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CONTACTLESS RUNNING WATER FLOW DETECTION AND WATER FLOW MEASUREMENT SYSTEM

Miss. Prajakta Ajay Dhane
Department of Electronics & Telecommunication,
Rajarambapu Institute of Technology,
Islampur, India.
padhane26@gmail.com

Dr. A. B. Kakade
Assistant Professor
Department of Electronics & Telecommunication,
Rajarambapu Institute of Technology,
Islampur, India.
anandrao.kakade@ritindia.edu

***Abstract*-Contactless running water detection and water flow measurement system detects whether water in the pipe is stationary or running. The main purpose of the system is to measure water flow without contact of water. The system is suitable for plastic and metal pipes. The low cost water flow detection system is most useful for domestic purpose.**

Piezoelectric vibration sensor is used as flow sensor for measurement purpose. It detects the flow induced vibration signal from flow of water in the pipe. It converts flow induced vibrations due to water flow inside the pipe into electrical signal. This weak electrical signal is filtered and amplified with the help of operational amplifier. Operational amplifier amplifies the signal and gives required output voltage level. Amplified signal is given to peak detector and Schmitt trigger. Peak detector detects the positive peak value of the voltage which is the proportional to the frequency. Schmitt trigger gives output in the form of pulsating DC voltage i.e. digital output.

Digital output is given to the microcontroller. Microcontroller counts these pulses to determine flow rate. Microcontroller executes program to control all devices which is helpful for flow measurement. The microcontroller indicates water flow on the display. These type of system till now not available in the market.

Index Terms-Flow induced vibrations, contactless running water detection, and piezoelectric vibration sensor

I. INTRODUCTION

Water is important resource in our daily life. It is used for specific purpose such as domestic use, irrigation, and industrial processing. To understand water availability, water distribution and its use, water flow information is necessary. The water flow measurement and running water detection is essential to avoid wastage of water.

Available water resources- water resources are sources of water that are useful or potentially useful for humans. 97% of water on the earth is salt water and only 3 % is fresh water, slightly over two thirds of this is frozen in glaciers.

Usable water in the present water resources- The remaining unfrozen water is found mainly as groundwater, with only a small fraction present above ground or in the air.

Need of water resources- Uses of water includes agriculture, industrial, household, recreational and environmental activities. All living things require water to grow and reproduce.

Water crisis on the earth- Fresh water is renewable resource, yet the world's supply of groundwater is steadily decreasing, depletion occurring most prominently in Asia, South America, although it is still unclear how much natural renewable balances this usage, and whether ecosystems are threatened. The framework for allocating water resources to water users is known as water rights.

Need of water flow measurement in the industry as well as for domestic use- According to World Business Council for Sustainable Development, it applies to situations where there is not enough water for all uses i.e. domestic as well as industrial or other works. This is due to more wastage of water.

Importance of water flow measurement & need of water flow measurement in the house: In the house, water is useful for all household works. Importance of water flow measurement & need of water flow measurement in the industry: In the industry, water flow measurement is essential for industrial purposes.

Therefore for running water flow detection and water flow measurement, Contactless running water flow detection and water flow measurement system is useful.

II. PRESENT THEORY AND PRACTICES

There are several flow measurement techniques available in the market. Most useful techniques are ultrasonic flow meter, electromagnetic flow meter, flow meter based on Hall Effect. The features of ultrasonic sensor are easy installation, no moving parts and no contact between sensor and liquid. But main drawback of ultrasonic sensor is high cost. Installation of electromagnetic flow sensor is made by cutting pipe. Electromagnetic flow meter comes in contact of water. The requirement of electromagnetic flow meter is different for different pipe diameters. Also, electromagnetic flow meter does not work properly when particles in water accumulate on turbine. Another flow meter i.e. obstruction type flow meter, turbine type flow meter, open channel flow meter, pressure flow meter available in the market is very costly. When we use this flow meter regularly then these flow meters do not work properly after few days.

