[index of all my hygrometer testing.]

Compare DHT22, DHT11 and Sensirion SHT71

Introduction

My previously published results compared six AM2302 (a.k.a. DHT22, RHT03 and I use the names interchangably throughout) hygrometers. Here I repeat that experiment using the same apparatus and techniques but replace two of the sensors with alternative models, a DHT11 and a Sensirion SHT71. The objectives of the earlier work were to establish whether a sensor as cheap as the AM2302/DHT22 could live up to their claimed accuracy. My conclusion was that in my experiments they did not, but they did deliver surprisingly good performance and very good value for money for most non-safety-critical, domestic DIY projects. The next obvious question is whether my tests would show a more expensive device to be better. Since I was re-running the experiment I also included the even cheaper and lower specification DHT11.

Data sheets for the DHT11 and DHT22 devices tend to be brief. The numbers in the following table appear on datasheets and are typically quoted by retailers. The Sensirion datasheet on the other hand is detailed and comprehensive providing accuracy as a function of humidity as well as details of recommended calibration and linearization procedures. Note how Sensirion's absolute accuracy claims are less strict and more believable than those normally quoted for the DHT devices.

Manufacturers' Specification

	AM2302 / DHT22	DHT11	SHT71
Range	0-100%	20-90%	0-100%
Absolute accuracy	±2%	±5%	±3% (20<RH<80) ±5% (RH<20, RH>80)
Repeatability	±1%	±1%	±0.1%
Long term stability	±0.5% per year	±1% per year	<0.5% per year
Typical street price	US$ 4-10	US$ 1-5	US$ 30-50

Accurately and repeatably measuring relative humidity is notoriously tricky. The procedures used here were developed over a period of about a year and are detailed on my DHT22/AM2302 calibration page. I am no expert in hygrometers. I just devised the best experiment I could based on my reading of several papers on the topic and using a few items of household equipment I had lying around.

The Devices and Test Apparatus

The AM2302/DHT22 devices are the same units as I used previously. They are A,B,D,E and F from my previous write-up. Though five are mentioned, only four were under test at any one time. Sensor B failed during the experiment and was replaced by E. I have added a DHT11 and a Sensirion SHT71.

Apparatus setup is as previously described. All sensors were powered from a 5V d.c. switching power supply. New software needed to be added to microcontroller to read the Sensirion device and was based on Markus Schatzl and Carl Jackson's Sensirion Arduino library.

The reference calibration sources are still the same too, eleven saturated salt solutions and distilled water. Data were all collected in a similar manner to before with the sensors being allowed to stabilise for a few hours with each solution.

All data so far (Nov 2014) have been collected at either 22°C or 30°C. I do not yet have any detailed data on the thermal coefficient of the SHT71 and DHT11.

Quality of build

At more than ten times the price the SHT71 is unsuprisingly far superior to the others. It is both smaller and feels more solid. The gold plated Cu/Be alloy pins are very robust in comparison to the DHT22 on which the pins honestly feel like they are made of thick aluminium foil. Note that the SHT71 has 1.27mm separation pins which does make it less easy to hook up to common hobbyist 2.54mm Arduinos and bread-boards. I mounted mine in a 2.54mm header block for easy handling.

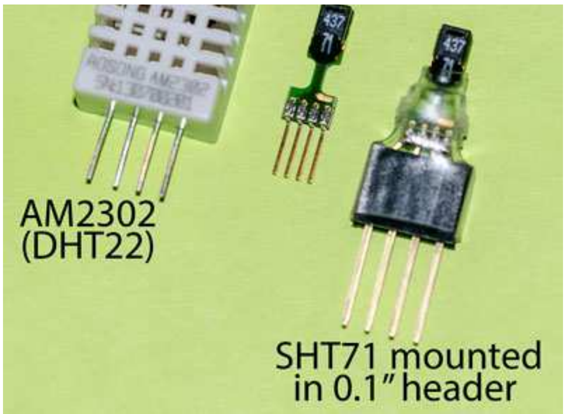


Figure 1. Comparison of the packaging of the SHT71 compared to AM2302. DHT11 looks similar to the AM2302. Though somewhat smaller, it also has 0.1" separation pins. The SHT71 has 0.05" separation pins.

