TEXAS INSTRUMENTS

具有中断输出和配置寄存器的 PCA9554 远程 8 位 I2C 和 SMBus I/O 扩展器

1 特性

- I²C 至并行端口扩展器
- 开漏电路低电平有效中断输出
- 2.3 V 至 5.5V 的工作电源电压范围
- 耐受 5V 电压的 I/O
- 400kHz 快速 I²C 总线
- 3 个硬件地址引脚可在 I²C/SMBus 上支持最多 8 个器件
- 输入/输出配置寄存器
- 极性反转寄存器
- 内部加电复位
- 所用通道在加电时被配置为输入
- 在加电时无毛刺脉冲
- 针对直接驱动 LED 的具有高电流驱动最大能力的锁存输出
- 锁断性能超过 100mA，符合 JESD 78 II 类规范的要求）
- ESD 保护性能超过 JESD 22 规范要求
  - 2000V 人体放电模型 (A114-A)
  - 200V 机器放电模型 (A115-A)
  - 1000V 带电器件模型 (C101)

2 说明

这个用于两线双向总线 (I2C) 的 8 位 I/O 扩展器设计用于在 2.3V 至 5.5V VCC 之间运行。通过 I²C 接口 [串行时钟 (SCL)，串行数据 (SDA)]，它为大多数微控制器系列产品提供通用远程 I/O 扩展。

PCA9554 包含一个 8 位配置（输入或输出可选）、输入、输出和极性反转（高电平有效或低电平有效）寄存器。加电时，I/O 被配置为到 V$_{CC}$ 的弱上拉输入。但是，系统主控制器可以通过写入 I/O 配置位将 I/O 启用为输入或输出。每个输入或输出的数据均保存在相应的输入或输出寄存器中。输入端口寄存器的极性可借助极性反转寄存器进行转换。所有寄存器都可由系统主控器读取。

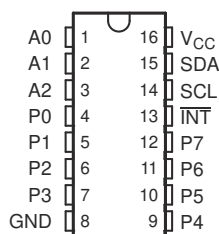发生超时或其他不当操作时，系统主控器可通过使用上电复位功能，将寄存器置于其默认状况并初始化 I2C/SMBus 状态机来复位 PCA9554。

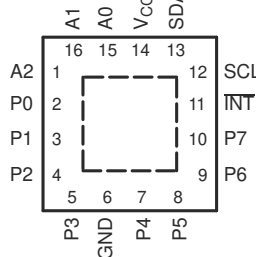PCA9554 开漏中断 (INT) 输出在任意输入状态与其对应的输入端口寄存器状态不同时被激活，并用于向系统主控器指明输入状态已改变。

器件信息[(1)]

器件型号	封装	封装尺寸（标称值）
PCA9554	SSOP (16)	6.20mm x 5.30mm
	VQFN (16)	4.00mm x 4.00mm
	四方扁平无引线 (QFN) (16)	3.00mm × 3.00mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。

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

RGV PACKAGE (TOP VIEW)
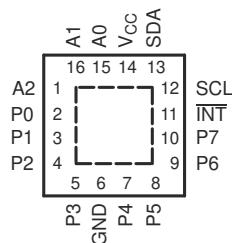

RGT PACKAGE (TOP VIEW)

English Data Sheet: SCPS128

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3 Revision History

Changes from Revision C (May 2021) to Revision D (March 2021)   **Page**

- Moved the "Storage temperature range" to the *Absolute Maximum Ratings* 5
- Moved the "Package thermal impedance" to the *Thermal Resistance Characteristic* 5
- Changed the V_{IH} High-level input voltage (SDL, SDA) Max value From: 5.5 V To: V_{CC} in the *Recommended Operating Conditions* 5
- Changed the V_{IH} High-level input voltage (A0, A1, A2, P7－P0) MIN value From: 5.5 V To: 0.7 x V_{CC} in the *Recommended Operating Conditions* 5
- Changed the V_{IL} Low-level input voltage (A0, A1, A2, P7－P0) MAX value From: 0.8 V To: 0.3 x V_{CC} in the *Recommended Operating Conditions* 5
- Added the *Thermal Information* table.. 6
- Changed V_{PORR} in the *Electrical Characteristics* 6
- Added V_{PORF} to the *Electrical Characteristics* 6
- Changed the I_{CC} Standby mode values in the *Electrical Characteristics* 6
- Changed the C_i SCL Max value From: 5 pF To: 8 pF in the *Electrical Characteristics* 6
- Changed the C_{io} SDA Max value From: 6.5 pF To: 9.5 pF in the *Electrical Characteristics* 6
- Changed the t_{pv} Output data valid MAX values From: 200 ns To 350 ns in the *Swirtching Characteristics* 8
- Changed the *Typical Characteristics* graphs... 9
- Changed the *Power Supply Recommendations* 24

Changes from Revision B (August 2008) to Revision C (May 2014)   **Page**

- Added Interrupt Errata section..16

4 Description (Continued)

$\overline{\text{INT}}$ can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I^{2}C bus. Thus, the PCA9554 can remain a simple slave device.

The device's outputs (latched) have high-current drive capability for directly driving LEDs and low current consumption.
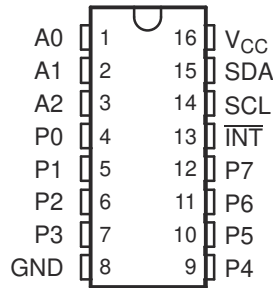
Three hardware pins (A0, A1, and A2) are used to program and vary the fixed I^{2}C address and allow up to eight devices to share the same I^{2}C bus or SMBus.

The PCA9554 is pin-to-pin and I^{2}C address compatible with the PCF8574. However, software changes are required, due to the enhancements in the PCA9554 over the PCF8574.
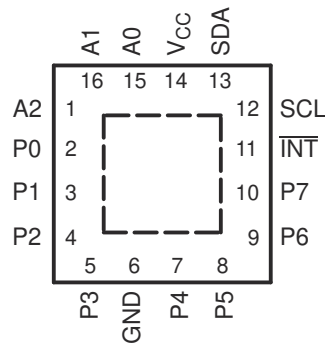
The PCA9554 and PCA9554A are identical except for their fixed I^{2}C address. This allows for up to 16 of these devices (eight of each) on the same I^{2}C/SMBus.

5 Pin Configuration and Functions

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

A0	1	16	V_CC
A1	2	15	SDA
A2	3	14	SCL
P0	4	13	$\overline{\text{INT}}$
P1	5	12	P7
P2	6	11	P6
P3	7	10	P5
GND	8	9	P4

RGV PACKAGE
(TOP VIEW)

RGT PACKAGE
(TOP VIEW)
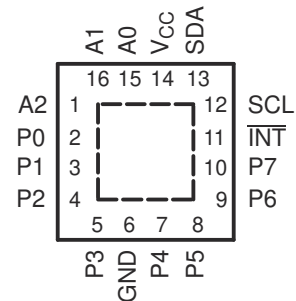
表 5-1. Pin Functions

PIN			DESCRIPTION
NAME	QSOP (DBQ) SOIC (DW), SSOP (DB), TSSOP (PW), AND TVSOP (DGV)	QFN (RGT) AND QFN (RGV)	
A0	1	15	Address input. Connect directly to V_{CC} or ground.
A1	2	16	Address input. Connect directly to V_{CC} or ground.
A2	3	1	Address input. Connect directly to V_{CC} or ground.
P0	4	2	P-port input/output. Push-pull design structure.
P1	5	3	P-port input/output. Push-pull design structure.
P2	6	4	P-port input/output. Push-pull design structure.
P3	7	5	P-port input/output. Push-pull design structure.
GND	8	6	Ground
P4	9	7	P-port input/output. Push-pull design structure.
P5	10	8	P-port input/output. Push-pull design structure.
P6	11	9	P-port input/output. Push-pull design structure.
P7	12	10	P-port input/output. Push-pull design structure.
$\overline{\text{INT}}$	13	11	Interrupt output. Connect to V_{CC} through a pullup resistor.
SCL	14	12	Serial clock bus. Connect to V_{CC} through a pullup resistor.
SDA	15	13	Serial data bus. Connect to V_{CC} through a pullup resistor.
V_{CC}	16	14	Supply voltage

Product Folder Links: *PCA9554*

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) [1]

			MIN	MAX	UNIT
V_{CC}	Supply voltage range		– 0.5	6	V
V_I	Input voltage range[2]		– 0.5	6	V
V_O	Output voltage range[2]		– 0.5	6	V
I_{IK}	Input clamp current	$V_I < 0$		– 20	mA
I_{OK}	Output clamp current	$V_O < 0$		– 20	mA
I_{IOK}	Input/output clamp current	$V_O < 0$ or $V_O > V_{CC}$		±20	mA
I_{OL}	Continuous output low current	$V_O = 0$ to V_{CC}		50	mA
I_{OH}	Continuous output high current	$V_O = 0$ to V_{CC}		– 50	mA
I_{CC}	Continuous current through GND			– 250	mA
	Continuous current through V_{CC}			160	mA
T_{stg}	Storage temperature range		– 65	150	°C

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The input negative-voltage and output voltage ratings may be exceeded if the input and output current ratings are observed.

6.2 ESD Ratings

			MIN	MAX	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins[1]	0	2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins[2]	0	1000	

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

6.3 Recommended Operating Conditions

			MIN	MAX	UNIT
V_{CC}	Supply voltage		2.3	5.5	V
V_{IH}	High-level input voltage	SCL, SDA	$0.7 \times V_{CC}$	V_{CC} [1]	V
		A2 – A0, P7 – P0	2	V_{CC}	
V_{IL}	Low-level input voltage	SCL, SDA	– 0.5	$0.3 \times V_{CC}$	V
		A2 – A0, P7 – P0	– 0.5	$0.3 \times V_{CC}$	
I_{OH}	High-level output current	P7 – P0		– 10	mA
I_{OL}	Low-level output current	P7 – P0		25	mA
T_A	Operating free-air temperature		– 40	85	°C

(1) For voltages applied above V_{CC}, an increase in ICC will result.

