

TCA6408A-Q1 Low-Voltage 8-Bit I²C and SMBus I/O Expander With Interrupt Output

1 Features

- I²C to Parallel Port Expander
- Operating Power-Supply Voltage Range of 1.65 V to 3.6 V
- Allows Bidirectional Voltage-Level Translation and GPIO Expansion Between 1.8-, 2.5-, and 3.3-V I²C Bus and P-Ports
- Low Standby Current Consumption
- 400-kHz Fast I²C Bus
- Hardware Address Pin Allows Two TCA6408A-Q1 Devices on the Same I²C/SMBus Bus
- Active-Low Reset ($\overline{\text{RESET}}$) Input
- Open-Drain Active-Low Interrupt ($\overline{\text{INT}}$) Output
- Input and 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 meets 100 mA Per AEC Q100-004
- Schmitt-Trigger Action Allows Slow Input Transition and Better Switching Noise Immunity at the SCL and SDA Inputs
- ESD Protection
 - 2000-V Human Body Model (Q100-002)
 - 1000-V Charged-Device Model (Q100-011)

2 Applications

- Automotive Infotainment
- Advanced Drive Assistance Systems (ADAS)
- Automotive Body Electronics
- HEV, EV, and Power train
- Industrial, Factory, and Building Automation
- Test & Measurement
- EPOS

3 Description

The TCA6408A-Q1 is a 16-pin device that provides 8-bits of general purpose parallel input and output (I/O) expansion for the two-line bidirectional I²C bus (or SMBus) protocol. This device can operate with a power supply voltage ranging from 1.65 V to 3.6 V on both the I²C bus side (V_{CCI}) and on the P-port side (V_{CCP}). This allows the TCA6408A-Q1 to interface with next-generation microprocessors and microcontrollers on the SDA/SCL side, where supply levels are dropping down to conserve power. In contrast to the dropping power supplies of microprocessors and microcontrollers, some PCB components such as LEDs remain at a higher power supply.

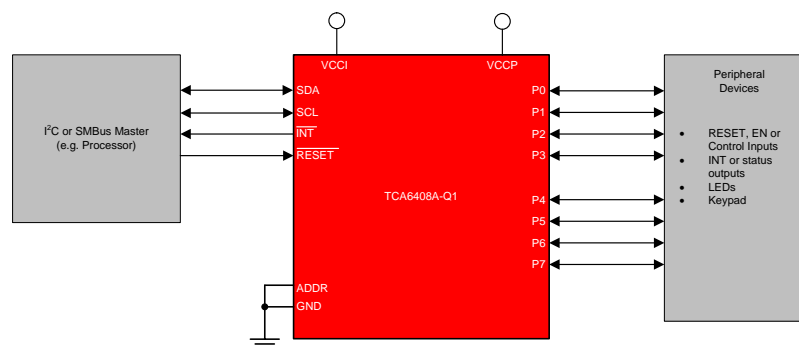
The device supports both 100-kHz (Standard-mode) and 400-kHz (Fast-mode) clock frequencies. I/O expanders such as the TCA6408A-Q1 provide a simple solution when additional I/Os are needed for switches, sensors, push-buttons, LEDs, fans, and so forth.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TCA6408A-Q1	TSSOP (16)	5.00 mm x 4.40 mm

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

Simplified Schematic



Copyright © 2016, Texas Instruments Incorporated



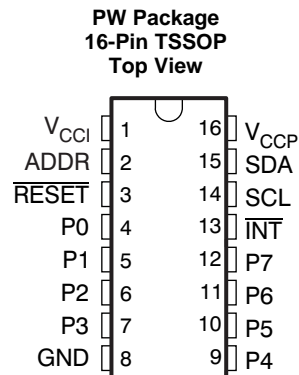
Table of Contents

1	Features	1	8.3	Feature Description.....	18
2	Applications	1	8.4	Device Functional Modes.....	19
3	Description	1	8.5	Programming	19
4	Revision History	2	8.6	Register Map.....	23
5	Pin Configuration and Functions	3	9	Application and Implementation	25
6	Specifications	4	9.1	Application Information.....	25
6.1	Absolute Maximum Ratings	4	9.2	Typical Application	26
6.2	ESD Ratings.....	4	10	Power Supply Recommendations	29
6.3	Recommended Operating Conditions.....	4	10.1	Power-On Reset Requirements	29
6.4	Thermal Information	5	11	Layout	31
6.5	Electrical Characteristics.....	5	11.1	Layout Guidelines	31
6.6	I ² C Interface Timing Requirements.....	6	11.2	Layout Example	31
6.7	Reset Timing Requirements	7	12	Device and Documentation Support	32
6.8	Switching Characteristics	7	12.1	Receiving Notification of Documentation Updates	32
6.9	Typical Characteristics	8	12.2	Community Resources.....	32
7	Parameter Measurement Information	11	12.3	Trademarks	32
8	Detailed Description	15	12.4	Electrostatic Discharge Caution.....	32
8.1	Overview	15	12.5	Glossary	32
8.2	Functional Block Diagrams	16	13	Mechanical, Packaging, and Orderable Information	33

4 Revision History

DATE	REVISION	NOTES
September 2016	*	Initial release.

5 Pin Configuration and Functions



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
ADDR	2	I	Address input. Connect directly to V _{CCP} or ground
GND	8	—	Ground
INT	13	O	Interrupt output. Connect to V _{CCI} through a pull-up resistor
P0	4	I/O	P-port input-output (push-pull design structure). At power on, P0 is configured as an input
P1	5	I/O	P-port input-output (push-pull design structure). At power on, P1 is configured as an input
P2	6	I/O	P-port input-output (push-pull design structure). At power on, P2 is configured as an input
P3	7	I/O	P-port input-output (push-pull design structure). At power on, P3 is configured as an input
P4	9	I/O	P-port input-output (push-pull design structure). At power on, P4 is configured as an input
P5	10	I/O	P-port input-output (push-pull design structure). At power on, P5 is configured as an input
P6	11	I/O	P-port input-output (push-pull design structure). At power on, P6 is configured as an input
P7	12	I/O	P-port input-output (push-pull design structure). At power on, P7 is configured as an input
RESET	3	I	Active-low reset input. Connect to V _{CCI} through a pull-up resistor, if no active connection is used
SCL	14	I	Serial clock bus. Connect to V _{CCI} through a pull-up resistor
SDA	15	I/O	Serial data bus. Connect to V _{CCI} through a pull-up resistor
V _{CCI}	1	—	Supply voltage of I ² C bus. Connect directly to the V _{CC} of the external I ² C master. Provides voltage level translation
V _{CCP}	16	—	Supply voltage of TCA6408A-Q1 for P-ports

6 Specifications

6.1 Absolute Maximum Ratings

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

				MIN	MAX	UNIT
V _{CCI}	Supply voltage for I ² C pins			-0.5	3.6	V
V _{CCP}	Supply voltage for P-ports			-0.5	3.6	V
V _I	Input voltage ⁽²⁾			-0.5	3.6	V
V _O	Output voltage ⁽²⁾			-0.5	3.6	V
I _{IK}	Input clamp current	ADDR, $\overline{\text{RESET}}$, SCL	V _I < 0		±20	mA
I _{OK}	Output clamp current	$\overline{\text{INT}}$	V _O < 0		±20	mA
I _{IOK}	Input/output clamp current	P-port	V _O < 0 or V _O > V _{CCP}		±20	mA
		SDA	V _O < 0 or V _O > V _{CCI}		±20	
I _{OL}	Continuous output low current	P-port	V _O = 0 to V _{CCP}		50	mA
	Continuous output low current	SDA, $\overline{\text{INT}}$	V _O = 0 to V _{CCI}		25	
I _{OH}	Continuous output high current	P-port	V _O = 0 to V _{CCP}		50	mA
I _{CC}	Continuous current through GND				200	mA
	Continuous current through V _{CCP}				160	
	Continuous current through V _{CCI}				10	
T _{j(MAX)}	Maximum junction temperature				135	°C
T _{stg}	Storage temperature			-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. 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

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human body model (HBM), per AEC Q100-002 ⁽¹⁾	±2000	V
		Charged-device model (CDM), per AEC Q100-011	±1000	

- (1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

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

				MIN	MAX	UNIT
V _{CCI} ⁽¹⁾	Supply voltage for I ² C pins	SCL, SDA, $\overline{\text{INT}}$		1.65	3.6	V
V _{CCP}	Supply voltage for P-ports	P-ports, ADDR, $\overline{\text{RESET}}$		1.65	3.6	V
V _{IH}	High-level input voltage	SCL, SDA		0.7 × V _{CCI}	V _{CCI}	V
		$\overline{\text{RESET}}$		0.7 × V _{CCI}	3.6	
		ADDR, P7–P0		0.7 × V _{CCP}	3.6	
V _{IL}	Low-level input voltage	SCL, SDA, $\overline{\text{RESET}}$		-0.5	0.3 × V _{CCI}	V
		ADDR, P7–P0		-0.5	0.3 × V _{CCP}	
I _{OH}	High-level output current	P00-P07			10	mA

- (1) For voltages applied above V_{CCI}, and increase in I_{CC} will result.

Recommended Operating Conditions (continued)

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

			MIN	MAX	UNIT
I _{OL} ⁽²⁾	Low-level output current	P00-P07	T _j = 65°C	25	mA
			T _j = 85°C	18	
			T _j = 105°C	9	
			T _j = 125°C	4.5	
	INT̄, SDA		T _j = 135°C	3.5	
			T _j = 85°C	6	
			T _j = 105°C	3	
			T _j = 125°C	1.8	
		T _j = 135°C	1.5		
T _A	Operating free-air temperature		-40	125	°C

- (2) The values shown apply to specific junction temperature. See the [Calculating Junction Temperature and Power Dissipation](#) section on how to calculate the junction temperature.

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TCA6408A-Q1	UNIT
		PW (TSSOP)	
		16 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	122	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	56.4	°C/W
R _{θJB}	Junction-to-board thermal resistance	67.1	°C/W
ψ _{JT}	Junction-to-top characterization parameter	10.8	°C/W
ψ _{JB}	Junction-to-board characterization parameter	66.5	°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 recommended operating free-air temperature range, V_{CCI} = 1.65 V to 3.6 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	V _{CCP}	MIN	TYP ⁽¹⁾	MAX	UNIT
V _{IK}	Input diode clamp voltage	I _I = -18 mA	1.65 V to 3.6 V	-1.2		V
V _{PORR}	Power-on reset voltage, V _{CCP} rising ⁽²⁾	V _I = V _{CCP} or GND, I _O = 0	1.65 V to 3.6 V	1.2	1.5	V
V _{PORF}	Power-on reset voltage, V _{CCP} falling ⁽²⁾	V _I = V _{CCP} or GND, I _O = 0	1.65 V to 3.6 V	0.6	1	V
V _{OH}	P-port high-level output voltage	I _{OH} = -8 mA	1.65 V	1.2	V	
			2.3 V	1.8		
			3 V	2.6		
			3.6 V	3.3		
	I _{OH} = -10 mA		1.65 V	1.0		
			2.3 V	1.7		
			3 V	2.5		
			3.6 V	3.2		

- (1) All typical values are at nominal supply voltage (1.8-V, 2.5-V, or 3.3-V V_{CC}) and T_A = 25°C.

- (2) When power (from 0 V) is applied to V_{CCP}, an internal power-on reset holds the TCA6408A-Q1 in a reset condition until V_{CCP} has reached V_{PORR}. At that time, the reset condition is released, and the TCA6408A-Q1 registers and I²C/SMBus state machine initialize to their default states. After that, V_{CCP} must be lowered to below V_{PORF} and back up to the operating voltage for a power-reset cycle.

