HY11P12
Application Notes

Silicon Pressure Sensor Application

Table of Contents

Attention：

1. HYCON Technology Corp. reserves the right to change the content of this datasheet without further notice. For most up-to-date information, please constantly visit our website: http://www.hycontek.com .
2. HYCON Technology Corp. is not responsible for problems caused by figures or application circuits narrated herein whose related industrial properties belong to third parties.
3. Specifications of any HYCON Technology Corp. products detailed or contained herein stipulate the performance, characteristics, and functions of the specified products in the independent state. We does not guarantee of the performance, characteristics, and functions of the specified products as placed in the customer's products or equipment. Constant and sufficient verification and evaluation is highly advised.
4. Please note the operating conditions of input voltage, output voltage and load current and ensure the IC internal power consumption does not exceed that of package tolerance. HYCON Technology Corp. assumes no responsibility for equipment failures that resulted from using products at values that exceed, even momentarily, rated values listed in products specifications of HYCON products specified herein.
5. Notwithstanding this product has built-in ESD protection circuit, please do not exert excessive static electricity to protection circuit.
6. Products specified or contained herein cannot be employed in applications which require extremely high levels of reliability, such as device or equipment affecting the human body, health/medical equipments, security systems, or any apparatus installed in aircrafts and other vehicles.
7. Despite the fact that HYCON Technology Corp. endeavors to enhance product quality as well as reliability in every possible way, failure or malfunction of semiconductor products may happen. Hence, users are strongly recommended to comply with safety design including redundancy and fire-precaution equipments to prevent any accidents and fires that may follow.
8. Use of the information described herein for other purposes and/or reproduction or copying without the permission of HYCON Technology Corp. is strictly prohibited.

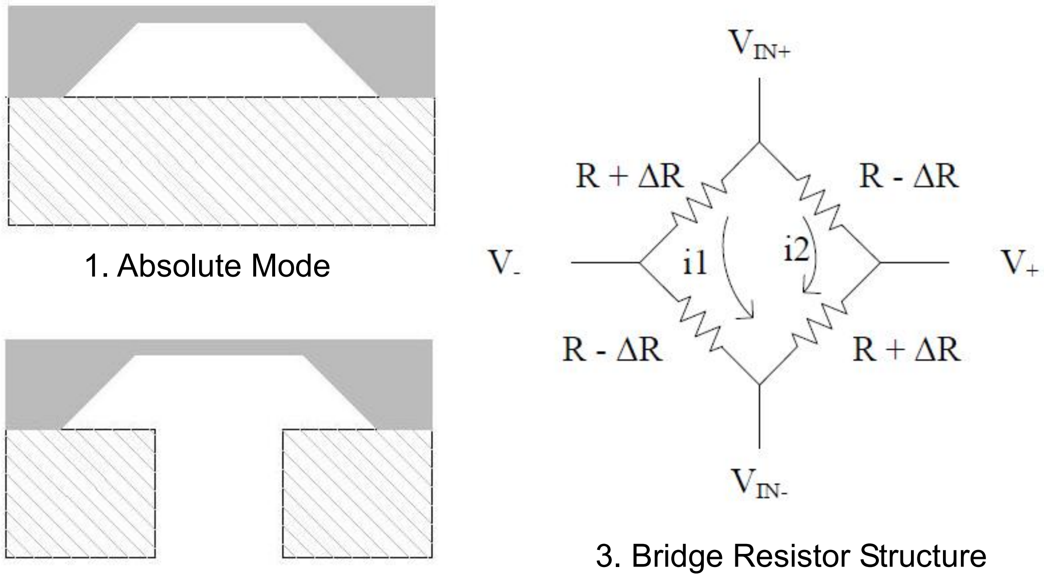
1. Introduction

Silicon pressure sensors have cost advantages and are widely used for tire pressure meter, pressure meter, blood pressure meter, barometer, altimeter, weather forecast, water depth measurement, air pressure control...etc.. This article aims to give description of silicon pressure sensor application by featuring HY11P series microcontrollers.

