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A REVIEW OF INTERNET OF THINGS (IOT) FOR THE DESIGN OF SMART SYRINGE PUMP IN BIOMEDICAL APPLICATION

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Abstract

Syringe pumps are vastly used in biomedical application to deliver a small amount of fluids or medications at specific periods of time to the patients. One of the significant features in the development of a syringe pump is to control the movement of the piston of a syringe for delivery of fluids into the intravenous line tubing. This feature is essential to avoid functional failure and errors while administering the fluids. Therefore, it is important to be able to detect and minimise such error by integrating syringe pump with the application of the Internet of Things (IoT) which allows human interaction through mobile application. This paper discusses the current research, methods, and open issues of future research related to the implementation of IoT for potential development of a smart syringe pump in biomedical and healthcare applications. The main aim of the proposed project is to design a system that can be used to detect line occlusion and end alarm for syringe pump application. The proposed system could potentially be used to notify the users or clinicians for the occurrence of occlusion flow or whether the fluids is completely infused to the patient. The findings of this study would be beneficial for our proposed project which is to design a system that can be used to detect line occlusion and end alarm for syringe pump application. The proposed system integrates a KY-037 sound sensor device which is driven by a NodeMCU ESP 8266 using a blynk application interface. The proposed system could potentially be used to notify the users or clinicians for the occurrence of occlusion flow or whether the fluids is completely infused to the patient.

Keywords: Syringe Pump, KY-037, Internet of Things, End Alarm, Mobile Application

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1. INTRODUCTION

At present, the number of patients who are admitted to the hospital is increasing gradually due to certain diseases. Commercial intelligent syringe pumps nowadays have advanced features. Based on (Merhi et al., 2019), it have the features of syringe pump such as drug libraries, wireless communication, and a barcode scanner. Syringe pumps or syringe drives are vastly used in biomedical application motorized devices that precisely control the movement of liquid in a syringe by mechanically inserting or retracting a plunger. Syringe pumps are very useful tools to ensure constant and pulsation-free flow rates, but their availability is limited to batch processing. Clinicians complain the problem for most of the syringe pump when the machine is infused completely, it will show 'END ALARM'. According to (Dönmez et al., 2005), detection of occlusion to flow of an infusion is an important problem with syringe pumps. it is even more important to be able to detect and resolve line occlusion quickly in these patients. In healthcare, it used by medical professionals in the in vivo diagnosis, treatment, and care of patients. They are typically used in settings such as hospitals and nursing homes, sometimes (but not always) in palliative care, rather than research setting. There are 2 type of Syringe Pump used in Hospital which is Medical and Laboratory Syringe Pump).

The Internet of Things, or IoT, refers to the collective network of linked devices as well as the technology that enables communication between devices and the cloud, as well as between devices. For the proposed project, Blynk will be used as an IoT platform to control the alarm of syringe pump. Blynk is a new platform that lets you quickly create interfaces to control and monitor hardware projects from iOS and Android devices. The advantage of implement Blynk in Healthcare is to enable patient monitoring in real time, thus significantly cutting down unnecessary visits to doctors, hospital stays and re-admissions It also helps to improve treatment by enabling physicians to make evidence-based informed decisions and brings absolute transparency. The objective of the proposed project is to design a system that can be used to detect line occlusion and end alarm for syringe pump application. Paper discusses the current research, methods, and open issues of future research related to the implementation of IoT for potential development of a smart syringe pump. The aim of this review paper is to review studies on the most important and widely used summary parameters proposed in the literature, with a focus on clinical studies and discussion of the benefits and drawbacks of these parameters

2. METHOD

To provide a comprehensive overview on syringe pump, and KY-037 sound sensor summary literature search were performed from previous journals and articles which provided idea and information that needed for the project. By studying relevant literature, I would like to make an improvement from the previous project by implementing sound sensor and Internet of Things (IoT) system to the syringe pump in order to overcome the problem. I am also searching previous studies that related to my project on Google Scholar, Academia, and other academic platforms.

