TANGO-M48

Capacitive Touch Sensor Controller

48 Sense channels – IIC slave interface

Specification

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V6	Update the RAM and data flash table	53	Reed	2011-04-14
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V8	Add the internal_enable register for single M48 solution. Reset timing sequence.	58	Reed	2011-07-06
V9	Add more features in the M48 and M48+F32 table; Add more function explain on the button_raw_enable register ; improve the button layout on the M48 and M48+F32 schematic	58	Reed	2011-08-01
V10	Add marking, MSL and packing number information	59	Lisa	2011-08-09
V11	Improve the single M48 RAM table and single M48 Dataflash table	61	Reed	2011-09-03
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1 Overview

1.1 Description

The TANGO M48 is a single-chip, general purpose capacitive sensor front end, with a bidirectional serial interface (I^2C). It senses variations of capacitance using an innovative proprietary concept. Its unique capabilities make the system insensitive to environmental conditions such as temperature, humidity and also other variations. The chip adapts itself to large series resistance of long lines, especially seen when using ITO technology. The device has low power consumption. The internal Micro Control Unit provide the clock to the Sensor Control Unit.TANGO M48 can cascade an external TANGO Chip for large touch panel solution. And when the chip is in freeze mode, the current is typically 2 uA.

1.2 Features

- 48 Capacitive sense channels
- Fully programmable scan sequences
- Up to 30'000 line scans per second
- I^2C 2 wire serial interface
- 16 bit Micro Control Unit with 20MHZ internal OCO
- 3.0V to 5.5V operating voltage
- Cascade an external TANGO Chip with SPI interface
- 2uA consumption in freeze mode
- Insensitive to environment variations
- Insensitive to touch variations
- Accommodates large resistance of lines

1.3 Applications

The TANGO M48 can accommodate a wide palette of applications ranging from a set of buttons up to a 2D sensing device on glass. The fully programmable scan sequences allow also realizing slider and wheel functions.

- Portable media player, MP3
- Handset, mobile phone, smart phone
- Game console, Navigation system
- Notebook, PDA,Home entertainment devices
- Keyboard, keypad, mouse, remote control
- Information Kiosk, House appliances
- Set top box, television, Digital camera
- In-cell capacitor applications
- Wide screens

1.4 Specifications

Table 1: Specifications for TANGO M48 (1)

Item	Function	Specification
CPU	Central processing unit	R8C CPU Core Number of fundamental instructions:89 Minimum instruction execution time: 50ns Multiplier : 16 bits x 16 bits => 32 bits Multiplier-accumulate instruction : 16 bits x 16 bits + 32 bits => 32 bits
Memory	ROM,RAM,Data flash	Program ROM : 32 Kbytes; Data Flash : 1 Kbyte x 4 RAM : 2.5 Kbytes
Power Supply Voltage Detection	Voltage detection circuit	Power-on reset Voltage detection 3 (detection level of voltage detection 0 and voltage detection 1 selectable)
Clock	Clock generation circuits	2 circuits : XIN clock oscillation circuit Low-speed on-chip oscillator. Oscillation stop detection :XIN clock oscillation stop detection function Frequency divider circuit: Dividing selectable 1,2,4,8, and 16 Low power consumption modes :Standard operation mode (high-speed clock,low-speed clock, low-speed on-chip oscillator), wait mode, stop mode.
Interrupts		External Interrupt number: 3 (SPI_DI, Xin/Attb, Tango_CSB)
Watchdog Timer		14 bits x 1 (with prescaler); Reset start selectable Low-speed on-chip oscillator for watchdog timer selectable
DTC (Data Transfer Controller)		1 channel ; Activation sources:23 ; Transfer modes:2.

Table 2: Specifications for TANGO M48 (2)

Item	Function	Specification
Timer RA		8 bits x 1 (with 8-bit prescaler); Timer mode (period timer).
Timer RB		8 bits x 1 (with 8-bit prescaler); Timer mode (period timer).
Timer RC		16 bits x 1(with 4 capture/compare registers) ; Timer mode (input capture function,output compare function).
Timer RE		8 bits x 1 ; Real-time clock mode (count seconds, minutes, hours, days of week)
Serial Communication		Clock synchronous serial I/O/UART
I^2C bus		I^2C bus mode
Flash Memory		Programming and erasure voltage: VCC=3.0 to 5.5V Programming and erasure endurance: 10,000 times(data flash).1,000 times (program ROM) Program security:ROM code protect, ID code check
Operation Frequency/Supply Voltage		Internal OCO :20 MHz (VCC=3.0V to 5.5V)
Current Consumption		Typ. 7.45mA(VCC=5.0 V,Active Mode) Typ. 0.45mA(VCC=5.0 V,Sleep Mode with 10HZ) Typ. 2uA(VCC=5.0 V,Freeze Mode)
Operation Ambient Temperature		-30 to 85ºC
Package		64-pin LGA

1.5 Block diagram

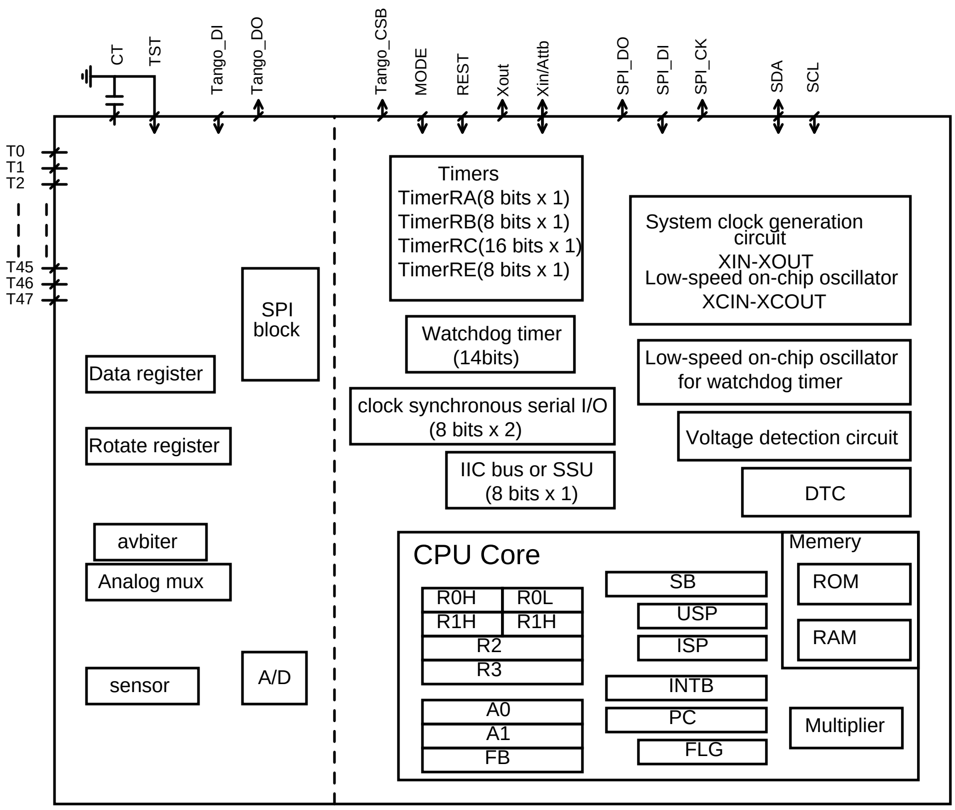


Figure 1: Block diagram (top view)

1.6 Pins Assignment

Figure 2 shows the TANGO M48 pins assignment and table 3 shows the pins description of the circuit.

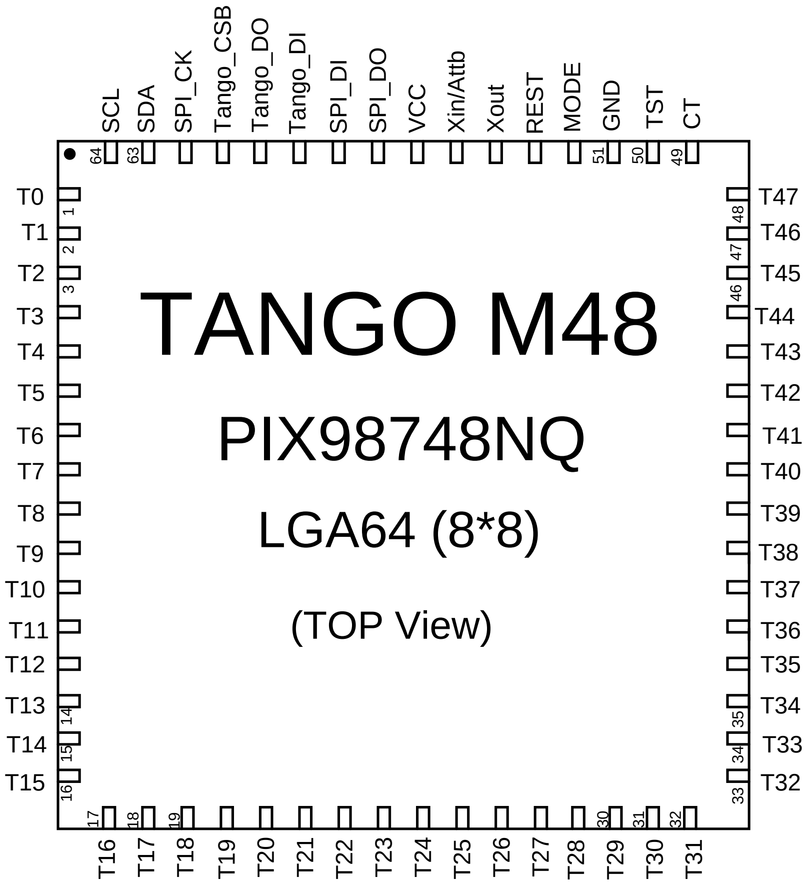


Figure 2: Pins assignment (top view)

Table 3: Pins description

Signal	Pin type	Pin number	Function
CT	Analog	49	Optional capacitor (for further use)
TST	I	50	Test mode, Must be set to GND.
GND	Power	51	Ground.
MODE	I	52	For Micro Control Unit programming, Must be pull high.
RESET	I	53	Reset pin, Must be pulled high.
Xout	O	54	External clock oscillator output.
Xin/Attb	I/O	55	External clock oscillator input/Attention request line, Should be pulled high.
VCC	Power	56	Positive supply.
SPI_DO	O	57	SPI Data output pin of Micro Control Unit.
SPI_DI	I	58	SPI Data input pin of Micro Control Unit.
Tango_DI	I	59	SPI Data input pin of Sensor Control Unit.
Tango_DO	O	60	SPI Data output pin of Sensor Control Unit.
Tango_CSB	O	61	Chip select pin of Micro Control Unit, active low.
SPI_CK	O	62	SPI clock pin of Micro Control Unit.
SDA	I/O	63	I^2C data signal. Must be pulled high.
SCL	I	64	I^2C clock signal. Must be pulled high.
T0 - T47	Analog	1-48	Sensor pin

I :Input; O:Output; I/O:Input and output

2 Electrical Characteristics

2.1 Absolute Maximum Ratings

Table 4: Absolute Maximum Ratings

Symbol	Parameter	Conditions	Unit
VCC	Power supply	-0.3 to 6.5	V
V_I	Input voltage	-0.3 to VCC + 0.3	V
V_O	Output voltage	-0.3 to VCC + 0.3	V
V_{op}	Operation temperature	-30 to 85	ºC
V_{stg}	Storage temperature	-55 to 125	ºC
V_{ESD}	Electrostatic discharge (HBM model)	2’000	V

Stresses or exposure above these maximum ratings may cause permanent damages to the device.

2.2 Recommended Operation Conditions

Table 5: Recommended Operation Conditions

<table>
<tr><th rowspan="2">Symbol</th><th rowspan="2" colspan="2">Parameter</th><th colspan="3">Standard</th><th rowspan="2">Unit</th></tr>
<tr><th>Min.</th><th>Typ.</th><th>Max.</th></tr>
<tr><td>VCC</td><td colspan="2">Power supply</td><td>3.0</td><td>-</td><td>5.5</td><td>V</td></tr>
<tr><td>GND</td><td colspan="2">Power supply</td><td>-</td><td>0</td><td>-</td><td>V</td></tr>
<tr><td>V_{IH}</td><td colspan="2">Input “H” voltage</td><td>0.8VCC</td><td>-</td><td>VCC</td><td>V</td></tr>
<tr><td>V_{IL}</td><td colspan="2">Input “L” voltage</td><td>0</td><td>-</td><td>0.2VCC</td><td>V</td></tr>
<tr><td rowspan="2">V_{OH}(peak)</td><td rowspan="2">Peak output “H” current</td><td>Driver capacity Low</td><td>-</td><td>-</td><td>-10</td><td>mA</td></tr>
<tr><td>Driver capacity High</td><td>-</td><td>-</td><td>-40</td><td>mA</td></tr>
<tr><td rowspan="2">V_{OL}(peak)</td><td rowspan="2">Peak output “L” current</td><td>Driver capacity Low</td><td>-</td><td>-</td><td>10</td><td>mA</td></tr>
<tr><td>Driver capacity High</td><td>-</td><td>-</td><td>40</td><td>mA</td></tr>
<tr><td>-</td><td colspan="2">System clock frequency</td><td>-</td><td>-</td><td>20</td><td>MHz</td></tr>
<tr><td>-</td><td colspan="2">CPU clock frequency</td><td>-</td><td>-</td><td>20</td><td>MHz</td></tr>
<tr><td>-</td><td colspan="2">Operating temperature</td><td>-20</td><td>-</td><td>75</td><td>ºC</td></tr>
</table>

2.3 Flash Memory Electrical Characteristics

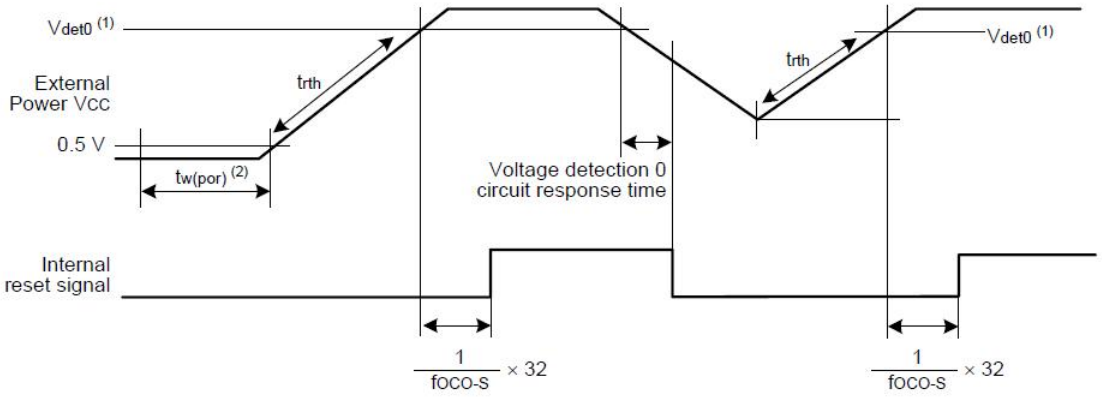
Table 6: Flash Memory(Program ROM) Electrical Characteristics

