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Capacitive Transducer Circuits for Liquid Level Measurement

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Abstract

This work is making use of the capacitive element that is made of two electrodes - a column of liquid the level of which is to be measured, and a metallic tube that is pulled and fitted over a PVC tube of accordingly smaller dimensions. Both of the electrodes are provided with contact terminals for easy connection within a bridge circuit, which is powered by a sinusoidal source of given amplitude and known frequency. Precautionary measures are taken for improved linearity and minimal interference of the power supply on experimental data obtained as a result of measurement. The experimental data shows good consistency with the theoretical details and derivations.

Key words: *Capacitive Transducers, Bridge Circuits, Liquid Level Measurement*

1. Introduction

Measurement of liquid level is very much important in a number of industry processes [1-4]. This measurement process is making use of some liquid properties such as buoyancy, pressure and dielectric constant. The short comings of most of these processes are the wear and tear that they suffer from physical and chemical reaction as a result of contact Non-contact type of measurement methods currently in use, are costly and require a number of environmental and other precautionary measures during the course of experimentation [5-7]. Most of such con-contact measurement procedures suffer from the inaccuracies related to transducers' nonlinearity besides the errors accrued from noisy and polluted power supply onboard.

The work in this paper is in fact an experimental and reproduced proof of what is already reported, but with an addendum of experimental measurement and with and analysis on the issues of nonlinearity of transducers. The results obtained show a good level of accuracy and linearity that could be used for the identification of liquids having an identifiable level of specific solvent. The experimental results are found to have good repeatability, linearity, and resolution. Further, proposed level-sensing transducer reduces the effect of stray capacitance between the output leads of the bridge network.

2. Experimental Methodology and Measurement Circuit

The experimental setup of this work consists of a custom made water container with a circular tube alongside running from bottom-to-top as shown in Figure 1. Among the extra hardware tools used are digital and analogue oscilloscopes.

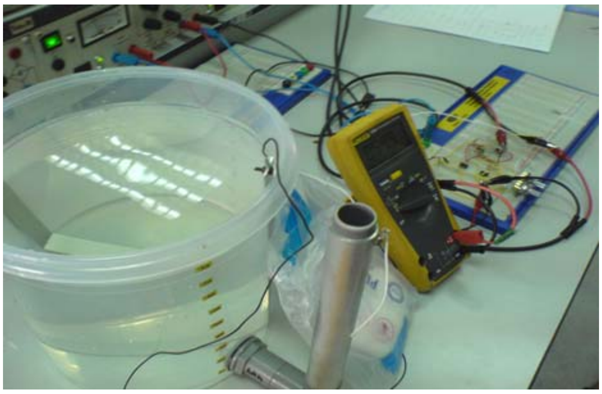

Fig. 1 Experimental Setup of Proposed Measurement Circuit

The measuring circuit is making use of a bridge circuit, where the unknown capacitance is found by balancing the bridge with the extra capacitance. The actual measurement circuit is as shown in Figure 2.

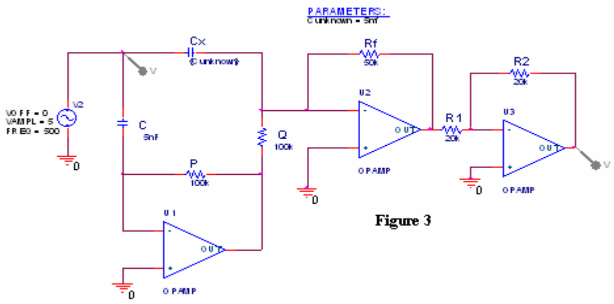

Fig. 2 Basic Measurement Electronic Circuit

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The over all transfer function is hence calculated through a sum of the two transfer functions given as under:

