Transient Threats - What are Transients?

Voltage Transients are defined as short duration surges of electrical energy and are the result of the sudden release of energy previously stored or induced by other means, such as heavy inductive loads or lightning. In electrical or electronic circuits, this energy can be released in a predictable manner via controlled switching actions, or randomly induced into a circuit from external sources.

Repeatable transients are frequently caused by the operation of motors, generators, or the switching of reactive circuit components. Random transients, on the other hand, are often caused by Lightning and Electrostatic Discharge (ESD). Lightning and ESD generally occur unpredictably, and may require elaborate monitoring to be accurately measured, especially if induced at the circuit board level. Numerous electronics standards groups have analyzed transient voltage occurrences using accepted monitoring or testing methods. The key characteristics of several transients are shown in the table below.

|	VOLTAGE	CURRENT	RISE-TIME	DURATION
Lighting	25kV	20kA	10 μs	1ms
Switching	600V	500A	50μs	500ms
EMP	1kV	10A	20ns	1ms
ESD	15kV	30A	<1ns	100ns

Table 1: Examples of transient sources and magnitude

Characteristics of Transient Voltage Spikes

Transient voltage spikes generally exhibit a "double exponential" wave, as shown below for lightning and ESD.
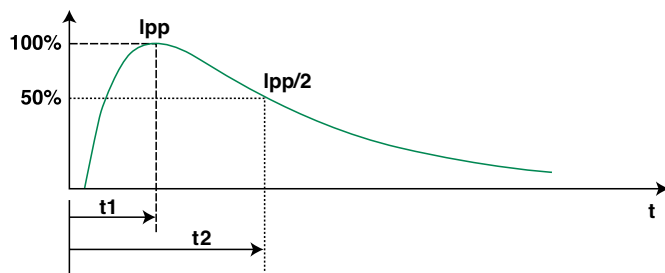
Figure 1: Lightning Transient Waveform
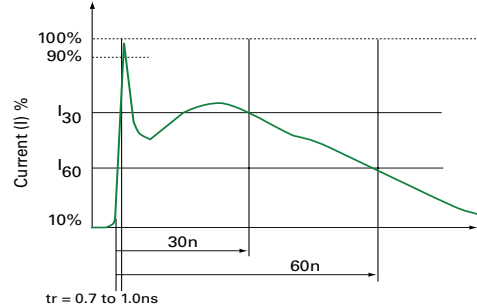
Figure 2: ESD Test Waveform

The exponential rise time of lightning is in the range 1.2μsec to 10μsec (essentially 10% to 90%) and the duration is in the range of 50μsec to 1000μsec (50% of peak values). ESD on the other hand, is a much shorter duration event. The rise time has been characterized at less than 1.0ns. The overall duration is approximately 100ns.

Why are Transients of Increasing Concern?

Component miniaturization has resulted in increased sensitivity to electrical stresses. Microprocessors for example, have structures and conductive paths which are unable to handle high currents from ESD transients. Such components operate at very low voltages, so voltage disturbances must be controlled to prevent device interruption and latent or catastrophic failures.

Sensitive microprocessors are prevelant today in a wide range of devices. Everything from home appliances, such as dishwashers, to industrial controls and even toys use microprocessors to improve functionality and efficiency.

Most vehicles now also employ multiple electronic systems to control the engine, climate, braking and, in some cases, steering, traction and safety systems.

Many of the sub- or supporting components (such as electric motors or accessories) within appliances and automobiles present transient threats to the entire system.

Careful circuit design should not only factor environmental scenarios but also the potential effects of these related components. Table 2 below shows the vulnerability of various component technologies.

Device Type	Vulnerability (volts)
VMOS	30-1800
MOSFET	100-200
GaAsFET	100-300
EPROM	100
JFET	140-7000
CMOS	250-3000
Schottky Diodes	300-2500
Bipolar Transistors	380-7000
SCR	680-1000

TVS Diode Transient Voltage Scenarios

Electrostatic Discharge (ESD)

Electrostatic discharge is characterized by very fast rise times and very high peak voltages and currents. This energy is the result of an imbalance of positive and negative charges between objects.

