Hardware realization of measurement and monitoring system for level of groundwater

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Abstract—**In this paper, we present a hardware realization of system for measuring and monitoring of groundwater level. Level of groundwater is needed to create hydrodynamic models of inland excess water, which causes significant environmental and economic problem worldwide, because large parts of the flat terrain can be covered by inland excess water. On areas of interest, continuous measurement of groundwater level on several measurement points over long periods of time (several years) is needed as input data for hydrodynamic models. Measurements of groundwater level are made by acoustic system, which measure time of travel of sound to and from level of water inside wells. Every measurement point is equipped with GPRS transceiver, which sends data over GSM network to server connected to internet. Software on server collects and saves measured data in databases in adequate data format. System is realized and in current use, hardware realization and measurement results are presented.**

Keywords - groundwater, measurement, acoustic signals.

I. Introduction

Large parts of the flat terrain can be covered by inland excess water, which causes significant environmental and economic problem worldwide. Inland excess water represents a contemporary problem in Hungary, particularly in Csongrád County and in Serbia, especially in its northern part of Vojvodina [1].

The appearance of excess inland waters is primarily a result of several consecutive rainy years that lead to the accumulation of water in flatlands. These areas tend to contain relatively shallow phreatic aquifers that rise further, and even smaller amounts of rainfall can cause flooding, which occurs mainly during the spring season.

Causes of excess water are: climate (rainfall, snow melt), hydrological(shallow phreatic released, high water levels on rivers, flow of water from neighboring areas), geomorphologic (low leveled ground without surface runoff), soil conditions (soil heavier loamy texture, poor filtration capability). This system is developed for continuous measurement of groundwater level on several measurement points over long periods of time (several years), which is needed as input data for hydrodynamic models. With this model some excess water types could be forecasted, and actions could be taken [2].

Various techniques are used in water measurement. Industry solution usually employs pressure measurement systems which are very robust and precise, but are usually large in size and wouldn't fit in our monitoring wells. Laser measurements gives very precise result, but are very expensive. Ultrasonic measurements are widely used, but this type of measurement requires empty space between sensors and surface which level is measured. Since our monitoring wells are realized with relative small diameter of plastic pipe, signals would be reflected from walls of the pipe giving false measurement [3]. In this paper approach of measuring water level with acoustic signals of smaller frequency is described.

In Section II, monitoring network is explained in details. Measurement system is presented in details in in Section III. Measurement results are presented in Section IV, followed by Conclusion in Section V.

II. Monitoring network

Monitoring network is shown in Fig.1. To measure level of inland water, a series of wells are drilled on locations where excess water can appear.

To create initial hydrodynamic models there should be about thirty wells with distance of 2-4 km between them. Measurement system is set at the top of the well, and by measuring time measure time of travel of sound to and from level of water inside wells information of level of groundwater is obtained.

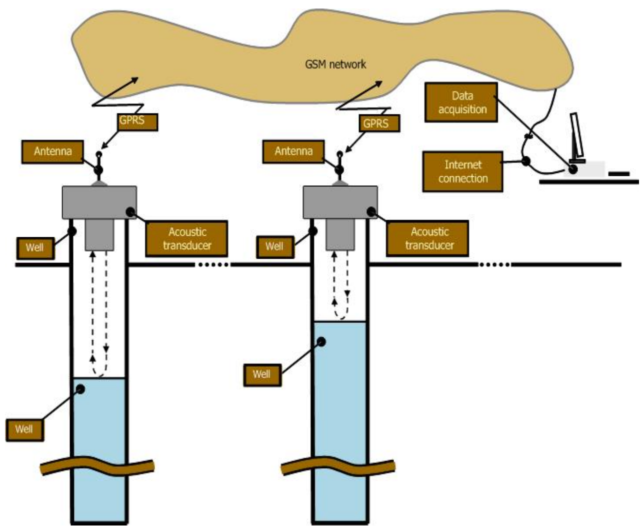

Figure 1. Monitoring network

This information is send by General Packet Radio Service (GPRS) modules over Global System for Mobile Communications (GSM) network to server connected to internet. GPRS modules were selected because of existing GSM network on entire territory where wells are set. If radio transceivers were used, transceivers with significant power would be necessary because of significant distance between wells, and permits for use of this equipment should be acquired.

Measurements are made once a day, since water levels cannot significantly change in smaller periods of time. Quantity of data send over GPRS is small, so there won't be significant expenses to GSM companies for its transmission.

III. MEASUREMENT SYSTEM

Block diagram of measurement system is shown in Fig.2.

Measurement system consists of: Sensor block, Microcontroller (MCU) block, battery board and GPRS module.Each module is designed on separate printed circuit board (PCB).All modules are placed one on top of another, to minimize dimensions of the system.

Being designed for outdoor use, the measuring unit shall be enclosed in a robust waterproof sealing which can be easily installed on the top of the well. To avoid the influence of metalwork inside the well, an external antenna shall be attached to the unit.

