Messrs.

SPECIFICATION

Preliminary
Semiconductor Pressure Sensor

Model: AL4 series (Differential Pressure Type)

Project:

Distributor:

Reference:

Y. Uchiumi

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Sensor Business Unit
Electronic Component Business Company
Fujikura Ltd.

Fujikura Ltd.

Table of Contents

Table shown below is revision records of this specification

Est.	July 4, 2019	Y. Uchiumi	Preliminary	
	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										
				-10 (-100)	-7 (-70)	-4 (-40)	-2 (-20)	-1 (-10)	0	1 (10)	2 (20)	4 (40)	7 (70)	10 kPa (100) cmH$_2$0
AL4	Differential	5.0 Vdc 3.3 Vdc 3.0 Vdc	±1.5%FS						001KD					
								002KD						
						004KD								
					007KD									
				010KD										

Features

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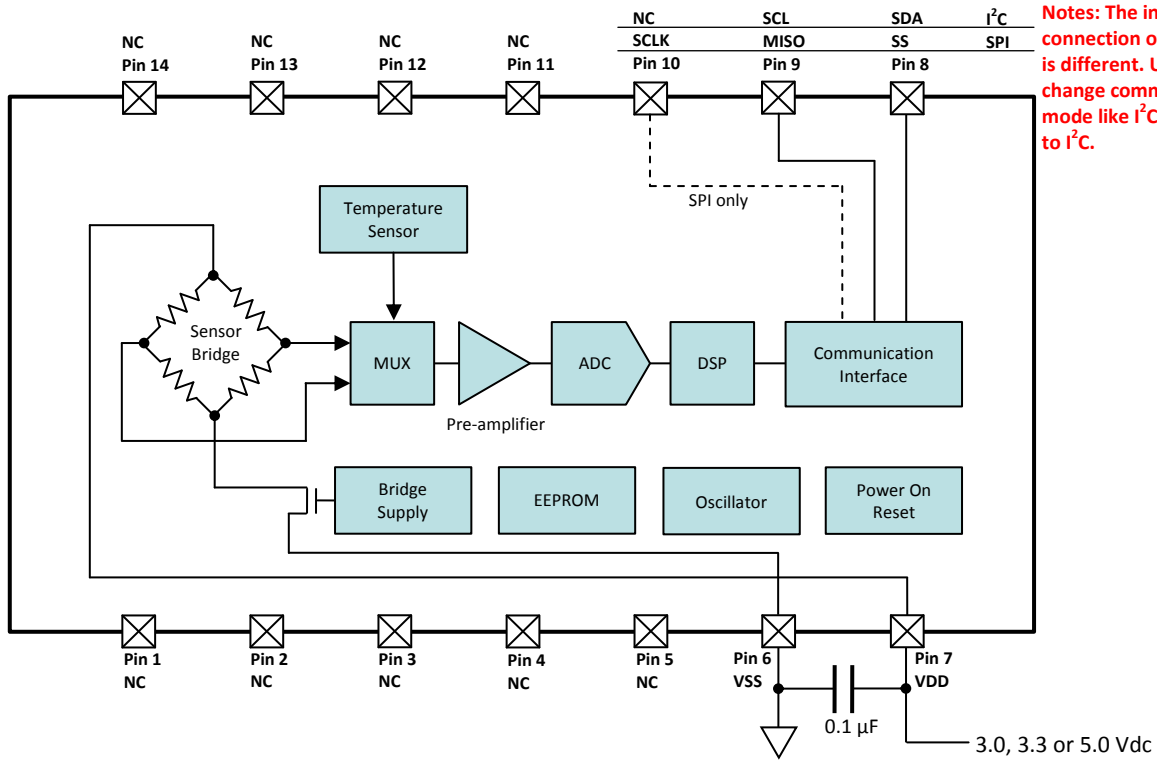✓ Low power consumption
✓ High accuracy
✓ Modification available

