Pressure MEMS Sensor and Readout Circuit for Arteries Stent

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Abstract

This paper presents a blood pressure (BP) sensing system. In modern medicine, a lot of people are suffered by Cardiovascular disease like hypertension and heart disease. A pressure sensor and nearby hospital calling service can reduce mortality of patients. Design using 180-nm CMOS MEMS process, the BP sensing system is consisted of a micro-electro-mechanical systems (MEMS) capacitive sensor, capacitor-to-voltage converter (CVC) and a switched-capacitor amplifier. The MEMS capacitive sensor has a simulated sensitivity of 0.55 fF/mmHg with a sensing range of 0-300 mmHg. The overall system has a simulated conversion gain of 0.643 mV/mmHg.

Key words: MEMS, pressure sensor, CMOS, arteries stent.

Introduction

The purpose of this research is to estimate the trend of blood stent pressure of surgical patients. Blood pressure (BP) is the pressure exerted by circulating blood upon the walls of blood vessels [1]. Blood pressure is usually expressed in terms of the systolic (maximum) pressure over diastolic (minimum) pressure and is measured in millimeters of mercury (mm Hg). There are two major ways to measure blood pressure during medical treatment: invasive and noninvasive methods. Invasive and noninvasive methods have their advantages and disadvantages. The noninvasive auscultatory and oscillometric measurements are simpler and quicker than invasive measurements, require less expertise, have virtually no complications, are less unpleasant and less painful for the patient. However, noninvasive methods may yield somewhat lower accuracy and small systematic differences in numerical results. The invasive system is that pressure is constantly monitored beat-by-beat, and a waveform (a graph of pressure against time) can be displayed. It is used for surgical operations, and it can response the true situation of arterial blood pressure. In this work, a pressure MEMS sensor and readout circuit for arteries stent is proposed for capturing the signal (blood pressure signal) if signal was unusual, it can send message to neighboring hospitals. On patient to ensure the patient can anytime be observed, and they can do they want to do, instead of lying on the bed to allow doctors to collect information.

System Architecture

CMOS micro-electric-mechanical system (MEMS) technology is used to fabricate a monolithically integrated pressure sensor [2]. In this paper, a CMOS-MEMS implemented pressure sensor is designed for blood pressure monitoring. Due to the small device size, a high sensitivity is expected. Otherwise, a readout circuit consisted of a CMOS capacitance-to-voltage converter (CVC) and a switched-capacitor amplifier is designed to cooperate with the CMOS-MEMS implemented pressure sensor.

Implemented by CMOS-MEMS technology, a parallel-plate capacitor with two conducting plates separated by a dielectric is adopted for high performance capacitive sensing. Upside plate of the capacitor will be moved by the blood stent pressure which results in a changing of the distance between the parallel plates. Consequently, the capacitance of the parallel-plate capacitor changes. The readout circuit converts the capacitance of the CMOS-MEMS implemented parallel-plate capacitor into an output voltage. The voltage signal we get can be used to be further processed by other backend circuit. The CMOS-MEMS capacitive sensor has a simulated sensitivity of 0.55 fF/mmHg with a sensing range of 0-300 mmHg. The overall system has a simulated conversion gain of 0.643 mV/mmHg. The power dissipation of the whole circuit is 6.46 uW.

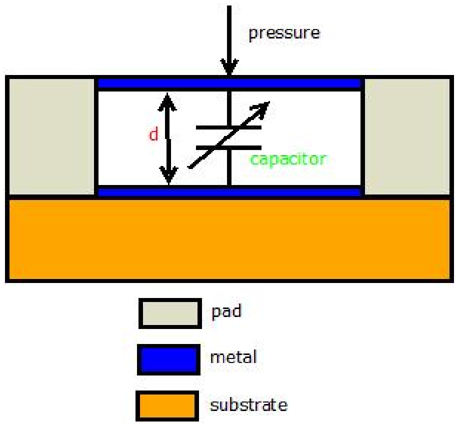

Fig. 1 MEMS capacitive sensor structure.

Circuit Design

A. MEMS Sensor Design

As shown in Fig. 1, the MEMS capacitive sensor is composed of parallel electrode plates with one fixed plate and the other plate is a movable conductive membrane which will has a Z-axis displacement under different pressure. The

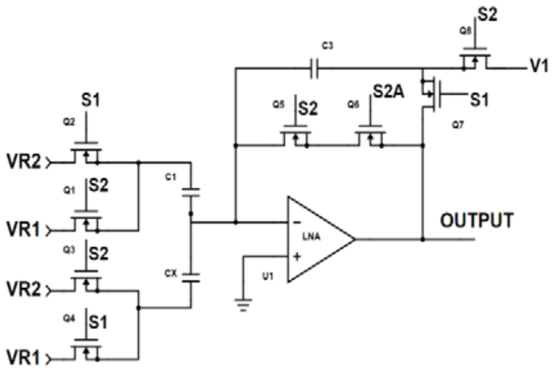

Fig. 2 Schematics of CVC circuit.

