

# GT928

## 10-Point Capacitive Touch Controller for Large-Screen Mobile Phones

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Rev.08——Nov. 14, 2014

===== Disclaimer =====

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# 1. Overview

GT928, a new-generation 10-point capacitive touch solution designed for 7" to 10.1" portable devices, consists of up to 32 Transmitter electrodes and 24 Receiver electrodes to achieve higher accuracy and resolution.

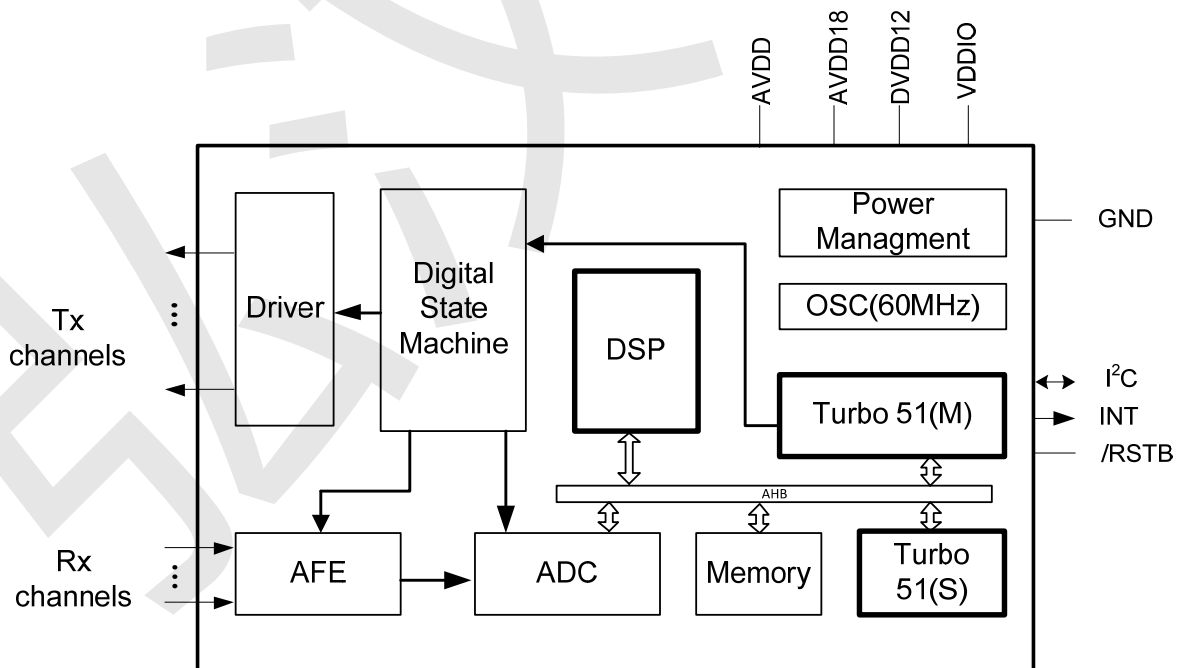
GT928 supports up to 10 concurrent touches with real-time tracking of accurate position and motion trajectory as well as touch area. Furthermore, it is able to report such information to the host as required.

# 2. Features

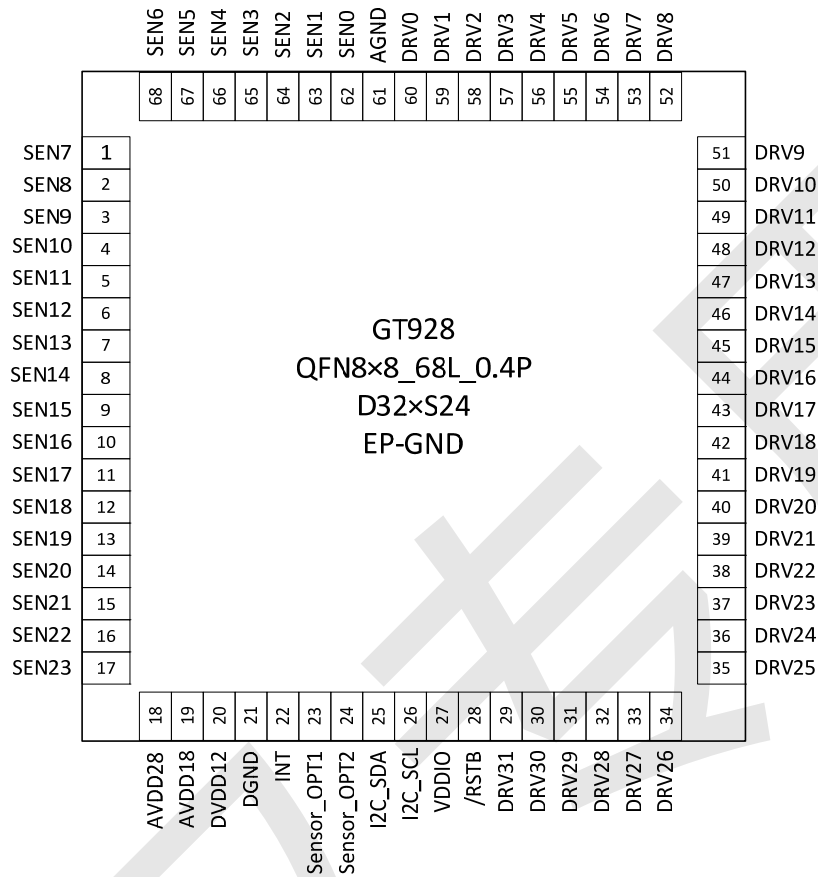
- ✧ Built-in capacitive sensing circuit and high-performance MPU
  - Report rate: 100Hz
  - Outputs touch coordinates in real time
  - Unified software applicable to capacitive touch screens of various sizes
  - Single power supply, internal 1.8V LDO
  - Flash embedded; In-system reprogrammable
  - HotKnot integrated
- ✧ Capacitive touch screen sensor
  - Channels: 32(Tx channels)\*24(Rx channels)
  - Supports capacitive touch screen sizes: 7" to 10.1" (diagonal)
  - Supports touch key design on FPC
  - Supports ITO glass and ITO Film
  - Cover Lens thickness supported: 0.7mm ≅ Glass ≅ 2mm  
0.5mm ≅ Acrylic ≅ 1.2mm
  - Adaptive frequency hopping
  - Supports OGS full lamination
- ✧ HotKnot
  - Transmission rate: 7.0Kbps (max)
  - Data frame maximum capacity: 128 bytes
  - Applicable sensor types: OGS/conventional, GFF/GG/ GF
- ✧ Environmental adaptability
  - Self-calibration during initialization
  - Automatic drift compensation
  - Operating temperature: -40°C to +85°C; humidity: ≅ 95%RH
  - Storage temperature: -60°C to +125°C; humidity: ≅ 95%RH
- ✧ Host interface
  - Standard I<sup>2</sup>C interface