Usually we use pump for the lifting of water to the overhead tank on the house as well as in the farms for the supply of water to the crops. In the industry, we use water pump for giving water supply to the overhead tanks and water flow measurement purpose. Current transformer is useful for measuring current flowing through the water pump. A water pump can be damaged by conditions that cause the pump to run continuously, particularly if the pump is running "dry" - without water passing through its mechanical parts. Therefore pump does not give water supply properly.

After few days current transformer does not work properly because of dry run condition of water. To confirm the physical condition and electrical characteristics of current transformer is complicated process. These drawbacks will be overcome in proposed system. In the proposed system, we use simple center tap transformer for measuring the current rating. The sensor used for measurement purpose which is the electrolytic plate. With the help of this electrolytic plate we measure flow induced vibrations from the water pipe.

Motivation of the present work:

Therefore, the main purpose of the project is to measure water flow without contact of water. For accurate flow measurement, piezoelectric plate is used. This plate is low cost and easily available in the market. The output of the piezoelectric plate is based on flow induced vibration. The motivation of the work is measurement of flow induced vibration signal without contact of water.

The system is suitable for all type of pipe materials such as plastic pipe, metal pipe. The proposed system detects either water flow in the pipe is stationary or running. The system detects dry run condition of water. The low cost water flow measurement system is most useful for domestic purpose.

III. PREVIOUS WORKS

Khrissy Arcelly Reis Medeiros, et al. presents the "Optimization of flow rate measurement using piezoelectric accelerometers: Application in water industry". This paper shows that method of measurement of water flow rate using piezoelectric accelerometer. The piezoelectric accelerometer is useful for measurement of vibration. Hence, system is based on FIV technique i.e. Flow Induced Vibration. This system is specifically used in water industry. System is unable to measure flow variation during measurement so obtained flow rate is not accurate. [1]

Shiv Kumar Jaiswal presents the "Design and development of a novel water flow measurement system". The multiple weighing techniques are used in measurement system. This technique is advantageous for avoiding wastage of water as well as reducing time for collecting large amount of water in a tank. The measurement of flow is determined by collecting mass of flowing water over a measured time. Since the flow is dynamic therefore output of the flow is averaged during collection interval. [2]

Jae Yong Cho et al. works on piezoelectric harvesters and electromagnetic harvesters. For generating electrical energy from original energy source, two energy harvesters are suitable. Therefore system becomes self-powered. These self-powered water meter measures water flow rate data send to user. [3]

Ria Sood et al. provide low cost turbine type water flow meter. For measurement of water flow and water detection, hall-effect sensor is used. The system mainly used for irrigation pipelines. [4]

Peter Mwangi et al. presents low cost water meter based on the global system for mobile communication. The system measures accurate water meter reading as well as send message to user for water billing purposes. [5]

Michele Norgia et al. presents flow measurement technique based on laser diode instrument. Bare laser diode depends on Doppler shift induced by scattering particles inside the fluid. Interferometers are the device used in this system is useful for measurement of small distances. Self-mixing interferometer means laser beam is reflected from on object back to laser. [6]

Piezo-Technologies Technical Resource paper presents the study of properties piezoelectric plate and study of material used for making piezoelectric plate. In this paper, we have studied the properties of piezoelectric plate, i.e. Dielectric constant, coupling coefficient, resonance frequencies, Frequency constant, Quality Factor (Q). [7]

Limitations of above systems will be overcome in proposed system. The main aim of the system is to measure accurate water flow rate and running water flow detection.

IV. DESIGN AND DEVELOPMENT OF THE PROPOSED SYSTEM

The proposed system is about detection of running water and measurement of water flow. PIC microcontroller 18F4520 is used as controlling device. It is interfaced with LCD display. Vibration sensor can be used as input for measuring amplitude of flow induced vibration signal. This vibration signal is amplified by using signal conditioning circuit. When appropriate output is obtained from peak detector, then this signal is digitized using PIC microcontroller. Finally water flow measurement output is displayed on LCD.

