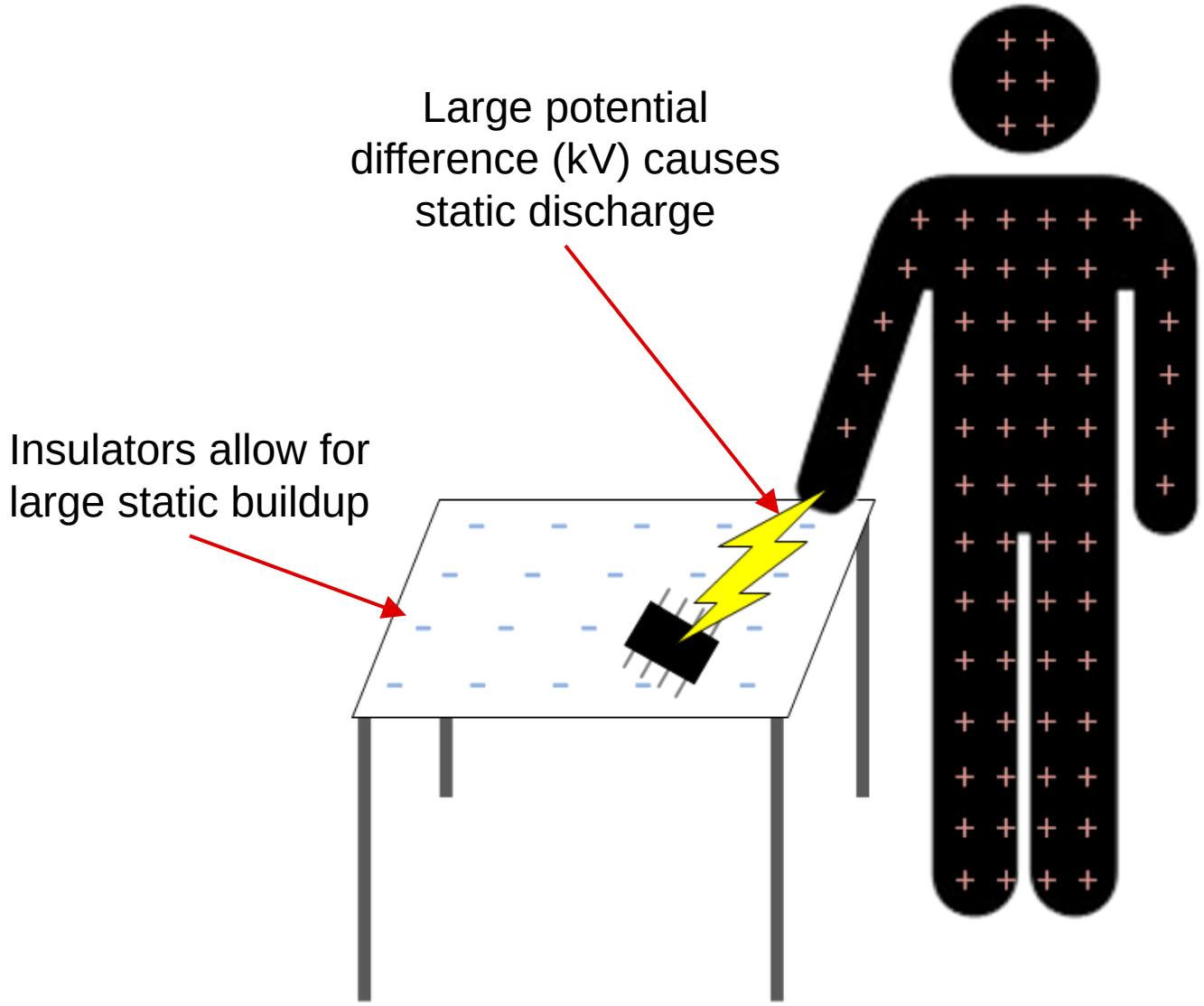
Electrostatic Discharge (ESD)

TIPL 1401
TI Precision Labs – Op Amps

Presented by Marek Lis

Electrostatic Discharge (ESD)



ESD Generation vs. Relative Humidity (RH)

Means of Generation	10-25% RH	65-90% RH
Walking across carpet	35,000V	1,500V
Walking across vinyl tile	12,000V	250V
Worker at bench	6,000V	100V
Poly bag picked up from bench	20,000V	1,200V
Chair with urethane foam	18,000V	1,500V

Source: ESD Association

ESD Generation vs. Human Awareness

Discharge	Awareness
>3500V	Feel
>5000V	Hear
>8000V	See

Some ICs can be damaged at <10V !
You will not even feel the ESD !

