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Design and Performance of an Impedance Analyzer for Nondestructive Moisture Content Determination of In-Shell Peanuts

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Moisture Content (MC)

- Measurement important in harvesting, storage, marketing and processing
- MC after harvest – up to 40%
- Grading standard – Less than 11%

MC of Peanuts

- MC value periodically measured.
- Commercial instruments mostly capacitance type.
- Peanuts have to be shelled and cleaned. Samples are usually discarded.

Measurement of MC in In-Shell Peanuts

Advantages

- No shelling and cleaning required
- Saves time and labor
- Method is fast and **nondestructive**
- Economical

Basic Principles

For A Parallel-Plate Capacitor

- $C_1 = \varepsilon_{r1}\varepsilon_0 A/d$ at frequency f_1
- $C_2 = \varepsilon_{r2}\varepsilon_0 A/d$ at frequency f_2
- $\varepsilon_{r1} - \varepsilon_{r2} = (C_1 - C_2)d / \varepsilon_0 A$

d is the thickness and A is the surface area of the sample

MC as a function of Capacitance

- (ε_{r1}- ε_{r2}) and thus (C_1 – C_2) should be good indicators of MC if d and A are constant.
- However, the Peanuts are of different shapes and sizes and d and A are not constants.

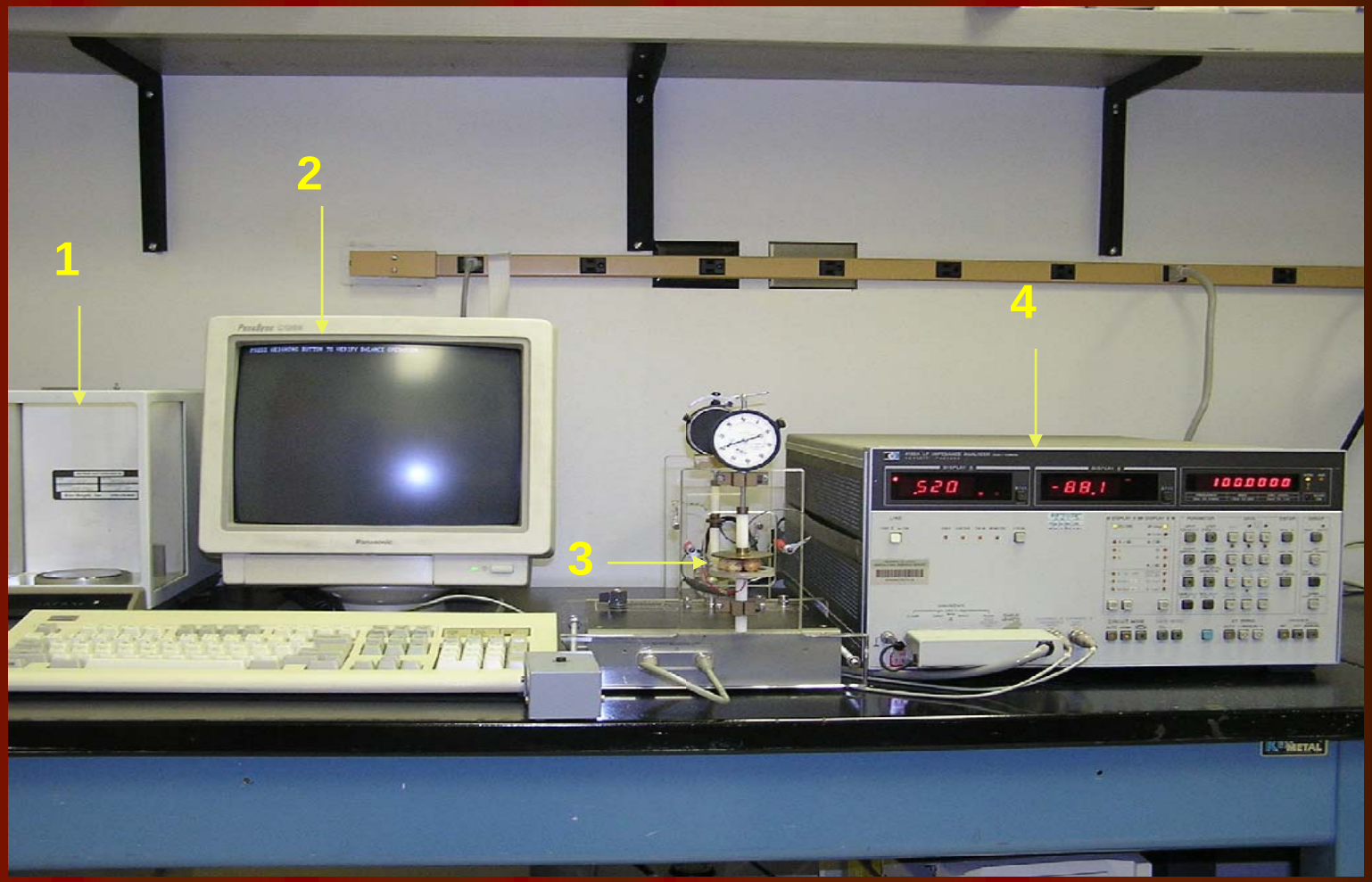
Other Dielectric Parameters

- Impedance (Z) and Phase angle (θ) were measured at 1, 5 and 9 MHz.
- Capacitance (C) was computed.

