Application Note 33

Sensirion SHT11 Temperature and Humidity Sensor

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This application note shows how to use the uM-FPU V3 floating point coprocessor with the Sensirion SHT11 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 SHT11 module.
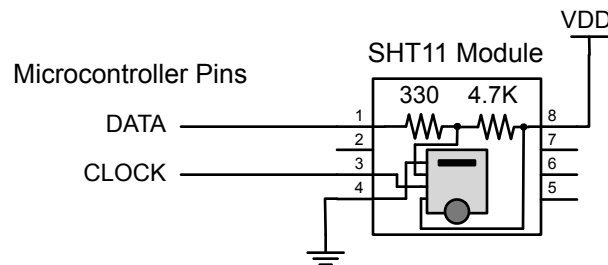
Brief Overview of Sensirion SHT11

The Sensirion SHT11 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:

$$Temperature_C = -40.0 + 0.01 * SO_T$$
$$RH_{linear} = -4.0 + 0.0405 * SO_{RH} + (-2.8 * 10^{-6} * SO_{RH}^2)$$
$$RH_{true} = (Temperature_C - 25.0) * (0.01 + 0.0008 * SO_{RH}) + RH_{linear}$$
$$H = (\log_{10}(RH_{true}) - 2.0) / 0.4343 + (17.62 * Temperature_C) / (243.12 + Temperature_C)$$
$$DewPoint = 243.12 * H / (17.62 - H)$$

Temperature Calculation

The formula for converting the 14-bit raw temperature reading to degrees Celsius is defined as follows:
$$Temperature_C = -40.0 + 0.01 * SO_T$$

The SO_T reading is called `RawTemp` and the formula is rearranged as follows:

```
TempC = 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:

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

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 * C3) + C2) * 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 25ºC (~77 ºF) the temperature coefficient of the humidity sensor should be considered. The following formula adjusts for the temperature coeffiecient:

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

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
RHtrue = TempC - 25.0 * (T2 * RawHumidity + T1) + RHlinear
```

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:

$$H = (\log_{10}(RH_{true}) - 2.0) / 0.4343 + (17.62 * Temperature_C) / (243.12 + Temperature_C)$$

$$DewPoint = 243.12 * H / (17.62 - H)$$

The $Temperature_C$ reading is called TempC, RH_{true} is called RHtrue, 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 = (LOG10(RHtrue) − 2) / K1) + (K2 * TempC) + (K3 + TempC)
```

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

```
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:

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

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 RH_{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