ESD that is generated by everyday activities can far surpass the vulnerability threshold of standard semiconductor technologies. Following are a few examples:

- **Walking across a carpet:**
  35kV @ RH = 20%; 1.5kV @ RH = 65%

- **Walking across a vinyl floor:**
  12kV @ RH = 20%; 250V @ RH = 65%

- **Worker at a bench:**
  6kV @ RH = 20%; 100V @ RH = 65%

- **Vinyl envelopes:**
  7kV @ RH = 20%; 600V @ RH = 65%

- **Poly bag picked up from desk:**
  20kV @ RH = 20%; 1.2kV @ RH = 65%

Lightning Induced Transients

Even though a direct strike is clearly destructive, transients induced by lightning are not the result of a direct strike.

When a lightning strike occurs, the event creates a magnetic field which can induce transients of large magnitude in nearby electrical cables.

A cloud-to-cloud strike will effect not only overhead cables, but also buried cables. Even a strike 1 mile distant (1.6km) can generate 70 volts in electrical cables.
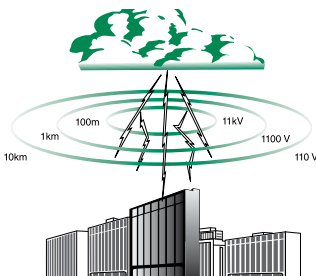
In a cloud-to-ground strike (as shown at right) the transient-generating effect is far greater.

This diagram shows a typical current waveform for induced lightning disturbances.
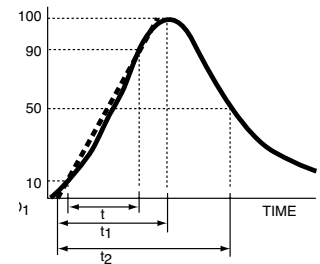

Inductive Load Switching

The switching of inductive loads generates high energy transients which increase in magnitude with increasingly heavy loads. When the inductive load is switched off, the collapsing magnetic field is converted into electrical energy which takes the form of a double exponential transient. Depending on the source, these transients can be as large as hundreds of volts and hundreds of Amps, with duration times of 400 milliseconds.

Typical sources of inductive transients include:

- **Generator** • **Motor**
- **Relay**   • **Transformer**

These examples are common in electrical and electronic systems. Because the sizes of the loads vary according to the application, the wave shape, duration, peak current and peak voltage are all variables which exist in real world transients. Once these variables can be approximated, a suitable suppressor technology can be selected.

The diagram at right shows a transient which is the result of stored energy within the alternator of an automobile charging system.