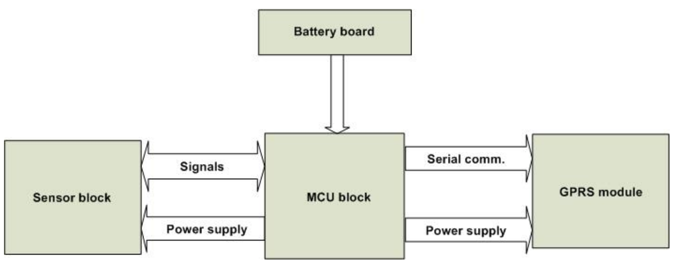

Figure 2. Block diagram of measurement system

In Fig.3 design of the well is presented, measurement system is placed on the top of the plastic pipe, and inside steel enclosure, used for security reasons.

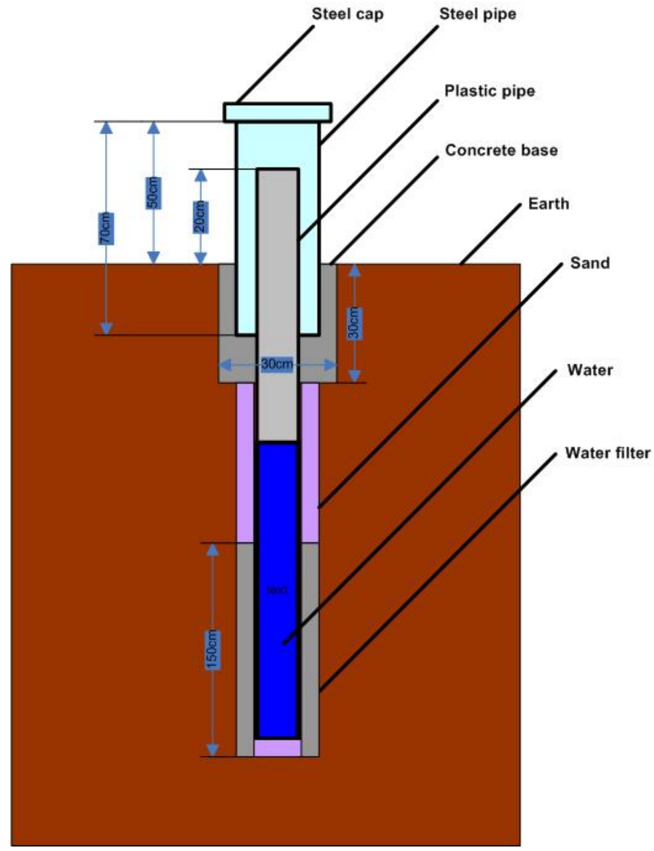

Figure 3. Well design

A. *Sensor block*

Sensor block consists of acoustic transmitter and receiver, and electronics for processing receiver signal and driving transmitter. It is presented in Fig.4.

Initial testing was made with ultrasonic signals, but it was determined that this frequencies weren't adequate for this application. Main problem with ultrasonic measurement was that since wells are designed with casing consisted of PVC pipes mounted one on other, there were significant reflections from joints of pipes. Amplitude of these reflections is similar as amplitude of useful signal. Additional "ghost" signals make it impossible to distinguish them from useful signals. By lowering measurement frequencies, joint reflections decreased, and frequencies of around 4 kHz were selected, because with them this reflection was almost insignificant.

