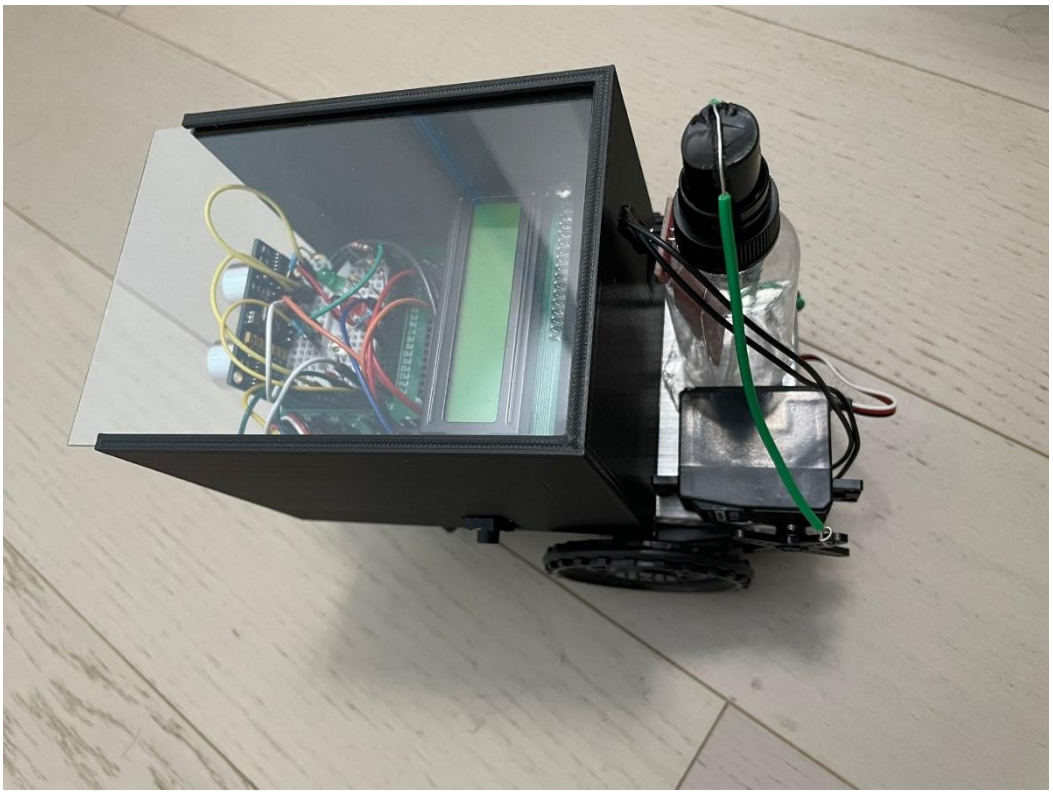

Disinfection Robot
Integrated Term Project
ROB-GY5103 -Mechatronics (Section A)
Fall 2021

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

NEW YORK UNIVERSITY

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Content

Abstract	2
Introduction and Motivation	3
Mathematical background	3
Mechanical Designs	4
Document of hardware	6
Sensor actuators ICs justification	10
Electronic circuits analysis	12
Circuit design diagram	16
Working of the robot	17
Bill of material and prototype cost	18
Cost analysis for mass production	18
Further improvement	19
PBASIC Code	19
Reference	24

Abstract

To combat deadly viruses and ensure our safety and security, Sanitation has become an essential part. Automated sanitation not only guarantees timely and regular disinfection but it also protects the sanitation workers from being exposed to potentially harmful viruses. The intended application of the Bot is to move around in its environment and spray sanitizer on the surfaces for disinfection purposes. It also senses data about the level of sanitizer in the bottle and gives back feedback to refill the sanitizer.
Some of the features included in the programming of the Bot are: Obstacle Avoidance, Automatic Spray using Standard Servo Motor, Detect the Sanitizer level in the bottle, Displays the Sanitizer level on LCD, LEDs, and Buzzer as work status indicator and Phototransistor as an initiating button

Introduction and Motivation

We live in a world today where deadly viruses keep popping up everywhere at an accelerated rate all the time. To get back to a new normal we have to ensure that we return to a safe working environment. To ensure our own safety as well as that of others sanitation has become crucial. Keeping this in mind, we have made our project to contribute to the same cause. The disinfection robot, as its name suggests, sanitizes our working environment. This helps in ensuring regular and timely sanitation. The primary function of the robot is to disinfect the surfaces in a closed room using spray sanitizer. In the Post-Covid world, disinfection has become a necessity in our daily lives. The aim of this project is to incorporate this aspect in our daily life with ease and style.

