Instruction Manual

PID Temperature Controllers for Espresso Machines – 09/08/2007

Figure 1

Note: This manual is written for various Chinese controllers available **AFTER** approximately 9/1/06. Controllers purchased **BEFORE** this date may have slightly different parameters available under Code 0089 and Code 0036. These are detailed in the file PID_Manual_1.doc.

1. Product Highlights
Thermocouple Compatibility: T, K, J, and others (B, R, S, E, Wre3, & Wre25).
Resistance Temperature Detectors (RTD's): Pt100, Cu50.
Outputs: 1 Relay output and 1 SSR controlled output.
Time-proportional PID controlled output to either Relay or SSR
Three built-in algorithms that fit most control objects and various applications.
Temperature Display: Degrees Fahrenheit or Degrees Celsius.

2. Specifications
Supply Voltage Range: 20-260V AC or DC
Power consumption: < 2 Watts
Sampling speed: 4/sec.
SSR driving output: 10VDC, 40mA.
Accuracy: 0.2% of full scale
Resolution: 1 F, 1 C or 0.1 F, 0.1 C only when using P10.0 RTD for input signal
LED Display: Red, 0.28 inch tall
Out of range indication /no input to controller: "EEEE"
Ambient temperature requirements: 0 to 50 C (32 to 122 F)
Humidity requirement: < 85% RH
Relay Contact Rating: 240VAC, 3A
Controller dimensions: 48 mm x 24 mm x 75 mm (1/32 DIN).
Required Installation Opening (cut-out): 44 mm x 20 mm

3. Panel Illustration and Description

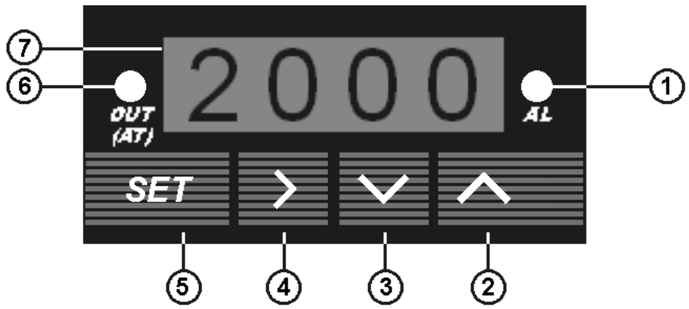

Figure 2

1 - AL, Relay J1 Indicator.
2 - Select next parameter / value increment.
3 - Selection previous parameter / value decrement.
4 - Digit select / Auto tuning.
5 - Setting / Confirm.
6 - Output, controlled output indicator. (AT) is blinking during the auto-tuning process.
7 - Temperature reading, degrees F or degrees C (as chosen)

4. Initialization Parameter Setting (power required)

a. Temporarily connect power and, optionally, your temperature sensor to the PID unit – see **Section 8.**

b. Press (SET) to enter the setting mode, then enter code "**0089**" and press (SET) again.

c. The first parameter, **"Inty"** will appear on screen. Press (SET) and scroll through the various sensor types by pressing the▼ or ▲ key until the one you want appears. Press (SET) to select that particular sensor. Note that the symbols for a "t" or "k" thermocouple are slightly garbled.

d. Press the▲ key to see the next parameter, **"Outy",** and then press (SET). Press the ▼ or ▲ key to scroll through the choices (0, 1, or 2) and press (SET) when the one you want is shown.

e. Press the ▲ key to see the next parameter, **"Atdu"** and then press (SET). Press (>) and then ▼ or ▲ to select the value in degrees you desire for the autotune offset and then press (SET) when the value you want is displayed. The autotune offset is typically 10% of the Sv value (23 degrees F or 11 degrees C

f. Continue the same process for the remaining three parameters.

