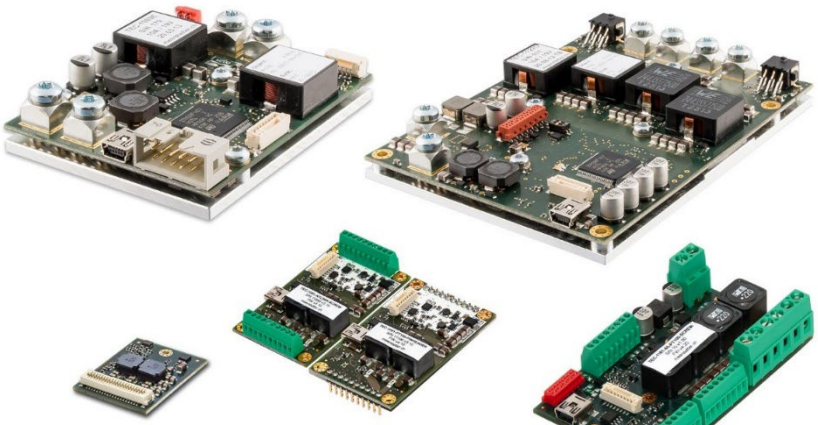
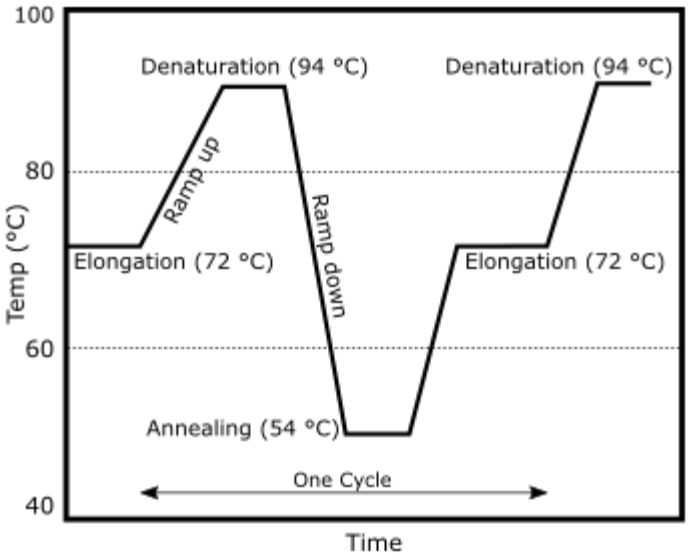
Temperature Cycling – Application Note





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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.

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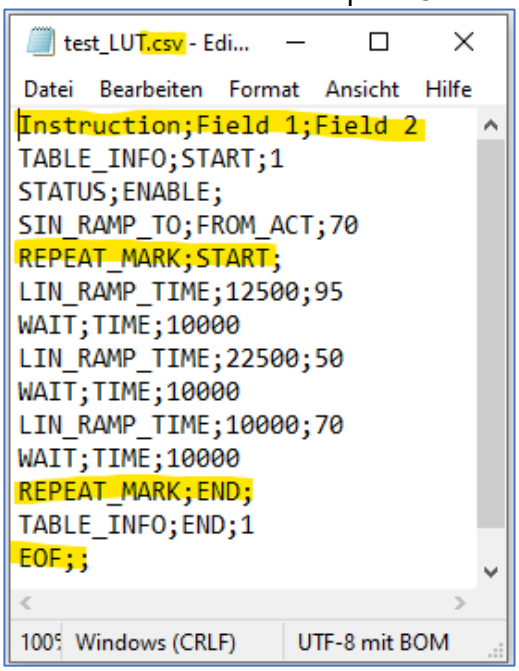
2 Procedure

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 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

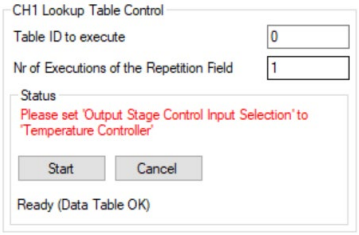
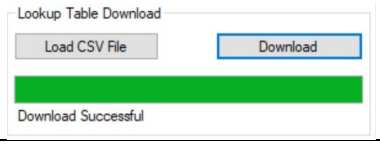
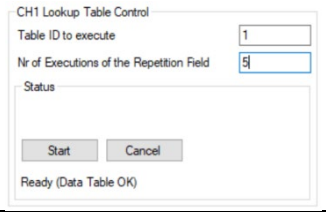
Step	Action	Information / Feedback

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 s and moves down to 50°C, waits another 10 s until raises again up to 70°C, to hold this temperature again for 10 s.
		ⓘ 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 overdrive.

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 LUT, two options must first be defined in the Meerstetter 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).	Information (at tab “Advanced” → tab “Lookup Table”) if settings are not changed correctly:  Consider the channel(s) you use.
3.2	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".	Successful download: 
3.3	Then select the table ID to execute and the number of runs in the same tab under "CH1 Lookup Table Control" 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: 
3.4	You can tune the setup by adjusting some settings in the TEC-Service Software: I.E., “Coarse Temp Ramp” at the “Temperature Control”-Tab. This parameter defines the maximal 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 on tab “Monitor” Error Description Object Temperature Measurement Error: Measured object temperature > 'Upper Error Threshold' [user set]
2	🛠 Look at the datasheet of your TEC Controller to verify the allowed object temperature range of the corresponding temperature sensor.	ⓘ Screenshot Datasheet: **Object Temperature Monitoring Configurations (NTC Probes)** NTC thermistor resistive input characteristics translate into temperature ranges valid for only one type of NTC probe. Below example is given in the case of an NTC $B_{25/85}$ 3988K R_{25} 10k temperature sensor. Symbol / Parameter / Test Conditions / Min / Typ / Max / Units $R_{OBJ,\ RANGE}$ — ADC Gain PGA = 1 — Low-°T Configuration NTC56K (Corresponding temperature range 51.8 to -10.1) — 3360 — 55720 — Ω / °C $R_{OBJ,\ RANGE}$ — ADC Auto Gain PGA = 1 or 8 — High-°T Configuration NTC18K (Corresponding temperature range 164.0 to 12.2) — 135 — 17910 — Ω / °C Mid-°T Configuration NTC39K (Corresponding temperature range 131.0 to -3.4) — 293 — 38805 — Ω / °C Very Low-°T Configuration NTC1M (Corresponding temperature range 131.0 to -55.5) — 293 — 1M — Ω / °C $R_{OBJ,\ RANGE}$ is resistance range of the NTC sensor
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]” at the tab “Object Temperature” and press “Write Config” (bottom right)	ⓘ Change value: CH1 Actual Object Temperature Error Limits Actual / New Upper Error Threshold [°C] 65 160 Lower Error Threshold [°C] -20 Max Temp Change [°C/s] 200

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

Datum	Version	Bearbeiter/ Freigabe	Änderung / Grund
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