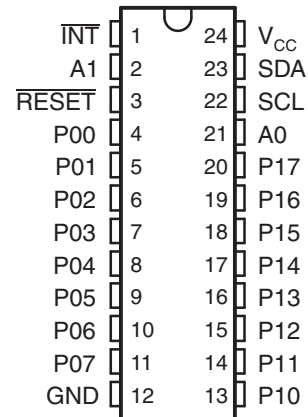


# LOW VOLTAGE 16-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS

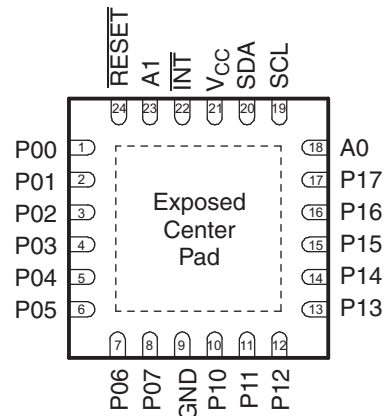
## FEATURES

- Low Standby-Current Consumption of 3  $\mu$ A Max
- I<sup>2</sup>C to Parallel Port Expander
- Open-Drain Active-Low Interrupt Output
- Active-Low Reset Input
- 5-V Tolerant I/O Ports
- Compatible With Most Microcontrollers
- 400-kHz Fast I<sup>2</sup>C Bus
- Polarity Inversion Register
- Address by Two Hardware Address Pins for Use of up to Four Devices
- Latched Outputs With High-Current Drive Capability for Directly Driving LEDs
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 1000-V Charged-Device Model (C101)
  - 200-V Machine Model (A115-A)

**PW PACKAGE  
(TOP VIEW)**



**RTW PACKAGE  
(TOP VIEW)**



The exposed center pad, if used, must be connected as a secondary ground or left electrically open.

## DESCRIPTION/ORDERING INFORMATION

This 16-bit I/O expander for the two-line bidirectional bus (I<sup>2</sup>C) is designed for 1.65-V to 5.5-V V<sub>CC</sub> operation. It provides general-purpose remote I/O expansion for most microcontroller families via the I<sup>2</sup>C interface [serial clock (SCL), serial data (SDA)].

The TCA9539 consists of two 8-bit Configuration (input or output selection), Input Port, Output Port, and Polarity Inversion (active-high or active-low operation) registers. At power-on, the I/Os are configured as inputs. The system master can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input or output register. The polarity of the Input Port register can be inverted with the Polarity Inversion register. All registers can be read by the system master.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

The system master can reset the TCA9539 in the event of a time-out or other improper operation by asserting a low in the  $\overline{\text{RESET}}$  input. The power-on reset puts the registers in their default state and initializes the I<sup>2</sup>C/SMBus state machine. Asserting  $\overline{\text{RESET}}$  causes the same reset/initialization to occur without depowering the part.

The TCA9539 open-drain interrupt ( $\overline{\text{INT}}$ ) output is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system master that an input state has changed.

$\overline{\text{INT}}$  can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I<sup>2</sup>C bus. Thus, the TCA9539 can remain a simple slave device.

The device outputs (latched) have high-current drive capability for directly driving LEDs. The device has low current consumption.

The TCA9539 is identical to the PCA9555, except for the removal of the internal I/O pullup resistor, which greatly reduces power consumption when the I/Os are held low, replacement of A2 with  $\overline{\text{RESET}}$ , and a different address range.

Two hardware pins (A0 and A1) are used to program and vary the fixed I<sup>2</sup>C address and allow up to four devices to share the same I<sup>2</sup>C bus or SMBus.

### ORDERING INFORMATION

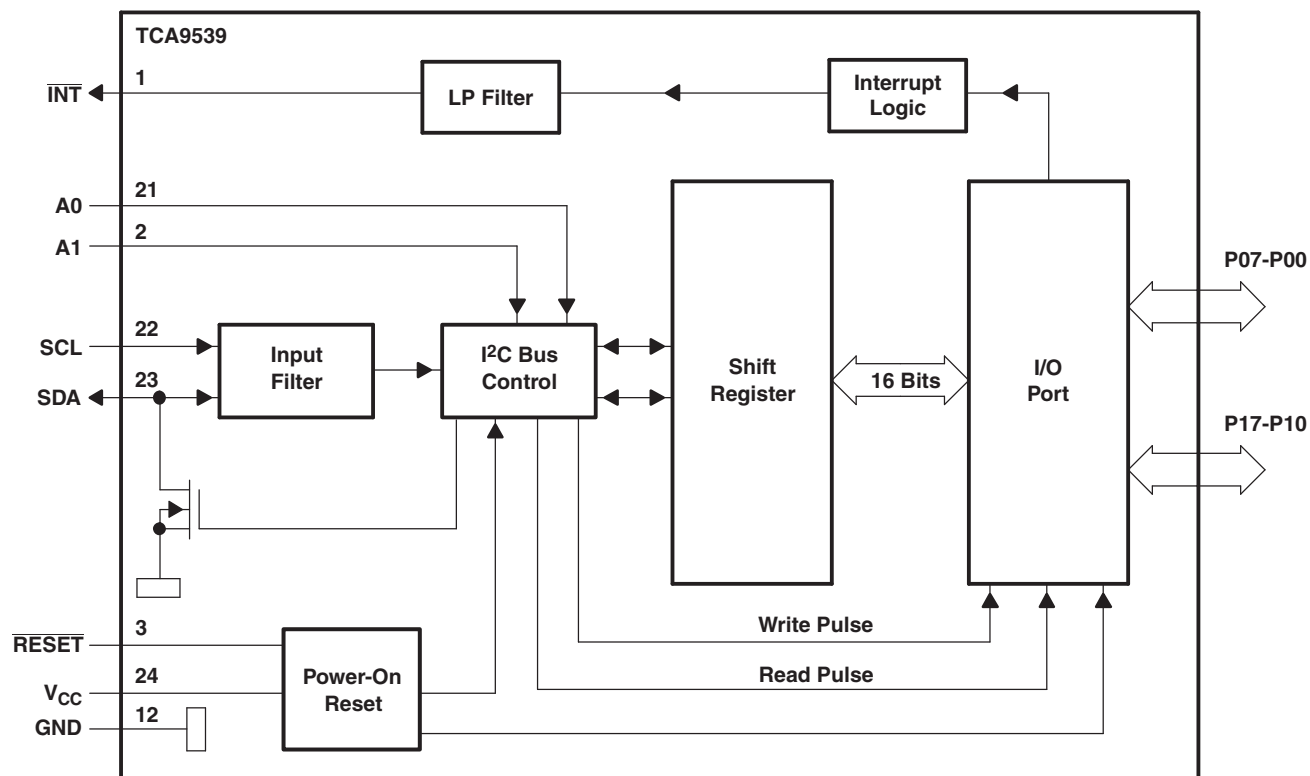
T <sub>A</sub>	PACKAGE <sup>(1)(2)</sup>		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	TSSOP – PW	Reel of 2000	TCA9539PWR	PW539
	QFN – RTW	Reel of 3000	TCA9539RTWR	PW539

(1) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

(2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

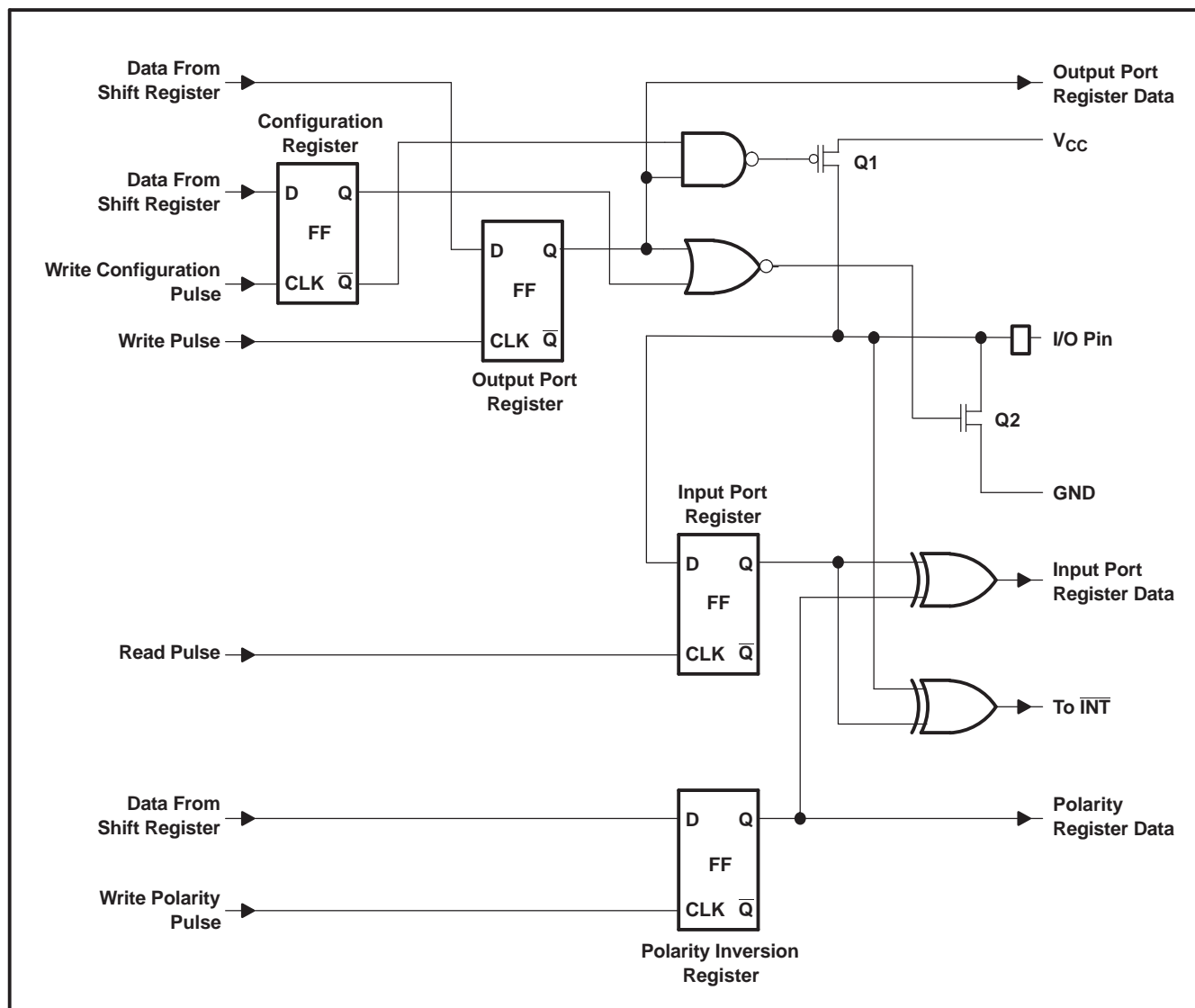
### TERMINAL FUNCTIONS

NO.			NAME	DESCRIPTION
TSSOP (PW)	QFN (RTW)	BGA (ZQS)		
1	22	A3	$\overline{\text{INT}}$	Interrupt output. Connect to $V_{CC}$ through a pullup resistor.
2	23	B3	A1	Address input. Connect directly to $V_{CC}$ or ground.
3	24	A2	$\overline{\text{RESET}}$	Active-low reset input. Connect to $V_{CC}$ through a pullup resistor if no active connection is used.
4	1	A1	P00	P-port input/output. Push-pull design structure. At power on, P00 is configured as an input.
5	2	C3	P01	P-port input/output. Push-pull design structure. At power on, P01 is configured as an input.
6	3	B1	P02	P-port input/output. Push-pull design structure. At power on, P02 is configured as an input.
7	4	C1	P03	P-port input/output. Push-pull design structure. At power on, P03 is configured as an input.
8	5	C2	P04	P-port input/output. Push-pull design structure. At power on, P04 is configured as an input.
9	6	D1	P05	P-port input/output. Push-pull design structure. At power on, P05 is configured as an input.
10	7	E1	P06	P-port input/output. Push-pull design structure. At power on, P06 is configured as an input.
11	8	D2	P07	P-port input/output. Push-pull design structure. At power on, P07 is configured as an input.
12	9	E2	GND	Ground
13	10	E3	P10	P-port input/output. Push-pull design structure. At power on, P10 is configured as an input.
14	11	E4	P11	P-port input/output. Push-pull design structure. At power on, P11 is configured as an input.
15	12	D3	P12	P-port input/output. Push-pull design structure. At power on, P12 is configured as an input.
16	13	E5	P13	P-port input/output. Push-pull design structure. At power on, P13 is configured as an input.
17	14	D4	P14	P-port input/output. Push-pull design structure. At power on, P14 is configured as an input.
18	15	D5	P15	P-port input/output. Push-pull design structure. At power on, P15 is configured as an input.
19	16	C5	P16	P-port input/output. Push-pull design structure. At power on, P16 is configured as an input.
20	17	C4	P17	P-port input/output. Push-pull design structure. At power on, P17 is configured as an input.
21	18	B5	A0	Address input. Connect directly to $V_{CC}$ or ground.
22	19	A5	SCL	Serial clock bus. Connect to $V_{CC}$ through a pullup resistor.
23	20	A4	SDA	Serial data bus. Connect to $V_{CC}$ through a pullup resistor.
24	21	B4	$V_{CC}$	Supply voltage

**LOGIC DIAGRAM (POSITIVE LOGIC)**

- A. Pin numbers shown are for PW package.
- B. All I/Os are set to inputs at reset.

