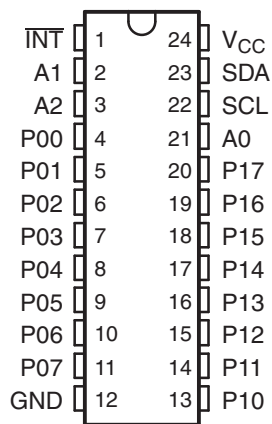
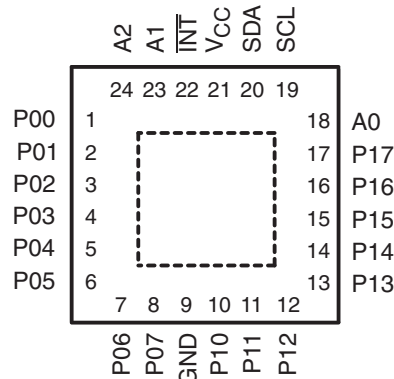
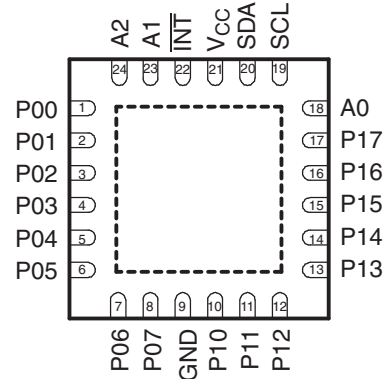


# REMOTE 16-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT AND CONFIGURATION REGISTERS

## 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)

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

RGE PACKAGE  
(TOP VIEW)

RTW PACKAGE  
(TOP VIEW)


## DESCRIPTION/ORDERING INFORMATION

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.

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



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

## DESCRIPTION/ORDERING INFORMATION (CONTINUED)

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.

### ORDERING INFORMATION

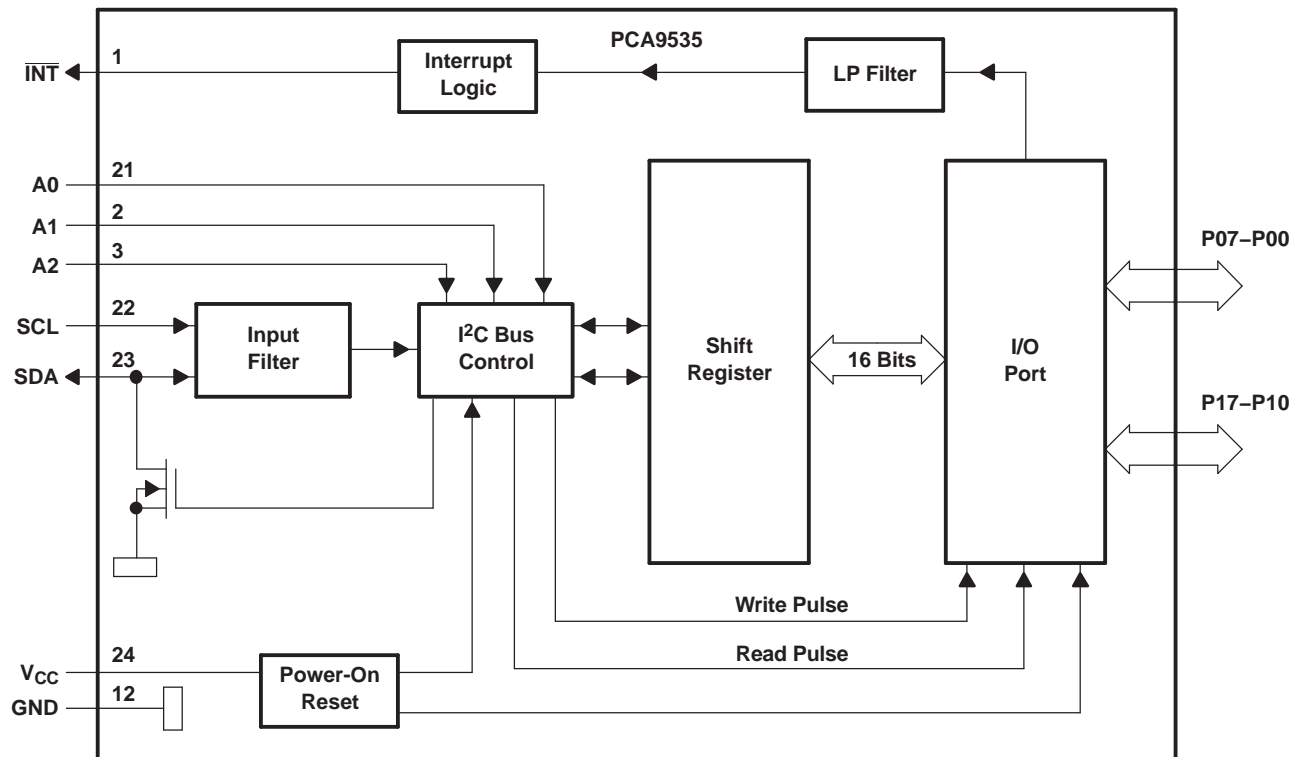
| T <sub>A</sub> | PACKAGE <sup>(1)(2)</sup> |              | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|---------------------------|--------------|-----------------------|------------------|
| –40°C to 85°C  | SSOP – DB                 | Reel of 2000 | PCA9535DBR            | PD9535           |
|                |                           | Tube of 60   | PCA9535DB             |                  |
|                | QSOP – DBQ                | Reel of 2500 | PCA9535DBQR           | PCA9535          |
|                | TVSOP – DGV               | Reel of 2000 | PCA9535DGVR           | PD9535           |
|                | SOIC – DW                 | Tube of 25   | PCA9535DW             | PCA9535          |
|                |                           | Reel of 2000 | PCA9535DWR            |                  |
|                | TSSOP – PW                | Tube of 60   | PCA9535PW             | PD9535           |
|                |                           | Reel of 2000 | PCA9535PWR            |                  |
|                | QFN – RGE                 | Reel of 3000 | PCA9535RGER           | PD9535           |
|                | QFN – RTW                 | Reel of 3000 | PCA9535RTWR           | PD535            |

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

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

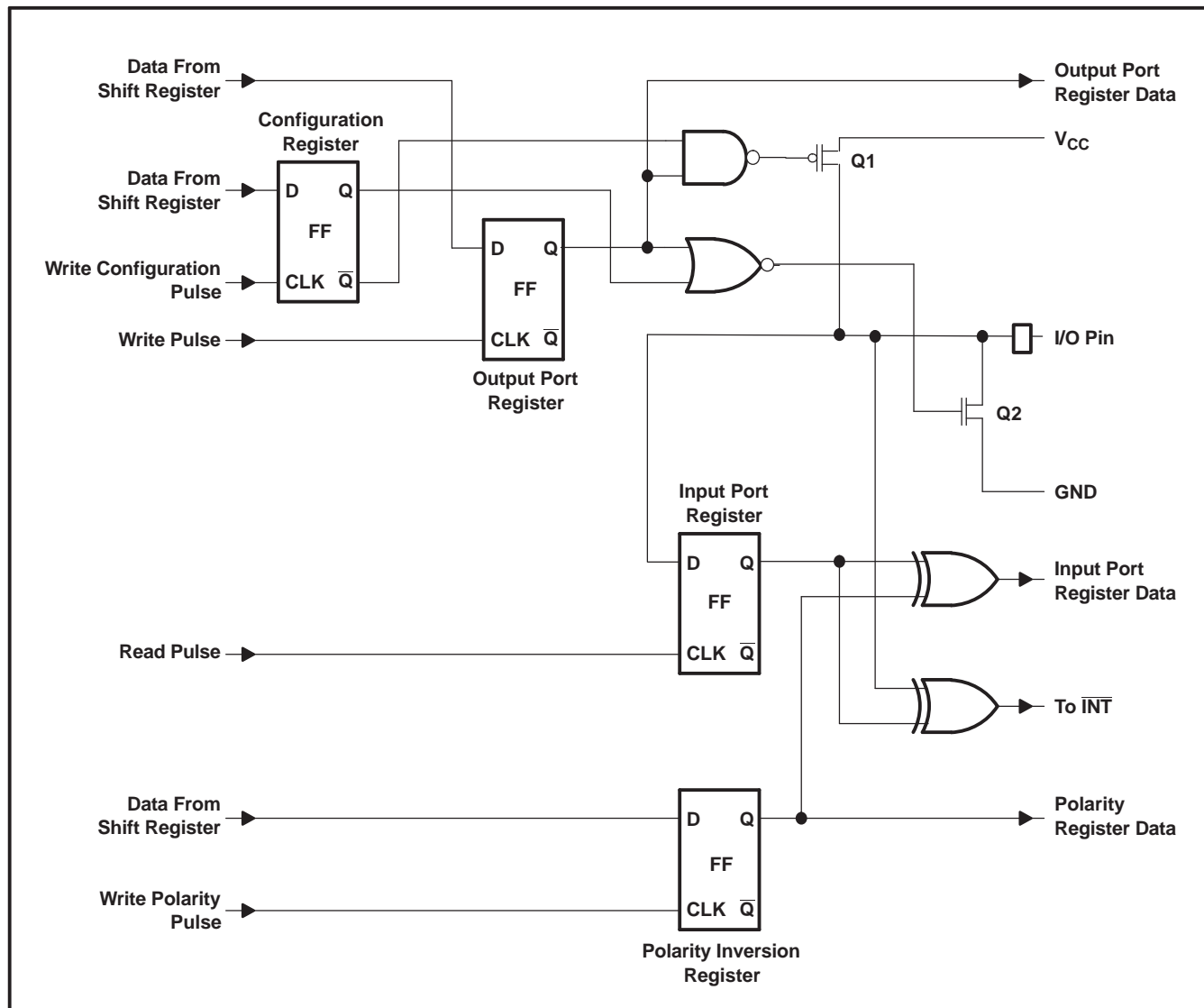
**TERMINAL FUNCTIONS**

| NO.  |                         | NAME                    | DESCRIPTION  |
|--|-------------------------|-------------------------|--|
| SOIC (D),<br>SSOP (DB),<br>QSOP (DBQ),<br>TSSOP (PW), AND<br>TVSOP (DGV) | QFN<br>(RGE AND<br>RTW) |                         |  |
| 1  | 22                      | $\overline{\text{INT}}$ | Interrupt output. Connect to $V_{CC}$ through a pullup resistor. |
| 2  | 23                      | A1                      | Address input. Connect directly to $V_{CC}$ or ground.           |
| 3  | 24                      | A2                      | Address input. Connect directly to $V_{CC}$ or ground.           |
| 4  | 1                       | P00                     | P-port input/output. Push-pull design structure.                 |
| 5  | 2                       | P01                     | P-port input/output. Push-pull design structure.                 |
| 6  | 3                       | P02                     | P-port input/output. Push-pull design structure.                 |
| 7  | 4                       | P03                     | P-port input/output. Push-pull design structure.                 |
| 8  | 5                       | P04                     | P-port input/output. Push-pull design structure.                 |
| 9  | 6                       | P05                     | P-port input/output. Push-pull design structure.                 |
| 10   | 7                       | P06                     | P-port input/output. Push-pull design structure.                 |
| 11   | 8                       | P07                     | P-port input/output. Push-pull design structure.                 |
| 12   | 9                       | GND                     | Ground   |
| 13   | 10                      | P10                     | P-port input/output. Push-pull design structure.                 |
| 14   | 11                      | P11                     | P-port input/output. Push-pull design structure.                 |
| 15   | 12                      | P12                     | P-port input/output. Push-pull design structure.                 |
| 16   | 13                      | P13                     | P-port input/output. Push-pull design structure.                 |
| 17   | 14                      | P14                     | P-port input/output. Push-pull design structure.                 |
| 18   | 15                      | P15                     | P-port input/output. Push-pull design structure.                 |
| 19   | 16                      | P16                     | P-port input/output. Push-pull design structure.                 |
| 20   | 17                      | P17                     | P-port input/output. Push-pull design structure.                 |
| 21   | 18                      | A0                      | Address input. Connect directly to $V_{CC}$ or ground.           |
| 22   | 19                      | SCL                     | Serial clock bus. Connect to $V_{CC}$ through a pullup resistor. |
| 23   | 20                      | SDA                     | Serial data bus. Connect to $V_{CC}$ through a pullup resistor.  |
| 24   | 21                      | $V_{CC}$                | Supply voltage   |

