Signal Actuation Circuit for Capacitive Gas Sensors

Final Report, submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology (B.Tech)

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Month, 2022

Final Report on

Signal Actuation Circuit for Capacitive Gas Sensors

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Introduction:

Objective: Designing and developing a Signal Actuation Circuit for Capacitive Gas Sensor

Framework: We get ideas from a resistive gas sensor and to enhance its performance we replace the resistor by a capacitor; thus, we get a more precise and accurate result by a capacitive gas sensor.

Gas sensor is a transducer which detects the gas molecules by altering its physical properties like resistance or capacitance and produces electrical signals which are proportional to the gas concentration.

Need, Identification and Justification:

- Resistive gas sensor devices, irrespective of their popularity owing to low cost, robustness, and large-scale production, suffer from poor selectivity and limited sensor response.

- The performance of resistive gas sensing is primarily governed by the adsorption-induced depletive resistance change caused by exposure to test gases , which are somewhat indistinguishable among the same group of vapours/species (like alcohols, ketones).

- The main objective of the project is to provide a gas sensor which shows good selectivity and sensitivity.

- So far, very little is known about the fundamentals of capacitive type chemical sensors, specifically gas sensors based on capacitance change. However, capacitive-type sensors have a bright future because the capacitor structure is so simple, allowing for miniaturisation while maintaining high reliability and low cost. Furthermore, because oscillator circuits can easily multiply capacitance, capacitive type sensors enable sensitive detection. Furthermore, oscillator circuits are made up of only a standard resistor and a sensor capacitor. As a result, the signal treatment circuit is also very simple and inexpensive. Furthermore, the capacitive-type sensor has the advantage of selectively detecting specific gas molecules.

Concept Generation:

- Sensor researchers were tasked with finding alternative sensing methods (modes) and devices to improve selectivity.

- A critical bottleneck for resistive sensor devices is the selective detection of vapour species, particularly those from the same group. With this Capacitive gas sensor , methanol, ethanol, and 2-propanol detection using a Pd/TiO2 nanorod array/Ti device in capacitive mode with improved selectivity was accomplished using a resonant frequency tuning technique. Identifying the resonant frequency over the frequency range of 0.01-200 kHz yielded the optimal capacitive response of the device.

- When compared to conductometric detection, capacitive mode detection is an efficient measurement technique that achieves high response magnitude (RM)/sensitivity and fast detection. The dielectric change of the semi-insulating sensing layer (in the presence and absence of gas) is the major factor in achieving higher response magnitude/sensitivity in capacitive mode. As a result, there may be a discernible difference in response magnitude, and thus selectivity, between test gases with different dielectric constants. Furthermore, because the device's resonant frequency is inversely proportional to the square root of the

- Detection of the concentration of a specific gas molecule in mixtures of various gas molecules is increasingly required for control and monitoring of various industrial or medical processes. There is a strong need for low cost and reliable gas state sensors**.**

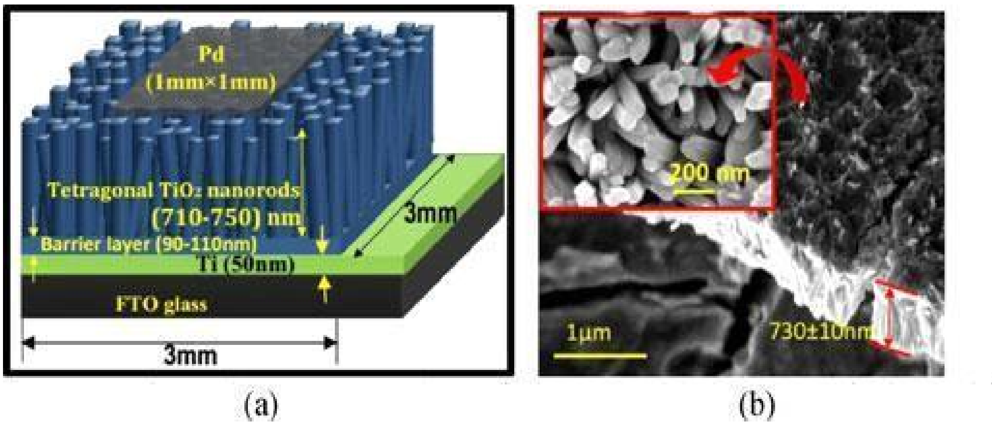


Fig no .1) Schematic Representation of the Capacitive Sensor with Requisite dimension.