Table 1 - Initialization Parameters (Code **0089**)

Symbol	Description	Range	Default	Setting	Comment
Inty	Temperature Sensor Type	See Table 2	PT100		
outy	Method of controlled output	0,1,2	2		Note 1
Atdu	Autotune offset	0 to 200 degrees	10		Note 2
PSb	Temperature Sensor Correction	-100 to +100 degrees F, C	0		Note 3
rd	Heating = 0;Cooling = 1	0,1	0		
CorF	Celsius = 0;Fahrenheit = 1	0,1	0		Note 4
End	Exit	***********	*******	**********	**********

Table 2 - Temperature Sensor Type (**Inty**)

Symbol	Description	Original Range	Range (Omega)	Comment
t	**T Thermocouple**	**0 ~ 400 C 32 ~ 752 F**	**-200 ~ 350 C -328 ~ 662 F**	**Internal Resistor**
r	R Thermocouple	0 ~ 1600 C 32 ~ 2912 F	0 ~ 1450 C 32 ~ 2642 F	Internal Resistor
J	**J Thermocouple**	**0 ~ 1200 C 32 ~ 2192 F**	**0 ~ 750 C 32 ~ 1382 F**	**Internal Resistor**
WrE	WRe Thermocouple	0 ~ 2300 C 32 ~ 4172 F		Internal Resistor
b	B Thermocouple	350 ~ 1800 C 32 ~ 3272 F	0 ~ 1700 C 32~ 3092 F	Internal Resistor
S	S Thermocouple	0 ~ 1600 C 32 ~ 2912 F	0 ~ 1450 C 32 ~ 2642 F	Internal Resistor
K	**K Thermocouple**	**0 ~ 1300 C 32 ~ 2372 F**	**-200 ~ 1250 C -328 ~ 2282 F**	**Internal Resistor**
E	E Thermocouple	0 ~ 900 C 32 ~ 1652 F	-200 ~ 900 C -328 ~ 1652 F	Internal Resistor
P10.0	**P100 RTD**	**-200 ~ 600 C**		**Constant Output**
P100	Pt100 RTD	-200 ~ 600 C		Constant Output
Cu50	Cu50 RTD	-50.0 ~ 150.0 C		Constant Output

Note 1 (applies to “outy”) :

0: Relay J1 as alarm output; SSR Disabled, normally used for upper or lower limit alarm trigger control

1: Relay J1 PID controlled output: SSR Disabled. Contact controlled output

2: Relay J1 as alarm output; SSR PID controlled 10 Volts DC output. No Contact controlled output

Note 2: (applies to “Atdu”):

The autotune offset will shift the Sv value down by the chosen “Atdu” value during the autotuning process. This will prevent any damage to the system (espresso machine, kiln furnace, BBQ smoker, etc.) which is being controlled during the autotuning process.

Note 3: (applies to “PSb”) :

Inputting a value for this parameter allows you to “at-home-calibrate” your temperature measuring system. You can use a large pot of boiling water and place your thermocouple at the midpoint of the pot or you can use a distilled water ice slurpy in a covered thermos jug. The boiling water temperature will vary with your altitude and barometric pressure whereas the slurpy temperature will not be affected by either. Of course, the boiling water temperature is closer to the “range of interest”. Your choice – or do both.

Note 4: (applies to “CorF”) :

This parameter sets the display to either degrees C (“0”) or degrees F (“1”). Some users have reported that the TET-7100 and possibly other controllers “work better” when all data and readings are in degrees Centigrade vice degrees Fahrenheit. Obviously, some users are also more accustomed to seeing and thus thinking in terms of degrees C vice degrees F. The controller was designed in and around degrees Centigrade measurement/display and degrees Fahrenheit is simply displayed as a multiplier (1.8C + 32).

5. PID Parameter Setting

To enter the PID parameter setting mode, press (SET), enter code “**0036**”, and then press (SET) again. The first parameter, “P” will be displayed. Press (SET) again and the default value will be displayed (5.0). Press (SET) again to accept that value or use the arrow buttons to change the value to that desired. When finished, press (SET) again.

