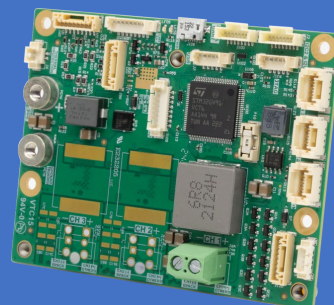
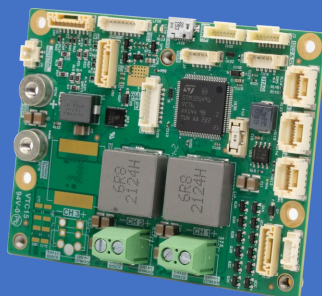
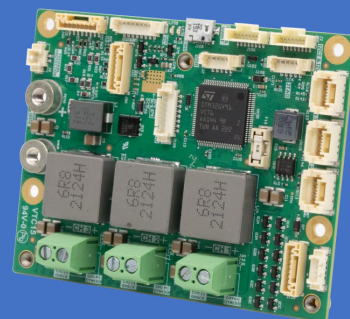
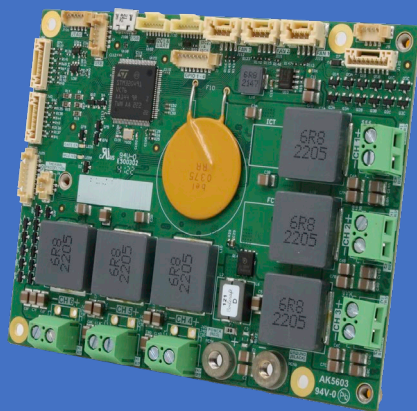


VTC SOFTWARE MANUAL



INTRODUCTION

The VTC series is a thermoelectric temperature controller with DC bipolar outputs. The VTC series features our patent pending technology that delivers temperature stability to within $\pm 0.002^{\circ}\text{C}^1$ with high-power efficiency of 95%². The VTC series has an input voltage range of 12 – 36V, and it delivers up to 16A @ 36V to control each Peltier module.

The VTC series supports both analogue and digital inputs for temperature sensing. There are 8 analogue inputs for NTC, PT100, PT1000, TMP61/63/64 temperature probes, and 16 digital sensors (e.g., TMP117, TMP116, TMP1075, MAX30208) for inputs on the I2C bus. There are 4 configurable GPIOs that can use as inputs or outputs for customer applications.

The VTC can operate in stand-alone mode or be remotely controlled with USB, using APIs or the supplied VTC Utility Software. Configuration of the controller is done using the VTC Utility Software. The auto-tuning feature of VTC enables user to easily determine the appropriate PID control parameters for their application. Users familiar with PID loops, can fine-tune the PID control parameters with the manual tuning feature. VTC series also supports thermal profile control, making this controller ideal for applications that requires thermal cycling (e.g., PCR machines).

The VTC has built-in multiple levels of thermal protection. To protect the device, hot and cold limits can be set independently via the VTC Utility Software. This safety feature ensures that your TEC will not be driven beyond the specified limits. Additionally, VTC series continuously monitors the temperature sensors and when a fault is detected, the controller will alert user, and automatically turn off the power to your TEC. Lastly, for system protection thermal fuse are supported.

Besides being a highly precise highly efficient TEC controller, the VTC series is also highly flexible. With many parameters configurable using the supplied VTC Utility Software

This makes the VTC series an ideal thermoelectric controller to be very desirable against other competitors, due to its flexibility in addition to the efficiency/performance aspect whilst operating it.

Other models in the VTC series offer configuration in various number of channels.

¹ $\pm 0.002^{\circ}\text{C}$ 1 hour duration @ 25°C ambient temperature

² 95% efficacy @ 50% load

TABLE OF CONTENTS

Introduction	2
Table of Contents	3
List Of Figures	5
List Of Tables	6
1. Overview	7
2. VTC Utility	8
2.1. GUI Layout	8
2.2. Tab: Operation	10
2.2.1. Panel: Channel Status	11
2.2.2. Panel: Temperature Profile	12
2.2.3. Panel: AutoPush Data Logging	17
2.3. Tab: Configuration	24
2.4.1. Tab: System Configuration	24
2.4.2. Tab: Analog Temperature Sensor	28
2.4.3. Tab: Digital Temperature Sensor	31
2.4.4. Tab: Fan	33
2.4.5. Tab: TEC	35
2.4.6. Tab: Auto Tuning	38
2.5. Tab: Advanced	39
2.5.1. Panel: Licensed function	39
2.5.2. Panel: ADC Gain Calibration	41
2.5.3. Panel: Firmware Update	41
2.5.4. Panel: Board Information	42
3. Configuration and Operation	44
3.1. Configuration	44
3.1.1. Connecting to the VTC Utility	44
3.1.2. System Configuration	46
3.1.3. Temperature Sensor Setup	47
3.1.4. Fan Setup	50
3.1.5. TEC Setup	51

3.1.6.	Pre-Check and Tuning	52
3.2.	Operation	54
3.2.1.	Constant Voltage Control	55
3.2.2.	Constant Current Control	56
3.2.3.	Constant Temperature Control	56
3.2.4.	Temperature Profile	57
3.2.5.	Follow temperature	58
4.	Appendix	59
4.1.	Troubleshooting	59
4.1.1.	Check for Firmware Version	59
4.1.2.	Hardware Status	60
5.	Revision History	64
6.	Legal Notices	65

LIST OF FIGURES

Figure 2.1: The Channel Info panel	8
Figure 2.2: The Status Panel.....	9
Figure 2.3: The Operation tab	10
Figure 2.4: Channel Status panel	11
Figure 2.5: The Operation Mode panel.....	12
Figure 2.6: Temperature Profile panel.....	12
Figure 2.7: Temperature Profile.....	13
Figure 2.8: Steps to Create/Edit Temperature Profile	15
Figure 2.9: Temperature Profile Pop-up	16
Figure 2.10: Autopush selection	17
Figure 2.11: Sample Data	18
Figure 2.12: The Waveform tab	20
Figure 2.13: Options 7-12	20
Figure 2.14: Data Analysis.....	23
Figure 2.15: System Configuration GUI.....	24
Figure 2.16: Analog Sensor Setup GUI	28
Figure 2.17: Analog Sensor Database	30
Figure 2.18: Digital Sensor setup GUI	31
Figure 2.19: Digital Temperature Sensor Database	32
Figure 2.20: Fan Setup GUI	33
Figure 2.21: TEC setup GUI	35
Figure 2.22: Auto Tuning GUI.....	38
Figure 2.23: Advanced Tab GUI.....	39
Figure 2.24: Licensed function panel	39
Figure 2.25: ADC Gain Calibration panel.....	41
Figure 2.26: Firmware Update panel	41
Figure 2.27: Board Information panel.....	42
Figure 3.1: VTC Utility connects to VTC Series.....	44
Figure 3.2: Connection Indicator	45
Figure 3.3: System configuration	46
Figure 3.4: Setup analog temperature sensor	48
Figure 3.5: Setup digital temperature sensor	49
Figure 3.6: Setup Fan	50
Figure 3.7: Setup TEC	51
Figure 3.8: Pre-Check	52
Figure 3.9: Auto-tune	53
Figure 3.10: Executing Constant Voltage control	55
Figure 3.11: Executing Constant Current control	56
Figure 3.12: Executing Constant Temperature Control	56

Figure 3.13: Temperature Profile Setting	57
Figure 3.14: Executing a temperature profile	57
Figure 4.1: Firmware Update	59
Figure 4.2: Hardware Status button	60
Figure 4.3: Hardware Status dialog.....	60

LIST OF TABLES

Table 2.1: Description of the Status panel	9
Table 2.2: Description of the Channel Status panel.....	11
Table 2.3: Description of the Temperature Profile panel settings.....	13
Table 2.4: Section 1 of the Temperature Profile dialog.....	14
Table 2.5: Section 2 of the Temperature Profile dialog.....	14
Table 2.6: Section 3 of the Temperature Profile dialog.....	15
Table 2.7: Autopush data selection	18
Table 2.8: Autopush format	19
Table 2.9: Dropdown menu for options 7-12	22
Table 2.10: System Configuration Layout Description.....	25
Table 2.11: Input/output Options	26
Table 2.12: GPIO Functions Description	26
Table 2.13: Configured GPIO Example	27
Table 2.14: Analog Temperature Sensor Subtab Description.....	28
Table 2.15: Selection of Gain for Temperature Sensors	29
Table 2.16: Options for Gain Selection	29
Table 2.17: Analog Database Layout Description	30
Table 2.18: Digital Temperature Sensor Description.....	31
Table 2.19: Digital Temperature Sensor Database Description.....	33
Table 2.20: Fan Subtab Description	34
Table 2.21: TEC Subtab Description	37
Table 2.22: Clarification of terms For Autotune Subtab	38
Table 2.23: Description of the Board Information panel	43
Table 3.1: Auto-tuning options	53
Table 4.1: Fault Status Register 1.....	62
Table 4.2: Fault Status Register 1 fields	62
Table 4.3: Fault Status Register 2.....	63
Table 4.4: Fault Status Register 2 fields	63

1. OVERVIEW

This manual explains the functionality of the VTC Utility software. When setting up the VTC series using the VTC Utility Software for the first time, it is recommended that you read and understand this user manual.

The VTC Utility Software allows the users to configure and control the VTC series according to the user defined system and their requirements. The following sections will show the basic components which the user would need to connect to the VTC board for heating/cooling functions.

The VTC Utility software and related firmware can be downloaded from the website, in the following link: <https://v-bmb.com/precision-thermal-control>

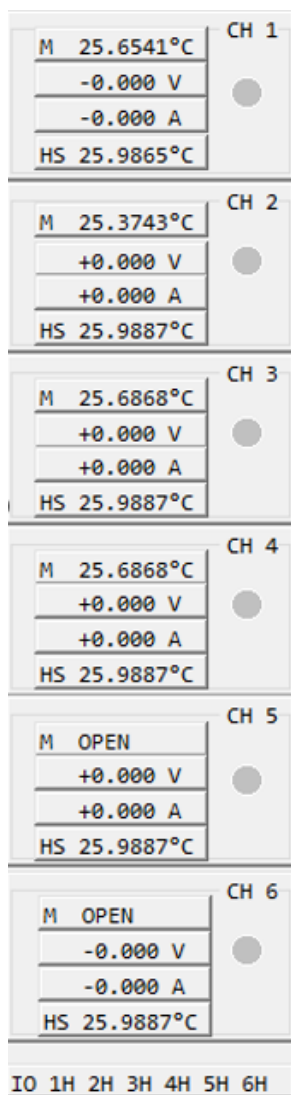
The VTC series is connected via USB, allowing users to command and control it using the VTC Utility or Venture's middleware APIs (Application Programming Interface).

2. VTC UTILITY

2.1. GUI LAYOUT

The VTC Utility software has a clean and simple interface. Utility functions are categorized and organized by tab for clarity. The contents change accordingly as user navigates from tab to tab. Where applicable, sub tabs are created for sub categories of functions.

Certain status and information are grouped together and displayed on the right and bottom section of the utility. These are always available regardless of which tab the users select.



- The **Channel Info** panel a.k.a. the “**right**” panel displays the status of each of the 6 output channels of the controller.

- Depending on the model of the controller, the appropriate channel and its status will be presented.

- As seen in

- Figure 2.1 on the left, each channel has the following display structure

M	Refers to the temperature reported by the Main sensor
	Voltage across the channel
	Current flowing through the channel
HS	Refers to the heatsink temperature

- Each channel also has an LED to indicate the state of the channel.

LED	Description
	No conditions are applied to channel
	Conditions have been applied but not met
	All applied conditions have been met and are within system tolerances
	Channel has an error

- The status of the VTC GPIO pins is shown at the very bottom. An H indicates “High Impedance” implying that the GPIO pins are not connected. Refer to Table 2.12 for detailed info about GPIO configurations.

Figure 2.1: The Channel Info panel

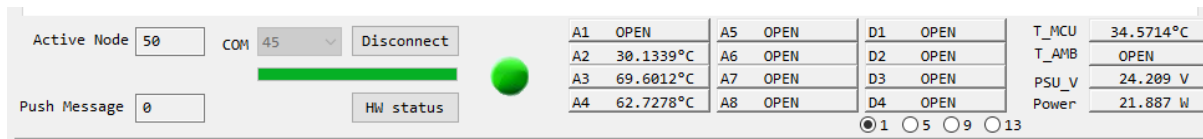


Figure 2.2: The Status Panel

The **Status** panel a.k.a. the “**bottom**” panel (Figure 2.2) displays the various readings taken from the VTC board. Table 2.1 provides details about the parameters displayed in the Status panel.

Keyword	Description/important aspects of keyword
Active Node	The current unique number which is assigned to the connected TEC controller.
Push Message	The count of the latest Autopush message. Refer to 2.2.3: Panel: AutoPush Data Logging for more info
COM	The COM port dropdown which lists the COM ports of all VTC boards connected to the user’s PC via USB
Connect/Disconnect	Button to connect/disconnect to the selected COM port
Connection indicator	The Connection indicator has two colours ● No power ● Normal working conditions
HW status	Button to check the status of connected hardware. Refer to 4.1.2: Hardware Status for more info
A1 - A8	The assigned analog temperature sensors and the temperature detected
D1 - D16	The assigned digital temperature sensors and the temperature detected. Only 4 sensors are displayed at a time. Users can use the radio buttons below the sensors to view the next set of sensor readings
T_MCU	The temperature of the microcontroller unit
T_AMB	The reading of the ambient temperature sensor
PSU_V	The amount of voltage which the power supply is giving
Power	The amount of electric power from the supply.

Table 2.1: Description of the Status panel

2.2. TAB: OPERATION

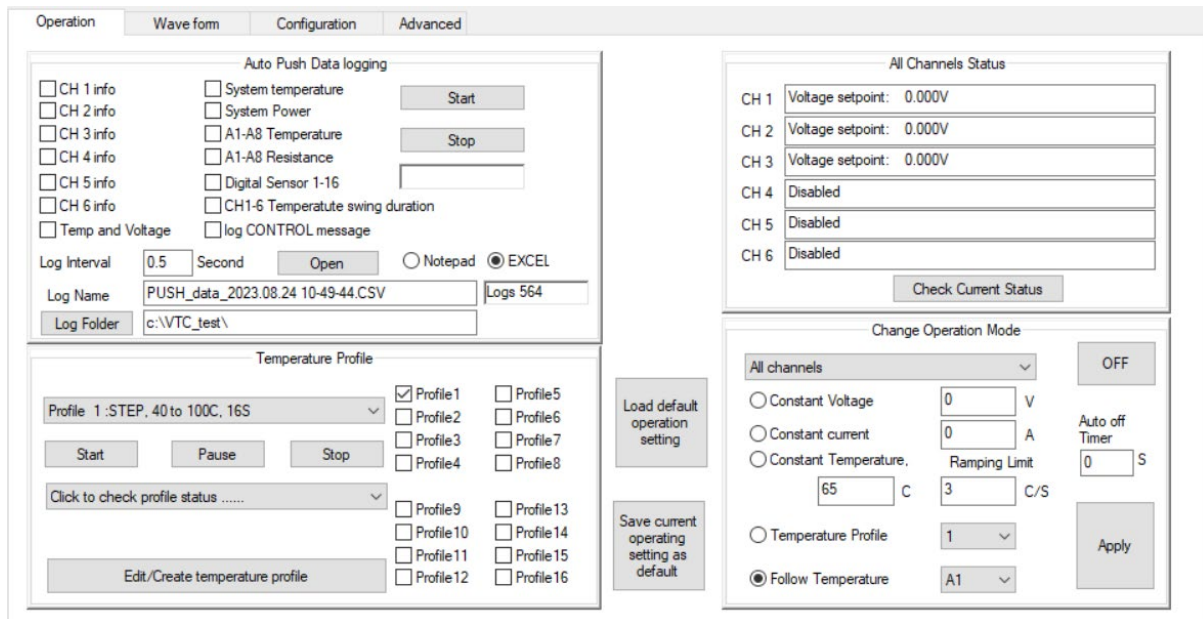


Figure 2.3: The Operation tab

Figure 2.3 shows the overall layout when the operation tab is selected. The layout is divided into 4 sub-panels.

- **Channel Status:** Sub-panel on the **top-right**. It shows the individual channels and the conditions put in place for that particular channel. If “**Heatsink temperature over shutdown level**” is shown, refer to section [4.1.2: Hardware Status](#).
- **Operation Mode:** Sub-panel on the **bottom right**. It shows the layout to select the desired channel and TEC operation mode.
- **Temperature Profile:** Sub-panel on the **bottom left**. It shows the option to choose the temperature profile stored and allows the user to start, pause and stop the temperature profile once selected.
- **Autopush Data logging:** Sub-panel on the **top left**. It allows the user to record sensor readings, system info and various TEC channel statuses and save them to a file. Refer to [2.2.3: Panel: AutoPush Data Logging](#) for more info

Refer to subsection 2.2: Tab: Operation for details on how to use the various sub-panels

2.2.1. Panel: Channel Status

Figure 2.4 shows the channel status panel. Table 2.2 Provides a description of the various possible status messages displayed in this panel.

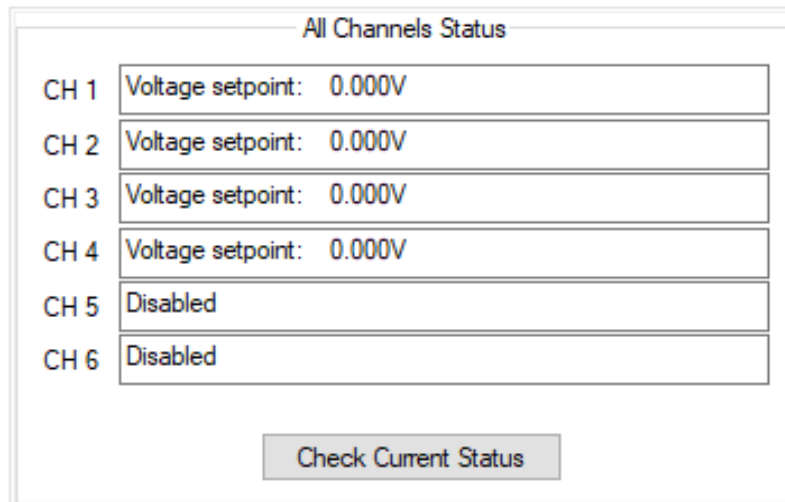


Figure 2.4: Channel Status panel

Status Message	Description
Voltage setpoint	Displays the active voltage setpoint (in V) for the channel when operating in Constant Voltage mode. Refer to 3.2.1: Constant Voltage Control for details on operating the VTC in Constant Voltage mode
Current setpoint	Displays the active current setpoint (in A) for the channel when operating in Constant Current mode. Refer to 3.2.2: Constant Current Control for details on operating the VTC in Constant Current mode
Temperature setpoint	Displays the active temperature setpoint (in °C) and the ramping rate (in °C/s) for the channel when operating in Constant Temperature mode. Refer to 3.2.3: Constant Temperature Control for details on operating the VTC in Constant Temperature mode
Temperature profile	Displays the number of currently active temperature profile for the channel when executing a temperature profile. Refer to 3.2.4: Temperature Profile for details on executing temperature profiles
TEC temperature over shutdown level	Displayed when the TEC temperature is beyond the shutdown limits for the channel
Heatsink temperature over shutdown level	Displayed when the Heatsink temperature is beyond the shutdown limits for the channel
Disabled	Displayed when the channel is disabled

Table 2.2: Description of the Channel Status panel

Figure 2.5 shows the Operation Mode panel.

