Architecture for testing Capacitive Transducers

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ABSTRACT: *This article has described first the architecture for Testing Of Capacitive Transducers For Measuring Small Linear Displacement. Later we have studied the application for measuring the small linear displacement of the capacitive transducers. For testing we have calculated the distance between electrodes and the overlapping part of the electrodes and addressed the functions of the capacitive transducers' formation.*

Keywords: Small Linear Displacement, Capacitive Transducer, Wheatstone Bridge, Resonant Circuit, Oscillator

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1. Introduction

1. Capacitive Transducers for Measurement of Small Linear Displacement

1.1. Capacitive Transducers
Capacitive transducers are capacitors that change their capacity under the influence of the input magnitude, which can be linear or angular movement.

The capacity of a flat capacitor, composed of two electrodes with sizes $a \times b$, with area of overlapping s, located at a distance $\boldsymbol{\delta}$ from each other (in $\boldsymbol{\delta} << a/10$ and $\boldsymbol{\delta} << b/10$) is defined by the formula [4], [7]:

$$C = \frac{\varepsilon_0 \varepsilon . s}{\delta} \qquad (1)$$

where: $\varepsilon_0 = 8{,}854.10^{-12}$ F/m is the dielectric permittivity of vacuum;

ε - permittivity of the area between the electrodes (for air $\varepsilon = 1{,}0005$);

$s = a.b$ – overlapping cross-sectional area of the electrodes.

The capacity can be influenced by changing the air gap δ, the active area of overlapping of the electrodes s and the dielectric properties of the environment ε. Used in single (Figure 1) or differential performance (Figure 2) [1].

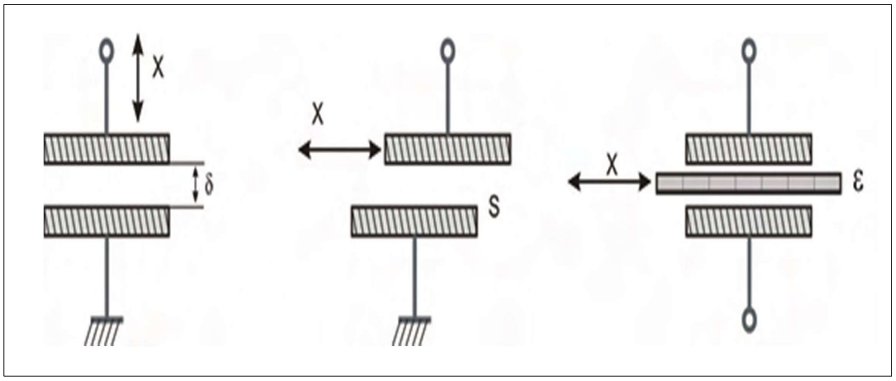

Figure 1. Single capacitive transducers

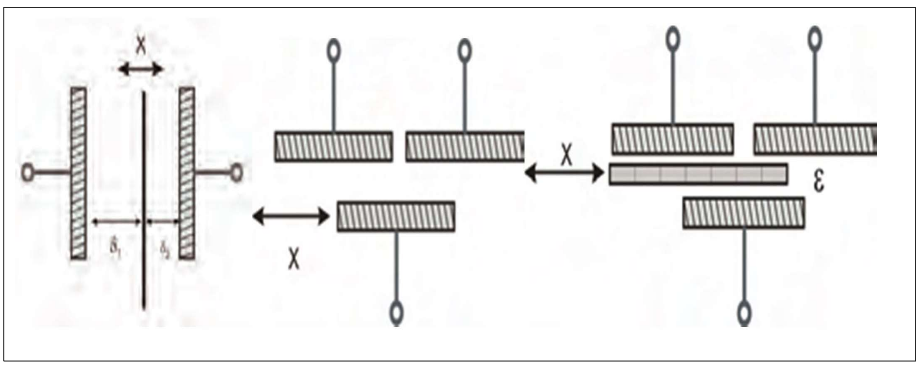

Figure 2. Differential capacitive transducers

1.2. Application of Capacitive Transducers

Capacitive sensors have found wide application in automated systems that require precise determination of the placement of the objects, processes in microelectronics, assembly of precise equipment associated with precise positioning, accurate measurements of shafts, axes of disk devices, spindles for high speed drilling machines, ultrasonic welding machines and in equipment for vibration measurement. They can be used not only to measure displacements (large and small), but also the level of fluids, fuel bulk materials, humidity environment, concentration of substances and others [6].

