<u>SENSORS AND SIGNAL CONDITIONING</u>

<u>CHALLENGING EXPERIMENT</u>

<u>DESIGN OF SIGNAL CONDITIONING CIRCUIT FOR CAPACITIVE SENSOR TO MEASURE LIQUID LEVEL</u>

By

ADRIJA CHAKRABORTY,18BEI0012

AISHWARYA BALAJEE,18BEI0007

M SACHIN KUMAR, 18BEI0006

SURYA SAI, 18BEI0022

GOUTHAM KRISHNA, 18BEI0004

AIM : To determine the liquid level using a capacitive sensor by converting capacitance change to voltage and also get the output voltage and liquid level wirelessly in mobile.

APPARATUS:

1. Function generator
2. 15V RPS power supply
3. Fluid (oil)
4. Capacitive sensor
5. Power chord
6. NodeMCU microcontroller(ESP8266)
7. Breadboard
8. Full wave rectifier D3SB60
9. LM-741 OP-AMP
10. Resistors,1k ohm, 180 ohm and 1 ohm.

11. Capacitor, 100nF

12. Connecting wires

THEORY:

Liquid level measurement can be utilized from the characteristic of the liquid itself; such as permittivity, permeability, conductivity, etc. One type of sensor which developed for liquid level measurement is capacitive sensor. Capacitive sensor can be categorized as reactive sensor. It needs specific signal conditioning devices. The principle of capacitive transducer is based upon the following equation,

