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Capacitive touch switch controller IC series

Capacitive touch switch controller

BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F Rev.05-E

Introduction

"Capacitive tcouh switch controller IC" a capasitive touch switch controller used for operating switches.
The result of having determined the switch state is hold in a register and is notified to the host by a interrupt terminal.It is possible to reduce current consumption of MPU because it does not need periodical monitoring.
This IC activates the automatic self-calibration when external noise and temperature drit are detected.

Features

- Single power supply (3V or 5V)
- 2-wire serial bus interface
- Notification of detect result by a interruplt terminal
- Single switch , multiple switch , slider switch , matrix switch
- Continued touch detection
- Automatic self-caribcation
- LED controller with PWM function (BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV)
- Built-in interrupt operation mode for saving cunnret consumption (BU21079F)
- Built-in Power-On-Reset and Oscillator

Application

- Electronic devices with multiple switches.
- AV appliances like TV and HDD recorder.
- PC appliances like Notebook PC , printers
- Household electric appliances like Air-conditioner , Regrigerator , Electrical rise cooker

Line-up

	BU21072MUV	BU21078MUV BU21078FV	BU21170MUV	BU21079F
Sensor terminal	10 sensors	12 sensors	5 sensors	8 sensors
LED controller with PWM	Yes	Yes	Yes	No
Single switch	Yes	Yes	Yes	Yes
Matrix switch	Yes	Yes	No	Yes
Interrupt operation mode	No	No	No	Yes
Supply Voltage Range(V)	3.0 - 5.5	3.0 - 5.5	3.0 - 5.5	3.0 - 5.5
Temperature Range(℃)	-20 - 85	-20 - 85	-20 - 85	-20 - 85
Host I/F	2-wire serial bus	2-wire serial bus	2-wire serial bus	2-wire serial bus
Slave Addres	0x5C	0x5D	0x4C (ADR=L) 0x4D (ADR=H)	0x5C
PKG	VQFN024V4040	VQFN028V5050 (MUV) SSOP-B28 (FV)	VQFN020V4040	SOP16

Sensor characteristic

	BU21072MUV	BU21078MUV BU21078FV	BU21170MUV	BU21079F
Detect capacitance value	0.1p - 5pF	0.1p - 5pF	0.1p - 5pF	0.1p - 5pF
PCB capacitance value	- 22.5pF	- 22.5pF	- 22.5pF	- 22.5pF
A allowaable resister value for sensor terminal	- 1kΩ	- 1kΩ	- 1kΩ	- 1kΩ

Contents

Absolute maximum ratings

【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F】

Parameter	Symbol	Rating	Unit	
Power supply voltage	VDD	-0.5 ～ 7.0	V	
Input voltage	VIN	-0.5 ～ VDD+0.3	V	
Power dissipation	Pd	272 *1	mW	BU21072MUV BU21170MUV
		304 *2		BU21078MUV
		640 *3		BU21078FV
		300 *4		BU21079F
Storage temperature range	Tstg	-55 ～ 125	℃	

*1 Ambient temperature reduces a permission loss by 2.72mW per case more than 25 degree Celsius (IC only)
*2 Ambient temperature reduces a permission loss by 3.04mW per case more than 25 degree Celsius (IC only)
*3 Ambient temperature reduces a permission loss by 6.4mW per case more than 25 degree Celsius (IC only)
*4 Ambient temperature reduces a permission loss by 3.00mW per case more than 25 degree Celsius (IC only)

Recommned operating conditions

【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F】

Parameter	Symbol	Rating			Unit	
		MIN	TYP	MAX		
Power supply voltage	VDD	3.0	3.3	5.5	V	
Operating temperature range	Topr	-20	25	85	℃	

Electrical charcteristic (DC)

【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV】

（Ta=25□、VDD=3.3V）

Parameter	Symbol	Rating			Unit	
		MIN	TYP	MAX		
Input High voltage	V_{IH}	VDDx0.7	-	VDD+0.3	V	
Input Low voltage	V_{IL}	VSS-0.3	-	VDDx0.3	V	
Output High voltage	V_{OH}	VDD-0.5	-	VDD	V	IOH=-4mA
Output Low voltage	V_{OL}	VSS	-	VSS+0.5	V	IOL=4mA
Osillator clock frequency	fosc	45	50	55	MHz	
DVDD voltage	V_{DVDD}	1.35	1.50	1.65	V	
AVDD voltage	V_{AVDD}	2.63	2.73	2.83	V	
Power-on-reset Release voltage	-	2.25	2.5	2.55	V	
Power-on-reset Detect voltage	-	2.10	2.25	2.40	V	
Operating current	I_{DD}	-	2.5	-	mA	Full scan mode Without load of sensors

【BU21079F】

（Ta=25□、VDD=3.3V）

Parameter	Symbol	Rating			Unit	
		MIN	TYP	MAX		
Input High voltage	V_{IH}	VDDx0.7	-	VDD+0.3	V	
Input Low voltage	V_{IL}	VSS-0.3	-	VDDx0.3	V	
Output High voltage	V_{OH}	VDD-0.5	-	VDD	V	IOH=-4mA
Output Low voltage	V_{OL}	VSS	-	VSS+0.5	V	IOL=4mA
Osillator clock frequency1	fosc1	45	50	55	MHz	
Osillator clock frequency2	fosc2	51.2	64	76.8	KHz	
DVDD voltage	V_{DVDD}	1.33	1.50	1.67	V	
AVDD voltage	V_{AVDD}	2.58	2.71	2.84	V	
Operating current1	I_{DD}	-	2.5	-	mA	Full scan mode Without load of sensors
Operating current2	I_{INIT}	-	75	-	uA	Interrupt scan mode 200ms

HOST-I/F specificatin (2-wire serial bus)

【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F】

These have 2-wire serial bus interface. It is compatible with I2C protocol and are a slave device. Slave address of these is like below. And it supports Standard-mode (100 KHz) and Fast-mode (400 kHz).

Slave Address = 5Ch 【BU21072MUV】
Slave Address = 5Dh 【BU21078MUV / BU21078FV】
Slave Address = 4Ch (ADR=L) / 4Dh (ADR=H)【BU21170MUV】
Slave Address = 5Ch 【BU21079F】

Timming Chart

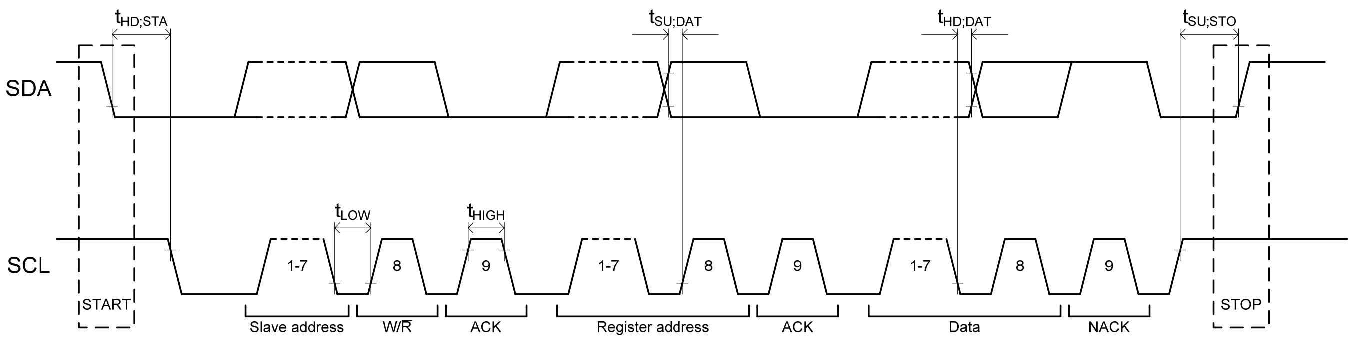


Fig.1 I2C timming chart

Electrical charceristics(AC)

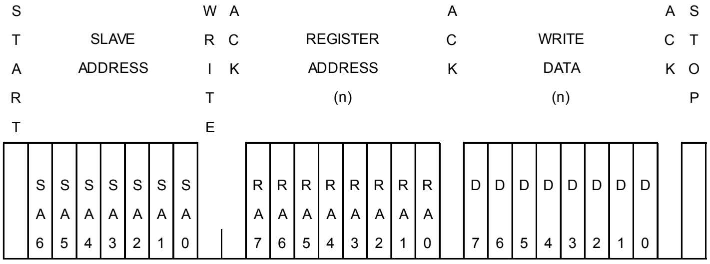
【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F】

(Ta=25□、VDD=3.3V)

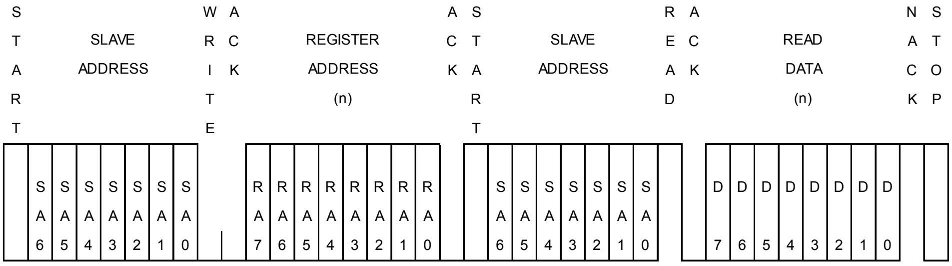
Parameter	Standard-mode		Fast-mode		Unit
	MIN	MAX	MIN	MAX	
f_{SCL} SCL clock frequency	0	100	0	400	kHz
$t_{HD;STA}$:hold time (repeated) START condition	4.0	-	0.6	-	usec
t_{LOW} Low period of the SCL clock	4.7	-	1.3	-	usec
t_{HIGH} High period of the SCL clock	4.0	-	0.6	-	usec
$t_{HD;DAT}$ Data hold time	0.1	3.45	0.1	0.9	usec
$t_{SU;DAT}$ Data setup time	0.25	-	0.1	-	usec
$t_{SU;STA}$: Set-up time for a repeated START condition	4.7	-	0.6	-	usec
$t_{SU;STO}$: Set-up time for STOP condition	4.0	-	0.6	-	usec
t_{BUF} : Bus free time between a STOP and START condition	4.7	-	1.3	-	usec

Protocol

・Byte Write



・Random Read



・Sequential Read

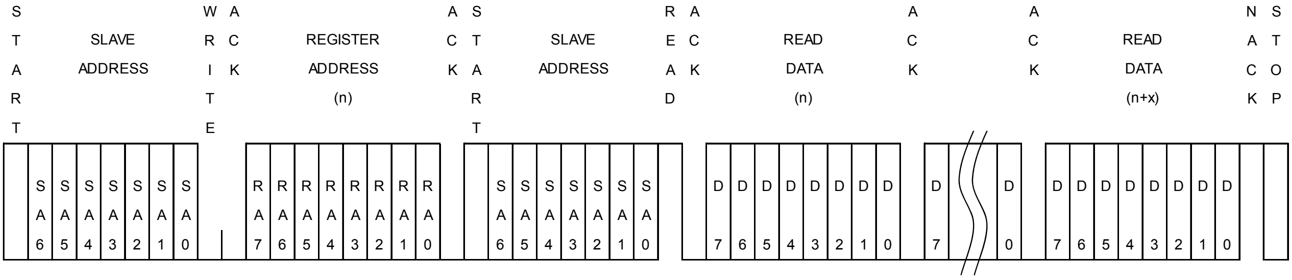


Fig.2 I2C protocol

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Block diagram / Each block description

【BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV】

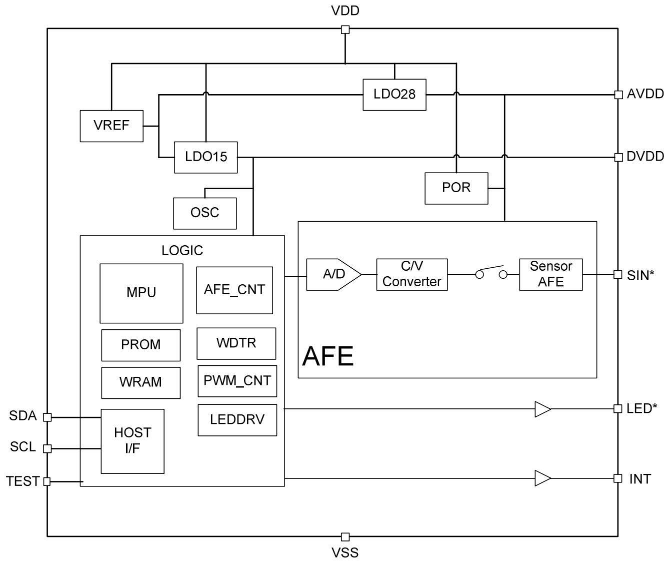

Fig.3 BU21072MUV / BU21078MUV / BU21078FV / BU21170 MUV block diagram

Sensor AFE、C/V Converter	: Circuits converting from capacitance to voltage
A/D	: A/D converter
LDO28	: 2.73V output LDO for Sensor AFE, C/V Converter and A/D
LDO15	: 1.5V output LDO for OSC and digial blocks
OSC	: 50MHz Ring oscillator as the system clock
POR	: Power-On-Reset circuits
MPU	: Microprocessor circuit detecting the switch state (Touch/ Release/Hold)
PROM	: Program memory for MPU
WRAM	: Work memory for MPU
HOST I/F	: 2-wire serial bus
AFE_CNT	: Sequencer of Sensor AFE, C/V converter and A/D
PWM_CNT	: PWM timers for the LED ports.
LEDDRV	: LED port drivers.
WDTR	: Watch Dog Timer Reset

【BU21079F】

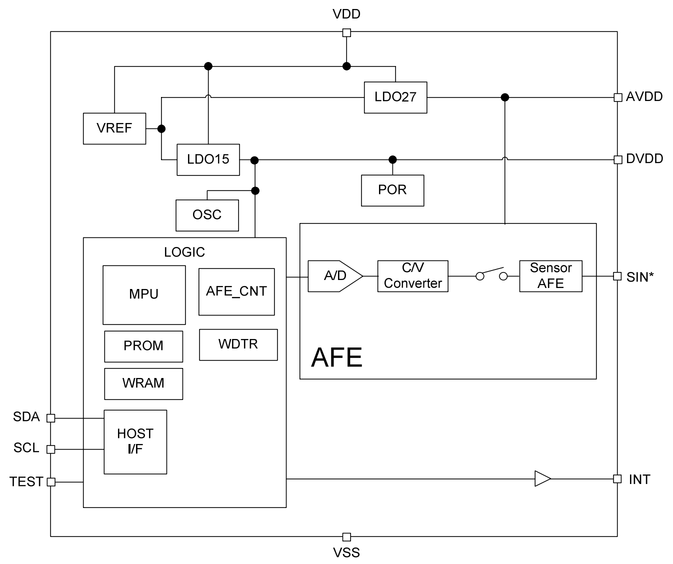

Fig.4 BU21079 block diagram

Sensor AFE、C/V Converter	: Circuits converting from capacitance to voltage
A/D	: A/D converter
LDO28	: 2.71V output LDO for Sensor AFE, C/V Converter and A/D
LDO15	: 1.5V output LDO for OSC and digial blocks
OSC	: 50MHz Ring oscillator as the system clock
POR	: Power-On-Reset circuits
MPU	: Microprocessor circuit detecting the switch state (Touch/ Release/Hold)
PROM	: Program memory for MPU
WRAM	: Work memory for MPU
HOST I/F	: 2-wire serial bus
AFE_CNT	: Sequencer of Sensor AFE, C/V converter and A/D
PWM_CNT	: PWM timers for the LED ports.
LEDDRV	: LED port drivers.
WDTR	: Watch Dog Timer Reset