3. RESULT

From our research, we focus on 2 things (Syringe Pump and Sound Sensor) for our literature review based on the previous research. We study the parameters, methods, results of the previous analysis and journals that can be used for the idea of making analysis of the proposed project.

Table 3.1: Summaries of Research

	Findings
Syringe Pump	Syringe pumps are very useful tools to ensure a constant and pulsation-free flow rate, however usability is limited to batch processes (Iannone et al., 2022)
	It uses a stepper motor to control a delivery of a drug which is supervised by a microcontroller (Merhi et al., 2019)
	It enables to have controlled discharge of drugs and controls the period of drug infusion as required (Dubey et al., 2018)
	Type of Syringe Pump (Griffin, 2017): 1. Medical Syringe Pump 2. Laboratory Syringe Pump
	Medical syringe pump (Griffin, 2017): It is similar to infusion pumps, however they deliver therapy through a syringe rather than an intravenous bag **Laboratory syringe pump** : It has been developed for specific uses, laboratory syringe pumps are designed to be versatile and adaptable
Sound Sensor	Type of Sensor (John, 2018): • Position Sensors • Pressure Sensors • Temperature Sensors • Force Sensors • Vibration Sensors • Piezo Sensors • Fluid Property Sensors • Humidity Sensors • Strain gauges • Photo Optic Sensors • Flow and Level Switches
	A sound sensor is a module that detects sound waves based on their strength and converts them to electrical signals (McMan, 2020)
	It can detect noise levels within DBs (decibels) at frequencies ranging from 3 kHz to 6 kHz, roughly where the human ear is sensitive (McMan, 2020)
	KY-037 emits a signal if the sensor detects a noise. The sensitivity of the sensor can be adjusted by means of a controller (Lee, n.d.)

Table 3.2: Summaries of Literature Review

Journal/ Article	**Method**	**Finding/ Result**
A low-cost push–pull syringe pump for continuous flow applications (Iannone et al., 2022)	- Driven by an Arduino nano ATmega328P which controls a NEMA 17 in microstepping via the A4988 stepper driver. - Pump setup is configurable by means of a digital encoder and an oled screen programmed using C ++.	- The product has been tested to evaluate the flow rates and the linearity of the flow. - The device is achievable with a cost of less than 100 €. - The performance of the device is same as the actual syringe pump. - Push and pull principle of syringe pump has been developed
IoT application for the Design of Digital Drug Administration Interface (Dubey et al., 2018)	- It used an IoT based operation can be performed using the web link that has been developed for the access and regulation of the syringe pump over the internet. - Another alternative could be the use of the mobile application	- Internet of Things (IoT) is used in the proposed work for the dual control of the syringe pump. - It enables to have controlled discharge of drugs. - An operator can use the pump manually or by using the developed link or through a dedicated Mobile

		application which increases its accessibility. - The application can also serve as a Monitoring device which indicates the infused volume as well as the time remaining. - It reduces the workload of hospital staff in terms of manpower required and reduction in the required intensity of the task. This saves resources and time simultaneously.
Syringe pumps take too long to give occlusion alarm (Dönmez et al., 2005)	- Forty syringe pumps (20 JMS SP-100 and 20 JMS SP-500 machines) were tested using two types (JMS and Hayat) and two sizes (20 and 50 ml) of syringes at four infusion rates (0.5, 1, 2 and 5mlÆh)1). - From 3 levels (low-, medium-, high-pressure) on two levels (low or high sensitivity) , it displayed by a lamp on each pump. - No iv tubing was used to avoid the compliance of the tubing. Care was taken to ensure that - Syringe was positioned with its ears inserted correctly into the slots on the pump - The band holding the syringe in place was snug. - Occlusion pressure levels of each pump were checked prior to the study. - The pump was then run at a specified infusion rate, and the time from the start to occlusion alarm activation for each rate was recorded. - Recording was terminated when the alarm time exceeded 120 min, and occlusion alarm times were taken as 120 min for statistical purposes in these circumstances. - Power analysis was performed prior to the study. - Results are reported as mean ± SD, median and range. - Differences between the two pumps were analyzed with Mann–Whitney U-test and occlusion alarm times at four infusion rates were compared with Wilcoxon test. $P < 0.05$ was considered statistically significant	- A total of 560 alarm-time measurements were made during the experiment. They are given as mean ± SD, median, and minimum to maximum ranges. - The mean time to triggering of the occlusion alarm varied significantly with syringe size and infusion rate, and was significantly longer with low infusion rates ($P < 0.05$) and larger syringes ($P < 0.05$) - For both syringe sizes and at all infusion rates, the occlusion alarms on the SP-500 infusion pump alarms were activated significantly faster than the alarms on the SP-100 units ($P < 0.05$ for all). - Results showed that activation of occlusion alarms on both pumps takes a considerable time, and that the mean time to alarm activation was longer with low infusion rates and larger syringes. To reduce occlusion alarm delays smaller sized syringes with low compliance should be used and staff be alerted when using low flow rates with highly concentrated potent drugs.

