TOUCH SENSOR

TYPE: B6TS-04LT

USER MANUAL

OMRON KURAYOSHI Co., Ltd.   2795064-1A

Introduction

Thank you very much for purchasing the touch sensor.
The touch sensor is a product that has been developed based on Omron's advanced technology and rich experience.
This user manual describes the information necessary for use of the sensor, such as its functions, capabilities and proper usage. When using the touch sensor, please keep the following in mind:

Only specialists with knowledge of electricity must handle the touch sensor.

Please read and understand the contents of this manual thoroughly to use the touch sensor appropriately.

Keep this manual handy to refer to at any time you need it.

Points to note when using the touch sensor

• Although Omron makes constant efforts to improve the quality and reliability of its semiconductor products, products such as this touch sensor may malfunction or break. Before using the touch sensor, please contact Omron's business development personnel, if necessary, to confirm product specifications, while also paying attention to using the sensor with a sufficient margin allowed for its ratings and capabilities, and taking safety measures such as installing safety circuits to minimize hazards in the unlikely event that a failure of the sensor might occur.

• Basically, this product is not designed and manufactured for use in equipments or systems operated under potentially hazardous conditions. If you intend to use the touch sensor with any of the following systems, facilities or equipment, be sure to consult Omron sales personnel or an agent or dealership first:

(A)   Atomic power control equipment, incineration facilities, railroads, aircraft, vehicle equipment, medical appliances, amusement machines, safety devices, and facilities that must comply with the regulations of administrative agencies and their respective industries.

(B)   Systems, machines and devices that are potentially hazardous to humans and property.

(C)   Other usages that require a high degree of safety.

The technical information contained in this manual is prepared only to describe typical performances and application examples of the product. Application of the products based on the information does not infer the grant of any Omron or third party intellectual property, right or license.

1.   Preventing malfunction caused by contact with an electric conductor other than a human finger with the touch electrode

Because this product measures the electrostatic capacitance of the detector (electrode), the product may operate if something other than a human finger is brought into contact with the electrode. Therefore, a fail-safe design is required for use of the product so that it does not cause any functional or safety problem even on such occasions. Substances, etc., that may cause a malfunction if they are present near to or on the detector are:

• Water, metal, animals, other conductive materials

2.   Preventing operational error

Because this product detects human touch, it may operate if the detector (electrode) is touched only lightly or if somebody remains nearby. When incorporating this product into a device, check the detection range thoroughly, and employ measures to prevent the device from malfunctioning caused by operational error. Especially, if the device is used where children may come into contact with it, provide some safety measure such as a child safety lock.

3.   Preventing the entry of water or corrosive gases

If water or a corrosive gas enters the operating part of the sensor (electrode), in the event of a short circuit or corrosion of the electrode, the sensor may malfunction or its detection sensitivity may be lowered. If the product is supposed to be used in an environment where this may occur, employ some structure to prevent the entry of water or gas, and check to be sure in actual operation that the device is protected securely against such an event.

4.   Preventing malfunction caused by noise

The product may malfunction if subjected to excessive noise.

Check to be sure that no safety problems are caused by excessive noise.

5.   Preventing direct touching of the electrode

Do not employ any structure that exposes the surface of the touch electrode to the air and allows somebody to touch the metal part of the touch electrode directly. Otherwise, the safety of the product may be impaired, accumulated electrostatic charges may damage the product, or the electrode may corrode. Adopt a structure that covers the surface of the touch electrode with nonconductive material and does not allow anybody to touch the metal part of the electrode directly.

The recommended thickness for the nonconductive material is:

Resin material (dielectric constant of 2 to 3): no more than 2mm

Glass material (dielectric constant of about 5): no more than 4mm

Proper usage

1. Method of transportation and storage
   1) Do not drop or apply any shock to the touch sensor because it is a precision device.
      If the sensor is thrown or dropped, it may break.

   2) When carrying or storing the touch sensor, keep its packaging properly oriented.
      If the packaging is placed upside down or tilted, the sensor may be subjected to some undue force and may break.

   3) Store the touch sensor under the following conditions to prevent the package from absorbing moisture:
      Otherwise, the sensor may break when the package is mounted.
      <Storage conditions>
      A. Before opening the moisture-proof pack (aluminum laminate pack):
         [Temperature, humidity]   5-40°C, 20-80% RH
         [Term of validity]   One year
               When the sensor is used after a long period of storage, make sure that no damage, dirt, or rust
               is present on the pack.
      B. After opening the moisture-proof pack (aluminum laminate pack):
         Until the package is mounted, the following conditions are recommended for storage of the package:
         [Temperature, humidity]   No higher than 30°C, No more than 70% RH
         [Term of validity]   One week
      C. Temporary storage after opening the moisture-proof pack:
         When storing an unused sensor package temporarily, restore the package together with some
         desiccating agent into a moisture-proof bag as early as possible (within about 10 minutes), fold the
         opening of the bag in two, seal the bag tightly with adhesive tape or the like, and keep the bag under
         the following recommended conditions:
         [Temperature, humidity]   5-40°C, 20-80% RH
         [Term of validity]   One month

   4) Do not use or store the touch sensor where it will be subject to corrosive gases such as hydrosulfuric gas or salt
      air, or exposed to oil or direct sunlight.

   5) Where either of the following conditions [1] or [2] is applicable, baking the sensor package in the following
      manner is recommended in order to remove moisture:
      The tray used in the moisture-proof pack can be stored in a high-temperature chamber because it is heat-
      resistant. However, place the tray on a flat base such as a level block, and then cool it down on the base to
      prevent deformation after baking.
      [1] The above storage conditions A-C are exceeded.
      [2] The color of the 30% RH detection part of the indicator changes to lavender or pink.

      <Baking method>
              [Temperature]   125°C
              [Time]   20-24 hours
              [Number of times baking]   Up to three
              (Cumulative time limit: 72 hours)

2. Measures against electrostatic charges during handling
   Keep the relevant electric equipment, work-bench and worker at the same potential.
   Lay a conductive mat with a surface resistance of 10 kΩ - 10 MΩ on the work-bench, and ground the mat.
   The worker must make sure that there is no electric leakage from the electric equipment and ground himself/herself
   through a resistor of about 1 MΩ for safety.
   All safety regulations must be observed.
   Any electric leakage from the electric equipment is undesirable from the viewpoint of worker safety.
   Check to be sure that there is no electric leakage from the tester, curve tracer, oscilloscope, or the like, and then
   ground the equipment. Any electric leakage can break the MOS IC.
   The same precautions apply to soldering irons.

3. Recommended soldering conditions

   Temperature conditions for mounting the IC chip

   When mounting the IC chip at a high temperature using reflow soldering, the melting temperature of the solder depends on the mounting board and paste adhesive materials. Referring to the mounting temperature profile shown in Fig. 1, choose the optimum soldering temperature within the profile.

[1] Reflow method (infrared light reflow and air reflow)

   [Number of times]   Up to three times
                        (Complete the last reflow under storage condition B in Section 1.)
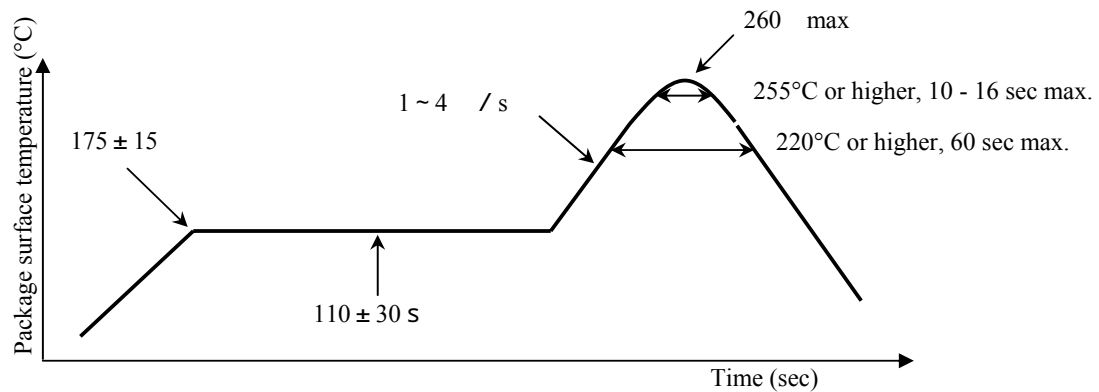   [Temperature]   The surface temperature profile of the device is shown in Fig. 1.

