

# PCA9535 Remote 16-BIT I<sup>2</sup>C and SMBus Low-Power I/O Expander With Interrupt Output and Configuration Registers

## 1 Features

- Low standby-current consumption of 1  $\mu$ A Max
- I<sup>2</sup>C to Parallel port expander
- Open-drain active-low interrupt output
- 5-V Tolerant I/O ports
- Compatible with most microcontrollers
- 400-kHz Fast I<sup>2</sup>C Bus
- Address by three hardware address pins for use of up to eight devices
- Polarity inversion register
- 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)

## 2 Description

This 16-bit I/O expander for the two-line bidirectional bus (I<sup>2</sup>C) is designed for 2.3-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 PCA9535 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 Port 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 PCA9535 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<sup>2</sup>C/SMBus state machine.

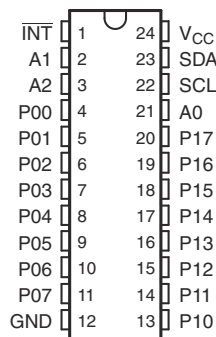
The PCA9535 open-drain interrupt ( $\overline{\text{INT}}$ ) output is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system master that an input state has changed.

### Device Information (1)

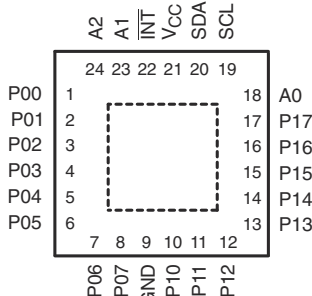
PART NUMBER	PACKAGE	BODY SIZE (NOM)
PCA9535	SSOP (16)	6.20 mm $\times$ 5.30 mm
	VQFN (16)	4.00 mm $\times$ 4.00 mm
	QFN (16)	3.00 mm $\times$ 3.00 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

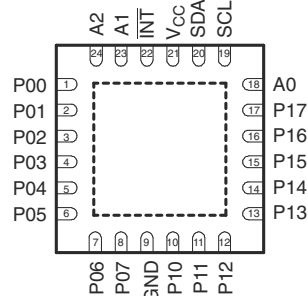
DB, DBQ, DGV, DW, OR PW PACKAGE  
(TOP VIEW)



RGE PACKAGE  
(TOP VIEW)



RTW PACKAGE  
(TOP VIEW)



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## 3 Revision History

Changes from Revision J (May 2014) to Revision K (March 2021)	Page
• Moved the "Storage temperature range" to the <i>Absolute Maximum Ratings</i> .....	<b>5</b>
• Moved the "Package thermal impedance" to the <i>Thermal Resistance Characteristic</i> .....	<b>5</b>
• Changed the V <sub>CC</sub> Supply voltage Max value From: 5.5 V To: V <sub>CC</sub> in the <i>Recommended Operating Conditions</i> .....	<b>5</b>
• Changed the V <sub>PORR</sub> Typ value From: 1.5 V To 1.2 V in the <i>Electrical Characteristics</i> .....	<b>6</b>
• Added V <sub>PORF</sub> to the <i>Electrical Characteristics</i> .....	<b>6</b>
• Changed the I <sub>CC</sub> Standby mode values in the <i>Electrical Characteristics</i> .....	<b>6</b>
• Changed the C <sub>i</sub> SCL Max value From: 7 pF To: 8 pF in the <i>Electrical Characteristics</i> .....	<b>6</b>
• Changed the C <sub>io</sub> SDA Max value From: 7 pF To: 9.5 pF in the <i>Electrical Characteristics</i> .....	<b>6</b>
• Changed the <i>Typical Characteristics</i> graphs.....	<b>8</b>
• Changed the <i>Power Supply Recommendations</i> .....	<b>26</b>

Changes from Revision I (May 2008) to Revision J (May 2014)	Page
• Added Interrupt Errata section.....	<b>16</b>

## 4 Description Continued

$\overline{\text{INT}}$  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 PCA9535 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.

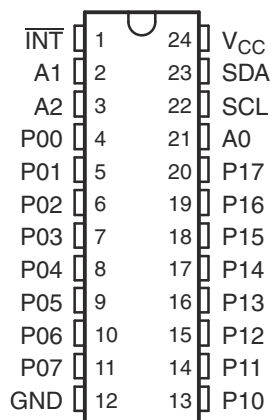
Although pin-to-pin and I<sup>2</sup>C address compatible with the PCF8575, software changes are required due to the enhancements.

The PCA9535 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.

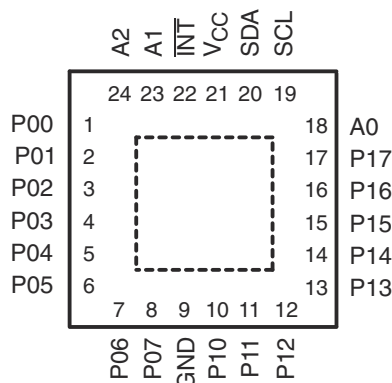
Three hardware pins (A0, A1, and A2) are used to program and vary the fixed I<sup>2</sup>C address and allow up to eight devices to share the same I<sup>2</sup>C bus or SMBus. The fixed I<sup>2</sup>C address of the PCA9535 is the same as the PCA9555, PCF8575, PCF8575C, and PCF8574, allowing up to eight of these devices in any combination to share the same I<sup>2</sup>C bus or SMBus.

## 5 Pin Configuration and Functions

DB, DBQ, DGV, DW, OR PW PACKAGE  
(TOP VIEW)



RGE PACKAGE  
(TOP VIEW)



RTW PACKAGE  
(TOP VIEW)

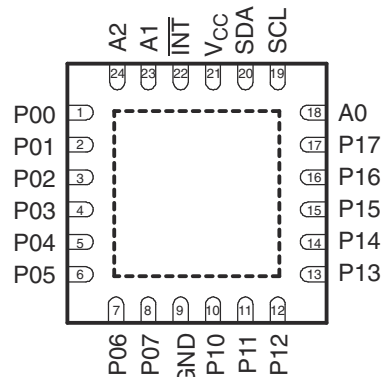


Table 5-1. Pin Functions

PIN			DESCRIPTION
NAME	SOIC (D), SSOP (DB), QSOP (DBQ), TSSOP (PW), AND TVSOP (DGV)	QFN (RGE AND RTW)	
INT	1	22	Interrupt output. Connect to $V_{CC}$ through a pullup resistor.
A1	2	23	Address input. Connect directly to $V_{CC}$ or ground.
A2	3	24	Address input. Connect directly to $V_{CC}$ or ground.
P00	4	1	P-port input/output. Push-pull design structure.
P01	5	2	P-port input/output. Push-pull design structure.
P02	6	3	P-port input/output. Push-pull design structure.
P03	7	4	P-port input/output. Push-pull design structure.
P04	8	5	P-port input/output. Push-pull design structure.
P05	9	6	P-port input/output. Push-pull design structure.
P06	10	7	P-port input/output. Push-pull design structure.
P07	11	8	P-port input/output. Push-pull design structure.
GND	12	9	Ground
P10	13	10	P-port input/output. Push-pull design structure.
P11	14	11	P-port input/output. Push-pull design structure.
P12	15	12	P-port input/output. Push-pull design structure.
P13	16	13	P-port input/output. Push-pull design structure.
P14	17	14	P-port input/output. Push-pull design structure.
P15	18	15	P-port input/output. Push-pull design structure.
P16	19	16	P-port input/output. Push-pull design structure.
P17	20	17	P-port input/output. Push-pull design structure.
A0	21	18	Address input. Connect directly to $V_{CC}$ or ground.
SCL	22	19	Serial clock bus. Connect to $V_{CC}$ through a pullup resistor.
SDA	23	20	Serial data bus. Connect to $V_{CC}$ through a pullup resistor.
$V_{CC}$	24	21	Supply voltage

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage range	–0.5	6	V
V <sub>I</sub>	Input voltage range <sup>(2)</sup>	–0.5	6	V
V <sub>O</sub>	Output voltage range <sup>(2)</sup>	–0.5	6	V
I <sub>IK</sub>	Input clamp current	V <sub>I</sub> < 0	–20	mA
I <sub>OK</sub>	Output clamp current	V <sub>O</sub> < 0	–20	mA
I <sub>IOK</sub>	Input/output clamp current	V <sub>O</sub> < 0 or V <sub>O</sub> > V <sub>CC</sub>	±20	mA
I <sub>OL</sub>	Continuous output low current	V <sub>O</sub> = 0 to V <sub>CC</sub>	50	mA
I <sub>OH</sub>	Continuous output high current	V <sub>O</sub> = 0 to V <sub>CC</sub>	–50	mA
I <sub>CC</sub>	Continuous current through GND		–250	mA
	Continuous current through V <sub>CC</sub>		160	
T <sub>stg</sub>	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.

### 6.2 ESD Ratings

			MIN	MAX	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>	0	2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	0	1000	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

			MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage		2.3	V <sub>CC</sub>	V
V <sub>IH</sub>	High-level input voltage	SCL, SDA	0.7 × V <sub>CC</sub>	V <sub>CC</sub>	V
		A2–A0, P07–P00, P17–P10	0.7 × V <sub>CC</sub>	5.5	
V <sub>IL</sub>	Low-level input voltage	SCL, SDA	–0.5	0.3 × V <sub>CC</sub>	V
		A2–A0, P07–P00, P17–P10	–0.5	0.3 × V <sub>CC</sub>	
I <sub>OH</sub>	High-level output current	P07–P00, P17–P10		–10	mA
I <sub>OL</sub>	Low-level output current	P07–P00, P17–P10		25	mA
T <sub>A</sub>	Operating free-air temperature		–40	85	°C

## 6.4 Thermal Resistance Characteristics

THERMAL METRIC <sup>(1)</sup>		PCA9535						UNIT
		DB (SSOP)	DBQ (SSOP)	DVG (TVSOP)	DW (SOIC)	PW (TSSOP)	RGV (VQFN)	
		16 PINS	16 PINS	16 PINS	16 PINS	16 PINS	16 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	92.9	61	86	108.8	48.4	43.6	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC package thermal metrics](#) application report.

## 6.5 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	2.3 V to 5.5 V	−1.2			V
V <sub>PORR</sub>	Power-on reset voltage, V <sub>CC</sub> rising	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0			1.2	1.65	V
V <sub>PORF</sub>	Power-on reset voltage, V <sub>CC</sub> falling	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0		0.75	1		V
V <sub>OH</sub>	P-port high-level output voltage <sup>(2)</sup>	I <sub>OH</sub> = −8 mA	2.3 V	1.8			V
			3 V	2.6			
			4.75 V	4.1			
		I <sub>OH</sub> = −10 mA	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	2.3 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		
	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	2.3 V to 5.5 V			±1	μA
	A2–A0					±1	
I <sub>IH</sub>	P port	V <sub>I</sub> = V <sub>CC</sub>	2.3 V to 5.5 V			1	μA
I <sub>IL</sub>	P port	V <sub>I</sub> = GND	2.3 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	
	Standby mode	V <sub>I</sub> = GND, I <sub>O</sub> = 0, I/O = inputs, f <sub>SCL</sub> = 0 kHz	5.5 V		1.5	8.7	
			3.6 V		0.9	4	
			2.7 V		0.6	3	
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	2.3 V to 5.5 V			200	μA
C <sub>I</sub>	SCL	V <sub>I</sub> = V <sub>CC</sub> or GND	2.3 V to 5.5 V		3	8	pF
C <sub>io</sub>	SDA	V <sub>IO</sub> = V <sub>CC</sub> or GND	2.3 V to 5.5 V		3	9.5	pF
	P port				3.7	9.5	

- (1) All typical values are at nominal supply voltage (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 limited externally 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).

## 6.6 I<sup>2</sup>C Interface Timing Requirements

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 7-1](#))

			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<sub>b</sub> = total capacitance of one bus line in pF

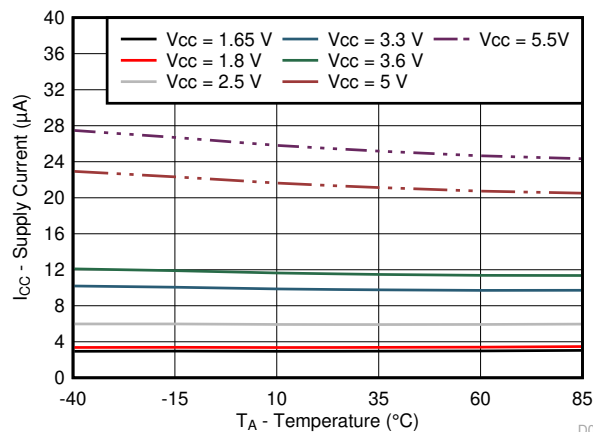
## 6.7 Switching Characteristics

over recommended operating free-air temperature range, C<sub>L</sub> ≤ 100 pF (unless otherwise noted) (see [Figure 7-2](#) and [Figure 7-3](#))

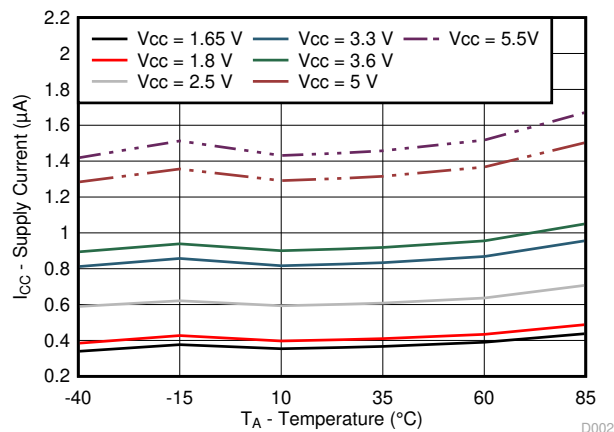
PARAMETER	FROM (INPUT)	TO (OUTPUT)	MIN	MAX	UNIT
t <sub>iv</sub>	Interrupt valid time	P port		4	μs
t <sub>ir</sub>	Interrupt reset delay time	SCL		4	μs
t <sub>pV</sub>	Output data valid	SCL		200	ns
t <sub>ps</sub>	Input data setup time	P port	150		ns
t <sub>ph</sub>	Input data hold time	P port	1		μs

