TCM-Series Temperature Controllers V1.06

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1 Introduction

Our TCM series of Temperature Controllers are designed for use with thermoelectric coolers also known as TEC's or Peltier devices. These offer precise temperature control from –200 ºC to 100ºC at up to 0.001ºC stability. Our controller can be setup or controlled from a PC via RS232 or USB this allows access to output limits, PID terms, deviation alarms and operating modes.

A typical use for any precise temperature control system would be with laser diodes, infrared detection, high gain amplifiers and cold plate assemblies.

The TCM series temperature controller is suitable for controlling single and multiple TEC arrays. It provides a pulse width modulated output which effective provides a continuously variable output for cooling and heating.

It is programmable from a PC allowing configuration and tuning to meet system requirements. This configuration data is stored internally allowing standalone operation once programmed. Its RS232 interface and command set allow the unit to be controlled remotely, in particular this allows changing of the set point and alarm temperature settings.

2 Controller Functions

The controller has the following functional parts –

2.1 Sensor measurement

The input stage provides measurement for resitive and voltage output sensors. These are measured by a sophisticated delta-sigma ADC which gives excellent accuracy and noise suppression.

Suitable for Pt100 sensors - 100 R accuracy 0.001 C over –200 to +400 C range
Voltage sensors accuracy 0.01 mv or better

2.2 CPU

This provides all the intelligent control, measuring the input values and calculating the output required for the control type. It also provides storage for the configuration parameters .

2.3 Output driver

This provides a bi-directional variable output drive to the TEC element(s). The output switches at the preset repetition rate and adjusting for output value by setting the PWM duty cycle.

2.4 Communications

This is provided via RS232

2.5 Power

The drive to the TEC's is provided directly from the voltage supplied so this should be the same as the TEC's maximum rating or less.

3 Connections

3.1 PT100 Measurements

For PT100 measurements configure the following links on the TCM PCB

Lk1 connect pins 2 and 3

No other links

Connect PT100 sensor to J8 on pins 3 and 4 with screen to pin 6.

3.2 Voltage sensor measurements

For voltage outputs sensors, LM35, LM50, LM51, LM 60, LM 61 configure the following links on the TCM PCB

Lk1 link pins 1 and 2

Lk2 link pins 2 and 3

No other connections

Connect sensor to J8, Sensor + to pin 1, sensor output to pin 3 and sensor gnd to pin4 with screen if used to pin 6.
In this configuration LM35 operates down to zero degrees C but not below

3.3 LM 35 operation below zero

This requires biasing in order for its output to go below zero.

LK1 link pins 1 and 2
LK2 link pins 1 and 2
LK4 link pins 2 and 3
No other connections

Connect sensor to J8, Sensor + to pin 1, sensor output to pin 3 and sensor gnd to pin4 with screen if used to pin 6.

3.4 NTC thermistors

To connect NTC thermistors –

LK1 link pins 1 and 2
LK2 link pins 2 and 3
LK4 link pins 1 and 2
No other connections

Connect thermistor to J8 between pins 3 and pins 4, connect screen if used to pin 6

For best operation stick with 10K types these have a better range in this circuit. Other values can be accommodated if required
Consult Electron Dynamics for possibilities

