MSP with CapTIvate™ Technology

Liquid Level Detection
Calibration with water present

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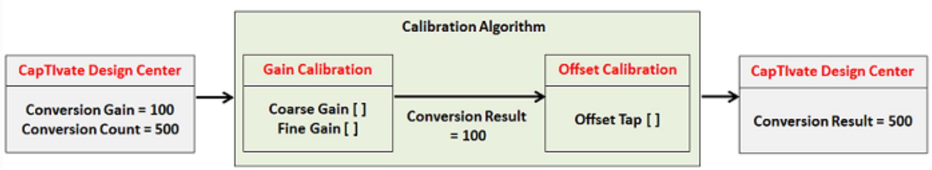
Understanding CapTIvate Calibration

- The purpose of calibration is to ensure target sensitivity is maintained over changing temperature and humidity conditions.
- Calibration attempts to adjust these 3 parameters in order to achieve the <u>target conversion count,</u> independent of temperature or presence of a finger or, in this example liquid.
  - Coarse gain, Fine gain and Offset tap
- After calibration, the LTA (long-term average) is reset to the target conversion count and all measurements are made “relative” to the LTA.
- Calibration must be performed at power on and any time the LTA drifts from its last calibration point to maintain sensitivity.

Sensitivity

- Conversion count and gain determine the system's sensitivity
- Example: gain = 100, conversion count target = 500
- Step #1 - Gain Calibration
  - Coarse and fine gain are adjusted to achieve conversion result = 100
  - Offset set = 0 during this portion of the calibration
- Step #2 – Offset Calibration
  - Offset tap selected to achieve conversion result = 500

Here is calibration process example, user sets Conversion Count and Conversion Gain in CapTIvate Design Center to get desired conversion results:



The four parameters influence the charge transfer process in the following way:

$$Q_{out} = (gain_{coarse} * gain_{fine})Q_{in} - (offset_{scale} * Q_{offset})$$

Fig. 191 Signal Conditioning Mathematical Model

LTA – How it works

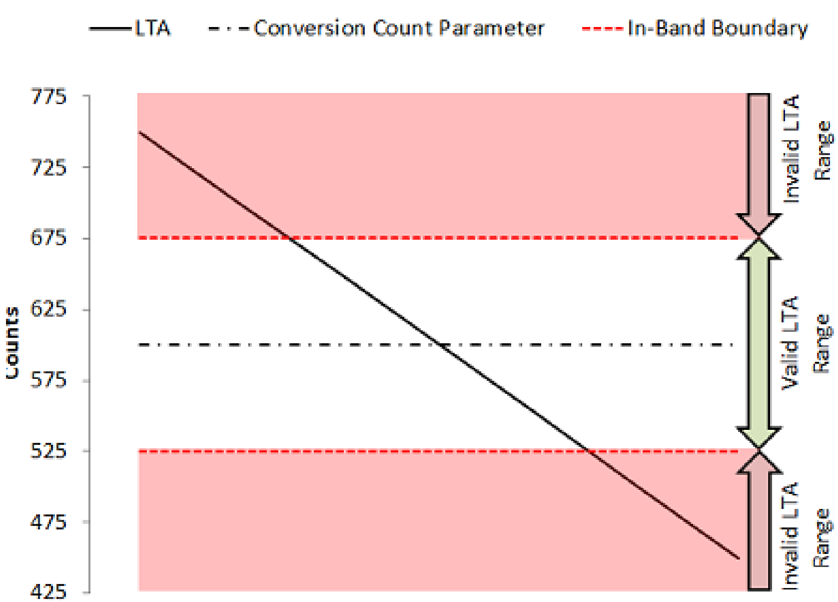
Runtime Re-Calibration

The runtime re-calibration feature provides a runtime check of each element in the sensor to ensure that it is within the resolution and sensitivity band that was specified. The conversion count and conversion gain parameters (in the *Conversion Control* section) specify the desired measurement resolution and sensitivity for the sensor. At device power-up, each element in the sensor is calibrated according to these values. However, environmental drift due to temperature, voltage, humidity, and other factors may cause elements within the sensor to slowly drift from their initial calibration target over time.

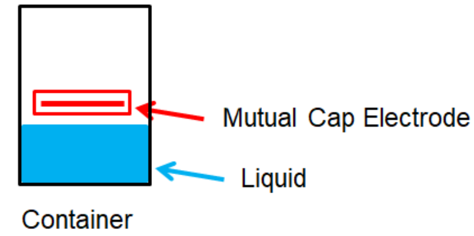
Run-time re-calibration, if enabled, checks each element after every measurement to ensure that the long term average (LTA) is within range of the specified conversion count. If the LTA happens to drift out of range, the sensor will be re-calibrated to bring the LTA back in line with the specified conversion count. The valid range is +/- 1/8th of the conversion count, as shown in the equation below.

$$LTA_{ValidRange} = \text{ConversionCount}\left(1 \pm \frac{1}{8}\right)$$

The plot below shows the valid and invalid ranges for the LTA if the conversion count is specified as 600. If the LTA tracks into an invalid range, the sensor will be re-calibrated to return the LTA and count to the specified conversion count.

