BMP280: Bosch Barometric Pressure Sensor

By Owen Helfrich

Fundamentals: Sensing

The BMP280 measures pressure and temperature by detecting the deformation of a diaphragm with strain gauges in a Wheatstone Bridge

- Called a Micro-Electronic Mechanical System (MEMS) Chip

Because pressure varies by height, it can also measure altitude

- This is not very accurate, unless it is calibrated for the pressure at sea level at the location and day

Fundamentals: Wiring

Can be wired in two ways:

- Inter-Integrated Circuit (I2C) Protocol
  - Uses Serial Data (SDA), Serial Clock (SCL), Power, and Ground
  - Allows sensors to be daisy-chained together instead of each connected to the host circuit, at the cost of a slower response time

- Serial Peripheral Interface (SPI) Protocol
  - Uses Clock (SCLK), Chip Select (CS), Main-out, Subnode-In (MOSI), and Main-In, Subnode-Out (MISO), Power, and Ground wires

Data Sheet

1. Specification

If not stated otherwise,

- All values are valid over the full voltage range
- All minimum/maximum values are given for the full accuracy temperature range
- Minimum/maximum values of drifts, offsets and temperature coefficients are $\pm 3\sigma$ values over lifetime
- Typical values of currents and state machine timings are determined at 25 °C
- Minimum/maximum values of currents are determined using corner lots over complete temperature range
- Minimum/maximum values of state machine timings are determined using corner lots over 0...+65 °C temperature range

The specification tables are split into pressure and temperature part of BMP280

Table 2: Parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Units
Operating temperature range	T_A	operational	-40	25	+85	°C
		full accuracy	0		+65	
Operating pressure range	P	full accuracy	300		1100	hPa
Sensor supply voltage	V_{DD}	ripple max. 50mVpp	1.71	1.8	3.6	V
Interface supply voltage	V_{DDIO}		1.2	1.8	3.6	V
Supply current	$I_{DD,LP}$	1 Hz forced mode, pressure and temperature, lowest power		2.8	4.2	µA
Peak current	I_{peak}	during pressure measurement		720	1120	µA
Current at temperature measurement	I_{DDT}			325		µA
Sleep current[1]	I_{DDSL}	25 °C		0.1	0.3	µA
Standby current (inactive period of normal mode)[2]	I_{DDSB}	25 °C		0.2	0.5	µA
Relative accuracy pressure V_{DD} = 3.3V	A_{rel}	700 ... 900hPa 25 ... 40 °C		±0.12		hPa
				±1.0		m

[1] Typical value at VDD = VDDIO = 1.8 V, maximal value at VDD = VDDIO = 3.6 V.

[2] Typical value at VDD = VDDIO = 1.8 V, maximal value at VDD = VDDIO = 3.6 V.

Data Sheet

Offset temperature coefficient	TCO	900hPa		±1.5		Pa/K
		25 ... 40 °C		12.6		cm/K
Absolute accuracy pressure	A^P_{ext}	300 ... 1100 hPa -20 ... 0 °C		±1.7		hPa
	A^P_{full}	300 ... 1100 hPa 0 ... 65 °C		±1.0		hPa
Resolution of output data in ultra high resolution mode	R^P	Pressure		0.0016		hPa
	R^T	Temperature		0.01		°C
Noise in pressure	$V_{p,full}$	Full bandwidth, ultra high resolution See chapter 3.5		1.3		Pa
				11		cm
	$V_{p,filtered}$	Lowest bandwidth, ultra high resolution See chapter 3.5		0.2		Pa
				1.7		cm
Absolute accuracy temperature[3]	A^T	@ 25 °C		±0.5		°C
		0 ... +65 °C		±1.0		°C
PSRR (DC)	PSRR	full V_{DD} range			±0.005	Pa/mV
Long term stability[4]	ΔP_{stab}	12 months		±1.0		hPa
Solder drifts		Minimum solder height 50 μm	-0.5		+2	hPa
Start-up time	$t_{startup}$	Time to first communication after both $V_{DD} > 1.58V$ and $V_{DDIO} > 0.65V$			2	ms
Possible sampling rate	f_{sample}	osrs_t = osrs_p = 1; See chapter 3.8	157	182	tbd[5]	Hz
Standby time accuracy	$\Delta t_{standby}$			±5	±25	%

Data Sheet

2. Absolute maximum ratings

The absolute maximum ratings are provided in Table 3.

