Запропоновані оптичні елементи на основі спряжених поліаренів є м'якими для людського ока, не дають шкідливого електромагнітного та іонізуючого випромінення, і тому можуть застосовуватись в побутовій електронній техніці, дисплеях і моніторах, а також для конструювання світлових клапанів, оптичних фільтрів, сенсорних пристроїв.

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ELECTRONIC PSYCHROMETER BASED ON AUGUST – ASSMANN METHOD

Наведено результати розробки, моделювання та описано функціонування електронного психрометра на основі методу Огуста–Асмана.

The design, modelling and operation of electronic psychrometer based on August-Assmann method are considered at the paper.

1. Introduction

Psychrometer is a classical tool for measurements of air humidity. It is based on well known phenomenon of different decrease of temperature of moist and dry surfaces placed in the same environmental conditions. This phenomenon is caused by diversion of certain heat related with evaporation of water form moist surface.

Temperature registered by thermometer wrapped in moisten gauze is called the temperature of wet thermometer. This temperature is influenced by starting temperature of water in gauze and heat exchange between gauze surface and environment. Those mechanisms are described below.

Let us assume a drop of water suspended in moisten air. Temperature of the drop is t_k, and related pressure of saturation p_k. Temperature of surrounding air is t, and partial pressure of water vapour p_w.

When $p_k > p_w$, water evaporates, what demands bringing to the drop (by convection or radiation) external heat from the environment. If starting value of t_k is higher then t, certain amount of heat is taken from the drop. If starting value of t_k is lower then t, certain value of heat collected by the drop from the environment increases temperature of the drop and supports evaporation process.

In equilibrium state evident heat collected by the drop is equal to the losses of latent heat delivered to the environment as evaporation heat. Temperature of water is then t_m and is called the temperature of wet thermometer of moisten air surrounding the drop.

Described process may be described by equation:

$$(\alpha_k + \alpha_r) A (t - t_m) = \sigma A r (p''_{wm} - p_w) \qquad [1]$$

where: α_k – heat interception coefficient (by convection of gas layer surrounding the drop),

α_r - heat interception coefficient (by radiation of surfaces surrounding the drop),

A – area of the drop,

r – water evaporation heat in equilibrium state,

σ – mass interception coefficient (as a result of vapour particles penetration)

Basing on described phenomenon it is possible to measure humidity of air. August described in 1828 a measuring system consisting of 2 thermometers with special construction and he called it psychrometer. Improved construction was created in 1886 by Assmann. Thanks to this improvement it was possible to measure humidity in any environmental conditions.

2. Electronic Psychrometer

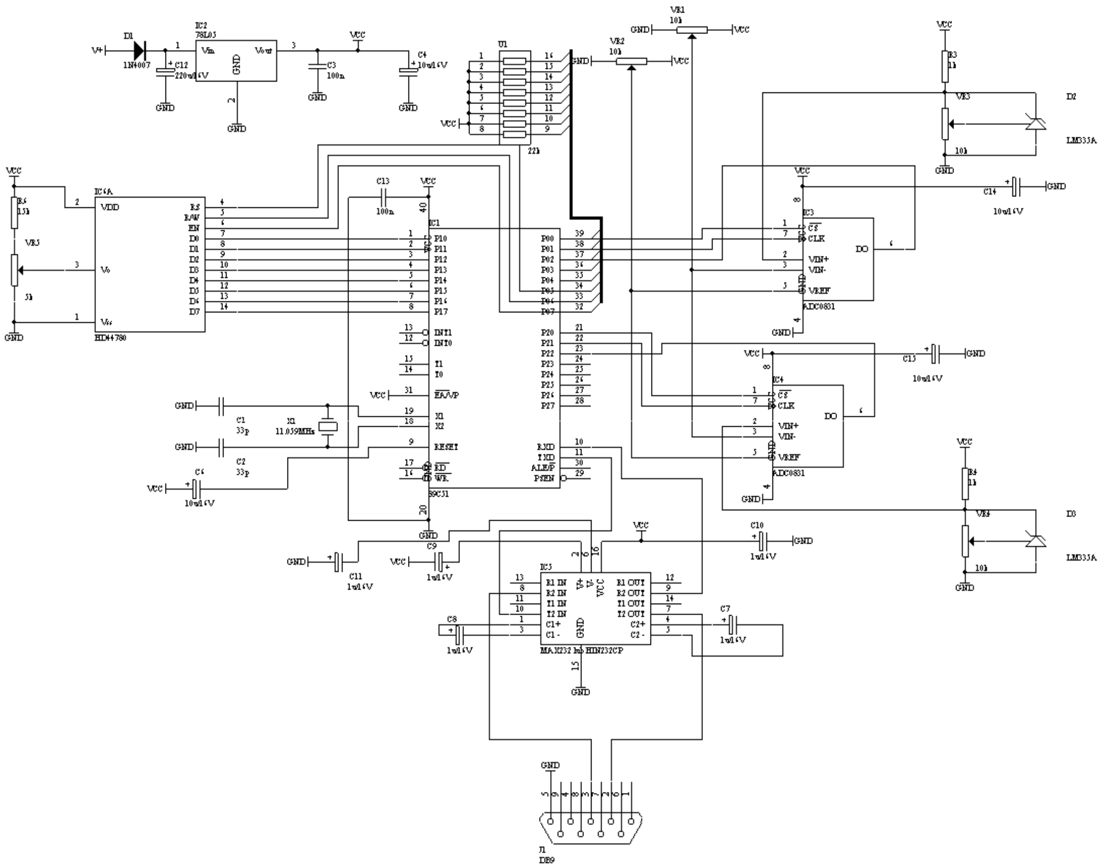
Idea of traditional psychrometer is based on measurement of temperature with use of dry and wet thermometer and then calculation of relative humidity with use of tables, charts or nomograms. There are also nomograms built into the instrument but in this case read out of the humidity is not direct. Our aim was to design and construct an instrument making possible direct read out of the humidity.

