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Volume Measuring System Using Arduino for Automatic Liquid Filling Machine

M.H. Muhammad Sidik[1] and S.A. Che Ghani[2]

[1]Universiti Kuala Lumpur International College, Seksyen 14, Jalan Teras Jernang, 43650 Bandar Baru Bangi, Selangor, Malaysia.
[2]Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

Abstract

Food industry is one of the most important industry in order to make sure all of human being keep existed on this earth. By using automatic machine, quality and quantity of the product can be improved and even the profit can be increased. But automatic filling machine that available on market is complicated and difficult to clean up due to installation of cylinder piston that need pneumatic system to operate. In order to make it simple and easy to clean up, a new water volume measuring system using ultrasonic sensor developed to replace cylinder piston. An additional tank called measuring tank with ultrasonic sensor installed to measure the volume of water as desired before fill up inside the bottle. Two solenoid valve to control flow of water between storage tank to measuring tank and measuring tank to nozzle. Combinations between solenoid valve and ultrasonic sensor able to perform as well as cylinder piston and reduce the complexity of the machine. Besides that the cost this new system is very low and it can be implemented by small beverage company to boost up their production and profit.

Keywords: component; formatting; style; styling; insert (key words)

INTRODUCTION

Nowadays, world is moving towards automation. Same goes with food industries. Automation will improve quality and quantity of their product to meet customer demand[1]. The automation of bottle filling involves use of cylinder, pneumatic system and PLC to operate but it is costly. Even though all of this available on market, but there are small industries still using manual method to filling up the bottle. The constraint for them not to use these convenient technology is due to the cost of the machine. This study focus on create a system to measure liquid volume filled up inside the bottle using Arduino and build a prototype of low-cost filling machine. Arduino microcontroller is cheap and very reliable to do the task.

Before filling machine using cylinder and pneumatic developed, workers needs to manually filling up the bottle using taps and tanks. It bring many disadvantages to the product and the company itself. Water spilling out, quantity of water is not the same, slow in production, hygiene problem and can cause loss to the company. Automatic filling machine will reduce these disadvantages and labor cost can be reduced and eliminate other problem faced by small food industries [2]. Production process will be smooth, number of man power and production time will reduce and the most important the cost will be lower. Rajesh G. Khatod, Chandrashekhar Sakhale and their team members developed a less complexity and less cost chemical liquid dispenser machine for pharmaceutical industries[3]. Their system controlled by AT89C52 microcontroller to improve the volume measuring quality of dispenser machine. A.S.C.S. Sastry and K.N.H. Srinivas used the same system to build a temperature and volume liquid mixing machine using microcontroller[4]. The main function is to mix different liquids that need specific ration and temperature. AT89S51 microcontroller and two LM35 temperature sensors used to in developing these system.

T. kalaiselvi, R. Praveena and their team members built a filling and capping machine[5]. The machine has section for filling and capping controlled by programmable logic controller to control the time to avoid things that can contribute to rejection of the product. Amount of desired volume can be set through the PLC and it make it more flexible and save the production time.

COMPONENTS OF AUTOMATIC FILLING SYSTEM

Layout

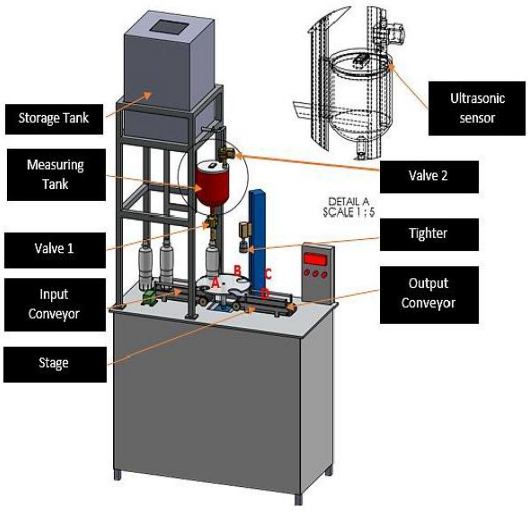


Figure 1: Prototype of an Automatic filling machine

Layout of Automatic filling machine as in Figure 1.It consists of 2 valves, 1 ultrasonic sensor, storage tank, measuring tank and conveyor.