Table 3: Absolute maximum ratings

Parameter	Condition	Min	Max	Unit
Voltage at any supply pin	V_{DD} and V_{DDIO} Pin	-0.3	4.25	V
Voltage at any interface pin		-0.3	V_{DDIO} + 0.3	V
Storage Temperature	≤ 65% rel. H.	-45	+85	°C
Pressure		0	20 000	hPa
ESD	HBM, at any Pin		±2	kV
	CDM		±500	V
	Machine model		±200	V

Important Characteristics

- Resolution – The smallest change in input detectable by the sensor
- Accuracy – The variation between the correct value and the sensor reading
- Drift – The variation in the sensor reading given an unchanging input over time
- Range – The inputs between the absolute highest and lowest inputs the sensor can read
- Linearity – The region where the sensor's readings can be approximated as linear
- Sensitivity – The change in the sensor's output based on the change in input

Testing

Notes:

- Each data point is taken after a one-second delay to allow the sensors' oversampling process to occur

Flaws:

- My pressure chamber leaks air slowly; the silicone sealant doesn't stick well to the plastic-coated wires even after being lightly scored
- I can't test over the sensor's full range; lowering the pressure much below 1 atm is not possible within my means, testing scheme, and deadlines
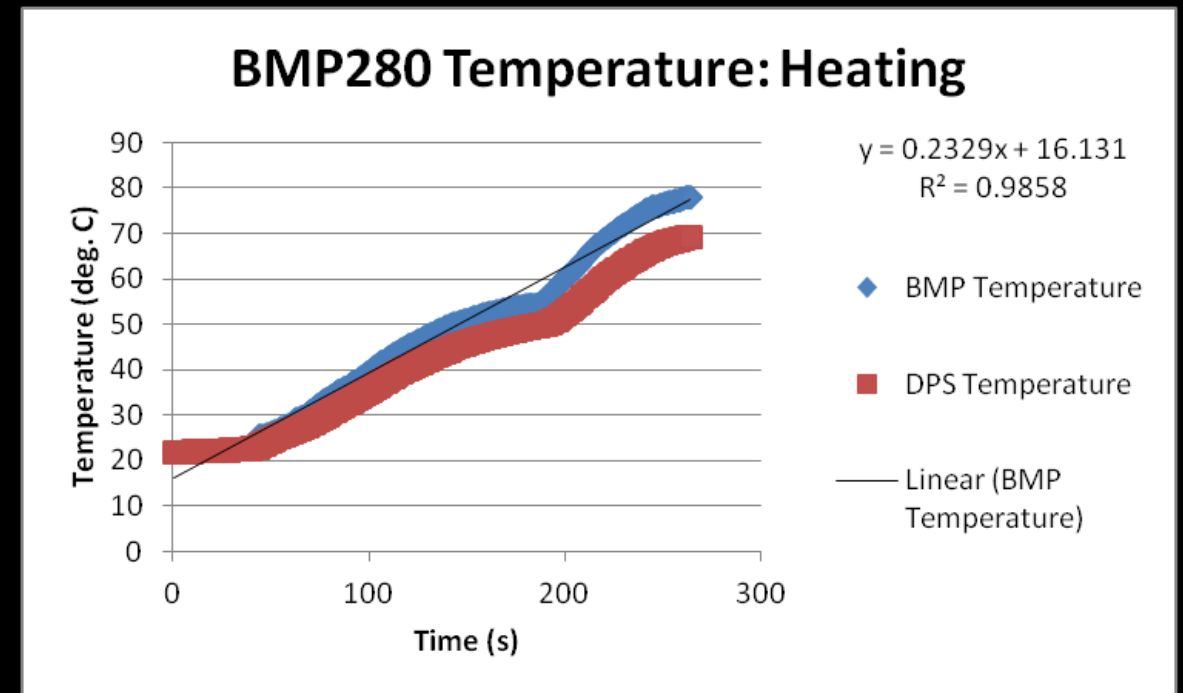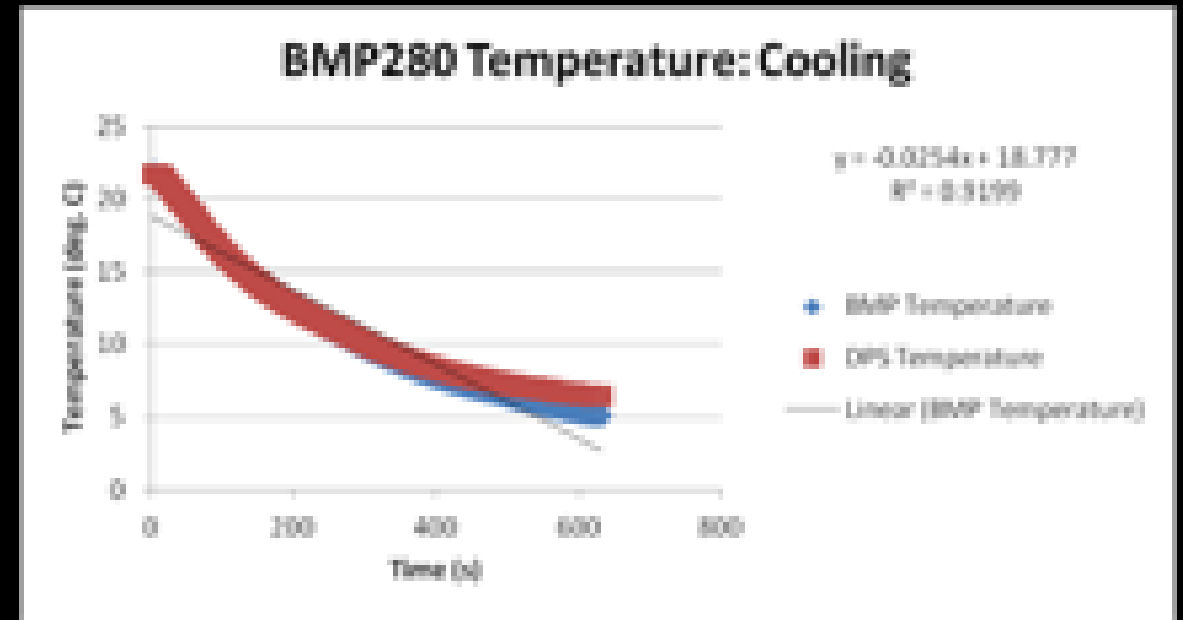
Testing
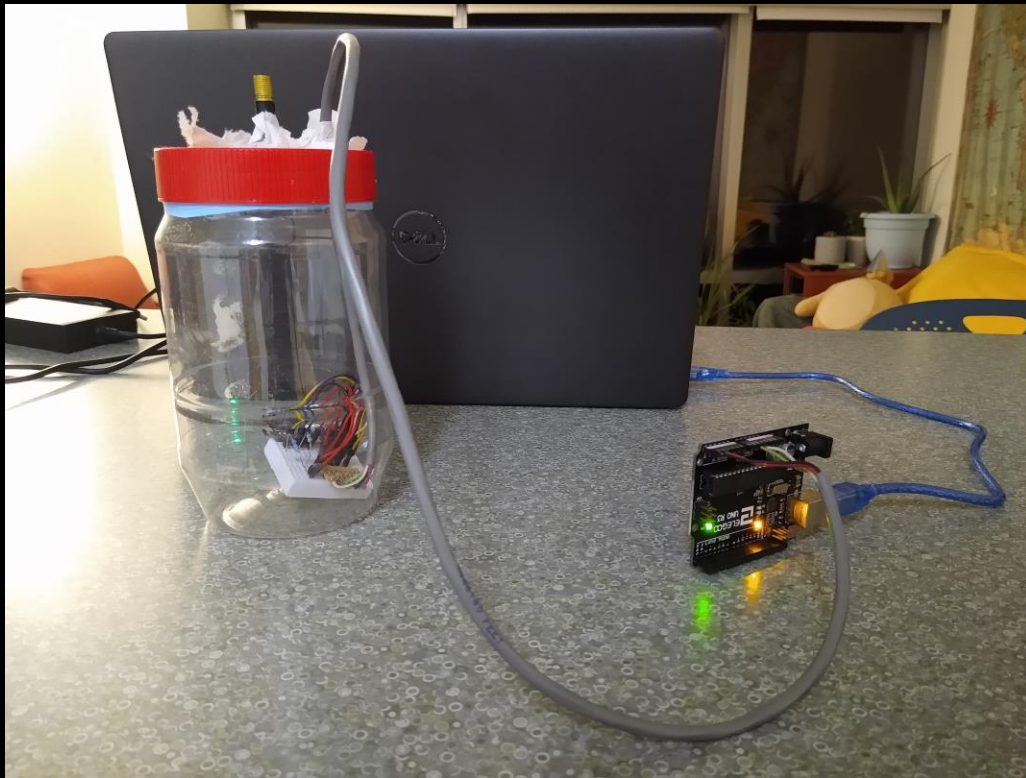
Range

