YEDITEPE UNIVERSITY

ELECTRICAL & ELECTRONICS ENGINEERING DEPARTMENT

EE 226 - Fundamentals of Electromagnetic Fields

Term Project:
Design and Implementation of a Fluid Gauge

By

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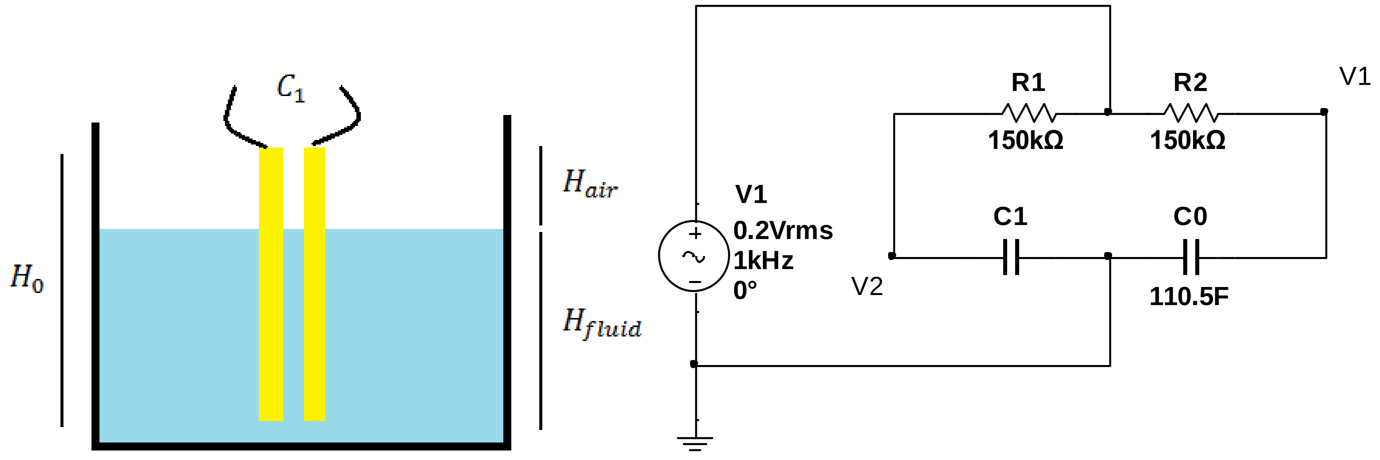
1 Project Summary

In this project how to measure liquid level in a tank. Based on the Wheatstone Bridge liquid can measure linearly with paralel plate capacitor. $C_1(H_0)$ when the tank has liquid level of H_0 so, the capacitance of C_1 change with respect of liquid level. . C_0 capacitans of when the tank empty and no liquid between paralel plates.

Through to Wheatstone Bridge each capacitance value change the voltage value V_2 shown in Figure 1b.



(a) (b)

Figure 1: a) Measurement of fluid height in a tank. b) Bridge Circuit for level measurement.

In this case capacitance of C_1 only increase or decrease when the water level change. While the water level increase H_{fluid} increase and H_{air} decrease. In reverse case H_{fluid} decrease and H_{air} increase.

Because of the this differance we have different capacitance value so, we have capacitance function of liquid level.

$$A_{water} = W * H_{fluid}$$

$$A_{air} = W * H_{air}$$

$$C_1 = \frac{K_2 * e_0 * A_{water}}{d} + \frac{eW * e_0 * A_{air}}{d}$$

K_2 : Dielectrict constant

e_0 : Vacuum permitivity

W : Width of paralel plate

H : Height of paralel plate

d : Distance between paralel plate

C_0 : (Measured Capacitance when the tank is empty): 110.5pF

C_1 : (Measured Capacitance when the tank is full): 11.6nF

Working Principle of Wheatstone Bridge

We have 3 constant variables those are R_1 R_2 and C_0. When the change impedance at C_1 the current flow change and it create voltage difference. This difference, linear with C_1 value. So this variable capasitans value can use determine liquid level.

We want to create maximum $V_2 - V_1$ potential diffrence at 1kHz. To do that we need to spesifed R_1 and R_2 values. In multisim we try 100kΩ, 150kΩ 200kΩ R_1 and R_2 values, end of tryies **150kΩ** resistor make the maximum $V_2 - V_1$ at 1kHz.