**10-point Capacitive Touch Controller GT928**

- Works in slave mode
- Supports 1.8V to 3.3V host interface voltage
- ✧ Response time
  - Green mode: <48ms
  - Sleep mode: <200ms
  - Initialization: <200ms
- ✧ Power supply voltage:
  - Single supply: 2.8V to 3.3V
- ✧ Power supply ripple:
  - $V_{pp} \leq 50\text{mV}$
- ✧ Package: 68 pins, 8mm\*8mm QFN\_0.4P
- ✧ Tools provided to support application development:
  - TP module parameter detector and generator
  - Integrated tool for TP module performance test
  - Tool for quality inspection during module mass-production
  - Reference driver code and documentary guide for host software development

**3. Block Diagram**

# 4.Pin Configurations



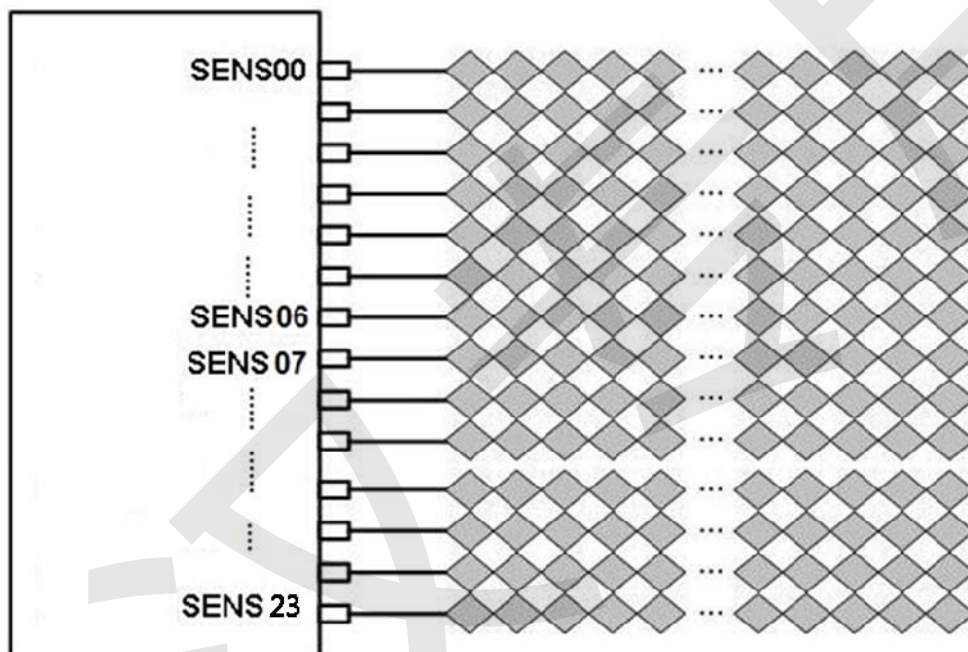
Pin No.	Name	Function description	Remarks
1~17	SENS7~SENS23	Receiver electrodes	Output drive signal while HotKnot function is on
18	AVDD28	Analog power	2.2uF filter capacitor to GND
19	AVDD18		2.2uF filter capacitor to GND
20	DVDD12		2.2uF filter capacitor to GND
21	DGND	Digital signal ground	
22	INT	Interrupt signal	
23	Sensor_OPT1	Module ID pin	
24	Sensor_OPT2	Module ID pin	External pull-down resistor required
25	I2C_SDA	I <sup>2</sup> C data signal	
26	I2C_SCL	I <sup>2</sup> C clock signal	
27	VDDIO	Supply voltage of GPIO	2.2uF filter capacitor to GND Floating: 1.8V Connect to AVDD: AVDD
28	RSTB	Reset pin	External 10K pull-up resistor required, active-low reset
29~60	DRV31~DRV0	Transmitter electrodes	
61	AGND	Analog signal ground	
62~68	SEN0~SEN6	Receiver electrodes	Output drive signal while HotKnot function is on

## 5. Sensor Design

### 5.1 Layout of Rx Channels

SENS0 to SENS23 are 24 Rx channels on the chip directly connected to 24 ITO Rx channels on the sensor either in sequence or reverse sequence. Please refer to *GT928 Series Channel Selector* for channel selection when there are less ITO Rx channels on the sensor than Rx channels on the chip.

Sample Layout: the ITO Rx channels on the sensor are connected to the Rx channels on the chip in sequence from SENS0 to SENS23:



### 5.2 Layout of Tx Channels

DRV0 to DRV31 are 32 Tx channels on the chip directly connected to 32 ITO Tx channels on the sensor. Please refer to *GT9 Series Channel Selector* for DRV line channel selection and assignment.

After the layout of the Tx channels is determined, relevant registers of GT928 shall be configured to ensure logic positions of Tx channels are consistent with their physical positions, so that the reported coordinates match the physical coordinates.

For details of sensor design, please refer to layout guidelines.

