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Purity Sensor Activated Smart Toilet Flushing System

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Abstract: Toilet flushers are known for consuming almost one third of the water in buildings. This paper introduces a smart system to reduce the amount of toilet flushing water while keeping it clean. The proposed system is using a pH sensor to monitor the toilet impurities and a microcontroller to control the amount of water need to clean it. The preliminary results of the implemented system shows that half of the amount of water can be saved during flushing compared to the smallest fixed value flushing system of 3.75 liter per flush (LPF).

Key words: Toilet flushers · pH sensor · Implemented system · Water conservation

INTRODUCTION

As the world's population is increasing, more of the water supplies have been used and contaminated leaving less fresh water available. This makes it necessary to ensure that adequate and sustainable water supplies can still be made available for this and future generations. Presently, there are three ways to do this; water recycling, water desalination and water conservation.

Conservation strives to save and reduce water use. There are many positive benefits to conserving water, not only does it curb the amount of fresh water we consume, but it also decreases waste water discharges and the associated effects of pollution. Thus, conservation applies the principle that one liter of water saved is better than one liter of water supplied. Therefore, conservational practices had to be invoked in order to reduce water consumption while still supporting the growing population.

Water savings potential varies greatly at houses, hotels and workplaces, depending mainly on the type of facility and the how people use it. An initial conservation plan might start by analyzing each building or facility according to its specific water use profile. In addition, people need to be educated in water-saving habits, such as, using low-flow shower heads and small size toilet flushers. Toilet flushing typically account for nearly one-third of a building's total water consumption and this end-use is one of the simplest and lowest cost areas to target for significant water and sewer savings. This can be achieved by replacing, for example, older model toilets using 13.2 liter per flush (LPF) or greater with new 6.1 LPF ultra-low flush toilets (ULFTs), 4.84 LPF high efficiency toilets (HETs), or dual flush toilets using 6.1 LPF for solid waste and 3.75 LPF for liquid waste. The benefit-cost ratio is dependent upon the frequency of using the toilet flushes which varies from person to person with an average of 6 to 7 flushes per person. Some earlier versions of ULFTs designed to meet this standard had some operational problems and were prone to clogging or required double flushing.

Some toilet flushing mechanisms were activated using infra red sensors. However, there is no scientific evidence that sensor-activated toilet flushers saves water, as these devices prone to waste water by flushing more frequently than necessary [1]. They provide user convenience, but are now known to be wasters of water.

In present study we propose a smart toilets flushing system that operate automatically only whenever toilets actually need flushing with adequate amount of water just enough to clean them.

Flushing Mechanisms: The flushing mechanism provides a large flow of water into the bowl. ULFTs are offered in three classifications; flush valve, pressure-assisted and gravity toilets. In general, the flush valve and pressure-assisted ULFTs perform better than gravity toilets since they use the water system pressure to assist in their operation.

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Tank Style Gravity-Flow Toilets: The system works by releasing the water in the attached tank once the flushing button pressed which falls into the bowl by gravity. A float valve is often used to regulate the filling of a tank or cistern. When the fluid level drops, the float descends, levering the valve opening and allowing more fluid to enter. Once the float reached the 'full' position, the arm presses the valve shut again.

Tank Style Pressure-Assist Toilets: This system utilizes mains water pressure to pre-pressurize a plastic tank located inside what otherwise appears to be the more typical flush tank. A flush cycle begins each time a user flushes the bowl. After a user flushes and the water in the pre-pressurized tank has finished emptying into the bowl, the outlet valve in the plastic tank shuts. Then the high pressure water from the city main refills the plastic tank. Inside the tank is an air-filled balloon-like rubber diaphragm. As the higher-pressure mains water enters the tank, the rubber diaphragm is also pressurized and shrinks accordingly. During flushing, the compressed air inside the diaphragm pushes the water into the bowl at a flow rate which is significantly higher than a tank style gravity-flow toilet. They seldom clog, but require replacement about once every 10 years and they tend to be noisier, a concern for residential settings. The inner bowl stays cleaner than gravity counterparts because of the larger water surface area and the toilet's forceful flush. Newer pressure-assisted toilets use 4.2 to 5.3 LPF.

Tankless Style High-Pressure Toilets (Flushometer): Since they have no tank, they have zero recharge time and can be used immediately by the next user of the toilet. Some Flushometer models require a button to be pressed, which in turn opens a flush valve allowing mains-pressure water to flow directly into the toilet bowl. Other models are electronically triggered, using an infrared sensor. In retrofit installations, a self-contained battery-powered or hard-wired unit can be added to an existing manual Flushometer to flush automatically when a user departs.

The Flushometer system requires no storage tank, but requires a high volume of water in a very short time, thus a minimum of 1 inch pipe, must be used. As the high volume is used only for a short duration, very little water is used for the amount of flushing efficacy delivered. Water main pressures must be above 2.1 bars and still requires approximately the same amount of water as a gravity system to operate (6 LPF).