## 6.8 Typical Characteristics

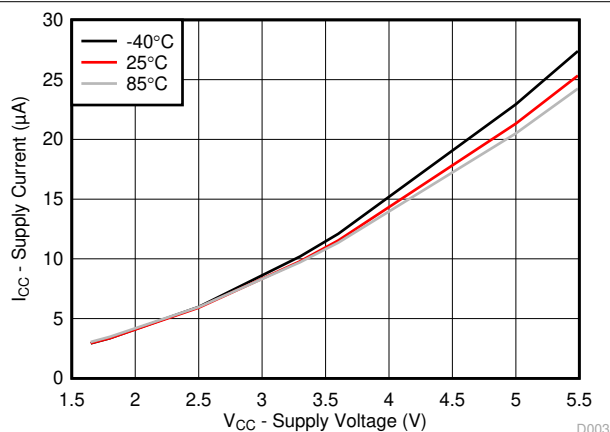
$T_A = 25^\circ\text{C}$  (unless otherwise noted)



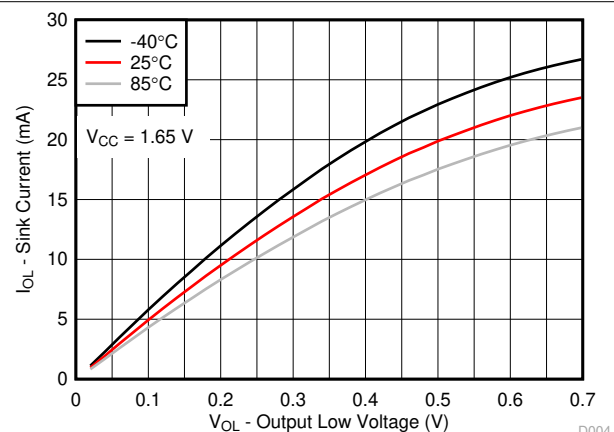
**Figure 6-1. Supply Current vs Temperature for Different Supply Voltage ( $V_{CC}$ )**



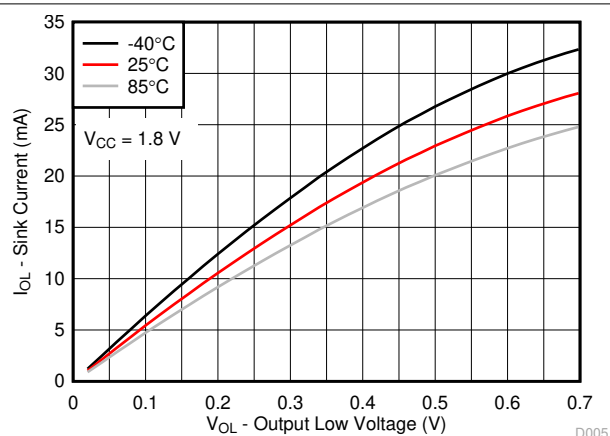
**Figure 6-2. Standby Supply Current vs Temperature for Different Supply Voltage ( $V_{CC}$ )**



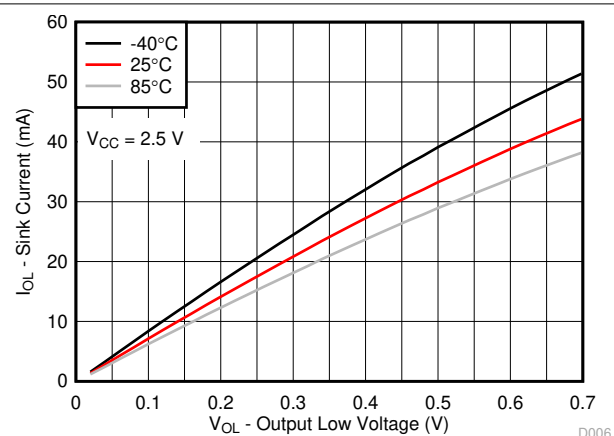
**Figure 6-3. Supply Current vs Supply Voltage for Different Temperature ( $T_A$ )**



**Figure 6-4. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 1.65\text{ V}$**



**Figure 6-5. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 1.8\text{ V}$**



**Figure 6-6. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 2.5\text{ V}$**



## 6.8 Typical Characteristics (continued)

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

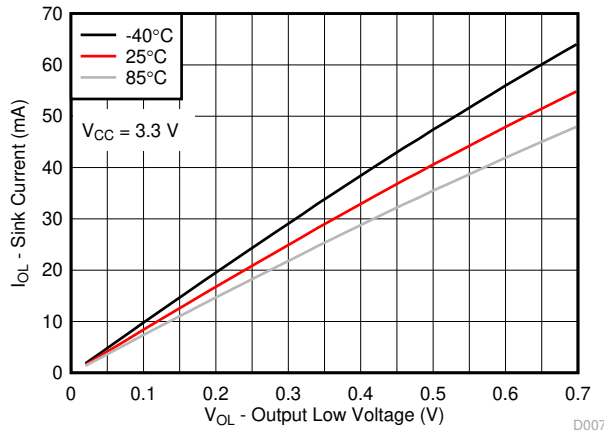


Figure 6-7. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 3.3\text{ V}$

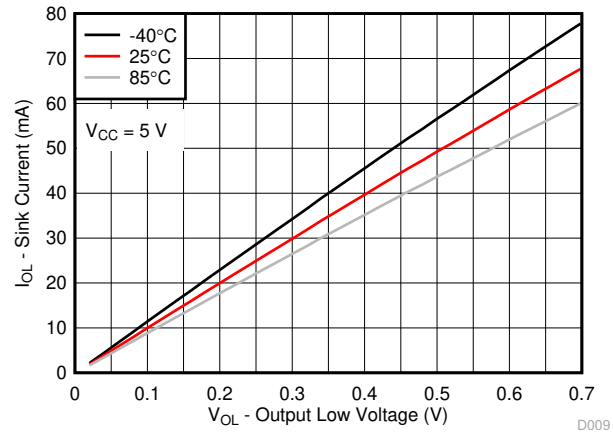


Figure 6-8. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 5\text{ V}$

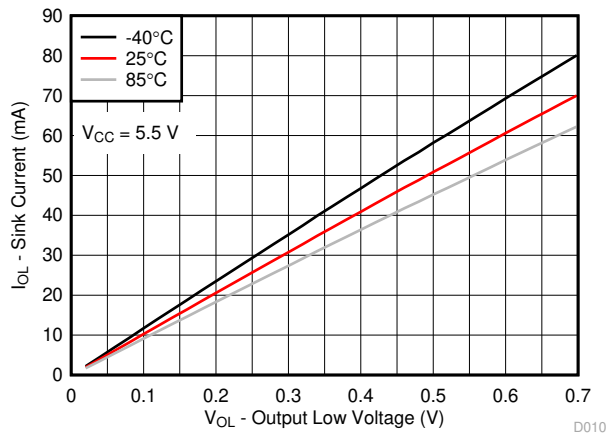


Figure 6-9. I/O Sink Current vs Output Low Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 5.5\text{ V}$

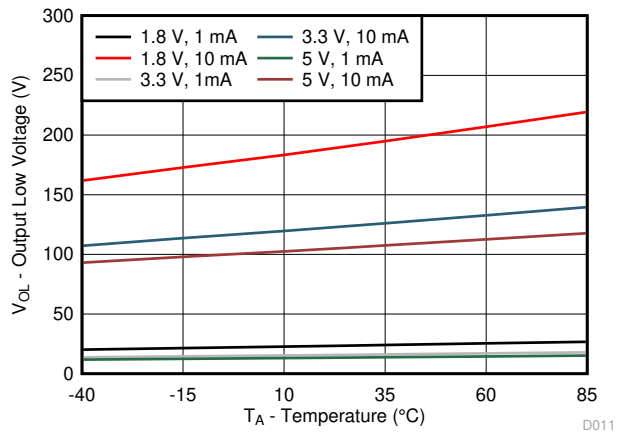


Figure 6-10. I/O Low Voltage vs Temperature for Different  $V_{CC}$  and  $I_{OL}$

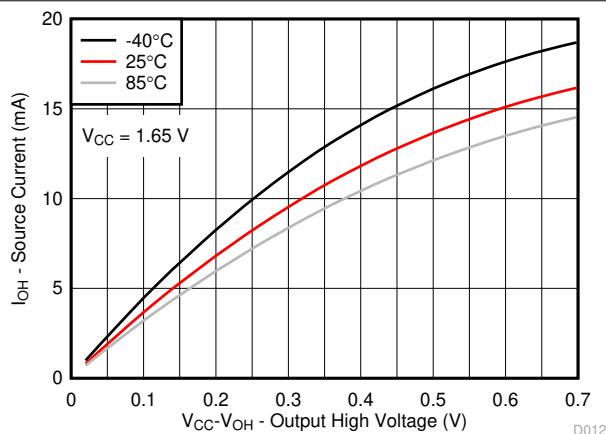


Figure 6-11. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 1.65\text{ V}$

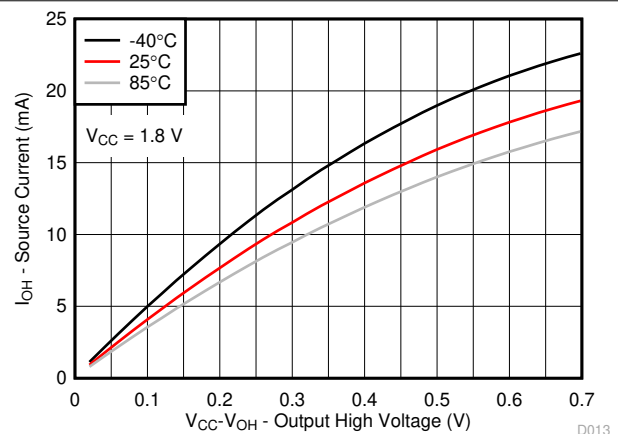


Figure 6-12. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 1.8\text{ V}$

## 6.8 Typical Characteristics (continued)

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

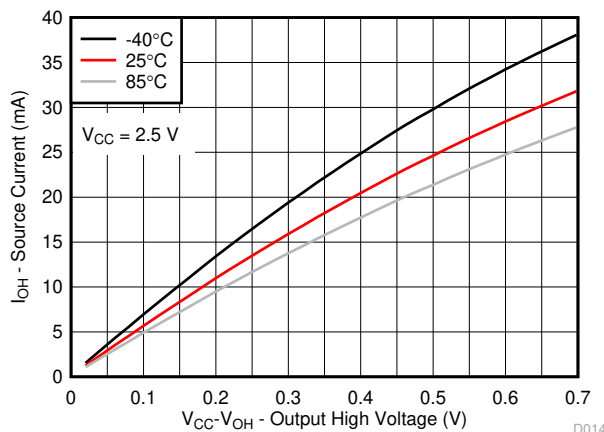


Figure 6-13. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 2.5\text{ V}$

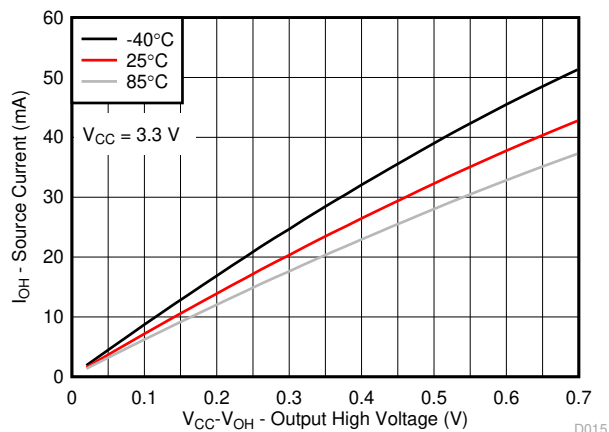


Figure 6-14. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 3.3\text{ V}$

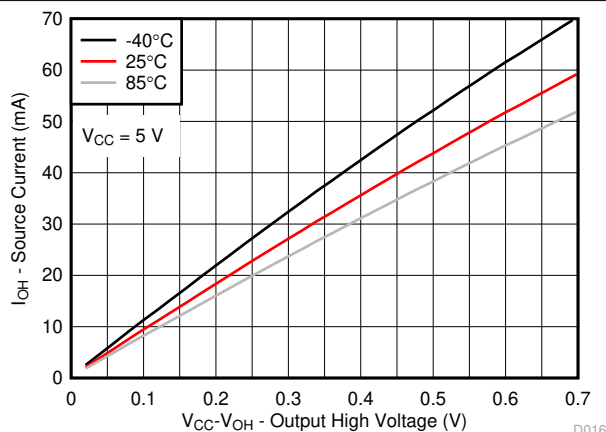


Figure 6-15. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 5\text{ V}$

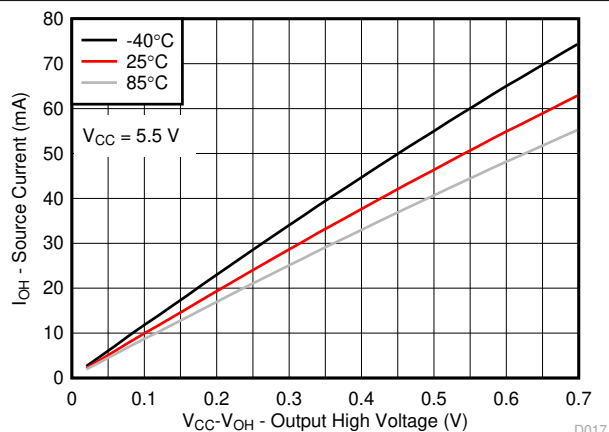


Figure 6-16. I/O Source Current vs Output High Voltage for Different Temperature ( $T_A$ ) for  $V_{CC} = 5.5\text{ V}$

