

SENSOR FOR THE DETECTION OF A PREDETERMINED FILLING LEVEL OF A CONTAINER

The invention concerns a sensor for the detection of a predetermined filling level of a container.

Such sensors are suitable for example for the detection of the point in time at which a container becomes empty and must be replaced by a full container. In the semiconductor industry, capacitive sensors are
5 used with the bonding of chips in order to monitor the level of a syringe filled with epoxy and to give an alarm signal as soon as the syringe is emptied beyond a predetermined quantity. Such sensors are available, for example, from the company IMF under the designation KI-3015-BPKG.

These sensors have inherent serious disadvantages. Their relatively large diameter of approx. 10 mm has the result that, when exchanging the emptied syringe, a considerable amount of the expensive epoxy still
10 remains in the syringe. In addition, the sensor signal is subject to large fluctuations, ie, after each syringe replacement, the switching threshold of the sensor must somehow be readjusted.

From US 4'002'996, a capacitive sensor for measuring the level of a container is known with three capacitive electrodes which present capacitors arranged in two rows and which are stuck onto the container. The level signal is formed from the differential signal of the two capacitors. Also with this
15 sensor, the level is also located relatively far away from the outlet of the container and a relatively large amount of the material remains in the container.

The object of the invention is to suggest a sensor for the detection of the level of syringes with epoxy used in die bonding which enables the detection of a very low level of the syringe so that a minimum of material remains in the syringe and which is easy to handle. A further task exists in the suggesting of an
20 electronic circuit which enables operation of the sensor without adjustment.

The named task is solved in accordance with the invention by means of the characteristics of Claim 1. Advantageous further developments are the subject of the dependent claims.

The sensor for the detection of a predetermined level of a container in accordance with the invention has three capacitive electrodes which form a first and second capacitor. The three capacitive electrodes are
25 arranged in three planes running parallel to each other. A drill hole passing through the three capacitive electrodes accepts the container. The first capacitor is preferably part of a first RC element and the second capacitor part of a second RC element whereby both RC elements have different time constants. Measurement of the relative change of the two time constants enables operation of the sensor without any adjustment.

30 In the following, an embodiment of the invention is described in more detail based on the drawing.

It is shown in: Fig. 1 a cross-section of a sensor for the detection of a predetermined level of a container containing adhesive.

Fig. 2 a plan view of the sensor,

Fig. 3 a further sensor,

Fig. 4 an electronic circuit for operation of the sensor,

Fig. 5 an output signal of the sensor, and

Fig. 6 a schematic drawing of the electrodes of an electrically isolated sensor.

5 Fig. 1, not drawn to scale, shows a container in the form of a syringe 1, which is used, for example, by die bonders for the application of adhesive 2 to a substrate. The adhesive 2 is preferably pressed through the opening 3 of the syringe 1 in portions by means of compressed air. As adhesives 2, epoxies of all types are used, especially epoxy resins containing silver powder or silver flakes. For the detection of a predetermined ^{Filling} level of the container 1, a sensor 4 is used with three capacitive electrodes 5 - 7, which are
10 arranged in planes running parallel to each other and which, as suggested in Figure 1, form two capacitors 8 and 9 connected in series. The sensor 4 is preferably produced from a multi-layered printed circuit board 10 with three electrically conducting layers which are separated by two electrically non-conducting layers 11 and 12. The printed circuit board 10 has a circular drill hole 13 passing through the three capacitive electrodes 5 - 7 for acceptance of the syringe 1 so that the capacitive electrodes 5 - 7
15 completely surround the syringe 1. The diameter of the drill hole 13 preferably corresponds to the diameter of the syringe 1. The capacitive electrodes 5 - 7 no longer extend parallel as in prior art but vertically to the surface of the syringe 1. The adhesive 2 is therefore located in the leakage field of the capacitive electrodes 5 - 7. In the Figure, the level of the adhesive 2 is located between the two upper capacitive electrodes 5 and 6. Replacement of the syringe 1 will be due shortly. Typically, each of the
20 non-conducting layers 11 and 12 is around 0.2 mm to 2 mm thick, each of the conducting layers around 30 - 50 μm , the sensor 4 therefore around 0.5 mm to 2 mm. The capacitive electrodes 5 and 7 are, for example, ring-shaped (see Fig. 2), while the middle capacitive electrode 6 extends practically over the entire area of the printed circuit board 10.

