DATE January 9, 2020
No. V-70284-E

Messrs.

SPECIFICATION

Semiconductor Pressure Sensor

Model: AL4 series (Differential Pressure Type)

Project:

Distributor:

Reference:

Yoshiyuki Uchiumi, Application Engineer
Sensor Business Unit
Electronic Component Business Company
Fujikura Ltd.

Fujikura Ltd.

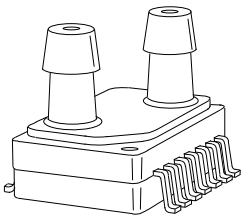
Table of Contents

Table shown below is revision records of this specification

Est.	Jan. 9, 2020	Y. Uchiumi	Issued	
	Date	Name	Comment	Mark

1. General

This document describes the specifications of the AL4 pressure sensors for differential pressure type.



2. Principle

Fujikura pressure sensor is composed of a silicon piezo-resistive pressure sensing chip and a signal conditioning integrated circuit. The low-level signal from the sensing chip is amplified, temperature compensated, calibrated, and finally converted to digital data that is proportional to the applied pressure.

3. Device Lineup

This device has the following lineup.

Model	Pressure Type	Supply Voltage	Accuracy	Pressure Range
AL4	Differential	5.0 Vdc 3.3 Vdc 3.0 Vdc	±1.5%FS	-10 (-100) -7 (-70) -4 (-40) -2 (-20) -1 (-10) 0 +1 (+10) +2 (+20) +4 (+40) +7 (+70) +10 kPa (+100 cmH_2O) 001KD 002KD 004KD 007KD 010KD

Features

- ✓ Digital output
- ✓ Low pressure
- ✓ High proof pressure
- ✓ Moisture sensitivity level (MSL) 1
- ✓ Low power consumption
- ✓ High accuracy
- ✓ Modification available

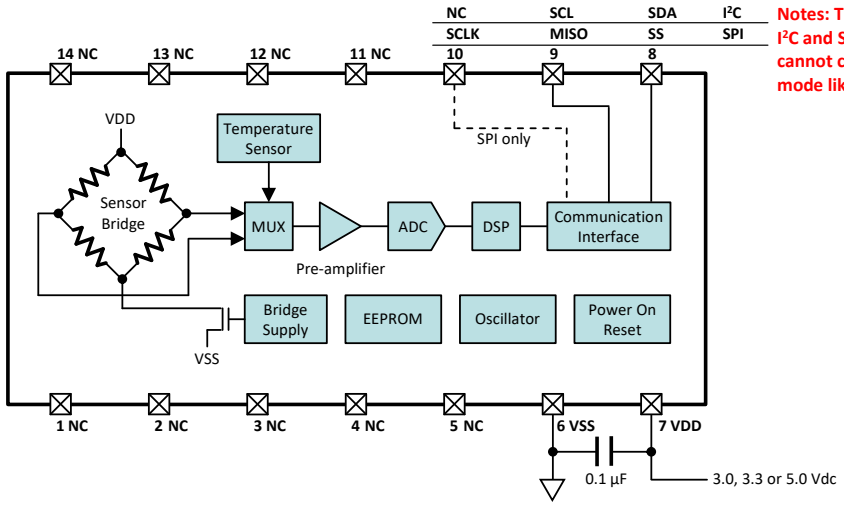
Applications

- ✓ Battery-operated devices
- ✓ Medical devices
- ✓ Industrial pneumatic devices
- ✓ Consumer devices

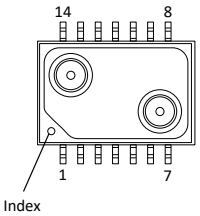
4. RoHS

This device is compliant with the Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS).

5. Block Diagram and Pin Connections



Notes: The internal connection of I²C and SPI is different. User cannot change communication mode like I²C to SPI or SPI to I²C.

Pin Assignment	Pin No.		Pin Name	I/O	Type	Function	
	1		NC	-	-	Non-connection	*3
	2		NC	-	-	Non-connection	*3
	3		NC	-	-	Non-connection	*3
	4		NC	-	-	Non-connection	*3
	5		NC	-	-	Non-connection	*3
	6		VSS	-	-	Common voltage connection	*1
	7		VDD	-	-	Power supply connection	*1
	8	I²C	SDA	I/O	Digital	Serial bidirectional data	*2
		SPI	SS	I	Digital	Slave select	
	9	I²C	SCL	I	Digital	Serial clock input	*2
		SPI	MISO	O	Digital	Master-In-Slave-Out	
	10	I²C	NC	-	-	Non-connection	*2
		SPI	SCLK	I	Digital	Serial clock input	
	11		NC	-	-	Non-connection	*3
	12		NC	-	-	Non-connection	*3
	13		NC	-	-	Non-connection	*3
	14		NC	-	-	Non-connection	*3

Notes:
*1) Put a 0.1µF capacitor between VDD Pin 7 and VSS.
*2) I²C or SPI is factory setting. User cannot change communication mode.
*3) NC pins must be open.

