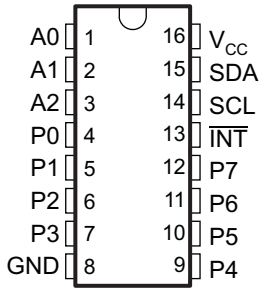
LOW VOLTAGE 8-BIT I²C AND SMBus I/O EXPANDER WITH INTERRUPT OUTPUT AND CONFIGURATION REGISTERS

Check for Samples: TCA9554

FEATURES

- **I²C to Parallel Port Expander**
- **Open-Drain Active-Low Interrupt Output**
- **Operating Power-Supply Voltage Range of 1.65 V to 5.5 V**
- **5-V Tolerant I/Os**
- **400-kHz Fast I²C Bus**
- **Three Hardware Address Pins Allow up to Eight Devices on the I²C/SMBus**
- **Input/Output Configuration Register**
- **Polarity Inversion Register**
- **Internal Power-On Reset**
- **Power-Up With All Channels Configured as Inputs**
- **No Glitch on Power Up**
- **Latched Outputs With High-Current Drive Maximum 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)**
  - **200-V Machine Model (A115-A)**
  - **1000-V Charged-Device Model (C101)**

PW PACKAGE
(TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

This 8-bit I/O expander for the two-line bidirectional bus (I^2C) is designed for 1.65-V to 5.5-V V_{CC} operation. It provides general-purpose remote I/O expansion for most microcontroller families via the I^2C interface [serial clock (SCL), serial data (SDA)].

The TCA9554 consists of one 8-bit Configuration (input or output selection), Input, Output, and Polarity Inversion (active high or active low) registers. At power on, the I/Os are configured as inputs with a weak pullup to V_{CC}. However, 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.

The system master can reset the TCA9554 in the event of a timeout or other improper operation by utilizing the power-on reset feature, which puts the registers in their default state and initializes the I^2C/SMBus state machine.

The TCA9554 open-drain interrupt ($\overline{INT}$) 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.

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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DESCRIPTION/ORDERING INFORMATION (CONTINUED)

$\overline{INT}$ 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^2C bus. Thus, the TCA9554 can remain a simple slave device.

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

Three hardware pins (A0, A1, and A2) are used to program and vary the fixed I^2C address and allow up to eight devices to share the same I^2C bus or SMBus.

The TCA9554 is pin-to-pin and I^2C address compatible with the PCF8574A. However, software changes are required, due to the enhancements in the TCA9554 over the PCF8574A.

The TCA9554 and TCA9554A are identical except for their fixed I^2C address. This allows for up to 16 of these devices (8 of each) on the same I^2C/SMBus.

ORDERING INFORMATION

T_A	PACKAGE(1) (2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	TSSOP – PW	Reel of 2000	TCA9554PWR	PW554

(1) Package drawings, thermal data, and symbolization are available at 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.

Table 1. TERMINAL FUNCTIONS

NO.		NAME	DESCRIPTION
TSSOP (PW)	µQFN (RSV)		
1	15	A0	Address input. Connect directly to V_{CC} or ground.
2	16	A1	Address input. Connect directly to V_{CC} or ground.
3	1	A2	Address input. Connect directly to V_{CC} or ground.
4	2	P0	P-port input/output. Push-pull design structure. At power-on, P0 is configured as an input.
5	3	P1	P-port input/output. Push-pull design structure. At power-on, P1 is configured as an input.
6	4	P2	P-port input/output. Push-pull design structure. At power-on, P2 is configured as an input.
7	5	P3	P-port input/output. Push-pull design structure. At power-on, P3 is configured as an input.
8	6	GND	Ground
9	7	P4	P-port input/output. Push-pull design structure. At power-on, P4 is configured as an input.
10	8	P5	P-port input/output. Push-pull design structure. At power-on, P5 is configured as an input.
11	9	P6	P-port input/output. Push-pull design structure. At power-on, P6 is configured as an input.
12	10	P7	P-port input/output. Push-pull design structure. At power-on, P7 is configured as an input.
13	11	$\overline{INT}$	Interrupt output. Connect to V_{CC} through a pullup resistor.
14	12	SCL	Serial clock bus. Connect to V_{CC} through a pullup resistor.
15	13	SDA	Serial data bus. Connect to V_{CC} through a pullup resistor.
16	14	V_{CC}	Supply voltage

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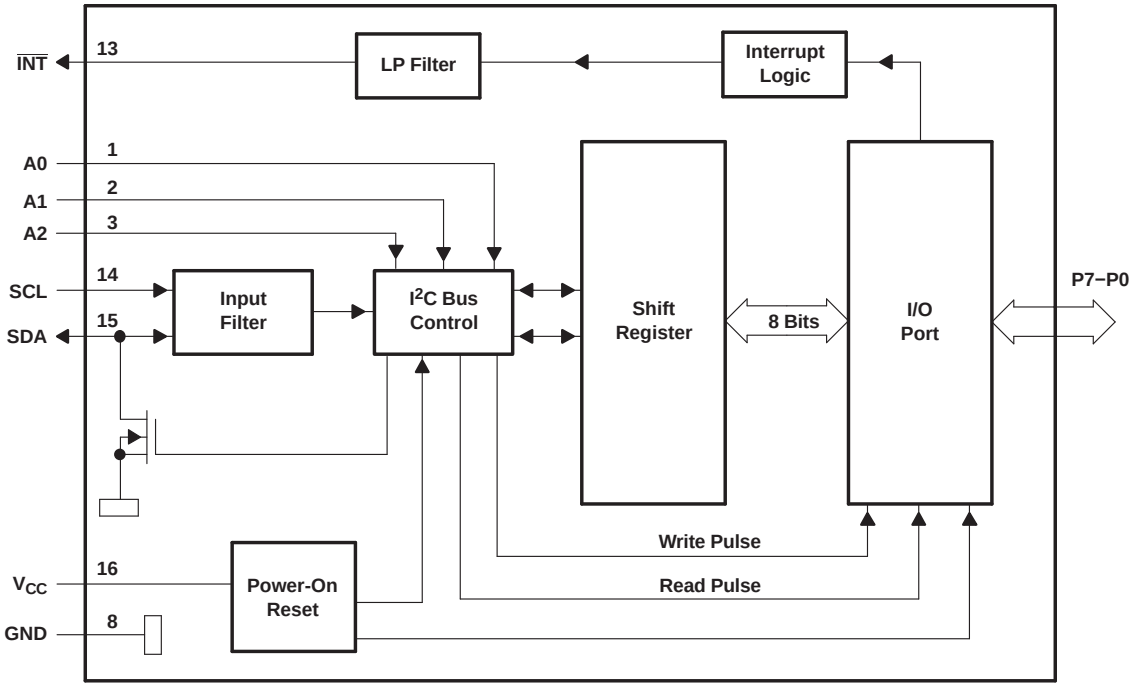
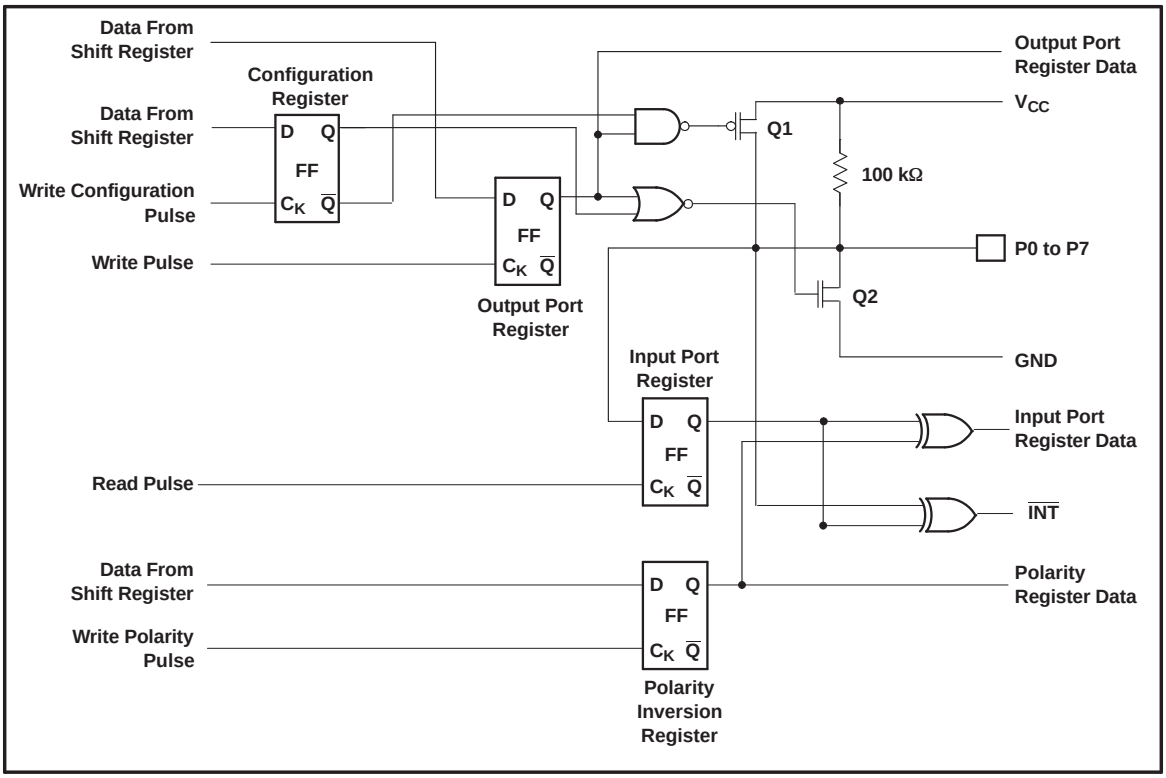
Figure 1. FUNCTIONAL BLOCK DIAGRAM



A. Pin numbers shown are for the PW package.

B. All I/Os are set to inputs at reset.

Figure 2. SIMPLIFIED SCHEMATIC OF P0 TO P7



A. 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 with a weak pullup (100 kΩ typ) to V_{CC}. 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^2C Interface

The bidirectional I^2C bus consists of the serial clock (SCL) and serial data (SDA) lines. Both lines must be connected to a positive supply through 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^2C 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 3). After the Start condition, the device address byte is sent, most significant bit (MSB) first, including the data direction bit (R/$\overline{W}$).

After receiving the valid address byte, this device responds with an acknowledge (ACK), a low on the SDA input/output during the high of the ACK-related clock pulse. The address inputs (A0–A2) of the slave device must not be changed between the Start and Stop conditions.

On the I^2C 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 4).

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 3).

Any number of data bytes can be transferred from the transmitter to receiver between the Start and 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 5). 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 will signal 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.

