Sensor Fabrication and On-Chip Impedance Spectroscopy for Milk Adulteration Detection

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Dedication

To my parents

Shri. Ramesh Ghole & Smt. Sunita Ghole

Abstract

Milk adulteration has become a major problem in Indian subcontinent with commercially available milk being adulterated with variety of adulterants, which may cause hazardous and irreversible health damage to the consumers. The current trend to detect the adulterants in the milk are adulterant specific, or require a high end laboratory equipment. This work focuses on developing a hand held low power platform to detect adulterants in the milk so that pure milk and contaminated milk can be distinguished on-site, rather than focusing on the particular adulterant. Here conductivity of milk as inherent physical property of milk is studied, and chosen as a marker to differ pure milk from adulterated one. Experiments are performed to study the effects of various adulterants on milk conductivity. An on-chip impedance sensor with glass substrate and gold electrode is fabricated to further lab-on-chip platform. Based on the conducted study an on-chip impedance read-out circuit is designed to with concluded specifications, so that low-power handheld platform can be implemented. An on-chip circuit for impedance spectroscopy circuit is realized using a UMC-180nm technology. This low power, on-chip impedance spectroscopy based system for milk adulteration detection consists of an instrumentation amplifier(IA) with rail-to-rail ICMR, a high resolution comparator, Gm cancellation based integrator, peak detector and a low pass Biquad filter. A novel OTA structure with high gain and low bandwidth is used. The power consumption of each block is kept minimum keeping into mind the application of the full system for portable battery powered operation.

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Chapter 1

Introduction

1.1 Motivation

Milk is a primary source of nutrition for young kids across the globe. Throughout the world, there are more than 6 billion consumers of milk and milk products. Over 750 million people live within dairy farming households. India is one of the largest producers and consumers of milk in the world. But the availability of quality milk has been a major problem in the Indian subcontinent as milk adulteration becomes a norm across the country [1]. It has been a real challenge in India to circumvent the problem of milk adulteration due to lack of proper device and methodology to tackle. Dilution of milk by water to increase the overall volume for commercial purposes is the most common form of milk adulteration. However, milk diluted with fresh water is not very harmful for the consumer, apart from the nutritional issues. The problem has become very severe with the availability of chemically synthesized milk in the market. Commercially available milk is found to be adulterated with number of chemical such as hydrated lime, sodium hydroxide, sodium carbonate, sodium bicarbonate, hydrogen peroxide, formalin, sugar, urea, benzoic and salicylic acids, tertiary nitrogen compounds, borax and boric acids [1]. These adulterants are hazardous and cause irreversible damage to the organs. The Indian Council of Medical Research in an earlier report had mentioned that detergents in milk caused food poisoning and gastrointestinal complications; the other synthetic compounds cause impairments, heart problems, cancer and even death. The immediate effect of drinking adulterated milk with urea, caustic soda and formalin is gastroenteritis but the long term effects are known to be far more serious. Urea in milk can lead to vomiting, nausea and gastritis apart from being particularly harmful for the kidneys. Milk adulterated with caustic

soda can be dangerous for people suffering from hypertension and heart ailments whereas formalin in milk can cause severe damage to the body such as liver damage. The health impact of drinking milk adulterated with these chemicals is worse for children. Caustic soda harms the mucosa of the food pipe, especially in kids. The chemical which contains sodium, can act as slow poison for those suffering from hypertension and heart ailments [1]. This leads to a major worry for milk consumers and public health regulators in general.

1.2 Composition of milk

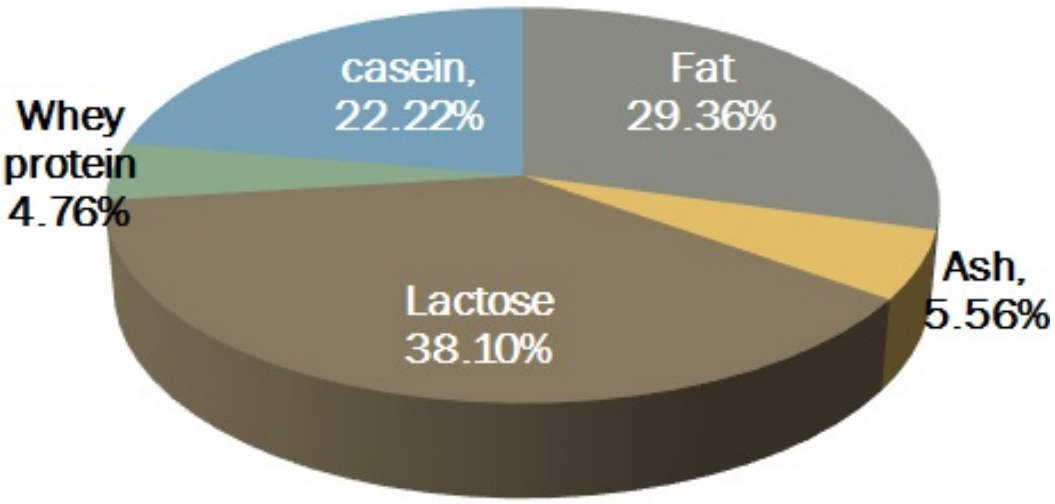

Figure 1.1: Distribution of Components in Milk

Milk is a food of exceptional interest. Not only is milk an excellent food for the very young but humans have also adopted milk, specifically cow's milk, as a food substance for persons of all ages. Many specialized milk products, such as cheese, yogurt, butter, and ice cream are staples of our diet. Milk is probably the most nutritionally complete food that can be found in nature. This property is important for milk, because it is the only food young mammals consume in the nutritionally significant weeks following birth. Whole milk contains vitamins (principally thiamine. riboflavin. pantothenic acid, and vitamins A, D. and K). minerals (calcium, potassium, sodium, phosphorus.

and trace metals). proteins (which include all the essential amino acids), carbohydrates (chiefly lactose), and lipids (fats).

1.2.1 Fats

Whole milk is an oil-water type of emulsion. containing about 4% fat dispersed as very small (5-10 microns in diameter) globules. The globules are so small that a drop of milk contains about a million of them. Because the fat in milk is so finely dispersed, it is digested more easily than fat from any other source. The fat emulsion is stabilized to some extent by complex phospholipids and proteins that are absorbed on the surfaces of the globules. The fat globules, which are lighter than water, coalesce on standing and eventually rise to the surface of the milk, forming a layer of cream. Because Vitamins A and D are fat-soluble vitamins, they are carried to the surface with the cream. Commercially, the cream is often removed by centrifugation and skimming and is either diluted to form coffee cream ('half and half '), sold as whipping cream, converted to butter, or converted to ice cream. The milk that remains is called skimmed milk. Skimmed milk, except for lacking the fats and Vitamins A and D, has approximately the same composition as whole milk. If milk is homogenized, its fatty content will not separate. Milk is homogenized by forcing it through a small hole. This breaks up the tat globules and reduces their size to about $1 - 2\mu m$ in diameter. The fats in milk are primarily triglycerides. About two thirds of all the fatty acids in milk are saturated, and about one-third are unsaturated. Milk is unusual in that about 12% of the fatty acids are short-chain fatty acids (C2-C10), such as butyric, caproic, and caprylic acids. Additional lipids (fats and oils) in milk include small amounts of cholesterol, phospholipids, and lecithins (phospholipids conjugated with choline). The phospholipids help to stabilize the whole-milk emulsion; the phosphate groups help to achieve partial water solubility for the fat globules. All the fat can be removed from milk by extraction with petroleum ether or a similar organic solvent.

1.2.2 Proteins

Proteins may be classified broadly in two general categories: globular and fibrous. Globular proteins are those that tend to fold back on themselves into compact units that approach nearly spheroidal shapes. These types of proteins do not form intermolecular interactions between protein units (hydrogen bonds and so on) as fibrous proteins do, and they are more easily solubilized as colloidal suspensions. There are three kinds of proteins in milk: caseins, lactalbumins, and lactoglobulins.

All are globular. Casein is a phosphoprotein, meaning that phosphate groups are attached to some of the amino acid side chains. These are attached mainly to the hydroxyl groups of the serine and threonine moieties. Actually, casein is a mixture of at least three similar proteins, principally α, β, and κ caseins. These three proteins differ primarily in molecular weight and amount of phosphorus they contain (number of phosphate groups). These three proteins differ primarily in molecular weight and amount of phosphorus they contain (number of phosphate groups). Casein exists in milk as the calcium salt calcium caseinate. This salt has a complex structure. It is composed of α, β, and κ caseins, which form a micelle, or a solubilized unit. Neither the α nor the βcasein is soluble in milk, and neither is soluble either singly or in combination. If κ casein is added to either one or to a combination of the two, however, the result is a casein complex that is soluble owing to the formation of the micelle. The κ casein is thought to stabilize the micelle. Because both α and β casein are phosphoproteins. They are precipitated by calcium ions. The κ casein protein, however, has fewer phosphate groups and a high content of carbohydrate bound to it. It is also thought to have all its serine and threonine residues (which have hydroxyl groups), as well as its bound carbohydrates, on only one side of its outer surfaces. This portion of its outer surface is easily solubilized in water because these polar groups are present. The other portion of its surface binds well to the water-insoluble α and β casein and solubilizes them by forming a protective colloid or micelle around them. Because the entire outer surface of the micelle can be solubilized in water, the unit is solubilized as a whole. thus bringing the α and β casein, as well asκ casein, into solution. Calcium caseinate has its isoelectric (neutrality) point at pH 4.6. Therefore, it is insoluble in solutions of pH less than 4.6. The pH of milk is about 6.6; therefore, casein has a negative charge at this pH and is solubilized as a salt. If acid is added to milk, the negative charges on the outer surface of the micelle are neutralized (the phosphate groups are protonated), and the neutral protein precipitates. The calcium ions remain in solution. When milk sours, lactic acid is produced by bacterial action and the consequent lowering of the pH causes the same clotting reaction Albumins are globular proteins that are soluble in water and in dilute salt solutions. They are, however, denatured and coagulated by heat. The second most abundant protein types in milk are the lactalbumins. The typical albumin has a molecular weight of about 41,000. A third type of protein in milk is the lactoglobulins. They are present in smaller amounts than the albumins. The lactoglobulins carry the immunological properties of milk. They protect the young mammal until its own immune systems have developed.