### SIMPLIFIED SCHEMATIC OF P-PORT I/Os<sup>(1)</sup>



(1) At power-on reset, all registers return to default values.

### I/O Port

When an I/O is configured as an input, FETs Q1 and Q2 are off, which creates a high-impedance input. The input voltage may be raised above  $V_{CC}$  to a maximum of 5.5 V.

If the I/O is configured as an output, Q1 or Q2 is enabled, depending on the state of the Output Port register. In this case, there are low-impedance paths between the I/O pin and either  $V_{CC}$  or GND. The external voltage applied to this I/O pin should not exceed the recommended levels for proper operation.

## I<sup>2</sup>C Interface

The bidirectional I<sup>2</sup>C bus consists of the serial clock (SCL) and serial data (SDA) lines. Both lines must be connected to a positive supply via a pullup resistor when connected to the output stages of a device. Data transfer may be initiated only when the bus is not busy.

I<sup>2</sup>C communication with this device is initiated by a master sending a Start condition, a high-to-low transition on the SDA input/output while the SCL input is high (see Figure 1). After the Start condition, the device address byte is sent, MSB first, including the data direction bit (R/W). This device does not respond to the general call address.

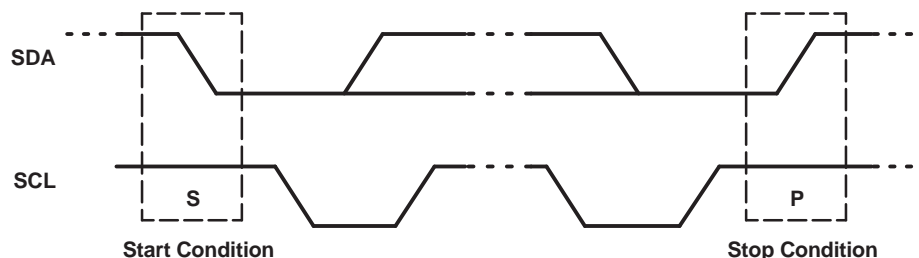
After receiving the valid address byte, this device responds with an ACK, a low on the SDA input/output during the high of the ACK-related clock pulse. The address inputs (A0 and A1) of the slave device must not be changed between the Start and Stop conditions.

On the I<sup>2</sup>C bus, only one data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the high pulse of the clock period, as changes in the data line at this time are interpreted as control commands (Start or Stop) (see Figure 2).

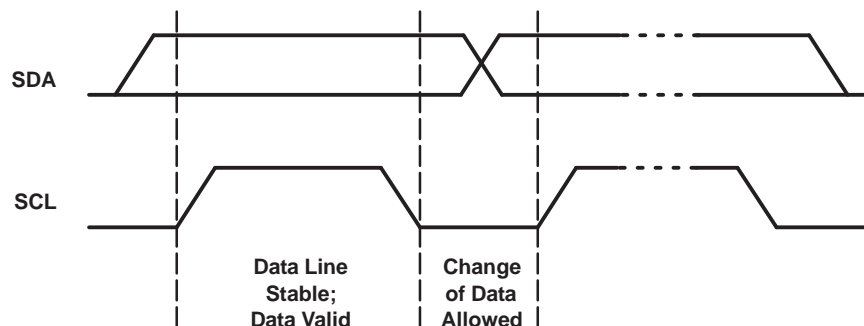
A Stop condition, a low-to-high transition on the SDA input/output while the SCL input is high, is sent by the master (see Figure 1).

Any number of data bytes can be transferred from the transmitter to the receiver between the Start and the Stop conditions. Each byte of eight bits is followed by one ACK bit. The transmitter must release the SDA line before the receiver can send an ACK bit. The device that acknowledges must pull down the SDA line during the ACK clock pulse so that the SDA line is stable low during the high pulse of the ACK-related clock period (see Figure 3). When a slave receiver is addressed, it must generate an ACK after each byte is received. Similarly, the master must generate an ACK after each byte that it receives from the slave transmitter. Setup and hold times must be met to ensure proper operation.

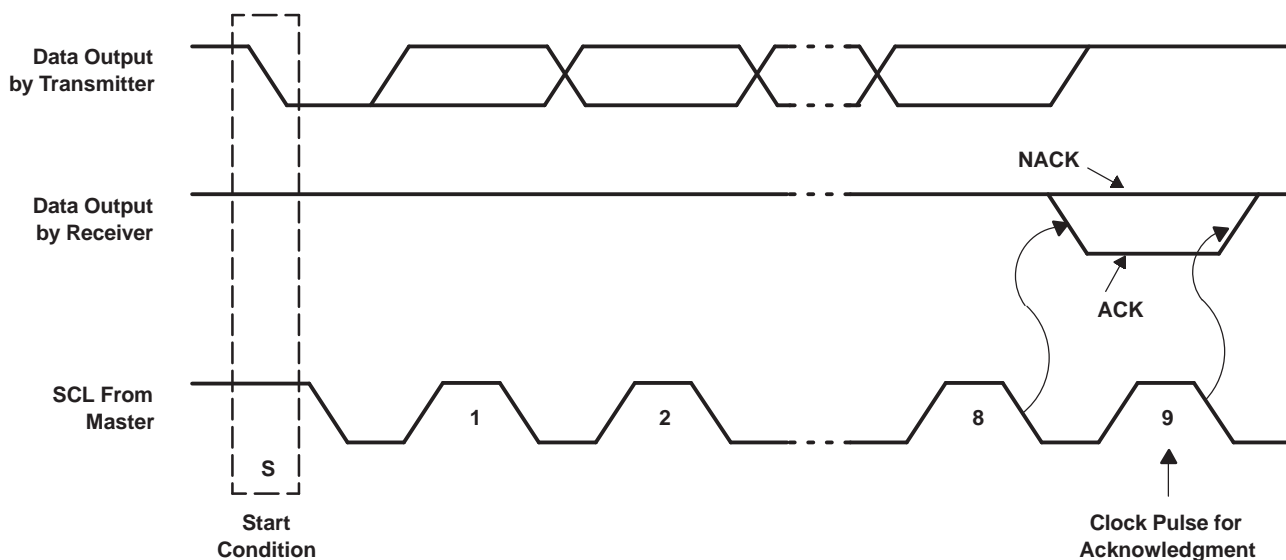
A master receiver signals an end of data to the slave transmitter by not generating an acknowledge (NACK) after the last byte has been clocked out of the slave. This is done by the master receiver by holding the SDA line high. In this event, the transmitter must release the data line to enable the master to generate a Stop condition.



**Figure 1. Definition of Start and Stop Conditions**



**Figure 2. Bit Transfer**



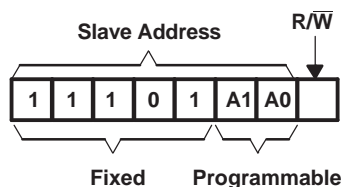
**Figure 3. Acknowledgment on I<sup>2</sup>C Bus**

### Interface Definition

BYTE	BIT							
	7 (MSB)	6	5	4	3	2	1	0 (LSB)
I <sup>2</sup> C slave address	H	H	H	L	H	A1	A0	R/W
P0x I/O data bus	P07	P06	P05	P04	P03	P02	P01	P00
P1x I/O data bus	P17	P16	P15	P14	P13	P12	P11	P10

## Device Address

Figure 4 shows the address byte of the TCA9539.



**Figure 4. TCA9539 Address**

### Address Reference

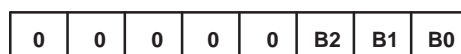
INPUTS		I <sup>2</sup> C BUS SLAVE ADDRESS
A1	A0	
L	L	116 (decimal), 74 (hexadecimal)
L	H	117 (decimal), 75 (hexadecimal)
H	L	118 (decimal), 76 (hexadecimal)
H	H	119 (decimal), 77 (hexadecimal)

The last bit of the slave address defines the operation (read or write) to be performed. A high (1) selects a read operation, while a low (0) selects a write operation.

## Control Register and Command Byte

Following the successful acknowledgment of the address byte, the bus master sends a command byte that is stored in the control register in the TCA9539. Three bits of this data byte state the operation (read or write) and the internal register (input, output, Polarity Inversion or Configuration) that will be affected. This register can be written or read through the I<sup>2</sup>C bus. The command byte is sent only during a write transmission.

Once a command byte has been sent, the register that was addressed continues to be accessed by reads until a new command byte has been sent.



**Figure 5. Control Register Bits**

### Command Byte

CONTROL REGISTER BITS			COMMAND BYTE (HEX)	REGISTER	PROTOCOL	POWER-UP DEFAULT
B2	B1	B0				
0	0	0	0x00	Input Port 0	Read byte	xxxx xxxx
0	0	1	0x01	Input Port 1	Read byte	xxxx xxxx
0	1	0	0x02	Output Port 0	Read/write byte	1111 1111
0	1	1	0x03	Output Port 1	Read/write byte	1111 1111
1	0	0	0x04	Polarity Inversion Port 0	Read/write byte	0000 0000
1	0	1	0x05	Polarity Inversion Port 1	Read/write byte	0000 0000
1	1	0	0x06	Configuration Port 0	Read/write byte	1111 1111
1	1	1	0x07	Configuration Port 1	Read/write byte	1111 1111



## Register Descriptions

The Input Port registers (registers 0 and 1) reflect the incoming logic levels of the pins, regardless of whether the pin is defined as an input or an output by the Configuration register. It only acts on read operation. Writes to these registers have no effect. The default value, X, is determined by the externally applied logic level.

Before a read operation, a write transmission is sent with the command byte to indicate to the I<sup>2</sup>C device that the Input Port register will be accessed next.

### Registers 0 and 1 (Input Port Registers)

Bit	I0.7	I0.6	I0.5	I0.4	I0.3	I0.2	I0.1	I0.0
Default	X	X	X	X	X	X	X	X
Bit	I1.7	I1.6	I1.5	I1.4	I1.3	I1.2	I1.1	I1.0
Default	X	X	X	X	X	X	X	X

The Output Port registers (registers 2 and 3) show the outgoing logic levels of the pins defined as outputs by the Configuration register. Bit values in this register have no effect on pins defined as inputs. In turn, reads from this register reflect the value that is in the flip-flop controlling the output selection, not the actual pin value.

### Registers 2 and 3 (Output Port Registers)

Bit	O0.7	O0.6	O0.5	O0.4	O0.3	O0.2	O0.1	O0.0
Default	1	1	1	1	1	1	1	1
Bit	O1.7	O1.6	O1.5	O1.4	O1.3	O1.2	O1.1	O1.0
Default	1	1	1	1	1	1	1	1

The Polarity Inversion registers (registers 4 and 5) allow Polarity Inversion of pins defined as inputs by the Configuration register. If a bit in this register is set (written with 1), the corresponding port pin's polarity is inverted. If a bit in this register is cleared (written with a 0), the corresponding port pin's original polarity is retained.

### Registers 4 and 5 (Polarity Inversion Registers)

Bit	N0.7	N0.6	N0.5	N0.4	N0.3	N0.2	N0.1	N0.0
Default	0	0	0	0	0	0	0	0
Bit	N1.7	N1.6	N1.5	N1.4	N1.3	N1.2	N1.1	N1.0
Default	0	0	0	0	0	0	0	0

The Configuration registers (registers 6 and 7) configure the directions of the I/O pins. If a bit in this register is set to 1, the corresponding port pin is enabled as an input with a high-impedance output driver. If a bit in this register is cleared to 0, the corresponding port pin is enabled as an output.

### Registers 6 and 7 (Configuration Registers)

Bit	C0.7	C0.6	C0.5	C0.4	C0.3	C0.2	C0.1	C0.0
Default	1	1	1	1	1	1	1	1
Bit	C1.7	C1.6	C1.5	C1.4	C1.3	C1.2	C1.1	C1.0
Default	1	1	1	1	1	1	1	1

## Power-On Reset

When power (from 0 V) is applied to V<sub>CC</sub>, an internal power-on reset holds the TCA9539 in a reset condition until V<sub>CC</sub> has reached V<sub>POR</sub>. At that point, the reset condition is released and the TCA9539 registers and I<sup>2</sup>C/SMBus state machine initialize to their default states. After that, V<sub>CC</sub> must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

## RESET Input

A reset can be accomplished by holding the  $\overline{\text{RESET}}$  pin low for a minimum of  $t_{\text{W}}$ . The TCA9539 registers and I<sup>2</sup>C/SMBus state machine are held in their default states until  $\overline{\text{RESET}}$  is once again high. This input requires a pullup resistor to  $V_{\text{CC}}$ , if no active connection is used.

## Interrupt ( $\overline{\text{INT}}$ ) Output

An interrupt is generated by any rising or falling edge of the port inputs in the input mode. After time,  $t_{\text{iv}}$ , the signal  $\overline{\text{INT}}$  is valid. Resetting the interrupt circuit is achieved when data on the port is changed to the original setting or data is read from the port that generated the interrupt. Resetting occurs in the read mode at the acknowledge (ACK) bit or not acknowledge (NACK) bit after the falling edge of the SCL signal. Interrupts that occur during the ACK or NACK clock pulse can be lost (or be very short) due to the resetting of the interrupt during this pulse. Each change of the I/Os after resetting is detected and is transmitted as  $\overline{\text{INT}}$ .

Reading from or writing to another device does not affect the interrupt circuit, and a pin configured as an output cannot cause an interrupt. Changing an I/O from an output to an input may cause a false interrupt to occur if the state of the pin does not match the contents of the Input Port register. Because each 8-bit port is read independently, the interrupt caused by port 0 is not cleared by a read of port 1, or vice versa.