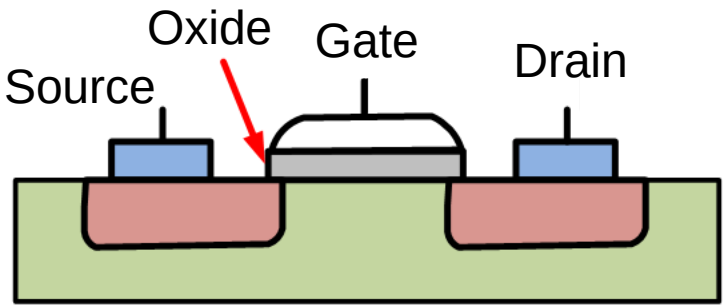
Source: http://emp.byui.edu/fisherr/esd/esd_control_handbook.pdf

Typical IC Device Sensitivity Thresholds

Device Type	Threshold Susceptivity (V)
MOSFET	10-100
VMOS	30-1800
NMOS	60-100
GaAsFET	60-2000
EPROM	100+
CMOS	200-3000
JFET	140-7000
SAW	150-500
Op-AMP	190-2500
Schottky Diodes	300-2500
Film Resistors	300-3000
Bipolar Resistors	300-7000
ECL	500+
SCR	500-1000
Schottky TTL	500-2500

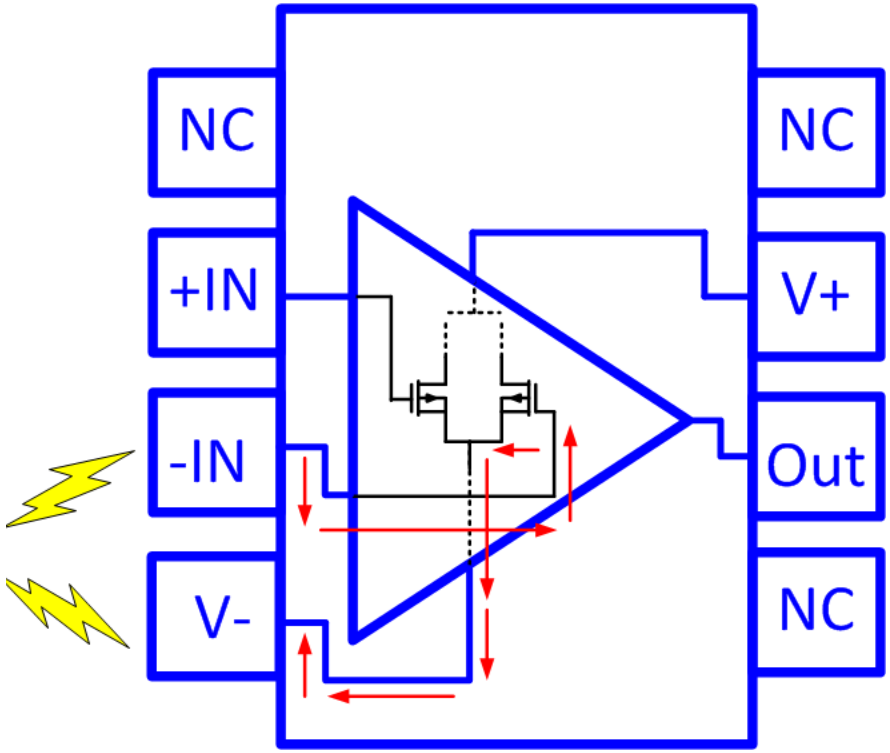
Source: http://emp.byui.edu/fisherr/esd/esd_control_handbook.pdf

ESD Can Damage Semiconductors



Oxide is very thin (nm)