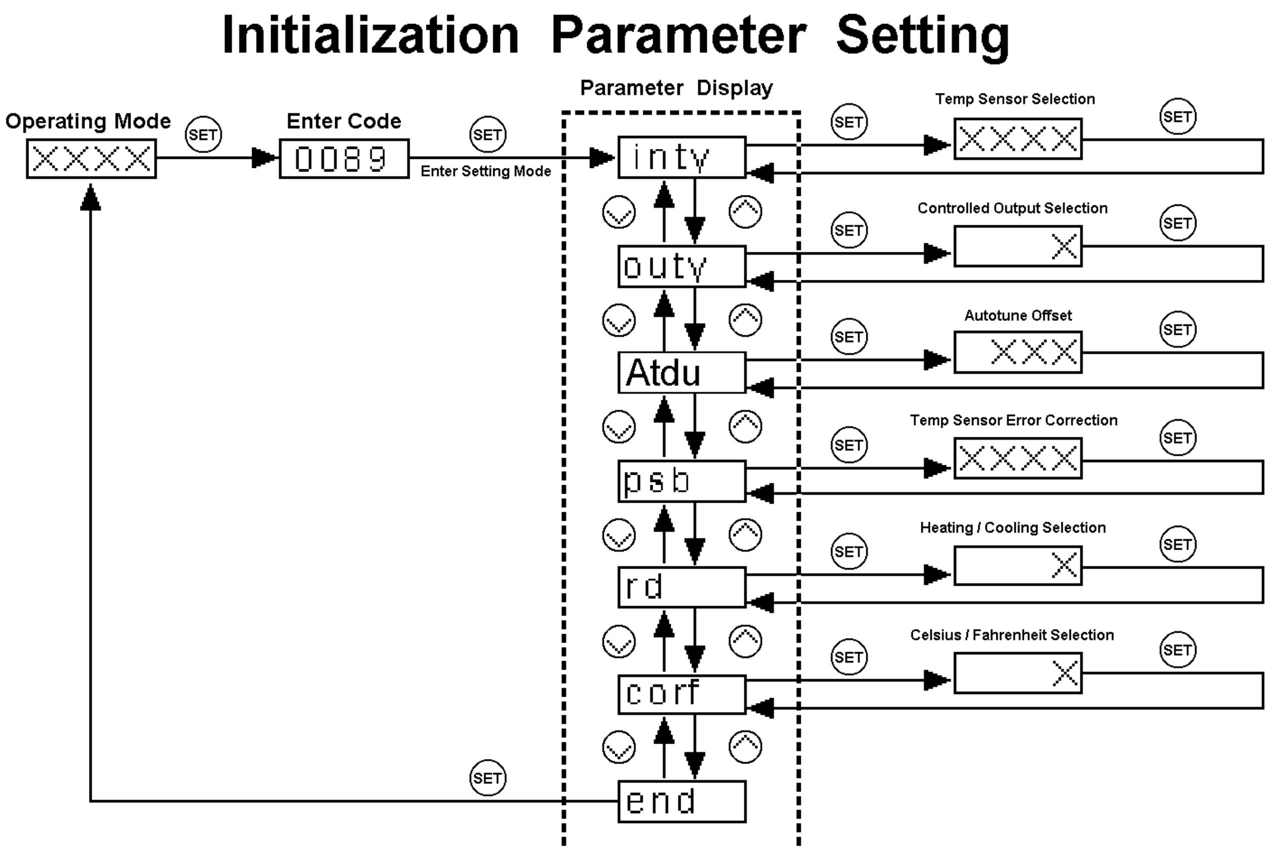

Figure 3

Table 3 - PID and Relevant Parameters (Code 0036)

Symbol	Description	Range	Default	Setting	Comment
P	Proportional Constant	0.1 ~ 99.9 (%)	5.0		Note 5
I	Integral Time	2 ~ 1999 (Sec)	100		Note 6
d	Derivative Time	0 ~ 399 (Sec)	20		Note 7
SouF	Damping Constant	0.1 ~ 1.0	0.2		Note 8
ot	Control Period	2 ~ 199 (Sec)	2		Note 9
FILt	Digital Filtering Strength	0 ~ 3	0		Note 10
End	Exit	************	*******	*********	**********

The P, I, and d parameters control the response accuracy and the response time of the temperature controller. Auto-tuning is recommended for users who are not familiar with PID control theory and as initial “ball-park” settings which can easily be fine-tuned later. P, I and d values should only be adjusted in relatively small steps and only after writing down what the existing “auto-tuned” values are prior to making adjustments. For espresso machine use, “P” should be no higher than 5.0 and “d” should be about 25% of “I”. Typical values of “I” are 20-44 and for “d”, 5-11.

Note 5

Proportional Constant (P): The Proportional Constant represents the gain of the signal amplifier. It is entered as a percent of the input range of the controller. The problem comes in knowing what is meant by input range. The minimum and maximum values that can be entered for SV with the SYL-1512 are -199 and 2999 F or C, respectively. That translates into an input range of about 3200 degrees. Given a P value of 2.0 (2.0 %), the proportional constant would be 64. As P is increased, temperature fluctuation of the object being controlled decreases but the time to return to the setpoint in a stable manner increases. Conversely, as P is reduced, the temperature fluctuation of the object being controlled increases but the time to return to the setpoint in a stable manner decreases. If P is too small, the system may become non-convergent.