$\overline{\text{INT}}$  has an open-drain structure and requires a pullup resistor to  $V_{\text{CC}}$ .

## Bus Transactions

Data is exchanged between the master and TCA9539 through write and read commands.

### Writes

Data is transmitted to the TCA9539 by sending the device address and setting the least-significant bit to a logic 0 (see Figure 4 for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte.

The eight registers within the TCA9539 are configured to operate as four register pairs. The four pairs are Input Ports, Output Ports, Polarity Inversion ports, and Configuration ports. After sending data to one register, the next data byte is sent to the other register in the pair (see Figure 6 and Figure 7). For example, if the first byte is sent to Output Port 1 (register 3), the next byte is stored in Output Port 0 (register 2).

There is no limitation on the number of data bytes sent in one write transmission. In this way, each 8-bit register may be updated independently of the other registers.

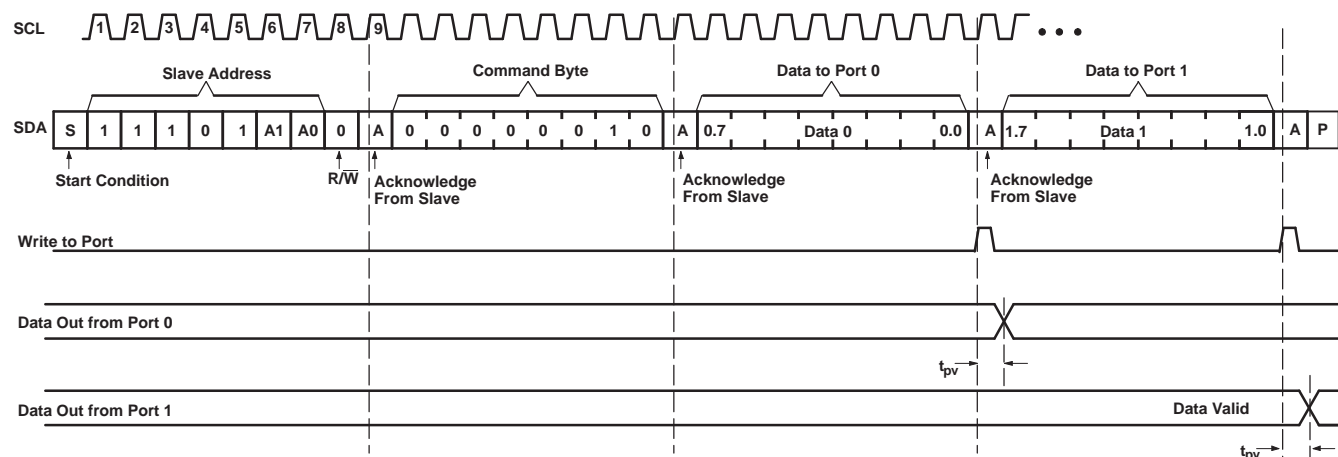
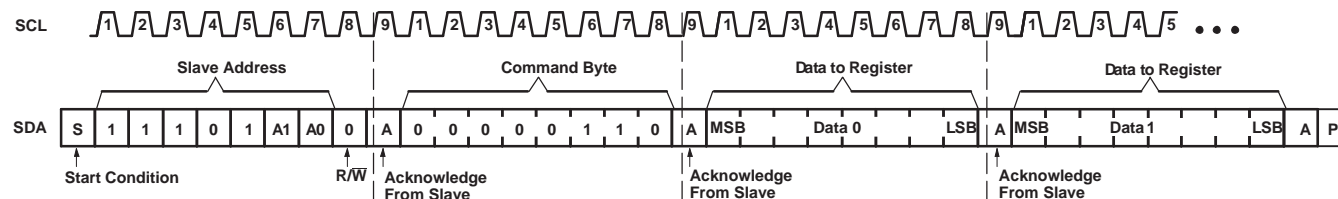


Figure 6. Write to Output Port Registers



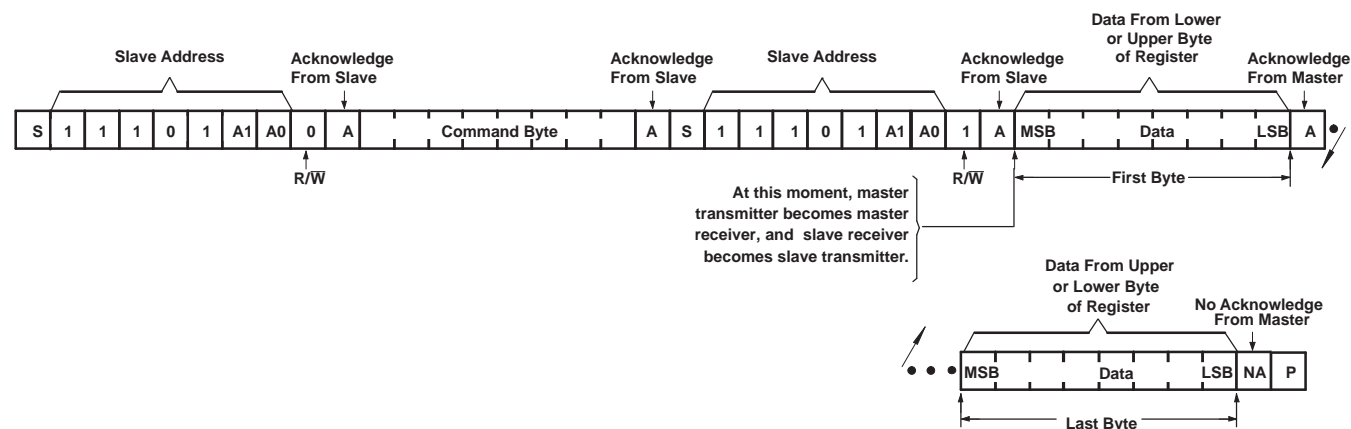
**Figure 7. Write to Configuration Registers**

## Reads

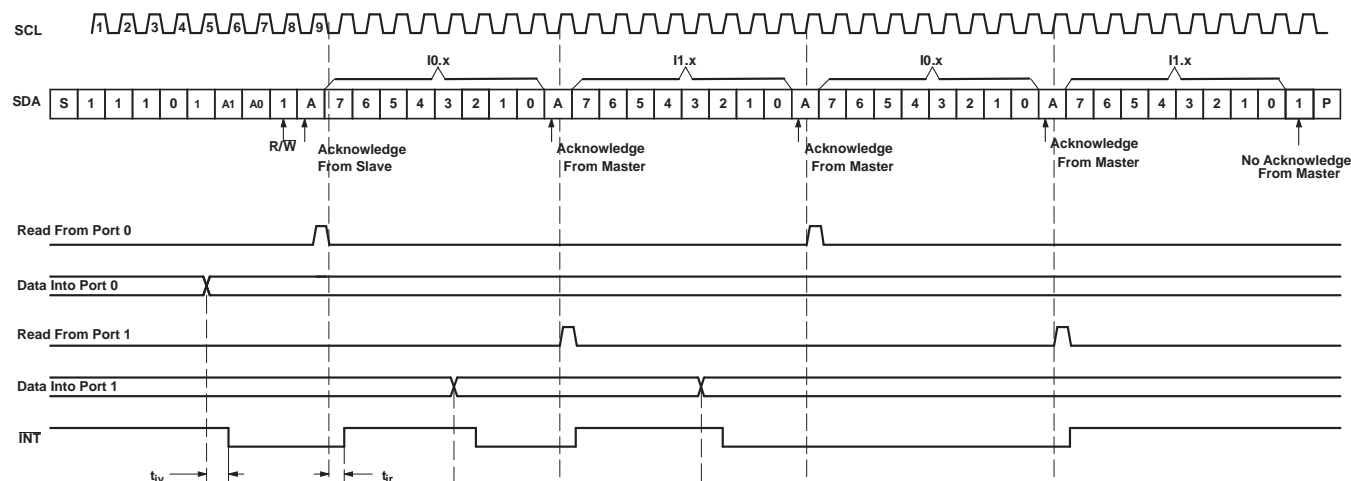
The bus master first must send the TCA9539 address with the least-significant bit set to a logic 0 (see [Figure 4](#) for device address). The command byte is sent after the address and determines which register is accessed. After a restart, the device address is sent again, but this time, the least-significant bit is set to a logic 1. Data from the register defined by the command byte then is sent by the TCA9539 (see [Figure 8](#) through [Figure 10](#)).

After a restart, the value of the register defined by the command byte matches the register being accessed when the restart occurred. For example, if the command byte references Input Port 1 before the restart, and the restart occurs when Input Port 0 is being read, the stored command byte changes to reference Input Port 0. The original command byte is forgotten. If a subsequent restart occurs, Input Port 0 is read first. Data is clocked into the register on the rising edge of the ACK clock pulse. After the first byte is read, additional bytes may be read, but the data now reflect the information in the other register in the pair. For example, if Input Port 1 is read, the next byte read is Input Port 0.

Data is clocked into the register on the rising edge of the ACK clock pulse. There is no limitation on the number of data bytes received in one read transmission, but when the final byte is received, the bus master must not acknowledge the data.

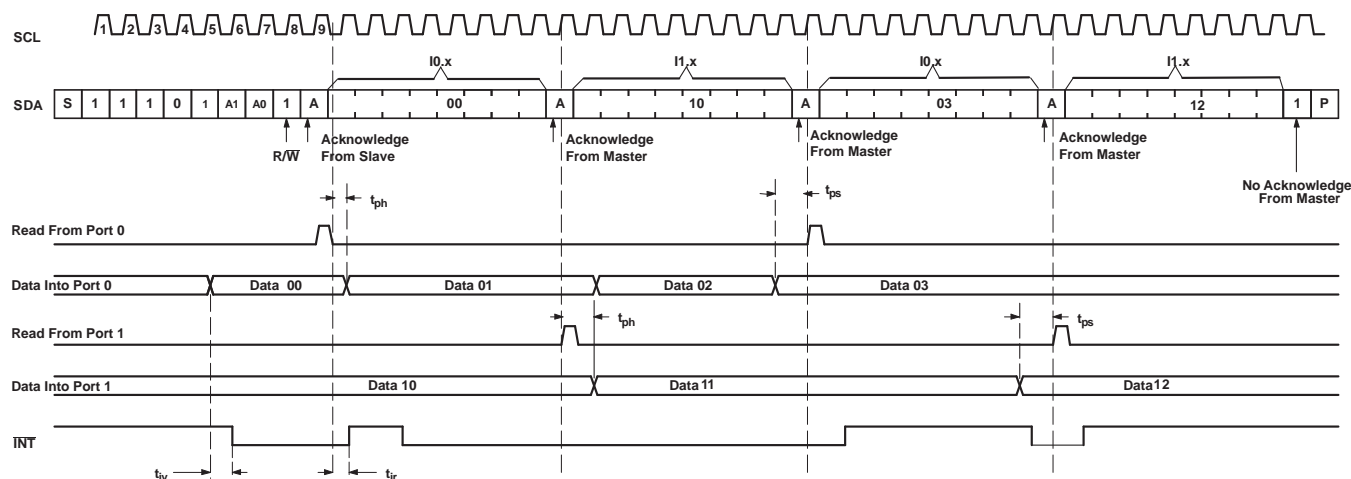


**Figure 8. Read From Register**



- Transfer of data can be stopped at any time by a Stop condition. When this occurs, data present at the latest acknowledge phase is valid (output mode). It is assumed that the command byte previously has been set to 00 (Read Input Port register).
- This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from the P port (see [Figure 8](#) for these details).

**Figure 9. Read Input Port Register, Scenario 1**



- Transfer of data can be stopped at any time by a Stop condition. When this occurs, data present at the latest acknowledge phase is valid (output mode). It is assumed that the command byte previously has been set to 00 (Read Input Port register).
- This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from the P port (see [Figure 8](#) for these details).

**Figure 10. Read Input Port Register, Scenario 2**

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
$V_{CC}$	Supply voltage range		–0.5	6	V
$V_I$	Input voltage range <sup>(2)</sup>		–0.5	6	V
$V_O$	Output voltage range <sup>(2)</sup>		–0.5	6	V
$I_{IK}$	Input clamp current	$V_I < 0$		–20	mA
$I_{OK}$	Output clamp current	$V_O < 0$		–20	mA
$I_{IOK}$	Input/output clamp current	$V_O < 0$ or $V_O > V_{CC}$		±20	mA
$I_{OL}$	Continuous output low current	$V_O = 0$ to $V_{CC}$		50	mA
$I_{OH}$	Continuous output high current	$V_O = 0$ to $V_{CC}$		–50	mA
$I_{CC}$	Continuous current through GND			–250	mA
	Continuous current through $V_{CC}$			160	
$\theta_{JA}$	Package thermal impedance, junction to free air <sup>(3)</sup>	PW package		88	°C/W
		RTW package		66	
$T_{stg}$	Storage temperature range		–65	150	°C

- (1) 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 under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The input negative-voltage and output voltage ratings may be exceeded if the input and output current ratings are observed.
- (3) The package thermal impedance is calculated in accordance with JESD 51-7.