EARLIER MEASUREMENTS

With Commercial
Impedance Analyzers

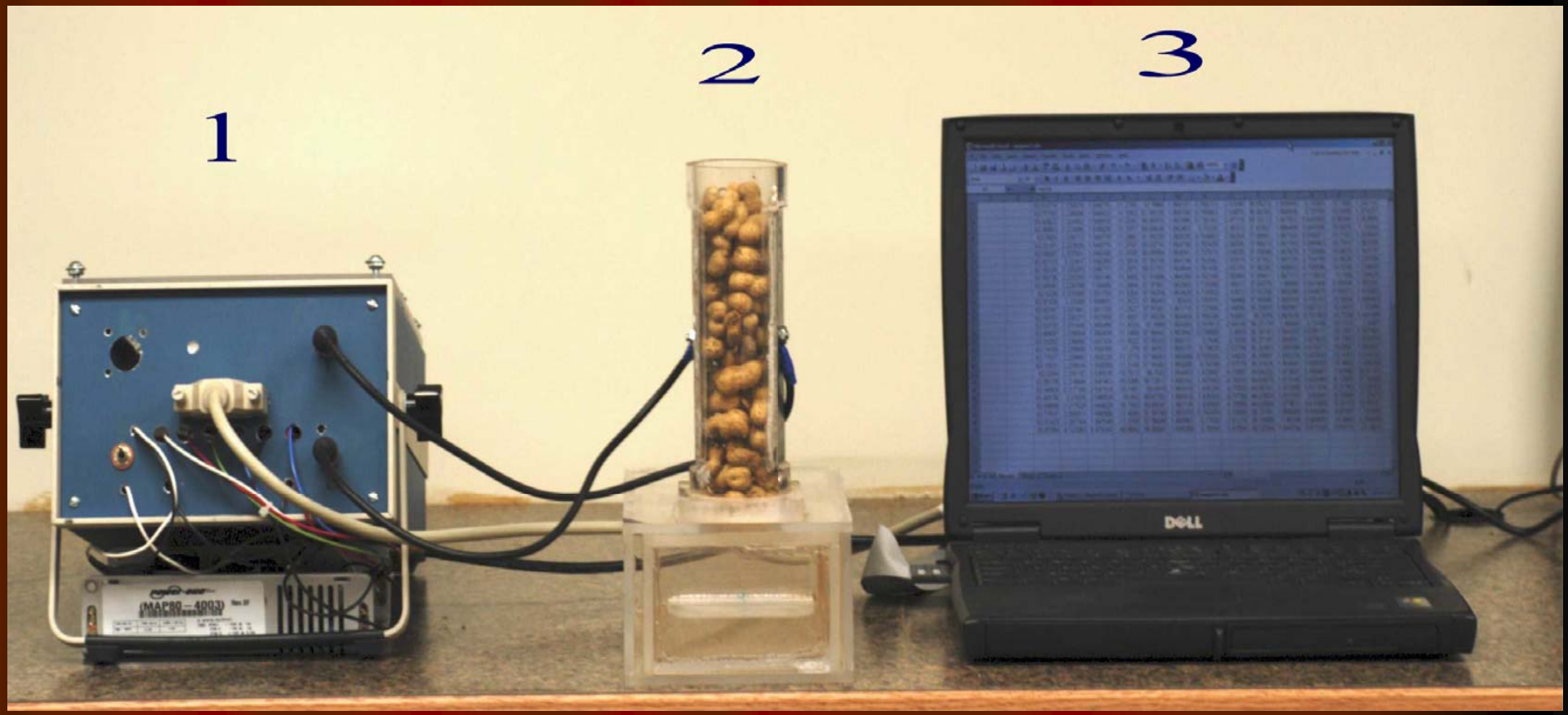
Measurement System