Product Folder Links: *PCA9554*

6.4 Thermal Information

THERMAL METRIC[1]		PCA9538					UNIT
		DB (SSOP)	DBQ (SSOP)	DGV (TVSOP)	DW (SOIC)	PW (TSSOP)	
		16 PINS	16 PINS	16 PINS	16 PINS	16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	113.2	121.7	120	57	63.2	°C/W

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

6.5 Electrical Characteristics

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

	PARAMETER	TEST CONDITIONS	V_{CC}	MIN	TYP[1]	MAX	UNIT
V_{IK}	Input diode clamp voltage	I_I = – 18 mA	2.3 V to 5.5 V	– 1.2			V
V_{PORR}	Power-on reset voltage, V_{CC} rising	$V_I = V_{CC}$ or GND, I_O = 0			1.2	1.5	V
V_{PORF}	Power-on reset voltage, V_{CC} falling	$V_I = V_{CC}$ or GND, I_O = 0		0.75	1		V
V_{OH}	P-port high-level output voltage[2]	I_{OH} = – 8 mA	2.3 V	1.8			V
			3 V	2.6			
			4.5 V	3.1			
			4.75 V	4.1			
		I_{OH} = – 10 mA	2.3 V	1.7			
			3 V	2.5			
			4.5 V	3			
			4.75 V	4			
I_{OL}	SDA	V_{OL} = 0.4 V	2.3 V to 5.5 V	3	8		mA
	P port[3]	V_{OL} = 0.5 V	2.3 V	8	10		
			3 V	8	14		
			4.5 V	8	17		
			4.75 V	8	35		
		V_{OL} = 0.7 V	2.3 V	10	13		
			3 V	10	19		
			4.5 V	10	24		
			4.75 V	10	45		
	$\overline{INT}$	V_{OL} = 0.4 V	2.3 V to 5.5 V	3	10		
I_I	SCL, SDA	$V_I = V_{CC}$ or GND	2.3 V to 5.5 V			±1	µA
	A2 – A0					±1	
I_{IH}	P port	$V_I = V_{CC}$	2.3 V to 5.5 V			1	µA
I_{IL}	P port	V_I = GND	2.3 V to 5.5 V			– 100	µA

Product Folder Links: *PCA9554*

6.5 Electrical Characteristics (continued)

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

	PARAMETER	TEST CONDITIONS	V_{CC}	MIN	TYP[1]	MAX	UNIT
I_{CC}	Operating mode	$V_I = V_{CC}$, $I_O = 0$, I/O = inputs, $f_{scl} = 400$ kHz, No load	5.5 V		104	175	μA
			3.6 V		50	90	
			2.7 V		20	65	
		$V_I = V_{CC}$, $I_O = 0$, I/O = inputs, $f_{scl} = 100$ kHz, No load	5.5 V		60	150	
			3.6 V		15	40	
			2.7 V		8	20	
	Standby mode	$V_I = $ GND, $I_O = 0$, I/O = inputs, $f_{scl} = 0$ kHz, No load	5.5 V		450	700	
			3.6 V		300	600	
			2.7 V		225	500	
		$V_I = V_{CC}$, $I_O = 0$, I/O = inputs, $f_{scl} = 0$ kHz, No load	5.5 V		1.9	3.5	
			3.6 V		1.1	1.8	
			2.7 V		1	1.6	
ΔI_{CC}	Additional current in standby mode	One input at V_{CC} – 0.6 V, Other inputs at V_{CC} or GND	2.3 V to 5.5 V			1.5	mA
		Every LED I/O at $V_I = 4.3$ V, $f_{scl} = 0$ kHz	5.5 V			1	
C_i	SCL	$V_I = V_{CC}$ or GND	2.3 V to 5.5 V		4	8	pF
C_{io}	SDA	$V_{IO} = V_{CC}$ or GND	2.3 V to 5.5 V		5.5	9.5	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_{CC}) and $T_A = 25°C$.
(2) The total current sourced by all I/Os must be limited to 85 mA.
(3) Each I/O must be externally limited to a maximum of 25 mA, and the P port (P0 to P7) must be limited to a maximum current of 200 mA.

6.6 I²C Interface Timing Requirements

over operating free-air temperature range (unless otherwise noted) (see 图 7-1)

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

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

6.7 Switching Characteristics

over operating free-air temperature range (unless otherwise noted) (see 图 7-2 and 图 7-3)

	PARAMETER	FROM (INPUT)	TO (OUTPUT)	STANDARD MODE I²C BUS		FAST MODE I²C BUS		UNIT
				MIN	MAX	MIN	MAX	
t_{iv}	Interrupt valid time	P port	$\overline{INT}$		4		4	μs
t_{ir}	Interrupt reset delay time	SCL	$\overline{INT}$		4		4	μs
t_{pv}	Output data valid	SCL	P7 – P0		350		350	ns
t_{ps}	Input data setup time	P port	SCL	100		100		ns
t_{ph}	Input data hold time	P port	SCL	1		1		μs

6.8 Typical Characteristics

T_A = 25°C (unless otherwise noted)

f_{SCL} = 400 kHz   I/Os = High or Low Inputs
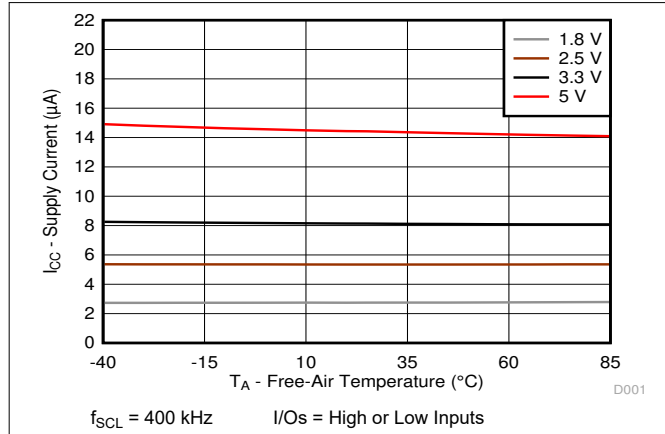
图 6-1. Supply Current (I_{CC}, Operating Mode) vs Temperature (T_A) at Four Supply Voltages

f_{SCL} = 0 kHz   I/Os = High Inputs
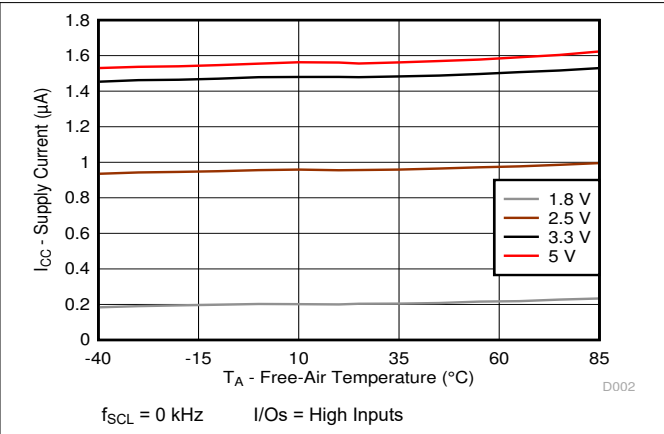
图 6-2. Supply Current (ICC, Standby Mode) vs Temperature (T_A) at Four Supply Voltages

f_{SCL} = 400 kHz   I/Os = High or Low Inputs T_A = 25°C
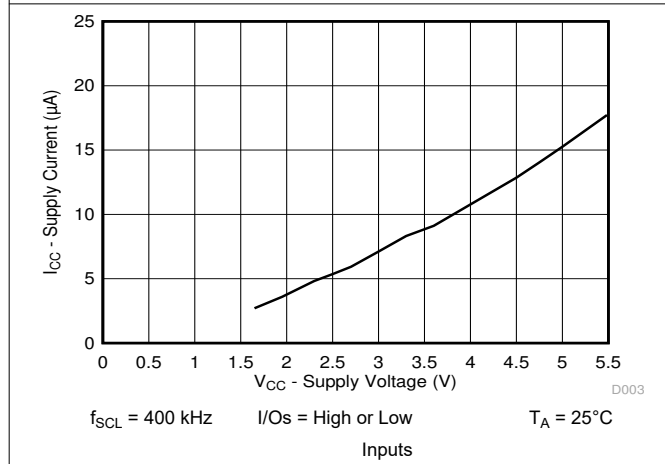
图 6-3. Supply Current (I_{CC}, Operating Mode) vs Supply Voltage (V_{CC})
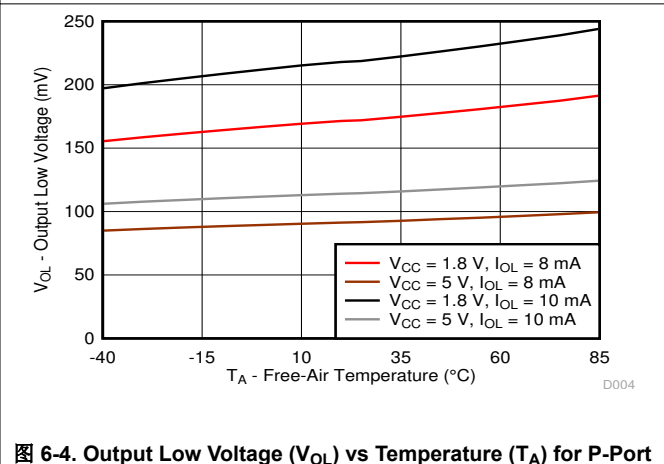
图 6-4. Output Low Voltage (V_{OL}) vs Temperature (T_A) for P-Port I/Os
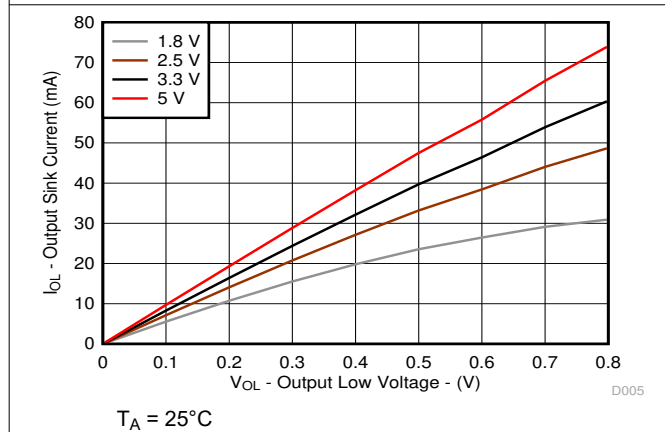
T_A = 25°C