1.2.3 Carbohydrates

The main carbohydrate in milk is lactose. Lactose, a disaccharide, is the only carbohydrate that mammals synthesize. Hydrolysed, it yields one molecule of D-glucose and one of D -galactose. It is synthesized in the mammary glands. In this process, one molecule of glucose is converted to galactose and joined to another of glucose. The galactose is apparently needed by the developing infant to bui1d brain and nervous tissue. Brain cells contain glycolipids as a part of their structure. A glycolipid is a triglyceride in which one of the fatty acid groups has been replaced by a sugar, in this case galactose. Galactose is more stable (to metabolic oxidation) than glucose and affords a better material for forming structural units in cells. Although almost all human infants can digest lactose, some adults lose this ability on reaching maturity, because milk is no longer an important part of their diet. An enzyme called lactase is necessary to digest lactose. Lactase is secreted by the cells of the small intestine, and it cleaves lactose into its two component sugars, which are easily digested. Persons lacking the enzyme lactase do not digest lactose properly. Because it is poorly absorbed by the small intestine, it remains in the digestive tract, where its osmotic potential causes an influx of water. This results in cramps and diarrhoea for the affected individual. Persons with a lactase deficiency cannot tolerate more than one glass of milk a day.

Chapter 2

Detection of adulterants

Conventional way of determining the adulterants in the milk are generally chemical in nature, and thus are adulterant specific. Some methods which can determine number of adulterants are huge setups, and require high end laboratory setup examples of these include Mass spectroscopy, Raman spectroscopy, etc.. To detect the adulteration of the milk onsite we need a hand-held portable platform. Here in this work we try to detect if the milk is adulterated or not by looking at inherent physical properties of the milk. some of these physical properties of the milk are listed below in the Table 2.1.

2.1 Choosing a proper marker

Here we are trying to choose a physical property of the milk as a marker. Choosing the marker is based on the following points:

1. The marker should be affected by a large number of the adulterants.

Table 2.1: List Of Physical Properties Of Milk

Conductivity	Viscosity
pH	Freezing/ boiling point
Colour	Refractivity
Density and specific gravity	Osmotic pressure
Surface tension	Dielectric property

2. Change in the marker should be significant on addition of the adulterants.

3. Equipment used to sense the property should be scalable enough to be made into a hand-held platform.

2.1.1 Conductivity of the milk

In this work conductivity of the milk is chosen as a marker. Conductivity of the milk best satisfies the above mentioned criteria. Current passes through the milk by virtue of the activity of its ionic mineral constituents, of which the chloride ions carry 60−68% of the current. There is therefore a close correlation between the electrical conductivity of milk and its chloride content. The electrical conductivity of normal milk corresponds to that of approximately 0.25% sodium chloride solution. Lactic acid accumulates as a result of fermentation, converting calcium and magnesium to ionic form and thereby increasing the conductivity reading. Thus, the progress of fermentation can be followed by increases in the conductivity of milk. Also, demineralization of whey proteins and its fractions, leading to loss of ionic minerals, results in increased milk conductivity.

2.2 Setup to characterize the milk impedance

An impedance spectroscopy is carried out the sample. The frequency applied is in the range of 1 Hz to 100 kHz. Samples of the milk used are always 10ml pure and raw cow milk obtained from various local sources. A glassy carbon electrode is used as working electrode, and a platinum is used as reference/counter electrode, with a supply voltage of 0.3 volts. The addition of the adulterants is above the given quantity of the milk. The instrument used for this is form CH instruments namely Chi660e. The graph in Fig. 2.1 shows the impedance of the pure milk. From exhaustive study of milk samples from various sources it is observed that:

1. Impedance of the milk is very high for the lower frequencies.

2. Impedance goes on decreasing as the frequency of applied voltage signal goes on increasing.

3. Impedance of milk is reaches at it lowest at frequencies above 100kHz, and remains constant thereafter.

Conclusions form above observations:

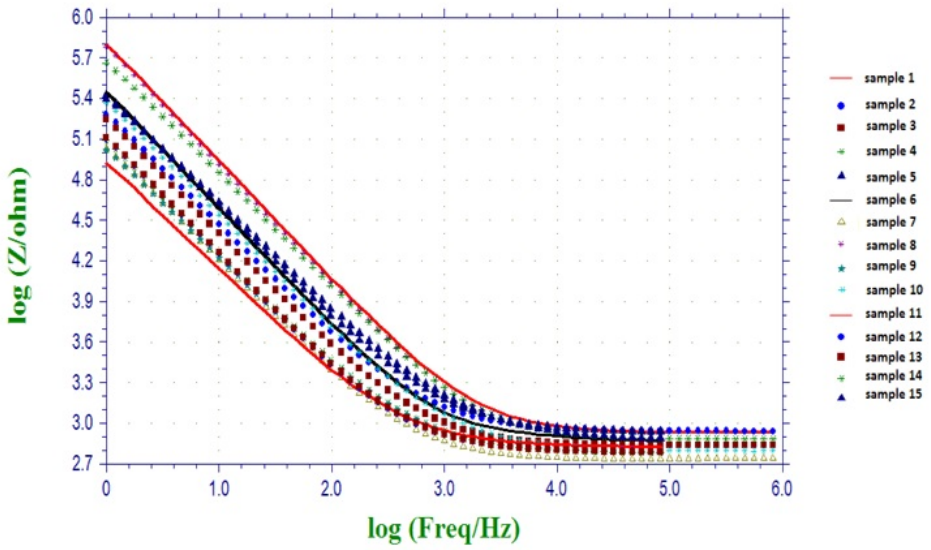

Figure 2.1: Impedance of Pure Milk.

1. Impedance of the milk is dominated by capacitive components for lower frequencies.

2. When the frequency of signal increases this capacitive components try to fade out, and pure resistive part dominates.

The experimental observations lead to the conclusion that the high frequency impedance of the unadulterated milk can be standardized within the range 615−640 ohms (subject to locality, breed and seasonal factors). Throughout the experiments, this value has been used as a reference to separate adulterated milk sample from the pure milk sample.

2.3 Effect of various adulterants on impedance of the milk

Effect of some the commonly know adulterants are shown in the below:

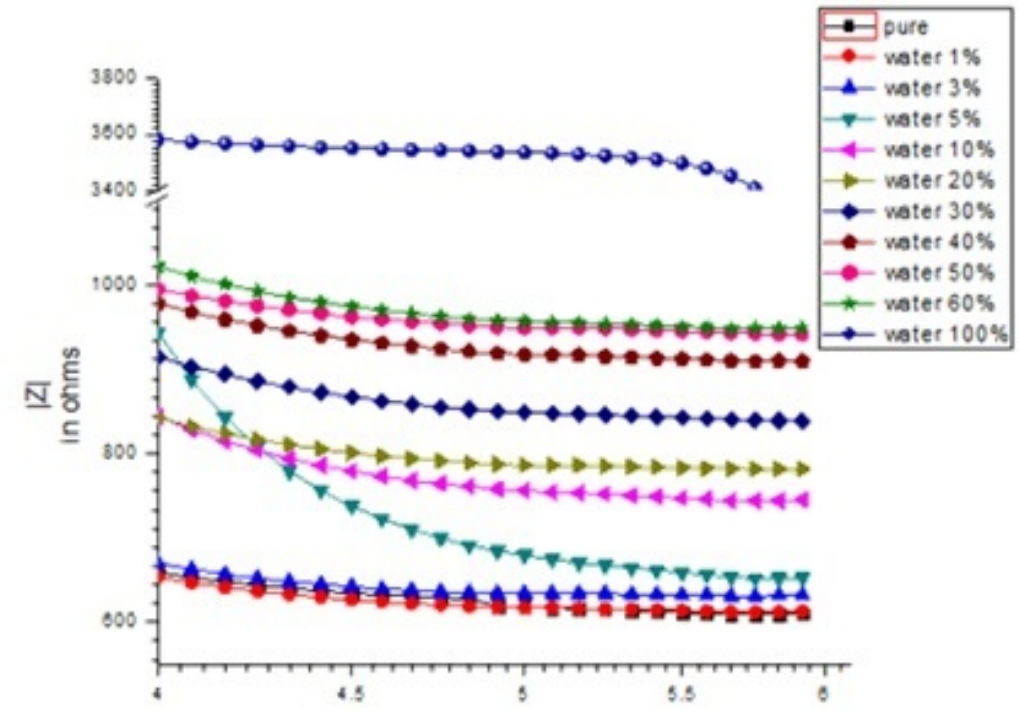

Figure 2.2: Effect of addition of water on Impedance of Milk

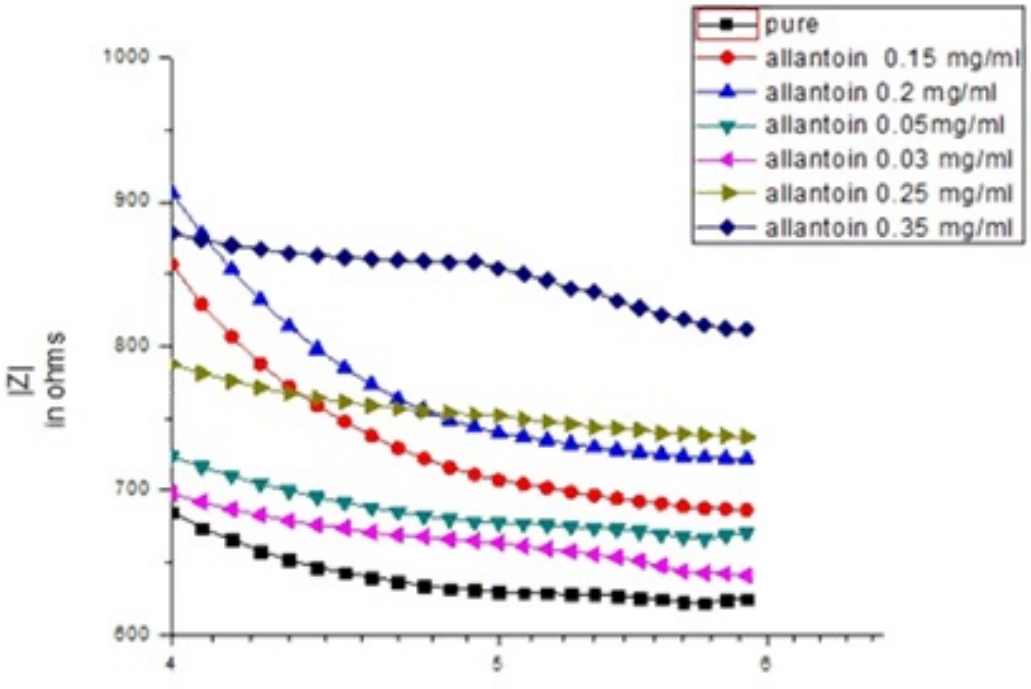

Figure 2.3: Effect of addition of Allantoin on Impedance of Milk.

