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Research of Silicon MEMS Pressure Transducers Crystals for Robotics and Tactile Diagnostics Devices

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Abstract: Owing to rapidly developing methods of minimally invasive surgery a new class of devices appeared. These devices are known as tactile sensors for remote palpation. They give a possibility to the surgeon not to enter into direct contact with the internal organs of the patient and obtain tactile data. The article presents the circuitry design of a silicon crystal matrix of piezoresistive pressure sensing elements MIPD-32 for tactile diagnostics devices. The crystal is manufactured by means of combination of MEMS and CMOS technologies. The research results of the characteristics of the crystals are shown.

Key words: Minimally Invasive Surgery (MIS), MEMS, tactile sensor, pressure, diagnostic

INTRODUCTION

The presence of tactile features in technical solutions is becoming popular in many application areas. So, in the field of medicine the direction of mechanoreceptor tactile diagnostics is actively developing (Dahiya and Valle, 2013). One of the main methods of clinical examination of the patients the palpation is often not applicable to modern minimally invasive methods of surgical intervention which are carried out through the local sections. Tactile function is needed for robotic manipulators, working with soft or fragile objects and substances. In addition, the ability to recognize surface textures allows the creation of a new generation of prostheses.

MATERIALS AND METHODS

Theoretical part: The main trend in the creation of tactile sensors is to reproduce haptic properties of human skin. Tactile devices of matrix type meet this condition in the best way because each cell in the matrix which is a microelectronic pressure sensor, provides specific information and together the cells form a holistic view of the form of the object (Amelichev *et al*., 2012).

Based on many years of experience (Gusev *et al*., 2015; Sadovnichii *et al*., 2012) in the creation of tactile transducers in SPC “Technological Center” MIPD-32 crystal was developed. The crystal is manufactured according to the technology of silicon bulk micromachining. The crystal is a matrix of 32 pressure sensitive elements with a membrane thicknessc of 17±3 μm (Gusev *et al*., 2015). Sensitive elements of the matrix use tensoelectrical effect that occurs in silicon under external mechanical impact and are designed for use in the pressure range 0÷100 kPa. The pressure impacts the lower side of the crystal. The average value of the pressure sensitivity is 0.1 mV/[VkPa]. The dimensions of the crystal are 6.85×6.85 mm.

In addition to the 32 pressure sensitive elements temperature sensor for temperature compensation is integrated in the crystal (Fig.1). Each sensing element is sequentially polled using the 33-bit shift register with static synchronous D-triggers, clocked by the signal level, and flow keys on complementary transistors. Pass keys and register are integrated directly into the MIPD-32 crystal which means the combination of MEMS and CMOS technologies on a single chip.

RESULTS AND DISCUSSION

Figure 2 shows the graph of the current consumption in static mode from the supply voltage. Crystal is able to operate at standard voltages +3.3 and +5 V which significantly expands the scope of its application .

To ensure greater reliability of crystal models made in the framework of the research, crystals have one metallization layer for routing signal wires. Polysilicon conductors are used at the intersections which increase the resistance magnitude of the signal circuits (Table 1).

In direct series connection of two crystals with supply voltage +3.3 V voltage at the second crystal will be equal to:

$$V_{cc2} = V_{cc} - I_{?}(R_{Vcc} + R_{GND})3.3 - 19 \cdot 10^{-3}(8.1 + 24.0) \cong 2.713 \quad (1)$$