ESD pulse can break down thin gate oxide and other structures

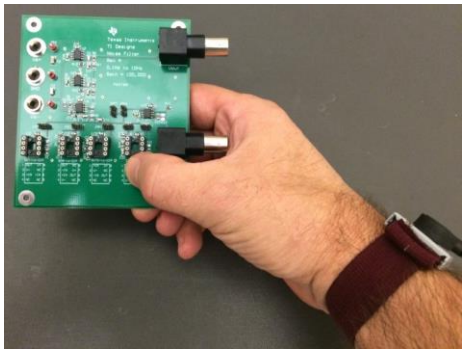


Out-of-Circuit vs. In-Circuit

PCB assembly

Factory test

Note: ESD robustness depends on device and environment

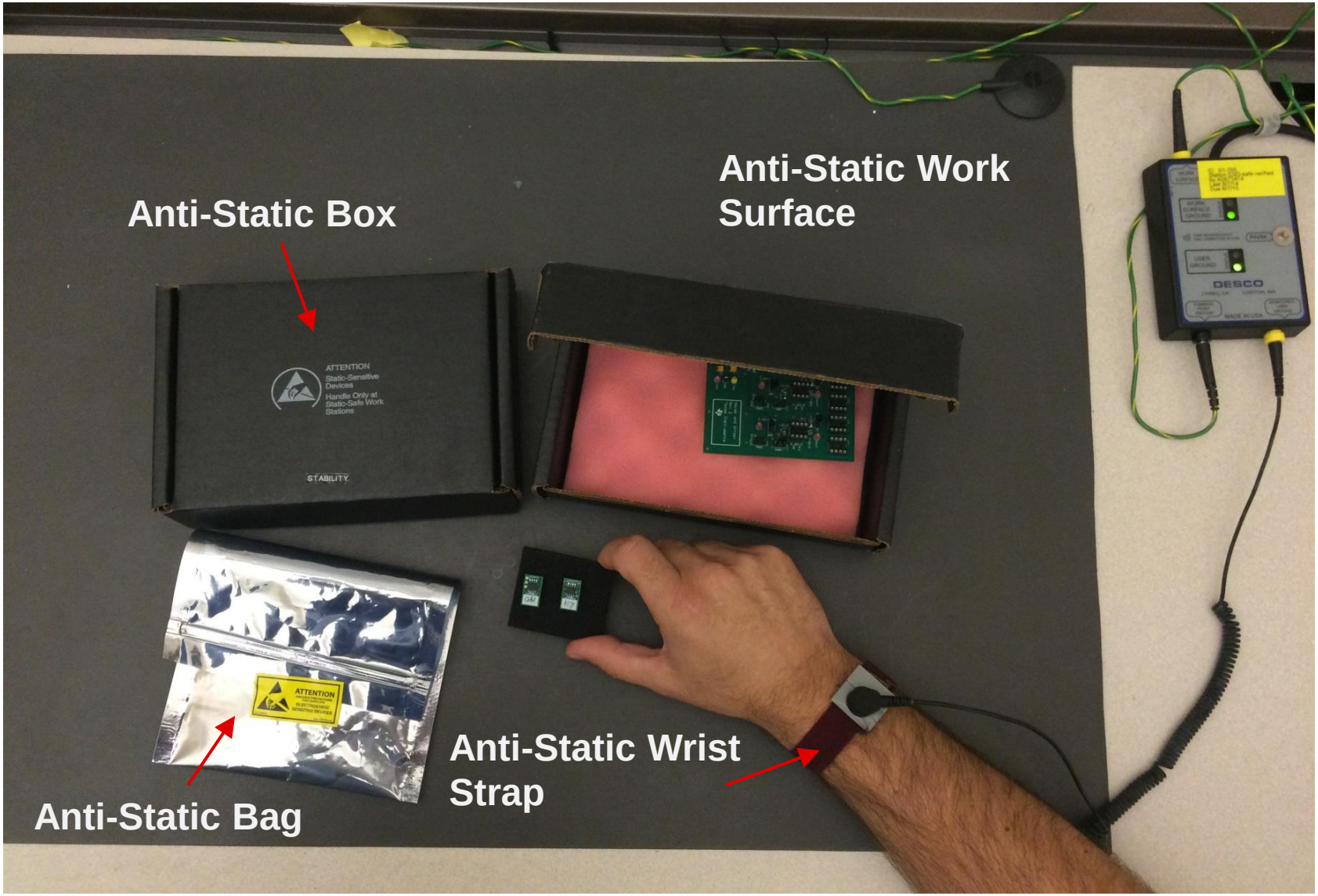


Fully-assembled PCB

End product

Note: ESD robustness depends on system design, packaging, and device

ESD Handling and Protection



Characterization of Device ESD Robustness

Comprehensive test of device
- Using automated equipment
- Most specified parameters tested

