

# System-Level ESD/EMI Protection Guide



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### Introduction

System-level electrostatic discharge (ESD) protection is very important in today's world, not only in the industrial space, but also in the consumer space as devices become portable, haptic and widely used. It only takes one ESD strike to permanently damage a product, making ESD protection a critical component of system design.

Electromagnetic interference (EMI) is another challenge often faced in system design. EMI is a radio frequency (RF) (800 MHz to 2 GHz) disturbance that affects an electrical circuit due to electromagnetic conduction from an external source. EMI can be avoided by using EMI filters that eliminate RF noise and maintain signal integrity.

#### ESD/EMI Protection Solutions

TI produces ESD/EMI devices with solutions that protect the majority of external connections to the outside world. Learn more about our ESD/EMI product portfolio.

[www.ti.com/esd](http://www.ti.com/esd)

#### Applications

- USB 2.0/3.0\*
- HDMI\*
- DVI\*
- DisplayPort
- eSATA
- 1394\*
- LVDS
- Gigabit Ethernet\*
- Audio headphones
- Microphone ports
- Speaker ports
- SDIO
- SIM



\*Featured section within this guide.

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# System-Level ESD/EMI Protection Guide

## → Why External ESD?

Semiconductor devices based off of advanced processes only offer device-level ESD specifications like the charge device model (CDM) and the human body model (HBM) shown below. Device-level ESD specifications are not sufficient to protect devices in a system.

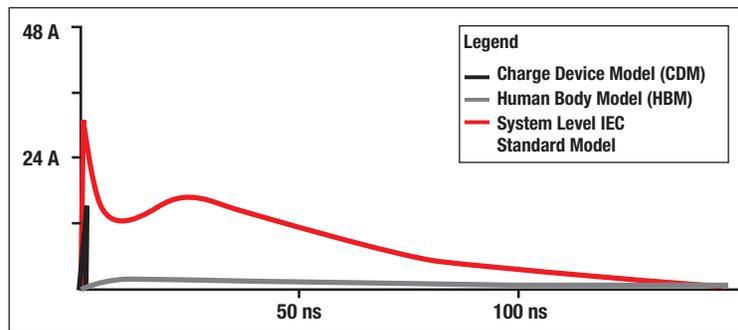
The energy associated with a system-level ESD strike is much higher than a device-level ESD strike. In order to protect against this excess energy, a more robust design is required. The silicon area required to design system-level ESD protection is much larger than is required for HBM or

CDM. This difference in silicon area translates to additional cost. As technology nodes become smaller, it becomes more difficult and costly to integrate robust system-level ESD protection with microcontroller or core chipsets. This is illustrated below.

System-level ESD protection can be implemented using discrete diodes or capacitors. However, in many applications, discrete solutions consume board space, complicate layout, and compromise signal integrity at high data rates. Texas Instruments stand-alone ESD devices provide space-saving,

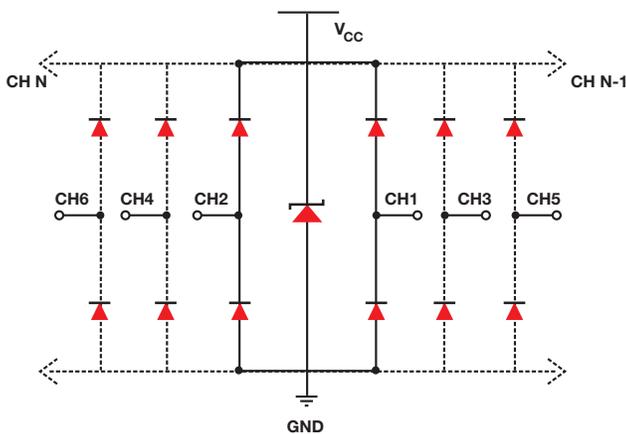
cost-effective solutions to protect system interconnects from external ESD strikes while maintaining signal integrity.

Often ESD protection is considered at the last phase of system design. Designers need flexibility to select an ESD component that does not compromise the PCB layout or consume additional board space. Texas Instruments ESD solutions with flow-through packaging allow designers to add ESD components in the final stages of a design without any change in the board layout.



ESD models.

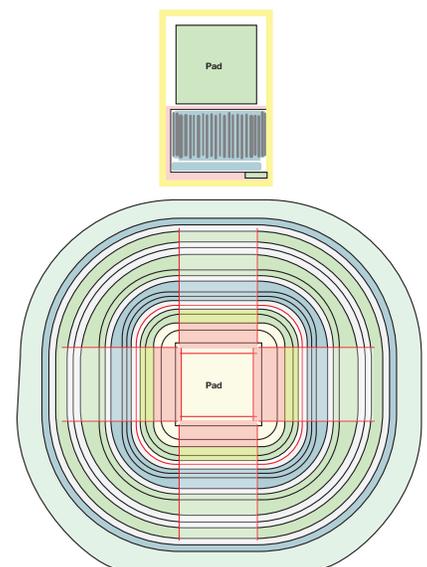
Silicon die areas for device-level ESD (12 KV HBM).



Typical circuit diagram for N number of unidirectional channels.



Typical circuit diagram for single bidirectional channel.



Silicon die areas for system-level ESD (IEC 8-KV contact).

## → ESD Protection for USB Charger Interface

### 4-Channel USB ESD Solution with Power Clamp

#### TPD4S012

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD4S012](http://www.ti.com/sc/device/TPD4S012)

#### Key Features

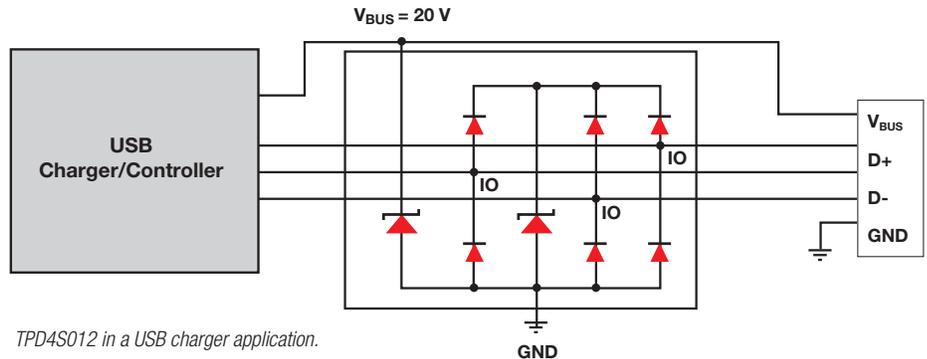
- Integrated ESD clamps for D+, D-, V<sub>BUS</sub> and ID pins to provide single-chip ESD protection
- IEC 61000-4-2 (level 4) system-level ESD compliance measured at the D+, D- and ID pins
  - ±10-kV contact discharge
  - ±10-kV air-gap discharge
- 3 amps peak pulse current (8/20-μs pulse)
- USB signal pins (D+, D-, ID)
  - 0.8-pF line capacitance
  - Tolerates 6-V signal
- V<sub>BUS</sub> line (V<sub>BUS</sub>)
  - 11-pF line capacitance
  - Tolerates 20-V signal

#### Applications

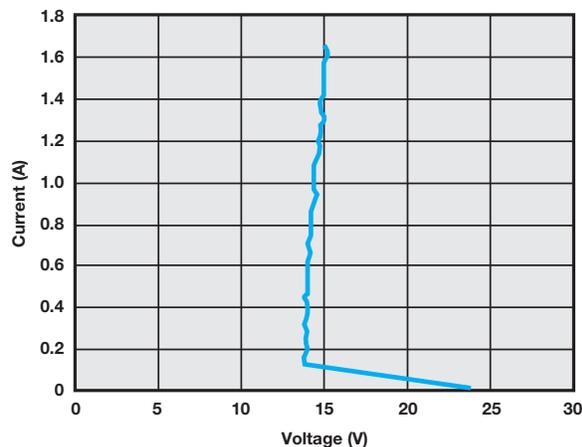
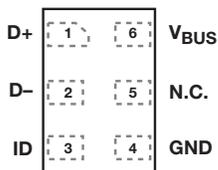
- Cellular phones
- Digital cameras
- Global positioning systems (GPS)
- Portable digital assistants (PDAs)

The TPD4S012 is a single-chip ESD protection solution for the USB charger interface. Many after-market chargers generate more than 5 V at the USB V<sub>BUS</sub> pin. A common industry solution is to use a high-voltage clamp for the V<sub>BUS</sub> line. The TPD4S012 offers a combination of two separate clamps: a 6-V clamp for the D+, D- and ID pins and a 20-V clamp for the V<sub>BUS</sub> pin.

The TPD4S012 allows single-layer flow-through PCB layout. This simplifies PCB design and allows for flexible design with a small form factor. It supports data rates in excess of 480 Mbps. Snap-back technology allows high-voltage tolerance during normal operation while reducing the clamp voltage during system-level ESD stress.



TPD4S012 DRY Package (Top View)



*V<sub>BUS</sub> clamp voltage under ESD event.*

# System-Level ESD/EMI Protection Guide

## → ESD Protection for High-Speed USB 2.0

### Complete Protection Solution for USB Charger Port Including ESD Protection for All Lines and Over-Voltage Protection on $V_{BUS}$

#### TPD4S014

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD4S014](http://www.ti.com/sc/device/TPD4S014)

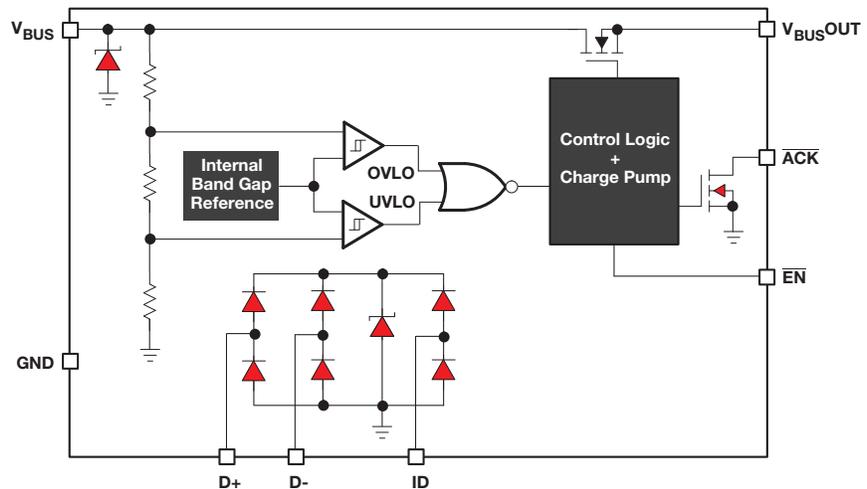
#### Key Features

- Input voltage protection at  $V_{BUS}$  up to 28 V
- Low  $R_{ON}$  nFET switch
- Supports >2A charging current
- Over-voltage and under-voltage lock-out features
- Low capacitance TVS ESD clamp for USB 2.0 high-speed data rate
- Internal 16 ms startup delay
- Integrated input enable and status output signal
- Thermal shutdown feature
- ESD performance D+/D-/ID/ $V_{BUS}$  pins
  - $\pm 15$ -kV contact discharge (IEC 61000-4-2)
  - $\pm 15$ -kV air gap discharge (IEC 61000-4-2)
- Space saving QFN package (2 mm  $\times$  2 mm)

#### Applications

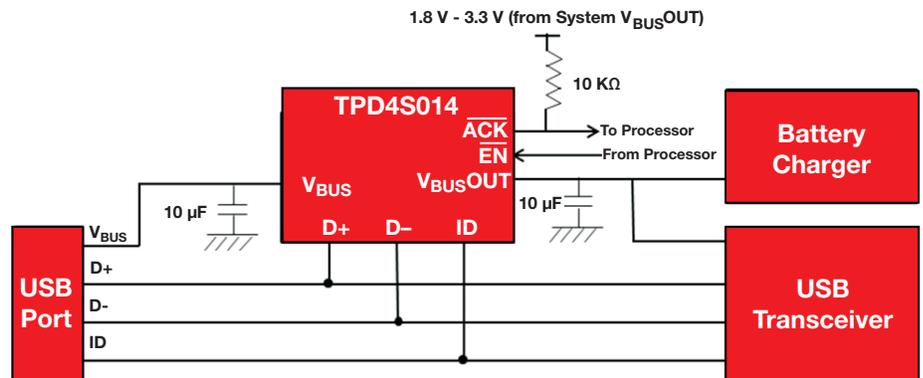
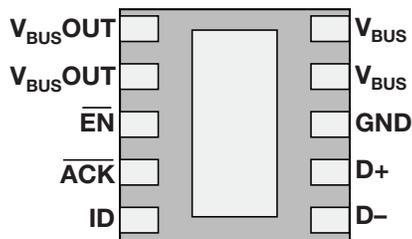
- Cell phones
- eBook
- Portable media players
- Digital camera

The TPD4S014 is a single-chip solution for USB charger port protection. This device offers low capacitance TVS type ESD clamps for the D+, D- and standard capacitance for the ID pin. On the  $V_{BUS}$  pin, this device can handle over-voltage protection up to 28V. The over-voltage lock-out feature ensures that if there is a fault condition at the  $V_{BUS}$  line, the TPD4S014 is able to isolate the  $V_{BUS}$  line and protect the internal circuitry from damage. There is a 16ms turn-on delay after  $V_{BUS}$  crosses the under-voltage lock-out threshold, in order to let the voltage stabilize before closing the switch. This function acts as a deglitch and prevents unnecessary switching if there is any ringing on the line during connection.



TPD4S014 circuit schematic diagram.

#### DSQ Package (Top side/see through view)



TPD4S014 standard implementation for non-OTG USB system.

# System-Level ESD/EMI Protection Guide

## → ESD Protection for High-Speed USB 2.0

### USB OTG Companion Device with $V_{BUS}$ Over-Voltage, Over-Current Protection, and 4-Channel ESD Clamps

#### TPD4S214

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD4S214](http://www.ti.com/sc/device/TPD4S214)

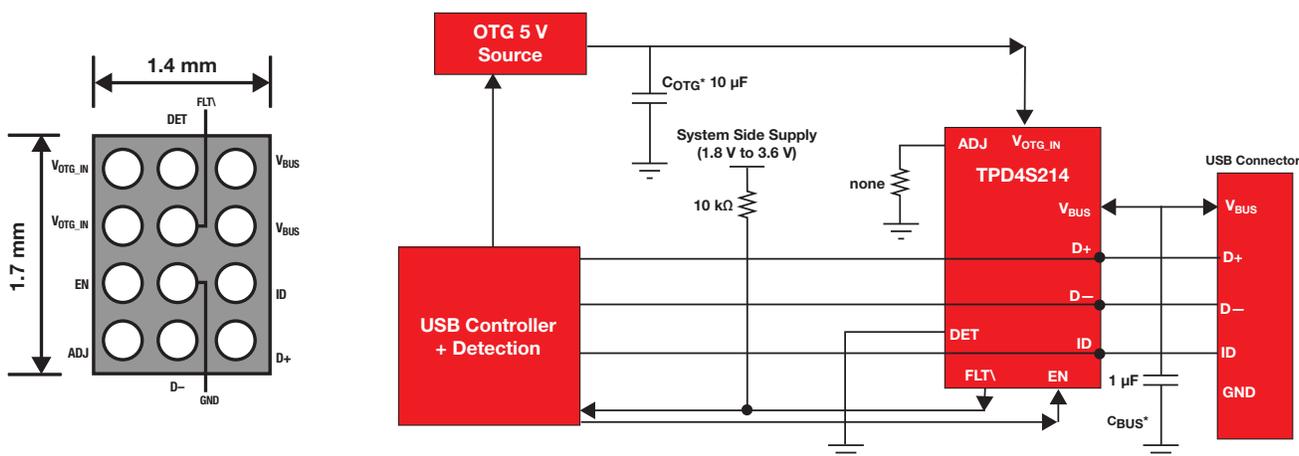
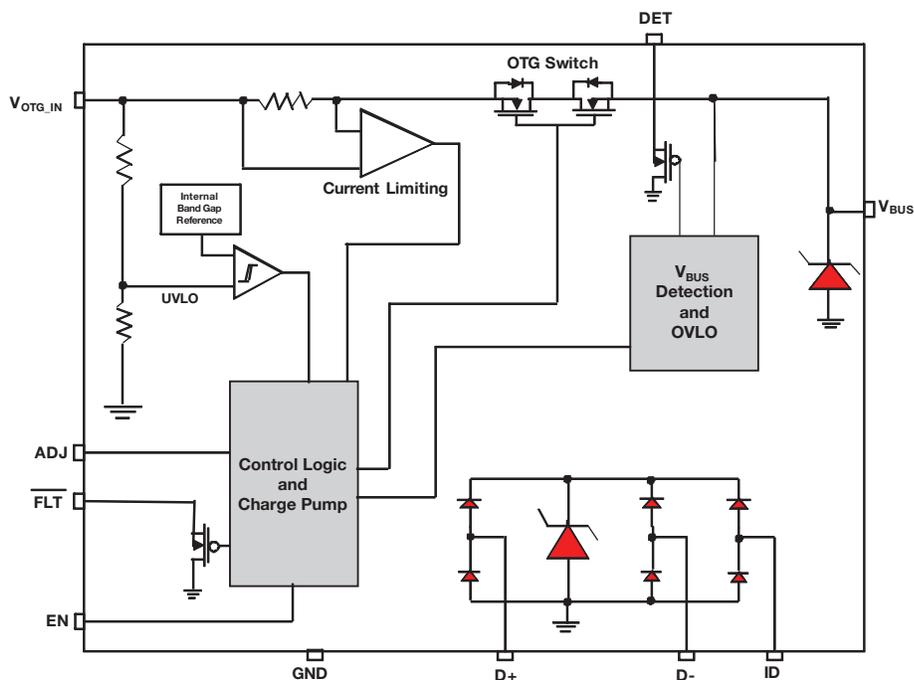
#### Key Features

- Input voltage protection at  $V_{BUS}$  up to 30 V
- Low  $R_{ON}$  nFET switch
- Compliant with USB 2.0 and USB 3.0 OTG spec
- User adjustable current limit from 250 mA to beyond 900 mA
- Built-in soft-start
- Reverse current blocking
- Over-voltage lock-out for  $V_{BUS}$
- Under-voltage lock-out for  $V_{OTG\_IN}$
- Integrated  $V_{BUS}$  detection circuit
  - $\pm 8$ -kV contact discharge (IEC 61000-4-2)
  - $\pm 15$ -kV air gap discharge (IEC 61000-4-2)

#### Applications

- Cell phones
- Tablet/eBook
- Portable media players
- Digital camera
- Set top box

The TPD4S214 is a single-chip solution for USB on-the-go charger protection. This device includes an integrated low  $R_{ds\_on}$  N-channel MOSFET for OTG current supply to peripheral devices. TPD4S214 offers low capacitance TVS ESD clamps for the D+, D-, ID pins for both USB 2.0 and USB 3.0 applications. The  $V_{BUS}$  pin can handle continuous voltage ranging from -2 V to 30 V. The over voltage lock-out (OVLO) at the  $V_{BUS}$  pin ensures that if there is a fault condition at the  $V_{BUS}$  line, the TPD4S214 is able to isolate it and protects the internal circuitry from damage. Similarly, the under-voltage lock-out (UVLO) at the  $V_{OTG\_IN}$  pin ensures that there is no power drain from the internal OTG supply to external  $V_{BUS}$  if  $V_{OTG\_IN}$  droops below safe operating level.



TPD4S214 schematic diagram.

## → ESD Protection for Super-Speed USB 3.0

### 2- or 4-Channel ESD Solution for Super-Speed USB 3.0 Interface

#### TPDxEUSB30, TPD2EUSB30, TPD4EUSB30

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD2EUSB30A](http://www.ti.com/sc/device/TPD2EUSB30A)  
or [www.ti.com/sc/device/TPD2EUSB30](http://www.ti.com/sc/device/TPD2EUSB30) or [www.ti.com/sc/device/TPD4EUSB30](http://www.ti.com/sc/device/TPD4EUSB30)

#### Key Features

- Single-pair differential lines to protect the differential data and clock lines of the USB 3.0, eSATA, or LVD interface
- ESD protection meets or exceeds IEC 61000-4-2 (level 4)
  - ±8-kV contact discharge
  - ±8-kV air-gap discharge
- 5-A peak pulse current (8/20- $\mu$ s pulse) for D+, D- lines
- 0.05-pF matching capacitance between the differential signal pair
- Supports data rates in excess of 6 Gbps

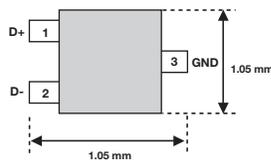
The TPDxEUSB30 provides two ESD clamp circuits with flow-through pin mapping for ease of board layout. This device has been designed to protect sensitive components that are connected to ultra high-speed data and transmission lines. The TPDxEUSB30 offers protection from stress caused by ESD. This device also offers 5-A (8/20- $\mu$ s) peak pulse current ratings per IEC 61000-4-5 (lightning) specification.

This device has 0.05-pF matching capacitance between differential lines and pin capacitance less than 0.7 pF. These features enable the TPDxEUSB30 to support data rates in excess of 6 Gbps supporting applications such as USB 3.0, eSATA or LVDS interface.