6. Device Name Code

The device name code is consisted of Sensor code, Pressure code, Slave address code and Packing. For the exact ordering device number, please refer to Chapter 22 Ordering Information.

Sensor code **Pressure code**

AL4 1 DB - 007K D - 2 - TP

Packing	**TP:**	Tape & Reel	
Custom ID		if applicable	
Communication code	**S:**	SPI mode	
	2:	0x28	Slave address for I²C mode
	3:	0x38	
	4:	0x48	
	5:	0x58	
	6:	0x68	
	7:	0x78	
Pressure type	**D:**	Differential pressure	
Pressure range	**001KD:**	-1 kPa to +1 kPa	
	002KD:	-2 kPa to +2 kPa	
	004KD:	-4 kPa to +4 kPa	
	007KD:	-7 kPa to +7 kPa	
	010KD:	-10 kPa to +10 kPa	
Port option	**DB:**	Dual axial barbed ports	
Supply voltage	**0:**	5.0 Vdc	
	1:	3.3 Vdc	
	2:	3.0 Vdc	
Model	**AL4:**	Low pressure | SMD | Digital output	

Pressure Range Conversion (Reference)

Pressure Code	kPa	mbar	cmH_2O	$inchH_2O$	psi	mmHg
001KD	-1 - +1	-10 - +10	-10.1972 - +10.1972	-4.01865 - +4.01865	-0.145038 - +0.145038	-7.50062 - +7.50062
002KD	-2 - +2	-20 - +20	-20.3943 - +20.3943	-8.03729 - +8.03729	-0.290075 - +0.290075	-15.0012 - +15.0012
004KD	-4 - +4	-40 - +40	-40.7886 - +40.7886	-16.0746 - +16.0746	-0.580151 - +0.580151	-30.0025 - +30.0025
007KD	-7 - +7	-70 - +70	-71.3801 - +71.3801	-28.1305 - +28.1305	-1.01526 - +1.01526	-52.5043 - +52.5043
010KD	-10 - +10	-100 - +100	-101.972 - +101.972	-40.1865 - +40.1865	-1.45038 - +1.45038	-75.0062 - +75.0062

Note:

*1) The device is calibrated based on the unit of "kPa". Other converted pressure values are for reference.

7. Absolute Maximum Ratings

Item	Condition	Symbol	Rating		Unit
			Min.	Max.	
Supply Voltage		VDD_{max}	-0.3	6	Vdc
Voltage at Digital I/O pins		V_{diomax}	-0.3	VDD+0.3	Vdc
Operating Temperature		T_{opt}	-40	+85	°C
Storage Temperature		T_{stg}	-40	+85	°C

Notes:

*1) Absolute maximum ratings are the limits that the device will withstand without damage.

8. Environmental Specifications

Item	Condition	Symbol	Rating			Unit	
			Min.	Typ.	Max.		
Operating Humidity	Non-condensing, +65°C		-	-	95	%RH	*1, 2
Storage Humidity	Non-condensing, +65°C		-	-	95	%RH	*1, 2

Notes:

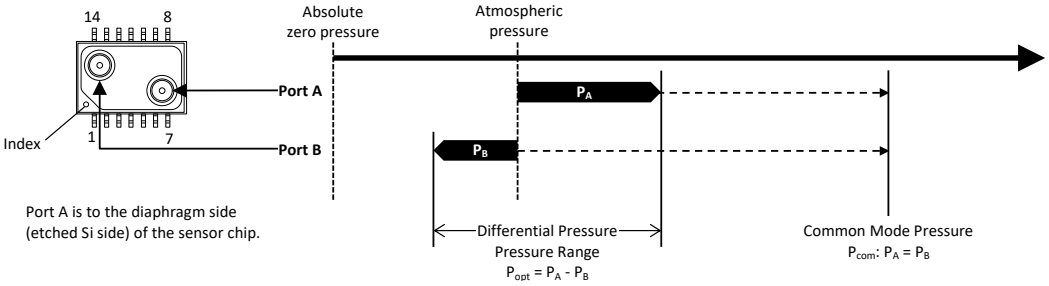
*1) Do not wet the device with dew.

*2) If the device is operated or storage at above +65°C in 95%RH, accuracy of the output is subject to be out of the specifications.

