Multichannel Temperature Monitor Compatible with PC

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A temperature monitor to measure cryogenic temperatures by means of resistive temperature sensors is presented. This is a box of 172×76×24 mm^3 connected to COM-port (RS232) of a personal computer. A four-lead technique is used to measure the resistance of the temperature sensor with respect to the precision reference resistor. The main characteristics are as follows: the number of measured channels/sensors can be from 1 up to 15 or 16; the range of measuring direct current is from 0.5 μA to 5 mA; the range of measured resistances, R, is from 1 Ohm to 100 kOhm; the accuracy of measurements is $\Delta R/R<0.01$ %. The temperature monitor was successfully used during the 18 months operation with the rhodium-iron, carbon- glass and TVO temperature sensors.

INTRODUCTION

Modern superconducting installations require the systems to control operation characteristics of cooled devices - magnets, cavities, detectors etc. and to monitor the thermodynamic state of cryogens with rather high accuracy. The value of temperature is one of the main parameters to determine the state of a cryogen or a cooled device. The aim of this work was to create a measuring system to operate with a big number of temperature sensors to test the quality of a superconducting cavity like [1] for steady state conditions. The total number of sensors at the tested cavity should be 256. In principle, there are some ways to solve this problem. We have chosen a schematic of multichannel system shown in Figure 1. This variant supposes the usage of several remote devices (with standard 12/15 V d.c. power supply) which are connected with a usual PC via standard interface RS232. To realize this variant, one needs several electronic modules, each of them allows to measure signal of 15 or 16 sensors. In principle, 16 devices can be connected to the COM-port of the PC: in this case the maximum number of sensors can be 256. A 15/16 channel temperature monitor (TM) is a module of multichannel system to measure temperatures by means of resistive temperature sensors whose resistance can be of a wide range in principle. This module is described below.

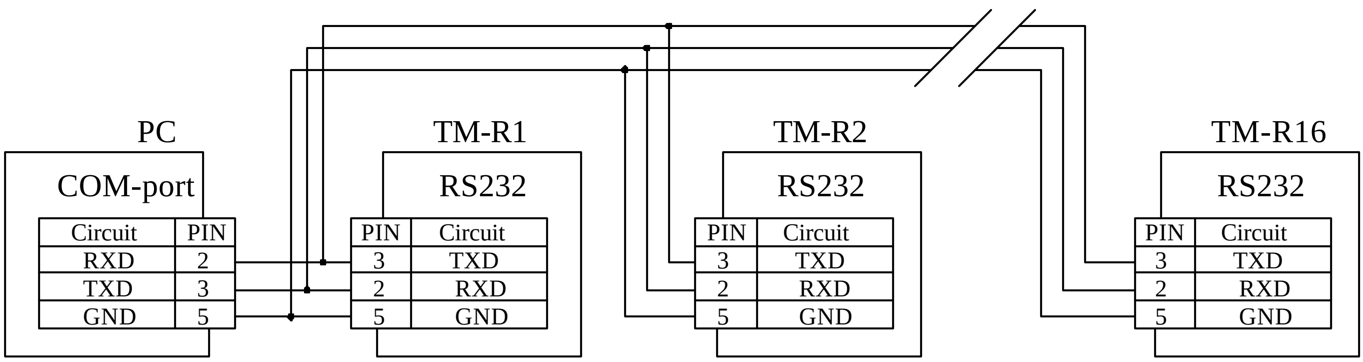

Figure 1 Schematic of multichannel system (16×16=256 temperature sensors) with remote temperature monitors connected to PC via RS232

15/16 CHANNEL TEMPERATURE MONITOR

Principle of measuring

A four-lead technique is used to measure the resistance of the temperature sensor with respect to the precision reference resistor. To avoid the influence of parasitic voltages, measurements are performed with a direct current source whose polarity can be changed. In this case the measured resistance R_m can be found as $R_m = [(U_m/U_r)^+ + (U_m/U_r)^-]\times R_r/2$, where U_m is a voltage drop at the measured resistor, U_r – a voltage drop at the reference resistor R_r, symbols «+» and «-» correspond to the positive and negative polarities. The advantage of this method of relative measurements is that it does not require any calibration of the measuring device or verification of its zero offset. In order to check the accuracy of measurements from time to time, it is necessary to connect the certified precision reference resistor of 0.001 %, for example, instead of the measured resistor R_m.

Structural schematic

The structural schematic of the temperature monitor is shown in Figure 2. The sixteen measured resistive sensors (or only one sensor) can be connected to the measuring device via 44-pin connector. These sensors are connected in series. The measuring device has a temperature sensor/chip whose readings allow to correct the value of the reference resistances depending on temperature. The electronic board includes, in particular, a direct current source with reversible polarity, multiplexers for 15 or 16 resistive temperature sensors, reference resistors of 0.005 % and ADC. The value of the current can be regulated from 0.5 μA to 5 mA. This device can be supplied with reference resistors of 10 Ohm, 100 Ohm, 1 kOhm and 10 kOhm which allows to measure the signals of the sensors whose resistance can be from 1 Ohm to 100 kOhm. In principle, there is no problem to support ISA-interface if one needs to manufacture an electronic board which should be inserted into the industrial PC.