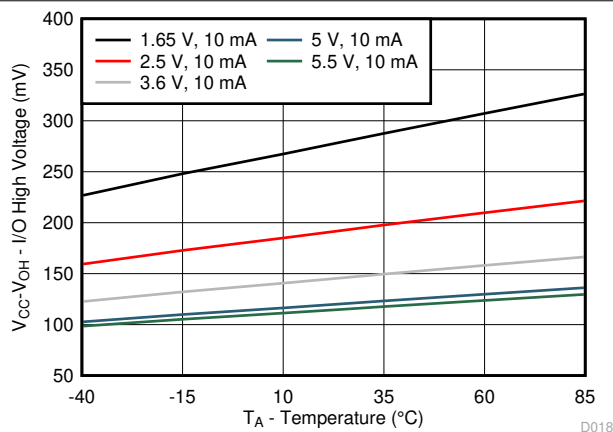


Figure 6-17.  $V_{CC} - V_{OH}$  Voltage vs Temperature for Different  $V_{CC}$

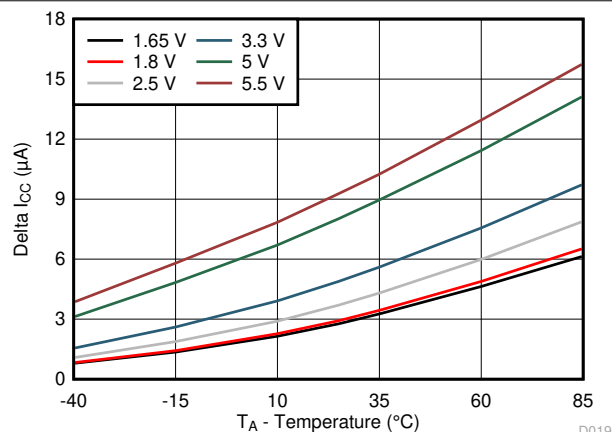
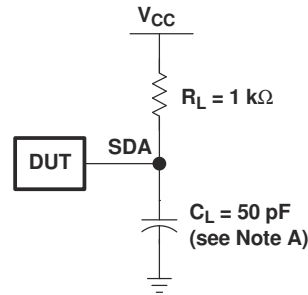
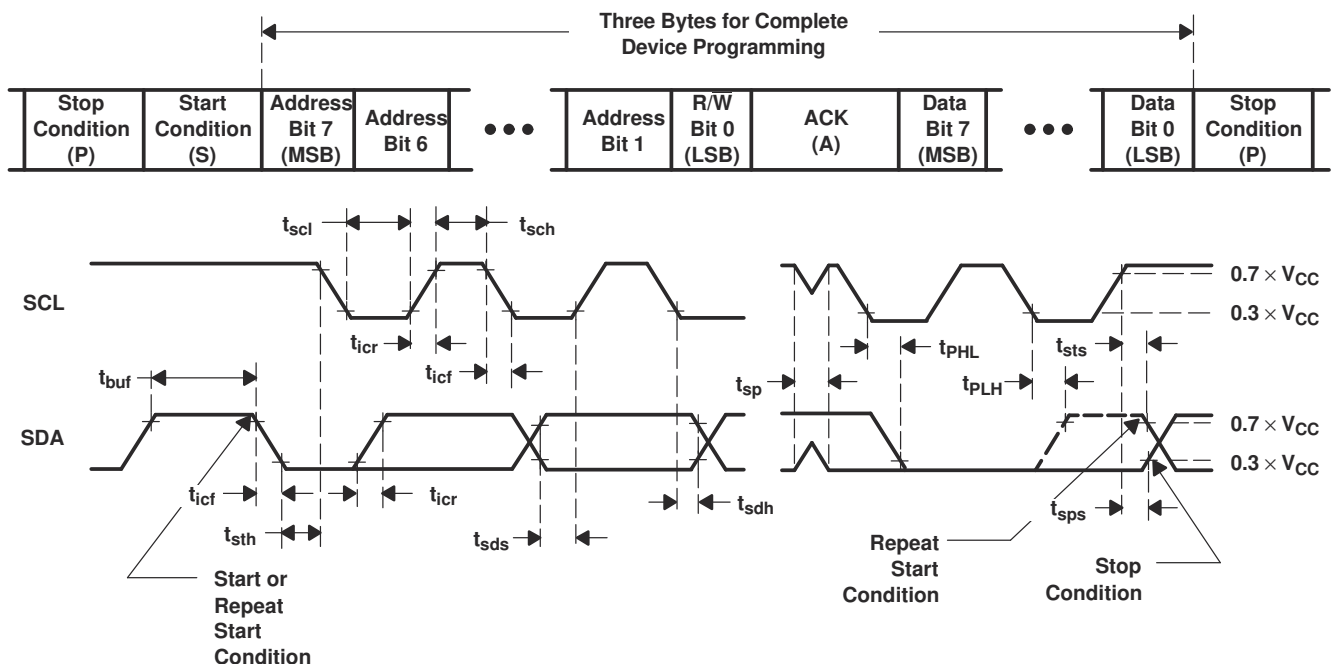


Figure 6-18.  $\Delta I_{CC}$  vs Temperature for Different  $V_{CC}$  ( $V_I = V_{CC} - 0.6\text{ V}$ )

## 7 Parameter Measurement Information



SDA LOAD CONFIGURATION

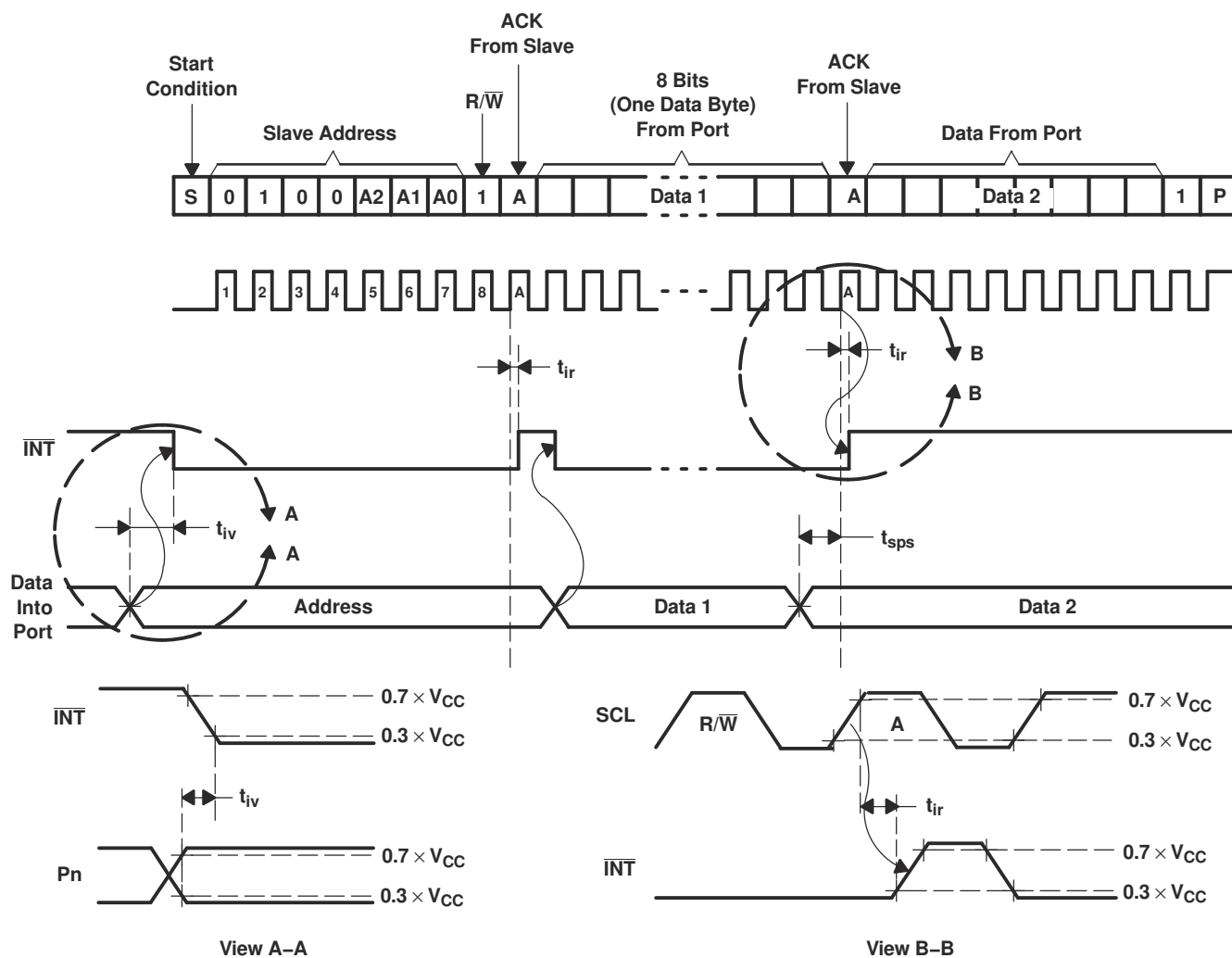
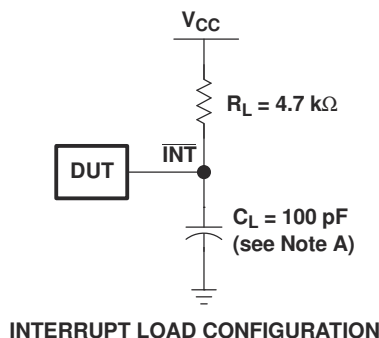


VOLTAGE WAVEFORMS

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:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.  
 C. All parameters and waveforms are not applicable to all devices.

**Figure 7-1. I<sup>2</sup>C Interface Load Circuit And Voltage Waveforms**

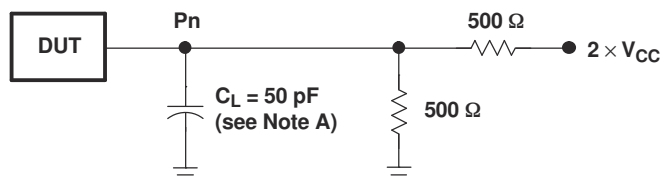


A.  $C_L$  includes probe and jig capacitance.

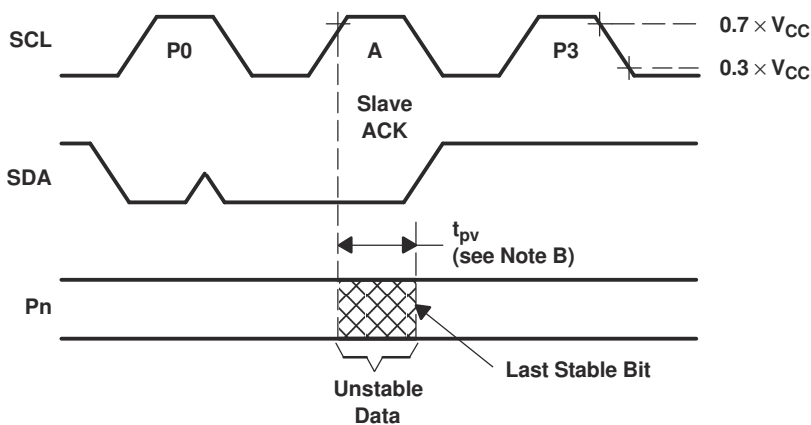
B. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r/t_f \leq 30\text{ ns}$ .

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

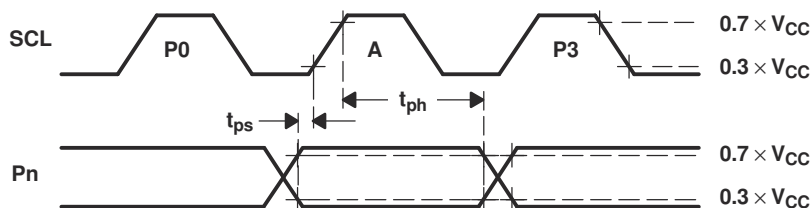
**Figure 7-2. Interrupt Load Circuit And Voltage Waveforms**



P-PORT LOAD CONFIGURATION



WRITE MODE (R/W = 0)