For operation of the sensor 4, an electronic circuit is foreseen the components 14 of which equip the
25 multi-layer printed circuit board 10 on one or both sides. On production of the printed circuit board 10 in the conventional way, the three electrically conducting layers are structured so that, on the one hand, the capacitive electrodes 5 - 7 and on the other hand, the printed conductors for connection of the components 14 are created. Appropriate plated through-holes are available for connecting the capacitive electrodes 5 - 7 to the components 14.

30 The field lines of the electrical field going out from the capacitive electrodes 5 - 7 flow through the inside of the syringe 1 in an optimal way as all capacitive electrodes 5 - 7 directly touch the syringe 1 with the exception of some play.

Any temperature or humidity fluctuations change the distance between the capacitive electrodes 5 and 6 to the same extent as the distance between capacitive electrodes 6 and 7 so that the capacitances of the
35 capacitors 8 and 9 alter to the same extent.

The sensor 4 can be positioned at any height on the syringe 1, however, especially at the neck of the throat leading to the opening 3. The sensor 4 in accordance with the invention therefore enables the syringe 1 to be practically completely emptied before replacement of the syringe 1 is indicated.

Fig. 2 shows a plan view of the sensor 4. The electronic components 14 are arranged immediately next to the capacitive electrode 5.

Fig. 3 shows a further sensor 4, with which the three capacitive electrodes 5 - 7 are formed from three parallel arranged metallic plates, each of which has a circular drill hole 13 through which the syringe 1 is inserted. Bodies made of dielectric material are located as spacers between the plates.

Fig. 4 shows a circuit, particularly suited for operation of the sensor 4, with an oscillator 15, a signal detector 16 with two inputs and an integrator 20 formed from resistors 17, 18 and a capacitor 19. Furthermore, the circuit has a microprocessor 21 with an integrated A/D converter 22 and an output 23 carrying either logical "0" or logical "1". Logical "0" means that the syringe 1 still contains adhesive, logical "1" means that the syringe 1 must be replaced. At its output, the oscillator 15 delivers a rectangular alternating voltage signal U_1 of a predetermined frequency related to a ground m which typically lies in the range of 200 kHz to 400 kHz. The frequency is selected so that the electrical field created by the capacitors 8 and 9 penetrates into the adhesive 2 as long as there is still adhesive 2 present. The capacitor 8 and a resistor 24 form a first RC element in the form of a low-pass, the capacitor 9 and a resistor 25 form a second RC element in the form of a low-pass.

The alternating voltage signal U_1 delivered from the oscillator 15 is applied to the two low-passes while the capacitive electrode 6 lies on the ground m. The alternating voltage signals U_2 or U_3 appearing at the output of both low-passes are led directly or via a coupling capacitor 26 to the two inputs of the signal detector 16. At its output, the signal detector 16 delivers a rectangular voltage U_4 the duty cycle of which is dependent on the shape of the alternating voltages U_2 and U_3 . The voltage U_4 is smoothed by means of the integrator 20 and is fed either directly as voltage U_5 or indirectly as voltage U_6 diverted directly from voltage U_5 to the A/D converter 22 of the microprocessor 21.

The capacitive sensor 4 should deliver a signal which enables the easy distinction between the following three conditions:

Condition 1

No syringe 1 is located in the drill hole 13.

Condition 2

A syringe 1 filled with adhesive 2 is located in the drill hole.

Condition 3

Condition 3 is a dynamic condition and occurs when the syringe 1 becomes empty and replacement of

the syringe 1 should be indicated by the sensor 4. The syringe 1 is located in the drill hole 13. The level of the adhesive 2 falls below the level of the uppermost capacitive electrode 5 but remains higher than the level of the second capacitive electrode 6.

In operation, the two capacitors 8 and 9 are continually charged and discharged by the alternating voltage signal U_1 . The time constants τ_1 and τ_2 of the two low-passes determine the speed of the charge reversals of the two capacitors 8 and 9. The signal detector 16 serves to divert a signal from the charge reversal times of capacitors 8 or 9 which enables the automatic differentiation between the three conditions given above. In accordance with the invention, the two low-passes are therefore dimensioned so that they have different time constants τ_1 and τ_2 . From the equations $\tau_1 = R_1 * C_1$ and $\tau_2 = R_2 * C_2$, whereby R_1 denotes the value of the resistor 24, R_2 the value of the resistor 25, C_1 the capacitance of the capacitor 8 and C_2 the capacitance of the capacitor 9, various possibilities can be derived which could influence the time constants τ_1 and τ_2 . Three examples are explained in more detail here:

Example 1

The capacitive electrodes 5 and 7 are of the same geometrical form. The two capacitors C_1 and C_2 therefore have the same capacitance under identical conditions. The resistance values R_1 and R_2 of the two resistors 24 and 25 are selected different, eg, $R_2 = 50 * R_1$.

