DESIGN OF COUPLED COIL BASED SIGNAL CONDITIONING CIRCUIT FOR WIRELESS pH MEASUREMENT

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Abstract: **This paper presents a coupled coil signal conditioning circuit for continuous, high resolution, wireless pH measurement. The circuit comprises of sensor part and interrogator coil. The combined pH electrode is the sensor, physically in contact with the solution gives voltage which is a function of pH value of the solution under observation. The sensed voltage is amplified and converted into frequency by a timer circuit. This frequency signal is transmitted over a distance by phenomenon of electromagnetic induction. [2] The Induced frequency in an interrogator circuits i.e. a coil; is a function of pH of the solution under test. [1]**

Keywords: **High resolution, wireless pH measurement, induced frequency is a function of pH.**

I. INTRODUCTION

Measurement of pH has always been a vital consideration for various industries like chemical, fertilizer, water treatment, food and dairy, pharmaceuticals, agriculture, etc. Measurement of pH is undertaken to determine whether a particular solution is acidic, neutral or alkaline. It also determines the hydrogen ion content of the solution.

pH value is an instantaneous value of hydrogen content which changes with respect to ion concentration and temperature change. This concentration is generally expressed as negative logarithm to the base 10 of hydrogen ion concentration.
The main component of any pH measurement technique is the pH electrode. This electrode is nothing but an electrochemical cell which generates some potential difference when exposed to ion containing solution. [5]

Conventional methods demand samples of solution whose pH is to be examined from the field where the solution is present to the analytical lab. This procedure is highly time consuming and leads to various errors arising due to mishandling of samples, contaminated sample holders, difference in temperature from field and laboratory, inadequate knowledge about measurement, etc.

To overcome these shortcomings we propose a new technique for pH measurement. In this new technique the pH value is converted to respective frequency. This technique overcomes the shortcomings like mishandling of samples, alligation of samples due to contaminated containers, temperature difference between field and lab and most importantly the time elapsed between sampling and analyzing. In addition, this technique also facilitates the operator comfort by providing a wireless pH measurement. [1][2][3]

II. DESIGN OF SYSTEM

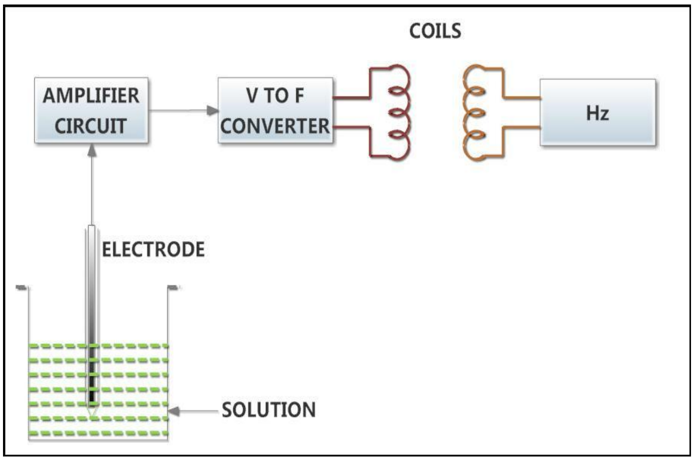

Fig.1. Block Diagram of Proposed System.

Block diagram of the proposed system is as shown in fig 1. It consist of:

1. Sensor
2. Amplifier
3. V to F Converter
4. Coils

A. Sensor

A glass electrode is a type of an ion selective electrode made of doped gas membrane that is sensitive to a specific ion. An electrolyte solution from the reference electrode leaks out of the liquid junction, which mixes with the solution being measured, completes an electrical circuit, and the combined solution gives an ionic charge on the glass electrode. [4]

If the liquid is acidic the glass electrode receives the positive ionic charge which results in a pH value less than 7. If the liquid is alkaline the glass electrode receives a negative charge which results in a pH value greater than 7. If the liquid does not give a positive or a negative charge which results in a pH value equal to 7.[5] [9]