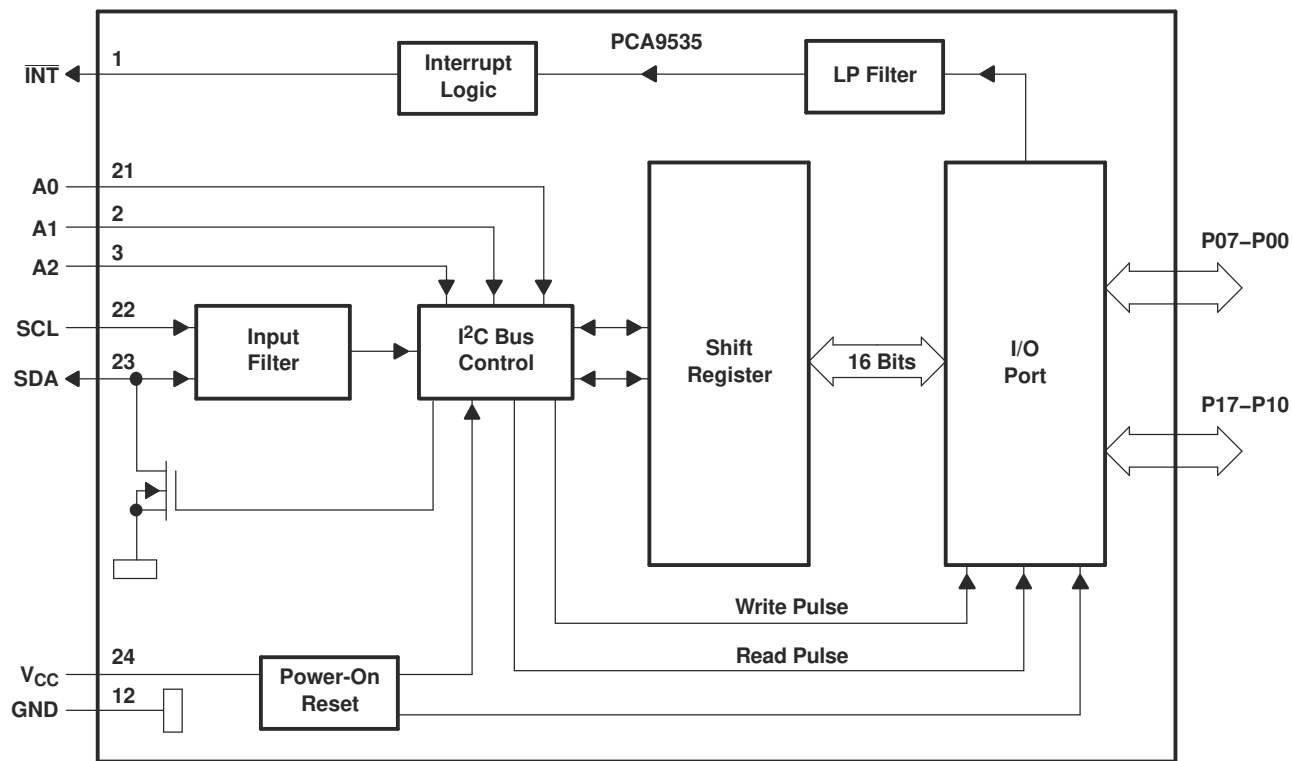
READ MODE (R/W = 1)

- A. C<sub>L</sub> includes probe and jig capacitance.
- B. t<sub>pv</sub> is measured from 0.7 × V<sub>CC</sub> on SCL to 50% I/O (Pn) output.
- C. All inputs are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub>/t<sub>f</sub> ≤ 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 7-3. P-Port Load Circuit And Voltage Waveforms**

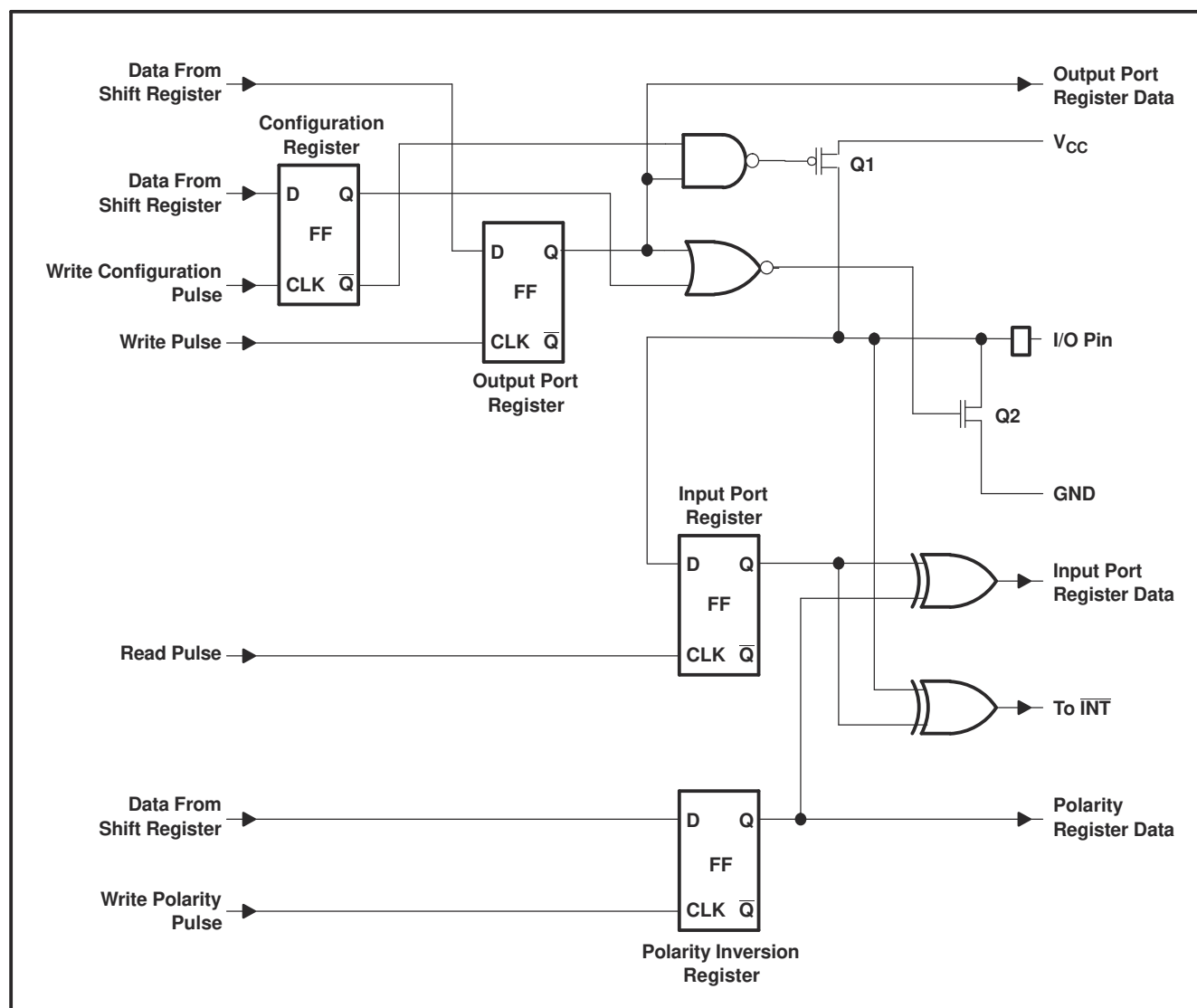
## 8 Detailed Description

### 8.1 Functional Block Diagram



- A. Pin numbers shown are for DB, DBQ, DGV, DW, and PW packages.  
 B. All I/Os are set to inputs at reset.

**Figure 8-1. Logic Diagram (Positive Logic)**



A. At power-on reset, all registers return to default values.

**Figure 8-2. Simplified Schematic Of P-Port I/Os**

## 8.2 Device Functional Modes

### 8.2.1 Power-On Reset

When power (from 0 V) is applied to  $V_{CC}$ , an internal power-on reset holds the PCA9535 in a reset condition until  $V_{CC}$  has reached  $V_{POR}$ . At that point, the reset condition is released and the PCA9535 registers and I<sup>2</sup>C/SMBus state machine 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.

### 8.2.2 I/O Port

When an I/O is configured as an input, FETs Q1 and Q2 (in [Simplified Schematic Of P-Port I/Os](#)) 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.

### 8.2.3 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,  $t_{iv}$ , the signal  $\overline{\text{INT}}$  is valid. Resetting the interrupt circuit is achieved when data on the port is changed to the original setting, data is read from the port that generated the interrupt. Resetting occurs in the read mode at the acknowledge (ACK) 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  $\overline{\text{INT}}$ . 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-pin port is read independently, the interrupt caused by port 0 is not cleared by a read of port 1 or vice versa.

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

#### 8.2.3.1 Interrupt Errata

##### Description

The INT will be improperly de-asserted if the following two conditions occur:

1. The last I<sup>2</sup>C command byte (register pointer) written to the device was 00h.

---

##### Note

This generally means the last operation with the device was a Read of the input register. However, the command byte may have been written with 00h without ever going on to read the input register. After reading from the device, if no other command byte written, it will remain 00h.

---

2. Any other slave device on the I<sup>2</sup>C bus acknowledges an address byte with the R/W bit set high

##### System Impact

Can cause improper interrupt handling as the Master will see the interrupt as being cleared.

##### System Workaround

Minor software change: User must change command byte to something besides 00h after a Read operation to the PCA9535 device or before reading from another slave device.

---

##### Note

Software change will be compatible with other versions (competition and TI redesigns) of this device.

---

## 8.3 Programming

### 8.3.1 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 8-3](#)). 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–A2) of the slave device must not be changed between the Start and Stop conditions.

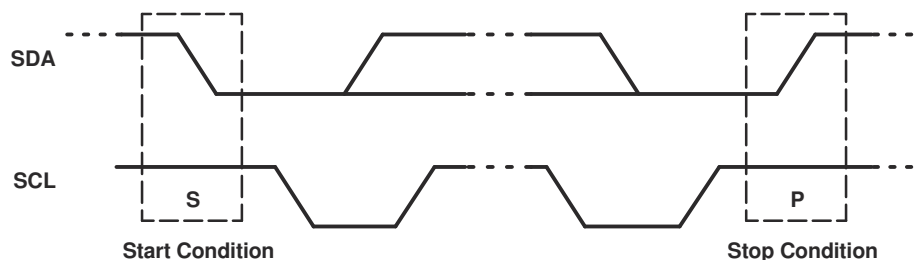


On the I<sup>2</sup>C bus, only one data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the high pulse of the clock period, as changes in the data line at this time are interpreted as control commands (Start or Stop) (see [Figure 8-4](#)).

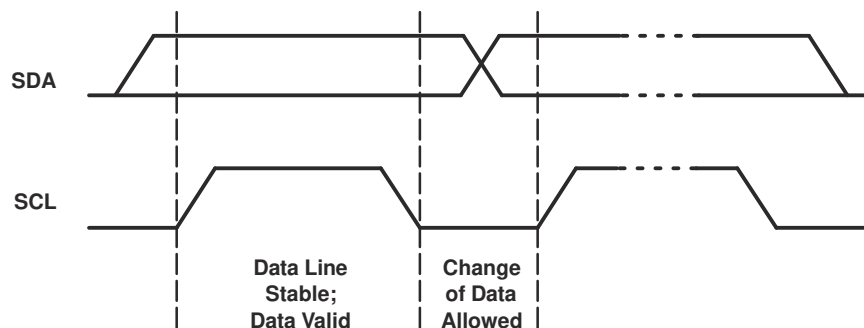
A Stop condition, a low-to-high transition on the SDA input/output while the SCL input is high, is sent by the master (see [Figure 8-3](#)).

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 8-5](#)). 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.

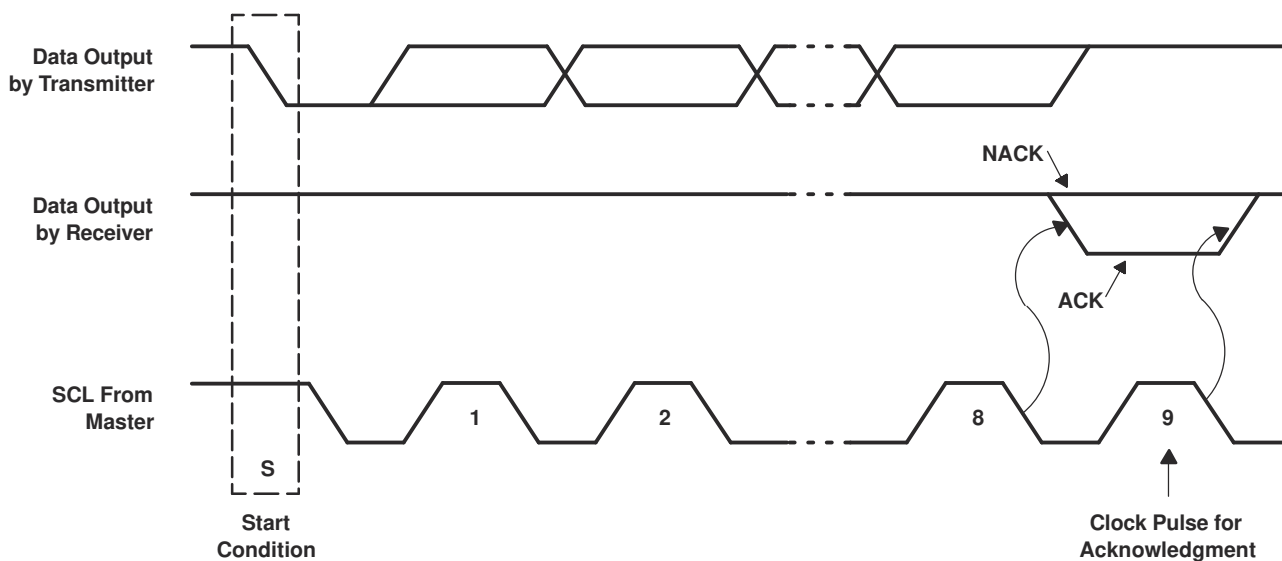
A master receiver signals an end of data to the slave transmitter by not generating an acknowledge (NACK) after the last byte has been clocked out of the slave. This is done by the master receiver by holding the SDA line high. In this event, the transmitter must release the data line to enable the master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



**Figure 8-3. Definition Of Start And Stop Conditions**



**Figure 8-4. Bit Transfer**

Figure 8-5. Acknowledgment On I<sup>2</sup>C Bus

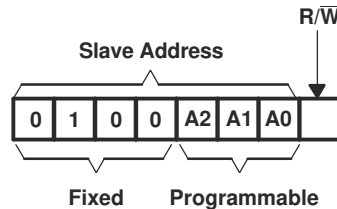
### 8.3.2 Register Map

Table 8-1. Interface Definition

BYTE	BIT							
	7 (MSB)	6	5	4	3	2	1	0 (LSB)
I <sup>2</sup> C slave address	L	H	L	L	A2	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

### 8.3.2.1 Device Address

Figure 8-6 shows the address byte of the PCA9535.