Symbol	Parameter	Conditions	Standard			Unit
			Min.	Typ.	Max.	
–	Program/erase endurance (2)		1,000 (3)	–	–	times
–	Byte program time		–	80	–	µs
–	Block erase time		–	0.3	–	s
td(SR-SUS)	Time delay from suspend request until suspend		–	–	5+CPU clock × 3 cycles	ms
–	Interval from erase start/restart until following suspend request		33	–	–	ms
–	Suspend interval necessary for auto-erasure to complete		33	–	–	ms
–	Time from suspend until erase restart		–	–	30+CPU clock × 1 cycle	µs
–	Program, erase voltage		2.7	–	5.5	V
–	Read voltage		1.8	–	5.5	V
–	Program, erase temperature		0	–	60	°C
–	Data hold time (7)	Ambient temperature = 55°C	20	–	–	year

Table 7: Flash Memory(Data Flash Block A to Block D) Electrical Characteristics

Symbol	Parameter	Conditions	Standard			Unit
			Min.	Typ.	Max.	
–	Program/erase endurance (2)		10,000 (3)	–	–	times
–	Byte program time (program/erase endurance ≤ 1,000 times)		–	160	–	µs
–	Byte program time (program/erase endurance > 1,000 times)		–	300	–	µs
–	Block erase time (program/erase endurance ≤ 1,000 times)		–	0.2	–	s
–	Block erase time (program/erase endurance > 1,000 times)		–	0.3	–	s
td(SR-SUS)	Time delay from suspend request until suspend		–	–	5+CPU clock × 3 cycles	ms
–	Interval from erase start/restart until following suspend request		33	–	–	ms
–	Suspend interval necessary for auto-erasure to complete		33	–	–	ms
–	Time from suspend until erase restart		–	–	30+CPU clock × 1 cycle	µs
–	Program, erase voltage		2.7	–	5.5	V
–	Read voltage		1.8	–	5.5	V
–	Program, erase temperature		–20 (7)	–	85	°C
–	Data hold time (8)	Ambient temperature = 55 °C	20	–	–	year

2.4 Power-on Reset



Notes:

1. V_{det0} indicates the voltage detection level of the voltage detection 0 circuit. Refer to **6. Voltage Detection Circuit** of Hardware Manual (REJ09B0472) for details.
2. $t_{w(por)}$ indicates the duration the external power Vcc must be held below the valid voltage (0.5 V) to enable a power-on reset. When turning on the power after it falls with voltage monitor 0 reset disabled, maintain $t_{w(por)}$ for 1 ms or more.

Figure 3: Power-on Reset Circuit Electrical Characteristics

2.5 Low-speed On-Chip Oscillator

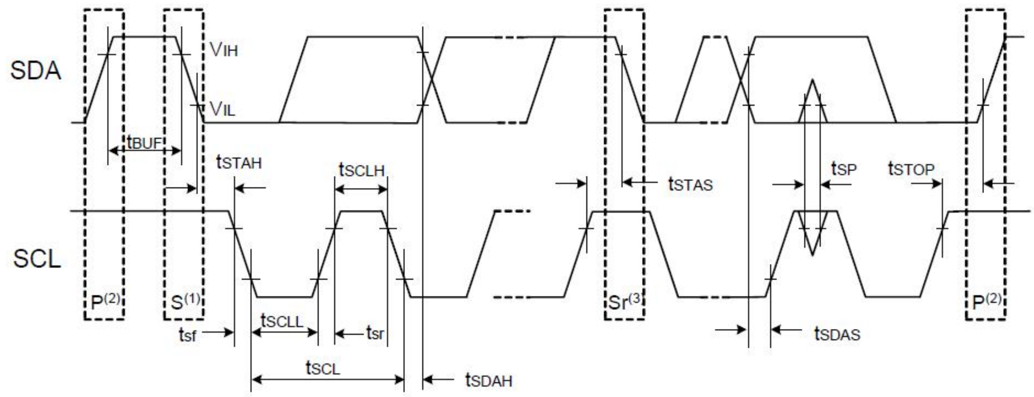
Table 8: Low-speed On-Chip Oscillator Circuit Electrical Characteristics

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
fOCO-S	Low-speed on-chip oscillator frequency		60	125	250	kHz
–	Oscillation stability time	Vcc = 5.0 V, Topr = 25°C	–	30	100	µs
–	Self power consumption at oscillation	Vcc = 5.0 V, Topr = 25°C	–	2	–	µA

2.6 I^{2}C bus Interface

Table 9: Timing Requirements of I^{2}C bus Interface

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
t_{SCL}	SCL input cycle time		$12t_{CYC}$ + 600 (2)	–	–	ns
t_{SCLH}	SCL input "H" width		$3t_{CYC}$ + 300 (2)	–	–	ns
t_{SCLL}	SCL input "L" width		$5t_{CYC}$ + 500 (2)	–	–	ns
t_{sf}	SCL, SDA input fall time		–	–	300	ns
t_{SP}	SCL, SDA input spike pulse rejection time		–	–	$1t_{CYC}$ (2)	ns
t_{BUF}	SDA input bus-free time		$5t_{CYC}$ (2)	–	–	ns
t_{STAH}	Start condition input hold time		$3t_{CYC}$ (2)	–	–	ns
t_{STAS}	Retransmit start condition input setup time		$3t_{CYC}$ (2)	–	–	ns
t_{STOP}	Stop condition input setup time		$3t_{CYC}$ (2)	–	–	ns
t_{SDAS}	Data input setup time		$1t_{CYC}$ + 40 (2)	–	–	ns
t_{SDAH}	Data input hold time		10	–	–	ns



Notes:
1. Start condition
2. Stop condition
3. Retransmit start condition

Figure 4: I/O Timing of I^{2}C bus Interface

2.7 Serial Interface

Table 10: Serial Interface when VCC=5V

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(CK)}$	CLKi input cycle time	200	–	ns
$t_{W(CKH)}$	CLKi input "H" width	100	–	ns
$t_{W(CKL)}$	CLKi input "L" width	100	–	ns
$t_{d(C-Q)}$	TXDi output delay time	–	50	ns
$t_{h(C-Q)}$	TXDi hold time	0	–	ns
$t_{su(D-C)}$	RXDi input setup time	50	–	ns
$t_{h(C-D)}$	RXDi input hold time	90	–	ns

i = 0, 2

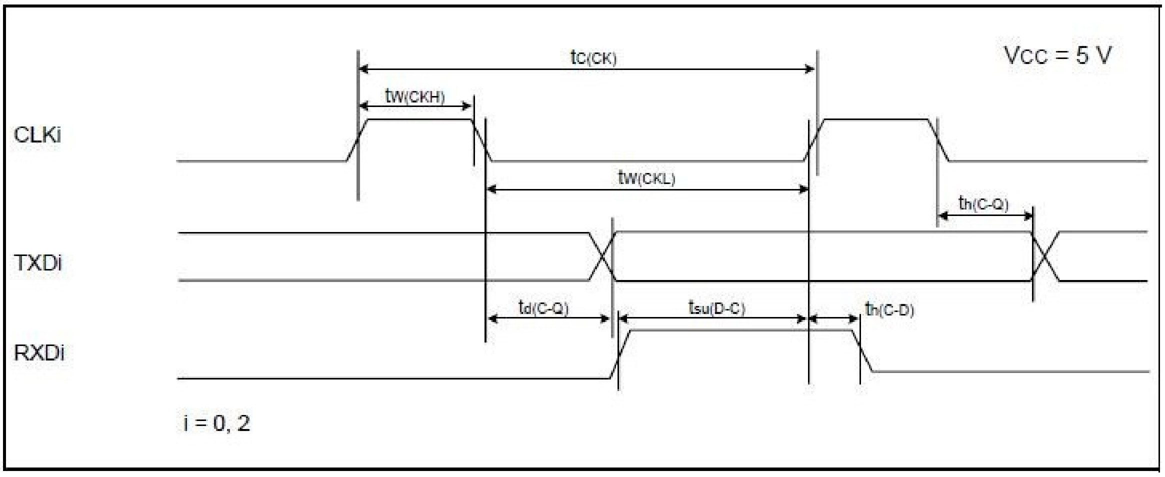


Figure 5: Serial Interface Timing Diagram when VCC=5V

Table 11: Serial Interface when VCC=3V

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(CK)}$	CLKi input cycle time	300	–	ns
$t_{W(CKH)}$	CLKi input "H" width	150	–	ns
$t_{W(CKL)}$	CLKi Input "L" width	150	–	ns
$t_{d(C-Q)}$	TXDi output delay time	–	80	ns
$t_{h(C-Q)}$	TXDi hold time	0	–	ns
$t_{su(D-C)}$	RXDi input setup time	70	–	ns
$t_{h(C-D)}$	RXDi input hold time	90	–	ns

i = 0, 2

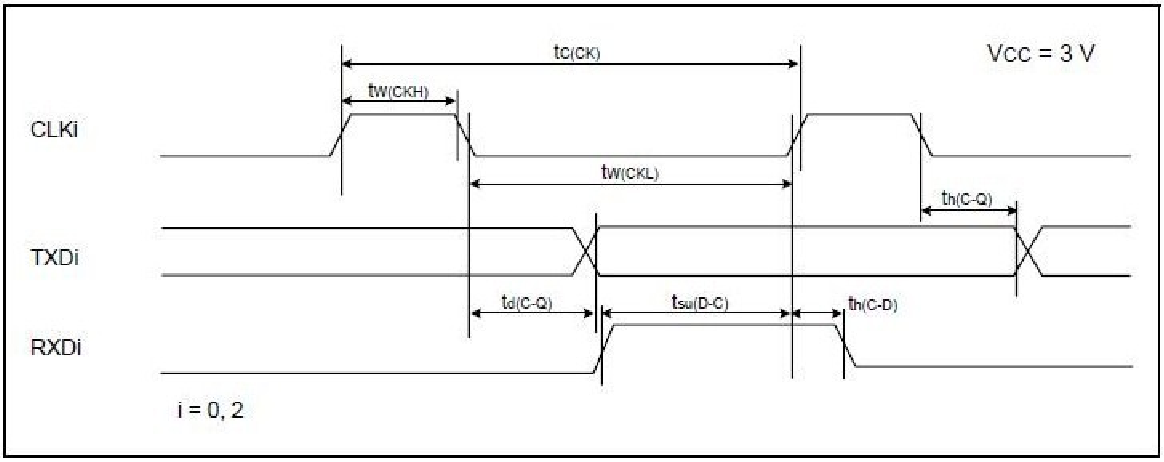


Figure 6: Serial Interface Timing Diagram when VCC=3V

3 Electrical interface

The MSI interface has a minimum of 3 signals. The data communication between the MSI controller and the host uses 3 wires. An attention line, called ATTb, and the I^2C signals SDA and SCL, as shown in figure 7. The MSI controller is allowed to set the ATTb line . The full schematic is shown in figure 8 and figure 9.

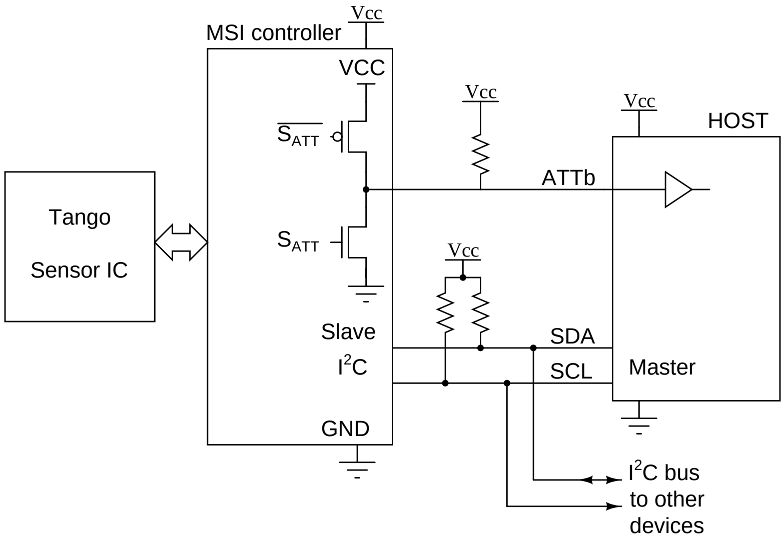


Figure 7: MSI interface

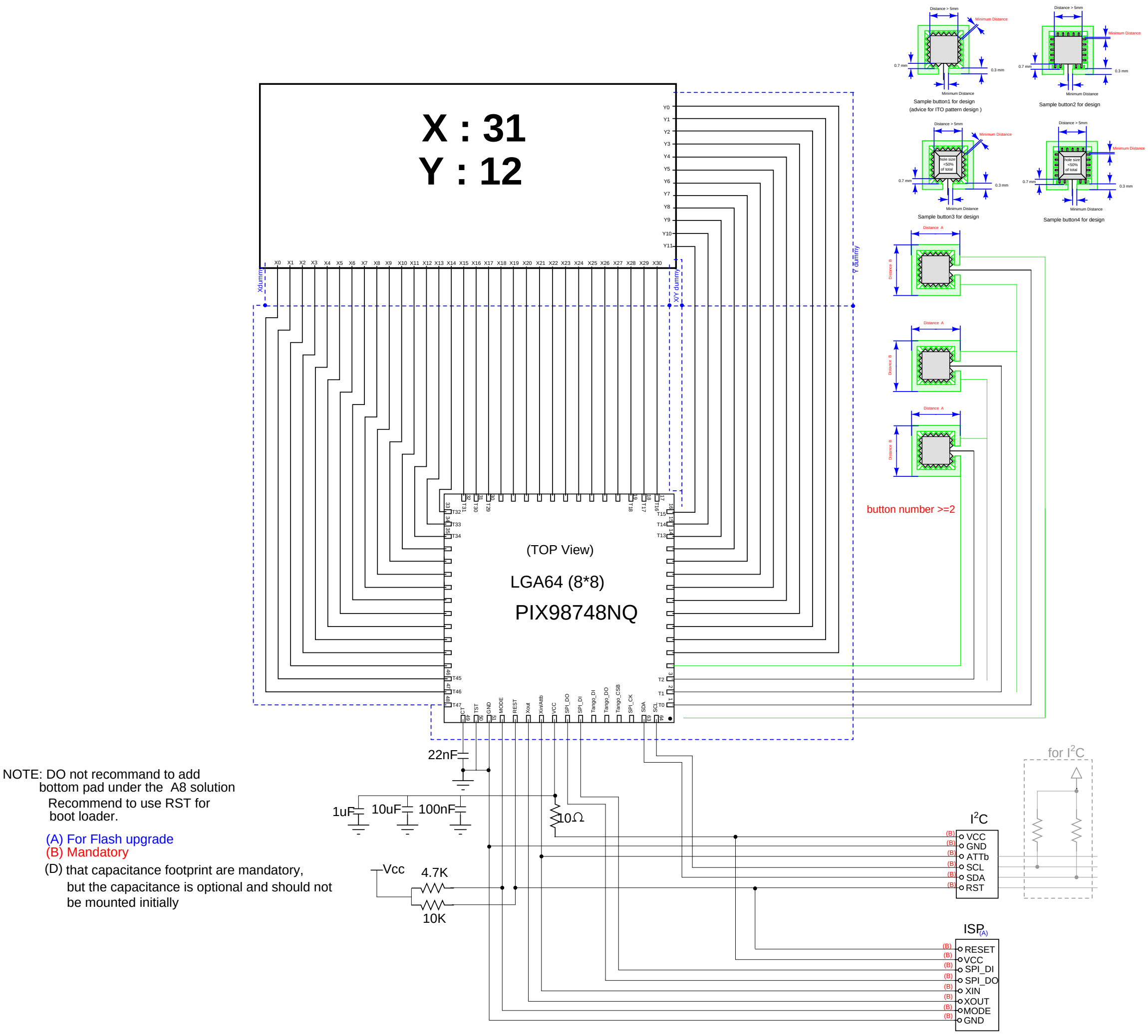


Figure 8: Full schematic-A (1 chip solution)