2. Theory Description

- Sensor Characteristics

Silicon pressure sensor is composed by a bridge resistor that can be divided by Gauge mode and Absolute mode. Gauge mode takes an atmospheric pressure as zero point and the absolute press sets zero point when vacuum.



1. Absolute Mode

2. Gauge Mode

3. Bridge Resistor Structure

Figure 1

When pressure presses on the sensor, the output voltage signal is positive value.

$$\text{Count} = (V_+ - V_-) / (V_{IN+} - V_{IN-}) = \Delta R / R$$

$$= \text{Span} \times (1 + \text{TCS} \times \Delta T) \times P / FS + \text{Offset} + \text{Span} \times \text{TCO} \times \Delta T$$

$$P \fallingdotseq \text{Gain} \times (1 - \text{TCS} \times \Delta T) \times (\text{Count} - \text{Offset}) - \text{TCO} \times FS \times \Delta T$$

Among it,

$\Delta T = T - T_c$: Temperature differences of now and the time when calibration was implemented.

Span unit is Count

TCS is the temperature coefficient of span (Unit: %/℃)

TCO is the temperature coefficient of offset (Unit: %/℃)

Gain = FS / Span (Unit: mBar/Count)

In terms of US9173 sensor, the temperature drift of sensor offset falls in the range of ±0.08%/℃ (normally, it’ s around -0.02%/℃). When measuring the gauge pressure, the offset can be deducted before pressurizing. However, when measuring the absolute pressure, this offset must be taken into account seriously.

Additionally, the resistance temperate drift of general silicon pressure sensors are high. Thus, if the reference voltage is set as input voltage, temperature drift of span will fall in -0.17~0.27%/℃. It is suggested to connect to a reference resistor, take the voltage difference of reference resistor as voltage reference, as Figure 2.

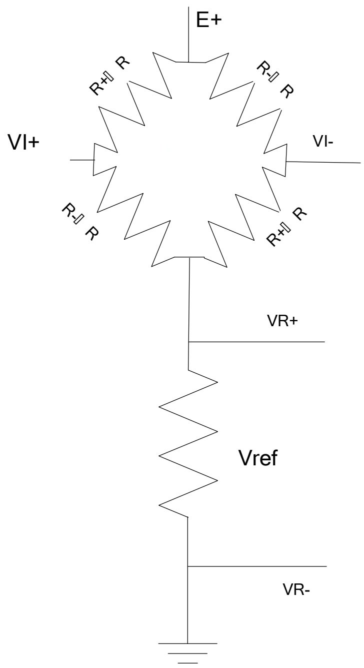


Figure 2

Gain：

Count = (V_+ - V_-) / (VR_+ - VR_-) = ΔR / R_{ref}

Given the reason that R_{ref} temperature drift is smaller than R of sensor and its response to temperature is more regular, using 50ppm resistor, which Span temperature drift is reduced to ±0.05%/℃, typical ±0.02%/℃, is far better than taking

VDDA as reference voltage.

Please note TCO and TCS to temperature is not constants. If in real applications, which sets higher standard of temperature drift, users can conduct temperature experiment of different lot sensor and to obtain its average TCS and TCO temperature curve. During measurement, the built-in temperature sensor of HY11P can be utilized to test the change of temperature and to find out TCS and TCO value to compensate temperature.

About the methods of using built-in temperature sensor please refer to <<Voltage and Temperature Measurement >> (APD-SD18012).

