

# PCA9546A Low Voltage 4-Channel I<sup>2</sup>C and SMBus Switch with Reset Function

## 1 Features

- 1-of-4 Bidirectional Translating Switches
- I<sup>2</sup>C Bus and SMBus Compatible
- Active-Low Reset Input
- Three Address Pins, Allowing up to Eight PCA9546A Devices on the I<sup>2</sup>C Bus
- Channel Selection Via I<sup>2</sup>C Bus, in Any Combination
- Power-up With All Switch Channels Deselected
- Low R<sub>ON</sub> Switches
- Allows Voltage-Level Translation Between 1.8-V, 2.5-V, 3.3-V, and 5-V Buses
- No Glitch on Power-up
- Supports Hot Insertion
- Low Standby Current
- Operating Power-Supply Voltage Range of 2.3 V to 5.5 V
- 5.5 V Tolerant Inputs
- 0 to 400-kHz Clock Frequency
- Latch-Up Performance Exceeds 100 mA Per JESD 78
- ESD Protection Exceeds JESD 22
  - 2000-V Human-Body Model (A114-A)
  - 1000-V Charged-Device Model (C101)

## 2 Applications

- Servers
- Routers (Telecom Switching Equipment)
- Factory Automation
- Products With I<sup>2</sup>C Slave Address Conflicts (e.g. Multiple, Identical Temp Sensors)

## 3 Description

The PCA9546A is a quad bidirectional translating switch controlled via the I<sup>2</sup>C bus. The SCL/SDA upstream pair fans out to four downstream pairs, or channels. Any individual SC<sub>n</sub>/SD<sub>n</sub> channel or combination of channels can be selected, determined by the contents of the programmable control register.

An active-low reset ( $\overline{\text{RESET}}$ ) input allows the PCA9546A to recover from a situation in which one of the downstream I<sup>2</sup>C buses is stuck in a low state. Pulling  $\overline{\text{RESET}}$  low resets the I<sup>2</sup>C state machine and causes all the channels to be deselected, as does the internal power-on reset function.

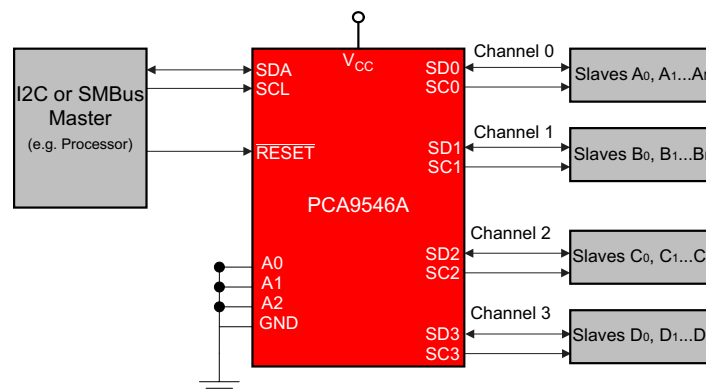
The pass gates of the switches are constructed such that the VCC pin can be used to limit the maximum high voltage, which will be passed by the PCA9546A. This allows the use of different bus voltages on each pair, so that 1.8-V, 2.5-V, or 3.3-V parts can communicate with 5-V parts without any additional protection. External pull-up resistors pull the bus up to the desired voltage level for each channel. All I/O pins are 5.5-V tolerant.

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
PCA9546A	TSSOP (16)	5.00 mm x 4.40 mm

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

## 4 Simplified Application Diagram



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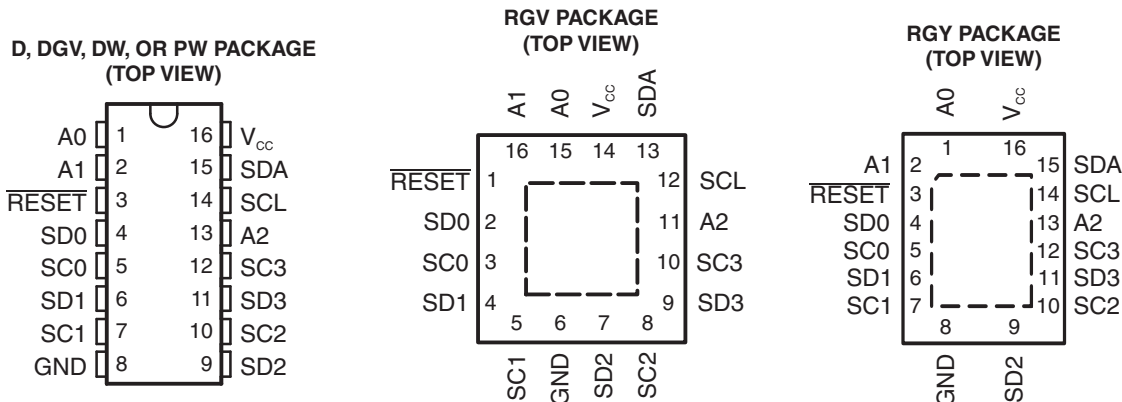
## 5 Revision History

### Changes from Revision E (January 2008) to Revision F

Page

• Added <b>RESET</b> Errata section. ....	<b>10</b>
• Added Power-On Reset Errata section. ....	<b>18</b>

## 6 Pin Configuration and Functions



### Pin Functions

NAME	PIN NO.		DESCRIPTION
	D, DGV, DW, PW, AND RGY	RGV	
A0	1	15	Address input 0. Connect directly to V <sub>CC</sub> or ground.
A1	2	16	Address input 1. Connect directly to V <sub>CC</sub> or ground.
RESET	3	1	Active low reset input. Connect to V <sub>DPUM</sub> <sup>(1)</sup> through a pull-up resistor, if not used.
SD0	4	2	Serial data 0. Connect to V <sub>DPU0</sub> <sup>(1)</sup> through a pull-up resistor.
SC0	5	3	Serial clock 0. Connect to V <sub>DPU0</sub> <sup>(1)</sup> through a pull-up resistor.
SD1	6	4	Serial data 1. Connect to V <sub>DPU1</sub> <sup>(1)</sup> through a pull-up resistor.
SC1	7	5	Serial clock 1. Connect to V <sub>DPU1</sub> <sup>(1)</sup> through a pull-up resistor.
GND	8	6	Ground
SD2	9	7	Serial data 2. Connect to V <sub>DPU2</sub> <sup>(1)</sup> through a pull-up resistor.
SC2	10	8	Serial clock 2. Connect to V <sub>DPU2</sub> <sup>(1)</sup> through a pull-up resistor.
SD3	11	9	Serial data 3. Connect to V <sub>DPU3</sub> <sup>(1)</sup> through a pull-up resistor.
SC3	12	10	Serial clock 3. Connect to V <sub>DPU3</sub> <sup>(1)</sup> through a pull-up resistor.
A2	13	11	Address input 2. Connect directly to V <sub>CC</sub> or ground.
SCL	14	12	Serial clock line. Connect to V <sub>DPUM</sub> <sup>(1)</sup> through a pull-up resistor.
SDA	15	13	Serial data line. Connect to V <sub>DPUM</sub> <sup>(1)</sup> through a pull-up resistor.
VCC	16	14	Supply power

(1) V<sub>DPUX</sub> is the pull-up reference voltage for the associated data line. V<sub>DPUM</sub> is the master I<sup>2</sup>C reference voltage while V<sub>DPU0</sub>–V<sub>DPU3</sub> are the slave channel reference voltages.

## 7 Specifications

### 7.1 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	7	V
V <sub>I</sub>	Input voltage range <sup>(2)</sup>	-0.5	7	V
I <sub>I</sub>	Input current		±20	mA
I <sub>O</sub>	Output current		±25	mA
	Continuous current through V <sub>CC</sub>		±100	mA
	Continuous current through GND		±100	mA
θ <sub>JA</sub>	Package thermal impedance <sup>(3)</sup>	D package		°C/W
		DGV package		
		DW package		
		PW package		
		RGV package		
		RGY package		
P <sub>tot</sub>	Total power dissipation		400	mW
T <sub>A</sub>	Operating free-air temperature range	-40	85	°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.

### 7.2 Handling Ratings

		MIN	MAX	UNIT
T <sub>stg</sub>	Storage temperature range	-65	150	°C
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>		V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>		
		0	2000	
		0	1000	

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

### 7.3 Recommended Operating Conditions<sup>(1)</sup>

		MIN	MAX	UNIT
V <sub>CC</sub>	Supply voltage	2.3	5.5	V
V <sub>IH</sub>	High-level input voltage	SCL, SDA		V
		0.7 × V <sub>CC</sub>	6	
V <sub>IL</sub>	Low-level input voltage	A2–A0, $\overline{\text{RESET}}$		V
		0.7 × V <sub>CC</sub>	V <sub>CC</sub> + 0.5	
V <sub>IL</sub>	Low-level input voltage	SCL, SDA		V
		-0.5	0.3 × V <sub>CC</sub>	
V <sub>IL</sub>	Low-level input voltage	A2–A0, $\overline{\text{RESET}}$		V
		-0.5	0.3 × V <sub>CC</sub>	
T <sub>A</sub>	Operating free-air temperature	-40	85	°C

- (1) All unused inputs of the device must be held at V<sub>CC</sub> or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

## 7.4 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>POR</sub>	Power-on reset voltage <sup>(2)</sup>	No load,	V <sub>I</sub> = V <sub>CC</sub> or GND	V <sub>POR</sub>	1.6	2.1		V
V <sub>pass</sub>	Switch output voltage	V <sub>SWin</sub> = V <sub>CC</sub> ,	I <sub>SWout</sub> = -100 μA	5 V	3.6			V
				4.5 V to 5.5 V	2.6	4.5		
				3.3 V	1.9			
				3 V to 3.6 V	1.6	2.8		
				2.5 V	1.5			
I <sub>OL</sub>	SCL, SDA	V <sub>OL</sub> = 0.4 V	I <sub>O</sub> = 0	2.3 V to 5.5 V	3	7		mA
		V <sub>OL</sub> = 0.6 V			6	10		
I <sub>I</sub>	SCL, SDA	V <sub>I</sub> = V <sub>CC</sub> or GND	I <sub>O</sub> = 0	2.3 V to 5.5 V			±1	μA
	SC3–SC0, SD3–SD0						±1	
	A2–A0						±1	
	RESET						±1	
I <sub>CC</sub>	Operating mode	f <sub>SCL</sub> = 100 kHz	V <sub>I</sub> = V <sub>CC</sub> or GND, I <sub>O</sub> = 0	5.5 V	3	12	μA	
				3.6 V	3	11		
				2.7 V	3	10		
	Standby mode	Low inputs	V <sub>I</sub> = GND, I <sub>O</sub> = 0	5.5 V	0.3	1		
				3.6 V	0.1	1		
		High inputs	V <sub>I</sub> = V <sub>CC</sub> , I <sub>O</sub> = 0	2.7 V	0.1	1		
				5.5 V	0.3	1		
				3.6 V	0.1	1		
ΔI <sub>CC</sub>	Supply-current change	SCL, SDA	SCL or SDA input at 0.6 V, Other inputs at V <sub>CC</sub> or GND			8	15	μA
			SCL or SDA input at V <sub>CC</sub> – 0.6 V, Other inputs at V <sub>CC</sub> or GND	2.3 V to 5.5 V	8	15		
C <sub>i</sub>	A2–A0	V <sub>I</sub> = V <sub>CC</sub> or GND	I <sub>O</sub> = 0	2.3 V to 5.5 V	4.5	6	pF	
	RESET				4.5	5.5		
C <sub>i(OFF)</sub> <sup>(3)</sup>	SCL, SDA	V <sub>I</sub> = V <sub>CC</sub> or GND, Switch OFF	I <sub>O</sub> = 0	2.3 V to 5.5 V	15	19	pF	
	SC3–SC0, SD3–SD0				6	8		
R <sub>ON</sub>	Switch on-state resistance	V <sub>O</sub> = 0.4 V, I <sub>O</sub> = 15 mA	I <sub>O</sub> = 15 mA	4.5 V to 5.5 V	4	9	16	Ω
				3 V to 3.6 V	5	11	20	
				2.3 V to 2.7 V	7	16	45	

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

 (2) The power-on reset circuit resets the I<sup>2</sup>C bus logic with V<sub>CC</sub> < V<sub>POR</sub>. V<sub>CC</sub> must be lowered to 0.2 V to reset the device.