Design

The described variant of the electronic board is mounted within a plastic box of 172×76×24 mm^3 shown in Figure 3. Its weight is about 0.19 kg. A RS232-connector and power supply input are located in the front side of the box, and the 44-pin connector for temperature sensors is mounted at its reverse side. A standard 220/110 V 50/60 Hz adapter with 12 V d.c. and 500 mA output is used for power supply. Figure 3 also shows a connecting cable for the sensors with the cable connectors and hermetic wire connector which should be mounted at the cap of the cryostat. If a standard 32-pin wire connector is used, one can realize a 15 channel variant of the temperature monitor: 2 pins – for current leads and 15×2 =30 pins – for potential leads. The next Russian standard for connectors is 50-pin variant which allows to realize the 16 channel version. If it is necessary, one can manufacture one more 16 channel version - with two independent 19-pin wire connectors when each group of 8 sensors, connected in series, is mounted at a separate connector at the cap of the cryostat.

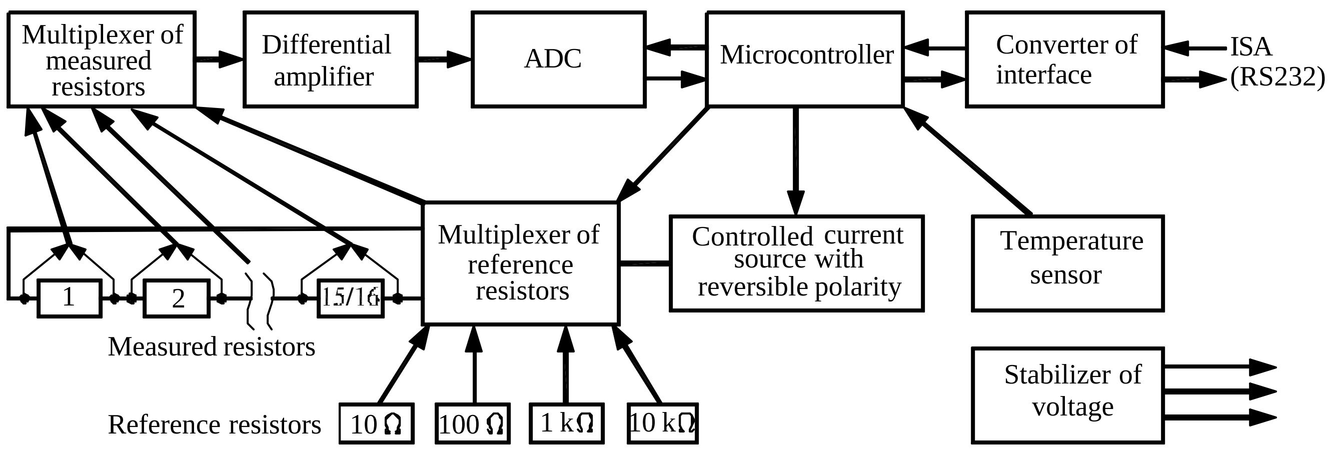

Figure 2 The structural schematic of the temperature monitor

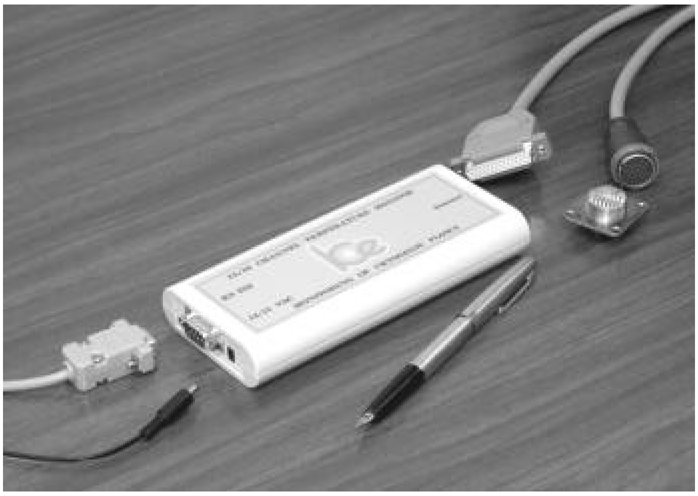

Figure 3 Temperature monitor with interface RS232 and connecting cables

Software

A DOS-program allows one to find: values of the resistances (Ohm-meter regime), temperatures T(R-resistance), temperatures depending on time T(R, t-time), to compare a found value of the temperature with a reference value T_r (in this case any connected sensor can be used as the reference one or the reference temperature T_r can be entered as the reading of the chosen thermometer), to enter a new calibration curve T(R) for a replaced sensor if necessary. If the system operates with TVO temperature sensors under magnetic field, one can find the corresponding temperature shift due to magnetic field ΔT(R, B-magnetic field) for each TVO-sensor in accordance with [2]. While operating in the regimes “Measurements of resistances” or “Measurements of temperatures”, one can change the measuring current according to the certificate for the connected sensor. There are automatic regimes to choose the current for the TVO and carbon-glass temperature sensors [3].