图 6-5. Sink Current (I_{OL}) vs Output Low Voltage (V_{OL}) for P-Ports at Four Supply Voltages
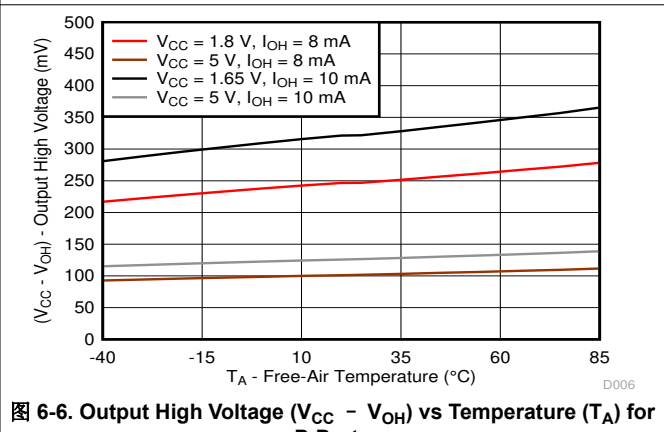
图 6-6. Output High Voltage (V_{CC} – V_{OH}) vs Temperature (T_A) for P-Ports

Product Folder Links: PCA9554

6.8 Typical Characteristics (continued)

T_A = 25°C (unless otherwise noted)
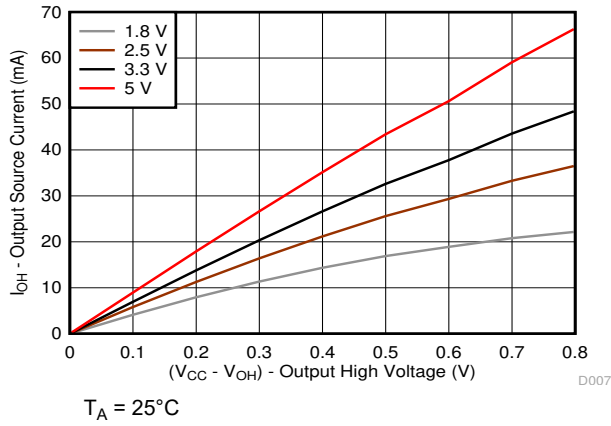
图 6-7. Source Current (I_{OH}) vs Output High Voltage (V_{OH}) for P-Ports at Four Supply Voltages
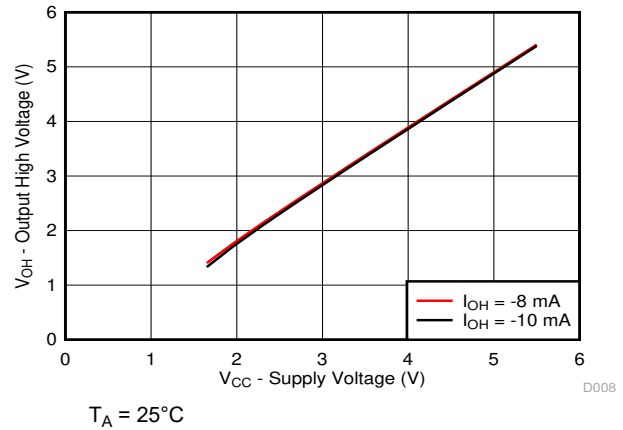
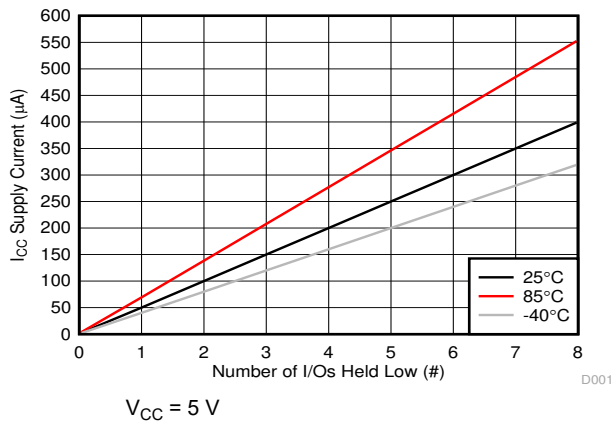图 6-8. Output High Voltage (V_{OH}) vs Supply Voltage (V_{CC}) for P-Ports

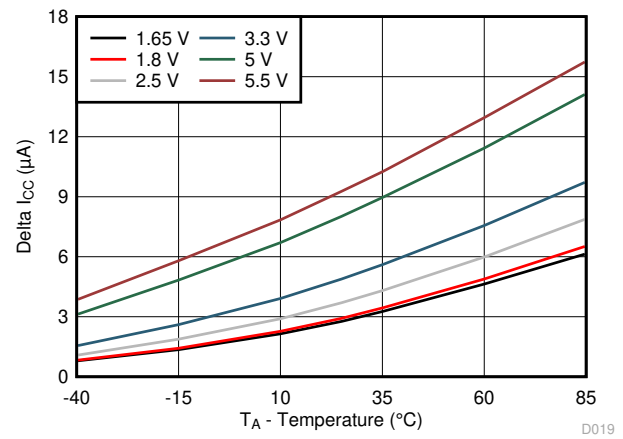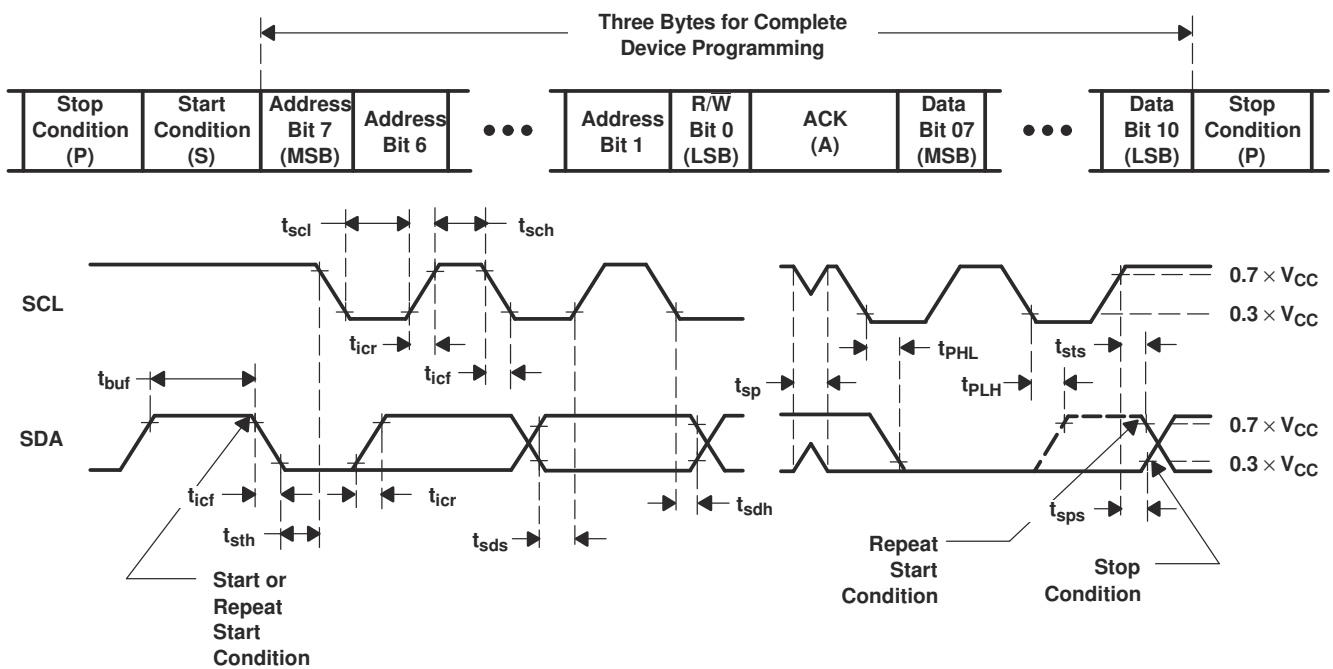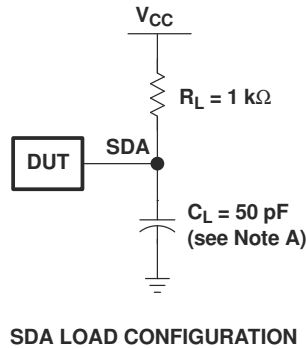图 6-9. Supply Current (I_{CC}) vs Number of I/Os Held Low (#)