**LOGIC DIAGRAM (POSITIVE LOGIC)**

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

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



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

### I/O Port

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

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

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

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

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

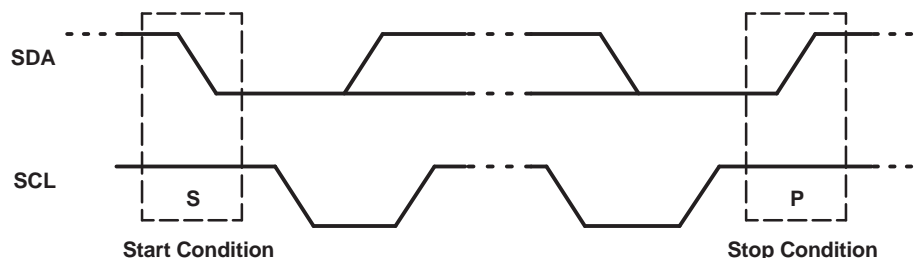
After receiving the valid address byte, this device responds with an ACK, a low on the SDA input/output during the high of the ACK-related clock pulse. The address inputs (A0–A2) of the slave device must not be changed between the Start and Stop conditions.

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 2).

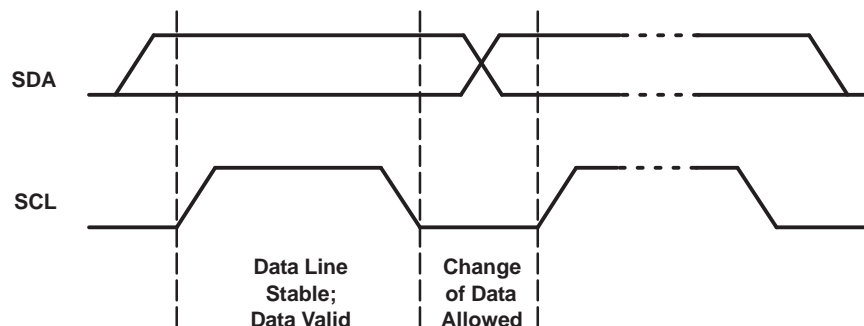
A Stop condition, a low-to-high transition on the SDA input/output while the SCL input is high, is sent by the master (see Figure 1).

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

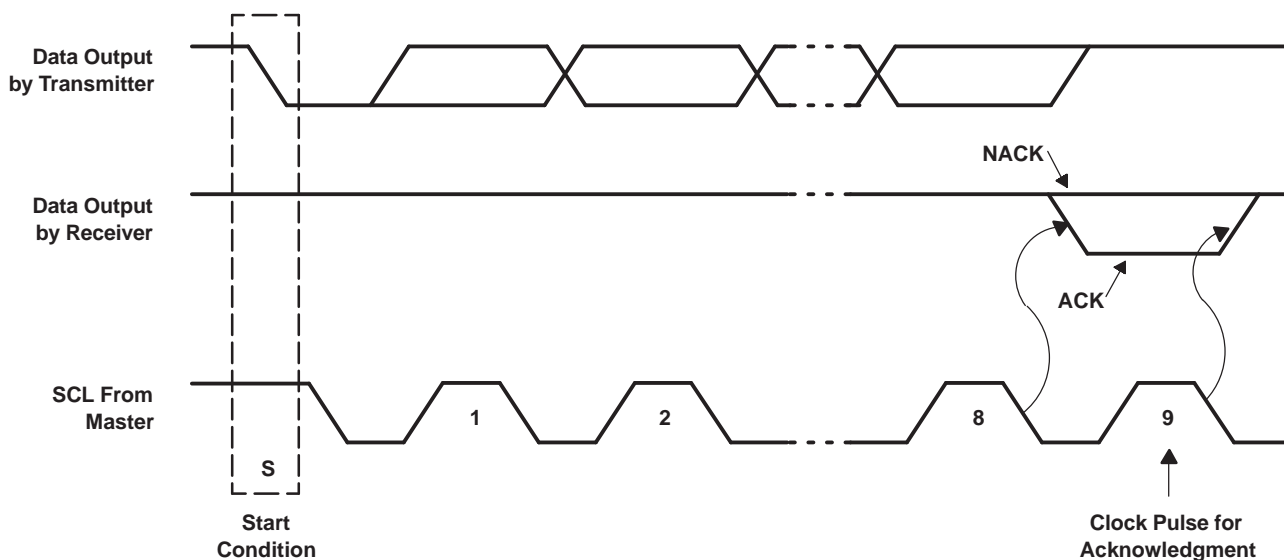
A master receiver signals an end of data to the slave transmitter by not generating an acknowledge (NACK) after the last byte has been clocked out of the slave. This is done by the master receiver by holding the SDA line high. In this event, the transmitter must release the data line to enable the master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



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



**Figure 2. Bit Transfer**



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

### Interface Definition

| BYTE                           | BIT     |     |     |     |     |     |     |                   |
|--------------------------------|---------|-----|-----|-----|-----|-----|-----|-------------------|
|                                | 7 (MSB) | 6   | 5   | 4   | 3   | 2   | 1   | 0 (LSB)           |
| I <sup>2</sup> C slave address | L       | H   | L   | L   | A2  | A1  | A0  | R/ $\overline{W}$ |
| P0x I/O data bus               | P07     | P06 | P05 | P04 | P03 | P02 | P01 | P00               |
| P1x I/O data bus               | P17     | P16 | P15 | P14 | P13 | P12 | P11 | P10               |

## Device Address

Figure 4 shows the address byte of the PCA9535.

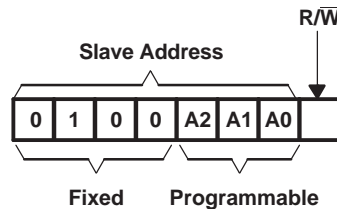


Figure 4. PCA9535 Address

### 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.

## 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.

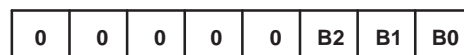


Figure 5. Control Register Bits

### Control Register

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



## Register Descriptions

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

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

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

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

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

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

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

The Polarity Inversion registers (registers 4 and 5) allow polarity inversion of pins defined as inputs by the Configuration register. If a bit in this register is set (written with 1), the corresponding 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.

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

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

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

### Registers 6 and 7 (Configuration Registers)

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

## Power-On Reset

When power (from 0 V) is applied to V<sub>CC</sub>, an internal power-on reset holds the PCA9535 in a reset condition until V<sub>CC</sub> has reached V<sub>POR</sub>. At that point, the reset condition is released, and the PCA9535 registers and I<sup>2</sup>C/SMBus state machine initialize to their default states. After that, V<sub>CC</sub> must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

## 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 or data is read from the port that generated the interrupt or in a Stop event. Resetting occurs in the read mode at the acknowledge (ACK) bit or not acknowledge (NACK) bit after the falling edge of the SCL signal. Interrupts that occur during the ACK or NACK clock pulse can be lost (or be very short) due to the resetting of the interrupt during this pulse. Each change of the I/Os after resetting is detected and is transmitted as  $\overline{\text{INT}}$ .

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

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

## Bus Transactions

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

### Writes

Data is transmitted to the PCA9535 by sending the device address and setting the least-significant bit to a logic 0 (see Figure 4 for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte.

The eight registers within the 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 6 and Figure 7). For example, if the first byte is sent to Output Port 1 (register 3), the next byte is stored in Output Port 0 (register 2).