V_S = 25V to 125V T_1 = 5ms to 10ms
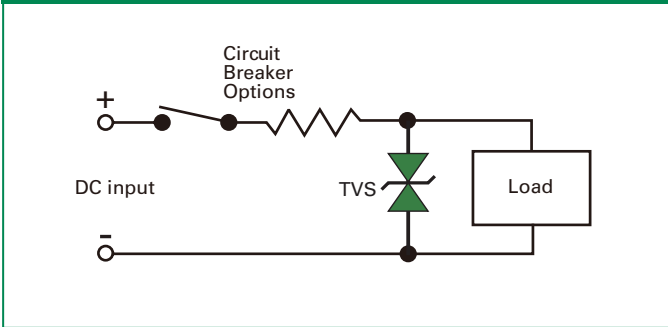V_B = 14V   R = 0.5Ω to 4Ω
T = 40ms to 400ms
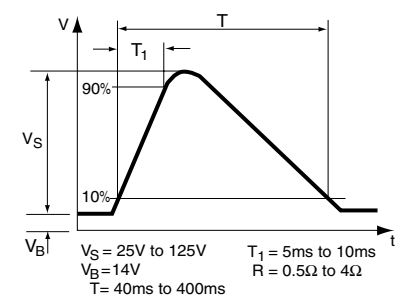
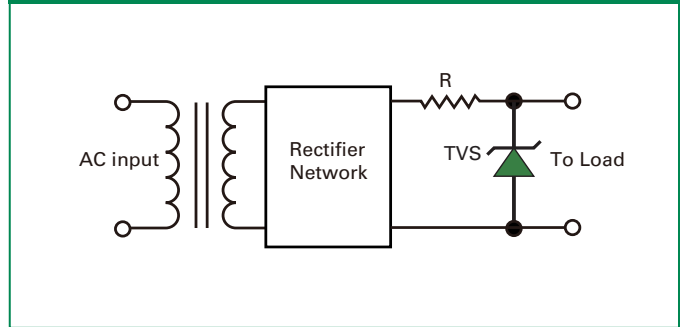A similar transient can also be caused by other DC motors in a vehicle.
For example, DC motors power amenities such as power locks, seats and windows. These various applications of a DC motor can produce transients that are just as harmful to the sensitive electronic components as transients created in the external environment.
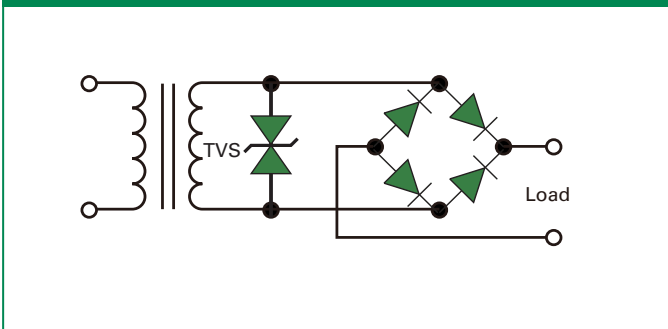
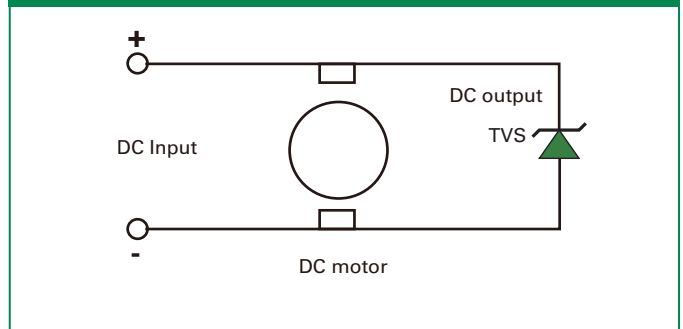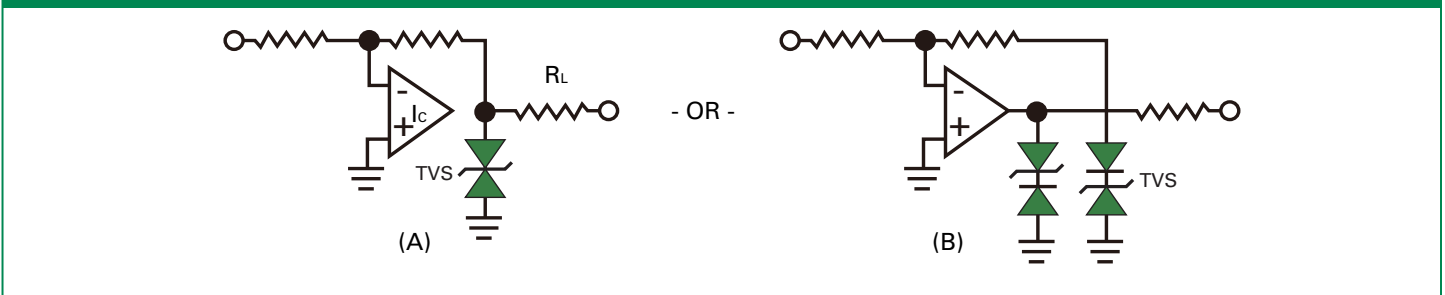# TVS Diode Device Typical Applications

