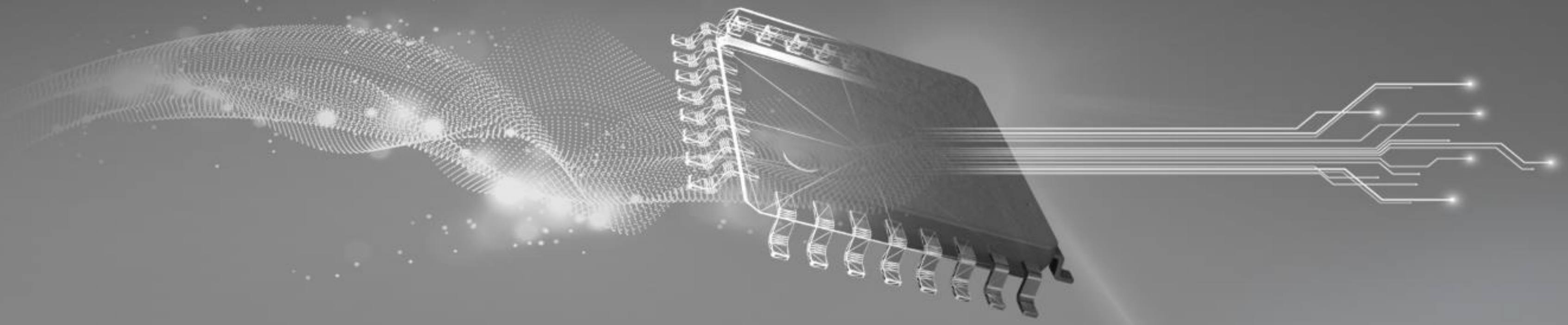
TI TECH DAYS



eFuses | All-in-one system power protection for industrial systems

Paul Kundmueller

Power Switches

Texas Instruments

Goal of the presentation

There are four main objectives for this presentation

- Familiarize you with the protection functions of an eFuse and how to use them
- Discuss & compare eFuses to traditional discrete protection
- Introduce new eFuse devices that have recently released
- Share where you can find out more information on eFuses on ti.com and the resource available to you on ti.com

Agenda

- Power switches overview
- Analysis of a common discrete protection circuit
- eFuse overview
- eFuse vs. discrete comparison
- Features and applications of an eFuse
- New generation devices available with enhanced protection features
  - TPS25947
  - TPS2663
  - TPS2661
- eFuse portfolio & Where to find more information and resources on eFuse

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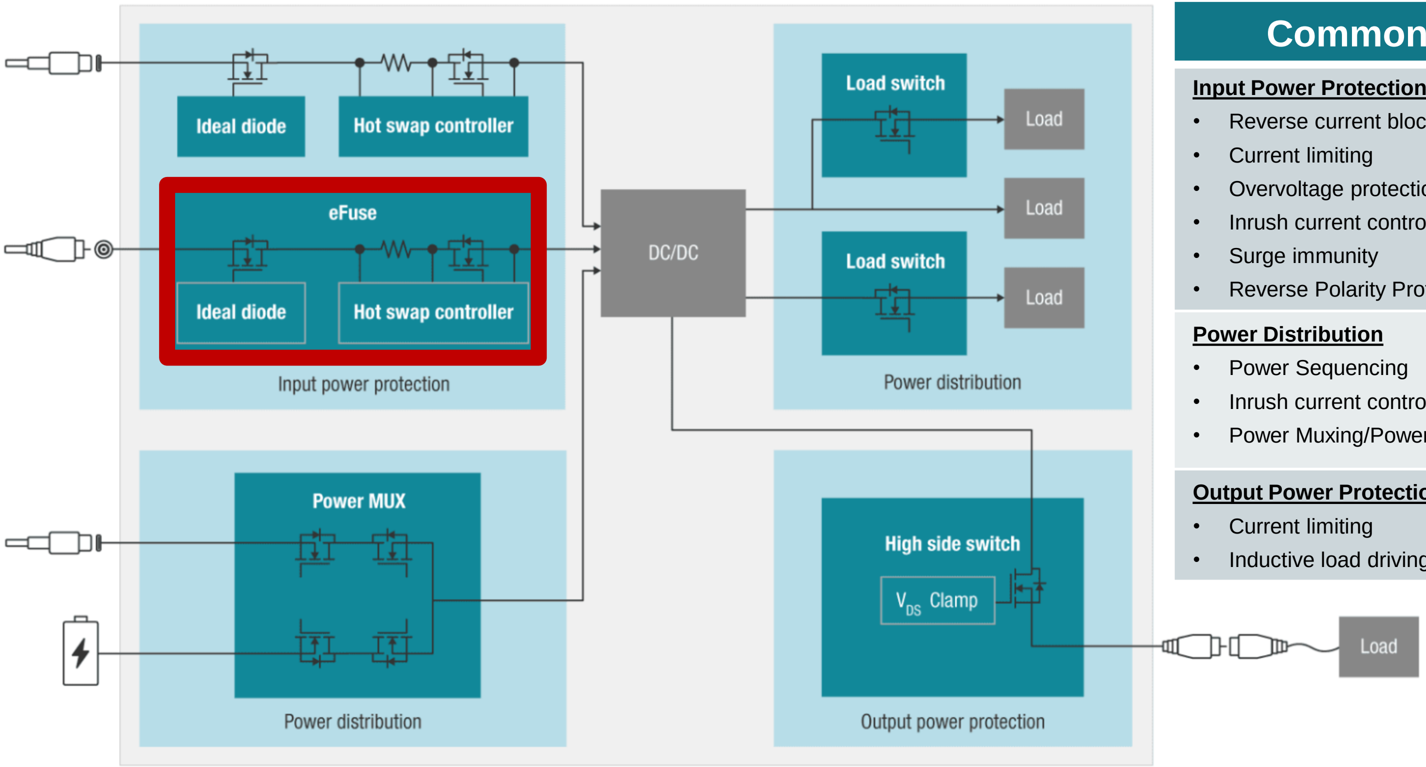
Power Switches Overview



Common Design Challenges

Input Power Protection

- Reverse current blocking
- Current limiting
- Overvoltage protection
- Inrush current control
- Surge immunity
- Reverse Polarity Protection

Power Distribution

- Power Sequencing
- Inrush current control
- Power Muxing/Power Oring

Output Power Protection

- Current limiting
- Inductive load driving

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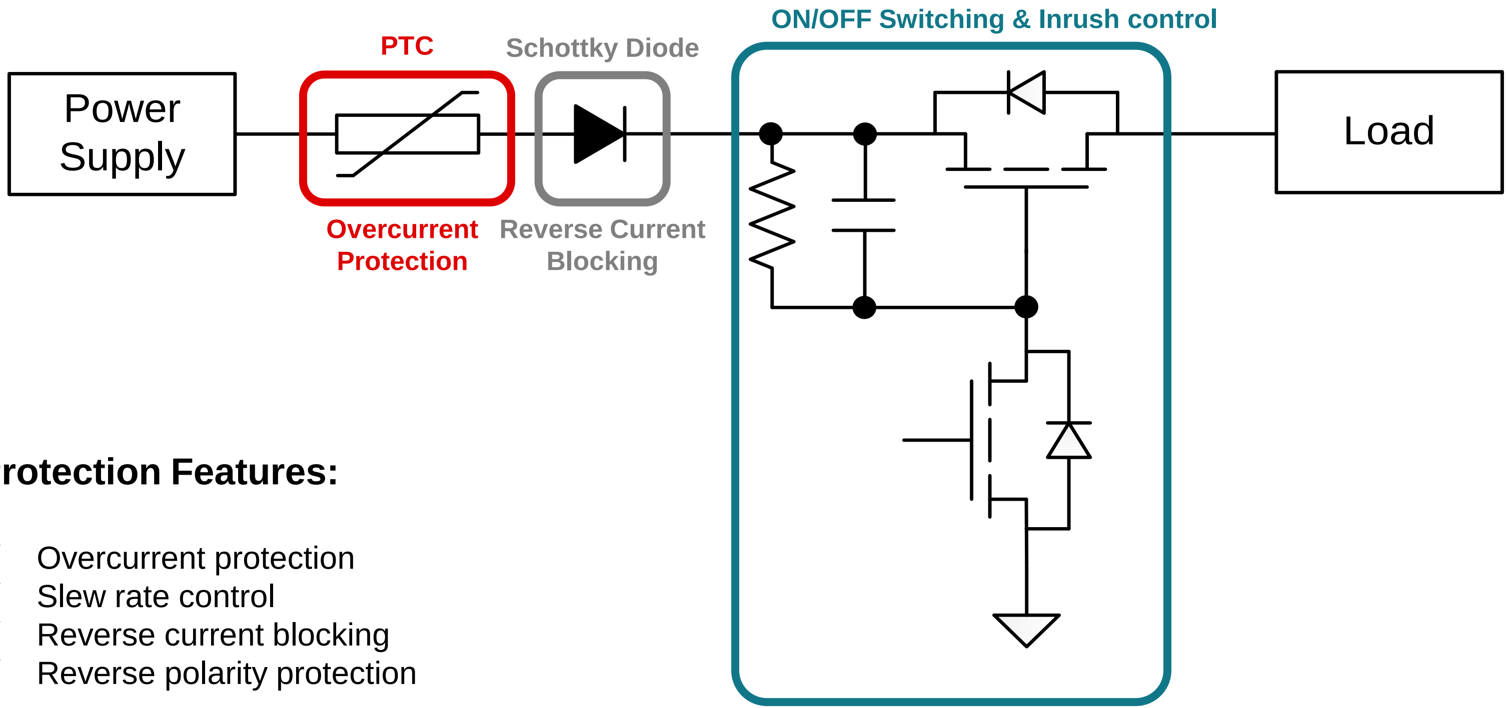
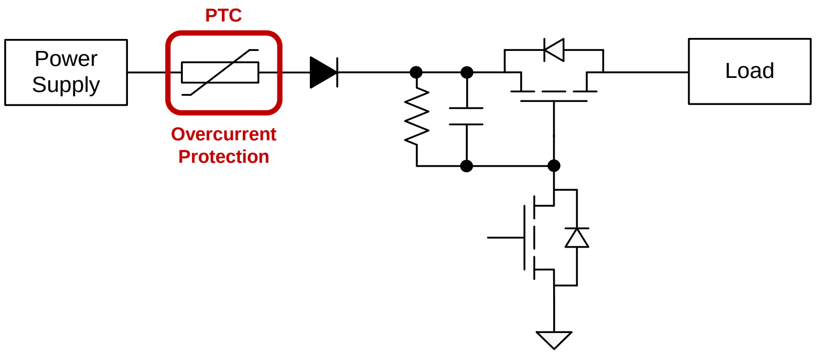
Discrete Input Protection Circuit



Protection Features:

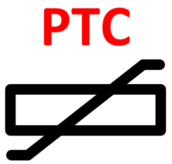
- ✓ Overcurrent protection
- ✓ Slew rate control
- ✓ Reverse current blocking
- ✓ Reverse polarity protection

Discrete Input Protection Circuit | Summary



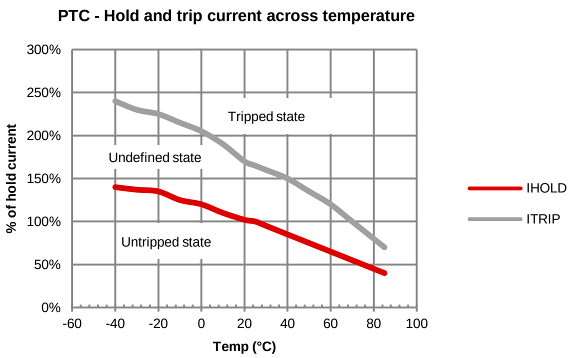
PTCs | Basics

What are PTCs?



- PTCs are positive temperature coefficient (PTC) devices which are used for overcurrent protection.
- During an overcurrent event, a PTC limits current and changes from a ***low resistance*** state to a ***high resistance*** state.
- When a PTC is in a ***"tripped state"*** it reduces the current flow to a ***low value*** due to its ***high resistance*** state.
- The procedure for resetting the device is to completely remove power and allow the device to reduce its temperature.

PTC – I_{TRIP} & I_{HOLD} vs temperature



Tripped State: Device will trip and enter a high resistance state

Undefined state: The device can either trip or remain in an untripped state

Untripped state: Device will remain in an untripped state

To ensure the PTC will not trip, I_{HOLD} line should be considered to be the max operating current for the system

The max I_{TRIP} current should be considered in power dissipation calculations when sizing other system components

PTC Considerations

Limitation #1: Large variation in hold and trip current across temperatures

Limitation #2: Slow reaction time to overcurrent events

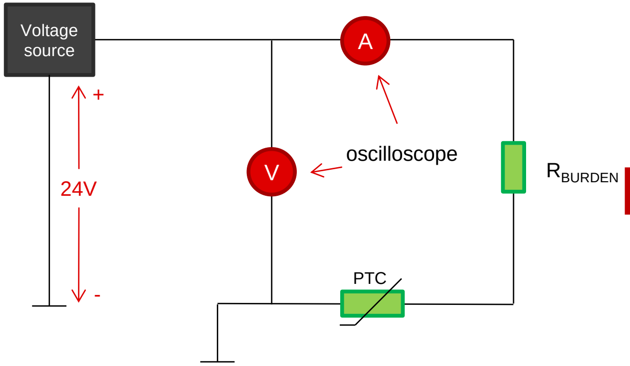
Limitation #3: High power dissipation during tripped state

Limitation #4: No fault indication

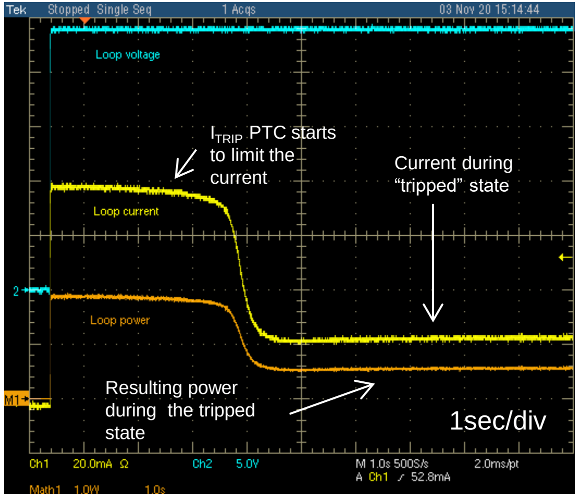
PTC | Example

Generic PTC	
Specification @ 25C	**Value**
ITRIP	100mA
IHOLD	50mA
ITRIP response time @ 100mA	2s
P_{DISS} during tripped state @ 24V	480mW