 (3) C<sub>i(OFF)</sub> depends on internal capacitance and external capacitance added to the SC<sub>n</sub> lines when channels(s) are ON.

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

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

		STANDARD MODE I <sup>2</sup> C BUS		FAST MODE I <sup>2</sup> C BUS		UNIT		
		MIN	MAX	MIN	MAX			
$f_{scl}$	I <sup>2</sup> C clock frequency	0	100	0	400	kHz		
$t_{sch}$	I <sup>2</sup> C clock high time	4		0.6		μs		
$t_{scl}$	I <sup>2</sup> C clock low time	4.7		1.3		μs		
$t_{sp}$	I <sup>2</sup> C spike time		50		50	ns		
$t_{sds}$	I <sup>2</sup> C serial-data setup time	250		100		ns		
$t_{sdh}$	I <sup>2</sup> C serial-data hold time	0 <sup>(1)</sup>		0 <sup>(1)</sup>		μs		
$t_{icr}$	I <sup>2</sup> C input rise time		1000	20 + 0.1C <sub>b</sub> <sup>(2)</sup>	300	ns		
$t_{icf}$	I <sup>2</sup> C input fall time		300	20 + 0.1C <sub>b</sub> <sup>(2)</sup>	300	ns		
$t_{ocf}$	I <sup>2</sup> C output fall time	10-pF to 400-pF bus			300	20 + 0.1C <sub>b</sub> <sup>(2)</sup>	300	ns
$t_{buf}$	I <sup>2</sup> C bus free time between stop and start	4.7		1.3		μs		
$t_{sts}$	I <sup>2</sup> C start or repeated start condition setup	4.7		0.6		μs		
$t_{sth}$	I <sup>2</sup> C start or repeated start condition hold	4		0.6		μs		
$t_{sps}$	I <sup>2</sup> C stop condition setup	4		0.6		μs		
$t_{vdL(Data)}$	Valid-data time (high to low) <sup>(3)</sup>	SCL low to SDA output low valid			1	μs		
$t_{vdH(Data)}$	Valid-data time (low to high) <sup>(3)</sup>	SCL low to SDA output high valid			0.6	μs		
$t_{vd(ack)}$	Valid-data time of ACK condition	ACK signal from SCL low to SDA output low			1	μs		
$C_b$	I <sup>2</sup> C bus capacitive load		400		400	pF		

- (1) A device internally must provide a hold time of at least 300 ns for the SDA signal (referred to the V<sub>IH</sub> min of the SCL signal), in order to bridge the undefined region of the falling edge of SCL.
- (2) C<sub>b</sub> = total bus capacitance of one bus line in pF
- (3) Data taken using a 1-kΩ pull-up resistor and 50-pF load (see [Figure 1](#))

## 7.6 Switching Characteristics

over recommended operating free-air temperature range, C<sub>L</sub> ≤ 100 pF (unless otherwise noted) (see [Figure 1](#))

PARAMETER		FROM (INPUT)	TO (OUTPUT)	MIN	MAX	UNIT
$t_{pd}$ <sup>(1)</sup>	Propagation delay time	R <sub>ON</sub> = 20 Ω, C <sub>L</sub> = 15 pF	SDA or SCL	SDn or SCn	0.3	ns
		R <sub>ON</sub> = 20 Ω, C <sub>L</sub> = 50 pF			1	

- (1) The propagation delay is the calculated RC time constant of the typical ON-state resistance of the switch and the specified load capacitance, when driven by an ideal voltage source (zero output impedance).

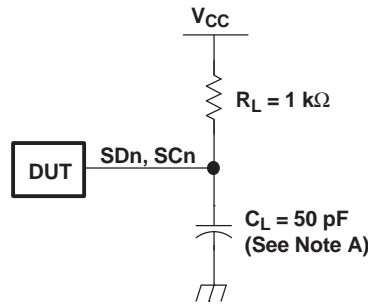
## 7.7 Interrupt and Reset Timing Requirements

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

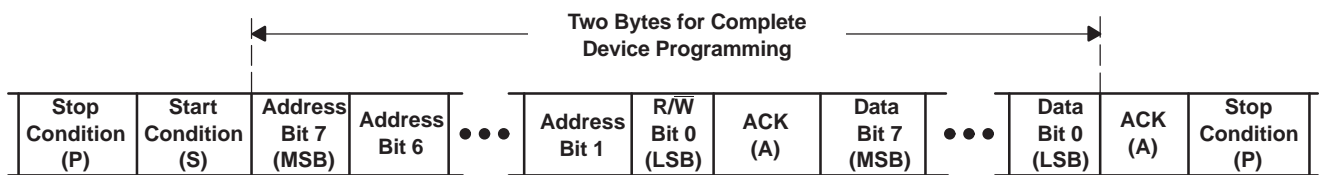
PARAMETER		MIN	MAX	UNIT
$t_{WL}$	Pulse duration, $\overline{\text{RESET}}$ low	6		ns
$t_{rst}$ <sup>(1)</sup>	$\overline{\text{RESET}}$ time (SDA clear)		500	ns
$t_{REC(STA)}$	Recovery time from $\overline{\text{RESET}}$ to start	0		ns

- (1)  $t_{rst}$  is the propagation delay measured from the time the  $\overline{\text{RESET}}$  pin is first asserted low to the time the SDA pin is asserted high, signaling a stop condition. It must be a minimum of  $t_{WL}$ .

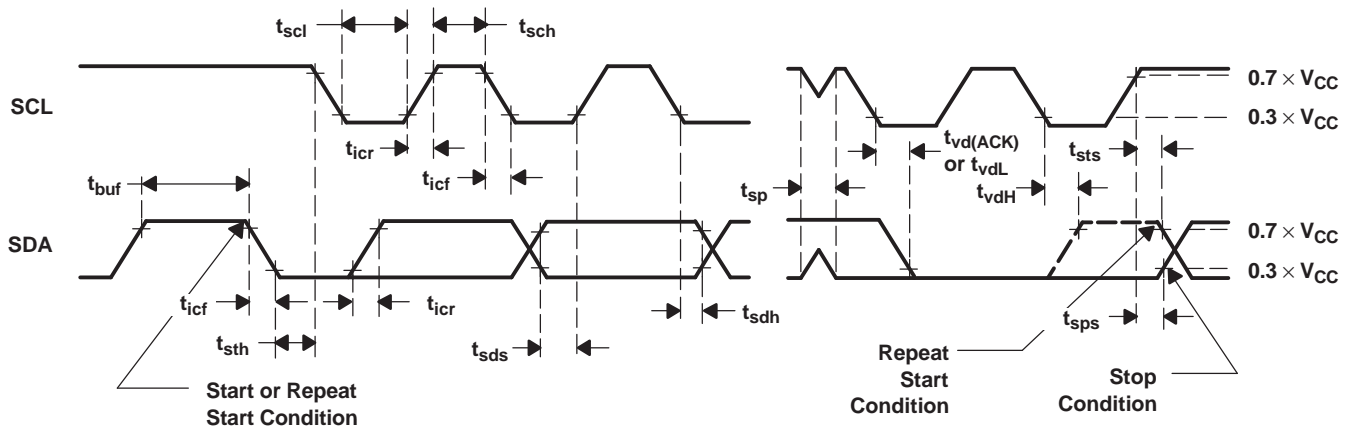
## 8 Parameter Measurement Information



I<sup>2</sup>C PORT LOAD CONFIGURATION



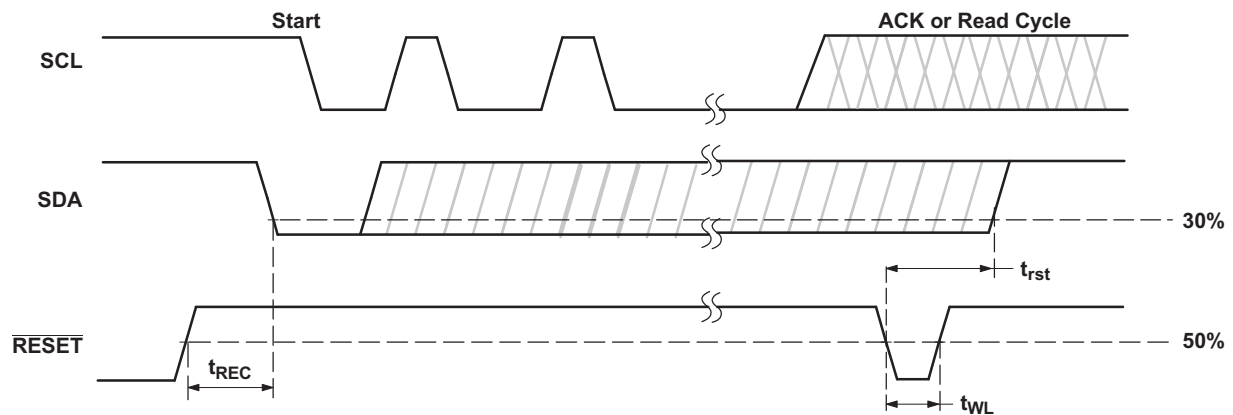
BYTE	DESCRIPTION
1	I <sup>2</sup> C address + R/W
2	Control register data



VOLTAGE WAVEFORMS

- $C_L$  includes probe and jig capacitance.
- All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10\text{ MHz}$ ,  $Z_O = 50\ \Omega$ ,  $t_r/t_f \leq 30\text{ ns}$ .
- The outputs are measured one at a time, with one transition per measurement.