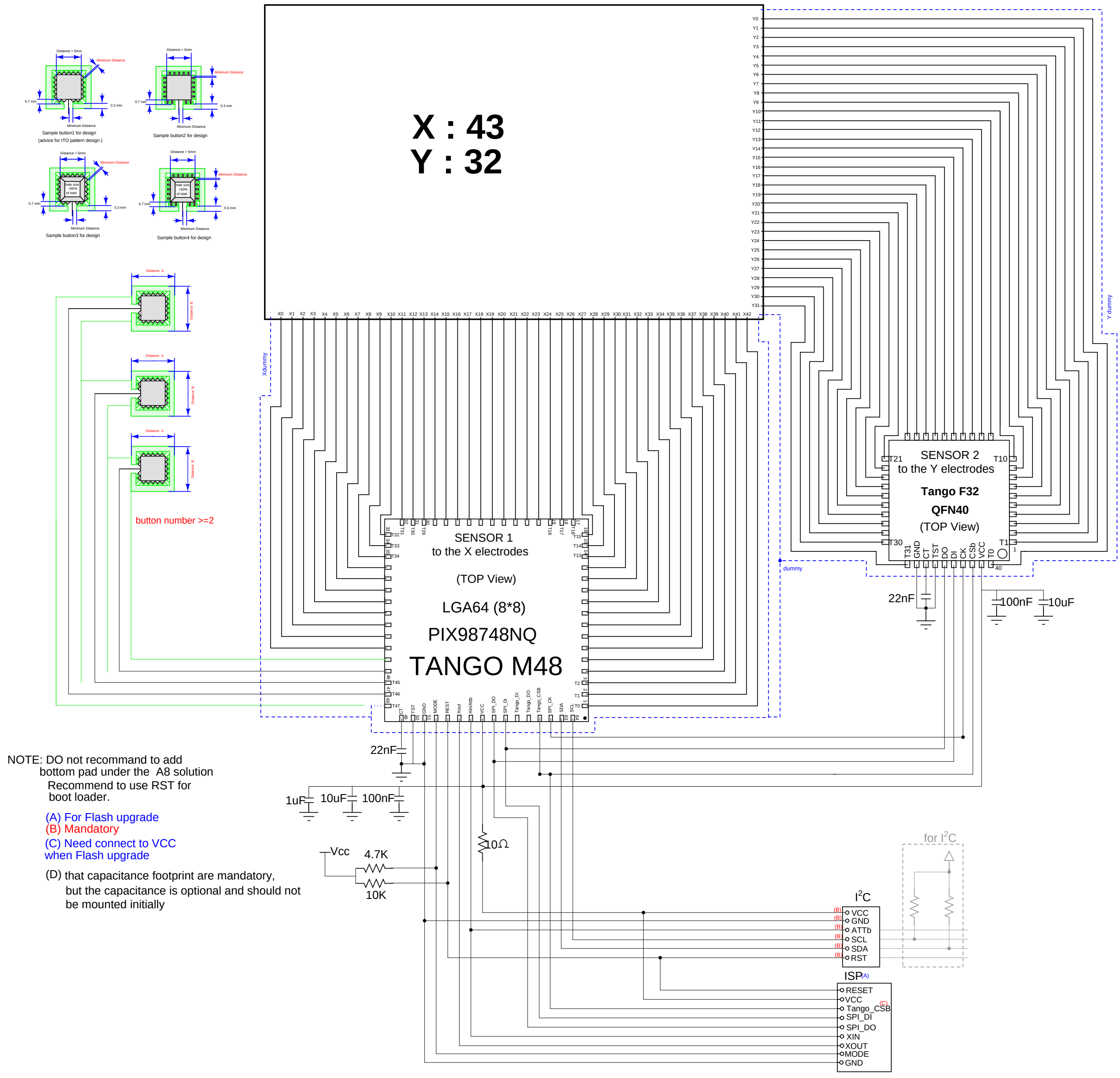


Figure 9: Full schematic-B (2 chip solution)

3.1 States of ATTb line

The slave can set the ATTb line, and host can read and write MSI device. so the MSI controller behaves like an I^2C slave device and fully complies with I^2C addressing and usual I^2C hand shake protocol. As such, a MSI controller is suitable in an bus shared with other I^2C slaves.

3.2 Transition of ATTb line

When INT_MODE=00 in the INT mode register, the slave will set the ATTb line with INT_width pulse width after each scan in order to request the attention from the host, as shown in figure 10 and figure 11

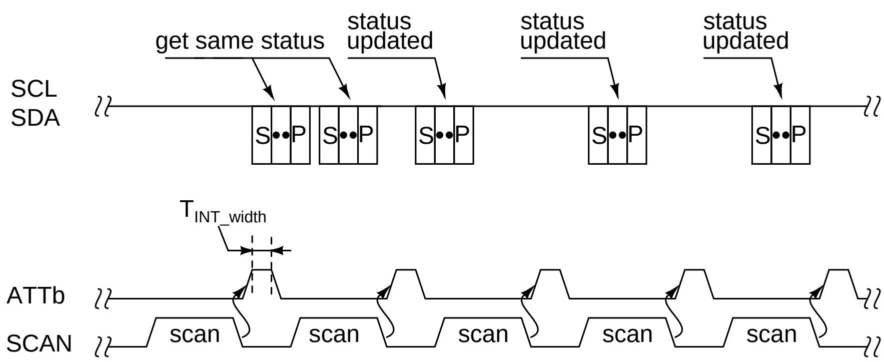


Figure 10: ATTb line pull up by slave (INT_POL=1,INT_MODE=00 in the INT mode register)

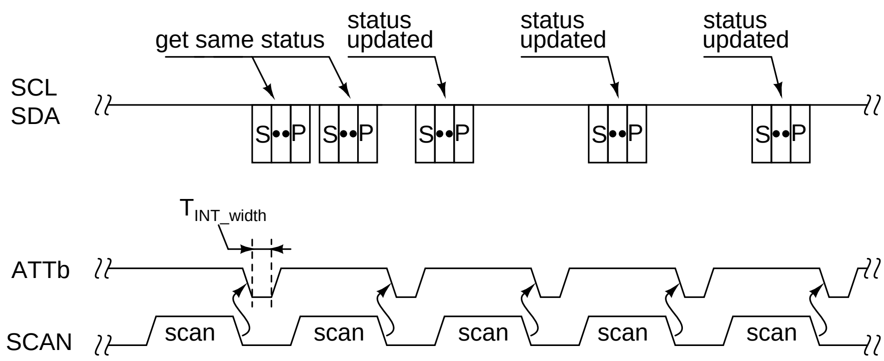


Figure 11: ATTb line pull down by slave(INT_POL=0, INT_MODE=00 in the INT mode register)

When INT_Mode=01 in the INT mode register and finger moving on the panel, the slave will set the ATTb line after each scan, as shown in figure 12. When finger leaves the panel, the slave will continue to pulse ATTb line for each scan; but once the master has serviced this request and become now aware that there is no more finger touching, the slave will stop pulse the ATTb line, and will also gradually reduce the scan speed,as shown in figure 13.

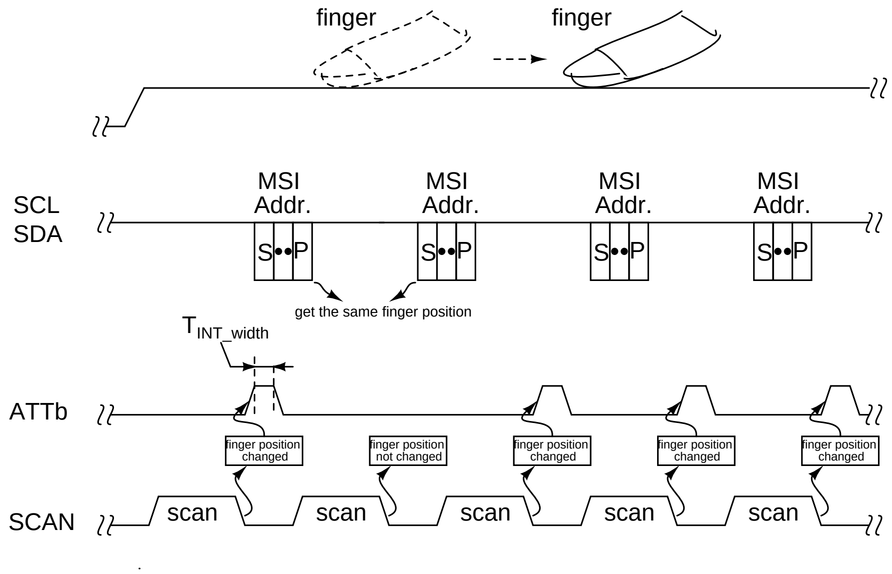


Figure 12: ATTb line pull up when finger moving (INT_POL=1, INT_MODE=01 in the INT mode register)

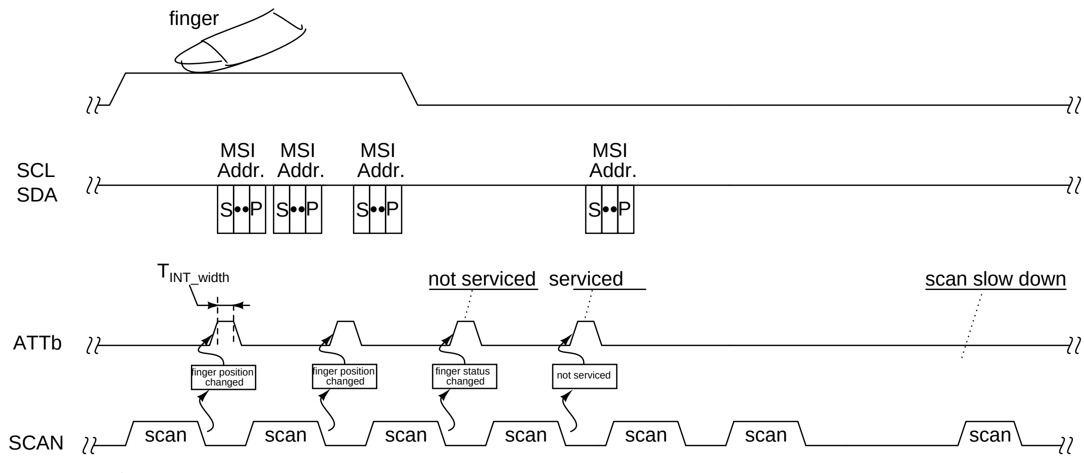


Figure 13: ATTb line will stop pulse when finger leaves and master has acknowledged the situation (INT_POL=1 in the INT mode register)

When INT_Mode=10 in the INT mode register and finger touch the panel, the slave will set the ATTb line after each scan, as shown in figure 14. When finger leaves the panel, the slave will continue keep ATTb line status for each scan; but once the master has serviced this request and become now aware that there is no more finger touching, the slave will release the ATTb line, and will also gradually reduce the scan speed,as shown in figure 15.

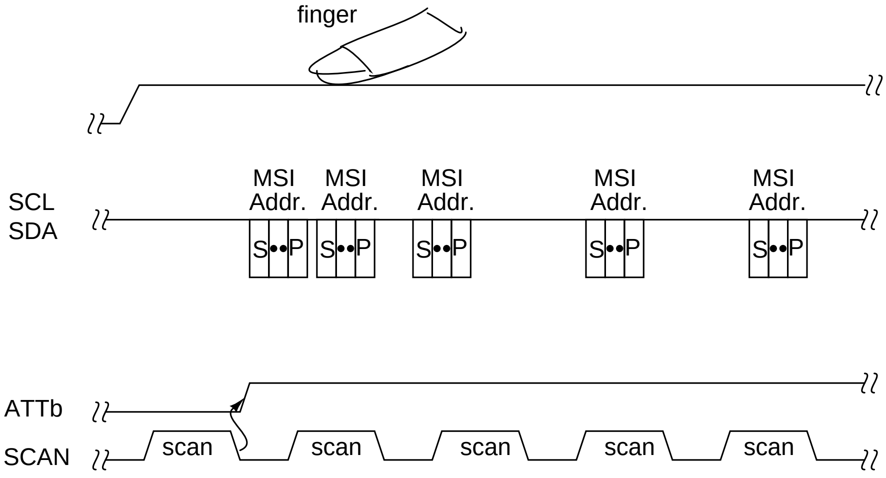


Figure 14: ATTb line pull up when finger touch (INT_POL=1, INT_MODE=10 in the INT mode register)

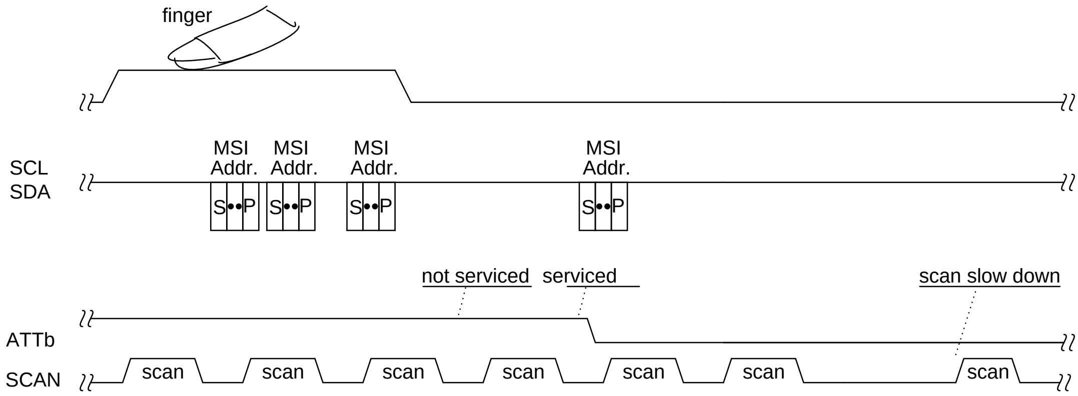


Figure 15: ATTb line will stop pulse when finger leaves and master has acknowledged the situation (INT_POL=1 in the INT mode register)