**Figure 8-6. Pca9535 Address**

**Table 8-2. Address Reference**

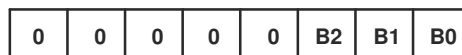
INPUTS			I <sup>2</sup> C BUS SLAVE ADDRESS
A2	A1	A0	
L	L	L	32 (decimal), 20 (hexadecimal)
L	L	H	33 (decimal), 21 (hexadecimal)
L	H	L	34 (decimal), 22 (hexadecimal)
L	H	H	35 (decimal), 23 (hexadecimal)
H	L	L	36 (decimal), 24 (hexadecimal)
H	L	H	37 (decimal), 25 (hexadecimal)
H	H	L	38 (decimal), 26 (hexadecimal)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

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

### 8.3.2.2 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 PCA9535. 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 8-7. Control Register Bits**

**Table 8-3. Control Register**

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

### 8.3.2.3 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 let the I<sup>2</sup>C device know that the Input Port registers will be accessed next.

**Table 8-4. 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.

**Table 8-5. 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 pin's polarity is inverted. If a bit in this register is cleared (written with a 0), the corresponding pin's original polarity is retained.

**Table 8-6. 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.

**Table 8-7. 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

### 8.3.2.4 Bus Transactions

Data is exchanged between the master and the PCA9535 through write and read commands.

#### 8.3.2.4.1 Writes

Data is transmitted to the PCA9535 by sending the device address and setting the least-significant bit to a logic 0 (see [Figure 8-6](#) 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 PCA9535 are configured to operate as four register pairs. The four pairs are Input Ports, Output Ports, Polarity Inversions, and Configurations. After sending data to one register, the next data byte is sent to the other register in the pair (see Figure 8-8 and Figure 8-9). 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.

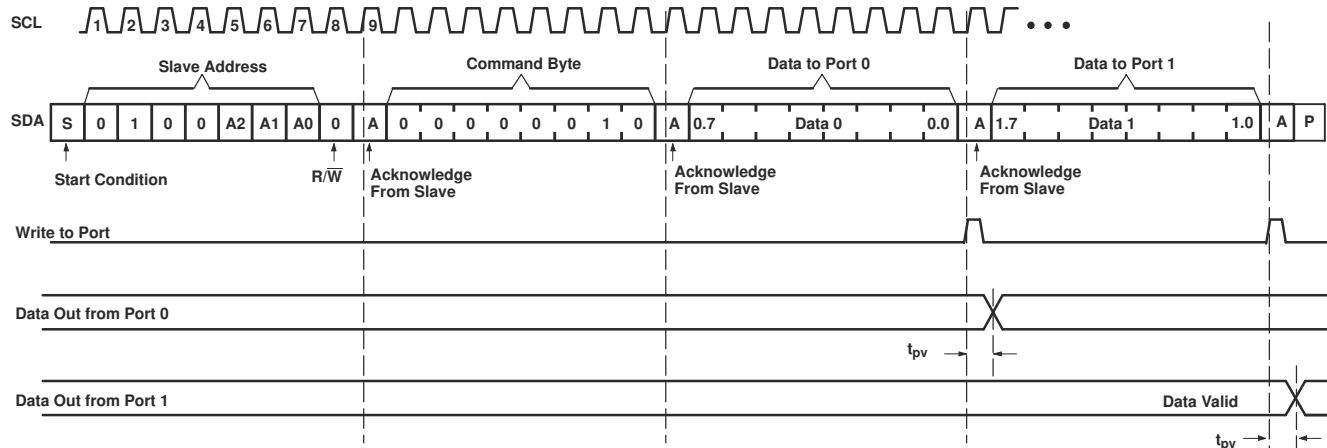


Figure 8-8. Write To Output Port Registers

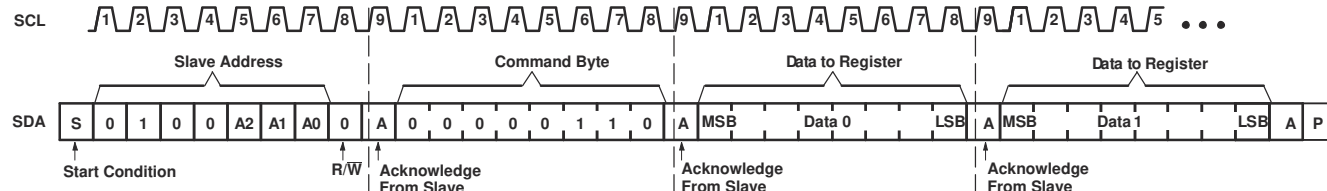


Figure 8-9. Write To Configuration Registers

#### 8.3.2.4.2 Reads

The bus master first must send the PCA9535 address with the least-significant bit set to a logic 0 (see Figure 8-6 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 least-significant bit is set to a logic 1. Data from the register defined by the command byte then is sent by the PCA9535 (see Figure 8-10 through Figure 8-12).

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

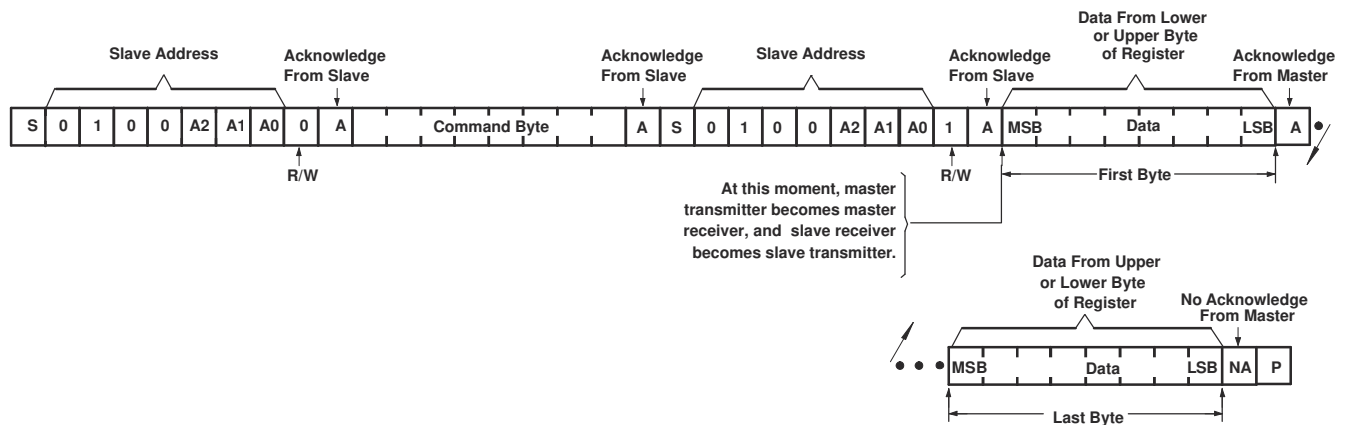
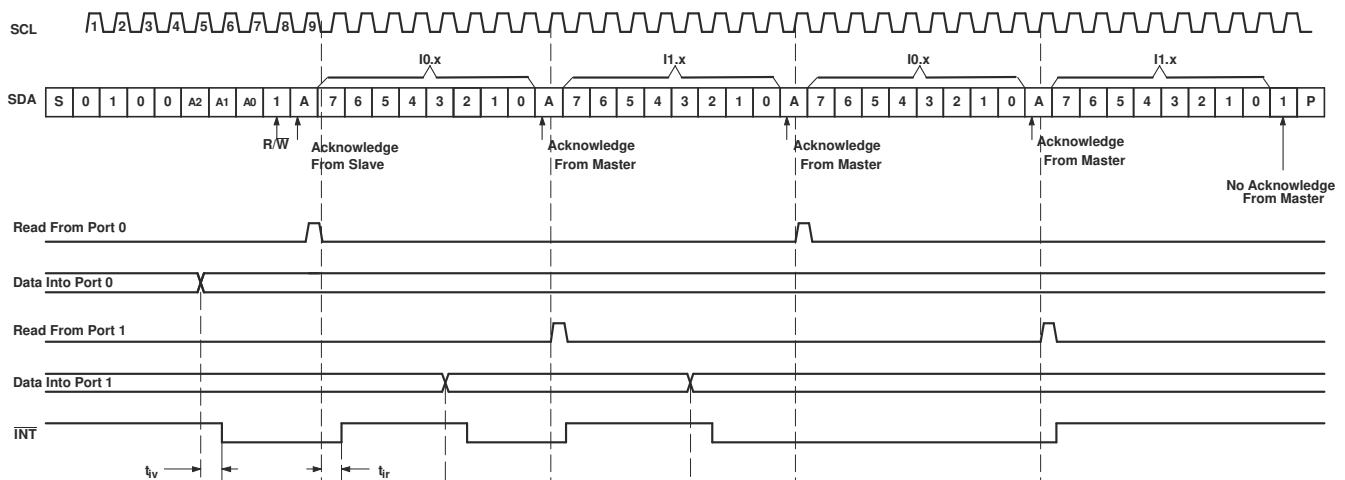
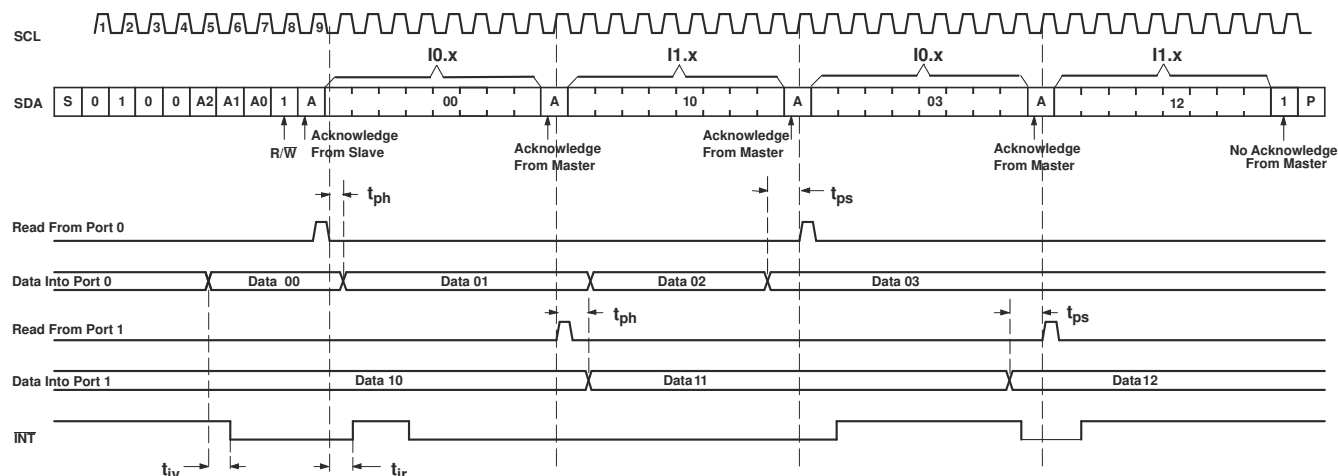


Figure 8-10. Read From Register



- A. 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).
- B. This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from P port (see Figure 8-10 for these details).

Figure 8-11. Read Input Port Register, Scenario 1



- A. 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).
- B. This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from P port (see [Figure 8-10](#) for these details).

**Figure 8-12. Read Input Port Register, Scenario 2**

## 9 Application Information Disclaimer

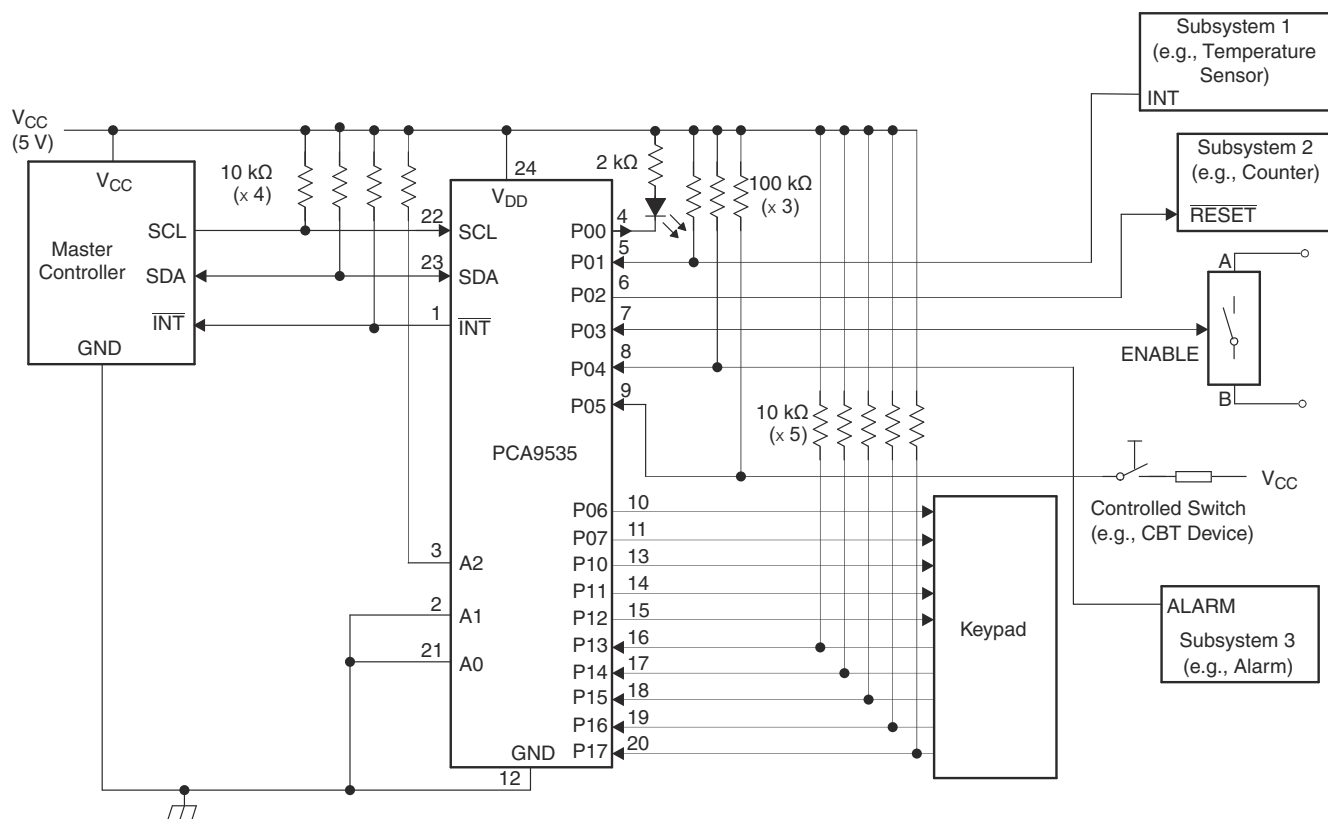
## Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

## 9.1 Application Information

## 9.2 Typical Application

Figure 9-1 shows an application in which the PCA9535 can be used.



