Insight — Application Note 2.15

Calculating A/D Ratio and Base Capacitance

Introduction

The cross section of the planar electrodes shown in Figure 15-1 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.
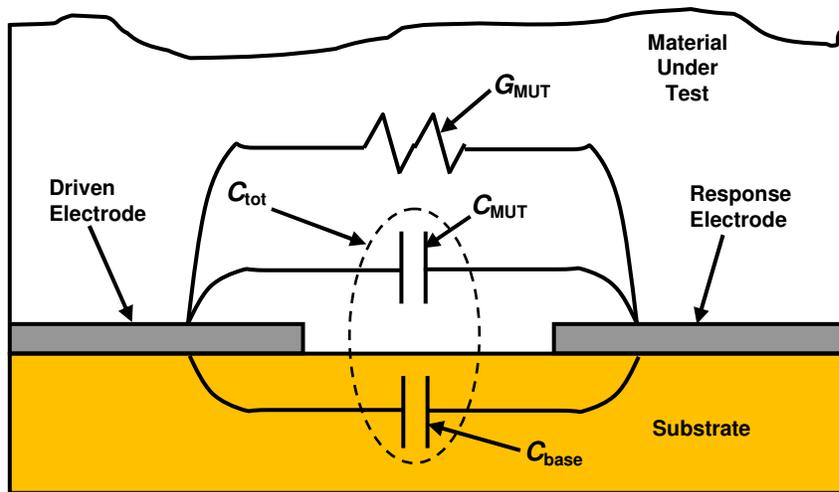

Figure 15-1
Cross section of interdigitated electrode structure

The total capacitance measured by the interdigitated electrodes is:

(eq. 15-1) $$C_{tot} = C_{MUT} + C_{base}$$

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

(eq. 15-2) $$C_{MUT} = \varepsilon_o\, \varepsilon'_{MUT}\, A/D$$

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. 15-3) $$C_{tot\text{-}air} = C_{MUT\text{-}air} + C_{base}$$

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. 15-4) $$C_{TOT\text{-}oil} = C_{MUT\text{-}oil} + C_{base}$$

Sum together equations 15-3 and 15-4.

(eq. 15-5) $$C_{tot\text{-}air} + C_{tot\text{-}oil} = C_{MUT\text{-}oil} + C_{MUT\text{-}oil} + 2\,C_{base}$$

C_{tot} is measured in each case, and C_{MUT} is calculated in each case from equation 15-2 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 15-6:

(eq. 15-6) $$C_{base} = 1/2\,[(C_{tot\text{-}air} + C_{tot\text{-}oil}) - (C_{MUT\text{-}air} + C_{MUT\text{-}oil})]$$

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 15-3 and 15-4 are repeated below:

(eq. 15-3) $$C_{tot\text{-}air} = C_{MUT\text{-}air} + C_{base}$$
(eq. 15-4) $$C_{TOT\text{-}oil} = C_{MUT\text{-}oil} + C_{base}$$

The capacitance for the Material Under Test for equations 15-3 and 15-4 can be rewritten using equation 15-2:

(eq. 15-7) $$C_{TOT\text{-}air} = (\varepsilon'_{MUT\text{-}air}\,\varepsilon_o)\,A/D + C_{base}$$

(eq. 15-8) $$C_{TOT\text{-}oil} = (\varepsilon'_{MUT\text{-}oil} \, \varepsilon_o) \, A/D + C_{base}$$

Equations 15-7 and 15-8 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. 15-9) $$A/D = (C_{TOT\text{-}air} - C_{TOT\text{-}oil}) / (\varepsilon_o \, (\varepsilon'_{MUT\text{-}air} - \varepsilon'_{MUT\text{-}oil}))$$

Knowing the *A/D* ratio, C_{base} can then be calculated from equations 15-6 and 15-2.

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