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

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

Notes:
*1) Put a 0.1µF capacitor between VDD Pin 7 and VSS.
*2) I^2C or SPI is factory setting. User can not 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 style. 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
	S:	SPI mode
	2:	0x28
	3:	0x38
	4:	0x48 Slave address
	5:	0x58 for I²C mode
	6:	0x68
Communication mode	**7:**	0x78
Pressure type	**D:**	Differential pressure
	001K:	1 kPa
	002K:	2 kPa
	004K:	4 kPa
	007K:	7 kPa
Pressure value	**010K:**	10 kPa
Port option	**DB:**	Dual axial barbed ports
	0:	5.0 Vdc
	1:	3.3 Vdc
Supply voltage	**2:**	3.0 Vdc
Model	**AL4:**	Low pressure / SMD / Digital output

Pressure Range Conversion (Reference)

Pressure Code	kPa	mbar	cmH₂O	inchH₂O	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.	Typ.	Max.		
Proof Pressure	Port A, B	Pmax	-	-	+100	kPa	*2
Burst Pressure	Port A, B	Pburst	+100	-	-	kPa	*3
Common Mode Pressure	Port A and B	Pcom	-	-	+100	kPa	*4
Supply Voltage		VDDmax	-0.3	-	6	Vdc	
Voltage at Digital I/O pins		Vdiomax	-0.3	-	VDD+0.3	Vdc	
Operating Temperature		Topt	-40	-	+85	°C	
Storage Temperature		Tstg	-40	-	+85	°C	

Notes:

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

*2) Proof Pressure is defined as maximum applied pressure to the device without damage.

*3) The device will be damaged, if applied pressure is beyond Burst Pressure.

*4) Common Mode Pressure is defined as maximum pressure applied to Port A and B simultaneously.

8.   General Specifications

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		
Type of Pressure			-	Differential pressure				*2
Pressure Media			-	Non-corrosive gases				*3
Pressure Range	Pressure Code	001KD	Popt	-1	-	+1	kPa	*4
		002KD		-2	-	+2	kPa	
		004KD		-4	-	+4	kPa	*5
		007KD		-7	-	+7	kPa	
		010KD		-10	-	+10	kPa	
				-5	-	+65	°C	*6
				-	-	95	%RH	*7
				-	-	95	%RH	*7
Dielectric Strength				-	-	1	mA	*8
Insulation Resistance				100	-	-	MΩ	*9

Notes:

*1)   Supply voltage (VDD) should be constant.

*2)   Differential pressure is defined as the difference between the pressure applied to Port A and that to Port B.

*3)   Ensure the pressure media contains no particulates. The device is not compatible with liquids.

*4)   Output is the difference between the pressure applied to Port A and the pressure applied to Port B. (Port A - Port B)

*5)   Pressure range is defined as the measurable pressure range of the device. Do not expose intentionally beyond minimum Popt and maximum Popt.

*6)   Please also refer to Chapter 17 Transfer Function.

*7)   Do not wet the device with dew.

*8)   Dielectric strength is defined as the leakage current between all pins and the package with AC 500 V, 1 minute.

*9)   Insulation resistance is defined as the resistance value between all pins and the package with DC 500 V.

9.   Electrical Characteristics

Ambient temperature Ta=25°C

| Item	Condition		Symbol	Rating			Unit	
				Min.	Typ.	Max.		
Offset Pressure Data	Min. Popt, Port A < Port B		Doff	598	819	1040	Count	*1, 2
Balanced Pressure Data	Port A = Port B		Dbal	7971	8192	8413		*3
Full Scale Pressure Data	Max. Popt, Port A > Port B		Dfs	15344	15565	15786	Count	*4
Span Pressure Data	Min. to Max. Popt		SD	-	14746	-	Count	*5
Accuracy	-5 to +65°C		Error1	-1.5	-	+1.5	%FS	*6, 7
		Exclude Dbal error	Error2	-1.0	-	+1.0		*6, 7
Supply Current	VDD = 5 Vdc		Ic	-	-	4.5	mAdc	*8
	VDD = 3.3, 3.0 Vdc			-	-	3.5		
Initializing Time	After VDD reaching 2.7 V		T_{INIT}	-	-	10	msec.	*9
Response Time	for reference		tr	-	1	-	msec.	*10
Temperature Data	for reference	-5°C	Dtmp	-	461	-	Count	*11
		+25°C		-	768	-		
		+65°C		-	1177	-		

Notes:

*1)   Offset pressure data (Doff) is defined as the pressure data at minimum Popt.

