

SCPS124F - SEPTEMBER 2006-REVISED JUNE 2010

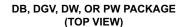
REMOTE 8-BIT I²C AND SMBus LOW-POWER I/O EXPANDER WITH INTERRUPT OUTPUT AND CONFIGURATION REGISTERS

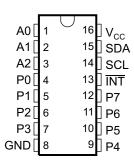
Check for Samples: PCA9534

FEATURES

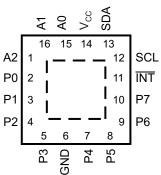
- Low Standby Current Consumption of 1 μA Max
- I²C to Parallel Port Expander
- Open-Drain Active-Low Interrupt Output
- Operating Power-Supply Voltage Range of 2.3 V to 5.5 V
- 5-V Tolerant I/O Ports
- 400-kHz Fast I²C Bus
- Three Hardware Address Pins Allow up to Eight Devices on the I²C/SMBus
- Allows Up to 16 Devices on the I²C/SMBus When Used in Conjunction with the PCA9534A See Table 1 for I²C Expander offerings
- Input/Output Configuration Register

- Polarity Inversion Register
- Internal Power-On Reset
- Power-Up With All Channels Configured as Inputs
- No Glitch on Power Up
- Noise Filter on SCL/SDA Inputs
- Latched Outputs With High-Current Drive Maximum Capability for Directly Driving LEDs
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Protection Exceeds JESD 22
 - 2000-V Human-Body Model (A114-A)
 - 200-V Machine Model (A115-A)
 - 1000-V Charged-Device Model (C101)

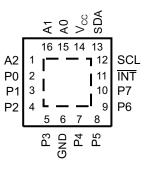




RGV PACKAGE (TOP VIEW)



RGT PACKAGE (TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

This 8-bit I/O expander for the two-line bidirectional bus (I^2C) is designed for 2.3-V to 5.5-V V_{CC} operation. It provides general-purpose remote I/O expansion for most microcontroller families via the I^2C interface [serial clock (SCL), serial data (SDA)].

The PCA9534 consists of one 8-bit Configuration (input or output selection), Input Port, Output Port, and Polarity Inversion (active high or active low) register. At power on, the I/Os are configured as inputs. However, the system master can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input or Output register. The polarity of the Input Port register can be inverted with the Polarity Inversion register. All registers can be read by the system master.

The system master can reset the PCA9534 in the event of a timeout or other improper operation by utilizing the power-on reset feature, which puts the registers in their default state and initializes the I²C/SMBus state machine.

The PCA9534 open-drain interrupt (INT) output is activated when any input state differs from its corresponding input port register state and is used to indicate to the system master that an input state has changed.



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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 I²C bus. Thus, the PCA9534 can remain a simple slave device.

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

Three hardware pins (A0, A1, and A2) are used to program and vary the fixed I²C address and allow up to eight devices to share the same I²C bus or SMBus.

The PCA9534 is pin-to-pin and I²C address compatible with the PCF8574. However, software changes are required due to the enhancements in the PCA9534 over the PCF8574.

The PCA9534 is a low-power version of the PCA9554. The only difference between the PCA9534 and PCA9554 is that the PCA9534 eliminates an internal I/O pullup resistor, which dramatically reduces power consumption in the standby mode when the I/Os are held low.

The PCA9534A and PCA9534 are identical, except for their fixed I²C address. This allows for up to 16 of these devices (8 of each) on the same I²C bus.

ORDERING INFORMATION

T _A	PA	CKAGE ^{(1) (2)}	ORDERABLE PART NUMBER	TOP-SIDE MARKING
	QFN – RGT	Reel of 3000	PCA9534RGTR	PREVIEW
	QFN – RGV	Reel of 2500	PCA9534RGVR	PD534
	SOIC - DW	Tube of 40	PCA9534DW	DCA0524
	301C - DW	Reel of 2000	PCA9534DWR	PCA9534
-40°C to 85°C	SSOP – DB	Reel of 2000	PCA9534DBR	PD534
	330P - DB	Tube of 80	PCA9534DBT	PD534
	TCCOD DW	Tube of 90	PCA9534PW	DDC04
	TSSOP – PW	Reel of 2000	PCA9534PWR	PD534
	TVSOP - DGV	Reel of 2000	PCA9534DGVR	PD534

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

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

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Table 1. I²C Expander Offerings

