The LCRB001D standard electronics is designed to allow easy integration in process industry sensors and general industry measurement devices. I²C outputs allow for easy communication due to its simplicity and flexibility. The slim design caters to various OEM housing needs, fitting into compact spaces.

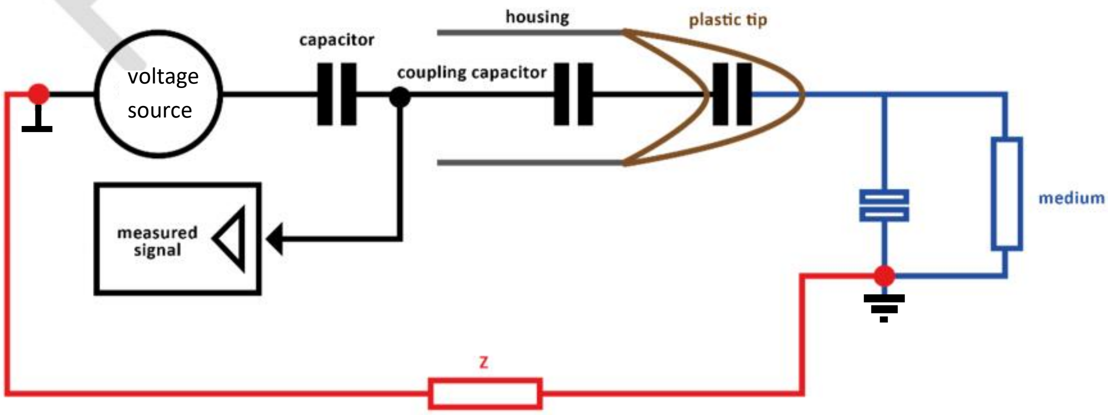
In order to achieve the best performance for the sensor in a customized housing this document provides technical explanations and recommendations which may be helpful for housing and application specific design.

Fundamental of capacitive measurement principle

The LCRB001D measurement circuit is designed as a capacitive voltage divider. Therefore, several capacitors are placed in series, using the center tap for extracting the measured signal. The media determines the last series capacitance.

The sensor uses an AC voltage signal source in the range of 40-50 MHz, which drives the connected capacitive voltage divider. This chain of impedances forms a voltage divider consisting of an internal circuit capacitance, a defined coupling capacitance, an unknown transition capacitance in the form of an insulating plastic cap and the media capacitance C_M to be measured in parallel.

A measurement signal is tapped via the voltage divider, which is proportional to the media capacitance C_M.



Measuring circuit

The capacitive voltage divider measures the media capacitance or media resistance via earth.

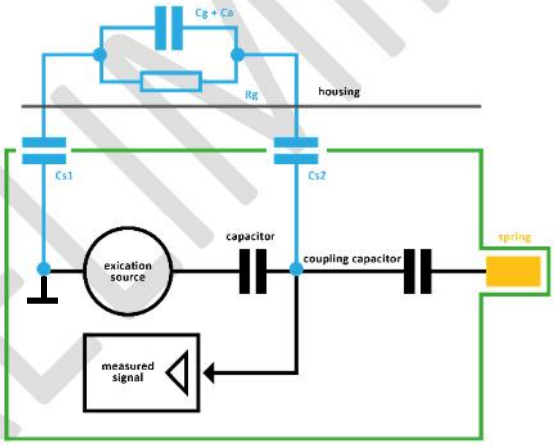
The measuring circuit is closed via the impedance Z. This impedance is influenced by the following parameters, among others:

- Coupling capacity / resistance of the media tank to earth
- Coupling capacitance / resistance of the sensor power supply to earth
- Stray capacitances between sensor housing and earth

If the components of the impedance Z are variable, these can have an influence on the measurement signal. The greater the impedance Z compared to the medium impedance, the greater the influence on the measurement signal due to variations in the components of the measuring circuit impedance Z.

Stray capacitances on sensor housing

Stray impedances (**C_{s1}, C_{s2}, C_g,** R_g and C_a) are formed between the sensor board and the housing. These impedances depend on the type and distance of the housing to the sensor board.