3.1. Syringe Pump

It established the key elements of intravenous infusion that are still observed today: a slow infusion process, awareness and avoidance of the risk of air embolism, and avoidance of volume overload. Early prototype infusion pumps were invented in the early 1800s to control the flow rate during intravenous injections.

The 20th century saw tremendous advances in intravenous medicine, including IV pumps. The two world wars spurred general advances in medicine—needles were improved, rubber tubes were replaced by plastic, and vacuum bottles were developed to reduce the risk of air embolism. Vacuum bottles themselves were replaced by plastic bags in the 1950s (Merhi et al., 2019). One of the most important developments in infusion pumps was the portable infusion pump invented by Dean Kamen in the early 1970s. Kamen's brother, a doctor, complained that the infusion pumps at the time were too bulky. As a result, Dean Kamen invented the first mobile pump. Not only does it allow patients to move freely during treatment, but it also enables them to receive medication on an outpatient basis. For patients like diabetics who require round-the-clock injections, this advance is a godsend. Kamen pumps can also automatically administer precise doses on a regular basis and have led to many advances in infusion pumps and other medical devices such as portable dialysis machines.

Syringe pumps, also known as syringe drivers, are motorised devices that precisely control the flow of fluid from a syringe by mechanically inserting or retracting the plunger. According to (Iannone et al., 2022), syringe pumps are very useful tools to ensure a constant and pulsation-free flow rate, however usability is limited to batch processes. There are a variety of syringe pumps available on the market with flow rates of 0.012–300 mL/min (Kurth et al., 2020). Most syringe pumps are standardized instruments because they are designed to be compatible with a variety of syringes. Their flow stability and intuitive user experience make them the first choice for biologists, but their capacity is limited by the volume of the syringe. This can be supported by (Dubey et al., 2018), It enables to have controlled discharge of drugs and controls the period of drug infusion as required.

Figure 3.1. A Model of Syringe Pump

Previous Study conducted in 2018, it shows IoT application for the design of digital drug administration interface. The aim of this study was to design, build and test a low-cost push–pull syringe pump for continuous flow applications. By One of the methods of this study is the device used an IoT based operation can be performed using the web link that has been developed for the access and regulation of the syringe pump over the internet. Another alternative could be the use of the mobile application. Figure 3.2 below shows frame work of the syringe pump.

