Capacitance level sensor with integrated cold electronics

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Abstract

Capacitance type level sensors are extensively used for level measurement both for cryogenic and room temperature applications. The measurement of capacitance was carried out using various commercially available electronic circuits. All these circuits are designed to operate at room temperatures. A cold electronics based level measurement circuit is prepared which operates from 300 K down to 4.2 K. The frequency of the cold electronics oscillator is a function of the liquid leel due to the change in capacitance value of the leel sensor. The details of the calibration setup are discussed. Liquid Nitrogen was used as cryogen for the calibration. The details of developed cold electronics and its performance are discussed in this paper.

Introduction

- Different types of cryogenic level measurement used are, capacitance, weight measurement type, superconductor based etc.
- The change in capacitance value for small change in level of cryogen requires a precision capacitance bridge.
- These delecate instruments are usually kept at room temperature and requres long length cabling.
- These long cable length may introduce added errors in measurement.
- A cold electronics based signal conditioning unit is coupled with capacitance level sensor to negate these errors.

Main Objectives

1. Design and develop a capacitance type cryogenic level sensor.
2. Develop a cold electronic signal conditioning unit.
3. Caliberate the designed sensor against standard capacitance bridge in LN_2.
4. Determine linearity and sensitivity of the sensor.

Experimental Setup

The setup consists of two capacitance based level sensors of 600 mm active length, capacitance bridge, digital multi-meter for frequency measurement and data acquisition system.

Capacitance Level Sensor

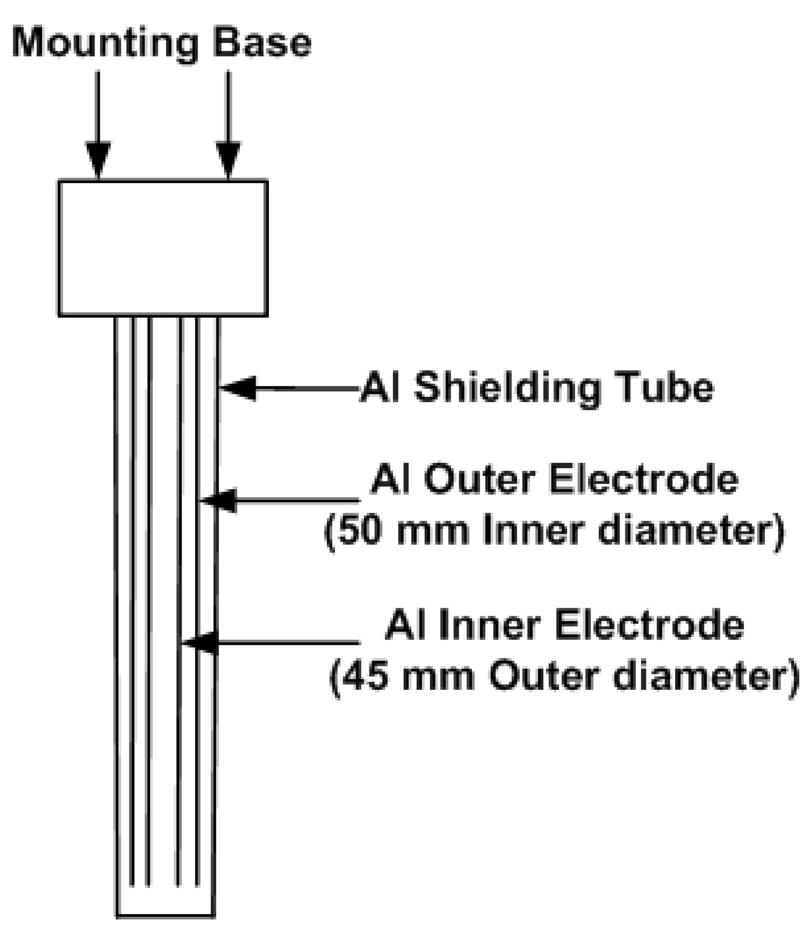

Figure 1: Schematic of interfacing DAQ

- Cylindrical outer and inner electrode of 600 mm active length covered by shielding tube.
- Outer diameter of the inner electrode is 45 mm.
- Inner diameter of the outer electrode is 50 mm.
- Gap between the two electrodes is maintained uniformly at 2.5 mm

Cold Electronics

- An LC oscillator is used to convert capacitance change into frequency change
- All the components have been cryotreated before using
- The circuit performance was tested from 300K-4.2K
- A Detailed analysis for the circuit is given in [2].

DAQ and Caliberation procedure

The sensor connections were brought out of cryostat via feedthrough. Figure 2 shows schematic of data acquisition system. The capacitance bridge and multi-meter were interfaced to the LabVIEW program using GPIB. The capacitance values from the bridge were used for level indication. The frequency was logged automatically for corresponding change in level.

