I²C to 8-Bit GPIO Expander with Interrupt

Features

- I²C-Bus to 8-Bit GPIO Expander
- Operating Power Supply Voltage from 1.65 V to 5.5 V
- Low Standby Current
- 400-kHz Fast-Mode I²C-Bus
- 5-V Tolerant I/Os
- Open-Drain Active Low Interrupt Output ($\overline{INT}$)
- Configurable Slave Address with 3 Address Pins
- Internal Power-on Reset
- Power-up with all Channels Configured as Inputs with Weak Pull-up Resistors
- ESD Protection Exceeds JESD 22
  - 4000-V Human Body Model
  - 1500-V Charged-Device Model

Applications

- Servers/Storages
- Routers (Telecom Switching Equipment)
- Personal Computers

Description

The TPT29554A is an 8-bit GPIO expander with interruption and weak pull-up resistors for I²C-bus applications. The power supplier voltage range is from 1.65 V to 5.5 V, allowing the TPT29554A to interconnect with 1.8-V microcontrollers.

The TPT29554A contains the register set of 8-bit Configuration, Input, Output, and Polarity Inversion registers. The open-drain interrupt ($\overline{INT}$) output is changeable when any input state changes from its related register state and is used to indicate the system master that an input state has changed. $\overline{INT}$ can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I²C bus. Thus, the TPT29554A can remain a simple slave device. The power-on reset sets the registers to their default values and initializes the device state machine.

All input/output pins have internal weak pull-up resistors to remove external components. Three hardware pins (A0, A1, A2) select the fixed I²C-bus address and allow up to eight devices to share the same I²C bus.

TPT29554A is available in the TSSOP16 package.

Typical Application Circuit

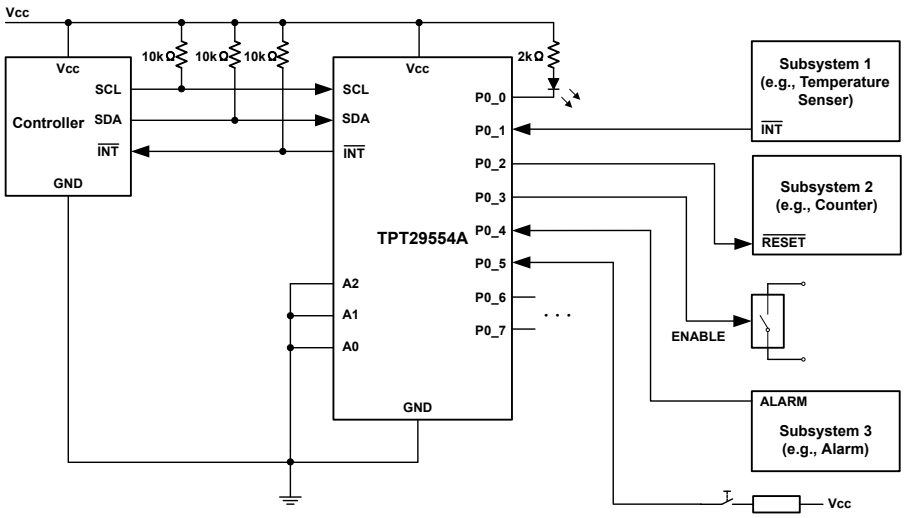


Table of Contents

Revision History

Date	Revision	Notes
2024-09-14	Rev.P.0	Initial version
2024-10-21	Rev.A.0	Released version

Pin Configuration and Functions

TSSOP16 Package
Top View

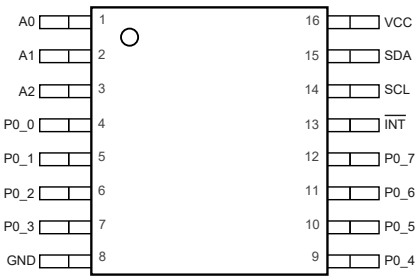


Table 1. Pin Functions: TPT29554

Pin	Name	I/O	Description
1	A0	Input	Address input 0. Connect directly to VCC or ground
2	A1	Input	Address input 1. Connect directly to VCC or ground
3	A2	Input	Address input 2. Connect directly to VCC or ground
8	GND	GND	Ground
13	$\overline{INT}$	Output	Interrupt output. Connect to VCC through a pull-up resistor
4	P0_0	I/O	P-port I/O. Push-pull design structure. At power on, P0_0 is configured as an input
5	P0_1	I/O	P-port I/O. Push-pull design structure. At power on, P0_1 is configured as an input
6	P0_2	I/O	P-port I/O. Push-pull design structure. At power on, P0_2 is configured as an input
7	P0_3	I/O	P-port I/O. Push-pull design structure. At power on, P0_3 is configured as an input
9	P0_4	I/O	P-port I/O. Push-pull design structure. At power on, P0_4 is configured as an input
10	P0_5	I/O	P-port I/O. Push-pull design structure. At power on, P0_5 is configured as an input
11	P0_6	I/O	P-port I/O. Push-pull design structure. At power on, P0_6 is configured as an input
12	P0_7	I/O	P-port I/O. Push-pull design structure. At power on, P0_7 is configured as an input
14	SCL	Input	Serial clock bus. Connect to VCC through a pull-up resistor
15	SDA	Input	Serial data bus. Connect to VCC through a pull-up resistor
16	VCC	Supply	Supply voltage