9. Pressure Specifications

Type of Pressure	Differential pressure	*1
Pressure Media	Non-corrosive gases for wetted materials	*2, 3

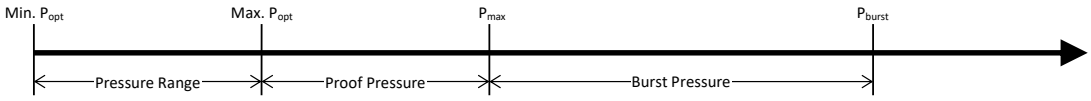
Notes:
*1) Differential pressure is defined as the difference between the pressure applied to Port A and that to Port B. See the figure below.
*2) Wetted materials are PPS resin, silicone resin, silicon, gold, Cu alloy and silver.
*3) Ensure the pressure media contains no particulates. The device is not compatible with liquids.



Pressure Table

Pressure Code / Item / Symbol	Pressure Range *1 Min. P_{opt}	Pressure Range *1 Max. P_{opt}	Proof Pressure *2 P_{max}	Burst Pressure *3 P_{burst}	Common Mode Pressure *4 P_{com}	Unit
001KD	-1	+1	+100	+100	+100	kPa
002KD	-2	+2	+100	+100	+100	kPa
004KD	-4	+4	+100	+100	+100	kPa
007KD	-7	+7	+100	+100	+100	kPa
010KD	-10	+10	+100	+100	+100	kPa

Notes:
*1) In Pressure Range(P_{opt}), the output is proportional to difference between the pressure applied to Port A and Port B, meeting the specified accuracy.
*2) Proof Pressure(P_{max}) is defined as maximum applied pressure to the device without damage.
*3) The device will be damaged, if applied pressure is beyond Burst Pressure(P_{burst}).
*4) Common Mode Pressure is defined as maximum applied pressure to Port A and B simultaneously.

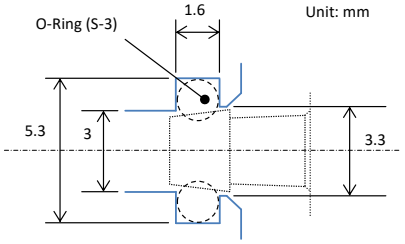


Pressure Port Connection

Recommended Tube (Reference)
Flexible tubing is recommended. The following tubing is for reference. Please select appropriate tubing considering material, Durometer hardness and maximum pressure. Manifold connection can also be available with O-ring or sealing fixtures.

Unit	I.D.	O.D.	Wall thickness
inch	3/32	7/32	1/16
mm	2	4	1

Manifold Connection (Reference)
Manifold connection can also be available with O-ring or sealing fixtures. There are parting lines on the surface of the pressure port at the base side. Top part of the pressure port (barbed part) is recommended for sealing with fixtures.



10. Electrical Characteristics

Ambient temperature T_a=25°C

Item	Condition		Symbol	Rating			Unit	
				Min.	Typ.	Max.		
Supply Voltage	Sensor Code	AL40DB	VDD	4.75	5	5.25	Vdc	*1
		AL41DB		3.135	3.3	3.465		
		AL42DB		2.85	3.0	3.15		
Offset Pressure Data	Min. P_{opt}, $P_A < P_B$		D_{off}	598	819	1040	Count	*2, 3
Balanced Pressure Data	$P_A = P_B$		D_{bal}	7971	8192	8413		*4
Full Scale Pressure Data	Max. P_{opt}, $P_A > P_B$		D_{fs}	15344	15565	15786	Count	*5
Span Pressure Data	Min. to Max. P_{opt}		SD	-	14746	-	Count	*6
Accuracy	in Compensated Temperature		Error	-1.0	-	+1.0	%FS	*7, 8, 9
Compensated Temperature			T_c	-5	-	+65	°C	*10
Supply Current	VDD = 5 Vdc		I_c	-	-	4.5	mAdc	*11
	VDD = 3.3, 3.0 Vdc			-	-	3.5		
Initializing Time	After VDD reaching 2.7 V		t_{init}	-	-	10	msec.	*12
Sampling Frequency			f_{smp}	-	2	-	kHz	*13
Response Time	for reference		t_r	-	1	-	msec.	*14
Temperature Data	for reference	-5°C	D_{tmp}	-	461	-	Count	*15
		+25°C		-	768	-		
		+65°C		-	1177	-		
Dielectric Strength				-	-	1	mA	*16
Insulation Resistance				100	-	-	MΩ	*17

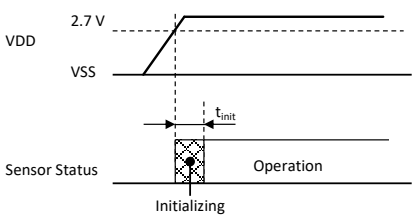
Notes:

*1) Supply voltage (VDD) should be constant.
*2) Offset pressure data (D_{off}) is defined as the pressure data at minimum P_{opt}.
*3) Balanced pressure data (D_{bal}) is defined as the pressure to Port A equals that to Port B.
*4) Balanced pressure data error is calibration error of Balanced pressure data (D_{bal}) at production. It does not include Long term drift. It would be suggested that applications have Auto-zeroing function.
*5) Full scale pressure data (D_{fs}) is defined as the pressure data at maximum P_{opt}.
*6) Span pressure data (SD) is defined as the pressure data difference between Offset pressure data (D_{off}) and Full scale pressure data (D_{fs}).
*7) The unit of Accuracy "%FS" is defined as a percent error by Span pressure data (SD).
*8) Accuracy (Error) is the specs of out-going inspection at Fujikura. It consists of the following:
- Non-linearity
- Temperature errors over the temperature range -5 to 65°C
- Pressure hysteresis
- Calibration errors of sensitivity and offset

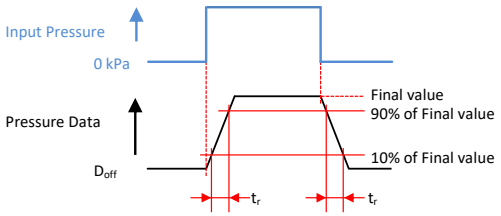
*9) The following errors are NOT included to Accuracy (Error):
- Offset change due to port orientation sensitivity, soldering thermal stress and assembling mechanical stress
- Offset drift over time

*10) Please also refer to Chapter 18 Transfer Function.
*11) Lower power mode is available for a modification product. Please ask Fujikura.
*12) Initializing process starts when VDD reached 2.7 V. After initializing process, ready to data read. See the figure below.
*13) Sampling frequency is time to data ready.
*14) Response time (t_r) is defined as the time for the change in the pressure data from 10% to 90% or from 90% to10% of its final value when the input pressure makes a step change. See the figure below.
*15) Temperature Data (D_{tmp}) is for reference.
*16) Dielectric strength is defined as the leakage current between all pins and the package with AC 500 V, 1 minute.
*17) Insulation resistance is defined as the resistance value between all pins and the package with DC 500 V.

Initializing Time



Response Time



11. Electrical Characteristics for I²C or SPI Interface

Communication interface (communication mode) of I²C or SPI is factory setting. User cannot change communication mode like from I²C to SPI or from SPI to I²C.

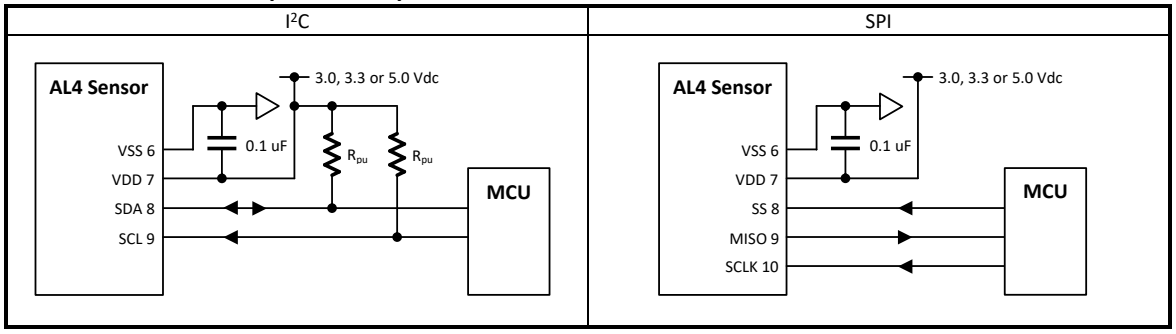
Ambient temperature T_a=25°C

Item	Condition		Symbol	Rating			Unit
				Min.	Typ.	Max.	
Interface				I²C or SPI			*1
Input Low Voltage	Sensor Code	AL40DB	V_{IL}	0	-	1	V
		AL41DB		0	-	0.66	V
		AL42DB		0	-	0.6	V
Input High Voltage	Sensor Code	AL40DB	V_{IH}	4	-	5	V
		AL41DB		2.64	-	3.3	V
		AL42DB		2.4	-	3	V
Output Low Voltage	Sensor Code	AL40DB	V_{OL}	-	-	0.5	V
		AL41DB		-	-	0.33	V
		AL42DB		-	-	0.3	V

Notes:

*1) I²C is a trademark of NXP Semiconductors.