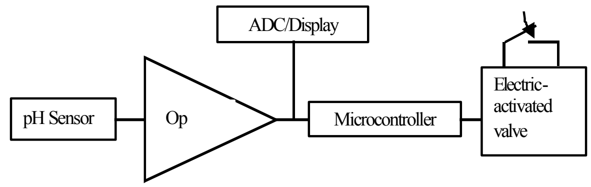

Fig. 1: A block diagram of the proposed smart flushing system.

The system proposed in this paper will be applied to Flushometer systems.

System Requirements: To implement the idea of automatically flushing the toilet with just enough water to clean it, a water purity sensor is attached at the bottom of the toilet bowl. If the sensor detects a change in water purity from a present value, it will activate a controllable flushing system using a microcontroller based circuit which stops immediately whenever the sensor detects the initial water purity value back. In order to make the system work only when the person finishes using the toilet, the flushing mechanism is activated either manually or automatically when the impurity level of the water reaches a stable value over a short time. The block diagram of the smart flushing system is shown in Figure 1.

Water Purity Sensors: There are different types of sensors which can be used to measure purity of water. This includes conductivity sensors, pH sensors and optical sensors. High purity sensors are not a requirement for our application.

Conductivity Sensor: The conductivity sensor measures the conductivity of aqueous solutions in industrial and municipal process applications. It is designed to perform in the harshest of environments. Electrolytic conductivity is a strong function of temperature and conductivity readings are typically converted to the value at a reference temperature.

Optical Sensors: Optical sensors are based on reversible changes in optical properties, which include absorbance, reactance and refractive index [2-4]. One technique is to use a fiber optic sensor [5] to measure the color changes of a liquid which are trapped in a thin porous glass membrane. An optical light source sends a pulse of light via fiber to a colored solution. A reflected light pulse is measured by a Photodetector. The reflected

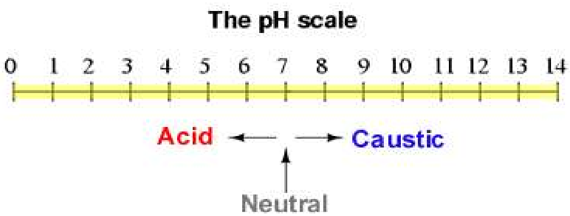

Fig. 2: The scale of pH of different solutions.

pulse depends on the absorbance (color) of the solution. An increase of the absorbance of the solution will result in a smaller reflected light pulse.

Ph Sensor: The pH of a solution indicates how acidic or alkaline it is. The pH term translates the values of the hydrogen ion concentration, which ordinarily ranges between about 1 and 10^{-14} gram-equivalents per liter, into numbers between 0 and 14.

On the pH scale a very acidic solution has a low pH value, which corresponds to a large concentration of hydrogen ions; while a very alkaline solution has a high pH value, which corresponds to a small number of hydrogen ions. A neutral solution such as water has a pH of approximately 7. This scale is shown in Figure 2.

In this work we used pH100 pH sensor to detect the change in the water impurity of the toilets.

Circuit Design and Implementation: The pH sensor (pH100) is immersed in the water at the neck of the S shape at the bottom of a bowl to keep it away from direct contact with any dirt. A very high-input impedance MAX406 CMOS op amp is used to buffer the extremely high output impedance of a pH probe ($10^{12}\Omega$). The advantage gained is the use of a standard low-cost cable instead of high-cost Teflon dielectric coax cable. The resistive divider R_1/R_2 shown in Figure 3, whose output is midway between the battery's terminals, provides a reference potential for the pH probe.

The output of the MAX406 amplifier is directly connected to PIC16F88 microcontroller that converts the pH data digitally and compares its value with the preset initial water pH value. The microcontroller is programmed to add a delay till the value of the pH becomes stable before it sends a signal to release the water valve for flushing. An override switch button is added for manual valve operation, while keeping the amount of flushing water automatically adjusted. If desired, we can install the op amp and its power