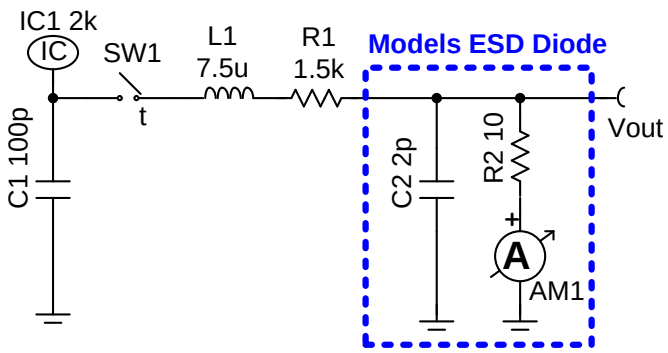
Apply ESD Pulse
- Simulator generates repeatable pulses
- Different levels are applied, 1kV, 2kV…
- Different pin combinations are tested

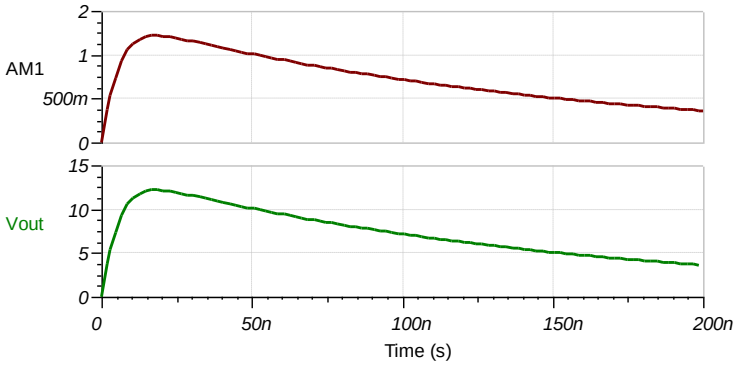
Repeat Comprehensive Test
- Look for failures
- ESD specification set by highest pulse that doesn't damage device

ESD Simulator

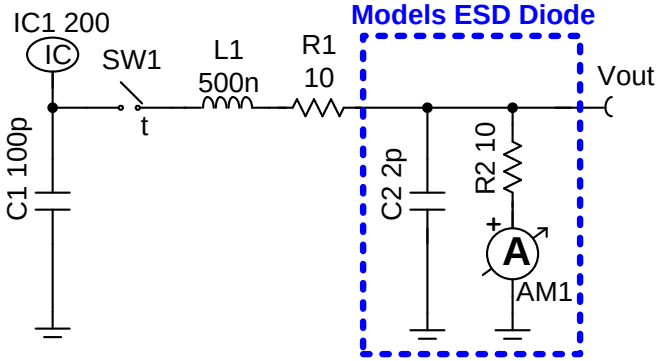
Types of ESD Simulator Pulses

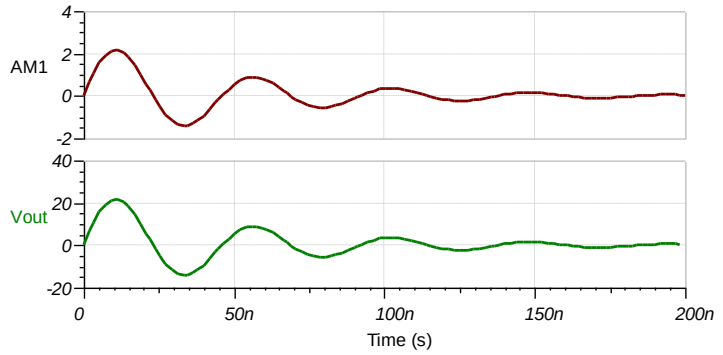
Human Body Model (HBM)