### 5.3 Sensor Design Specifications

GT928	DITO	SITO
Tx routing trace Impedance	$\cong 3K\Omega$	$\cong 3K\Omega$
Tx channel Impedance	$\cong 10K\Omega$	$\cong 10K\Omega$
Rx routing trace Impedance	$\cong 10K\Omega$	$\cong 10K\Omega$
Rx channel Impedance	$\cong 40K\Omega$	$\cong 10K\Omega$
Node capacitance	$\cong 4pF$	$\cong 4pF$

To ensure data consistency and uniformity on the entire screen, it is necessary to ensure the sensor design complies with the above requirements. For detailed requirements, please refer to *Sensor Design Guidelines* of Goodix.

In addition, when Tx channel/trace and Rx channel/trace are adjacent and parallel to each other, separate the channels/traces with a ground trace. For ground trace width, please refer to *Sensor Design Guidelines*. Note that ground trace width should be no less than 0.2mm.

### 5.4 Touch Key Design

GT928 supports at most 4 separated touch keys in the following two ways:

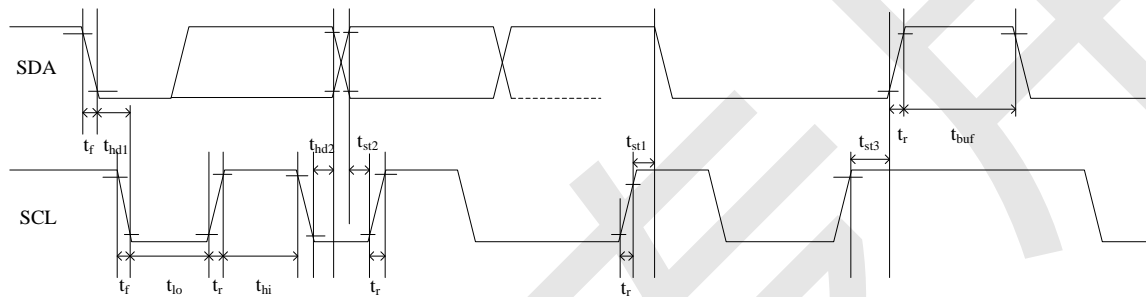
- 1) *Touch key design on sensor*: Take one Tx channel as a common port for the touch keys and connect the Tx channel to four Rx channels to enable four touch keys. The touch keys must not share their Tx channel with the touch screen. However, Rx channels have to be shared.
- 2) *Touch key design on FPC*: Connect one separate Tx channel to four Rx channels to enable four touch keys. The touch keys have to share their Rx channels with the touch screen. Touch key pattern on FPC should be designed independently.



## 6. I<sup>2</sup>C Communication

### 6.1 I<sup>2</sup>C Timing

GT928 provides a standard I<sup>2</sup>C interface for SCL and SDA to communicate with the host. GT928 always serves as slave device in the system with all communication being initialized by the host. It is strongly recommended that transmission rate be kept at or below 400Kbps. The I<sup>2</sup>C timing is shown below:



**Test condition 1: 1.8V host interface voltage, 400Kbps transmission rate, 2K pull-up resistor**

Parameter	Symbol	Min.	Max.	Unit
SCL low period	$t_{lo}$	1.3	-	us
SCL high period	$t_{hi}$	0.6	-	us
SCL setup time for Start condition	$t_{st1}$	0.6	-	us
SCL setup time for Stop condition	$t_{st3}$	0.6	-	us
SCL hold time for Start condition	$t_{hd1}$	0.6	-	us
SDA setup time	$t_{st2}$	0.1	-	us
SDA hold time	$t_{hd2}$	0	-	us

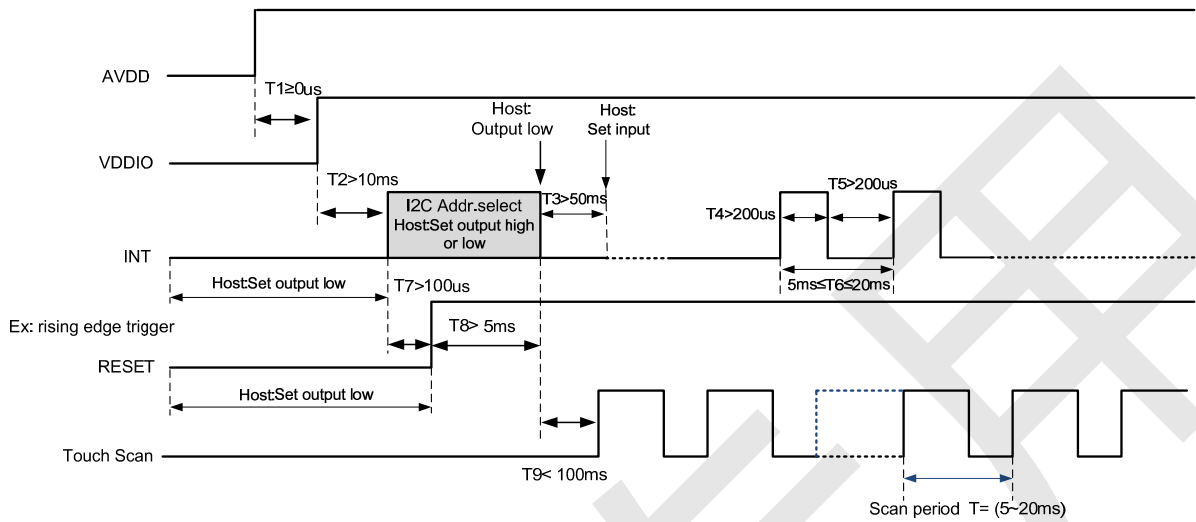
**Test condition 2: 3.3V host interface voltage, 400Kbps transmission rate, 2K pull-up resistor**