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
V_{CC}	Supply Voltage	−0.5	6	V
V_I	Input Voltage	−0.5	6	V
V_O	Output Voltage	−0.5	6	V
I_{IK}	Input Clamp Current, $V_I < 0$		−20	mA
I_{OK}	Output Clamp Current, $V_O < 0$		−20	mA
I_{IOK}	Input-Output Clamp Current, $V_O < 0$ or $V_O > V_{CC}$		±20	mA
I_{OL}	Continuous Output Low Current, V_O = 0 to V_{CC}		50	mA
I_{OH}	Continuous Output High Current, V_O = 0 to V_{CC}		−50	mA
I_{CC}	Continuous Current through GND		−250	mA
	Continuous Current through V_{CC}		160	mA
T_J	Maximum Junction Temperature		150	°C
T_{stg}	Storage Temperature	−65	150	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) This data was taken with the JEDEC low effective thermal conductivity test board.
(3) This data was taken with the JEDEC standard multilayer test boards.

ESD, Electrostatic Discharge Protection

Parameter		Condition	Value	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	±4	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	±1.5	kV

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

Recommended Operating Conditions

Over-operating free-air temperature range (unless otherwise noted).

Parameter			Min	Max	Unit
V_{CC}	Supply Voltage		1.65	5.5	V
V_{IH}	High-Level Input Voltage	SCL, SDA	0.7 × V_{CC}	V_{CC}	V
		A2 ~ A0, P0_7 ~ P0_0	0.7 × V_{CC}	5.5	V
V_{IL}	Low-Level Input Voltage	SCL, SDA	−0.5	0.3 × V_{CC}	V
		A2 ~ A0, P0_7 ~ P0_0	−0.5	0.3 × V_{CC}	V
I_{OH}	High-Level Output Current	P0_7 ~ P0_0		−10	mA
I_{OL}	Low-Level Output Current	P0_7 ~ P0_0		25	mA
		$\overline{INT}$, SDA		6	mA
T_A	Operating Temperature Range	V_{CC} = 1.65 ~ 3.6 V	−40	125	°C
		V_{CC} = 4.5 ~ 5.5 V	−40	105	°C

(1) The algebraic convention, in which the least positive (most negative) limit is designated as the minimum, is used in this datasheet.

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
TSSOP16	120	61	°C/W

Electrical Characteristics

All test conditions: V_{CC} = 1.65 V ~ 3.6 V, T_A = −40 ~ +125°C; V_{CC} = 4.5 V ~ 5.5 V, T_A = −40 ~ +105°C, unless otherwise noted.

Parameter		Conditions		Min	Typ	Max	Unit
Input Electrical Specifications							
V_{POR}	Power-on Reset Voltage, V_{CC} Rising	V_I = V_{CC} or GND; I_O = 0 mA			1.25	1.5	V
	Power-on Reset Voltage, V_{CC} Falling	V_I = V_{CC} or GND; I_O = 0 mA		0.7	1.2		V
I_{OL}	Low-Level Output Current, SDA	V_{OL} = 0.4 V; V_{CC} = 1.65 V to 5.5 V		3			mA
	Low-Level Output Current, INT	V_{OL} = 0.4 V; V_{CC} = 1.65 V to 5.5 V		3			mA
V_{OL}	Low-Level Output Voltage, P port	I_{OL} = 8 mA; V_{CC} = 1.65 V				0.5	V
		I_{OL} = 8 mA; V_{CC} = 2.3 V				0.5	V
		I_{OL} = 8 mA; V_{CC} = 3.0 V				0.5	V
		I_{OL} = 8 mA; V_{CC} = 4.5 V				0.5	V
	Low-Level Output Voltage, P port	I_{OL} = 10 mA; V_{CC} = 1.65 V				0.7	V
		I_{OL} = 10 mA; V_{CC} = 2.3 V				0.7	V
		I_{OL} = 10 mA; V_{CC} = 3.0 V				0.7	V
		I_{OL} = 10 mA; V_{CC} = 4.5 V				0.7	V
V_{OH}	High-Level Output Voltage, P port	I_{OH} = −8 mA; V_{CC} = 1.65 V		1.2			V
		I_{OH} = −8 mA; V_{CC} = 2.3 V		1.8			V
		I_{OH} = −8 mA; V_{CC} = 3.0 V		2.6			V
		I_{OH} = −8 mA; V_{CC} = 4.75 V		4.1			V
	High-Level Output Voltage, P port	I_{OH} = −10 mA; V_{CC} = 1.65 V		1.0			V
		I_{OH} = −10 mA; V_{CC} = 2.3 V		1.7			V
		I_{OH} = −10 mA; V_{CC} = 3.0 V		2.5			V
		I_{OH} = −10 mA; V_{CC} = 4.75 V		4.0			V
I_I	Input Current: A0, A1, A2;	V_{CC} = 1.65 V to 5.5 V, V_I = V_{CC} or GND		−1		1	μA
	Input Current: SCL, SDA	V_{CC} = 1.65 V to 5.5 V, V_I = V_{CC} or GND		−1		1	μA
I_{IH}	High-Level Input Current: P port	V_I = V_{CC}; V_{CC} = 1.65 V to 5.5 V				1	μA
I_{IL}	Low-Level Input Current: P port	V_I = GND; V_{CC} = 1.65 V to 5.5 V		−100			μA
I_{cc}	Supply Current	Active mode, IO = 0 mA; I/O = inputs; fSCL = 400 kHz	V_{CC} = 5.5 V		24.3	33	μA
			V_{CC} = 3.6 V		12.2	16	μA
			V_{CC} = 2.7 V		8.2	11	μA
			V_{CC} = 1.95 V		5.6	8	μA

Parameter		Conditions		Min	Typ	Max	Unit
		Standby Mode, input low, IO = 0 mA; I/O = inputs; fS_{SCL} = 0 kHz	V_{CC} = 5.5 V		0.45	0.5	mA
			V_{CC} = 3.6 V		0.29	0.35	mA
			V_{CC} = 2.7 V		0.22	0.26	mA
			V_{CC} = 1.95 V		0.16	0.22	mA
		Standby Mode, input high, IO = 0 mA; I/O = inputs; f_{SCL} = 0 kHz	V_{CC} = 5.5 V		0.74	6	μA
			V_{CC} = 3.6 V		0.43	3	μA
			V_{CC} = 2.7 V		0.3	2.5	μA
			V_{CC} = 1.95 V		0.19	2	μA
C_i	Input Capacitance	V_I = V_{CC} or GND; V_{CC} = 1.65 V to 5.5 V (1)			3		pF
C_{io}	Input/Output Capacitance	$V_{I/O}$ = V_{CC} or GND; V_D = 1.65 V to 5.5 V (1)			3		pF
		$V_{I/O}$ = V_{CC} or GND; V_{CC} = 1.65 V to 5.5 V (1)			5		pF

(1) Parameters are provided by lab bench tests and design simulation. Not tested in production.

I²C Interface Timing Requirements (1)

Over recommended operating free-air temperature range, unless otherwise noted.

Description		Conditions	Standard Mod		Fast Mode		Unit
			Min	Max	Min	Max	
fscl	I²C clock frequency		0	100	0	400	kHz
tsch	I²C clock high time		4		0.6		μs
tscl	I²C clock low time		4.7		1.3		μs
tsp	I²C spike time			50		50	ns
tsds	I²C serial-data setup time		250		100		ns
tsdh	I²C serial-data hold time		0		0		ns
ticr (2)	I²C input rise time			1000	20	300	ns
Ticf (3)	I²C input fall time			300	20 × (V_{CC}/ 5.5 V)	300	ns
tocf (3)	I²C output fall time	10-pF to 400-pF bus		300	20 × (V_{CC}/ 5.5 V)	300	ns
tbuf	I²C bus free time between stop and start		4.7		1.3		μs
tsts	I²C start or repeated start condition setup		4.7		0.6		μs
tsth	I²C start or repeated start condition hold		4		0.6		μs
tsps	I²C stop condition setup		4		0.6		μs
tvd(data)	Valid data time	SCL low to SDA output valid		3.5		0.9	μs
tvd(ack)	Valid data time of ACK condition	ACK signal from SCL low to SDA (out) low		3.5		0.9	μs
Cb	I²C bus capacitive load			400		400	pF

(1) All timing requirements should refer to the I²C standard, and all parameters in the table are NOT tested in production.
(2) ticr is decided by input signal rising time.
(3) Data is provided by bench validation, test condition: 150 ohm series resistor connect to SDA pin, then 2.2 Kohm pull up to VCC, 150 pF Cload pull down to GND, t_{icr} = 29 ns, t_{ocf} = 25 ns, V_{OL} = 166 mv

Switching Characteristics

Over recommended operating free-air temperature range, C_L ≦ 100 pF, unless otherwise noted.

Description		From (Input)	To (Output)	Standard Mod		Fast Mode		Unit
				Min	Max	Min	Max	
tiv	Interrupt valid time	P port	INT		4		4	μs
tir	Interrupt reset delay time	SCL	INT		4		4	μs
tpv	Output data valid; For V_{CC} = 2.3 V ~ 5.5 V	SCL	P port		400		400	ns
	Output data valid; For V_{CC} = 1.65 V ~ 2.3 V				400		400	ns
tps	Input data setup time	P port	SCL	150		150		ns
tph	Input data hold time	P port	SCL	1		1		μs

(1) Parameters are provided by lab bench tests and design simulation. Not tested in production.

Parameter Measurement Waveforms

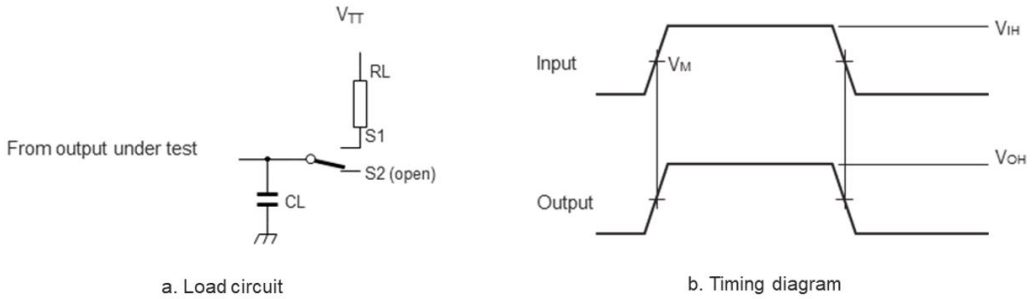


Figure 1. Load Circuit for Outputs

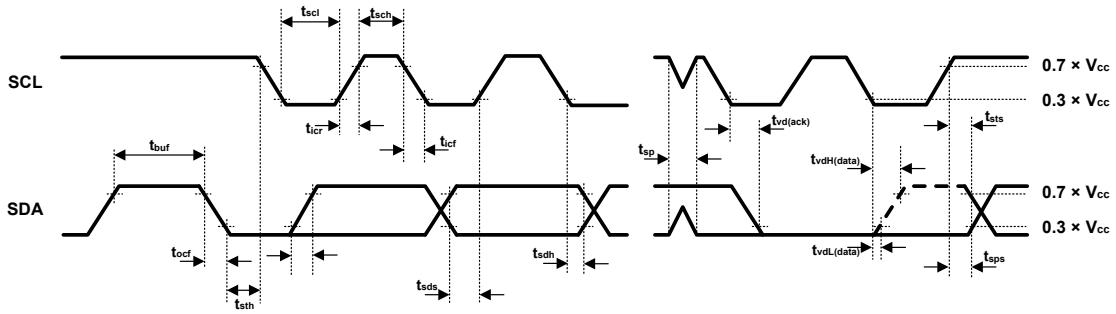


Figure 2. Definition of Timing on the I²C Bus

Typical Performance Characteristics

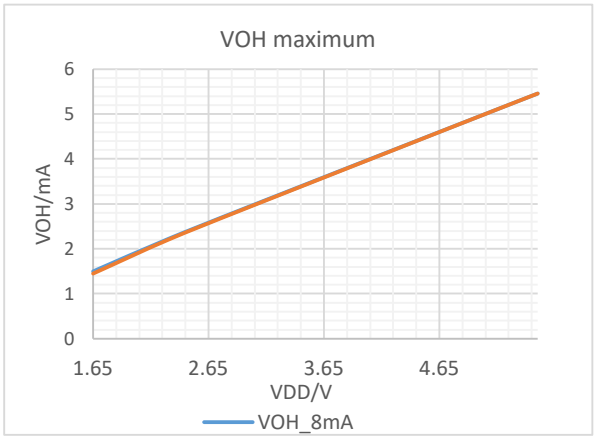


Figure 3. VOH Maximum Measurement

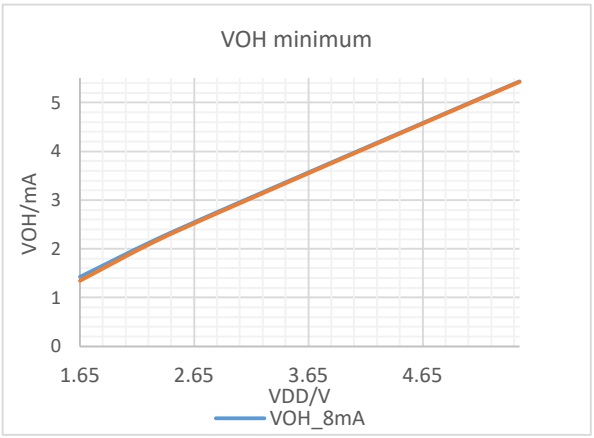


Figure 4. VOL Minimum Measurement

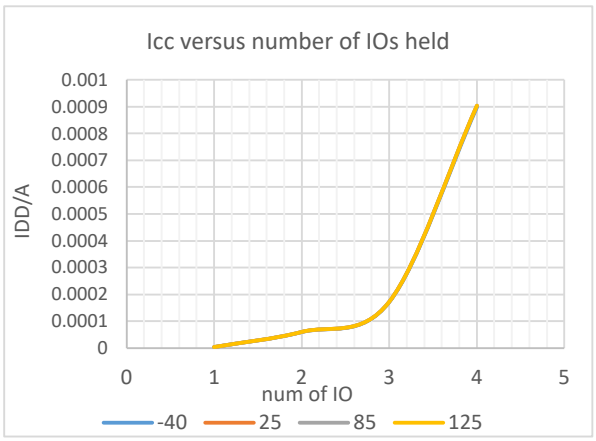


Figure 5. I_{CC} versus Number of I/Os Measurement

Detailed Description

Overview

The TPT29554A is an 8-bit GPIO expander with interrupt and weak pull-up resistors for I²C-bus applications. The power supplier voltage range is from 1.65 V to 5.5 V that allows the TPT29554A to interconnect with 1.8-V microcontrollers.