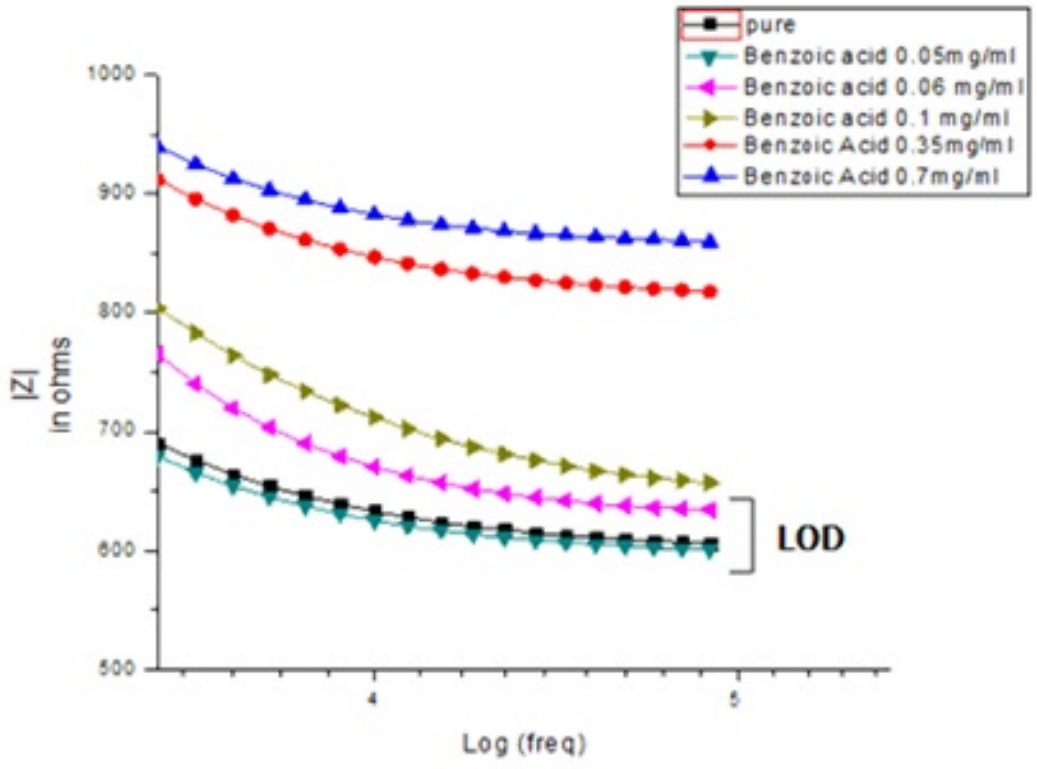

Figure 2.4: Effect of addition of Benzoic Acid on Impedance of Milk

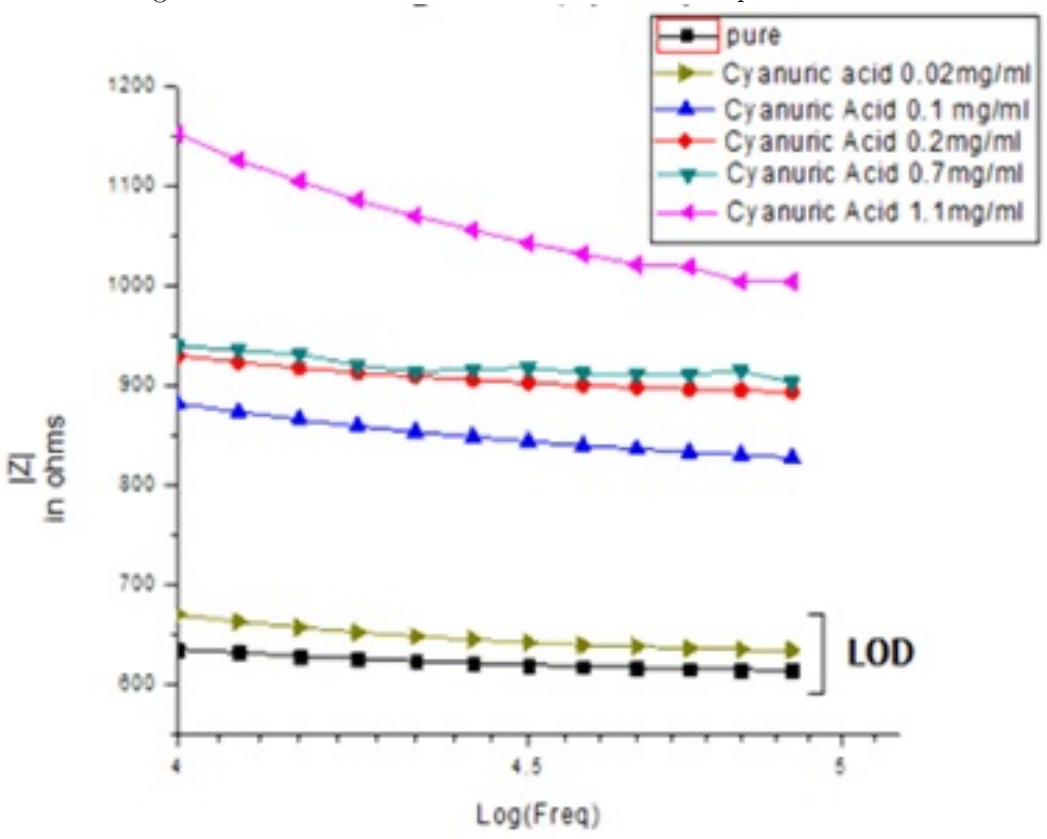

Figure 2.5: Effect of addition of Cynauric Acid on Impedance of Milk

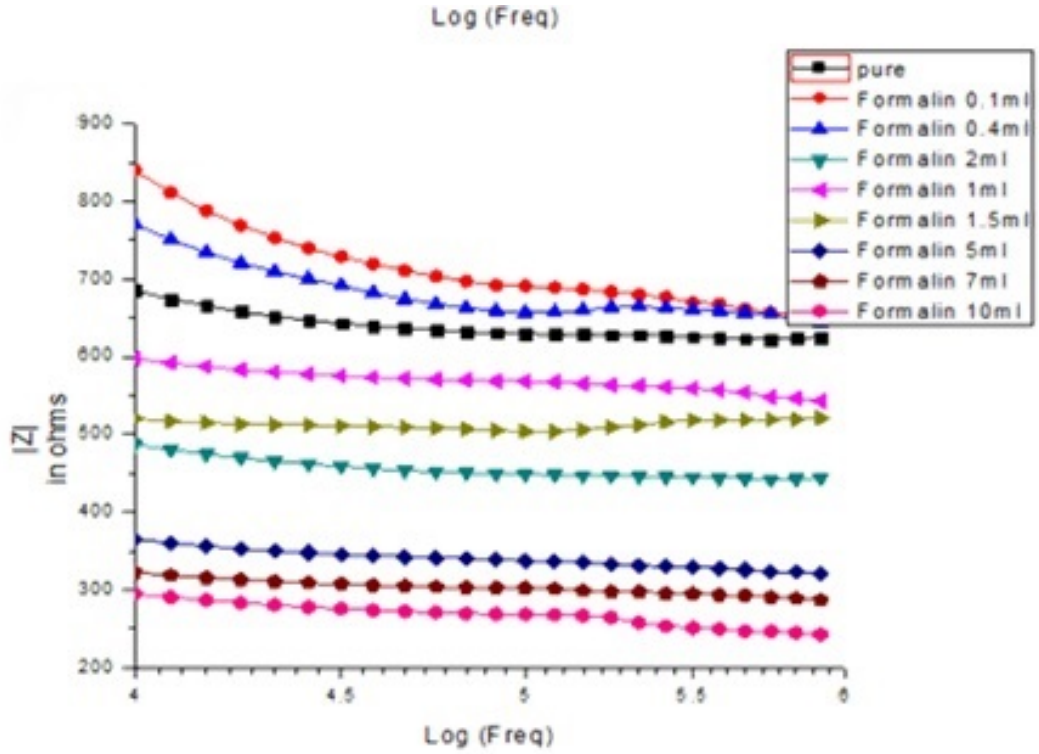

Figure 2.6: Effect of addition of Formalin on Impedance of Milk

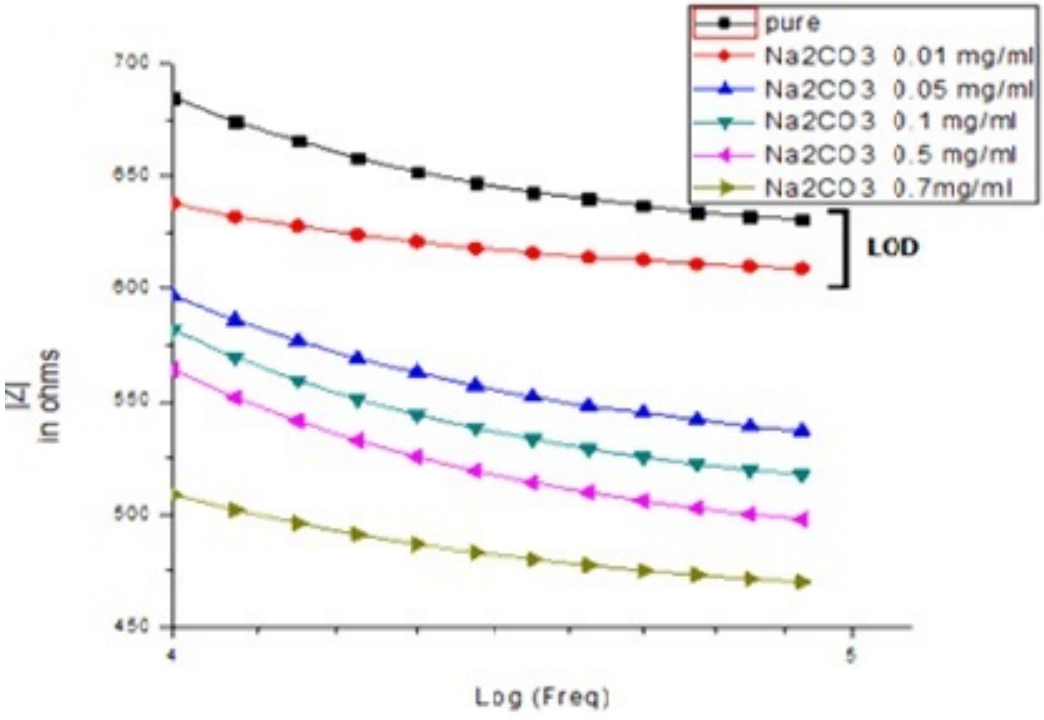

Figure 2.7: Effect of addition of Sodium Carbonate on Impedance of Milk

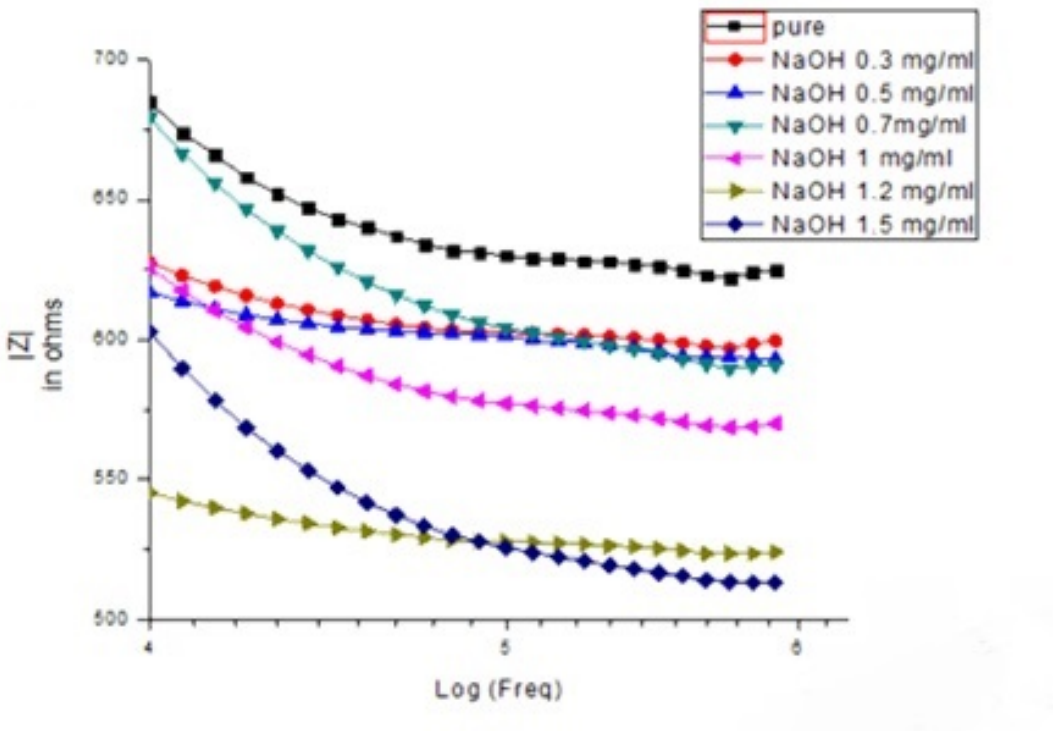

Figure 2.8: Effect of addition of NaOH on Impedance of Milk

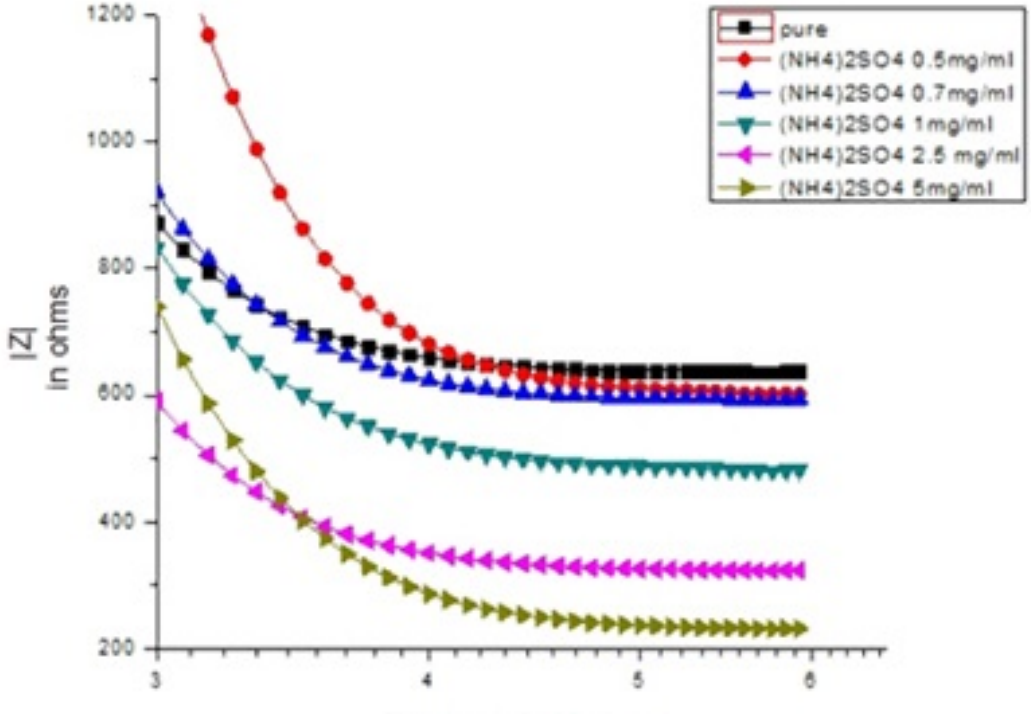

Figure 2.9: Effect of addition of Ammonium Sulphate on Impedance of Milk

From Fig. 2.2, Fig. 2.3, Fig. 2.4, Fig. 2.5 it can be concluded addition of water, benzoic acid, cynauric acid, and allantoin increases