*2)   Balanced pressure data (Dbal) is defined as the pressure to Port A equals that to Port B.

*3)   Balanced pressure data error is calibration error of Balanced pressure data (Dbal) at production. It does not include Long term drift. It would be suggested that applications have Auto-zeroing function.

*4)   Full scale pressure data (Dfs) is defined as the pressure data at maximum Popt.

*5)   Span pressure data (SD) is defined as the pressure data difference between Offset pressure data (Doff) and Full scale pressure data (Dfs).

*6)   The unit of Accuracy "%FS" is defined as a percent error by Span pressure data (SD).

*7)   Accuracy of Error1 consists of the following:
    Non-linearity
    Temperature errors over the temperature range -5 to 65°C
    Pressure hysteresis
    Error1: Calibration errors of sensitivity and offset
    Error2: Exclude Calibration error of Balanced pressure (Auto-zeroing is required.)
*8)   We can offer lower power mode products as modification product. Please ask Fujikura.
*9)   Initializing process starts when VDD reached 2.7 V. After initializing process, ready to the operation.
*10) Response time (tr) 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.
*11) Temperature Data (Dtmp) is for reference.

Initializing Time
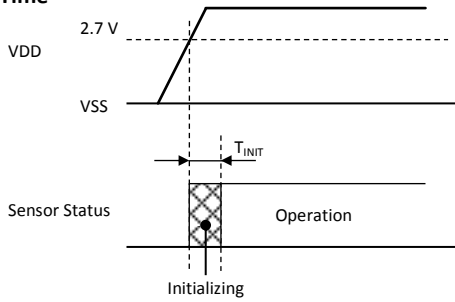
Response Time
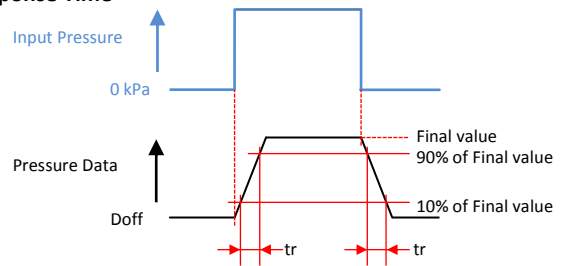
10. Electrical Characteristics for I^{2}C or SPI Interface

Communication interface (communication mode) of I^{2}C or SPI is factory setting. User can not change communication mode like from I^{2}C to SPI or from SPI to I^{2}C.
Ambient temperature Ta=25°C

Item	Condition		Symbol	Rating			Unit	
				Min.	Typ.	Max.		
Interface					I^{2}C or SPI			*1
Input Low Voltage	Sensor Code	AL40DB	VIL	0	-	1	V	
		AL41DB		0	-	0.66	V	
		AL42DB		0	-	0.6	V	
Input High Voltage	Sensor Code	AL40DB	VIH	4	-	5	V	
		AL41DB		2.64	-	3.3	V	
		AL42DB		2.4	-	3	V	
Output Low Voltage	Sensor Code	AL40DB	VOL	-	-	0.5	V	
		AL41DB		-	-	0.33	V	
		AL42DB		-	-	0.3	V	

Notes:
*1)   I^{2}C is a trademark of NXP Semiconductors.

