A novel hybrid integrated system for capacitive pressure MEMS sensors

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Abstract:
The paper deals with a novel hybrid integrated system for capacitive pressure MEMS sensors. This system should be splitted into the two parts. One is novel integrated capacity-to-current converter (C/I) and the second is auxiliary part made from standard SMD devices. The C/I converter was designed in CMOS process with technology AMIS 0,7 um. The second part consists of the sigma-delta converter, microcontroller, communication and data bus.
The designed system profits from the previous works, where the capacity-to-digital output converter AD 7745 is the main part of the processing stage. This converter is substituted by the novel C/I converter. The C/I converter with digital calibration handled in microcontroller provide almost the same accuracy and linearity as the mentioned AD 7745 converter, but with less complexity of the whole circuitries.

INTRODUCTION

The basic aim of the project was to design and fabricate the processing circuitries, which will be able to measure and process the capacitance MEMS sensor readout with high accuracy. Another task was the low power consumption of the whole system [1, 2, 3].

DESIGN OF THE MEASUREMENT SYSTEM

As has been mentioned the measurement system should be splitted into the two parts. One is simple integrated circuit, which works as C/I converter and it substitutes AD 7745 converter and second are the auxiliary stages (microcontroller, communication part). The block scheme of the proposed system is depicted in Fig. 1.

The microcontroller has been selected upon wide comparing study. The Tab. 1 shows comparison of the most important features demanded from microcontroller. The key feature is power consumption in active and sleep mode. That is why the ATMEGA 16 microcontroller was choosed as suitable stage.

The input/output signals of the whole system correspond with I2C communication standard. Since the analog output should be current, the current loop of 4 – 20 mA was designed.

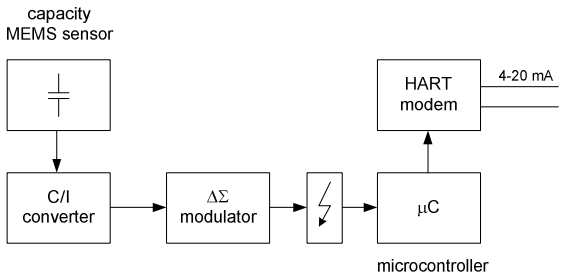

Fig. 1: The block scheme of the designed integrated hybrid system

Tab. 1: The comparison of the most important feature sof the microcontroller

Power Save Current Consumption with 32 kHz Running

Device	Typical 2.2V @25°C	Maximum 2.2V @85°C	Comment
MSP430F435	1.1 uA	6 uA	With zero power BOR
MSP430F2131	0.8 uA	2.3 uA	With zero power BOR
ATmega165P	0.65 uA	NA	With Sleeping BOD

Power Down Current Consumption

Device	Typical 3.0V/5.0V @25°C	Maximum 3.0V/5.0V @85°C	Comment
78KO/Kx2 5.0V	NA / 1 uA	NA / 20 uA	3.0V numbers not available
R8C/tiny 3.0/5.0V	0.7 uA/ 0.8 uA	3 uA/ 3 uA	
MSP430F4xxx	0.1 uA / NA	3.5 uA/ NA	Max 3.6V Vcc
MSP430F2xxx	0.1 uA / NA	1.9 uA/ NA	Max 3.6V Vcc
ATmega165P	0.1 uA / 0.6 uA	2 uA/ NA	5.0V numbers not available

The C/I converter

The novel part of the presented system is integrated stage. It is utilized for capacity measurement and it works as capacity-to-current converter. This stage is depicted in Fig. 2.