Fig.1 Reflow method temperature profile

2] Wave soldering method (known as flow soldering or dip soldering)

   [Number of times]   Once
   [Temperature]   The temperature profile is shown in Fig. 2.
                        (The optimum preheating temperature must be set according to the type of flux.)
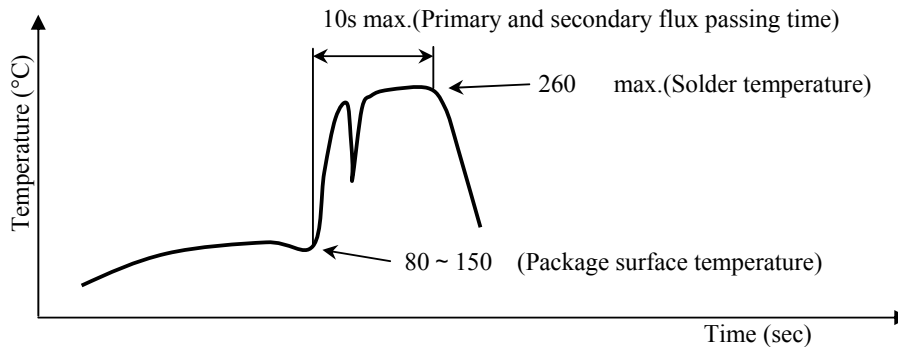

Fig.2 Wave soldering method temperature profile

[3] Soldering iron (manual soldering)
   Solder using a soldering iron for semiconductor devices under the following conditions:

   [Iron tip temperature]   No higher than 370°C
   [Soldering time]   No longer than 5 sec/pin

4. Recommended wash conditions
   When using rosin flux wash, check the following items:
   1) Amount of contamination containing residual ions (or no ions)
   2) Administrative directions and regulations
   3) Melting resistance of parts

5. Handling after mounting parts on PWB
   When dividing a PWB on which ICs are mounted, do not apply any excessive force to the ICs. Otherwise, the internal IC chips may be broken.

6. Applied voltages and currents
   1) Do not apply to any pin any voltage or current that exceeds the maximum absolute rating.

   2) Use the device within the recommended specifications to enhance the quality of the device.

   3) Do not apply any forward bias to any of the pins. Otherwise, excessive forward current may cause thermal breakdown of the IC.

   4) Do not connect any output pin directly to power. If any output pin is directly connected to low-impedance power, the internal wiring may melt down or break thermally due to excessive current.

CONTENTS

1. Overview

This chip is a sensor IC to detect micro capacitances and can be used in touch sensors.
Internally, the chip employs the CMOS process and is contained in a 20-pin SSOP plastic package.
The IC has 4 independent measurement pins, each of which can measure capacitance independently.
On/off output or serial communication output can be selected as the output form.
The IC is provided with an EEPROM that can store operation mode and other parameters.

## 2. Pin connections

2.1 Pin arrangement diagram
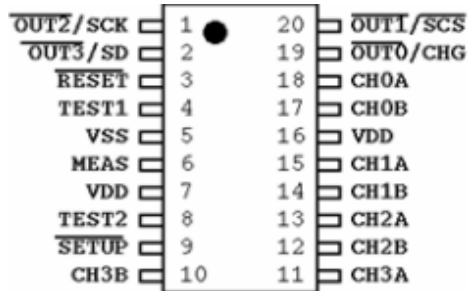
Note 1: Pins TEST1, and TEST2 are used for testing during manufacture of the IC.
When using these pins, connect them to VDD through a pull-up resistor.

2.2 Pin functions

Pin No.	Desig-nation	Input/ Output	Function
1	‾‾‾‾ OUT2 SCK	I/O	Output pin for measured result [On/off output mode] channel 2 output (active low) [Serial communication mode] serial communication clock input
2	‾‾‾‾ OUT3 SD	I/O	Output pin for measured result [On/off output mode] channel 3 output (active low) [Serial communication mode] serial communication data (duplex)
3	‾‾‾‾ RESET	I	Reset signal input. Inputting low to this pin resets the chip. Connect this pin to VDD through a pull-up resistor of about 5k . When VDD starts up, the power-on reset function operates and the chip is initialized. When the power-on reset function is used, no other reset signal is needed when power is turned on.
4	TEST1	I	(Connect to VDD through a pull-down resistor.)
5	VSS	I	Ground
6	MEAS	I	Initiation of measurement. Capacitance measurement is initiated by inputting high to this pin. While low is input to this pin, the chip is held in standby status.
7,16	VDD	I	Supply input (3.0 - 5.5V)
8	TEST2	I	(Connect to VDD through a pull-down resistor.)
9	‾‾‾‾ SETUP	I	Setup mode. Low input to this pin moves the chip into setup mode.
10, 12, 14, 17	CH3B CH2B CH1B CH0B	I/O	Measurement pins B (channel 3 - 0) Connect these pins to the touch electrode through resistors.
11, 13, 15, 18	CH3A CH2A CH1A CH0A	I/O	Measurement pins A (channel 3 - 0) Connect these pins to the touch electrode through resistors.

Pin No.	Desig-nation	Input/Output	Function

19	‾‾‾‾
	OUT0
	CHG
		O	Output pin to indicate operation.
			[Normal measurement mode] outputs measured results.
			    [On/off output mode] channel 0 output (active low)
			    [Serial communication mode] output of measurement finish.
			    Two output modes are available in serial communication mode:
			        1. High-signal outputs every time a measurement finishes.
			        2. High-signal outputs when the condition changes in any one of the channels (touch → no touch, no touch → touch).
			[Setup mode] When the setup mode is entered, CHG pin changes to high. However, when an EEPROM write command is received and data is being written into EEPROM, this pin is low.

20	‾‾‾‾ OUT1 ‾‾‾ SCS	I/O	Output pin for measured result [On/off output mode] channel 1 output (active low) [Serial communication mode] serial communication chip select input

2.3 An example circuit
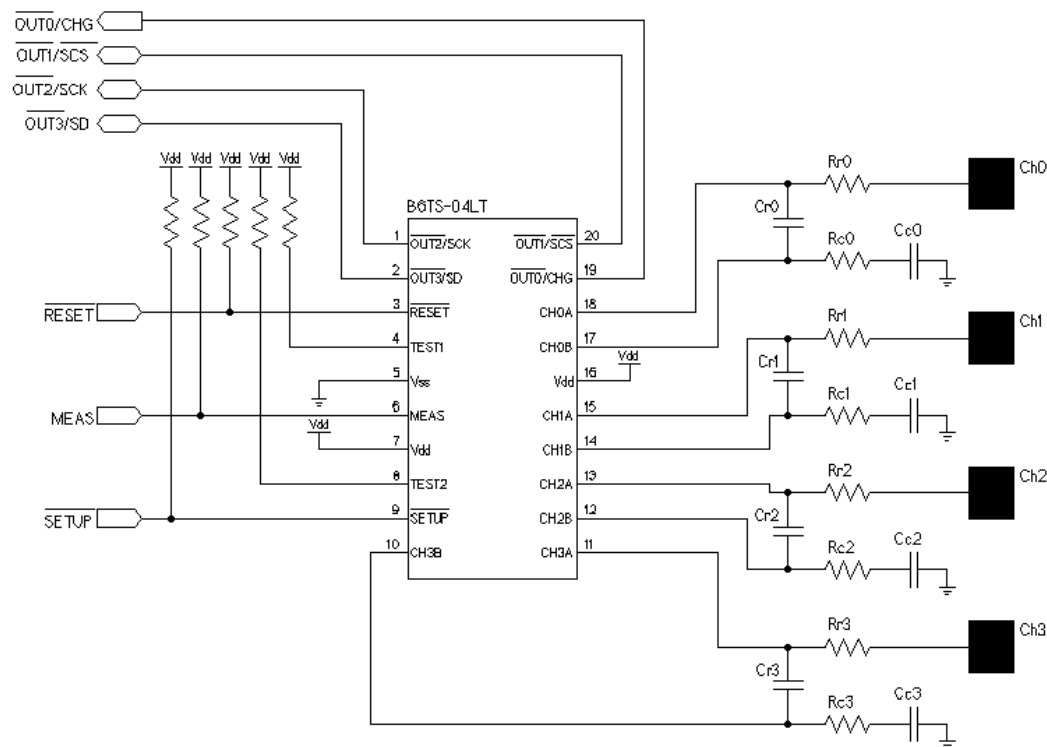
Note 1:   Connect Rr, Cr, Rc, and Cc to each touch electrode, as shown in the above figure.
            Refer to the design tool (B6TWWorkbench) for their actual values.
                Rr0–3: Protective resistors
                Cr0–3: Capacitors for comparison
                Rc0–3: Resistors for charge control
                Cc0–3: Charge capacitors
Note 2:   Connect a bypass capacitor of about 0.1 μF between Vdd and Vss using as short wires as possible.

3. Operating modes

This chip has three operating modes. Each mode is selected by inputs to the MEAS pin and /SETUP pin.

(1)   Normal measurement mode ----   Mode to detect touch/no-touch. In this mode, one of the following modes can be selected according to the output signal form.

    (1-1) On/off output mode ----   Out0-3 signals are used.
         Touch/no-touch detection results are output from the respective channels with low/high signal.

    (1-2) Serial communication mode --- Measured results are transmitted in serial with a three-wire SPI function using SCK, SD and SCS signals.

