Indian Institute Of Technology, Bombay

Electronic Design Lab

System for Moisture Measurement of Grains

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1 Aim/Objectives

To develop an affordable moisture measurement system for various grain types and give a concluding comparison between two different methods achieving the same goal.

2 Abstract

Agriculture is an important sector of the Indian economy, accounting for 14% of the nations GDP, about 11% of its exports, about half of the population still relies on agriculture as its principal source of income and it is a source of raw material for a large number of industries. During 2011-12, India reached 259.32 million tonnes of food grain production. (State of Indian Agriculture, 2012-13). Population explosion, shrinkage of cultivable land along with grain losses is a major problem in a developing country like India.

Indias grain production has steadily increased due to advances in technology, but post-harvest loss is constant at 10%. Losses during storage, accounts for around 6% of the total losses as proper storage facilities are not available. In India, food grains are stored using traditional structures by small farmers. The surplus grains are stored with government agencies like: Food Corporation of India (FCI), Central and State warehousing Corporations. The commonly used storage method is Cover and Plinth (CAP) storage, which is economical but loss of grains is inevitable. Very few scientific storage structures like silos are available with these agencies. The government is taking initiatives now in building silos for long-term safe storage of grains since we do not have enough storage capacity as of now.
Even with government taking steps to build silos, we need economical methods to monitor the quality of storage grains so as we can efficiently know when spoilage starts and can take measures to s. top it. This is extremely important as the post-harvest loss (in 2010) if measured in solid numbers turns out **12 to 16 million metric tons of food grains each year, an amount that the World Bank stipulates could feed one-third of India's poor.** The monetary value of these losses amounts to more than Rs. 50,000 crores per year (Singh, 2010). Even in current times the conditions have not improved.

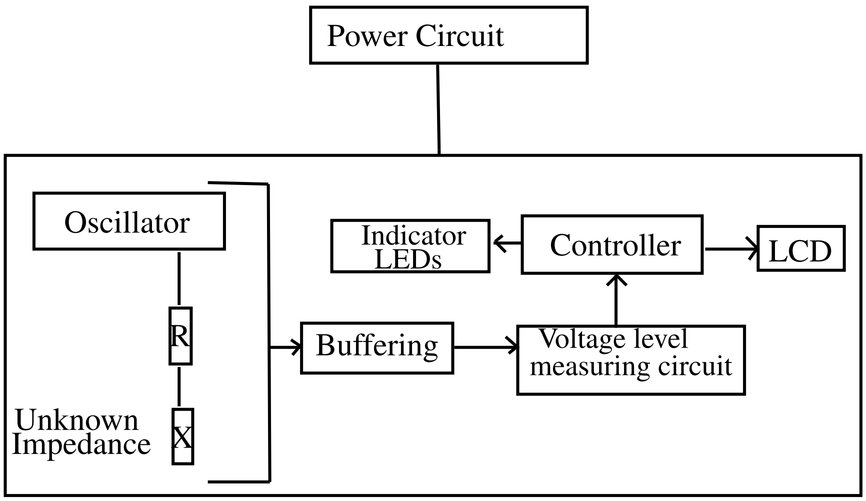
There is an urgent need for economical grain health monitors which cater to Indian grain storage methods and can help in prevention of grain spoilage in go-downs.

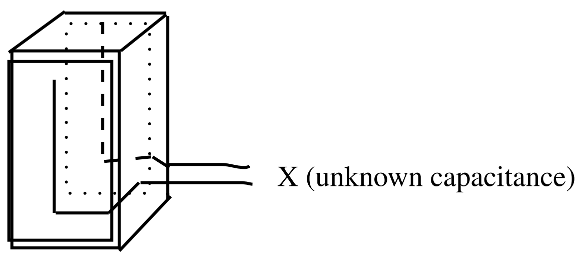
3 Introduction

In this project, we have explored two different methods to measure grain moisture content.
One of the methods utilizes the fact that dielectric constant of water is much higher than that of air or grains, so a slight change in water content leads to a significant change in dielectric constant and thus a noticeable change in capacitance.
Another method exploits the conductivity of water. As the moisture content in grains increases, their conductance increases (ie resistive component decreases).
Thus we have designed circuits to measure conductance and capacitance (impedance) of grain sample at any point of time. The former method tries to calculate capacitance from the measured impedance; ie it measures both resistive as well as capacitive parts of the moist grains. It is observed that resistance is highly frequency dependent and the former circuit uses sinusoidal input for its application, so the resistance (conductance) values obtained by later method are much more accurate as those observations are made at DC supply.
We look into the individual components and their working in more detail in ensuing paragraphs.

4 Block Diagram and description of blocks

4.1 Capacitive Sensing





1. **Sensing circuit**
   As shown in the figure, this block comprises of a box with 2 copper plates attached, thus forming a capacitance. When grains are filled in this box, the net impedance of the box changes depending on the moisture of the grain.

2. **Voltage inverter**
   Power circuit of the sensor which provides dual rail supply (+/-5V) to all the opamps.

3. **Oscillator**
   Wein Bridge oscillator to generate a sine wave at 30 kHz frequency.

This sinusoidal wave is given as input to the R-C circuit as shown in the figure.

4. **Buffers**
   It buffers the voltages to be measured so as to avoid loading by measuring circuit.

