Application Report

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On TSC2004 Power Consumption

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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.

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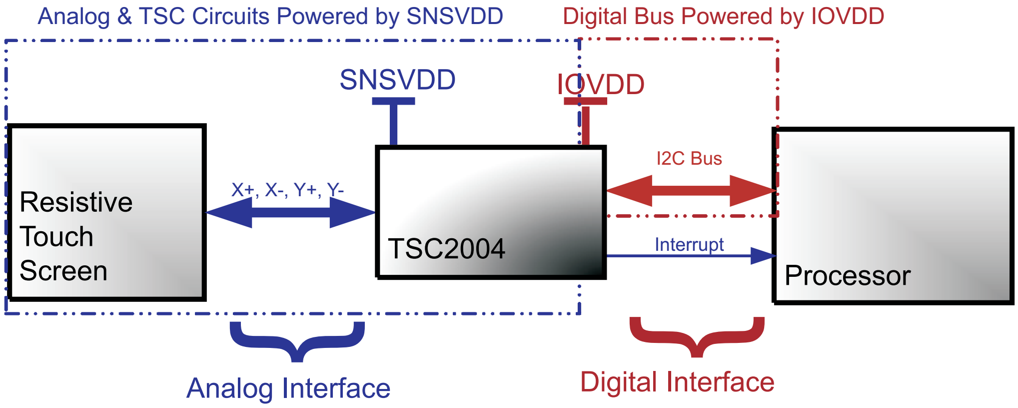
1 Introduction

TSC2004 is a high-performance, 4-wire resistive, touch screen controller, with I^2C 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 (I^2C) 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 I^2C 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 $\overline{\text{PENIRQ}}$ 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_{PENIRQ} is:

$$I_{PENIRQ} = \frac{V_{SNSVDD}}{R_{IRQ}} \quad (1)$$

Where V_{SNSVDD} is the SNSVDD voltage, and R_{IRQ} is the internal pullup resistance, which is either 51 kΩ or 90 kΩ, software programmable.