the impedance of the milk, while Fig. 2.7, Fig. 2.8, Fig. 2.9, suggest that sodiumcarbonate, sodiumhydroxide and ammoniumsulphate decrease the impedance.

2.3.1 Addition of Multiple Adulterants

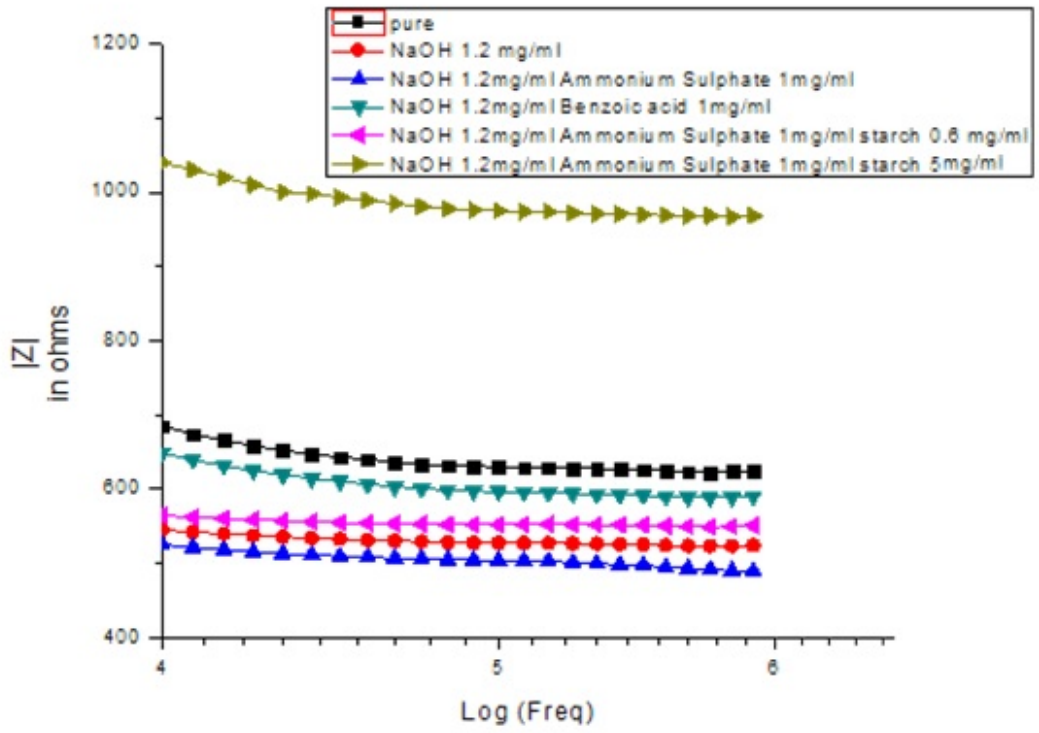

Figure 2.10: Effect of addition of Ammonium Sulphate and starch on Impedance of Milk

From Fig. 2.10, Fig. 2.11, Fig. 2.12, it is infered that, it is possible to nullify the changes in milk impedance due to adulteration by careful selection of a group of adulterants which are to be added simultaneously.

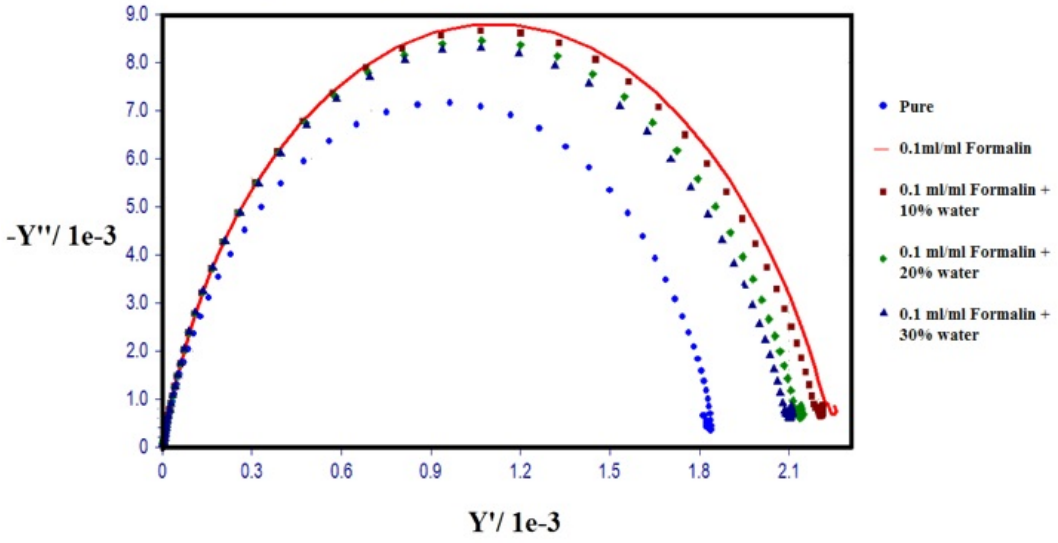

Figure 2.11: Effect of addition of Formalin and Water on Impedance of Milk

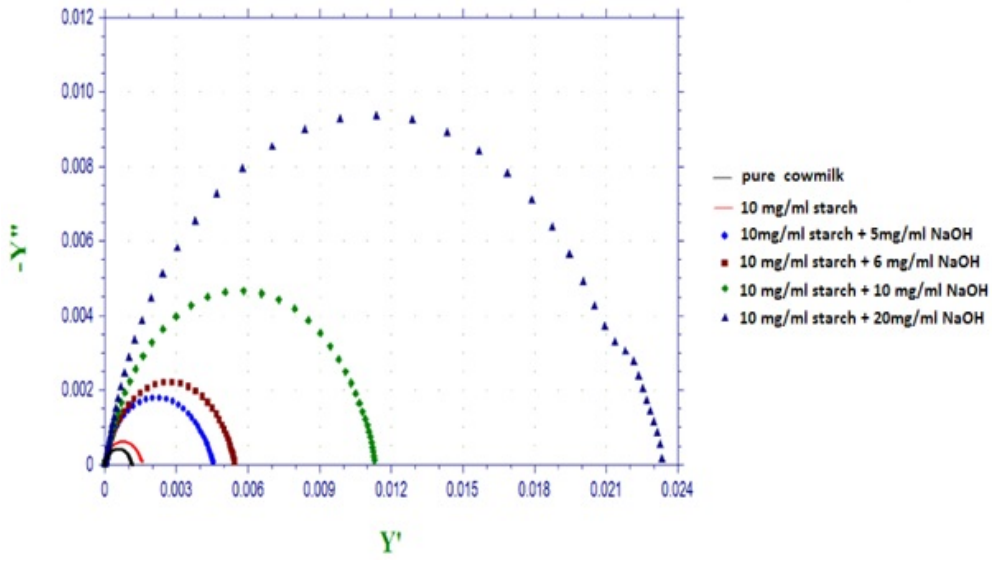

Figure 2.12: Effect of addition of Starch and Sodium hydroxide on conductivity of Milk