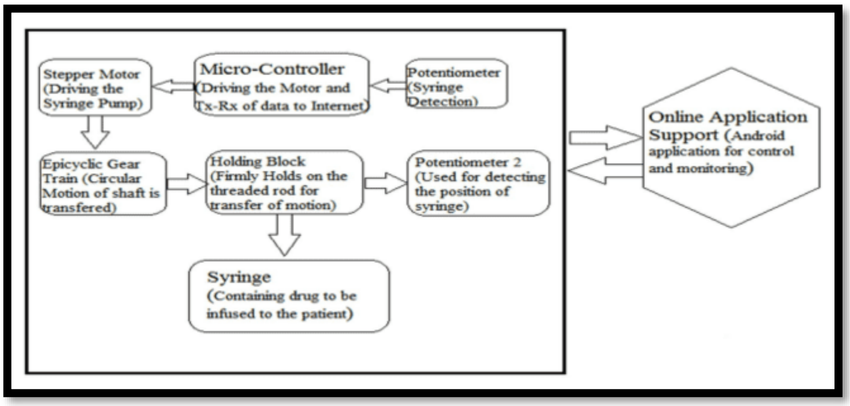

Figure 3.2. Frame Work of Syringe Pump

From this study, it shows that Internet of Things (IoT) is used in the proposed work for the dual control of the syringe pump that enable to have controlled discharge of drugs. After that, an operator can use the pump manually or by using the developed link or through a dedicated Mobile application which increases its accessibility. Thus, the application can also serve as a Monitoring device which indicates the infused volume as well as the time remaining. Finally, it reduces the workload of hospital staff in terms of manpower required and reduction in the required intensity of the task. This saves resources and time simultaneously.

Another study conducted in 2015, it shows the syringe pumps take too long to give occlusion alarm. The aim of this study was to assess the time needed to trigger an occlusion alarm, and the influence of the type of infusion pump, type and size of the syringe, and the set infusion rate. For the methods, this study uses forty syringe pumps (20 JMS SP-100 and 20 JMS SP-500 machines) that were tested using two types (JMS and Hayat) and two sizes (20 and 50 ml) of syringes at four infusion rates (0.5, 1, 2 and 5mlÆh)1). After that, syringes filled with saline were occluded with a stopcock, and times to activation of the occlusion alarm were recorded. Statistical analysis was performed with Wilcoxon and Mann–Whitney U-tests, $P < 0.05$ was considered significant. Table 3.3 shows the table of occlusion alarm times (min) with JMS syringes pump and Table 3.4 shows the table occlusion alarm times (min) with Hayat syringes pump. From both tables, the results showed that the mean time to occlusion alarm activation was longer when lower infusion rates and larger syringes were used. The data also revealed that the type of syringes we used had no effect on alarm times.

Table 3.3: Occlusion Alarm Times (min) with JMS Syringes Pump (Dönmez et al., 2005)

Pump	JMS SP-100 (n ¼ 20) [mean ± SD; median (minimum–maximum)]		JMS SP-500 (n ¼ 20) [mean ± SD; median (minimum–maximum)]	
Syringe Pump	20 ml	50 ml	20 ml	50 ml
Infusion Rate (ml/h)				
0.5	94.1 ± 28.2ab; 103.2 (32.4–120.0)	112.7 ± 16.5; 116.3 (63.2–120.0)	39.3 ± 17.0; 33.3 (19.6–87.2)	-
1.0	33.4 ± 21.2ab; 31.7 (1.0–105.3)	95.6 ± 32.2; 105.9 (24.5–120.0)	17.6 ± 8.0; 14.3 (7.3–42.0)	-
2.0	13.2 ± 8.2ab; 9.9 (4.3–30.4)	42.4 ± 17.6; 40.2 (7.5–82.3)	8.6 ± 3.0; 7.2 (5.1–16.1)	-
5.0	8.1 ± 4.3ab; 7.8 (2.3–19.3)	17.5 ± 6.9; 16.8 (7.0–27.2)	3.7 ± 1.8; 3.3 (1.2–9.2)	-

Table 3.4: Occlusion Alarm Times (min) with Hayat Syringes Pump (Dönmez et al., 2005)

Pump	JMS SP-100 (n ¼ 20) [mean ± SD; median (minimum–maximum)]		JMS SP-500 (n ¼ 20) [mean ± SD; median (minimum–maximum)]	
Syringe Pump	20 ml	50 ml	20 ml	50 ml
Infusion Rate (ml/h)				
0.5	86.4 ± 32.2ab; 82.9 (40.0–120.0)	117.3 ± 9.4a; 118.7 (79.4–120.0)	48.2 ± 25.3b; 39.4 (17.6–120.0)	83.0 ± 24.8; 83.2 (38.3–120.0)
1.0	49.8 ± 39.4ab; 27.8 (9.2–120.0)	85.5 ± 33.1a; 84.5 (31.6–120.0)	14.3 ± 4.4b; 13.3 (7.3–26.6)	34.4 ± 15.2; 30.7 (10.3–63.1)
2.0	20.4 ± 14.4ab; 16.4 (5.4–57.1)	38.6 ± 17.1a; 39.5 (12.0–62.0)	7.2 ± 2.2b; 6.4 (5.2–13.5)	15.9 ± 8.5; 15.4 (3.6–40.4)
5.0	11.6 ± 8.4ab; 9.3 (2.3–31.4)	15.0 ± 7.1a; 15.8 (1.2–27.3)	4.5 ± 7.2b; 2.5 (1.6–35.0)	6.4 ± 2.2; 6.0 (3.2–11.5)