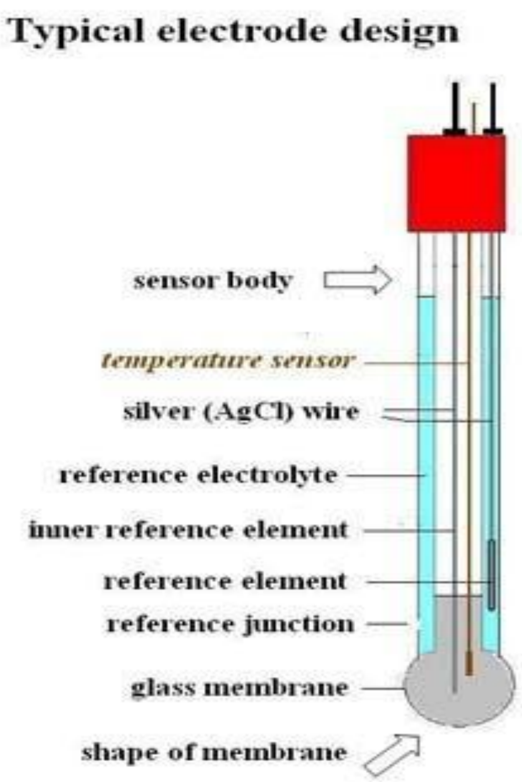

Fig.2. Combined pH Electrode.

B. Amplifier

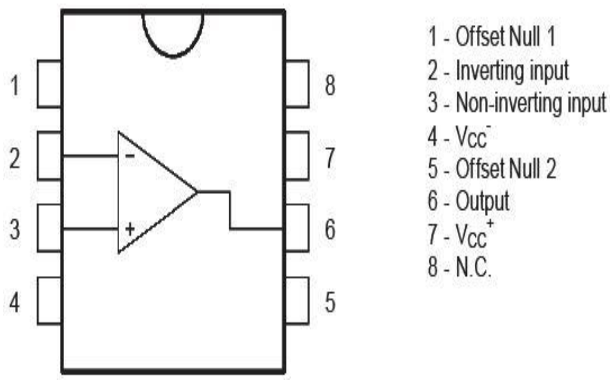

Fig.3. Pin Diagram of TL081 Amplifier.

Every pH electrode has a junction resistance of 50-500M .Also, the potential developed is very low. To overcome these problems we choose TL081 low cost, high input impedance, high CMRR, JFET amplifier to amplify the voltage signal generated by the electrode.[4][9]

C. V to F converter

Voltage to frequency converter performs the task of converting the pH signal into the respective frequency signal. We have used NE555 timer circuit as voltage to frequency converter. We are running the circuit in astable mode with an external control voltage provided at pin 5. Output of this circuit is a wave with a duty cycle varying with control voltage. Thus giving us frequency reading which is a function of pH.[6][7]

D. Coils

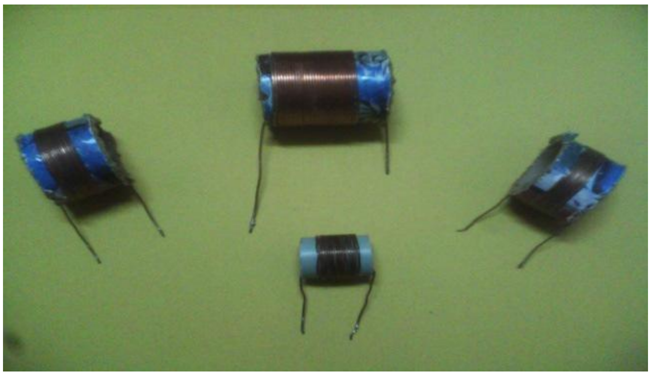

Fig.4. Copper coils wound on cardboard with air core

An electric current flowing through a conductor, such as a wire, carries electrical energy. When an electric current passes through a circuit there is an electric field in the dielectric surrounding the conductor. In an alternating current circuit, the fields also alternate; that is, with every half wave of current and of voltage, the magnetic and the electric field start at the conductor and run outwards into space with the speed of light. Where these alternating fields impinge on another conductor a voltage and a current are induced. The electrodynamic induction wireless transmission technique is near filed technique. With electrodynamics induction, electric current flowing through a primary coil creates a magnetic that acts on a secondary coil producing a current within it. Coupling must be tight in order to achieve high efficiency. As the distance from the primary is increased, more and more of the magnetic field misses the secondary.

E. Measurement Device

Measurement device used here is multimeter with $3^{1/2}$ display with facility of the frequency measurement. Alternatively, a cathode ray oscilloscope or a universal counter can be used. At the measuring device we connect the secondary or interrogator coil to the leads of measuring device.