3.5 Other temperature sensors
These are possible please consult Electron Dynamics for advice.

3.6 TEC connection
Connect to J3 noting polarity, actual drive polarity can be configured by software

3.7 Power connection
Power should be applied to J2

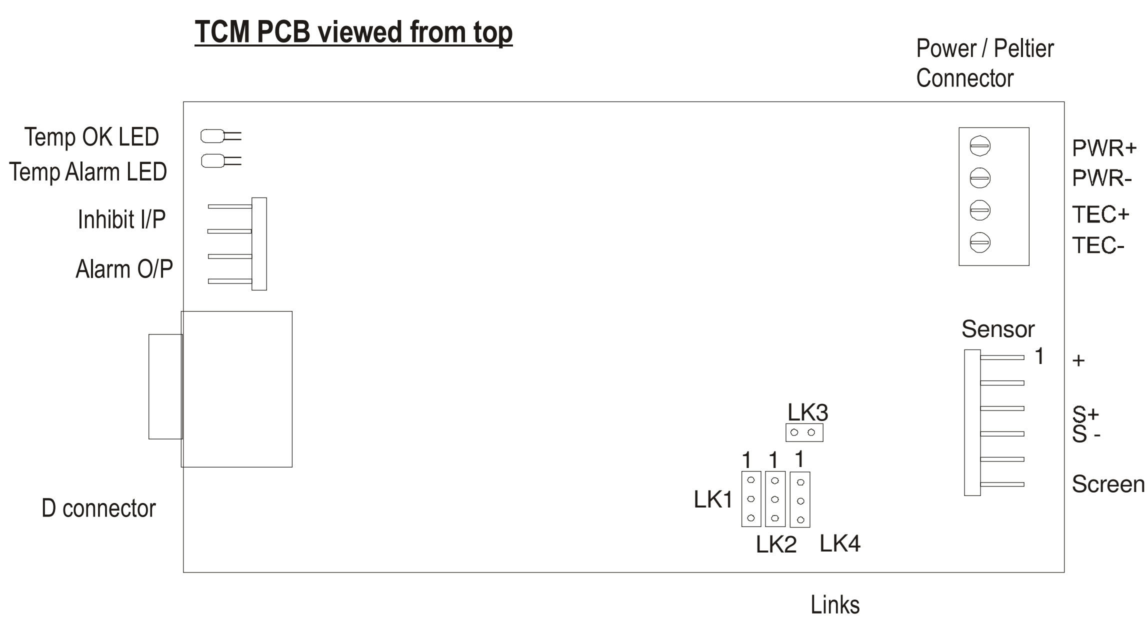
3.8 Alarm output
This is provided from J4, this is active when low.

3.9 Inhibit
This is provide from J1 and inhibits the drive when the pins of j1 are connected together.

For multiple uses the TCM temperature controller can be made to inhibit control of other TCM controllers by its alarm output indicated by LED2. To achieve this, the alarm output will need to be daisy chained to the inhibit switch of the respective controller.

3.10 RS232
This is provided from J5.
Baud rate is 19200 1 stop bit, no parity
Note you should use the special RS232 lead provided

3.11 PCB Connector / Link positions



4 LED Status

The TCM series temperature controller has two LEDs that show the status of the controller.

TEMP OK (LED 1) ON – Temperature ok in relation to set point and user defined settings

TEMP OK (LED 1) OFF – Temperature out of range

TEMP ALARM (LED 2) ON – Indicates an alarm or inhibit (External or Internal)

TEMP ALARM (LED 2) OFF – Temperature controller working correctly

5 Thermal Issues

5.1 Sensor Selection

The TCM series of temperature has many options for different sensor types. Each sensor type has different characteristics which will affect your choice -

Sensor type	Accuraccy	Resolution	Range
PT100 RTD	<0.1 deg	<0.005 deg	-260 to +850 deg C
LM35,LM50 etc	<2 deg	< 0.005 deg	-40 to 100 deg C

There are variations in size with some types so choose a suitable size for your application.

5.2 Thermal Assembly

This is a critical component in the system design, typically there are 2 problems –

- the heatsink is not large enough
- the thermal conduction between components is poor

It is worth reading the extensive material available from the peltier / TEC manufacturers to find out the requirements for this.
See www.marlow.com and www.melcor.com

5.2.1 Heat sink size

The size of this should be chosen using the manufacturers calculations, it will need to be large enough to radiate the heat required, typically they have a large heat capacity but often are more limited in there capability to dissipate the heat. This is often seen when operating under temperature control there is a continuous rise in heatsink temperature or rise in drive current. It should be noted that there is a point in where the system can go into thermal runaway, as the heatsink is unable to dissipate the heat properly and the temperature of the sample and heatsink will continuously climb.
So this should be chosen to be larger than necessary.
Also using a fan on the heatsink can improve the thermal resistance to air by as much as 3 times so this will give a significant improvement.

5.3 Thermal Conduction

It is important to ensure that there is a good thermal path between the Sample, TEC and heatsink. Not only does this provide good heat removal / dissipation but will improve the temperature stability.