a. Arduino UNO Microcontroller

The Arduino Uno development board is based on the Atmel ATmega328, an 8-bit, 16 MHz microcontroller with 14 digital input/output (I/O) pins, 6 of which are capable of pulse-width modulation (PWM), as well as a 6-channel, 10-bit analog-to-digital converter. Digital communication capabilities include UART TTL serial, SPI serial, and two-wire interface serial (I2C). The Arduino development platform features a cross-platform, Java-based IDE as well as a C/C++ library which offers high-level access to hardware functions[6].

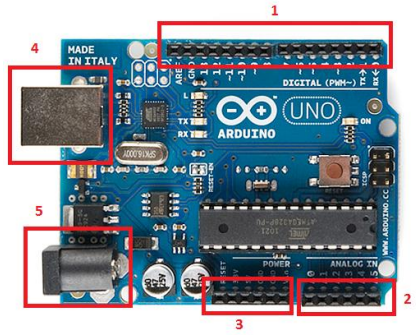


Figure 2: Arduino UNO Board

The important parts of the Arduino UNO are in red box.

1. Digital Pins USB connector
2. Analog pins
3. Power Pins
4. USB connector
5. Power Connector

b. Ultrasonic sensor

Ultrasonic sensor is a device that uses electrical –mechanical energy transformation to measure the distance of an object located at the front of it. Ultrasonic sensor produces sound waves with frequency above the human audible range. It doesn't require physical contact of object to perform its task[7]. So it is a good sensor that can be used in automatic filling machine by detecting level of water inside the bottle without touching the water that can affect product quality. In this project, one unit of ultrasonic sensor used to measure amount of liquid filled inside the bottle in order to reduce the overfilled.

HC-SR04 ultrasonic sensors as above selected and installed because of the price and performance. It can provides 2cm to 400cm of non-contact measurement functionality with a ranging accuracy that can reach up to 3mm and operational voltage is between 3 – 5 V.

Figure 3: Ultrasonic sensor

c. Solenoid Valve

Solenoid valve needs electric power to operate to control liquid or gas. Valve clos and open controlled by a solenoid that has an electric coil with a movable ferromagnetic core in its center and it's called plunger. Plunger close the orifice when there is no electric flows into coil. If there is electric flows, coil will create a magnetic field and it's exerts a force on plunger by pulling it toward center of coil to open the orifice. A brass solenoid valve is able to operate up to 10bar pressure. Two brass solenoid valves installed in this project, 1 to control liquid flows from storage tank to measuring tank and second controls from measuring tank to bottle.

Figure 4: 2V DC 1/4 inch Electric Solenoid Valve

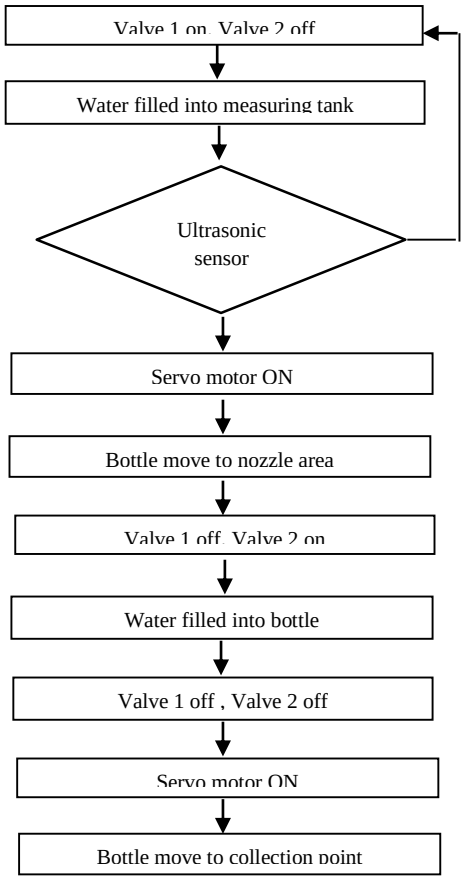
d. Servo motor

A Towerpro MG995 360° high torque metal gear servomotor used to rotate the conveyor. Below is a specification for Towerpro MG995.

