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A Simplified and Portable Capacitance Sensor to Measure Moisture Content of Paddy

Divya NATHK [1], Prabhu RAMANATHAN [2,*]

[1,2] *School of Electrical Engineering, Vellore Institute of Technology, Vellore, India. 632014*

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Abstract

The moisture content in agricultural products will affect the quality. Fungi development happens if the moisture content is not optimum. This paper presents a non – destructive, simple, fast and low cost interface circuit to measure the moisture content of paddy grains heated in different temperature. The arrangement used is a high precision impedance converter. Ceramic capacitors of different values were used to check the measuring circuit. Using this circuit, moisture content of representative standard samples was measured and dielectric constant was calculated. The paper discusses the principle, technique, methodology and experimental set up used and the results obtained.

1. INTRODUCTION

The main source of income in India is agriculture. For storage of agricultural products like paddy, nuts or any type of grains the moisture content [MC] is an important factor. The moisture content in food grains should be known by the farmers for its processing and storage else fungi affect the grains [1]. During the time of harvesting, the water content in grains will be approximately 20% - 40%, which has to be reduced to 10% -13% for storing, processing and trading [2].

The direct or indirect method can be used to measure the moisture content. In direct technique moisture content is calculated using the standard equation (1)

$$\text{Dry basis \% MC} = \frac{(\text{Wet weight of sample} - \text{Dry weight of Sample})}{\text{Dry weight of sample}} \qquad (1)$$

Time consumption and complexity are more for this process, as the water content of samples has to be removed completely. In the indirect technique any of the physical property having relation with moisture is measured and moisture content is calculated. For example the resistance of the grain as a physical property which has the relation with moisture, the moisture content will be less as the resistance increases. Moisture content can be measured either by destructive or non-destructive way. In destructive method samples are cleaned and shells are removed, where as in non-destructive method samples can be directly used so that the time and labour cost can be reduced.

The moisture measurement was initially calculated using time consuming capacitive type moisture meters. Later the electrical grain moisture meters were developed [3- 6]. In electric resistance method when current is passed through the samples (soil & wheat) whose MC have to be measured, got cracked

*Corresponding author, e-mail: ishupa@gmail.com

and the samples were wasted. The advantage of this technique was its low cost [7- 10]. With the concept of dielectric property, grain moisture meter was developed. Rice and barley were tested. At high frequency calibration variation happens due to ionic conduction and in low frequency variation in calibration is not accountable. So microwave signals with moisture density and attenuation at 10.5 GHz was used to measure the MC [8]. The double capacitor cell with immersion method as the principle the dielectric constant of twelve grains like rice, soybean, wheat, linseed, paddy, mustard in the frequency range 200 Hz to 2 KHz were measured [11]. The electrical spectroscopy was used to measure the moisture content of tea leaves. The electrical properties, the capacitance and impedance were measured for the range of frequency from 10 Hz to 1 MHz [12]. By measuring the magnetic strength produced by samples, moisture content was measured [13]. It is clear that at any designed frequency the moisture content can be obtained accurately and the disadvantage was that only few quantity of samples were used at a time to measure moisture content. Moisture content was measured for different types of wheat, nuts, grains, in-shell peanut, wood chips, dry cherries by Kandala. Initially RF impedance method was used to measure the moisture content [2, 14]. Later he developed CI (Chari Impedance) meter and calculated impedance and phase angle from the observed values em_1, er_1, and ep_1 where er_1 is the actual input voltage, em_1 is the output voltage after passing through samples, ep_1 is the output voltage of phase detector. The impedance and phase angle were substituted in empirical formula and moisture content was calculated [1, 15-18]. With the same experiment and with slightly modified empirical formula oil content in peanut kernels was also measured at three different frequencies and compared with Soxhlet result [19]. By using electrical or magnetic properties of food grains many indirect and non-destructive techniques for analyzing moisture content have been developed over last few decades. Most of the techniques developed to calculate content of moisture were complex and time consuming and can use only for few grams as samples. The comparative study were done [20-22].

In this paper a novel technique is been used to measure the moisture content. The moisture meter was developed by designing an integrated circuit interfaced with PC. The capacitance of paddy was measured using the circuit which helped to calculate dielectric constant of the grains. Larger the value of relative permittivity, the moisture content is more but the increase is not uniform for all the food commodities. Since this method is a non-destructive technique, labour required is less to clean and crush. The method developed is very simple to measure the moisture content, requires less time and it is very economic. Large quantity of samples can be used to measure moisture content at a time.