Capacitive sensors are often used for non-contact measurement of the thickness of various materials, such as silicon wafers, brake discs and plates of hard discs. Among the possibilities of the capacitive sensors is the measurement of density, thickness and location of dielectrics.

When used to measure linear or angular displacement, they are composed from movable and fixed electrodes. The movable is attached to the object, whose parameters of the movement are being measured. When moving the capacity of the transducer is changing and because of it there is a change in the output information.

1.3. Measuring circuits

The most preferred for measurement of physical quantities with transducers are bridge circuits, they are characterized by high accuracy measurement in the equilibrium mode. In this mode, the display is independent of the calibration uncertainty

Very often, the measuring methods using bridge circuits are inappropriate because of the specific characteristics of the transducers, that is why other methods are used.

In the upper quoted applications is important to know not the exact capacity change of the condenser, but the relationship between the measured value and the output.

Perhaps one of the most commonly used measurement schemes in this context is the so-called resonant oscillating circuit. It contains inductance and capacitance, operating at resonance (Fig. 3) [5]. The principle of this scheme lies in the well-known formula of the resonant circuit:

$$f_r = \frac{1}{2\pi\sqrt{RC}} \quad (2)$$

where it is obvious that when there is a change in C or L the resonant frequency fr will change too.

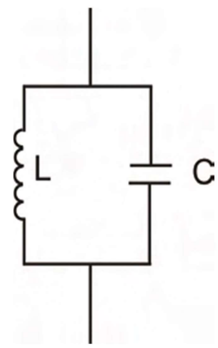

Figure 3. L-C oscillating circuit

The resonant circuit can be used together with an amplifier circuit, thereby forming a scheme known as oscillator. The oscillator generates a sinusoidal AC output signal with a frequency equal to the resonant frequency of the LC circuit.

Therefore, if the resonant frequency of the oscillating circuit is changed by modifying the capacity C, the variable frequency signal to the oscillator output will also change.

2. Schemes For Testing Of Capacitive Transducers For Measuring Small Linear Displacement

The block diagram for the examination of capacitive transducers measuring small linear displacement is shown in Figure 4.

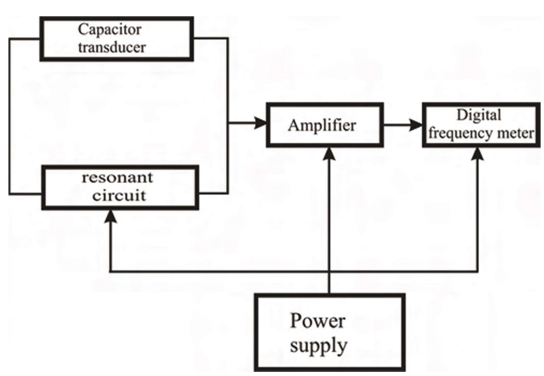

Figure 4. Block diagram for the examination of capacitive transducers

In it the oscillating circuit is realized by the coil *L*, a capacitor with a capacitance 290 pF and parallel the examined capacitive transducer Cx (Figure 5). Using a variable capacitor it is possible a change in the capacity of *C*, hence the frequency of the oscillating circuit and hence the frequency of the oscillator.