- The upper limit of the pressure range is 1100 hPa

- The upper limit of the temperature range is 80 deg. C

- The functional limit of the altitude range is bounded by the lower pressure limit; 29000 ft

From Data Sheet:

- Pressure: 300 – 1100 hPa total

- Temperature:-40 deg. C– 85 deg. C

BMP280 Temperature: Cooling

$y = -0.0254x + 18.777$
$R^2 = 0.9199$

- BMP Temperature
- DPS Temperature
- Linear (BMP Temperature)

BMP280 Temperature: Heating

$y = 0.2329x + 16.131$
$R^2 = 0.9858$

- BMP Temperature
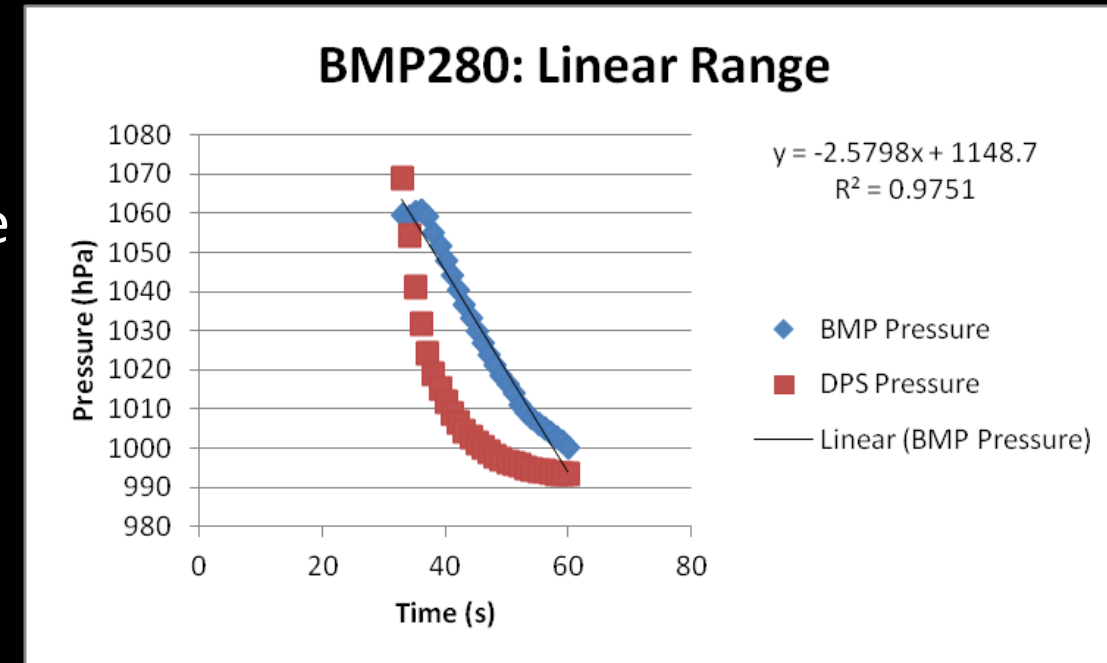- DPS Temperature
- Linear (BMP Temperature)