5. **Voltage level detector**

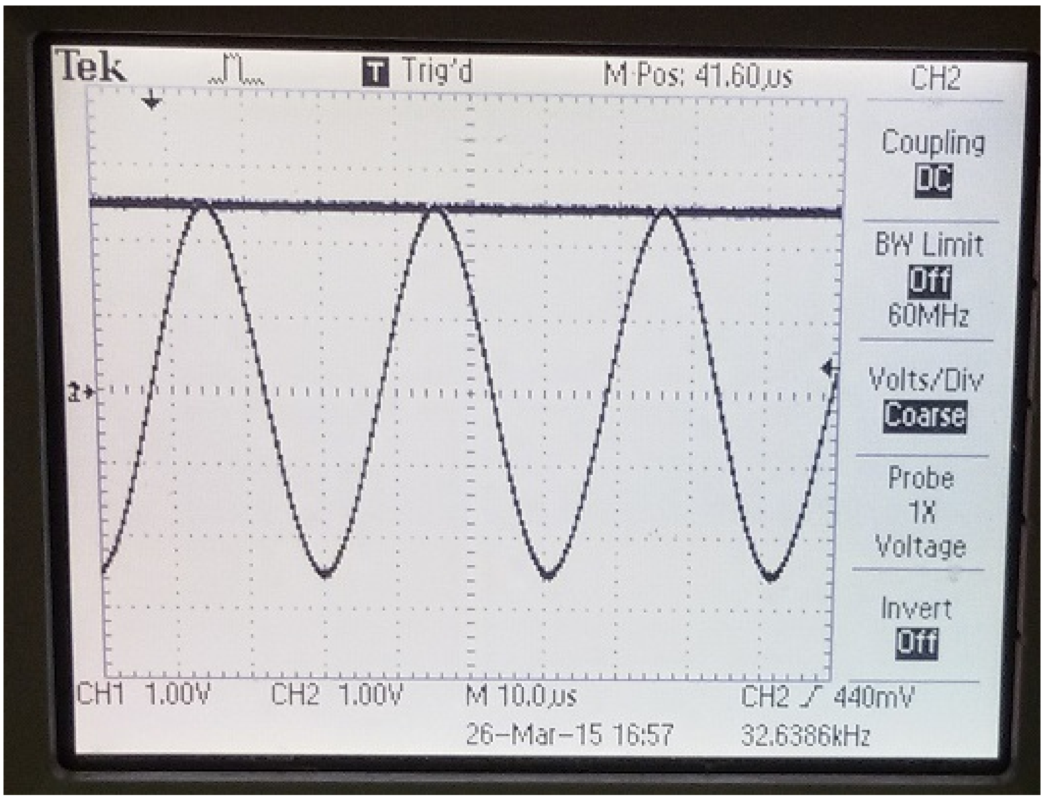


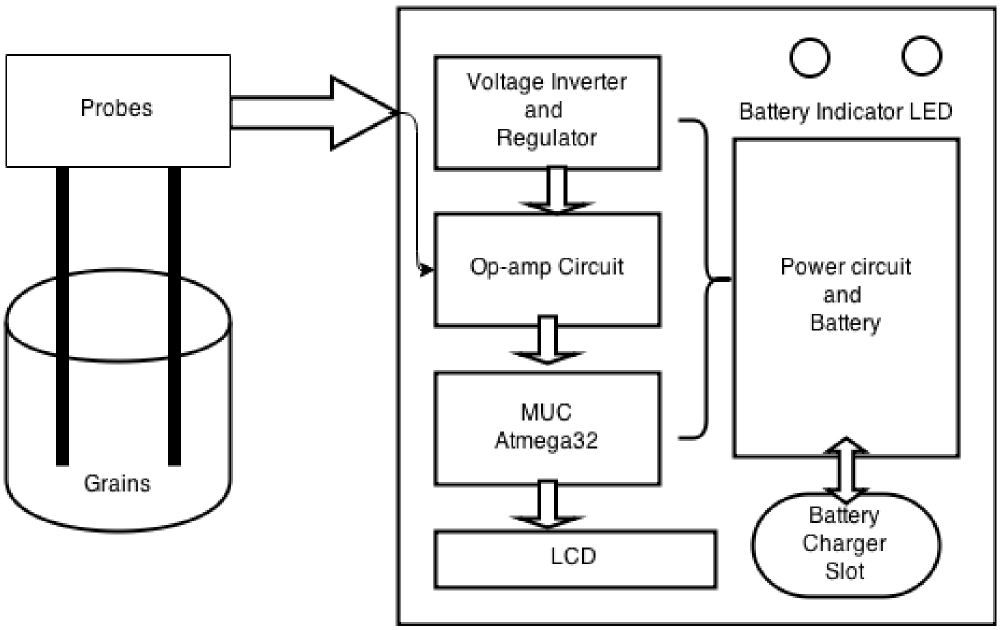
Figure 1: Result

   This circuit comprises of a difference amplifier and three peak detectors. This detects the peak value of sinusoidal voltage of the source and voltage drop across resistor and unknown impedance. The result is shown in figure 1.

6. **Processing unit**
   Atmega 32 microcontroller is used for processing with lcd and red,

yellow, green leds to provide necessary details to the user. As of now, lcd displays the peak voltage read by ADC of the controller and the leds light up according to the extent of danger to the grains.

4.2 Conductance Sensing



1. **Battery and Related Circuit**
   We have used a 2 cell - lithium ion battery, ordered from robosoft systems. It's Specifications are noted below.

   - Discharge rate upto 4A * Full Charge in 3 to 4 hours
   - Long life with full capacity for upto 1000 charge cycles
   - 2X Li-ion 4.2V 2000mAh cells (2S1P)

   We have made a battery indicator circuit which warns the user when the battery voltage drops below 7V, through and battery indicator LED.
   Along with this we have bought a 2 cell Li-ion battery charger, which

is attached with the main circuit in a way that user can just plug in with the adapter and charge it.