Design process was taking into account:

– accuracy
– cost of production
– functionality
– reliability
– long term of utilisation.

Additionally the shortest measurement time as well as communication with PC through RS232C interface has to be assured in order to automate measurement process. Designed instrument is portable and easy to calibrate. Measurement is performed with use of two sensors suitable even for very small vessels, where traditional psychrometer can not be used. Scheme of the psychrometer is presented on fig. 1.

Temperature of dry and wet thermometer is measured with use of high precision temperature sensors LM335. Elements are properly polarised by the voltage source and resistor. LM335 registers break voltages proportional to the absolute temperature (expressed in Kelvins). Break voltage for LM 335 at 273K is 2.73V and at 298K – 2.98V. Operation temperature for LM 335 are from 233K to 373K. Devices are mounted in hermetic plastic housings type TO-92.



Rys. 1 Scheme of the psychrometr

Properties of the instrument:
– calibration in Kelvins,
– basic accuracy 1K,
– current range 400uA to 5mA,
– dynamic impedance less then 1Ω ,
– easy to calibrate,
– linear scale coefficient +10mV/°C,
– wide range of operation temperatures,
– admissible overheat up to 200°C,
– low price.

Easy calibration of LM335 sensors increasing the accuracy of the instrument is realised in following way: High precision potentiometers VR3 and VR4 (fig. 1) with slider attached to the correction knob are attached parallel to LM 335. It makes possible one point calibration of the instrument correcting inaccuracy in entire temperature range. One point calibration is efficient because output signal of LM335 is proportional to the absolute temperature (with assumed extrapolation of output voltage 0V at 0K). Errors of output voltage (in function of temperature) are caused only slope or range errors. Thus calibration of the slope at selected temperature corrects errors for the entire temperature range. Output signal of the system (calibrated or not) is given by equation:

$$V_{out}(T) = V_{out}(To)\ T/To \qquad [3\text{-}1]$$

where T - unknown temperature in Kelvins,

To – reference temperature in Kelvins.

After correction of the output signal at one selected temperature, output measures for all other temperatures are also correct. Nominally output signal is calibrated at 10mV/K.

