Application Note 33

Sensirion SHT1
Temperature and Humidity Sensor

This application note shows how to use the uM-FPU V3 floating point coprocessor with the Sensirion SHT1 humidity and temperature sensor to calculate temperature, relative humidity and the dewpoint. The uM-FPU V3 chip makes it easy to implement the formulas described below on virtually any microcontroller.

Connections
The following diagram shows the connections required for the Sensirion SHT1 module.

![Connections Diagram]

Brief Overview of Sensirion SHT1
The Sensirion SHT1 humidity and temperature sensors are single chip modules that provide calibrated digital output over a 2-wire serial interface. These modules are easily connected to a microcontroller, but to achieve full accuracy, floating calculations must be performed. These calculations compensate for the non-linearity of the humidity sensor, convert the data to standard units of temperature and relative humidity, and determine the dewpoint using a logarithmic equation.

For $V_{DD} = 5V$, the Sensirion SHT1x/SHT7x Datasheet defines the following formulas:

\[
\begin{align*}
\text{Temperature}_C &= -40.0 + 0.01 \times \text{SO}_T \\
\text{RH}_{\text{linear}} &= -4.0 + 0.0405 \times \text{SO}_{\text{RH}} + (-2.8 \times 10^{-6} \times \text{SO}_{\text{RH}}^2) \\
\text{RH}_{\text{true}} &= (\text{Temperature}_C - 25.0) \times (0.01 + 0.0008 \times \text{SO}_{\text{RH}}) + \text{RH}_{\text{linear}} \\
H &= (\log_{10}(\text{RH}_{\text{true}}) - 2.0) / 0.4343 + (17.62 \times \text{Temperature}_C) / (243.12 + \text{Temperature}_C) \\
\text{DewPoint} &= 243.12 \times H / (17.62 - H)
\end{align*}
\]

Temperature Calculation
The formula for converting the 14-bit raw temperature reading to degrees Celsius is defined as follows:

\[
\text{Temperature}_C = -40.0 + 0.01 \times \text{SO}_T
\]

The SO$_T$ reading is called RawTemp and the formula is rearranged as follows:

\[
\text{Temp}_C = \frac{\text{RawTemp}}{100 - 40}
\]
The uM-FPU V3 instructions for calculating temperature in degrees Celsius are as follows:

```
SELECTA, TempC
FSET, RawTemp
FDIVI, 100
FSUBI, 40
```

**Relative Humidity**

To compensate for the non-linearity of the humidity sensor and to obtain full accuracy, the following formula is defined:

$$RH_{linear} = -4.0 + 0.0405 \times SO_{RH} + (-2.8 \times 10^{-6} \times SO_{RH}^2)$$

The $SO_{RH}$ reading is called RawHumidity, the floating point constants are assigned to C2 and C3, and the formula is rearranged as follows:

- $C2 = 0.0405$
- $C3 = -2.8E10^{-6}$
- $RhLinear = (((RawHumidity \times C3) + C2) \times RawHumidity) - 4.0$

The uM-FPU V3 instructions for performing the initial relative humidity calculation are as follows:

```
SELECTA, RhLinear
FSET, RawHumidity
FMUL, C3
FADD, C2
FMUL, rawHumidity
FSUBI, 4
```

For temperatures significantly different than 25°C (~77 ºF) the temperature coefficient of the humidity sensor should be considered. The following formula adjusts for the temperature coefficient:

$$RH_{true} = (Temperature_C - 25.0) \times (0.01 + 0.0008 \times SO_{RH}) + RH_{linear}$$

The $Temperature_C$ reading is called TempC, the floating point constants are assigned to T1 and T2, and the formula is rearranged as follows:

- $T1 = 0.01$
- $T2 = 0.00008$
- $RH_{true} = TempC - 25.0 \times (T2 \times RawHumidity + T1) + RH_{linear}$

The uM-FPU V3 instructions for adjusting the relative humidity for the temperature coefficient are as follows:

```
SELECTA, RHtrue
FSET, TempC
FSUBI, 25
LEFT
FSET, T2
FMUL, RawHumidity
FADD, T1
RIGHT
FMUL0
FADD, RHLinear
```
**Dewpoint**

Since humidity and temperature are both measured on the same monolithic chip, the SHT11 allows superb dewpoint measurements. The Sensirion Application Note on dewpoint calculation provides the following formulas:

\[
H = \frac{\log_{10}(RH_{\text{true}}) - 2.0}{0.4343} + \frac{17.62 \times \text{Temperature}_C}{243.12 + \text{Temperature}_C}
\]

DewPoint = \(243.12 \times H / (17.62 - H)\)

The Temperature\(_C\) reading is called TempC, RH\(_{\text{true}}\) is called RH\(_{\text{true}}\), the floating point constants are assigned to K1, K2 and K3, and the formula is rearranged as follows:

\[
K1 = 0.4343 \\
K2 = 17.62 \\
K3 = 243.12 \\
H = \frac{\log_{10}(RH_{\text{true}}) - 2}{K1} + (K2 \times \text{TempC}) + (K3 + \text{TempC})
\]

The uM-FPU V3 instructions for calculating the dewpoint are as follows:

```assembly
SELECTA, H
FSET, RHTrue
LOG10
FSUBI, 2
FDIV, K1
LEFT
FSET, K2
FMUL, TempC
LEFT
FSET, K3
FADD, TempC
RIGHT
FDIV0,
RIGHT,
FADD0

SELECTA, DewPoint
FSET, K3
FMUL, H
LEFT
FSET, K2
FSUB, H
RIGHT
FDIV0
```
Using the POLY Instruction for the Relative Humidity Calculation

The formula used to compensate for the non-linearity of the humidity sensor is a second order polynomial:

\[ \text{RH}_{\text{linear}} = -4.0 + 0.0405 \times \text{SO}_{\text{RH}} + (-2.8 \times 10^{-6} \times \text{SO}_{\text{RH}}^2) \]

If a user-defined function is defined using the uM-FPU V3 IDE, an alternative to the step-wise calculation is the POLY instruction which automatically computes polynomial expressions. The POLY instruction specifies the number of coefficients, then each coefficient is stored immediately following the instruction, from the highest order to the lowest order. The following example shows the POLY instruction for calculating \( \text{RH}_{\text{linear}} \):

```
POLY, 3
#float -2.8E-6
#float 0.0405
#float -4.0
```

Further Information

See the Micromega website (http://www.micromegacorp.com) for additional information regarding the uM-FPU V3 floating point coprocessor, including:

- uM-FPU V3 Datasheet
- uM-FPU V3 Instruction Set

See the Sensirion website (http://www.sensirion.com) for additional information regarding the Sensirion SHT11 and other temperature and humidity sensors, including:

- Datasheet: Humidity Sensor SHT1x/SHT7x
- Application Note: Dewpoint Calculation Humidity Sensor
- Application Note: Introduction to Relative Humidity