$$C = \frac{\mathcal{E}_0 \mathcal{E}_r A}{d}$$

Where,

C=Capacitance

$\mathcal{E}_0$= permittivity of free space

$\mathcal{E}_r$= permittivity of free given medium

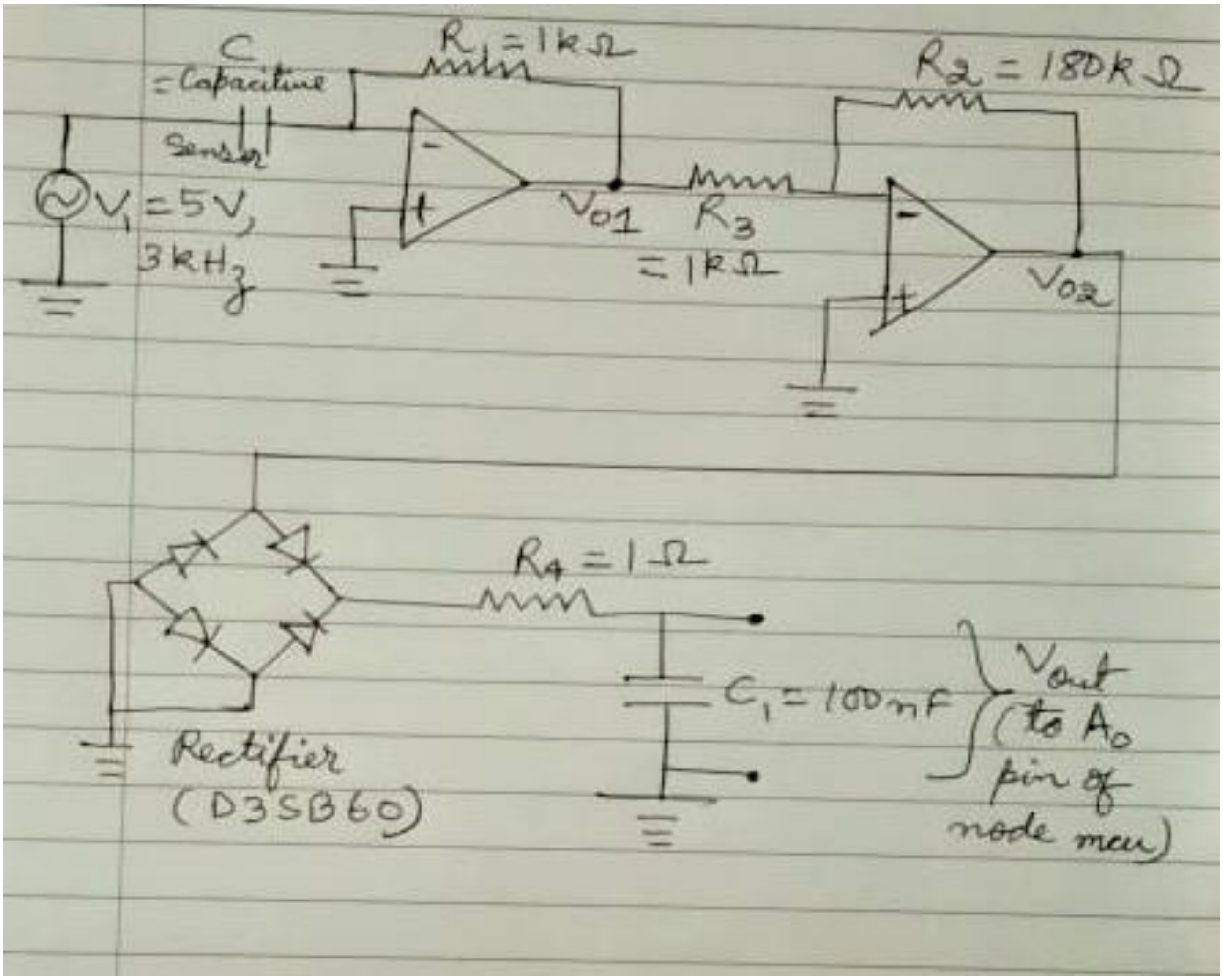
A = area of the plates

D=distance between the plates

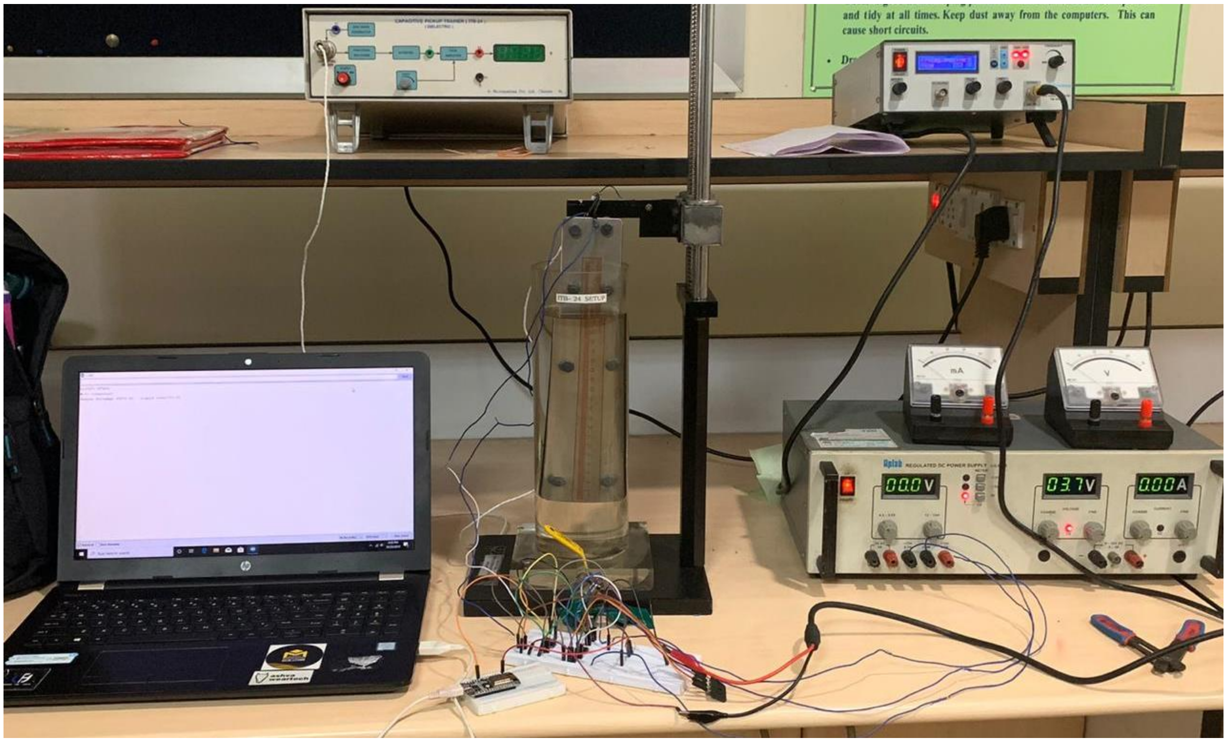
Change in capacitance may be due to:

- Change in overlapping area
- Change in distance between the plates
- Change in dielectric constant

CIRCUIT DIAGRAM



EXPERIMENTAL SETUP



PROCEDURE:

In this experiment, the change in capacitance is converted into voltage by a suitable signal conditioning circuit. Capacitive sensor is a passive sensor. Therefore, it needs some signal conditioning device(s) to obtain other quantities (voltages or currents) which can be processed on the other conditioning or processing devices. Here, there are three types of signal conditioning circuits: (1) linearization circuit; (2) Op-Amp inverting amplifier circuit; and (3) rectifier.

The sensor is located between power source and linearization circuit. Linearization circuit is a circuit which used to obtain linear correlation between its input and output signal. It used as the feeder of other devices. It consists of resistor, Op-Amp device, and the capacitive sensor. As the ac input is applied, the output equation can be expressed as

$$V_{01} = -2\pi f C R_1 V_1$$

Other signal conditioning devices which are used in these experiments are operational amplifier and rectifier. Operational amplifier is operated on the inverting mode since it has linear amplification characteristics

$$V_{02} = -\frac{R_2}{R_3} V_{01}$$

The value of capacitance thus obtained is,

$$C = \frac{V_{02} R_3}{2\pi f R_2 R_1 V_1}$$

We know that capacitance is given by,

$$C = \frac{\mathcal{E}_0 b}{d} [\mathcal{E}_r x + h - x]$$

Where,

$\mathcal{E}_0$= permittivity of free space

$\mathcal{E}_r$= permittivity of free given liquid (taken as 2.2 for transformer oil)

b = breadth of the plates = 6cm

d = distance between the plates = 0.5cm

h= total height of plate =25 cm

x= liquid level

Therefore, we get

$$x = \frac{\frac{Cd}{\mathcal{E}_0 b} - h}{\mathcal{E}_r - 1}$$

Where,

$C = \frac{V_{02} R_3}{2\pi f R_2 R_1 V_1}$ is obtained from the following code written in Arduino IDE.

CODE:

sensorProject | Arduino 1.8.8

File Edit Sketch Tools Help

sensorProject

```
#include <FirebaseArduino.h>
#include  <ESP8266WiFi.h>
#define FIREBASE_HOST "levelmeasurement-a4360.firebaseio.com"//host name of firebase
#define FIREBASE_AUTH "BThxQGl7xWWDPcgISRiBRvTtsF6P4eYozIo8ULU9" //authentication key
#define WIFI_SSID "vivo 1724" //wifi ssid
#define WIFI_PASSWORD "1234abc" //wifi password

float v02=0.0,f=3000.0,v1=5.0;
float r1=1000.0,r2=180000.0,r3=1000.0;
float epsilon0=8.85e-12,epsilonr=2.2,c=0.0,x=0.0,b=0.06,d=0.005,h=0.25,avg=0.0,m=0.0;
int v0=0;
//variable initialization

void setup() {

   Serial.begin(9600);
   WiFi.begin (WIFI_SSID, WIFI_PASSWORD);
   while (WiFi.status() != WL_CONNECTED) {
   delay(500);
   Serial.print(".");
  }
```

