1 Humidity measurement using a microcontroller circuit (EP 1 574 847 B1 // US 7,084,644 B2)

1.1 Requirements for the microcontroller

1.) 3 to 4 digital I/O pins, switchable between output and (analog) input
2.) Integrated comparator (switchable to digital I/O output)
External component also possible
3.) Integrated voltage divider (used as reference voltage at comparator)
External component also possible

1.2 Schematic circuit diagram

1.2.1 Non adjusted HCT01-00

If the non adjusted HCT01-00 humidity sensor is used within the schematic circuit in figure 1, the whole PCB must be calibrated at a defined humidity.

1.2.2 Adjusted HCT01-02/03

There are three measurement paths:

1.) **Sensor** (capacitance) path with R1 + HCT01 + D1 + C2 (= C_L)
2.) **Reference** (capacitance) path with R2 + C_REF + D1 + C2 (= C_L)
3.) **Calibration** (capacitance) path with R3 + C_CAL + D1 + C2 (= C_L)

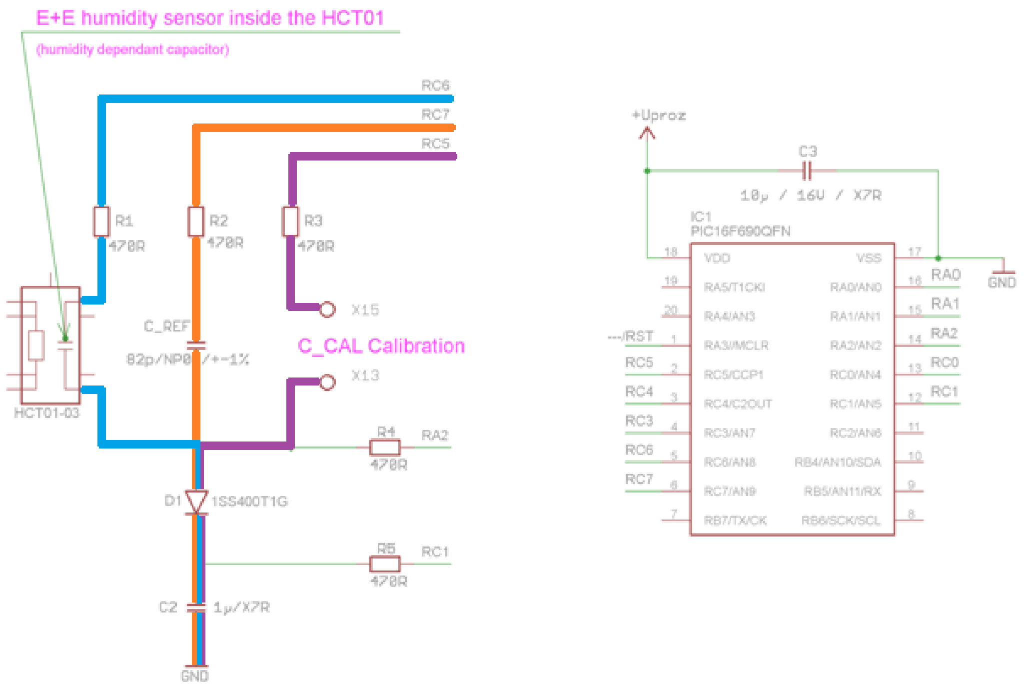


Figure 1: Schematic circuit design[1]

[1] C_REF = ±1% ➔ @82pF = ±0.82pF ≈ ±3.4%RH
C_Cal= Capacitance which is used for calibration end testing [no soldering necessary]

