A Technical Overview of Circuit Protection and EMC Requirements for Industrial Systems

Alec Forbes
Agenda

• Overview
  – Why is Circuit Protection is important?
  – Common Circuit Protection Examples
  – What is an eFuse?

• Protection requirements in Industrial Applications
  – Circuit protection examples
  – IEC61000-4-x Test standards
  – Surge performance of a TVS and implications on the system

• System Example # 1: Low Power Systems
  – Protection Requirements and EMC considerations
  – TPS2662 (60V, 800mA eFuse) : Overview & Performance

• System Example # 2: High Power System
  – Protection Requirements and EMC considerations
  – TPS2663 (60V, 6A eFuse) : Overview & Performance
Circuit Protection: Where is it Needed?

- Personal Electronics
- Industrial
- Automotive
- Enterprise/Comms
Power Switches Overview

Load Switches
Power Distribution & Savings
- Benefits
  - Extends battery life
  - Simplifies power sequencing
  - Mitigates inrush current damage
  - Saves space & reduces solution size
  - Inrush current control
- Product Families
  - Non-current / Current Limited
  - Power Mux
  - Solid State Relays
- Sectors/EE’s
  - Industrial PC cards
  - Industrial PCs
  - PLC, power sequencing

eFuse
Input Power Protection
- Benefits
  - Protects against under/over-voltage, over-current, and inrush events
  - Maximizes equipment uptime & reduces maintenance costs
  - Prevents failure during hot-plugging, hot-swapping & transient events
  - Faster time to market – UL recognized
- Product Families
  - > 40V eFuse
  - < 30V eFuse
  - Hot Swap Controllers
  - Ideal Diode Controllers
- Sectors/EE’s
  - PLC
  - Factory Automation
  - Motor Drives

Smart High Side Switches
Output Power Protection
- Benefits
  - Increased reliability against short-circuit
  - Accurate, real-time load diagnostics
  - Drive inductive loads like solenoids, relays
- Product Families
  - Smart High Side (HS) Switch
- Sectors/EE’s
  - Remote I/Os
  - Digital I/Os
  - CNC controllers
  - Motor Drives

ESD & Surge
Port Protection
- Benefits
  - Meets or exceeds the maximum specified level in the IEC 61000-4-x standard
  - Packages are 80-90% smaller than that of the competition
  - Low leakage provides better fidelity
- Product Families
  - Flat-clamp TVS
  - ESD port protection
- Sectors/EE’s
  - Appliances
  - Building Automation
  - Grid Infrastructure
  - Body Electronics & Lighting

www.ti.com/LoadSwitch
www.ti.com/eFuse
www.ti.com/HighSideSwitch
http://www.ti.com/esd
Circuit Protection Needs

Common Circuit Protections
• Short Circuit Protection
• Overload Current limiting
• Over Voltage Protection
• Inrush Control
• ESD Protection

Special Circuit Protections
• Surge Protection
• Electrical Fast Transient Protection
• Power Fail Protection
• Reverse Polarity Protection
• Reverse Current Protection

Results of Improper Protection
Example Protection Need: “mis-wiring”

- Manual wiring by a field engineer is required to make the necessary equipment connections for a complex industrial system. Manual wiring introduces the opportunity for human error which can occur when the field engineer incorrectly wires the system.

- As a result an incorrect, negative voltage can be placed on the input of a given module. This is known as mis-wiring.

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Power Supply Spec:
Vout: 17V … 29V cont.
35V for 1s

**Correct**

**Incorrect**
Circuit Protection Example: Discrete

- **Input Fuse**
- **Surge Protector**
- **LC Filter Circuit**
- **Inrush Control Circuit**

**Input Transient Snubber**

**Reverse Polarity Protection Circuit**

**Over Current, & Short Circuit Protection**

**UV/OV protection circuit**
Circuit Protection Example: Hot-Swap + ORing Controllers & eFuse

Protection features
- Inrush Current Control
- Over Voltage Protection
- Under Voltage Lockout
- Short Circuit Protection
- Over Load current limit
- Reverse Polarity Protection
- Reverse Current Blocking
- Robust Surge protection

