International Journal of Electrical and Electronic Science
2019; 6(2): 8-16
http://www.aascit.org/journal/ijees
ISSN: 2375-2998

American Association for Science and Technology

Design and Evaluation of an Intelligent Monitoring and Alarm System Based on a Noninvasive Fluid Level Sensor for Patients with Fibromyalgia

Hamidreza Shirzadfar[1], Narsis Gordoghli[2]

[1]Department of Biomedical Engineering, Sheikhbahaee University, Isfahan, Iran
[2]Independent Researcher, Isfahan, Iran

Email address
h.shirzadfar@shbu.ac.ir (H. Shirzadfar), h.shirzadfar@gmail.com (H. Shirzadfar)

Citation
Hamidreza Shirzadfar, Narsis Gordoghli. Design and Evaluation of an Intelligent Monitoring and Alarm System Based on a Noninvasive Fluid Level Sensor for Patients with Fibromyalgia. *International Journal of Electrical and Electronic Science.* Vol. 6, No. 2, 2019, pp. 8-16.

Received: November 10, 2019; **Accepted**: December 9, 2019; **Published**: December 21, 2019

Abstract: Fibromyalgia syndrome (FMS) is a chronic disorder that causes pain and dryness in the muscles, tendons and joints and is also associated with sleep disorders, chronic fatigue, morning fatigue, anxiety, depression and gastrointestinal disorders. One of the most prominent symptoms of fibromyalgia is urinary tract infection (UTI). Patients with fibromyalgia complain of self-urination, a common symptom in fibromyalgia, especially in women. Urinary incontinence has both physical and psychological consequences, including skin damage, urinary tract infections and an increased risk of falls. Various methods and treats likes self-urination include medications, medical instruments, interventional treatments, surgery, absorbent layers and catheters, implants have been developed and designed for fibromyalgia syndrome and urinary diseases which each method had unique and specific features but each technique had significant disadvantages that can be problematic for the patient. In this article, we decided to propose a new method based on anatomical and physiological investigations related to the bladder after this study in patients with fibromyalgia and treatment modalities so far. In this investigation, a method will be present that it is a very smart non-invasive method which allows the patient to be aware of his or her urine volume level before reaching the bladder. The purpose method of this study is to design an intelligent device for the treatment and resolution of self-urinary dysfunction, especially in patients with fibromyalgia.

Keywords: Fibromyalgia Syndrome (FMS), Urinary Bladder, Pain Threshold, Liquid Surface Sensor, Alarm Detection System

1. Introduction

Fibromyalgia syndrome is characterized by a set of symptoms, not just a functional disorder, and is diagnosed according to the American College of Rheumatology criteria. Most people with fibromyalgia are women. These patients usually do not have enough fitness and have a lot of problems with their daily activities. One of the symptoms of fibromyalgia is frequent urination, which leads to urinary incontinence. Some effective treatments for urinary problems include pharmacological, non-pharmacological and alternative therapies, including the use of protective pads, catheters, Botox, catheterization, and more [1, 2]. Many women suffer from an inability to control their urine. Women are twice as likely as men to have urinary incontinence due to pregnancy and childbirth, which is more common with age. In this type of disease, the person who loses urine in the bladder immediately loses control and ability to hold urine and has no control over their urinary tract.

Our goal in this article is to design a non-invasive system to prevent self-urinary disorders in patients, especially patients with fibromyalgia. In the previous article we have presented the simulation part of this project. The COMOSL software was used to simulate bladder, urinary bladder, ureter and the sensing areas of four sensors. In the simulation part, the effects of electric currents and magnetic fields are studied. We also examined the effect of magnetic fields and electric currents, including: magnetic flux density, electrical conductivity, impedance, relative permeability and relative permittivity in the duty area of the sensors [3].

Since aging is an important and key parameter in the onset and increase of the disease, it can cause many problems for people. These diseases even have a negative impact on social relationships, so trying to treat them is of particular importance. Urinary bladder and urinary tract are also important parts that will have problems with age. One of these problems is self-urinary disease [4]. Our goal is to review the methods to date and develop a new intelligent method to treat the psychological consequences of the disease. As we know the sensors are playing very important roles in the word particularly in the medicine [5-10] and various unreachable projects well done due to the intelligent sensors [11-20].

In this project, a non-invasive device for the treatment and self-urination of a non-invasive device has been used to measure the level of non-contact digital fluid and its associated range and the designed module determines the level of urine in the bladder. The fluid level sensor uses a high-power chip (XKC-Y25-T12V) to detect the liquid surface without direct contact with the bladder. The noninvasive diagnostic model is embedded in a belt and the urine level in the body's urinary system is continuously evaluated and when the urine level in the bladder reaches near the pain threshold, the patient's hand system is monitored. Patient is aware of him or herself and is aware of this condition before the bladder gets out of control and becomes self-urinating. In addition, we aim to measure the increased bladder volume and the sensors must send an alert before the patient's first pain threshold in order to inform the patient the amount of urine in the bladder before the bladder gets out of control.

