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INSTALLATION WITH A COMPUTER DESIGNED AND CONTROLLED THERMOSTAT

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Abstract: *The work exposes the computer design of a digital thermostat, having a temperature measuring and display system based on the microcontroller Atmega 128, programmed with AVAR Studio 4. Operational amplifiers supply was designed using Orcad Capture. This device is working with previous imposed parameters, established taking into account the practical applications for studying liquid crystal samples, in a temperature controlled installation. Advantages of this system are the scalability, fiability and low cost.*
Keywords: *digital thermostate, computer design, liquid crystal, fatty acids, laser, thermal neutron*

1. INTRODUCTION

It is generally accepted that, at some temperatures, for some organic substances, there are multiple phases between solid and liquid state. These are the so-called “mesophases”or liquid crystals (LC), which have common properties with the solid (S) and isotropic liquid (LI) state **[1, 2]**.

As it is known, those substances, which achieve the LC state under the influence of temperature, are named thermo tropic liquid crystals. Their study is of a great interest either for the technical purposes, or for biology and medicine. In such situations, the temperature must be continuously controlled.

This paper presents an installation for studying LC samples, with a digital thermostat based on the Atmega128 microcontroller following the guidelines: interior and exterior temperature measuring using two temperature sensors; display of these two temperatures using two ±XX.X format displays; setting of interior (room temperature) in 0.1°C increments. During temperature setting, phase the exterior temperature display switches to requested temperature display. A cooling or heating output is turned on if measured temperature is greater or less than the requested temperature by 0.5°C. Power is supplied by standard power grid (220V/50Hz). After the computer layout was made, the layered circuits were printed.

Advantages of this system are the scalability, stability and low cost [3]. The work exposes shortly some general and basic ideas of the project, bloc diagrams and detailed description of the bias supply, sensors for interior and exterior temperature, display and control system, and data processing of the results. Details are given on programming the Atmega128 microcontroller (AVR Studio 4), layout design, and a list of components. The power supply, necessary for transforming power network voltage in a D.C. 5V voltage for the microcontroller, sensors and operational amplifiers supply was designed using **Orcad Capture**. Sensors are analogical devices, and because of that the majority of physical amounts have continuous spectra; the output voltage can be written in terms of the unknown temperature. The display and control devices are designed for user interaction interact with the user. For the microcontroller programming, **AVR Studio 4** (ATMEL) has been used [4]. A description of the functions used in the program is given, followed by the commented program. Then, the electric design was exported in **Orcad Layout**, and the functional zones were created, verified and realized on the cable bay-up (top and bottom layers). Real cabling was printed (TOP, BOTTOM, DRILL, and SOLDERING MASK).

By using this thermostat, LC samples made by fatty acids from the biological membrane, were studied. Some results are presented, in order to exemplify the importance of the temperature control.

2. THERMOSTAT DESIGN

The functional diagram of the data acquisition system contains six units (Fig.1):

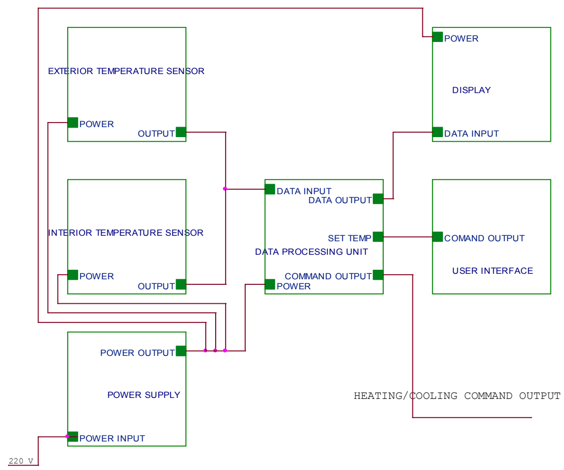

Fig. 1. System overview

2.1 Interior and exterior temperature sensors

Temperature sensors, as devices that allow room temperature transformation in an electrical signal for further processing and data acquisition, have a certain functioning range, a thermal spectrum with linear response, so the voltage or the current from the output is directly related, through a known formula, to the room temperature. The sensors used for this project must have an optimal functioning at normal temperatures. After the temperature is transformed to an electrical signal, the numeric conversion and digital processing of the signal occurs.

