On TSC2004 Power Consumption

Wendy Fang, James Wang, and Tony Chang

Nyquist Product Group, Precision Analog

ABSTRACT
This application report discusses analog and digital power consumption of the TSC2004 and provides the mathematical expressions of the consumed currents under full operating modes. The document thereby offers users a guideline on using the TSC2004 to perform the required functions and features with optimal low power consumption.

Contents
1 Introduction .................................................................................................................. 1
2 Power Supply .............................................................................................................. 2
3 SNSVDD Power Consumption .................................................................................... 2
4 IOVDD Power Consumption ....................................................................................... 6
5 Other Power Consumption .......................................................................................... 7

List of Figures
1 Block Diagram of TSC2004 Touch Screen System ....................................................... 2
2 TSC Internal PENIRQ Circuit ...................................................................................... 3
3 Touch Panel Drive Current ......................................................................................... 4

List of Tables
1 TSC2004 Internal Current, $I = f(V_{SNSVDD})$ .......................................................... 3
2 $S$, Number of Samples for a Set ................................................................................ 5
3 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 3.3$ VDC and $F = 2$ MHz .... 5
4 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 3.3$ VDC and $F = 1$ MHz ..... 5
5 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 2.5$ VDC and $F = 2$ MHz .... 6
6 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 2.5$ VDC and $F = 1$ MHz ..... 6
7 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 1.8$ VDC and $F = 2$ MHz ..... 6
8 TSC2004 SNSVDD Power Consumption Under $V_{SNSVDD} = 1.8$ VDC and $F = 1$ MHz ..... 6
9 TSC2004 Internal Digital IO Power Consumption ......................................................... 7

1 Introduction
TSC2004 is a high-performance, 4-wire resistive, touch screen controller, with I²C digital interface. One of its many advantages is very low power consumption, in addition to its small package, high-ESD level, MAV filtering, batch delay, self-test, and other advanced features.

This application report discusses TSC2004 power consumptions on its analog and digital interfaces. This discussion provides users with a guideline for using the TSC2004 to perform required functions and features with optimal low power consumption.
2 Power Supply

To operate the TSC2004 device, the power supply needs to be connected to the TSC2004’s analog and digital power pins SNSVDD (+1.2 VDC ~ 3.6 VDC) and IOVDD (+1.2 VDC ~ SNSVDD). SNSVDD is the analog power for driving the touch screen and other internal circuits of the TSC2004; the IOVDD is for the digital I/O (I2C) interface (see Figure 1).

NOTE: Note that the supply voltage on IOVDD must be the same as or lower than SNSVDD

Figure 1. Block Diagram of TSC2004 Touch Screen System

In Figure 1, the blocks inside the blue box are powered by SNSVDD, the analog power supply, and that inside the red box draw current from IOVDD, the digital I/O supply. Besides the I2C digital bus, all other sections of a TSC2004 touch system draw current from SNSVDD.

Users can use a single power supply for both SNSVDD and IOVDD, or use two separated supplies, whichever is more convenient or practical for the users.

3 SNSVDD Power Consumption

On the analog interface of a TSC2004 touch system (Figure 1), between the touch screen and the TSC2004, the power consumed from SNSVDD consists of two parts: internal by the TSC2004 device itself and external by the touch panel and the analog interface.

3.1 TSC2004 Operation Power

When running, the TSC2004 internal circuits consume power supplied by SNSVDD, including the SAR ADC, the system clocks, and other circuits.

As an example, look at the PENIRQ circuit shown in Figure 2 (see Figure 28 in the TSC2004 data sheet, SBAS408). No current is in the circuit when the panel is not touched (point A in Figure 2 is open); however, when the panel is touched, a current runs from SNSVDD to ground (the yellow highlighted current flow), and the value of the current $I_{\text{PENIRQ}}$ is:

$$I_{\text{PENIRQ}} = \frac{V_{\text{SNSVDD}}}{R_{\text{IRQ}}}$$  \hspace{1cm} (1)

Where $V_{\text{SNSVDD}}$ is the SNSVDD voltage, and $R_{\text{IRQ}}$ is the internal pullup resistance, which is either 51 kΩ or 90 kΩ, software programmable.
Figure 2. TSC Internal PENIRQ Circuit

With $R_{IRQ} = 51\, \text{k}\Omega$, from Equation 1, it can be seen that the current $I_{PENIRQ}$ for the TSC2004 can be as high as 71 $\mu$A (when SNSVDD = 3.6 VDC, maximal) or as low as 23.5 $\mu$A (when SNSVDD = 1.2 VDC, minimal), when the panel is pressured.