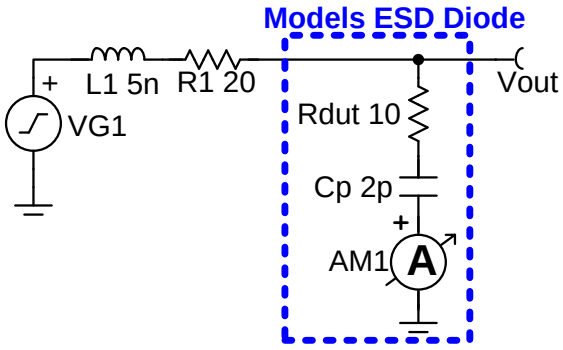


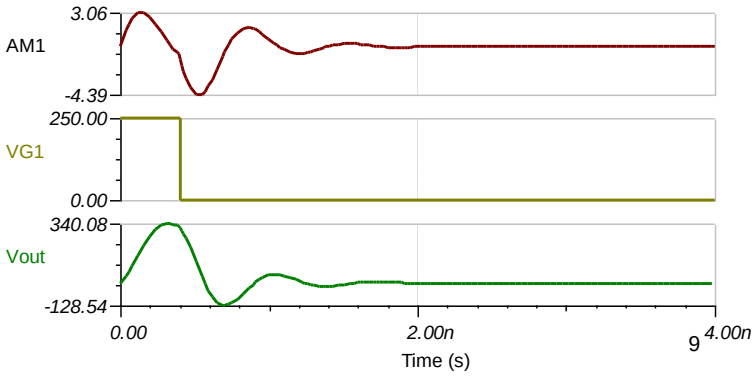
Machine Model (MM)