Mathematical background

Ultrasonic Sensor

The basic mathematics for calculating distance is by using the formula Speed = Distance/Time. Where speed is considered to be the speed of ultrasonic waves in air and time is calculated when the ultrasonic sound is first sent by the transmitter and when it is received by the receiver. When the time is calculated the following formula is used to calculate the distance to the object in front of the sensor.

$$S = C_{air}\, t\, S_{object} = \frac{S}{2} = \frac{C_{air}\, t}{2}$$

S = Distance to the object
C = Speed of ultrasonic waves
t = Time till a PLUSIN is received

Water Level Sensor

The basic principle behind the working of a water level sensor is that when the water level increases the conductivity increases. Thus it has the principle that when the water level increases the resistance decreases thus we can detect the water level accordingly.

$$Water\ Level \propto 1/R$$

$$R \propto \sigma$$

R = Resistance
α = Conductivity

Mechanical Designs

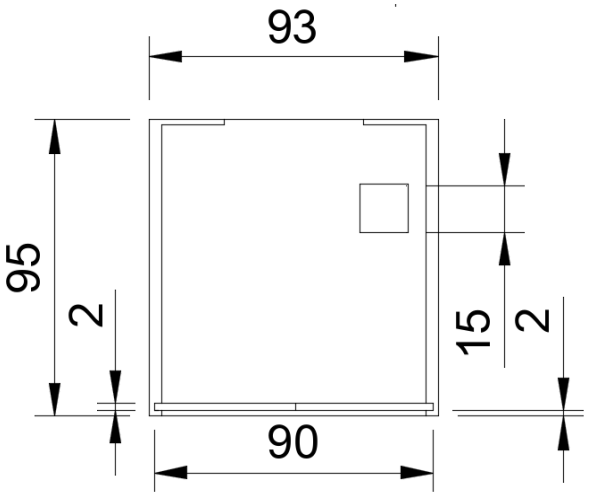

Figure 1. Top View

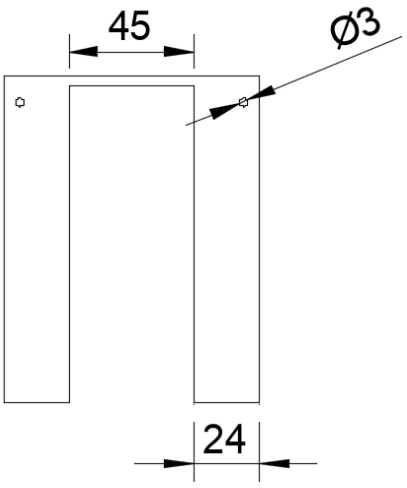

Figure 2. Front View

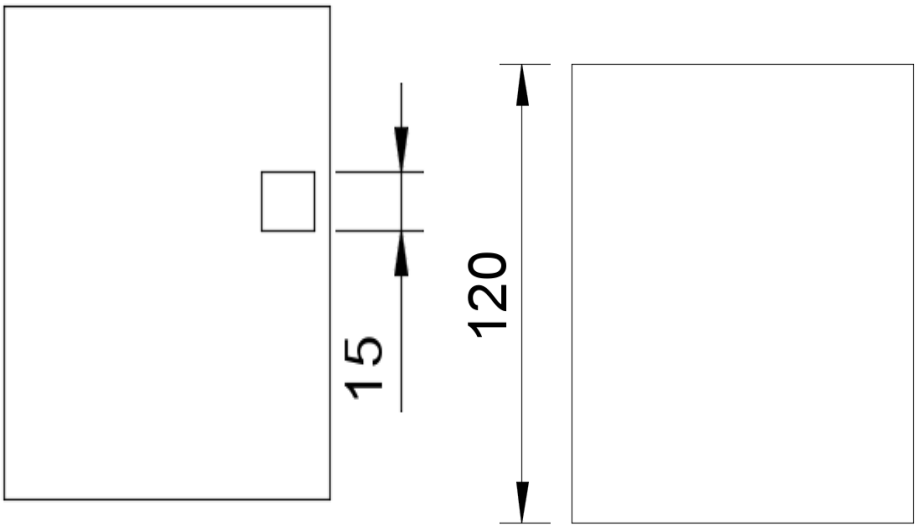

Figure 3. Side View

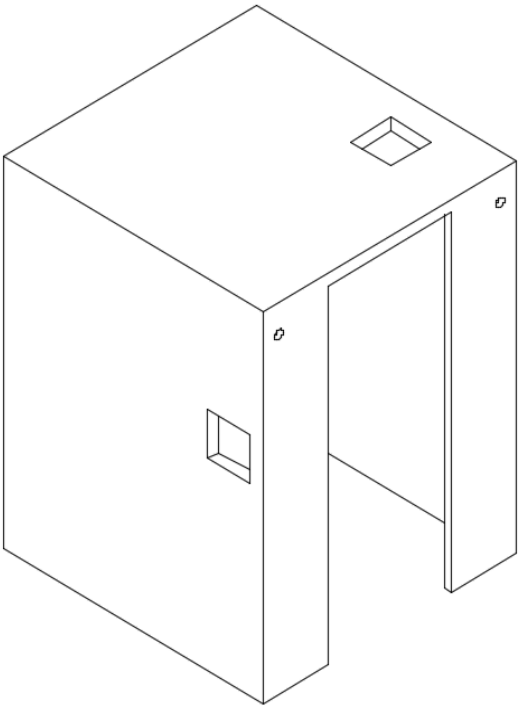

Figure 4. Isometric View

Document of hardware

Phototransistor

A phototransistor is used to perceive light. It is more responsive to light compared with photoresistor, and has higher maximum resistance in darkness. Besides, the effective resistance of phototransistor varies less with temperature and the cost is less than photoresistor. However, the current-carrying capacity of phototransistor is not as good as photoresistor.