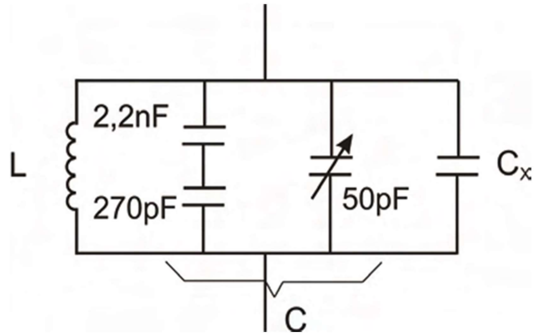

Figure 5. Scheme of resonant circuit

For the tests two types of capacitive transducers are used:

• Cylindrical (coaxial) transducer with a change of the active area of the electrodes overlap "s" - (Figure 6.) This transducer has internal movable electrode. The capacity of this capacitor, calculated by formula 2 is 20, 2 pF;

• Capacitive transducer with a change of the distance "d" between its flat electrodes (Figure 7).

The principal electrical circuit for examining the transformation functions of the capacitive transducers is shown in figure 8.

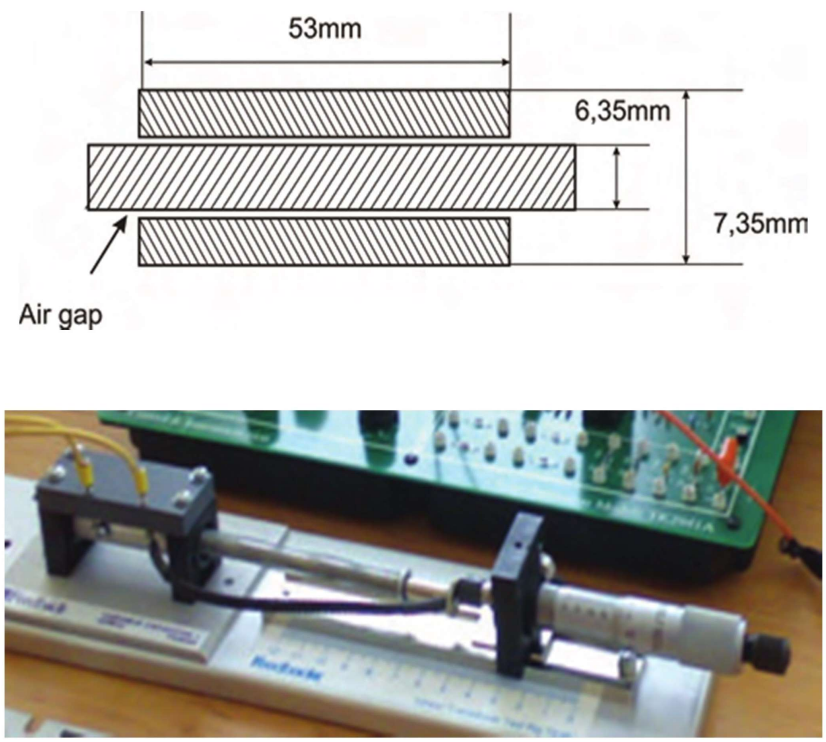

Figure 6. Capacitive transducer with a change of the active area of overlap

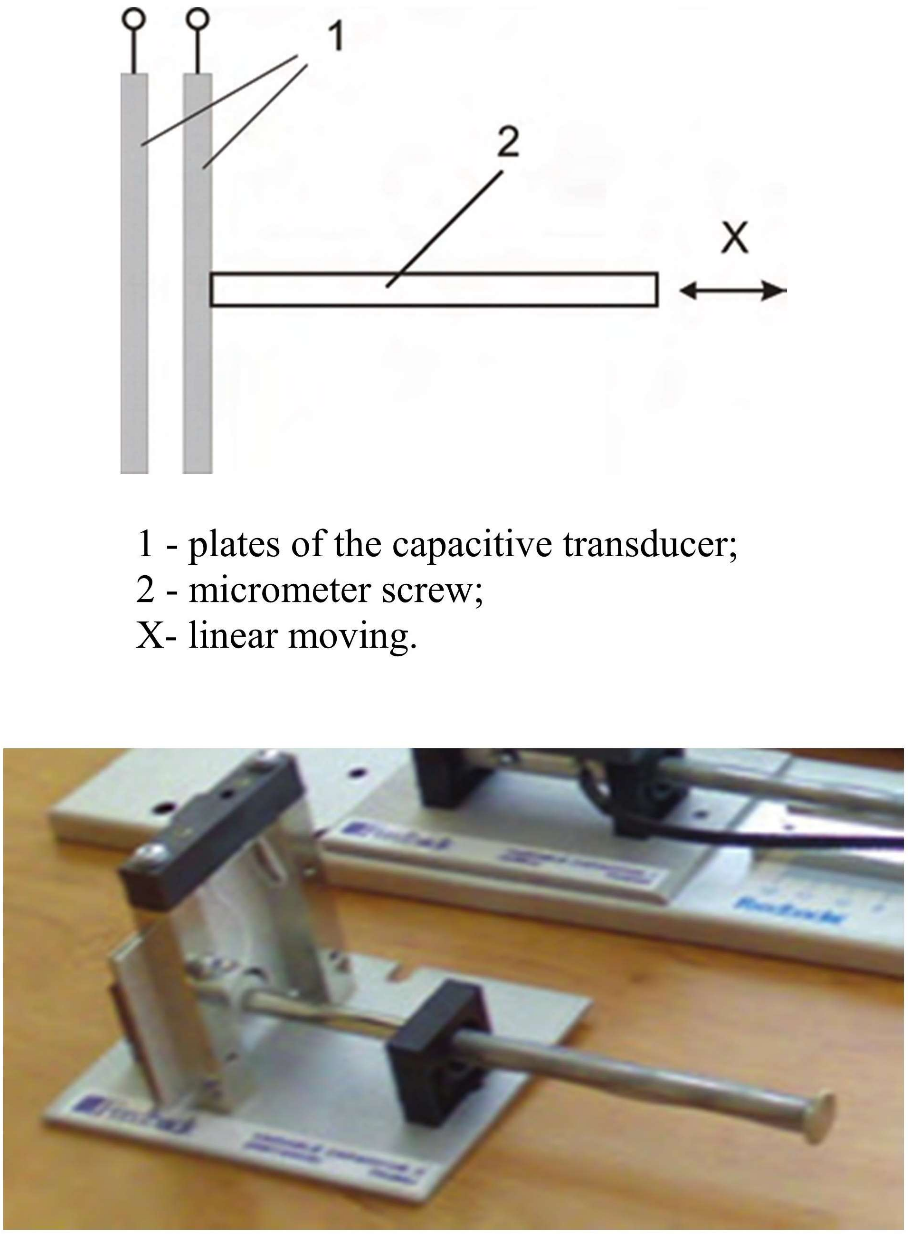

Figure 7. Capacitive transducer with change of the distance between the plates

3. Measurement Results

3.1. Examination of Capacitive Cylindrical Transducer's transfer functions with variable overlapping area

There is full overlapping of the active electrodes' area in position of 20 mm of the micrometric screw. The transducer is studied when changing the position of the slider micrometer screw between 20 and 65, which corresponds to a linear shift from 0 to 45 mm and three values of the capacity of the included vibrating capacitor circuit (30 pF, 40 pF and 50 pF). The results are given in the table (Table 1) and graphically (figure 9). Figure 9 shows that almost linear function of conversion for linear displacement of 45 mm can be achieved.