12. I²C or SPI Circuits (Reference)



13. I²C Digital Interface

Item	Condition	Symbol	Rating			Unit	
			Min.	Typ.	Max.		
SCL clock frequency		f_{SCL}	100	-	400	kHz	
Start condition hold time relative to SCL edge		t_{HDSTA}	0.1	-	-	µsec.	
Minimum SCL clock low width		t_{LOW}	0.6	-	-	µsec.	*2
Minimum SCL clock high width		t_{HIGH}	0.6	-	-	µsec.	*2
Start condition setup time relative to SCL edge		t_{SUSTA}	0.1	-	-	µsec.	
Data hold time on SDA relative to SCL edge		t_{HDDAT}	0	-	-	µsec.	
Data setup time on SDA relative to SCL edge		t_{SUDAT}	0.1	-	-	µsec.	
Stop condition setup time on SCL		t_{SUSTO}	0.1	-	-	µsec.	
Bus free time between stop condition and start condition		t_{BUS}	2	-	-	µsec.	
Load Capacitance	Pin8 SDA, 400kHz	C_{max}	-	-	200	pF	
Pull-up Resistor	Pin8 SDA, Pin9 SCL	R_{pu}	1	-	-	kΩ	
Slave address	7 bit, Factory setting		0x28 to 0x78				*3

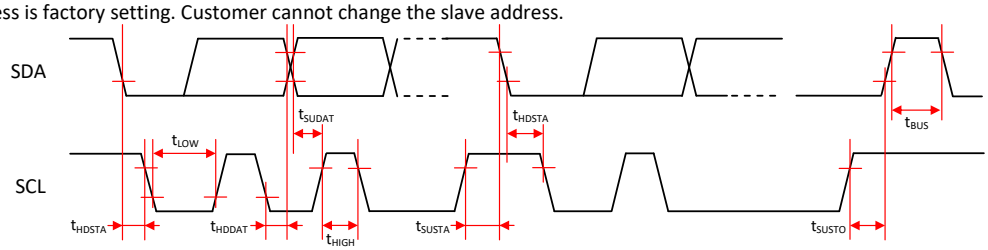
Notes:

*1) There are three differences in this device protocol compared with the original I²C™ protocol:
- Sending a start-stop condition without any transitions on the CLK line (no clock pulses in between) creates a communication error for the next communication, even if the next start condition is correct and the clock pulse is applied. An additional start condition must be sent, which results in restoration of proper communication.
- The restart condition - a falling SDA edge during data transmission when the CLK clock line is still high - creates the same situation. The next communication fails, and an additional start condition must be sent for correct communication.
- A falling SDA edge is not allowed between the start condition and the first rising SCL edge. If using an I2C™ address with the first bit 0, SDA must be held low from the start condition through the first bit.

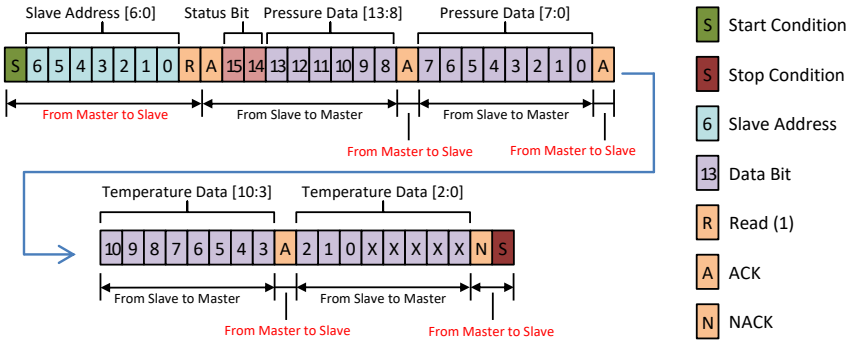
*2) Combined low and high widths must equal or exceed minimum SCLK period.

*3) Slave address is factory setting. Customer cannot change the slave address.

Timing Diagram



14. I²C Communication Protocol

Item		Measurement Packet	
Data Fetch			
Status bits	00	Normal operation , good data packet	
	01	Device in Command Mode	*1
	10	Stale data: Data has aleady been feched since the last measurement cycle.	*2
	11	EEPROM Error	*3

Notes:

*1) If the status bits are 01, the device must be re-started to turn power supply off and on again.

*2) If a data fetch is performed before or during the first measurement after power-on reset, then “stale” will be returned, but this data is actually invalid because the first measurement has not been completed.

*3) If the status bits are 11, do not use the device anymore.

