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Multi-sensory Device for Real-time Monitoring of Environmental Parameters

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Abstract
The need for constant monitoring of our environment require the invention of multi-sensors devices that are able to provide changes of parameters of our environment and to make this information available on the Internet. In this work we present a multi-sensory device that gives information about the temperature and humidity, illumination and electromagnetic radiation, vibration, air pressure changes, air contamination with CO, CO2 gases and fine particulate matter in a residential area. Information provided by this device is processed by single-chip microcontroller with ultra-low power consumption. The obtained information is transmitted through the Internet intermediary device (middleware), which is in direct connection with a standard internet router. Transferred information is stored in a database on a server and visualize through Web based system that allows to monitor the measured parameters from anywhere in the world through a standard internet browser.

Keywords: Multi-sensory devices, environmental parameter monitoring, electronic, detectors, Internet

1. Introduction

The development of microelectronics, the advancement of sensor technologies and the great popularity of the Internet allows the development of multi-sensor devices which can be communicated and managed via the global network. The sensor is a device that converts physical and / or biological parameters into electrically measurable currents and voltages. The measured electrical quantities must be calibrated. After that, it is converted to a digital format and sent to a microcontroller for further processing and control. Most of the sensors, regardless of their type, can be included as part of a unified system that has the capability to communicate between their individual elements. In this way, it is possible to continuously monitoring the data from the sensor device, recording them in databases for an indefinite time period, which allows for more in-depth and more accurate analyses and consequently possible solutions to problems or their prevention.

Multi-sensor devices can be used to monitor environmental parameters and evaluate factors that affect people's health. Every day, the human body is exposed to a number of external physical factors such as temperature, humidity, atmospheric pressure, light, sound, vibration, various sources of electromagnetic radiation. The concentration of CO and CO_2 dust particles in the air also strongly affect the state of the human body. Going out of range for each one of these parameters may be associated with a serious risk to human health.

The change in atmospheric pressure is often associated with insomnia, fatigue, dizziness and nausea [1] and may also aggravate depressive states [2] as well as to increase neuropathic pain [3]. The main physiological challenge for the body when atmospheric pressure varies is the change in pulmonary gas exchange and in particular – low atmospheric pressure – hypobaric hypoxia [4]. The concentration of dust particles indoors is associated with an increased risk of pulmonary diseases [5, 6]. Inhalation of fine particles less than 2.5 microns in diameter may lead to short-term and chronic respiratory disorders, such as asthma exacerbation, increased sensitivity to pulmonary infections and decreased lung function [7]. Concentration of dust particles in enclosed spaces is considered to be a cause of dry and irritated lining of eyes and airways but some researches [8] show that low relative humidity is the main factor influencing air quality and causing irritation symptoms. Temperature is another important factor in the room environment, which affects air humidity, working capacity and the general state of the body [9] and should be considered along with the other parameters. Increased concentration of CO_2 leads to poor working capacity and a feeling of fatigue [10]. CO long-lasting binds to hemoglobin in the blood, thus preventing oxygen transmission to the tissues, resulting in a disturbance of the functions of the nervous and cardiovascular systems [11]. Vibration in buildings disturbs the feeling of comfort [12], and environmental noise is a risk factor for elevated blood pressure, that may have temporary and lasting effects on the blood system [13] and lead to sleep disturbances [14]. The level of illumination in the living and working premises also affects the self-esteem, the working capacity and the psychological status of the person [15]. With the introduction of mobile technology in the countryside over the last 15 years, the level of electromagnetic loading in large cities has increased many times. The effect on the human body is still being investigated [16], but many authors, including the European Commission [17], suggest that there is a significant effect on electromagnetic fields (0 Hz to 300 GHz) on human health.

There are developments of multi-sensors that combine temperature and humidity [18], UV radiation, ozone and ozone concentration [19]. Szewcyzk and co-authors (2009) focus on how data is visualized without serious adjustments being required, while data is most useful to the user, focusing mainly on the software part of the devices [20]. It is noteworthy that none of the multi-sensors are included in a complete system, some authors have focused on software development, others are only concerned with the sensor part. Moreover, there are no devices that are specialized in enclosed living quarters in which the received data are interpreted and related to the creation of a healthy environment for the people.

The creation of a device as part of a complete real-time monitoring system for the above-mentioned parameters is applicable both for individual monitoring and optimization of indoor environments and for conducting a real longitudinal study of the effects of the surrounding environment on the human body. This publication presents the basic layout of the multi-sensor for surveillance of environmental parameters specialized for closed residential premises – called MOPHIP, made by the authors' team.

2. Specific instructions

On Fig. 1 is presented the main scheme of the surveillance system of environmental parameters specialized for closed residential premises. The environment parameters are monitored by intelligent multi-sensors that transmit the received information to an interconnect connected to the Internet. The resulting information is recorded and processed in a user-oriented Web portal where the user can monitor it at any time and from anywhere on the planet. On the other hand, from a user-oriented Web portal to the system, the user can switch on or off or transmit commands of different types to intelligent sensors or other types of devices to adjust the desired parameters.