Example 2

The capacitive electrodes 5 and 7 are of different geometrical form. The two capacitors 8 and 9 therefore have different capacitances C_1 or C_2 under identical conditions. The resistance values of the two resistors R_1 and R_2 are selected the same or different.

Example 3

The capacitive electrodes 5 and 7 are of the same geometrical form. An additional capacitor is connected parallel to capacitor 9. The resistance values of the two resistors R_1 and R_2 are selected the same or different.

An electronic circuit particularly suited for example 1 is now explained in more detail. The signal detector 16 serves to extract the information contained in the time constants τ_1 and τ_2 from the two alternating voltage signals U_2 and U_3 and to present it in signal U_4 . For this purpose, the use of a commercial PLL component (eg, MC14046 from Motorola or CD4046 from National Semiconductor) is preferred. Such a PLL component contains an oscillator as well as generally several phase detectors of which one is formed as XOR (exclusive OR) element. The phase detector formed as XOR element preferably serves as the signal detector 16. The signal U_2 is fed to one input of the XOR element, the signal U_3 to the other input. As is known, the XOR element then carries a logical "0" signal at its output when the same logical signal is applied at both inputs, and a logical "1" signal when different logical signals are applied at both inputs. The rise time of alternating voltage signal U_2 defined by the time constant τ_1 determines the point in time at which the signal at the corresponding input of the XOR

element changes from logical "0" to logical "1" or back from logical "1" to logical "0". The rise time of the alternating voltage signal U_3 defined by the time constant τ_2 analogously determines the switching instant of the other input of the XOR element. Therefore, when at least one of the two time constants τ_1 and τ_2 changes, then the alternating voltage signal U_4 and the voltage U_5 also change.

- 5 In order that a change in the time constants τ_1 and τ_2 is measurable, the time constants τ_1 and τ_2 must be comparable with the period of oscillation $T = 1/f$ of the frequency f of the alternating voltage signal U_1 . This means that the frequency f should be greater than the cut-off frequencies of the two low-passes. The disadvantage is that the low-passes then work as filters for the alternating voltage signal U_1 and therefore cause a relatively small amplitude of alternating voltage signals U_2 and U_3 . It turned out that the
- 10 amplitude of alternating voltage signal U_2 is sufficiently large but that the amplitude of alternating voltage signal U_3 is too small and must be amplified. One input of the XOR element already has a circuit which automatically amplifies an applied alternating voltage signal until its level is sufficient in order to initiate switching operations in the XOR element. For this reason, the alternating voltage signal U_3 is fed to this input of the XOR element via the coupling capacitor 26. A separate amplifier is therefore not
- 15 required.

Although this circuit works satisfactorily, it turned out that the differentiability of the three conditions is even better when the voltage U_5 at the output of the integrator 20 is used to control the frequency f of the oscillator 15. It is therefore preferable to feed the voltage U_5 into a feedback loop 27 of an amplifier 28 where it is amplified by a predetermined factor and shifted in level by a fixed direct voltage component

20 and fed to the oscillator 15 as frequency controlling voltage U_6 .

The behaviour of the electronic circuit in Example 1 is as follows:

Condition 1

Based on the different time constants τ_1 and τ_2 of the two low-passes, this results in a maximum value of the voltage U_6 of 4.5 V and a frequency of the alternating voltage signal U_1 of around 360 kHz.

25 Condition 2

The capacitance values C_1 and C_2 of the two capacitors 8 and 9 change to the same extent compared with their values in condition 1. The time constants change to a different extent. For the voltage U_6 this results in a lower value of around 2 V and the frequency of the alternating voltage signal U_1 drops to around 310 kHz.