$$H(s) = H_L + H_H = -s\Delta CR_f \text{ ------------------------- (1)}$$

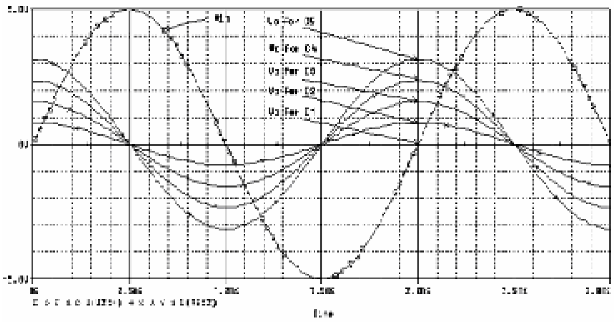
The bridge is balanced for the original residual capacitance without the liquid, hence a liquid-level increase beyond which will lead to an output voltage given by

$$V_o = V_{in} H(s)_{TOTAL} = \left(\frac{R_2}{R_1} s\Delta CR_f\right) V_{in} \text{ ---------------- (2)}$$

The increase in output voltage is proportional to changes in capacitance and if the input voltage applied is constant with a stable frequency.

The PSPICE simulation output voltage for five discrete capacitance values is as shown in Figure 3, where a sinusoidal input voltage gives an inverted output which is advanced by 90^0 and in direct proportion to the capacitance values.

Fig. 3. PSPICE Simulation of Output Voltage Waveforms



A modified version of the circuit is as shown in Figure 4, where the source is directly applied to the positive of on op amp (U2) and through a divider (R7, R8) to another op amp. The bridge under balanced condition will reproduce the input at the input terminal to R3 and hence to op amp U1. Thus the op amp U3 acts as a differentiator, with the input coming from the bridge circuit higher in value than the one coming form the divider circuit, hence giving to a voltage value in phase with the input for a balanced bridge circuit. This circuit is aimed at improving the stability of measurement from reasons related to ground.

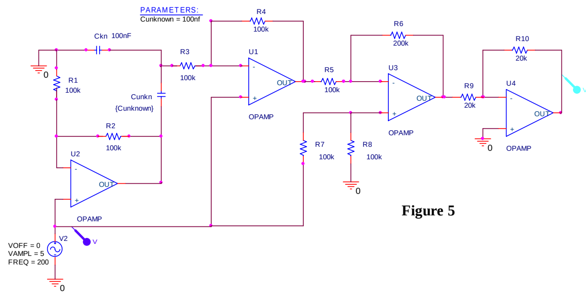


Fig. 4. The second amplification circuit

The output voltage in this case is independent of frequency, inversely proportional to the change in capacitance but it is in phase with the input voltage as shown in Figure 6.

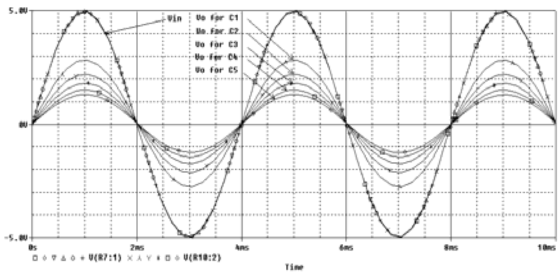


Fig.5. PSPICE Simulation of Modified Circuit Output Voltage

3. Results and Experimental Data

Extensive experiments are carried out to obtain data on salted solution, both for increasing and decreasing values of liquid levels, showing a good level of linearity as shown in Figures 6, 7, 8, 9.