1. Balance. 2. Computer. 3. Parallel plates with peanuts. 4. Analyzer

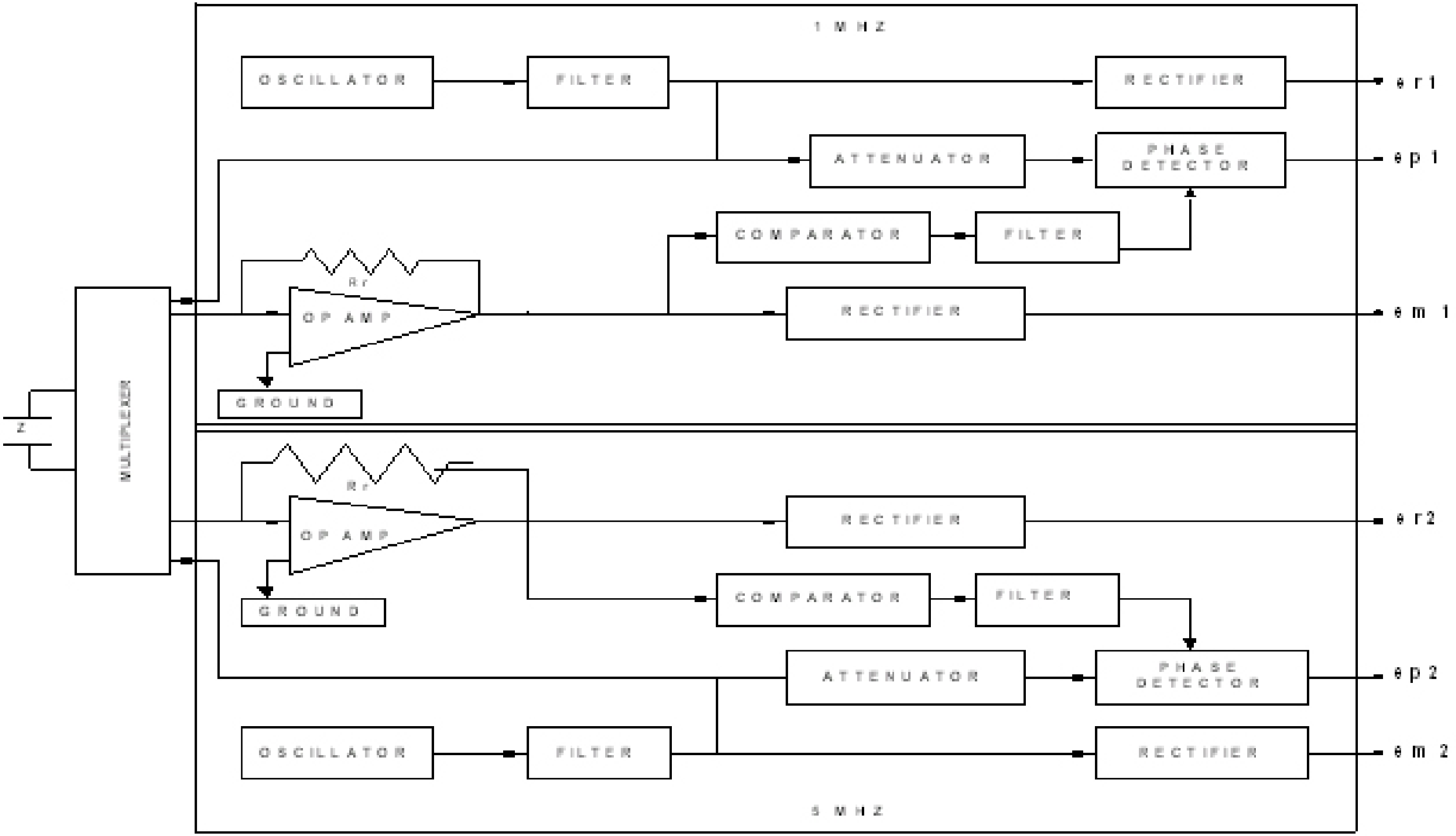
New Impedance Meter and System Set up