Integrated FETs!!!
UL Certification

- **UL2367 – Solid State Overcurrent Protectors**
  - Most of the TI eFuses are recognized by UL as protection devices
  - Assists in designing system as “limited energy” or “low power” circuits to expedite the UL certification process

- **UL60950 – Safe During Single-point Failure**
  - Most of the TI eFuses are UL 60950 (safe during single-point failure) recognized
  - Restricts the voltage, current within the circuit limits under any single fault
  - TI eFuses ensure there is a safe current limit setting if a short or open circuit is present at the ILIM pin
eFuse Selection Tree

### MV – 18V Rated
- **TPS25921x**: VIN 4.5–18V, 30mΩ, 1.6A, ABS MAX 20V
- **TPS25200**: VIN 2.5–6.5V, 60mΩ, 2.9A, ABS MAX 20V
- **TPS2595x**: VIN 2.7–18V, 34mΩ, 4A, ABS MAX 20V
- **TPS2475x**: VIN 2.5–18V, 3mΩ, 10A, ABS MAX 30V

### MV – 20V Rated
- **TPS2420**: VIN 3–20V, 33mΩ, 5A, ABS MAX 25V
- **TPS2421-x**: VIN 3–20V, 33mΩ, 5A, ABS MAX 25V
- **TPS2590**: VIN 3–20V, 30mΩ, 5.5A, ABS MAX 25V
- **TPS25910**: VIN 3–20V, 30mΩ, 5.5A, ABS MAX 22V
- **TPS2598x**: VIN 2.7–24V, 3mΩ, 15A, ABS MAX 30V

### HV – 60V Rated
- **TPS2662x**: VIN 4.2–57V, 500mΩ, 0.88A, ABS MAX 60V
- **TPS2663x**: VIN 4.5–60V, 31mΩ, 6A, ABS MAX 63V
- **TPS1663x**: VIN 4.5–60V, 31mΩ, 6A, ABS MAX 62V

**Key**
- **IRP** = Input Reverse Polarity
- **ORP** = Output Reverse Polarity
- **Ext** = External Blocking FET
- **B2B** = Integrated Back-to-Back FET
- **L** = Active Low
- **IMON** = Current monitoring
- **PLIM** = Power Limiting

**Production**
- **New**
- **Sampling**
Where can I use this?

PLC CPU (Controller) Medium Power (up to 80W – 100W) CPU Block Diagram

Protection Requirements
- Reverse Polarity Protection
- Over voltage protection
- Over current protection

Key System level tests:
- Surge test (IEC61000-4-5) – Protection + Criteria-A system performance
- Voltage interruption test (IEC61000-4-29) – Reverse Current Blocking + Criteria-A system performance
- EFT (IEC61000-4-4) – Ride through and class-A performance
IEC61000-4-2/4/5: EMC Immunity Test Standards

Most commonly applied transient immunity tests:
- IEC61000-4-2: Electrostatic Discharge Immunity
- IEC61000-4-4: Electrical Fast Transient Immunity
- IEC61000-4-5: Surge Immunity

Comparison of power and energy levels

High energy content of surge can potentially destroy the products if appropriate protection circuits are not used.
IEC61000-4-5: Surge Immunity

Voltage Level & Subsystem requirements

<table>
<thead>
<tr>
<th>Level</th>
<th>Open Circuit Test Voltage [kV]</th>
<th>Description</th>
<th>Maximum Peak Current [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>Partly protected electrical environment</td>
<td>R&lt;sub&gt;ext&lt;/sub&gt;=2Ω: 250** R&lt;sub&gt;ext&lt;/sub&gt;=12Ω: 42 R&lt;sub&gt;ext&lt;/sub&gt;=42Ω: 12</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Electrical environment where the cables are well-separated, even at short runs</td>
<td>500 R&lt;sub&gt;ext&lt;/sub&gt;=12Ω: 84 R&lt;sub&gt;ext&lt;/sub&gt;=42Ω: 24</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Electrical environment where cables run in parallel</td>
<td>1000 R&lt;sub&gt;ext&lt;/sub&gt;=12Ω: 167 R&lt;sub&gt;ext&lt;/sub&gt;=42Ω: 48</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Electrical environment where the interconnections are run as outdoor cables along with power cables, and the cables are used for both electronic and electric circuits</td>
<td>2000 R&lt;sub&gt;ext&lt;/sub&gt;=12Ω: 334 R&lt;sub&gt;ext&lt;/sub&gt;=42Ω: 96</td>
</tr>
<tr>
<td>X</td>
<td>Custom</td>
<td>Special conditions specified in the product specification</td>
<td>x x x</td>
</tr>
</tbody>
</table>

