3 Control and functional elements

Alpha immersion thermostat

1 Mains switch

2 Temperature controller with four segment LED display

3 Heater active (yellow LED is lit)

4 Cooler active (blue LED is lit)

5 Error signal (red LED is flashing)

6 Menu functions, select and Enter keys

7 Tubular heater

8 Temperature probe Pt100

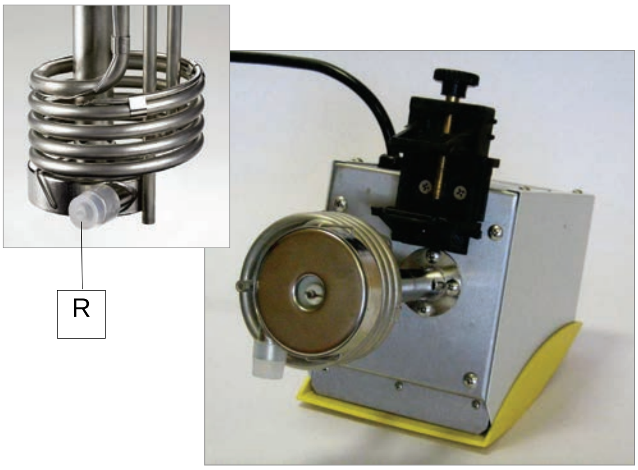
9 Pump outflow with pump outflow reducer

10 Pump housing

6 Preparations

6.1 Assembly and Setting Up

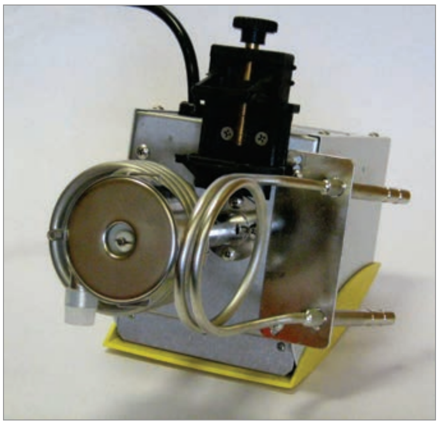
> Do not connect with power mains before assembly and setup is complete!!



Place the unit on a flat surface. If necessary, attach the appropriate pump outflow reducer R onto the pump nozzle. In small baths use the pressure reducer to prevent any splashing of heat transfer liquid.

Immersion/Heating thermostats only:

Fix the clamp at the bottom of the control head by two screws M4 x 6 A3 (1.4541) ISO 7046 (recessed countersunk flat heads).

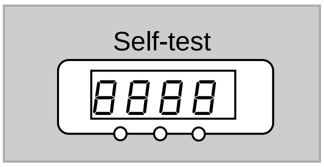


Accessory "cooling coil set":

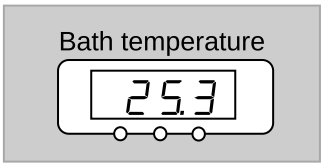
Fix the cooling coil set at the bottom of the control head by means of the two screws (pan head with cross recess). The cooling coil set belongs to the left side of the head.

7.2 Switching on

– Switch on at the mains switch; an acoustic signal is emitted for about one second.



– Initial check of display and indicators; software version is shown and the self-test becomes initiated.



– The current bath temperature is shown on the display.

– If necessary add more heat transfer liquid to replace the amount pumped out to the external circuit.

7.3 General key functions and pilot lamps

Your Alpha Thermostat is easy to operate.

Enter Key

– Switch from the current bath temperature display to the main menu;

– activates input, display flashes;

– saves input, display ceases to flash and menu point is left.

 / 

Smart Decrement / Increment Button

– Selection of sub menu or setting of numerical values.

Speeds up entry by moving the counting position to the left:

– Keys are pressed and held down.

Moves counting position to the right:

– Switching one place to the right occurs by briefly (1 second) releasing the key, followed by another pressing of the key.

 (or 4 sec.)

– Most relevant settings are accepted automatically after approximately 4 seconds

or

– the setting is accepted immediately pressing the <Enter> key.

and	– Fault signal: Flashing red Alarm LED and acoustic signal.
	– Heating is active when the yellow LED is lit.
	– Cooling is active. When the setpoint temperature is lowered, it may take up to one minute before the blue LED is lit.