Experimental Setup



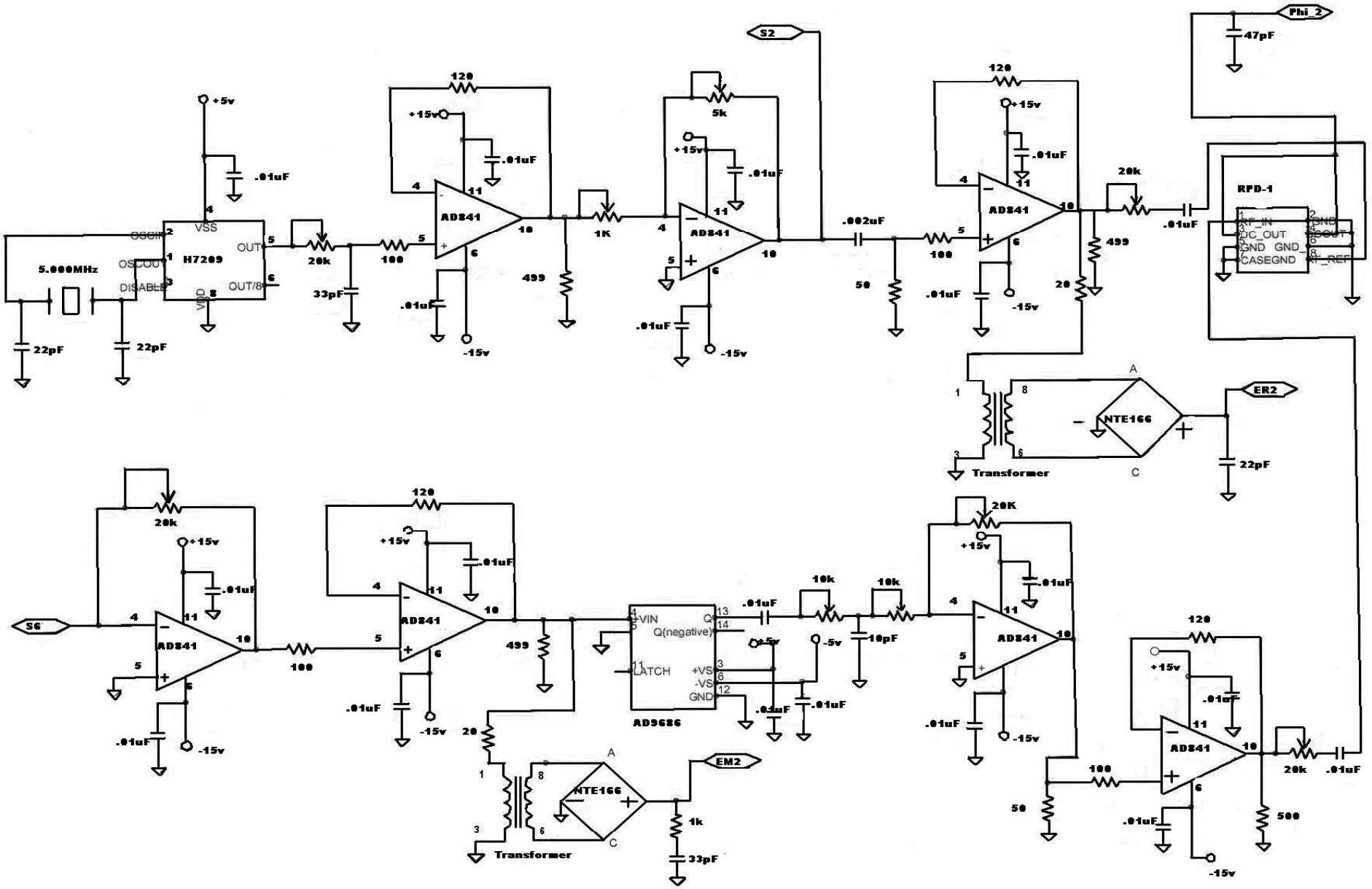
1. LCR Bridge, 2. Cylinder with electrodes, 3. Computer