Also important is that the mating surfaces are reasonably flat and and that just enough heatsink compound is used to make the thermal connection. A misconception is that more compound will be better, but this reduces the thermal connection, always dramatically compromising the temperature stability.

5.4 Peltier Size

This should be calculated from the manufacturers selection.
It is important that the TEC is not driven beyond its maximum, the device will certainly be damaged if the maximum current is exceeded. Due to the nature of the peltier device as the drive is increased above between 60 and 75% of maximum it becomes progressively less efficient and in this situation will tend to just provide more local heating that heat pumping. This can possibly lead to thermal runaway if the limit is not set . We feel that there is little point in working the devices in their inefficient region and recommend that device are run at a maximum of 70% of maximum drive.

5.5 Drive Limit

On the TCM series the TEC drive limits allow maximum cooling and heating rates. Where the maximum drive is 100%. So to reduce a 12v device to half power, if we are powered at 12v then the max and mins should be –50% and 50%.
The situation if powered from 9v would be 9/12 * 100 = 75%

5.6 Important stability issues

Some important factors to remember.

Facilitate faster settling time and response

- by reducing thermal mass of sample
- reduce distance between TEC and item being cooled

Improve accuracy by locating sensor near to cooled device as possible

Reduce thermal load by reducing thermal feedback from heatsink to sample by using thermal insulation.

6 Temperature Controlling

6.1 Off mode

This is purely a mode in which under temperature control the output drive is off. This is intended for diagnostics or to ensure a failsafe condition.

6.2 On/Off control

This mode of temperature control is the most basic, it benefits from being relatively easy to set up. Simply specify the setpoint, and dead band. However there are some problems with this approach, due to full on / full off nature of the output, the temperature stability is relatively poor. Though will be sufficient for some applications. The other problem is that TEC is cycled fully heating and the fully cooling, this may cause reliability issues with the TEC itself.

6.3 PID Control

PID control comprises of 3 elements Proportional, Integral and Derivative.
These can be operated separately or together, the selection can made through the modes or by the PID values themselves.

The Proportional term provides a variable output which as the temperature deviates further from the set point then the output drive increases until the maximum is reached. The response of this is defined by the value of the P term.

Where Output = (setpoint-actual temperature) * proportional term

The main problem with Proportional only control is there is always a temperature error, this is due to the fact that in order to provide an output then there needs to be a temperature error.

Using an integral term overcomes the problem of steady state errors, practically it acculmulates any error and applies this to the output drive to compensate, Increasing or decreasing it accordingly. Though there are direct benefits in temperature accuracy there is some sacrifice in system stability particularly as the integral effect is increased.

The derivative term provides an output proportion which varies with the rate of the input error or output. This provides a faster response to temperature variations and also provides a stability balancing effect to the integral term. Please note that for best stability there must be a fixed ratio between the I term and the D term normally 4 to 1.

Due to the inherently large gain of the derivative at high frequencies at filter, the derivative TC is provided to attenuated high frequency noise.

6.4 Tuning the PID parameters

The PID parameters can be tuned using various methods,
There are many methods of tuning the PID parameters required, some of these also allow you to tailor the response in certain ways.

Three of the main ones are –

- Relay feedback – closed loop
- Ziegler - Nichols open loop – step response
- Ziegler – Nichols closed loop – ultimate gain method

The basic methods are mentioned below however you should look at the articles available for detailed explanation.

6.5 Relay Feedback – Autotuning

The TCM features an auto tuning function as standard using the relay feedback method, this makes this tuning very much easier. The user is able to select the setpoint around which the auto tuning should occur and how long for the unit to make measurements. The unit then sets up the relay feedback conditions under which oscillation occurs, these peaks are analysed and from these the PID parameters are calculated. The test aborts at the end and uses the new PID parameters for temperature control.