From this study, it showed that activation of occlusion alarms on both pumps takes a considerable time, and that the mean time to alarm activation was longer with low infusion rates and larger syringes. Finally, to reduce occlusion alarm delays smaller sized syringes with low compliance should be used and staff be alerted when using low flow rates with highly concentrated potent drugs.

3.1.1. Principle of Syringe Pump

Syringe pump is a reciprocating pump that deliver exact volume of fluids. This can be supported by (Tariq, n.d.) that it uses a stepper motor to control a delivery of a drug. A stepper motor is controlled via a stepper motor drive, which is supervised by a microcontroller (Merhi et al., 2019). The stepper motors can be primarily separated into two main families or categories of stepper motors (Figure 3.3): unipolar and bipolar [3]. Previously, most commercial syringe infusion pumps had used unipolar stepper motor to deliver medications and any other fluids to patients. However, presently most commercial devices use bipolar stepper motors in the manufacturing of their devices. Figure 3.3 below shows the 2 types of Stepper Motor.

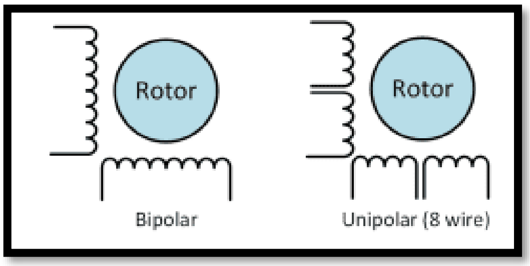

Figure 3.3. Type of Stepper Motor (Merhi et al., 2019)

A guide screw is threaded via a push block. This guide screw uses to turn the stepper motor of the pump. This will move the push block. As the pusher block pushes the plunger of the fixed syringe in the infusion pump mode, then the liquid expels at the precise speed. The push block holder's brackets secure the syringe plunger and offer a pull-out function. As the stepper motor rotates in the opposite direction, the pusher block will move and pull the plunger of the syringe to draw the liquid into the syringe. The pusher block moves toward the right side for infusions and left for withdrawals for Fusion series syringe pumps. Figure 3.4 below shows the principle of syringe pump.

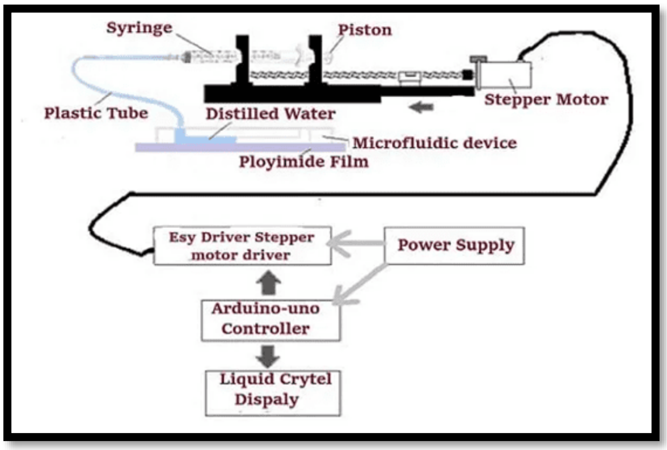

Figure 3.4. Principle of Syringe Pump (Tariq, n.d.)

3.1.2. Type of Syringe Pump

There are two types of syringe pumps: those intended for medical usage and those intended for laboratory use. Other distinctions can be made based on the characteristics provided by the syringe pump, such as whether or not it is programmable or how many syringes it can operate.

