JUNIOR V2 User Guide

Version 1.03

17th September 2024

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 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 NTC sensor inputs
- Two K-Type Thermocouple inputs
- Two operating mode feedback LEDs
- Manual set temperature
- Three fan driver outputs
- Alarm output
- Solid state relay (SSR) output
- Thermoelectric driver output
- Optional RS232 Optically Isolated Interface – Part Number: ADC-SI
- Optional RS485 Optically Isolated Interface – Part Number: ADC-485-I

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 thermocouple, NTC thermistor
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.

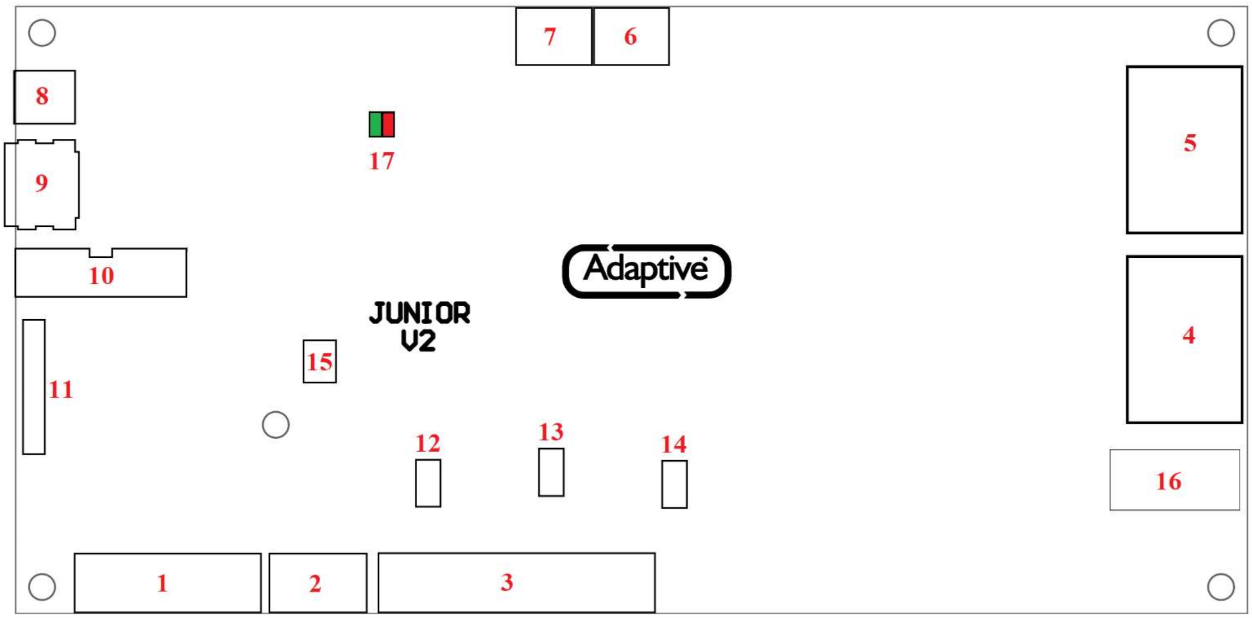

Figure 1. Board Connections and Functions (Top View)

ID	Function	Comment
1	Sensor Inputs	Supports NTC thermistors
2	Sensor inputs	Supports K-type thermocouples
3	Fan driver interface	Supports 2, 3 and 4 wire fans
4	Power Input	Main power to the board
5	Power Output	Thermoelectric Module or Assembly – PWM output **Warning:** The PWM output voltage closely follows the Power Input DC voltage supplied to the controller. If a high input voltage (e.g., 24V) is applied to the controller while a low-voltage thermoelectric module (e.g., 2-18V TEG) is connected, a short circuit may occur. This can result in damage to both the thermoelectric module and the controller. Ensure that the input voltage does not exceed the voltage rating of the connected TEG(s). Avoid using long wires between the output and the thermoelectric assembly. It is always good practice to keep output power wires as short as possible (<50cm)
6	Alarm output	Relay contacts (NC/NO)
7	Serial interface	RS232 level interface
8	SSR driver output	PWM output to drive DC or AC solid state relays
9	USB serial interface	USB 2.0 interface (Type-C connector) – Standard communication interface
10	Expansion No. 2 interface	Reserved for future use
11	Expansion No. 1 interface	Supporting optional plug-in modules (isolated RS485 and RS232)
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	Analog control	Manual set temperature control in offline mode
16	Current limit fuse	Auto mini blade fuse (20A / 58V DC)
17	Status LEDs	Visual feedback. Green: normal operation, Alternating: alarm, Red: shutdown

Table 2. Connector Descriptions

1.4. Electrical Installation

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

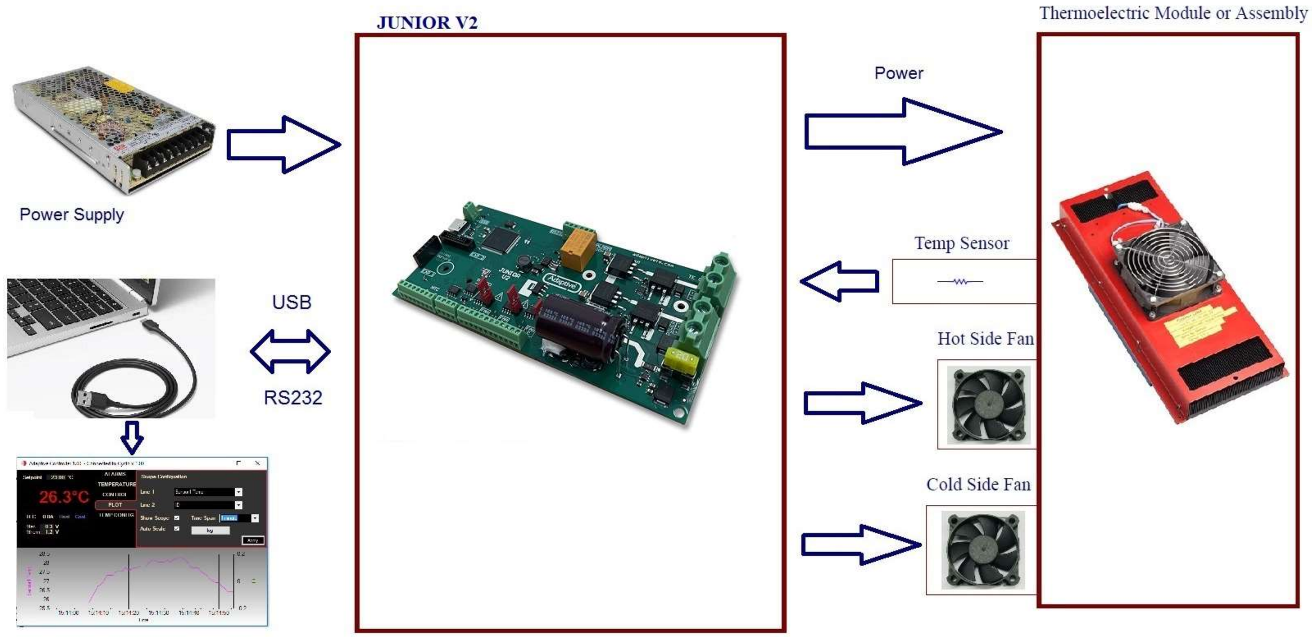

Figure 2. Thermoelectric Cooling / Heating Application Setup

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.