## RECOMMENDED OPERATING CONDITIONS

			MIN	MAX	UNIT
$V_{CC}$	Supply voltage		1.65	5.5	V
$V_{IH}$	High-level input voltage	SCL, SDA	$0.7 \times V_{CC}$	5.5	V
		A0, A1, $\overline{\text{RESET}}$ , P07–P00, P17–P10	$0.7 \times V_{CC}$	5.5	
$V_{IL}$	Low-level input voltage	SCL, SDA	–0.5	$0.3 \times V_{CC}$	V
		A0, A1, $\overline{\text{RESET}}$ , P07–P00, P17–P10	–0.5	$0.3 \times V_{CC}$	
$I_{OH}$	High-level output current	P07–P00, P17–P10		–10	mA
$I_{OL}$	Low-level output current	P07–P00, P17–P10		25	mA
$T_A$	Operating free-air temperature		–40	85	°C

## ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	V <sub>CC</sub>	MIN	TYP <sup>(1)</sup>	MAX	UNIT
V <sub>IK</sub>	Input diode clamp voltage	I <sub>I</sub> = −18 mA	1.65 V to 5.5 V	−1.2			V
V <sub>POR</sub>	Power-on reset voltage	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0	1.65 V to 5.5 V		1.5	1.65	V
V <sub>OH</sub>	P-port high-level output voltage <sup>(2)</sup>	I <sub>OH</sub> = −8 mA	1.65 V	1.2			V
			2.3 V	1.8			
			3 V	2.6			
			4.75 V	4.1			
		I <sub>OH</sub> = −10 mA	1.65 V	1.8			
			2.3 V	1.7			
			3 V	2.5			
			4.75 V	4			
I <sub>OL</sub>	SDA	V <sub>OL</sub> = 0.4 V	1.65 V to 5.5 V	3			mA
	P port <sup>(3)</sup>	V <sub>OL</sub> = 0.5 V		8	20		
		V <sub>OL</sub> = 0.7 V		10	24		
	$\overline{\text{INT}}$	V <sub>OL</sub> = 0.4 V		3			
I <sub>I</sub>	SCL, SDA	V <sub>I</sub> = V <sub>CC</sub> or GND	1.65 V to 5.5 V			±1	μA
	A0, A1, $\overline{\text{RESET}}$					±1	
I <sub>IH</sub>	P port	V <sub>I</sub> = V <sub>CC</sub>	1.65 V to 5.5 V			1	μA
I <sub>IL</sub>	P port	V <sub>I</sub> = GND	1.65 V to 5.5 V			−1	μA
I <sub>CC</sub>	Operating mode	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0, I/O = inputs, f <sub>SCL</sub> = 400 kHz	5.5 V		100	200	μA
			3.6 V		30	75	
			2.7 V		20	50	
			1.95 V		10	45	
	Standby mode	V <sub>I</sub> = GND, I <sub>O</sub> = 0, I/O = inputs, f <sub>SCL</sub> = 0 kHz	5.5 V		1.1	1.5	
			3.6 V		0.7	1.3	
			2.7 V		0.5	1	
			1.95 V		0.3	0.9	
ΔI <sub>CC</sub>	Additional current in standby mode	One input at V <sub>CC</sub> − 0.6 V, Other inputs at V <sub>CC</sub> or GND	1.65 V to 5.5 V			1.5	mA
C <sub>I</sub>	SCL	V <sub>I</sub> = V <sub>CC</sub> or GND	1.65 V to 5.5 V		3	7	pF
C <sub>io</sub>	SDA	V <sub>IO</sub> = V <sub>CC</sub> or GND	1.65 V to 5.5 V		3	7	pF
	P port				3.7	9.5	

(1) All typical values are at nominal supply voltage (1.8-V, 2.5-V, 3.3-V, or 5-V V<sub>CC</sub>) and T<sub>A</sub> = 25°C.

(2) Each I/O must be externally limited to a maximum of 25 mA, and each octal (P07–P00 and P17–P10) must be limited to a maximum current of 100 mA, for a device total of 200 mA.

(3) The total current sourced by all I/Os must be limited to 160 mA (80 mA for P07–P00 and 80 mA for P17–P10).

## I<sup>2</sup>C INTERFACE TIMING REQUIREMENTS

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 11](#))

			MIN	MAX	UNIT
f <sub>scl</sub>	I <sup>2</sup> C clock frequency		0	400	kHz
t <sub>sch</sub>	I <sup>2</sup> C clock high time		0.6		μs
t <sub>scl</sub>	I <sup>2</sup> C clock low time		1.3		μs
t <sub>sp</sub>	I <sup>2</sup> C spike time			50	ns
t <sub>sds</sub>	I <sup>2</sup> C serial-data setup time		100		ns
t <sub>sdh</sub>	I <sup>2</sup> C serial-data hold time		0		ns
t <sub>icr</sub>	I <sup>2</sup> C input rise time		20 + 0.1C <sub>b</sub> <sup>(1)</sup>	300	ns
t <sub>icf</sub>	I <sup>2</sup> C input fall time		20 + 0.1C <sub>b</sub> <sup>(1)</sup>	300	ns
t <sub>ocf</sub>	I <sup>2</sup> C output fall time	10-pF to 400-pF bus	20 + 0.1C <sub>b</sub> <sup>(1)</sup>	300	ns
t <sub>buf</sub>	I <sup>2</sup> C bus free time between Stop and Start		1.3		μs
t <sub>sts</sub>	I <sup>2</sup> C Start or repeated Start condition setup		0.6		μs
t <sub>sth</sub>	I <sup>2</sup> C Start or repeated Start condition hold		0.6		μs
t <sub>sps</sub>	I <sup>2</sup> C Stop condition setup		0.6		μs
t <sub>vd(data)</sub>	Valid-data time	SCL low to SDA output valid	50		ns
t <sub>vd(ack)</sub>	Valid-data time of ACK condition	ACK signal from SCL low to SDA (out) low	0.1	0.9	μs
C <sub>b</sub>	I <sup>2</sup> C bus capacitive load			400	pF

(1)  $C_b$  = total capacitance of one bus line in pF

## RESET TIMING REQUIREMENTS

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 14](#))

		MIN	MAX	UNIT
$t_W$	Reset pulse duration	6		ns
$t_{REC}$	Reset recovery time	0		ns
$t_{RESET}$	Time to reset	400		ns

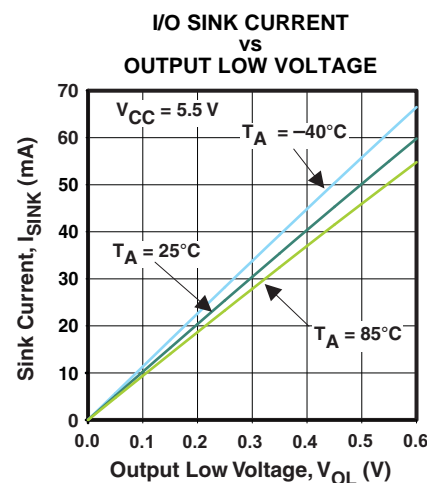
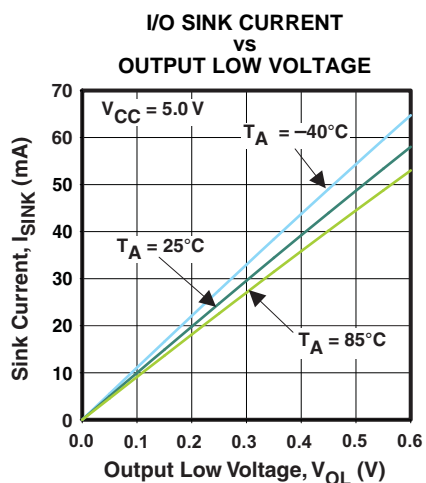
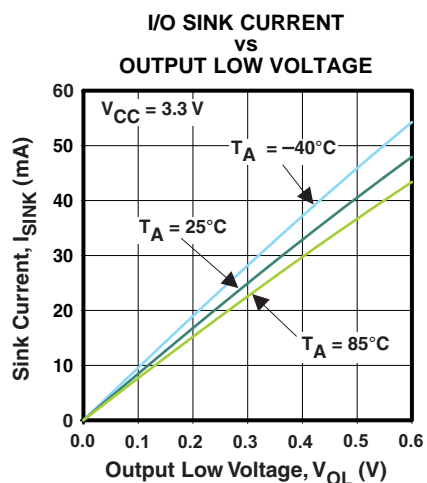
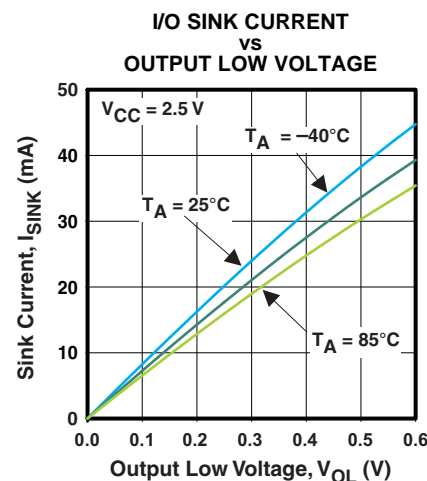
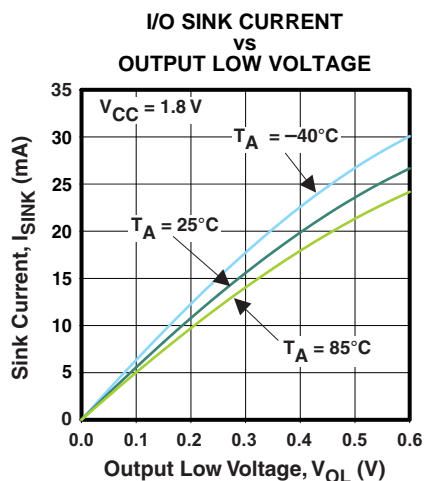
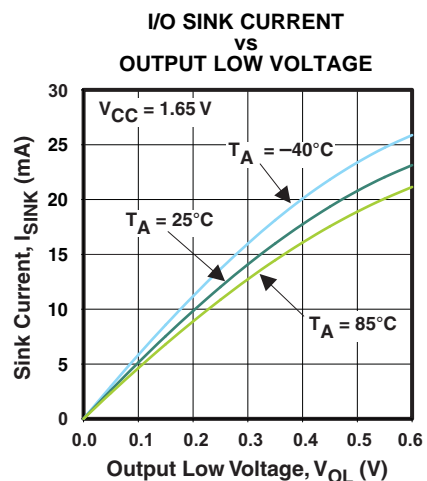
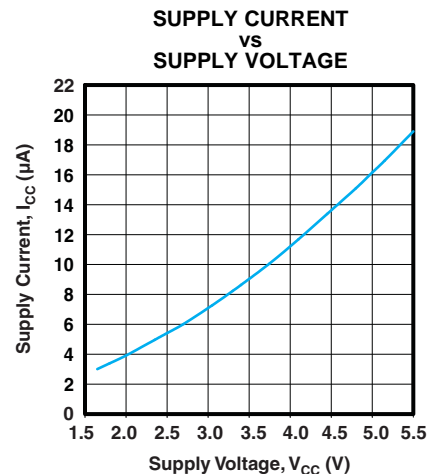
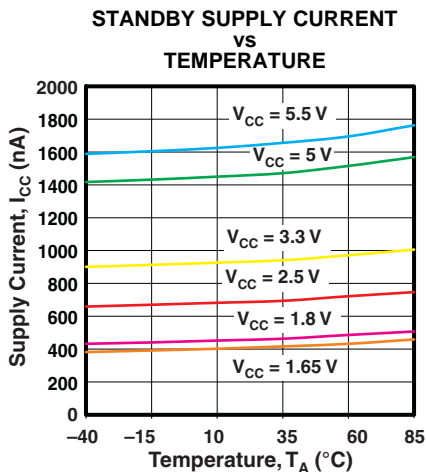
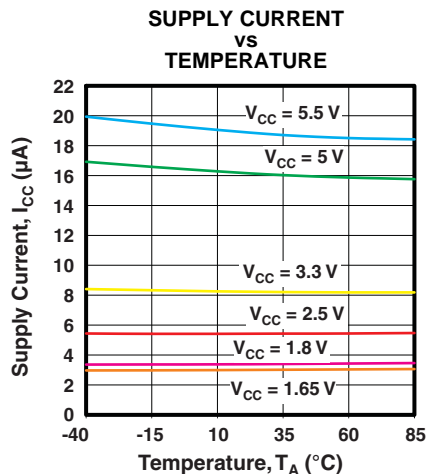
## SWITCHING CHARACTERISTICS

over recommended operating free-air temperature range,  $C_L \leq 100$  pF (unless otherwise noted) (see [Figure 12](#) and [Figure 13](#))

PARAMETER	FROM (INPUT)	TO (OUTPUT)	MIN	MAX	UNIT
$t_{iv}$	Interrupt valid time	P port	$\overline{INT}$	4	μs
$t_{ir}$	Interrupt reset delay time	SCL	$\overline{INT}$	4	μs
$t_{pv}$	Output data valid	SCL	P port	200	ns
$t_{ps}$	Input data setup time	P port	SCL	150	ns
$t_{ph}$	Input data hold time	P port	SCL	1	μs