- A. Device address is configured as 0100100 for this example.
- B. P00, P02, and P03 are configured as outputs.
- C. P01, P04–P07, and P10–P17 are configured as inputs.
- D. Pin numbers shown are for DB, DBQ, DGV, DW, and PW packages.

### Figure 9-1. Typical Application



## 9.2.1 Design Requirements

### 9.2.1.1 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 as shown in Figure 9-3. 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 9-2 shows a high-value resistor in parallel with the LED. Figure 9-3 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 prevent additional supply-current consumption when the LED is off.

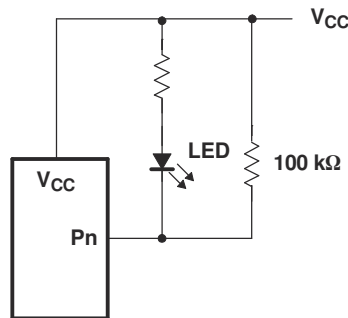


Figure 9-2. High-Value Resistor In Parallel With Led

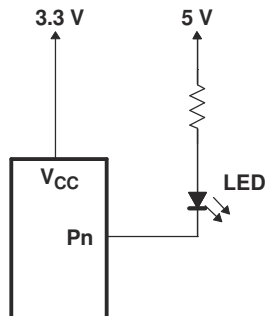


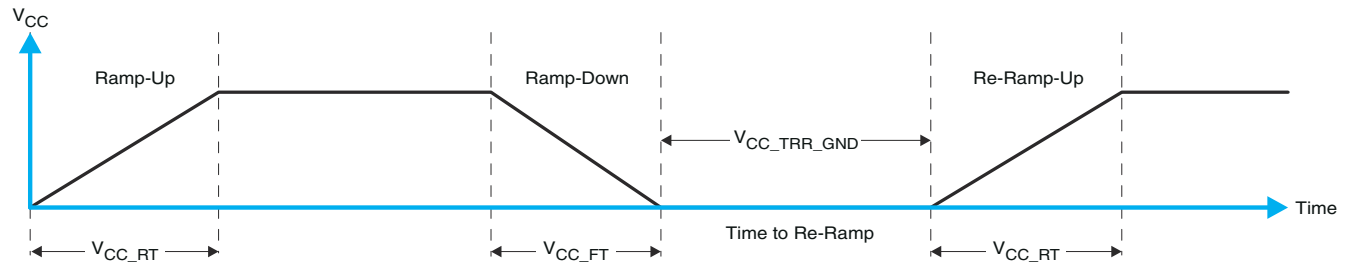
Figure 9-3. Device Supplied By Lower Voltage

## 10 Power Supply Recommendations

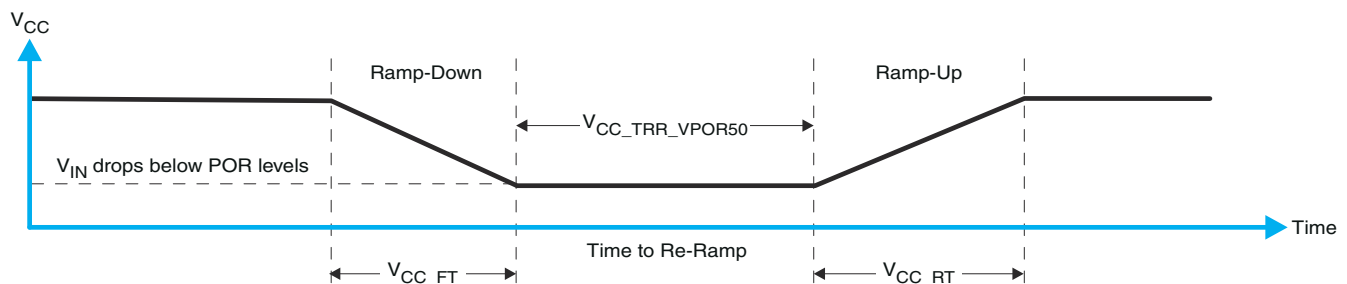
### 10.1 Power-On Reset Requirements

In the event of a glitch or data corruption, PCA9535 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 application 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 10-1](#) and [Figure 10-2](#).



**Figure 10-1.  $V_{CC}$  Is Lowered Below 0.2 V Or 0 V And Then Ramped Up To  $V_{CC}$**



**Figure 10-2.  $V_{CC}$  Is Lowered Below The Por Threshold, Then Ramped Back Up To  $V_{CC}$**

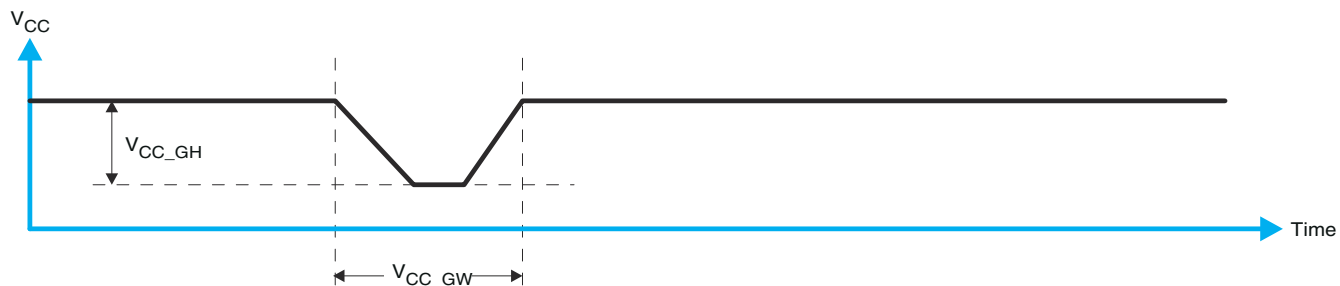
[Table 10-1](#) specifies the performance of the power-on reset feature for PCA9535 for both types of power-on reset.

**Table 10-1. Recommended Supply Sequencing And Ramp Rates <sup>(1)</sup>**

PARAMETER			MIN	TYP	MAX	UNIT
$V_{CC\_FT}$	Fall rate	See <a href="#">Figure 10-1</a>	1		100	ms
$V_{CC\_RT}$	Rise rate	See <a href="#">Figure 10-1</a>	0.01		100	ms
$V_{CC\_TRR\_GND}$	Time to re-ramp (when $V_{CC}$ drops to GND)	See <a href="#">Figure 10-1</a>	0.001			ms
$V_{CC\_TRR\_POR50}$	Time to re-ramp (when $V_{CC}$ drops to $V_{POR\_MIN} - 50$ mV)	See <a href="#">Figure 10-2</a>	0.001			ms
$V_{CC\_GH}$	Level that $V_{CCP}$ can glitch down to, but not cause a functional disruption when $V_{CCX\_GW} = 1$ $\mu$ s	See <a href="#">Figure 10-3</a>			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 <a href="#">Figure 10-3</a>				$\mu$ s
$V_{PORF}$	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

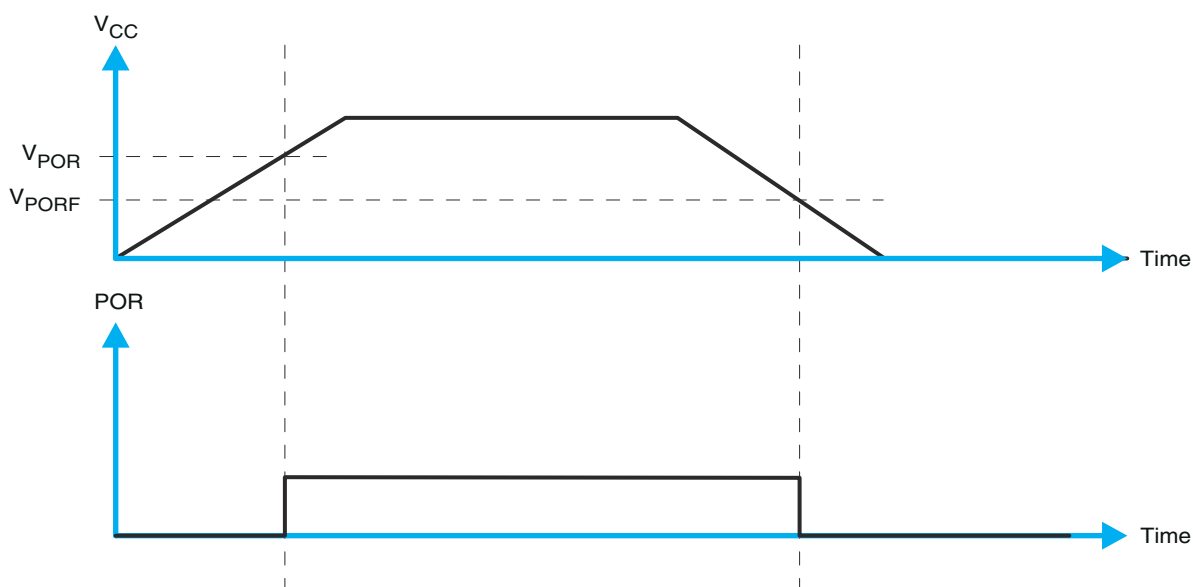
(1)  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$  (unless otherwise noted)

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 the device impedance are factors that affect power-on reset performance. [Figure 10-3](#) and [Table 10-1](#) provide more information on how to measure these specifications.



**Figure 10-3. 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 10-4](#) and [Table 10-1](#) provide more details on this specification.



**Figure 10-4.  $V_{POR}$**

## 11 Device and Documentation Support

### 11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.2 Support Resources

TI E2E™ [support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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### 11.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 11.4 Electrostatic Discharge Caution



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.

### 11.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PCA9535DB	ACTIVE	SSOP	DB	24	60	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD9535	<a href="#">Samples</a>
PCA9535DBQR	ACTIVE	SSOP	DBQ	24	2500	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PCA9535	<a href="#">Samples</a>
PCA9535DBR	ACTIVE	SSOP	DB	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD9535	<a href="#">Samples</a>
PCA9535DGVR	ACTIVE	TVSOP	DGV	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD9535	<a href="#">Samples</a>
PCA9535DW	ACTIVE	SOIC	DW	24	25	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9535	<a href="#">Samples</a>
PCA9535DWR	ACTIVE	SOIC	DW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9535	<a href="#">Samples</a>
PCA9535PWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD9535	<a href="#">Samples</a>
PCA9535RGER	ACTIVE	VQFN	RGE	24	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PD9535	<a href="#">Samples</a>
PCA9535RTWR	NRND	WQFN	RTW	24	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PD535	

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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## 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
PCA9535DBQR	SSOP	DBQ	24	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
PCA9535DBR	SSOP	DB	24	2000	330.0	16.4	8.2	8.8	2.5	12.0	16.0	Q1
PCA9535DGVR	TVSOP	DGV	24	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
PCA9535DWR	SOIC	DW	24	2000	330.0	24.4	10.75	15.7	2.7	12.0	24.0	Q1
PCA9535PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
PCA9535RGER	VQFN	RGE	24	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
PCA9535RTWR	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)
PCA9535DBQR	SSOP	DBQ	24	2500	853.0	449.0	35.0
PCA9535DBR	SSOP	DB	24	2000	853.0	449.0	35.0
PCA9535DGVR	TVSOP	DGV	24	2000	853.0	449.0	35.0
PCA9535DWR	SOIC	DW	24	2000	350.0	350.0	43.0
PCA9535PWR	TSSOP	PW	24	2000	853.0	449.0	35.0
PCA9535RGER	VQFN	RGE	24	3000	853.0	449.0	35.0
PCA9535RTWR	WQFN	RTW	24	3000	853.0	449.0	35.0



## TUBE



\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
PCA9535DB	DB	SSOP	24	60	530	10.5	4000	4.1
PCA9535DW	DW	SOIC	24	25	506.98	12.7	4826	6.6

DBQ (R-PDSO-G24)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15) per side.
  - D. Falls within JEDEC MO-137 variation AE.