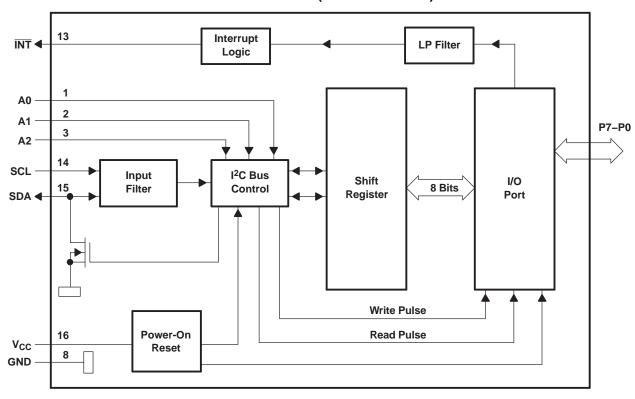
DEVICE	MAX FREQUENCY	I ² C ADDRESS	V _{CC} RANGE	NO. OF GPIOs	INTERRUPT OUTPUT	RESET	CONFIGURATION REGISTERS	5-V TOLERANT	PUSH-PULL I/O TYPE	OPEN-DRAIN I/O TYPE	COMMENT
TCA6408	400	0100 00x	1.65 to 5.5	8	Yes	Yes	Yes	Yes	Yes	No	Power on reset, $t_{\rm f}$ (fall time) > 100 ms and $t_{\rm r}$ (ramp time) < 10 ms
TCA6408	400	0100 00x	1.65 to 5.5	8	Yes	Yes	Yes	Yes	Yes	No	Unrestricted power on reset ramp/fall time. Both t _r (fall time) and TRT (ramp time) can be between 0.1 ms and 2000 ms
TCA6416	400	0100 00x	1.65 to 5.5	16	Yes	Yes	Yes	Yes	Yes	No	Power on reset, t _f (fall time) > 100 ms and TRT (ramp time) < 10 ms
TCA6416A	400	0100 00x	1.65 to 5.5	16	Yes	Yes	Yes	Yes	Yes	No	Unrestricted power on reset ramp/fall time. Both t _r (fall time) and TRT (ramp time) can be between 0.1 ms and 2000ms
TCA6424	400	0100 00x	1.65 to 5.5	24	Yes	Yes	Yes	Yes	Yes	No	Power on reset, t _f (fall time) > 100 ms and TRT (ramp time) < 10 ms
TCA9535	400	0100 xxx	1.65 to 5.5	16	Yes	No	Yes	Yes	Yes	No	
TCA9539	400	1110 1xx	1.65 to 5.5	16	Yes	Yes	Yes	Yes	Yes	No	
TCA9555	400	0100 xxx	1.65 to 5.5	16	Yes	No	Yes	Yes	Yes	No	
PCA6107	400	0011 xxx	2.3 to 5.5	8	Yes	Yes	Yes	Yes	Yes P1—P7 bits	Yes P0 bit	One open drain output; eight push pull outputs
PCA9534	400	0100 xxx	2.3 to 5.5	8	Yes	No	Yes	Yes	Yes	No	PCA9534 has a different slave address as the PCA9534A, allowing up to 16 devices '9534 type devices on the same I ² C bus
PCA9534A	400	0111 xxx	2.3 to 5.5	8	Yes	No	Yes	Yes	Yes	No	PCA9534A has a different slave address as the PCA9534, allowing up to 16 devices '9534 type devices on the same I ² C bus
PCA9535	400	0100 xxx	2.3 to 5.5	16	Yes	No	Yes	Yes	Yes	No	
PCA9536	400	1000 001	2.3 to 5.5	4	No	No	Yes	Yes	Yes	No	
PCA9538	400	1110 0xx	2.3 to 5.5	8	Yes	Yes	Yes	Yes	Yes	No	
PCA9539	400	1110 1xx	2.3 to 5.5	16	Yes	Yes	Yes	Yes	Yes	No	
PCA9554	400	0100 xxx	2.3 to 5.5	8	Yes	No	Yes	Yes	Yes	No	
PCA9554A	400	0111 xxx	2.3 to 5.5	8	Yes	No	Yes	Yes	Yes	No	
PCA9555	400	0100 xxx	2.3 to 5.5	16	Yes	No	Yes	Yes	Yes	No	
PCA9557	400	0011 xxx	2.3 to 5.5	8	No	Yes	Yes	Yes	Yes	Yes	
PCF8574	400	0100 xxx	2.5 to 6.0	8	Yes	No	No	Yes	Yes	No	PCA8574 has a different slave address as the PCA8574A, allowing up to 16 devices '9534 type devices on the same I²C bus
PCF8574A	400	0111 xxx	2.5 to 6.0	8	Yes	No	No	Yes	Yes	No	PCA8574A has a different slave address as the PCA8574, allowing up to 16 devices '9534 type devices on the same I ² C bus
PCF8575	400	0100 xxx	2.5 to 5.5	16	Yes	No	No	Yes	Yes	No	
PCF8575C	400	0100 xxx	4.5 to 5.5	16	Yes	No	No	Yes	No	Yes	



Table 2. TERMINAL FUNCTIONS

NO			
SOIC (DW), SSOP (DB), TSSOP (PW), AND TVSOP (DGV)	QFN (RGT AND RGV)	NAME	DESCRIPTION
1	15	A0	Address input. Connect directly to V _{CC} or ground.
2	16	A1	Address input. Connect directly to V _{CC} or ground.
3	1	A2	Address input. Connect directly to V _{CC} or ground.
4	2	P0	P-port input/output. Push-pull design structure.
5	3	P1	P-port input/output. Push-pull design structure.
6	4	P2	P-port input/output. Push-pull design structure.
7	5	P3	P-port input/output. Push-pull design structure.
8	6	GND	Ground
9	7	P4	P-port input/output. Push-pull design structure.
10	8	P5	P-port input/output. Push-pull design structure.
11	9	P6	P-port input/output. Push-pull design structure.
12	10	P7	P-port input/output. Push-pull design structure.
13	11	ĪNT	Interrupt output. Connect to V _{CC} through a pullup resistor.
14	12	SCL	Serial clock bus. Connect to V _{CC} through a pullup resistor.
15	13	SDA	Serial data bus. Connect to V _{CC} through a pullup resistor.
16	14	V _{CC}	Supply voltage

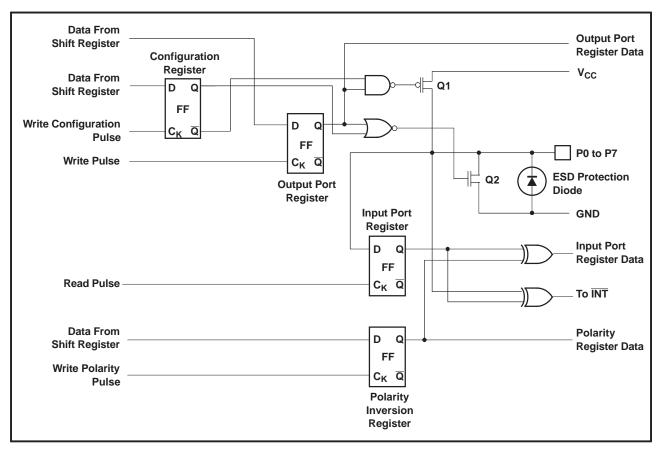
LOGIC DIAGRAM (POSITIVE LOGIC)



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



SIMPLIFIED SCHEMATIC OF P0 TO P7



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

I/O Port

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

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

I²C Interface

The bidirectional I²C 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.

I²C communication with this device is initiated by a master sending a Start condition, a high-to-low transition on the SDA input/output while the SCL input is high (see Figure 1). After the Start condition, the device address byte is sent, most significant bit (MSB) first, including the data direction bit (R/W).

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

On the I²C bus, only one data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the high pulse of the clock period, as changes in the data line at this time are interpreted as control commands (Start or Stop) (see Figure 2).