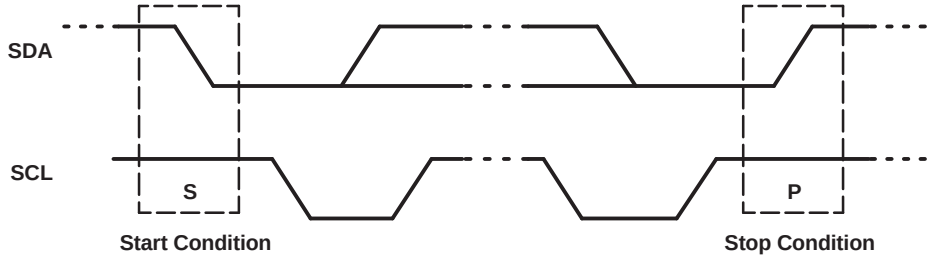


Figure 3. Definition of Start and Stop Conditions

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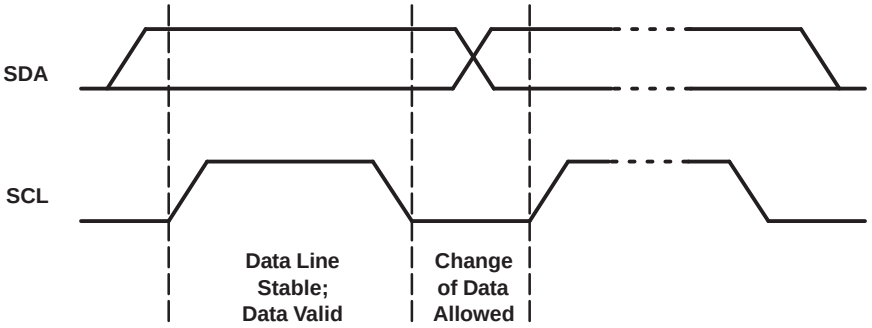

Figure 4. Bit Transfer

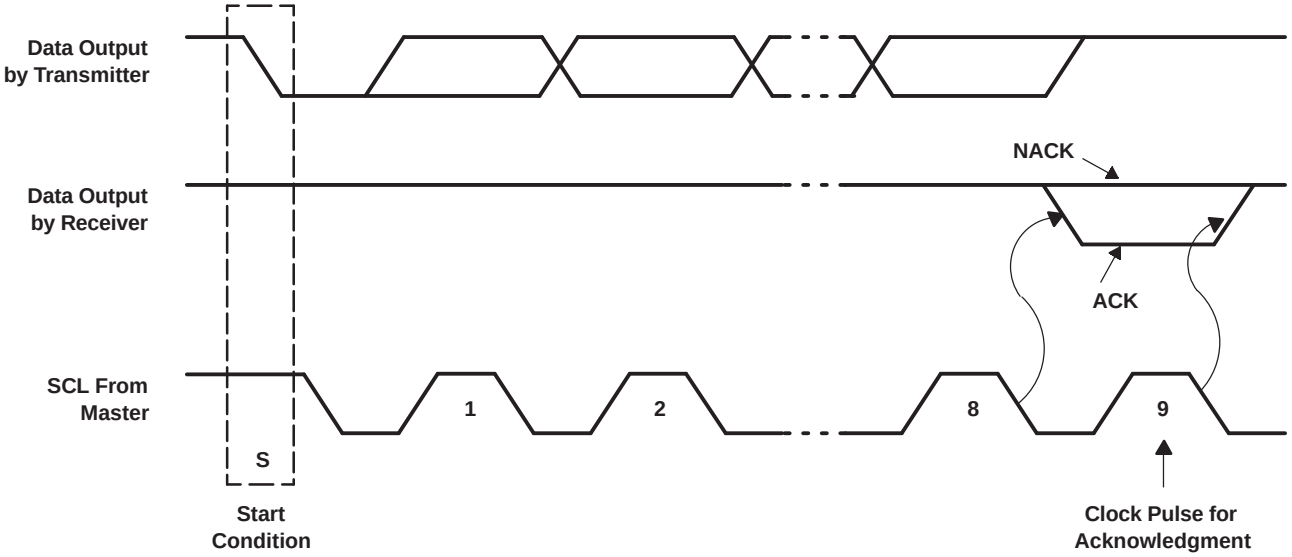

Figure 5. Acknowledgment on the I^2C Bus

Table 2. Interface Definition

BYTE	BIT							
	7 (MSB)	6	5	4	3	2	1	0 (LSB)
I^2C slave address	L	H	L	L	A2	A1	A0	R/$\overline{W}$
Px I/O data bus	P7	P6	P5	P4	P3	P2	P1	P0

Device Address

Figure 6 shows the address byte for the TCA9554.

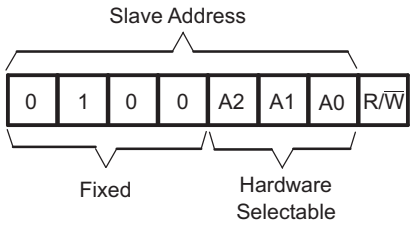

Figure 6. TCA9554 Address

Table 3. Address Reference

INPUTS			I^2C BUS SLAVE ADDRESS
A2	A1	A0	
L	L	L	32 (decimal), 20 (hexadecimal)
L	L	H	33 (decimal), 21 (hexadecimal)
L	H	L	34 (decimal), 22 (hexadecimal)
L	H	H	35 (decimal), 23 (hexadecimal)
H	L	L	36 (decimal), 24 (hexadecimal)
H	L	H	37 (decimal), 25 (hexadecimal)
H	H	L	38 (decimal), 26 (hexadecimal)
H	H	H	39 (decimal), 27 (hexadecimal)

The last bit of the slave address defines the operation (read or write) to be performed. When it is high (1), a read is selected. 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 TCA9554. Two bits of this command 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^2C 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.

0	0	0	0	0	0	B1	B0

Figure 7. Control Register Bits

Table 4. Command Byte

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

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Register Descriptions

The Input Port register (register 0) reflects 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 let the I^2C device know that the Input Port register will be accessed next.

Table 5. Register 0 (Input Port Register)

BIT	I7	I6	I5	I4	I3	I2	I1	I0
DEFAULT	X	X	X	X	X	X	X	X

The Output Port register (register 1) shows 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.

Table 6. Register 1 (Output Port Register)

BIT	O7	O6	O5	O4	O3	O2	O1	O0
DEFAULT	1	1	1	1	1	1	1	1

The Polarity Inversion register (register 2) allows 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 polarity is inverted. If a bit in this register is cleared (written with a 0), the corresponding port pin original polarity is retained.

Table 7. Register 2 (Polarity Inversion Register)

BIT	N7	N6	N5	N4	N3	N2	N1	N0
DEFAULT	0	0	0	0	0	0	0	0

The Configuration register (register 3) configures 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 high impedance output driver. If a bit in this register is cleared to 0, the corresponding port pin is enabled as an output.

Table 8. Register 3 (Configuration Register)

BIT	C7	C6	C5	C4	C3	C2	C1	C0
DEFAULT	1	1	1	1	1	1	1	1

Power-On Reset

When power (from 0 V) is applied to V_{CC}, an internal power-on reset holds the TCA9554 in a reset condition until V_{CC} has reached V_{POR}. At that point, the reset condition is released and the TCA9554 registers and I^2C/SMBus state machine will initialize to their default states. After that, V_{CC} must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

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Interrupt Output ($\overline{INT}$)

An interrupt is generated by any rising or falling edge of the port inputs in the input mode. After time, t_{iv}, the signal $\overline{INT}$ is valid. Resetting the interrupt circuit is achieved when data on the port is changed to the original setting; 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 rising 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 $\overline{INT}$.

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.

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

Bus Transactions

Data is exchanged between the master and TCA9554 through write and read commands.

Writes

Data is transmitted to the TCA9554 by sending the device address and setting the least-significant bit to a logic 0 (see Figure 6 for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte (see Figure 8 and Figure 9). There is no limitation on the number of data bytes sent in one write transmission.

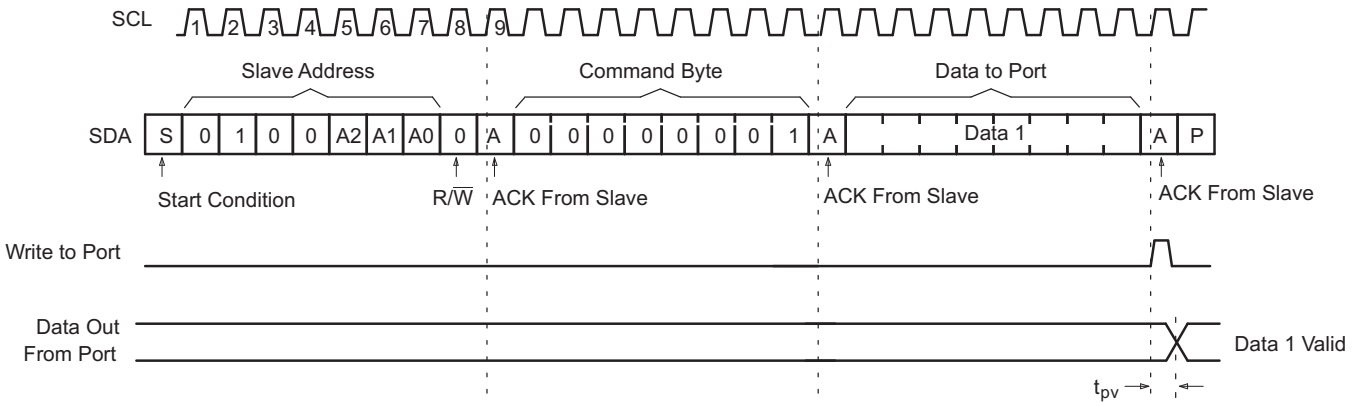

Figure 8. Write to Output Port Register

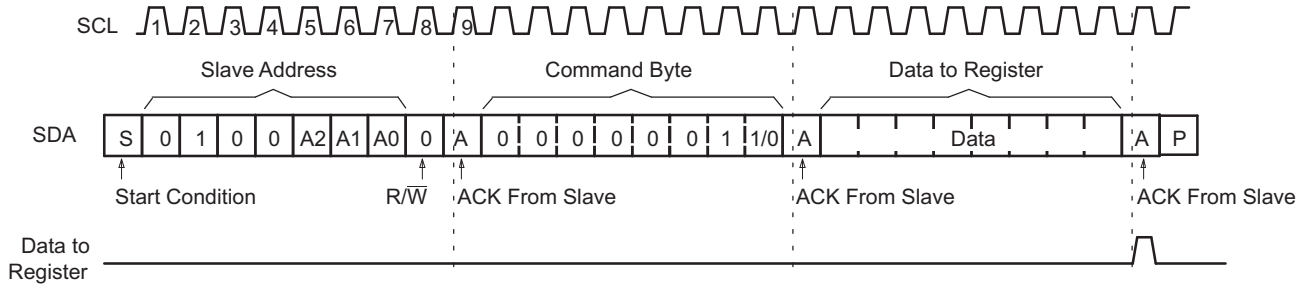

Figure 9. Write to Configuration or Polarity Inversion Registers

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Reads

The bus master first must send the TCA9554 address with the least significant bit (LSB) set to a logic 0 (see Figure 6 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 LSB is set to a logic 1. Data from the register defined by the command byte then is sent by the TCA9554 (see Figure 10 and Figure 11). After a restart, the value of the register defined by the command byte matches the register being accessed when the restart occurred. 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.