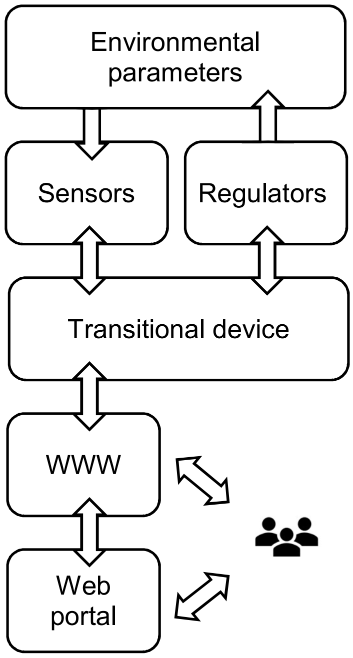

Fig. 1. Main scheme of the surveillance system of environmental parameters

3. Specific instructions

The multi-sensor combines various sensors. Its principle scheme is shown on Fig. 2. The coordination of the sensors in the multi-sensor, as well as the transmission of the received information, is carried out by a microcontroller MSP430G2553.

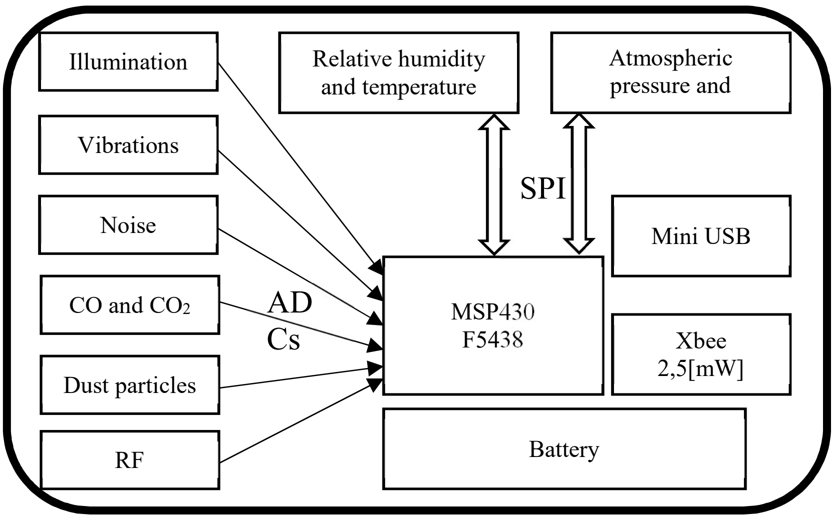

Fig. 2. Main scheme of the multisensor for monitoring and control

The transmission of the collected information to an intermediary device is via a radio link (XBee) from where the data is forwarded to a personal computer. The multi-sensor is a recording device with an acceptable measurement error. The tool error is related to its circuit design and the quality of the elements used, it is expected to work in the climate temperature zone and has no destabilizing effect on external factors. It is relatively small and is due to deviating the parameters of the elements from their nominal values. Methodological errors are greater and are due to the simplification of the functional dependencies of the sensors – linearization of transformation functions and tabulation and from discretization.

For construction of the multi-sensor we use industrial sensor blocks that are available on our market. They have the advantage of being pre-calibrated, consuming low power. The sensor blocks we use are:

- HIH6130 relative humidity and temperature sensor. It is a temperature compensated relative humidity sensor with digital output. Enables communication with the processors via I2C and SPI. Works reliably in the temperature range from -25°C to 85°C. It is powered by a 3.3V battery and has a working consumption of 1mA. Its ability to enter "sleep" mode gives extra battery life and implies long use without the need to change it.

- The MPL115A1 is calibrated by the manufacturer digital temperature and atmospheric pressure sensor. It measures absolute pressure within the range of 50 to 115kPa with an accuracy of ±1kPa. Just as the previous sensor is powered by a 3.3V battery at 10mA consumption. The CPU connection is via the SPI interface. Works reliably in the temperature range of -20°C to 85°C.

- GP2Y1010AU0F is an optical particle sensor that distinguishes between household dust and cigarette smoke. One of its advantages is the possibility of changing the input impulses, which enables energy-saving control when using the sensor. The power saving mode, as well as a multivariate power supply in the range of 3 to 5V, and the relatively low power consumption of max 20mA at full, allow both normal and long-term battery operation. In the range of 0 to 0.5m/m3 the characteristic is linear with an error of 1.5% which allows correct reading to be given in case of low level of dust particles and/or smoke in the rooms.
Sensors with high sensitivity to higher concentrations of certain gases have special requirements to voltage supply and have higher consumption. This determines their use only in the presence of a mains supply and the corresponding stabilization schemes.