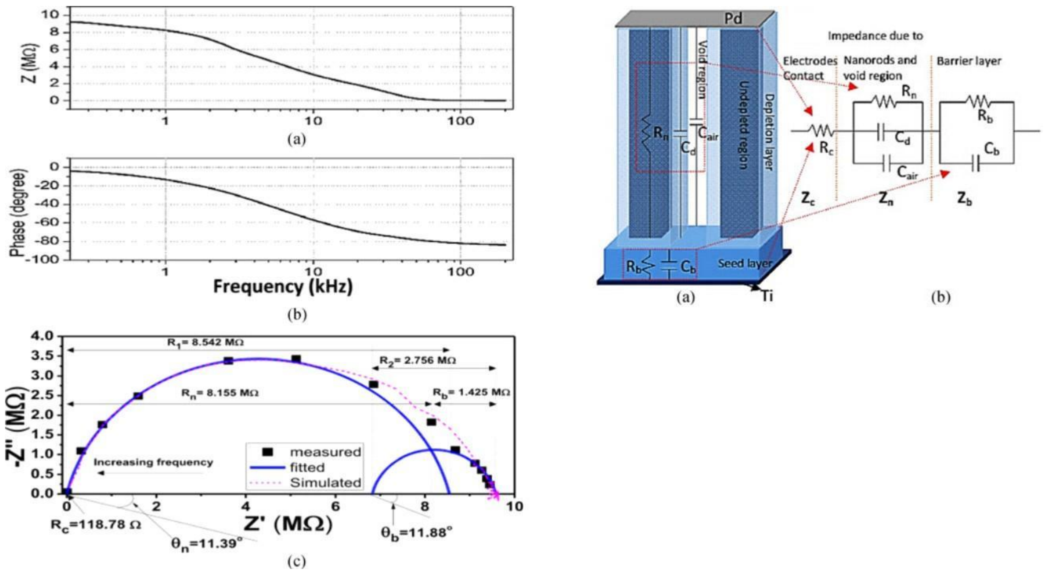


Fig no .2) Cross sectional Representation of the TiO_2 nanorod based capacitive sensor showing impedance contribution from different sections.

Circuit Design Detailing:

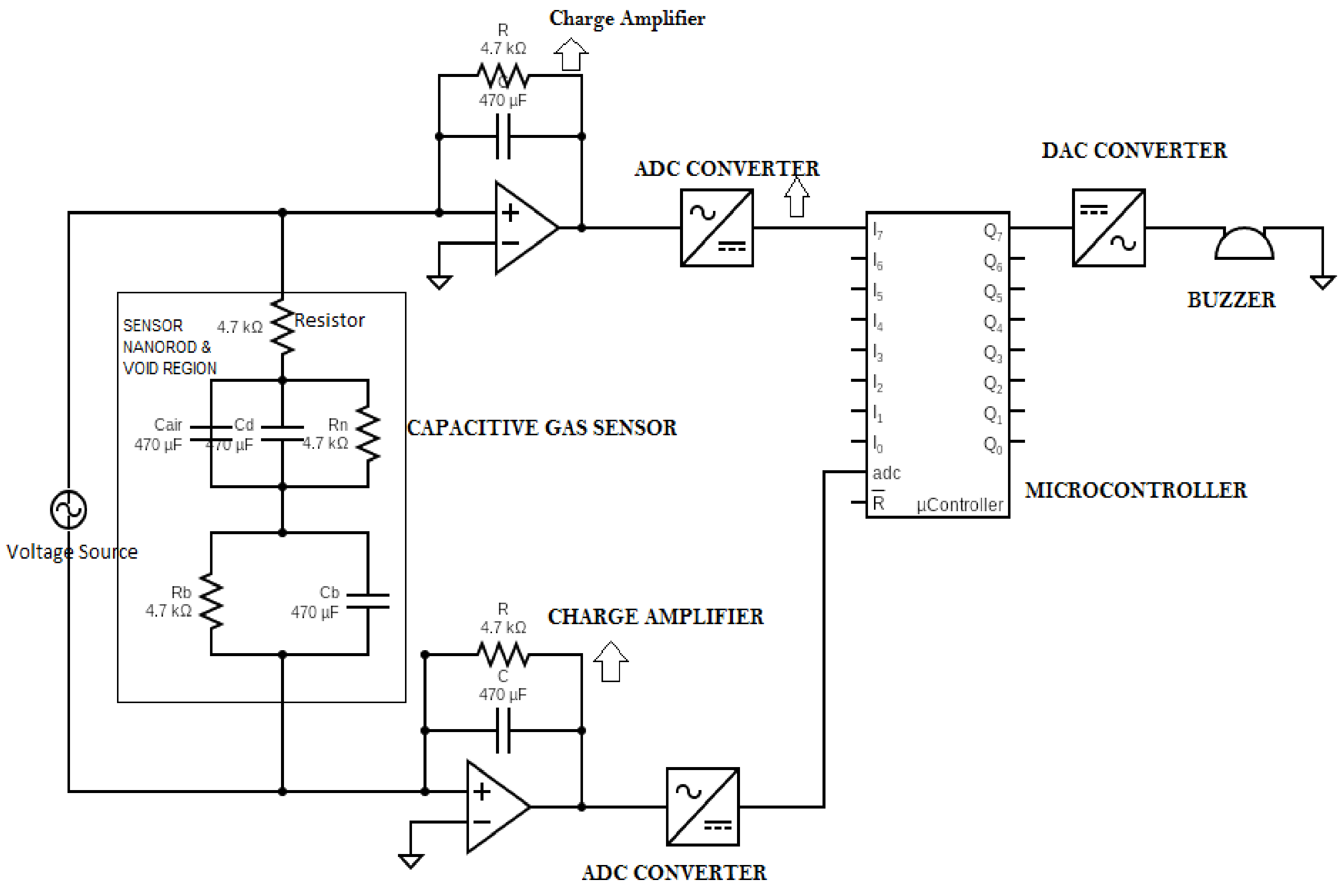


Fig no .3) The circuit design

Capacitive type gas sensors are used to detect the target gases so for are presented. As known, the value of capacitance varies due to variation in any of parameters like area of an electrodes or distance between electrodes or relative permittivity.

First we add an AC source with capacitor and then we add 2 amplifiers for amplification of analog signal value. Then we add 2 analog to digital converters to the microprocessor for the conversion value which we get from amplifiers. Now we add a Digital to Analog converter (to convert digital signal values to analog signal values), then we connect Digital to Analog converter to an alarm or indicator which gives the signal of different gases.

Note:- The capacitor values will lie in some range and the voltage obtained from the microprocessors will give us different colours of indicators for different values of voltage ranges.

Functionality:

- In general, a capacitive structure is composed of a dielectric layer sandwiched between two conductive electrodes. In the case of a gas sensor device, the semiconducting oxide layer is regarded as a leaky dielectric layer with a conductive and insulating path (resistance in parallel with capacitance).
- Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.
- Our vision is how the circuit will work. We are assuming that we have a capacitive gas sensor in our hand and some interfacing circuit will be there to pursue an alarm or buzzer to blow some indication with controlling of microcontroller power.
- Here there is a challenge to control or change the input frequency as well as amplify the output of the capacitance.
- So, to amplify the capacitance we need some amplification due to the presence of the capacitor in feedback loop of charge.
- The changes in frequency due to change in dielectric constant Er, are called resonance frequency.
- When come in void region the volumetric changes are high, but it is confined so then we see effective changes in capacitive gas sensor.
- So imaginary part of impedance is deep or lowest in region that is called resonance frequency.
- Those have low dielectric constant having imaginary part going down slowly.
- So dielectric constant having high value means capacitance of the that gas is high.

Working:

- By Capacitive gas sensor, we get, Methanol, ethanol, 2-propanol detection using a Pd/TiO_2 nanorod array/ Ti device in capacitive mode.
- The input of sensor is determined by two methods.
  - Input voltage (frequency)
  - Gas interaction in sensor of different gaseous same group species.
- The sensor output is capacitance that is indirectly the charge so output of sensor is charge(Q).