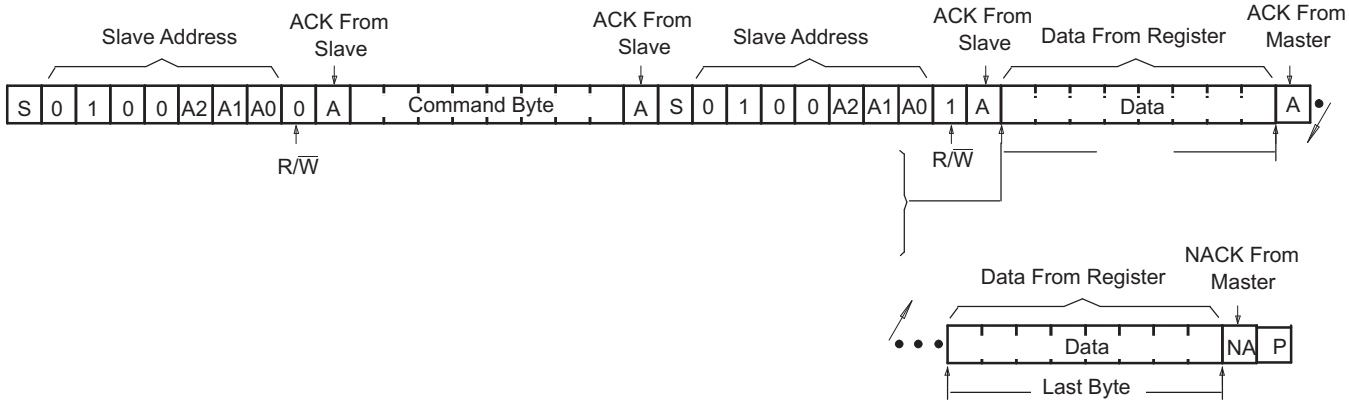
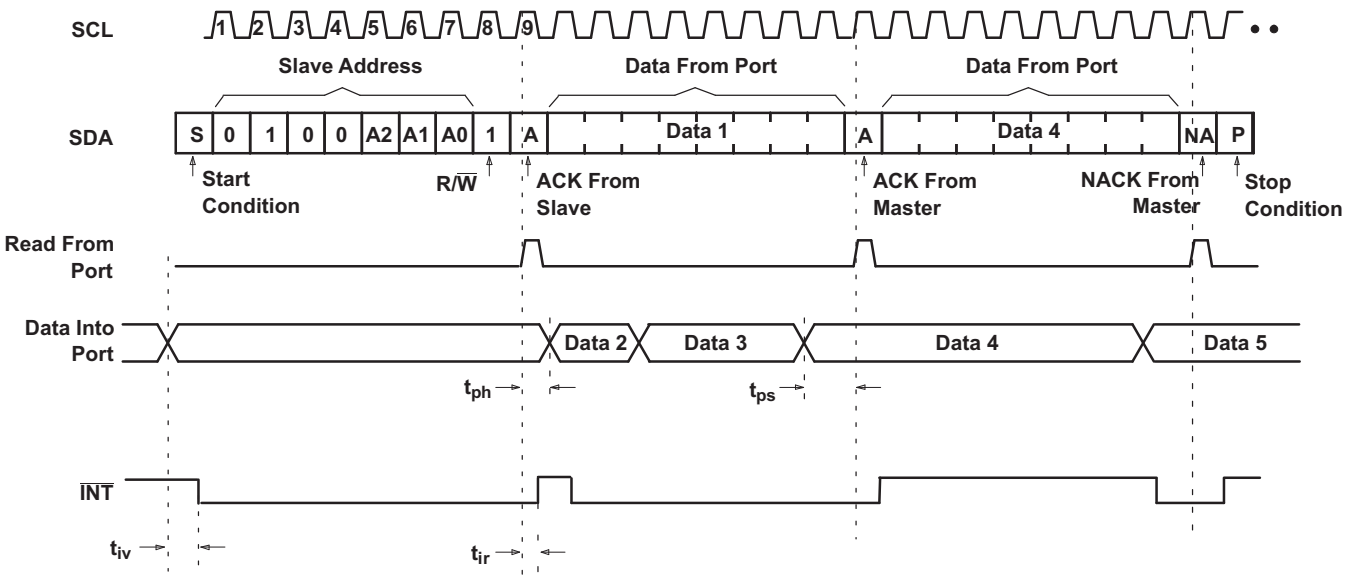


Figure 10. Read From Register



A. This figure assumes the command byte has previously been programmed with 00h.

B. Transfer of data can be stopped at any moment by a Stop condition.

C. 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 10 for these details.

Figure 11. Read From Input Port Register

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Absolute Maximum Ratings(1)

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(2)		–0.5	6	V
V_O	Output voltage range(2)		–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	
θ_{JA}	Package thermal impedance(3)	PW package		108	°C/W
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 × V_{CC}	5.5	V
		A2–A0, P7–P0	V_{CC} = 1.65 V to 2.3 V	0.7 × V_{CC}	5.5	
			V_{CC} = 2.3 V to 5.5 V	2	5.5	
V_{IL}	Low-level input voltage	SCL, SDA		–0.5	0.3 × V_{CC}	V
		A2–A0, P7–P0	V_{CC} = 1.65 V to 2.3 V	–0.5	0.3 × V_{CC}	
			V_{CC} = 2.3 V to 5.5 V	–0.5	0.8	
I_{OH}	High-level output current	P7–P0			–10	mA
I_{OL}	Low-level output current	P7–P0			25	mA
T_A	Operating free-air temperature			–40	85	°C

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Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP(1)	MAX	UNIT
V_{IK}	Input diode clamp voltage	I_I = –18 mA	1.65 V to 5.5 V	–1.2			V
V_{POR}	Power-on reset voltage	$V_I = V_{CC}$ or GND, I_O = 0	1.65 V to 5.5 V		1.5	1.65	V
V_{OH}	P-port high-level output voltage(2)	I_{OH} = –8 mA	1.65 V	1.2			
			2.3 V	1.8			V
			3 V	2.6			
			4.5 V	3.1			
			4.75 V	4.1			
		I_{OH} = –10 mA	1.65 V	1.1			
			2.3 V	1.7			
			3 V	2.5			
			4.5 V	3			
			4.75 V	4			
I_{OL}	SDA	V_{OL} = 0.4 V	1.65 V to 5.5 V	3	8		mA
	P port(3)	V_{OL} = 0.5 V	1.65 V	8	10		
			2.3 V	8	10		
			3 V	8	14		
			4.5 V	8	17		
			4.75 V	8	35		
		V_{OL} = 0.7 V	1.65 V	10	13		
			2.3 V	10	13		
			3 V	10	19		
			4.5 V	10	24		
			4.75 V	10	45		
	$\overline{INT}$	V_{OL} = 0.4 V	1.65 V to 5.5 V	3	10		
I_I	SCL, SDA	$V_I = V_{CC}$ or GND	1.65 V to 5.5 V			±1	µA
	A2–A0					±1	
I_{IH}	P port	$V_I = V_{CC}$	1.65 V to 5.5 V			1	µA
I_{IL}	P port	V_I = GND	1.65 V to 5.5 V			–100	µA
I_{CC}	Operating mode	$V_I = V_{CC}$, I_O = 0, I/O = inputs, f_{scl} = 400 kHz, No load	5.5 V		104	175	µA
			3.6 V		50	90	
			2.7 V		20	65	
			1.95 V		40	45	
		$V_I = V_{CC}$, I_O = 0, I/O = inputs, f_{scl} = 100 kHz, No load	5.5 V		60	150	
			3.6 V		15	40	
			2.7 V		8	20	
			1.95 V		20	20	
	Standby mode	V_I = GND, I_O = 0, I/O = inputs, f_{scl} = 0 kHz, No load	5.5 V		450	700	
			3.6 V		300	600	
			2.7 V		225	500	
			1.95 V		225	500	
		$V_I = V_{CC}$, I_O = 0, I/O = inputs, f_{scl} = 0 kHz, No load	5.5 V		2.8	3	
			3.6 V		1.6	1.8	
			2.7 V		1.4	1.6	
			1.95 V		1.4	1.6	

(1) All typical values are at nominal supply voltage (2.5-V, 3.3-V, or 5-V V_{CC}) and T_A = 25°C.
(2) The total current sourced by all I/Os must be limited to 85 mA.
(3) Each I/O must be externally limited to a maximum of 25 mA, and the P port (P0 to P7) must be limited to a maximum current of 200 mA.

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Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP(1)	MAX	UNIT
ΔI_{CC}	Additional current in standby mode	One input at V_{CC} – 0.6 V, Other inputs at V_{CC} or GND	1.65 V to 5.5 V			1.5	mA
		Every LED I/O at V_I = 4.3 V; f_{scl} = 0 kHz	5.5 V			1	
C_I	SCL	$V_I = V_{CC}$ or GND	1.65 V to 5.5 V		4	5	pF
C_{io}	SDA	$V_{IO} = V_{CC}$ or GND	1.65 V to 5.5 V		5.5	6.5	pF
	P port				8	9.5	

I²C Interface Timing Requirements

over operating free-air temperature range (unless otherwise noted) (see Figure 12)

			STANDARD MODE I²C BUS		FAST MODE I²C BUS		UNIT
			MIN	MAX	MIN	MAX	
f_{scl}	I²C clock frequency		0	100	0	400	kHz
t_{sch}	I²C clock high time		4		0.6		µs
t_{scl}	I²C clock low time		4.7		1.3		µs
t_{sp}	I²C spike time			50		50	ns
t_{sds}	I²C serial-data setup time		250		100		ns
t_{sdh}	I²C serial-data hold time		0		0		ns
t_{icr}	I²C input rise time			1000	$20 + 0.1C_b$ (1)	300	ns
t_{icf}	I²C input fall time			300	$20 + 0.1C_b$ (1)	300	ns
t_{ocf}	I²C output fall time	10-pF to 400-pF bus		300	$20 + 0.1C_b$ (1)	300	ns
t_{buf}	I²C bus free time between Stop and Start		4.7		1.3		µs
t_{sts}	I²C Start or repeated Start condition setup		4.7		0.6		µs
t_{sth}	I²C Start or repeated Start condition hold		4		0.6		µs
t_{sps}	I²C Stop condition setup		4		0.6		µs
$t_{vd(data)}$	Valid data time	SCL low to SDA output valid	300		50		ns
$t_{vd(ack)}$	Valid data time of ACK condition	ACK signal from SCL low to SDA (out) low	0.3	3.45	0.1	0.9	µs
C_b	I²C bus capacitive load			400		400	ns