2.2 Display and control system

The display and control system facilitates user interfacing. Its purpose is displaying measured and user set temperatures in a ±XX.X°C format. The set temperature is controlled using UP/DOWN push-buttons, and switching between the two operating modes (set/measure) is done using a switch button and both act as inputs on microcontroller ports. Also, by microcontroller reprogramming, the control features of the system can be extended in whichever way the user needs (i.e. more complex control functions can be added).

2.3 Data processing systems

The sensors output electrical signals are analogical. The conversion to a numerical (digital) signal and also processing of this data is done by the microcontroller. The conversion is done by the microcontroller's ADC (analog to digital converter). The data processing stage is done using the internal registers and ALU (arithmetical logical unit) and the output is transmitted to the display system. Functionality programming of the microcontroller is done using code from an integrated flash memory. Reprogramming can also be done to extend functionality features of the system, in case the user needs more complex processing of data or automation features (i.e. data collecting in memory, data comparison).
Both interior and exterior temperature acquisition systems have an identical electrical structure, built around the LM135 integrated circuit temperature sensor. The output voltage of this device is given by a linear variation: $V_{out} = V_{outT0} \frac{T}{T_0}$, where T_0 is the calibration temperature.

2.4 Temperature acquisition operation

First, calibration at a known temperature is done using the R35 and R45 potentiometers (Fig. 4). Because of the linearity of the sensor, the circuit will be calibrated at any temperature in the operating range.

After this calibration, the voltage-temperature variation characteristic of the device shows that in the -50°C ... +50°C temperature range, the voltage output will vary between 2.2315V and 3.2315V. Because the sensor's minimum current is 0.3mA, a rounded value 1mA current will be injected through the sensor, to ensure good operating conditions.

Knowing the fact that at +50°C the voltage on the sensor's terminals must be 3.2315V and the sensor is powered from VCC (+5V), a 1.7685kΩ resistance is needed in the powering circuit. A rounded value of 1.8kΩ is chosen, resulting in a bias current of 0.98mA. Also, it is easy to see that at -50°C through the sensor will pass a 1.54mA current which is in the specified range, ensuring a correct operation even at bottom of the temperature scale.

Because the microcontroller's ADC input needs a voltage between 0 and 2.5V, a LM336 voltage reference (2.5V) IC will be used. Next, the 2.5V from the voltage reference is lowered by the operational amplifier U_{32} to 2.2315V and then added to the sensor's output voltage to obtain a [0,1]V output interval corresponding to the -50°C ... +50°C temperature interval .The resulting voltage needs to be amplified 2.5 times to obtain a correct input voltage for the ADC. This is done by using the U_{31} operational amplifier and adjacent resistances. Following these conversions, a [0,2.5]V voltage interval and a 25mV/°C sensibility is obtained at the output of the temperature acquisition system.

Next, the acquired data is inputted in the 10 bit ADC which has an internal voltage reference of 2.56V. Because of the 10 bit ADC, there will be 1024 possible levels of quantization. As a result, corresponding to a voltage of 2.5V, is the number 1000, which eases further calculation (there will be 500 levels corresponding to negative temperatures and 500 levels for the positive ones), and also sets temperature quantization in 0.1°C increments.

2.5 Atmega128 microcontroller

The Atmega128 is a powerful, easy to adapt, cost effective microcontroller produced by the Atmel corporation, a full set of characteristics for this microcontroller can be obtained from its datasheet catalogue.

For this digital thermostat, the internal oscillator was used to generate the 8MHz clock frequency, using bits CKSEL (3, 2, 1 and 0) from the first byte of the Fuse register and setting them to 0100. The oscillator input pins have been left disconnected. The first two pins of the F port were used to connect the ADC to the temperature sensors and because of that a 2.56V voltage reference was needed. As a consequence, the AREF pin has been connected to VCC.

