JUNIOR User Guide

Version 1.04

09th Jan 2019

Contents

1. Hardware

1.1. Introduction

The Adaptive JUNIOR is a PID capable pulse width modulator intended for thermoelectric cooler or heater applications requiring either uni- or bi-directional operation. The Adaptive JUNIOR thermoelectric controller features all the hardware and software necessary to complete standalone heating or cooling applications based on thermoelectric devices (TEG). The board is also capable of driving isolated solid state relays in higher power AC applications. The controller allows users to easily evaluate a thermoelectric set up with the help of the auto tuning facility and make decisions once the behaviour of the system is known. It offers an on-board micro USB and RS232 connection allowing direct interface to a PC for easy programming and evaluation. Users can download the latest version of the Adaptive HMI control software to configure and monitor applications using the JUNIOR board.

The board features include:

- RS232 and USB programming interface
- Four thermocouple or NTC sensor inputs
- Two operating mode feedback LEDs
- Manual set temperature
- Three fan driver output
- Alarm output
- Solid state relay (SSR) output
- Thermoelectric driver output

1.2. Electrical Specification

The electrical parameters for the Adaptive JUNIOR board are shown in Table 1 Electrical Specification below.

Input voltage range	11 – 48V DC
Maximum Load	15 A
Control temperature range	-50°C to +250°C
Operating temperature	-20°C to +50°C
Compatible fan	2, 3 and 4 wire fans
Fan output voltage range	11 – 48V DC
Compatible sensors	K-type, NTC
Communication interface	USB 2.0, RS232
Temperature control accuracy	+/- 0.1 C°

Table 1. Electrical specification

1.3. Board Overview

Figure 1. shows the Adaptive JUNIOR connections details and features, which are further detailed in Table 2.

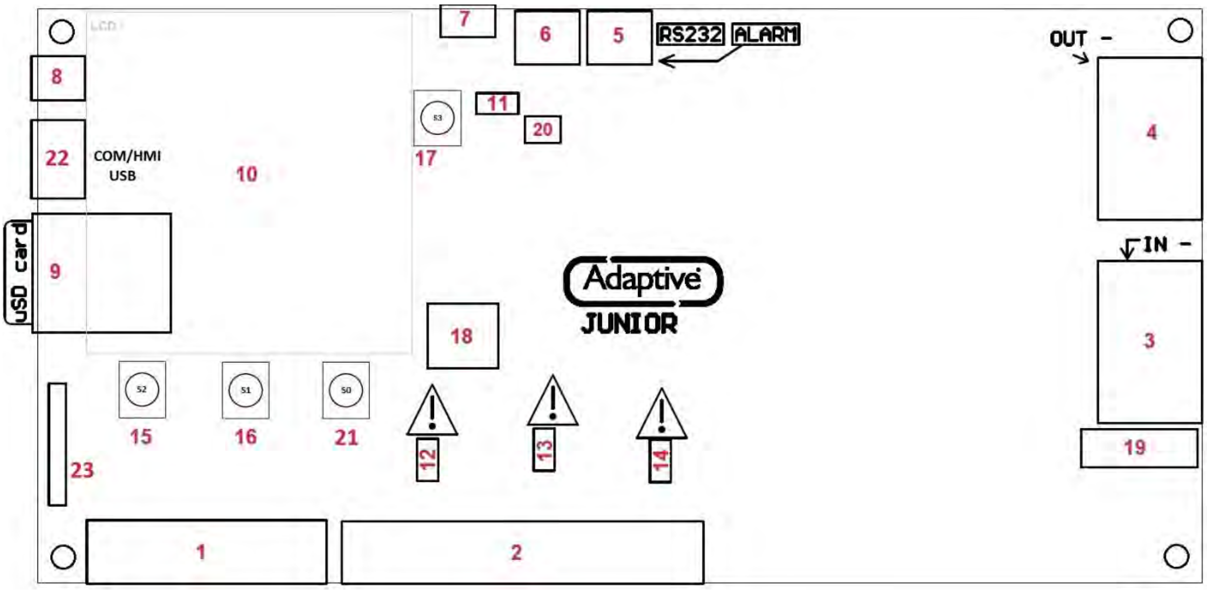


Figure 1. Board Connections and Functions (Top View)

ID	Function	Comment
1	Sensor Input	NTC and K-type thermocouples
2	Fan driver interface	Supports generally available fans
3	Power Input	Main power to the board
4	Power Output	Thermoelectric Module or Assembly PWM power
5	Alarm output	SPDT relay contacts
6	Serial interface	RS232 level interface
7	BOOT interface	USB 2.0 interface (micro USB connector) – Firmware upgrade only!
8	SSR driver output	3.3V level PWM output to drive DC/AC solid state relays
9	SD card interface	Log data in offline mode
10	LCD interface	Optional LCD display to monitor parameters in offline mode
11	Service mode	Special boot mode activated if jumper fitted (eg. Firmware upgrade)
12	Fan 1 direct power	Fan 1 directly powered from the power input connector if jumper fitted
13	Fan 2 direct power	Fan 2 directly powered from the power input connector if jumper fitted
14	Fan 3 direct power	Fan 3 directly powered from the power input connector if jumper fitted
15	Display control 1	Various functions
16	Display control 2	Various functions
17	Service mode control	Special boot mode trigger (eg. Firmware upgrade)
18	Analog control	Manual set temperature control in offline mode
19	Current limit fuse	Auto mini blade fuse (58V DC)
20	Status LEDs	Visual feedback. Green: normal operation, Alternating: alarm, Red: shutdown
21	Display control 3	Various functions
22	Serial Interface	USB 2.0 interface (micro USB connector) – Standard communication interface
23	Expansion Interface	Reserved for future use

Table 2. Connector pin functions

1.4. Electrical Installation

Figure 2. shows the required hardware for a thermoelectric control application using Adaptive JUNIOR.

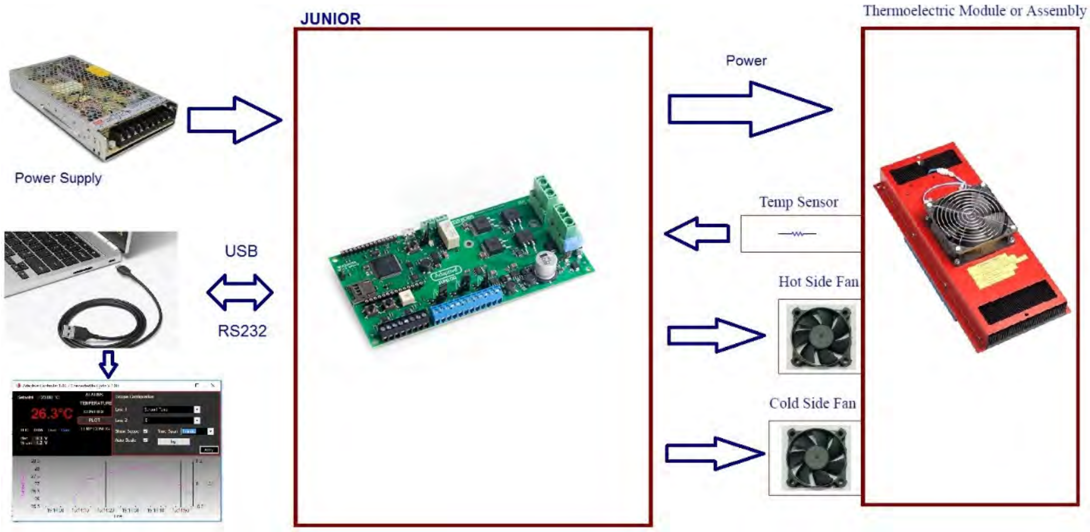


Figure 2. Thermoelectric Cooling / Heating Application Setup

Figure 3a. below, shows the recommended wiring diagram for connecting the components making up a typical thermoelectric system. To keep potential interference problems to a minimum ensure that the wires used for connecting the power supply to the controller, and especially from the controller to the thermoelectric assembly ('TE OUT-' and 'TE OUT+'), are sized correctly for the module's power and kept as short as possible. Wire lengths can be optimised by mounting the JUNIOR controller right at the thermoelectric assembly's connection output.

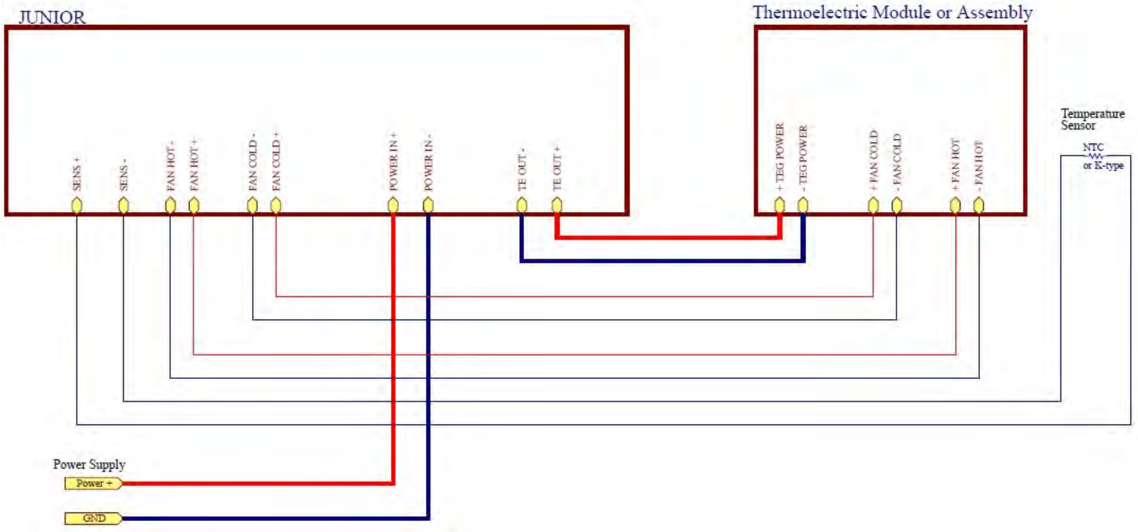


Figure 3a. Wiring diagram of minimum level installation

Figure 3a. shows the JUNIOR controller in a complete system setup.