**Note:** Supply bus in Factory Automation system require most often to test with 500V / 2 Ω differential mode, customers apply even common mode

Definition of Immunity Criteria Levels

<table>
<thead>
<tr>
<th>Criteria Level</th>
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<tr>
<td>A</td>
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Source: App Report; IEC 61000-4-x Tests for TI’s Protection Devices; slva711
Why the 60V rating?

- **Motivation:** >60V VDS stress can occur during surge events, even with an SMCJ33CA diode
  - During surge events, the voltage difference between the input and the output of TPS2660 could be up to 60V.
  - If there is a large amount of hold-up capacitance on the output then the VDS voltage when VIN goes negative from the surge pulse can be as high as \( V_{\text{OUT}} + V_{\text{TVS\_CLAMP}} \)
  - TPS266x family is rated to 70V transient tolerance to handle this pulse
IEC61000-4-4: EFT Immunity

Why is Electrical Fast Transient (EFT) Immunity needed?

- In Factory Automation and Motor Drive environments, large amount of power and energy is being transferred throughout the environment. Because of this large amount of energy, electrical coupling of all sorts can occur which can unintentionally affect nearby circuitry causing it to malfunction. These coupling events are referred to as EFT events.
- To avoid malfunction, systems need to be immune to these EFT events.

How to test EFT immunity?

- To test the immunity of a system to EFT, a standardize test procedure is used
- This test procedure injects a burst of voltage transients with the characteristics shown in figure 5 to the right
- The table to the right shows the voltage & current levels of the transients
- Systems are classified based on their immunity to EFT, below are the different classifications for EFT immunity

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Voltage & Current Levels for Test Pulses

<table>
<thead>
<tr>
<th>Level</th>
<th>Power Supply Port</th>
<th>I/O, Signal, Data &amp; Control Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VCC (kV)</td>
<td>ISC (A)</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>80</td>
</tr>
</tbody>
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Source: App Report; IEC 61000-4-x Tests for TI’s Protection Devices, slova711
TPS2662 has EFT immunity Criteria-A on both input and output!

**IEC61000-4-4: Input side**

<table>
<thead>
<tr>
<th>EFT Level</th>
<th>Pass/Fail</th>
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<tr>
<td>± 500V</td>
<td>Pass with Criteria-A performance</td>
</tr>
<tr>
<td>± 1000V</td>
<td>Pass with Criteria-A performance</td>
</tr>
<tr>
<td>± 2000V</td>
<td>Pass with Criteria-A performance</td>
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**IEC61000-4-4: Output side**

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- Criteria - A performance means internal FETs are ON during the EFT test and output voltage does not dip
- Tests are performed on EVM

**Definition of Immunity Criteria Levels**

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System Example # 1: Analog Input Module for PLC

Protection and EMC requirements
- Reverse polarity protection on input and output side
- Over Voltage protection from 60V DC SELV faults
- Current Limiting
- Protection from Surge (IE61000-4-5)
- EFT (IEC61000-4-4) immunity on input and output side
### TPS2662x: 60V, 25mA – 870mA, 500mΩ Industrial eFuse with Integrated Reverse Polarity Protection

