TSC2005 Power Consumption Under Different Mode

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ABSTRACT

This application report discusses the TSC2005 power consumption under different touch screen operating modes, addresses the function and power of various TSC2005 converting functions and status states, and provides a guideline for using the TSC2005 to perform the required functions and features with the optimal low power consumption.

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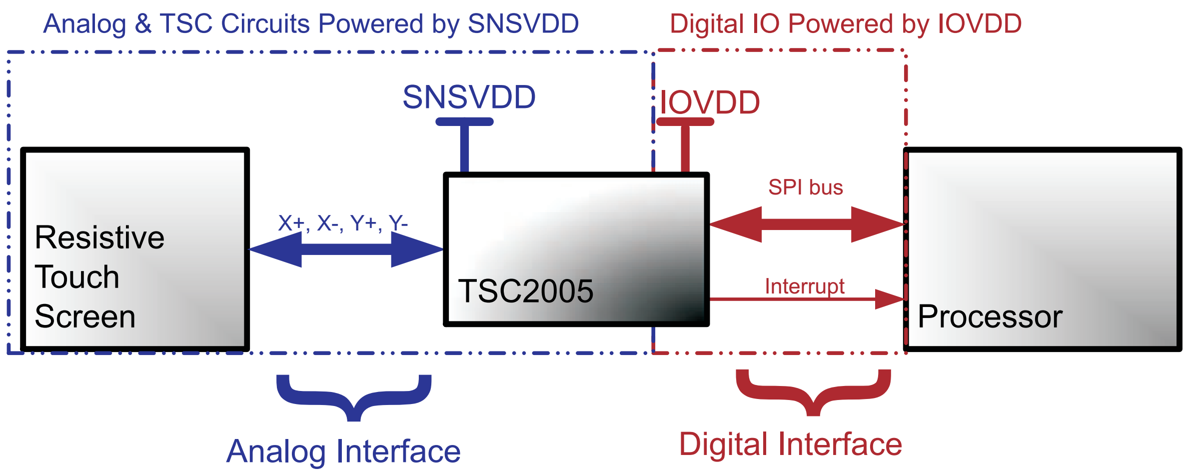
1 Introduction

TSC2005 is a 4-wire resistive touch screen controller with an SPI digital interface. In addition to its low power consumption, the TSC2005 features a small-package, high-ESD level, MAV filtering, batch delay, self-test, and other advantages.

The TSC2005 is a register-based touch screen controller with full software-programmable features; it can operate under many different modes by setting its control registers. Although the TSC2005 data sheet (SBAS379) provides the power consumption ranges, power performance is different under various TSC2005 converting functions and status states. This application report addresses how to use and operate the TSC2005 at its highest performance and lowest power consumption during the different TSC2005 operating modes.

2 Power Supply

To operate the TSC2005 device, power supplies need to be connected to the TSC2005 pins SNSVDD (+1.6 VDC ~ 3.6 VDC) and IOVDD (+1.2 VDC ~ SNSVDD). The SNSVDD pin receives the power for driving the touch screen and the TSC2005 internal circuits; and the IOVDD pin receives the power for only driving the digital I/O interface to the host processor (see Figure 1).



NOTE: The supply voltage on IOVDD must be the same as or lower than SNSVDD.

Figure 1. TSC2005 Touch Screen System Block Diagram

In Figure 1, the blocks inside the blue box are powered by SNSVDD, and those inside the red box draw current from IOVDD power supply.

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

Power consumption is closely related to power supply voltage, as Figure 2 shows. Figure 2 shows only a power consumption tendency and is the example for a specific operating mode, test conditions, and settings. For details of the Figure 2 test conditions/settings, see the TSC2005 data sheet (SBAS379).

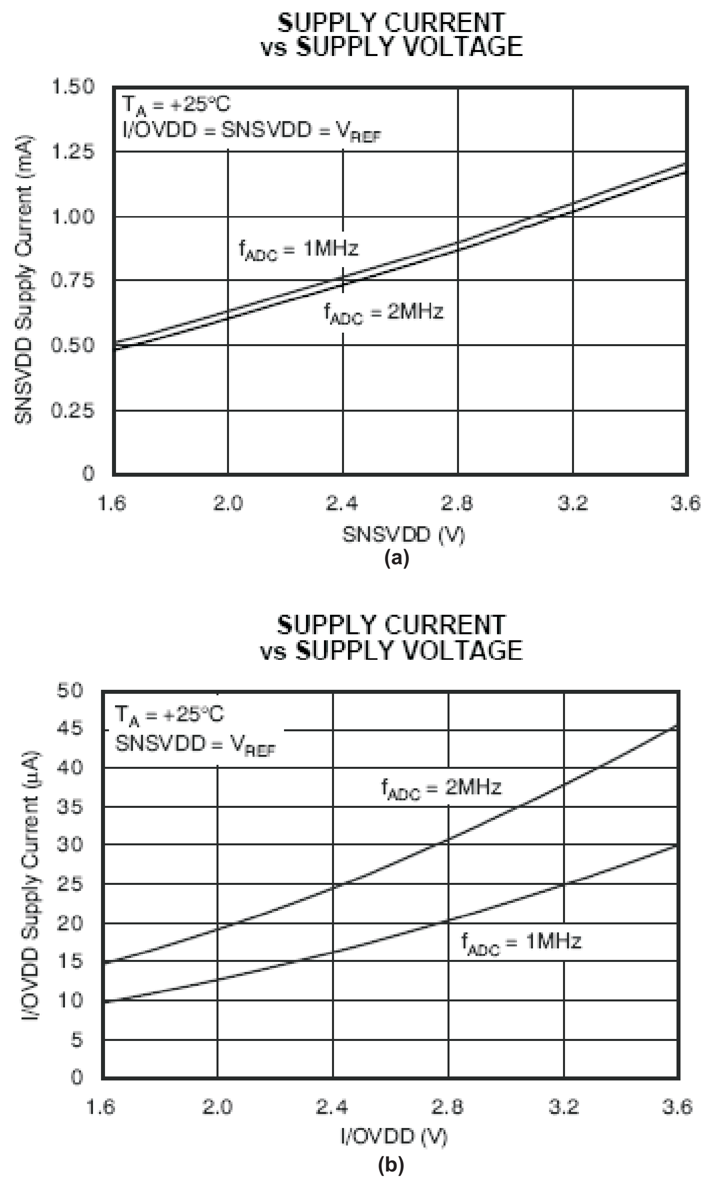


Figure 2. Power Supply Current With Different Power Supply Voltage for (a) Analog and (b) Digital Circuitries

Two observations can be made from Figure 2 :

1)The higher the power supply, the higher the consumed current (power).

2) The analog power supply to SNSVDD (Figure 2a) consumes much more power than the digital power supply to IOVDD (Figure 2b).

The power supply current or power consumption changes with different operating modes, different configurations, and different control registers settings, as is discussed in the following sections.

3 TSC2005 Power Consumption

This application report focuses on power consumption in different TSC2005 Converting modes, Status states, and Operating modes.

The Converting mode indicates how the TSC2005 ADC converting is started or initialized. TSC2005 converting is either in the Host Controlled mode or the TSC Controlled mode.

The Status state specifies a TSC2005 status and condition, including Power-Down state, Wait state, Batch-Wait state, Driving/Converting/Processing state, and Reading/Writing state.

The Operating mode is a TSC2005 operating or working sequence, which is the combination of the selected converting function in the different status states. The TSC2005 Operating mode has been classified into TSMode1, TSMode2, and TSMode3, as defined in the TSC2005 data sheet (SBAS379).

3.1 Converting Modes

The TSC2005 ADC converter can be initialized by a command from the host processor (host-controlled converting mode) or automatically when it detects pressure on the touch panel (TSC-controlled converting mode).

The TSC2005 default converting mode is host controlled. The mode can be changed by setting the PSM (bit 15) in TSC2005 Configuration Register 0 (CR0). If PSM is set to 0, the TSC2005 is in the host-controlled converting mode; if the PSM is 1, the converting mode is TSC controlled.

The host-controlled converting mode is valid to perform all types of ADC converter functions listed in Table 1. The TSC-controlled converting mode, however, can only be used with two touch screen functions: the X/Y scan or X/Y/Z1/Z2 scan, highlighted in yellow at Table 1.