30 Condition 3

The capacitance C_1 of capacitor 8 and therefore the time constant τ_1 change as a function of the level of the adhesive 2. The capacitance C_2 of capacitor 9 and therefore the time constant τ_2 do not change. The voltage U_6 increases with increasing change of capacitance C_1 of capacitor 8 and therefore of time constant τ_1 . When the level of the adhesive 2 has reached the level of the second capacitive electrode 6,

the value of voltage U_6 amounts to around 2.6 V and the frequency of the alternating voltage signal U_1 has a value of around 323 kHz.

The voltage U_6 is supplied to the A/D converter 22 of the microprocessor 21. The microprocessor 21 continually interrogates the A/D converter 22 and behaves in example 1 as follows:

- 5 - If U_6 is greater than 4 V, then the output 23 of the microprocessor 21 carries logical "1".
- If U_6 is less than 2.6 V, then the microprocessor 21 stores the value of U_6 as value Z_0 . Output 23 of the microprocessor 21 then carries logical "0".
- If U_6 is less than 2.6 V and less than Z_0 , then the microprocessor 21 stores the value of U_6 as new value Z_0 . Output 23 of the microprocessor 21 carries logical "0".
- 10 - If U_6 is less than 2.6 V and greater than $Z_0 + \Delta Z$, whereby ΔZ denotes a predetermined threshold value of around 0.4 V (or 0.5 V), then the output 23 of the microprocessor 21 is set to logical "1" to indicate that the syringe 1 is empty and must be replaced.

The diagram in Fig. 5 shows the process of U_6 in time t . Clearly recognisable are the two voltage levels which correspond to the conditions 1 = "no syringe 1" and 2 = "syringe 1 filled with adhesive" as well as
 15 the increase in voltage U_6 from the point in time t_0 during condition 3 = "syringe 1 becoming empty". At point in time t_1 the voltage U_6 achieves the value $Z_0 + \Delta Z$ at which the microprocessor 21 indicates changing the syringe 1 and further emptying of the syringe 1 is stopped. The voltage U_6 is subject to slight fluctuations because of external influences such as the temperature of the syringe 1, the temperature of the adhesive 2, the environmental temperature, etc. These fluctuations however are less
 20 than ΔZ . The level of voltage U_6 in condition 2 is additionally dependent on the adhesive 2 itself. The sensor 4 automatically adapts itself to different adhesives. It is neither necessary to readjust the sensor 4 after changing the adhesive nor to reset the sensor 4 after changing the syringe.

It is possible to foresee high-passes as RC elements instead of low-passes, ie, in the circuit to swop over the capacitor 8 and the resistor 24 on one side and to swop over the capacitor 9 and the resistor 25 on the
 25 other side.

Fig. 6 shows a schematic cross-section of the electrodes of a further sensor 4. The sensor 4 has five electrodes 5, 6, 7, 29 and 30 arranged in parallel. Primarily, the two outer electrodes 29 and 30 serve to shield the inner electrodes 5, 6 and 7. They are electrically connected to the middle electrode 6 directly (as shown) or via a coupling capacitor. With this sensor 4 the measurement sensitive area is doubled on
 30 the one hand, on the other hand, in event that they are grounded, the two outer electrodes 29 and 30 shield the middle electrodes 5, 6, and 7 against external influences. The two outer electrodes 29 and 30 can also be realised as part of a housing.



PATENT CLAIMS

- filling
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1. Sensor for the detection of a predetermined level of a container with three capacitive electrodes (5 - 7), which form a first and a second capacitor (8, 9), **characterised in that** the three capacitive electrodes (5 - 7) are arranged in three planes running parallel to each other and that a drill hole (13) running
5 through the three capacitive electrodes (5 - 7) is available for acceptance of the container.
 2. Sensor (4) in accordance with Claim 1, **characterised in that** the first capacitor (8) and a first resistor (24) form parts of a first RC element, that the second capacitor (9) and a second resistor (25) form parts of a second RC element and that both RC elements have different time constants.
 3. Sensor (4) in accordance with Claim 2, **characterised in that** the second resistor (25) of the second
10 RC element is at least ten times larger than the first resistor (24) of the first RC element.
 4. Sensor in accordance with one of Claims 1 to 3, **characterised in that** the three capacitive electrodes (5 - 7) are formed from three electrically conducting layers of a multi-layer printed circuit board (10) which are separated by two electrically non-conducting layers (11) and (12).
 5. Sensor in accordance with one of Claims 1 to 4, **characterised in that** two further capacitive
15 electrodes (29, 30) are foreseen which are connected to the middle electrode (6) either directly or via a coupling capacitor.