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

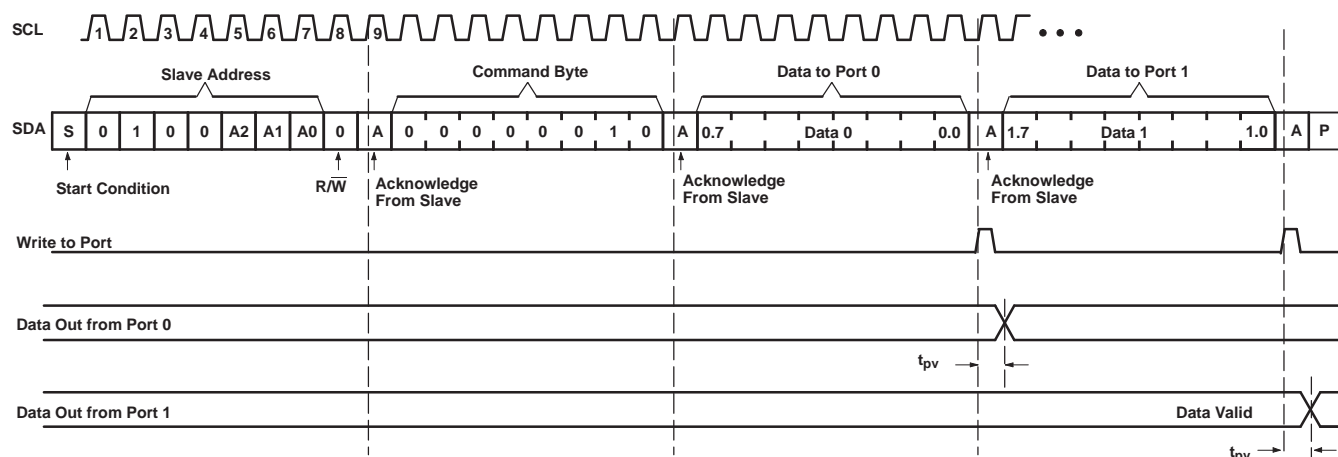


Figure 6. Write to Output Port Registers

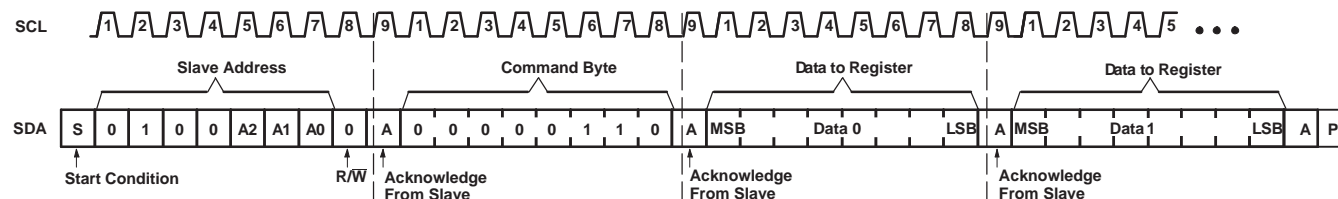


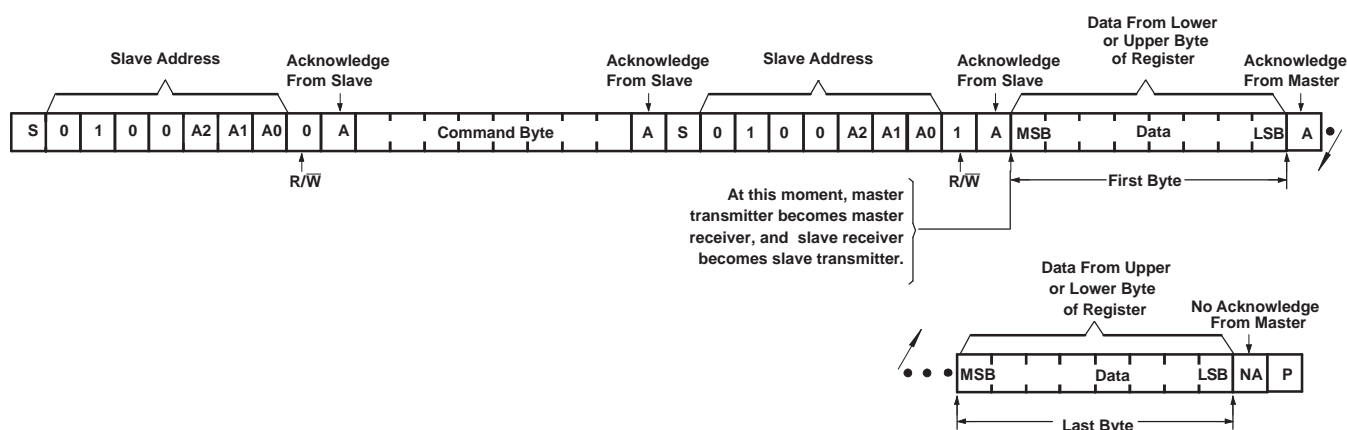
Figure 7. Write to Configuration Registers

## Reads

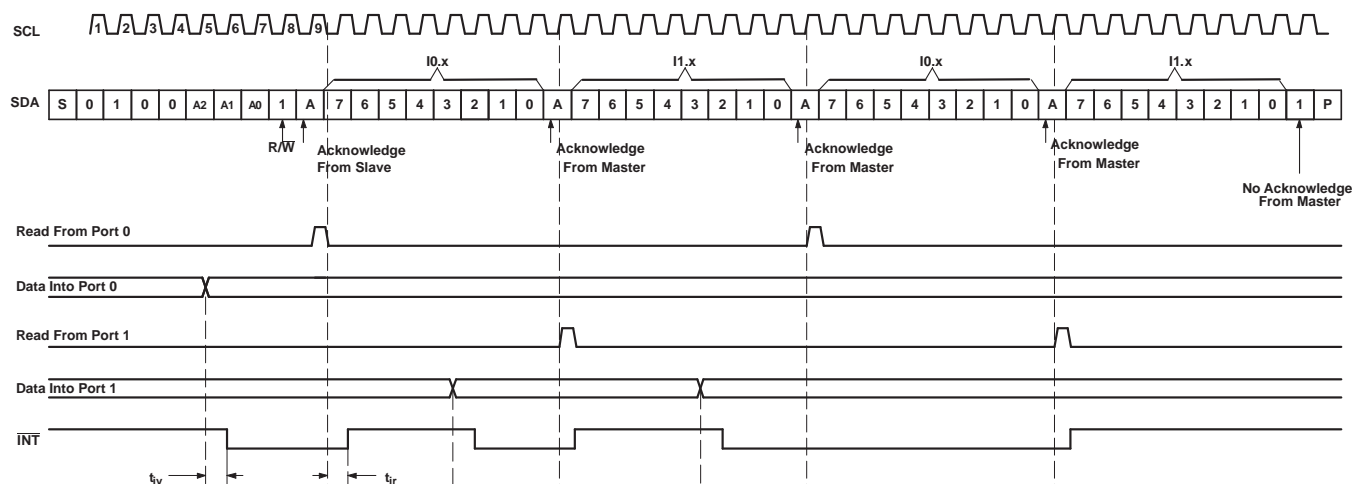
The bus master first must send the PCA9535 address with the least-significant bit set to a logic 0 (see [Figure 4](#) for device address). The command byte is sent after the address and determines which register is accessed. After a restart, the device address is sent again, but this time, the least-significant bit is set to a logic 1. Data from the register defined by the command byte then is sent by the PCA9535 (see [Figure 8](#) through [Figure 10](#)).

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

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

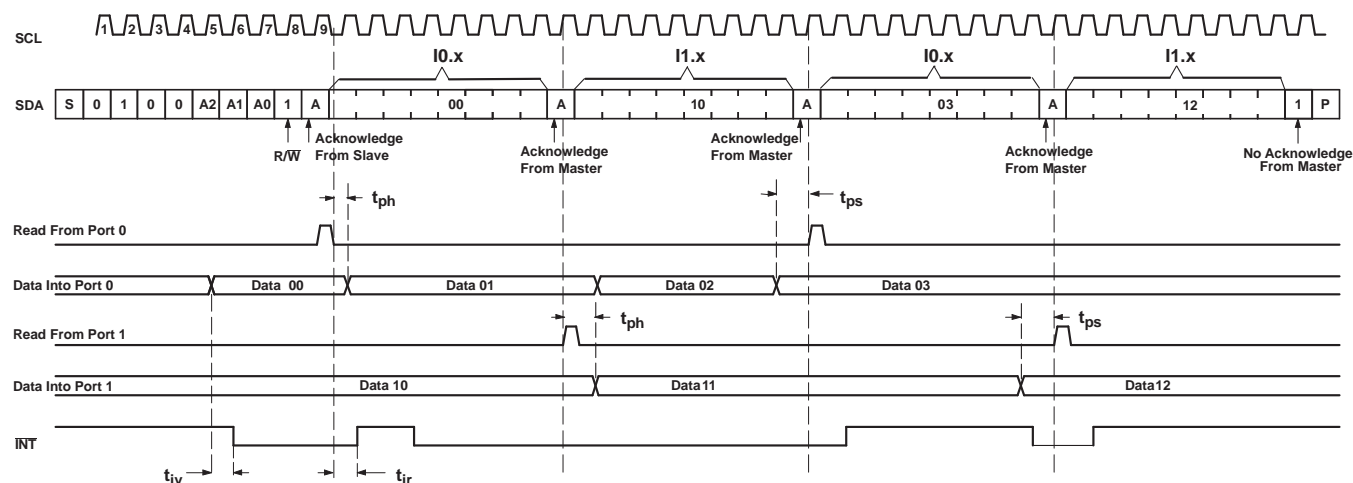


**Figure 8. Read From Register**



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

Figure 9. Read Input Port Register, Scenario 1



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

Figure 10. Read Input Port Register, Scenario 2

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

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

|                  |  |  | MIN  | MAX  | UNIT |
|------------------|--|--|------|------|------|
| V <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  |      |
| θ <sub>JA</sub>  | Package thermal impedance, junction to free air <sup>(3)</sup> | DB package   |      | 63   | °C/W |
|                  |  | DBQ package  |      | 61   |      |
|                  |  | DGV package  |      | 86   |      |
|                  |  | DW package   |      | 46   |      |
|                  |  | PW package   |      | 88   |      |
|                  |  | RGE package  |      | 45   |      |
|                  |  | RTW package  |      | 66   |      |
| θ <sub>JP</sub>  | Package thermal impedance, junction to pad                     | RGE package  |      | 1.5  | °C/W |
| 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.
- (3) The package thermal impedance is calculated in accordance with JESD 51-7.

## RECOMMENDED OPERATING CONDITIONS

|                 |                                |                         | MIN                   | MAX                   | UNIT |
|-----------------|--------------------------------|-------------------------|-----------------------|-----------------------|------|
| V <sub>CC</sub> | Supply voltage                 |                         | 2.3                   | 5.5                   | V    |
| V <sub>IH</sub> | High-level input voltage       | SCL, SDA                | 0.7 × V <sub>CC</sub> | 5.5                   | 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   |

## 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>POR</sub> | Power-on reset voltage                          | V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0  | V <sub>POR</sub> |      | 1.5                | 1.65 | 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,<br>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,<br>f <sub>SCL</sub> = 0 kHz                      | 5.5 V            |      | 0.5                | 1    |      |
|                  |   |  | 3.6 V            |      | 0.4                | 0.9  |      |
|                  |   |  | 2.7 V            |      | 0.25               | 0.8  |      |
| ΔI <sub>CC</sub> | Additional current in standby mode              | One input at V <sub>CC</sub> – 0.6 V,<br>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                  | 7    | pF   |
| C <sub>IO</sub>  | SDA   | V <sub>IO</sub> = V <sub>CC</sub> or GND   | 2.3 V to 5.5 V   |      | 3                  | 7    | 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).

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

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

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

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

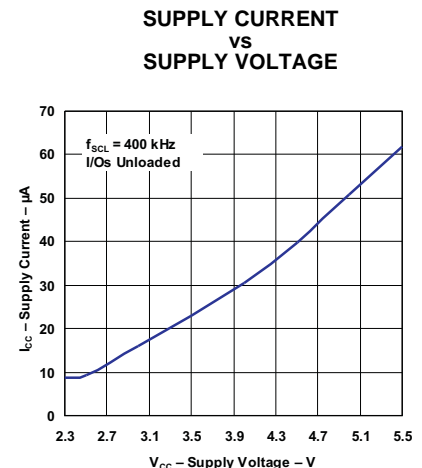
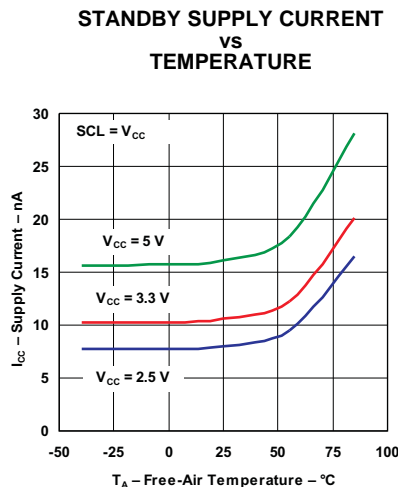
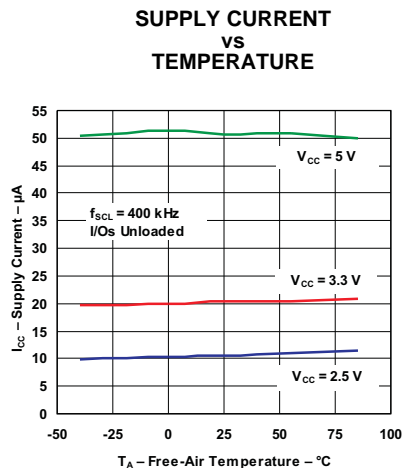
## SWITCHING CHARACTERISTICS