2. METHODOLOGY

2.1. Calibration and Testing

Moisture meter is an impedance converter integrated circuit in which frequency sweep can be done. The maximum range of impedance, Zmax or maximum reactance is calculated for the capacitor value of 2 pF. The minimum range of impedance, Zmin or minimum reactance is for capacitor value of 100 pF. Assuming capacitance of paddy can be varied from 2 to 80 pF.

Initially, calibration of the meter was done with feedback resistor and calculated resistor which are obtained using the equation (2) and (3). For the values of resistors R_{fb} and R_{cal} the frequency sweep can be done efficiently with the help of the circuit in Figure 1.

$$R_{fb} = \frac{(\frac{V_{DD}}{2} - 0.2)Z_{min}}{V_{pk} + \frac{V_{DD}}{2} - V_{DC\,offset}} \times \frac{1}{gain} \tag{2}$$

$V_{DD} = 3.2\,V \text{ and } V_{PK} = V_{p-p} = 1V$

V_{DD} is the biasing voltage and V_{PK} is the peak voltage.

Setting of V_{P-P} and gain is done in the display screen of user interface.

$R_{fb} = 82893.34\Omega \approx 10K\,\Omega$

$$R_{cal} = \frac{Z_{max}+Z_{min}}{3} \quad (3)$$

$R_{cal} = 906298.9667\Omega \approx 1\text{M}\,\Omega.$

After calibration, calculated resistor is replaced by ceramic capacitor of values 27 pF, 10 pF, and 2.2 pF. The AD5933 is an impedance converter IC and frequency sweep can be done. In the experiment the frequencies swept were from 20 kHz to 50 kHz as the circuits were designed to this frequency range. The impedances were measured and noted ten such readings and tabulated in Table 1[23].The voltage divider resistors, R = 50KΩ, R1 =20KΩ and capacitance, C = 47nF. The operational amplifier used is CMOS.