2. **Probes**

   These are two steel rods, of diameter and length each, these will conduct some current when put in grain sample, which is equivalent to that of probes having a resistance in grain sample. This resistance is decreasing with moisture content of the grains (all this for a specific grain type). This connected to the circuit box through a BNC cable.

3. **Analog Circuit**

   This comprises of an two op-amp circuit in series, a voltage inverter circuit to power the dual rail opamp, and other peripheral circuit, for more information see the circuit description below.

4. **ATMEGA 32**

   This measures the analog input coming from the analog circuit and converts the relevant analog value to the calibrated moisture content, to the LCD and the warning LEDs.

5 Complete circuit Diagram

5.1 Capacitance Sensing

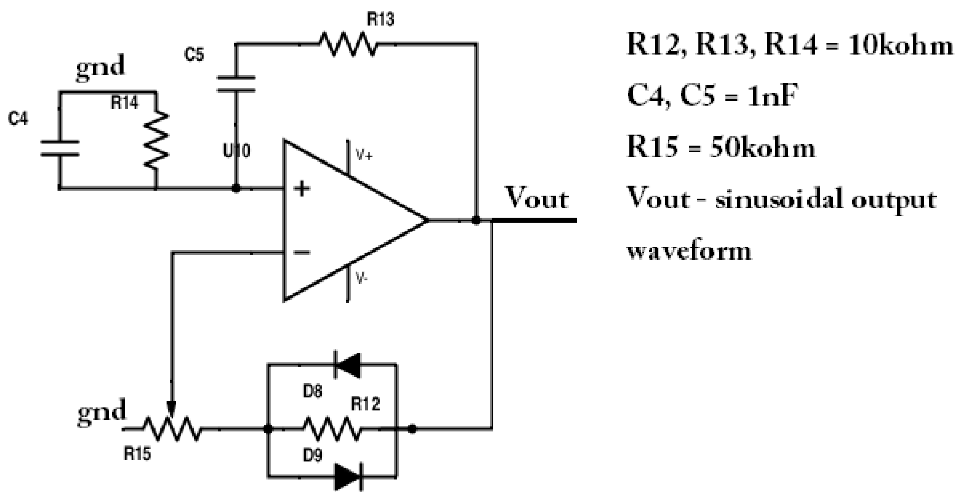


Figure 2: Capacitive: Wein-Bridge Oscillator circuit

Find the brd file below.

5.2 Conductance Sensing

Find the brd file below.