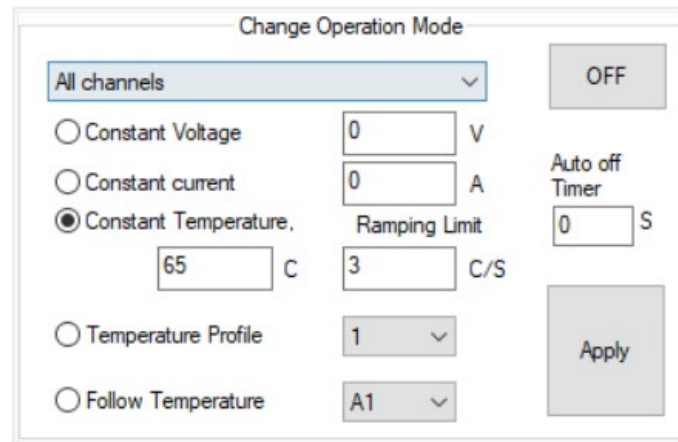


Figure 2.5: The Operation Mode panel

As its name suggests, this panel contains settings to operate each of the 6 TEC channels in one of the 4 available operation modes. Refer to section [3.2: Operation](#) for details on how to operate the settings in the “**Operation Mode**” panel.

2.2.2. Panel: Temperature Profile

A. Overview

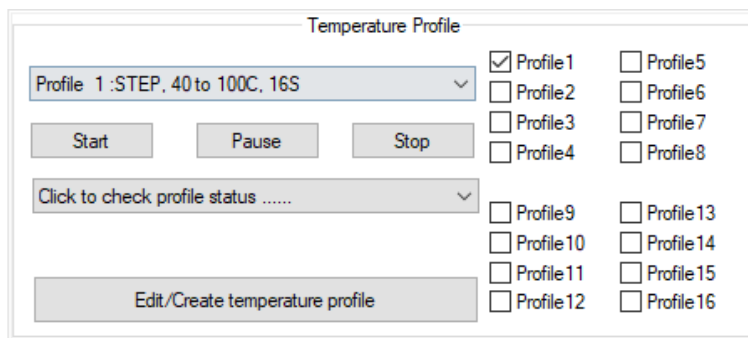


Figure 2.6: Temperature Profile panel

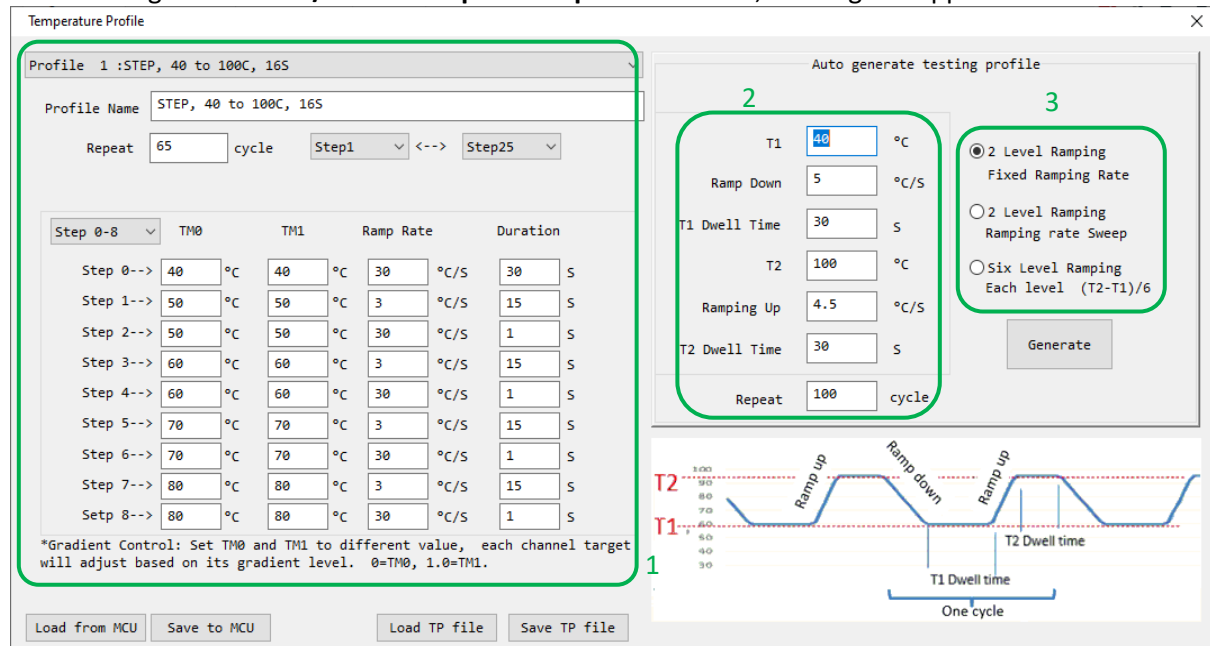
Figure 2.6 shows the layout of the Temperature profile panel. Table 2.3 provides details about the various settings found in this panel.

Status Message	Description
Profile dropdown	Allows users to select one of the 16 temperature profiles stored in the VTC Users can select multiple temperature profiles by using the checkboxes on the right instead of using the dropdown
Start button	Starts the selected temperature profile(s)

Pause button	Pauses the selected temperature profile(s) and maintains the current active setpoint
Stop button	Stops executing the selected temperature profile(s)
Edit/Create temperature profile button	Allows users to create/edit a temperature profile.

Table 2.3: Description of the Temperature Profile panel settings

After clicking on the “Edit/Create temperature profile” button, a dialog will appear as shown in



Temperature Profile

Profile 1 :STEP, 40 to 100C, 16S

Profile Name: STEP, 40 to 100C, 16S

Repeat: 65 cycle Step1 <--> Step25

Step 0-8	TM0	TM1	Ramp Rate	Duration
Step 0-->	40 °C	40 °C	30 °C/S	30 S
Step 1-->	50 °C	50 °C	3 °C/S	15 S
Step 2-->	50 °C	50 °C	30 °C/S	1 S
Step 3-->	60 °C	60 °C	3 °C/S	15 S
Step 4-->	60 °C	60 °C	30 °C/S	1 S
Step 5-->	70 °C	70 °C	3 °C/S	15 S
Step 6-->	70 °C	70 °C	30 °C/S	1 S
Step 7-->	80 °C	80 °C	3 °C/S	15 S
Step 8-->	80 °C	80 °C	30 °C/S	1 S

*Gradient Control: Set TM0 and TM1 to different value, each channel target will adjust based on its gradient level. 0=TM0, 1=TM1.

Auto generate testing profile

T1: 40 °C

Ramp Down: 5 °C/S

T1 Dwell Time: 30 S

T2: 100 °C

Ramping Up: 4.5 °C/S

T2 Dwell Time: 30 S

Repeat: 100 cycle

Generate

2 Level Ramping Fixed Ramping Rate

2 Level Ramping Ramping rate Sweep

Six Level Ramping Each level (T2-T1)/6

Graph showing temperature profile over time, with labels for T1, T2, Ramp up, Ramp down, and Dwell time.

Figure 2.7.

Figure 2.7: Temperature Profile

In the dialog, (1) is mainly used for editing an existing profile. Users can also create a profile from scratch³. Information on the various parameters can be found in Table 2.4

The main function of (2) is to control the parameters before auto-generating a temperature profile. Information on the important keywords can be found in the Table 2.5

(3) is like (2) as it is mainly used for auto-generating a temperature profile. Information on the type of ramping for the temperature profile could be found in Table 2.6.

³ Recommended to use the right segment for temperature profile generation

Keyword	Description
Profile name	The name of the temperature profile, which can be edited
Repeat	The number of times the steps chosen will be repeated ⁴
Heater cover temperature	The temperature of the heater cover, which is measured by user
TM0	First reference temperature for the particular step, to be used for gradient control
TM1	Second reference temperature for the particular step, to be used for gradient control
TM0 and TM1 are used for temperature gradient, with the main intention of efficient, specific amplification of all targets/channels. This means that less runs will be needed to find out which is the optimum temperature, especially for the assays used in PCR. ⁵	
Ramp rate	The ramp rate limits how fast a system will be able to change from one temp to another. ⁶
Duration	Refers to how much time would be used for the particular step

Table 2.4: Section 1 of the Temperature Profile dialog

Keyword	Description
Ramp Up/Down	The ramp rate limits how fast a system will be able to change from one temp to another ⁷ .
Up/Down Duration	Refers to how much time would be used for that particular step
T1	Lowest desired temperature range
T2	Highest desired temperature range
Dwell	The amount of time it stays when T1/T2 is achieved.
Repeat	The number of times the profile will restart the process

Table 2.5: Section 2 of the Temperature Profile dialog

⁴ Different from “Repeat” in the right segment. In the right segment, it is mainly used for generating a profile while on the left, it is mainly for editing an existing profile.

⁵ Should TM0 and TM1 be different, every channel will be adjusted based on the gradient position of the channel. This was configured during the TEC setup

E.g.: Channel 0 => TM0 = 30, TM1 = 40, gradient position= 0.2

=> Target temperature for channel 0 = $30 + 0.2(40-30) = 32$

⁶ If the system is not able to attain the temperature in that step, it will just skip and carry on with the next step when the duration is up.

⁷ If the system is not able to attain the temperature in that step, it will just skip and carry on with the next step when the duration is up.

Keyword	Description
Ramping fixed rate	The ramp rate will stay consistent
Ramping sweep rate	The ramp rate will experience an increment of 1°C/s for every two steps, with a max of 12°C/s
Ramping each level (T2-T1)/6	The temperature range is from T1°C to T2°C For each segment, there will be continual increments in the temperature by $((T2-T1)/6)$ °C till it reaches T2°C. It stays at each segment, for a short period of time. After reaching T2°C, the system will then start to decrease its temperature by decrements of $((T2-T1)/6)$ °C for every segment till it reaches T1. Thereafter, the cycle repeats based on the number of times the user defined⁸.

Table 2.6: Section 3 of the Temperature Profile dialog

B. Edit/Creating a temperature profile

There are 4 pre-set temperature profiles which users can choose from, while being able to store up to 16 unique temperature profiles. Each profile is able to change its name, the steps to repeat and the number of repetitions. Users can choose to edit the settings in these profiles or create entirely new profiles to overwrite them.

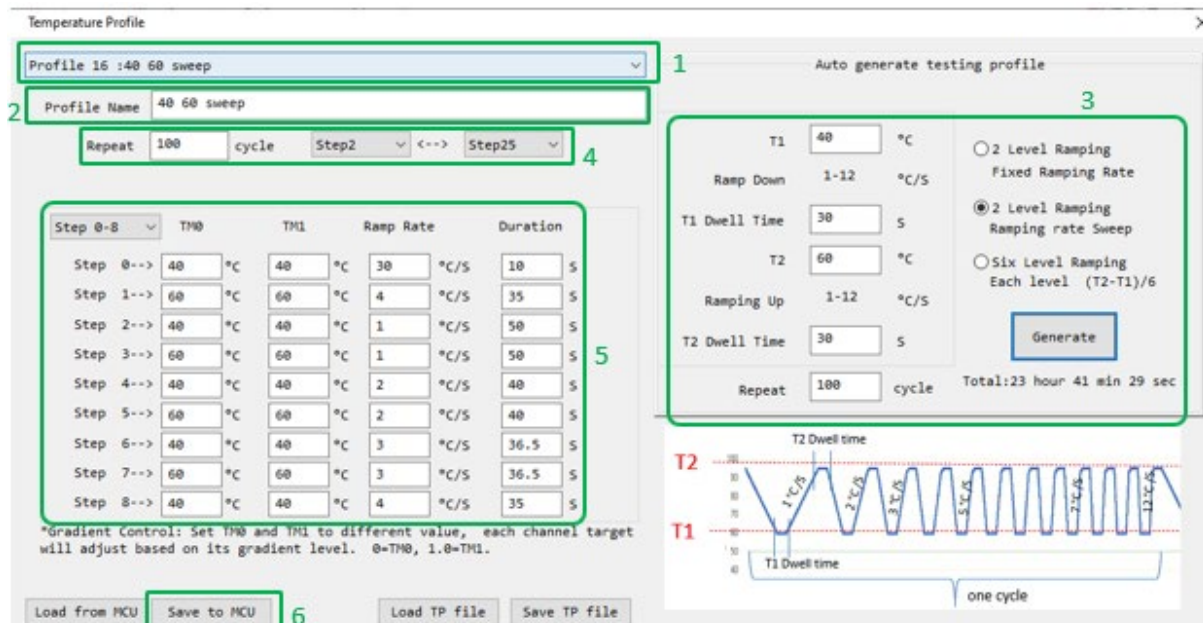


Figure 2.8: Steps to Create/Edit Temperature Profile

⁸ Only the ramp up/down, up/down duration and number of repeats can be modified

Figure 2.8 shows the steps used to create/edit a profile:

- (1) To make a **new** profile, go to the profile which you want to edit (be it existing or user defined profile)
- (2) Name the profile
- (3) Choose the user specified profile mode and parameters (T1 & T2). After which, click on **generate**⁹. This would result in a pop-up appearing as shown in Figure 2.9.
- (4) If the user has steps which need to be repeated, insert the number of times to be repeated.
- (5) The information would have been generated. However, the user is able to change the duration and ramp rate as you like¹⁰.
- (6) After you have done making input into the profile, save the settings by clicking on **“Save to MCU”** and you have successfully made a temperature profile. After saving, you would be able to save the project file as shown in [2.5: Tab: Advanced](#)

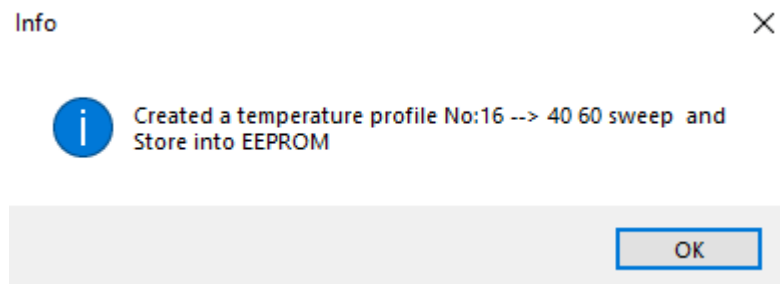


Figure 2.9: Temperature Profile Pop-up

⁹ For “six level ramping each level” mode, only the up/down duration can be changed

¹⁰ The user defined ramp rate needs to be able to be supported by your system (Peltier element)

2.2.3. Panel: AutoPush Data Logging

The VTC Utility has the capability to Autopush data i.e. automatically record all TEC data in the background and save it to either a .csv or .txt file. It allows the users to retrieve critical information of the system such as the temperature of the specific channels, as well as the ADC, etc. As seen in

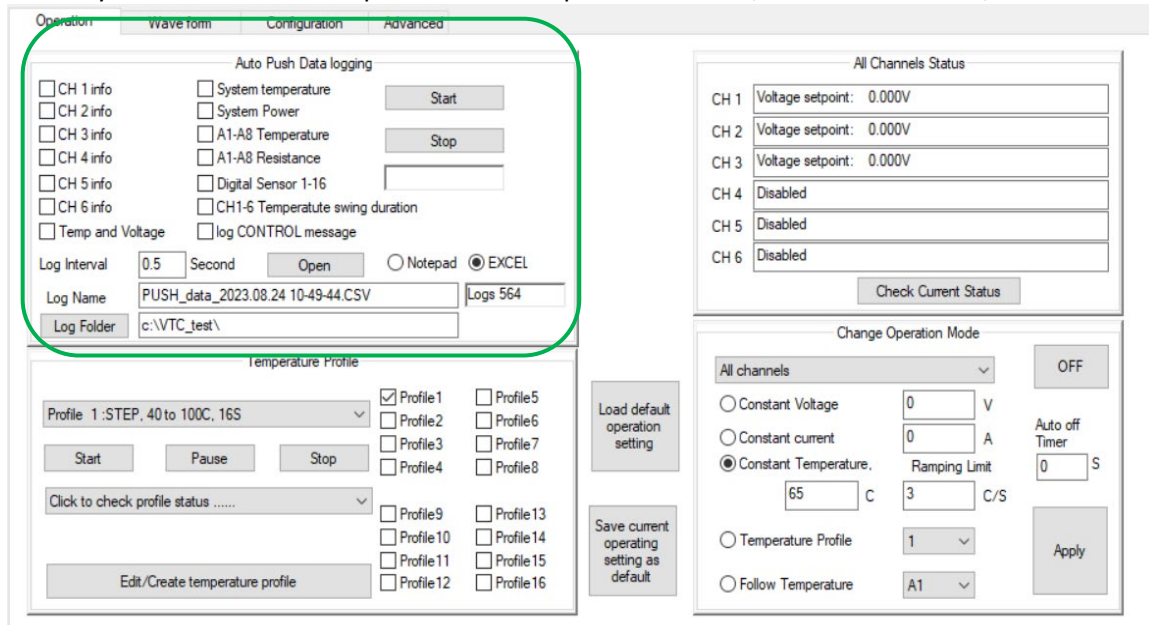


Figure 2.10 users can choose to enable/disable system parameters from being recorded in the Autopush data. Each system parameter corresponds to a bit from a 16-bit register in firmware which is set to 1 or 0 depending on whether that parameter was enabled or disabled respectively. The value of this register is displayed in the panel under “**Log Control**” as an integer.

Table 2.7 describes the various system parameters that can be monitored via Autopush.

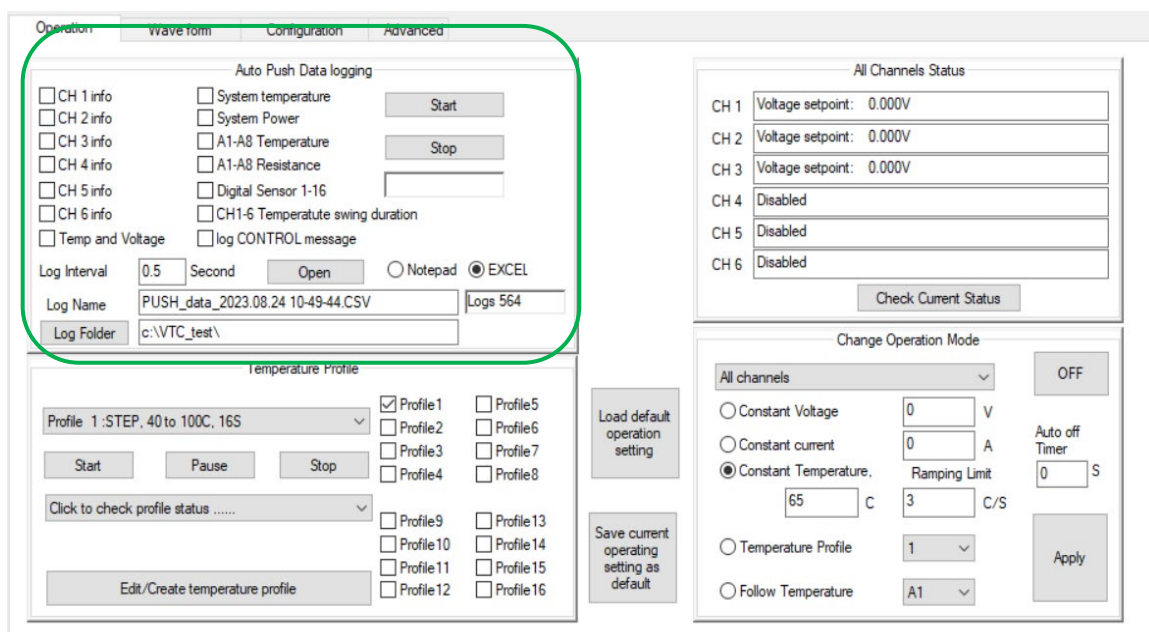


Figure 2.10: Autopush selection

Auto Push Selection	Description
Channel 1-6 info	Retrieves temperature of heatsink, object sensor, voltage and current applied to the channel
System temperature	Retrieves the temperature of the MCU and ADC
System power	Retrieves the amount of electrical power from the supply
A1 - A8, D1 - D16 temperature	Retrieves the temperature of the various RTD/digital sensors attached to the system/channel
A1 - A8 resistance	Retrieves the resistance values of the sensors, as the resistance will change as the temperature rises.
Temperature swing duration	The duration of time where the channel is at a temperature which is above/below the set temperature and tries to revert back to the set temperature

Table 2.7: Autopush data selection

The relevant steps below will highlight the method to retrieve data using the auto push data logging.