Comparing this same circuit to one in a TSC2003, another TI I$^2$C TSC device, the TSC2004’s $I_{PENIRQ}$ is much lower than that of the TSC2003 because the TSC2003 uses a 10-$\text{k}\Omega$ PENIRQ internal pullup resistor (see Figure 16 in the TSC2003 data sheet SBAS162), and thus the TSC2003 has an approximate 250-$\mu$A (when $VDD = 2.5$ VDC, minimal) to 525-$\mu$A (when $VDD = 5.25$ VDC, maximal) power consumption for solely the PENIRQ internal circuit.

Similar to $I_{PENIRQ}$, the current consumed by other internal circuits is a function of SNSVDD and is affected by TSC2004 operations and modes and by the touching location or other factors. For additional information, see the TSC2005 application report (SLAA370).

Generally, the total internal power consumption of TSC2004 can be expressed by:

$$I_{\text{Internal}} = f(\text{SNSVDD})$$

(2)

Because the TSC2004 internal current consumption, $f(\text{SNSVDD})$, is a little more complicated, only the experimental values are presented in this document for users’ reference (Table 1).

<table>
<thead>
<tr>
<th>SNSVDD (VDC)</th>
<th>$I_{\text{Internal}}$ ($\mu$A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>860</td>
</tr>
<tr>
<td>2.5</td>
<td>590</td>
</tr>
<tr>
<td>1.8</td>
<td>360</td>
</tr>
</tbody>
</table>
SNSVDD Power Consumption

See the TSC2004 data sheet (SBAS408) for the typical value of a TSC2004 \( I_{\text{internal}} \) current.

3.2 Touch Panel Operation Power

The TSC2004 provides power through SNSVDD to drive and operate the touch panel, which is one of the most significant power consumptions in the touch system, and is determined by:

- the touch panel's resistance
- the voltage of the power supply (i.e., SNSVDD)
- the driving ON time.

When the touch screen driver is ON, the current, \( I_{\text{on}} \) (see Figure 3) is:

\[
I_{\text{on}} = \frac{V_{\text{SNSVDD}}}{R}
\]  

(3)

Where \( V_{\text{SNSVDD}} \) is the SNSVDD voltage, and \( R \) is the average resistance of the touch panel.

![Figure 3. Touch Panel Drive Current](image)

The touch screen is driven by touch screen controller; the panel's resistance determines the peak drive current from the touch screen controller from the SNSVDD power supply.

In Equation 3, the TSC's internal driving-ON resistance is ignored because it is very small (typical 5 \( \Omega \)) compared to the touch panel's average resistance \( R \) (typically, several hundreds to thousands of Ohms).

Thus, the external average current within a second is:

\[
I_{\text{External}} = I_{\text{on}} \times \tau
\]

\[
= I_{\text{on}} \times \text{SSPS} \times S \times B/F
\]

(4)

Where \( \tau = \text{SSPS} \times S \times B/F \), the driving-ON time per second. SSPS is sample sets per second; \( S \) is the number of data in a set of the samples; \( B \) is the TSC resolution, either 10 bits or 12 bits; and \( F \) is ADC clock frequency, 1, 2 or 4 MHz.

Table 2 provides the \( S \), under X/Y or X/Y/Z mode and with MAV filter's window width \( N = 1, 7, \) or 15, respectively.
Table 2. S, Number of Samples for a Set

<table>
<thead>
<tr>
<th>TSC Set</th>
<th>Read X/Y and N(^{(1)}) = 1 Read</th>
<th>Read X/Y and N = 1</th>
<th>Read X/Y and N = 7</th>
<th>Read X/Y and N = 15</th>
<th>Read X/Y and N = 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
<td>4</td>
<td>14</td>
<td>28</td>
<td>30</td>
</tr>
</tbody>
</table>

\(^{(1)}\) N is the MAV filter's window width. The MAV filter is bypassed when N = 1.

3.3 Total Power

The approximate total current provided by SNSVDD is

\[
I = I_{\text{Internal}} + I_{\text{External}}
\]

\[
= f(SNSVDD) + \left(\frac{V_{\text{SNSVSS}}}{R}\right) \times \text{SSPS} \times S \times B / F
\]

Equation 5

In Equation 5, the panel voltage stability (PVS) timing has been set to 0 μs, and the PVS timing does affect SNSVDD power consumption. For details, see the application report SLAA362.