Also the circuit diagram

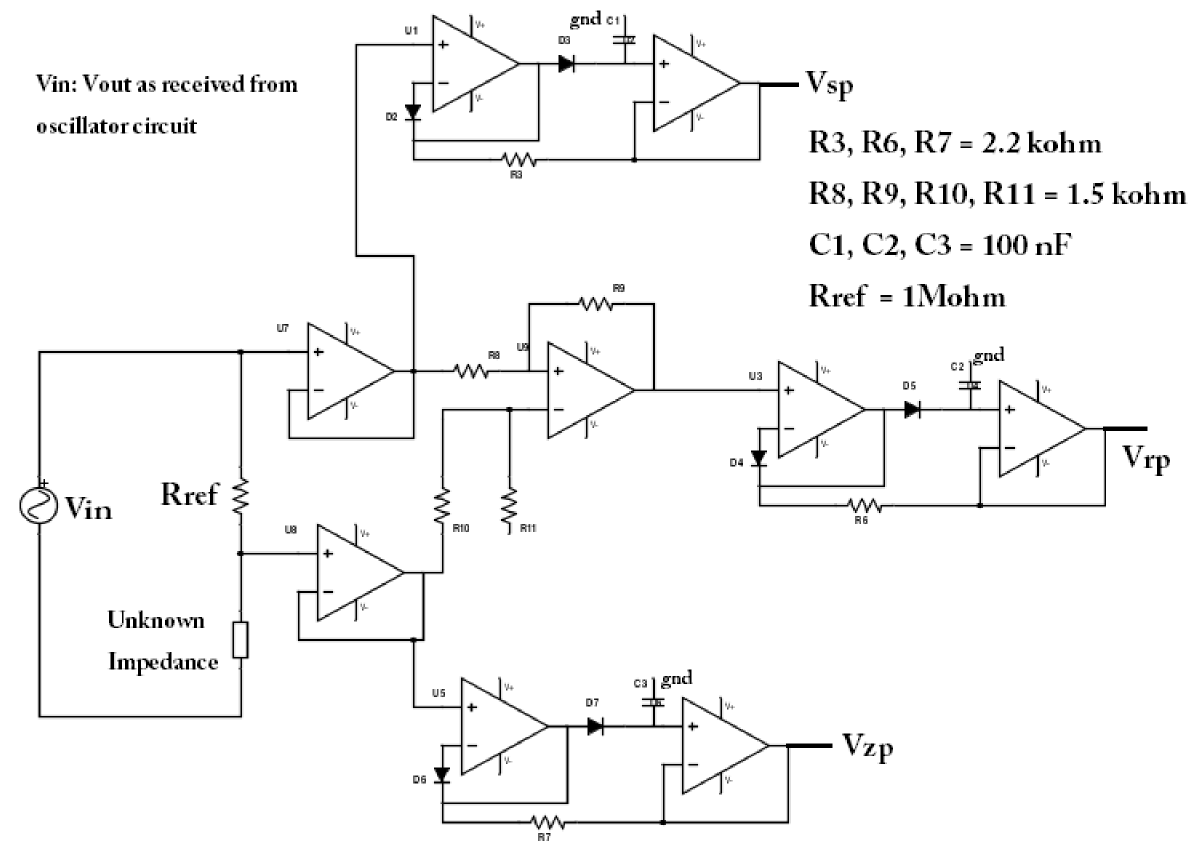


Figure 3: Capacitive: Sensor circuit

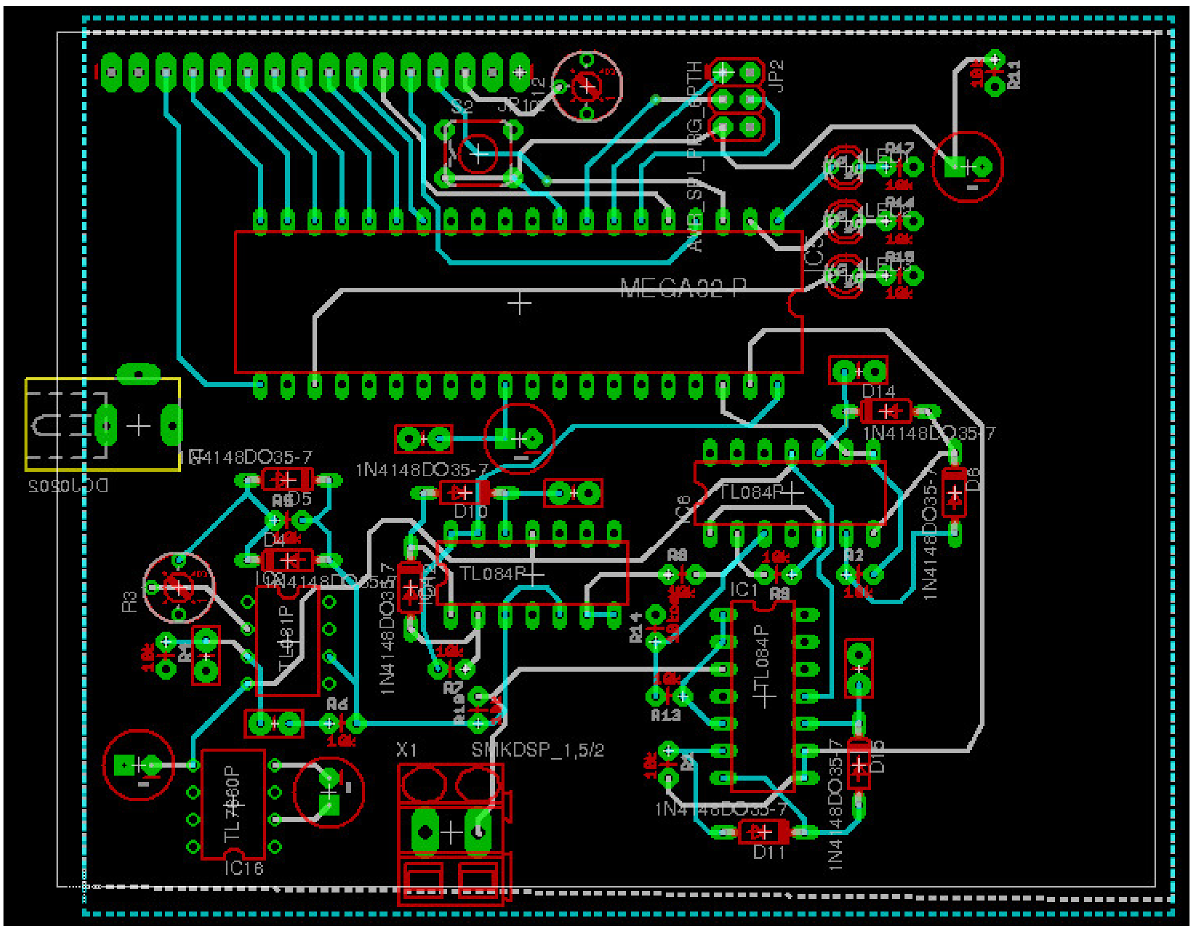


Figure 4: Capacitive Sensing: BRD file

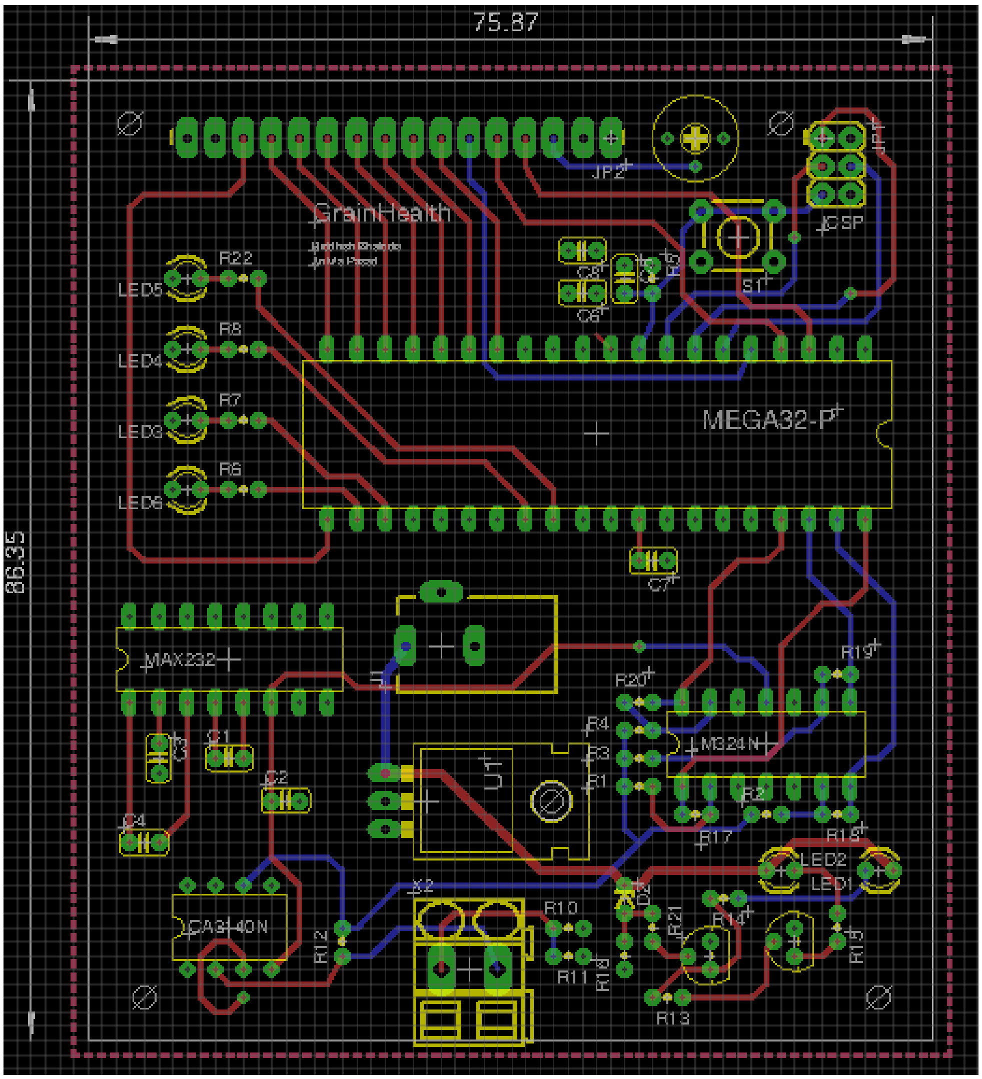


Figure 5: Conductance Sensing: BRD file

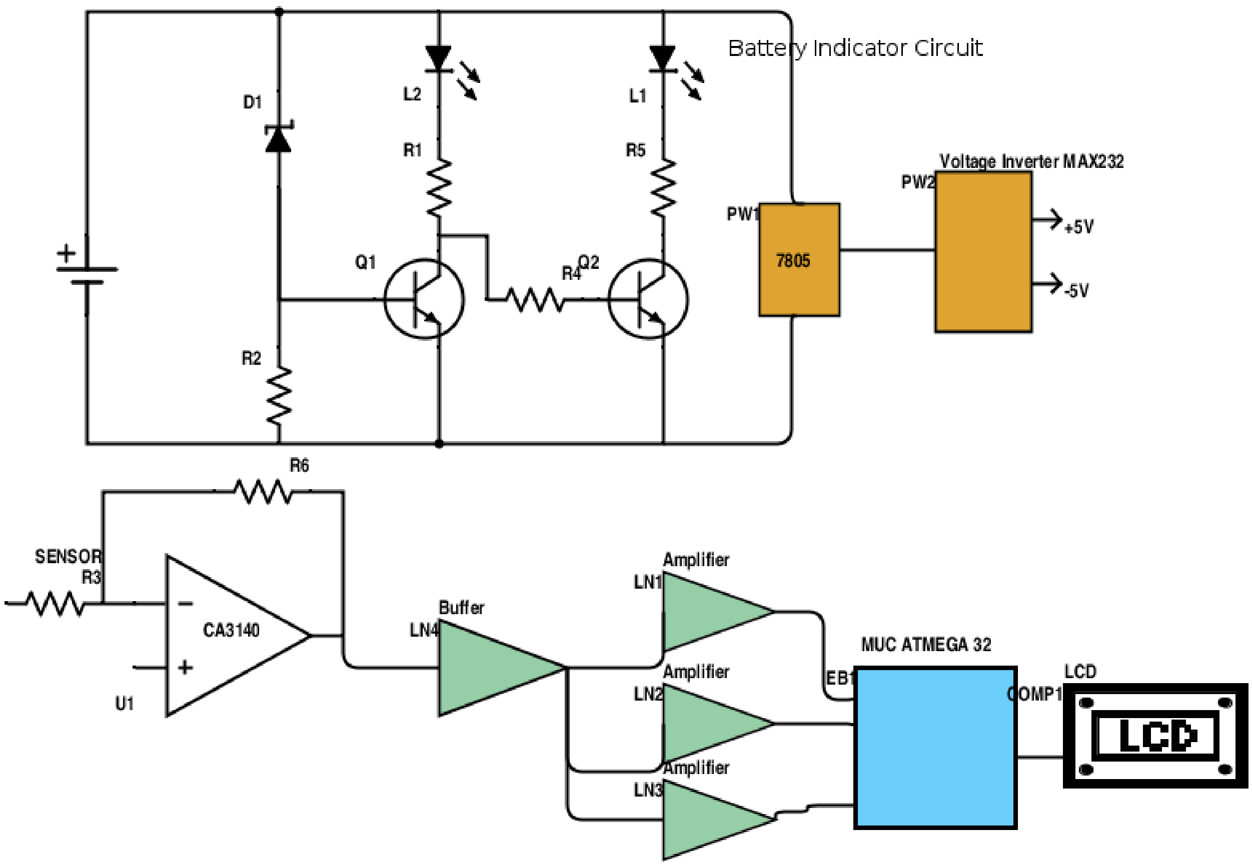


Figure 6: Conductance : The circuit diagram

6 Photographs of the units/ waveform etc

- Capacitive Sensing

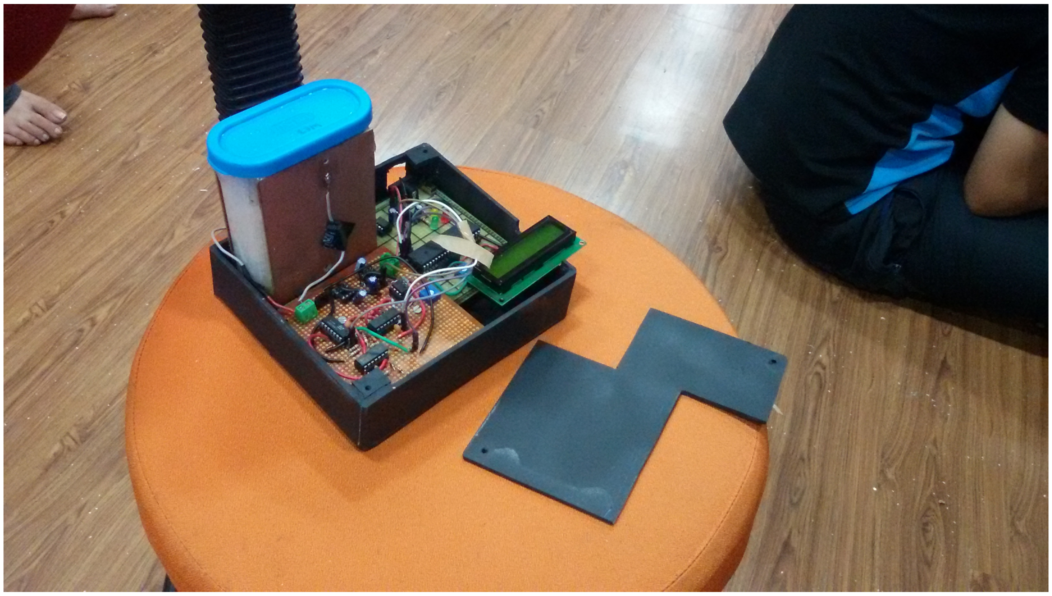