- 1) Select the **“Operation”** tab.
- 2) Select the **“Channels”** you want to monitor and other system data you want to record.
- 3) Select your **“Log Interval”**.
- 4) Type in the name of your log file in the **“Log name”** input box
- 5) Select **“Log Folder”** path
- 6) Click **Start** to start collecting your data.
- 7) Click **Stop** when you are done collecting your data.
- 8) Select **“Open”** to open the log file with the recorded data. An example of Ch 1 data over a short sample time is shown in Figure 2.11.

x32	1	Time(S)	Set_P_1	T_obj_1	BD_SP_1	Body_1	S_obj_1	S_lid_1	Nex_V_1	TEC_V_1	TEC_Ts_1	HS_T_1	REF_T_1	TEC_I_1	PSU_I_1	Amb_T
x32	1	26902.8	23.853	24.025	0	23.853	800	25.5	0	0	23.853	25.4989	23.853	0	0.002	800
x32	1	26902.9	23.853	24.025	0	23.854	800	25.5	0	0	23.8532	25.4993	23.853	0	0.002	800
x32	1	26903	23.854	24.025	0	23.857	800	25.501	0	0	23.8539	25.4997	23.853	0	0.002	800
x32	1	26903.1	23.854	24.025	0	23.857	800	25.501	0	0	23.8544	25.5001	23.853	0	0.002	800
x32	1	26903.2	23.855	24.025	0	23.858	800	25.501	0	0	23.855	25.5005	23.853	0	0.001	800
x32	1	26903.3	23.856	24.025	0	23.86	800	25.502	0	0	23.8558	25.5008	23.852	0	0.001	800
x32	1	26903.4	23.857	24.026	0	23.86	800	25.502	0	0	23.8566	25.5012	23.852	0	0.002	800
x32	1	26903.5	23.857	24.026	0	23.861	800	25.502	0	0	23.8574	25.5015	23.853	0	0.002	800
x32	1	26903.6	23.858	24.026	0	23.859	800	25.502	0	0	23.8577	25.5018	23.853	0	0.002	800
x32	1	26903.7	23.858	24.026	0	23.861	800	25.503	0	0	23.8582	25.5021	23.853	0	0.002	800
x32	1	26903.8	23.859	24.026	0	23.86	800	25.503	0	0	23.8585	25.5024	23.854	0	0.002	800
x32	1	26903.9	23.858	24.026	0	23.856	800	25.503	0	0	23.858	25.5027	23.854	0	0.002	800
x32	1	26904	23.858	24.027	0	23.858	800	25.503	0	0	23.858	25.5029	23.855	0	0.002	800
x32	1	26904.1	23.858	24.027	0	23.858	800	25.504	0	0	23.858	25.5031	23.856	0	0.002	800
x32	1	26904.2	23.858	24.027	0	23.858	800	25.504	0	0	23.858	25.5033	23.857	0	0.002	800
x32	1	26904.3	23.858	24.027	0	23.856	800	25.504	0	0	23.8577	25.5035	23.857	0	0.002	800
x32	1	26904.4	23.857	24.027	0	23.854	800	25.504	0	0	23.8571	25.5036	23.858	0	0.003	800

Figure 2.11: Sample Data

Param (n = 1 to 6)	Description
Time	Time stamp (in seconds) indicating the total running time from the last reset. After 7 days, the counter will roll-over to 0
Set_P_n	Actual control path.
T_obj_n	Temperature of the sample object being heated/cooled by the TEC. Calculated based on object model
BD_SP_n	TEC temperature setpoint ¹¹ .
Body_n	TEC temperature without sensor delay.
S_obj_n	Sample object temperature sensor (if it was set). This value is for reference only and is not used in any control algorithm.
S_lid_n	Lid sensor temperature
Nex_V_n	Required voltage in the next PID sampling period
TEC_V_n	Actual voltage in the current PID sampling period
TEC_Ts_n	Reading from the sensor configured as the “Main Sensor” for that TEC channel. Refer to 2.4.5: Tab: TEC for more info on how to configure TEC sensors
HS_T_n	Heatsink sensor
REF_T_n	Original setpoint
TEC_I_n	Current (in A) passing through the TEC at the moment.
PSU_I_n	Current (in A) supplied by the PSU to the specified channel ¹²
Amb_T	Ambient temperature sensor reading

Table 2.8: Autopush format

¹¹ When the Control target is selected as “Object Model”, TEC temperature is different from the target object temperature.

¹² $PSU_I * PSU_V = TEC_I * TEC_V$

Tab: Waveform

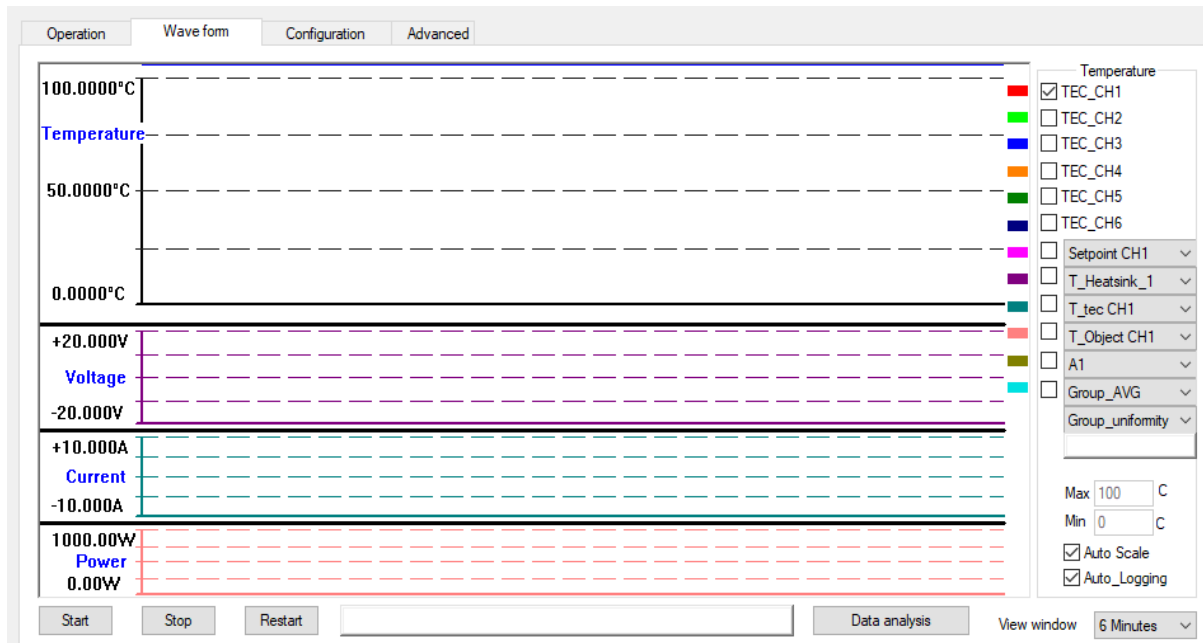


Figure 2.12: The Waveform tab

The “Waveform” tab allows users to do the following:

- Check the temperatures of different channels
- Monitor the variation between actual temperature and setpoint
- Check the stability of the device (when “Data Analysis” is clicked)
- (7-12) in Figure 2.13 have a dropdown menu which allows users to view the setpoint for each of the TEC channels, group average temperature etc. The dropdown options are shown in Table 2.9

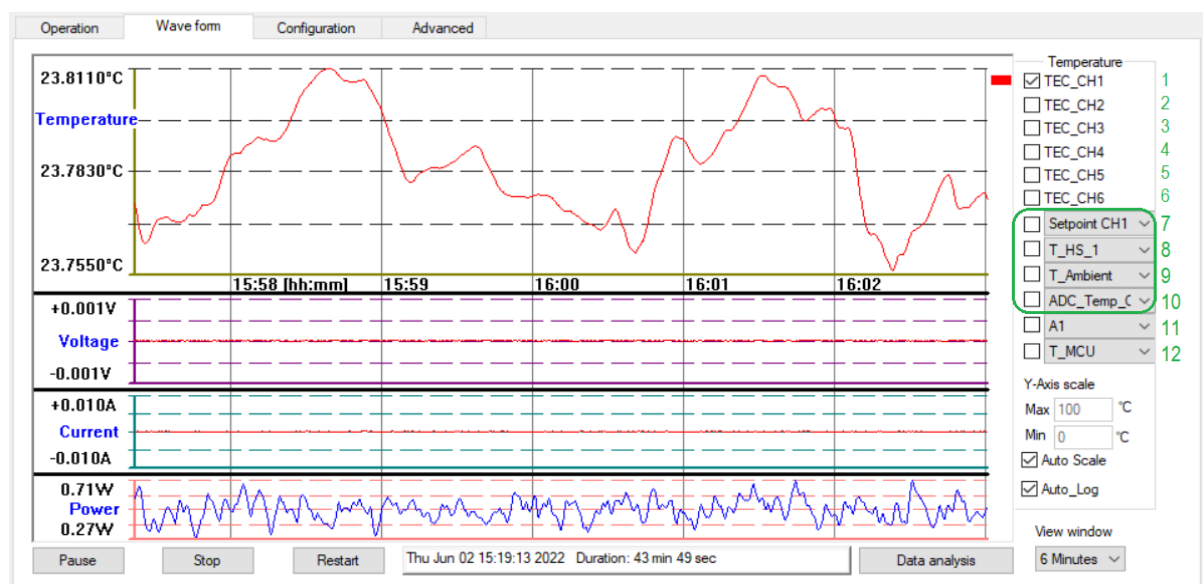


Figure 2.13: Options 7-12

Users can select from a total of 36 different options in the dropdown

Name	Image	Description
Group Settings	Group_Setpoint Group_AVG Group_offset Group_uniformity	Group settings are valid when channels are grouped together using Group control. Refer to 2.4.1: Tab: System Configuration
Channel Setpoints	Setpoint CH1 Setpoint CH2 Setpoint CH3 Setpoint CH4 Setpoint CH5 Setpoint CH6	The ideal ramping path based on user defined ramping rate. It is essentially a straight line to the target temperature
Heatsink temperature	T_Heatsink_1 T_Heatsink_2 T_Heatsink_3 T_Heatsink_4 T_Heatsink_5 T_Heatsink_6	The heatsink temperature for each channel
Object temperature	T_Object CH1 T_Object CH2 T_Object CH3 T_Object CH4 T_Object CH5 T_Object CH6	The TEC channel temperature when the control target is selected by the object model instead of the main sensor. Refer to 2.4.5: Tab: TEC for more details on Control Target
Swing duration	Tswing 1(S) Tswing 2(S) Tswing 3(S) Tswing 4(S) Tswing 5(S) Tswing 6(S)	The peak-to-peak duration for each channel used during manual PID tuning.
TEC temperature	T_tec CH1 T_tec CH2 T_tec CH3 T_tec CH4 T_tec CH5 T_tec CH6	The TEC temperature for each channel
Control Point temperature	Tpoint CH1 Tpoint CH2 Tpoint CH3 Tpoint CH4 Tpoint CH5 Tpoint CH6	The actual control point temperature. It may differ from the ideal ramping path depending on the type of ramp and approach speed selected by the user.
Ramp value	Ramp CH1 Ramp CH2 Ramp CH3 Ramp CH4 Ramp CH5 Ramp CH6	Real-time ramp value for each channel
TEC surface temperature	TEC_SP1 TEC_SP2 TEC_SP3 TEC_SP4 TEC_SP5 TEC_SP6	The TEC surface temperature control point when the main sensor delay time compensation is non-zero. The main TEC setpoint shall be different from the ideal TEC setpoint in this case. Refer to 2.4.6: Tab: Auto Tuning for more details about Sensor Delay Compensation

Analog Sensor Values	A1 A2 A3 A4 A5 A6 A7 A8	The readings on the Analog sensors
Digital Sensor Values	D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16	The readings on the Digital sensors
Temperature Profiles	Tprofile_1 Tprofile_2 Tprofile_3 Tprofile_4 Tprofile_5 Tprofile_6 Tprofile_7 Tprofile_8 Tprofile_9 Tprofile_10 Tprofile_11 Tprofile_12 Tprofile_13 Tprofile_14 Tprofile_15 Tprofile_16	Target setpoint of the currently active temperature profile
T_ambient		The ambient sensor reading
T_MCU		The MCU die temperature
T_ADC		The ADC chip temperature

Table 2.9: Dropdown menu for options 7-12

Clicking on **Start** would cause the waveform mode to be engaged and depending on the TEC channels selected, different max points and patterns would be seen.

Clicking on **Stop** would disengage the process and would stop the waveform mode.

Stability analysis ×

Data channel: CH 6_T

Analysis period: last 30 Minutes

Data used for analysis: 22 sec

The population mean: 40 °C

Standard deviation: 0.000114389 °C

Highest: 40.0001 °C

Lowest: 39.9997 °C

Stability result: 0.000343167 °C

Stability = 3X standard deviation, the error will stay within this range 99.73% of the time

☒ Notepad ☐ EXCEL

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

σ = population standard deviation
 N = the size of the population
 x_i = each value from the population
 μ = the population mean

Ambient Temperature

Average: 25.374 °C

Highest: 25.4191 °C

Lowest: 25.3087 °C

Data logging start: Mon May 09 10:00:49 2022

Monitor Duration: 22 sec

Figure 2.14: Data Analysis

Clicking on **Reset** would cause the deletion of all the data points in the graph.

Clicking on the **“Data Analysis”** button would lead to a popup window appearing, as shown in Figure 2.14.

In this dialog, it allows the user to compute basic data analysis for the VTC series such as the population mean and standard deviation based on the analysis period. This information could then be retrieved in a notepad format through the clicking of the **“Export one channel analysis”** or **“Export all channel raw data”**, based on the user’s setup and interest.

2.3. TAB: CONFIGURATION

The configuration tab is an area where you import critical information into the system, such as the resistance and type of sensors used. It will adversely impact the effectiveness of the system should the sensors and dimensions be wrongly declared.

2.4.1. Tab: System Configuration

Refer to Figure 2.15 for the system configuration subsection GUI layout. Table 2.10 highlights the keywords in the GUI.

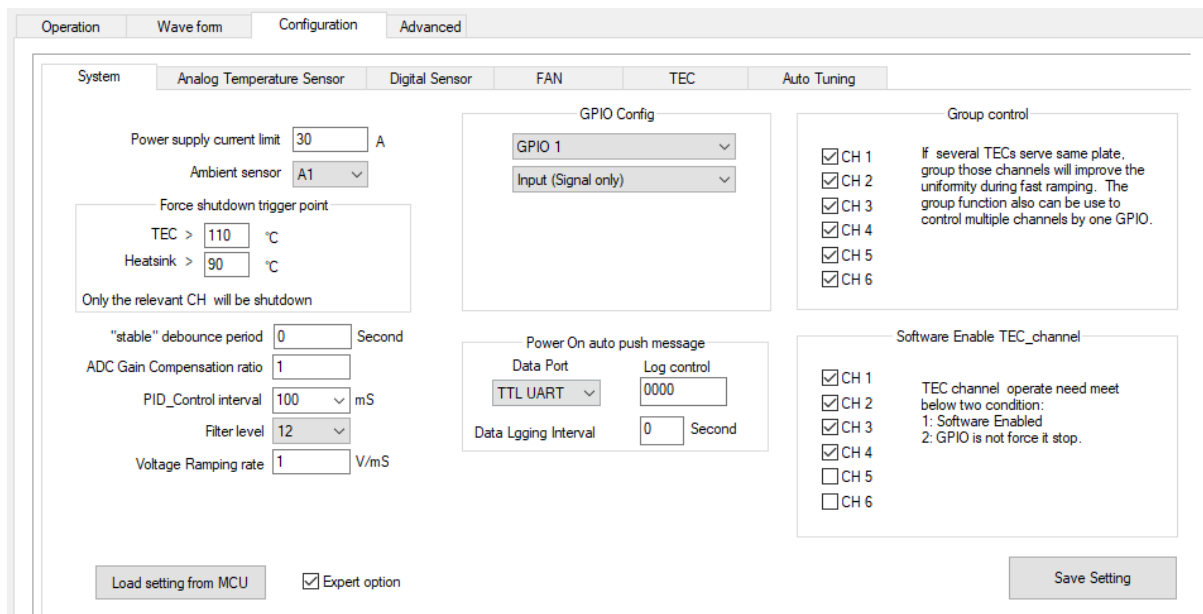


Figure 2.15: System Configuration GUI

Keyword	Description/important aspect of keyword
Power Supply Unit current limit	Indicates the maximum current which the power supply would be able to input into the system
TEC force shutdown	The highest temperature which the TEC will be able to handle before power supply to the TEC will be cut off.
Heatsink force shutdown	Similar to TEC shutdown, the system will stop operating when T of the heatsink is reached
Ambient sensor	The location of the thermal sensor on the TEC controller board, responsible for ambient temperature.
PID_control interval	The duration between two PID control. PID will change output voltage based on input information.
Filter level	Filtering at a higher level will reduce the amount of noise, whilst affecting response. A value of 12 is recommended

Group control	Group TEC channels together for smoother setpoint ramps as a group. Group control has 3 functions: 1) It provides identification when there is a need to apply the same settings on parameters such as the charging voltage, temperature, PID settings, etc to the whole group 2) When TECs within the group have the same target temperature and ramp rate requirement, the MCU will have additional control to improve uniformity during ramping. 3) It is used by the GPIO system to control the whole group member start/stop or display group stable status.
Software enable TEC channel	Enable/Disable a TEC channel in software. Enabling a TEC channel would require three conditions: 1) It would have to be selected and enabled 2) The GPIO status is running 3) The TEC channel is installed
Power On Auto Push Message ¹³	The VTC can start sending system information/stats as soon as power is applied. This data is sent through any connected TTL UART¹⁴/USB CDC/RS485 port. The following steps are required to configure the power on auto-push message: 1) In the AutoPush data logging tab, when items are selected, a Log Control value is displayed. Enter this value into the “Log Control” box on the “Power On Auto Push Message” panel. Refer to 2.2.3: Panel: AutoPush Data Logging for more info about Log Control 2) Select the port type in the “Data Port” dropdown 3) Set the data logging interval 4) Click “Save Setting” 5) Users can set the log control and data logging interval to 0 to disable power on auto push messages
GPIO Config	Allows users to configure one of the 4 available GPIOs¹⁵ to designated functions. The available GPIO functions are shown in Table 2.11 and their descriptions are available in Table 2.12

Table 2.10: System Configuration Layout Description

¹³ Power On Auto Push messages can be received without clicking the Connect button as long as correct power is applied to the VTC

¹⁴ UART operates at 115200 baud

¹⁵ Refer to the VTC Hardware Setup guide (VTC-UM-0001) for more information about GPIO pinout

List of input/output	
1	No connection
2	Input (TEC Enable)
3	Input (T_profile_enable)
4	Output (TEC_Run)
5	Output (T_Stable)
6	Output (T_Ramping/Stable)

Table 2.11: Input/output Options

Keyword	Description
No connection	The GPIOx has no connection. The pin would be at a state of high impedance.
TEC enable	GPIOx signal is used as an input to enable the output of the channel. If the signal is logic 1, the TEC controller will be enabled.
T_profile_Enable	The GPIOx signal is used as an input to enable the temperature profile on a particular channel.
TEC_RUN	The GPIOx signal is logic 1 if TEC controller is in the “Run” status.
T_stable	The GPIOx signal is logic 1 if the temperature of the corresponding channel is stable.
T_ramping/stable	The GPIOx signal is logic 1 if the temperature of the corresponding channel is stable. The GPIOx signal toggles between 1 and 0 at 1Hz, when the corresponding channel is ramping to the target temperature. This would lead to 3 different actions: (1) Before system starts ramping up (2) Temperature stabilized (3) Ramping phase
Push/Pull	Output doesn’t allow connecting multiple devices together in a bus configuration, like the open drain output. Push-pull configuration is most commonly used in interfaces that have unidirectional lines (transmission on the line is only in a single direction – SPI, UART etc.).
Open Drain	Outputs are most commonly used in communication interfaces where multiple devices are connected on the same line (e.g. I2C, One-Wire etc.). When all of the outputs of the devices connected to the line are in Hi-Z state, the line is driven to a default logic 1 level by a pull-up. Any device can pull the line to logic 0 using its open drain output and all devices can see this level.
Normal Polarity	Low to high voltage
Reverse Polarity	High to low voltage

Table 2.12: GPIO Functions Description

For instance, the example below will paint a clearer picture on what and how to choose.