2.6 Temperature display system (in/ext)

The display system is made up of two groups of four rectangular LEDs used to display the sign(+/-) and six 7-digit displays (7 SEG-AC). These have 7 rectangular LEDs and a dot LED, with a common anode. Through the anode current the sequential lighting of each 7-digit display is controlled (AN0-AN5). The digit displayed is controlled by the logical combination of the input port (IN0-IN7). The two temperatures are displayed as follows:

- 10X digit will be displayed on U11 and U14;
- 1X digit will be displayed on U12 and U15; the pin controlling the dot lightis connected to the ground through a 330 Ω resistance to ensure permanent lighting
- 0.1X will be displayed on U13 and U16

Several 330 Ω resistances were used so that the voltage applied on the LEDs is below 3V (maximum current 10mA) and the displays are protected from over-current

As mentioned before, the lighting of the six displays is done sequentially, but with a high enough frequency to give the impression that they are switched on permanently. The numerical combination on the input ports is outputted by the microcontroller. Thus, corresponding to each digit, there is an 8 bit combination of 0 and 1. These are used to program the microcontroller and are given later on in a table. The MSB of these codes is always 0 so it is grounded.

The sign inputs (+/-) for both interior and exterior temperature are connected to the two 4 LED groups so that if an input is in a logical 1 state (+5V) , the + sign is displayed and if the input is null the - sign is displayed. The pair of LEDs corresponding to the - sign is always on.

The wiring schematic contains 3 switches (Fig. 2), connected to port D. Two of them are push-buttons, used for UP/DOWN temperature setting of 0.1°C, and one of them is a switch that controls the operation mode (temperature measurement/setting).

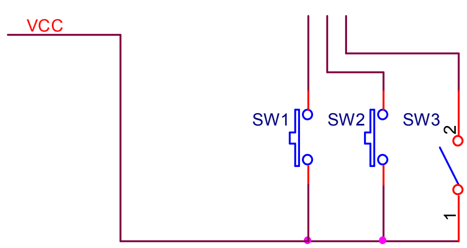

Fig. 2. Temperature control schematic

The outputs (Fig.3) of the thermostat, through which the system controls the heating and cooling elements or relays, are simple output pins. The microcontroller decides whether heading or cooling is necessary (by making a comparison between interior and set temperature) and sends a command signal through the outputs: if the interior temperature is lower by 0.5°C than the set temperature, it enables the PB0 pin (heating) or if the temperature is higher by 0.5°C than the set temperature, it enables the PB1 pin (cooling).

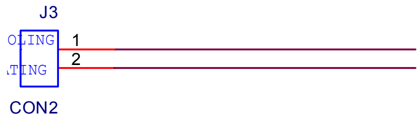

Fig. 3. Cooling/Heating outputs

2.7 Microcontroller programming (AVR Studio 4)

Programming of the Atmega128 microcontroller is done by using the AVR Studio 4.0 application, produced also by Atmel. The AVR architecture is compatible with a broad range of C compliers, debuggers and emulators. The assembler programming language was used for obvious code execution speed advantages.

The program starts by setting up the microcontroller and initializing the ADC conversion for interior temperature. Resulting data is saved in xh and xl registers. Next, an amount of 500 is subtracted from the result to obtain the 50.0°C...+50.0°C range needed. In stead of the XX.X form numbers , XXX form numbers were used to simplify calculations. The dot is obtained in the display module. Next, the bin2bcd function transforms the resulted value from binary code into binary coded digits which are stored into 3 separate registers. The result is outputted to the display module through the afis function. This function associates each digit a hexa code equivalent to the combination of signals needed to display the digit.

Control is the function controlling the heating/cooling process. It compares interior temperature to the set temperature and decides whether to activate one of the outputs.

The temp_ext function has the role of processing data similarly to the interior temperature function, and provides data necessary to display exterior temperature

The process of temperature setting always begins with the value of the interior temperature. While the temperature set switch is enabled, the second display shows set temperature allowing user to set it by pushing the up/down buttons

2.8 PCB Layout (Orcad Layout)

After the completion of the electric schematic and functionality and error checking, the netlist was made and exported to Orcad Layout. Here, proper encapsulations were chosen for each component, according to their datasheets. After that, a PCB layout was made, and components were placed and routed according to their functionality.

