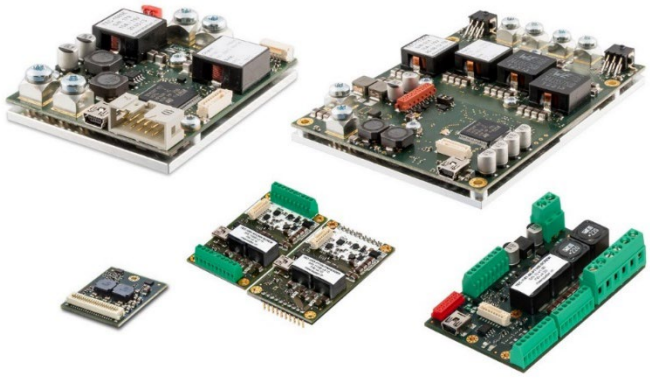
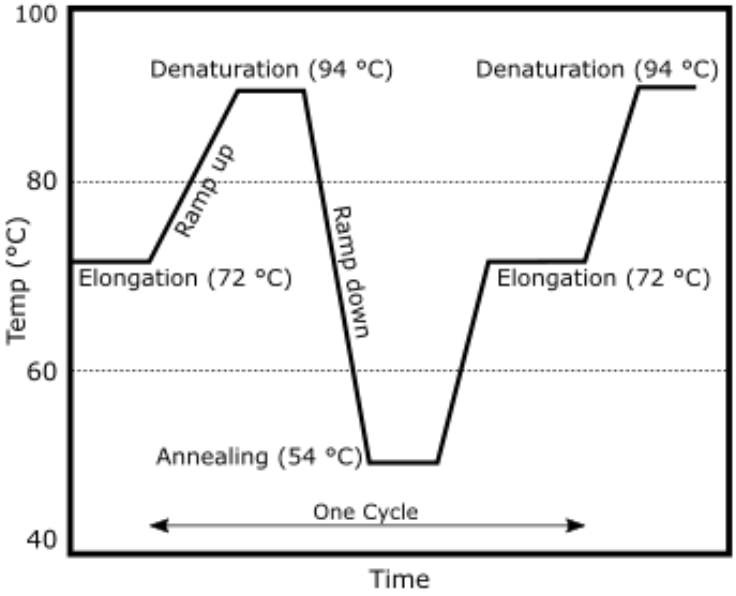
Temperature Cycling with TEC Controller – Application Note





meerstetter engineering

Member of Berndorf Group

Developed, assembled, and tested in Switzerland

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Meerstetter Engineering GmbH
Schulhausgasse 12
CH-3113 Rubigen
Switzerland

Phone: +41 31 529 21 00
Email: contact@meerstetter.ch

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1 Introduction and scope

During the Covid-19 pandemic, the need for fast and reliable PCR tests increased massively. The Meerstetter TEC Controllers are able to autonomously drive the temperature curves of the reactants typical for the polymerase chain reaction (PCR).

This paper addresses system integrator engineers and developers, that are building a PCR test apparatus or any other device, that periodically performs temperature curves, which we call temperature cycling.

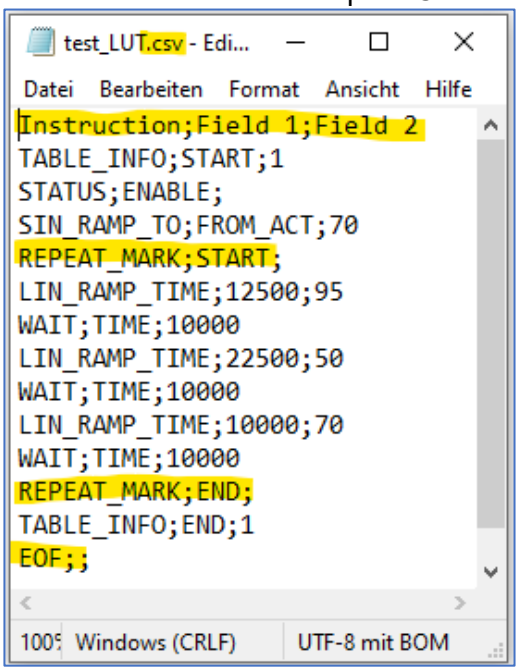
Therefore, this paper describes how temperature profiles for temperature cycling are created and executed with a Meerstetter TEC Controller. So-called “Lookup Tables” (*LUT*) are used for this purpose. LUT are tables with operations which the TEC Controller processes and thus generates the desired temperature curve.

