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Research Article

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Design and implementation of food intelligent monitoring system based on pH sensor

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ABSTRACT

Food spoilage has detrimental effects both in terms of health risks for consumers as well as increased costs for producers. This prompted the development of a system for detecting food spoilage that was compact, low-maintenance, and simple to manufacture. The design of said system is discussed in this paper. This paper proposes a design and implementation of food intelligent monitoring system based on pH sensor. The results of our paper show that it is possible to use pH sensor technology and near field communication technology to detect changes in pH to avoid food spoilage.

Keywords: pH, RFID, Sensor

INTRODUCTION

Spoilage is the process in which food deteriorates to the point in which it is not edible to humans or its quality of edibility becomes reduced. Various external forces are responsible for the spoilage of food. Food that is capable of spoiling is referred to as perishable food. Every year, food spoilage leads to wastage and millions of food poisoning cases worldwide. The absence of adequate food monitoring technology could compromise the quality of food products during transit. The ability to wirelessly monitor the quality of food produce reduces costs for producers and ensures consumers health and safety hence making food quality measurement an indispensable requirement. Current means of monitoring food quality are through the use of sensors which observe changes in temperature, release of gases (such as ammonia) and secretion of enzymes. These methods are not entirely practical due to cost-constraints, bulky proportions, complex fabrication processes and the need for regular maintenance. Due to the aforementioned reasons, we were motivated to develop a simple and cost-effective wireless food monitoring device.

Our paper introduces Near Field Communication and comprises a pH sensor and an external interrogator that interact to provide information on the quality of food products. The pH sensor is further divided into electrodes and resonant circuit. The electrodes of the sensor are coated with hydrogel [1]; a hydrophilic polymer which acts as an electrolytic solution where the electrodes interact. The resonant circuit consists of an inductive coil and sensor electronics. The interrogator consists of an inductive coil, discrete components, a switch controller and a data acquisition system. The interrogator uses a time-domain gating method to interact with the pH sensor through inductive coupling [2].

The goal of our paper was to detect food spoilage through pH change. The change in pH of the food being tested causes a change in the voltage across the electrodes and this voltage change varies the capacitance of the near field communication tag. The near field communication tag will therefore resonate at a different frequency as pH changes. The interrogator will obtain this new frequency through inductive coupling which will be used to detect pH changes. This will enable the user to determine whether or not food spoilage has occurred.

DESIGN AND IMPLEMENTATION

Near Field Communication is a wireless communication technology that is used to exchange data in a short range. The near field communication technology implemented in the food spoilage monitoring device is based on inductive coupling. It comprises a transmitter coil and a receiver coil. The alternating current in the transmitter coil generates a magnetic field which couples to the receiver coil. The amount of energy transferred through inductive coupling from the transmitter to the receiver depends on the coupling factor between the two coils. The coupling factor depends on the size of the coils and their relative positions, and is inversely proportional to the cube of the distance between the coils. The quality of the coupling is also determined by the Q factor of the system. A higher Q factor indicates that the amount of energy dissipated by resistive elements is small relative to the amount stored by the reactive elements. The higher the Q factor, the more efficiently energy is transferred to the receiver. At greater distances less energy is coupled to the receiver, meaning that the energy transfer must be more efficient in order for the same amount of energy to be stored. Therefore the minimum operating distance between the coils depends on the Q factor. For our purposes, the minimum distance between the transmitter coil and the receiver coil for guaranteed operation will be 3 cm.

pH

PH is a measure of the hydrogen ion concentration in a substance. It is the measure of the acidity or alkalinity of a solution [3]. Based on the definition by Bronsted and Lowry, an acid is a substance capable of donating protons to other molecules or ions while a base is a substance that is capable of accepting such protons. All acid base reactions can be written as follows:

$HA + B \rightarrow BH^+ + A^-$

Acid + base = conjugate acid of base B + conjugate base of acid HA^+

PH can be measured in both aqueous and non-aqueous solutions using different scales. PH measurements are very important in a multitude of applications and in our specific case, it will be used to measure the level of food spoilage. Specifically, the pH of an aqueous solution can be calculated using the following equation:

$pH = -\log[H^+]$

Where $[H^+]$ is the concentration of hydrogen ions in mol/L.