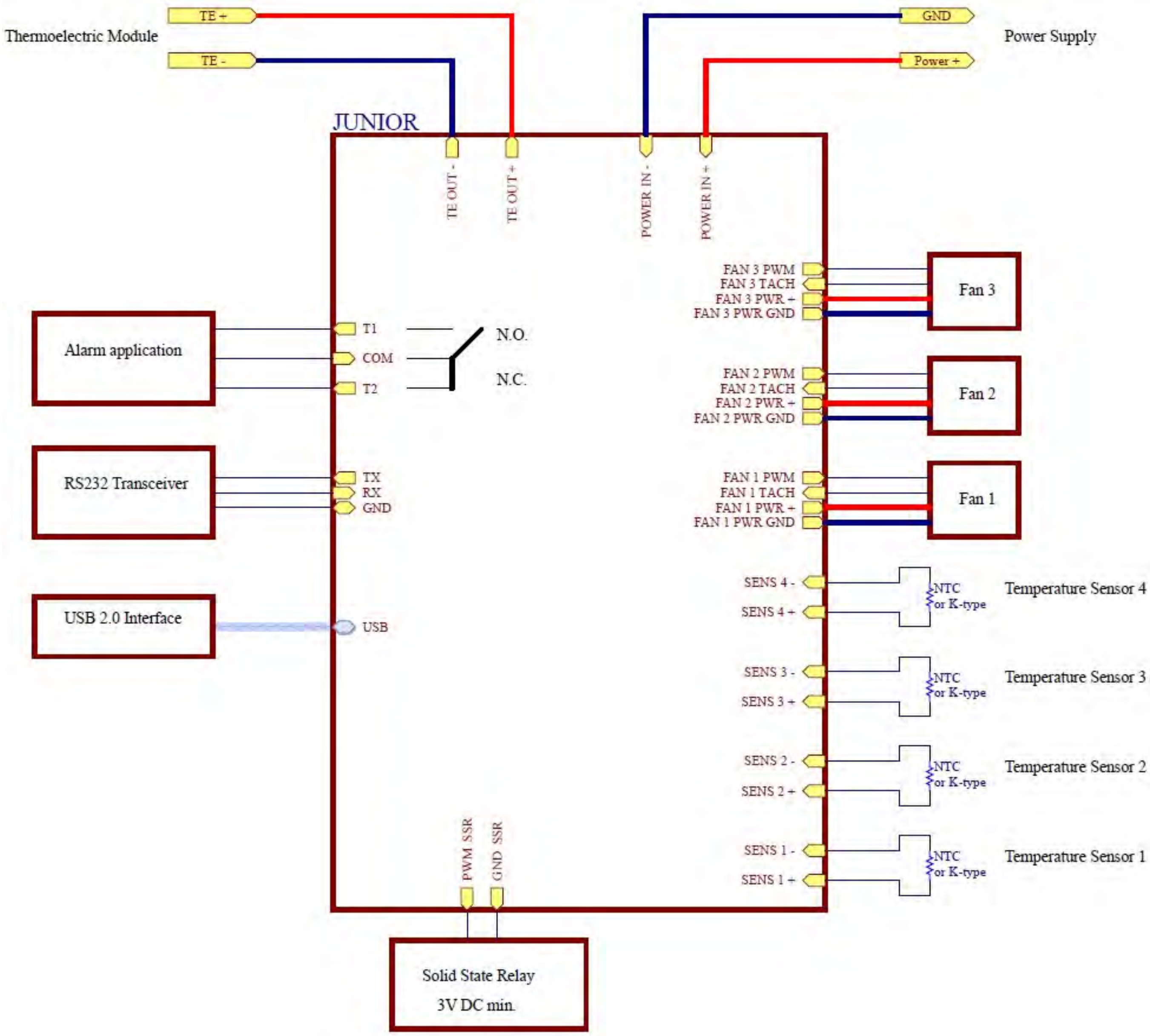


Figure 3b. Wiring diagram of complete installation

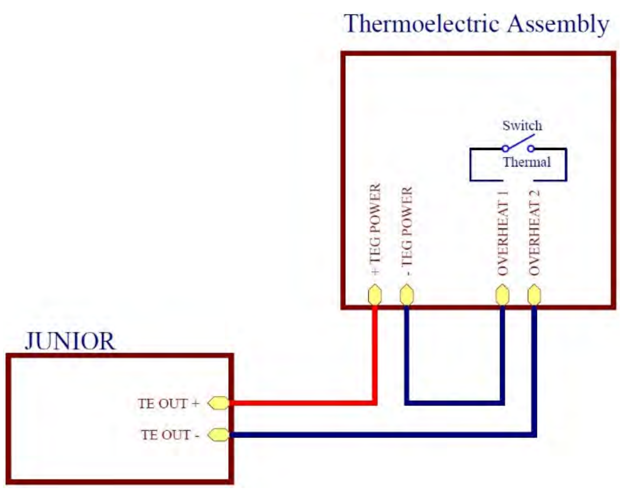


Figure 3c. Wiring diagram for Thermoelectric Assemblies with thermal protection.

The connectors used for integrating the board into a typical system are shown in the connector layout diagram below.

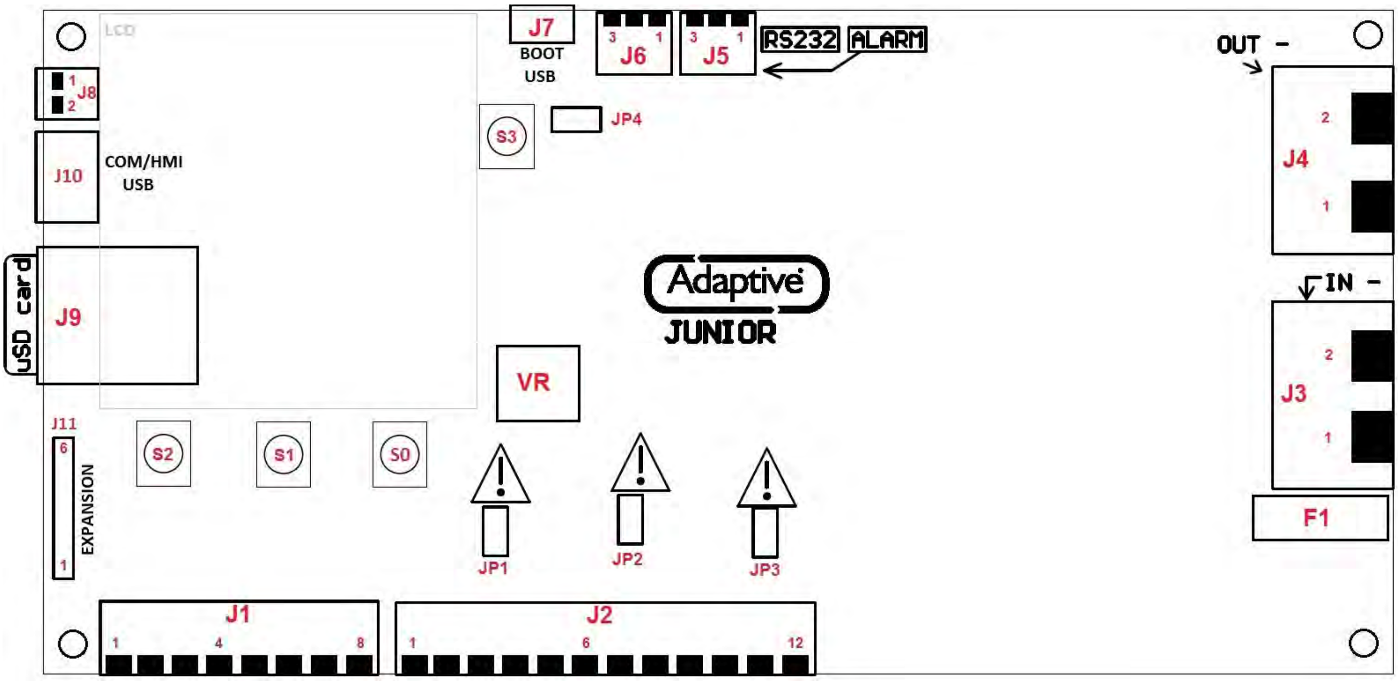


Figure 4. Connector map (top view)

Connector ID	Pin ID	Name	I/O	Type	Voltage max [V]	Current max. [A]
J1	1	SENS **A** or **1** +	Input	Sensor No. 1 positive	3.3	0.001
J1	2	SENS **A** or **1** -	Input	Sensor No. 1 negative	0	0.001
J1	3	SENS **B** or **2** +	Input	Sensor No. 2 positive	3.3	0.001
J1	4	SENS **B** or **2** -	Input	Sensor No. 2 negative	0	0.001
J1	5	SENS **C** or **3** +	Input	Sensor No. 3 positive	3.3	0.001
J1	6	SENS **C** or **3** -	Input	Sensor No. 3 negative	0	0.001
J1	7	SENS **D** or **4** +	Input	Sensor No. 4 positive	3.3	0.001
J1	8	SENS **D** or **4** -	Input	Sensor No. 4 negative	0	0.001
J2	1	Fan **1** or **A** GND (-)	Output	Fan 1 power negative	0	2
J2	2	Fan **1** or **A** PWR (+)	Output	Fan 1 power positive	48	2
J2	3	Fan **1** or **A** TACH	Input	Fan 1 TACH signal	3.6	0.01
J2	4	Fan **1** or **A** PWM	Output	Fan 1 PWM signal	3.6	0.01
J2	5	Fan **2** or **B** GND (-)	Output	Fan 2 power negative	0	2
J2	6	Fan **2** or **B** PWR (+)	Output	Fan 2 power positive	48	2
J2	7	Fan **2** or **B** TACH	Input	Fan 2 TACH signal	3.6	0.01
J2	8	Fan **2** or **B** PWM	Output	Fan 2 PWM signal	3.6	0.01
J2	9	Fan **3** or **C** GND (-)	Output	Fan 3 power negative	0	2
J2	10	Fan **3** or **C** PWR (+)	Output	Fan 3 power positive	48	2
J2	11	Fan **3** or **C** TACH	Input	Fan 3 TACH signal	3.6	0.01
J2	12	Fan **3** or **C** PWM	Output	Fan 3 PWM signal	3.6	0.01

J3	1	POWER IN +	Input	Main power positive	48	15
J3	2	POWER IN -	Input	Main power negative	0	15
J4	1	TE OUT +	Output	TE Module/Assembly +	48	15
J4	2	TE OUT -	Output	TE Module/Assembly -	0	15
J5	1	Alarm N.O.	Output	Alarm normally open pin	48	2
J5	2	Alarm COM	Output	Alarm common pin	48	2
J5	3	Alarm N.C.	Output	Alarm normally closed pin	48	2
J6	1	RS232 TXD	Output	Serial transmit signal	±12	0.04
J6	2	RS232 RXD	Input	Serial receive signal	±12	0.002
J6	3	RS232 GND	Output	Serial ground	0	
J7	-	BOOT / UPDATE USB	-	USB 2.0	5	0.1
J8	1	SSR PWM	Output	Solid state relay PWM	3.3	0.01
J8	2	SSR GND	Output	Solid state relay GND	0	0.01
J9	-	Standard SD card	-	-	-	-
J10		COM USB	-	USB 2.0	5	0.1
J11	-	EXPANSION	-	Expansion Interface (reserved for future use)	-	-

Table 4. Connector Pin description and electrical parameters

1.5. Temperature Sensors

It is recommended that adequate thermal flow is maintained to the temperature sensor. Tight thermal coupling results better temperature control accuracy. The JUNIOR controller is capable to handle K-type thermocouples and NTC resistor sensors. There are four independent sensor channels available for the user.