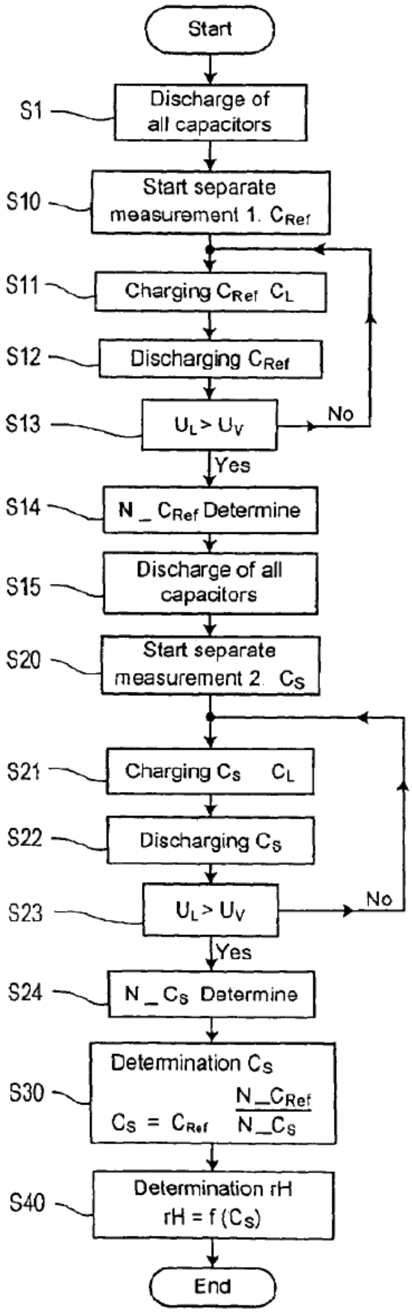
1.3 Bill of Material

1 pcs ....HCT01-03xTR1 (E+E Elektronik)
1 pcs ....D1; Fast Si-Diode (e.g.1SS400T1G)
1 pcs ....C2; 1µF, ceramic / X7R
1 pcs ....Existing microcontroller (e.g.: Microchip PIC16F690) [check requirements in Chapter 1.1]
1 pcs ....C_REF; 82pF, ceramic / NP0 / CG0
5 pcs R1-R5; 470Ohm

1.4 Circuit design

U_L = voltage at C_L (=C2)

U_V = Voltage at the voltage divider (reference voltage)



Measurement of the three paths ("sensor" or "reference" or "calibration") is done in the same way.

Example: reference path:

1.) Discharge all capacitors (I/O pins RC1, RC5, RC6, RC7 and RA2 = output LOW)
2.) Charging reference capacitor and C_L (RC6, RC5, RA2 = input, RC1 = switched to comparator input, RC7 = output HIGH). The charge from the reference capacitor is also transferred in the capacitor C2 (=C_L) and the voltage in C2 (=C_L) rises a little bit. The capacitance of C2 is approx. 10.000 times higher than C_REF.
3.) Discharging reference capacitor (RC6, RC5 = input, RC1 = switched to comparator input, RA2, RC7 = output LOW).
4.) Increment the number of charge/discharge events (in this case N_C_{Ref}).
5.) Check if the voltage at the pin RC1 (comparator) reaches the voltage at the voltage divider:
no ➔ go to point 2.) and recharge the reference.
yes ➔ end of loop and save the numbers of charge/discharge events.
6.) One normal measuring cycle measures the path reference and the path sensor and calculates the sensor capacitance from these measurements

On request, there is also a code example available (PIC16F690, HITECH PICC Compiler)

2 Development procedure

2.1 Circuit layout

This is a capacitance measurement circuit which does not differ between the humidity sensor and the PCB. Keep the PCB- and humidity sensor stray capacitance as low as possible. That means also the stray capacitances to GND which bypasses the diode D1 (C2 near D1,R5 & RC1) are low.
The sensor sensitivity is approx. 0.25pF/%RH.

2.2 Evaluation of nominal values (only during development)

There are four options to find the nominal values:

1. Measure an appropriate amount of prototypes at defined environmental (humidity) conditions
2. Measure an appropriate amount of prototypes with defined capacitors (measure each capacitor) instead of the humidity sensor HCT01
3. Simulate the circuit without any stray capacitance
    - Layout the PCB
    - Back annotation of the layout stray capacitances
    - Re simulate the schematic circuit as accurately as possible
4. Simulate the circuit without any stray capacitance
    - Measure the PCB stray capacitances
    - Include the measured values in the designed schematics
    - Re simulate the schematic

If options three or four are used take care that the simulation is as accurate as the models used in the simulation.

3 Example

This sample PCB includes a humidity and temperature measurement with an I²C similar digital output.

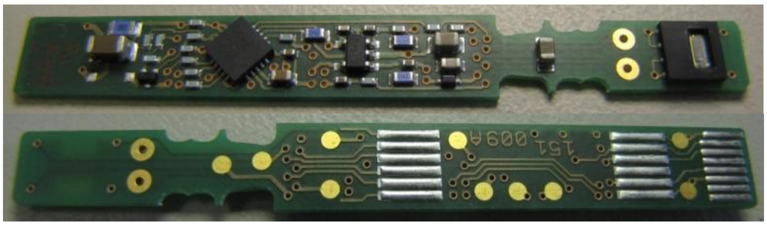


Figure 2: Sample PCB

In this case the nominal values were found under defined humidity conditions. The measured values were compared with ideal sensor characteristics without any correction of the layout capacitances.