(2)   Setup mode ----   Chip operation is set for serial communication in this mode.

(3)   Teaching mode ----   Teaching refers to the automatic setting of threshold values for touch and no-touch while somebody touches the sensor.

/SETUP pin	MEAS pin	Operation mode
High	High	Normal measurement mode
High	Low	Normal measurement mode (standby status without executing measurement)
Low	High	Teaching mode
Low	Low	Setup mode

MEAS pin = High or MODE command bit15 = 1)
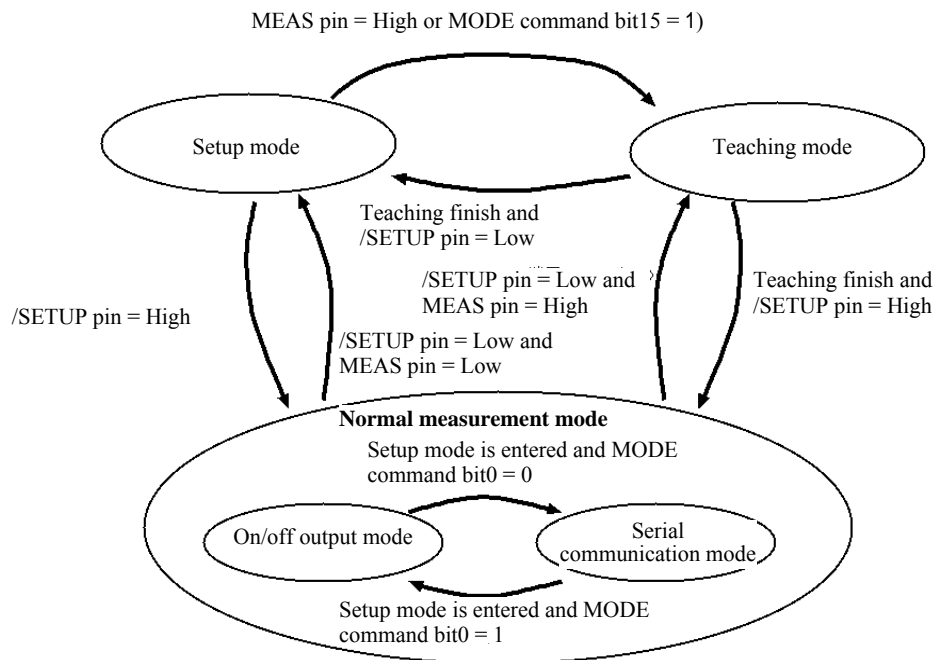
4. Measurement

The chip measures the discharge of the charge stored in the charge capacitor. When a finger is placed close to the touch electrode, the electrostatic capacitance of the electrode increases and the discharge period for the charge becomes shorter. The chip has a built-in counter to measure the discharge period, and whether or not the sensor has been touched is judged according to whether the length of the discharge period exceeds a specified value or not. Hereafter, the length of the discharge period is referred to as the measured value.

With this chip, the measured value when the sensor is not touched (reference value), the amount of variation of the measured value which allows a judgment that the sensor is touched (amount judged on), and the amount of variation of the measured value when returning from on status (hysteresis) can be set for each channel respectively.
The relationships between the measured value and the above values are as follows:

[Measured value] < [Reference value]-[Variation judged on] →   Touch
[Measured value] > [Reference value]-[Variation judged on]+[Hysteresis] →   Return from touch to no-touch
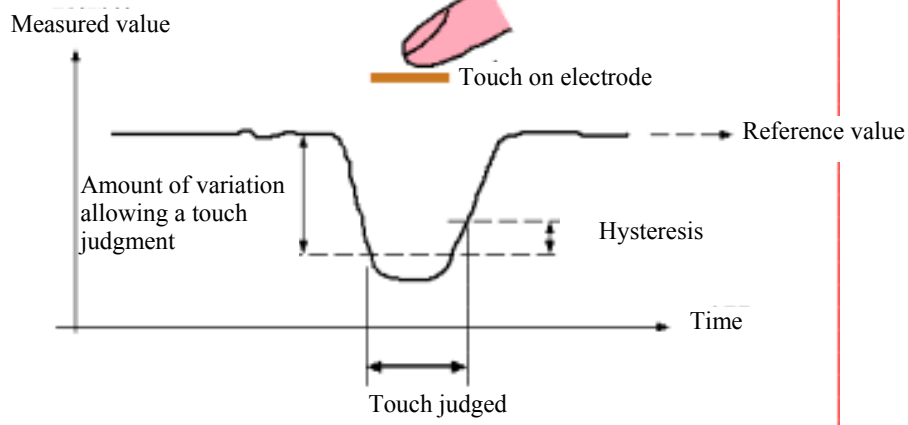
Even in the touched state, the measured value changes according to variation in the environment (output drift). The chip is provided with an automatic drift-correction function, which can cancel mild changes of the measured value due to variation in the environment (drift correction function).
It is possible to select whether or not to execute drift correction in setup mode.

5. Serial communication

It is possible to read out measured values and set the operation mode by sending/receiving data to/from this chip through serial communication.

Serial communication is performed by a three-wire type SPI-compliant method using SCS (chip select), SCK (transfer clock) and SD (data (bi-directional)).
The SPI communication method works as follows:
(Refer to "Electrical specifications" for specific communication timing, etc.)

- Operation in SPI slave mode
      Supply /SCS (chip select) and SCK (transfer clock) from outside.
- SCK (transfer clock) is set to high during idling. The data is latched at the rising edge of the clock.
- The data is MSB first.

This chip sends/receives data using 4 bytes, consisting of commands, dummy data, and data.
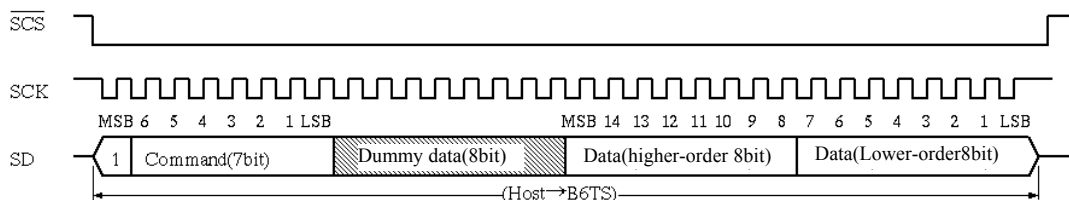   Command: 1 byte (MSB 1 bit is used for the read/write flag.)
      Dummy data: 1 byte (ignored)
      Data: 2 bytes

Read(data flow:B6T   host)
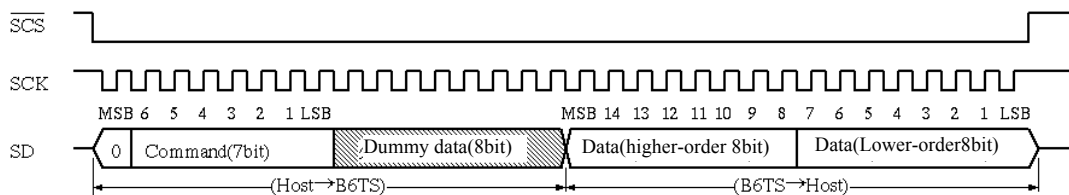
Write(data flow: host   B6T)

If data communication is performed during normal measurement mode, the measurement operation stops while the data is communicated.
After communication finishes, measurement restarts.

6. Commands

The commands and data used in serial communication are listed below:

The data comprises read only data (read) and read/write data (read/write). If serial communication is made to write read only data, the operation will be invalid.

Some of the data are not accessible in some operation modes. If inaccessible data are read out, the read data is indefinite. If inaccessible data are written, the data is ignored.

Command code (Designation)	Main function	Read/write restriction	Access restriction	
			Normal measurement mode (in serial communication mode)	Setup mode
0x00(ID)–0x19(CHYS3)	Measured data	Read only	Accessible	Accessible
0x39(CHEN) –0x53(RHYS3)	Parameter setting	Read/write	Inaccessible	

When writable data are written in this chip, the built-in register corresponding to each command is rewritten. Then, if the normal measurement mode is entered, the chip can be operated with the written parameters (mode, etc.). In this case, because only the built-in register is rewritten, the value in each register returns to its original value (value stored in EEPROM) when power is turned off and on again.

To store the built-in register value in EEPROM, an EEPROM write command must be received. When an EEPROM write command is received, the content of the register is stored in EEPROM.