2. Material & Methods

Different methods have been designed and suggested so far to treat self-urinary tract problems in individuals. Therefore, a method for controlling this complication in fibromyalgia is presented below, an important feature of the proposed method is that it is non-invasive and is the least effective method for the elimination of self-urinary disorder. It will have a devastating effect. In this method, a non-contact digital fluid level sensor is used to measure the level of urine in the bladder according to the designed module. It is a fluid level sensor that utilizes a high-speed chip (XKC-Y25-T12V) with high-speed operating capacity to detect advanced signal processing technology to detect Achieve liquid level without direct contact with the bladder. The sensor is sensitive to all liquids with different conductive properties and therefore the sensor can be suitable for all types of liquids in different containers. Then, the interface board connects to the interface board which uses the Arduino Uno interface board to design this interface board. The final diagnostic model is mounted on a belt and the urine level in the urinary tract is continuously evaluated and when the urine level in the bladder reaches near the pain threshold or pain threshold, the alert system is activated on the patient's hand. The alarm system will receive the information which is reached from detector by Bluetooth module. With this intelligent system, the patient is informed of the status of the urine level in the bladder by receiving a message and alerting himself to the problem before he or she has a problem. The schematic of the detection and warning system is illustrated in Figure 1.

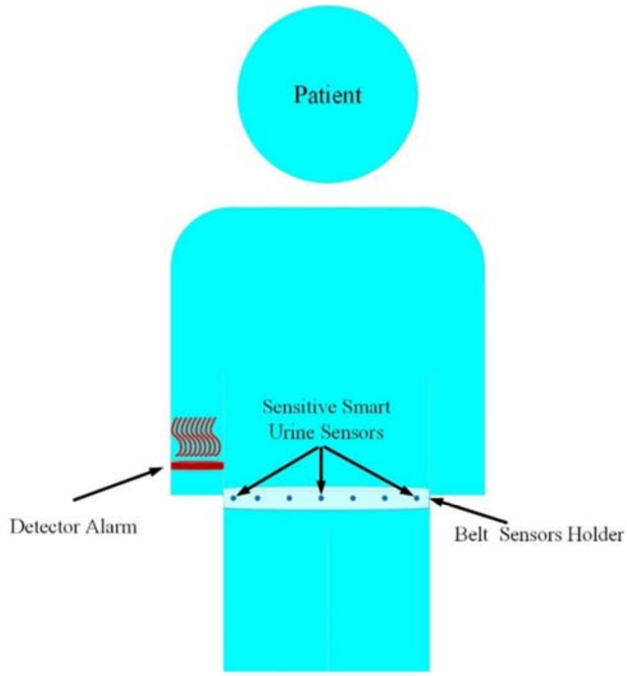

Figure 1. *The detector intelligent system to determine the urine level in bladder [1].*

The equipment which employed in this project are: Liquid level sensor chip, sensor adapter board, Arduino Uno board, HC-05 Bluetooth module, Arduino Nano board, the vibrating alarm system and the software used is Arduino IDE V1.6.5.

The Figure 2 illustrates how to connect different parts of the sensor including the sensor (XKC-Y25-T12V), power supply adapter board, Arduino Uno board, and Bluetooth module as transmitter to determine the level of fluid.

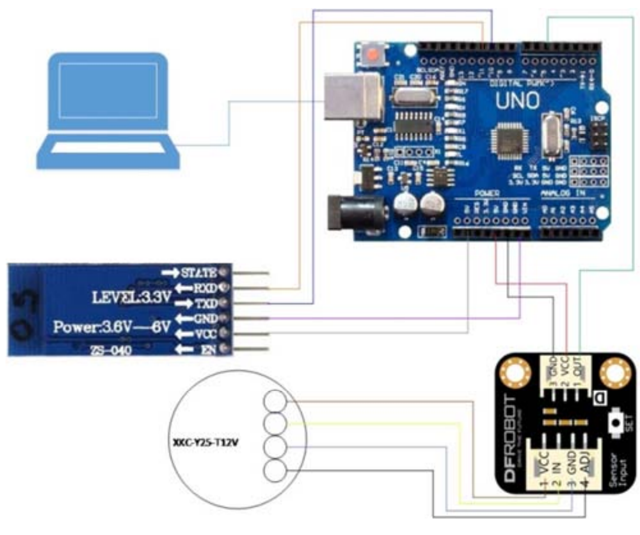

Figure 2. *The schematic of the liquid detector, Arduino Uno Adapter Board and the Bluetooth module.*

2.1. The Specification of Liquid Sensor

The liquid level smart sensor is one of the most important parts of this project, the XKC-Y25-T12V sensor was selected according to various investigations, the properties of this sensor are described in Table 1.

Table 1. *The specifications of liquid sensor XKC-Y25-T12V.*

IN-VCC – The operation voltage	24V~5 DC
Consumption Current	mA 5
Output voltage (high level)	In VCC
Output voltage ((low level	
Output Current	mA 50~1
Response time	500 mS
Operating temperature	°C 105~0
Diagnostic thickness range (sensitivity)	mm 13~0
Humidity	5 %~100%
Material	Acrylonitrile Butadiene Styrene (ABS)
Waterproof Performance Type	IP67
Dimensions	mm 28×28- inches 1.1×1.1

The real image of sensor type XKC-Y25-T12V is illustrated in Figure 3, which is connected to a 50 cm cable to connect to the power supply interface board (Figure 5) with four wires. The schematic of the sensor and its Adapter Board is presented in Figure 6.

