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THORLABS

TC200 - October 05, 2021

Item # TC200 was discontinued on October 05, 2021 For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

HEATER CONTROLLER

- **Heating from 20 - 200 °C**
- **User Selectable Display Units (°F, °C, or K)**
- **Programmable Ramp and Soak Cycles**

TC200

LCD Detail

OVERVIEW

Features

- Heating from 20 °C to 200 °C
- User-Selectable Display Units (°F, °C, or K)
- Run Standalone or via Software
- Adjustable PID
- Compatible with Positive and Negative Temperature Coefficient Thermistors

Click to Enlarge
The TC200 Heater Controller GUI is available on the *Software* tab.

The TC200 Heater Controller is a benchtop controller intended for use with resistive heating elements rated up to 18 W. This general-purpose instrument can drive various types of heaters, including foil (HT10K) and resistive coil (HT15W) types. The unit accepts feedback from either positive (TH100PT) or negative (TH10K) temperature coefficient thermistors, has programmable P, I, and D gains, and will display the temperature in either °F, °C, or K. In addition, the TC200 can be programmed for up to five sequential temperature settings along with associated ramp and hold times for each level. A user programmable maximum temperature limit provides protection to the device being heated and a user-programmable power limit protects the heating element from being 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 stand-alone operation from a simple keypad interface, the TC200 can be interfaced with a PC using a standard USB Type B connector and our TC200 Application Program, shown in the image to the right. Interfacing with a PC can also be achieved by using LabVIEW or LabWindows with a simple command-line interface from any terminal window.

Please note that the cable for connecting this heater controller to a heating element is not provided. The TC200 uses a Hirose connector to read the

temperature of the heating element and supply current. For the pin assignments needed to adapt the TC200 to your heater, please see the *Pin Diagrams* tab.

The unit also includes an auxiliary output for use with our GCH25-75 Glass Cell Heater. This auxiliary connection provides an unregulated output current that is proportional to the current supplied by the main output. Please see chapter 11 of the TC200 manual for more details about this feature. These outputs may also be used with other heater pairs, for instance when using two GCH25R cap heaters with a glass cell.

The TC200 is shipped with a 120 VAC power cord for use in the US while the TC200-EC is shipped with a 230 VAC power cord for use in Europe. If you require a power cord for another country, please contact your local sales office.

Click to Enlarge
Front Panel of the TC200 Heater Controller

Click to Enlarge
Back Panel of the TC200 Heater Controller

SPECS

TC200 Specifications			
Thermal Specifications	**Min**	**Typ.**	**Max**
Temperature Control Range[a]	20.0 °C	-	200.0 °C
Set-point Resolution	0.1 °C	-	-
Actual Temperature Display Accuracy[b]	-	±0.1 °C	±0.5 °C
Temperature Stability, 24-hour[c]	-	±0.1 °C	-
Electrical Specifications	**Min**	**Typ.**	**Max**
Input Voltage[d]	100 VAC	-	240 VAC
Input Power	-	-	25 VA
Output Power	-	-	18 W DC
Output Current	-	-	0.75 ADC
Output Voltage	-	-	24 VDC
Sensor Types	Platinum 100 Ω, Platinum 1000 Ω, NTC 10 KΩ		
Output Connector	HIROSE HR10A-7R-6S		
Mating Connector	HIROSE HR10A-7P-6P (73)		
USB Interface	USB 2.0, Type B Plug		
General Specifications			
Operating Temerature	10 - 40 °C		
Storage Temperature	0 - 50 °C		
Dimensions (W x H x L)	153.5 mm x 81.8 mm x 299.4 mm (6.04" x 3.22" x 11.79")		
Weight	5 lbs (2.3 kg)		

