

# ADSemiconductor®

" Free from Common Mode Noise "

---

**TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)**

---



**TSM16C**

---

16-CH Auto Sensitivity Calibration Capacitive Touch Sensor

---

## SPECIFICATION

VER. 1.1

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### General

The TSM16C is 16-Channel capacitive sensor with auto sensitivity calibration. And the supply voltage range is from 1.8 to 5.0V.

The TSM16C has the SLEEP mode to save the consumption. And the current consumption is 8 uA.

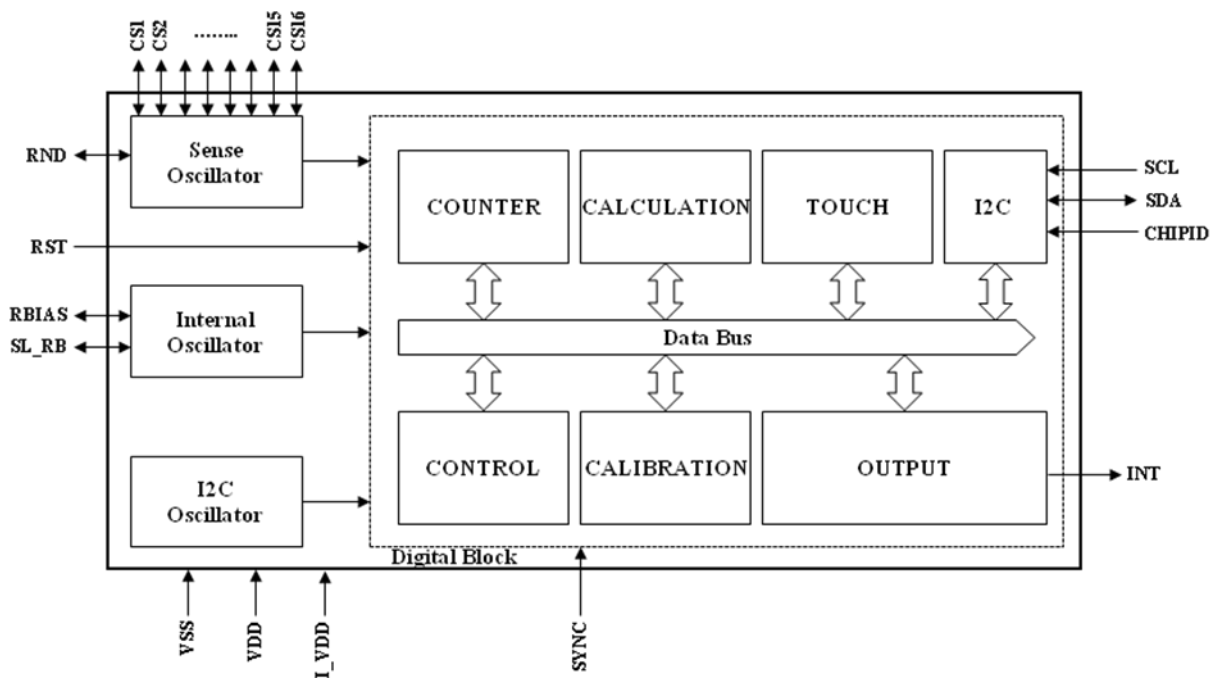
The TSM16C offers fast touch detection with fast response operation.

The result of touch sensing can be checked by the I<sup>2</sup>C serial interface. And touch intensity can be detectable within 3 steps (Low, Middle and High).

### Feature

- 16-Channel capacitive sensor with auto sensitivity calibration
- Selectable output operation (single mode / multi-mode)
- Independently adjustable in 8 step sensitivity
- Adjustable internal frequency with external resistor
- Adjustable response time and interrupt level by the control registers
- I2C serial interface
- Embedded high frequency noise elimination circuit
- Typical current consumption xxx 45 uA (@3.0V)
- Sleep mode current consumption 8 uA (@3.0V)
- RoHS compliant 28QFN package

### Block Diagram



### Application

- Mobile application (mobile phone / PDA / PMP etc)
- Membrane switch replacement
- Sealed control panels, keypads
- Door key-lock matrix application
- Touch screen replacement application

### Ordering Information

Part No.	Package
TSM16C	28 QFN

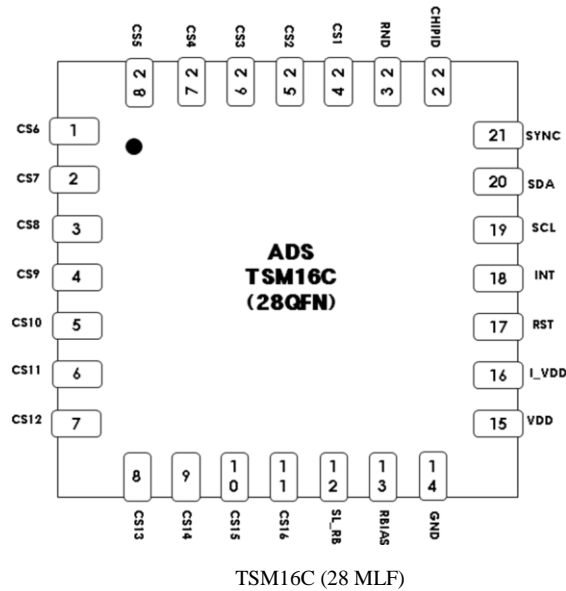
## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### Content

General.....	2
Revision History .....	3
1 Pin Configuration .....	5
2 Pin Description .....	6
2.1 Pin Map (28 QFN package).....	7
Note 1 : Refer to 6.3 SYNC implementation.....	7
3 Absolute Maximum Rating .....	8
4 ESD & Latch-up Characteristics .....	8
4.1 ESD Characteristics .....	8
4.2 Latch-up Characteristics .....	8
5 Electrical Characteristics .....	9
6 TSM16C Implementation.....	10
6.1 RBIAS & SRBIAS implementation .....	10
6.2 CS implementation .....	11
6.3 SYNC implementation.....	12
6.4 RESET implementation .....	13
7 I <sup>2</sup> C Interface.....	14
7.1 IRBIAS Implementation .....	14
7.2 Start & Stop Condition .....	15
7.3 Data validity.....	16
7.4 Byte Format .....	16
7.5 Acknowledge .....	16
7.6 First Byte .....	17
7.7 Transferring Data.....	18
7.8 I <sup>2</sup> C write and read operations in normal mode .....	18
7.9 I <sup>2</sup> C timing diagram .....	19
8 TSM16C control register.....	20
8.1 I <sup>2</sup> C Register Map .....	20
8.2 Details.....	21
9 Recommended TSM16C Initialize Flow (Example) .....	25
10 Recommended Circuit Diagram .....	26
10.1 Application Example in clean power environment .....	26
10.2 Application Example in noisy environment .....	27
10.3 Example – Power Line Split Strategy PCB Layout.....	28
11 MECHANICAL DRAWING .....	29
11.1 Mechanical Drawing of TSM16C (28 QFN).....	29
12 MARKING DESCRIPTION .....	31
12.1 Marking Description of TSM16C (28 MLF).....	31
NOTES: .....	32

TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

1 Pin Configuration



## 2 Pin Description

### **VDD, VSS**

Supply voltage and ground pin.

### **I\_VDD**

Supply voltage pin for IO pads.

### **RND**

Reference channel capacitive sensor input pin.

### **CS1 ~ CS16**

Capacitive sensor input pins.

### **SCL, SDA**

SCL is I<sup>2</sup>C clock input pin and SDA is I<sup>2</sup>C data input-output pin.

### **INT**

Touch sensing interrupt output pin.

### **RBIAS**

Internal bias adjust input.

### **SL\_RB**

Internal bias adjust input for the SLEEP mode.

### **RBIAS**

Internal bias adjust input.

### **RST**

System reset input.

### **I2C\_EN**

I2C Enable input. The I2C block is enabled when I2C\_EN pin goes low.

### **CHIPID**

I2C address selection input.

### **SYNC**

The output mode selection input and sync pulse input/output for the sync operation.

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 2.1 Pin Map (28 QFN package)

Pin Number	Name	I/O	Description	Protection
PIN No.	Name	I/O	Description	Protection
1	CS6	Analog Input	CH6 capacitive sensor input	VDD/GND
2	CS7	Analog Input	CH7 capacitive sensor input	VDD/GND
3	CS8	Analog Input	CH8 capacitive sensor input	VDD/GND
4	CS9	Analog Input	CH9 capacitive sensor input	VDD/GND
5	CS10	Analog Input	CH10 capacitive sensor input	VDD/GND
6	CS11	Analog Input	CH11 capacitive sensor input	VDD/GND
7	CS12	Analog Input	CH12 capacitive sensor input	VDD/GND
8	CS13	Analog Input	CH13 capacitive sensor input	VDD/GND
9	CS14	Analog Input	CH14 capacitive sensor input	VDD/GND
10	CS15	Analog Input	CH15 capacitive sensor input	VDD/GND
11	CS16	Analog Input	CH16 capacitive sensor input	VDD/GND
12	SL_RB	Analog Input	SLEEP Mode Internal bias adjust input	VDD/GND
13	RBIAS	Analog Input	Internal bias adjust input	VDD/GND
14	GND	Ground	Supply ground	VDD
15	VDD	Power	Power (2.5V~5.0V)	GND
16	L_VDD	Power	IO PAD Power (2.5V~5.0V)	GND
17	RST	Digital Input	System reset (High reset)	VDD/GND
18	INT	Digital Output	Interrupt output (Open drain)	VDD/GND
19	SCL	Digital Input	I2C clock input	VDD/GND
20	SDA	Digital Input/Output	I2C data (Open drain)	VDD/GND
21	SYNC	Digital Input/Output	Sync pulse input /output	VDD/GND
22	CHIPID	Digital Input	I2C address selection	VDD/GND
23	RND	Analog Input	Ref. Ch capacitive sensor input	VDD/GND
24	CS1	Analog Input	CH1 capacitive sensor input	VDD/GND
25	CS2	Analog Input	CH2 capacitive sensor input	VDD/GND
26	CS3	Analog Input	CH3 capacitive sensor input	VDD/GND
27	CS4	Analog Input	CH4 capacitive sensor input	VDD/GND