Figure 3. *The view of the XKC-Y25-T12V sensor [21].*

2.2. The Adapter Board of Sensor

The electrical circuit embedded on the board is shown in Figure 4.

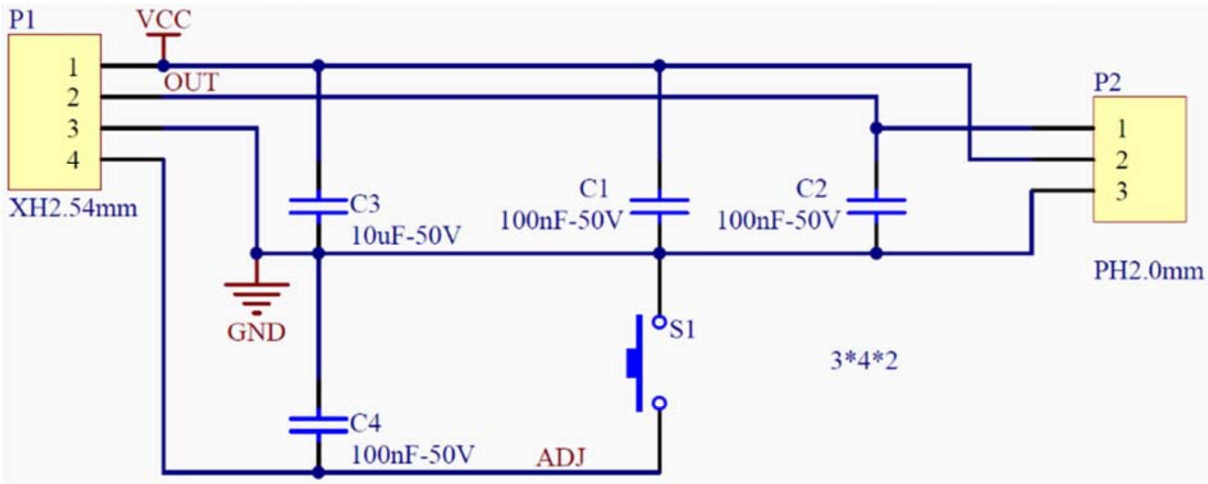

Figure 4. *The electrical circuit of the sensor's adapter board.*

The working principle of the sensor is that it uses a water measuring capacitor to detect the presence or absence of liquid near the sensor until the time to create distributed capacitance. For this purpose, there are several constant capacitances relative to the sensor ground. As the liquid surface approaches the sensor gradually, the capacitance is created and coupled to the constant capacitance. The value of the final capacitance is increased and then the modified capacitive signal is input to the control IC in reason to the convert the signal. The IC changes the new capacitance relative to the electrical signal changes and then senses and detects the value of these changes using a specific algorithm. When the amount of variation exceeds the specified threshold, it means that the liquid level has reached the target point.

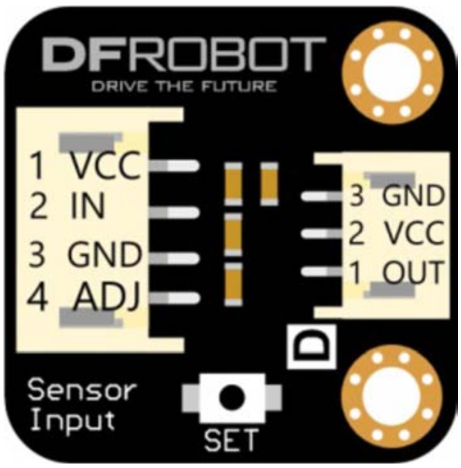

Figure 5. *The Sensor's Adapter Board [22].*

Figure 6. *The Sensor Connector (XKC-Y25-T12V) with the Sensor's Adapter Board [23].*

2.3. Arduino Uno Board

The Arduino Uno is an ATmega328P-based microcontroller board. It has 14 input/output pins, 6 analog inputs, a 16 MHz quartz crystal, USB connection, ICSP header and reset button that all require microcontroller support. The board simply connects to the computer via a USB cable or can be plugged in with an AC adapter or battery to get started. The digital fluid level sensor connects to the Arduino interface board (Figures 2-3) with its own adapter and then connects to the computer via the Arduino. The liquid level sensor detects the results on Arduino software in real-time (serial, at any time). The program is embedded so that the zero number (LOW) indicates that the liquid level does not reach the level at which the sensor is located, and the number 1 (HIGH) reports leveling the liquid and sensor. So when the sensor detects the liquid level, HIGH will be the output and the LED will be turned on. When no fluid is detected, the LOW will be output and the LED will be off (the LED is located on the sensor (see Figure 7)).