3.1.2.1 Medical Syringe Pump

Medical syringe pumps are approved for use by medical professionals in the diagnosis, treatment, and care of patients in the field. They are primarily employed in facilities such as hospitals and nursing homes, as well as occasionally (but not always) in palliative care, rather than in research settings. Medical syringe pumps are similar to infusion pumps, however they deliver therapy through a syringe rather than an intravenous bag. Syringe drivers, as opposed to infusion pumps, manage the flow of significantly smaller quantities of medication.

The accuracy and control supplied by medical syringe pumps are often less than that provided by scientific syringe pumps. Instead, a typical medical syringe driver includes drug-specific presets as well as pre-programmed hard and soft limits to assure the patient's safety. Although medical syringe pumps are very simple equipment in theory, because patient safety is a concern, medical practitioners must be trained in their use. The main advantage of a medical syringe pump over manual use of a syringe is that it can provide medication at a consistent rate over a longer length of time.

Figure 3.5. Medical Syringe Pump

3.1.2.2. Laboratory Syringe Pump

Laboratory syringe pumps (also known as scientific syringe pumps or research syringe pumps) are often more precise than medical syringe pumps in moving smaller amounts of liquid. Furthermore, they can typically be programmed with more complicated procedures. Unlike medical syringe pumps, which are developed for specific uses, laboratory syringe pumps are designed to be versatile and adaptable. A syringe pump can be used in a variety of research applications, including thin film manufacturing, mass spectrometry, flow chemistry, microfluidics, and others.

Figure 3.6: Laboratory Syringe Pump

3.2. Sound Sensor

Sensor is widely used in biomedical application. Sensor consists of position sensors, pressure sensors, temperature sensors, force sensors, vibration sensors, piezo sensors, fluid property sensors, humidity sensors, strain gauges, photo optic sensors, flow and level switches (John, 2018). A sound sensor is a module that detects sound waves based on their strength and converts them to electrical signals (McMan, 2020). This module's primary applications include switching, security, and monitoring. This sensor's accuracy can be adjusted for convenience of use. Figure 3.7 below shows the type of sensor which is widely sold in the market

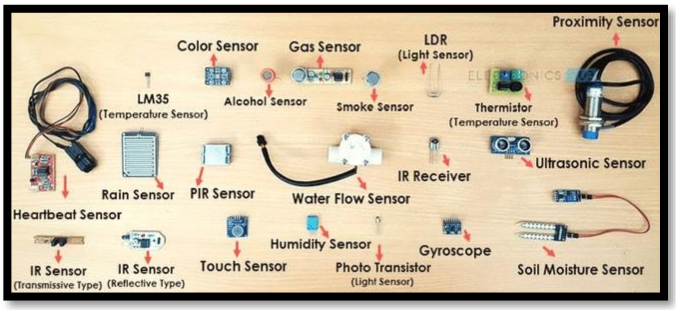

Figure 3.7. Type of Sensor

A microphone is used in this sensor to provide input to a buffer, peak detector, and amplifier. This sensor detects sound and transmits an o/p voltage signal to a microcontroller. Following that, it does the necessary processing. This sound sensor can detect noise levels within DBs (decibels) at frequencies ranging from 3 kHz to 6 kHz, roughly where the human ear is sensitive (*Sound Sensor: Working, Pin Configuration and Its Applications*, n.d.). To measure the sound level on a smartphone, there is an Android application called decibel metre.

3.2.1. Principle of Sound Sensor

Pressure vibrations in the air are perceived as sound. For example, a speaker causes air to vibrate in the pattern (wave) shown in the diagram below, and our ears pick this up as sound. The sound sensors convert the vibration into audio signal (voltage and current proportional) with the help of a microphone. This microphone has an inbuilt diaphragm, made up of magnets which are coiled by metal wire. Whenever sound waves hits the diaphragm, magnets vibrate and at the same time coil induces the current (Anton, n.d.)