Table 1. TSC2005 ADC Converter Function Selection

C3	C2	C1	C0	FUNCTION (1) (2)
0	0	0	0	Touch screen scan function: X-, Y-, Z-, and Z_2-coordinates converted and the results returned to X, Y, Z_1, and Z_2 data registers. Scan continues until either the pen is lifted or a stop bit is sent.
0	0	0	1	Touch screen scan function: X- and Y-coordinates converted and the results returned to X and Y data registers. Scan continues until either the pen is lifted or a stop bit is sent.
0	0	1	0	Touch screen scan function: X-coordinate converted and the results returned to X data register.
0	0	1	1	Touch screen scan function: Y-coordinate converted and the results returned to Y data register.
0	1	0	0	Touch screen scan function: Z_1-, and Z_2-coordinates converted and the results returned to Z_1 and Z_2 data registers.
0	1	0	1	Auxiliary input converted and the results returned to the AUX data register.
0	1	1	0	A temperature measurement is made and the results returned to the Temperature Measurement 1 data register.
0	1	1	1	A differential temperature measurement is made and the results returned to the Temperature Measurement 2 data register.
1	0	0	0	Auxiliary input is converted continuously, and the results are returned to the AUX data register.
1	0	0	1	Touch screen panel connection to X-axis drivers is tested. The test result is output to $\overline{\text{PINTDAV}}$ and shown in STATUS register.
1	0	1	0	Touch screen panel connection to Y-axis drivers is tested. The test result is output to $\overline{\text{PINTDAV}}$ and shown in STATUS register.
1	0	1	1	RESERVED (Note: any condition caused by this command can be cleared by setting the STS bit to 1).
1	1	0	0	Touch screen panel short-circuit (between X and Y plates) is tested through Y-axis. The test result is output to $\overline{\text{PINTDAV}}$ and shown in the STATUS register.
1	1	0	1	Turn on X+, X– drivers
1	1	1	0	Turn on Y+, Y– drivers
1	1	1	1	Turn on Y+, X– drivers

(1) Set with bits 6 ~3 in control byte 1 (CB1).
(2) See TSC2005 data sheet (SBAS379).

In the host-controlled converting mode, the touch system works with the following sequence:

- when the touch panel is pressed, the TSC senses the touch and sends a $\overline{\text{PENIRQ}}$ interrupt to the host;

- the host receives the interrupt from the TSC, and responses to the TSC in the order based on its tasks and priority;

- the host then sends the 8-bit CB1 (Control Byte 1) to the TSC and specifies which converting function in Table 1 should start;

- after receiving the command from the host, the TSC starts powering the corresponding driver and converting the signal.

Obviously, some wait occurs at TSC2005 between the time a touch is sensed on the panel and before TSC2005 starts a conversion.

In the TSC-controlled mode, on other hand, the touch system works in a different sequence:

- after power up or RESET, the host programs the TSC into either a X/Y or X/Y/Z1/Z2 scan function, that is, the C3-C0 (in Table 1) is set to 0000b or 0001b;

- when the touch panel is pressed, the TSC senses the touch and starts the corresponding conversion automatically and immediately;

- the TSC sends an interrupt to the host after all data is ready to be read, and the host thus reads the data registers.

Compared to the host-controlled converting mode, the TSC-controlled converting mode does not wait for the host to response and starts the touch data converting whenever the panel is touched. The TSC2005 can produce thousands of sets of coordinates in its TSC-controlled converting mode if a touch continues to press on the panel.

However, the TSC's fast converting function may not be necessary in real-world applications. For example, most touch screen applications need only 100 to 500 sets of good touch data per second for human interfacing. Thus, the advantage of the host-controlled converting mode is apparent because the host can control the time and interval of the TSC2005 driving/sampling and samples only needed touch data sets; therefore, this eliminates unnecessary current for driving the touch panel, reduces the analog interface traffic, and reduces the system power consumption.

Furthermore, the advanced Batch-Delay feature of TSC2005 can perform even better. With the TSC2005 Batch-Delay feature in its TSC-controlled converting mode, TSC2005 can control the time and interval of the touch screen samples, taking over the task from the host and thus not only reducing analog interface traffic, but also reducing digital interface traffic and saving resources at the host. For additional details about the Batch-Delay feature, see the TSC2005 data sheet (SBAS379).

3.2 Status States

The power consumption of the different TSC2005 status states varies. To optimize TSC2005 performance and reduce power consumption, an understanding of the TSC2005 main status states and their power consumption can benefit the user.

3.2.1 Power-Down State

Besides physically turning off power to the TSC2005, the next best power-saving state is to bring the TSC2005 into its power-down or sleeping state, which consumes very low current, typically in nanoamperes (nA) (see Figure 3), See the specifications in the TSC2005 data sheet.(SBAS379).

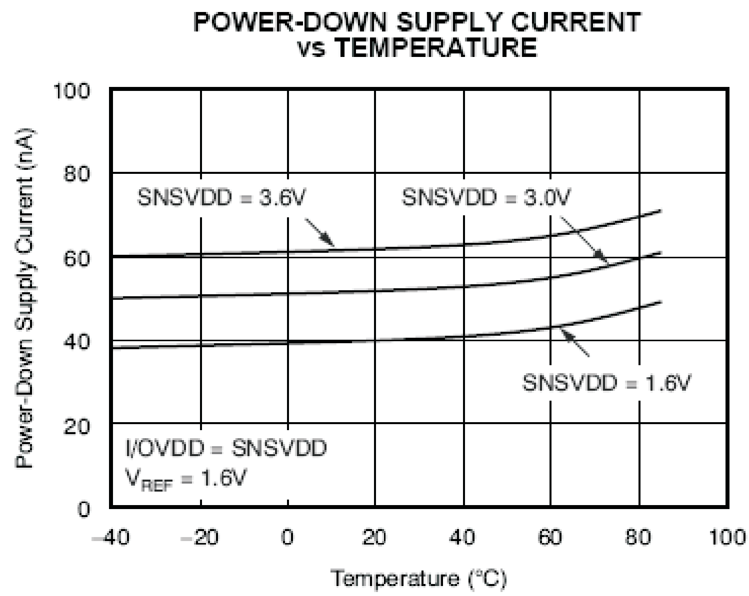


Figure 3. Power Supply Current Under Power-Down State

TSC2005 enters power-down state after power up or RESET by default, and returns to the power-down state whenever the TSC2005 ADC is stopped.

3.2.2 Wait State

The wait state occurs only under the host-controlled converting mode and between the times after the panel is touched and before the host sends a command to TSC2005 (see Section 3.1).

In the host-controlled converting mode, the TSC2005 $\overline{\text{PINTDAV}}$ pin should be programmed as $\overline{\text{PENIRQ}}$ or $\overline{\text{PENIRQ}}$ AND $\overline{\text{DAV}}$, by bits 15-14 of CR2 (Configuration Register 2). Thus, the TSC2005 can detect whether the panel is touched or not, and sends the $\overline{\text{PENIRQ}}$ interrupt to the host whenever the panel is touched.

During the wait state, the power is mainly consumed by the internal pullup resistor R_{IRQ}, which is approximately 51 kΩ or 90 kΩ (programmble). See Figure 4.

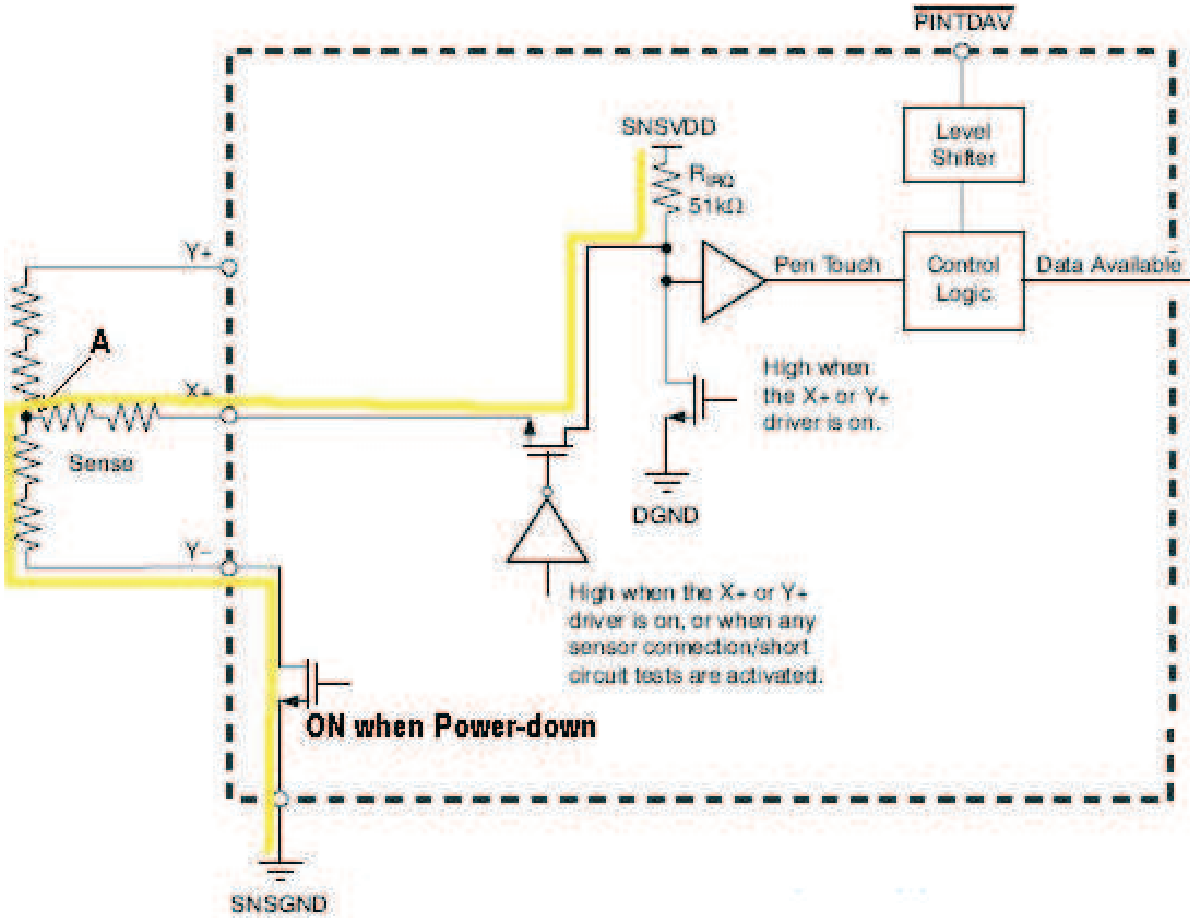


Figure 4. R_{IRQ} is Connected to Ground (Through the Yellow Line) During the Wait State

When the panel is not pressured, the X- and Y-layers of the touch panel are separated and thus no circuit is connected between the SNSVDD and its ground SNSGND. A touch on the panel connects the X- and Y-layer at the point A (Figure 4), and an electric loop starts from the SNSVDD pin, through the internal pullup resistor R_{IRQ} and through the touch panel and point A, to the ground SNSGND, as shown by the yellow line in Figure 4.