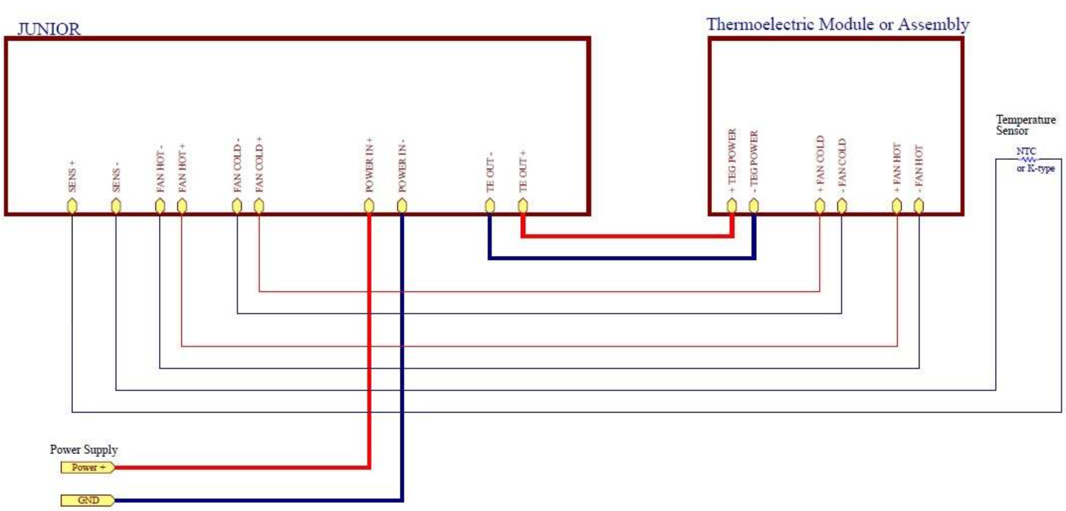

Figure 3. Wiring diagram of minimum level installation

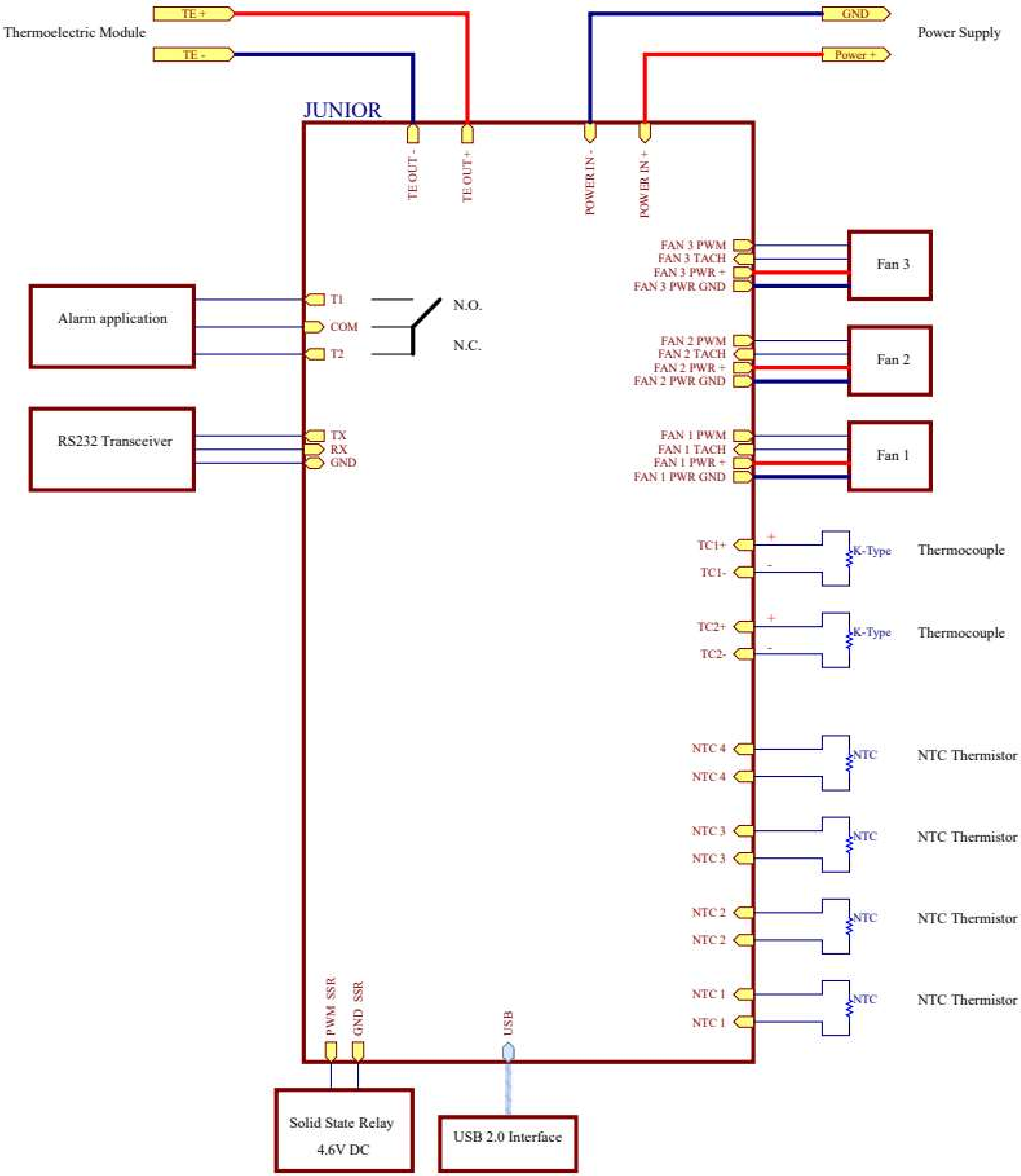

Figure 4. Wiring diagram of complete installation

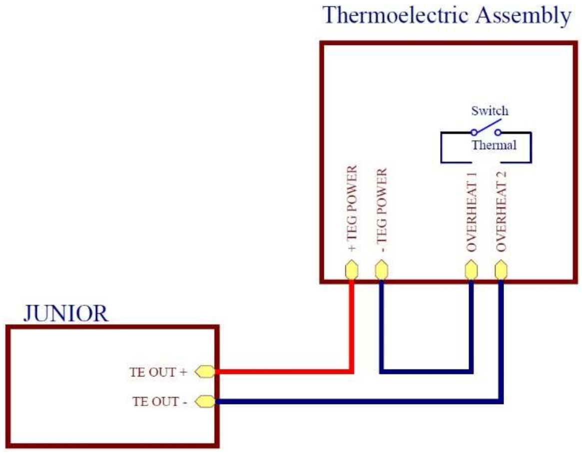

Figure 5. Wiring diagram for Thermoelectric Assemblies with thermal protection

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

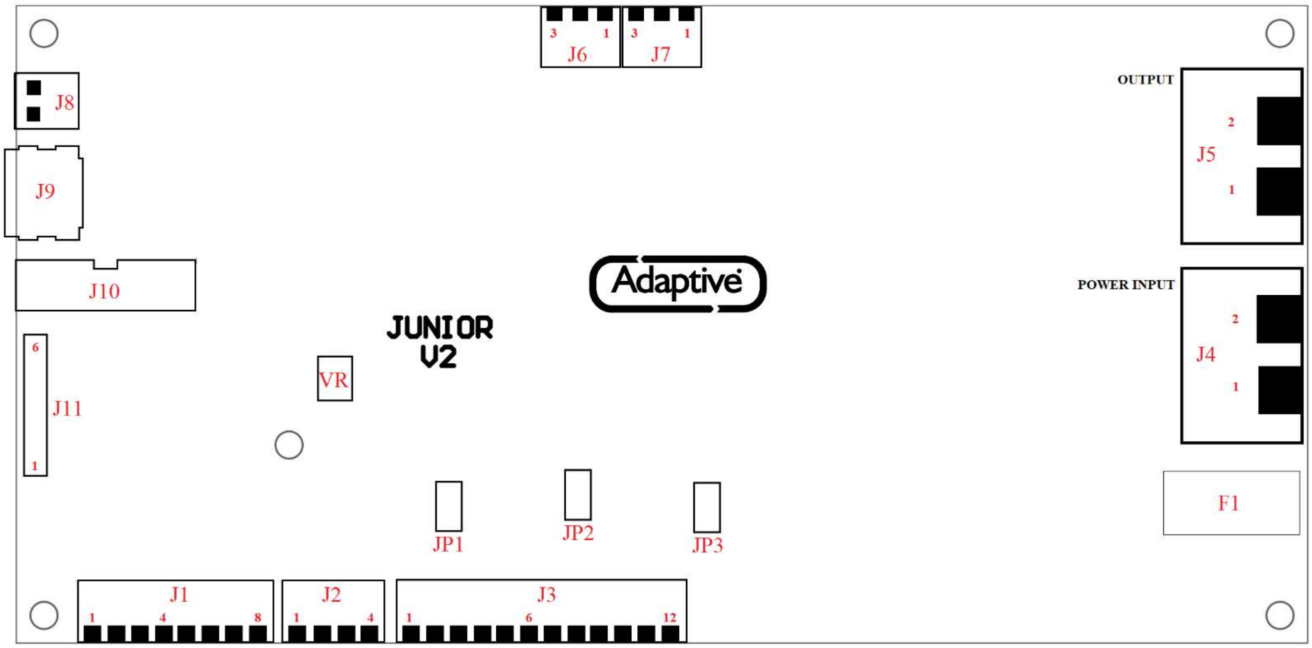

Figure 6.Connector map (top view)