Selection of Components:

Fig.1 shows block diagram of proposed system. It consists following components,

Vibration sensor: It is used for measurement of flow induced vibration. Piezoelectric plate is used as vibration sensor. Piezoelectric plate converts flow induced vibrations into electrical signal.

Low Noise Amplifier- In second amplifier stage, low pass filter is used for filtration and elimination of noise signal. Then next stage integrator produces output voltage (i.e. flow induced vibration signal) which is proportional to the integral of the input voltage.

Amplifier- Amplifier amplifies signal and shows appropriate output signal.

Schmitt Trigger- It is comparator circuit with hysteresis loop implemented by applying positive feedback to the non-inverting input of comparator. Schmitt trigger is used to convert analog input signal into digital output signal.

Proposed Block Diagram:

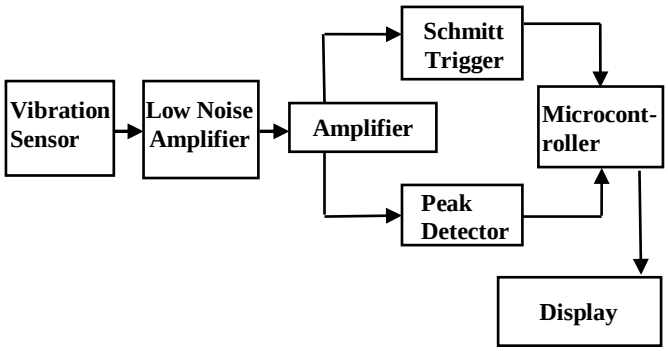

Fig. 1 Block Diagram of the proposed system

Peak Detector: Peak detector detects and holds the most positive value of attained by the input signal prior to the time when the switch is closed.
Microcontroller- Microcontroller controls all input process. It interfaces with ADC, LCD display as well as an analog part of the system i.e. Signal condition circuit.
Display- Display shows the output of the proposed system in the digital form.

Piezoelectric vibration sensor is fitted on the outer surface of water pipe. Vibration sensor detects the vibration signal from flow of water in the pipe. It converts flow induced vibrations due to water flow inside the pipe into electrical signal. This electrical signal is given to low noise amplifier for amplification.

Third stage of amplifier amplifies the signal and gives required output. Third stage of amplifier is connected to Schmitt trigger as well as peak detector. Schmitt trigger gives output in the form of square wave i.e. digital output. The voltage amplitude of the Schmitt trigger is directly proportional to flow rate of water inside the pipe. Peak detector gives pulsating output which is proportional to the frequency. Digital output is given to the microcontroller. Microcontroller counts these pulses to determine flow rate. The microcontroller indicates water flow on the display. Accurate water flow measurement output is obtained with help of proposed system.

Study of properties of piezoelectric sensor:

Piezoelectric Vibration Sensor: In these work we have studied properties of piezoelectric sensor. Piezoelectric plate is a transducer which converts mechanical energy into electrical energy. In water flow measurement, piezoelectric plate used to measure changes in flow induced vibration and converting them into electrical charge. A piezoelectric plate can be modeled as a proportional voltage source and filter network.

Piezoelectric plate is formed into a disk with one electrode covering the entire top surface and a second electrode covering the entire bottom surface.[7]

Selection of proper operational amplifier:-

For the proposed system, LM324 operational amplifier is useful for amplification and measurement of amplitude of flow induced vibration signal.

Selection of microcontroller:-

Controller selection is most important in all the components as it is the main processing and controlling element in the system. The controller cost holds a major position in overall cost. PIC microcontrollers are designed using the Harvard Architecture. PIC 18F series of microcontroller is suitable for programming. Therefore for proposed system, PIC18F4520 Microcontroller is selected.