Electrical Characteristics (continued)

 over recommended operating free-air temperature range, $V_{CCI} = 1.65\text{ V to }3.6\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	V_{CCP}	MIN	TYP ⁽¹⁾	MAX	UNIT	
V_{OL}	P-port low-level output voltage	$I_{OL} = 8\text{ mA}$	1.65 V			0.45	V	
			2.3 V			0.25		
			3 V			0.25		
			3.6 V			0.23		
		$I_{OL} = 10\text{ mA}$	1.65 V			0.6		
			2.3 V			0.3		
			3 V			0.25		
			3.6 V			0.23		
I_{OL}	SDA	$V_{OL} = 0.4\text{ V}$	1.65 V to 3.6 V	3			mA	
	$\overline{\text{INT}}$			3	15			
I_I	SCL, SDA, $\overline{\text{RESET}}$	$V_I = V_{CCI}$ or GND	1.65 V to 3.6 V			± 0.1	μA	
	ADDR	$V_I = V_{CCP}$ or GND				± 0.1		
I_{IH}	P-port	$V_I = V_{CCP}$	1.65 V to 3.6 V			1	μA	
I_{IL}	P-port	$V_I = \text{GND}$	1.65 V to 3.6 V			1	μA	
I_{CC} ($I_{CCI} + I_{CCP}$)	Operating mode	SDA, P-port, ADDR, $\overline{\text{RESET}}$	$V_I = V_{CC}$ or GND, I/O = inputs, $f_{SCL} = 400\text{ kHz}$, No load	2.3 V to 3.6 V		9	36	μA
				1.65 V to 2.3 V		5	33	
	Standby mode	SCL, SDA, P-port, ADDR, $\overline{\text{RESET}}$	$V_I = V_{CC}$ or GND, I/O = inputs, $f_{SCL} = 0\text{ kHz}$, No load	2.3 V to 3.6 V		1.2	10	
				1.65 V to 2.3 V		0.6	7	
ΔI_{CCI}	Additional current in standby mode	SCL, SDA	1.65 V to 3.6 V			6	10	μA
		$\overline{\text{RESET}}$				$\overline{\text{RESET}}$ at $V_{CCI} - 0.6\text{ V}$, Other inputs at V_{CCI} or GND	6	
ΔI_{CCP}		P-port, ADDR	1.65 V to 3.6 V			6	80	μA
C_i	SCL	$V_I = V_{CCI}$ or GND	1.65 V to 3.6 V			7	9	pF
C_{io}	SDA	$V_{IO} = V_{CCI}$ or GND	1.65 V to 3.6 V			8	10.5	pF
	P-port	$V_{IO} = V_{CCP}$ or GND				7	8	

6.6 I²C Interface Timing Requirements

 over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 17](#))

		MIN	MAX	UNIT
I²C BUS—STANDARD MODE				
f_{scl}	I ² C clock frequency	0	100	kHz
t_{sch}	I ² C clock high time	4		μs
t_{scl}	I ² C clock low time	4.7		μs
t_{sp}	I ² C spike time	0	50	ns
t_{sds}	I ² C serial data setup time	250		ns
t_{sdh}	I ² C serial data hold time	0		ns
t_{icr}	I ² C input rise time		1000	ns
t_{icf}	I ² C input fall time		300	ns
t_{ocf}	I ² C output fall time, 10-pF to 400-pF bus		300	ns
t_{buf}	I ² C bus free time between Stop and Start	4.7		μs
t_{sts}	I ² C Start or repeater Start condition setup time	4.7		μs
t_{sth}	I ² C Start or repeater Start condition hold time	4		μs
t_{sps}	I ² C Stop condition setup time	4		μs

I²C Interface Timing Requirements (continued)

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 17](#))

		MIN	MAX	UNIT
$t_{vd(data)}$	Valid data time, SCL low to SDA output valid		1	μ s
$t_{vd(ack)}$	Valid data time of ACK condition, ACK signal from SCL low to SDA (out) low		1	μ s
I²C BUS—FAST MODE				
f_{scl}	I ² C clock frequency	0	400	kHz
t_{sch}	I ² C clock high time	0.6		μ s
t_{scl}	I ² C clock low time	1.3		μ s
t_{sp}	I ² C spike time	0	50	ns
t_{sds}	I ² C serial data setup time	100		ns
t_{sdh}	I ² C serial data hold time	0		ns
t_{icr}	I ² C input rise time	20	300	ns
t_{icf}	I ² C input fall time	$20 \times (V_{cc}/5.5 \text{ V})$	300	ns
t_{ocf}	I ² C output fall time, 10-pF to 400-pF bus	$20 \times (V_{cc}/5.5 \text{ V})$	300	ns
t_{buf}	I ² C bus free time between Stop and Start	1.3		μ s
t_{sts}	I ² C Start or repeater Start condition setup time	0.6		μ s
t_{sth}	I ² C Start or repeater Start condition hold time	0.6		μ s
t_{sps}	I ² C Stop condition setup time	0.6		μ s
$t_{vd(data)}$	Valid data time, SCL low to SDA output valid		1	μ s
$t_{vd(ack)}$	Valid data time of ACK condition, ACK signal from SCL low to SDA (out) low		1	μ s

6.7 Reset Timing Requirements

over recommended operating free-air temperature range (unless otherwise noted) (see [Figure 20](#))

		MIN	MAX	UNIT
I²C BUS—STANDARD and FAST MODE				
t_W	Reset pulse duration	40		ns
t_{REC}	Reset recovery time	0		ns
t_{RESET}	Time to reset	600		ns

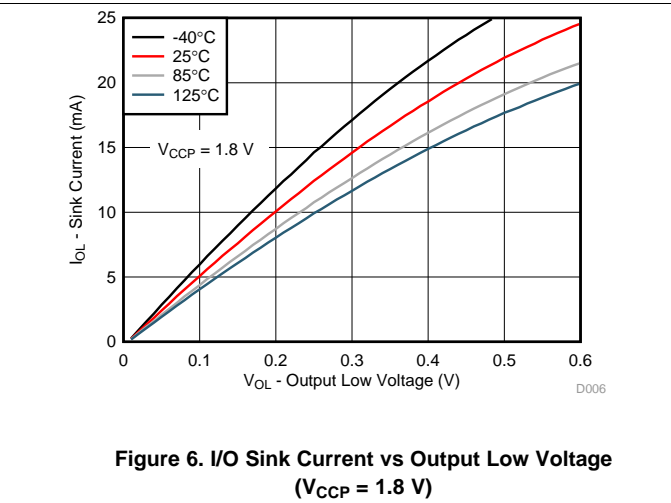
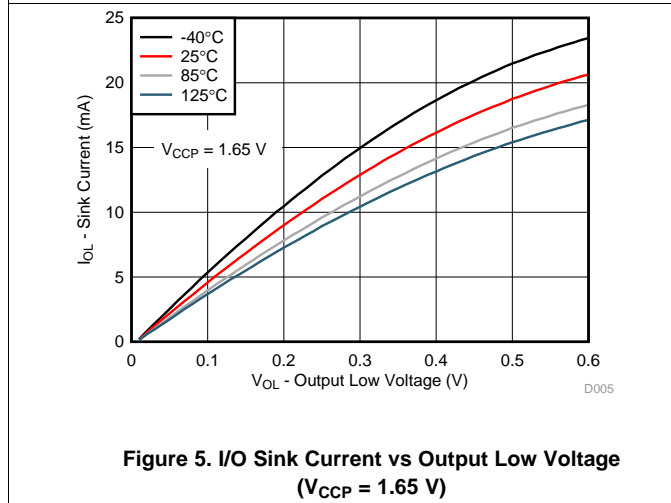
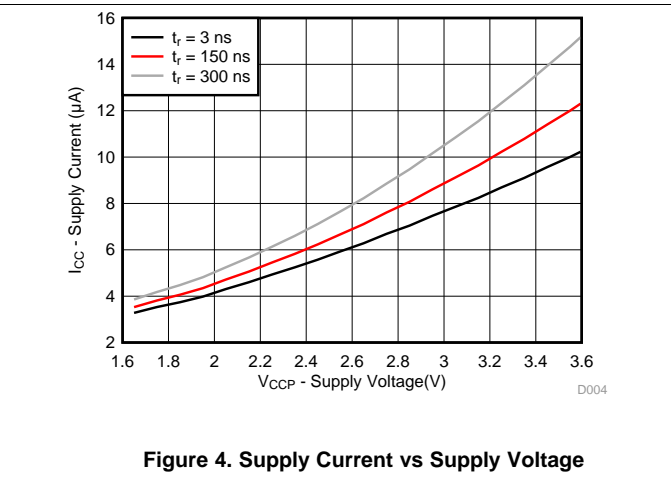
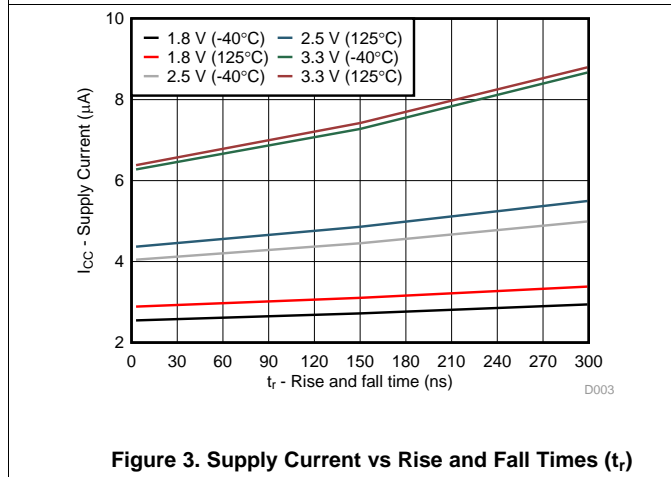
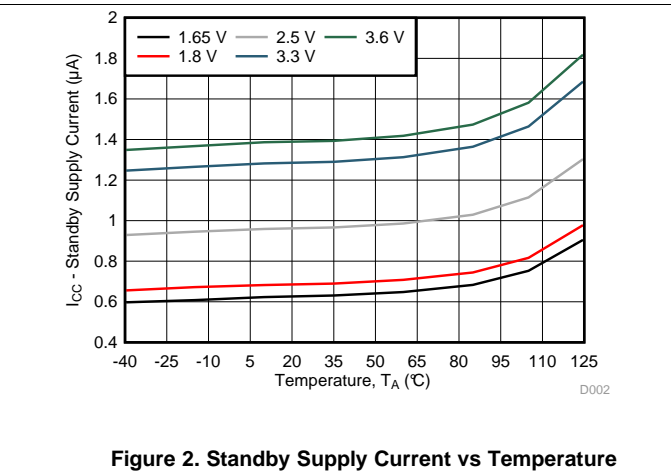
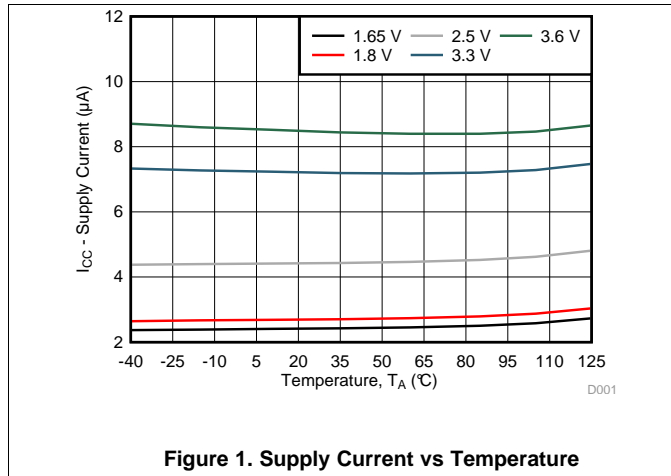
6.8 Switching Characteristics

over recommended operating free-air temperature range, $C_L \leq 100$ pF (unless otherwise noted) (see [Figure 17](#))

PARAMETER	FROM (INPUT)	TO (OUTPUT)	MIN	MAX	UNIT
I²C BUS—STANDARD and FAST MODE					
t_{iv}	Interrupt valid time	P-Port		4	μ s
t_{ir}	Interrupt reset delay time	SCL		4	μ s
t_{pv}	Output data valid	SCL		400	ns
t_{ps}	Input data setup time	P-Port	0		ns
t_{ph}	Input data hold time	P-Port	300		ns

6.9 Typical Characteristics

T_A = 25°C (unless otherwise noted)



Typical Characteristics (continued)

T_A = 25°C (unless otherwise noted)

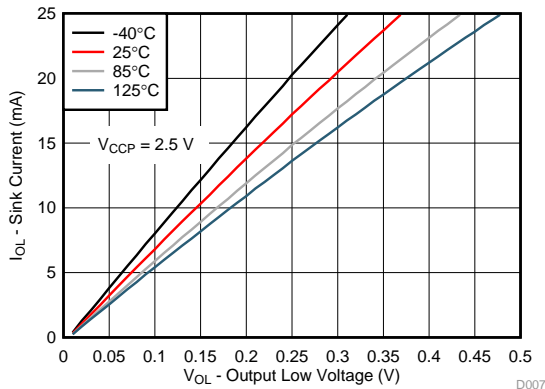


Figure 7. I/O Sink Current vs Output Low Voltage (V_{C_{CP}} = 2.5 V)

