

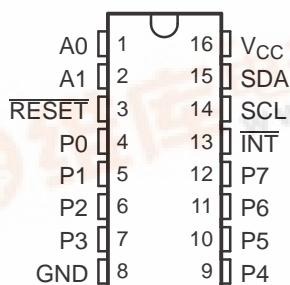
# REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS

SCPS126D–SEPTEMBER 2006–REVISED MARCH 2007

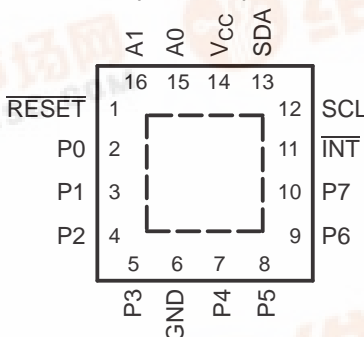
## FEATURES

- Low Standby Current Consumption of 1  $\mu$ A Max
- I<sup>2</sup>C to Parallel Port Expander
- Open-Drain Active-Low Interrupt Output
- Active-Low Reset Input
- Operating Power-Supply Voltage Range of 2.3 V to 5.5 V
- 5-V Tolerant I/O Ports
- 400-kHz Fast I<sup>2</sup>C Bus
- Two Hardware Address Pins Allow up to Four Devices on the I<sup>2</sup>C/SMBus
- Input/Output Configuration Register
- Polarity Inversion Register
- Power-Up With All Channels Configured as Inputs
- No Glitch on Power Up
- Noise Filter on SCL/SDA Inputs
- Latched Outputs With High-Current Drive Maximum Capability for Directly Driving LEDs
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 200-V Machine Model (A115-A)
  - 1000-V Charged-Device Model (C101)

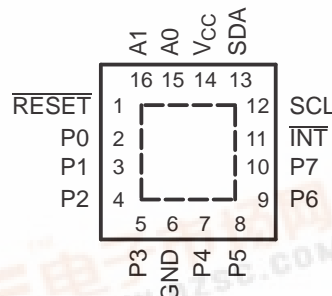
DB, DBQ, DGV, DW, OR PW PACKAGE  
(TOP VIEW)



RGV PACKAGE  
(TOP VIEW)



RGT PACKAGE  
(TOP VIEW)



## DESCRIPTION/ORDERING INFORMATION

This 8-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  $V_{CC}$  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 PCA9538 consists of one 8-bit Configuration (input or output selection), Input Port, Output Port, and Polarity Inversion (active high or active low) registers. At power on, the I/Os are configured as inputs. However, the system master can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input Port 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 PCA9538 in the event of a timeout or other improper operation by asserting a low in the RESET input. The power-on reset puts the registers in their default state and initializes the I<sup>2</sup>C/SMBus state machine. The RESET pin causes the same reset/initialization to occur without powering down the part.

The PCA9538 open-drain interrupt ( $\overline{INT}$ ) output is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system master that an input state has changed.

$\overline{INT}$  can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I<sup>2</sup>C bus. Thus, the PCA9538 can remain a simple slave device.

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

# PCA9538

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

#### ORDERING INFORMATION

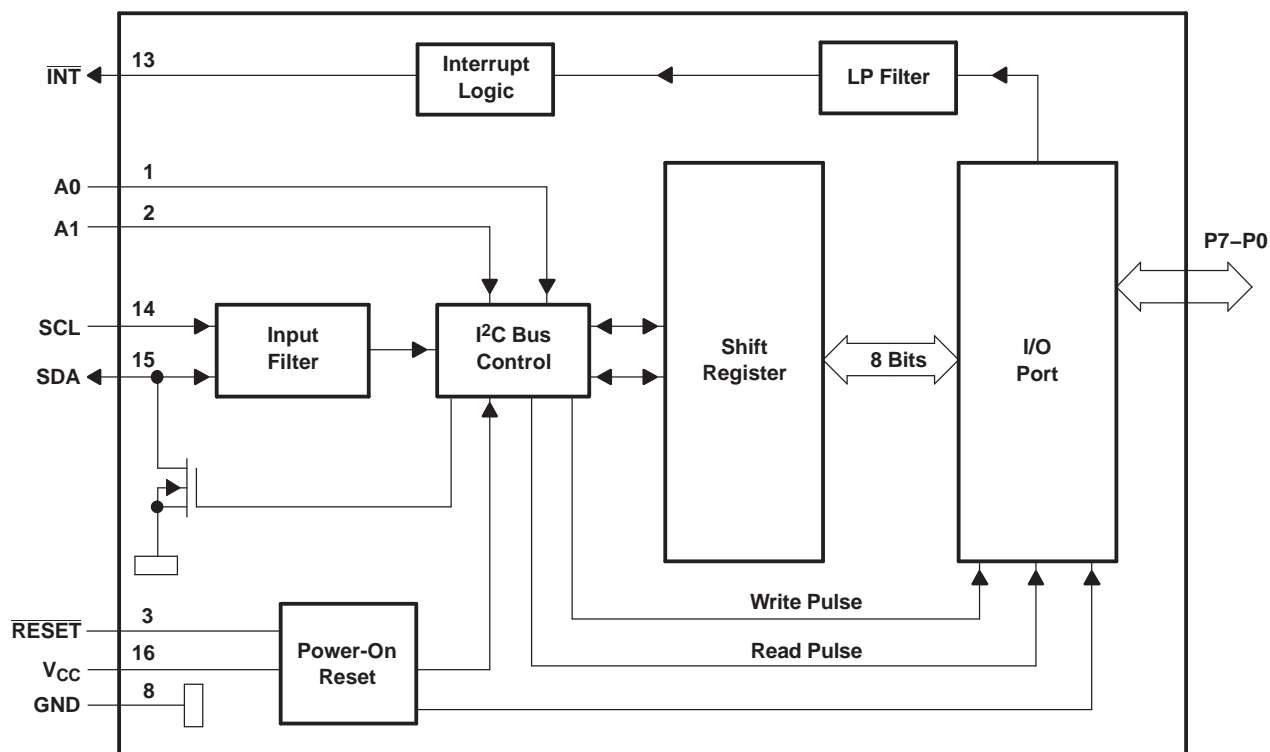
| T <sub>A</sub> | PACKAGE <sup>(1)</sup> |              | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|------------------------|--------------|-----------------------|------------------|
| –40°C to 85°C  | QFN – RGT              | Reel of 3000 | PCA9538RGTR           | PREVIEW          |
|                | QFN – RGV              | Reel of 2500 | PCA9538RGVR           | PREVIEW          |
|                | QSOP – DBQ             | Reel of 2500 | PCA9538DBQR           | PD538            |
|                | SOIC – DW              | Tube of 40   | PCA9538DW             | PCA9538          |
|                |                        | Reel of 2000 | PCA9538DWR            |                  |
|                | SSOP – DB              | Reel of 2000 | PCA9538DBR            | PD538            |
|                |                        | Tube of 80   | PCA9538DB             |                  |
|                | TSSOP – PW             | Tube of 90   | PCA9538PW             | PD538            |
|                |                        | Reel of 2000 | PCA9538PWR            |                  |
|                | TVSOP – DGV            | Reel of 2000 | PCA9538DGVR           | PD538            |

(1) 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   |
|--|---------------------------|-----------------|---|
| QSOP (DBQ),<br>SSOP (DB),<br>TSSOP (PW), OR<br>TVSOP (DGV) | QFN (RGT) OR<br>QFN (RGV) |                 |   |
| 1  | 15                        | A0              | Address input. Connect directly to V <sub>CC</sub> or ground.   |
| 2  | 16                        | A1              | Address input. Connect directly to V <sub>CC</sub> or ground.   |
| 3  | 1                         | RESET           | Active-low reset input. Connect to V <sub>CC</sub> through a pullup resistor if no active connection is used. |
| 4  | 2                         | P0              | P-port input/output. Push-pull design structure.  |
| 5  | 3                         | P1              | P-port input/output. Push-pull design structure.  |
| 6  | 4                         | P2              | P-port input/output. Push-pull design structure.  |
| 7  | 5                         | P3              | P-port input/output. Push-pull design structure.  |
| 8  | 6                         | GND             | Ground  |
| 9  | 7                         | P4              | P-port input/output. Push-pull design structure.  |
| 10   | 8                         | P5              | P-port input/output. Push-pull design structure.  |
| 11   | 9                         | P6              | P-port input/output. Push-pull design structure.  |
| 12   | 10                        | P7              | P-port input/output. Push-pull design structure.  |
| 13   | 11                        | INT             | Interrupt output. Connect to V <sub>CC</sub> through a pullup resistor.                                       |
| 14   | 12                        | SCL             | Serial clock bus. Connect to V <sub>CC</sub> through a pullup resistor.                                       |
| 15   | 13                        | SDA             | Serial data bus. Connect to V <sub>CC</sub> through a pullup resistor.  |
| 16   | 14                        | V <sub>CC</sub> | Supply voltage  |

## FUNCTIONAL BLOCK DIAGRAM



A. Pin numbers shown are for the DB, DBQ, DGV, DW, or PW package.

# PCA9538

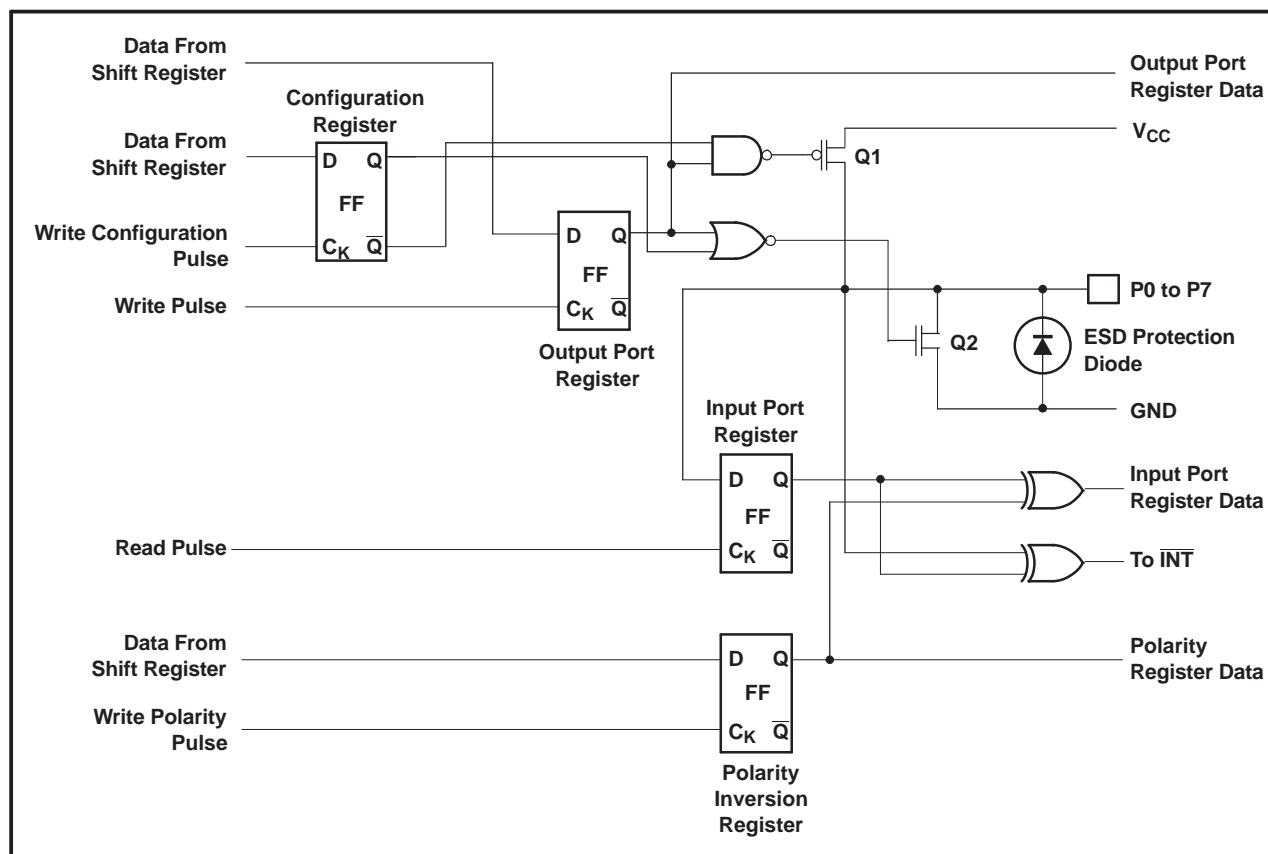
## REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER

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#### SIMPLIFIED SCHEMATIC OF P0 TO P7



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

#### I/O Port

When an I/O is configured as an input, FETs Q1 and Q2 are off, creating 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 through a pull-up 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, most significant bit (MSB) first, including the data direction bit (R/W).

After receiving the valid address byte, this device responds with an acknowledge (ACK), a low on the SDA input/output during the high of the ACK-related clock pulse. The address inputs (A0–A1) of the slave device must not be changed between the Start and the 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 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 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 will signal an end of data to the slave transmitter by not generating an acknowledge (NACK) after the last byte has been clocked out of the slave. This is done by the master receiver by holding the SDA line high. In this event, the transmitter must release the data line to enable the master to generate a Stop condition.

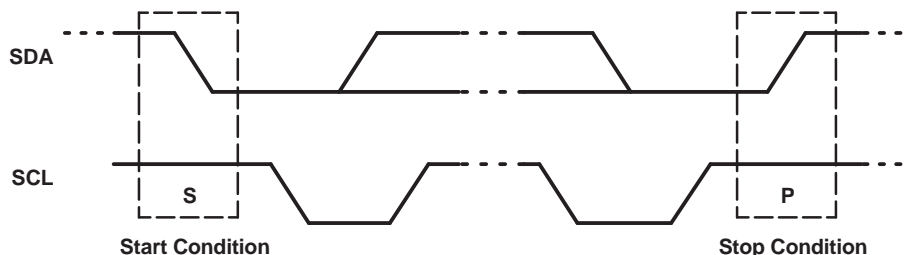


Figure 1. Definition of Start and Stop Conditions

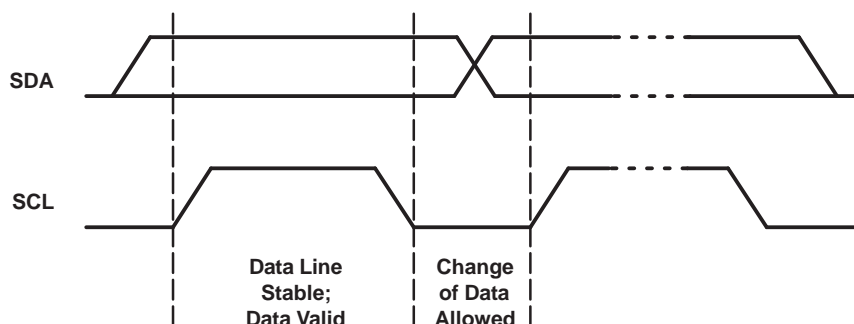


Figure 2. Bit Transfer

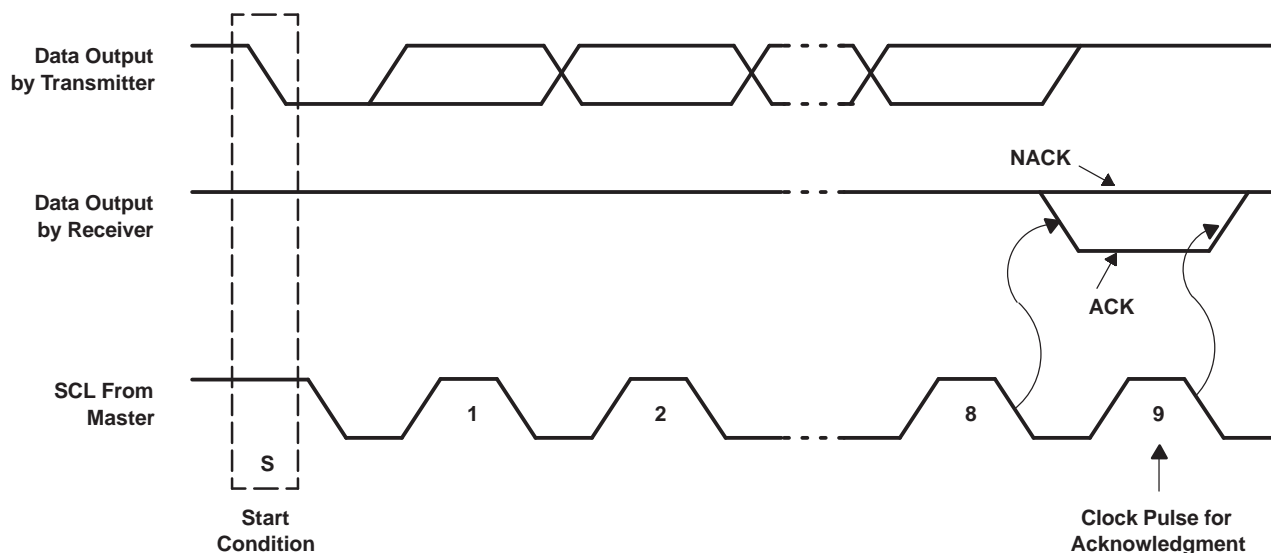


Figure 3. Acknowledgment on I<sup>2</sup>C Bus

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Interface Definition Table

| BYTE                           | BIT     |    |    |    |    |    |    |         |
|--------------------------------|---------|----|----|----|----|----|----|---------|
|                                | 7 (MSB) | 6  | 5  | 4  | 3  | 2  | 1  | 0 (LSB) |
| I <sup>2</sup> C slave address | H       | H  | H  | L  | L  | A1 | A0 | R/W     |
| Px I/O data bus                | P7      | P6 | P5 | P4 | P3 | P2 | P1 | P0      |

## Device Address

Figure 4 shows the address byte of the PCA9538.

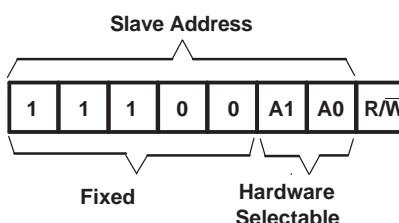


Figure 4. PCA9538 Address

Address Reference Table

| INPUTS |    | I <sup>2</sup> C BUS SLAVE ADDRESS |
|--------|----|------------------------------------|
| A1     | A0 |                                    |
| L      | L  | 112 (decimal), 70 (hexadecimal)    |
| L      | H  | 113 (decimal), 71 (hexadecimal)    |
| H      | L  | 114 (decimal), 72 (hexadecimal)    |
| H      | H  | 115 (decimal), 73 (hexadecimal)    |

The last bit of the slave address defines the operation (read or write) to be performed. When it is high (1), a read is selected 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 which is stored in the control register in the PCA9538 (see Figure 5). Two bits of this command byte state the operation (read or write) and the internal register (input, output, polarity inversion or configuration) that will be affected. This register can be written or read through the I<sup>2</sup>C bus. The command byte is sent only during a write transmission.

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

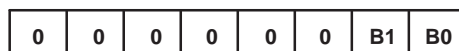


Figure 5. Control Register Bits

Command Byte Table

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

## Register Descriptions

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

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

**Register 0 (Input Port Register) Table**

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

The Output Port register (register 1) shows the outgoing logic levels of the pins defined as outputs by the Configuration register. Bit values in this register have no effect on pins defined as inputs. In turn, reads from this register reflect the value that is in the flip-flop controlling the output selection, not the actual pin value.

**Register 1 (Output Port Register) Table**

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

The Polarity Inversion register (register 2) allows polarity inversion of pins defined as inputs by the Configuration register. If a bit in this register is set (written with 1), the corresponding port pin polarity is inverted. If a bit in this register is cleared (written with a 0), the corresponding port pin original polarity is retained.

**Register 2 (Polarity Inversion Register) Table**

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

The Configuration register (register 3) configures the directions of the I/O pins. If a bit in this register is set to 1, the corresponding port pin is enabled as an input with a high-impedance output driver. If a bit in this register is cleared to 0, the corresponding port pin is enabled as an output.

**Register 3 (Configuration Register) Table**

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

## Power-On Reset

When power (from 0 V) is applied to  $V_{CC}$ , an internal power-on reset holds the PCA9538 in a reset condition until  $V_{CC}$  has reached  $V_{POR}$ . At that point, the reset condition is released and the PCA9538 registers and SMBus/I<sup>2</sup>C state machine will initialize to their default states. After that,  $V_{CC}$  must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

## RESET Input

The  $\overline{\text{RESET}}$  input can be asserted to reset the system while keeping the  $V_{CC}$  at its operating level. A reset can be accomplished by holding the  $\overline{\text{RESET}}$  pin low for a minimum of  $t_W$ . The PCA9538 registers and I<sup>2</sup>C/SMBus state machine are changed to their default states once  $\overline{\text{RESET}}$  is low (0). Once  $\overline{\text{RESET}}$  is high (1), the I/O levels at the P port can be changed externally or through the master. This input requires a pullup resistor to  $V_{CC}$  if no active connection is used.

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

An interrupt is generated by any rising or falling edge of the port inputs in the input mode. After time  $t_{iv}$ , the signal  $\overline{\text{INT}}$  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 or in a Stop event. Resetting occurs in the read mode at the acknowledge (ACK) or not acknowledge (NACK) bit after the rising edge of the SCL signal. In a Stop event,  $\overline{\text{INT}}$  is cleared after the rising edge of SDA. 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.

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

#### Bus Transactions

Data is exchanged between the master and PCA9538 through write and read commands.