The power consumption at wait state changes with the touch location on the panel. The approximate maximal current for R_{IRQ} = 51-kΩ:

$$I_{wait-max} \cong \frac{V_{SNSVDD}}{51000}. \qquad (1)$$

And approximate maximal power consumption is:

$$P_{wait-max} \simeq V_{SNSVDD} \times V_{SNSVDD}/51000. \qquad (2)$$

Where V_{SNSVDD} is the SNSVDD voltage, $I_{wait\text{-}max}$ is the maximal wait-state current drawing from SNSVDD; and $P_{wait\text{-}max}$ the maximal wait-state power consumption from the SNSVDD. Figure 5 shows the current and power during the wait state, under R_{IRQ} = 51-kΩ, from a different SNSVDD value.

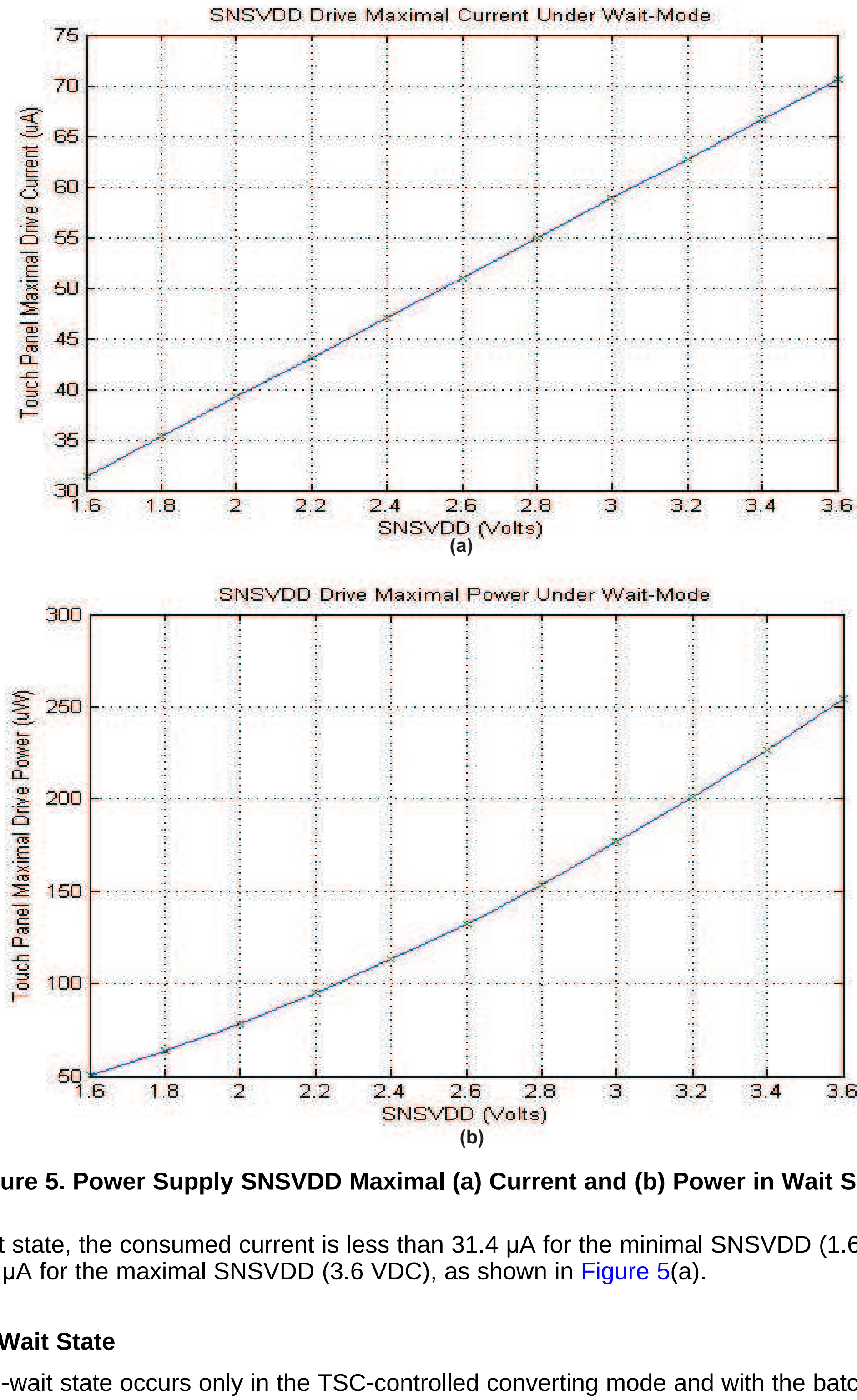


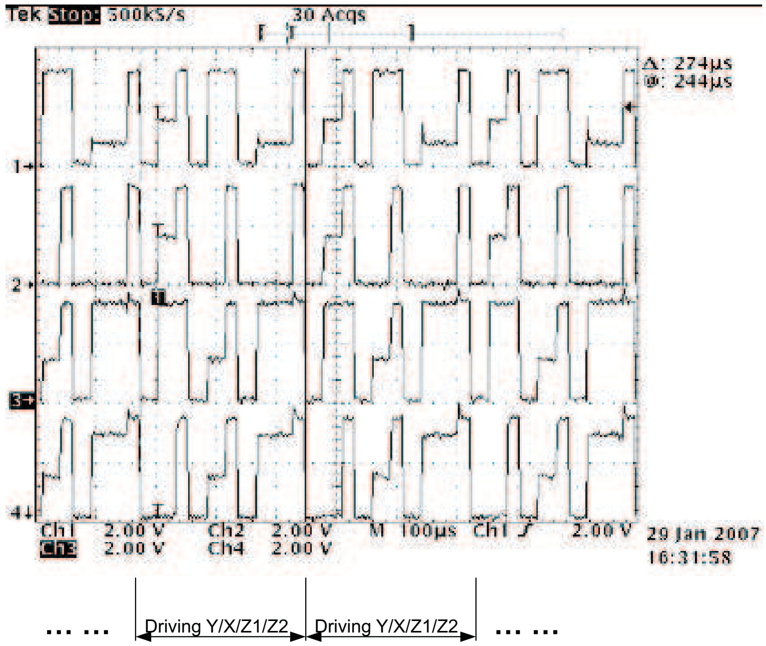
Figure 5. Power Supply SNSVDD Maximal (a) Current and (b) Power in Wait State

In the wait state, the consumed current is less than 31.4 µA for the minimal SNSVDD (1.6 VDC) and less than 70.6 µA for the maximal SNSVDD (3.6 VDC), as shown in Figure 5(a).

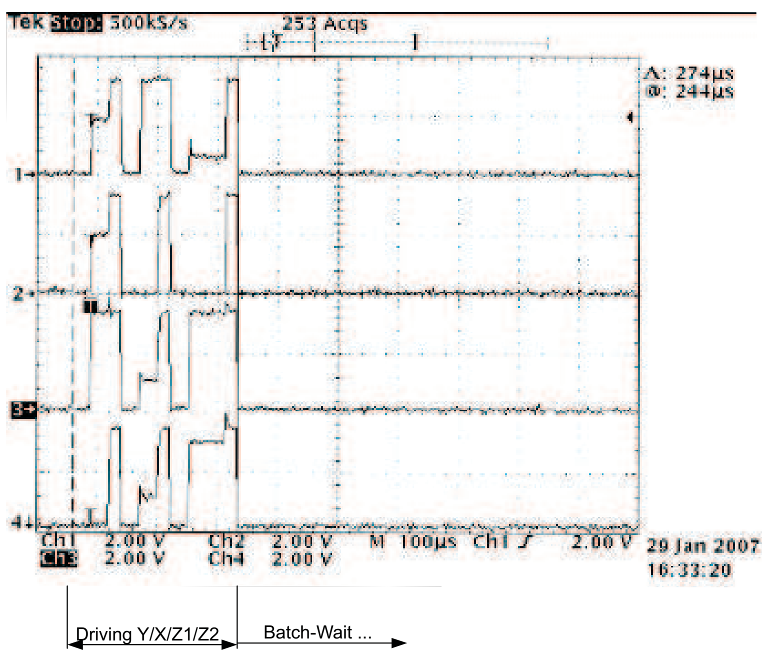
3.2.3 Batch-Wait State

The batch-wait state occurs only in the TSC-controlled converting mode and with the batch-delay timing being set larger than 0 ms, by BDT2 ~ BDT0, D2~D0 of CFR1 (Configuration Register 1). The TSC2005 batch delay can be programmed to 1 ms, 2 ms, 4 ms 10 ms, 20 ms, 40 ms, or 100 ms, corresponding to 1000, 500, 250, 100, 50, 25 or 10 SSPS (sample sets per second). For additional information, see the TSC2005 data sheet (SBAS379).