Figure 1. I<sup>2</sup>C Interface Load Circuit, Byte Descriptions, and Voltage Waveforms

**Parameter Measurement Information (continued)**

**Figure 2. Reset Timing**

## 9 Detailed Description

### 9.1 Overview

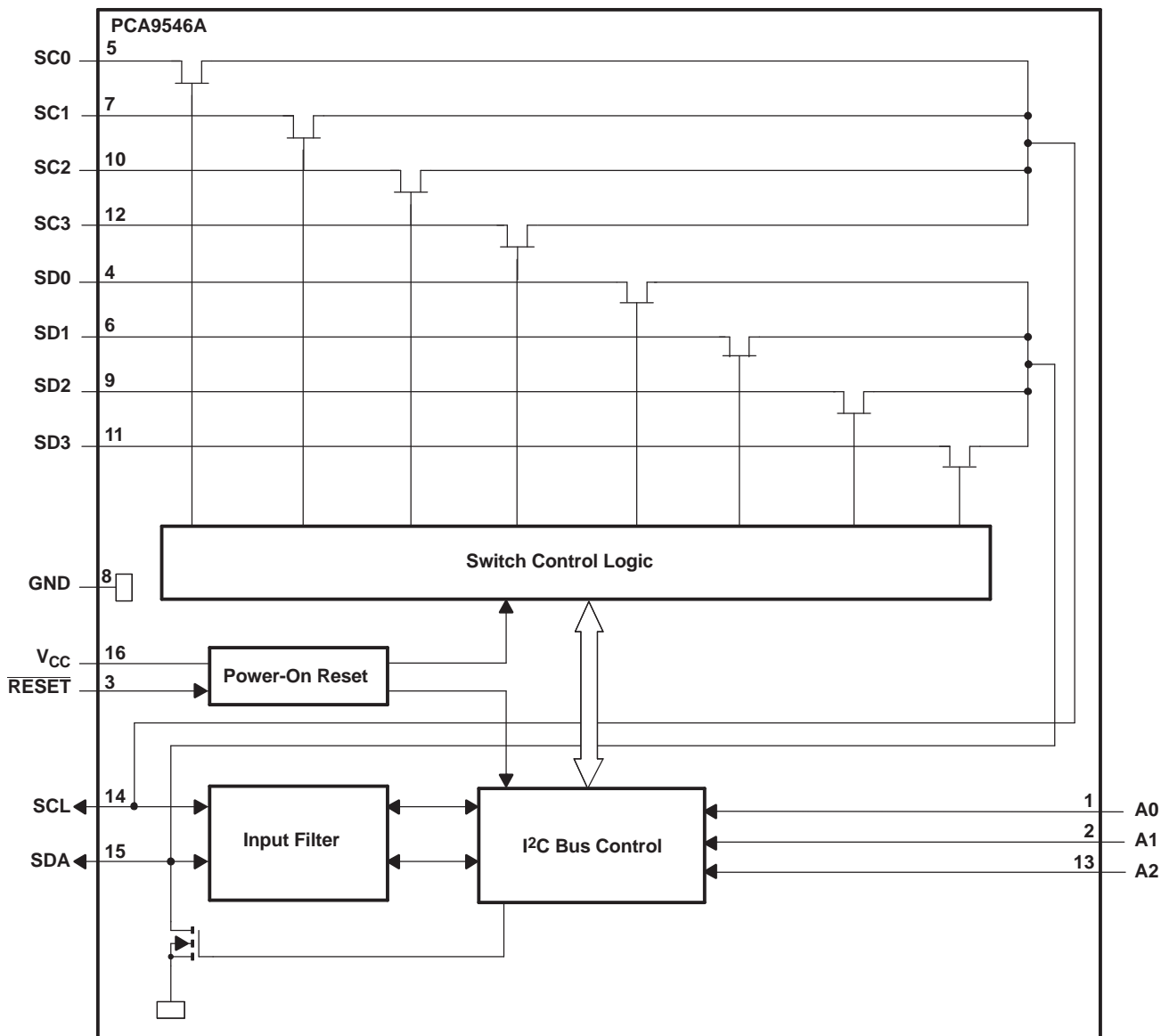
The PCA9546A is a 4-channel, bidirectional translating I<sup>2</sup>C switch. The master SCL/SDA signal pair is directed to four channels of slave devices, SC0/SD0-SC3/SD3. Any individual downstream channel can be selected as well as any combination of the four channels.

The device offers an active-low  $\overline{\text{RESET}}$  input which resets the state machine and allows the PCA9546A to recover should one of the downstream I<sup>2</sup>C buses get stuck in a low state. The state machine of the device can also be reset by cycling the power supply,  $V_{CC}$ , also known as a power-on reset (POR). Both the  $\overline{\text{RESET}}$  function and a POR will cause all channels to be deselected.

The connections of the I<sup>2</sup>C data path are controlled by the same I<sup>2</sup>C master device that is switched to communicate with multiple I<sup>2</sup>C slaves. After the successful acknowledgment of the slave address (hardware selectable by A0 and A1 pins), a single 8-bit control register is written to or read from to determine the selected channels.

The PCA9546A may also be used for voltage translation, allowing the use of different bus voltages on each SCn/SDn pair such that 1.8-V, 2.5-V, or 3.3-V parts can communicate with 5-V parts. This is achieved by using external pull-up resistors to pull the bus up to the desired voltage for the master and each slave channel.

## 9.2 Functional Block Diagram



### 9.3 Feature Description

The PCA9546A is a 4-channel, bidirectional translating switch for I<sup>2</sup>C buses that supports Standard-Mode (100 kHz) and Fast-Mode (400 kHz) operation. The PCA9546A features I<sup>2</sup>C control using a single 8-bit control register in which the four least significant bits control the enabling and disabling of the 4 switched channels of I<sup>2</sup>C data flow. Depending on the application, voltage translation of the I<sup>2</sup>C bus can also be achieved using the PCA9546A to allow 1.8-V, 2.5-V, or 3.3-V parts to communicate with 5-V parts. Additionally, in the event that communication on the I<sup>2</sup>C bus enters a fault state, the PCA9546A can be reset to resume normal operation using the  $\overline{\text{RESET}}$  pin feature or by a power-on reset which results from cycling power to the device.

### 9.4 Device Functional Modes

#### 9.4.1 $\overline{\text{RESET}}$ Input

The  $\overline{\text{RESET}}$  input is an active-low signal that may be used to recover from a bus-fault condition. When this signal is asserted low for a minimum of  $t_{\text{WL}}$ , the PCA9546A resets its registers and I<sup>2</sup>C state machine and deselects all channels. The  $\overline{\text{RESET}}$  input must be connected to  $V_{\text{CC}}$  through a pull-up resistor.

##### 9.4.1.1 $\overline{\text{RESET}}$ Errata

If RESET voltage set higher than VCC, current will flow from RESET pin to VCC pin.

#### System Impact

VCC will be pulled above its regular voltage level

#### System Workaround

Design such that  $\overline{\text{RESET}}$  voltage is same or lower than VCC

#### 9.4.2 Power-On Reset

When power is applied to  $V_{\text{CC}}$ , an internal power-on reset holds the PCA9546A in a reset condition until  $V_{\text{CC}}$  has reached  $V_{\text{POR}}$ . At this point, the reset condition is released, and the PCA9546A registers and I<sup>2</sup>C state machine are initialized to their default states, all zeroes, causing all the channels to be deselected. Thereafter,  $V_{\text{CC}}$  must be lowered below  $V_{\text{POR}}$  to reset the device.

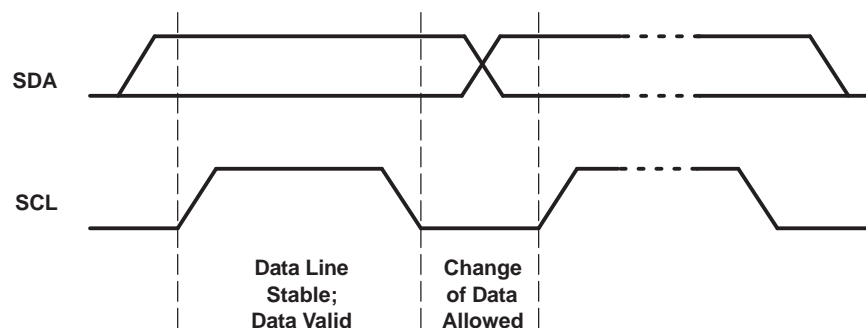
Refer to the [Power-On Reset Errata](#) section.

### 9.5 Programming

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

The I<sup>2</sup>C bus is for two-way two-line communication between different ICs or modules. The two lines are a serial data line (SDA) and a serial clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor when connected to the output stages of a device. Data transfer can be initiated only when the bus is not busy.

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the high period of the clock pulse, as changes in the data line at this time are interpreted as control signals (see [Figure 3](#)).



**Figure 3. Bit Transfer**

### Programming (continued)

Both data and clock lines remain high when the bus is not busy. A high-to-low transition of the data line while the clock is high is defined as the start condition (S). A low-to-high transition of the data line while the clock is high is defined as the stop condition (P) (see Figure 4).

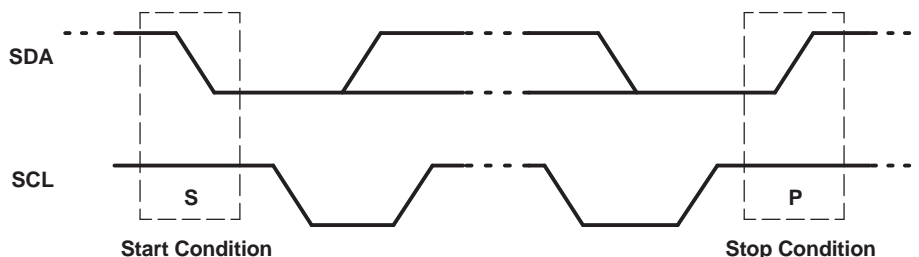


Figure 4. Definition of Start and Stop Conditions

A device generating a message is a transmitter; a device receiving is the receiver. The device that controls the message is the master, and the devices that are controlled by the master are the slaves (see Figure 5).

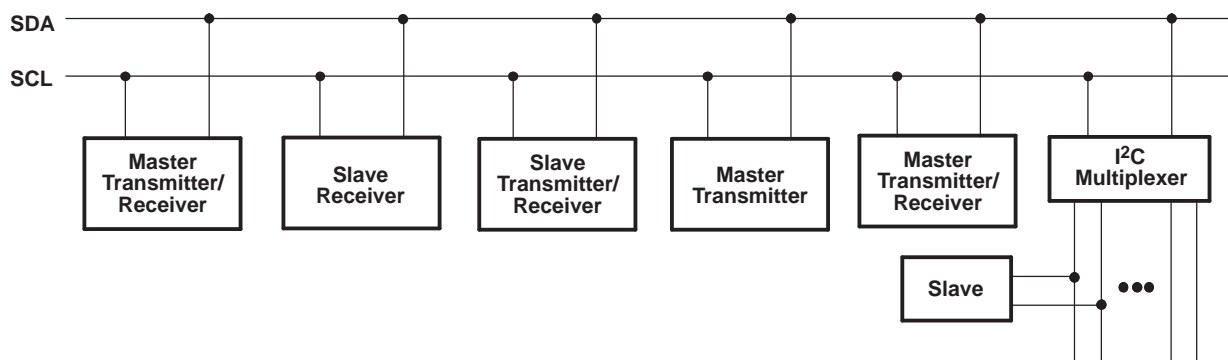


Figure 5. System Configuration

The number of data bytes transferred between the start and the stop conditions from transmitter to receiver is not limited. Each byte of eight bits is followed by one acknowledge (ACK) bit. The transmitter must release the SDA line before the receiver can send an ACK bit.

When a slave receiver is addressed, it must generate an ACK after the reception of each byte. Also, a master must generate an ACK after the reception of each byte that has been clocked out of the slave transmitter. 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 6). Setup and hold times must be taken into account.

