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AUTOMATED COLLECTION OF TEMPERATURE DATA FROM THE SOIL PROFILE

A relatively simple solution for collecting temperature data from soil profile is presented. The first step was to choose the appropriate thermal sensors for the system as the system was intended to measure typical outside temperatures in Central Europe with an accuracy of ±0.5 °C. Multiple parameters had to be considered, such as the type of sensor, resolution, energy consumption, scalability, ease of use, etc. It was decided to use Maxim DS18B20 sensor with an accuracy of ±0.5 °C and highest resolution of 0.0625 °C using one-wire communication protocol. The second step involved rapid proto-typing of interface allowing connection of the sensor network to the supervisory computer. The final stage dealt with the software layers of the system. The firmware interfaces input commands from the serial port of the computer and a network of sensors via a set of commands. A simple script was programmed to store measured data into the database. A website as a graphical user interface to access data evaluation tools and create output of graphical representation of the measured data was created. The measured data were used to analyze correlation between temperature changes and damages on water pipelines.

Key words: one-wire line, temperature data, automated data collection.

We are experiencing an unprecedented boom in the requirements for distributed measurement of physical quantities in many different industrial areas from heavy industry, construction and energy to the building management. Requirements for such systems include scalability, extensibility, ease of use for the end user, measurement repeatability, the maximum length of lines, a certain level of system‘s autonomy, simple processing and data visualization on the customers side.

In this paper is presented a proposal for measuring temperatures ranging from –55 °C to +85 °C using a digital thermometer, Maxim DS18B20, with an accuracy of +/– 0,5 °C and highest resolution of 0,0625 °C communicating on 1-wire protocol. The advantage of this solution over analog thermometers, is that the communication with a host computer is fully digital and uses only two-wire line with a maximum length of up to 500 meters with a parallel connection of multiple addressable sensors. To communicate with a 1-wire network, a microprocessor based interface and a firmware to interface computer serial port to the network of sensors was built. There was also programmed a software layer to store the measured data into the database in given time intervals. In this case a period of 5 minutes was set. For user interaction, a simple website as a graphical user interface for data evaluation and graph creation was programmed. The software is running on an Intel Atom based computer with GNU/LINUX UBUNTU 9.10 operating software and was created using exclusively open-source tools.

HARDWARE

To communicate with the 1-wire network, a simple interface communicating with a host computer through a serial UART interface was created. The main part of the device is a CY8C29466-PXI microprocessor by Cypress Semiconductors. Architecture of this microprocessor allows us to configure peripheral devices i. e. UART and OneWireSW directly to the pins of the microprocessor. For the voltage levels translation from RS-232 to TTL was connected MAX232N based converter in block schematics in Figure 1 [1].

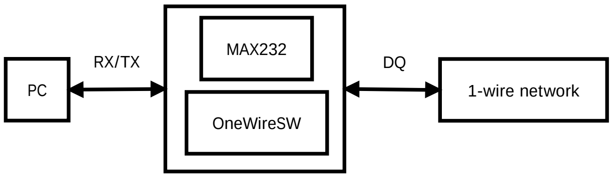

Figure 1. Block schematics of Serial to 1-wire interface

The DS18B20 temperature sensors are supplied in a TO-92 package. It has an operating temperature range of –55 °C to +125 °C and is accurate to ±0,5 °C over the range of –10 °C to +85 °C. A standard connection with three pins used for device 5 V power, GND and DQ pin (1-wire communication) is not suitable for our needs of a “power-less” sensor. Instead, “parasite power” mode of the sensor was used, where the DS18B20 can derive power directly from the data line (“parasite power”), eliminating the need for an external power supply and using only 2 pins. Each DS18B20 has an unique 64-bit serial code stored in the onboard ROM. This addressing allows multiple DS18B20s to function on the same 1-wire network. Using this advantage it is possible to simply use one microprocessor to control many DS18B20s distributed over a large area. For enhanced protection in aggressive environments, sensors have been inserted into additional aluminum enclosures that were filled with epoxy resin with a coefficient of thermal conductivity of 1,2 W/m.K in Figure 2.