Batch delay is a feature that allows the TSC2005 to control the time interval between two sets of touch screen data. With batch delay, the TSC2005 drives and samples the touch data in a fixed interval (batch delay) while a touch keeps pressure on the panel.



(a)



(b)

NOTE: a) Touch screen controller keeps driving, sampling, and converting X, Y, Z1, and Z2 data at a rate of 1/(274 µs) = 3650 sets per second without Batch Delay. b) The rate is controllable and the analog interface traffic is greatly reduced with Batch Delay. Where Ch1 is X+; Ch2 is X–, Ch3 is Y+, and Ch4 is Y–.

Figure 6. Touch Screen Controller Analog Interface Traffic

As previously discussed, in the TSC-controlled converting mode, the TSC2005 starts to drive, sample, and convert X /Y or X/Y/Z1/Z2 as soon as a touch is sensed on the panel. If the touch remains on the panel without any batch delay, the TSC2005 continuously drives the touch panel and samples and converts the data. Thus, the touch panel is powered up/down without stopping, and the traffic on the analog interface continues and becomes heavy, as shown by Figure 6(a).

On other hand, with the batch delay, the TSC enters the batch-wait state after the first processed sample set is completed and stays in it until the end of the batch-delay time, even though the pen touch is still detected during the entire time. Therefore, the panel driver is not unnecessarily on, ADC conversion is eliminated during the batch delay, the analog interface traffic is reduced, and power is saved.

During the Batch-Wait state, the current from SNSVDD is a function of V_{SNSVDD} or

$$I_{batch-wait} = f'(V_{SNSVDD}) \quad (3)$$

and $I_{batch\text{-}wait}$ is less than 100 μA with V_{SNSVDD} = 3.3 VDC, consisting of:

– power for an internal batch-delay timer

– the current through the $\overline{\text{PINTDAV}}$ pullup resistor, i.e., the Equation 1 as discussed in Section 3.2.2.

3.2.4 DCP State

The DCP (Driving/Converting/Processing) state is for acquiring touch screen data, such as X/Y/Z. It is the highest power-consuming period or state. To get touch screen data, the TSC2005 powers on the touch panel, converts the sampled voltage into digital data, and preprocesses the touch data if the MAVF is programmed ON. The TSC2005 SNSVDD provides the power under the DCP state.

The power consumed from SNSVDD consists of two parts: internal by the TSC2005 device itself and external by driving the touch panel and the analog interface. That is:

$$I_{DCP} = I_{Internal} + I_{External} \quad (4)$$

Where: $I_{Internal}$ is the current used by TSC2005 internal SAR ADC, system clocks, and other processing circuits, such as the $\overline{\text{PENIRQ}}$ circuit shown in Figure 4. Thus, $I_{Internal}$ can be expressed by a function of V_{SNSVDD} or

$$I_{Internal} = f(V_{SNSVDD}) \quad (5)$$

The $f(V_{SNSVDD})$ can be affected by temperature and may vary a little from part to part.

Example 1: Some experiential data with a TSC2005EVM shows that: in the fully operational DCP state, the TSC2005 internal DCP current under SNSVDD = 3.3 VDC is approximately 900 μA and that under SNSVDD = 2.5 VDC is approximately 680 μA. Using a first-order curve fit produces the following equation:

$$f(V_{SNSVDD}) \cong k \times V_{SNSVDD} \quad \text{and} \quad k \cong 0.2724 \times 10^3. \quad (6)$$

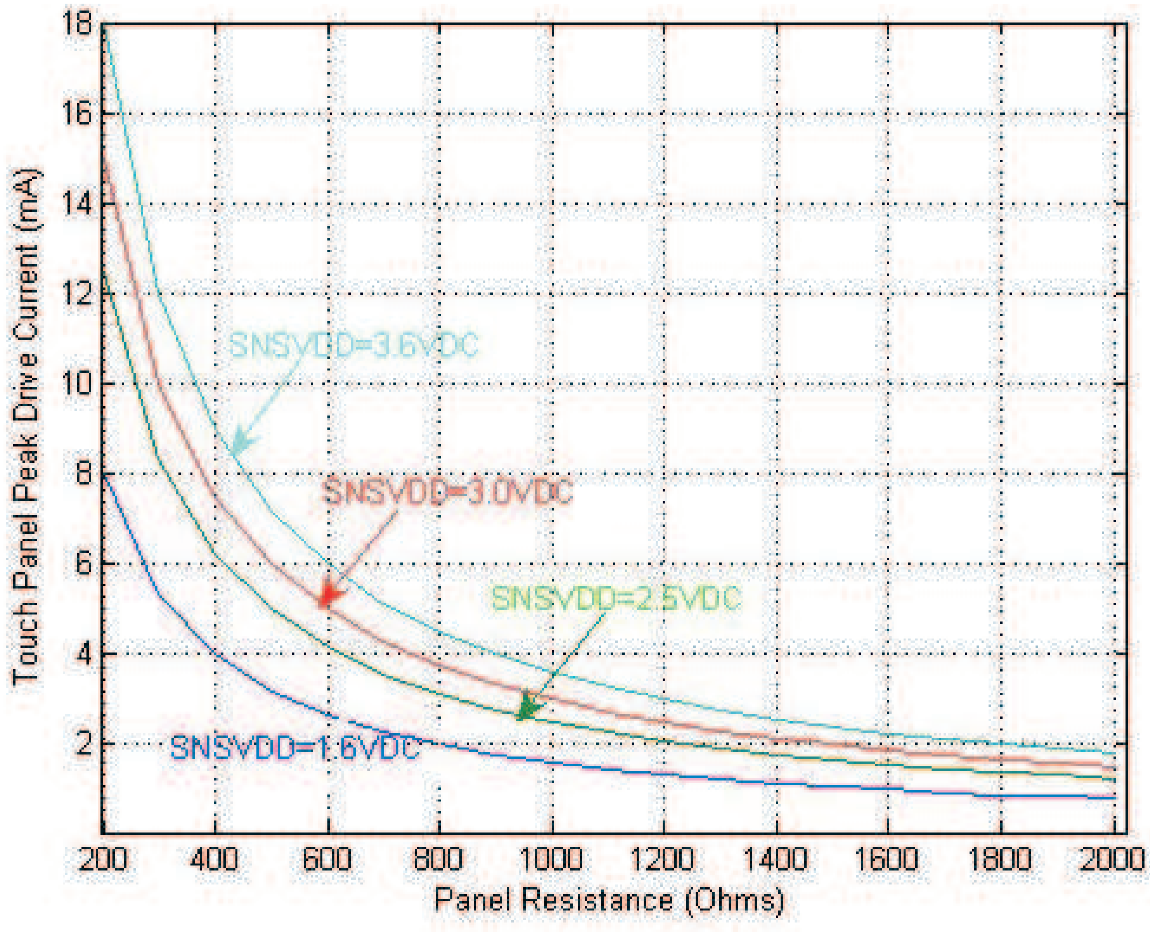
To drive the touch panel, TSC2005 consumes $I_{External}$ from SNSVDD power supply. The $I_{External}$ is decided by:

– SNSVDD voltage

– the touch panel resistance

– the ratio of the driver's power ON and OFF timing.

The peak or maximal panel driving current $I_{External\text{-}max}$ (= V_{SNSVDD} / R_{touch}) has been shown in Figure 7, where the R_{touch} is the touch panel average resistance. For example, if the resistance between a touch panel's X+ and X- pins is 600 Ω and that between Y+ and Y- is 400 Ω, the R_{touch} is 500 Ω (= (600+400)/2).



NOTE: The touch screen is driven by the touch screen controller; the panel resistance R_{touch} determines the peak drive current from the touch screen controller from the SNSVDD power supply.

Figure 7. Touch Panel Drive Current

Figure 7 considers only the ideal TSC driving condition where the TSC's internal driving ON resistance has been ignored (because it is small compared to the touch panel's resistance). Thus, the actual power consumption in this case should be a little less than that shown in Figure 7.

The average external current within a second is:

$$I_{External} = I_{External-max} \times \tau = \frac{V_{SNSVDD}}{R_{touch}} \times \frac{SSPS \times S \times B}{F} \qquad (7)$$

Where $\tau = SSPS \times S \times B/F$, the driving–ON time per second. SSPS is sample sets per second that indicates how many sets of touch data the host gets within a second; S is the number of data in a set of samples; B is the TSC resolution, either 10 bit or 12 bit; and F is ADC clock frequency, which can be 4, 2, or 1 MHz.

The number of data in a set of samples, or the S in Equation 6, is the total number of samples in a set. For example, if the needed touch coordinates consist of X and Y, and the MVA filter is disabled, then S = 2, an X and a Y data. If needing X, Y, Z1, and Z2 (with MVA filter still disabled), S = 4; and if needing X, Y, Z1, and Z2 and with MVA filter enabled, $S = 4 \times N$, where N is the filter's window width.