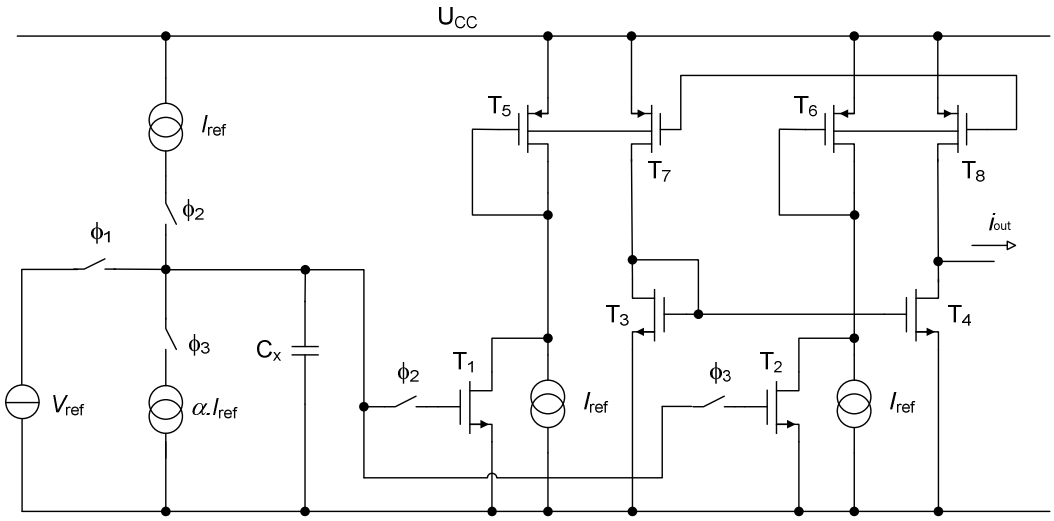

Fig. 2: The C/I converter scheme

The principle of the function should be devided into the three phases. During the first phase Φ1 the measured capacity Cx is charged by voltage reference source Vref. In second phase Φ2 this capacity is charged by current reference source Iref. Thanks to this fact the voltage increases on the measured capacity. This voltage is connected through the switch with the gate of the T1 transistor. When Vg < Vth, then the transistors T5 and T7 on this gate works as current mirror. This current mirror is mirroring the reference current Iref2, which flows into the transistor T3 drain. The transistors T3 and T4 form another current mirror, which mirrors the current I1 into the output. During last phase Φ3 the measured capacity is discharged by means of the current α.Iref. The voltage is connected with transistor T2 gate, which has the same function as T1. The current I2 is generated at the end of the phase Φ3. The result is difference of the currents I1-I2. This difference is available during next phase Φ1-2, when the measured capacity is charged on the reference voltage level. The Fig. 3 shows currents in important nodes of the circuit.

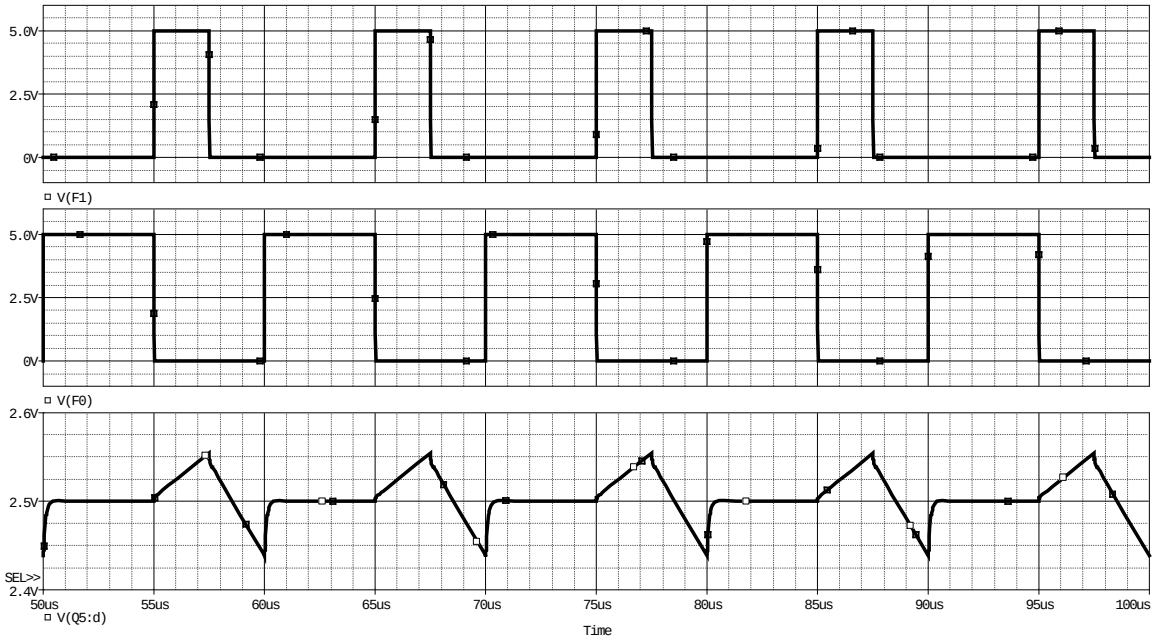

Fig. 3: The currents which flows through important nodes of the C/I stage

The output current dependency on the various values of the measured capacity is shown in Fig. 4. The Fig. 5 shows transfer characteristic of the designed C/I converter. The transfer characteristic is derived from characteristics of the transistors T2 and T4. This couple of the transistors should satisfy matching request to prevent the offset error. The matching demand must be satisfied also with transistors T5 and T8.

The calibration is calculated in microcontroller using 3rd polynomial, which is described by formula 0.0041x3-0.5038x2+21.126x-355.52. The accuracy of this polynomial equation is 99.94 %.