The TPT29554A contains the register set of 8-bit Configuration, Input, Output, and Polarity Inversion registers. The open-drain interrupt ($\overline{INT}$) output is changeable when any input state changes from its related register state and is used to indicate the system master that an input state has changed. $\overline{INT}$ can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I²C bus. Thus, the TPT29554A can remain a simple slave device. The power-on reset sets the registers to their default values and initializes the device state machine.

All input/output pins have internal weak pull-up resistors to remove external components. Three hardware pins (A0, A1, A2) select the fixed I²C-bus address and allow up to eight devices to share the same I²C bus.

Functional Block Diagram

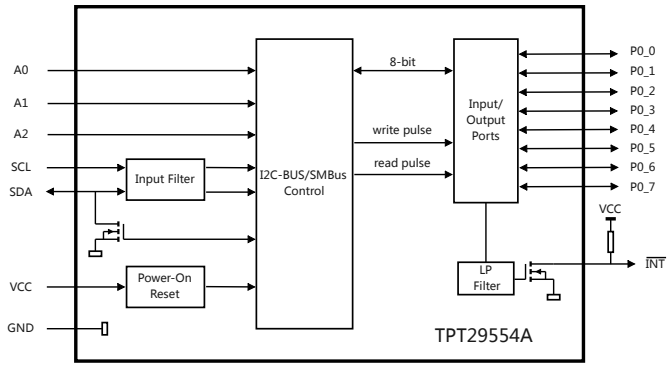


Figure 6. Functional Block Diagram

Feature Description

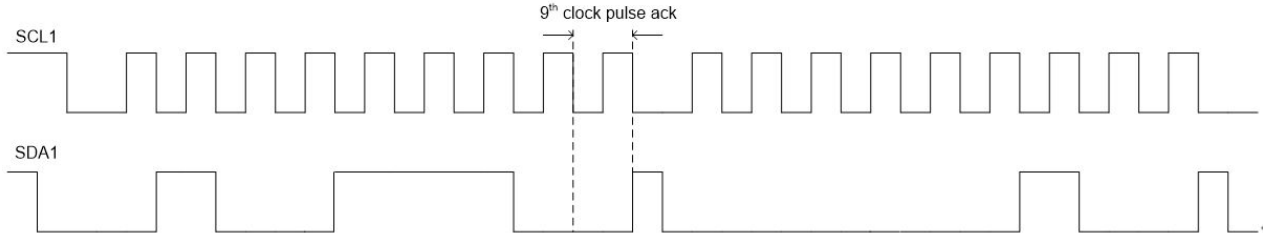


Figure 7. I²C BUS (1.65 V ~ 5.5 V) Waveform

5-V Tolerant I/O Ports

The TPT29554A supports the I/O voltage from 1.8 V to 5 V and allows the TPT29554A to connect to kinds of devices with I/O communication. To minimize the current consumption, suggest the input signal should meet the VIH and VIL spec in

the Electrical Characteristics table. There is a weak pull-up resistor inside, and 100-K ohm for each I/O port. The user can choose certain value pull-up resistors for external circuits depending on different applications.

Power-on Reset

When power is connected to TPT29554A V_{CC}, an internal Power-On Reset (POR) is in a reset condition until V_{CC} has reached V_{POR}. At this point, the reset condition is released, and the TPT29554A registers and state machine set up to their default states. The V_{CC} must be lowered V_{PORF} to reset the device and then restored to the operating voltage.

Hardware Address Pins

The TPT29554A has 3 hardware address pins (A0, A1, and A2), the user can program the I²C address of the device by pulling high or low level to the address pin. This allows the same bus to support 8 TPT29554A without address conflicts. To avoid the possible I²C glitches causing the device address to change during a transmission, the voltage on the pins cannot be changed while the device is powered up. All the pins must be tied either to V_{CC} or GND and cannot be left floating.

Interrupt ($\overline{INT}$) Output

In the input mode, an interrupt is generated by any rising or falling edge of the port inputs. After time t_{iv}, the output signal $\overline{INT}$ is valid. When data on the port is changed to the original setting, or data is read from the port that generated the interrupt, it resets the interrupt circuit. The reset operation should be in the read mode, and at the acknowledge (ACK) bit after the SCL rising edge. Note that the $\overline{INT}$ is reset at the ACK just before the byte of changed data is sent. Interrupts that occur during the ACK clock pulse can be lost since the resetting of the interrupt during this pulse. Each change of the I/O after resetting is detected and generates the $\overline{INT}$ output.

Reading or writing another device does not affect the interrupt circuit, and a pin configured as an output cannot trigger an interrupt. However, changing an I/O from output to input may cause a false interrupt if the pin state does not match the setting of the Input Port register. Because each port is read independently, for example, the interrupt caused by port 0 is not cleared by a read of port 1.

$\overline{INT}$ is an open-drain structure and requires a pull-up resistor to V_{CC}, suggesting 10 kΩ as a typical value.