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

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

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

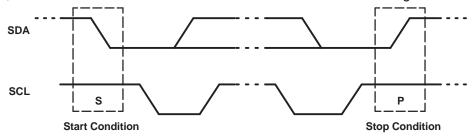


Figure 1. Definition of Start and Stop Conditions

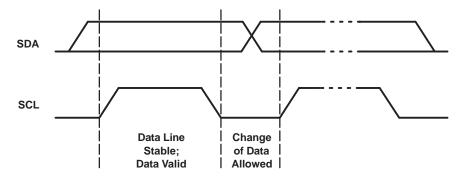


Figure 2. Bit Transfer

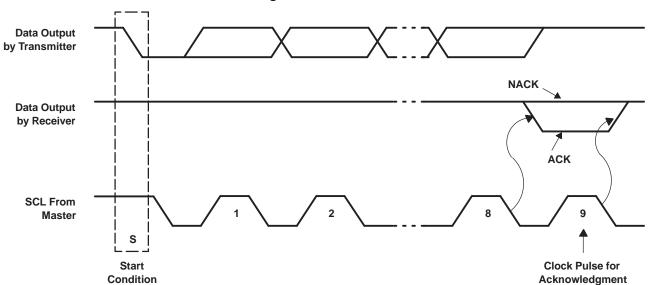


Figure 3. Acknowledgment on I²C Bus



Table 3. Interface Definition

вуте	BIT									
	7 (MSB)	6	5	4	3	2	1	0 (LSB)		
I ² C slave address	L	Н	L	L	A2	A1	A0	R/W		
Px I/O data bus	P7	P6	P5	P4	P3	P2	P1	P0		

Device Address

Figure 4 shows the address byte of the PCA9534.

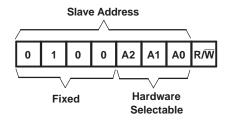


Figure 4. PCA9534 Address

Table 4. Address Reference

	INPUTS		I ² C BUS SLAVE ADDRESS
A2	A1	A0	I-C BUS SLAVE ADDRESS
L	L	L	32 (decimal), 20 (hexadecimal)
L	L	Н	33 (decimal), 21 (hexadecimal)
L	Н	L	34 (decimal), 22 (hexadecimal)
L	Н	Н	35 (decimal), 23 (hexadecimal)
Н	L	L	36 (decimal), 24 (hexadecimal)
Н	L	Н	37 (decimal), 25 (hexadecimal)
Н	Н	L	38 (decimal), 26 (hexadecimal)
Н	Н	Н	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.

Control Register and Command Byte

Following the successful acknowledgment of the address byte, the bus master sends a command byte, which is stored in the control register in the PCA9534. 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 I²C bus. The command byte is sent only during a write transmission.

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

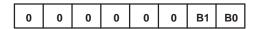


Figure 5. Control Register Bits

Table 5. Command Byte

	TROL ER BITS	COMMAND REGISTER		PROTOCOL	POWER-UP DEFAULT	
B1	В0	DITE (HEX)			DEFAULT	
0	0	0x00	Input Port	Read byte	XXXX XXXX	

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Table 5. Command Byte (continued)

	TROL ER BITS	COMMAND BYTE (HEX)	REGISTER	PROTOCOL	POWER-UP DEFAULT	
B1	В0	DITE (HEX)			DEFAULT	
0	1	0x01	Output Port	Read/write byte	1111 1111	
1	0	0x02	Polarity Inversion	Read/write byte	0000 0000	
1	1	0x03	Configuration	Read/write byte	1111 1111	

Register Descriptions

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

Before a read operation, a write transmission is sent with the command byte to let the I²C device know that the Input Port register will be accessed next.

Table 6. Register 0 (Input Port Register)

BIT	17	16	15	14	13	12	I1	10
DEFAULT	Х	Х	Х	Х	Х	Х	Х	Х

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.

Table 7. Register 1 (Output Port Register)

BIT	07	O6	O5	O4	О3	O2	O1	O0
DEFAULT	1	1	1	1	1	1	1	1

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

Table 8. Register 2 (Polarity Inversion Register)

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.

Table 9. Register 3 (Configuration Register)

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

Power-On Reset

When power (from 0 V) is applied to V_{CC} , an internal power-on reset holds the PCA9534 in a reset condition until V_{CC} has reached V_{POR} . At that point, the reset condition is released and the PCA9534 registers and $I^2C/SMBus$ state machine will initialize to their default states. After that, V_{CC} must be lowered to below 0.2 V and then back up to the operating voltage for a power-reset cycle.

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Interrupt Output (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 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 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} .

Bus Transactions

Data is exchanged between the master and PCA9534 through write and read commands.

Writes

Data is transmitted to the PCA9534 by sending the device address and setting the least significant bit (LSB) to a logic 0 (see Figure 4 for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte (see Figure 6 and Figure 7). There is no limitation on the number of data bytes sent in one write transmission.

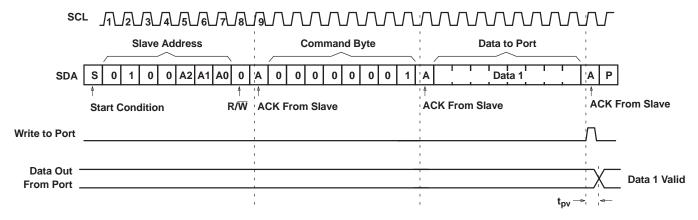


Figure 6. Write to Output Port Register

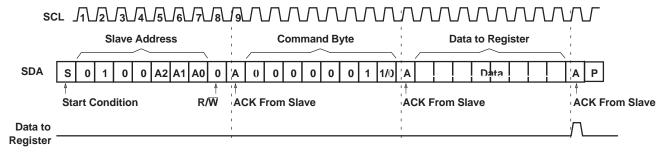


Figure 7. Write to Configuration or Polarity Inversion Registers



Reads

The bus master first must send the PCA9534 address with the LSB set to a logic 0 (see Figure 4 for device address). The command byte is sent after the address and determines which register is accessed. After a restart, the device address is sent again but, this time, the LSB is set to a logic 1. Data from the register defined by the command byte then is sent by the PCA9534 (see Figure 8 and Figure 9). After a restart, the value of the register defined by the command byte matches the register being accessed when the restart occurred. Data is clocked into the register on the rising edge of the ACK clock pulse. There is no limitation on the number of data bytes received in one read transmission, but when the final byte is received, the bus master must not acknowledge the data.

