Temperature calibration

Introduction

The purpose of this experiment is to establish a relation between the Arduino input voltage registered at the surface of the aluminum tube in response to the action of the heating resistors and the temperature of the culture obtained by the use of a thermometer. Once this transfer function has been obtained the turbidostat can act automatically to maintain the temperature of the LB medium at a fixed level set by the user.

Materials

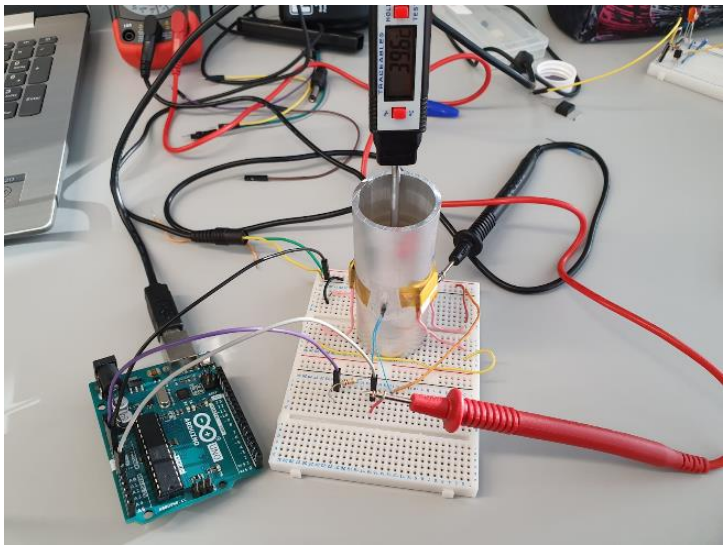
- 2 heating resistors
- Thermistor
- Electronic circuit (*see electronics module* in *Hardware* page)
- Thermometer
- Glass vial
- Aluminium tube
- ~15 mL LB medium

Procedure

First of all, it must be understood how the heat propagates within the turbidostat. As explained in the *Hardware* page, the 2 heating resistors as well as the thermistor are placed in direct contact with the aluminum tube. When these heaters are activated, they generate heat, which will be rapidly propagated over the aluminum tube and will slowly warm up the LB medium (placed inside the glass vial). The thermistor will "capture" the temperature, that is, its resistance will change as the temperature varies. It has to be taken into account that the temperature to be targeted is inside the cell culture, not in the aluminum tube. Therefore, in order to reach a certain temperature within the culture, the heating resistors must get to higher temperatures.

Before starting the calibration some setup has to be done. A vial containing 14 ml (to know the reason for the selected volume check *Volume effect* document) and a stirring magnet are placed inside the aluminum tube. Note that during the whole experiment the fan will be turned on in order to homogenize the sample. The turbidostat is then covered with its box in order to match the conditions at which it will operate and avoid possible future performance distortions. Regarding the code that will govern the experiment, the setup value to which the system will tend (check *Temperature control* section in *Software* page) is defined as the analog value that the thermistor will record at the aluminum tube's surface, and not as the desired temperature of the culture.

Once everything is prepared the process of calibration can start. One value per second is registered at the Arduino input pin connected with the thermistor, which is continuously compared to the previously defined setup value, leading thus to the automatic activation and deactivation of the heating resistors mediated by the PID controller. Before measuring the temperature associated with that specific analog value, around 30 minutes must pass. This time delay emerges due to the differences among the thermokinetic characteristics of the aluminum tube and the LB medium: heat gradients are generated between both materials, which will generate calibration distortions unless enough time is waited for them to reach equilibrium. The indicated steady state is reached when the heating resistors fall into a continuous activation and deactivation process. At this moment, a thermometer directly touching the medium is utilized with the aim to correlate the previously defined analog value with the real temperature.



This process is performed for various analog values until a proper characterization of the behaviour of the turbidostat is achieved, yielding a table that correlates the temperature at the thermometer and the value at the Arduino input pin. As many measurements as needed can be done, ours can be appreciated in the next section, *Results*. It also has to be taken into account that in order to calculate the intra-variability of the turbidostat two subsequent measurements are taken for each analog value.

At last, a scatter plot of Arduino input versus temperature is drawn in Excel, where linear regression is performed to establish a transfer function. The inverse of this transfer function is computed, yielding a function that correlates temperature with respect to Arduino input voltage, which will be introduced into the final code of the turbidostat so that it can work automatically.

Results

Arduino INPUT pin	LB Temperature (ºC) Mean of Trial 1 and Trial 2
500	31,2
490	32,3
480	33,4
470	34,5
460	35,6
450	36,6
440	37,7
430	38,75
420	39,9
410	41,1

Table1: correspondence between thermistor analogic value and the measured real temperature with the thermometer

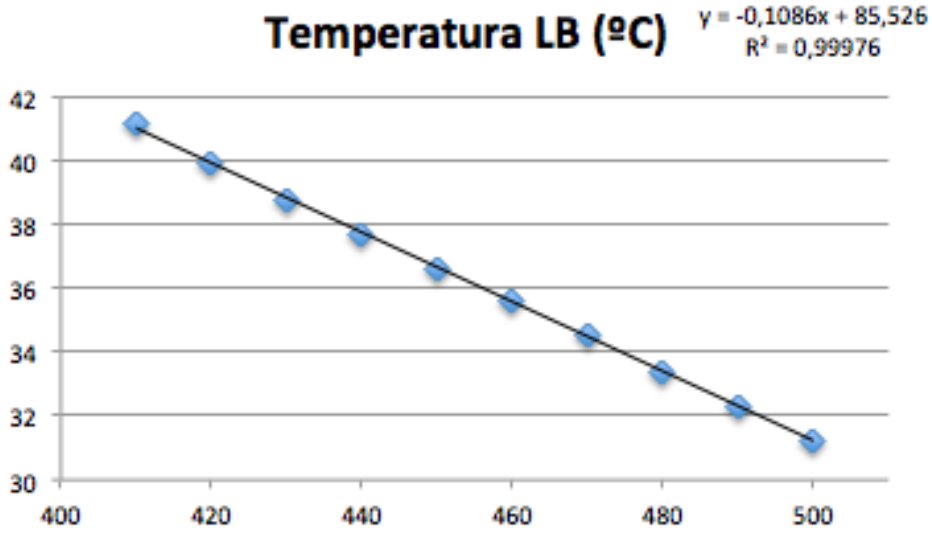


Figure 1. Linear regression of the obtained data.