- The gas sensor MQ-6 (Henan Hanwei Electronics Co., Ltd) is characterized by high sensitivity to isopropane, butane and other flammable gases used in households but has a low sensitivity to alcohols and cigarette smoke. The sensor part consists of a SnO_2 semiconductor, which has less resistance to fresh air. The resistivity of the sensing element increases in proportion to the amount of gas in the room. It is suitable for detecting gas leakage in households and industrial premises. It is powered by a 5V supply voltage with consumption ≤900mW, and additionally 24V supply voltage is required for the measuring circuit. The output signal is buffered with an operational amplifier which allows pre-amplification and calibration of the signal before its digital processing and analysis. The output signal of the base test circuit is calculated by the formula (1):

$$R_S = \left(\frac{V_C}{VR_L} - 1 \right) R_L \quad (1)$$

where R_S is the resistance of the sensor, VR_L is the measured voltage on selected load resistance R_L and V_C is the test voltage.

- The CO Sensor MQ-7 (Henan Hanwei Electronics Co., Ltd) is used to determine the relative concentration of carbon monoxide in residential and industrial premises. As with MQ-6, the sensitive material of MQ-7 is SnO_2, which has a lower conductivity for pure air. Detection of CO is performed by cyclic method at high and low temperature. CO is adsorbed upon the sensitive element at low temperature (heating is done with 1.5V). The conductivity of the sensor increases as the gas concentration increases. At high temperature heating the voltage goes to 5V. This cycle is used to clean the sensor from residual or other gases. The mode of operation of the sensor requires a power supply, which is carried out with two voltages – 5V with 70mA of heating element consumption and 10V for the measuring circuit. As with MQ-6 for signal processing, a buffer operational amplifier is used. For calculation of the resistance of the sensor it is used formula (1).

For the normal functioning of the CO sensor MQ-7, the following conditions must be met: Exposure to organic silicon vapor, highly aggressive and corroding gases, alkalis, alkali metal salts, halogen pollutants, wetting and freezing is strictly forbidden. It is also advisable to avoid condensation of water on the sensor, usage in highly concentrated gas environment, exposed for a long time in adverse conditions, vibrations and shocks.

- The CO_2 sensor MG811 (Henan Hanwei Electronics Co., Ltd) is characterized by good selectivity for carbon dioxide and can be used for air quality control and indoor CO_2 concentration determination. The carbon dioxide registration mechanism is based on the following chemical reactions:

Cathodic reaction: $2Li^+ + CO2 + ½O_2 + 2e^- = Li_2CO_3$

Anodic reaction: $2Na^+ + ½O_2 + 2e^- = Na_2O$

Complete reaction: $Li_2CO_3 + 2Na^+ = Na_2O + 2Li^+ + CO_2$

As a result of this reaction an electromotive voltage (EMF) is generated, which is calculated on the Nernst equation (2):

$$EMF = E_C - \frac{RT}{2Fln(P(CO_2))} \tag{2}$$

where $P(CO_2)$ is the partial pressure of the CO_2 gas, E_C is a constant volume, R is the bulk gas constant, T-temperature, and F is the Faraday constant. For correct operation of the sensor, a stabilized power supply of 6V. The relatively high consumption of 200mA requires the use of a power supply rather than a battery. Boosting the signal with an operational amplifier allows for easier data processing and analysis.

- The electromagnetic emission sensor is built on the LMH2120 (Texas Instruments), which is a power detector particularly suitable for measuring the power of modulated RF signals. Its output voltage is linearly dependent on the power of the input radio frequency. This makes it easy to integrate using equation 3 and decreasing the calibration effort. The device operates with a supply voltage of 2.7V to 5V. Through this sensor, the electromagnetic radiation from different types of wireless telecommunication networks can be registered. The frequency range of the sensor is 50 to 6000MHz. The dynamic range is 40dB.

$$V_{RMS} = \sqrt{\frac{1}{T}\int v^2(t)dt}; \quad P = \frac{V_{RMS}}{R} \tag{3}$$

where T is the integration interval, v(t) is the momentary measured voltage, V_{RMS} is the mean square signal voltage, R is the load impedance, and P is the signal power.

The described sensors can be successfully replaced by equivalent by another manufacturer.

For the determination of luminance, noise and vibrations, relatively simple circuits are used, the signal from which is amplified and calibrated by operational amplifiers. These circuits give signal with good precision. In our work, we have been striving to create power-saving sensors that use a 3.3V battery and control the multi-sensor by an inexpensive one-chip microcontroller with low power consumption. The illumination is measured with a photoresistor connected in bridge circuit. The noise sensor is made up by an electronic microphone whose signal is amplified with an operational amplifier in the frequency range from 40 to 16000Hz. For determining the level of low frequency mechanical vibrations, piezo plate is used, the signal is amplified and filtered in the frequency range of 0.5 to 35 Hz.

4. Conclusion

This paper presents the principle of a multi-sensor, called MOPHIP, composed of various sensitive elements for temperature, humidity, atmospheric pressure, illumination, sound, vibration, various sources of electromagnetic emissions, particle concentration, air concentration CO and CO2.

This multi-sensor is part of a complete system for individually monitoring and optimizing indoor environments. The system is implemented as a combination of MOPHIP and coordinating devices without interfering with normal data exchange.

MOPHIP can operate in low-consumption mode and wake up by the user when submitting command. Once the command is executed, the sensor modules re-enter the low-consumption mode.

The ability to transmit information to a user web portal on the Internet and to receive commands from it makes it extremely convenient to work from anywhere in the globe.

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