In Equation 7, the TSC2005 programmable parameter PVS (panel voltage stabilization) delay time is set to 0 µs, so as to simplify the discussion. The PVS delay (>0 µs) adds touch driver ON time prior to ADC sampling and thus more SNSVDD power is consumed (see SLAA362).

Example 2: Using a TSC2005EVM to measure the power consumption with the condition that:

V_{SNSVDD} = 3.3, 2.5, or 1.8 VDC

R_{touch} = 450 Ω

SSPS = 100, 250, or 500

S = 4, 12, 28, or 60

B = 12 bit

F = 1 or 2 MHz

Table 2 to Table 7 list the measured I_{DCP}, on a TSC2005EVM, and the modeled I_{DCP}, by using Equation 5 and Equation 7 .

Table 2. TSC2005 I_{DCP} (in µA) Under 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)	1000	987	940	943	900	917
S = 12 (Read X/Y/Z and N=3)	1250	1163	1070	1031	960	952
S = 28 (Read X/Y/Z and N=7)	1610	1515	1240	1207	1030	1022
S = 60 (Read X/Y/Z and N=15)	2320	2219	1600	1559	1170	1163

Table 3. TSC2005 I_{DCP} (in µA) Under 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)	1080	1075	980	987	920	934
S = 12 (Read X/Y/Z and N=3)	1490	1427	1190	1162	1000	1005
S = 28 (Read X/Y/Z and N=7)	2170	2131	1520	1515	1140	1145
S = 60 (Read X/Y/Z and N=15)	3490	3539	2220	2219	1400	1427

Table 4. TSC2005 I_{DCP} (in µA) Under 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)	710	748	670	714	640	694
S = 12 (Read X/Y/Z and N=3)	910	881	770	781	680	721
S = 28 (Read X/Y/Z and N=7)	1240	1148	900	914	750	774
S = 60 (Read X/Y/Z and N=15)	1880	1681	1180	1181	880	881

Table 5. TSC2005 I_{DCP} (in µA) Under 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)	780	814	700	748	660	707
S = 12 (Read X/Y/Z and N=3)	1150	1081	880	881	730	761
S = 28 (Read X/Y/Z and N=7)	1740	1614	1130	1148	860	868
S = 60 (Read X/Y/Z and N=15)	2930	2681	1650	1681	1090	1081

Table 6. TSC2005 I_{DCP} (in μA) Under 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)	538	514	500
S = 12 (Read X/Y/Z and N=3)	634	562	519
S = 28 (Read X/Y/Z and N=7)	826	658	558
S = 60 (Read X/Y/Z and N=15)	1210	850	634

Table 7. TSC2005 I_{DCP} (in μA) Under 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)	586	538	506
S = 12 (Read X/Y/Z and N=3)	778	634	548
S = 28 (Read X/Y/Z and N=7)	1162	826	625
S = 60 (Read X/Y/Z and N=15)	1930	1210	778

The above examples show how TSC2005 touch driving power consumption is effected by SSPS, S, and F, as well as SNSVDD power voltage. To reduce TSC2005 power consumption, users can focus on these factors and properly select SSPS, S, F, and SNSVDD based on the system requirement.

3.2.5 SCP State

Section 3.2.4 discussed the DCP state for touch screen data. This section is addressing the same process for nontouch data (such as AUX). The state is denoted as the SCP or Sampling/Converting/Processing state. During SCP state, the TSC2005 samples the nontouch input, converts the voltage, and preprocesses the data if programmed ON.

Compared to DCP state, the SCP state requires no panel driving for nontouch input. Thus, the SCP state is similar to the $I_{Internal}$ in Equation 7 and usually consumes much less power than the DCP state.

The SCP state is not discussed further in this application report because its focus is on touch screen modes and power consumption.

3.2.6 R/W State

The R/W state concerns only digital interface and digital power consumption.

Another power supply, IOVDD, is used to provide power for the digital interface while the host is reading/writing (R/W) from/to the TSC2005 through the SPI bus. The IOVDD power consumption is usually 100s or even 1000s of times smaller than the SNSVDD power consumption.

The digital I/O current is positively proportional to the IOVDD voltage and positively proportional to the digital bus traffic density. This relationship can be expressed approximately by:

$$I_{IOVDD} \cong \frac{K_{IOVDD}}{F_{IOVDD}} \times V_{IOVDD} \times SSPS \qquad (8)$$

Where I_{IOVDD} is the current drawing from IOVDD under the R/W state; k_{IOVDD} is a constant that can be affected by temperature and may change from part to part; V_{IOVDD} is IOVDD voltage and ranges from 1.2 VDC to 3.6 VDC; SSPS is the Sample Sets Per Second as previously discussed; and F_{IOVDD} is the SPI clock (SCLK) frequency. The faster SCLK can transfer the same amount of data within a shorter time, reduce digital interface time, and thus consume less IOVDD power.

Example 3: Using a TSC2005EVM to measure the IOVDD power consumption with the same conditions listed in Example 2, with V_{IOVDD} = 3.3, 2.5, or 1.8 VDC and SSPS = 100, 250, or 500. The EVM is plugged into the TI USB-MODEVM board where a C8052 core processor (TAS1020B USB controller) is running and controlling the SPI. Table 9 lists the measured I_{IOVDD}, and the modeled I_{IOVDD} by using Equation 8 with

$$\frac{K_{IOVDD}}{F_{IOVDD}} \cong \frac{1}{1650} \tag{9}$$

Table 8. TSC2005 Digital I/O Consumed Current I_{IOVDD} (in µA)

	SSPS = 500		SSPS = 250		SSPS = 100		SSPS = 50	
	Measured	**Modeled**	**Measured**	**Modeled**	**Measured**	**Modeled**	**Measured**	**Modeled**
V_{IOVDD} = 3.3 VDC	0.9 ~ 1.1	1	0.6	0.5	0.3	0.20	0.2	0.100
V_{IOVDD} = 2.5 VDC	0.7 ~ 0.9	0.76	0.3 ~ 0.6	0.38	0.1 ~ 0.3	0.15	<0.1	0.076
V_{IOVDD} = 1.8 VDC	–	0.55	–	0.27	–	0.11	–	0.055
V_{IOVDD} = 1.2 VDC	–	0.48	–	0.24	–	0.10	–	0.049

Comparing with SNSVDD power consumption, the digital interface power IOVDD consumes much less power. It is even lower when the digital traffic is lower.

3.3 Touch Screen Operating Modes

After users select TSC2005 ADC converting mode and set up TSC2005 control bytes and configuration registers, TSC2005 can be placed into one of its three touch screen operating modes, TSMode1, TSMode2, and TSMode3, as defined in the TSC2005 data sheet (SBAS379).

Table 9 summarizes the operating modes that correspond to the PSM bit and C3-C0 settings.

Table 9. TSC2005 Operating Modes

Operating Mode	PSM (D15 of CR0)	C3 C2 C1 C0 (D6-D3 of CB1)
TSMode1	PSM = 1b (TSC-Controlled Converting Mode)	C3~C0 = 0000b (X/Y/Z1/Z2 scan function) C3~C0 = 0001b (X/Y scan function)
TSMode2	PSM = 0b (Host-Controlled Converting Mode)	C3~C0 = 0000b (X/Y/Z1/Z2 scan function) C3~C0 = 0001b (X/Y scan function)
TSMode3	PSM = 0b (Host-Controlled Converting Mode)	C3~C0 = 0010b (X scan function) C3~C0 = 0011b (Y scan function) C3~C0 = 0100b (Z1/Z2 scan function)

TSMode1 is always in the TSC-controlled converting mode. That is, the ADC is initialized to start work and be controlled by TSC. There are two types of conditions: without the batch delay and with the batch delay. Without the batch delay, the TSMode1 sequence includes Power-Down, DCP, and R/W status states, as the example that is shown in Figure 8. With the batch delay, the TSMode1 consists of Power Down, Batch Wait, DCP, and R/W status states, as the examples that are shown in Figure 9 and Figure 10.

TSMode2 is similar to TSMode1 but is in the Host-Controlled converting mode. This means that the ADC is initialized to start work by the host responding to the $\overline{\text{PENIRQ}}$ interrupt from the TSC and then controlled by the TSC thereafter. The two types of conditions are without the batch delay and with the batch delay. Without the batch delay, its sequence includes Power Down, Wait, DCP, and R/W status states, as the example shown in Figure 11. With the batch delay, it consists of Power Down, Wait, Batch Wait, DCP, and R/W status states, as the example shown in Figure 12.

TSMode3 is under the Host-Controlled converting mode totally. This means that the ADC is initialized to start work by the host and is controlled by the host. The sequence includes Power Down, Wait, DCP, and R/W status states, as the examples that are shown in Figure 13 and Figure 14.

Figure 8 through Figure 14 provide the TSC2005 power consumption under the various touch screen operating modes. See the previous sections on the SNSVDD and IOVDD current consumed, under each specific status states.

