P524: Survey of Instrumentation and Laboratory Techniques
Week 11

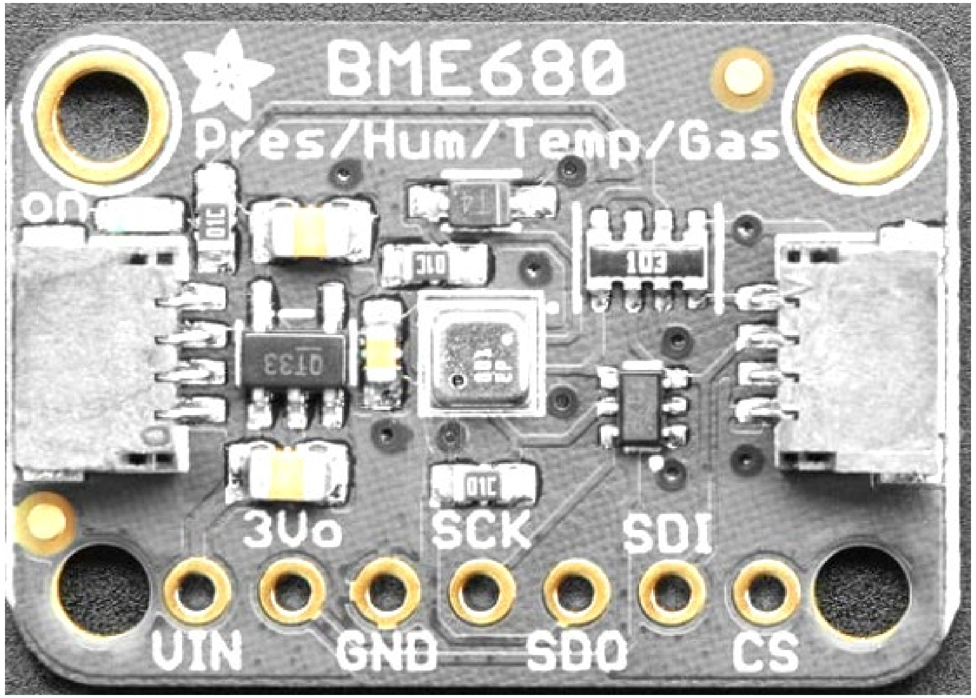
11/5/2024

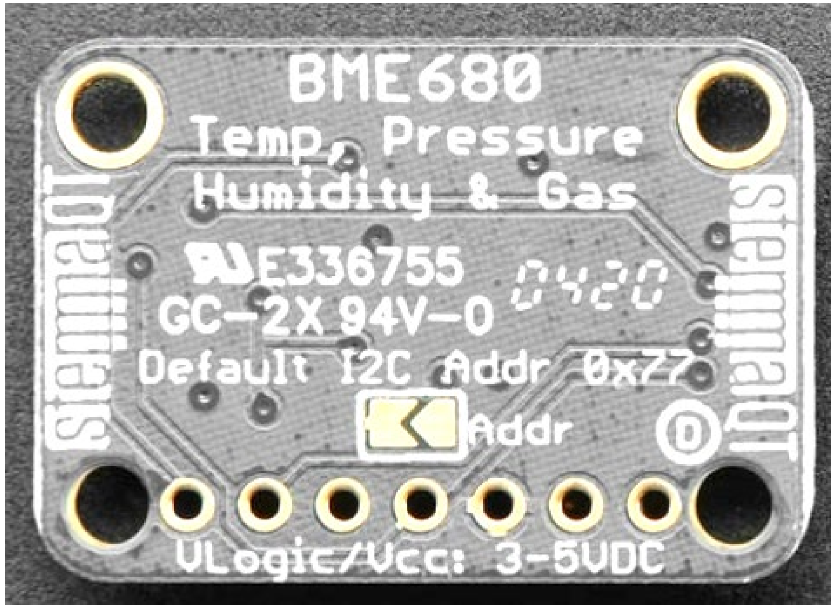
Week 11: sensors-6

Atmospheric Sensors:

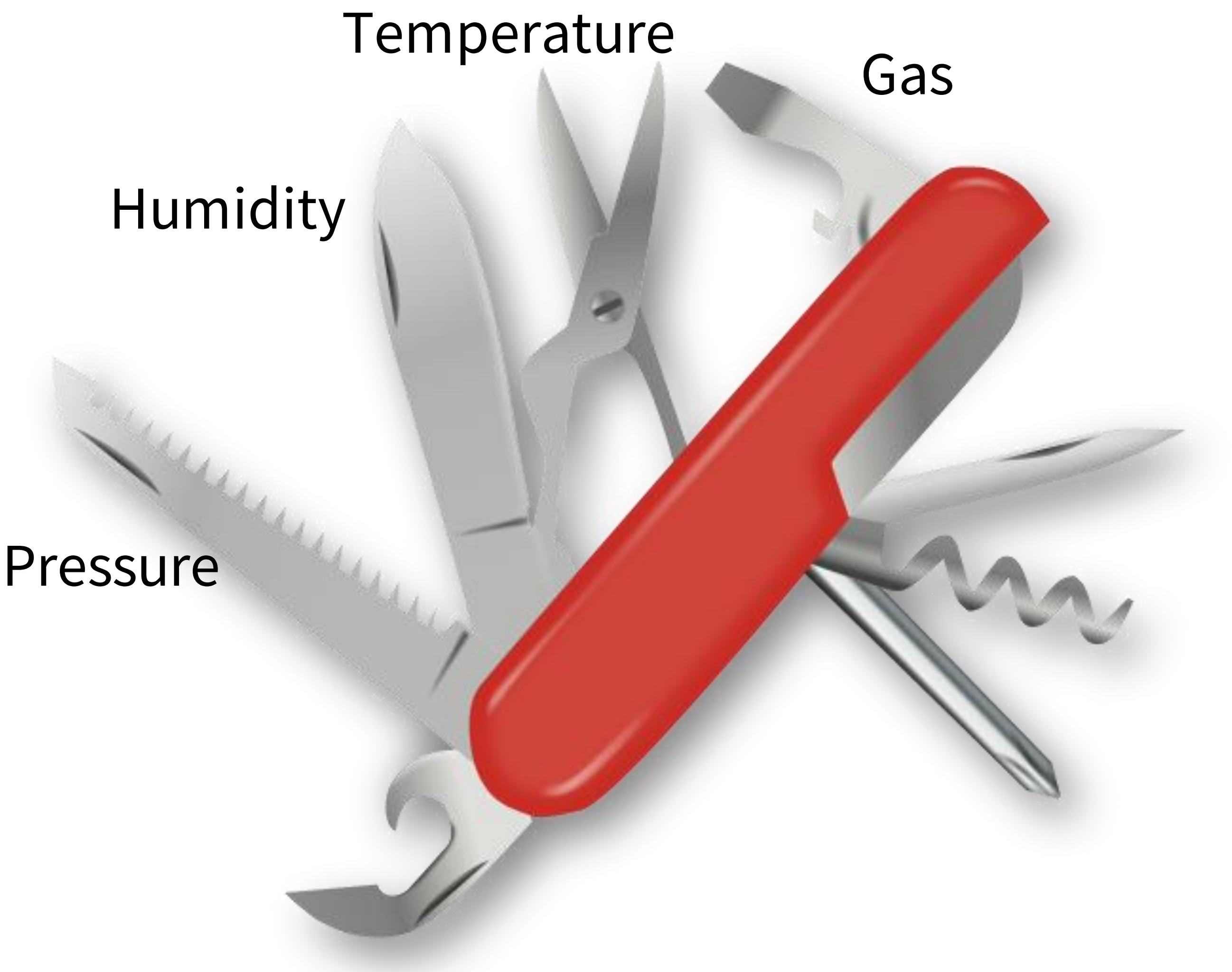
BME680: this precision sensor from Bosch can measure

- humidity with ±3% accuracy,
- barometric pressure with ±1 hPa absolute accuracy, and
- temperature with ±1.0°C accuracy.
- Contains a small MOX sensor. The heated metal oxide changes resistance based on the volatile organic compounds (VOC) in the air, so it can be used to detect gasses & alcohols such as Ethanol, Alcohol and Carbon Monoxide and perform air quality measurements.
- Note it will give you one resistance value, with overall VOC content, it cannot differentiate gasses or alcohols.