Programming (continued)

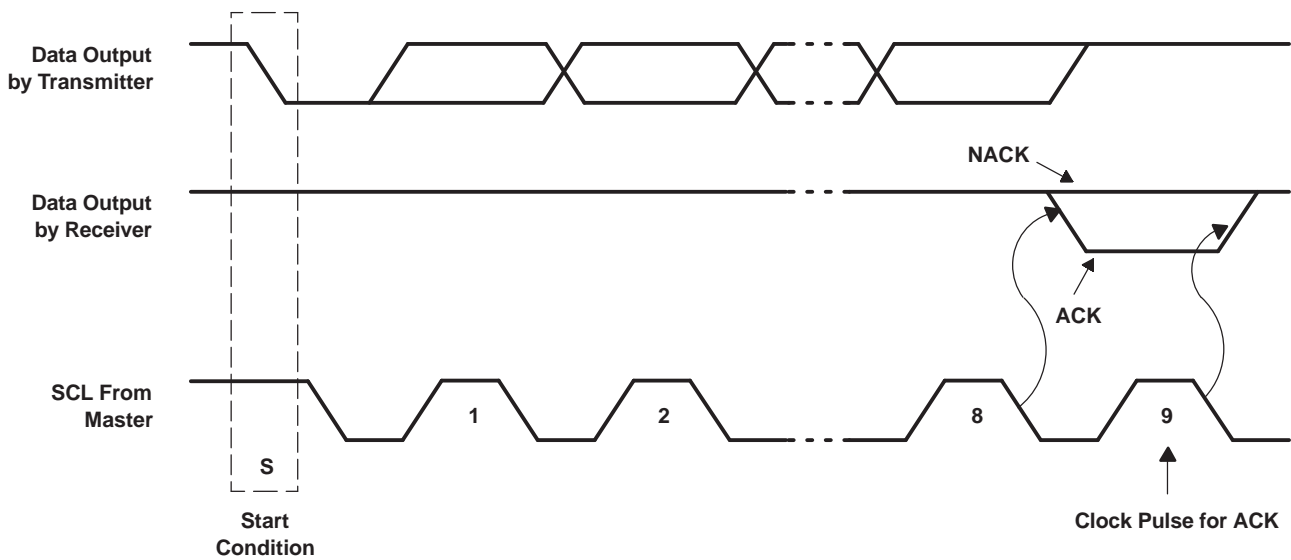


Figure 6. Acknowledgment on the I<sup>2</sup>C Bus

Data is transmitted to the PCA9546A control register using the write mode shown in Figure 7.

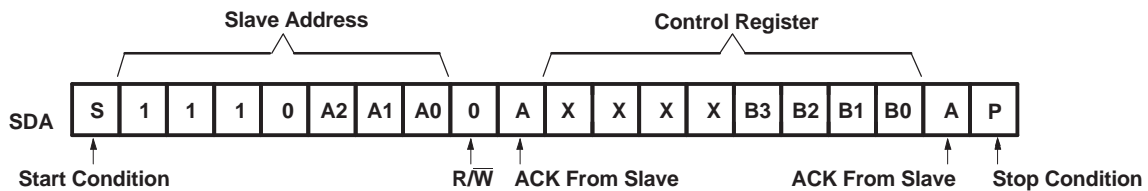


Figure 7. Write Control Register

Data is read from the PCA9546A control register using the read mode shown in Figure 8.

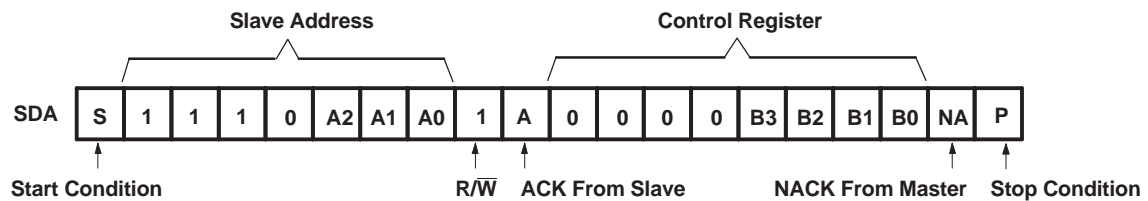


Figure 8. Read Control Register



**Control Register (continued)**
**Table 1. Control Register Write (Channel Selection), Control Register Read (Channel Status)<sup>(1)</sup>**

B7	B6	B5	B4	B3	B2	B1	B0	COMMAND
X	X	X	X	X	X	X	0	Channel 0 disabled
							1	Channel 0 enabled
X	X	X	X	X	X	0	X	Channel 1 disabled
								1
X	X	X	X	X	0	X	X	Channel 2 disabled
					1			Channel 2 enabled
X	X	X	X	0	X	X	X	Channel 3 disabled
				1				Channel 3 enabled
0	0	0	0	0	0	0	0	No channel selected, power-up/reset default state

(1) Several channels can be enabled at the same time. For example, B3 = 0, B2 = 1, B1 = 1, B0 = 0 means that channels 0 and 3 are disabled, and channels 1 and 2 are enabled. Care should be taken not to exceed the maximum bus capacity.

## 10 Application and Implementation

### 10.1 Application Information

Applications of the PCA9546A will contain an I<sup>2</sup>C (or SMBus) master device and up to four I<sup>2</sup>C slave devices. The downstream channels are ideally used to resolve I<sup>2</sup>C slave address conflicts. For example, if four identical digital temperature sensors are needed in the application, one sensor can be connected at each channel: 0, 1, 2, and 3. When the temperature at a specific location needs to be read, the appropriate channel can be enabled and all other channels switched off, the data can be retrieved, and the I<sup>2</sup>C master can move on and read the next channel.

In an application where the I<sup>2</sup>C bus will contain many additional slave devices that do not result in I<sup>2</sup>C slave address conflicts, these slave devices can be connected to any desired channel to distribute the total bus capacitance across multiple channels. If multiple switches will be enabled simultaneously, additional design requirements must be considered (See [Design Requirements](#) and [Detailed Design Procedure](#)).

### 10.2 Typical Application

A typical application of the PCA9546A will contain anywhere from 1 to 5 separate data pull-up voltages,  $V_{DPUX}$ , one for the master device ( $V_{DPU0}$ ) and one for each of the selectable slave channels ( $V_{DPU0} - V_{DPU3}$ ). In the event where the master device and all slave devices operate at the same voltage, then the pass voltage,  $V_{PASS} = V_{DPUX}$ . Once the maximum  $V_{PASS}$  is known,  $V_{CC}$  can be selected easily using [Figure 12](#). In an application where voltage translation is necessary, additional design requirements must be considered (See [Design Requirements](#)).

[Figure 11](#) shows an application in which the PCA9546A can be used.

Typical Application (continued)

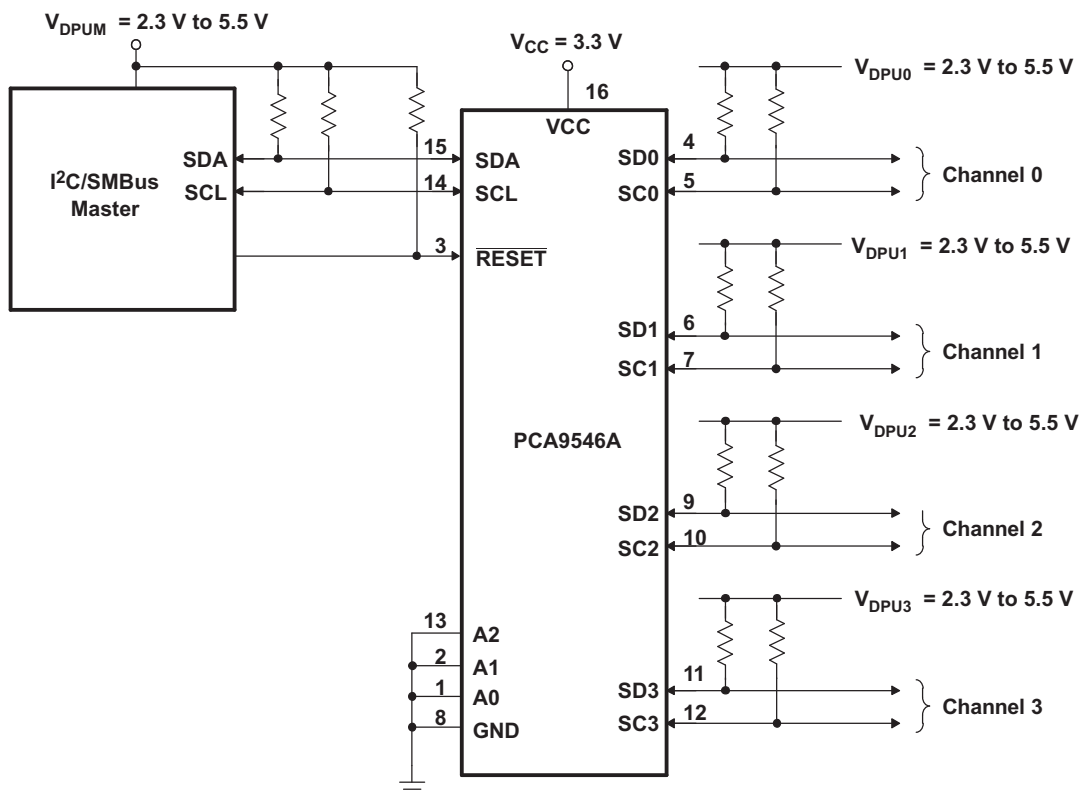


Figure 11. PCA9546A Typical Application Schematic

## Typical Application (continued)

### 10.2.1 Design Requirements

The A0, A1, and A2 pins are hardware selectable to control the slave address of the PCA9546A. These pins may be tied directly to GND or  $V_{CC}$  in the application.

If multiple slave channels will be activated simultaneously in the application, then the total  $I_{OL}$  from SCL/SDA to GND on the master side will be the sum of the currents through all pull-up resistors,  $R_p$ .

The pass-gate transistors of the PCA9546A are constructed such that the  $V_{CC}$  voltage can be used to limit the maximum voltage that is passed from one I<sup>2</sup>C bus to another.

Figure 12 shows the voltage characteristics of the pass-gate transistors (note that the graph was generated using data specified in the [Electrical Characteristics](#) section of this data sheet). In order for the PCA9546A to act as a voltage translator, the  $V_{pass}$  voltage must be equal to or lower than the lowest bus voltage. For example, if the main bus is running at 5 V and the downstream buses are 3.3 V and 2.7 V,  $V_{pass}$  must be equal to or below 2.7 V to effectively clamp the downstream bus voltages. As shown in Figure 12,  $V_{pass(max)}$  is 2.7 V when the PCA9546A supply voltage is 4 V or lower, so the PCA9546A supply voltage could be set to 3.3 V. Pull-up resistors then can be used to bring the bus voltages to their appropriate levels (see Figure 11).