6.1   List of commands

Command code	Desig-nation	Description	Read (R) Write (W)	Normal measurement mode	Setup mode	Remark
0x00	ID	Chip ID	R		○	
0x01	BDATA	Detected result of each channel	R	○	○	1 channel 1 bit
0x02	DCH0	Ch0 measured value	R	○	○	
0x03	DCH1	Ch1 measured value	R	○	○	
0x04	DCH2	Ch2 measured value	R	○	○	
0x05	DCH3	Ch3 measured value	R	○	○	
0x06 : 0x0D		(System reservation)				
0x0E	CREF0	Current Ch0 reference value	R	○	○	Result of drift correction is reflected.
0x0F	CTHR0	Current Ch0 variation judged as on	R	○	○	Result of drift correction is reflected.
0x10	CHYS0	Current Ch0 hysteresis value	R	○	○	Result of drift correction is reflected.
0x11	CREF1	Current Ch1 reference value	R	○	○	Result of drift correction is reflected.
0x12	CTHR1	Current Ch1 variation judged as on	R	○	○	Result of drift correction is reflected.
0x13	CHYS1	Current Ch1 hysteresis value	R	○	○	Result of drift correction is reflected.

Command code	Desig-nation	Description	Access limit			Remark
0x14	CREF2	Current Ch2 reference value	R	○	○	Result of drift correction is reflected.
0x15	CTHR2	Current Ch2 variation judged as on	R	○	○	Result of drift correction is reflected.
0x16	CHYS2	Current Ch2 hysteresis value	R	○	○	Result of drift correction is reflected.
0x17	CREF3	Current Ch3 reference value	R	○	○	Result of drift correction is reflected.
0x18	CTHR3	Current Ch3 variation judged as on	R	○	○	Result of drift correction is reflected.
0x19	CHYS3	Current Ch3 hysteresis value	R	○	○	Result of drift correction is reflected.
0x1A : 0x38			(System reservation)			
0x39	CHEN	Channel measurement enable	R/W		○	
0x3A	TCAL	Teaching count number	R/W		○	
0x3B	TOG	Toggle action	R/W		○	
0x3C	ACD	Cumulative judgment count	R/W		○	
0x3D	SLP	Sleep time	R/W		○	
0x3E	MODE	Operation mode	R/W		○	
0x3F	ROMSTR	EEPROM write	R/W		○	Writing into ROM with dummy write
0x40	REF0	Ch0 reference value	R/W		○	
0x41	THR0	Ch0 variation judged as on	R/W		○	
0x42	HYS0	Ch0 hysteresis	R/W		○	
0x43	RTHR0	Ch0 on-judgment ratio	R/W		○	Used in teaching
0x44	RHYS0	Ch0 hysteresis ratio	R/W		○	Used in teaching
0x45	REF1	Ch1 reference value	R/W		○	
0x46	THR1	Ch1 variation judged as on	R/W		○	
0x47	HYS1	Ch1 hysteresis	R/W		○	
0x48	RTHR1	Ch1 on-judgment ratio	R/W		○	Used in teaching
0x49	RHYS1	Ch1 hysteresis ratio	R/W		○	Used in teaching
0x4A	REF2	Ch2 reference value	R/W		○	
0x4B	THR2	Ch2 variation judged as on	R/W		○	
0x4C	HYS2	Ch2 hysteresis	R/W		○	
0x4D	RTHR2	Ch2 on-judgment ratio	R/W		○	Used in teaching
0x4E	RHYS2	Ch2 hysteresis ratio	R/W		○	Used in teaching
0x4F	REF3	Ch3 reference value	R/W		○	
0x50	THR3	Ch3 variation judged as on	R/W		○	
0x51	HYS3	Ch3 hysteresis	R/W		○	
0x52	RTHR3	Ch3 on-judgment ratio	R/W		○	Used in teaching
0x53	RHYS3	Ch3 hysteresis ratio	R/W		○	Used in teaching
0x54 : 0x7F			(System reservation)			

6.2 Description of commands

6.2.1 ID: Chip ID (read only)

Used as ID of the chip. The data is fixed to 0x0141.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1

6.2.2 BDATA: Detection result of touch/no-touch for each channel (read only)

Measured value for each channel is indicated by 1/0.
1: Off (no-touch), 0: On (touch)

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x01	1	1	1	1	1	1	1	1	1	1	1	1	Ch3	Ch2	Ch1	Ch0

6.2.3 DCHx: Measured value for each channel (read only)

Measured value for each channel is indicated by an unsigned 16-bit integer.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x02..0x05	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (DCH0) – Command code 0x02
Channel 1 (DCH1)   Command code 0x03
Channel 2 (DCH2)   Command code 0x04
Channel 3 (DCH3)   Command code 0x05

6.2.4 CREFx: Current reference value for each channel (read only)

Current reference value for each channel is indicated by an unsigned 16-bit integer.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x0E..0x17	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (CREF0) – Command code 0x0E
Channel 1 (CREF1)   Command code 0x11
Channel 2 (CREF2)   Command code 0x14
Channel 3 (CREF3)   Command code 0x17

6.2.5 CTHRx: Current variation for each channel judged as on (read only)

Current variation for each channel judged as on is indicated by an unsigned 16-bit integer.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x0F..0x18	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (CTHR0) – Command code 0x0F
Channel 1 (CTHR1)   Command code 0x12
Channel 2 (CTHR2)   Command code 0x15
Channel 3 (CTHR3)   Command code 0x18

6.2.6 CHYSx: Current hysteresis for each channel (read only)
Current hysteresis for each channel is indicated by an unsigned 16-bit integer.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x10..0x19	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (CHYS0)– Command code 0x10
Channel 1 (CHYS1) Command code 0x13
Channel 2 (CHYS2) Command code 0x16
Channel 3 (CHYS3) Command code 0x19

6.2.7 CHEN: Measurement enable for each channel (read/write enabled only in setup mode)
Whether or not measurement is executed in each channel is set with 1/0.
1: measurement executed, 0: not executed
Only lower-order 4 bits are valid. If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x39	1	1	1	1	1	1	1	1	1	1	1	1	Ch3	Ch2	Ch1	Ch0

6.2.8 TCAL: Teaching measurement count (read/write enabled only in setup mode)
Sets the measurement count when teaching.
Teaching measurement is executed 32 times the value of TCAL. The teaching operation must be performed during this period (each electrode must be touched three times or more).
Reference value (REFx), quantity of variation judged as on (THRx), and hysteresis (HYSx) are changed by teaching.
When TCAL is set to "0", only the reference value (THRx) is changed in teaching.
Only lower-order 8 bits are valid. If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3A	1	1	1	1	1	1	1	1	D7	D6	D5	D4	D3	D2	D1	D0

6.2.9 TOG: Toggle action (read/write enabled only in setup mode)
Sets whether or not to make each channel perform toggle action. This setting takes effect on the signals output from OUT0-3 and BDATA command data.
1: Toggle mode off (momentary action: turned on only with a touch)
0: Toggle mode on (alternate action: turned on with a touch and off with the next touch)
Only lower-order 4 bits are valid. If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3B	1	1	1	1	1	1	1	1	1	1	1	1	Ch3	Ch2	Ch1	Ch0

6.2.10 ACD: Cumulative judgment count (read/write enabled only in setup mode)
Only after consecutive measurement ACD value one times, a touch (or no-touch) is judged and this output is varied. This output takes effect on the signals output from OUT0 - 3 and BDATA command data.
For example, with ACD = 2, only after three consecutive measurements are judged as a touch (or no-touch), does this output signal turn on (or off).
Only lower-order 8 bits are valid. If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3C	1	1	1	1	1	1	1	1	D7	D6	D5	D4	D3	D2	D1	D0

6.2.11 SLP: Sleep time (read/write enabled only in setup mode)

Sets the standby time between one measurement and the next measurement (sleep time).

Sleep continues for SOP value×10mS (typ)

When SLP is set to "0", measurements are made consecutively without sleep time.

Only lower-order 8 bits are valid. If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3D	1	1	1	1	1	1	1	1	D7	D6	D5	D4	D3	D2	D1	D0

6.2.12 MODE: Operation mode (read/write enabled only in setup mode)

Sets various modes.

Only the bits described are valid.

If the other bits are written, they are ignored.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3E	TS	TER	1	1	1	1	1	1	1	1	1	1	1	DC	CHG	CON

TS: Teaching start

> Teaching mode is entered when "1" is written in this bit.
>
> (During read out this bit is always "0")

TER: Teaching error flag

> Set/reset according to result of teaching.
>
> Set to "1" when teaching finishes normally.
>
> If a teaching error occurs, this bit is set to "0".
>
> This flag is not cleared automatically. To clear this flag, write "1" to this bit.

DC: Drift correction

> Sets whether or not to execute drift correction.
>
> 1: Drift correction executed, 2: Not executed

CHG: CHG pin function

> The signal is specified from the CHG pin in normal measurement mode (serial communication mode). With this pin set to "1", when on/off changes in any channel (when any channel is touched (comes on) or changes from touch to no-touch (goes off)), the signal is high.
>
> When this pin is set to "0", the signal is high every time a measurement finishes.

CON: Output setting

> Sets output mode in normal measurement mode.
>
> When set to "1", on/off output mode is entered.
>
> When set to "0", serial communication mode is entered.