Figure 5. Phototransistor

Water Level Sensor

The sensor has a series of ten exposed copper traces, five of which are power traces and five are sense traces. These traces are interlaced so that there is one sense trace between every two power traces. Usually, these traces are not connected but are bridged by water when submerged. There's a Power LED on the board which will light up when the board is powered. This water level sensor is cheap and easy to implement. However, the container of sanitizer needs to be specially manufactured, in order to put the sensor into the water.

Figure 6. Water Level Sensor

Specifications:

- 1. Operating voltage: DC3-5V
- 2. Operating current: less than 20mA
- 3. Sensor Type: Analog
- 4. Detection Area: 40mmx16mm
- 5. Production process: FR4 double-sided HASL
- 6. Operating temperature:10℃-30℃
- 7. Humidity: 10% -90% non-condensing
- 8. Product Dimensions: 62mmx20mmx8mm

Parallax LCD

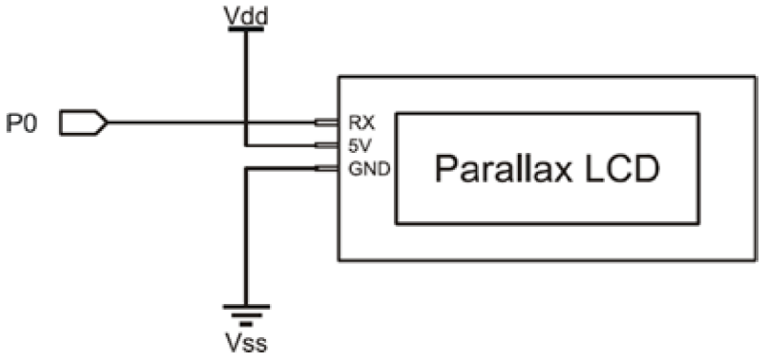

Figure 7. Parallax LCD circuit

LCD is used to display working status including water level data and working mode of the robot in an intuitive way. Though more power is needed compared to LED indicators, LCD shows information in the form of text which makes human-robot action more friendly. The LCD from Parallax is considered to have good compatibility with the Basic Stamp2 chip, as a well-written document of the LCD is provided by the Parallax company. Detailed descriptions of the function of LCD are as follows:

When the phototransistor perceives light, which is an instruction to turn the robot from standby mode to working mode, text “Working!” will be shown on the LCD.

When the robot turns to avoid a collision, LCD will output the text “Turning!” then play a note.

While the robot performs the task, LCD will output the text “Water level is”, followed by the data from the water level sensor. This message will be shown every 5 seconds.

The drawback of LCD is that it slows down the whole program when displaying the message since BS2 is single thread. A carefully designed function is implemented to tackle this issue.

Parallax Standard Servo/ Continuous Servo

Features

- Holds any position between 0 and 180 degrees
- 38 oz-in torque at 6 VDC
- Accepts four mounting screws
- Easy to interface with any Parallax microcontroller or
- PWM-capable device

- Simple to control with the PULSOUT command in PBASIC
- High-precision gear made of POM (polyacetal) resin makes for smooth operation with no backlash
- Weighs only 1.55 oz (44 g)

Figure 8. Parallax Standard Servo

Key Specifications

- Power requirements: 4 to 6 VDC*; Maximum current draw is 140 +/- 50 mA at 6 VDC when operating in no-load conditions, 15 mA when in a static state
- Communication: Pulse-width modulation, 0.75–2.25 ms high pulse, 20 ms intervals
- Dimensions approx 2.2 x 0.8 x 1.6 in (5.58 x 1.9 x 40.6 cm) excluding servo horn
- Operating temperature range: 14 to 122 °F (-10 to +50 °C)

Standard servo and continuous servos are designed for the components of the Boe-Bot of Parallax. Standard servo and continuous servo have the same design and are operated in the same way. Documents with details are provided.

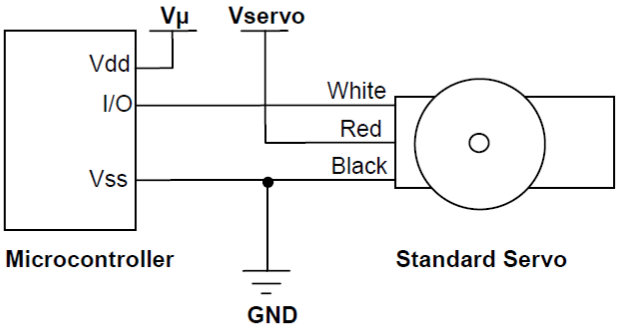

Figure 9. Circuit of standard servo/continuous servo

The Parallax Standard Servo is controlled through pulse width modulation, where the position of the servo shaft is dependent on the duration of the pulse. In order to hold its position, the servo needs to receive a pulse every 20 ms. Below is a sample timing diagram for the center position of the Parallax Standard Servo.

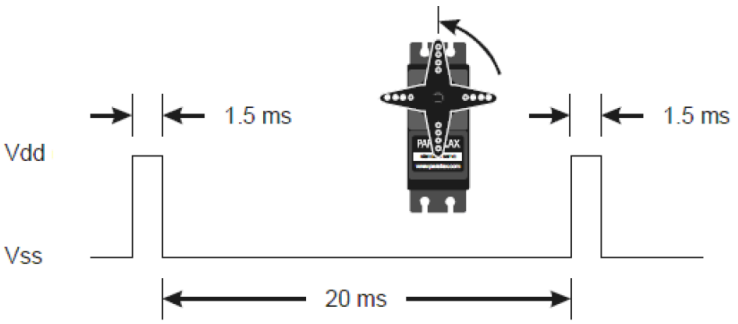

Figure 10. Communication Protocol

3D printed waterproof shell.