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Pin description
【BU21072MUV】

Pin Number	Pin Name	Type	Function	Note	Power	Initial condition	I/O Equivalence circuit
1	SIN3	Ain	Sensor port12		AVDD	Hi-Z	A
2	SIN2	Ain	Sensor port2		AVDD	Hi-Z	A
3	SIN1	Ain	Sensor port11		AVDD	Hi-Z	A
4	SIN0	Ain	Sensor port1		AVDD	Hi-Z	A
5	AVDD	Power	LDO terminal for ANALOG		VDD	—	—
6	VDD	Power	Power terminal		—	—	—
7	DVDD	Power	LDO terminal for DIGITAL		VDD	—	—
8	VSS	GND	Ground terminal		—	—	—
9	TEST	In	Ground terminal	Fix “L” at the normal operation	VDD	—	B
10	SCL	In	Host I/F : SCL terminal		VDD	Hi-Z	B
11	SDA	InOut	Host I/F : SDA terminal		VDD	Hi-Z	B
12	INT	Out	Interrupt terminal	H Active	VDD	L	C
13	LED0	Out	LED control port0	H Active	VDD	Hi-Z	C
14	LED1	Out	LED control port1	H Active	VDD	Hi-Z	C
15	LED2	Out	LED control port2	H Active	VDD	Hi-Z	C
16	LED3	Out	LED control port3	H Active	VDD	Hi-Z	C
17	LED4	Out	LED control port4	H Active	VDD	Hi-Z	C
18	LED5	Out	LED control port5	H Active	VDD	Hi-Z	C
19	SIN9	Ain	Sensor port9		VDD	Hi-Z	A
20	SIN8	Ain	Sensor port8		VDD	Hi-Z	A
21	SIN7	Ain	Sensor port7		VDD	Hi-Z	A
22	SIN6	Ain	Sensor port6		AVDD	Hi-Z	A
23	SIN5	Ain	Sensor port5		AVDD	Hi-Z	A
24	SIN4	Ain	Sensor port4		AVDD	Hi-Z	A

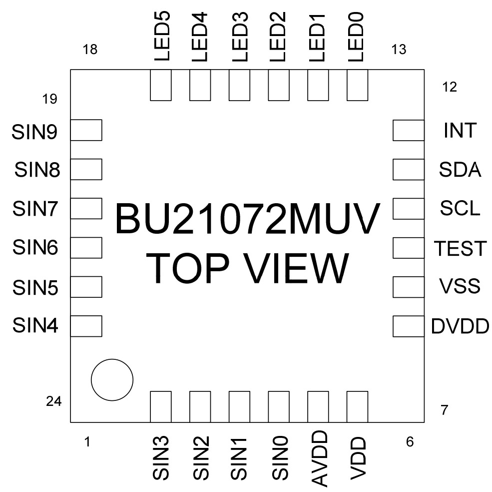

Fig.5 BU21072MUV pin configuration

【BU21078MUV】

Pin Number	Pin Name	Type	Function	Note	Power	Initial condition	I/O Equivalence circuit
1	SIN12	Ain	Sensor port12		AVDD	Hi-Z	A
2	SIN2	Ain	Sensor port2		AVDD	Hi-Z	A
3	SIN11	Ain	Sensor port11		AVDD	Hi-Z	A
4	SIN1	Ain	Sensor port1		AVDD	Hi-Z	A
5	SIN0	Ain	Sensor port0		AVDD	Hi-Z	A
6	AVDD	Power	LDO terminal for ANALOG		VDD	–	–
7	VDD	Power	Power terminal		–	–	–
8	DVDD	Power	LDO terminal for DIGITAL		VDD	–	–
9	VSS	GND	Ground terminal		–	–	–
10	TEST	In	Test terminal	Fix “L” at the normal operation	VDD	–	B
11	SCL	In	Host I/F : SCL terminal		VDD	Hi-Z	B
12	SDA	InOut	Host I/F : SDA terminal		VDD	Hi-Z	B
13	INT	Out	Interrupt terminal	H Active	VDD	L	C
14	LED0	Out	LED control port0	H Active	VDD	Hi-Z	C
15	LED1	Out	LED control port1	H Active	VDD	Hi-Z	C
16	LED2	Out	LED control port2	H Active	VDD	Hi-Z	C
17	LED3	Out	LED control port3	H Active	VDD	Hi-Z	C
18	LED4	Out	LED control port4	H Active	VDD	Hi-Z	C
19	LED5	Out	LED control port5	H Active	VDD	Hi-Z	C
20	LED6	Out	LED control port6	H Active	VDD	L	C
21	LED7	Out	LED control port7	H Active	VDD	L	C
22	SIN7	Ain	Sensor port7		AVDD	Hi-Z	A
23	SIN6	Ain	Sensor port6		AVDD	Hi-Z	A
24	SIN13	Ain	Sensor port13		AVDD	Hi-Z	A
25	SIN5	Ain	Sensor port5		AVDD	Hi-Z	A
26	SIN14	Ain	Sensor port14		AVDD	Hi-Z	A
27	SIN4	Ain	Sensor port4		AVDD	Hi-Z	A
28	SIN3	Ain	Sensor port3		AVDD	Hi-Z	A

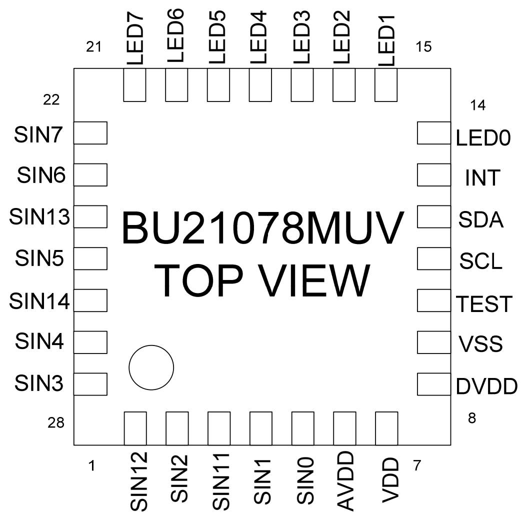

Fig.6 BU21078MUV pin configuration

【BU21078FV】

Pin Number	Pin Name	Type	Function	Note	Power	Initial condition	I/O Equivalence circuit
1	LED5	Out	LED control port5	H Active	VDD	Hi-Z	C
2	LED6	Out	LED control port6	H Active	VDD	L	C
3	LED7	Out	LED control port7	H Active	VDD	L	C
4	SIN7	Ain	Sensor port7		AVDD	Hi-Z	A
5	SIN6	Ain	Sensor port6		AVDD	Hi-Z	A
6	SIN13	Ain	Sensor port13		AVDD	Hi-Z	A
7	SIN5	Ain	Sensor port5		AVDD	Hi-Z	A
8	SIN14	Ain	Sensor port14		AVDD	Hi-Z	A
9	SIN4	Ain	Sensor port4		AVDD	Hi-Z	A
10	SIN3	Ain	Sensor port3		AVDD	Hi-Z	A
11	SIN12	Ain	Sensor port12		AVDD	Hi-Z	A
12	SIN2	Ain	Sensor port2		AVDD	Hi-Z	A
13	SIN11	Ain	Sensor port11		AVDD	Hi-Z	A
14	SIN1	Ain	Sensor port1		AVDD	Hi-Z	A
15	SIN0	Ain	Sensor port0		AVDD	Hi-Z	A
16	AVDD	Power	LDO terminal for ANALOG		VDD	—	—
17	VDD	Power	Power terminal		—	—	—
18	DVDD	Power	LDO terminal for DIGITAL		VDD	—	—
19	VSS	GND	Ground terminal		—	—	—
20	TEST	In	Test terminal	Fix “L” at the normal operation	VDD	—	B
21	SCL	In	Host I/F : SCL terminal		VDD	Hi-Z	B
22	SDA	InOut	Host I/F : SDA terminal		VDD	Hi-Z	B
23	INT	Out	Interrupt terminal	H Active	VDD	L	C
24	LED0	Out	LED control port0	H Active	VDD	Hi-Z	C
25	LED1	Out	LED control port1	H Active	VDD	Hi-Z	C
26	LED2	Out	LED control port2	H Active	VDD	Hi-Z	C
27	LED3	Out	LED control port3	H Active	VDD	Hi-Z	C
28	LED4	Out	LED control port4	H Active	VDD	Hi-Z	C

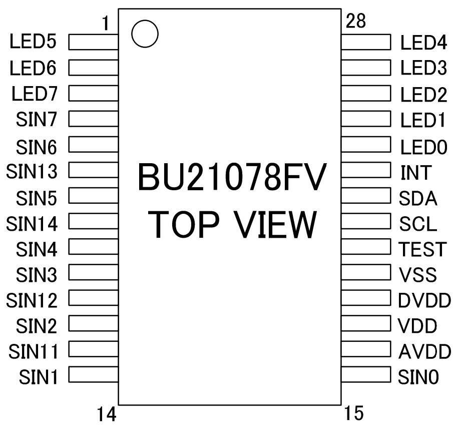

Fig.7 BU21078FV pin configuration

【BU21170MUV】

Pin Number	Pin Name	Type	Function	Note	Power	Initial condition	I/O Equivalence circuit
1	SIN1	Ain	Sensor port1		AVDD	Hi-Z	A
2	SIN0	Ain	Sensor port0		AVDD	Hi-Z	A
3	AVDD	Power	LDO terminal for ANALOG		―	Hi-Z	―
4	VDD	Power	Power terminal		―	Hi-Z	―
5	DVDD	Power	LDO terminal for DIGITAL		―	Hi-Z	―
6	VSS	GND	Ground terminal		―	―	―
7	TEST	In	Test terminal	Fix “L” at the normal operation	VDD	―	B
8	SCL	In	Host I/F ： SCL terminal		VDD	Hi-Z	B
9	SDA	InOut	Host I/F ： SDA terminal		VDD	Hi-Z	B
10	INT	Out	Interrupt terminal	H Active	VDD	L	C
11	ADR	In	Host I/F slave select terminal	L:slave address 0x4C H:slave address 0x4D	VDD	Hi-Z	B
12	LED0	Out	LED control port0	H Active	VDD	Hi-Z	C
13	LED1	Out	LED control port1	H Active	VDD	Hi-Z	C
14	LED2	Out	LED control port2	H Active	VDD	Hi-Z	C
15	LED3	Out	LED control port3	H Active	VDD	Hi-Z	C
16	LED4	Out	LED control port4	H Active	VDD	Hi-Z	C
17	N.C.	-	―		―	―	―
18	SIN4	Ain	Sensor port4		AVDD	Hi-Z	A
19	SIN3	Ain	Sensor port3		AVDD	Hi-Z	A
20	SIN2	Ain	Sensor port2		AVDD	Hi-Z	A

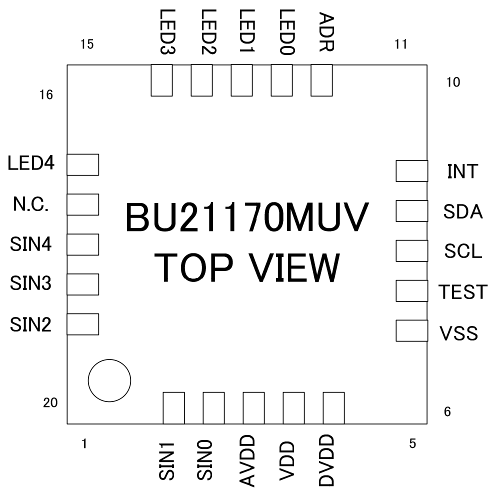

Fig.8　BU21170MUV pin configuration

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【BU21079F】

Pin Number	Pin Name	Type	Function	Note	Power	Initial condition	I/O Equivalence circuit
1	SIN3	Ain	Sensor port3		AVDD	Hi-Z	A
2	SIN2	Ain	Sensor port2		AVDD	Hi-Z	A
3	SIN1	Ain	Sensor port1		AVDD	Hi-Z	A
4	SIN0	Ain	Sensor port0		AVDD	Hi-Z	A
5	AVDD	Power	LDO terminal for ANALOG		–	–	–
6	DVDD	Power	LDO terminal for DIGITAL		–	–	–
7	VDD	Power	Power terminal		–	–	–
8	VSS	GND	Ground terminal		–	–	–
9	SCL	In	Host I/F ： SCL terminal		VDD	Hi-Z	B
10	SDA	InOut	Host I/F ： SDA terminal		VDD	Hi-Z	B
11	INT	Out	Interrupt terminal	H Active	VDD	L	B
12	TEST	In	Test terminal	Fix “L” at the normal operation	VDD	–	D
13	SIN7	Ain	Sensor port7		AVDD	Hi-Z	A
14	SIN6	Ain	Sensor port6		AVDD	Hi-Z	A
15	SIN5	Ain	Sensor port5		AVDD	Hi-Z	A
16	SIN4	Ain	Sensor port4		AVDD	Hi-Z	A

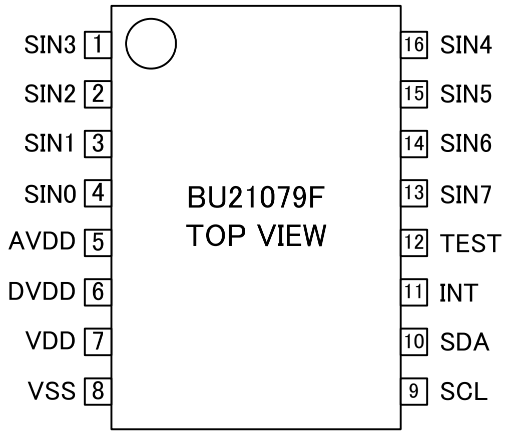

Fig.9 BU21079F pin configuration

I/O Equivalent circuits

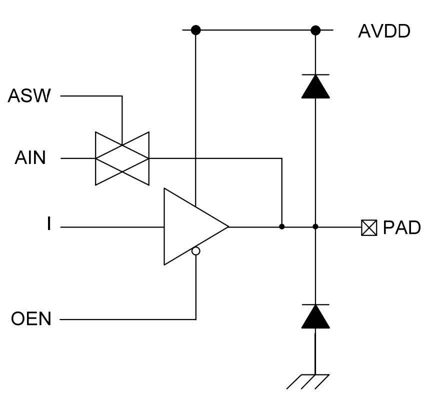

Fig.A

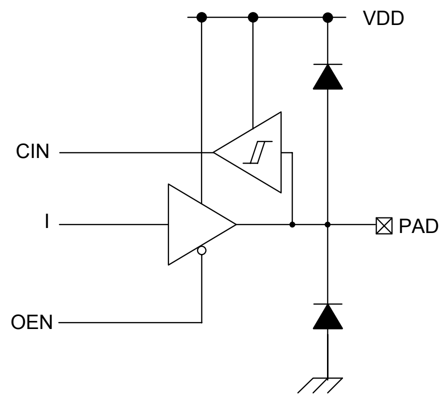

Fig.B

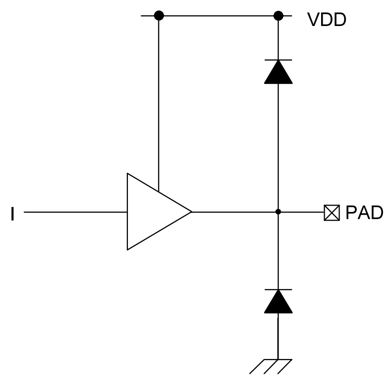

Fig.C

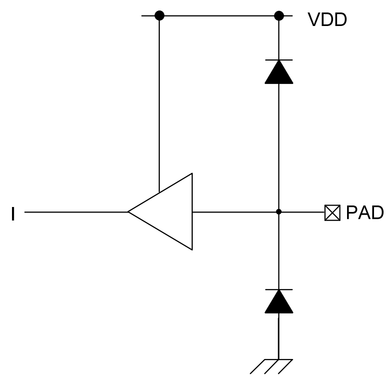

Fig.D

Fig.10 BU21072MUV / BU21078MUV / BU21078FV / BU21170MUV / BU21079F equivalent circuits