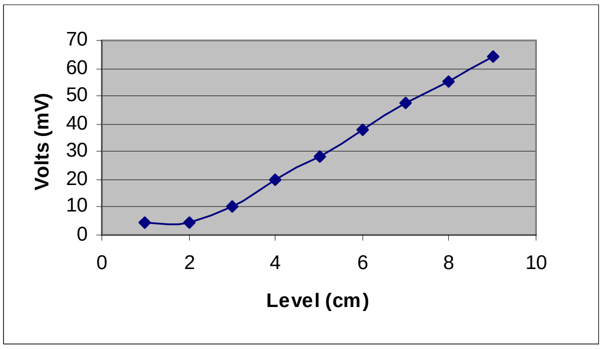


Fig. 6. Measurement for an Increasing Level of Two Spoon Salted Water

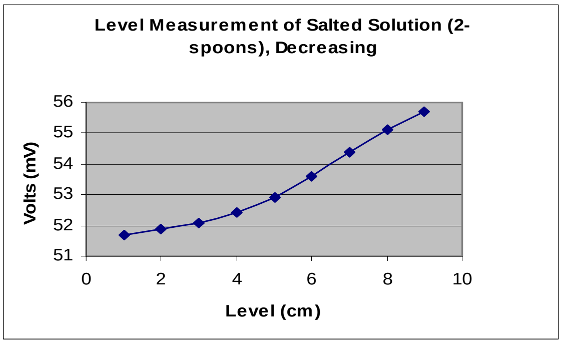


Fig. 7.
Measurement for a Decreasing Level of Two Spoon Salted Water

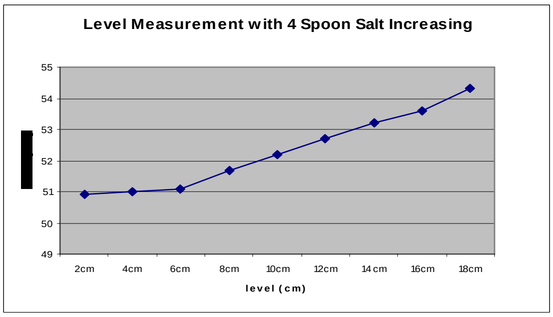


Fig. 8. Measurement for an Increasing Level of Four Spoon Salted Water

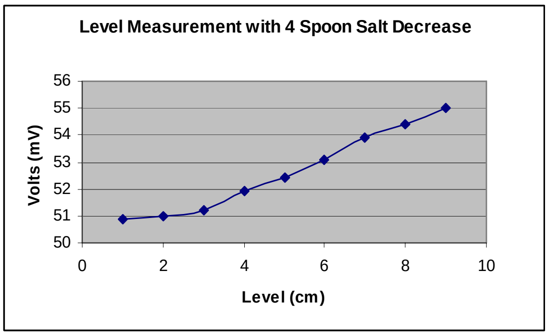


Fig. 9. Measurement for an Decreasing Level of Four Spoon Salted Water

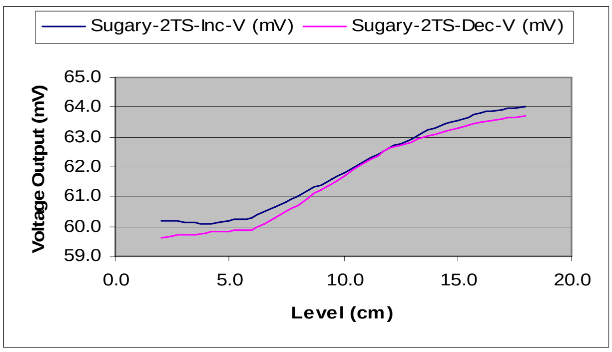


Fig. 10. Measurement for Increasing and Decreasing Level of Water Mixed with Four Spoon Sugar

The above experiment is repeated with water mixed with four spoon of sugar, both for increasing and decreasing levels as shown in Figure 10

4. Conclusions

The results show good linearity and an acceptable level of accuracy in all of the measurements, however, a few critical points need to be mentioned:

- The results follow an approximately horizontal straight line until the liquid level reaches around 6 cm where the metal casing is connected to plastic water tank, a point where from a good linearity is obtained.
- Even when there is no liquid inside the tank, there is still some small output voltage, which means some residual capacitance is present.
- The second circuit appears to give more accurate and consistent data than the old op-amp circuit.

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