Design of signal conditioning circuit:-

In the design of signal conditioning circuit, first stage of operational amplifier is low noise amplifier. Low noise amplifier is useful for eliminating noise and amplification of vibration signal. The second stage of op-amp is integrator which is used to improve the peak voltage of vibration signal. The third stage of op-amp is Schmitt trigger. The Schmitt trigger gives the pulsating output. The last stage of op-amp is peak detector. The peak detects and holds the positive peak voltage values. Peak detector voltage output is proportional to the water flow rate in the pipe.

First we designed signal conditioning circuit on the Dip-Trace software. Then we fabricated Printed Circuit Board of signal conditioning circuit.

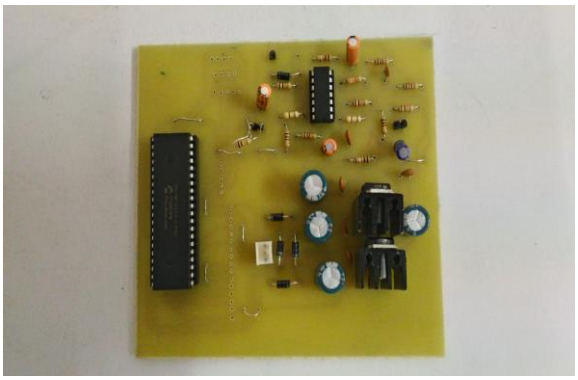

Fig. 2 Final Printed Circuit Board of the system

Results:

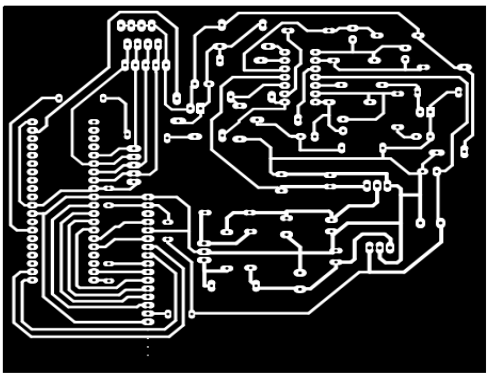

Fig. 3 PCB layout of the system

V. CALIBRATION AND ANALYSIS

Analytical results of the flow measurement output:

We have measured amplitude of vibration signal for different positions of piezoelectric plate. When we measured amplitude of vibration signal without obstruction then the major problem was very low amplitude of voltage signal. When water is in flowing condition vibration signal obtained from the pipe are very weak.

We have measured amplitude of vibration signal for different positions of piezoelectric plate. When we fixed screw as an obstruction on the pipe, then amplitude of the flow induced vibration signal is improved i.e. voltage output is increased as compared to without obstruction condition. Therefore obstruction is essential for water flow measurement. Measurement of vibration signal and their amplitudes are depending on the position of the piezoelectric plate and screw fitted on the pipe.

The position of the piezoelectric plate is main parameter in the analysis. When position of the piezoelectric plate is near the screw then amplitude of the vibration signal is high. The position of piezoelectric plate away from the screw then amplitude of vibration signal is low. We have measured amplitude of vibration signal for two conditions. First condition is amplitude of flow measurement without flowing water. Second condition is flow measurement with flowing water. High water flow, low water flow and medium flow of water is considered in flowing water condition.

Analysis of amplitude of vibration signal:

In the following table, observations are given. Table no. 1 includes without obstruction results and table no. 2 includes with obstruction results.

Without obstruction and with obstruction results are mentioned below:

Table no. 1: Results without obstruction

Without Water Flow (Amplitude of the signal) = 0.08 v		
With Water flow:		
Low Water Flow	**Medium Water Flow**	**High Water Flow**
0.2V	0.8V	1.2V
0.24V	0.89v	1.6V

Table no. 2: Results with obstruction

Without Water Flow (Amplitude of the signal) = 0.8 v		
With Water flow:		
Low Water Flow	**Medium Water Flow**	**High Water Flow**
2V	3.2V	3.6V
2.8V	3.2V	3.6V

In analytical result of the system, we include figure 4 which describes about amplitude of signal without water flow. Also, Figure 5 which describes amplitude of signal with low water flow. Figure 6 which describe amplitude of signal with medium water flow. Figure 7 which describe amplitude of the signal with high water flow. In these observations, we proved that, frequency and amplitude of the various signal are changed as per the condition of water flow i.e. vibration signal for condition: without water flow, with water flow (low, medium, high).