The 3D printed waterproof shell is used to prevent short circuit and erosion from the water of sanitizer, which is sprayed at the back of the robot, and is closed to the location of the circuits. The design of the shell was done by SolidWorks, and printed by the Ultimaker 3D printer with a line width of 0.8mm, which took 1 hour and 57 minutes to complete.

LED

LED is considered to be a low-cost electrical component. They are used as an intuitive indicator of different working modes of the robot. When the robot is in working mode, the green LED will be turned on, while when the emergency button is pressed, the red LED will be turned on and the green will be turned off.

Figure 11. LED

SPST Switch

An SPST switch is used in the circuit as the emergency shut down button when the robot does not work properly or needed to be shut down at instance. The detail and circuit analysis will be presented in the following chapter.

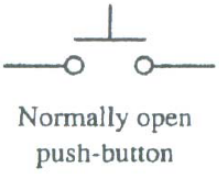

Figure 12. SPST switch

Buzzer

A Buzzer is used to play a note for an emergency stop. The circuit of a buzzer is the same as LEDs. The diagram is shown in figure 13.

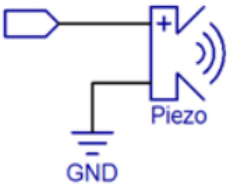

Figure 13. Speaker Circuit

Sensor actuators ICs justification

Ultrasonic Sensor

The ultrasonic sensor interfaced with a BS2 microcontroller is being used to find and detect objects so that our robot can avoid a collision. This ultrasonic sensor has a range of 3cm to 3.3 meters. It is capable to detect objects accurately down to centimeter.

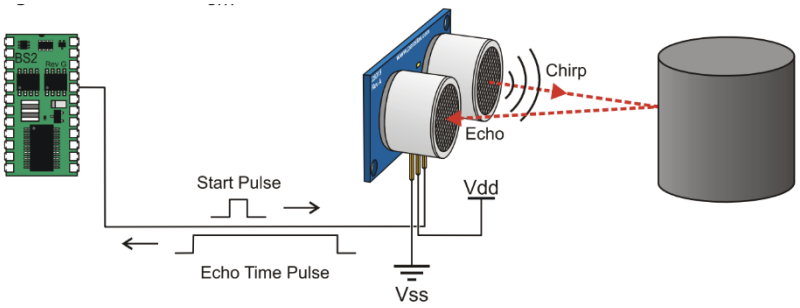

Figure 14. Working of Ultrasonic Sensor

Water Level Sensor

The water level sensor interfaced with the BS2 microcontroller is being used to detect the level of liquid in the sanitizer bottle so that our robot can indicate if the level of sanitizer is low and give alerts.

Phototransistor

The phototransistor is interfaced with the BS2 microcontroller in such a way that when there is light being shined on the sensor the robot will start its operation. This feature allows the robot to start hands-free.

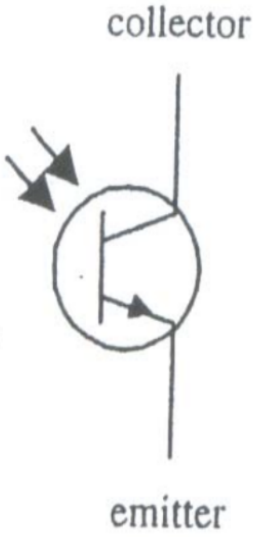

Figure 15. Representation of Phototransistor

Continuous Servo Motor

Continuous servo motors are used to control the motion of our robot. When the robot starts the continuous servo rotates in forward direction and moves the robot in forward direction and when it detects an obstacle the left mounted servo turns in the opposite direction as compared to earlier so the robot makes a right turn.

Standard Servo Motor

A standard servo is used to control the actuation of the sprayer. A wire is attached to the servo and the wire is attached to a stationary point on the other side. The middle portion of the wire rests on top of the sprayer head and when the servo rotates at an angle of 30 degrees it presses the sprayer head down.

Parallax LED Board

The Parallax LED board is used to display the sanitizer level in the bottle so that the user can know every time how much sanitizer is present and it will also showcase when the sanitizer level is down, thus alerting the user to fill it up.

Buzzer

The buzzer is interfaced with the BS2 microcontroller so that when the emergency shutdown button is pressed it rings thrice thus notifying that the robot operation has been suspended due to an emergency case.

Electronic circuits analysis

Instantaneous Shutdown Design

A normal open active low button circuit was applied to instantaneous shut down the system if the sanitizer bot conducted an incorrect or unsafe operation. P1 was set as an input pin that was continuously receiving input from the circuit. 10K ohms resistor is called a pull-up resistor, and it allows the circuit to achieve either high or low states. Otherwise, the BS2 will read a high-low floating impedance state. When voltage is higher than a certain level, the input will be high, and vice versa. The 270 ohms resistor is for preventing I/O pin from short circuit. When the button is pressed, the signal goes low due to the ground path has weaker resistance. When the button is unpressed, the signal goes high due to an open circuit on the ground path.