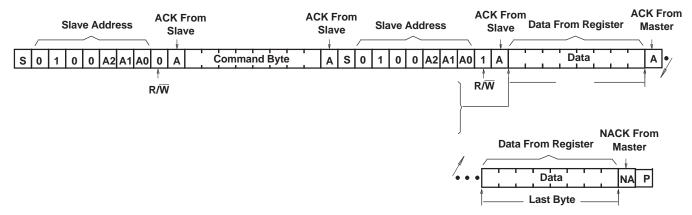
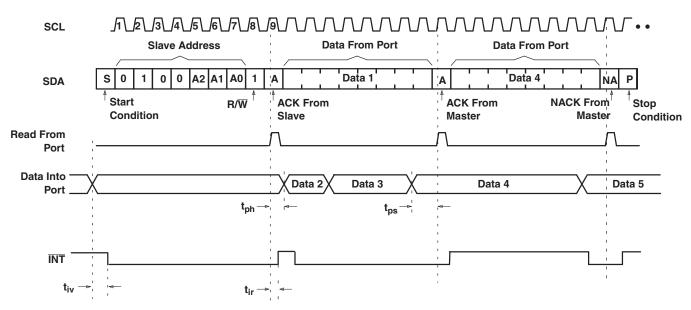


Figure 8. Read From Register



- A. This figure assumes that 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 the actual data transfer from the P Port. See Figure 8 for these details.

Figure 9. Read Input Port Register



ABSOLUTE MAXIMUM RATINGS(1)

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

			MIN	MAX	UNIT
V _{CC}	Supply voltage range		-0.5	6	V
VI	Input voltage range ⁽²⁾		-0.5	6	V
Vo	Output voltage range ⁽²⁾		-0.5	6	V
I _{IK}	Input clamp current	V _I < 0		-20	mA
lok	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
_	Continuous current through GND			-250	m ^
I _{CC}	Continuous current through V _{CC}			160	mA
	•	DB package		82	
		DGV package		86	
0	Declare the weed instead on a (3)	DW package		46	00/14/
θ_{JA}	Package thermal impedance	PW package		88	°C/W
		RGT package		TBD	
		RGV package	51		
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.

RECOMMENDED OPERATING CONDITIONS

			MIN	MAX	UNIT	
V_{CC}	Supply voltage	2.3	5.5	V		
V _{IH}	High lovel input voltage	SCL, SDA	0.7 × V _{CC}	5.5	V	
	High-level input voltage	A0, A1, A2, P7-P0	2	5.5	V	
V	Land land Carrett and Carre	SCL, SDA	-0.5	$0.3 \times V_{CC}$	V	
V_{IL}	Low-level input voltage	A0, A1, A2, P7-P0	-0.5	0.8	V	
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	

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 ⁽²⁾ The input negative-voltage and output voltage ratings may be exceeded in the
 (3) The package thermal impedance is calculated in accordance with JESD 51-7. The input negative-voltage and output voltage ratings may be exceeded if the input and output current ratings are observed.



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 _{POR}	Power-on reset voltage	$V_I = V_{CC}$ or GND, $I_O = 0$	V _{POR}		1.5	1.65	V
			2.3 V	1.8			
		0.554	3 V	2.6			
	2)	$I_{OH} = -8 \text{ mA}$	4.5 V	4.1			
			4.75 V	4.1			
VoH	P-port high-level output voltage ⁽²⁾		2.3 V	1.7			V
			3 V	2.5			
		$I_{OH} = -10 \text{ mA}$	4.5 V	4			
			4.75 V	4			
	SDA	V _{OL} = 0.4 V	2.3 V to 5.5 V	3	8		
			2.3 V	8	10		
			3 V	8	14		
		V _{OL} = 0.5 V	4.5 V	8	17		
	(0)		4.75 V	8	35		
OL	P port ⁽³⁾		2.3 V	10	13		mA
			3 V	10	19		
		$V_{OL} = 0.7 V$	4.5 V	10	24		
			4.75 V	10	45		
		V _{OL} = 0.4 V	2.3 V to 5.5 V	3	10		
	SCL, SDA					±1	
ı	A0, A1, A2	$V_I = V_{CC}$ or GND	2.3 V to 5.5 V			±1	μΑ
Ін	P port	$V_{I} = V_{CC}$	2.3 V to 5.5 V			1	μА
IL	P port	$V_1 = GND$	2.3 V to 5.5 V			-1	μА
IL.	. pon	11 3.12	5.5 V		104	175	μ, ,
		$V_I = V_{CC}$ or GND, $I_O = 0$,	3.6 V		50	90	
		$I/O = inputs, f_{scl} = 400 \text{ kHz}$	2.7 V		20	65	
	Operating mode		5.5 V		60	150	
CC		$V_1 = V_{CC}$ or GND, $I_0 = 0$, $I/O = inputs$, $f_{scl} = 100 \text{ kHz}$	3.6 V		15	40	μА
CC		I/O = inputs, f _{scl} = 100 kHz	2.7 V		8	20	μι
			5.5 V		0.25	1	
	Standby mode	$V_I = GND$, $I_O = 0$,	3.6 V		0.23	0.9	
	Ctanaby mode	$I/O = inputs, f_{scl} = 0 \text{ kHz}$	2.7 V		0.2	0.8	
	Additional current in standby	One input at V _{CC} - 0.6 V, Other inputs at V _{CC} or GND	2.3 V to 5.5 V		0.1	1.5	
∆I _{CC} Mode	Additional current in standby mode	All LED I/Os at $V_I = 4.3 \text{ V}$, $f_{scl} = 0 \text{ kHz}$	5.5 V			1	mA
C _i	SCL	$V_I = V_{CC}$ or GND	2.3 V to 5.5 V		4	5	pF
	SDA				5.5	6.5	r- ·
C_{io}	P port	$V_{IO} = V_{CC}$ or GND	2.3 V to 5.5 V		8	9.5	pF

All typical values are at nominal supply voltage (2.5-V, 3.3-V, or 5-V V_{CC}) and T_A = 25°C. The total current sourced by all I/Os must be limited to 85 mA. Each I/O must be externally limited to a maximum of 25 mA, and the P port (P7–P0) must be limited to a maximum current of 200 mA.