#### Writes

Data is transmitted to the PCA9538 by sending the device address and setting the least-significant bit (LSB) 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 (see Figure 6 and Figure 7). There is no limitation on the number of data bytes sent in one write transmission.

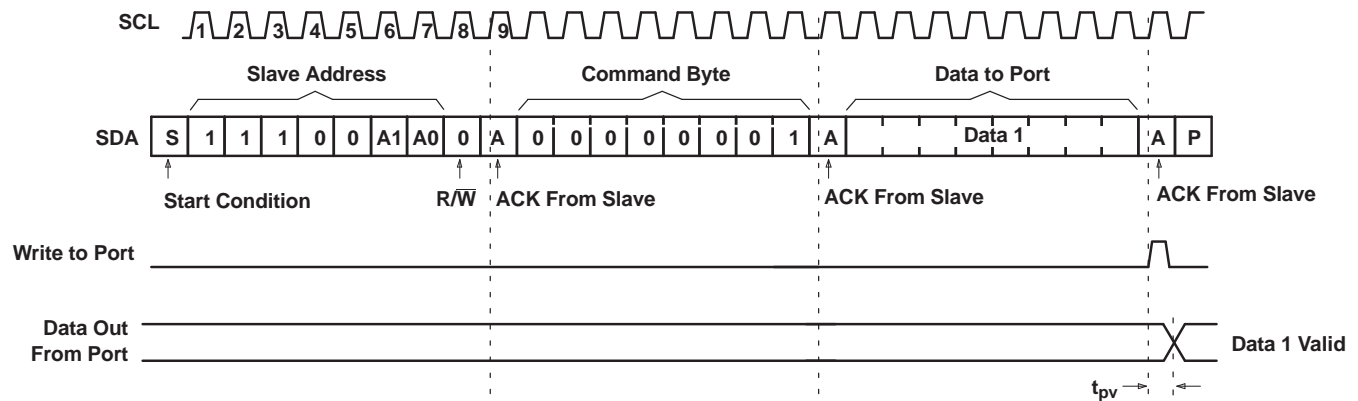


Figure 6. Write to Output Port Register

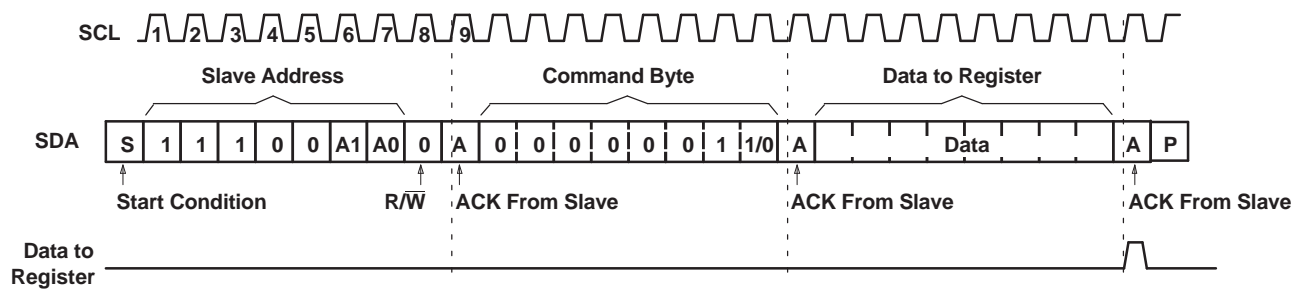


Figure 7. Write to Configuration or Polarity Inversion Registers



## Reads

The bus master first must send the PCA9538 address with the LSB 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 LSB is set to a logic 1. Data from the register defined by the command byte then is sent by the PCA9538 (see Figure 8 and Figure 9). After a restart, the value of the register defined by the command byte matches the register being accessed when the restart occurred. Data is clocked into the register on the rising edge of the ACK clock pulse. There is no limitation on the number of data bytes received in one read transmission, but when the final byte is received, the bus master must not acknowledge the data.

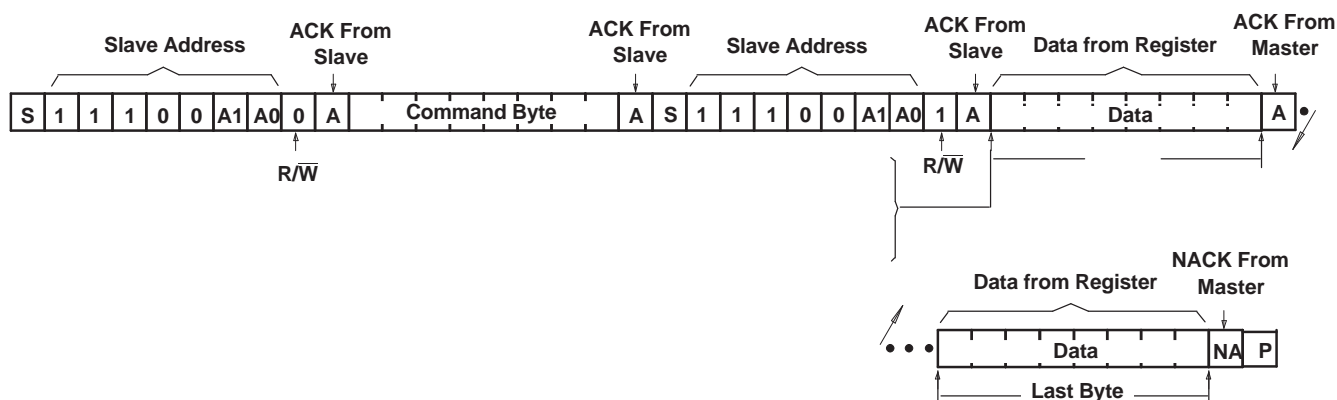
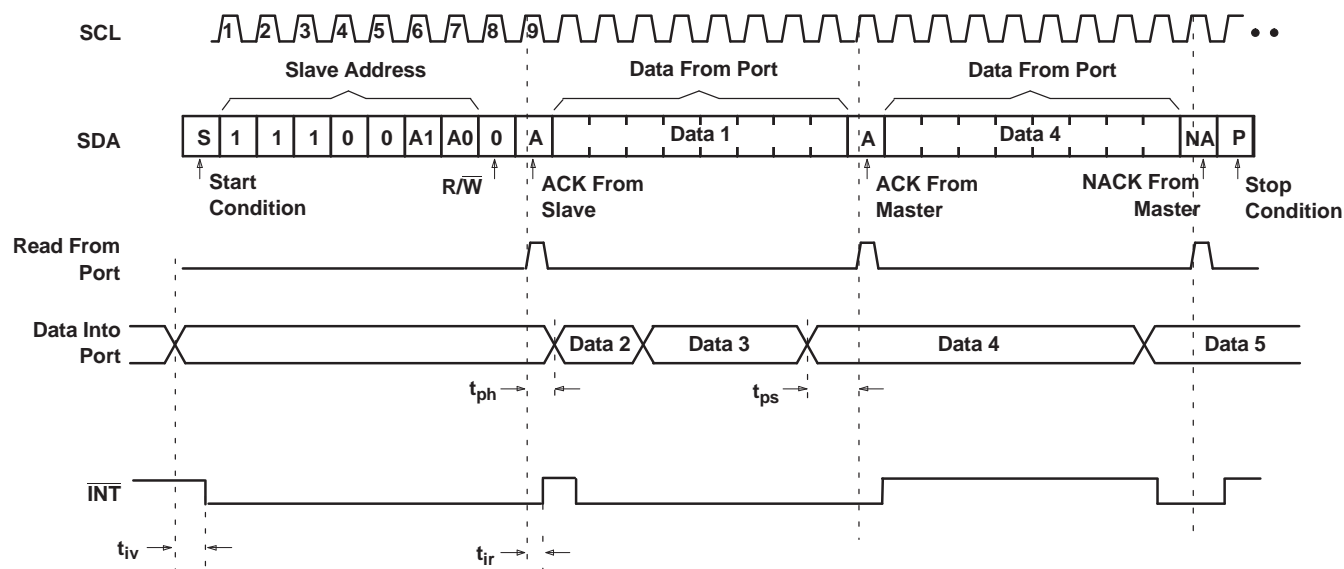


Figure 8. Read From Register



- This figure assumes the command byte has previously been programmed with 00h.
- Transfer of data can be stopped at any moment by a Stop condition.
- This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from the P port. See Figure 8 for these details.

Figure 9. Read From Input Port Register

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#### 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 <sup>(3)</sup>   | DB package   |      | 82   | °C/W |
|                  |  | DBQ package  |      | 90   |      |
|                  |  | DGV package  |      | 86   |      |
|                  |  | DW package   |      | 46   |      |
|                  |  | PW package   |      | 88   |      |
|                  |  | RGT package  |      | TBD  |      |
|                  |  | RGV package  |      | TBD  |      |
| 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> | V    |
|                 |                                | A0, A1, RESET, P7–P0 | 2                     |      |
| V <sub>IL</sub> | Low-level input voltage        | SCL, SDA             | −0.5                  | V    |
|                 |                                | A0, A1, RESET, P7–P0 | −0.5                  |      |
| I <sub>OH</sub> | High-level output current      | P7–P0                | −10                   | mA   |
| I <sub>OL</sub> | Low-level output current       | P7–P0                | 25                    | mA   |
| T <sub>A</sub>  | Operating free-air temperature | −40                  | 85                    | °C   |