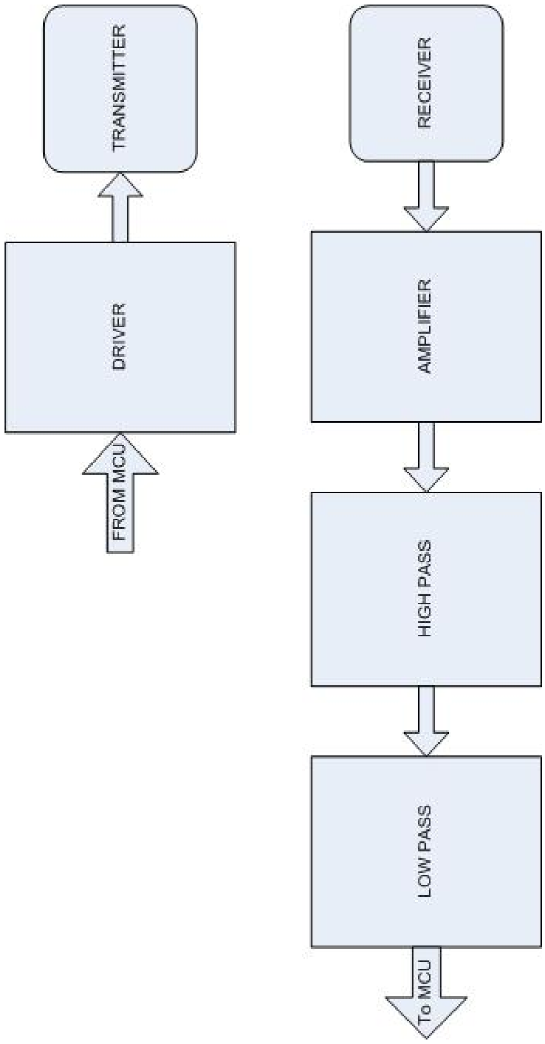

Figure 4. Sensor block

Microphone ABM-713 is used as receiver. Amplifier block consist of buffer connected to microphone, and amplifier designed with operational amplifier (OP) and digital potentiometer controlled by MCU, so amplification level is easily changed in software. High pass block consist of three 2-pole high pass filters realized with OP-s. All OP-u used in system are low cost rail to rail 2-OP circuits MCP6022. Six-pole high pass filter is used since measurement frequency is in audio range, and receiver microphone is wide range, so all external sounds will be detected by it. These signals must be attenuated as much as possible, so high pass filter is used. Low pass block consists of 2-pole low pass filter with cutoff frequency of 4 kHz. This filter is used to attenuate external sounds on higher frequencies and also to attenuate high frequencies noise. As received signal is send to MCU for A/D conversion there should not be any signals below half of sample frequency.

As acoustic transmitter KPEG-272 buzzer is used. Since battery voltage used in system is below 4V, step up converted is used to supply buzzer with higher voltages, achieving higher audio signal.

B. MCU block

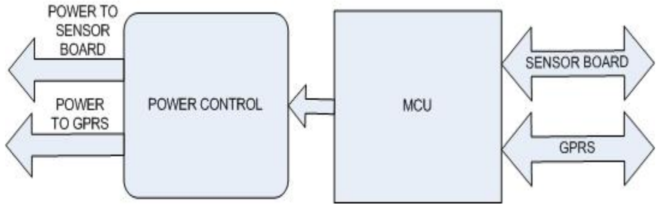

Figure 5. MCU block

MCU block is shown in Fig.5. It consist of low consumption MCU which have several functions:

- To communicate with GPRS module by sending and receiving data over serial port.
- To control transmitter on sensor board, and to perform A/D conversion of receiver signal
- To control power control block consist of switches that can completely turn off power to power supply to GPRS and sensor board.

MCU used in this system is PIC24F16KA102, extreme low power consumption microcontroller. Used MCU can be adjusted to use “sleep” mode and then the power consumption is extremely low, order of uA. With power control block, it could allow power supply to other blocks only when necessary. This MCU has internal 10-bit ADC converter, more than adequate for this system. Battery used in system is 3,6V so it could be used for direct supply of MCU, without losing energy on voltage regulators.

C. Battery board

Batteries used for this system are Lithium Thionyl Chloride type. These types of batteries are used since they can work on very small temperatures, up to minus forty degree of Celsius, and have low self-discharge rate. Voltage of this battery is 3,6V and capacity is 19Ah, which should be adequate to power this system for 2 years.

Flaw of this battery is that output voltage depends on temperature, and when external temperatures falls below zero, voltage that this battery gives is around 3V, which is not sufficient for GSM module, which input voltage is between 3.4V and 4.2V. Also, GSM module working current can go up to 2A for short periods of time, but enough to additionally drop voltage on battery. Since maximum current for this type of battery is below 300mA, additional capacitor with very high capacitance of 2,5F is connected parallel with battery, significantly extending its current capabilities. To ensure proper operation of GSM module, step up converter ADP1613 with output voltage of 4.1V and current capabilities of 2A is used.

IV. Measurement results

System is realized and tested in laboratory conditions. To ensure correct measurement, besides time of travel, amplitude of reflected signal was measured and compared to expected values for corresponding time of travel, thus eliminating false measurements.

Measurement resolution of 1 cm was obtained, with measurement range of 15 meters. Higher measurement range and resolution could be obtained with stronger transceiver and more precise time measurement, but obtained values were adequate for this application. Measurement below 30 cm are omitted, because useful signals from water and direct signal from transmitter are mixed, and peak signal from useful signal cannot be found, so measurement error can be up to 15cm.

V. Conclusion

This monitoring system is realized as low-cost and robust system for measurement of level of groundwater. By permitting power supply only when necessary to measure and send information, battery life is extended to over one year, which is very important feature when measured point of groundwater are in areas hard to reach, especially during winter. Using GSM network for sending data and battery for power supply, system can be placed almost anywhere. With special care about power supply, our system is capable working during all seasons, even with temperatures below zero, up to -30 degree of Celsius.

This monitoring system can be easily adapted to be used in wide range of environmental measurements, like humidity, temperature, etc. Using battery supply and GSM communication, this system can function properly almost anywhere.

Acknowledgments

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