Test case: Mis-wire 24V power supply to 4-20mA current loop



Resulting waveform



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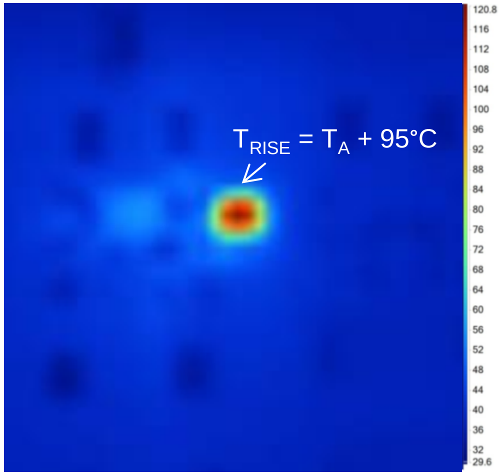
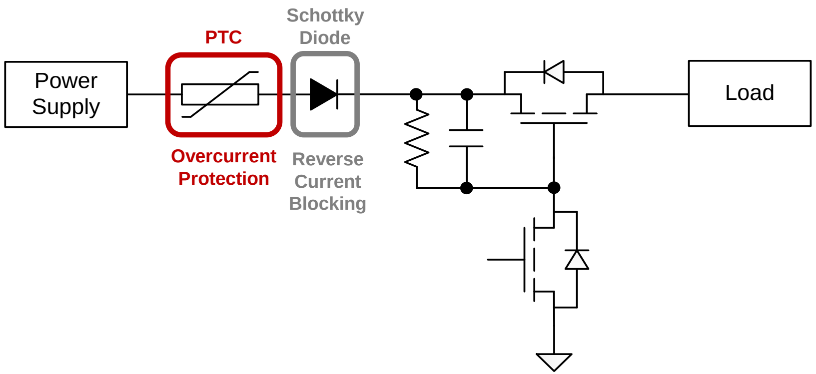


No fault reporting available with the PTC

Discrete Input Protection Circuit | Summary



PTC Considerations

Consideration #1: Large variation in hold and trip current across temperatures

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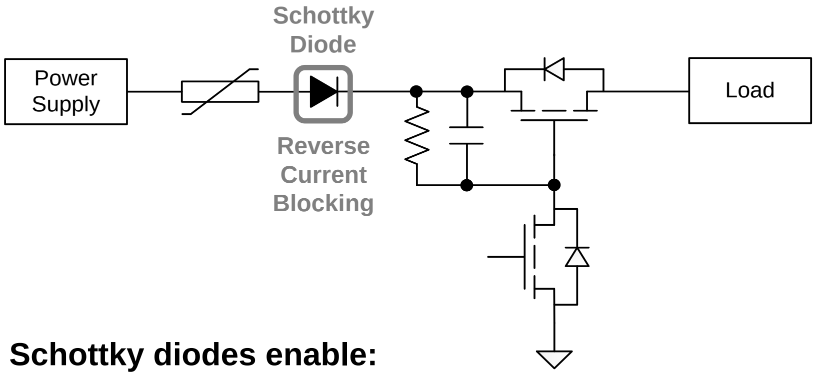
Diode in Discrete Implementation

Typical Discrete Implementation



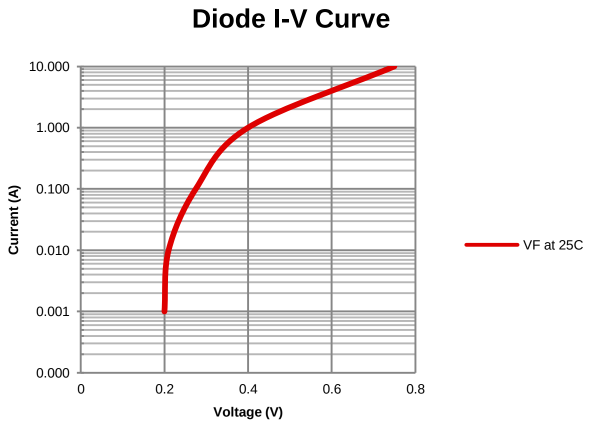
Schottky diodes enable:

- ✓ Reverse current blocking
- ✓ Reverse polarity protection

Diode I-V curve

Generic Diode

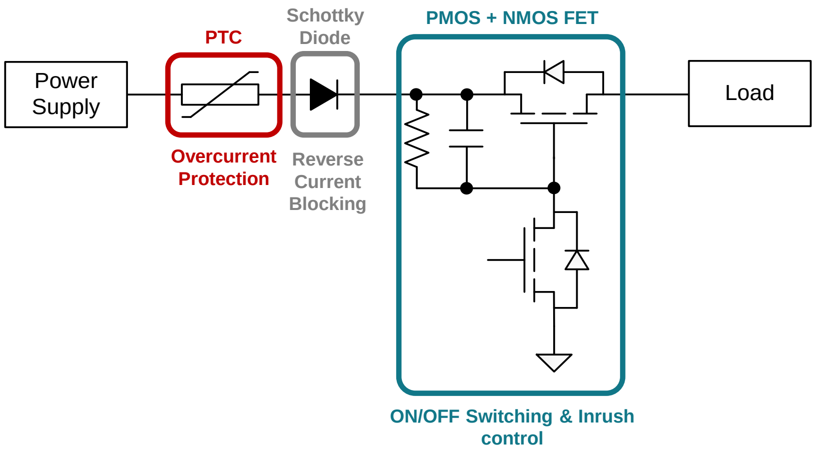
Specification	Value
$I_{FORWARD}$	5A
V_{REV}	40V
TJ	150C
$V_{F(typ)}$	0.4V



Diode Considerations

- Power Dissipation
  - Diodes dissipate a large amount of power, for example if we have a 2A application the above diode were to be used then it would dissipate approximately 0.9W of power
- Size
  - To handle this amount of power, power diode come in large packages such as SOD128 or SMB packages

Discrete Input Protection Circuit | Summary



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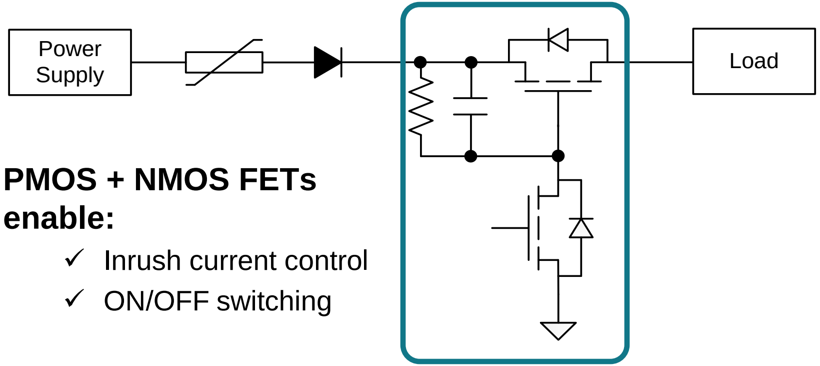
PMOS & NMOS FET in Discrete Implementation

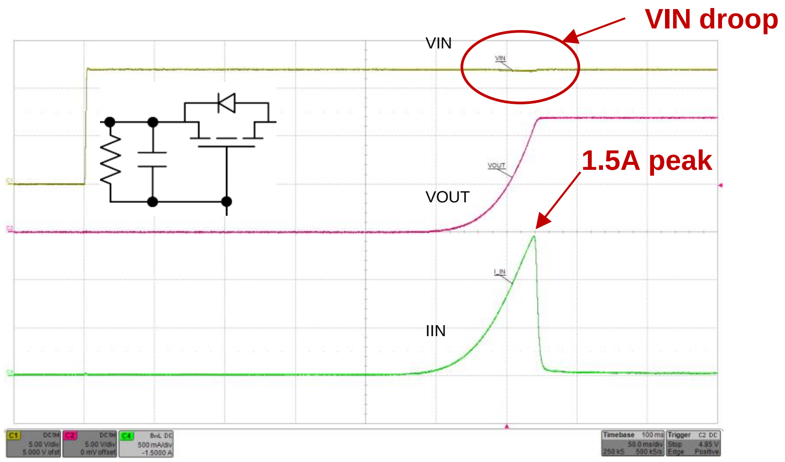
Typical Discrete Implementation



PMOS + NMOS FETs enable:

- ✓ Inrush current control
- ✓ ON/OFF switching

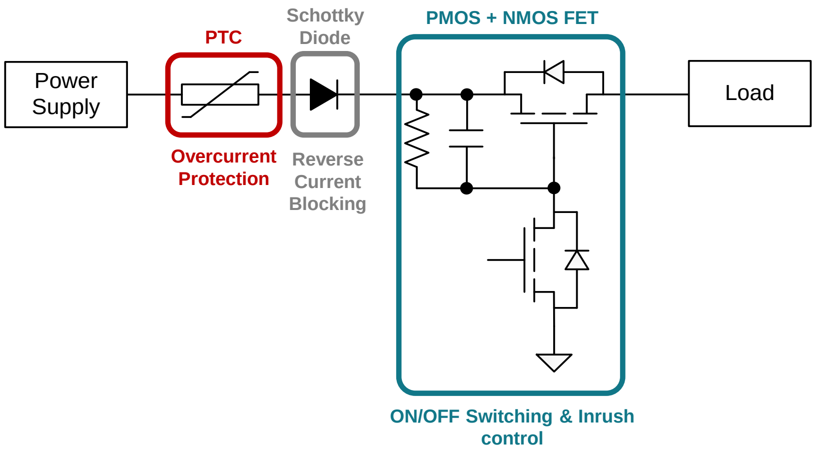
Non-linear inrush current control



PMOS & NMOS FET Considerations

- Non-linear inrush current control
  - Due to the RC mechanism, the inrush current during start up of the system will have an exponential rise in current resulting in large peak currents which could collapse the upstream supply
- Size
  - Two components are required to realize the ON/OFF control as well as some additional discrete components to realize the inrush current control

Discrete Input Protection Circuit | Summary



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Size

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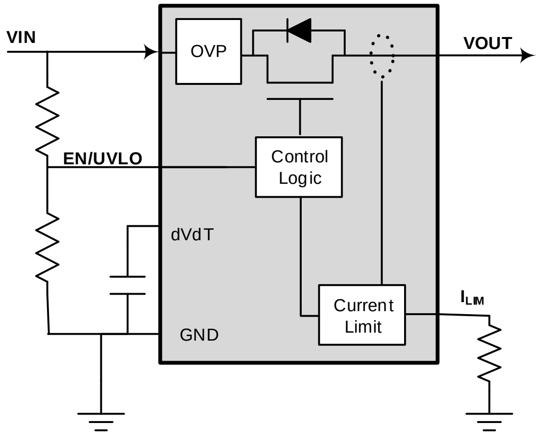
TI eFuse Overview

eFuses are integrated power protection switches that provide voltage and current protection during fault events.

eFuses are used at the input of a system.



Features & Benefits

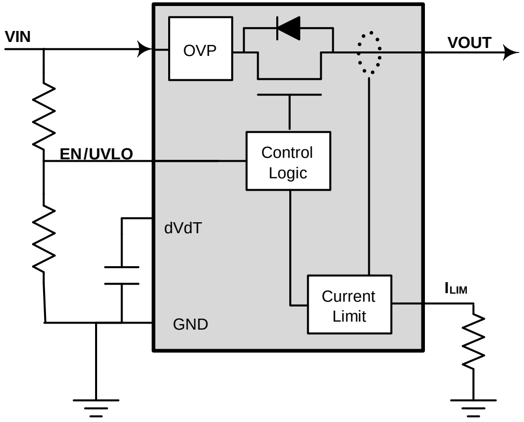
Feature	Benefits
Adjustable current limit & Adjustable slew rate control	• More flexibility in system design • Enables the same device to be used across different applications
Short circuit protection	• Very fast (<200ns) response time to severe short circuit events
Over & under voltage protection	• Programmable OVP & UVLO helps to eliminate supervisory circuits
Reverse current & reverse polarity protection	• Protects against mis-wiring • Reserves holdup capacitor charge during power failure (Last Gasp) • Enables Power Muxing
Status & power good signals	• PG signal provides sequencing in the application • Fault intelligence provided to the micro controller etc • Real Time Analog Load current monitor
UL recognized	• All eFuses are UL recognized, this enables faster certification of the end product since a UL device is being used

eFuse Topologies

Basic Topologies

- eFuses utilize a charge pump to drive internal NMOS FET(s) to act as protection switches
- eFuses are available in two different topologies
  - Single FET
  - Back-to Back FET (B2B)

Single FET Topology



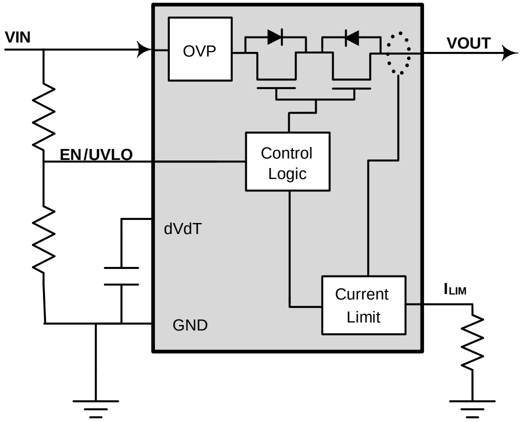
Consists of a single hot-swap FET to enable:

- ✓ Overvoltage protection
- ✓ Current limiting
- ✓ Slew rate control

Features NOT included:

- × Reverse current blocking
- × Reverse polarity protection

Back-to-back FET (B2B) Topology



Consists of two back-to-back FETs to enable the same features and more:

- ✓ Overvoltage protection
- ✓ Current limiting
- ✓ Slew rate control

Features included:

- ✓ Reverse current blocking
- ✓ Reverse polarity protection

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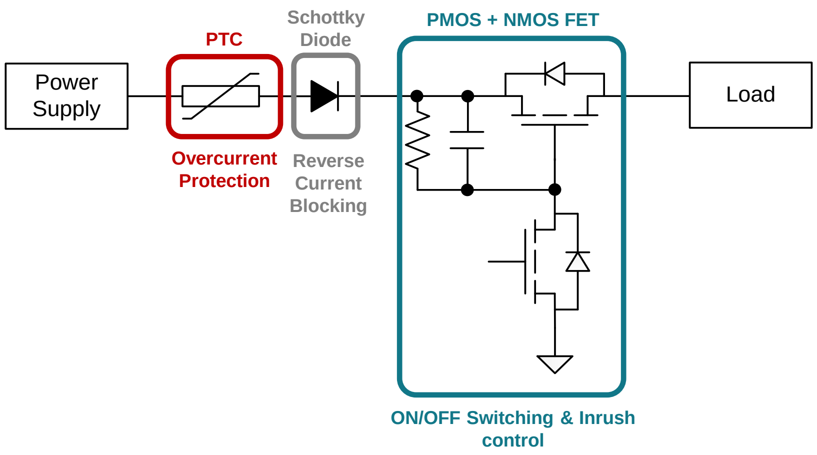
Discrete vs. Integrated | eFuse

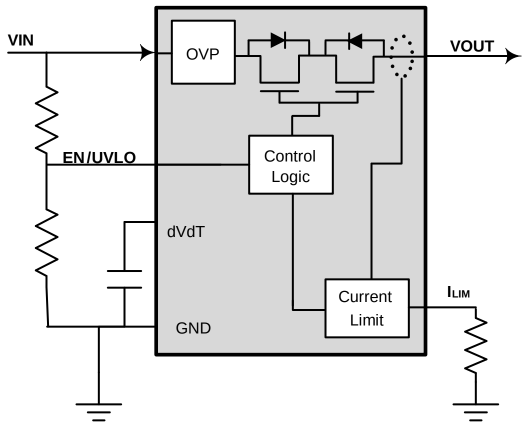
Discrete Input Protection Circuit



Features:

- ✓ Overcurrent protection ➡ - *Slow reaction time, wide variation, high P_{DISS}*
- ✓ Slew rate control ➡ - *Non-linear rise time, high peak inrush*
- ✓ Reverse current blocking ➡ - *High power dissipation (P_{DISS})*
- ✓ Reverse polarity protection
- × Overvoltage protection
- × Fault/PGOOD Indicator

Integrated eFuse



Features:

- ✓ Overcurrent protection ➡ + *Accurate & fast response, low P_{DISS} due auto-retry & latch off response*
- ✓ Slew rate control ➡ + *Linear rise time reduces peak inrush current*
- ✓ Reverse current blocking ➡ + *Integrated blocking FET enables low P_{DISS}*
- ✓ Reverse polarity protection
- ✓ Overvoltage protection ➡ + *Also provides OVP*
- ✓ Fault/PGOOD Indicator ➡ + *Enables fault reporting for smarter protection*

PTC | Example

Generic PTC	
Specification @ 25C	**Value**
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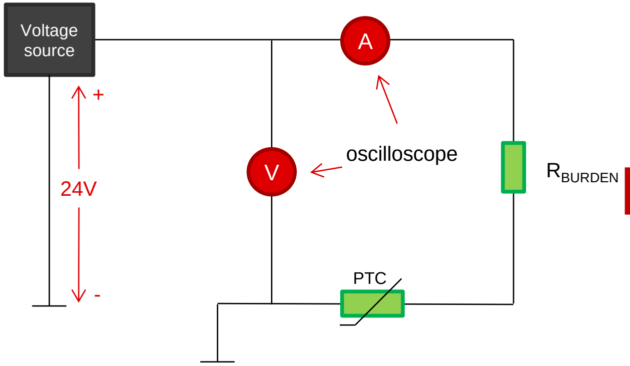
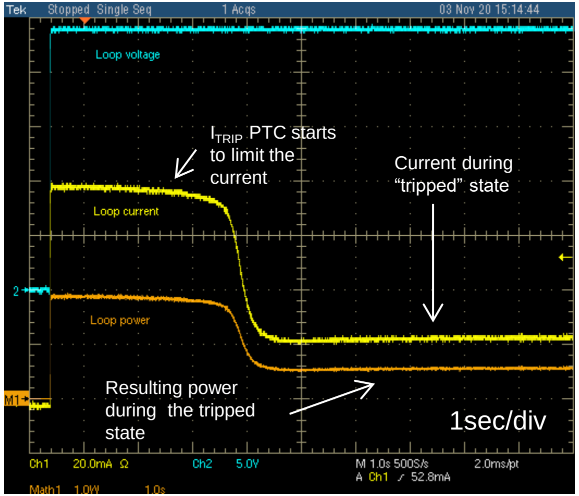
P_{DISS} during tripped state @ 24V	480mW

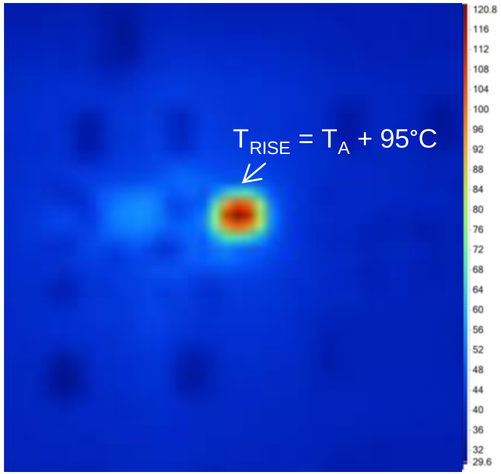
Test case: Mis-wire 24V power supply to current loop



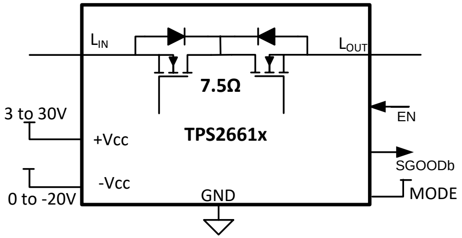
Resulting waveform



Resulting Thermal Image



eFuse | Current limiting performance



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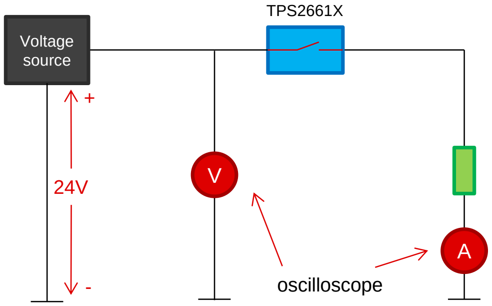


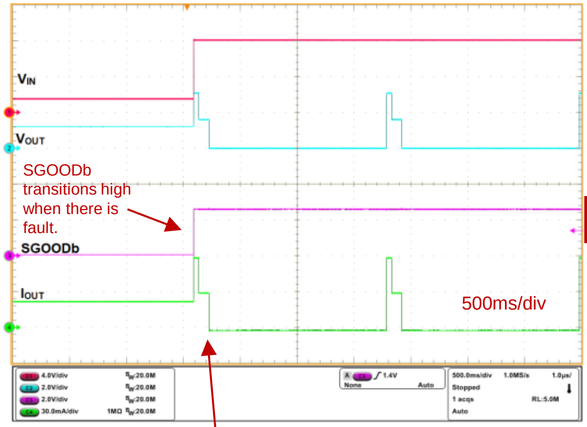
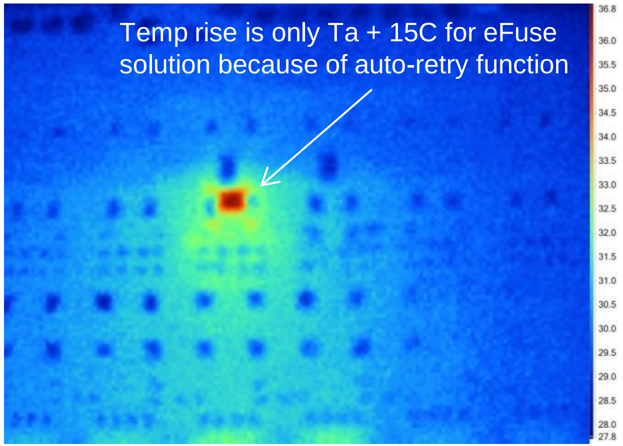


Figure 7-3. Auto Retry with MODE = 180 kΩ

TPS2661 limits the current to the 2x ILIM for 40ms then folds back to 30mA ILIM for 80ms then hits thermal shutdown and retries after a set interval which helps to reduce the heat dissipation inside the module



eFuse vs. PTC | Summary

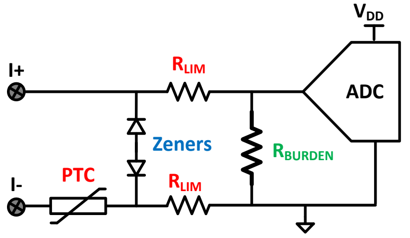
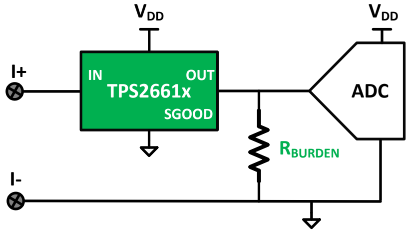
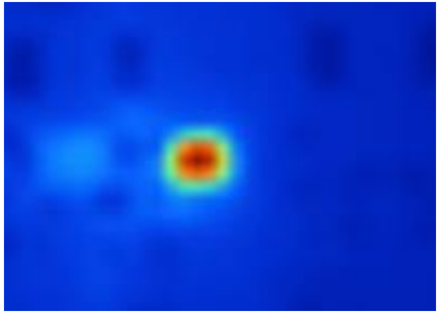
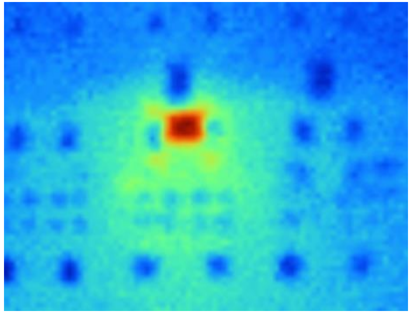
Why is protection needed?

- ✓ Short-circuit events
- ✓ Mis-wiring during installation
- ✓ Overvoltage transients

Why TI?

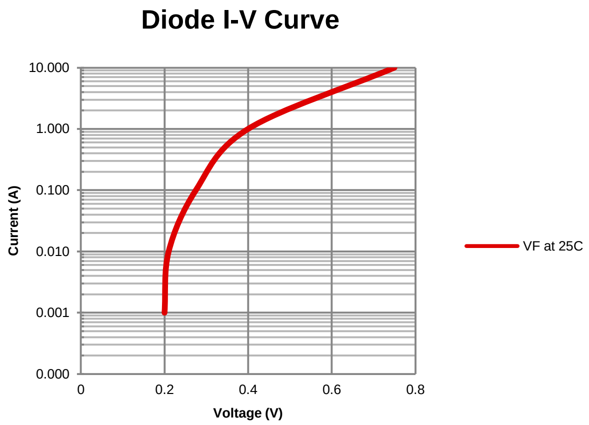
- ✓ Higher current limit accuracy
- ✓ Faster response time to overcurrent
- ✓ Compact packaging
- ✓ Lower heat dissipation during fault
- ✓ Fault indication

PTC based solution vs. Integrated protection

Specifications	PTC based protection	TPS2661 | Integrated solution
Simplified Schematic		
I_{LIM} accuracy	+140/-72%	+/-16%
I_{LIM} response time @ 25C	2s	120ms
Fault Indication	No	Yes, through SGOOD pin
T_{RISE} during overcurrent fault @ 20°C	T_A + 95°C 	T_A + 15°C 

eFuse vs. diode | Power dissipation

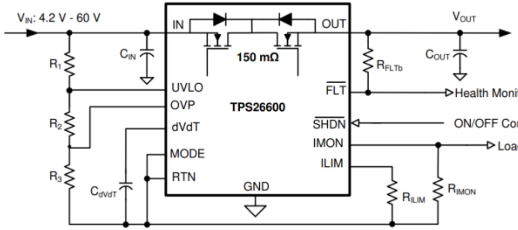
Diode



Power Dissipation for Diode at 25C, 2A		
V_F (V)	I_{OUT} (A)	P_{DISS} (W)
0.45	2	0.9

eFuse

- For eFuse devices with B2B FETs, the R_{ON} value in the datasheet is the combined resistance of both the blocking FET and the hot-swap FET
- The R_{ON} value is split evenly between the two FETs
- So to compare the power dissipation versus a diode, the blocking FET resistance should be consider
- See below for an example with TPS2660

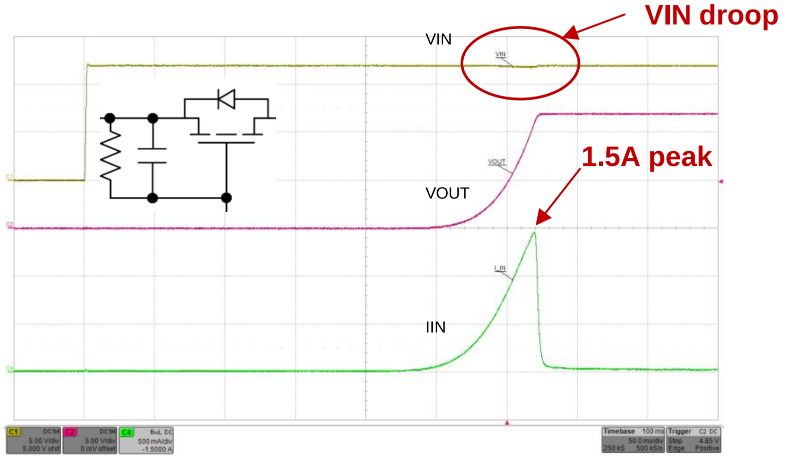


Power Dissipation for TPS2660 at 25C, 2A			
BFET R_{ON} (Ω)	V_F (V)	I_{OUT} (A)	P_{DISS} (W)
0.075	.150	2	0.3

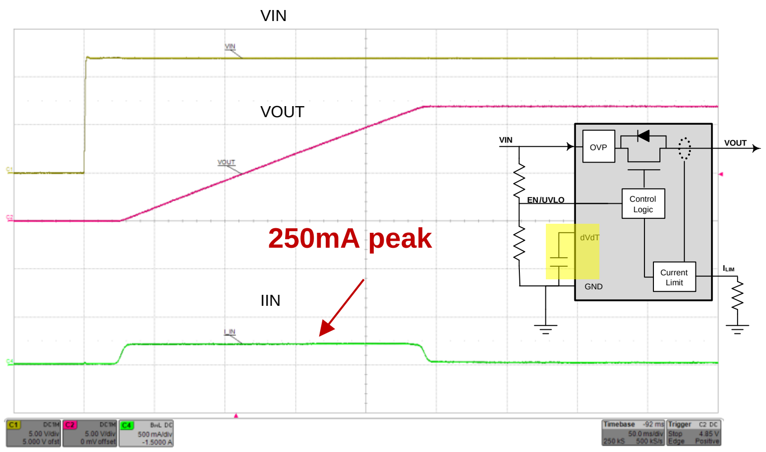
*TPS2660 offers **66% reduction** in power dissipation compared to a diode*