Parameter	Symbol	Min.	Max.	Unit
SCL low period	$t_{lo}$	1.3	-	us
SCL high period	$t_{hi}$	0.6	-	us
SCL setup time for Start condition	$t_{st1}$	0.6	-	us
SCL setup time for Stop condition	$t_{st3}$	0.6	-	us
SCL hold time for Start condition	$t_{hd1}$	0.6	-	us
SDA setup time	$t_{st2}$	0.1	-	us
SDA hold time	$t_{hd2}$	0	-	Us

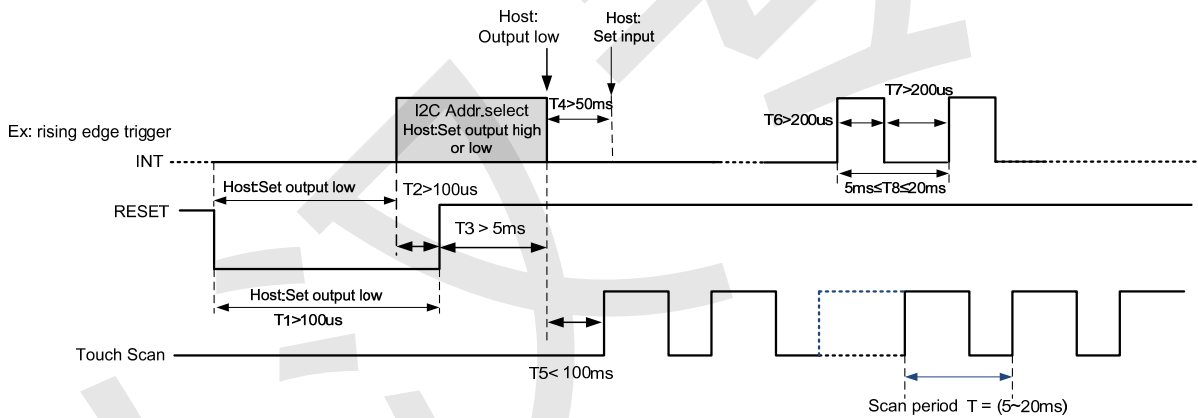
GT928 supports two I<sup>2</sup>C slave addresses: 0xBA/0xBB and 0x28/0x29. The host can select the address by changing the status of Reset and INT pins during the power-on initialization phase. See the diagram below for detailed timings:

10-point Capacitive Touch Controller GT928

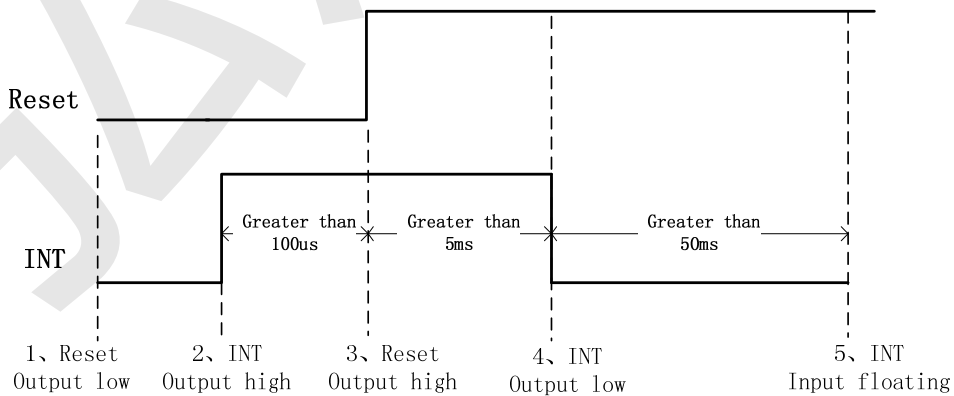
Power-on Timing:



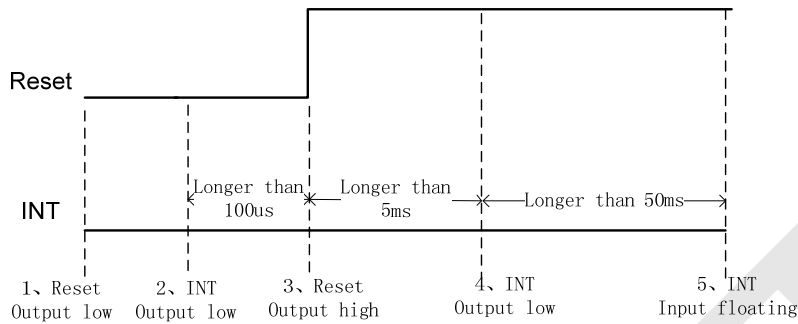
Timing for host resetting GT928:



Timing for setting slave address to 0x28/0x29:



**Timing for setting slave address to 0xBA/0xBB:**



**a) Data Transmission**

(For example: slave address is 0xBA/0xBB)

Communication is always initiated by the host. Valid Start condition is signaled by pulling SDA line from high to low when SCL line is high. Data flow or address is transmitted after the Start condition.

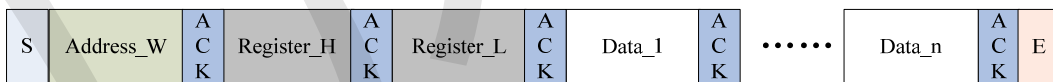
All slave devices connected to I<sup>2</sup>C bus should detect the 8-bit address issued after Start condition and send the correct ACK. After receiving matching address, GT928 acknowledges by configuring SDA line as output port and pulling SDA line low during the ninth SCL cycle. When receiving unmatched address, namely, not 0XBA or 0XBB, GT928 will stay in an idle state.

For data bytes on SDA, each of 9 serial bits will be sent on nine SCL cycles. Each data byte consists of 8 valid data bits and one ACK or NACK bit sent by the recipient. The data transmission is valid when SCL line is high.

When communication is completed, the host will issue the Stop condition which implies the transition of SDA line from low to high when SCL line is high.