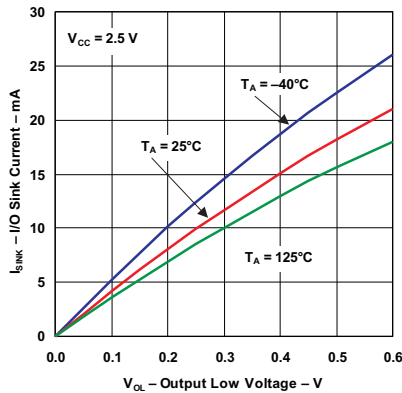
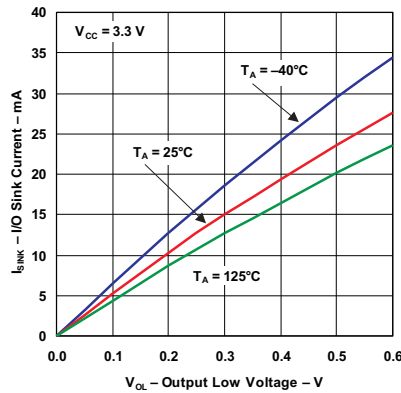
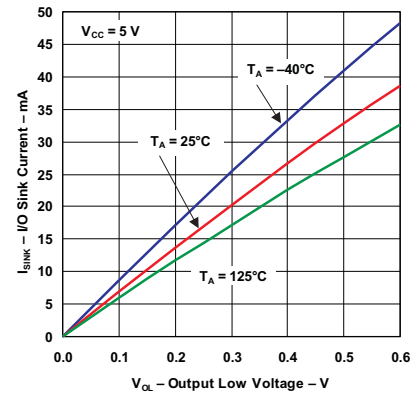
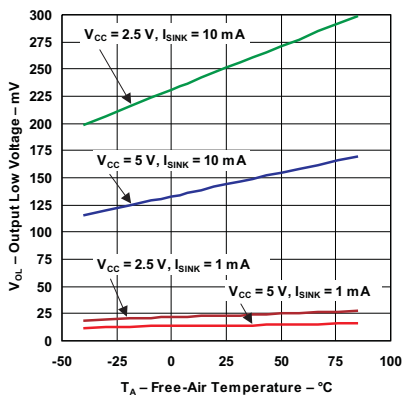
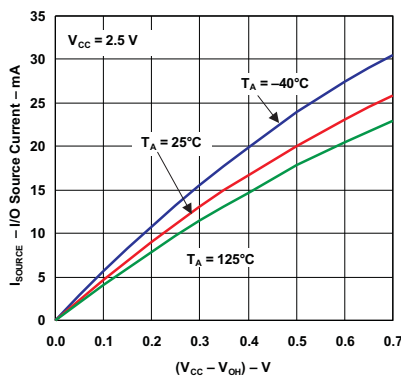
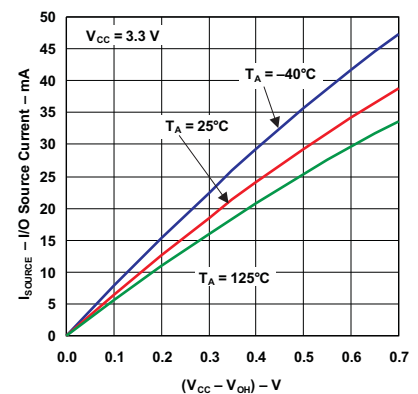
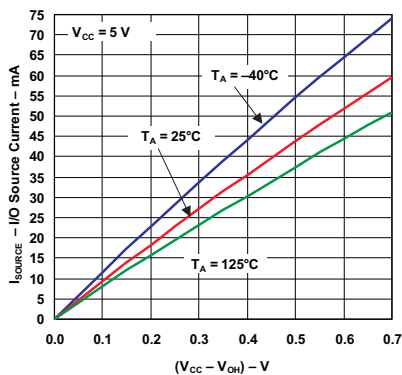
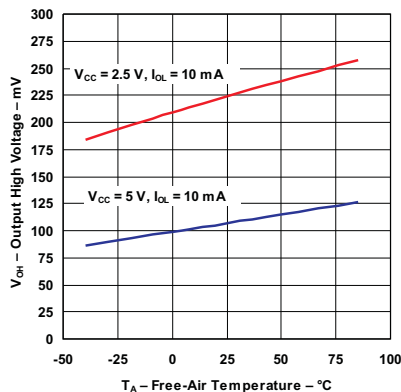
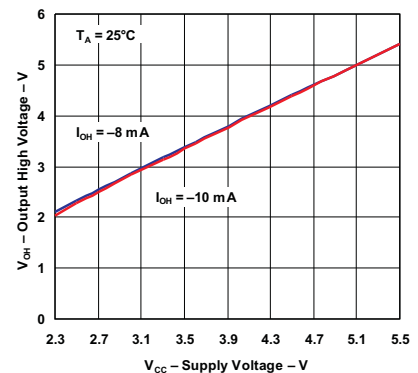
over recommended operating free-air temperature range,  $C_L \leq 100$  pF (unless otherwise noted) (see [Figure 12](#) and [Figure 13](#))

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

## TYPICAL CHARACTERISTICS

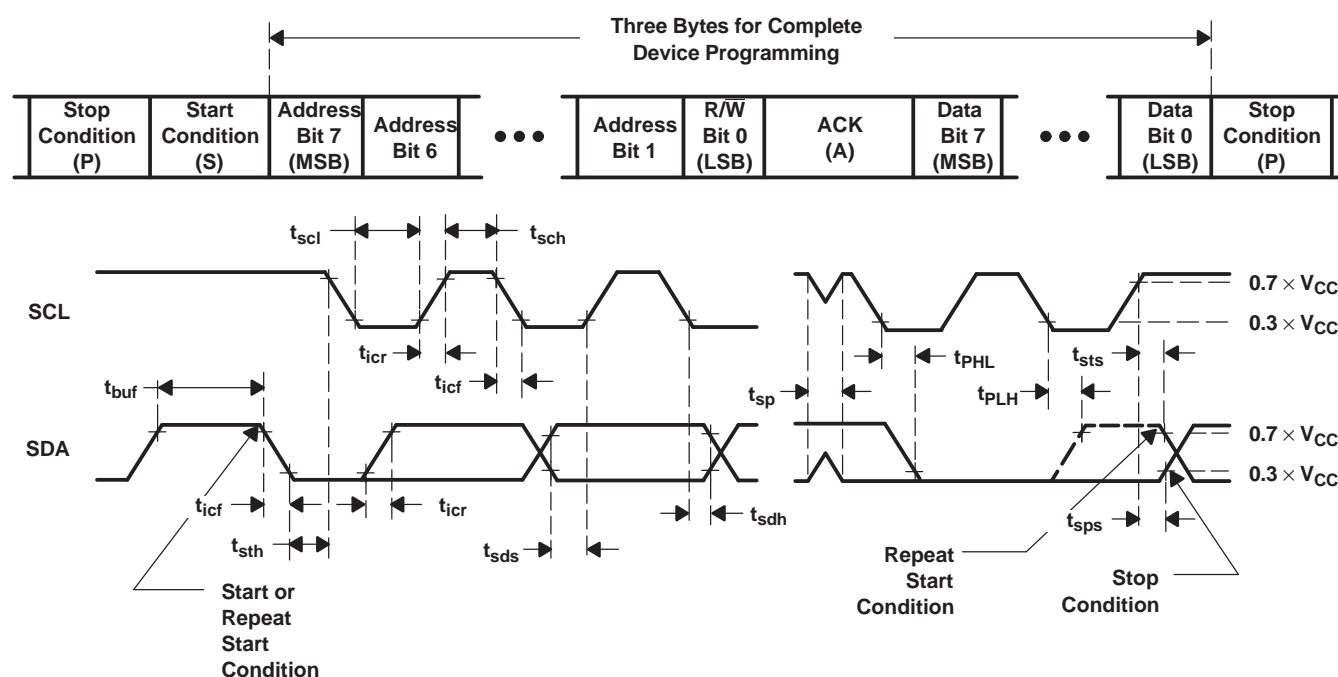
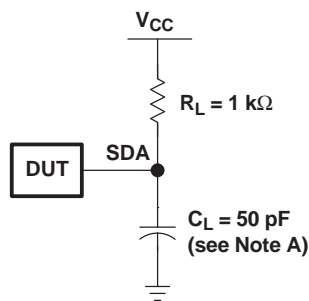
$T_A = 25^\circ\text{C}$  (unless otherwise noted)



**TYPICAL CHARACTERISTICS (continued)** $T_A = 25^\circ\text{C}$  (unless otherwise noted)**I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE****I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE****I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE****I/O OUTPUT LOW 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****I/O HIGH VOLTAGE  
VS  
TEMPERATURE****OUTPUT HIGH VOLTAGE  
VS  
SUPPLY VOLTAGE**



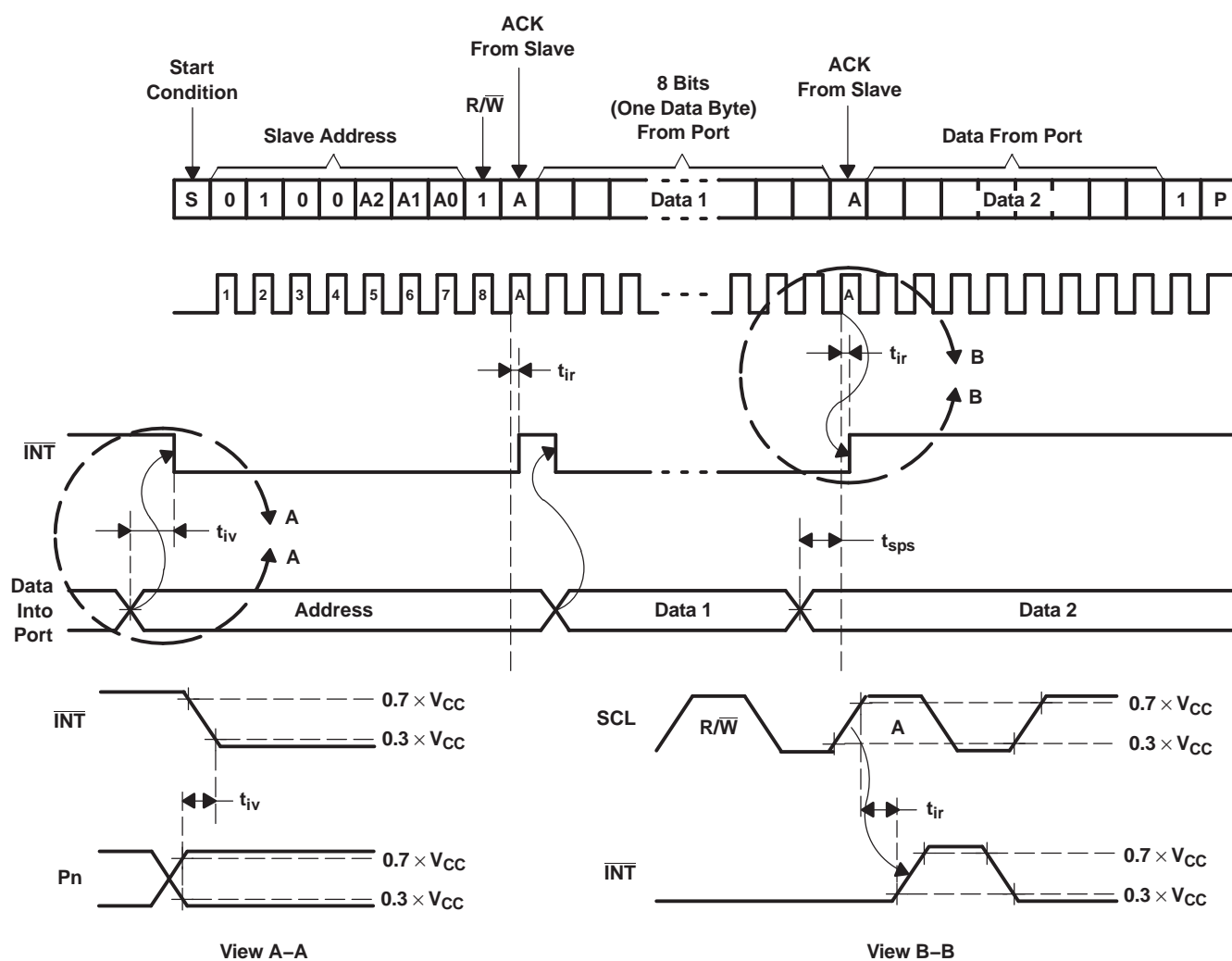
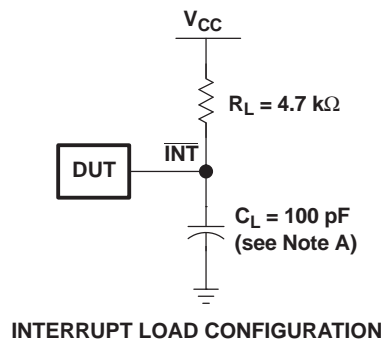
## PARAMETER MEASUREMENT INFORMATION



| 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.