1.6. Fan Interface

There are three independent fan interfaces for the user to access on the board. Each channel can be used to drive a hot or cold side fan on a thermoelectric assembly. Speed monitoring or control also supported for three and four wire fans. Signals TACH and PWM are internally pulled up to 3.3V DC and care should be taken selecting a suitable fan.

1.7. Alarm Interface

An isolated relay is available for user applications requiring alarm signalling. In case of an alarm condition energises the relay pin 1 and pin 2 will make connection. Pin 2 and pin 3 breaks the connection on connector J5.

1.8. RS232 Interface

Serial interface is compatible with EIA/TIA-232 and V.28/V.24 specifications.

1.9. BOOT / UPDATE USB Interface

The USB 2.0 compatible interface is available through a micro USB connector for future firmware updates. This interface is not intended to be used for communicating with the board. It only provides a fail-safe field firmware update facility.

1.10. Solid State Relay Driver (SSR)

For special applications using AC solid state relays the JUNIOR controller provides a PWM output signal. Care should be taken to avoid any high voltage risk to the controller board. In SSR control mode the PWM signal is available on connector J8 and driven by the thermoelectric control parameters. In SSR mode the thermoelectric outputs are disabled. Most SSR are suitable to use with the controller however the control voltage should allow for a 3V DC signal (eg. Part number: SSR-40 DA)

1.11. COM USB Interface

The USB 2.0 compatible interface is available through a micro USB connector providing a serial communication interface to be used with the Adaptive HMI software or the standard serial protocol detailed within this document.

1.12. Mechanical Dimensions

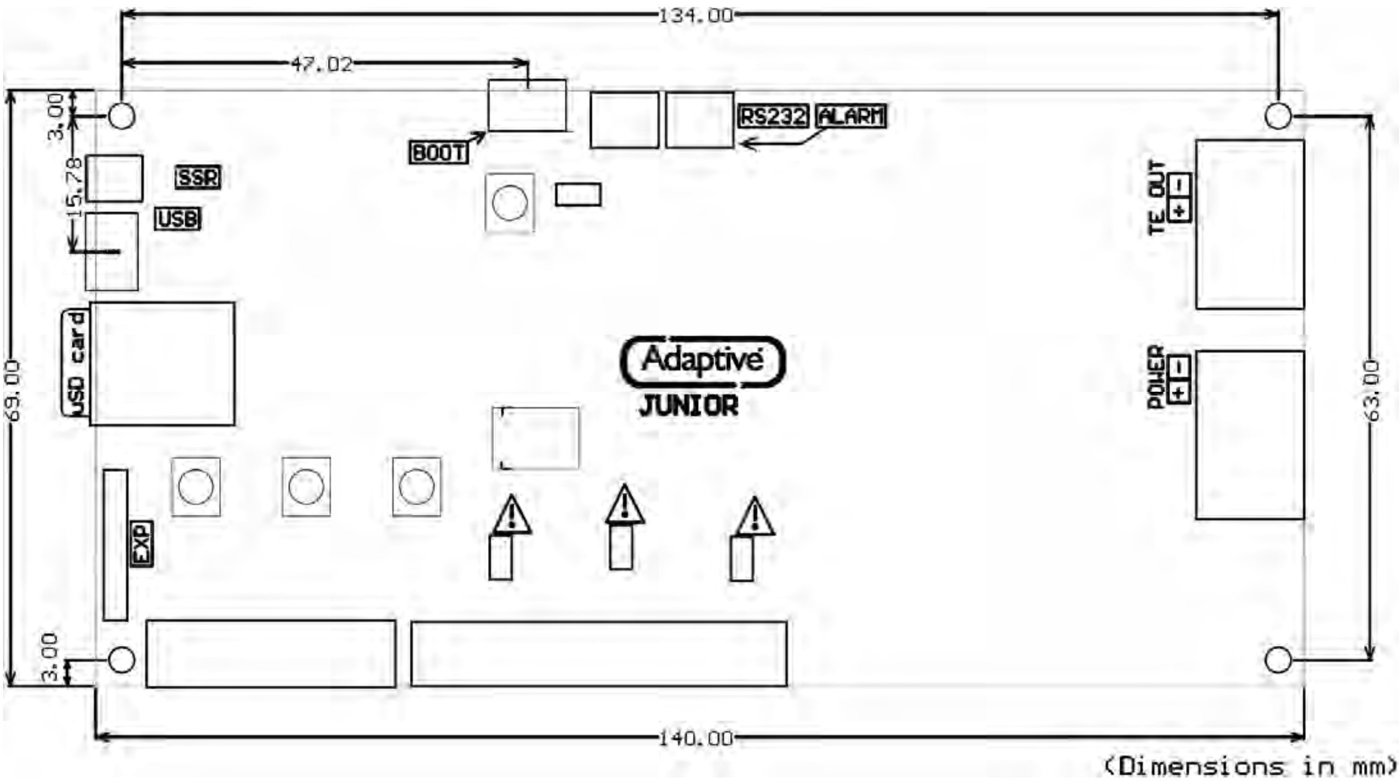


Figure 5. Mechanical Dimensions

Height and clearance information is shown in Table 5.

Component height on the bottom side	3mm
PCB substrate thickness	1.6mm
Component height on the top side	22mm
Total height	26.6mm
Recommended minimum clearance around the board	5mm
SD card protrusion	1.5mm
Micro USB connector protrusion	1.5mm

Table 5 Board height information and Clearance

2. Software

2.1. Introduction

All Adaptive controllers have a simple text based serial interface available for configuring and setting the various internal registers used to control the device. This is straightforward when the device is simple to configure or needs only initial setup and occasional monitoring, however for more complicated configurations, monitoring or ease of use the Adaptive HMI can be used. The HMI is compatible with all the Adaptive controller products providing one common graphical interface that adjusts to the product it is connected to. The HMI provides easy setup and configuration but also basic plotting and data log capabilities. This document describes the Adaptive HMI and how it can be used with the Adaptive JUNIOR.

2.2. Minimum PC System Requirements

The Adaptive Controller HMI has been designed for use with Microsoft Windows versions 7,8 & 10. It has not been tested or verified with Windows Vista. Windows XP is not supported as XP does not meet the minimum .Net requirements.

The application requires .Net support and during installation will check and prompt if necessary the installation of the required Microsoft .Net framework (size of the installation is approx. 50MB)

Depending on the Adaptive controller product being used the PC will require either 1 free USB or RS232 serial port. Note if the PC does not have a serial port a USB to serial port adapter may be used.

2.3. Installing the Software

To install the software you must have admin rights for the user account. Locate the installation package, unzip if necessary to a temporary location and run the setup.exe installation file. Follow the on-screen instructions provided, note if the Microsoft .Net version needs to be upgraded you will be prompted to download or obtain it before continuing. Once installed a new Adaptive HMI icon will be placed on the desktop and in the All Programs menu.

2.4. JUNIOR Quick Setup Guide

The user is encouraged to read this manual fully to familiarise themselves with the operation, however for those already familiar with the Adaptive HMI and JUNIOR operation this section serves as a quick reminder for setting up a new JUNIOR controller.

1) Wire up the supply and thermistor / thermocouple to the sensor D input on the JUNIOR. Connect the USB cable or RS232 port to the PC, switch on and start the HMI.
2) Select the temperature sensor type being used on the Temperature Config page and enter the Steinhart coefficients if using a thermistor. See 4.8 Temperature Configuration Page.
3) Connect one or more fans to the board and configure the type and voltage supply using the Fan Configuration page, see section 4.7 Fan Configuration Page **Note:** Ensure the jumpers P11, 12 & 13 are fitted if needed.
4) Configure and enable any desired temperature and fan alarms, see sections 4.3.1 Temperature Sensor Alarm Configuration Pageand 4.3.2 Fan Alarm Configuration Pages.
5) Set the Control operating mode to off, see section 4.5 Control Page.
6) Switch off the JUNIOR, connect to the Thermoelectric Cooler Module (TEC), the hot and cold side fans, reapply power and start the HMI.
7) Reconnect the HMI to the JUNIOR, verify the temperature sensor and fans are working correctly.
8) Set the Control operating mode and setpoint, see section 4.5 Control Page.

3. Overview of HMI Display

The HMI display is split into three main sections as detailed in the table and diagram below;

The live display is visible at all times and shows the important operating variables. The menu buttons are used to swap the configuration area between the various pages that can be used to view alarms, status, allow settings to be configured or the operating mode to be changed. On connection the HMI detects the connected product and automatically configures the displays and menu options to suit allowing easy connection to different products and firmware versions.

Live Display	This shows the current values of the device such as temperature, drive voltage and current, mode and status. This is typically updated every second.
Menu Buttons	These buttons select the various configuration and alarm pages available for the device. The number and type will vary according to the device that is connected.
Configuration	This area shows the available configuration or alarm parameters that can be changed.

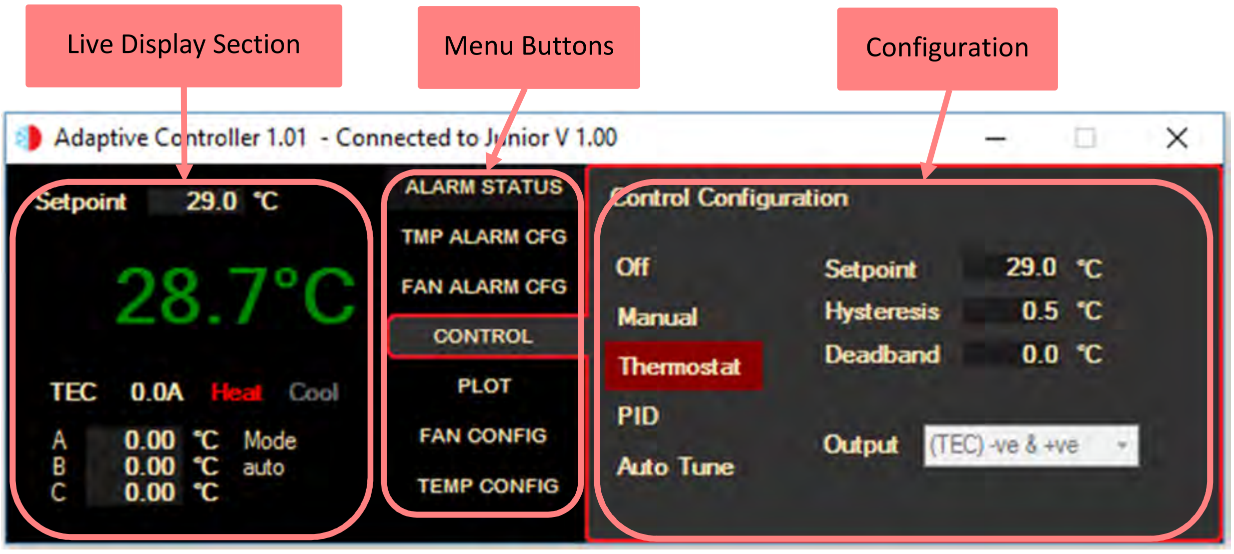


Figure 6 Example HMI display layout

Whenever an item has been edited or changed on the HMI an 'Apply' button appears, click to apply the new values or flip to a different page and back to ignore and restore the original value. If a value is entered that exceeds the limit for the item in question it will simply revert to the previous value.