The power consumption may be slightly different from chip-to-chip; and from system-to-system. The following Table 3 through Table 8 show the test results (measured) and the computed results from Equation 4 (modeled), on a TSC2004EVM-PDK evaluation module system (SLAU215), provided for reference only.

The setups and test conditions are:

- \(V_{\text{SNSVDD}} = 3.3, 2.5, \text{or } 1.8 \text{ VDC}\)
- \(R = 450 \Omega \) (average of the X- and the Y-layers resistance)
- \(\text{SSPS} = 100, 250, \text{or } 500\)
- \(S = 2, 4, 14, 28, 30 \text{ or } 60 \) (see Table 2)
- \(B = 12 \text{ bits}\)
- \(F = 2 \text{ or } 1 \text{ MHz}\)

Table 3. TSC2004 SNSVDD Power Consumption Under \(V_{\text{SNSVDD}} = 3.3 \text{ VDC and } F = 2 \text{ MHz}\)

<table>
<thead>
<tr>
<th></th>
<th>(\text{SSPS }= 500)</th>
<th>(\text{SSPS }= 250)</th>
<th>(\text{SSPS }= 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured</td>
<td>Modeled</td>
<td>Measured</td>
</tr>
<tr>
<td>(S = 4) (Read X/Y/Z and N = 1)</td>
<td>930</td>
<td>949</td>
<td>870</td>
</tr>
<tr>
<td>(S = 12) (Read X/Y/Z and N = 3)</td>
<td>1180</td>
<td>1147</td>
<td>1000</td>
</tr>
<tr>
<td>(S = 28) (Read X/Y/Z and N = 7)</td>
<td>1540</td>
<td>1543</td>
<td>1170</td>
</tr>
<tr>
<td>(S = 60) (Read X/Y/Z and N = 15)</td>
<td>2290</td>
<td>2335</td>
<td>1520</td>
</tr>
</tbody>
</table>

Table 4. TSC2004 SNSVDD Power Consumption Under \(V_{\text{SNSVDD}} = 3.3 \text{ VDC and } F = 1 \text{ MHz}\)

<table>
<thead>
<tr>
<th></th>
<th>(\text{SSPS }= 500)</th>
<th>(\text{SSPS }= 250)</th>
<th>(\text{SSPS }= 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured</td>
<td>Modeled</td>
<td>Measured</td>
</tr>
<tr>
<td>(S = 4) (Read X/Y/Z and N = 1)</td>
<td>1010</td>
<td>1048</td>
<td>920</td>
</tr>
<tr>
<td>(S = 12) (Read X/Y/Z and N = 3)</td>
<td>1410</td>
<td>1444</td>
<td>1120</td>
</tr>
<tr>
<td>(S = 28) (Read X/Y/Z and N = 7)</td>
<td>2080</td>
<td>2236</td>
<td>1430</td>
</tr>
<tr>
<td>(S = 60) (Read X/Y/Z and N = 15)</td>
<td>3400</td>
<td>3820</td>
<td>2090</td>
</tr>
</tbody>
</table>
### 4 IOVDD Power Consumption

Similar to the analog interface, the power consumption of the digital interface consists of two parts: internal by TSC2004 digital I/O and external by the I2C bus.

#### 4.1 TSC 2004 Internal Digital I/O Power

TSC2004 internal digital I/O consumes very little current, in nA, which is a function of $V_{\text{IOVDD}}$ and SSPS. The experimental test with TSC2004EVM-PDK evaluation module (SLAU215) with IOVDD = 3.3 VDC, 2.5 VDC and 1.8 VDC, and I2C standard (100 kHz) mode obtained the results listed in Table 9, where each set of data includes four touch coordinates, X, Y, Z1, and Z2.
### Table 9. TSC2004 Internal Digital IO Power Consumption

<table>
<thead>
<tr>
<th>( V_{\text{SNSVDD}} )</th>
<th>( I_{\text{IOVDD-Internal}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 VDC</td>
<td>( 0.0048 \times \text{SSPS} )</td>
</tr>
<tr>
<td>2.5 VDC</td>
<td>( 0.0020 \times \text{SSPS} )</td>
</tr>
<tr>
<td>1.8 VDC</td>
<td>( 0.0010 \times \text{SSPS} )</td>
</tr>
</tbody>
</table>

For example: if \( \text{SSPS} = 500 \) and \( V_{\text{SNSVDD}} = 1.8 \) VDC, then \( I_{\text{IOVDD-Internal}} = 0.001 \times 500 = 0.5 \mu\text{A} \).