6.6 Ziegler - Nichols open loop – step response

This is open loop so there is no the control function is off, it involves making a step change at the output The input / thermal response should be noted, then using graphical means should be analysed, to give the initial process dead time and the process time constant. From these the respective terms can be calculated -

Td is Process time constant t is pseudo dead time and Kp the process gain

From this the PID terms are calculated

P term is 1.2 (t/ (Td * Kp)) I term is Td / 0.5 and D term is Td * 0.5

6.7 Ziegler - Nichols closed loop – ultimate gain method

This is a closed loop so the control function in on. With the P term set low and the I term and D term off. Monitoring the temperature the gain or P term is increased until there is sustained and continuous oscillation of the temperature. The Gain (P term) required and the period of the oscillation should be noted. From these the PID terms can be calculated.

Where

Gu is the gain and Tu is the period

From this the PID terms can be calculated

Where

P term = 0.6 Gu I term = 0.5* Tu D term = 0.125 Tu

7 Graphical User Interface

The TCM series Temperature Controller can be operated via the *Graphical User Interfaces,* one written in Java and the other in C++. They are very similar with minor differences.

The GUI will be broken down into seven functional categories, each will be explained in the remainder of this section of the manual:

I. Pull Down Menus
II. Control
III. Set Point
IV. Sensor
V. Output
VI. Alarms
VII. Report

7.1 Pull Down Menus

7.1.1 File Menu

Save as defaults allows the user to save a copy of the current GUI set up, which can be loaded using the load defaults command.

The exit command closes the GUI.

7.1.2 Port

The desired communication port can be chosen and the TCM Series Temperature Controller can be connected or disconnected. Please note port needs to be selected and opened at the outset in order to communicate with the controller.

7.1.3 Help

Displays help information

7.2 Control

7.2.1 Type

The control algorithm can be single or a combination of *Proportional, Integral, Derivative* terms. The list box allows the user to define the controller terms required.

The available options are;

0. None
1. On/Off
2. Proportional

3. Proportional and Integral

4. Proportional, Integral and Derivative

User defined values can manually be entered here for the controller to operate from.

7.2.2 None

This is a default off mode for diagnostic or fail safe purposes.

7.2.3 On/Off

With On /off control the output drive is only fully On, heating or cooling or off.
Its response is –

Temperature > setpoint + deadband Fully Cooling
Temperature < setpoint - deadband Fully Heating
Temperature <setpoint +deadband and >setpoint-deadband output off

7.2.4 Proportional

With proportional action, the controller output is proportional to the temperature error from the setpoint. The proportional terms sets the gain for this where

Output = (setpoint-actual temperature) * proportional term

7.2.5 Integral

With integral action, the controller output is proportional to the amount of time the error is present. Integral action eliminates offset. The integral term is a time unit in seconds. NB for larger effects of integration reduce the integral time, also for operation without integral, integral time can be set to a large number e.g. 1,000,000.

7.2.6 Derivative

With derivative action, the controller output is proportional to the rate of change of the measurement or error. The controller output is calculated by the rate of change of the measurement with time, in seconds. To increase the derivative action increase the derivative value. See also Derivative Filter

7.2.7 Derivative Filter

The derivative filter is a low pass filter function on the derivative value. This allows the filtration of noise components which are a problem with a pure derivative function.

The filter value should be set to between 0 and 1.

7.2.8 Dead band

For use with On/Off control the dead band specifies the temperature range around the set point where the output is zero.

7.2.9 Power Up State

This sets the temperature control state from power up, where this can be set as On or Off or where Last is selected it sets its last setting prior to power off.

Dead band

7.3 Set point

7.3.1 Method

The temperature set point can be set via the PC or by altering the pot on the TCM series Temperature controller hardware.

For setting via the PC select the PC radio button and enter the set point value into the edit box directly following the radio button.

7.3.2 Pot Range

This sets the temperature range that the pot gives values for.

7.3.3 Pot Offset

This sets the minimum temperature point on the pot.

7.3.4 PC Set Point

This allows the set point to be fixed via the GUI

7.3.5 Control

The control radio button if checked inhibits the temperature control.

7.3.6 Output

The output edit box allows the a fixed output to be set. To use this the control should be disabled otherwise any setting made will be over ridden by the control. Range 0 to +/- 1000

7.4 Sensor

7.4.1 Type

The supported sensor types are selectable from the list box; refer to the specification section 7.6 in this manual for supported temperature sensors.

