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AK4188

Touch Screen Controller for Dual Touch Gestures

GENERAL DESCRIPTION

The AK4188 is a 4-wire resistive touch screen controller with an integrated 12-bit SAR A/D converter. It is capable of supporting dual touch gestures, and can detect both the pressed screen location and touch pressure. It can also detect the dual touch center location and the parameters related to two touch points distance. The AK4188 is available in a 16pin QFN, and it is ideal for touch screens for mobile phones, DSC, DVC, smart phones, and other portable devices.

FEATURES

- **4-wire Touch Screen Interface**
- **SPI^{TM} Serial Interface**
- **12bit SAR A/D Converter with S/H circuit**
- **Dual Touch Functions**
    - **Dual Touch Judgment**
    - **Dual Touch Information Outputs**
        - **(1) Center Location**
        - **(2) Parameter that Related to Dual Touch Distance**
- **Pen Pressure Measurement**
- **Continuous Read Function**
- **Integrated Internal Osc (Sequence Mode)**
- **Integrated Median Averaging Filter**
- **Low Voltage Operation: VDD = 2.7V ~ 3.6V**
                                      TVDD = 1.6V ~ 3.6V (Digital I/F)
- **PENIRQN Buffer Output**
- **General Purpose Analog Input**
- **Low Power Consumption: typ. 276uA @ 450Hz**
- **Auto Power Down**
- **Ta = −40 ~ 85 °C**
- **Package: 16pin QFN (3.0mm x 3.0mm, pitch 0.5mm)**

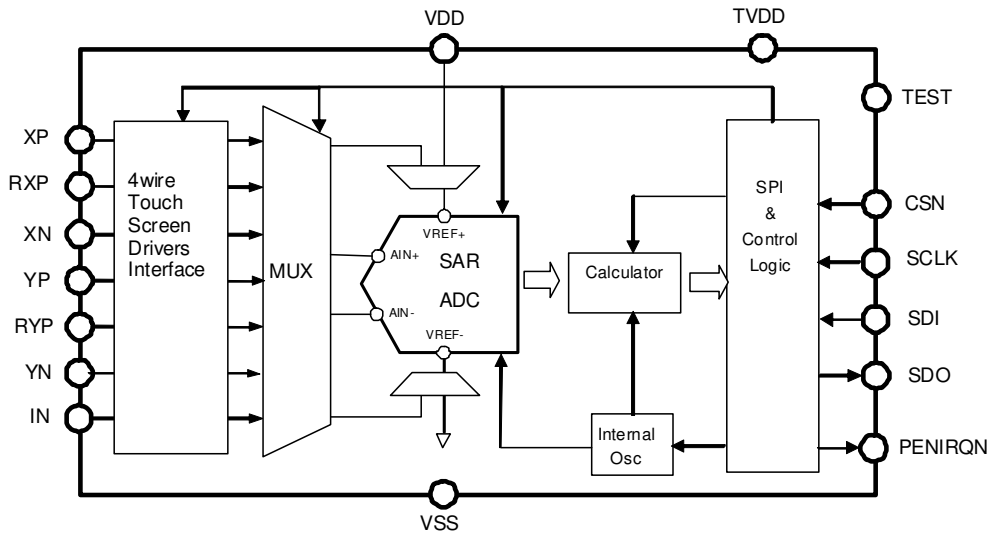SPI^{TM} is a registered trademark of Motorola, Inc.

Figure 1. Block Diagram

■ Ordering Guide

AK4188EN	−40 ~ +85°C	16pin QFN (3mm x 3mm, 0.5mm pitch)
AK4188VN	−40 ~ +85°C	16pin QFN (3mm x 3mm, 0.5mm pitch)
AKD4188	AK4188EN/VN Evaluation Board (*The AK4188EN is used for this board.)	

■ Pin Layout

AK4188EN/VN
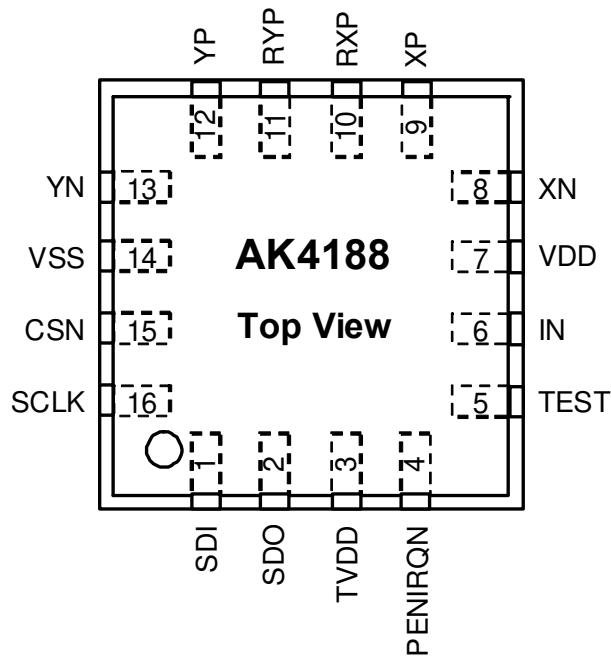
PIN/FUNCTION (AK4188EN/VN)

Pin No.	Pin Name	I/O	Function
1	SDI	I	Serial Data Input
2	SDO	O	Serial Data Output
3	TVDD	-	Digital I/F Power Supply : 1.6V ~ 3.6V

4	PENIRQN	O	Pen Interrupt Output (CMOS output)
			    The PENIRQN pin is "L" when touch-screen press is detected. This pin is always
			    "H" or "Hi-z" irrespective of touch-press in sleep mode.
			    This pin acts as "Busy"(active low) in internal calculations.

5	TEST	I	TEST pin
			    This pin must be connected to VSS.
			    TEST pin has internal pull-down device, nominally 100 kΩ

6	IN	I	Auxiliary Analog Input
7	VDD	-	Power Supply and External Reference Input: 2.7V ~ 3.6V
8	XN	I/O	Touch Panel X- Input Touch Panel X- Driver pin through a resistor for dual touch
9	XP	I/O	Touch Panel X+ Input Touch Panel X+ Driver pin
10	RXP	O	Touch Panel X+ Driver pin through a resistor for dual touch
11	RYP	O	Touch Panel Y+ Driver pin through a resistor for dual touch
12	YP	I/O	Touch Panel Y+ Input Touch Panel Y+ Driver pin
13	YN	I/O	Touch Panel Y- Input Touch Panel Y- Driver pin through a resistor for dual touch
14	VSS	-	Ground
15	CSN	I	Active-Low Chip Select Input
16	SCLK	I	Serial Clock Input

Note 1. All digital input pins (CSN, SCLK, SDI) must not be allowed to float.

■ Handling of Unused Pin

The unused I/O pin must be processed appropriately as below.

Classification	Pin Name	Setting
Analog	IN	This pin must be open

ABSOLUTE MAXIMUM RATINGS

(VSS = 0V (Note 2))

Parameter	Symbol	min	max	Unit
Power Supply	VDD	-0.3	4.6	V
	TVDD	-0.3	4.6	V
Input Current Any Pins except for supply	IIN	-	±10	mA
Touch Panel Drive Current	IOUTDRV	-	50	mA
Analog Input Voltage (Note 3)	VINA	-0.3	VDD+0.3 or 4.6	V
Digital Input Voltage (Note 4)	VIND	-0.3	TVDD+0.3 or 4.6	V
Ambient Temperature (power applied)	Ta	-40	85	°C
Storage Temperature	Tstg	-65	150	°C

Note 2. All voltages with respect to ground
Note 3. XP, XN, YP, YN, RXP, RYP, IN and TEST pins. The maximum value is smaller value between (VDD+0.3) V and 4.6V. Although the RXP and RYP pins are not input pins, it is necessary to set the minimum and maximum ratings of the input voltage as they are connected to the XP and YP pins respectively via a resistor.
Note 4. CSN, SCLK and SDI pins. The maximum value is smaller value between (VDD+0.3) V and 4.6V.