15. SPI Digital Interface

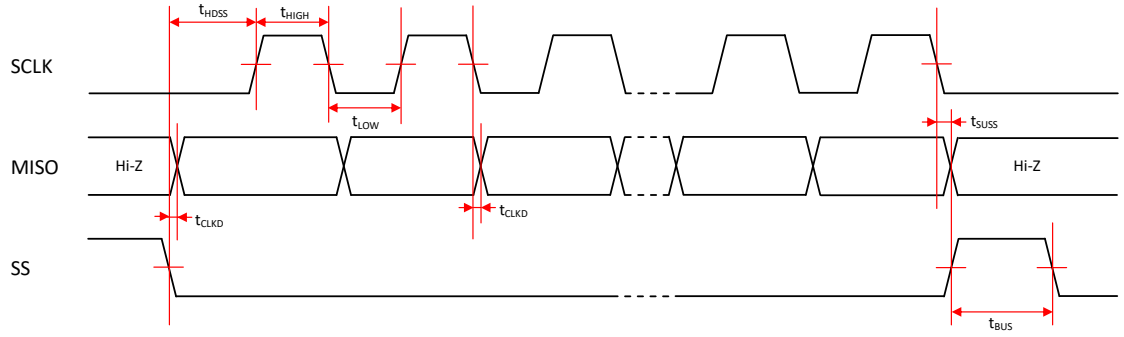
This mode is half duplex (read-only).

Item	Condition	Symbol	Rating			Unit	
			Min.	Typ.	Max.		
SCLK clock frequency	4 MHz clock	f_{SCL}	50	-	800	kHz	
SS drop to first clock edge		t_{HDSS}	2.5	-	-	µsec.	
Minimum SCLK clock low width		t_{Low}	0.6	-	-	µsec.	*1
Minimum SCLK clock high width		t_{HIGH}	0.6	-	-	µsec.	*1
Clock edge to data transition		t_{CLKD}	0	-	0.1	µsec.	
Rise of SS relative to last clock edge		t_{SUSS}	0.1	-	-	µsec.	
Buss free time between rise and fall of SS		t_{BUS}	2	-	-	µsec.	

Notes:

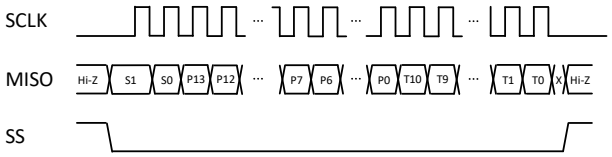
*1) Combined low and high widths must equal or exceed minimum SCLK period.

Timing Diagram

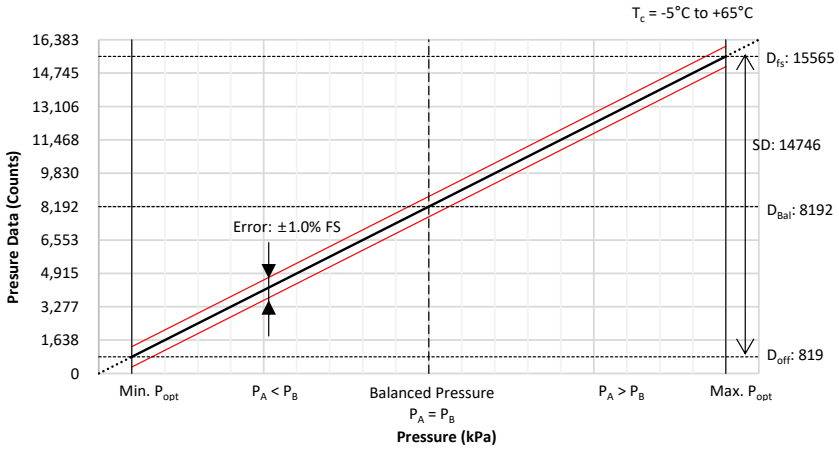


16. SPI Communication Protocol

The master should sample MISO on the rise of SCLK.

Item	Measurement Packet
Data Fetch	 Packet = [{S(1:0),B(13:8)},{B(7:0)},{T(10:3)},{T(2:0),xxxxx}] S(1:0) = Status bits of packet (Normal, Command, Busy, EEPROM Error) P(13:8) = Upper 6 bits of 14-bit pressure data P(7:0) = Lower 8 bits of 14-bit pressure data T(10:3) = Corrected temperature data (if application does not require corrected temperature data, terminate read only.) T(2:0),xxxxx = Remaining bits of corrected temperature data for full 11-bit resolution Hi-Z = High impedance