7.4.2 X2, X, C Coefficients

These are quadratic coefficients than can be input to convert the sensor voltage measured into a temperature. This can be used for other sensors so that these can calibrated.

Where temperature = (v * v * X2) + (v * X) + C

v is measured sensor voltage and temperature is calculated temperature

The C term allows the user to adjust / shift the temperature to compensate for variations in sensor accuracy. It can be seen that this value simply added to the temperature value. So if your sensor was 1 degree out then make C = 1.
Also provided is buttons to decrease / increase this value in 1 degree steps.

For NTC thermistors different parameters are required

7.4.3 NTC thermistors

For NTC thermistors different parameters are required .

Beta as specified for thermistor type

Resistance at 25 deg C
C coefficient degree offset
Rl drive resistance on TCM 22000 as standard

7.4.4 Units

The temperature can be displayed in degrees Centigrade, Kelvin or Fahrenheit.

7.5 Output

7.5.1 Polarity

This sets the polarity of the output drive,

7.5.2 Minimum

Sets the minimum value limit of the output. Range 0 to +/- 1000

7.5.3 Maximum

Sets the maximum value limit of the output. Range 0 to +/- 1000

7.5.4 Frequency

Sets the PWM repetition frequency of the output drive. Range 20 to 1000 Hz

7.6 Alarms

7.6.1 Minimum Alarm

Sets the temperature below which the alarm is activated. Select via check box to enable.

7.6.2 Maximum Alarm

Sets the temperature above which the alarm is activated. Select via check box to enable.

7.6.3 Minimum OK Temperature

Sets the lower temperature difference point from the set point for temperature OK.

7.6.4 Maximum Temperature

Sets the higher temperature difference point from the set point for temperature OK.

7.6.5 Operational temperature max (Only available on certain GUI)

Sets the temperature maximum, above which the drive output is disabled.

7.6.6 Maximum Temperature (Only available on certain GUI)

Sets the temperature minimum, below which the drive output is disabled..

7.7 Report

7.7.1 Set point

Displays the set point, can be used to ensure the controller has accepted the set point entered in the control category; refer to section 5.3.

7.7.2 Temperature

Displays the measured temperature, the measured temperature units can be Celsius, Fahrenheit or Kelvin and can be selected in the sensors category; refer to section 5.4.3

7.7.3 Control

Displays the condition of the output drive either On or Off.

7.7.4 Output

Displays the output value is set to. Range 0 to +/- 1000

7.7.5 Alarms

Displays whether an alarm is active.

7.7.6 Faults

Displays any fault codes.