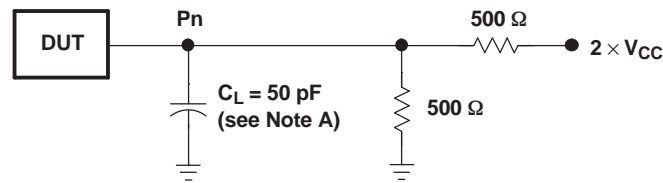
**Figure 11. I<sup>2</sup>C Interface Load Circuit and Voltage Waveforms**

**PARAMETER MEASUREMENT INFORMATION (continued)**

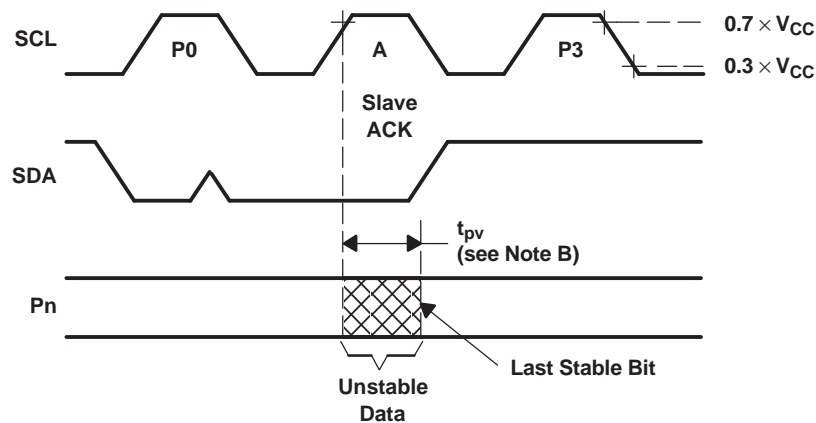
- A.  $C_L$  includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics:  $\text{PRR} \leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r/t_f \leq 30\text{ ns}$ .
- C. All parameters and waveforms are not applicable to all devices.

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

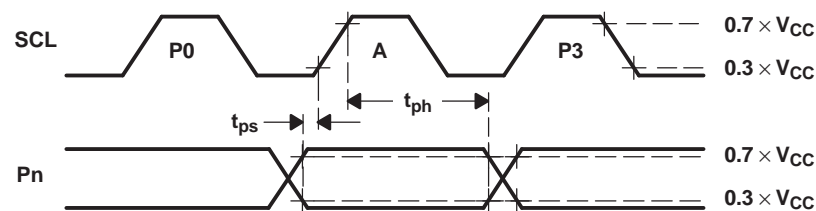
## PARAMETER MEASUREMENT INFORMATION (continued)



**P-POR T LOAD CONFIGURATION**



**WRITE MODE ( $R/\overline{W} = 0$ )**

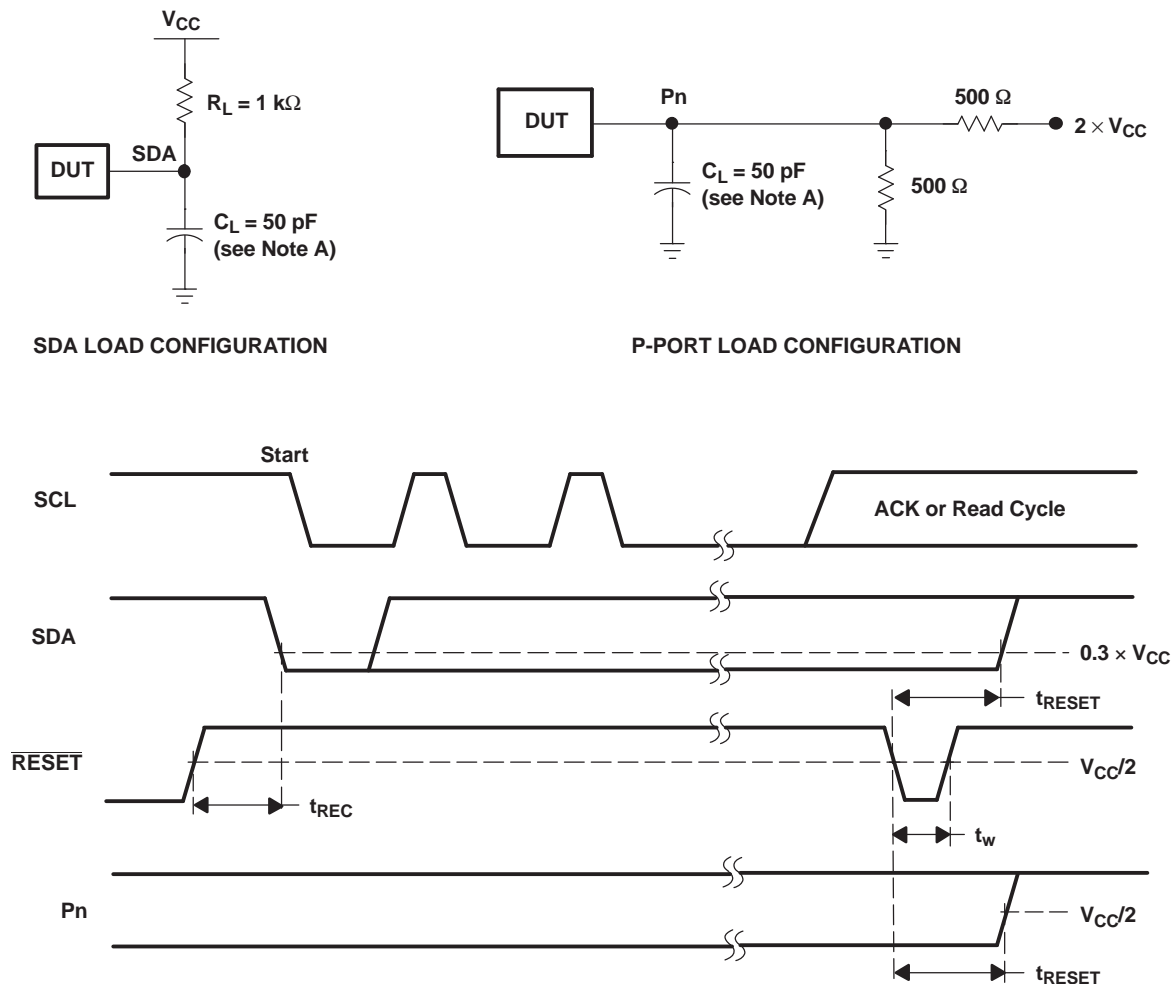


**READ MODE ( $R/\overline{W} = 1$ )**

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

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

## PARAMETER MEASUREMENT INFORMATION (continued)

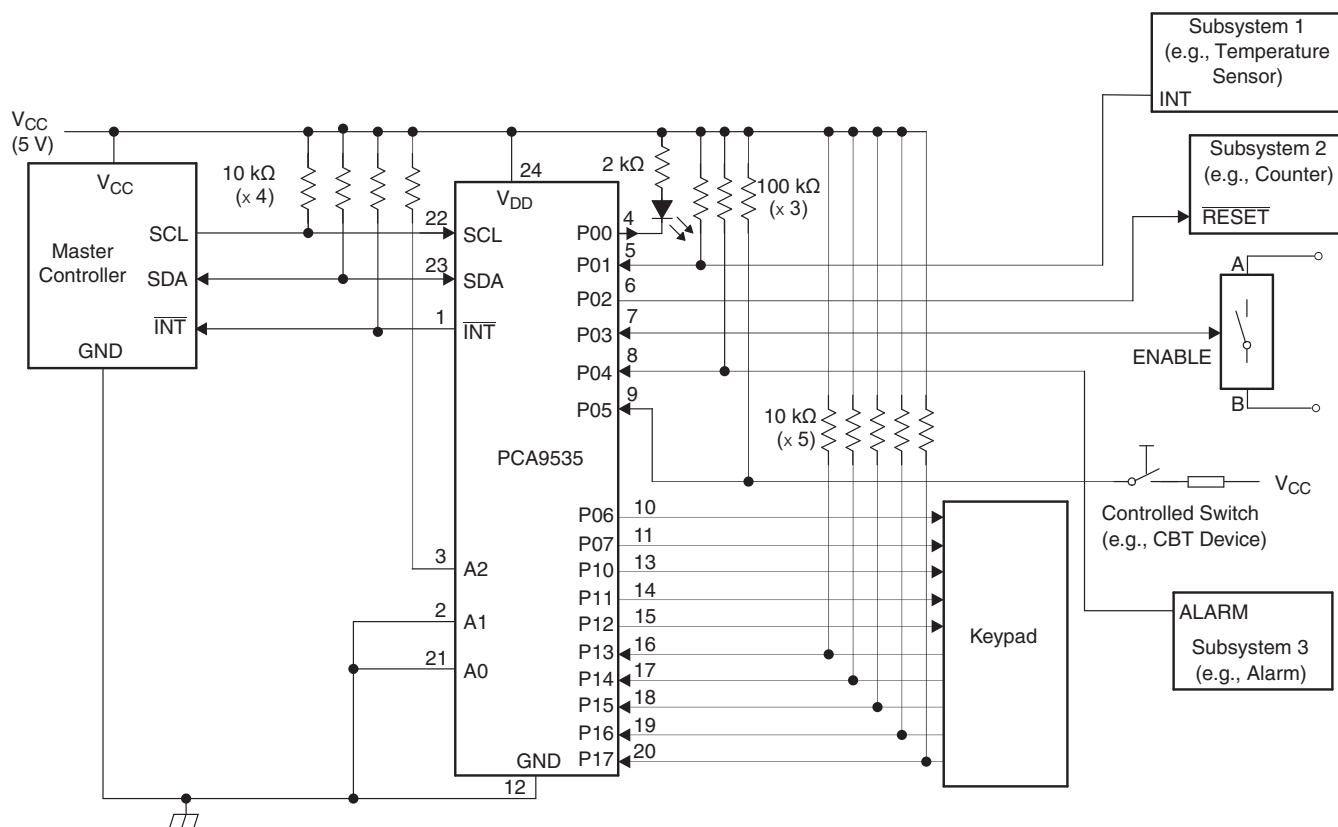


- A.  $C_L$  includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10$  MHz,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30$  ns.
- C. The outputs are measured one at a time, with one transition per measurement.
- D. I/Os are configured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

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

## APPLICATION INFORMATION

Figure 15 shows an application in which the 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 15. Typical Application**