图 6-10. Δ I_{CC} vs Temperature for Different V_{CC} (V_I = V_{CC} － 0.6 V)

Product Folder Links: *PCA9554*

7 Parameter Measurement Information

SDA LOAD CONFIGURATION

VOLTAGE WAVEFORMS

BYTE	DESCRIPTION
1	I^{2}C address
2, 3	P-port data

A. C_L includes probe and jig capacitance.

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

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

图 7-1. I^{2}C Interface Load Circuit And Voltage Waveforms
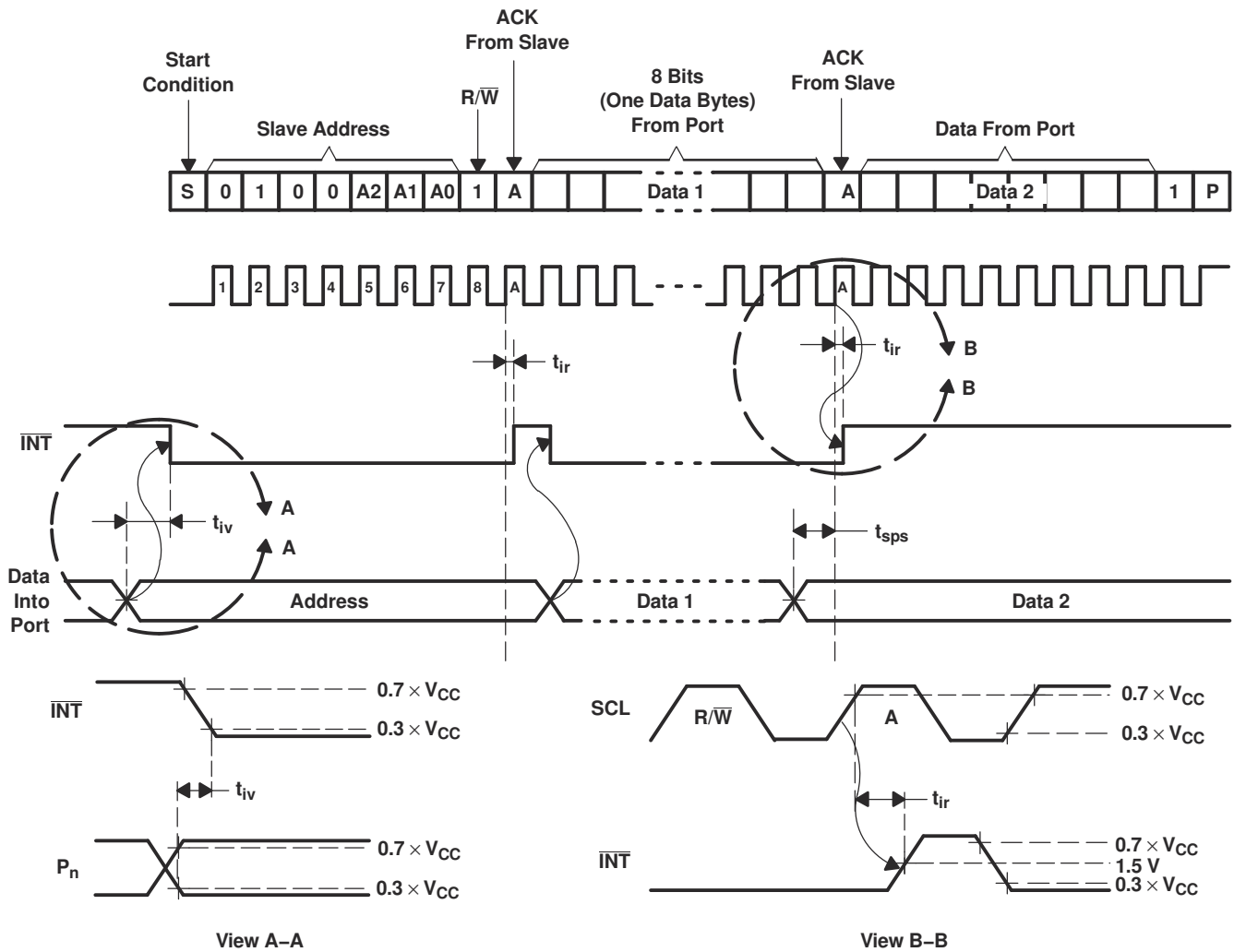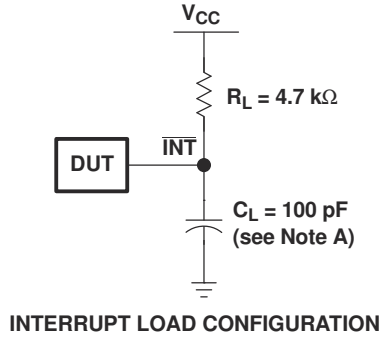
Product Folder Links: PCA9554

INTERRUPT LOAD CONFIGURATION

图 7-2. Interrupt Load Circuit And Voltage Waveforms
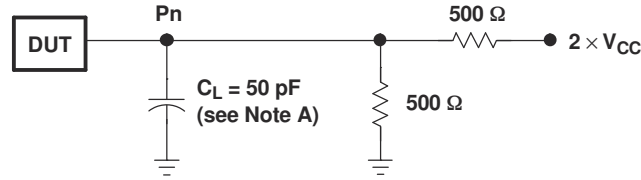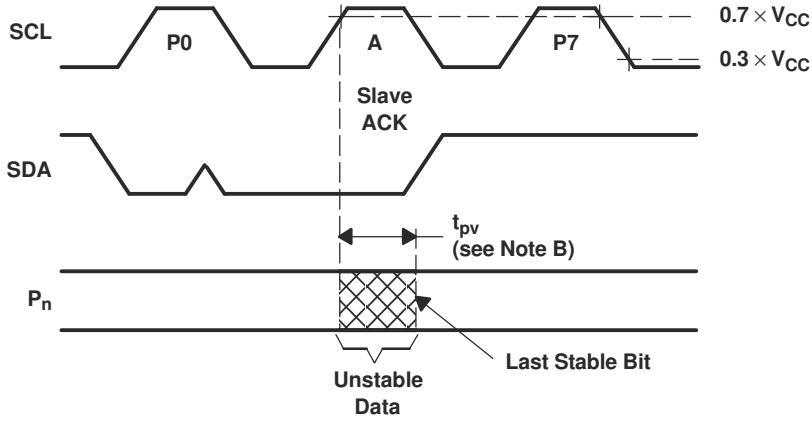
A. C_L includes probe and jig capacitance.

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

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

DUT Pn 500 Ω 2 × V$_{CC}$

C$_L$ = 50 pF
(see Note A)

500 Ω

P-PORT LOAD CONFIGURATION

SCL P0 A P7 0.7 × V$_{CC}$ 0.3 × V$_{CC}$

Slave
ACK

SDA

t$_{pv}$
(see Note B)

P$_n$

Last Stable Bit

Unstable
Data

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

SCL P0 A P7 0.7 × V$_{CC}$ 0.3 × V$_{CC}$

t$_{ps}$ t$_{ph}$

P$_n$ 0.7 × V$_{CC}$
1.5 V
0.3 × V$_{CC}$
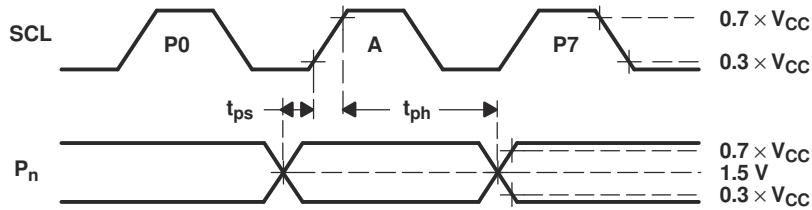
READ MODE (R/$\overline{W}$ = 1)

A. C$_L$ includes probe and jig capacitance.
B. t$_{pv}$ is measured from 0.7 × V$_{CC}$ on SCL to 50% I/O pin output.
C. All inputs are supplied by generators having the following characteristics: PRR ⩽ 10 MHz, Z$_O$ = 50 Ω, t$_r$/t$_f$ ⩽ 30 ns.
D. The outputs are measured one at a time, with one transition per measurement.
E. All parameters and waveforms are not applicable to all devices.