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Control flow chart

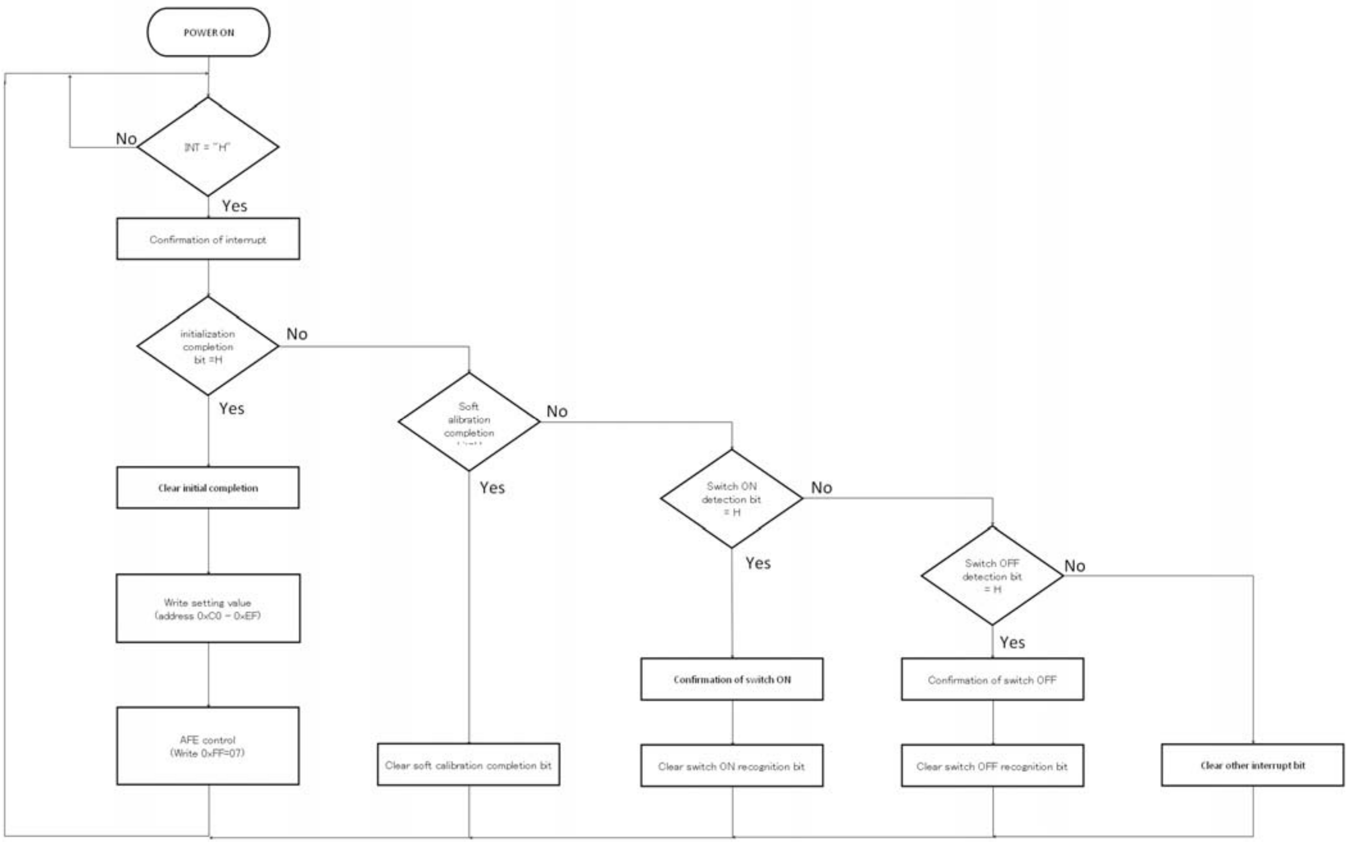


Fig.11 control flow chart

Power on sequence

Power on sequence【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】

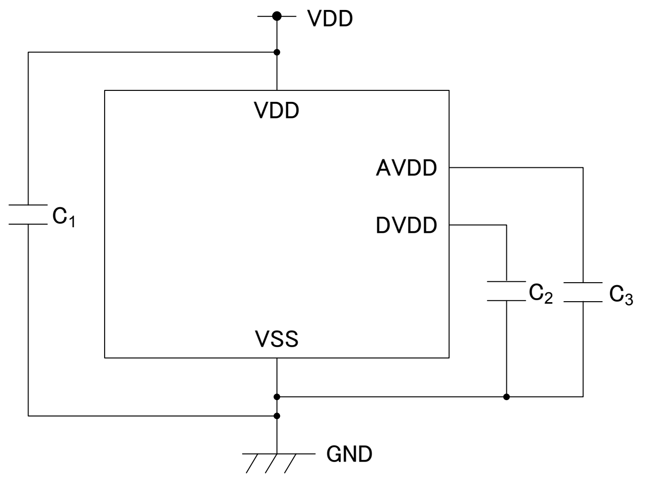
Power supply pin is only VDD. AVDD and DVDD are supplied by built-in LDO. When VDD is supplied, DVDD and AVDD boot automatically. When VDD reaches to the effective voltage, power-on-reset is released and initializes the digital block.

Power on sequence【BU21079F】

Power supply pin is only VDD. AVDD and DVDD are supplied by built-in LDO. When VDD is supplied, DVDD boot automatically. When DVDD reaches to the effective voltage, power-on-reset is released and initializes the digital block.

Settings after initialization【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV/BU21079F】

When power-on-reset is released, MPU starts initialization sequence. Initailization competion is informed by the INT port to the host. Please send initial settings command after confirming that the initialization has completed.The initialization is executed in case of watch dog timmer reset as well and all register is initialized. Please send initial settings command again when detecting interrupt that the initialization has completed.



Recommended value of external capacitors

C1	0.1uF	VDD decoupling capacitor
C2	1.0uF	DVDD decoupling capacitor
C3	2.2uF	AVDD decoupling capacitor

Fig.12 Arrangement of external decoupling capacitors

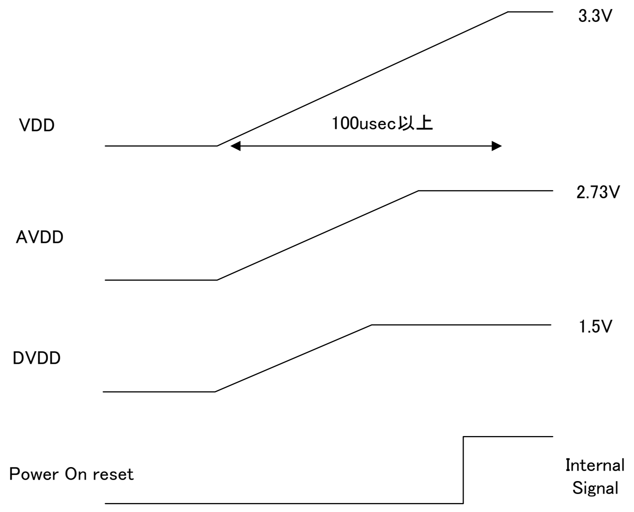


Fig.13 Power on timming chart
（BU21072MUV/BU21078MUV/BU21170MUV）

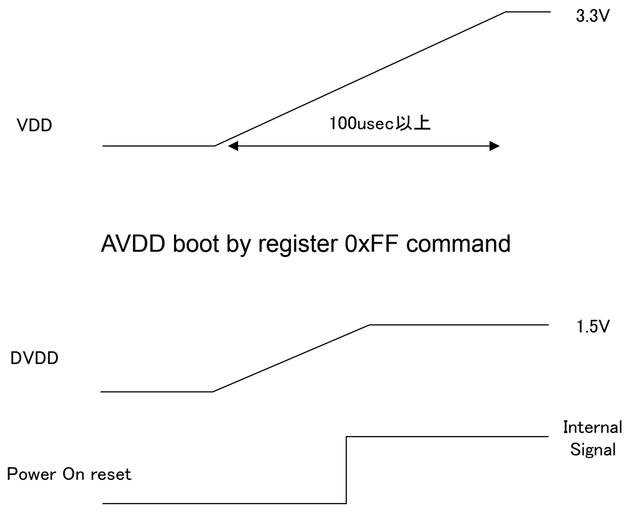


Fig.14 Power on timming chart
（BU21079F）

Initialization settings

This IC is initialized and all registers are cleared by Power-on reset, WDT time-out reset, and Software reset command. When initialization is complete, the register INI is set to '1' and I/O port INT is set to “H”.
After the IC is initialized, write the configuration values to registers. After setting configuration values, the next action is sensor calibration. Set ‘1’ to the registers ACT, CFG and CAL on Address 0xFF, so calibration sequence is performed.

- IC’s initialization after hardware reset

  - Power-on-reset
  - WDT time-out-reset
  - Software reset command

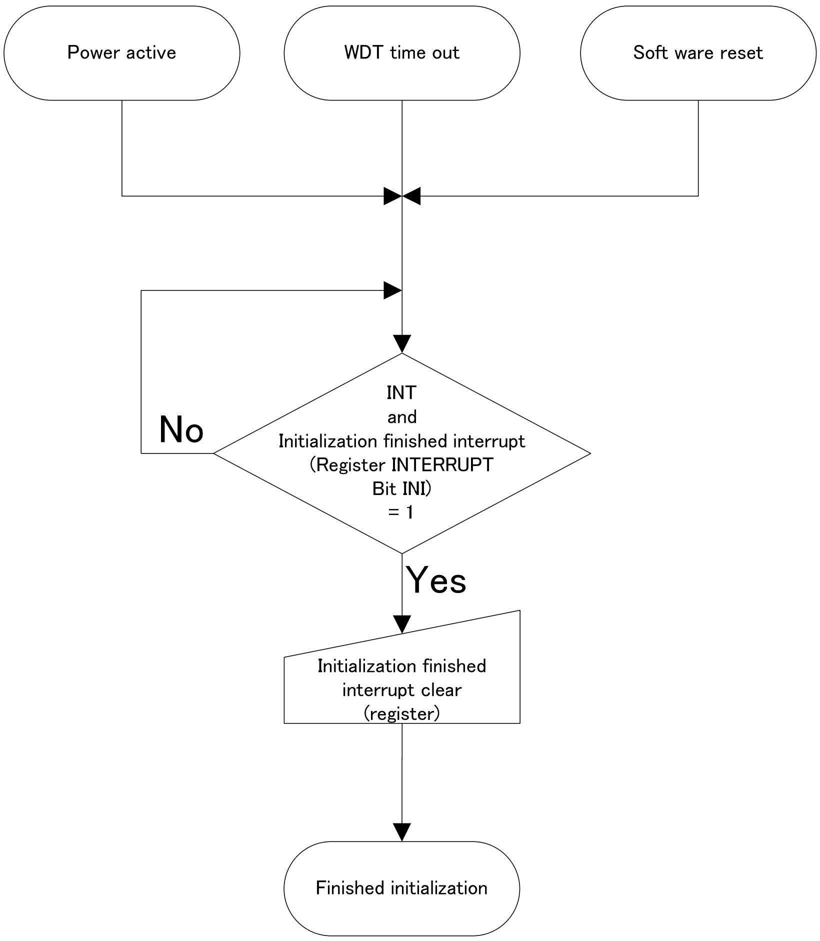


Fig.15 Initialization flow chart after hardware reset

The above actions act hardware reset to the IC. Hardware reset clear the all registers to the default value and initialize MPU. After hardware reset, MPU runs the initial sequence of firmware on Program ROM.

Timming chart at power on

【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】

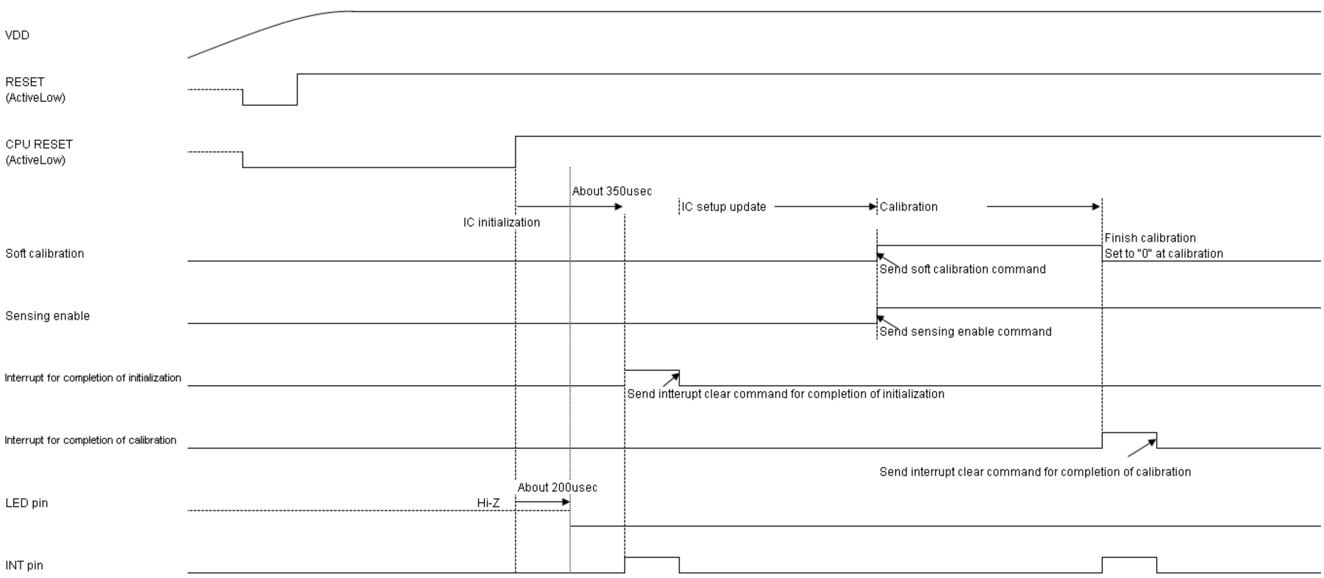


Fig.16 Timming chart at boot(BU21072/BI21078/BU21170)