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I²C INTERFACE TIMING REQUIREMENTS

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

			STANDARD MODE I ² C BUS		FAST MOD I ² C BUS	E	UNIT
			MIN	MAX	MIN	MAX	
f _{scl}	I ² C clock frequency		0	100	0	400	kHz
t _{sch}	I ² C clock high time		4		0.6		μS
t _{scl}	I ² C clock low time		4.7		1.3		μS
t _{sp}	I ² C spike time			50		50	ns
t _{sds}	I ² C serial-data setup time		250		100		ns
t _{sdh}	I ² C serial-data hold time				0		ns
t _{icr}	I ² C input rise time		1000	20 + 0.1C _b ⁽¹⁾	300	ns	
t _{icf}	I ² C input fall time			300	20 + 0.1C _b ⁽¹⁾	300	ns
t _{ocf}	I ² C output fall time	10-pF to 400-pF bus		300	20 + 0.1C _b ⁽¹⁾	300	ns
t _{buf}	I ² C bus free time between stop and	start	4.7		1.3		μS
t _{sts}	I ² C Start or repeated Start condition	setup	4.7		0.6		μS
t _{sth}	I ² C Start or repeated Start condition	hold	4		0.6		μS
t _{sps}	I ² C 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	I ² C bus capacitive load			400		400	ns

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

SWITCHING CHARACTERISTICS

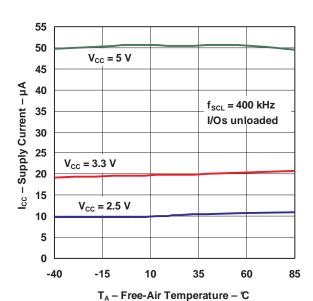
over operating free-air temperature range (unless otherwise noted) (see Figure 11 and Figure 12)

	PARAMETER	PARAMETER FROM		STANDARD I ² C BU	FAST M I ² C B	UNIT		
		(INPUT)	(OUTPUT)	MIN	MAX	MIN	MAX	
t _{iv}	Interrupt valid time	P port	ĪNT		4		4	μS
t _{ir}	Interrupt reset delay time	SCL	ĪNT		4		4	μS
t _{pv}	Output data valid	SCL	P7-P0		200		200	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

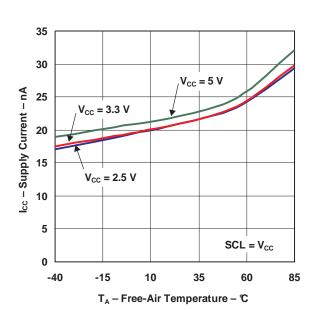


TYPICAL CHARACTERISTICS

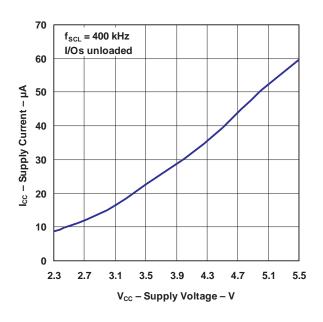
SUPPLY CURRENT vs TEMPERATURE



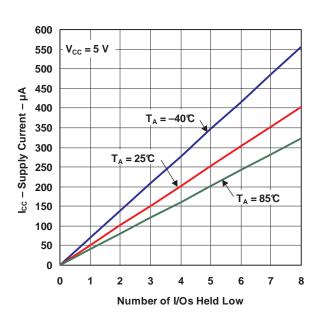
QUIESCENT SUPPLY CURRENT vs TEMPERATURE



SUPPLY CURRENT vs SUPPLY VOLTAGE



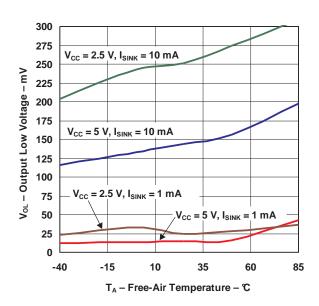
SUPPLY CURRENT vs NUMBER OF I/Os HELD LOW



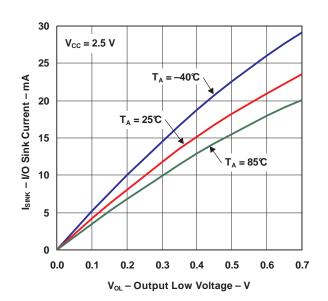


TYPICAL CHARACTERISTICS (continued)

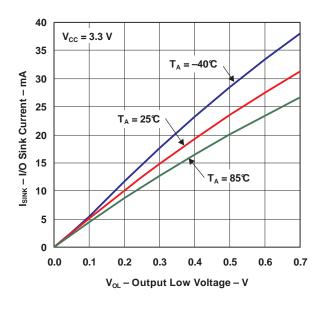
I/O OUTPUT LOW VOLTAGE vs TEMPERATURE



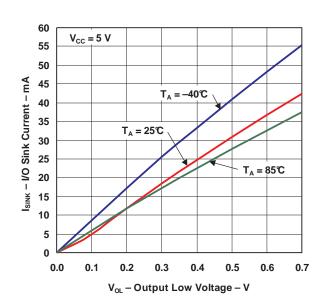
I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



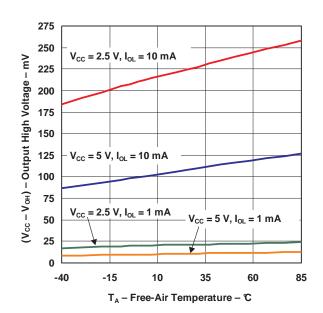
I/O SINK CURRENT vs OUTPUT LOW VOLTAGE



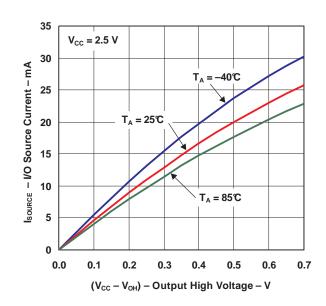


TYPICAL CHARACTERISTICS (continued)

