REMOTELY-CONTROLLED UNIT FOR CONDUCTIVE CEMENT-BASED MATERIALS WITH CARBON NANOFIBERS

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ABSTRACT

This paper deals with conductive concrete materials and its testing. Multi-purpose remotely-controlled thermostat, called iTHERMST, was designed and built to test and evaluate new samples of the cement-based material with high specific heat and high thermal conductivity. iTHERMST tests and collects various data that can be imported directly to Microsoft® Excel™ for further evaluations.

1. INTRODUCTION

“Smart materials” are drawing more and more attention these days. One of the most common structural materials used in engineering construction is cement and its mixtures (concrete and mortar). “Smart concrete” (SC) and its derivatives could be consider as a material of the future. Due to its attractive features, SC can be used as a strain-sensing element, as a resistive heating or as an EMI shielding.

Using SC as a resistance heating is a complementary method that needs to be investigated. Cement is slightly conducting material, but its electrical conductance, EMI shielding effectiveness and wave absorbing property are very poor. In order to increase the ability of cement materials to conduct and shield EMI, additional conductive or absorbent fillings and loadings have to be introduced to admixture to provide higher EMI preventing effectiveness. The resistivity of concrete can be diminished by using an electrically conductive admixture, such as discontinuous carbon nanofibres, discontinuous steel fibres, steel shaving and graphite particles. Combining and changing an admixture ratio leads to different value of resistivity. There was a call for a testing device that could support an academic research and help with finding a proper admixture ratio and pattern that is suitable for a heating elements fabrication.

A multi-purpose remotely-controlled thermostat, also called iTHERMST, was designed and built in order to test and evaluate new samples of the cement-based material with high specific heat and high thermal conductivity.

2. GENERAL DESCRIPTION

The iTHERMST was carefully designed to meet the future standards and brings some new innovative features as well. It serves primarily as an intelligent thermostat with datalogger. Anyway, the modified iTHERMST can be also integrated as a part of so called “intelligent house” to provide self-deicing barrier-free entrances and pathways. Together with the powerful software with ECO mode support, it has a great potential to contribute to better environment. For example, it can be expected a reduction in demand for spreading of roads and pavements with expensive salt or sand and slag during a cold or winter season. The iTHERMST offers multiple ways of control: local - using buttons and LCD or remote – via Bluetooth or via Ethernet.

3. ELECTRONIC DESIGN

The entire system consists of several major electrical parts that include a microcontroller unit (MCU), a high-contrast alphanumeric LCD display with a white backlight, main temperature and additional sensors, a SD/MMC memory card, a power supply unit with high-efficiency step-down switching regulator, 10 A relays, a Bluetooth module and a terminal server (XPort) for Ethernet communication. A block diagram is shown in figure 1.