2.4 Fabrication of On-Chip Electrodes

To have a handheld device we need on-chip electrodes. The process flow to fabricate these eletrodes is as shown in

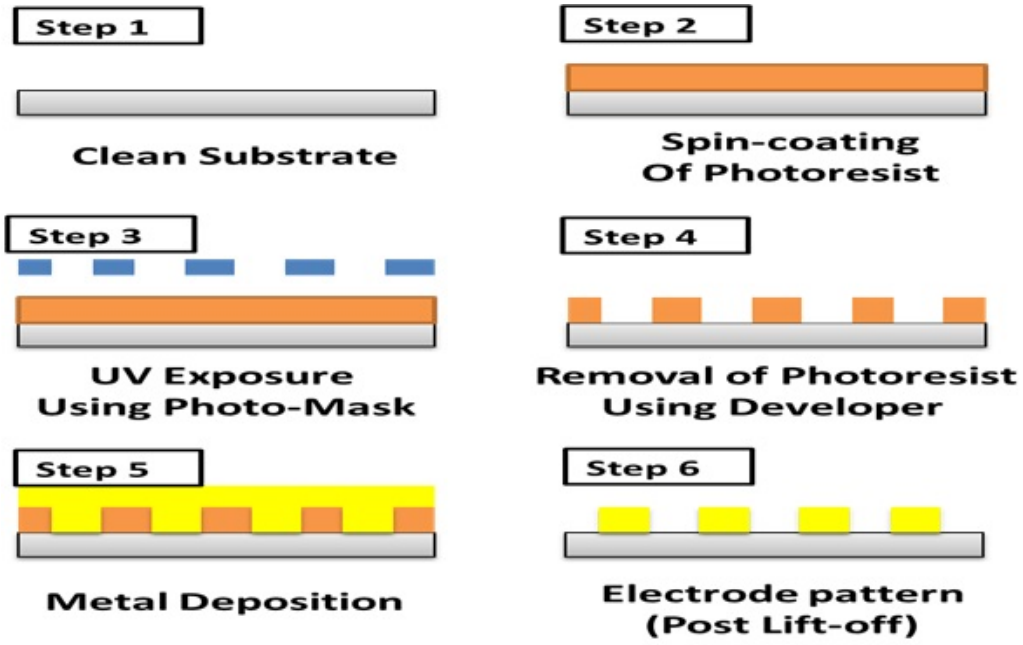

Figure 2.13: Process flow to fabricate on-chip electrodes

- A glass substrate is of dimension 5cm by 2cm in used. This substrate is cleaned using piranha cleaning process.
- Now this substrate is spin coated with positive photoresist(PPR) S1813, and soft baked.
- This is now exposed to UV radiation with a presence of a proper mask in between the source and the substrate.
- This is now developed in developer. This makes the resist to strip off from the region where the gold deposition in needed. Rest area on the substrate is still covered in PPR.
- A 200nm of gold deposition is made on it using RF-Sputtering.
- Lift-off is done in acetone.

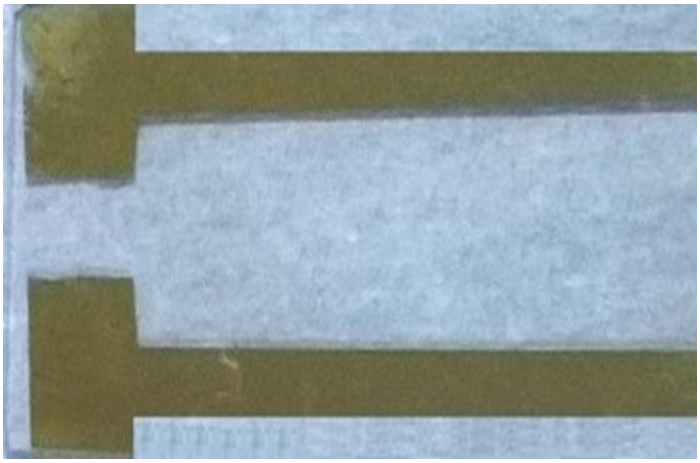

Figure 2.14: On-Chip Electrodes

Fig. 2.14 shows final on-chip electrodes. The dimensions of this electrodes is chosen in a way to match of that of the platinum and glassy-carbon electrodes.

Table 2.2: Limit of detection for various Adulterants

Name of the Adulterant	**LOD (with Glassy carbon and Platinum Electrode)**	**LOD (with Gold electrode)**
Tap water	5% (by volume)	5% (by volume)
Urea	0.5 mg/ml	0.5 mg/ml
Sodium hydroxide	0.3 mg/ml	0.5 mg/ml
Sodium carbonate	0.05 mg/ml	0.05 mg/ml
Ammonium sulphate	1 mg/ml	1 mg/ml
Allantoin	0.05 mg/ml	0.1 mg/ml
Sodium bicarbonate	0.03 mg/ml	0.03 mg/ml
Starch	0.12 mg/ml	0.3 mg/ml
Benzoic Acid	0.06 mg/ml	0.1 mg/ml
Boric Acid	0.1 mg/ml	0.1 mg/ml
Salicylic Acid	0.1 mg/ml	0.1 mg/ml
Cyanuric Acid	0.1 mg/ml	0.1 mg/ml
Semicarbazide	5 mg/ml	5 mg/ml
Formalin	0.1 ml/ml (volume ratio)	0.15 ml/ml (volume ratio)

Tha Table 2.2 shows limit of detection for various adulterants with normal electrodes and On-Chip electrodes. Thus it is clearly observed that liimit of detection does not change much with use of OnChip electrodes.

Chapter 3

Sensing Circuit

3.1 System and IC Architecture

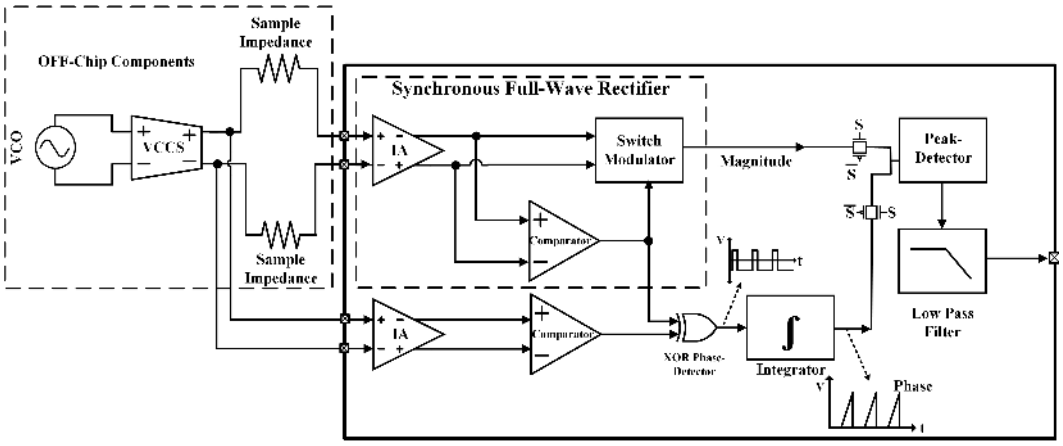

Figure 3.1: System Architecture.

Fig. 3.1 shows the full system design [4]. System contains an off-chip power supply shown as VCCS. This VCCS gives a constant current input. This input is in the form of sine wave ranging from 100kHz to 1 MHz. this input is applied to the sample impedance. Now the signal is taken at the chip. This signal is received by the instrumentation amplifier(IA), which provides an initial gain for further processing. The second IA receives the input in same phase as the input from the VCCS.

3.1.1 Magnitude detection

Synchronous full wave rectifier, it forms a major part for the detection of magnitude attenuation given by the sample. The differential input signal received by amplifier is amplified by its gain. This input is applied to comparator which generates a clock in synchronous with the applied input. This clock is fed to the switch modulator. Which gives a full-wave rectified output.

3.1.2 Phase detection

Input from the second IA is fed to another comparator. Out from both the comparator are compared using EXOR gate. Since the signal given by the first comparator only has suffered a phase shift given by the sample impedance. Thus EXOR gate generates a high output only for that period. Thus an output of the EXOR gate is pulse width modulated wave which corresponds to the phase shift at the input. This output is fed to the integrator circuit which generates the peaks. The integrator charges the capacitor only for the time for which it receives a high input. So the peaks are generated of different heights for different phase shifts.

3.1.3 Output Block

The signals from above blocks are fed to the peak-detector thorough transmission gates. These gates are used to timeinterleave the signals from the rectifier or phase detector. Peakdetector gives a constant DC output corresponding to the peaks at the input. A lowpass biquad structure filters out any distortions in the signal, and thus acts as an antialiasing filter for any ADC that can be used at the output. Thus a single ADC is required to digitize the output. This output is pure DC, so a ultralow power ADC can be employed owing to the fact that speed of the ADC is not of any concern.

3.2 Individual block elements

3.2.1 Instrumentation amplifier

A recycling folded cascode (RFC) amplifier [5] architecture based on the folded cascode transconductance amplifier is used. The proposed amplifier delivers an appreciably enhanced performance over that of the conventional folded. This is achieved by using previously idle devices in the signal

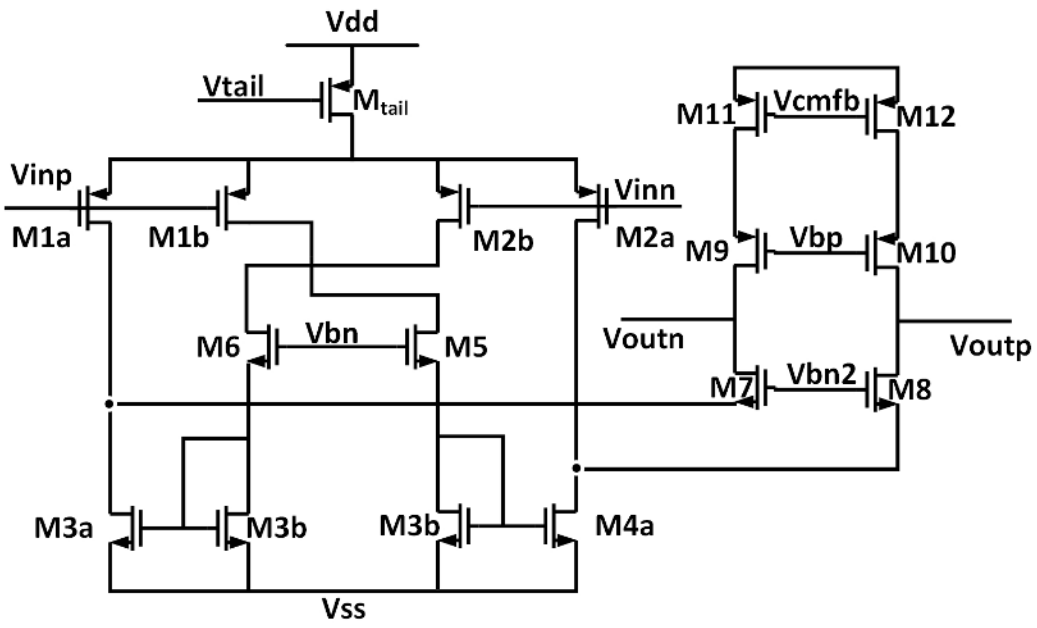

Figure 3.2: Recycling Folded Cascode as IA

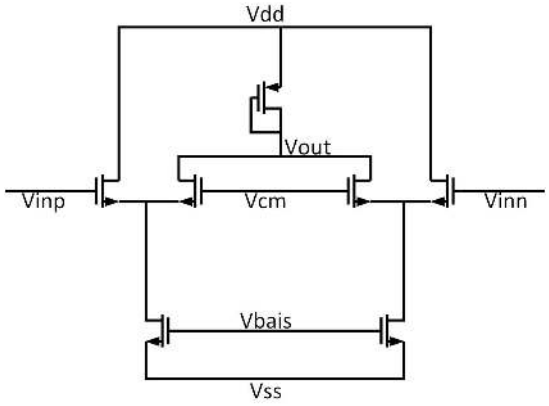

Figure 3.3: Common Mode Feedback Circuit

path, which results in an enhanced transconductance, gain, and slew rate. A common mode feedback circuit (CMFB) is used to stabilize the DC operating point and make the circuit less sensitive to process and temperature [6]. The structure gives a high ICMR range, since both NMOS, and PMOS transistor are used in signal path to provide gain. G_m by I_D method is used to bias the amplifier. The Fig. 3.4 , Fig. 3.5 shows unity gain frequency (UGB) for differential and commone mode signal.

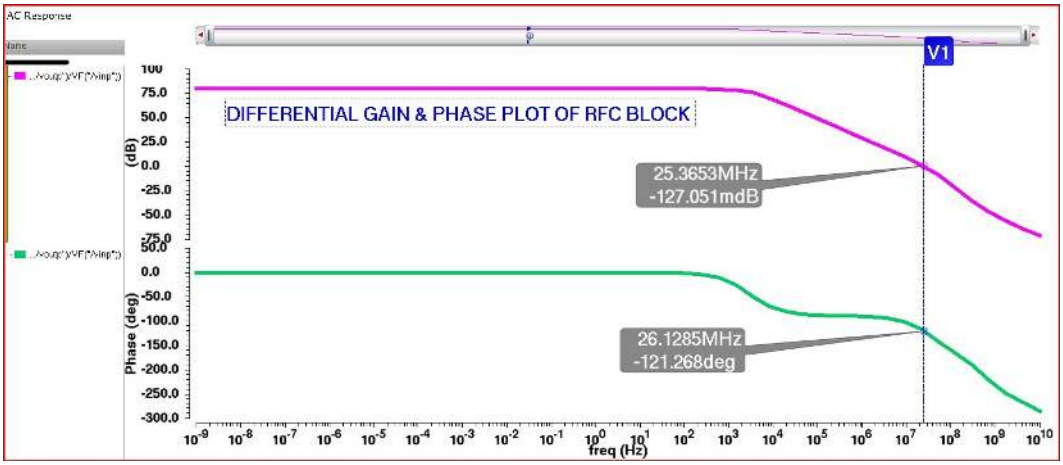

Figure 3.4: Differenatial mode gain and phase plot for IA

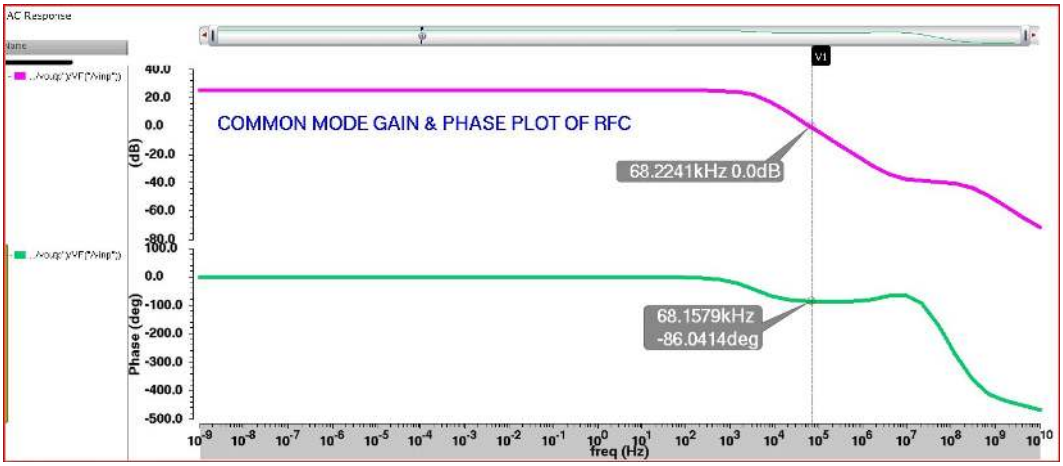

Figure 3.5: Common mode gain and phase plot for IA

3.2.2 Comparator

A continuous time comparator with minimum resolution of 540 V and power-consumption of 200 W is implemented [7]. The requirements of comparator are high resolution, faster slew rate, low power, low offset etc. As seen in the above diagram the minimum input at which the output of comparator switches completely to VSS (-900mV) is 540uV. Giving minimum resolution of comparator is 540uV. The slew rate, which is rate of change of output i.e. has been found to be 14 for the comparator. And the total power consumed in the comparator is 200 Watt. The comparator for this project is simulated using Cadence spectre simulator and cadence virtuoso is used as a schematic editor.

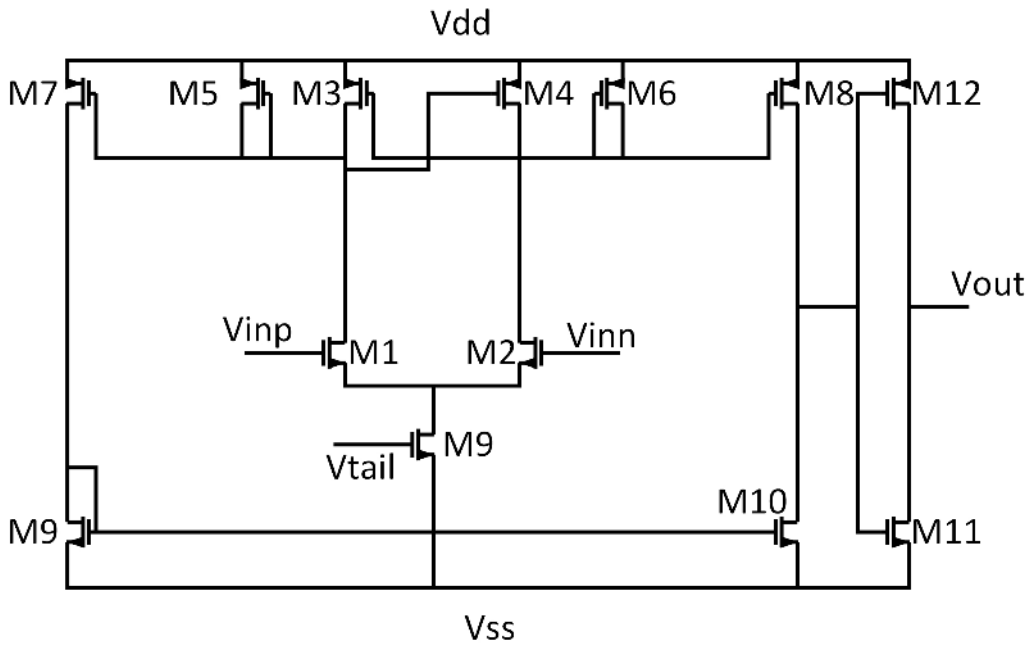

Figure 3.6: Circuit diagram of the comparator.

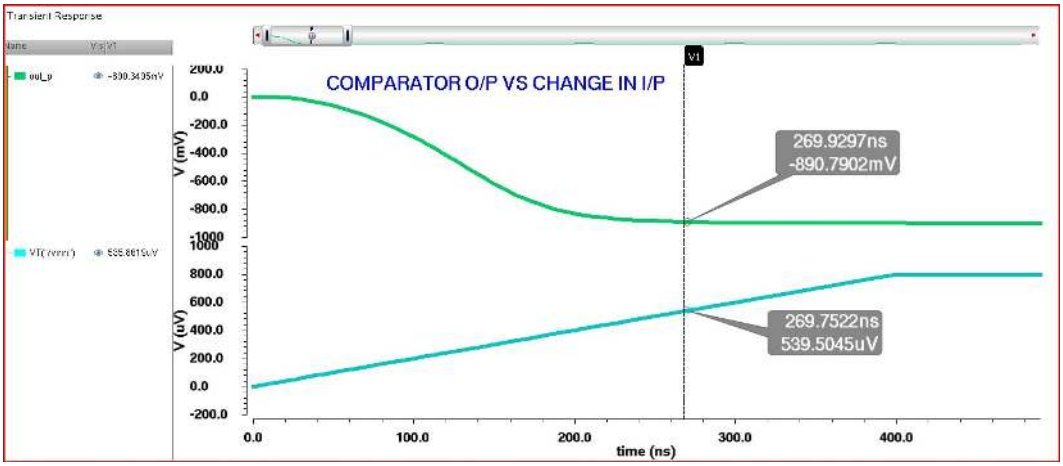

Figure 3.7: Resolution detection of comparator.