eFuse vs. PFET | Inrush current control

Non-linear inrush current control

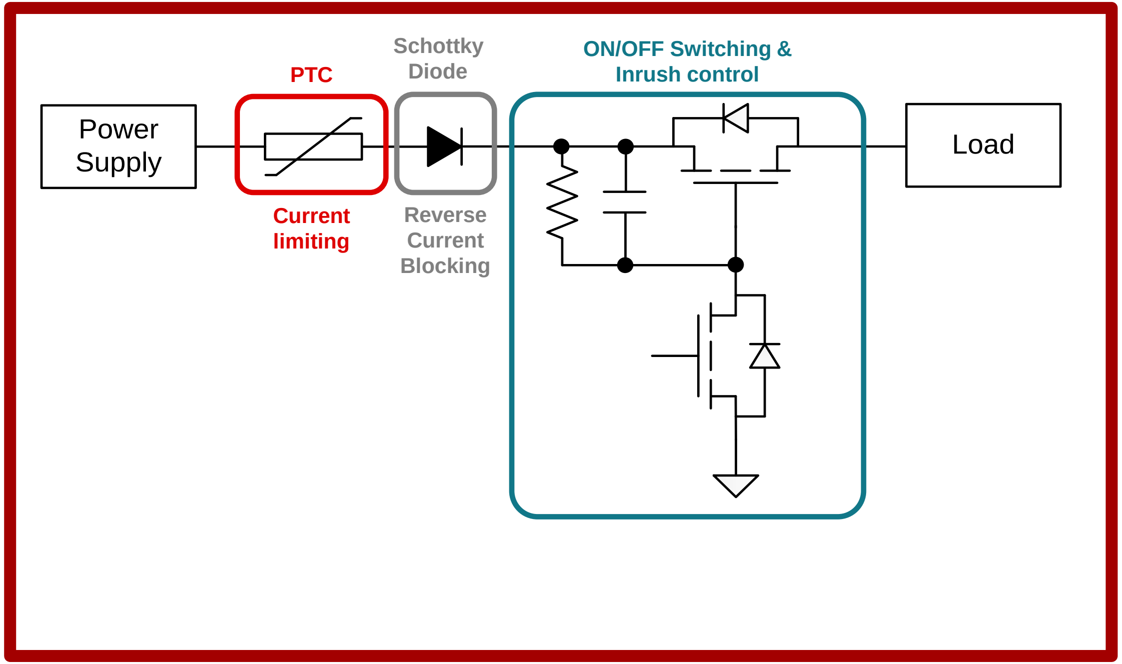


linear inrush current control with eFuse



Size Comparison | Discrete vs. Integrated

How eFuses add features & decrease solution size



Reverse polarity protection

Current limiting

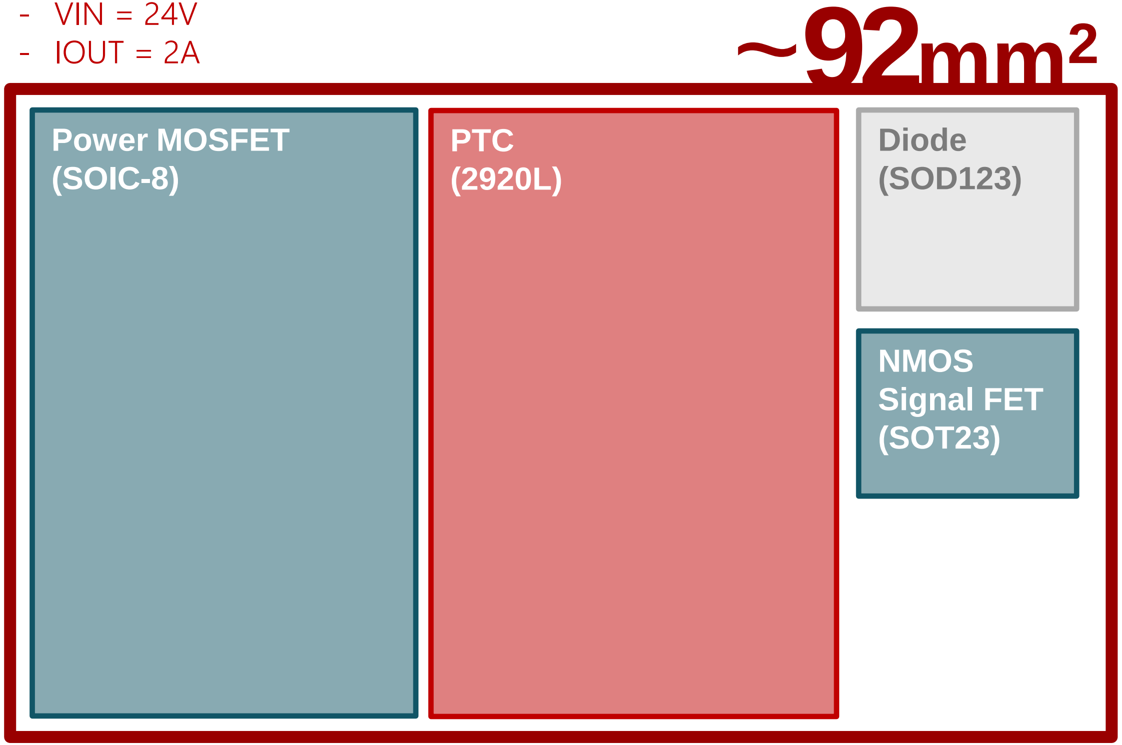
Inrush current control

Size Comparison | Discrete vs. Integrated

How eFuses add features & decrease solution size

Discrete component for below application example:

- VIN = 24V
- IOUT = 2A



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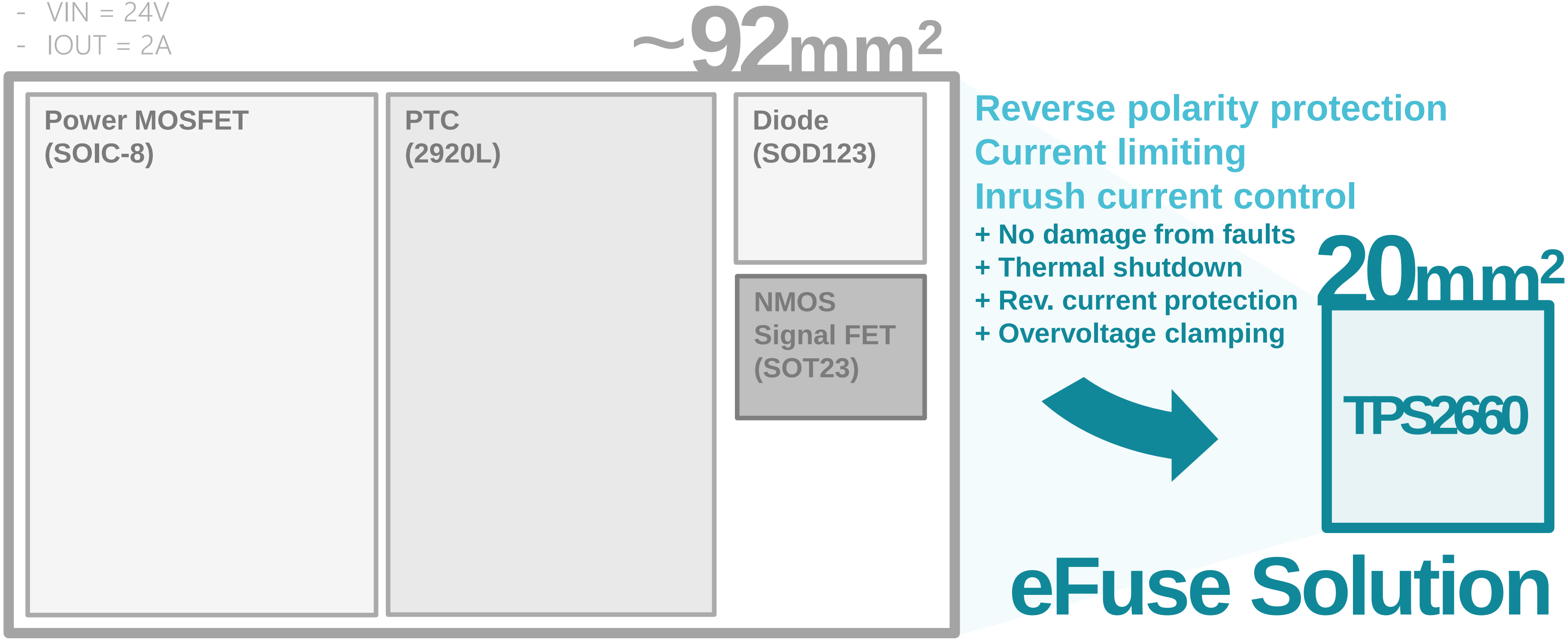
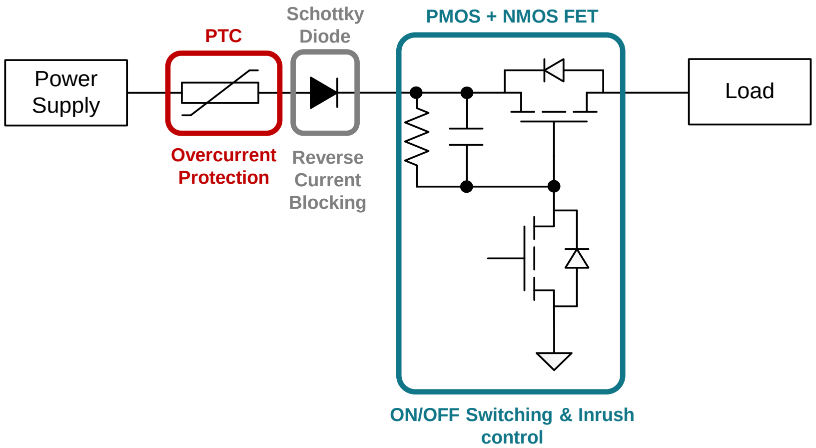


Discrete vs. Integrated | eFuse

Discrete Input Protection Circuit



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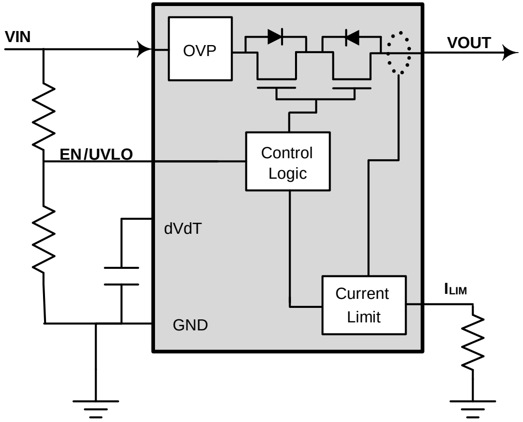
- × Overvoltage protection
- × Fault/PGOOD Indicator

Integrated eFuse



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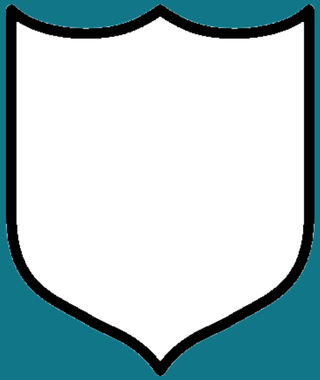
Benefits of TI eFuse

Integration

Protection

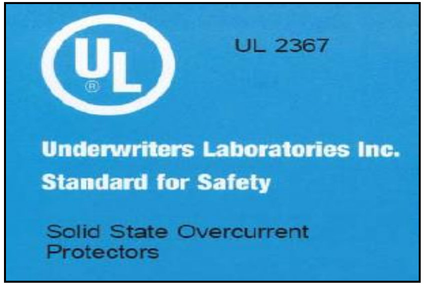


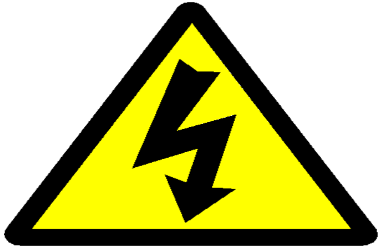
Recognition

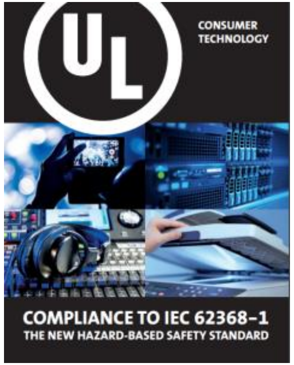
eFuse | UL Recognition

Certification

- *Tight current limit during overloads & startup*
  - *Prevents fires, overheating, bus droop, supply stress*
- *Significantly lower peak currents during short circuit*
  - *Often by 5x → 20x*
- *Significantly faster short circuit shut off*
  - *Microseconds not 10s of milliseconds*
- *Most TI eFuses recognized by UL as Protection Devices*
  - *UL2367 “Solid State Overcurrent Protectors”*



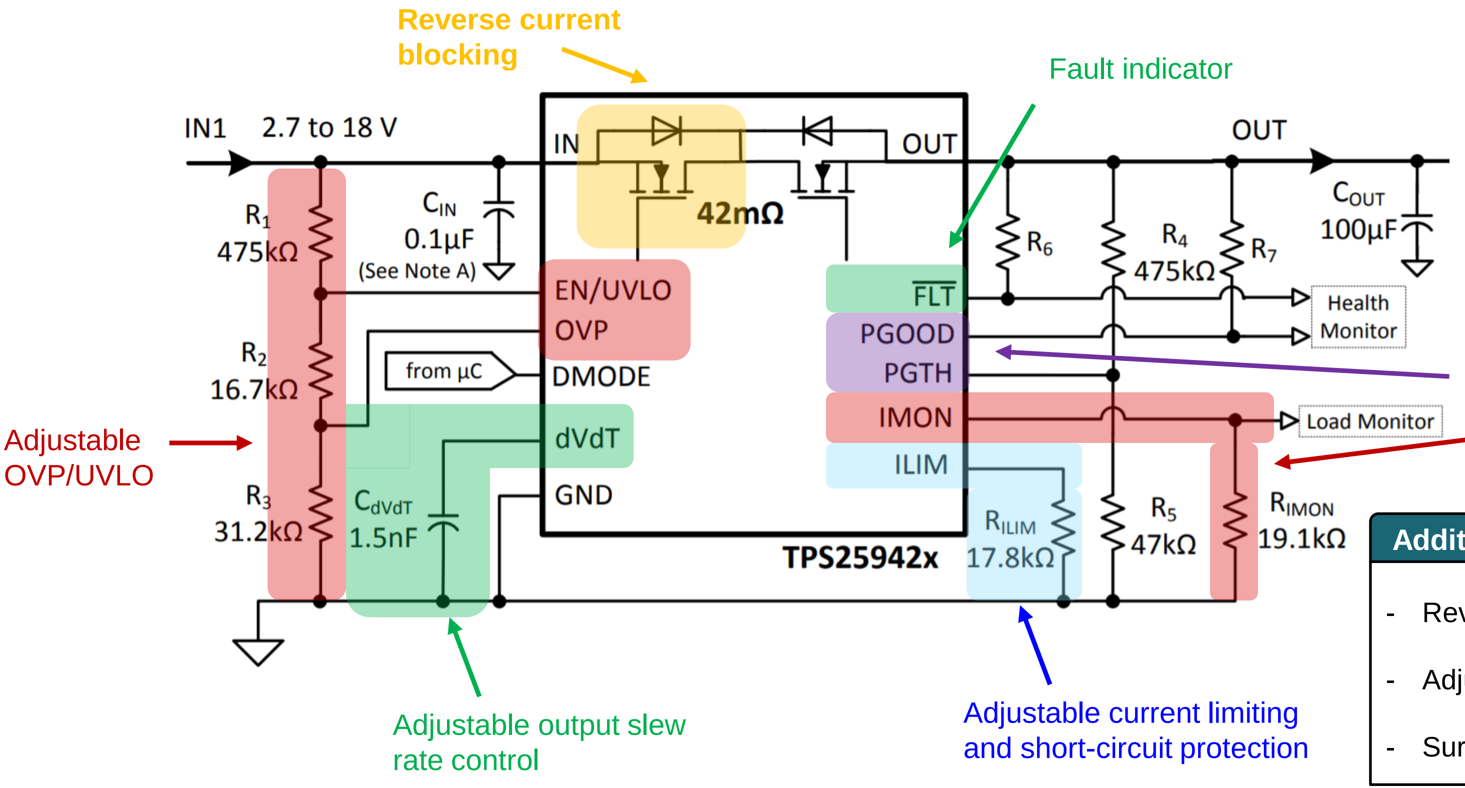




eFuse | Integration & Flexibility

Integration

Protection

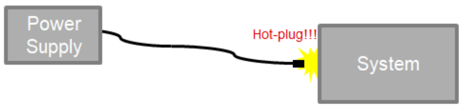


Additional Features

- Reverse Polarity Protection
- Adjustable Power Limiting
- Surge & EFT immunity

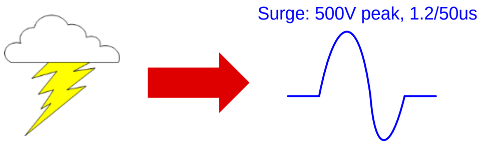
eFuse | Applications & Functions

Overvoltage Protection



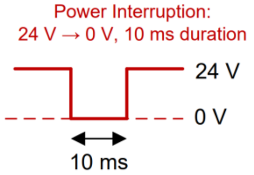
eFuses can help to protect the interior of the system from external overvoltage events that can occur during hot-swap or other events.