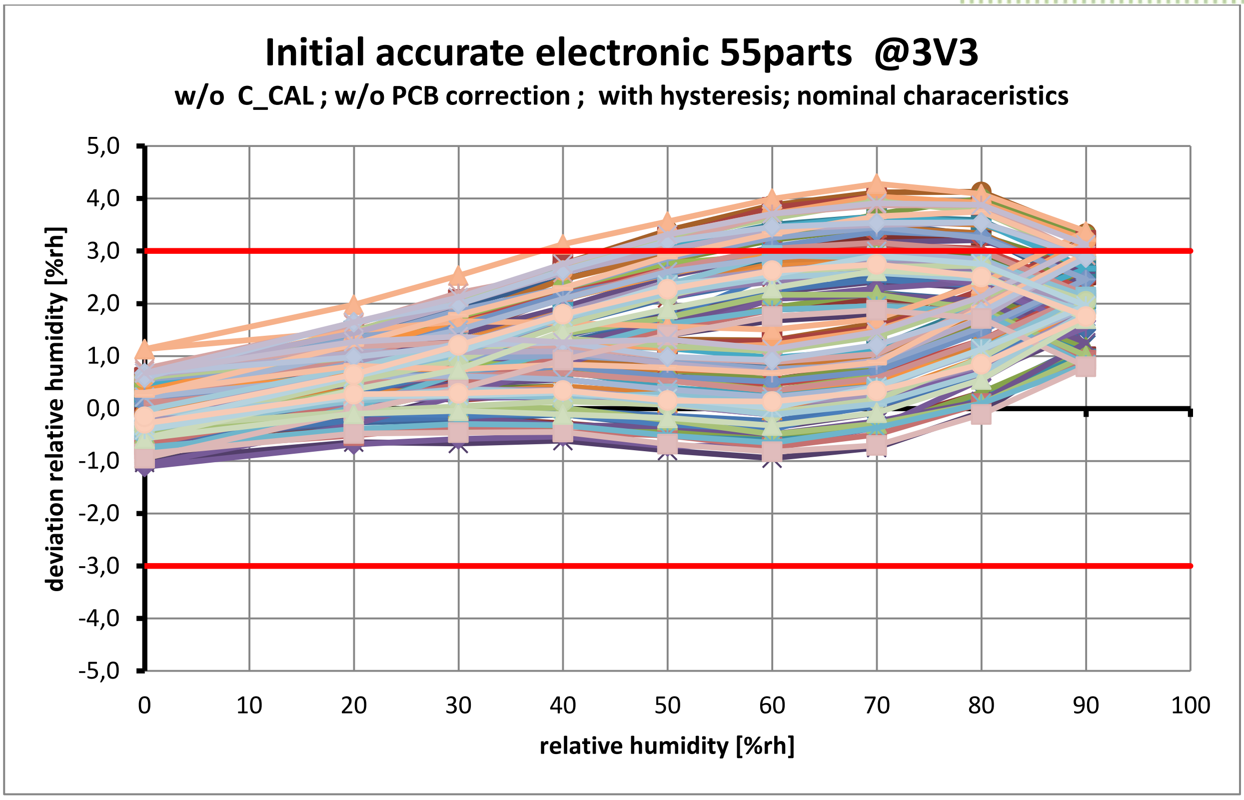
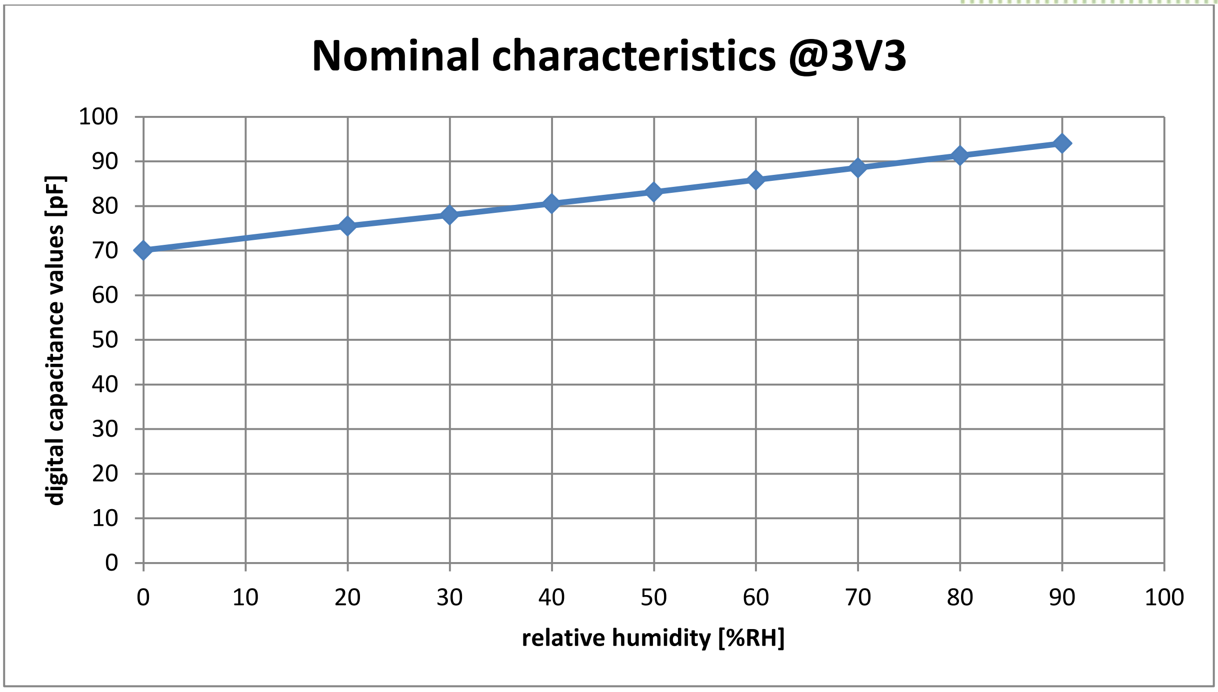