图 7-3. P-Port Load Circuit And Voltage Waveforms
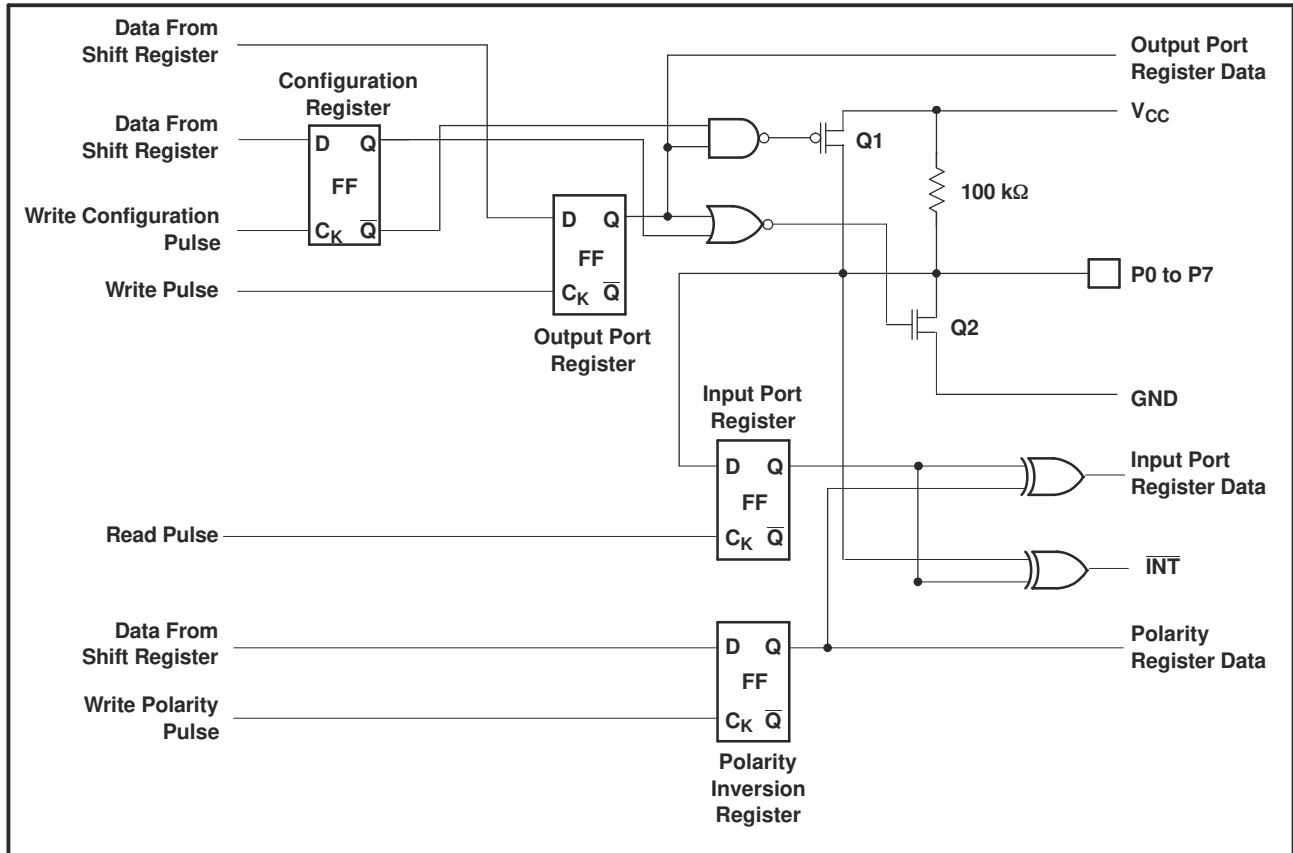
Product Folder Links: PCA9554

8 Detailed Description

8.1 Functional Block Diagram
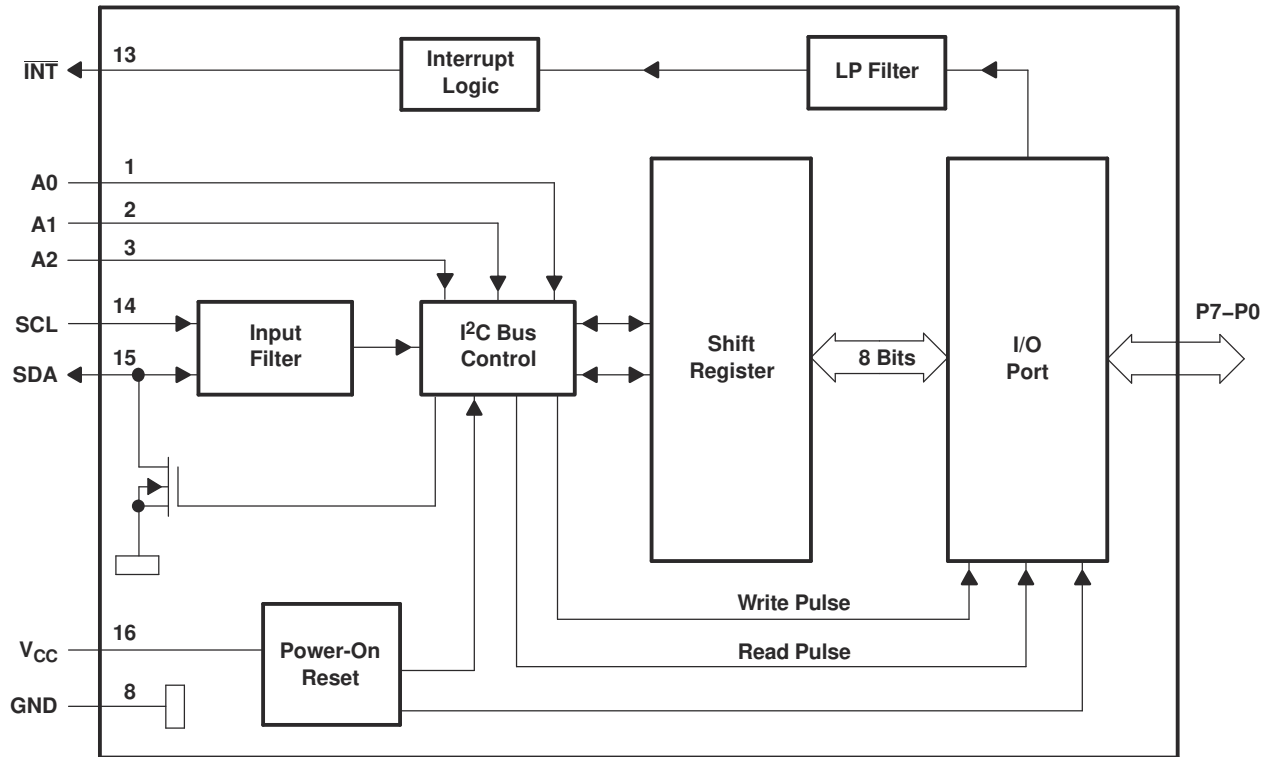
A.   Pin numbers shown are for the DB, DBQ, DGV, DW, N, or PW package.

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

图 **8-1. Logic Diagram**

Product Folder Links: *PCA9554*

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

图 8-2. Simplified Schematic Of P0 To P7

8.2 Device Functional Modes

8.2.1 Power-On Reset

When power (from 0 V) is applied to V_{CC}, an internal power-on reset holds the PCA9554 in a reset condition until V_{CC} has reached V_{POR}. At that point, the reset condition is released and the PCA9554 registers and I²C/SMBus state machine initialize to their default states. After that, V_{CC} must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

8.2.2 I/O Port

When an I/O is configured as an input, FETs Q1 and Q2 (in 图 8-2) are off, which creates a high-impedance input with a weak pullup (100 kΩ typ) to V_{CC}. The input voltage may be raised above V_{CC} to a maximum of 5.5 V.

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

8.2.3 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. Resetting occurs in the read mode at the acknowledge (ACK) or not acknowledge (NACK) bit after the rising edge of the SCL signal.

Interrupts that occur during the ACK or NACK clock pulse can be lost (or be very short) due to the resetting of the interrupt during this pulse. Each change of the I/Os after resetting is detected and is transmitted as $\overline{\text{INT}}$. Writing to another device does not affect the interrupt circuit, and a pin configured as an output cannot cause an interrupt. Changing an I/O from an output to an input may cause a false interrupt to occur, if the state of the pin does not match the contents of the Input Port register. Because each 8-pin port is read independently, the interrupt caused by port 0 is not cleared by a read of port 1 or vice versa.

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

8.2.3.1 Interrupt Errata

Description

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

1. The last I^{2}C command byte (register pointer) written to the device was 00h.

Note

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

---

2. Any other slave device on the I^{2}C bus acknowledges an address byte with the R/W bit set high

8.2.3.1.1

System Impact

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

8.2.3.1.2

System Workaround

Minor software change: User must change command byte to something besides 00h after a Read operation to the PCA9554 device or before reading from another slave device.

Note

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

8.3 Programming

8.3.1 I^{2}C Interface

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

I^{2}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 图 8-3). After the start condition, the device address byte is sent, MSB first, including the data direction bit (R/ $\overline{\text{W}}$).

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

On the I^{2}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 图 8-4).

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

Any number of data bytes can be transferred from the transmitter to the receiver between the start and the stop conditions. Each byte of eight bits is followed by one ACK bit. The transmitter must release the SDA line before the receiver can send an ACK bit. The device that acknowledges must pull down the SDA line during the ACK clock pulse so that the SDA line is stable low during the high pulse of the ACK-related clock period (see 图 8-5). When a slave receiver is addressed, it must generate an ACK after each byte is received. Similarly, the master must generate an ACK after each byte that it receives from the slave transmitter. Setup and hold times must be met to ensure proper operation.