3.2.3 Proposed G_m cancellation OTA

G_m cancellation circuits are required for the low frequency operation [8]. Here we propose a novel architecture for a very low bandwidth, high gain structure. The bandwidth of the structure is in mHz range with a unity gain bandwidth of 93Hz with no compromise in open loop gain of the OTA. This structure is achieved by combination of the Gm cancellation by direct coupling in RFC structure instead of routine cross coupling, and gain boosting technique at the cascode node to improve the output resistance.

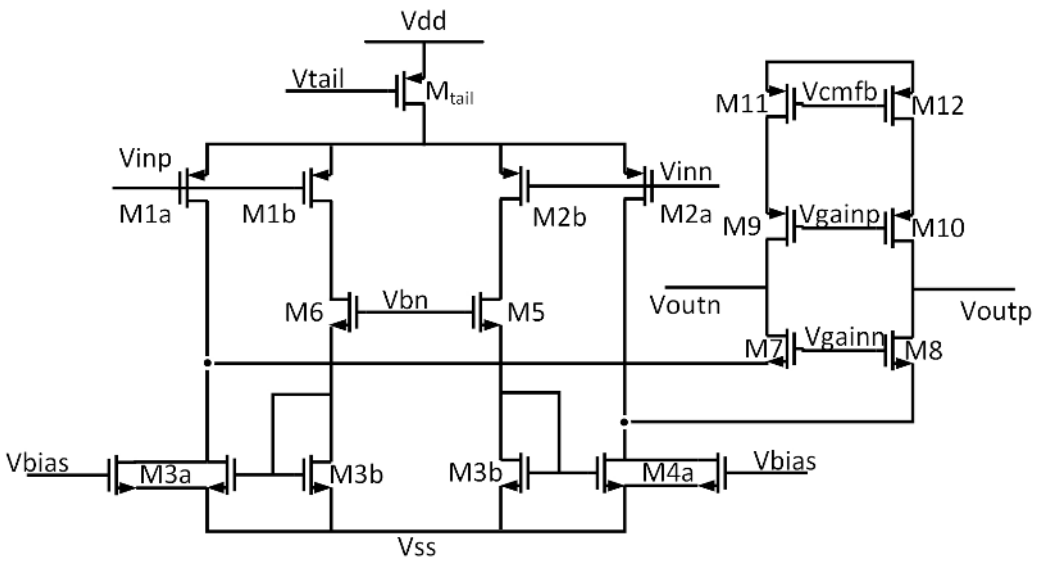

Figure 3.8: G_m cancellation OTA Structure.

3.2.4 Integrator

Above mentioned OTA is used to implement integrator. A G_m-C based integrator produces saw-tooth wave, whose peak corresponds to the phase shift of the two input signals coming from EXOR gate. Depending on the phase difference between the signals, the duty cycle of XOR output will not always be 50%, leading to unequal charging and discharging of the integrator capacitor. Thus in order to produce a symmetrical signal that will not reach the power supplies and saturate, a switch is placed across the capacitor, driven by one of the EXOR outputs, thus synchronously discharging the capacitor at the end of every pulse. In this way a saw tooth wave is generated, the peak of which is proportional to the pulse duration and thus the phase.

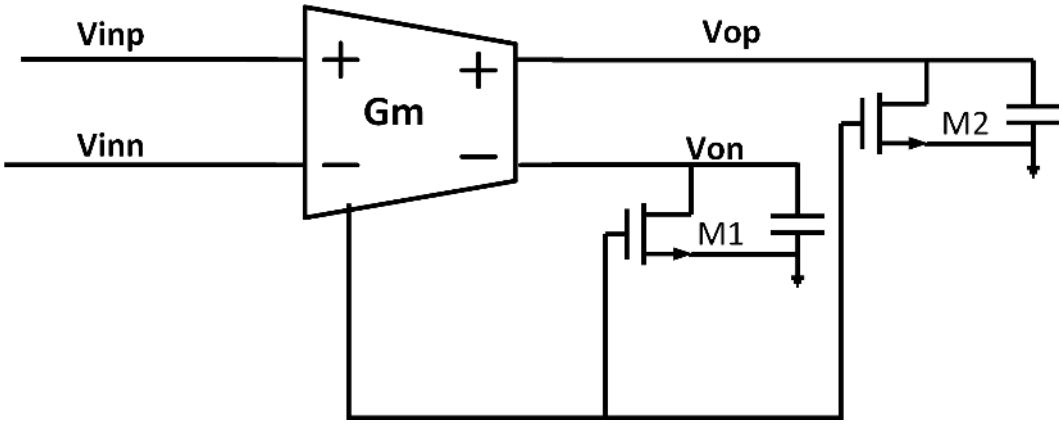

Figure 3.9: Circuit diagram of the integrator.

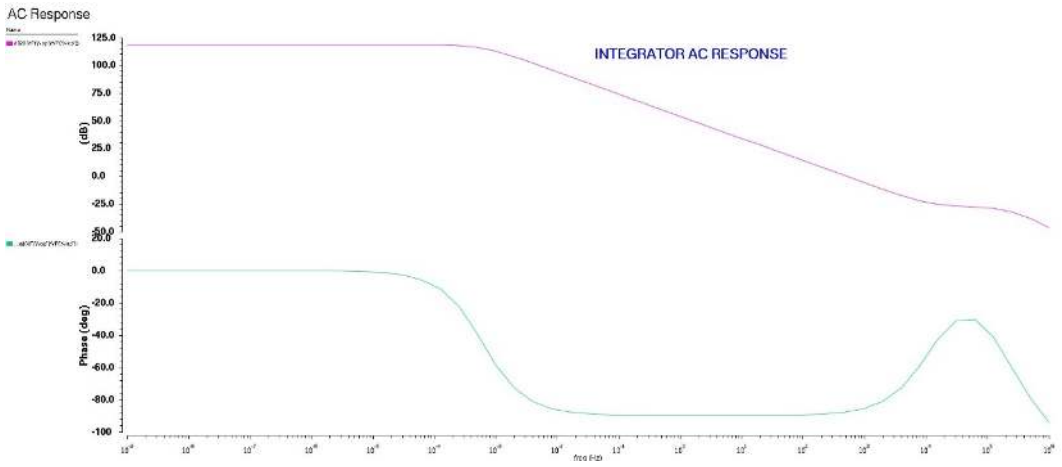

Figure 3.10: Gain and phase plot for Integrator, it is same for G_m cancellation OTA

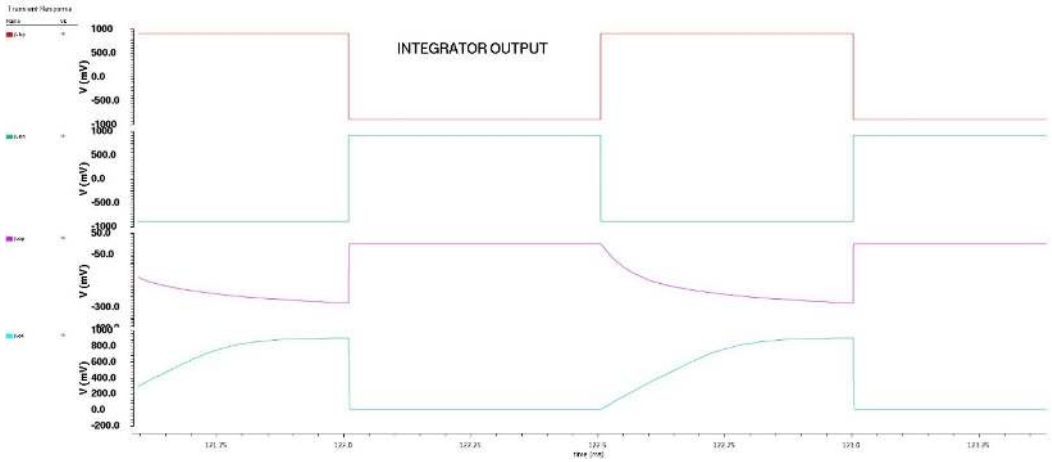

Figure 3.11: Transient Response of Integrator for 1KHz input signal.

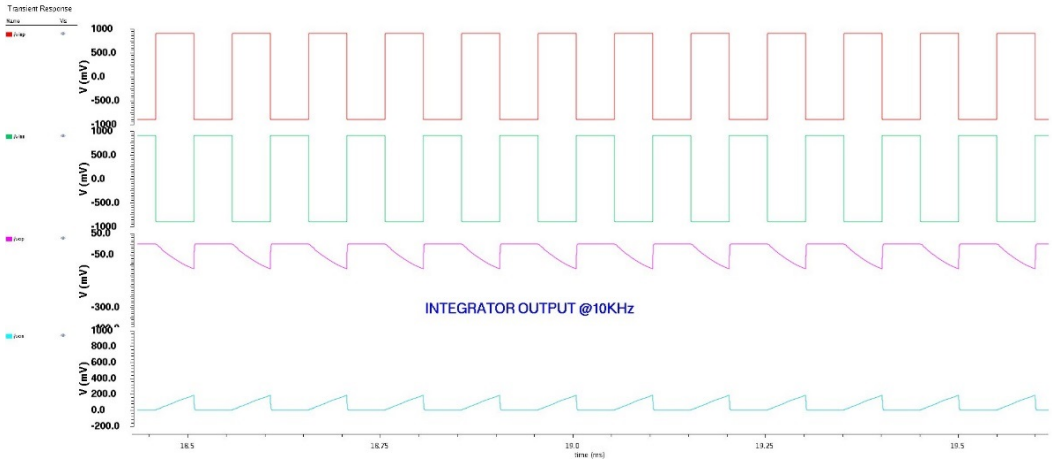

Figure 3.12: Transient Response of Integrator for 10KHz input signal.

3.2.5 Peak detector

This block captures the peak of saw tooth wave generated by Integrator. Output of the peak detector is DC value that corresponds to the phase difference given by the sample. This block is used to sense the DC value of rectified signal coming from switch modulator. After getting the DC value for each of different modulated signal coming from switch modulator, the DC signal is fed to SAR ADC for digitizing and further processing.