Each I/O pin of BS2 can source up(output current) to 20mA current and sink up (input) to 25mA current.

$$I_{source(limit)} = 20mA$$

$$I_{sink(limit)} = 25mA$$

270 ohms is connected to protect the I/O pins from the sink-up current limitation.

$$I_{sink(protect)} = \frac{V_{source}}{R_{protect}} = \frac{5V}{270\Omega} = 18mA$$

For the normal method to calculating the resistance for pull-up resistors

$$R_{pull-up} = \frac{V_{source} - V_{H(min)}}{I_{sink}}$$

According to the BS2 datasheet [6]: BASIC Stamp I/O pins are configured as TTL level logic thresholds by default. TTL stands for Transistor-Transistor Logic. It is a logic family made of Bipolar Junction Transistors and performs logic gate functions.

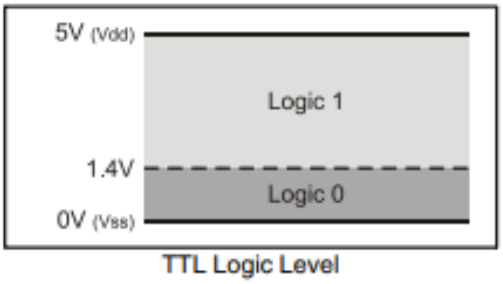

Figure 16. TTL logic level [6] pp.144

The voltage input to I/O pins higher than 1.4 V is considered as high, and vice versa.

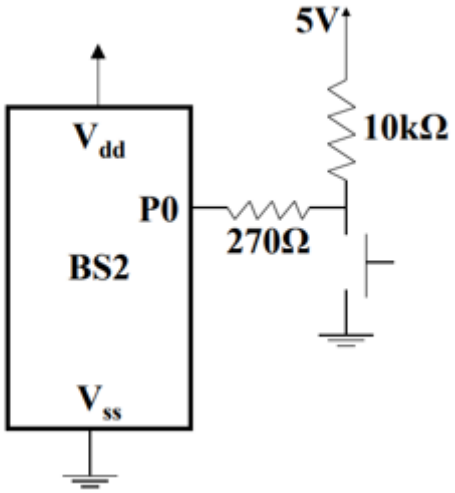

Figure 17. NO active-low circuit design[1]

Working Status LED Indicator design

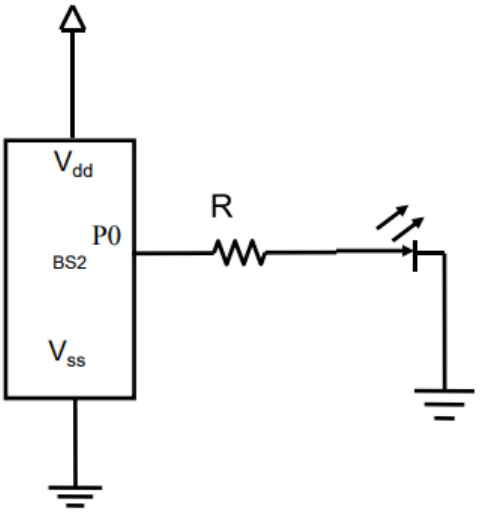

Figure 18. LED circuit design[2]

LED requires 1.4V and approximately 10mA, and proper resistance is required to limit the circuit current. The minimum resistance can be calculated as:

$$R_{min} = \frac{V_{source} - V_{LED}}{I_{LED}} = \frac{5V - 1.4V}{10mA} = 360\Omega$$

470Ω resistors were chosen in this project.

I_{LED} in this case, will be:

$$I_{LED} = \frac{V_{source} - V_{LED}}{R} = \frac{5V - 1.4V}{470\Omega} = 7.66mA$$

The LED will be dimmer than LED using 360 ohms.

One Green LED is used to indicate the robot program is running; One Red LED is used to indicate the robot program is stopped

Phototransistor as an initialize switch

The phototransistor is a transistor that only conducts a light-sensitive surface and base detects the light source.

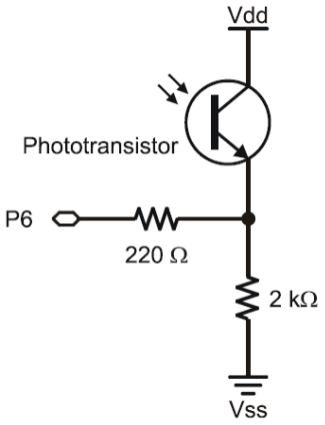

Figure 19. Phototransistor button design.[3]

220 ohms resistor is used to protect I/O pins. 2000 ohms resistor is used to determine the light-sensitive of the phototransistor. The phototransistor allows more current to pass when the light-sensitive surface and base detect more light. The current generated that set P9 to 5V is smaller when a larger resistor is connected in series. It means only a small amount of light is needed to make the phototransistor pass a small amount of current to satisfy the required voltage to set I/O high.[4]

Water level sensor

The water level sensor has three pins: Ground, VCC, and signal output. The signal output pin sends the analog signal of water level information to the microcontroller. Since BS2 does not support analog input, the simple analog to digital converter circuit (charge transfer circuit[7]) is designed to receive the analog signal from the sensor, as shown in figure 6. The BASIC Stamp will measure how long it takes for each capacitor's voltage to decay to determine how quickly it loses its charge through its photoresistor. The brightness of the light incident on the photoresistor's base determines the decay time. Faster decay means more light and lower RCtime value, and less light means slower decay and high RCtime value. The OUT pin is not used in this project.