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

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

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

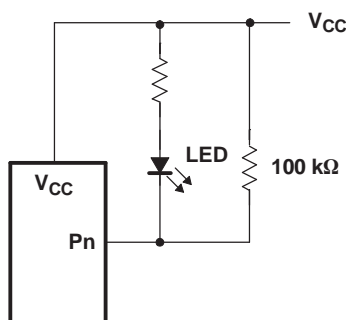


Figure 16. High-Value Resistor in Parallel With LED

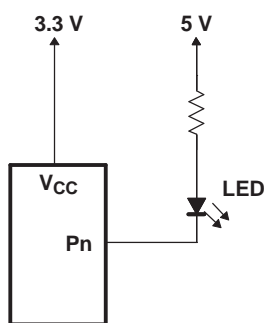


Figure 17. Device Supplied by Lower Voltage

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| PCA9535DB        | NRND                  | SSOP         | DB              | 24   | 60          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DBG4      | NRND                  | SSOP         | DB              | 24   | 60          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DBQR      | NRND                  | SSOP         | DBQ             | 24   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| PCA9535DBQRG4    | NRND                  | SSOP         | DBQ             | 24   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| PCA9535DBR       | NRND                  | SSOP         | DB              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DBRG4     | NRND                  | SSOP         | DB              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DGVR      | NRND                  | TVSOP        | DGV             | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DGVRG4    | NRND                  | TVSOP        | DGV             | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DW        | NRND                  | SOIC         | DW              | 24   | 25          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DWG4      | NRND                  | SOIC         | DW              | 24   | 25          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DWR       | NRND                  | SOIC         | DW              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535DWRG4     | NRND                  | SOIC         | DW              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535PW        | NRND                  | TSSOP        | PW              | 24   | 60          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535PWE4      | NRND                  | TSSOP        | PW              | 24   | 60          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535PWG4      | NRND                  | TSSOP        | PW              | 24   | 60          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535PWR       | NRND                  | TSSOP        | PW              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535PWRE4     | NRND                  | TSSOP        | PW              | 24   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|----------------------|------------------------------|-----------------------------|
| PCA9535PWRG4     | NRND                  | TSSOP        | PW              | 24   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| PCA9535RGER      | NRND                  | VQFN         | RGE             | 24   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| PCA9535RGERG4    | NRND                  | VQFN         | RGE             | 24   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| PCA9535RTWR      | NRND                  | WQFN         | RTW             | 24   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| PCA9535RTWRG4    | NRND                  | WQFN         | RTW             | 24   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |

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

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

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

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

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

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

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

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

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

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

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

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

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

**TAPE DIMENSIONS**


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

**TAPE AND REEL INFORMATION**

\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| 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 | 367.0       | 367.0      | 38.0        |
| PCA9535DBR  | SSOP         | DB              | 24   | 2000 | 367.0       | 367.0      | 38.0        |
| PCA9535DGVR | TVSOP        | DGV             | 24   | 2000 | 367.0       | 367.0      | 35.0        |
| PCA9535DWR  | SOIC         | DW              | 24   | 2000 | 367.0       | 367.0      | 45.0        |
| PCA9535PWR  | TSSOP        | PW              | 24   | 2000 | 367.0       | 367.0      | 38.0        |
| PCA9535RGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| PCA9535RTWR | WQFN         | RTW             | 24   | 3000 | 367.0       | 367.0      | 35.0        |

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.

DBQ (R-PDSO-G24)

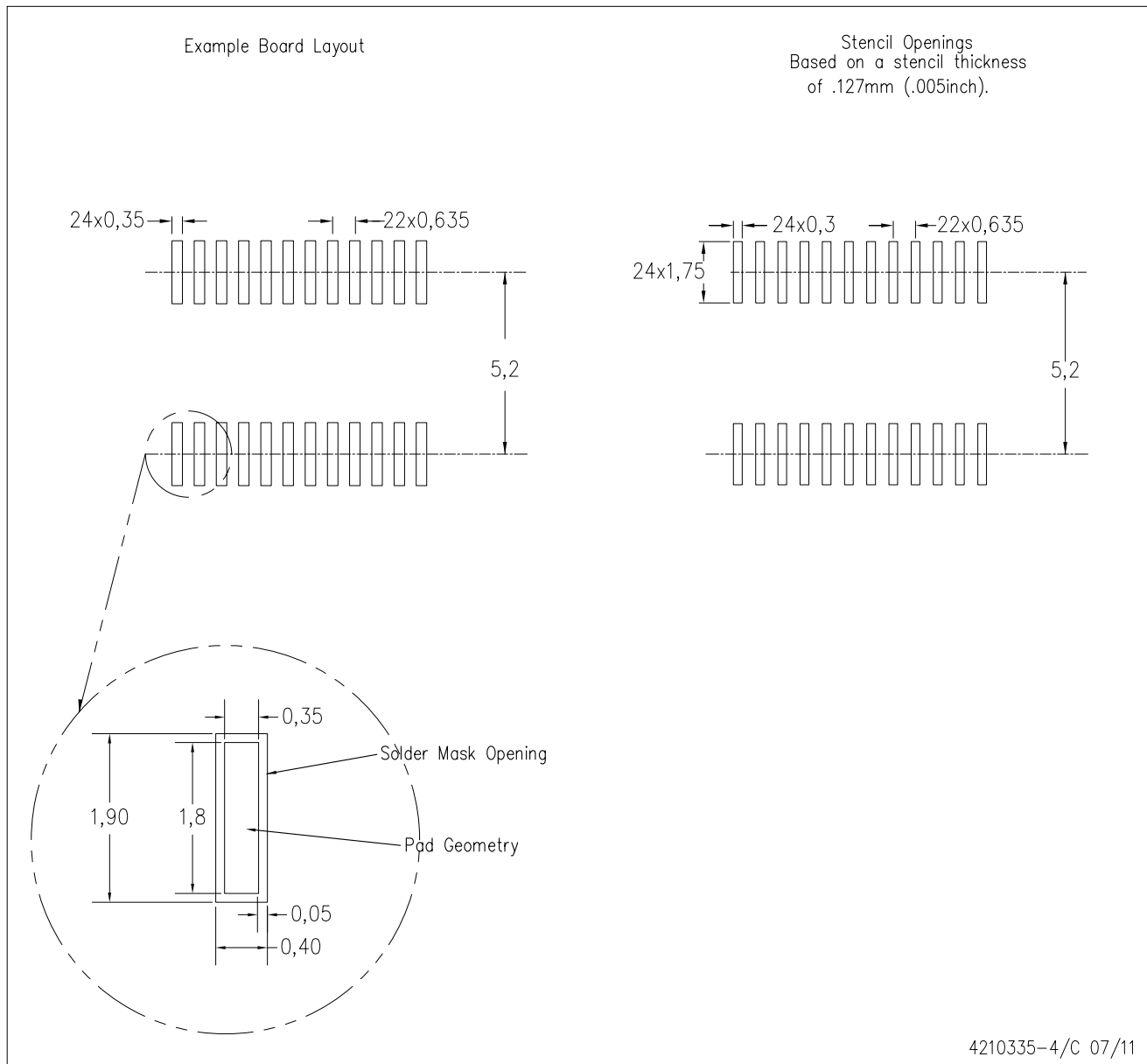
PLASTIC SMALL-OUTLINE PACKAGE



- 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.

DBQ (R-PDSO-G24)

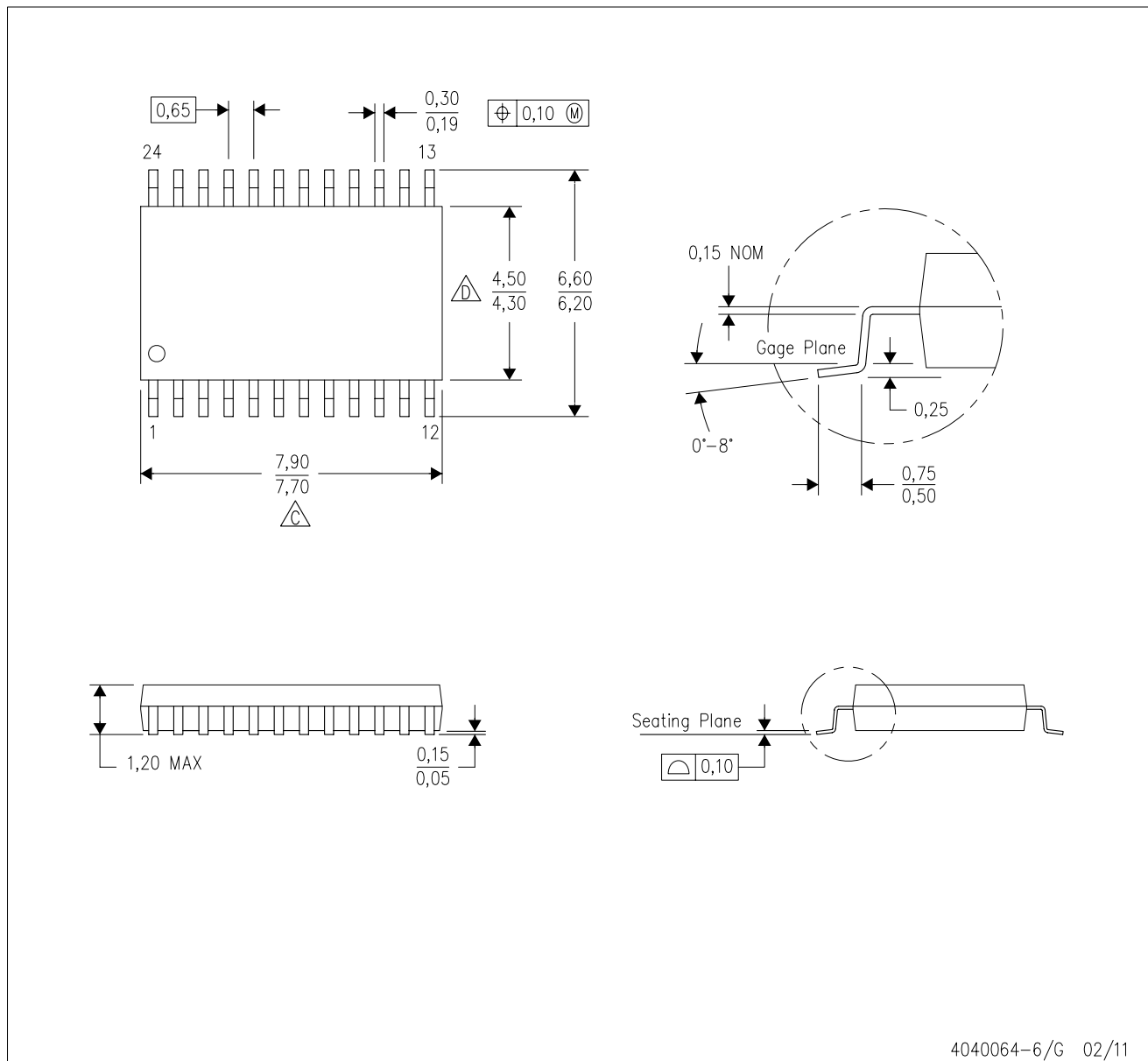
PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

PW (R-PDSO-G24)