III. SYSTEM OPERATION

When the glass electrode is dipped in the solution under test, it gives the voltage proportional to the hydrogen ion content. This relation is stated by Nernst equation [5] [9] [4] given as follows:

$$\mathbf{E = E^0 - (2.303RT/F)\ pH}$$

Amplifier circuit comprises of high input impedance, JFET, high CMRR, low cost amplifier available in 8 pin DIP package. Every pH electrode has junction impedance of the order of 50-500 M. To overcome the problems of loading effect and high source impedance we choose high input impedance amplifier TL081 with the input impedance of 1000G. Suitable amplifier gain is adjusted so that the amplified voltage is able to act as control voltage for V to F converter.

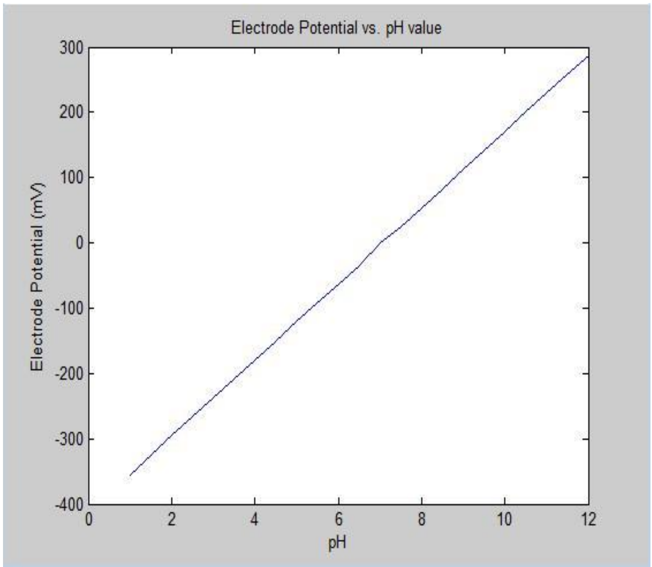

Fig.5. Response of Combined Electrode for Different pH Values

Voltage to frequency converter generates frequency signal which is a function of pH.

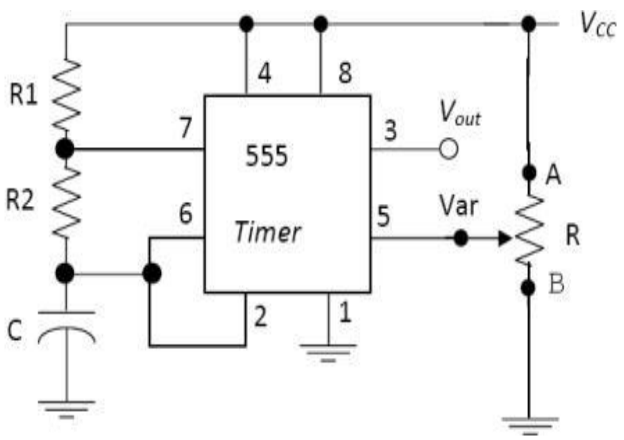

Fig.6. Typical Circuit of V to F Converter.

Pin 5 is connected to the inverting input of the upper comparator (comparator 1) which is at a potential of 2/3ofVcc. When 555 timer is operated as an astable multivibrator, pin 5 is bypassed to ground through a capacitor, so that VTH = 2/3 of Vcc and is undisturbed from noise. However, when 555 timer is used as a VCO, the voltage from the potentiometer R overrides the internal 2/3 of VCC voltage, producing another voltage Vcon determined by the position of the potentiometer. By adjusting the potentiometer, Vcon can be changed from VCC to 0 V. [7]

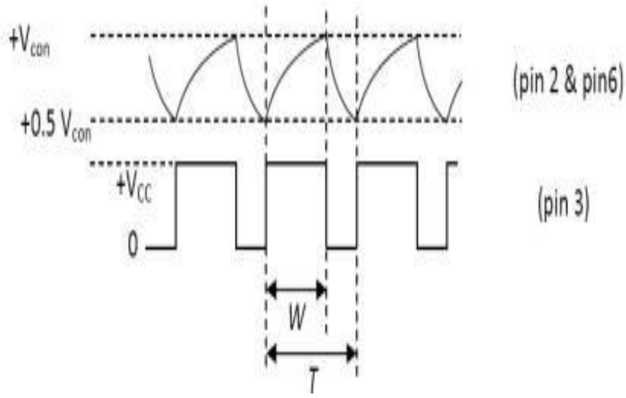

Fig.7. Output of V to F Converter.