In any case where you have trouble, please get in contact with our great support staff for questions, the requirement of further assistance and feedback.

support@meerstetter.ch
Tel: +41 31 529 21 00 (Time Zone Berlin, Berne)

2 Procedure

2.1 LUT Instructions Preparation

Step	Action	Information / Feedback
1.1	✂ We propose to write a LUT with an editor. There, a LUT instruction is defined and introduced by a line with three elements divided by semicolons. (Instruction; Field 1; Field 2). ✂ The end of the File is always set with the "EOF;;" ✂ Basic Instruction with a Repeat-Circle:  ✂ Save the LUT as a *.csv file and in the "UTF-8 with BOM" coding.	ⓘ With each installation of Meerstetter TEC Service Software or TEC Configuration Software, the routine puts a folder link with the name "TEC Software vX.XX Additional" on your desktop. In it you will find the "Lookup-Table Dok". You can use LUT from it for testing purposes. ⓘ On the second sheet of each Excel table, you will find further explanations of the commands. ⓘ *.csv-files can be opened either in Excel or with an editor.
1.2	✂ If you are working with Excel tables, let the ";" beside and use a colon for each element. ✂ Export the table with "Save as" and choose the "CSV-UTF8" format.	ⓘ Before exporting a LUT from Excel, be sure to delete the fourth column completely.

2.2 Write a Thermocycling LUT

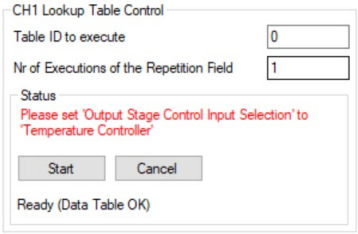
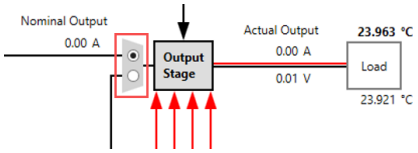
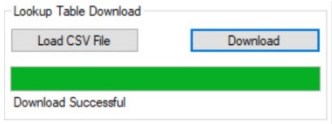
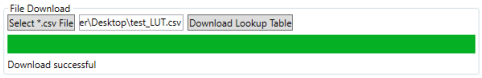
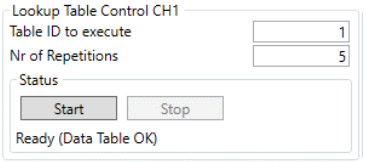
Step	Action	Information / Feedback

2.1	✕ Assuming the thermocycling process needs to target tree temperature zones at 95, 50 and 70°C. The LUT looks like this:
	
	`Instruction;Field 1;Field 2`
	`TABLE_INFO;START;1`
	`STATUS;ENABLE;`
	`SIN_RAMP_TO;FROM_ACT;70`
	`REPEAT_MARK;START;`
	`LIN_RAMP_TIME;12500;95`
	`WAIT;TIME;10000`
	`LIN_RAMP_TIME;22500;50`
	`WAIT;TIME;10000`
	`LIN_RAMP_TIME;10000;70`
	`WAIT;TIME;10000`
	`REPEAT_MARK;END;`
	`TABLE_INFO;END;1`
	`EOF;;`
		ⓘ This process starts at any temperature and targets firstly a temperature of 70°C to get a consistent starting temperature. After which the temperature is increased to 95°C, then holds this temperature for 10 seconds and moves down to 50°C, waits another 10 seconds until raises again up to 70°C, to hold this temperature again for 10 seconds.
		ⓘ The REPEAT_MARK;END; indicates the Point, where the process jumps up to REPEAT_MARK;START; and starts over again, if set (see 3.3).
		ⓘ Using the command SIN_RAMP_TO assures that the aimed temperature will be approached smoothly and with a minimal overshoot.

2.2	✕ From now it's easy to adjust the parameters the way you desire, i.e., reduce the wait ratio or use other temperatures.	

2.3	✕ You can also define very steep heating/cooling curves in a LUT by using the command LIN_RAMP_TIME, for example:
	
	`Instruction;Field 1;Field 2`
	`TABLE_INFO;START;1`
	`STATUS;ENABLE;`
	`SIN_RAMP_TO;FROM_ACT;70`
	`REPEAT_MARK;START;`
	`LIN_RAMP_TIME;3000;95`
	`WAIT;TIME;10000`
	`LIN_RAMP_TIME;3000;50`
	`WAIT;TIME;10000`
	`LIN_RAMP_TIME;3000;70`
	`WAIT;TIME;10000`
	`REPEAT_MARK;END;`
	`TABLE_INFO;END;1`
	`EOF;;`
		ⓘ The capacity of following this curve is mostly defined by your hardware setup. For example: The bigger the mass of the tempered equipment, the slower your curve can rise or fall. Additionally, the matching TEC Controller for the desired performance is needed. Further information about finding the best configuration see our Compendium.
		ⓘ Using steeper curves increases the risk of overshoot.
		ⓘ Very fast rise times can be defined in the lookup table. But consider, the TEC Controller might not be able to drive those temperature curves.