Note 6

Integral time (I): The integral time is the speed at which a corrective increase or decrease in output is made to compensate for offset. As “I” is increased, the controller action slows down. A decrease in “I” results in faster action, i.e. as “I” is lowered, response time is reduced but the system is less stable.

Note 7

Derivative time (d): The derivative time is that time used in calculating the rate of change and thermal lag in helping eliminate overshoot. The derivative action dampens proportional and integral action as it anticipates where the process should be. The more derivative time entered, the greater the damping action. The derivative time should only be as large as necessary to eliminate overshoot without over-damping the process, resulting in oscillation.

Note 8

Damping Constant (SouF): This constant can help the PID control further improve the control quality as it helps to dampen the temperature overshoot. When SouF is set too low, the system might overshoot. When it is set too high, the system will be overdamped and may not reach the value set for Sv.

Note 9

Control Period (ot): As “ot” is set lower, the heating/cooling cycle is driven faster, and thus system response speed is faster. When using an electro-mechanical contact control (relay), the mechanical contacts will wear out faster. When an electro-mechanical contact control (relay) is used, normally set ot = 5~30. When a non-contact control relay (SSR) is used, normally set ot = 2 (the minimum value which can be set).

Note 10
Digital Filtering (Filt): Filt = 0, filter disabled; Filt = 1, weak filtering effect; Filt = 2, moderate filtering effect; Filt = 3, strongest filtering effect. The stronger the filtering, the more stable the readout, but the controller will have more readout display delay.

6. Temperature and Alarm Parameter Setting

To enter the temperature and alarm parameter setting mode, press (SET), enter code "**0001**", then press (SET) again.

Table 4 - Temperature Setting and Alarm Related Parameters (Code 0001)

Symbol	Description	Range	Default	Setting	Comments
Sv	Target Temperature	Within testing range	80.0		
AH1	Relay Closed	Within testing range	80.0		
AL1	Relay Opened	Within testing range	90.0		
End	Exit	****************	******	**********	**********

During Normal Operation mode, pressing (^) or (v), the display will show SV. Pressing (^) or (v) again would increase or decrease SV by 1 degree.

a) Set AH1 = AL1, relay is disabled.

b) Set AH1 > AL1: Normally used for upper limit alarm trigger. See Figure 4.

c) Set AH1 < AL1: Normally used for lower limit alarm trigger. See Figure 5.

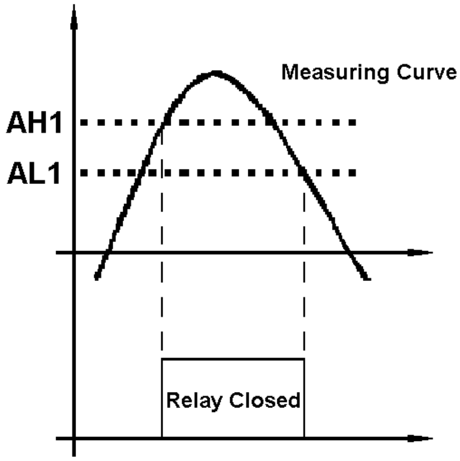

Figure 4

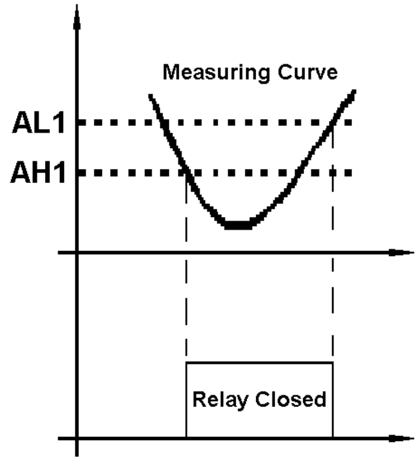

Figure 5

7. Auto-Tuning

By pressing a single button, the built-in artificial intelligence is activated to automatically calculate and set parameters (P, I, d, SouF) that fit the condition to be controlled.