## TYPICAL CHARACTERISTICS

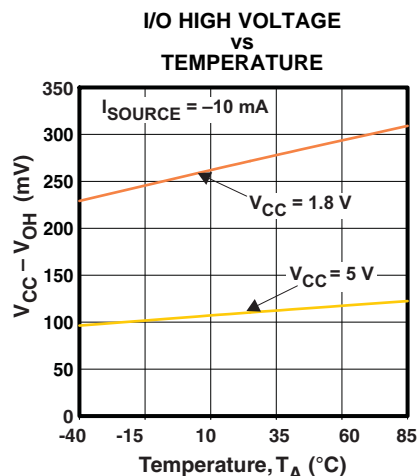
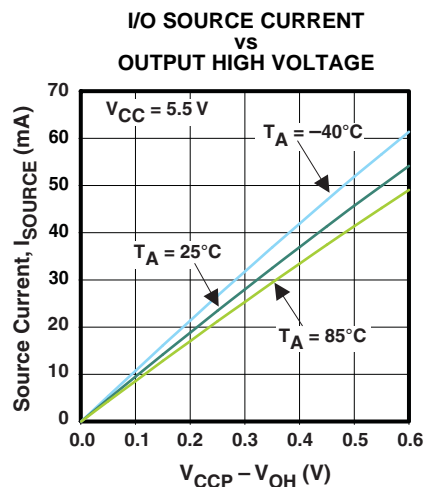
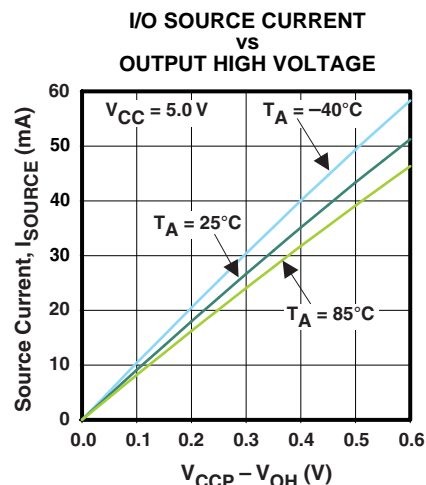
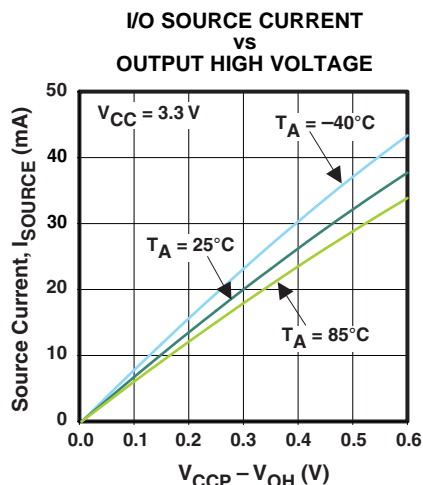
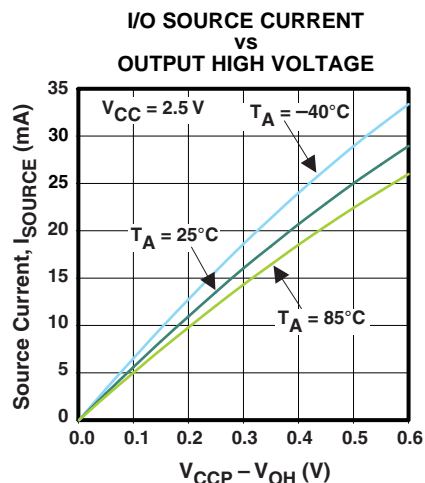
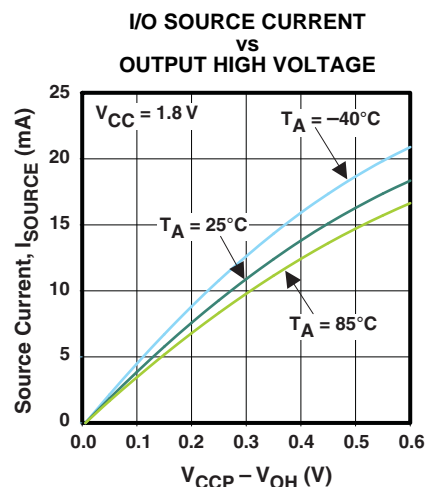
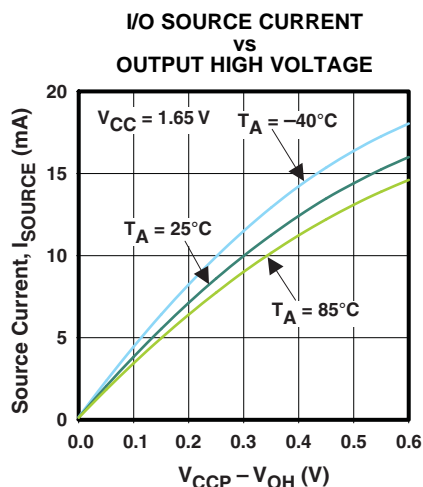
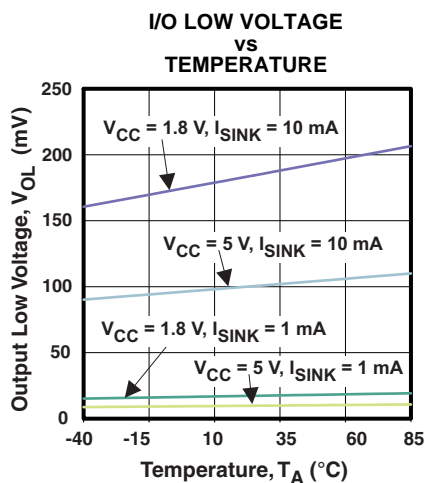
$T_A = 25^\circ\text{C}$  (unless otherwise noted)



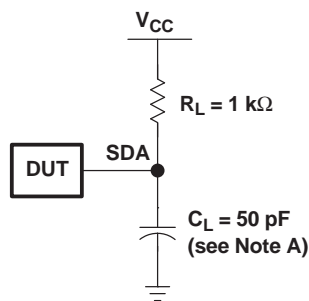


## TYPICAL CHARACTERISTICS (continued)

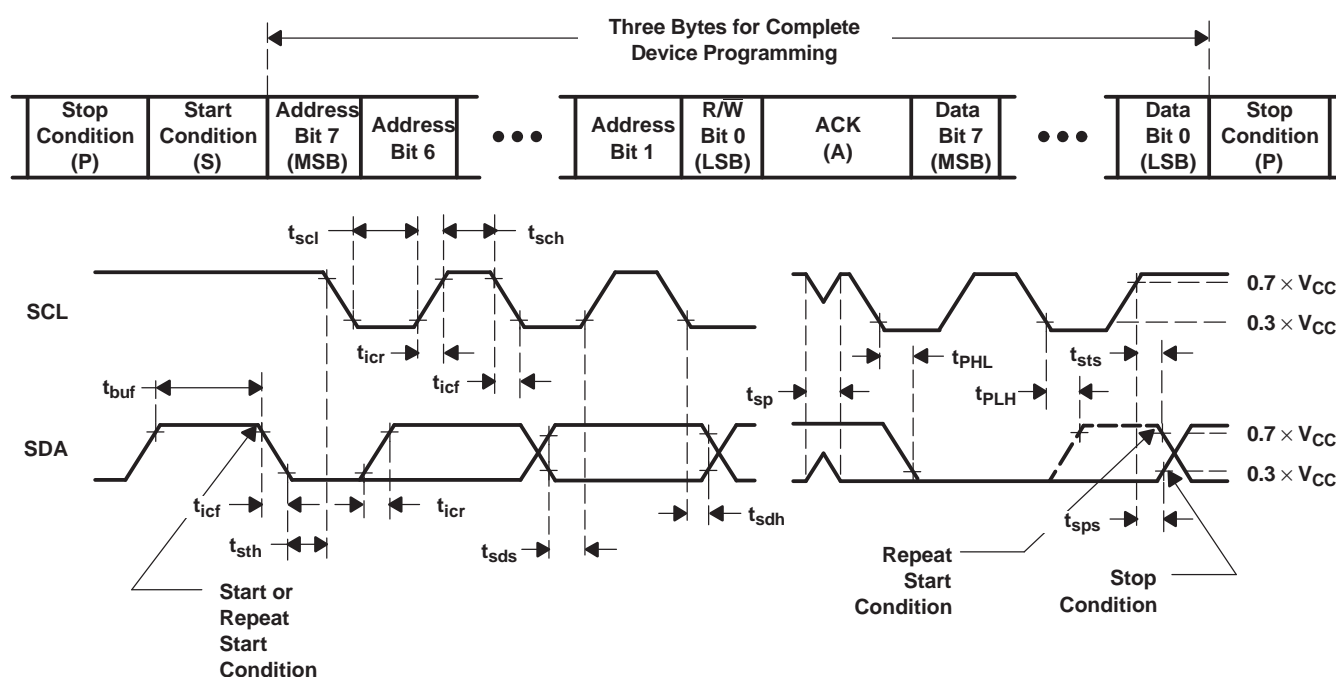
$T_A = 25^\circ\text{C}$  (unless otherwise noted)



## PARAMETER MEASUREMENT INFORMATION



SDA LOAD CONFIGURATION



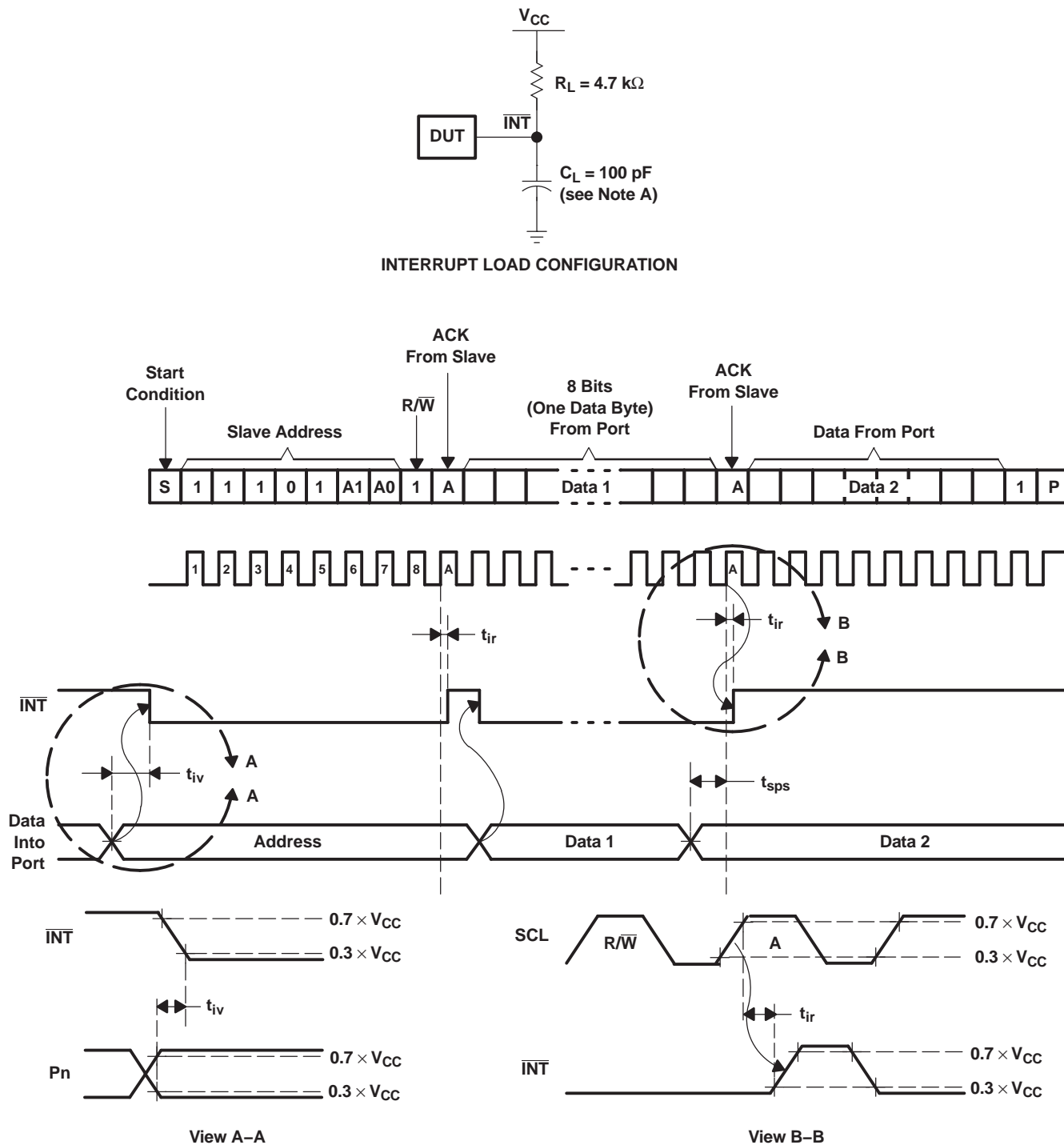
VOLTAGE WAVEFORMS

BYTE	DESCRIPTION
1	I <sup>2</sup> C address
2, 3	P-port data

- A.  $C_L$  includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r/t_f \leq 30\text{ ns}$ .
- C. All parameters and waveforms are not applicable to all devices.