Device Address

Following a START condition, the bus master must output the address of the slave it is accessing. All input/output pins have internal weak pull-up resistors to remove external components. Three hardware pins (A0, A1, A2) select the fixed I²C-bus address and allow up to eight devices to share the same I²C bus. To conserve power, address pins (A0, A1, A2) must be pulled HIGH or LOW. The address of the TPT29554A is shown below.

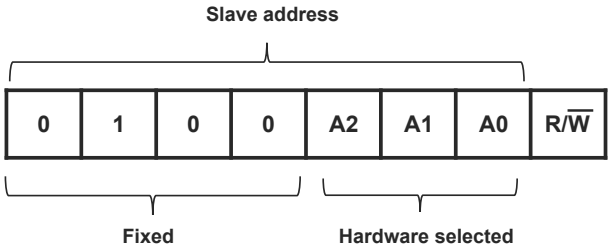


Figure 8. Slave Device Address

Control Register

Command Byte

The command byte is the first byte to follow the address byte during a write transmission. It is used as a pointer to determine which of the following registers is written or read.

Table 2. Command Byte Description

Command	Protocol	Register
0	Read byte	Input port
1	Read/write byte	Output port
2	Read/write byte	Polarity Inversion
3	Read/write byte	Configuration

Register 0: Input port registers

This register is an input-only port, which means the incoming logic levels of the pins, regardless of whether the pin is defined as an input or an output by Register 1, and writes to this register have no effect.

The default value 'X' is determined by the external logic level.

Table 3. Input Port Register

Bit	7	6	5	4	3	2	1	0
Symbol	I0.7	I0.6	I0.5	I0.4	I0.3	I0.2	I0.1	I0.0
Default	X	X	X	X	X	X	X	X

Register 1: Output port registers

This register is an output-only port, which means the outcoming logic levels of the pins are defined as outputs by Register 3. Bit values in this register have no effect on pins defined as inputs. In fact, the value reading from this register is in the flip-flop controlling the output selection, not the actual pin value.

Table 4. Output Port Register

Bit	7	6	5	4	3	2	1	0
Symbol	O0.7	O0.6	O0.5	O0.4	O0.3	O0.2	O0.1	O0.0
Default	1	1	1	1	1	1	1	1

Register 2: Polarity Inversion registers

This register allows the user to invert the polarity of the input port register data. If a bit in this register is set (written with '1'), the input port data polarity is inverted. If a bit in this register is cleared (written with '0'), the input port data polarity is retained.

Table 5. Polarity Inversion Register

Bit	7	6	5	4	3	2	1	0
Symbol	N0.7	N0.6	N0.5	N0.4	N0.3	N0.2	N0.1	N0.0
Default	0	0	0	0	0	0	0	0

Register 3: Configuration registers

This register configures the directions of the I/O pins. If a bit in this register is set (written with '1'), the corresponding port pin is enabled as an input with a high-impedance output driver. If a bit in this register is cleared (written with '0'), the corresponding port pin is enabled as an output. Note that there is a high-value resistor tied to V_{DD} at each pin. At reset, the device's ports are inputs with a pull-up to V_{DD}.

Table 6. Configuration Register

Bit	7	6	5	4	3	2	1	0
Symbol	C0.7	C0.6	C0.5	C0.4	C0.3	C0.2	C0.1	C0.0
Default	1	1	1	1	1	1	1	1

Application and Implementation

> Note
>
> Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

The TPT29554A is an 8-bit GPIO expander with interrupt and weak pull-up resistors for I²C-bus applications. The power supplier voltage range is from 1.65 V to 5.5 V that allows the TPT29554A to interconnect with 1.8-V microcontrollers.

The TPT29554A contains the register set of 8-bit configuration, input, output, and polarity inversion registers. The open-drain interrupt ($\overline{INT}$) output is changeable when any input state changes from its related register state and is used to indicate the system master that an input state has changed. $\overline{INT}$ can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I²C bus. Thus, the TPT29554A can remain a simple slave device. The power-on reset sets the registers to their default values and initializes the device state machine.

All input/output pins have internal weak pull-up resistors to remove external components. Three hardware pins (A0, A1, A2) select the fixed I²C-bus address and allow up to eight devices to share the same I²C bus.

Typical Application

The following figure shows an application in which the TPT29554A can be used to control multiple subsystems and read inputs from buttons.