WARNING: Operation at or beyond these limits may result in permanent damage to the device.
Normal operation is not guaranteed at these extremes.

RECOMMEND OPERATING CONDITIONS

(VSS = 0V (Note 2))

Parameter		Symbol	min	typ	max	Unit
Power Supply	Analog, Calculator	VDD	2.7	3.0	3.6	V
	Digital I/F (Note 5)	TVDD	1.6	1.8	VDD	V

Note 2. All voltages with respect to ground
Note 5. CSN, SCLK, SDI, SDO and PENIRQN pins.

WARNING: AKM assumes no responsibility for the usage beyond the conditions in this datasheet.

ANALOG CHARACTERISTICS

(Ta = -40°C to 85°C, VDD = 3.0V, TVDD = 1.8V, SCLK=5MHz)

Parameter	min	typ	max	Unit
A/D Converter				
Resolution	-	12	-	Bits
No Missing Codes	11	-	-	Bits
Integral Nonlinearity (INL) Error	-	-	±2	LSB
Differential Nonlinearity (DNL) Error	-	±1	+3/-2	LSB
Offset Error	-	-	±6	LSB
Gain Error	-	-	±4	LSB
Touch Panel Drivers Switch On-Resistance				
XP, YP : RL = 300Ω	2.5	6	12	Ω
XN, YN : RL = 300Ω	2.5	6	12	Ω
RXP, RYP : RL = 450Ω	95	126	180	Ω
PENIRQN Pull Up Resistance	30	50	70	kΩ
Auxiliary IN Input				
Input Voltage Range	0	-	VDD	V
Power Supply Current				
VDD Power Current 1 (1 touch mode, FLT bits = "101") (Note 6)	-	195	365	uA
VDD Power Current 2 (2 touch mode, FLT bits = "001") (Note 7)	-	265	500	uA
TVDD Power Current	-	11	20	uA
Full Power Down (SDI = SCLK = "L", CSN = "H", No-touch)	-	0	5	uA

Note 6. SEQM3-0 bits = "0000". Write command period = 1.1ms (SEQM Write => Measurement => Register Read).
      Expect for Power Consumption of Touch Panel driver.
Note 7. SEQM3-0 bits = "1010". Write command period = 2.2ms (SEQM Write => Measurement => Register Read).
      Expect for Power Consumption of Touch Panel driver.

DC CHARACTERISTICS (Logic I/O)

(Ta=-40°C to 85°C, VDD=2.7V to 3.6V, TVDD = 1.6V to 3.6V)

Parameter	Symbol	min	typ	max	Unit
"H" level input voltage	VIH	0.8xTVDD	-	-	V
"L" level input voltage	VIL	-	-	0.2xTVDD	V
Digital Input/Tri-state Leakage Current (Note 8)	IILK	-10	-	10	μA
"H" level output voltage (Iout = -250μA)	VOH	TVDD-0.4	-	-	V
"L" level output voltage (Iout = 250μA)	VOL	-	-	0.4	V
Analog Input/Tri-state Leakage Current	IOLK	-3	-	3	μA

Note 8. Expect for TEST pin.

SWITCHING CHARACTERISTICS

(Ta=-40°C to 85°C, VDD = 2.7V to 3.6V, TVDD = 1.6V to VDD, CL = 30pF)

Parameter	Symbol	min	typ	max	Unit
Internal OSCILLATOR					
Clock frequency	fosc	2.5	3.6	5.1	MHz
SPI Interface					
SCLK clock frequency	f_{SCLK}	-	-	5000	kHz
CSN edge to First SCLK rising	tCSS	50	-	-	ns
SCLK High Pulse Width	tCKH	80	-	-	ns
SCLK Low Pulse Width	tCKL	80	-	-	ns
Data SDI Setup Time	tDS	25	-	-	ns
Data SDI Hold Time	tDH	35	-	-	ns
Data Output Delay after SCLK Falling	tDOD	-	-	75	ns
CSN rising edge to SCLK Ignored	tCSI	50	-	-	ns
SCLK Setup Time	tCLS	50	-	-	ns
CSN Hold Time	tCSH	150	-	-	ns
CSN rising edge to DOUT Hi-Z state	tCCZ	-	-	90	ns
CSN Disable Time	tCSD	100	-	-	ns

Digital Input Tr/Tf=5ns (Input swing between TVDD and VSS)
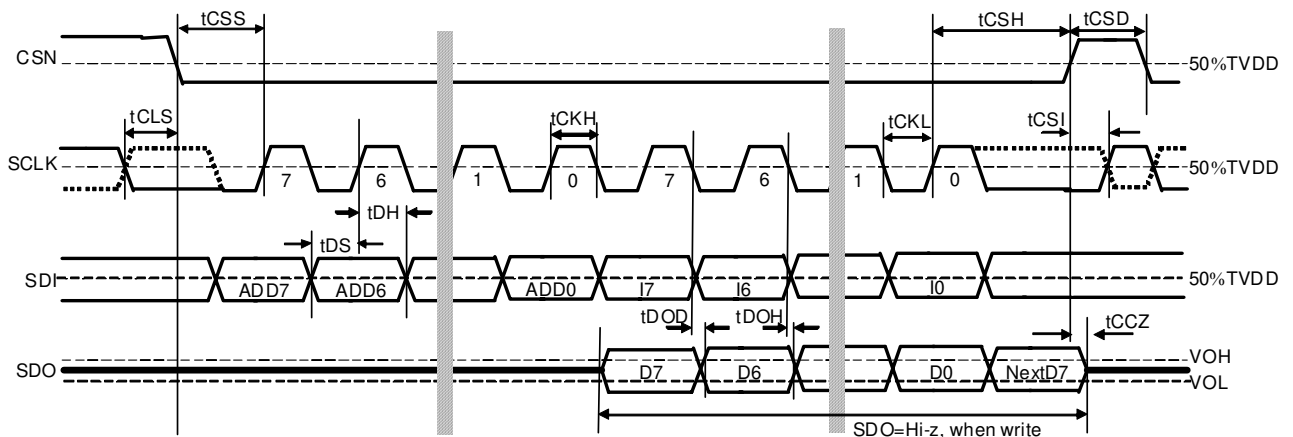
Figure 2. Timing Diagram

	OPERATION OVERVIEW	

■ Function Overview

The AK4188 consists of the following blocks:
- 12-bit Successive Approximation Register(SAR) A/D converter
- 4-wire resistive touch screen controller interface with dual touch detection(6-wire connection)
- Continuous A/D converter
- Calculator
- Internal Clock Generator for SAR A/D converter
- SPI I/F

Figure 3 shows the system connection diagram for the AK4188. Normally, a touch screen controller is connected to 4-wire resistive touch screen by 4 wires, but the AK4188 is connected to the screen by 6 wires that add the RXP and RYP pin connections for dual touch gestures.

AK4188 pin	Connection between the AK4188 and Touch Panel
XP	This pin is directly connected to X+ metal contact of touch panel.
XN	This pin is connected to X- metal contact of touch panel via resistor R4. For dual touch detection.
YP	This pin is directly connected to Y+ metal contact of touch panel.
YN	This pin is connected to Y- metal contact of touch panel via resistor R3. For dual touch detection.
RXP	This pin is connected to X+ metal contacted of touch panel via resistor R2.
RYP	This pin is connected to Y+ metal contacted of touch panel via resistor R1.