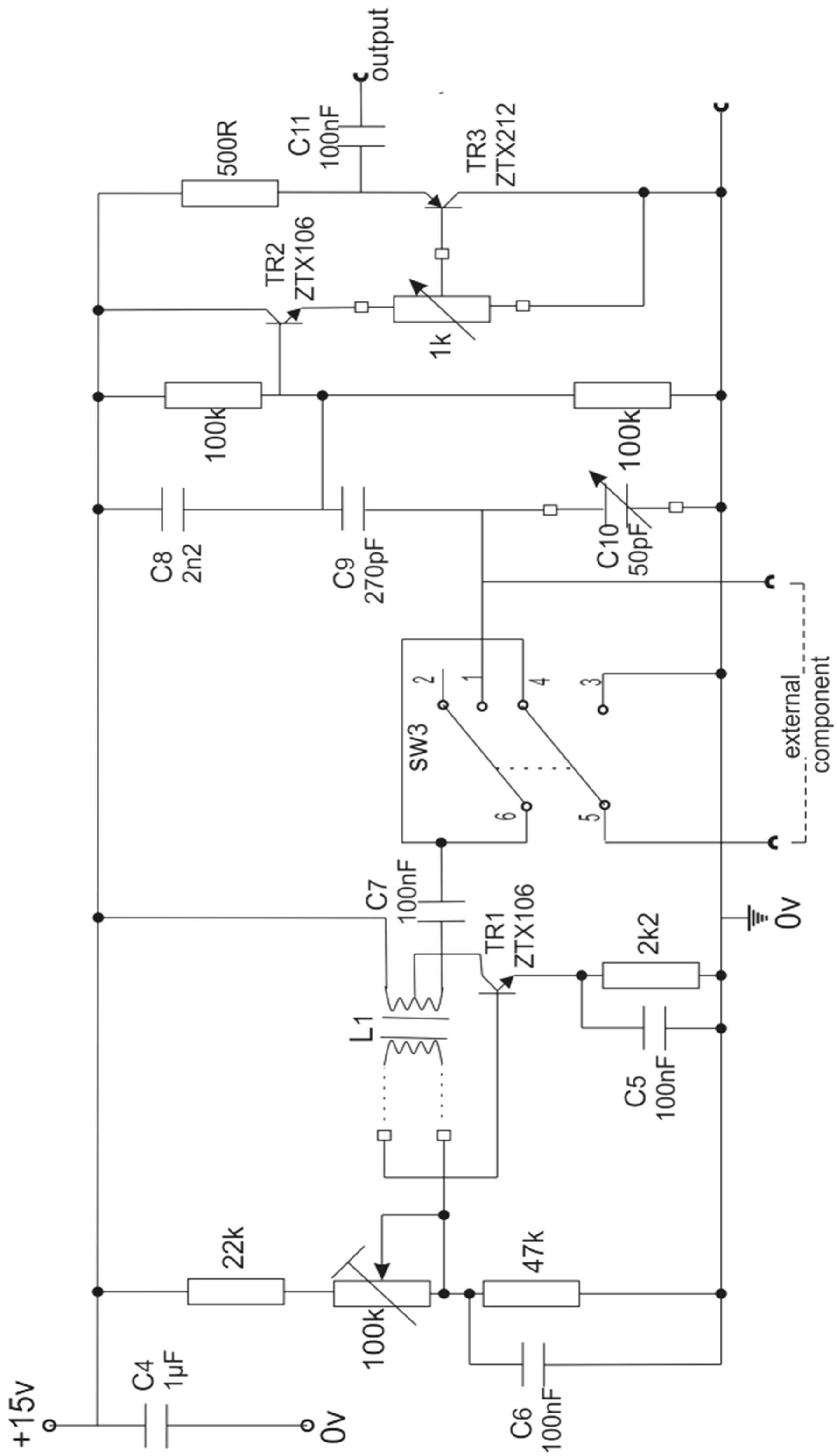

Figure 8. Oscillator circuit

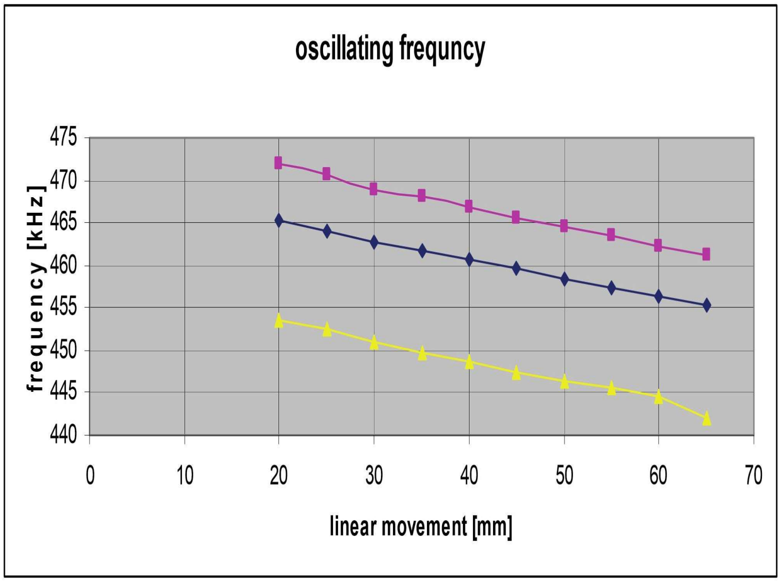

Figure 9.Cylindrical capacitive transducer’s transfer function

Slider position [mm]	Frequency [kHz] with C_{var}=30 pF	Frequency [kHz] with C_{var}=40 pF	Frequency [kHz] with C_{var}=50 pF
20	465,3	471,97	453,65
25	463,96	470,60	452,40
30	462,76	468,84	451,09
35	461,7	468,01	449,68
40	460,59	466,89	448,60
45	459,61	465,67	447,50
50	458,47	464,53	446,46
55	457,33	463,39	445,54
60	456,27	462,27	444,49
65	455,43	461,32	442,15

Table 1. Investigation of cylindrical capacitive transducer

3.2 Examination of the transfer function of a capacitive transducer with a variable distance between the plates of a flat capacitive transducer

The transducer is studied when changing the position of the slider micrometer screw between position 10 and 15, which corresponds to a linear shift from 0 to 5 mm The results are given in the table (Table 2) and graphically (figure 10). Figure 10 shows that linear function of conversion for linear displacements of about 5 mm cannot be achieved, but this type of very successful transducers can be used to measure displacements of the order of µm.