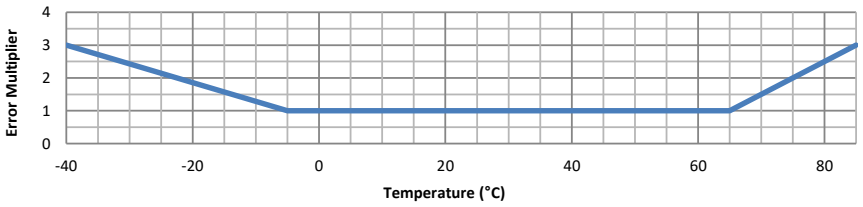
17. Output versus Input Pressure



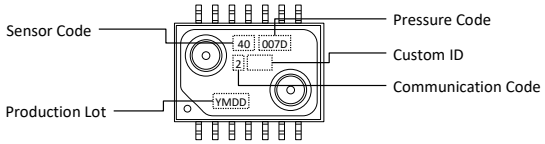
18. Transfer Function

Item	Transfer Function
Pressure Data	Pressure Data (Counts) = P × α + β ± (Error × Temperature Error Multiplier) ⇕ $P\ (kPa) = \frac{\text{Pressure Data} - \beta \pm (\text{Error} \times \text{Temperature Error Multiplier})}{\alpha}$
Temperature Data	$D_{tmp}\ (\text{Counts}) = \frac{2047}{200} \times (T + 50) \Longleftrightarrow T\ (°C) = \frac{200}{2047} \times D_{tmp} - 50$

Pressure Code	P (kPa)	α	β	Error
001KD	-1 to +1	7373	8192	147
002KD	-2 to +2	7373/2	8192	147
004KD	-4 to +4	7373/4	8192	147
007KD	-7 to +7	7373/7	8192	147
010KD	-10 to +10	7373/10	8192	147



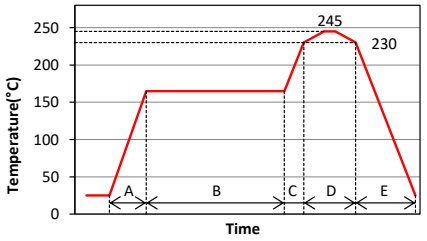
19. Device Marking



Production Lot *1	Marking	Sensor Code	Marking	Pressure Code	Marking	Communication Code	Marking	Custom ID Marking
Y: Last digit of year	0 to 9	AL40DB	40	001KD	001D	2	2	If applicable
M: Month Jan. to Sep.	1 to 9	AL41DB	41	002KD	002D	3	3	
October	X	AL42DB	42	004KD	004D	4	4	
November	Y			007KD	007D	5	5	
December	Z			010KD	010D	6	6	
DD: Date	00 to 31					7	7	
						S	S	

Notes:
*1) Production Lot is 10 year cycle.

20. Soldering

Items	Condition
Moisture Sensitivity Level	Level 1 *1
Reflow Soldering Profile	 *2 *3 *4 *5

A	Ramp up	2 to 4°C / sec.
B	Pre-heating	150 to 180°C 60 to 120 sec.
C	Ramp up	2 to 4°C / sec.
D	Heating	Above 230°C, 45 sec. max. 245°C max., 10 sec. max.
E	Ramp down	2 to 4°C / sec.

Notes:
*1) This device is classified as moisture sensitivity level (MSL) 1 that is defined in Jedec standard J-STD-20. Floor life time is unlimited. However, the plating of pins is silver (Ag) that could be discolored to black or brown by sulfur in the environment. Discoloration of pins could impact soldering reliability. The device should be sealed in the embossed carrier tape before soldering.
*2) NEVER wash the device with any washing liquid. NEVER wash the device with any ultrasonic washing machine.
*3) Do not put the solder and flux on the device's package.
*4) Temperature means Surface temperature of the device's package.
*5) Do not reflow more than twice.

21. Dimensions and Weights

Refer to the following drawing as attached. 3D CAD model is available. Please ask Fujikura distributor.

Sensor Code	Dimension Drawing	Weight
AL4xDB	9-772-006	approx. 0.55 grams

22. Ordering Information

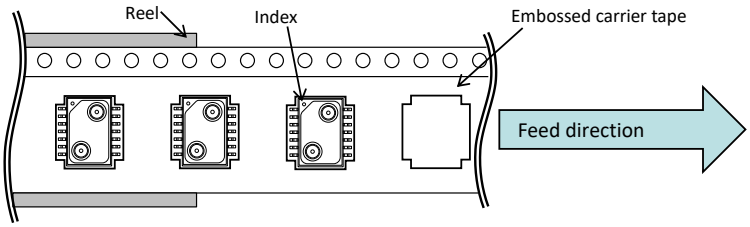
Model	Package	Supply Voltage	Packing	Ordering Device Number	Qty./Packing
AL4	SMD	5.0 Vdc	Tape & Reel	AL40DB-[Pressure Code]-[Com Code]-TP	350 Pcs/Reel
		3.3 Vdc	Tape & Reel	AL41DB-[Pressure Code]-[Com Code]-TP	350 Pcs/Reel
		3.0 Vdc	Tape & Reel	AL42DB-[Pressure Code]-[Com Code]-TP	350 Pcs/Reel

Pressure Range	Pressure Code
-1 kPa to +1 kPa	001KD
-2 kPa to +2 kPa	002KD
-4 kPa to +4 kPa	004KD
-7 kPa to +7 kPa	007KD
-10 kPa to +10 kPa	010KD

		Communication Code
I^2C Slave address	0x28	2
	0x38	3
	0x48	4
	0x58	5
	0x68	6
	0x78	7
SPI		S

I2C or SPI is factory setting.
User cannot change the communication mode.