Response Speed

The SHT71 consistently responded to changes the fastest, registering a change in a few seconds. The DHT22/AM2302 takes about 30sec and the DHT11 can take a couple of minutes. Since I am only sampling every 30sec, these response times are not precisely determined.

All sensors (including the SHT71) can take several hours to fully stabilize at high humidities. Though some of this may be the device, I suspect it genuinely takes several hours to equilibrate and saturate the air inside the jar after a swap. Still, the relative fact that the SHT71 is the fastest and DHT11 the slowest is obviously real since they are all together measuring the same air.

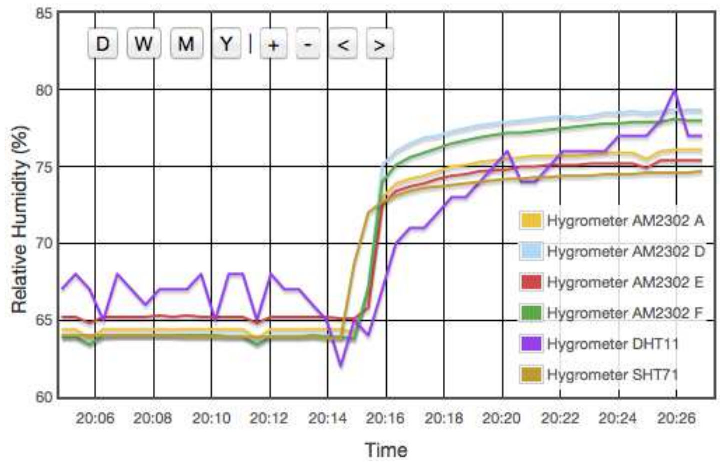


Figure 2. A typical example of humidity measurements as the sample solution is changed. Output values from the SHT71 consistently respond on the first reading after the change and shows an abrupt step change. The DHT22s typical respond within one or two samples. The DHT11 shows some sort of reponse with a minute or two, but can take a while to gradually drift towards the new measurement.

Results

Part 1: As a Function of Humidity

First we look at the varying response of the sensor to different reference humidities, all measured at a single fixed temperature.

Compound	**Ref.**			**Measured RH %**			
	RH %	**A**	**B**	**D**	**F**	**SHT71**	**DHT11**
NaOH	6.8	9.7	12.5	10.2	8.4	12.7	31.8
LiCl	11.2	14.0	15.8	14.8	12.9	16.6	31.9
MgCl	32.8	31.6	29.2	33.9	31.4	35.4	38.9
K_2CO_3	42.6	41.4	37.0	45.3	42.6	45.4	46.5
NaBr	56.6	54.4	46.5	59.0	56.7	57.4	57.9
NH_4NO_3	59.4	57.1	48.9	61.9	59.7	60.7	61.9
KI	67.9	65.0	54.6	71.8	69.1	68.4	70.3

NaCl	75.3	71.8	60.1	80.3	78.9	75.8	80.3
NH_4SO_4	79.9	75.9	63.4	85.7	84.6	80.1	86.3
KCl	84.0	79.1	65.6	89.6	91.3	83.8	89.6
K_2NO_3	91.7	87.4	71.1	98.0	-	91.6	91.0
H_2O	100.0	96.4	77.8	-	-	98.1	92.0

Experimental results at run 2 (August 2014), taken at 30°C. 'Reference RH' is the expected value taken from published literature interpolated to the temperature at the time the measurement was obtained. 'Measured RH' are the values as returned from the DHT22, DHT11 and SHT71 devices. In the case of SHT71, these numbers have already been temperature corrected and linearized using the default paramaters from the manufacturer's datasheet. Each value is average of two or three measurements obtained over a period of two weeks. For sensors A,B,D and F these are new measurements and may be compared to previous data obtained from the same sensors. Temperature is entirely defined by the readings from the devices themselves without any external calibration.