Figure 7: Capacitive : The Circuit Box

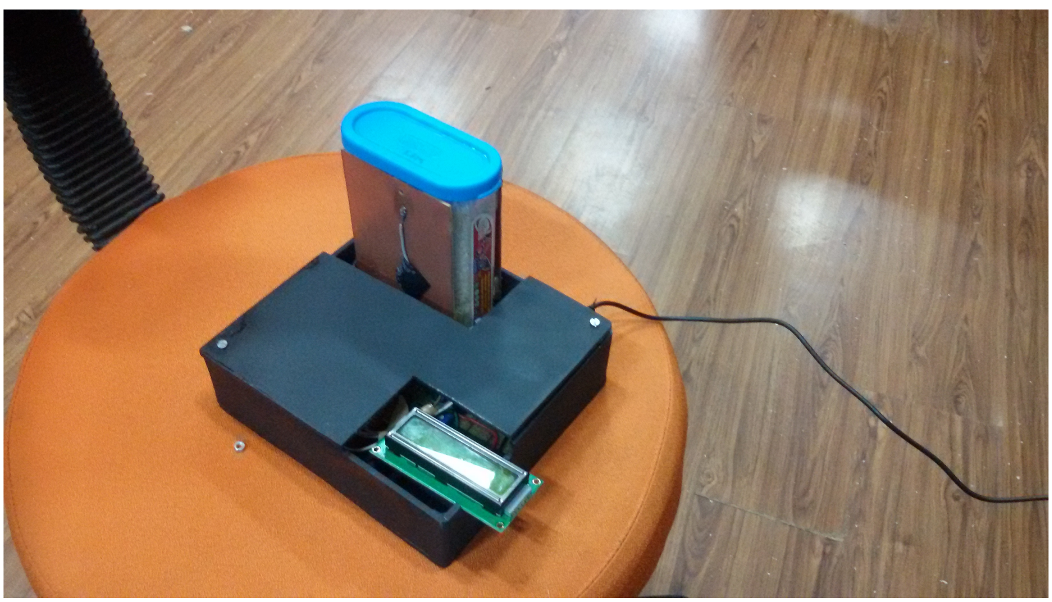


Figure 8: Capacitive : The Overall Setup

- Conductance Sensing

Figure 9: Conductance : The Circuit Box

Figure 10: Conductance : The Circuit Box and probe, normal working

Figure 11: Conductance : The Charging mode

7 Results/Objectives achieved

This is how capacitance and resistance of the 'unknown impedance' varies with frequency (as measured by LCR meter)