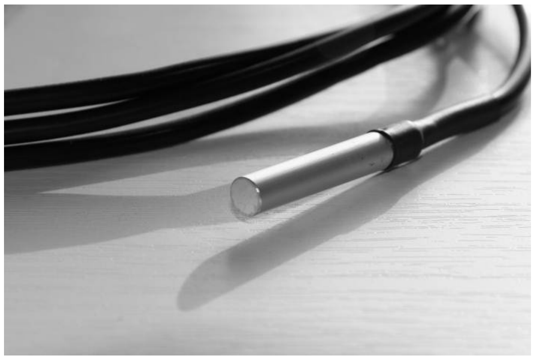

Figure 2. DS18B20 in an aluminum enclosure

Получено 14.11.11

To build the probe, five sensors were used. The probe body was made of plastic and the sensors were attached to it using industrial glue. Connections were sealed by a silicone paste and the lead wires were connected to our interface. In the soil the sensors are placed in depths of 1,5 m, 0,75 m and 0,10 m and above the soil to the heights of 0,10 m and 1 m on the probe body above the ground level.

SOFTWARE

FIRMWARE

Microprocessor firmware was written in C language. The host computer controls the interface by commands transmitted over the serial port:

DNR – shows the number of sensors connected in 1-wire network

ADR – shows the addresses of sensors connected in 1-wire network

TMP <64-bit address> - temperature measurement, the parameter is the sensor address

Temperature measurement takes 0,75 seconds. This is due to the phasing of the various operations occurring when using the parasite connection of the sensors. In the first phase of the high-line state, the internal capacitor of the sensor is charging; the second phase is a conversion from analog to digital temperature value, and finally in the third phase the digital value is sent to the host computer.

DATA COLLECTION

For data collection, GNU / Linux Ubuntu 9.10 as a host computer operating system was chosen. A decision had to be made about which programming language and database system would be the most suitable for our intended interconnection with the graphical user interface; and would also fulfill the meaning of open and free. Eventually Python programming language, because of its wide support in GNU/Linux based systems, was selected. There are available scientific, graphical and database libraries for Python; which are crucial for collecting and entering the data to the database and for processing the data into graphs and charts [2].

For this project was finally selected MySQL based database solution. From the support libraries in Python; “MySQLdb” for communication with the database and “python-serial” to communicate with the 1-wire network over serial port were used. Both work under the GNU/Linux operating system and also under MS Windows [3].

WEB SITE

The presentation layer plays an important role in the whole system. Measured data can be presented in various forms. It can be represented in a simple tabular information, static or dynamic (in time changing) graphs. Tabular representation of data is usually less transparent and less efficient, but with this type of data representation, the most accurate values can be read [4].

A suitable form of visualization is to use graphs showing temperature dependent on time. The authors decided to use module Matplotlib for generating graphs from measured data in the Python environment. For user interaction a simple web site running on the very same server as the database system (available at http://ggaspar.selfip.com/~meranie) was designed. To set up the web server, the well known Apache web server with its library mod-python enabling the use of Python scripts in the Apache was installed.

The web site consists on the left side, of 4 buttons for displaying the graphs for the last record, current day, week and month graphs; 2 date fields for date-from and date-to with the submit button. Clicking on any of these buttons results in mathematical optimization of data from the selected time period, and generates a graph. On the right side there are check-boxes to enable or disable (enabled by default) the given sensor in the graph, a locality and save graph buttons.

PRACTICAL RESULTS

The probe was installed into the soil with the distance of 3 meters from the building walls in October 2009. The first practical experiments began in November 2009 and the system started recording data into the database in 5 minute intervals on February 6th 2010. In Figure 3 it is visible how the temperature in different layers was changing over the period of 1 year in one given location.