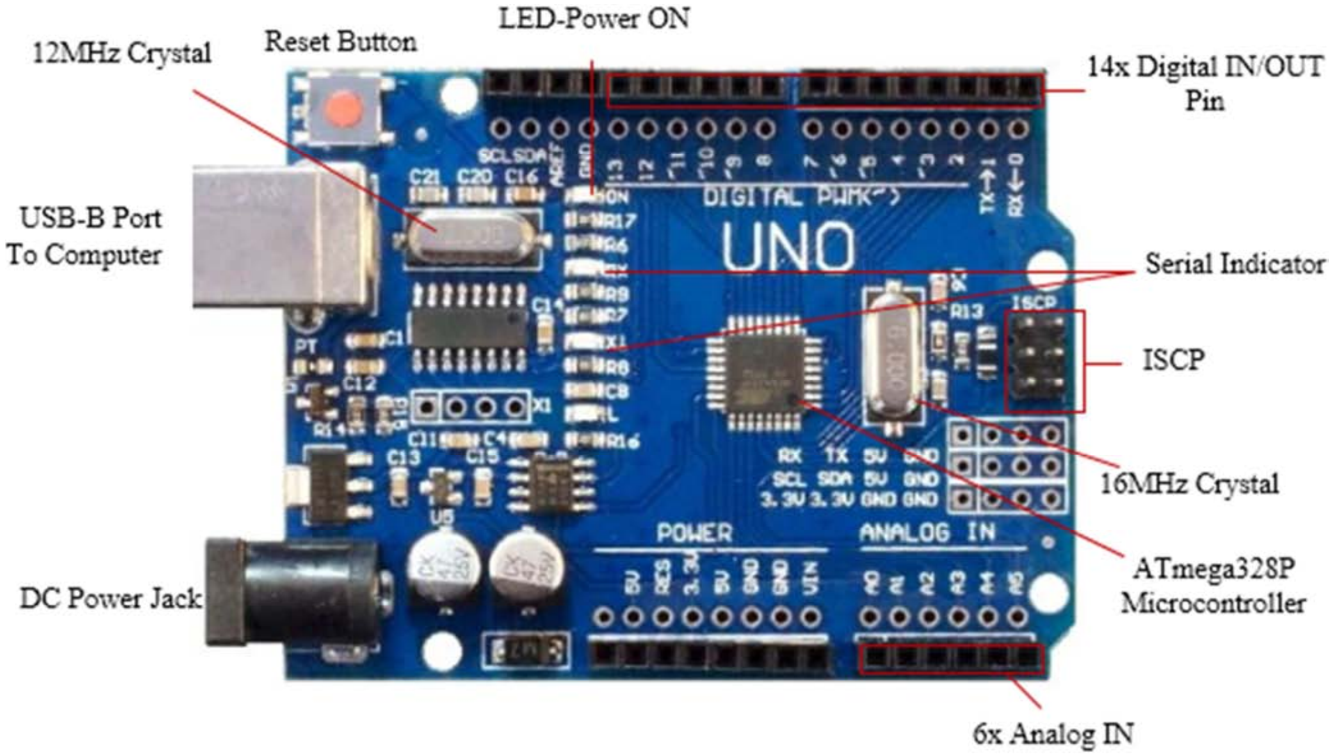

Figure 7. *The details schematic of the Arduino Uno board.*

The Arduino is able to sense the surroundings by receiving input from a variety of sensors. The board-mounted microcontroller is programmed using the Arduino programming language (wiring based) and the Arduino development configuration (processing based). Arduino projects can be independent or communicate with software running on a computer. The following commands as presented in Figures 8, 9 and 10 are utilized in Arduino software for this project:

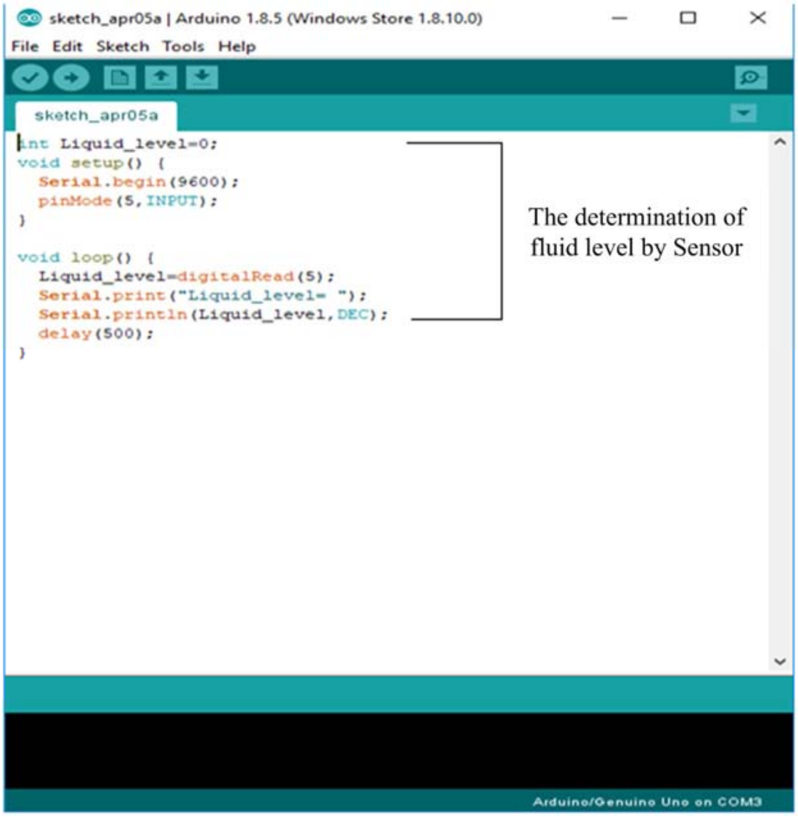

Figure 8. *The program of the liquid sensor in Arduino software.*

2.4. The Bluetooth Type HC-05

The HC series modules are used to communicate via Bluetooth, which are built in different numbers as follows: HC-03, HC-04, HC-05 and HC-06. Figure 11 shows the real image and PCB board of the Bluetooth Type HC-05.

