Touch Sensors

Detection of fluid levels with the PE5004 capacitive sensing controller

SERMA PRODUCTIVITY ENGINEERING

Introduction

The PE5004 is a high precision capacitive sensing circuit which uses amplitude modulation for very fast stimulating and reading of capacitive sensor arrays and single sensors.
A number of up to 100 sensors per chip can be selected by user, multiple sensor arrays can be cascaded. All Sensors can be addressed individually making it possible to integrate several different types of buttons, sliders, wheels and touch matrix arrays with one single PE5004.

Capacitive sensor elements are highly sensitive to changes of the relative permittivity (or electric constant) of surrounding material. This makes them ideal for a contactless detecting of fluid levels.
The needed sensors can be made with little effort out of copper foil or pcb boards.

This application note provides information on how to set up an application for capacitive detection of liquid levels. It describes different detection principles and shows how to choose the optimal set up depending on the used fluid and surrounding system.

For hints and information on sensor layout, calibration and firmware please refer to AppNote13.
For information on the working principle and complete description of the PE5004 and a guide how to design capacitive sensors please refer to the PE5004 data sheet.

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1 Revision History

Version	Date	Changes	Page
Initial Version V1.0	09/2010		

2 Measuring Principle

The measuring of liquid levels is based on changes of the capacitance between two sensor electrodes due to changes of the dielectric constant (non conducting fluid) or adding of additional capacitor plates (conducting fluid). In both cases the overall capacitance of the sensor is increased if a material different to air gets in the range of the fringe field between both electrodes. The material of the container must be non-conducting as a metal container would shield the electrodes from the fluid. A high dielectric constant of the container material and a low thickness of the container wall increase the influence of the liquid on the capacitance change. The material of the sensor PCB should be of low permittivity to lower parasitic capacitance.

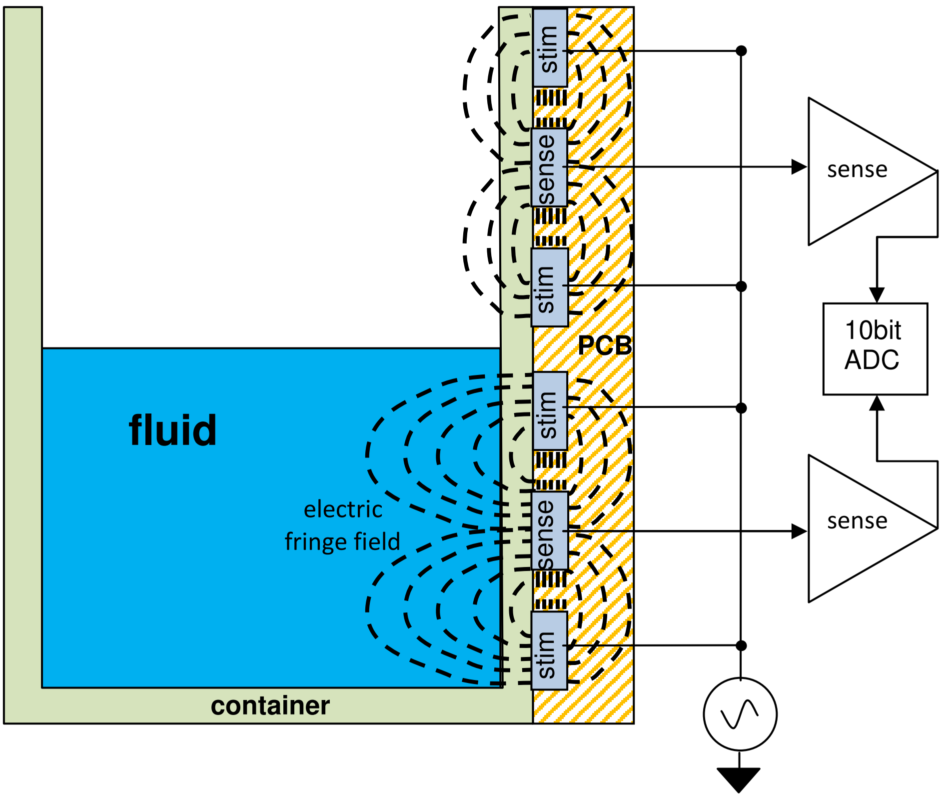

Figure 1 - measuring principle (not to scale)

The used setup mainly depends on the difference of relative permittivity of the measured fluid compared to air and the electric conductance of the fluid. If the fluid is conductive the influence of nearby ground levels must be considered.