## Electrical Characteristics

over 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  |                    |      |      |
|                  |   |   | 4.5 V            | 4.1  |                    |      |      |
|                  |   |   | 4.75 V           | 4.1  |                    |      |      |
|                  |   | I <sub>OH</sub> = –10 mA  | 2.3 V            | 1.7  |                    |      |      |
|                  |   |   | 3 V              | 2.5  |                    |      |      |
|                  |   |   | 4.5 V            | 4    |                    |      |      |
|                  |   |   | 4.75 V           | 4    |                    |      |      |
| I <sub>OL</sub>  | SDA   | V <sub>OL</sub> = 0.4 V   | 2.3 V to 5.5 V   | 3    | 8                  |      | mA   |
|                  | P port <sup>(3)</sup>                           | V <sub>OL</sub> = 0.5 V   | 2.3 V            | 8    | 10                 |      |      |
|                  |   |   | 3 V              | 8    | 14                 |      |      |
|                  |   |   | 4.5 V            | 8    | 17                 |      |      |
|                  |   |   | 4.75 V           | 8    | 35                 |      |      |
|                  |   | V <sub>OL</sub> = 0.7 V   | 2.3 V            | 10   | 13                 |      |      |
|                  |   |   | 3 V              | 10   | 19                 |      |      |
|                  |   |   | 4.5 V            | 10   | 24                 |      |      |
|                  |   |   | 4.75 V           | 10   | 45                 |      |      |
|                  | INT   | V <sub>OL</sub> = 0.4 V   | 2.3 V to 5.5 V   | 3    | 10                 |      |      |
| 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   |
|                  | A0, A1, RESET                                   |   |                  |      |                    | ±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, No load | 5.5 V            |      | 104                | 175  | μA   |
|                  |   |   | 3.6 V            |      | 50                 | 90   |      |
|                  |   |   | 2.7 V            |      | 20                 | 65   |      |
|                  |   | V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0,<br>I/O = inputs, f <sub>scl</sub> = 100 kHz, No load | 5.5 V            |      | 60                 | 150  |      |
|                  |   |   | 3.6 V            |      | 15                 | 40   |      |
|                  |   |   | 2.7 V            |      | 8                  | 20   |      |
|                  | Standby mode                                    | V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0,<br>I/O = inputs, f <sub>scl</sub> = 0 kHz, No load   | 5.5 V            |      | 0.25               | 1    |      |
|                  |   |   | 3.6 V            |      | 0.2                | 0.9  |      |
|                  |   |   | 2.7 V            |      | 0.1                | 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   |      |                    | 1.5  | mA   |
|                  |   | All LED I/Os at V <sub>I</sub> = 4.3 V,<br>f <sub>scl</sub> = 0 kHz   | 5.5 V            |      |                    | 1    |      |
| C <sub>i</sub>   | SCL   | V <sub>I</sub> = V <sub>CC</sub> or GND   | 2.3 V to 5.5 V   |      | 4                  | 5    | pF   |
| C <sub>io</sub>  | SDA   | V <sub>IO</sub> = V <sub>CC</sub> or GND  | 2.3 V to 5.5 V   |      | 5.5                | 6.5  | pF   |
|                  | P port  |   |                  |      | 8                  | 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) The total current sourced by all I/Os must be limited to 85 mA.

(3) Each I/O must be externally limited to a maximum of 25 mA, and the P port (P7–P0) must be limited to a maximum current of 200 mA.

# PCA9538

## REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS

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

over operating free-air temperature range (unless otherwise noted) (see [Figure 10](#))

|                       |  |  | STANDARD MODE<br>I <sup>2</sup> C BUS |      | FAST MODE<br>I <sup>2</sup> C BUS     |     | UNIT |
|-----------------------|--|--|---------------------------------------|------|---------------------------------------|-----|------|
|                       |  |  | MIN                                   | MAX  | MIN                                   | MAX |      |
| f <sub>scl</sub>      | I <sup>2</sup> C clock frequency                         |  | 0                                     | 100  | 0                                     | 400 | kHz  |
| t <sub>sch</sub>      | I <sup>2</sup> C clock high time                         |  | 4                                     |      | 0.6                                   |     | μs   |
| t <sub>scl</sub>      | I <sup>2</sup> C clock low time                          |  | 4.7                                   |      | 1.3                                   |     | μs   |
| t <sub>sp</sub>       | I <sup>2</sup> C spike time                              |  |                                       | 50   |                                       | 50  | ns   |
| t <sub>sds</sub>      | I <sup>2</sup> C serial-data setup time                  |  | 250                                   |      | 100                                   |     | ns   |
| t <sub>sdh</sub>      | I <sup>2</sup> C serial-data hold time                   |  | 0                                     |      | 0                                     |     | ns   |
| t <sub>icr</sub>      | I <sup>2</sup> C input rise time                         |  |                                       | 1000 | 20 + 0.1C <sub>b</sub> <sup>(1)</sup> | 300 | ns   |
| t <sub>icf</sub>      | I <sup>2</sup> C input fall time                         |  |                                       | 300  | 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                      |                                       | 300  | 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    |  | 4.7                                   |      | 1.3                                   |     | μs   |
| t <sub>sts</sub>      | I <sup>2</sup> C Start or repeated Start condition setup |  | 4.7                                   |      | 0.6                                   |     | μs   |
| t <sub>sth</sub>      | I <sup>2</sup> C Start or repeated Start condition hold  |  | 4                                     |      | 0.6                                   |     | μs   |
| t <sub>sps</sub>      | I <sup>2</sup> C Stop condition setup                    |  | 4                                     |      | 0.6                                   |     | μs   |
| t <sub>vd(data)</sub> | Valid data time  | SCL low to SDA output valid              | 300                                   |      | 50                                    |     | ns   |
| t <sub>vd(ack)</sub>  | Valid data time of ACK condition                         | ACK signal from SCL low to SDA (out) low | 0.3                                   | 3.45 | 0.1                                   | 0.9 | μs   |
| C <sub>b</sub>        | I <sup>2</sup> C bus capacitive load                     |  |                                       | 400  |                                       | 400 | ns   |

(1) C<sub>b</sub> = Total capacitance of one bus in pF

### RESET Timing Requirements

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

| PARAMETER                                |                      | STANDARD MODE<br>I <sup>2</sup> C BUS |     | FAST MODE<br>I <sup>2</sup> C BUS |     | UNIT |
|--|----------------------|---------------------------------------|-----|-----------------------------------|-----|------|
|  |                      | MIN                                   | MAX | MIN                               | MAX |      |
| t <sub>Subscri</sub><br>pt>w</Subscript> | Reset pulse duration | 4                                     |     | 4                                 |     | ns   |
| t <sub>REC</sub>                         | Reset recovery time  | 0                                     |     | 0                                 |     | ns   |
| t <sub>RESET</sub>                       | Time to reset        | 400                                   |     | 400                               |     | ns   |

### Switching Characteristics

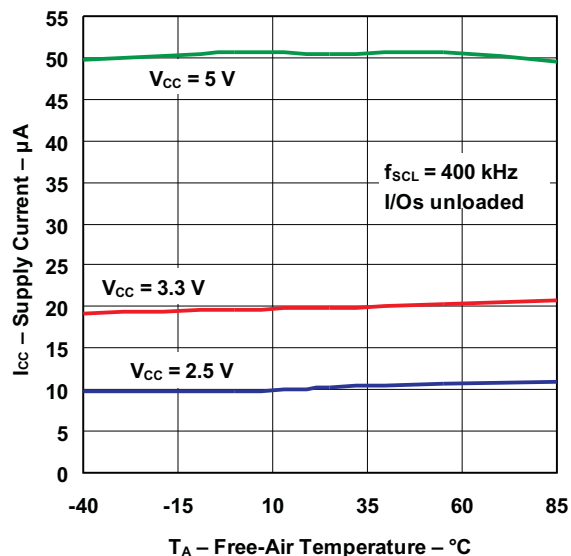
over operating free-air temperature range (unless otherwise noted) (see [Figure 11](#) and [Figure 12](#))

| PARAMETER       | FROM<br>(INPUT)            | TO<br>(OUTPUT) | STANDARD MODE<br>I <sup>2</sup> C BUS |     | FAST MODE<br>I <sup>2</sup> C BUS |     | UNIT |
|-----------------|----------------------------|----------------|---------------------------------------|-----|-----------------------------------|-----|------|
|                 |                            |                | MIN                                   | MAX | MIN                               | MAX |      |
| t <sub>iv</sub> | Interrupt valid time       | P port         |                                       | 4   |                                   | 4   | μs   |
| t <sub>ir</sub> | Interrupt reset delay time | SCL            |                                       | 4   |                                   | 4   | μs   |
| t <sub>pV</sub> | Output data valid          | SCL            |                                       | 200 |                                   | 200 | ns   |
| t <sub>ps</sub> | Input data setup time      | P port         | 100                                   |     | 100                               |     | ns   |
| t <sub>ph</sub> | Input data hold time       | P port         | 1                                     |     | 1                                 |     | μs   |

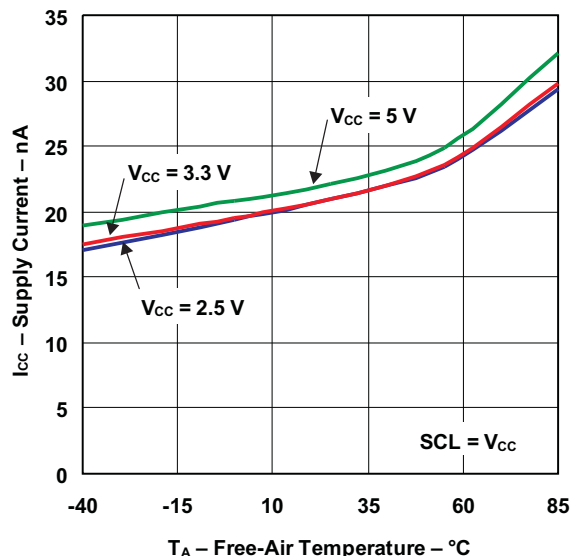
## TYPICAL CHARACTERISTICS

T<sub>A</sub> = 25°C (unless otherwise noted)

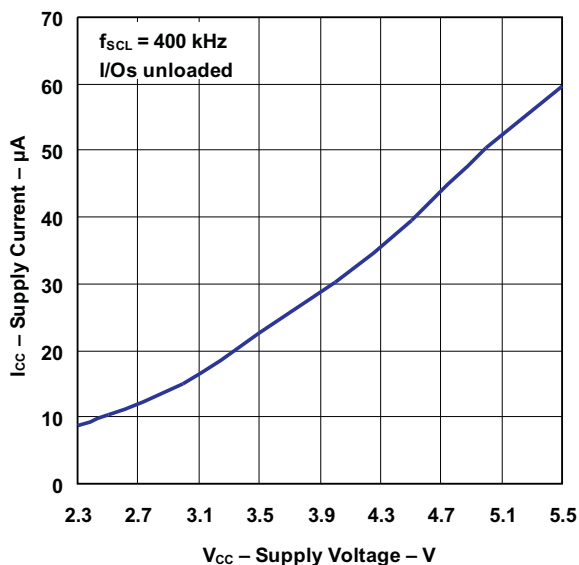
SUPPLY CURRENT  
vs  
TEMPERATURE



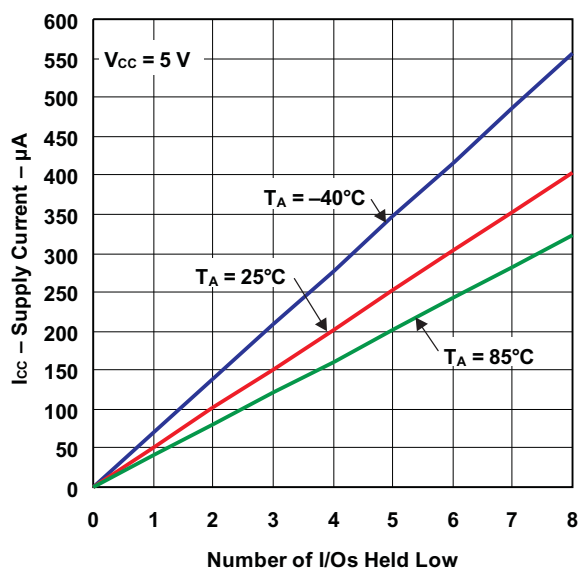
QUIESCENT SUPPLY CURRENT  
vs  
TEMPERATURE



SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE



SUPPLY CURRENT  
vs  
NUMBER OF I/Os HELD LOW



# PCA9538

## REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS

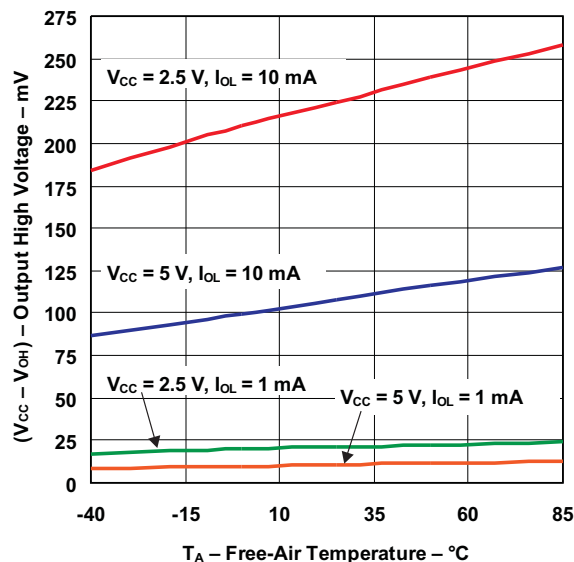
SCPS126D–SEPTEMBER 2006–REVISED MARCH 2007



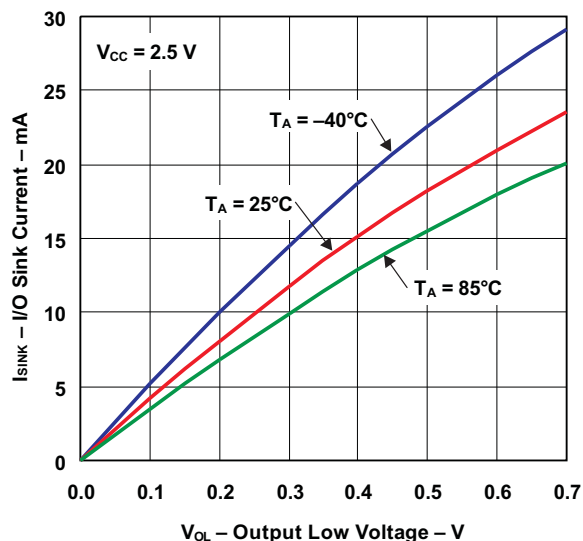
### TYPICAL CHARACTERISTICS (continued)

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

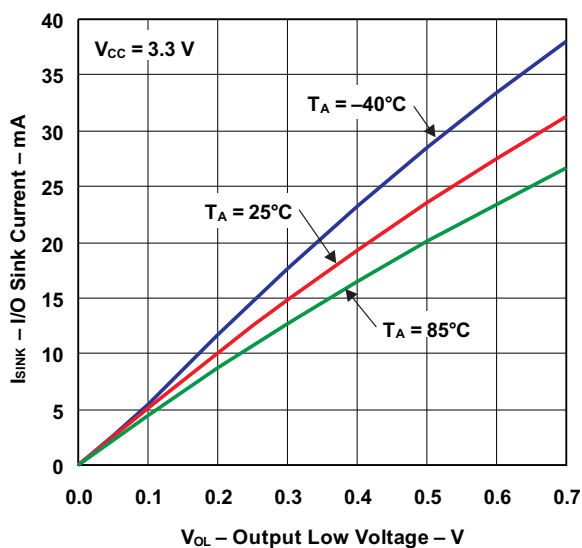
I/O OUTPUT LOW VOLTAGE  
VS  
TEMPERATURE



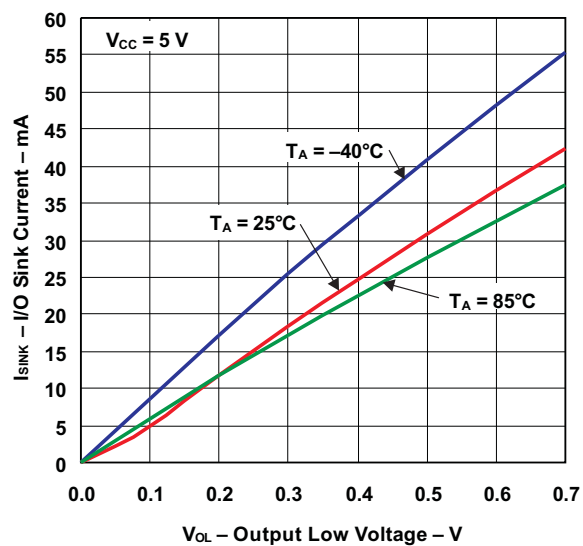
I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE



I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE



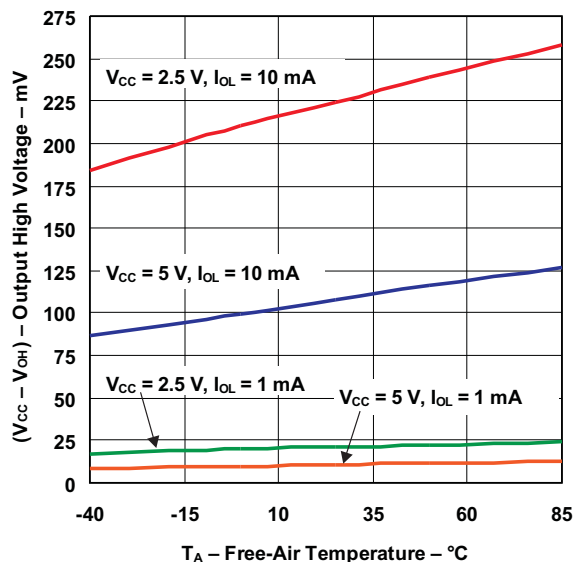
I/O SINK CURRENT  
VS  
OUTPUT LOW VOLTAGE



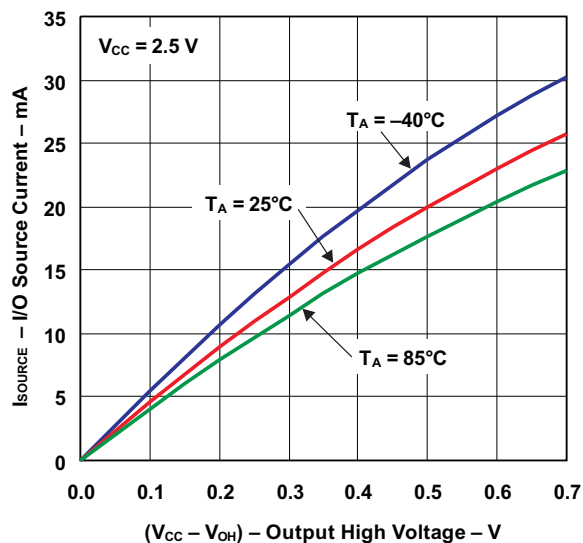
## TYPICAL CHARACTERISTICS (continued)

T<sub>A</sub> = 25°C (unless otherwise noted)

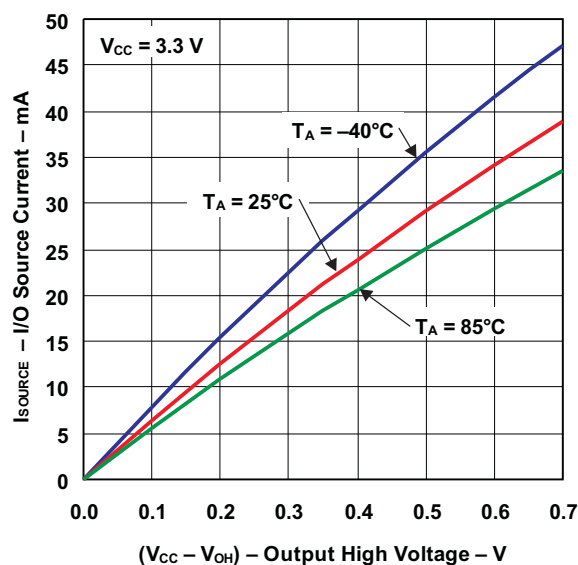
I/O OUTPUT HIGH VOLTAGE  
VS  
TEMPERATURE



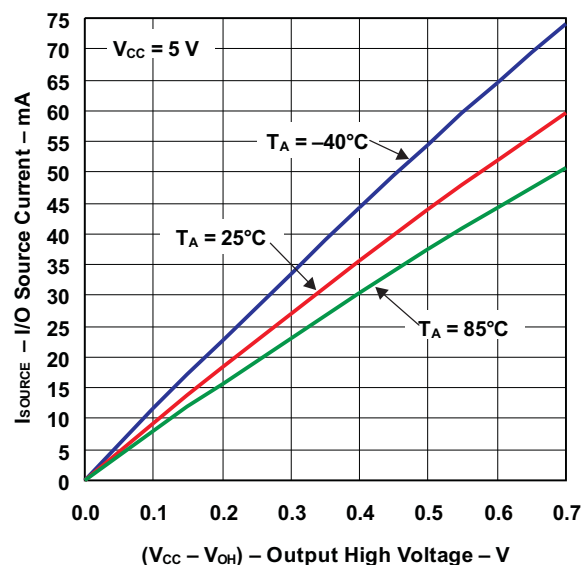
I/O SOURCE CURRENT  
VS  
OUTPUT HIGH VOLTAGE



I/O SOURCE CURRENT  
VS  
OUTPUT HIGH VOLTAGE



I/O SOURCE CURRENT  
VS  
OUTPUT HIGH VOLTAGE



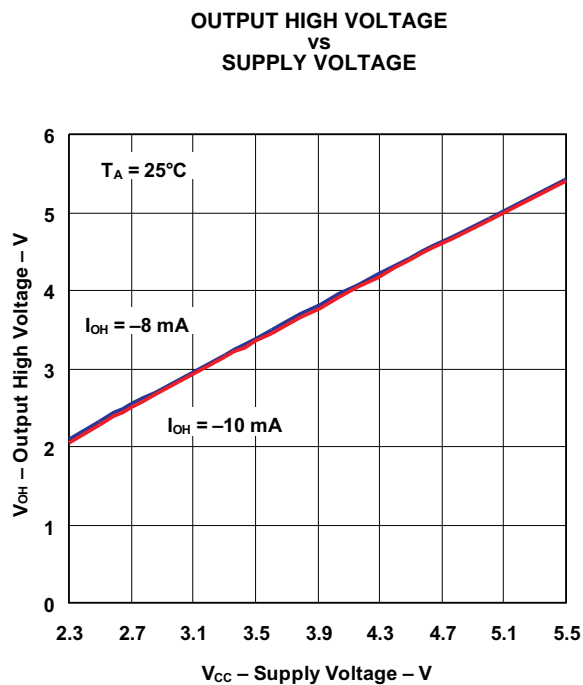
**PCA9538**  
**REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER**  
**WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS**