DC Supply Protection

Circuit Breaker Options

DC input

+

−

TVS

Load

DC Load Protection

AC input

Rectifier Network

R

TVS

To Load

AC Supply Protection

TVS

Load

Elector-Magnetic Interference Limiting

+

−

DC Input

DC output

TVS

DC motor

Operational Amplifier Protection

R_L

I_C

TVS

(A)

- OR -

TVS

(B)

Combined MOV Varistor and TVS Diode Protection Scenarios

MOV + TVS Combination:

Inductor

MOV

TVS

MOV Varistor
High Energy Withstand

TVS Diode
Low Clamping Voltage
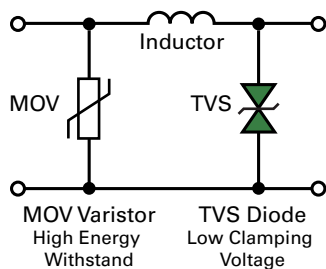
MOV + Choke + TVS Combination:

24VDC

Choke

MOV

Capacitor

TVS

GND

Choke

MOV Varistor
V33ZA70PX
Special low voltage
20mm diameter MOV
3KA@8/20µs (1 time)

TVS Diode
SMBJ28A/SMBJ30A
SMCJ28A/SMCJ30A
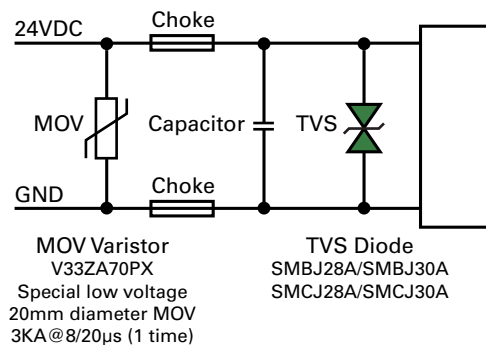
Telecom DC/DC Protection

For 48vdc Lightning Protection:
TVS Diode: AK6-66CL
Lightning Fuse: LVSP15-R
Power fuse: TLS035L/456020