Linearity, Sensitivity: Pressure

- Linear from 1000 hPa to 1059 hPa
  - Agrees with the datasheet's reported relative accuracy range (1050hPa–950hPa)
- Sensitivity is –2.580 hPa/s

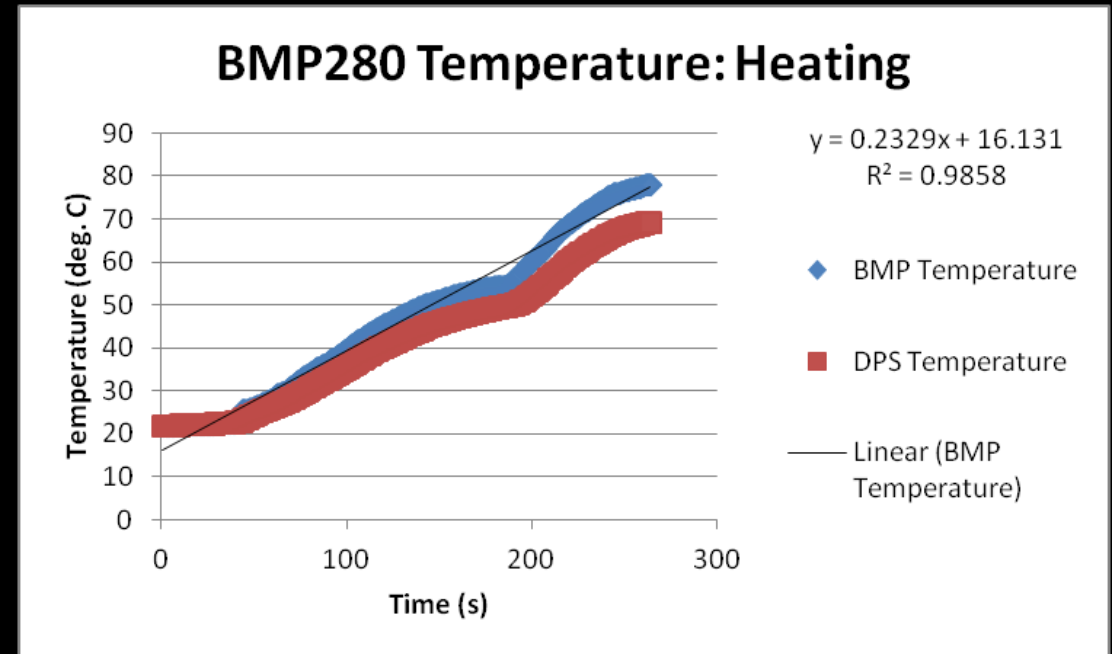From Data Sheet:

- Relative accracy range: 950 hPa – 1050 hPa

BMP280: Linear Range

$y = -2.5798x + 1148.7$
$R^2 = 0.9751$

- BMP Pressure
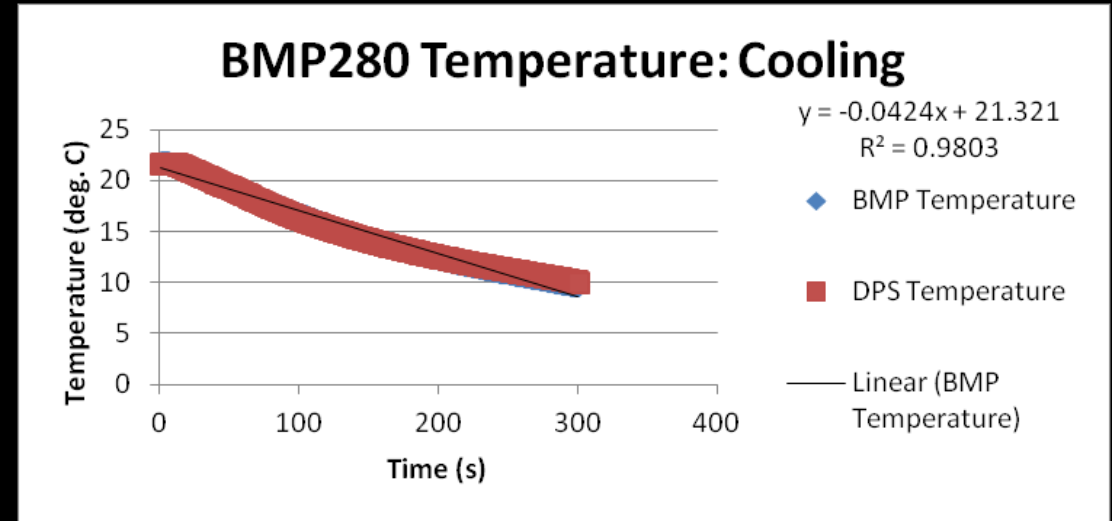- DPS Pressure
- Linear (BMP Pressure)

Linearity, Sensitivity: Temperature

- Linear from 0 deg. C - 50 deg. C
- Sensitivity of the temperature curve is 0.2329 deg. C / s

From Data Sheet:

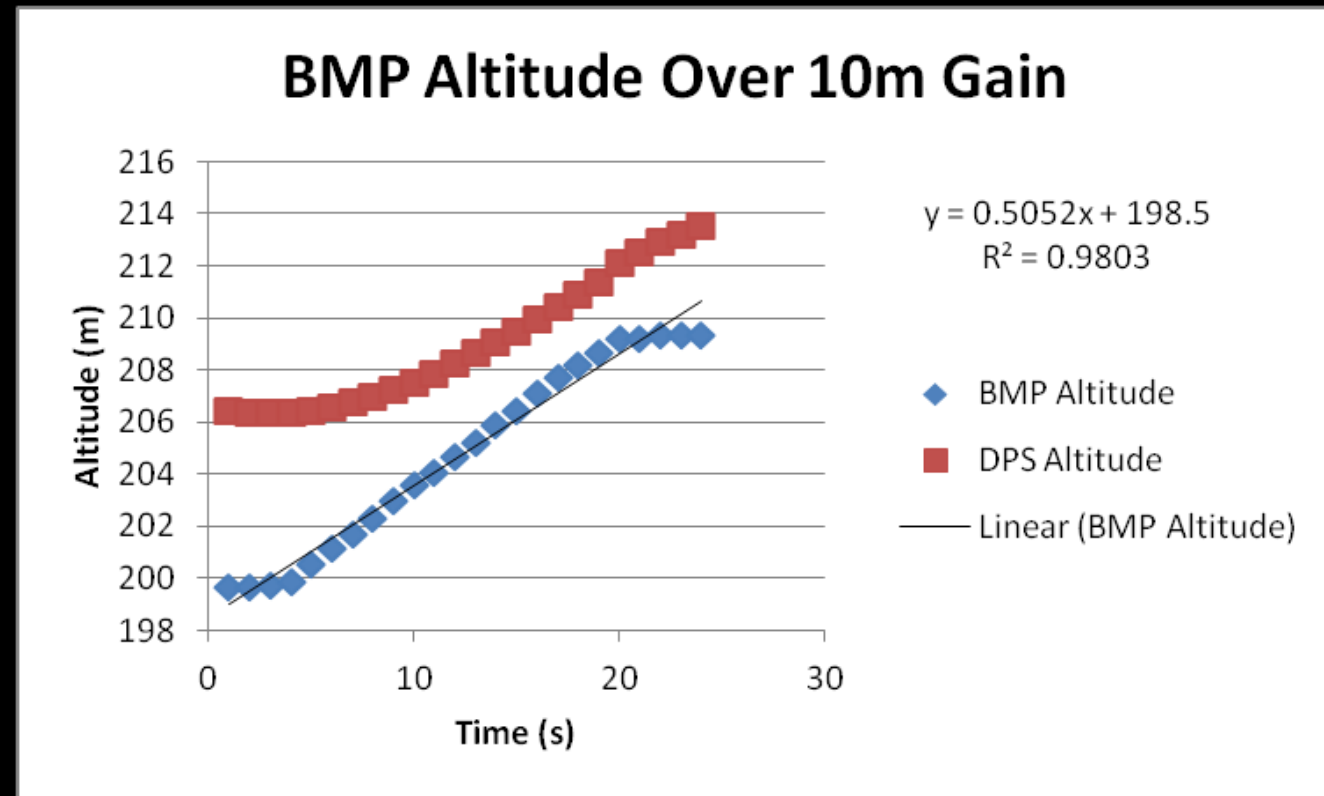- Relative accuracy range from 0 deg. C – 40 deg. C