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 4.5V - 57V DC operation, 60V Abs Max</td>
<td>- Tolerates $V_{BUS}$ transients</td>
</tr>
<tr>
<td>- $I_{Q(\text{Operation})} &lt; 300\mu A, I_{Q(\text{shutdown})} &lt; 30\mu A$</td>
<td>- 4.8 mW Power dissipation @24V</td>
</tr>
<tr>
<td>- Integrated B2B MOSFETs with 500mΩ total RON</td>
<td>- Save board space</td>
</tr>
<tr>
<td>- Programmable Output Slew Rate</td>
<td>- Inrush slew can be tuned to load</td>
</tr>
<tr>
<td>- 25mA to 870mA Accurate current limit (±8%)</td>
<td>- Enables Smart Power Management</td>
</tr>
<tr>
<td>- Integrated Reverse Polarity Protection – (Input/Output) versions available</td>
<td>- Protects against mis-wiring in the field</td>
</tr>
<tr>
<td>- Load protection during Surge (IEC61000-4-5),</td>
<td>- Robust Industrial Power Protection with noise immunity</td>
</tr>
<tr>
<td>- Criteria-A EFT (IEC61000-4-4) performance</td>
<td>- Fault response can be tuned to app</td>
</tr>
<tr>
<td>- Latch-off, retry versions available</td>
<td>- Flexible Design Options</td>
</tr>
<tr>
<td>- Programmable UVLO; OVP Cut-Off</td>
<td>- Small footprint for dense boards</td>
</tr>
<tr>
<td>- Fixed 38 V OV Clamp version available (TPS26622)</td>
<td></td>
</tr>
<tr>
<td>- 10 - DRC, 3mmx3mm Package</td>
<td></td>
</tr>
</tbody>
</table>

### Applications
- Sensors & Controls
- PLCs
- Reverse polarity protection
- Fire Alarm Strobes
- Thermostats
- PoE high side protection
- Output port protection

![Diagram](image-url)
Key Performance Graphs of TPS2662x: 1.0

Reverse input polarity protection (TPS2662x)

Internal FETs are OFF during reverse input polarity protecting the load from field input mis-wiring

Output remains at 0V when -5V is applied at input due to field mis-wiring

Output Reverse Polarity Protection (TPS26624/5)

Internal FETs turn OFF during reverse output polarity fault protecting the upstream power supply
Key Performance Graphs of TPS2662x: 1.1

Input Hot-Plug response

Current Limit Response

Programmable slew rate control limits inrush current

eFuse limits load current when load is changes from 120ohm to 24ohm

Output recovers after over load is removed
IEC61000-4-5 (Surge) and IEC61000-4-4 (EFT) performance of TPS2662x
IEC61000-4-5: VIN side Surge Performance

+ 1000V, 42 ohm, Surge Performance

- 1000V, 42 ohm, Surge Performance

* A SMBJ33CA TVS is used across IN and GND input of TPS2662x
IEC61000-4-5: VOUT side Surge Performance with TPS26624/5

+ 1000V, 42 ohm, Surge Performance

- 1000V, 42 ohm, Surge Performance

*A SMBJ33CA TVS is used across OUT and GND of TPS2662x
* Please see slide #21 and # 22 for more details
IEC61000-4-4: VIN and VOUT side EFT performance

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- Criteria - A performance means internal FETs are ON during the EFT test and output voltage does not dip
- Tests are performed on EVM
System Example # 2: CPU (PLC Controller)

Medium Power (up to 80W – 100W) CPU Block Diagram

Protection Requirements
- Reverse Polarity Protection
- Over voltage protection
- Over current protection

Key System level tests:
- Surge test (IEC61000-4-5) – Protection + Criteria-A system performance
- Voltage interruption test (IEC61000-4-29) – Reverse Current Blocking + Criteria-A system performance
- EFT (IEC61000-4-4) – Ride through and class-A performance
TPS2663x: 60V, 6A, Power Limiting, Surge Protection eFuse with class-A performance

**Features**

- 4.5V - 60V DC operation
- Integrated 31mΩ MOSFET
- Input Reverse polarity protection and reverse current blocking support with external N-channel FET
- Load protection with criteria-A system performance during Surge (IEC61000-4-5), EFT (IEC61000-4-4), Voltage interruptions (IEC61000-4-29)
- 0.6 to 6 A Accurate current limit (±15%)
- Programmable UVLO; OVP Cut-Off (TPS26630/31), OV clamp (35Vmax) (TPS26632/33)
- Programmable Output Slew Rate using $dV/dt$ pin
- Output power limiting scheme (PLIM) – TPS26632/TPS26633
- PGOOD output with Programmable detection threshold (PGTH)
- Pulse current /power support with circuit breaker mode – TPS26331/33
- 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