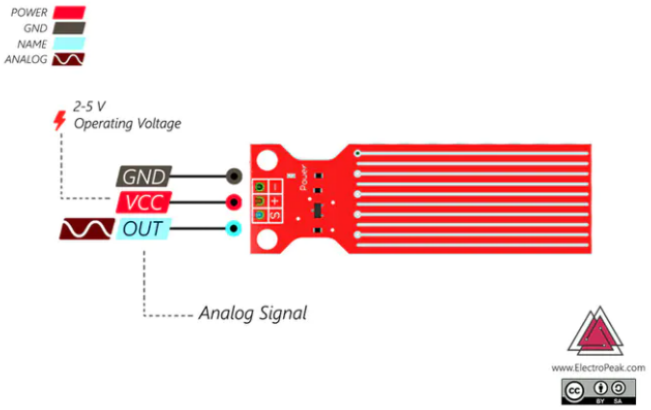

Figure 20. water level sensor schematics [5]

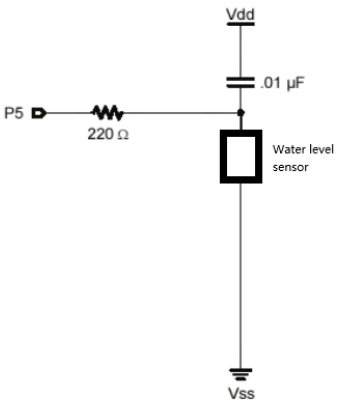

Figure 21

The time constant for the system reaches 63.2% of applied voltage:

$$\tau = RC = 220\Omega \times 1 \times 10^{-8} F = 2.2 \times 10^{-6}\ s$$

The voltage across the capacitor is

$$V = V_0\left(1 - e^{-t/\tau}\right)$$

The current across the capacitor is

$$I = I_0\left(-\frac{t}{\tau}\right)$$

The water level sensor is similar to a photoresistor, in which the water level sensor's resistance is varied from different water levels. The water level sensor has parallel conductivity lines connected to the ground. The lines are the paths of the current. When some lines are submerged in the water, the lines will be short-circuited, the resistance of the water level sensor will be decreased.[5] Therefore, the RCtime number will be decreased. The capacitor is selected to measure the decay time, and 220 ohms is connected to protect the I/O pin from a short circuit.

Ultrasonic Distance Sensor (#28015)

The sensor operates by sending out an ultrasonic burst and receiving an output pulse corresponding to the time for the burst echo to return to the sensor. The distance to the target can be estimated by evaluating the echo pulse width(Digital signal).[8]

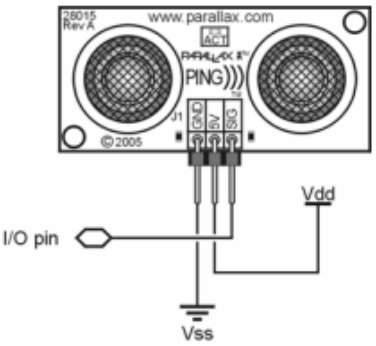

Figure 22. 28015 Ultrasonic Distance Sensor

The Vss and Vdd have connected accordingly, and the signal pin is connected directly to the I/O pin.

In the code, after activating the sensor using 'PULSOUT Ping, Trigger' and measuring echo pulse using 'PULSIN Ping, IsHigh, rawDist'

Buzzer

A buzzer is connected to the microcontroller to beep three times when the emergency button is pressed.

Circuit design diagram

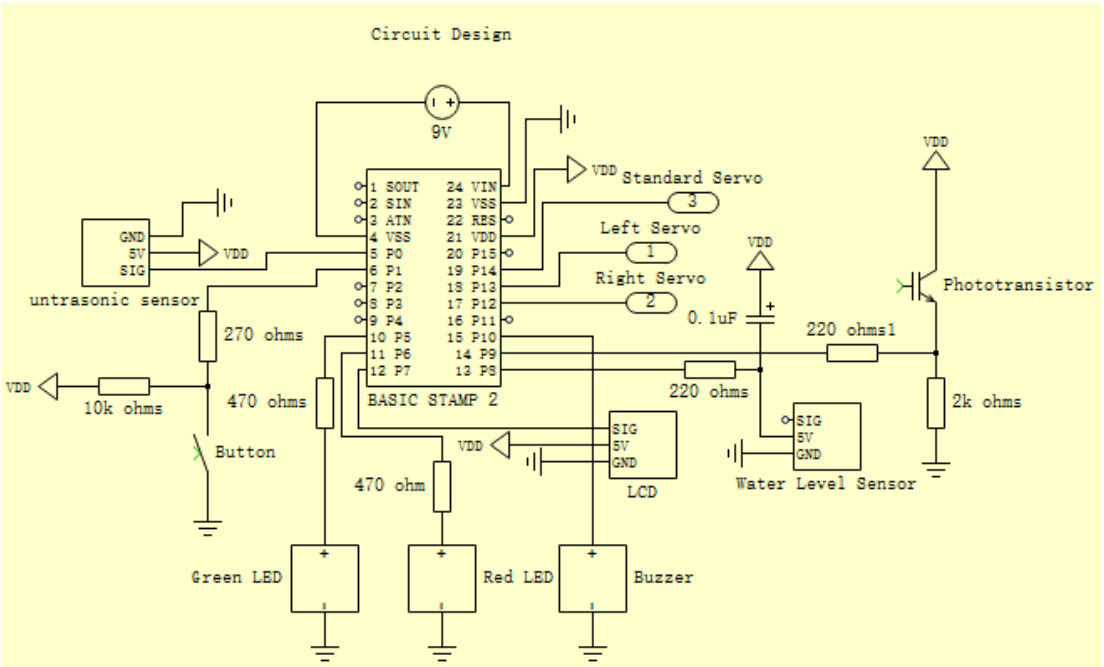

Figure 23. Circuit design diagram

Working of the robot

the Sprayer is operated by a Standard Servo Motor. When the servo rotates by 30 degrees the sprayer is initiated