- Microcontroller

  Competitive edges of HY11P series：

  - Low operation voltage → Min. ADC operation voltage: 2.4V
  - Low power consumption → Use internal 2MHz to initiate ADC, the max. power consumption is less than 1mA
  - ADC Gain amplification → ×1/4 ~ ×16
  - Built-in pre-amplify circuit (PGA) → ×1 ~ ×8
  - High resolution and low temperature drift ADC → 18 bits output, Gain drift: 5PPM/℃
  - IC Offset cancel function
  - Built-in temperature sensor to be used for temperature measurement and temperature compensation of sensors
  - Low voltage detection → Multi-step power voltage detection
  - Serial SPI communication
  - PWM/PDM output

3. Theory and ADC Measurement Network

- Theory

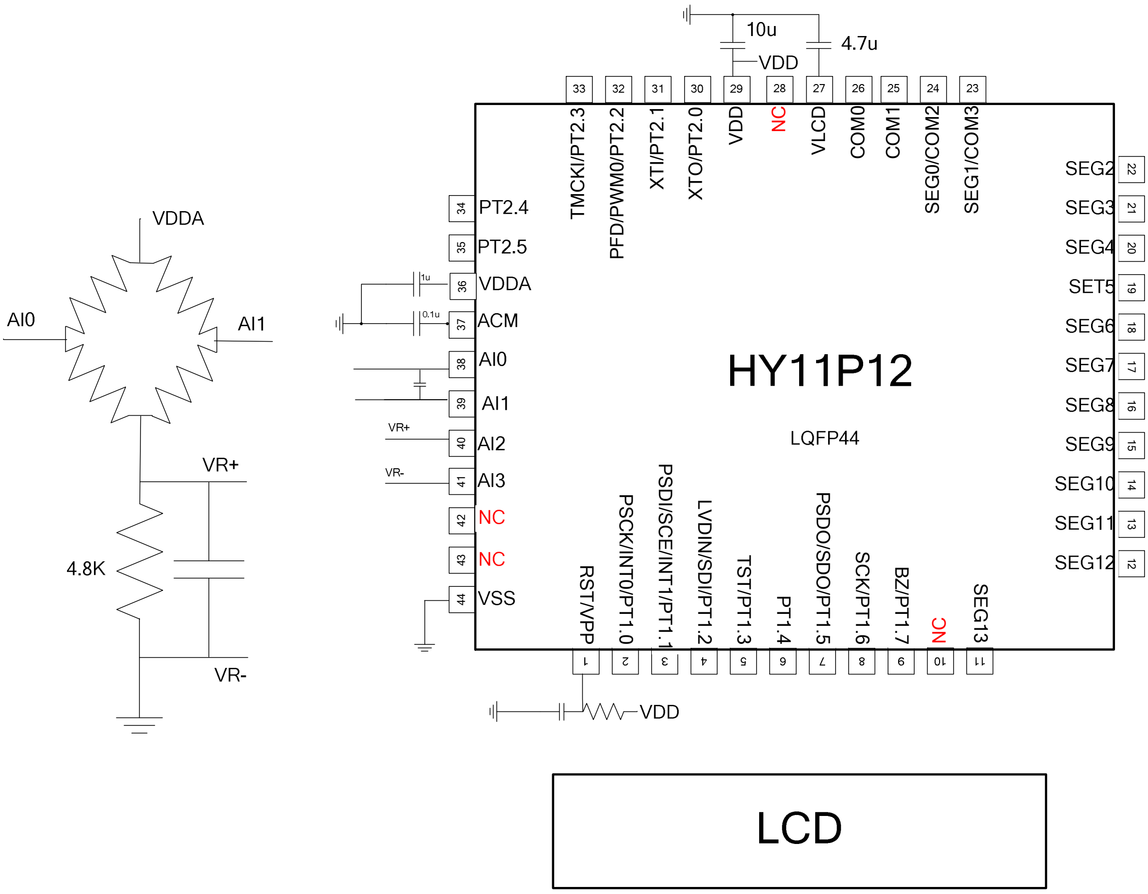


Figure 3

- Network Configurations of Temperature Measurement
  - VDDA = 2.4V
  - VR+：VDDA
  - VR-：VSS
  - PGA = OFF
  - SI GAIN = 1X
  - VR GAIN = 1/2 X
  - Vin/VR Buffer=OFF
- Network Configurations of Pressure Sensor Measurement
  - VDDA = 2.4V
  - PGA = OFF
  - SI GAIN = 16X
  - VR GAIN = 1X
  - Vin/VR Buffer=OFF

4. Experiment Results

- This experiment adopted pressure sensor of US-9173-H15-A.