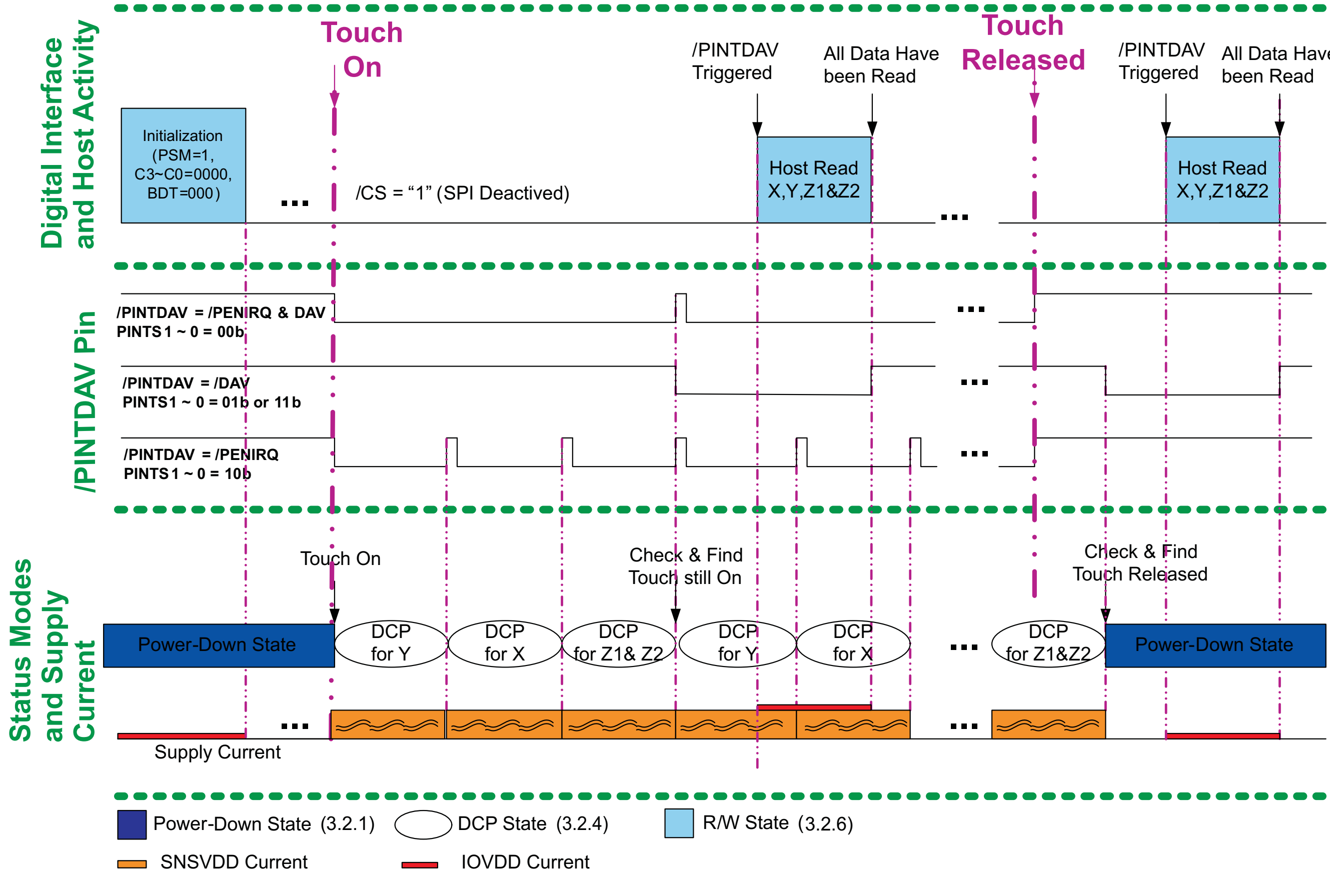


Figure 8. TSMode1 With X/Y/Z1/Z2 Converting and Without Batch Delay

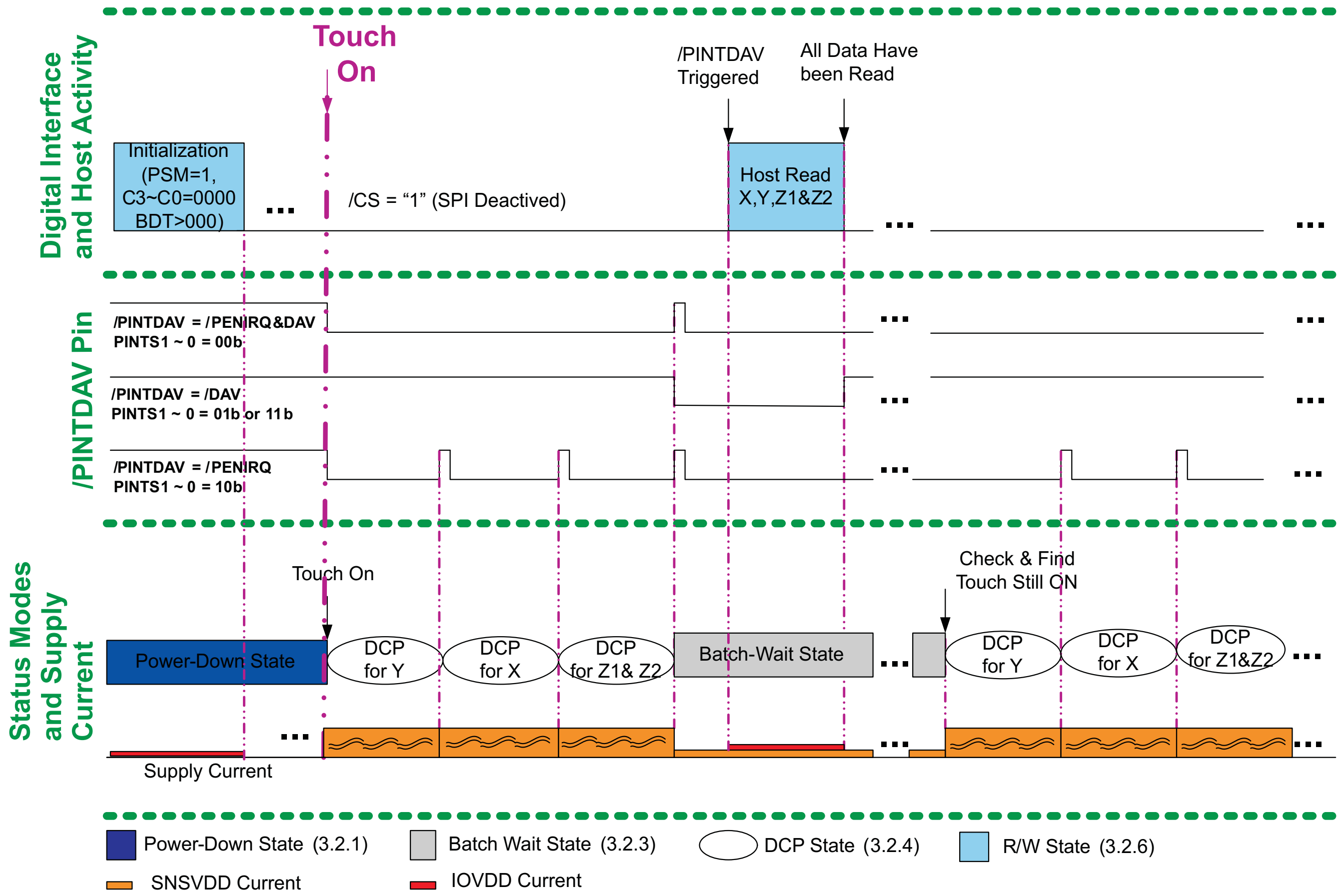


Figure 9. TSMode1 With X/Y/Z1/Z2 Converting and With Batch Delay

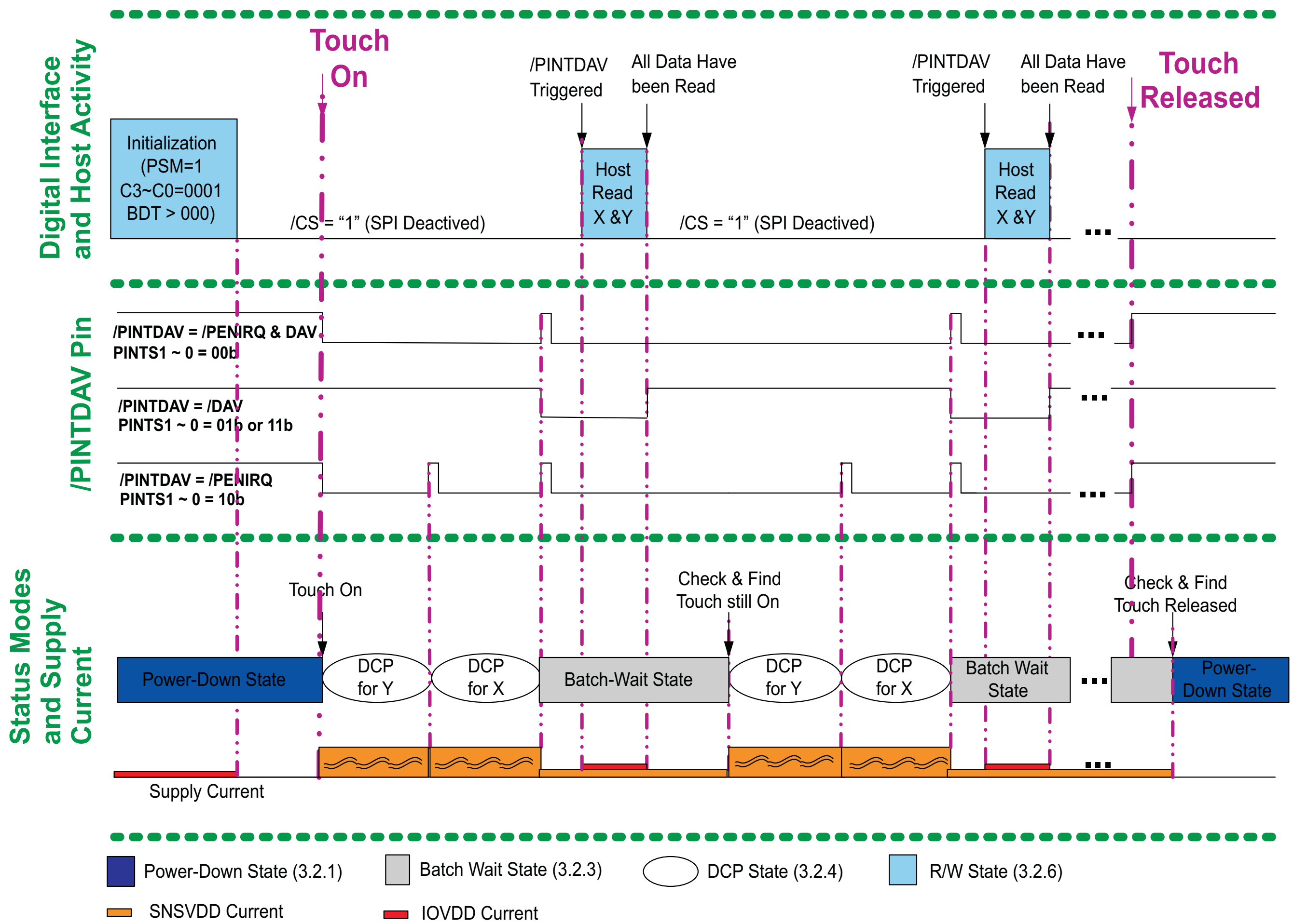


Figure 10. TSMode1 With X/Y Converting and With Batch Delay

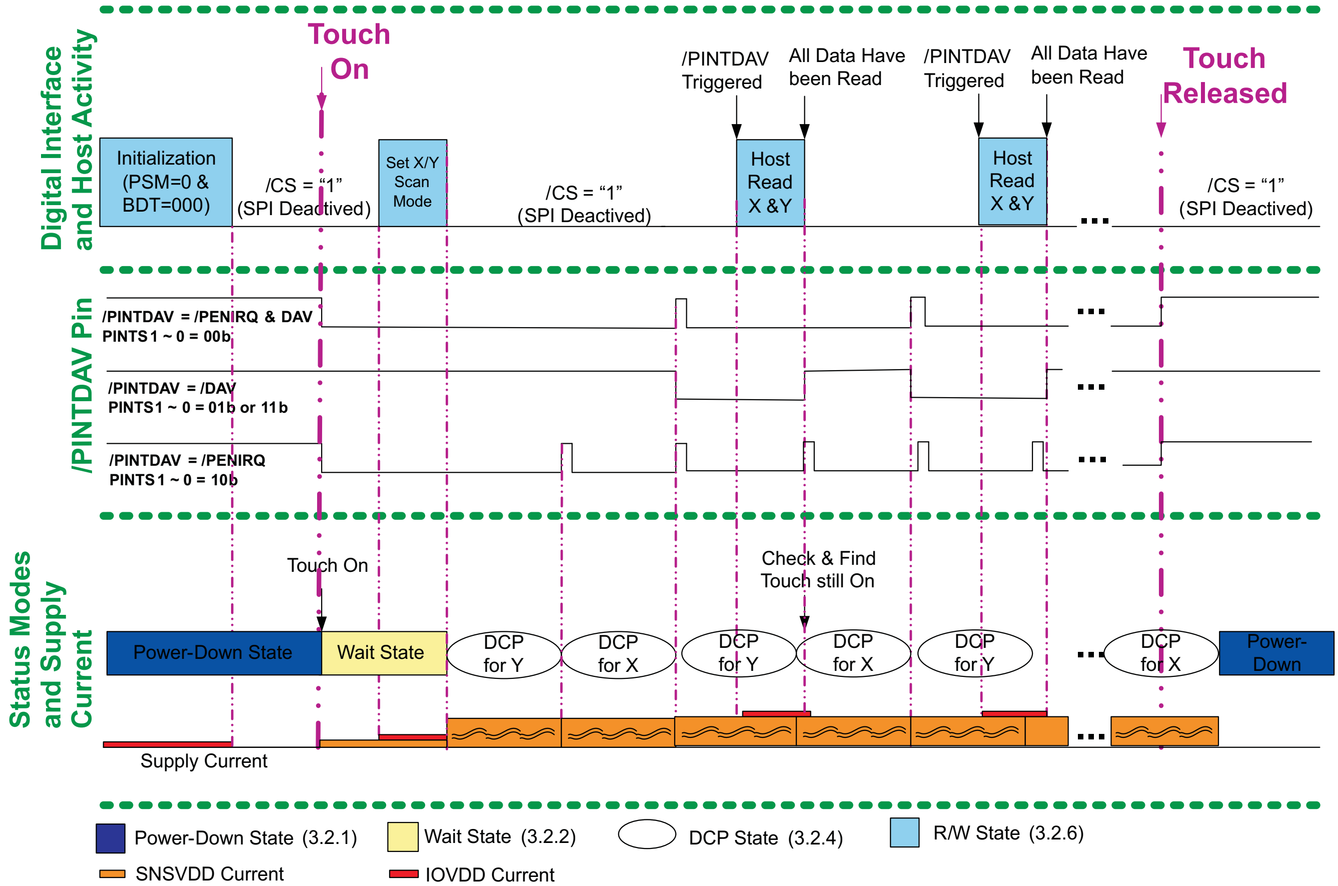


Figure 11. TSMode2 With X/Y Converting Without Batch Delay

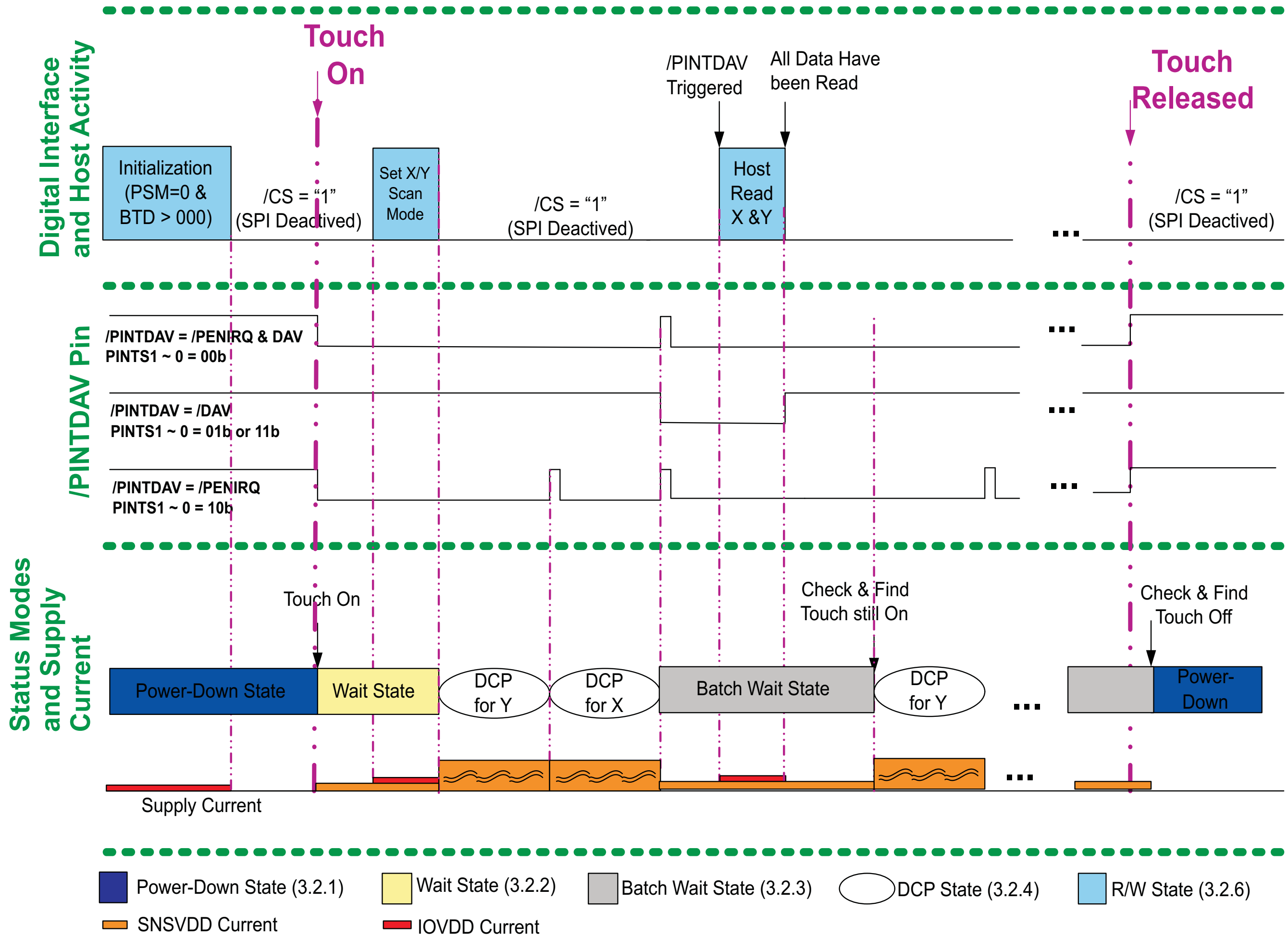


Figure 12. TSMode2 With X/Y Converting With Batch Delay

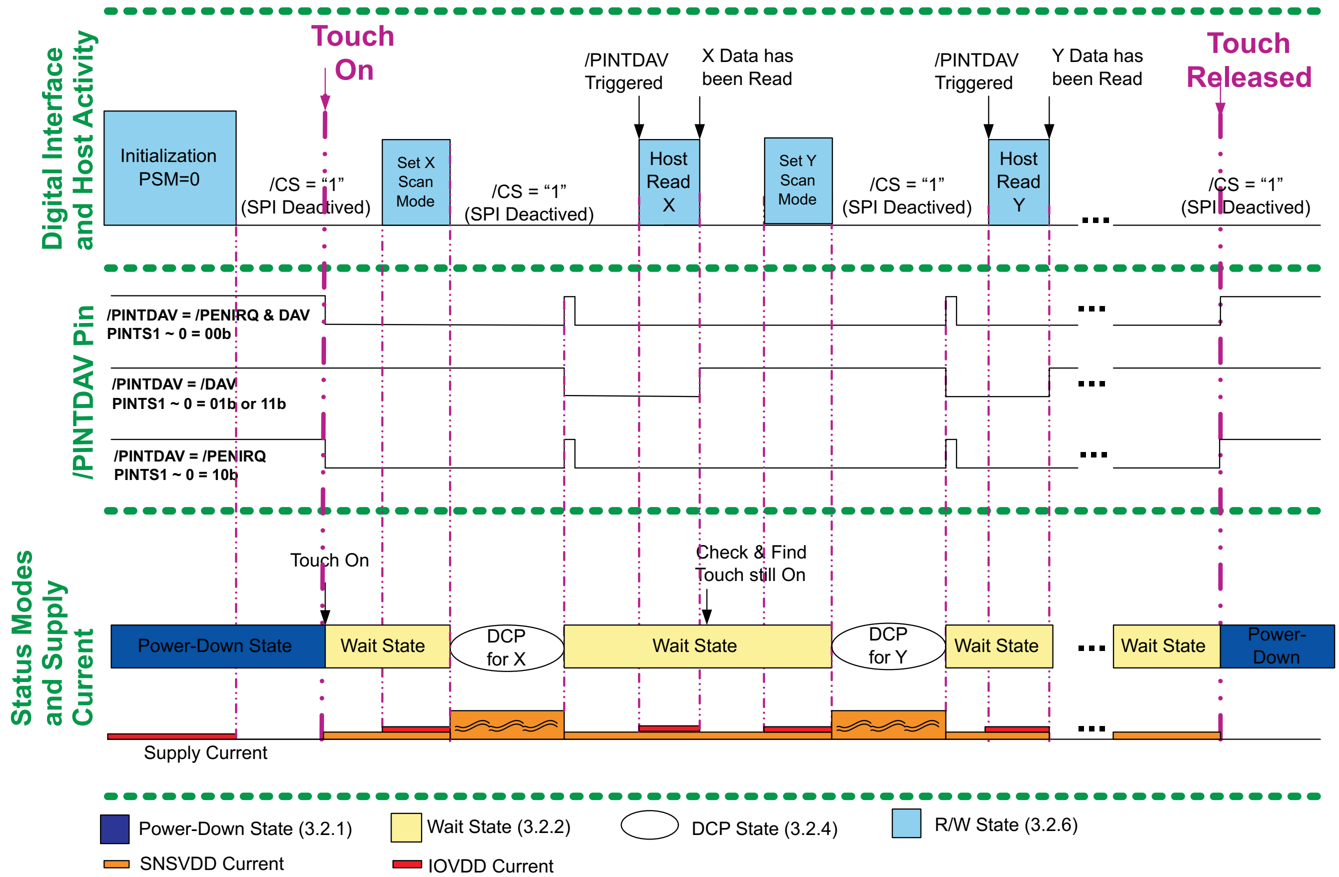