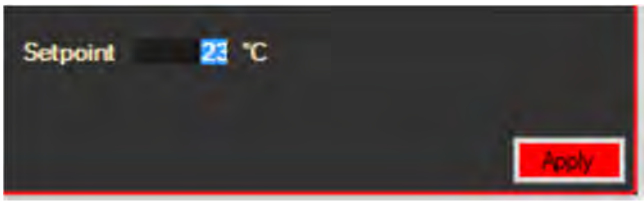


Figure 7 Apply button appears when settings are changed

4. Using the Software

4.1. Starting the Software and Connecting the Controller

The JUNIOR has RS232 and USB ports, either of which can be used to connect the JUNIOR to a PC for configuration and control. If using the USB serial port, a USB cable must be plugged in and the JUNIOR powered on **<u>before</u>** the HMI is started, so that it detects the USB port. If using the RS232 serial port simply connect it to the PC. If the PC does not have a free serial port, a USB to serial port adapter can be used instead. Whichever port is chosen, if it is not visible in the drop-down list double check the connection and power, and if using either of the USB types verify that the correct USB drivers have been loaded.

To start the HMI, double click on the Adaptive HMI shortcut icon or select it from the start menu Adaptive group. This will bring up the connection window where the serial port being used can be selected. Select the port from the available port list and click the connect button. On successful connection the main display will appear otherwise a communication error message will be displayed if there are problems talking to the unit. If so double check the connection cable, power and that you have selected the correct port connected to the JUNIOR.

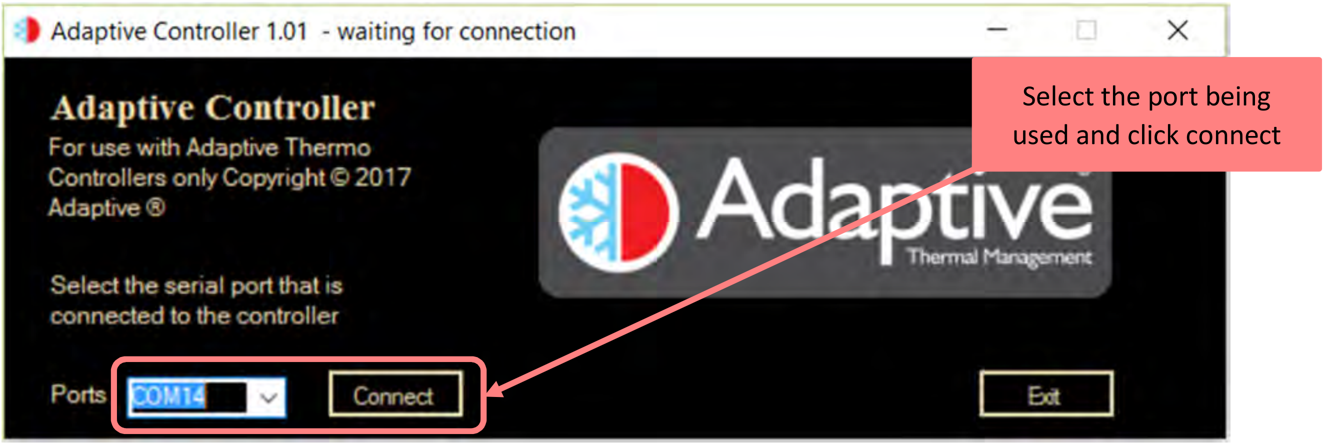


Figure 8 HMI connection screen

4.2. Software Flow

The HMI software provides four main options depending on the product that it is connected to; 1 live monitoring of the variables and alarm status, 2 configuration of the alarm limits and enables, 3 selection of the control mode 4 and configuration / calibration of the connected temperature sensors and fans[1]. A plotting page is also provided to view trends and allow logging to file.

The menu section of the display is arranged so that the most frequently used pages are shown at the top and lesser used below. When configuring a device for the first time the menu is normally worked in reverse upwards as the configuration of the sensors should be completed before attempting to use the device in an operational mode. The menu items vary according to the product connected but the Alarm Status button will always be topmost, see Figure 6**Error! Reference source not found.**. Whenever an active alarm is present in the system and the Alarm Status page is not on display, its button will flash to indicate the presence of an alarm which the user should investigate.

When the HMI successfully connects to a device the Alarm Status page is automatically displayed.

[1] Options depend on product being used e.g. Fans available on JUNIOR

4.3. Alarm Configuration Pages

The JUNIOR has configurable alarms for each sensor that can be connected, giving two alarm configuration pages; the first for the temperature sensors and the second for the fans. The specific temperature or fan is selected by using the selection buttons available.

Each alarm has individual trip threshold, Enable, Relay and Shutdown options. If the Relay option is selected any enabled alarm that trips will activate the onboard relay for the duration that the alarm is present. This relay can be used to signal externally connected equipment for example a light stack or sounder. When shutdown is enabled for an alarm, and it trips, the output drive is switched off and remains latched off until the operating mode or power is cycled.

Note: The configurable alarm limits cannot be set beyond the limits as specified in the JUNIOR datasheet.

4.3.1. Temperature Sensor Alarm Configuration Page

Two configurable alarms are available for each temperature sensor detailed below. Up to four sensors can be connected and the alarms individually configured using the A, B, C or D sensor selection buttons at the top right of the configuration page – see Figure 9 below.

Note: the alarms only operate if a sensor is enabled on its configuration page irrespective of the 'alarm enables' configured on this page.

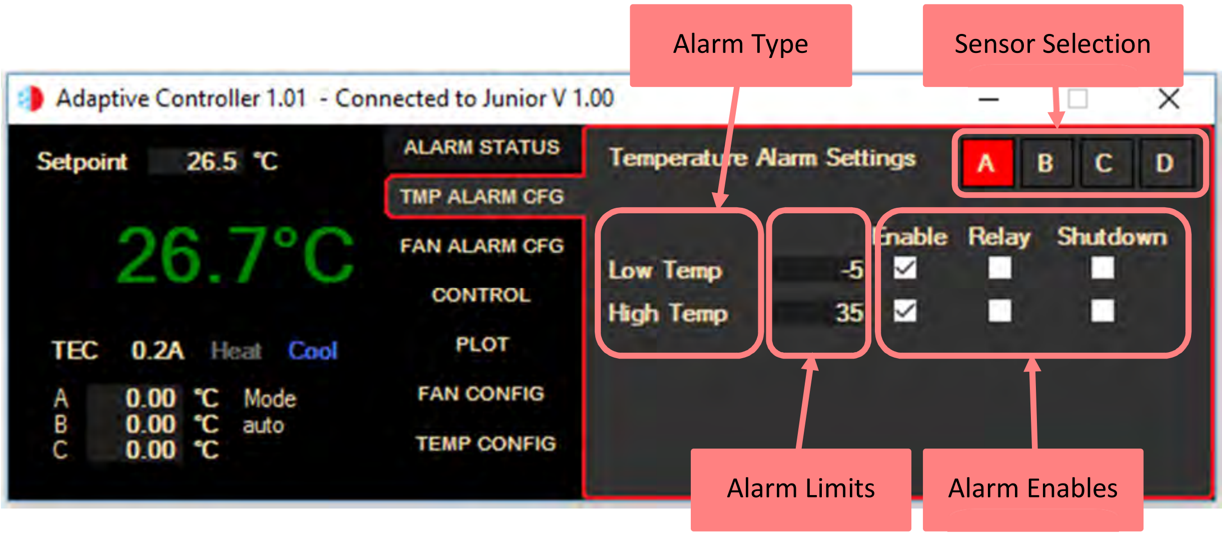


Figure 9 Example JUNIOR Temperature Alarm configuration page

Alarm Settings

Alarm Type	Description / Cause
Low Temp °C	Sets lower temperature limit. Alarm trips when the measured temperature falls below this value.
High Temp °C	Sets upper temperature limit. Alarm trips when the measured temperature rises above this value.

Alarm Enables	Result on limit exceeded
Enable	Sets the alarm state while limit is exceeded.
Relay	Activates the onboard relay for the duration that the alarm is present.
Shutdown	Switches output drive off until reset by control mode being switched to off or board power cycled.

4.3.2. Fan Alarm Configuration Page

Up to four configurable alarms are available for each connected fan as detailed below. Fan speed alarms are only available for 3 & 4 wire fans that have their tacho output connected. Up to three fans can be connected and the alarms individually configured using the A, B or C fan selection buttons at the top right of the configuration page – see Figure 10 below.

Note the alarms only operate if a fan is enabled on its configuration page irrespective of the alarm enables configured on this page.

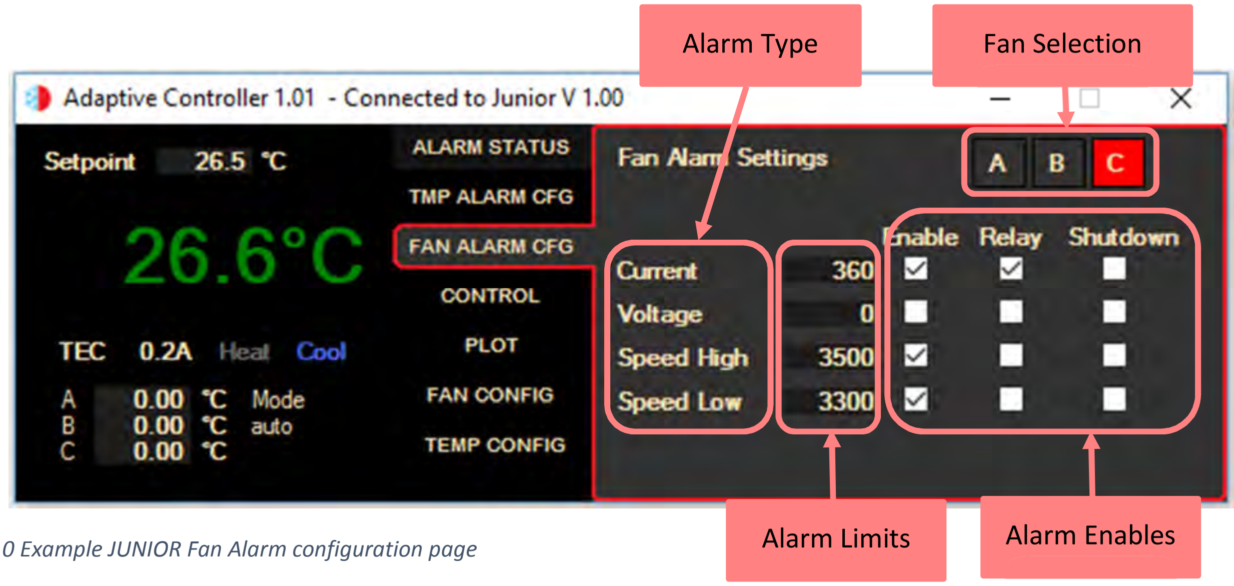


Figure 10 Example JUNIOR Fan Alarm configuration page

Alarm Settings

Alarm Type	Description / Cause
Current (mA)	Sets maximum fan current limit. Alarm trips when the measured current exceeds this value.
Voltage (V)	Sets maximum fan voltage limit. Alarm trips when the measured voltage exceeds this value.
Speed High (RPM)	Sets the upper rotational speed limit. Alarm trips if the fan speed rises above this value[2].
Speed Low (RPM)	Sets the lower rotational speed limit. Alarm trips if the fan speed drops below this value[2].