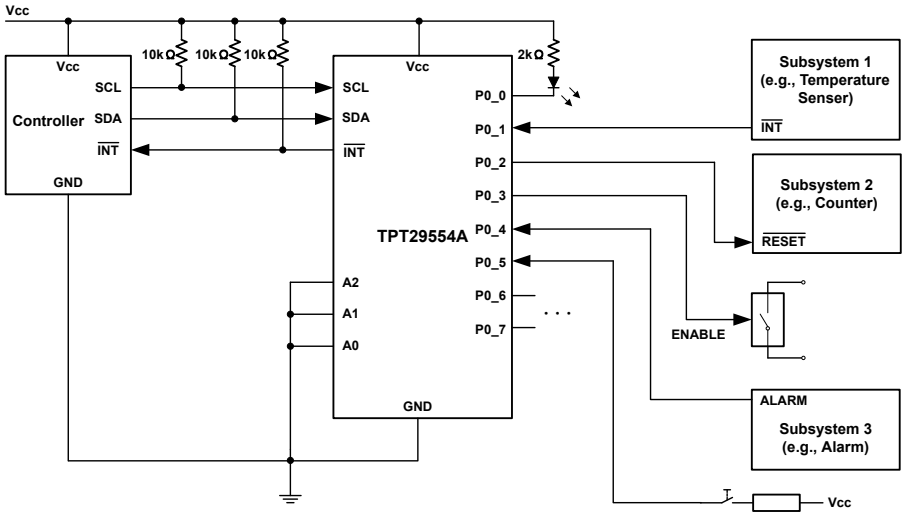


Figure 9. Typical Application Reference Circuit

Layout

Layout Guideline

Reflections and matching are closely related to loop antenna theory, but different enough to warrant their own discussion. When a PCB trace turns a corner at a 90° angle, a reflection can occur. This is primarily due to the change in the width of the trace. At the apex of the turn, the trace width is increased to 1.414 times its width. This change in width upsets the transmission line characteristics, especially the distributed capacitance, and self-inductance of the trace, thus resulting in the reflection. Not all PCB traces can be straight, so they will have to turn corners. Figure 10 shows progressively better techniques of rounding corners. Only the last example (BEST) maintains constant trace width and minimizes reflections.

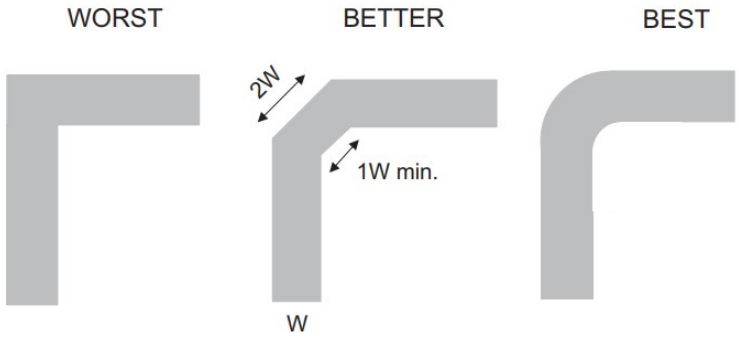


Figure 10. Trace Example

Route high-speed signals using a minimum of vias and corners which reduces signal reflections and impedance changes. When a via must be used, increase the clearance size around it to minimize its capacitance. Each via introduces discontinuities in the signal's transmission line and increases the chance of picking up interference from the other layers of the board. Be careful when designing test points, through-hole pins are not recommended at high frequencies.

Layout Example

Figure 11 illustrates an example of a PCB layout with the TPT29554A. Some key considerations are as follows:

- Decouple the VDD pin with a 0.1-μF capacitor, and place it as close to the pin as possible. Make sure that the capacitor voltage rating is sufficient for the VDD supply.
- Keep the input lines as short as possible.
- Use a solid ground plane to help reduce electromagnetic interference (EMI) noise pickup.
- Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible and only make perpendicular crossings when necessary.