(1) C_b = Total capacitive load of one bus in pF

Switching Characteristics

over operating free-air temperature range (unless otherwise noted) (see Figure 13 and Figure 14)

PARAMETER		FROM (INPUT)	TO (OUTPUT)	STANDARD MODE I²C BUS		FAST MODE I²C BUS		UNIT
				MIN	MAX	MIN	MAX	
t_{iv}	Interrupt valid time	P port	$\overline{INT}$		4		4	µs
t_{ir}	Interrupt reset delay time	SCL	$\overline{INT}$		4		4	µs
t_{pv}	Output data valid	SCL	P7–P0		200		200	ns
t_{ps}	Input data setup time	P port	SCL	100		100		ns
t_{ph}	Input data hold time	P port	SCL	1		1		µs

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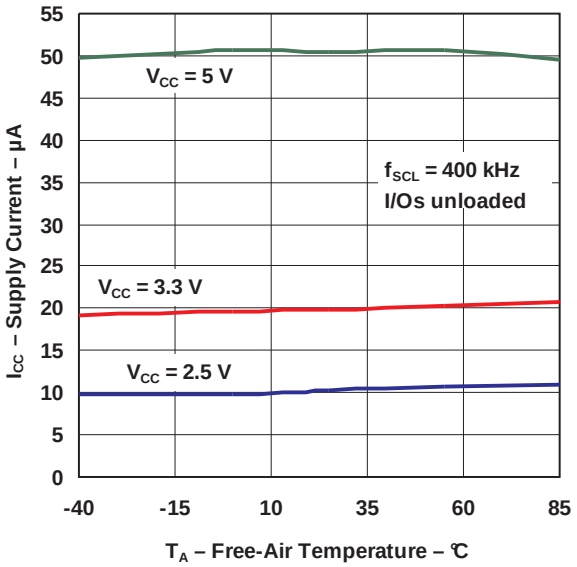
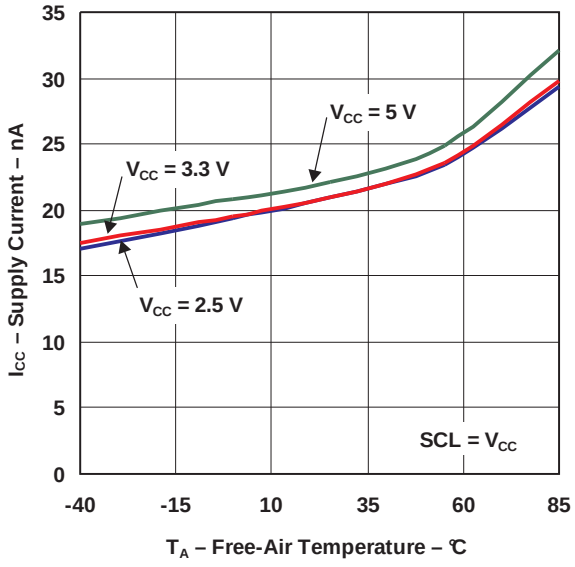
TYPICAL CHARACTERISTICS

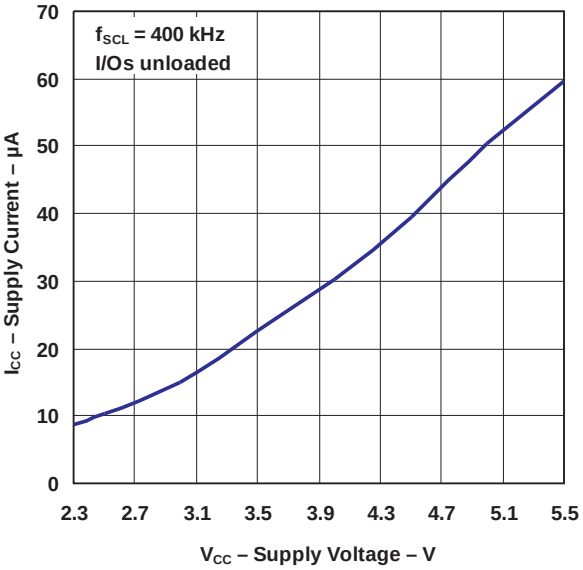
SUPPLY CURRENT vs TEMPERATURE



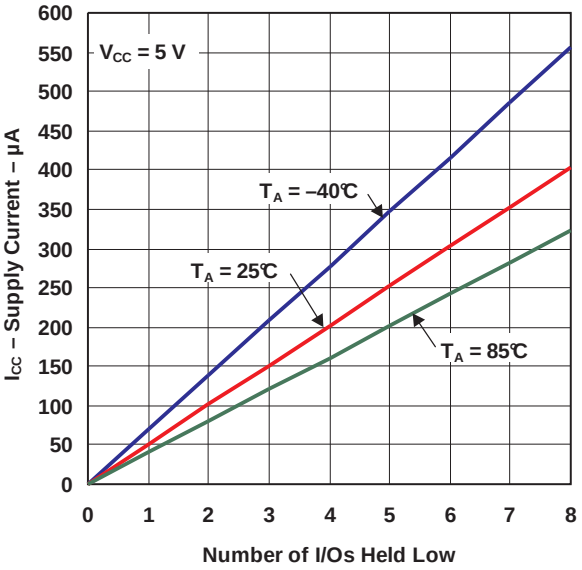
QUIESCENT SUPPLY CURRENT vs TEMPERATURE



SUPPLY CURRENT vs SUPPLY VOLTAGE



SUPPLY CURRENT vs NUMBER OF I/Os HELD LOW



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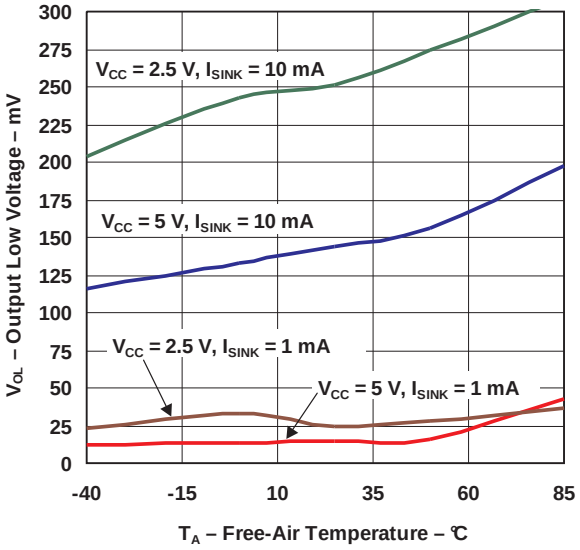
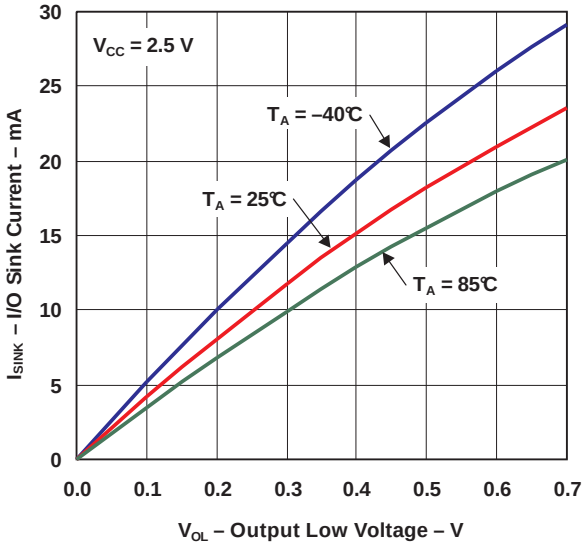
TYPICAL CHARACTERISTICS (continued)

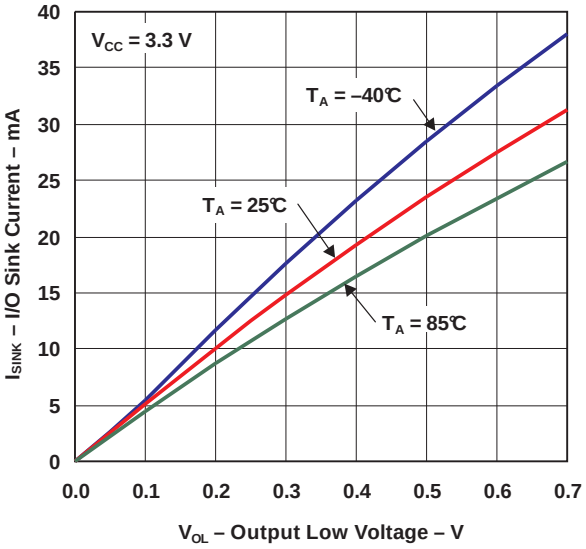
I/O OUTPUT LOW VOLTAGE vs TEMPERATURE



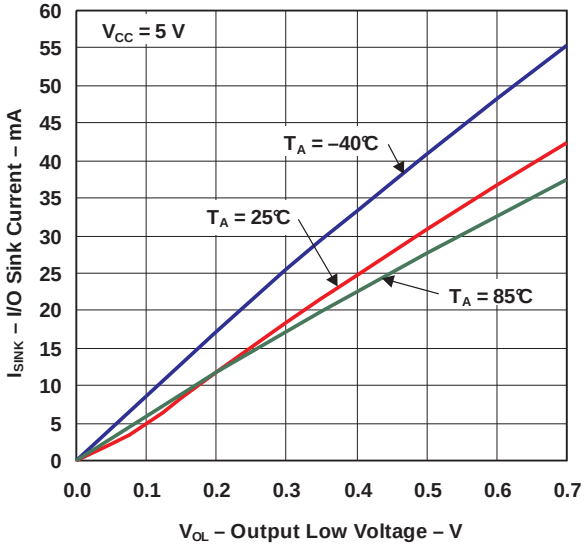
I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