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 (Note 1)	3.3	0.001
J1	2	SENS **A** or **1** -	Input	Sensor No. 1 negative (Note 1)	0	0.001
J1	3	SENS **B** or **2** +	Input	Sensor No. 2 positive (Note 1)	3.3	0.001
J1	4	SENS **B** or **2** -	Input	Sensor No. 2 negative (Note 1)	0	0.001
J1	5	SENS **C** or **3** +	Input	Sensor No. 3 positive (Note 1)	3.3	0.001
J1	6	SENS **C** or **3** -	Input	Sensor No. 3 negative (Note 1)	0	0.001
J1	7	SENS **D** or **4** +	Input	Sensor No. 4 positive (Note 1)	3.3	0.001
J1	8	SENS **D** or **4** -	Input	Sensor No. 4 negative (Note 1)	0	0.001
J2	1	SENS **F** / TC2-	Input	Sensor TC2 negative (Note 2)	-5mV/+40mV	-100nA/+100nA
J2	2	SENS **F** / TC2+	Input	Sensor TC2 positive (Note 2)	-5mV/+40mV	-100nA/+100nA
J2	3	SENS **E** / TC1-	Input	Sensor TC1 negative (Note 2)	-5mV/+40mV	-100nA/+100nA
J2	4	SENS **E** / TC2+	Input	Sensor TC1 positive (Note 2)	-5mV/+40mV	-100nA/+100nA
J3	1	Fan **1** or **A** GND (-)	Output	Fan 1 power negative	0	1.2
J3	2	Fan **1** or **A** PWR (+)	Output	Fan 1 power positive	48	1.2
J3	3	Fan **1** or **A** TACH	Input	Fan 1 TACH signal (Note 3)	3.6	0.022
J3	4	Fan **1** or **A** PWM	Output	Fan 1 PWM signal (Note 4)	4.6	0.025
J3	5	Fan **2** or **B** GND (-)	Output	Fan 2 power negative	0	1.2
J3	6	Fan **2** or **B** PWR (+)	Output	Fan 2 power positive	48	1.2
J3	7	Fan **2** or **B** TACH	Input	Fan 2 TACH signal (Note 3)	3.6	0.022
J3	8	Fan **2** or **B** PWM	Output	Fan 2 PWM signal (Note 4)	4.6	0.025
J3	9	Fan **3** or **C** GND (-)	Output	Fan 3 power negative	0	1.2
J3	10	Fan **3** or **C** PWR (+)	Output	Fan 3 power positive	48	1.2
J3	11	Fan **3** or **C** TACH	Input	Fan 3 TACH signal (Note 3)	3.6	0.022
J3	12	Fan **3** or **C** PWM	Output	Fan 3 PWM signal (Note 4)	4.6	0.025
J4	1	POWER IN +	Input	Main power positive	48	15
J4	2	POWER IN -	Input	Main power negative	0	15
J5	1	TE OUT +	Output	TE Module/Assembly +	48	15
J5	2	TE OUT -	Output	TE Module/Assembly -	0	15
J6	1	Alarm N.C.	Output	Alarm normally closed pin	30	1
J6	2	Alarm COM	Output	Alarm common pin	30	1
J6	3	Alarm N.O.	Output	Alarm normally open pin	30	1
J7	1	RS232 TXD	Output	Serial transmit signal	±12	0.04
J7	2	RS232 RXD	Input	Serial receive signal	±12	0.002
J7	3	RS232 GND	Output	Serial ground	0	0.004
J8	1	SSR PWM	Output	Solid state relay PWM (Note 5)	4.6	0.025
J8	2	SSR GND	Output	Solid state relay GND	0	0.025
J9		COM USB	I/O	USB 2.0	5	0.1
J10		EXPANSION 2	-	Expansion Interface (reserved for future use)	-	-
J11	-	EXPANSION 1	-	Expansion Interface	-	-

Note 1: This signal is pulled up to 3.3V via an internal 10K Ohm resistor.
Note 2: Internally biased input for thermocouple only.
Note 3: This signal is pulled up to 3.3V via an internal 4.99K Ohm resistor.
Note 4: Push-Pull output. No external pull-up or pull-down required.
Note 5: PWM frequency is 1Hz.

Table 3. 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 has inputs for 2 K-Type thermocouples and 4 NTC resistor sensors. Any combination of these can be used but only 1 can be selected for control of the bridge output.

1.6. Fan Interface

The board supports up to 3 independent fans which can be 2, 3 or 4 wire or a combination. These can be used to drive the hot or cold side fans of the connected thermoelectric assembly. Speed can be measured on fans having 3 or 4 wires using the TACH pin and the speed on 4 wire fans can be controlled by connecting the PWM pin. The TACH and PWM signals are internally pulled up and care should be taken to select suitable fans. Refer to Table 3. for electrical parameters.

1.7. Alarm Interface

For user applications that need alarm signalling, an isolation relay output is provided on J5. When an alarm condition occurs, relay pins 1 and 2 open, while pins 2 and 3 closes.

1.8. RS232 Interface

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

1.9. USB Serial Communication Interface

The USB C interface provides a standard serial interface for communication with the Adaptive HMI software or talk directly using the serial protocol detailed in Appendix 1 JUNIOR Communication Interface. The HMI also provides the ability to perform in-field upgrades of the firmware.

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 single phase or 3 phase SSR are suitable to use with the controller however the control voltage should allow for a 4.6V DC signal (e.g. Part number: SSR-40 DA). Refer to Table 3. for electrical parameters.