Note 9. The RXP pin and the RYP pin are additional pins for dual touch operation.
Note 10. The resistance of R1 should be 75% value as the touch panel resistance in Y axis direction.
Note 11. The resistance of R2 should be 75% value as the touch panel resistance in X axis direction.
Note 12. The resistance of R3 should be quarter value of the touch panel resistance in Y axis direction.
Note 13. The resistance of R4 should be quarter value of the touch panel resistance in X axis direction.
Note 14. ±20% tolerance of resistance is allowed for R1~R4

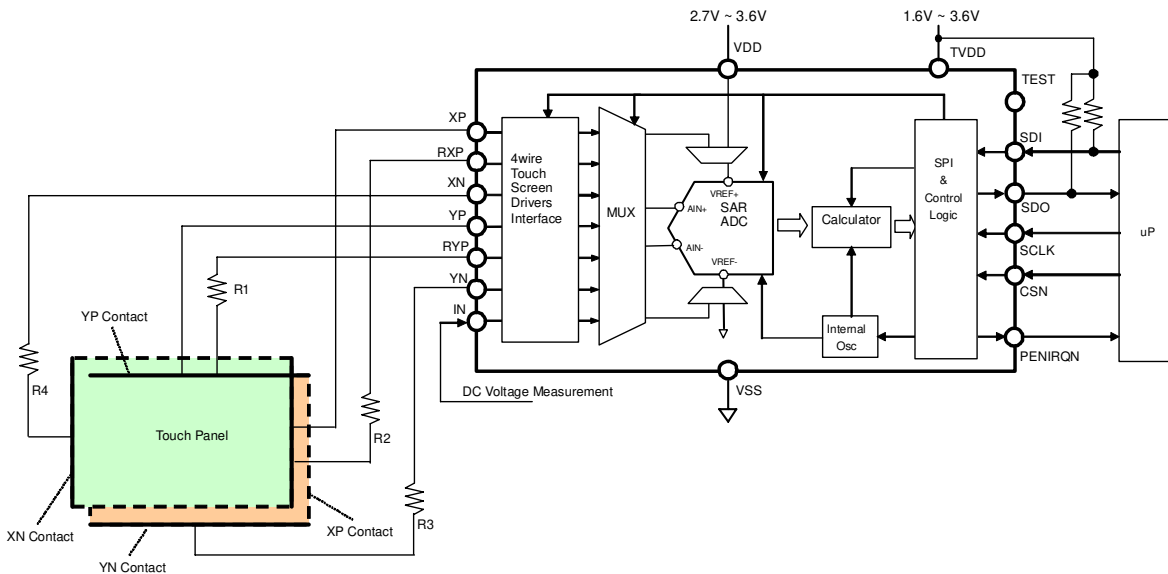Table 1. The Connection between the AK4188 and Touch Panel

Figure 3. The Connection Diagram of AK4188

■ A/D Converter for Touch Screen

The AK4188 integrates a 12bit successive approximation register (SAR) A/D converter for position measurement and auxiliary input. The architecture is based on capacitive redistribution algorithm, and an internal capacitor array functions as a sample/hold (S/H) circuit.

The SAR A/D converter output is a straight binary format as shown below:

Input Voltage	Output Code
(ΔVREF-1.5LSB) ~ ΔVREF	FFFH
(ΔVREF-2.5LSB) ~ (ΔVREF-1.5LSB)	FFEH
---------	---------
0.5LSB ~ 1.5LSB	001H
0 ~ 0.5LSB	000H

ΔVREF: (VREF+) – (VREF-)

Table 2. Output Code

The f_{OSC} clock of an internal oscillator is used for A/D conversion. The full scale (ΔVREF) of the A/D converter depends on the input mode. Position and pen pressure are measured in differential mode, and IN is measured in single-ended mode. The AK4188 is controlled by 8bit serial command. A/D conversion result is 12bit data output on the SDA pin.

■ Single Touch Process

The analog input channel is automatically selected. When position detection (X-axis and Y-axis) and pen pressure are selected as analog inputs in differential mode, the full scale (ΔVREF) is the voltage difference between the non-inverting terminal and the inverting terminal of the measured axis (e.g. X-axis measurement: (XP) - (XN)). Analog input to A/D converters (ΔAIN) is the voltage difference between the non-inverting terminal of the non-measured axis and the inverting terminal of the measured axis. At single-ended mode, the full scale of A/D converter (ΔVREF) is the voltage difference between the VDD and the VSS. The analog input of A/D converter (ΔAIN) is the voltage difference between the selected channel (IN) and the VSS.

If the source of analog input is high impedance, longer tracking time is required. Then A/D conversion should be started.

Channel Selection	Status of Driver Switch		ADC input (ΔAIN)		Reference Voltage (ΔVREF)		Ref. Mode
	X-Driver	Y-Driver	AIN+	AIN-	VREF+	VREF-	
AIN Measure	OFF	OFF	IN	GND	VREF	GND	SER
X-axis Measure (Xp1)	ON	OFF	YP	XN	XP	XN	DFR
Y-axis Measure (Yp1)	OFF	ON	XP	YN	YP	YN	DFR
Z1 Measure (Pressure)	XN-ON	YP-ON	XP	XN	YP	XN	DFR
Z2 Measure (Pressure)	XN-ON	YP-ON	YN	XN	YP	XN	DFR

Table 3. Measurement Mode

■ Position Detection of Touch Screen

The position on the touch screen is detected by taking the voltage of one axis when the voltage is supplied between the two terminals of another axis.

a)   X-Position Measurement Differential Mode   b)   Y-Position Measurement Differential Mode
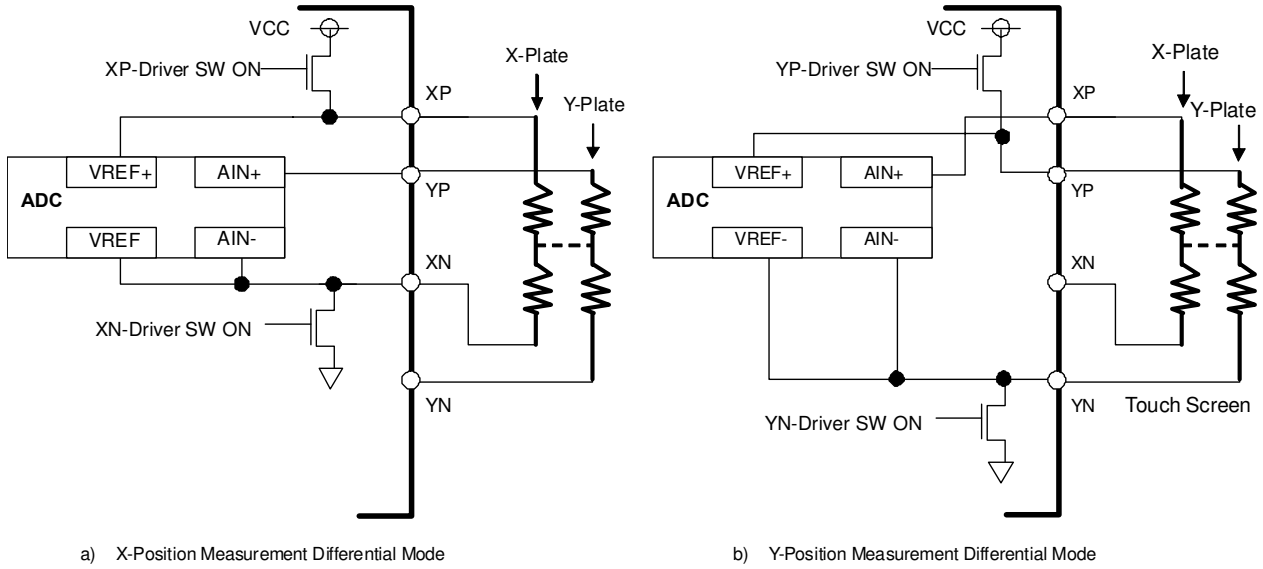
The X-plate and Y-plate are connected on the dotted line when the panel is touched.
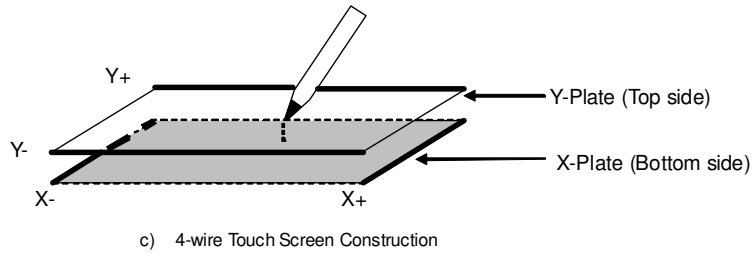

c)   4-wire Touch Screen Construction

Figure 4. Axis Measurements for 4-wire Touch Screen

■ Pen Pressure Measurement

The touch screen pen pressure can be derived from the measurement of the contact resistor between two plates. The contact resistance depends on the size of the depressed area and the pressure. The area of the spot is proportional to the contact resistance.