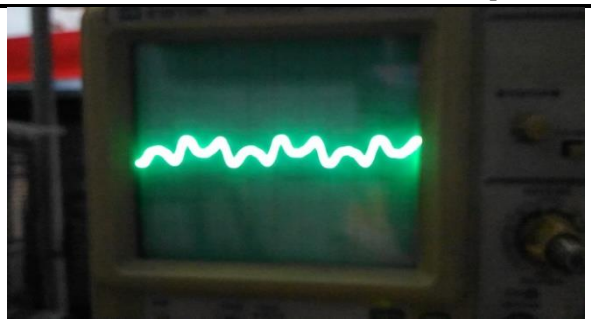

Fig. 4 Amplitude of the Signal (without water flow)

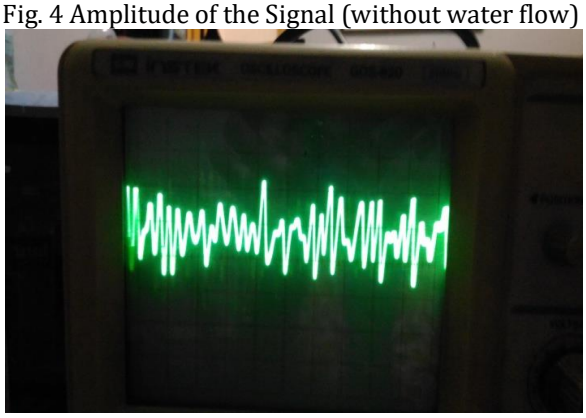

Fig. 5 Amplitude of the Signal (with low water flow)

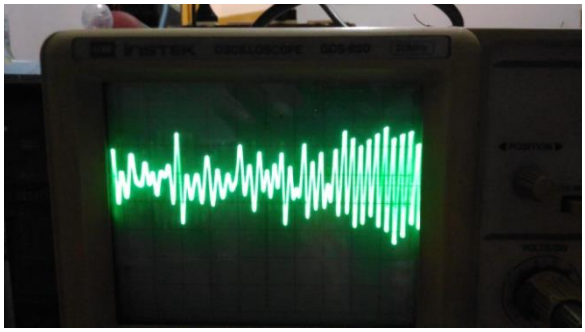

Fig. 6 Amplitude of the Signal (with medium water flow)

Fig. 7 Amplitude of the Signal (with high water flow)

VI. CONCLUSION

With the help of calibration and analysis, we have developed low cost contactless running water flow detection and water flow measurement system which is useful for domestic as well as industrial application.

The piezoelectric plate is successfully used as vibration sensor for measurement of flow induced vibration signal through water. Also it differentiates water flow condition i.e. stationary water flow or running water

flow. The amplitude of the vibration signal changes when speed of water changes i.e. for low flow of water amplitude of vibration signal is low, for medium flow of water amplitude of vibration signal is medium, for high flow of water amplitude of vibration signal is high.

VII. FUTURE WORKS

With the help of proposed system, we measured water flow speed without contact of water. And the main purpose of the system which useful in household water distribution purposes is to detect the running water flow condition and stationary water flow condition.

Detection of the flow induced vibrations of water is very easy because of use of piezoelectric plate i.e. Vibration sensor. Our future works is to detect vibration signal with the help of stethoscope. When we try to detect flow induced vibrations using stethoscope various major changes are occurred. That's why we decided to use stethoscope for detection of vibration signal of water flow.

When final testing set up is developed then in the final result, amplitude and frequency variations of vibration signal are occurred. So it is the best way to detect flow induced variations of the water using stethoscope.

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