1.11. Mechanical Dimensions

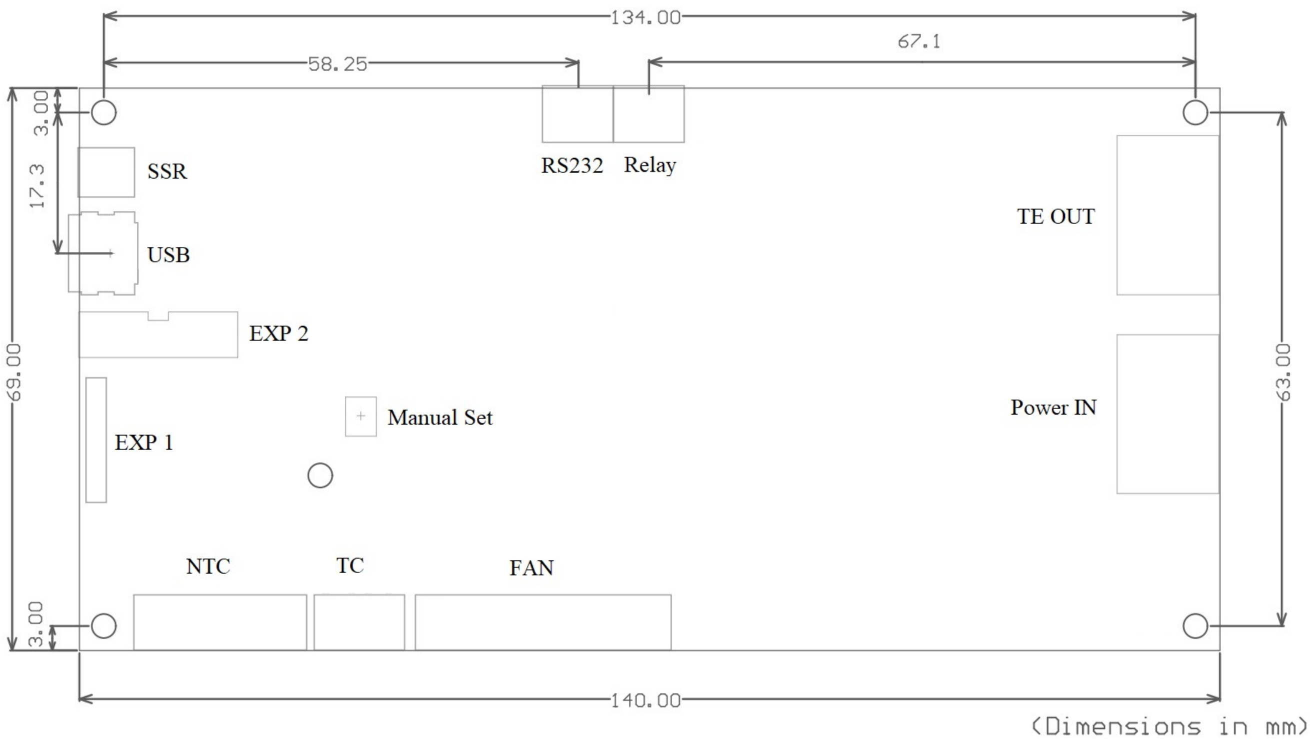

Figure 7. Mechanical Dimensions

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
Type-C USB connector protrusion	1.5mm

Table 4. 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. It also allows the firmware of the devices to be upgraded in-field when a new version becomes available. This document describes the Adaptive HMI in detail 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.

During install the application will check and prompt if it needs to install an updated Microsoft .Net framework.

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 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. Thermistors can be connected to inputs A to D (sensor 1 to 4) and thermocouples to input TC1 & TC2 (sensors 5 & 6). Connect the USB cable or RS232 port to the PC, switch on and start the HMI. Note switch on the Junior before starting the HMI so that the USB serial port is detected.
2) Select the temperature sensor 1 to 6 being used on the Temperature Config page, click enable and enter the Steinhart coefficients if using a thermistor and then click apply. 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 P12, 13 & 14 are fitted if needed.
4) Configure and enable any desired temperature and fan alarms, see sections 4.3.1 Temperature Sensor Alarm Configuration Page and 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.

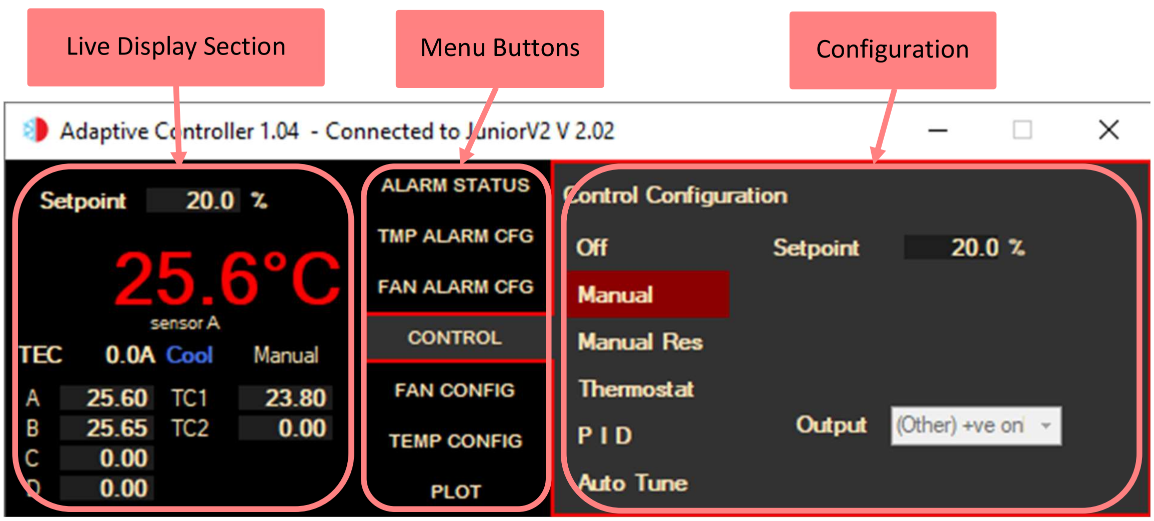

Figure 8. Example HMI display layout

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 9. Apply button appears when settings are changed

4. Using the Software

4.1. Starting the Software and Connecting the Controller

The JUNIOR has RS232, USB serial and optional isolated RS485 ports, any 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 **before** the HMI is started, so that it detects the USB port. If using the RS232 serial port simply connect it to the PC. If using the optional RS485 board ensure it is fitted to EXP 1.

To start the HMI, double click on the Adaptive HMI shortcut icon Adaptive HMI or select it from the start menu Adaptive group. This will bring up the connection window see below

For RS232 Connections select the port from the available port list and click the connect button. For RS485 connections select the port and click scan to get the list of connected devices, then select the address of the device required and click connect.

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.

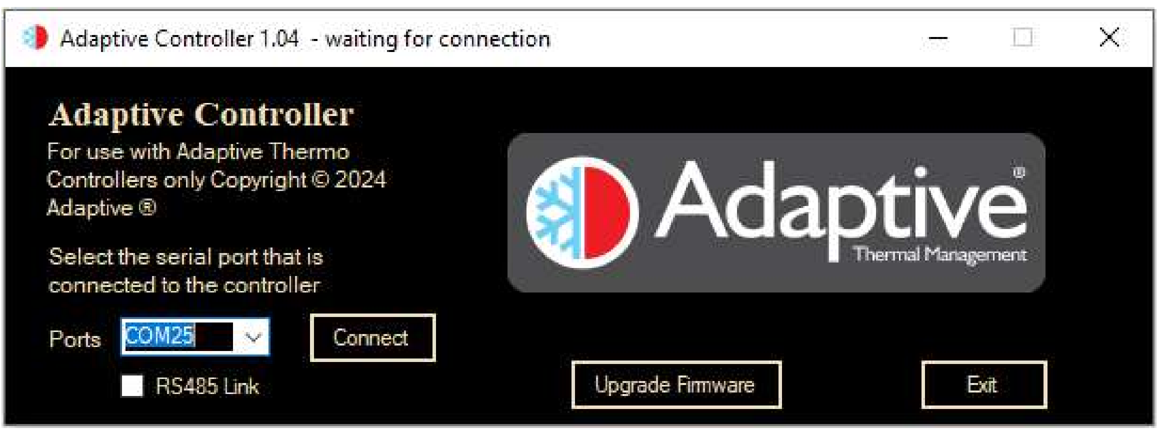

Figure 10. HMI Connection Screen

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 the most frequently used pages are shown at the top. 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 8. Example HMI display layout. Whenever an active alarm is present and the Alarm Status page is not visible, its button will flash to

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

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.

4.3. Alarm Configuration Pages

The JUNIOR has configurable alarms for each sensor and fan, split into two pages, one for the temperature sensors and one for the fans. The specific temperature or fan is selected by using the selection buttons at the top right.

Each alarm has individual trip threshold, Enable, Relay and Shutdown options. If the Relay option is also enabled it will activate the onboard relay for the duration of the alarm. This relay can be used to signal externally connected equipment for example a light stack or sounder. When shutdown is enabled 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

Up to six sensors can be connected, use the selection buttons 1 to 6 to configure each alarm – see Figure 11. Example JUNIOR Temperature Alarm configuration page, below.