### 10.2.2 Detailed Design Procedure

Once all the slaves are assigned to the appropriate slave channels and bus voltages are identified, the pull-up resistors,  $R_p$ , for each of the buses need to be selected appropriately. The minimum pull-up resistance is a function of  $V_{DPUX}$ ,  $V_{OL(max)}$ , and  $I_{OL}$ :

$$R_{p(min)} = \frac{V_{DPUX} - V_{OL(max)}}{I_{OL}} \quad (1)$$

The maximum pull-up resistance is a function of the maximum rise time,  $t_r$  (300 ns for fast-mode operation,  $f_{SCL} = 400$  kHz) and bus capacitance,  $C_b$ :

$$R_{p(max)} = \frac{t_r}{0.8473 \times C_b} \quad (2)$$

The maximum bus capacitance for an I<sup>2</sup>C bus must not exceed 400 pF for fast-mode operation. The bus capacitance can be approximated by adding the capacitance of the PCA9546A,  $C_{io(OFF)}$ , the capacitance of wires/connections/traces, and the capacitance of each individual slave on a given channel. If multiple channels will be activated simultaneously, each of the slaves on all channels will contribute to total bus capacitance.

Typical Application (continued)  
10.2.3 PCA9546A Application Curves

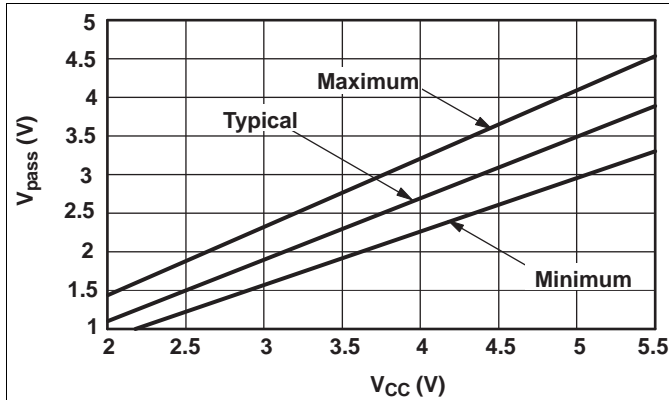
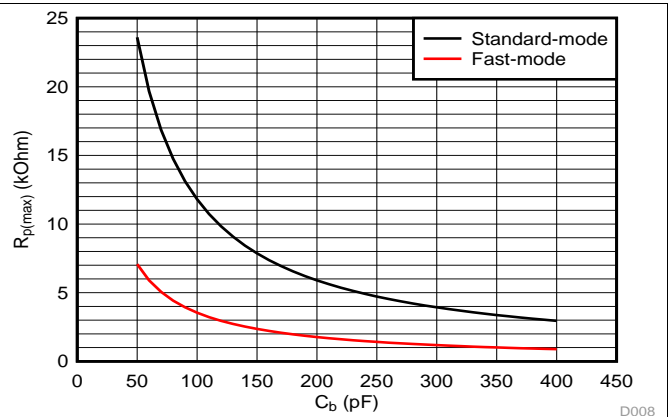
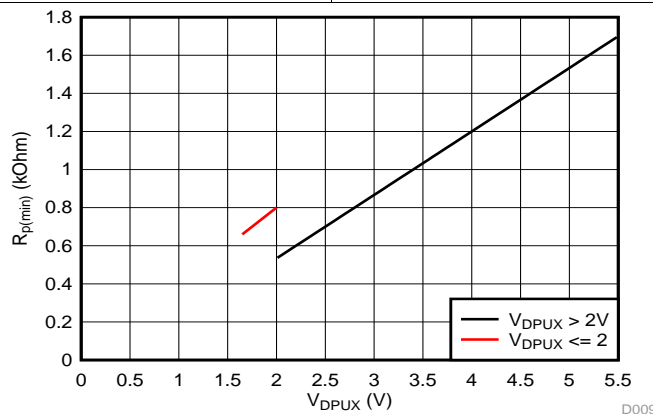


Figure 12. Pass-Gate Voltage ( $V_{pass}$ ) vs Supply Voltage ( $V_{CC}$ ) at Three Temperature Points



Standard-mode ( $f_{SCL} = 100 \text{ kHz}$ ,  $t_r = 1 \mu\text{s}$ )      Fast-mode ( $f_{SCL} = 400 \text{ kHz}$ ,  $t_r = 300 \text{ ns}$ )

Figure 13. Maximum Pull-Up resistance ( $R_{p(max)}$ ) vs Bus Capacitance ( $C_b$ )



$V_{OL} = 0.2 \cdot V_{DPUX}$ ,  $I_{OL} = 2 \text{ mA}$  when  $V_{DPUX} \leq 2 \text{ V}$   
 $V_{OL} = 0.4 \text{ V}$ ,  $I_{OL} = 3 \text{ mA}$  when  $V_{DPUX} > 2 \text{ V}$

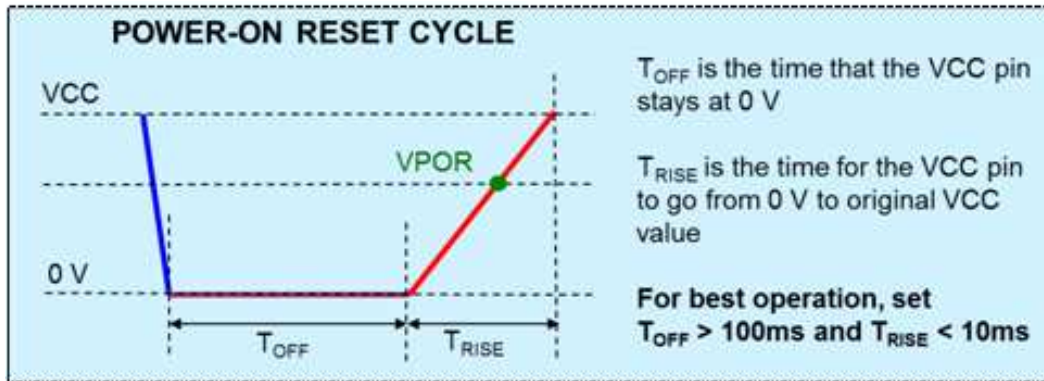
Figure 14. Minimum Pull-Up Resistance ( $R_{p(min)}$ ) vs Pull-Up Reference Voltage ( $V_{DPUX}$ )

## 11 Power Supply Recommendations

The operating power-supply voltage range of the PCA9546A is 2.3 V to 5.5 V applied at the VCC pin. When the PCA9546A is powered on for the first time or anytime the device needs to be reset by cycling the power supply, the power-on reset requirements must be followed to ensure the I<sup>2</sup>C bus logic is initialized properly.

### 11.1 Power-On Reset Errata

A power-on reset condition can be missed if the VCC ramps are outside specification listed below.



#### System Impact

If ramp conditions are outside timing allowances above, POR condition can be missed, causing the device to lock up.

## 12 Layout

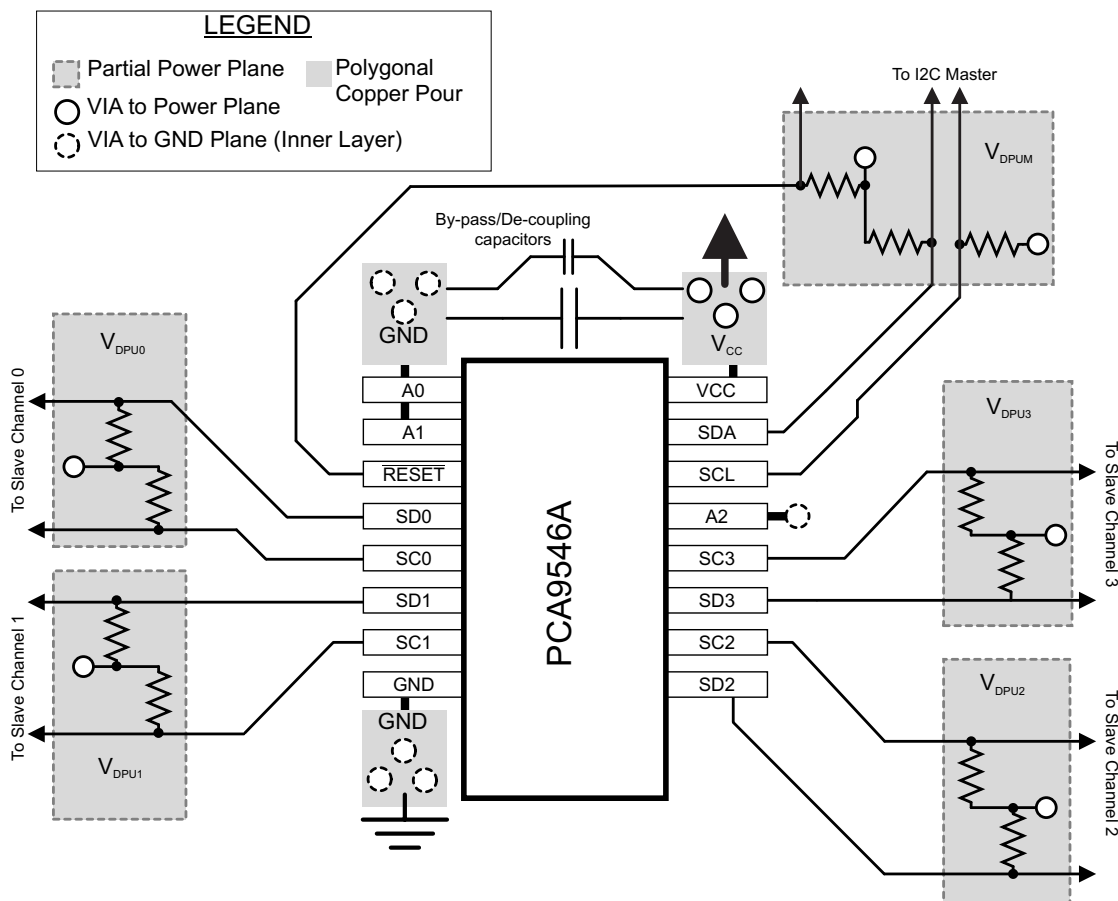
### 12.1 Layout Guidelines

For PCB layout of the PCA9546A, common PCB layout practices should be followed but additional concerns related to high-speed data transfer such as matched impedances and differential pairs are not a concern for I<sup>2</sup>C signal speeds. It is common to have a dedicated ground plane on an inner layer of the board and pins that are connected to ground should have a low-impedance path to the ground plane in the form of wide polygon pours and multiple vias. By-pass and de-coupling capacitors are commonly used to control the voltage on the VCC pin, using a larger capacitor to provide additional power in the event of a short power supply glitch and a smaller capacitor to filter out high-frequency ripple.

In an application where voltage translation is not required, all  $V_{DPUX}$  voltages and  $V_{CC}$  could be at the same potential and a single copper plane could connect all of pull-up resistors to the appropriate reference voltage. In an application where voltage translation is required,  $V_{DPU0}$ ,  $V_{DPU1}$ ,  $V_{DPU2}$ , and  $V_{DPU3}$  may all be on the same layer of the board with split planes to isolate different voltage potentials.

To reduce the total I<sup>2</sup>C bus capacitance added by PCB parasitics, data lines (SCn and SDn) should be as short as possible and the widths of the traces should also be minimized (e.g. 5-10 mils depending on copper weight).

## 12.2 Layout Example



## 13 Device and Documentation Support

### 13.1 Trademarks

All trademarks are the property of their respective owners.

### 13.2 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 13.3 Glossary

[SLYZ022](#) — TI Glossary.



This glossary lists and explains terms, acronyms, and definitions.

