Texas Instruments

CapTIvate™ Technology

Internal Reference Cap

Background - Percent Change in Capacitance

CapTIvate measures relative capacitance, not absolute. Using percent change in capacitance vs. change in measurement counts removes any dependencies on the conversion settings.

The unit of choice for analyzing capacitive touch is percent change in capacitance. Capacitive touch sensing is based on measuring relative changes over time in an existing, but unknown, electrode capacitance. As such, it is most straightforward to work in terms of percent change. Another benefit of this perspective is that it removes any dependencies on the conversion settings. Filtered count and LTA values can vary with conversion settings and other factors, but percent change in capacitance is a function of the electrical hardware (the PCB) and the mechanical hardware (the overlay material). Percent change in capacitance can be easily computed for a given filtered count, LTA and conversion gain value using the relationship shown below.

$$\Delta Cx = \left(\frac{gain}{count + delta} - \frac{gain}{LTA}\right) * 100\%$$

Assuming the conversion count = LTA (electrode no touch), we can substitute and simplify the formula.

$$\Delta Cx = gain\left(\frac{1}{count + delta} - \frac{1}{LTA}\right) * 100\%$$

For example, let's assume the following:

- Conversion gain is set = 100
- LTA = 500cnts
- Baseline electrode measurement = 500cnts
- Electrode measurement with finger touch = 400cnts (500 - 100 counts)
- Calculate %change

Note delta is calculated as (conversion count – LTA), so self capacitive electrodes delta will be (-) and (+) for mutual capacitive electrodes.

$$gain\left(\frac{1}{count + delta} - \frac{1}{LTA}\right) * 100\%$$

$$100\left(\frac{1}{400} - \frac{1}{500}\right) * 100\% = 5\%$$

Internal Reference Capacitors

The CapTIvate™peripheral comes equipped with a set of reference or self-test capacitors. These capacitors vary in size and can be measured in parallel with an internal load or independent of the external connection as a self-test mechanism. There is **only one** reference test bank of capacitors, so only one block can be tested at a time.

Applying the reference capacitor is done with the MAP_CAPT_enableRefCap() API. Similar to the channel IO control APIs this API must be called within the context of a sensor and the sensor parameters must have been applied (MAP_CAPT_apply_SensorParams). Removing the reference capacitor from the measurement circuit is done by simply calling the API, MAP_CAPTdisableRefCap().

The reference capacitor size is dependent upon the mode (mutual or self) as defined by the sensor. Throughout this document the term “ref cap” or “reference capacitor” is used generically and represents any one of the possible capacitor values.

Reference Capacitor Selection	Self Mode (Typical. pF)	Mutual Mode (Typical. pF)
0	1.0	0.1 (RX cap = 1pF)
1	1.0	0.5 (RX cap = 1pF)
2	5.0	0.1 (RX cap = 5pF)
3	1.0	0.5 (RX cap = 5pF)
4	1.1	0.1 (RX cap = 1pF)
5	1.5	0.1 (RX cap = 1pF)
6	5.1	0.1 (RX cap = 1pF)
7	5.5	0.1 (RX cap = 1pF)

Uses for the internal reference capacitor include:

- Checking for shorts and opens in electrodes
- Calculating base electrode capacitance
- Custom calibration routines

Keep in mind that changes in temperature and humidity can impact the base capacitance of the electrode and extreme temperatures can also impact the value of the internal ref cap, so these must be considered for those applications that expect to operate under those conditions.

Using Reference Capacitor

In the previous example we calculated the percent change in capacitance without knowing either the electrode or finger capacitance. Next we can calculate the baseline electrode capacitance using an internal reference capacitor.

The first step is to measure Cx of electrode by performing a measurement without the ref cap applied. The second step is to repeat the measurement with the ref cap applied and record the %change. For example let's say that Cx = 10pF and then we apply 1pF ref cap causes a 10% change in capacitance.

Calculate % change Example

1. Conversion gain is set = 100
2. Measure electrode capacitance = 492cnts
3. Enable 1pF reference capacitor
4. Measure electrode + refcap capacitance= 335 cnts
5. Calculate %change

$$gain\left(\frac{1}{count + delta} - \frac{1}{LTA}\right) * 100\%$$

$$100\left(\frac{1}{335} - \frac{1}{492}\right) * 100\% = 9.5\%$$

Calculate electrode base capacitance

Using the 9.5 %change in capacitance from the earlier example, it is possible to calculate the base electrode capacitance. The base electrode capacitance *Cx* can be expressed as:

$$1.095 = \frac{Cx + 1pF}{Cx}$$

$$1.095Cx = Cx + 1pF$$

$$1.095Cx - Cx = 1pF$$

$$Cx(1.095 - 1) = 1pF$$

$$Cx(0.95) = 1pF$$

$$Cx = \frac{1pF}{0.095} = 10.53pF$$

So what was the finger capacitance?

- Baseline Electrode capacitance, Cx = 10.53pF
- %change in capacitance with finger applied = 5%

Calculate finger capacitance, Cf.

$$1.05 = \frac{Cx + Cf}{Cx}$$

$$1.05Cx = Cx + Cf$$

$$Cx(1.05 - 1) = Cf$$

$$Cx(0.05) = Cf$$

$$Cf = 0.52pF$$