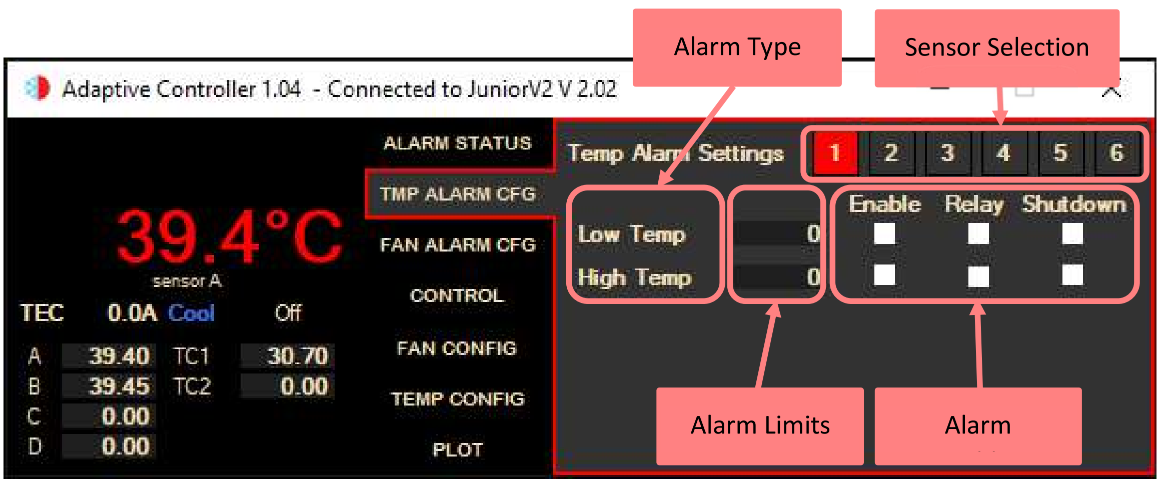

Figure 11. Example JUNIOR Temperature Alarm configuration page

Note: the alarms only operate if a sensor is enabled on its configuration page irrespective of the 'alarm enables' configured on this 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 12 below.

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

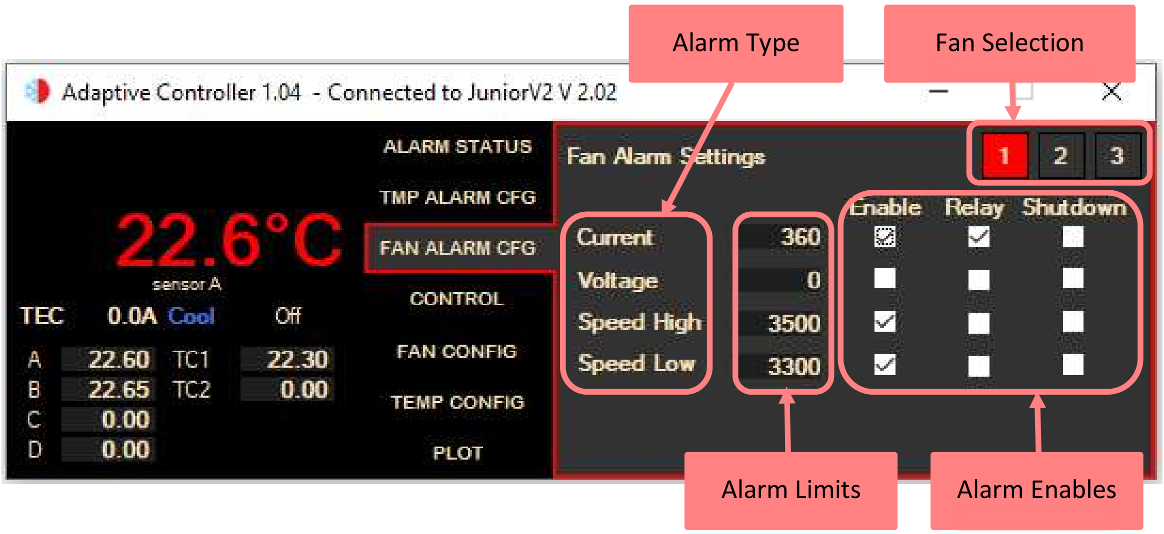

Figure 12. Example JUNIOR Fan Alarm configuration page

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 13 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.

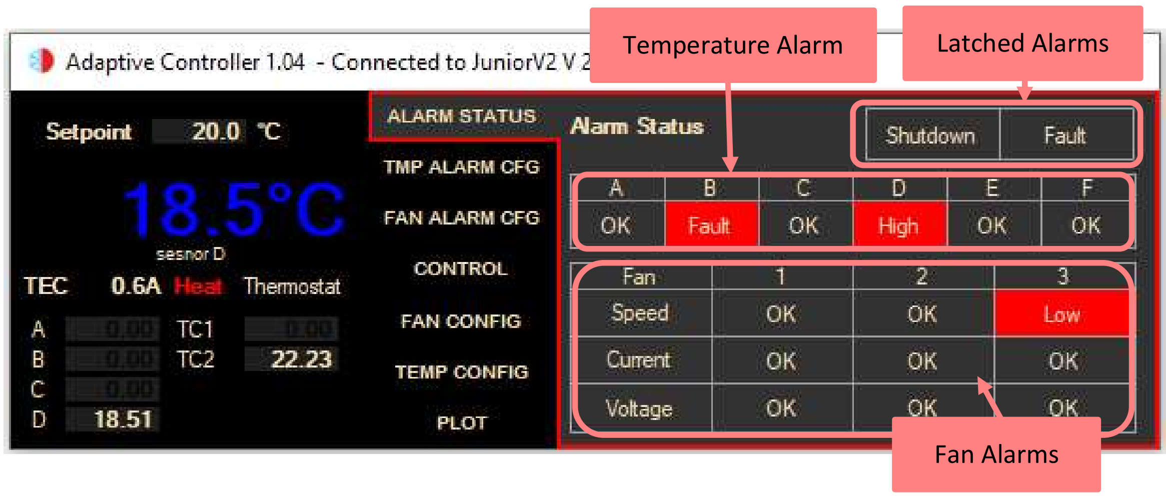

Figure 13. Example JUNIOR Alarm status page

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.

Alarm Status

	Alarm Type	Alarm Status	Description / Cause
Latched Alarms	Shutdown	Active	At least one alarm with shutdown option selected has tripped, no valid sensor selected for the control sensor or Internal fault has occurred.
	Fault	Active	Indicates an internal fault has occurred.
Temperature Sensors	Sensor A Sensor B Sensor C Sensor D Sensor E Sensor F	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

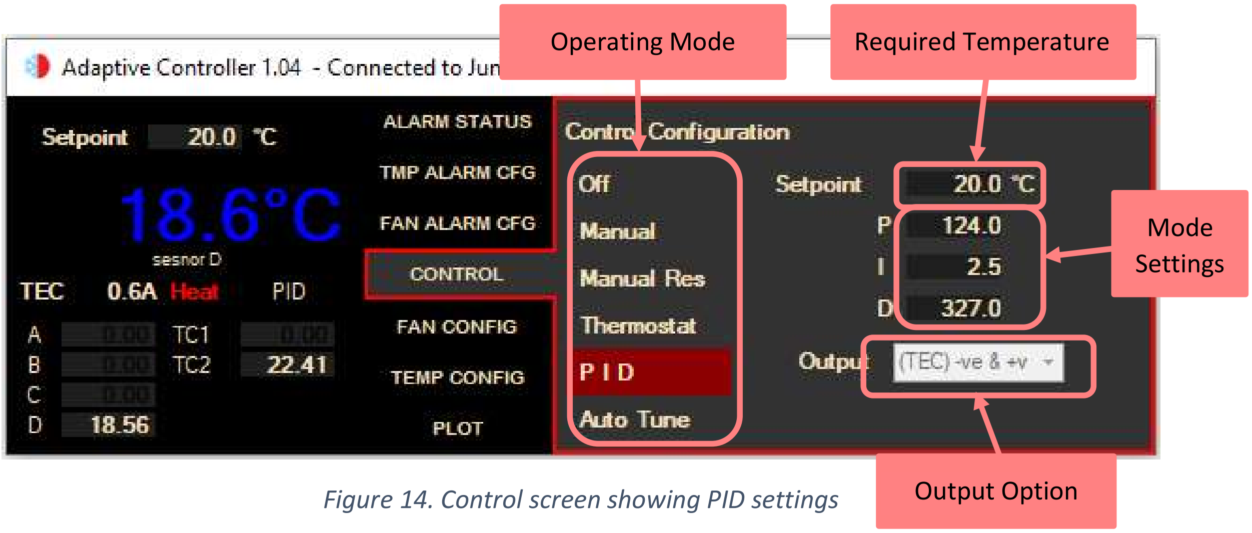

Figure 14. Control screen showing PID settings

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. There is no temperature sensor feedback used for this mode and the setpoint is entered as a percentage of the output demand (0 to 100%) instead of degrees C.