IMPEDANCE AND PHASE ANGLE MEASURING CIRCUIT



Block diagram of the electronic circuit

1 MHz Circuit


Phi_2
47pF
S2
+5v
.01uF
120
+15v
5k
AD841
1K
.002uF
20k
RPD-1
RF_IN
DC_OUT
GND GND
CASEGND
RF_REF
499
100
50
20
-15v
5.000MHz
22pF
H7209
VSS
OSCIN
OSCOUT
DISABLE
OUT
OUT/8
33pF
A
NTE166
C
ER2
Transformer
S6
10k
10pF
AD9686
VIN
Q
Q(negative)
LATCH
+VS
-VS
GND
-5v
EM2
1k
500

PHASE ANGLE AND IMPEDANCE

- Phase angle (θ) is related to loss angle (δ) as $\tan \theta = 1/ \tan \delta$ and is measured directly.
- Impedance $IZI = R_r (e_r/e_m)$.
- Capacitance $C = -1/2\pi fX$
  where $X = IZI \sin \theta$.

CALIBRATION EQUATION

$$mc = A_0 + A_1 (\Delta C_1) + A_2 (\Delta \theta) + A_3 (\Delta Z) + A_4 (\Delta C_2) + A_5 (\Delta C_1)^2 + A_6 (\Delta C_1/\Delta Z)$$

where ΔC_1, $\Delta \theta$ and ΔZ are the differences between the capacitance, phase angle and impedance at 1 and 5 MHz while ΔC_2 is the difference in the capacitance at 1 and 9 MHz.

CALIBRATION MEASUREMENTS

- Made on 30 samples from each of the 6 calibration sub-lots.
- Impedance and Phase angle values at 1, 5 and 9 MHz were measured. MC of each sample determined by the oven method.
- Values of the constants of the equation were determined (SAS).

Calibration Constants

$A_0 = -35.388,\ A_1 = -12.004,\ A_2 = 0.849,$
$A_3 = 81.078,\ A_4 = 0.833,\ A_5 = -0.118,\ A_6 = -1.354$

$R^2 = 0.99$

VALIDATION MEASUREMENTS

- Made on 30 Peanut samples from each of the 5 sub-lots marked for prediction.
- From the measured impedance and phase angle values at 1,5 and 9 MHz, mc of each sample calculated using the equation, and compared with the oven determined values

RESULTS

Comparison of Oven and Calculated MC Values for 6 Calibration Lots

(Average of 30 pod samples in each level)