6.2.13 ROMSTR: EEPROM write (only write is enabled in setup mode)

> When this command is issued by setting the data to 0x5354, all the parameter data are written in the EEPROM built in this chip.
>
> When the data is other than 0x5354, this command is ignored.
>
> Until this command is issued, received write data are stored in volatile memory.
>
> While data is being written in EEPROM, the CHG pin is low.
>
> Also, during the write, inputs to the /SETUP and MEAS pins are ignored. Accordingly, it is not possible to change the operation mode.

| Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x3F	0	1	0	1	0	0	1	1	0	1	0	1	0	1	0	0

6.2.14 REFx: Reference value for each channel (read/write enabled only in setup mode)

> The reference value for each channel can be set with an unsigned 16-bit integer.
>
> Users can alter this setting (in setup mode), or rewrite it by teaching. It cannot be changed by drift correction or the like.

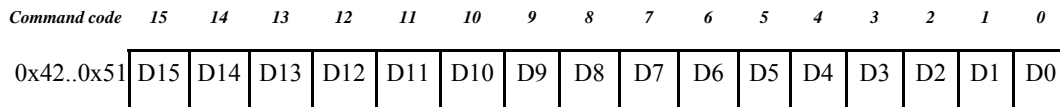| Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x40..0x4F	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (REF0) – Command code 0x40
Channel 1 (REF1)   Command code 0x45
Channel 2 (REF2)   Command code 0x4A
Channel 3 (REF3)   Command code 0x4F

6.2.15 THRx: Quantity of variation judged as on for each channel (read/write enabled only in setup mode)
Quantity of variation judged as on for each channel can be set with an unsigned 16-bit integer.
Users can alter this setting (in setup mode) or rewrite it by teaching. It cannot be changed by drift correction or the like.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x41..0x50	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
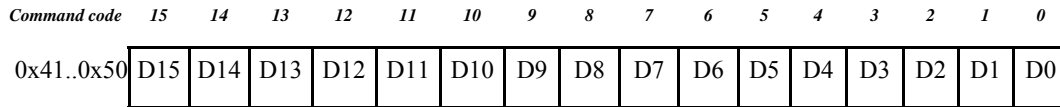
Channel 0 (THR0) – Command code 0x41
Channel 1 (THR1)   Command code 0x46
Channel 2 (THR2)   Command code 0x4B
Channel 3 (THR3)   Command code 0x50

6.2.16 HYSx: Hysteresis for each channel (read/write enabled only in setup mode)
Hysteresis for each channel can be set with an unsigned 16-bit integer.
Users can alter this setting (in setup mode) or rewrite it by teaching. It cannot be changed by drift correction or the like.

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x42..0x51	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Channel 0 (HYS0) – Command code 0x42
Channel 1 (HYS1)   Command code 0x47
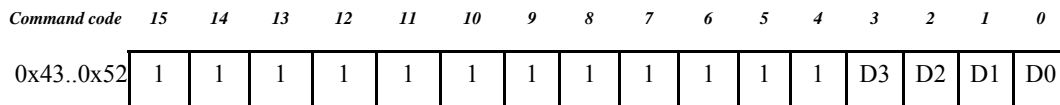Channel 2 (HYS2)   Command code 0x4C
Channel 3 (HYS3)   Command code 0x51

6.2.17 RTHRx: On-judgment ratio for each channel (read/write enabled only in setup mode)
Used in teaching.
Sets the ratio of the quantity of variation judged as on (THRx) to the measured value observed in teaching with an unsigned 4-bit integer. (Refer to "7. Teaching" for details)
Only the lower-order 4 bits are valid. If the other bits are written to, they are ignored.

If the measured value changes by ΔA due to a touch during teaching, the quantity of variation judged as on that is newly set in teaching (THRx) is calculated as:
Quantity of variation judged as on (THRx)
$= \Delta A \times$ (on-judgment ratio (RTHRx) 1)/16

For example, if RTHRx = 10, the quantity of variation judged as on (THRx) is:
THRx = $\Delta A \times (10 \quad 1)/16 \quad \Delta A \times 0.69$ (about 70% of ΔA)

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x43..0x52	1	1	1	1	1	1	1	1	1	1	1	1	D3	D2	D1	D0

Channel 0 (RTHR0)– Command code 0x43
Channel 1 (RTHR1)   Command code 0x48
Channel 2 (RTHR2)   Command code 0x4D
Channel 3 (RTHR3)   Command code 0x52

6.2.17 RHYSx: Hysteresis ratio for each channel (read/write enabled only in setup mode)
Used in teaching.
Sets the ratio of hysteresis (HYSx) to the measured value observed in teaching with an unsigned 4-bit integer. (Refer to "7. Teaching" for details.)
Only the lower-order 4 bits are valid. If the other bits are written to, they are ignored.

If the measured value changes by ΔA due to a touch during teaching, the new hysteresis that is set in teaching (HYSx) is calculated as:

$$\text{Hysteresis (HYSx)} = \Delta A \times (\text{Hysteresis ratio (RHYSx)})/16$$

For example, if RHYSx = 2, hysteresis (HYSx) is:

$$\text{HYSx} = \Delta A \times 2/16 \qquad \Delta A \times 0.13 \text{ (about 13\% of } \Delta A)$$

Command code	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x44..0x53	1	1	1	1	1	1	1	1	1	1	1	1	D3	D2	D1	D0

Channel 0 (RHYS0)– Command code 0x43
Channel 1 (RHYS1) Command code 0x49
Channel 2 (RHYS2) Command code 0x4E
Channel 3 (RHYS3) Command code 0x53

7. Teaching
7.1 Outline of teaching

Such parameters as the quantity of variation judged as on can be set automatically through actual touches on the electrode. This operation is called "Teaching".

When teaching, the reference value (REFx), quantity of variation judged as on (THRx) and hysteresis (HYSx) are updated appropriately, and stored in the EEPROM built into the chip.
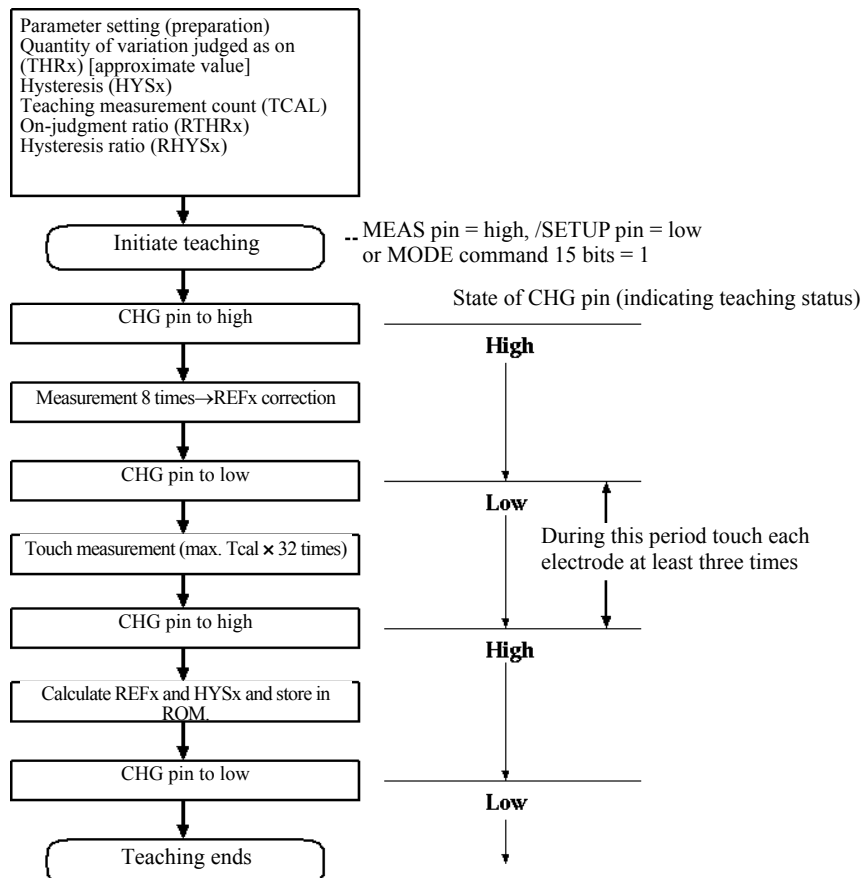Before performing a teaching operation, some preparation is required.
The processing flow is as follows:

During teaching, serial communication is not available.
However, checking the CHG pin allows status to be checked.
Once teaching mode is entered, any input other than /RESET is invalid until the measurement finishes and the chip comes out of teaching mode. Be aware that serial communication cannot be performed concurrently.