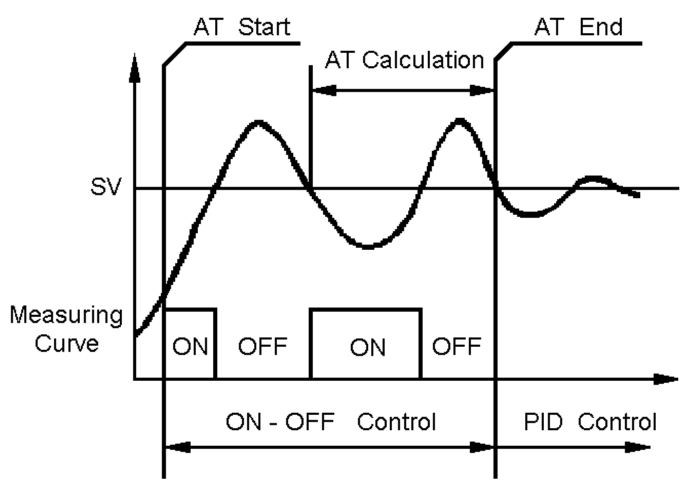

Figure 6

a. To activate auto-tuning, press and hold (>) until "AT" indicator is blinking, which indicates auto-tuning is in progress. Activate auto-tuning when the machine to be controlled is at or 10% below your typical setpoint temperature (SV). When auto-tuning finishes, the "AT" indicator light turns off. Now newly calculated PID parameters are stored in memory and will be used by the controller from this point forward.

b. To EXIT during the auto-tuning process, press and hold (>) until the "AT" indicator stops blinking. The previously entered PID parameters values are now used by the controller.

8. Connection Terminals (back view)

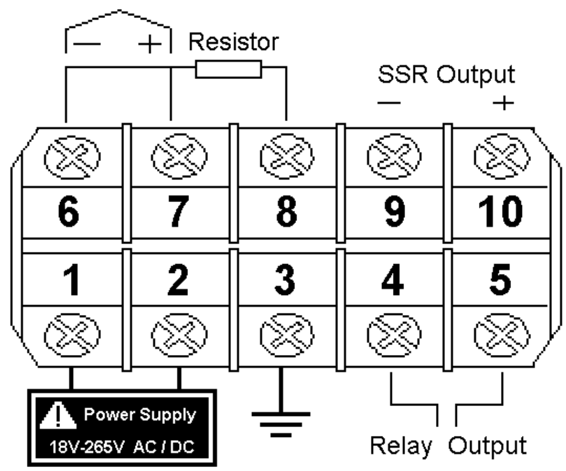

Figure 7

Prior to installing the unit in a panel or other enclosure, some of the basic parameters which are not set during the auto-tuning process should be established. Note that the controller can not be set up in any fashion unless power is supplied. Proceed as follows:

a. Supply the unit with power to terminals 1 and 2 – an 18 gage extension cord with striped ends works fine. Note that the polarity of power at these terminals does not matter.

b. Attach the leads of a thermocouple to terminals 6 and 7, observing correct polarity.

c. Note that if a 2-wire RTD is used as the temperature input signal, terminals 6 and 7 **MUST** be electrically shorted (jumpered) as shown in Figure 7.

9. Supplied Thermocouple

These inexpensive PID controllers are often (**but not necessarily**) supplied with a Type K thermocouple. This thermocouple has “loose” ¼-20 threads and is designed to be used PRIMARILY in conjunction with a thermowell or measuring ambient temperature inside a kiln or roaster where there is high temperature but zilch pressure. While it **COULD BE** adapted to an espresso machine, $10 + shipping would buy you the “proper” type of thermocouple from Omega or other reputable thermocouple supplier. The easiest to install would be a washer-style thermocouple and the “best” from a control/accuracy standpoint would be a Type T with special limits of error (SLE) wire.

10. Application Example

Assume you want to control the water temperature of an espresso machine's boiler by measuring the surface temperature of the boiler top. A surface mounted, washer-style, Type T thermocouple is chosen. Boiler surface is to be maintained at 230 deg F which coincides with an internal temperature of approximately 240 F. Available power supply is 110-120 VAC and a solid state relay (SSR) with a rating of 25A will be used to control the boiler's 800 watt heating element.

a) Choose a PID temperature controller with input from a Type T thermocouple
b) See Figure 8 for connection diagram
c) Enter parameter settings