In order to measure the pH of a solution, very precise pH meters or pH indicators could be used. These pH meters give very specific results regarding the pH of the solution being tested. They usually include a silver chloride reference electrode and a glass pH electrode.

Electrodes

Electrodes are solid conductors used in electrochemical measurements to obtain information on the induced potential of an electrolyte [4]. They are used in cathode and anode pairs. The silver/silver chloride electrode used in this design is a cathode and it acts as a reference electrode that undergoes reduction in an electrolyte. The mixed-metal oxide electrode is an anode and it acts as a sensing electrode, which undergoes oxidation. The following expression is used to calculate the potential measured by the following electrodes:

$$E = \frac{RT}{F} ln(\frac{a_{H+}}{(p_{H2}/p^0)^{1/2}}) = \frac{-2.303RT}{F} pH - \frac{RT}{2F} ln(\frac{p_{H2}}{p^0})$$

Where E is the measured potential
R is the universal gas constant
T is the temperature (Kelvin)
F is the Faraday constant
a_{H+} is the activity of hydrogen ions
p_{H2} is the partial pressure of the hydrogen gas
p^0 is the standard pressure.

A solid-state reference electrode and a mixed-metal oxide (MMO) sensing electrode are used in this design. The mixed-metal oxide electrode is used for detection since the potential across its terminal changes in response to fluctuations in pH level. The solid-state reference electrode does not respond to changes in pH and acts as a reference for the MMO electrode. A hydrophilic polymer called hydrogel is used to coat the electrodes. Hydrogel absorbs gases that are released during food spoilage. It also acts as an electrolytic solution where ions are exchanged between the reference and mixed-metal electrodes to provide voltage changes.

Near Field Communication System

This food spoilage monitoring device comprises the following main components: the interrogator and the near field communication tag. The transmitter coil is part of the interrogator, and the receiver coil is one of the components of the tag [5]. There are two approaches for establishing near field communication that were considered. One approach is to use an impedance analyzer which generates a sine wave that is swept over a specified frequency range. The impedance analyzer accurately measures the impedance of the circuit connected to its terminals. The interrogator coil is connected to the impedance analyzer and the tag is placed nearby. The interrogator coil and the tag coil couple thereby allowing the frequency response of the tag to be determined. The resonant frequency of the near field communication tag responds to voltage changes across the electrodes (as seen in Figure 2.2).

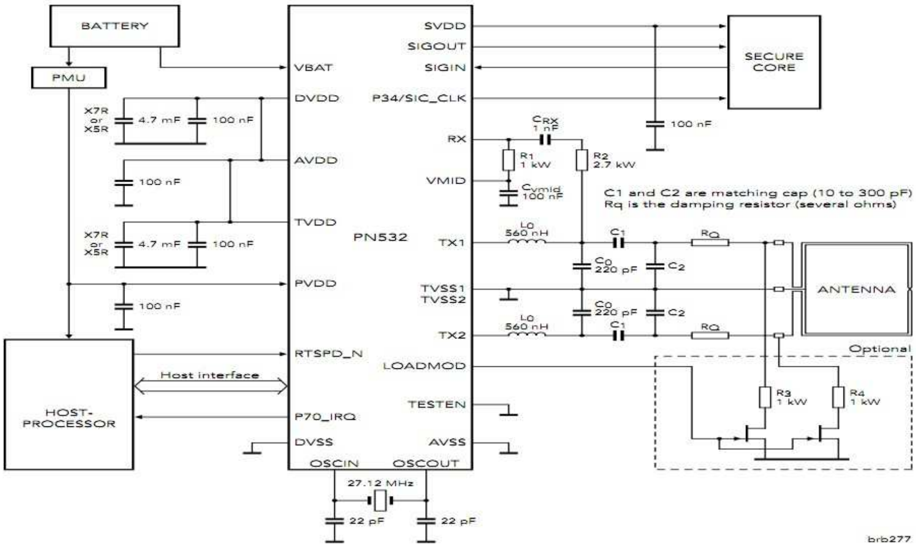

Figure 1. near field communication System

The sensor and interrogator coils can establish Near Field Communication through inductive coupling. The sensor coil can either be hand wound or milled on a printed circuit board. When the sensor coil is in parallel with the voltage controlled capacitor (varactor), a resonant circuit is formed and the resonant frequency can be determined using the following equation.