A master receiver 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.
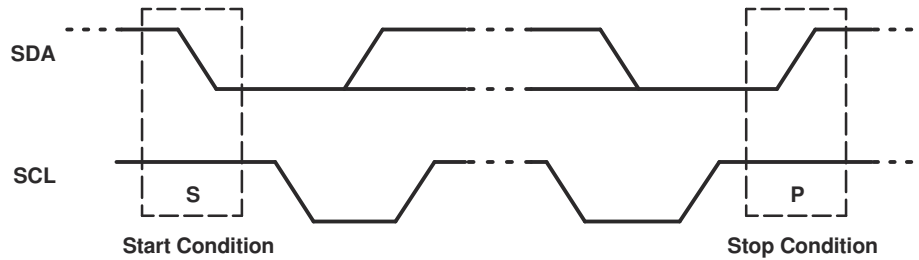
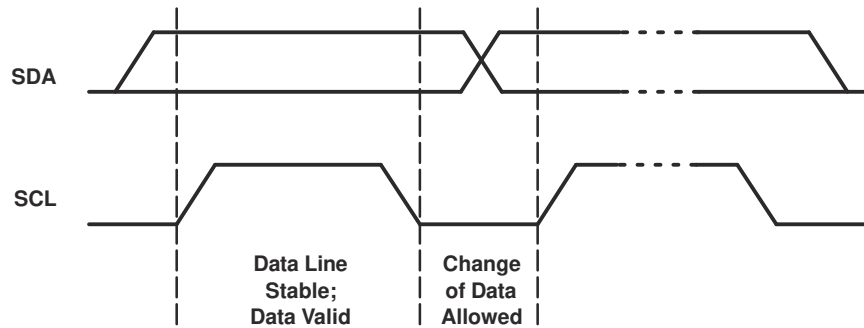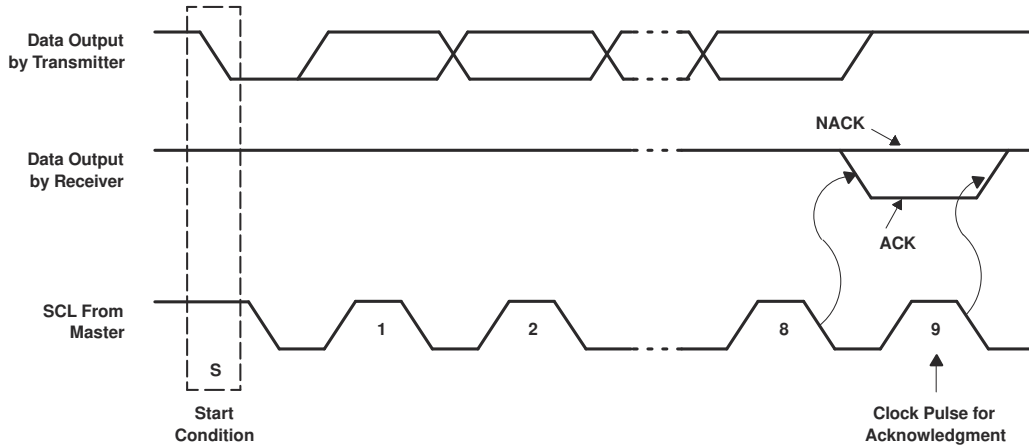**图 8-3. Definition Of Start And Stop Conditions**

图 8-4. Bit Transfer

图 8-5. Acknowledgment On The I^{2}C Bus

8.3.2 Register Map

表 8-1. Interface Definition

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

8.3.2.1 Device Address

图 8-6 shows the address byte for the PCA9554.
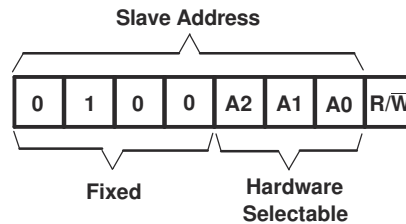
图 8-6. PCA9554 Address

表 8-2. Address Reference

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

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

8.3.2.2 Control Register And Command Byte

Following the successful acknowledgment of the address byte, the bus master sends a command byte that is stored in the control register in the PCA9554. 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^{2}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 readsuntil a new command byte has been sent.
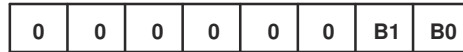
0	0	0	0	0	0	B1	B0

图 8-7. Control Register Bits

表 8-3. Command Byte

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

8.3.2.3 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^{2}C device that the Input Port register will be accessed next.

表 8-4. 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.

表 8-5. 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's original polarity is retained.

表 8-6. 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 high impedance output driver. If a bit in this register is cleared to 0, the corresponding port pin is enabled as an output.

表 8-7. Register 3 (Configuration Register) Table

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

8.3.2.4 Bus Transactions

Data is exchanged between the master and PCA9554 through write and read commands.

8.3.2.4.1 Writes

Data is transmitted to the PCA9554 by sending the device address and setting the least-significant bit to a logic 0 (see 图 8-6 for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte. There is no limitation on the number of data bytes sent in one write transmission.
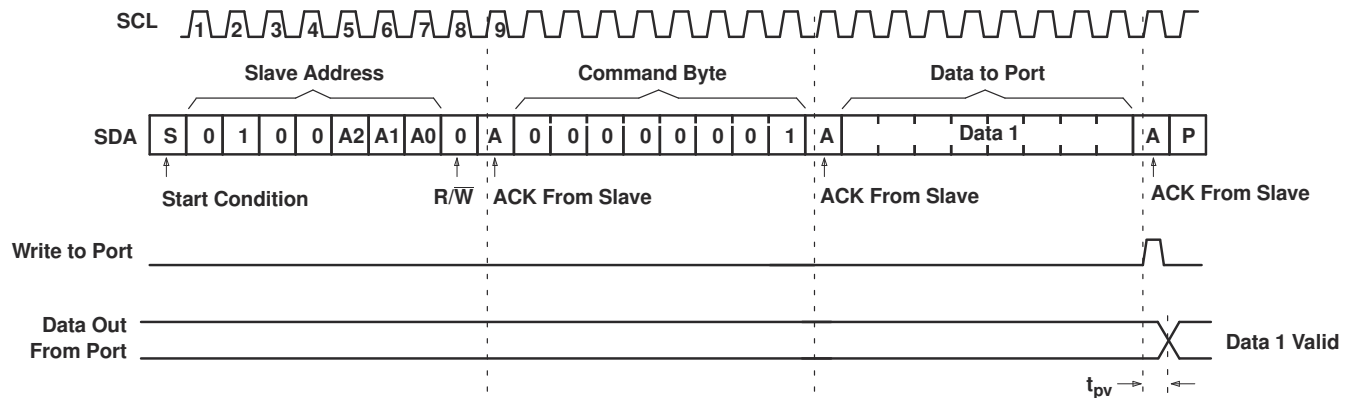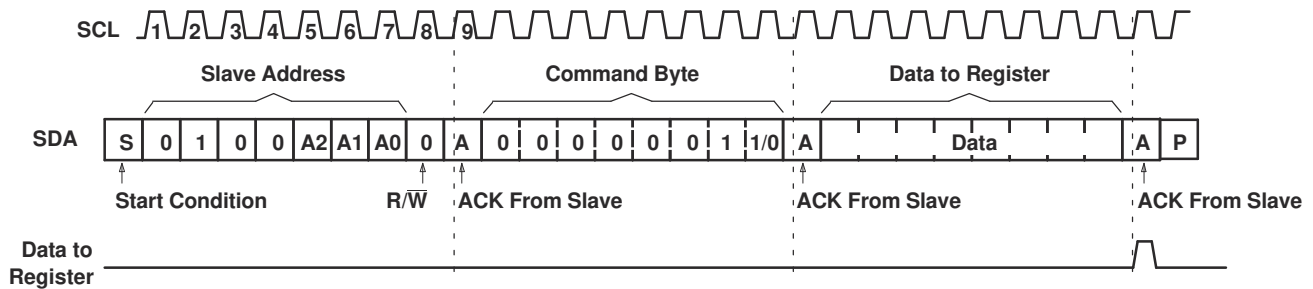

图 8-8. Write To Output Port Register

图 8-9. Write To Configuration Or Polarity Inversion Registers

8.3.2.4.2 Reads

The bus master first must send the PCA9554 address with the least-significant bit set to a logic 0 (see 图 8-6 for device address). The command byte is sent after the address and determines which register is accessed. After a restart, the device address is sent again but, this time, the least-significant bit is set to a logic 1. Data from the register defined by the command byte then is sent by the PCA9554 (see 图 8-10 and 图 8-11). After a restart, the value of the register defined by the command byte matches the register being accessed when the restart occurred. Data is clocked into the register on the rising edge of the ACK clock pulse. There is no limitation on the number of data bytes received in one read transmission, but when the final byte is received, the bus master must not acknowledge the data

Product Folder Links: *PCA9554*

图 8-10. Read From Register
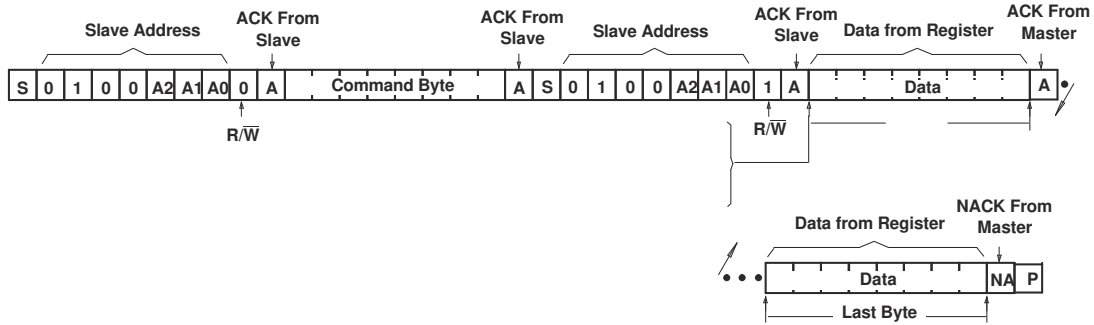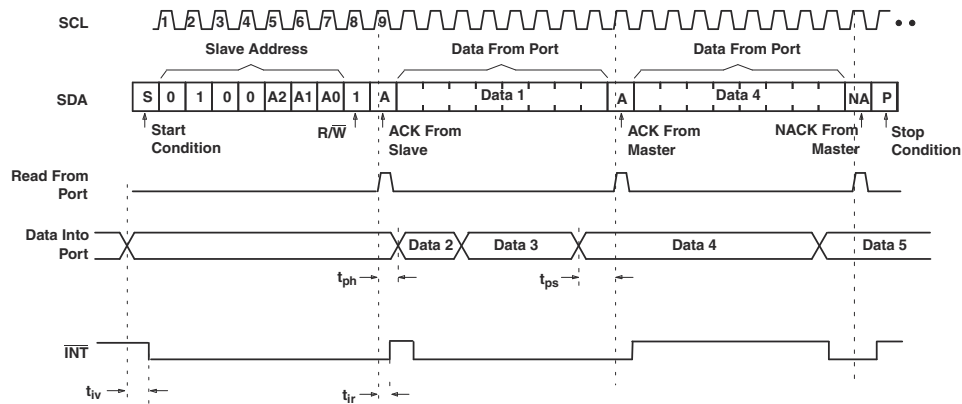