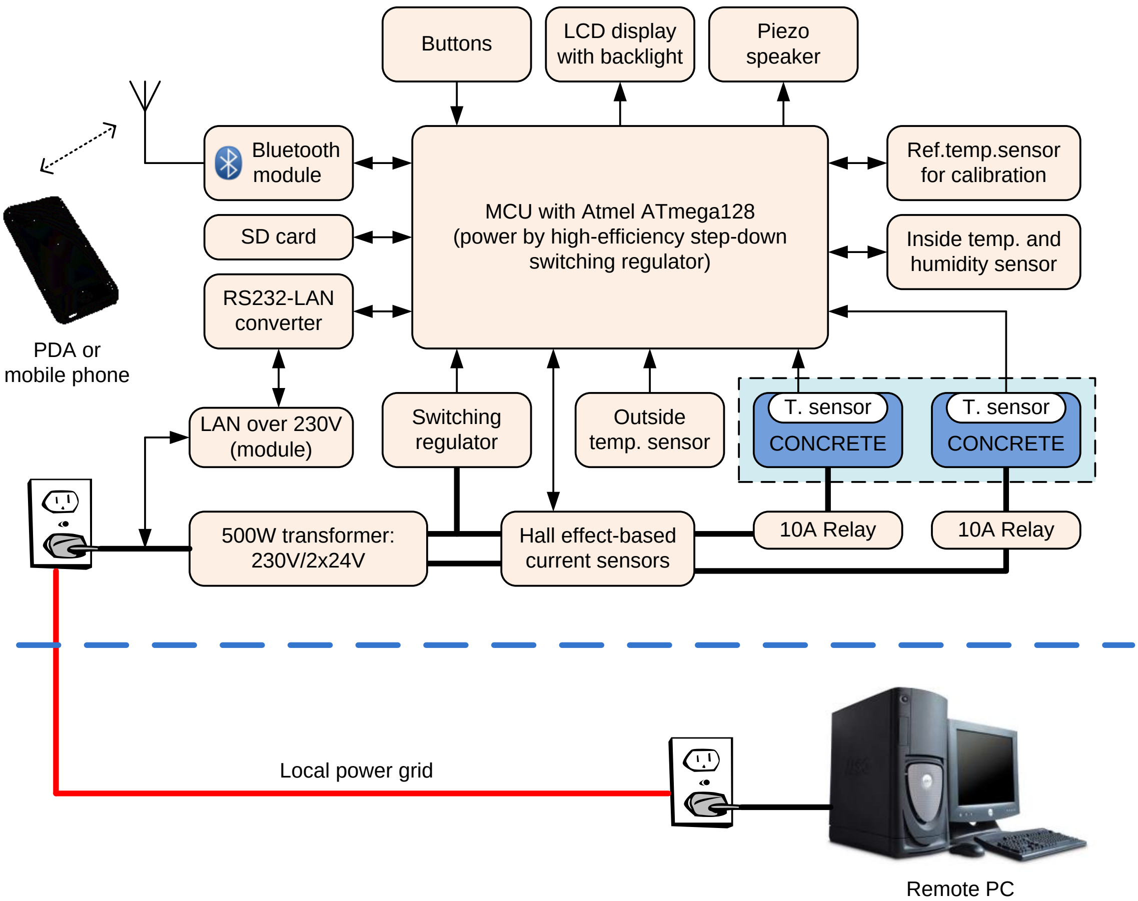

Figure 1: Block diagram of the iTHERMST 1.0A

3.1. MICROCONTROLLER UNIT

MCU is the heart of the entire device. MCU processes every sensor data, switches relays, drives SD/MMC memory card and takes control of the communication with the remote PC, PDA or mobile phone. A powerful ATmega128A microcontroller made by ATMEL is used to provide sufficient computing performance.

3.2. SENSORS

As this device serves primarily for temperature logging, several temperature sensors are available for measuring and switching relays. There are three analogue inputs that can handle three PTC thermistors (e.g. KTY81). Two of them are used to control the temperature inside tested concrete samples, the third one measures the outside temperature. In order to calibrate these PTC thermistors, 12-bit precise one-wire digital sensor DS18B20 from Dallas-Maxim is present and can be used any time to calibrate new PTC sensors imbedded in tested samples. Furthermore, precise temperature and humidity sensor SHT75, produced by Sensirion, monitors the internal state of the device. The power-supply system is also under surveillance due to the voltage and currency measurements. All sensors together with MCU provide the real-time measurement.

3.3. RELAYS AND POWER-SUPPLY SYSTEM

The entire system is connected to the standard 230 V / 50 Hz local power grid with 500 W toroidal transformers, secondary windings give 2 x 24 V. The iTHERMST control unit is hooked up to the first winding but there is a possibility to powered it either with AC or DC voltage source within range from 7 V to 35 V. The high-efficiency step-down switching regulator provides 3.3 V and 5 V source, most of the parts run at 3.3 V.

The iTHERMST is able to turn on and off two independent loads (two concrete samples) with the current consumption up to 8 A. Currents that flow trough concrete samples are measured by Hall effect-based current sensors and controlled by 10 A relays. If the instant currents flow exceeds set current limits (within range 3 A to 8 A), over-current protection is activated and the output load is turned off. On top of that, both relay outputs are protected by 10 A fuses.

3.4. COMMUNICATION

The iTHERMST is fitted with Class 1 Bluetooth 2.1+ EDR module produced by Bluegiga that offers 100 m range data transmission. Any device that incorporates Bluetooth may be used to control the iTHERMST remotely.

The other way how to control the iTHERMST is Ethernet. A terminal server – the XPort – converts UART signal to Ethernet and vice versa. The XPort support a 10BASE-T/100BASE-TX Ethernet connection, an embedded web server, a full TCP/IP protocol stack, and standards-based (AES) encryption. The XPort embedded software runs on a DSTni-EX controller which has 256 KB of SRAM, 16 KB of boot ROM, and a MAC with integrated 10/100BASE-TX PHY. The output from the XPort goes to Edimax HP-8501 HomePlug Ethernet Bridge (LAN over 230 V power line). It enables the iTHERMST to be connected to local power grid. Connecting the iTHERMST to the Internet gives the user unlimited possibilities of control from every computer all over the world.

3.5. SD/MMC MEMORY CARD

A standard SD/MMC memory card can be used to store acquired data. SDHC memory cards are also supported. A presence of the memory card and card lock state are recognized during the iTHERMST initialization. Data can be written in various formats according to the user requirements. Output data can be directly imported to Microsoft® Excel™.

