TC300 - July 29, 2024

Item # TC300 was discontinued on July 29, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

HEATER TEMPERATURE CONTROLLER

- ▶ Heating from -200 °C to 400 °C
- ▶ Two Channels Capable of Independent or Synchronized Operation
- ▶ User-Configurable PID

TC300
Heater Temperature Controller

Front Panel Allows Stand-Alone Operation

Hide Overview

OVERVIEW

Features

- Heating from -200 °C to 400 °C
- Run Standalone or via Software
- Dual Channel Resistive Heater Controller
- Can Drive Various Types of Heaters, Including Foil and Resistor Types
- User-Configurable PID
- Compatible 6-Pin Hirose Cables Available:
    - 3.0 m (9.84') Long Male-to-Male Cable
    - 1.8 m (5.90') Cable with Breakout Box for Custom Applications

Specifications	
Output Power per Channel	48 W (Max)
Output Current per Channel	2 A (Max)
Output Voltage per Channel	24 V (Max)
Temperature Setting Range	-200 to 400 °C Max[a]
Set Point Resolution	0.1 °C
Temperature Stability	±0.1 °C
Sensor Types	Thermistor, AD590, Thermocouple, 2-Wire and 4-Wire Platinum 100 Ω, 2-Wire and 4-Wire Platinum 1000 Ω
Output Connector Type	Hirose HR10A-7R-6S(73)
USB Interface	USB 2.0, Standard B
Power Supply	100 - 240 VAC, 50 - 60 Hz, 165 VA Max
Operating Temperature	0 - 40 °C
Storage Temperature	-15 - 65 °C
Dimensions (H x W x D)	86.6 mm x 154.3 mm x 327.8 mm (3.41" x 6.07" x 12.91")
Weight	1.8 kg

Thorlabs' TC300 Heater Temperature Controller is a general-purpose benchtop controller intended for use with resistive heating elements, including foil (such as Item # HT10K) and resistive coil (such as Item # HT15W) types. It also accepts feedback from a variety of temperature sensor types including positive (such as Item # TH100PT) or negative (such as Item # TH10K) temperature coefficient thermistors and thermocouples.

The two channels of the front of the TC300 controller are capable of either independent or synchronized operation. Each channel has programmable P, I, and D gains. The back of the TC300 controller has connectors for analog output and input and output triggers for each channel. An output proportional to the actual temperature of the channel is given in the analog output, and the input and output trigger allows the user to enable or disable the channel. For more information, please see the *Front & Back Panel* tab.

Sensor Dependent

User-programmable maximum temperature and current/voltage limits protect the connected heating element from being overheated or over driven. Other safety features include an Open Sensor Alarm that will shut down the driver if the temperature sensing element is missing or becomes disconnected.

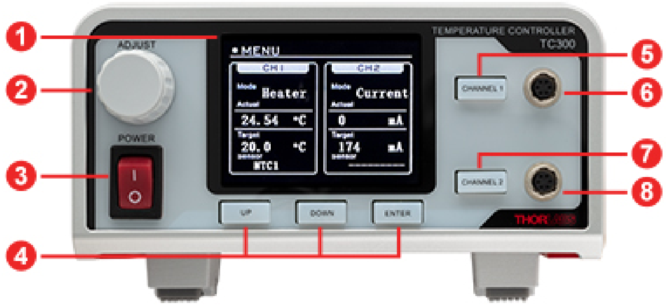
A simple keypad interface allows stand-alone operation, but the TC300 can also be interfaced with a PC using a standard USB Type B connector and our TC300 Application Program. Interfacing with a PC can also be achieved by using LabVIEW™ or LabWindows with a simple command-line interface from any terminal window.

The TC300 heater controller uses female Hirose connectors to read the temperature of the heating element and supply current. Please note that the cable for connecting this heater controller to a heating element is not provided; we recommend the HR10CAB1 Male-to-Male Hirose Connector Cable or the HR10AD1 Hirose Connector Cable with Breakout Box, both sold separately below. For the pin assignments needed to adapt the TC300 controller to your heater, please see the *Front & Back Panel* tab.