This resistance (Rtouch) can be calculated using two different methods. The first method is that when the total resistance of the X-plate sheet is already known. The resistance, Rtouch, is calculated from the results of three conversions, X-position, Z1-position, and Z2-position, and then using following formula:

$$R_{TOUCH} = R_{X\text{-plate}} \cdot \frac{X_{Position}}{4096} \left(\frac{Z_2}{Z_1} - 1 \right)$$

The second method is that when both the resistances of the X-plate and Y-plate are known. The resistance, Rtouch, is calculated from the results of three conversions, X-position, Y-position, and Z1-position, and then using the following formula:

$$R_{TOUCH} = \frac{R_{X\text{-plate}} \cdot X_{Position}}{4096} \left(\frac{4096}{Z_1} - 1 \right) - R_{Y\text{-plate}} \cdot \left(1 - \frac{Y_{Position}}{4096} \right)$$
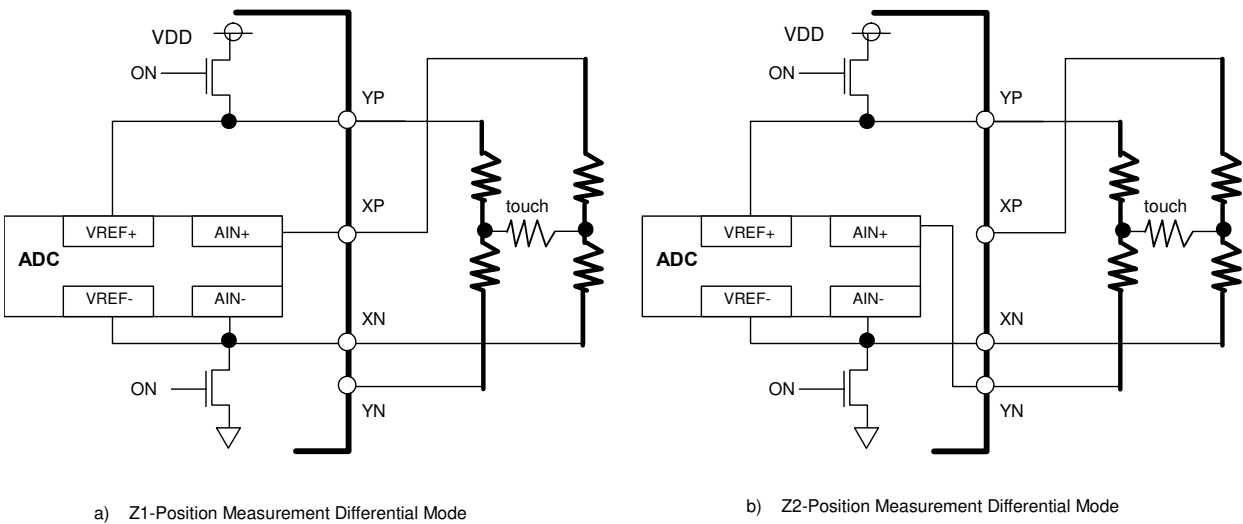

a) Z1-Position Measurement Differential Mode

b) Z2-Position Measurement Differential Mode

Figure 5. Pen Pressure Measurements

■ **Pen Interrupt**

The AK4188 has pen interrupt function to detect pen touches. (Figure 6). The YN pin is connected to VSS at the PEN interrupt enabled state. The XP pin is pulled up via an internal resistor (R_{IRQ}: typ.50kΩ). The PENIRQN pin is connected to the XP pin internally. If the touch plate is pressed by a pen, the current flows via <VDD> - <Ri> - <XP> - <YN> (4-wire). The resistance of the plate is generally 1kΩ or less, PENIRQN is forced to "L" level. If the pen is released, the PENIRQN pin returns "H" level because two plates are disconnected, and the current does not flow via two plates.

During Sequence measurement or calculations, the pen interrupt function is disabled, and the PENIRQN pin is operated as "Busy" signal. While in sleep mode, the pen interrupt function is disabled, and the PENIRQN pin is "H" or "Hi-z". (Refer to Table 9. Sleep Mode)

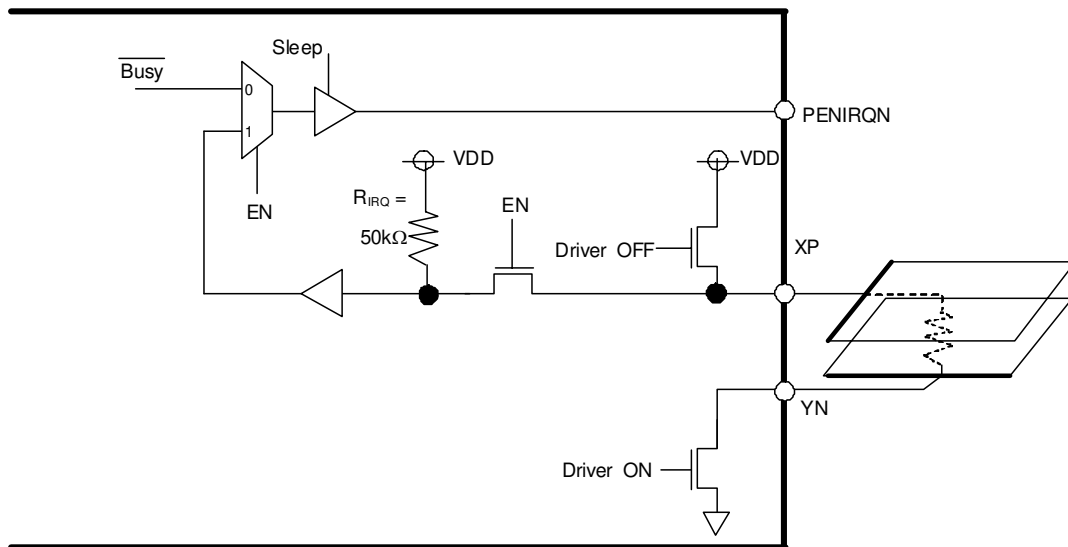It is recommended that the micro controller masks the pseudo-interrupts while the sequence measurement is busy.

Figure 6. PENIRQN Function Block Diagram

■ Dual Touch Process

The AK4188 has the function for dual touch processing. The AK4188 registers the center location of dual touch and the parameter that related to dual touch distance when SEQM3-0bits is set to "1010".