**Note 1 :** Refer to 6.3 SYNC implementation

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 3 Absolute Maximum Rating

Maximum supply voltage	5.5V
Maximum voltage on any pin	VDD+0.3
Maximum current on any PAD	100mA
Power Dissipation	800mW
Storage Temperature	-50 ~ 150 °C
Operating Temperature	-20 ~ 75 °C
Junction Temperature	150 °C

**Note** Unless any other command is noted, all above are operated in normal temperature.

### 4 ESD & Latch-up Characteristics

#### 4.1 ESD Characteristics

Mode	Polarity	Max	Reference
H.B.M	Pos / Neg	8000V	VDD
		8000V	VSS
		8000V	P to P
M.M	Pos / Neg	400V	VDD
		400V	VSS
		400V	P to P
C.D.M	Pos / Neg	800V	DIRECT
		800V	

#### 4.2 Latch-up Characteristics

Mode	Polarity	Max	Test Step
I Test	Positive	200mA	25mA
	Negative	-200mA	
V supply over 5.0V	Positive	8.25V	1.0V

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 5 Electrical Characteristics

▪  $V_{DD}=3.3V$ ,  $R_B=510k$ , Sync Mode ( $R_{sync} = 2M\Omega$ ) (Unless otherwise noted),  $T_A = 25^\circ C$

Characteristics	Symbol	Test Condition	Min	Typ	Max	Units
<b>Power supply requirement and current consumption</b>						
Operating supply voltage	$V_{DD}$		1.8	3.3	5.0	V
Current consumption	$I_{DD}$	$V_{DD}= 3.3V$ $R_B=510k$ $R_{SB}=0$	-	25	-	$\mu A$
		$V_{DD}= 5.0V$ $R_B=510k$ $R_{SB}=0$	-	46	-	
		$V_{DD}= 3.3V$ $R_B=510k$ $R_{SB}=2M$	-	8	-	
		$V_{DD}= 5.0V$ $R_B=510k$ $R_{SB}=2M$	-	18	-	
<b>Touch sensing performance</b>						
Minimum detectable capacitance difference	$\Delta C$	$C_S = 10pF$ , $C_{DEG} = 200pF$ (I2C default sensitivity select)	0.2	-	-	$pF$
Sense input capacitance range (Note1)	$C_S$		-	10	100	$pF$
Sense input resistance range	$R_S$		-	200	1000	$\Omega$
Output impedance (open drain)	$Z_O$	$\Delta C > 0.2pF$ , $C_S = 10pF$ , (I2C default sensitivity select)	-	12	-	$\Omega$
		$\Delta C < 0.2pF$ , $C_S = 10pF$ , (I2C default sensitivity select)	-	30M	-	
		$V_{DD} = 5.0V$ $R_B = 510k$	-	80	-	
<b>System performance</b>						
External reset high pulse width	$V_{DD\_RST}$	$T_A = 25^\circ C$	10	-	-	ms
Self calibration time after system reset	$T_{CAL}$	$V_{DD} = 3.3V$ $R_B = 510k$	-	100	-	ms
		$V_{DD} = 5.0V$ $R_B = 510k$	-	80	-	
Output maximum sink current	$I_{OUT}$	$T_A = 25^\circ C$	-	-	4.0	mA
Recommended bias resistance range (Note2)	$R_B$	$V_{DD} = 3.3V$	200	510	820	k $\Omega$
		$V_{DD} = 5.0V$	330	620	1200	
Maximum bias capacitance	$C_{B\_MAX}$		-	820	1000	$pF$
Recommended sync resistance range	$R_{SYNC}$		1	2	20	M $\Omega$
Max. I <sup>2</sup> C SCL clock speed	$f_{SCL\_MAX}$	Maximum internal I <sup>2</sup> C clock	-	-	2	MHz

**Note 1 :** The sensitivity can be increased with lower  $C_S$  value.

The recommended value of  $C_S$  is 10pF when using 3T PC(Poly Carbonate) cover and 10 mm x 7 mm touch pattern.

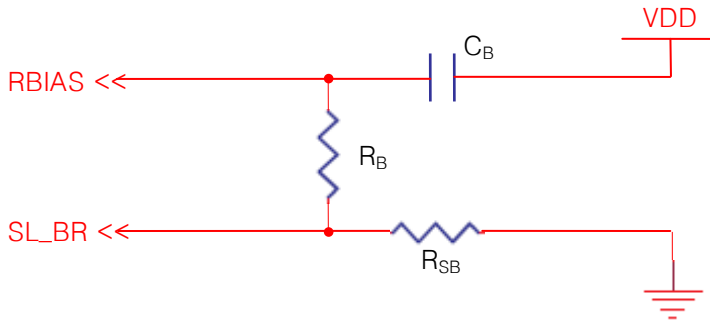
**Note 2 :** The lower  $R_B$  is recommended in noisy condition.



## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

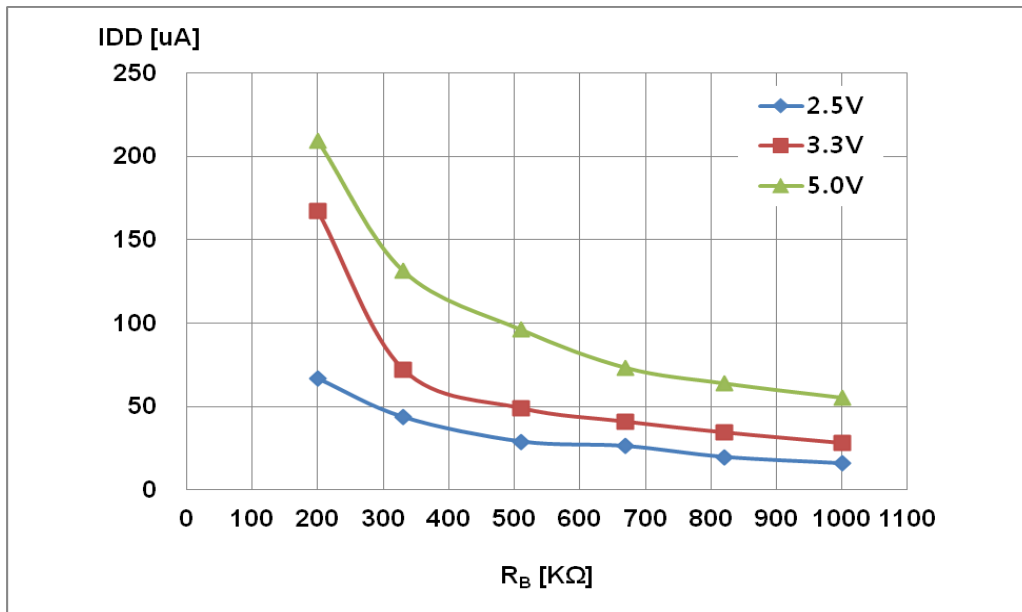
### 6 TSM16C Implementation

#### 6.1 RBIAS & SRBIAS implementation



The RBIAS is connecting to the resistor to decide the oscillator and internal bias current. The sensing frequency, internal clock frequency and current consumption are therefore able to be adjusted with  $R_B$ . A voltage ripple on RBIAS can make critical internal error, so  $C_B$  is connected to the VDD (not GND) is recommended. (The typical value of  $C_B$  is 820pF and the maximum Value is 1nF.)

The  $R_{SB}$  should be connected as above figure when the TSM16C operates in SLEEP Mode to save the current consumption. In this case, the consumption depends on the sum of the serial resistors and the response time might be longer.

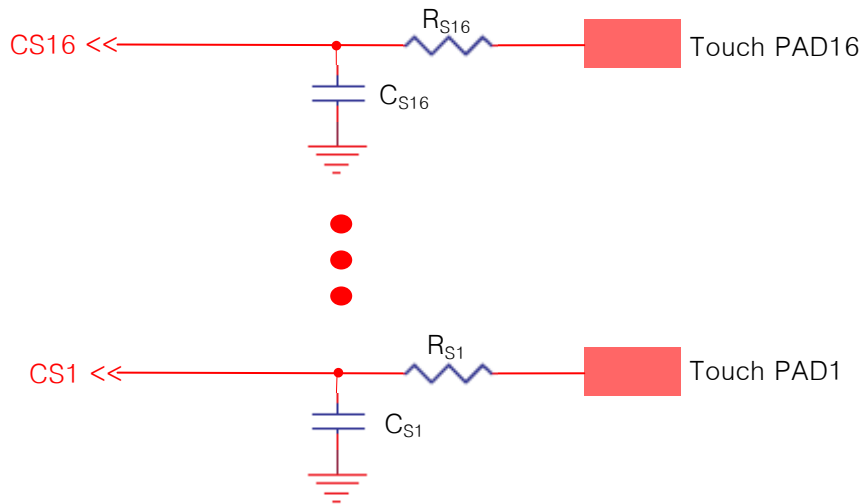


Normal operation current consumption curve

The current consumption curve of TSM16C is represented in accordance with  $R_B$  value as above. The lower  $R_B$  requires more current consumption but it is recommended in noisy application. For example, refrigerator, air conditioner and so on. **And the change of the internal system frequency affects the sensitivity. The slow frequency has higher sensitivity than the fast frequency.**

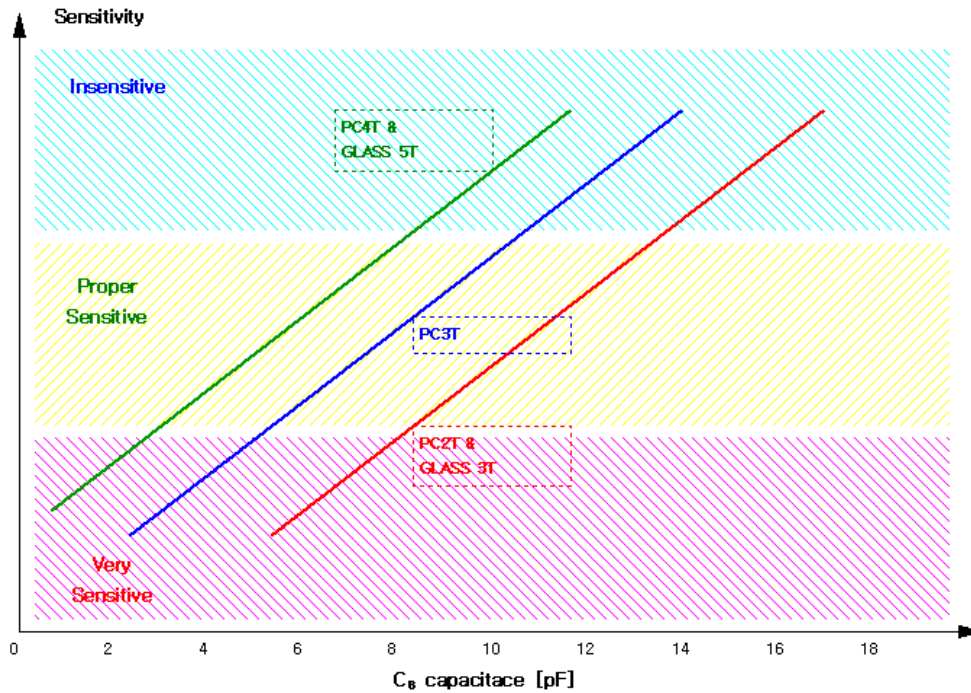
## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 6.2 CS implementation



The TSM16C has basically eight steps sensitivity, which is available to control with internal register by I2C interface. The parallel capacitor  $C_{S1}$  is added to CS1 and  $C_{S16}$  to CS16 to adjust sensitivity. The sensitivity will be increased when smaller value of  $C_S$  is used. (Refer to the below Sensitivity Example Figure) It could be useful in case detail sensitivity mediation is required. The internal touch decision process of each channel is separated from each other. The twelve channel touch key board application can therefore be designed by using only one TSM16C without coupling problem. The  $R_S$  is serial connection resistor to avoid mal-function from external surge and ESD. (It might be optional.) From  $200\Omega$  to  $1k\Omega$  is recommended for  $R_S$ . The size and shape of PAD might have influence on the sensitivity. The sensitivity will be optimal when the size of PAD is approximately an half of the first knuckle (it's about  $10\text{ mm} \times 7\text{ mm}$ ). The connection line of CS1 ~ CS16 to touch PAD is recommended to be routed as short as possible to prevent from abnormal touch detect caused by connection line. The unused CS pin must be connected with the ground to prevent the unpredictable mal-function that occurred in the floating CS pin.

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

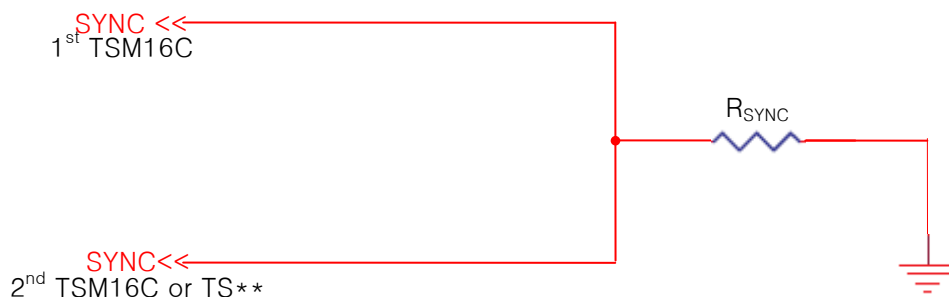


Sensitivity example figure with default sensitivity selection

### 6.3 SYNC implementation

#### 6.3.1 Multi Chip Application

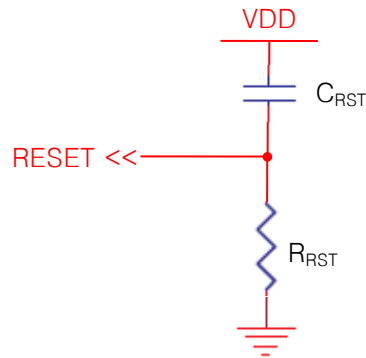
Over two TSM16C can work on the one application at the same time thanks to SYNC function with this pin. The SYNC pulse prevents over two sensing signal from interfering with each other.  $R_{SYNC}$  is pull-down resistor of SYNC pin. Too big value of  $R_{SYNC}$  makes the SYNC pulse falling delay, and too small value of  $R_{SYNC}$  makes rising delay. Typical value of  $R_{SYNC}$  is  $2M\Omega$ . The Sync pin should be implemented as below. The TSM16C can also be used with the other TSXX series by employing this SYNC function. The TSM16C could only operate on multi output mode in this configuration.



## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 6.4 RESET implementation

TSM16C has internal data latches, so initial state of these latches must be reset by external reset pulse before normal operation starts. The reset pulse can be controlled by host MCU directly or other reset device. If not, the circuit should be composed as below figure. The reset pulse must have high pulse duration about a few msec to cover power VDD rising time. The recommended value of  $R_{RST}$  and  $C_{RST}$  are 330K $\Omega$  and 100nF.



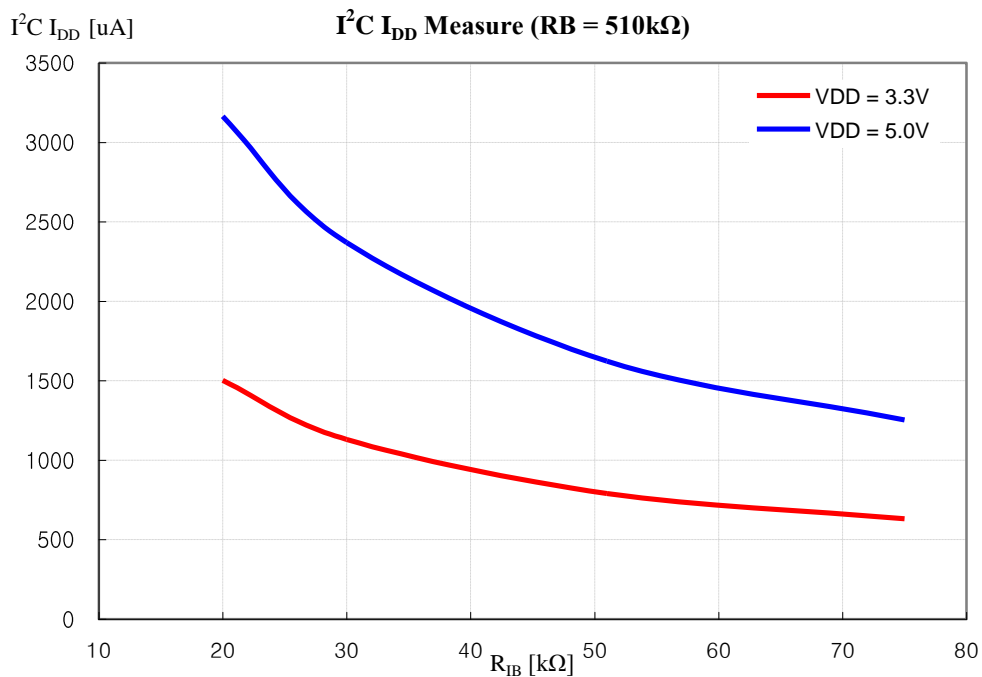
Recommended reset circuits 1

### 7 I<sup>2</sup>C Interface

#### 7.1 IRBIAS Implementation

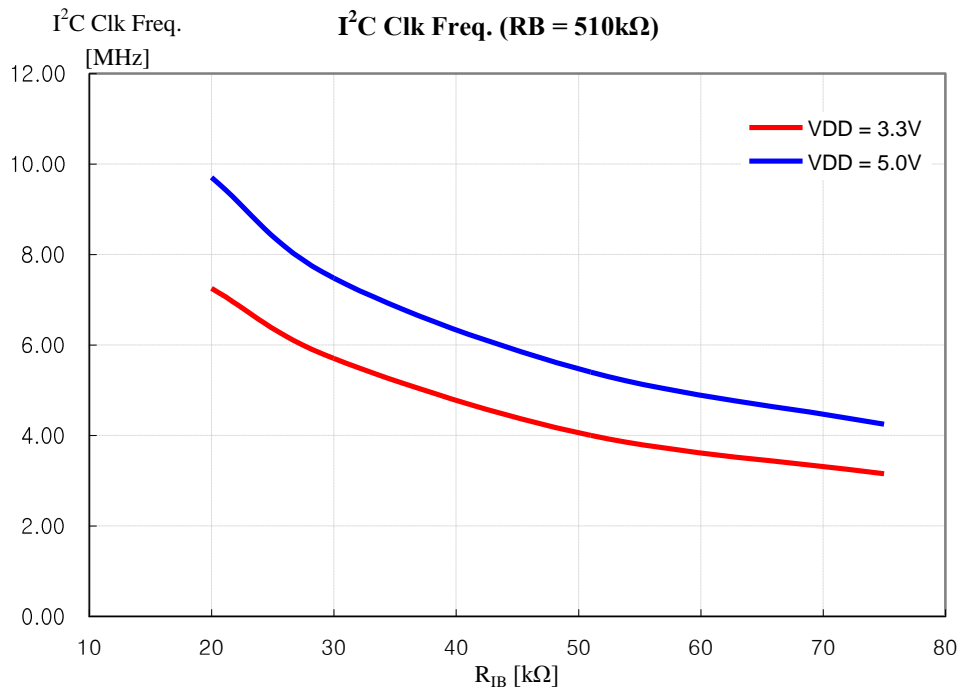


The  $R_{IB}$  is only charged in making the I2C internal clock and should be implemented as above figure. The smaller  $R_{IB}$  will increase the I2C internal clock frequency and current consumption. (Refer to the following consumption curve)



I2C Block operation current consumption curve

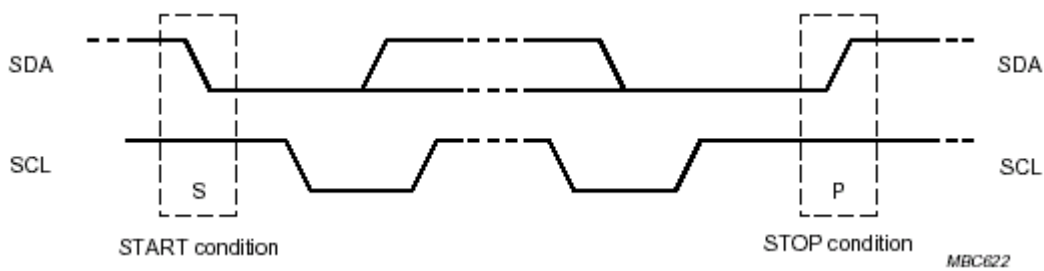
## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)



I2C clock frequency curve

### 7.2 Start & Stop Condition

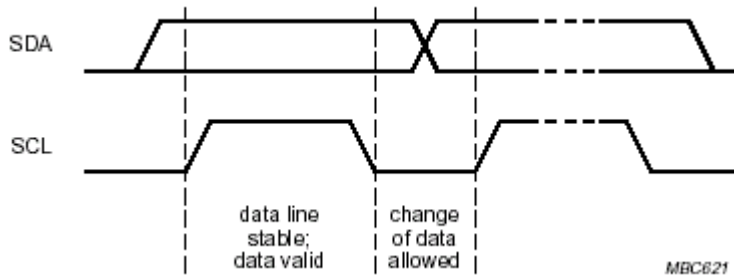
- ◀ Start Condition (S)
- ◀ Stop Condition (P)
- ◀ Repeated Start (Sr)



## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 7.3 Data validity

The SDA should be stable when the SCL is high and the SDA can be changed when the SCL is low.

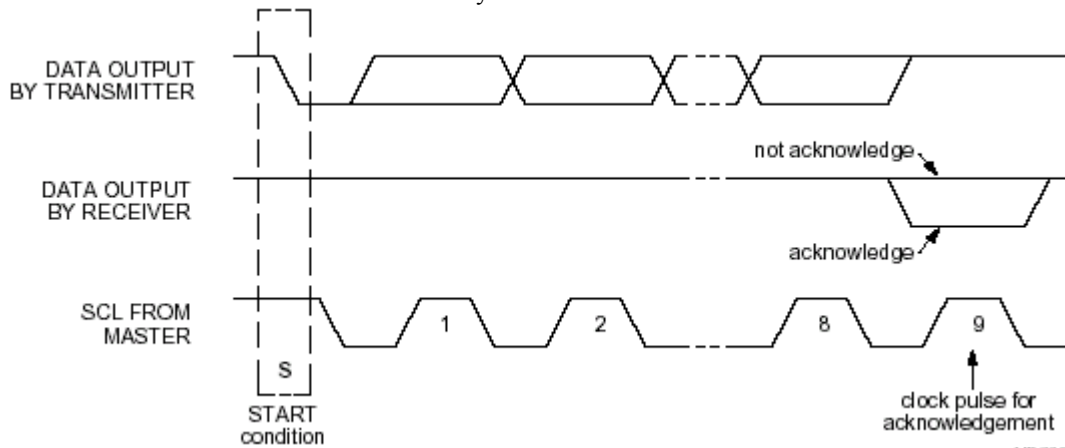


### 7.4 Byte Format

The byte structure is composed with 8Bit data and an acknowledge signal.

### 7.5 Acknowledge

It is a check bit whether the receiver gets the data from the transmitter without error or not. The receiver will write '0' when it received the data successfully and '1' if not.



## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 7.6 First Byte

#### 7.6.1 Slave Address

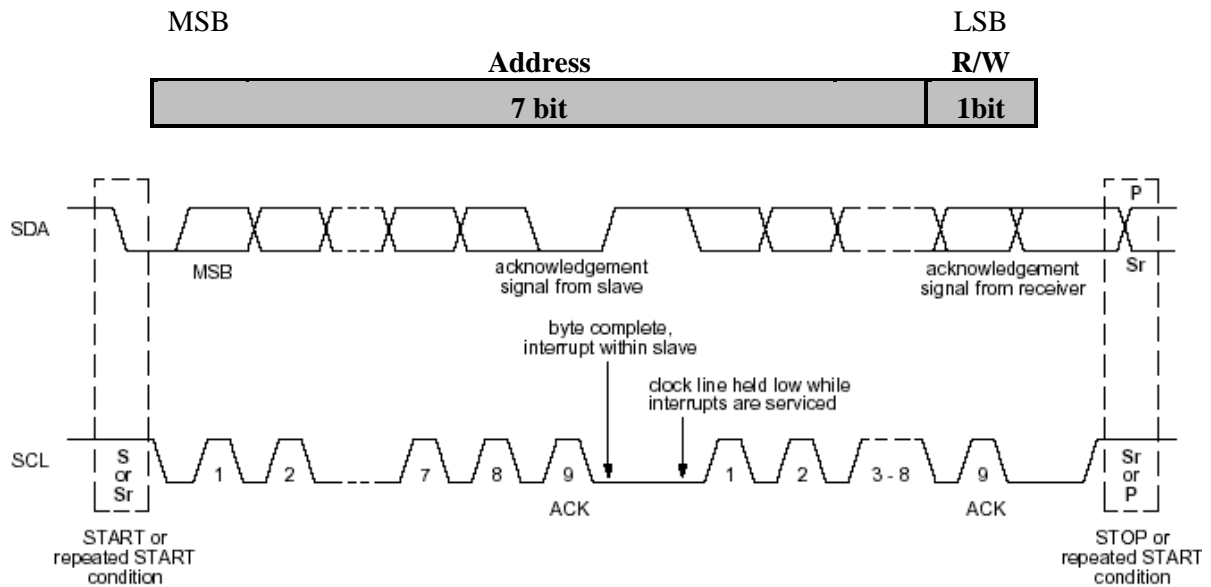
It is the first byte from the start condition. It is used to access the slave device.

**TSM16C Chip Address : 7bit**

CHIPID	Address
GND	0xD0
VDD	0xF0

#### 7.6.2 R/W

The direction of data is decided by the bit and it follows the address data.





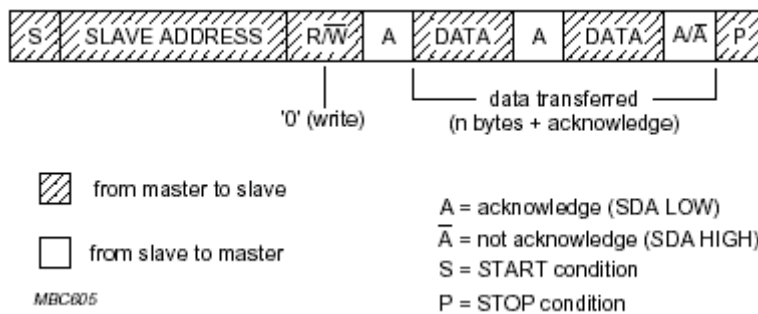
## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 7.7 Transferring Data

#### 7.7.1 Write Operation

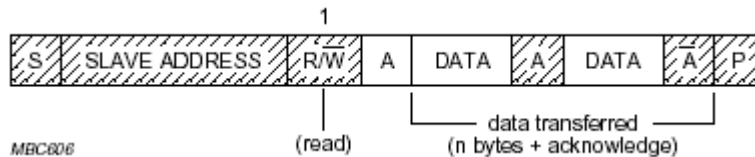
The byte sequence is as follows:

- the first byte gives the device address plus the direction bit (R/W = 0).
- the second byte contains the internal address of the first register to be accessed.
- the next byte is written in the internal register. Following bytes are written in successive internal registers.
- the transfer lasts until stop conditions are encountered.
- the TSM16C acknowledges every byte transfer.

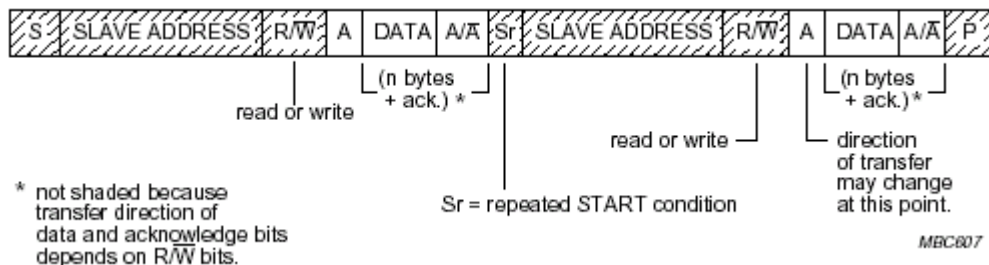


#### 7.7.2 Read Operation

The address of the first register to read is programmed in a write operation without data, and terminated by the stop condition. Then, another start is followed by the device address and R/W= 1. All following bytes are now data to be read at successive positions starting from the initial address.



#### 7.7.3 Read/Write Operation



### 7.8 I<sup>2</sup>C write and read operations in normal mode

The following figure represents the I<sup>2</sup>C normal mode write and read registers.

☞ Write register 0x00 to 0x01 with data AA and BB

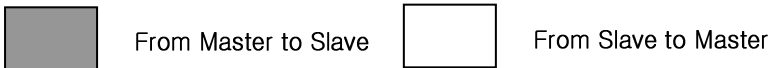
## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

Start	Device Address 0xD0	ACK	Register Address 0x00	ACK	Data AA	ACK	Data BB	ACK	Stop
-------	---------------------	-----	-----------------------	-----	---------	-----	---------	-----	------

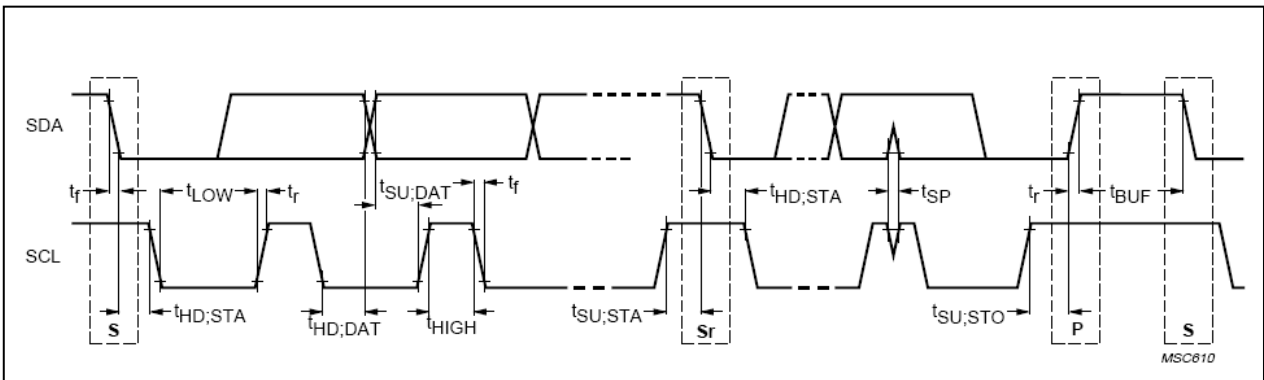
Read register 0x00 and 0x01

Start	Device Address 0xD0	ACK	Register Address 0x00	ACK	Stop
-------	---------------------	-----	-----------------------	-----	------

Start	Device Address 0xD1	ACK	Data Read AA	ACK	Data Read BB	$\overline{\text{ACK}}$	Stop
-------	---------------------	-----	--------------	-----	--------------	-------------------------	------



### 7.9 I<sup>2</sup>C timing diagram



PARAMETER	SYMBOL	100kbps		400kbps		UNIT
		MIN.	MAX.	MIN.	MAX.	
Hold time (repeated)START condition.	t <sub>HD;STA</sub>	4.0	-	0.6	-	us
LOW period of the SCL clock	t <sub>LOW</sub>	4.7	-	1.3	-	us
HIGH period of the SCL clock	t <sub>HIGH</sub>	4.0	-	0.6	-	us
Set-up time for a repeated START condition	t <sub>SU;STA</sub>	4.7	-	0.6	-	us
Data hold time	t <sub>HD;DAT</sub>	1.0	-	-	-	us
Data set-up time	t <sub>SU;DAT</sub>	250	-	100	-	ns
Rise time of both SDA and SCL signals	t <sub>r</sub>	-	1000	20	300	ns
Fall time of both SDA and SCL signals	t <sub>f</sub>	-	300	20	300	ns
Set-up time for STOP condition	t <sub>SU;STO</sub>	4.0	-	0.6	-	us
Bus free time between a STOP and START condition	t <sub>BUF</sub>	4.7	-	1.3	-	us
Noise margin at the LOW level for each connected device	V <sub>nL</sub>	0.1V <sub>DD</sub>	-	0.1V <sub>DD</sub>	-	V
Noise margin at the HIGH level for each connected device	V <sub>nH</sub>	0.2V <sub>DD</sub>	-	0.2V <sub>DD</sub>	-	V
Input Low level				0	V <sub>DD</sub> *0.2	V
Input High level				V <sub>DD</sub> *0.8	V <sub>DD</sub>	V

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 8 TSM16C control register

- ◀ Note: The unused bits (defined as reserved) in I<sup>2</sup>C registers must be kept to zero.
- ◀ Note: The bit0 and bit1 of CTRL2 register must be written by 0b11 after power on during an initialize phase. (Refer to the chapter 9. initialize flow)
- ◀ Note: HS (High Sensitivity) / MS (Middle Sensitivity) / LS (Low Sensitivity)
- ◀ Note: Low Output (light touch) / Middle Output (middle touch) / High Output (hard touch)

#### 8.1 I<sup>2</sup>C Register Map

Name	Addr. (Hex)	Reset Value (Bin)	Register Function and Description							
			Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Sensitivity1	02h	1011 1011	Ch2HL	Ch2M		Ch1HL		Ch1M		
Sensitivity2	03h	1011 1011	Ch4HL	Ch4M		Ch3HL		Ch3M		
Sensitivity3	04h	1011 1011	Ch6HL	Ch6M		Ch5HL		Ch5M		
Sensitivity4	05h	1011 1011	Ch8HL	Ch8M		Ch7HL		Ch7M		
Sensitivity5	06h	1011 1011	Ch10HL	Ch10M		Ch9HL		Ch9M		
Sensitivity6	07h	1011 1011	Ch12HL	Ch12M		Ch11HL		Ch11M		
Sensitivity5	22h	1011 1011	Ch14HL	Ch14M		Ch13HL		Ch13M		
Sensitivity6	23h	1011 1011	Ch16HL	Ch16M		Ch15HL		Ch15M		
CTRL1	08h	0010 0010	MS	FTC		ILC		RTC		
CTRL2	09h	0000 0001	0	0	MULTI	IMP_SEL	SRST	SLEEP	Bits	
Ref_rst1	0Ah	1111 1110	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
Ref_rst2	0Bh	1111 1111	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9
Ch_hold1	0Ch	1111 1110	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
Ch_hold2	0Dh	1111 1111	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9
Cal_hold1	0Eh	0000 0000	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
Cal_hold2	0Fh	0000 0000	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9
Output1	10h	0000 0000	OUT4		OUT3		OUT2		OUT1	
Output2	11h	0000 0000	OUT8		OUT 7		OUT6		OUT5	
Output3	12h	0000 0000	OUT12		OUT11		OUT10		OUT9	
Output3	13h	0000 0000	OUT16		OUT15		OUT14		OUT13	
Lock_mask	3Bh	0000 0000	LOCK_MASK							

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 8.2 Details

#### 8.2.1 Sensitivity Control Register

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
02h	Sensitivity1	Ch2HL		Ch2M		Ch1HL		Ch1M	
03h	Sensitivity2	Ch4HL		Ch4M		Ch3HL		Ch3M	
04h	Sensitivity3	Ch6HL		Ch6M		Ch5HL		Ch5M	
05h	Sensitivity4	Ch8HL		Ch8M		Ch7HL		Ch7M	
06h	Sensitivity5	Ch10HL		Ch10M		Ch9HL		Ch9M	
07h	Sensitivity6	Ch12HL		Ch12M		Ch11HL		Ch11M	
22h	Sensitivity7	Ch14HL		Ch14M		Ch13HL		Ch13M	
23h	Sensitivity8	Ch16HL		Ch16M		Ch15HL		Ch15M	

#### Description

The sensitivity of channel 1 and 2 are adjustable by Sensitivity\_1 register. ChxM[2:0] allows various middle sensitivity and also the high and low sensitivities are decided with ChxHL.

Bit name	Reset	Function	
ChxM[2:0]	011	Middle sensitivity T (= thickness of PC) @Cs = 0pF	
		✚ 000 : 0.50%	✚ 100 : 1.50%
		✚ 001 : 0.70%	✚ 101 : 2.05%
		✚ 010 : 0.90%	✚ 110 : 2.55%
		✚ 011 : 1.20%	✚ 111 : 3.55%
ChxHL	1	High and Low sensitivity selection for channel x	
		0	1
		Low Sensitivity	
		✚ 000 : 0.40%	✚ 000 : 0.6%
		✚ 001 : 0.55%	✚ 001 : 0.85%
		✚ 010 : 0.70 %	✚ 010 : 1.10%
		✚ 011 : 0.95%	✚ 011 : 1.45%
		✚ 100 : 1.20%	✚ 100 : 1.85%
		✚ 101 : 1.60%	✚ 101 : 2.45%
		✚ 110 : 2.05%	✚ 110 : 3.05%
✚ 111 : 2.85%	✚ 111 : 4.30%		

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 8.2.2 General Control Register1

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
08h	CTRL1	MS	FTC[1:0]		ILC[1:0]		RTC[2:0]		

#### Description

The calibration speed just after power on reset is very high during the time which is defined by FTC[1:0] to have a good adoption against unstable external environment.

Bit name	Reset value	Function
MS	0	Mode Selection 0: auto alternate (fast/slow) mode 1: fast mode
FTC[1:0]	01	First Touch Control 00 : $19 * 16^1 * 1\text{-Period (ms)}$ 01 : $37 * 16 * 1\text{-Period (ms)}$ 10 : $56 * 16 * 1\text{-Period (ms)}$ 11 : $74 * 16 * 1\text{-Period (ms)}$
ILC[1:0]	00	Interrupt Level Control 00: Interrupt is on middle or high output. 01: Interrupt is on low or middle or high output. 10: Interrupt is on middle or high output. 11: Interrupt is on high output.
RTC[2:0]	011	Response Time Control Response period = $RTC[2:0] + 2$

### 8.2.3 General Control Register2

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
09h	CTRL2	0	0	MULTI	IMP_SEL	SRST	SLEEP	0	1

#### Description

Single/Multi output mode is selected according to MULTI bit. For impedance, IMP\_SEL bit is used. All the digital blocks except analog and I2C block are reset when SRST is set. The SLEEP function allows getting very low current consumption when it is set. But the response time will be longer than normal operation. The bit0 and bit1 must be written with 0b'11 by host MCU.

Bit name	Reset	Function
MULTI	0	Single/Multiple Output Select 0: Multiple Output 1: Single Output
IMP_SEL	0	Impedance Select 0: High Impedance 1: Low Impedance
SRST	0	Software Reset 0: Disable Software Reset 1: Enable Software Reset
SLEEP	0	Sleep Mode Enable 0: Disable Sleep Mode

<sup>1</sup> The number, 16 is the time control constant value

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

		1: Enable Sleep Mode
Bit[1:0]	01	These bits must be written by 2b'11 during a system initialize phase. (refer to the chapter 9 "initialize flow example")

### 8.2.4 Channel Reference Reset Control Register

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0Ah	Ref_rst1	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
0Bh	Ref_rst2	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9

#### Description

The reference value of each channel will be renewing when Chx is set.

Bit name	Reset	Function
Chx	1	0: Disable reference reset 1: Enable reference reset
Ch1	0	0: Disable reference reset 1: Enable reference reset

### 8.2.5 Channel Sensing Control Register

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0Ch	Ch_hold1	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
0D	Ch_hold2	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9

#### Description

The operation of each channel is independently available to control. A channel doesn't be worked and the calibration is paused when it is set.

Bit name	Reset	Function
Chx	1	0: Enable operation (sensing + calibration) 1: Hold operation (No sensing + Stop calibration)
Ch1	0	0: Enable operation (sensing + calibration) 1: Hold operation (No sensing + Stop calibration)

### 8.2.6 Channel Calibration Control Register

Type: R/W

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0Eh	Cal_hold1	Ch8	Ch7	Ch6	Ch5	Ch4	Ch3	Ch2	Ch1
0Fh	Cal_hold2	Ch16	Ch15	Ch14	Ch13	Ch12	Ch11	Ch10	Ch9

#### Description

The calibration of each channel is independently available to control. Each channel is working even if a bit is set.

Bit name	Reset	Function
Chx	0	0: Enable reference calibration (sensing + calibration) 1: Disable reference calibration (sensing + No calibration)

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 8.2.7 Output Register

Type: R

Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
10h	output1	OUT4[1:0]		OUT3[1:0]		OUT2[1:0]		OUT1[1:0]	
11h	output2	OUT8[1:0]		OUT7[1:0]		OUT6[1:0]		OUT5[1:0]	
12h	output3	OUT12[1:0]		OUT11[1:0]		OUT10[1:0]		OUT9[1:0]	
13h	output3	OUT16[1:0]		OUT15[1:0]		OUT14[1:0]		OUT13[1:0]	

#### Description

The each channel output of TSM16C is compressed with 2 bits. It has 3 level output information that is low, middle and high.

Bit name	Reset value	Function
OUT1[1:0] ~ OUT16[1:0]	00	Output of channels 00: No output 01: low output 10: middle output 11: high output

### 8.2.8 Lock Mask Register

Type: R/W

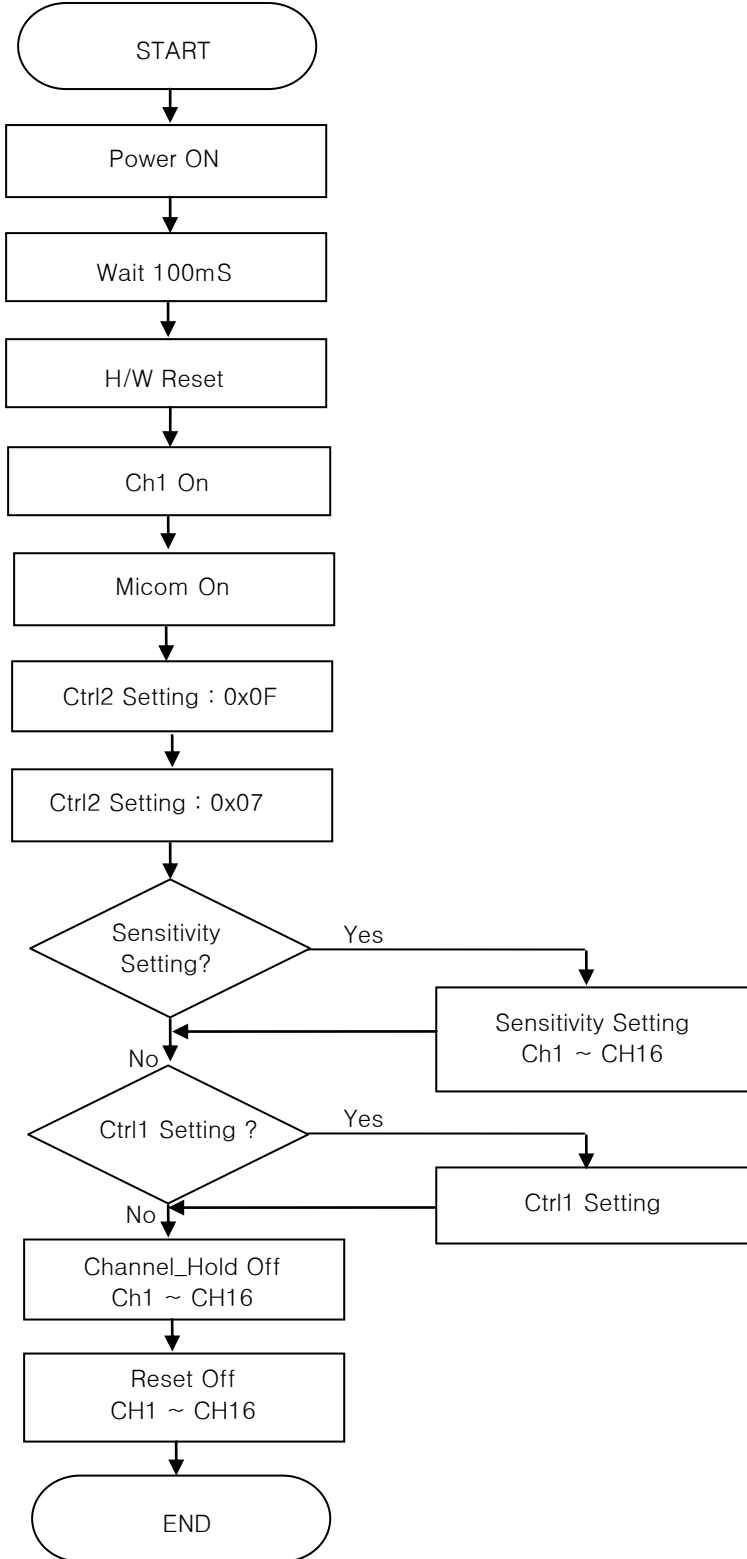
Address	Register Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
3Bh	Lock_mask	LOCK_MASK							

#### Description

Lock mask bits prevent the specific bits in TSM16C from changing in noise environments.

Bit name	Reset value	Function
LOCK_MASK	0000 0000	For applying MULTI bit(0x09[5]), Lock mask bits should be 8'h10100101

### 9 Recommended TSM16C Initialize Flow (Example)

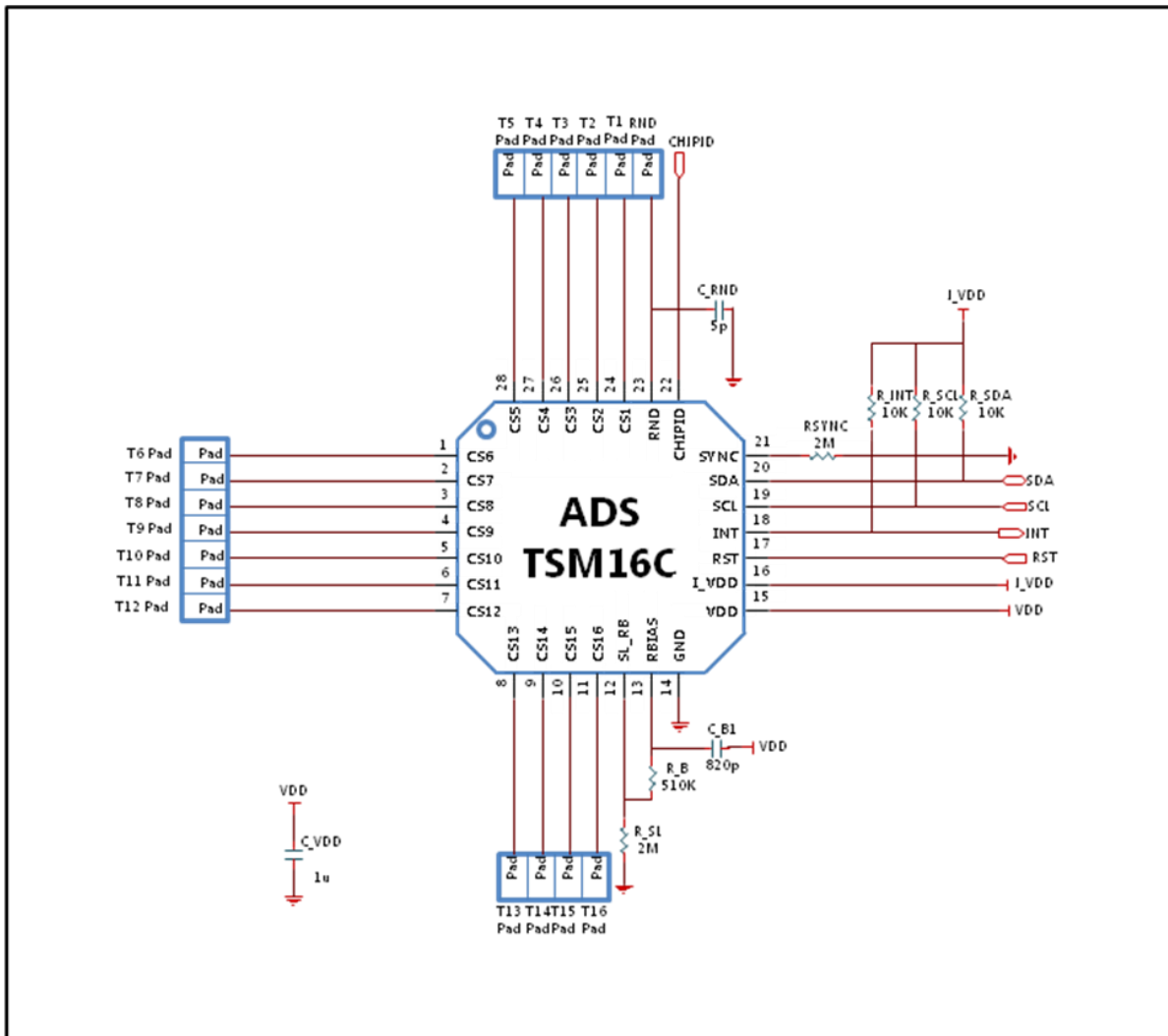




## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 10 Recommended Circuit Diagram

#### 10.1 Application Example in clean power environment

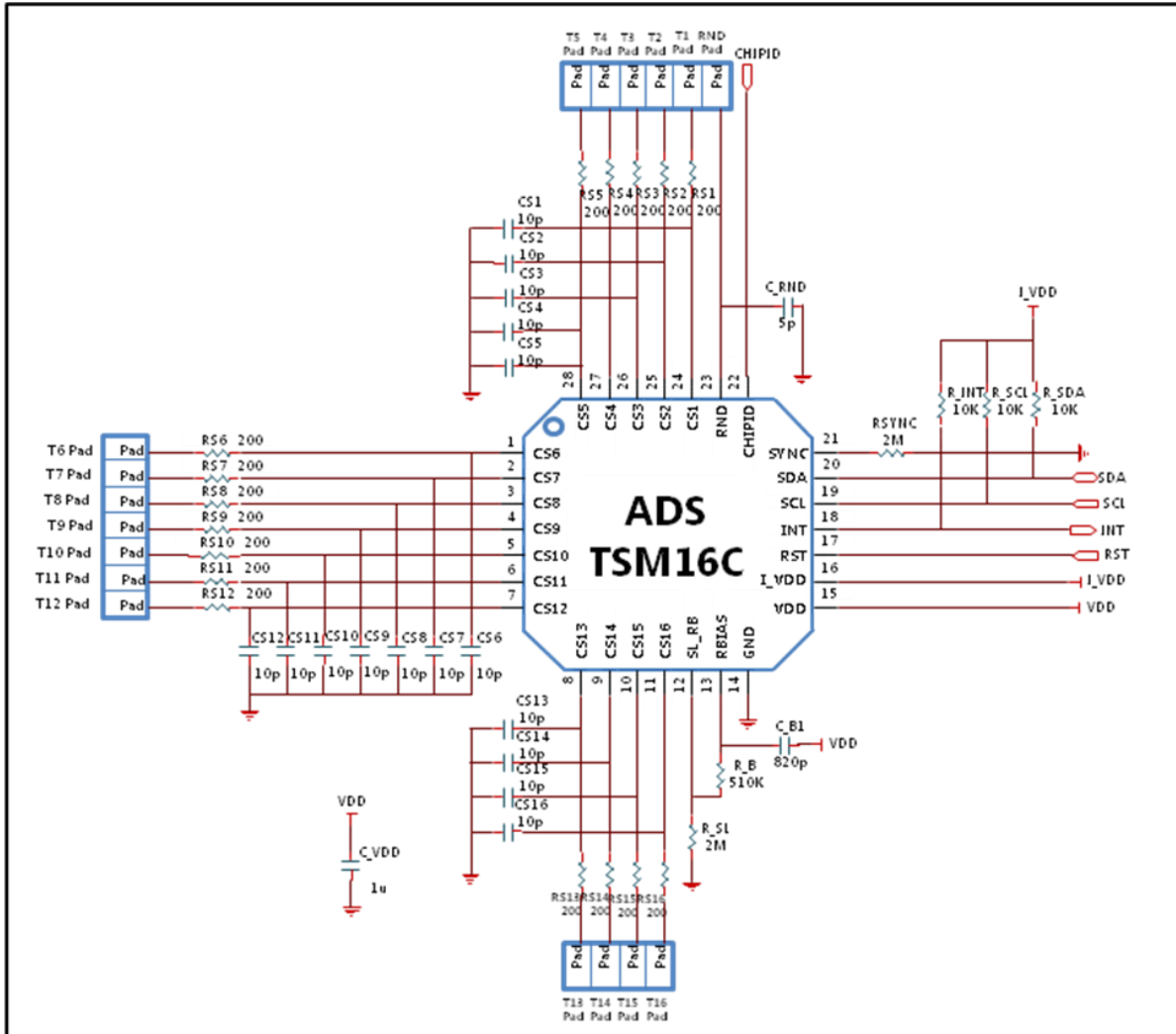


TSM16C Application Example Circuit (Clean power environment)

- ✓ In PCB layout, R\_B should not be placed on touch pattern. If not, C\_B has to be connected. The R\_B pattern should be routed as short as possible.
- ✓ The CS patterns also should be routed as short as possible and the width of line might be about 0.25mm.
- ✓ The capacitor that is between VDD and GND is an obligation. It should be located as close as possible from TSM16C.
- ✓ The CS pattern routing should be formed by bottom metal (opposite metal of touch PAD).
- ✓ The empty space of PCB must be filled with GND pattern to strengthen GND pattern and to prevent external noise from interfere with sensing frequency.
- ✓ The TSM16C is reset if RST Pin is high. (See 6.5 Reset implementation chapter)
- ✓ The TSM16C is working with single output mode if the SYNC/OPT pin is high and it will be in multi output mode when it's low. The resistor which is connected with GND should be connected with SYNC pin when the application is required over two TSM16C devices (Multi output mode).

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

### 10.2 Application Example in noisy environment



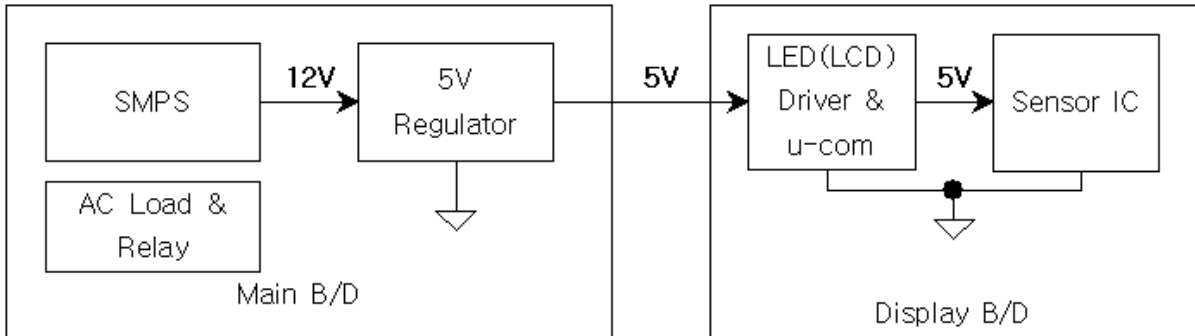
TSM16C Application Example Circuit (Noisy environment)

- ✓ The VDD periodic voltage ripple over 50mV and the ripple frequency is lower than 10 kHz can cause wrong sensitivity calibration. To prevent above problem, power (VDD, GND) line of touch circuit should be separated from other circuit. Especially LED driver power line or digital switching circuit power line certainly should be treated to be separated from touch circuit.
- ✓ The smaller R\_B is recommended in noisy environments.
- ✓

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

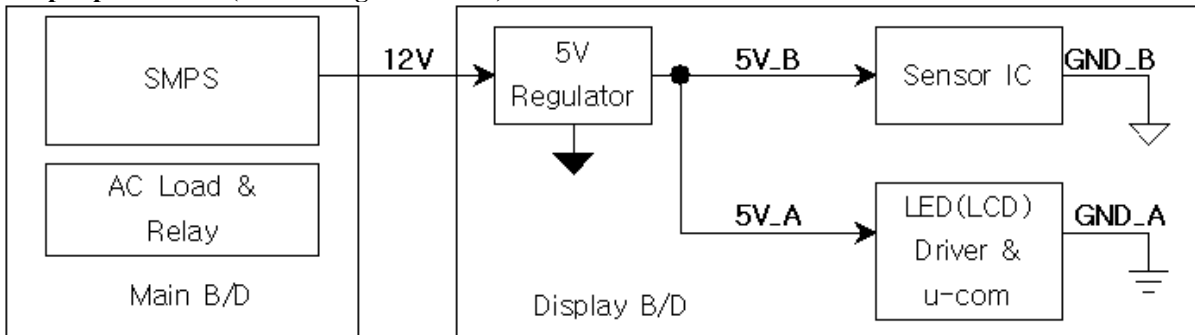
### 10.3 Example – Power Line Split Strategy PCB Layout

#### A. Not split power Line (Bad power line design)

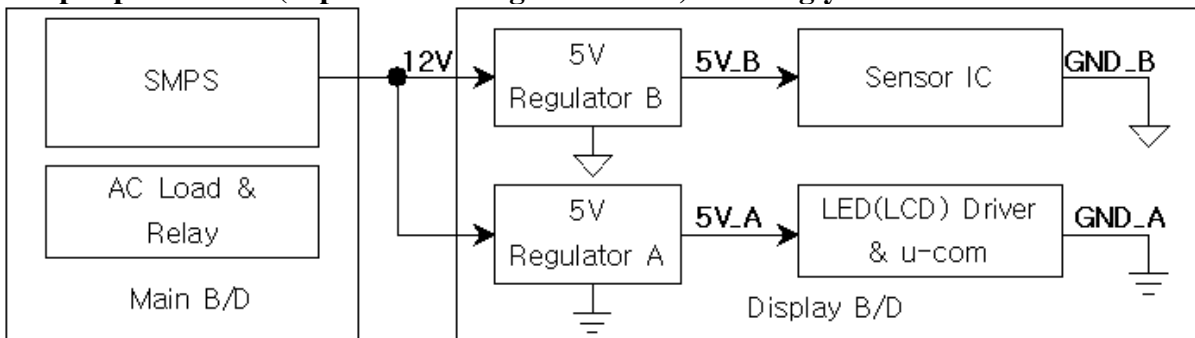


- ✓ The noise that is generated by AC load or relay can be loaded at 5V power line.
- ✓ A big inductance might be appeared in case of the connection line between main board and display board is too long, moreover the voltage ripple could be generated by LED (LCD) display driver at VDD (5V).

#### B. Split power Line (One 5V regulator used) – Recommended

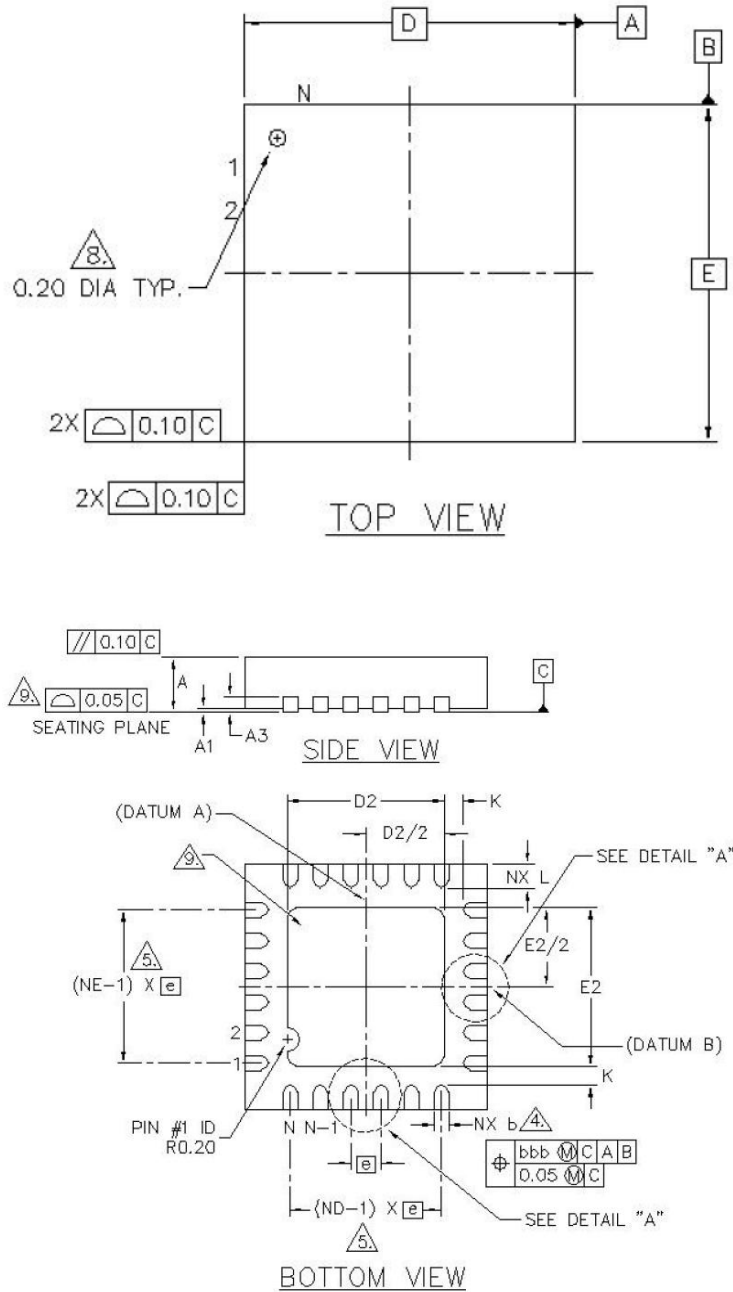


#### C. Split power Line (Separated 5V regulator used) – Strongly recommended



### 11 MECHANICAL DRAWING

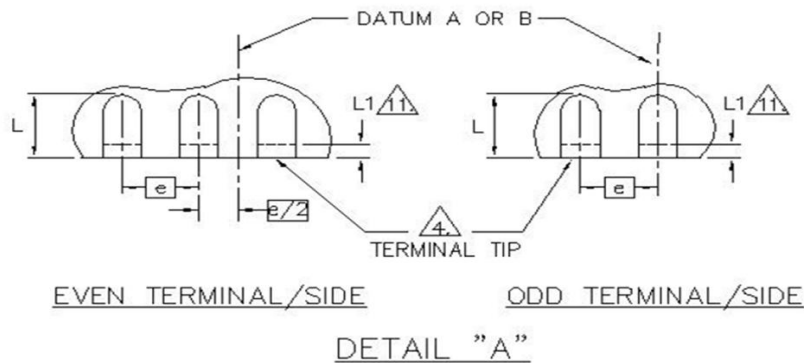
#### 11.1 Mechanical Drawing of TSM16C (28 QFN)



# AD Semiconductor®

" Free from Common Mode Noise "

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)



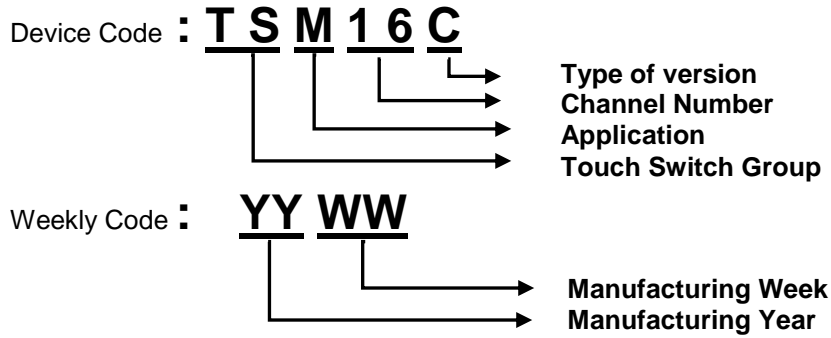
SYMBOL	0.40mm LEAD PITCH						NOTE	SYMBOL	COMMON DIMENSIONS			NOTE
	VARIATION A			VARIATION B					MIN.	NOM.	MAX.	
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.			MIN.	NOM.	MAX.	
Ⓢ	0.40 BSC			0.40 BSC				A	0.70	0.75	0.80	
N	28			32			3	A1	0.00	0.02	0.05	
ND	7			8			⚠	A3	0.20 REF.			
NE	7			8			⚠	⊙	0	—	12	2
L	0.35	0.40	0.45	0.35	0.40	0.45	⚠	K	0.20 MIN.			
b	0.15	0.20	0.25	0.15	0.20	0.25	⚠	D	4.0 BSC			
D2	2.50	2.60	2.70	2.50	2.60	2.70		E	4.0 BSC			
E2	2.50	2.60	2.70	2.50	2.60	2.70		L1	0.15 mm MAX			⚠

### NOTES :

- DIMENSIONING AND TOLERANCING CONFORME TO ASME Y14.5M – 1994.
- ALL DIMENSIONS ARE IN MILLIMETERS,  $\theta$  IS IN DEGREES.
- N IS THE TOTAL NUMBER OF TERMINALS.
- ⚠ DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL TIP. IF THE TERMINAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION b SHOULD NOT BE MEASURED IN THAT RADIUS AREA.
- ⚠ ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
- MAX. PACKAGE WARPAGE IS 0.05 mm.
- MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.
- ⚠ PIN #1 ID ON TOP WILL BE LASER MARKED.
- ⚠ BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
- THIS DRAWING CONFORMES TO JEDEC REGISTERED OUTLINE MO-220
- ⚠ DEPENDING ON THE METHOD OF LEAD TERMINATION AT THE EDGE OF THE PACKAGE, PULLBACK (L1) MAYBE PRESENT
- ⚠ PULLBACK DESIGN OPTION IS FOR 0.50mm NOMINAL LANDLENGTH ONLY.

### 12 MARKING DESCRIPTION

#### 12.1 Marking Description of TSM16C (28 MLF)



# ADSemiconductor®

" Free from Common Mode Noise "

---

## TSM16C (16-CH Auto Sensitivity Calibration Capacitive Touch Sensor)

---

NOTES:

### LIFE SUPPORT POLICY

AD SEMICONDUCTOR'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF AD SEMICONDUCTOR CORPORATION

The ADS logo is a registered trademark of AD Semiconductor

© 2006 AD Semiconductor – All Rights Reserved

[www.adsemicon.com](http://www.adsemicon.com)  
[www.adsemicon.co.kr](http://www.adsemicon.co.kr)