7.4 Main menu structure

25.3 Current bath temperature

↓

SEt Set setpoint (⇨ 7.5)
ASd Timer, AutoShutDown (⇨ 7.6)
Hi Maximum Temperature (⇨ 7.7)
Lo Minimum Temperature (⇨ 7.7)
CooL Configure refrigeration system (⇨ 7.8)
CAL Calibrate offset probe (⇨ 7.9)
dEF Factory default settings (⇨ 7.10)
End End of menu

7.5 Temperature setpoint setting SEt

The setpoint is the temperature, which the thermostat should reach and maintain constant.

	– Press key to show SEt (Setpoint).
	– Press, display flashes.
or	– Decrement or increment the Temperature Setting (⇨ 7.3). (Temperature can be set from -25 °C up to 100 °C depending on limits Hi and Lo).
Wait 4 seconds or	– Display flashes 4 seconds → new value is automatically accepted, **or** value is accepted immediately with <Enter> key.
☞	– When the setpoint temperature is set below the bath temperature, it may take up to one minute before the blue LED ✳ lights.
☞	– Entering value closer than 5 °C to the maximum or minimum temperature limit (Hi and Lo) are not accepted. A buzzer signal appears. If necessary, first change the temperature limits (⇨ 7.7).

7.6 Automatic Shut-Down Timer ASd

The automatic Shut Down Timer can be activated/deactivated, read out or be set. At shut-down time, the pump, heater and compressor are deactivated, the display then shows "StbY" (⇨ 7.11).

1x to ASd	– call the Automatic Shut-Down Timer ASd .
	Read Timer: The display shows… "00.00": timer not active; The display shows… "*hh.mm*" (any value): timer active, (*hh.mm* minutes remaining to Shut Down)
or	Set Timer: Increment or decrement "hh.mm" (maximum 99:59) *Within 4 seconds after the last change of values confirm the timer value by pressing <Enter>.* You then proceed to Main Menu "Bath Temperature": A blinking point indicates that the timer is running!!
☞	– No change is done without confirmation by <Enter>! – You can deactivate the timer any time by setting the value "00.00".

Theory and Evaluation

In restricted temperature ranges the change in the resistance of the electrical components can be assumed to be linear. In these regions, the general formula for the dependence of the resistance on the temperature is valid

$$R(T) = R_{20} + R_{20} \cdot \alpha \cdot (T - 20\,°C)$$

where $R(T)$ = Resistance at temperature T

R_{20} = Resistance at 20 °C

α = Temperature coefficient

T = Temperature at time of measurement

By rearranging and substituting the measured values the temperature coefficient can be determined using the formula.

1. In copper wire the free path of the electrons in the electron vapour, which contribute to charge transport, becomes shorter with increasing temperature. The change in resistance can be clearly seen: the resistance increases. The result is a positive temperature coefficient

   $\alpha_{Cu} = 5.3 \cdot 10^{-3}$ /K

   The resistance of the CuNi wire is nearly constant over the measured range. This is in accordance with Mathies rule, which states that $R_{tot} = R_{20} + R(T)$. The change in the resistance with the temperature is very slight in the measured temperature range. Consequently, the absolute resistance (R_{20}) is predominant. This experiment provides a negative temperature coefficient of

   $\alpha_{CuNi} = -1.4 \cdot 10^{-4}$ /K

   In the carbon-layer resistor, the absolute resistance is very high to begin with. The change with the temperature is, as is the case with CuNi, small and has practically no effect. A negative temperature coefficient results

   $\alpha_{C} = -2.3 \cdot 10^{-3}$ /K

   The metallic layer resistor also has a relatively high absolute resistance at 20 °C. And the change in the measured temperature range is even lower than for carbon. Thus, the temperature coefficient approaches zero.

   $\alpha_{met} = \Rightarrow 0$

   The two NTC and PTC resistors consist of alloys. Depending on their compositions, great changes in resistance can be realised in a small temperature range. The curves that are recorded in this experiment can no longer be considered linear. They serve only to illustrate the behaviour of NTC and PTC resistors.

   Literature values:

   $\alpha_{Cu} = 4.0 \cdot 10^{-3}$ /K

   $\alpha_{CuNi} = -3.0 \cdot 10^{-3}$ /K

   $\alpha_{C} = -2.4 \cdot 10^{-4}$ /K

   α_{met} $\pm\, 0 \ldots 50 \cdot 10^{-6}$ /K

   $\alpha_{NTC} = -6.15\,\%$ /K

   $\alpha_{PTC} = 20\,\%$ /K

   The value for PTC is valid in the steepest region of the characteristic line.