Example of a configured GPIO	
1	Selected GPIO1
2	Function selected: Output (TEC_run)
3	Channel selected: Channel 1
4	Output type selected: Pushpull
5	Current polarity: Normal polarity

Table 2.13: Configured GPIO Example

GPIO 1 Example: If GPIO 1 is connected to a LED. The user selects the output command to be “TEC run” for channel 1 of the TEC. With normal polarity (when there is an increase in voltage), the LED will turn on when the TEC operates and vice versa.

2.4.2. Tab: Analog Temperature Sensor

A. Overview

Refer to Figure 2.16 for the layout of the analog temperature sensor subtab.

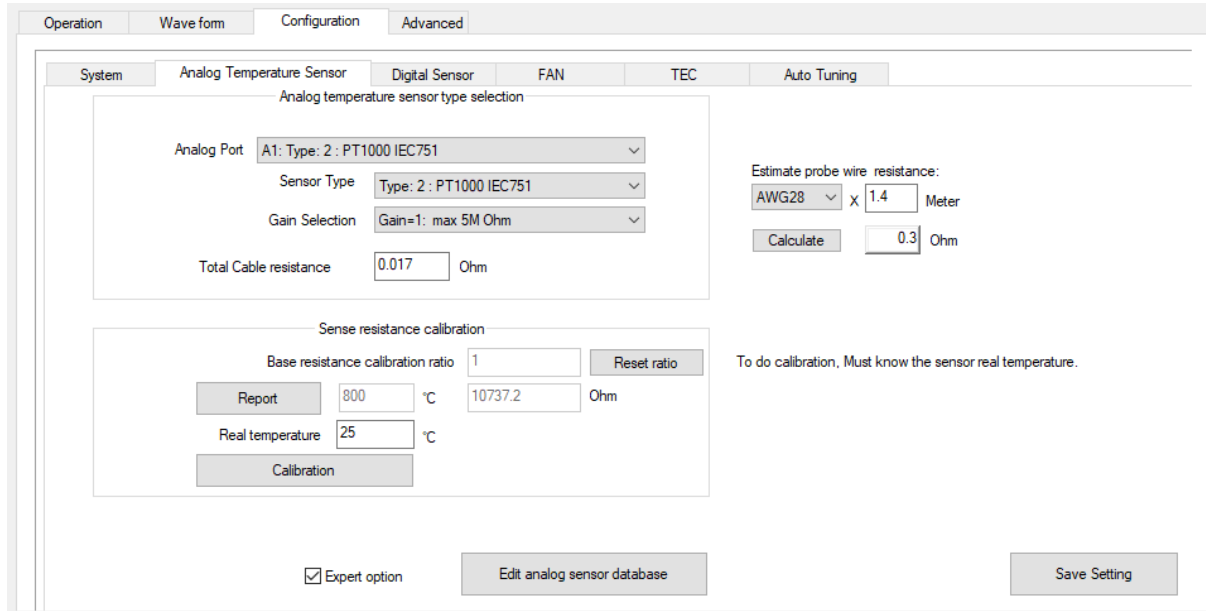


Figure 2.16: Analog Sensor Setup GUI

The various keywords for analog sensors have been described in Table 2.14.

Variable	Description
Analog Port	Position of pin in the TEC controller for analog temperature sensor
Sensor type	The brand and type of thermal sensor
Actual temperature	Measured temperature, after using 3 rd party application to determine the validity of the temperature
Report temperature	Current temperature reported by sensor on the TEC Do note that if it shows up 800 °C = port is open, 805 °C = port is short Hitting on calibration would align the TEC to adjust the sensor temperature to the actual temperature.
Gain selection	Higher gain selected will improve the signal to noise ratio, but this is restricted by the resistive properties of the wires and thermal sensors.

Table 2.14: Analog Temperature Sensor Subtab Description

To choose an appropriate gain, refer to [Table 2.15](#). It is based on the temperature sensor's resistance value at a given temperature. Gain=1 suitable for most of case.

Temperature Sensor Type	Resistance (k Ω) @-40 °C	Resistance (k Ω) @0 °C	Resistance (k Ω) @125 °C	Resistance (k Ω) @800 °C
PT100	0.084	0.1	0.148	0.375
PT1000	0.842	1	1.480	3.75
SEMITEC 103JT	204.7	27.7	0.533	
TMP61	6.588	8.451	17.609	
TE GA10K3A1i	336.1	32.65	0.341	
NTCALUG01A103JA	414	22.9	0.348	

Table 2.15: Selection of Gain for Temperature Sensors

An example on how to choose the gain for the temperature sensor (TMP61) will be shown in Table 2.16.

Say, maximum resistance of TMP61 = 17.609K ohm. A Gain of TMP61 = 1 as the resistance is greater than 14.9K ohms but less than 380K ohms.

Gain	Maximum Resistance
1	380K Ohm
2	14.9K Ohm
4	5.0K Ohm
8	2.2K Ohm
16	1.0K Ohm
32	500 Ohm
64	240 Ohm
128	120 Ohm

Table 2.16: Options for Gain Selection

B. Adding a new analog temperature sensor

Upon clicking the “**Edit analog sensor database**” button, a popup will appear as shown in Figure 2.17

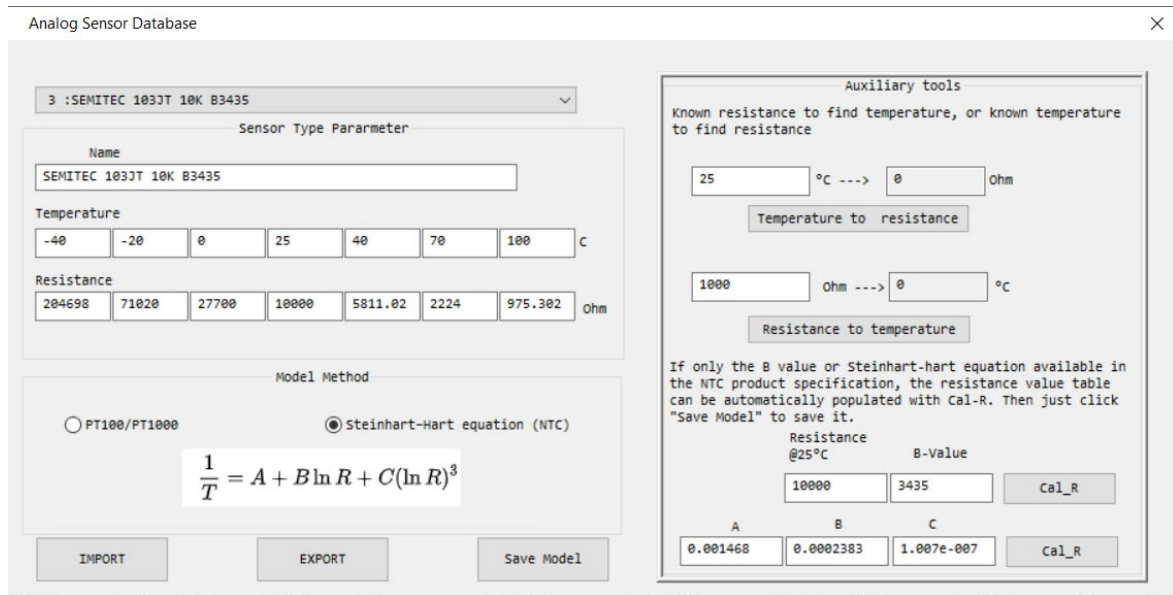


Figure 2.17: Analog Sensor Database

Key terms are described in Table 2.17

Keyword	Description
Name	Name refers to the name of the thermal sensor
Temperature & Resistance	Retrieved from manufacturer’s datasheets for that particular model of thermal sensor. From there, you will be able to fill in the resistance for the particular temperature
Model method	A PT100/1000 thermal sensor would have a model different from a thermistor, which would require the Steinhart-hart equation. Only PT100/PT1000 sensors would be required to fill in details, which is the A, B and C values found in the data sheet.
Cal_R	Supposedly, if the user is only able to obtain the B-value (beta value) as well as the R_25 (the resistance at room temperature) after going through the data sheet, the Cal_R function would calculate the resistance based on the temperature range which the user inputs. One thing to note would be that this method of calculating resistance would be not as accurate. As such, a detailed datasheet from the manufacturer would be preferred

Table 2.17: Analog Database Layout Description

2.4.3. Tab: Digital Temperature Sensor

A. Overview

Figure 2.18 shows the layout of the temperature subtab.

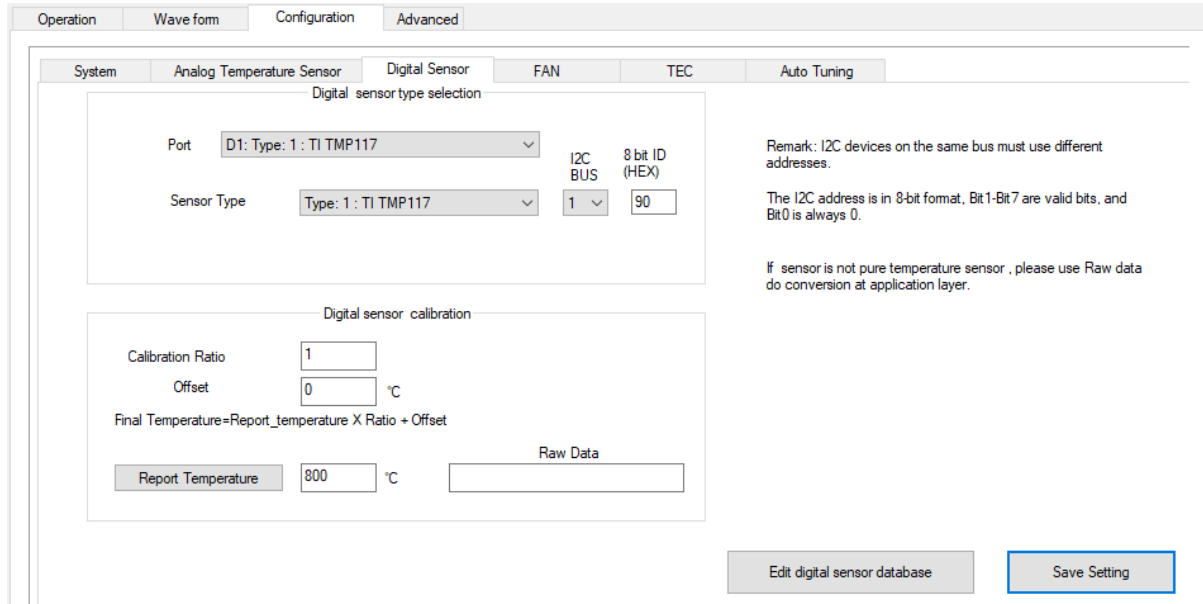


Figure 2.18: Digital Sensor setup GUI

Several keywords have been used to describe the digital temperature sensors as shown in Table 2.18

Keyword	Description
Port	Position of pin ¹⁶ in the TEC controller for the digital temperature sensor
Sensor type	The brand and type of the thermal sensor
Calibration ratio	Measured temperature of the surrounding (ambient)
Offset	This is required when the sensor output is higher/lower than the actual temperature by a constant value, this is known as the offset.
Report temperature	Current temperature reported by the VTC series 800 °C = port is open 805 °C = the port is short.

Table 2.18: Digital Temperature Sensor Description

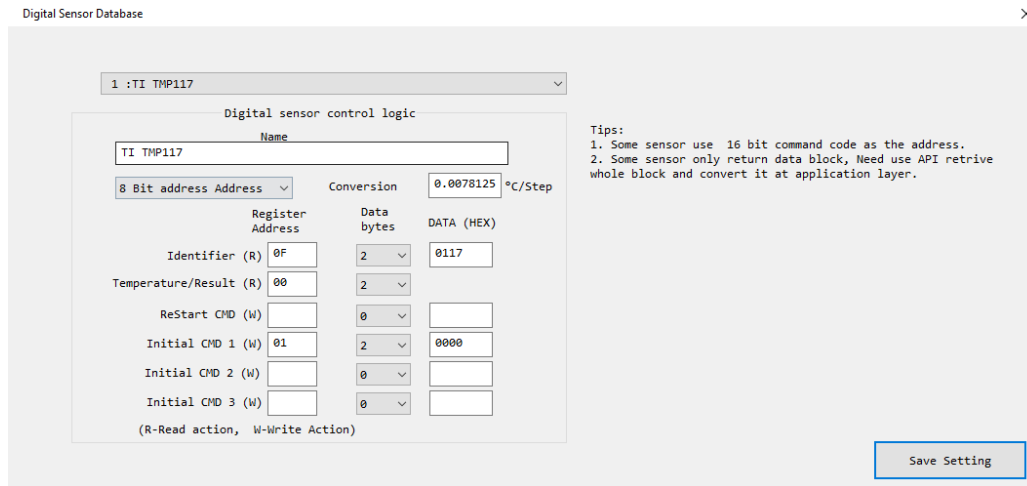
For the sensor types which are “User Defined” and the user wants to add a new sensor, it can be configured.

¹⁶ Refer to the VTC Hardware Setup guide (VTC-UM-0001) for details about I2C connector pinout

Adding a new digital temperature sensor

This is recommended for users who have studied the I2C datasheet, as the input data (in hex) is based on the individual bits of the register of the digital sensor.

Upon clicking the **“Edit digital sensor database”** button, a popup will appear as shown in Figure 2.19



Digital Sensor Database

1 : TI TMP117

Digital sensor control logic

Name: TI TMP117

8 Bit address Address: 8 Bit address Address Conversion: 0.0078125 °C/Step

Register Address	Data bytes	DATA (HEX)
Identifier (R) 0F	2	0117
Temperature/Result (R) 00	2	
ReStart CMD (W)	0	
Initial CMD 1 (W) 01	2	0000
Initial CMD 2 (W)	0	
Initial CMD 3 (W)	0	

(R-Read action, W-Write Action)

Save Setting

Tips:
 1. Some sensor use 16 bit command code as the address.
 2. Some sensor only return data block, Need use API retrieve whole block and convert it at application layer.

Figure 2.19: Digital Temperature Sensor Database

Several keywords are described in Table 2.19:

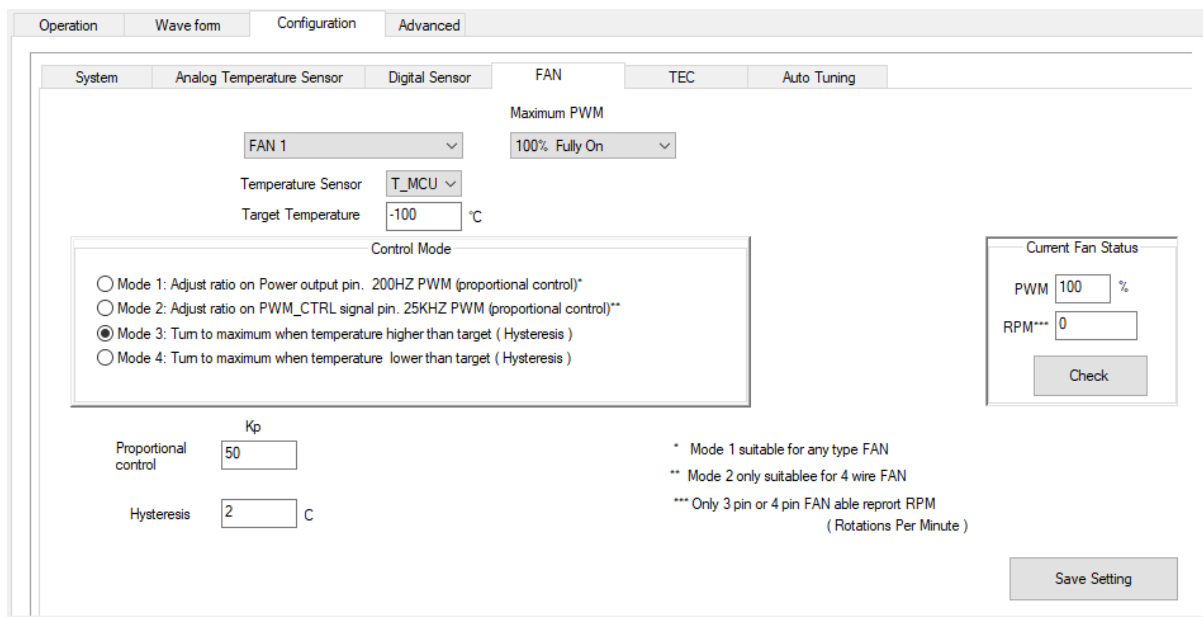
Keyword	Description
Name	The brand and model of the digital thermal sensor
Conversion ratio	This variable is found in the datasheet, which is critical in the calculation of the temperature.
For each type of digital sensor, there would be a unique register address and when you read its corresponding data bytes, there would be an output. There are 2 read actions and 4 write actions, which are depicted by (R) and (W) respectively. An example would be the TI TMP117 as shown in Figure 2.19	
Identifier	This is a read-only register which indicates the device ID. The number of bytes required for it to be read is dependent on the chip used for the sensor. In the case of TI TMP117, under the register address of “0Fh”, the data of “0117” will be the device’s unique ID.
Temperature	This register is a 16-bit, read-only register that stores the output of the most recent conversion.
Restart CMD	It is a write action which would be triggered when the data has been collected. In the case of TI TMP117, there is no need for a command prompt to convert the temperature as it has an automatic conversion function and as such it would not need the restart CMD prompt.

Initial CMD 1	It is a write action for a one-time initialization process to start the sensor and configure the register, be it the conversion cycle or any of the bits in the configuration register field. In the case of TI TIMP117, inputting “0000” into “01” register would initialize/start the sensor to the desired settings based on the data sheet.
Initial CMD 2	
Initial CMD 3	

Table 2.19: Digital Temperature Sensor Database Description

2.4.4. Tab: Fan

Figure 2.20 shows the layout of the fan subsection GUI. Table 2.20 shows the keyword and its associated description.