Weight: 55g
Dimension: 40.7×19.7×42.9mm
Stall torque: 9.4kg/cm (4.8v)
Operating speed: 0.20sec/60degree (4.8v)
Operating voltage: 4.8~ 6.6v
Gear Type: aluminum 6061-T6
Temperature range: 0- 55deg

A lot of aspect looked into to choose Towerpro MG995 to rotate the conveyer to place the bottle at the programmed place. It's weight and size that small can fit to the machine since aim for this project to build a small automatic filling machine. 5v supplied to servomotor which is came from Arduino UNO board that has ability to provide 3 – 5 v of electric. Aluminum 6061-T6 is the material for gear system to prevent rust effect the performance of the servomotor.

e. Process flow



Flow of filling process start from water flows into measuring tank from storage tank controlled by Solenoid Valve 1. This is where the desired amount to be filled inside bottle is set and an ultrasonic sensor placed at the top of the tank. Amount of water filled inside measuring tank is monitor by ultrasonic sensor by producing sound wave and measure the distance all the time to prevent the water from over filled. After desired amount of water filled inside measuring tank, ultrasonic sensor will send a message to off solenoid valve 1 to stop the flow. Servo motor will move the empty bottle below nozzle that connected to measuring tank and there is solenoid valve 2 between them.

Solenoid valve 1 will remain off but solenoid valve 2 will start to open after an empty bottle well placed for a period that set before to let all water inside measuring flows out. Servo motor start again to move filled up bottle to the next stage.

f. Coding

```
#define trigPin 13
#define echoPin 12
#define led 11 //red LED
#define led2 10 //green LED

#include <Servo.h>
Servo myservo;


void setup() {
  Serial.begin (9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(led, OUTPUT);
  pinMode(led2, OUTPUT);

  myservo.attach(9);
}

void loop() {

  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(10000);

  myservo.write(0);
  delay(2790);


 digitalWrite(trigPin, HIGH);
 delayMicroseconds(10000);

 myservo.write(90);
 delay(20000);

 digitalWrite(trigPin, LOW);
 duration = pulseIn(echoPin, HIGH);
 distance = (duration/2) / 29.1;
 if (distance < 14) {
 digitalWrite(led,HIGH);
 digitalWrite(led2,LOW);


}
else {
  digitalWrite(led,LOW);
  digitalWrite(led2,HIGH);

  }
  if (distance >= 14 || distance <= 0){
    Serial.println("Out of range");
  }
  else {
    Serial.print(distance);
    Serial.println(" cm");
  }
  delay(40000);
}
```

Figure 5: Arduino Programming

Coding for the whole process as shown in figure 5 .

```
#define trigPin 13
#define echoPin 12
#define led 11 //red LED
#define led2 10 //green LED
```

Figure 6: Arduino Programming Part 1

All 4 pins defined at the first line to make sure Arduino board knew which of signal it need to look into. Digital input pin no 13 is for transmitter and pin no 12 is receiver for ultrasonic sensor. Signal from pin no 12 will be used to determine current distance between ultrasonic sensor and water surface inside measuring tank. Since two solenoid valves are involved, 2 output has to be connected from pin 11 and 10. Pin 11 will send signal to solenoid valve 1 and a red LED is used to know either the signal is transmitting correctly or not. Pin 10 for solenoid valve 2 with a green LED connected between them.

```
void setup() {
  Serial.begin (9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(led, OUTPUT);
  pinMode(led2, OUTPUT);

  myservo.attach(9);
}
```

Figure 7: Arduino Programming Part 2

9600 baud or bits per second is used to show the result. Transmitter recognized as trigPin set as output same with led and led2. Receiver of ultrasonic named as echoPin set as input. A servo motor is connected at pin number 9 to rotate the conveyer.

```
void loop() {

  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(10000);

  myservo.write(0);
  delay(2790);
```

Figure 8: Arduino Programming Part 3

Distance used in this system to represent the distance between ultrasonic sensor and top water level in measuring tank. LOW means that pin is off. As above, transmitter is off and 10000 milliseconds later servo is rotating for 2790 milliseconds. 0 means servo motor is rotating in clockwise direction.