3.2.1 Specifications

1. MSI device address = 0x5C.

3.3 Reset sequence

Tango M48 Reset pin pull up with 10Kohm resistance. Master side need to reset the Tango M48 in some application, so need follow the below timing sequence in the figure 16

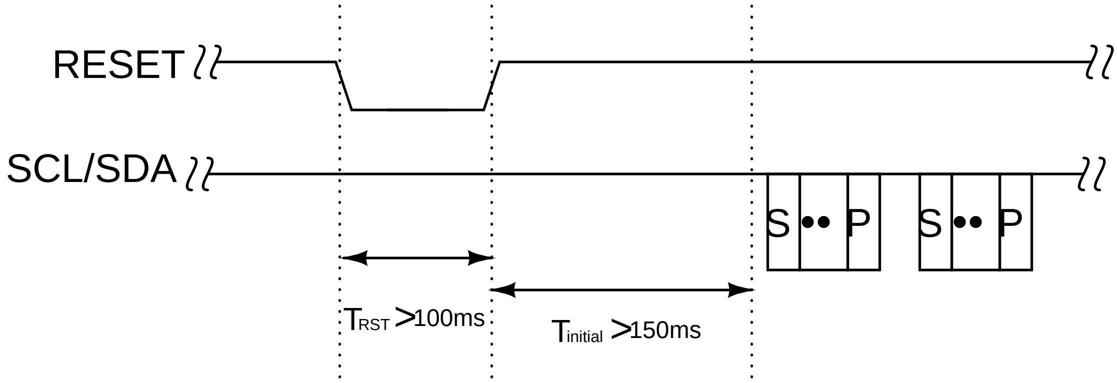


Figure 16: Reset Timing Sequence

4 I2C Protocol Specifications

1. Supports a baud rate up to 400kHz in Active Mode.
2. Only support single master solution.
3. Only support 7-BIT addressing.
4. If I^2C master can't finish 1byte data in 100ms, I^2C slave will restart.
5. I^2C slave can hold off the master in the middle of a transaction using what's called clock stretching (the slave keeps SCL pulled low until it's ready to continue). Refer to figure 17 for a example.

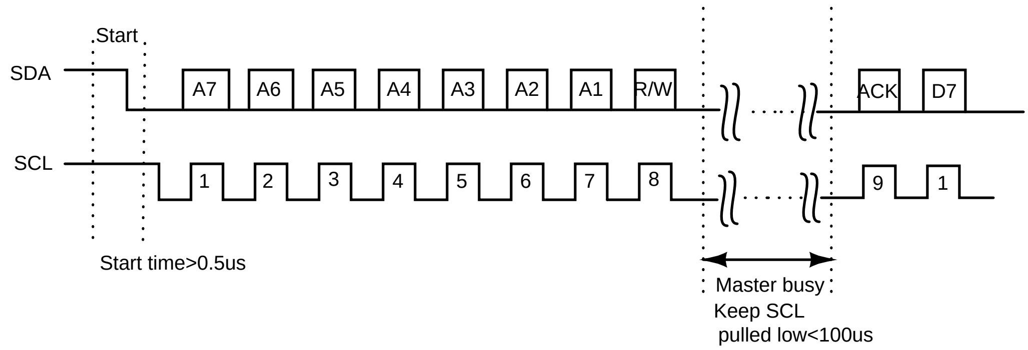


Figure 17: I^2C clock stretching example

4.1 Data Protocol

The communication follows I^2C convention. Refer to figure 18 for a definition of the symbols used.

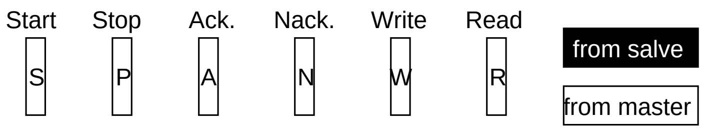


Figure 18: I^2C symbols

4.2 Introduction

The protocol for data exchange has been designed with the following considerations

- Most of the data traffic are read operation to get the finger or fingers position
- Read operation do need an initial write operation.
- Write operations are most of the time power management and interrupt setting instructions
- Interrupt pulse width setting adjustments need a write operation.

4.3 Read operation

Read packets have variable content length, decided by the host. It is available to do a single read operation or a sequential read operation. Therefore, the beginning register address is need to set before a read operation. And the data sent exactly follow the register table **??**. And,the firmware in the slave will use a memory copy of the register for I^{2}C slave read operation, so that firmware can continue updates, and I^{2}C slave is still using a consistent (but old) coordinates for read operation.

- In a sequential read operation, the first data sent by the MSI device is therefore the touching register, and then the old_touching , then X and Y coordinates of the first finger, then coordinates of the 2nd finger, and so on. referred in Figure 20
- If the host do not finish the read operation when the ATTb line is set again, the slave firmware will delay to update coordinates registers for I2C read operation until the host finish the read operation. referred to first part of Figure 21
- I2C stop condition will release data protection and allow the slave firmware update the coordinates registers for I2C read operation. So, the host has the change to give incorrect data when it get the coordntes data with single read operation. Because the host send many times of I2C stop condtion in each multi-fingers coordnates postion reading, it will give the slave firmware chance to update the coordinates registers for I2C read operation, the host will give a combines unrelated data (combines new and old coordinates together), referred to the second part of Figure 21

Figure 19: Read operation

Figure 20: Coordinates read operation

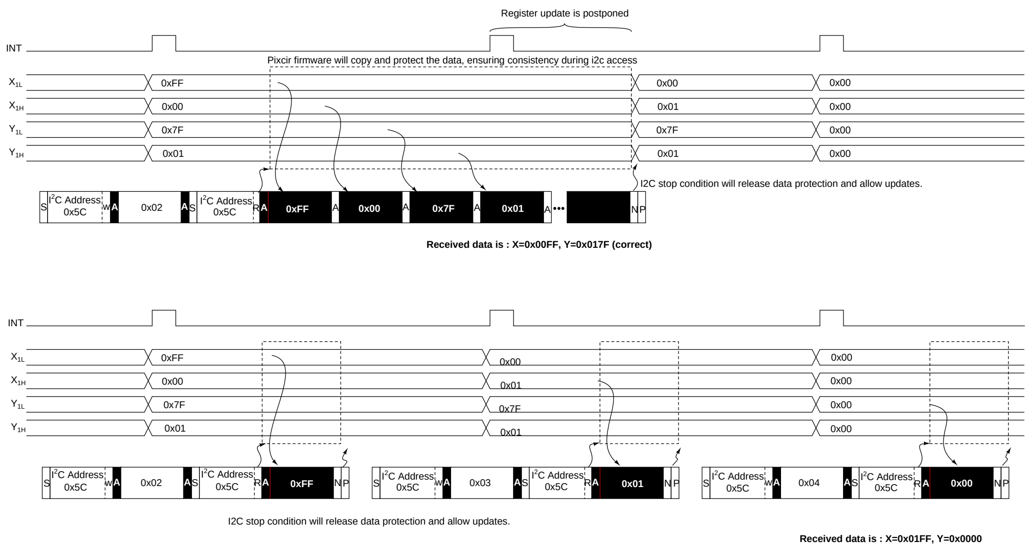


Figure 21: Coordinates read operation explanation

4.4 Write operation

Write packets have variable content length, decided by the host. Write operation stops when host issues an I^{2}C STOP symbol. The write packet is illustrated in figure 22 and figure 23. Following the I^{2}C device address, the first byte of the write packet is always the destination register address, referred in table 12. Subsequent data value are written at the register pointed by the address, immediately upon reception of the byte. The address counter is automatically incremented. Subsequent data bytes are treated in continuation of the writing operation.

S	I^{2}C Address 0x5C	W	A	Mem. Address	A	Data[0]	A	• • •	Data[n-1]	A	Data[n]	A	P

Figure 22: Write operation.

S	I^{2}C Address 0x5C	W	A	0x14	A	power_mode	A	INT_mode	A	INT_width	A	P

Figure 23: Write mode setting operation .

4.5 MSI Registers

The accessible registers are shown in the tables 12 and 14. These registers are technically accessible both for reading or writing direction. However, most registers have only one meaningful direction: finger position registers, for example, are typically used in read direction, and writing to them will have no effect; their content will be overridden after a new sensor scan.

Table 12: One Tango RAM-registers

Address	Name	Description	R/W
0	touching	New touching Finger status. See §8	R
1	old_touching	Previous scan finger status.	R
2 (low part) 3 (high part)	posX	X coordinate of the first finger .	R
4 (low part) 5 (high part)	posY	Y coordinate of the first finger.	R
6 (low part) 7 (high part)	posX2	X coordinate of the second finger.	R
8 (low part) 9 (high part)	posY2	Y coordinate of the second finger.	R
10	X1_W	X1 coordinate touch area of the first finger	R
11	Y1_W	Y1 coordinate touch area of the first finger	R
12	X2_W	X2 coordinate touch area of the second finger	R
13	Y2_W	Y2 coordinate touch area of the second finger	R
14	X1_Z	X1 coordinate of the first finger to panel distance	R
15	Y1_Z	Y1 coordinate of the first finger to panel distance	R

Address	Name	Description	R/W
16	X2_Z	X2 coordinate of the second finger to panel distance	R
17	Y2_Z	Y2 coordinate of the second finger to panel distance	R
18 (low part) 19 (high part)	strength	An estimator of the total signal strength. Even when no finger or three fingers are detected. This value can be used for pressure estimation.	R
20	power_mode	power_mode switching register. See §4.5.1	R/W
21	INT_mode	INT_mode register.See §4.5.2	R/W
22	INT_width	Interrupt pulse width.	R/W
23	noise_mode	NOT IMPLEMENTED.	-
24	noise_threshold	NOT IMPLEMENTED.	-
25	noise_level	NOT IMPLEMENTED.	-
26-30	reserved_1[0-4]	Reserved for customer	R
31	USB_status	show the USB VID,PID information in the xy_raw1 buffer when set that bit to 1.	R/W
32	boot_version	show the bootloader version	R
33	algorithm_version	show the algorithm firmware version	R
34	calib_status	Set to “1” after the calibration success	R
35	palm	Set to “1” if a palm touch be detected	R
36	button_raw_enable	Report the button data in xy_raw1[0-46] and disable the TSP function if set the value bigger than zero. Report the button internal data if it to 3, report the button raw data if it to 1, report the button calibrated data if it to 2.	R/W
37	ac_adapter	Enable some internal parameters(Dataflash address from 317 to 323 for single IC solution; from 460 to 469 for two IC solution) which is in the dataflash if set to 1	R/W
38	m1_frame	M1 raw data with X as sensor if set to 1	R/W
39	reserved_2	PIXCIR internal keep it	-
40	button_scan	Button function enable if that bit equal to “1”	R
41	button_flags	Button touch status, support eight buttons solution. See §4.5.3	R
42 (low part) 43 (high part)	initial_distance	initial value of the two fingers distance	R
44 (low part) 45 (high part)	distance	the current two fingers distance value	R
46 (low part) 47 (high part)	ratio	the variable-ratio of the two fingers distance	R
48-51	version[0-3]	Firmware version refer to the program code stored in flash memory.	R
52	subversion	Firmware subversion	R
53-54	crc	Whole program memory checksum.	R
55	specop	Special operation. See §6.	R/W
56-57	EEPROM_read_addr	Start address of the EEPROM read operation	R/W
58	xthr	Sensitivity along the X electrodes.	R/W
59	ythr	Sensitivity along the Y electrodes.	R/W

Address	**Name**	**Description**	R/W
60	synch	Synchronization on the LCM Vcom signal	R/W
61-154	xy_raw1[0-46]	Raw data Y (2 bytes per data in little-endian, coded in signed magnitude format on bits 0-9, bit 8 as sign, bits 0-7 as magnitude).	R
155-248	xy_raw2[0-46]	Raw data X (see above description).	R
249	cross_enable	0:RASTER feature is disabled. 1: feature is enabled	R/W
250	cross_x	X index.(For the meaning of index, refer to §8 Coordinates characteristics).	R/W
251	cross_y	Y index.(For the meaning of index, refer to §8 Coordinates characteristics).	R/W
252-253	crossing	return value.	R
254	internal_enable	0:check internal algorithm variables is disabled . 1: feature is enabled	R/W

Table 14: Two Tangos RAM-registers

Address	**Name**	**Description**	R/W
0	touching	New touching Finger status. See §8	R
1	old_touching	Previous scan finger status.	R
2 (low part) 3 (high part)	posX	X coordinate of the first finger .	R
4 (low part) 5 (high part)	posY	Y coordinate of the first finger.	R
6 (low part) 7 (high part)	posX2	X coordinate of the second finger.	R
8 (low part) 9 (high part)	posY2	Y coordinate of the second finger.	R
10	X1_W	X1 coordinate touch area of the first finger	R
11	Y1_W	Y1 coordinate touch area of the first finger	R
12	X2_W	X2 coordinate touch area of the second finger	R
13	Y2_W	Y2 coordinate touch area of the second finger	R
14	X1_Z	X1 coordinate of the first finger to panel distance	R
15	Y1_Z	Y1 coordinate of the first finger to panel distance	R
16	X2_Z	X2 coordinate of the second finger to panel distance	R
17	Y2_Z	Y2 coordinate of the second finger to panel distance	R
18 (low part) 19 (high part)	strength	An estimator of the total signal strength. Even when no finger or three fingers are detected. This value can be used for pressure estimation.	R
20	power_mode	power_mode switching register. See §4.5.1	R/W
21	INT_mode	INT_mode register.See §4.5.2	R/W
22	INT_width	Interrupt pulse width.	R/W