2. In semiconductors the number of charge carriers and the charge carrier density increases with temperature (charge carrier generation, electron-hole pair formation). From the law

   $$\sigma = e \cdot n \cdot \mu$$

   where σ = Intrinsic conductivity

   e = Elementary charge

   n = Charge carrier density

   μ = Mobility

   one can see that the intrinsic conductivity of the semiconductor thus increases. The mobility indeed decreases with increasing temperature, but the increase in the charge carrier density compensates for this effect. A definite drop in resistance is observed; this allows one to infer that there is a negative temperature coefficient. Through the calculation with the above-mentioned formula for the temperature dependence, rearranged for the voltage U_p, the following values are obtained.

   $\alpha_{Si} = -3.4 \cdot 10^{-3}$ /K

   $\alpha_{Ge} = -4.6 \cdot 10^{-3}$ /K

3. p-n junctions consist of 2 separate regions made of n- and p-type semiconductors. While n-type semiconductor provides electron carriers (also called donors), p-type semiconductors accept electron carriers (also called acceptors). The n indicates "negative" for electrons and p indicates "positive" for holes. When these two types of semiconductors form an interface without external field, partial electrons diffuse into the p-type region (Fig. 1 (a)), leaving holes in the n-type region in thermal equilibrium and the product of pn is constant. Figure 1(b) shows the build in electric potential across the interface due to the diffusion. The build-in electric field sets up a potential difference within a region termed depletion area. The diffusion pushes electrons towards p-type while the electric filed pushed electrons back to the n-type region, eventually two balancing two forces and creating a zero net carrier diffusion.
   A current will flow if a forward bias is applied (Fig. 2(a)), and a current barely moves if a reverse bias is applied (Fig. 2(b)). A forward bias will smear the depletion region as carriers in depletion are free to move; namely electrons of n-type semiconductor move further into p-type whereas holes move further into n-type. The build-in electric filed decreases and cannot resist the negative charge flow from n-type (and positive charge flow from the p-type).
   On the other hand, the reverse bias sets up a higher electric field and potential barrier. When the voltage becomes high enough, either Zener or avalanche break down occurs.

Electrical measurements under various temperatures

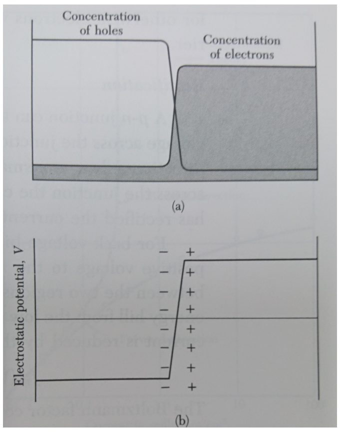


Fig. 1

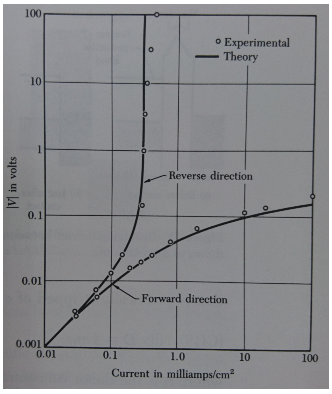


Fig. 2

4. At low voltages, around 3 V, a Zener breakdown occurs in Z diodes. As a result of the strong electric field, electron-hole pairs are spontaneously generated in the inner elec-tron shells in the barrier-layer zone. Under the influence of the field charge carrier, they cross the barrier layer. A high-er temperature increases the energy of the bound charge carriers. As a consequence, the Zener effect can occur at lower voltages. In the avalanche effect, the charge carriers are accelerated by the electric field to such a great degree that they in turn release other charge carriers on colliding with other atoms, which in turn are accelerated. The high-er temperature shortens the free path, so that the voltage must increase with the temperature in order to continue to release charge carriers. From the calculations, the follow-ing values result for α:

   $\alpha_{ZPD2.7} = -7.3 \cdot 10^{-4}$ /K
   $\alpha_{ZPD6.8} = +4.5 \cdot 10^{-4}$ /K

   Literature values:

   $\alpha_{ZPD2.7} = -9\ldots-4 \cdot 10^{-4}$ /K
   $\alpha_{ZPD6.8} = +2\ldots+7 \cdot 10^{-4}$ /K

Electrical measurements under various temperatures

Warning: During or after heating the water, the bath is hot and it could hurt your skin.
Caution: Proceed the connection of voltage supply carefully by following the wiring schemes !!!!!

Related topics

Carbon film resistor, metallic film resistor, PTC, NTC; Z diode, avalanche effect, Zener effect, charge carrier generation, free path, Mathies rule.