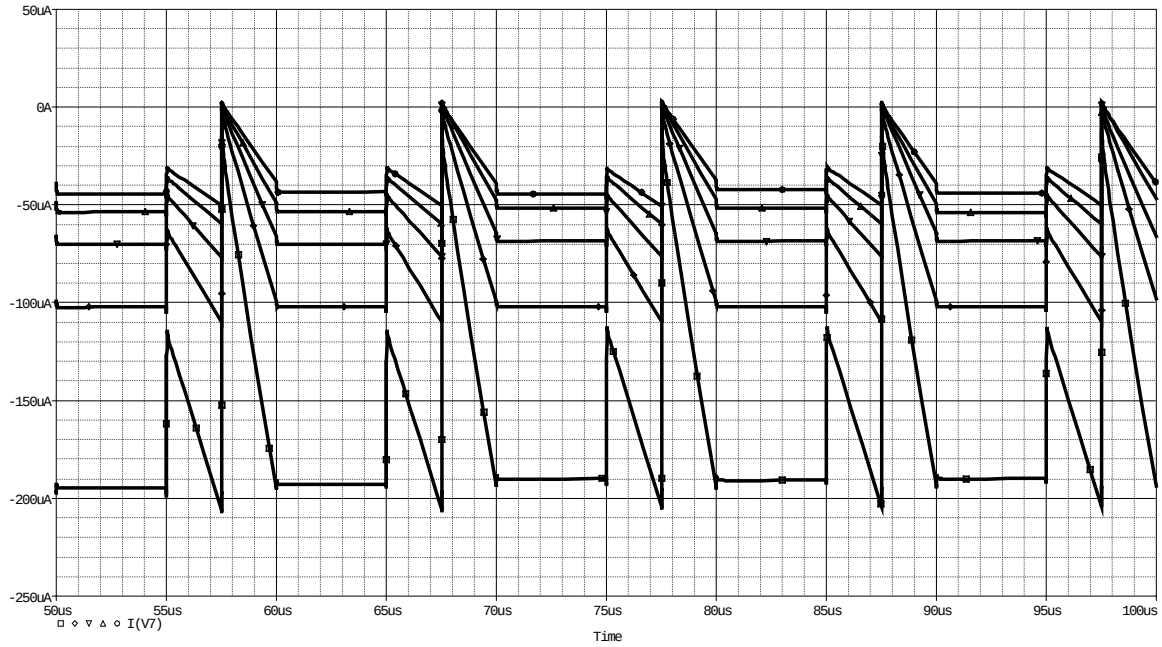

Fig. 4: The current dependency on the various values of the measured capacity

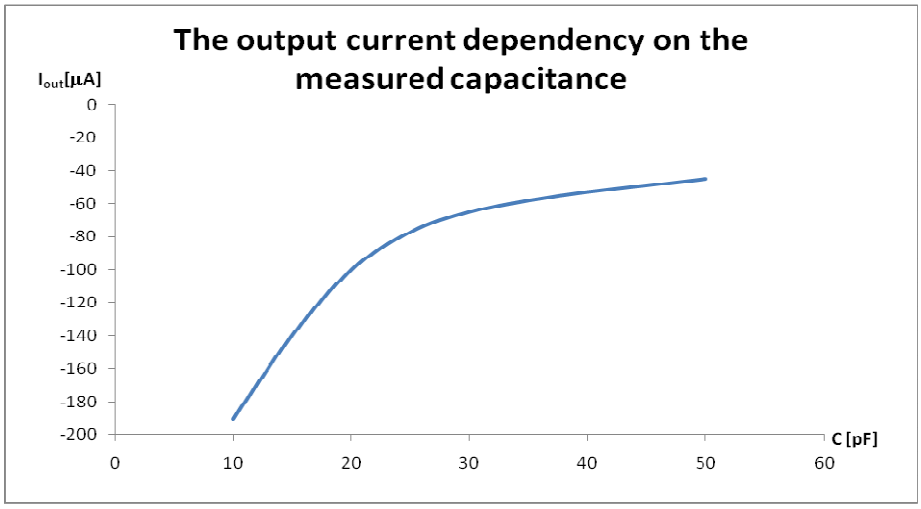

Fig. 5: The transfer characteristic of the C/I converter

CONCLUSIONS

The article shows new possibilities of the sensor signal processing. The hybrid integrated circuit is intended for MEMS based capacity sensors. Now, the layout of the CMOS part is almost finished, after the fabrication the very first test results will proceed with the whole measurement system.

ACKNOWLEDGMENTS

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