Operation Wave form Configuration Advanced

System Analog Temperature Sensor Digital Sensor **FAN** TEC Auto Tuning

FAN 1 Maximum PWM
100% Fully On

Temperature Sensor T_MCU
Target Temperature -100 °C

Control Mode

- ☐ Mode 1: Adjust ratio on Power output pin. 200HZ PWM (proportional control)*
- ☐ Mode 2: Adjust ratio on PWM_CTRL signal pin. 25KHZ PWM (proportional control)**
- ☒ Mode 3: Turn to maximum when temperature higher than target (Hysteresis)
- ☐ Mode 4: Turn to maximum when temperature lower than target (Hysteresis)

Proportional control Kp 50

Hysteresis 2 °C

* Mode 1 suitable for any type FAN
** Mode 2 only suitable for 4 wire FAN
*** Only 3 pin or 4 pin FAN able report RPM (Rotations Per Minute)

Current Fan Status
PWM 100 %
RPM*** 0
Check

Save Setting

Figure 2.20: Fan Setup GUI

Keyword	Description
Temperature sensor	The digital/analog port on the VTC series board which was used for temperature sensing.
Target temperature	The desired temperature which you want to cool the system to, based on the temperature sensor selected
Control Mode	VTC allows users to configure fan speed control to one of 4 modes • Mode 1: 200 Hz PWM, proportional control • Mode 2: 25 KHz PWM, proportional control • Mode 3: Positive Hysteresis control • Mode 4: Negative Hysteresis control
K _p	Proportional term based on PID Control
Hysteresis	Hysteresis occurs when the fan/heater will turn on when the temperature has a higher than the target temperature the system. The system would decrease the temperature beyond the target temperature, by X°C where X is the value of hysteresis. This is mainly used in order to reduce the on/off frequency of the fan/heater. E.g.: For mode 3 if the target temperature is 27°C and the hysteresis is 2°C, the heater will turn on when the temperature is less than 27°C and will only turn off when the temperature reaches 29°C.

Table 2.20: Fan Subtab Description

2.4.5. Tab: TEC

Figure 2.21 shows the layout of the TEC subsection GUI. Table 2.21 below shows the keywords present in the tab and its associated descriptions.

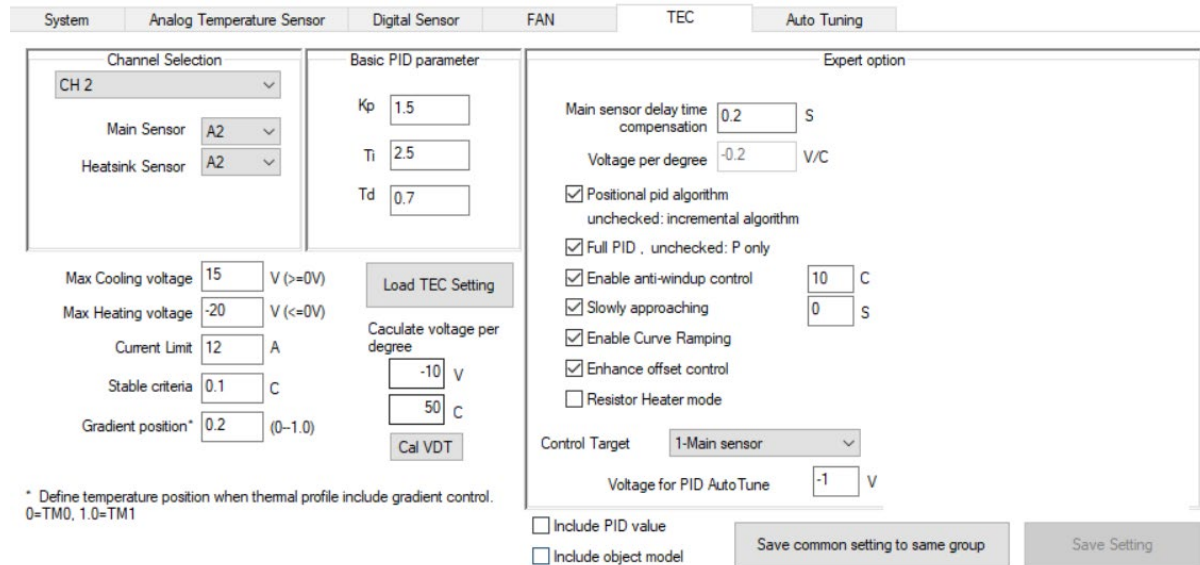
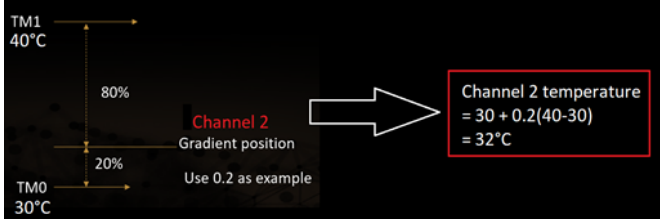


Figure 2.21: TEC setup GUI

Keyword	Description
Channel selection	Allows the user to select the channel of the TEC controller to be configured
Main sensor	Refers to the sensor attached to the TEC.
Heatsink sensor	Refers to the sensor connected to the heatsink
Max cooling voltage	Positive voltage supplied to cool the TEC.
Max heating voltage	Negative voltage supplied to heat up the TEC
Current limit	Secondary protection mechanism to prevent frying of the TEC controller board
Stable limit	The waypoint that would be used in determining where the temperature is stable, and is often indicated by the green light beside the channel. For instance, if the target temperature is 40°C, the green indicator beside the channel would be lit up in the range of 39.9°C – 40.1°C should the stable limit be 0.1°C ¹⁷ .

¹⁷ The green LED colour is not tied to the actual control loop. E.g.: Although the LED will turn green at 39.9 – 40.1°C, the system will still continue controlling the temperature to reach the target of 40°C. In contrast, setpoint boundary affects the control loop and TEC will stop heating/cooling when within the boundary range

Gradient position	Defines the position of a channel when gradient control is required. It occurs when certain segments of the temperature profile have different TM0 and TM1, then the actual point will be calculated based on the gradient position setting. The main purpose of this technique is to determine the optimal annealing temperature for PCR using the least number of steps. 
Sensor delay time compensation	The known/tested delay in time due to the property of the thermal sensor, which the user can input to compensate and get a system with higher accuracy. This is based on the sensor data sheet
Voltage per degree	The amount of voltage required for an increase of one °C. There will be a default value. If the setup is changed, do the tuning as per subsection 3.1.6: Pre-Check and Tuning for the respective channel and save the settings and the value of Vdt will be changed.
Positional PID algorithm:	This algorithm is typically used to perform closed-loop motion control on a position feedback axis. Requires the user to select the anti-windup control in the GUI. There is no need to change the parameters after doing the autotune process. Generally, this algorithm helps to minimise undershoot/overshoot better than the incremental algorithm.
Incremental algorithm:	Contains native anti-windup function, as such there is no need to select the anti-windup control option. However, if the user wants to improve its performance, use different PID parameters at different temperature points.
Full PID	When checked all variables of PID will be used. Should be unchecked when only P is to be used .
Anti-windup control	Takes the integral component of the PID into consideration, and minimises the accumulation of errors. In essence, it saturates the integral term to keep the system from overshooting the set point.
Slowly Approaching	Reduce the overshoot/undershoot by controlling the rise time when very close to the setpoint
Enable Curve Ramping	Use a sine curve instead of a straight line when trying to ramp towards a setpoint
Enhanced Offset control	Special handling of heatsink temperature drift
Resistor Heater Mode	Uses a different object model to control the temperature
Control Target	The reference to follow in the PID algorithm. The channel will follow its Main Sensor by default, but users can choose to control based on a thermal model of the object ¹⁸ instead.

¹⁸ Object refers to the body and material whose temperature is being regulated by the TEC

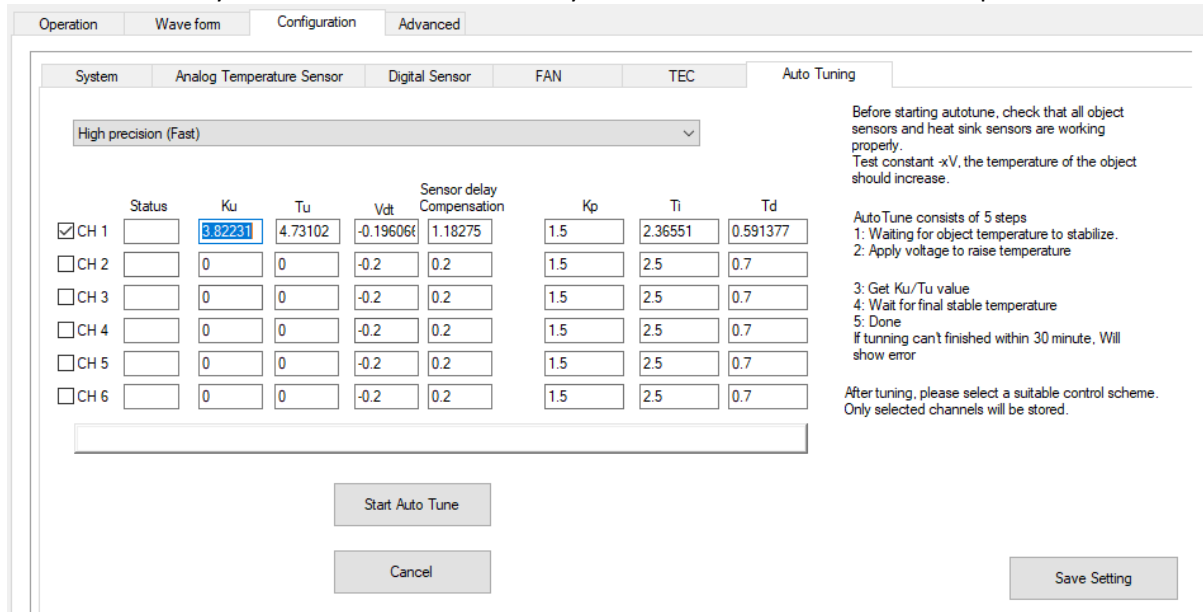
Voltage for PID autotune

It is the voltage used during the autotune process, to raise the TEC temperature during the tuning process. It is recommended for the input voltage to be 2V.

Table 2.21: TEC Subtab Description

2.4.6. Tab: Auto Tuning

The VTC series uses an open loop system for its implementation¹⁹. Figure 2.22 shows the autotune subsection GUI layout. Table 2.22 shows the keywords and their associated descriptions.



Before starting autotune, check that all object sensors and heat sink sensors are working properly.
Test constant $\propto V$, the temperature of the object should increase.

AutoTune consists of 5 steps
1: Waiting for object temperature to stabilize.
2: Apply voltage to raise temperature
3: Get K_u/T_u value
4: Wait for final stable temperature
5: Done
If tuning can't finished within 30 minute, Will show error

After tuning, please select a suitable control scheme.
Only selected channels will be stored.

Figure 2.22: Auto Tuning GUI

Keyword	Description
Status	1: Remove power and wait for the object temperature to be stable before trying again 2: Apply voltage and ramp up, raising temperature 3: Calibrating/obtaining K_u/T_u values 4: Waiting for final stable temperature 5: Autotune process is complete
K_u	Ultimate gain margin for loop stability
T_u	Period of the oscillation frequency at the stability limit
V_{dt}	Voltage/delta t
Sensor Delay Compensation	The known/tested delay in time due to the property of the thermal sensor, which the user can input to compensate and get a system with higher accuracy or reduce overshoot.
K_p	Gains of the P element
T_i	Integral time
T_d	Derivative time

Table 2.22: Clarification of terms For Autotune Subtab

¹⁹ End user can use close loop for manual tune

2.5. TAB: ADVANCED

This section mainly describes the addition of certain details which are mainly for the maintenance of the system²⁰. Figure 2.23 shows the layout of the Advanced tab. This tab has the following sub-panels:

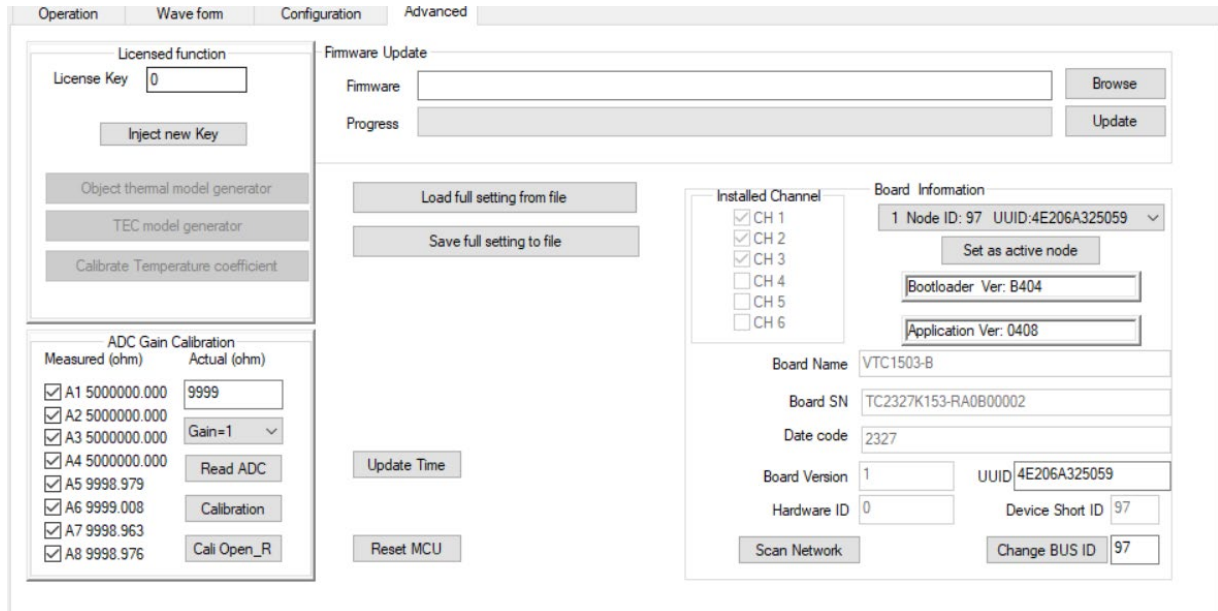


Figure 2.23: Advanced Tab GUI

2.5.1. Panel: Licensed function

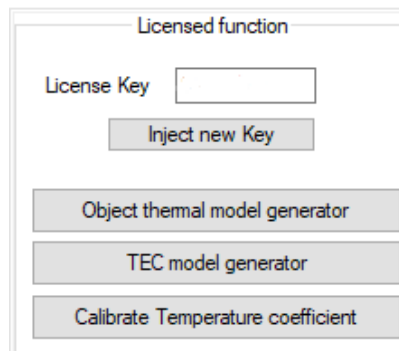


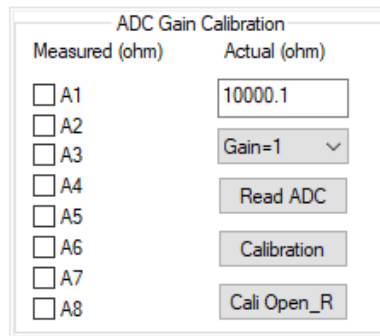
Figure 2.24: Licensed function panel

²⁰ It is not recommended for the users to edit the information in this tab, unless you are sure of the individual values for the variables. Rather than that, feel free to contact the engineers on the values to be input into the system.

Figure 2.24 shows the layout of the ***“Licensed function”*** panel. Sub-panel on the **top left**, it allows for license key injection. Contact VBMB for more details about license keys.

The Object Thermal Model Generator, TEC Model Generator and Calibrate Temperature Coefficient buttons each open a dialog box which guides users on performing the relevant operation in a step-by-step manner.

2.5.2. Panel: ADC Gain Calibration



The screenshot shows the 'ADC Gain Calibration' panel. It features two columns: 'Measured (ohm)' and 'Actual (ohm)'. Under 'Measured (ohm)', there are checkboxes for A1 through A8. Under 'Actual (ohm)', there is a text input field containing '10000.1', a dropdown menu set to 'Gain=1', and three buttons: 'Read ADC', 'Calibration', and 'Cali Open_R'.

Figure 2.25: ADC Gain Calibration panel

Figure 2.25 shows the layout of the “**ADC Gain Calibration**” panel. This panel allows users to manually calibrate the ADCs for the A1 - A8 sensors.

To perform calibration, follow the below steps:

- Step 1)* Plug fixed resistors of known value on A1 - A8 connector.
- Step 2)* Key in this resistance value in the “**Actual (ohm)**” input box and click on “**Read ADC**” following which the VTC will measure the resistance for each of the analog channel.
- Step 3)* If there is a difference, click on the “**Calibration**” to configure the data and store it into the EEPROM. Usually, the factory will do this step before shipment²¹.



The screenshot shows the 'Firmware Update' panel. It has two rows: 'Firmware' and 'Progress'. Each row has a text input field and a button. The 'Firmware' row has a 'Browse' button, and the 'Progress' row has an 'Update' button.

2.5.3. Panel: Firmware Update

Figure 2.26 shows the layout of the “**Firmware Update**” panel. It allows users to update the firmware for the software when the file for the firmware has been downloaded.

Figure 2.26: Firmware Update panel

Refer to section [4.1.1: Check for Firmware Version](#) for steps to update the firmware for the VTC series board.

²¹ This would only be applicable for devices which needs a recalibration after a few years, as a result of thermal drift.

2.5.4. Panel: Board Information

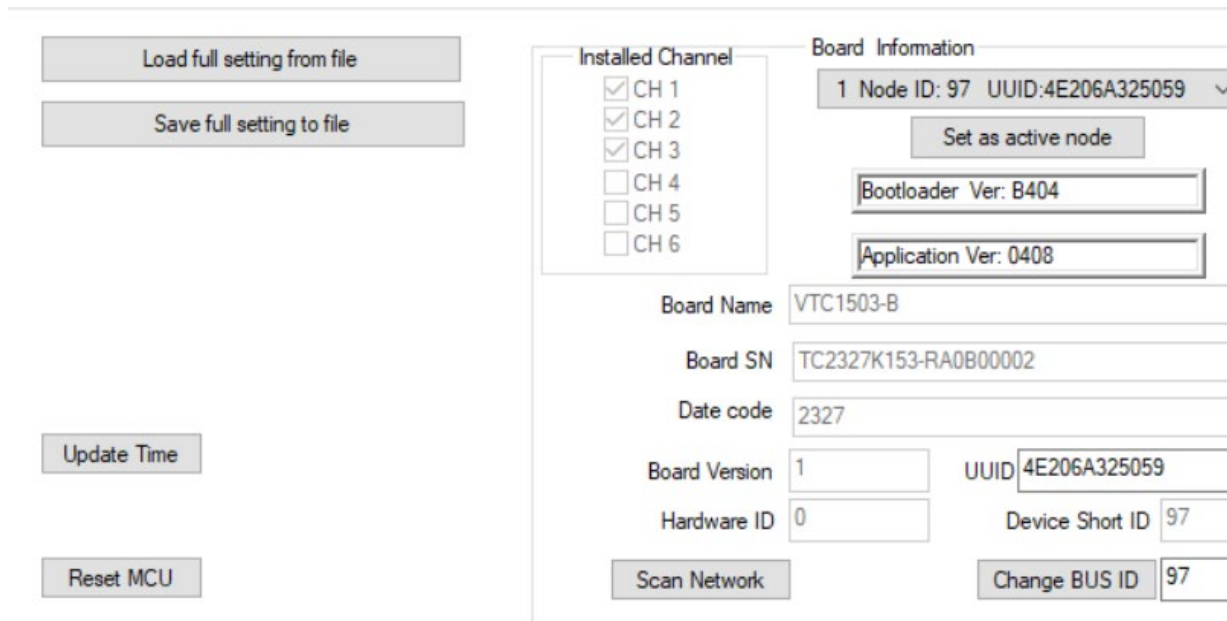


Figure 2.27: Board Information panel

Figure 2.27 shows the layout of the board information panel. Table 2.23 explains the various settings available in the **“Board Information”** panel.