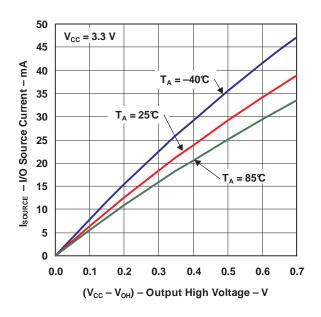
I/O OUTPUT HIGH VOLTAGE vs TEMPERATURE



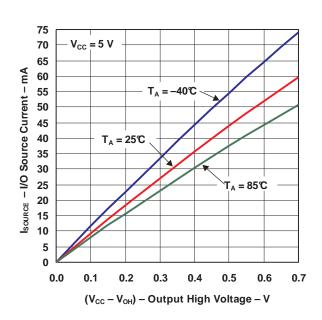
I/O SOURCE CURRENT vs
OUTPUT HIGH VOLTAGE



I/O SOURCE CURRENT vs OUTPUT HIGH VOLTAGE



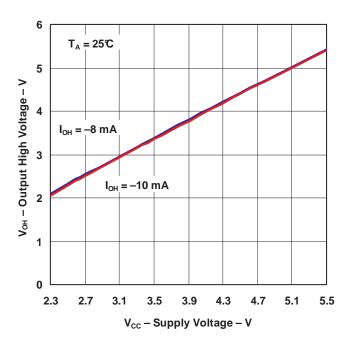
I/O SOURCE CURRENT vs OUTPUT HIGH VOLTAGE





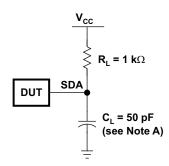
TYPICAL CHARACTERISTICS (continued)

OUTPUT HIGH VOLTAGE vs SUPPLY VOLTAGE

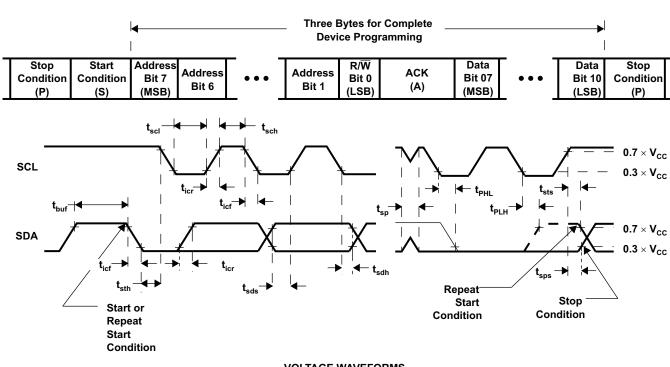




PARAMETER MEASUREMENT INFORMATION



SDA LOAD CONFIGURATION



VOLTAGE WAVEFORMS

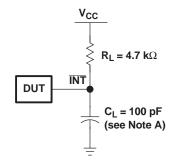
BYTE	DESCRIPTION
1	I ² C address
2, 3	P-port data

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

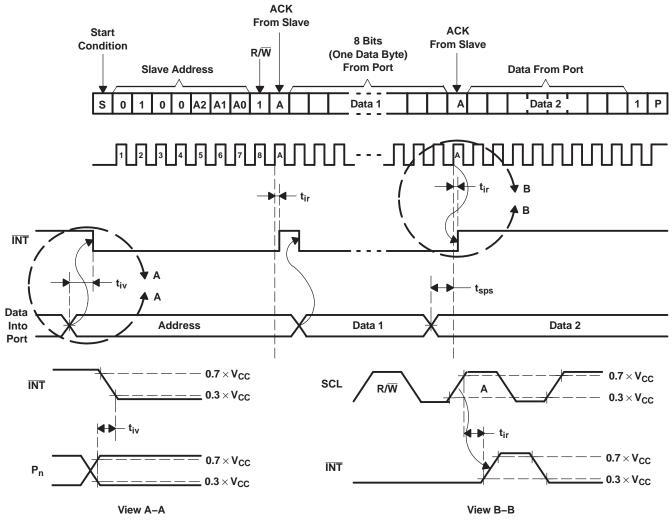
Figure 10. I²C Interface Load Circuit and Voltage Waveforms



PARAMETER MEASUREMENT INFORMATION (continued)



INTERRUPT LOAD CONFIGURATION

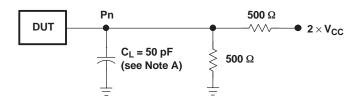


- A. C_L includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics: PRR \leq 10 MHz, $Z_0 = 50 \Omega$, $t_r/t_f \leq$ 30 ns.
- C. All parameters and waveforms are not applicable to all devices.

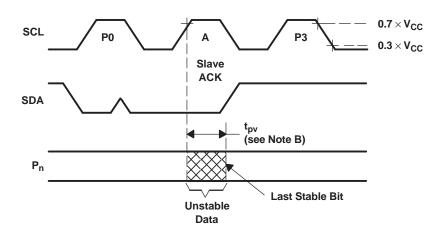
Figure 11. Interrupt Load Circuit and Voltage Waveforms



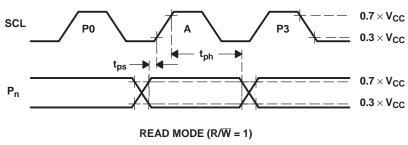
PARAMETER MEASUREMENT INFORMATION (continued)



P-PORT LOAD CONFIGURATION



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

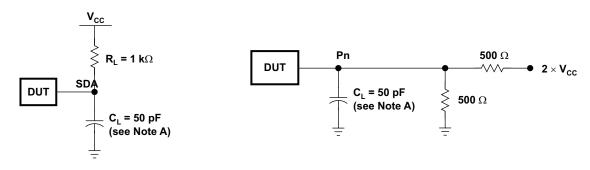


- A. C_L includes probe and jig capacitance.
- B. t_{pv} is measured from 0.7 x V_{CC} on SCL to 50% I/O (Pn) output.
- C. All inputs are supplied by generators having the following characteristics: PRR \leq 10 MHz, $Z_0 = 50 \Omega$, $t_r/t_f \leq$ 30 ns.
- D. The outputs are measured one at a time, with one transition per measurement.
- E. All parameters and waveforms are not applicable to all devices.