【BU21079F】

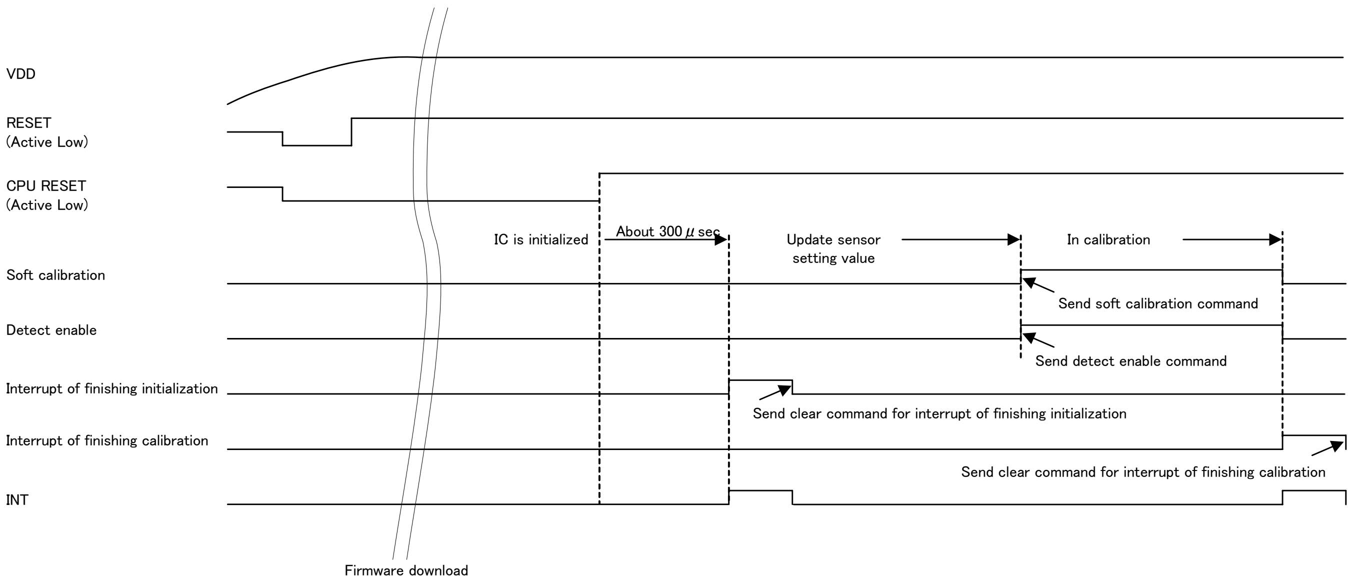


Fig.17 Timming chart at boot(BU21079)

Initial register settings

Ex.) Initial register settings【BU21072MUV/BU21078MUV/BU21078FV】

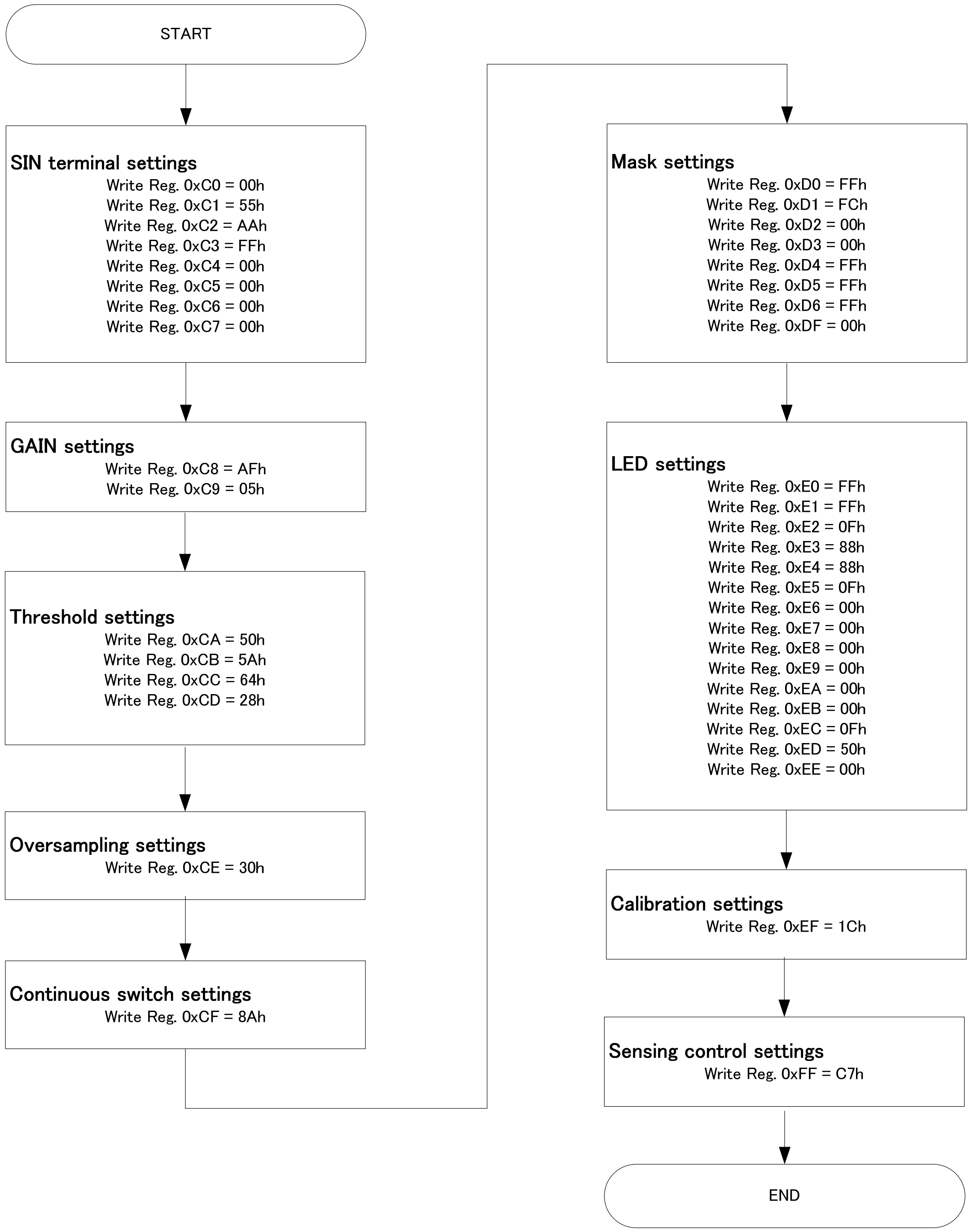


Fig.18 Initial register settings(BU21072MUV/BU21078MUV/BU21078FV)

Ex.) Initial register settings【BU21170MUV】

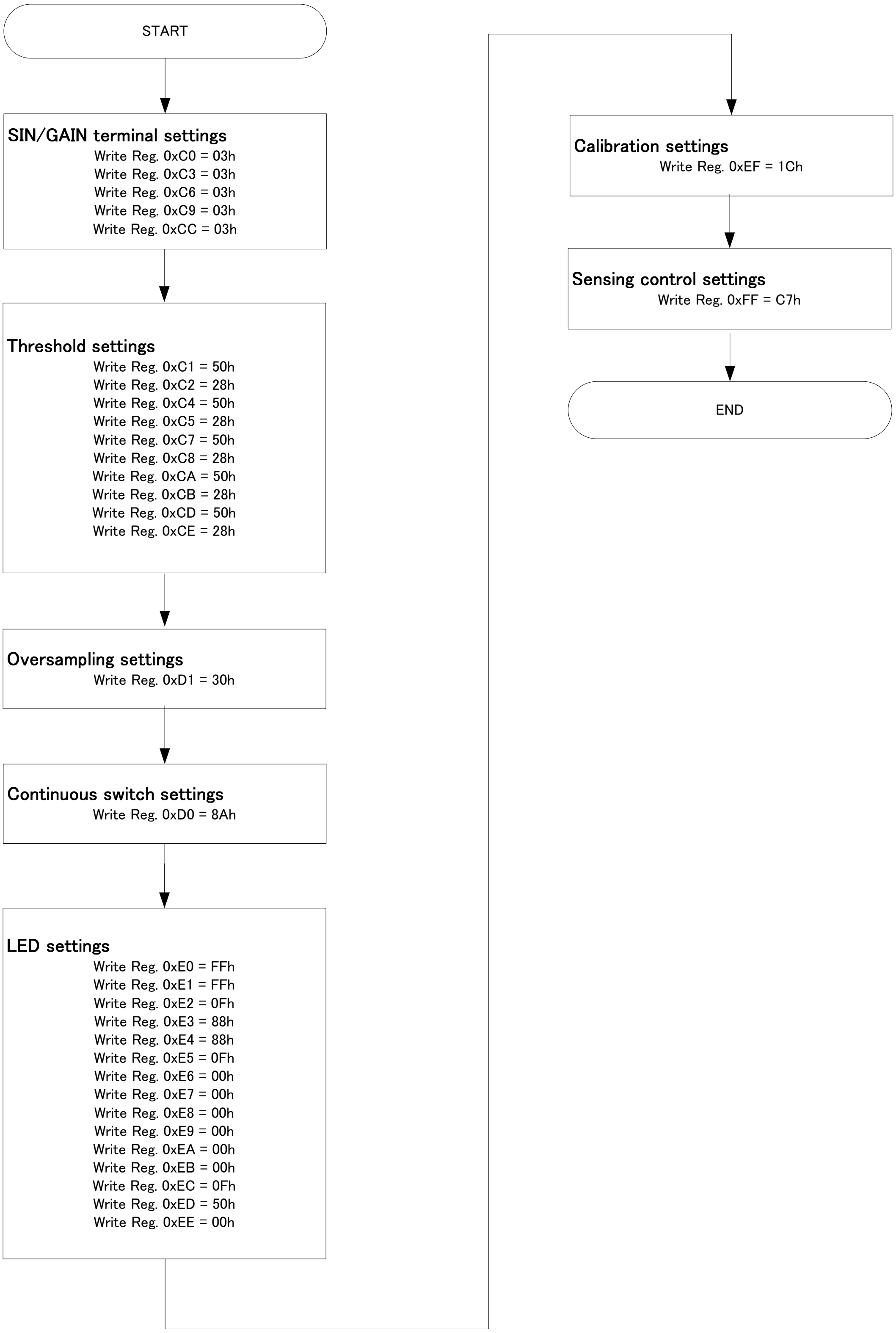


Fig.19 Initial register settings(BU21170)

Ex.) Initial register settings【BU21079F】

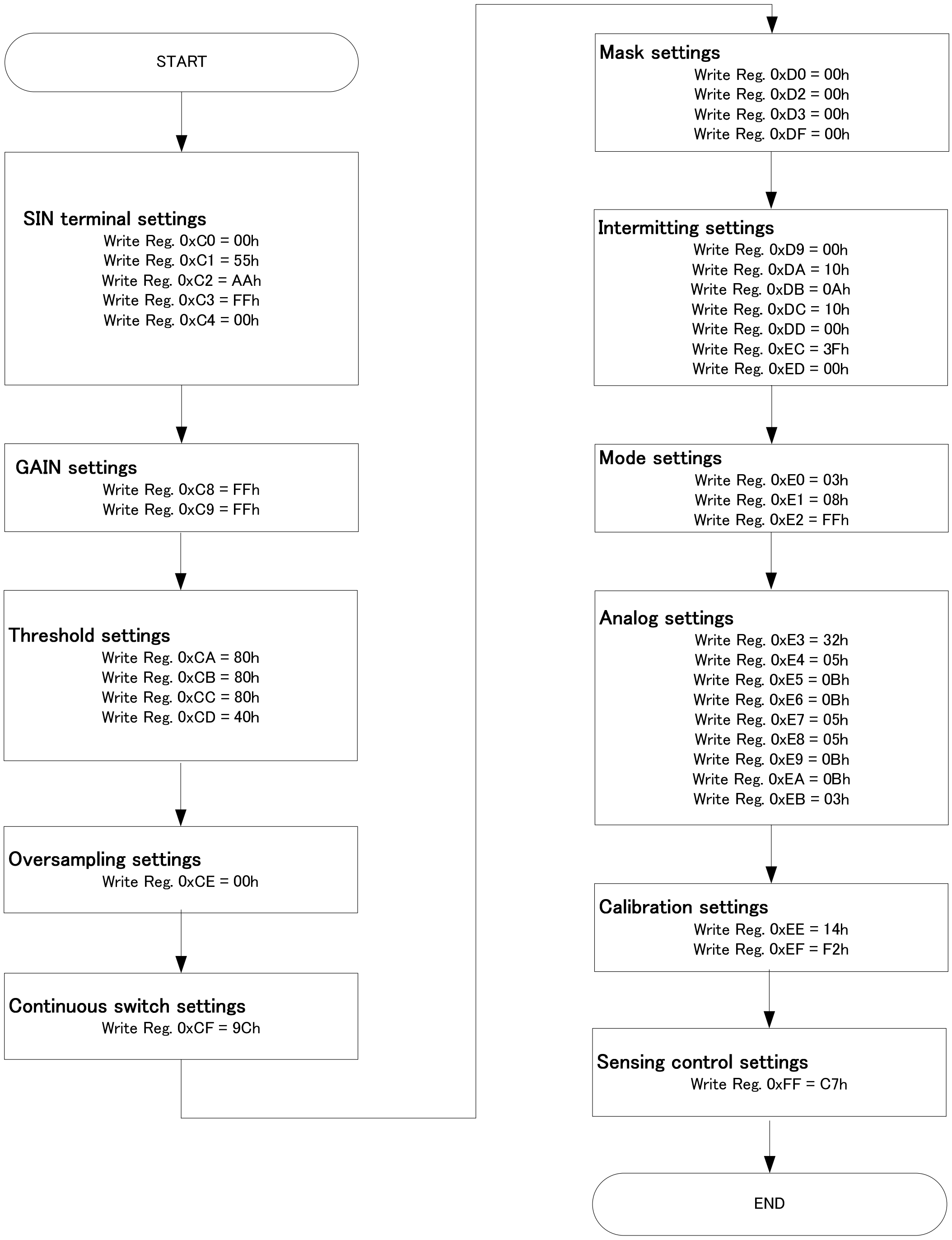


Fig.20 Initial register settings(BU21079)

Gain,Threshold settings【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV/BU21079F】

Register:0xC0～0xCD【BU21072MUV/BU21078MUV/BU21078FV】
Register:0xC0～0xCE【BU21170MUV】
Register:0xC0～0xCD【BU21079F】

The sensitivity of sensor depends on the area of sensor electrode, overlay thickness and parasitic capacitance. Therefore the sensitivity may be different every sensor terminal even if those are the same shape.BU21072MUV / BU21078MUV / BU21078FV / BU21079F can set 3 GAIN value and can select one from three groups. BU21170MUV can select GAIN setting from 4bit register. Please adjust GAIN settings each sensor terminals.

Threshold settings are are function to prevent the sensor from wrong recognition by noise. It is possible to set sensor value to recognize switch ON and OFF. BU21072MUV / BU21078MUV / BU21078FV / BU21079F can set 3 ON threshold value and 1 OFF threshold value. BU21170MUV can set ON/OFF threshold from 8bit register. Please adjust ON / OFF threshold value.