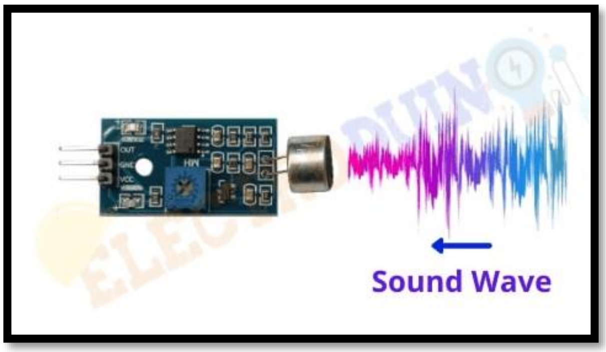

Figure 3.8. Sound Sensor Principle

For the relationship between ear and sound sensor, it starts form outer ear. From outer ear, these vibrations pass through ear canal and reach the middle ear. In the middle ear, the vibrations hit the ear drum (tymphanic membrane)and cause it to vibrate as well. The ear drum vibrates three small bones in the ear in turn, the hammer, anvil and stirrup (ossicles). Then the stirrup passes these vibrations to a coiled tube in the inner ear called the cochlea. The cochlea is filled with fluid and hair-like small nerve endings called "cilia," which pass the information to the auditory nerve. The auditory nerve carries the signal to the brain. Figure 3.9 below shows how the relationship between ear and sound sensor.

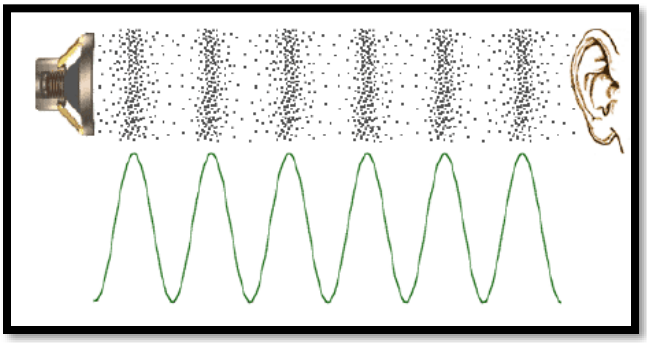

Figure 3.9. Principle of Ear and Sound Sensor

3.2.2. KY-037 Sound Sensor

For the proposed project, it uses KY-037 as sound sensor. This module consists of a sensitive capacitance microphone for detecting sound and an amplifier circuit. The output of this module is both analog and digital (*How to Use KY-037 Sound Detection Sensor with Arduino - Arduino Project Hub*, n.d.). The digital output acts as a key, and it activates when sound intensity has reached a certain threshold. The sensitivity threshold can be adjusted via the potentiometer on the sensor. The analog output voltage changes with the intensity of sound received by the microphone. You can connect this output to Arduino analog pins and process the output voltage.

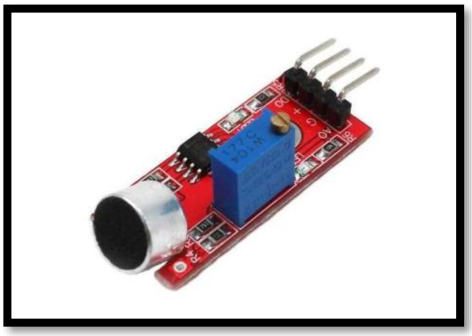

Figure 3.10. KY-037 Sound Sensor

4. CONCLUSION

The objective of this research paper has been achieved. The aim of this review paper is to review studies on the most important and widely used summary parameters proposed in the literature, with a focus on clinical studies and discussion of the benefits and drawbacks of these parameters. All that is stated have been discussed in this review paper.

In this review paper, we have elaborated mainly about syringe pump and sound sensor that related to previous research of IoT Syringe Pump. We are also able to make some suggestions to make an improvement of our project and consider the suitable features of the project. By implementing sound sensor and Internet of Things (IoT) system to the syringe pump, it helps for notifying the clinicians for the occurrence of occlusion flow or whether the fluids is completely infused to the patient. Other than that, IoT gives more benefits in biomedical application.

For the future research, we propose to add more features that can detect any alarm for syringe pump. Not only for the Occlusion and End-Alarm.

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