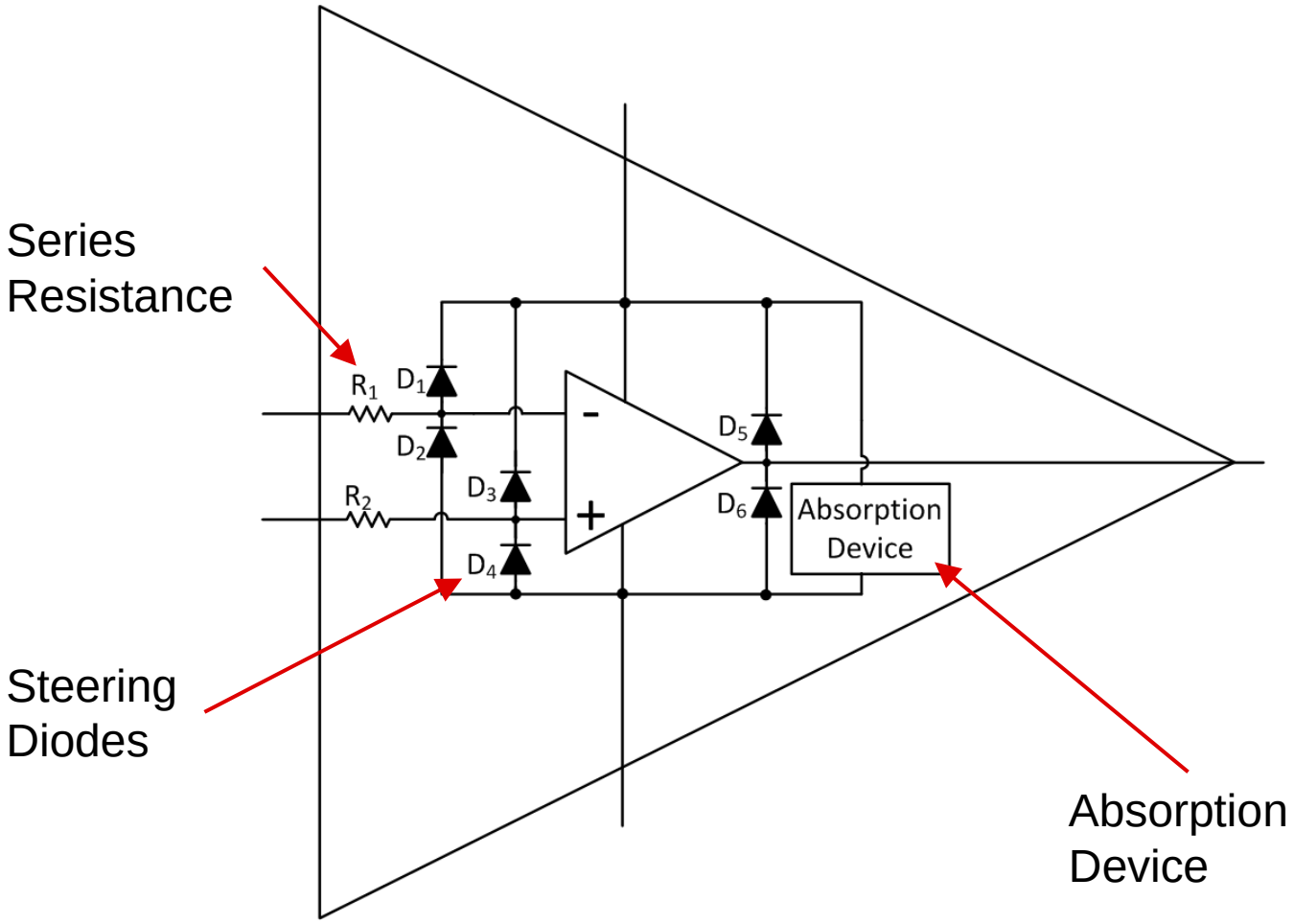


Charged Device Model (CDM)