SCPS126D–SEPTEMBER 2006–REVISED MARCH 2007



**TYPICAL CHARACTERISTICS (continued)**

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





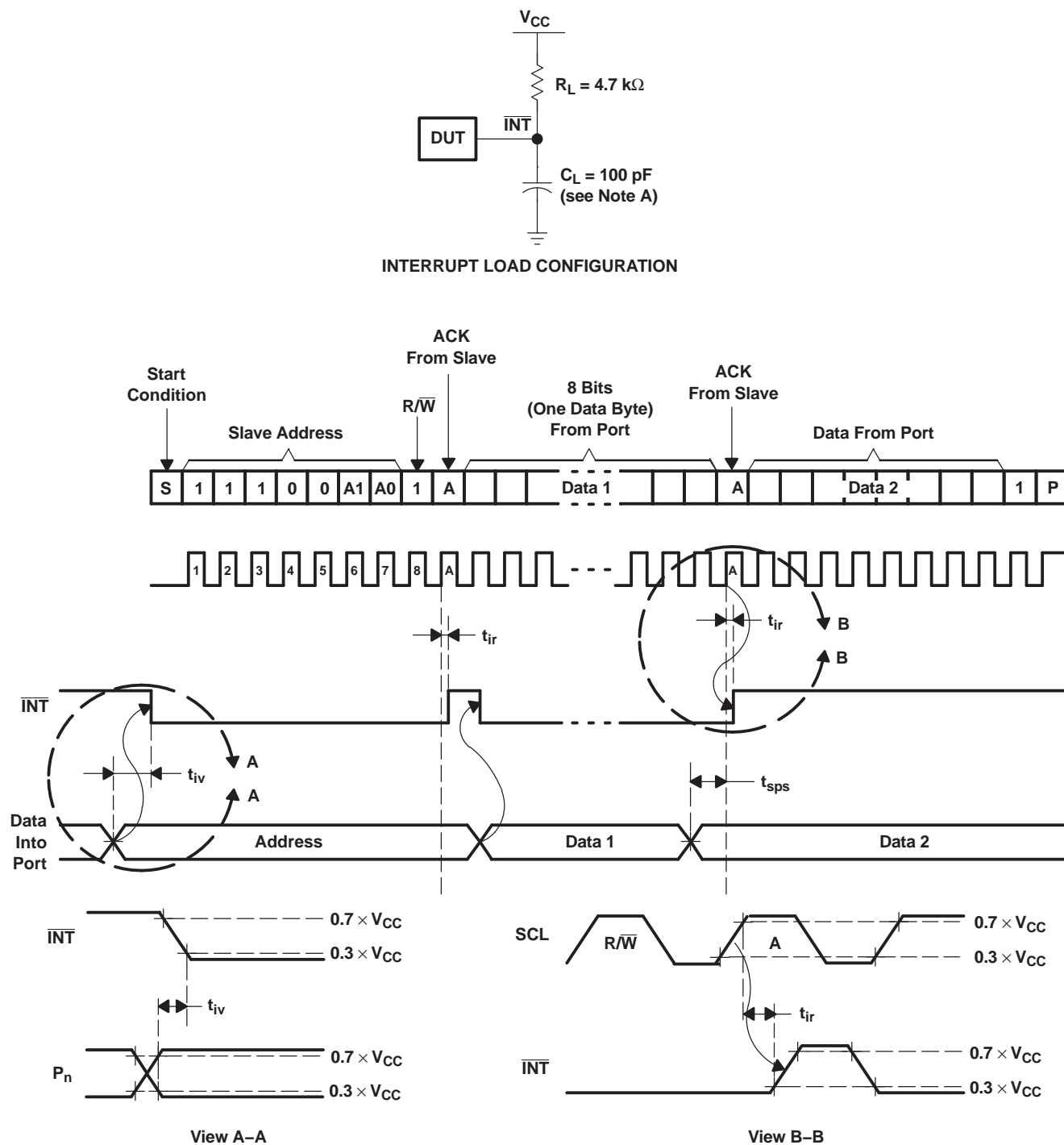


**PCA9538**  
**REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER**  
**WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS**

SCPS126D–SEPTEMBER 2006–REVISED MARCH 2007



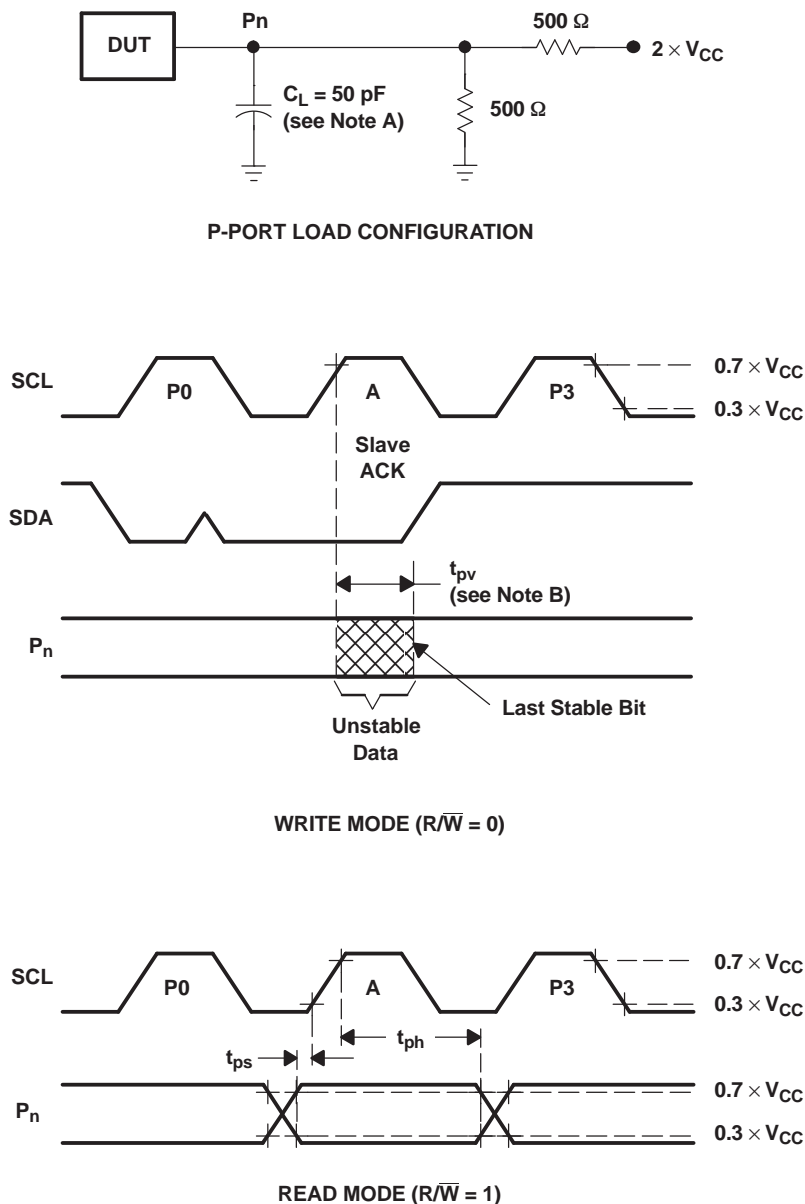
**PARAMETER MEASUREMENT INFORMATION (continued)**



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

**Figure 11. Interrupt 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. All parameters and waveforms are not applicable to all devices.

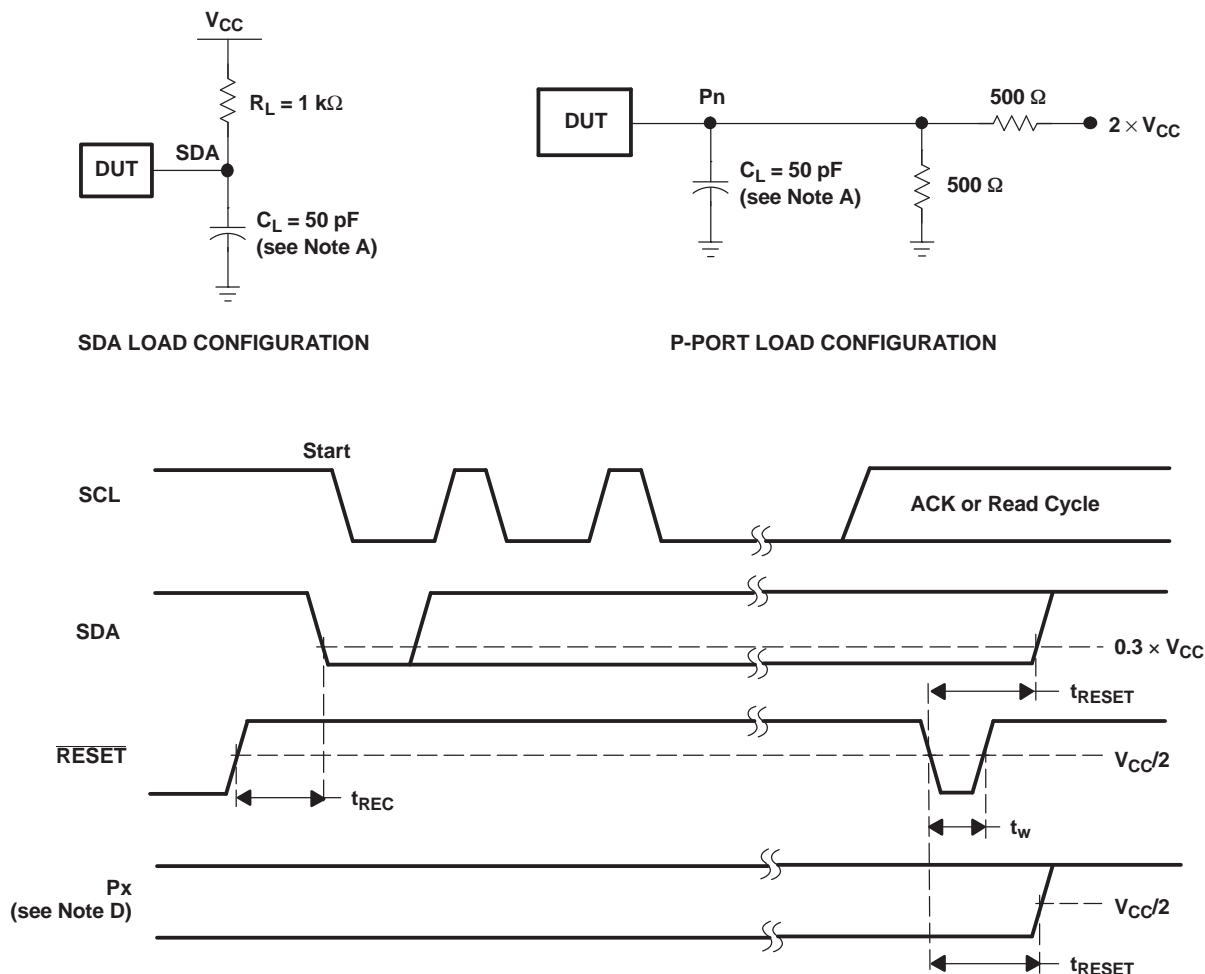
**Figure 12. P-Port Load Circuit and Voltage Waveforms**