sensorProject | Arduino 1.8.8

File Edit Sketch Tools Help

sensorProject

```

  Serial.println ("");
  Serial.println ("WiFi Connected!");
  Firebase.begin(FIREBASE_HOST,FIREBASE_AUTH);//connecting to firebase
  }

void loop() {

 for(int i=1;i<=100;i++)//loop for calculating average of 10 successive voltage values
 {
  v0=analogRead(A0);
  v02=v0*(3.3/1024.0);
  m=m+v02;
  delay(200);
```

sensorProject | Arduino 1.8.8

File Edit Sketch Tools Help

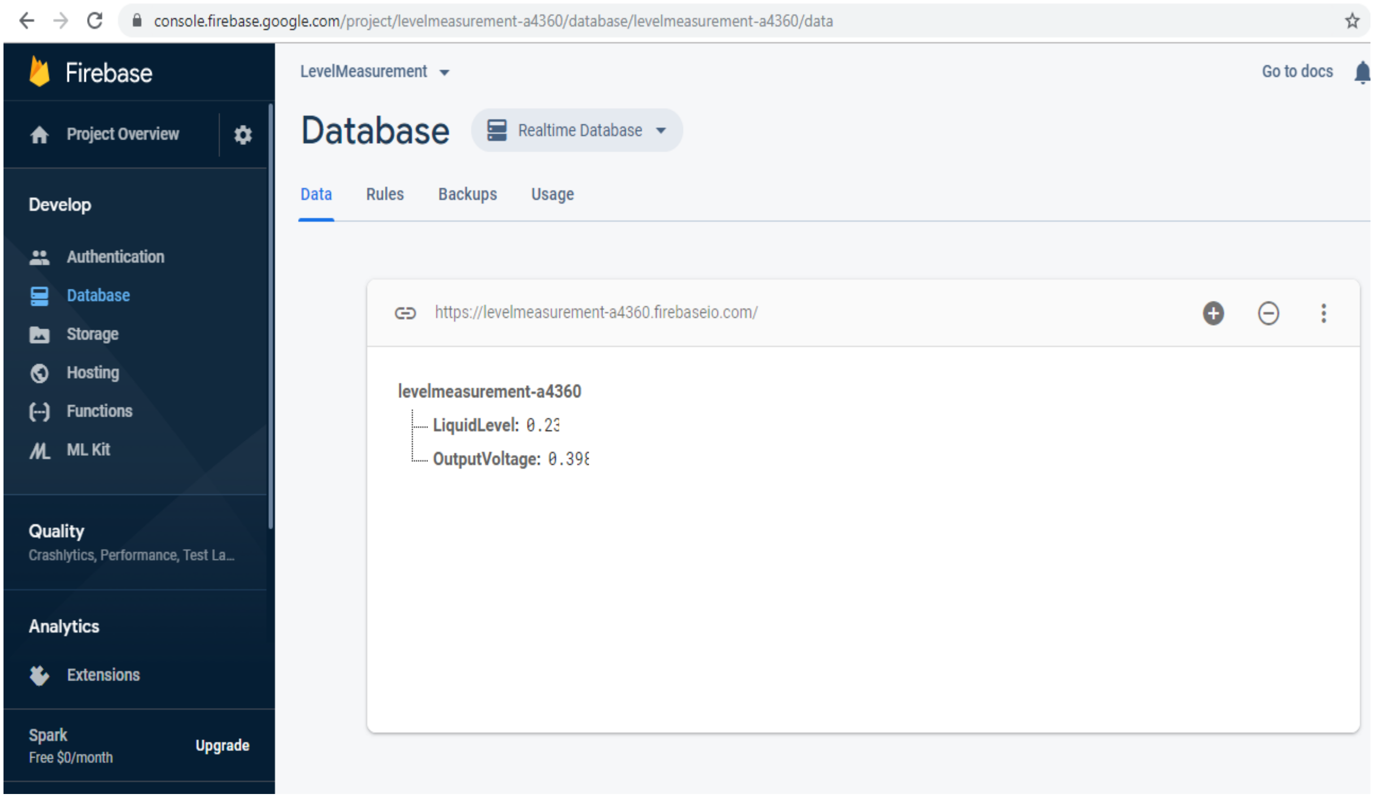
sensorProject

```
    m=m+v02;
    delay(200);
  }
  avg=m/100;
  m=0.0;
  v02=avg;

  c=(v02*r3)/(2*(22.0/7.0)*f*r1*r2*v1);//calculating capacitance
  x=((((c*d)/(epsilon0*b))-h)/(epsilonr-1))*100.0;//calculating displacement

  Serial.print("Output voltyage v02=");
  Serial.print(v02);
  Serial.print("    ");
  Serial.print("Liquid level=");
  Serial.print(x);
  Serial.println();

  Firebase.setFloat ("LiquidLevel",x);
  Firebase.setFloat ("OutputVoltage",v02);
  //sending data to google firebase

  delay(1000);
}
```