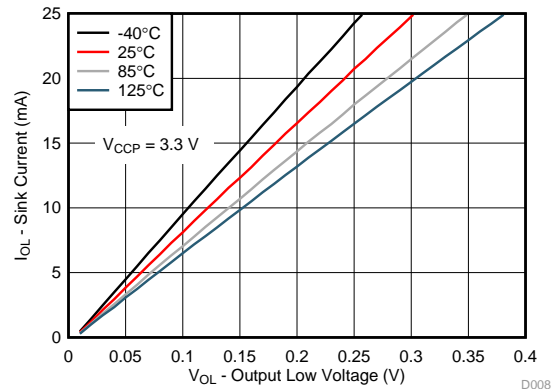


Figure 8. I/O Sink Current vs Output Low Voltage (V_{C_{CP}} = 3.3 V)

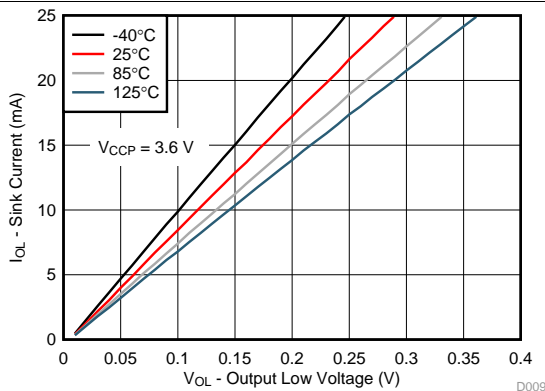


Figure 9. I/O Sink Current vs Temperature (V_{C_{CP}} = 3.6 V)

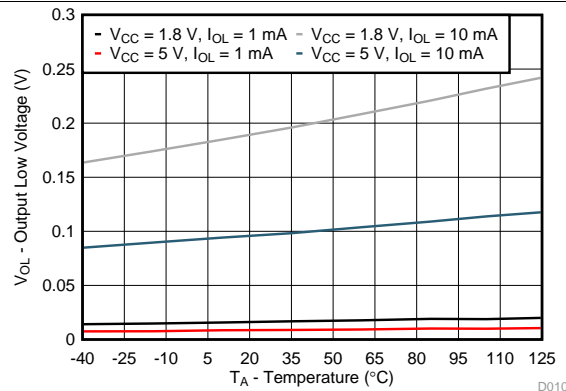


Figure 10. I/O Low Voltage vs Temperature

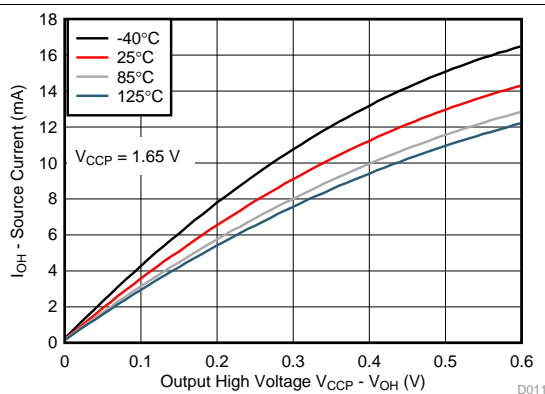


Figure 11. I/O Source Current vs Output High Voltage (V_{C_{CP}} = 1.65 V)

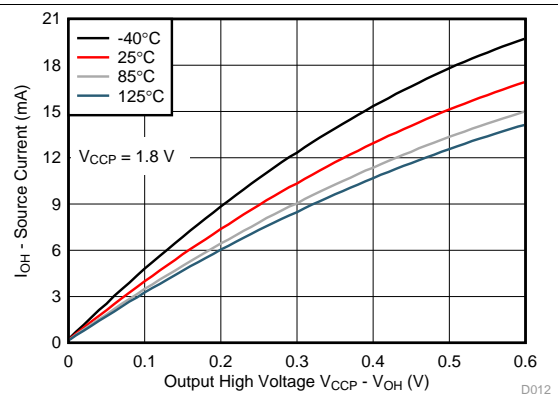


Figure 12. I/O Source Current vs Output High Voltage (V_{C_{CP}} = 1.8 V)

Typical Characteristics (continued)

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

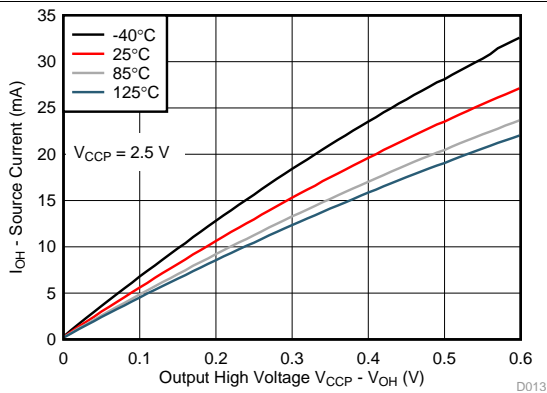


Figure 13. I/O Source Current vs Output High Voltage ($V_{CCP} = 2.5\text{ V}$)

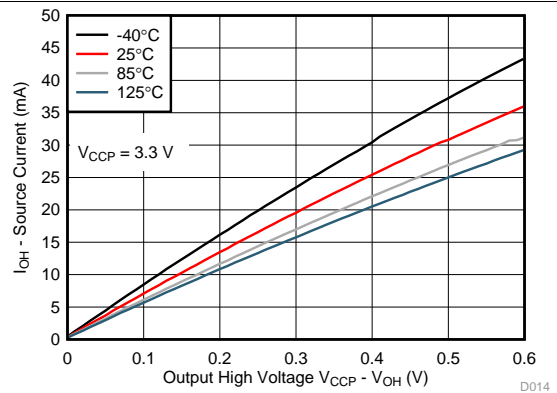


Figure 14. I/O Source Current vs Output High Voltage ($V_{CCP} = 3.3\text{ V}$)

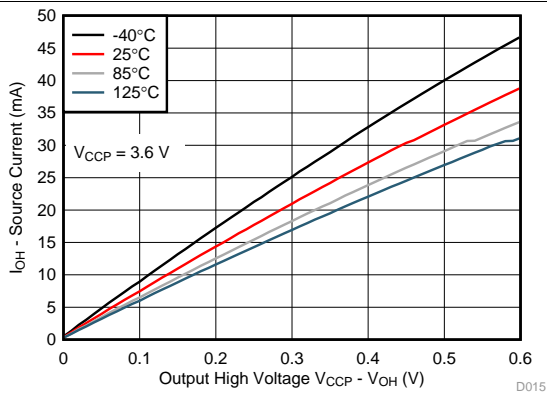


Figure 15. I/O Source Current vs Output High Voltage ($V_{CCP} = 3.6\text{ V}$)

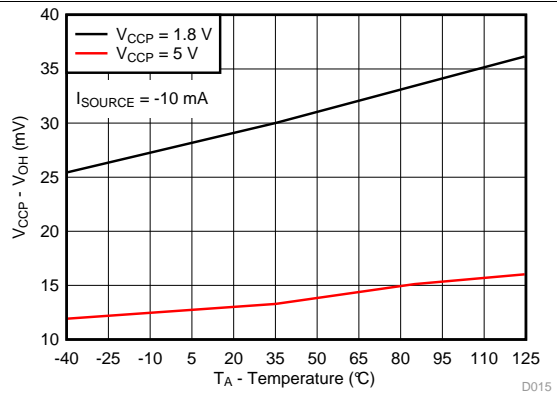
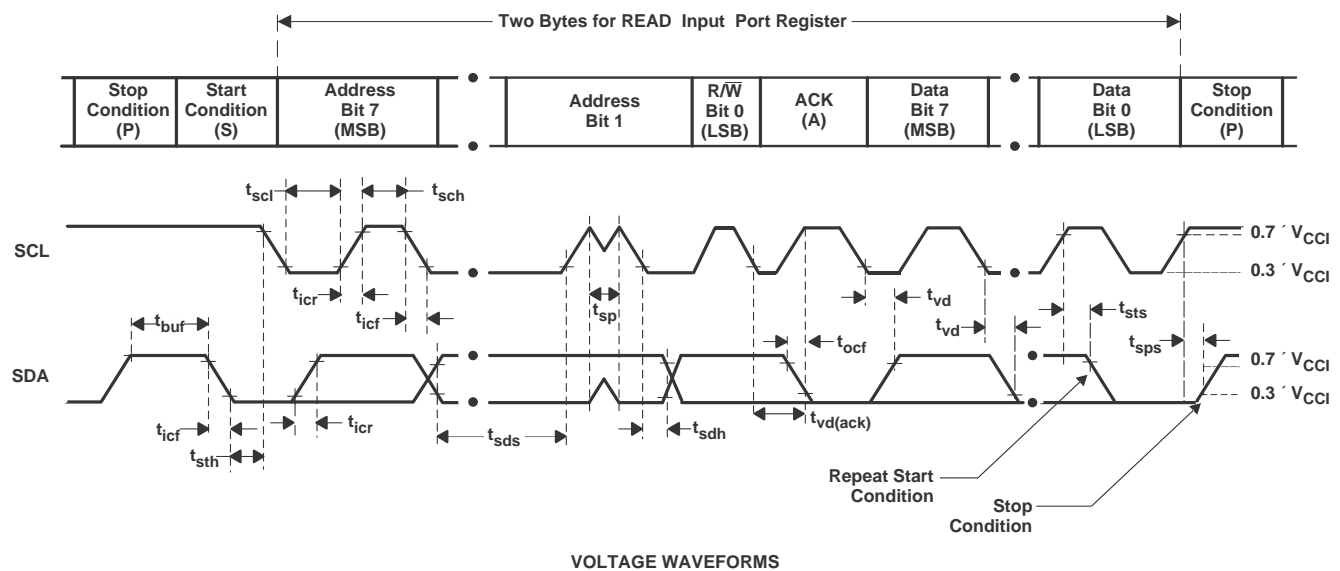
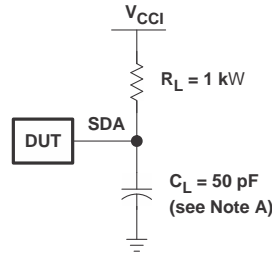