Detected Value		Symbol	Register Address	bit
X center location of dual touch (12bit)	Upper 8bit	Xp21	11H	D7-D0
	Lower 4bit		12H	D7-D4
Y center location of dual touch (12bit)	Upper 8bit	Yp21	13H	D7-D0
	Lower 4bit		14H	D7-D4
Parameter that related to dual touch X distance (12bit)	Upper 8bit	XDual	15H	D7-D0
	Lower 4bit		16H	D7-D4
Parameter that related to dual touch Y distance (12bit)	Upper 8bit	YDual	17H	D7-D0
	Lower 4bit		18H	D7-D4
Status bit of insufficient pressure in dual touch 0: Sufficient pressure 1: Insufficient pressure		TPRND	10H	D5
Status bit for insufficient pressure in single touch 0: Sufficient pressure 1: Insufficient pressure		TPRNS	10H	D4
Status bit of dual touch direction. The sign bit of Δy, if $\Delta x \geq 0$. $\Delta x = (x2-x1)$, $\Delta y = (y2-y1)$ 0: $\Delta y \geq 0$ 1: $\Delta y < 0$		DSNG	10H	D3
Dual touch detection bit 0: Single Touch Detection 1: Dual Touch Detection		Dual	10H	D2

Table 4. Output Data of Dual Touch Processing

■ Digital I/F

The AK4188 is controlled by a microprocessor via the SPI bus. The digital I/O of AK4188 operates off of supply voltage down to 1.6V in order to connect a low voltage microprocessor. The protocol on the SPI bus starts on the falling edge of the CSN signal.
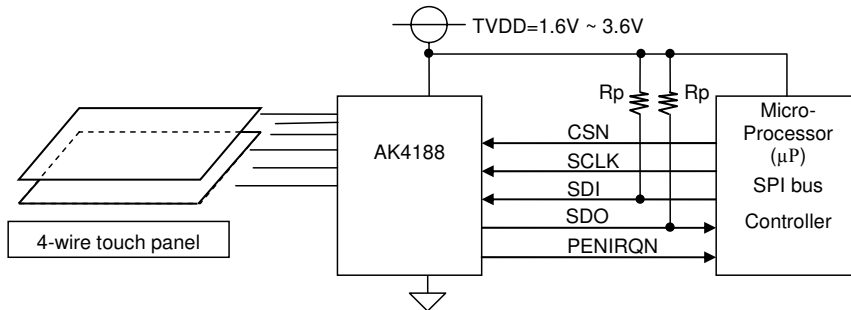
Figure 7. Digital I/F

1. SPI Mode

The AK4188 has two SPI modes in terms of the relationship between the clock polarity and the phase; mode 0 (Figure 8) and mode 3 (Figure 9). In the mode 0, the clock Leading Edge is rising, and the Trailing Edge is falling. In the mode 3, the clock Leading Edge is falling, and the Trailing Edge is rising. The following chart shows a general relation between a Clock and Data.

Refer to Figure 2 for the timing regulations. In this paragraph, following figures are describing timings in mode 0 unless otherwise noted.

Figure 8. SPI Mode 0

Figure 9. SPI Mode 3

2. WRITE Operations

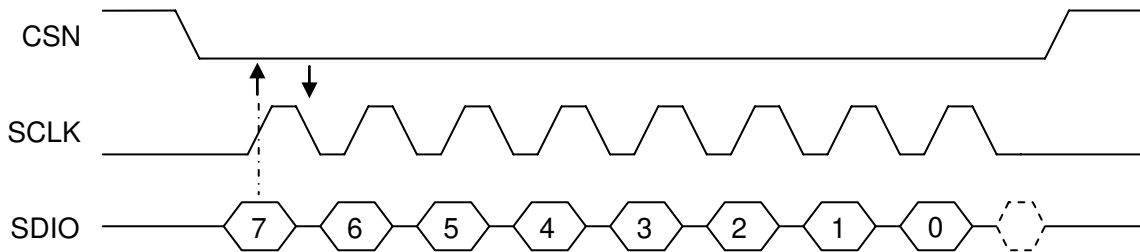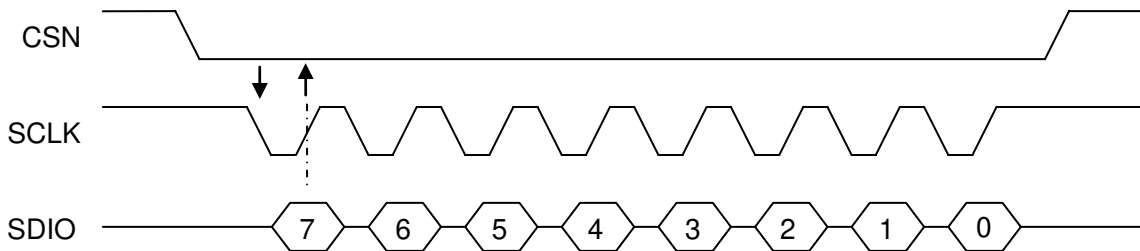Figure 10 shows the data transfer sequence of the SPI-bus. To access the AK4188 on the bus, change the CSN pin to "L" from "H" at first, and send 1byte control header, that includes a WRITE address, to the SDI pin by synchronizing with the SCLK. Then a write data (Figure 12) is transmitted. The AK4118 stores write data to the register on the eighth SCLK rising edge after the write data is received. The AK4118 ignores input data when the CSN pin = "H". The SDO output is "Hi-z" in write operations.

The AK4188 supports continuous write operation. When data are kept transmitting after writing of one byte data, the write address is automatically increased, and the data is stored. (Writing to the read only register is ignored. If the address exceeds "24H", the address counter will "roll over" to 00H.)
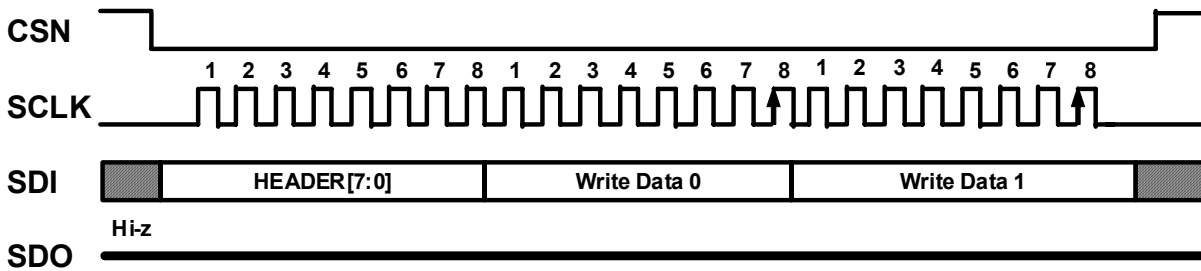
Figure 10. Data Write Sequence

R/W 0	0	A5	A4	A3	A2	A1	A0

Figure 11. WRITE Header Data Configuration

D7	D6	D5	D4	D3	D2	D1	D0

Figure 12. WRITE Data Configuration

3. Read Operation

Figure 13 shows the data transfer sequence of the SPI-bus. To access the AK4188 on the bus, change the CSN pin to "L" from "H" at first, and send 1byte control header (Figure 14), that includes a READ address, to the SDI pin by synchronizing with the SCLK. By continuing SCLK input, the AK4188 outputs register data from the SDO pin synchronizing with falling edge of the SCLK.

When the CSN pin = "H" or during the input of header data (8SCLK), the AK4188 does not output the data from the SDO pin. The SDO pin is in Hi-z state.