Setting Name	Description
Load full setting from file	Load all board settings from a config file
Save full setting to file	Save all board settings to a config file
Reset MCU	Soft reset the VTC board. The board will disconnect and re-connect after the reset
Installed Channel	distinguish between the 1-channel, 2-channel and 6-channel variants of the VTC
Update Time	Make VTC time stamp follow computer current time.used for push messag time synchronization.
Node ID	If multiple VTC series are connected to a computer, users can select the node ID and click on the “Set as active node” button. This is done to switch to that particular TEC, without having the need to disconnect and reconnect.
Bootloader Version	The bootloader version inside the VTC board selected as the active node
Application Version	The firmware application version inside the VTC board selected as the active node
Board Name	The name of the VTC board selected as the active node

Board SN	The serial number of the VTC board selected as the active node
Date Code	The date code of the VTC board selected as the active node
Board Version	The version of the VTC board selected as the active node
Hardware ID	The hardware revision of the VTC board selected as the active node
UUID	The UUID of the VTC board selected as the active node
Device Short ID	The modbus ID of the VTC board selected as the active node
Change BUS ID	This button can be used to change the modbus ID of the VTC in case of a clash
Scan Network	This button will search all serial ports for connected VTC boards and populate the Node ID dropdown accordingly

Table 2.23: Description of the Board Information panel

3. CONFIGURATION AND OPERATION

3.1. CONFIGURATION

Configuration of the various parameters of VTC is required to ensure correct functioning of the application.

3.1.1. Connecting to the VTC Utility

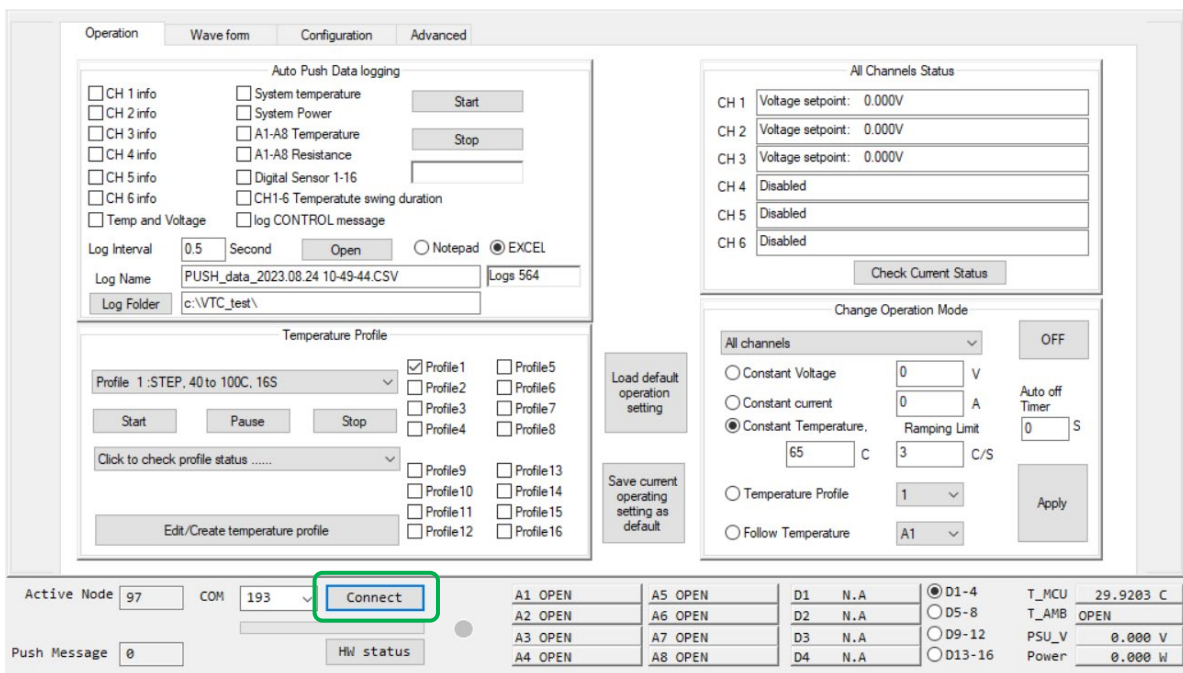


Figure 3.1: VTC Utility connects to VTC series

Step 1) Begin by inserting the **micro-USB²²** connector into the VTC series. This will allow the VTC to communicate with the user's computer.

Step 2) Click on "Connect" and wait a few seconds for the software to search for a suitable COM port to be connected. If multiple VTC boards are connected, users are required to select the appropriate COM port from the dropdown before clicking "**Connect**".

Step 3) Once a COM port attached to a VTC has been found, the connection indicator will turn **Green**, as shown in Figure 3.2. The connected COM port is also displayed in the COM window.

²² Refer to the VTC Hardware Setup guide (VTC-UM-0001) for more information about the micro-USB connector

Step 4) When connected, the VTC Utility will load the currently stored settings inside the VTC. The VTC series board will only have a default setting for new unmodified boards which have undergone FCT (Functional Testing). For the default settings²³, all of the channels will have 0V output as the default to ensure that the board will be safe.

Step 5) Users can load settings from a project file as shown in section 2.5: Tab: Advanced²⁴

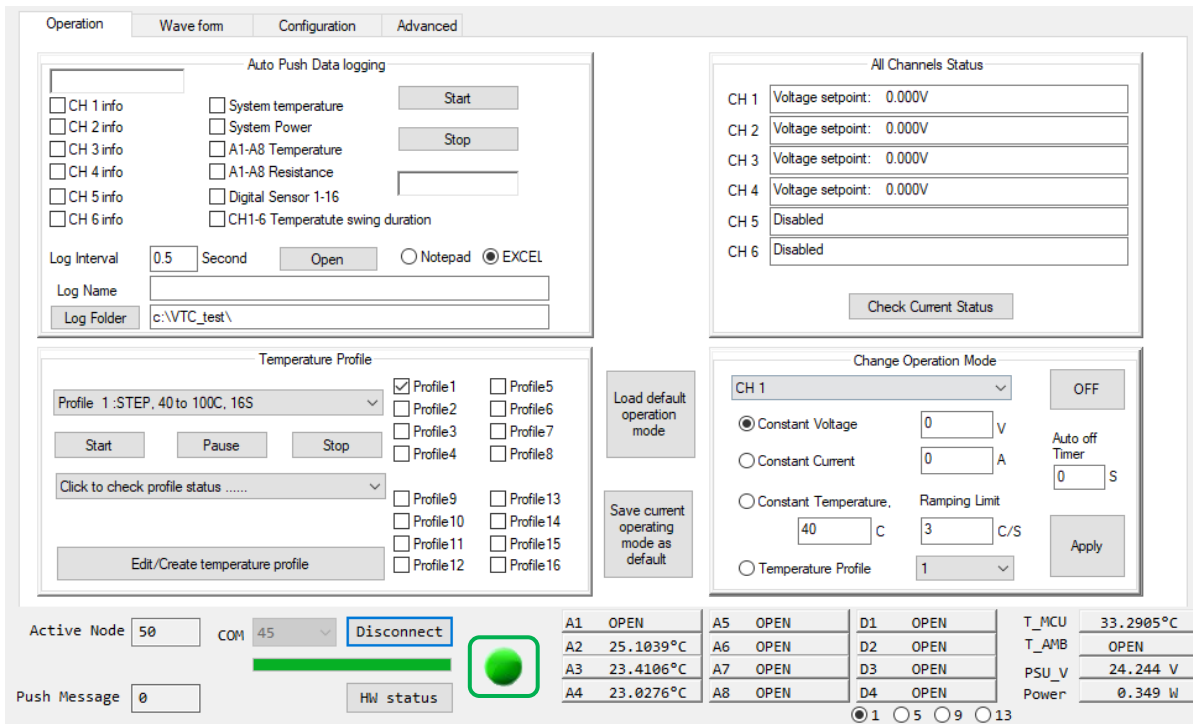


Figure 3.2: Connection Indicator

If your indicator is **Red**, instead of **Green** when you connect, refer to section [4.1: Troubleshooting](#) to look for possible root causes.

²³ If the end user changed the channel settings and clicked on “Save operating mode as default”, the default setting will be changed.

²⁴ Project file will only be provided for TEC Module/Assembly purchased together with VTC. Users who have purchased only the VTC series, can skip ahead to Step 4.

3.1.2. System Configuration

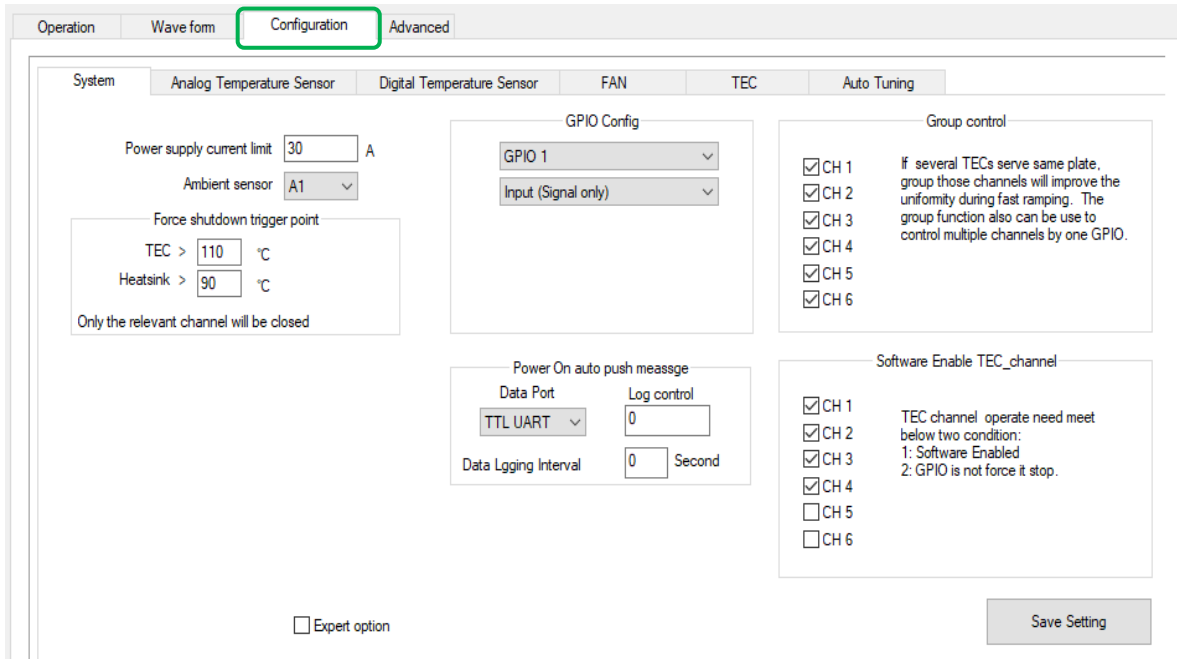


Figure 3.3: System configuration

Step 6) Click on **Configuration** → **System**. This will bring you to the “**System**” sub-tab, which will show the current default settings (Figure 3.3).

Step 7) Users can edit the settings and click on the “**Save Setting**” button to store the settings into the VTC. These stored settings shall take effect immediately and will be loaded every time the VTC is reset/power cycled.

The detailed description of the key terms can be found in section 2.4.1: Tab: System Configuration
The important parameters to be filled in would include:



Current Limit

The current limit for the board must be lower than the current supplied by the power supply. Otherwise, this would result in the VTC series experiencing a power brownout.



Product shutdown conditions

The force shutdown trigger point to prevent overheating of the board.

Sensor Selection

The ambient sensor should be selected, based on the position of the analog port on the VTC series

3.1.3. Temperature Sensor Setup

The VTC series has the capability to support both analog and digital sensors. Based on the user's system requirements, sensors can be configured as shown below.

A. *Analog temperature sensor*

Step 1) Click on **Configuration (1)** → **Analog Temperature Sensor (2)**. This will bring you to the **"Analog Temperature Sensor"** subtab as shown in Figure 3.4. This subtab will show the current default factory settings. Based on the user's setup, select the **"Analog Port" (3)** and assign the correct **"Sensor Type" (4)**

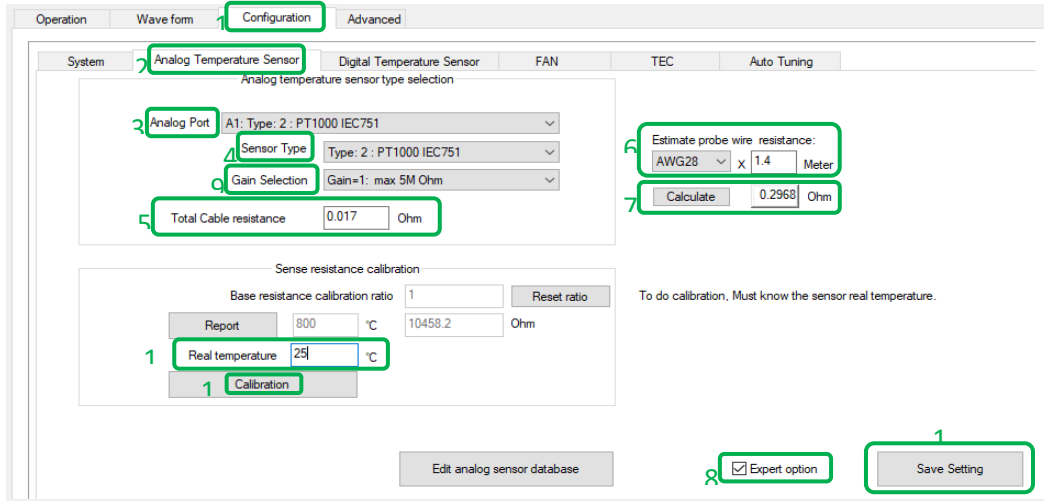
Step 2) Users can enter the sensor probe wire resistance in the **"Total Cable Resistance"** input box (5). Alternatively, users can estimate the probe wire resistance by specifying the wire length (6) and clicking **"Calculate" (7)** and choose to input this value in (5).

Step 3) Advanced users can check the **"Expert Option" (8)** checkbox to gain access to detailed config settings like **"Gain Selection" (9)**. Refer to section [2.4.2: Tab: Analog Temperature Sensor](#) for more details.

Step 4) Next, measure the ambient room temperature and enter it into the **"Real temperature" (10)** and click on **"Calibration" (11)**²⁵.

Step 5) Lastly, click the **"Save Setting" (12)** to save the configuration into the VTC. The purpose of this step is to assign the sensor to the respective analog port on the microcontroller, as well as identifying the type of sensor and length of the wire (for the calculation of resistance of wire). After assigning the sensors, the configuration of the sense resistance calibration is to alter the parameters within the software in order to increase the accuracy of the system.

²⁵ If it is not possible to measure the actual room temperature, users can let all sensors settle and reach steady state, then take the average of the sensor readings and enter this value in (10).



Operation Wave form **1 Configuration** Advanced

System **2 Analog Temperature Sensor** Digital Temperature Sensor FAN TEC Auto Tuning

Analog temperature sensor type selection

3 Analog Port A1: Type: 2 : PT1000 IEC751

4 Sensor Type Type: 2 : PT1000 IEC751

5 Gain Selection Gain=1: max 5M Ohm

6 Total Cable resistance **7** 0.017 Ohm

Estimate probe wire resistance:
AWG28 X 1.4 Meter

7 Calculate 0.2968 Ohm

Sense resistance calibration

Base resistance calibration ratio 1 Reset ratio

Report 800 °C 10458.2 Ohm

1 Real temperature 25 °C

1 Calibration

Edit analog sensor database

☒ Expert option

1 Save Setting

To do calibration, Must know the sensor real temperature.

Figure 3.4: Setup analog temperature sensor

B. Digital temperature sensor

Step 1) Click on “Configuration” (1) → “Digital Temperature Sensor” (2).

Step 2) This will bring you to the “**Digital Temperature Sensor**” subtab, which will show the current default factory settings. Based on the user’s setup, select the digital sensor “**Port**” (3) and choose the “**Sensor Type**” (4).

Step 3) Refer to the sensor’s data sheet for the “**Calibration Ratio**” and “**Offset**” values and input them in (5)²⁶.

Step 4) Lastly, click on “**Save Settings**” (6) to save the configuration to the VTC.

Refer to subsection [2.4.3: Tab: Digital Temperature Sensor](#) for more information.

Figure 3.5: Setup digital temperature sensor

²⁶ Skip this step if the values for the calibration ratio as well as the offset value could not be found.

3.1.4. Fan Setup

The VTC series supports upto three fans.

Step 1) Click on **Configuration** (1) → **Fan**²⁷ (2). This will bring you to the “Fan” subtab, which will show the current default settings. Based on the user’s setup, select the appropriate fan in the dropdown (3) and set its max PWM in (4). A PWM of 0 shall turn the fan off.

Step 2) Users can select a temperature sensor and its target temperature (5). When specified temperature is reached, the Fan will be turned on/off accordingly. The fan behaviour w.r.t the target temperature can be set by selecting the “Control Mode” in (6).

- Three-wire fans have wires for power, ground and a tachometer output. If you are using a three-wire fan, select **Mode 1**
- Four-wire fans have wires for power, ground, a tachometer output and a dedicated PWM input pin. If you are using a four-wire fan, select **Mode 2**.
- Both three and four wire fans can also use **Mode 3** and **Mode 4**, which functions as a programable hysteresis, where the user fills in a hysteresis value in °C. The hysteresis value can be entered in the “Hysteresis” input box (8).

Step 3) In **Modes 1 and 2**, users can edit the value in “Proportional Control” (7) input box to alter the K_p of the PID loop controlling the fan. **Modes 3 and 4** don’t require specific PID values²⁸.

Step 4) Users can read the current fan PWM and RPM by clicking “Check” in (9).

Step 5) Lastly, click on “Save Settings” (10) to save the configuration to the VTC.

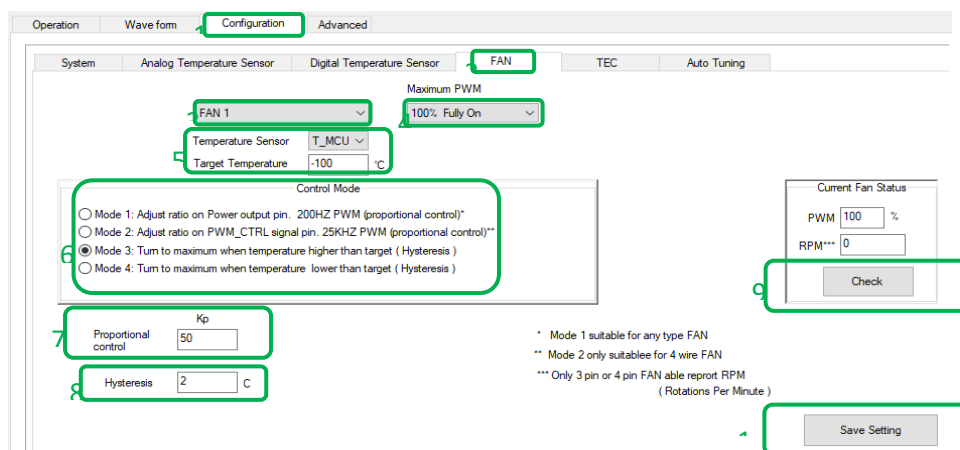


Figure 3.6: Setup Fan

²⁷ Fan config is optional and can be skipped if no fans are connected. Connecting a fan is recommended as it cools the system faster thus preventing overheating.

²⁸ Although the hysteresis mode is easier to use, the accuracy of this mode is not as effective as Mode 1 and 2.

3.1.5. TEC Setup

The aim of performing this step is to assign the main sensors for the channel as well as the voltage limit for the system. Refer to section [2.4.5: Tab: TEC](#) for clarity of the key terms used in this subtab.