PLASTIC SMALL OUTLINE

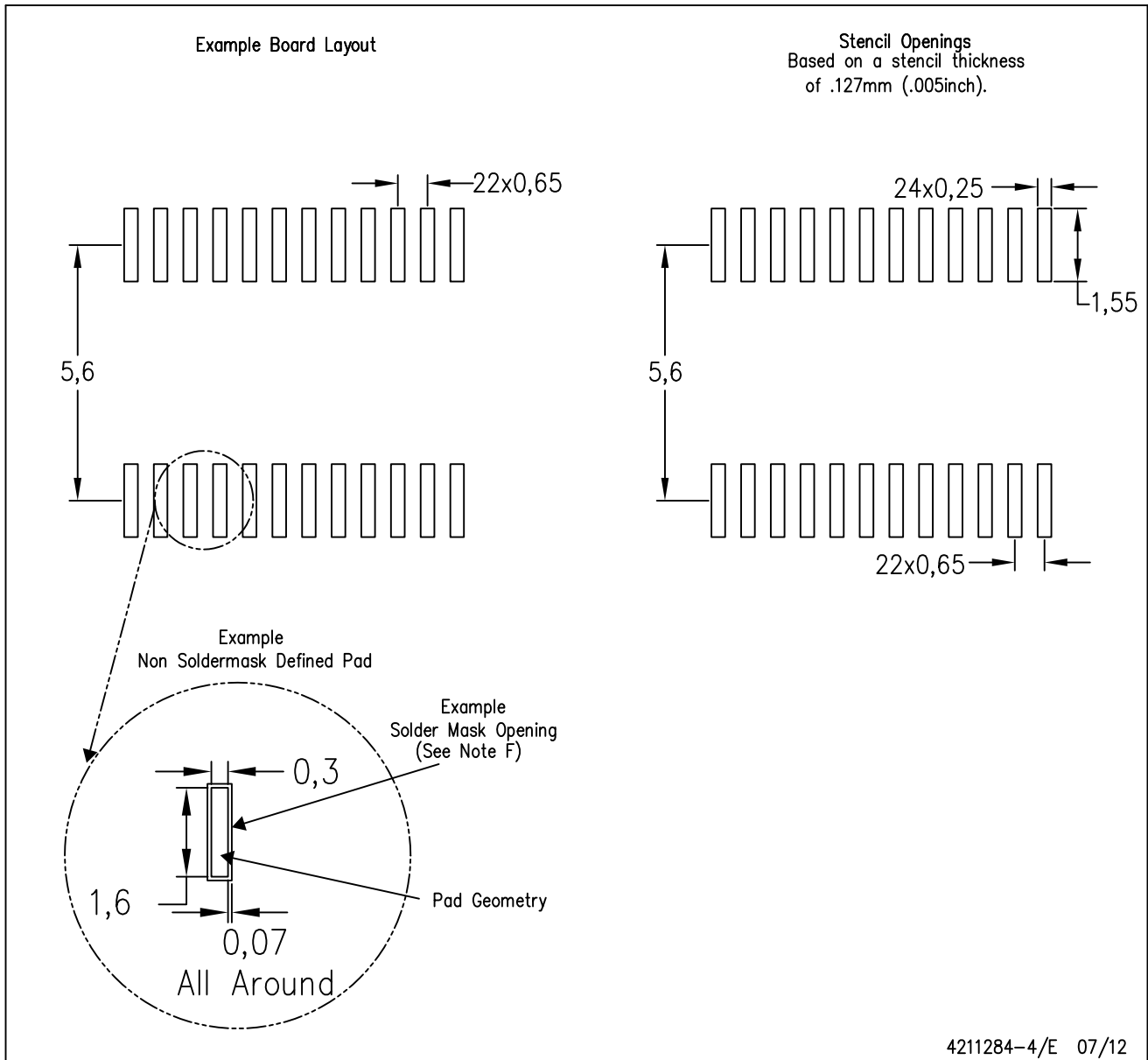


4040064-6/G 02/11

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

PW (R-PDSO-G24)

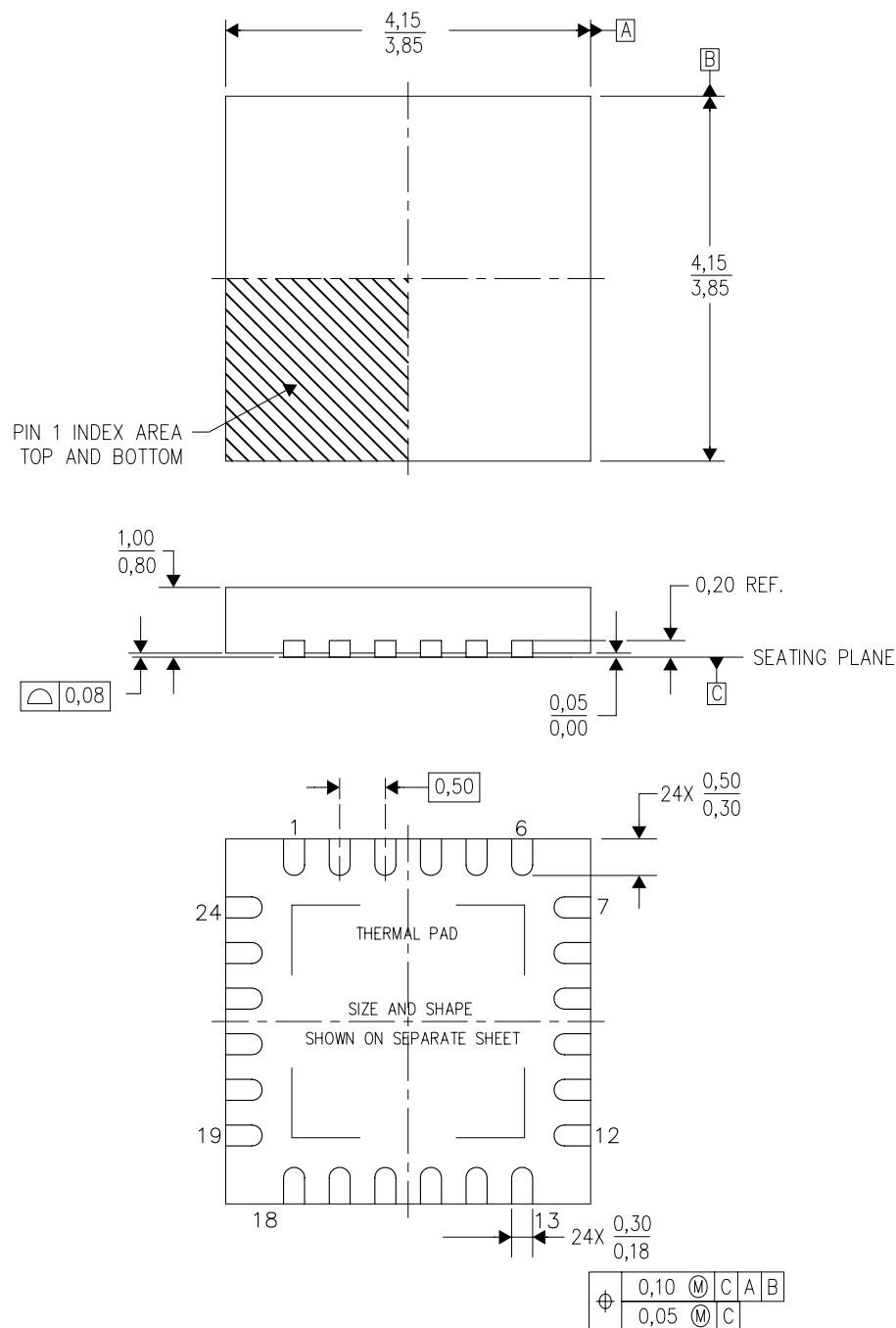
PLASTIC SMALL OUTLINE



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

RGE (S-PVQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



4204104/G 07/11

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



## THERMAL PAD MECHANICAL DATA

RGE (S-PVQFN-N24)