Alarm Enables	Result on limit exceeded
Enable	Sets the alarm state while limit is exceeded.
Relay	Activates the onboard relay for the duration that the alarm is present.
Shutdown	Switches output drive off until reset by control mode being switched to off or board power cycled.

[2] Only available for 3 and 4 wire fans providing a tacho output signal

4.4. Alarm Status Page

Figure 11 shows a typical alarm page for JUNIOR. It displays the current status of the alarms for up to four temperature sensors and three fans[3]. When an alarm is active the text indicates the condition, and is highlighted in red. The latched alarms for shutdown and fault are indicated separately. A latched fault indicates an internal fault has occurred and the unit should be power cycled to clear it.

The alarms are updated once every second and clear automatically when the alarm condition clears except the shutdown or fault which have to be cleared either by switching the control mode to off or power cycling the unit.

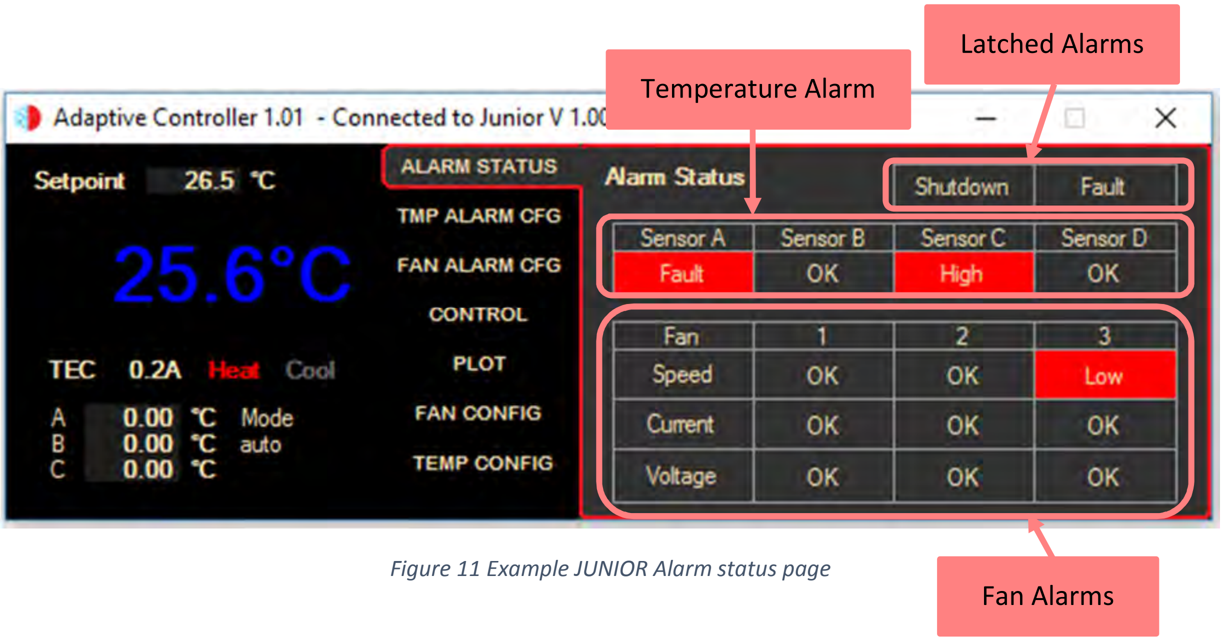


Figure 11 Example JUNIOR Alarm status page

Alarm Status

	Alarm Type	Alarm Status	Description / Cause
Latched Alarms	Shutdown	Active	At least one alarm with shutdown option selected has tripped or Internal fault has occurred.
	Fault	Active	Indicates an internal fault has occurred.
Temperature Sensors	Sensor A Sensor B Sensor C Sensor D	Low	The measured temperature value has fallen below the Low Temp limit value.
		High	The measured temperature value has risen above the High Temp limit value.
		Fault	The sensor is short circuit, open circuit or not connected.
Fans	Speed	Low	The fan speed has fallen below the Speed Low limit.
		High	The fan speed has gone above the Speed High limit.
	Current	Fault	The average bridge current exceeds the Current High limit value.
	Voltage	Fault	The maximum bridge voltage exceeds the Voltage High limit value.

[3] Alarms are only valid for the sensors or fans that are connected and enabled.

4.5. Control Page

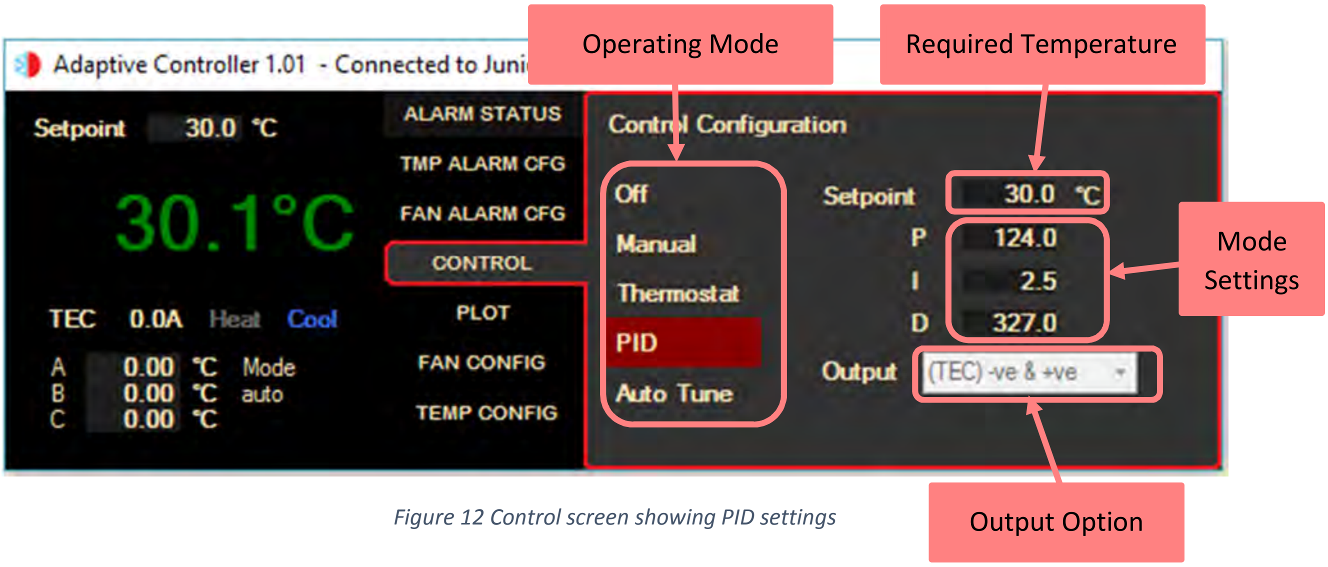


Figure 12 Control screen showing PID settings

The control page provides access to the three Junior operating modes; Manual, Thermostat and PID. These are used with the temperature feedback from sensor D to maintain the temperature of the external device to the required setpoint. The Off mode is provided to switch off the control and output bridge completely. An auto-tune option is provided to aid the automatic configuration of the PID gain settings, depending on the system being controlled it will generally allow the operator to quickly set an initial PID tuning that can then be fine tuned for performance.

The output drive is also flexible, allowing bi-directional output for the TEC which is capable of both heating and cooling or uni-directional control for single heating or cooling elements. A third option is the ability to drive a logic level TRIAC module via the auxiliary output. The output mode is only selectable when the controller is in the Off mode. Care should be taken to ensure that the connected device is compatible with the selected output drive method.

Note: Off mode is also used for clearing shutdown alarms.

4.5.1. Manual Control Mode

This is an open loop mode that allows the user to set the drive output at a fixed value of its maximum. The temperature sensor connected to sensor D is not used as there is no temperature feedback, likewise the setpoint entered is a percentage of output instead of degrees C.

This mode would normally be used to confirm the operation of the heating, cooling or heating/cooling module that is attached, or for a system that requires a constant heat input where its effect from its external environmental is very low.

Figure 13 Manual operating mode

The actual output value is also determined by what output mode has been selected see Table 6 and Figure 14 below. Note the output mode can only be changed when the control mode is set to Off. Before changing modes ensure that the module connected is suitable for the polarity chosen.

	Setpoint 0 to 100 % of full input voltage		
Output mode	0%	50%	100%
(TEC) -ve & +ve	Full negative output	0v	Full positive output
(Other) +ve only	Zero output	50% of positive output	100 % of positive output
(Other) TRIAC	0% duty cycle	50% duty cycle	100 % duty cycle

Table 6 Output drive polarity based on output mode and drive level

Figure 14 Selecting the output drive method when the control mode is OFF

4.5.2. Thermostat Control Mode

This mode works in the same way that a mechanical thermostat would except that it has programmable hysteresis and dead band controls. It maintains the temperature measured on sensor D's input to the setpoint entered using the values entered for hysteresis and dead band.

Hysteresis is used in systems to stop the control from continually switching back and forth when the temperature is close to the setpoint. In a mechanical system this reduces wear and tear of the parts and also energy. Wear is less of a problem in modern systems but energy and switching are still important.

Figure 15 Thermostat operating mode

Dead-band is similar to hysteresis, but where hysteresis is used to prevent the output switching unnecessarily, dead-band switches off the output completely while the temperature is within its window.