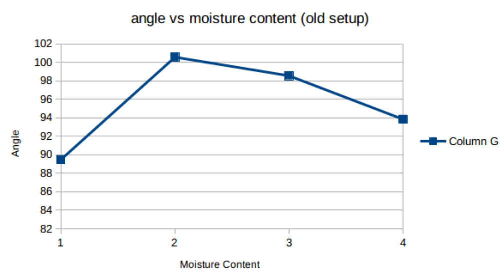
Frequency (kHz)	Capacitance (pF)
30	3.5
100	3.48
1000	3.44

Table 1: Capacitance with air as dielectric

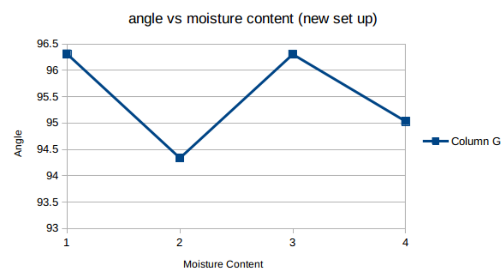
Frequency (kHz)	Resistance (kohm)
1	1700
10	73
100	4.4
1000	0.339

Table 2: Resistance with air as dielectric

With rice as the medium, resistance was observed to be highly unstable particularly at low frequencies of the order of 1 kHz.