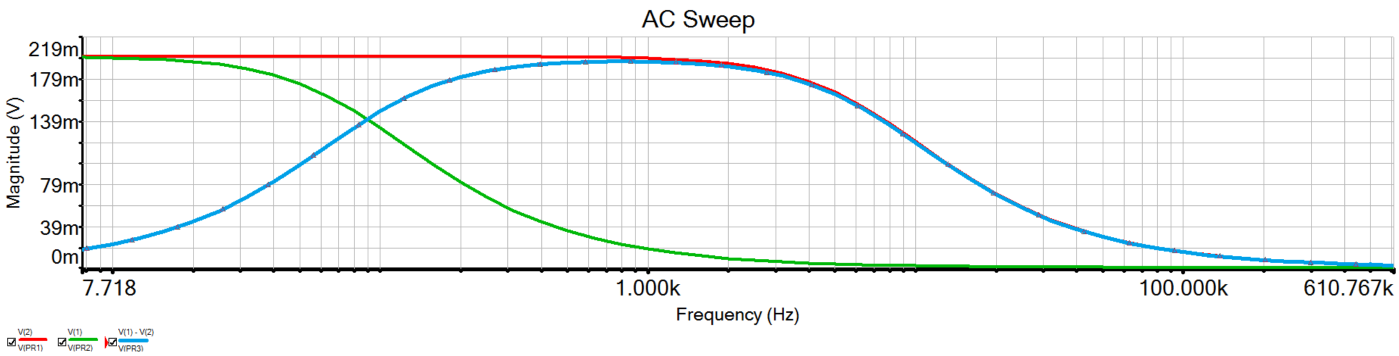


Figure 2: Multisim Analysis

R :150kΩ. , fpeak :1kHz

In Figure 1b potetial difference between V_2 and V_1 will be called V_{WB} .

Wheatstone Bridge Voltage Calculation :

$$V_2 - V_1 = \frac{Z_1}{Z_1 + Z_0} * V_1$$

$$V_{WB} = \frac{X_1}{X_1 + X_0} * V_1$$

$$X = \frac{1}{wC}$$

$$V_{WB} = \frac{C_1}{C_1 + C_0} * V_1$$

So we can use the variable V_{WB} for the estimating liquid level. But the output value so small to determine. To fix this problem we use the instrumental amplifier. This amplifier multiply the input with calculated gain.

