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Printed Capacitance-Voltage-Converter

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Abstract
The focus of this paper is a printed Capacitive-Voltage (CV)-
converter, which is integrated on an acceleration sensor unit. Both
parts sensor and electronic are produced by printing on the same
substrate by using polymer-electronic materials. The simulated and
measured characteristics of the CV-converter are discussed in
comparison to the FET device parameters.

1. Introduction
Many efforts are undertaken to print RFID-tags [1]. The goal
of it is to use printing and other roll-to-roll technologies to
produce devices in the lower cent region. On the other side,
there are efforts to make the devices smarter by adding of
sensors on the tag [2]. But both ambitions could only result in
a low price, if for both parts, sensor and electronic, are used
the same technologies and materials.
Our approach is to create capacitive acceleration sensor and a
capacitive-voltage-converter (CV-converter) by polymer-
electronically materials and printing technologies. It should
be one module of a tool box to design smart printed RFID-
tags.

2. Sensor Approach
A new sacrificial layer technology allows producing
freestanding polymer structures. As substrate a printed circuit
board is used with solder resist as spacer. The sacrificial layer
is a saturated hydrocarbon (cyclododecan). The cavity
between the spacer is filled up with the cyclododecan. The
technology is shown in Figure 1.

Figure 1. Schematics of a complete printed RFID with acceleration sensor

The displacement of the sensor membrane in z-direction by
1g changes the capacity of the sensor. The sensitivity of
about 0.8 pF/g will be detected with the printed CV-converter.

3. CV-Converter
To convert the sensor capacity to an analog output voltage a
CV-converter structure is chosen, which contains as less as
possible active devices. This makes sure, that the CV-
converter is printable, with an acceptable yield.
Figure 4 shows the CV-converter, which is powered by an external generator and convert the capacity difference (C1ext-C1ext) into a analog output voltage UA.

\[ U_A = 2 \pi f \cdot R_{int} \cdot U_E \cdot (C_{1ext} - C_{2ext}) \]

Furthermore the RC-member with Cin and Rint is smoothing the ripple of the output voltage. To realize the CV-converter the diodes are produced by organic field effect transistors (OFET).

Advantages and disadvantages of the use of OFETs as diode are shown in [5]. In our case the gate capacities is the important parameter, because the drain-gate-capacity shortens the drain-source path of the OFET, in case the capacity is much larger than the sensor capacities C1ext.

3.1. OFET
OFETs are realized by top gate architecture. The drain-source-structures are ink-jet printed with PEDOT:PSS on PA-substrate. The organic semiconductor is also ink-jetted. Afterwards a double layer insulator (high/low-k) is screen printed. The gate is realized by carbon black with the same technology. Figure 6 shows the transfer and output characteristic of the OFET.

Table 1. Geometry parameter of the OFET-structures

<table>
<thead>
<tr>
<th>Channel Width</th>
<th>Channel Length</th>
<th>Specific Gate-Capacity</th>
</tr>
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<tbody>
<tr>
<td>120 ( \mu )m</td>
<td>18000 ( \mu )m</td>
<td>2.5E-9 F/cm**2</td>
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Table 2. Electrical parameter of the OFET

<table>
<thead>
<tr>
<th>Mobility</th>
<th>Threshold Voltage</th>
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<tr>
<td>7 e-3 cm**2/Vs</td>
<td>- 3 V</td>
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If the gate is connected to the drain, one receives a diode characteristic.

3.2. Simulation
From the output and transfer characteristics spice parameters for an OFET- model [4] are extracted and the behavior of the CV-converter is simulated (Figure 8).
3.3. Circuit design
The design of the OFETs had to recognize conflicting parameters. To reduce the drain-source capacity to a minimum the channel width has to be preferably small. Otherwise causes an adequate current flow a larger channel width and a channel length as small as possible. The printing technology sets the lower limit in realizing a minimal channel length. Furthermore, for quality control, the measurement of all PEDOT structures should be possible easily.

Assembling on Substrate

The assembling is done as following:

The first step is the printing of the conducting structures of drain and source of the OFETs, the connecting of the elements and the one half of the capacities with PEDOT:PSS. Second step is printing the semiconductor on top of the drain-source structure. Next step is to superimpose a low K material via spin coating as first isolator.

Then the contacts for building the diodes and connecting to extern devices are masked. Next to last is to build up the high K isolator via spin coating. The final step is a coating with conducting material that builds the gates of the OFETs, the connection between gates and drains for the diode function, the upper layer of the capacities and contact pads for connecting extern devices.

The extern components are at first the capacitive sensor, a generator for driving the CU-converter and a device to measure the voltage UA.

Measurements

In the following diagram the output voltage of the circuit is shown. \( V_{GS} = 46 \) V, the capacities \( C_{ext} \) vary around the value of \( C_{ext} = 20 \) pF.

In reference to the formula for calculating UA the theoretical sensitivity of the CU-converter is 1.46 V/pF. The sensitivity of the real circuit is different for the positive and negative voltage.

For positive voltage the value is 0.031 V/pF, for negative voltages it is 0.052 V/pF.

The difference between the theory and the real circuit is based on the supposition that the diodes are ideal.

The different values for the sensitivity below and above \( C_{ext} = 20 \) pF come from differences in the efficiency of the different diodes.

4. Summary
It is shown that basically the simulated CU-converter is realizable as inkjet printed circuit. There are two parameters that have to be optimized, the sensitivity and the reproducibility. Furthermore the long time stability is to be improved.

5. Acknowledgements
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6. References