## 14 Mechanical, Packaging, and Orderable Information

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

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PCA9546AD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADGVR	ACTIVE	TVSOP	DGV	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546ADR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADT	ACTIVE	SOIC	D	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546ADWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9546A	<a href="#">Samples</a>
PCA9546APW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWE4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWRE4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWT	ACTIVE	TSSOP	PW	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546APWTG4	ACTIVE	TSSOP	PW	16	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD546A	<a href="#">Samples</a>
PCA9546ARGVR	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PD546A	<a href="#">Samples</a>

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PCA9546ARGVRG4	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PD546A	
PCA9546ARGYR	ACTIVE	VQFN	RGY	16	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	PD546A	

(1) The marketing status values are defined as follows:

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

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

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

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

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

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

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

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

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

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

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

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

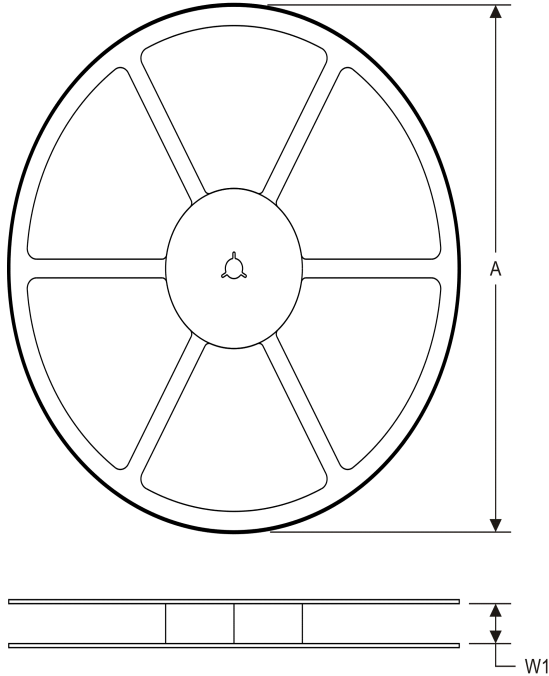
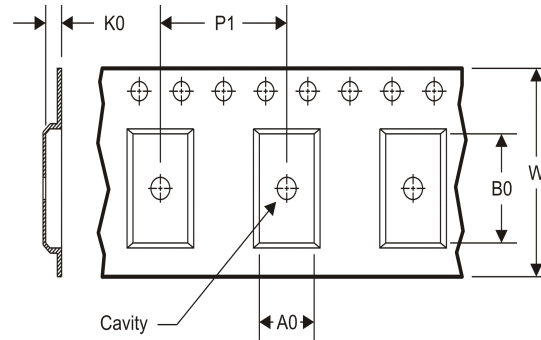
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



**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
PCA9546ADGV	TVSOP	DGV	16	2000	330.0	12.4	6.8	4.0	1.6	8.0	12.0	Q1
PCA9546ADR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0	16.0	Q1
PCA9546ADWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1
PCA9546APWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
PCA9546APWT	TSSOP	PW	16	250	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
PCA9546ARGVR	VQFN	RGV	16	2500	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
PCA9546ARGYR	VQFN	RGY	16	3000	330.0	12.4	3.8	4.3	1.5	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCA9546ADGVR	TVSOP	DGV	16	2000	367.0	367.0	35.0
PCA9546ADR	SOIC	D	16	2500	333.2	345.9	28.6
PCA9546ADWR	SOIC	DW	16	2000	367.0	367.0	38.0
PCA9546APWR	TSSOP	PW	16	2000	367.0	367.0	35.0
PCA9546APWT	TSSOP	PW	16	250	367.0	367.0	35.0
PCA9546ARGVR	VQFN	RGV	16	2500	367.0	367.0	35.0
PCA9546ARGYR	VQFN	RGY	16	3000	367.0	367.0	35.0

D (R-PDSO-G16)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - 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 0.006 (0,15) each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G16)

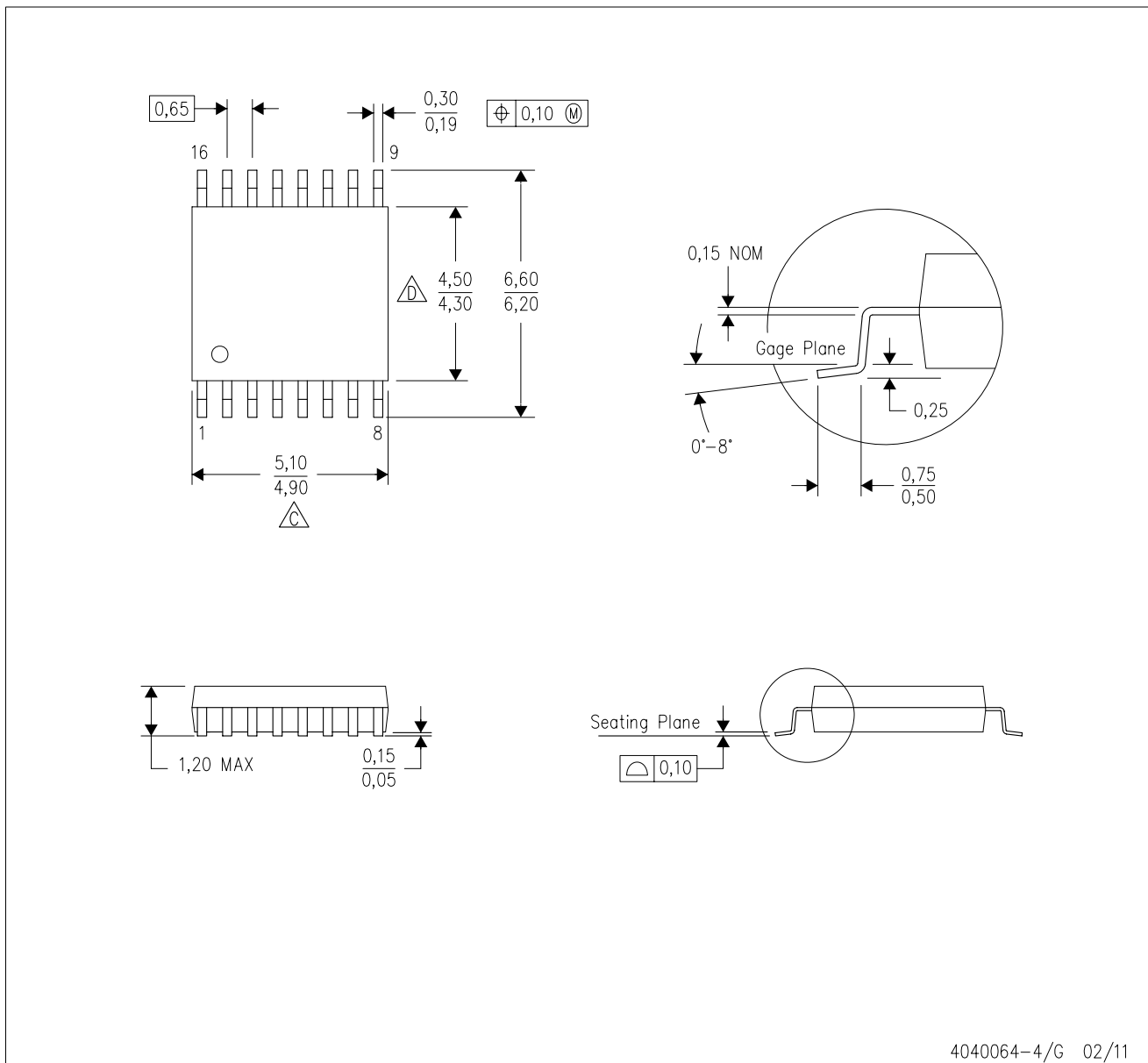
PLASTIC SMALL OUTLINE



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

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE

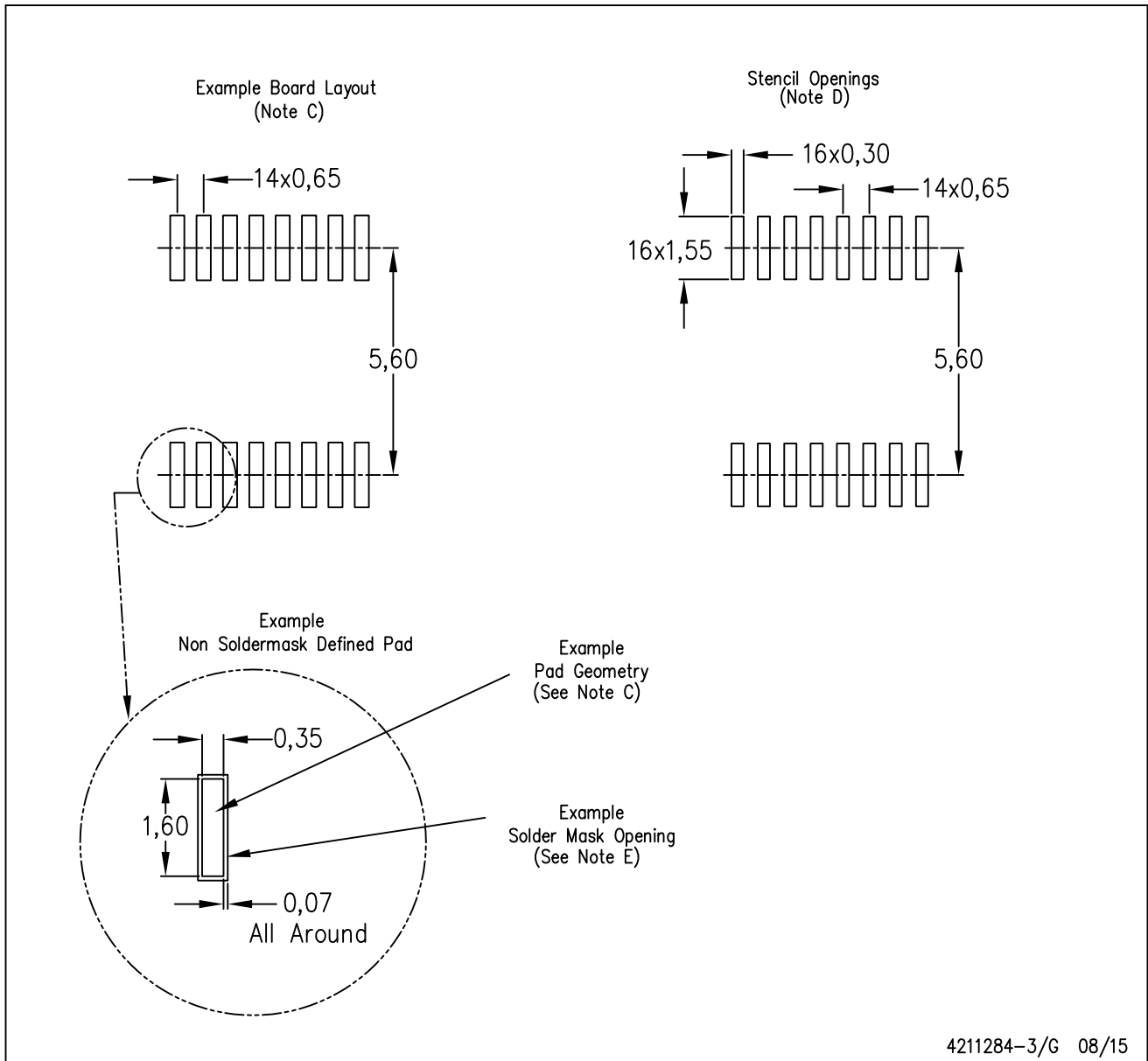


4040064-4/G 02/11

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

PW (R-PDSO-G16)