**Benefits**

- Tolerates $V_{BUS}$ transients
- Lower Power Dissipation
- Protects against mis-wiring in the field
- Support Reverse Current Protection
- Robust industrial 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 ckt)

- Flexible Design Options
- QFN package for dense boards
- Standard leaded package

**Applications**

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

---

Optional components for RCB and RPP

- VIN $\_\_\_sys$ (24V from External field supply)
- B_GATE
- 2N7002
- SMCJ36CA
- DC-DC
- CSD19537Q3
Typical Application Circuit

- **Components to support**
  1) Reverse Polarity Protection
  2) Reverse Current Blocking

- **TVS for Surge clamping**

- **Vin_sys (24V from External field supply)**

- **SMCJ36CA**

- **2N7002**

- **CSD19537Q3**

- **TPS26632**

- **R1, R2, R3, R4, R5**

- **Rpu**

- **EN**

- **I_LOAD**

- **DC-DC**

- **VIN**

- **GND**

- **I_OUT, I_LOAD**

- **UVLO**

- **PLIM**

- **IN_SYS**

- **B_GATE**

- **DRV**

- **PGOOD**

- **PGTH**

- **FLT**

- **SHDN**

- **MODE**

- **IMON**

- **ILIM**

- **dVdT**

- **C1953**

- **Q3**

- **VIN, I_SYS** (24V from External field supply)
Input Reverse Polarity Performance

-60V Input reverse polarity
Input Hot-plug Response

Cout = 1mF, Load: DC-DC

Inrush current limiting by output slew rate control can be achieved by placing a \( \frac{dV}{dt} \) capacitor.

Use PGOOD as DC-DC EN control.
Input Hot-Short Response

Short with VOUT charged at 24V

A fast 320nsec turn OFF time, limits reverse current and holds the output voltage during the supply interruption testing.

Zoom In at the instance of short

320nsec response time
Input Voltage Interruption Test

TPS26630: $P_{out} = 15W$, $C_{out} = 1mF$

$V_{IN\_SYS} = 24V$

Voltage recovery detection (by PGTH sensing) and fast turn on of the internal switch during the voltage recovery event ensures quick recovery.

Fast turn ON within 140µs
IMON Performance

Load is switched from 110Ω to 10Ω

Imon Pin provides load current information
Power Limiting eFuse (IEC61010-1)

System requirement to comply with IEC61010-1 (section 9 :Protection against spread of fire):

- **Max output power limited to < 150W (Eliminating the source of ignition)**
- A fixed ILIMIT scales the output power capability linearly with voltage
- Need to foldback ILIM w.r.t voltage

Electrical industrial process-control equipment (PLC CPU) included in the scope of IEC61010-1.

IEC61010-1, section 9.4

9.4 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

a) The voltage appearing in the circuit is not more than 30 V r.m.s., 42.4 V peak, or 60 V d.c.

b) The current that can appear in the circuit is limited by one of the following means:

1) the maximum available current is limited inherently or by impedance so that it cannot exceed the applicable value of Table 17;

2) current is limited by an overcurrent protection device so that it cannot exceed the applicable values of Table 10;

3) a regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 17 in normal condition or as a result of a fault in the regulating network.

c) It is separated by at least basic insulation from other circuits having energy values exceeding the limits a) and b) above.

If an overcurrent protection device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity is checked by inspection and by measuring the potentials appearing in the circuit and the maximum available current, under the following conditions:

i) the potentials appearing in the circuit are measured in the load condition that maximizes the voltage;

ii) output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.