Compound	**Ref.**			**Measured RH %**				
	RH %	**A**	**B**	**D**	**E**	**F**	**DHT11**	**SHT71**
NaOH	7.3	9.7	9.7	8.4	9.4	7.8	35.8	12.6
LiCl	11.8	14.0	13.3	12.8	13.8	12.1	35.9	16.3
MgCl	33.1	33.3	31.0	31.9	32.7	30.9	38.9	35.5
K_2CO_3	43.4	44.1	41.7	42.8	45.4	41.6	48.6	45.3
NaBr	58.1	59.2	56.1	59.2	61.0	58.3	63.3	59.7
NH_4NO_3	64.7	64.1	61.0	63.9	65.4	64.1	67.4	64.2
KI	69.5	70.2	66.7	72.3	71.3	71.2	74.0	70.4
NaCl	75.3	76.4	72.2	79.0	76.4	79.3	82.4	76.2
NH_4SO_4	80.2	82.0	77.3	84.7	81.0	86.6	91.4	81.4
KCl	85.3	86.3	82.0	88.0	85.1	93.0	93.7	85.2
K_2NO_3	93.5	96.3	-	98.0	95.3	-	95.0	93.5
H_2O	100.0	-	-	-	-	-	-	98.7

Experimental results at run 3 (November 2014), taken at 22°C.

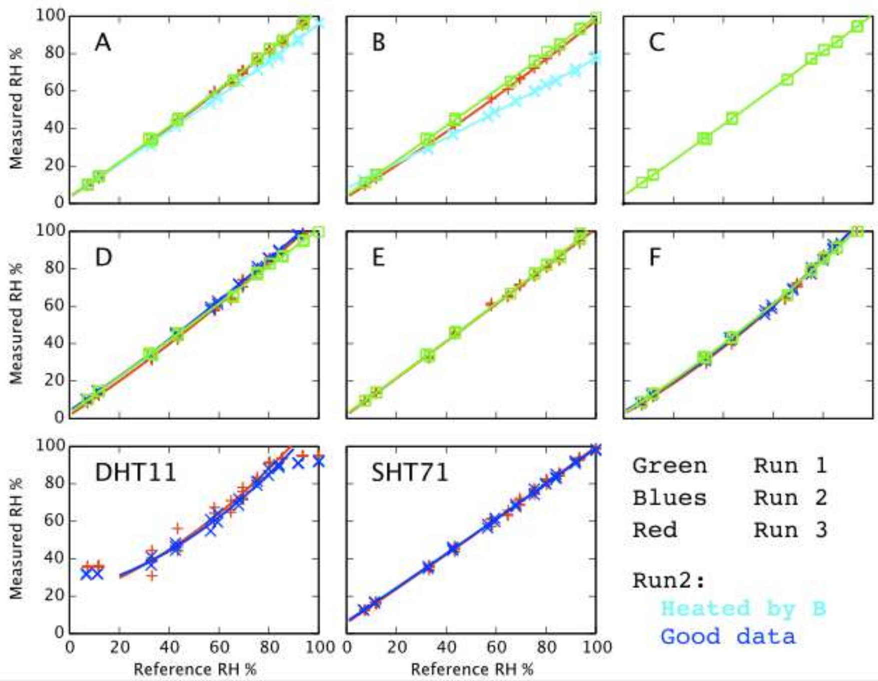
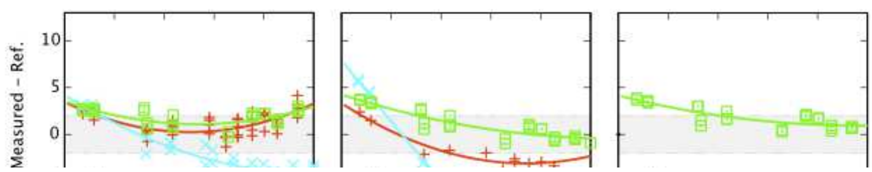


Figure 3. Plots of values read from hygrometer against the known reference humidity. Three epochs are shown. Green is run 1 from May 2014. Blues are run 2 from August 2014 and split into cyan fot those data known to be corrupted by B self-heating and dark blue for data thought to be good. Red are run 3 from November 2014.