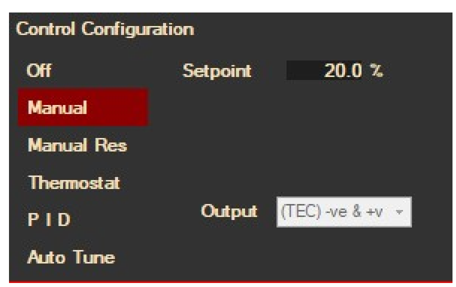

Figure 15. Manual operating mode

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.

The actual output value is also determined by what output mode has been selected see Table 5 and Figure 16 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 5. Output drive polarity based on output mode and drive level

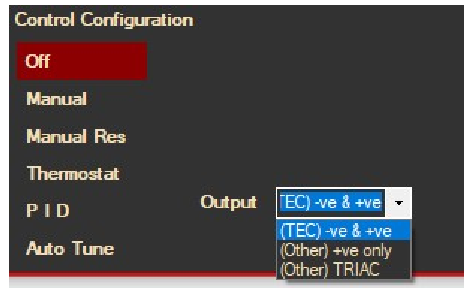

Figure 16. Selecting the output drive method when the control mode is OFF

4.5.2. Manual Res Mode

This mode uses the onboard variable resistor VR200 located above the TC1 and TC2 thermocouple input connector as a manual method to adjust the setpoint temperature. The temperature range of the Junior can be set between -50°C and 250°C. Turning the variable resistor to the left (anticlockwise) reduces the temperature and right (clockwise) increases it. The current setpoint value is shown at the top of the live section display. Note: This is used as a setpoint input to the PID controller so to use this mode the PID gains must have been configured.

4.5.3. 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 at the control sensor input (see 4.8.3 Control Sensor Selection) to the setpoint using the values entered for hysteresis and dead band.

Figure 17. Thermostat operating mode

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.

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.

Warning: Thermostat mode is not recommended for use with standard thermoelectric devices as care needs to be taken to prevent excessive thermal cycling which can rapidly shorten its lifespan.

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.

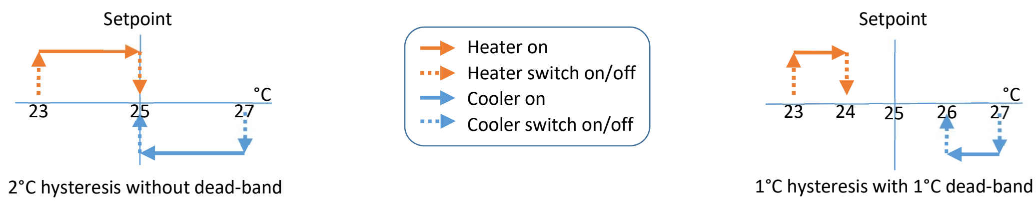

Figure 18. Example configuration shown hysteresis and dead-band for bidirectional drive

4.5.4. 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 the control sensor (see 4.8.3 Control Sensor Selection) and the P, I & D terms to maintain the setpoint accurately.

Figure 19. 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.

4.5.5. 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 20. 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.

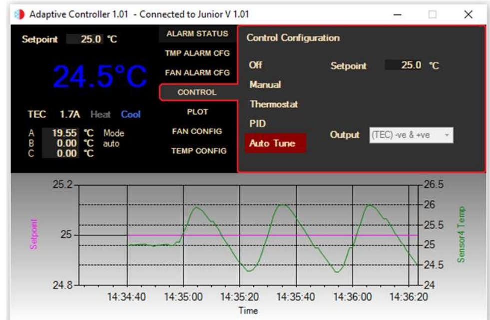

Figure 20. Start of the Auto Tune process

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 21 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.

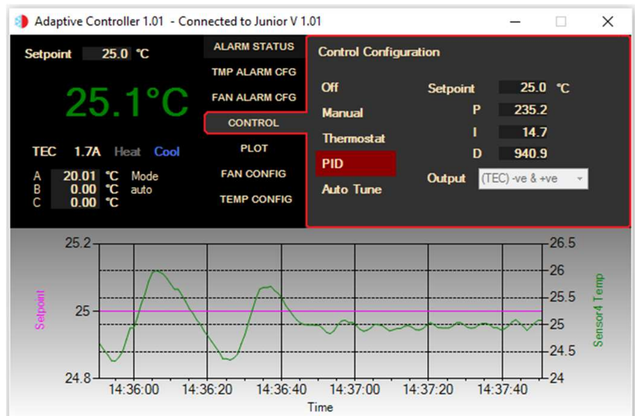

Figure 21. End of Auto Tune sequence

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.**

4.5.6. PID Basics Explained

The PID control method works by first calculating the error between the actual and desired temperature (setpoint – sensor 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

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

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

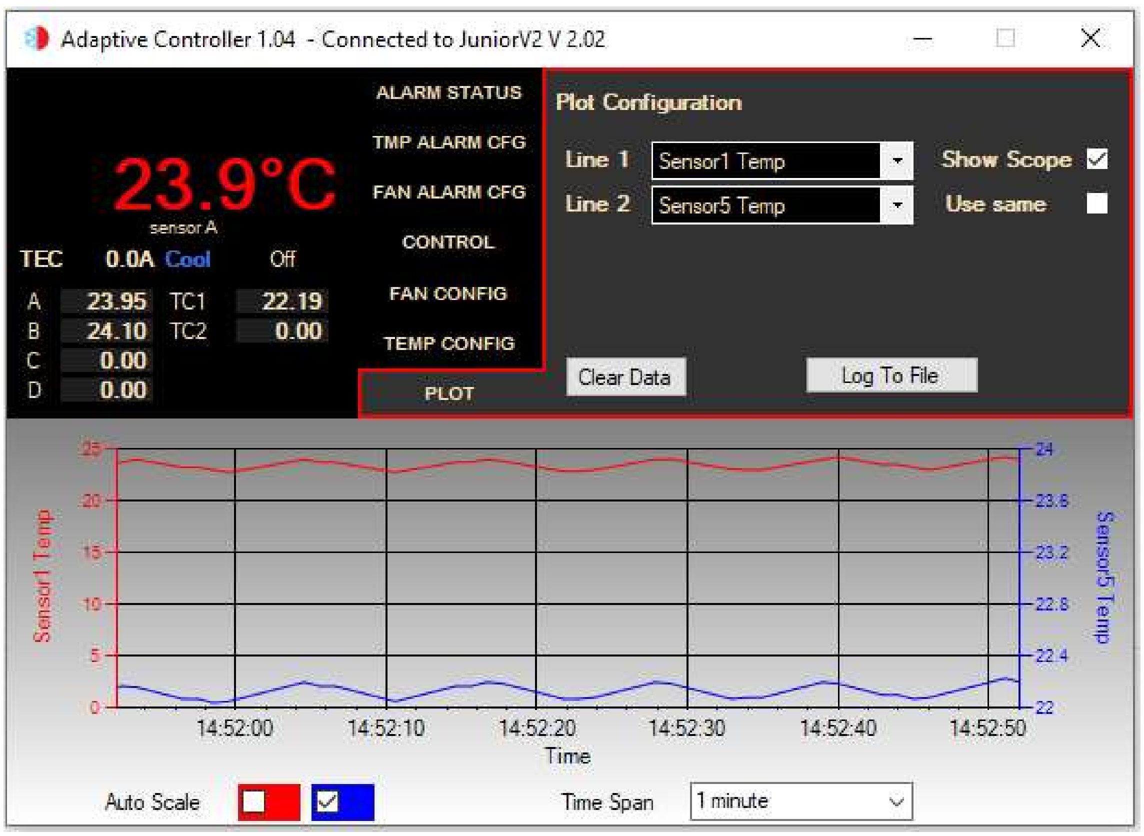

Figure 22. Realtime plotting and logging

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 the datapoints are also recorded to the text file. 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 has no effect on logging.