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Where:
f_0 is the resonant frequency of the circuit.
L is the inductance of the coil.
C is the capacitance of the varactor.

A varactor is a voltage controlled capacitor that changes its capacitance in response to changes in the bias voltage. In the near field communication tag, when the capacitance of the varactor changes, the resonant frequency of the circuit changes as well [6]. The interrogator coil interacts with the sensor coil. The low pass filter consists of a resistor in series with a capacitor. The filter prevents the electrodes from being affected by the output signal of the interrogator. The cutoff frequency of low pass RC circuit is calculated based on the following equation.

$$f_c = \frac{1}{2\pi RC}$$

Where:
f_c is the cut-off frequency.

R represents the resistance.
C represents the capacitance.

Time Domain Gating Interrogation

Time Domain Gating is a method of interrogation, used to obtain information from sensors in wireless systems that employ technologies such as RFID or near field communication. In systems based on electrical resonance, Time Domain Gating allows for the natural frequency of the sensor to be determined. The main components of a Time Domain Gating based interrogator are a signal generator, a switch, a switch controller, as well as an inductive coil in the case of near field communication based systems.It also includes either an oscilloscope or lock-in amplifier, depending on the specific mode of operation [7].

Time Domain Gating based interrogation has 3 phases: a transmit phase, a receive phase, and a short delay phase in between transmitting and receiving. The timing of these phases is set by the switch controller. Figure 2.4 shows a timing diagram of these 4 phases.

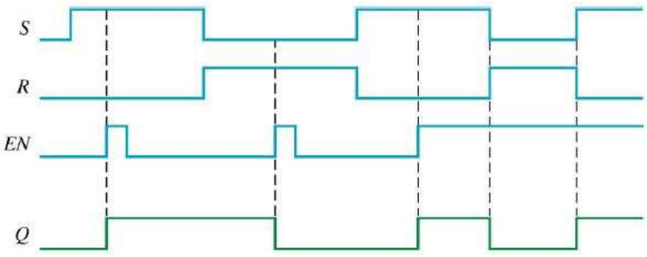

Figure 2. Timing Diagram of Time Domain Gating

During the transmit phase the signal generator is connected to the interrogator coil via the switch. The energy sent from the interrogator coil couples to the sensor coil, and the sensor coil begins to resonate. The interrogator then exits the transmit phase, and the signal generator is disconnected from the interrogator coil. In the case of near field communication systems, the delay phase allows for energy stored in the coil, due self-resonance, to dissipate. For RFID systems, the delay phase allows for any waves that are reflected by the environment to pass by and not interfere with the interrogation [8]. The interrogator then transitions to the receive phase, and the energy stored in the resonant circuit of the sensor couples back to the interrogator in the form of an exponentially decaying sine wave. There are two methods of analyzing the received signal in order to obtain the resonant frequency: measuring the amplitude and measuring the frequency.

PH SENSOR AND IMPEDANCE ANALYZER TESTING

The purpose of this test was to observe the performance of the final device, where every component had been integrated. This test demonstrated the overall response of the device to gases of varying pH levels. This setup involves the electrodes attached to the tag with jumper cables, the interrogator, and a computer running OpenChoice and MATLAB. An airtight glass chamber was used to contain the gases to be tested from the environment. To ensure that the chamber was airtight, the bottom and sides were made from one piece of acrylic and a rubber gasket was incorporated into the lid. The chamber was also designed to have a shelf-like compartment with adjustable height where the electrodes were placed. The separation distance between the pH sensor and interrogator coil was maintained at approximately 3 cm. We also conducted experiments using the impedance analyzer to replace the interrogator. Figure 4.27 illustrates the basic setup for the testing of the near field communication pH sensor with the impedance analyzer.

The hydrogel-coated electrodes, connected to the tag, were enclosed in a glass chamber containing demonized milk and left for 3 days. This was done to allow the voltage between the electrodes stabilize before any further testing. After the voltage across the electrodes stabilized, demonized milk was quickly replaced with vinegar and the setup was left for 3 hours to stabilize. The interrogator was used to energize the tag and the resulting data was captured from an oscilloscope using OpenChoice software, and then saved to a computer.