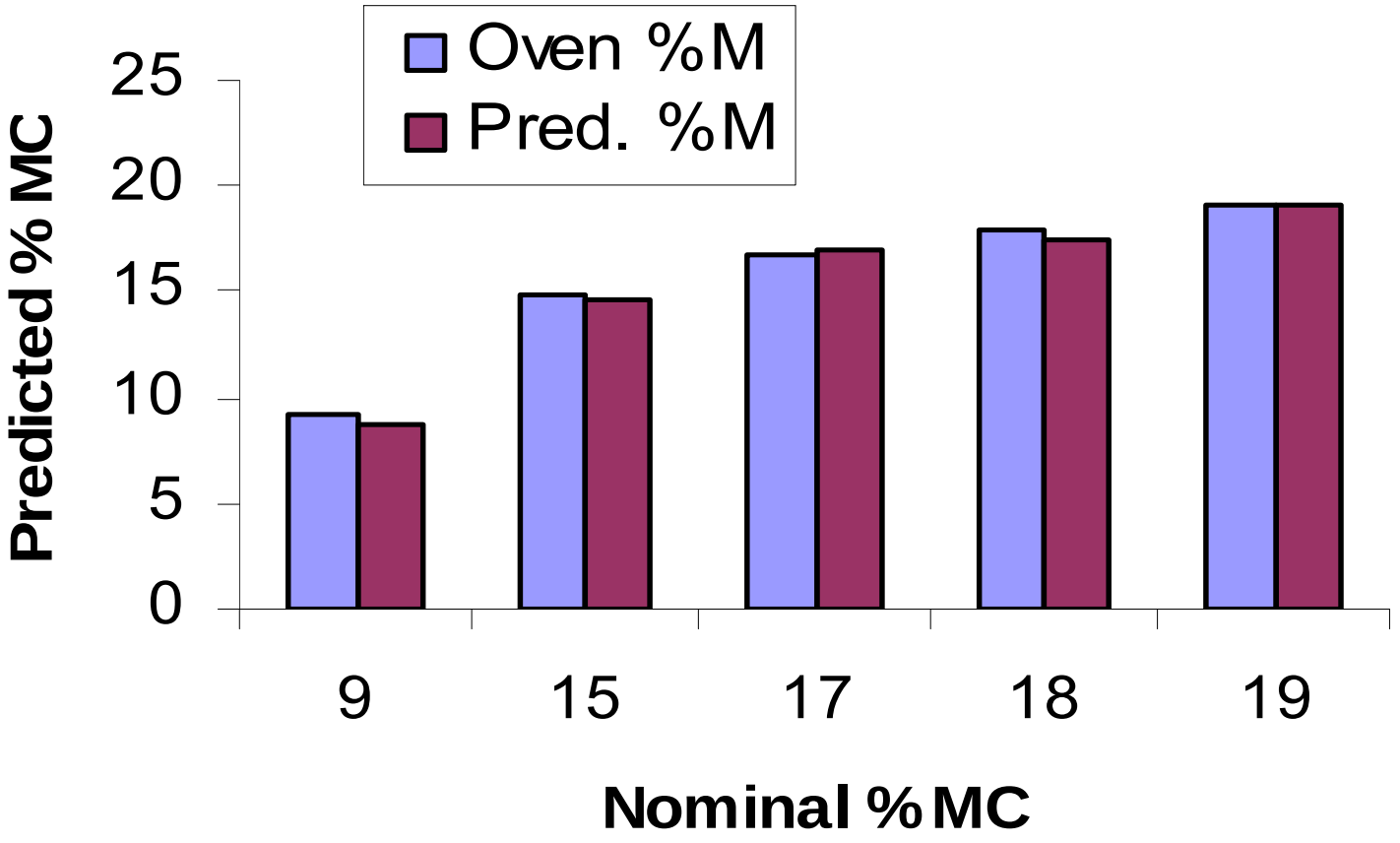
Nominal % mc	Bulk oven % mc	Moisture Content (%) from Equation	Difference (%)	Predictability (%)
8	8.01	8.02 ± 0.28	-0.01	100
11	11.05	11.01 ± 0.59	0.04	100
13	13.55	13.74 ± 0.40	-0.19	100
16	16.12	16.20 ± 0.51	-0.08	100
20	19.98	20.03±0.70	-0.05	100
23	22.94	22.65±0.88	0.29	77

Comparison of Oven and Calculated mc Values for 5 Validation lots

(Average of 30 pod samples in each level)

Nominal % mc	Bulk oven % mc	Moisture Content (%) From Equation	Difference (%)	Predictability (%)
9	9.20	8.75 ± 0.41	0.45	100
15	14.84	14.69 ± 0.56	0.15	97
17	16.76	17.03 ± 0.47	-0.27	97
18	17.81	17.52 ± 0.65	0.29	93
19	19.15	19.13± 0.99	0.12	73

Comparison of Predicted and Oven MC Values (Ave. of 30 Pod Samples)



CONCLUSIONS

- Moisture content of Peanuts can be determined without shelling and cleaning by impedance measurements
- The method is rapid and nondestructive. A practical instrument can be developed that could be helpful in the peanut industry. It would save considerable time and labor.

Thank You !