<table>
<thead>
<tr>
<th>Table 17 – Limits of maximum available current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-circuit output voltage (U or ( U_i ))</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>2 ( \leq U \leq 12.5 )</td>
</tr>
<tr>
<td>2 ( \leq U &lt; 12.5 )</td>
</tr>
<tr>
<td>12.5 ( \leq U &lt; 18.7 )</td>
</tr>
<tr>
<td>18.7 ( \leq U &lt; 30 )</td>
</tr>
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</table>

The peak value (\( U_i \)) applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %, and is provided for convenience. The r.m.s. value of the maximum available current shall be determined as that value is related to heating.
Output Power Limiting

TPS26632

VIN_SYS = 24V

VOUT

POUT = 100W

Use a resistor across PLIM to GND to adjust the output power limiting

TPS26633

VIN_SYS = 24V

VOUT

POUT = 100W
Driving an un-known load/Huge output capacitances

Cout = 30mF

By leaving \( \frac{dv}{dt} \) pin floating the device starts up in thermal regulation loop proving faster and reliable start up.
IEC Surge and EFT (Burst) performance of TPS2663x
IEC61000-4-5: Surge Performance

+ 500V, 2 ohm, Surge Performance

Fast OVP, RCB, Dynamic RPP & Fast Recovery blocks of TPS2663x work in tandem and ensure load protection and also criteria-A system performance during surge tests.

- 500V, 2 ohm, Surge Performance
### IEC61000-4-4: EFT performance

<table>
<thead>
<tr>
<th>EFT Level</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 500V</td>
<td>Pass with Criteria-A performance</td>
</tr>
<tr>
<td>± 1000V</td>
<td>Pass with Criteria-A performance</td>
</tr>
<tr>
<td>± 2000V</td>
<td>Pass with Criteria-A performance</td>
</tr>
<tr>
<td>± 4000V</td>
<td>Pass with Criteria-A performance</td>
</tr>
</tbody>
</table>

- Criteria - A performance means internal FETs are ON during the EFT test and output voltage does not dip
- Tests are performed on EVM
**eFuse Overview**

- **Integrated FET & current sense** an active circuit protection device that commonly replaces fuses and Polyfuse/PTC
- **Prevents failure** during hot-plug/swap by protecting against under/over-voltage, over-current, and inrush events
- **Save Space** and reduced solution size by integrating discrete protection circuitry
- **Faster Time to Market** and increased reliability through UL/IEC recognition

### eFuse Features

<table>
<thead>
<tr>
<th>eFuse</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS2660x</td>
<td>60V, 2A, 150mΩ, ILIM, CT pin, RCB, ISNS, RPP, OVP, HTSSOP</td>
</tr>
<tr>
<td>TPS25940/2/4</td>
<td>18V, 5.2A, 42mΩ, ILIM, IMON, CT pin, RCB, ISNS, OVP, QFN</td>
</tr>
<tr>
<td>TPS24750/1</td>
<td>18V, 12A, 3mΩ, ILIM, SON</td>
</tr>
<tr>
<td>TPS25923x/4x/7x</td>
<td>18V, 5A, 28mΩ, ILIM, CT pin, OVC,BFET, SON</td>
</tr>
<tr>
<td>TPS2595x NEW</td>
<td>18V, 4A, 34mΩ, ILIM, IMON, CT pin, OVP/OVC, FLT, WSON</td>
</tr>
<tr>
<td>TPS2662x*</td>
<td>60V, 870mA, ILIM, CT pin, RCB, RPP, OVP, VSON</td>
</tr>
</tbody>
</table>

* Sampling Now

### After Fault:

<table>
<thead>
<tr>
<th></th>
<th>Broken after fault</th>
<th>Auto-retry</th>
<th>Auto-retry; latch off</th>
</tr>
</thead>
</table>

### Reliability:

<table>
<thead>
<tr>
<th></th>
<th>Must be replaced</th>
<th>R&lt;sub&gt;ON&lt;/sub&gt; increases after fault</th>
<th>Not damaged by fault</th>
</tr>
</thead>
</table>

### Time to trip:

<table>
<thead>
<tr>
<th></th>
<th>Slow trip (s/ms)</th>
<th>Slow trip (ms)</th>
<th>Fast trip (&lt;1.5 us)</th>
</tr>
</thead>
</table>

### Accuracy:

<table>
<thead>
<tr>
<th></th>
<th>Needs time to heat up and melt</th>
<th>Current limit depends on ambient temp.</th>
<th>Up to ±2% current limit accuracy</th>
</tr>
</thead>
</table>