Figure 12. P-Port Load Circuit and Voltage Waveforms

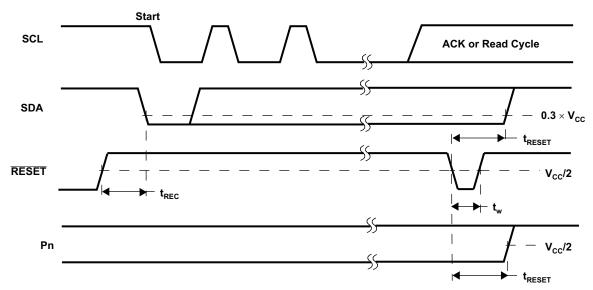


PARAMETER MEASUREMENT INFORMATION (continued)



SDA LOAD CONFIGURATION

P-PORT LOAD CONFIGURATION



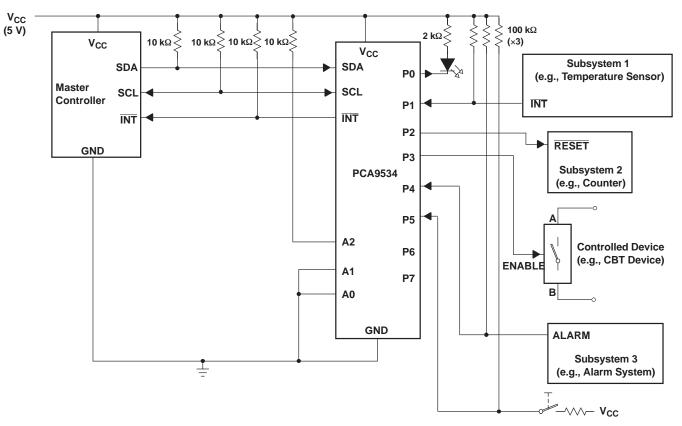
- A. C_L includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, t_r/t_f ≤ 30 ns.
- C. I/Os are configured as inputs.
- D. All parameters and waveforms are not applicable to all devices.

Figure 13. Reset Load Circuits and Voltage Waveforms



APPLICATION INFORMATION

Figure 14 shows an application in which the PCA9534 can be used.



- A. Device address is configured as 0100100 for this example.
- B. P0, P2, and P3 are configured as outputs.
- C. P1, P4, and P5 are configured as inputs.
- D. P6 and P7 are not used and must be configured as outputs.

Figure 14. Typical Application



Minimizing I_{CC} When the I/O Controls LEDs

When the I/Os are used to control LEDs, they are normally connected to V_{CC} through a resistor, as shown in Figure 14. Because the LED acts as a diode, when the LED is off, the I/O V_{IN} is about 1.2 V less than V_{CC} . The supply current, I_{CC} , increases as V_{IN} becomes lower than V_{CC} and is specified as ΔI_{CC} in *Electrical Characteristics*.

For battery-powered applications, it is essential that the voltage of the I/O pins is greater than or equal to V_{CC} when the LED is off to minimize current consumption. Figure 15 shows a high-value resistor in parallel with the LED. Figure 16 shows V_{CC} less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V_{IN} at or above V_{CC} and prevents additional supply-current consumption when the LED is off.

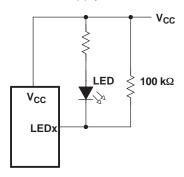


Figure 15. High-Value Resistor in Parallel With the LED

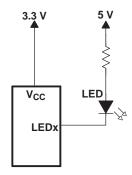


Figure 16. Device Supplied by a Lower Voltage

Power-On Reset Requirements

In the event of a glitch or data corruption, PCA9534 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 Figure 17 and Figure 18.

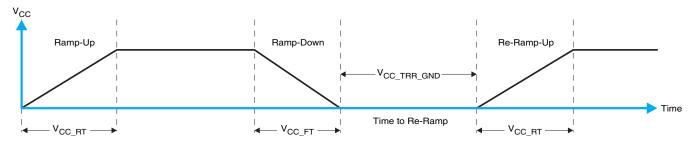


Figure 17. V_{CC} is Lowered Below 0.2 V or 0 V and Then Ramped Up to V_{CC}



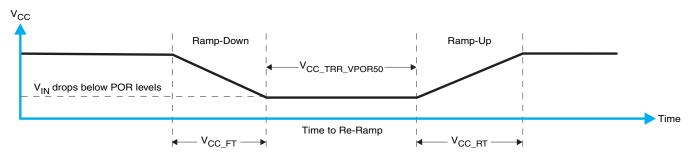


Figure 18. V_{CC} is Lowered Below the POR Threshold, Then Ramped Back Up to V_{CC}

Table 10 specifies the performance of the power-on reset feature for PCA9534 for both types of power-on reset.

Table 10. RECOMMENDED SUPPLY SEQUENCING AND RAMP RATES(1)

	PARAMETER	MIN	TYP	MAX	UNIT	
V _{CC_FT}	Fall rate	See Figure 17	1		100	ms
V _{CC_RT}	Rise rate	See Figure 17	0.01		100	ms
V _{CC_TRR_GND}	Time to re-ramp (when V _{CC} drops to GND)	See Figure 17	0.001			ms
V _{CC_TRR_POR50}	Time to re-ramp (when V_{CC} drops to $V_{POR_MIN} - 50 \text{ mV}$)	See Figure 18	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 μs	See Figure 19			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 Figure 19				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 fising 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 device impedance are factors that affect power-on reset performance. Figure 19 and Table 10 provide more information on how to measure these specifications.