Surge & EFT Immunity



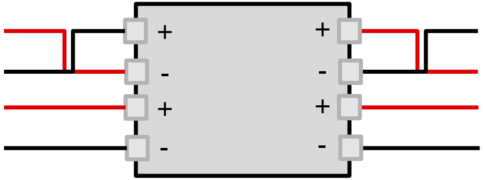
eFuses are designed to provide up to criteria-A surge and EFT immunity to prevent system downtime

Reverse Current Blocking



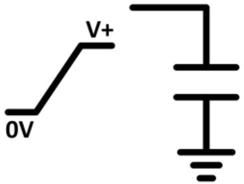
Some TI eFuses have back-to-back integrated FETs to prevent holdup capacitors and super-capacitors from discharging.

Mis-wiring protection



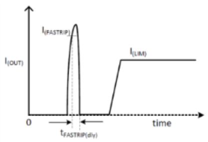
eFuses have integrated circuitry to prevent damage from mis-wiring without sacrificing power dissipation

Inrush Current Control



eFuses provide inrush current control for charging large output capacitances during hot-swap events.

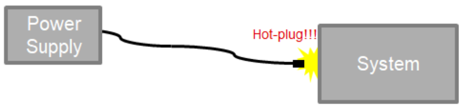
Short-circuit & current limiting protection



When there is a sudden short to ground, an eFuse can be used to quickly turn power OFF to protect the system.

eFuse | Applications & Functions

Overvoltage Protection



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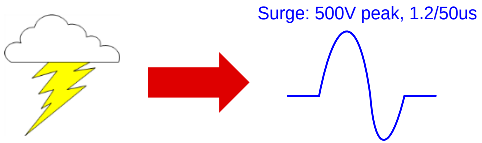

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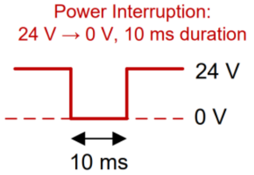

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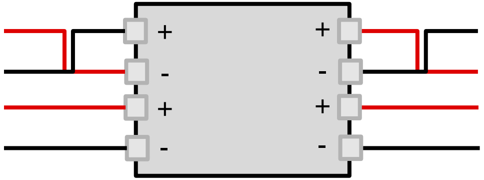

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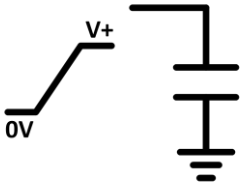

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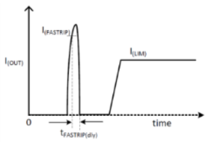


When there is a sudden short to ground, an eFuse can be used to quickly turn power OFF to protect the system.

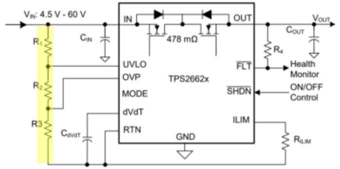
eFuse | Overvoltage Protection

Overvoltage protection schemes

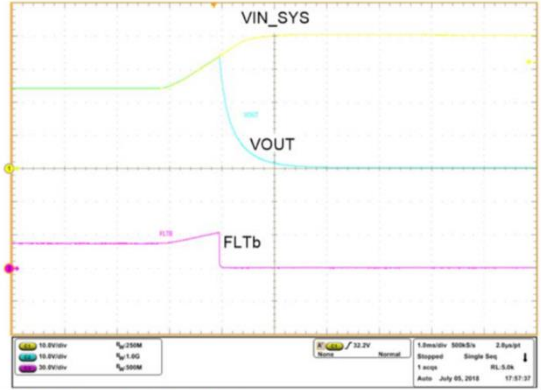
Two Options

- ***Overvoltage cutoff –*** Immediately turns off the MOSFET to block the overvoltage event
- ***Overvoltage clamping –*** Clamps the output voltage to a certain threshold
- Depending on the device, both options can be adjustable via external resistor ladders or have fixed values

Simplified Schematic

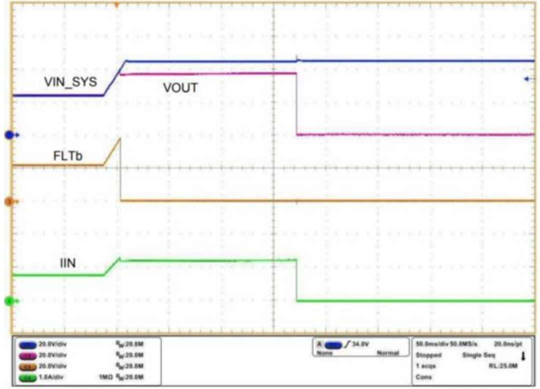


Overvoltage cutoff



TPS26630 and TPS26631

Overvoltage clamping



TPS26635

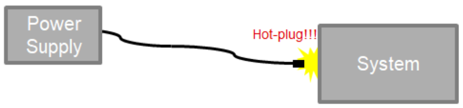
R_{LOAD} = 30Ω, $\overline{FLT}$

Application Examples

End equipment	Application
Factory Automation & Motor Drives	- Backplane power protection for hot-swap events and surge events - Field power protection for surge events and where long cables are present which can create large inductive spikes
Building Automation	- Field power protection for surge events and where long cables are present which can create large inductive spikes
Personal Electronics	- Long cables for connecting power to portable electronics

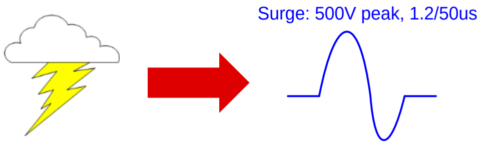
eFuse | Applications & Functions

Overvoltage Protection



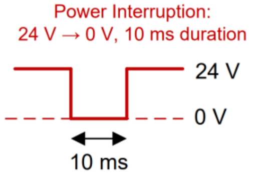
eFuses can help to protect the interior of the system from external overvoltage events that can occur during hot-swap or other events.

Surge & EFT Immunity



eFuses are designed to provide up to criteria-A surge and EFT immunity to prevent system downtime

Reverse Current Blocking



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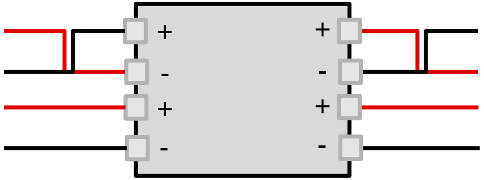
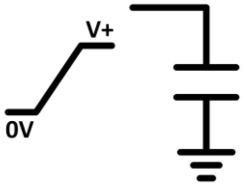
Mis-wiring protection



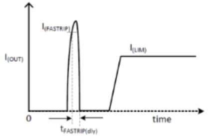
eFuses have integrated circuitry to prevent damage from mis-wiring without sacrificing power dissipation

Inrush Current Control



eFuses provide inrush current control for charging large output capacitances during hot-swap events.

Short-circuit & current limiting protection

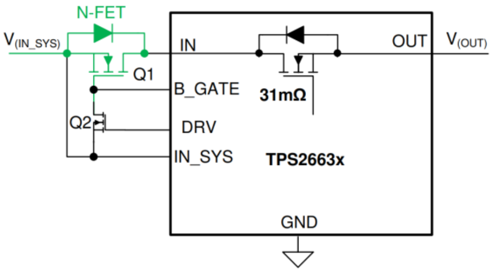


When there is a sudden short to ground, an eFuse can be used to quickly turn power OFF to protect the system.

eFuse | Reverse Current Blocking

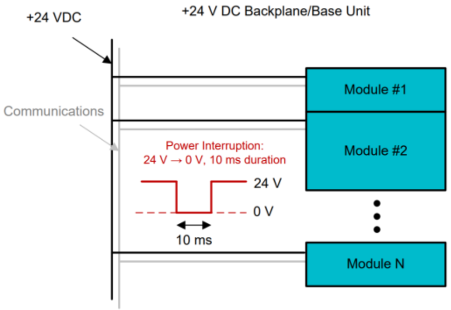
Reverse current blocking example

TPS2663 Simplified Diagram



There is an internal comparator in the device to detect the reverse current and shutoff the blocking FET to block reverse current

TPS2663 response to IEC61000-4-29 Power Interruption Test



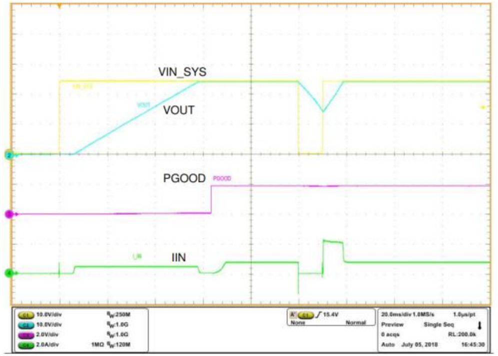
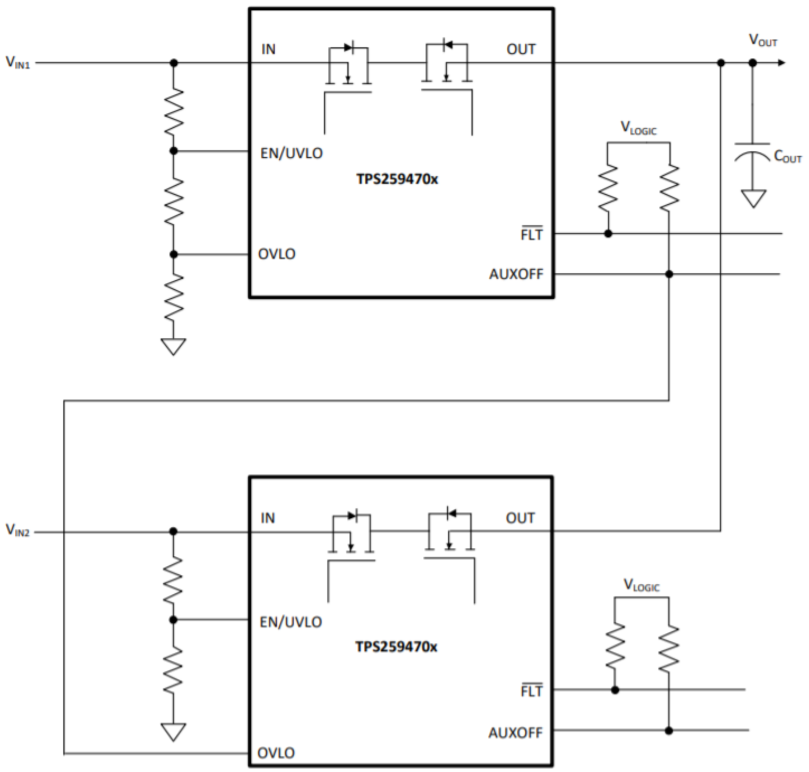


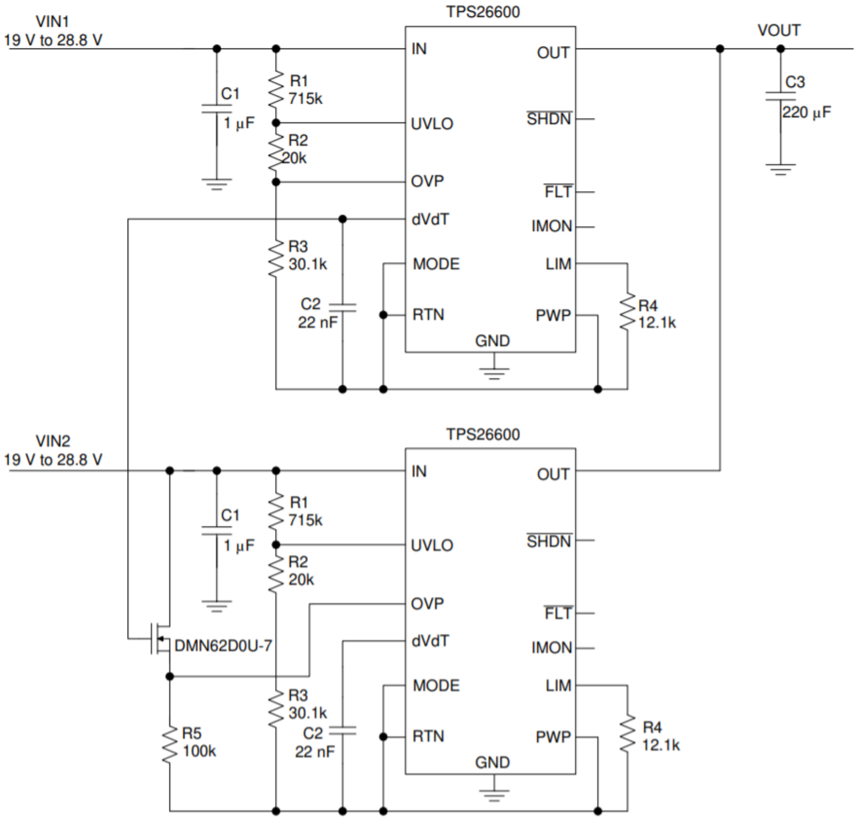
Figure 47. Power Up Followed With Voltage Interruption With TPS26630

Application Examples

End equipment	Application
Factory Automation & Motor Drives	- IEC61000-4-29 Power Interruption Testing - Blocking reverse current to ensure Motor Drive powers down in a safe state
Building Automation	- Backup battery switchover for Fire Alarm Control Panels and Building Security Systems - Blocking reverse current to ensure HVAC system powers down in a safe state
Grid Infrastructure	- Last gasp transmission in eMeters and data concentrators

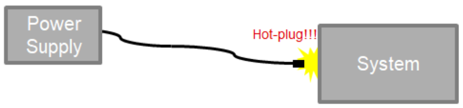
Power Mux examples with eFuses | TPS25947x & TPS2660x





eFuse | Applications & Functions

Overvoltage Protection



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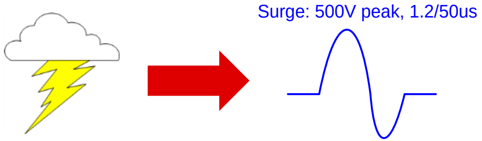
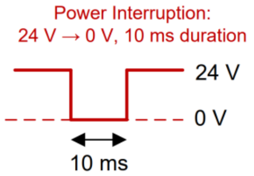
Surge & EFT Immunity



eFuses are designed to provide up to criteria-A surge and EFT immunity to prevent system downtime

Reverse Current Blocking



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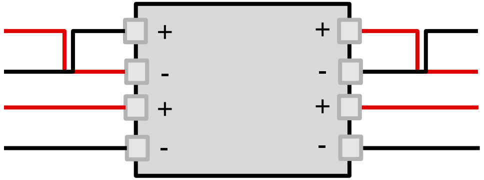
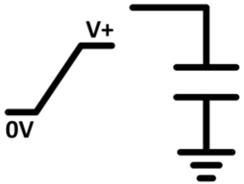
Mis-wiring protection



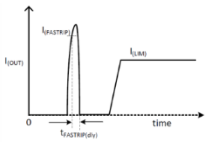
eFuses have integrated circuitry to prevent damage from mis-wiring without sacrificing power dissipation

Inrush Current Control



eFuses provide inrush current control for charging large output capacitances during hot-swap events.