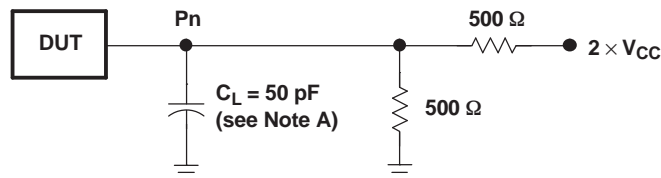
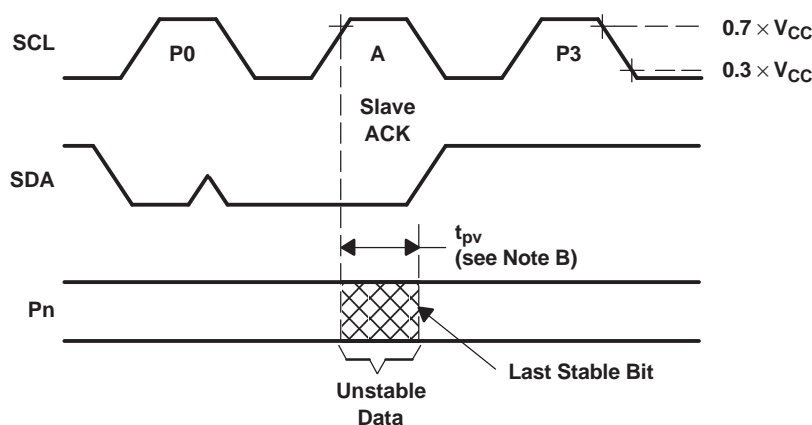
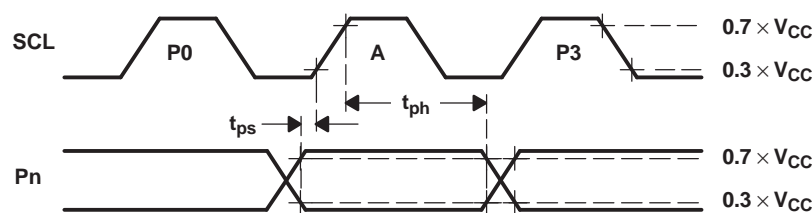
**Figure 11. I<sup>2</sup>C Interface Load Circuit and Voltage Waveforms**

## PARAMETER MEASUREMENT INFORMATION (continued)



- A.  $C_L$  includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30 \text{ ns}$ .
- C. All parameters and waveforms are not applicable to all devices.

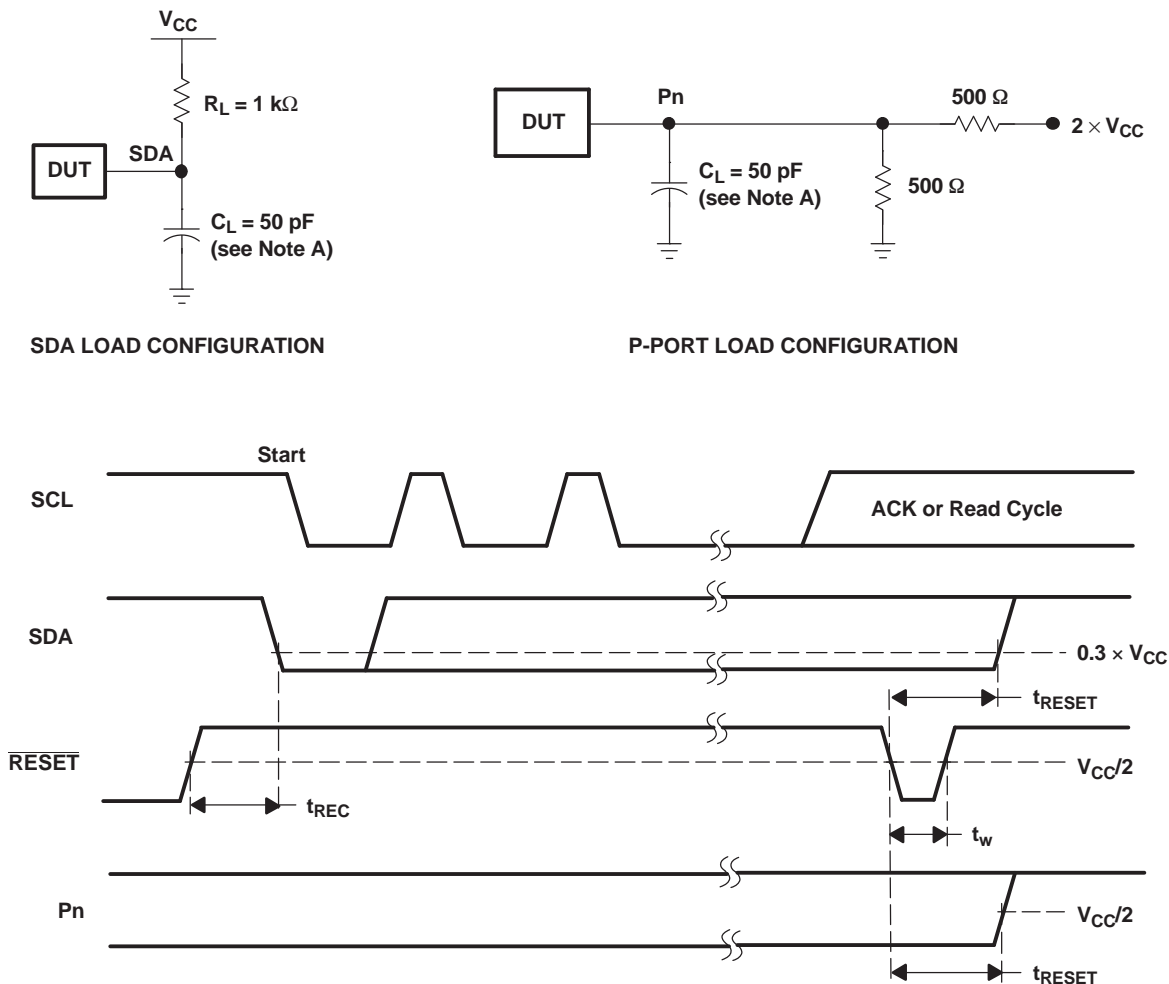
**Figure 12. Interrupt Load Circuit and Voltage Waveforms**

**PARAMETER MEASUREMENT INFORMATION (continued)****P-PORT LOAD CONFIGURATION****WRITE MODE ( $R/\overline{W} = 0$ )****READ MODE ( $R/\overline{W} = 1$ )**

- A.  $C_L$  includes probe and jig capacitance.
- B.  $t_{pv}$  is measured from  $0.7 \times V_{CC}$  on SCL to 50% I/O ( $P_n$ ) output.
- C. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.
- D. The outputs are measured one at a time, with one transition per measurement.
- E. All parameters and waveforms are not applicable to all devices.

**Figure 13. P-Port Load Circuit and Voltage Waveforms**

## PARAMETER MEASUREMENT INFORMATION (continued)

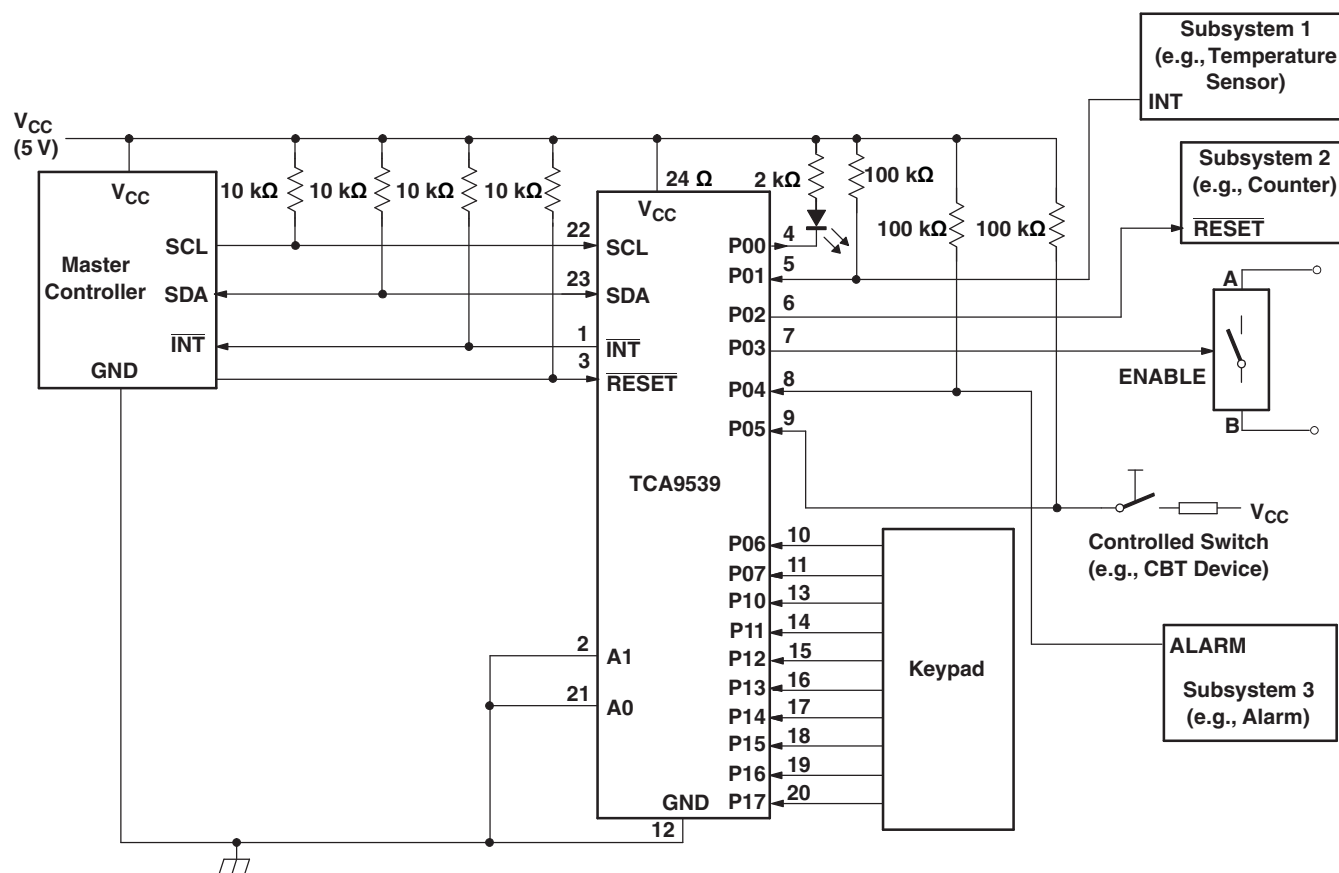


- $C_L$  includes probe and jig capacitance.
- All inputs are supplied by generators having the following characteristics:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.
- The outputs are measured one at a time, with one transition per measurement.
- I/Os are configured as inputs.
- All parameters and waveforms are not applicable to all devices.

**Figure 14. Reset Load Circuits and Voltage Waveforms**

## APPLICATION INFORMATION

Figure 15 shows an application in which the TCA9539 can be used.



- A. Device address is configured as 1110100 for this example.
- B. P00, P02, and P03 are configured as outputs.
- C. P01 and P04 to P17 are configured as inputs.
- D. Pin numbers shown are for the PW package.

**Figure 15. Typical Application**

## Minimizing $I_{CC}$ When I/O Is Used to Control LED

When an I/O is used to control an LED, normally it is connected to  $V_{CC}$  through a resistor (see Figure 15). Because the LED acts as a diode, when the LED is off, the I/O  $V_{IN}$  is about 1.2 V less than  $V_{CC}$ . The  $\Delta I_{CC}$  parameter in Electrical Characteristics shows how  $I_{CC}$  increases as  $V_{IN}$  becomes lower than  $V_{CC}$ . For battery-powered applications, it is essential that the voltage of I/O pins is greater than or equal to  $V_{CC}$ , when the LED is off, to minimize current consumption.

Figure 16 shows a high-value resistor in parallel with the LED. Figure 17 shows  $V_{CC}$  less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O  $V_{CC}$  at or above  $V_{CC}$  and prevent additional supply-current consumption when the LED is off.

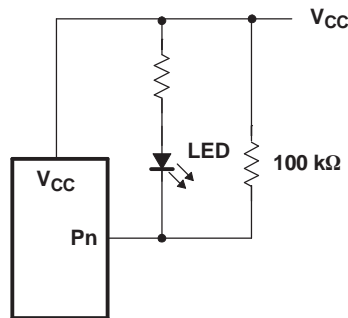


Figure 16. High-Value Resistor in Parallel With LED

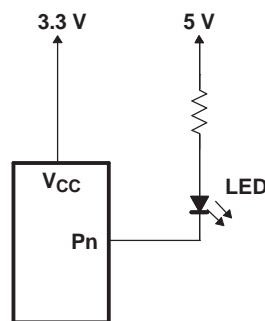


Figure 17. Device Supplied by Lower Voltage

## Power-On Reset Requirements

In the event of a glitch or data corruption, TCA9539 can be reset to its default conditions by using the power-on reset feature. Power-on reset requires that the device go through a power cycle to be completely reset. This reset also happens when the device is powered on for the first time in an application.

The two types of power-on reset are shown in Figure 18 and Figure 19.