Hide Front & Back Panel

FRONT & BACK PANEL

Front Panel

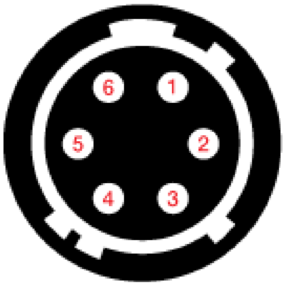


Click to Enlarge

Callout	Connection	Callout	Connection
1	LCD Screen	5	Enable/Disable Button for Channel 1
2	Adjustment Knob	6	Hirose Connector for Channel 1
3	Power Switch	7	Enable/Disable Button for Channel 2
4	Keypads	8	Hirose Connector for Channel 2

Channel 1 and Channel 2 Hirose Connectors

HR10A-7R-6S(73)



Pin	Assignment
1	Heater Output +
2	Heater Output -
3	Sensor + (4-Wire PT100/PT1000 Only)
4	Sensor +
5	Sensor -
6	Sensor - (4-Wire PT100/PT1000 Only)

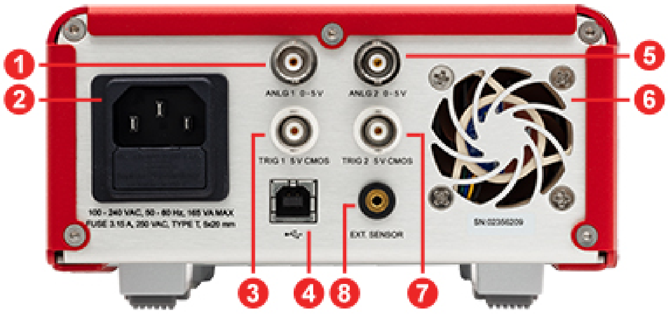
Back Panel

ANLG1 and ANLG2

BNC Female

TRIG1 and TRIG2

BNC Female



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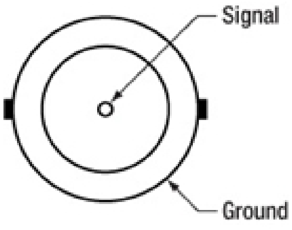
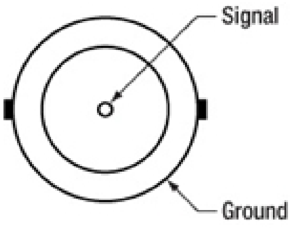


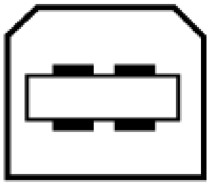
0 to +5 V, 20 kΩ Impedance
roportional to the actual temperature of the channel; 0 V corresponds to the minimum mperature setting and +5 V corresponds to the maximum temperature setting



+5 V CMOS
When set to input: +5 V input will enable the channel, and 0 V input will disable it.
When set to output: outputs +5 V when the channel is enabled and outputs 0 V when the channel is disabled.

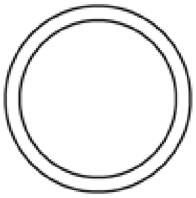
Callout	Connection	Callout	Connection
1	Analog Output of Channel 1 (ANLG1)	5	Analog Output of Channel 2 (ANLG2)
2	AC Input Connector	6	Cooling Fan
3	Trigger of Channel 1 (TRIG1)	7	Trigger of Channel 2 (TRIG2)
4	USB Type B Connector	8	Mono Jack for External Sensor

Computer Connection
USB Type B



USB Standard B Cable Included

External Sensor Connector
2.5 mm Mono Jack



Accepts 2.5 mm stereo earphone jack. The TC300 controller can support thermistors with resistance up to 999 kΩ.

Hide Sensor Specs

SENSOR SPECS

The TC300 controller is compatible with thermistors such as the TH10K thermistor as well as PT100 (such as Item # TH100PT) and PT1000 types of Platinum Resistance Temperature Detectors. The following specifications are used for determining the set-point and read back values for these types of thermistors and sensors.

Thermistors

When the sensor type is set to NTC1, the TC300 controller measures the resistance value of the thermistors wired to the Hirose connectors on front panel and calculates the temperature based on the “Beta” formulas defined below.

$R = R_0 * e^{\beta[(1/T) - (1/T_0)]}$

R is the resistance in Ω at temperature T
R_0 is the nominal resistance in Ω at temperature T_0
β is the constant associated with the particular thermistor
T is the temperature in K
T_0 is the nominal temperature temperature (usually 298.15 K = 25 °C)

The TC300 controller allows users to set the values of β, R_0, and T_0. For different thermistors, the actual value of these parameters can vary and can usually be found on their datasheets.