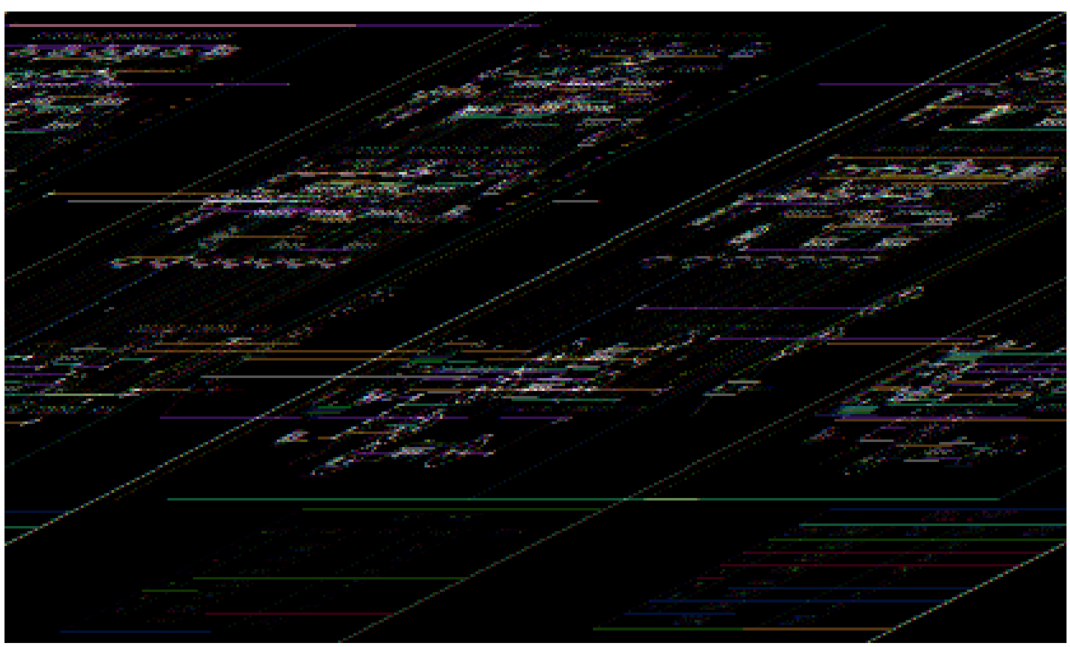

Fig. 3. Orcad Layout placing and routing

After the computer layout was made the layered circuits were printed (TOP, BOTTOM, DRILL).

3. EXPERIMENTAL RESULTS

For T = *ct.*, a certain extern stimulus, like for example the electric field of the order of 10^4-10^5 V/m, a laser weak (mW) field, or a n^0 thermal neutron beam of $4,15 \cdot 10^{12}$ neutron/cm^2 -, gives rise to a so called memory effect in LC samples **[5].**

Considering a microscopic scale, such transitions takes place because a co-operative interaction between different parts of the system, which under some specific conditions can lead to abrupt changes. It was shown that, for example, the arachidic acid $C_{20}H_{36}O_2$ at room temperature looks like a white polycrystalline powder. Increasing the temperature, at 76°C with a heating speed v>4°C/min, it passes to the isotropic liquid state. If heated with v<4°C/min, the LC state becomes visible at 69°C and when 76°C is reached, the system turns into LI **[6]**.
Some specific textures, as a function of the temperature, are presented below:

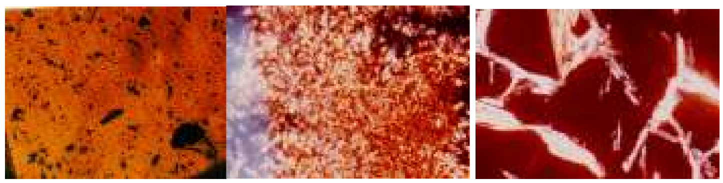

Fig.2. Fatty acids textures in thermo tropic LC state at the temperature decreasing ($T_a>T_b>T_c$)
These images were obtained by using the polarizing microscope, with an attached camera.

We studied the effect of the thermal neutron irradiation on some fatty acids: Arachidonic, Linoleic, Elaidic Acid- as unsaturated ones, and saturated –such as arachidic acid etc.
Taking into account some previous result obtained by us with a low power c.w.He-Ne laser and verified on the basis of some computer software and models **[5]**, the laser light absorption by the non-irradiated and irradiated samples was studied in the LC state, by using an Ar^+ laser of 100 mW, at the following wavelengths: 5145 Å, 4880 Å and 4765 Å at the incident power increasing and decreasing. The experimental setup contains as usually the laser, a polarizer, the sample unity, equipped with the thermostat, and a detector.
Once the work temperature was reached, it should be kept constant during the experiment, under the action of the external perturbation, in order to not create undesirable parasite effects (thermal nonlinear refractive index etc).
The temperature is monitored and kept constant during the experiment, by the digital thermostat, attached to the sample, designed and realized in our laboratory.