Figure 13. TSMode3 With X/Y Converting

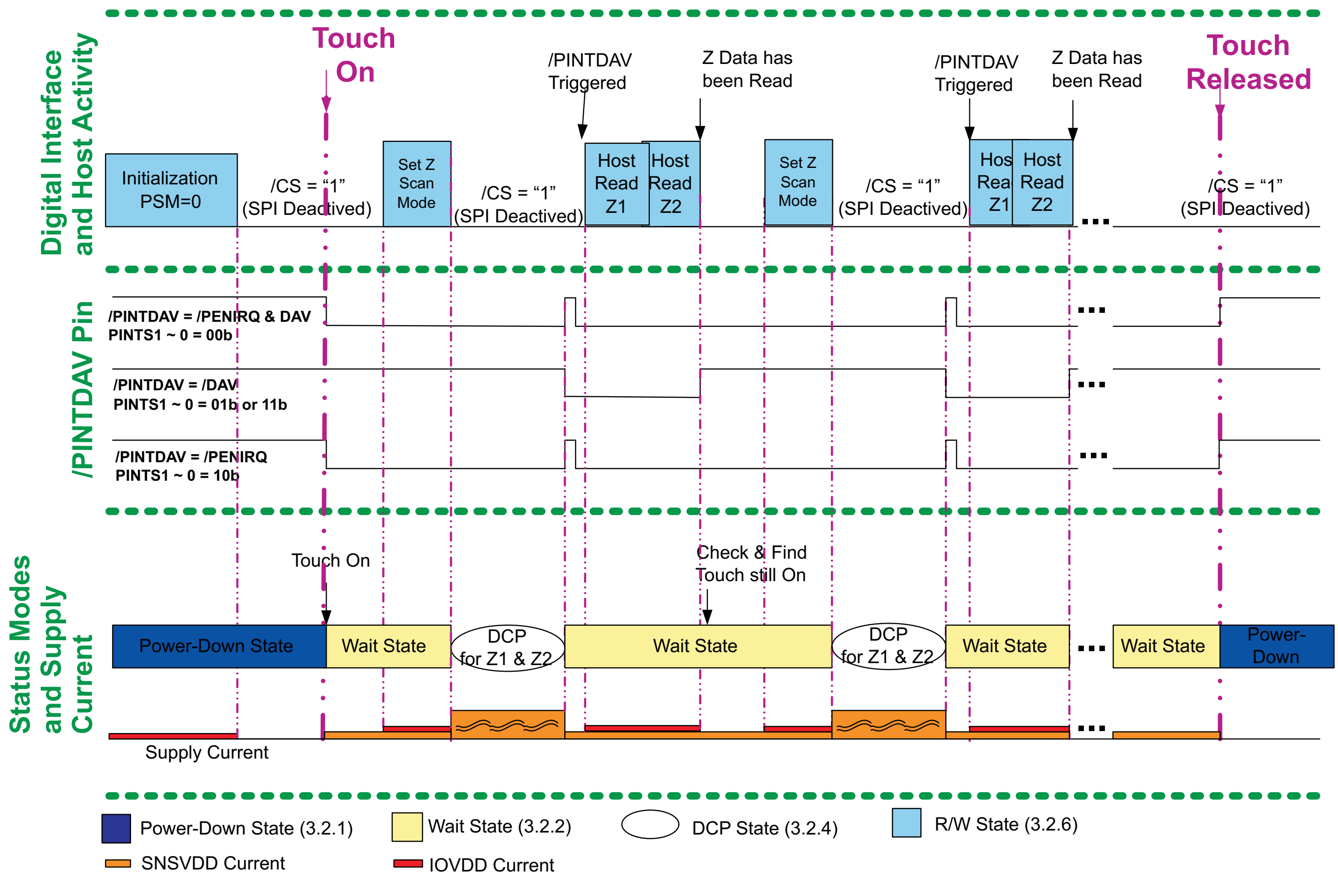


Figure 14. TSMode3 With Z1/Z2 Converting

4 Conclusion

This application report discusses the TSC2005 power consumption in different operating modes so as to provide a guideline for using the TSC2005 to perform the required functions and features with optimal low-power consumption.

A touch screen system can be set up to operate in one of the three touch screen operating modes, TSMode1, TSMode2, or TSMode3. During any one of the touch screen operating modes, the power consumptions are greatly varied during different periods (or status states). One of the main power consumption is during the DCP state, provided from the SNSVDD supply that is expressed by Equation 4. Users can reduce the power consumption during the DCP state with selected touch panel (resistance) and SNSVDD voltage, and reduce the time under the DCP state by reducing the touch panel power ON time, applying host-controlled converting mode or, better, applying TSC-controlled converting mode with the batch-delay feature.

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