WIRELESS READOUT:

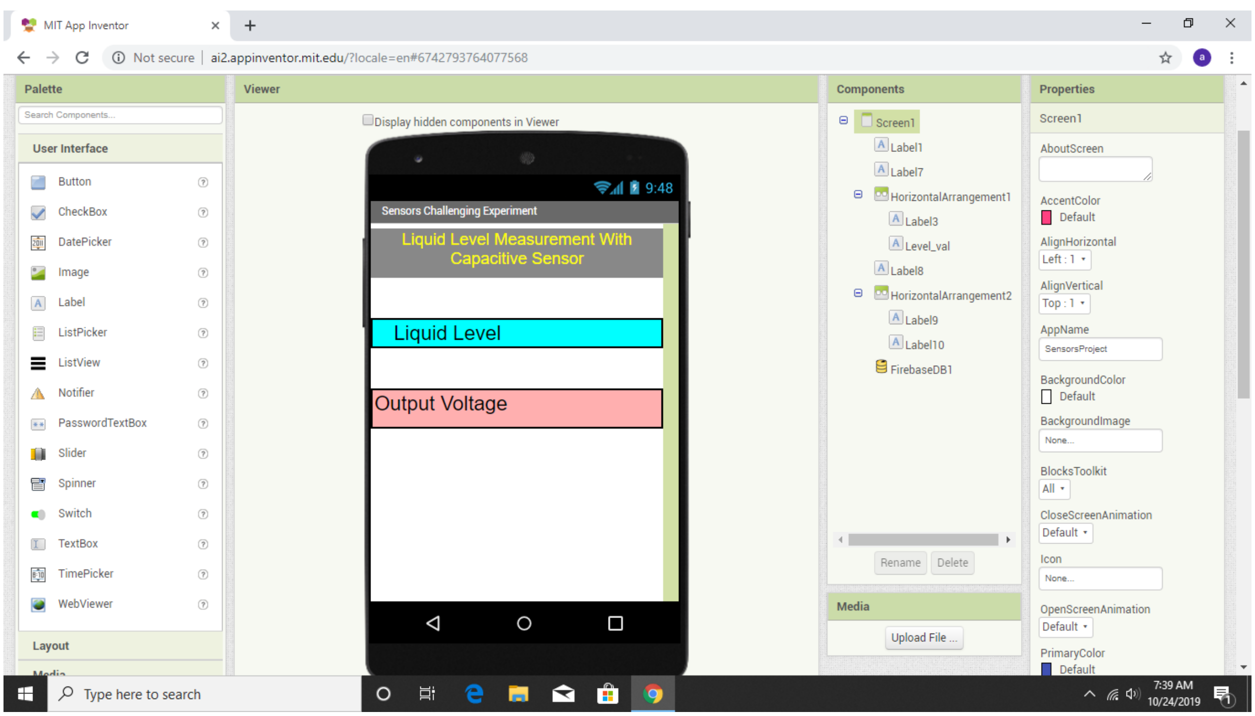
For wireless readout of the output voltage and liquid level, google firebase and an android app is used.

The ESP8266 Wi-Fi module sends the data to google firebase.