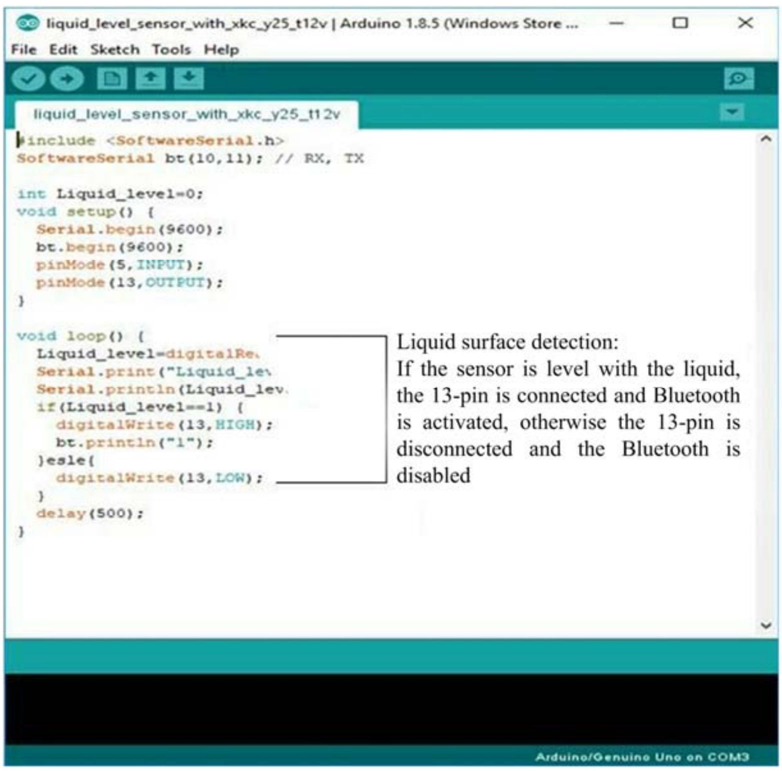

Figure 9. *The Bluetooth program in transmitter mode in Arduino software.*

Even numbers can only work in one Master or Slave role, but odd numbers can be both Master and Slave. In the role of Master, it finds another Bluetooth tool module (such as a mobile phone) and starts the communication. But in the Slave role the module has to wait for the connection to start from the other tool. The most popular module in this family is the HC-05, which can work both as a Master and as a Slave.

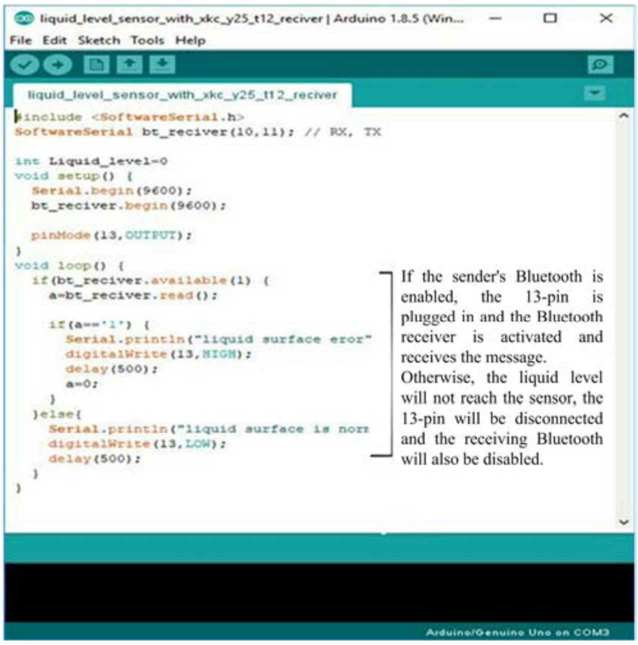

Figure 10. The Bluetooth program in receiver mode in Arduino software.

2.5. Arduino Nano Interface Board

The Arduino Nano is a compact Uno-like screen (see Figure 12). The difference is that the jack does not have DC power and works with a USB Mini-B cable instead of a standard USB cable. It's a small, complete board based on the ATmega328P. If Bluetooth sender is enabled, the 13-pin is connected and the Bluetooth receiver is activated and receives the message. Otherwise, the liquid level will not reach the sensor, the 13-pin will be disconnected and the receiving Bluetooth will also be disabled.