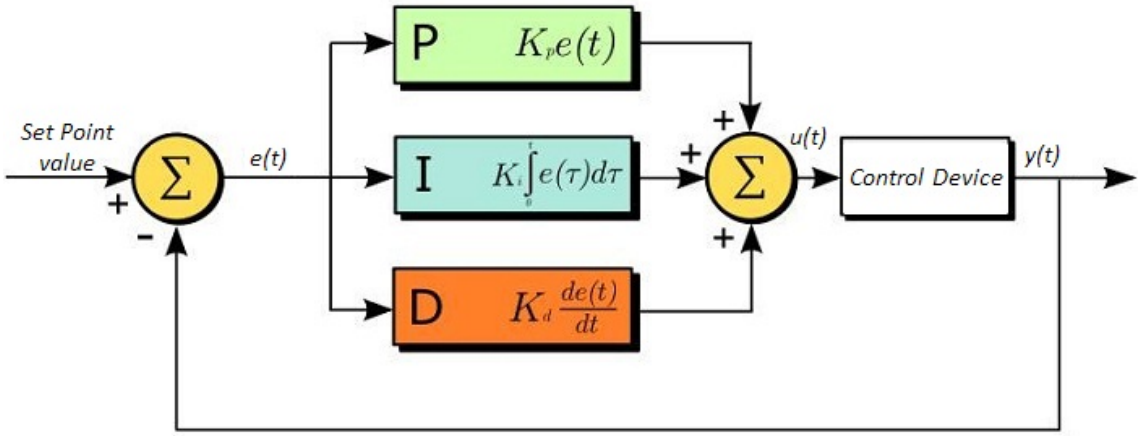
a. Heating mode only. Ambient temperature must always be less than set-point temperature. The capability to attain the Maximum Temperature is load dependent.
b. Does not account for errors due to sensor tolerances.c
c. Measured in a constant ambient temperature. Accuracy is strongly dependant on the individual heating system and P, I, and D gain parameters.
d. Universal input 50 - 60 Hz, no line switching required.

All technical data valid at 23 ± 5 °C and 45 ± 15% humidity.

PID TUTORIAL

PID Basics

The PID circuit is often utilized as a control loop feedback controller and is very 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 very simply 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 just 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. If, for instance, 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 in order 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 is 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. In general 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 are for various control circuits are then given below in the chart.

Control Type	K_p	K_i	K_d
P	0.50 K_u	-	-
PI	0.45 K_u	1.2 K_p/P_u	-
PID	0.60 K_u	2 K_p/P_u	$K_pP_u/8$

PIN DIAGRAMS

Main and Auxillary Output Connectors

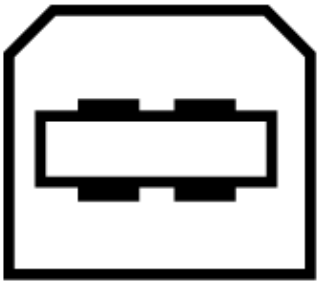
HIROSE HR10A-7R-6S

This view of the connectors is as seen from the rear panel.

Pin	Assignment
1	Heater Output Positive
2	Heater Output Return (Ground)
3	Reserved (Do not Connect to this Pin)
4	Sensor Input (+)
5	Sensor Input (Ground)
6	Reserved (Do not Connect to this Pin)

Computer Connection

USB Type B



USB Type B to Type A Cable Included

SENSOR SPECS

The TC200 is compatible with PT100 (Item # TH100PT) and PT1000 types of Platinum Thermistors, as well as the TH10K thermistor. The following specifications are used for determining the set-point and read back values for these types of thermistors.

PT100 and PT1000 Sensors

For the temperature range of 0 to 850 °C:

$R_T = R_0 (1 + AT + BT^2)$

(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_T 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

TH10K Sensor

$R_T = 10000\exp^{\beta[(1/T) - (1/298)]}$

R_T is the resistance in Ω at temperature T

T is the temperature in K

β is the constant associated with the particular thermistor

SOFTWARE

Software for the TC200 Heater Controller

Software

Version 1.6.0

Software package to operate the TC200 including a GUI, drivers, and LabVIEW™/C++ SDK for third-party development.

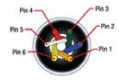
Software

Heater Controller

Part Number	Description	Price	Availability
TC200-EC	Temperature Controller, 230 VAC Power Cord	$621.13	5-8 Days
TC200	Temperature Controller, 120 VAC Power Cord	$621.13	Lead Time

6-Pin Hirose Cable

- 6-Pin, Male-to-Male Hirose Connector Cable
- Compatible with Several Thorlabs Products
  - TC200 Temperature Controller
  - SC10 Shutter Controller
  - SH05 Beam Shutter, Ø1/2" Aperture
  - SH1(/M) Beam Shutter, Ø1" Aperture
- Cut and Expose Wire for Custom Applications



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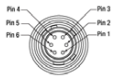

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Specifications	More [+]
Connectors	6-Pin, Male Hirose
Length	10 Feet (3 m)

The TC200CAB10 is a 6-pin, male-to-male Hirose connector cable. This 10-foot-long cable is compatible with our TC200 temperature controller, SH05 and SH1 beam shutters, and SC10 shutter controller. The wires in this cable cross as seen in the drawing to the right. This is not a straight-through cable.

a. Of the speed of light.

This Hirose connector cable can also be cut to any length leaving one connectorized end and one bare end. The colored wire diagram to the right shows the relationship between the six colored wires and the pins in the connector so the cut cable can be incorporated into a variety of custom applications.

Part Number	Description	Price	Availability

TC200CAB10	6-Pin, Male-Male Hirose Connector Cable, 10' Long	$95.50	Today