For 5vdc Lightning Protection:
Fuse: 461 Series
TVS:AK3-7.5CL, 5.0SMDJ
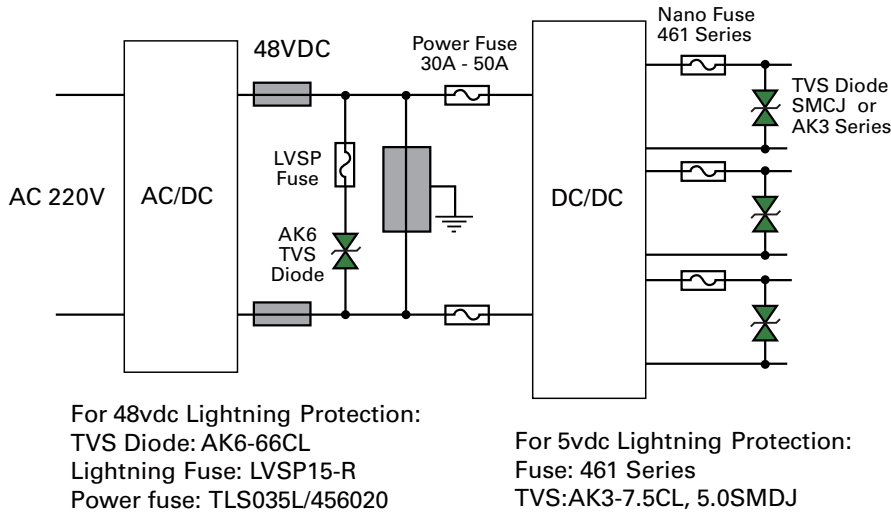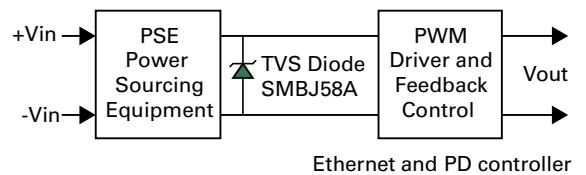
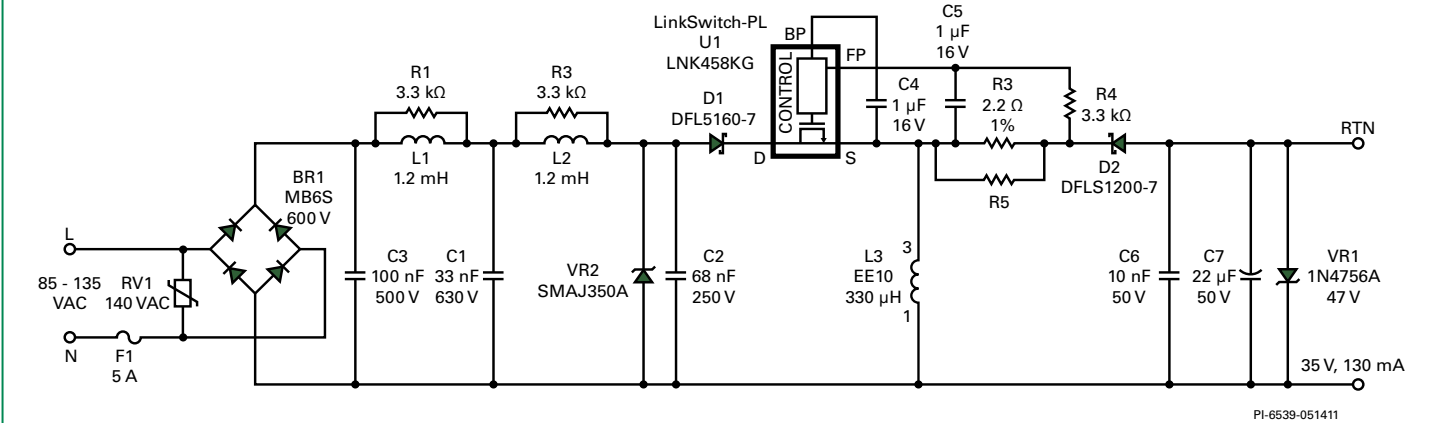## Circuit Protection of 24VDC with High Surge Capatbility
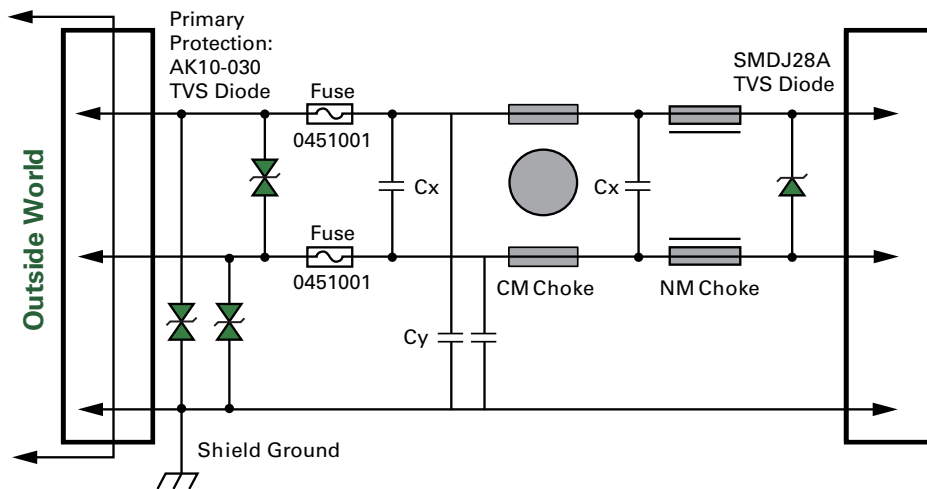
Pulse Width Modulated (PWM) Driver Protection
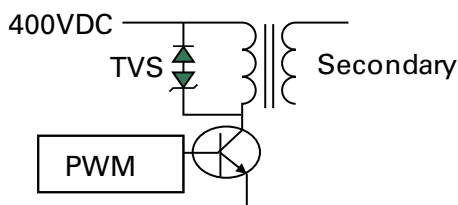
Power Over Ethernet (PoE) Protection
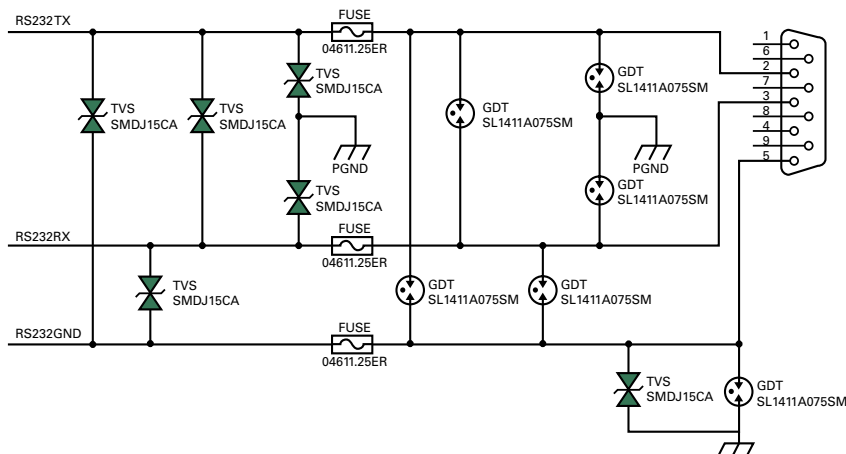
LED Driver Protection