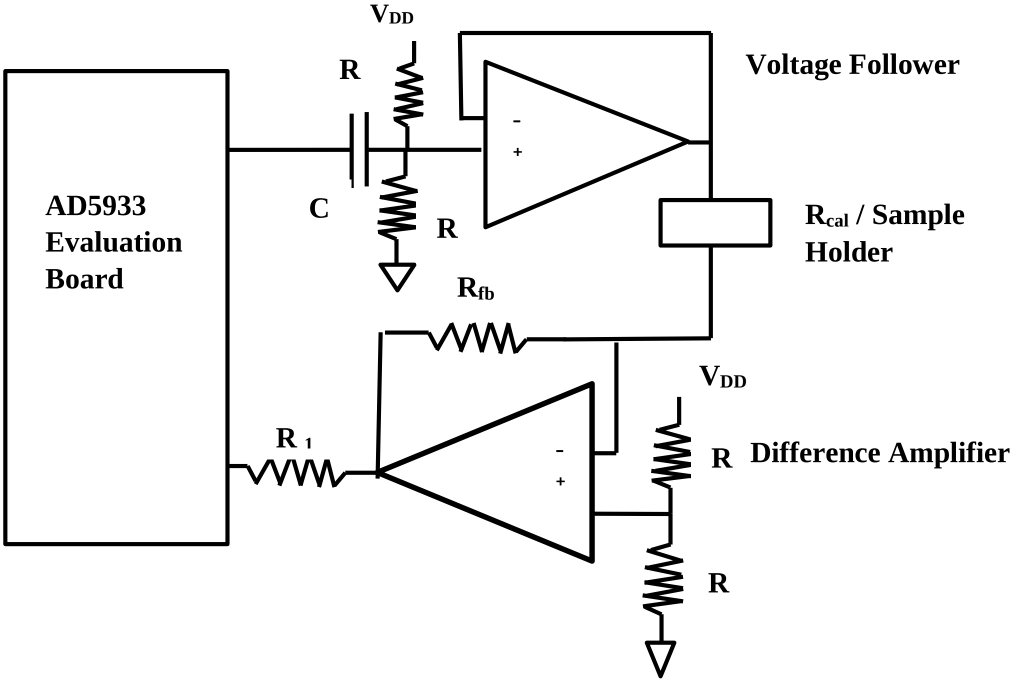

Figure 1.*Circuit Diagram to measure the capacitance value*

Table 1.*Readings of Different Ceramic Capacitor Values*

	Actual Ceramic Capacitor of value 10 pF		Actual Ceramic Capacitor of value 27 pF		Actual Ceramic Capacitor of value 2.2 pF	
Frequency (KHz)	Impedance (Ω)	Obtained Capacitor Value (pF)	Impedance (Ω)	Obtained Capacitor Value (pF)	Impedance (Ω)	Obtained Capacitor Value (pF)
20	788778.0000	10.094	294536.1517	27.032	3770371.289	2.112
25	630187.5000	10.107	235947.5146	26.995	3173762.418	2.007
30	523933.7500	10.131	196160.0524	27.059	2377408.276	2.233
32	490632.5000	10.140	184228.2159	27.011	2397472.487	2.076
33	476485.5000	10.127	178519.9669	27.030	2291167.038	2.106
35	449098.2500	10.131	168341.2468	27.026	2143467.929	2.123
40	392731.5313	10.136	146917.5165	27.096	1921806.289	2.071
45	348667.5313	10.149	130946.1319	27.023	1770249.45	1.999

49	320546.0938	10.138	120547.5028	26.958	1600461.407	2.030
50	314835.2188	10.116	117846.2856	27.024	1541528.551	2.066

Using the readings tabulated in the Table 1, graph was plotted for different frequencies versus different ceramic capacitor values and are shown in Figure 2. The graph clearly indicates that capacitor value remains almost constant for different frequencies from 20 KHz to 50 KHz. From the value of impedance obtained, capacitor values were calculated using the equation (4) and (5).

$$X_c = \frac{1}{2\pi f\, C} \quad (4)$$

and $$C = \frac{1}{2\pi f\, X_c} \quad (5)$$

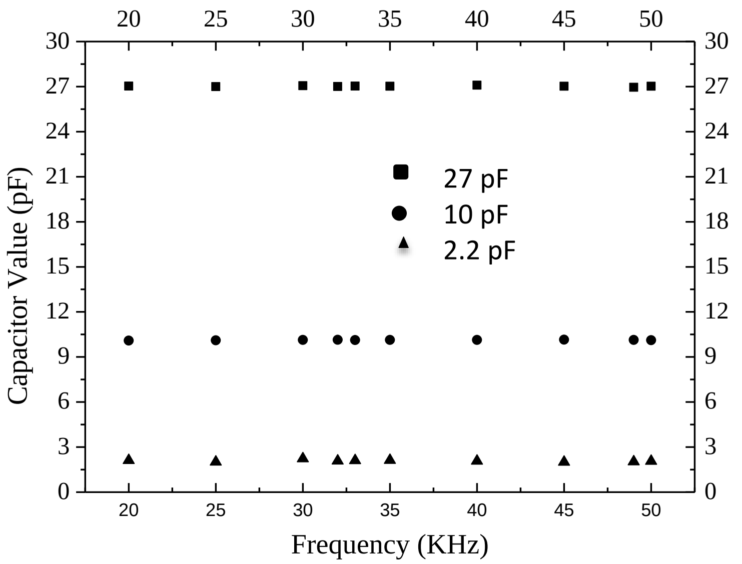

Figure 2.*The graph between different ceramic capacitor value and frequency*

2.2. Parallel Plate Sensor

To measure the moisture content of paddy, sample holder is required to place the samples. The parallel plate technique to measure the capacitance is relatively simple and accurate. The sample holder is made up of glass of 5 mm and copper plates of 2 mm thickness.

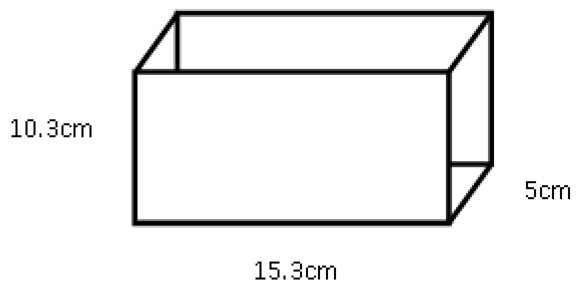

Figure 3*.Parallel plate Sensor*

The copper plates of size 10.3 cm long and 15.3 cm wide are the two parallel plate electrodes of the sample holder. The base of the sample holder is of the size 5 cm × 15.3 cm. The distance between two parallel plate electrodes is 5 cm. The parallel plate sensor/ sample holder is shown Figure 3.