The switching on point for the heater is (setpoint – dead-band – hysteresis) and for switching on the cooler (setpoint + dead-band + hysteresis). The heater switches off at (setpoint – dead-band) and the cooler switches off at (setpoint + dead-band).

Examples of typical output switching for both these modes is shown in the diagram below. Note to make the switching points clearer in the diagram below, the heater will always be on below 23°C and the cooler always on above 27°C.

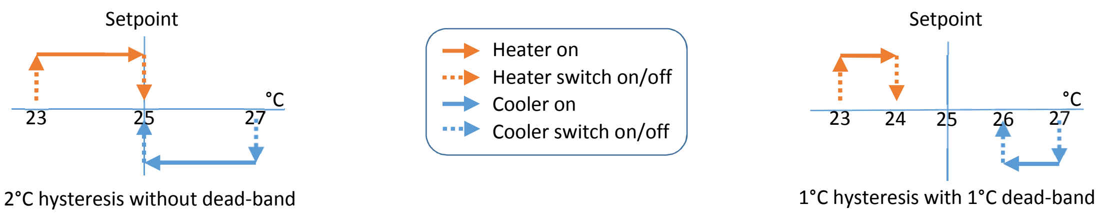


Figure 16 Example configuration shown hysteresis and dead-band for bidirectional drive

4.5.3. PID Control Mode

This mode provides access to Proportional, Integral and Differential control (PID). In this mode the output is continuously adjusted based on feedback from temperature sensor D and the P, I & D terms to maintain the setpoint accurately.

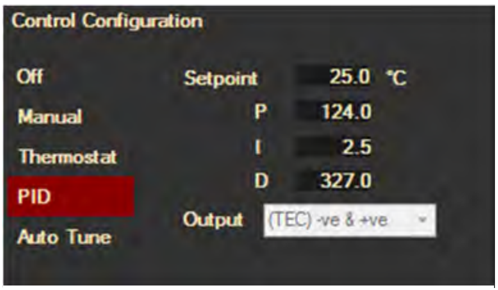


Figure 17 PID Operating mode

The controller can also be used in PI or just P control with lower accuracy by setting the I or D terms to zero. To use this mode simply enter the P, I and D terms as necessary. If you are setting up a new system it is recommended to use the auto tune mode described below and then fine tune the values for performance. If you are manually tuning the PID loop then note that the values entered during tuning can often cause the system to oscillate and also drive the output bridge to either limit very easily, so could easily damage process product.

4.5.4. PID Auto Tune Mode

Tuning PID control systems can be a difficult task, taking significant time to produce the best compromise between speed of response, minimal over shoot, tight control band and stability. JUNIOR provides a built-in method to achieve this for you. The auto tune process will drive the output in both directions while measuring the resultant response of the connected system. After a number of cycles, the software will analyse the data and produce P, I and D terms that will be suitable for most systems. These settings will not be as aggressive as they could be so that JUNIOR can tune the widest range of systems, and provide stable control. It is therefore suggested that the auto tune procedure is performed to quickly provide a usable set that can later be tuned and optimised for the expected operating conditions.

Warning: The auto tune process will provide full positive and negative step outputs, so the connected system must be able to handle the maximum drive levels safely and without causing damage. The time taken to perform the auto tune varies with each system but is normally 5 to 10 minutes, however it may continue considerably longer if the output of the system is low or faulty. **The system should be supervised until the auto tune process has completed.**

Tips for the auto tune process

- Before starting the tuning process ensure that you have tested all the sensor inputs and output connections that will be used and that they are working correctly. Note the outputs can be driven fully positive and negative easily by using the manual control mode to test.
- Tune the system when it is at or close to its normal operating conditions.
- Use the plot window to observe sensor D output and the bridge current. This will give you visual feedback of the process and see the cyclic steps being produced.

To start the auto tune select the control page, press the Auto Tune button and click apply, see Figure 18. The process will now start and will complete after a minimum of three cycles have been observed or stop at ten if the measurements are noisy or uneven[4]. If ten cycles pass, it indicates that the auto tune algorithm could not determine the measurements correctly and the mode will switch to off. If this is the case verify the connections including the polarity of the temperature sensors and output drive and repeat if necessary.

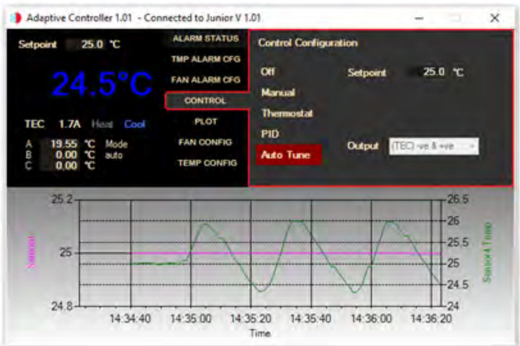


Figure 18 Start of the Auto Tune process

[4] Note if the measurements are low or unobservable it may continue indefinitely.

When the auto tune completes successfully the P, I and D gain terms will be automatically updated with the results and the control mode will swap to PID. Figure 19 shows the plot after tuning, you can see the end of the last tuning cycle and then the transient to the new setpoint value.

The system should now be tested for transient response and at the expected extremes of the system range to ensure it remains stable at all times. The tuning results can now be used as a starting point for finer tuning to increase system performance.

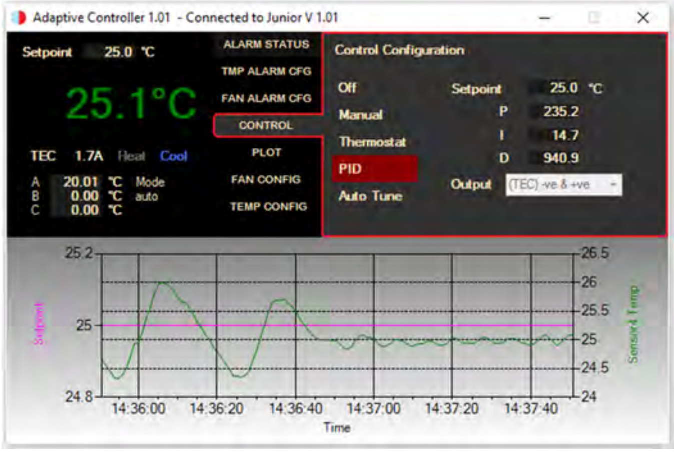


Figure 19 End of Auto Tune sequence

Warning: As an algorithm is being used to perform the auto tune and cannot be exposed to all the disturbances or adjustments possible, it is up to the user to confirm the tuning is suitable. **Over temperature, under temperature and over current alarms should always be employed in the system to ensure adequate protection to the user and equipment from oscillatory or prolonged full-scale outputs.**

4.5.5. PID Basics Explained

The PID control method works by first calculating the error between the actual and desired temperature (setpoint – sensor D feedback). This error is then multiplied by the P (Proportional) gain value to give an output that is proportional to the error. This output will reduce the resulting error and so on. However, this has a limitation as there must be an error present to produce an output to maintain the temperature. The larger the drive that is required the larger the error is needed to produce it. The P gain could be increased to reduce the error but repeatedly doing so will eventually cause the system to oscillate as the output is driven strongly on the small errors. Proportional control will give output that will overshoot the setpoint and always remain short of the desired temperature. It is not suited to situations that have large variations in the load.

The I (Integral) term is used to reduce the remaining error left by the P term. It does this by accumulating the error over time (integrating) and adding the result to the output. As the temperature reaches the setpoint and the error becomes too small to have any effect on the P term the I term becomes dominant and continues to reduce the error to zero. Although this results in little or no error it comes at the cost of speed as the system response is reduced.

The final option to control the output is to look at the change of the error over time, this is the Differential and it is adjusted using the D term. When the error isn't changing much the output from this term will be low, however if there is sudden disturbance or the setpoint is adjusted the resulting error will change sharply. This large change over a short period will provide a strong output to quickly move the temperature, and as the temperature starts to move towards the setpoint the rate of change will start to reduce, reducing the output drive. This has the effect of being able to quickly respond to changes without overdriving the output as the error reduces.

Tuning a system is finding the right combination of PI or PID values that produce the best response. For example, too much P will give overshoot, too large I will reduce the response speed and too much D will amplify any noise present in the system. Incorrect values will also lead to instability and oscillation of the temperature around the setpoint.