**PCA9538**  
**REMOTE 8-BIT I<sup>2</sup>C AND SMBus LOW-POWER I/O EXPANDER**  
**WITH INTERRUPT OUTPUT, RESET, AND CONFIGURATION REGISTERS**

SCPS126D–SEPTEMBER 2006–REVISED MARCH 2007



**PARAMETER MEASUREMENT INFORMATION (continued)**

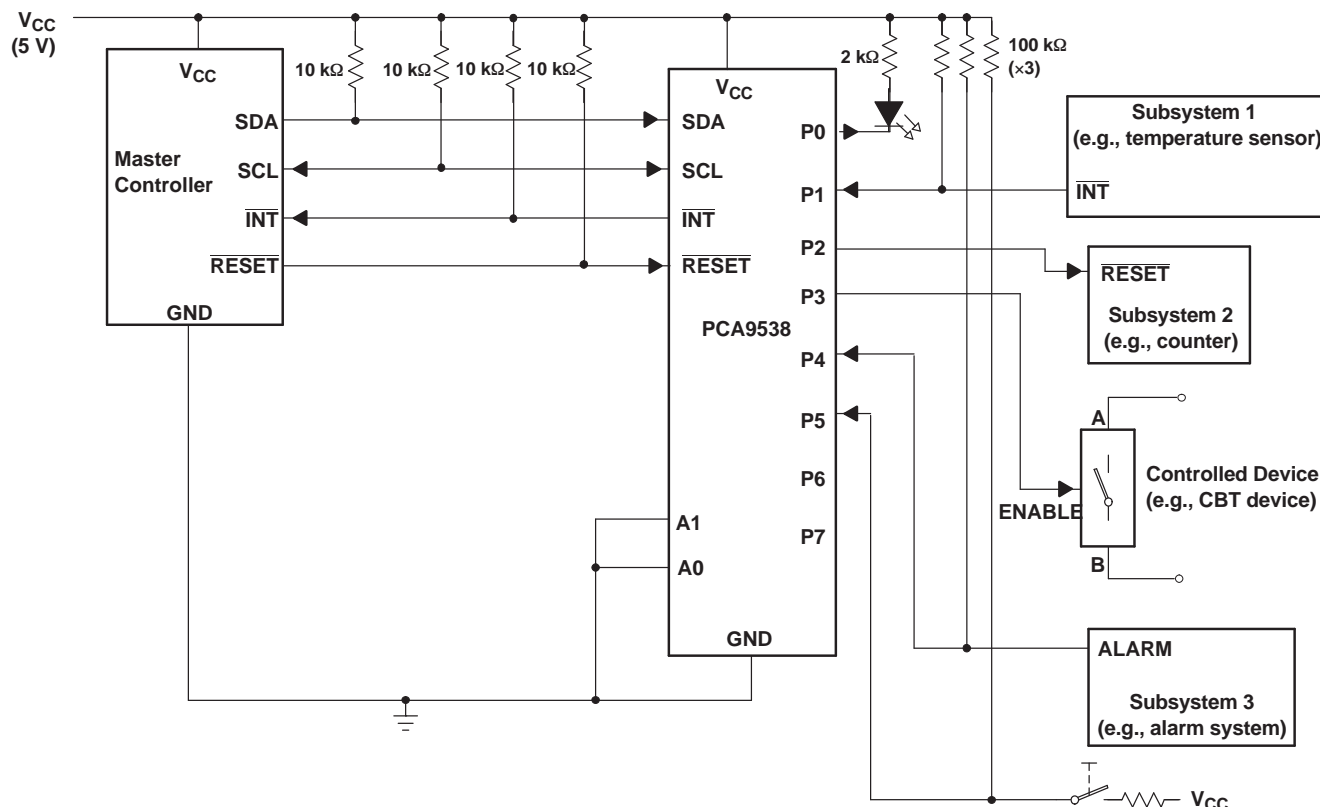


- A.  $C_L$  includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $t_r/t_f \leq 30 \text{ ns}$ .
- C. The outputs are measured one at a time, with one transition per measurement.
- D. I/Os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

**Figure 13. Reset Load Circuits and Voltage Waveforms**

## APPLICATION INFORMATION

Figure 14 shows an application in which the PCA9538 can be used.



- A. Device address is configured as 1110000 for this example.
- B. P0, P2, and P3 are configured as outputs.
- C. P1, P4, and P5 are configured as inputs.
- D. P6 and P7 are not used and must be configured as outputs.

**Figure 14. Typical Application**

## APPLICATION INFORMATION (continued)

### Minimizing $I_{CC}$ When I/Os Control LEDs

When the I/Os are used to control LEDs, normally they are connected to  $V_{CC}$  through a resistor as shown in Figure 14. The LED acts as a diode, so when the LED is off, the I/O  $V_{IN}$  is about 1.2 V less than  $V_{CC}$ .  $I_{CC}$  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 15 shows a high-value resistor in parallel with the LED. Figure 16 shows  $V_{CC}$  less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O  $V_{IN}$  at or above  $V_{CC}$  and prevents additional supply current consumption when the LED is off.

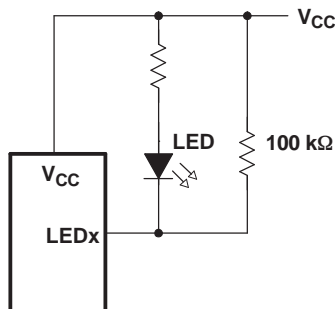


Figure 15. High-Value Resistor in Parallel With LED

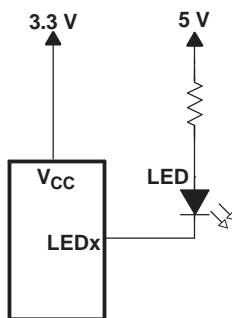


Figure 16. Device Supplied by a Lower Voltage

## PACKAGING INFORMATION

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| PCA9538DB        | ACTIVE                | SSOP         | DB              | 16   | 80          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DBG4      | ACTIVE                | SSOP         | DB              | 16   | 80          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DBR       | ACTIVE                | SSOP         | DB              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DBRG4     | ACTIVE                | SSOP         | DB              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DGVR      | ACTIVE                | TVSOP        | DGV             | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DGVRG4    | ACTIVE                | TVSOP        | DGV             | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DW        | ACTIVE                | SOIC         | DW              | 16   | 40          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538DWR       | ACTIVE                | SOIC         | DW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538PW        | ACTIVE                | TSSOP        | PW              | 16   | 90          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538PWG4      | ACTIVE                | TSSOP        | PW              | 16   | 90          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538PWR       | ACTIVE                | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| PCA9538PWRG4     | ACTIVE                | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |

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

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

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

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

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

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

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

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

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

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

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

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

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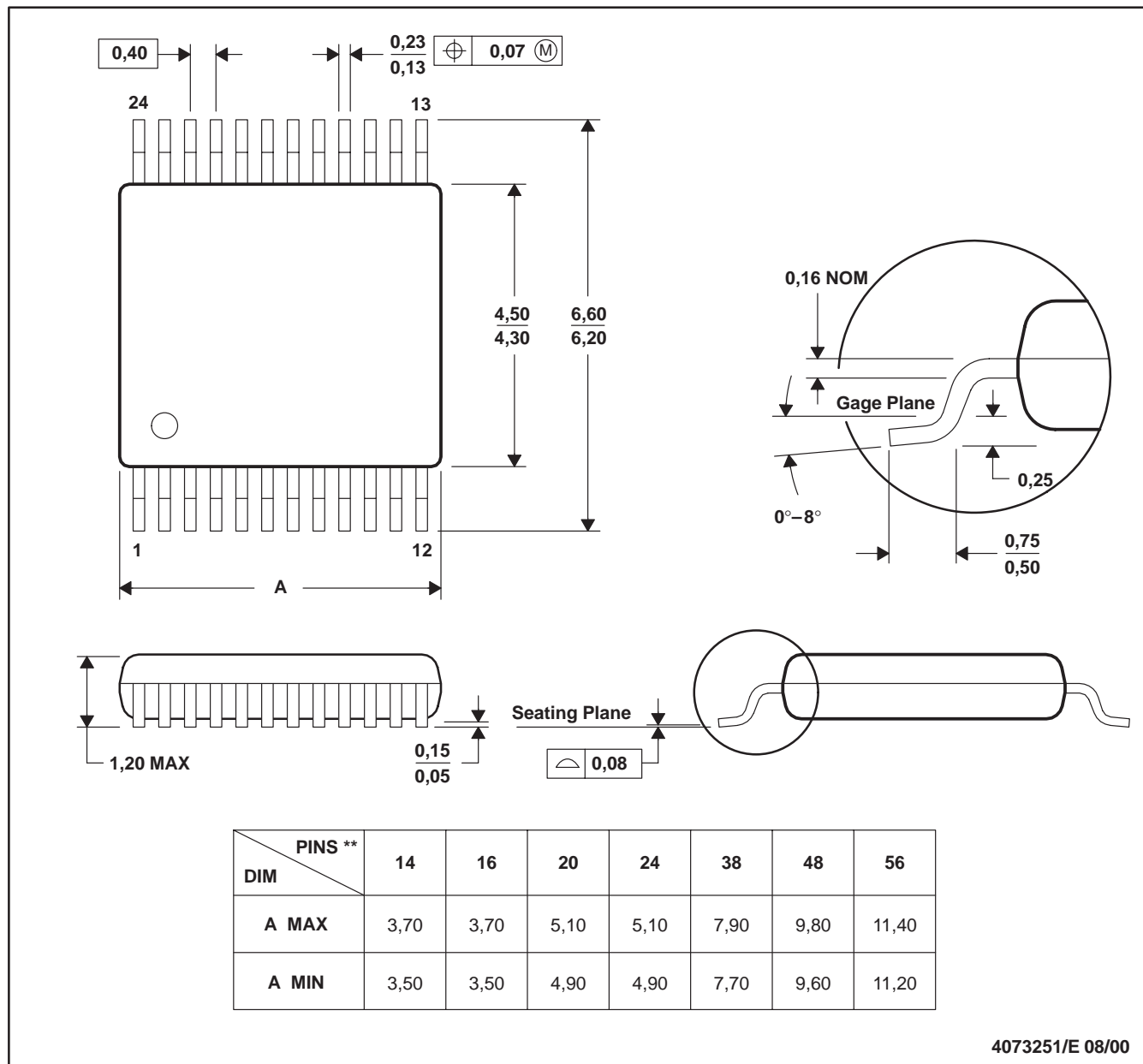
# MECHANICAL DATA