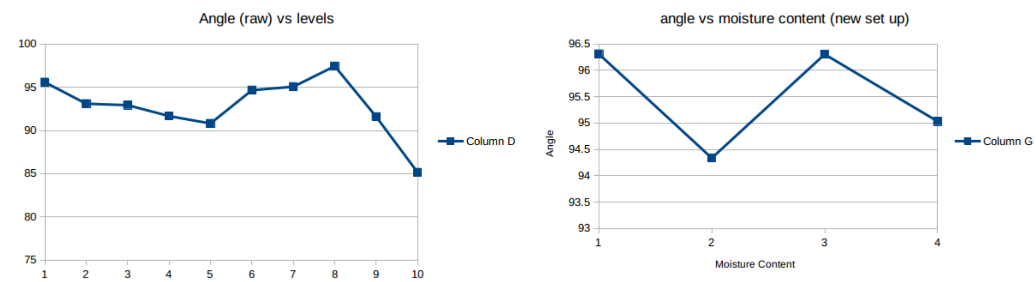
(a) With old setup



(b) With new setup

Figure 12: Comparison of readings taken with two different setups. Old Setup: One with copper plates inside the box New Setup: One with copper plates attached outside the box

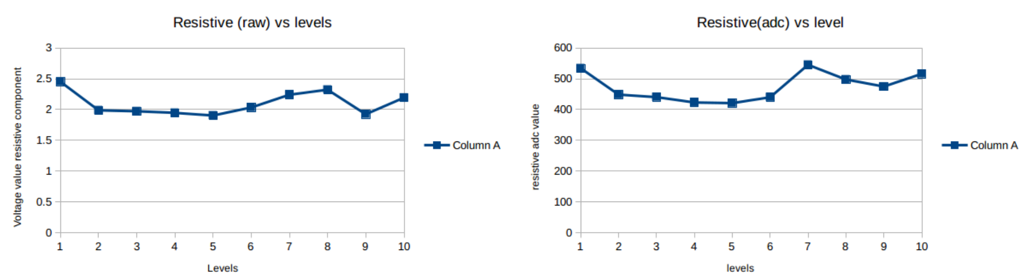
It was observed that angle values do not vary much for the new setup; whereas there is a variation in the angle values for old setup though no significant pattern is observed.
All the following readings are taken using old setup



(a) Angle values calculated using directly measured peak voltage outputs

(b) Angle values calculated using values as read by adc

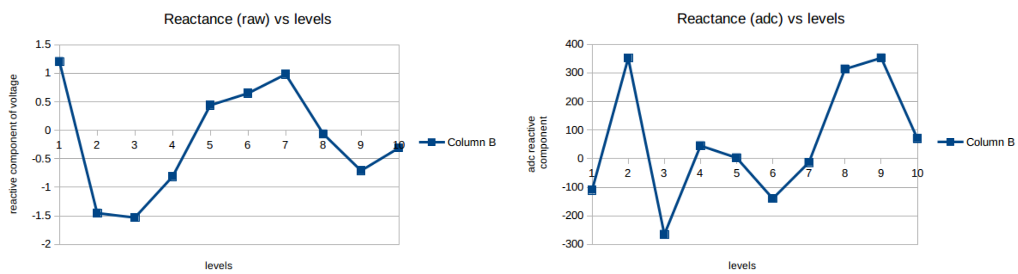
Figure 13: Comparison of raw readings with the readings taken by adc



(a) Resistive voltage components (raw data)

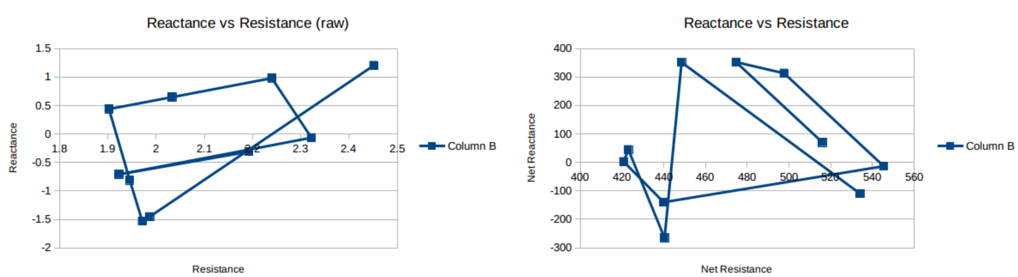
(b) Resistive voltage components via ADC

Figure 14: Comparison of raw resistive readings with the readings taken by adc



(a) Reactive voltage components (raw data) (b) Reactive voltage components via ADC

Figure 15: Comparison of raw reactive readings with the readings taken by adc



(a) Root Locus of Impedance (raw)) (b) Root Locus of Impedance (via ADC)