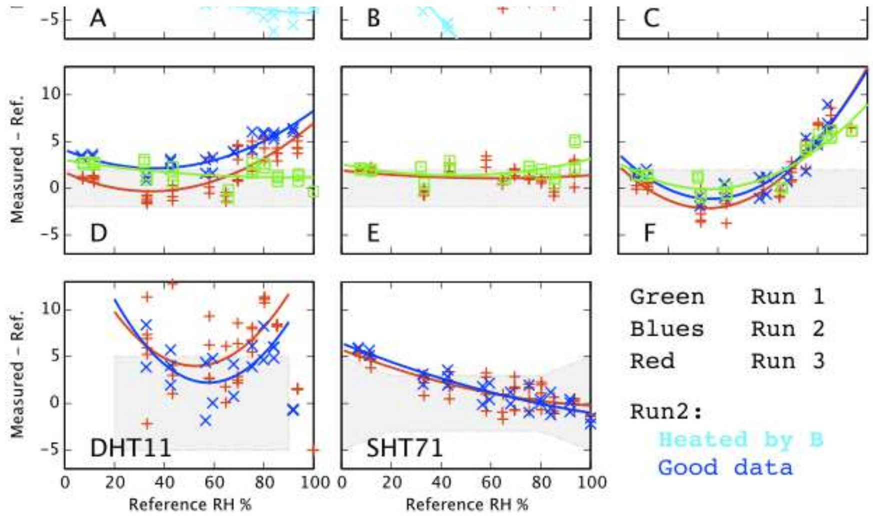


Figure 4. The same data as Figure 3 with the same quadratic polynomial fits are replotted but the vertical axis is now the difference between measured and reference values. These plots present the error that would result from using the factory calibrated values. For DHT11 and DHT22 these are read directly from the sensor without any re-calibration. For SHT71 these values have been temperature corrected and linearized using the default paramaters from the manufacturer's datasheet. Three epochs are shown. Green is run 1 from May 2014. Blues are run 2 from August 2014 and split into cyan fot those data known to be corrupted by B self-heating and dark blue for data thought to be good. Red are run 3 from November 2014. Grey shaded area is the specification from datasheets.

Sensirion SHT71

This is probably the best of the sensors. It is the most linear and arguably the one with the smallest absolute deviations though cherry picking the best of the DHT22s, they are comparable. It may justify its cost if you have a need for that extra accuracy. For most everyday purposes the other sensors are probably adequate except for the gross inconsistency caused by sensor B's self-heating. Repeatability and consistency is where the SHT71 seems to win easily. Finer manufacturing tolerances and quality control are presumably what you are paying for with the more expensive devices. Long term reliabilty of the SHT71 is so far untested though over six months covered here it is perfectly consistent within my experimental errors. RMS scatter around the fit line is 2%RH, but this is only an estimate of the overall accuracy if the correction curve is applied and for as long as that correction curve remains unchanged. Note that that 2%RH scatter includes systematic errors in my apparatus as well as measurement errors in the sensors. The true humidity generated by each solution is only known to about 2%RH. For example all the sensors give 1–2% lower than expected readings for ammonium nitrate at 22°C, suggesting it is the reference data I am using that is in error rather then the sensors. Without my own correction curve, errors from the sensor after applying the manufacturer's default calibration from the datasheet are up to 5%. All my data points nearly remain within the shaded area of the manufacturer's specification.

DHT11

As specified on the data sheet, this device is of no use below 20% or above 90%, but then in terms of physical comfort, anything above 90% humidity feels the same, i.e., wet. Similarly at anything below 20% my lips start cracking so for many uses the difference between 5% and 15% may not be important. The repeatability (scatter of the data points) is markedly worse than all the other sensors (±5%) but within its valid range (20 < %RH < 90) its absolute calibration is almost as good as the DHT22s. A calibration curve is not justified by these data though a constant offset of about 4% would appear to improve reading accuracy. If the self-heating of sensor B was effecting the adjacent DH11 then the required offset could be slightly greater. A data run without the slef-heating B is underway.