A. This figure assumes the command byte has previously been programmed with 00h.

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

C. This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from P port. See 图 8-10 for these details.

图 8-11. Read From Input Port Register

9 Application Information Disclaimer

Note

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

9.1 Application Information

9.1.1 Typical Application

图 9-1 shows an application in which the PCA9554 can be used.
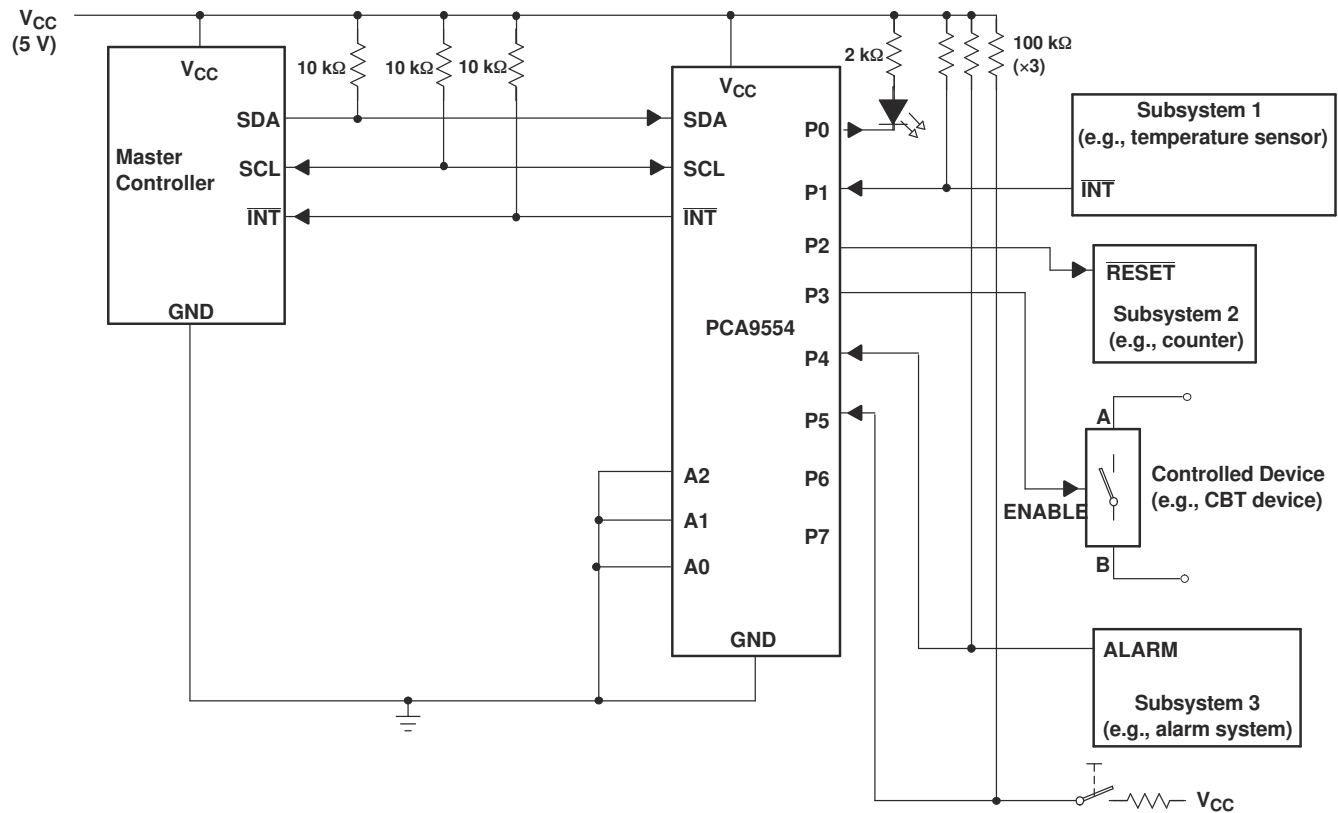
A.   Device address is configured as 0100000 for this example.

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

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

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

图 **9-1. Typical Application**

Product Folder Links: *PCA9554*

9.1.1.1 Design Requirements

9.1.1.1.1 Minimizing I_{CC} When I/Os Control Leds

When the I/Os are used to control LEDs, they are normally connected to V_{CC} through a resistor as shown in 图 9-1. 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}. $\triangle I_{CC}$ 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. 图 9-2 shows a high-value resistor in parallel with the LED. 图 9-3 shows V_{CC} less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V_{IN} at or above V_{CC} and prevent additional supply-current consumption when the LED is off.
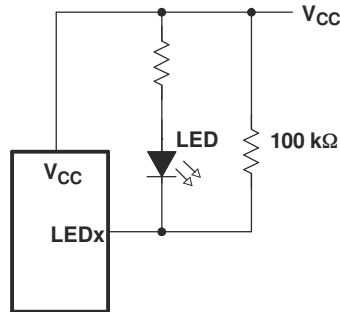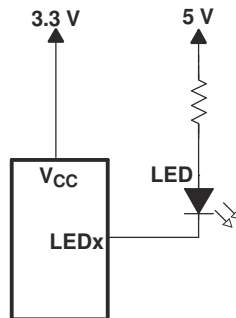

图 9-2. High-Value Resistor In Parallel With Led

图 9-3. Device Supplied By A Lower Voltage

Product Folder Links: *PCA9554*

10 Power Supply Recommendations

10.1 Power-On Reset Requirements

In the event of a glitch or data corruption, PCA9554 can be reset to its default conditions by using the power-on reset feature. Power-on reset requires that the device go through a power cycle to be completely reset. This reset also happens when the device is powered on for the first time in an application.

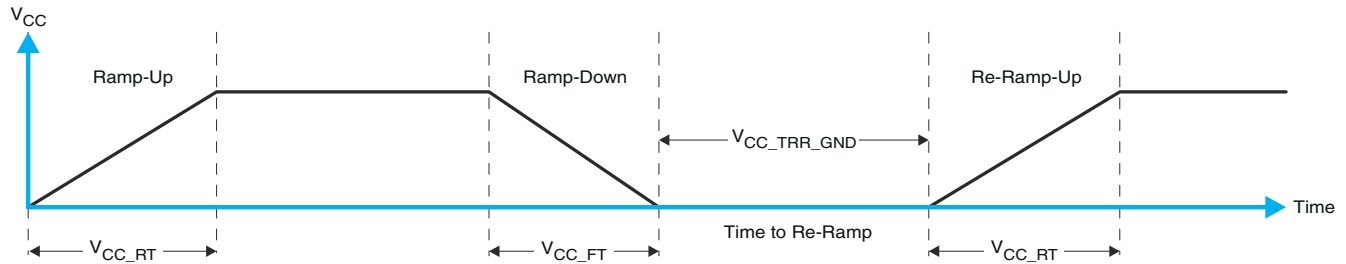The two types of power-on reset are shown in 图 10-1 and 图 10-2.

图 **10-1. V_{CC} Is Lowered Below 0.2 V Or 0 V And Then Ramped Up To V_{CC}**
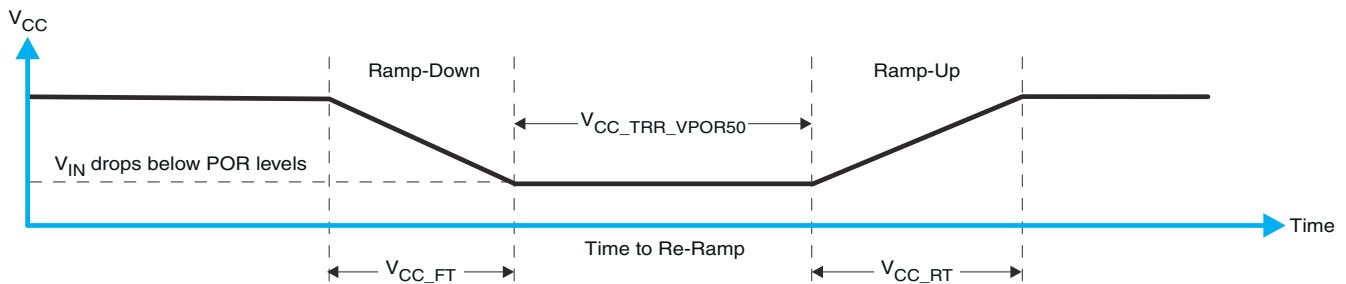
图 **10-2. V_{CC} Is Lowered Below The Por Threshold, Then Ramped Back Up To V_{CC}**

表 10-1 specifies the performance of the power-on reset feature for PCA9554 for both types of power-on reset.

表 **10-1. Recommended Supply Sequencing And Ramp Rates**[1]

PARAMETER			MIN	TYP	MAX	UNIT
V_{CC_FT}	Fall rate	See 图 10-1	1		100	ms
V_{CC_RT}	Rise rate	See 图 10-1	0.01		100	ms
$V_{CC\_TRR\_GND}$	Time to re-ramp (when V_{CC} drops to GND)	See 图 10-1	0.001			ms
$V_{CC\_TRR\_POR50}$	Time to re-ramp (when V_{CC} drops to V_{POR_MIN} – 50 mV)	See 图 10-2	0.001			ms
V_{CC_GH}	Level that V_{CCP} can glitch down to, but not cause a functional disruption when $V_{CCX\_GW} = 1 \mu s$	See 图 10-3			1.2	V
V_{CC_GW}	Glitch width that will not cause a functional disruption when $V_{CCX\_GH} = 0.5 \times V_{CCx}$	See 图 10-3				μs
V_{PORF}	Voltage trip point of POR on falling V_{CC}		0.767		1.144	V
V_{PORR}	Voltage trip point of POR on rising V_{CC}		1.033		1.428	V

(1) T_A = –40°C to 85°C (unless otherwise noted)

Glitches in the power supply can also affect the power-on reset performance of this device. The glitch width (V_{CC_GW}) and height (V_{CC_GH}) are dependent on each other. The bypass capacitance, source impedance, and the device impedance are factors that affect power-on reset performance. 图 10-3 and 表 10-1 provide more information on how to measure these specifications.