LinkSwitch-PL
U1
LNK458KG

BP FP CONTROL D S

C5 1 µF 16 V
C4 1 µF 16 V
R3 2.2 Ω 1%
R5
R4 3.3 kΩ

R1 3.3 kΩ
L1 1.2 mH
R3 3.3 kΩ
L2 1.2 mH
D1 DFL5160-7

BR1 MB6S 600 V

L
85 - 135 VAC
RV1 140 VAC
N
F1 5 A

C3 100 nF 500 V
C1 33 nF 630 V
VR2 SMAJ350A
C2 68 nF 250 V
L3 EE10 330 µH

D2 DFLS1200-7
RTN
C6 10 nF 50 V
C7 22 µF 50 V
VR1 1N4756A 47 V

35 V, 130 mA

PI-6539-051411

RS485 Interface Protection

TVS
FUSE 0461.600
CHOKE
GDT SL1421A090
FUSE 0461.600
TVS SMBJ6.0CA
VDD5V

8 VCC RO 1 RXD
7 B RE 2 SEN
6 A DE 3
5 GND DI 4 TXD

3
2
1

VDD5V

RS232 Interface Protection with High Surge Requirement

RS232TX
FUSE 04611.25ER
TVS SMDJ15CA
TVS SMDJ15CA
TVS SMDJ15CA
PGND
TVS SMDJ15CA
GDT SL1411A075SM
GDT SL1411A075SM
PGND
GDT SL1411A075SM

RS232RX
FUSE 04611.25ER
TVS SMDJ15CA
GDT SL1411A075SM
GDT SL1411A075SM

RS232GND
FUSE 04611.25ER
TVS SMDJ15CA
GDT SL1411A075SM

1
6
2
7
3
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9
5

Inverter / VFD protection in IGBT Module Protection

TVS Diode AK3-430

IGBT Gate Protection