For decision flow chart of GAIN settings

1. Please set same GAIN value for all sensor terminals.

2. Please adjust GAIN value for sensor value to be within 100-254 at touch.

3. Please set GAIN settings to other groups about the sensor when the sensor value is not within 100-254.

4. Please confirm the sensor vlalue is within 100-254 at touch.

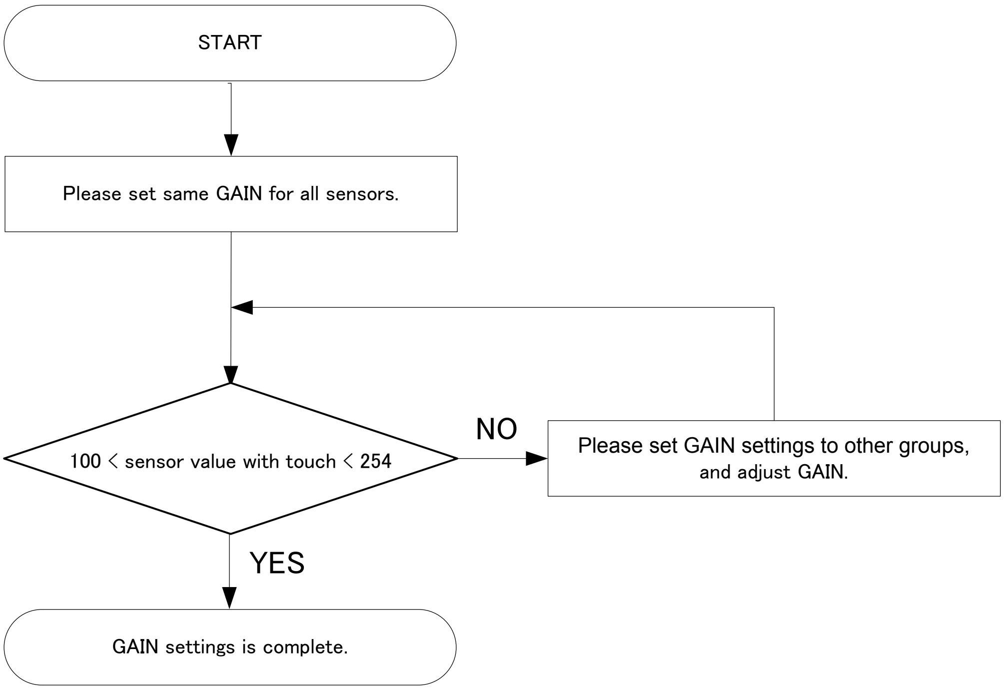


Fig.21 Flow chart for Gain settings

For decision flow chart of TH_ON / TH_OFF settings

Please set threshold value (TH_ON / TH_OFF) referring to below.

1. Please confirm the maximum sensor value with non-touch. (Floor noise)
2. Please confirm the maximum sensor value with touch at External noise test. (External noise)
3. Please set TH_OFF threshold value to be over than (External noise + Floor noise).
4. Please set TH_ON threshold value to be over than 2 * (External noise + Floor noise).
5. Please execute the noise examination and confirm to be able to recognize switch ON/OFF correctly.
   Please confirm that sensor value is over than TH_ON at touch by small finger.
   If the value is less than TH_ON, please adjust GAIN settings.

Ex.)

1. External noise = 30 count
2. Floor noise = 10 count
3. TH_OFF = 30 + 10 = 40 count
4. TH_ON = 2 x (30 + 10) = 80 count
5. Please confirm “Sensitivity when the thickness of the finger down 20% > TH_ON

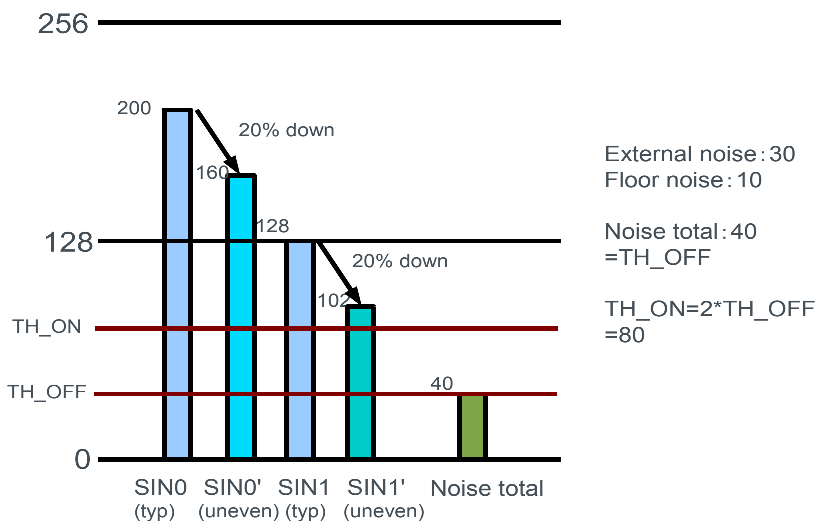


Fig.22 Threshold settings

Oversampling settings【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV/BU21079F】

Register:0xCE【BU21072MUV/BU21078MUV/BU21078FV】
Register:0xD1【BU21170MUV】
Register:0xCE【BU21079F】

Oversampling settings are function to prevent the sensor from wrong recognition by noise.
BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV recognizes as switch ON when touch state continues for oversampling setting value + 1 times. BU21079F recognizes as switch ON when touch state continues for oversampling setting value + 4 times. If you expect stable working, please set oversampling settings. But oversampling settings and response time for switch is like Fig.23. Please set an appropriate value.

Oversampling settings	ON detect time[msec] (typ.)		
	BU21072MUV BU21078MUV BU21078FV	BU21170MUV	BU21079F
0	48	44.4	30
1	48	44.4	30
2	64	59.2	36
3	80	74	42
4	96	88.8	48
5	112	103.6	54
6	128	118.4	60
7	144	133.2	66
8	160	148	72
9	176	162.8	78
10	192	177.6	84
11	208	192.4	90
12	224	207.2	96
13	240	222	102
14	256	236.8	108
15	272	251.6	114

Fig.23 The relation between oversampling and ON detection time

Continuous touch【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV/BU21079F】

Register:0xCF【BU21072MUV/BU21078MUV/BU21078FV】
Register:0xD0【BU21170MUV】
Register:0xCF【BU21079F】

This IC has the function to recognize continuous touch. It is possible to recognize continuous touch by setting this register. Please set if you need.

【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】
Continuous touch period = 0.1[sec] x setting value (0.1[sec] ≦continous touch period ≦6.3[sec])

【BU21079F】
Continuous touch period = 0.036[sec] x setting value (0.036[sec] ≦continous touch period ≦2.3[sec])

Confidential

LED settings【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】

Register: 0xE0-0xEE

It is possible to set PWM settings to GPIO terminal settings.PWM settings has 5 parameters.

1. RIS : Rising Period
2. FAL : Falling Period
3. ON : Lighting-On Period
4. OFF : Lighting-Off Period
5. REP : Repeat Count

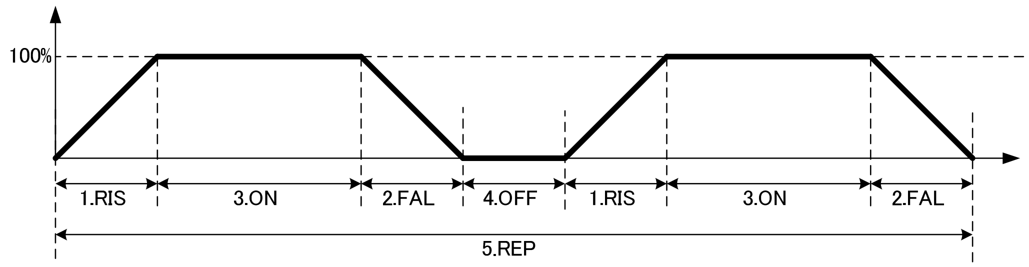


Fig.24 PWM settings

<u>Recommendation of external LED component</u>

Please have a circuit as shown in Fig.25 in case of using LED.
Resistor, Digital-transistor, and LED are needed.

Recommnedation parts
NPN Digital Transistor : DTC series (ROHM)
LED : SML series (ROHM)
R : MCR series (ROHM)

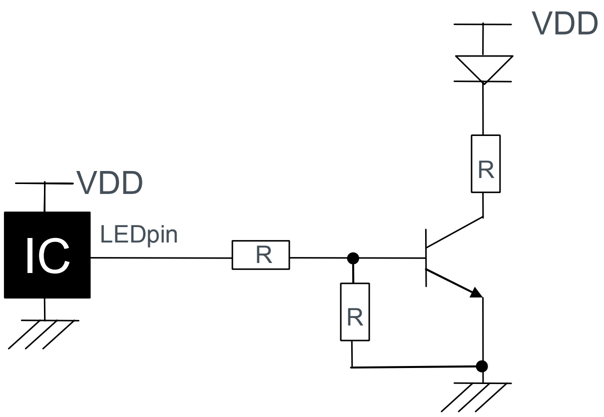
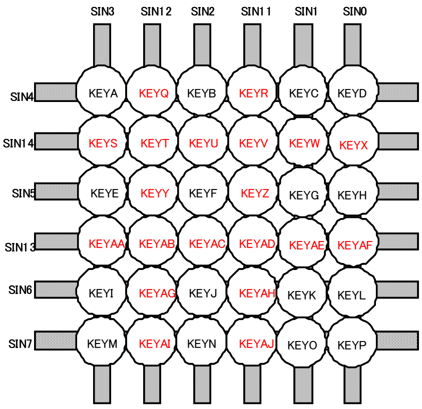


Fig.25 LED composition

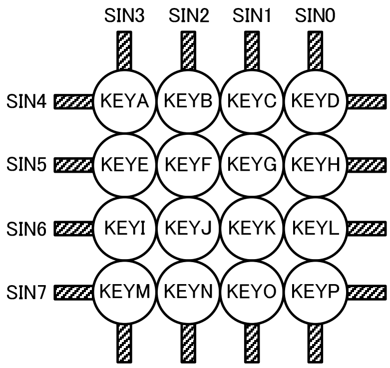
Matrix settings【BU21072MUV/BU21078MUV/BU21078FV/BU21079F】

Register: 0xD2-0xD3

It is possible to use cross point as key switch by arranging sensor terminals as matrix. Each matrix switch has the registers of detected Touch(DETECT_ON) / Release(DETECT_OFF) / Hold(DETECT_COND) operations. And Matrix switches do not support to multi-detect Touch / Release / Hold.



Layout for matrix switch
(BU21072MUV/BU21078MUV)



Layout for matrix switch
(BU21079F)

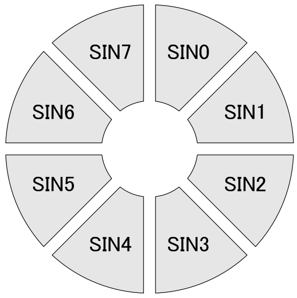
Fig.26 Layout for matrix switch

Slider settings【BU21079F】

Register: 0x14
Register: 0x17
Register: 0xD9
Register: 0xE0
Register: 0xF5

This is the function to detect the amount of movement of finger by using several sensor electrodes.It is possible to select sensor is used for slider and get a large amount of movement by placing sensor electrode as a loop-shaped electrode.
IC recognize the slider when the gravity center position move over than one, and the data “1” is written to the register EN_SLIDER(0x14[7]). IC recognize the movement like SIN0→SIN1→SIN2→…→SIN7 as a plus slider and the movement like SIN7→SIN6→SIN5→…→SIN0 as a minus slider. SLIDER_CNT is incremented by 1 when the gravity center position move by plus 0.5. SLIDER_CNT is decremented by 1 when the gravity center position move by minus 0.5. The slider recognition is finished when all sensor is OFF or the amount of movement for one sampling is over than 2. When the slider is finished, the data “1” is written to the register SLIDER_OFF(0x17[7]) and the register SLIDER_ON become to zero.
The register SLIDER_OFF is cleared by writing “0” to the register C_SLIDER_OFF(0xF5[7]).

Confidential



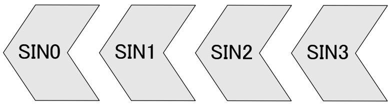


Fig.27 Layout for slider switch

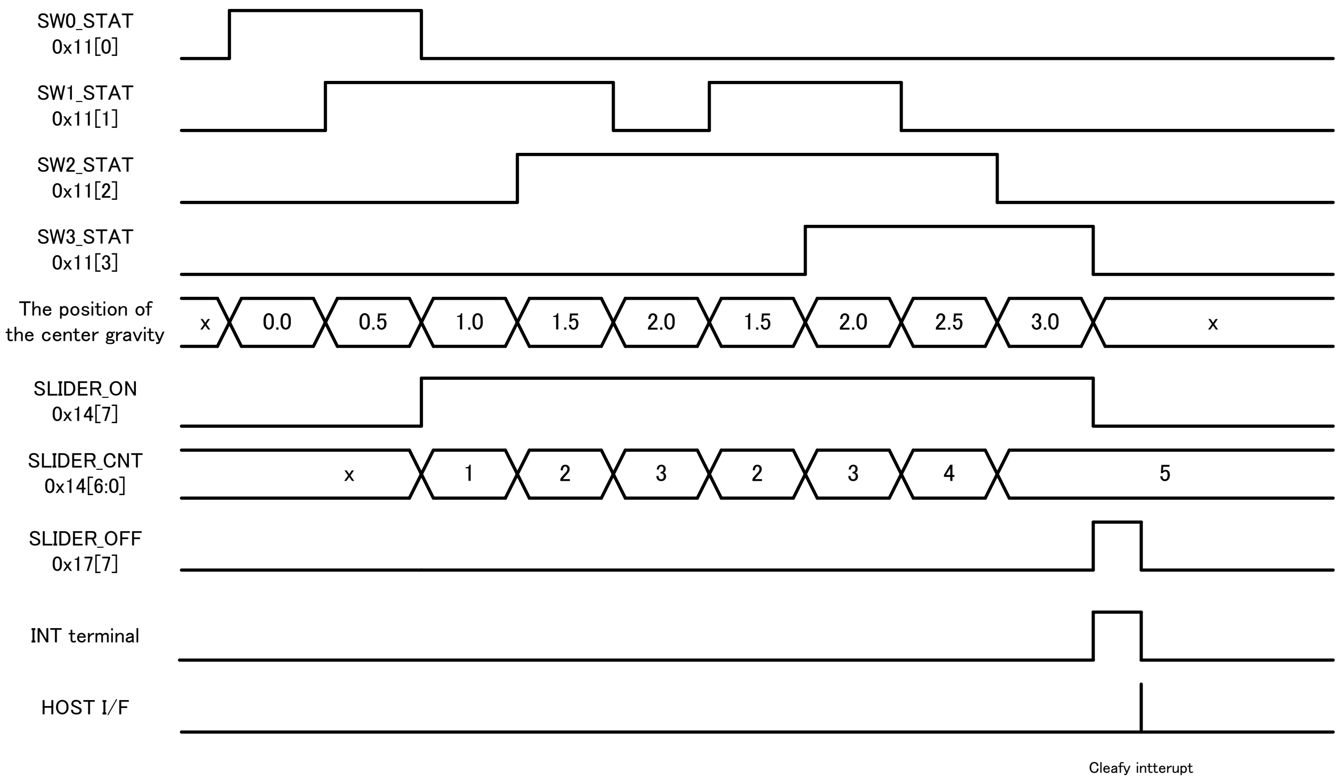


Fig.28 Slider function timming

Interrupt operation mode【BU21079F】

Register:0xDA～0xDD
Register:0xE0

This IC has three operational modes, [Stop mode], [Intermittent mode], and [Normal mode].

【Stop mode】
It is the state where detection is disabled.
Detection is stopped by setting '0' to ACT of the sensor motion control register CNT (address 0xFF).
A detection process is stopped and consumption current decreases by performing the power down of AFE.

【Normal mode】
In normal mode, detection is continuous.
Sensing is started by setting '1' to ACT of the sensor motion control register CNT (address 0xFF).
Starting detection and soft calibration is operated simultaneously.
Sensing in normal mode is defined as normal sensing.

【Intermittent mode】
Detection is thinned out. If the touch detection beyond a definite period of time is not recognized, it will shift to intermittent operation. In this state, since the frequency of sensing is low, current consumption can be reduced.
Sensing in intermittent operation is defined as check sensing.