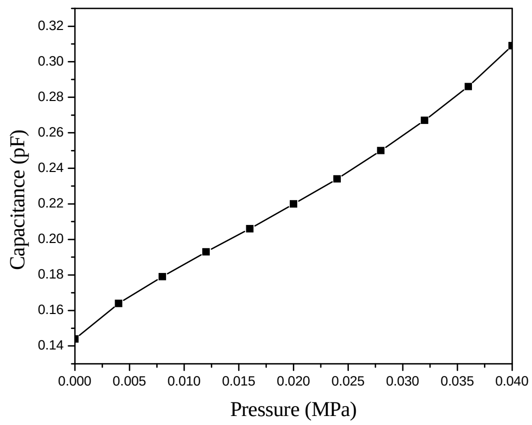

Fig. 3 Simulated output capacitance v.s. pressure.

deflection of membrane occurs over a micro-fabricated cavity. Boding pads are connected to the two electrode plates for supporting the entire structure.

Capacitance of the two electrode plates can be changed by the pressure acting on the top electrode membrane, as:

$$C = \varepsilon \frac{A}{d} \tag{1}$$

where the A and d are area of the parallel electrode plates and distance between the two electrode plates, respectively.

B. Readout Circuit Design

The readout circuit is consisted of a capacitance-to-voltage converter (CVC) and a switched-capacitor amplifier. The schematics of the CVC is shown in Fig. 2. The CVC transfers the sensed capacitance of the MEMS capacitive sensor to an electronic signal. The VR1 and VR2 are connected to 0 V and 1.8 V (VDD), respectively. S1 and S2 are the non-overlapped clocks. S2A with a time delay to the S2 is used to cancel the noise of the OP-Amp of the . When the S2 is turned on, the C_x has been charged to:

$$Q_{in\,1} = C_x \cdot VR\ 2 \tag{2}$$

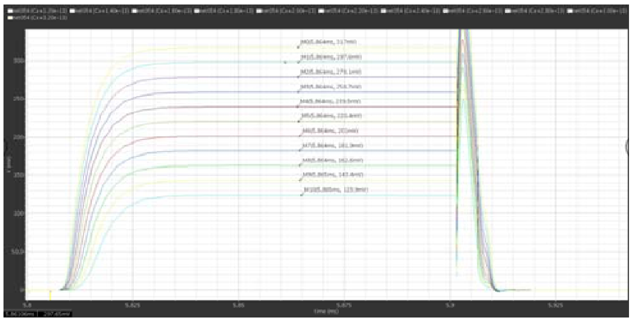

Fig. 4 Simulated output voltage under the pressure varies from 0 MPa to 0.04 MPa.

Then the S1 is turned on, the C1 has been charged. At the same time, the charge stored in C_x is transferred to C3. Therefore, output voltage of the CVC circuit is:

$$Q_{in\,2} = C_1 \cdot VR\ 2 \tag{3}$$

$$V_{out} = \frac{(C_x - C_1) \cdot VR\ 2}{C_3} \tag{4}$$

Finally, an amplifier with a gain of 20 dB is used to amplify the output voltage of the CVC circuit.

Simulated Result

The simulated output capacitance of the MEMS capacitive sensor under different pressure is shown in Fig. 3. The simulated output capacitance varies from 0.144 pF to 0.309 pF under the pressure varies from 0 MPa (0 mmHg) to 0.04 MPa (300 mmHg). As shown in Fig. 4, the simulated output voltage of the readout circuit is from 123.9 mV to 317 mV as the pressure varies from 0 MPa (0 mmHg) to 0.04 MPa (300 mmHg).

Conclusion

A blood pressure (BP) sensing system consisted by a MEMS capacitive sensor, a capacitance-to-voltage converter and a switched-capacitor amplifier was presented in this paper. Designed in 180-nm CMOS-MEMS process, the MEMS capacitive sensor has a simulated sensitivity of 0.55 fF/mmHg with a sensing range of 0-300 mmHg. The overall system achieves a simulated conversion gain of 0.643 mV/mmHg.

References

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