- By implementing the configurations and circuit listed above, one point calibration was conducted at 25℃, 1000mBar. And the results before temperature compensation is as follows:

	Sample#1			Sample#2			Sample#3			Sample#4			Sample#5		
	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃
1000mBar	1003	1000	1004	1003	1000	1001	1003	1000	1005	1005	1000	1005	1004	1000	1007
800mBar	790	786	790	805	800	802	797	794	798	792	787	791	802	798	803
600mBar	577	573	576	606	601	603	592	589	592	580	576	578	598	596	599
400mBar	365	361	362	409	404	406	386	384	386	369	364	365	397	394	397
Offset*	-60	-66	-66	12	6	8	-25	-27	-26	-55	-60	-62	-8	-10	-10
Span*	1063	1066	1070	991	994	993	1028	1027	1031	1060	1060	1066	1012	1010	1017
TCO*	-0.020%	-	-0.001%	-0.022%	-	0.010%	-0.007%	-	0.002%	-0.019%	-	-0.006%	-0.005%	-	-0.003%
TCS*	0.011%	-	0.019%	0.009%	-	-0.003%	-0.005%	-	0.020%	0.001%	-	0.028%	-0.001%	-	0.035%

- 400mBar~1000mBar is actual measured value, others that marked with * are calculated results.
- TCS and TCO are not constant; they are related to temperature and vary with every sensor. However, within 0℃~45℃, 0.035%/℃ and -0.02%/℃, TCS method is obviously better than constant voltage measurement.
- Normally, high temperature cause larger temperature drifts to SPAN while low temperature impacts the temperature drift of Offset. At 0℃, average TCO and TCS is -0.015%/℃ and 0%/℃ ; at 45℃, average TCO and TCS is 0%/℃ and 0.02%/℃.

- Using the above mentioned average TCO and TCS value to compensate, the results are as follows:

	Sample#1			Sample#2			Sample#3			Sample#4			Sample#5		
	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃
1000mBar	999	1000	1000	1000	1000	997	1000	1000	1001	1001	1000	1001	1000	1000	1002
800mBar	786	786	787	801	800	798	793	794	795	788	787	787	798	798	800
600mBar	573	573	573	603	601	601	588	589	589	576	576	575	595	596	597
400mBar	362	361	361	405	404	404	383	384	385	365	364	364	393	394	395
Offset	-64	-66	-66	8	6	8	-29	-27	-26	-59	-60	-61	-12	-10	-10
Span	1063	1066	1066	991	994	989	1028	1027	1027	1060	1060	1062	1012	1010	1013

- To reach 0~1000mBar range and +/-5mBar precision, two-point calibration is needed. For example, 1000mBar and 600mBar @25℃. The calculation is as follows：

	Sample#1			Sample#2			Sample#3			Sample#4			Sample#5		
	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃	0℃	25℃	45℃
1000mBar	999	1000	1000	1000	1000	997	1000	1000	1001	1001	1000	1001	1000	1000	1002
800mBar	800	800	800	801	800	797	799	800	800	800	799	799	800	800	802
600mBar	600	600	600	602	600	600	599	600	600	600	600	599	599	600	601
400mBar	402	401	401	404	403	403	400	401	401	401	400	400	399	400	401

5. Conclusion

- Adopting the measurement method of Figure 2 helps to reduce considerably sensor span temperature drift.
- Average value of TCO and TCS of sensors can be measured through experimental method and the temperature curve of TCO and TCS can be gained accordingly. After temperature compensation, it can reach 60ppm/℃ effect.
- +/-5mBar resolution can be achieved by two-point calibration.

6. Reference

- UniSense Datasheet: SP-017 US9173-datasheet-1.3.pdf
- Intersema Application Notes_Calibration.pdf
- HYCON Technology Corporation, Application Notes: APD-SD18012 Voltage and Temperature Measurement