Parameter setting (preparation)
Quantity of variation judged as on (THRx) [approximate value]
Hysteresis (HYSx)
Teaching measurement count (TCAL)
On-judgment ratio (RTHRx)
Hysteresis ratio (RHYSx)

Initiate teaching
-- MEAS pin = high, /SETUP pin = low
or MODE command 15 bits = 1

State of CHG pin (indicating teaching status)

CHG pin to high
High

Measurement 8 times→REFx correction

CHG pin to low
Low

Touch measurement (max. Tcal× 32 times)
During this period touch each electrode at least three times

CHG pin to high
High

Calculate REFx and HYSx and store in ROM.

CHG pin to low
Low

Teaching ends

7.2 Preparation for teaching

To perform teaching, this chip must be brought into setup mode and some parameters must be set.
The parameters (commands) associated with teaching are as follows:

7.2.1 Teaching measurement count (Refer to "6.2.8 TCAL: Teaching measurement count")
During teaching, measurement is executed x number of times where x is the value of this parameter $\times$ 32.
(Hereafter, this is referred to as the teaching measurement count)
It takes 30–100 msec for one teaching measurement (depending on external circuit constants), and if this parameter is set to 10, the touches must be executed within 10-30 seconds.
Unless each electrode is touched three times within the number of teaching measurements after starting teaching, the teaching is regarded as faulty, and none of the parameters are updated.
However, when this parameter is set to "0", only the reference value (REFx) is updated. In this case, no touching is required, and the teaching is not regarded as faulty even if no touches are executed.

7.2.2 Quantity of variation judged as on (Refer to "6.2.15 THRx: Quantity of variation judged as on".)
This parameter contains the quantity of variation of the measured value that will allow judgment of a touch (approximate value).
To distinguish between variation of the measured value caused by a noise or the like and variation caused by touching during teaching, this parameter must be set to an approximate value.
If variation of half of this set value occurs during teaching, the electrode is judged touched. Therefore, an approximate value for variation likely to have been caused by touch may be entered.

7.2.3 Hysteresis (Refer to "6.2.16 HYSx: Hysteresis of each channel".)
This parameter sets the hysteresis value in teaching (approximate value).

7.2.4 On-judgment ratio (Refer to "6.2.17 RTHRx: On-judgment ratio for each channel") &
Hysteresis ratio (Refer to "6.2.17 RHYSx: Hysteresis ratio for each channel")
These parameters set the ratios of the quantity of variation judged as on (THRx) and hysteresis (HYSx) to the variation of the measured value caused by touch.
During teaching, each electrode must be touched three times or more. Then, the minimum value of the quantity of variation caused by touch is calculated for each electrode of the chip. (Minimum value of quantity of variation)
The new quantity of variation judged as on and the new hysteresis are calculated using the minimum value of quantity of variation ΔA as:

Quantity of variation judged as on (THRx) = $\Delta A \times$(On-judgment ratio (RTHRx) 1)/16
Hysteresis (HYSx) = $\Delta A \times$(Hysteresis ratio (RHYSx))/16

THRx = $\Delta A \times$(On-judgment ratio (RTHRx) 1)/16
HYSx = $\Delta A \times$(Hysteresis ratio (RHYSx))/16
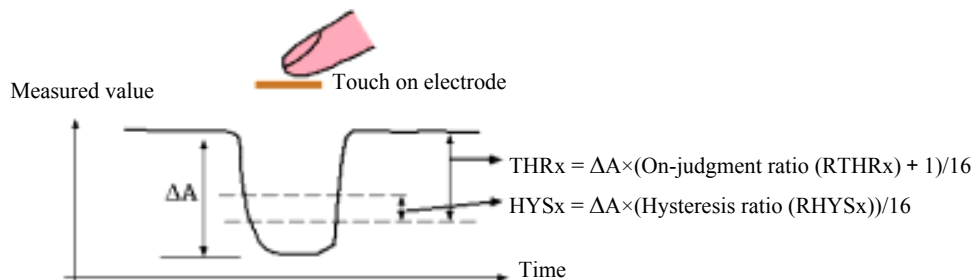
7.3 Performing teaching

There are two ways to enter teaching mode:
(1) /SETUP pin = low, and MEAS pin = high
(2) Write "0" into bit15 (TS) using the MODE command in setup mode.
When entering teaching mode by method (1), set the /SETUP pin to high or the MEAS pin to low before teaching finishes. If /SETUP pin = high and the MEAS pin = low, teaching will commence again.
When entering teaching mode, the CHG pin changes to high, indicating entry to teaching mode.

Just after teaching has started, the chip calibrates the reference value (REFx) (the measured value with no-touch). The measurement is performed eight times for each electrode, and the average of the eight measured values is taken as REFx. After the calibration finishes, the CHG pin output changes to low. Do not touch the touch electrode until the CHG pin changes to low.

After REFx has been calibrated, the chip starts the teaching measurement count ((TCAL)× 32 times). During this period, touch each electrode three times or more. The order for touching each of the electrodes is not defined. After the specified number of teaching measurements have finished, the CHG pin changes to high. However, if the number of touches (the number of times the chip recognizes a touch) reaches 32, the chip finishes measuring and changes the CHG pin to high, even if the teaching measurement count has not been reached.
When touching the electrodes, do not touch two or more electrodes at the same time. If you do, teaching cannot be performed correctly. If more than one electrode is touched simultaneously in error, touch each of the electrodes touched simultaneously again. Touch all of the electrodes three times or more within the teaching measurement time.

After the touch measurements have finished, the chip updates the quantity of variation judged as on (THRx), and hysteresis (HYSx) according to the calculation formula described in "7.2.4 On-judgment ratio and hysteresis ratio" (updates the values stored in the built-in ROM). After the values are updated, the CHG pin changes to low and teaching finishes.

7.4 Checking the result of teaching

When teaching finishes correctly, bit14 (TER bit) of the data, which can be read with the MODE command, changes to "1". If teaching is not completed normally because the specified number of touches are not executed within the teaching measurement time or for some other reason, the TER bit changes to "0" and the quantity of variation judged as on (THRx) and hysteresis (HYSx) are not updated. (In this event, only the reference value (REFx) is updated.)
To reset the TER bit, set it to "1" using the MODE command, or perform teaching again (and finish the teaching operation normally).

8. Electrical characteristics

8.1 Absolute maximum ratings

Designation	Item	Condition	Rated value	Unit
V_{dd}	Supply voltage		-0.3 – 6.5	V
V_I	Input voltage		-0.3 – V_{dd} +0.3	V
V_O	Output voltage		-0.3 – V_{dd} +0.3	V
P_d	Power dissipation	T_{opr}=25°C	300	mW
T_{opr}	Ambient operating temperature		-20 – 85	°C
T_{stg}	Storage temperature		-65 – 150	°C

8.2 Recommended operating conditions

Designation	Item	Condition	Rated value			Unit
			Minimum	Standard	Maximum	
V_{dd}	Supply voltage		3.0		5.5	V
V_{IH}	High input voltage		$0.8V_{dd}$		V_{dd}	V
V_{IL}	Low input voltage		0		$0.2V_{dd}$	V
I_{OH}	High output current				-5	mA
I_{OL}	Low output current				5	mA

Note 1: Unless otherwise specified, Vdd = 3.0-5.5V, Topr = -20-85°C

8.3 Electrical characteristics (1) [Vdd=5V]

Designation	Item	Condition	Rated value			Unit
			Minimum	Standard	Maximum	
V_{OH}	High output voltage	I_{OH}=-5mA	V_{dd}-2.0		V_{dd}	V
		I_{OH}=-200µA	V_{dd}-0.3		V_{dd}	V
V_{OL}	Low output voltage	I_{OL}=5mA			2.0	V
		I_{OH}=200µA			0.45	V
I_{IH}	High input current	V_I=5V			5	µA
I_{IL}	Low input current	V_I=0V			-5	µA
I_{CC}	Supply current	Normal measurement mode		5		mA
		During sleep		0.4		mA

Note 1: Unless otherwise specified, Vdd = 4.2-5.5V, Topr = -20-85°C

8.4 Electrical characteristics (2) [Vdd=3V]

Designation	Item	Condition	Rated value			Unit
			Minimum	Standard	Maximum	
V_{OH}	High output voltage	I_{OH}=-1mA	V_{dd} -0.5		V_{dd}	V
V_{OL}	Low output voltage	I_{OL}=1mA			0.5	V
I_{IH}	High input current	V_I=3V			4	μA
I_{IL}	Low input current	V_I=0V			-4	μA
I_{CC}	Supply current	Normal measurement mode		4.8		mA
		During sleep		0.4		mA

Note 1: Unless otherwise specified, Vdd = 3.0-3.3V, Topr = -20-85°C.