Figure 16. I/O High Voltage vs Temperature

7 Parameter Measurement Information

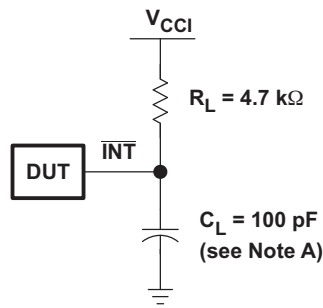


BYTE	DESCRIPTION
1	I ² C address
2	Input register port data

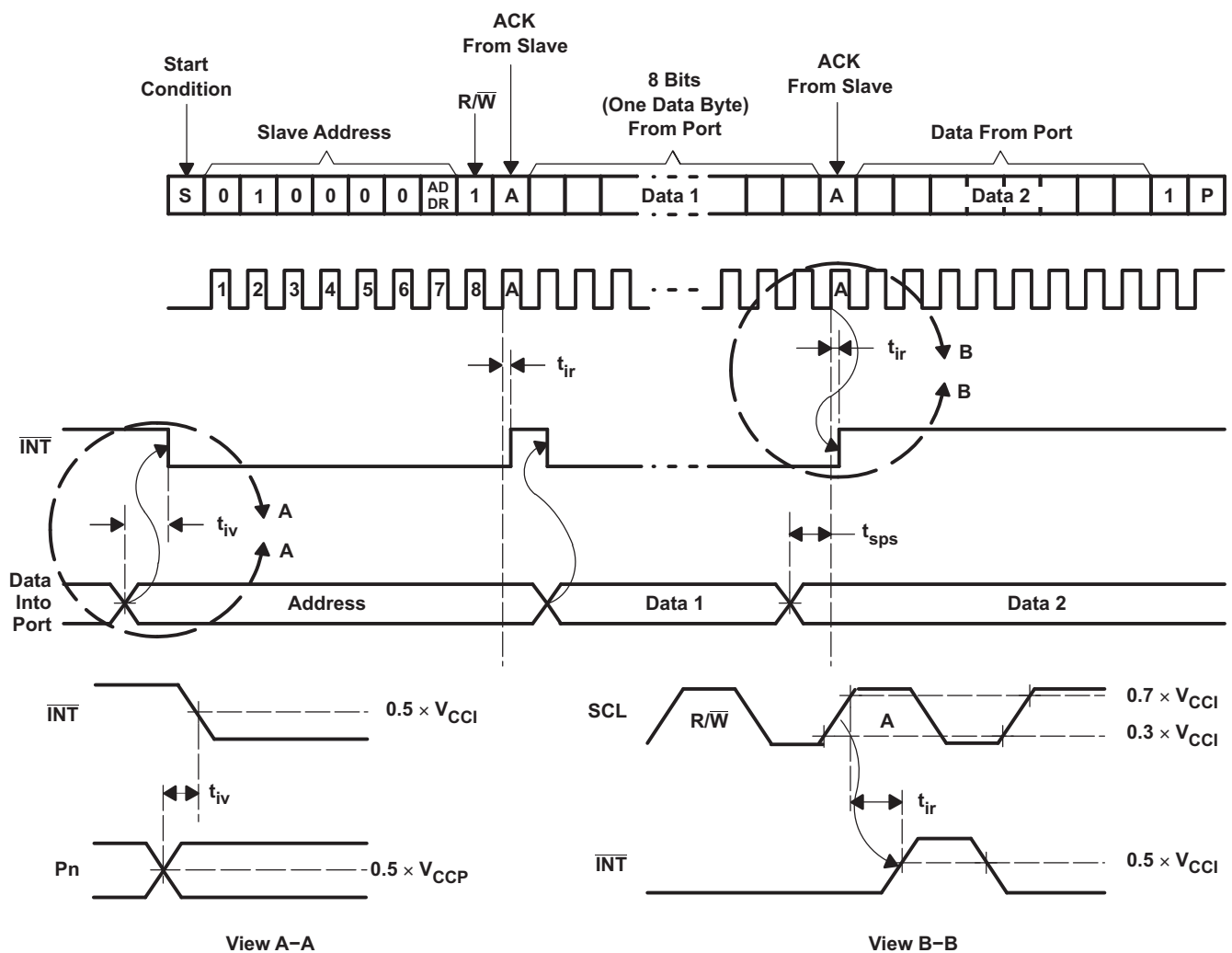
- A. C_L includes probe and jig capacitance. t_{ocf} is measured with C_L of 10 pF or 400 pF.
 B. All inputs are supplied by generators having the following characteristics: PRR \leq 10 MHz, $Z_0 = 50 \Omega$, $t_r/t_f \leq 30$ ns.

Figure 17. I²C Interface Load Circuit and Voltage Waveforms

Parameter Measurement Information (continued)



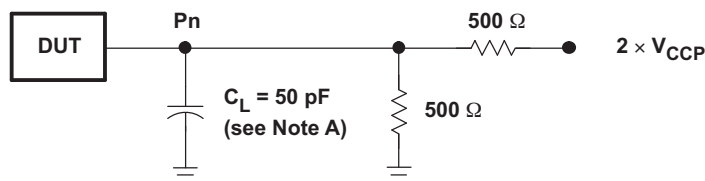
INTERRUPT LOAD CONFIGURATION



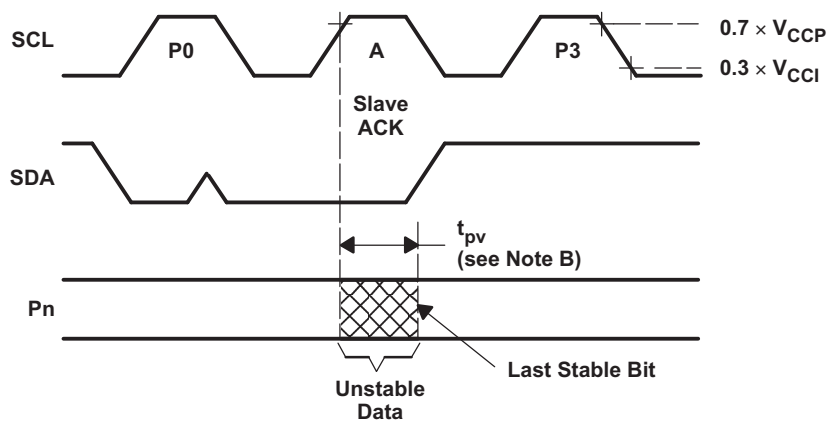
- A. C_L includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics: $PRR \leq 10$ MHz, $Z_O = 50 \Omega$, $t_r/t_f \leq 30$ ns.

Figure 18. Interrupt Load Circuit and Voltage Waveforms

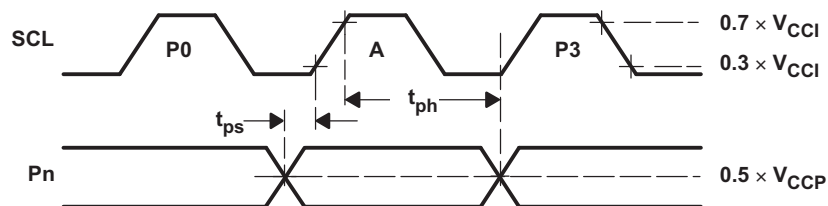
Parameter Measurement Information (continued)



P-PORT LOAD CONFIGURATION



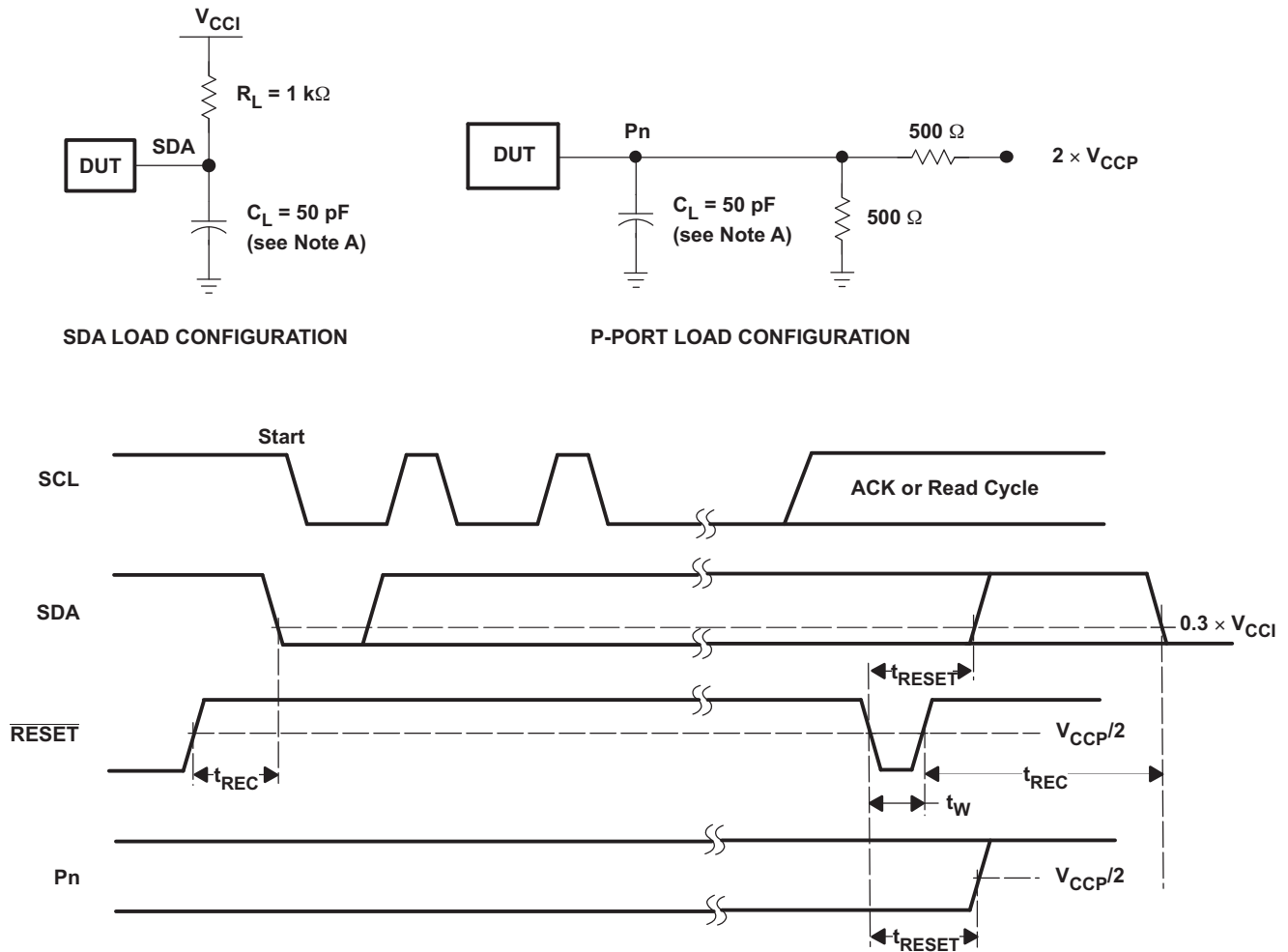
WRITE MODE ($R/\bar{W} = 0$)



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

- A. C_L includes probe and jig capacitance.
- B. t_{pv} is measured from $0.7 \times V_{CC}$ on SCL to 50% I/O (P_n) output.
- C. All inputs are supplied by generators having the following characteristics: $PRR \leq 10$ MHz, $Z_0 = 50 \Omega$, $t_r/t_f \leq 30$ ns.
- D. The outputs are measured one at a time, with one transition per measurement.

Figure 19. P-Port Load Circuit and Timing Waveforms

Parameter Measurement Information (continued)


- A. C_L includes probe and jig capacitance.
- B. All inputs are supplied by generators having the following characteristics: $PRR \leq 10$ MHz, $Z_O = 50 \Omega$, $t_r/t_f \leq 30$ ns.
- C. The outputs are measured one at a time, with one transition per measurement.
- D. I/Os are configured as inputs.

Figure 20. Reset Load Circuits and Voltage Waveforms

8 Detailed Description

8.1 Overview

The bidirectional voltage-level translation in the TCA6408A-Q1 is provided through V_{CCI} . V_{CCI} must be connected to the V_{CC} of the external SCL/SDA lines. This indicates the V_{CC} level of the I²C bus to the TCA6408A-Q1. The voltage level on the P-port of the TCA6408A-Q1 is determined by V_{CCP} .

The TCA6408A-Q1 consists of one 8-bit Configuration (input or output selection), Input, Output, and Polarity Inversion (active high) 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 TCA6408A-Q1 in the event of a timeout or other improper operation by asserting a low in the $\overline{\text{RESET}}$ input. The power-on reset puts the registers in their default state and initializes the I²C/SMBus state machine. The $\overline{\text{RESET}}$ pin causes the same reset/initialization to occur without depowering the part.