## PACKAGE OUTLINE

## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



4220208/A 02/2017

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

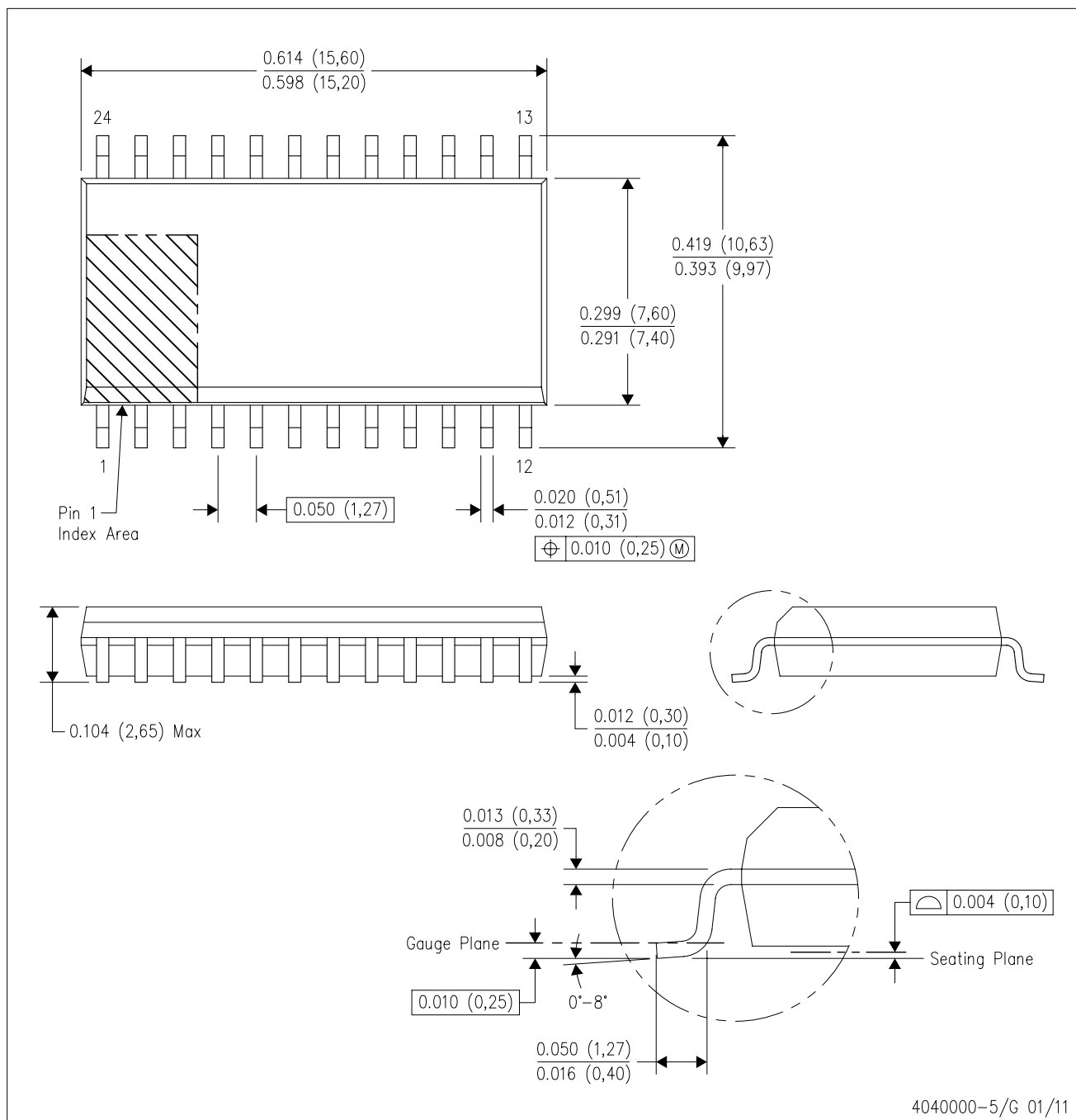
4220208/A 02/2017

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

DW (R-PDSO-G24)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - D. Falls within JEDEC MS-013 variation AD.

## GENERIC PACKAGE VIEW

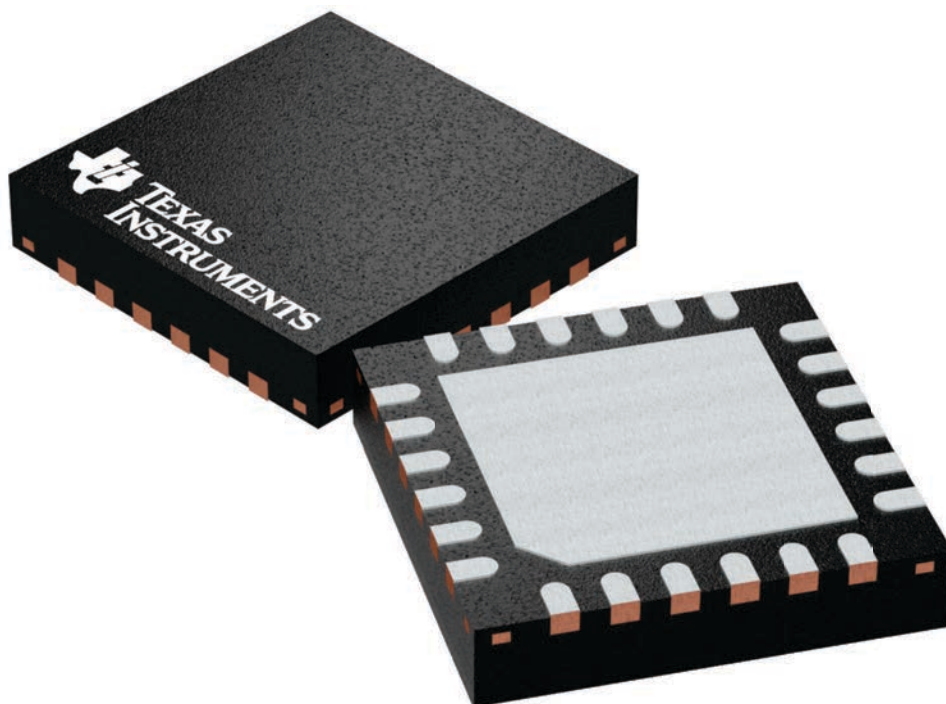
**RTW 24**

**WQFN - 0.8 mm max height**

4 x 4, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4224801/A

## PACKAGE OUTLINE

WQFN - 0.8 mm max height

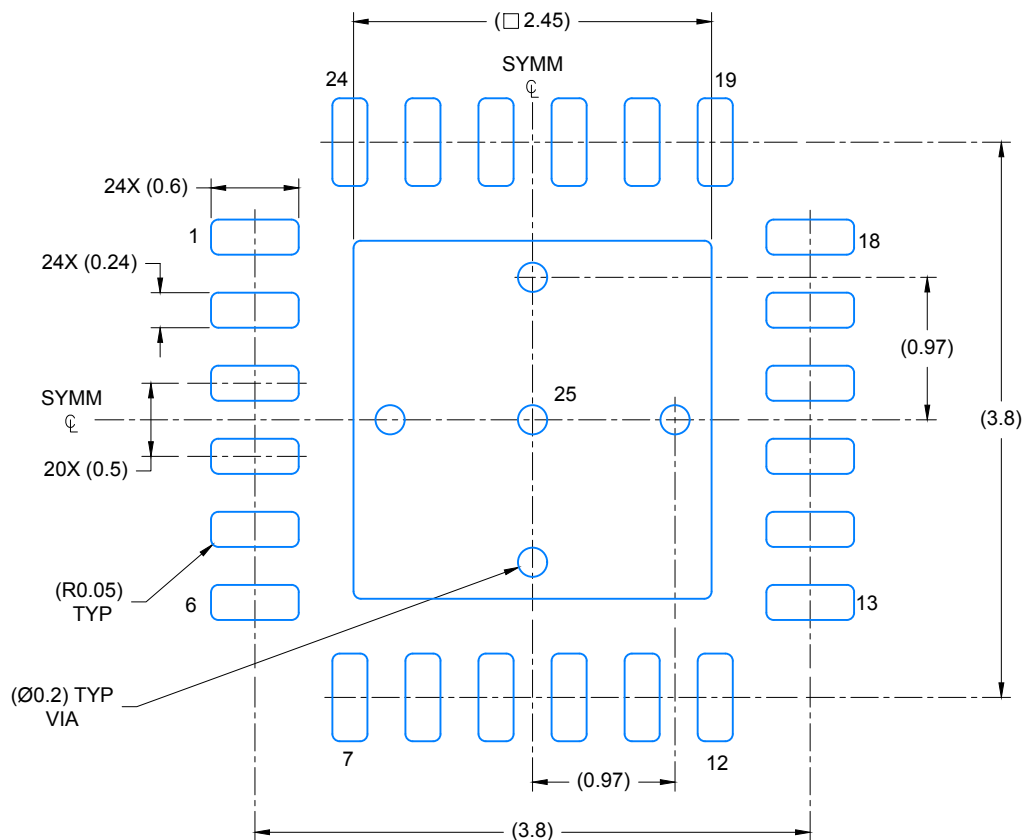
The drawing illustrates the mechanical specifications of the QFN package across three views:

- Top View:** Shows a square package with a side length of 4.15 mm (3.85 mm BSC). A shaded region on the left is designated as the "PIN 1 INDEX AREA".
- Side View:** Shows the package height with a maximum of 0.8 mm. The bottom surface features a "SEATING PLANE" with a flatness tolerance of 0.08 mm. The solder mask thickness is specified as 0.05 mm to 0.00 mm.
- Detail View:** Provides a close-up of the package perimeter, showing 24 pins (12 on each long side) with a pitch of 0.5 mm. The central square area has a side length of 2.5 mm. The exposed thermal pad is 2.45 ± 0.1 mm square. The package is symmetrical (SYMM) about both horizontal and vertical centerlines. A "PIN 1 ID (OPTIONAL)" is indicated on the left side. A detail of the pin profile shows a width of 0.2 mm typical.

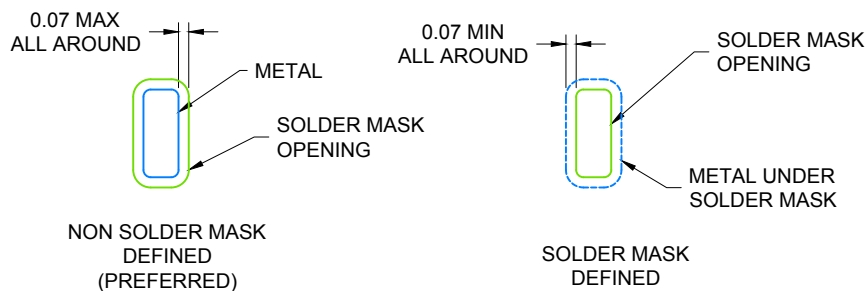
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.





LAND PATTERN EXAMPLE  
SCALE: 20X

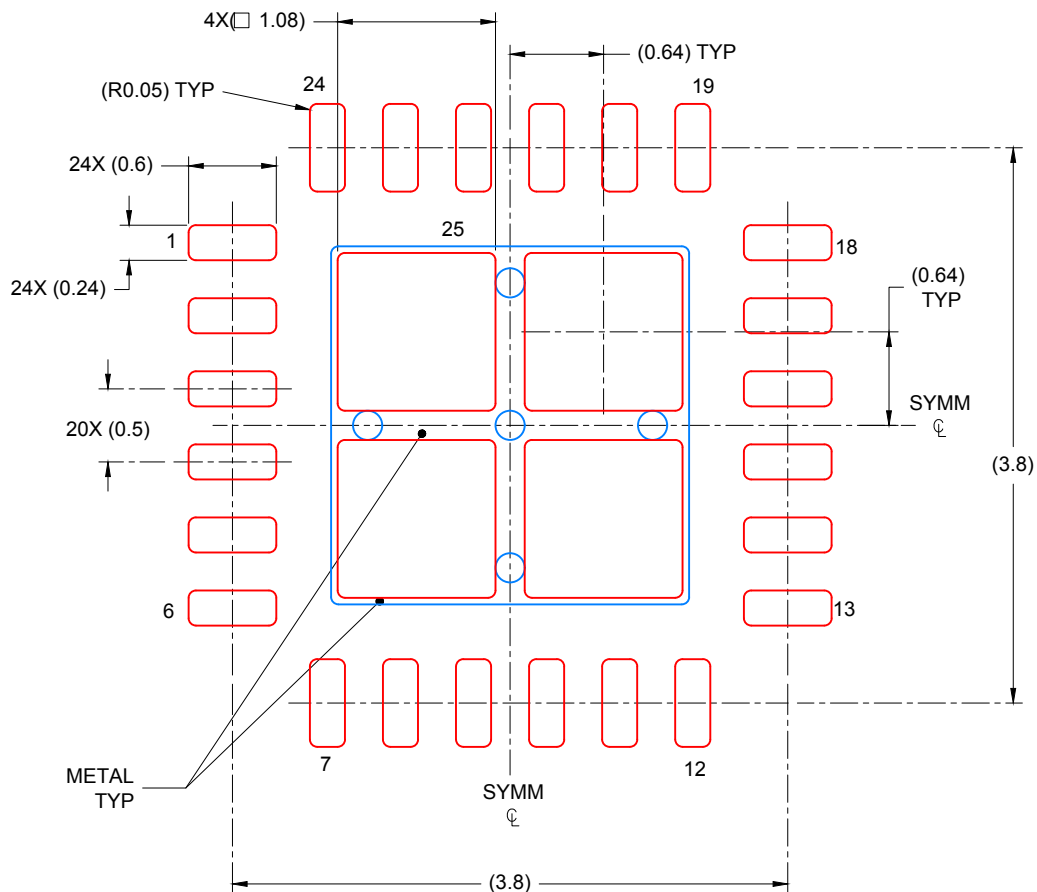


SOLDER MASK DETAILS

4219135/B 11/2016

NOTES: (continued)

- For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).