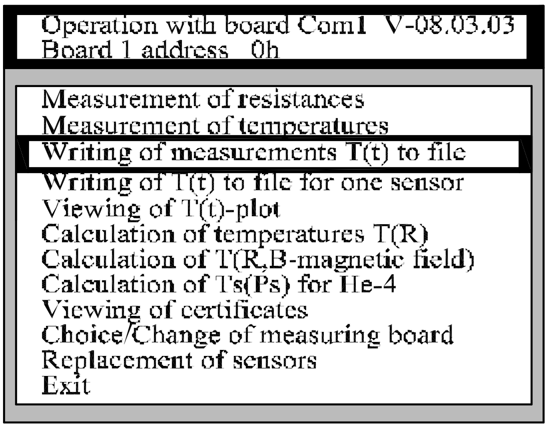

Figure 4 The main menu

The software consists of several files: T_meter.exe, T_meter.ini, T_board.ini, alarm.ini, HIEW.EXE. T_meter.exe is the main program, its possibilities are briefly described above. The main menu is shown in Figure 4. The T_meter.exe-program operates in accordance with all items of the menu if there are files containing the information about calibration points and polynomial coefficients. They can look as “jinr_001.pas”, for example, where 001…128 is the identification number of the sensor. Such information is written into the file “T_meter.ini”. This file defines the correspondence between the really connected sensors and their certificates/calibration data. In principle, this is the text file whose lines look as follows: *“nkk file_name”* where “n” is the number of the board (1..16), “kk” is the number of the measuring channel/connected sensor (1..15/16), “file_name” is a certificate of the sensor which can look as “JINR\jinr_120.pas”. The ancillary file “T_board.ini” provides an operation with several boards - up to 16 pieces. In principle, this is also the text file whose lines look as *“board n = xxx”*, where “n” is the number of the board and “xxx” is the hexadecimal base address. A range of base addresses is from 0h to 15h which can be changed by four jumpers at the electronic board. The file “alarm.ini” activates the low and high alarm capability. The program “HIEW.EXE” reviews the certificates of the used sensors.

The measurement process is arranged as follows. The software transfers commands of tuning (values of current, reference resistor and so on) to the electronic board and sends the command to start measurements. Then it receives and represents the results after the readiness signal. The data swapping with the board is done by using the interruption mode since the measurement process is relatively slow and the board is connected with COM-port which has a standard interruption. This enables one to use a processor for another applications while starting the operation under Windows-system.

This software and hardware can be used for operation with sensors calibrated not only by us but for sensors of another firms. In this case one needs to convert the calibration data to a compatible format.

RESULTS OF TESTING

The temperature monitor was tested with rhodium-iron, carbon-glass and TVO resistive temperature sensors [3]. It provides two modes of measurements: the continuous mode when measurements are done during all the time and the single one when only one measurement for the sensors could be performed. A kind of measurements can be carried out with one chosen sensor and with all 15/16 sensors. The time to measure all the channels is about 1.6 sec. and 0.3 sec. for one chosen sensor. The tests have shown that the effective resolution of the analog to digital converter is 20 bit. The biasing current can be regulated as follows: 0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500 μA and 1, 2, 5 mA. All the measurements have been carried out with the connecting cable (between the temperature monitor and the cryostat) of 10 m. In principle, the results with a shorter cable could be better. However we have not seen any difference for the 3 m and 10 m cable at our laboratory. The accuracy of measurement is estimated as $\Delta R/R<0.01$ % for all the channels. This accuracy allows to use this temperature monitor not only for routine measurements but also for calibration of cryogenic temperature sensors with moderate accuracy – not worse than ± 10 mK at 4.2 K. The time to reach the operation regime is up to 15 minutes, and the time of continuous operation is not restricted. The service life is estimated as 10 years and longer. One can note that there was no error revealed during the 18 months period of operation with the tested temperature monitor.

CONCLUSIONS

The designed, manufactured and tested temperature monitor, TM, of the compact size ($172\times76\times24$ mm^3) meets the technical requirements for measurements with any cryogenic resistive sensors whose resistance can be from 1 Ohm to 100 kOhm or wider. The TM is connected with a personal computer via COM-port (RS232). It provides an operation with 15 or 16 sensors connected in series. The accuracy of measurements of the resistance, R, is $\Delta R/R<0.01$ %. The software allows one to carry out writing of the temperature dependence on time (t) to file and observing of the corresponding T(t)-plot on the screen, to glance at the certificates of the sensors with calibration data, to calculate deviations due to the magnetic field for TVO sensors and to compare the measured temperatures with the reference value.

In principle, 16 temperature monitors can be connected to COM-port of the PC to provide measurements with 256 resistive temperature sensors.

ACKNOWLEDGEMENTS

Many thanks to our colleague V.M. Miklayev for the suggestions to improve the software based on his long-term experience to operate with the tested temperature monitor.

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