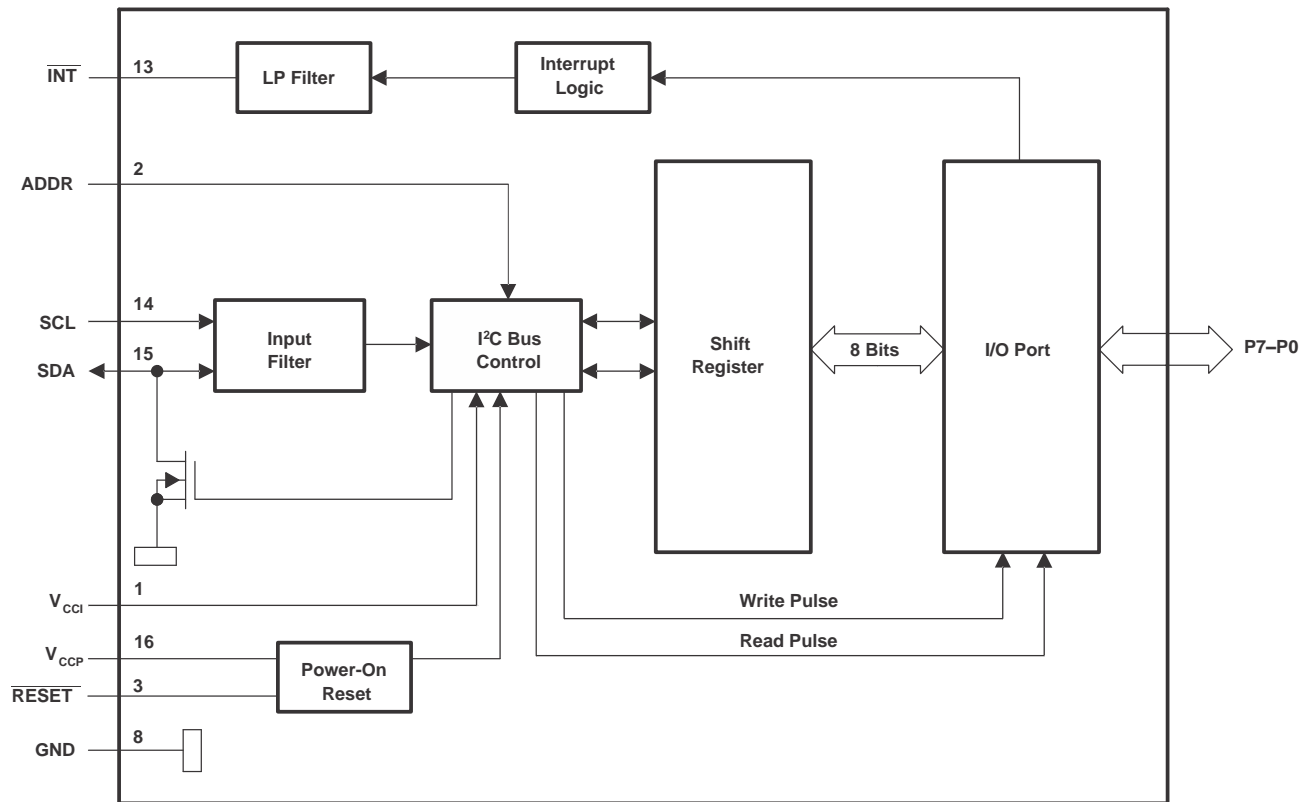
The TCA6408A-Q1 open-drain interrupt ($\overline{\text{INT}}$) output is activated when any input state differs from its corresponding Input Port Register state and is used to indicate to the system master that an input state has changed.

$\overline{\text{INT}}$ can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I²C bus. Thus, the TCA6408A-Q1 can remain a simple slave device.

The device P-port outputs have high-current sink capabilities for directly driving LEDs while consuming low device current.

One hardware pin (ADDR) can be used to program and vary the fixed I²C address and allow up to two devices to share the same I²C bus or SMBus.

8.2 Functional Block Diagrams



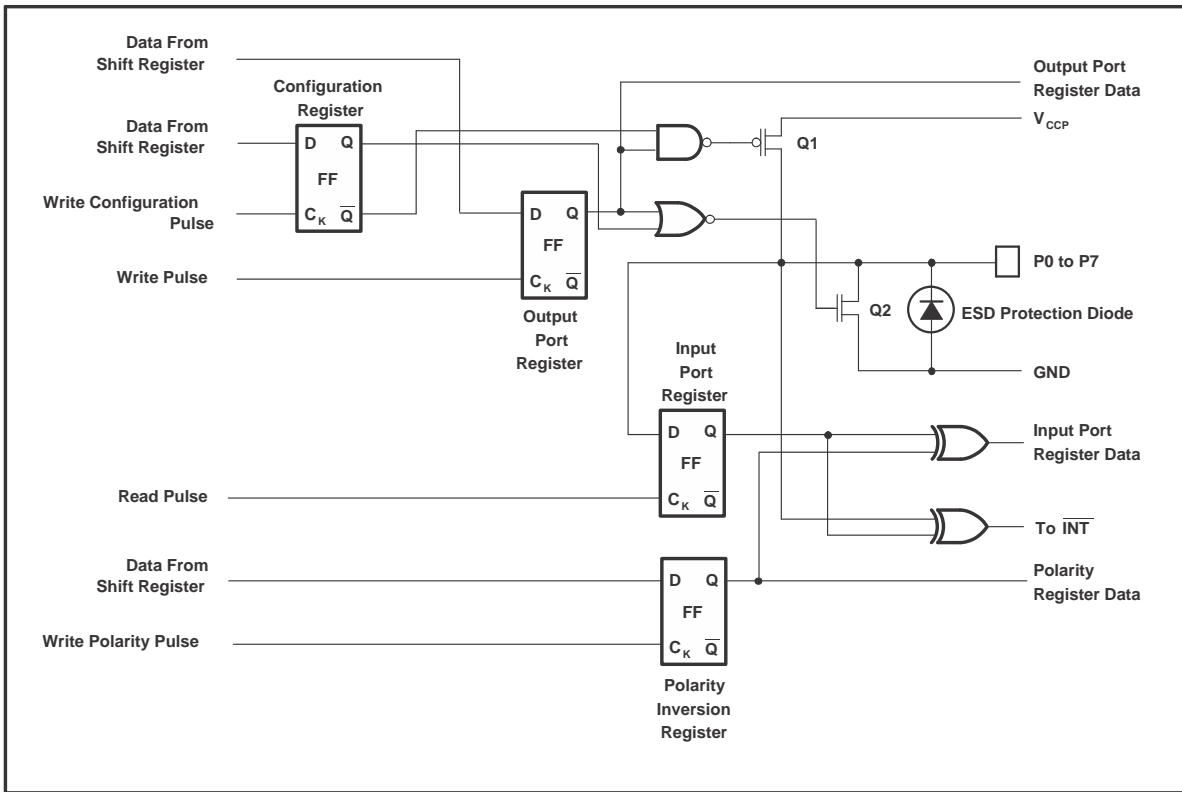
Copyright © 2016, Texas Instruments Incorporated

All pin numbers shown are for the PW package.

All I/Os are set to inputs at reset.

Figure 21. Logic Diagram (Positive Logic)

Functional Block Diagrams (continued)



Copyright © 2016, Texas Instruments Incorporated

On power up or reset, all registers return to default values.

Figure 22. Simplified Schematic of P0 to P7

8.3 Feature Description

8.3.1 Voltage Translation

Table 1 shows some common supply voltage options for voltage translation between the I²C bus and the P-ports of the TCA6408A-Q1.

Table 1. Voltage Translation

V _{CCI} (SCL AND SDA OF I ² C MASTER) (V)	V _{CCP} (P-PORT) (V)
1.8	1.8
1.8	2.5
1.8	3.3
2.5	1.8
2.5	2.5
2.5	3.3
3.3	1.8
3.3	2.5
3.3	3.3

8.3.2 I/O Port

When an I/O is configured as an input, FETs Q1 and Q2 are off, which creates a high-impedance input. The input voltage may be raised above V_{CC} to a maximum of 3.6 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 must not exceed the recommended levels for proper operation.

8.3.3 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 or when 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 $\overline{\text{INT}}$.

Reading from or writing to another device does not affect the interrupt circuit, and a pin configured as an output cannot cause an interrupt. Changing an I/O from an output to an input may cause a false interrupt to occur if the state of the pin does not match the contents of the Input Port register.

The $\overline{\text{INT}}$ output has an open-drain structure and requires pull-up resistor to V_{CCP} or V_{CCI}, depending on the application. $\overline{\text{INT}}$ must be connected to the voltage source of the device that requires the interrupt information.

8.3.4 Reset Input ($\overline{\text{RESET}}$)

The $\overline{\text{RESET}}$ input can be asserted to initialize the system while keeping the V_{CCP} at its operating level. A reset can be accomplished by holding the $\overline{\text{RESET}}$ pin low for a minimum of t_w. The TCA6408A-Q1 registers and I²C/SMBus state machine are changed to their default state when $\overline{\text{RESET}}$ is low (0). When $\overline{\text{RESET}}$ is high (1), the I/O levels at the P-port can be changed externally or through the master. This input requires a pull-up resistor to V_{CCI}, if no active connection is used. It is not recommended to assert the $\overline{\text{RESET}}$ pin during communication with the TCA6408A-Q1. Assertion of $\overline{\text{RESET}}$ during communication can result in data corruption.

8.4 Device Functional Modes

8.4.1 Power-On Reset (POR)

When power (from 0 V) is applied to V_{CCP} , an internal power-on reset holds the TCA6408A-Q1 in a reset condition until V_{CCP} has reached V_{PORR} . At that time, the reset condition is released, and the TCA6408A-Q1 registers and I²C/SMBus state machine initialize to their default states. After that, V_{CCP} must be lowered to below V_{PORF} and back up to the operating voltage for a power-reset cycle.

8.4.2 Powered-Up

When power has been applied to both V_{CCP} and V_{CCI} and a POR has taken place, the device is in a functioning mode. The device is always ready to receive new requests via the I²C bus.

8.5 Programming

8.5.1 I²C Interface

The TCA6408A-Q1 has a standard bidirectional I²C interface that is controlled by a master device in order to be configured or read the status of this device. Each slave on the I²C bus has a specific device address to differentiate between other slave devices that are on the same I²C bus. Many slave devices require configuration upon startup to set the behavior of the device. This is typically done when the master accesses internal register maps of the slave, which have unique register addresses. A device can have one or multiple registers where data is stored, written, or read.

The physical I²C interface consists of the serial clock (SCL) and serial data (SDA) lines. Both SDA and SCL lines must be connected to V_{CC} through a pull-up resistor. The size of the pull-up resistor is determined by the amount of capacitance on the I²C lines. (For further details, see the application report, *I²C Pull-up Resistor Calculation (SLVA689)*). Data transfer may be initiated only when the bus is idle. A bus is considered idle if both SDA and SCL lines are high after a STOP condition. See [Figure 23](#) and [Figure 24](#).

The following is the general procedure for a master to access a slave device:

1. If a master wants to send data to a slave:
 - Master-transmitter sends a START condition and addresses the slave-receiver.
 - Master-transmitter sends data to slave-receiver.
 - Master-transmitter terminates the transfer with a STOP condition.
2. If a master wants to receive or read data from a slave:
 - Master-receiver sends a START condition and addresses the slave-transmitter.
 - Master-receiver sends the requested register to read to slave-transmitter.
 - Master-receiver receives data from the slave-transmitter.

Programming (continued)

- Master-receiver terminates the transfer with a STOP condition.

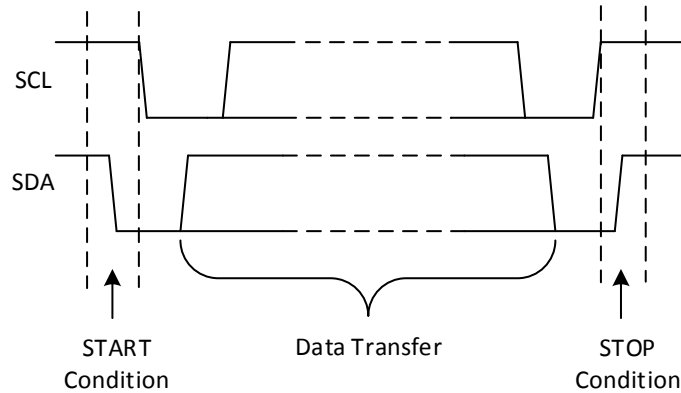


Figure 23. Definition of Start and Stop Conditions

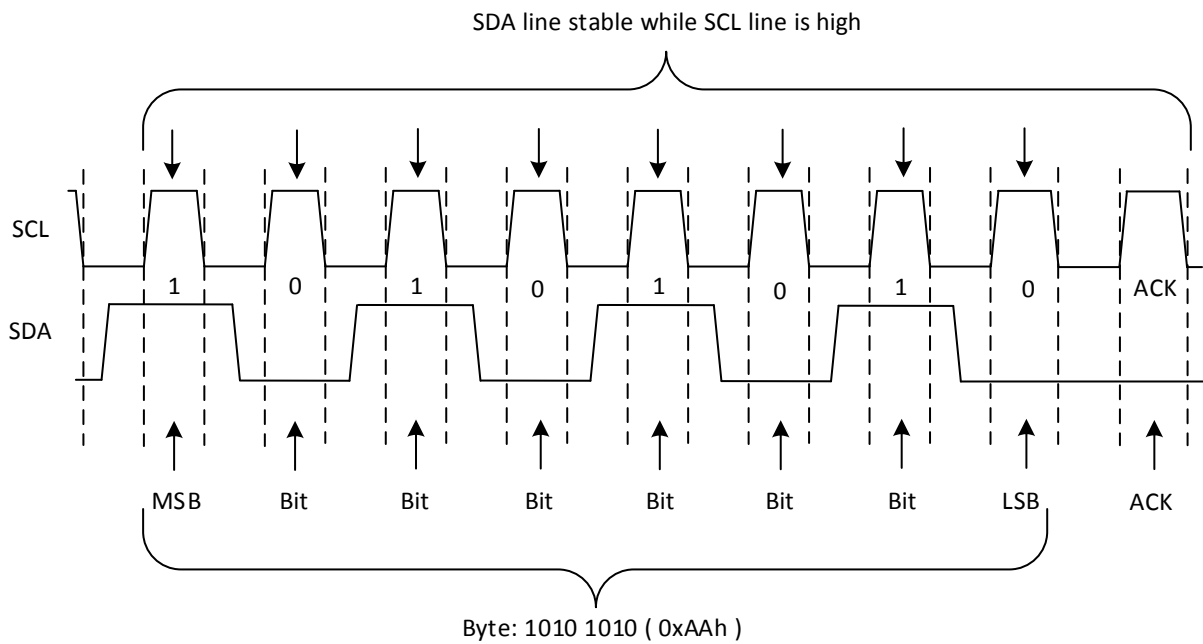


Figure 24. Bit Transfer

Table 2 shows the interface definition for the TCA6408A-Q1 device.