8.5 Electrical characteristics (3)

Designation	Item	Condition	Rated value			Unit
			Minimum	Standard	Maximum	
-	Number of times of EEPROM write	T_{OPR}=0 60°C	10000			Times
-	EEPROM write time	V_{dd}=5V, T_{OPR}=25°C (Note 2)		0.3		S
-	EEPROM data retention period	T_{OPR}=55°C	20			Years

Note 1: Unless otherwise specified, Vdd = 3.0-5.5V, Topr = -20-85°C
Note 2: The period following receipt of the EEPROM write command in setup mode until the data write finishes.
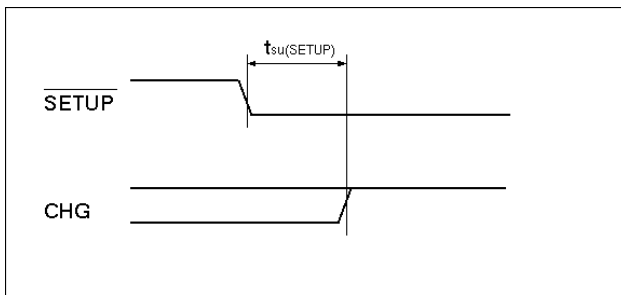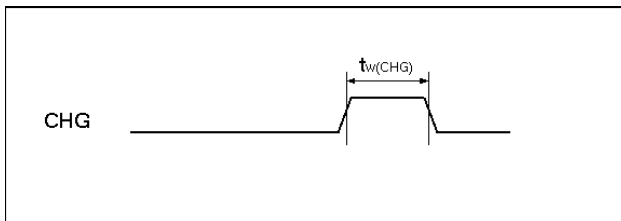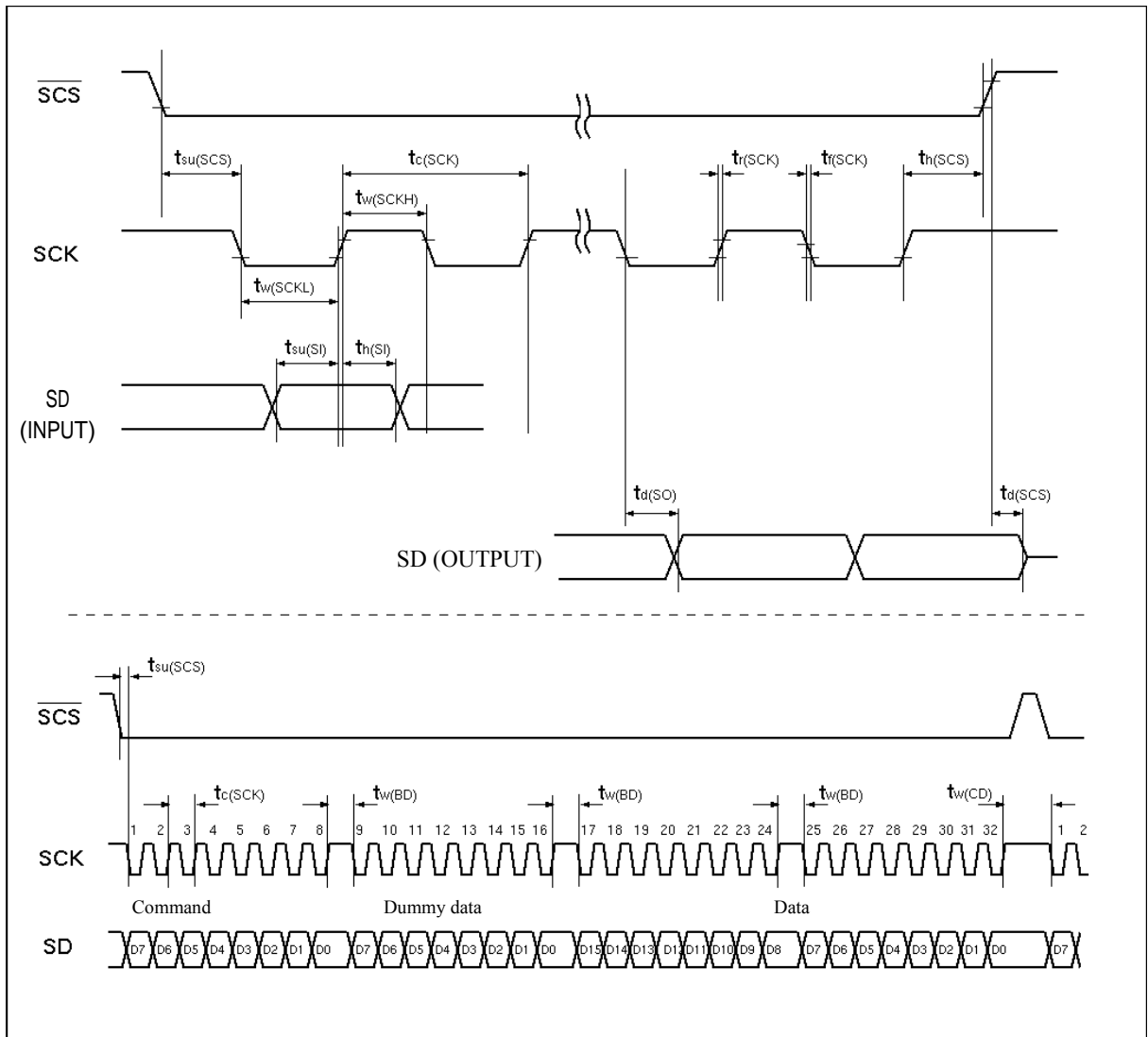
8.6 Necessary timing conditions

Designation	Item	Condition	Rated value		Unit
			Minimum	Maximum	
$t_{c(SCK)}$	Serial communication clock cycle time		15		μS
$t_{w(SCKH)}$	Serial communication clock high pulse width		0.4	0.6	$t_{c(SCK)}$
$t_{w(SCKL)}$	Serial communication clock low pulse width		0.4	0.6	$t_{c(SCK)}$
$t_{r(SCK)}$	Serial communication clock rise time			1	μS
$t_{f(SCK)}$	Serial communication clock fall time			1	μS
$T_{su(SCS)}$	Serial communication chip select setup time		320		nS
$T_{h(SCS)}$	Serial communication chip select hold time		320		nS
$t_{d(SO)}$	Serial communication output delay time			280	nS
$T_{d(SCS)}$	Serial communication chip select delay time			320	nS
$T_{su(SI)}$	Serial communication input setup time		100		nS
$t_{h(SI)}$	Serial communication input hold time		280		nS
$t_{w(BD)}$	Serial communication byte to byte interval		90		μS
$t_{w(CD)}$	Serial communication command reception interval		130		μS
$T_{w(CHG)}$	CHG pulse width	(Note 2)	50		μS
$T_{su(SETUP)}$	Mode shift delay time	(Note 3)		95	μS
$T_{w(RESET)}$	Reset pulse width		500		μS

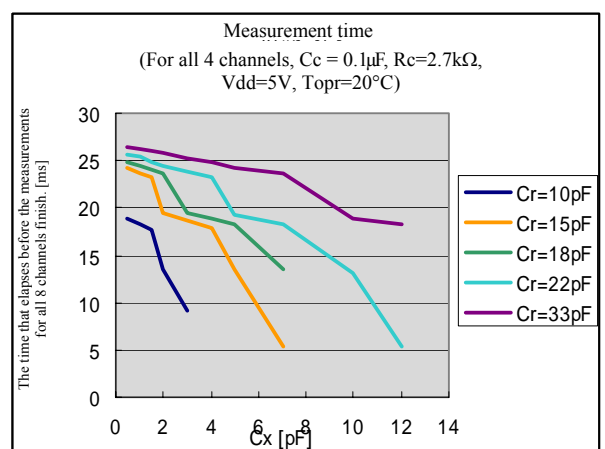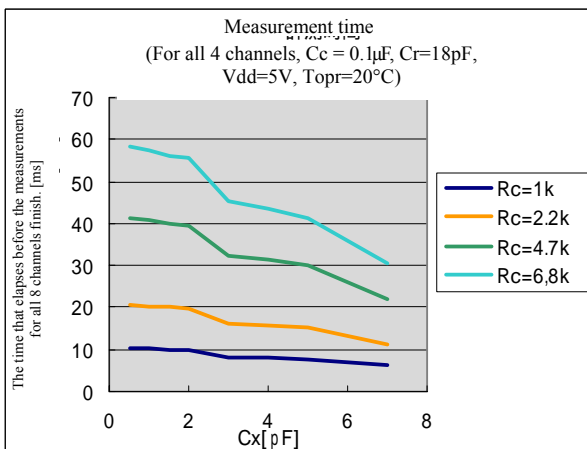Note 1: Unless otherwise specified, Vdd = 3.0-5.5V, Topr = 25°C.
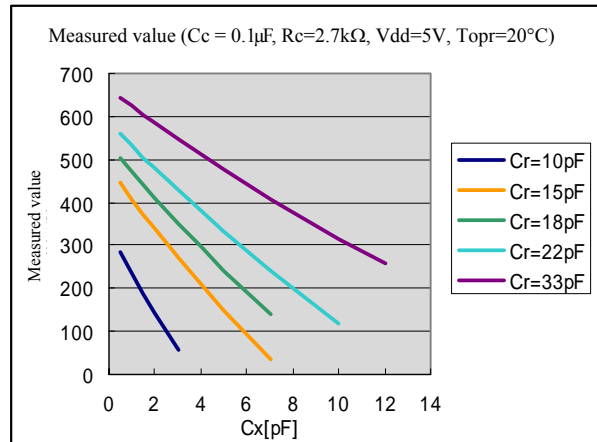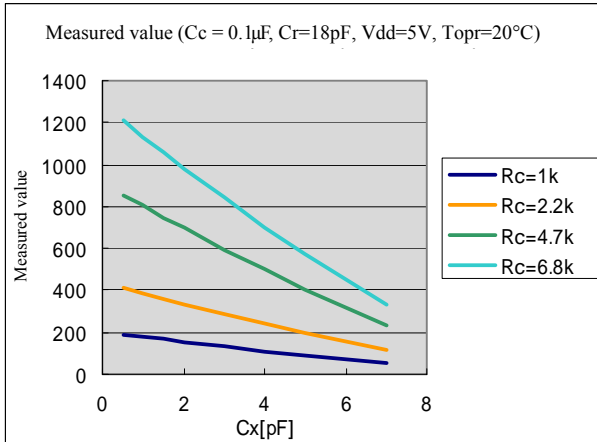Note 2: This is the time period when the condition that CHG pulse width is at its minimum in the serial communication mode of normal measurement mode is set.
(CHG pin function is set to output at the end of every measurement [CHG bit = 0 with MODE command]) and the sleep time is set to zero [SLP command value = 0]).
Note 3: The delay time for the mode shift between normal measurement mode and setup mode.