### 4.2 TSC2004 I2C Bus Power

IOVDD power is consumed mainly by the I²C bus, through the bus pullup resistors or circuit. No power is consumed when there is no I²C activity and both SCL and SDA are high. When the I²C bus is active, the bus lines are driven low and the IOVDD current is drawn by the pullup resistors. The power depends on the I²C bus speed, traffic condition, and, most importantly, the pullup resistors (or circuit).

Under a specific I²C mode (Standard mode: 100 kHz; Fast mode: 400 kHz; or High-Speed mode: 3.4 MHz), an important factor for the external IOVDD power consumption is:

- the IOVDD voltage
- the pullup resistors (or circuit)
- the number of data moving through the bus lines

For an I²C line, for example, SDA, when it is low, the current consumed is:

\[
I_{\text{bus-low}} = \frac{V_{\text{IOVDD}}}{R_{\text{pullup}}}
\]

Where \( V_{\text{IOVDD}} \) is IOVDD voltage and \( R_{\text{pullup}} \) is the resistance of the line pullup. For the specification of I²C pullup resistance or circuit, see *The I²C Bus Specification*.

Thus, the IOVDD current \( I_{\text{IOVDD-I2C}} \) within a second can be expressed as:

\[
I_{\text{IOVDD}} = \frac{V_{\text{IOVDD}}}{R_{\text{pullup}}} \times (\tau_{\text{SCL}} + \tau_{\text{SDA}})
\]

Where \( \tau_{\text{SCL}} \) is the time per second when SCL is low; and \( \tau_{\text{SDA}} \) is the time per second when SDA is low.

The I²C bus line active time relates to how much data goes through the bus and to the I²C bus speed. The more data, the longer the \( \tau_{\text{SCL}} \) and \( \tau_{\text{SDA}} \) can be; the higher the bus speed is, the shorter the \( \tau_{\text{SCL}} \) and \( \tau_{\text{SDA}} \) can be.

Even though the I²C bus with higher speed needs a little higher energy to drive, the higher I²C bus speed, on the other hand, greatly shortens bus working time. For example, data transmitted with a 400-kHz bus speed transmits in 25% of the time the same data transmitted using a 100-kHz bus speed; data transmitted with a 3.4-MHz bus speed transmits in 2.94% of the time that the same data takes to transmit with the 100-kHz bus speed. Basically, higher bus clocks in the touch screen system dissipate less average IOVDD power.

### 5 Other Power Consumption

The reference voltage from TSC2004’s Vref pin is needed only for nontouch analog inputs, such as the AUX and the device temperature measurements. Touch screen measurements use ratiometric (differential) conversion from SNSVDD, and do NOT need Vref.

There is no other power consumption.
# IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI’s standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise concerning the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related ramifications of their applications, and that they have conducted the analysis and testing necessary to verify compliance with applicable standards, if any, and that they are solely responsible for obtaining any necessary licenses.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or “enhanced plastic.” Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>audio</td>
<td><a href="http://www.ti.com/audio">www.ti.com/audio</a></td>
</tr>
<tr>
<td>Data Converters</td>
<td>automotive</td>
<td><a href="http://www.ti.com/automotive">www.ti.com/automotive</a></td>
</tr>
<tr>
<td>DSP</td>
<td>broadband</td>
<td><a href="http://www.ti.com/broadband">www.ti.com/broadband</a></td>
</tr>
<tr>
<td>Interface</td>
<td>digitalcontrol</td>
<td><a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a></td>
</tr>
<tr>
<td>Logic</td>
<td>military</td>
<td><a href="http://www.ti.com/military">www.ti.com/military</a></td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>opticalnetwork</td>
<td><a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a></td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>security</td>
<td><a href="http://www.ti.com/security">www.ti.com/security</a></td>
</tr>
<tr>
<td>RFID</td>
<td>telephony</td>
<td><a href="http://www.ti.com/telephony">www.ti.com/telephony</a></td>
</tr>
<tr>
<td>Low Power</td>
<td>video &amp; imaging</td>
<td><a href="http://www.ti.com/video">www.ti.com/video</a></td>
</tr>
<tr>
<td>Wireless</td>
<td>wireless</td>
<td><a href="http://www.ti.com/wireless">www.ti.com/wireless</a></td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2007, Texas Instruments Incorporated