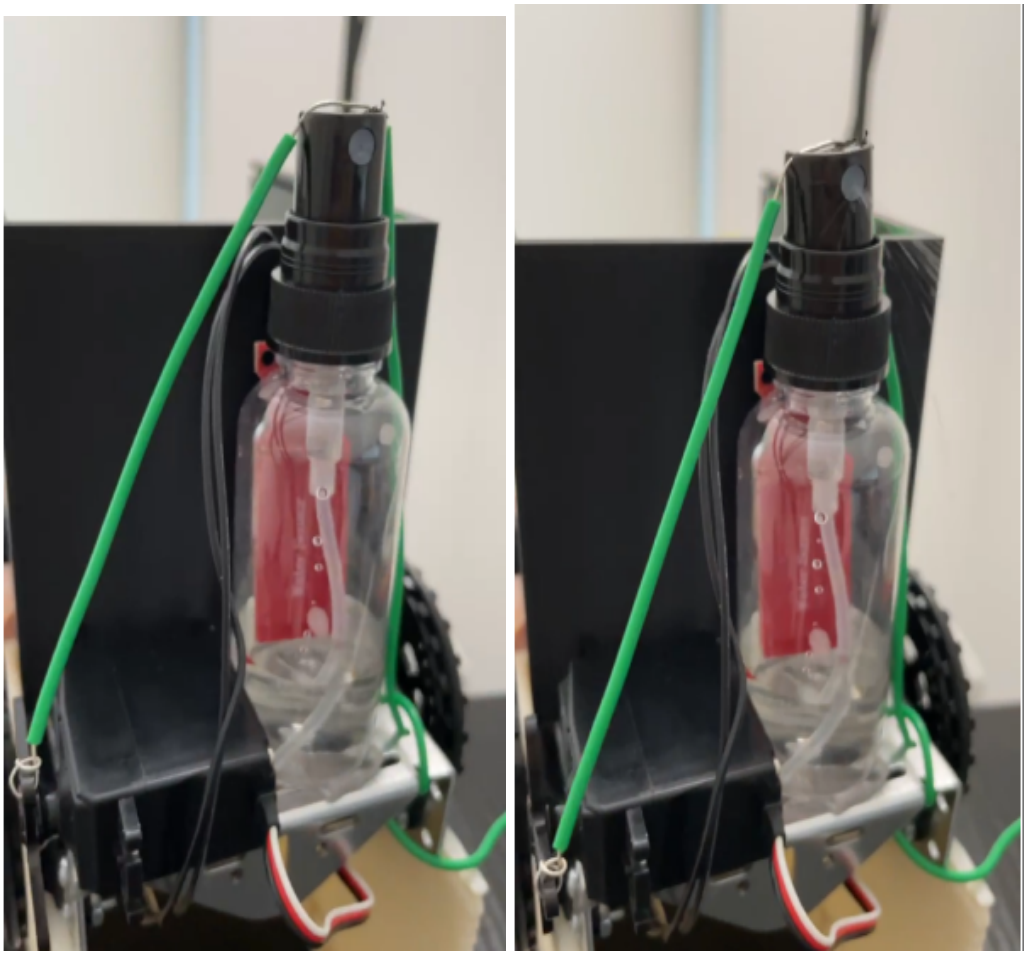

Figure 24. Mechanism of the Sprayer

We are thinking of a scenario that the lightness of the room changes from dark to bright When the light is detected by the phototransistor, the green LED turns on. the robot starts to move like a vacuum and spray the liquid every 3 seconds when it goes a straight path. The LCD will keep updating real-time liquid quantity in the container provided by the water level sensor. It will keep operating for 30 seconds if the Instantaneous Shutdown button is not pressed. When the button is pressed, the red LED will turn on, the buzzer will beep three times, and the robot will stop.

Bill of material and prototype cost

Description	Quantity	Unit cost
Boe‑Bot Robot Kit ‑ USB Version	1	239
PING))) Ultrasonic Distance Sensor	1	34.95
Parallax Standard Servo	1	17.95
Parallax 2 x 16 Serial LCD with Piezo Speaker (Backlit)	1	34.95
Spray Bottle	1	0.5
Phototransistor	1	1.49
Button	1	0.25
Water Level Sensor	1	0.4
Approximate Cost		$330

Cost analysis for mass production

Components	Price ($/1000pc)
Car Structure	~ 25
Microcontroller	0.99
Ultrasonic Sensor	0.8
Automatic Spray	10
Container for Sanitizer	0.1
Water-Level Sensor	5
LCD display	0.6
Approximate Cost	$45

Further improvement

With the addition of a WIFI module, the robot can be controlled wirelessly with the help of an application for our smartphones or a website. It can also help us get real-time updates of the sanitization status, the sanitizer level status and many more updates.