The MATLAB program was run, generating a frequency value output as well as a graph of the signal in the frequency domain, which was saved. Since this above setup takes considerable amount of days, the above procedure was only repeated for acetic acid. To test ammonia, the voltage across the electrodes was simulated using a DC power supply connected to the tag. The results obtained using the interrogator were inconsistent so the test was repeated, using an impedance analyzer. The frequency results obtained using the interrogator were not linear, so we repeated measurements with an impedance analyzer and compared the results. Figures 4.28, 4.29, 4.30 below show signals obtained with an impedance analyzer during the testing of ammonia, deionized milk and acetic acid.

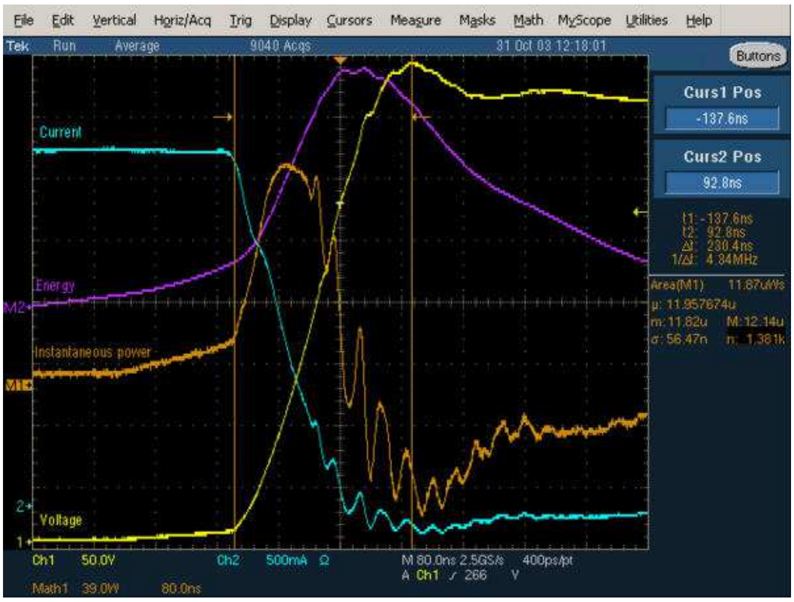

Figure 3. Test result with deionized milk

CONCLUSION

The results of our system show that it is possible to use pH sensor technology and near field communication technology to detect changes in pH. A near field communication based pH sensor was developed, which was comprised of an electrode based pH sensing circuit and a resonant circuit. The function of the sensing circuit was to detect changes in pH, while the purpose of the resonant circuit was to translate these pH changes into measurable changes in frequency. Methods for interrogating the sensor were investigated, and near field communication based method called Time Domain Interrogation was chosen, followed by additional design work to tailor it for our system. The key component of this was the design of a switch controller capable of controlling the interrogator timing. The interrogator allowed changes in the natural frequency of the resonant circuit to be monitored wirelessly.

REFERENCES

[1] Shailesh N. Zala; *Journal of Chemical and Pharmaceutical Research*, **2013**(2), 122-130.
[2] S. Fouladgar; B. Mainaud; K. Masmoudi; H. Afifi, in Proceedings of the 3rd European conference on Security and Privacy in Ad-Hoc and Sensor Networks, **2006**, 32-42.
[3] T. Kothmayr; C. Schmitt; W. Hu; M. Brünig; G. Carle, in 37th IEEE International Workshop on Practical Issues in Building Sensor Network Applications, **2012**, 69-86.
[4] Alan Demers; Johannes Gehrke; Biswanath P; Proceedings of the Conference. Innovative Data Systems Research(CIDR), **2007**, 412–422.
[5] J. Hui; D. Culler, Proceedings of the IEEE, **2010**(98), 1865-1878.
[6] Nihal Dindar; Peter M. Fischer; Merve Soner; Nesime Tatbul; Proceedings of the 5th ACM international conference on Distributed event-based system, **2011**(5), 33-69.
[7] Marcelo R. N. Mendes; Pedro Bizarro; Paulo Marques; Proceedings of the second international conference on Distributed event-based systems, **2008**, 313–316.
[8] Trimurti Lambat; Sujata Deo; Tomleshkumar Deshmukh; *Journal of Chemical and Pharmaceutical Research*, **2014**(4), 888-892.