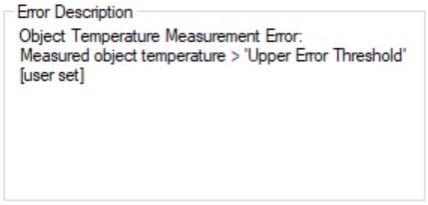
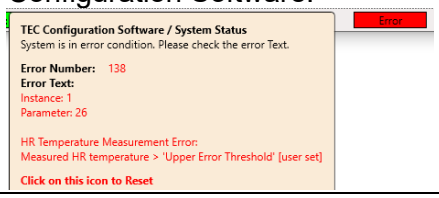
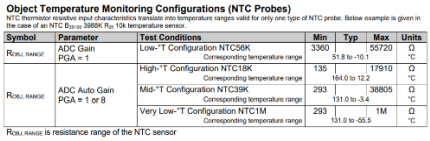
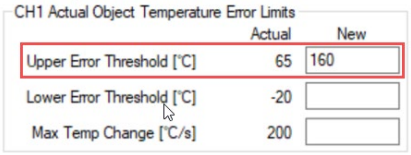
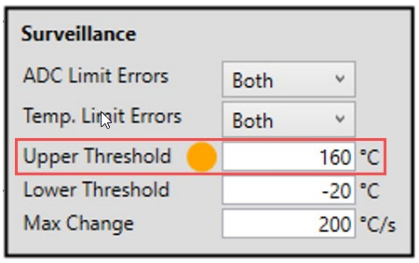
2.3 Execution

Step	Action	Information / Feedback
3.1	🛠 To use a LUT, two options must first be defined: ***TEC Service Software*:** - In the tab “Operation” at “CH1 Output Stage Control Input Selection” set the value to “Temperature Controller” - In the same tab under “CH1 Output Stage Enable” set the value to “Live OFF/ON”. - Transfer both values to the TEC Controller with “Write Config” (bottom right). ***TEC Configuration Software*:** - Open the “Temperature Controller” window by clicking on the corresponding TEC Channel. - Here, set “Temperature Controller” as source for the output stage. - Transfer the new configuration to the TEC Controller by pressing the “Enter” key or the button on the bottom right of the screen.	***TEC Service Software*:** 🔍 Information (in the “Advanced” → “Lookup Table” tab) if settings are not changed correctly:  ⓘ Consider the channel(s) you use. ***TEC Configuration Software*:** ⓘ Source set to “Temperature Controller”: 
3.2	***TEC Service Software*:** 🛠 In tab “Advanced” you find the tab “Lookup Table”. Click on “Load CSV File” and select a table (*.csv File). 🛠 Load the table into the TEC Controller with “Download”. ***TEC Configuration Software*:** 🛠 In the main window, click on “Lookup Table”. 🛠 Click on “Select *.csv File” and select a table (*.csv File). 🛠 Load the table into the TEC Controller with “Download Lookup Table”.	🔍 Successful download in the Service Software:  🔍 Successful download in the Configuration Software: 
3.3	🛠 Select the table ID to execute and the number of runs in the same tab under “Lookup Table Control CH1” and start the process with a click on “Start”.	ⓘ Table ID is defined in your LUT on the line with the instruction TABLE_INFO; START; X (See Point 2.1.). 🔍 Table 1 will be executed five times: 

Step	Action	Information / Feedback
3.4	✕ You can tune the setup by adjusting some settings: e.g., the “Coarse Temp Ramp” in the TEC Service Software within the “Temperature Control” tab or in the TEC Configuration Software within the “Temperature Controller” window. This parameter defines the maximum rate of temperature change allowed by the TEC Controller.	

3 Troubleshooting

3.1 Object Temperature Limit

Step	Action	Information / Feedback
1	ⓘ What if the object temperature limit of the TEC controller is too low for the desired temperature?	ⓘ Error Description in the “Monitor” tab of the Service Software:  ⓘ Error Description in the Configuration Software: 
2	🛠 Look at the datasheet of your TEC Controller to verify the allowed object temperature range of the corresponding temperature sensor.	ⓘ Screenshot datasheet: 
3	🛠 If the upper value from step 2 is big enough for your cycling, set it as a new value for the “Upper Error Threshold [°C]”: ***TEC Service Software*:** - In the tab “Object Temperature” and press “Write Config” (bottom right). ***TEC Configuration Software*:** - In the Analog Input Window (“HR Input x”, “LR Input x”) in the “Surveillance” box and press the “Enter” key to accept the new value.	ⓘ Value in the Service Software:  ⓘ Value in the Configuration Software: 

4 Further Literature

- Meerstetter compendium entry about “Temperature Cycling”
- TEC-Family User Manual (Chapter 4 about Control Loop and Temperature Control; Chapter 7 on Lookup Table)

A Change History

Date	Version	Changed / Approved	Change / Reason
02. Sept. 2021	A	RK	Created document
Oct. 2021	B	MR	Corrections, extended introduction
12. Nov. 2021	B	RK / CU	Updates from review CU, added Troubleshooting
18. Oct. 2022	C	HS / RK	Example Lookup table updated Information under 2.3 updated
29. Nov. 2024	D	SR / XF	Added instructions for the TEC Configuration Software