Figure 3: Initial accuracy of PCB / 0%-90%-0%RH in 10 digit steps, 20 min waiting time/step

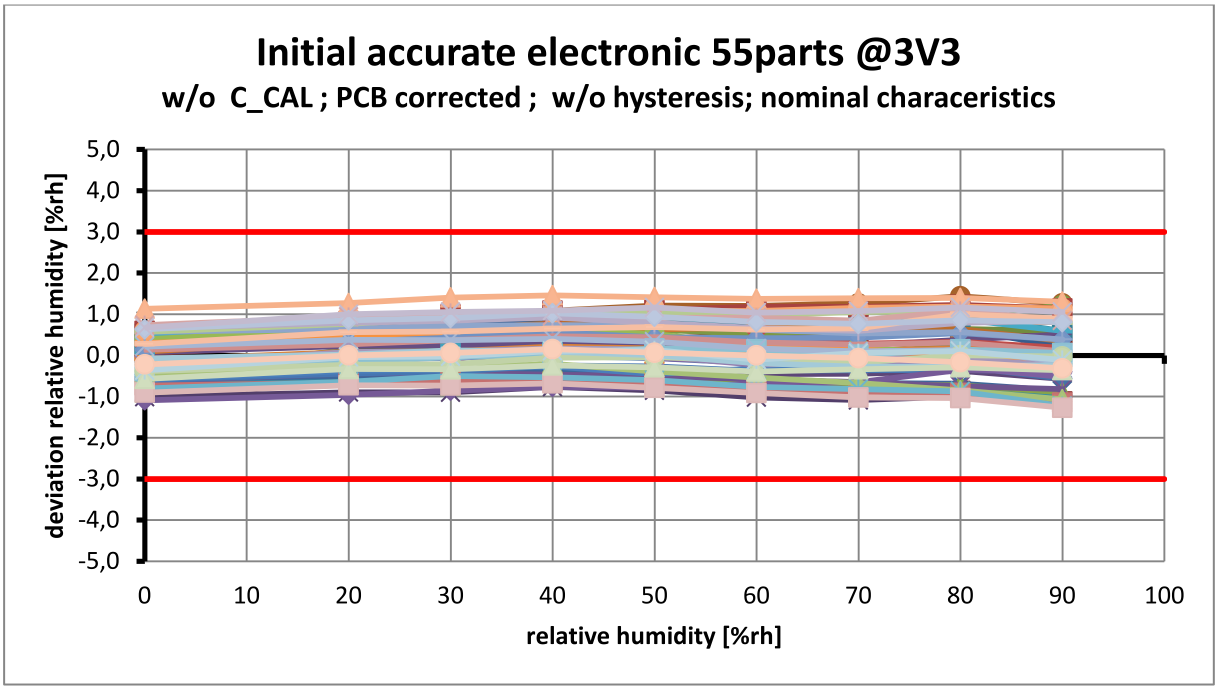
In this diagram (Figure 3) you can see the following:

- Hysteresis of the sensor (approx. 1.8%RH)
- The parasitic PCB Layout capacitances are not corrected (mean value of deviation isn't 0)
- The small deviations due to tolerances from part to part (HCT01 & C_REF) e.g. at 0%RH result due to good PCB parts.

With this measurement you can correct the ideal sensor characteristics with the parasitic PCB layout capacitances and get a nominal system characteristic.

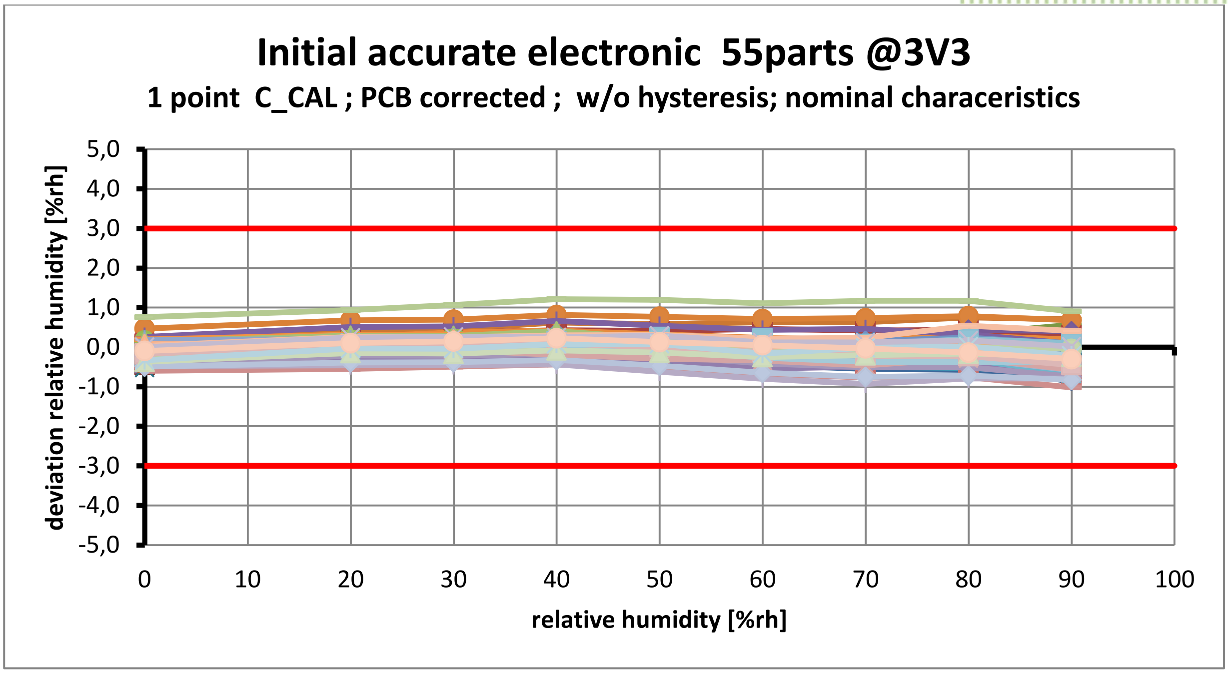


If you correct the PCB influences (0%RH@0%RH and -2.3%RH@100%RH) and eliminate the hysteresis, you'll get the following deviation diagram:



- In this case the part to part deviation of the HCT01 and the C_REF are approx. ±1.4%RH.
- Measure each PCB with a very well defined C_CAL during the electrical test of the PCB. Correct the C_REF with this measurement (or determine the exact value of C_REF during the PCB in circuit test).
- In the code example you can use the values ANZ_CS, ANZ_CREF, ANZ_CCAL meaning the number of charge/discharge cycles to reach the reference voltage at the comparator (measure all 3 paths).

If C_CAL of 82.79pF is used the result is shown in the following diagram:



The system part to part deviation is reduced to approx ±1%RH.

4 Contact information

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Revision history

Date	Revision number	Changes
November 2011	V_0.1	Initial release