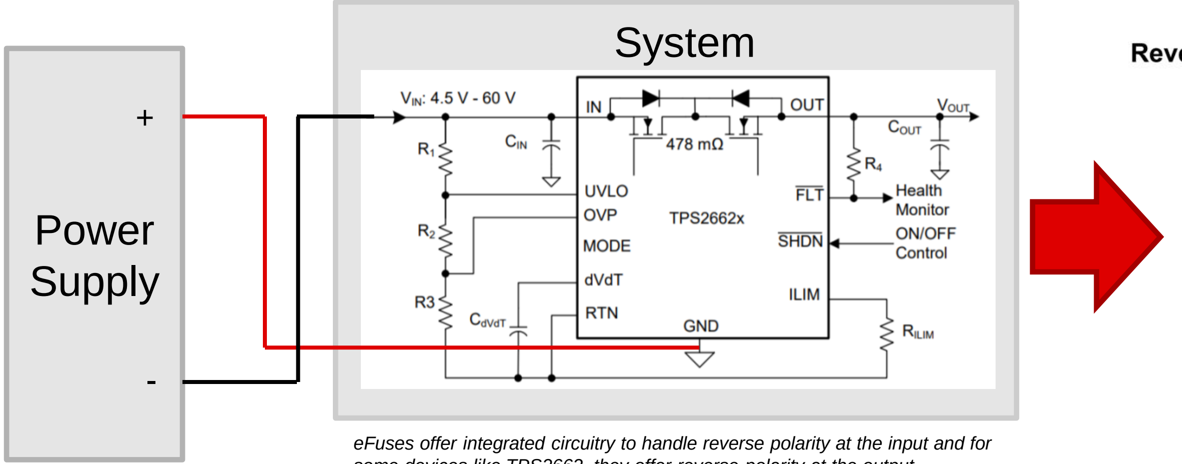
Short-circuit & current limiting protection



When there is a sudden short to ground, an eFuse can be used to quickly turn power OFF to protect the system.

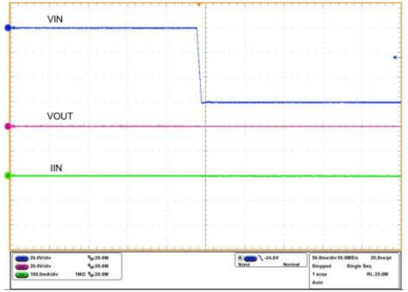
eFuse | Mis-wiring protection

Reverse polarity protection example



eFuses offer integrated circuitry to handle reverse polarity at the input and for some devices like TPS2662, they offer reverse polarity at the output

Reverse Input Polarity Protection at –60-V Supply

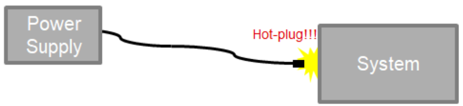


Application Examples

End equipment	Application
Factory Automation & Motor Drives	- Analog Input & Outputs - Digital Outputs - Field Power Supply Input
Building Automation	- Analog Input & Outputs - Sensor Supply Outputs - Supply Inputs
Automotive & Industrial Transport	- Reverse battery
Personal Electronics	- Barrel Jack Inputs

eFuse | Applications & Functions

Overvoltage Protection



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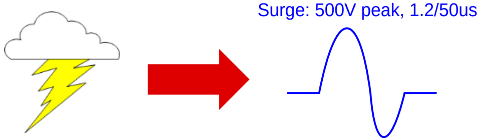
Surge & EFT Immunity



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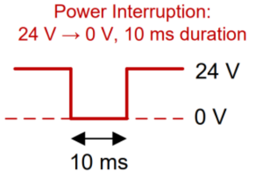

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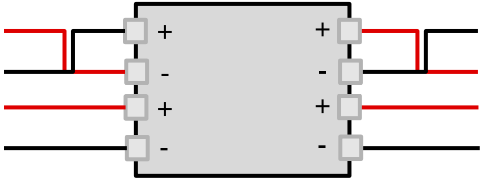

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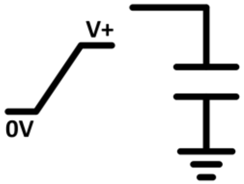

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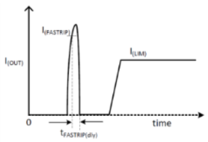
Short-circuit & current limiting protection



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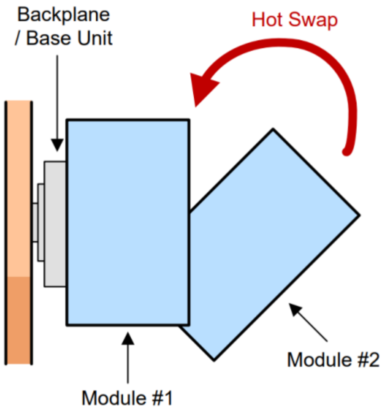
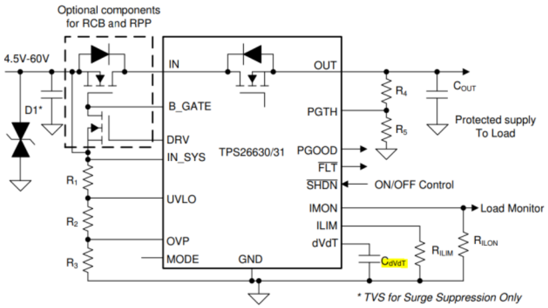
eFuse | Inrush current control

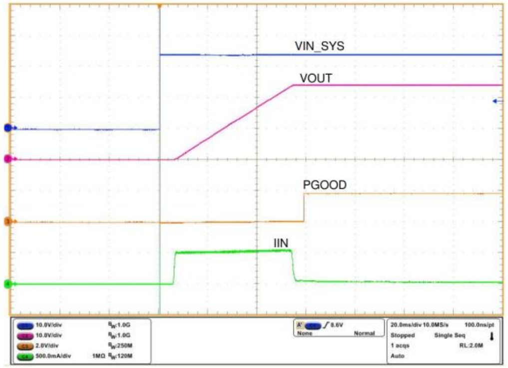
Inrush current control example



Simplified Schematic



*eFuses offer a **dv/dt** pin which can be used to adjust the output slew rate of the switch to control the amount of inrush current needed to charge up the output capacitance*



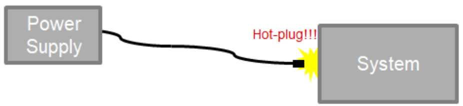
C_{dVdT} = 100 nF C_{OUT} = 1000 µF R_{ILIM} = 4.02 kΩ

Application Examples

End equipment	Application
Factory Automation & Motor Drives	- Backplane power protection where hot-swap events can occur - Systems with large holdup capacitances for power failures
Building Automation	- Backplane power protection where hot-swap events can occur - Systems with large holdup capacitances for power failures
Grid infrastructure	- Charging up supercapacitors for last gasp transmission

eFuse | Applications & Functions

Overvoltage Protection



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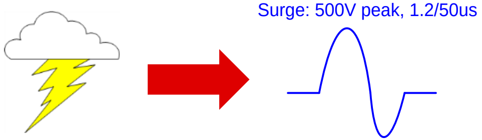

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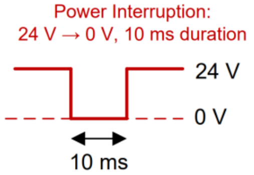

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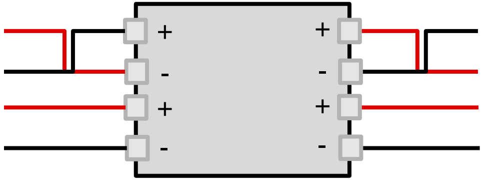

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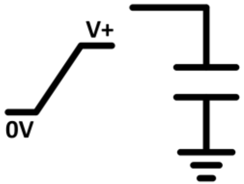

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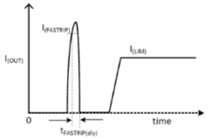

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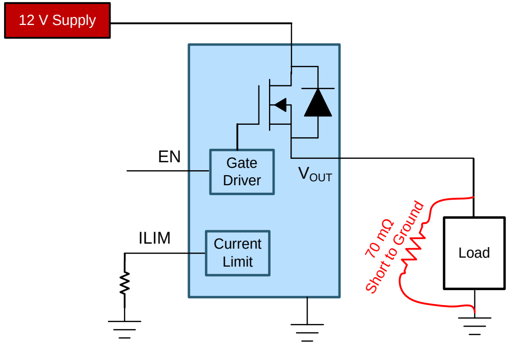
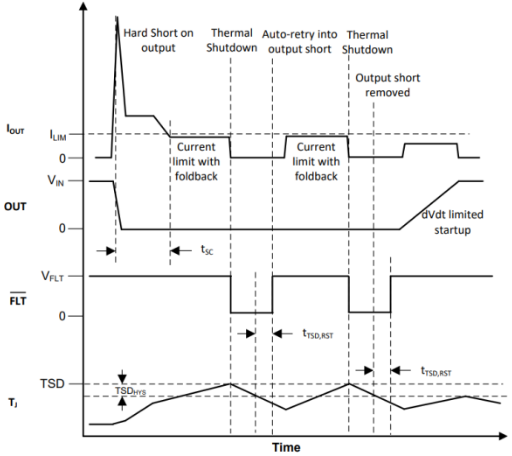
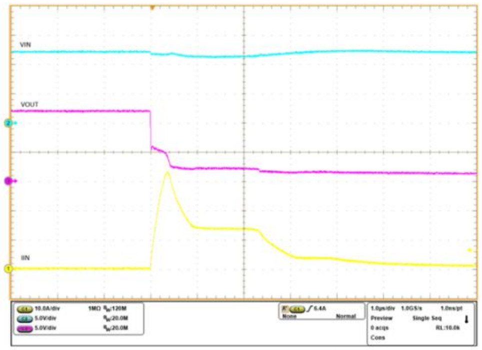
eFuse | Short-circuit protection & current limiting

Short-circuit & current limiting protection







V_{IN} = 12 V, R_{ILM} = 453 Ω

Response & recovery to overcurrent events

There are two types of responses to an overcurrent:

- Circuit breaker
- Current clamping

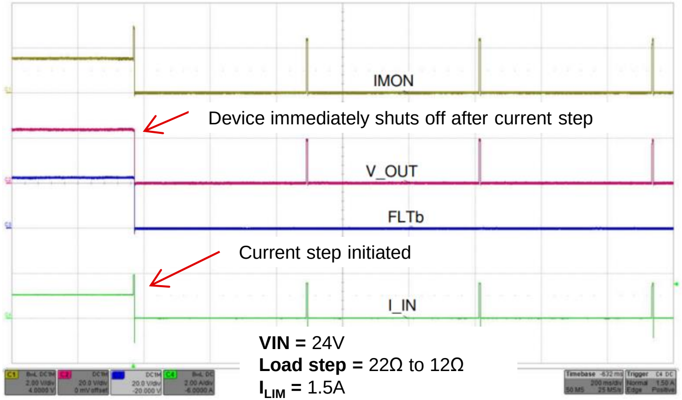
Additionally, there are two types of recoveries from an overcurrent event:

- Auto-retry
- Latch-off

Both the response and recovery of overcurrent events will be discussed in more details on the next coming slides

eFuse | Overcurrent response types

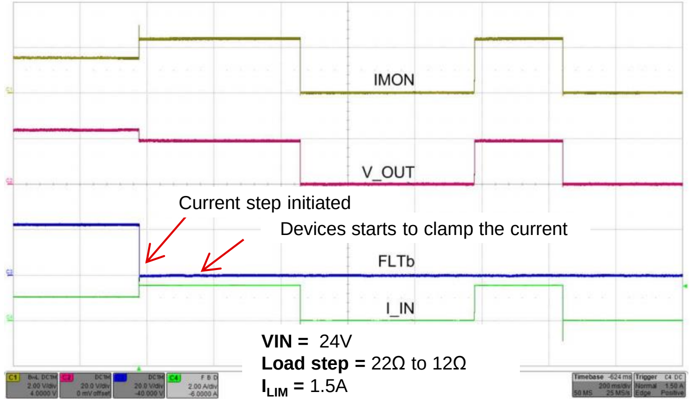
Circuit breaker waveform



Circuit breaker

- This function disables the output after a certain current threshold has been reached for a defined blanking time
- The level of the current threshold can be programmed via an external resistor
- The blanking time behavior to disable the eFuse can varies from device to device. Below are couple of options on the blanking time:
    - Immediate shutdown
    - Fixed blanking time
    - Adjustable blanking time

Current clamping waveform

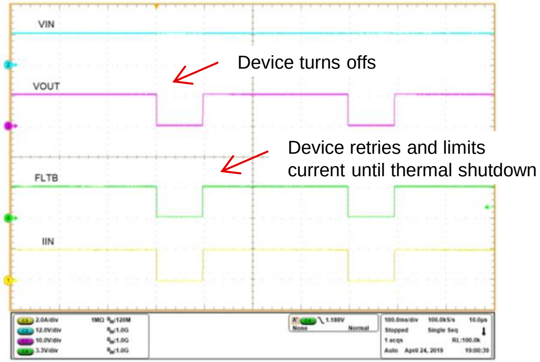


Current Clamping

- This function will clamp the current to a specified level until the device reaches a certain temperature where the device will then shut down to protect itself from overheating
- The level of the current threshold can be programmed via an external resistor

eFuse | Fault recovery types

Auto-retry waveform

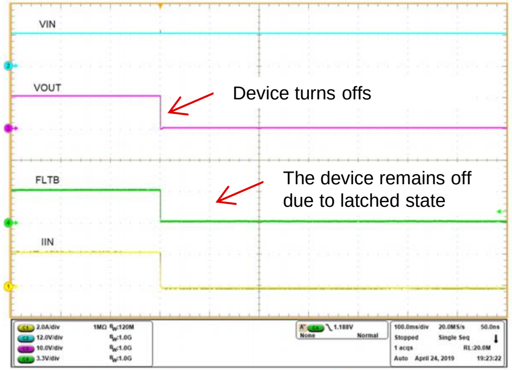


VIN = 12V, **I_{LIM} =** 2A, **ROUT =** 5Ω

Auto-retry

- There could be a need for the system to auto-retry if there is a fault in the system due to an overcurrent
- This helps to reduce the MCU overhead to manage faults on multiple rails
- eFuses enable this auto-retry function by disabling the switch once an overcurrent event has been detected the device will disable itself
- The eFuse device will then re-enable itself after a fixed retry delay timer has expired in the device
- The retry delay time can vary based on the device that is selected. The eFuse datasheet will define the exact timing specification