T_{ON} = $(R_1+R_2).C \ln ((V_{cc} - 0.5V_{CON})/ (V_{cc} - 0.5V_{CON})$

$T_{OFF} = R_2C \ln 2$
$T = T_{ON} + T_{OFF}$
$F = 1/T$

As the formulae state the values of R_1, R_2 and C play an important role in determining the frequency of voltage to frequency converter. Sensitivity of this circuit can be stated as change in frequency per change in pH. [7]

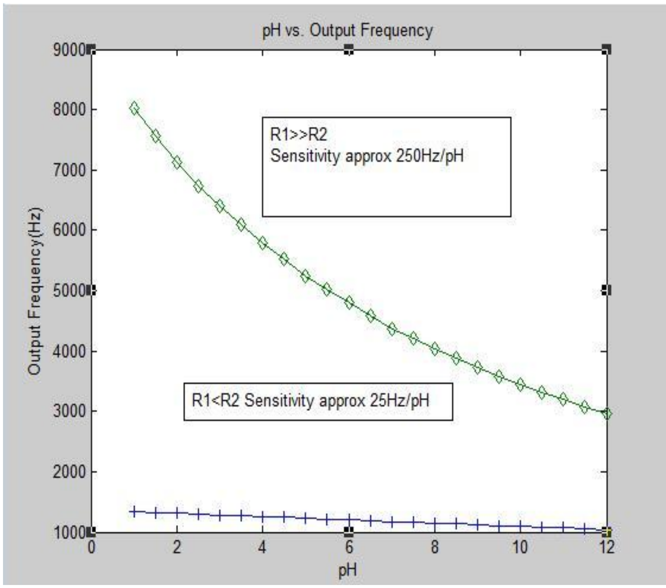

Fig.8. Frequency Response of V to F Converter

As it can be seen from the graph that if value of charging resistance R_1 is greater than discharge resistor R_2 better sensitivity is obtained.
Supply voltage is the next concern to be critically designed.
As it is seen from the graph that 12V gives best bandwidth of frequency offering us very high resolution to read the pH

value.

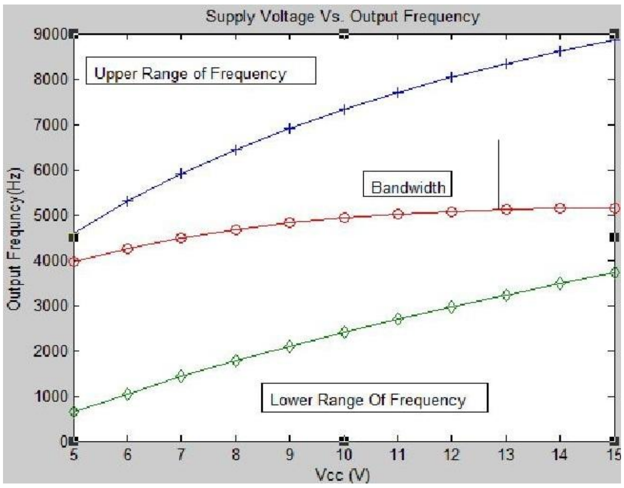

Fig.9. Frequency Response for Various Supply Voltages.

IV. SIMULATION RESULTS

The simulation results are taken on NI Multisim 11.0 software. The results are taken for standard pH of 4, 7 and 9.

1) Results for 4pH

pH = 4, E° = -180mV, V_{con} = 1.976V

F=1/T=5.076 KHz

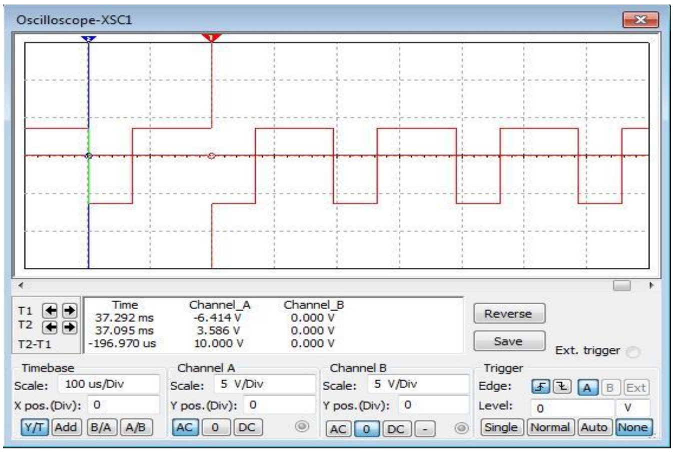

Fig.10. Output waveforms for pH value 4.