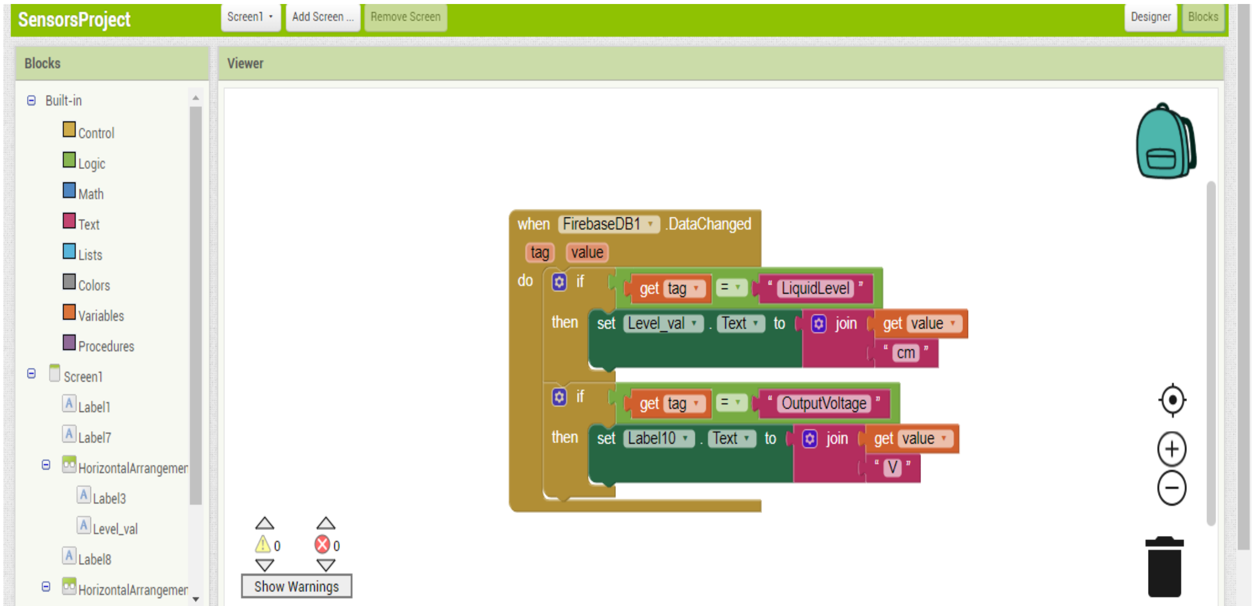


A simple android app built through MIT App-Inventor gets this data from the firebase console and displays it.