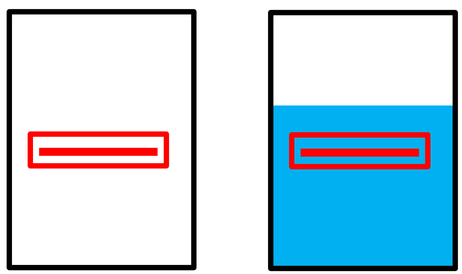


Setup



- Mutual Capacitive electrode
- Assuming conversion gain = 100 and target conversion count = 1000
- Calibration with and without water present

No water present
After calibration conversion count goes up with water present.

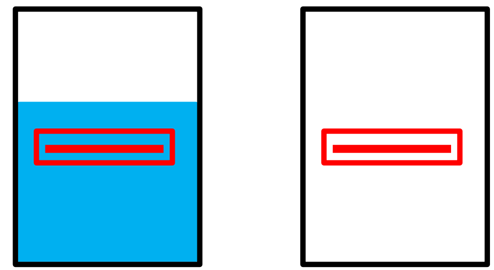


Calibrated with Air
cc = 980

Water added
cc = 1280

~(2.39%) change in capacitance

Water Present
After calibration conversion count goes down with absence of water



Calibrated with water
cc = 970

Water removed
cc = 800

~(2.1%) change in capacitance

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

→

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

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

Problem Statement

- How to detect the presence of a liquid if calibration is performed in the presence of a liquid?

Suggested Solution- Temperature Profile

- The following is suggested - TI has not been verified this works
  1. Requires at least an external temperature sensor (best to measure humidity too)
  2. Calibrate dry (no water) and record coarse, fine gains and offset value
  3. Measure and record temperature near MCU and capacitive sensor
  4. Force a recalibration (do this in the GUI) to collect new settings for this temperature
  5. Repeat across anticipated operating temperatures (ex. 0C to 50C)
  6. Store temperature and calibration settings in memory
- How it works
  - At POR do not perform normal CapTIvate calibration and also disable automatic run-time calibration
  - Measure temperature and populate coarse, fine gains and offsets from lookup table for the current operating temperature (doesn't matter if water present or not)
  - Continue to monitor temperature change parameters as needed. (see next slide for temp drift data)
- Limitations
  - Limited to single device
  - If building more than one device (product), repeat steps for each device

Temperature Compensation

- Important: The temperature profile shown is just for MSP430
  - Basically this profiles the CapTIvate AFE and does not include any sensor
  - Changes in sensor capacitance can be much greater than MCU due to exposure to different temperatures and humidity
- Chart shows temperature slope is (-0.2cnt / deg) @ 250 conversion cnt
- Slope will vary depending on conversion count setting
  - Plan on performing this test to determine slope for your conversion count
  - Include sensor as part of the test so you get a complete accurate profile

Device Generation	Conversion Results Drift
1st Gen	-0.2 counts/°C
2nd Gen	-0.1 counts/°C

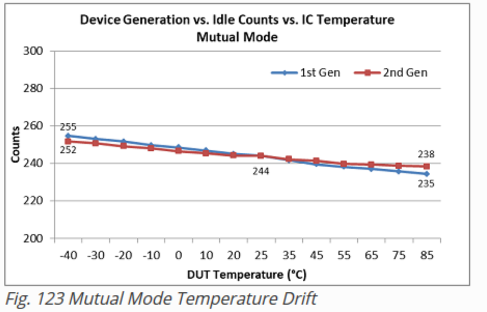


Fig. 123 Mutual Mode Temperature Drift

Do I even need to recalibrate?

- Depends
  - Based on only MCU AFE temperature profile, probably not, but this is not realistic – must include changes due to sensor
  - MCU Example: Assuming conversion count = 250
    - LTA normally recalibrates if 12.5% change = +/-32 cnts
    - 32 cnt X 1deg/0.2cnt = 160Cdeg
  - Based just on MCU, recalibration never needed, but this is not realistic
  - Remember, this is temperature of only the MCU AFE so plan on performing your own temperature profile that includes the sensor changes

Do I even need to recalibrate - Example

- Let's say a temperature profile is taken on the MCU and sensor from 0C to 50C (don't bother below 0C as water becomes ice)
  - Calculated slope = 8cnt / degC change
- Let's assume conversion count target = 1000
- Calculate how often to apply updated coarse and fine gain, and offset
    - 12.5% change in LTA = +/- 125cnts
    - 125cnt -> 125cnt x C/8cnt = 15.3C
    - Therefore, must update every 15.3deg C change in temperature