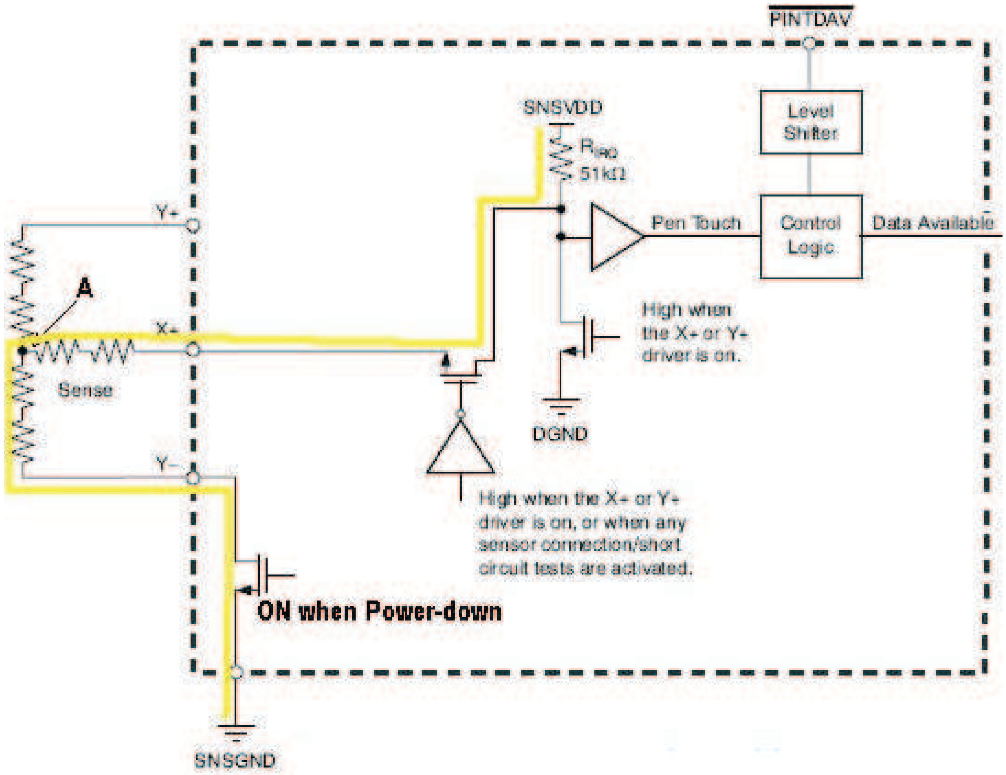


Figure 2. TSC Internal $\overline{PENIRQ}$ Circuit

With R_{IRQ} = 51 kΩ, from Equation 1, it can be seen that the current I_{PENIRQ} for the TSC2004 can be as high as 71 µA (when SNSVDD = 3.6 VDC, maximal) or as low as 23.5 µA (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-kΩ $\overline{PENIRQ}$ internal pullup resistor (see Figure 16 in the TSC2003 data sheet SBAS162), and thus the TSC2003 has an approximate 250-µA (when VDD = 2.5 VDC, minimal) to 525-µA (when VDD = 5.25 VDC, maximal) power consumption for solely the $\overline{PENIRQ}$ 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:

$$I_{Internal} = f(SNSVDD) \quad (2)$$

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

Table 1. TSC2004 Internal Current, I = f(SNSVDD)

SNSVDD (VDC)	$I_{Internal}$ (µA)
3.3	860
2.5	590
1.8	360

See the TSC2004 data sheet (SBAS408) for the typical value of a TSC2004 $I_{Internal}$ current.

3.2 Touch Panel Operation Power

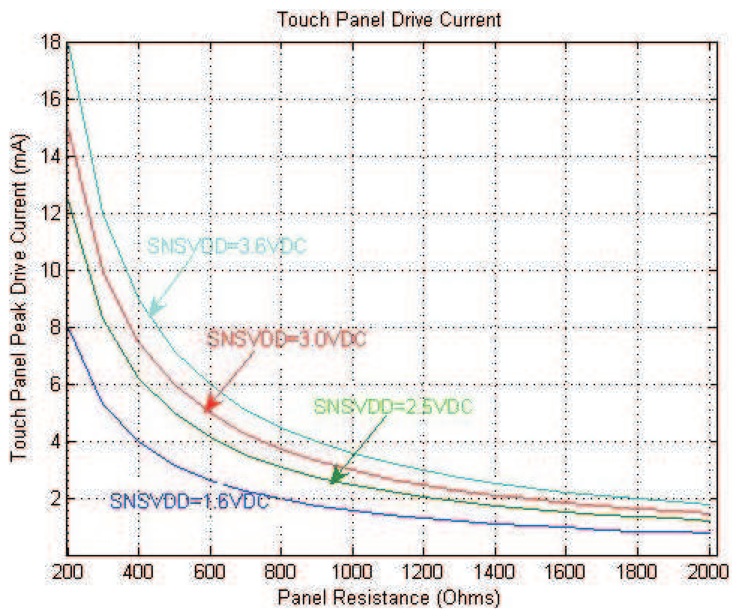
The TSC2004 provides power through SNSVDD to drive and operate the touch panel, which is one of the most significant power consumptions in the touch system, and is determined by:

- 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_{on}, (see Figure 3) is:

$$Ion = \frac{V_{SNSVDD}}{R} \tag{3}$$

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



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.

Figure 3. Touch Panel Drive Current

In Equation 3, the TSC's internal driving-ON resistance is ignored because it is very small (typical 5 Ω) 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:

$$\begin{aligned} I_{External} &= Ion \times \tau \\ &= Ion \times SSPS \times S \times B/F \end{aligned} \tag{4}$$

Where τ = SSPS x S x 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

TSC Set	Read X/Y and N[(1)] =1 Read	X/Y/Z and N=1	Read X/Y and N=7	Read X/Y/Z N=7	Read X/Y and N=15	Read X/Y/Z N=15
S	2	4	14	28	30	60

(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

$$I = I_{Internal} + I_{External}$$
$$= f(SNSVDD) + \left(V_{SNSVSS}/R\right) \times SSPS \times S \times B/F \quad (5)$$

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

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

	SSPS = 500		SSPS = 250		SSPS = 100	
	Measured	Modeled	Measured	Modeled	Measured	Modeled
S = 4 (Read X/Y/Z and N=1)	930	949	870	900	840	870
S = 12 (Read X/Y/Z and N=3)	1180	1147	1000	999	890	910
S = 28 (Read X/Y/Z and N=7)	1540	1543	1170	1197	960	989
S = 60 (Read X/Y/Z and N=15)	2290	2335	1520	1593	1100	1147

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

	SSPS = 500		SSPS = 250		SSPS = 100	
	Measured	Modeled	Measured	Modeled	Measured	Modeled
S = 4 (Read X/Y/Z and N=1)	1010	1048	920	949	860	890
S = 12 (Read X/Y/Z and N=3)	1410	1444	1120	1147	940	969
S = 28 (Read X/Y/Z and N=7)	2080	2236	1430	1543	1070	1127
S = 60 (Read X/Y/Z and N=15)	3400	3820	2090	2335	1330	1444