4.6. Plot Window

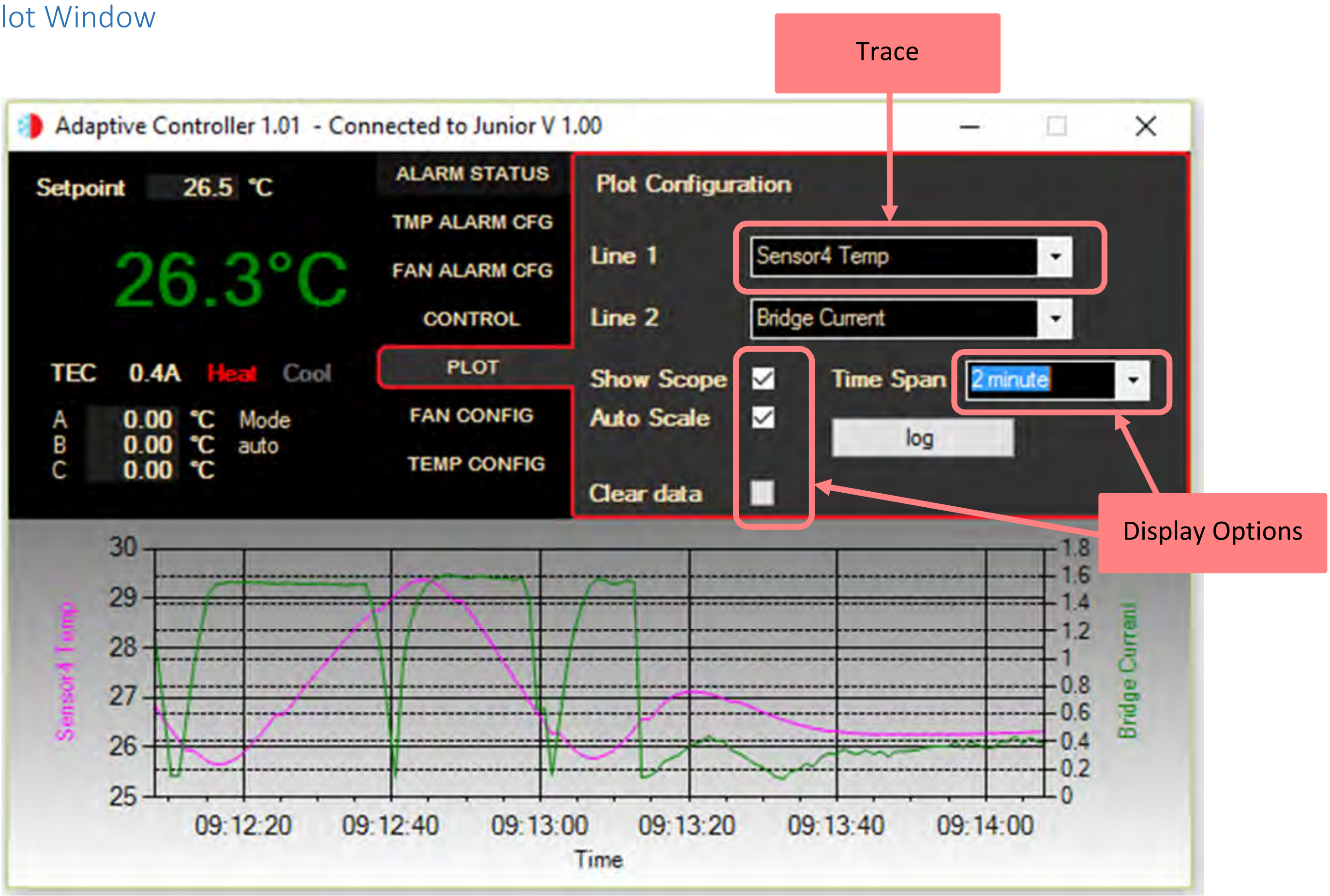


Figure 20 Realtime plotting and logging

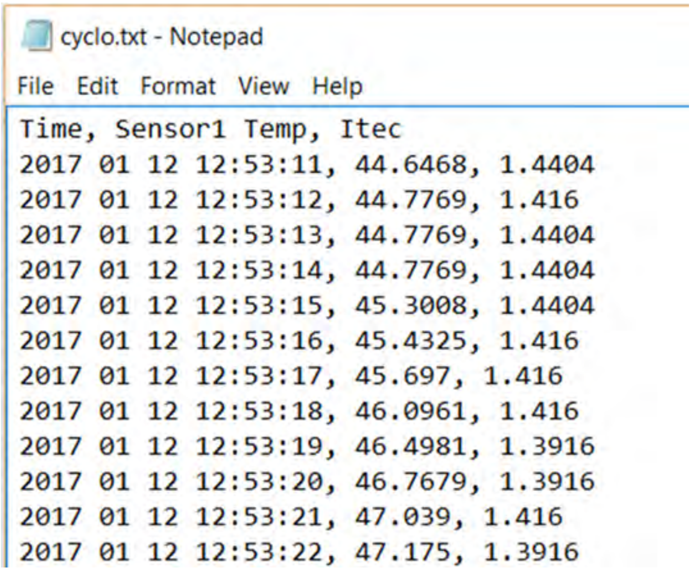
The HMI provides basic plotting and logging facilities that can be used to check the operation of the system or monitor the performance. It is not intended for production or extended logging as the log is maintained in one plain text file with minimum validation.

Up to two traces can be selected using the drop-down lists Line 1 & 2. The items are sampled once a second and added to the trace. If logging has been selected they are also recorded to the text file that was selected. The items selected can be changed at any point, but on doing so the trace is cleared before plotting resumes with the new items. If the items are changed whilst logging to a file is in progress the logging simply carries forward with the new items being logged, causing a discontinuity in the log file.

The display options settings affect how the scope data is displayed this no effect on logging.

Display Option	Effect
Show Scope	Displays the scope in a window below the main application display.
Auto scale	Increases or decreases the Y axis range so that all the recorded Y values fit within the axis.
Clear data	Erases the current data from the trace, using this when Auto Scale is selected causes the axis to expand the range to fit
Time Span	This can be used to adjust the plots X axis from 1 minute to 24 hours, this can be done at any point and does not cause any loss of data as the data is stored in a rolling 24-hour buffer.

The data being plotted can also be logged to a file, this is achieved by clicking on the log button and entering a file name. The data is recorded in a comma separated format, which if the file name ends with the extension '.csv' can easily be opened in Microsoft Excel. When logging is in progress the button changes to 'Stop logging'.




```
Time, Sensor1 Temp, Itec
2017 01 12 12:53:11, 44.6468, 1.4404
2017 01 12 12:53:12, 44.7769, 1.416
2017 01 12 12:53:13, 44.7769, 1.4404
2017 01 12 12:53:14, 44.7769, 1.4404
2017 01 12 12:53:15, 45.3008, 1.4404
2017 01 12 12:53:16, 45.4325, 1.416
2017 01 12 12:53:17, 45.697, 1.416
2017 01 12 12:53:18, 46.0961, 1.416
2017 01 12 12:53:19, 46.4981, 1.3916
2017 01 12 12:53:20, 46.7679, 1.3916
2017 01 12 12:53:21, 47.039, 1.416
2017 01 12 12:53:22, 47.175, 1.3916
```

Figure 21 Sample log file showing CSV data format

4.7. Fan Configuration Page

One to three fans can be connected to JUNIOR and can range from simple 2 wires with no feedback, 3 wires with speed feedback or 4 wires with both speed feedback and control. Each connected fan can be any of the allowed types the only restriction is that all the fans MUST use the same supply voltage. The fan supply voltage can either be the same as the JUNIOR supply or use the programmable onboard fan supply.

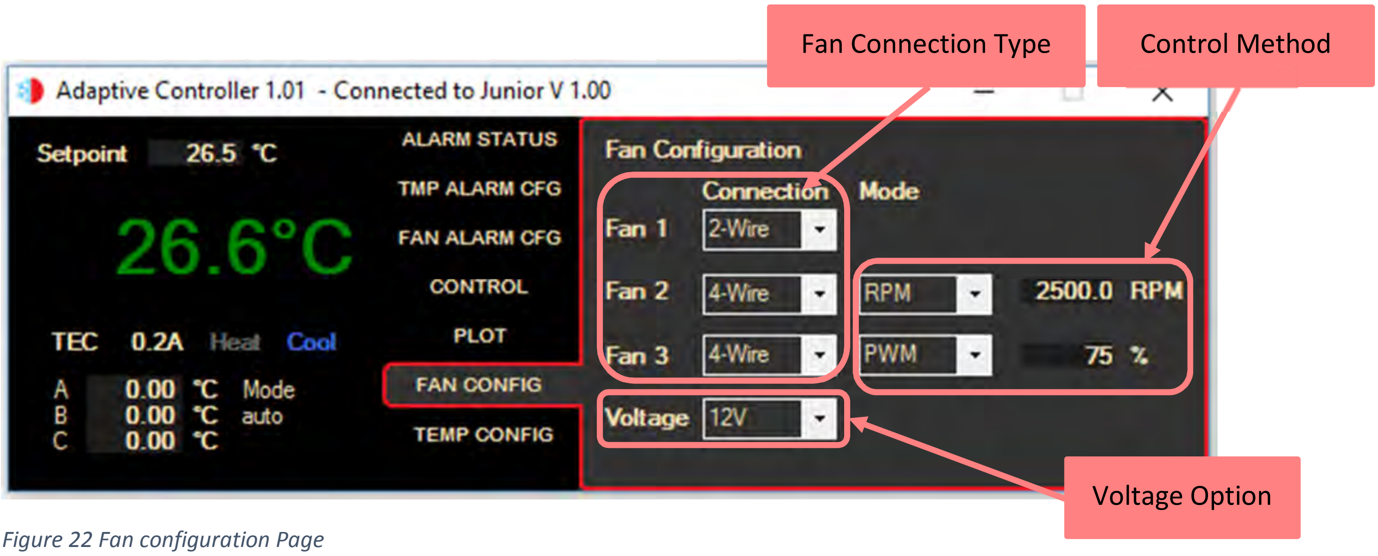


Figure 22 Fan configuration Page

To use the JUNIOR supply for powering the fans fit shorting jumpers across the 2-pin headers P11, 12 & 13 for the fans intended to be driven. Alternatively, to use the on board programmable supply ensure all three jumpers P11, 12 & 13 are removed (any that are fitted will cause that particular fan to be supplied from the input) and then select the required supply voltage of 5V, 12V or 24V from the fan voltage option drop down list.

Note: When using the programmable PSU the supply voltage should be above the selected fan voltage to ensure correct regulation of the fan supply.

Use the instruction list below to configure each fan that is connected.

1. Use the Connection drop down selection box for the selected fan number and choose 2,3 or 4-wire to suit the fan being connected.
2. If the fan is 4-wire the desired speed control mode should be selected using the Mode selection box.
3. For PWM enter the required demand 0 to 100% to set the nominal fan speed.
4. For RPM enter the fan speed required, noting the acceptable limits available.
5. Set up the fan alarms as required for current, voltage and speed using the Fan Alarm Configuration Page.

4.8. Temperature Configuration Page

JUNIOR can use either NTC thermistor or K-type thermocouples for sensing temperature. Up to four sensors can be connected and all can be individually selected as NTC or thermocouple.

Note: Sensor D is used for the temperature feedback for the controller so must always be fitted.

This page is used to configure both the number and type of sensors that are connected to the JUNIOR. This will only be required the first time the JUNIOR is setup or if any of the sensors are replaced. To configure a sensor, select it using the sensor selection buttons at the top right of the page, select the sensor type from the drop-down box and enter any required parameters then click apply.

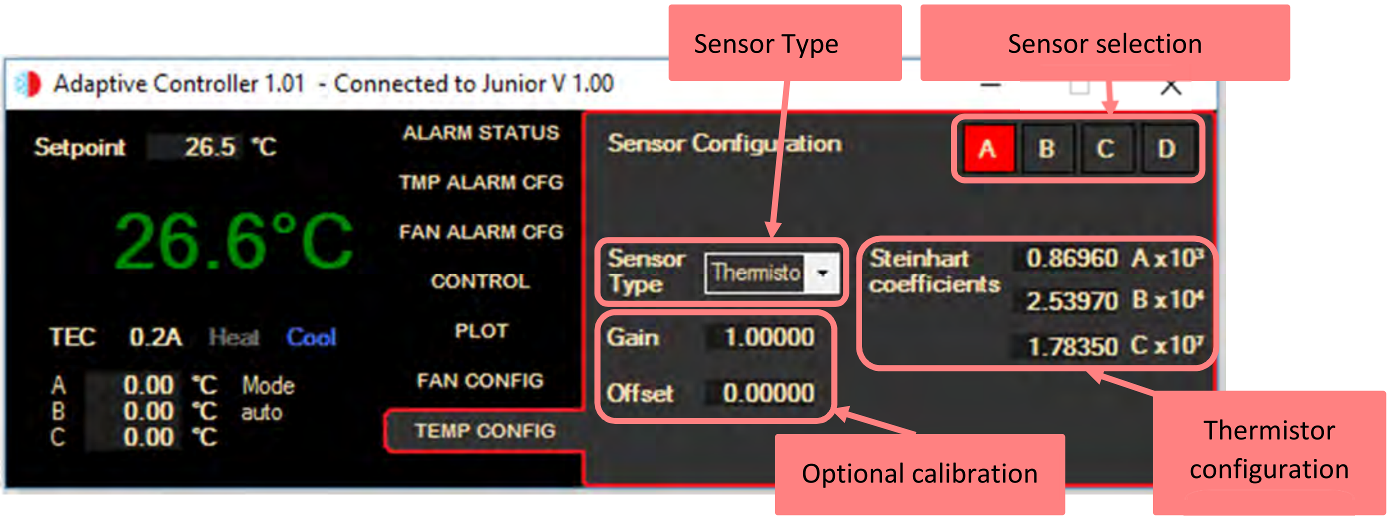


Figure 23 Sensor configuration for JUNIOR

4.8.1. Using NTC Thermistors

The resistance of a thermistor changes with temperature which is highly dependent on the materials used for its manufacture. Manufacturers therefore provide constants for use in the conversion between resistance and temperature. If the datasheet does not provide the A, B and C constants required for the configuration they can be calculated by using freely available NTC coefficient calculators. These take three temperature / resistance pairs from the datasheet and produce the A, B and C coefficients, choose temperatures at the extremes of the expected operating conditions for the unit to achieve the best accuracy when the temperature is converted. Note the form expects the small coefficients to be multiplied as shown before being entered.