The stray capacitance C_{s1} is formed between the signal ground and the housing. If the distance between the housing and the PCB is greater, the stray capacitance C_{s1} decreases. This stray capacitance also depends on the medium between the housing and the PCB. If the PCB is encapsulated in the housing, the stray capacitance C_{s1} increases.

The stray capacitance C_{s2} is formed between the signal path and the housing. If the distance between the housing and the PCB is greater, the stray capacitance C_{s2} decreases. This stray capacitance also depends on the medium between the housing and the PCB. If the PCB is encapsulated in the housing, the stray capacitance C_{s2} increases.

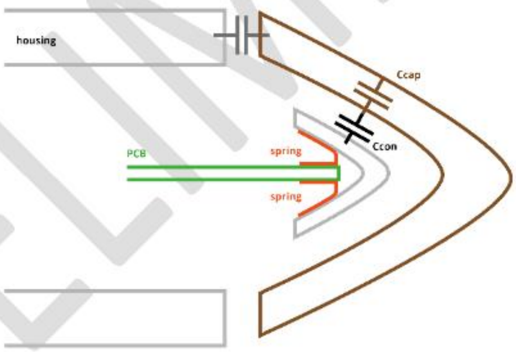
The housing wall connects the stray capacitances C_{s1} and C_{s2} with each other. Depending on the material of the housing wall, this connecting resistor R_g is low-resistance (e.g. when using metal) or high-resistance (in the case of plastics). If the housing is made of plastic, a housing capacitance C_g is formed parallel to the high-impedance housing resistance R_g. The environment around the housing can also act as an additional capacitor C_a on the connection between C_{s1} and C_{s2} in the case of high-impedance housings.

There must be no low-impedance connection between the circuit board and housing in order to avoid short circuits on the sensor circuit board.

The path through the stray impedances C_{s1}, C_{s2}, R_g or C_g+C_a act on the measurement signal like a signal offset. If these values change, e.g. due to temperature or mechanical changes, this signal offset changes, which increases the measurement uncertainty of the sensor. With a plastic housing, the ambient capacitance can have an effect on the signal stability.

Coupling sensor board with plastic sensor tip

The medium is separated from the sensor board by a cap on the sensor tip. If a plastic cap is used e.g. a PEEK based cap, a conductive metal cap should also be used. This metal cap should touch the inside of the plastic cap with ideal no air gap between. The metal cap establishes an electrical connection to the signal path of the measurement signal via the springs on the sensor board.



A low-resistance connection should be created between the springs and the metal cap. This connection must not be separated by shock, vibration or temperature. The metal cap must be moulded accordingly on the inside in order to create a sufficient connection with the springs on the sensor board. It must also be ensured that any potting or bonding does not impair or even isolate the ohmic connection between the spring and the metal cap.

There must be no low-resistance connection between the metal cap and the housing.

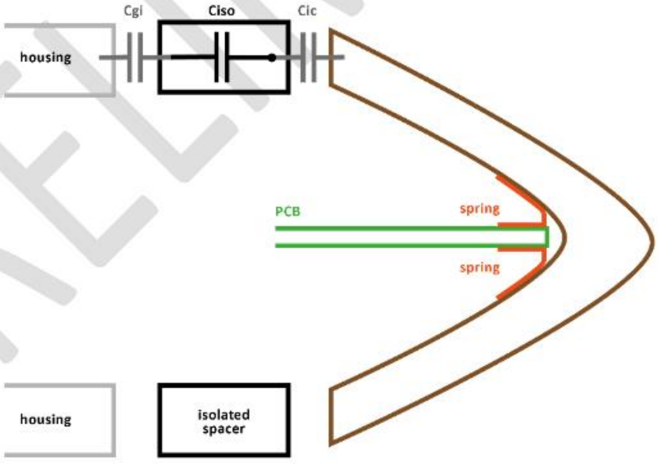
A capacitor C_{con} is formed between the metal cap and the plastic cap. This capacitor should be as large as possible and should not change due to temperature, shock or vibration. In order for the capacitor C_{con} to be large, the distance between the metal cap and the plastic cap must be as small as possible and the metal cap must form a large surface with the plastic cap. There should be no air gap between the metal cap and the plastic cap. The metal cap can also be glued into the plastic cap. The air between the metal cap and plastic cap should be able to escape during the bonding process. This can be achieved by drilling one or more holes in the metal cap to allow the air to escape when connecting. However, the holes should be as small as possible so as not to reduce the contact surface between the metal cap and the inside of the plastic cap too much.