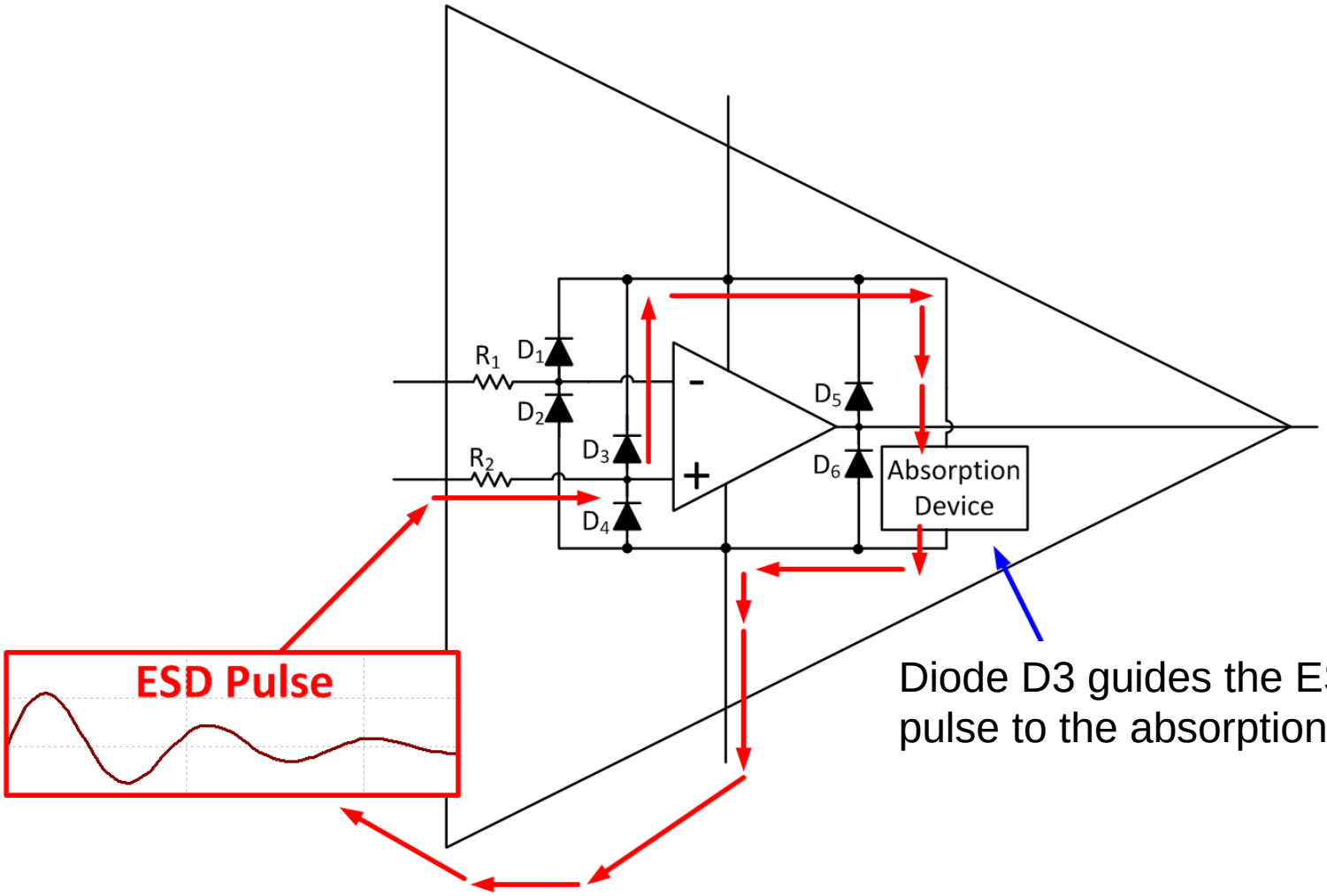




ESD Protection Inside an IC



ESD Protection with Pulse Applied

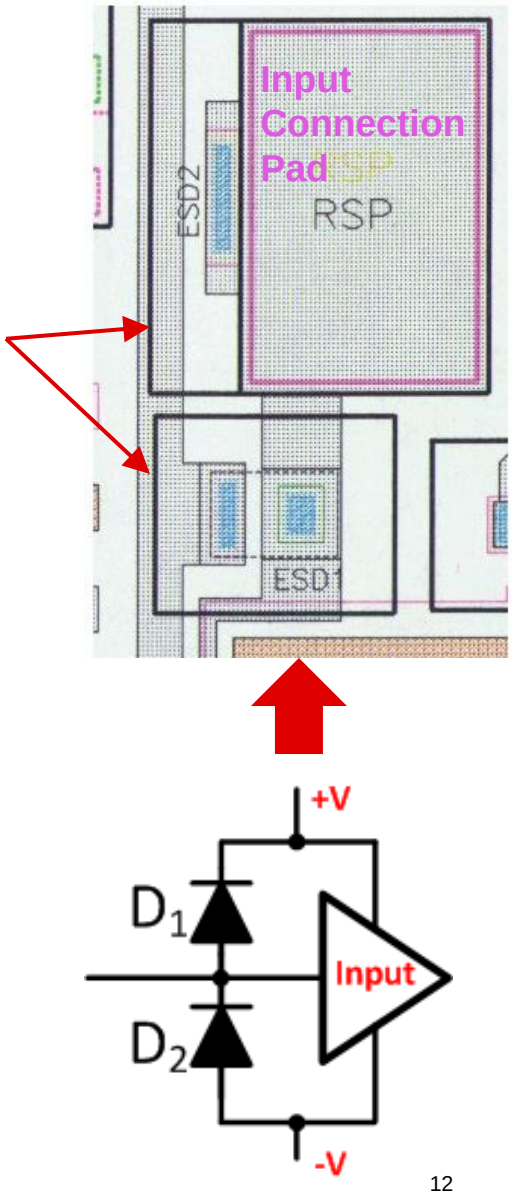


Diode D3 guides the ESD pulse to the absorption device

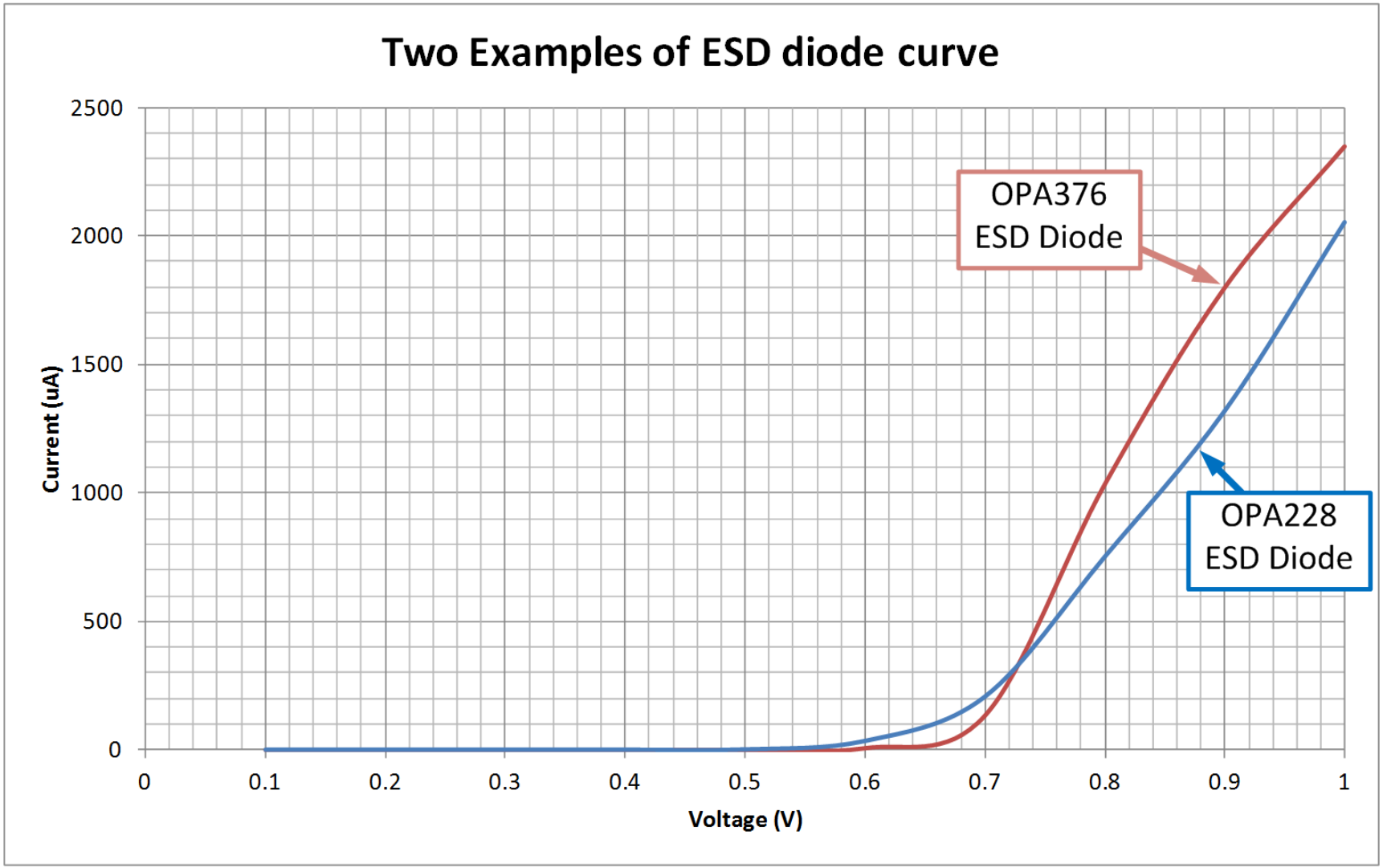
ESD Diode Specifications