MPDS006C – FEBRUARY 1996 – REVISED AUGUST 2000

DGV (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE

24 PINS SHOWN

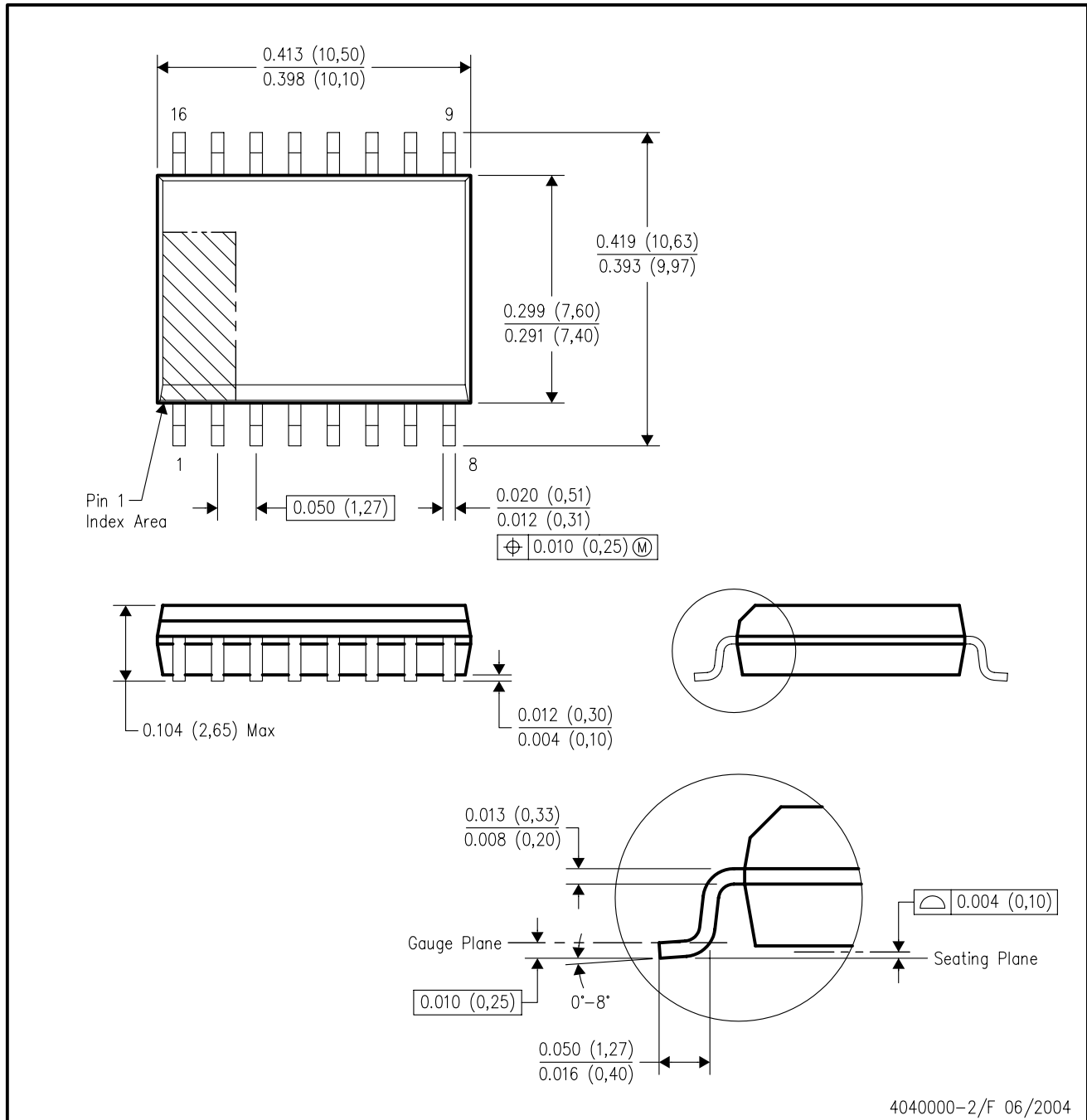


- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15 per side.  
 D. Falls within JEDEC: 24/48 Pins – MO-153  
 14/16/20/56 Pins – MO-194

# MECHANICAL DATA

DW (R-PDSO-G16)

PLASTIC SMALL-OUTLINE PACKAGE



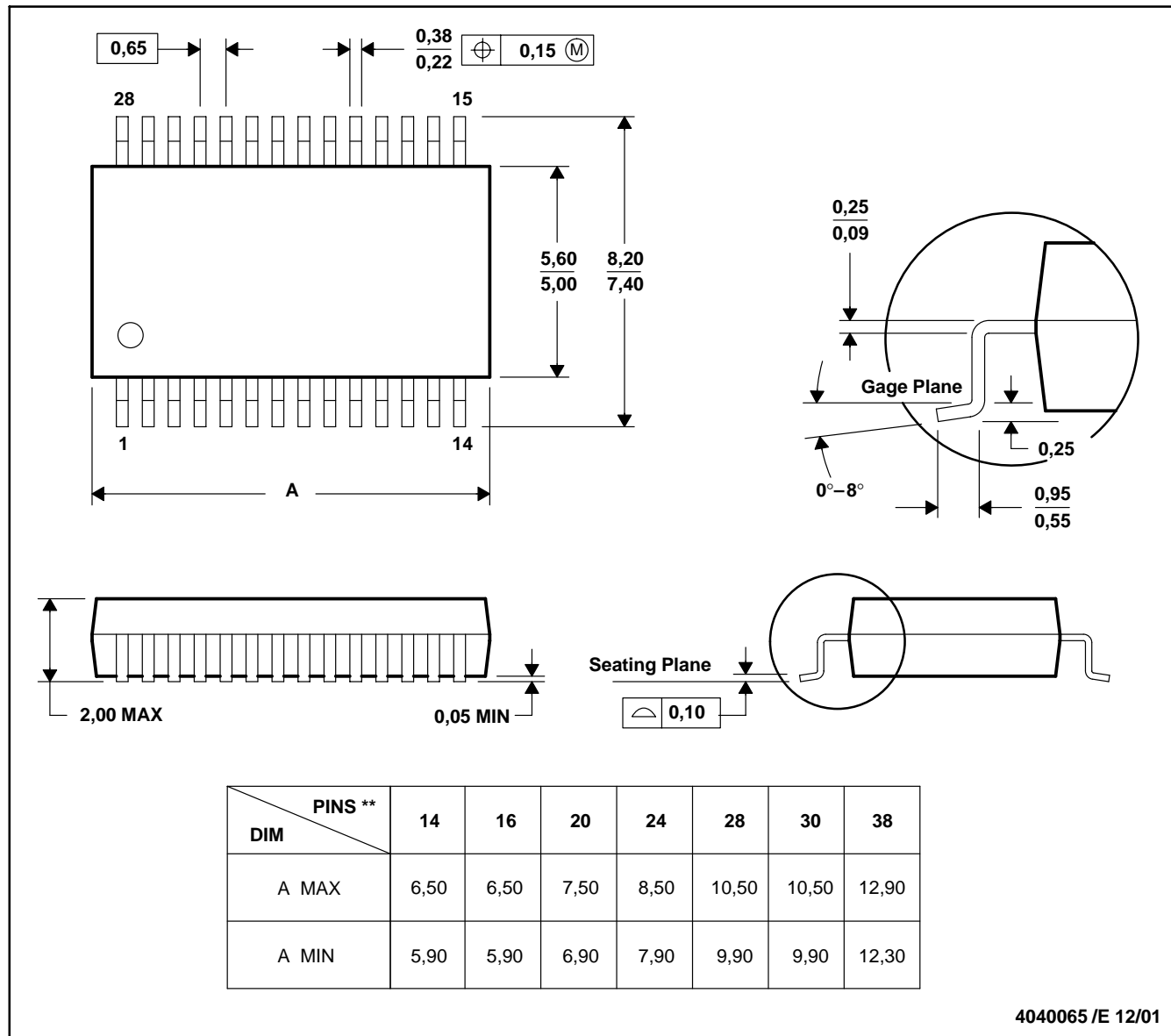
# MECHANICAL DATA

MSS0002E – JANUARY 1995 – REVISED DECEMBER 2001

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

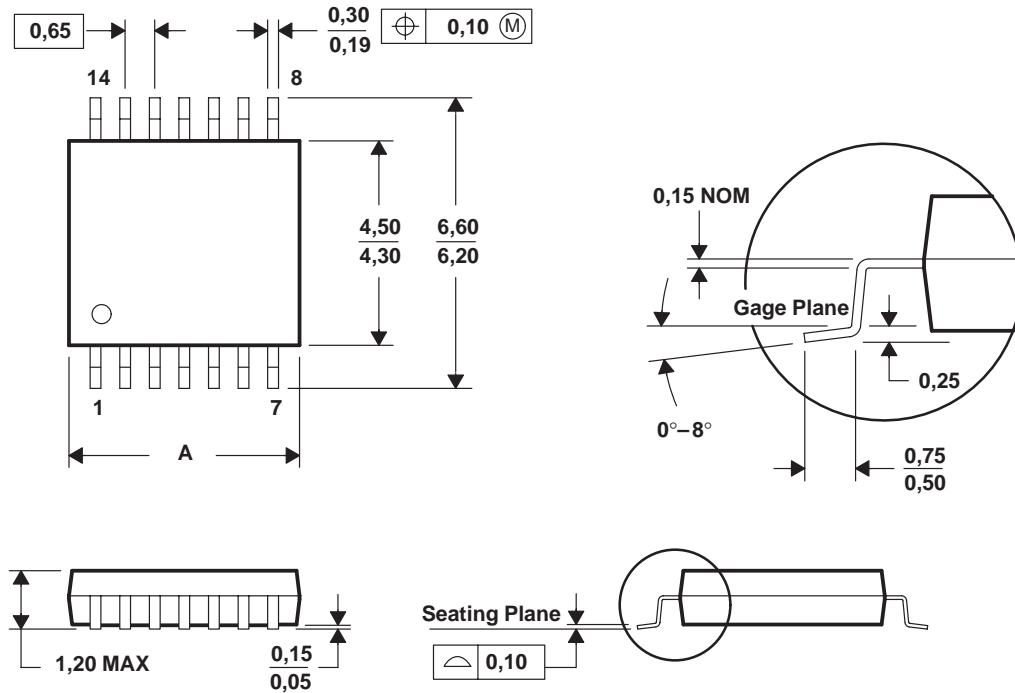
# MECHANICAL DATA

MTSS001C – JANUARY 1995 – REVISED FEBRUARY 1999

PW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



| PINS ** | 8    | 14   | 16   | 20   | 24   | 28   |
|---------|------|------|------|------|------|------|
| DIM     |      |      |      |      |      |      |
| A MAX   | 3,10 | 5,10 | 5,10 | 6,60 | 7,90 | 9,80 |
| A MIN   | 2,90 | 4,90 | 4,90 | 6,40 | 7,70 | 9,60 |

4040064/F 01/97

- 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-153

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