The plastic cap (e.g. Peek) forms a further capacitor C_{cap} to the medium. This capacitor should also be as large as possible. In addition to the media compatibility of the plastic material, a material with a large ε_r should be used to form a large transition capacitance C_{cap}. Furthermore, the thickness of the plastic cap should be as small as possible to enable a large transition capacitor. If necessary, the metal cap can be used to dissipate force and support the plastic cap (see next chapter).

A capacitance C_{gc} is formed between the plastic cap and a sensor metal housing. This should be kept as small as possible. To do this, minimize the direct connected surface between the plastic cap and the metal housing or increase the distance by using a material with a low dielectric value ε_r. Pay attention that the spacer material has a very low conductance.

Coupling sensor board with metal sensor tip

The medium can be separated from the sensor board via a metal cap as sensor tip as well. The metal cap establishes an electrical connection to the signal path of the measurement signal via the springs on the sensor board.



A low-resistance connection should be created between the springs and the metal cap. This connection must not be separated by shock, vibration or temperature. The metal cap must be designed properly on the inside in order to create a sufficient connection with the springs on the sensor board. It must also be ensured that any potting or bonding does not impair or even isolate the ohmic connection between the spring and the metal cap.

There must be no low-resistance connection between the metal cap and the housing.

If the housing is a conductive metal housing, an insulator material must be used between the metal cap and the housing. In addition to media compatibility, the insulator material should have the lowest possible dielectric value ε_r in order to minimize the transition capacitance C_{iso} between the metal cap and the housing. If the distance between the housing and the metal cap is increased by a correspondingly thick insulator, the transition capacitance C_{iso} is also reduced, which is advantageous.

The transition capacitances C_{ic} between insulator and metal cap or C_{gi} between housing and insulator should be small. However, as the insulator may also fulfil a sealing function, the distance between the metal cap and the insulator will be very small. Accordingly, the transition capacitance is negligible. If O-rings or similar are used here, the capacitors C_{gi} and C_{ic} can be assumed.

The series connection of C_{gi}, C_{iso} and C_{ic} forms a signal offset with the stray impedance between the sensor board and housing. It should be noted that the values may change due to shock and vibration or temperature and can therefore cause a drift or shift in the signal offset.

Comparison plastic vs. metal cap

Plastic cap	Metal cap
PEEK material often preferred for food / hygiene / demanding media applications	Defined coupling capacitor between medium and sensor electronics
Potentially lower cost in high quantity	Further improved temperature stability
Preferable with high measuring capacities (e.g. water) to avoid reaching upper limit of measuring range.	Even higher measurement signal (e.g. may be advantage for low measuring capacities such as oils)

EMC

If a conductive metal housing is used, it should be ensured that there is a very good capacitive coupling between the signal GND and the metal housing near the connector plug. Using a high frequency grounding to attach the metal housing will deliver best results.

Coupling capacitances of typ. 1nF / 2kV between housing and circuit board for HF currents ae assembled on the PCB. Lower values than 1nF might improve EMC, depending on the design of the housing.

An ESD protection for the tip is already placed on the PCB.

For the power supply to the sensor, additional filter elements for limiting RF currents can improve the EMC robustness. A TVS diode may increase Burst and Surge robustness, dependant on the design of the main power supply.

DISCLAIMER

The information contained in this document is for general guidance only. The user is responsible for determining the suitability of the technical information referred to herein for his application. On delivery of the component, EBE is only obliged to implement those properties set out and agreed upon in this technical data sheet. Further properties are not included. No guarantee is given. The component has been designed for installation in our customer's products. Manufacturer of the resulting product and consequent liability according to the Product Liability Act lies with the customer.

EBE Elektro-Bau-Elemente GmbH
Sielminger Str. 63
70771 Leinfelden-Echterdingen (Germany)