4.8.2. Using K Type Thermocouples

Thermocouples are devices that use two dissimilar metals to create a voltage that is relative to the temperature that the junction is held at. The way the voltage changes over temperature is dependent of the material used for the two wires and these are classified into a number of types. The JUNIOR is configured to only work with K-Type thermocouples. To setup the JUNIOR to use a thermocouple, select K-Type from the sensor type drop down box and click apply, there are no other settings required for using thermocouples.

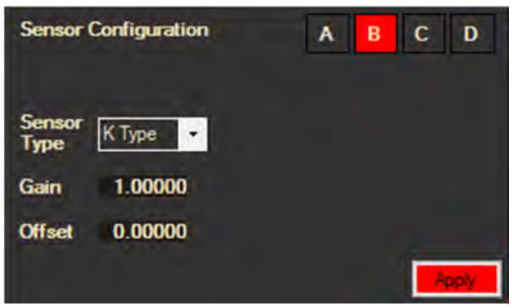


Figure 24 Selection of a K type thermocouple from the sensor configuration page

Note: ensure the thermocouple has been wired to the board with the correct polarity.

4.8.3. Optional Calibration

The firmware provides an optional calibration facility which can be used to either improve the accuracy of the temperature sensors being used or adjust for thermal offsets present in the system. For example, a thermistor will be specified over a given temperature range for a specified accuracy, but this may be much larger than the required operating range. By calibrating it over a smaller range the accuracy can be increased. The calibration can also be used to minimise errors when a temperature offset exists such as when the temperature sensor is not located close to the energy source.

The gain and offset values are used to apply a straight-line adjustment to the temperature measurement. The values are typically calculated by taking two measurements of both the indicated temperature on the controller and that from a separate calibrated temperature indicator at the two extremes of the range being used. These four values are then used to calculate the gain and offset to apply, minimising the error across the range.

Each sensor has a set of Gain and Offset parameters that can be entered in the boxes shown in Figure 23 above.

5. Appendix 1 JUNIOR Communication Interface

5.1. Serial Protocol and Settings

The JUNIOR serial connection provides a serial communication port with the following settings;

Baud rate	Data bits	Stop bits	Parity
115,200	8	1	None

Although this document describes the use of the Adaptive HMI with the JUNIOR, any Terminal program may be used to communicate and control the JUNIOR as long as it adheres to the protocol outlined below.

All commands are sent using 8-bit ASCII characters starting with $ and terminated with carriage return, line feed. The characters can be upper case, lower case or mixed and with or without spaces.

Numeric values may be integer or real, however exponent forms are not accepted and will return an 'Error_6 unexpected data <command that was used>'

Some example commands are shown below, note the < and > are not part of the command and are not typed.

Command	Result	Description
$ID<cr><lf>	ID=Junior Temperature Controller V1.01 ETDYN (c) Nov 27 2017<cr><lf>	Reads the identification
$REG 1<cr><lf>	REG 1=320<cr><lf>	Reads the status register
$REG 4=25<cr><lf>	REG 4=25.0000<cr><lf>	Writes to the setpoint register and returns the new value stored

5.2. Commands, Register Set and Limits

The table below shows the commands available using the interface.

Command	Description	Notes
VER	Returns the version of firmware programmed	
ID	Returns the device identifier string	
REG	Provides access to the internal registers	Use REG n to read register n Use REG n = x.y to write value x.y to register n
RUN	Turns on the output drive	Unconditionally starts control
STOP	Turns off the output drive	Unconditionally stops control (uses shutdown)

The following tables lists the registers available in the JUNIOR with a brief description and any restrictions.

Register Number	Type	Limits	Description
0	Integer	Read only	Firmware Version number
1	Integer	See Table 7	Status
2	Integer	0 to 4	Control mode 0 = OFF 1 = Manual 2 = Thermostat 3 = PID 4 = Auto tune
3	Integer	0 to 3	Output drive option 0 = Positive only 1 = Negative only 2 = Bidirectional 3 = TRIAC output
4	Floating point	-50 to +250°C	Setpoint
5	Floating point	-10000.0 to +10000.0	Proportional gain term
6	Floating point	-10000.0 to +10000.0	Integral gain term
7	Floating point	-10000.0 to +10000.0	Differential gain term
8	Floating point	-10.0°C to +10.0°C	Hysteresis
9	Floating point	-10.0°C to +10.0°C	Deadband
10	Integer	0 to 255	Slew rate on output 0 = none 1 = max 255 = min
11=A, 12=B, 13=C, 14=D	Integer	0 to 2	Temperature sensor type connected to input (x) 0 = None 1 = K type 2 = NTC Thermistor
15=A, 16=B, 17=C	Floating point	-100000.0 to +100000.0	Steinhart Coefficient (x) for sensor A
18=A, 19=B, 20=C	Floating point	-100000.0 to +100000.0	Steinhart Coefficient (x) for sensor B
21=A, 22=B, 23=C	Floating point	-100000.0 to +100000.0	Steinhart Coefficient (x) for sensor C
24=A, 25=B, 26=C	Floating point	-100000.0 to +100000.0	Steinhart Coefficient (x) for sensor D
27=A, 29=B, 31=C, 33=D	Integer	-1000 to +1000°C	Temperature alarm low limit for sensor (x)
28=A, 30=B, 32=C, 34=D	Integer	-1000 to +1000°C	Temperature alarm high limit for sensor (x)
35	Integer	See Table 8	Temperature alarm enables
36	Integer	See Table 8	Temperature relay enables
37	Integer	See Table 8	Temperature shutdown enables
38	Integer	See Table 9	Current temperature alarm status
39=1, 47=2, 55=3	Integer	0 to 3	Fan Type for fan (x) 0 = None 1 = 2 Wire 2 = 3 Wire 3 = 4 Wire
40=1, 48=2, 56=3	Integer	0 to 2	Fan Mode 0 = OFF 1 = PWM 2 = RPM
41=1, 49=2, 57=3	Integer	0 to 16000 RPM or 0 to 100% PWM	Speed demand for fan (x)
42=1, 50=2, 58=3	Integer	0 to 5000mA	Fan (x) over current alarm limit
43=1, 51=2, 59=3	Integer	0 to 50V	Fan (x) over voltage alarm limit
44=1, 52=2, 60=3	Integer	0 to 16000 RPM	Fan (x) lower speed alarm limit
45=1, 53=2, 61=3	Integer	0 to 16000 RPM	Fan (x) upper speed alarm limit

46=1, 54=2, 62=3	Integer	See Table 10	Fan (x) alarm enables
63	Integer		Fan PSU supply voltage setting 0 = Off – use voltage in supply 1 = 5V 2 = 12V 3 = 24V
64	Integer	See Table 11	Current fan alarm status
65=A, 66=B, 67=C, 68=D	Floating point	Read only	Temperature sensor (x) value
69=1, 72=2, 75=3	Floating point	Read only	Fan (x) current value
70=1, 73=2, 76=3	Floating point	Read only	Fan (x) voltage value
71=1, 74=2, 77=3	Integer	Read only	Fan (x) speed
78	Floating point	Read only	Bridge voltage (TEC) value
79	Floating point	Read only	Current monitoring voltage
80	Floating point	Read only	Bridge current (TEC) value
82	Integer	Read only	Current PWM output value
83	Floating point	Read only	Supply voltage value
84	Floating point	Read only	On board potentiometer reading
90=A, 92=B, 94=C, 96=D	Floating point		Calibration gain for sensor (x)
91=A, 93=B, 95=C, 97=D	Floating point		Calibration offset for sensor (x)

Table 7 Status bit details

Bit number	Status (1 = alarm active)
0	Shutdown
1	Relay active
6	Heat or cool
11	Auto tune complete
12	Auto tune failed
13	Internal fault
14	Communications fault
15	Communications fault

Bit = 1 indicates condition is active

Table 8 Bit arrangement for alarm enable, relay and shutdown registers

Sensor	Sensor D		Sensor C		Sensor B		Sensor A	
Alarm type	High	Low	High	Low	High	Low	High	Low
Bit number	7	6	5	4	3	2	1	0

Bit = 0 disabled, Bit = 1 enabled

Table 9 Temperature alarm status bits

Sensor	Sensor D		Sensor C		Sensor B		Sensor A	
Alarm type	High	Low	High	Low	High	Low	High	Low
Bit number	7	6	5	4	3	2	1	0

Bit = 1 indicates alarm condition is active

Table 10 Bit arrangement for alarm enable, relay and shutdown bits for fan

Type	Shutdown				Relay				Enable			
Alarm	low speed	high speed	over voltage	over current	low speed	high speed	over voltage	over current	low speed	high speed	over voltage	over current
Bit number	11	10	9	8	7	6	5	4	3	2	1	1

Note: There is one register for each fan. Each register is split into three segments, each having individual enable bits for the four alarms that can be set. Bits 0 to 3 in the enable segment are also used to qualify the upper shutdown and relay segments. If a bit is set in the upper segments an active alarm will only cause the relay or shutdown to become active if the associated bit has been set in the enable segment.

Table 11 Fan alarm status bits

Type	Shutdown				Relay				Alarm			
Alarm	low speed	high speed	over voltage	over current	low speed	high speed	over voltage	over current	low speed	high speed	over voltage	over current
Bit number	11	10	9	8	7	6	5	4	3	2	1	1

Bit = 1 indicates alarm condition is active

IMPORTANT NOTICE

European Thermodynamics Ltd. reserve the right to change, amend or modify the specifications or features of software and hardware designs as necessary without notice.

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