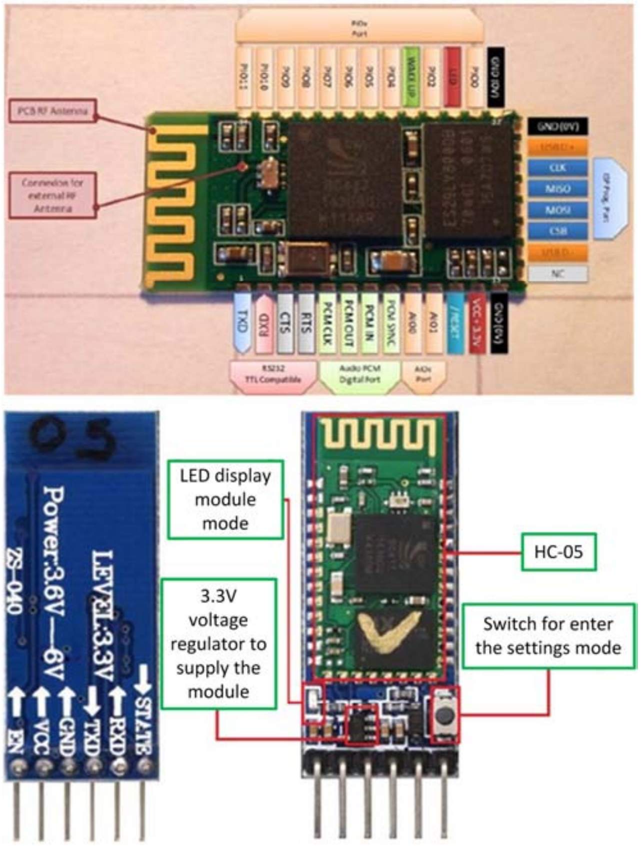

Figure 11. The view of the Bluetooth type HC-05 [24].

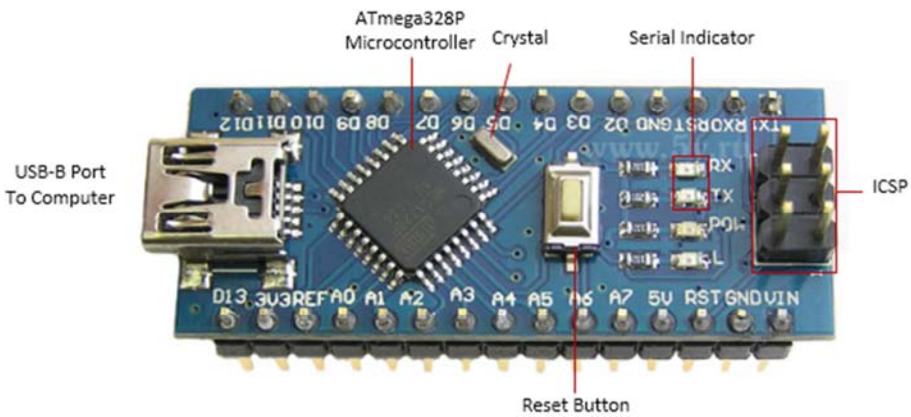

Figure 12. The Schematicof the Arduino Nano board [24].

2.6. Vibration Motor

The patient detector is a small vibration motor disk for tactile and silent projects. These electric motors are small disks that are fully sealed to make them easy to use and embed. All moving parts are protected inside a protection box. By an operating range between 2-5 V, this device works perfectly. When the sensing element connected to a PCB or mounted on a board, the device shakes slowly but this shake is noticeable. The two wires are used to control the vibration power and can easily provide power from a battery or a microcontroller pin.

The higher the voltage caused the higher the current and also the higher the vibration. The current flow can be reduced by adding resistance (100 to 1000 ohms) to the series current.

Figure 13 shows the various parts of the alarm system and its connections. The alarm system uses the Arduino nano board, the HC-05 Bluetooth module as the receiver and vibration motor, as well as a 100-ohm resistor and a BC547 transistor.

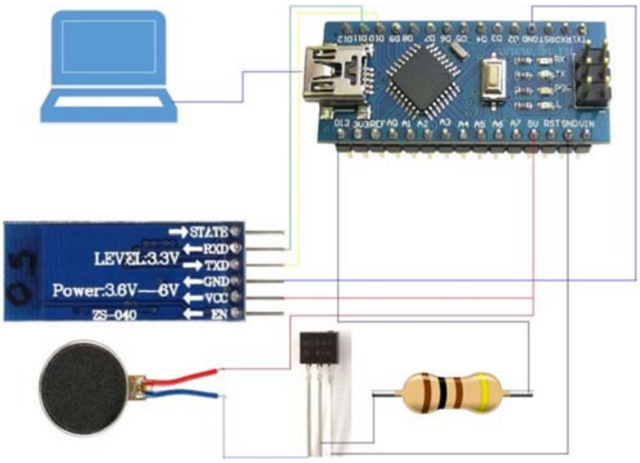

Figure 13. The circuit of the Alarm detection system.

3. Results

In this study, we investigated the sensor's sensitivities to better understand and analysis the performance of this intelligent system. For this purpose, the sensor was tested in different situations to investigate the effects of fluid types, kind of interface materials and their thickness on the detector's response time.

In the first experiment, the response of the detector to the interface between the liquid and the sensor was considered. The three interface materials such as glass, ceramic and plastic in the same thickness were selected and exanimated and water was poured at all three interfaces. By using a chronometer, the response time of the detector to each of these three materials was recorded.