SOLDER PASTE EXAMPLE  
 BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 25:  
 78% PRINTED COVERAGE BY AREA UNDER PACKAGE  
 SCALE: 20X

4219135/B 11/2016

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

## DB (R-PDSO-G\*\*)

## PLASTIC SMALL-OUTLINE

28 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.  
 D. Falls within JEDEC MO-150

**RGE 24**

**GENERIC PACKAGE VIEW**

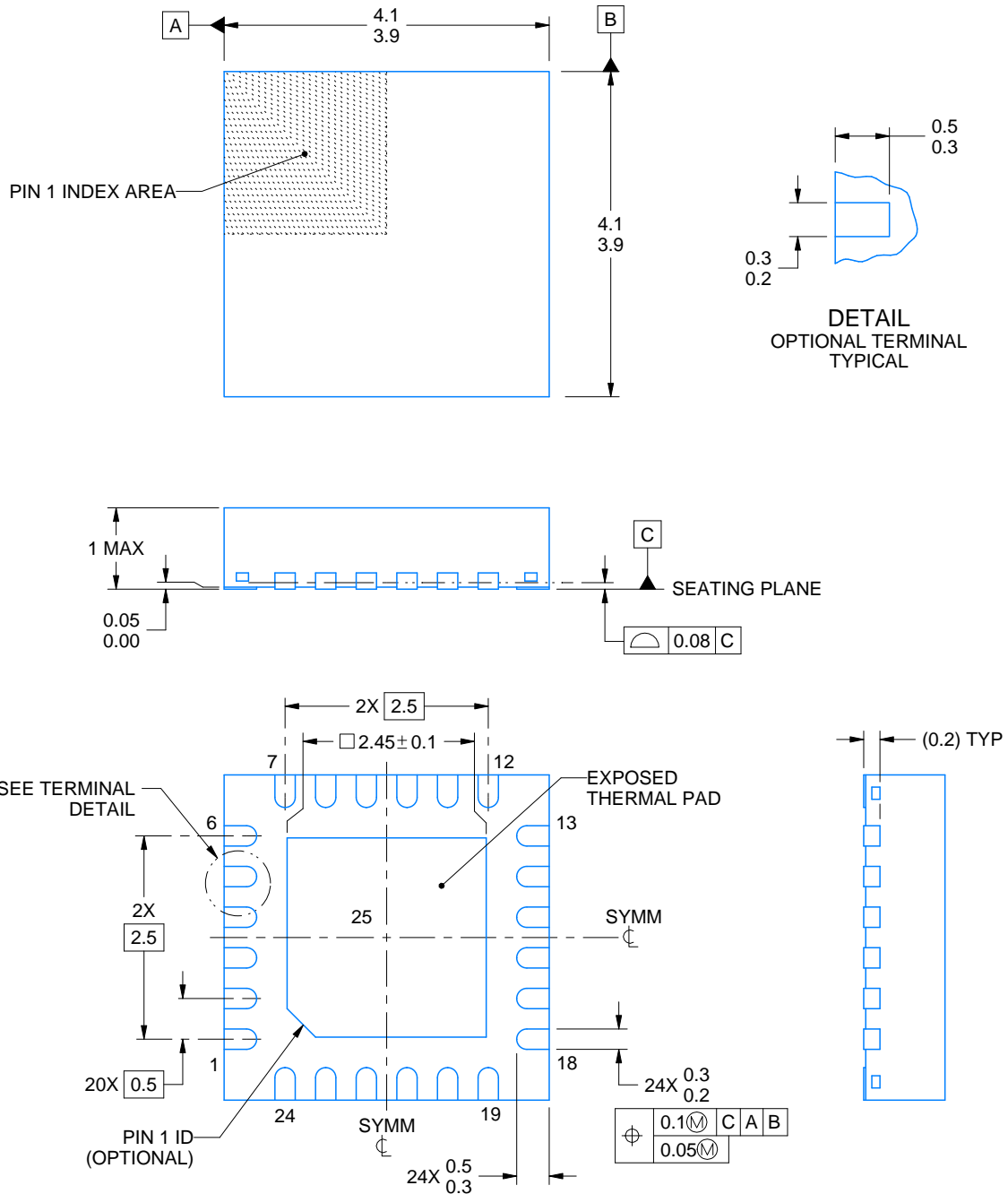
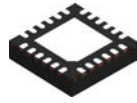
**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4204104/H



4219013/A 05/2017

## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

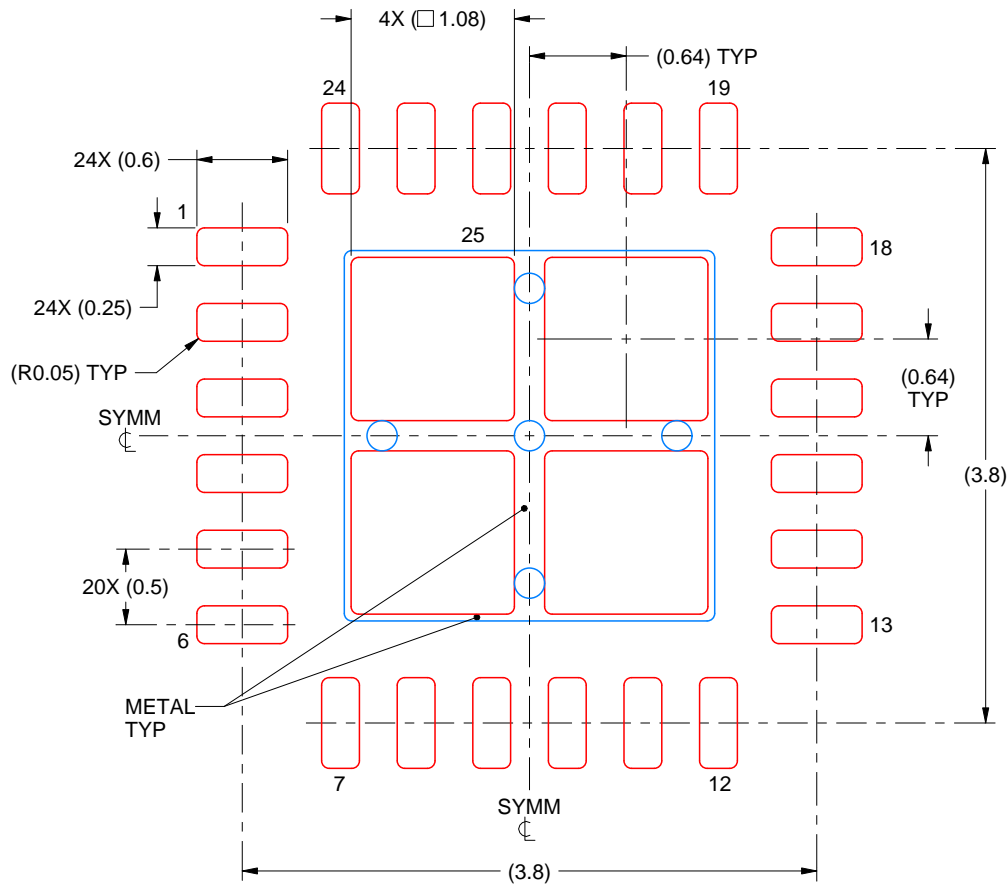


# EXAMPLE STENCIL DESIGN

RGE0024B

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



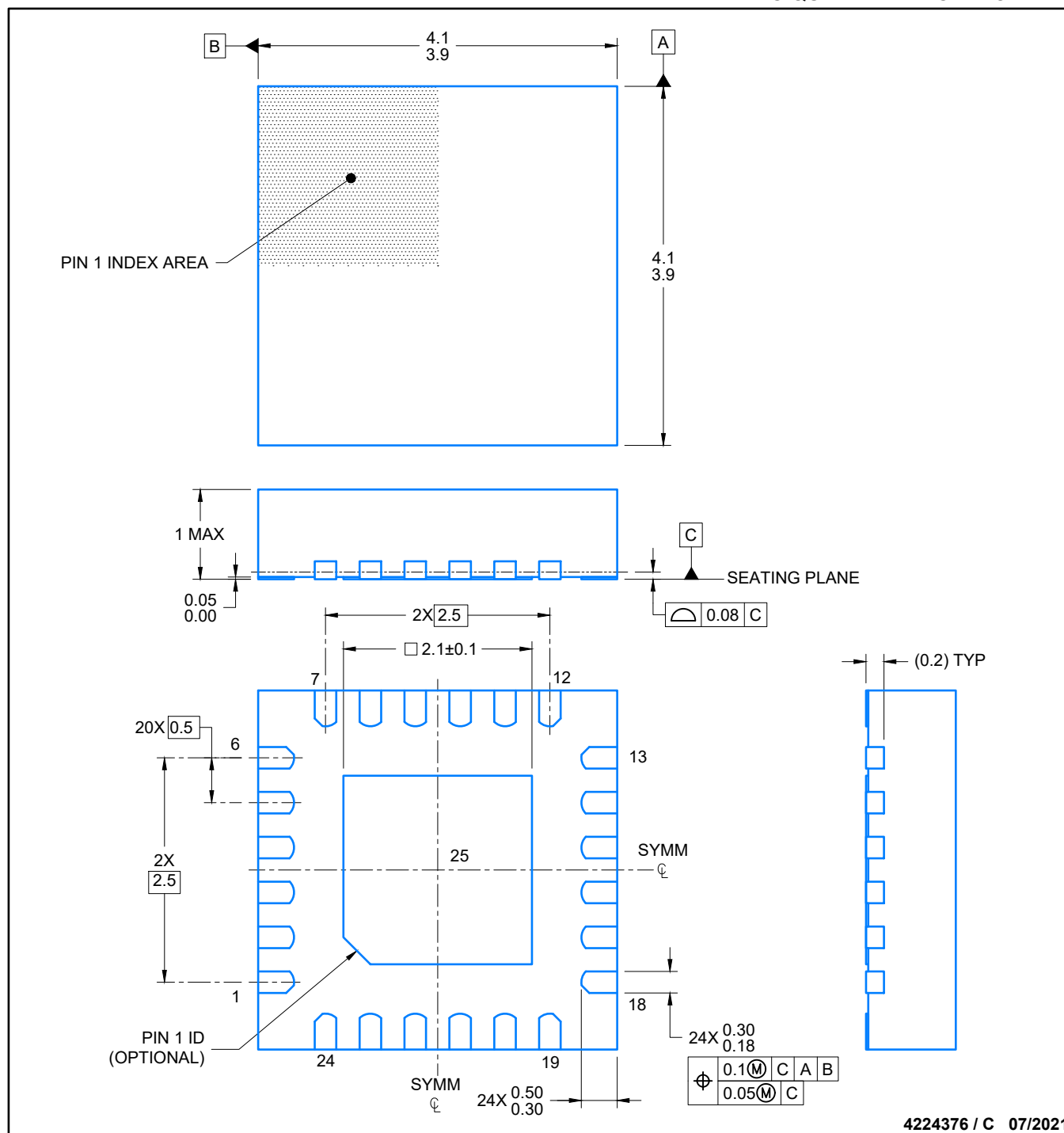
**SOLDER PASTE EXAMPLE**  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 25  
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:20X

4219013/A 05/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



4224376 / C 07/2021

## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



### VQFN - 1 mm max height

[illegible]

0.07 MAX  
ALL AROUND

METAL

SOLDER MASK  
OPENING

NON SOLDER MASK  
DEFINED  
(PREFERRED)

0.07 MIN  
ALL AROUND

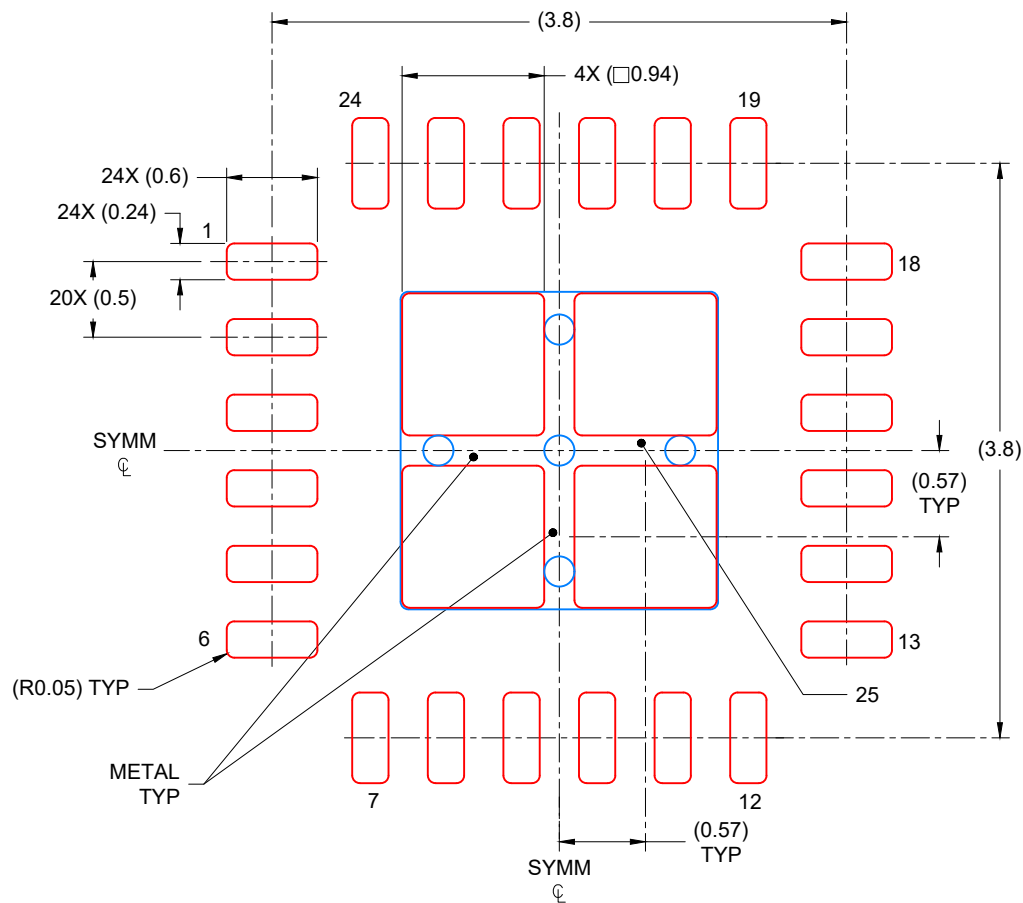
SOLDER MASK  
OPENING

METAL UNDER  
SOLDER MASK

SOLDER MASK  
DEFINED

SOLDER MASK DETAILS

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



## SOLDER PASTE EXAMPLE BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
80% PRINTED COVERAGE BY AREA  
SCALE: 20X

4224376 / C 06/2021

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations..

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