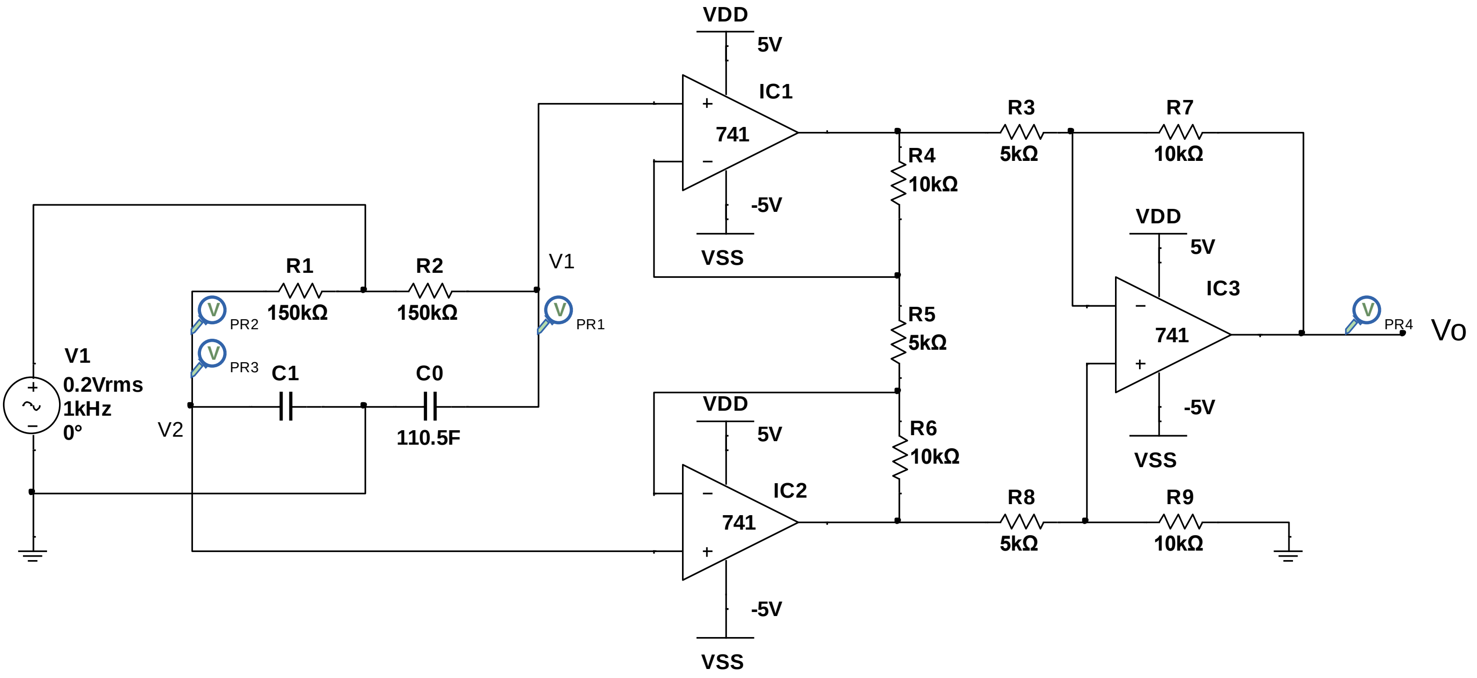


Figure 3: Wheatstone Bridge and Instrumental Amplifier

$$V_O = V_{WB} * Gain$$

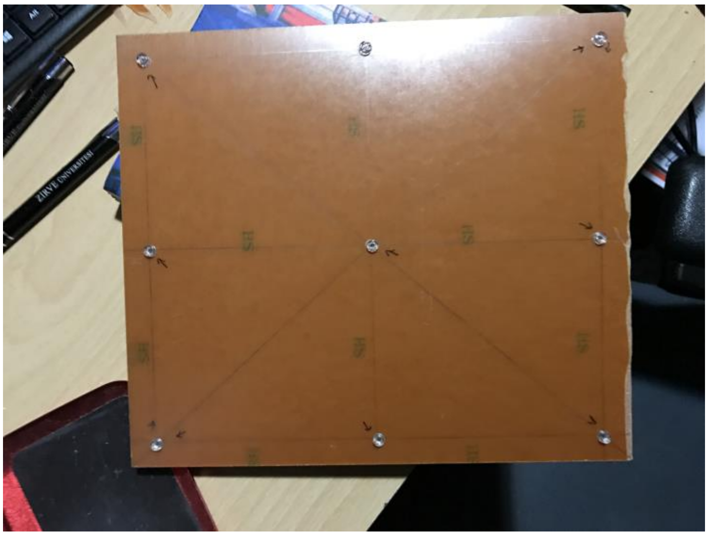
V_O shown in Figure 3 will be gained potential diffeance between V_1 and V_2.

$$Gain = \left(1 + \frac{2\,R_6}{R_5}\right) * \frac{R_7}{R_3}$$ *

2 Paralel Plate Capacitor

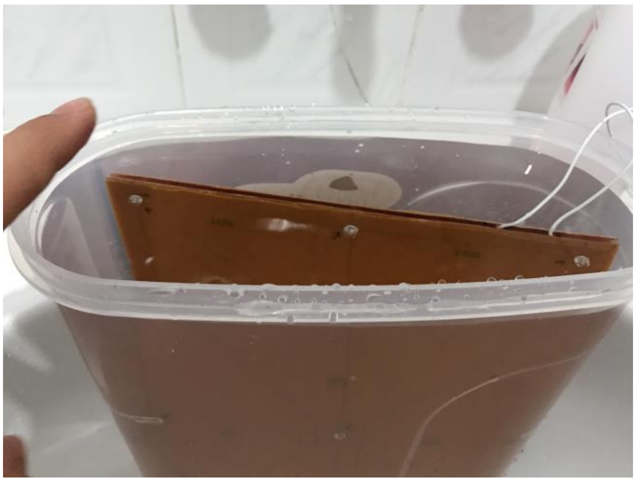
We use 2 copper plate and together this plate with plastic screw at 9 point. We fix at 9 point because when we try to fix 4 point screw distance of plate can change with pressure. This method not reliable so, we increase 9 point screw fix at Figure 4a.

Our first try we measure paralel plate capasitans of resistance nearly 80Ω. The water behave like a conductor, this result not linear and we try to isolate from water to copper side. Our isolation material garbage bag at Figure 4b. But this method also not linear because the water can be flow in to the copper side, because of that every minutes resistance of the paralel paletes increase but this isolation method better result than unisolated paralel plate.