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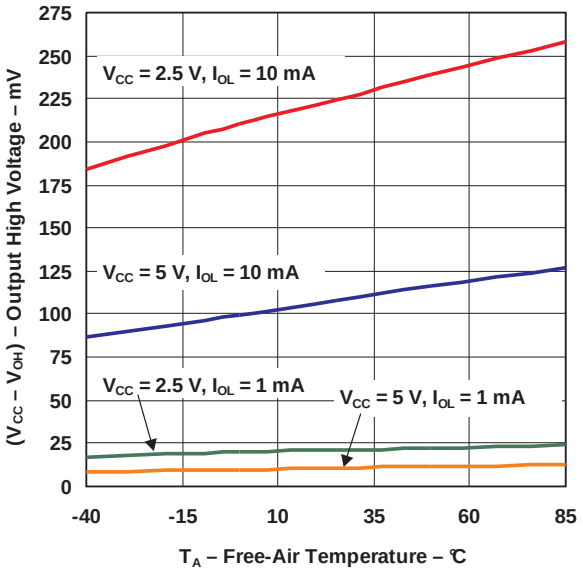
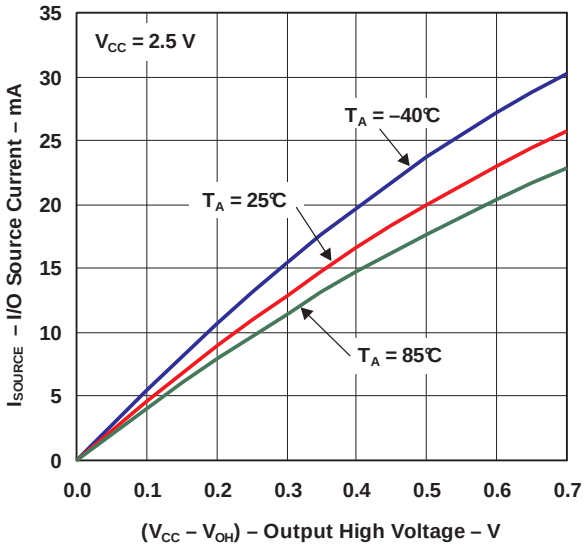
TYPICAL CHARACTERISTICS (continued)

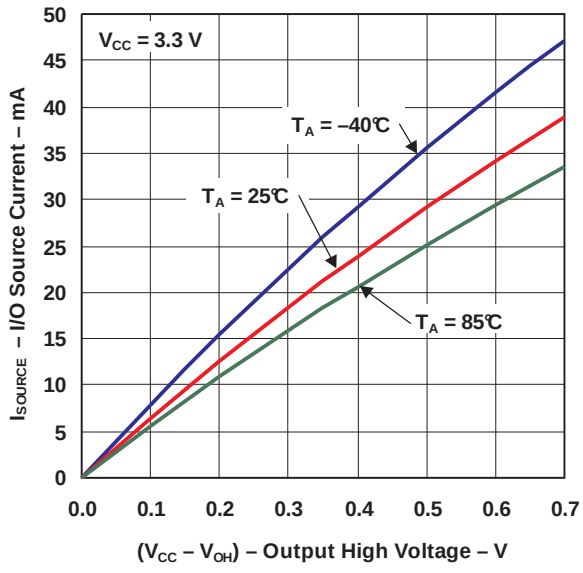
I/O OUTPUT HIGH VOLTAGE vs TEMPERATURE



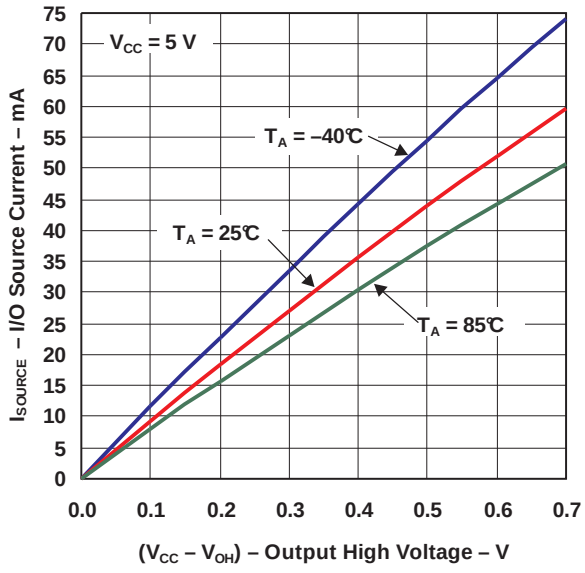
I/O SOURCE CURRENT vs OUTPUT HIGH VOLTAGE



I/O SOURCE CURRENT vs OUTPUT HIGH VOLTAGE



I/O SOURCE CURRENT vs OUTPUT HIGH VOLTAGE



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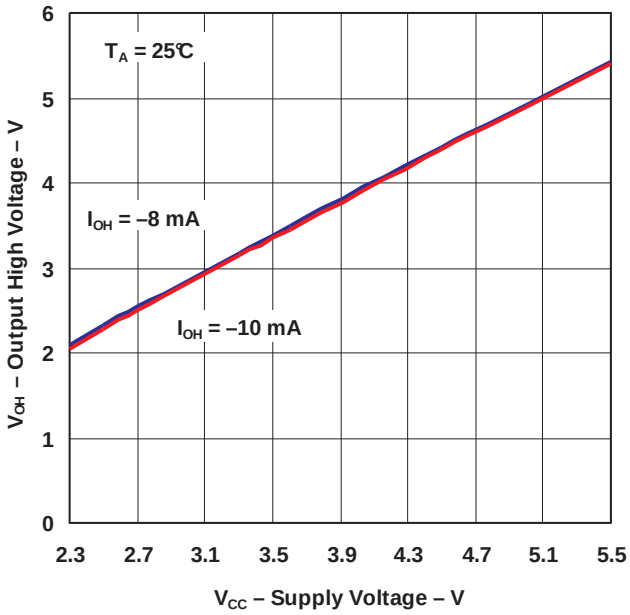
TYPICAL CHARACTERISTICS (continued)

OUTPUT HIGH VOLTAGE
vs
SUPPLY VOLTAGE



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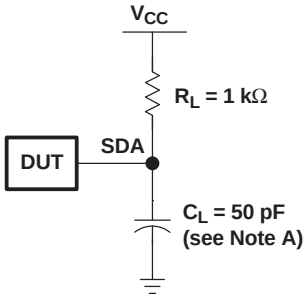
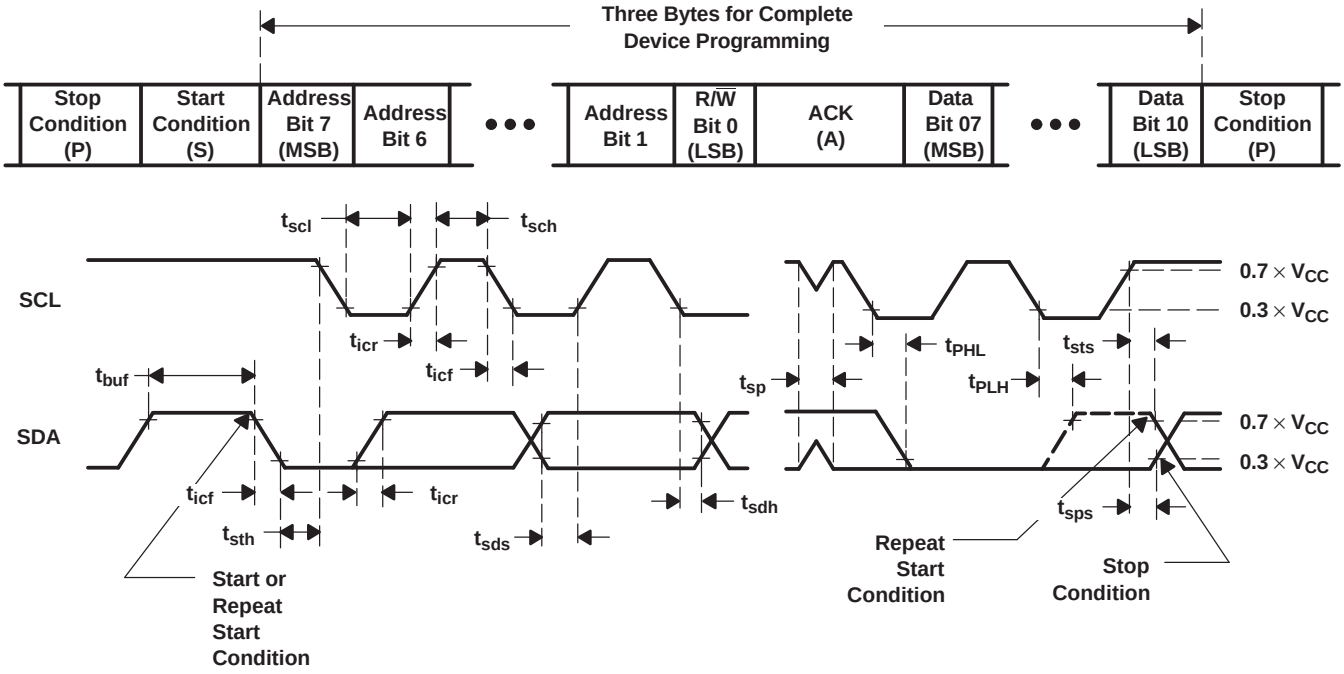
PARAMETER MEASUREMENT INFORMATION



SDA LOAD CONFIGURATION



VOLTAGE WAVEFORMS

BYTE	DESCRIPTION
1	I^2C 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 ≤ 10 MHz, Z_O = 50 Ω, t_r/t_f ≤ 30 ns.