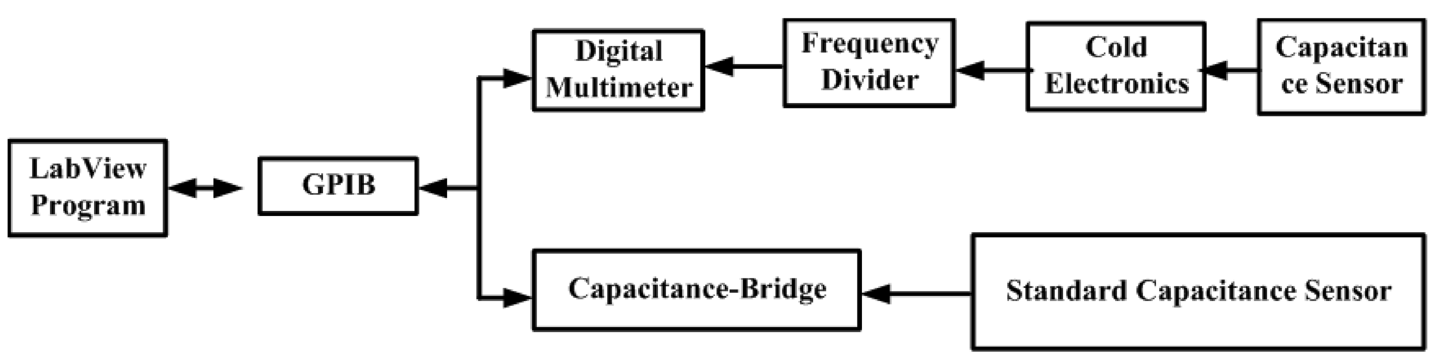

Figure 2: Schematic of interfacing DAQ

The calibration procedure is given below,

1. Mount the capacitance sensors on the same height
2. After sealing the top flange of the vessel, fill the outer container with LN2 till it is full and then start filling the inner container.
3. Observe the values of capacitance level sensor using the Capacitance Bridge and keep filling the liquid in inner container till the time the capacitance value become stable i.e. no more change in capacitance up to the top of the level sensor.
4. Allow the setup to cool for half an hour for thermal equilibrium.
5. Drain the liquid till the capacitance value becomes minimum.
6. Change the log file and restart the program for ascending calibration and fill the liquid gradually.
7. Ensure that the pressure inside the inner container is maintained at 0.5 bar.
8. Fill the liquid till the capacitance value becomes stable at maximum value.