11. I^{2}C or SPI Circuits (Reference)
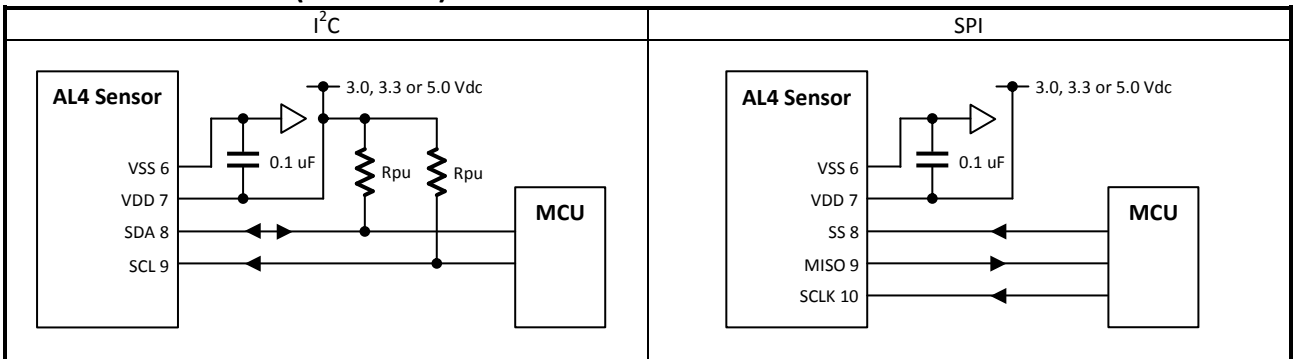
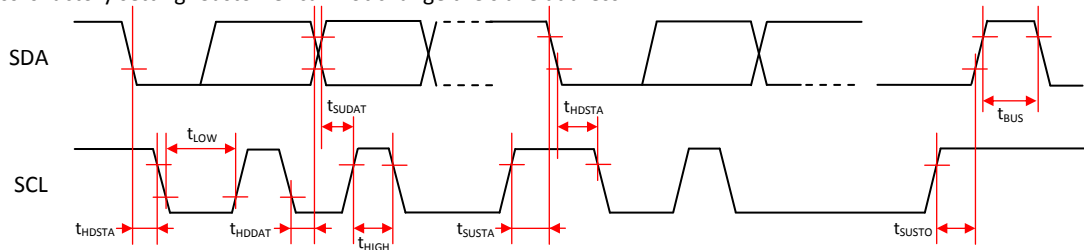## 12. I²C Digital Interface

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	Cmax	-	-	200	pF	
Pull-up Resistor	Pin8 SDA, Pin9 SCL	Rpu	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 can not change the slave address.

Timing Diagram

13. 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.