Table 5. TSC2004 SNSVDD Power Consumption Under V_{SNSVDD} = 2.5 VDC and F = 2 MHz

	SSPS = 500		SSPS = 250		SSPS = 100	
	Measured	Modeled	Measured	Modeled	Measured	Modeled
S = 4 (Read X/Y/Z and N=1)	650	667	610	629	590	607
S = 12 (Read X/Y/Z and N=3)	840	817	710	704	620	637
S = 28 (Read X/Y/Z and N=7)	1100	1117	840	854	680	697
S = 60 (Read X/Y/Z and N=15)	1640	1717	1100	1154	780	817

Table 6. TSC2004 SNSVDD Power Consumption Under V_{SNSVDD} = 2.5 VDC and F = 1 MHz

	SSPS = 500		SSPS = 250		SSPS = 100	
	Measured	Modeled	Measured	Modeled	Measured	Modeled
S = 4 (Read X/Y/Z and N=1)	710	742	640	667	600	622
S = 12 (Read X/Y/Z and N=3)	1020	1042	790	817	660	682
S = 28 (Read X/Y/Z and N=7)	1530	1642	1040	1117	760	802
S = 60 (Read X/Y/Z and N=15)	2560	2842	1540	1717	970	1042

Table 7. TSC2004 SNSVDD Power Consumption Under V_{SNSVDD} = 1.8 VDC and F = 2 MHz

	SSPS = 500	SSPS = 250	SSPS = 100
	Modeled	Modeled	Modeled
S = 4 (Read X/Y/Z and N=1)	419	392	376
S = 12 (Read X/Y/Z and N=3)	527	446	398
S = 28 (Read X/Y/Z and N=7)	743	554	441
S = 60 (Read X/Y/Z and N=15)	1175	770	527

Table 8. TSC2004 SNSVDD Power Consumption Under V_{SNSVDD} = 1.8 VDC and F = 1 MHz

	SSPS = 500	SSPS = 250	SSPS = 100
	Modeled	Modeled	Modeled
S = 4 (Read X/Y/Z and N=1)	473	419	387
S = 12 (Read X/Y/Z and N=3)	689	527	430
S = 28 (Read X/Y/Z and N=7)	1121	743	517
S = 60 (Read X/Y/Z and N=15)	1985	1175	689

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 I^2C 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_{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 I^2C 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

V_{SNSVDD}	$I_{IOVDD\text{-}Internal}$
3.3 VDC	0.0048 × SSPS
2.5 VDC	0.0020 × SSPS
1.8 VDC	0.0010 × SSPS

For example: if SSPS = 500 and V_{SNSVDD} = 1.8 VDC, then $I_{IOVDD\text{-}Internal}$ = 0.001 × 500 = 0.5 μA .

4.2 TSC2004 I2C Bus Power

IOVDD power is consumed mainly by the I^2C bus, through the bus pullup resistors or circuit. No power is consumed when there is no I^2C activity and both SCL and SDA are *high*. When the I^2C bus is active, the bus lines are driven *low* and the IOVDD current is drawn by the pullup resistors. The power depends on the I^2C bus speed, traffic condition, and, most importantly, the pullup resistors (or circuit).

Under a specific I^2C 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 I^2C line, for example, SDA, when it is low, the current consumed is:

$$I_{bus-low} = \frac{V_{IOVDD}}{R_{pullup}} \tag{6}$$

Where V_{IOVDD} is IOVDD voltage and R_{pullup} is the resistance of the line pullup. For the specification of I^2C pullup resistance or circuit, see *The I^2C Bus Specification*.

Thus, the IOVDD current I_{IOVDD_I2C} within a second can be expressed as:

$$I_{IOVDD} \cong \frac{V_{IOVDD}}{R_{pullup}} \times \left(\tau_{SCL} + \tau_{SDA}\right) \tag{7}$$

Where τ_{SCL} is the time per second when SCL is low; and τ_{SDA} is the time per second when SDA is low.

The I^2C bus line active time relates to how much data goes through the bus and to the I^2C bus speed. The more data, the longer the τ_{SCL} and τ_{SDA} can be; the higher the bus speed is, the shorter the τ_{SCL} and τ_{SDA} can be.

Even though the I^2C bus with higher speed needs a little higher energy to drive, the higher I^2C 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.