$\overline{SCS}$

$t_{su(SCS)}$ $t_{c(SCK)}$ $t_{r(SCK)}$ $t_{f(SCK)}$ $t_{h(SCS)}$

$t_{w(SCKH)}$

SCK

$t_{w(SCKL)}$

$t_{su(SI)}$ $t_{h(SI)}$

SD
(INPUT)

$t_{d(SO)}$ $t_{d(SCS)}$

SD (OUTPUT)

$t_{su(SCS)}$

$\overline{SCS}$

$t_{c(SCK)}$ $t_{w(BD)}$ $t_{w(BD)}$ $t_{w(BD)}$ $t_{w(CD)}$

1 2 3 4 5 6 7 8   9 10 11 12 13 14 15 16   17 18 19 20 21 22 23 24   25 26 27 28 29 30 31 32   1 2

SCK

Command   Dummy data   Data

SD   D7 D6 D5 D4 D3 D2 D1 D0 D7 D6 D5 D4 D3 D2 D1 D0 D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 D1 D0 D7

$t_{w(CHG)}$

CHG

$t_{su(SETUP)}$

$\overline{SETUP}$

CHG

8.7   Measurement characteristics (typical example)

Measured value (Cc = 0.1μF, Cr=18pF, Vdd=5V, Topr=20°C)

Measured value (Cc = 0.1μF, Rc=2.7kΩ, Vdd=5V, Topr=20°C)

Measurement time
(For all 4 channels, Cc = 0.1μF, Cr=18pF,
Vdd=5V, Topr=20°C)

Measurement time
(For all 4 channels, Cc = 0.1μF, Rc=2.7kΩ,
Vdd=5V, Topr=20°C)

Temperature characteristics
(Cc = 0.1μF, Cr=18pF, Rc=2.7 kΩ, Cx=3.3pF, Vdd=5V)

Supply voltage characteristics
(Cc = 0.1μF, Cr=18pF, Rc=2.7 kΩ, Cx=3.3pF,
Topr=20°C)
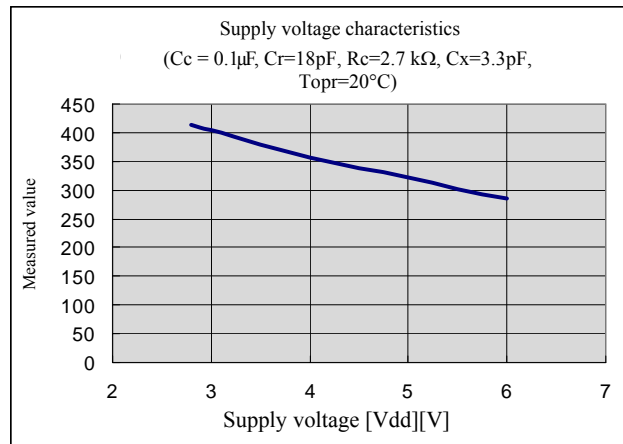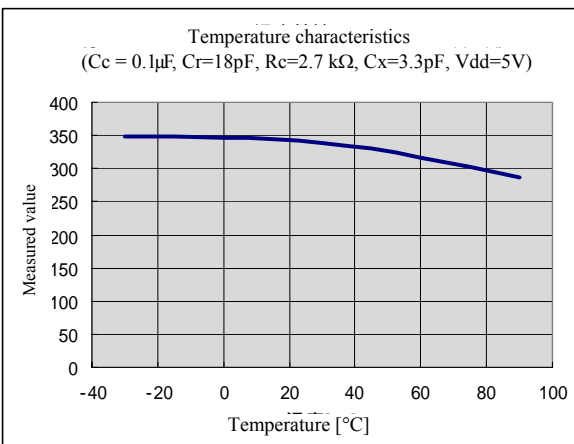
9. Appearance and dimensions

Recommended pad dimensions
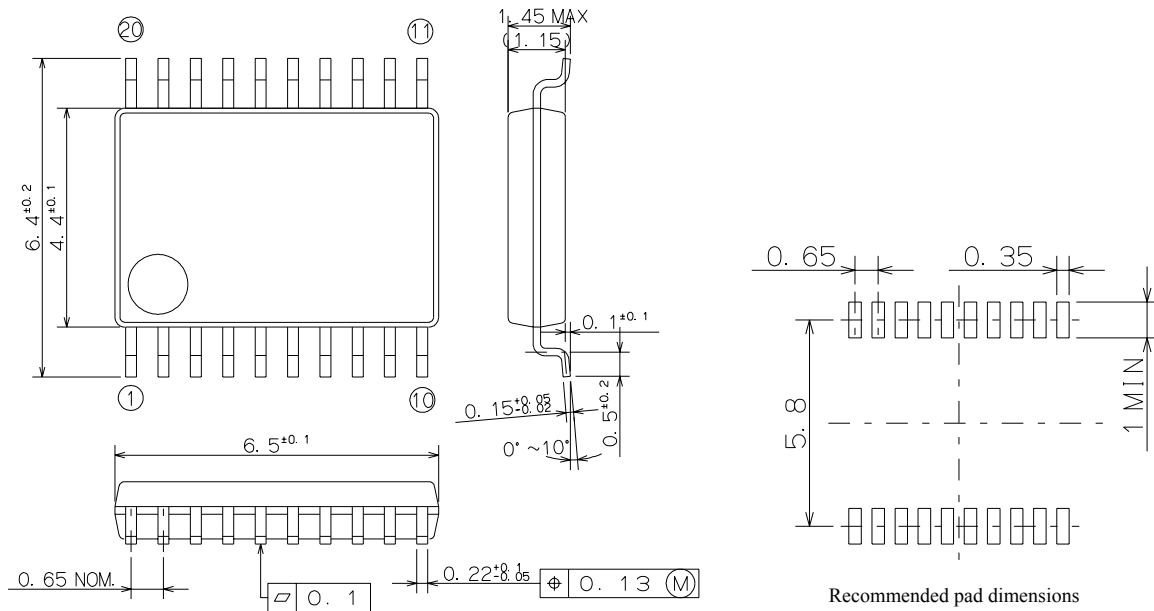
Warranty Details

1. Warranty period
   The warranty period for an Omron product is one year from purchase or delivery to a customer-specified place.
2. Scope of warranty
   If any Omron product fails under Omron liability within the above warranty period, Omron shall supply a replacement or repair the product free of charge at the place of purchase. However, if the reason for the product failure falls into any of the following categories, the warranty will not apply:
   a) The product has been used or handled under conditions or in an environment not listed in the product's specifications, catalog, or operation manual (hereinafter referred to as the "catalog and the like").
   b) The failure has been caused by a non-Omron product.
   c) The product has been modified or repaired by somebody or corporation other than Omron.
   d) The product has been used for other than its intended use.
   e) The failure could not have been predicted based on the level of science or technology at the time of shipment.
   f) The failure has been caused by a natural or other disaster, an accident or the like that is not Omron's liability. This warranty applies only to the Omron product itself, and any damage induced by a failed Omron product is excluded from this warranty.

3. Scope of service
    The price of an Omron product does not include service expenses such as the cost of sending out technicians.
    If you wish to request non-inclusive services, please consult Omron sales personnel.

4. Scope of application
    The above apply only to business and usage in Japan.
    Please consult Omron sales personnel about business and usage in other countries.