< Timming chart with normal operation >

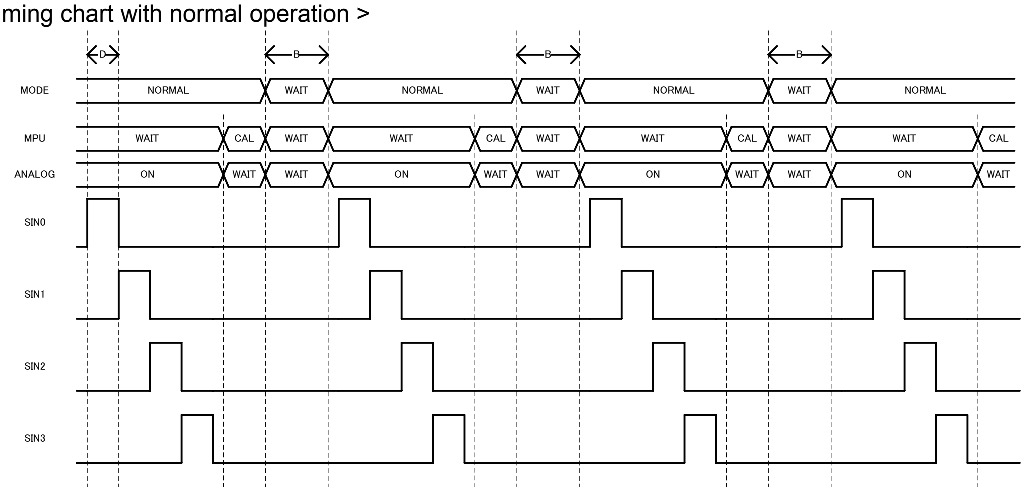


Fig.29 Timming chart with normal operation

<Timming chart with intermittent operation>

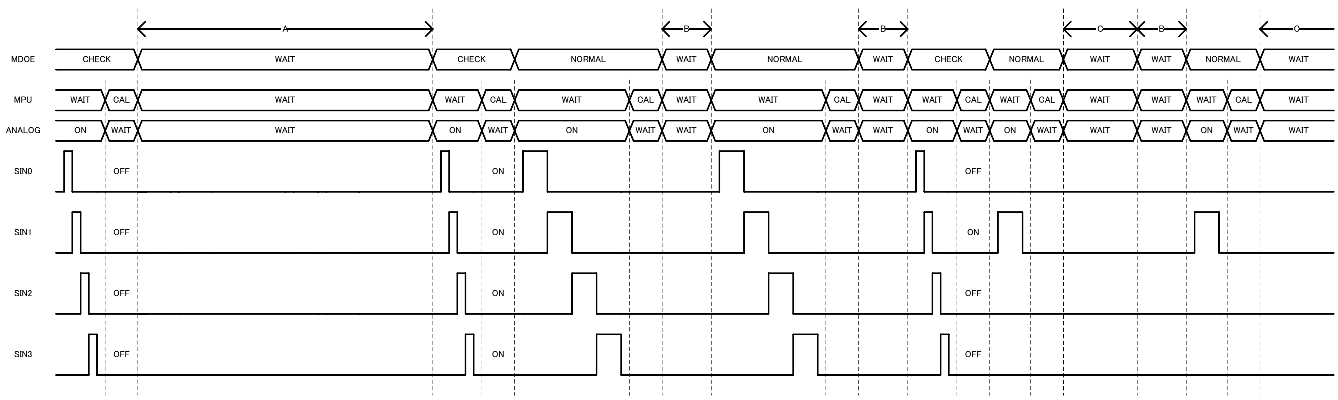


Fig.30 Timming chart with intermittent operation

Analog settings【BU21079F】

Register: 0xE3～0xEA【BU21079F】

It is possible to set integration times and sampling time in normal mode or intermitting mode. These recommended settings depend on the capacitance of sensor electrode and series resistance. If sensor electrode is within 22.5pF and series resitance is within 1k ohms, please set like below.

Register: 0xE3=32 (AFE integration number setting in normal mode)
Register: 0xE4=05 (AFE sampling time1 setting in normal mode)
Register: 0xE5=0B (AFE sampling time2 setting in normal mode)
Register: 0xE6=0B (AFE initial setting time in normal mode)
Register: 0xE7=05 (AFE integration number setting in intermittent mode)
Register: 0xE8=05 (AFE sampling time1 setting in intermittent mode)
Register: 0xE9=0B (AFE sampling time2 setting in intermittent mode)
Register: 0xEA=0B (AFE initial setting time in intermittent mode)

Caribration settings【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】

This IC has several kinds of calibration function.It takes about 150msec to finish the calibration.

Manual calibration

This calibration is executed manually by the host command (0xFF=03h).

・Soft calibration (0x10 / 0x1C / 0xDF / 0xF0 / 0xFF)
When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=02h), INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=02h).
The sensor value is not updated during a calibration, the sensor operation is disabled. The calibration is executed at next sampling in case soft calibration is sent during a sensor sampling.

*Please execute soft calibration when IC boots or reset.

Auto calibration

These calibration is executed automatically when IC detect the temperature drift and noise by sensor value.

・Periodic calibration (0x10 / 0x1C / 0xDF / 0xEF / 0xF0 / 0xFF)
This calibration is executed periodically by setting period calibration (0xEF). When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=01h), INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=10h).This calibration is not executed for the sensor detected ON, and is executed after the sensor become OFF.

*We recommend to setting periodic calibration in case it is easy for the sensor value to change by environmental change.

・Drift calibration (0x10 / 0x1C / 0xDF / 0xF0)
This calibration is excuted automatically when IC detects a change with time.IC recognizes a change with time when sensor value is over than a half of ON→OFF threshold value for several sensors. When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=04h).This calibration is not executed for the sensor detected ON, and is executed after the sensor become OFF.

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a change with time.

・Hopping calibration (0x10 / 0x1C / 0xCA-0xCD / 0xDF / 0xF0)
The sensing frequency is changed and this calibration is excuted automatically when IC detects noise.IC recognizes a noise when the sensor value less than minus ON→OFF threshold value. When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=04h).

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a noise.

・Calib-error calibration (0x10 / 0x1C / 0xDF / 0xF0)
When the calibaration is executed with finger on sensor electrode, sensor value become less than reference value after releasing finger. The calibration is executed automatically when IC detects this state. IC recognizes calib-error when the sensor value less than minus ON→OFF threshold value. When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=04h).

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a noise.

・LED calibration (0x10 / 0x1C / 0xDF / 0xEF / 0xF0 / 0xFA)
This calibration is executed automatically to calibrate the offset by LED when host access LED toun ON/OFF register 0xFA. When calibration is finished, the data “1” is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. This bit is masked by writing “1” to interrupt mask bit (0xDF=04h).

*Please set LED calibration when you use LED.

Caribration settings【BU21079F】

This IC has several kinds of calibration function.It takes about 150msec to finish the calibration.

Manual calibration

・Soft calibration (0x10 / 0x1C / 0xDF / 0xF0 / 0xFF)
This calibration is executed by the host command (0xFF=03h). When calibration is finished, the data "1" is wrrinten to the interrupt bit (0x10=02h), INT terminal become high. This bit is masked by writing "1" to interrupt mask bit (0xDF=02h). The sensor value is not updated during a calibration, the sensor operation is disabled. The calibration is executed at next sampling in case soft calibration is sent during a sensor sampling.

*Please execute soft calibration when IC boots or reset.

Auto calibration

These calibration is executed automatically when IC detect the temperature drift and noise by sensor value.

・Periodic calibration (0x10 / 0x1C / 0xDF / 0xE1 / 0xEF / 0xF0 / 0xFF)
This calibration is executed periodically by setting period calibration (0xE1). When calibration is finished, the data "1" is wrrinten to the interrupt bit (0x10=01h), INT terminal become high. This bit is masked by writing "1" to interrupt mask bit (0xDF=10h).This calibration is not executed for the sensor detected ON, and is executed after the sensor become OFF.

*We recommend setting periodic calibration in case it is easy for the sensor value to change by environmental change.

・Drift calibration (0x10 / 0x1C / 0xDF / 0xE1 / 0xEF / 0xF0)
This calibration is excuted automatically when IC detects a change with time.IC recognizes a change with time when sensor value is over than a half of ON→OFF threshold value for several sensors. When calibration is finished, the data "1" is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. This bit is masked by writing "1" to interrupt mask bit (0xDF=04h).This calibration is not executed for the sensor detected ON, and is executed after the sensor become OFF.

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a change with time.

・Hopping calibration (0x10 / 0x1C / 0xCA-0xCD / 0xDF / 0xE1 / 0xF0)
The sensing frequency is changed and this calibration is excuted automatically when IC detects noise.IC recognizes a noise when the sensor value less than minus ON→OFF threshold value. When calibration is finished, the data "1" is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. This bit is masked by writing "1" to interrupt mask bit (0xDF=04h).

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a noise.

・Calib-error calibration (0x10 / 0x1C / 0xDF / 0xE1 / 0xF0)
When the calibaration is executed with finger on sensor electrode, sensor value become less than reference value after releasing finger. The calibration is executed automatically when IC detects this state. IC recognizes calib-error when the sensor value less than minus ON→OFF threshold value. When calibration is finished, the data "1" is wrrinten to the interrupt bit (0x10=04h), INT terminal become high. INT terminal become high. This bit is masked by writing "1" to interrupt mask bit (0xDF=04h).

*Please set OFF→ON threshold value and ON→OFF threshold value properly to detect a noise.

・Return calibration (0xC1 / 0xDF / 0xE1 / 0xEF)
This calibration is executed automatically when IC don't detect touch ON over than for sensing times (0xEF) after changing from intermitting mode to normal mode.When calibration is finished, the data "1" is wrrinten to the interrupt bit (0xC1=01h), INT terminal become high. INT terminal become high.

*Please set return calibration when you use at intermitting mode.

Seinsing control settings【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV/BU21079F】

Register: 0xFF

The settings for initial register are enable by writing “1” to this register (CFG). Please send “1” when you change settings.
The sensing starts by sending “1” to this register (ACT).

Typical application circuits

【BU21072MUV/BU21078MUV/BU21078FV/BU21170MUV】

BU21072MUV / BU21078MUV / BU21078FV offer 2 type switches. One is simple switch, another is matrix switch. The maximum number of matrix swithes are 16 switches (4 x 4) in case BU21072MUV, 36 switches (6x6) in case BU21078MUV / BU21078FV. BU21170 offer only simple switch. LED ports have PWM function, and can control brightness as fade-in / fade-out function.

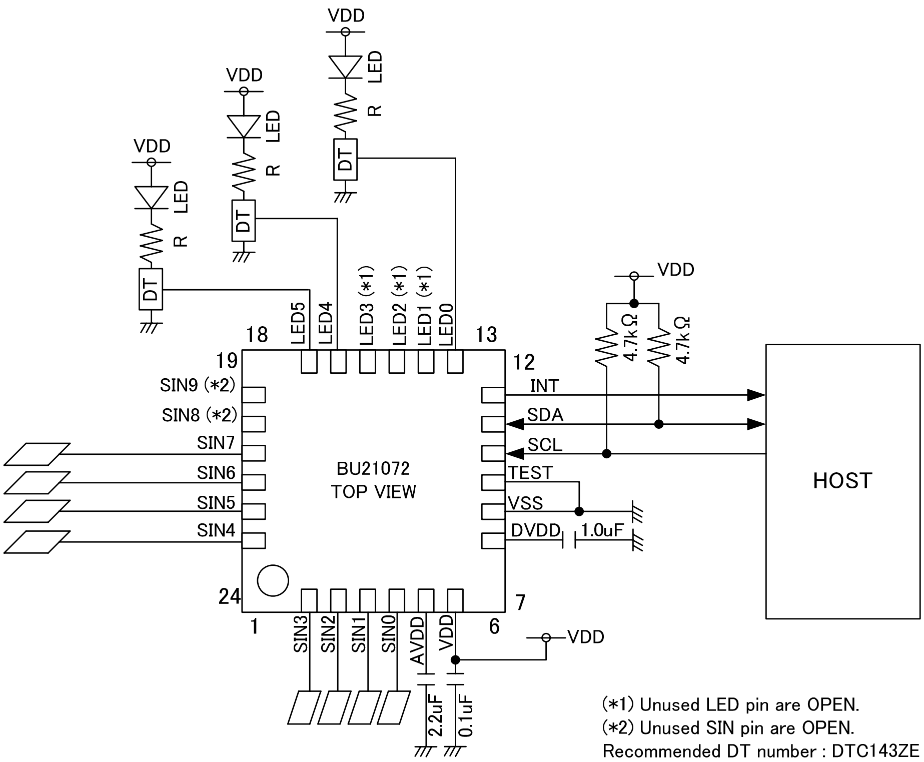


Fig.31: Application example1 (BU21072MUV / 8 single switches, 3-LEDs)

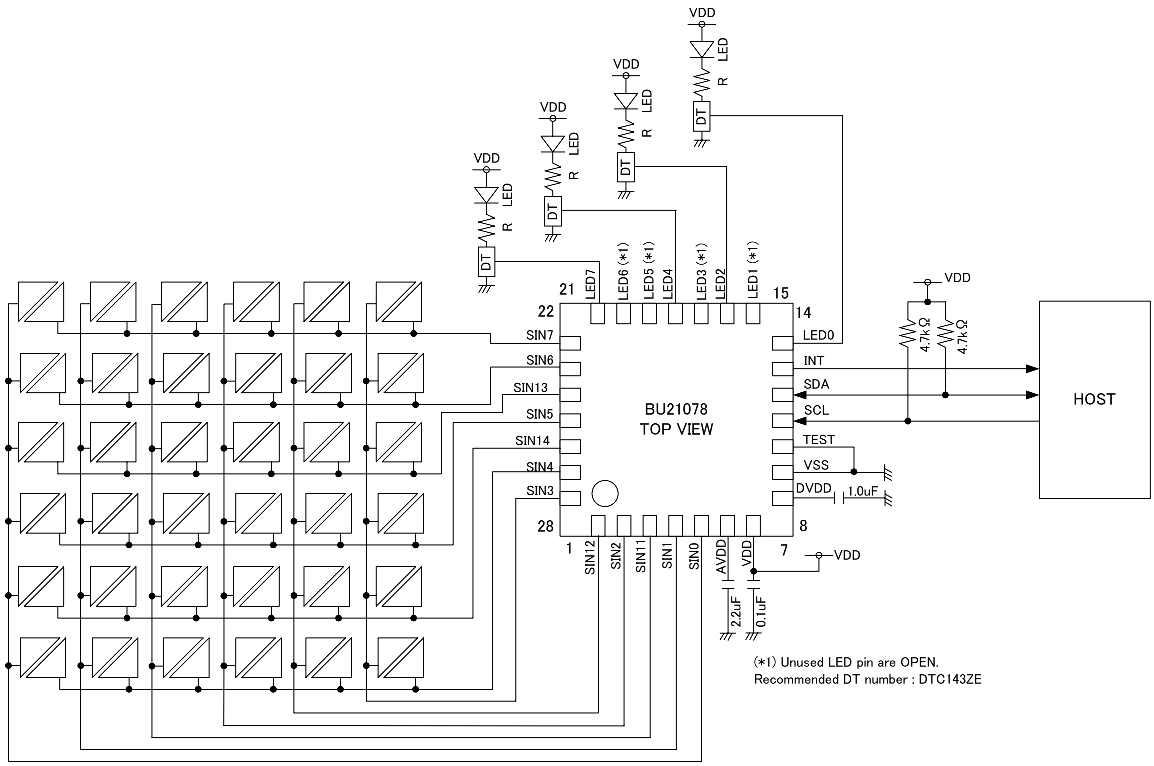


Fig.32: Application example2 (BU21078MUV / 6 x 6 matrix switches, 4-LEDs)