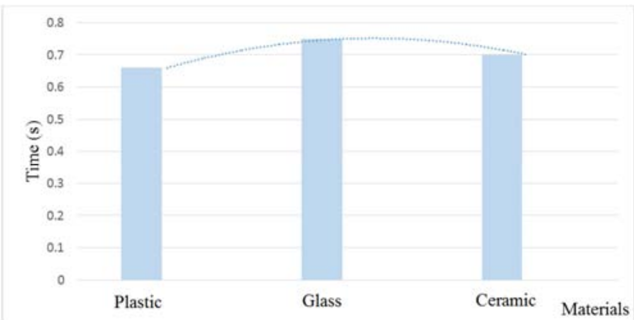

***Figure 14.** The effect of different martials used to determine the sensor's response time.*

The results of this study show that the sensor responded to Plastic Material in the short time, while the glass took more time due to its strong crystalline structure. But this difference in order to the time is about a few hundredths of a second, and because of the person's measurement error during recording the time. The material of the measuring surface is not playing an important role and this selected sensor is able to sense all materials with same sensitivity or in other word the kind of interface material between the liquid and sensor and the type of liquid is not effect in the sensitivity of the sensor. The obtained result from this part is demonstrated in Figure 14.

In the second experiment, the effect of thickness on the response time of the sensor was investigated, since the thickness of the bladder wall was 3.25±1.01 mm in the empty state and 2.01±0.6 mm in the full state [25] use a device by the same material with different thicknesses to test the effect of thickness and use the same amount of water as the previous test conditions and record the response time using the stopwatch. According to the different recorded numbers and the minor difference between the response time as function of the various thicknesses as well as the measurement error when recording the time, the measurement of the thickness surface at the sensor's response time was not significant. In the consequences, the sensitivity of the sensor is no changes according to the different thicknesses and the obtained results are presented in Figure 15.

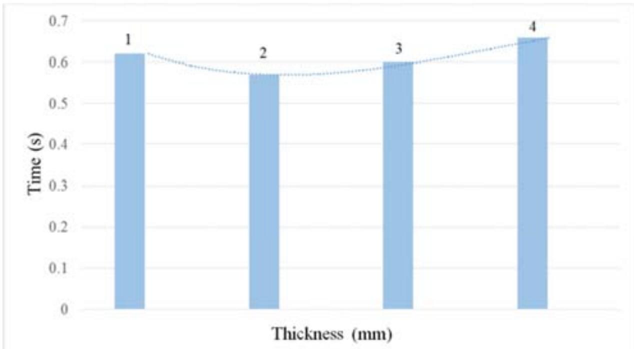

***Figure 15.** The influence of thickness on the sensor's response time.*

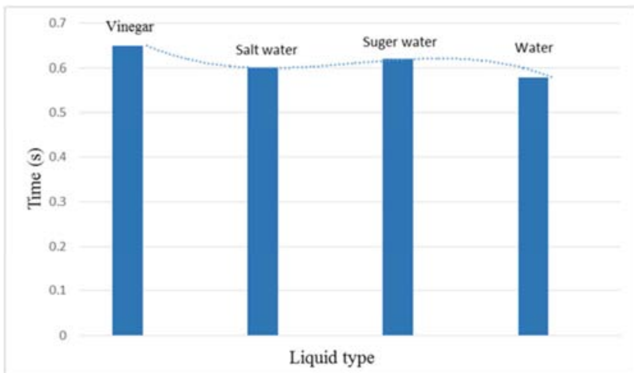

***Figure 16.** The sensor's response time as a function of several fluids.*

In the last experiment, we compared and analyzed the different liquids including vinegar, salt water, sugar water, and water. For all liquids, a same surface separator (a same interface material) was used and the liquids were poured into a container with the equal levels. As demonstrated in the

Figure 16, that in the above liquids due to their constituent contents, the sensor needs more time (about a few hundred seconds) to detect them surface compared to the water.

4. Conclusion

As a result, it can be pointed out that the treatment of a disease should be considered to the its safety, such as low risk of treatment and medical costs. The methods that are being considered to treat this type of disease each have difficulties that may not be possible for some patients. Therefore, a safe, low-cost, and applicable method is desperately needed for all members of society.

The proposed method is a completely non-invasive method for fibromyalgia syndrome (FMS) patients with any devastating effect. The fluid level sensor with the specific designed circuit permits to detect the liquid surface without direct contact with the bladder. The fluid level sensor is sensitive to all fluids with different conductive properties.

To investigate the more accurately sensitivity of the sensor, it was tested in different situations. The different fluid types, several interface materials and their surface thickness to determine the response time of the sensor were tested. The results showed that the sensor responded shorter than the plastic material compared to the glass and ceramic materials. In the next step, the sensitivity of the sensor for the various liquids such as vinegar, salt water, sugar water and drinking water was exanimated and the results showed that the sensor takes longer time to detect the liquids with different contents compared to the water.

In the final diagnostic model, urine level sensors will be mounted on a belt and placed on the bladder to continuously evaluate the body's urinary system and when the urine level within the bladder reaches near the pain threshold, the patient detector will be activated and informs the patient.

References

[1] Shirzadfar H, Mohammadi A, Sadeghpour Z, Sadeghi M (2017) Focus on Treatment for Bladder Control Problems (Urinary Incontinence). J Pharmacovigil Pharm Ther 2017: 109.

[2] Russell, I. J. (2000). Fibromyalgia syndrome. In S. Mense, Simons, D., Russell, I. J. (ED). Muscle Pain: understanding is nature, diagnosis and treatment (pp. 289-337). New York: Lippincott, Williams & Wilkins.

[3] Shirzadfar H, Mohammadi A and Sadeghi M. Modeling and Simulation of Bladder Problems in Patients with Fibromyalgia. Austin J Biosens & Bioelectron. 2018; 4 (1): 1028.

