.9	31.3
Setpoint Response, with D term, 2A	14.081	1.408	1.594	15	29.7	43.6
Disturbance Rejection, with D term, 2A	22.295	0.929	2.120	15	29.2	40
Manually tuned, Overdamped at 15ºC, 3A	46.820	0.929	4.452	15	24	22.8

DISTURBANCE RESPONSE TESTS

TC10 LAB with all PID values derived from a single IntelliTune scan at 15ºC. Recovery time to an approximate 1.1ºC drop in temperature from 23.5ºC

Mode/settings	P	I	D	Setpoint (ºC)	1st Crossing (sec)	Time to Stability (sec)	Min Temp (ºC)
Disturbance Rejection, without D term	21.064	0.527	OFF	23.5	6	26.6	22.43
Disturbance Rejection, with D term	33.352	1.390	3.172	23.5	2.8	14.3	22.42
Setpoint Response, without D term	12.287	1.024	OFF	23.5	3.5	40.8	22.61
Setpoint Response, with D term	21.064	2.107	2.385	23.5	2.2	23.8	22.49
Manually tuned, Overdamped at 15ºC	46.820	0.929	4.452	23.5	4.9	21.4	22.47

STEP RESPONSE – SETPOINT 35°C TESTS

TC10 LAB with all PID values derived from a single IntelliTune scan at 15ºC. Step response time to reach 35ºC ± 0.05°C setpoint from 23.5ºC

Mode/settings	P	I	D	Setpoint (ºC)	1st Crossing (sec)	Time to Stability (sec)
Setpoint Response, step with D term, 3A	35.187	3.519	3.984	35	19.3	36.2
Disturbance Rejection, with D term, 3A	55.713	2.322	5.299	35	22.4	31.8
Manually tuned, Overdamped at 15ºC	46.820	0.929	4.452	35	22.5	39.8

DISTURBANCE RESPONSE – SETPOINT 35°C TESTS

TC10 LAB with all PID values derived from a single IntelliTune scan at 15ºC. Recovery time from an approximately 2ºC drop in temperature at 35°C.

Mode/settings	P	I	D	Setpoint (ºC)	1st Crossing (sec)	Time to Stability (sec)	Min Temp (ºC)
Disturbance Rejection, with D term, 3A	55.713	2.322	5.299	35	6.6	16.3	33.1
Manually tuned, Overdamped at 15ºC, 3A	46.820	0.929	4.452	35	6.6	24.5	33.28

CONVENTIONAL AUTOTUNE COMPARISON TESTS

Step response to reach 15ºC and 35ºC each from 23.5ºC, instrument tuned at 15ºC. Disturbance tests at 23.5°C and 35°C.

Mode/settings	P	I	D	Setpoint (ºC)	1st Crossing (sec)	Time to Stability (sec)	Min Temp (ºC)
Competitor A, step	37.000	0.400	19.000	15	43.9	29.25	
Competitor A, step	37.000	0.400	19.000	35	112.7	67.3	
Competitor A, disturbance	37.000	0.400	19.000	23.5	10.2	27.7	22.9
Competitor A, disturbance	37.000	0.400	19.000	35	N/A	44+	34.2
Competitor B, step	8.369	10.243	1.710	15	19	17 *	
Competitor B, step	8.369	10.243	1.710	35	19	19 *	
Competitor B, disturbance	8.369	10.243	1.710	23.5	3	4 *	22.5
Competitor B, disturbance	8.369	10.243	1.710	35	4	4 *	33.5
Competitor C, step	5.2989	0.2504	15.4116	15	23	28 **	
Competitor C, step	5.2989	0.2504	15.4116	35	19	19 **	
Competitor C, disturbance	5.2989	0.2504	15.4116	23.5	2	11 **	22.18

* Stability is 5 times worse than TC10 LAB
** Stability measurement not possible because data was truncated by instrument at 2 decimal places

KEYWORDS

characterize load, Autotune, IntelliTune, Setpoint Response, Disturbance Rejection, PID control, precision temperature control, step response, optimize PID coefficients, temperature stabilization, thermal load stabilization, time to temperature, load profiling, thermal mass stabilization, Proportional, Integral, Derivative Control

REVISION HISTORY
Document Number: AN-TC13

REVISION	DATE	NOTES
A	December-2016	Initial Release