14. 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.
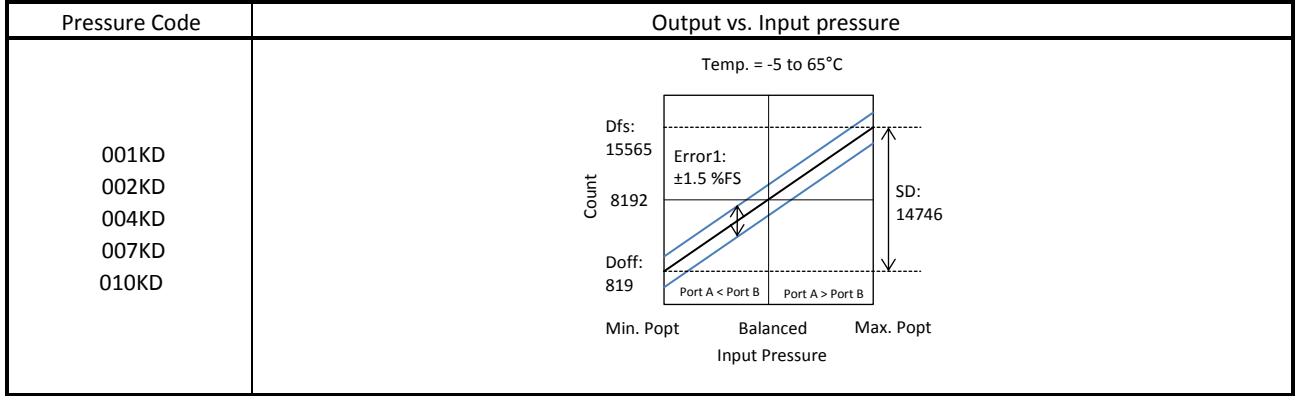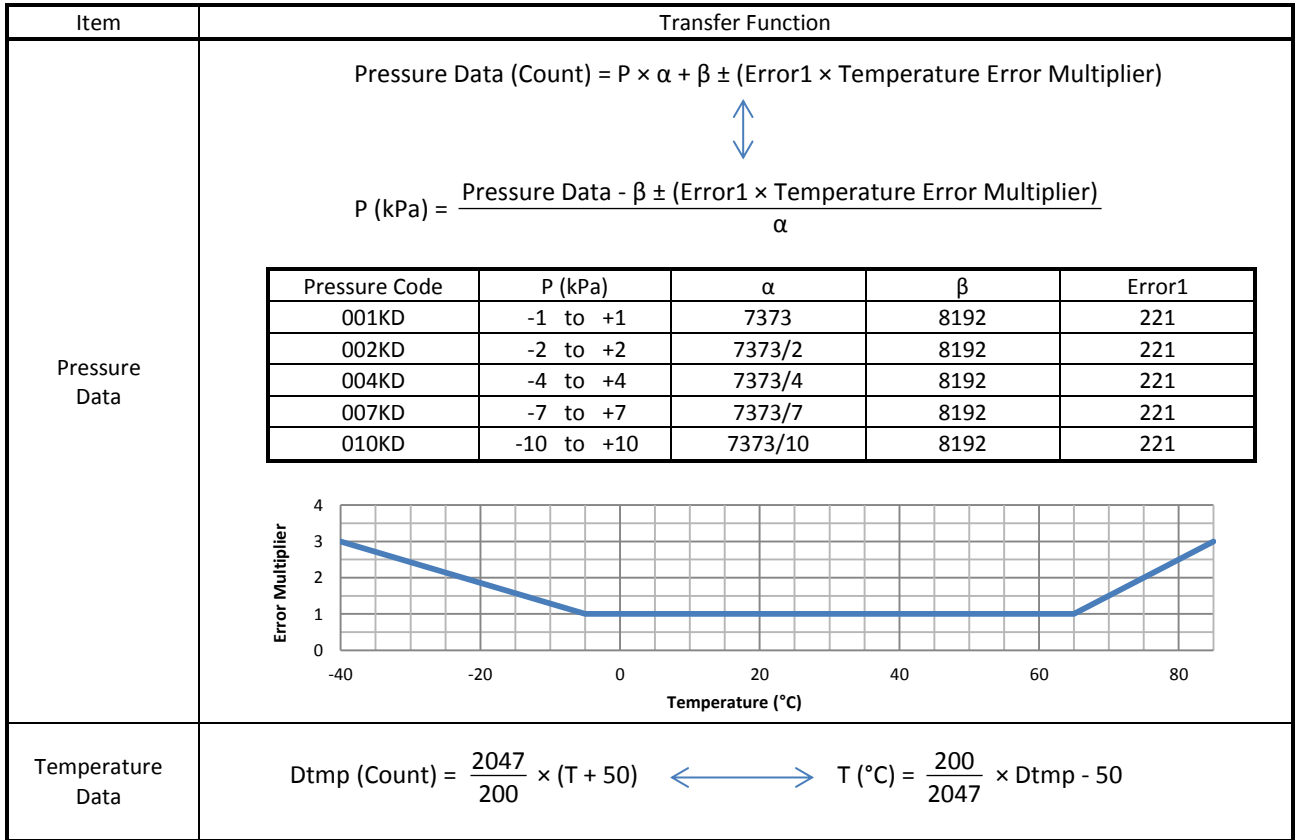
Timing Diagram
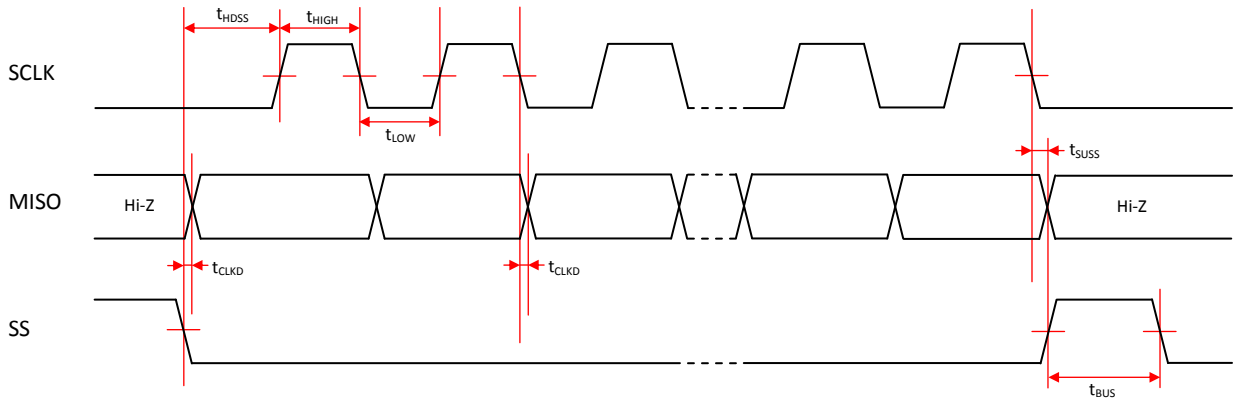
15. SPI Communication Protocol