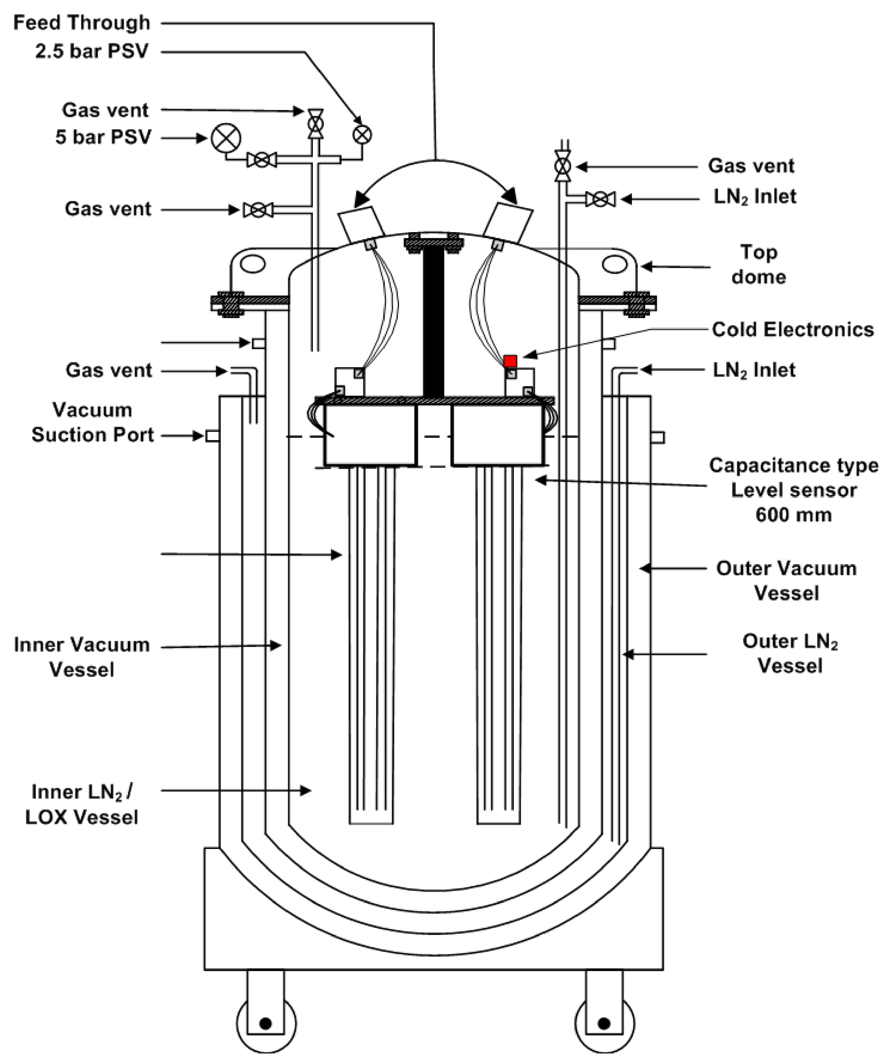

Figure 3: Calibration setup

Results

The calibration graph shows frequency variation of cold electronics based oscillator for capacitance sensor against the level of cryogen is shown in figure 5. The calibration was carried out at constant flow rate of 1.4 lit/min and pressure inside the inner vessel was maintained at 0.5 bar throughout the experiment. The graph shows a linear response of frequency for the corresponding change in level. The sensitivity of the sensor is 14.7 kHz/mm for a capacitance change of 0.22 pF/mm.

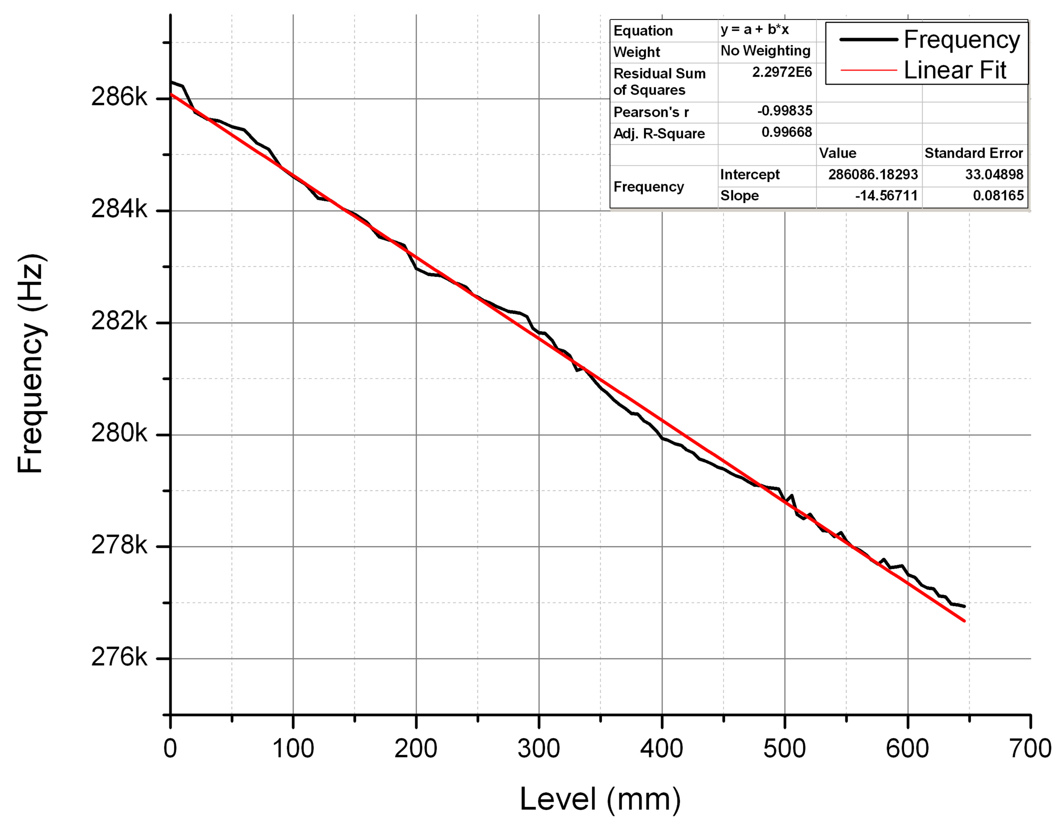

Figure 4: Output frequency vs level along with a linear cure fit

Conclusions

- A cryogenic capacitnce type level sensor was designed and tested for LN_2
- A cold electronics based signal conditioning circuit was designed to work at LN_2 temperatures.
- The designed sensor was found to have a sensitivity of 14.7 kHz/mm
- The sensor was found to have linear response

References

[1] R Karunanithi, S Jacob, DS Nadig, MVN Prasad, Abhay S Gour, S Pankaj, M Gowthaman, and H Sudharshan. Calibration of a hts based lox 400mm level sensor. *Physics Procedia*, 67:1169–1174, 2015.

[2] Pankaj Sagar, Abhay S. Gour, and R. Karunanithi. Effect of temperature variation on cold electronics based oscillator for rrr measurement. *14th International Cryogenic Conference*, March 2017.