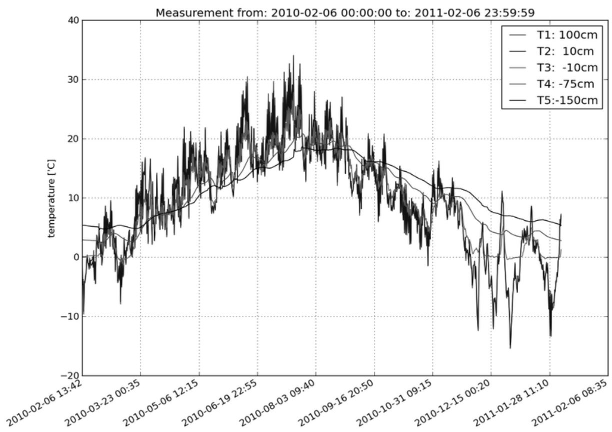

Figure 3. One year in the graph

The damage reports on pipelines were supplied by a local water company, to compare the correlation of the temperature changes and damages on the water pipelines in Figure 4. The fact is that most of the failures happened during the winter time. Data on the damages comes from the same area where temperatures were measured in the soil profile. The soil profile in the given locality consists almost entirely of gravel, and the level of ground water starts on average at –2 m. Pipelines are not laid in a constant depth, but go through numerous layers of different temperatures; but are almost always laid below the frost line – at least 80 cm below the surface. The ground water level prevents going to greater depths. An important fact is that the installation of pipes takes place almost exclusively in the summer months, which defines length parameters in terms of thermal dilatation. Coefficient of thermal expansion alpha has a typical value for steel around:

$$\alpha = 13 \times 10^{-6} \left[K^{-1} \right].$$

Figure 4. Cracked fragment of water pipeline

For plastic pipelines (HDPE, polyethylene, polypropylene) this value is one more place-value higher. From this we can estimate the change of the steel pipes extension in the period of maximum stress:

$$\frac{\Delta L}{L} = \alpha \times \Delta T.$$

At the difference in temperatures of 10 degrees during the given period, the relative elongation of the ideally straight 100 meters long empty water pipeline reaches:

$$\Delta L = 100 \text{ m} \times 10 \text{ deg} \times 13{,}10^{-6} = 0{,}013 \text{ m}.$$

In reality, the situation is considerably more complicated, pipeline is not ideally straight and there may be points of considerable stress, concentrating on curves and junctions.

CONCLUSION

This application of our system for measuring temperature data uses a simple network of addressable digital 1-wire temperature sensors. The concept allows installing multiple sensors on the same line, and connecting them to one host computer. The system has been online since February 2009, and its results were used to compare the correlation of the temperature changes and damages on the water pipelines. Overall, it is also necessary to consider the impact of fluctuations in the temperature of water in the pipeline; it is minimal just in the time period when the temperatures of the ground and underground layers are equalizing. In this period the pipeline is under maximum stress. An important factor is the nature of the flow during the day and night, when the average flow rates vary considerably and thus the temperature of water flowing through the pipeline, which may cause periodic stress to the pipeline.

From the above it appears that the studied problem is considerably more complicated. For objective assessment of the actual stress of pipelines, it would be necessary to acquire additional data from multiple points of water mains, typical flow values, climatic data, etc., and create a mathematical model that will take these factors into account. The output of this model can be a prediction of the areas with potential risk of increased incidence of damage.

The measuring system proved itself not only accurate, but also reliable and durable—as well highly successful in gathering data. For future endeavors, it will be redesigned to work autonomously from the host computer; as a highly mobile and energy efficient device.

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Автоматизированный сбор данных о температуре поверхности почвы

В статье представлено сравнительно простое решение для сбора данных о температуре из слоя почвы. На первом этапе были выбраны соответствующие температурные датчики для системы, предназначенной для измерения типовых температур наружного воздуха в Центральной Европе с точностью ±0,5 °C. Учитывались такие параметры, как тип датчика, разрешение, потребление энергии, масштабируемость, простота использования и т. д. Было решено использовать датчик Maxim DS18B20 с точностью ±0,5 °C и высоким разрешением 0,0625 °C с использованием протокола однопроводной линии. На втором этапе проведено моделирование с использованием разработанного интерфейса, позволяющего подключение сенсорных сетей к центральному компьютеру. На заключительном этапе рассматриваются программные слои системы. Передача команд через последовательный порт компьютера и сети датчиков осуществляется с помощью интерфейса пользователя. Кроме того создан простой способ для хранения данных об измерениях и графический интерфейс веб-сайта для оценки измерений и их графического представления. Измеренные данные были использованы для анализа корреляции между изменениями температуры и повреждениями водопроводов.

Ключевые слова: однопроводная линия, данные о температуре, автоматизированный сбор данных.