Design of an On Chip Read-out Circuit for Piezo-Resistive MEMS Pressure Sensor

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Abstract: The proposed read-out circuit has a traditional two stage Operational amplifier (op-amp), a Gilbert cell and a Difference amplifier. The sensitivity of the sensor, known as primary with pressure variation can be increased with the help of an additional sensor, which act as a reference sensor. Here, we have used a current bias to increase the sensitivity. The current through both the sensors are controlled by a composite resistor and an op-amp having 70db PSRR. The advantage of using composite resistor is its immunity to process variation as well as stabilization of current sourced into the sensors. The simulation of the sensor along with the read out bias circuit is performed in cadence environment with AMS (Austria Microsystems) 0.35 µm technology design kit. The simulation for in-house fabricated MEMS pressure sensor is done by macro-modeling. The simulated output of the read-out circuit along with the macro model of sensor is showing almost rail-to rail output swing (around 3 V for a 3.3 V supply). The total power dissipation (including the sensor) is less than 10 mW for a 3 mA bias current. The total area occupied by the readout circuit is less than 0.04 mm^2. MEMS pressure sensor was fabricated by SNG group of CEERI, fabricated sensor occupies 0.14 mm^2 of area.

Motivation: A piezo-resistive pressure sensor consists of four poly resistors connected as wheat-stone bridge, fabricated on a flexible diaphragm [1]. Depending on the input bias, sensor can be classified into two categories - voltage biased and current biased. Various architectures have been proposed using voltage bias [2,3] but scaling of on-chip supply voltage with technology miniaturization is creating a major challenge for efficient operation[4]. So the current bias is an efficient alternate as technology scaling does not pose a major limitation on current source performance [5]. Till now current source based bias circuits using mirrors have been proposed [6]. All these circuits source current depending on the aspect ratio of the mirror transistor. The matching of mirror transistors plays a vital role in overall performance of the bias circuit. In the proposed design current in the bridge is controlled by a process independent [7] composite poly resistor and an op-amp. Differential output voltage of sensor is compared with that of reference sensor by a Gilbert cell and the final output is collected through a difference amplifier.

Results: A prototype of the fabricated pressure sensor and its response is shown in fig-1 and fig-2. As shown in fig-4, modified Gilbert cell is used to track the sensor output. Thus, a large dynamic input range is essential. This can be achieved by decreasing gain, which increases band-width. The dominant pole is at a high frequency (order of MHz) i.e. all variations of sensor are transferred to the difference amplifier without attenuation. Difference amplifier is composed of op-amp and poly resistor. Op-amp used is a traditional two stage miller compensated amplifier. A similar op-amp is also used in the current source shown in fig-3. Current I_{EX} is controlled by a composite resistor R_{COMP}[7]. Pressure is varied from 0 to 20 PSI, amplified output is shown in fig-5. Fig-5 is showing a highly linear output voltage variation with pressure. Amplified voltage is well suited for subsequent ADC for further signal processing. Further amplification can be done by increasing the gain of amplifier. Modified gilbert cell has substituted two parallel differential amplifiers efficiently. Hence, additional control signals necessary for controlling two parallel differential amplifiers have been removed. Pressure is sensed by four symmetrically placed poly resistor. Variation of four poly resistors with temperature is shown in fig-6. Due to the symmetrical placement, variation of difference voltage at the output terminal of wheat-stone bridge is almost negligible. Complete circuit is simulated using 0.35µm AMS technology. The total power dissipation (including the sensor) is less than 10 mW for a 3 mA of bias current. The total area occupied by the readout circuit is less than 0.04 mm^2. Area of fabricated pressure sensor is 0.14 mm^2.

Reference:

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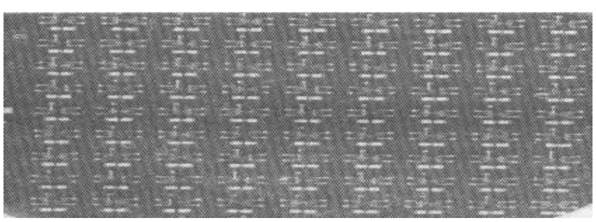

Fig. 1. Fabricated pressure sensor

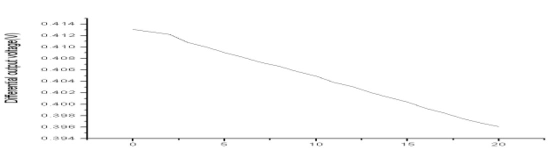

Fig. 2. Response of pressure sensor

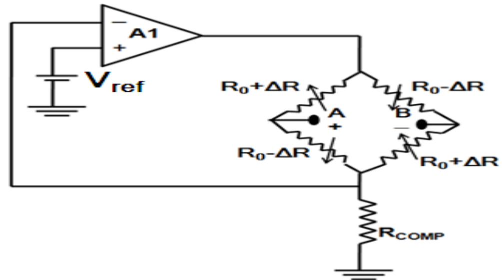

Fig.3. Current bias circuit of pressure sensor

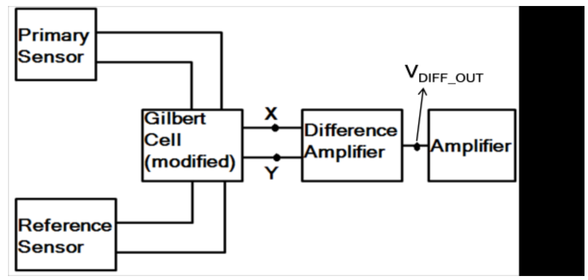

Fig.4. Block diagram of complete circuit

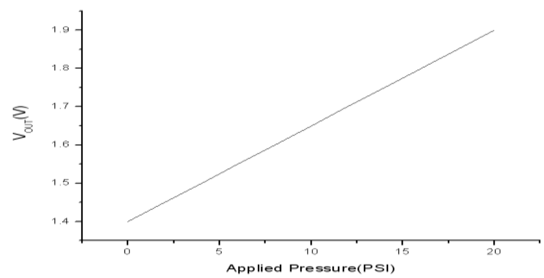

Fig.5.Amplified output of pressure sensor

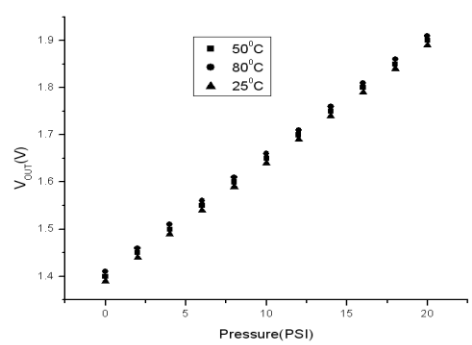

Fig.6.Amplified output of pressure sensor

(sensor at different temperatures)