C. All parameters and waveforms are not applicable to all devices.

Figure 12. I^2C Interface Load Circuit and Voltage Waveforms

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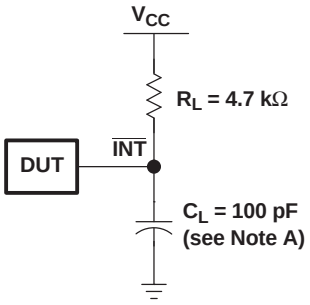
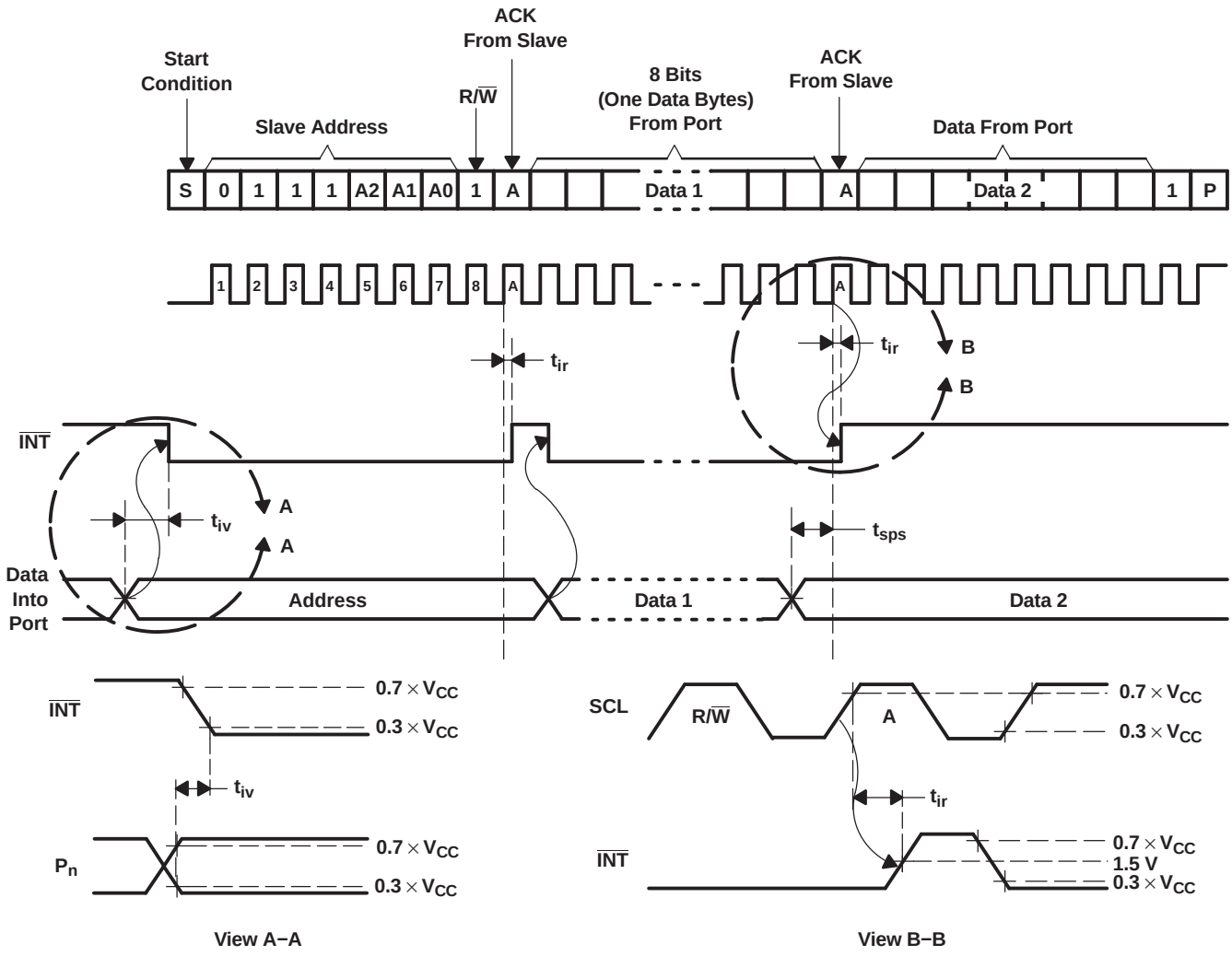
PARAMETER MEASUREMENT INFORMATION (continued)



INTERRUPT LOAD CONFIGURATION



View A–A View B–B

A. C_L includes probe and jig capacitance.

B. All inputs are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, t_r/t_f ≤ 30 ns.

C. All parameters and waveforms are not applicable to all devices.

Figure 13. Interrupt Load Circuit and Voltage Waveforms

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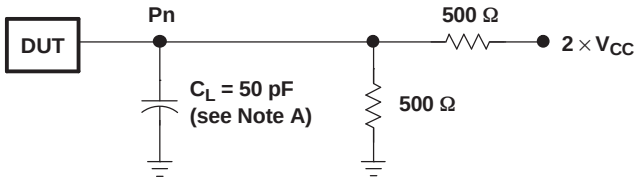
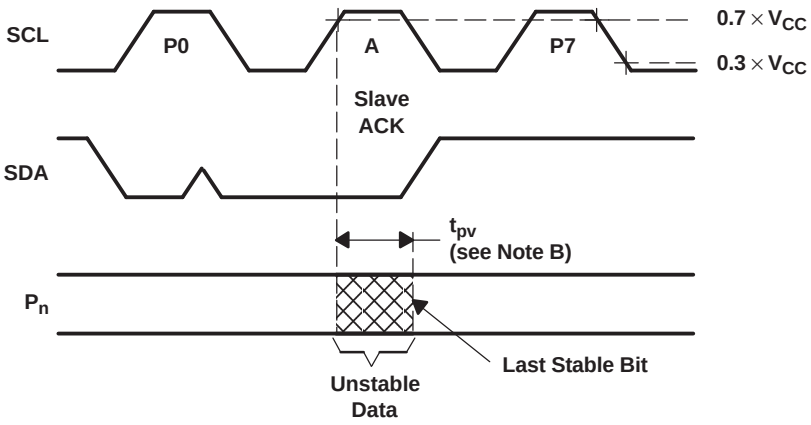
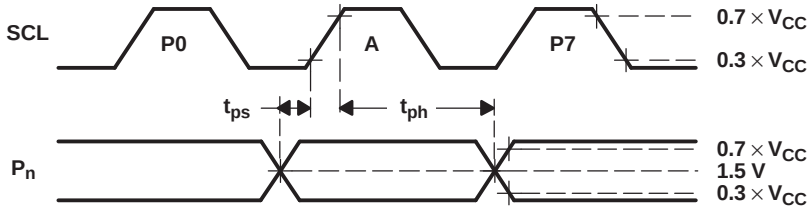
PARAMETER MEASUREMENT INFORMATION (continued)



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 × V_{CC} on SCL to 50% I/O pin output.
C. All inputs are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, t_r/t_f ≤ 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 14. P-Port Load Circuit and Voltage Waveforms

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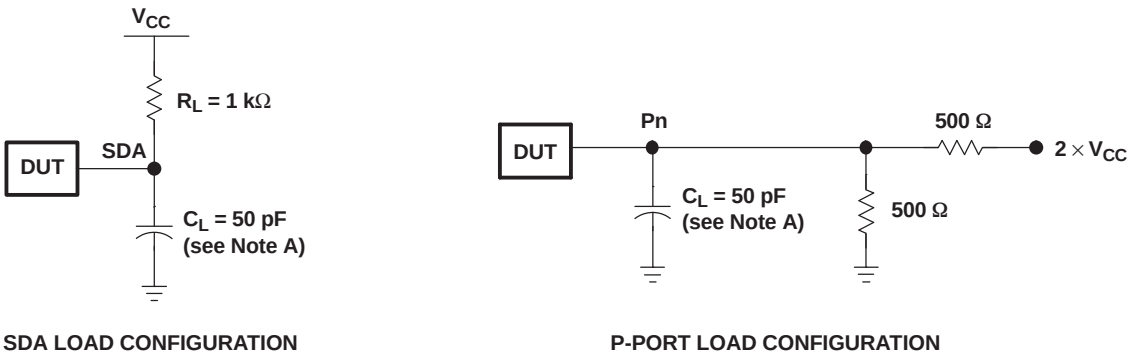
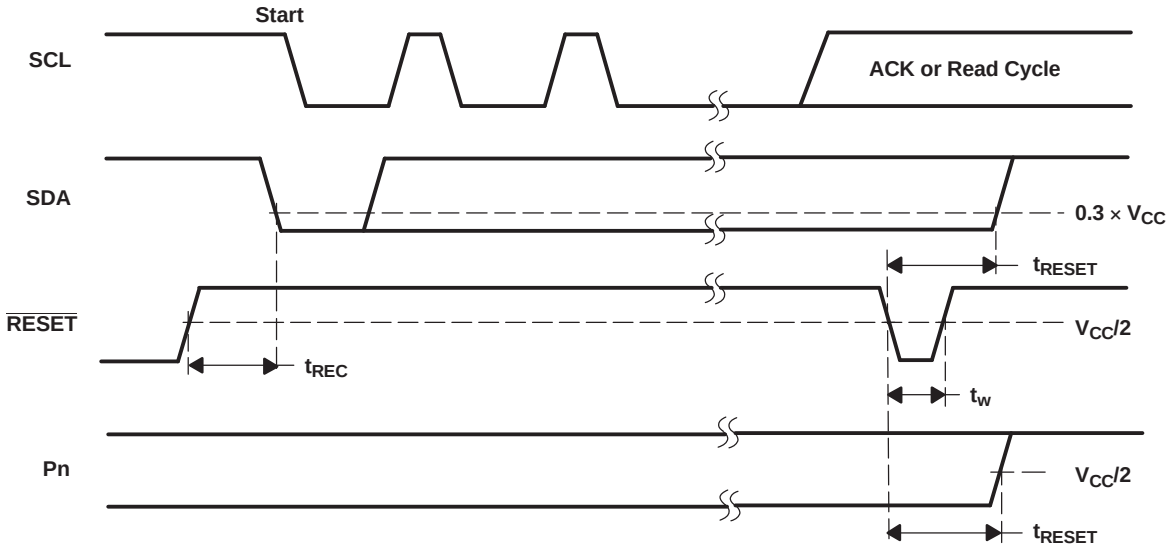
PARAMETER MEASUREMENT INFORMATION (continued)



SDA LOAD CONFIGURATION

P-PORT LOAD CONFIGURATION



A. C_L includes probe and jig capacitance.

B. All inputs are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, t_r/t_f ≤ 30 ns.

C. All parameters and waveforms are not applicable to all devices.

Figure 15. Reset Load Circuits and Voltage Waveforms

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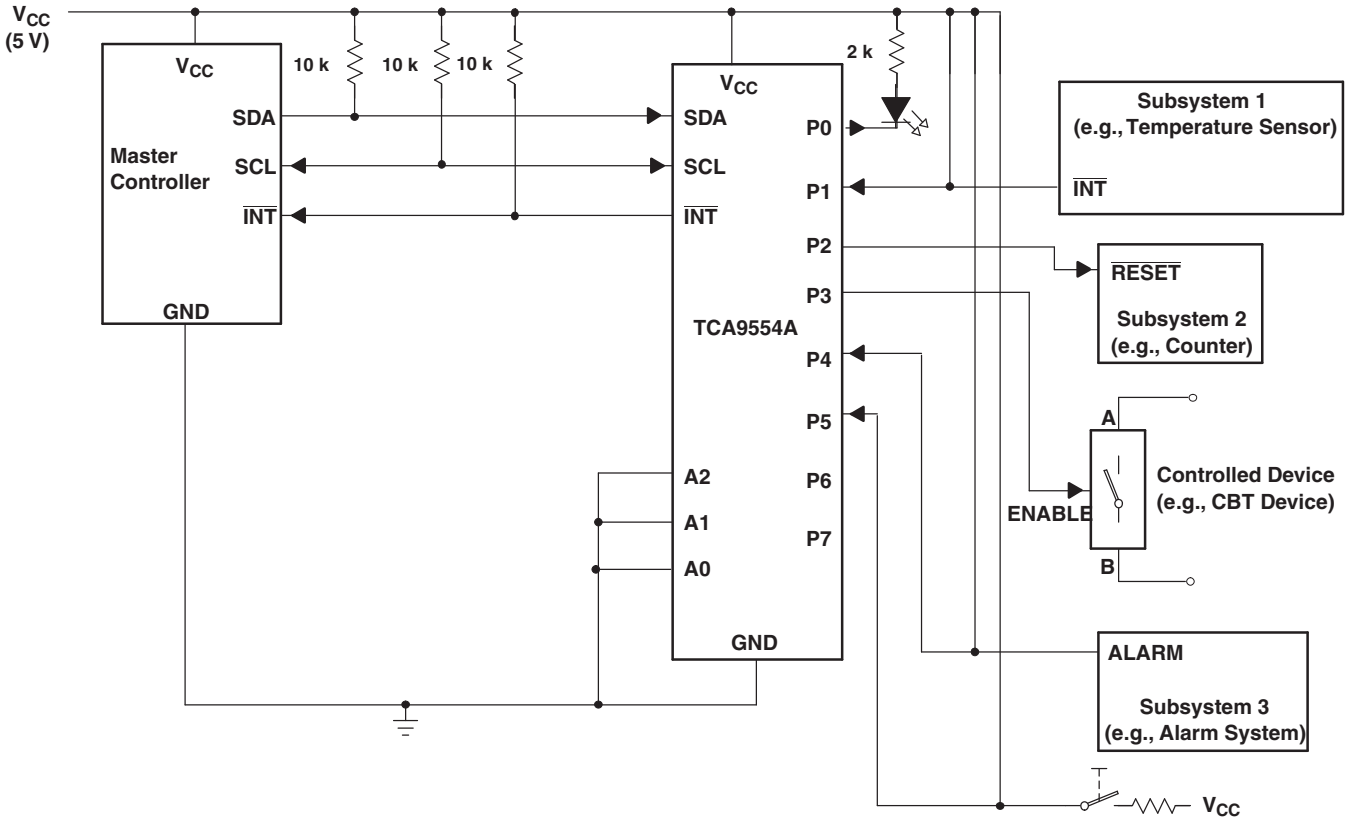
APPLICATION INFORMATION

Figure 16 shows an application in which the TCA9554 can be used.