Address	**Name**	**Description**	R/W
23	noise_mode	NOT IMPLEMENTED.	-
24	noise_threshold	NOT IMPLEMENTED.	-
25	noise_level	NOT IMPLEMENTED.	-
26-31	reserved_1[0-5]	Reserved for customer	R
32	boot_version	show the bootloader version	R
33	algorithm_version	show the algorithm firmware version	R
34	calib_status	Set to “1” after the calibration success	R
35	palm	Set to “1” if a palm touch be detected	R
36	button_raw_enable	Report the button data in xy_raw1[0-46] and disable the TSP function if set the value bigger than zero. Report the button internal data if it to 3, report the button raw data if it to 1, report the button calibrated data if it to 2.	R/W
37	ac_adapter	Enable some internal parameters(Dataflash address from 317 to 323 for single IC solution; from 460 to 469 for two IC solution) which is in the dataflash if set to 1	R/W
38	m1_frame	M1 raw data with X as sensor if set to 1	R/W
39	reserved_2	PIXCIR internal keep it	-
40	button_scan	Button function enable if that bit equal to “1”	R
41	button_flags	Button touch status, support eight buttons solution. See §4.5.3	R
42 (low part) 43 (high part)	initial_distance	initial value of the two fingers distance	R
44 (low part) 45 (high part)	distance	the current two fingers distance value	R
46 (low part) 47 (high part)	ratio	the variable-ratio of the two fingers distance	R
48-51	version[0-3]	Firmware version refer to the program code stored in flash memory.	R
52	subversion	Firmware subversion	R
53-54	crc	Whole program memory checksum.	R
55	specop	Special operation. See §6.	R/W
56-57	EEPROM_read_addr	Start address of the EEPROM read operation	R/W
58	xthr	Sensitivity along the X electrodes.	R/W
59	ythr	Sensitivity along the Y electrodes.	R/W
60	synch	Synchronization on the LCM Vcom signal	R/W
61-122	xy_raw1[0-30]	Raw data Y (2 bytes per data in little-endian, coded in signed magnitude format on bits 0-9, bit 8 as sign, bits 0-7 as magnitude).	R
123-216	xy_raw2[0-46]	Raw data X (see above description).	R
217	cross_enable	0:RASTER feature is disabled. 1: feature is enabled	R/W
218	cross_x	X index.(For the meaning of index, refer to §8 Coordinates characteristics).	R/W
219	cross_y	Y index.(For the meaning of index, refer to §8 Coordinates characteristics).	R/W
220-221	crossing	return value.	R

Address	**Name**	**Description**	R/W
222	internal_enable	0:check internal algorithm variables is disabled . 1: feature is enabled	R/W
223-224	x_signal	X position signal	R
225-226	y_signal	Y position signal	R

4.5.1 `POWER_MODE` register

The POWER_MODE register controls the power management and operation of the MSI device. However, modification becomes effective at any time.There are shown in the table 16

Table 16: Power_mode register

Address	Name	Description
7-4	IDLE_PERIOD[3-0]	refer to ALLOW_SLEEP function description. Idle_period_time = k * 16 * Active_scan_period_time [s] , with k = value of IDLE_PERIOD[3-0] Active_scan_period_time = duration [s] of a scan period in active mode.
3	-	Not used
2	ALLOW_SLEEP	Allow self demotion from active to sleep mode, provide that this flag is set. If the MSI device is in active mode and no finger is detected for more than IDLE_PERIOD time, then it allow automatically jumps to sleep mode. If this flag is not set, the host must explicitly switch the device from active to sleep mode.
1-0	POWER_MODE[1-0]	Power mode setting of the MSI device: 00: Active Mode 01: Sleep Mode 10: Deep Sleep Mode 11: Freeze Mode

4.5.2 `INT_MODE` register

Table 17: INT_mode register

Address	Name	Description
7-4	-	Not used
3	EN_INT	0: disable interrupt mode 1: enable interrupt mode
2	INT_POL	0: the interrupt is low-active(default) 1:the interrupt is high-active
1-0	INT_MODE[1-0]	00: INT assert periodically 01: INT assert only when finger moving 10: INT assert only when finger touch (default)

4.5.3 BUTTON_FLAGS register

Table 18: BUTTON_FLAGS register

Address	Name	Description
7	BUTTON_8	1: button touched 0: button no touch
...	...	.....
1	BUTTON_2	1: button touched 0: button no touch
0	BUTTON_1	1: button touched 0: button no touch

5 Power management

There are four power modes. The master can change the power mode by writing into the slave POWER_MODE register. This operation can be executed at any time.

5.1 Active mode

In this mode, the slave resumes with a new scan directly after each I^2C transfer (after ATTb rising edge). This is used to reach the highest refesh rate.but also has the highest current consumption. Figure 24 shows how to force the slave into Active mode.

S	I^2C Address 0x5C	W	A	0x14	A	0x00	A	P

Figure 24: Active mode sequence

5.2 Sleep mode

This mode is selected to decrease the current consumption during low activity phases on the sensor, which need a lower refresh rate. The MSI can automatically switch to Active mode(when finger is detected, provided that ALLOW_SLEEP bit is set in the POWER_MODE register) or by set POWER_MODE register. Also, the MSI can automatically switch from Active to Sleep mode when no finger is detected for more than IDLE_PERIOD time, provided that ALLOW_SLEEP bit is set in the POWER_MODE register.Figure 25 shows how to force the slave into Sleep mode. Figure 26 shows how to force the slave into Sleep mode can automatically switch, provided IDLE_PERIOD=10.

S	I^2C Address 0x5C	W	A	0x14	A	0x01	A	P

Figure 25: Sleep mode sequence

S	I^2C Address 0x5C	W	A	0x14	A	0xA4	A	P

Figure 26: Sleep mode automatically switch sequence

5.3 Deep Sleep mode

This mode is selected to acheive the minimum consumption during very low activity phases on the sensor, which need a lowest refresh rate(1Hz). The MSI only can switch to Deep Sleep mode by set POWER_MODE register. Figure 27 shows how to force the slave into Deep Sleep mode.

S	I^2C Address 0x5C	W	A	0x14	A	0x02	A	P

Figure 27: Deep Sleep mode sequence

5.4 Freeze mode

In this mode, the slave MCU internal clock source is stopped, and consumption is only MOS leakage.Figure 28 shows how to force the slave into Freeze mode.There are two ways to wake up from freeze mode.

- RST pin pull down (connect to the Ground) (default)
- ATTb pin change (“1 to 0” or “0 to 1”)

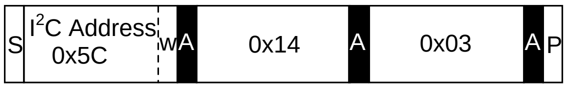


Figure 28: Freeze mode sequence

5.5 Power consumption

Table 19: Power Consumption list

Power Supply	3.3V			5V			
Power Mode	Min.	Typ.	Max.	Min.	Typ.	Max.	Unit
Active mode		-	7.0		-	7.2	mA
Sleep mode (10HZ)		-	1.6		-	2.0	mA
Deep sleep mode (1HZ)		-	1.0		-	1.0	mA
Freeze mode		-	1.9		-	1.9	uA

5.6 Power mode diagram

Figure 29 shows the power mode change diagram.

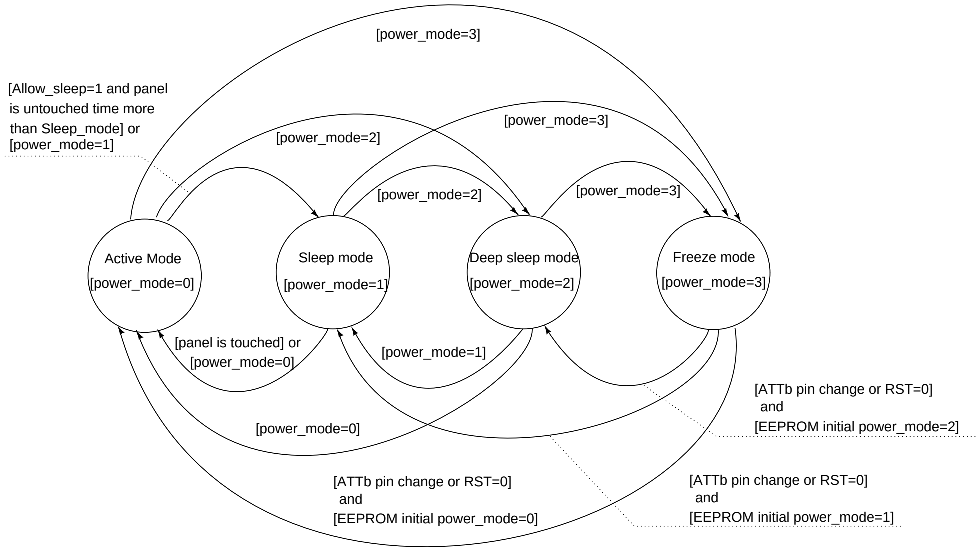


Figure 29: Power mode diagram sequence

6 Special operations

The SPECOP register is used to request maintenance operations.

6.1 Normal Mode

When SPECOP is written with the code 0x00, the following read and write operation will transmit the RAM.

6.2 Data Flash read operation

Data Flash content can be read by the host. When SPECOP is written with the code 0x01, the following read operation will transmit the Data Flash memory.Master device will read the Data Flash memory from address previously stored in EEPROM_read_addr.

6.3 Data Flash write operation

The Data Flash can be written by the host through the MSI interface, as shown in figure 30. The SPECOP register must be set to 0x02. Following this command, ATTb line will be kept low during the whole operation. The MSI device now interprets write commands as addressed to the Data Flash. These write operation must only contain one byte of data, which means the requests contains Data Flash address (16 bits) and Data Flash data (8 bits). After each such writing request, a delay (no I2C traffic) of T ms $> T_{\text{Data Flash A erease time}} + 512 * T_{\text{Data Flash byte write time}}$ ms must be respected in order to guaranty the erase and write cycle of the Data Flash (Data Flash Block A erease time need 200 ms, Data Flash one byte program time need 160us) . The Data Flash writing mode is ended by performing a dummy read operation.

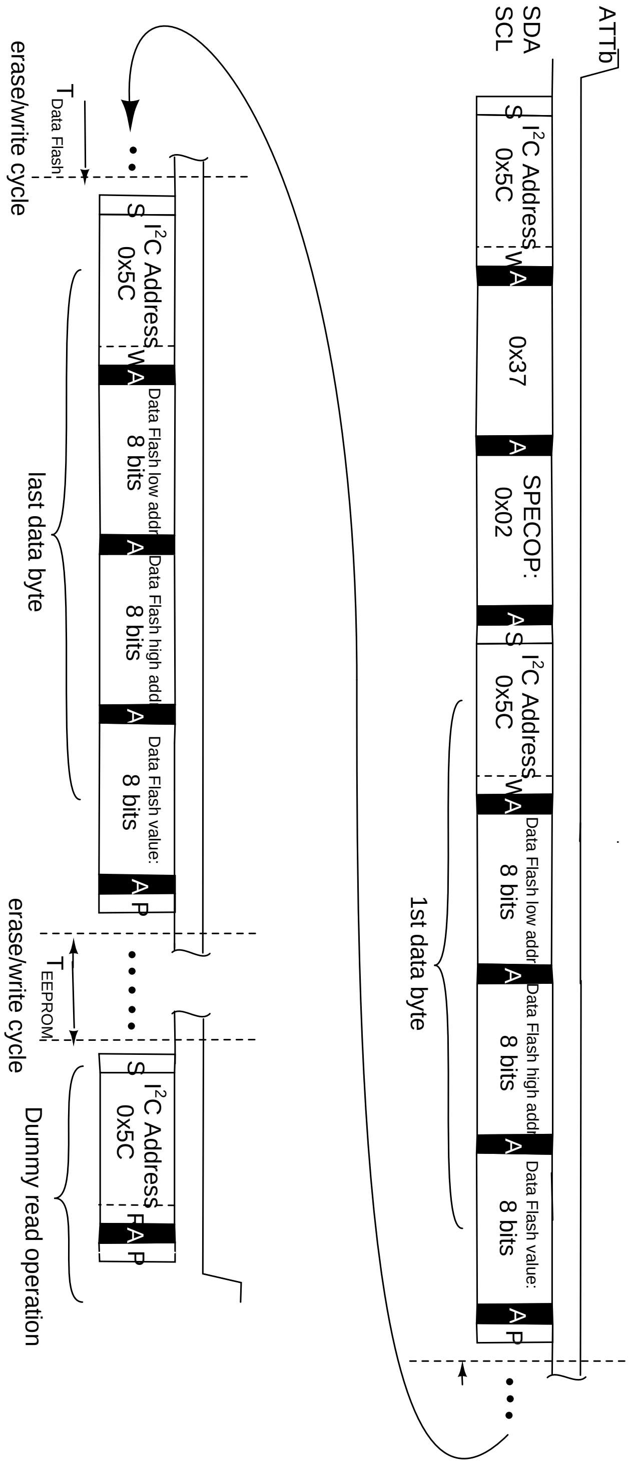


Figure 30: Data Flash write operation

6.4 Calibration

The objective of the calibration need to do one-time total calibrration before product packaged and enable the border tracking calibration action in the product life.

6.4.1 One-time total calibration

The objective of the one-time calibration is to measure the capacitance offsets of the electrode system when no finger is touching, and to store these values into Data Flash. After this, during normal operation, this calibration data is subtracted from the values measured. This operation should be necessary only once in the product life, as part of the final adjustment after the sensor module is mounted in its destination case. The calibration must be done with a clean sensor surface. When `SPECOP` is written with the code 0x03, the following will transmit to do calibration function and then he `SPECOP` register will take back its default zero value.The sequence for calibration is shown in the figure 31. Also the measurement for the calibration lasts no longer than 10 ms, the Data Flash erase and write cycle requires that the power supply be kept on for a duration of at most $T_{\text{CAL}} < 10$ s.(M0 and M1 total calibration). The ATTb line will be pulled up after finish calibration.

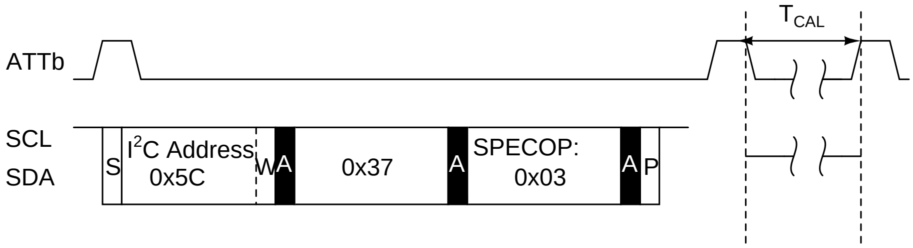


Figure 31: Calibration sequence

```
//calibration code
#define I2C_SLAVE_APP 0x5C
#define I2C_WRITE_APP (I2C_SLAVE_APP<<1)
unsigned char calibration( void)
{
i2c_start ();
i2c_write (I2C_WRITE_APP); //write data from master 2 slave
i2c_write (POS_ADDR(pos.specop)); //specop register address
i2c_write (3); //set specop to 3
i2c_stop ();
_delay_ms (8000); // Wait for 8 second
i2c_start ();
i2c_write (I2C_WRITE_APP); //write data from master 2 slave
i2c_write (POS_ADDR(pos.specop));
i2c_start ();
i2c_write (I2C_READ_APP);
calibration_flag= i2c_read (0);
if(!calibration_flag)
return 0 ; //Calibration PASS
else
return 1; //Calibration FAIL
}
```


6.4.2 Auto tracking calibration

Drift values will be permanently monitored and adjusted the internal data. And drift change is much slower than finger signal change.