**b) Writing Data to GT928**

(For example: slave address is 0xBA/0xBB)



**Timing for Write Operation**

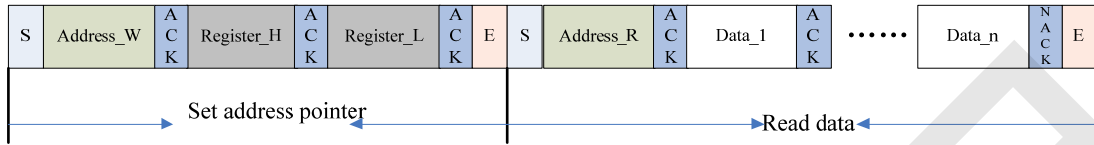
The diagram above displays the timing sequence of the host writing data onto GT928. First, the host issues a Start condition. Then, the host sends 0XBA (address bits and R/W bit; R/W bit as 0 indicates Write operation) to the slave device.

After receiving ACK, the host sends the 16-bit register address (where writing starts) and the 8-bit data bytes (to be written onto the register).

The location of the register address pointer will automatically add 1 after every Write Operation. Therefore, when the host needs to perform Write Operations on a group of registers of continuous addresses, it is able to write continuously. The Write Operation is terminated when the host issues the Stop condition.

**c) Reading Data from GT928**

(For example: slave address is 0xBA/0xBB)



**Timing for Read Operation**

The diagram above is the timing sequence of the host reading data from GT928. First, the host issues a Start condition and sends 0xBA (address bits and R/W bit; R/W bit as 0 indicates Write operation) to the slave device.

After receiving ACK, the host sends the 16-bit register address (where reading starts) to the slave device. Then the host sets register addresses which need to be read.

Also after receiving ACK, the host issues the Start condition once again and sends 0xBB (Read Operation). After receiving ACK, the host starts to read data.

GT928 also supports continuous Read Operation and, by default, reads data continuously. Whenever receiving a byte of data, the host sends an ACK signal indicating successful reception. After receiving the last byte of data, the host sends a NACK signal followed by a STOP condition which terminates communication.

## 7. HotKnot Mode

### 7.1 Start HotKnot

When data needs to be sent, the host sends command 0x21 to GT928, enabling GT928 to enter " Master Approach mode" and work as a transmitting terminal. GT928 will then be able to detect the receiving terminal communicating with it. When GT928 succeeds in detecting the receiving terminal, it will notify the the host to shut off LCD using an interrupt signal and then transmit data to the receiveing terminal.

### 7.2 Data Transmission between TPs

After GT928 and another Hotknot terminal successfully detect one another, the host sends the HotKnot transmission firmware to both terminals. While the transmission firmware runs, the two terminals are ready for data transmission, entering Receive mode by default. When the GT928 Transmit Buffer is flushed correctly, GT928 works as the transmitting terminal and immediately transmits data to the other HotKnot terminal, which works as a receiving terminal detecting data sent by GT928.

### 7.3 Host Receives Data from GT928

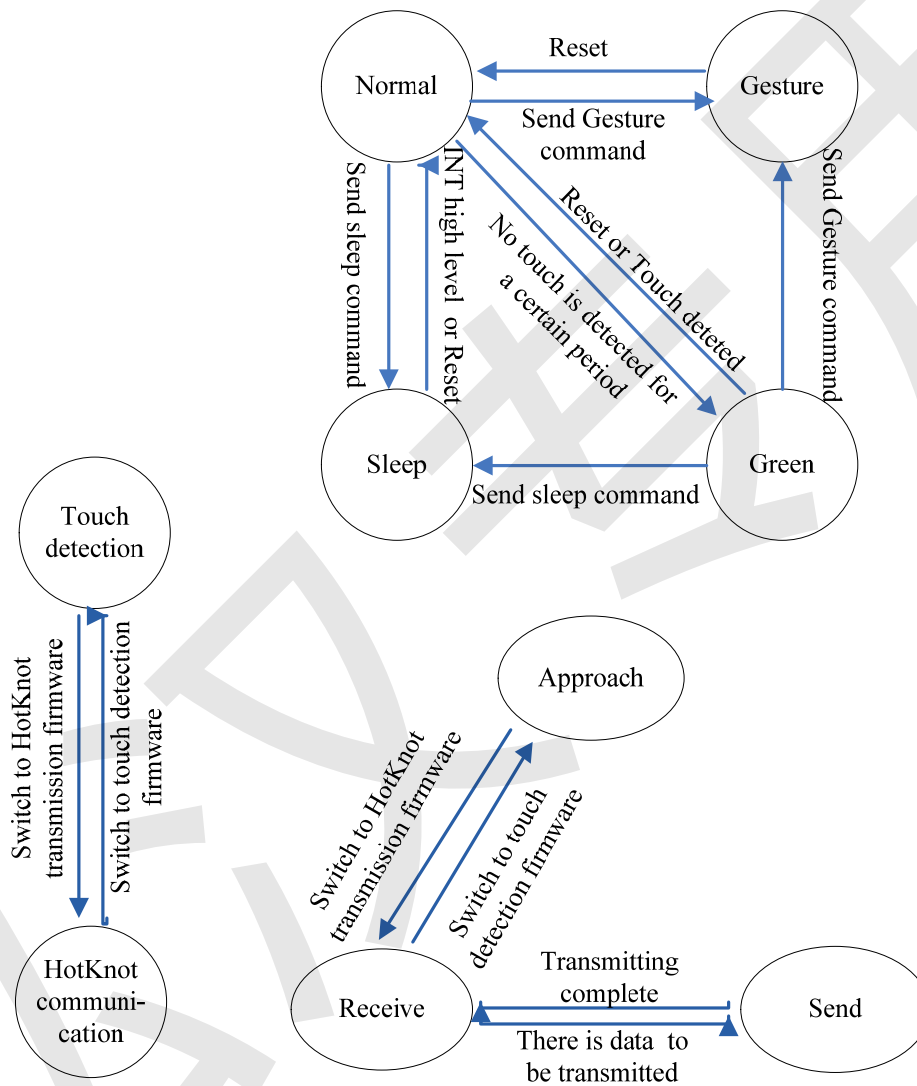
Following recieval or transmission of a data frame, GT928 inverts INT to notify the host to process data.