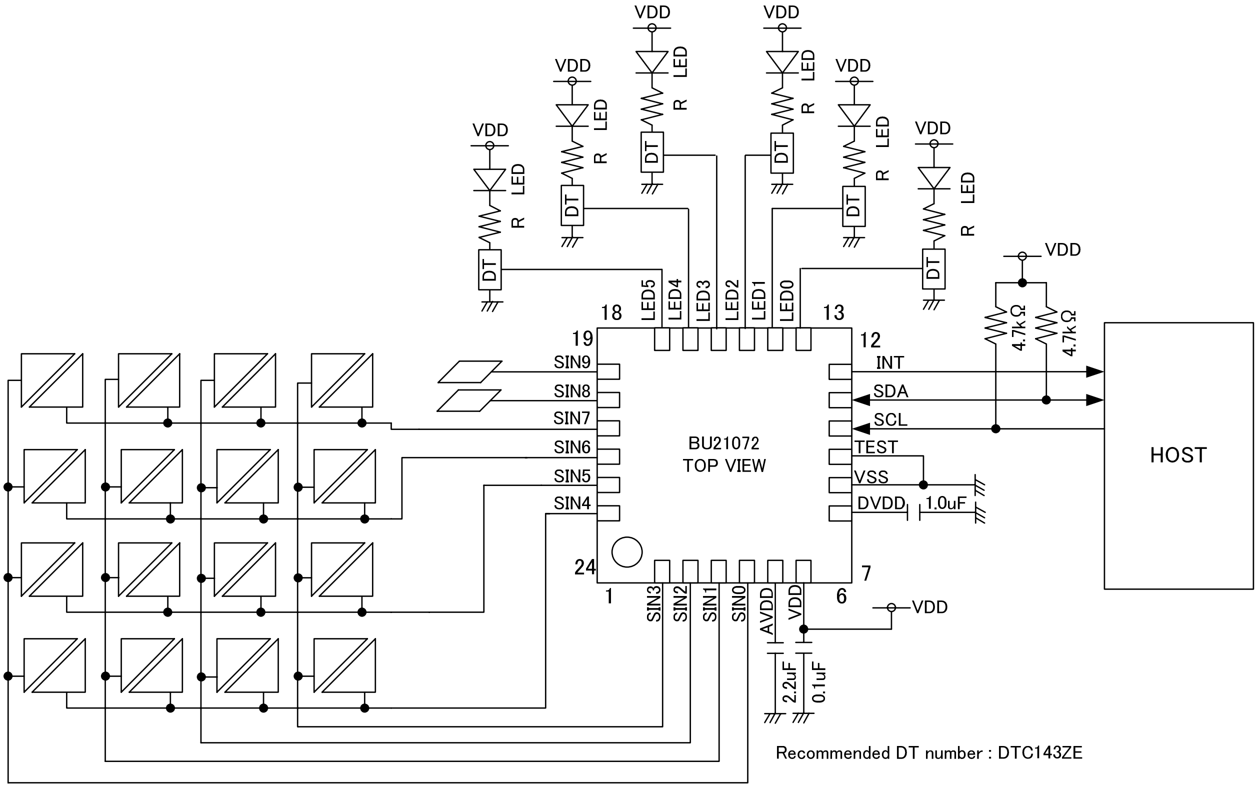


Fig.33: Application example3 (BU21072MUV / 4 x 4 matrix switches, 2 single switch, 6-LEDs)

【BU21079F】

BU21079F offer 2 type switches. One is simple switch, another is matrix switch. The maximum number of matrix swith are 16 switches (4 x 4) in case BU21079F.

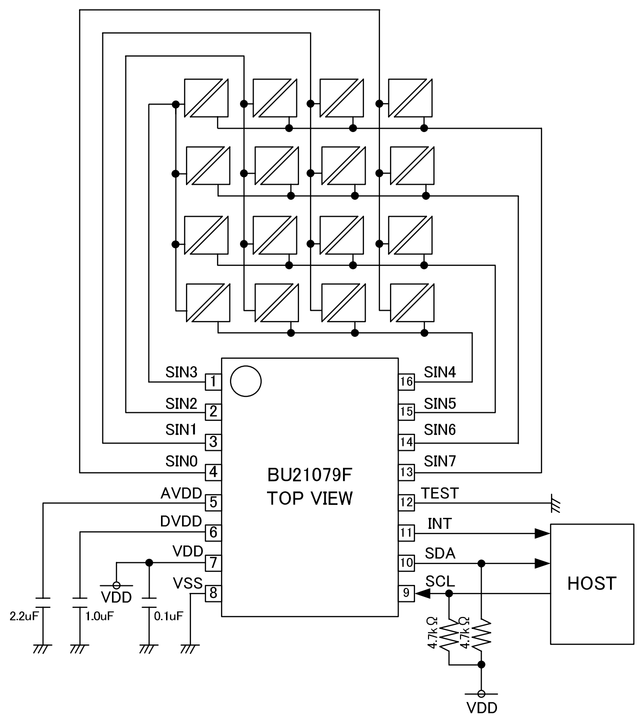


Fig. 34: Application example4 (BU21079F / 4 x 4 matrix switches)

PCB layout guideline
PCB parasitice capasitance

It is necessary to reduce the parasitic capacitance of a sensor terminal to increase sensitivity
The place where parasitic capacitance is formed easily is like below. Please be carefull at PCB design.

1. Cpad1 : Metal of the back side layer of the sensor electrode
2. Cpad2 : Metal of the back side layer of the sensor electrode
3. Cline1 : Metal of the back side layer of the sensor wiring
4. Cline2 : Metal of the same layer to side by side with sensor wiring

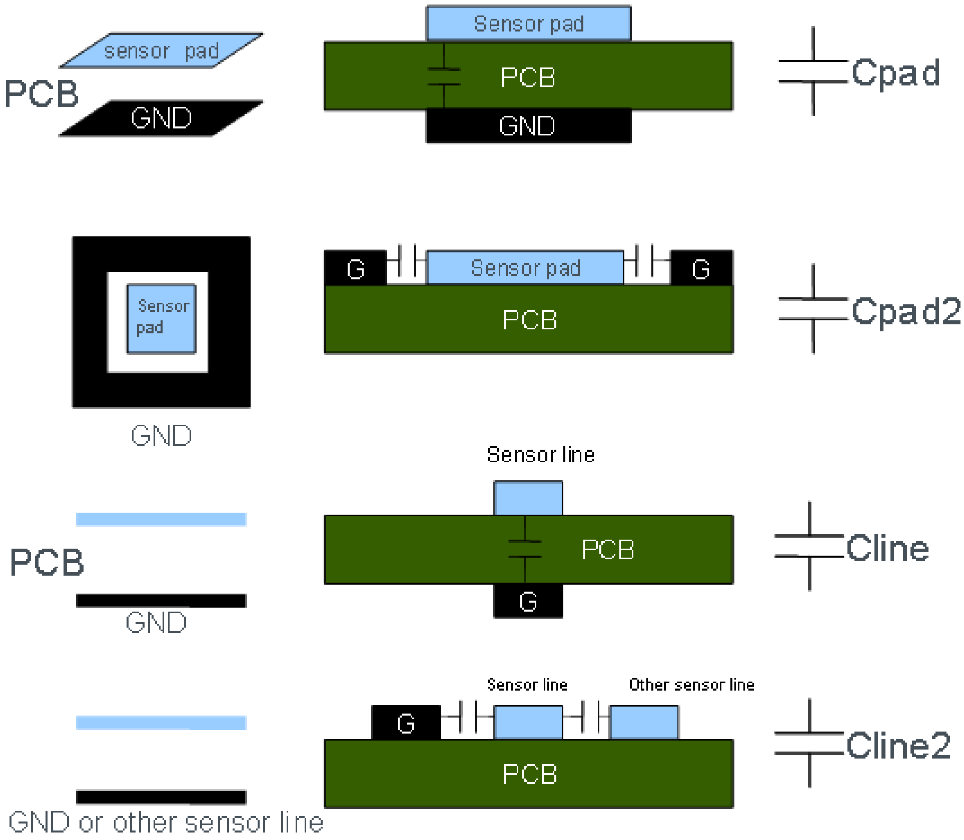


Fig.35 Parasitic capacitance structure of sensor terminal

The estimation for parasitic capacitance

Parasitic capacitance C = e0 ∗ er ∗ S / d

e0: The dielectric constant of the vacuum:8.85e-12 F/m
er: The dielectric constant of board materials:5.2(FR4)
S: Area
d: Distance

The dominant capacitance is Cpad. Please don't place GND except for the case where a noise source is expected from the backface of a sensor electrode.

ESD portection

Please place GND to the board circumference (both sides) in order to increase the ESD resisting pressure of the sensor module. In addition, please connect double-sided GND every 5mm - 10mm by VIA. By doing in this way, when serge rushes in from the module exterior, serge flies to VIA of GND. That serge flies to the GND line of low impedance can fly outside serge besides a module efficiently.

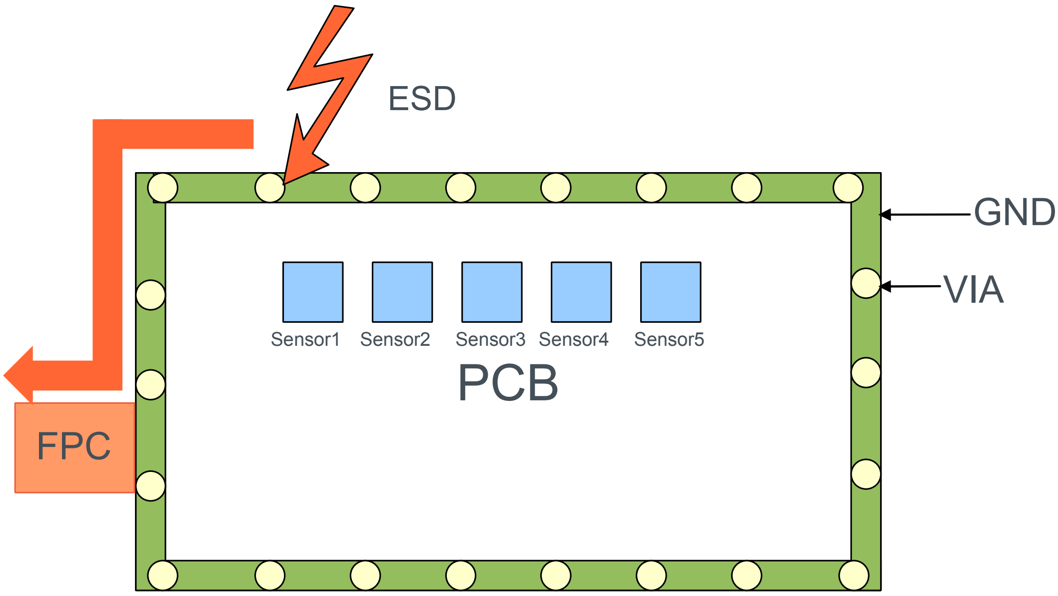


Fig.36 Layout for ESD protection

EMI protection

The sensor terminal which is carrying out charge and discharge at high speed may become the cause of raising an EMI level (ringing wave). It will raise an EMI level that a ringing wave pattern occurs when making it short-circuit with the inside of IC after charge, when doing H charge and L charge of a sensor terminal. Moreover, small parasitic capacitance is advantageous, since the size of a ringing wave pattern is proportional to the size of the parasitic capacitance of a sensor electrode.
Please insert resistance in a sensor terminal not to take out a ringing wave pattern; (1kΩMAX). This resistance can restrict current, ringing can be limited and an EMI level can be decreased.
*When limit resistance is enlarged too much, a sensitivity decline will be happen.
*The sensitivity of the IC does not have the temperature characteristics. However, please keep in mind that there is a possibility of changing the sensitivity of IC if resistance has temperature characteristics.

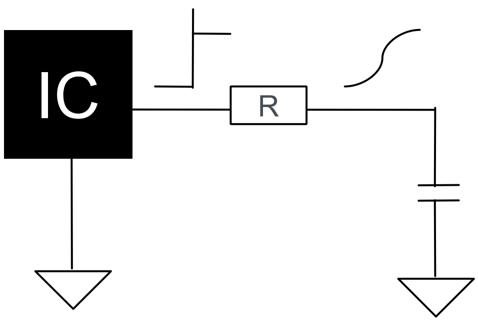


Fig.37 EMI control resistance

When ringing wave pattern in the IC side of resistance R passes R like Fig.37, it will be filtered. Therefore, Please place resistance R near the IC pin.

Effect of GND node around sensor electrode

GND wiring around sensor electrode become a reason to decrease sensitivity because of increasing parasitic capacitance.But it is necessary to place GND wiring around sensor electrode from the point of view of stability of sensor value.In case GND connected to human body and GND connected to IC is same potential, the IC realize that the finger of the ground electric potential has approached the sensor electrode when touched with a finger, and sensor value is increased for increased capacity. But the sensor value is affected because GND connected to IC and GND connected to human finger is different potential when GND potential of IC changes by the noise.The sensor value is stable when GND on application and GND connected to human body is same potenatial. But this is so difficult and we recommend placing GND around a sensor electrode for these GND to be same potential. (it separates from an electrode 1 mm or more).

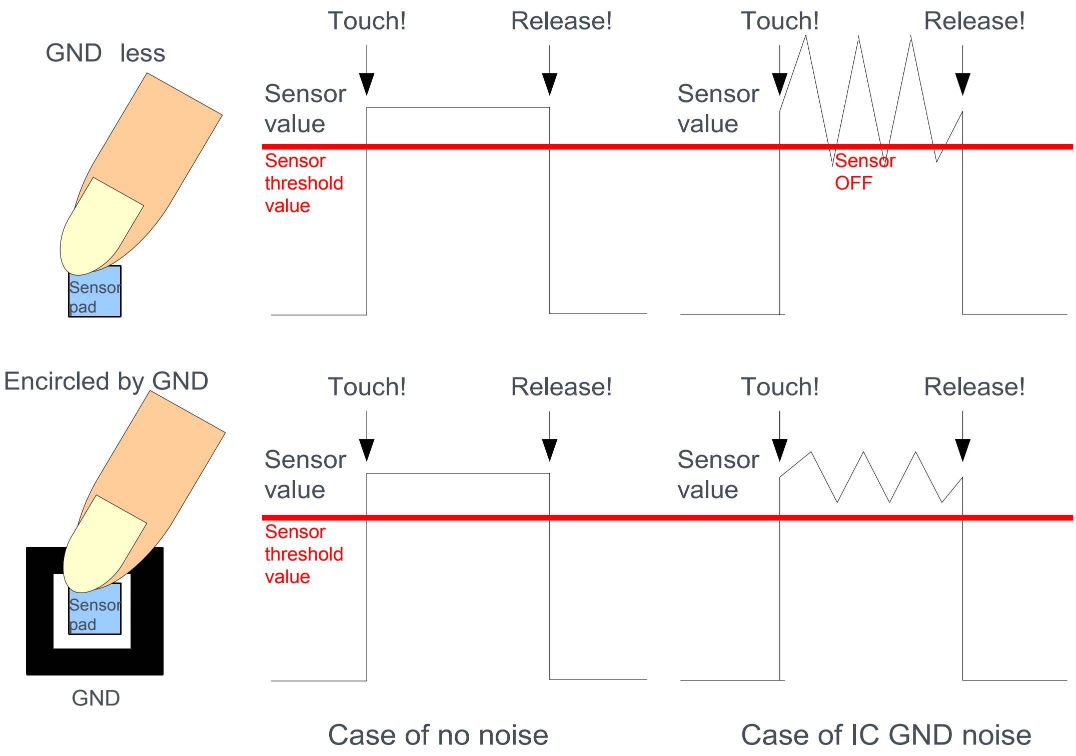


Fig.38 Coupling of PCB GND and human body

Recommendation for sensor electrode and sensor line shape

<Sensor electrode shape>

Fig.39 Recommendation for sensor elecrode shape

Circle and square shape are recommended by considering finger shape. If it is impossible to use circle and square shape, please consider finger shape and decide the shape.