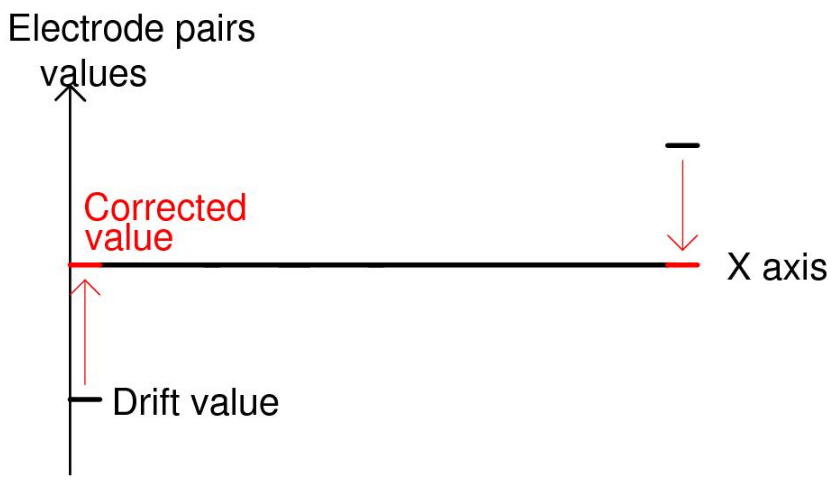


Figure 32: Electrodes value drift example

- Select “drift_comp” as 0x01 to active the auto tracking calibration, please refer to chapter 9 Data Flash table.
- Auto tracking algorithm permanently monitors and adjusts offsets of the internal data. The algorithm can monitore the fingers status during the drift.

6.5 CRC checksum

When `SPECOP` is written with the code 0x04, the following will transmit to CRC checksum operation, then the `SPECOP` register will take back its default zero value. The whole program memory checksum result will be wrote in the crc register.After each such writing request, a delay (no I2C traffic) of $200\,\text{ms} > T_{\text{Data Flash}} > 150\,\text{ms}$ must be respected in order to guaranty checksum cycle of CRC.ATTb line will pull up when finish the crc checksum.

6.6 Bootloader

When `SPECOP` is written with the code 0x05, the following will transmit to bootloader operation, then jump to the start address of the bootloader section and the `SPECOP` register will take back its default zero value. See §10.

7 Coordinates characteristics

The reported posX and posY integer coordinates of the finger(s) position(s) are related to the indexes illustrated on figure 33, where X_0 to $X_{n\text{-}1}$ and Y_0 to $Y_{k\text{-}1}$ represent the X respectively Y electrodes. The scaling factor is 512 units per index pitch. For example, a finger touching the active area over X index 2.7 and Y index 1.4 will have the reported coordinates posX = 2.7 * 512 = 1382 and posY = 1.4 * 512 = 717.

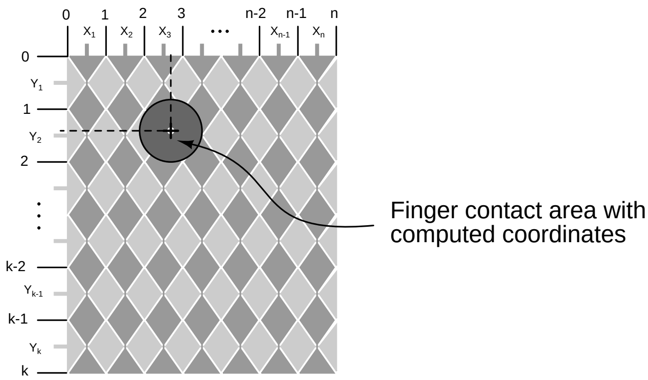


Figure 33: Active area coordinates indexes

As illustrated on figure 34, in the boarders of the active area the reported coordinate of the axis in which the finger is over or close to index 0 (X in this example) will be slightly shifted from the real finger position ($\triangle x \neq 0$ in this example), whereas the coordinate of the other axis (Y in this example) is not affected ($\triangle y = 0$ in this example). This is not any more the case in the accurate area which lays from X indexes 1.5 to (n-1.5) and Y indexes 1.5 to (k-1.5). Note that in any case, the coordinates are bounded inside the dark gray area shown on figure 35.

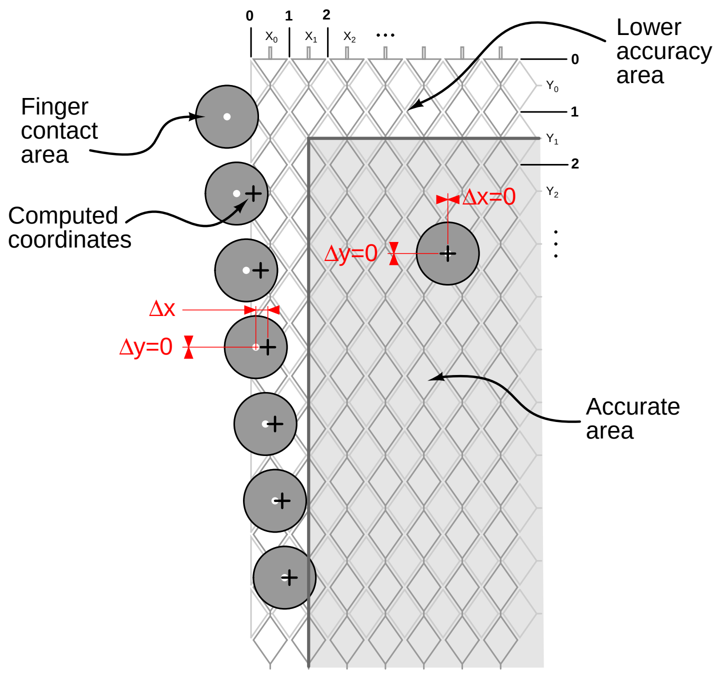


Figure 34: Accuracy of the coordinates vs real finger position on active area

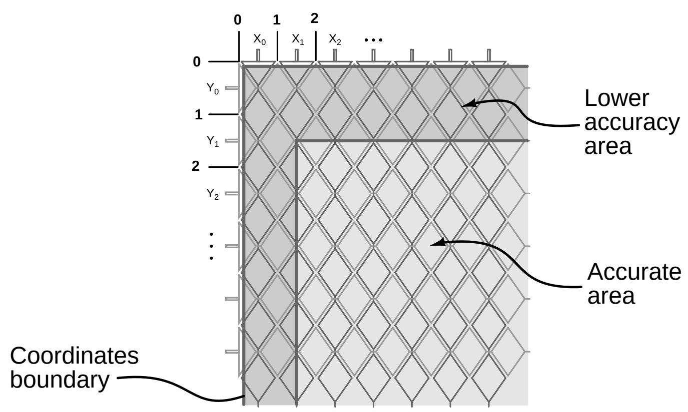


Figure 35: Active area accuracy zones and coordinates boundary

8 Finger reporting

In the dataflash table, there has a “finger_id” feature. it will help solve the finger ID issue if need

8.1 NO Finger ID

Set the finger_id =0 in the dataflash

The protocol will only report the number of fingers, and has no provision for finger ID tracking . Therefore, “swapping” between finger ID #1 and finger ID #2 can occur in the case of a brief transition from 2 fingers to 1 finger, then back to 2 fingers.However, on the host side, this situation is easy to correct, by implementing a finger ID tracking system.

Table 20: Possible transitions

From	To	Result
0 finger	1 finger	Finger is number 1
1 finger	2 fingers	New finger is number 2
2 fingers	1 finger	Remaining finger becomes number 1

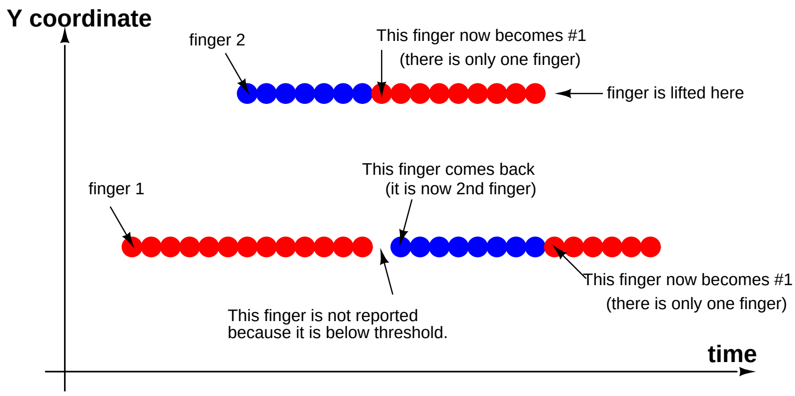


Figure 36: Finger numbering

8.2 Finger ID

Set the finger_id =1 in the dataflash

The protocol will report the finger ID status on the touching register .

Table 21: Finger ID Tracking

Touching Register	Result
0b01	First finger touched available
0b10	Second finger touched available
0b11	Two fingers touched available

9 Data Flash Table

9.1 One Tango Data Flash Table

Address	**#elements**	#bytes per element	name	**Description**
0-31	32	1	disto	Distortion function on the coordinates.
32-79	48	1	X electrodes	Mapping table between Tango pins and corresponding X electrodes Each Tango Pin can be individually compensated by setting +64 or/and +128 or/and +192 flags.
80,81	1	2	X nbr	Number of X electrodes
82,83	1	2	Reserved	RESERVED FOR PIXCIR
84-95	6	2	X stamp	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
96-143	48	1	X sensitivity	Table which stores the X raw data adjustment coefficients to correct the sensitivity
144-145	1	2	X setup	Setup command for the X axis scanning (CF Tango data sheet p.5).
146	1	1	X threshold	Threshold for the X axis scanning.
147-194	48	1	Y electrodes	Mapping table between Tango pins and corresponding Y electrodes Each Tango Pin can be individually compensated by setting +64 or/and +128 or/and +192 flags.
195-196	1	2	Y nbr	Number of Y electrodes
197-198	1	2	Reserved	RESERVED FOR PIXCIR
199-210	6	2	Y stamp	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
211-258	48	1	Y sensitivity	Table which stores the Y raw data adjustment coefficients to correct the sensitivity.
259,260	1	2	Y setup	Setup command for the Y axis scanning (CF Tango data sheet p.5).
261	1	1	Y threshold	Threshold for the Y axis scanning.
262	1	1	M0 SPI	Method 0 sensing speed (SPI data rate). High nibble for X, low nibble for Y. SPI CLK high pulse width = ((k-1)*2+10)/5us SPI CLK low pulse width = ((k-1)*2+13)/5us k=M0 SPI and k>=1

Address	#elements	#bytes per element	name	Description
263	1	1	M1 SPI	Method 1 sensing speed (SPI data rate). (same pulse length as above)
264	1	1	scan enalbe	Scanning is enabled only if set to 1
265-268	1	4	version	Firmware version
269,270	1	2	X resolution	X axis resolution of LCM
271,272	1	2	Y resolution	Y axis resolution of LCM
273	1	1	move threshold	Threshold for the coordinate compare mode on INT.
274	1	1	ghost threshold	Threshold for special cases rejection.
275	1	1	fast option	report rate is higher (but noise immunity is reduced) if set to 1 instead of 0„and even more if set to 2.When set to 3, the mode is automatically switching between 1 and 2 when needed.
276	1	1	special borders	NOT IMPLEMENTED.
277	1	1	Z threshold	Threshold from which the Z function will display its value when no finger is touching. 0 otherwise.
278	1	1	power mode	Power mode setting register
279	1	1	INT_mode	Interrupt mode setting register
280	1	1	INT_width	Interrupt width register
281	1	1	drift_comp	Drift compensation is enabled if set to 1.
282	1	1	subversion	Firmware subversion
283	1	1	noise threshold	The dispersion of each RAW data measure is compared to this threshold to consider whether the system is noisy or not during auto-noise mode.
284	1	1	noise delay	Number of successive scans without noise detected to do before leaving the noisy condition during auto-noise mode.
285	1	1	noise mode	noise mode is always disabled if cleared. noise mode is always enabled if set to 1. noise mode is automatic ON/OFF if set to 2.
286	1	1	I2C time-out	Disabled if set to 0. Enabled if set to 1, with MCU reset if time-out is reached. Enabled if set to 2, with I2C lines released if time-out is reached.

Address	#elements	#bytes per element	name	Description
287	1	1	I2C time-out period	I2C time-out period = (k*50) ms @ 20MHz CPU with k = I2C time-out period.
288	1	1	inerval	the buffer of coordinates recorded at promotion from Sleep to Active mode, once finger is touching, is filled in every N points (N=interval). The buffer feature is disabled if set to 0.
289	1	1	extra_offset	NOT IMPLEMENTED.
290	1	1	extra_offset_flag	NOT IMPLEMENTED.
291-294	4	1	extra_offset_out	NOT IMPLEMENTED.
295-298	4	1	extra_offset_in	NOT IMPLEMENTED.
299	1	1	raw1_delta_offset	NOT IMPLEMENTED.
300	1	1	raw2_delta_offset	NOT IMPLEMENTED.
301	1	1	M1 calibrate	Enable the additional calibration of the whole panel crossing nodes(raster) in ME1 if set to 1 (of course the caliration duration is increased).
302	1	1	button_scan	Enable the button scan function if set to 1. Disable it if set to 0.
303	1	1	button_delay_touch	Delay the button touch report scan loop time. default set to 2.
304,305	1	2	button_setup_command	setup command for the buttons axis scanning
306	1	1	button_nbr	buttons number
307	1	1	button_spi_speed	ME0 sensing speed for buttons
308	1	1	button_thr_press	level for buttons press status threshold
309	1	1	button_noise	level for buttons data noise threshold,default set to 15
310	1	1	finger_id	Enable the finger ID function if set to 1
311	1	1	swap_x_y	All X and Y registers are swapped in the I2C table if set to 1 (change between portrait and landscape formats)
312	1	1	frame_m1	M1 auotmatic scan with X or Y as sensor pin if set to 1. Default to 0.
313	1	1	pattern_m1	M1 scan with more sensertivity if set to 1. Default to 0.
314	1	1	noise_m1	Improve to filter the M1 data if set to 1. Default to 0.

