ABSTRACT

Calibration is required to maximize accuracy for liquid level sensing applications. This is a step by step guide to performing this calibration with the FDC1004 for two sensor systems (see Figure 1). Refer to Capacitive Sensing: Out-of-Phase Liquid Level Technique (SNOA925) for an introduction to liquid level sensing with the FDC1004.

There are two main phases of calibration with the FDC1004:
1. Baseline measurement: $C_{\text{level}}(0)$ and $C_{RL}(0)$
2. Absolute error correction

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Performing the baseline measurement

1. Empty the reservoir completely
2. Measure the $C_{\text{level}}$ (capacitance of the LEVEL sensor) and $C_{\text{RL}}$ (capacitance of the REFERENCE sensor) while empty. These will correspond to $C_{\text{level}}(0)$ and $C_{\text{RL}}(0)$
3. **Equation 1** can be used to calculate the liquid level.
   \[
   \text{Level} = h_{\text{RL}} \frac{C_{\text{level}} - C_{\text{level}}(0)}{C_{\text{RL}} - C_{\text{RL}}(0)}
   \]  
   \(1\)

   Where:
   - $h_{\text{RL}}$ = the unit height of the reference liquid sensor (often 1). Note: the unit here will determine the unit of **Equation 1**
   - $C_{\text{level}}$ = capacitance of the LEVEL sensor
   - $C_{\text{level}}(0)$ = capacitance of the LEVEL sensor when reservoir is empty
   - $C_{\text{RL}}$ = capacitance of the REFERENCE sensor
   - $C_{\text{RL}}(0)$ = capacitance of the REFERENCE sensor when reservoir is empty

2. **Performing the Absolute error correction**

   The absolute error correction accounts for gain and offset errors in the sensor and device. To perform the absolute error correction, a "wet calibration" must be done, where liquid is added to the reservoir and capacitance levels are measured. The steps are as follows:
   1. Add liquid to a known level height
   2. Read the capacitance levels from the FDC device ($C_{\text{level}}$, $C_{\text{RL}}$)
   3. Use equation 1 to determine calculated liquid level height (remember the units for equation 1 will be the same as the units used to measure the reference liquid sensor, $h_{\text{RL}}$)
   4. Repeat steps 1-3 at least once with different known level height(s) to gain enough sample points
   5. Compare the calculated liquid level heights to the actual level height. Example:

   ![Figure 2. Calculated and Actual Liquid Level Height](image)

   6. Draw a best fit line through the calculated data.
7. To determine the gain and offset registers values (registers 0x0D-0x14, see datasheet for more details) use Equation 2 and Equation 3.

Best fit line: \( y = m \times x + b \), where \( m \) is the slope and \( b \) is the y-intercept

\[
\text{Gain} = \frac{1}{m} \tag{2}
\]

\[
\text{Offset} = -\frac{b}{m} \tag{3}
\]

For more details on these equations, see Section 3.

Once the gain and offset registers are updated in the FDC1004 equation 1 will yield the corrected level.

Figure 3. Corrected and Actual Liquid Level Height

Now the corrected data overlaps the ideal response and your system is calibrated.
Appendix

3 Appendix

Proof of Equation 2 and Equation 3:

- Height measured: \( y_1 = x_1 \times m + b \)
- Ideal result: \( y' = x_1 \) (where \( y' \) is corrected \( y \))
- \( y' = (y_1) \times \text{gain} + \text{offset} \)
- Let \( \text{gain} = \frac{1}{m} \), and \( \text{offset} = -\frac{b}{m} \)
- \( y' = (x_1 \times m + b)m - \frac{b}{m} \)
- \( y' = x_1 \times m/m + b/m - \frac{b}{m} \)
- \( y' = x_1 \)
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