Slider position [mm]	Oscillating frequency [kHz]
10,0	466,7
10,5	466,17
11,0	465,43
11,5	464,53
12,0	463,39
12,5	461,91
13,0	459,9
13,5	457,0
14,0	445,16
14,5	435,12
15,0	425,0

Table.2. Investigation of flat capacitive transducer

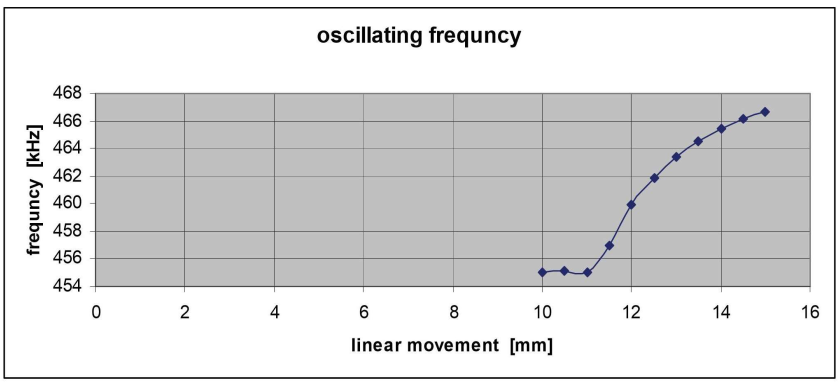

Figure 10.Transfer function of a capacitive transducer with a variable distance between the flat plates

4. Conclusions

The article is dedicated to the capacitive transducers and their applications for measurement of small linear displacements in the order of mm. Experimentally were defined and investigated the transfer functions of two capacitive transducers: with a variable overlapping area of the plates and variable distance between the plates. Transducers are included in the resonant circuit and the received signals are amplified. They can very well be used where a precise determination of the location of objects in the order of µm and mm.

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