<Sensor wiring shape>

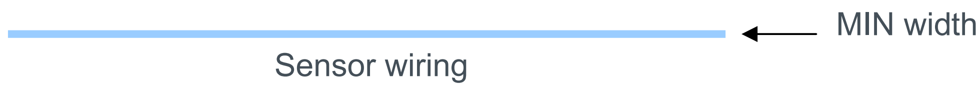


Fig.40 Recommendation for sensor wiring shape

Please wire between IC and sensor electrode with minimum width. Sensor wiring is same as sensor electrode.
It is hard for sensor wiring to response by using minmum width.

Recommendation for GND node arounde sensor electrode

<Around sensor electrode >

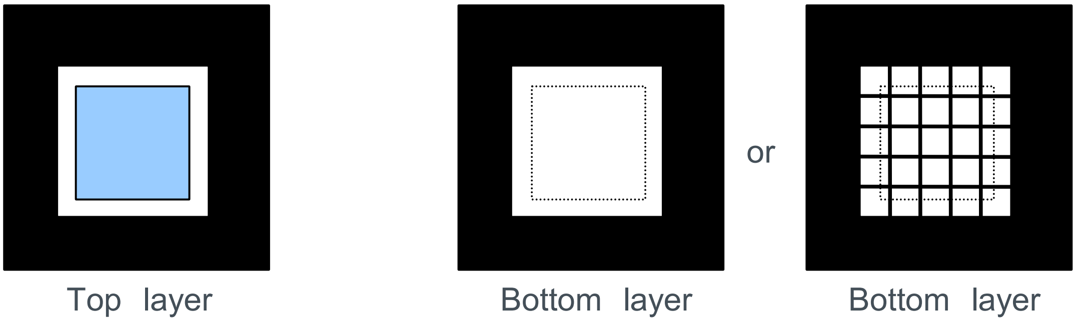


Fig.41 GND around sensor electrode

Top layer
Distance between a sensor electrode and the GND: 1mm or more

Bottom layer
The sensor electrode back side: There is no GND or mesh.

<Around sensor wiring>

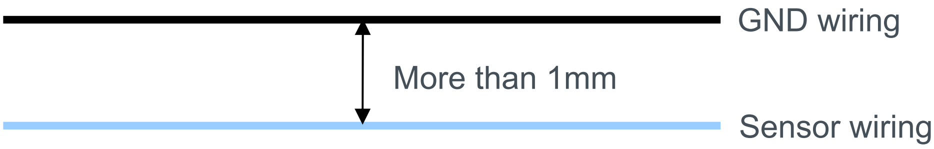


Fig.42 GND of around sensor wiring

Please keep the space over than 1mm between sensor wiring and GND wiring.

Recommendation of the wiring for sensor line

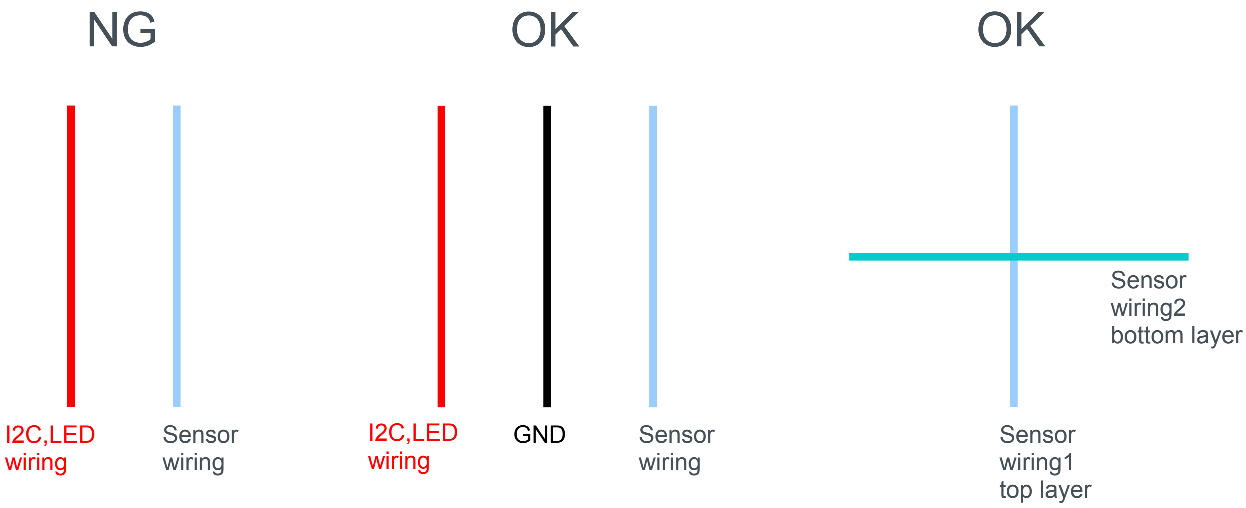


Fig.43 Wiring for sensor

Please avoid the side-by-side of a digital line and a sensor line. When a sensor line and a digital line draw side by side reluctantly, please insert GND in between. In addition, the cross between sensor lines does not have any problem because sensing does not do sensors more than two at the same time.

Influence and protectiion for water

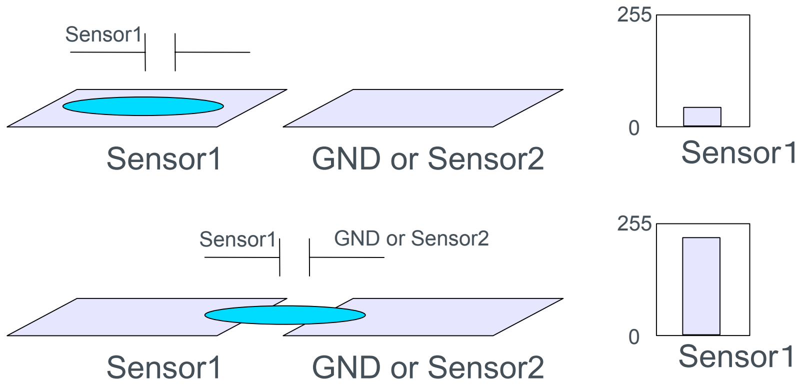


Fig.44 Influence by water on a sensor electrode

Fig.44 shows the change of the sensor value when water is attached on a sensor electrode. It does not become a large change of sensor value by water being attached on one sensor. But it become a large change of sensor value by water being attached on two sensor or GND layer because the capacitance is formed between a sensor electrode and other sensor. If you prevent from wrong recognition by water, please connect sensor terminal to Guard sensor which made on PCB for protection (Fig.45)

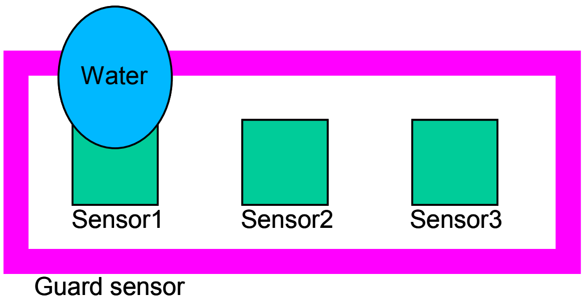


Fig.45 Water protection by Guard sensor

Guard sensor become ON state when water is on sensor electrode and Guard sensor. Please prohibit recognizing interrupt of switch state and execute the host calibration when Guard sensor become ON state. It is possible to detect touch because offset is calibrated by the host calibaration and the sensor value become to zero. Please be carefule of the distance between sensor electrode and guard sensor because guard sensor may become ON by finger touch.

Caution for evaluation by mechanical finger

Tha capacitance (C1) is formed depending on the contact area between a sensor electrode and a finger. The capacitance of a human body (C2) is connected to earth ground with strong conbined states. The capacitance of a tentative finger (C3) is connected to other dielectric with weak conbined state through air.The sensitivity become low because combination is weak and electric potential of tentative finger is not stable.When you evaluate by using tentative finger, please connect tentative finger to ground of application for the sensitivity of tentative finger to be same as the sensitivity of human finger.

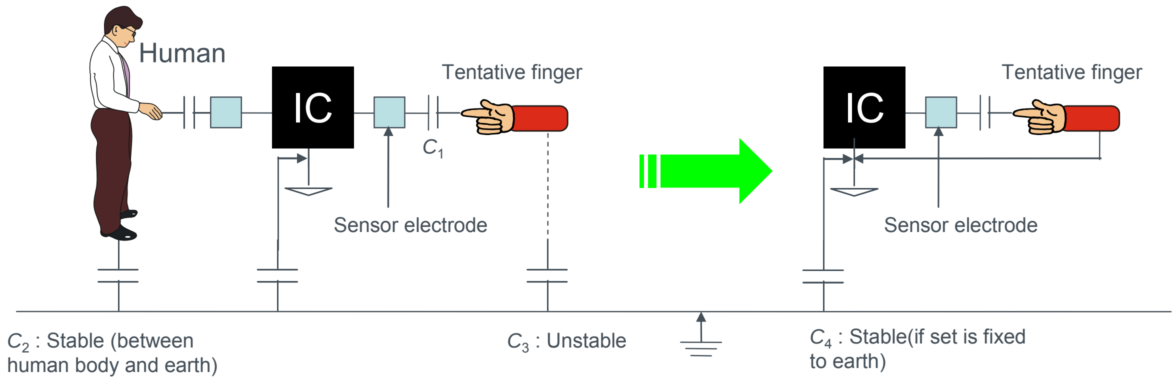


Fig.46 Connection for tentative finger

Ex.) PCB layout

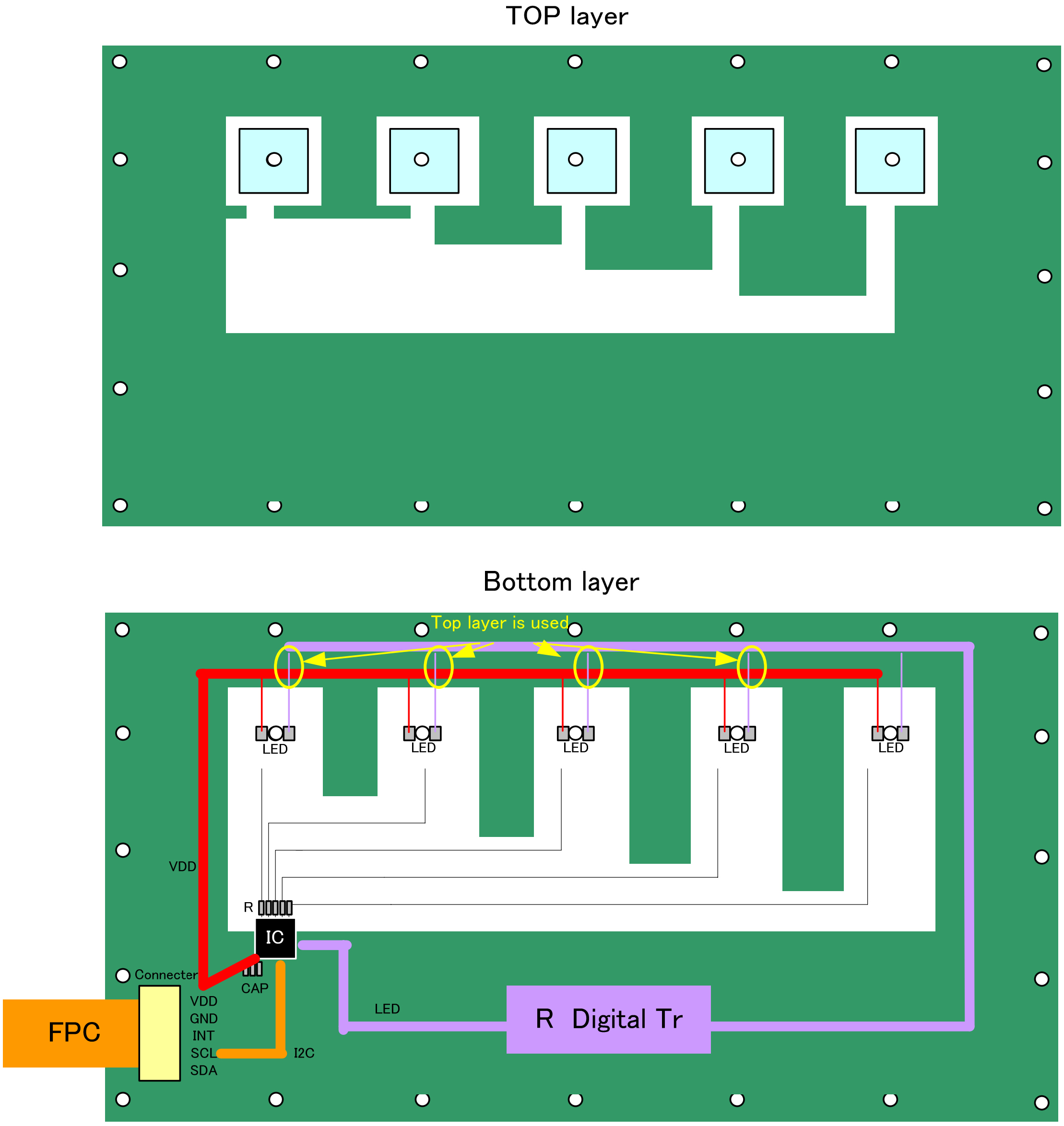


Fig.47 Example for PCB layout

1. Please insert series resistance in a sensor terminal for EMI measures.(up to 1kohm)
2. Please insert GND and VIA in board bouds for ESD measures.
3. We recommend placing parts on backface side. The surface of PCB flats, and overlay processing is unnecessary.
4. We recommend placing sensor line on bottome layer for sensor value not to change by touch.
5. Please don't place GND line around sensor line.
6. Please place IC near FPC to reduce the impedance of VDD,GND,I2C signal line.
7. Please place the capasitor for VDD, AVDD and DVDD near IC terminals.
8. Please don't place the LED wiring along with a sensor line.
9. Please be open for SIN and LED terminals not to use.

Operatinal Notes

1. **Reverse Connection of Power Supply**
Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. **Power Supply Lines**
Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. **Ground Wiring Pattern**
When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Thermal Consideration**
Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

6. **Recommended Operating Conditions**
These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

7. **Inrush Current**
When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

8. **Operation Under Strong Electromagnetic Field**
Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

9. **Testing on Application Boards**
When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

10. **Inter-pin Short and Mounting Errors**
Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

11. **Unused Input Pins**
Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

12. **Regarding the Input Pin of the IC**
In the construction of this IC, P-N junctions are inevitably formed creating parasitic diodes or transistors. The operation of these parasitic elements can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions which cause these parasitic elements to operate, such as applying a voltage to an input pin lower than the ground voltage should be avoided. Furthermore, do not apply a voltage to the input pins when no power supply voltage is applied to the IC. Even if the power supply voltage is applied, make sure that the input pins have voltages within the values specified in the electrical characteristics of this IC.

Operational Notes – continued

13. **Ceramic Capacitor**
    When using a ceramic capacitor, determine the dielectric constant considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

14. **Area of Safe Operation (ASO)**
    Operate the IC such that the output voltage, output current, and power dissipation are all within the Area of Safe Operation (ASO).

15. **Over Current Protection Circuit (OCP)**
    This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.