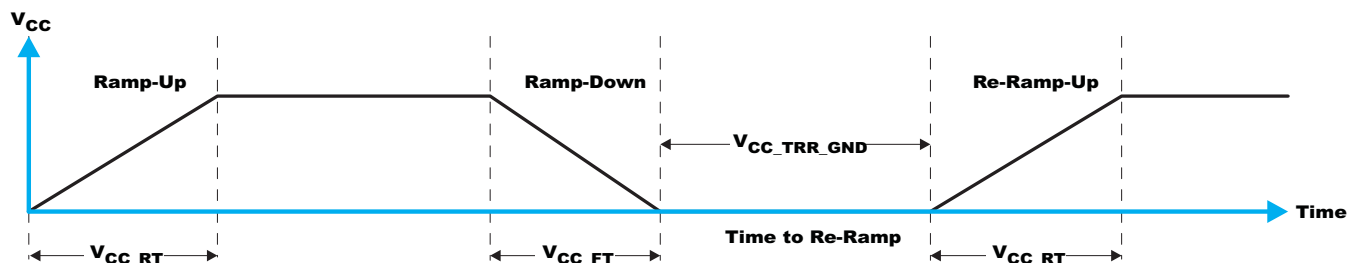


Figure 18.  $V_{CC}$  is Lowered Below 0.2 V or 0 V and Then Ramped Up to  $V_{CC}$

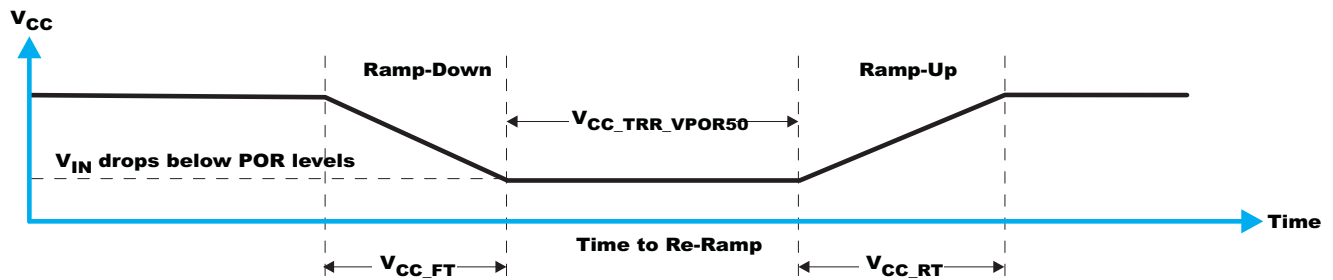


Figure 19.  $V_{CC}$  is Lowered Below the POR Threshold, Then Ramped Back Up to  $V_{CC}$

Table 1 specifies the performance of the power-on reset feature for TCA9539 for both types of power-on reset.

Table 1. RECOMMENDED SUPPLY SEQUENCING AND RAMP RATES<sup>(1)</sup>

PARAMETER			MIN	TYP	MAX	UNIT
$V_{CC\_FT}$	Fall rate	See Figure 18	0.1	2000		ms
$V_{CC\_RT}$	Rise rate	See Figure 18	0.1	2000		ms
$V_{CC\_TRR\_GND}$	Time to re-ramp (when $V_{CC}$ drops to GND)	See Figure 18	1			$\mu$ s
$V_{CC\_TRR\_POR50}$	Time to re-ramp (when $V_{CC}$ drops to $V_{POR\_MIN} - 50$ mV)	See Figure 19	1			$\mu$ s
$V_{CC\_GH}$	Level that $V_{CCP}$ can glitch down to, but not cause a functional disruption when $V_{CCX\_GW} = 1$ $\mu$ s	See Figure 20			1.2	V
$V_{CC\_GW}$	Glitch width that will not cause a functional disruption when $V_{CCX\_GH} = 0.5 \times V_{CCX}$	See Figure 20			10	$\mu$ s
$V_{PORF}$	Voltage trip point of POR on falling $V_{CC}$		0.7			V
$V_{PORR}$	Voltage trip point of POR on rising $V_{CC}$				1.4	V

(1)  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  (unless otherwise noted)

Glitches in the power supply can also affect the power-on reset performance of this device. The glitch width ( $V_{CC\_GW}$ ) and height ( $V_{CC\_GH}$ ) are dependent on each other. The bypass capacitance, source impedance, and device impedance are factors that affect power-on reset performance. Figure 20 and Table 1 provide more information on how to measure these specifications.

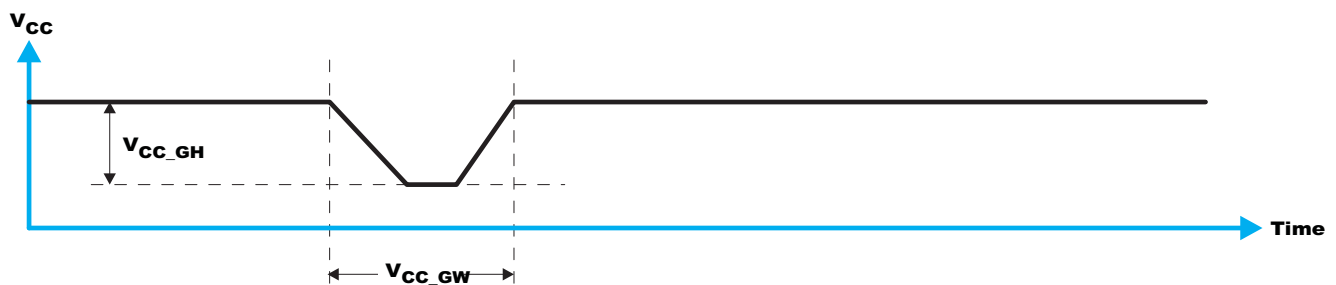


Figure 20. Glitch Width and Glitch Height

$V_{POR}$  is critical to the power-on reset.  $V_{POR}$  is the voltage level at which the reset condition is released and all the registers and the I<sup>2</sup>C/SMBus state machine are initialized to their default states. The value of  $V_{POR}$  differs based on the  $V_{CC}$  being lowered to or from 0. Figure 21 and Table 1 provide more details on this specification.



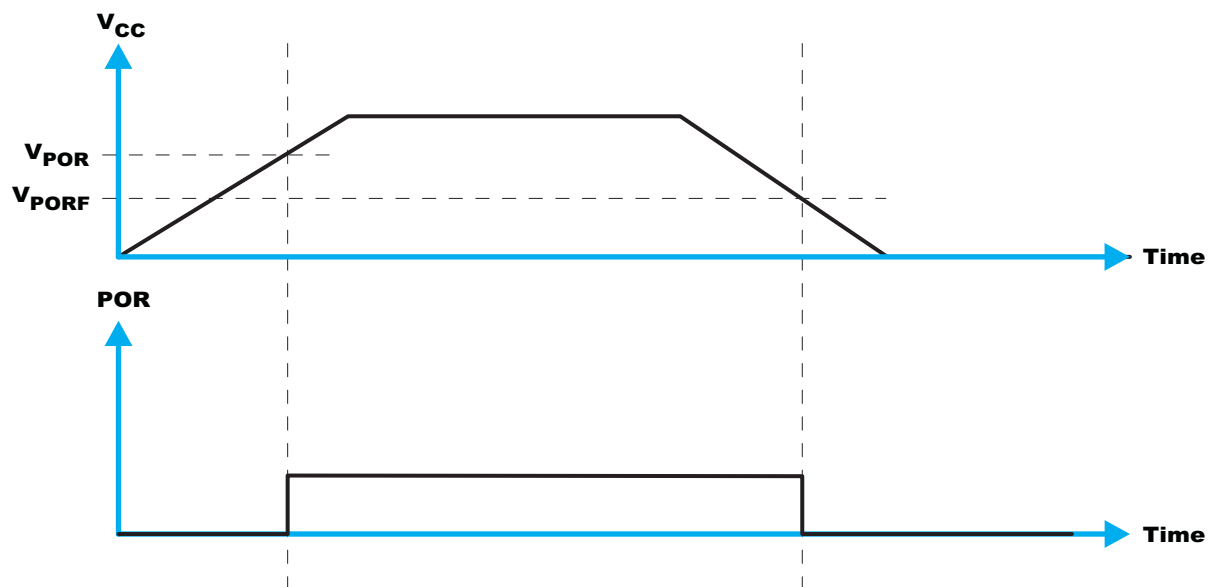


Figure 21.  $V_{POR}$

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
TCA9539PWR	ACTIVE	TSSOP	PW	24	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	
TCA9539RTWR	ACTIVE	WQFN	RTW	24	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

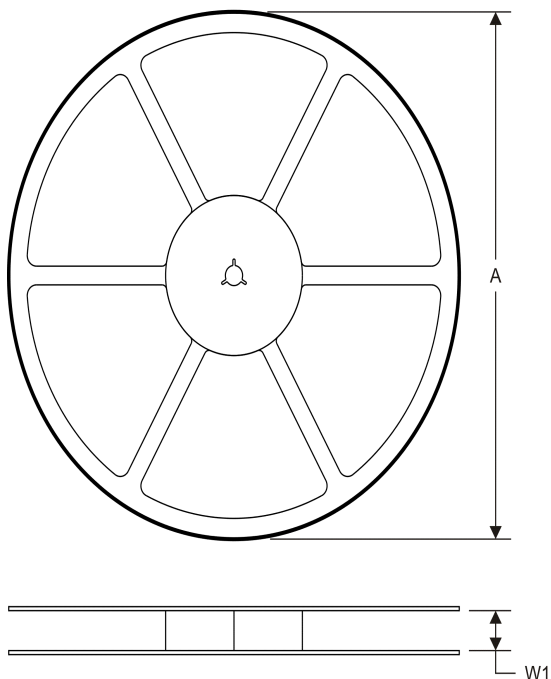
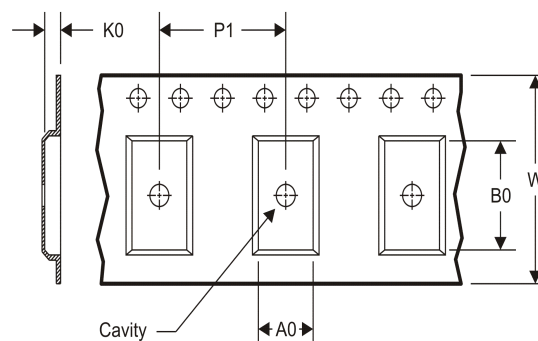
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**TAPE AND REEL INFORMATION**
**REEL DIMENSIONS**

**TAPE DIMENSIONS**


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

**TAPE AND REEL INFORMATION**

\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TCA9539PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
TCA9539RTWR	WQFN	RTW	24	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2

## TAPE AND REEL BOX DIMENSIONS

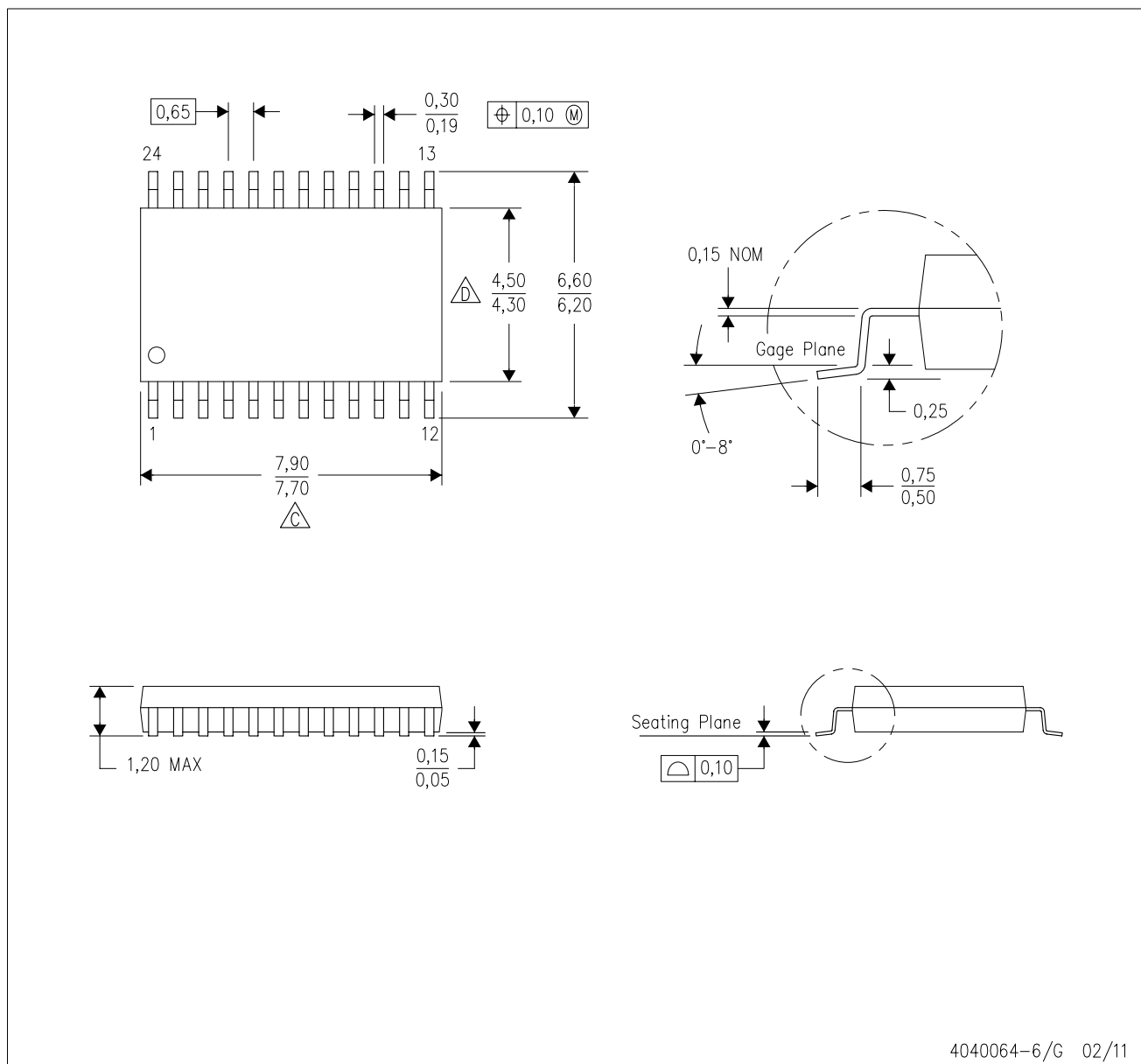


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCA9539PWR	TSSOP	PW	24	2000	367.0	367.0	38.0
TCA9539RTWR	WQFN	RTW	24	3000	367.0	367.0	35.0