When the sensor type is set to NTC2, the TC300 controller also supports the Steinhart-Hart method to approximate the relation between temperature and thermistor resistance, defined by the following formula:

$$1/T = A + B * \ln(R) + C * (\ln(R))^3$$

T is the temperature in K
R is the resistance in Ω at temperature T
A, B, and C are Steinhart-Hart parameters

The TC300 controller allows user input of the A, B, and C parameters. For thermistors that support the Steinhart-Hart method, the actual value of A, B, and C can usually be found on their datasheets.

PT100 and PT1000 Sensors

When the sensor type is set to PT100 or PT1000, the TC300 controller measures the resistance and calculates the temperature of the PT100 or PT1000 platinum resistance temperature detector using the following formula:

$$R = R_0 (1 + A * T + B * T^2)$$

(In accordance with IEC 751, 2:1995-07 [DIN EN 60751; 1996-07])

$A = 3.9083 \times 10^{-3}$ °C^{-1}
$B = -5.775 \times 10^{-7}$ °C^{-2}
R is the resistance in Ω at temperature T
T is the temperature in °C
R_0 = 100 Ω for the PT100
R_0 = 1000 Ω for the PT1000

The TC300 controller supports 2- and 4-wire connections for both PT100 and PT1000 sensors. When the sensor type is set to PT100 or PT1000, select the “Parameter” option to toggle between the 2-wire and 4-wire connection setting.

Hide Software

SOFTWARE

Software for the TC300 Heater Temperature Controller

Software

Version 1.2.3

Click to Enlarge
Software GUI

Software package to operate the TC300 including a GUI, drivers, and LabVIEW™/C++/Python SDK for third-party development.

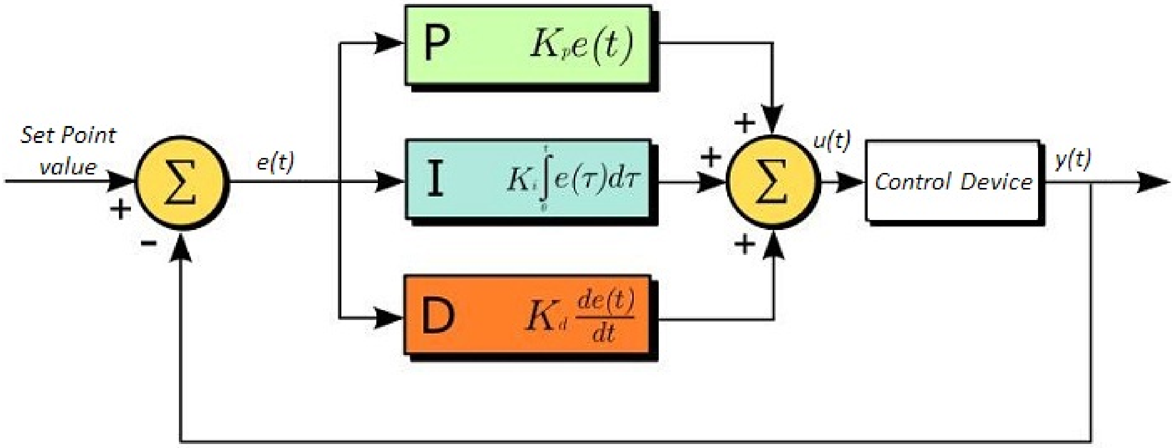
Software

Hide PID Tutorial

PID TUTORIAL

PID Basics

The PID circuit is often utilized as a control loop feedback controller and is commonly used for many forms of servo circuits. The letters making up the acronym PID correspond to Proportional (P), Integral (I), and Derivative (D), which represents the three control settings of a PID circuit. The purpose of any servo circuit is to hold the system at a predetermined value (set point) for long periods of time. The PID circuit actively controls the system so as to hold it at the set point by generating an error signal that is essentially the difference between the set point and the current value. The three controls relate to the time-dependent error signal. At its simplest, this can be thought of as follows: Proportional is dependent upon the present error, Integral is dependent upon the accumulation of past error, and Derivative is the prediction of future error. The results of each of the controls are then fed into a weighted sum, which then adjusts the output of the circuit, u(t). This output is fed into a control device, its value is fed back into the circuit, and the process is allowed to actively stabilize the circuit's output to reach and hold at the set point value. The block diagram below illustrates the action of a PID circuit. One or more of the controls can be utilized in any servo circuit depending on system demand and requirement (i.e., P, I, PI, PD, or PID).