Table 1: MIPD-32 signal circuit resistance

Circuit	Resistance (Ω)
V_{cc} (supply voltage)	8.1
GND	24.0

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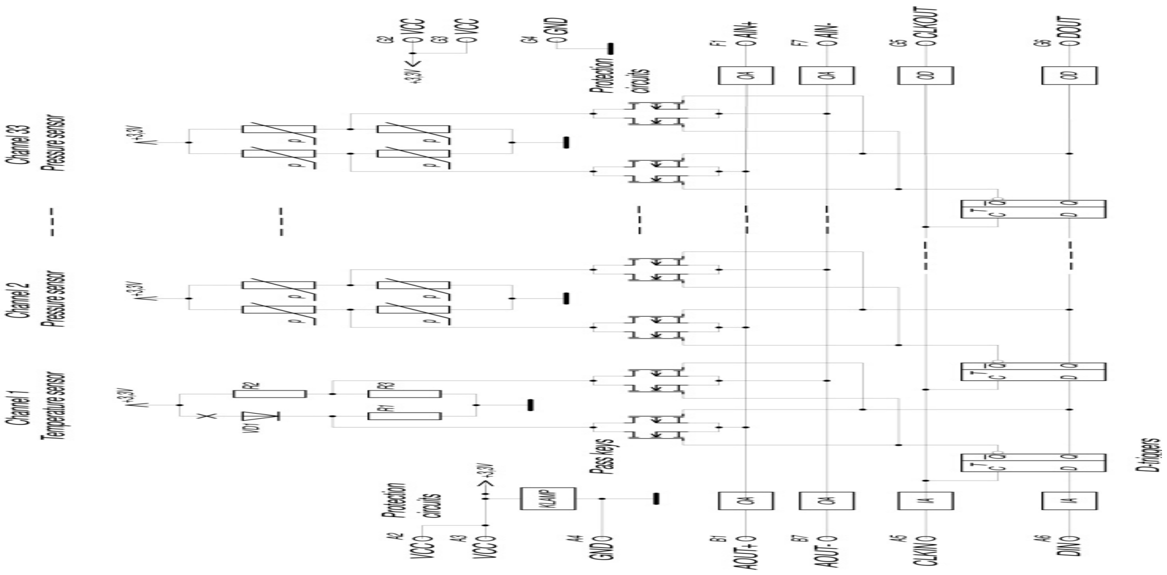

Fig. 1: Circuitry of MIPD-32 crystal

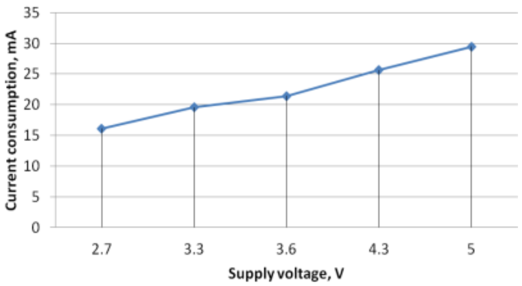

Fig. 2: MIPD-32 current consumption

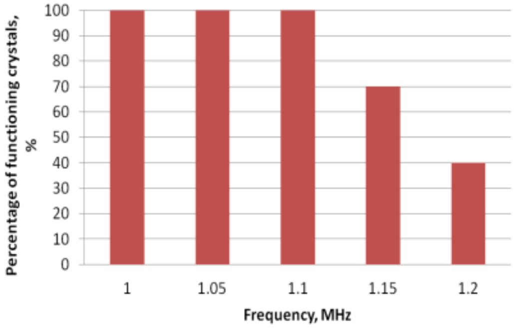

Fig. 3: Percentage of functioning crystals depending on operating frequency

what is the operating voltage for the MIPD-32 crystal. Direct connection, bypassing the conductors on the circuit board, allows to achieve higher density by combining multiple crystals into a single device.

To determine the maximum operating frequency to the input DIN of the crystal bit stream data was supplied (33 digits by the number of channels in the crystal). By the presence of distortions of signal at the output DOUT at a given frequency the proportion of functioning crystals was determined (Fig. 3).

According to the study of the passage of the digital signal, the maximum operating frequency of the crystals is 1.1 MHz. In normal mode the crystal operates at 100 KHz. As a result there is a tenfold frequency reserve.

CONCLUSION

The developed silicon crystal MIPD-32 can be used in haptic diagnostic devices as a sensor for obtaining tactile information. During the research it was established that the crystal was able to operate at standard voltages +3.3 and +5 V. Also, there is a possibility to connect two crystals directly to minimize the size of the final device. A tenfold frequency reserve reflects the reliability of the device, operating in normal mode.

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