Table 2. Interface Definition

BYTE	BIT							
	7 (MSB)	6	5	4	3	2	1	0 (LSB)
I ² C slave address	L	H	L	L	L	L	ADDR	R/W
I/O data bus	P7	P6	P5	P4	P3	P2	P1	P0

8.5.2 Bus Transactions

Data must be sent to and received from the slave devices, and this is accomplished by reading from or writing to registers in the slave device.

Programming (continued)

Registers are locations in the memory of the slave which contain information, whether it be the configuration information or some sampled data to send back to the master. The master must write information to these registers in order to instruct the slave device to perform a task.

While it is common to have registers in I²C slaves, note that not all slave devices will have registers. Some devices are simple and contain only 1 register, which may be written to directly by sending the register data immediately after the slave address, instead of addressing a register. An example of a single-register device is an 8-bit I²C switch, which is controlled via I²C commands. Since it has 1 bit to enable or disable a channel, there is only 1 register needed, and the master merely writes the register data after the slave address, skipping the register number.

8.5.2.1 Writes

To write on the I²C bus, the master sends a START condition on the bus with the address of the slave, as well as the last bit (the R/W bit) set to 0, which signifies a write. After the slave sends the acknowledge bit, the master then sends the register address of the register to which it wishes to write. The slave will acknowledge again, letting the master know it is ready. After this, the master starts sending the register data to the slave until the master has sent all the data necessary (which is sometimes only a single byte), and the master terminates the transmission with a STOP condition.

Figure 25 and Figure 26 show an example of writing a single byte to a slave register.

- Master controls SDA line
- Slave controls SDA line

Write to one register in a device

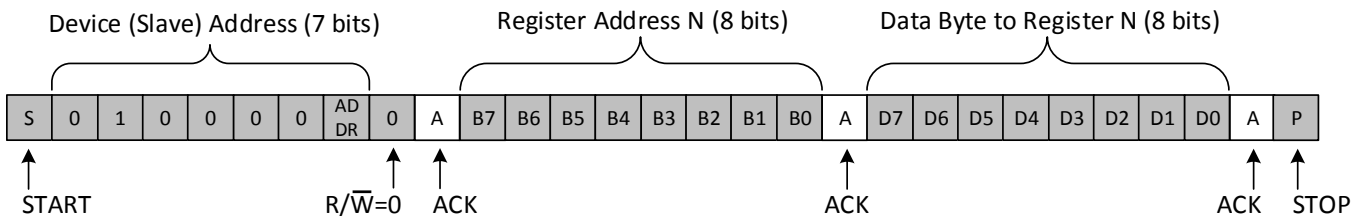


Figure 25. Write to Register

- Master controls SDA line
- Slave controls SDA line

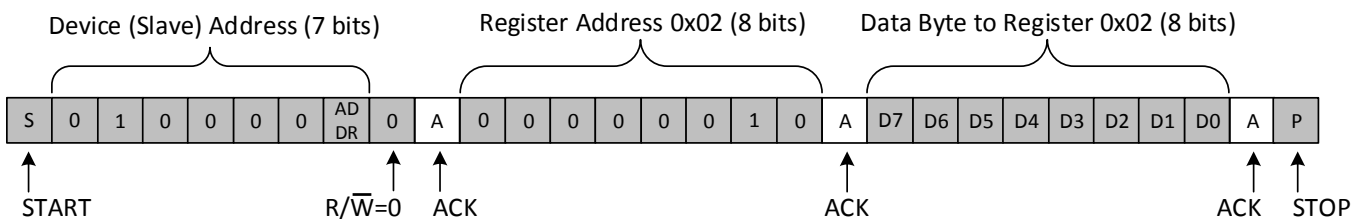


Figure 26. Write to the Polarity Inversion Register

Programming (continued)

8.5.2.2 Reads

Reading from a slave is very similar to writing, but requires some additional steps. In order to read from a slave, the master must first instruct the slave which register it wishes to read from. This is done by the master starting off the transmission in a similar fashion as the write, by sending the address with the R/W bit equal to 0 (signifying a write), followed by the register address it wishes to read from. When the slave acknowledges this register address, the master sends a START condition again, followed by the slave address with the R/W bit set to 1 (signifying a read). This time, the slave acknowledges the read request, and the master releases the SDA bus but continues supplying the clock to the slave. During this part of the transaction, the master becomes the master-receiver, and the slave becomes the slave-transmitter.

The master continues to send out the clock pulses, but releases the SDA line so that the slave can transmit data. At the end of every byte of data, the master sends an ACK to the slave, letting the slave know that it is ready for more data. When the master has received the number of bytes it is expecting, it sends a NACK, signaling to the slave to halt communications and release the bus. The master follows this up with a STOP condition.

Read transactions that are performed without writing to the address of the device and simply supply the command byte will result in a NACK.

Figure 27 and Figure 28 show an example of reading a single byte from a slave register.

- Master controls SDA line
- Slave controls SDA line

Read from one register in a device

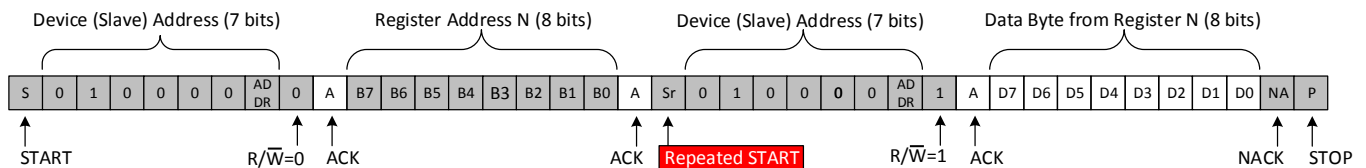
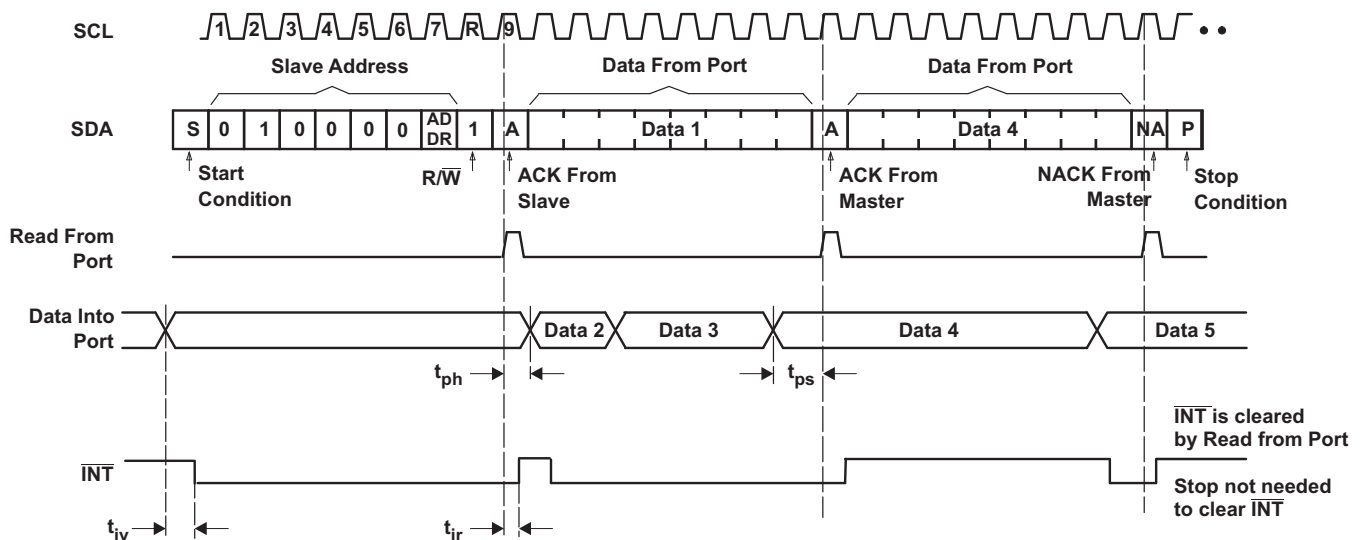


Figure 27. Read from Register



- A. Transfer of data can be stopped at any time by a Stop condition. When this occurs, data present at the latest acknowledge phase is valid (output mode). It is assumed that the command byte previously has been set to 00 (read Input Port Register).
- B. This figure eliminates the command byte transfer, a restart, and slave address call between the initial slave address call and actual data transfer from P-port (see Figure 27).

Figure 28. Read from Input Port Register

8.6 Register Map

8.6.1 Device Address

The address of the TCA6408A-Q1 is shown in [Figure 29](#).

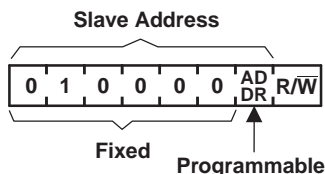


Figure 29. TCA6408A-Q1 Address

[Table 3](#) shows the TCA6408A-Q1 address reference.

Table 3. Address Reference

ADDR	I ² C BUS SLAVE ADDRESS
L	32 (decimal), 20 (hexadecimal)
H	33 (decimal), 21 (hexadecimal)

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

8.6.2 Control Register and Command Byte

Following the successful acknowledgment of the address byte, the bus master sends a command byte (see [Table 4](#)), which is stored in the Control Register in the TCA6408A-Q1. Two bits of this data byte state both the operation (read or write) and the internal registers (Input, Output, Polarity Inversion, or Configuration) that is affected. This register can be written or read through the I²C bus. The command byte is sent only during a write transmission. See [Figure 30](#).

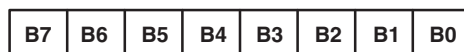


Figure 30. Control Register Bits

Table 4. Command Byte

CONTROL REGISTER BITS								COMMAND BYTE (HEX)	REGISTER	PROTOCOL	POWER-UP DEFAULT
B7	B6	B5	B4	B3	B2	B1	B0				
0	0	0	0	0	0	0	0	00	Input Port	Read byte	xxxx xxxx
0	0	0	0	0	0	0	1	01	Output Port	Read/write byte	1111 1111
0	0	0	0	0	0	1	0	02	Polarity Inversion	Read/write byte	0000 0000
0	0	0	0	0	0	1	1	03	Configuration	Read/write byte	1111 1111

8.6.3 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. They act only on read operation. Writes to this register 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 I²C device that the Input Port Register will be accessed next. See [Table 5](#).

Table 5. Register 0 (Input Port Register)

BIT	I-7	I-6	I-5	I-4	I-3	I-2	I-1	I-0
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. See [Table 6](#).

Table 6. Register 1 (Output Port Register)

BIT	O-7	O-6	O-5	O-4	O-3	O-2	O-1	O-0
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 polarity of the corresponding port pin is inverted. If a bit in this register is cleared (written with a 0), the original polarity of the corresponding port pin is retained. See [Table 7](#).

Table 7. Register 2 (Polarity Inversion Register)

BIT	N-7	N-6	N-5	N-4	N-3	N-2	N-1	N-0
DEFAULT	0	0	0	0	0	0	0	0

The Configuration Register (register 3) configures the direction of the I/O pins. If a bit in this register is set to 1, the corresponding port pin is enabled as an input with a high-impedance output driver. If a bit in this register is cleared to 0, the corresponding port pin is enabled as an output. See [Table 8](#).

Table 8. Register 3 (Configuration Register)

BIT	C-7	C-6	C-5	C-4	C-3	C-2	C-1	C-0
DEFAULT	1	1	1	1	1	1	1	1

9 Application and Implementation

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. Customers should validate and test their design implementation to confirm system functionality.