DHT22 / AM2302

Sensor A Ignoring run 2 which was corrupted by faulty sensor B, this device looks good. It consistenltly reads 2% high.
Sensor B is highly problematic. During the second data run the device was faulty and running hot. The heat was also influencing its own local environment so it has little use as a measure of the surrounding ambient conditions. Even when not self-heating in run 3 its behavious seems to have changed to some degree. This device has been scrapped.
Sensor C Only tested once so far during which its reults were remarkably similar to the SHT71.
Sensor D has changed more than the specification allows, but is still tolerable with a 5% error or so. Its changes are not explained by local heating from sensor B. Applying any of the correction curves would improve the other measurements, but it has clearly changed.
Sensor E looks good. Divergence at 100% could just be a couple of deviant data points in run 1 and if you were to ignore them it has remained very consistent.

Sensor F has changed little between measurements. Unfortunately it has the most aggressively curved of all the calibration curves, but it has at least remained reasonably constant. If I were applying a correction curve derived from the old data it would still be valid now.

Part 2: As a Function of Temperature

This is a very preliminary first look and it opens as many questions and it answers. DHT22 sensors A,D,E,F, the DHT11 and the SHT71 were tested with saturated potassium carbonate over the temperature range 22–35°C. Results are shown in Figure 5. All the DHT22s show humidity readings that rise with temperature. This is consistent with my DHT22-only study. The results from the SHT71 and DHT11 are very flat, show no dependence on temperature. That is good, but with a large proviso; only if the equilibrium humidity generated by potassium carbonate is not temperature dependent.

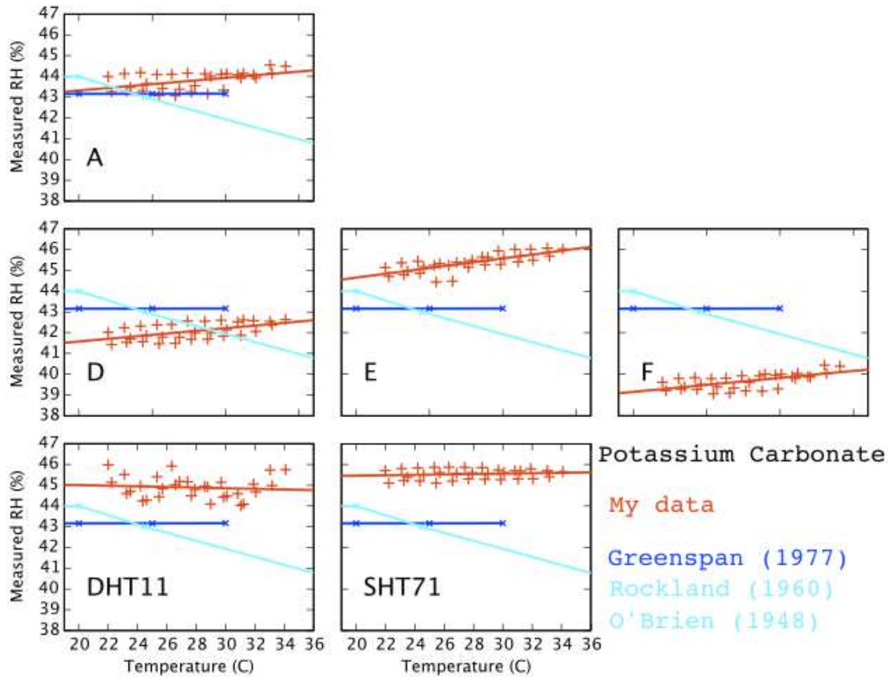
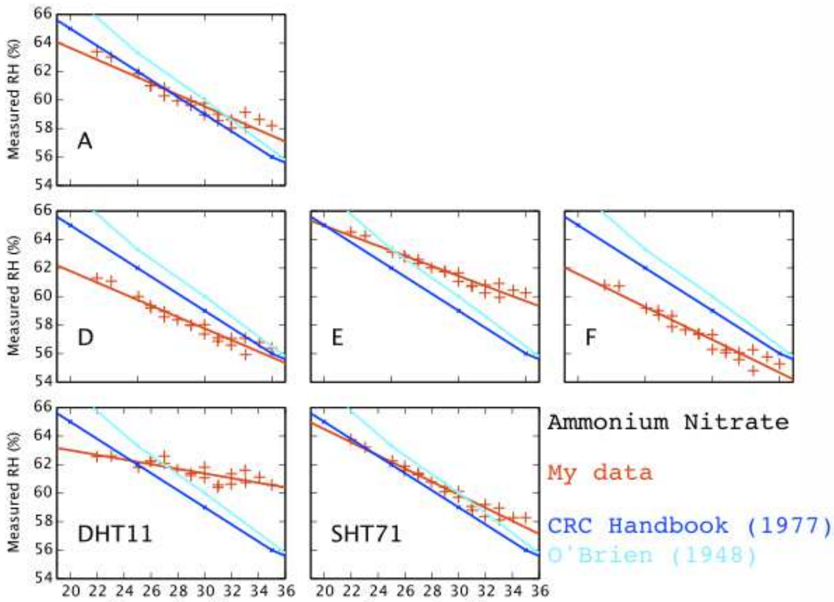