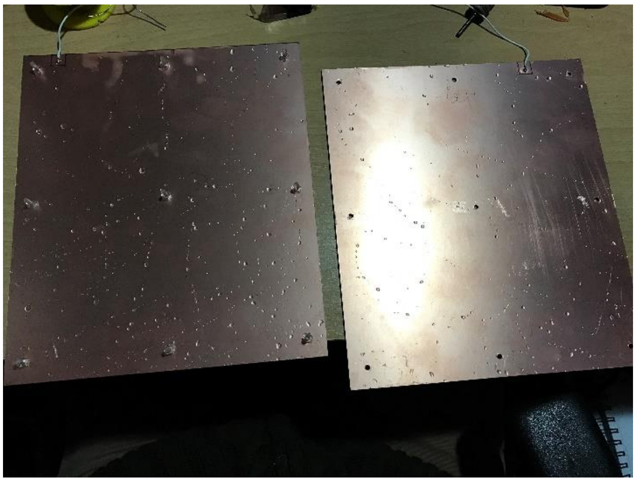


(a)

(b)



(c)

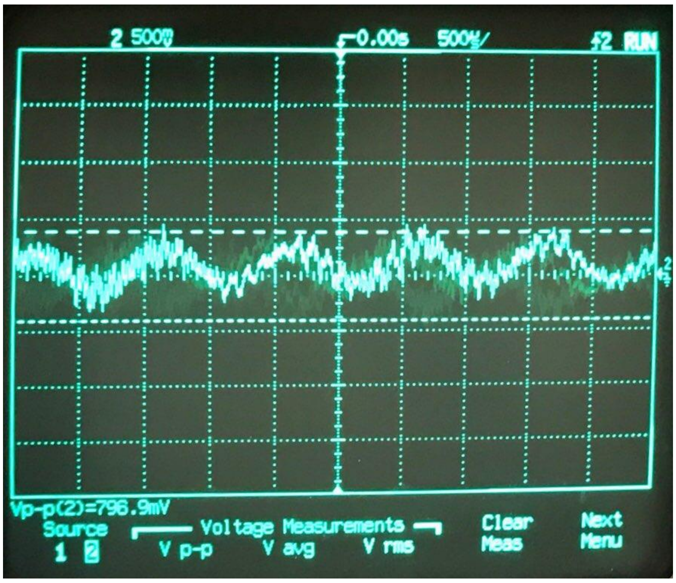


(d)

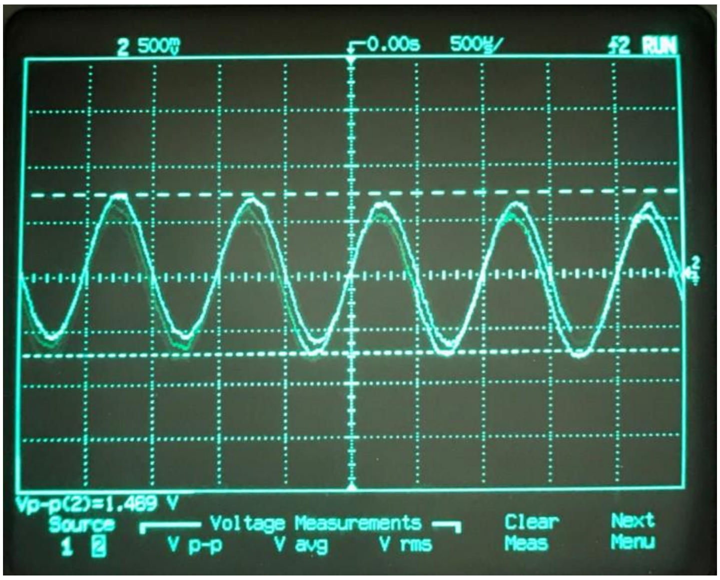
Figure 4: a) 9 point screw paralel plate. b) Water isolated plate. c) Before Water isolation.

d) Copper side of paralel plate.