3. 1 Results and discussions

Some memory effects were evidenced in all samples, as for example in arachidic acid, after thermal neutron irradiation **[5]**, which means a non-linear behavior of the samples (Fig.5)

Fig.5. Memory effects in arachidic acid under a thermal neutron flow

Taking into account these previous results, we represented the output laser power versus the input one, for different wavelengths of the Ar^+ laser, in non-irradiated and irradiated samples. We exemplify here with some of them, similar results being obtained for the others:

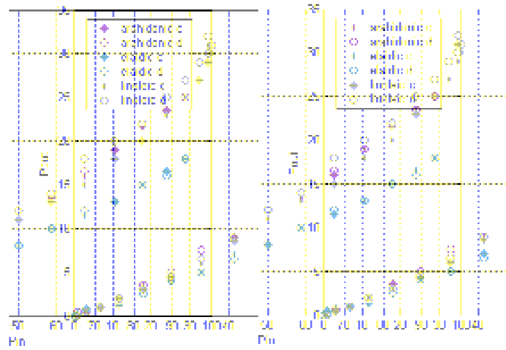

Fig.6 c. Irradiated unsaturated fatty acids (λ=4880Å)

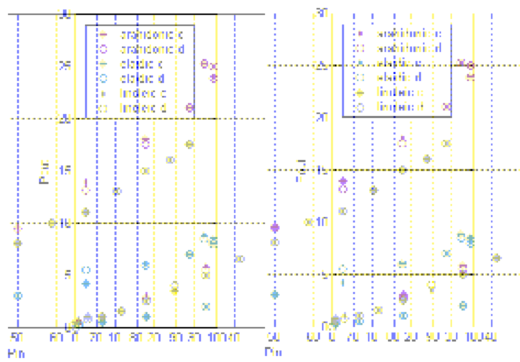

Fig.6d. Non-irradiated reference samples (λ=4880Å)

By summarizing the experimental results, we can observe:
- arachidonic (C_{20}), elaidic (C_{18}), linoleic (C_{12})

- They present a small hysteretic area for both irradiated and unirradiated samples
- Samples with smaller carbon atom number are more influenced by the neutron
- Transmittance is increasing with carbon atom number, on the opposite with the saturated ones; transmittance increased for the irradiated samples

- dodecanoic (C_{12}), caprilic (C_8), caproic (C_6)

- Transmitted intensity increased with the carbon atom number decreasing. C_6 presents a bigger hysteresis, decreasing with the carbon atom number increasing, almost null for C_{12}
- Transmittance is higher for the irradiated samples
- The sense of the hysteretic curve is in general the same, except the unirradiated caproic acid; in this case, at low laser incident powers soma oscillations appeared

By analyzing the samples with the polarizing microscope, we can state the following:

For the unsaturated fatty acids

- After irradiation the textures are unchanged

These observations evidenced that thermal neutrons irradiation influences the fatty acids, components or forerunner of the biological membrane, and this could be studied by using laser low power technologies, at constant temperature [7].

4. CONCLUSIONS

In conclusion, we presented in this paper the method used for designing a digital thermostat, having a temperature measuring and display system based on the microcontroller Atmega128. The device is working with previous imposed parameters, required by the practical applications. For the microcontroller programming, **AVR Studio 4** (ATMEL) has been used. A description of the functions used in the program was given, followed by the commented program. Then, the electric design was exported in **Orcad Layout**, and the functional zones were created, verified and realized on the cable bay-up (top and bottom layers). Real cabling was printed (TOP, BOTTOM, DRILL, and SOLDERING MASK).

LC samples of fatty acids thin film samples in LC state when heating with a specific speed, before reaching the IL state, were studied. This state is maintained between some temperature values. Their microscopic texture was evidenced by using a polarizing microscope. The action of the thermal neutron irradiation on these substances was studied by using an Ar^+ laser. In order to avoid parasite effects, the temperature was kept constant by using a digital thermostat designed and realized by us.

Nonlinear optical effects were evidenced in the samples, and the modificationhs uinduced by thermal neutron irradiation were evidenced. These observations lead to the conclusion that the neutron influenced in a different manner the saturated and unsaturated fatty acids, and this influence can be evidenced by using low power laser beam, at a constant temperature.

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