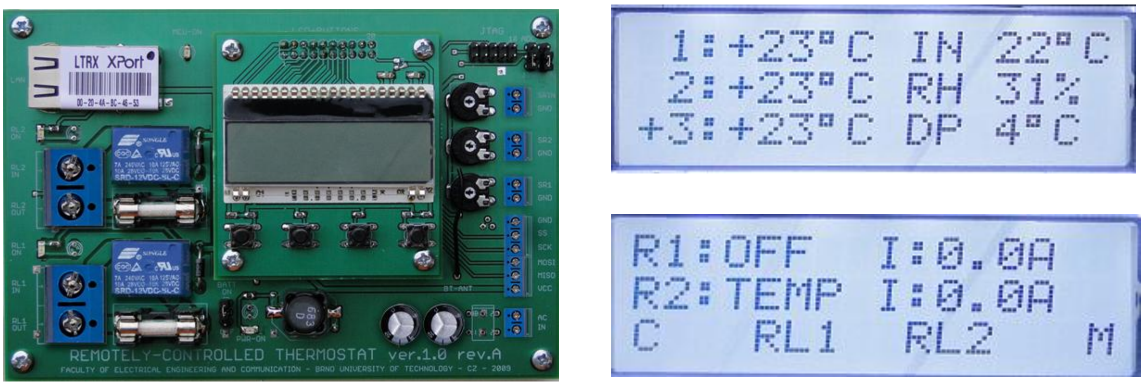

Figure 2: **a)** Physical appearance of the iTHERMST 1.0A, **b)** Main screen, **c)** Relay status

4. SOFTWARE

As for software, both MCU firmware and PC interface had to be programmed. MCU firmware (contemporary version is 1.5.0) is what makes the iTHERMST so special. The iTHERMST comes with additional relay driving modes that can overtake the other industrial thermostat offered at the market.

The iTHERMST can be controlled locally using LCD display (Fig. 2a). User-friendly navigation in the menu is provided by four buttons (CANCEL, DOWN, UP and ENTER) situated just below LCD. Main screen shows the most important values and system status (Fig. 2b). Furthermore, a lot of settings can be done in the menu: Different relay modes and ECO mode; display of extreme (MIN / MAX) values, data from calibration sensor, voltages and currents; digital calibration of PTC sensors; temperature hysteresis and threshold settings; over-current limitation; setup for LCD display (contrast and backlight options), piezo speaker, communication (output data format); system reset and restore to factory defaults; firmware version and total system running time. Remote controlled is done by either AT commands or PC interface software. All settings are stored in ATmega128 internal EEPROM memory and are loaded during the system start-up.

As far as relay modes are concerned, there are three differential modes. The first mode reads temperatures from two imbedded PTC sensors and drives the loads independently according to the set thresholds. The second mode (COMMON mode) reads temperature from the outside PTC sensor and drives both loads at the same time. The third one (ECO mode) is improved COMMON mode where temperatures are also read from two imbedded PTC sensors and if any of the temperature exceed set limits, loads are shut down. This mode is efficient in electricity saving, since there is no use to heat the blocks up when outside temperature is too low (e.g. -15 °C) or the output power of the concrete blocks is not sufficient to reach desired temperatures.

5. RESULTS

As mentioned, both concrete samples include the temperature sensor integrated in the middle of the concrete block to provide precise internal temperature. Currents that flow through concrete samples are measured by Hall effect-based current sensors and controlled by 10A relays. Together with the outside temperature sensor, the iTHERMST can effectively control dissipation power of the resistive heating and hold set temperatures. As an example, two concrete blocks were tested (Fig. 3). Resistance varies from 4 Ω to 6 Ω that gives output power up to 114 W when using 24 V voltage source.

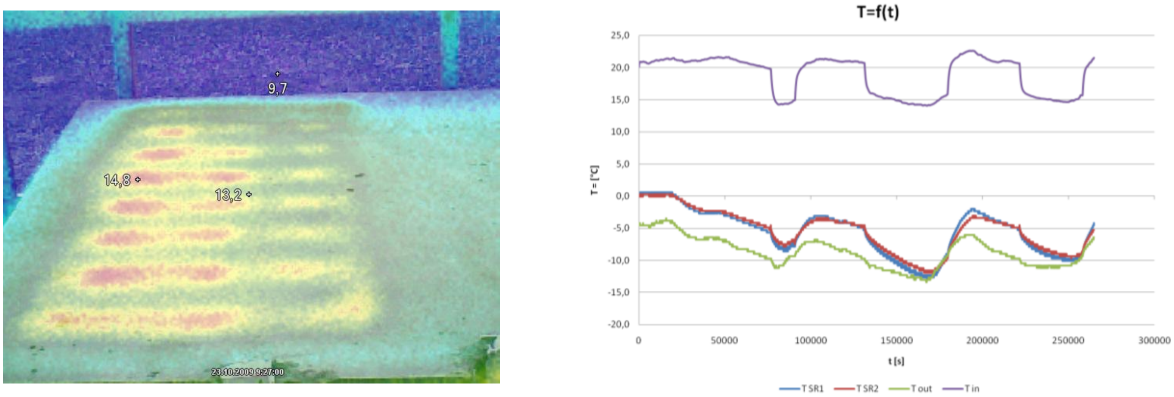

Figure 3: **a)** Infrared photo of the concrete with admixture of conductive fillings during heating up, **b)** Graph of temperatures acquired from sensors

6. CONCLUSION

The proposed device has been already tested, redesigned and has been in service for more than 3000 hours. The iTHERMST can support academic research and help to find a proper admixture ratio and pattern that is suitable for a heating elements fabrication. The iTHERMST offers the new effective way of testing, saves research time and reduces total costs. The iTHERMST is considered to become a part of industrial design.

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