Figure 5. DHT22 sensors A,D,E,F, the DHT11 and the SHT71 tested with saturated potassium carbonate over the temperature range 22–35°C. Over-plotted for comparison are values taken from the published literature.

In Figure 5 I show my data plus the reference calibration values from two different data sources. All these publications are collations of data from many previous sources rather than direct experimental measurements. Greenspan (1977) is frequently regarded as the most complete and definitive work on the subject. Rockland (1960) and O'Brien (1948) have been plotted together because they give identical results despite citing different sources. It seems likely that they are ultimately both citing the same underlying source even though they collated their data from different publications. These data demonstrate again a point made repeatedly that these tests are only as accurate as the availability of calibration references and the literature shows a considerable variation. In this case it is tempting to believe the Greenspan data, assume potassium carbonate has near zero temperature dependence and conclude that the SHT71 and DHT11 are performing correctly with no thermal dependence.



Temperature (C) Temperature (C)

Figure 6. DHT22 sensors A,D,E,F, the DHT11 and the SHT71 tested with saturated ammonium nitrate over the temperature range 22–35°C. Over-plotted for comparison are values taken from the published literature.

Figure 6 follows ammonium nitrate over the range 22–35°C. This is the one compound being used that has a strong thermal gradient in the reference values. We are expecting the humidity to change by 10% RH over that temperature range. Again these data are preliminary (December 2014) and will be updated later, but first indications are that the SHT71 again traces the expected values well. I.e., it looks probable that the thermal stability of this device is good. Similarly it looks probable that we should use only the Greenspan data for potassium carbonate. All these suppositions will be better tested once we have a full thermal trange test on multiple solutions.

Conclusion

- The SHT71 does seem to be generally superior to the DHT22. It is better made, at least as accurate, more precise and responds more quickly to change. It does of course also cost ten times as much.
- Reliability may justify the higher cost, but I have not yet had the Sensirion device long enough to make any comment on that.
- In principle installing and averaging ten DHT22s could provide a very accurate if not convenient solution. You could then reject deviant points if a device change like B.
- I do not have any long term tests of the SHT71. To be fair, I was quite impressed with the DHT22 when I first used it. It was only over long term monitoring that I saw problems.

If you have comments or suggestions feel free to contact me. robert -AT- kandrsmith.org

References

Acknowledgements

Almost vaguely related is a test I have started monitoring radon in the house too.

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Front page | Wedding | Kimberly | Robert
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