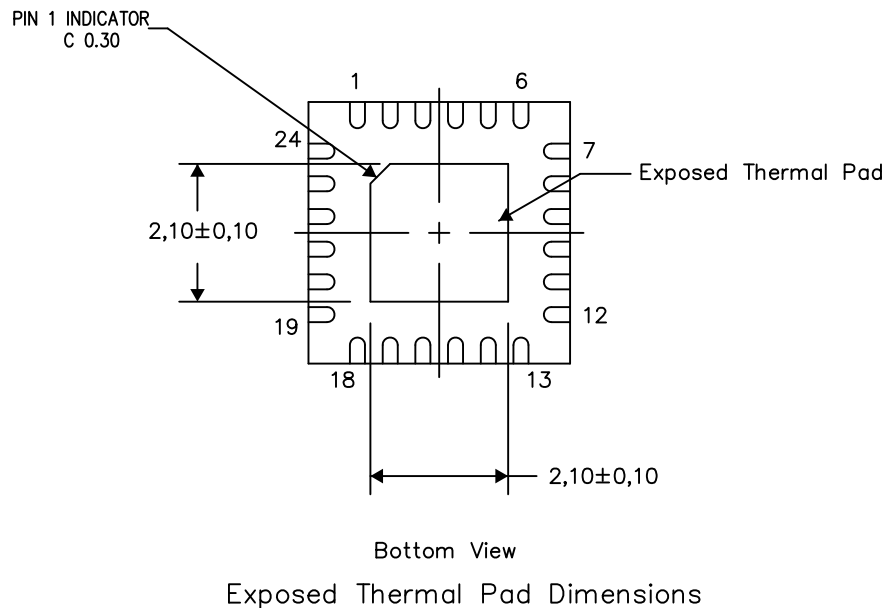
PLASTIC QUAD FLATPACK NO-LEAD

### THERMAL INFORMATION

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

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

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

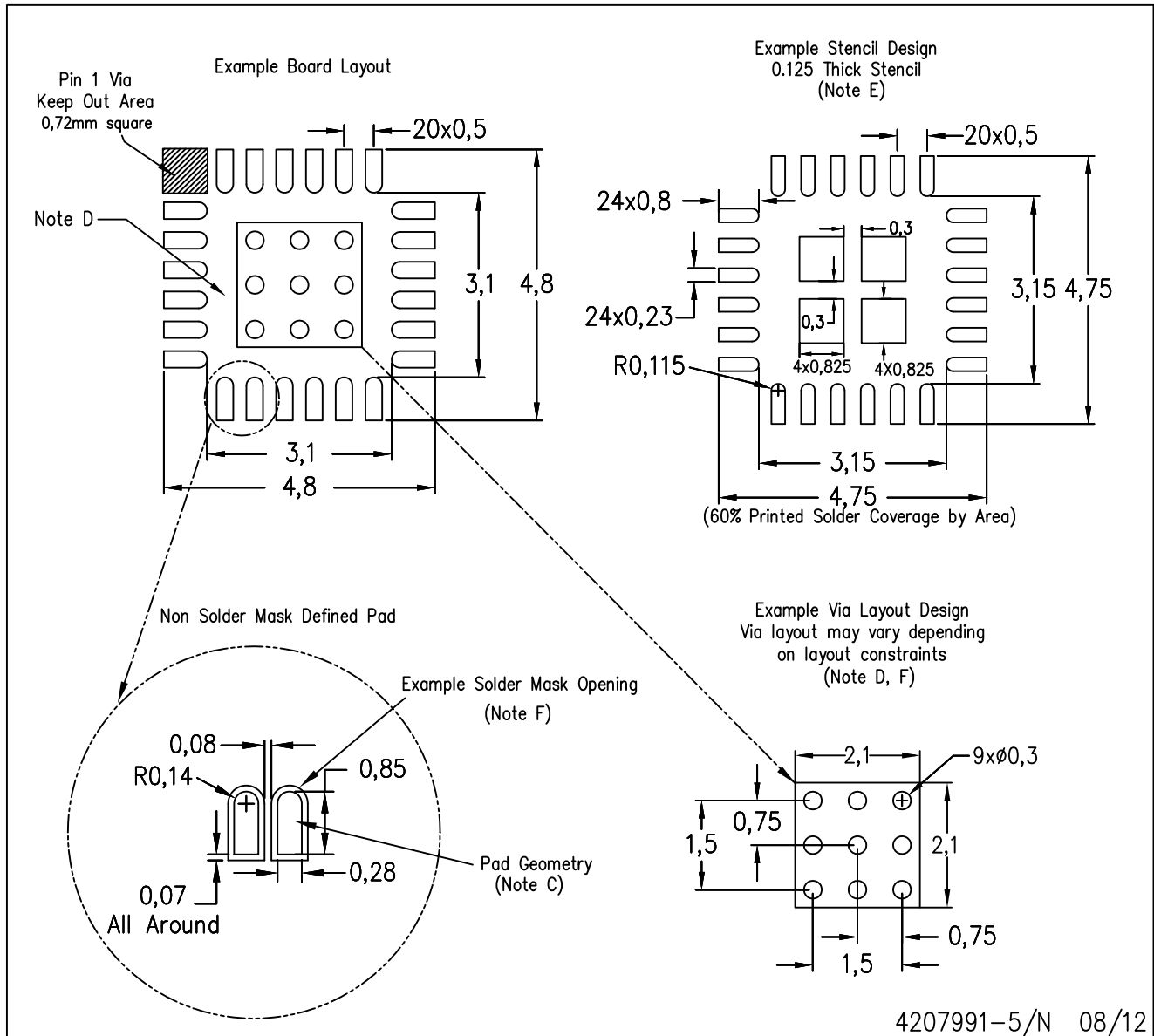


4206344-6/AA 04/12

NOTES: A. All linear dimensions are in millimeters

RGE (S-PVQFN-N24)

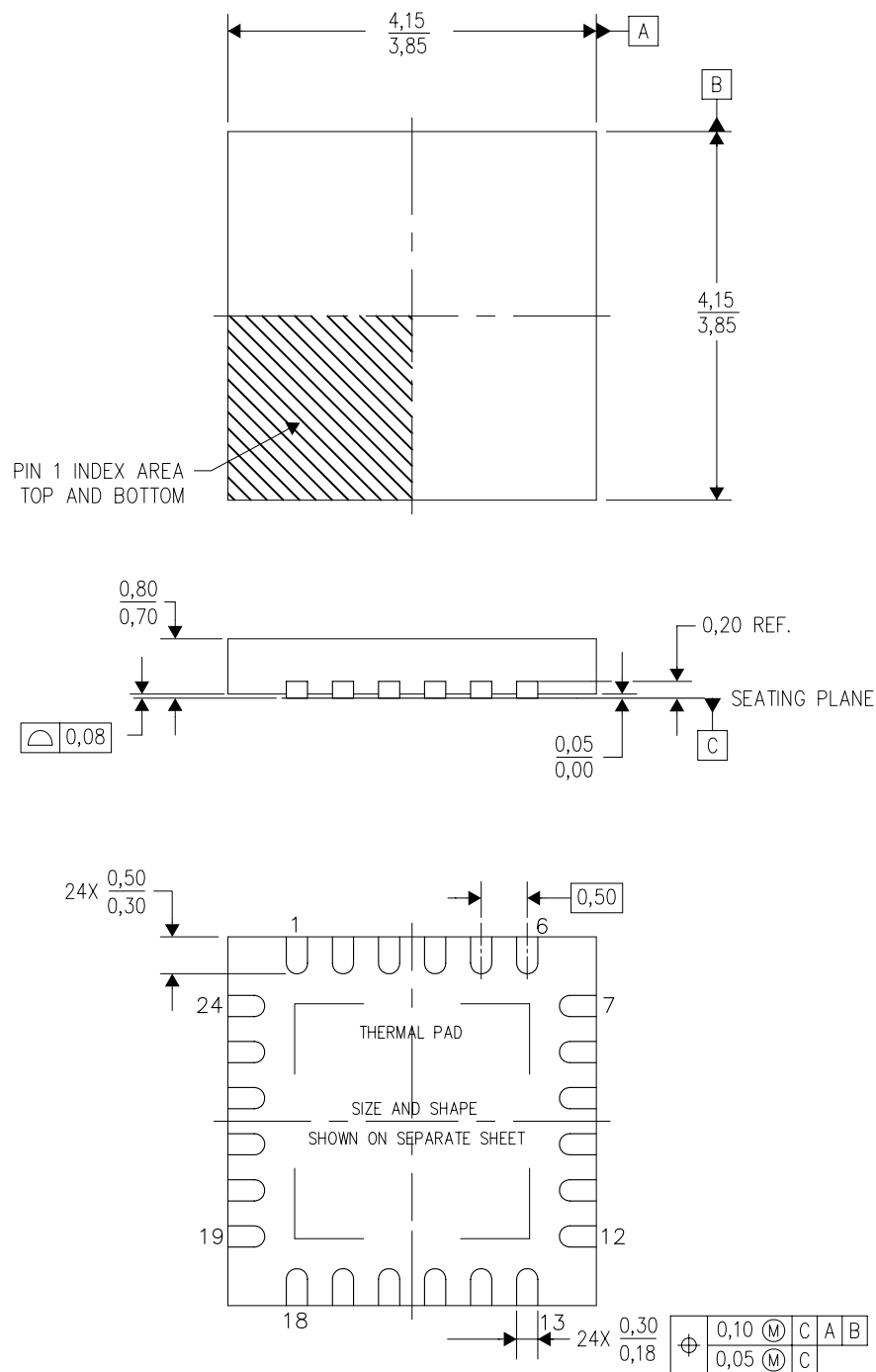
PLASTIC QUAD FLATPACK NO-LEAD



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

RTW (S-PWQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



4206244/C 07/11

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

RTW (S-PWQFN-N24)

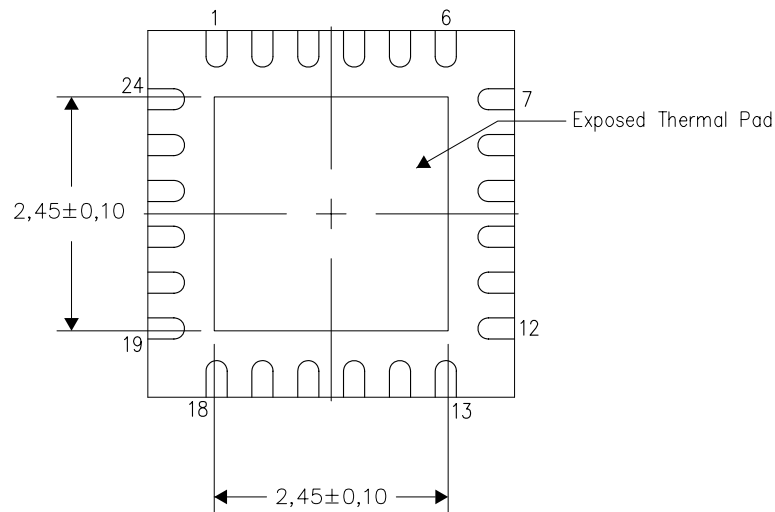
PLASTIC QUAD FLATPACK NO-LEAD

## THERMAL INFORMATION

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

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

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



Bottom View

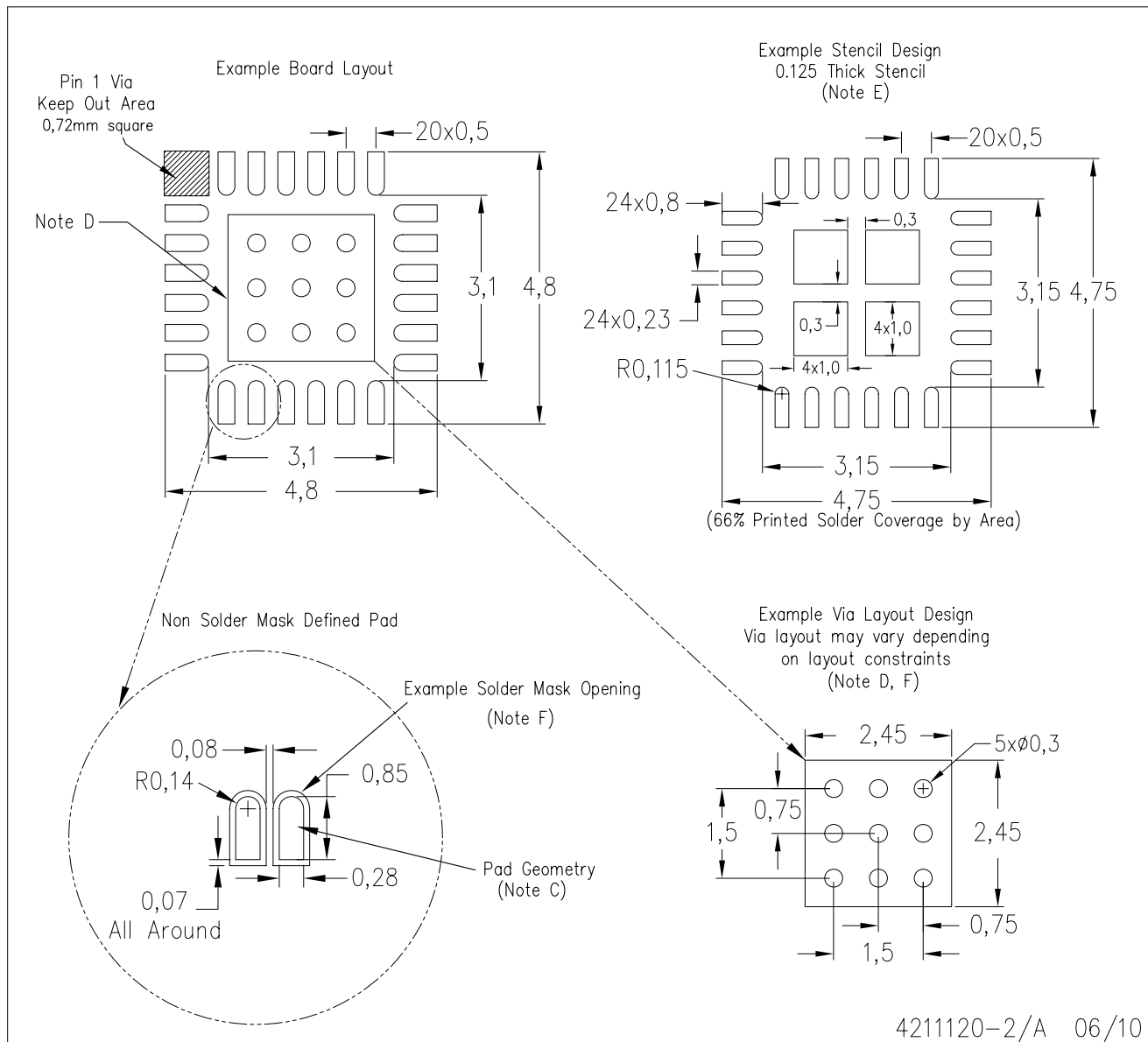
Exposed Thermal Pad Dimensions

4206249-3/L 07/11

NOTES: A. All linear dimensions are in millimeters

RTW (S-PWQFN-N24)

PLASTIC QUAD FLATPACK NO-LEAD



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

## 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

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