BMP280 Temperature: Cooling

$y = -0.0424x + 21.321$
$R^2 = 0.9803$

♦ BMP Temperature

■ DPS Temperature

— Linear (BMP Temperature)

BMP280 Temperature: Heating

$y = 0.2329x + 16.131$
$R^2 = 0.9858$

♦ BMP Temperature

■ DPS Temperature

— Linear (BMP Temperature)

Linearity, Sensitivity: Altitude

- Not enough data to determine linearity

- Sensitivity: 0.5052 m/s

From Data Sheet:

- N/A

BMP Altitude Over 10m Gain

$y = 0.5052x + 198.5$
$R^2 = 0.9803$

- BMP Altitude
- DPS Altitude
- Linear (BMP Altitude)

Resolution

- Pressure: 0.04 hPa

- Temperature: Unkown, not testable with my setup

- Altitude: Impossible to measure, too much noise

From Data Sheet:

- 0.0016 hPa

- 0.01 deg. C @ 25 deg. C

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BMP Pressure: 987.89 hPa
DPS Pressure: 988.82 hPa


BMP Pressure: 987.89 hPa
DPS Pressure: 988.83 hPa


BMP Pressure: 987.90 hPa
DPS Pressure: 988.87 hPa
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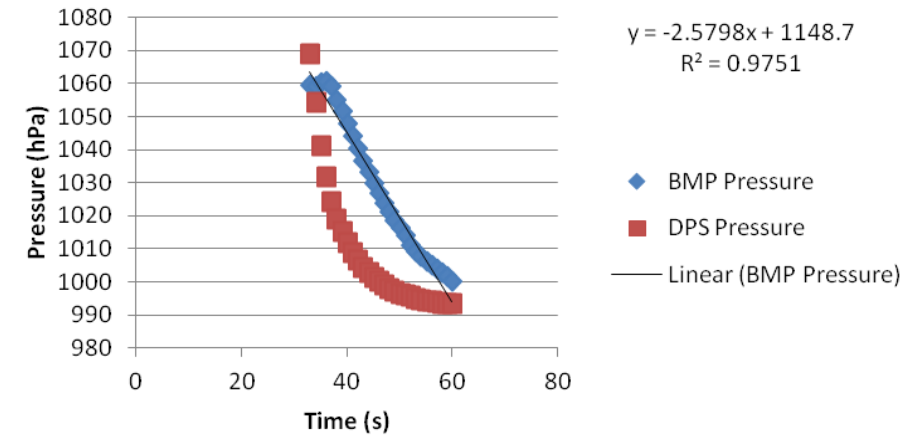
Accuracy