[4] Hamidreza Shirzadfar, Aida Mohammadi, Mehrnaz Sadeghi. The Pathophysiology of Fibromyalgia: Diagnosis and Treatment. AASCIT Journal of Medicine. Vol. 4, No. 1, 2018, pp. 1-13.

[5] Shirzadfar, Hamidreza. "Design and evaluation of a GMR-biosensor for magnetic characterization of biological medium." PhD diss., Université de Lorraine, 2014.

[6] Shirzadfar, H., & Mahtab, K. (2018). Application of Biomarkers and Biosensors to Detect and Track Pathogenic Agents. *Int. J. Anal. Tech*, *4* (1), 1-5.

[7] Shirzadfar, H., Khanahmadi, M. (2018). General Review on the Properties and Applications of Magnetic Nanoparticles in Biomedicine. Biomaterials & Medical Applications (BMA) Journal.

[8] Ngo, Thanh-Tuan, Hamidreza Shirzadfar, Djilali Kourtiche, and Mustapha Nadi. "A planar interdigital sensor for bio-impedance measurement: theoretical analysis, optimization and simulation." (2014).

[9] Shirzadfar, H., Mokhtari, N., & Claudel, J. (2018). Optimize the Geometrical Parameters of Interdigital Micro-Electrodes Used in Bioimpedance Sensing System. Journal of Nano-and Electronic Physics, 10 (5).

[10] Shirzadfar, Hamidreza, Mahsa Sadat Ghaziasgar, Zeinab Piri, and Mahtab Khanahmadi. "Heart beat rate monitoring using optical sensors." International Journal of Biosensors & Bioelectronics 4, no. 2 (2018).

[11] Claudel, Julien, M. Ibrahim, Hamidreza Shirzadfar, Mustapha Nadi, Omar Elmazria, and Djilali Kourtiche. "Hybrid Microfluidic Biosensor for Single Cell Flow Impedance Spectroscopy: Theoretical Approach and First Validations." In XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013, pp. 841-844. Springer, Cham, 2014.

[12] Ngo, Thanh-Tuan, Hamidreza Shirzadfar, Ayoub Bourjilat, Djilali Kourtiche, and Mustapha Nadi. "A method to determine the parameters of the double layer of a planar interdigital sensor." In Proceedings of the 8th International Conference on Sensing Technology, pp. 2-4. 2014.

[13] Shirzadfar, H., Nadi, M., Kourtiche, D., Yamada, S. and Hauet, T., 2015. Needle-type GMR sensor to estimate the magnetic properties of diluted ferrofluid for biomedicine application. *IRBM*, *36* (3), pp. 178-184.

[14] Shirzadfar, Hamidreza, Mustapha Nadi, Djilali Kourtiche, and Sotoshi Yamada. "Characterization of a Needle-Type Probe GMR sensor for Biomedical applications." In SENSORS, 2013 IEEE, pp. 1-4. IEEE, 2013.

[15] Shirzadfar, Hamidreza, Julien Claudel, Mustapha Nadi, Djilali Kourtiche, and Sotoshi Yamada. "Analysis Sensitivity by Novel Needle-Type GMR Sensor Used in Biomedical Investigation." In XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013, pp. 833-836. Springer, Cham, 2014.

[16] Hamidreza Shirzadfar, Mustapha Nadi, Djilali Kourtiche, Sotoshi Yamada, Payman Shahabi: Characterization of a Needle-Type Giant Magnetoresistance Sensor for Detection of Escherichia Coli's Magnetic Marker. International Journal on Smart Sensingand Intelligent Systems, p. 220-234, 2015.

[17] Ngo, T. T., H. Shirzadfar, D. Kourtiche, and M. Nadi. "A Planar Interdigital Sensor for Bio-impedance Measurement: Theoretical analysis." Optimization and Simulation," journal of Nano-and Electronic Physics 6 (2014).

[18] Hamidreza Shirzadfar, Mahtab Khanahmadi: Application of Biomarkers and Biosensors to Detect and Track Pathogenic Agents. International Journal of Analytical Techniques, 2018, p. 1-5.

[19] H Shirzadfar, D Kourtiche, R Haraszczuk, M Nadi, S Yamada: Detecting and estimating magnetic fluid properties by a needle-type GMR sensor, Proceedings of the International Conference Nanomaterials: Applications and Properties, p. 02NNBM29-02NNBM29, 2012.

[20] Shirzadfar, H., Kourtiche, D., Haraszczuk, R., Nadi, M., & Yamada, S. (2012). Detecting and Estimating Magnetic Fluid Properties by a Needle-Type GMR Sensor. In Proceedings of the International Conference Nanomaterials: Applications and Properties (No. 1, no. 2, pp. 02NNBM29). Sumy State University Publishing.

[21] Non-contact Liquid Level Sensor XKC-Y25-T12V SKU: SEN0204.

[22] https://www.aliexpress.com/item/1PCS-XKC-Y25-T12V-liquid-level-switch-water-non-contact-manufacturer-induction-switch-stick-type-Durable/32727003138.html.

[23] https://store.arduino.cc/usa/arduino-uno-rev3.

[24] https://store.arduino.cc/usa/arduino-nano.

[25] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4857925/.