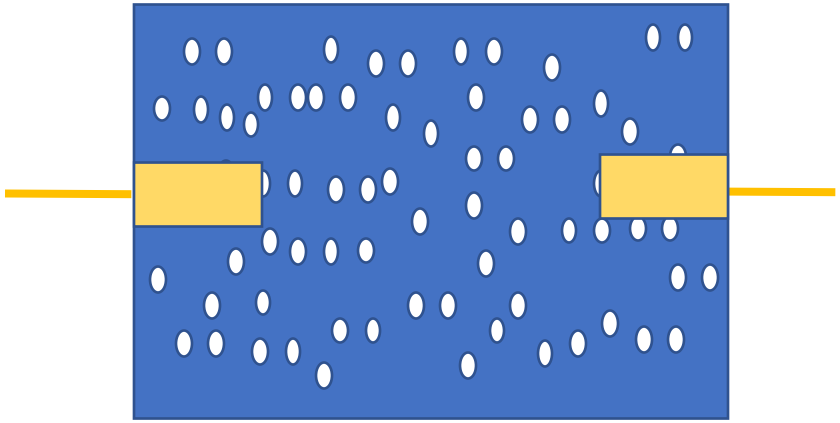




BME680 – the atmospheric Swiss army knife



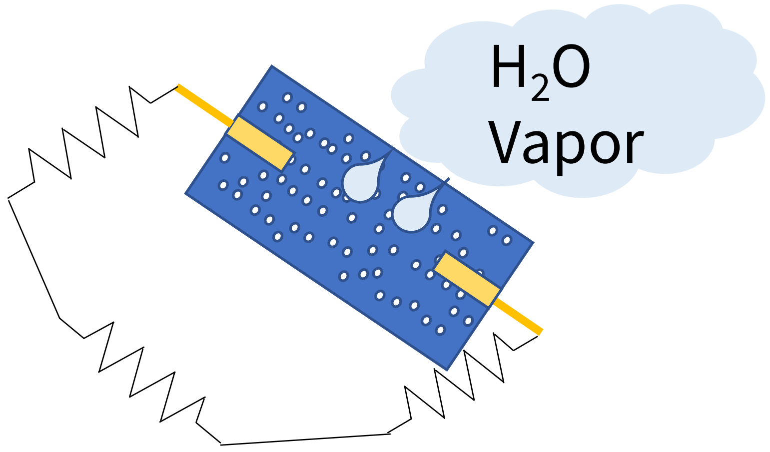
Pressure and temperature: Porous Silicon Membrane



- Sensor is a porous membrane in an internal cavity
- Porous silicon is *piezoresistive* – resistivity changes with strain
- 2 different sources of strain: temperature variation (differences in thermal expansion of different materials) and pressure change.
- Device converts change in resistivity to change in temperature and pressure

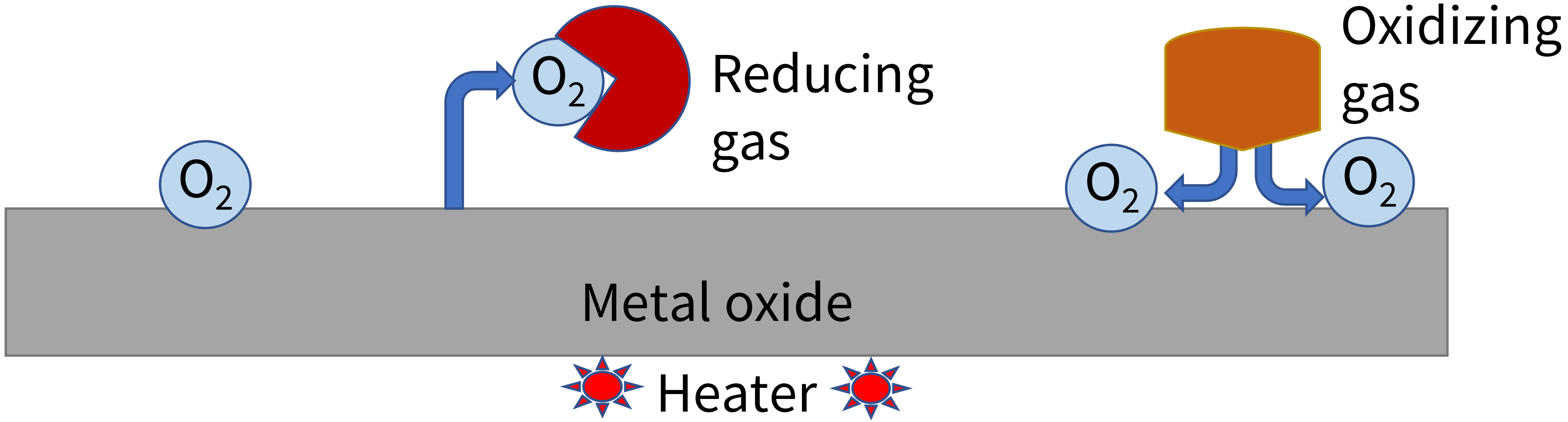
Relative humidity – you guessed it, porous silicon!

- Same membrane technology can be used to measure relative humidity
- Water adsorption onto a specially-designed surface changes the capacitance/resistivity of the device
- Measuring that gives the % relative humidity.



Something slightly different – VOCs & Metal-Oxide gas sensors

- VOC – volatile organic compound, harmful for air quality (ex: solvent fumes)
- Metal oxide adsorbs oxygen molecules to its surface when heated, reducing electron mobility -> increasing resistivity
- Reducing/oxidizing gases change surface oxygen level
- Change in resistivity thus gives gas concentration.