A. Device address is configured as 0100000 for this example.

B. P0, P2, and P3 are configured as outputs.

C. P1, P4, and P5 are configured as inputs.

D. P6 and P7 are not used and have internal 100-kΩ pullup resistors to protect them from floating.

Figure 16. Typical Application

Minimizing I_{CC} When I/Os Control LEDs

When the I/Os are used to control LEDs, they are normally connected to V_{CC} through a resistor as shown in Figure 16. 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 supply current, I_{CC}, increases as V_{IN} becomes lower than V_{CC} and is specified as ΔI_{CC} in *Electrical Characteristics*.

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 17 shows a high-value resistor in parallel with the LED. Figure 18 shows V_{CC} less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V_{IN} at or above V_{CC} and prevents additional supply-current consumption when the LED is off.

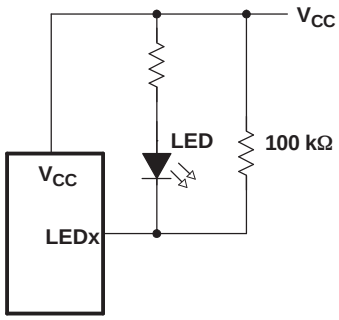


Figure 17. High-Value Resistor in Parallel With the LED

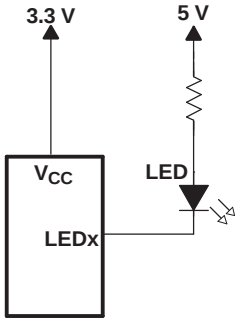


Figure 18. Device Supplied by a Lower Voltage

Power-On Reset Requirements

In the event of a glitch or data corruption, TCA9554 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 19 and Figure 20.

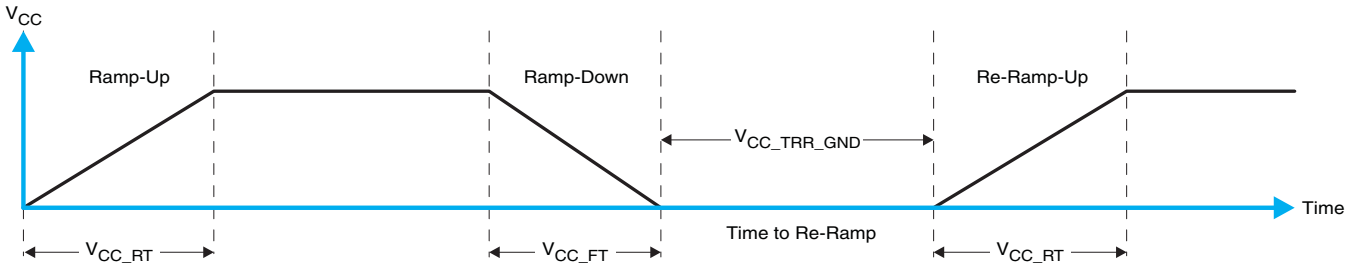


Figure 19. V_{CC} is Lowered Below 0.2 V or 0 V and Then Ramped Up to V_{CC}

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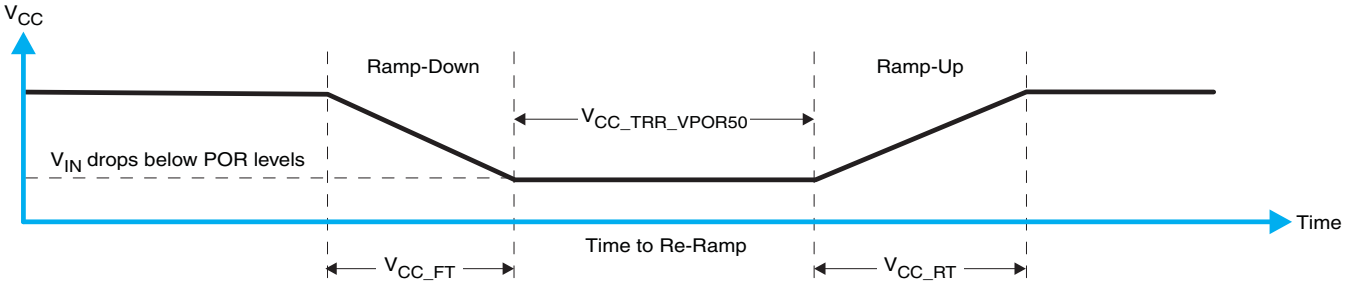

Figure 20. V_{CC} is Lowered Below the POR Threshold, Then Ramped Back Up to V_{CC}

Table 9 specifies the performance of the power-on reset feature for TCA9554 for both types of power-on reset.

Table 9. RECOMMENDED SUPPLY SEQUENCING AND RAMP RATES(1)

PARAMETER			MIN	TYP	MAX	UNIT
V_{CC_FT}	Fall rate	See Figure 19	1		100	ms
V_{CC_RT}	Rise rate	See Figure 19	0.01		100	ms
$V_{CC_TRR_GND}$	Time to re-ramp (when V_{CC} drops to GND)	See Figure 19	40			µs
$V_{CC_TRR_POR50}$	Time to re-ramp (when V_{CC} drops to V_{POR_MIN} – 50 mV)	See Figure 20	40			µs
V_{CC_GH}	Level that V_{CCP} can glitch down to, but not cause a functional disruption when V_{CCX_GW} = 1 µs	See Figure 21			1.2	V
V_{CC_GW}	Glitch width that will not cause a functional disruption when V_{CCX_GH} = 0.5 × V_{CCx}	See Figure 21			10	µs
V_{PORF}	Voltage trip point of POR on falling V_{CC}		0.767		1.144	V
V_{PORR}	Voltage trip point of POR on rising V_{CC}		1.033		1.428	V

(1) T_A = –40°C to 85°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 21 and Table 9 provide more information on how to measure these specifications.

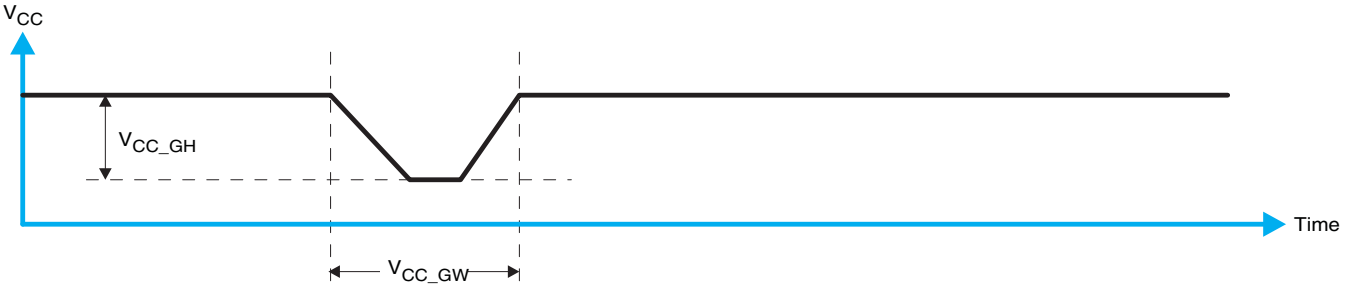

Figure 21. Glitch Width and Glitch Height

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^2C/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 22 and Table 9 provide more details on this specification.

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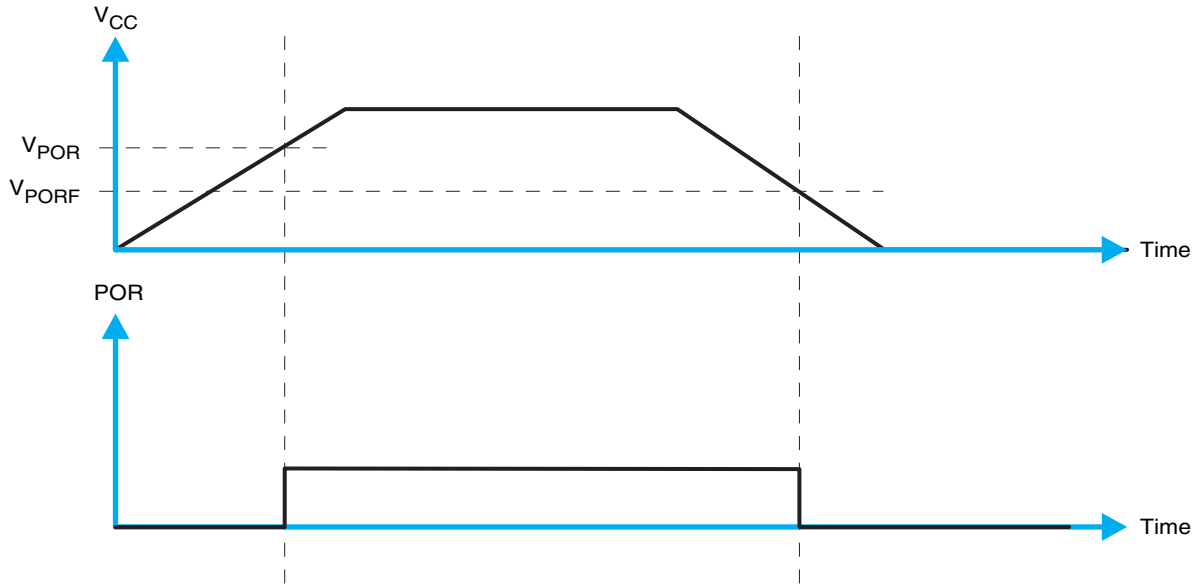

Figure 22. V_{POR}

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REVISION HISTORY

Changes from Original (November 2011) to Revision A	Page
• Updated part number in DESCRIPTION/ORDERING INFORMATION section.	2

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
TCA9554PWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	

(1) 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.