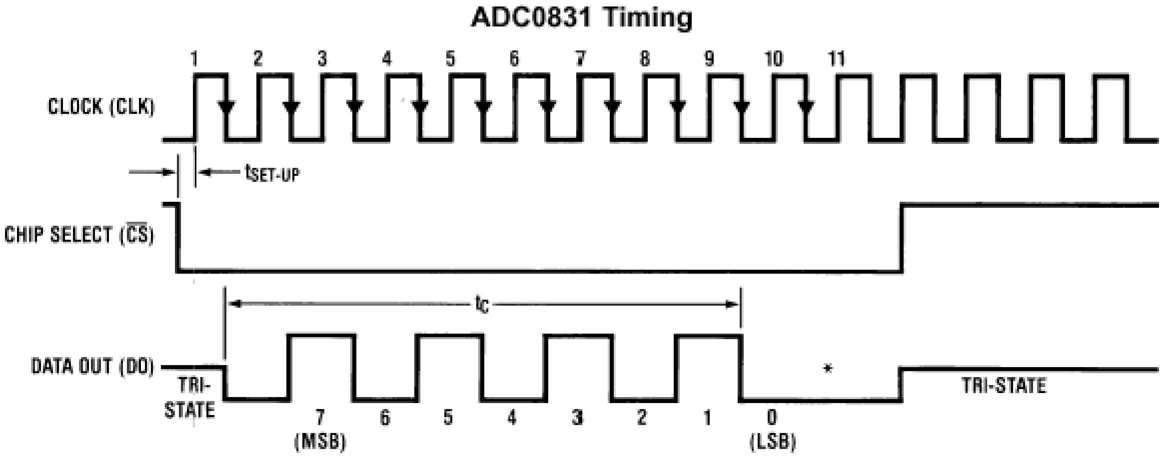
In order to assure proper quality of the measurements it is necessary to take into consideration some restrictions. As in case of other temperature sensors self-heating may decrease accuracy. LM335 should operate at lowest current accessible in given application. Of course current value should be sufficient for steering both sensor and calibration potentiometer at maximum operation temperature and maximum external charge.

In case when sensor is utilised in constant thermal resistance environment errors related with self-heating can be corrected. It is possible when system works at temperature constant current. Self-heating is then proportional to the Zener voltage and at the same time to the temperature. Thus error related with self-heating is proportional to the absolute temperature in the same way as slope errors.

Signals from temperature sensors are processed by 8-bit A/D converters ADC0831 with differential input amplifier built in, what makes possible to shift analogue zero. It makes possible regulation of reference voltage, so signals from the temperature sensors may be processed with full resolution of the converter without additional adapters. This is important feature because in the range of measured temperatures (0 - 60 °C) there is limited range of changes of output voltage of LM335 unit whereas its constant component is relatively high. Regulation of output signal is made with use of VR1 and VR2 potentiometers. Potentiometer VR1 sets voltage feeding the input of inverting amplifier and it should be about 2,73V what is adequate to the lower limit of measured temperatures – 273K. Potentiometer VR2 sets the referential voltage which is about 0,6V. With potentiometers set to these values one bit on the output of the converter is adequate to about. 0.24K, what is satisfactory.

ADC0831 converter is equipped with interface consisting of output data line (D0) and clock line (CLK). Unit is activated by low state of CS input. In order to perform A/D processing the CS input has to be fed by low state. At the same time 11 clock impulses (declining slopes) has to be fed on CLK input. Resulting bits of conversion are appearing sequentially at the DO output after appearing declining slopes of clock impulses from 2 to 9. The most standing bit appears as a first. After 11-th clock impulses processing is blocked by feeding high state to the CS line. Illustration of this process is presented on rys. 2.

Operation of converters and entire psychrometer is controlled by one unit micro-controler AT89C51. Program residing in ROM memory makes measurements of temperature of dry and wet thermometers, calculates humidity from psychrometric table and displays the results. It also controls transmission of the measurements through the interface RS232C. Micro-controler is equipped in quartz oscillator X1 and frequency 11,059MHz. This frequency was selected because of necessity of communication through the interface RS232C. Processors belonging to the '51 family are equipped with hardware and software facilities making possible easy creation of serial connections working with this standard. Because serial connection is designed for data transmission between two devices with use of external cable, in order to increase its reliability and improve signal quality specific standard of voltage levels (different then TTL 0/5V) was selected. Low state is adequate to voltage from the range +5 do +12V, and high level is adequate to voltage from the range +5 do -12V. This makes necessary application of intermediate units adapting signals of processor to RS. Specialised unit MAX232 was used to make this adaptation.



Rys. 2 Przebiegi czasowe przetwornika A/C ADC0831.

LCD module MDLS162S65-LV-S with controller HD44780 was used to display measurements. HD44780 can be treated as a sequence of 1 bit registers and memory addresses. Characters may be displayed by proper addressing. Access to the controller is possible through the data bus D0...D7 and three steering lines:

– Register Select RS,

– Read/Write !R/W,

– Enable.

LCD contrast is controlled by voltage fed to the third ending of MDLS162S65-LV-S module.

Psychrometer is supplied by DC 6V power supply. Unit L7805CV with current efficiency 1,5A is a voltage stabiliser. Result of the measurement is displayed on LCD and refreshed periodically. Upper line of the display presents temperatures of dry and wet thermometer what makes possible utilisation of optional psychrometric tables or nomograms. Lower line of the display presents the value of relative humidity calculated on the base built in psychrometric table.

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