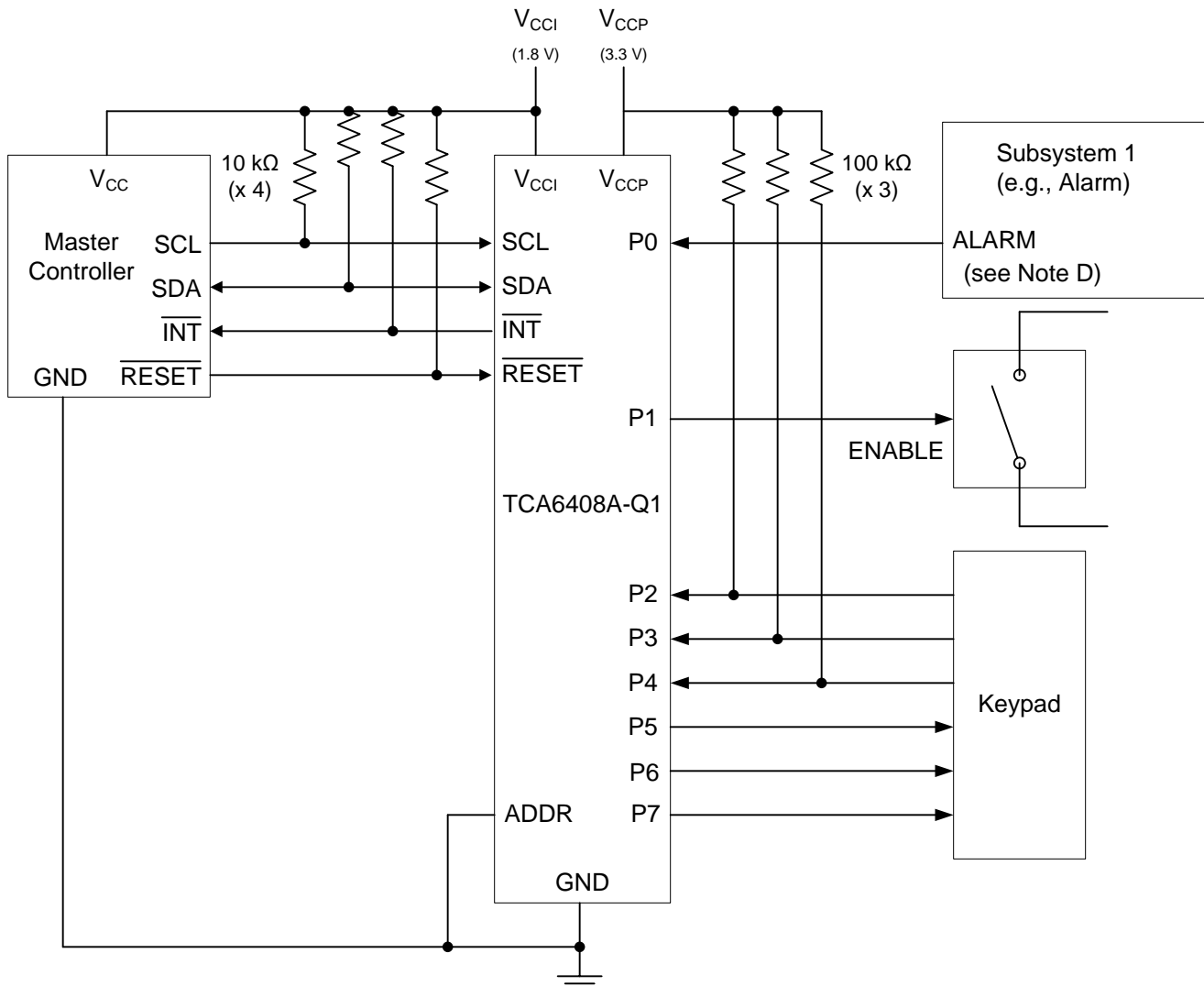
9.1 Application Information

Applications of the TCA6408A-Q1 has this device connected as a slave to an I²C master (processor), and the I²C bus may contain any number of other slave devices. The TCA6408A-Q1 is in a remote location from the master, placed close to the GPIOs to which the master needs to monitor or control.

A typical application of the TCA6408A-Q1 operates with a lower voltage on the master side (V_{CC1}), and a higher voltage on the P-port side (V_{CCP}). The P-ports can be configured as outputs connected to inputs of devices such as enable, reset, power select, the gate of a switch, and LEDs. The P-ports can also be configured as inputs to receive data from interrupts, alarms, status outputs, or push buttons.

9.2 Typical Application

Figure 31 shows an application in which the TCA6408A-Q1 can be used.



Copyright © 2016, Texas Instruments Incorporated

- A. Device address configured as 0100000 for this example.
- B. P0 and P2–P4 are configured as inputs.
- C. P1 and P5–P7 are configured as outputs.
- D. Resistors are required for inputs (on P-port) that may float. If a driver to an input will never let the input float, a resistor is not needed. Outputs (in the P-port) do not need pull-up resistors.

Figure 31. Typical Application Schematic

9.2.1 Design Requirements

9.2.1.1 Calculating Junction Temperature and Power Dissipation

When designing with the TCA6408A-Q1, it is important that the *Recommended Operating Conditions* not be violated. Many of the parameters of this device are rated based on junction temperature. So junction temperature must be calculated in order to verify that safe operation of the device is met. The basic equation for junction temperature is shown in Equation 1.

$$T_j = T_A + (\theta_{JA} \times P_d) \tag{1}$$

Typical Application (continued)

θ_{JA} is the standard junction to ambient thermal resistance measurement of the package, as seen in [Thermal Information](#) table. P_d is the total power dissipation of the device, and the approximation is shown in [Equation 2](#).

$$P_d \approx (I_{CC_STATIC} \times V_{CC}) + \sum P_{d_PORT_L} + \sum P_{d_PORT_H} \quad (2)$$

[Equation 2](#) is the approximation of power dissipation in the device. The equation is the static power plus the summation of power dissipated by each port (with a different equation based on if the port is outputting high, or outputting low. If the port is set as an input, then power dissipation is the input leakage of the pin multiplied by the voltage on the pin). Note that this ignores power dissipation in the \overline{INT} and SDA pins, assuming these transients to be small. They can easily be included in the power dissipation calculation by using [Equation 3](#) to calculate the power dissipation in \overline{INT} or SDA while they are pulling low, and this gives maximum power dissipation.

$$P_{d_PORT_L} = (I_{OL} \times V_{OL}) \quad (3)$$

[Equation 3](#) shows the power dissipation for a single port which is set to output low. The power dissipated by the port is the V_{OL} of the port multiplied by the current it is sinking.

$$P_{d_PORT_H} = (I_{OH} \times (V_{CC} - V_{OH})) \quad (4)$$

[Equation 4](#) shows the power dissipation for a single port which is set to output high. The power dissipated by the port is the current sourced by the port multiplied by the voltage drop across the device (difference between V_{CC} and the output voltage).

9.2.1.2 Minimizing I_{CC} When I/O is Used to Control LEDs

When the I/Os are used to control LEDs, normally they are connected to V_{CC} through a resistor as shown in [Figure 31](#). 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} . The ΔI_{CC} parameter in the [Electrical Characteristics](#) table shows how I_{CC} increases as V_{IN} becomes lower than V_{CC} . Designs that must minimize current consumption, such as battery power applications, must consider maintaining the I/O pins greater than or equal to V_{CC} when the LED is off.

[Figure 32](#) shows a high-value resistor in parallel with the LED. [Figure 33](#) shows V_{CC} less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V_{IN} at or above V_{CC} and prevent additional supply current consumption when the LED is off.

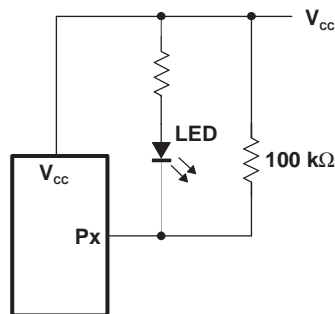


Figure 32. High-Value Resistor in Parallel With LED

Typical Application (continued)

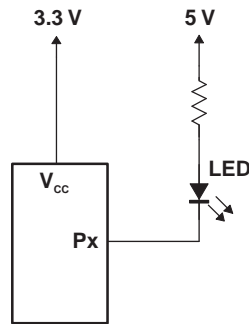


Figure 33. Device Supplied by a Low Voltage

9.2.2 Detailed Design Procedure

The pull-up resistors, R_p , for the SCL and SDA lines need to be selected appropriately and take into consideration the total capacitance of all slaves on the I²C bus. The minimum pull-up resistance is a function of V_{CC} , $V_{OL(max)}$, and I_{OL} as shown in Equation 5.

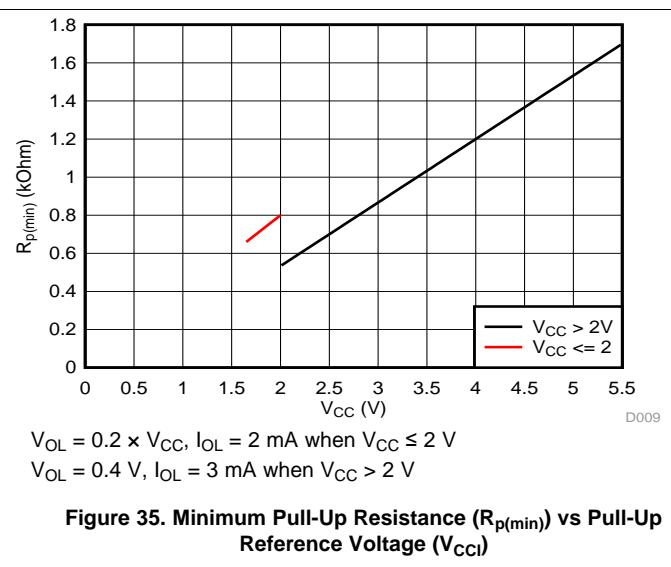
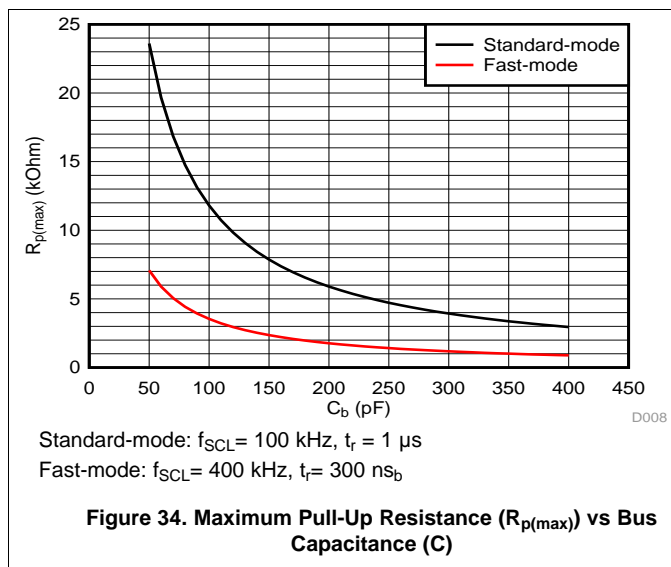
$$R_{p(min)} = \frac{V_{CC} - V_{OL(max)}}{I_{OL}} \tag{5}$$

The maximum pull-up resistance is a function of the maximum rise time, t_r (300 ns for fast-mode operation, $f_{SCL} = 400$ kHz) and bus capacitance, C_b as shown in Equation 6.

$$R_{p(max)} = \frac{t_r}{0.8473 \times C_b} \tag{6}$$

The maximum bus capacitance for an I²C bus must not exceed 400 pF for standard-mode or fast-mode operation. The bus capacitance can be approximated by adding the capacitance of the TCA6408A-Q1, C_i for SCL or C_{io} for SDA, the capacitance of wires, connections, traces, and the capacitance of additional slaves on the bus.

9.2.3 Application Curves



10 Power Supply Recommendations

10.1 Power-On Reset Requirements

In the event of a glitch or data corruption, TCA6408A-Q1 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 36](#) and [Figure 37](#).