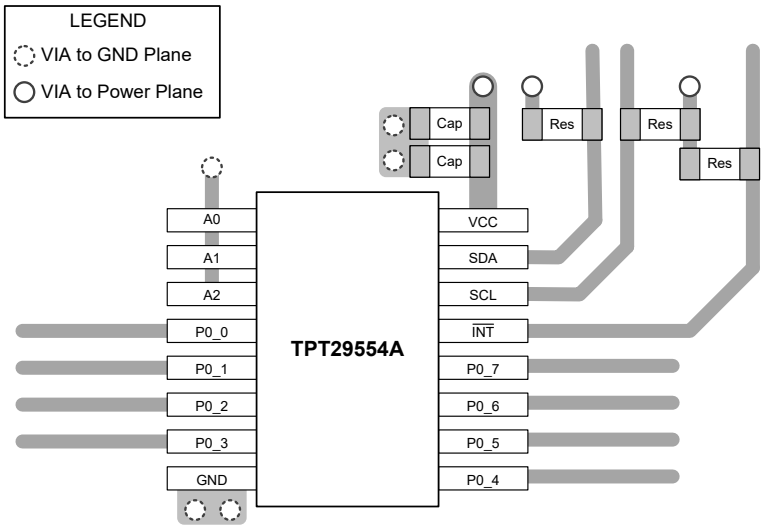
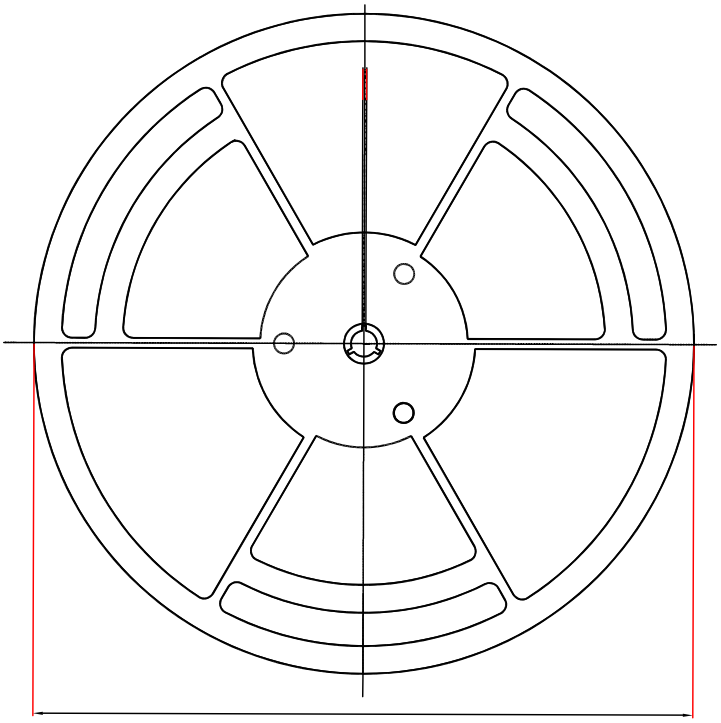
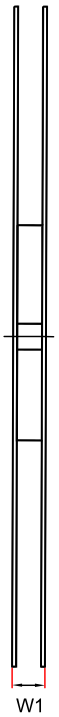
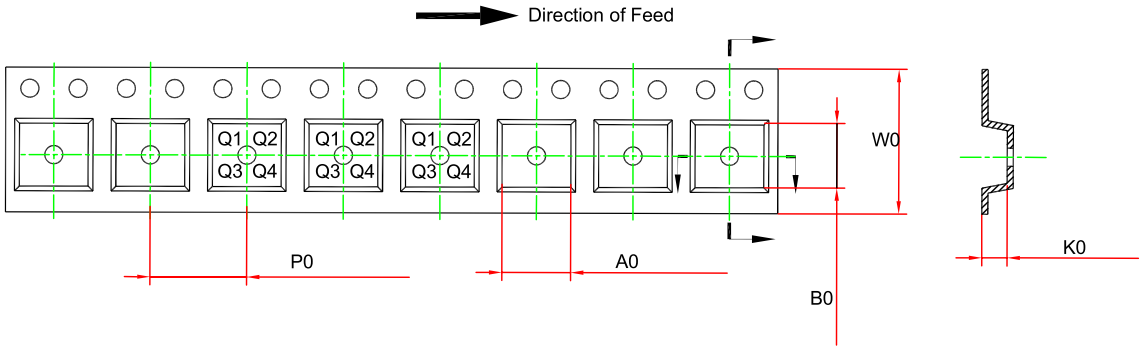


Figure 11. TPT29554A Layout Example

Tape and Reel Information





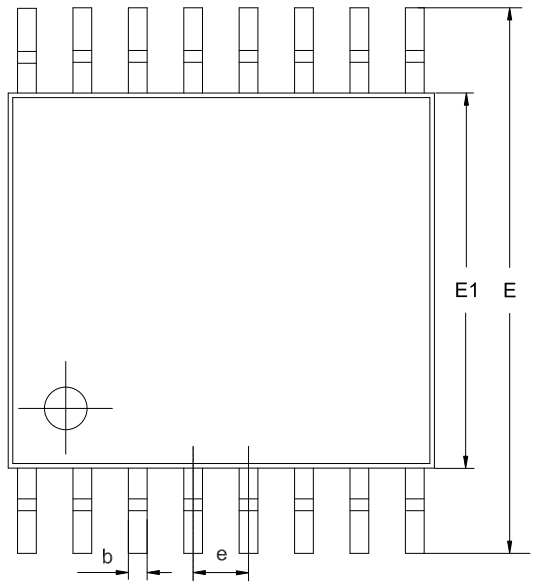


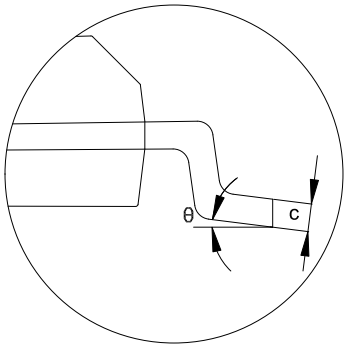
Order Number	Package	D1 (mm)	A0 (mm)	K0 (mm)	W0 (mm)	W1 (mm)	B0 (mm)	P0 (mm)	Pin1 Quadrant
TPT29554A-TS3R	TSSOP16	330.0	6.8	1.3	12.0	17.6	5.5	8.0	Q1

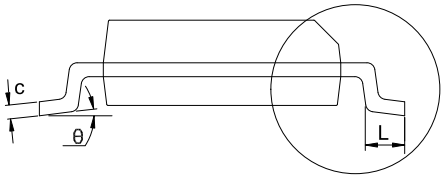
Package Outline Dimensions

TSSOP16

Package Outline Dimensions TS3(TSSOP-16-A)







Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.900	5.100	0.193	0.201
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPT29554A-TS3R	−40 to 125°C	TSSOP16	9554A	MSL3	3,000	Green

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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