Through proper setting of the controls in a PID circuit, relatively quick response with minimal overshoot (passing the set point value) and ringing (oscillation about the set point value) can be achieved. Let's take as an example a temperature servo, such as that for temperature stabilization of a laser diode. The PID circuit will ultimately servo the current to a Thermo Electric Cooler (TEC) (often times through control of the gate voltage on an FET). Under this example, the current is referred to as the Manipulated Variable (MV). A thermistor is used to monitor the temperature of the laser diode, and the voltage over the thermistor is used as the Process Variable (PV). The Set Point (SP) voltage is set to correspond to the desired temperature. The error signal, e(t), is then the difference between the SP and PV. A PID controller will generate the error signal and then change the MV to reach the desired result. For example, if e(t) states that the laser diode is too hot, the circuit will allow more current to flow through the TEC (proportional control). Since proportional control is proportional to e(t), it may not cool the laser diode quickly enough. In that event, the circuit will further increase the amount of current through the TEC (integral control) by looking at the previous errors and adjusting the output to reach the desired value. As the SP is reached (e(t) approaches zero), the circuit will decrease the current through the TEC in anticipation of reaching the SP (derivative control).

Please note that a PID circuit will not guarantee optimal control. Improper setting of the PID controls can cause the circuit to oscillate significantly and lead to instability in control. It is up to the user to properly adjust the PID gains to ensure proper performance.

PID Theory

The output of the PID control circuit, u(t), is given as

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dt} e(t)$$

where

K_p= Proportional Gain

K_i = Integral Gain

K_d = Derivative Gain

e(t) = SP - PV(t)

From here we can define the control units through their mathematical definition and discuss each in a little more detail. Proportional control is proportional to the error signal; as such, it is a direct response to the error signal generated by the circuit:

$$P = K_p e(t)$$

Larger proportional gain results in larger changes in response to the error, and thus affects the speed at which the controller can respond to changes in the system. While a high proportional gain can cause a circuit to respond swiftly, too high a value can cause oscillations about the SP value. Too low a value and the circuit cannot efficiently respond to changes in the system.

Integral control goes a step further than proportional gain, as it is proportional to not just the magnitude of the error signal but also the duration of the error.

$$I = K_i \int_0^t e(\tau)d\tau$$

Integral control is highly effective at increasing the response time of a circuit along with eliminating the steady-state error associated with purely proportional control. In essence integral control sums over the previous error, which was not corrected, and then multiplies that error by K_i to produce the integral response. Thus, for even small sustained error, a large aggregated integral response can be realized. However, due to the fast response of integral control, high gain values can cause significant overshoot of the SP value and lead to oscillation and instability. Too low, and the circuit will be significantly slower in responding to changes in the system.

Derivative control attempts to reduce the overshoot and ringing potential from proportional and integral control. It determines how quickly the circuit is changing over time (by looking at the derivative of the error signal) and multiplies it by K_d to produce the derivative response.

$$D = K_d \frac{d}{dt} e(t)$$

Unlike proportional and integral control, derivative control will slow the response of the circuit. In doing so, it is able to partially compensate for the overshoot as well as damp out any oscillations caused by integral and proportional control. High gain values cause the circuit to respond very slowly and can leave one susceptible to noise and high frequency oscillation (as the circuit becomes too slow to respond quickly). Too low and the circuit is prone to overshooting the SP value. However, in some cases overshooting the SP value by any significant amount must be avoided and thus a higher derivative gain (along with lower proportional gain) can be used. The chart below explains the effects of increasing the gain of any one of the parameters independently.

Parameter Increased	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
K_p	Decrease	Increase	Small Change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Decrease Significantly	Degrade
K_d	Minor Decrease	Minor Decrease	Minor Decrease	No Effect	Improve (for small K_d)

Tuning

In general the gains of P, I, and D will need to be adjusted by the user in order to best servo the system. While there is not a static set of rules for what the values should be for any specific system, following the general procedures should help in tuning a circuit to match one's system and environment. A PID circuit will typically overshoot the SP value slightly and then quickly damp out to reach the SP value.

Manual tuning of the gain settings is the simplest method for setting the PID controls. However, this procedure is done actively (the PID controller turned on and properly attached to the system) and requires some amount of experience to fully integrate. To tune your PID controller manually, first the integral and derivative gains are set to zero. Increase the proportional gain until you observe oscillation in the output. Your proportional gain should then be set to roughly half this value. After the proportional gain is set, increase the integral gain until any offset is corrected for on a time scale appropriate for your system. If you increase this gain too much, you will observe significant overshoot of the SP value and instability in the circuit. Once the integral gain is set, the derivative gain can then be increased. Derivative gain will reduce overshoot and damp the system quickly to the SP value. If you increase the derivative gain too much, you will see large overshoot (due to the circuit being too slow to respond). By playing with the gain settings, you can maximize the performance of your PID circuit, resulting in a circuit that quickly responds to changes in the system and effectively damps out oscillation about the SP value.