---

**Highly Integrated Protection Features**

\[
\text{Load} = R_L + C_L
\]

\[
R_{\text{SINK}} = \frac{V_{\text{OVP}}}{I_{\text{OVP}} + I_{\text{CT}}}
\]

\[
I_{\text{CT}} = \frac{V_{\text{SINK}}}{R_{\text{SINK}}}
\]

---

**Texas Instruments**
Input Protection and Backup Supply Design for 25W PLC Controller Unit

Features
- 19.2V - 28.8V Input, 28W output power
- Overload, over voltage, under voltage, reverse current protections
- Protects against field miswiring or Reverse polarity
- ±500V Surge, EFT, System ESD compliance (IEC61000-4 family)
- Continuous operation for 10ms power fail (IEC61000-4-29)
- 120ms backup time at 7W output

Target Applications
Target End Equipment's:
- PLC, DCS and PAC
- CNC Automation

Tools & Resources
- TIDA-03031 Tools Folder
  - User Guide
  - Relevant Design Files
- Device Datasheets:
  - TPS26600
  - LM5002
  - LM5160

Benefits
- Integrated solution for surge protection saves board area
- No supervisory circuit for power fail indication signal
- Energy storage at high voltage results in small storage capacitor size
Resources

**Application note:**
The TPS2660 Simplifies Surge and Power Fail Protection Circuits in PLC System

**TI Design:**
Input Protection and Backup Supply Reference Design for 25-W PLC Controller Unit

**Training video:**
eFuse protection for 24V and 48V supply rail systems

Simplify Surge protection using the TPS2660 eFuse
https://training.ti.com/simplify-surge-protection-tps2660-efuse

**Blog:**
How an eFuse can help provide robust industrial power path protection
http://e2e.ti.com/blogs_/b/powerhouse/archive/2016/10/31/how-an-efuse-can-help-to-provide-robust-industrial-power-path-protection
Summary

• Due to the harsh environment and exposure to threats like ESD, EFT and lightning surges, Industrial system is always susceptible to catastrophic failure.

• Robust power circuit protection with class-A system performance is a common need during EMC testing.

• TPS266x family of devices offer plug and play solutions for these system challenges
<table>
<thead>
<tr>
<th>Feature</th>
<th>TPS2660 (Released)</th>
<th>TPS2662 (Released)</th>
<th>TPS2663 (Samples Now, RTM 1Q19)</th>
<th>TPS1663 (Samples Now, RTM 1Q19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power path Topology</td>
<td><img src="VIN-VOUT" alt="VIN-VOUT" /></td>
<td><img src="VIN-VOUT" alt="VIN-VOUT" /></td>
<td><img src="VIN-VOUT" alt="VIN-VOUT" /></td>
<td><img src="VIN-VOUT" alt="VIN-VOUT" /></td>
</tr>
<tr>
<td>Operating Voltage/Current limits/Rdson</td>
<td>4.2V-55V / 100mA-2.23A/150mΩ</td>
<td>4.5V-57V / 25mA -870mA/500mΩ</td>
<td>4.5V-60V / 600mA-6A/31mΩ</td>
<td>4.5V-60V / 600mA-6A/31mΩ</td>
</tr>
<tr>
<td>Reverse Polarity Protection</td>
<td>Input side</td>
<td>Input and Output side</td>
<td>Input side</td>
<td>N/A (No B2B FETs)</td>
</tr>
<tr>
<td>Surge Protection</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes with class-A system performance</td>
<td>Yes</td>
</tr>
<tr>
<td>EFT Immunity</td>
<td>Yes</td>
<td>Yes with Class A system performance</td>
<td>Yes with class-A system performance</td>
<td>Yes with class-A system performance</td>
</tr>
<tr>
<td>Output Power Limiting (IEC61010-1, fire safety)</td>
<td>N/A (Max output power for 24V rail is 36x2 = 72W)</td>
<td>N/A</td>
<td>Yes, Adjustable</td>
<td>Yes, Adjustable</td>
</tr>
<tr>
<td>PGOOD</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>IMON</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>