- Pressure: 3.56% max error

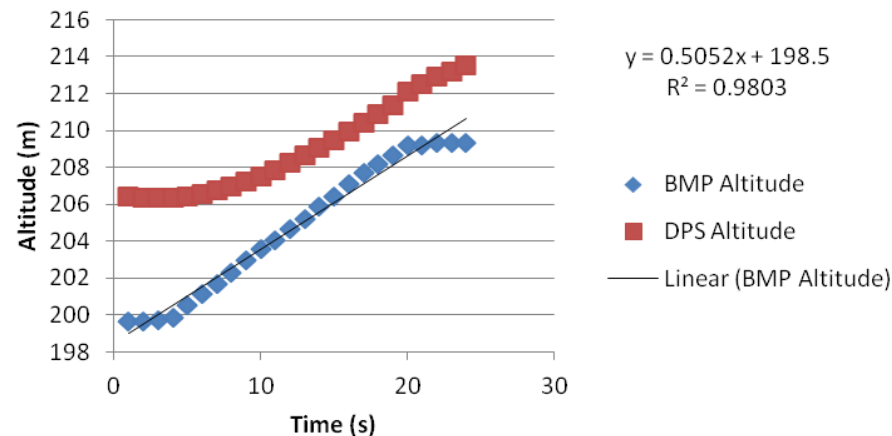- Temperature: 13.59% max error

- Altitude: 3.27% error
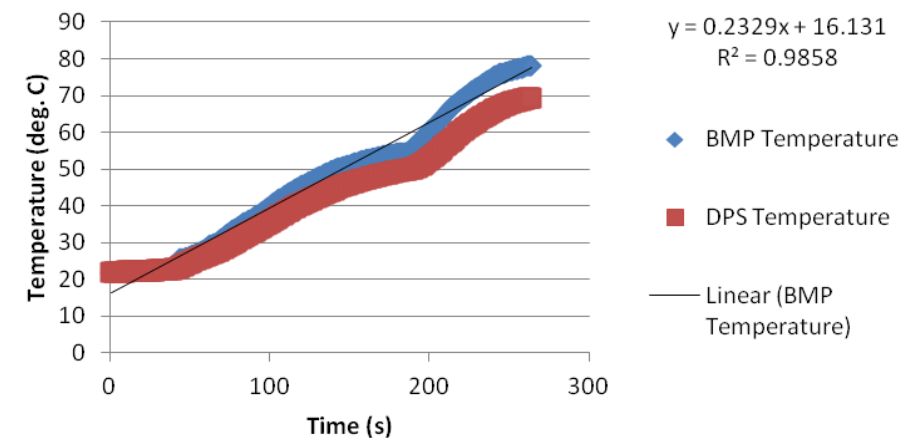
From Data Sheet:

- +/- 12 hPa

- +/- 0.5 deg. C

- +/-1 m

BMP280: Linear Range

$y = -2.5798x + 1148.7$
$R^2 = 0.9751$

BMP Altitude Over 10m Gain

$y = 0.5052x + 198.5$
$R^2 = 0.9803$

BMP280 Temperature: Heating

$y = 0.2329x + 16.131$
$R^2 = 0.9858$

Drift

- Pressure drift: +4.46/-2.16 hPa per 10 minutes
- Temperature: +0.0733 deg. C/-0.117 deg. C per 10 minutes
- Altitude: +/- 3.3 m per 3 minutes
  - For reference, the DPS310 is accurate to the centimeter

  From Data Sheet:
  - +/- 1.0 hPa per 12 months

Summary

BMP280 isn't bad at sensing:

- Pressure: It's linear, if not stable for drift

- Temperature: It's linear, if not accurate

- Altitude: It's accurate for elevation changes, not altitude

The BMP280 is useful for at-home measurements that don't need to be very accurate, and with calibration it can be even better. It fulfills its purpose as a DIY weather-sensing chip.