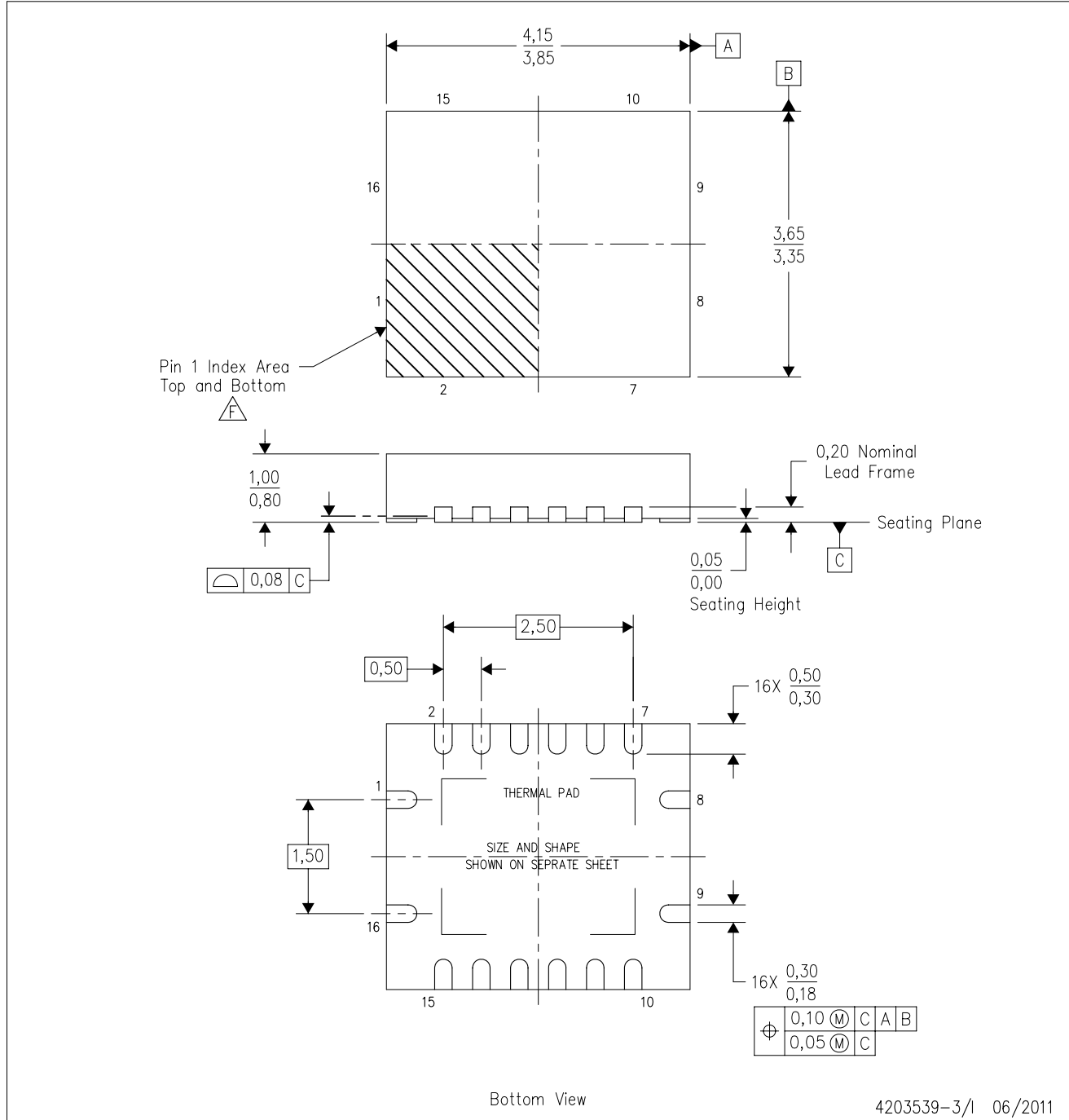
PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - 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.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

RGY (R-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



- 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. QFN (Quad Flatpack No-Lead) 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. Pin 1 identifiers are located on both top and bottom of the package and within the zone indicated. The Pin 1 identifiers are either a molded, marked, or metal feature.
  - G. Package complies to JEDEC MO-241 variation BA.

RGY (R-PVQFN-N16)

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

4206353-3/P 03/14

NOTE: All linear dimensions are in millimeters

RGY (R-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD

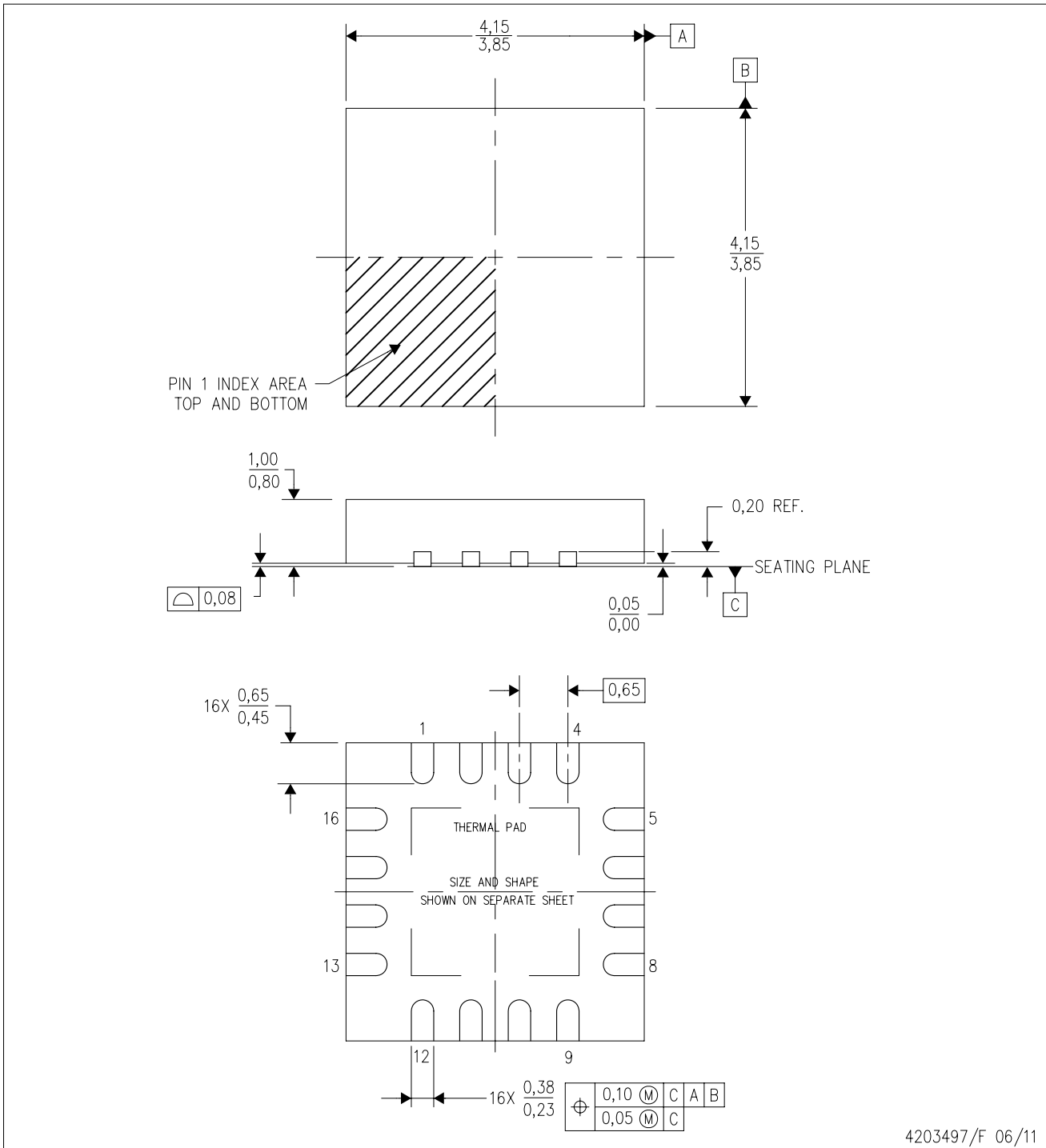


4208122-3/P 03/14

- 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 QFN/SON PCB Attachment, 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 minimum solder mask web tolerances between signal pads.

RGV (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



4203497/F 06/11

- 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

RGV (S-PVQFN-N16)