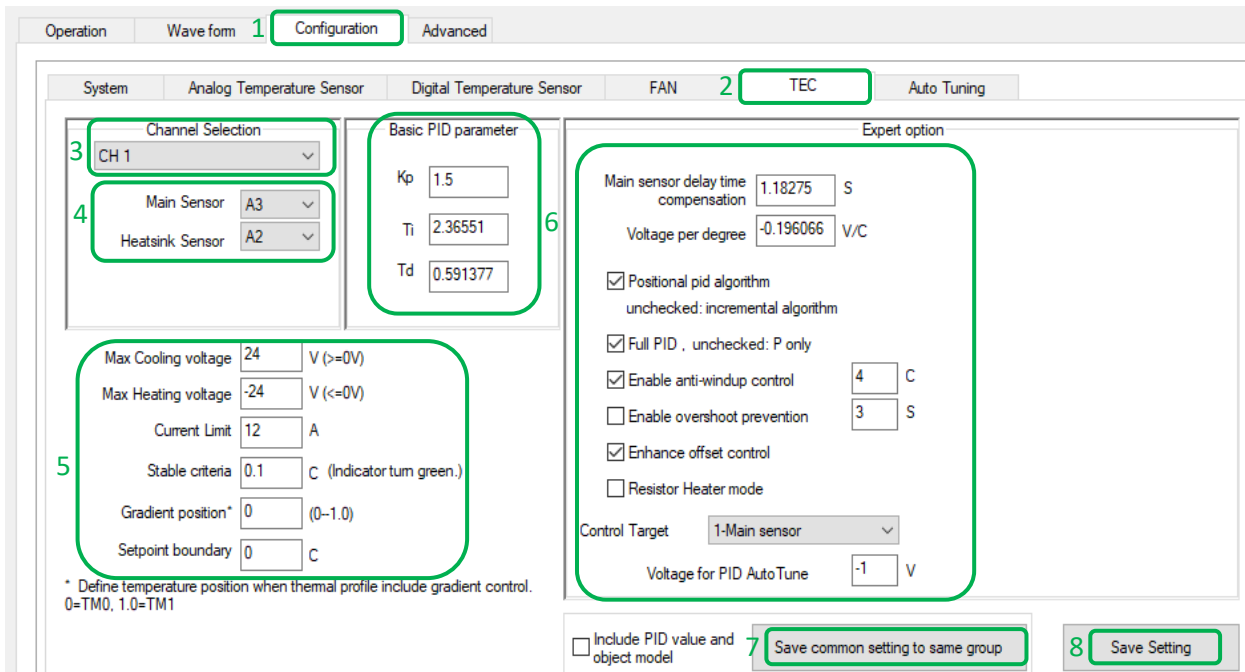
Step 1) Click on **Configuration** (1) → **TEC** (2)

Step 2) This will bring you to the “**TEC**” subtab, showing the current factory default settings. Based on the user’s setup, select the TEC channel in the “**Channel Selection**” dropdown (3).

Step 3) Select the “**Main**” and “**Heatsink**” sensors for the channel in the respective dropdowns (4).

Step 4) Thereafter, fill in the other parameters such as the **voltage** (heating and cooling), **current limit**, **stable criteria**, **gradient position**²⁹ and **setpoint boundary** for the particular channel (5). Users well versed with PID tuning can also edit the basic as well as advanced PID parameters directly (6).

Step 5) Lastly, select “**Save Settings**” (8) to save the configuration to the VTC. Additionally, if this channel was previously assigned to a group, users can now apply the common settings to the whole group by selecting “**Save common setting to whole group**” (7).



The screenshot displays the VTC Configuration interface for the TEC subtab. The interface is divided into several sections:

- Channel Selection:** A dropdown menu showing "CH 1".
- Main Sensor:** A dropdown menu showing "A3".
- Heatsink Sensor:** A dropdown menu showing "A2".
- Basic PID parameter:** Fields for Kp (1.5), Ti (2.36551), and Td (0.591377).
- Expert option:** A section containing various control parameters and checkboxes.
 - Main sensor delay time compensation: 1.18275 S
 - Voltage per degree: -0.196066 V/C
 - ☒ Positional pid algorithm (unchecked: incremental algorithm)
 - ☒ Full PID, unchecked: P only
 - ☒ Enable anti-windup control (4 C)
 - ☐ Enable overshoot prevention (3 S)
 - ☒ Enhance offset control
 - ☐ Resistor Heater mode
 - Control Target: 1-Main sensor
 - Voltage for PID Auto Tune: -1 V
- Max Cooling voltage:** 24 V (>=0V)
- Max Heating voltage:** -24 V (<=0V)
- Current Limit:** 12 A
- Stable criteria:** 0.1 C (Indicator turn green.)
- Gradient position*:** 0 (0-1.0)
- Setpoint boundary:** 0 C

At the bottom, there are two buttons: "Save common setting to same group" (7) and "Save Setting" (8). A note at the bottom left states: "* Define temperature position when thermal profile include gradient control. 0=TM0, 1.0=TM1".

Figure 3.7: Setup TEC

²⁹ The gradient position is only used if the thermal profile used has gradient control

3.1.6. Pre-Check and Tuning

After the system has been correctly configured, the VTC series is ready to be used. However, there is a need to optimise the system as well as verify the functionality of the VTC0 series.

The following steps are required for optimization and system verification.

Step 1) Select the **“Operation”** tab.

Step 2) Set a -1 V to the selected channel and see if on the Channel Info panel (your selected channel), the temperature rises and that the heatsink temperature is normal ($\approx 26^{\circ}\text{C}$). Please check subsection [2.4.5: Tab: TEC](#) or section [4.1: Troubleshooting](#) should there be any anomaly.

Step 3) Click on **“Configuration”** → **“Auto Tuning”**

Step 4) The autotuning algorithm obtains its information from the system by applying a step voltage input across the TEC while a feedback loop observes the system response to this input. Based on the gathered data, a Ziegler-Nichols tuning equation is then used to calculate the optimum control parameters. The VTC Utility provides the following tuning mode options as shown in Table 3.1.

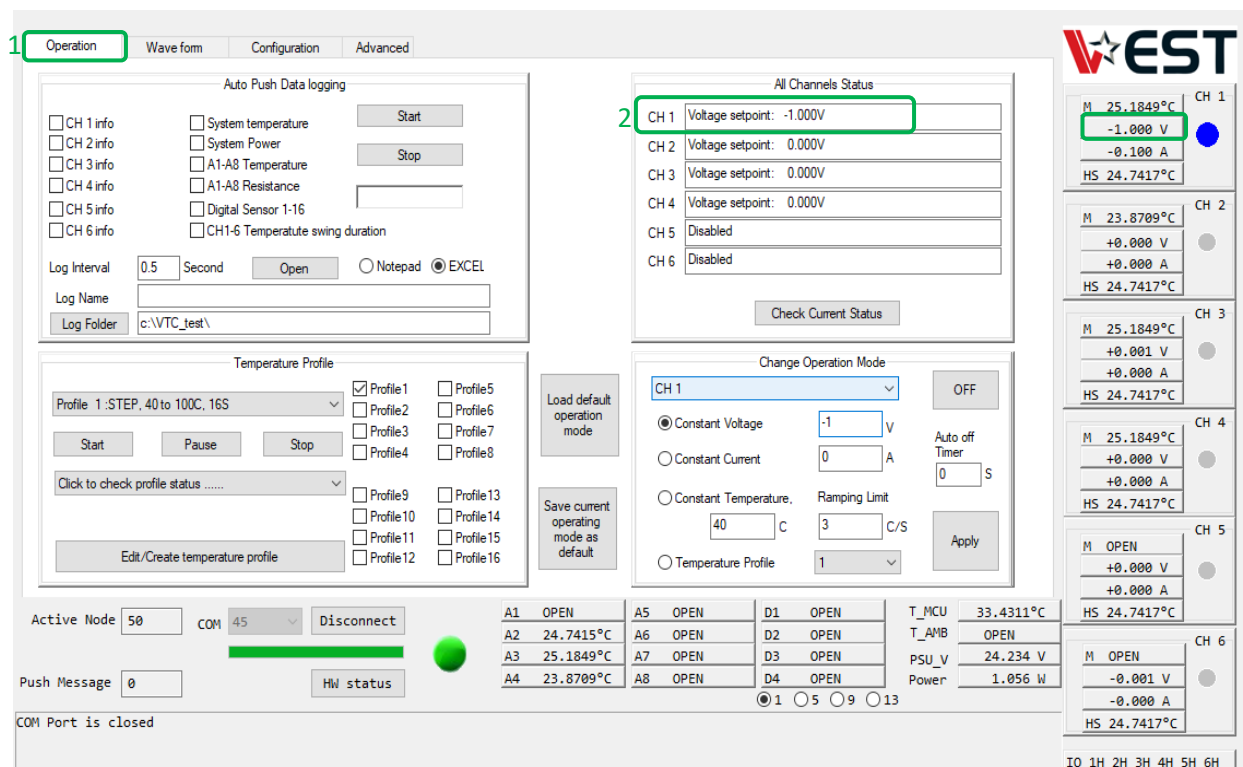


Figure 3.8: Pre-Check

Autotune Options	Description
High precision (Fast)	Fast response towards a setpoint
Less oscillation (Slow)	Minimizes overshoot
Standard (Middle)	Balanced tuning
Classic PID	PID control
Classic PI	PI control

Table 3.1: Auto-tuning options

Figure 3.9 shows the autotune GUI and the relevant steps needed to complete the process.

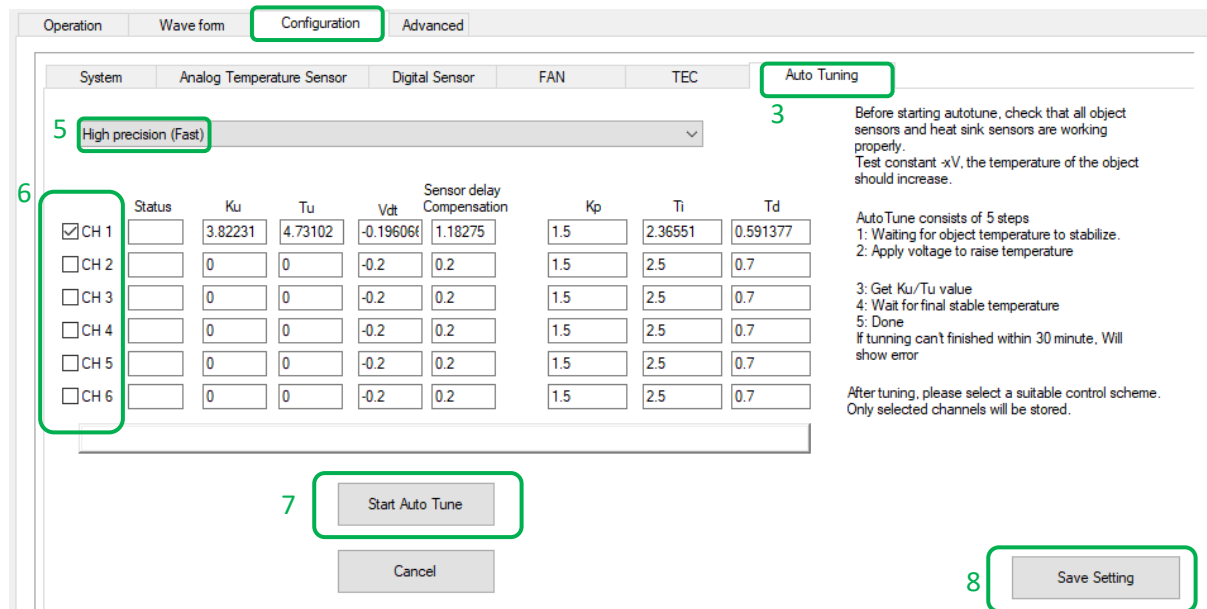


Figure 3.9: Auto-tune

Step 5) Select the auto-tuning option from the dropdown

Step 6) Choose the channels which you would like to auto-tune³⁰

Step 7) Click on “Start Auto Tune”

Step 8) Store the values to the selected channels by clicking on “Save Settings”³¹

³⁰ Refer to [2.4.6: Tab: Auto Tuning](#) for more info

³¹ If the user wants to input a specific set of values for the different variables, there is an option to write and store the values to the VTC board.

3.2. OPERATION

After going through the configuration, tuning and pre-check steps, the VTC can be operated by accessing settings in the “**Operation**” tab.

The VTC series supports 5 operating modes:

- 1) Constant voltage - controller attempts to achieve a constant voltage setpoint
- 2) Constant current - controller attempts to achieve a constant current setpoint
- 3) Constant temperature - controller attempts to achieve a constant temperature setpoint
- 4) Temperature profile – control follows a pre-defined sequence of temperature setpoints and ramp-up/ramp-down between them
- 5) Follow temperature – controller attempts to follow another temperature sensor real time value.

The status of each channel can be inferred from the state of the channel LED in the Channel Info panel on the right. Possible LED states in these modes are OFF, **BLUE**, **GREEN** or **RED**.

A **BLUE** LED implies the channel is active and moving toward the programmed conditions, while a **GREEN** indicator implies that the channel(s) have met the programmed temperature within the programmed error margins³².

³² In the case of **Constant voltage** and **Constant current** modes, since they do not have a temperature setpoint, the only possible LED states are OFF, **BLUE** or **RED**. To operate in **Constant temperature** or **Temperature Profile** mode, there should be a **GREEN** or **BLUE** LED on the selected channel(s) to show that the channel(s) are active.

3.2.1. Constant Voltage Control

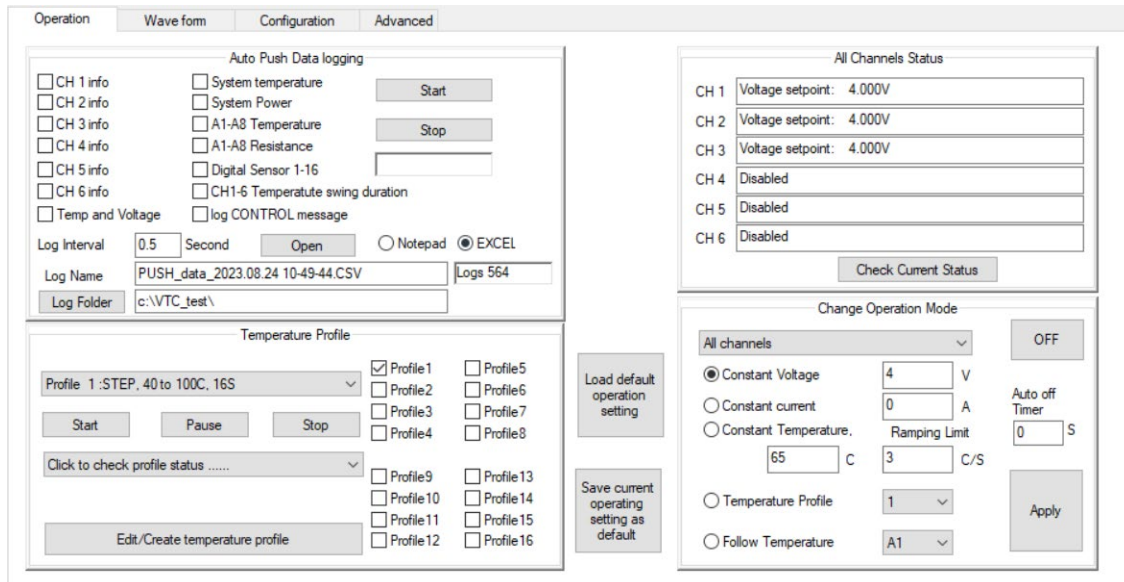
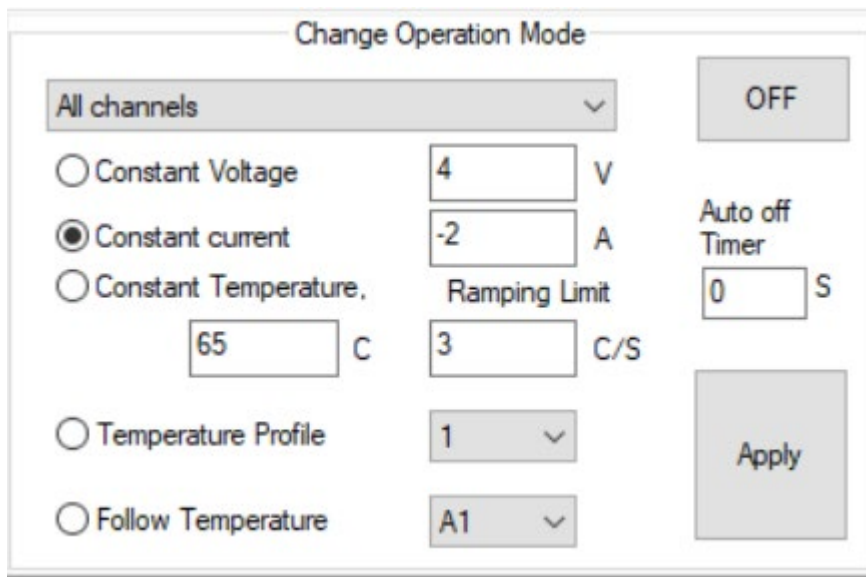


Figure 3.10: Executing Constant Voltage control

In the **“Change Operations Mode”** panel, select the **“Constant Voltage”** radio button, input the voltage setpoint for the particular channel and click on **“Apply”**. Refer to section [Error! Reference source not found.: Error! Reference source not found.](#) for more info about the layout of the panel.

The channel can be programmed to turn-off automatically after a certain period of time (in seconds) by inputting a non-zero value in the **“Auto off Timer”** input box. The Auto-off timer is ignored if it is set to 0

The indicator for the selected channel(s) shall turn **BLUE** indicating that the user specified conditions have been applied. To reset, apply 0V to the channel or click the **“OFF”** button and the indicator will no longer be lit. Figure 3.10 demonstrates Constant Voltage control.



Change Operation Mode

All channels

☐ Constant Voltage 4 V

☒ Constant current -2 A Auto off Timer 0 S

☐ Constant Temperature, 65 C Ramping Limit 3 C/S

☐ Temperature Profile 1

☐ Follow Temperature A1

Figure 3.11: Executing Constant Current control

3.2.2. Constant Current Control

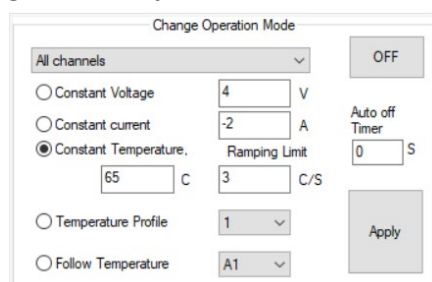
Similar to subsection [3.2.1:Constant Voltage Control](#), to use this function go to the “**Operation**” tab and select the “**Constant Current**” option, input the current setpoint and click “**Apply**”.

The channel can be programmed to turn-off automatically after a certain period of time (in seconds) by inputting a non-zero value in the “**Auto off Timer**” input box. The Auto-off timer is ignored if it is set to 0

The indicator for the selected channel(s) shall turn **BLUE** indicating that the user specified conditions have been applied. To reset, apply 0A to the channel or click the “**OFF**” button and the indicator will no longer be lit. Figure 3.11 demonstrates Constant current control.

3.2.3. Constant Temperature Control

Similar to 3.2.1: Constant Voltage Control and 3.2.2: Constant Current Control, to use this function go to the “**Operation**” tab and select the “**Constant Temperature**” option.



Change Operation Mode

All channels

☐ Constant Voltage 4 V

☐ Constant current -2 A Auto off Timer 0 S

☒ Constant Temperature, 65 C Ramping Limit 3 C/S

☐ Temperature Profile 1

☐ Follow Temperature A1

Figure 3.12: Executing Constant Temperature Control

Input the user temperature setpoint and ramping limit and click on the **“Apply”** button to start.

The **“Auto-off Timer”** works same as described in earlier operation modes.

The indicator for the selected channel(s) shall turn **BLUE** indicating that the specified temperature settings have been applied. When this indicator turns **GREEN** it shows that the desired setpoint has been reached. To reset, either apply 0V as demonstrated in to [3.2.1: Constant Voltage Control](#) or click the **“OFF”** button. Figure 3.12 demonstrates Constant temperature control.