PW (R-PDSO-G24)

PLASTIC SMALL OUTLINE

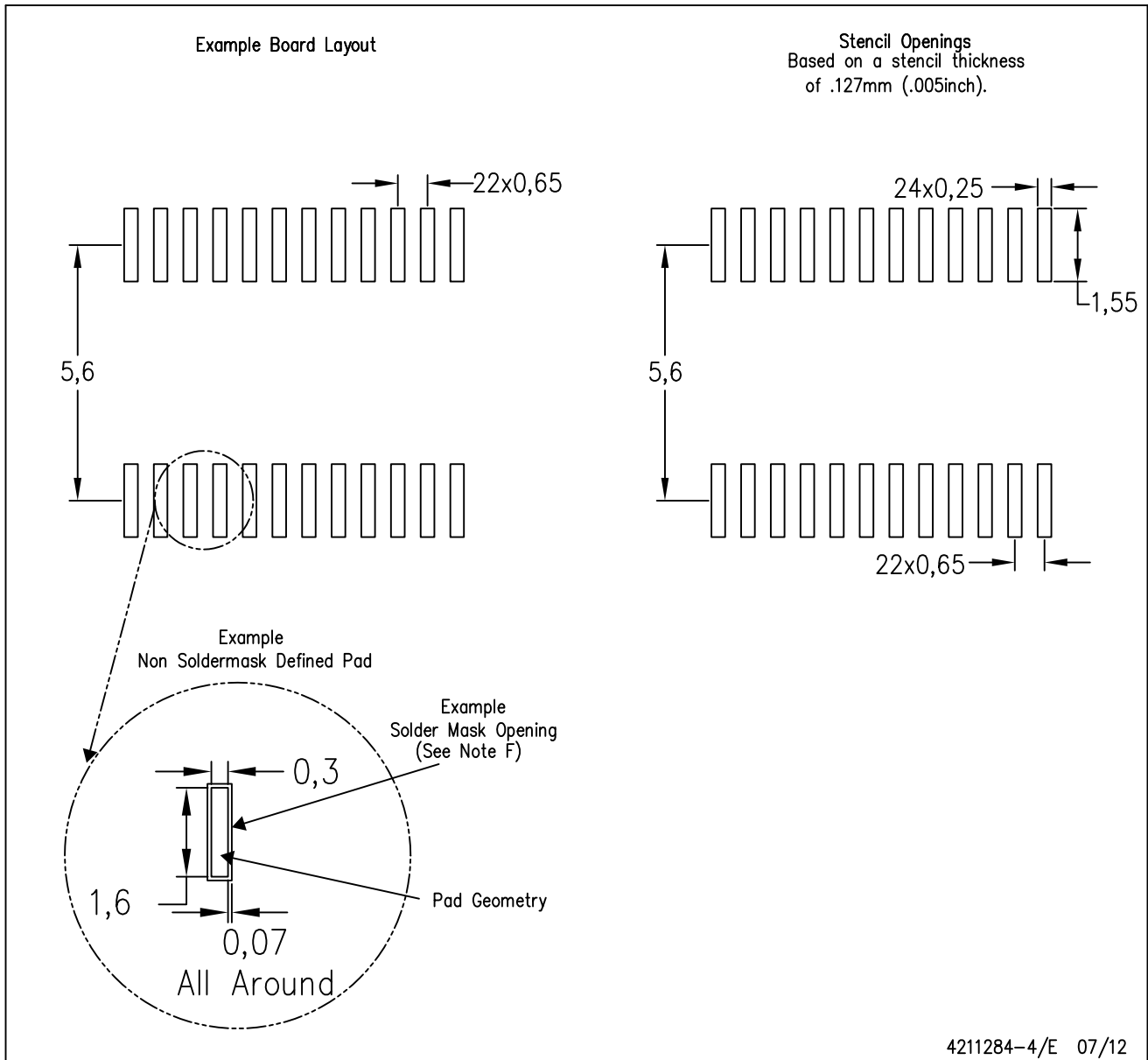


4040064-6/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

PW (R-PDSO-G24)

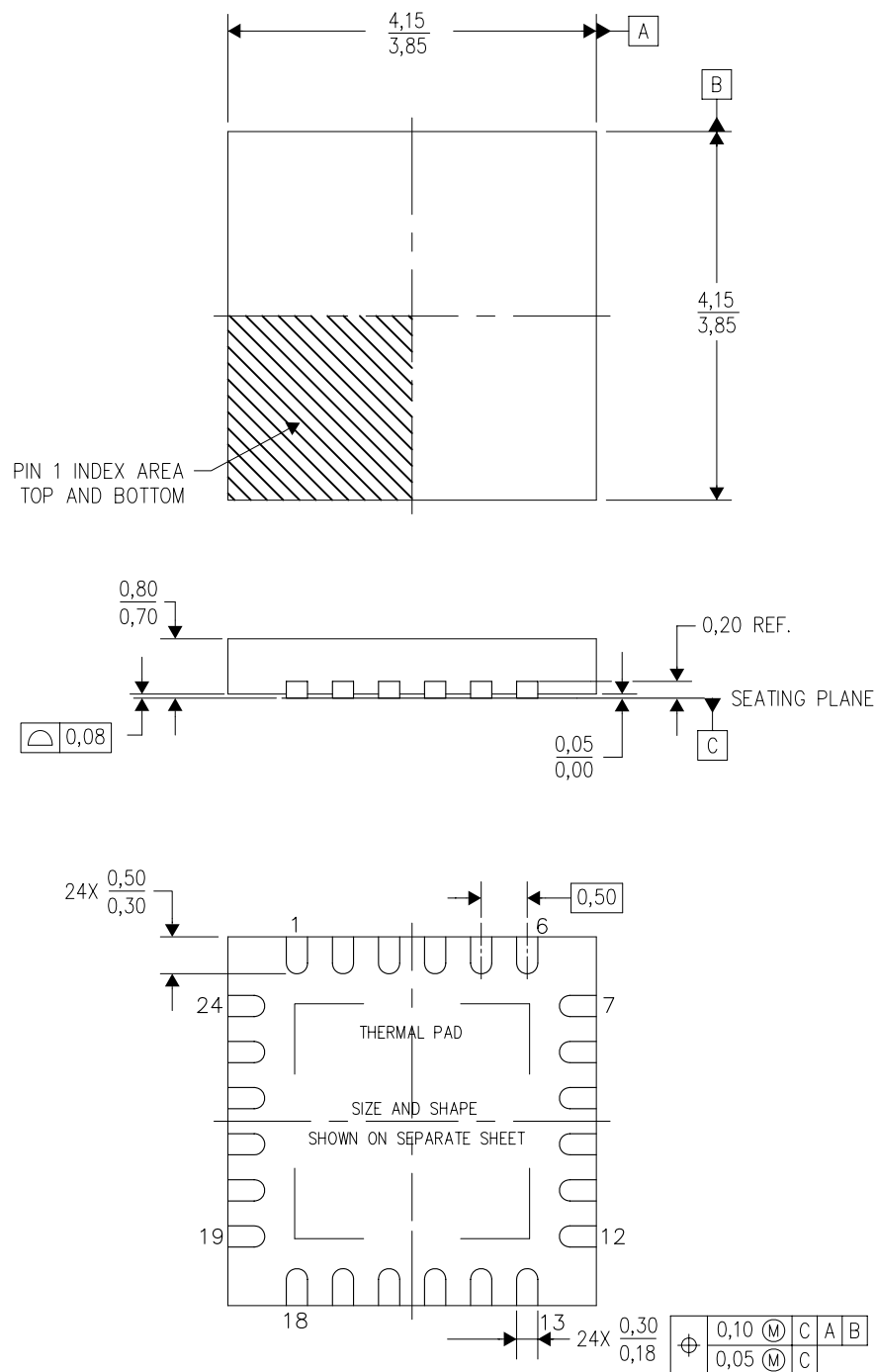
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate design.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

RTW (S-PWQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



4206244/C 07/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Quad Flatpack, No-Leads (QFN) package configuration.
  - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - F. Falls within JEDEC MO-220.

RTW (S-PWQFN-N24)

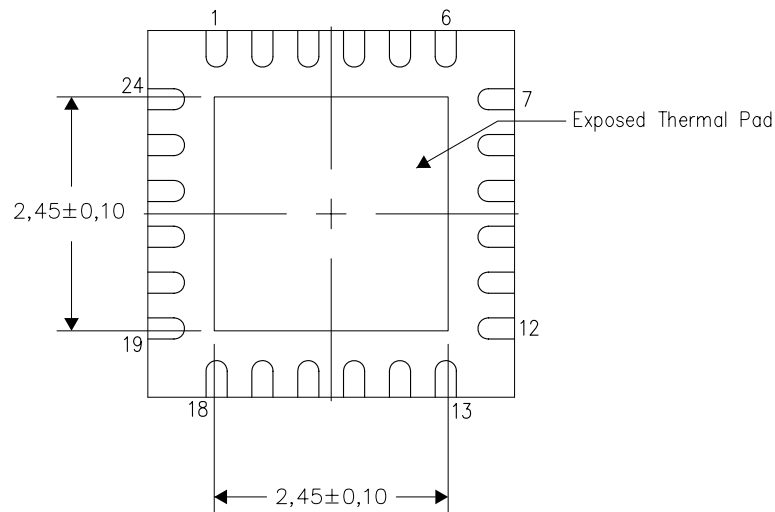
PLASTIC QUAD FLATPACK NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

Exposed Thermal Pad Dimensions

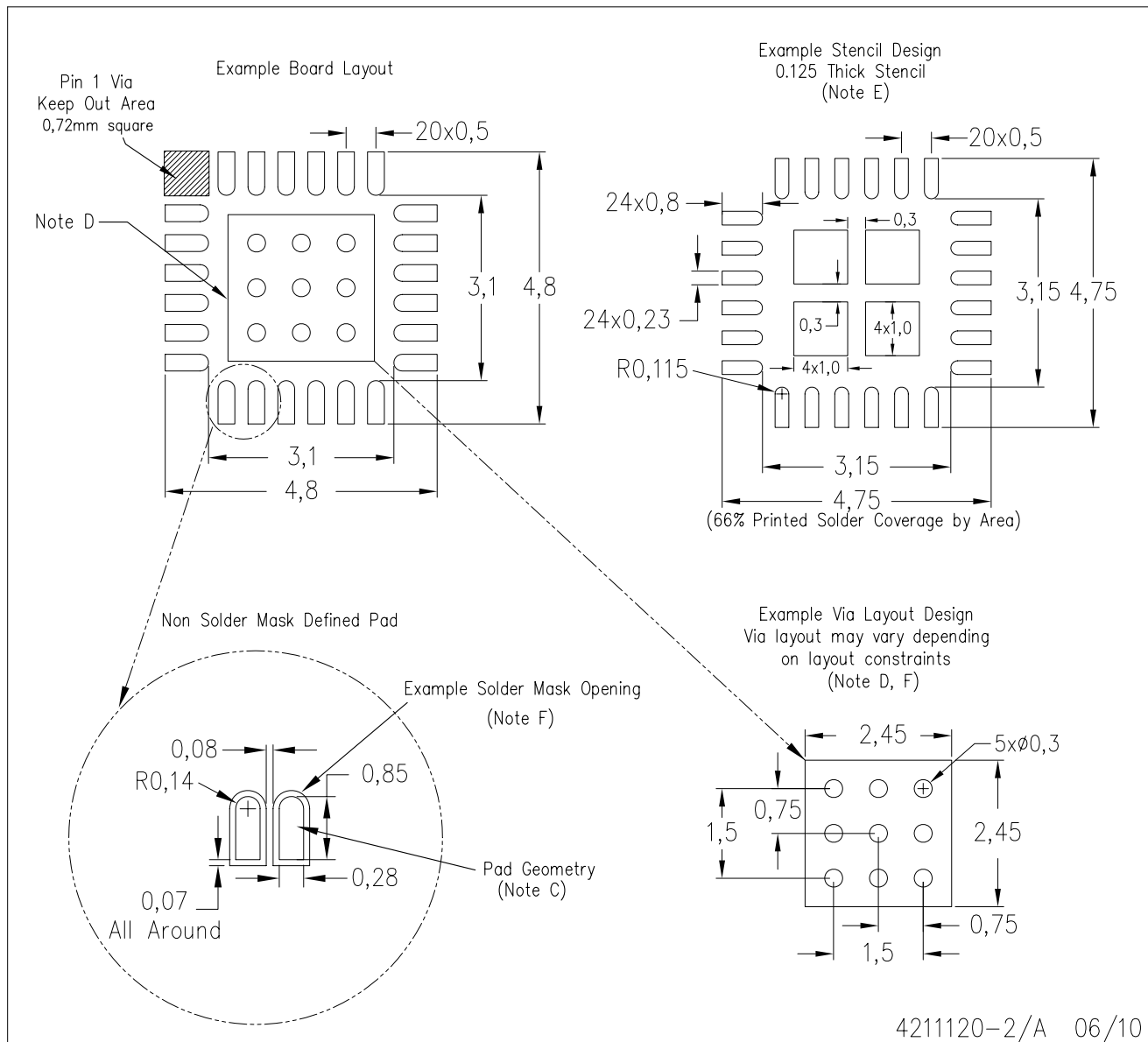
4206249-3/L 07/11

NOTES: A. All linear dimensions are in millimeters



RTW (S-PWQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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