7.7.7 Temperature OK

Displays if the temperature is in the ok range

7.7.8 Reading and Setting Parameters

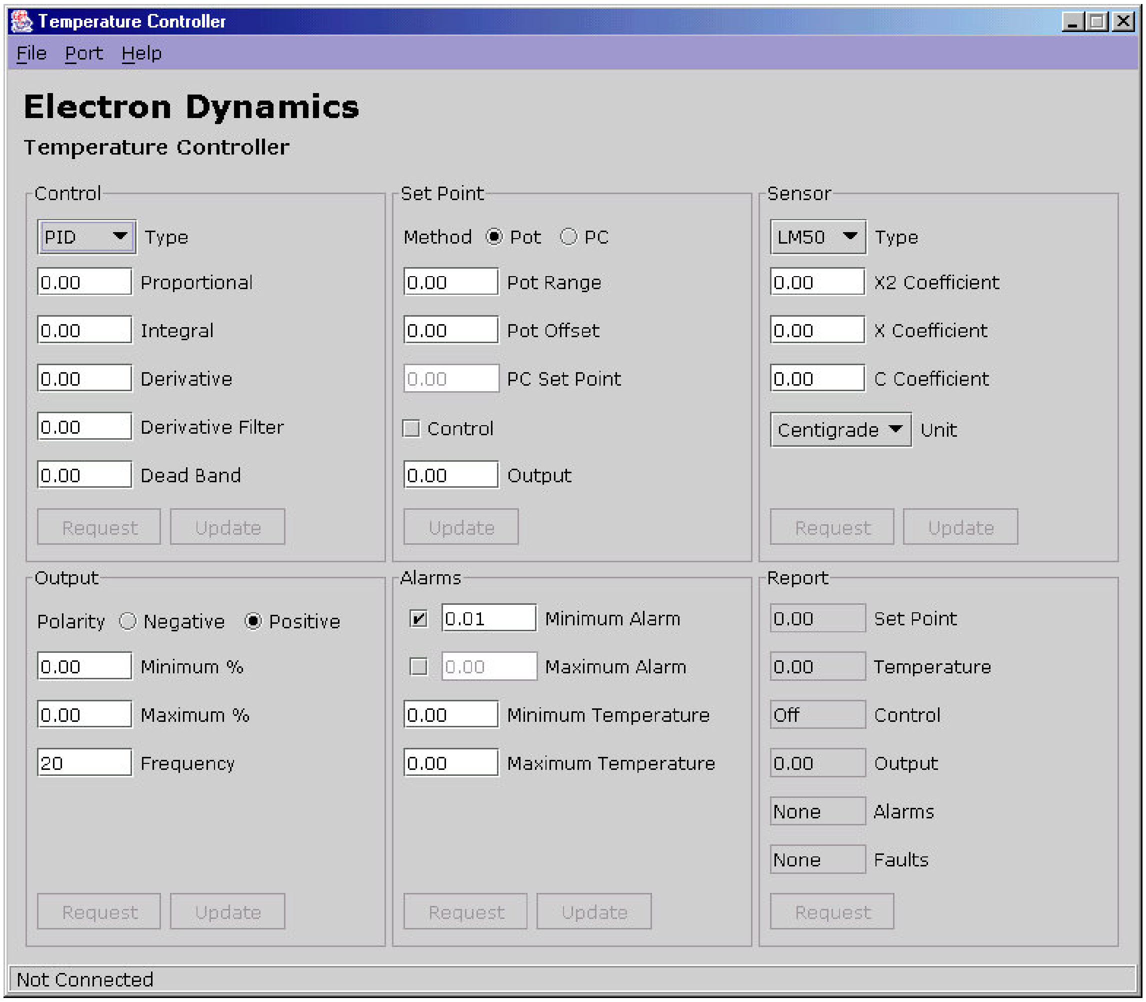
7.7.9 Read Button

The read button will load the respective GUI category with the current condition of the TCM Series Temperature Controller

7.7.10 Write Button

The wite button will load the TCM Series Temperature Controller with the current conditions entered in to the GUIs category.

7.7.11 Figure TCM series Temperature Controller GUI (Java)



7.8 C++ GUI

There are minor differences with the Java GUI as below.