Display Option	Description
Show Scope	Displays the scope in a window below the main application display.
Use same	Attempts to set both scales to the same range to allow comparisons between the traces
Auto scale	Increases or decreases the Y axis range so that all the recorded Y values fit within the Y 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'.

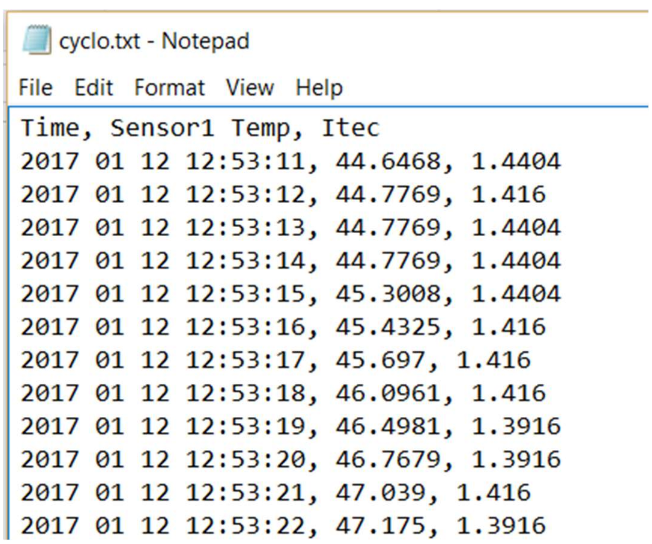

Figure 23. Sample log file showing CSV data format

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.

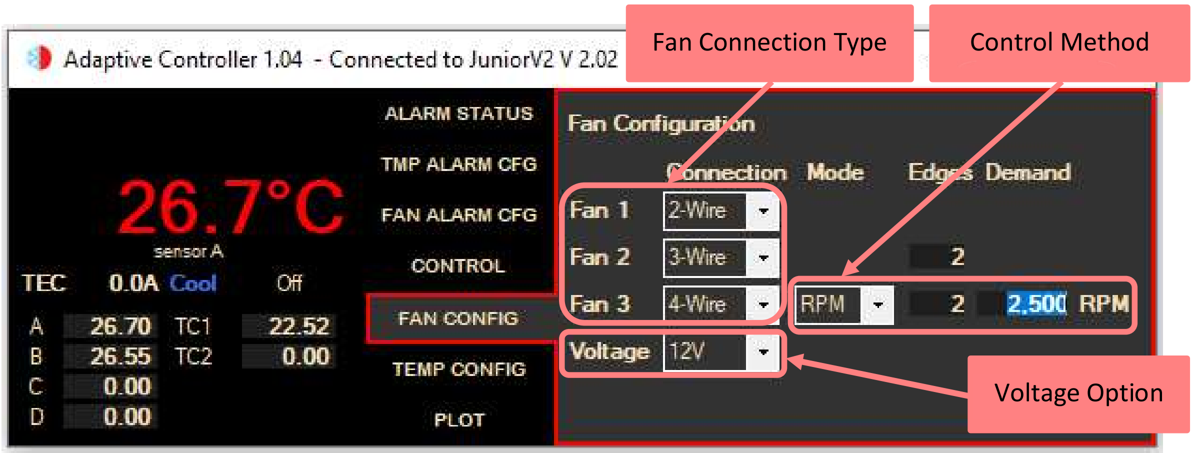

Figure 24. Fan configuration Page

To use the JUNIOR supply for powering the fans fit shorting jumpers across the 2-pin headers P12, 13 & 14 for the fans intended to be driven. Alternatively, to use the on-board programmable supply ensure all three jumpers P12, 13 & 14 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 has tacho feedback (3 or 4 wire fan) enter the number of edges per revolution into the edges column
3. If the fan is 4 wire the desired speed control mode should be selected using the Mode selection box.
4. For PWM enter the required demand 0 to 100% to set the nominal fan speed.
5. For RPM enter the fan speed required, noting the acceptable limits available.
6. 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 depending on which sensor input is used. Inputs 1 to 4 are for NTC and inputs 5 & 6 are for K-Type. Any combination of sensors can be used, but at least one must be connected and selected as the control sensor to provide temperature feedback.

To configure the sensors, select the sensor number 1 to 6 and then click on Enable to enter the values.

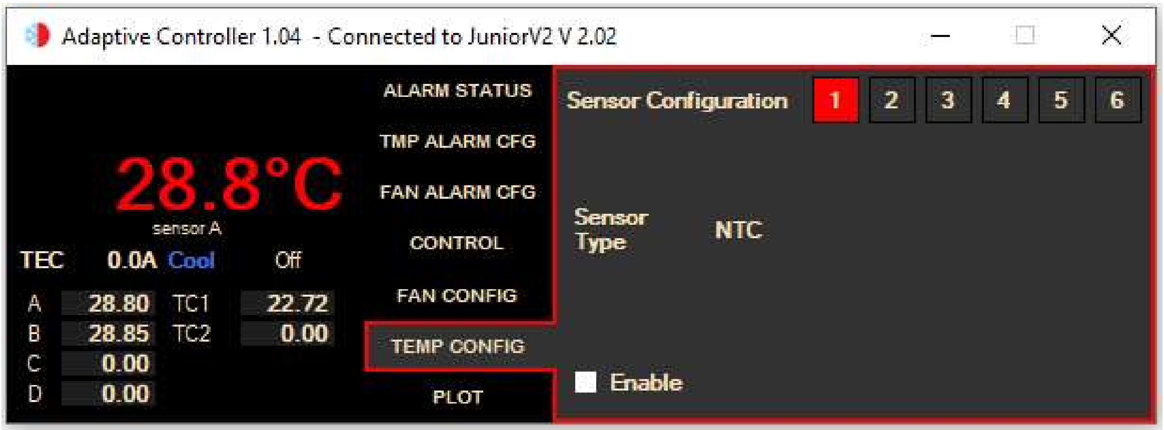

Figure 25. Sensor configuration page for JUNIOR

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.

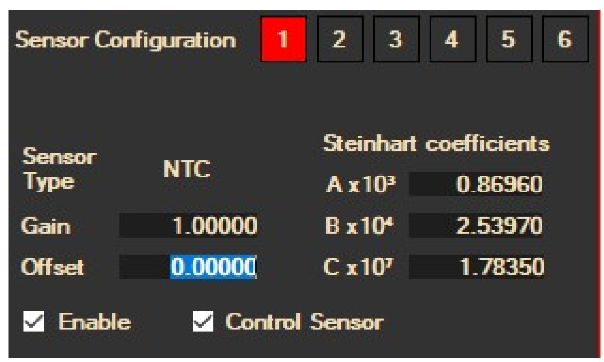

Figure 26. NTC Sensor configuration page

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. There is no configuration for thermocouples so just enable to use. Note: ensure the thermocouple has been wired to the board with the correct polarity.