After receiving a data frame, the the host reads the value of the HotKnot status register. If the value of the receive-status register indicates a successful reception, the host will read the data from the Receive Buffer via 12C. After reading the recieved data, the host writes 0xAA to the designated address and notifies GT928 that data reading is complete.

After GT928 transmits a data frame, the host reads the value of the HotKnot status register. If the value of the transmit-status register indicates a successful transmission, the host will read the data from the Transmit Buffer via I<sup>2</sup>C. After reading this data, the host writes 0xAA to the designated address and notifies GT928 that data reading is complete. GT928 will automatically switch to Receive mode and will not start transmitting until Transmit Buffer is flushed again.

## 8. Description on Functions

### 8.1 Operating Modes



#### d) Normal Mode

When GT928 is operating in Normal mode, its coordinate refresh period is configurable (5ms to 20ms valid, one step is 1ms).

When no touch is detected for a certain period (0s to 14s, subject to configuration; one step is 1s) in Normal mode, GT928 will automatically switch to Green mode to reduce power consumption.

**e) Green Mode**

In Green mode, the scanning period for GT928 is about 40ms. It automatically enters Normal mode if any touch is detected.

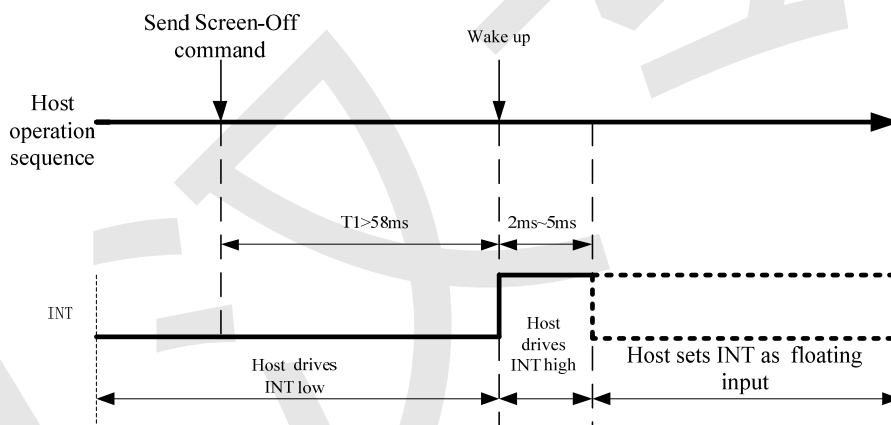
**f) Gesture Mode**

After the host enables GT928 to enter Gesture mode by sending I2C command 8 to 0x8046 and then to 0x8040, wake-up can be achieved by swipe, double-tap, or writing of specified letters on TP.

In Gesture mode, when GT928 detects any finger swipe for a sufficiently long distance, double-tap or writing of specified letters on TP, INT will output a pulse for longer than 250us or output a high level. After receiving such pulse or level, the host wakes up and turns on the screen.

**g) Sleep Mode**

GT928 enters Sleep mode if it receives the corresponding I<sup>2</sup>C command from the host (require INT output low before the command). GT928 exits Sleep mode and enters Normal mode when host outputs a high level to INT pin for 2ms to 5ms. The interval between sending screen-off command and wake-up should be longer than 58ms.

**h) Approach Mode**

When HotKnot proximity detection is enabled, GT928 is operating in Approach mode by default. If GT928 exit Approach mode, the host can send command 0x20 or 0x21 to enable GT928 to enter Approach mode again. In this mode, touch detection and HotKnot proximity detection alternate. If the host sends 0x21 to GT928, GT928 will work as a transmitting terminal and transmit signals with a specified pattern and frequency via Tx and Rx channels. Then, GT928 detects whether there are feedback signals with the same specified pattern and frequency from the receiving terminal. This helps to determine whether any receiving terminal exists. If the host sends 0x20 to GT928, GT928 will work as a Receiving terminal and detect signals with a specified pattern and frequency from the transmitting terminal. If such a signal is detected, GT928 responds using signals with the specified pattern and frequency to the transmitting terminal. In Approach mode, when detecting any HotKnot-compatible terminal within the near-field range, GT928 will notify the host via INT to capture status. To

ensure reliable detection between the transmitting terminal and the receiving terminal, it is required to keep detecting for a minimum of 150ms after the two terminals have detected each other. Then the host sends HotKnot transmission firmware to enable GT928 to enter Receive mode.

#### **i) Receive Mode**

In Approach mode, after notified that GT928 has successfully detected another HotKnot-compatible terminal, the host sends HotKnot transmission firmware to enable GT928 to enter Receive mode. In Receive mode, GT928 continues to detect frame start signal, once the signal is detected, GT928 begins to detect and receive data. When the receiving process is complete, GT928 verifies the data. If GT928 finds erroneous data, the receiving process begins again. If the data is found to be correct, GT928 notifies the host via INT to read data in the Receive Buffer.

#### **j) Send Mode**

When GT928 works in Receive mode, the host sends outgoing data to the Transmit Buffer. When detecting that the Transmit Buffer is flushed and there is data to be sent, GT928 automatically switches from Receive mode to Send mode. In Send mode, GT928 sends a frame start signal. If it detects ACK fed back from the receiving terminal, it continues to send the data signal. After sending a data chunk, GT928 begins to detect ACK. If it does not detect any ACK or if it detects an erroneous ACK, GT928 will resend the data chunk. If this resending fails over 5 times, it will resend the current data frame another time to the receiving terminal until the host enables GT928 to exit Send mode due to timeout. If GT928 detects ACK and sends the data successfully, it will automatically switch to Receive mode after the host completes the data processing or due to timeout.