Layout of the android app

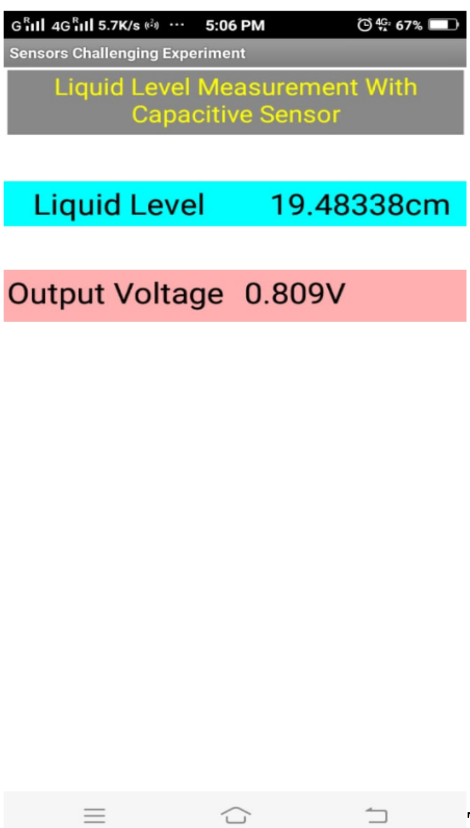


Designer blocks for android app

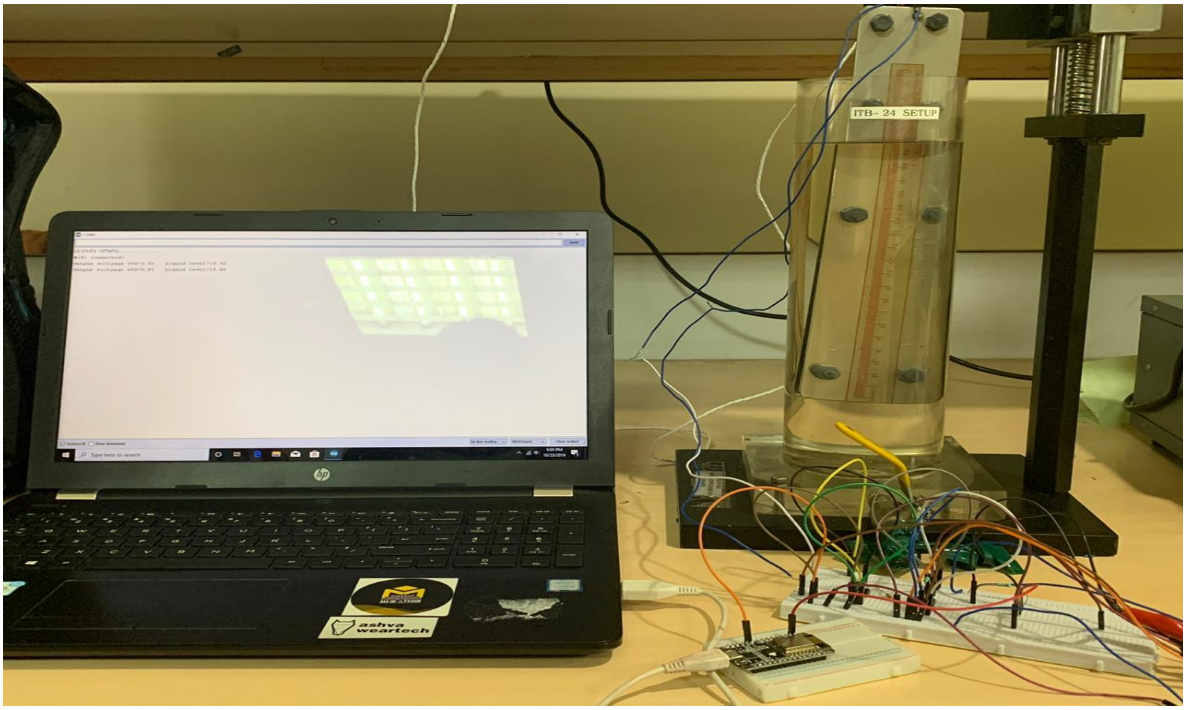


OBSERVATIONS AND SNAPS OF OUTPUT:

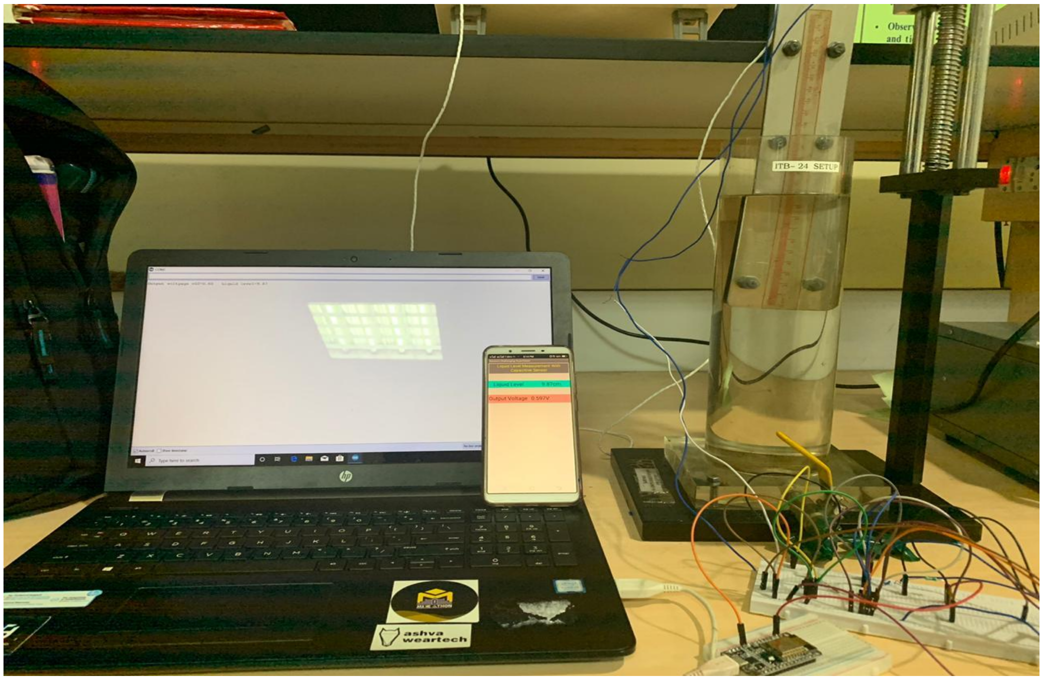
AT LIQUID LEVEL OF 20cm:



Theoretical output voltage=0.8828038V



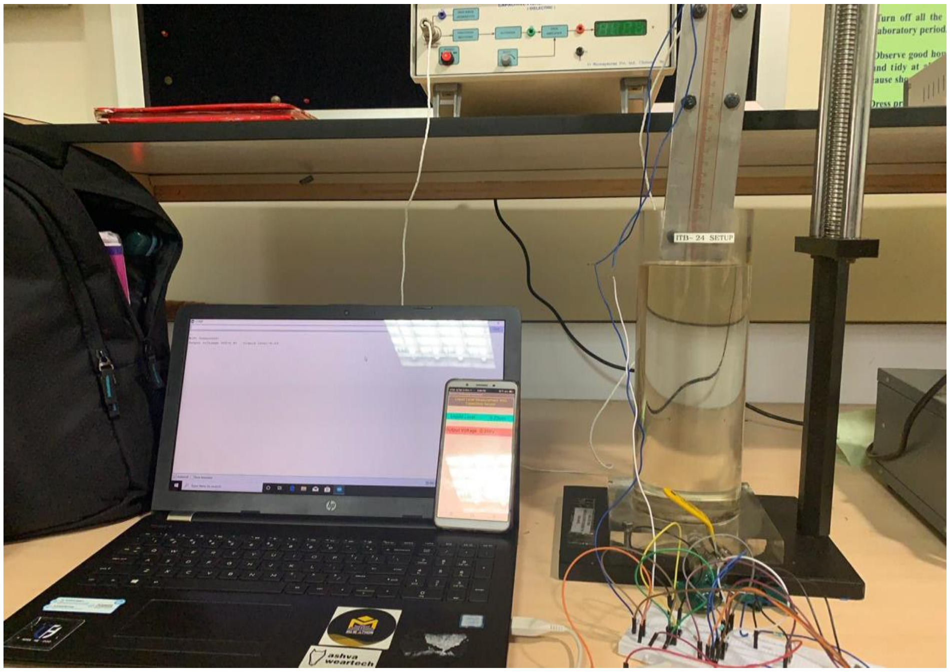
AT LIQUID LEVEL OF 10cm :



Theoretical output voltage=0.666607005V

AT LIQUID LEVEL OF 0cm

Theoretical output voltage=0.45041V



INFERENCE:

The results of the experiment yields values which are fairly close to the theoretical values. Due to non-ideal characteristics of op-amp, such as dc imperfection and slew rate as well as impurities of the sensor itself, we get slight deviations from the theoretical values and slight non-linear conditions.

These drawbacks can be reduced by either hardware or software approximations. In hardware approximation, adjustment and additional filter circuit can be added between rectifier and data acquisition device. On the other hand, statistical methods can be used in software approximation.