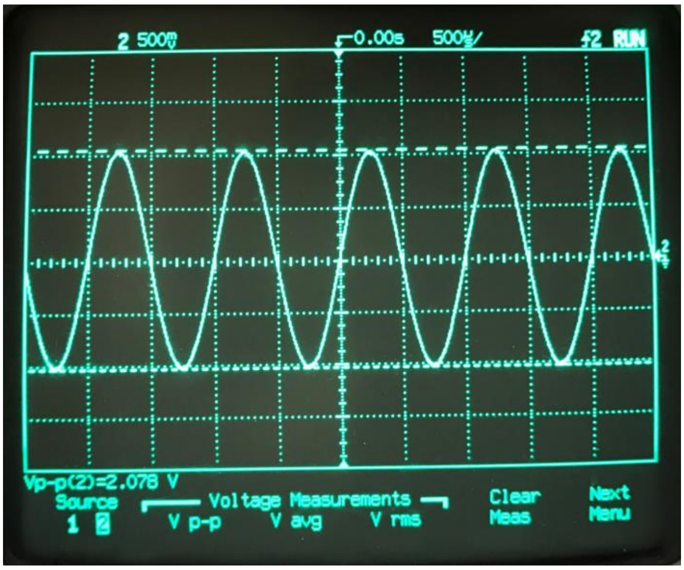
3 Measurements



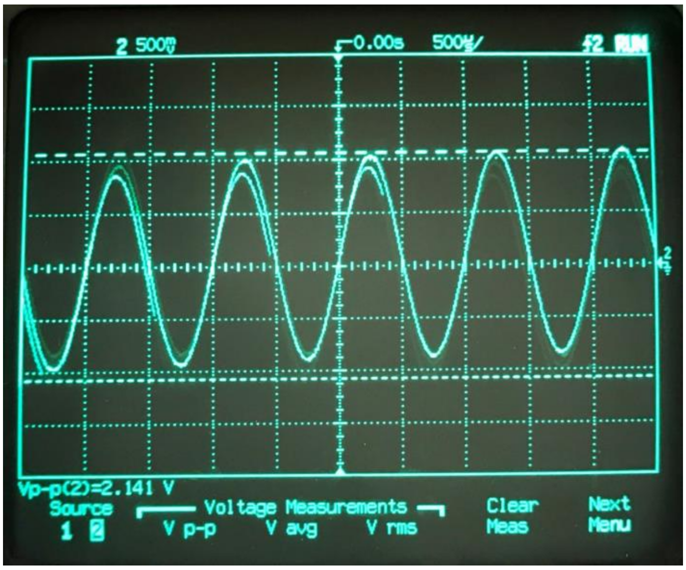
(a)



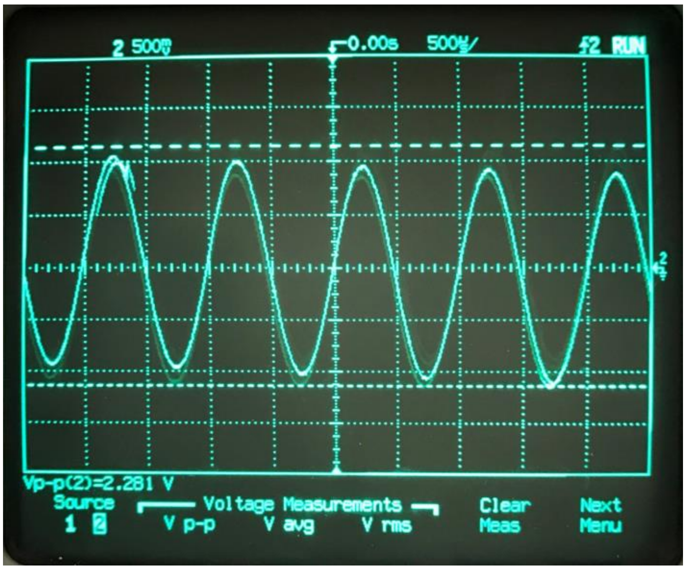
(b)



(c)



(d)



(e)

(f)