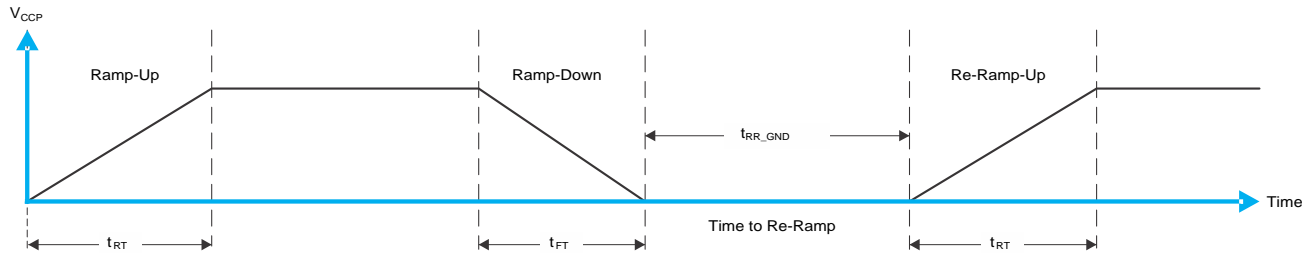


Figure 36. V_{CCP} is Lowered Below 0.2 V and then Ramped Up to V_{CCP}

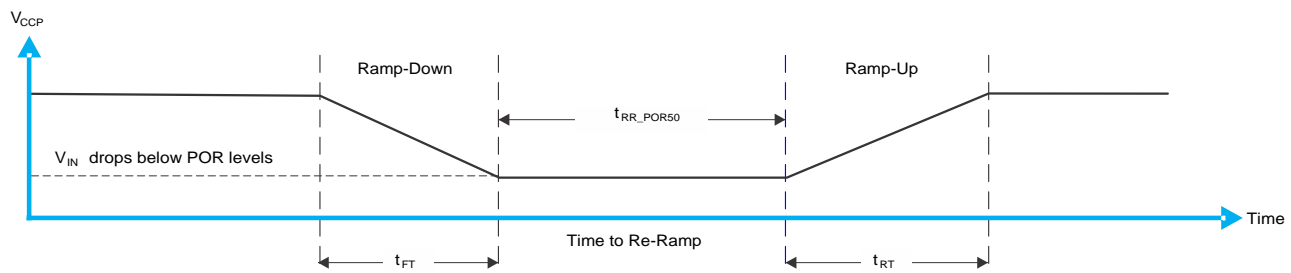


Figure 37. V_{CCP} is Lowered Below the POR Threshold, then Ramped Back Up to V_{CCP}

[Table 9](#) specifies the performance of the power-on reset feature for TCA6408A-Q1 for both types of power-on reset.

Table 9. Recommended Supply Sequencing and Ramp Rates at T_A = 25°C⁽¹⁾

PARAMETER			MIN	TYP	MAX	UNIT
t _{FT}	Fall rate	See Figure 36	0.1		2000	ms
t _{RT}	Rise rate	See Figure 36	0.1		2000	ms
t _{RR_GND}	Time to re-ramp (when V _{CCP} drops to GND)	See Figure 36	1			μs
t _{RR_POR50}	Time to re-ramp (when V _{CCP} drops to V _{POR_MIN} – 50 mV)	See Figure 37	1			μs
V _{CCP_GH}	Level that V _{CCP} can glitch down from V _{CCP} , but not cause a functional disruption when t _{VCCP_GW} = 1 μs	See Figure 38			1.2	V
V _{CCP_MV}	The minimum voltage that VCC can glitch down to without causing a reset (V _{CC_GH} must not be violated)	See Figure 38	1.5			V
t _{VCCP_GW}	Glitch width that does not cause a functional disruption when t _{VCCP_GH} = 0.5 × V _{CCx}	See Figure 38			10	μs
V _{PORF}	Voltage trip point of POR on falling V _{CCP}		0.6	1		V
V _{PORR}	Voltage trip point of POR on rising V _{CCP}			1.2	1.5	V

(1) Not tested. Specified by design.

Glitches in the power supply can also affect the power-on reset performance of this device. The glitch width ($t_{V_{CCP_GW}}$) and height (V_{CCP_GH}) are dependent on each other. The bypass capacitance, source impedance, and device impedance are factors that affect power-on reset performance. [Figure 38](#) and [Table 9](#) provide more information on how to measure these specifications.

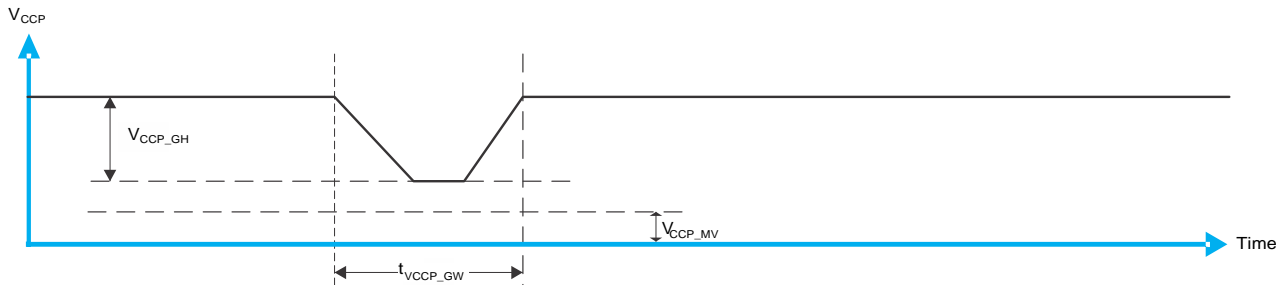


Figure 38. Glitch Width and Glitch Height

V_{POR} is critical to the power-on reset. V_{PORR} / V_{PORF} is the voltage level at which the reset condition is released/asserted and all the registers and the I²C/SMBus state machine are initialized to their default states (upon a release of a reset condition). The voltage that the device has a reset condition asserted or released differs based on whether V_{CCP} is being lowered to or from 0. [Figure 39](#) and [Table 9](#) provide more details on this specification.

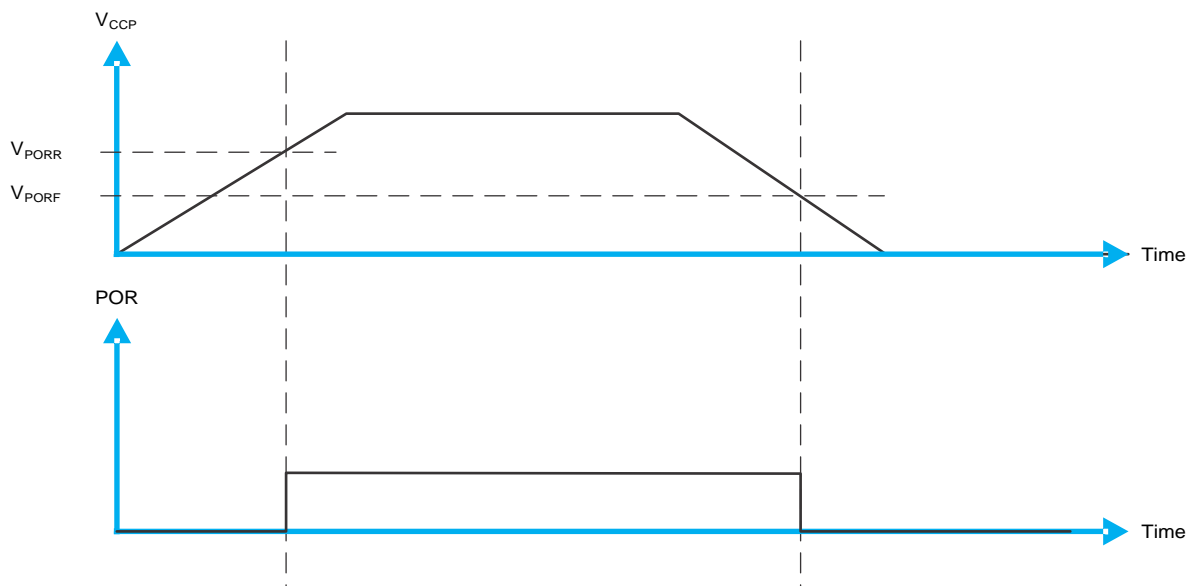


Figure 39. Power On Reset

11 Layout

11.1 Layout Guidelines

For printed circuit board (PCB) layout of the TCA6408A-Q1, common PCB layout practices must be followed, but additional concerns related to high-speed data transfer such as matched impedances and differential pairs are not a concern for I²C signal speeds.

In all PCB layouts, it is a best practice to avoid right angles in signal traces, to fan out signal traces away from each other upon leaving the vicinity of an integrated circuit (IC), and to use thicker trace widths to carry higher amounts of current that commonly pass through power and ground traces. By-pass and de-coupling capacitors are commonly used to control the voltage on the V_{CCI} and V_{CCP} pins, using a larger capacitor to provide additional power in the event of a short power supply glitch and a smaller capacitor to filter out high-frequency ripple. These capacitors must be placed as close to the TCA6408A-Q1 as possible. These best practices are shown in [Layout Example](#).

For the layout example provided in [Layout Example](#), it is possible to fabricate a PCB with only 2 layers by using the top layer for signal routing and the bottom layer as a split plane for power (V_{CCI} and V_{CCP}) and ground (GND). However, a 4-layer board is preferable for boards with higher density signal routing. On a 4-layer PCB, it is common to route signals on the top and bottom layer, dedicate one internal layer to a ground plane, and dedicate the other internal layer to a power plane. In a board layout using planes or split planes for power and ground, vias are placed directly next to the surface mount component pad which needs to attach to V_{CCI}, V_{CCP}, or GND and the via is connected electrically to the internal layer or the other side of the board. Vias are also used when a signal trace needs to be routed to the opposite side of the board, but this technique is not demonstrated in [Layout Example](#).

11.2 Layout Example

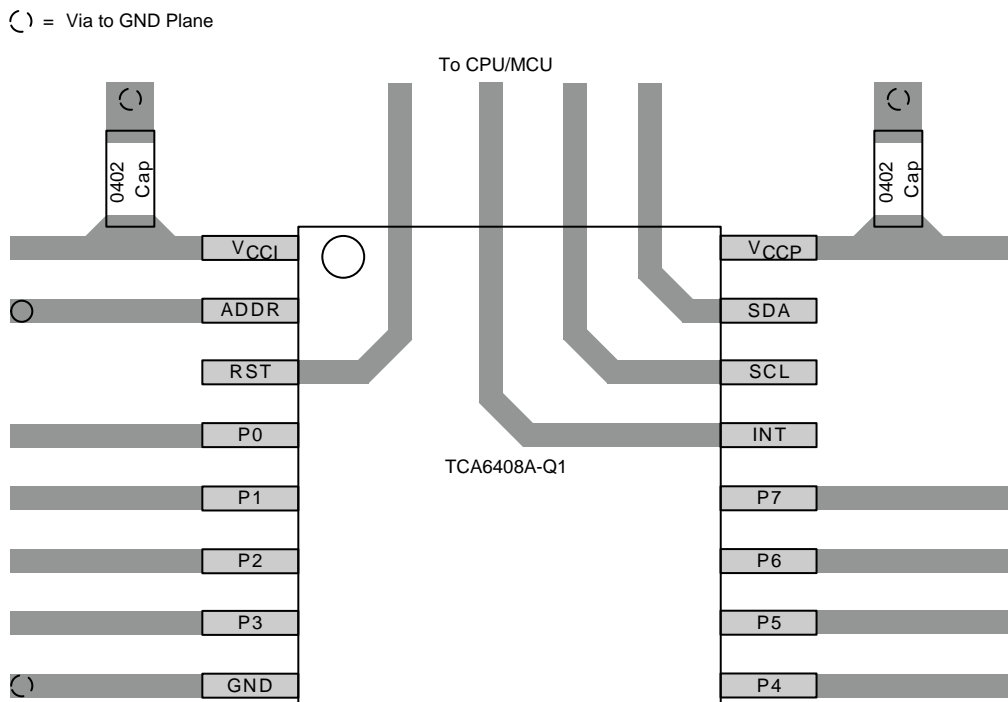


Figure 40. Example Layout (PW Package)

12 Device and Documentation Support

12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

12.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.4 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.

12.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

13 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TCA6408AQPWRQ1	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	6408AQ	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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

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

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

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

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

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

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

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

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

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

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

OTHER QUALIFIED VERSIONS OF TCA6408A-Q1 :

- Catalog: [TCA6408A](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TCA6408AQPWRQ1	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCA6408AQPWRQ1	TSSOP	PW	16	2000	367.0	367.0	35.0

PW0016A



PACKAGE OUTLINE

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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.

EXAMPLE BOARD LAYOUT

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



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.

EXAMPLE STENCIL DESIGN

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated