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EVALUATION KIT AVAILABLE

Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

General Description

The MAX11800–MAX11803 low-power touch-screen controllers operate from a single supply of 1.70V to 3.6V, targeting power-sensitive applications such as handheld equipment. The devices contain a 12-bit SAR ADC and a multiplexer to interface with a resistive touch-screen panel. A digital serial interface provides communications.

The MAX11800–MAX11803 include digital preprocessing of the touch-screen measurements, reducing bus loading and application-processor resource requirements. The included smart interrupt function generator greatly reduces the frequency of interrupt servicing to the devices. The MAX11800–MAX11803 enter low-power modes automatically between conversions to save power, making the devices ideal for portable applications.

The MAX11800/MAX11801 offer two modes of operation: direct and autonomous. Direct mode allows the application processor to control all touch-screen controller activity. Autonomous mode allows the MAX11800/MAX11801 to control touch-screen activity, thereby freeing the application processor to perform other functions. In autonomous mode, the devices periodically scan the touch screen for touch events without requiring host-processor intervention. This can be used to reduce system power consumption. An on-chip FIFO is used during autonomous mode to store results, increasing effective data throughput and lower system power.

The MAX11800–MAX11803 support data-tagging, which records the type of measurement performed; X, Y, Z1, or Z2, and the type of touch event; initial touch, continuing touch, or touch release.

The MAX11800/MAX11802 support the SPI™ serial bus. The MAX11801/MAX11803 support the I²C serial bus. The MAX11800–MAX11803 are available in 12-pin TQFN and 12-pin WLP packages, and are specified over the -40°C to +85°C (extended) and -40°C to +105°C (automotive) temperature ranges.

Applications

Mobile Communication Devices

PDAs, GPS Receivers, Personal Navigation Devices, Media Players

Portable Instruments

POS Terminals

Handheld Games

Automotive Center Consoles

Typical Operating Circuits and Pin Configurations appear at end of data sheet.

SPI is a trademark of Motorola, Inc.

Features

- **4-Wire Touch-Screen Interface**
- **X/Y Coordinate and Touch Pressure Measurement**
- **Ratiometric Measurement**
- **12-Bit SAR ADC**
- **Single 1.7V to 3.6V Supply**
- **Two Operating Modes—Direct and Autonomous**
- **Data Tagging Provides Measurement and Touch Event Information**
- **Data Filtering Provides Noise Reduction**
- **Aperture Mode Provides Spatial Filtering**
- **Digital Processing Reduces Bus Activity and Interrupt Generation**
- **Programmable Touch-Detect Pullup Resistors**
- **Auto Power-Down Control for Low-Power Operation**
- **25MHz SPI Interface (MAX11800/MAX11802)**
- **400kHz I²C Interface (MAX11801/MAX11803)**
- **1.6mm x 2.1mm, 12-Pin WLP and 4mm x 4mm, 12-Pin TQFN**
- **Low-Power Operation**
  343µW at V_{DD} = 1.7V, 34.4ksps
  888µW at V_{DD} = 3.3V, 34.4ksps
- **ESD Protection**
  ±4kV HBM
  ±8kV HBM (X+, X-, Y+, Y-)
  ±1kV CDM
  ±200V MM

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX11800ETC+	-40°C to +85°C	12 TQFN-EP*
MAX11800GTC/V+	-40°C to +105°C	12 TQFN-EP*
MAX11800EWC+T	-40°C to +85°C	12 WLP
MAX11801ETC+	-40°C to +85°C	12 TQFN-EP*
MAX11801GTC/V+	-40°C to +105°C	12 TQFN-EP*
MAX11801EWC+T	-40°C to +85°C	12 WLP
MAX11802ETC+	-40°C to +85°C	12 TQFN-EP*
MAX11802EWC+T	-40°C to +85°C	12 WLP
MAX11803ETC+	-40°C to +85°C	12 TQFN-EP*
MAX11803EWC+T	-40°C to +85°C	12 WLP

+Denotes a lead(Pb)-free/RoHS-compliant package.
/V denotes an automotive qualified part.
T = Tape and reel.
**EP = Exposed pad.*

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Table 1. Terminology

TERM	DEFINITION
Panel, Touch Screen, Touch Panel	**Resistive Touch Sensor:** Panel, or touch screen, or touch panel are used interchangeably to denote the resistive touch sensor.
TSC	**Touch-Screen Controller:** Devices attached to a touch screen that provide the interface between an application processor (AP) and touch screen.
X+	**X Position Positive I/O:** Analog I/O from resistive touch screen. See Figure 4 for configuration and measurement details.
X-	**X Position Negative I/O:** Analog I/O from resistive touch screen. See Figure 4 for configuration and measurement details.
Y+	**Y Position Positive I/O:** Analog I/O from resistive touch screen. See Figure 4 for configuration and measurement details.
Y-	**Y Position Negative I/O:** Analog I/O from resistive touch screen. See Figure 4 for configuration and measurement details.
R_{TOUCH}	**Touch Resistance:** Represents the resistance between the X and Y planes of a resistive touch screen during a touch event.
Z1	**Z1 Measurement:** A resistive touch-screen measurement to determine the resistance between the two planes within the panel sensor during a touch event (R_{TOUCH}). See Figure 5 for configuration and measurement details.
Z2	**Z2 Measurement:** A resistive touch-screen measurement to determine the resistance between the two planes within the panel sensor during a touch event (R_{TOUCH}). See Figure 5 for configuration and measurement details.
AUX	**Auxiliary Input:** Analog input to the MAX11800–MAX11803 that can be used to monitor external conditions such as battery voltage or temperature.
ADC	**Analog-to-Digital Converter:** Circuit used to transform analog information into a form suitable for digital operations.
AP	**Application Processor:** An external microcontroller or microprocessor that interfaces to and controls the general operation of the MAX11800–MAX11803.
AVG	**Averaging Mode:** The ability to average consecutive measurement results to reduce noise from switch bounce, power-supply ripple, and incomplete settling.
MAF	**Median Averaging Filter:** The MAF first removes the minimum and maximum samples before taking the average of the remaining sample set.
SAF	**Straight Averaging Filter:** The SAF takes the average of an entire sample set.
TDM	**Touch-Detect Mode:** An untimed mode that monitors the panel for a touch using a user-selectable panel pullup resistor of either 50kΩ or 100kΩ.
DCM	**Direct Conversion Mode:** A mode of operation in which the AP requests individual panel setup and conversion operations or automated combinations of measurements (X and Y, X and Y and Z1, or X and Y and Z1 and Z2). The AP maintains control over the initiation of panel setup, measurements, and the sampling
ACM	**Autonomous Conversion Mode:** A mode of operation in which the MAX11800/MAX11801 idle in TDM until a touch event occurs. After a touch is detected, the MAX11800/MAX11801 begin an automated sequence of measurements determined by the user configuration registers.
PSU	**Panel Setup Command:** User-programmable modes for the purpose of allowing the panel sufficient time to settle, prior to the start of measurements. PSU commands configure the on-chip multiplexer in preparation to perform either X, Y, Z1, or Z2 measurements. Durations can either be specified and managed by the MAX11800–MAX11803 (in ACM and DCM) or managed by the AP (in DCM).
PMC	**Panel Measurement Command:** Individual measurements of X or Y position and Z1 or Z2 pressure measurements.
CMC	**Combined Measurement Command:** Combinations of PMCs (X and Y, X and Y and Z1, or X and Y and Z1 and Z2) offered by the MAX11800–MAX11803 and executed in series to reduce AP bus and interrupt activity.

Table 1. Terminology (continued)

TERM	DEFINITION
FIFO	**First-In First-Out Memory:** The MAX11800–MAX11803 contain a 1024-bit FIFO that is used to store conversion results when operating in autonomous conversion mode. FIFO depth indicates the number of words (16-bit quantity) in the FIFO.
Scan	**Scan:** Generally, a single sequence of operations performed in DCM or ACM. The operations could include a panel setup operation, followed by a panel measurement operation, or a combined measurement operation.
Scan Block	**Scan Block:** Generally, a sequence of multiple operations performed in DCM or ACM. The operations could include panel-setup operations, panel-measurement operations, or combined measurement operations.
Timed Scan	**Timed Scan:** A scan or scan block operation that uses the on-chip oscillator and timer. The timer is controlled through the configuration registers and represents an array of fixed (time) quantities that are user selectable (MAX11800/MAX11801).
Untimed Scan	**Untimed Scan:** A scan or scan block operation that is controlled by the AP. This only applies to DCM.
TAG	**Data Tag:** Information appended to the end of an ADC conversion result. Tags indicate the type of measurement and touch status associated with each panel observation. See the definitions for ETAG and MTAG (also in Table 1).
ETAG	**Event Tag:** Data tags indicating the panel touch status observed during a measurement.
MTAG	**Measurement Tag:** Data tag indicating the type of measurement read back by the AP (either X, Y, Z1, or Z2).
$\overline{\text{TIRQ}}$	**Touch Interrupt Request:** Active-low interrupt, indicating that a touch is present (CINT) or has been initiated (EINT) in DCM, or that new data is available in the FIFO in ACM.
EINT	**Edge Interrupt Mode:** Indicates, through $\overline{\text{TIRQ}}$, that a touch has been initiated (EINT) in DCM. The duration that $\overline{\text{TIRQ}}$ is low is user programmable.
CINT	**Continuous Interrupt Mode:** Indicates, through $\overline{\text{TIRQ}}$, that a touch is present (CINT) in DCM. $\overline{\text{TIRQ}}$ goes low to indicate the presence of a touch and stays low until the touch event ceases.
CORINT	**Clear-on-Read Interrupt Mode:** Used in ACM only. $\overline{\text{TIRQ}}$ goes low to indicate the presence of new FIFO data. The interrupt is cleared when the data is read by the AP (MAX11800/MAX11801).
APER	**Aperture Mode:** Available in ACM only. Reduces data writes to the FIFO by spatially filtering measurement data.
CONT	**Continuous Bit:** An option in DCM to return the MAX11800–MAX11803 to a panel setup (wait) mode (PSU) after a conversion, rather than a return to TDM (recommended only for applications with very long panel settling times and request controlling their own averaging). The continuous bit resides in bit 0 (R0) of the PSU and PMC registers.
LPM	**Low-Power Mode:** An idle mode used in DCM/EINT or ACM modes, when a touch is detected at the conclusion of the last measurement. This indicates a new measurement needs to be requested or scheduled (the touch-detect pullup is not engaged to save power).
PUR	**Pullup Rough:** A fast pullup mode, which uses the main X+ switch in parallel with the on-chip resistive pullup (50kΩ/100kΩ) to quickly slew the touch panel capacitances. $R_{PUR} \le 10\Omega$ typical.
PUF	**Pullup Fine:** A slow (fine) pullup mode, which uses the on-chip resistive pullup to slew the touch-panel capacitances to their final values (R_{PUF} = 50kΩ or 100kΩ) typical and is required for all applications.
SAR ADC	**Successive Approximation Register ADC:** An analog-to-digital converter that converts a continuous analog waveform into a discrete digital representation through a binary search through all possible quantization levels before finally converging upon a digital output for each conversion.
I²C	**Inter-Integrated Circuit:** A multimaster serial computer bus that is used to attach low-speed peripherals to other components using two bidirectional open-drain lines, serial data (SDA) and serial clock (SCL), pulled up with resistors.
SPI	**Serial Peripheral Interface:** A serial interface in which a master device supplies clock pulses to exchange data serially with a slave over two data wires (master-slave and slave-master).

Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND .....-0.3V to +4.0V
X+, X-, Y+, Y-, AUX, $\overline{TIRQ}$ to GND .....-0.3V to +4.0V
SCL, CLK, SDA, DIN, A0, $\overline{CS}$, A1, DOUT to GND .-0.3V to +4.0V
Maximum Current into Any Pin .....±50mA
Continuous Power Dissipation (T_A = +70°C)
12-Pin TQFN (derate 24.4mW/°C above +70°C) 1951.2mW
12-Pin WLP (derate 6.5mW/°C above +70°C) 518.8mW
Operating Temperature Ranges
MAX1180_E_ _.....-40°C to +85°C
MAX1180_G_ _ .....-40°C to +105°C
Storage Temperature Range .....-65°C to +150°C
Junction Temperature .....+150°C
Lead Temperature (excluding WLP, soldering, 10s) .....+300°C
Soldering Temperature (reflow) .....+260°C

Note 1: All WLP devices are 100% production tested at T_A = +25°C. Specifications over temperature limits are guaranteed by design and characterization.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{DD} = 1.7V to 3.6V, T_A = -40°C to +85°C (MAX11800E–MAX11803E), T_A = -40°C to +105°C (MAX11800G/MAX11801G), unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = 3.3V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
ADC							
ADC Resolution		No missing codes		10	11		Bits
Differential Nonlinearity	DNL	12-bit resolution			±1.5		LSB
Integral Nonlinearity	INL	12-bit resolution			±1.5		LSB
Offset Error					±2		LSB
Gain Error					±4		LSB
Throughput				105			ksps
TOUCH SENSORS (X+, X-, Y+, Y-, AUX)							
Switch On-Resistance		V_{DD} = 1.7V			7		Ω
		V_{DD} = 3.3V			5		
Switch Driver Current		100ms pulse				50	mA
Input Voltage Range				0		V_{DD}	V
POWER SUPPLY (V_{DD})							
Supply Voltage	V_{DD}			1.7		3.6	V
Supply Current		Power-down mode. All digital inputs static.	1.7V		0.2		µA
			3.6V			2	
		TDM. All digital inputs static. Does not include panel currents when touched.	3.6V			7	
		Timed LPM. All digital inputs static. Does not include panel currents when touched.	1.7V		9		
			3.3V		16		
		AUX conversions at 34.4ksps equivalent rate, SPI	1.7V		216		
			3.3V		273	550	
		AUX conversions at 34.4ksps equivalent rate, I²C	1.7V		202		
			3.3V		269	550	
Power Consumption		AUX conversions at 34.4ksps equivalent rate, SPI	1.7V		367		µW
			3.3V		901		
		AUX conversions at 34.4ksps equivalent rate, I²C	1.7V		343		
			3.3V		888		

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = 1.7V to 3.6V, T_A = -40°C to +85°C (MAX11800E–MAX11803E), T_A = -40°C to +105°C (MAX11800G/MAX11801G), unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = 3.3V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL INPUTS (SDA, DIN, SCL, CLK, A0, $\overline{CS}$, A1)						
Input Logic-High Voltage	V_{IH}		0.7 x V_{DD}			V
Input Logic-Low Voltage	V_{IL}				0.3 x V_{DD}	V
Input Leakage Current	I_{IN}	V_{IN} = 0V or V_{DD}	-1		+1	µA
Input Hysteresis	V_{HYS}			0.5 x V_{DD}		V
Input Capacitance				6		pF
DIGITAL OUTPUTS (SDA, DOUT, $\overline{TIRQ}$)						
Output Logic-High	V_{OH}	DOUT, I_{SOURCE} = 1mA	0.9 x V_{DD}			V
		$\overline{TIRQ}$, CMOS configuration, I_{SOURCE} = 1mA	0.9 x V_{DD}			
Output Logic-Low—$\overline{TIRQ}$, DOUT	V_{OL}	I_{SINK} = 1mA			0.4	V
Output Logic-Low—SDA	V_{OL}	I_{SINK} = 3mA			0.4	V
$\overline{TIRQ}$ Pullup Resistor				125		kΩ

I²C TIMING CHARACTERISTICS

(V_{DD} = 1.7V to 3.6V, T_A = -40°C to +85°C (MAX11801E and MAX11803E), T_A = -40°C to +105°C (MAX11801G), unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = 3.3V, unless otherwise noted. See Figure 1.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Serial-Clock Frequency	f_{SCL}		0		400	kHz
Bus Free Time	t_{BUF}	Bus free time between STOP and START condition	1.3			µs
Hold Time for START Condition	$t_{HD;STA}$	After this period, the first clock pulse is generated	0.6			µs
SCL Pulse-Width Low	t_{LOW}		1.3			µs
SCL Pulse-Width High	t_{HIGH}		0.6			µs
Setup Time for Repeated START (Sr) Condition	$t_{SU;STA}$		0.6			µs
Data Hold Time	$t_{HD;DAT}$		0		900	ns
Data Setup Time	$t_{SU;DAT}$		100			ns
SDA and SCL Rise/Fall Time	t_R, t_F	Receiving	20 + C_B/10		300	ns
SDA and SCL Fall Time	t_{TF}	Transmitting	20 + C_B/10		250	ns
Setup Time for STOP Condition	$t_{SU;STO}$		0.6			µs
Bus Capacitance Allowed	C_B	V_{DD} = 1.7V to 2.7V	10		100	pF
		V_{DD} = 2.7V to 3.6V	10		400	
Pulse Width of Suppressed Spike	t_{SP}				50	ns

Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

SPI TIMING CHARACTERISTICS

(V_{DD} = 1.7V to 3.6V, T_A = -40°C to +85°C (MAX11800E and MAX11802E), T_A = -40°C to +105°C (MAX11800G), unless otherwise noted. Typical values are at T_A = +25°C and V_{DD} = 3.3V, unless otherwise noted. See Figure 2.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
CLK Frequency	f_{CLK}				25	MHz
CLK Period	t_{CP}		40			ns
CLK Pulse-Width High	t_{CH}		18			ns
CLK Pulse-Width Low	t_{CL}		18			ns
$\overline{CS}$ Low to 1st CLK Rise Setup	t_{CSS0}		18			ns
$\overline{CS}$ Low After 0th CLK Rise Hold	t_{CSH0}	To prevent a 0th CLK read from being taken as a 1st read in a free-running application	0			ns
$\overline{CS}$ High to 17th CLK Setup	t_{CSS1}	To prevent a 17th CLK read from being recognized by the device in a free-running application	18			ns
$\overline{CS}$ High After 16th CLK Falling Edge Hold	t_{CSH1}		0			ns
$\overline{CS}$ Pulse-Width High	t_{CSW}		18			ns
DIN to CLK Setup	t_{DS}		25			ns
DIN Hold After CLK	t_{DH}		0			ns
DOUT Transition Valid After CLK Rise	t_{DOT}	Output transition time			25	ns
DOUT Remains Valid After CLK Rise	t_{DOH}	Output hold time	3			ns
DOUT Valid Before CLK Rise	t_{DO1}	$t_{DO1} = t_{CP} - t_{DOT}$	10			ns
$\overline{CS}$ Rise to DOUT Disable	t_{DOD}	C_{LOAD} = 20pF			40	ns
CLK Rise to DOUT Enable	t_{DOE}	C_{LOAD} = 20pF. Minimum = hold time with regard to 8th CLK read. Maximum = transition time with regard to 8th CLK read.	3		25	ns

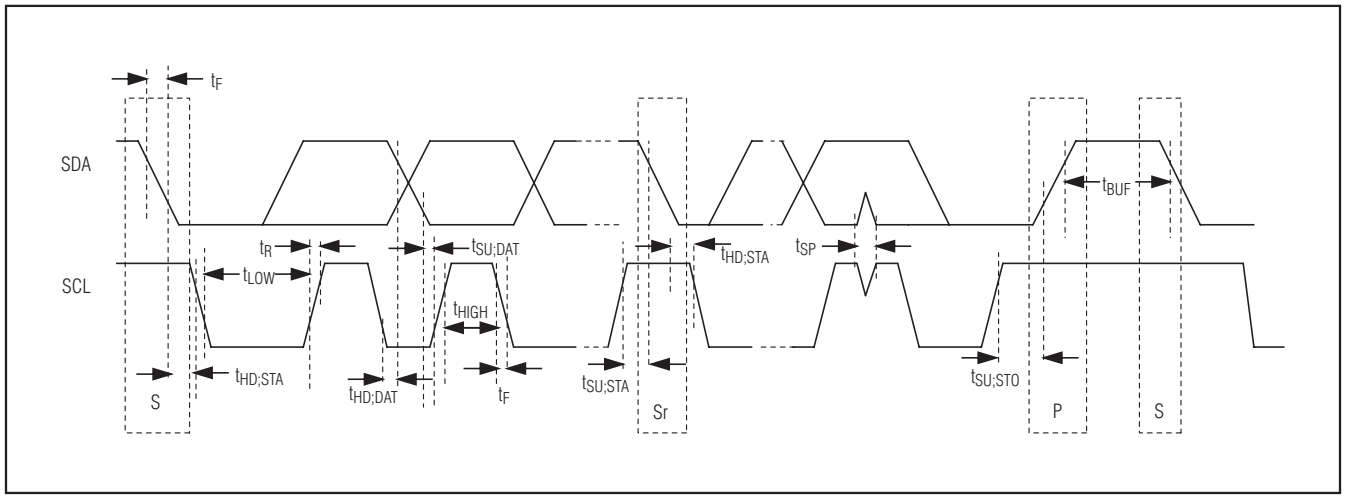


Figure 1. I²C Timing Diagram

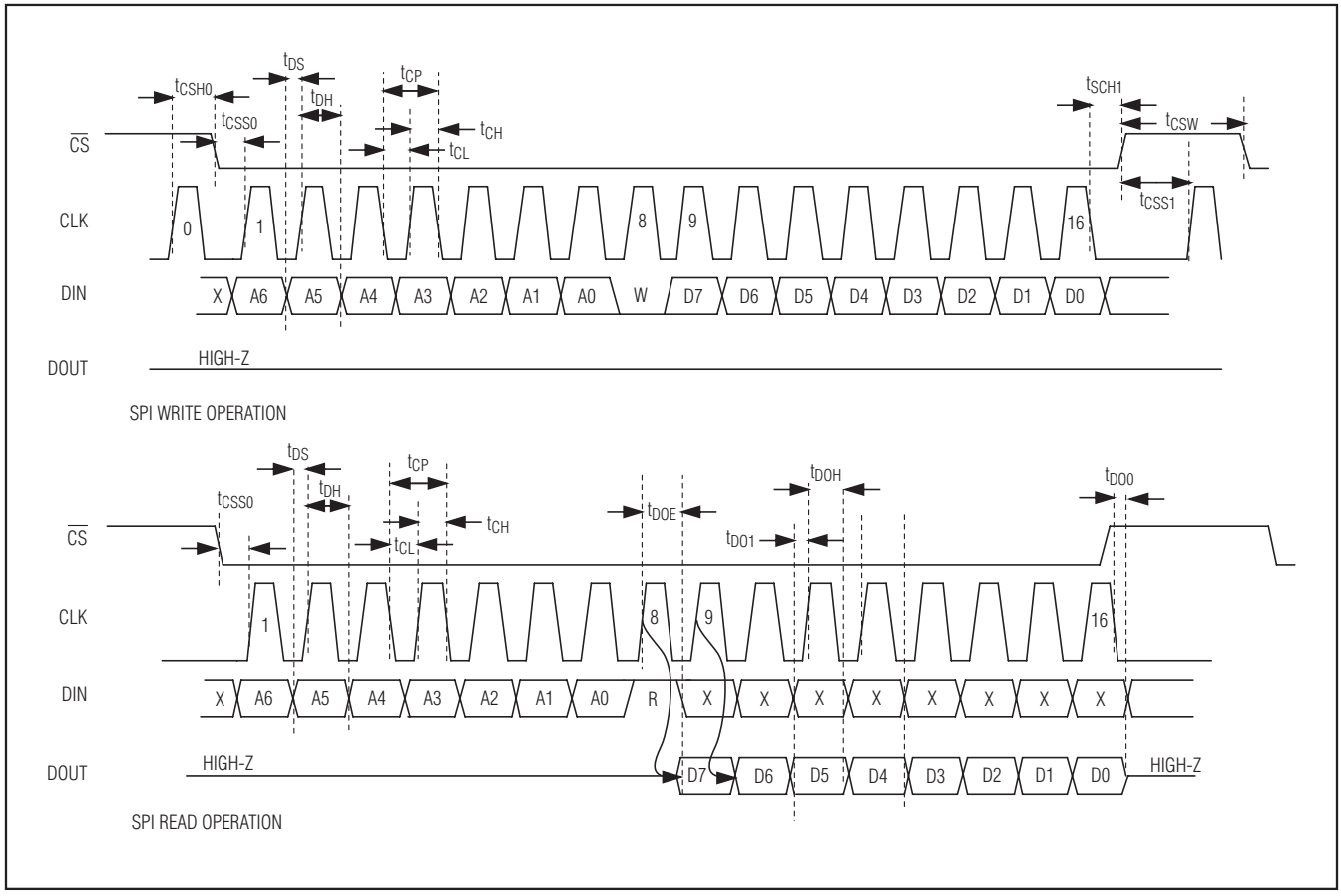


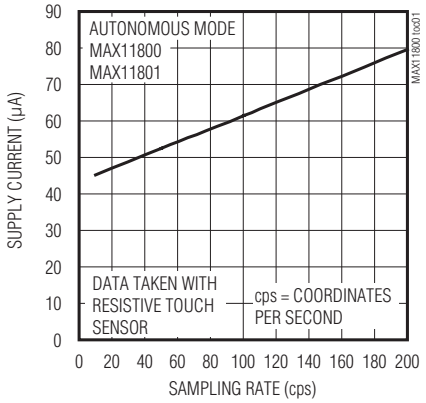
Figure 2. SPI Timing Diagram

Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

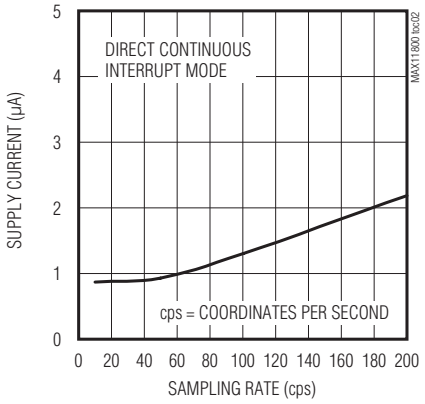
Typical Operating Characteristics

(V_{DD} = 1.8V at T_A = -40°C to +85°C (T_A = -40°C, T_A = 0°C, T_A = +25°C, and T_A = +85°C), 12-bit mode, all measurements using noncontinuous AUX input. SPI = 10MHz and I²C = 400kHz, unless otherwise noted. Resistive touch-screen panel (X+ to X- = 608Ω, Y+ to Y- = 371Ω).)

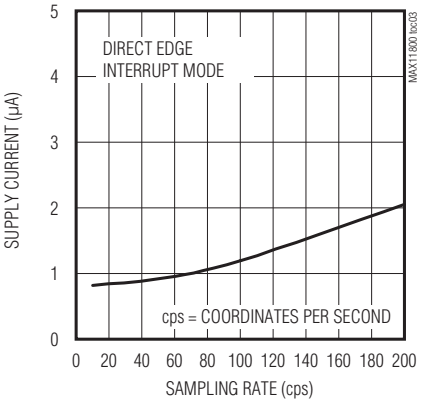
AVERAGE SUPPLY CURRENT vs. SAMPLING RATE



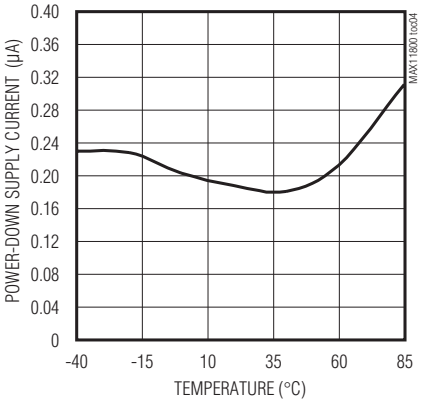
AVERAGE SUPPLY CURRENT vs. SAMPLING RATE



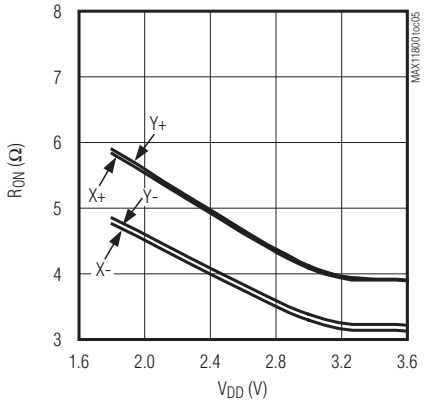
AVERAGE SUPPLY CURRENT vs. SAMPLING RATE



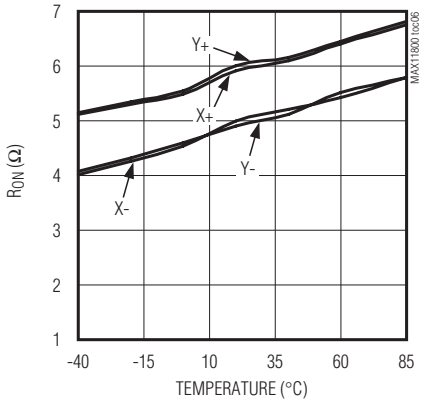
SUPPLY CURRENT IN POWER-DOWN vs. TEMPERATURE



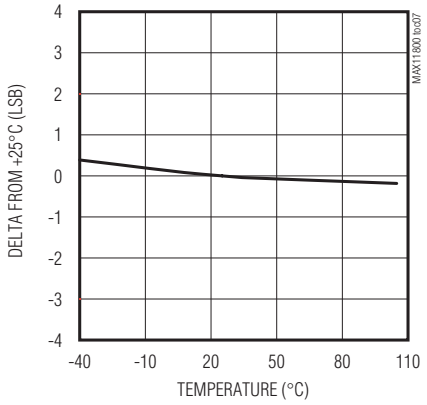
SWITCH RESISTANCE vs. SUPPLY VOLTAGE



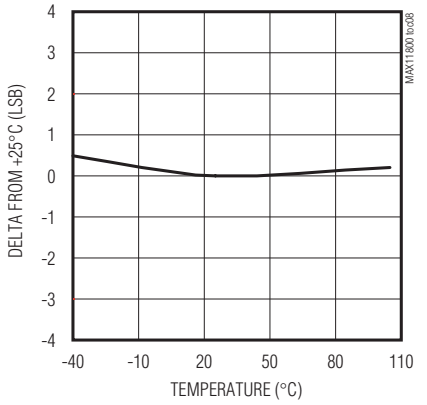
SWITCH RESISTANCE vs. TEMPERATURE



CHANGE IN ADC GAIN vs. TEMPERATURE



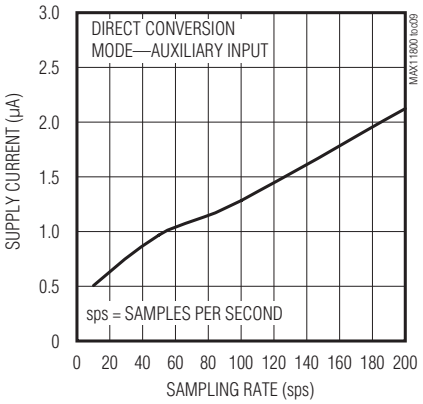
CHANGE IN ADC OFFSET vs. TEMPERATURE



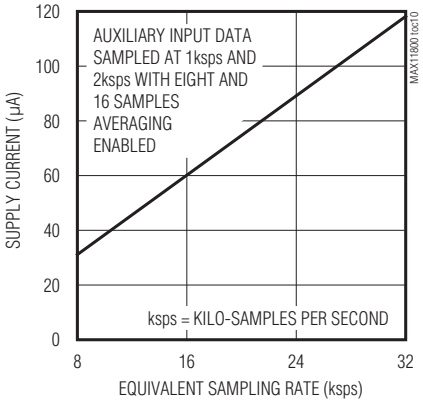
Typical Operating Characteristics (continued)

(V_{DD} = 1.8V at T_A = -40°C to +85°C (T_A = -40°C, T_A = 0°C, T_A = +25°C, and T_A = +85°C), 12-bit mode, all measurements using noncontinuous AUX input. SPI = 10MHz and I²C = 400kHz, unless otherwise noted. Resistive touch-screen panel (X+ to X- = 608Ω, Y+ to Y- = 371Ω).)

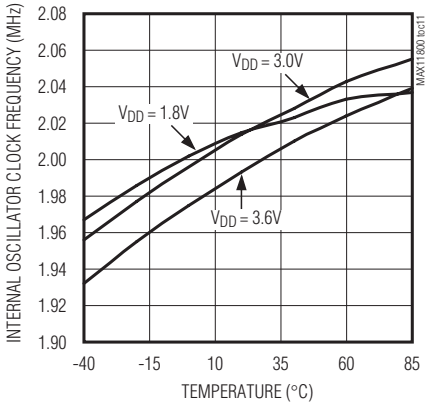
AVERAGE SUPPLY CURRENT vs. SAMPLING RATE



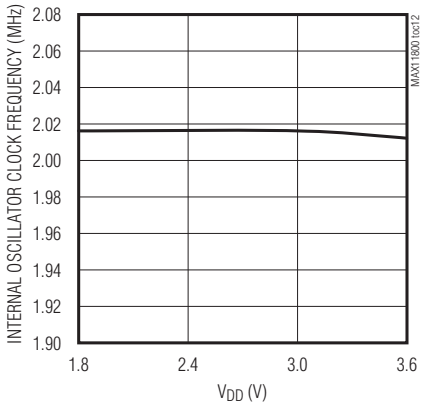
AVERAGE SUPPLY CURRENT vs. SAMPLING RATE



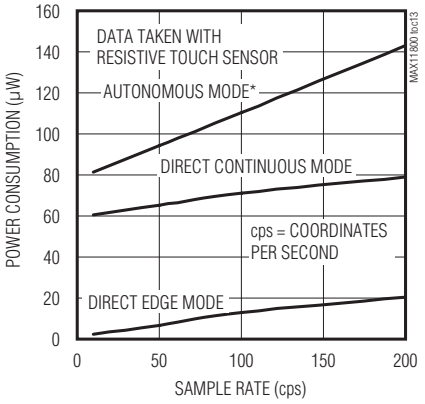
INTERNAL OSCILLATOR CLOCK FREQUENCY vs. TEMPERATURE



INTERNAL OSCILLATOR CLOCK FREQUENCY vs. SUPPLY VOLTAGE



POWER CONSUMPTION vs. SAMPLE RATE



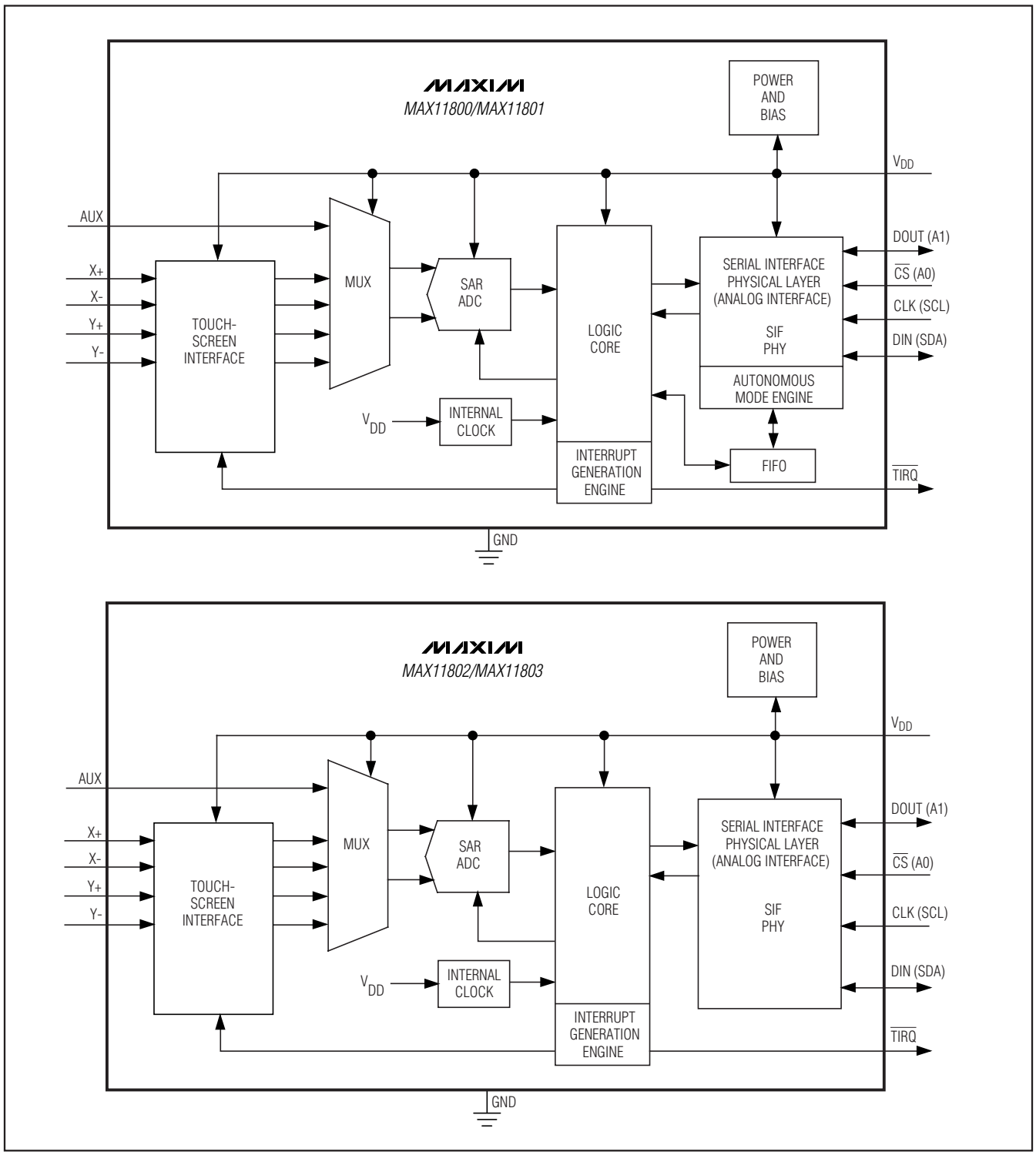
*MAX11800/MAX11801

Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

Pin Description

PIN				NAME	FUNCTION
MAX11800/MAX11802		MAX11801/MAX11803			
TQFN-EP	WLP	TQFN-EP	WLP		
1	A4	1	A4	X+	X+ Channel Input/Output
2	B4	2	B4	V_{DD}	Power Supply. Bypass V_{DD} to GND with a 1µF capacitor.
3	B3	3	B3	GND	Ground
4	C4	4	C4	X-	X- Channel Input/Output
5	C3	5	C3	Y-	Y- Channel Input/Output
6	C2	6	C2	$\overline{TIRQ}$	Active-Low Touch Interrupt Output
7	C1	—	—	DIN	SPI Serial Data Input
8	B1	—	—	CLK	SPI Serial Data Clock Input
9	A1	—	—	$\overline{CS}$	SPI Chip-Select Input
10	B2	—	—	DOUT	SPI Data Output
11	A2	11	A2	AUX	Auxiliary Input
12	A3	12	A3	Y+	Y+ Channel Input/Output
—	—	7	C1	SDA	I²C Serial Data Bus Input/Output
—	—	8	B1	SCL	I²C Serial Data Clock Input
—	—	9	A1	A0	I²C Address Input Bit 0
—	—	10	B2	A1	I²C Address Input Bit 1
—	—	—	—	EP	Exposed Pad (TQFN only). Connected to ground.

Functional Diagrams



Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface

Detailed Description

The MAX11800–MAX11803 contain standard features found in a typical resistive touch-screen controller as well as advanced features found only on Maxim touch-screen controllers. Standard features included in the MAX11800–MAX11803 are:

- 4-wire touch-screen interface
- X/Y coordinate measurement
- Touch pressure measurement
- Direct conversion operation—requires direct AP involvement
- Single commands—AP initiates all activity, one command at a time
- Ratiometric measurement
- 12-bit SAR ADC
- Single 1.7V to 3.6V supply
- Programmable touch-detect pullup—50kΩ or 100kΩ
- Auto power-down control for low-power operation

Advanced features found in the MAX11800/MAX11801 include:

- Autonomous conversion operation—minimal AP involvement
- On-chip FIFO—buffers up to 16 consecutive measurements
- Data tagging—records measurement and touch-event information
- Filtering—reduces noise using straight or median averaging
- Aperture mode—provides spatial filtering
- Combined commands—multiple operations performed with a single AP command
- User-programmable acquisition modes
- Programmable interrupt output drive

Advanced features found in the MAX11802/MAX11803 include:

- Data tagging—records measurement and touch event information
- Filtering—reduces noise using straight or median averaging
- Combined commands—multiple operations performed with a single AP command
- User-programmable acquisition modes
- Programmable interrupt output drive

The MAX11800/MAX11801 operate in one of two top-level modes: direct conversion mode (DCM) or autonomous conversion mode (ACM). Direct conversion mode requires the AP to initiate all activity to and from the MAX11800/MAX11801. DCM is the operating mode that most standard resistive touch-screen controllers use. ACM allows the MAX11800/MAX11801 to perform measurements automatically and inform the AP when they are complete, reducing data transfers on the serial bus as well as generating fewer interrupt requests. The MAX11802/MAX11803 operate in DCM only. DCM requires the AP to initiate all activity to and from the MAX11802/MAX11803. DCM is the operating mode that most standard resistive touch-screen controllers use.

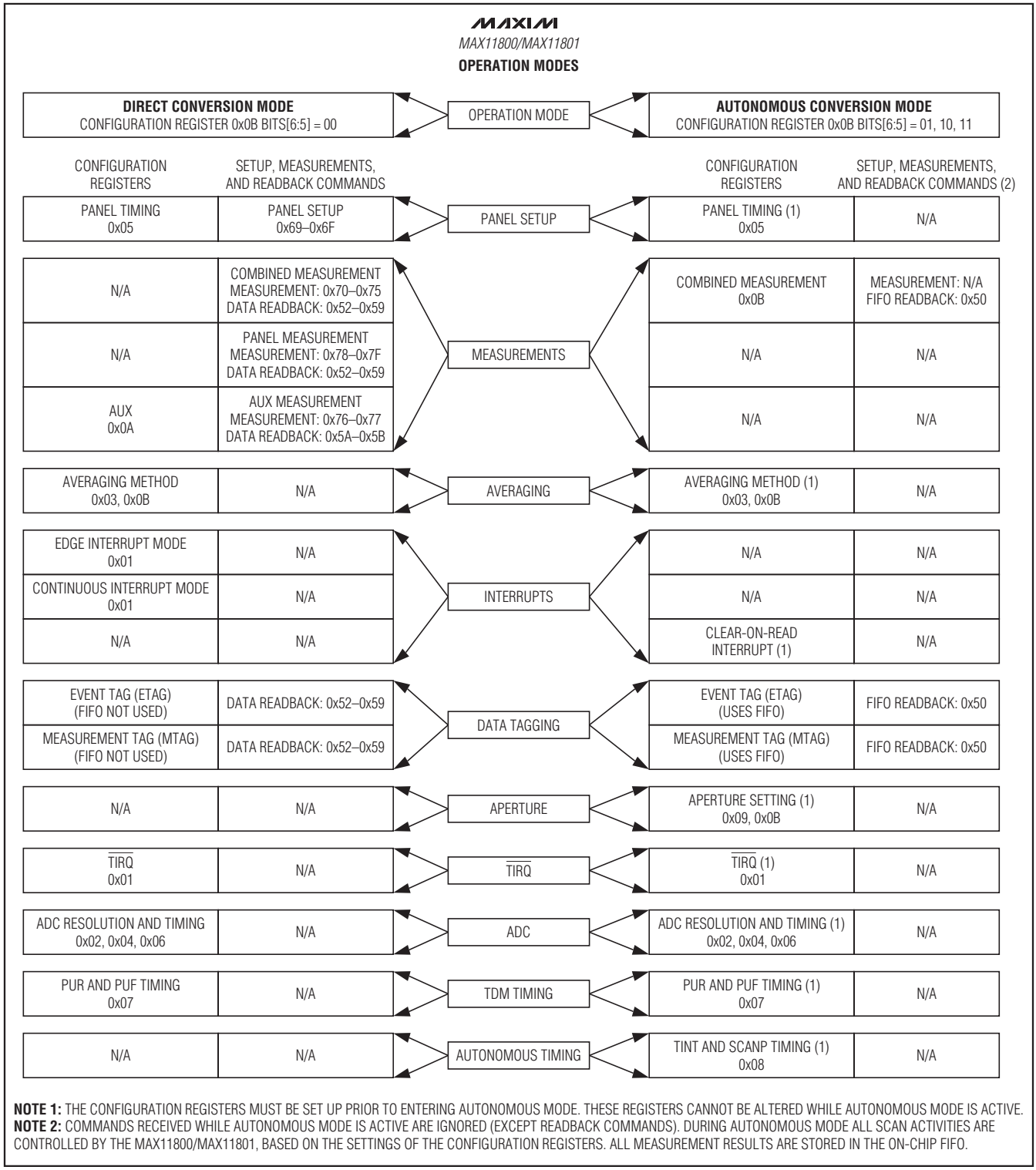
Both DCM and ACM support averaging, data tagging, and combined commands. Certain commands and operations are only available in DCM, while others are only available in ACM. See Figures 3a and 3b and Table 2 for details.

Position Measurements

Position measurements determine either the X or Y coordinates of the point of contact on the panel sensor. Allow adequate time for the panel to settle when switching between X and Y measurements. Figure 4 shows the physical setup of the panel when performing position measurements.

The element R_{TOUCH} represents the resistance between the X and Y planes of the panel sensor. R_{TOUCH} does not contribute to the error when performing position measurements. R_{TOUCH} affects the panel settling time required between each valid measurement.

The panel end-to-end resistance in the direction of measurement determines the power applied across the panel. The panel dissipates power in the X elements when performing an X direction measurement and dissipates power in the Y elements when performing a Y direction measurement.



NOTE 1: THE CONFIGURATION REGISTERS MUST BE SET UP PRIOR TO ENTERING AUTONOMOUS MODE. THESE REGISTERS CANNOT BE ALTERED WHILE AUTONOMOUS MODE IS ACTIVE.
NOTE 2: COMMANDS RECEIVED WHILE AUTONOMOUS MODE IS ACTIVE ARE IGNORED (EXCEPT READBACK COMMANDS). DURING AUTONOMOUS MODE ALL SCAN ACTIVITIES ARE CONTROLLED BY THE MAX11800/MAX11801, BASED ON THE SETTINGS OF THE CONFIGURATION REGISTERS. ALL MEASUREMENT RESULTS ARE STORED IN THE ON-CHIP FIFO.

Figure 3a. MAX11800/MAX11801 Operation Modes

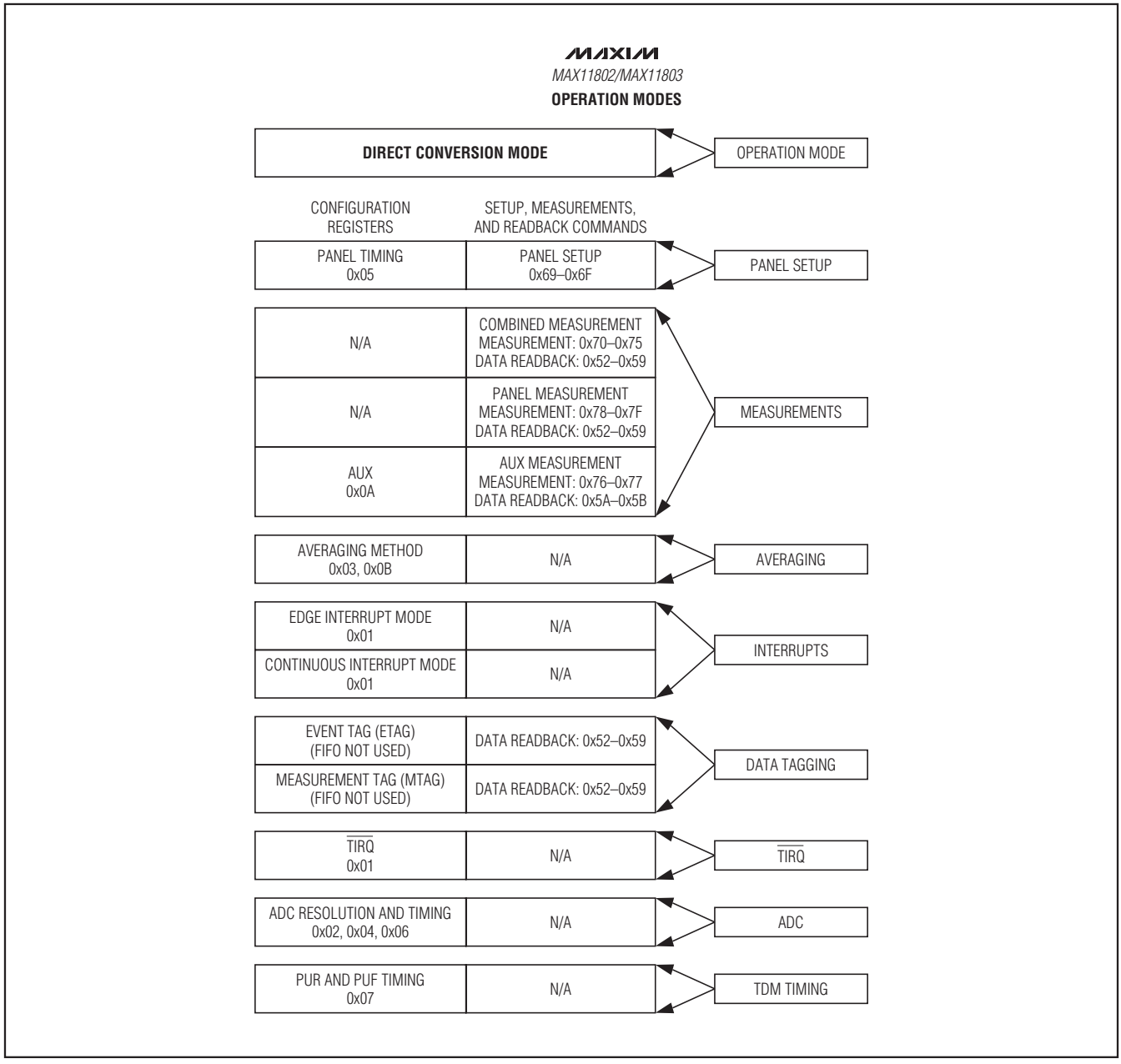


Figure 3b. MAX11802/MAX11803 Operation Modes

Table 2. Operating Modes, Conditions, and Options

OPERATION MODE	PSU	PMC	CMC	TDM	LPM	AVG	FIFO	APER	PUR PUF	CONT	MTAG	ETAG	X, Y, Z1, Z2	EINT	CINT	COR INT
DCM MAX11800–MAX11803	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes[2]	Yes[2]	Yes	Yes	Yes	No
ACM MAX11800/MAX11801	Yes[1]	Yes[1]	Yes[1]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes
AUX	No	Yes[3]	No	No	—	Yes[3]	No	No	No	No	No	No	No	No	No	No

[1] *In ACM, the choices are limited to X and Y scan, or X and Y and Z1 scan, or X and Y and Z1 and Z2 scan.*

[2] *In DCM, MTAG is always used. For DCM with CONT = 0, the following ETAGs are used: 00 = touch present (data valid), 10 = no touch present (data may be invalid), 11 = measurement in progress (data invalid). For DCM with CONT = 1, the panel cannot be scanned for a touch because panel setup switches are configured in a measurement mode; therefore, ETAG = 00 is used if a measurement is not in progress, or ETAG = 11 if a measurement is in progress.*

[3] *A separate configuration register for delay time, sampling time, averaging, and ADC resolution settings configures the AUX input.*

Pressure Measurements

Z1 and Z2 measurements determine the resistance between the two planes within the panel sensor during a touch (R_{TOUCH}). Depending on the known physical properties of the panel, one of two equations extract the value of R_{TOUCH}, providing information about the pressure and area of the touch applied to the panel. Allow adequate time for the panel to settle when switching between position and pressure measurements. Figure 5 shows the physical setup of the panel when performing pressure measurements.

Z1 and Z2 measurements allow observation of the voltage on either side of the effective R_{TOUCH} resistance.

With both Z1 and Z2 measurements available, compute R_{TOUCH} as follows:

$$R_{TOUCH} = R_{XPLATE}\left(\frac{X_{POSITION}}{2^{N_{BITX}}}\right)\left(\frac{Z_2}{Z_1} - 1\right)$$

If only a Z1 measurement is available, compute R_{TOUCH} as follows:

$$R_{TOUCH} = \left(\frac{R_{XPLATE}\,X_{POSITION}}{2^{N_{BITX}}}\right)\left(\frac{2^{N_{BITZ}}}{Z_1} - 1\right) - R_{YPLATE}\left(1 - \frac{Y_{POSITION}}{2^{N_{BITY}}}\right)$$

The power applied across the panel during pressure measurements is greatly dependent on R_{TOUCH} and the physical position of the touch. The maximum power dissipation in the panel during a pressure measurement is approximately $P_Z = V_{DD}^2/R_{TOUCH}$. This maximum

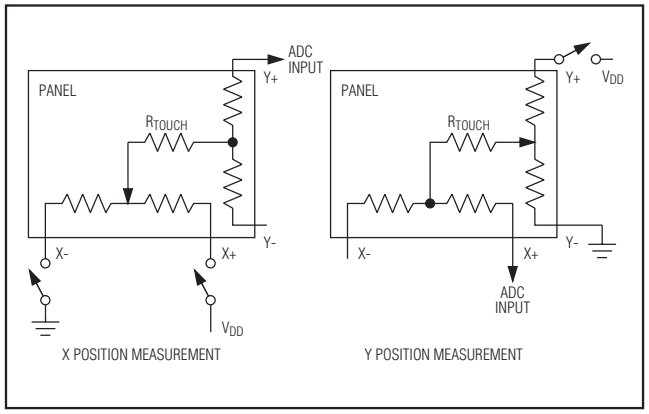


Figure 4. Position Measurements

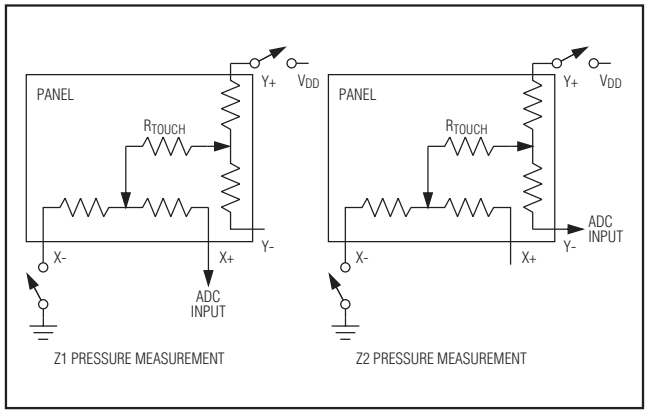


Figure 5. Pressure Measurements

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power dissipation condition is observed when the point of contact is in the top left corner of the panel sensor. The planar end-to-end resistance included in the current path is minimal at this location. Keep the averaging and panel settling durations to the minimum required by the application when pressure measurements are required. Table 3 summarizes the physical panel settings for supported measurement types.

Touch-Detect Modes and Options

Figure 6 shows the internal circuitry in the MAX11800–MAX11803 used to detect the presence of a touch on the panel. The selection of the pullup resistance value (R_{TD} = touch-detect resistance) and the durations of the rough pullup interval (PUR = low-impedance pullup) and fine pullup interval (PUF = high-impedance pullup) are user-defined.

The MAX11800–MAX11803 revert to the low-power panel setup when placed in touch-detect mode (TDM). Figure 6 shows the active panel drive switches (YMSW and XPSW are omitted for simplicity). TSW is a dedicated pullup switch used in TDM. TSW is also used during PUF and TDM. XPSW is activated during PUR periods. TDRSEL allows the selection of an internal pullup resistor value of either 50kΩ or 100kΩ.

The X and Y touch-screen plates create an open circuit with no current flow in the panel when the panel is not being touched. In this case, TOUCH (see Figure 6) is low. When a touch causes contact between the panel X and Y plates, a current path is created and TOUCH is pulled high, as long as R_{PX} + R_{PY} (the sum of panel end-to-end resistance) is much lower than R_{TD}. Typical open-circuit panel plate resistances range from 200Ω to 1000Ω.

The MAX11800–MAX11803 enter high-impedance pullup mode (50kΩ or 100kΩ) when the panel is not being touched. The device is idle in this mode until a touch is detected. The YMSW and TSW transistors are on, and the XPSW and PSW transistors are off. With no touch present, the Y- input of the TSC is at ground and the X+ input is at V_{DD} - V_{TN}, where V_{TN} is the threshold voltage of the TSW nMOS device. This is a low-power mode in which no current is consumed until a panel touch occurs. When a touch is present on the panel, the touch-screen controller (TSC) X+ input is pulled low by the touch panel plate resistance and the YMSW transistor. This causes TOUCH to assume a logic-high and the devices either issue the $\overline{TIRQ}$ interrupt for direct conversion modes (MAX11800–MAX11803) or begin self-timed scans for autonomous conversion mode (MAX11800/MAX11801).

The value of the user-defined R_{TD} depends on the characteristics of the panel. To ensure reliable detection values, worst-case panel resistance must be checked against R_{TD}. The interaction between R_{TD} and the panel (or external noise rejecting) capacitance determines how quickly the panel can be switched from measurement modes back to touch monitoring mode without reporting false touches or erroneous tags due to panel settling.

Panel touch status is also required to tag data from a completed scan and measurement operation. Following each scan operation, the panel **must** be returned to TDM to determine if the panel is still being touched and if the data obtained during the scan operation should be considered valid. This operation is required since the panel cannot be monitored for the presence of a touch during the scan and measurement procedure.

The MAX11800–MAX11803 must return to TDM after completing a measurement and making a decision on the touch status of the panel. The measurement procedure is only completed upon resolution of the touch status and when data is tagged and available for readback. The characteristics of the return to TDM and

Table 3. Summary of Physical Panel Settings for Supported Measurement Types

MODE	X+	X-	Y+	Y-	REF+	REF-
X	V_{DD}	GND	ADC_IN	U	X+	X-
Y	ADC_IN	U	V_{DD}	GND	Y+	Y-
Z1	ADC_IN	GND	V_{DD}	U	Y+	X-
Z2	U	GND	V_{DD}	ADC_IN	Y+	X-
PUR	V_{DD} (10Ω)	U	U	GND	U	—
TDM or PUF	V_{DD} through 50kΩ or 100kΩ	U	U	GND	U	—
LPM	U	U	U	U	U	—

Note: *The ADC input is fully differential with the negative input internally connected to GND. The MAX11800–MAX11803 control access to the PUR, PUF, TDM, and LPM, which do not require setup procedures.*

U *indicates unconnected node.*

the timing of the decision are configurable through the touch-detect pullup timing configuration register (0x07). Program the MAX11800–MAX11803 in the context of the application to maximize power efficiency and achieve the desired scan throughput.

PUR and PUF

PUR is a fast pullup mode, which uses the main X+ switch in parallel with the resistive pullup to quickly slew the panel capacitance. PUF uses only the touch-detect pullup resistor, R_{TD}. PUR and PUF serve the same function as TDM, but are timed so that the panel can settle after completing measurements and before rendering any decisions on the touch status of the panel.

Use the optional PUR mode to reduce the time to tag data by momentarily placing the panel in a low-impedance (< 10Ω) pullup mode instead of using the available 50kΩ/100kΩ touch-detection pullup resistors. This operation forces the monitored TSC input high during the PUR interval. Once the PUR interval expires, a PUF interval must be allowed so that the panel can recover and pull the TSC input low in case a touch is present. The purpose of the PUR mode is to reduce the time required to determine touch status by avoiding long pullup time constants caused by high-capacitance touch panels and the high-impedance on-chip pullup resistors (R_{TD}). When a touch is present during PUR intervals, the current through the low-impedance pullup (XPSW) and panel combination is significantly higher than that observed in the PUF mode. The durations in the PUR mode should be matched to the panel characteristics and the desired scan throughput rates to minimize power dissipation.

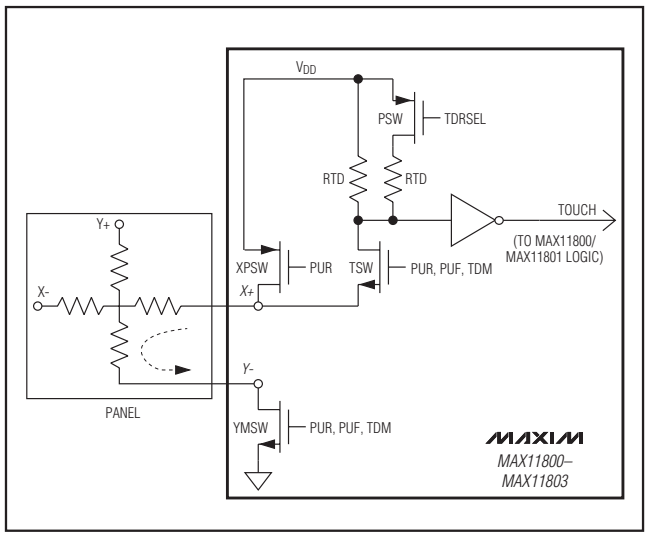

Figure 6. Touch-Detection Circuitry

While use of the PUR mode is optional, the PUF period is required for all applications. The PUF interval allows the panel to resettle following scan or optional PUR intervals. When a touch is not present, the panel capacitance settles toward V_{DD} through the internal pullup switch and a portion of the panel resistance (with the optional PUR mode disabled). When a touch is present, the panel capacitance settles toward ground through a portion of the panel resistance, ideally significantly lower than the selected pullup impedance, R_{TD}. Allow enough recovery time for settling through the panel resistance when using a PUR mode. Figure 7 illustrates the touch-detection operations.

Idle Modes

Once the PUF period expires, the preceding measurement data is tagged and made available for readback. The MAX11800–MAX11803 transition to an appropriate mode depending on the conversion and interrupt mode selected.

Features Available in the MAX11800–MAX11803 Averaging Modes

The MAX11800–MAX11803 contain a programmable averaging filter. When enabled, this feature allows collecting 4, 8, or 16 consecutive samples for each measurement type requested. The number of the samples for each measurement type is controlled by configuration register 0x03. Averaging can be assigned to each measurement type. For example, X and Y measurements can use an average of 16 samples, while Z measurements can use one or four samples to save power. The AUX depth is selected in configuration register 0x0A.

The MAX11800–MAX11803 can be configured to perform one of two statistical operations. One option is a median averaging filter (MAF). The MAF first removes the lowest and highest values before averaging the remaining sample set. The second filter type is a straight averaging filter (SAF), which takes the average of the entire sample set. Both filter types and position/pressure averaging are controlled by configuration register 0x0B. Table 4 presents the details of the median averaging operations of the MAX11800–MAX11803. For the MAX11800/MAX11801, averaging is supported in both direct conversion mode and autonomous conversion mode. The MAX11802/MAX11803 support only direct conversion mode.

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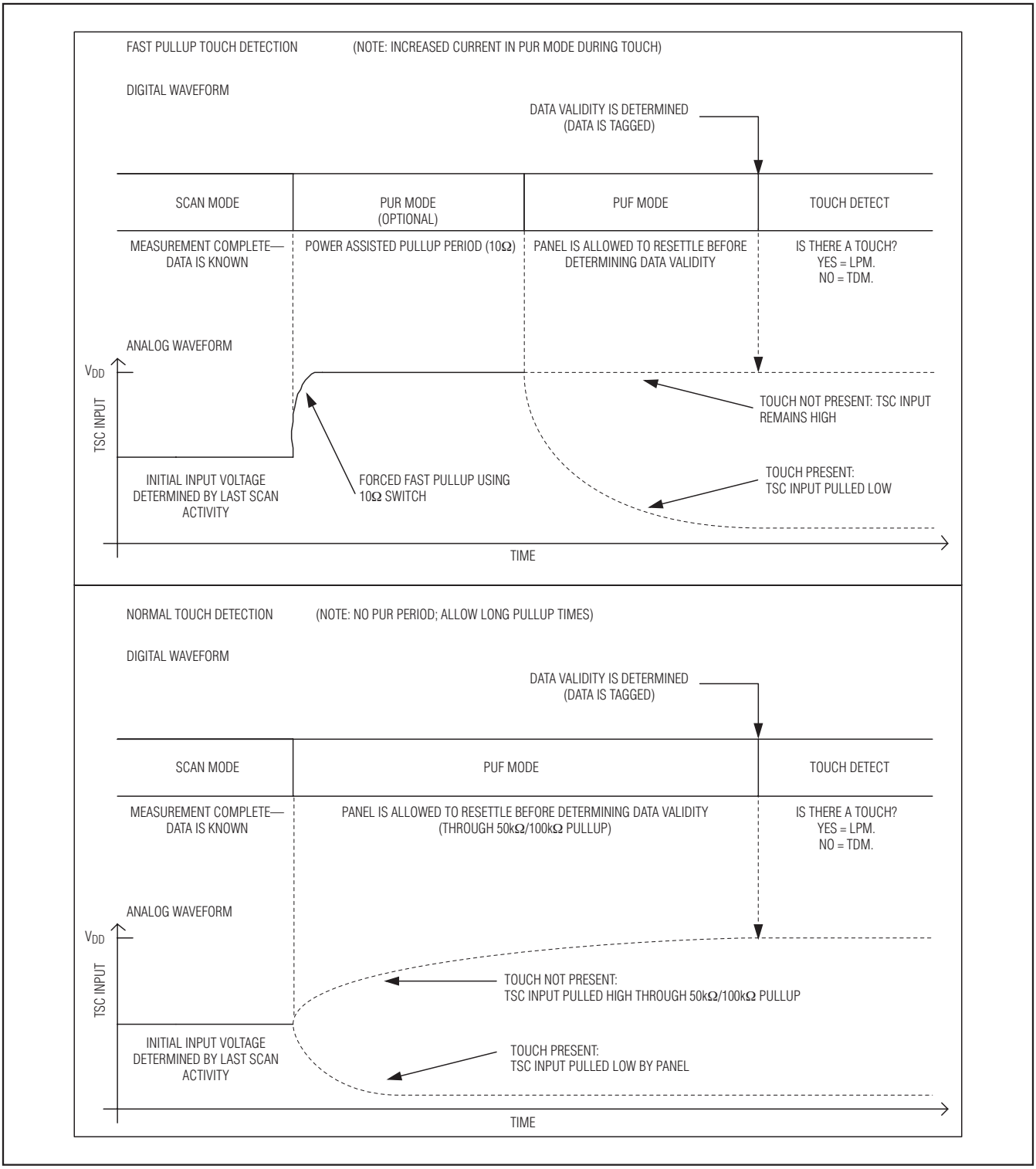

Figure 7. Touch-Detection Operations

Combined Commands

Combined commands reduce AP interaction with the MAX11800–MAX11803 by allowing multiple measurements. For example, the MAX11800–MAX11803 can be instructed to provide X and Y data, or X and Y and Z1 data, or X and Y and Z1 and Z2 data using a single command.

Data Tagging

In direct conversion modes, all measurement data is contained in a 16-bit word. X, Y, Z1, and Z2 information is stored independently. Each word consists of 12 bits of measurement data plus a 2-bit measurement type (MTAG) and a 2-bit event tag (ETAG). The measurement tag identifies whether the data represents an X, Y, Z1, or Z2 result. The event tag indicates the point at which the data is sampled (initial, midpress, or release) during the touch event. When trying to read a result that is pending, the entire data stream is read back as FFFFh and the event tag as 11b, indicating that the corresponding measurement is in progress and that the data stream is to be ignored. For combined commands, all data locations requested by the command are marked FFFFh, pending the completion of the entire command and the proper tagging of the data. See Table 5.

Direct conversion modes do not use the internal FIFO or support the aperture function (see the *Aperture Modes and Options* section). Each measurement type uses a single location in the (16-bit) memory. The AP must retrieve the data from the last requested measurement before moving on to the next measurement of the type.

Auxiliary measurement data is not tagged because it is not related to panel operation. Auxiliary measurement data is stored and read back identically to the other direct conversion data. The tag locations for auxiliary measurement data are always set to 0000b, unless the read occurs when an auxiliary measurement is in progress. In this situation, the tag locations read 1111b and the data stream reads back FFFFh.

Low-Power Modes

There are also two low-power modes, LPM and TDM. LPM only applies when in DCM with edge interrupt mode or ACM during periods following a conversion where the panel was observed to be touched and a subsequent panel measurement is required and/or scheduled.

During LPM, all circuitry is off, including the on-chip touch-detect pullup resistors used in the touch-detect circuitry. In direct conversion modes, a user-request initiates the next operation and all circuitry is off until a user-command is received. Therefore, the current consumption is primarily due to junction leakage. In autonomous conversion mode, an on-chip oscillator and timer are constantly running. Therefore, the device current consumption is primarily determined by the oscillator and timer.

During TDM, all circuitry is off except the on-chip pullup resistor. This is an untimed mode (oscillator and timer are off) for both ACM and DCM (no digital current). This mode only consumes current through the on-chip pullup resistor when a touch is present. The device can be powered down through register 0x0B when no panel input is expected or needed, and, therefore, no power is consumed through the panel.

Table 4. Median Averaging Operations

AVERAGING MODE	NUMBER OF SAMPLES TAKEN	NUMBER OF HIGH SAMPLES REMOVED	NUMBER OF LOW SAMPLES REMOVED	NUMBER OF REMAINING SAMPLES AVERAGED
1	4	1	1	2
2	8	2	2	4
3	16	4	4	8

Table 5. Data Word Structure (All Direct Conversion Modes)

INDEX	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Byte	MSB Byte								LSB Byte							
12-Bit Content	Position MSBs								Position LSBs				Measure		Event	
8-Bit Content	Position Data								Trailing Zeros*				Measure		Event	

**When using averaging with 8-bit conversions, these positions may be filled with fractional data due to averaging operations.*

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Features Available in the MAX11800/MAX11801 Only

Autonomous Mode

The MAX11800/MAX11801 can perform measurements automatically without the AP involvement, and is referred to as autonomous conversion mode (ACM). When operating in ACM, the MAX11800/MAX11801 use an on-chip FIFO to store measurement results. As each new data is written to the FIFO, an interrupt is generated. The AP can choose to service (read) the FIFO result after each interrupt or wait until the FIFO is full then read the entire FIFO contents at once. The AP can also read the contents of the FIFO at any time. See the *Autonomous Conversion Mode* section for a further description of operations.

Aperture

The MAX11800/MAX11801 contain a feature referred to as aperture. It is only available on the MAX11800/MAX11801 when operating in autonomous conversion mode. The aperture feature creates an invisible rectangle around a touch location within the MAX11800/MAX11801 hardware. The size of the rectangle is user programmable. One application of the aperture feature is to provide "spatial hysteresis." Spatial hysteresis can be useful for applications that require lower resolution touch accuracy without requiring the AP to handle the mathematics involved to filter out extraneous data. Another application would be to use the aperture feature to implement simple single finger or stylus gestures. See the *Using Aperture Mode* section for a further description of operations.

Panel Setup, Measurement, and Scan Commands

To simplify measurement procedures, the MAX11800–MAX11803 support three types of commands: panel setup commands (PSU), panel measurement commands (PMC), and combined measurement commands (CMC).

In direct conversion mode, the MAX11800/MAX11801 can use all three types of commands. Using individual panel setup and measurement commands allow for a high degree of customization based on decisions made by the AP, while using combined commands significantly simplifies the complete measurement process and reduces communications between the AP and the MAX11800–MAX11803.

In autonomous mode, the MAX11800/MAX11801 use combined commands to control and automate all aspects of panel setup, measurements, and timing. See the *Operating Mode Configuration Register (0x0B)* section for more details.

Direct Conversion Mode Operations

In direct conversion mode, the AP requests individual panel setup and conversion operations or automated combinations of measurements (X and Y, X and Y and Z1, or X and Y and Z1 and Z2 combined). Unlike autonomous conversion modes, the AP maintains control over the initiation of panel setup, measurements events, and the sampling frequency. Figure 8 shows the state machine transitions for direct conversion mode.

Interrupt Modes

The MAX11800–MAX11803 support two direct conversion interrupt modes. The two direct conversion modes are the continuous interrupt mode (CINT) and the edge interrupt mode (EINT).

Continuous Interrupt Mode

In continuous interrupt mode, the panel returns to TDM and idle. The current status of the panel is then sent through $\overline{TIRQ}$. The continuous interrupt mode is the least efficient mode in current consumption for long duration of touches. The power consumption is approximated by $P_{TOUCH} = V_{DD}^2/R_{PU}$. The power consumption levels observed when the panel is not touched is limited by the junction leakage currents of the MAX11800–MAX11803.

Procedure: The MAX11800–MAX11803 idle in TDM. The $\overline{TIRQ}$ output goes low when a touch is detected on the panel indicating to the AP that a touch is present and a measurement operation starts.

The AP requests specific panel measurements through the serial interface. $\overline{TIRQ}$ stays low during panel setup and measurement operations. Once a measurement is complete (with the "continuous" bit, CONT = 0, see Table 1), the MAX11800–MAX11803 check for the continued presence of a touch on the panel and tag the data accordingly (see Table 6). The duration of this operation is programmable, specified in the touch-detect pullup timing configuration register (0x07). After the data is tagged, the data is available for readback through the serial interface. The MAX11800–MAX11803 return to TDM and return control of $\overline{TIRQ}$ to the TDM circuitry. $\overline{TIRQ}$ stays low while a touch remains present, indicating further measurements are required, otherwise $\overline{TIRQ}$ goes high until a new touch is observed.

Continuous interrupt mode (CINT) allows the complete control over the measurement operations and direct observation of the touch status of the panel. Figure 9 shows the polling of $\overline{TIRQ}$ when other functions share the $\overline{TIRQ}$ bus. In the illustration of Figure 9, no '10' event tag is observed because the release occurs during a TDM period.

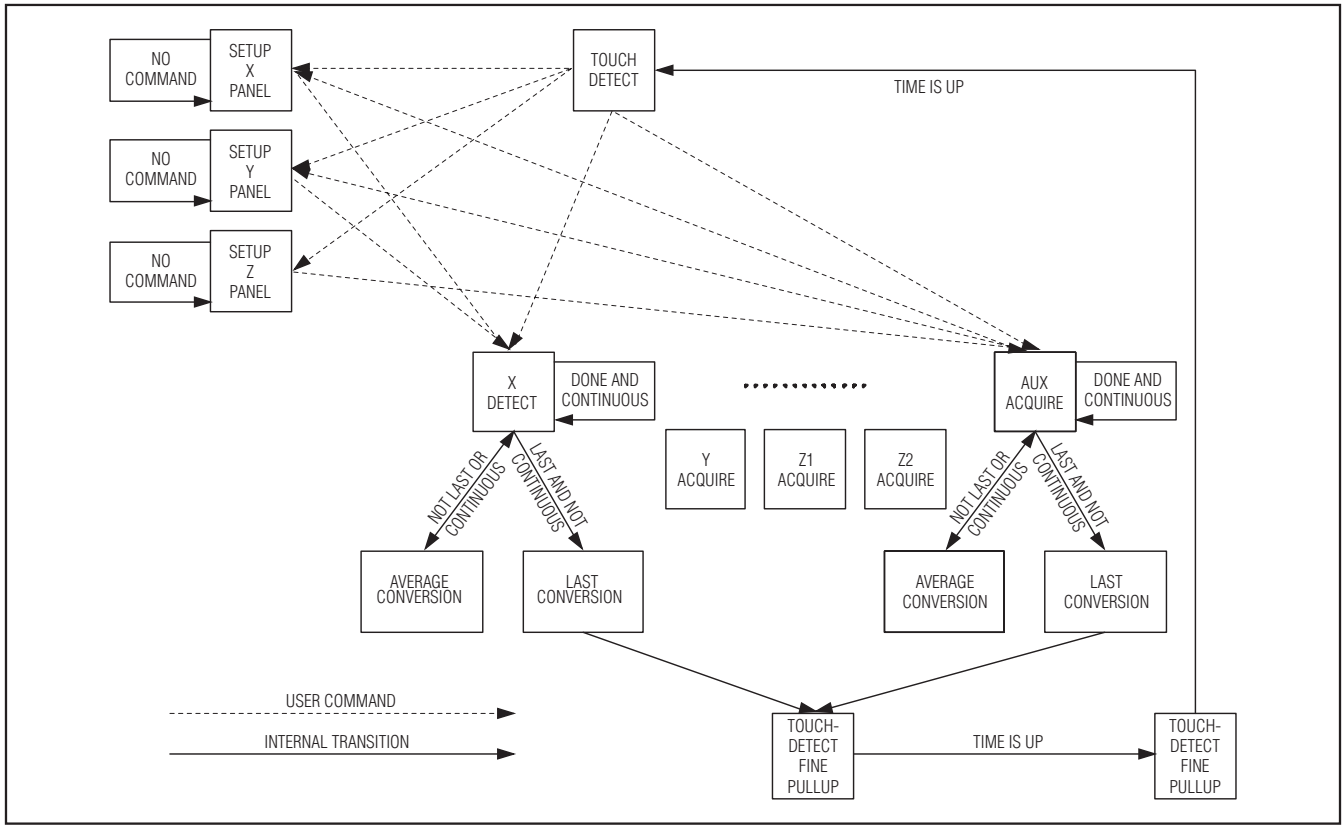

Figure 8. State Machine Transitions (Direct Conversion Mode)—MAX11800–MAX11803

Table 6. Measurement and Event Tags (Continuous Interrupt Mode)

MEASUREMENT	MTAG[3:2]
X	00
Y	01
Z1	10
Z2	11
EVENT	**ETAG[1:0]**
Touch (data valid)	00
N/A (not used)	01
No touch present (data invalid)	10
Measurement in progress (data invalid)	11

Edge Interrupt Mode

When a touch is present on the panel in edge interrupt mode, the MAX11800–MAX11803 return to an untimed high-impedance mode once data tagging operations are complete. In edge interrupt mode, the duration of a touch is determined by the tags applied to the measurement data. Data tagged as initial (00) or midpress (01) indicates the user needs to continue to scan the panel until a release is observed. In this state, there is no need to continue monitoring the touch status prior to the next requested measurement. If a panel touch is not present, data is tagged as release (10) and the MAX11800–MAX11803 idle in TDM continuously, issuing an interrupt only when the next panel touch is initiated.

The operation described in the preceding paragraph makes the edge interrupt mode more power-efficient than the continuous interrupt mode. However, the edge interrupt mode requires continuous scanning of the panel until a release (10) event is observed. Otherwise, the MAX11800–MAX11803 do not idle in TDM and are not able to recognize a change in touch status. New touches are not recognized and new interrupts are not issued if a release event is not detected before stopping the conversion sequence.