(2) 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)

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

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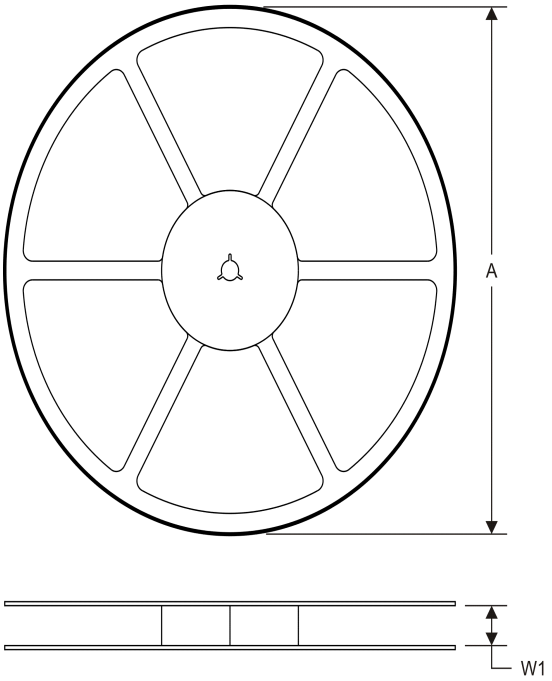
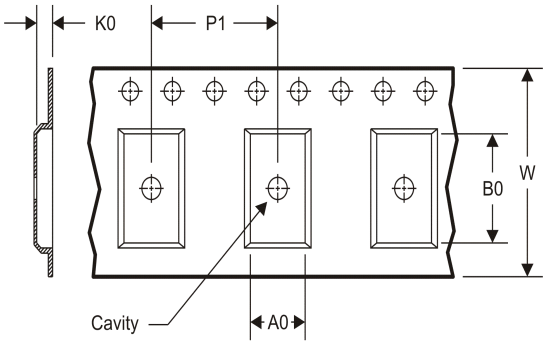
TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



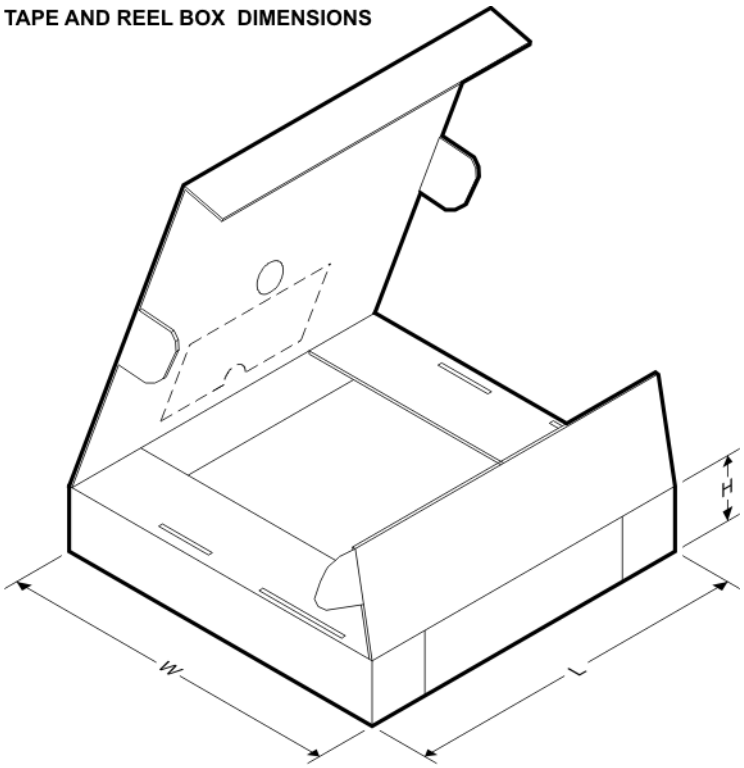
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
TCA9554PWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

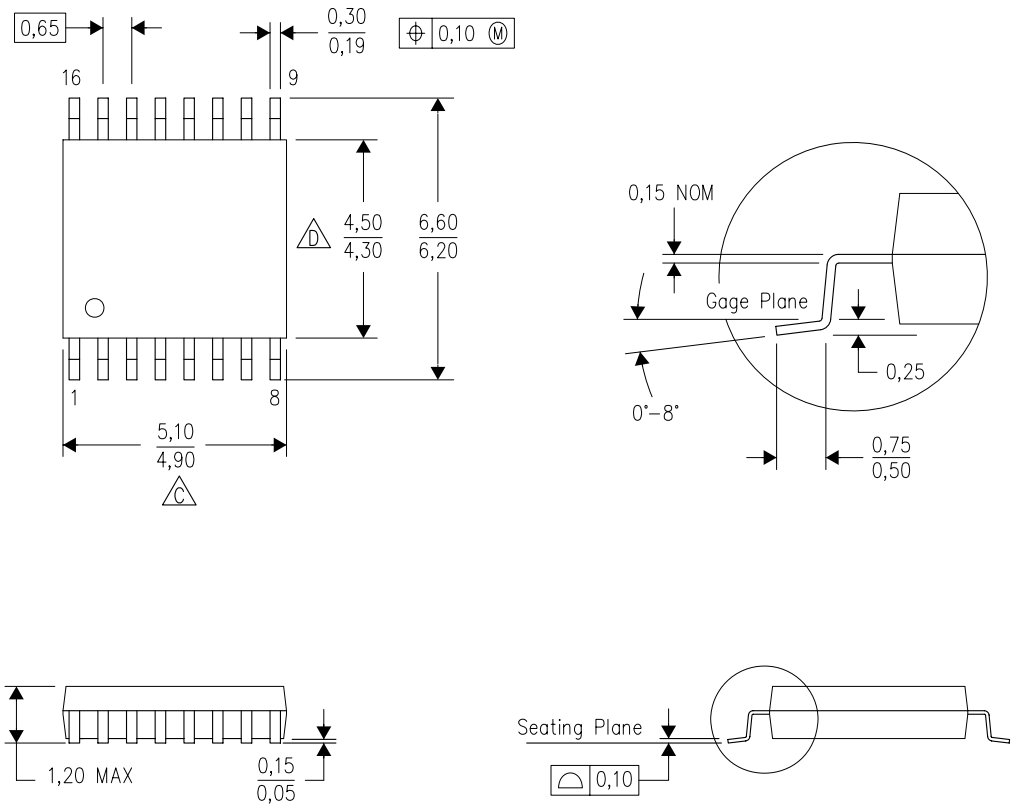
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCA9554PWR	TSSOP	PW	16	2000	367.0	367.0	35.0

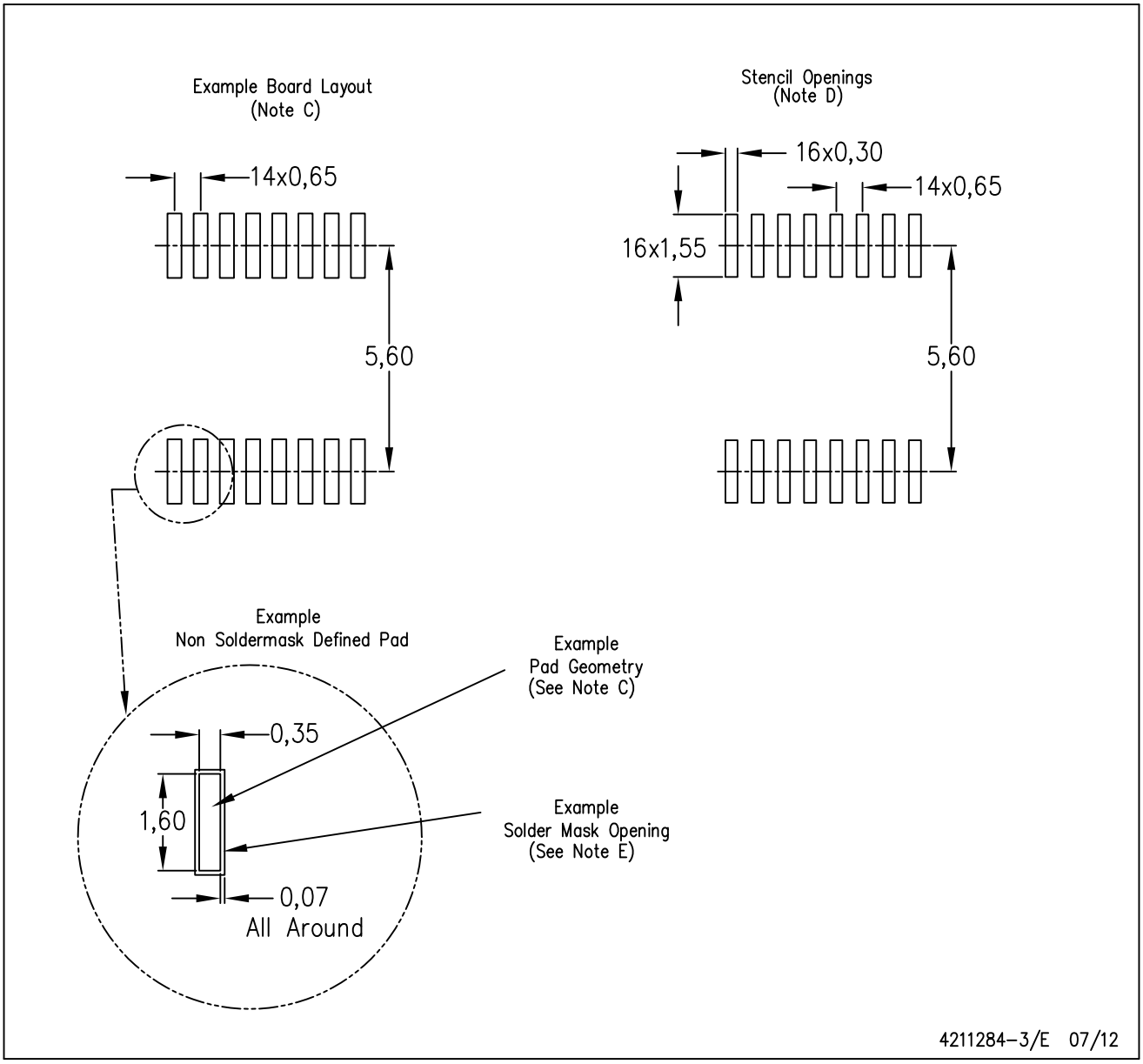
PW (R–PDSO–G16) PLASTIC SMALL OUTLINE



4040064–4/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–G16) 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 designs.
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.

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