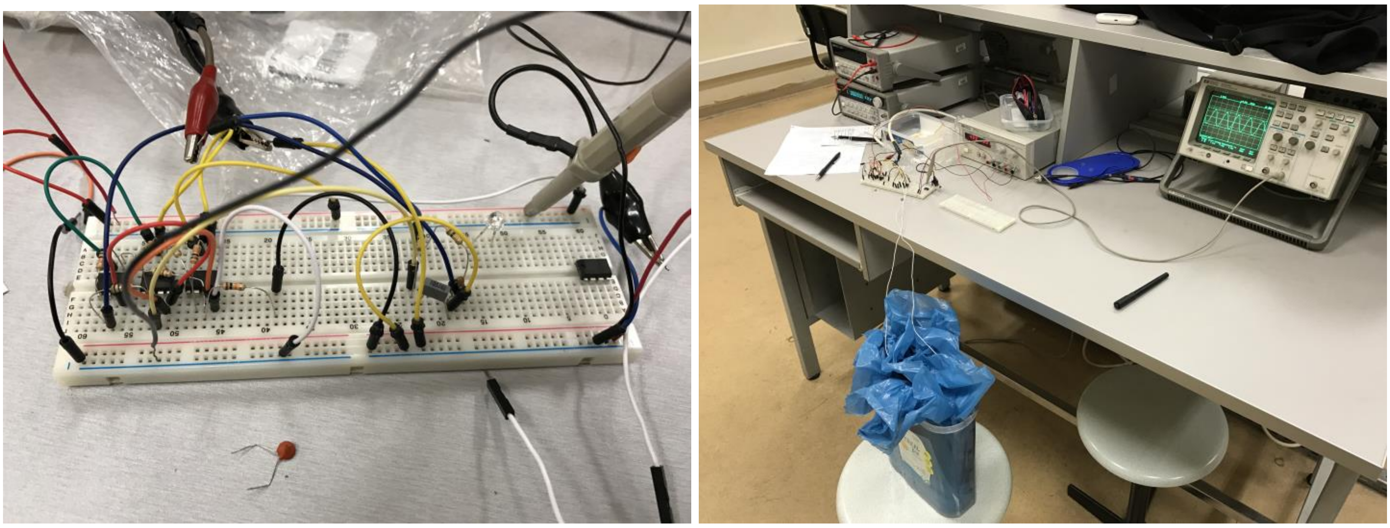
Figure 5: a) Empty Tank. b) (1/4) Filled with water. c) (2/4) Filled with water. d) (3/4) Filled with water. e) (4/4) Filled with water. f) Thickness of the paralel plate.

	Expected Output V_{p-p}	Actual Output V_{p-p}	Error V_{p-p}
Empty Tank	1.000V	0.796V	-0.204V
(1/4) Filled with water	1.915V	1.489V	-0.426V
(2/4) Filled with water	1.956V	2.078V	0.122V
(3/4) Filled with water	1.970V	2.141V	0.171V
(4/4) Filled with water	1.977V	2.281V	0.304V

Sum of square of errors (SSE) : 0.0011

Expected Output V_{p-p} and Error V_{p-p} calculated on matlab. Source code in **Calculation Codes** section.

(a) (b) (c) (d)



(e) (f)

Figure 6: a) (1/4) Filled with water. b) (2/4) Filled with water. c) (3/4) Filled with water.
d) (4/4) Filled with water. e) Wheatstone Bridge and Instrumental Amplifier. f) All systems are running.

4 Calculation Codes

```
%% Calculate Full And Emtpy Tank Capacitance
clc
clear all
e0= 8.854e-12;
eW=1; % on air
K2=88; % on water
W= 21e-2;
L= 23e-2;
A=W*L;
d= 0.3e-2;
C_full=(K2*e0*A)/d;
C_empty=(eW*e0*A)/d;

C_empty_Tank_pF=C_empty*1e12;      % pikofarad
C_full_Tank_nF=C_full*1e9;     %  nanofarad

C_empty_Tank_pF  % pikofarad
C_full_Tank_nF   %  nanofarad

%% Water Level Based, Capacitance and Voltage Calculation
clc
clear all
C0= 1.425494e-10;
Vi=0.2;              % Input 200mVp-p 1kHz
Gain=10;             % Instrumental amplifier gain
Water_Level = 4/4;   % 4/4 3/4 2/4 1/4 0/4 Water Level
e0= 8.854e-12;
eW=1;      % on air
K2=88;     % on water
W= 21e-2;
Ho= 23e-2;
H_fluid=Ho*Water_Level;
H_air=Ho-H_fluid;
A_water=W*H_fluid;
A_air=W*H_air;
d= 0.3e-2;
C_water=(K2*e0*A_water)/d;
C_air=(eW*e0*A_air)/d;
C_total = C_water +C_air ;

C_total_nF=C_total*1e9;        % nanofarad
if C_total_nF<1
 C_total_pF=C_total*1e12;      % pikofarad
    C_total_pF
else
    C_total_nF
end
Vo= ((C_total)/(C_total+C0))*Vi*Gain;
    Vo

%% Sum of Square of Errors
SSE=(-0.204-0.426+0.122+0.171+0.304)^2;
    SSE
```

5 Reference

* http://www.circuitstoday.com/instrumentation-amplifier