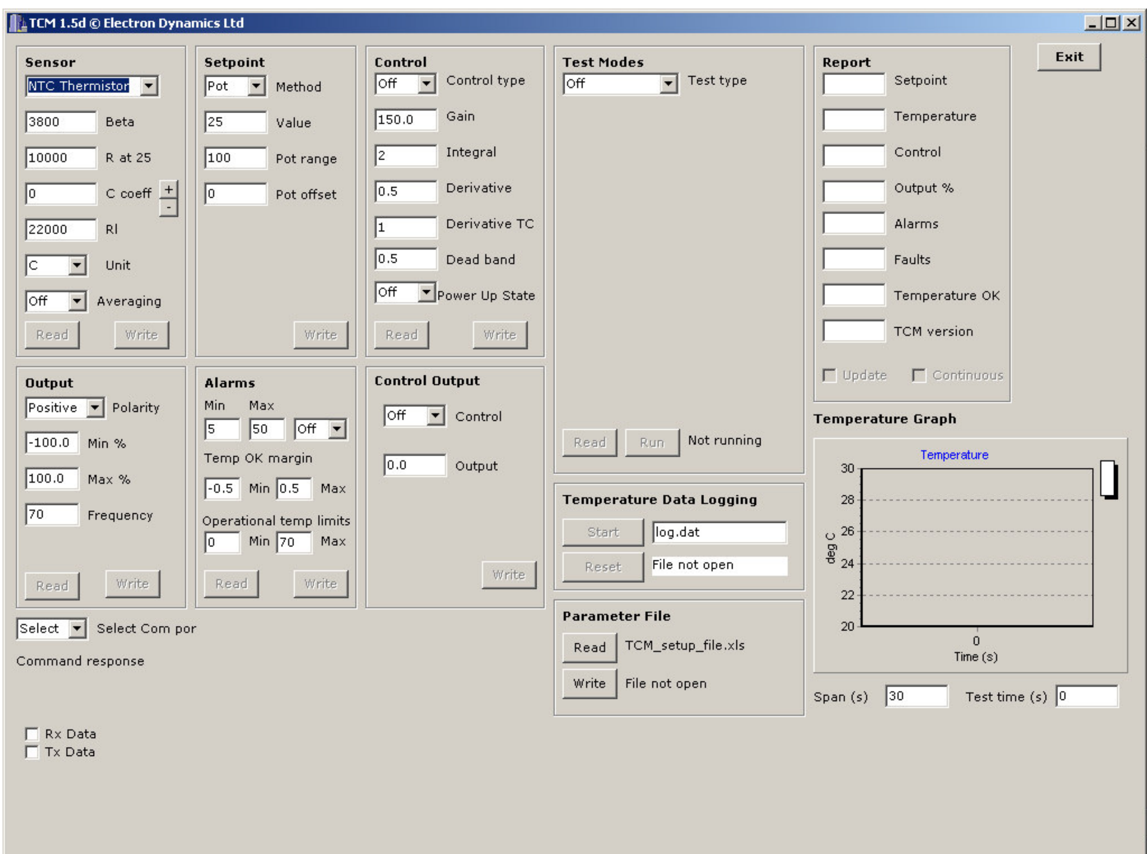
7.8.1 Additional features

The C++ GUI has feature for test mode, temperature cycling and temperature ramping, also included is an auto-tuning algorithm for setting up the PID terms automatically.

7.8.2 Data Logging

This function enables / disables a continuous stream of temperature and output information from the TCM controller. This is stored in a log file for compatible with excel for analysis. This allows the user to measure response graphs for tuning and stability anaysis.

7.8.3 C++ GUI



8 Communication Protocol

Please see the RS232 commands file on the resources CD-ROM.

9 Specification — TCM Series

9.1 Supply

5v to 28v DC

9.2 Output

0 to 5A (TCM 5A), 0 to 10A (TCM 10A), 0 to 25A (TCM 25A)

Bi-directional heating and cooling

Variable output – 0 to +/- 1000 0.1% resolution

PWM rate variable 20hz to 1000Hz

9.3 Control

From PC on RS232 or via USB adaptor

Programmable PID terms

Will operate as P, PI, PID or On/Off with Hysterysis

Resolution 0.001 deg C

Max stability 0.001 deg C depending on thermodynamics /setup etc

9.4 Set point

Set either by pot, or by PC

9.5 Alarm

PC configurable TTL output, active low

High temp. Low temp or out of band

9.6 Sensor

Voltage, PT100, LM35, LM50, LM60, LM61, NTC Thermistor, OTHER

Other versions can be calibrated using the quadratic coefficients

9.7 Measurement Accuraccy

PT100 0.001 deg C or better

LM35 etc 0.001 deg C or better

9.8 User

Windows control software allows access to all parameters

Can be controlled within a process environment

9.9 Format

PCB assembly or Module

10 Sources of Information

There is a lot of information on the internet with some of it relevant have a look at these -

http://www.peltier-info.com - TEC information site

http://www.melcor.com -TEC manufacturer

http://www.marlow.com -TEC manufacturer

http://www.jashaw.com/pid/ - Control E book

http://www.jashaw.com/pid/tutorial/pid6.html - PID tuning lecture notes

http://www.brewerscience.com/cee/otherprods/cee_pid.html - PID notes

http://lorien.ncl.ac.uk/ming/pid/PID.pdf - PID notes