SCP1000-D01/D11 Pressure Sensor as Barometer and Altimeter

General Descriptions

The SCP1000-D01/D11 detects the smallest barometric pressure changes, enabling easy local weather forecasting and altitude measurements. Its size (Ø 6.1mm, h = 1.7mm), supply voltage (2.4 – 3.3V) and current consumption (0 - 50µA, under normal conditions 0 - 30µA) make it easy to integrate into hand-held equipment such as outdoor and sports watches. SCP1000-D01/D11 includes a circular pressure port with a vertical wall for o-ring sealing and it is compatible with lead-free soldering processes. The onboard temperature sensor gives the possibility to correct weather forecasting or altitude calculations for local temperature changes. SCP1000-D01/D11 communicates over standard SPI and I2C interfaces.

Barometer

The typical accuracy of 18Pa is well below the required level of about 50Pa, for the detection of environmental pressure changes in local weather forecasting. Standard algorithms look for instance like below:

dP/dt > 250Pa/h	Unstable high pressure system
50Pa/h < dP/dt < 250Pa/h for some time	Stable good weather
-50Pa/h < dP/dt < 50Pa/h for some time	Stable weather
-250Pa/h < dP/dt < -50Pa/h for some time	Stable rainy weather
dP/dt < -250Pa/h	Unstable low pressure system

The excellent accuracy and resolution enable even new algorithms not seen in consumer weather stations or outdoor equipment before. In a barometer the SCP1000 could continuously operate in the ultra low power mode, with a resolution better than 10Pa, at 5.7µA or be switched to power down for sub-µA average current consumption.

Altimeter

The altitude measurement based on pressure is a relative measurement, i.e. it compares pressures at different places. This can be done with one pressure sensor and, in that case, is also sensitive to barometric pressure changes. Where accurate altitude information is needed over longer times, barometric reference pressure is often used.

Assuming a constant temperature gradient of dT/dH in accordance with the 1976 US Standard Atmosphere, the altitude H as a function of pressure P is obtained:

$$H = T_0/(-dT/dH) * [1 - (P/P_0)^{(-dT/dH)*R/g}] \quad (1)$$

Inserting dT/dH = –6.5°C/km, T_0 = 288.15K (+15°C), P_0 = 101325Pa, g = 9.82m/s^2 and R = 287.052m^2/s^2/K one gets:

$$H = 44.33km * [1 - (P/101325Pa)^{0.19}] \quad (2)$$

This basic formula (1) still applies in cases, where the temperature T_0 and/or reference pressure P_0 differ from those of the standard. This means that the relative change in pressure ($\Delta P/P_0 = (P - P_0)/P_0$) and the actual temperature determine the change in altitude regardless of altitude (Table 1: Model @ 4200m). The variation of the g-value at different latitudes causes a maximum error of about 30m from sea level to 9000m. This error can be minimized to about 20m by selecting g = 9.80665m/s^2 (Table 1: Model @ g = #). The effect of the g-value decreasing with height can be seen in first order as a decrease of about 1% in the absolute value of the temperature gradient in the basic formula (1). This effect is less than about 10m from sea level to 9000m (effect of g(h) in Table 1). Equation (1) can be approximated with a Taylorian polynomial of selected order of $\Delta P/P_0$ (Table 1: nth order polynomial). A slight modification of the coefficients in the polynomial would probably improve the result. In most cases, altitude changes to be measured are relatively small and the errors of the polynomial approximation negligible. Table 1 presents an altitude error calculation for latitude caused errors and polynomial approximations.

Basic Model		Model @ 4200m			Model @ g = 9.83217m/s2 North Pole		Model @ g = 9.78039m/s2 Equator		Effect of g(h)		3rd order polynom P0 @ 0m		6th order polynom P0 @ 0m	
Pressure	Alt.	Temp.	Alt.	Error	Alt.	Error	Alt.	Error	Alt.	Error	Alt.	Error	Alt.	Error
[Pa]	[m]	[°C]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
101325	0	15	0	0	0	0	0	0	0	0	0	0	0	0
91193	880	9	880	0	878	2	882	-2	880	0	880	0	880	0
82073	1742	4	1742	0	1738	4	1747	-5	1743	-1	1740	-2	1742	0
73866	2587	-2	2587	0	2581	7	2594	-7	2588	-1	2578	-10	2587	0
66479	3416	-7	3416	0	3407	9	3425	-9	3418	-2	3388	-28	3415	-1
59831	4228	-12	4228	0	4217	10	4239	-11	4231	-3	4168	-60	4226	-2
53848	5024	-18	5024	0	5012	12	5036	-13	5027	-3	4914	-110	5018	-6
48463	5804	-23	5804	0	5790	14	5818	-15	5809	-5	5622	-182	5790	-14
43617	6569	-28	6569	0	6553	16	6585	-16	6575	-6	6292	-277	6540	-28
39255	7318	-33	7318	0	7301	17	7336	-18	7326	-8	6922	-396	7267	-51
35330	8053	-37	8053	0	8034	19	8072	-20	8062	-9	7511	-541	7969	-84
31797	8773	-42	8773	0	8752	20	8794	-21	8784	-11	8061	-711	8642	-131

Table 1: Models and altitude errors

A very low power way to calculate ascent or descent is to do it in a recursive way based on the basic differential equation of the atmosphere:

$$\Delta H = -(R/g) * T * \Delta P/P \qquad (3)$$

Using (3) one has to make sure $\Delta P/P$ and $\Delta T/T$ are kept small to minimize error. In the high resolution mode the noise in SCP1000 will result in an error of about 2m, when just relying on recursive calculations for one minute. This value can be decreased by using the same reference pressure for a longer time, as long as the effect of $\Delta P/P$ and $\Delta T/T$ is kept small.

The high resolution mode of SCP1000 for the first time gives the possibility to measure accurately cumulated ascent, which is an important parameter for calculating training effect and energy consumption in e.g. heart rate monitors, sports watches and wrist top computers. This can be done with a rate of twice per second, a resolution better than 0.2m (2Pa) and a continuous power consumption of 20 - 30µA. When increasing the update interval to 2 seconds, one can reduce the current consumption to below 10µA. SCP1000 has a typical temperature dependence smaller than

1.5m and linearity better than 0.1m, when going from sea level to 3000m. This is smaller than fluctuations caused by local temperature gradients and air flow.

Fluid Level Measurement

The 120kPa sensor can also be limited (max. ~ 1m) used to measure fluid level. When measuring water and other fluids with the same density the resolution of the measurement is 0.2mm (2Pa) @ a rate of twice per second. The resolution can roughly be increased from this as the square root of integration time, when averaging over a longer time.

Document Change Control

Version	Date	Change Description
1.0	15.06.2006	Initial draft.