The capacitance of parallel plate sensor was calculated using the formula (6).

$$C = \frac{\varepsilon_0 \varepsilon_{r1} A}{d} = \frac{8.854\times10^{-12}\times1\times0.103\times0.153}{0.05} = 2.79\text{pF} \quad (6)$$

3. SAMPLE PREPARATION

Paddy being the most important crop in Kerala, India. The samples used are paddy named Jaya, harvested during April 2015 and collected from the Palakkad district of Kerala state, India. The collected samples were dried and packed. From the dried paddy representative amount of samples were taken to conduct the experiment.

The representative amount of samples was placed in sample holder and capacitive value was measured for the frequency of 30.1 KHz using the arrangement as in Figure 4. The Arrangement consists of a PC, evaluation board, bread broad, parallel plate sensor and an electronic balance. The samples were heated using conventional microwave oven with different temperature as set points (Example 40ºC, 100ºC, 120ºC, till 180ºC) for a fixed time of 10 minutes. For each temperature, the circuit was tested for the range of frequencies from 10 KHz to 1 MHz and found the ceramic capacitor value constant. So the circuit was set for the range of 20 KHz to 50 KHz. 30.1 KHz is the frequency which is in this range and capacitive value were measured at this fixed frequency using the same arrangement as in Figure 4 and tabulated in Table 2.

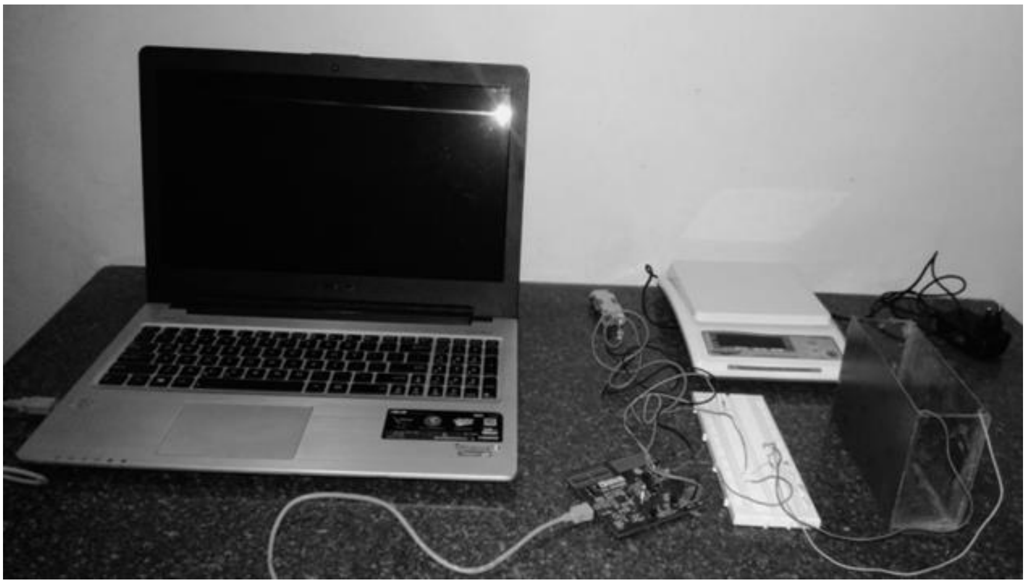

Figure 4.*The arrangement to measure the moisture content of paddy. 1. Personal Computer 2. Bread-Board 3. Evaluation Board 4. Parallel Plate Sensor 5. Electronic Balance*

Moisture of paddy was completely removed and the sample and its capacitive value was also measured. The capacitance value of dry sample obtained is 14.658pF.The predicted % moisture content is obtained by the formula 7.

$$\%\ \text{MC} = \frac{(\text{Capacitive value of wet sample} - \text{Capacitive value of dry Sample})}{\text{Capacitive value of wet sample}} \quad (7)$$

Table 2.*Capacitance value of paddy heated at different temperature for 10 minutes using microwave oven at the frequency of 30.1 KHz*