2.1 Measuring the liquid level of a non-conductive fluid

The measuring of a non-conducting fluid is only based on the capacity change of the sensor due to change of permittivity. Depending on the sensor layout the capacity between stimulating and sensing electrode can be split into a constant part and a part which is changed due to overlaying fluids.
The electric fringe field between both electrodes spreads in all directions, the field lines passing only through the PCB and container walls without touching the fluid determines the value of the basic capacitance C_{SENSOR}. The field lines which pass through the container walls and the inside of the container determine the sensing capacitance C_{SENSE} which is changed due to an overlaying fluid. Air has a permittivity of roughly 1, fuel reaches from typical 1.8 up to 5 which leads to an increase of C_{SENSE} by this factor. Distilled water even has a permittivity of 80 which makes sensors very sensitive but care has to be taken as not distilled water can be conducting.

$$C_{meas\_fluid} = C_{Sensor} + C_{Sense\_air} \cdot \varepsilon_{fluid} ; \frac{dC_{meas}}{dC_{Sense}} = \varepsilon_{fluid}$$

It is preferable to set the sensing capacitance part as high as possible compared to the base capacitance. This must not be achieved by making the base capacitance small (this would lead to poor noise rejection) but by increasing the electric fringe field into the container. This can be reached by thin container walls and single layer sensor electrodes which are big in area and very thin. This leads to very few field lines between the opposite electrode planes which run in parallel and a lot of field lines coming in vertical direction out of the planes facing the liquid.
Conducting plates on a DC level, e.g ground, near the electrodes form a parasitic capacitance which is lowering the measurable signal strength but can be used as shielding from external noise.

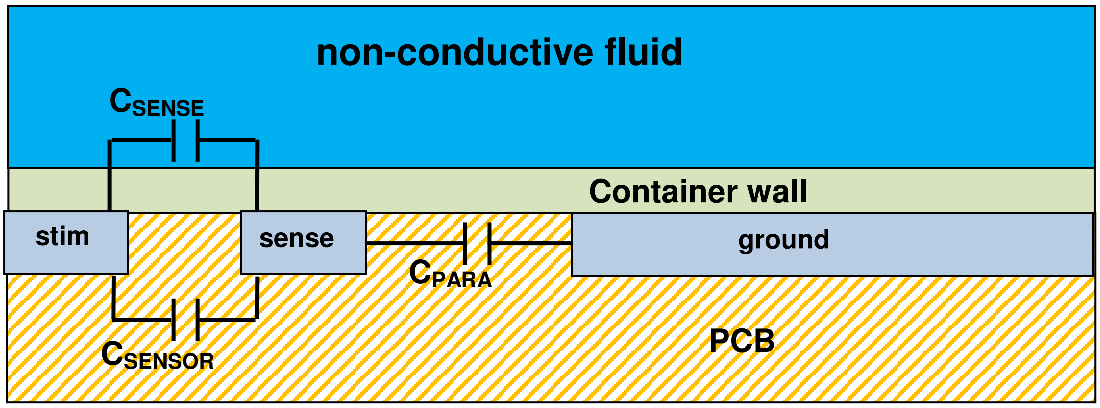

Figure 2 - equivalent circuit diagram for measuring non-conductive fluids (not to scale)

2.2 Measuring the liquid level of a conductive fluid

If measuring the fluid level of conducting liquids, the presence of a liquid over both electrodes forms a series connection of two Capacitors C_{STIM} and C_{SENSE} and a Resistor R_{SENSE}.
C_{STIM} and C_{SENSE} are plate capacitors with the container wall as dielectric, so their value can be changed by permittivity of the wall, thickness of the wall and electrode area parallel to the wall.
All Ground planes surrounding the container are AC connected to the liquid through their capacitance C_{GND} and form a voltage divider to the stimulating electrode.

