Insight — Application Note 3.28

Calculating A/D Ratio and Base Capacitance

Sensor capacitances

The cross section of the planar electrodes shown in Figure 28-1 shows that the total capacitance C_{tot} is the sum of C_{MUT} from the Material Under Test above electrodes and C_{base} from the substrate beneath the electrodes. This second component C_{base} is called the base capacitance.

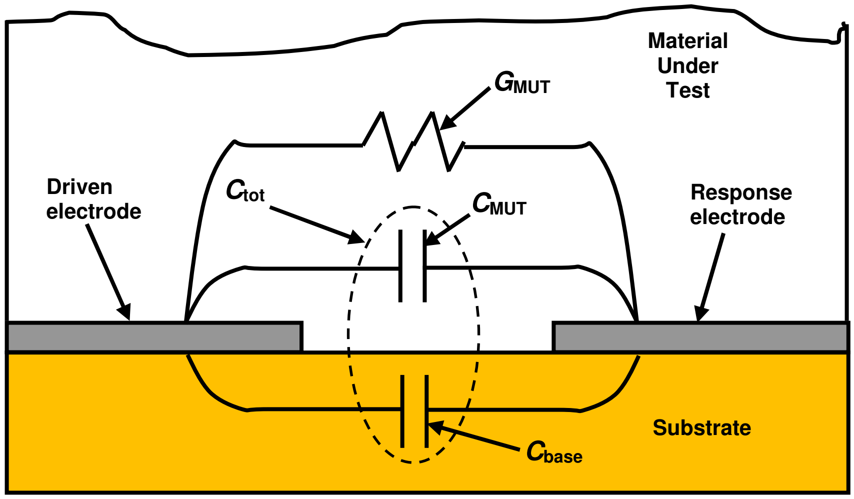

Figure 28-1
Cross section of interdigitated electrode structure

The total capacitance measured by the interdigitated electrodes is:

(eq. 28-1) $$C_{tot} = C_{MUT} + C_{base}$$

The capacitance of the Material Under Test is calculated as shown below:

(eq. 28-2) $$C_{MUT} = \varepsilon_o \, \varepsilon'_{MUT} \, A/D$$

Calculating base capacitance with known *A/D*

It is possible to determine the base capacitance of a sensor by measuring its response in two different, non-conducting materials of known permittivity. To determine base capacitance, measure the sensor capacitance in air.

(eq. 28-3) $C_{tot\text{-}air} = C_{MUT\text{-}air} + C_{base}$

Then measure the sensor capacitance in a second, non-conducting fluid. Food grade mineral oil is a good second fluid because it is readily available, has very low conductivity and uniform characteristics. The relative permittivity of food-grade mineral oil is about 2.2.

(eq. 28-4) $C_{TOT\text{-}oil} = C_{MUT\text{-}oil} + C_{base}$

Sum together equations 28-3 and 28-4.

(eq. 28-5) $C_{tot\text{-}air} + C_{tot\text{-}oil} = C_{MUT\text{-}oil} + C_{MUT\text{-}oil} + 2\, C_{base}$

C_{tot} is measured in each case, and C_{MUT} is calculated in each case from equation 28-2 using the known permittivity of each Material Under Test and the *A*/*D* ratio of the sensor. Then C_{base} can be calculated using equation 28-6:

(eq. 28-6) $C_{base} = 1/2\ [(C_{tot\text{-}air} + C_{tot\text{-}oil}) - (C_{MUT\text{-}air} + C_{MUT\text{-}oil})]$

Calculating base capacitance and *A/D* when both are unknown

Both the *A/D* ratio and the base capacitance are required to fully describe a sensor. If they are both unknown then the two measurements described previously can be used to create a system of two equations in two unknowns which can be solved with basic algebra. Equations 28-3 and 28-4 are repeated below:

(eq. 28-3) $C_{tot\text{-}air} = C_{MUT\text{-}air} + C_{base}$
(eq. 28-4) $C_{TOT\text{-}oil} = C_{MUT\text{-}oil} + C_{base}$

The capacitance for the Material Under Test for equations 28-3 and 28-4 can be rewritten using equation 28-2:

(eq. 28-7) $C_{TOT\text{-}air} = (\varepsilon'_{MUT\text{-}air}\, \varepsilon_o)\, A/D + C_{base}$
(eq. 28-8) $C_{TOT\text{-}oil} = (\varepsilon'_{MUT\text{-}oil}\, \varepsilon_o)\, A/D + C_{base}$

Equations 28-7 and 28-8 make up a system of two equations in two unknowns, where the unknowns are the *A/D* ratio and C_{base}. First, these equations can be solved for the *A/D* ratio:

(eq. 28-9) $A/D = (C_{TOT\text{-}air} - C_{TOT\text{-}oil}) / (\varepsilon_o \ (\varepsilon'_{MUT\text{-}air} - \varepsilon'_{MUT\text{-}oil}))$

Knowing the *A/D* ratio, C_{base} can then be calculated from equation 28-6 and equation 28-2.

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