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

16. Output versus Input Pressure

Pressure Code	Output vs. Input pressure
001KD 002KD 004KD 007KD 010KD	

17. Transfer Function

Item	Transfer Function
Pressure Data	Pressure Data (Count) = P × α + β ± (Error1 × Temperature Error Multiplier) $$P \text{ (kPa)} = \frac{\text{Pressure Data} - \beta \pm (\text{Error1} \times \text{Temperature Error Multiplier})}{\alpha}$$ <table><tr><th>Pressure Code</th><th>P (kPa)</th><th>α</th><th>β</th><th>Error1</th></tr><tr><td>001KD</td><td>-1 to +1</td><td>7373</td><td>8192</td><td>221</td></tr><tr><td>002KD</td><td>-2 to +2</td><td>7373/2</td><td>8192</td><td>221</td></tr><tr><td>004KD</td><td>-4 to +4</td><td>7373/4</td><td>8192</td><td>221</td></tr><tr><td>007KD</td><td>-7 to +7</td><td>7373/7</td><td>8192</td><td>221</td></tr><tr><td>010KD</td><td>-10 to +10</td><td>7373/10</td><td>8192</td><td>221</td></tr></table>
Temperature Data	$$\text{Dtmp (Count)} = \frac{2047}{200} \times (T + 50) \qquad\longleftrightarrow\qquad T\ (°C) = \frac{200}{2047} \times \text{Dtmp} - 50$$

18. Device Marking

Items			Marking						
	Production Lot								
	Y	Last digit of Production year	0 to 9						
	M	Production month	Jan	Feb	Mar	Apr	May	Jun	
			1	2	3	4	5	6	
			Jul	Aug	Sep	Oct	Nov	Dec	
			7	8	9	X	Y	Z	
	DD	Production date	01 to 31						
	Sensor Code								*1
		AL40DB	40						
		AL41DB	41						
		AL42DB	42						
	Pressure Code								
		001KD	001D						
		002KD	002D						
		004KD	004D						
		007KD	007D						
		010KD	010D						
	Communication Mode								
		2	2						
		3	3						
		4	4						
		5	5						
		6	6						
		7	7						
		S	S						
	Custom ID		If applicable						*2

Left diagram labels: Sensor Code, Pressure Code, Custom ID. Package markings: 40, 007D, 2, YMDD. Production Lot, Communication Mode.

Notes:
*1) Port option is not marked on the package.
*2) Custom ID will be added when product is customized for a customer.

19. Soldering

| Items	Condition				
Moisture Sensitivity Level	Level 1				*1
Reflow Soldering	**Soldering Profile**	A	Ramp up	2 to 4°C / sec.	*2 *3 *4 *5
		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.	

Soldering Profile graph: Temperature(°C) axis 0 to 250, peaks at 245 and 230; Time axis with segments A, B, C, D, E.

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.

20. Pressure Port Connection
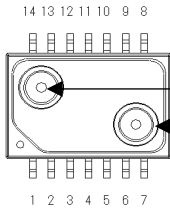
Port A is to the diaphragm side (etched Si side) of the sensor chip.

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.

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

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.
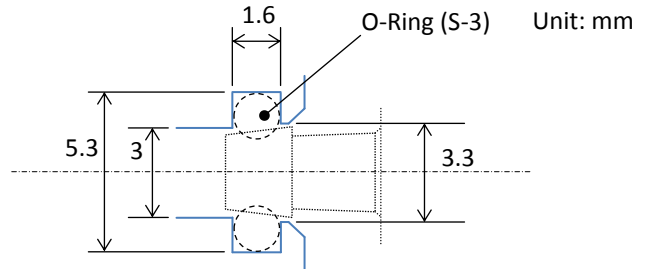
21. Dimensions and Weights

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 Mode]-TP	500	Pcs/Reel
		3.3 Vdc	Tape & Reel	AL41DB-[Pressure Code]-[Com Mode]-TP	500	Pcs/Reel
		3.0 Vdc	Tape & Reel	AL42DB-[Pressure Code]-[Com Mode]-TP	500	Pcs/Reel

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

Communication Mode		
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 can not change the communication mode.

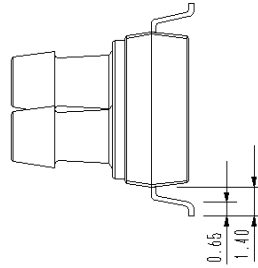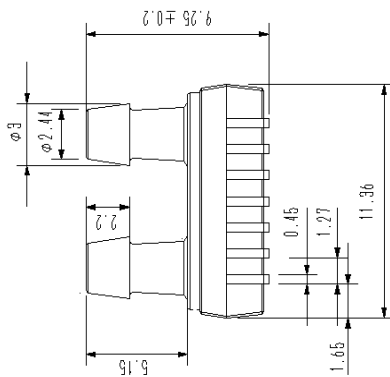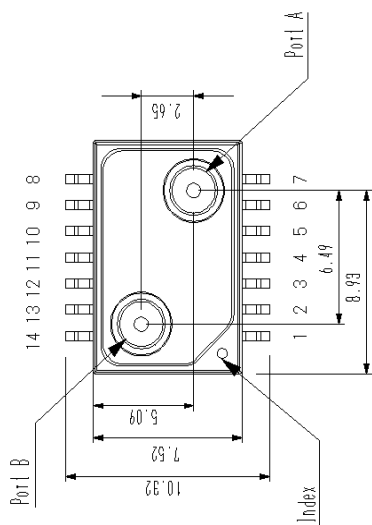## 23. Tape & Reel Information
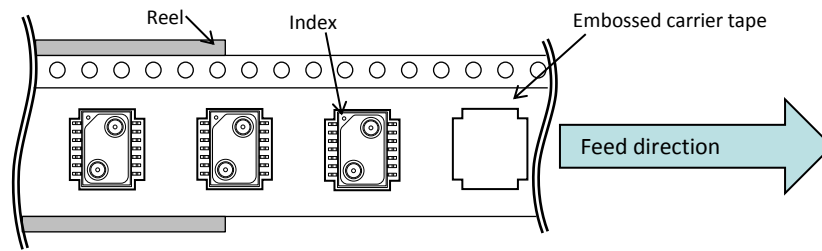
24. Handling Notes

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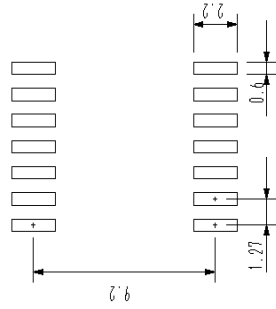
· To prevent discoloration of pins, please keep the devices sealed in static shielding bags before soldering.
· Do not solder the devices that have discolored pins.
· After soldering, pins would be discolored in black or brown in atmosphere. However it does not impact reliability of the device.

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.

Foot Print for PCB (Reference)

Port A

Port B

Index

2.65

6.49
8.93

14 13 12 11 10 9 8
1 2 3 4 5 6 7

5.09
7.62
10.32

9.25 ± 0.2

∅3
∅2.44

2.2

0.45
1.27
11.36

1.65
5.15

0.65
1.40

2.2
0.4

1.27
9.2

Unless otherwise specified, tolerance: +/-0.1mm

PART No. NO.

部品名 NAME OF PART

PROJECT NAME:

名称 TITLE

AL series
Outline diagram

第3角法 3rd ANGLE PROJECTION

単位 UNITS
mm

尺度 SCALE
Free

DATE OF ISSUE
Mar/18/2014

材質 MAT'L

個数 QTY

摘要 REMARKS

図面番号 DRAWING NO.
9-772-006-0

REV. MARK

年月日 DATE

変更 REVISIONS

MARK