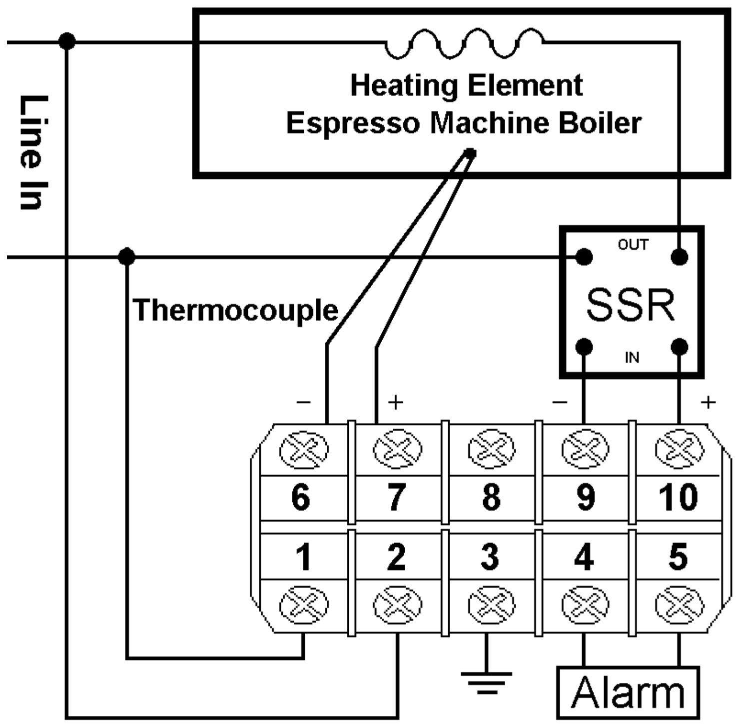

Figure 8

(Inty) =	t	(auto-tuning should be used to initially set	
(outy) =	2	PID parameters – P, I, d, SouF)	
(PSb) =	0	(SV) =	230 deg F
(Rd) =	0	(AH1) =	325 deg F
(CorF) =	1	(AL1) =	325 deg F
(FILt) =	0		

Power up the controller and press (>) to activate auto-tuning. I would recommend initiating the auto-tuning process when your machine is at setpoint or about 10% below setpoint (SV) and seeing what values are returned for P, I, d, and SouF. When "AT" stops blinking, new PID parameters are generated for the system and retained internally in non-volatile memory. The controller is now in normal operation mode. A data sheet is provided below for your adventures in manual tuning your PID should you find this necessary.

DATA SHEET

Date	SV	P 1.2-4.8	I 60-120	d 15-30	SouF 0.1-1.0	Comments (response time, overshoot/undershoot, etc.)

Enter Code 0036 to change parameters P, I, d, and SouF,

11. Using the PID Controller as a simple temperature meter
The inexpensive PID controllers (1/32 & 1/16 DIN) available on Ebay range in price from $25 to $35 + S&H. Although they display whole digits only, they all have the ability to correct their "readings" (but not their display) to tenths of a degree. They usually require a temperature correction of 2 to 4 degrees but once "calibrated" to a particular thermocouple, "system" accuracy is dramatically improved. Their disadvantage is that they require power (typically 110-120 VAC is used) but this is most easily accomplished with a shortened extension cord whose female plug end is snipped off. A very flexible 18 gauge appliance cord ($5) available from your local hardware store works best. Make sure the PID can read the type of thermocouple you want to use (Type T highly preferred) – most, if not all, 1/32 DIN controllers can while the 1/16 DIN controllers on Ebay are sometimes limited to Type K thermocouples. **READ THE ITEM DESCRIPTION VERY CAREFULLY AND ASK THE SELLER QUESTIONS.**

If you desire to not see/hear the alarm contacts activate, set AL1=AH1 in the alarm settings mode. However, please note that some interesting control schemes could be developed using the relay contacts of the alarm, i.e. automatically stop the pump (open the pump run circuit) when the cooling flush reads temperature "X".

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Editor's Notes: This is a **REVISED EDITION** of the manual that is shipped with a variety of inexpensive (but good value) PID temperature controllers available from Ebay and other sources. Their typical price is $ 25 - 35 + shipping.

The specific 1/32 DIN PID temperature controllers which this document is considered to be applicable to are: SYL-1512 from Auber Instruments, SET-712 from Tibet Electronics, and the TET-7100 from ColdfusionX.

Changed all color drawings to B&W and edited illustrations to make them clearer

Added columns to tables where you could pencil in "your" values

Added column to Table 2 to insert normal ranges (from Omega Engineering, Inc.) for the particular input chosen

Edited grammar and corrected some spelling

I'm still working on this document as I learn more and more – it is a work in progress. If you happen to disagree with anything I have written, PLEASE e-mail me with the suggested corrections – erics@erols.com