图 **10-3. Glitch Width And Glitch Height**

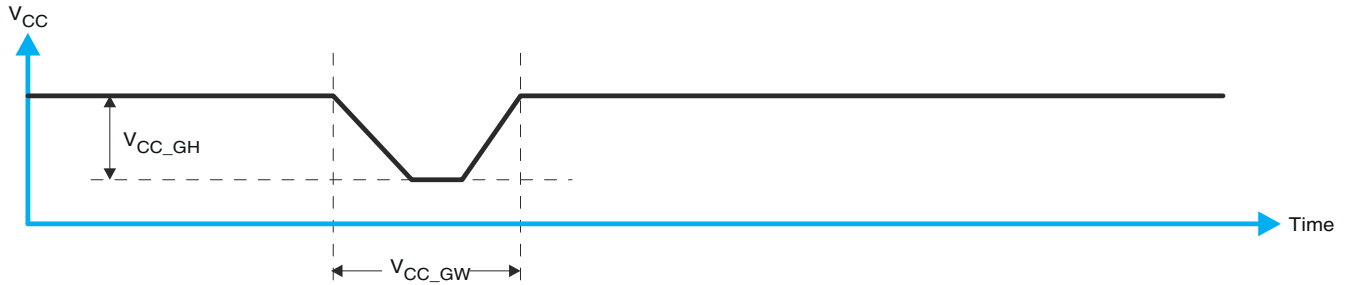V_{POR} is critical to the power-on reset. V_{POR} is the voltage level at which the reset condition is released and all the registers and the I²C/SMBus state machine are initialized to their default states. The value of V_{POR} differs based on the V_{CC} being lowered to or from 0. 图 10-4 and 表 10-1 provide more details on this specification.
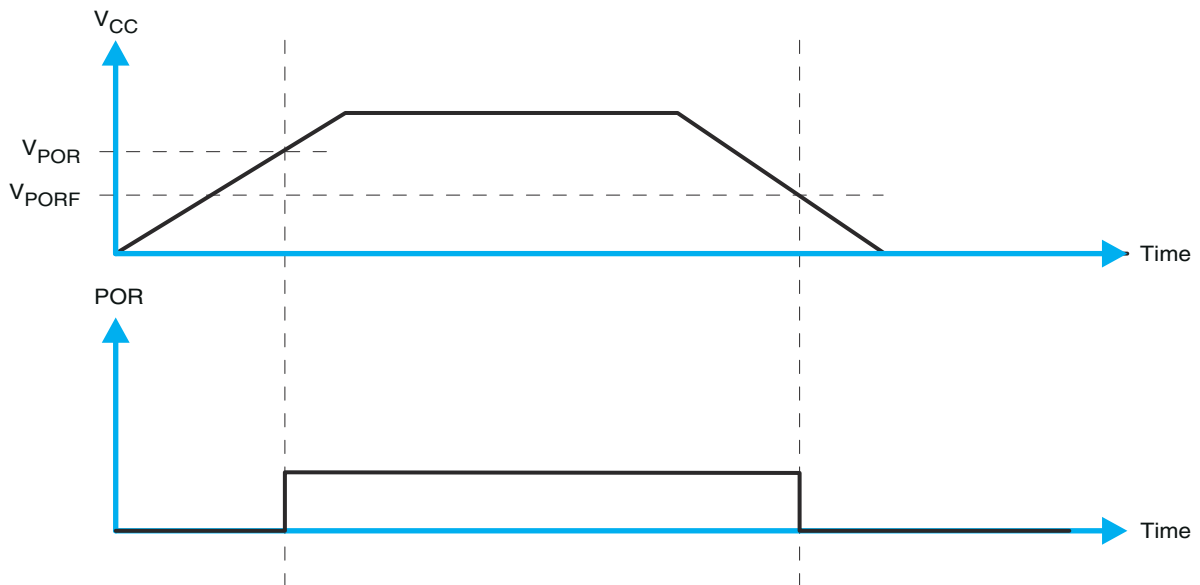

图 **10-4. V_{POR}**

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

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

11.2 Support Resources

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

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11.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

11.4 Electrostatic Discharge Caution

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

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

11.5 Glossary

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

12 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PCA9554DB	LIFEBUY	SSOP	DB	16	80	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD554	
PCA9554DBR	ACTIVE	SSOP	DB	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD554	Samples
PCA9554DGVR	LIFEBUY	TVSOP	DGV	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD554	
PCA9554DW	LIFEBUY	SOIC	DW	16	40	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9554	
PCA9554DWR	ACTIVE	SOIC	DW	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PCA9554	Samples
PCA9554PWR	ACTIVE	TSSOP	PW	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	PD554	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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TAPE AND REEL INFORMATION

REEL DIMENSIONS

Reel Diameter

Reel Width (W1)

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

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

Sprocket Holes

User Direction of Feed

Pocket Quadrants

*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
PCA9554DBR	SSOP	DB	16	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
PCA9554DGVR	TVSOP	DGV	16	2000	330.0	12.4	6.8	4.0	1.6	8.0	12.0	Q1
PCA9554DWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1
PCA9554PWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
PCA9554PWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

PACKAGE MATERIALS INFORMATION

TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCA9554DBR	SSOP	DB	16	2000	356.0	356.0	35.0
PCA9554DGVR	TVSOP	DGV	16	2000	356.0	356.0	35.0
PCA9554DWR	SOIC	DW	16	2000	350.0	350.0	43.0
PCA9554PWR	TSSOP	PW	16	2000	367.0	367.0	35.0
PCA9554PWR	TSSOP	PW	16	2000	356.0	356.0	35.0

![Texas Instruments logo] **PACKAGE MATERIALS INFORMATION**

TUBE

*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
PCA9554DB	DB	SSOP	16	80	530	10.5	4000	4.1
PCA9554DW	DW	SOIC	16	40	506.98	12.7	4826	6.6

4220204/A   02/2017

NOTES:

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

16X (1.5)

SYMM

(R0.05) TYP

1

16X (0.45)

16

SYMM

14X (0.65)

8

9

(5.8)

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

SOLDER MASK OPENING

METAL

EXPOSED METAL

0.05 MAX
ALL AROUND

NON-SOLDER MASK
DEFINED
(PREFERRED)

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

EXPOSED METAL

0.05 MIN
ALL AROUND

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4220204/A   02/2017

NOTES: (continued)

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

16X (1.5)

SYMM

1

16X (0.45)

(R0.05) TYP

16

SYMM

14X (0.65)

8

9

(5.8)

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

4220204/A   02/2017

NOTES: (continued)

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

8.2
7.4 TYP

A

PIN 1 INDEX AREA

14X 0.65

16

1

6.5
5.9
NOTE 3

2X
4.55

8

9

16X 0.38
0.22

B

5.6
5.0
NOTE 4

⊕ 0.1Ⓜ C A B

C

⌒ 0.1 C

SEATING PLANE

0.25
0.09

SEE DETAIL A

0.25
GAGE PLANE

2 MAX

0.05 MIN

0°-8°

0.95
0.55

DETAIL A
TYPICAL

4220763/A   05/2022

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-150.

16X (1.85)

1

16X (0.45)

14X (0.65)

8

SYMM

(R0.05) TYP

16

SYMM

9

(7)

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

SOLDER MASK
OPENING

METAL

EXPOSED METAL

0.05 MAX
ALL AROUND

NON-SOLDER MASK
DEFINED
(PREFERRED)

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

EXPOSED METAL

0.05 MIN
ALL AROUND

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4220763/A   05/2022

NOTES: (continued)

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

16X (1.85)

SYMM

1

16X (0.45)

(R0.05) TYP

16

SYMM

14X (0.65)

8

9

(7)

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

4220763/A   05/2022

NOTES: (continued)

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

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

4224780/A

14X 1.27

2X 8.89

10.63 / 9.97 TYP

10.5 / 10.1 NOTE 3

7.6 / 7.4 NOTE 4

16X 0.51 / 0.31

⊕ 0.25Ⓜ C A B

PIN 1 ID AREA

A

B

1

8

16

9

SEATING PLANE

C

◠ 0.1 C

2.65 MAX

SEE DETAIL A

0.33 / 0.10 TYP

GAGE PLANE

0.25

0° - 8°

1.27 / 0.40

(1.4)

0.3 / 0.1

DETAIL A
TYPICAL

4220721/A 07/2016

NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.
5. Reference JEDEC registration MS-013.

16X (2)

SYMM

SEE
DETAILS

1

16

16X (0.6)

SYMM

14X (1.27)

8

9

R0.05 TYP

(9.3)

LAND PATTERN EXAMPLE
SCALE:7X

METAL

SOLDER MASK
OPENING

SOLDER MASK
OPENING

METAL

0.07 MAX
ALL AROUND

0.07 MIN
ALL AROUND

NON SOLDER MASK
DEFINED

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4220721/A   07/2016

NOTES: (continued)

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

16X (2)

1

16

16X (0.6)

SYMM

SYMM

14X (1.27)

8

9

R0.05 TYP

(9.3)

SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:7X

4220721/A   07/2016

NOTES: (continued)

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