3.2.4. Temperature Profile

The VTC has the capability to store 16 thermal profiles. The board comes with 3 pre-defined profiles. However, all 16 profiles can be edited and customized to the user’s preference as explained in section [2.2.2: Panel: Temperature Profile](#).

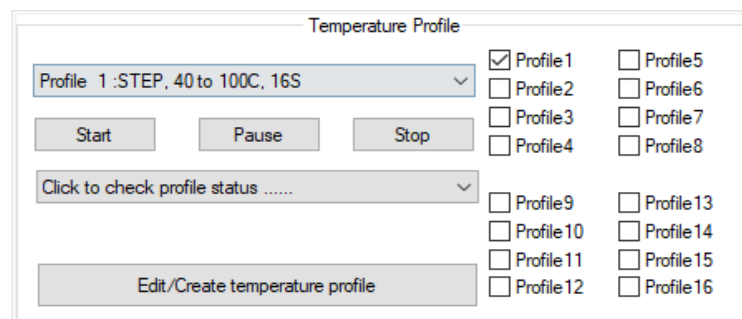


Figure 3.13: Temperature Profile Setting

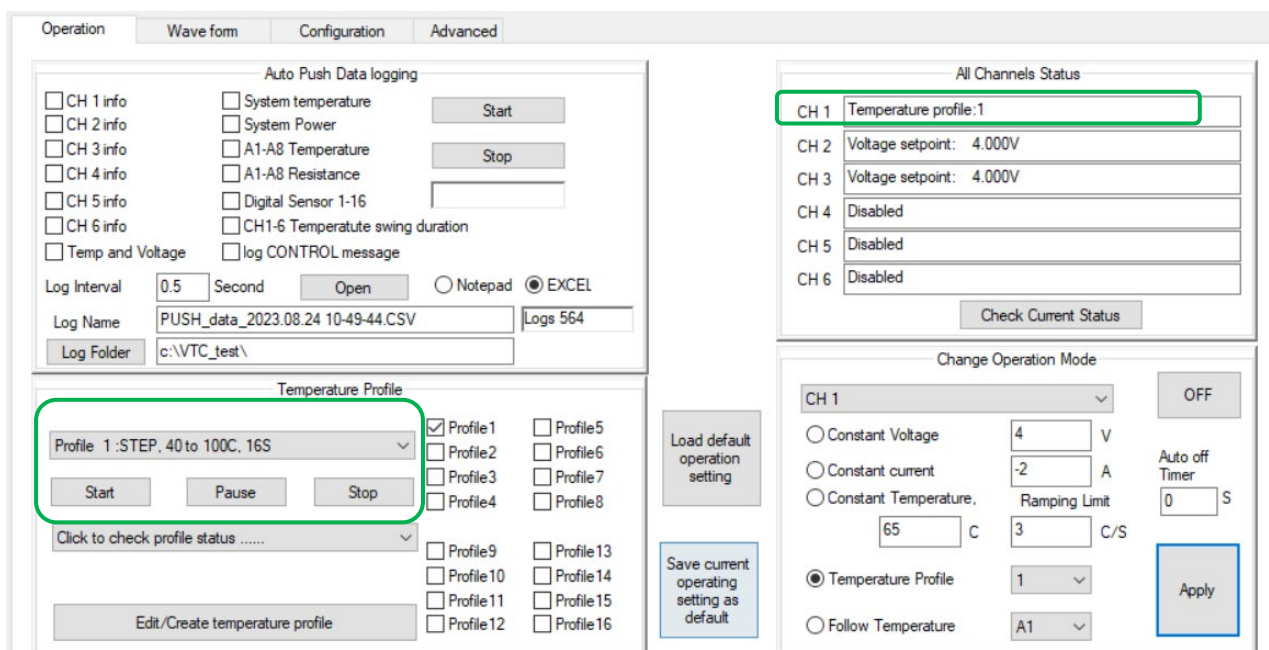


Figure 3.14: Executing a temperature profile

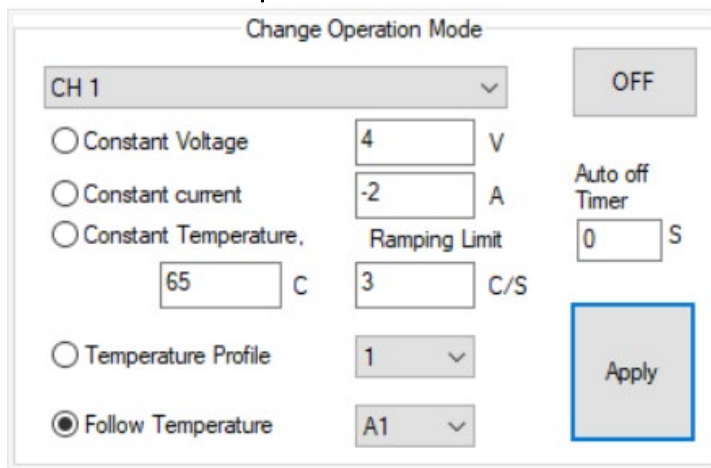
Users can assign multiple channels to a particular profile by selecting the **“Temperature Profile”** radio button and clicking on **“Apply”** for the selected channel. However, this does not execute the profile.

The channel can be programmed to turn-off automatically after a certain period of time (in seconds) by inputting a non-zero value in the **“Auto off Timer”** input box. The Auto-off timer is ignored if it is set to 0

Users can select the profile number and click **“Start”** in the **“Temperature Profile”** layout to run the profile on all channel(s) assigned to the profile. Similarly, users can pause or stop the profile by clicking the **“Pause”** and **“Stop”** buttons respectively.

Figure 3.14 demonstrates executing temperature profile.

3.2.5. Follow temperature



Change Operation Mode

CH 1

☐ Constant Voltage 4 V
☐ Constant current -2 A
☐ Constant Temperature, 65 C Ramping Limit 3 C/S
☐ Temperature Profile 1
☒ Follow Temperature A1

Auto off Timer 0 S

Apply

go to the **“Operation”** tab and select the **“Follow Temperature”** option, and **“Apply”**. Then this channel will be controled to follow selected temperature sensor.

4. APPENDIX

This section will highlight the potential problems users might face, as well as the troubleshooting steps for such issues. It will also list down all of the error codes which may be seen whilst using the software.

4.1. TROUBLESHOOTING

This section contains info on solving some issues commonly faced by users. If the issue persists, please contact Venture.

4.1.1. Check for Firmware Version

Check with the sales representative if the firmware version which you have downloaded is the latest as it may contain feature enhancement as well as certain bug fixes. If not, a firmware update of the VTC is required.

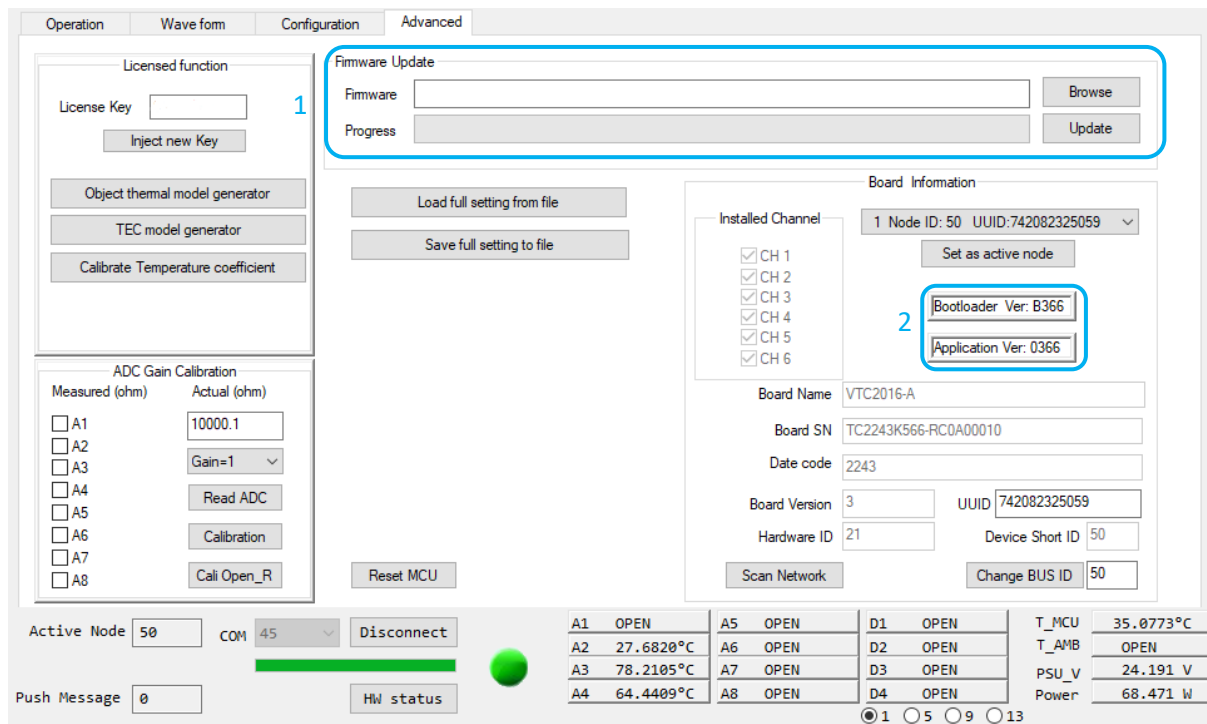


Figure 4.1: Firmware Update

As shown in Figure 4.1, users can update their bootloader and application firmware version in (1).

A firmware update can be performed by going to **Advanced** → **Browse** → Select the appropriate firmware file → Click on **“Update”**.

VTC Utility will automatically update³³ the current bootloader version as well as the application version, without a need for any user intervention. The current versions shall be visible in (2)

³³ Users need to disconnect and re-connect the VTC after a successful firmware update for the versions to be reflected in (2).

4.1.2. Hardware Status

A. Overview

Users can query VTC hardware status by clicking the “**Hardware Status**” button at the bottom of the screen (Figure 4.2). A popup dialog shall open which would show the potential hardware problems present in the VTC

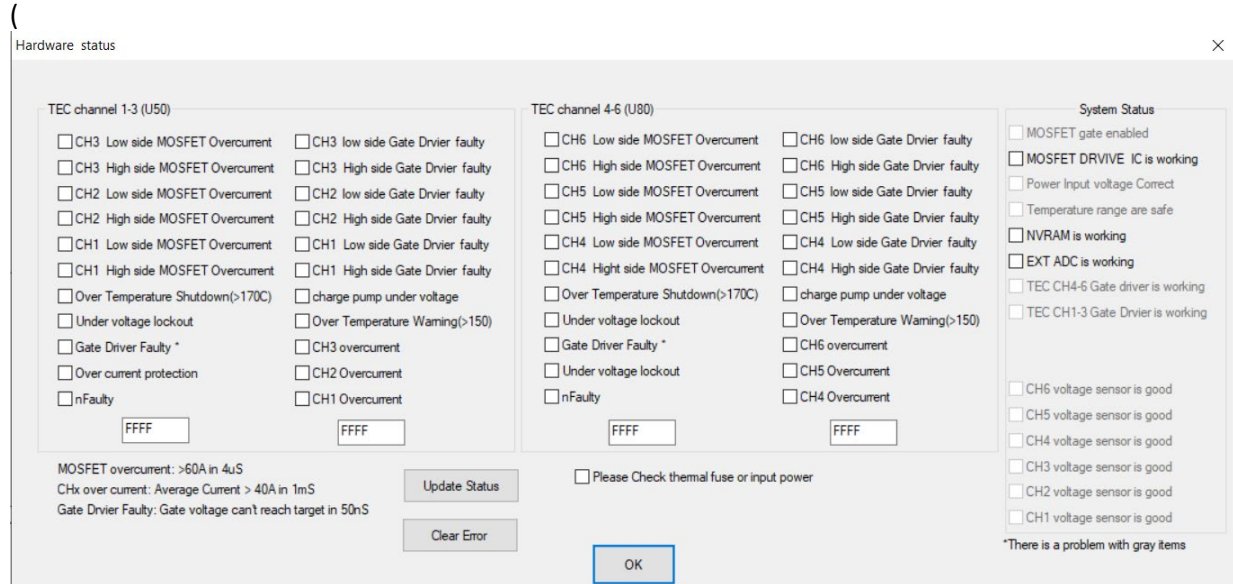


Figure 4.3).



Figure 4.2: Hardware Status button

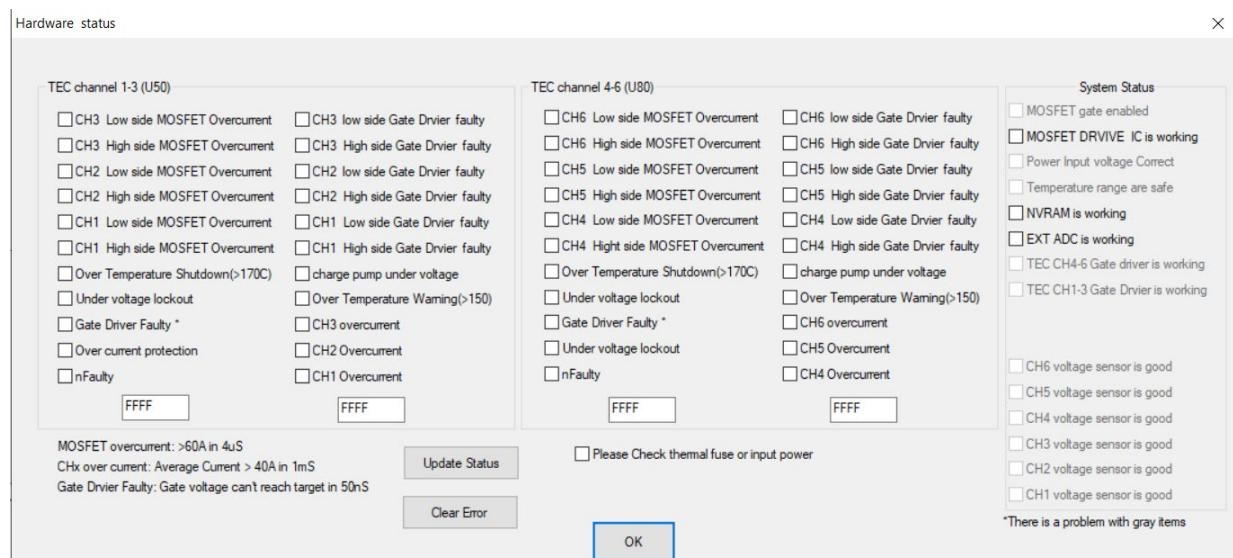
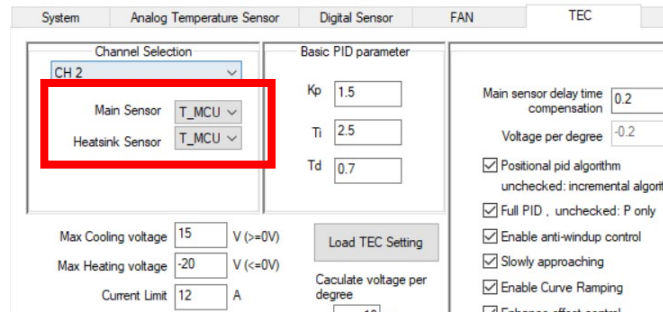


Figure 4.3: Hardware Status dialog

In system status, any item grey color mean this item is wrong. When Thermal fuse broken or no external Power supplier, you would see all channel have problem.

If system show grey on “temperature range are safe”, mostly cause by some channel temperature sensor Open, Short or Type miss match this channel will force output 0V.

if some application use VTC for output voltage/current without any concern on temprature, please select T_MCU as dummy sensor.



System Analog Temperature Sensor Digital Sensor FAN TEC

Channel Selection
CH 2

Main Sensor T_MCU
Heatsink Sensor T_MCU

Basic PID parameter
Kp 1.5
Ti 2.5
Td 0.7

Max Cooling voltage 15 V ($\geq 0V$)
Max Heating voltage -20 V ($\leq 0V$)
Current Limit 12 A

Load TEC Setting

Calculate voltage per degree

Main sensor delay time compensation 0.2
Voltage per degree -0.2

☒ Positional pid algorithm
unchecked: incremental algorithm
☒ Full PID, unchecked: P only
☒ Enable anti-windup control
☒ Slowly approaching
☒ Enable Curve Ramping
☒ Enhance effect control

B. List of Error Codes

This subsection shows all of the error codes present in this software, with its corresponding meaning.

In the case of Fault status register 1 (address = 0x00), the different errors are described in the tables below.

Register access type: Read only

10	9	8	7	6	5	4	3	2	1	0
FAULT	VDS_OCP	GDF	UVLO	OTSD	VDS_HA	VDS_LA	VDS_HB	VDS_LB	VDS_HC	VDS_LC
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b

Table 4.1: Fault Status Register 1

Bit	Field	Type	Default	Description
10	FAULT	R	0b	Logic OR of FAULT status registers. Mirrors nFAULT pin
9	VDS_OCP	R	0b	Indicates VDS monitor overcurrent fault condition
8	GDF	R	0b	Indicates gate drive fault condition
7	UVLO	R	0b	Indicates undervoltage lockout fault condition
6	OTSD	R	0b	Indicates overtemperature shutdown
5	VDS_HA	R	0b	Indicates VDS overcurrent fault on the A high-side MOSFET
4	VDS_LA	R	0b	Indicates VDS overcurrent fault on the A low-side MOSFET
3	VDS_HB	R	0b	Indicates VDS overcurrent fault on the B high-side MOSFET
2	VDS_LB	R	0b	Indicates VDS overcurrent fault on the B low-side MOSFET
1	VDS_HC	R	0b	Indicates VDS overcurrent fault on the C high-side MOSFET
0	VDS_LC	R	0b	Indicates VDS overcurrent fault on the C low-side MOSFET

Table 4.2: Fault Status Register 1 fields

Similarly, there is a fault register 2 (address = 0x01) and the different errors are described in the tables below.

Register access type: Read only

10	9	8	7	6	5	4	3	2	1	0
SA_OC	SB_OC	SC_OC	OTW	CPUV	VGS_HA	VGS_LA	VGS_HB	VGS_LB	VGS_HC	VGS_LC
R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b	R-0b

Table 4.3: Fault Status Register 2

Bit	Field	Type	Default	Description
10	SA_OC	R	0b	Indicates overcurrent on phase A sense amplifier (DRV8323xS)
9	SB_OC	R	0b	Indicates overcurrent on phase B sense amplifier (DRV8323xS)
8	SC_OC	R	0b	Indicates overcurrent on phase C sense amplifier (DRV8323xS)
7	OTW	R	0b	Indicates over temperature warning
6	CPUV	R	0b	Indicates charge pump undervoltage fault condition
5	VGS_HA	R	0b	Indicates gate drive fault on the A high-side MOSFET
4	VGS_LA	R	0b	Indicates gate drive fault on the A low-side MOSFET
3	VGS_HB	R	0b	Indicates gate drive fault on the B high-side MOSFET
2	VGS_LB	R	0b	Indicates gate drive fault on the B low-side MOSFET
1	VGS_HC	R	0b	Indicates gate drive fault on the C high-side MOSFET
0	VGS_LC	R	0b	Indicates gate drive fault on the C low-side MOSFET

Table 4.4: Fault Status Register 2 fields

5. REVISION HISTORY

Version	Date	Description of Change
0.0.1	26 May 2023	Initial Release
0.0.2	25 Aug 2023	Added follow mode
0.0.3	08 Sep 2023	Corrected some text alignment issues
0.0.4	02 Sep 2026	Corrected typographical errors

6. LEGAL NOTICES

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Except where required by law, specific testing of all parameters of each Product is not necessarily performed.

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