The sanitizer bottle is very small and can be replaced with a bigger container with an aluminium can or any metal container so that the sanitizer will be sufficient for any size of the room.

A refilling station can be made so that when the sanitizer is near completion the robot can go back to the station to fill up the container and then again start the operation. This refilling station can also act as a recharging station and recharge the batteries of the robot so that it does not run out of power.

A 555 timer can be used to operate the servo which is used for spraying operation so that the microcontroller has less load.

An automatic sprayer can be used instead of using a wire to actuate the sprayer as the wire can have wear and tear upon many uses.

A stronger servo can be used which has higher torque just to improve the speed and increase the force applied to the sprayer for a smoother operation and to ensure the proper operation.

PBASIC Code

```
' {$STAMP BS2}
' {$PBASIC 2.5}

'Final Project: Disinfection Robot

'pin 0 ultrasonic sensor
'pin 1 emergency button
'pin 5 green LED
'pin 6 red LED
'pin 7 LCD
'pin 8 water level sensor
'pin 9 phototransistor
'pin 10 speaker
'pin 12 right wheel
'pin 13 left wheel
'pin 14 standard servo

CmConstant      CON     2260
cmDistance      VAR     Word
time            VAR     Word
counter         VAR     Word
servo           VAR     Byte
x               VAR     Word
y               VAR     Word
i               VAR     Word
waterdata       VAR     Word
lcdcounter      VAR     Word
counter1        VAR     Word
counter2        VAR     Word
globalcounter   VAR     Word
TxPin           CON     7
Baud19200       CON     32
btn             PIN     1


OUTPUT 13   'left wheel   1000 forward
OUTPUT 12   'right wheel  500  forward
OUTPUT 14
OUTPUT 0

PAUSE 1000

servo=1     'initialize
lcdcounter=1
globalcounter=1

  DO                    'phototransistor wait for light
'    DEBUG HOME, "IN9 = ", BIN IN9
    IF IN9>0 THEN

        HIGH TxPin          'LCD message
```

```
      PAUSE 100
      SEROUT TxPin, Baud19200, ["Start!          ", CR]
      PAUSE 200
     GOTO main
     PAUSE 10
   ENDIF
  LOOP


main:
DO
  HIGH 5                  'LED green working mode

  GOSUB emergency
  GOSUB ultrasonic
  GOSUB forward
  GOSUB spray
  GOSUB water

  globalcounter=globalcounter+1   'automatically shut down after 20 senconds
  IF globalcounter>750 THEN
  LOW 5
  HIGH 6                      'turn on red LED
  STOP
  ENDIF
LOOP


ultrasonic:
PULSOUT 0, 5              'get distance from ultrasonic sensor
PULSIN 0, 1, time
cmDistance = cmConstant ** time
'DEBUG ? cmDistance, " cm"

DO WHILE(cmDistance<=15)  'near wall, rotate

      HIGH TxPin        'LCD message
      PAUSE 100
      SEROUT TxPin, Baud19200, ["Obstacle detected!", CR]

  FOR counter = 1 TO 60
    PULSOUT 12, 1000
    PAUSE 20
  NEXT
  GOTO ultrasonic
LOOP
RETURN


water:                    'this is for water sensor
IF lcdcounter>100 THEN       'reset counter
  lcdcounter=1
ENDIF
```

```
IF lcdcounter=100 THEN       'water sensor send data every 100 loops
  HIGH 8
  PAUSE 3
  RCTIME 8,1,waterdata
  DEBUG CR
  DEBUG ? waterdata

  IF waterdata <10 THEN       'LCD DISPLAY water data every 100 loops
  HIGH TxPin                 ' Set pin high to be a serial port
  PAUSE 100                  ' Pause for Serial LCD to initialize
  SEROUT TxPin, Baud19200, ["Water level is ", DEC waterdata, CR]
  ENDIF

  IF waterdata >=10 THEN
    HIGH TxPin
    PAUSE 100
    SEROUT TxPin, Baud19200, ["Need more water!    ", CR]
  ENDIF

ENDIF
lcdcounter=lcdcounter+1
RETURN


forward:
      PULSOUT 12,500           'go straight
      PULSOUT 13,1000
      RETURN


spray:
IF servo=100 THEN              'standard servo actuated every 100 loops
  servo=1
ENDIF

IF servo=50 THEN               'standard servo actuated every 100 loops (3.19 seconds)
      FOR x = 1 TO 45
      PULSOUT 14,200
      PAUSE 5
      NEXT

      FOR y = 1 TO 45
      PULSOUT 14,1200
      PAUSE 5
      NEXT
ENDIF
servo=servo+1
RETURN


emergency:                     'need real button, comment this function if there is no button!
    IF btn=0 THEN
    HIGH 6                   'LED red on
    LOW 5
```

```
    HIGH 10                 '0.5 second beep
    PAUSE 500
    LOW 10
    PAUSE 500
    HIGH 10                 '0.5 second beep
    PAUSE 500
    LOW 10
    PAUSE 500
    HIGH 10                 '0.5 second beep
    PAUSE 500
    LOW 10
    STOP                    'stop the robot
    ENDIF
RETURN
```

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