Datasheet info:

- https://www.bosch-sensortec.com/media/boschsensortec/downloads/datasheets/bst-bme680-ds001.pdf

1.5 Temperature sensor specification

Table 8: Temperature parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating temperature range	T_A	operational	-40	25	85	°C
Supply current	$I_{DD,T}$	1 Hz forced mode, temperature measurement only		1.0		µA
Absolute accuracy temperature[15]	$A_{T,25}$	25 °C		±0.5		°C
	$A_{T,full}$	0–65 °C		±1.0		°C
Output resolution	R_T	API output resolution		0.01		°C
RMS noise	N_T	Lowest oversampling		0.005		°C

1.4 Pressure sensor specification

Table 7: Pressure parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating temperature range	T_A	operational	-40	25	85	°C
		full accuracy	0		65	
Operating pressure range	P	full accuracy	300		1100	hPa
Supply current	$I_{DD,LP}$	1 Hz forced mode, pressure and temperature, lowest power		3.1	4.2	µA
Temperature coefficient of offset[13]	TCO_P	25–40 °C, 900 hPa		±1.3		Pa/K
				±10.9		cm/K
Absolute accuracy pressure	$A_{p,\ full}$	300–1100 hPa 0–65°C		±0.6		hPa
Relative accuracy pressure	A_{rel}	700–900hPa, 25–40 °C, at constant humidity		±0.12		hPa
	A_{rel}	900–1100hPa 25–40 °C, at constant humidity		±0.12		hPa
Resolution of pressure output data	R_P	Highest oversampling		0.18		Pa
Noise in pressure	$N_{P,fullBW}$	Full bandwidth, highest oversampling		1.4		Pa
				11		cm
		Reduced bandwidth, highest oversampling		0.2		Pa
				1.7		cm
Solder drift		Minimum solder height 50µm	-0.5	1.2	+2.0	hPa
Long-term stability[14]	P_{stab}	per year		±1.0		hPa
Possible sampling rate	f_{sample_P}	Lowest oversampling, see chapter 3.3.2	157	182		Hz

1.3 Humidity sensor specification

Table 6: Humidity parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating Range[10]			-40	25	85	°C
			0		100	% r.H.
Full accuracy range			0		65	°C
			10		90	% r.H.
Supply Current	$I_{DD,H}$	1 Hz forced mode, temperature and humidity measurement		2.1	2.8	µA
Absolute Accuracy	A_H	20–80 % r.H., 25 °C, including hysteresis		±3		% r.H.
Hysteresis[11]	H_H	10→90→10 % r.H., 25°C		±1.5		% r.H.
Nonlinearity	NL_H	10→90 % r.H., 25°C		1.7		% r.H.
Response time to complete 63% of step[12]	$\tau_{0\text{-}63\%}$	N_2 (dry) → 90 % r.H., 25°C		8		s
Resolution	R_H			0.008		% r.H.
Noise in humidity (RMS)	N_H	Highest oversampling		0.01		% r.H.
Long-term stability	ΔH_{stab}	10–90 % r.H., 25°C		0.5		% r.H./ year

Table 2: Gas sensor parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operational range[1]			-40		85	°C
			10		95	% r.H.
Supply Current during heater operation	I_{DD}	Heater target temperature 320 °C, constant operation (V_{DD} ≤ 1.8 V, 25°C)	9	12	13	mA
Peak Supply Current	I_{Peak}	Occurs within first ms of switching on the hotplate	15	17	18	mA
Average Supply Current (V_{DD} ≤ 1.8 V, 25°C)	$I_{DD,IAQ}$	Ultra-low power mode		0.09		mA
		Low power mode		0.9		mA
		Continuous mode		12		mA
Response time[2] (brand-new sensors)	$\tau_{33-63\%}$	Ultra-low power mode		92		s
	$\tau_{33-63\%}$	Low power mode		1.4		s
	$\tau_{33-63\%}$	Continuous mode		0.75		s
Resolution of gas sensor resistance measurement			0.05	0.08	0.11	%
Noise in gas sensor resistance (RMS)	N_R			1.5		%

Exercise: VOC sensor

Connect your BME680 to either MEGA or Adalogger.

- Using the example code, test that the BME680 is working and recording all four measurements
- Make sure you can turn the VOC/gas sensor on and off in the code.
- Make sure that you can modify the oversampling for the other sensors.

1. Ethanol:
   - Get some ethanol and a fan. Place your two sensors on the table and measure the distance between them. With proper PPE, take a small amount of ethanol and pipette it onto a tray to evaporate. Measure the output of the VOC sensor under different airflow conditions as a function of distance from the sensor and amount of ethanol evaporated.
2. Humidity & VOC in human breath:
   - The exhaled air from our lungs is often warmer, more humid, and has a higher VOC concentration than normal room air. With your partner, investigate the effects of human breath on the humidity & VOC measurements from the BME680
   - Suggested things to measure:
     - i. Measure the change in humidity & VOCs as a function of distance from your partner.
     - ii. Measure the effects of different kinds of breathing (talking, blowing, regular breathing, etc.)
     - iii. Come up with a way to estimate the number of people in a room based on your results.