The distance from the empty bottle is placed and nozzle is 37cm and radius of roller that rotate the conveyer is 3.8cm

1 revolution = 2π

1 revolution traveled distance = 2π r

$$\frac{37cm}{2\pi(3.8cm)} = 1.55rev$$

Angle servo to complete one cycle =

1.55 rev x 360°= 558°

Operating speed for servo that has given =

$$Operating\ speed = \frac{0.3s}{60°}$$

$$so, \quad \frac{558°}{60°} = 9.3$$

Total time for bottle reach filling stage =

$$9.3\ x\ 0.3s = 2.79\ s$$

So, roller needs to rotate 558º in 2.79 seconds or 2790 milliseconds to be placed below nozzle.

```
digitalWrite(trigPin, HIGH);
delayMicroseconds(10000);

myservo.write(90);
delay(20000);
```

Figure 9: Arduino Programming Part 4

After bottled placed below nozzle, transmitter is on and servo motor is set to 90 means stop for 20s.

```
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;
if (distance < 14) {
digitalWrite(led,HIGH);
digitalWrite(led2,LOW);
```

Figure 10: Arduino Programming Part 5

After the transmitter sent the wave signal, it set to off and receiver is on. Distance is measure by dividing time it's reached to receiver by 2 because of the wave bounce on the water surface before go into receiver. The unit is in microseconds. Then it divide by 29.1 due to:

Speed of sound = 343 (m/s)

Convert into centimeters per microseconds

$$\frac{343\ x\ 100}{1000000} = 0.0343cm/\mu s$$

$$\frac{1}{0.0343} = 29.1$$

If the distance is less than 14 cm, led or valve 1 is on and led2 or valve 2 is off

```
}
else {
  digitalWrite(led,LOW);
  digitalWrite(led2,HIGH);

  }
  if (distance >= 14 || distance <= 0){
    Serial.println("Out of range");
  }
  else {
    Serial.print(distance);
    Serial.println(" cm");
  }
  delay(40000);
}
```

Figure 11: Arduino Programming Part 6

If the current level is more than 14cm, valve 1 will remain off and valve 2 will on. And if level is more and equal to 14 and lower than 0, out of range signal is appeared. All the result is written in cm. Then it will stop for 40s before the system start again.

EXPERIMENT RESULT

A measuring tank with ultrasonic sensor placed at the tank's cap to measure amount of water filled inside it. Amount of water is measured by its weight to obtain better result since the weigh scale' accuracy is up to 0.1 gram. Desired amount of water set to 200g and the then using the same ultrasonic sensor to measure the distance and it shows 14cm.

Table 1: Experiment Result

Test No	Desired amount (g)	Experiment result (g)	Error (%)
1	200g	218	9
2	200g	212	6
3	200g	212	6
4	200g	210	5
5	200g	205	2.5
6	200g	215	7.5
7	200g	212	6
8	200g	208	4
9	200g	203	1.5
10	200g	203	1.5
Average			4.9

Experiment done for 10 times by connecting measuring tank to storage tank that placed at higher place. The gravity force help the water flow and no external force such as pump is used. The result as below

CONCLUSION

As in experiment result, percentage error is quite big 4.9%. For a big company, 4.9% error will increase their cost of product and reduce their profit. Error percentage is big due to fast water flow and its make surface of water moving (not stagnant). It will affect ultrasonic reading because of distance is measured from top of water level. Flowrate of water must be controlled to make the water more stagnant but filling time will increase. It will slow down the production time and reduce machine capability.

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