Latch-off waveform



VIN = 12V, **I_{LIM} =** 2A, **ROUT =** 5Ω

Latch-off

- In some applications, the need to disable the system to keep it safe after a fault is a requirement or to just reduce the temperature of the system during a fault condition
- eFuses help to do this with their latch-off function. After an overcurrent fault has occurred the device will latch-off and disable the output
- The device will remain in its latched state until either the power is cycled or the enable signal to the device is toggled OFF and ON
- This allows the system to be reset either through software or through a manual push button in the system

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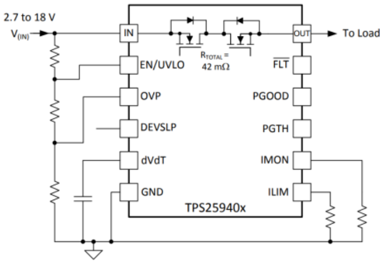
  - **TPS25947**
  - TPS2663
  - TPS2661
- eFuse portfolio & Where to find more information and resources on eFuse

TPS25947 | Next Generation & New Features

Current Generation



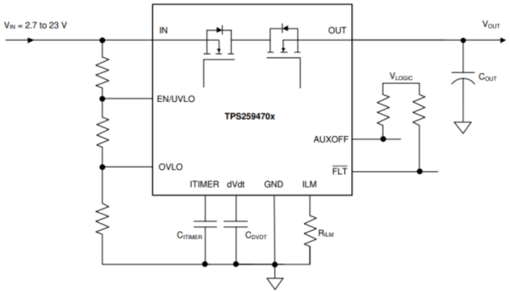
VIN: 2.7 – 18V operating, 20V Abs max
IOUT: 5.3A max current limit
R_{ON} : 42mΩ

Package: 3mm x 4mm

Protection Features

- ✓ Overvoltage protection
- ✓ Reverse current blocking
- ✓ Linear slew rate control
- ✓ Adjustable PGOOD
- ✓ Current monitoring
- ✓ Adjustable current limiting

Next Generation



VIN: 2.7 – 23V operating, 28V Abs max, ⬆ *higher VIN support*
IOUT: 5.5A max current limit
R_{ON} : 28mΩ, ⬇ *33% reduction in R_{ON}*

Package: 2mm x 2mm ⬇ *66% reduction in solution size*

Provides same protection functions of TPS25940 but is available in a ***smaller 2mm x 2mm package*** *with additional features*

Additional features

- ✓ Linear Oring control to reduce reverse current
- ✓ Programmable overcurrent blanking timer
- ✓ Integrated reverse polarity protection

Note: Preproduction samples of the TPS25947 are available on ti.com. The device will be fully released to market by end of 1Q21 or sooner.

TEXAS INSTRUMENTS

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TPS2663x | 60V, 31mΩ, 6A Power Limiting eFuse

Production

Features

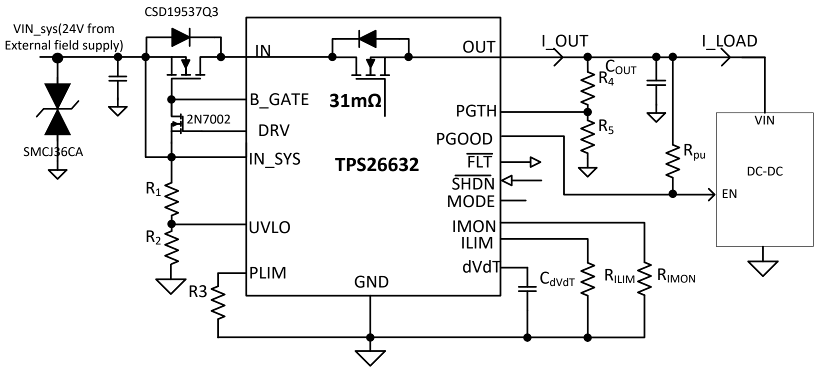
- 4.5V - 60V DC operation, -60V standoff
- Integrated **31mΩ** MOSFET
- Input Reverse polarity protection and reverse current blocking support with **external N-channel FET**
- 0.6 to 6 A Accurate current limit (±8%)
- Programmable UVLO; OVP Cut-Off
- Programmable Output Slew Rate using dVdT pin
- **Output power limiting scheme (PLIM) – TPS26632/TPS26633**
- PGOOD output with Programmable detection threshold (PGTH)
- Analog current monitor output (IMON)
- QFN-24, 4mmx4mm Package with 0.5mm pin pitch
- HTSSOP-24, 6.5mmx4.4mm Package with 0.65mm pin pitch
- UL2367 and IEC62638 recognized

Applications

- PLC (I/O Modules, CPU, HMI)
- AC and Servo Drives
- Electronic circuit Breakers
- Industrial Printer controls
- Sensors Hubs

Benefits

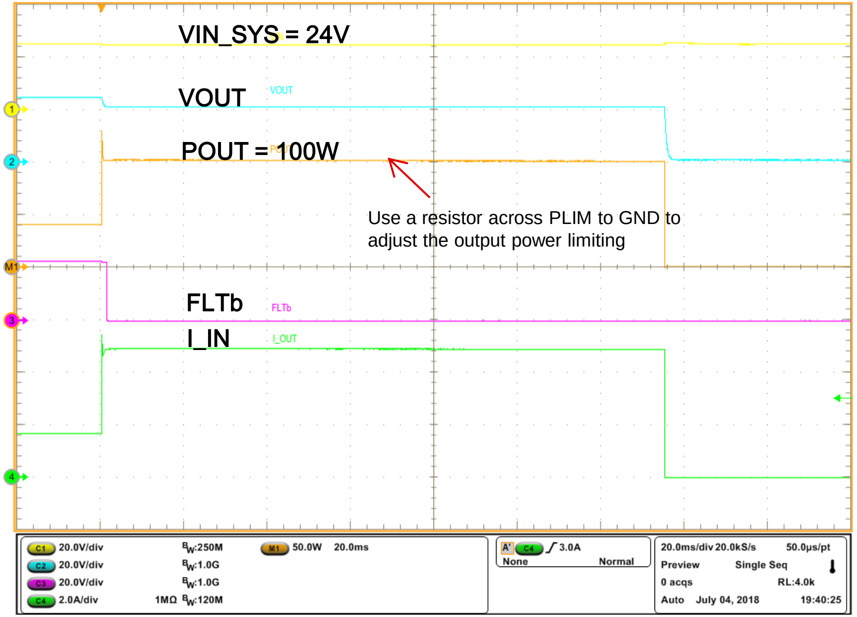
- Tolerates V_{BUS} transients
- Lower Power Dissipation
- Protects against mis-wiring in the field
- Support Reverse Current Protection
- *Tight current limit accuracy reduces upstream power supply cost*
- Flexible Design Options
- Inrush slew can be tuned to load
- Design flexibility with foldback current limit to pass IEC61010-1 (Limited Energy circuit)
- QFN package for dense boards
- Standard leaded package

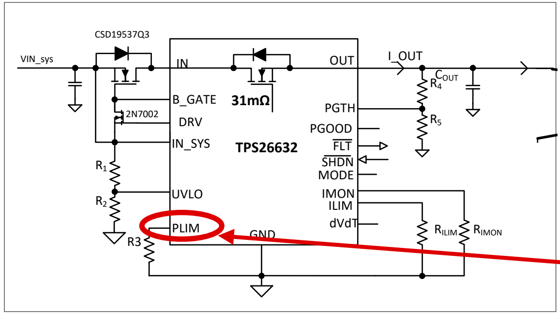


TPS2663 | Output Power Limiting

- There could be a use case where a system needs to remain below a certain power level
- This could be done by limiting the current but this would only be a function of the current and not of the voltage
- However, often times the output current of a system increases as voltage decreases (i.e. downstream buck converters)
- TPSx663 offers output power limiting to ensure the power is limited to certain power level
- This prevents the ***upstream power supply from collapsing in the event of a fault in a specific module***

TPS26632





The power limit of TPSx663 can be adjusted via an external resistor

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TPS2661x | Universal 4-20mA, +/- 20 mA Current loop protector

Features

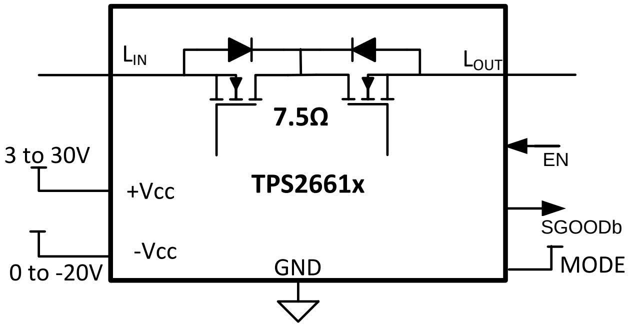
- Supports bidirectional current loops with **0V to ±50V operating** range (with external Vcc)
- Current drawn from loop $\mathbf{I_Q}$ **< 0.1uA** (external Vcc powered)
- Integrated 7.5Ω MOSFET
- Fixed $\mathbf{I_{LIMIT}}$ **= ± 30mA ±15%**
- **EN pin control**
- Device status reporting through SGOODb pin
- Protection against input side miswiring
- Thermal shutdown
- Available in 2.9x1.6mm SOT Package, with 0.65mm pin pitch

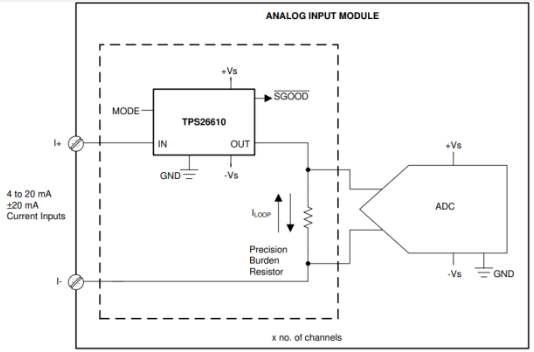
Benefits

- Tolerates V_{BUS} transients
- Ultra Low IQ for lower loss in current Loop
- Higher integration for ease of use
- Protection during Surge (IEC61000-4-5) – with external TVS
- EFT immunity (IEC61000-4-4)
- Protects against mis-wiring in the field
- Variants for Default ON and Default OFF when Vs Supply is absent
- Small footprint for dense boards

Applications

- Analog I/O module – PLC
- Grid Infrastructure – remote sensors
- Current Loops in Industrial Systems
- Temperature Controller
- Robotics





Note: Preproduction samples of the TPS2661 are available on ti.com. The device will be fully released to market by end of 1Q21 or sooner.

TPS2661 | 4-20mA current loop protector

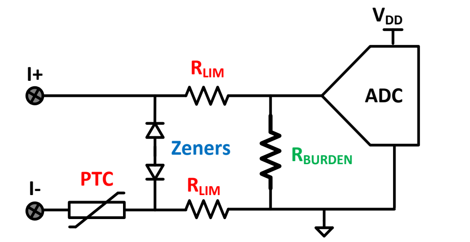
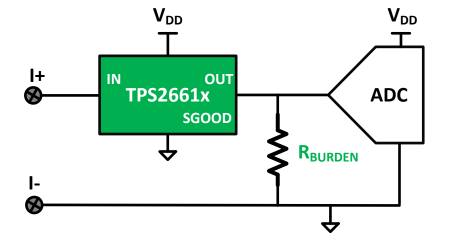
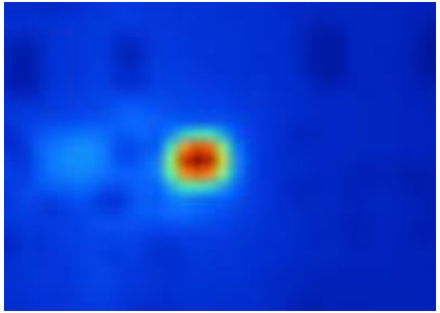
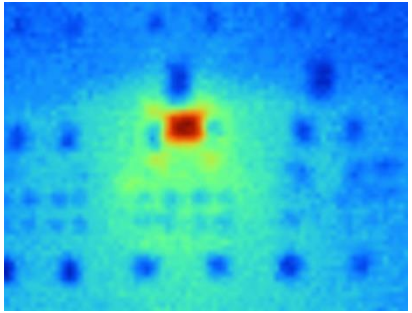
Why is protection needed?

- ✓ Short-circuit events
- ✓ Mis-wiring during installation
- ✓ Overvoltage transients

Why TI?