23. Tape & Reel Information



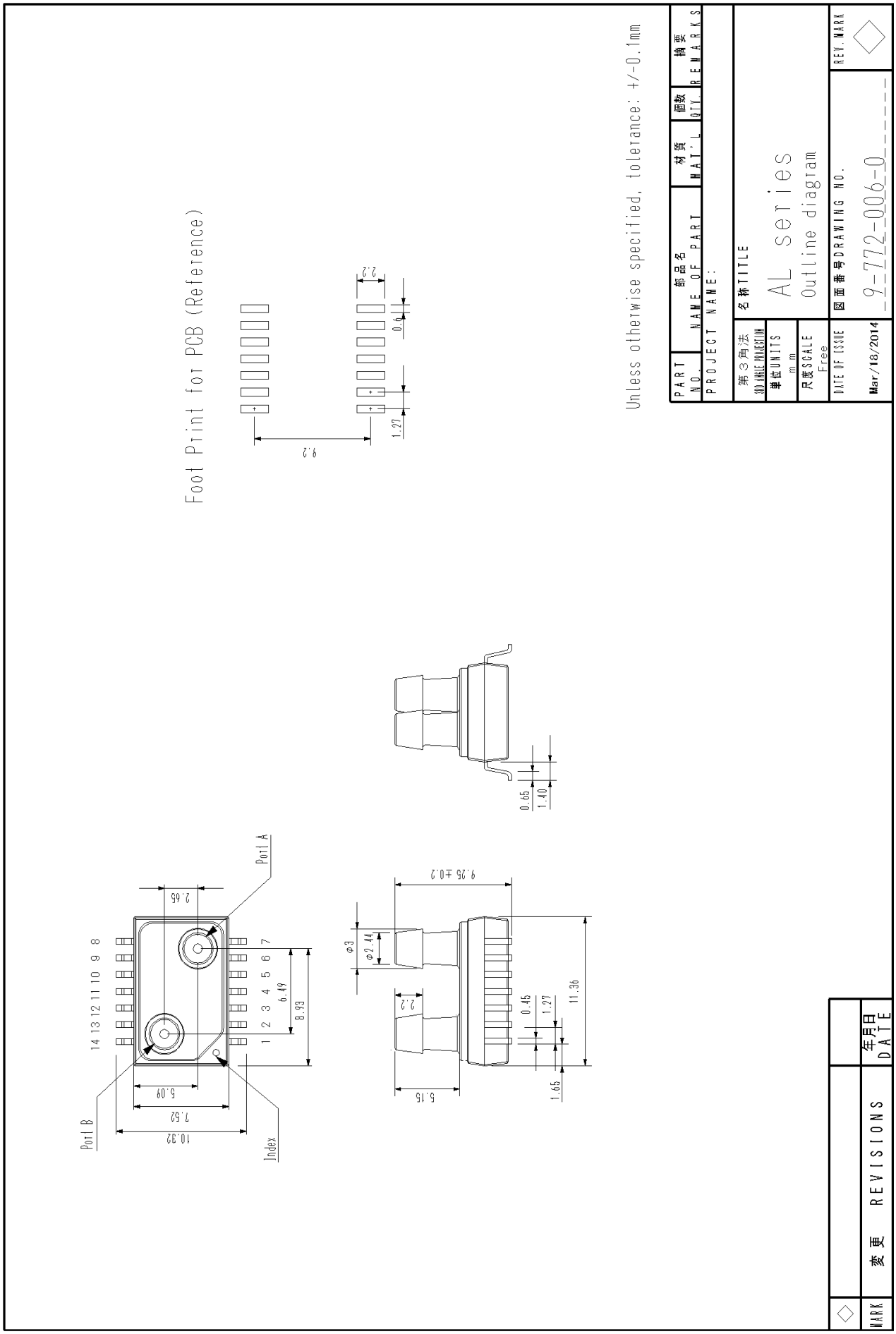
24. Handling Notes

Plating of pins is silver (Ag). Silver has physical property that is discolored to black or brown by sulfur. There are notes for handling as below:

- To prevent discoloration of pins, please keep the devices sealed in static shielding bags before soldering.
- Do not solder the devices that have discolored pins.
- After soldering, pins would be discolored in black or brown in atmosphere. However it does not impact reliability of the device.

25. Notes

- Fujikura reserves all rights.
- This document is subject to change without notice.
- Limitation, usage, environment, standard warranty and so on are listed on Fujikura web site.
- Please refer to the latest specifications.



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