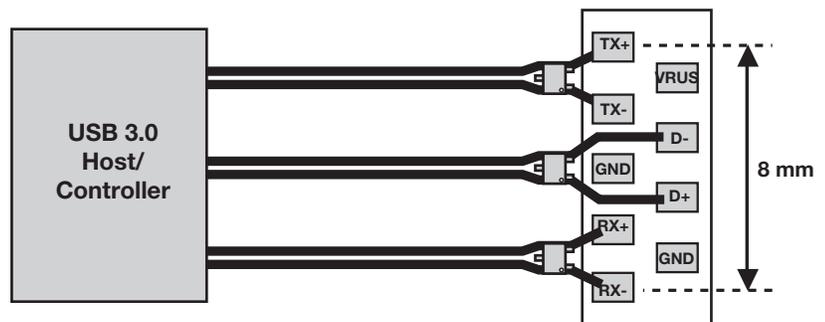
The TPDxEUSB30 conforms to IEC61000-4-2 (level 4) ESD protection.

#### Applications

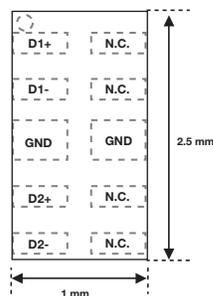
- USB 3.0 high-speed
- eSATA
- HDMI
- LVDS



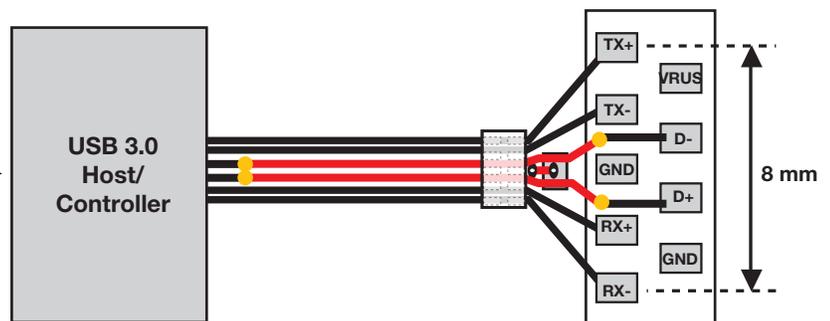
TPD2EUSB30 DRT package.



Three TPD2EUSB30 to protect USB 3.0 Class A connector (requires only one layer of routing).



TPD4EUSB30 DQA package.



One TPD4EUSB30 and one TPD2EUSB30 to protect USB 3.0 Class A connector (two-layer routing).

# System-Level ESD/EMI Protection Guide

## → ESD Protection for VGA and DVI-I Ports

### Integrated 7-Channel ESD Solution for the VGA Port

#### TPD7S019

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD7S019](http://www.ti.com/sc/device/TPD7S019)

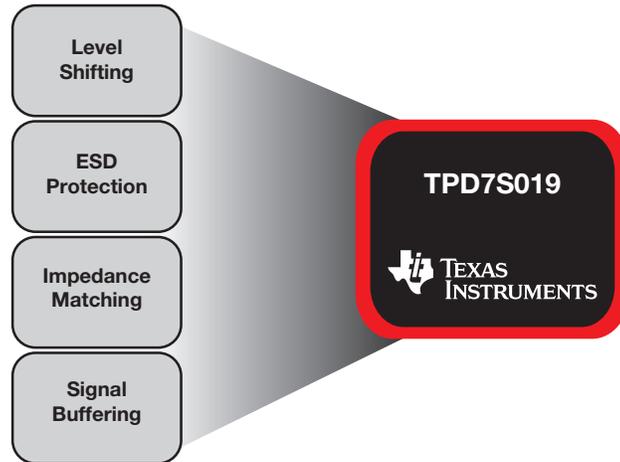
#### Key Features

- Integrated 7-channel ESD solution with level shifting, buffering and sync impedance
- Exceeds IEC61000-4-2 (level 4) ESD protection
  - $\pm 8$ -kV contact discharge
  - $\pm 15$ -kV human body model
- 4-pF loading cap on video lines
- Buffer and impedance matching resistor option for SYNC signals
  - 15  $\Omega$
  - 65  $\Omega$
  - 55  $\Omega$

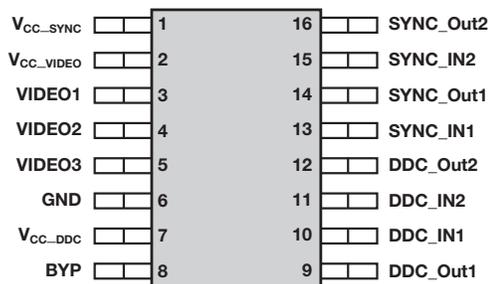
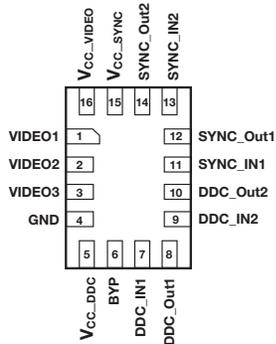
#### Applications

- VGA and DVI-I ports in:
  - PCs
  - Graphics cards
  - Set top boxes
  - TVs

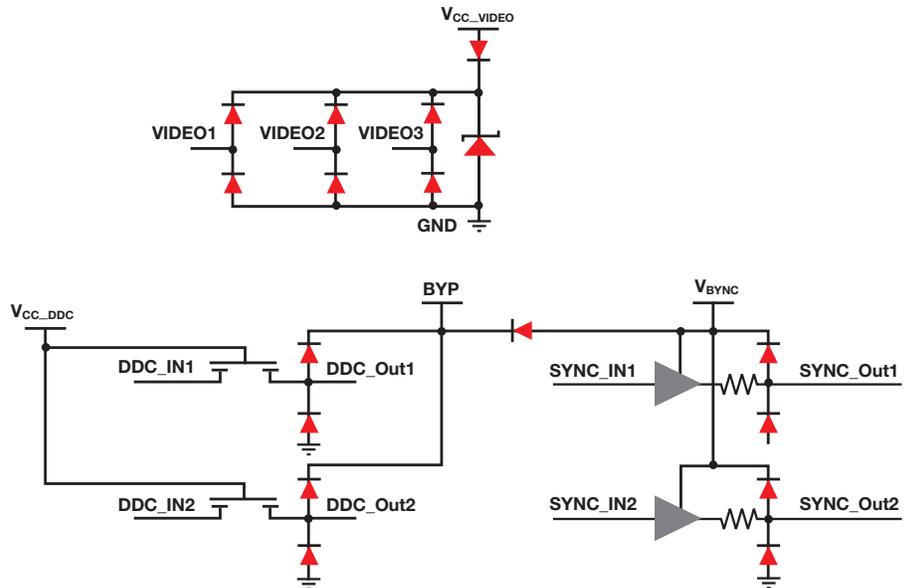
The TPD7S019 is TI's first integrated ESD solution for the VGA port. The device incorporates all of the necessary items for VGA lines: level shifting, ESD protection, buffering and impedance matching. All of this combined gives the designer a single-chip device for the VGA port, eliminating the need for additional ICs to complete the same functions that the TPD7S019 performs.



Preview: TPD7S019-15  
RSV Package  
(Top View)



TPD7S019-15 DBQ package.



## → ESD Protection for HDMI/DVI

### HDMI Receiver/Transmitter Port Protection and Interface Devices

#### TPD12S520/1

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD12S520](http://www.ti.com/sc/device/TPD12S520) or [www.ti.com/sc/device/TPD12S521](http://www.ti.com/sc/device/TPD12S521)

#### Key Features

- TPD12S520: single-chip ESD solution for HDMI receiver ports
- TPD12S521: single-chip ESD solution for HDMI transmitter ports; offers on-chip load switch with 55-mA current limit feature
- Meets IEC61000-4-2 (Level 4) ESD protection
  - ±8-kV contact discharge
- Integrated level shifting for control pins with additional LV supply
- Supports HDMI 1.3 data rate
- 0.8-pF ultra-low cap for I/O
- 0.05-pF matching cap between TMDS
- Control channel backdrive protection

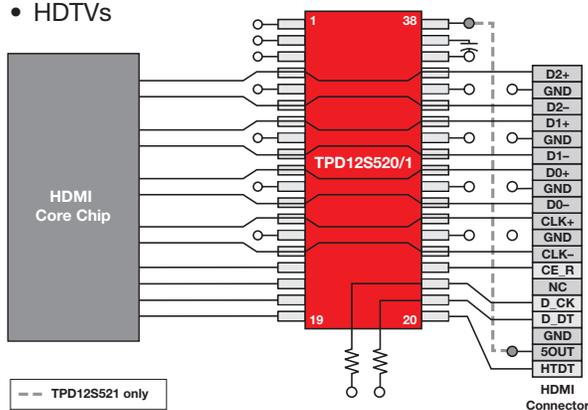
The TPD12S520 and TPD12S521 are single-chip ESD solutions for HDMI receiver and transmitter ports. In many cases, the core ICs, such as the scalar chipset, may not have robust ESD cells to sustain system-level ESD strikes. In these cases, the TPD12S520 and TPD12S521 provide the desired system-level ESD protection, such as the IEC61000-4-2 (level 4) ESD, by absorbing the energy associated with the ESD strike.

While providing ESD protection, these devices add little to no glitch in the high-speed differential signals due to the low I/O capacitance. Both of these devices offer a pin layout that is mapped to an HDMI connector, eliminating routing and reducing board layout complexity and cost. These devices also support  $I_{off}$  (backdrive) protection for current in-rush events.

The TPD12S521 for transmitter ports provides an on-chip regulator with current output ratings of 55 mA for pin 38. This current enables HDMI receiver detection even when the receiver device is powered off. This enables the TPD12S521 to provide ESD protection and line-drive capabilities on a single-chip solution.

#### Applications

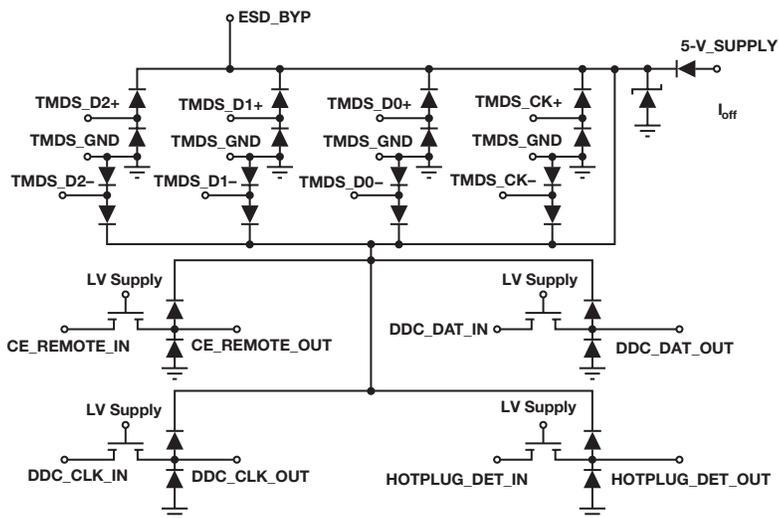
- PCs
- Consumer electronics
- Set-top boxes
- DVDRW players
- HDTVs



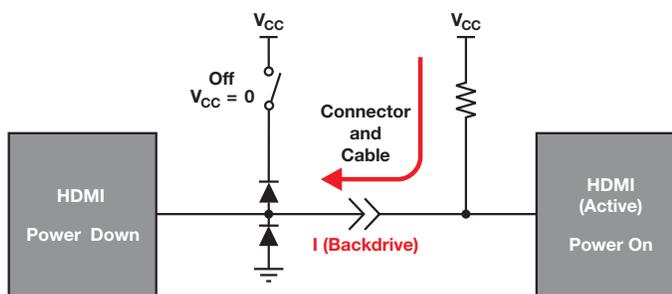
Board layout example for TPD12S520/1.



TPD12S521 Load Switch.



TPD12S520/1 electrical schematic.



$I_{off}$  (backdrive protection) is very important for any data-cable connection where one side may be in power-on mode while the other is in power-down mode. This prevents the current backflows to the power-down circuit from any damage, eliminating the need for an external diode.

# System-Level ESD/EMI Protection Guide

## → ESD Protection for Portable HDMI Connector

### HDMI Companion Chip with Step-Up Converter, I<sup>2</sup>C Level Shifter and High-Speed ESD Clamps

#### TPD12S015A

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD12S015A](http://www.ti.com/sc/device/TPD12S015A)

#### Key Features

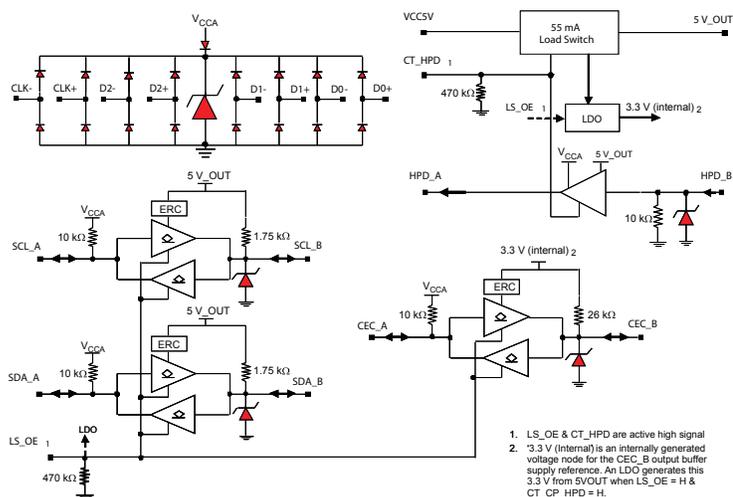
- Confirms to HDMI compliance tests without any external components
- Supports HDMI 1.4 data rate match class D and class C pin mapping
- Built-in pull-up and pull-down resistors
- Excellent matching capacitance (0.05 pF) in each differential signal pair
- Internal boost converter to generate 5 V from a 2.3- to 5.5-V battery voltage
- Auto-direction sensing level shifting in the CEC, SDA, and SCL paths
- IEC 61000-4-2 (Level 4) system level ESD compliance
- Improved drop-in replacement for the industry popular TPD12S015
- Industrial temperature range: -40°C to 85°C

#### Applications

- Smart phones
- eBook
- Tablet PC
- Digital camcorders
- Portable game console
- Digital still cameras

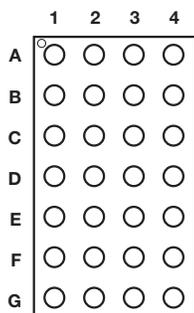
The TPD12S015A is an integrated HDMI companion chip solution. This device offers eight low capacitance ESD clamps allowing HDMI 1.4 data rates. The 0.4-mm pitch WCSP package pin mapping matches the HDMI type D or type C connectors. The integrated ESD clamps in monolithic silicon technology provide good matching between each differential signal pair. This provides an advantage over discrete ESD clamp solutions where variations between ESD clamps degrade the differential signal quality. This device also has built-in pull-up and pull-down resistors.

The TPD12S015A provides a regulated 5 V output (5 V\_OUT) for sourcing the HDMI power line. The 5 V\_OUT pin supplies minimum 55 mA to the HDMI receiver while meeting the HDMI 5 V\_OUT specifications. The 5 V\_OUT and the hot plug detect (HPD) circuitry are independent of the LS\_OE control signal; they are controlled by the CT\_CP\_HP\_D pin.



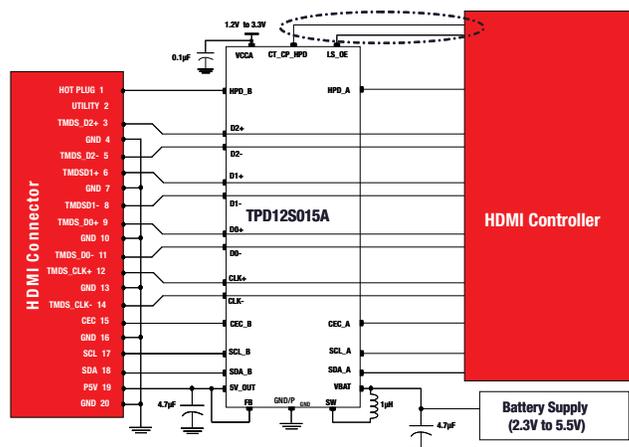
TPD12S015A circuit schematic diagram.

#### YFF Package (Top View)



#### YFF Package Pin Mapping

	1	2	3	4
A	LS_OE	V <sub>CCA</sub>	D2+	D2-
B	SCL_A	CEC_A	GND	D1+
C	SDA_A	HPD_A	GND	D1-
D	CT_CP_HP_D	GND	CEC_B	D0+
E	FB	GND	SCL_B	D0-
F	5V_OUT	SW	SDA_B	CLK+
G	P <sub>GND</sub>	V <sub>BAT</sub>	HPD_B	CLK-



YFF package high-speed routing.

## → ESD Protection for Portable HDMI Connector

### HDMI Companion Chip with I<sup>2</sup>C Level Shifting Buffer, 12 Channel ESD, and Current-Limit Load Switch

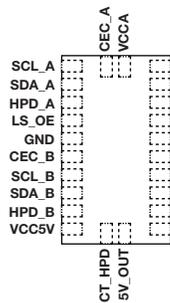
#### TPD12S016

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD12S016](http://www.ti.com/sc/device/TPD12S016)

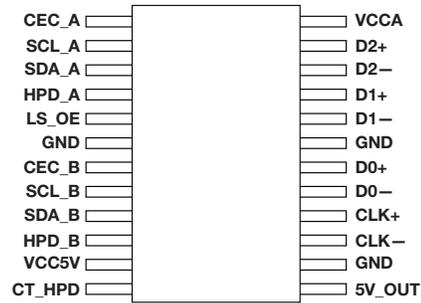
#### Key Features

- Confirms to HDMI compliance tests without any external components
- Supports HDMI1.4 data rate
- Match class D and class C pin mapping
- 8-channel ESD lines for four differential pairs with ultra-low differential capacitance matching (0.05 pF)
- On-chip load switch with 55 mA current limit feature at the HDMI 5V\_OUT pin
- Auto-direction sensing I<sup>2</sup>C level shifter with one-shot circuit to drive long HDMI cable (750pF Load)
- Back-drive protection on HDMI connector side ports
- Integrated pull-up and pull-down resistors per HDMI specification
- ±8-KV contact discharge rating at all external pins
- Space saving 24-pin RKT package and 24-TSSOP package

The TPD12S016 is a single-chip HDMI interface device with auto-direction sensing I<sup>2</sup>C voltage level shift buffers, load switch, and integrated high-speed ESD protection clamps. The device pin mapping matches the HDMI type D connector with four differential pairs. This device offers eight low-capacitance ESD clamps, allowing HDMI 1.4 data rates. The integrated ESD circuits provide good matching between each differential signal pair, which allows an advantage over discrete ESD solutions where variations between ESD protection clamps degrade the differential signal quality. The TPD12S016 provides a current limited 5 V output (5V\_OUT) for sourcing the HDMI power line. The current limited 5 V output supplies up to 55 mA to the HDMI receiver. The control of 5V\_OUT and the hot plug detect (HPD) circuitry is independent of the LS\_OE control signal, and is controlled by the CT\_HPDP pin. This independent CT\_HPDP control enables the detection scheme (5V\_OUT and HPD) to be active before enabling the HDMI link. An internal 3.3 V node powers the CEC pin eliminating the need for a 3.3 V supply on board.

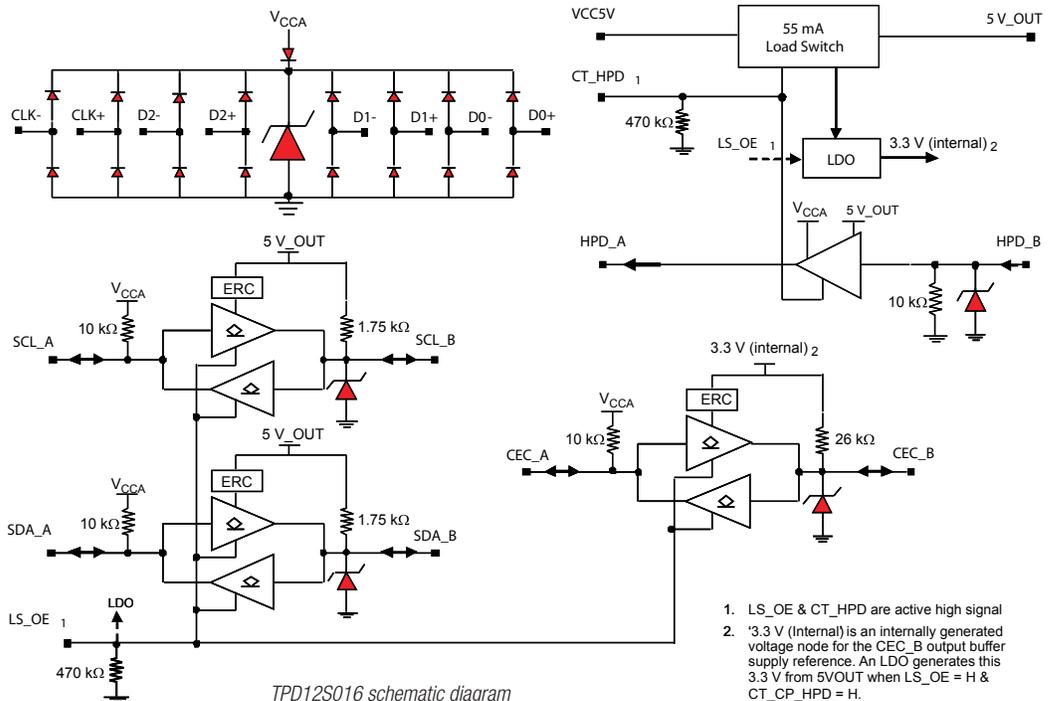


24-RKT Package (Top View)  
(4.0 mm x 2.0 mm x 0.5 mm)



24-PW Package (Top View)  
(7.8 mm x 6.1 mm x 1.2 mm)

Package options.



