International Conference on Innovative Trends in Electronics Communication and Applications 2015 [ICIECA 2015]

ISBN	978-81-929742-6-2
Website	icieca.in
Received	02 - April - 2015
Article ID	ICIECA002

VOL	01
eMail	icieca@asdf.res.in
Accepted	15 - November - 2015
eAID	ICIECA.2015.002

RF Based Online Food Quality Analyser

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Abstract: *Quality of food is determined in terms of food texture, taste and appearance but moisture content (MC) of food is a determination factor of quality & stability of the processed food. Determination of MC in the food product is important economically to big food industries as MC in different food products is measured at various stages of processing and storage. Many techniques have been developed to measure the MC of different food products. Impedance spectroscopy has several advantages over conventional moisture measurement methods and can be used for online moisture measurement. This paper presents the impedance spectroscopy to determine MC of grain samples and reviews the importance of Auto Balancing Bridge (ABB) Circuitry in impedance measurement for moisture analysis. Furthermore, wireless module is also been incorporated for online assessment of MC.*

Keywords: Impedance spectroscopy, Auto balancing bridge method, moisture content, food quality

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) gauges that 32 percent of all food delivered on the planet was lost or squandered in 2009. This evaluation is taking into account weight. At the point when changed over into calories, worldwide food misfortune and waste adds up to pretty nearly 24 percent of all nourishment delivered. Basically, one out of each four food calories proposed for individuals is not consumed by them.

Food loss and waste have many negative economic and environmental impacts. Economically, they represent a wasted investment that can reduce farmer's incomes and increase consumer's expenses. Environmentally, food loss and waste inflict a host of impacts, including unnecessary greenhouse gas emissions and inefficiently used water and land, which in turn can lead to diminished natural eco systems and the services they provide.

Quality of the food is determined in terms of food texture, taste and appearance but moisture content of the food is the prime determination factor of quality & stability of the processed food. Moisture content of the food material is important to consider whether the food is suitable before its consumption because moisture content affects the physical and chemical aspect of food which relates with the freshness and the stability for the storage of food for a long period of time. It is vital in deciding the best possible time for harvest and the potential for safe storage. It is also an important factor in determining the market price, because the dry matter of grain has more value than the water it contains and because costs of drying for safe storage must be taken into account. In the processing of grain for flour, other food products, and animal feeds, moisture content of the materials is important information for efficient processing, achieving desired behavior of the materials, and in obtaining high-quality products.

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Standard methods for determining moisture in grain require oven drying for specific time periods at specified temperatures by prescribed methods. Because such methods are tedious, time consuming, and expensive, they are not suitable for general use in the grain trade, and hence other rapid testing methods have been developed. Most of the modern practical grain moisture testers work on the principle of sensing electrical characteristics of the grain, which are highly correlated with moisture content.

As in [1] the author presented a portable electronic instrument that measures the complex impedance of a parallel plate capacitor with a sample of peanut kernels between its plates. The author used the measured values in empirical equation to estimate the moisture content of the sample which were in good agreement with the values obtained through the standard air oven method. For a similar purpose an impedance analyzer has also been designed [2] that too determines the moisture content in peanuts. These values obtained by the presented design in [2] were also in agreement with the standard air oven method. Similar techniques are presented in [3] where the author presents a low cost instrument to measure the impedance and phase angle along with a parallel plate capacitance system to determine the moisture content in yellow corn. This impedance spectroscopy is highly used in real time applications in measuring moisture content in various packaged food products. Like in cookie dough as in [4] where the author conducted experiments with concentric ring dielectric sensor in frequency range from 10 Hz to 10 KHz. The author calibrated the system with a linear model in which the dependence of capacitance and moisture content is determined. These methods as presented in [2] and [3] are non-destructive methods that provide rapid results and have considerable applications both in drying and storage processes of corn and grain and peanuts products.

Impedance spectroscopy also finds application in paper industry. The fringing field impedance spectroscopy is used in estimating the moisture content in paper pulp. This technique is able to measure moisture concentration in paper pulp at levels as high as 96%. The fringing field impedance method proposed in [6] uses single sided measurements and offers high sensitivity and unlike other methods doesn't require special operating conditions. The problem with all the reported research is that MC of samples highly influence by density, shape of the kernels and air gap between the capacitor plates. This problem can be solved by multi frequency approach. The multi frequency model of impedance spectroscopy is developed for moisture content measurement. This paper presents significance of ABB circuitry in overall design.

METHODOLOGY

Basic Principle

The basic principle behind the impedance spectroscopy is that the dielectric constant of the food sample varies with the moisture content present in it. This principle holds good especially at the lower Radio Frequencies (RF). Hence the variation of the dielectric constant at these frequencies is measured using a portable impedance analyzer and a predictive equation is generated from which the MC of the sample is calculated effectively. Here, we are using ABB for impedance measurement. The ABB method is commonly used in modern LF impedance measurement instruments. Its operational frequency range has been extended up to 110 MHz [10]. The comparison of ABB with other methods is shown in Figure 1[11].

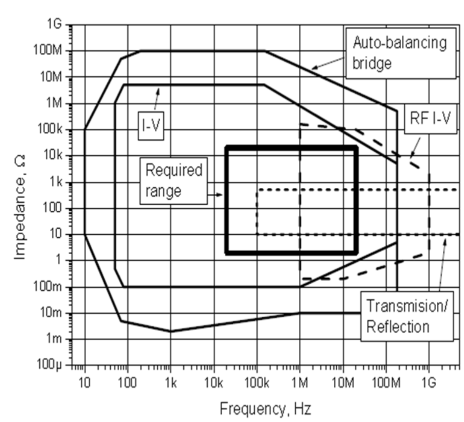

Fig 1. Impedance Measurement Method Characterization

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Impedance Spectroscopy

Impedance spectroscopy measures dielectric properties of a medium as a function of frequency. The increase in the dielectric constant with MC is found to be more pronounced at the lower frequencies. Hence the variation of the dielectric constant at these frequencies is a useful parameter in estimating the MC. The capacitance of a material is found at two different frequencies. The difference between the two measured capacitances gives a good estimate of the MC, but it gets highly influenced by the size and shape of the sample. Hence two other electrical parameters, which are the dissipation factor D and phase angle θ, are also measured at the two frequencies. Finally combining the values of C, θ, and D at the two frequencies, a predictive equation is generated from which the density independent MC of the sample is calculated effectively. ABB circuitary is crucial in this setup due to high frequency limitation of operational amplifier.

ABB Method

The ABB employs the inverting topology operational amplifier. Basically, in order to measure the complex impedance of the DUT it is necessary to measure the voltage of the test signal applied to the DUT and the current that flows through it. Accordingly, the complex impedance of the DUT can be measured with a measurement circuit consisting of a signal source, a voltmeter, and an ammeter as shown in Figure 2(a). The voltmeter and ammeter measure the vectors (magnitude and phase angle) of the signal voltage and current, respectively.

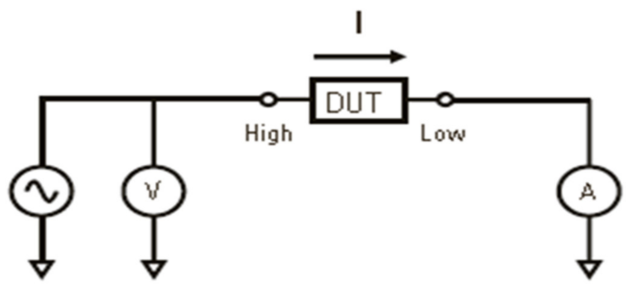

Fig 2(a). The simplest model for impedance measurement

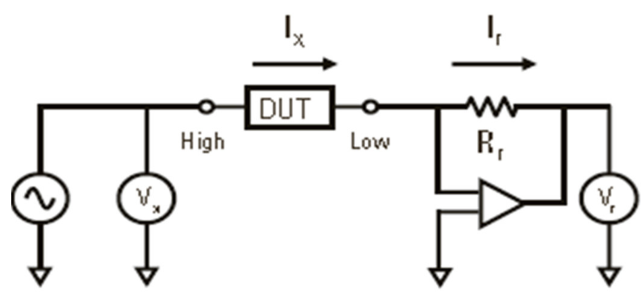

Fig 2(b). Impedance measurement using operational amplifier

The test signal current (Ix) flows through the DUT and also flows into the I-V converter. The operational amplifier of the I-V converter makes the same current as Ix flow through the resistor (Rr) on the negative feedback loop. Since the feedback current (Ir) is equal to the input current (Ix) flows through the Rr and the potential at the Low terminal is automatically driven to zero volts. Thus, it is called virtual ground. The I-V converter output voltage (Vr) is represented by the following equation:

$$V_r = I_r . R_r = I_x . R_r \qquad (2\text{-}1)$$

Ix is determined by the impedance (Zx) of the DUT and the voltage Vx across the DUT as follows:

$$I_x = \frac{V_x}{Z_x} \qquad (2\text{-}2)$$

From the equations 2-1 and 2-2, the equation for impedance (Zx) of the DUT is derived as follows:

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$$Z_x = \frac{V_x}{I_x} = R_{r.} \frac{V_x}{Z_x} \qquad (2\text{-}3)$$

The vector voltages Vx and Vr are measured with the vector voltmeters as shown in Figure 2(b).Since the value of Rr is known, the complex impedance Zx of the DUT can be calculated by using equation 2-3. The Rr is called the range resistor and is the key circuit element, which determines the impedance measurement range. The Rr value is selected from several range resistors depending on the Zx of the DUT. The operational amplifier also plays significant role in ABB. The reference resistor Rr and operational amplifier are chosen by performing ABB simulation in TINA Pro Software. For determining impedance magnitude and phase range we have used Agilent 4396B network/spectrum/impedance analyzer with 43961A Impedance test kit and 16092A spring clip fixture. The experimental setup for impedance measurement is shown in fig. 3

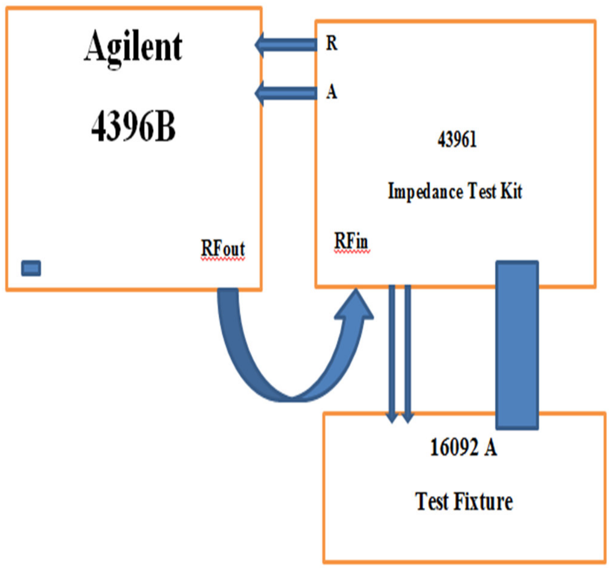

Fig.3 Impedance Measurement Setup

PROPOSED SYSTEM DESIGN

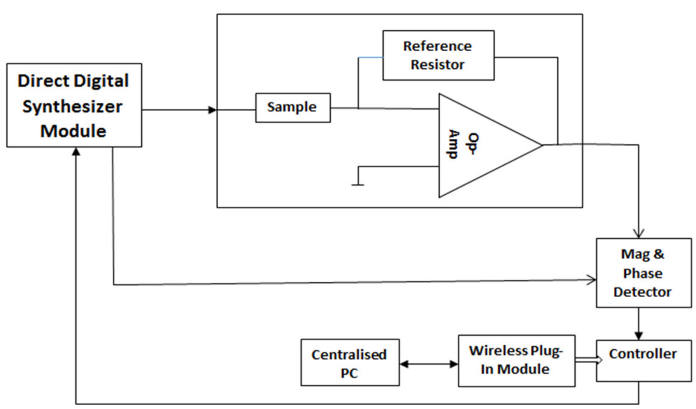

Fig 4. Basic block diagram of proposed module

The DDS module (AD9958) will generate multi frequency RF output based on 32-bit frequency word, which can be load into AD9958 from PIC controller (PIC32MX360F512L). The AD9958 will give 2V analog signal at different frequency, which will apply to ABB circuitry and Gain-Phase detector (AD8302). The op-amp and reference resistor will play important role in ABB arrangement. The op-amp and reference resistor are selected based on simulation result obtained by TINA 7. The output of ABB is measured

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voltage, which is second input of AD8302. The AD8302 will directly gives voltage ratio and phase difference of applied signal. From these voltage and phase we can compute the impedance of the sample, which can be calibrated further into moisture content. As discussed earlier we are doing multi frequency measurement to nullify the effect of density of the sample, air gap of the parallel plate assembly. Here, we will use Bluetooth plug-in module to provide wireless connectivity.

Results

We have prepared some samples in increment of 2% moisture content ranging from 13% to 29% by following proper procedure. For deciding impedance range we have measured the impedance of lowest and highest moisture sample at two different frequencies. Here, magnitude and phase are are measured using agilent 4396b network/spectrum/impedance analyzer with 43961a impedance test kit and 16092a spring clip fixture. The results obtained are shown in fig5and fig6.

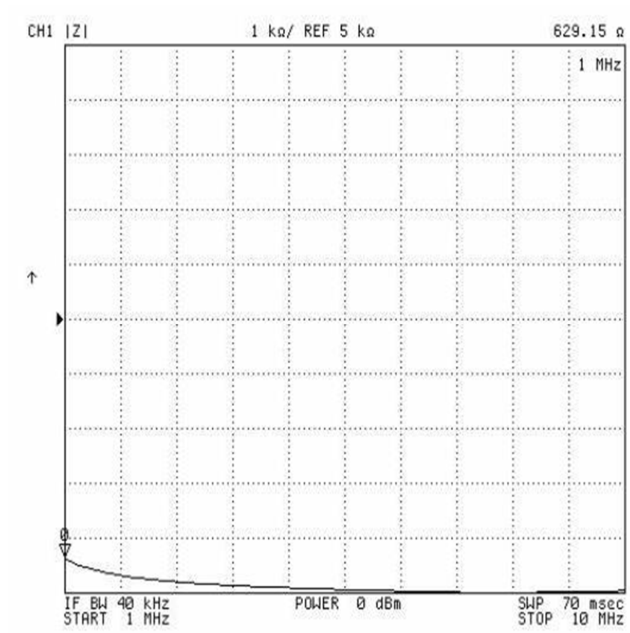

Fig 5a. Impedance mag of 13% sample @1 MHz

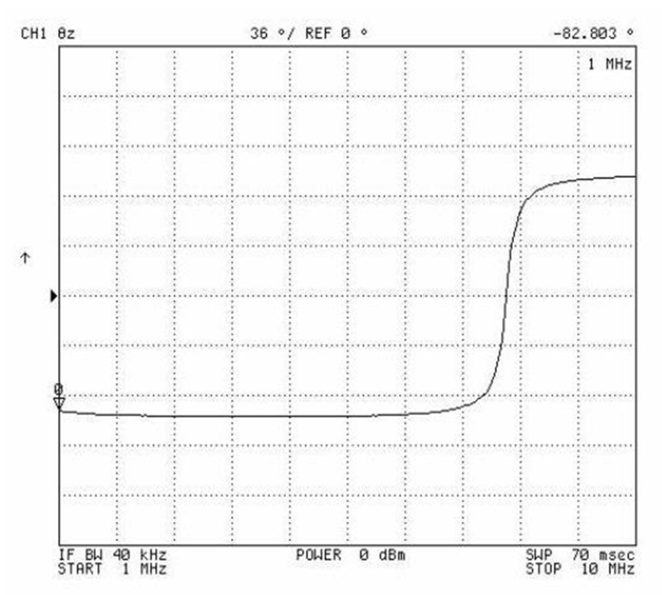

Fig 5b. Impedance phase of 13% sample @1 MHz

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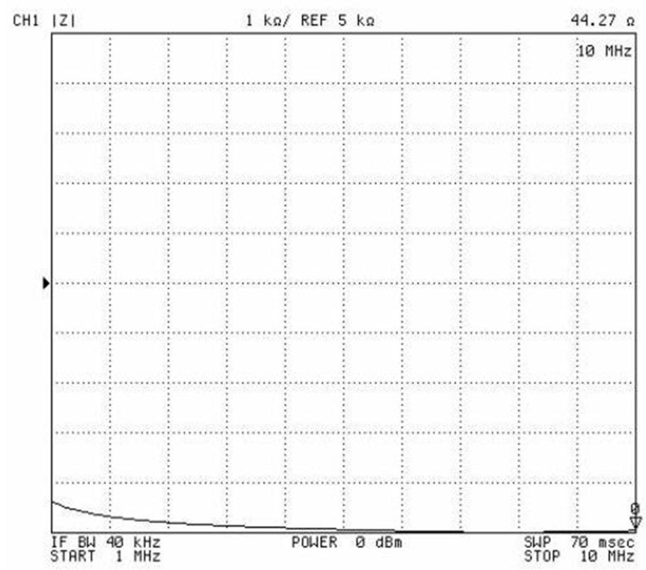

Fig 5c. Impedance mag of 13% sample @10 MHz

Fig 5d. Impedance phase of 13% sample @5 MHz

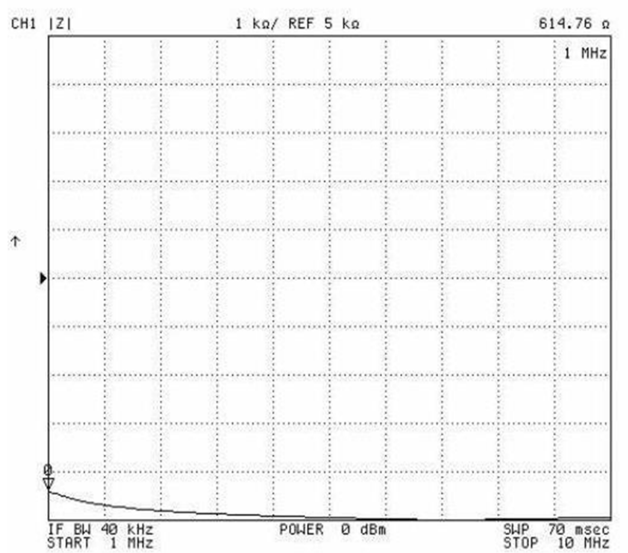

Fig 6a. Impedance mag of 29% sample @1 MHz

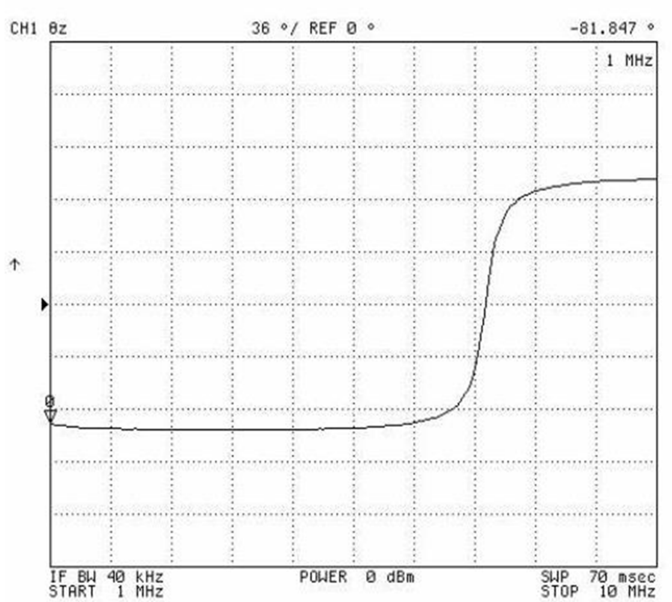

Fig 6b. Impedance phase of 29% sample @1 MHz

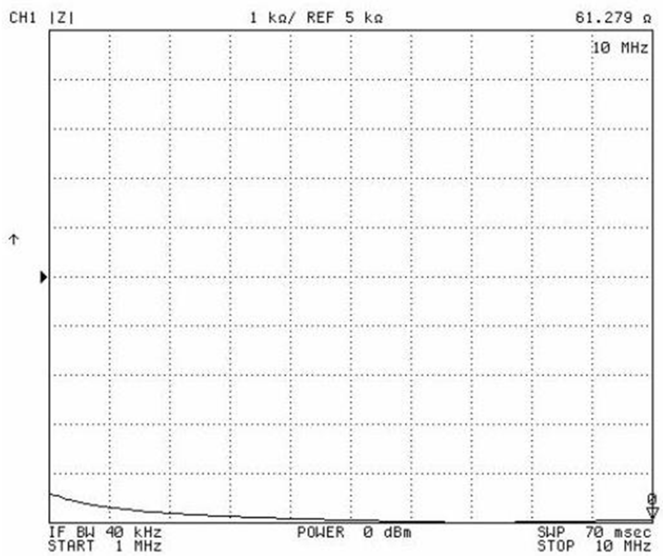

Fig 6c. Impedance mag of 29% sample @10 MHz

Fig 6d. Impedance phase of 29% sample @10 MHz

So, here we get the impedance magnitude range from 44 to 630 Ω and phase angle range from -82 deg to +86 deg. Now, we have simulated ABB circuit in TINA 7 as shown in fig 7. using different operational amplifier.

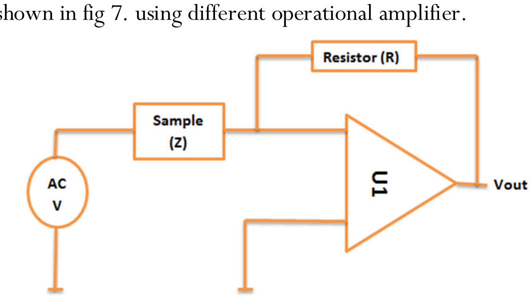

Fig 7. Basic schematic for ABB Circuit

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Here, we have used 2V ac power supply with frequency ranging from 1MHz to 10MHz. For sample we have taken different lowest and highest values of magnitude and phase. Here, U1 is operational amplifier. Table 1 shows different output voltage at different frequencies. But, we got best result with OPA657 at higher frequencies. Fig.8 shows how OPA 657 gives better spur free output signal than other operational amplifiers. So, we are using OPA657 with operating voltage ±6.5V and reference resistor value 5Ω. So, we get output voltage in terms of mV, which is as per our requirement.

U1	Supply Voltage	Frequency	Vout
AD8001	±5V	1-10 MHz	1.78 V rms to 1.91 V rms
LM318	±6V	1-10 MHz	370.02 mV rms to 1.51 V rms
OPA657	±6.5 V	1-10 MHz	308.77 mV rms to 458.77 mV rms
LTC1052/101	±6.5 V	1-10 MHz	2.34 V rms

Table 1. Op-amp comparison at different frequencies

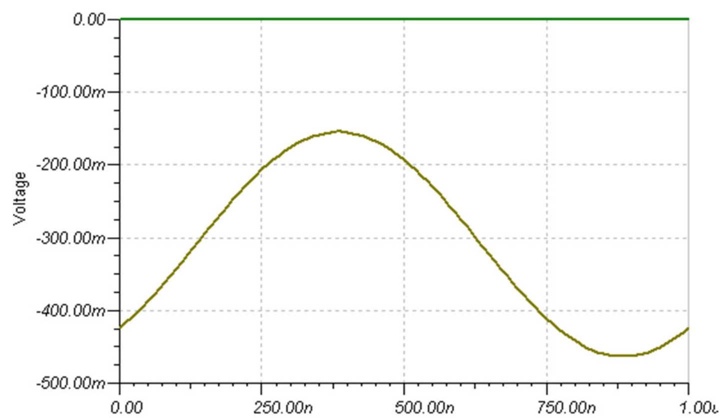

Fig 8a. Vout @1 MHz with OPA657

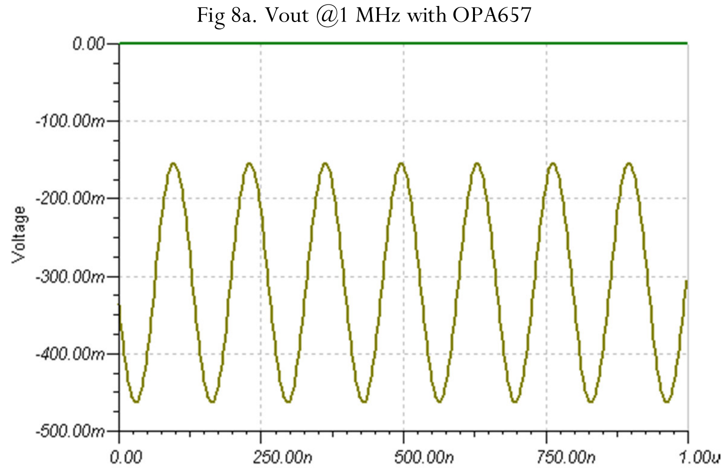

Fig 8b. Vout @10 MHz with OPA657

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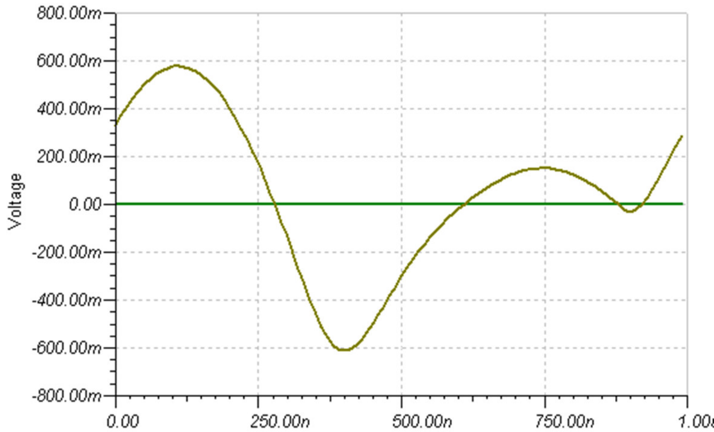

Fig 8c. Vout @1 MHz with LM318

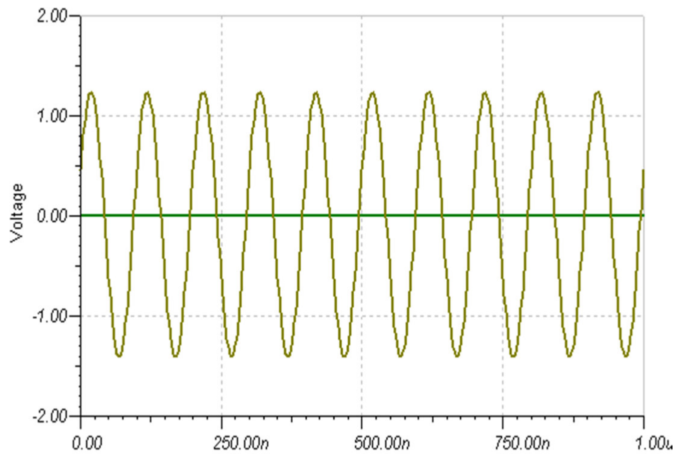

Fig 8d. Vout @10 MHz with LM318

ACKNOWLEDGMENT

Authors are thankful to Director, CSIR-CSIO, Chandigarh for his support and permission to carry out this work.

CONCLUSION

The existence of high correlation between the dielectric properties of grain and amount of water present in the grain at radio frequencies has facilitated the rapid and non-destructive sensing of moisture content. At lower radio frequencies, density-independent moisture content determination is achievable with multiple-frequency measurement. Due to operational amplifier's limitations at high frequencies ABB circuit is very crucial in the proposed circuit. So, we have simulate ABB circuit in TINA & using different operational amplifier and found that OPA657 is best suited for our application as it has very high Gain-BW product 1.66 GHz.

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