Sl . N	Temperature (^{o}C)	Impedance (Ω)	Capacitor value (pF)	Predicted % MC	Dielectric Constant
1	30	197916.8542	26.729	0.450597	9.580
2	40	209143.9626	25.294	0.419428	9.066
3	100	211492.1523	25.013	0.412905	8.965
4	110	214266.7189	24.689	0.405201	8.849
5	120	215392.8944	24.561	0.402077	8.803
6	130	224323.2416	23.583	0.377306	8.453
7	140	240706.4648	21.977	0.331801	7.877
8	150	246572.8366	21.455	0.315544	7.690
9	160	268495.5292	19.703	0.254682	7.062
1	170	272084.065	19.443	0.244727	6.969
1	180	283631.9253	18.652	0.212672	6.685

The dielectric constant of representative paddy sample can be calculated .The relative permittivity of parallel plate sensor without samples is, ε_{r1} =1. The capacitance value of parallel plate sensor without samples is given in equation (6). Let that be C_1. Let C_2 be the capacitance of representative amount of sample paddy heated at particular temperature, then ε_{r2}can be obtained by dividing equation (8) by (6) or by equation (9).

$$C_2 = \frac{\varepsilon_0 \varepsilon_{r2} A}{d} \tag{8}$$

$$\frac{\varepsilon_{r2}}{\varepsilon_{r1}} = \frac{C_2}{C_1} \tag{9}$$

4. RESULTS

Table 2 gives the capacitance value, percentage moisture content and dielectric constant of representative samples of paddy. The result obtained by conducting the experiment shows that the capacitance value is larger for the paddy having more moisture content.

Using the equation (7) predicted percentage moisture content was determined and Dielectric constant was calculated using equation (9) and plotted the variation with predicted % MC and is shown in Figure 5. Dielectric constant increases with increase in moisture content.

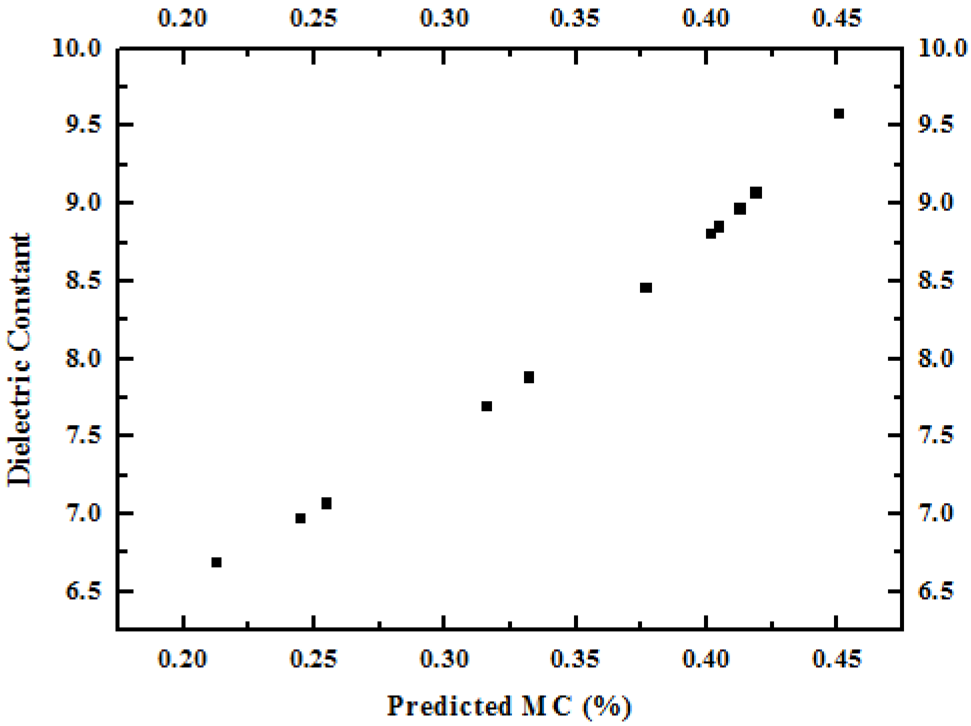

Figure 5*. Variation of dielectric constant with predicted percentage MC*

5. DISCUSSION / CONCLUSIONS

The present climatic conditions are unpredictable and are unfavorable for the cultivation of paddy due to global warming. Paddy has to be stored for long time for future use and trading. The preservation of paddy grain is very critical as the moisture present in it spoils the grain. When the grains have to be preserved for long time, moisture content of grains is an important factor to be considered. New and better technique using the designed integrated circuit which has been developed gives promising result for the measurement of moisture in paddy. The technique can be used by any person and moisture content can be measured easily. The technique is accurate, simple and requires less time.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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