Principle

The temperature dependence of an electrical parameter (e.g. resistance, conducting-state voltage, blocking voltage) of different components is determined. To do this, the immersion probe set is immersed in a water bath and the resistance is measured at regular temperature intervals.

Equipment

Immersion probes f. determining α	07163.00	1
Immersion thermostat TC10	08492.93	1
Bath for thermostat, Makrolon	08487.02	1
Accessory set for TC10	08492.01	1
Digital multimeter	07128.00	1
Power supply 0-12 V DC/6 V, 12 V AC	13505.93	1
PEK carbon resistor 1 W 5 % 4.7 kOhm	39104.27	1
Connection box	06030.23	1
Connecting cord, l = 500 mm, blue	07361.04	1
Connecting cord, l = 750 mm, red	07362.01	2
Connecting cord, l = 750 mm, blue	07362.04	2

Tasks

1. Measurement of the temperature dependence of the resistance of different electrical components.
2. Measurement of the temperature dependence of the conducting state voltage of semiconducting diodes.
3. Measurement of the temperature dependence of the voltage in the Zener and the avalanche effects.

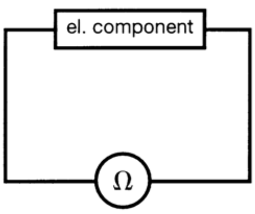


Fig. 3

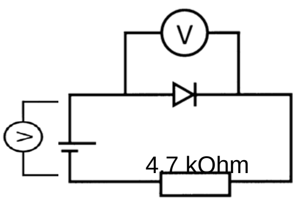


Fig. 4

Set-up and procedure

0. Fill the DI water in the plastic box to the color level. The DI water is available on the 7th floor of SC building. Place the temperature controller (Brand: LAUDA alpha) and secure it with the screw.

1. Place the immersion probe set, which is enclosed in a watertight plastic bag, into the water bath. The resistance values for the PTC, NTC, metallic film and carbon film resistors, as well as the Cu and CuNi wire resistors, can be measured directly with the digital hand multimeter (circuit diagram, Fig. 3). To do this, connect the multimeter to the ground jack, which is connected to all the components, and the jack located under the symbol corresponding to the respective component. Note the different resistance values, and plot them as a function of temperature.

   Repeating measurements for each materials listed above. Use 5 deg increment below T=40 deg, 2.5 deg increment for T=40-60 deg, and 5 deg increment for T=60-80 deg. Immerse temperature probe into the water, and thermocouple into the plastic bag. After both temperature readings reach the set point,you should wait ~5 mins for stabilization.

2. In order to measure the conducting-state voltage of the semiconducting diodes, connect them to a voltage of 10 V. Connect a 4.7 kΩ resistor in series with the component. Set a voltage of 10 V on the universal power supply, and adjust the current limiter to its maximum value. Measure the volt-age parallel to the component. Note the conducting-state voltage corresponding to the respective temperatures.
   In order to measure the correct output of the voltage supply, you need to connect another multimeter across the voltage supply.

3. To measure the blocking voltage for the Zener and avalanche effects with the set-up illustrated in Fig. 4. However, the diodes have already been wired in the blocking direction through their placement in the immersion probe set.
   Make sure you connect the ground to the correct input, otherwise, your forward and and reverse bias will be inverted. Apply the voltage from 0 V and gradually increase it (such as 0.2 V increment each time). Measure the voltage across Si, Ge, Z2.7, and Z6.8 separately. Compare the voltage across these diodes with the voltage across the voltage supply. Record each voltage and check where the discrepancy starts. Increase the voltage until the one across the Z2.7 and Z6.8 becomes a constant. This is the blocking voltage for each of them. Repeat them between temperature range of 25-80 deg (4 temperatures at least, including 25 and 80 deg.) Plot voltage across the diodes versus the measured input of total voltage.
   *Take home work: Calculate the resistance from the voltage you measure and deduce the temperature coefficient for each material.

Questions:
1. What is conductivity and resistivity? How do they play a role in your life?
2. Some materials conduct current better than others, and some do not even conduct at all. What is the origin of the conductivity (or resistivity) of the electrons in the solid materials? You should be able to explain this by using the physical microscopic point of view.
3. Can you give a scientific reason for the temperature-dependence change in resistivity of metals, semiconductors, and insulators?
4. What is a diode? How does the resistance change versus temperature? Is the V-I curve always linear for a diode?
5. What is the Zener effect and avalanche effect? How do they behave versus temperature?