Design of Signal Conditioning Circuit for MEMS Based Sensor and it’s Spice Modeling

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Abstract- This paper describes the sensor signal conditioning circuit of MEMS pressure sensor. The sensor control circuit is a key component that converts low level sensor output to useful electronic signal and perform signal conditioning. The proposed circuit is designed using a single stage diff-amp, which is implemented using dual input and single ended output methodology. Sensing is being implemented using a Wheatstone bridge principle.

Index: MEMS, Sensor, Actuator, Tanner EDA.

1. Introduction

Micro-Electro-Mechanical Systems (MEMS) sensors have received a great interest in recent years because of their potential to precisely measure physical variables in various applications. This, along with their low cost, small foot print, superior reliability, and possibility of integration into an array for multiplexed measurements have made the MEMS sensors a good candidate for future in sensing applications. MEMS is constructed to achieve a certain engineering functions by electromechanical or electrochemical means. The core element in MEMS generally consists of two principal components: a sensing or actuating element and a signal transduction unit. Micro-electromechanical system (MEMS) design is a unique engineering challenge as it is a multidisciplinary subject. MEMS are miniature versions of traditional electrical and mechanical devices, such as valves, pressure sensors, hinged mirrors, gears etc. The principle of sensor work is in variety of physical phenomenon are piezoresistive, capacitance, resonance, piezoelectric, pyroelectric, thermoelectric principle. In a structural simulation, the FEM is very effective in producing the visualized stiffness, the strength and also in the mathematical minimization of the weight, the materials and the costs. FEM expresses the visualization details of where the structures deform or twist, and indicates the distribution of stresses and the displacements. Presently dedicated FEM analysis software packages like ANSYS, COMSOL, Conventorware etc.

The compatibility between IC fabrication processes and micro-sensor design provides new opportunities for very good integration of sensing elements and electronic components [1]. This opportunity has lead to a trend towards miniaturizing and combining Micro-Electro-Mechanical Systems (MEMS) and associated interfaces, signal processing and networking [2-5]. So, the sensor interface circuit is a key component that converts low-level sensor outputs to useful electronic signal, performs signal conditioning, and provides communication to a microsystem controller.

Our research is focused on signal conditioning of MEMS pressure sensor. The sensor interface circuit is a key component that converts low-level sensor outputs to useful electronic signal, performs signal conditioning, and provides communication to a microsystem controller. We have developed a circuit to amplify the voltage output of a MEMS.

2. Pressure Sensor

The piezoresistive pressure sensor elements consist of a silicon chip with an etched diaphragm and, a glass base anodically bonded to the silicon at the wafer level. The front side of the chip contains four ion-implanted resistors in a Wheatstone bridge configuration. The resistors are located on the silicon membrane and metal paths provide electrical connections. When a pressure is applied, the membrane deflects, the piezoresistive effect causes a unbalancing in the bridge. Then a voltage develops proportional to the applied pressure. Silicon piezoresistive sensors have been widely used for industrial and biomedical electronics. The piezoresistive sensors have excellent electrical and mechanical stability that can be fabricated in a very small size. Thermal effect in integrated piezoresistive MEMS pressure sensor may be a problem of concerning in design for a application requiring high
precision measurement and in continuously monitoring array of sensor network.

The Pressure gauge used for conversion of displacement into the corresponding pressure. The amount of displacement is an indirect method to measure the pressure. In this paper SPICE model of pressure sensor is implemented using T-SPICE.

Fig. 1: Basic Block diagram of the system

3. Interface Circuit for Sensor

Sensor devices always need signal conditioners to modify their output for required signal processing, transmission, display, or recording. Signal conditioning involves amplification, level shifting, filtering, impedance matching, modulation, demodulation, isolation, and other functions[6]. Modulating sensors also need a voltage or current supply or bias. These circuits are very important for the performance of the sensors. The development of electronic circuits performing those functions are important not only for a better system performance but also for sensor structure, leading to the so-called smart sensors, which integrate sensing and processing.

The full load output voltage of any piezo-resistive MEMS based sensors, is in the range of millivolts, and may suffer difficult to measure small changes in resistance. A basic signal conditioning circuit to amplify this voltage signal is shown in Fig. 3. Fig 4 shows the block diagram of the configurable sensor signal conditioning circuit. It includes sensor, bridge and single ended differential amplifier working as amplifier.

Fig. 2: Cross Sectional View of the Sensor.

Fig. 3: Signal Conditioning Circuit
4. Working principle of the circuit

Proposed signal conditioning circuit is shown in this Fig.3. The proposed circuit is designed using a single stage op-amp, which is implemented using dual input and single ended output methodology. Sensing is being implemented using a whiskon bridge principle. In the proposed circuit the sensor is placed on one of the four arms of the bridge. Due to imbalance in the bridge caused by the pressure incident on the sensor there will be a error voltage. This error voltage is the output of the sensor.

Fig. 5: Input and output response of signal conditioning circuit

Conditioning of this signal is required because it is of the order of 2-3 mV. Output error voltage of the bridge will be applied to the single stage op-amp which will be amplified by the order of 10 times in each stage. So if we want a final output voltage of the order of volt we need to use three stages of the proposed circuit. Gain can be controlled by changing the DC input bias of the Op-amp.

The lower graph is for pressure versus voltage and upper one show the response of the signal conditioning circuit. From Fig.3 it is obvious that the circuit is having a linear response for a wide range of voltage, which will be helpful in implementing a sensor system for a wide dynamic range.

5. Conclusions

A configurable signal conditioning circuit for readout of capacitive, resistive, voltage, and current output sensors has been presented. The circuit provides multi-stages of amplification of inputs and features high gain.

6. References