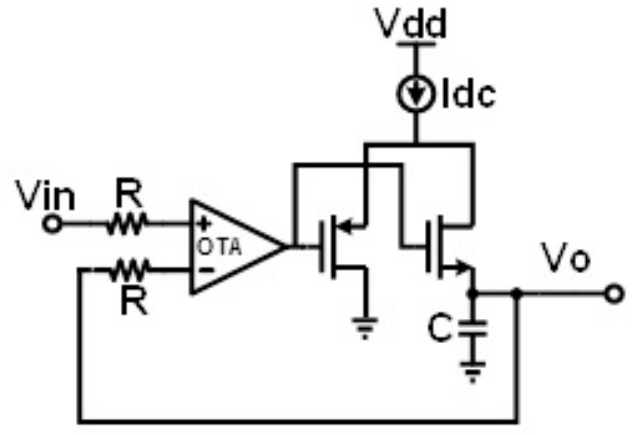

Figure 3.13: Peak Detector Circuit

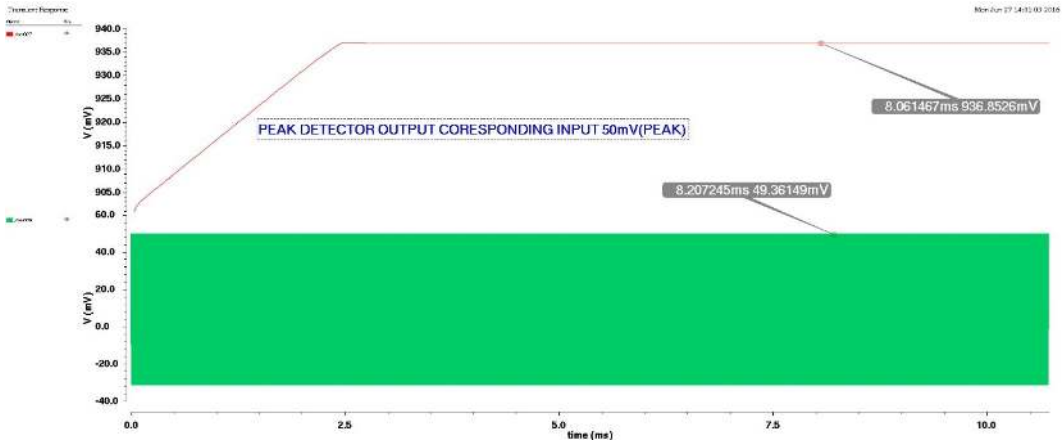

Figure 3.14: Peak detector output for 10mv input

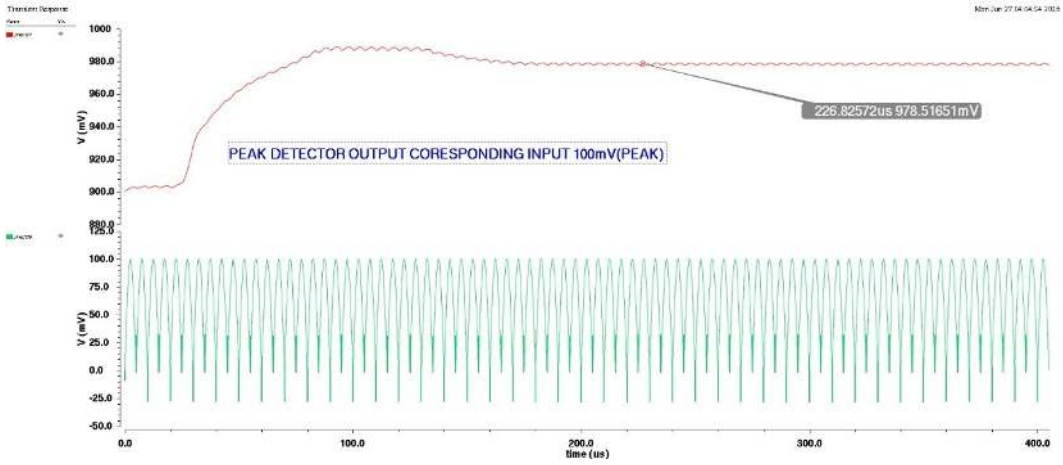

Figure 3.15: Peak detector output for 100mv input

3.2.6 Biquad lowpass filter

A chain of biquads are used to implement a fourth order low pass filter. This type of filter structure gives sharp cut-off frequency as well as gives flexibility of avoiding high resistance. But at the cost of more complex structure and higher power consumption. The block is used as anti-aliasing filter and to remove any ripple/noise at the input of ADC. As seen in fig. 22 the 3-dB cutoff frequency of low pass filter is found to be 26Hz.

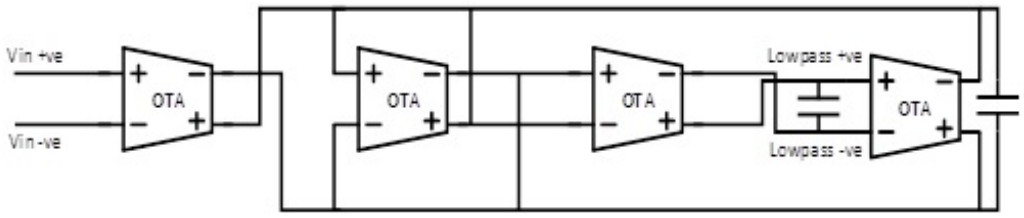

Figure 3.16: Circuit diagram of the integrator.

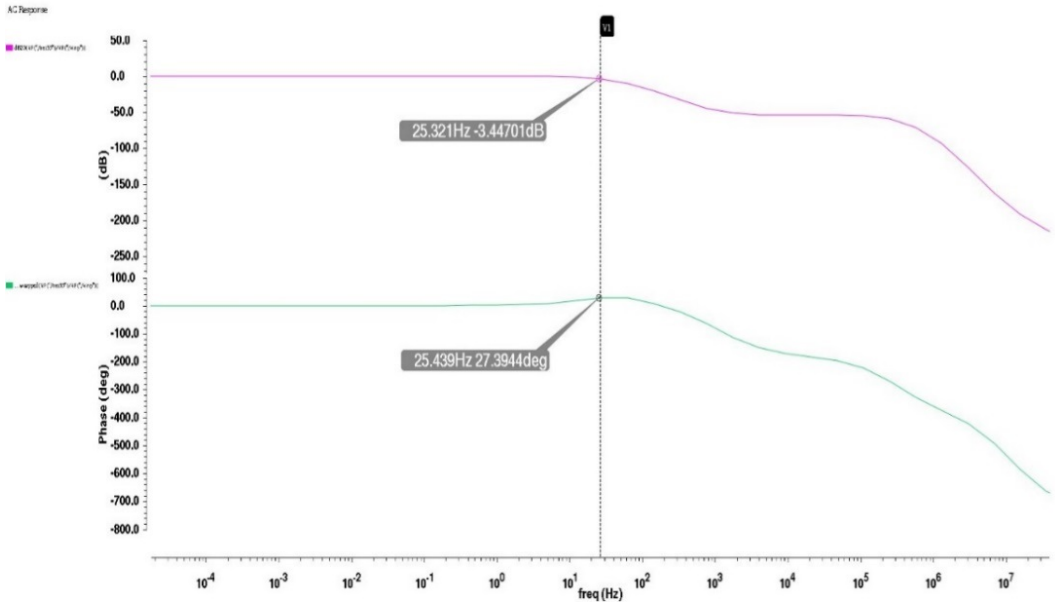

Figure 3.17: Circuit diagram of the integrator.

Chapter 4

Conclusion and Future Scope

4.1 Conclusion

Thus impedance of the pure cow milk is characterized, and is found out to be in the range of 615640 ohms. This property of milk is one that is affected by large number of adulterants, and hence can be used to mark the adulterated milk in real time environment. But with characterization of milk with more than one adulterant it is concluded that with proper selection of adulterants and their amount it is possible to nullify the effect on the impedance of the milk.

A sensing circuit is also designed for the same in UMC 180nm technology in cadence virtuoso. The circuit is low power, and can be used onsite in a handheld portable platform. Some of the specifications of the circuit blocks are mentioned in the Table 4.1.

Table 4.1: Circuit specifications

Parameters	**Value**
Current of OTA	250uA
Current of CMFB	50 nA
Supply voltage	-900m to +900mV
Technology	180 nm
Noise	8.78 V
OTA open loop gain	105 dB
Differential gain	20 dB
Common mode gain @60Hz	-50.975 dB
Common mode gain @250Hz	-41dB
High pass cutoff	30 mHz

4.2 Future Scope

The proposed work in this thesis can be further carried out as follows:

- To have a ADC at the output, complete the full layout, and get the circuit for the system.
- Integrate the system fully, and test in a real time environment.
- To get more than 1 marker to get the milk adulteration, since single marker can be made to nullify, as the number of markers increases it becomes more difficult to do the same. Microwave property of milk, and pH of the milk along with its impedance can act as strong set of markers.

Fig. 4.1 show a proposed architecture for future works.

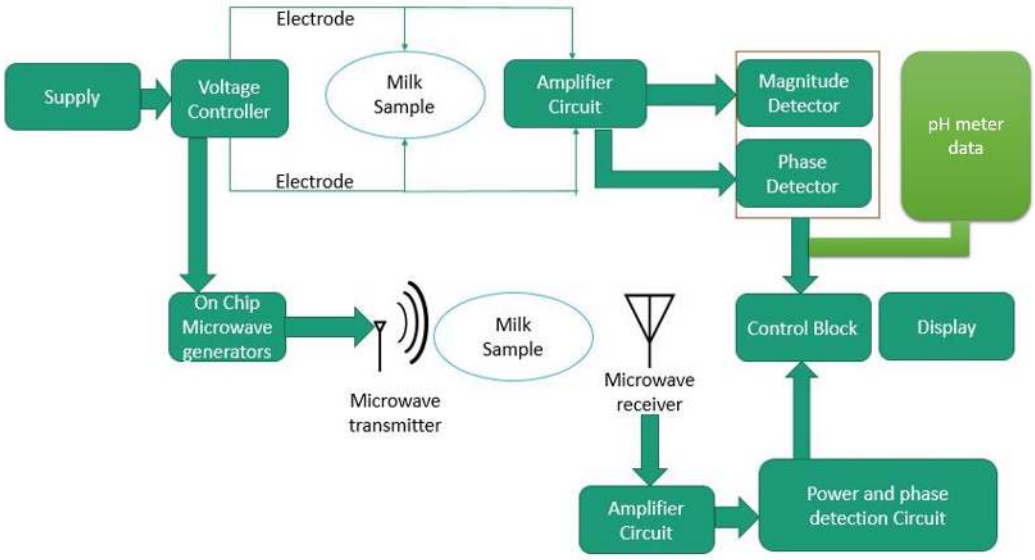

Figure 4.1: Proposed system architecture

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