TPD12S016 schematic diagram

1. LS\_OE & CT\_HPDP are active high signal
2. 3.3 V (internal) is an internally generated voltage node for the CEC\_B output buffer supply reference. An LDO generates this 3.3 V from 5VOUT when LS\_OE = H & CT\_CP\_HPDP = H.

#### Applications

- Cell phones
- eBook
- Portable media players
- Set top box

# System-Level ESD/EMI Protection Guide

## → ESD Protection for Portable HDMI Connector

### 13-Channel ESD Protection Solution with Current-Limit Load Switch for HDMI Port

#### TPD13S523

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD13S523](http://www.ti.com/sc/device/TPD13S523)

#### Key Features

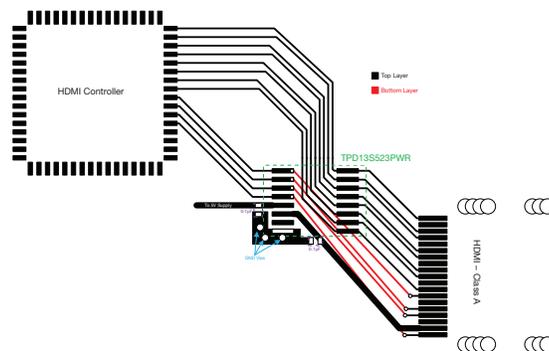
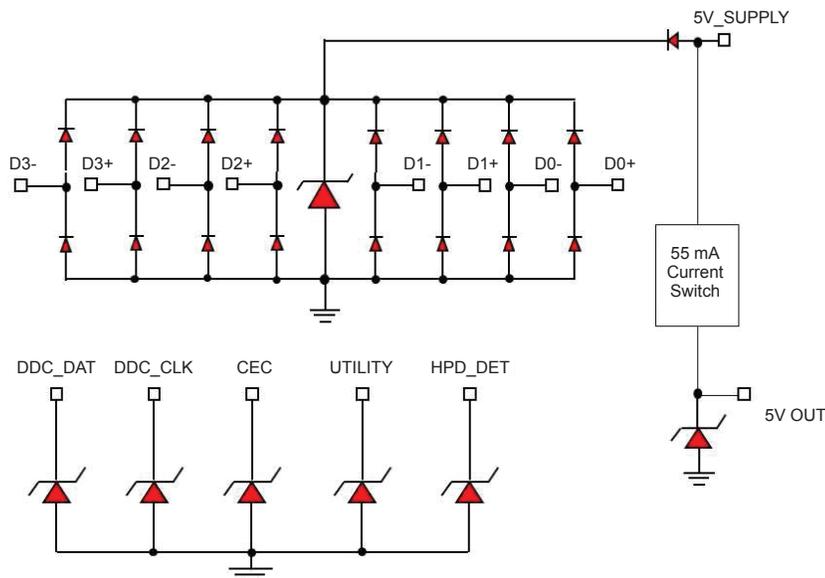
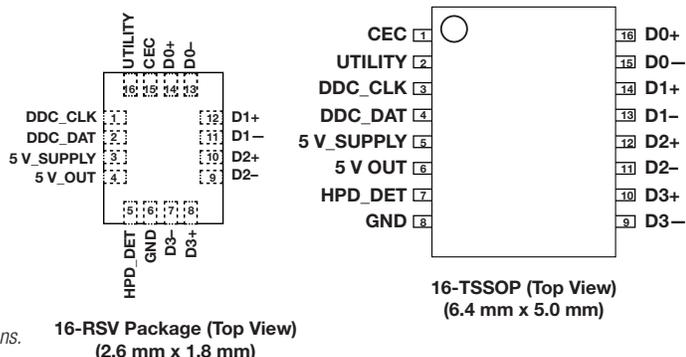
- Single chip ESD solution for HDMI 1.4 and HDMI 1.3 interface
- On-chip 5 V load switch with current limit and reverse current protection
- Supports UTILITY line protection for HDMI 1.4 Audio Return Line
- <0.05-pF differential capacitance between the TMDS signal pair
- Industry Standard 16-TSSOP and space saving 16-RSV package
- Supports data rates in excess of 3.3 Gbps
- RDYN 0.5 Ω
- IEC 61000-4-2 (level 4) ESD compliance
- Commercial temperature range: -40°C to 85°C

#### Applications

- Set top box
- Smart phone
- Digital camcorder
- Portable game console

The TPD13S523 is a single-chip integrated ESD protection solution for the HDMI 1.4 or HDMI 1.3 interface. This device offers 13-channel ESD clamp circuits with flow-through pin mapping matching the HDMI connector high-speed lines. While providing the ESD protection, the TPD13S523 adds little or no additional distortion to the high-speed differential signals. The monolithic integrated circuit technology ensures that there is excellent matching between the two-signal pair of the differential line (<0.05-pF differential matching between TMDS lines). This is a direct advantage over discrete ESD clamp solutions where variations between two different ESD clamps may significantly degrade the differential signal quality.

The TPD13S523 incorporates an on-chip current limited load switch that confirms the HDMI 5V\_OUT electrical specifications. The 55 mA current at the 5 V\_OUT pin enables HDMI receiver detection even when the receiver device is powered off. The short circuit protection ensures that the device is not damaged in case there is accidental short to GND. The load switch also incorporates the reverse current blocking feature which ensures that the HDMI driver side is not erroneously turned on when two HDMI drivers are connected together.



# System-Level ESD/EMI Protection Guide

## → General Purpose ESD Protection

### Single Channel ESD Protection for General Purpose I/O Ports

#### TPD1E10B09, TPD1E10B06, TPD1E6B06

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD1E10B09](http://www.ti.com/sc/device/TPD1E10B09), or [www.ti.com/sc/device/TPD1E10B06](http://www.ti.com/sc/device/TPD1E10B06), or [www.ti.com/sc/device/TPD1E6B06](http://www.ti.com/sc/device/TPD1E6B06)

#### Key Features

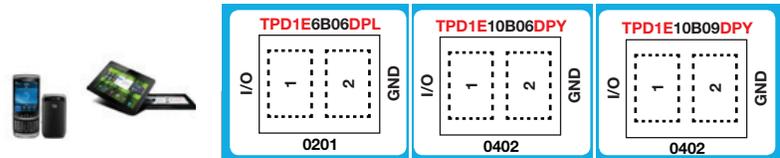
- IEC 61000-4-2 level 4
- DC breakdown voltage  $\pm 6\text{ V}$  to  $\pm 9\text{ V}$  (min)
- Ultra-low leakage current 10 nA (typ)
- Low ESD clamping voltage
- Industrial temperature range:  $-40^\circ\text{C}$  to  $125^\circ\text{C}$
- Space saving 0201 footprint (1 mm x 0.6 mm x 0.5 mm)

#### Applications

- Cell phones
- eBook
- Portable media players
- Digital camera

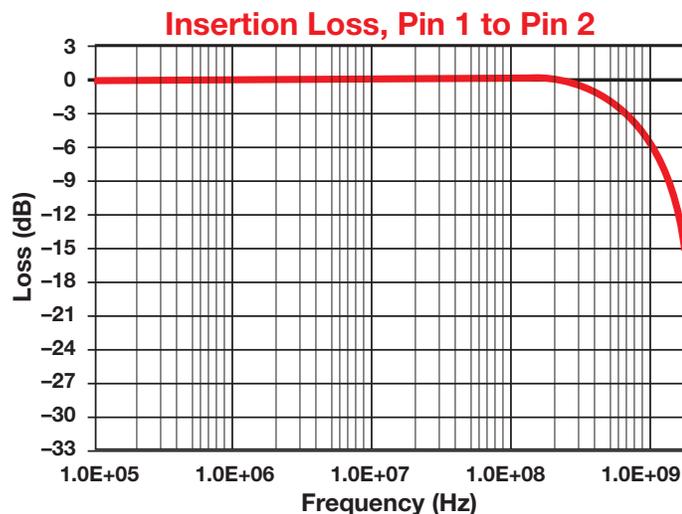
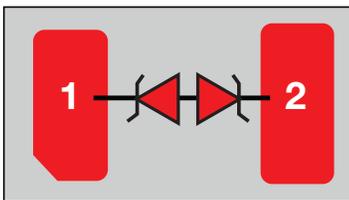
These are single channel ESD protection devices in 0402 and 0201 packages. They feature ESD clamp circuitry with back-to-back diodes for bipolar/bidirectional signal support. Typical application areas are audio lines (mic, earphone and speakerphone), SD interface, keypad or other buttons, and ID,  $V_{\text{BUS}}$  pins of USB ports.

#### Single-channel ESD

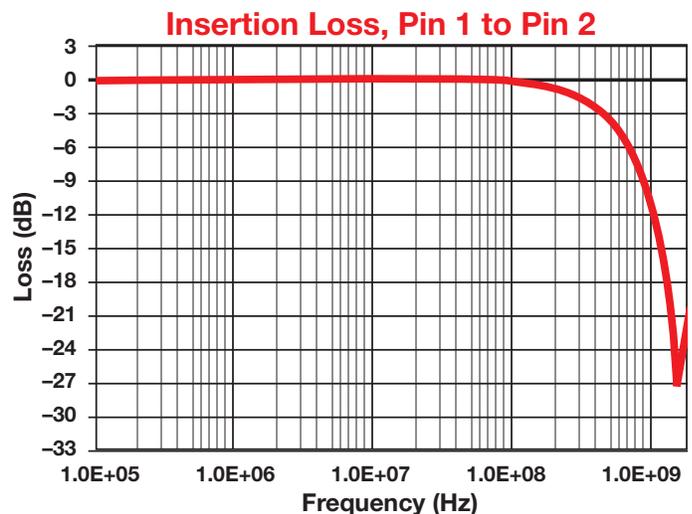


	TPD1E6B06DPL 0201	TPD1E10B06DPY 0402	TPD1E10B09DPY 0402
IEC61000-4-2 (Contact)	$\pm 15\text{ kV}$	$\pm 30\text{ kV}^*$	$\pm 20\text{ kV}$
IEC61000-4-2 (Airgap)	$\pm 15\text{ kV}$	$\pm 30\text{ kV}^*$	$\pm 20\text{ kV}$
IEC61000-4-5 (Surge)	3A	6A	4.5 A
$V_{\text{BR(MIN)}}$	6 V	6 V	9.5 A
$R_{\text{dynamic}}$	$0.5\ \Omega$	$0.325\ \Omega$	$0.5\ \Omega$
$V_{\text{CLAMP (MAX @ 1A)}}$	10 V	10 V	13 V
Capacitance (TYP)	6 pF	12 pF	10 pF

\* Test capability is only  $\pm 30\text{ kV}$ .



Insertion loss for TPD1E6B06.



Insertion loss for TPD1E10B09 and TPD1E10B06.

# System-Level ESD/EMI Protection Guide

## → ESD Protection for High-Speed Video and Data Interface

### Ultra-Low, 0.8-pF Capacitance for High-Speed Differential Interface Applications

#### TPD4S009, TPD4S010, TPD8S009

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD4S009](http://www.ti.com/sc/device/TPD4S009), or [www.ti.com/sc/device/TPD4S010](http://www.ti.com/sc/device/TPD4S010), or [www.ti.com/sc/device/TPD8S009](http://www.ti.com/sc/device/TPD8S009)

#### Key Features

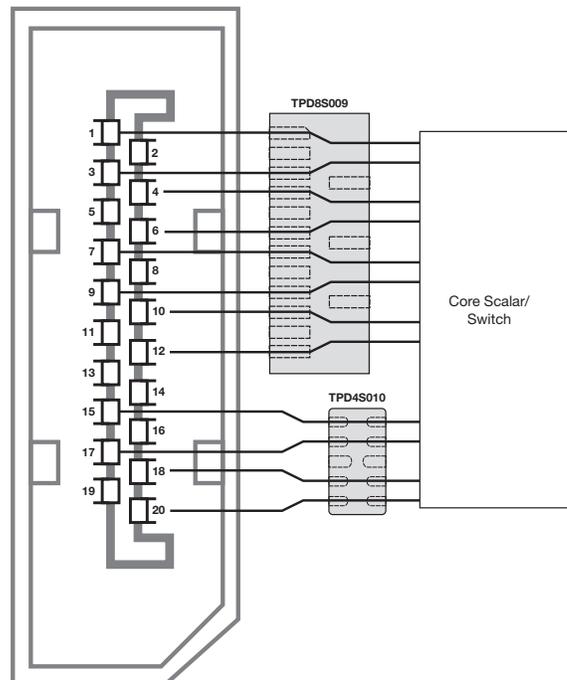
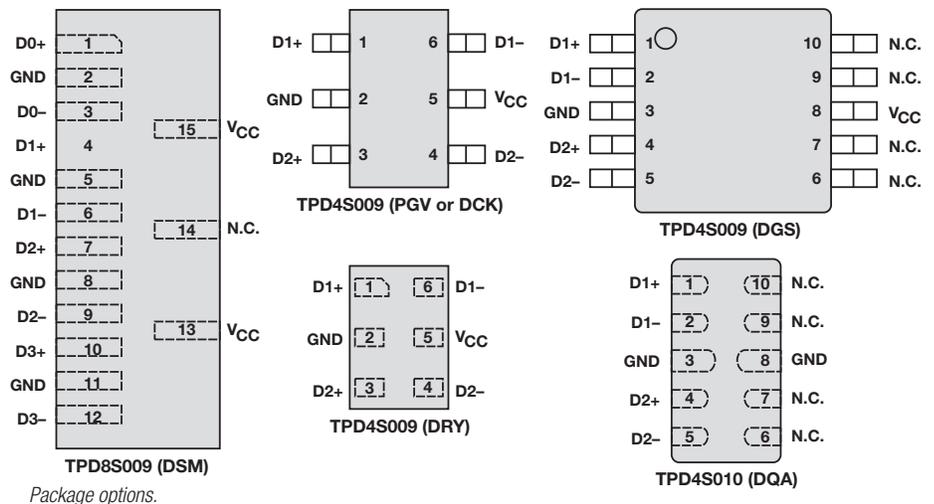
- Complies with the HDMI 1.3 and DisplayPort data rate
- System-level IEC-61000-4-2 (level 4) ESD protection
  - $\pm 8$ -kV contact discharge
- Differential matching of less than 0.05 pF
- Pin capacitance less than 0.8 pF
- $I_{off}$  feature for TPD8S009 and TPD4S009

#### Applications

- LVDS
- HDMI/DVI
- DisplayPort
- eSATA interface
- Serial link
- Ethernet
- PCI Express®

The TPD8S009, TPD4S009 and TPD4S010 provide ESD protection for high-speed differential bus interfaces. These devices are ideal for any high-speed application up to 6 Gbps.

These interfaces provide ESD protection with ultra-low, 0.8-pF capacitance for less distortion during data transfer. They also provide ultra-low matching capacitance to help improve the signal quality. All of these devices except for the TPD4S010 support  $I_{off}$  (backdrive) protection circuits with an additional diode on the  $V_{CC}$  line.



TPD8S009 and TPD4S010 in DisplayPort application.

## → ESD Protection for 1394 Ports

### FireWire™ ESD Clamp with Live-Insertion Detection Circuit

#### TPD4S1394

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD4S1394](http://www.ti.com/sc/device/TPD4S1394)

#### Key Features

- Integrated late V<sub>G</sub> detection mechanism generates FWPWR\_EN flag
- System-level IEC 61000-4-2 ESD protection for high-speed applications
  - Passes 8 kV in 1394 system interface
  - ±15-kV human body model
- Low I/O capacitance
  - 1.5 pF pin capacitance
- On-chip 600-ms timer delay mechanism
- Flow-through, single-in-line pin mapping

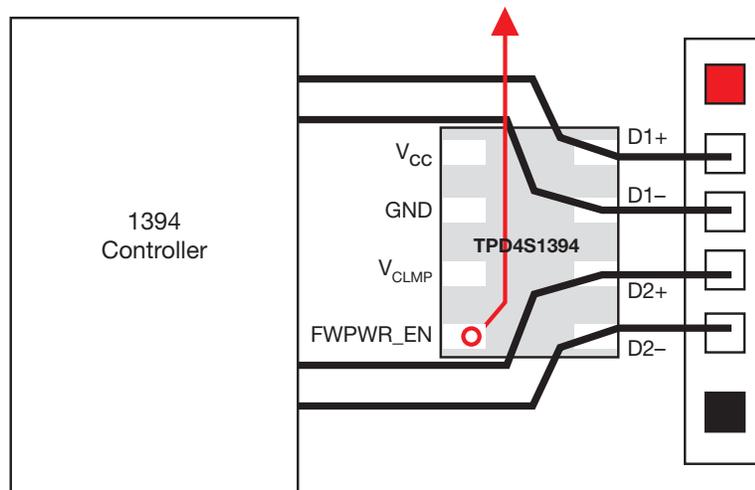
#### Applications

- IEEE 1394 live insertion protection
- LVDS

The TPD4S1394 provides a robust system-level ESD solution for the IEEE 1394 port along with a live insertion detection mechanism for high-speed lines interfacing a low-voltage, ESD-sensitive core chipset. This device protects and monitors up to two differential input pairs. The optimized line capacitance allows it to protect the data lines with data rates in excess of 1.6 GHz without degrading signal integrity.

The TPD4S1394 incorporates a live insertion circuit whose output state changes when improper voltage levels are present on the input data lines. The FWPWR\_EN signal controls an external FireWire™ port power switch. During the live insertion event, if there is a floating GND or a high-level signal at the D+, D- pins, the internal comparator will detect the changes and pull the FWPWR\_EN signal to low state. When FWPWR\_EN is driven low, there is an internal delay mechanism preventing it from being driven to the high state regardless of the inputs to the comparator.

Additionally, it performs ESD protection on the four input pins: D1+, D1-, D2+ and D2-. It conforms to the IEC61000-4-2 (level 4) ESD protection and ±15-kV HBM ESD protection. The TPD4S1394 is characterized for operation over ambient air temperatures of -40°C to 85°C.



1394 Connector.

## → ESD Protection for Keypads

### 8-Channel ESD Clamp Array

#### TPD8E003

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD8E003](http://www.ti.com/sc/device/TPD8E003)

#### Key Features

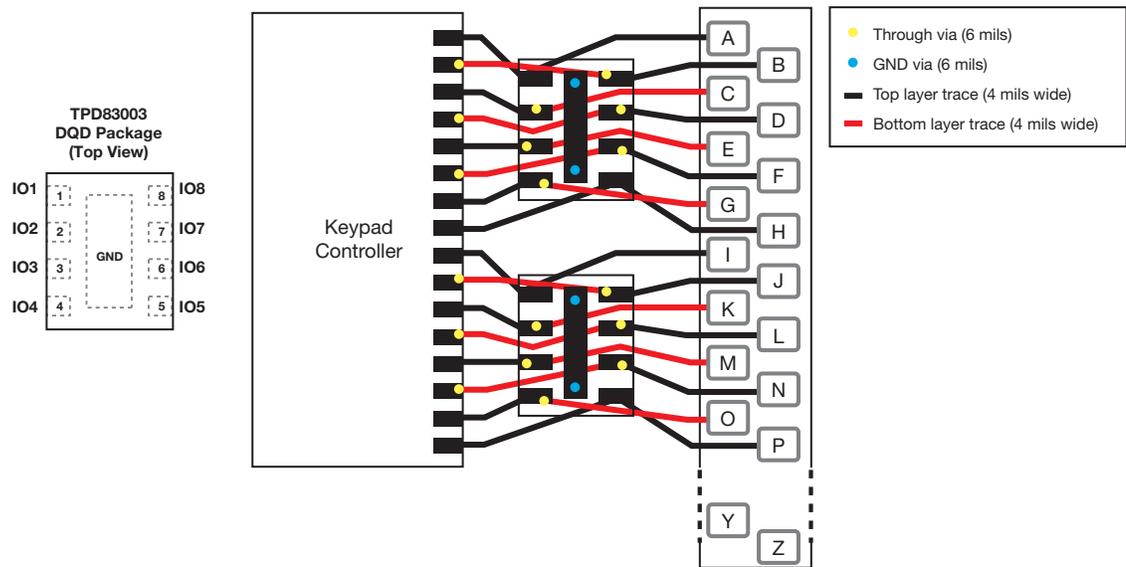
- Eight-channel ESD clamp array to enhance system-level ESD protection
- Exceeds IEC61000-4-2 (level 4) ESD protection
  - ± 12-kV contact discharge
  - ± 15-kV air-gap discharge
- 3.5-A peak pulse current (8/20 µsec)
- Low breakdown voltage of 6 V

#### Applications

- Keypad
- Touch-screen interface
- Memory interface
- Docking connector interface

The TPD8E003 is an array of eight ESD clamps in a space-saving SON (DQD) package. This integrated transient voltage suppressor device is designed for applications requiring system-level ESD robustness. It is intended for use in space-constrained equipment such as portable computers, cell phones, communication keypad systems and other applications. Its integrated design offers superior matching between multiple lines over discrete ESD clamp solutions.

The TPD8E003 includes ESD protection circuitry that prevents damage to the application when subjected to ESD stress exceeding IEC 61000-4-2 (level 4). The TPD8E003 is specified for -40°C to 85°C operation.



TPD8E003DQDR at keypad interface.

## EMI Filters

### 2-Channel EMI Filter for Audio Headphones

#### TPD2F702

Get samples, datasheets and evaluation modules at [www.ti.com/sc/device/TPD2F702](http://www.ti.com/sc/device/TPD2F702)

#### Key Features

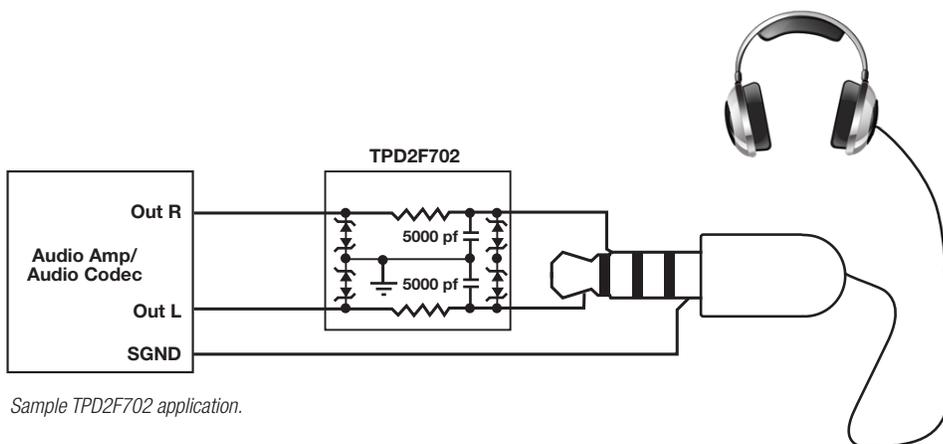
- 2-channel EMI filtering for audio ports
  - AVIF connector, headphone
- Exceeds level 4 ESD protection on connector
  - $\pm 30$ -kV contact discharge
  - $\pm 30$ -kV air-gap discharge
- Pi-style (C-R-C) filter configuration with -3-dB bandwidth at 1.2 MHz ( $R=15\ \Omega$ ,  $CTOTAL = 5000\ \text{pF}$ )
- Low 10-nA leakage current
- WCSP packages and flow-through pinout

#### Applications

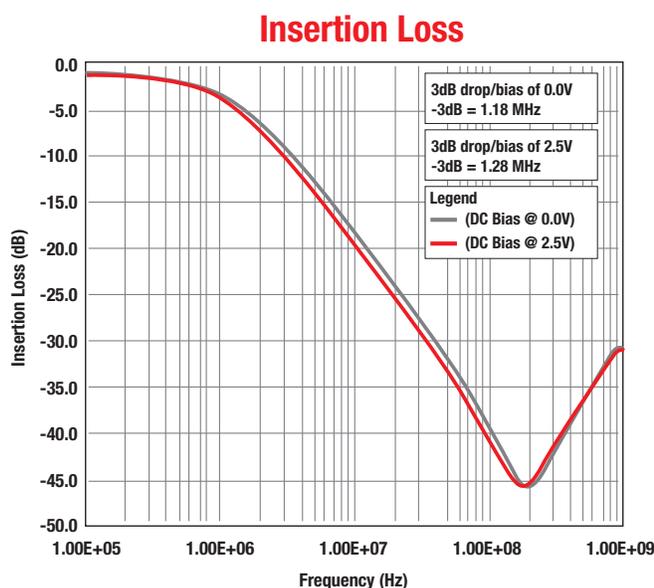
- Mobile phones
- Headsets
- PDAs
- Portable gaming

The TPD2F702 is a two-channel EMI filter for audio interface applications. With the integration of a 5000-pF capacitor in a space-saving low-noise WCSP package, the TPD2F702 offers superior EMI noise suppression (2 MHz to 6 GHz) compared to discrete implementation. The device is optimized for AVIF connector or speaker port interfaces. This low-pass filter array also provides system level ESD protection to eliminate the need for external ESD clamps. The TPD2F702 exceeds  $\pm 30$ -kV ratings per IEC61000-4-2 contact and air-gap specifications.

The TPD2F702 is a highly integrated device designed to suppress EMI/RFI noise in all systems subjected to electromagnetic interferences. This filter includes ESD protection circuitry, which prevents damage to the application when subjected to ESD surges far exceeding IEC 61000-4-2 (level 4).



Sample TPD2F702 application.



Frequency vs. dB for TPD2F702.

# System-Level ESD/EMI Protection Guide

## EMI Filters

### Space-Saving EMI Filters

#### TPD4F003, TPD6F003

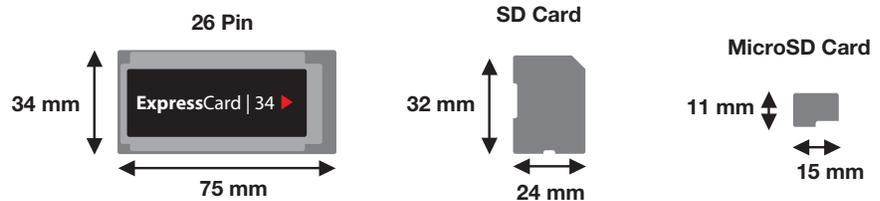
Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPD4F003](http://www.ti.com/sc/device/TPD4F003) or [www.ti.com/sc/device/TPD6F003](http://www.ti.com/sc/device/TPD6F003)

#### Key Features

- 4-, 6-, or 8-channel EMI filter with greater than 25-dB attenuation at 1 GHz
- System-level IEC 61000-4-2 ESD protection
  - $\pm 12$ -kV contact discharge
  - $\pm 20$ -kV air-gap discharge
  - $\pm 15$ -kV human body model
- Pi-style C-R-C topology with  $-3$ -dB bandwidth at 200 MHz ( $R = 100 \Omega$ ,  $C_{TOTAL} = 17$  pF)
- Flow-through package layout
- Operating I/O voltage range up to 5.5 V
- Low 10-nA leakage current

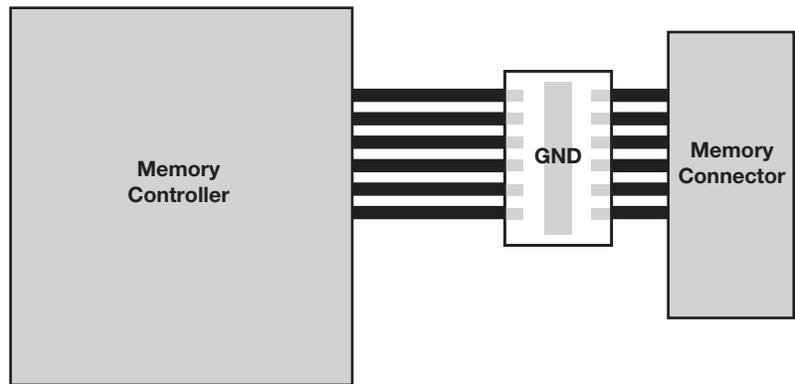
The TPD4F003, TPD6F003 and TPD8F003 are four-, six-, and eight-channel EMI filters in space-saving 0.4-mm pitch DQD packages. The low-pass filter arrays reduce EMI emissions and provide system-level ESD protection.

Because of its small package and easy-to-use pin assignments, TPDxF003 filters are suitable for a wide array of applications, such as mobile handsets, PDAs, video consoles, notebook computers, etc. In particular, these filters are ideal for EMI filtering and protecting data lines from ESD at the LCD display, keypad and memory interfaces.

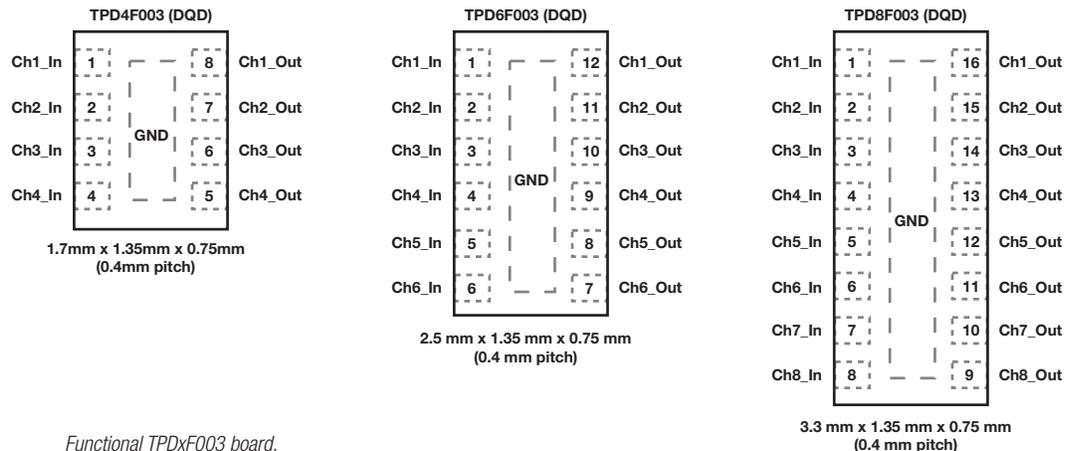


#### Applications

- LCD display interface
- Keypad
- Memory interface
- Cell phones
- SVGA video connections
- PDAs



TPDxF003 typical use circuit.



Functional TPDxF003 board.

## EMI Filters

### 4- and 6-Channel EMI Filters for LCD Display

#### TPDxF202

Get samples, datasheets and evaluation modules at: [www.ti.com/sc/device/TPDxF202](http://www.ti.com/sc/device/TPDxF202)

#### Key Features

- Low 10-nA leakage current
- Ultra-thin YFU package
  - 1.06 mm x 1.57 mm x 0.3 mm
- Exceeds IEC 61000-4-2 system-level ESD protection
  - ± 25-kV contact discharge
  - ± 25-kV air-gap discharge
- Pi-style (C-R-C) filter configuration with greater than -32 dB attenuation at 1 GHz ( $R = 100 \Omega$ ,  $CTOTAL = 15 \text{ pF}$ )
- Cut-off frequency at 108 MHz

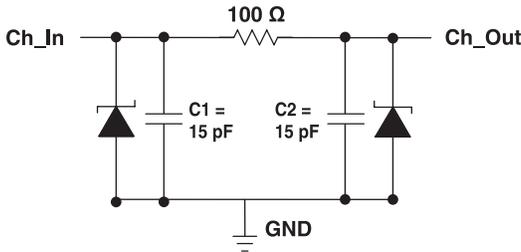
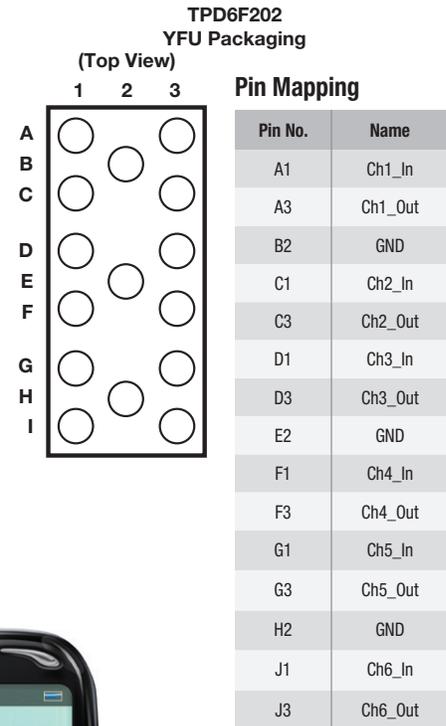
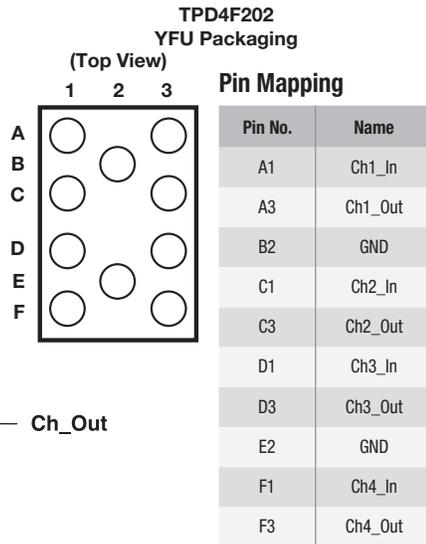
The TPDxF202 is a four- and six-channel EMI filter in space-saving SON packages. This low-pass filter array reduces EMI emissions and provides system-level ESD protection. It is used on mobile-phone LCD or memory interfaces. The pi-style (C-R-C) filter provides at least 30-dB attenuation in the carrier frequency range (800 to 2700 MHz).

The TPDxF202 is a highly integrated device designed to suppress EMI/RFI noise in all systems subjected to electromagnetic interferences. This filter includes an ESD protection circuitry that prevents damage to the application when subjected to ESD strikes up to IEC 61000-4-2 (level 4).

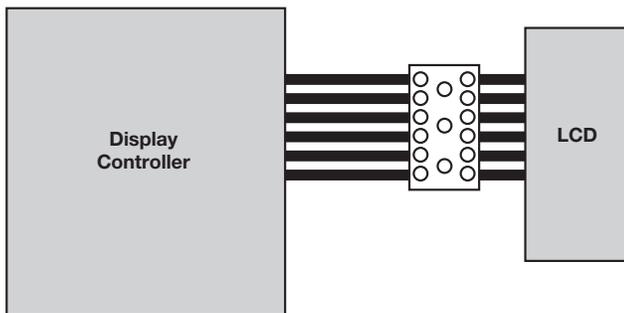
The TPDxF202 is specified for -40°C to 85°C operation.

#### Applications

- LCD interface
- Cell phones
- SVGA video connections
- PDAs



Equivalent schematic representation.



Top view of TPD6F202 usage example.



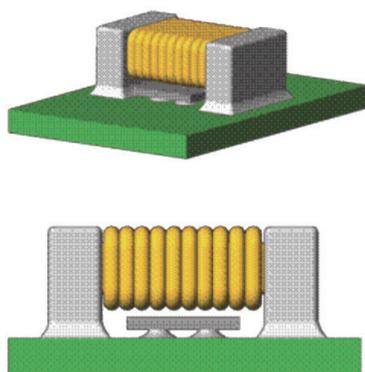
## → Packaging Solutions

TI offers the most robust packaging solutions for ESD/EMI devices. With over eight package types ranging from 0.18 mm<sup>2</sup> PicoStar™ packages to 62 mm<sup>2</sup> TSSOP, we have packaging solutions that can fit into any design. From the PicoStar™ package that can be embedded into the PCB to 38-pin TSSOP designed for easy board layout (see page 9), there are options for every design.

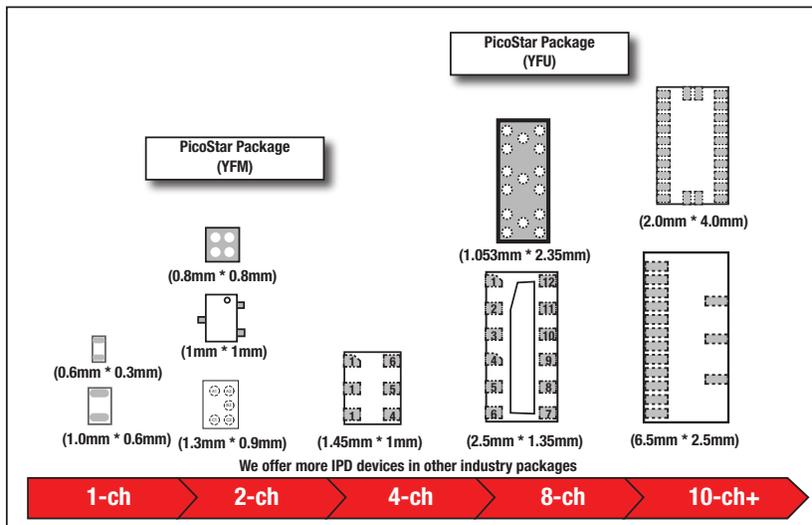
### PicoStar™ Package Solutions:

Portable consumer electronics designers can save board space with integrated circuits (ICs) in the PicoStar™ package from Texas Instruments. The ultra-thin package, about as thin as a human hair, is the first to give system designers the option to embed silicon components inside the printed circuit board (PCB) to maximize board space. Devices in this form factor are 50 percent thinner than similar chips in traditional packages and enable smaller, thinner end equipment.

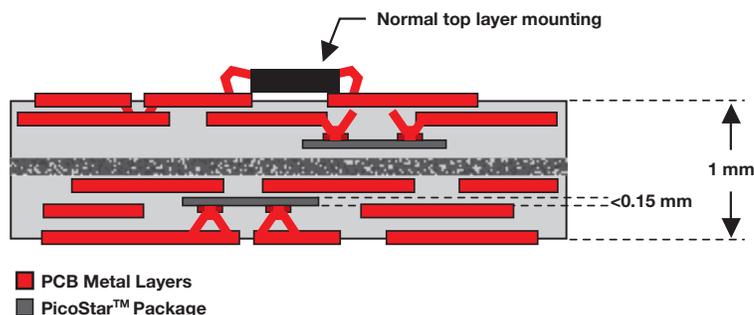
The PicoStar™ package is thin enough to be embedded inside the PCB, mounted under a connector, or placed under some discrete components. The images here show the space-saving capabilities of this package for board layout.



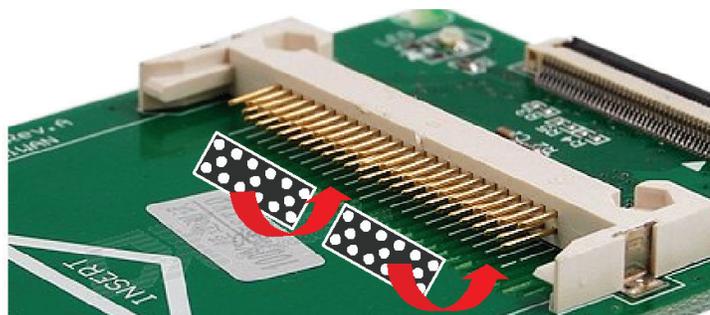
0.13 mm (height) PicoStar™ package under ceramic inductor.



TI packages for ESD/EMI solutions.



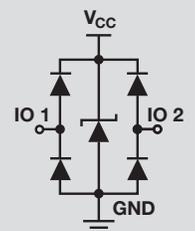
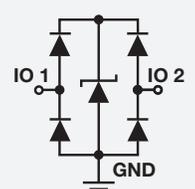
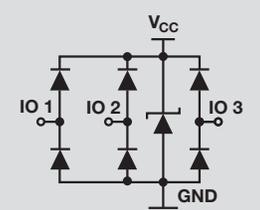
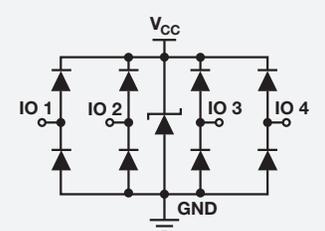
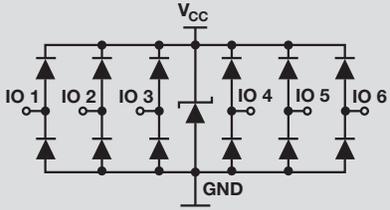
PicoStar™ package embedded in PCB board. Height of the total PCB board is 1 mm.



0.3 mm (height) YFU package under the Zif connector.

# ESD/EMI Protection Device List

## → General-Purpose ESD Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages
	Level 4 Protection						
TPD1E10B09, TPD1E10B06	Yes		1	n/a	$\pm 6$ to $\pm 9$ $-8$ to $+15$	10, 12	DPY
TPD1E6B06			1	n/a	$\pm 6$	6	DPL
TPD2E001	Yes		2	0.9 to 5.5	11	1.5	5-SOT, 6-SON, 4-SOP
TPD2E009	Yes		2	$-0.3$ to $6$	9	0.8	3-SOT, 6-SON
TPD3E001	Yes		3	0.9 to 5.5	11	1.5	5-SOT, 6-SON
TPD4E001	Yes		4	0.9 to 5.5	11	1.5	6-SOT, 6-SON
TPD6E001	Yes		6	0.9 to 5.5	11	1.5	10-/12-QFN

\*Subject to change. Call Product Information Center. See last page for contact information.

Preview products are listed in **bold blue**.

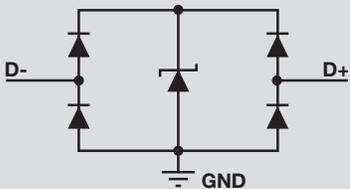
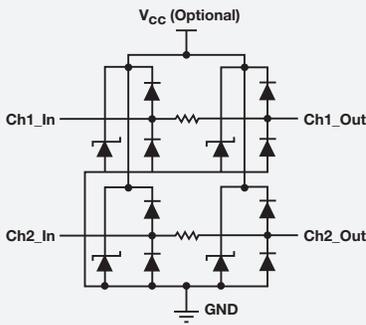
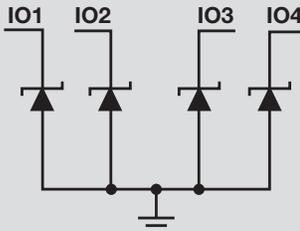
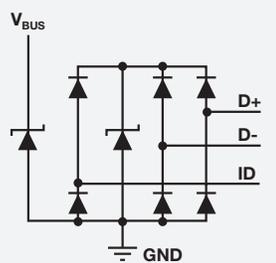
# ESD/EMI Protection Device List

## → General-Purpose ESD Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages
	Level 4 Protection						
TPD4E004	Yes		4	0.9 to 5.5	6	1.6	6-SOT, 6-SON
TPD6E004	Yes		6	0.9 to 5.5	6	1.6	8-QFN
TPD4S009	Yes		4	0.9 to 5.5	9	0.9	6-SOT, 6-SC70, 6-SON
TPD4S010	Yes		4	0.9 to 5.5	9	0.9	10-QFN
TPD2E007	Yes		2	n/a	±14	10	4-DSLGA (YFM) 3-SC70 (3-DCK)

# ESD/EMI Protection Device List

## → General-Purpose ESD Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages
	Level 4 Protection						
TPD2EUSB30	Yes		2	n/a	9	0.7	3-SOT
TPD2S017	Yes		2	0 to 5	11	1	6-SOT-23
TPD4E002	Yes		4	n/a	6	11	5-SOT
TPD4S012	Yes		4	-0.3 to 20	D+, D-, ID = 6 VBUS = 20	0.8	6-S0N

# ESD/EMI Protection Device List

## → General-Purpose ESD Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages
	Level 4 Protection						
TPD4S1394	Yes		4	0 to 4.6	4.2	1.5	8-SON
TPD8S009	Yes		8	-0.3 to 6	9	0.8	15-SON

## → General-Purpose EMI Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages	-3-dB Bandwidth
	Contact (kV)							
TPD2F702	$\pm 8$		2	$\pm 14$	15	5,000	5-WCSP	1.2 MHz
TPD4F003	$\pm 8$		4	6	100	17	8-WSON	200 MHz

# ESD/EMI Protection Device List

## → General-Purpose EMI Protection

Device	IEC61000-4-2	Diagram	No. of Channels	Supply Voltage ( $V_{dd}$ )	$V_{BR}$ (min) (V)	I/O Cap (pF)	Packages	-3-dB Bandwidth
	Contact (kV)							
TPD6F002	±20		6	6	100	34	12-SO8	100 MHz
TPD6F003	±8		6	6	100	17	12-WSON	200 MHz
TPD8F003	±8		8	6	100	17	16-WSON	200 MHz

## → ESD Protection Device List

Device	IEC61000-4-2 Contact (kV)	IEC61000-4-2 Level 4	No. Of Channels	Supply Voltage	VBR (min) (V)	I/O Capacitance (pF)	Pin/Package	Application
TPD12S016	+/-8kV	yes	12	VCCA: 0-3.6V; VCC5V: 0-5V	6.5V	1	TSSOP (PW); UQFN (RKT)	HDMI transmit port
TPD1E10B06	+/-30kV	yes	1	0-6V	6v	12	2xson (DPY)	General purpose
TPD1E10B09	+/-20kV	yes	1	0-9V	9.5V	10	2xson (DPY)	General purpose
TPD1E6B06	+/-15kV	yes	1	0-6V	6V	6	2xson (DPL)	General purpose
TPD4E004	±8	Yes	4	0.9 to 5.5	6	1.6	6-SO8 (DRY)	USB 2.0 High Speed, Ethernet, FireWire™, eSATA
TPD2E001	±8	Yes	2	0.9 to 5.5	11	1.5	4-SOP (DZD) 5-SOT (DRL) 6-SO8 (DRS,DRY)	USB 2.0, Ethernet, FireWire™
TPD2E007	±8	Yes	2	n/a	±14	10	4-DSLGA (YFM), 3-SC70, (3-DCK)	RS-232/RS-485, audio port
TPD2E009	±8	Yes	2	n/a	7	0.7	3-SOP (DBZ), 3-SOT (DRT)	Firewire™, eSATA, LVDS signaling

\*Subject to change. Call Product Information Center. See last page for contact information.

Preview products are listed in **bold blue**.

# ESD/EMI Protection Device List

## → ESD Protection Device List

Device	IEC61000-4-2 Contact (kV)	IEC61000-4-2 Level 4	No. Of Channels	Supply Voltage	VBR (min) (V)	I/O Capacitance (pF)	Pin/Package	Application
TPD2EUSB30	±8	Yes	2	n/a	7	0.7	3-SOT (DRT)	USB 3.0
TPD2S017	±11	Yes	2	0 to 5	11	1	6-SOT-23 (DBV)	USB 2.0 High Speed
TPD3E001	±8	Yes	3	0.9 to 5.5	11	1.5	5-SOT (DRL) 6-SON (DRS,DRY)	USB OTG
TPD4E001	±8	Yes	4	0.9 to 5.5	11	1.5	6-SON (DRS), 6-SOT (DRL)	USB 2.0, Ethernet, FireWire™, eSATA
TPD4E002	±15	Yes	4	n/a	6.1	11	5-SOT (DLR)	USB 2.0 Full Speed
TPD12S016	+/-8kV	yes	12	VCCA: 0-3.6V; VCC5V: 0-5V	6.5V	1	TSSOP (PW); UQFN (RKT)	HDMI transmit port
TPD4E004	±8	Yes	4	0.9 to 5.5	6	1.6	6-SON (DRY)	USB 2.0 High Speed, Ethernet, FireWire™, eSATA
TPD4S009	±8	Yes	4	0 to 5.5	9	0.8	10-MSOP (DGS) 6-SC-70 (DCK), 6-SON (DRY), 6-SOT-23 (DBV)	eSATA, LVDS signaling, HDMI
TPD4S010	±8	Yes	4	n/a	9	0.8	6-SON (DQA)	eSATA, LVDS signaling, HDMI
TPD4S012	±10	Yes	4	0 to 20	D+, D-, ID = 6 VBUS = 20	0.8	6-SON (DRY)	USB 2.0 High Speed (charging applications)
TPD4S1394	**±8	Yes	4	0 to 4.6	4.2	1.5	8-X2SON (DQL)	1394/FireWire™
TPD4S214	±8	yes	4	0-6V	ID, D+, D-: 6V, VBUS:30V	1.5	12-DSBGA (YFF)	USB
TPD6E001	±8	Yes	6	0.9 to 5.5	11	1.5	10-UQFN (RSE), 12-WQFN (RSF)	USB 2.0, Ethernet, FireWire™, eSATA
TPD6E004	±8	Yes	6	0.9 to 5.5	6	1.6	8-UQFN (RSE)	USB 2.0, Ethernet, FireWire™, eSATA
TPD7S019	±8	Yes	7	0 to 5.5	9	2.5	16-SSOP (DBQ), <b>16-UQFN (RSE)</b>	VGA DisplayPort
TPD8E003	±12	Yes	8	n/a	6	7	8-WSON (DQD)	Keypad, touch-screen interface, Memory, SDIO, SIM card
TPD8S009	±8	Yes	8	0 to 55	9	0.8	15-SON (DSM)	HDMI, DisplayPort, LVDS signaling
TPD12S015A	±8	Yes	12	2.3 to 5.5	9	1.3	28-DSBGA (YFP)	HDMI Class C/D connector
TPD12S520	±8	Yes	12	0 to 5.5	9	0.8	38-TSSOP (DBT)	HDMI receiver port
TPD12S521	±8	Yes	12	0 to 5.5	9	0.8	38-TSSOP (DBT)	HDMI transmit port

\*Subject to change. Call Product Information Center. See last page for contact information.

Preview products are listed in **bold blue**.

## → EMI Protection Device List

Device	Air-Gap (kV)	Contact (kV)	No. of Channels	VBR (min) (V)	Rline (typ) (Ohms)	Ctotal (typ) (pF)	Pin/Package	-3-dB Bandwidth	Application
TPD2F702	±30	±30	2	±14	15	5,030	5-WCSP (YFK)	1.2 MHz	Audio
TPD4F003	±20	±12	4	6	100	17	WSON (8-DQD)	200 MHz	Memory, LCD display, keypad
TPD4F202	±25	±25	4	6	100	30	DSBGA (10-YFU)	108 MHz	Memory, LCD display, keypad
TPD6F002	±30	±20	6	6	100	34	SON (12-DSV)	100 MHz	Memory, LCD display, keypad
TPD6F003	±20	±12	6	6	100	17	WSON (12-DQD)	200 MHz	Memory, LCD display, keypad
TPD6F202	±25	±25	6	6	100	30	DSBGA (15-YFU)	108 MHz	Memory, LCD display, keypad
TPD8F003	±20	±12	8	6	100	17	WSON (16-DQD)	200 MHz	Memory, LCD display, keypad
TPD3F303	±15	±8	3	6	47	20	SON (8-DQD)	300 MHz	SIM interface

## → Overview

Distributing and controlling power—even after the correct voltage is derived—is becoming more complex. Because increasing numbers of voltage rails are required in today’s advanced processing or embedded systems, distributing and managing these rails is a constant challenge.

In these systems, load switches, MUXes, or inrush-protection devices

are routinely required to safely route power where it is needed and deliver it properly. When power needs to be moved from system to system, issues like hot-swap control, safety certification, and monitoring are quickly top priorities.

Digital control takes all of these concerns and capabilities to yet another level. Microprocessor control

and monitoring in system health and power blocks gives designers even more options to improve the robustness of their system. Using digital interfaces to various functional blocks and sensors, it is possible to monitor the amount of power or current being consumed, the temperature of the system, or other variables, and then take action.

## → Power-over-Ethernet

The concept of providing power along with data is as old as plain old telephone service, but the formal standard for providing power along Ethernet lines is much more recent. Though the original Power-over-Ethernet (PoE) specification was approved in 2005, the IEEE ratified a superseding standard in summer 2009—the IEEE 802.3at. Both standards specify behavior for devices receiving power across Ethernet lines, known as “powered devices” (PDs), and methods for injecting power onto the line, used in equipment known as “power sourcing equipment” (PSE).

### Original PoE . . . Only Better!

The vast majority of PoE applications need less than 12.95 W. For this growing market area, TI has a large portfolio of options to consider:

#### TPS23753A

- Simplest, most elegant, lowest-cost solution for a standard PoE PD
- Incorporates rugged tolerance for extended ESD exposure
- Auxiliary power supplies are fully supported—down to 12 V!

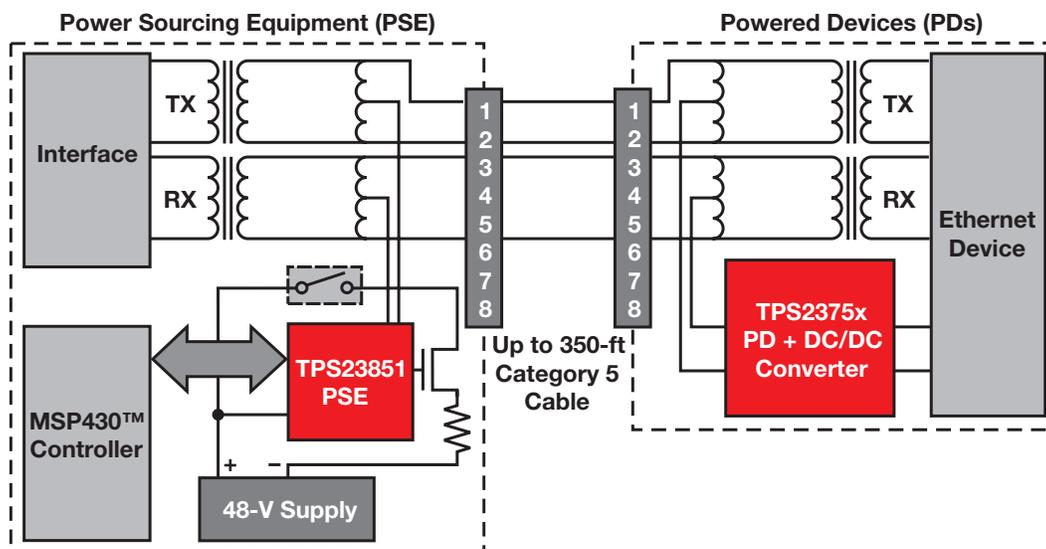
#### TPS23757

- Secondary gate driver enables high-efficiency, isolated topologies for applications requiring 12.95 W or less
- Pin-for-pin compatible with the TPS23756, providing an easy path for low- or high-power applications
- Operates with auxiliary input power supplies as low as 12 V

#### TPS23750

- TI’s original PD front end plus DC/DC converter
- Supports simple, low-cost, non-isolated buck-converter topologies with no transformer required

### New PoE Products for a New Standard!



The new TPS23851 and TPS2375x are IEEE 802.3at-compliant power-management ICs designed for managing the connection between Power Sourcing Equipment (PSE) and Powered Devices (PDs) over Ethernet cables (see: [www.ti.com/poe](http://www.ti.com/poe)). The TPS23851 is a quad-port PSE power manager with external FETs and individual ADCs per port for maximum monitoring and control.

## → Power-over-Ethernet

### IEEE 802.3at PoE High-Power PD Interface

#### TPS2378, TPS2379

Get samples, datasheets, evaluation modules and app reports at: [www.ti.com/product/TPS2378](http://www.ti.com/product/TPS2378) or [TPS2379](http://www.ti.com/product/TPS2379)

The new TPS2378 and TPS2379 PDs are specifically designed for high-power POE systems such as surveillance system cameras and wireless access points. Full 802.3at compliance along with a large and

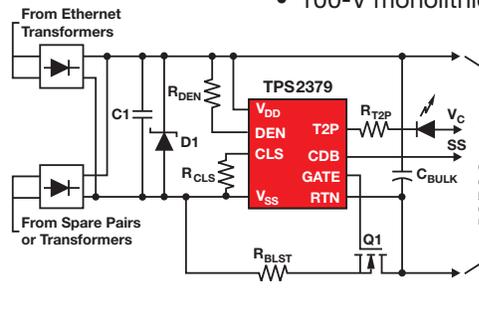
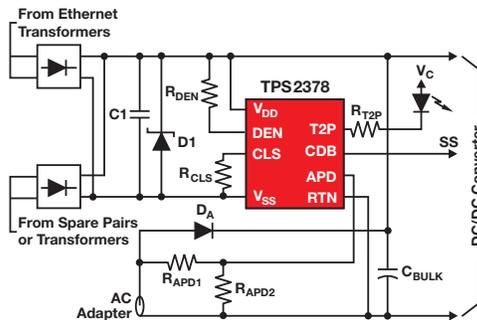
growing collection of proven reference designs makes it easy to create a robust, rugged and compliant PD system.

#### Key Features

- TPS2378 – Programmable AUX input

that forces load to be powered from AUX supply if available

- TPS2379 – Gate drive for external NFET allows designer to select external FET for desired current limit
- 802.3at-compliant hardware
- 100-V monolithic process



#### Selection Guide

Device	Description	Abs Max $V_{IN}$ (V)	Operating Temp (°C)	Full Inrush Current Limiting	Current Limit (mA)	Second Gate Driver for Maximum Efficiency	Package(s)	Price*
<b>Power-over-Ethernet (PoE) Powered Device (PD) Controllers with Integrated DC/DC Controllers</b>								
TPS23750/70	Integrated PD with PWM controller	100	-40 to 85	Fixed	405	No	TSSOP-20	1.50
TPS23753A	PD+controller with AUX ORing	100	-40 to 85	Fixed	405	No	TSSOP-14	1.45
TPS23754/6	High-power PD + high-efficiency controller	100	-40 to 125	Fixed	850	Yes	TSSOP-20 PowerPAD™	1.90
TPS23757	PD + high-efficiency controller	100	-40 to 125	Fixed	405	Yes	TSSOP-20	1.65
<b>TPS23751</b>	PD with Eco-mode™ PWM	100	-40 to 85	Fixed	800	No - VF	TSSOP-20	TBD
LM5070	Integrated PD with PWM controller	80	-40 to 125	Prog	500	No	TSSOP-16	1.45
LM5071	Integrated PD with PWM controller and AUX interface	80	-40 to 125	Fixed	390	No	TSSOP-16	1.45
LM5072	Integrated PD with PWM controller and AUX control	100	-40 to 125	Prog	800	No	TSSOP16	1.85

Device	Description	Detection	Classification	Abs Max $V_{IN}$ (V)	Operating Temp (°C)	Full Inrush Current Limiting	Current Limit (mA)	Auto Retry or Latch Off in Fault	UVLO	DC/DC Interface	Package(s)	Price*
<b>Power-over-Ethernet (PoE) Powered Device (PD) Interface Front-End Controllers</b>												
TPS2375/-1	Powered device controller	4	Yes, Class 0-4	100	-40 to 85	Programmable	450	Latch Off/Retry	802.3af (30.6/39.4 V)	PG	SOIC-8, TSSOP-8/TSSOP-8	1.00
TPS2376	Powered device controller	4	Yes, Class 0-4	100	-40 to 85	Programmable	450	Latch Off	Adjustable	PG	SOIC-8, TSSOP-8	1.00
TPS2376-H	High-power PD controller	4	Yes, Class 0-4	100	-40 to 85	Programmable	600	Auto Retry	Adjustable	PG	SOIC-8	1.25
TPS2377	Powered device controller	4	Yes, Class 0-4	100	-40 to 85	Programmable	450	Latch Off	Legacy (30.5/35.0 V)	PG	SOIC-8, TSSOP-8	1.00
TPS2377-1	Powered device controller	4	Yes, Class 0-4	100	-40 to 85	Programmable	450	Auto Retry	Legacy (30.5/35.0 V)	PG	SOIC-8	1.00
<b>TPS2378</b>	PD with AUX control	4	Yes, Class 0-4	100	-40 to 85	Fixed	800	Auto Retry	30.5/35	PG	SOIC-8	TBD
<b>TPS2379</b>	PD with high power	4	Yes, Class 0-4	100	-40 to 85	Fixed	800	Auto Retry	30.5/35	PG	SOIC-8	TBD
LM5073	PD controller w/AUX control	4	Yes, Class 0-4	100	-40 to 85	Programmable	800	Auto Retry	Adjustable	PG	TSSOP-14	1.30

Device	Applications	Channels	Abs Max $V_{IN}$ (V)	Operating Temp (°C)	IEEE Compliant	Interface	Disconnect	Measurements	Power FET	Package	Price*
<b>Power-over-Ethernet (PoE) Power Sourcing Equipment (PSE) Controllers</b>											
TPS2384	Routers, switches, SOHO hubs, midspans	4	80	-40 to 125	802.3af	i <sup>2</sup> C	Both AC and DC	Current, voltage, capacitance and temperature	Internal	64-pin LQFP	4.75
TPS23841	Proprietary, higher-power 24-V/48-V PoE switches, hubs, midspans	4	80	-40 to 125	802.3af	i <sup>2</sup> C	Both AC and DC	Current, voltage, capacitance and temperature	Internal	64-pin LQFP	7.50
TPS23851	High power PoE for switches, hubs, midspans and industrial applications	4	70	-20 to 125	802.3at Type 1 & 2	i <sup>2</sup> C	Both AC and DC	Current, voltage and temperature	External	36-pin SSOP	4.50

\*Suggested resale price in U.S. dollars in quantities of 1,000.

New devices are listed in bold red. Preview devices are listed in bold blue.

## → Protection and Power Switches

### Protection Circuitry

Protecting designs from unwanted inrush current, reverse current flow, or malfunction is challenging. The following questions and answers cover typical application design issues.

#### Can the board ever pull too much current?

If the design involves devices that plug into live systems (hot swaps), the answer is probably “yes.” Also, if the design has subsystems that need to be turned on and off via a pass FET or some other device, unwanted inrush current could be a problem when those systems are activated. In these cases, choosing a current-limiting switch or a hot-swap manager will control this input. Here are some key considerations that will make product selection easier:

1. *What is the voltage? How much nominal current does the system draw?* If the system has low voltage (< 20 V) and draws less than 5 A continuously, a hot-swap controller such as the TPS2420/1 with an internal FET and sense element is a likely choice. For higher voltages and/or higher currents, an external FET and a hot-swap controller IC such as the TPS2492/3 or LM5069 are good solutions.

2. *Are defined periods of time needed during which additional current can flow to the load (for example, during start-up)?* If so, a constant-current switch or a configurable timer on a hot-swap controller is important. Good examples of these are the TPS2552/3 devices, which are simple switches with only thermal shutdown, and the TPS2420, which has a configurable timer.
3. *Does the amount of current flowing to the load need to be monitored?* The TPS2420 and TPS2x58/9 have analog current-monitoring pins that are ideal for use with sequencers such as the UCD90124 on page 109 or with any microcontroller with an onboard ADC such as TI’s MSP430™ MCU. The LM(2)5066, LM5064 and TPS2480/1 external FET devices have directly addressable digital outputs of current readings via I<sup>2</sup>C or SMBus/PMBus.

#### Is the power supply at risk from reverse current flow?

If the system has a battery backup, supercapacitor, or alternate power supply, the answer is probably “yes.” Also, if it is important to control which

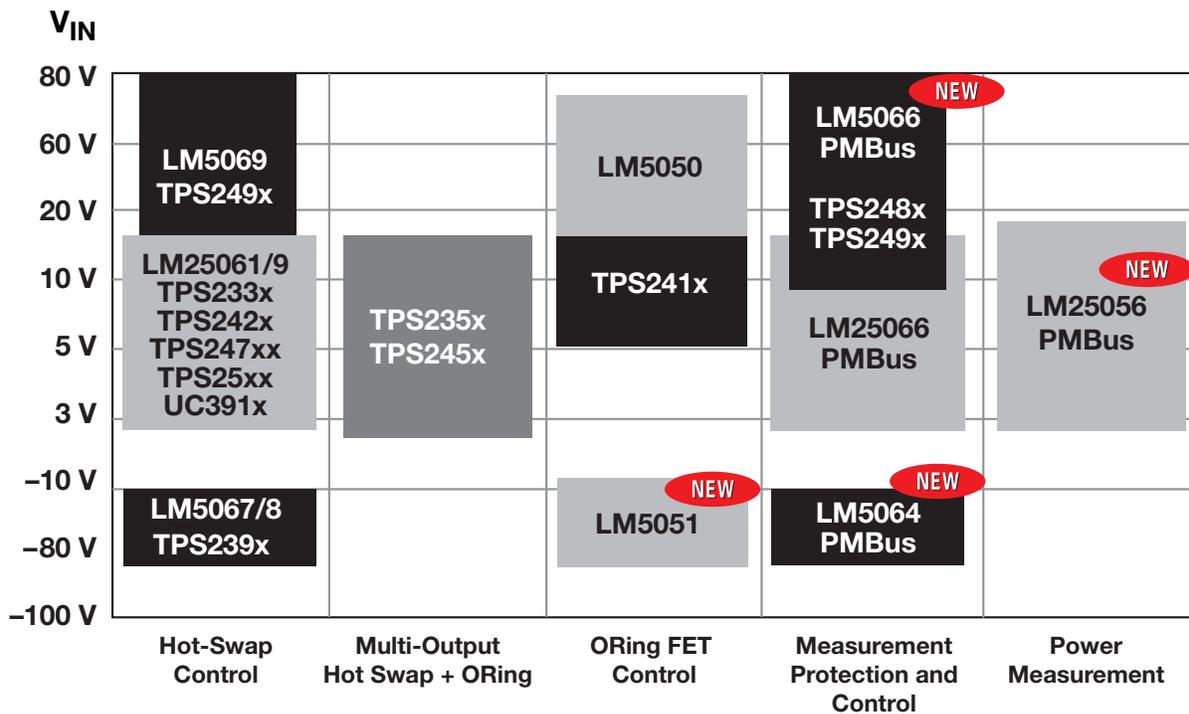
source is powering the board, ORing FET controllers such as the LM5050, TPS2410 or combination devices could be very useful. Here are some key questions to consider:

1. *What is the voltage? How much nominal current does the system draw?* For systems from 0.8 to 16.5 V, the TPS2410/1/2/3 are great options that control external FETs, providing flexibility for the amount of current passing through to the load. Features like soft start, nuisance trip filters, and external control via UV/OV pins are key aspects for many designs.
2. *Are the system’s currents and voltages low enough to use a single device?* Many lower-voltage (2.7- to 6.5-V) solutions that consume less than 1.5 A per rail could make use of integrated MUX devices.

If protection from both reverse current and inrush current is needed, check out the TPS2456/8/9 devices, which incorporate both an ORing FET controller and a hot-swap controller.

## → Protection and Power Switches

### Protection Power Portfolio



## System Power Management and Protection IC with PMBus

### LM25066

Get samples, datasheets, evaluation modules and app reports at: [www.ti.com/product/LM25066](http://www.ti.com/product/LM25066)

TI's PMBus-enabled system protection and management products combine hot swap control with embedded telemetry measurement, intelligence, and digital communications which enable them to deliver accurate power usage data back to the system to optimize power consumption, reduce operating expenses, and increase reliability

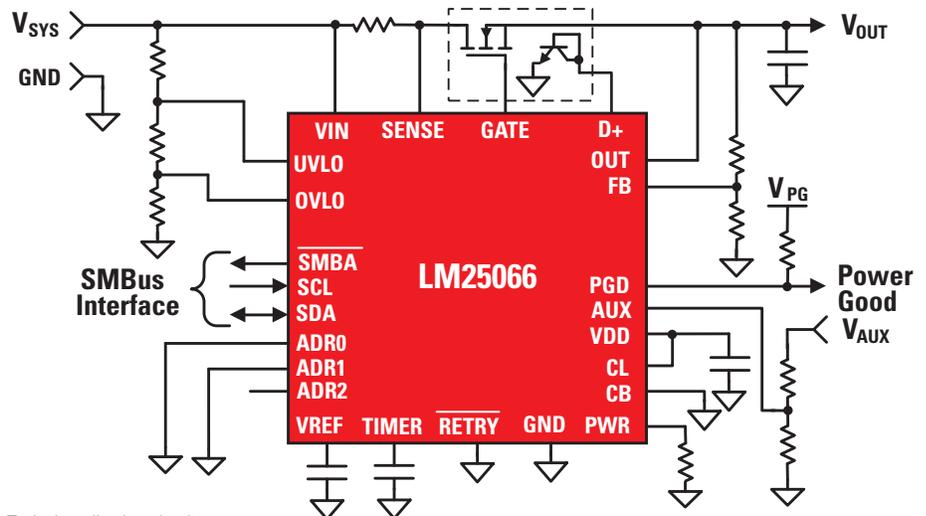
#### Key Features

- Hot swap with current and power limiting
- Adjustable current limit, circuit breaker thresholds
- Measure voltage, current, power and temperature
- Simultaneous sampling of current and voltage for true power measurement
- Peak and programmable average power capture
- Dynamic configuration of fault and warning levels

- I<sup>2</sup>C/SMBus interface with PMBus compliance

#### Applications

- Server backplane systems
- Base station power distribution systems
- Solid-state circuit breakers



Typical application circuit.

# Power Protection, Control and Monitoring

## → Protection and Power Switches

### Hot Swap Switches (Integrated FET) Selection Guide

Device	Target Applications	Channels	V <sub>IN</sub> (V)	Current Limit (A)	r <sub>DS(on)</sub> per FET (typ) (mΩ)	Enable/Shutdown	Ramp	Package(s)	Price*
TPS2420	Hot swap with current monitor & pwr limiting	1	3 to 20	1 to 5	20	1L	Current	16-pin SON	1.95
TPS2421-1	Hot swap with pwr limiting, latch-off on fault	1	3 to 20	1 to 5	20	1L	Current	SOIC-8	1.60
TPS2421-2	Hot swap with pwr limiting, retry on fault	1	3 to 20	1 to 5	20	1L	Current	SOIC-8	1.60
TPS2552	Current-limiting switch, constant-current	1	2.5 to 6.5	0.75 to 1.5	85	1L	Current	6-pin SOT-23, SON	0.70
TPS2552-1	Current-limiting switch, latch-off on fault	1	2.5 to 6.5	0.75 to 1.5	85	1L	Current	6-pin SOT-23, SON	0.70
TPS2553	Current-limiting switch, constant-current	1	2.5 to 6.5	0.75 to 1.5	85	1H	Current	6-pin SOT-23, SON	0.70
TPS2553-1	Current-limiting switch, latch-off on fault	1	2.5 to 6.5	0.75 to 1.5	85	1H	Current	6-pin SOT-23, SON	0.70
<b>TPS2554</b>	Current-limiting switch, constant-current	1	4.5 to 5.5	0.25 to 2.8	73	1H	Current	8-pin SON	0.80
<b>TPS2555</b>	Current-limiting switch, constant-current	1	4.5 to 5.5	0.25 to 2.8	73	1L	Current	8-pin SON	0.80
TPS2556	Current-limiting switch, constant-current	1	2.5 to 6.5	0.5 to 5	22	1L	Current	8-pin SON	0.90
TPS2557	Current-limiting switch, constant-current	1	2.5 to 6.5	0.5 to 5	22	1H	Current	8-pin SON	0.90
TPS2560/A	Current-limiting switch, constant-current	2	2.5 to 6.5	0.25 to 2.5	45	2L	Current	10-pin SON	0.90
TPS2561/A	Current-limiting switch, constant-current	2	2.5 to 6.5	0.25 to 2.5	45	2H	Current	10-pin SON	0.90
TPS2590	Current-limiting switch, configurable fault	1	3 to 20	1 to 5	20	1L	Current	16-pin SON	1.05
UCC3915	Enclosure management, general	1	7 to 15	0 to 3	150	1L	Current	SOIC-16, TSSOP-24	2.55
UCC3912	RAID, SCSI, general	1	3 to 8	0 to 3	150	1L	Current	SOIC-16, TSSOP-24	2.30
UCC3918	RAID, SCSI, general	1	3 to 6	0 to 4	75	1L	Current	SOIC-16, TSSOP-24	2.35

\*Suggested resale price in U.S. dollars in quantities of 1,000.

New devices are listed in bold red.

### Hot Swap Controllers (External FET) Selection Guide

Device	Target Applications	Channels	V <sub>IN</sub> Range (V)	Enable/Shutdown	UV	OV	Fault	PG	Latch	Auto Retry	Ramp	Power Limiting	Package(s)	Price*
TPS2300/01	CompactPCI <sup>®</sup> , general	2	3 to 13/3 to 5.5	1L/1H	✓		✓	✓	✓		Voltage	No	20-pin TSSOP	1.60
TPS2310/11	CompactPCI, general	2	3 to 13/3 to 5.5	1L/1H	✓		✓	✓	✓		Voltage	No	20-pin TSSOP	1.60
TPS2320/21	CompactPCI, general	2	3 to 13/3 to 5.5	1L/1H	✓		✓	✓	✓		Voltage	No	16-pin SOIC/TSSOP	1.35
TPS2330/31	CompactPCI, general	1	3 to 13	1L/1H	✓		✓	✓	✓		Voltage	No	14-pin SOIC/TSSOP	1.25
UCC3919	Low-voltage general hot swap	1	3 to 8	1H			✓		S <sup>1</sup>	S <sup>1</sup>	Current	No	16-pin SOIC/TSSOP	2.35
TPS2342	CompactPCI, PCI-X <sup>®</sup> , PC-X2.0	12	3.3, V <sub>aux</sub> , V <sub>IO</sub> , 5, +12, -12	1L	✓			✓	✓		Voltage	No	80-pin HTQFP	7.00
TPS2343	CompactPCI, PCI-X, PC-X2.0	12	3.3, V <sub>aux</sub> , V <sub>IO</sub> , 5, +12, -12	1L	✓			✓	✓		Voltage	No	80-pin HTVSOP	7.50
TPS2350	Full featured -48-V telecom, LS active ORing	2	-12 to -80	1H	✓	✓	✓	✓		✓	Current	No	14-pin SOIC/TSSOP	1.90
TPS2358	xTCA mezzanine cards, general 12 V	2	8.5 to 17	2L	✓		✓	✓	✓		Current	No	48-pin QFN	4.00
TPS2359	xTCA mezzanine cards, general 12 V	2	8.5 to 17	1H/1L	✓	✓	✓	✓	S <sup>1</sup>	S <sup>1</sup>	Current	No	36-pin QFN	5.00
TPS2363	PCI Express <sup>®</sup>	6	3.3 V <sub>aux</sub> , 3.3, +12	1L	✓		✓	✓	✓		Voltage	No	48-pin QFP	2.50
TPS2390	Simple -48-V telecom	1	-36 to -80	1H			✓		✓		Current	No	8-pin MSOP	1.00
TPS2391	Simple -48-V telecom	1	-36 to -80	1H			✓			✓	Current	No	8-pin MSOP	1.00
TPS2392	Full featured -48-V telecom	1	-20 to -80	1H	✓	✓	✓	✓	✓		Current	No	14-pin TSSOP	1.35
TPS2393	Full featured -48-V telecom	1	-20 to -80	1H	✓	✓	✓	✓		✓	Current	No	14/44-pin TSSOP	1.35
TPS2393A	Full featured -48-V telecom (Fast retry)	1	-20 to -80	1H	✓	✓	✓	✓		✓	Current	No	14-pin TSSOP	1.35
TPS2394	Full featured, ESD ruggedized -48-V hotswap	1	-12 to -80	1H	✓	✓	✓	✓		✓	Current	No	14-pin TSSOP	1.35
TPS2395	-48-V hot swap with I <sup>2</sup> C-based current monitor	1	-12 to -80	1H	✓	✓	✓	✓		✓	Current	No	20-pin TSSOP	TBD
TPS2398	Simple -48-V telecom with PG	1	-36 to -80	1H				✓	✓		Current	No	8-pin MSOP	1.35
TPS2399	Simple -48-V telecom with PG	1	-36 to -80	1H				✓		✓	Current	No	8-pin MSOP	1.35
TPS2400	Overvoltage/undervoltage protection IC	1	2 to 100	1H	✓	✓			✓		—	No	5-pin SOT-23	0.80
TPS2456	Inrush controller with reverse current control	2	8.5 to 15	2H	✓		✓	✓	✓		Current	No	36-pin QFN	3.75
TPS2458	xTCA mezzanine cards, general 12 V	1	8.5 to 15	1L	✓		✓	✓	✓		Current	No	32-pin QFN	2.00
TPS2459	xTCA mezzanine cards, general 12 V	1	8.5 to 15	1H/1L	✓	✓	✓	✓	S <sup>1</sup>	S <sup>1</sup>	Current	No	32-pin QFN	2.50

<sup>1</sup>S = Selectable.

\*Suggested resale price in U.S. dollars in quantities of 1,000.

# Power Protection, Control and Monitoring

## → Protection and Power Switches

### Hot Swap Controllers (External FET) Selection Guide (Continued)

Device	Target Applications	Channels	V <sub>IN</sub> Range (V)	Enable/Shutdown	UV	OV	Fault	PG	Latch	Auto Retry	Ramp	Power Limiting	Package(s)	Price*
<b>TPS24700</b>	Industrial, mass storage, servers, telecom	1	2.5 to 18	1H	✓			✓	✓		Current	No	8-pin MSOP	1.10
<b>TPS24701</b>	Industrial, mass storage, servers, telecom	1	2.5 to 18	1H	✓			✓		✓	Current	No	8-pin MSOP	1.10
<b>TPS24710</b>	Industrial, mass storage, servers, telecom	1	2.5 to 18	1H	✓		L	L	✓		Current	Yes	10-pin MSOP	1.25
<b>TPS24711</b>	Industrial, mass storage, servers, telecom	1	2.5 to 18	1H	✓		L	L		✓	Current	Yes	10-pin MSOP	1.25
TPS24712	Industrial, mass storage, servers, telecom	1	2.5 to 18	1L	✓		H	H	✓		Current	Yes	10-pin MSOP	1.25
TPS24713	Industrial, mass storage, servers, telecom	1	2.5 to 18	1L	✓		H	H		✓	Current	Yes	10-pin MSOP	1.25
<b>TPS24720</b>	Industrial, mass storage, servers, telecom	1	2.5 to 18	1H	✓	✓	✓	✓	S <sup>1</sup>	S <sup>1</sup>	Current	Yes	16-pin SON	1.40
TPS2480	Servers, basestations, +48 V, +12 V	1	9 to 80	1H	✓			✓	✓		Current	Yes	20-pin TSSOP	3.00
TPS2481	Servers, basestations, +48 V, +12 V	1	9 to 80	1H	✓			✓		✓	Current	Yes	20-pin TSSOP	3.00
TPS2490	Servers, basestations, +48 V, +12 V	1	9 to 80	1H	✓			✓	✓		Current	Yes	10-pin MSOP	1.40
TPS2491	Servers, basestations, +48 V, +12 V	1	9 to 80	1H	✓			✓		✓	Current	Yes	10-pin MSOP	1.40
TPS2492	Servers, basestations, industrial, +48 V, +12 V	1	9 to 80	1H	✓	✓	✓	✓	✓		Current	Yes	14-pin TSSOP	1.45
TPS2493	Servers, basestations, industrial, +48 V, +12 V	1	9 to 80	1H	✓	✓	✓	✓		✓	Current	Yes	14-pin TSSOP	1.45
LM25069	12-V hotswap controller with power limiting	1	2.9 to 17	1H	✓	✓	✓	H	-1	-2	Current	Yes	10-pin MSOP	1.19
LM25061	12-V hotswap controller with power limiting	1	2.9 to 17	1H	✓		✓	H	-1	-2	Current	Yes	10-pin MSOP	1.33
LM5060/Q	Low Iq high-side protection controller	1	5.5 to 65	1H	✓	✓	✓	L	✓		Voltage	No	10-pin MSOP	1.28/1.40
LM5069	+48-V hotswap controller with power limiting	1	9 to 80	1H	✓	✓	✓	H	-1	-2	Current	Yes	10-pin MSOP	1.35
LM5068	Simple -48-V hotswap controller family	1	-10 to -90	1H	✓	✓	✓	H/H/L/L	-1/-3	-2/-4	Current	No	8-pin MSOP	1.35
LM5067	-48-V hotswap controller with power limiting	1	-9 to -80	1H	✓	✓	✓	H	-1	-2	Current	Yes	10-pin MSOP/14-pin SOIC	1.50
<b>LM5064</b>	PMBus -48-V hotswap controller with system measurement	1	-10 to -80	1H	✓	✓	✓	✓	Prog	Prog	Current	Yes	28-pin eTSSOP	3.95
LM25066/A	PMBus 12-V hotswap controller with system measurement	1	2.9 to 17	1H	✓	✓	✓	✓	Prog	Prog	Current	Yes	24-pin LLP	2.45/2.95
<b>LM5066</b>	PMBus 48-V hotswap controller with system measurement	1	10 to 80	1H	✓	✓	✓	✓	Prog	Prog	Current	Yes	28-pin eTSSOP	3.95

<sup>1</sup>S = Selectable.

Pin function: L = active low, H = active high.

\*Suggested resale price in U.S. dollars in quantities of 1,000.

New devices are listed in bold red.

### ORing FET Controllers/MUX Devices Selection Guide

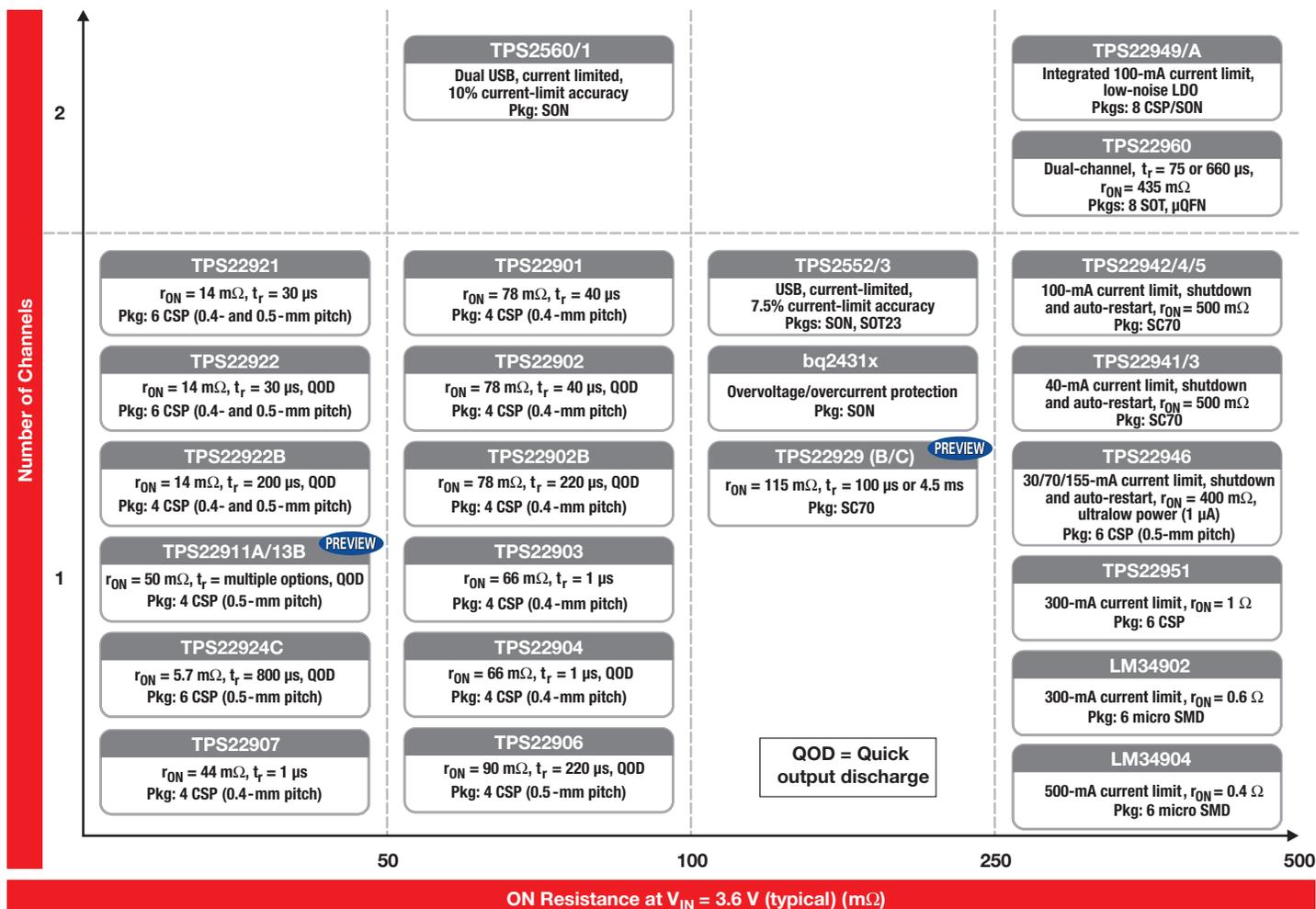
Device	Description	Channels	V <sub>IN</sub> Range (V)	Enable/Shutdown	UV	OV	Fault	PG	ORing Linear Gate Drive	On/Off ORing Function	Package(s)	Price*
TPS2410	ORing FET controller/MUX controller	1	0.8 to 16.5	1H	✓	✓	✓	✓	✓		14-pin TSSOP	1.70
TPS2411	ORing FET controller/MUX controller	1	0.8 to 16.5	1H						✓	14-pin TSSOP	1.70
TPS2412	ORing FET controller	1	0.8 to 16.5						✓		8-pin SOIC, 8-pin TSSOP	1.20
TPS2413	ORing FET controller	1	0.8 to 16.5							✓	8-pin SOIC, 8-pin TSSOP	1.20
TPS2419	ORing FET controller with OV/enable	1	3 to 16.5	1H		✓				✓	8-pin SOIC	1.20
TPS2456	Inrush/reverse current controller for dual sources	2	8.5 to 15	2H	✓		✓	✓	✓		36-pin QFN	3.45
TPS2358	Dual 12-V/3.3-V hotswap/ORing controller	2	8.5 to 15	2L							48-pin QFN	4.00
TPS2359	Dual 12-V/3.3-V hotswap/ORing controller	2	8.5 to 15	Via I <sup>2</sup> C							36-pin QFN	5.00
LM5050-1	Positive HV ORing controller with AUX input	1	5 to 80	L					✓	✓	6-pin TSOT	1.25
LM5050-2	Positive HV ORing controller with FET test	1	6 to 80	L			✓		✓	✓	6-pin TSOT	1.25
<b>LM5051</b>	Negative HV ORing controller with FET test	1	-6 to -100	L			✓		✓	✓	8-pin SOIC	1.25

\*Suggested resale price in U.S. dollars in quantities of 1,000.

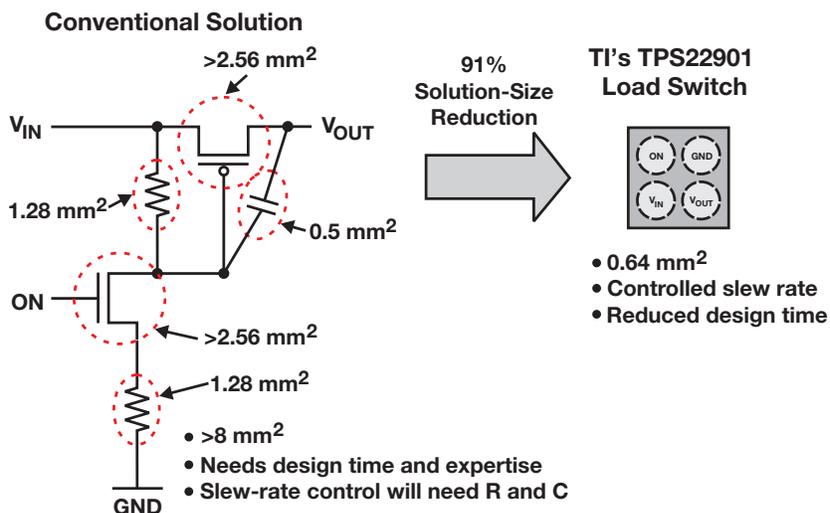
New devices are listed in bold red.

## → Protection and Power Switches

### Portable Electronics Integrated Load Switches Product Portfolio

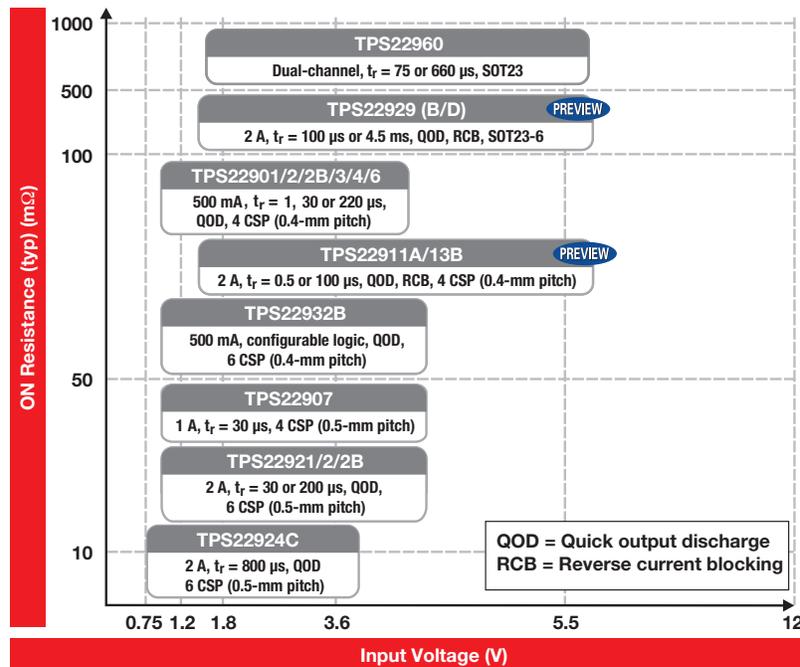


### The Integration/Size Advantage of Load Switches



## → Protection and Power Switches

### Non-Current-Limited Load Switches Product Portfolio



### Selection Guide

Device	Input Voltage Range (V)	Number of Channels	r <sub>ON</sub> at 3.6 V (mΩ)	Output Rise Time (μs)	Quick Output Discharge	Max Output Current	Enable	Package(s)	Price*
<b>Non-Current-Limiting Load Switches</b>									
TPS22901	1.0 to 3.6	1	78	40	No	500 mA	Active high	CSP (0.8x0.8 mm)	0.32
TPS22902/B	1.0 to 3.6	1	78	40/220	Yes	500 mA	Active high	CSP (0.8x0.8 mm)	0.32
TPS22903	1.1 to 3.6	1	66	1	No	500 mA	Active high	CSP (0.8x0.8 mm)	0.32
TPS22906	1.0 to 3.6	1	90	220	Yes	500 mA	Active high	CSP (0.9x0.9 mm)	0.32
TPS22907	1.1 to 3.6	1	44	36	No	1 A	Active high	CSP (0.9x0.9 mm)	0.38
TPS22921	0.9 to 3.6	1	14	30	No	2 A	Active high	CSP (0.8x1.2 mm or 0.9x1.4 mm)	0.43
TPS22922/B	0.9 to 3.6	1	14	30/200	Yes	2 A	Active high	CSP (0.8x1.2 mm or 0.9x1.4 mm)	0.43
<b>TPS22924B/C</b>	0.75 to 3.6	1	18.3	100/800	Yes	2 A	Active high	CSP (0.9x1.4x0.4/0.5 mm)	0.28
<b>TPS22920</b>	0.75 to 3.6	1	5.3	800	Yes	4 A	Active high	CSP, 0.9x1.9 mm	0.34
<b>TPS22966</b>	0.8 to 5.5	2	15	Adj.	Yes	6 A	Active high	SON-14, 3x2 mm	0.44
<b>Non-Current-Limiting Load Switches with Reverse Current Protection</b>									
<b>TPS22910A</b>	1.4 to 5.5	1	61	1	No	2 A	Active low	CSP (0.9x0.9x0.5 mm)	0.24
TPS22913B	1.4 to 5.5	1	61	100	Yes	2 A	Active high	CSP (0.9x0.9x0.5 mm)	0.24
<b>TPS22913C</b>	1.4 to 5.5	1	61	1000	Yes	2 A	Active high	CSP (0.9x0.9x0.5 mm)	0.24
<b>TPS22912C</b>	1.4 to 5.5	1	61	1000	No	2 A	Active high	CSP (0.9x0.9x0.5 mm)	0.24
TPS22929D	1.4 to 5.5	1	115	4000	Yes	2 A	Active high	SOT23-6 (3x3 mm)	0.24

Device	Input Voltage Range (V)	r <sub>ON</sub> at 1.8 V (Ω)	Current Limit (mA)	Current-Limit Blanking Time (ms)	Auto-Restart Time (ms)	Active	Package(s)	Price*
<b>Current-Limiting Load Switches</b>								
TPS22941	1.62 to 5.5	1.1	40	10	80	Low	5 SC70	0.42
TPS22942	1.62 to 5.5	1.1	100	10	80	Low	5 SC70	0.42
TPS22943	1.62 to 5.5	1.1	40	0	—	High	5 SC70	0.42
TPS22944	1.62 to 5.5	1.1	100	0	—	High	5 SC70	0.42
TPS22945	1.62 to 5.5	1.1	100	10	80	High	5 SC70	0.42
TPS22946	1.62 to 5.5	0.6	155/70/30	10	70	High	6 CSP	0.55
TPS22949/A	1.62 to 4.5	1	100	12	70	High	8 CSP/SON	0.70
TPS22951	2.8 to 5.3	1	600	—	—	High	6 CSP	0.45
<b>LM34902/4</b>	2.8 to 5.3	0.6/0.4	300/500	—	—	High	Micro SMD-6	TBD

\*Suggested resale price in U.S. dollars in quantities of 1,000.

New devices are listed in bold red. Preview devices are listed in bold blue.

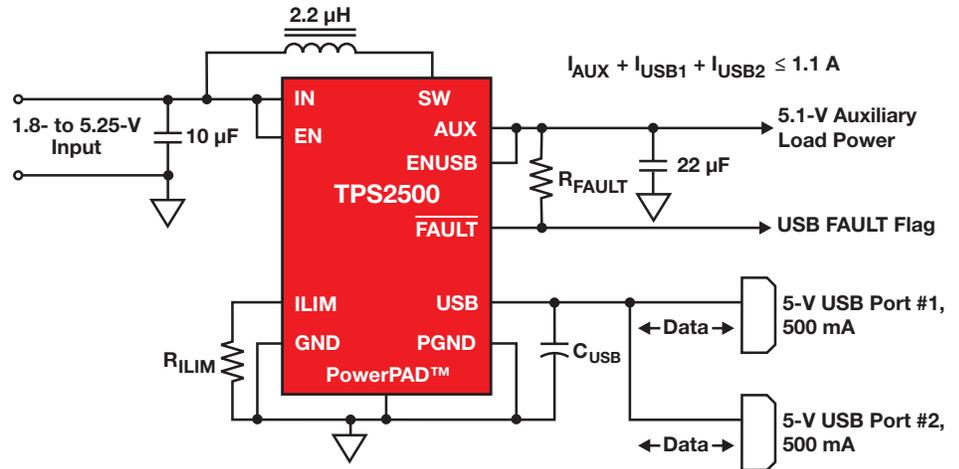
## → Protection and Power Switches

### USB Current-Limiting Power Switches

Power switches are used to intelligently turn power on/off and provide fault protection. They are ideal for power sequencing or segmentation and when controlled allocation of power is needed to circuit blocks, modules, add-in cards or cabled connections.

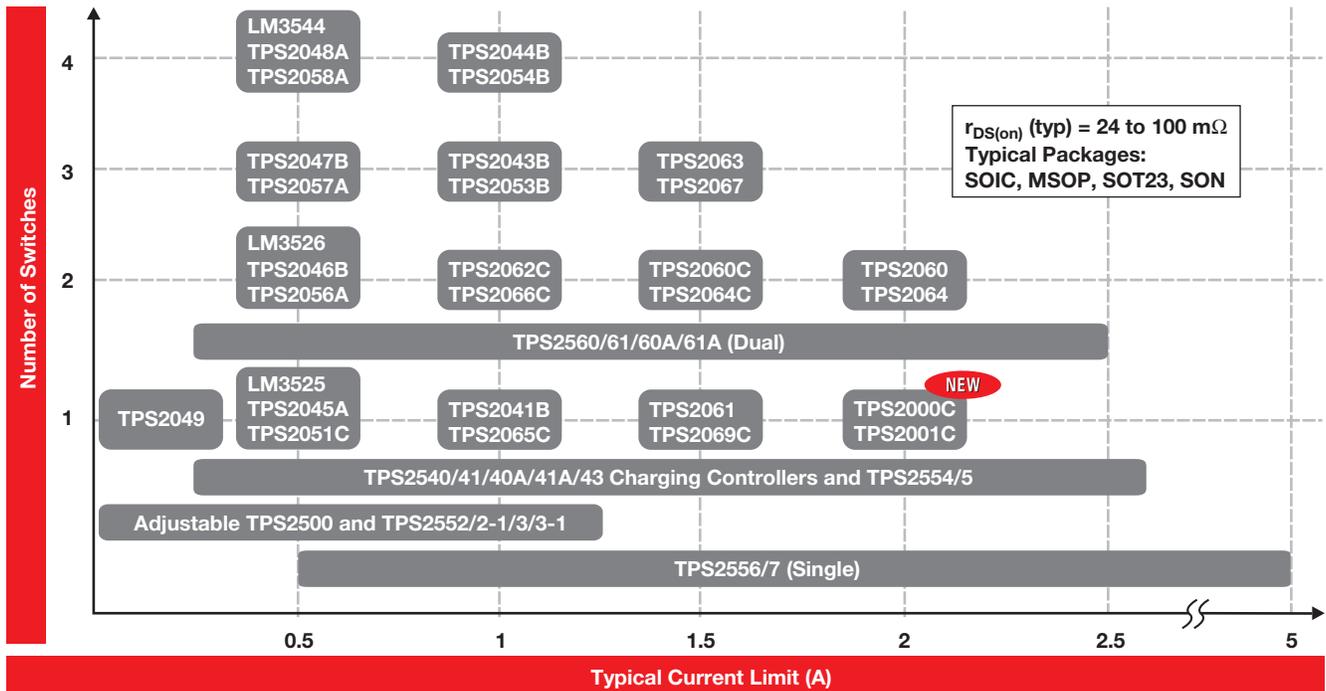
Universal Serial Bus (USB) ports are great examples of where this intelligent protection is vital for protecting your power supply and achieving regulatory compliance. TI's family of low-cost power switches are ideal for USB port designs.

To minimize voltage drop, select devices with the lowest  $r_{DS(on)}$  or drain-to-source on-resistance.



The TPS2500/1 combines a boost converter and a current-limiting switch for USB applications where the 5-V rail is not available. It is also ideal for devices with 1.8-V, 2.5-V or 3.3-V rails.

### Current-Limited Switch Matrix



## → Protection and Power Switches

### USB Mobile Device Charging

What is “universal charging”?

Consumers have long desired a universal device to charge their many mobile electronic devices. Governments (like the European Union and China) and industry groups around the world are now moving to provide just such a framework, with three goals:

1. Provide a universal form factor—the USB interface (Standard-A plug to Micro-B plug)
2. Minimize environmental impact by reducing electronics waste and no-load power consumption
3. Reduce charging times when possible

Consumers will soon expect all USB host ports to be able to charge their devices. So, if your design calls for a USB port, you may want to comply with this standard in your next product release. Common products for which consumers may want a USB charging port include LCD TVs, set-top boxes, notebook/desktop PCs and dedicated charging AC adapters. For all of these devices, the TPS2540/41/40A/41A/43 may be ideal.

The TPS2540 takes the standard USB power switch and combines it with the special data signaling required to comply with Universal

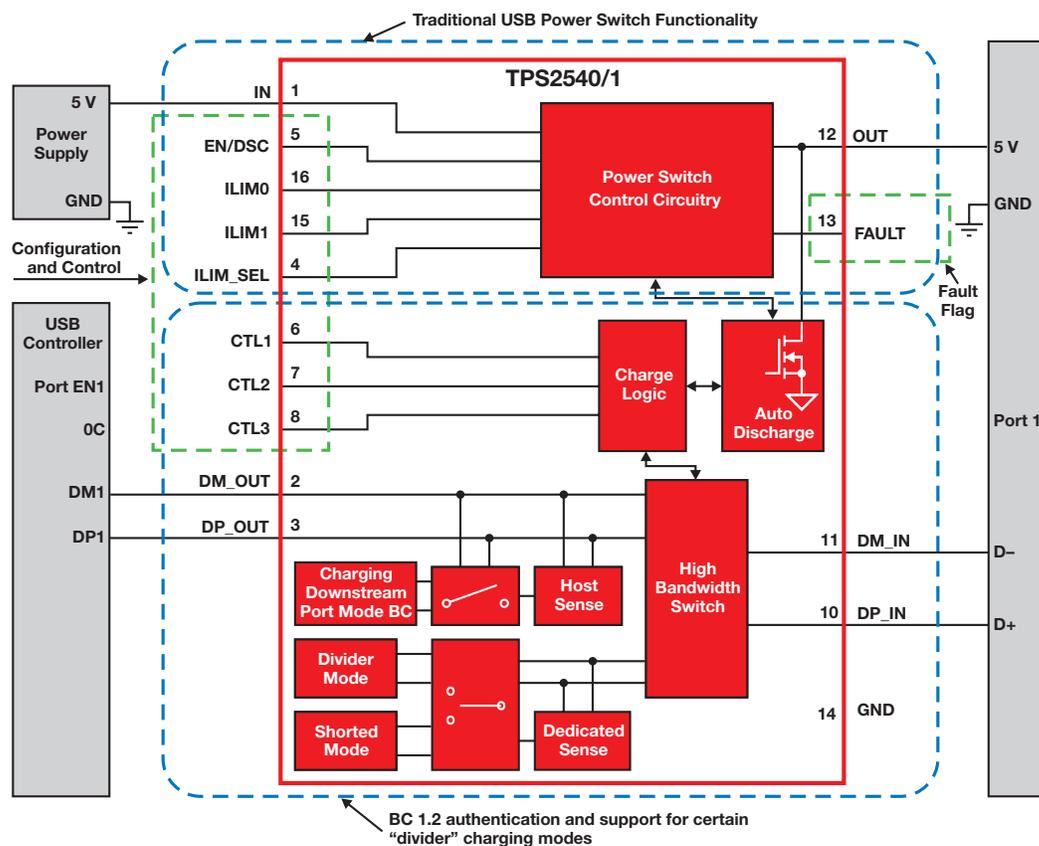
Charger Solution (UCS) requirements. This makes it possible for a USB port to quickly charge UCS-compliant devices and even many popular, proprietary devices that predate the standard (such as Apple devices). All this is accomplished without any special software.

The TPS2540/41/40A/41A/43 are fully released. Order an evaluation board or some samples today!

### Battery Charging 1.2 (BC 1.2)

BC 1.2 defines the type of charger, handshaking, allowable current draws, and PD decision-making flowchart that defines the interaction between PD and the host charger.

BC 1.2 Port Type	Definition	5-V Current Capability
Standard Downstream Port (SDP)	Compliant USB 2.0 port. No special charging capability	Up to 500 mA
Dedicated Charging Port (DCP)	Wall charger. No data communication capability	Up to 1.5 A
Charging Downstream Port (CDP)	A USB 2.0 compliant port with intelligent charging capability	Up to 500 mA if authenticated as SCP or up to 1.5 A if authenticated as CDP



The TPS2540/40A/41 incorporates a traditional USB power switch and the BC 1.2 intelligence for universal charging negotiation.

### TPS2540/40A/41 Comparison

Device	Identical Pinouts	Functionality	Applications Impact	Ideal Applications
TPS2540	Pin 5 is EN.	Output discharge requires all CTL pins to be low and separate from Enable control.	Discharging voltage on output caps is important during renegotiation. When a power adapter is added or removed, power should be renegotiated.	Notebook PCs or mobile devices.
TPS2540A	Pin 5 is EN.	Output discharge requires all CTL pins to be low and separate from Enable control.	Discharging voltage on output caps is important during renegotiation. When a power adapter is added or removed, power should be renegotiated.	For HDD or apps requiring longer detach detect delay.
TPS2541	Pin 5 is DSC.	Output discharge functionality and Enable control in one pin, the DSC.	A simple device, like an AC adapter, may not have much I/O available.	Dedicated chargers or anything with I/O constraints.

## → Protection and Power Switches

### USB Current-Limiting Switches Selection Guide

Device	Number of FETs	I <sub>OS</sub> (min) (A)	R <sub>DS(on)</sub> (mΩ)	V <sub>IN</sub> Range (V)	Supply Current (μA)	OC Logic Output	OT Logic Output	Enable	Predecessor	Price*
TPS2010A	1	0.22	30	2.7 to 5.5	73	No	No	L	TPS2010	0.75
TPS2011A	1	0.66	30	2.7 to 5.5	73	No	No	L	TPS2011	0.75
TPS2012A	1	1.1	30	2.7 to 5.5	73	No	No	L	TPS2012	0.75
TPS2013A	1	1.65	30	2.7 to 5.5	73	No	No	L	TPS2013	0.75
TPS2020/30	1	0.22	33	2.7 to 5.5	73	Yes	Yes	L/H	—	0.90
TPS2021/31	1	0.66	33	2.7 to 5.5	73	Yes	Yes	L/H	TPS2014	0.90
TPS2022/32	1	1.1	33	2.7 to 5.5	73	Yes	Yes	L/H	TPS2015	0.90
TPS2023/33	1	1.65	33	2.7 to 5.5	73	Yes	Yes	L/H	—	0.90
TPS2024/34	1	2.2	33	2.7 to 5.5	73	Yes	Yes	L/H	—	0.90
TPS2042B/52B	2	0.7 ea	70	2.7 to 5.5	50	Yes	Yes	L/H	TPS2042/52/42A/52A	0.70
TPS2043B/53B	3	0.7 ea	70	2.7 to 5.5	65	Yes	Yes	L/H	TPS2043/53/43A/53A	0.90
TPS2044B/54B	4	0.7 ea	70	2.7 to 5.5	75	Yes	Yes	L/H	TPS2044/54/44A/54A	1.10
TPS2045A/55A	1	0.3	80	2.7 to 5.5	80	Yes	Yes	L/H	TPS2045/55	0.60
<b>TPS2051C</b>	1	.67	96	4.5 to 5.5	60	Yes	Yes	L	TPS2051A, TPS2051B	0.45
<b>TPS2065C</b>	1	1.3	96	4.5 to 5.5	60	Yes	Yes	L	TPS2065	0.45
<b>TPS2069C</b>	1	1.7	70	4.5 to 5.5	60	Yes	Yes	L	TPS2069	0.65
<b>TPS2000C/1C</b>	1	2.35	72	4.5 to 5.5	60	Yes	Yes	L/H	—	0.45
<b>TPS2062C/6C</b>	2	1.25 ea	70	4.5 to 5.5	100	Yes	Yes	L/H	TPS2062/A, TPS2066/A	0.70
<b>TPS2060C/4C</b>	2	1.83 ea	70	4.5 to 5.5	100	Yes	Yes	L/H	TPS2060, TPS2064	0.70
<b>TPS2002C/3C</b>	2	2.43 ea	70	4.5 to 5.5	100	Yes	Yes	L/H	—	0.80
TPS2049	1	0.1	400	2.7 to 5.5	43	Yes	Yes	L	TPS2041/51/41A/51A	0.55
TPS2063/7	3	1.1 ea	70	2.7 to 5.5	65	Yes	Yes	L/H	—	0.90
TPS2068/9	1	1.5	70	2.7 to 5.5	43	Yes	Yes	L/H	—	0.75
TPS2080/1/2 <sup>1</sup>	2	0.7 ea	80	2.7 to 5.5	85	Yes	Yes	2H, 1L/1H, 2L	—	0.65
TPS2085/6/7 <sup>1</sup>	4	0.7 ea	80	2.7 to 5.5	85	Yes	Yes	4H, 2L/2H, 4L	—	1.05
TPS2090/1/2 <sup>1</sup>	2	0.3 ea	80	2.7 to 5.5	85	Yes	Yes	2H, 1L/1H, 2L	—	0.65
TPS2095/6/7 <sup>1</sup>	4	0.3 ea	80	2.7 to 5.5	85	Yes	Yes	4H, 2L/2H, 4L	—	1.05
<b>TPS2540/A/1/1A/3</b>	1	0.25 to 2.8	73	4.5 to 5.5	150	Yes	Yes	H	—	0.90
TPS2552/53	1	0.75 to 1.3	85	2.5 to 6.5	120	Yes	Yes	L/H	—	0.75
TPS2552-1/53-1	1	0.75 to 1.3	85	2.5 to 6.5	120	Yes	Yes	L/H	—	0.75
<b>TPS2554/55</b>	1	0.25 to 2.8	73	4.5 to 5.5	150	Yes	Yes	H/L	—	0.80
TPS2556/57	1	0.5 to 5	24	2.5 to 6.5	130	Yes	Yes	L/H	—	0.90
TPS2560/61	2	0.25 to 2.5	48	2.5 to 6.5	130	Yes	Yes	L/H	—	0.90

<sup>1</sup>Can be configured as power MUX ICs.

Preview devices are listed in **bold blue**. New devices are listed in **bold red**.

\*Suggested resale price in U.S. dollars in quantities of 1,000.

### Internal FET Power Switch Selection Guide

Device	Number of FETs	I <sub>OS</sub> (min) (A)	R <sub>DS(on)</sub> (mΩ)	V <sub>IN</sub> Range (V)	Supply Current (μA)	OC Logic Output	OT Logic Output	Enable	Price*
TPS2590	1	1 to 5	28	3 to 20	35	Yes	No	L	1.05
LM3525	1	0.5	80	2.7 to 5.5	0.15	Yes	Yes	H/L	0.69
LM3526	2	0.5 each	100	2.7 to 5.5	0.5	Yes	Yes	H/L	0.73
LM3544	4	0.5 each	90	2.7 to 5.5	1	Yes	Yes	H/L	1.80

\*Suggested resale price in U.S. dollars in quantities of 1,000.

## → Voltage Supervisors and Digital Sequencers

### Design Factors

**Manual Reset (MR)** — This feature allows the user to manually reset the circuit or control the supervisory circuit by another device of the application.

**Watchdog Input (WDI)** — In situations where the system processor may not be functioning properly, its onboard watchdog feature may fail to reset. Supervisors with integrated watchdog functionality increase system reliability by being able to trigger a reset.

**Active High Output** — Allows the use of processors with active high reset input without additional components.

**Delay Time** — Allows the voltage and other components in the circuit to stabilize first before the normal operation starts again.

**Open Collector** — Same as open drain, but the RESET output is connected to the collector of the internal transistor.

**Open Drain** — The RESET output of the supervisory circuit is connected to the drain of the internal MOSFET. Choose an open-drain reset output supervisor when more than one supervisor is connected on the bus.

**Push-Pull** — A push-pull reset output supervisor is recommended when only one supervisor is needed on the bus. This eliminates the need for a pull-up resistor and offers higher speed.

### Quad Supervisor with Programmable Delay and Watchdog Timer

**NEW**

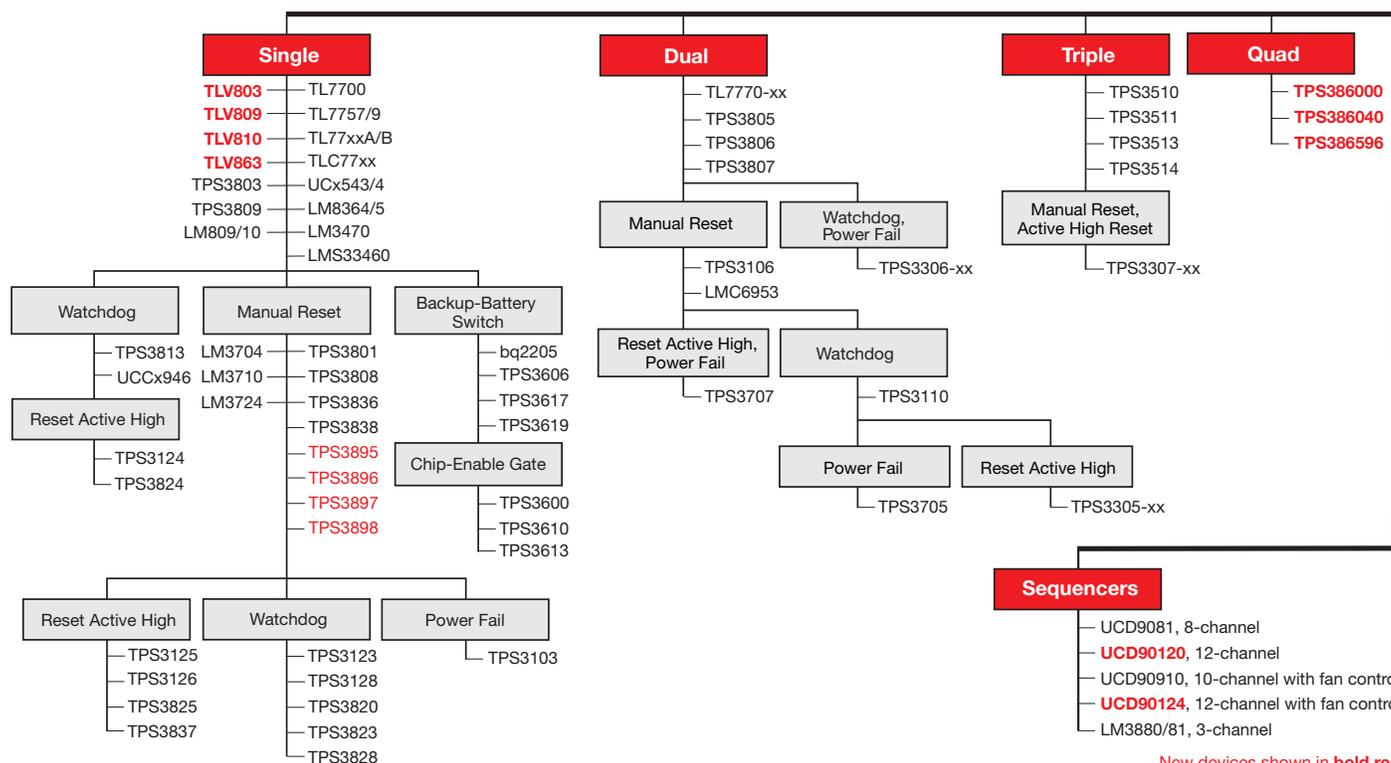
**TPS386000, TPS386020, TPS386040, TPS386060**

Get samples at: [www.ti.com/product/TPS386000](http://www.ti.com/product/TPS386000)

The TPS3860xx family can monitor four power rails that are greater than 0.4 V with a 0.25% threshold accuracy. With external resistors, the threshold of each SVS can be programmed. Each SVS has a programmable delay circuit, and the delay time can be set from 1.25 ms to 10 s. The quiescent current is very low with 12  $\mu$ A (typical). Available in a small 4x4-mm, 20-pin QFN package. Options:

- TPS386000: Open-Drain  $\overline{\text{RESET}}$  and  $\overline{\text{WDO}}$
- TPS386020: Open-Drain  $\overline{\text{RESET}}$  and  $\overline{\text{WDO}}$
- TPS386040: Push-Pull  $\overline{\text{RESET}}$  and  $\overline{\text{WDO}}$
- TPS386060: Push-Pull  $\overline{\text{RESET}}$  and  $\overline{\text{WDO}}$

### Supervisory Circuits, Reset ICs and Sequencers Family of Products



## ➔ Voltage Supervisors and Digital Sequencers

### Power-Supply Sequencer

#### UCD90120, UCD90124

Get samples at: [www.ti.com/product/UCD90120A](http://www.ti.com/product/UCD90120A)

The UCD90120/4 Power Supply Sequencer and System Health Controller sequences up to 12 independent voltage rails. The devices integrate a 12-bit, 200-ksps ADC with a 1% accurate internal reference for monitoring up to 13 inputs for power supply voltage, current, or temperature. There are 26 GPIO pins that can be used for power supply enables, power-on reset signals, or other system functions. Also, 12 of the 26 GPIO pins can be used as PWM outputs for power supply margining, fan control (UCD90124 only), or general-purpose PWM functions including multiphase clock generation for switch-mode power supplies. Both devices offer non-volatile fault logging for capturing power supply faults, peak rail voltages, and other important data that can aid in system failure analysis. JTAG and PMBus interfaces provide options for preproduction and in-system configuring and monitoring. The TI Fusion Digital Power™ Designer is provided for device configuration. This PC-based graphical user interface offers an intuitive interface for configuring, storing, and monitoring all system operating parameters.

#### Features

##### Sequence

- Sequence up to 12 rails on and off
- Dependencies on time, parent rails, GPIs, and I<sup>2</sup>C
- Independent turn-on and turn-off configurations
- Flexible GPIO for enables, power goods, and more
- Boolean logic builder

##### Monitor

- Respond to faults by configuring retries, shutdown delays, and slave rails to shutdown
- User settable scale factors convert to actual system units including voltage, current, and temperature

- 6 optional comparators for fault response in < 60 μs

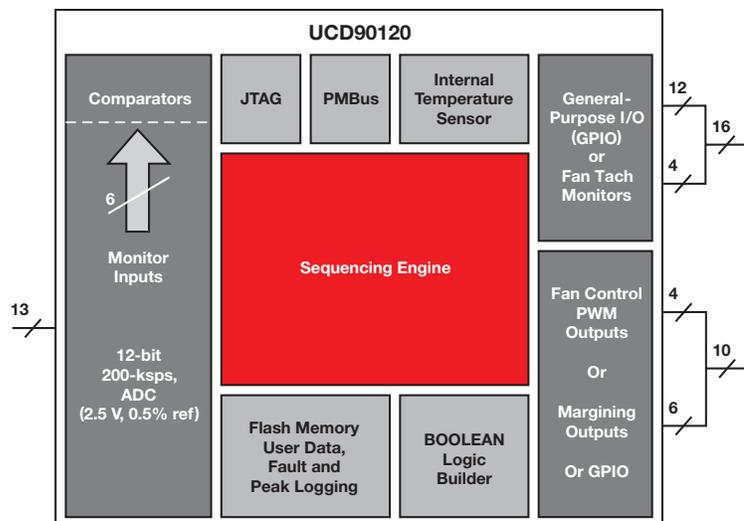
- Nonvolatile fault logging

##### Margin

- Simultaneously margin up to 10 rails using PWM outputs
- Support for open-loop or closed-loop methods
- Command rails high and low using I<sup>2</sup>C or GPIO pins
- All unused margining outputs can be used as GPIO

##### Fan control (UCD90124 only)

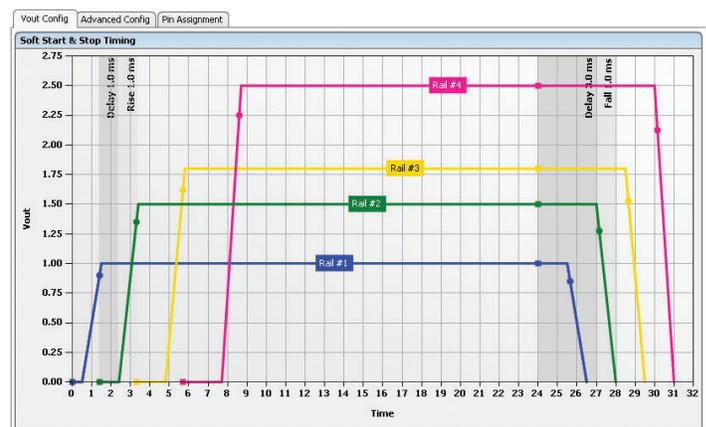
- Monitor and control up to 4 fans (2-, 3-, or 4-wire fans)



Typical application for UCD90120 sequencer.



Monitoring.



Sequencing.

# Power Protection, Control and Monitoring

## → Voltage Supervisors and Digital Sequencers

### Selection Guide

Device	Number of Supervisors	Supervised Voltages	Package(s)	V <sub>DD</sub> Range (V)	I <sub>DD</sub> (typ) (µA)	Time Delay (ms)	Watchdog Timer WDI (sec)	Reset Threshold Accuracy (%)	Manual Reset/Enable Reset	Active-Low Reset/Output	Active-High Reset/Output	Reset Output Topology <sup>1</sup>	Power-Fail PFI/PFO	Overvoltage Detection	Overcurrent Detection	Chip-Enabled Gating	HiRel (H) or Automotive (A) <sup>†</sup>	Comments	Price*
<b>General Purpose Supply Supervisors</b>																			
LM3724	1	2.5	SOT23-5, D, W	1 to 6	6	0.02		±2.5	✓	✓		OD	✓						0.95/0.80
LP3470	1		SOT23-5	0.5 to 5	16	0.3		±1		✓		OD							0.595/0.562
LM3704	1		Micro SMD-9, MSOP-10	1 to 5.5	28	0.02		±2	✓	✓		CMOS, OD	✓						0.77
LM3710	1	2.5	MINI SOIC	1 to 5.5	28	0.02	0.0062 to 25.6	±2	✓	✓		CMOS, OD	✓						1.10
LM8364	1		SOT23-5	1 to 6	0.65	0.3		±2.5		✓		CMOS, OD							0.239
LM8365	1		SOT23-5	1 to 6	0.65	0.1		±2.5		✓		CMOS, OD							0.249
LM809	1		SOT23-3, LLP-6, D, W	1 to 6	15	0.02		±1.5		✓		CMOS							0.229
LM810	1		SOT23-3, D, W	1 to 6	15	0.02		±1.5			✓	CMOS							0.229
LMS33460	1	3	SC-70	1 to 7	1	0.2		±5		✓		OD							0.169
LMC6953	2		SOIC-8	1.5 to 6	800	0.0005		±3	✓	✓		OD							1.44
LM3880	3		SOT23-6	2.7 to 5.5	25	fix			Power supply sequencer and monitor								A	0.50	
LM3881	3		MSOP-8	2.7 to 5.5	80	fix			Power supply sequencer and monitor									0.50	
<b>TPS3895</b>	1	Adj.	SON-6	1.7 to 6.5	6	0.04, Prog	—	0.25	✓		✓	PP						Ultra-small	0.60
<b>TPS3896</b>	1	Adj.	SON-6	1.7 to 6.5	6	0.04, Prog	—	0.25	✓	✓		PP						Ultra-small	0.60
<b>TPS3897</b>	1	Adj.	SON-6	1.7 to 6.5	6	0.04, Prog	—	0.25	✓		✓	OD						Ultra-small	0.60
<b>TPS3898</b>	1	Adj.	SON-6	1.7 to 6.5	6	0.04, Prog	—	0.25	✓	✓		OD						Ultra-small	0.60
<b>TLV803</b>	1	2.5/3/3.3/5	3SOT-23	1.1 to 6	9	200	—	2.00		✓		OD							0.20
<b>TLV810</b>	1	2.5/3/3.3/5	3SOT-23	1.1 to 6	9	200	—	2.00			✓	PP							0.20
TPS3808	1	Adj./0.9/1.2/1.5/1.8/2.5/3.0/3.3/5.0/EEPROM	SOT-23, SON-6	1.8 to 6.5	2.4	Prog	—	0.5	✓	✓		OD					H, A	Voltage detector	0.70
TPS3103	1	1.2/1.5/2.0/3.3	SOT-23	0.4 to 3.3	1.2	130	—	0.75	✓	✓		OD	✓						0.90
TPS3123	1	1.2/1.5/1.8	SOT-23	0.75 to 3.3	14	180	1.4	3.6	✓	✓		PP							0.85
TPS3124	1	1.2/1.5/1.8	SOT-23	0.75 to 3.3	14	180	1.4	3.6		✓	✓	PP							0.85
TPS3125	1	1.2/1.5/1.8/3.0	SOT-23	0.75 to 3.3	14	180	—	3.6	✓	✓	✓	PP							0.80
TPS3126	1	1.2/1.5/1.8	SOT-23	0.75 to 3.3	14	180	—	3.5	✓	✓	✓	OD							0.80
TPS3128	1	1.2/1.5/1.8	SOT-23	0.75 to 3.3	14	180	1.4	3.5	✓	✓		OD							0.85
TPS3800	1	2.7	SC-70	1.6 to 6.0	9	100	—	2	✓	✓		PP							0.40
TPS3801	1	Adj./1.8/2.5/3.0/3.3/5.0	SC-70	1.6 to 6.0	9	200	—	2	✓	✓		PP							0.40
TPS3802	1	3.0/3.3	SC-70	1.6 to 6.0	9	400	—	2	✓	✓		PP							0.40
TPS3803	1	Adj./1.5	SC-70	1.3 to 6.0	3	—	—	1.5		✓		OD					H, A	Voltage detector	0.25
<b>TLV809</b>	1	2.5/3.0/3.3/5.0	SOT-23	2.0 to 6.0	9	200	—	2.2		✓		PP							0.25
TPS3813	1	2.5/3.0/3.3/5.0	SOT-23	2.0 to 6.0	9	25	Window	2.2		✓		OD					H, A	Window watchdog	0.90
TPS3820/8-xx	1	3.3/5.0	SOT-23	1.1 to 5.5	15	25/200	0.2/1.6	2.4	✓	✓		PP/OD					A		0.65
TPS3823	1	2.5/3.0/3.3/5.0	SOT-23	1.1 to 5.5	15	200	1.6	2.4	✓	✓		PP					A		0.65
TPS3824-xx	1	2.5/3.0/3.3/5.0	SOT-23	1.1 to 5.5	15	200	1.6	2.2		✓	✓	PP					A		0.65
TPS3825-xx	1	3.3/5.0	SOT-23	1.1 to 5.5	15	200	—	2.2	✓	✓	✓	PP					A		0.55
TPS3836/8	1	1.8/2.5/3.0/3.3	SOT-23	1.6 to 6.0	0.22	10/200	—	2.5	✓	✓		PP/OD					H, A		0.85
TPS3837	1	1.8/2.5/3.0/3.3	SOT-23	1.6 to 6.0	0.22	10/200	—	2.4	✓	✓		PP					H, A		0.85
TLC77xx	1	Adj./2.5/3.3/3.0/5.0	SO-8, DIP-8, TSSOP-8	2.0 to 6.0	9	Prog	—	5.5		✓	✓	PP					H, A		0.65
TPS3807	2	3/3.5	SC-70	1.8 to 6.5	3.5	20	—	1		✓		OD							0.95
TPS3106	2	Adj./0.9/1.6/3.3	SOT-23	0.4 to 3.3	1.2	130	—	0.75	✓	✓		OD					H		0.90
TPS3110	2	Adj./0.9/1.2/1.5/3.3	SOT-23	0.4 to 3.3	1.2	130	1.1	0.75	✓	✓		PP							0.99
TPS3305-xx	2	1.8/2.5/3.3/5.0	SO-8, MSOP-8	2.7 to 6.0	15	200	1.6	2.7	✓	✓	✓	PP					A		1.00
TPS3306-xx	2	1.5/1.8/2.0/2.5/3.3/5.0	SO-8, MSOP-8	2.7 to 6.0	15	100	0.8	2.7	✓	✓		OD	✓				A		1.05
TPS3705-xx	2	3.0/3.3/5.0	SO-8, MSOP-8	2.0 to 6.0	30	200	1.6	2.1	✓	✓		PP	✓						0.80
TPS3707-xx	2	2.5/3.0/3.3/5.0	SO-8, MSOP-8	2.0 to 6.0	20	200	—	2.2	✓	✓	✓	PP	✓						0.75
TPS3805	2	Adj./3.3	SC-70	1.3 to 6.0	3	—	—	1.5		✓		PP					H, A	Voltage detector	0.34
TPS3806	2	Adj./2.0/3.3	SOT-23	1.3 to 6.0	3	—	—	2		✓		OD						Voltage detector	0.45

\*Suggested resale price in U.S. dollars in quantities of 1,000.

<sup>1</sup>PP = push-pull, OD = open drain, OC = open collector.

<sup>†</sup>Devices qualified for HiRel (H) or Automotive (A) applications are available. Certain voltage options are not available. Different pricing may apply.

Note: Custom voltages can be provided. Minimum order quantities may apply. Contact TI for details and availability.

New devices are listed in bold red.

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