The AK4188 supports the continuous read operation. When data are kept transmitting after reading of one byte data, the read address is automatically increased, and the data is output. ("00H" is read from the write only registers because there is no data. If the address exceeds "24H", the address counter will "roll over" to 00H.)
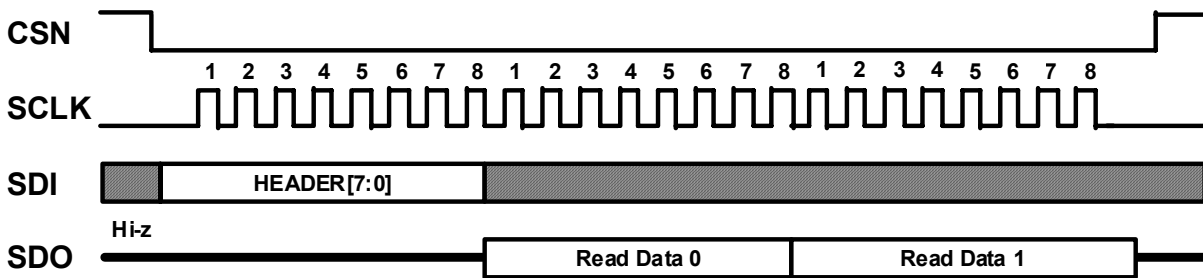
Figure 13. Data Read Sequence

R/W 1	0	A5	A4	A3	A2	A1	A0

Figure 14. READ Header Data Configuration

4. System Reset Operation

The AK4188 must be reset by a system reset command when powered-up. (Refer to "■ Power-up Sequence")
The internal registers are initialized by system reset, and the AK4188 is set to the touch detection waiting (stand-by) state.
The internal state of the AK4188 is fixed. The continuous access after the reset command is prohibited because the reset is asynchronous. Send the header data again to access registers after system reset command. (Figure 18)

The sequence measurement can be forcibly stopped by this command. All setting registers and measurement data are cleared.
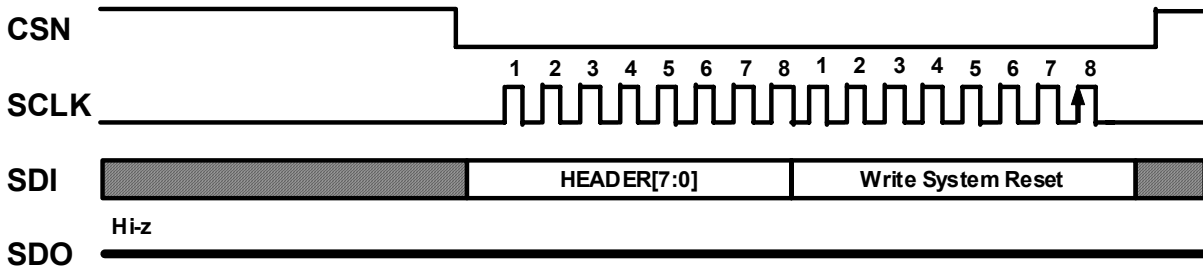
Figure 15. System Reset Sequence
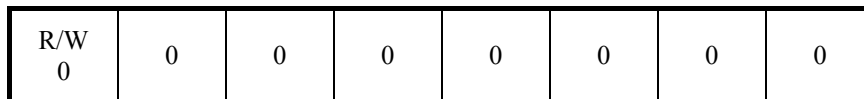
R/W 0	0	0	0	0	0	0	0

Figure 16. WRITE Header data Configuration at System Reset

0	0	0	0	0	0	0	1

Figure 17. System Reset Data Configuration
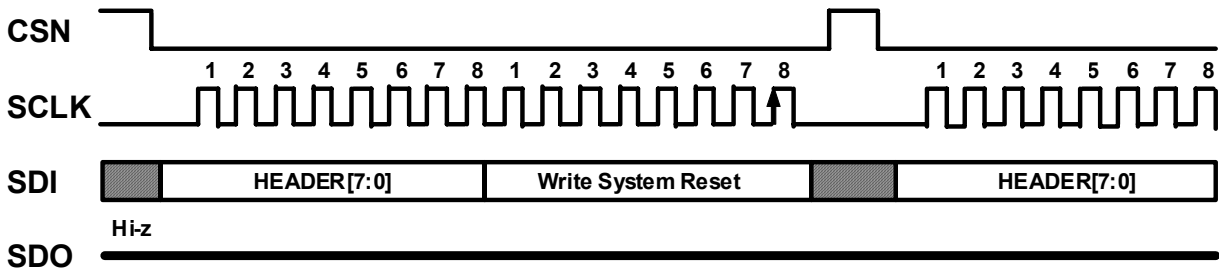
Figure 18. Register Access After System Reset

■ Register Map

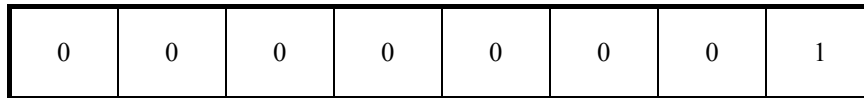| Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0	Stat
00H	System Reset	0	0	0	0	0	0	0	SRST	W
01H	Setup Command	0	0	SLEEP1	SLEEP0	0	FLT2	FLT1	FLT0	R/W
02H	Sequence Command	SEQM3	SEQM2	SEQM1	SEQM0	0	INTERVAL2	INTERVAL1	INTERVAL0	R/W
03H	Dual Touch Measure Paramer 1	0	RCMP2	RCMP1	RCMP0	0	INTER VALR2	INTER VALR1	INTER VALR0	R/W
04H	Touch Presure1	THXZS7	THXZS6	THXZS5	THXZS4	THXZS3	THXZS7	THXZS1	THXZS0	R/W
05H	Touch Presure2	THXZD7	THXZD6	THXZD5	THXZD4	THXZD3	THXZD7	THXZD1	THXZD0	R/W
06H	Dual Touch Judgment1	THDXY7	THDXY6	THDXY5	THDXY4	THDXY3	THDXY2	THDXY1	THDXY0	R/W
07H	Dual Touch Judgment2	SRCMP7	SRCPM6	SRCPM5	SRCPM4	SRCPM3	SRCPM2	SRCPM1	SRCPM0	R/W
08H	Dual Touch Parameter1	BX7	BX6	BX5	BX4	BX3	BX2	BX1	BX0	R/W
09H	Dual Touch Parameter2	CX7	CX6	CX5	CX4	CX3	CX2	CX1	CX0	R/W
0AH	Dual Touch Parameter3	BY7	BY6	BY5	BY4	BY3	BY2	BY1	BY0	R/W
0BH	Dual Touch Parameter4	CY7	CY6	CY5	CY4	CY3	CY2	CY1	CY0	R/W
0CH	Dual Touch Measure Paramer 2	RSTRC	DXYC	THDUAL5	THDUAL4	THDUAL3	THDUAL2	THDUAL1	THDUAL0	R/W
0DH-0FH	Reserved									
10H	Status	0	TOUCH	TPRND	TPRNS	DSNG	DUAL	SEQDVAL	SEQBSY	R
11H	Sequence Data 1H	D1T11	D1T10	D1T9	D1T8	D1T7	D1T6	D1T5	D1T4	R
12H	Sequence Data 1L	D1T3	D1T2	D1T1	D1T0	0	0	0	0	R
13H	Sequence Data 2H	D2T11	D2T10	D2T9	D2T8	D2T7	D2T6	D2T5	D2T4	R
14H	Sequence Data 2L	D2T3	D2T2	D2T1	D2T0	0	0	0	0	R
15H	Sequence Data 3H	D3T11	D3T10	D3T9	D3T8	D3T7	D3T6	D3T5	D3T4	R
16H	Sequence Data 3L	D3T3	D3T2	D3T1	D3T0	0	0	0	0	R
17H	Sequence Data 4H	D4T11	D4T10	D4T9	D4T8	D4T7	D4T6	D4T5	D4T4	R
18H	Sequence Data 4L	D4T3	D4T2	D4T1	D4T0	0	0	0	0	R
19H	XZ21	0	0	XZ9	XZ8	XZ7	XZ6	XZ5	XZ4	R
1AH		XZ3	XZ2	XZ1	XZ0	0	0	0	0	R
1BH-1FH	Reserved									
20H	R_XT0	RXTZ11	RXTZ10	RXTZ9	RXTZ8	RXTZ7	RXTZ6	RXTZ5	RXTZ4	R/W
21H		RXTZ3	RXTZ2	RXTZ1	RXTZ0	0	0	0	0	R/W
22H	R_YT0	RYTZ11	RYTZ10	RYTZ9	RYTZ8	RYTZ7	RYTZ6	RYTZ5	RYTZ4	R/W
23H		RXTZ3	RYTZ2	RYTZ1	RYTZ0	0	0	0	0	R/W
24H	DXYS	DXYS 7	DXYS 6	DXYS 5	DXYS 4	DXYS 3	DXYS 2	DXYS 1	DXYS 0	R

Table 5. AK4188 Register Map

Note 15. Changing the parameters during the sequence measurement is prohibited.
Note 16. The bits defined as 0 must contain a "0" value.
Note 17. Reading and writing to the reserved address is prohibited.

■ **Register Detail**

1. System Reset Configuration

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
00H	System Reset	0	0	0	0	0	0	0	SRST

Table 6. System Reset Register Format

Address and data of the system reset command. (Refer to "System Reset Operation")
The data is not stored because of no register.

2. Setup Command Configuration

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
01H	Setup Command	0	0	SLEEP1	SLEEP0	0	FLT2	FLT1	FLT0

Table 7. Setup Command Register Format

Bits	Name	Description	Default
D7-D6	Reserved	Must write "0"	
D5-D4	SLEEP1-0	Sleep Command 00: Normal Mode (default) 01: Sleep Mode 1 (PENIRQN disabled and output "H". Touch Panel is open.) 10: Sleep Mode 2 (PENIRQN disabled and open. Touch Panel is open.) 11: Reserved	0x0
D3	Reserved	Must write "0"	
D2-D0	FLT2-0	Median Average Filter Setting 000: Max/Min 1 Delete Average of 4 middle [6 time A/D] (default) 001: Max/Min 1 Delete Average of 8 middle [10 time A/D] 010: Max/Min 2 Delete Average of 4 middle [8 time A/D] 011: Max/Min 2 Delete Average of 8 middle [12 time A/D] 100: Max/Min 3 Delete Average of 2 middle [8 time A/D] 101: Max/Min 3 Delete Average of 8 middle [14 time A/D] 110-111: Reserved	0x0

Table 8. Setup Command Description

The AK4188 supports sleep mode that puts the touch panel to open state and disable pen interrupt function, effective for reducing power consumption caused by unnecessary pen touches. Sleep mode is controlled by SLEEP1-0 bits. All touch screen driver switches are powered down in this sleep mode, and it reduces power consumption to the minimum value. The PENIRQN output in this mode is shown below. (Table 9)

The AK4188 returns to normal operation out of sleep mode when the micro-controller writes "00" to SLEEP1-0 bits.

SLEEP1-0	Pen Interrupt Function	Touch Panel Driver	PENIRQN Output
00	Enable	Normal Operation	Pen Interrupt
01	Disable	Open	H
10	Disable	Open	Hi-z
11	N/A	N/A	N/A

(N/A: Not available)

Table 9. Sleep Mode

A/D conversion is available during sleep mode by issuing an ADC executing command (sequential). The AK4188 returns to sleep mode after completing an A/D conversion.

3.   Sequence Command Configuration

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
02H	Sequence Command	SEQM3	SEQM2	SEQM1	SEQM0	0	INTERVAL2	INTERVAL1	INTERVAL0

Table 10. Sequence Command Register Format

The AK4188 starts A/D conversion in sequence mode by setting the SEQM3-0, INTERVAL2-0 bits of the register address 02H. The AK4188 executes measurements by setting the FLT2-0 bits. The results are used to calculate the average value, discarding the minimum and maximum values, and the result sets the data register of sequence mode. If the address 02H is set again during a sequential measurement, this setting is ignored and the AK4188 continues the measurement. The master executes the register read operation to read the measurement data of sequence mode after confirming the PENIRQN pin turns to "H" (Data Available). This command must not be issued during the sequence measurement.

Bits	Name	Description	Default
D7-D4	SEQM3-0	Sequence Mode 0000: Xp1 → Yp1 → Z1 → Z2 Scan (default) 0001: Xp1 → Yp1 Scan 0010: Xp1 Scan 0011: Yp1 Scan 0100: Z1 → Z2 Scan 0101: Reserved 0110: A-IN 0111: Reserved 1000 – 1111: Table 12	0x0
D3	Reserved	Must write "0"	0x0
D2-D0	INTERVAL2-0	Sampling interval times. (Note 18) 000: 0μs (default) 001: 5μs 010: 10μs 011: 20μs 100: 50μs 101: 100μs 110: 200μs 111: 500μs	0x0

Note 18. INTERVALR2-0 bits controls sampling interval times of when measuring by the RXP and RYP pins. External resistor effects can be considered by this setting. (Table 14)

Table 11. Sequence Command Description

SEQM3-0 bits	Function
1000	Dual Touch Initialization. After power up the AK4188, the parameter for dual touch R_XT0 and R_YT0 (Addr0x20-0x23) must be initialized while the PENIRQN pin is "H".
1001	Dual Touch Calibration. This value must be written when the PENIRQN pin is "H". DXYS (Addr0x24) is initialized and R_XT0 and R_YT0 are updated by this setting.
1010	Dual Touch Measurement It must be executed when the PENIRQN pin is "L". The AK4188 measures the dual touch center location and the parameter that related to dual touch distance. If Panel touch is single touch, the single touch location is set to the data register.
1011-1111	Reserved

Table 12. Sequence Mode for Dual Touch

4. Dual Touch Measure Parameter 1

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
03H	Dual Touch Measure Parameter 1	0	RCMP2	RCMP1	RCMP0	0	INTERV ALR2	INTERV ALR1	INTERV ALR0

Table 13. Dual Touch Measure Parameter 1 Register Format

Bits	Name	Description	Default
D7	Reserved	Must write "0"	
D6-D4	RCMP2-0	XZ21 Correction: XZ21 = (XZ21 >> RCMP) The inter-electrode resistance and contact resistance are different depending on a touch panel. RCMP must be set in order to maintain XZ21 < 256 when dual touch. RCMP value should be les than 4.	0x2
D3	Reserved	Must write "0"	
D2-D0	INTERVALR2-0	Sampling interval time setting. 　This is the time from driver ON to ADC operation starting when measuring by the RXP and RYP pins. Different times are selectable according to resistor values when connecting a touch panel to the power supply via external resistors. ＿	0x0

INTERVALR2-0	Sampling interval times
000	5μs (default)
001	10μs
010	20μs
011	50μs
100	100μs
101	200μs
110	500μs
111	700μs

Table 14. Dual Touch Measure Parameter 1 Register Description

5. Touch Pressure Parameter

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
04H	Touch Pressure 1	THXZS7	THXZS6	THXZS5	THXZS4	THXZS3	THXZS2	THXZS1	THXZS0
05H	Touch Pressure 2	THXZD7	THXZD6	THXZD5	THXZD4	THXZD3	THXZD2	THXZD1	THXZD0

Table 15. Touch Pressure Parameter Register Format

Name	Description	Default
THXZS7-0	Single Touch Pressure Judgment When (XZ21/4) > THXZS, single touch pressure is insufficient.	0xC0
THXZD7-0	Dual Touch pressure Judgment When XZ21 > THXZD, dual touch pressure is insufficient.	0xC0

Table 16. Touch Pressure Parameter Description

6. Dual Touch Judgment

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
06H	Dual Touch Judgment 1	THDXY7	THDXY6	THDXY5	THDXY4	THDXY3	THDXY2	THDXY1	THDXY0
07H	Dual Touch Judgment 2	SRCMP7	SRCMP6	SRCMP5	SRCMP4	SRCMP3	SRCMP2	SRCMP1	SRCMP0

Table 17. Dual Touch Judgment Register Format

Name	Description	Default
THDXY7-0	Dual Touch pressure Judgment When DXYS > THDXY, dual touch is detected.	0x08
SRCMP7-0	DXY Calculation Correction Values DXY offset setting.	0x00

Table 18. Dual Touch Judgment Register Description

7. Dual Touch Parameter

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
08H	Dual Touch Parameter 1	BX7	BX6	BX5	BX4	BX3	BX2	BX1	BX0
09H	Dual Touch Parameter 2	CX7	CX6	CX5	CX4	CX3	CX2	CX1	CX0
0AH	Dual Touch Parameter 3	BY7	BY6	BY5	BY4	BY3	BY2	BY1	BY0
0BH	Dual Touch Parameter 4	CY7	CY6	CY5	CY4	CY3	CY2	CY1	CY0

Table 19. Dual Touch Parameter Register Format

Name	Description	Default
BX7-0	XDual Calculation Constant.	0x02
CB7-0	XDual Calculation Constant.	0x40
BY7-0	YDual Calculation Constant.	0x02
CY7-0	YDual Calculation Constant	0x40

Table 20. Dual Touch Parameter Register Description

8. Dual Touch Measure Parameter 2

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
0CH	Dual Touch Measure Parameter 2	RSTRC	DXYC	THDUAL5	THDUAL4	THDUAL3	THDUAL2	THDUAL1	THDUAL0

Table 21. Dual Touch Measure Parameter 2 Format

Bits	Name	Description	Default
D7	RSTRC	R_XT0 and R_YT0 update control when SEQM3-0 bits = "1001" (Dual Touch Calibration) 0: Not Update 1: Update	0x1
D6	DXYC	DXYC bit = "1": DXTS= (DXYS + DXY)/2 DXYC bit = "0" DXYS = DXY	0x1
D5-D0	THDUAL5-0	Single Touch Pressure Judgment When XDual<=THDUAL and YDual<=THDUAL, single touch is detected.	0x00

Table 22. Dual Touch Measure Parameter 2 Description

9. Data Register

The AK4188 starts A/D conversion in sequence mode by setting the SEQM3-0 and INTERVAL2-0 bits of the register address 02H. The AK4188 executes measurements by setting the FLT2-0 bits. The results are used to calculate the average value, discarding the minimum and maximum values, and the result sets the data register of sequence mode. The AK4188 registers data from address 11H in order of SEQM3-0 bits setting. The master can read the ADC data by a register read operation after confirming the PENIRQN pin turns to "H" or register status SEQDVAL bit= "1"(Data Available).
Status register bits; TPRND, TPRNS, DSNG and DUAL bits contain the values when SEQDVAL bit is "1". These values are cleared to "0" by executing sequential measurement. Therefore, status read should be made when SEQDVAL bit is "1" after sequential measurement.
The data register is Read Clear so that data will be cleared to "0" once it is read. Do not read data during a sequence measurement.

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
10H	Status	0	TOUCH	TPRND	TPRNS	DSNG	DUAL	SEQDVAL	SEQBSY
11H	Data 1H	D1T11	D1T10	D1T9	D1T8	D1T7	D1T6	D1T5	D1T4
12H	Data 1L	D1T3	D1T2	D1T1	D1T0	0	0	0	0
13H	Data 2H	D2T11	D2T10	D2T9	D2T8	D2T7	D2T6	D2T5	D2T4
14H	Data 2L	D2T3	D2T2	D2T1	D2T0	0	0	0	0
15H	Data 3H	D3T11	D3T10	D3T9	D3T8	D3T7	D3T6	D3T5	D3T4
16H	Data 3L	D3T3	D3T2	D3T1	D3T0	0	0	0	0
17H	Data 4H	D4T11	D4T10	D4T9	D4T8	D4T7	D4T6	D4T5	D4T4
18H	Data 4L	D4T3	D4T2	D4T1	D4T0	0	0	0	0

Table 23. Data Register for Sequence Mode (Read Only)

BIT	Name	Description	Default
D7	Reserved		
D6	TOUCH	Status bit of touch detection when the sequence command is issued. 0: Release State 1: Touch State	0
D5	TPRND	Status bit of insufficient pressure in dual touch 0: Sufficient pressure 1: Insufficient pressure	0
D4	TPRNS	Status bit of insufficient pressure in single touch 0: Sufficient pressure 1: Insufficient pressure	0
D3	DSNG	Status bit for dual touch direction. The sign bit of Δy, if $\Delta x \geq 0$. $\Delta x = (x2-x1)$, $\Delta y = (y2-y1)$ 0: $\Delta y \geq 0$ 1: $\Delta y < 0$	0
D2	DUAL	Dual touch detection bit 0: Single Touch Judgment 1: Dual Touch Judgment (*) This bit is even valid when the touch pressure is insufficient.	0
D1	SEQDVAL	Status bit for Sequence data register 0: No Data 1: Data Available	0
D0	SEQBSY	Status bit for the A/D or Calculator 0: Not Busy 1: Sequence Busy	0

Table 24. Status Register Description (Read Only)

Addr	Data	Output Data	Default
11-12H	Data1	First A/D conversion data	0x000
13-14H	Data2	Second A/D conversion data	0x000
15-16H	Data3	Third A/D conversion data	0x000
17-18H	Data4	Forth A/D conversion data	0x000

Table 25. Data Register for Single Touch Command

Addr	Data	Output Data	Default
11-12H	Data1	X Center location for dual touch "Xp21"	0x000
13-14H	Data2	Y Center location for dual touch "Yp21"	0x000
15-16H	Data3	The value that related to dual touch X distance "Δx". (absolute value) Set to "0", when Single Touch.	0x000
17-18H	Data4	The value that related to dual touch Y distance "Δy". (absolute value) Set to "0", when Single Touch.	0x000

Table 26. Data Register for Dual Touch Command

10. Pressure Data Register

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
19H	XZ21	0	0	XZ9	XZ8	XZ7	XZ6	XZ5	XZ4
1AH		XZ3	XZ2	XZ1	XZ0	0	0	0	0

Table 27. Pressure Data Format

Name	Description	Default
XZ9-0	Touch Pressure Parameter	0x000

Table 28. Pressure Data description

XZ21 registers are referred for setting tuning parameters and thresholds.
This registers are valid only when the sequence command for dual touch (SEQM3-0 bits = "1010") was issued.

11. Dual Touch Monitor Data Register

Addr	Register Name	D7	D6	D5	D4	D3	D2	D1	D0
20H	R_XT0	RXTZ11	RXTZ10	RXTZ9	RXTZ8	RXTZ7	RXTZ6	RXTZ5	RXTZ4
21H		RXTZ3	RXTZ2	RXTZ1	RXTZ0	0	0	0	0
22H	R_YT0	RYTZ11	RYTZ10	RYTZ9	RYTZ8	RYTZ7	RYTZ6	RYTZ5	RYTZ4
23H		RYTZ3	RYTZ2	RYTZ1	RYTZ0	0	0	0	0
24H	DXYS	DXYS7	DXYS6	DXYS5	DXYS4	DXYS3	DXYS2	DXYS1	DXYS0

Table 29. Dual Touch Monitor Data Format

Name	Description	Default
RXTZ11-0	X axis initial value Parameter This parameter is acquired by the sequence command of SEQM3-0 bits = "1000" or "1001". It is possible to write user settings via the SPI interface.	0x800
RYTZ11-0	Y axis initial value Parameter This parameter is acquired by the sequence command of SEQM3-0 bits = "1000" or "1001". It is possible to write user settings via the SPI interface.	0x800
DXYS7-0	Two points Detect Parameter	0x00

Table 30. Dual Touch Monitor Data Description

Registers in Table 30 are for internal status monitoring.
By reading R_XT0 and R_YT0, dual touch initializing command execution can be confirmed. User settings are available by writing to RXTZ11-0 and RYTZ11-0 bits externally.

DXYS register are referred for setting tuning parameters and thresholds.