## **8.2 Interrupt Triggering Mechanism**

When touched, GT928 sends a pulse via INT pin in every scanning cycle to notify the host to read coordinates. Host will then set a triggering mechanism via relevant register "INT" bit. INT as "0" indicates rising edge-triggered, which means GT928 will notify the host by driving INT output from low to high when operated by user; INT as "1" indicates falling edge-triggered, which means GT928 will notify the host by driving INT output from high to low when operated by user .

## **8.3 Sleep Mode**

When the touch screen is off or there are no running operations on the TP, the host sends I<sup>2</sup>C command to enable GT928 to enter Sleep mode, which reduces power consumption. When GT928 needs to operate, the host outputs a high level to INT pin for a certain period to awake it. For detailed timings of host enabling GT928 to enter and exit Sleep mode, please refer to section 8.1.

## **8.4 Stationary Configuration**

GT928 supports Stationary Configuration. After receiving configuration parameters from the host, GT928 will fix parameters to the latest version. Once these parameters are fixed, GT928 will



communicate with the host solely via I2C bus and will not receive any parameters of previous versions from the host.

## 8.5 Self-Calibration

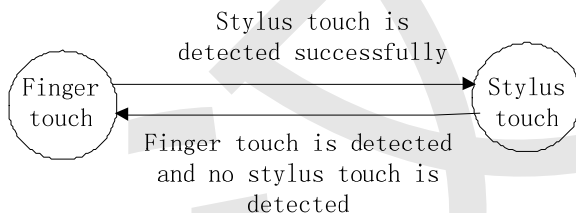
### k) Self-calibration during Initialization

Fluctuations in temperature, humidity and environment may affect the baseline of the capacitive sensor in idle state. GT928 will update detection baseline according to environmental conditions within the first 200ms of initialization. Then, GT928 will finish the initialization of the TP test.

### l) Automatic Drift Compensation

Gradual changes in environmental factors such as temperature, humidity, or dust may also affect the baseline of the capacitive sensor in idle state. GT928 will detect real-time changes in data and perform statistic analysis of historic data to revise baseline and thus reduce the impact that environmental changes have on the TP test.

## 8.6 Finger Touch and Stylus Touch Transition



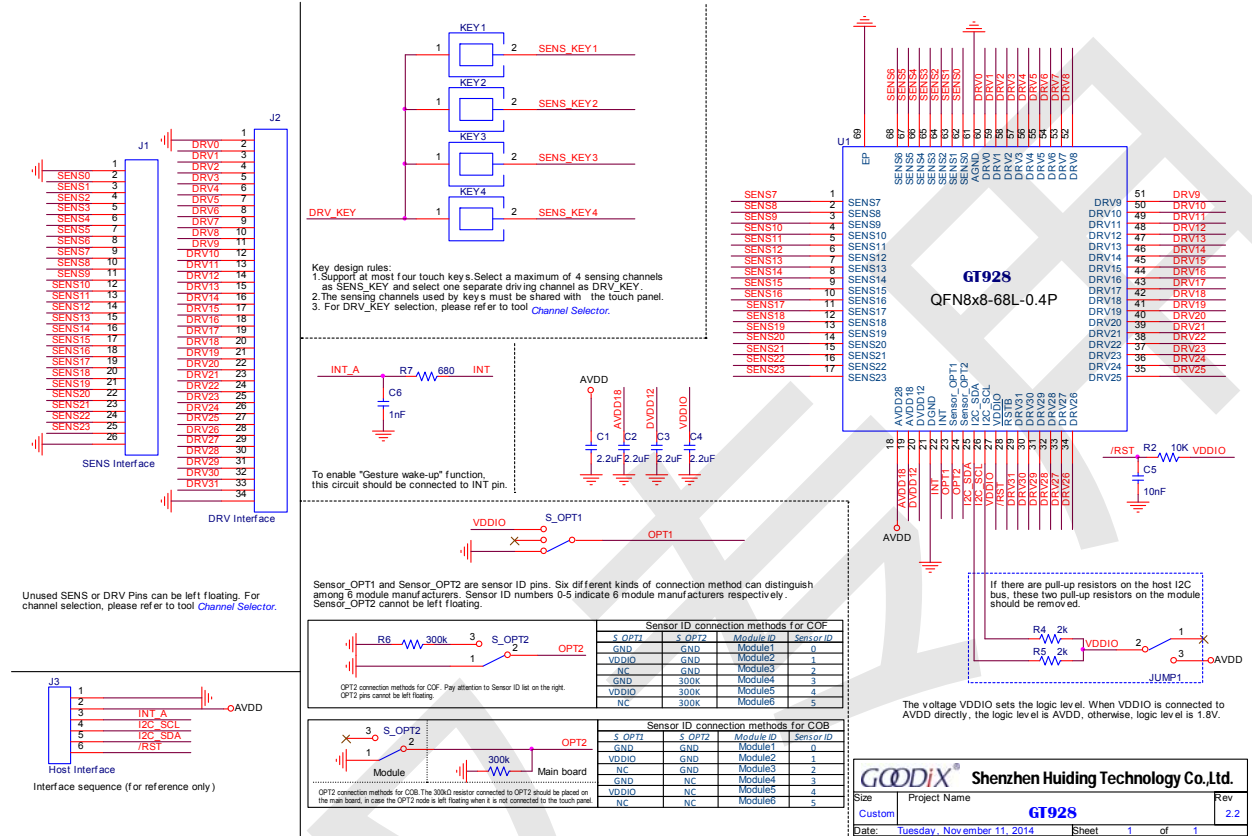
### m) Finger Touch

In finger touch state, software narrows the touch signal to locate the touch position, which reduces noise.

### n) Stylus touch

GT928 detects the touch signal in every cycle. When valid stylus touch signal is detected, GT928 enters stylus touch state. In this state, GT928 locates the touch position with the sampled touch signal and finger touch signal and other touch signals will be suppressed. Only the valid stylus touch will be reported.