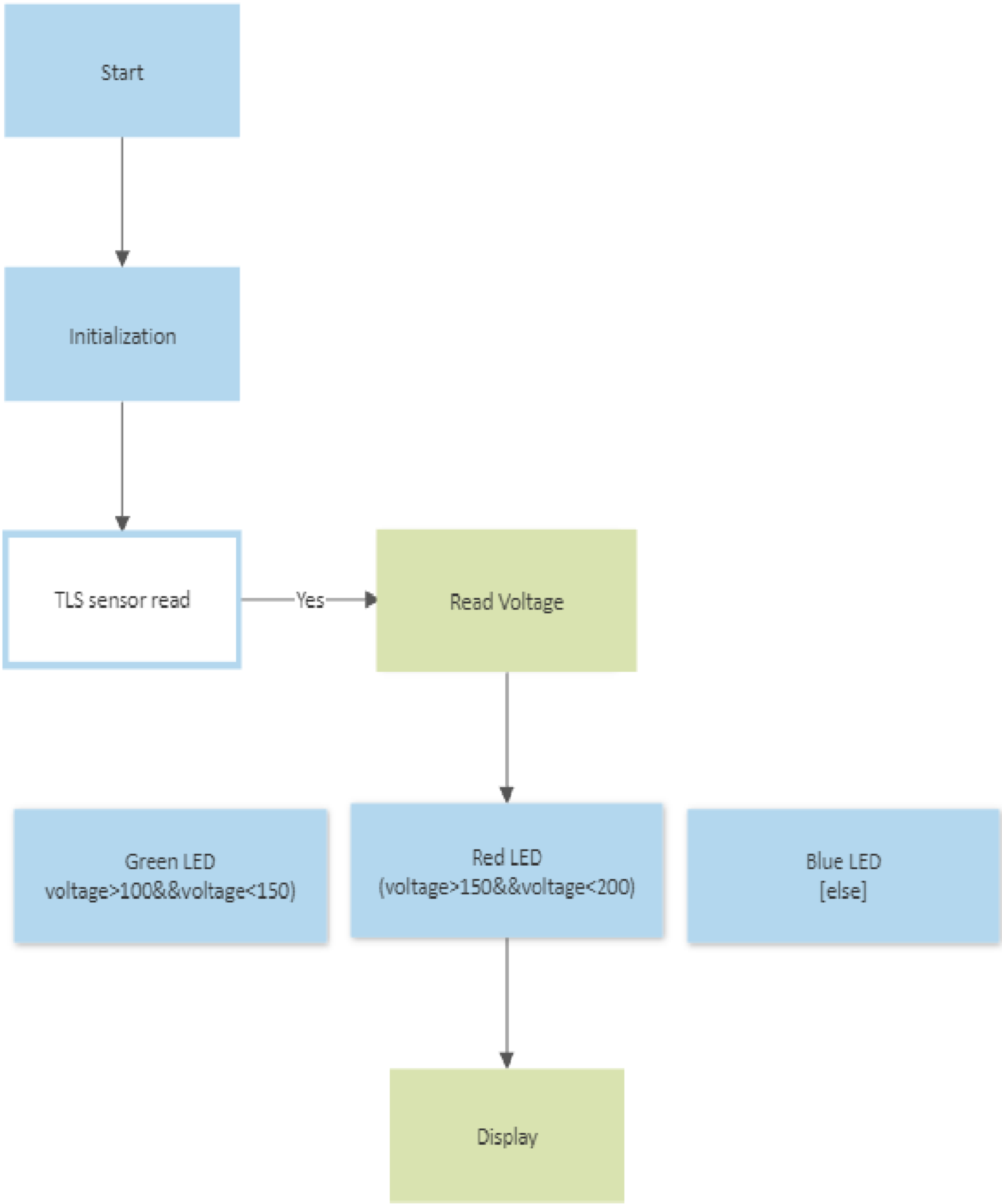
  When we pass through the charge amplifier, we get output in voltage.