2) Results for 7pH

pH = 7, E0 = 0mV, Vcon = 2.857

F=1/T=3.666 KHz

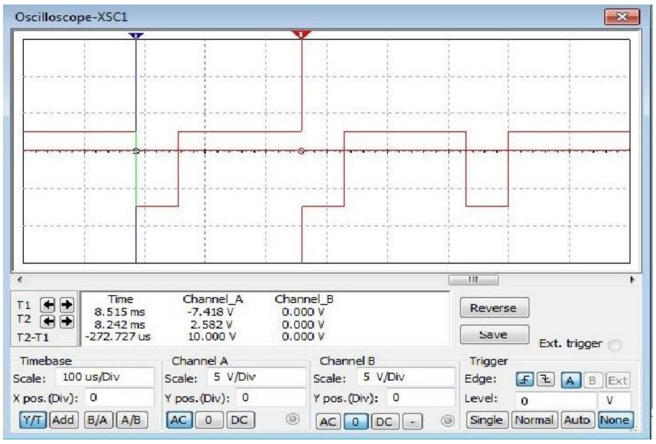

Fig.11. Output Waveforms for pH value 7.

3) Results for 9pH

pH=9, E°=112mV, V_{con}=3.406V

F=1/T=3.105 KHz

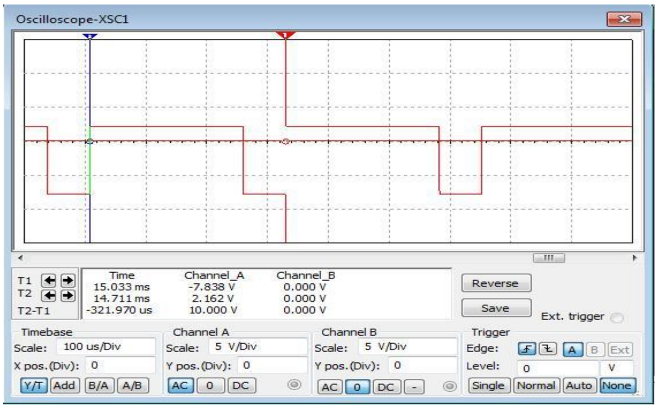

Fig.12. Output Waveforms for pH value 9.

It is clearly seen in the results that according to change in pH output frequency also changes.

V. CONCLUSION

This proposed system gives the high resolution. This system avoids errors related with contamination and allegation of sample under test. Facilitates user comfort by providing wireless transmission over a distance of few meters. It is observed from the experiments that the pH value is inversely proportional to the generated frequency.

VI. ACKNOWLEDGEMENT

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REFERENCES

[1] Sharmishtha Bhadra, Greg Bridges, Douglas Thomson and Michael Freund,"Electrode Potential Based Coupled Coil Sensor for Wireless pH Monitoring" IEEE Sensors Journal, Vol. 11, No.11, Nov.2011.
[2] Sharmishtha Bhadra, Greg Bridges, Douglas Thomson and Michael Freund,"A Wireless Passive Sensor for Temperature compensated Wireless pH Measurement"
[3] IEEE Sensors Journal, Vol. 13, No.06, June 2013.
[4] Brock Horton, Stephen Schweitzer, Andrew DeRouin, Keat Ghee Ong,"A Varactor-Based, Inductively Coupled Wireless pH Sensor." IEEE Sensors Journal, Vol. 11, No.04, April 2011.
[5] "Thermo Scientific pH Electrode Handbook "by Thermo Scientific. www.thermo.com/waterapps.
[6] D.V.S.Murthy, "Transducers and Instrumentation", Prentice Hall of India, Second Edition Feb. 2010.
[7] Ramakant A. Gayakwad"Op-Amps and Linear Integrated Circuits", Prentice Hall of India, Fourth Edition 2008.
[8] Datasheets "TL081","NE 555", www.alldatasheets.com.
[9] Ajay Kumar Kadel, Katmandu Engineering College, "Electronic Circuits".
[10] OAKTON TECHTIPS" pH Measurement and Control".

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