Figure 16: Comparison of raw impedance readings with the readings taken by adc

The validation chart of Analog circuit response with high resistances

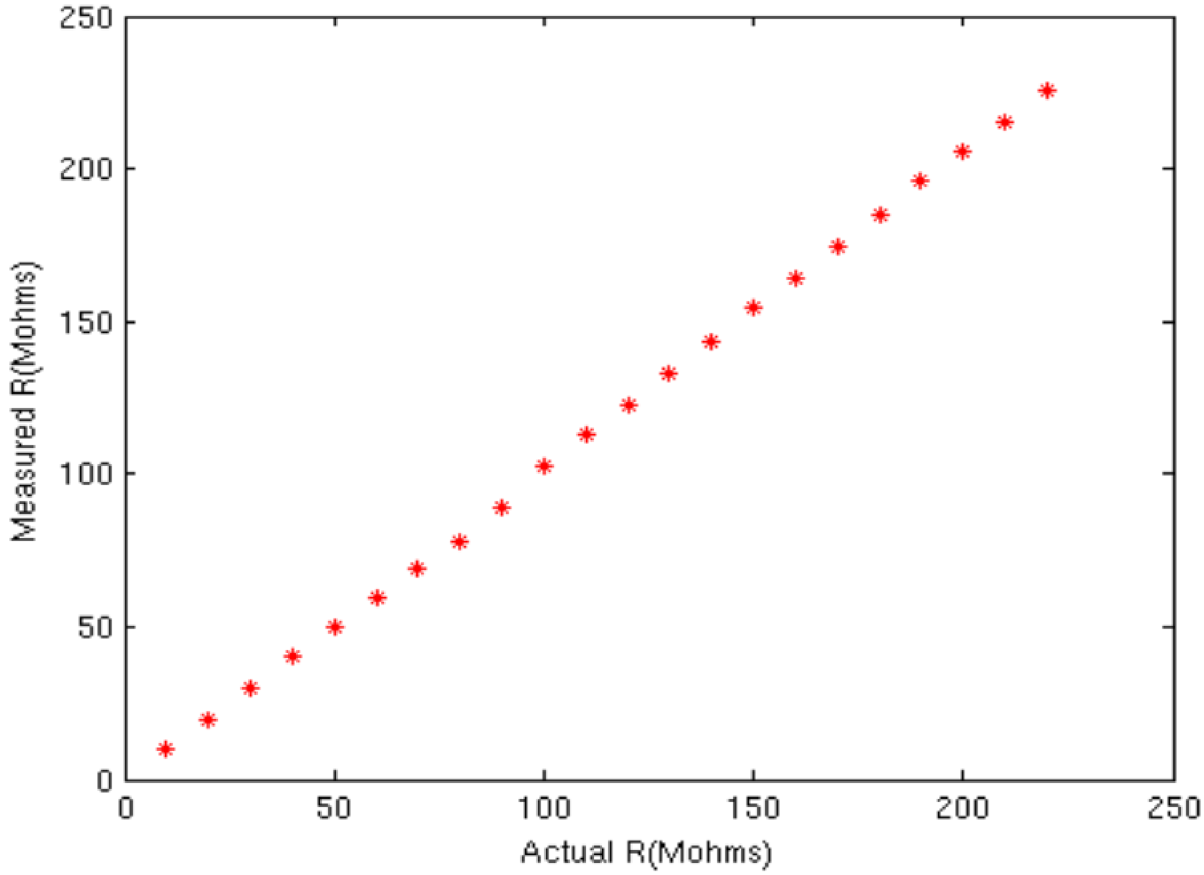


Figure 17: Conductance : Validation Results

When the capacitive sensor was validated with actual capacitance values, it was observed that the readings were not as expected but none-theless were different for the different values of capacitance. As our final aim is to identify different regions for moisture levels, the actual value of capacitance does not matter, also it was suggested that the readings are erroneous due to unavoidable noise while bread-boarding. So, we proceeded with the same circuit onto the pcb.

8 Problems faced

8.1 Capacitive sensing

- As it involved measuring capacitance in the order of picofarads, we had to deal with noise introduced by parasitic capacitance. This was tacked by fixing the length and orientation of wires from the capacitive element.
- An error offset of around 0.4 V was observed in the peak detector circuit which was eliminated by a slight modification in the circuit so that opamp is avoided from going into saturation region.
- High frequency application added to the errors. Systematizing the way in which measurements were taken and recorded helped improve the credibility of observations. It is hoped that shifting the application circuit on printed circuit board will further help reduce errors
- There was a problem (still remains unsolved) of accessing multiple ADC channels at the same time (which was needed for further calculation of angle) on the designed board.

9 Conclusions

- During experimentation, expected behavior was not observed (reasons still unknown) for capacitive based sensing. The output showed almost constant value for grains with different moisture content. The circuit did not prove to be sensitive enough. On the other hand, conductance sensing proved to be efficient for determining the regions for safe, moderately high and very high moisture levels.
- The only drawback of conductance sensing is that it is highly dependent on the external factors such as pressure, the length of probe inserted inside grains.

10 Cost Analysis

As shown in table 1

Component	Cost
Atmega 32	150
Capacitive box	50
Consumables (connectors, ICs)	under 300
Printed circuit boards(development cost)	3000
Casing and aesthetics	under 150
Battery and Charger	700

Table 3: Cost Analysis for development

11 Future work suggestions

- We need to do an actual calibration with the standard method of measuring moisture (Oven heating, available at Foods Labs). We kept that at on hold as we have not yet received the PCB's and some of the measurements might change when we shift to them from the soldered ones we are using right now.
- All of testing is currently done on rice grains. This can be extended further to multiple grains with different look-up tables for various grains. This will require functionality of user manually selecting which grain is it monitoring.
- To take the project further, we can also take input from temperature sensor and monitor internal as well as external temperature (as was planned at the beginning); the combined results for temperature and moisture will give a more efficient system for detecting risks to health of grain.

12 References

- A LOW COST FIELD USABLE PORTABLE DIGITAL GRAIN MOISTURE METER WITH DIRECT DISPLAY OF MOISTURE, AJST 2004

- Datasheets of CA3140, ATEMGA32, TL7660,TL081 and TL084
- Storage of food grains, http://www.fao.org/wairdocs/x5002e/x5002e02.htm