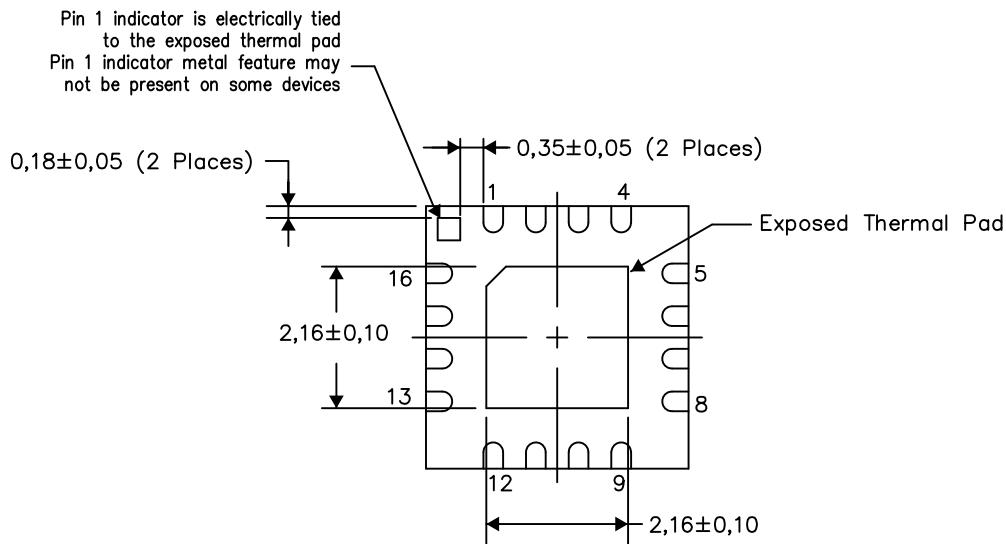
PLASTIC QUAD FLATPACK NO-LEAD

## 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

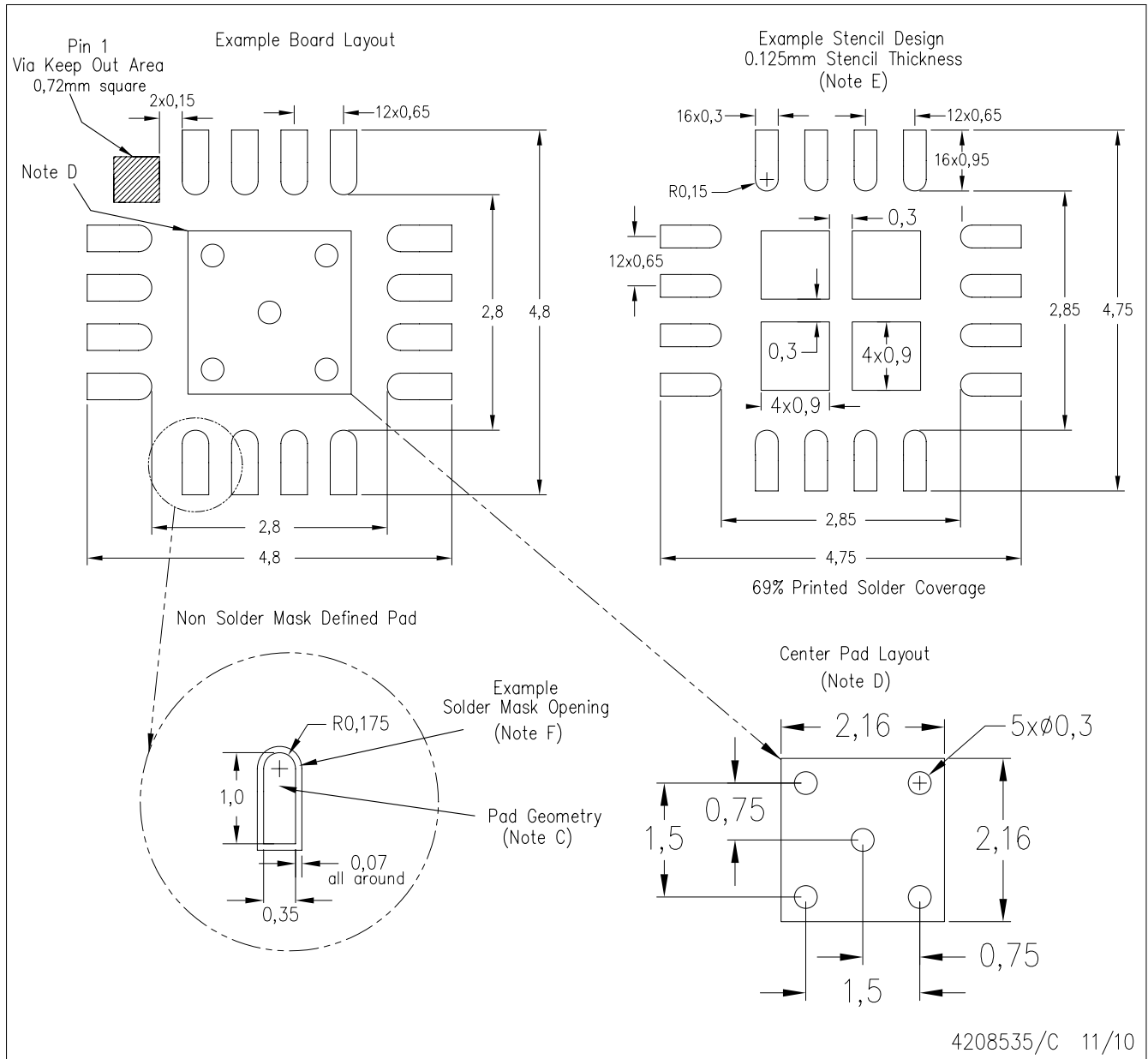
Exposed Thermal Pad Dimensions

4206351-2/L 05/13

NOTE: All linear dimensions are in millimeters

RGV (S-PVQFN-N16)

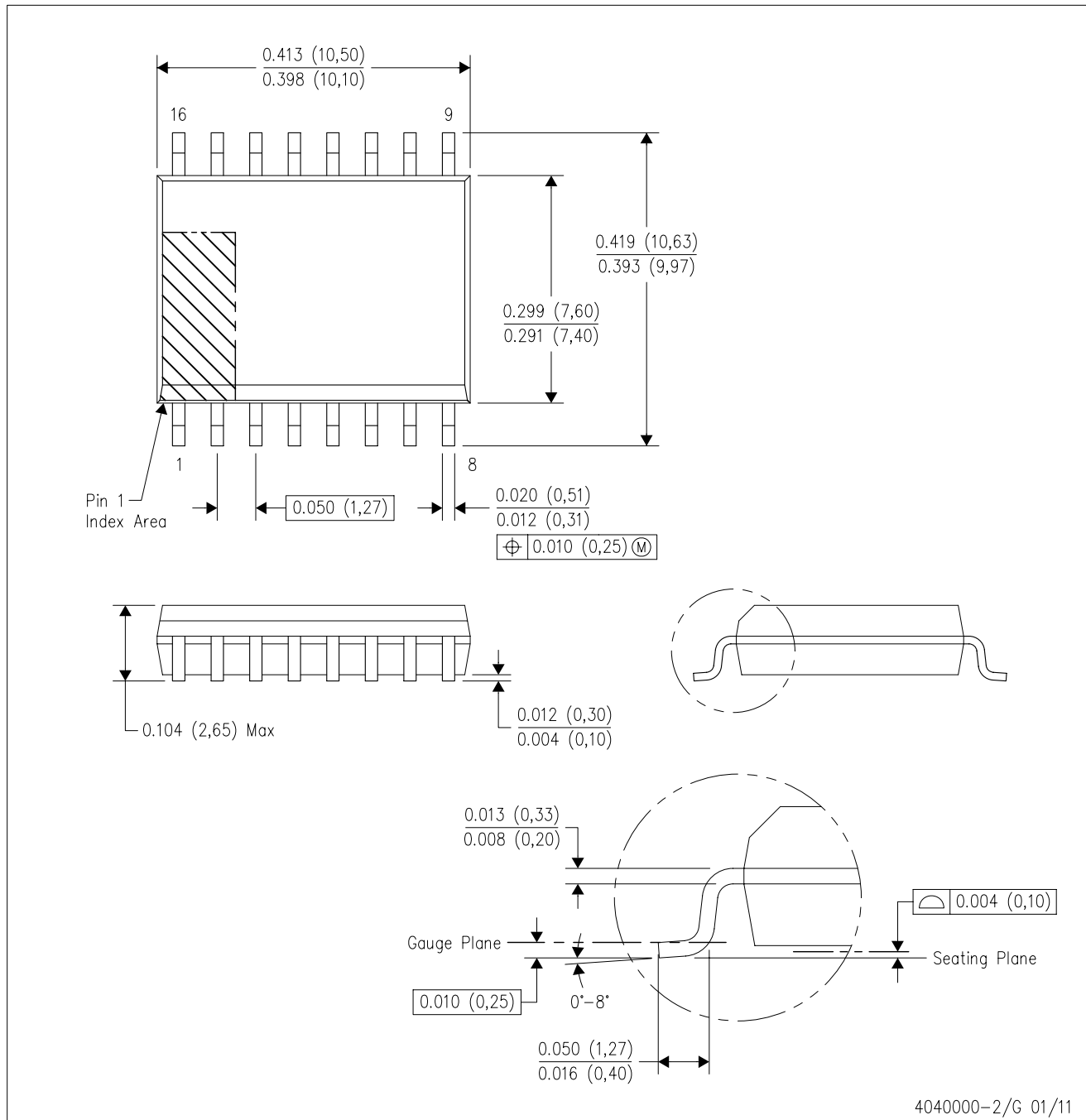
PLASTIC QUAD FLATPACK NO-LEAD



- 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, QFN 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 solder mask tolerances.

DW (R-PDSO-G16)

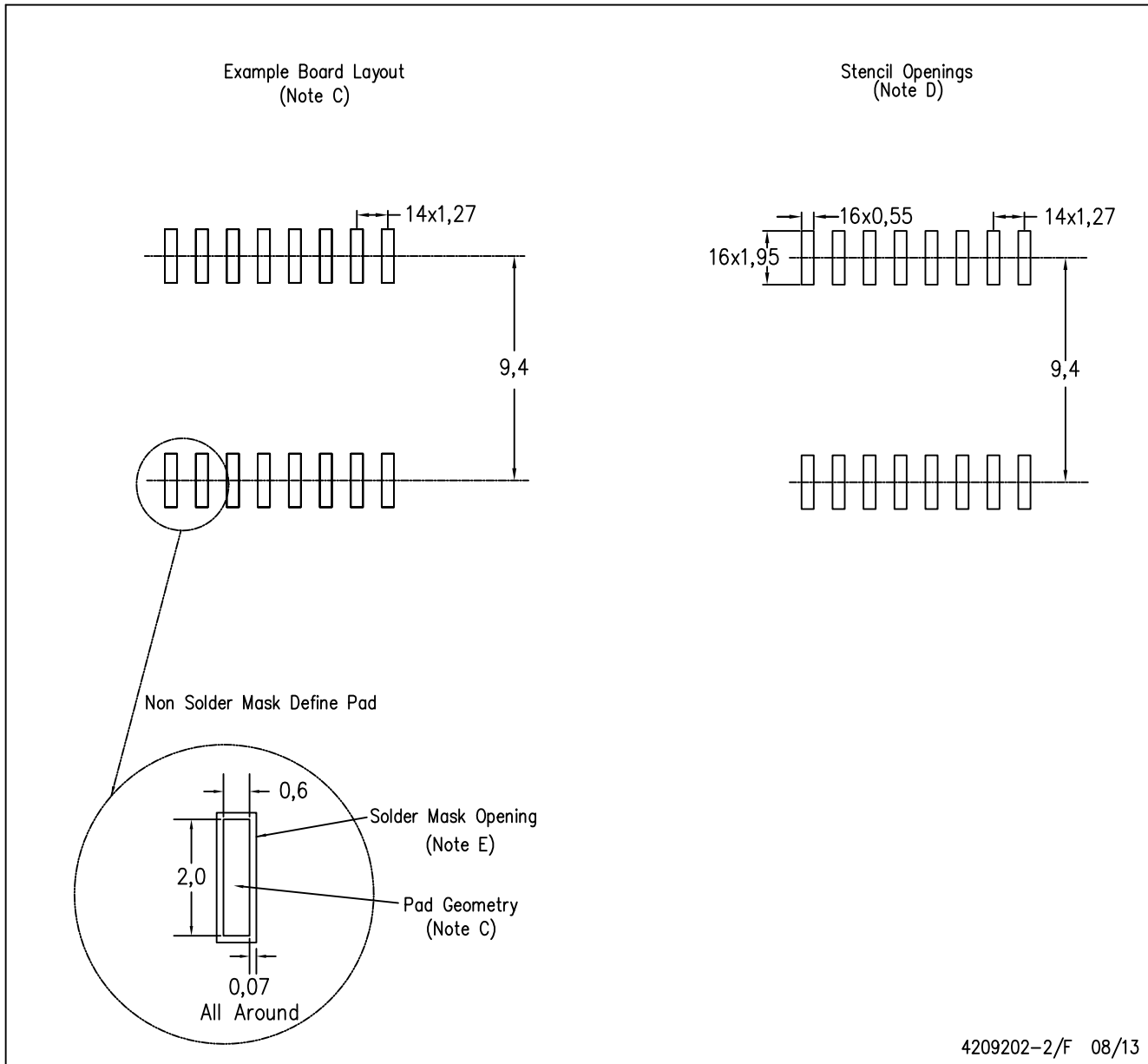
PLASTIC SMALL OUTLINE



- 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 AA.

DW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



4209202-2/F 08/13

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Refer to IPC7351 for alternate board 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
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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