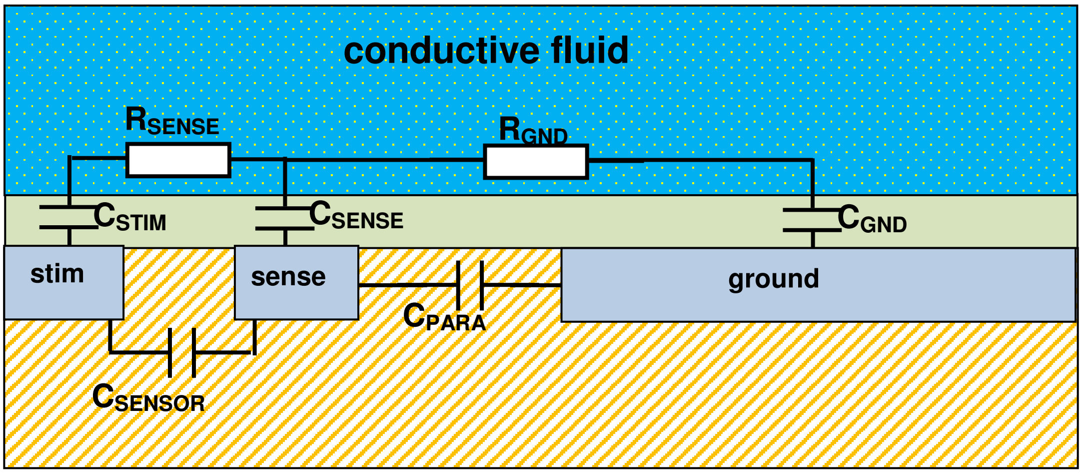

Figure 3 - equivalent circuit diagram for measuring conductive fluids (not to scale)

The value of the combined Capacitance connecting both electrodes in series is:

$$\frac{C_{SENSE} \cdot C_{STIM}}{C_{SENSE} + C_{STIM}}$$

In case of equal electrode plate areas the series connected capacitor will have half of the capacitance of one electrode to the fluid.
If the container is quasi floating, which means C_{GND} is very small compared to C_{STIM} and C_{SENSE} or R_{GND} is very large, the voltage divider formed between stimulating electrode and ground can be neglected.
The measured value will change from the fringe capacitance formed by air (equal to non-conductive fluid measuring) to the capacitance formed by the series connection between both electrodes, which will result in an increase of the measured value when using a proper layout.
It is preferable to choose a large area of the electrodes as this will result in a large C_{STIM} and C_{SENSE}.
The basic sensor capacitance can be enhanced by adding parallel capacitors between stimulating and sensing electrodes to prevent from noise.

It has to be kept in mind that such a floating System is very sensitive to all environmental changes when moving the container or bringing objects close to the tank. Therefore it is often better to force a connection to ground if it is not caused by the system itself.

If the AC connection to Ground cannot be neglected, the fluid will connect the sensing plate to ground through R_{GND} and C_{GND} leading to a lowering of the measured sensor value compared to air. This will produce a very good change in signal and it is recommended to add extra ground electrodes connected to the GND-Pin of the PE5004. They shall be ideally placed at the bottom of the container to prevent C_{GND} from changing with the fluid level.

3 Conclusion

The PE5004 integrated circuit provides functionality in conjunction with any simple 8 bit microcontroller that allows for robust capacitive sensing applications. It is eminently suited for contactless measuring of any fluids in non conducting containers, with very little system costs and easy setup.

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