- ✓ Higher current limit accuracy
- ✓ Faster response time to overcurrent
- ✓ Compact packaging
- ✓ Lower heat dissipation during fault
- ✓ Fault indication

PTC based solution vs. Integrated protection

Specifications	PTC based protection	TPS2661 | Integrated solution
Simplified Schematic		
I_{LIM} accuracy	+140/-72%	+/-16%
I_{LIM} response time @ 25C	2s	120ms
Fault Indication	No	Yes, through SGOOD pin
T_{RISE} during overcurrent fault @ 20°C	T_A + 95°C 	T_A + 15°C 
Solution size (mm^2)	39.52	8.12

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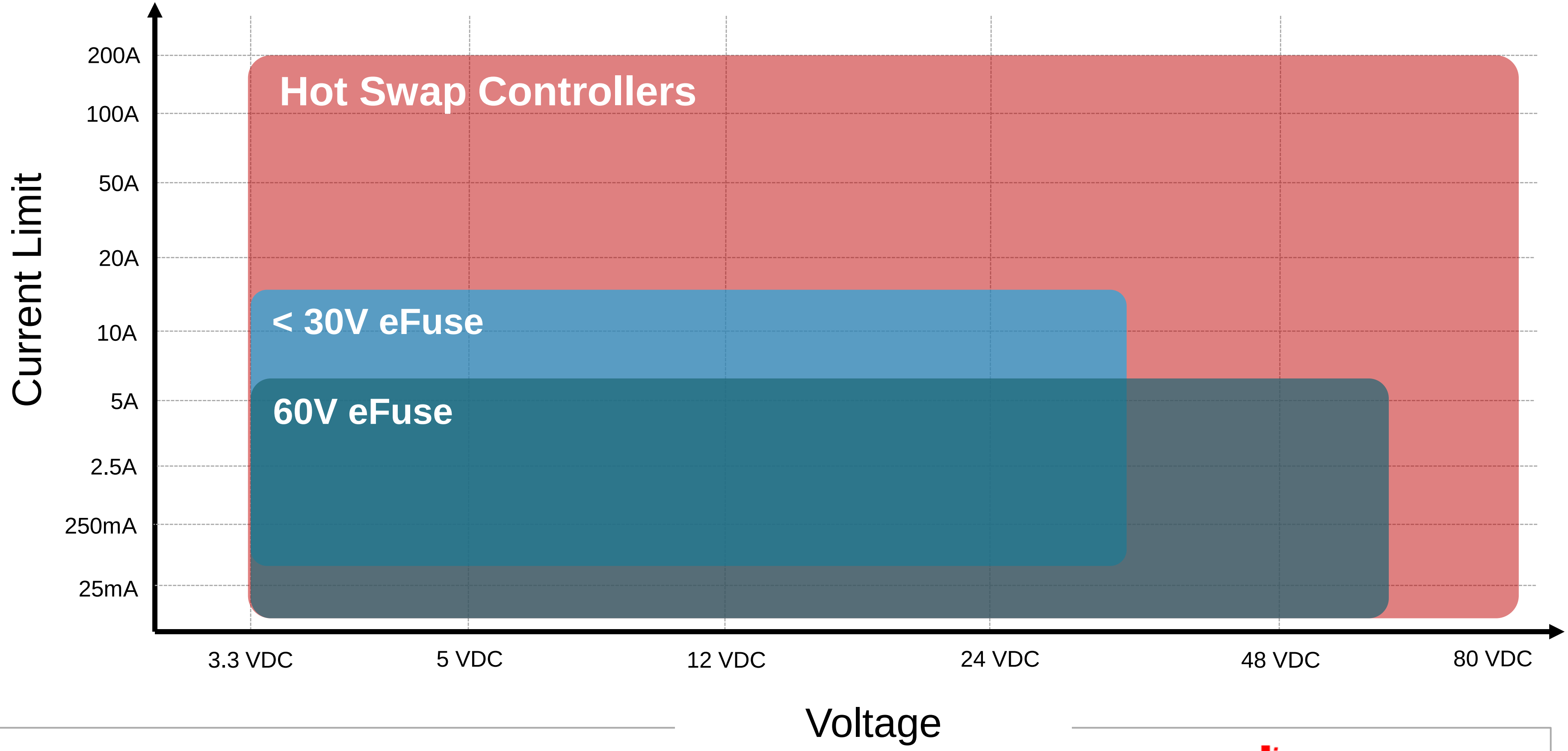
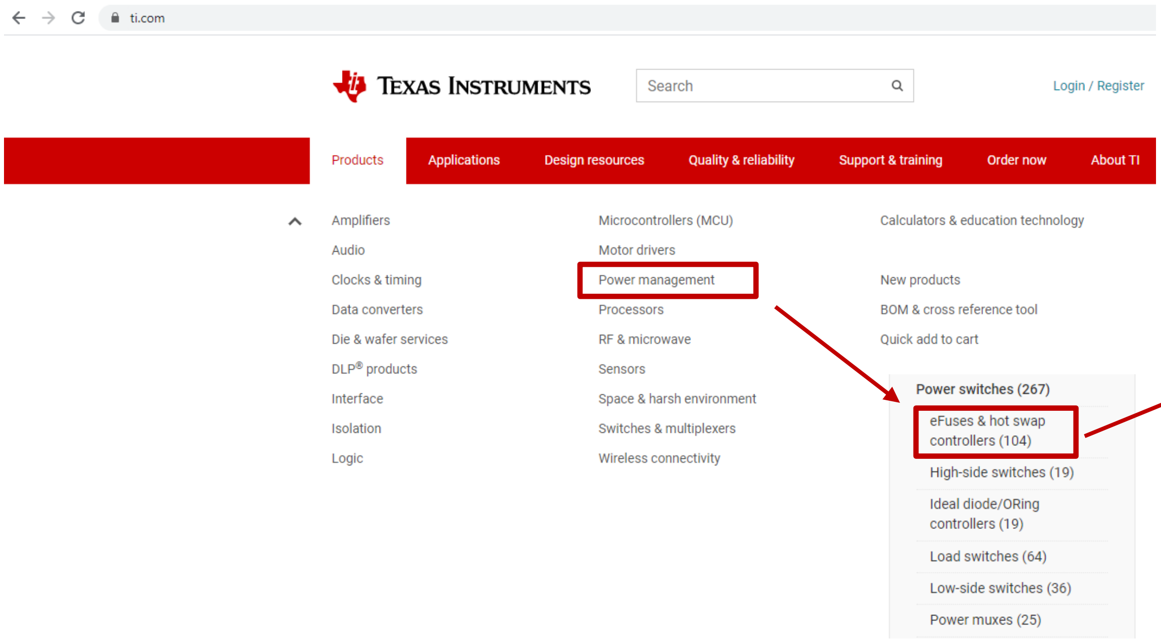
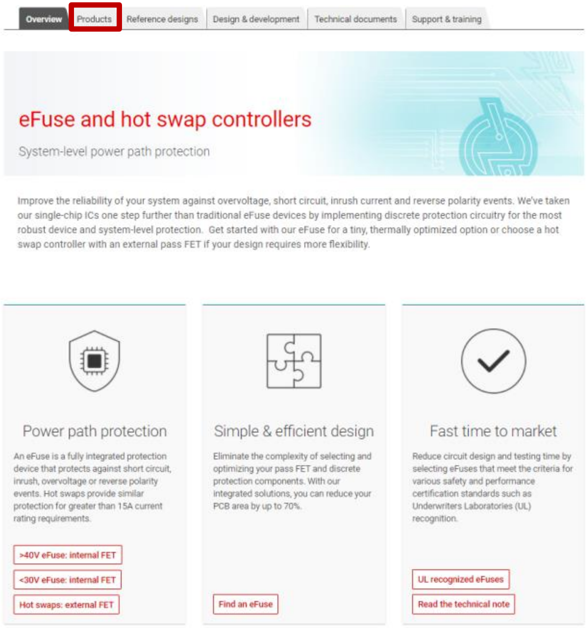
eFuse & hot-swap controller portfolio | Today



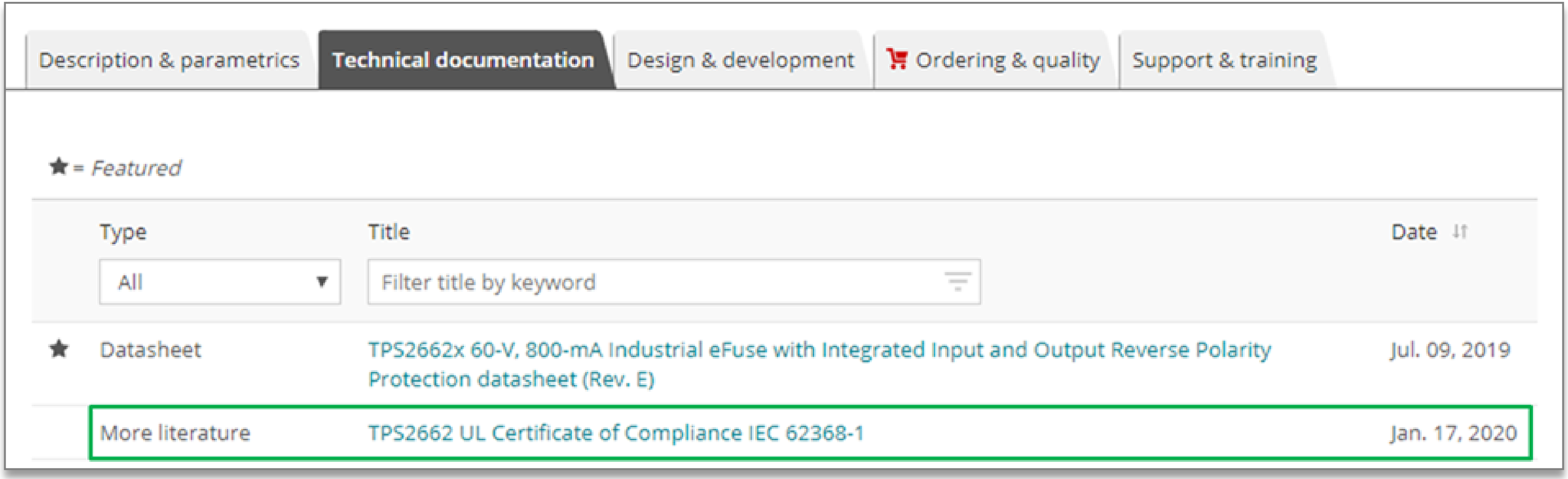
Where on ti.com





Or type ‘***ti.com/efuses’*** into your browser

UL certificate of compliance documents are available on ti.com



Description & parametrics | Technical documentation | Design & development | Ordering & quality | Support & training

★ = *Featured*

	Type	Title	Date
	All	Filter title by keyword	
★	Datasheet	TPS2662x 60-V, 800-mA Industrial eFuse with Integrated Input and Output Reverse Polarity Protection datasheet (Rev. E)	Jul. 09, 2019
	More literature	TPS2662 UL Certificate of Compliance IEC 62368-1	Jan. 17, 2020

Design Calculators for eFuses

To help determine the correct resistor and capacitor values to be used for an eFuse to configure features like overvoltage protection and slew rate control, TI offers a design calculator to ease component selection based on system requirements

These design calculators can be found in the device's product folder in the Design & development section under Design tools & simulation

Design & development

For additional terms or required resources, click any title below to view the detail page where available.

All Hardware development Design tools & simulation Reference designs CAD/CAE symbols

CALCULATION TOOL

TPS26600 Design Calculator

SLVC668.ZIP (72 KB)

Download

TPS26600 Design Calculator Tool

Constants Cells	Input / Select Cells	Calculation Cells		
	Calculated, but can be over-ridden by the user. Note: Once cells are over-ridden, new calculation sheet should be used for the next design			

Parameter	Description	Value	Units	Tolerance
V_{IN}(max)	Maximum System Input Voltage	30.0	V	
UVset	Undervoltage Lockout Threshold	18.00	V	
OVset	Over Voltage Cut-Off Threshold	30.00	V	
Cout	Load Capacitance	220.0	µF	10%
T_A(max)	Maximum Ambient Temperature	TA = 85C	°C	
RLstart	Load during start-up (Assumed to be resistive)	48.0	Ω	
Imax	Maximum continuous load current	1.0	A	
ILimit	Current Limit, 10% higher than the maximum continuous load current	1.10	A	

Functional Safety | Power Switches

Landing Page for Power Switches

http://www.ti.com/power-management/power-switches/overview.html

Power switches for functional safety

- Trying to meet the rigorous requirements of standards like ISO 26262 or IEC 61508? Our power switches not only comprise critical protection functions for safety-critical applications within ADAS, powertrain, factory automation, robotics and more, they also have functional safety documentation available.
- The device families below have functional-safety capable offerings, meaning you can easily access FIT rate calculations and failure mode distribution (FMD) and/or pin FMA documentation in the technical documents section of each product landing page.
- Navigate to the devices you need in the table below or take advantage of the additional resources we've created so you can get your safety system tested and into the market quicker.

Find functional safety devices	Functional safety-capable rating
High-side switches	✔
Ideal diodes & OR-ing controllers	✔
eFuses & hot swap controllers	✔
Load switches	✔

Functional safety design resources

TIDA-01599

Redundant dual-channel safe torque off (STO) reference design for AC inverters and servo drives reference design

View reference design ›

TIDA-010049

TUV-assessed digital input reference design for IEC 61508 (SIL-2)

View reference design ›

Functional safety systems and high-side switches

Learn how to perform an functional safety check through TINA TI simulations on high-side switches and more.

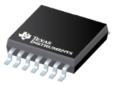
Watch now ›

Individual Functional Safety Documentation available in the Product Folder under 'Technical Documentation' tab

TPS1H100-Q1 ACTIVE

Alert me

40-V, 100-mΩ, 1-ch automotive smart high-side switch with adjustable current limit



DATASHEET

TPS1H100-Q1 40-V, 100-mΩ Single-Channel Smart High-Side Power Switch datasheet (Rev. D)

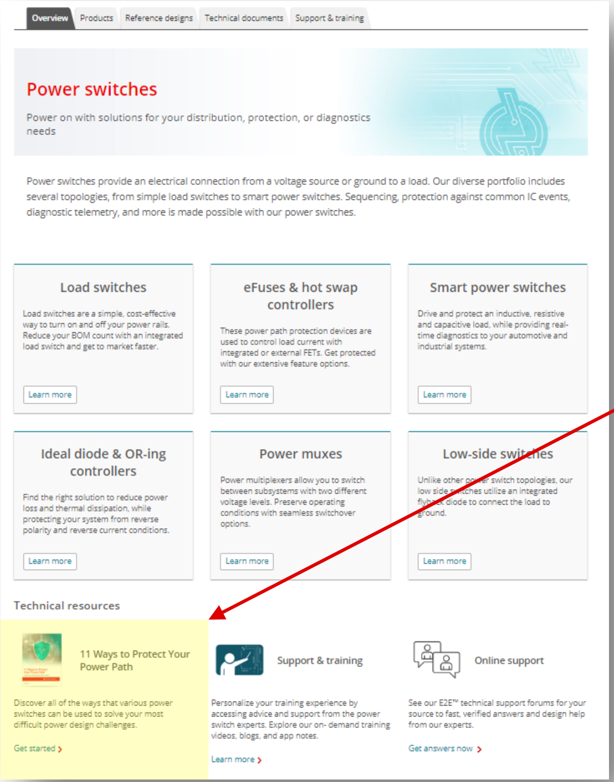
View now Download

Description & parametrics | Technical documentation | Design & development | Ordering & quality | Support & training

★ = Featured

	Type	Title	Date
	All	Filter title by keyword	
★	Datasheet	TPS1H100-Q1 40-V, 100-mΩ Single-Channel Smart High-Side Power Switch datasheet (Rev. D)	Dec. 17, 2019
	Application notes	TPS1H100-Q1 Functional Safety FIT Rate and Failure Mode Distribution	Dec. 16, 2019
	Application notes	High Accuracy Current Sense of Smart High Side Switches	Nov. 01, 2019

TI.com | 11 Ways to Protect Your Power Path



Get to the chapter you want quickly!

- Introduction: Types of Power Switches
- Inrush current control
- Adjustable current limit
- Short-circuit protection
- Reverse current blocking
- Reverse polarity protection
- Overvoltage protection
- Thermal shutdown
- Current monitoring
- Power-good signal
- Safely driving an inductive load
- Automotive load dump

Purpose

- Cookbook for solving power design challenges on system's power path

Location

- Bottom of Power Switches Portal page
- In each power switch product folder under the 'technical documents' tab

How to get there:

- **Through Product Tree:**
  - Products → Power Management → Power Switches
- **Quick link:**
  - ti.com/powerswitch

Summary

- eFuse provide small, flexible solutions to protect your system's inputs

- In comparison to traditional discrete circuits, eFuses offer:
  - lower power dissipation
  - higher protection accuracy
  - smaller solution size
  - fault reporting capabilities

- New eFuses have recently been released on ti.com
  - TPS25947, optimized for USB Type C systems and 12V systems
  - TPS2663, tailored to 24V DC bus in industrial systems
  - TPS2661, designed specifically for 4-20mA current loop protection

- To find out more information on eFuses, visit ti.com or type ***'ti.com/efuse'*** in your browser

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