Address	#elements	#bytes per element	name	Description
315	1	1	ac_adapter	Enable the these parameters from address 317 to 323 for improve the noise reject under AC adapter mode if set to 1.
316	1	1	x_g1g0_ac	X Pin Sensor resolution, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
317	1	1	y_g1g0_ac	Y Pin Sensor resolution, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
318	1	1	x_thr_ac	X threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
319	1	1	y_thr_ac	Y threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
320	1	1	ghost_thr_ac	Gost threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
321	1	1	M0_spi_ac	M0 SPI Speed, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
322	1	1	M1_spi_ac	M1 SPI Speed, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
323	1	1	border_gain	Improve the TP screen border finger touch. (can set from 127 to -128)
324	1	1	calibration_loop	Do 1 time scan for method1 calibration data if set to 0, do 2 time scan average for method1 calibration data with noise if set to 1, do 4 time scan for method1 calibration data with more noise if set to 2,
325	1	1	power_on_calib_one_time	If that bit has set to 1 and set the 326 address as zero, then will do one time calibration and set that bit and 326 address value as zero.
326	1	1	power_on_calibration	TP power on calibration if set to 1, disable the function if set to 0.
327	1	1	calibration_IIC_control	Disable the IIC interface during calibration if set to 1.
328	1	1	power_on_calib_dealy_time	Delay scan loop time for the power on calibration, default set to 50.
329	1	1	m1_neg_thr	M1 data negative value threshold, default set to -10
330	1	1	m1_pos_thr	M1 data positive value threshold, default set to 20

Address	#elements	#bytes per element	name	Description
331	1	1	m1_scan_length	More M1 scan point for more M1 noise if set to 1, less M1 scan point for less M1 noise. default set to 0.
332	1	1	one_finger_m1	M1 threshold for on fingers report.
333	1	1	palm	Enable the palm function if set to 1
334	1	1	palm_thr_x	Palm M0 threshold for X
335	1	1	palm_thr_y	Palm M0 threshold for Y
336	1	1	palm_thr_m1	Palm M1 threshold
337	1	1	palm_thr_x_float	Palm M0 threshold for X (floating mode)
338	1	1	palm_thr_y_float	Palm M0 threshold for Y (floating mode)
339	1	1	palm_thr_m1_float	Palm M1 threshold (floating mode)
340	1	1	palm_detect	palm detect number
341	1	1	palm_delay	Used for setting scan delay time after a palm touch be detected default set to “15”
342	1	1	palm_scale	Scale the datas which for detect palm status default set to “1”
343	1	1	drift_power_on	Disable the power on compulsory drift when set it to 1.
344	1	1	Andorid_power_on	Enable the Andorid open O/S function when set it to 1.
345	1	1	drift_threshold	threshold for drift function, Basically, keep it same as the ghost threshold
346-347	1	2	VID	USB VENDOR_ID
348-349	1	2	PID	USB PRODUCT_ID
350-351	1	2	release	USB release number
352-353	1	2	X_phys	TP panel X axis length: X_phys=(X axis length (mm)) *100 / 25.4
354-355	1	2	Y_phys	TP panel Y axis length: Y_phys=(Y axis length (mm)) *100 / 25.4
356-510	168	1	custom	custom area, can be freely used
511	1	1	boot lock	Flag to indicate the application FLASH content for boot loader. 0xA5 allows boot loader to excute application. Other values force boot loader to remain the boot mode.

9.2 Two Tangos Data Flash Table

Address	**#elements**	#bytes per element	name	**Description**
0-31	32	1	disto	Distortion function on the coordinates.
32-79	48	1	X electrodes	Mapping table between Tango pins and corresponding X electrodes Each Tango Pin can be individually compensated by setting +64 or/and +128 or/and +192 flags.
80,81	1	2	X nbr	Number of X electrodes
82,83	1	2	Reserved	RESERVED FOR PIXCIR
84-131	48	1	X sensitivity	Table which stores the X raw data adjustment coefficients to correct the sensitivity
132-143	6	2	X stamp0	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
144-155	6	2	X stamp1	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
156,157	1	2	X setup	Setup command for the X axis scanning (CF Tango data sheet p.5).
158	1	1	X threshold	Threshold for the X axis scanning.
159-206	48	1	X2 electrodes	Mapping table between Tango pins and corresponding X2 electrodes Each Tango Pin can be individually compensated by setting +64 or/and +128 or/and +192 flags.
207,208	1	2	X2 nbr	Number of X2 electrodes
209,210	1	2	Reserved	RESERVED FOR PIXCIR
211-258	48	1	X2 sensitivity	Table which stores the X2 raw data adjustment coefficients to correct the sensitivity
259-270	6	2	X2 stamp0	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
271-282	6	2	X2 stamp1	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
283,284	1	2	X2 setup	Setup command for the X2 axis scanning (CF Tango data sheet p.5).
285	1	1	X2 threshold	Threshold for the X2 axis scanning.

Address	**#elements**	#bytes per element	name	**Description**
286-333	48	1	Y electrodes	Mapping table between Tango pins and corresponding Y electrodes Each Tango Pin can be individually compensated by setting +64 or/and +128 or/and +192 flags.
334,335	1	2	Y nbr	Number of Y electrodes
336,337	1	2	Reserved	RESERVED FOR PIXCIR
338-385	48	1	Y sensitivity	Table which stores the Y raw data adjustment coefficients to correct the sensitivity.
386-397	6	2	Y stamp0	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
398-409	6	2	Y stamp1	Table which defines what electrodes are lifted or not during X axis scanning(CF Tango data sheet p.6).
410,411	1	2	Y setup	Setup command for the Y axis scanning (CF Tango data sheet p.5).
412	1	1	Y threshold	Threshold for the Y axis scanning.
413	1	1	SPI_X	Method 0 sensing speed (SPI data rate). for X SPI CLK high pulse width = ((k-1)*2+10)/5us SPI CLK low pulse width = ((k-1)*2+13)/5us k=M0 SPI and k>=1
414	1	1	SPI_Y	Method 0 sensing speed (SPI data rate). for Y (same pulse length as above)
415	1	1	SPI_M1	Method 1 sensing speed (SPI data rate). (same pulse length as above)
416	1	1	scan enalbe	Scanning is enabled only if set to 1
417-420	1	4	version	Firmware version
421,422	1	2	X resolution	X axis resolution of LCM
423,424	1	2	Y resolution	Y axis resolution of LCM
425	1	1	move threshold	Threshold for the coordinate compare mode on INT.
426	1	1	ghost threshold	Threshold for special cases rejection.
427	1	1	fast option	report rate is higher (but noise immunity is reduced) if set to 1 instead of 0„and even more if set to 2.When set to 3, the mode is automatically switching between 1 and 2 when needed.

Address	**#elements**	#bytes per element	name	**Description**
428	1	1	sleep rate	NOT IMPLEMENTED.
429	1	1	Z threshold	Threshold from which the Z function will display its value when no finger is touching. 0 otherwise.
430	1	1	power mode	Power mode setting register
431	1	1	INT_mode	Interrupt mode setting register
432	1	1	INT_width	Interrupt width register
433	1	1	drift_comp	Drift compensation is enabled if set to 1.
434	1	1	subversion	Firmware subversion
435	1	1	pen	NOT IMPLEMENTED.
436	1	1	I2C time-out	Disabled if set to 0. Enabled if set to 1, with MCU reset if time-out is reached. Enabled if set to 2, with I2C lines released if time-out is reached.
437	1	1	I2C time-out period	I2C time-out period = (k*50) ms @ 20MHz CPU with k = I2C time-out period.
438	1	1	inerval	the buffer of coordinates recorded at promotion from Sleep to Active mode, once finger is touching, is filled in every N points (N=interval). The buffer feature is disabled if set to 0.
439	1	1	swap XY	All X and Y registers are swapped in the I2C table if set to 1 (change between portrait and landscape formats).
440	1	1	delay_calibr	Add the time delay if set to 1
441	1	1	M1_calibr	Enable M1 all panel calibration if set to 1
442	1	1	water_thr	NOT IMPLEMENTED.
443	1	1	button_scan	Enable the button scan function if set to 1. Disable it if set to 0.
444	1	1	button_delay_touch	Delay the button touch report scan loop time. default set to 2.
445-446	1	2	button_setup_command	setup command for the buttons axis scanning
447	1	1	button_nbr	buttons number
448	1	1	button_spi_speed	ME0 sensing speed for buttons scan
449	1	1	button_thr_press	level for buttons press status threshold
450	1	1	button_noise	level for buttons data noise threshold,default set to 15
451	1	1	palm	Enable the palm function if set to 1

Address	**#elements**	#bytes per element	name	**Description**
452	1	1	palm_thr_x	palm threshold for X
453	1	1	palm_thr_y	palm threshold for Y
454	1	1	palm_detect	palm detect number
455	1	1	palm_delay	Used for setting scan delay time after a palm touch be detected default set to “15”
456	1	1	palm_scale	Scale the datas which for detect palm status default set to “1”
457	1	1	finger_id	Enable the finger ID function if set to 1
458	1	1	pattern_m1	M1 scan with more sensertivity if set to 1. Default to 0.
459	1	1	ac_adapter	Enable the these parameters from address 457 to 463 for improve the noise reject under AC adapter mode if set to 1.
460	1	1	x_g1g0_ac	X Pin Sensor resolution, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
461	1	1	y_g1g0_ac	Y Pin Sensor resolution, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
462	1	1	x_thr_ac	X threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
463	1	1	y_thr_ac	Y threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
464	1	1	ghost_thr_ac	Gost threshold, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
465	1	1	spi_x_ac	Method 0 sensing speed (SPI data rate). for X,enable that fuction if set the "ac_adapter" which in the dataflash or RAM
466	1	1	spi_y_ac	Method 0 sensing speed (SPI data rate). for Y,enable that fuction if set the "ac_adapter" which in the dataflash or RAM
467	1	1	M1_spi_ac	M1 SPI Speed, enable that fuction if set the "ac_adapter" which in the dataflash or RAM

Address	**#elements**	#bytes per element	name	**Description**
468	1	1	palm_thr_x_ac	palm threshold for X, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
469	1	1	palm_thr_y_ac	palm threshold for Y, enable that fuction if set the "ac_adapter" which in the dataflash or RAM
470	1	1	border_gain	Improve the TP screen border finger touch. (can set from 127 to -128)
471	1	1	calibration_loop	Do 1 time scan for method1 calibration data if set to 0, do 2 time scan average for method1 calibration data with noise if set to 1, do 4 time scan for method1 calibration data with more noise if set to 2,
472	1	1	power_on_calibration	TP power on calibration if set to 1, disable the function if set to 0.
473	1	1	M1_rotate_en	Method1 scan with rotate=1 if set to 0, method1 scan with rotate automatic if set to 1. Default set to 1.
474	1	1	m1_neg_thr	M1 data negative value threshold, default set to -10
475	1	1	m1_pos_thr	M1 data positive value threshold, default set to 20
476-510	35	1	custom	custom area, can be freely used
511	1	1	boot lock	Flag to indicate the application FLASH content for boot loader. 0xA5 allows boot loader to excute application. Other values force boot loader to remain the boot mode.

10 Bootloader

10.1 Introduction

The device can operate in two different modes:

Normal mode, which is the normal operation. The device uses the following I^{2}C address: 0x5C

Bootloader mode which allows bootloader operation. The device uses another I^{2}C address: 0x5D, and uses a specific syntax.

In bootloader mode, the device uses a different, more simple I^{2}C servicing firmware, which is totally separated from normal I^{2}C. This means that the entire firmware of normal mode can be reflashed, including the I^{2}C code itself

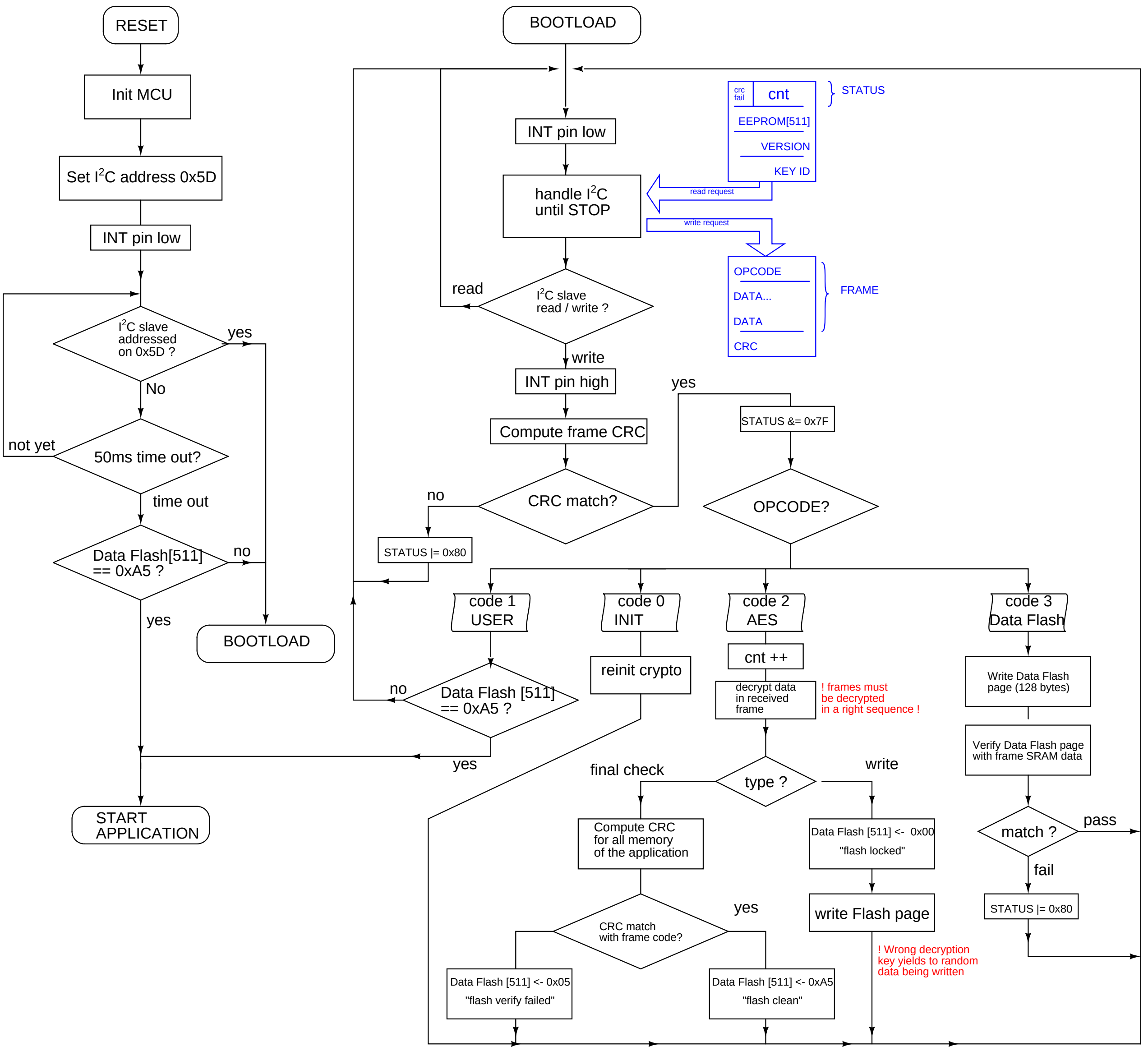


Figure 37: Bootloader flow diagram (for illustration purpose only)

10.2 Switching to bootloader

Switching from normal mode to bootloader mode can be done by two methods:

- by software, be modifying the SPECOP register by an I^2C command to address 0x5C.
- by power on reset, followed immediately by an appropriate I^2C command to address 0x5D.

10.3 Bootloader read operation

In bootloader mode, I^2Cread operation always send the same sequence of information:

- STATUS reports a status register
- FLASHLOCK reports the flash status as stored in Data Flash[511]:
  - 0xFF means Data Flash is erased, flash status is unknown. Jump to application is impossible.
  - 0x00 means the flash has been locked. Jump to application is impossible.
  - 0xA5 means the flash has been unlocked. Jump to application is possible.
- VERSION reports the bootloader version
- KEY reports the customer cryptographic key (this is just a “label”, not the actual key!)
- Reserved: further read will issue a stream of zero. These positions are reserved for future use.

10.4 Bootloader write operation

In bootloader mode, I^2C write operation always follow the same sequence of data

- OPCODE, which is a command to execute, followed by optional DATA, a variable length sequence.

The OPCODE command is executed after the end of the I^2C transaction. The bootloader can understand the following OPCODE commands:

- INIT (code 0): reinitialize the cryptography engine, and allow for a new upgrade
- USER (code 1): switch to normal mode.
- AES (code 2): load a frame. Frames are decrypted and interpreted after the I^2C STOP transition. The device will release the INT signal and will not respond to any I^2C solicitations during the execution of this instruction. These pages gave a secondary OPCODE, which selects either:
  - Actual writing of FLASH pages
  - Final check of the whole FLASH and unlocking
- Data Flash page (code 3): allow user to modify Data Flash without cryptography. The CRC error flag is set if either transmission or writing to the Data Flash failed

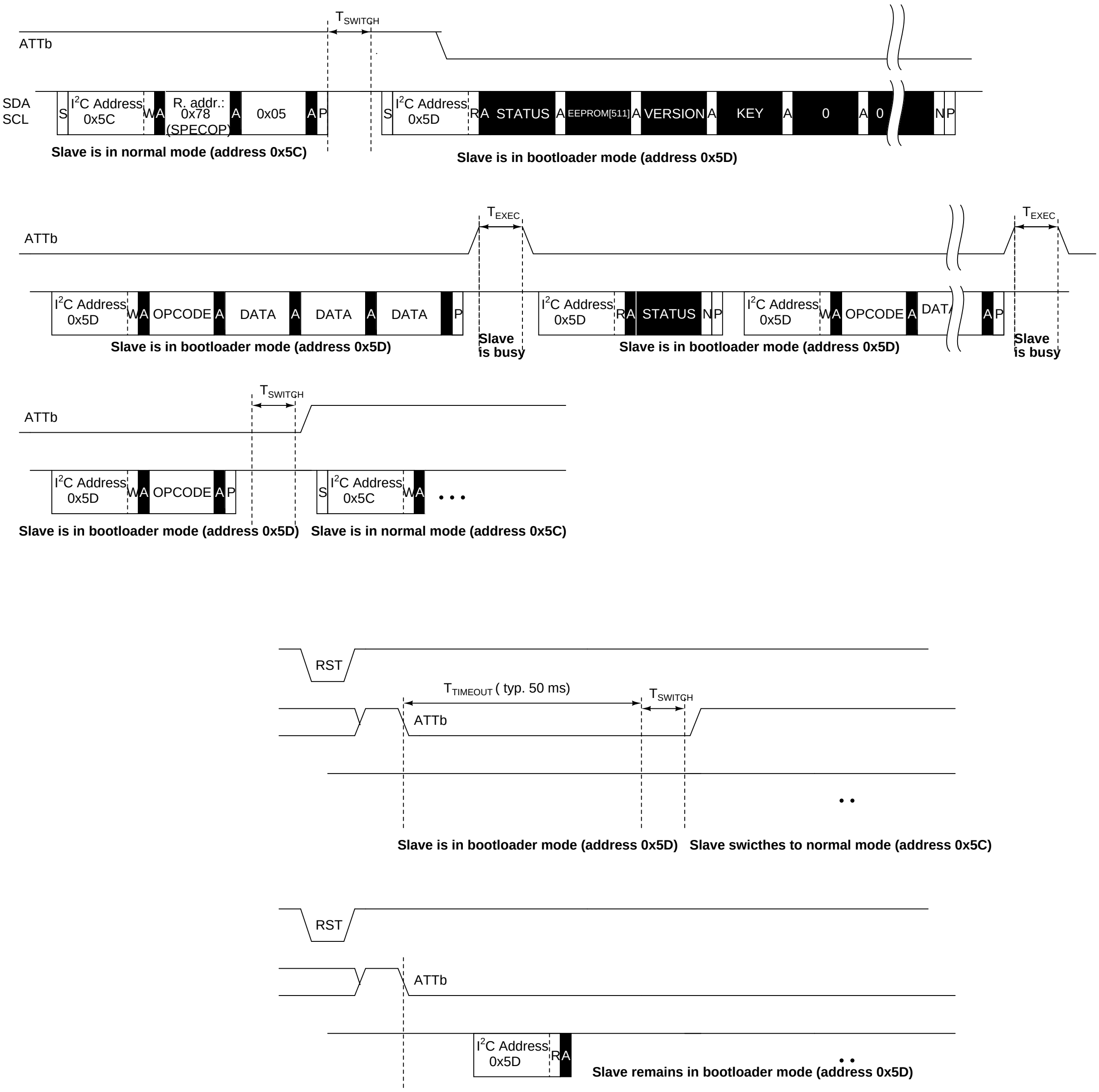


Figure 38: Examples of I^{2}C communication. Top row shows the transition from normal to boot loader mode, followed by a read operation which reads the status, bootloader version and crypto key information. The row in the middle shows the sequence of sending data frames, followed by a flashing operation, follow by checking the status register and a continuation of frame loading. The bottom row shows the switching from bootloader back to normal mode.

10.5 File format

10.5.1 Header

The header contains two lines starting with # sign:

- First line is the bootloader version (in hex code, single byte)
- Second line is the key identifier (in hex code, single byte)

10.5.2 Frame format

The frame format is shown in figure 39.

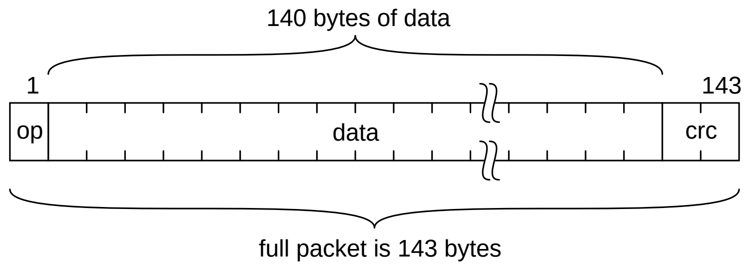


Figure 39: Format of a encrypted frame

The OPCODE (1 byte, code 02) and the CRC (2 bytes) values are already prepared and are already contained in the ASCII file. The format of the ASCII file is shown here under. Each frame starts with a '$' sign and ends with a UNIX like return carriage '\n'. Each frame is 143 bytes long, coded in HEX.

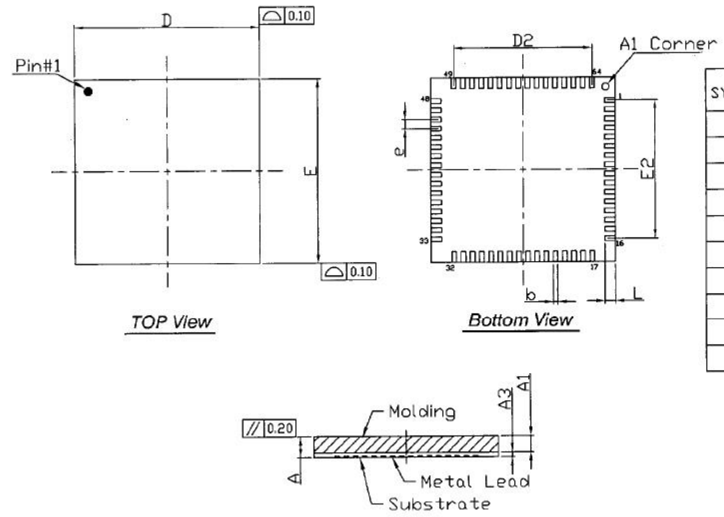
10.5.3 File example

```
#01
#A0
! Comment example
$023FD38AE5706C42BCDFD533DFD39D860C90FF9672AFC69E47CA035BE2775F
$029C081C92AD4FC9E74B000D0B669B0445E86DFC37824D0D7702D4BC6DBC34
! Comment again here
$02E3C7B35082AD22A61DF0EB571F758DFB61ED6D27964EE99B44AD5D31317D
```

The CRC of the part is computed out of the 141 first data bytes (it therefore includes the OPCODE field). The CRC function is CRC-16 with polynomial commonly called 0x8005. It is optional for the host loader to check the CRC value (this only prevents data corruption of the ASCII file).

11 Packaging information

11.1 Package Dimensions



SYMBOL	Dimension in mm			Dimension in inch		
	Min	Nor	Max	Min	Nor	Max
A	0.86	---	1.00	0.0339	---	0.0394
A1	0.68	0.70	0.71	0.0268	0.0276	0.0280
A3	0.18	0.21	0.24	0.0071	0.0083	0.0094
b	---	0.20TYP	---	---	0.008TYP	---
D	7.95	8.00	8.05	0.3130	0.3150	0.3170
D2	---	6.00TYP	---	---	0.236TYP	---
E	7.95	8.00	8.05	0.3130	0.3150	0.3170
E2	---	6.00TYP	---	---	0.236TYP	---
e	---	0.40TYP	---	---	0.016TYP	---
L	0.40	0.45	0.50	0.0157	0.0177	0.0197

Figure 40: TANGO M48 Packaging information

11.2 IC Orientation in tray

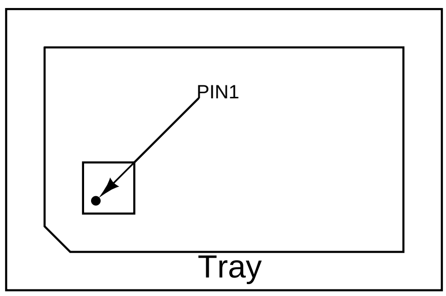


Figure 41: IC Orientation in tray

11.3 Tango M48 Package Tray Specification

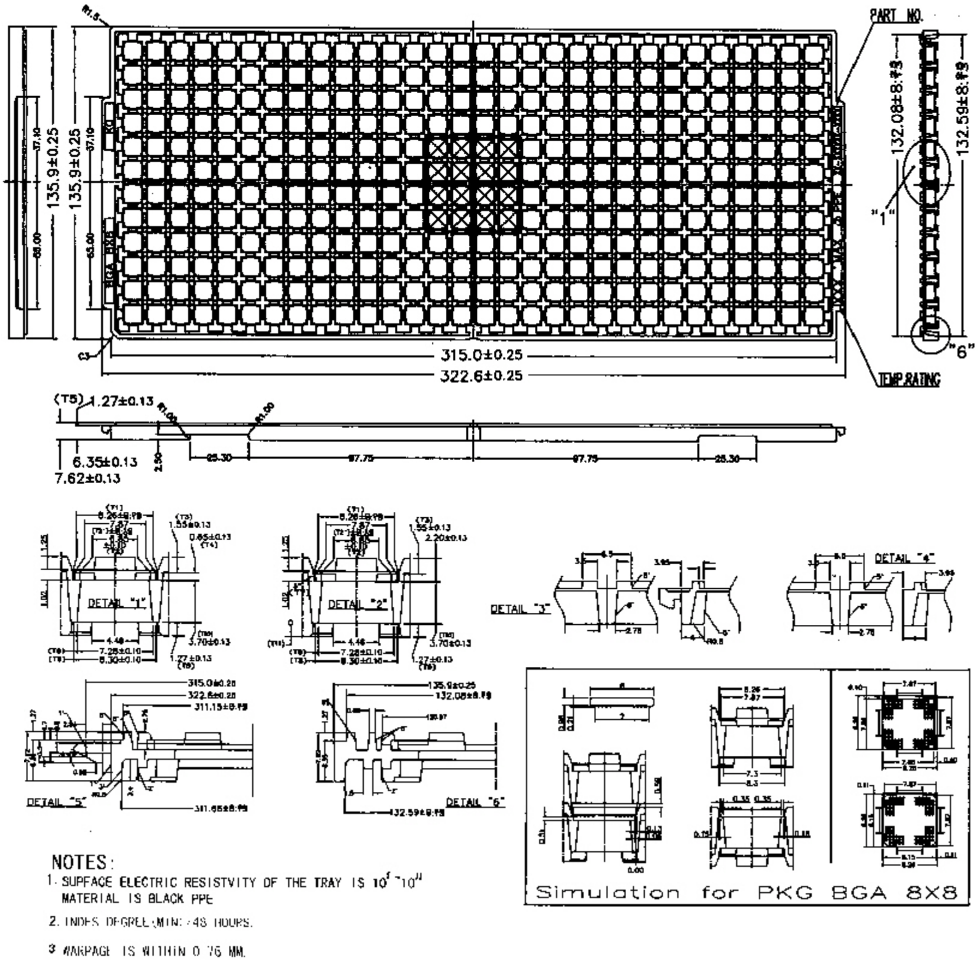


Figure 42: Tango M48 Package Tray Specification

11.4 Packing information

11.4.1 Marking information

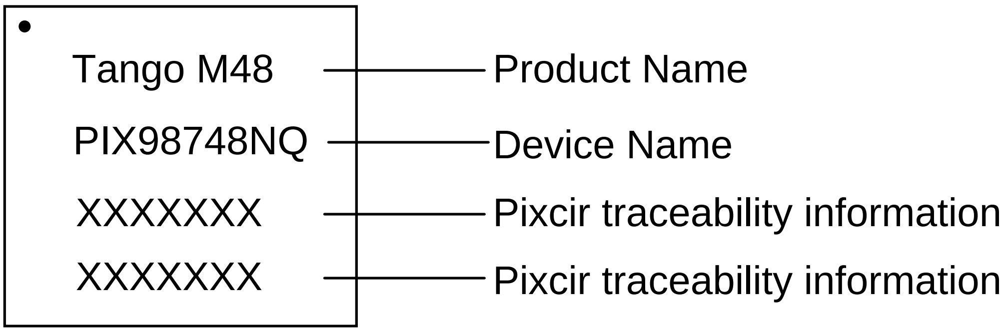


Figure 43: Tango M48 marking information

11.4.2 MSL information

MSL: level 3.

11.4.3 packing number

Tray :360 Pcs/tray,10tray/box.

12 Disclaimer

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