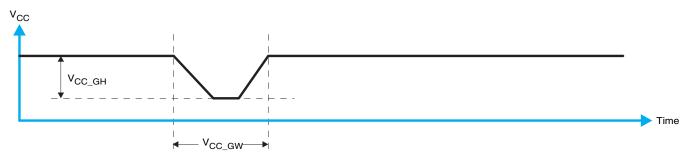
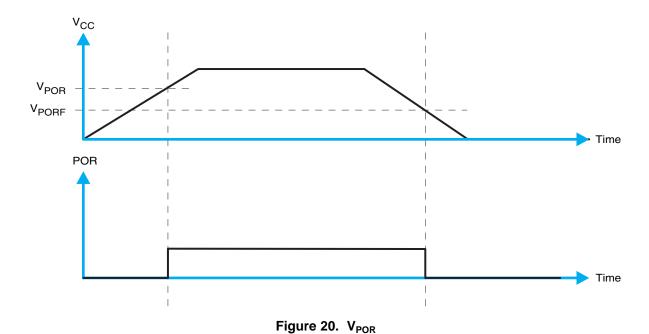


Figure 19. Glitch Width and Glitch Height

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. Figure 20 and Table 10 provide more details on this specification.





Interrupt Requirements

The expected performance of the interrupt feature is that $\overline{\text{INT}}$ is to be cleared (de-asserted) when the input register is read or all inputs return to the last read values. $\overline{\text{INT}}$ is also de-asserted when both of the following occur:

- The last I²C command byte (register pointer) written was 00h. This generally means the last operation with the device was a read of the input register, but the command byte may have been written with 00h without ever going on to read the Input register.
- Any other slave device on the I²C bus acknowledges an address byte with the R/W bit set high. This occurs when reading any other valid device on the bus.

In order to prevent $\overline{\text{INT}}$ from de-asserting when another device is read on the I²C bus, the user needs to change the command byte to something other than 00 (hex) after a read operation to the device.

PACKAGE OPTION ADDENDUM

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PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	e Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
PCA9534DB	ACTIVE	SSOP	DB	16	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DBG4	ACTIVE	SSOP	DB	16	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DBR	ACTIVE	SSOP	DB	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DBRG4	ACTIVE	SSOP	DB	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DGVR	ACTIVE	TVSOP	DGV	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DGVRG4	ACTIVE	TVSOP	DGV	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534DWRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534PW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534PWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534PWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534PWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
PCA9534RGVR	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
PCA9534RGVRG4	ACTIVE	VQFN	RGV	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

⁽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.

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)

⁽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.



PACKAGE OPTION ADDENDUM

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

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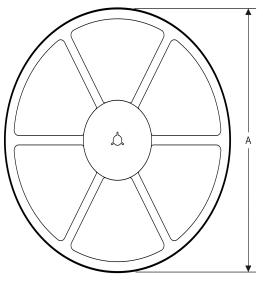
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PACKAGE MATERIALS INFORMATION

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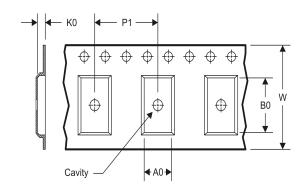
TAPE AND REEL INFORMATION

REEL DIMENSIONS





TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
В0	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		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
PCA9534DBR	SSOP	DB	16	2000	330.0	16.4	8.2	6.6	2.5	12.0	16.0	Q1
PCA9534DGVR	TVSOP	DGV	16	2000	330.0	12.4	6.8	4.0	1.6	8.0	12.0	Q1
PCA9534DWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1
PCA9534PWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
PCA9534RGVR	VQFN	RGV	16	2500	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2

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*All dimensions are nominal

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Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PCA9534DBR	SSOP	DB	16	2000	346.0	346.0	33.0
PCA9534DGVR	TVSOP	DGV	16	2000	346.0	346.0	29.0
PCA9534DWR	SOIC	DW	16	2000	346.0	346.0	33.0
PCA9534PWR	TSSOP	PW	16	2000	346.0	346.0	29.0
PCA9534RGVR	VQFN	RGV	16	2500	346.0	346.0	29.0

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



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.
- Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
- 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:

- 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.





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



RGV (S-PVQFN-N16)

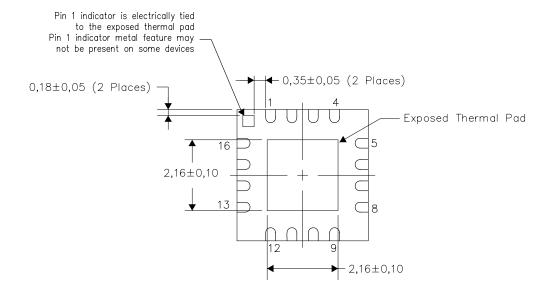
PLASTIC QUAD FLATPACK NO-LEAD

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.

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



Bottom View

Exposed Thermal Pad Dimensions

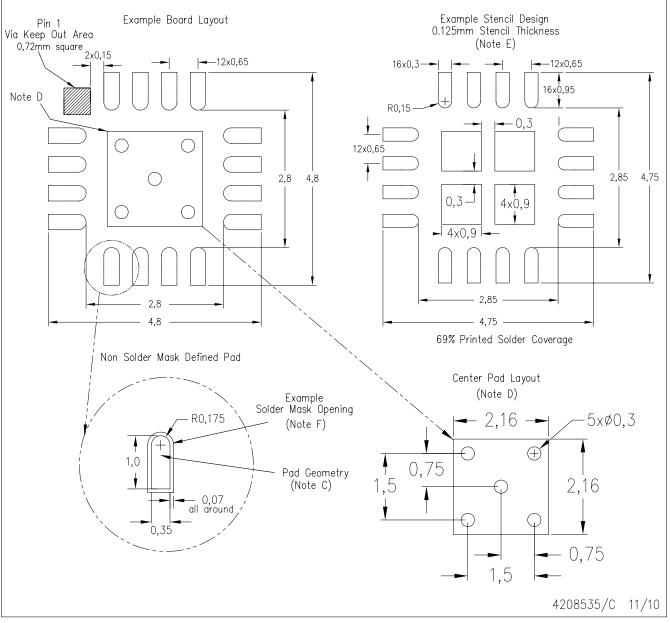
4206351-2/J 06/11

NOTE: All linear dimensions are in millimeters



RGV (S-PVQFN-N16)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES: A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, 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 https://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 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



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.



DB (R-PDSO-G**)

PLASTIC SMALL-OUTLINE

28 PINS SHOWN



NOTES: A. All linear dimensions are in millimeters.

B. This drawing is subject to change without notice.

C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.

D. Falls within JEDEC MO-150

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