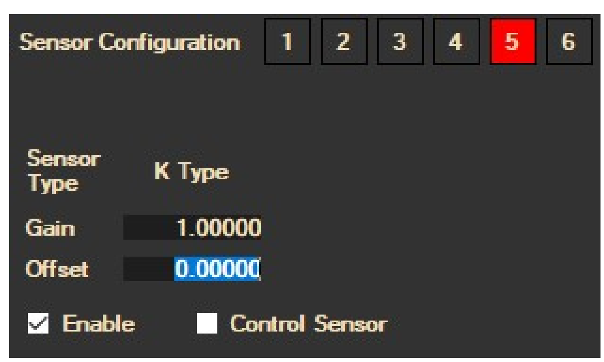

Figure 27. K-Type thermocouple configuration page

4.8.3. Control Sensor Selection

To enable bridge control to maintain the TEC temperature one of the sensors must be selected as the control sensor. This is selected by ticking the 'Control Sensor' box on the sensor page that you wish to use. If another sensor has already been selected, it will be deselected automatically. Note the current sensor being used for control is shown in small text below the temperature in the main display.

4.8.4. 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 26 and Figure 27 above.

5. Junior Optional Functions

5.1. Optional Functions

As the Junior product has matured various additional features and improvements have been made, some of these features are not available through the standard HMI application and therefore are only configurable via the serial interface. This is described in section 6 Appendix 1 JUNIOR Communication Interface

5.2. Power Interruption

The default operation of the Junior when the power is restored is to return to the last mode it was in. This could either be with the bridge active or not depending on its state when the power was lost. In a stand-alone system this operation is probably what is required, however there are situations where it is more suitable to always start-up the board with the bridge switched off.

The bridge can be forced off, on power up if it was previously active by setting bit 0 in the options register 102.

5.3. RS485 Single and Multidrop Option

With the use of an optional isolated RS485 board fitted to the Expansion port EXP 1, Juniors may be controlled either individually or as a group using a single RS485 bus. In single mode no configuration is required however by configuring each Junior with a unique address multidrop may be used.

Please refer to section 7 Appendix 2 RS485 Option for single and multiple Junior communication for details.

6. Appendix 1 JUNIOR Communication Interface

6.1. 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

Table 6. Example Command Layout

6.2. Commands, Register Set and Limits

The table below shows the commands available using the interface.

Command	Description	Notes
VER	Returns the firmware version	As a 16-bit word where version is MSB.LSB
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)
SER	Returns the serial number	
DEFAULT	Resets all parameters to default	To reset use the command $Default=1
ADDR	Return address set	

Table 7. Commands

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 9	Status
2	Integer	0 to 4	Control mode 0 = OFF 1 = Manual 2 = Thermostat 3 = PID 4 = Auto tune in progress
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
109	Integer	0 to 5	Sensor for the control feedback 0=Sensor A to 5=sensor F (TC2)
106	Integer	0 to 31	Temp sensors 0=disabled, 1=enabled Bit 0,1,2,3 = NTC Sensors A,B,C,D Bit 4 = K Type sensor E (TC1) Bit 5 = K Type sensor F (TC2)
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, 110=E (TC1), 112=F (TC2)	Integer	-1000 to +1000°C	Temperature alarm low limit for Sensor (x)
28=A, 30=B, 32=C, 34=D, 111=E (TC1), 113=F (TC2)	Integer	-1000 to +1000°C	Temperature alarm high limit for sensor (x)
35	Integer	See Table 10	Temperature alarm enables
36	Integer	See Table 10	Temperature relay enables
37	Integer	See Table 10	Temperature shutdown enables
38	Integer	See Table 11	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
120=1, 121=2, 122=3	Integer	1 to 16	Number of tacho pulses per fan revolution
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 12	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 13	Current fan alarm status
65=A, 66=B, 67=C, 68=D, 107=E (TC1), 108=F (TC2)	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, 114=E (TC1), 116=F (TC2)	Floating point		Calibration gain for sensor (x)
91=A, 93=B, 95=C, 97=D, 115=E (TC1), 117=F (TC2)	Floating point		Calibration offset for sensor (x)
102	Integer	0 to 65536	Various configurable control options, active when bit set
			Bit 0 – Force the bridge off when power interrupted, otherwise it will turn back on when power is restored
105	Integer	0 to 100	RS485 Address

Table 8 Status bit details

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

Table 9. Status Register Bit Fields

Sensor	F		E		D		C		B		A	
Alarm type	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Bit number	11	10	9	8	7	6	5	4	3	2	1	0
Note: a separate register holds the enable, relay and shutdown bits for all six temperature sensors. Setting a bit to 1 enables its alarm, relay or shutdown option respectively. The relay and shutdown bits are only actioned If the related enable bit is also set.												

Table 10. Bit arrangement for alarm enable, relay and shutdown registers

Sensor	F		E		D		C		B		A	
Alarm type	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Bit number	11	10	9	8	7	6	5	4	3	2	1	0
Alarm is active when its bit is set to 1												

Table 11. Temperature alarm status bits

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: each fan has a separate enable register. Alarm conditions can trigger an alarm warning if the enable bit is set, in addition it can activate the relay or shutdown the bridge if the relay or shutdown enable bits are also set together with the enable bit.												

Table 12. Bit arrangement for alarm enable, relay and shutdown bits for fan

Type	Fan 3				Fan 2				Fan 1			
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
Alarm is active when its bit is set to 1												

Table 13. Fan alarm status bits

7. Appendix 2 RS485 Option for single and multiple Junior communication

7.1. RS485 Option

An optional isolated RS485 expansion board is available to allow the Junior to use the 3-wire differential interface that provides improved noise immunity and ability to communication over longer distances. The RS485 board can be fitted by plugging the board into the expansion port labelled EXP 1 and using the spacer and screws to fix it in place. The RS485 cable can then be connected to the GND, A and B wires of the module.

RS485 provides the multidrop capability where two or more devices can be connected to the same RS485 interface to allow multiple devices to be controlled by one host. The Junior can be configured in either single board or multi-board modes as detailed in the following sections.

7.2. RS485 Single Board Operation

This is the simplest mode and is generally used when the RS485 option is used to allow for longer communication cable length or in noisy environments that would be problematic with RS232.

To configure this mode (default) the RS485 address register `105` must be set to the value 0. This disables the multidrop facility and the device will respond to the standard commands specified in Appendix 1 JUNIOR Communication Interface.

To use this mode fit the expansion board as described in 7.1. As the serial commands are unaltered in this mode the HMI can be used as normal, just set the serial port to the port being used to provide the RS485 connection.

7.3. RS485 Multi Board Operation

In this mode two or more boards may be connected and controlled from a single RS485 bus. To do this each board must be preconfigured with an address. This can be done using the USB interface or RS485 option if it is the only board connected to the RS485 interface.

The address is set using the address register `105`. If the address is set to 0, RS485 single board mode is selected and the normal serial protocol is used, however setting an address in the range 1 to 99 will enable RS485 multidrop mode allowing multiple Juniors to be addressed individually. Note after the address register is changed the board must be power cycled to enable the new mode and address to take effect.

When the board is in multidrop/board mode the serial commands have to be prefixed with an address. When one of these messages is sent all the connected boards will receive it, but only the board which matches the address in the command will action and reply to the command. If no boards match the address sent, then there will be no reply to the message.

The address is sent by prefixing the standard commands with ***!NN*** where NN is a two digit address, so for example if you wanted to send the ID command to device 5 you would send the command ***!05$ID*** instead of the usual command $ID. The JUNIOR will also prefix the reply with its address so for the same command ***!05$ID*** board number 5 would reply ***!05 ID=JuniorV2 Temperature Controller V2.00 ETDYN (c) Apr 3 2024*** Note that there is a space between the address prefix and the reply.

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.

European Thermodynamics Ltd.
8 Priory Business Park,
Wistow Road, Kibworth,
Leicestershire, LE8 0RX
UK
Tel: +44 (0) 116 279 6899
Email: info@etdyn.com
www.europeanthermodynamics.com