  So, the charge amplifier is basically a high gain inverting voltage amplifier with a very high input resistance configured as integrator.
- It converts high -impedance charge input into a usable output voltage.
- It also amplifying analog signal from the sensor which produce charge as output.
- The output voltage we get is convert into digital logic by passing through analog to digital convert.
- Then we get the logical circuit of different gaseous and color by detected through algorithms. And then convert through Digital to analog converter so that we get final value of gaseous signal in indicator.

Procedure & Problems Faced:

- Overall, the design of a signal actuator circuit for a capacitive gas sensor requires careful consideration of the sensor's electrical characteristics, the specific requirements of the application, and the available components and resources for implementing the circuit
- In order to amplify the signal, the circuit uses a combination of operational amplifiers (op-amps), filters, and voltage regulators. The amplified signal can then be used to drive the actuator or to trigger an alarm or warning light.
- After the checking the results, we find that it differentiates the gases and is highly responsive and fast in comparison of resistive sensor
- We also get benefit from the fact that it is easy to install and also covers a small area and is lightweight in comparison to other market products it is basically the first capacitive gases sensor that differentiates methanol propanol and other that segregate the alcohol group species
- We found many difficulties in starting where we diffuse the gases and we rectified many errors in circuit diagram and after doing many types of experiments we finally got the circuit right
- The Final circuit design matches the original design specifications and requirements. Deviations from the original design have occured due to changes in component availability, performance and other unforeseen issues which occurred during testing

Microcontroller Algorithm:



Pseudo Code (The code is written in C):

```
#include <avr/io.h> // Include the AVR IO header file
#include <util/delay.h>

int main(void) {
  DDRB |= 0x07; // Set the PB5 pin as an output PORTB=0x07;
  int voltage = PINA;
  while (1) { // Loop indefinitely if(voltage>100 && voltage<150){ PORTB=0xFE
            // //Green LED on
    _delay_ms(5000) PORTB = 0x07; // LED off
  }
  else if (voltage > 150 && voltage < 200) {
    PORTB = 0xFD                      // Red LED on
        _delay_ms(5000) PORTB = 0x07; // LED off
  }
  else {

    PORTB = 0xFB                      // blue LED on
        _delay_ms(5000) PORTB = 0x07; // LED off
  }

  return 0; // Return success
}
```

Circuit Component Values:

Resistor: 1.2-1.5 Ω.

Capacitor: 470 uF

Charge Amplifier: amplifies a 1.3-mV signal and frequency band of 10Hz to 10kHz.

Microcontroller: Provides a supply voltage of less than 2 V.

ADC: an ADC which converts the analog signal to a 12-bit digital value has a resolution of 12 bits.

DAC: 6-bit DAC will have 64 possible output values; if it has a 3.2 V reference, it will have a resolution (step size) of 50 mV.

Gas Sensor: Sensitivity varies with the gas, but a typical sensor can give a reading in the range 0 to 5 parts per million.

TYPE OF COMPONENT	COMPONENT NAME	VALUE
RESISTORS	R1	220Ω
	R2	2.5Ω
	R3	5Ω
	R4	200Ω
	R5	4Ω
	R6	10Ω
CAPACITORS	C1	4.5 uF
	C2	3.5uF
	C3	5uF
	C4	7uF
	C5	4.3uF
	C6	5uF
	C7	6.8uF

Conclusion:

Capacitive gas sensors are a type of gas sensor that operate based on changes in capacitance caused by the adsorption of gas molecules onto a sensing material. The sensor generates a charge, which is proportional to the amount of gas adsorbed. This charge is then converted into an output voltage that can be measured and used to determine the gas concentration.

The output voltage of a capacitive gas sensor is affected by the feedback capacitance and resistor, which provide DC stability to the circuit and define the lower frequency limit of the amplifier. The feedback resistor also fixes the low frequency gain (A) of the circuit to a fixed, small value, minimizing the impact of input offset voltage on the output offset voltage.

Additionally, it's important to note that input and cable capacitance have no influence on the output signal. Therefore, it's crucial to design the sensor with proper feedback capacitance and resistor values to ensure stable and accurate measurements.

In summary, capacitive gas sensors offer a reliable and sensitive way to detect gas concentrations. Understanding the principles of operation and the impact of circuit components on the output signal can help to design and optimize these sensors for specific applications.

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