# 9. Sample Schematic



GT928 sample schematic

**Note:**

- This schematic only represents basic application. Adjustments may be required to fit in with actual situations and application environments.
- It is recommended that the capacitor be ceramic X7R.

## 10. Electrical Characteristics

### 10.1 Absolute Maximum Ratings

(Ambient temperature: 25°C)

Parameter	Min.	Max.	Unit
Analog power AVDD28 (please refer to AGND)	2.66	3.47	V
VDDIO (please refer to DGND)	1.7	3.47	V
Voltage acceptable to digital I/O	-0.3	3.47	V
Voltage acceptable to analog I/O	-0.3	3.47	V
Range of operating temperature	-40	85	°C
Range of storage temperature	-60	125	°C
Welding temperature (10s)		300	°C
ESD protection voltage (HB Model)	—	±2	KV

### 10.2 Recommended Operating Conditions

Parameter	Min.	Typ.	Max.	Unit
AVDD28	2.8	-	3.3	V
VDDIO	1.8	-	3.3	V
Operating temperature	-20	25	85	°C

### 10.3 AC Electrical Characteristics

(Ambient temperature:25°C, AVDD=2.8V, VDDIO=1.8V)

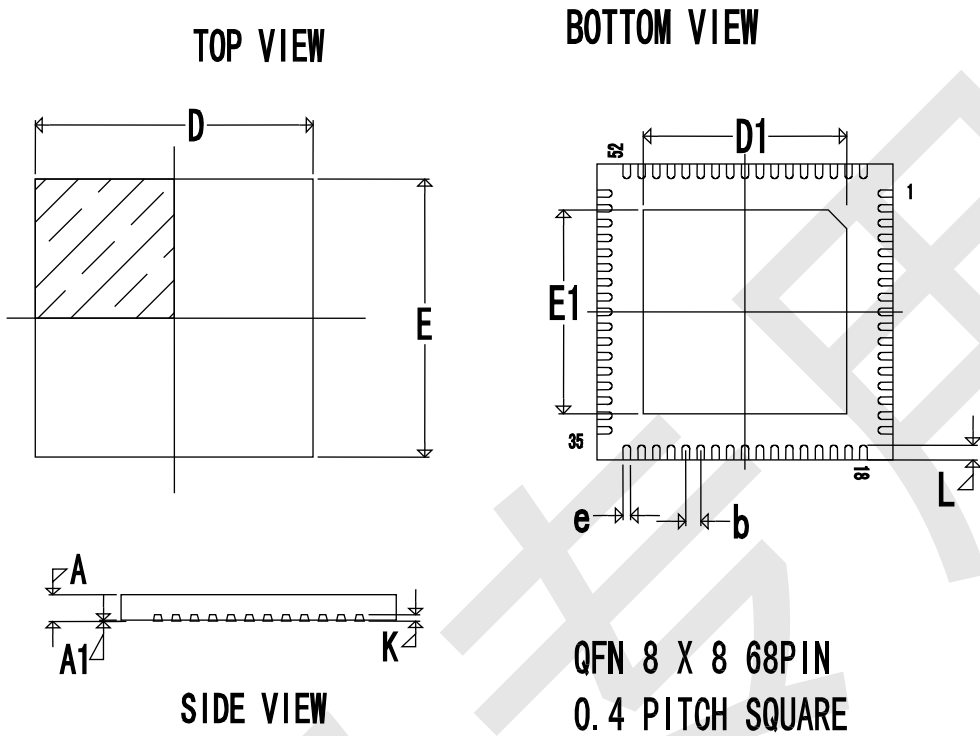
Parameter	Min.	Typ.	Max.	Unit
OSC oscillation frequency	59	60	61	MHz
I/O output rise time, low to high	-	14	-	ns
I/O output fall time, high to low	-	14	-	ns

## 10.4 DC Electrical Characteristics

(Ambient temperature:25°C, AVDD=2.8V)

Parameter	Min.	Typ.	Max.	Unit
Normal mode operating current	-	13		mA
Green mode operating current	-	4.5	-	mA
Sleep mode operating current	70		120	μA
Doze mode operating current		1.2		mA
Input low voltage/VIL	-0.3		0.25*VDDIO	V
Input high voltage/VIH	0.75*VDDIO		VDDIO+0.3	V
Output low voltage/VOL			0.15*VDDIO	V
Output high voltage/VOH	0.85*VDDIO			V

# 11. Package



Symbol	Dimensions In Millimeters		
	Min.	Normal	Max.
A	0.70	0.75	0.80
A1	0.00	0.035	0.05
b	0.40BSC		
D	8.00BSC		
D1	5.40	5.50	5.60
E	8.00BSC		
E1	5.40	5.50	5.60
e	0.15	0.20	0.25
L	0.30	0.40	0.50
K	0.203BSC		

## 12. Revision History

Revision	Date	Description
Rev.00	2012-09-13	Preliminary release
Rev.01	2012-09-20	Modified the power-on timing and DC characteristics
Rev.02	2012-10-26	Modified register map; Modified description on stationary configuration function; Modified DC characteristics; Updated sample schematic.
Rev.03	2012-12-08	Modified operating and storage temperatures; Modified power consumption of different modes;
Rev.04	2013-04-01	Modified the typical value of Green mode operating current
Rev.05	2013-09-12	Modified the sensor design parameters Modified IIC communication parameters Modified power-on timing Modified frequency hopping and passive stylus configuration Modified operating mode switchover chart Modified description on sleep mode and wakeup timing Added description on passive stylus Updated sample schematic Modified absolute maximum ratings
Rev.06	2014-07-18	Updated power-on and reset timings
Rev.07	2014-10-13	Added HotKnot to product features Modified pin definitions Updated IIC address selection timing Deleted register map Modified operating modes switchover chart Added description on Gesture mode and HotKnot Modified DC characteristics
Rev.08	2014-11-14	Updated sample schematic Modified Electrical Characteristics

## 13. Contact Information



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## DATA DISPLAY GROUP

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