While manual tuning can be very effective at setting a PID circuit for your specific system, it does require some amount of experience and understanding of PID circuits and response. The Ziegler-Nichols method for PID tuning offers a bit more structured guide to setting PID values. Again, you'll want to set the integral and derivative gain to zero. Increase the proportional gain until the circuit starts to oscillate. We will call this gain level K_u. The oscillation will have a period of P_u. Gains for various control circuits are

Control Type	K_p	K_i	K_d
P	0.50 K_u	-	-
PI	0.45 K_u	1.2 K_p/P_u	-

then given below in the chart.

PID	0.60 K_u	2 K_p/P_u	$K_pP_u/8$

Hide Heater Temperature Controller

Heater Temperature Controller

- Heating from -200 °C to 400 °C
- Run Standalone or via Software
- Programmable PID

The TC300 Heater Temperature Controller is a benchtop controller intended for use with resistive heating elements rated up to 48 W. User-programmable maximum temperature and current/voltage limits protect the connected heating element from being overheated or over driven. Other safety features include an Open Sensor Alarm that will shut down the driver if the temperature sensing element is missing or becomes disconnected.

Capable of standalone operation from a simple keypad interface, this controller can be interfaced with a PC using a standard USB Type B connector using our TC300 Application Program, LabVIEW drivers, LabWindows drivers, or using a simple command-line interface from any terminal window.

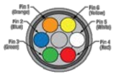
Part Number	Description	Price	Availability
TC300	**Customer Inspired! Heater Temperature Controller**	**$1,060.29**	**Lead Time**

Hide 6-Pin Hirose Cable and Breakout Box

6-Pin Hirose Cable and Breakout Box

Click to Enlarge
The ports of the HR10AD1 breakout box are labeled with pin numbers. Blank labels are also provided for custom pin assignments.

- Cables with Male 6-Pin Hirose Connectors:
  - 3.0 m (9.84') Long Male-to-Male Cable
  - 1.8 m (5.90') Long Cable with Breakout Box
- Compatible with Several of Our Products
  - TC300 Heater Temperature Controller
  - SH05R(/M) Beam Shutter, Ø1/2" Aperture
  - SH1(/M) Beam Shutter, Ø1" Aperture
  - SC10 Shutter Controller (Male-to-Male Cable Only)
  - KSC101 K-Cube Solenoid Controller (Male-to-Male Cable Only)



Click to Enlarge
Wire Diagram

Click to Enlarge
Male Hirose
Connector

Thorlabs' HR10CAB1 and HR10AD1 cables feature 6-pin Hirose connectors. The HR10CAB1 cable is 3.0 m (9.84') long and features two male connectors, while the HR10AD1 cable is 1.8 m (5.90') long and features one Hirose connector and one breakout box for connecting loose wires without the need for soldering.

These cables are compatible with our TC300 heater temperature controller, and the breakout box can be used to easily connect a custom combination of resistive heaters and thermistors, as shown in the image to the right. The HR10CAB1 cable can be used to connect an SH05R(/M) or SH1(/M) beam shutter to an SC10 shutter controller or KSC101 K-Cube solenoid controller.

If a custom soldered connection is required, these Hirose connector cables can also be cut to any length, leaving one connectorized end and one bare end. The colored wire diagram above shows the relationship between the six colored wires and the pins in the connector, allowing the cut cable to be incorporated into a variety of custom applications where the breakout box is unsuitable. Note that the wires in these cables cross over the length of the cable, so the insulation color should be used for pin identification.

The ports of the HR10AD1 breakout box are each labeled with the pin number corresponding to the male Hirose connector, as shown in the image to the left. In addition, blank labels are provided next to each pin number for custom pin assignment information to be added. A graphite pencil is recommended for filling in the blank labels, as the markings can be removed using a standard rubber eraser if the pin assignments are changed.

Part Number	Description	Price	Availability
HR10AD1	**6-Pin Male Hirose Connector Cable with Breakout Box, 1.8 m long**	**$68.34**	**Today**
HR10CAB1	**6-Pin, Male-to-Male Hirose Connector Cable, 3.0 m Long**	**$81.60**	**Today**