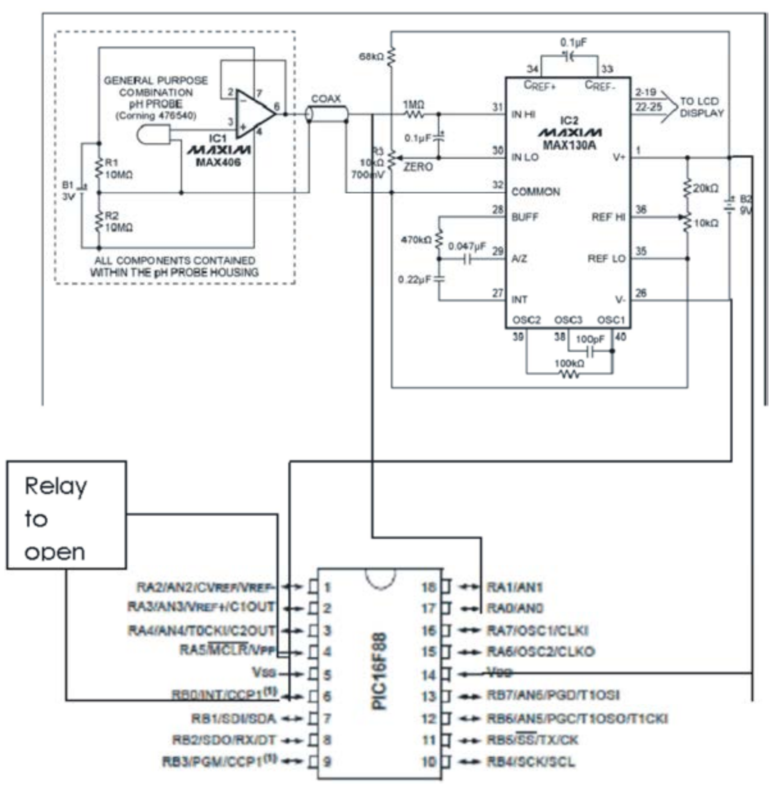

Fig. 3: The integrated smart flushing system which includes a pH100 electrode, a buffer circuit, PIC16F88 microcontroller and a MAX130A LCD-meter circuit based on a 3½-digit.

supply (a small lithium battery) within the probe housing. Battery drain is so low that the circuit can be continuously powered for thousands of hours on a single lithium cell.

An integrated ADC and LCD driver and display can also be connected to the output of the amplifier to display and calibrate the pH value. MAX130A integrated circuit is an example of such a driver/display system, as shown in Figure 3. Potentiometer R_3 introduces an adjustable 700mV offset. By shifting the probe's ±700mV output range to one of 0 to 1400mV, it provides an output compatible with the intended display range of 0 to 14pH.

The pH100 is automatically temperature compensated over the temperature range 0-50°C. An internal thermistor circuit matches the temperature curve and compensates for temperature changes. The sensor will reach full output reading in less than two seconds. When it is used in the circuit that have an adjustable power-on time feature, a minimum of two seconds is recommended.

RESULTS AND DISCUSSIONS

We applied the proposed system for flushing liquid waste of urine samples. The pH for normal urine ranges between 4.6 and 8.0, which corresponds to an output voltage of the sensor equivalent to +130 and -50mV. While signal magnitude ratio (SMR) varies with pH across a range somewhat wider than the specified limits for any given sensor, the narrower specified range is given, as it is the range over which the system is most responsive, as shown in Figure 4.

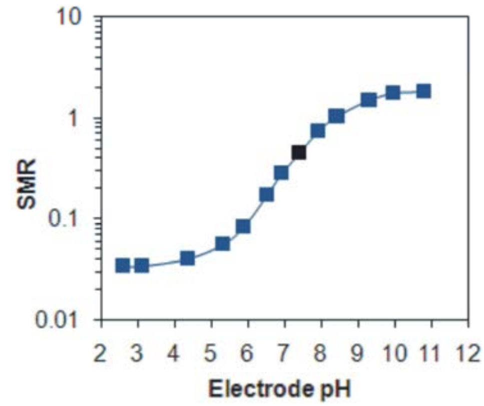

Fig. 4: The variation of the output signal magnitude ratio of the system with the pH.

Once the system detects a change in the pH above or below the preset value, (which is around 7.0) this value usually keeps increasing (or decreasing) linearly until the toilet user finishes, then it becomes almost constant. Te system is then encountering a delay of 30 seconds before it send a signal to the flushing valve to be released. The opening time of the valve will vary according to the change of the pH between the final stable value and the initial value (ΔpH). This time can be set using open or closed loop system. In case of the open loop the time used is stored as a table in the microcontroller memory for each value of ΔpH. However, there will be no information whether the toilet was over or under-flushed. This process can be improved using a learning phase of the smart system and the stored values can be continuously updated.

In case of the closed loop system, which is used in our case, the system monitor the pH value during flushing and will stop when the pH value returns to its initial value, which varies from time to time according to the value of pH. This ensures adequate cleaning with minimum water quantity. The minimum flushing water volume recorder during this experiment was 1.5 liter, well below the minimum standard flushing mechanism of 3.75 liter.

CONCLUSIONS

A smart toilet flushing system using a pH sensor and a microcontroller was introduced. The circuit was designed, implemented and tested. The preliminary results of the implemented circuit shows that an amount of water as low as 1.5 LPF is enough to flush the toilet clean, less than half of the smallest fixed value flushing system of 3.75 LPF.

Future Work: The present work was mainly applied for flushing of liquid waste. The next phase of the experiment will concentrate on the solid waste. The difference would be mainly in the slow change in pH which might direct us towards using different type of sensor integrated with the current system. One possibility is to use an optical sensor that receives an infra red light from a transmitter through the still water of the bowl.

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