Specification	Typical Value
Diode Drop (250mA)	0.7 V
Diode Drop (2A)	1 V
Pulse Current	A (for ns)
Continuous Current	10 mA
Leakage Current	0.5 pA (25°C, typical) 500 pA (125°C, typical)
Parasitic Capacitance	1 pF to 2 pF

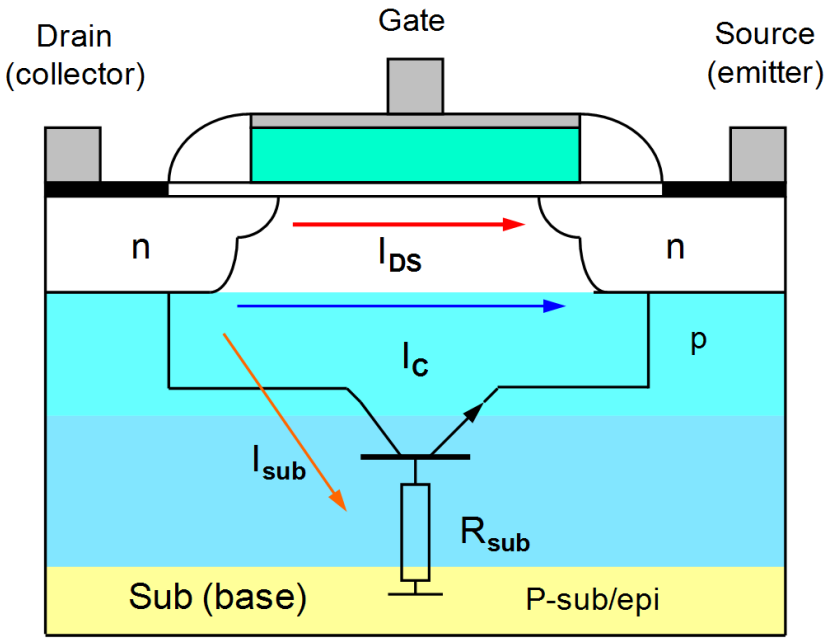
ESD diodes

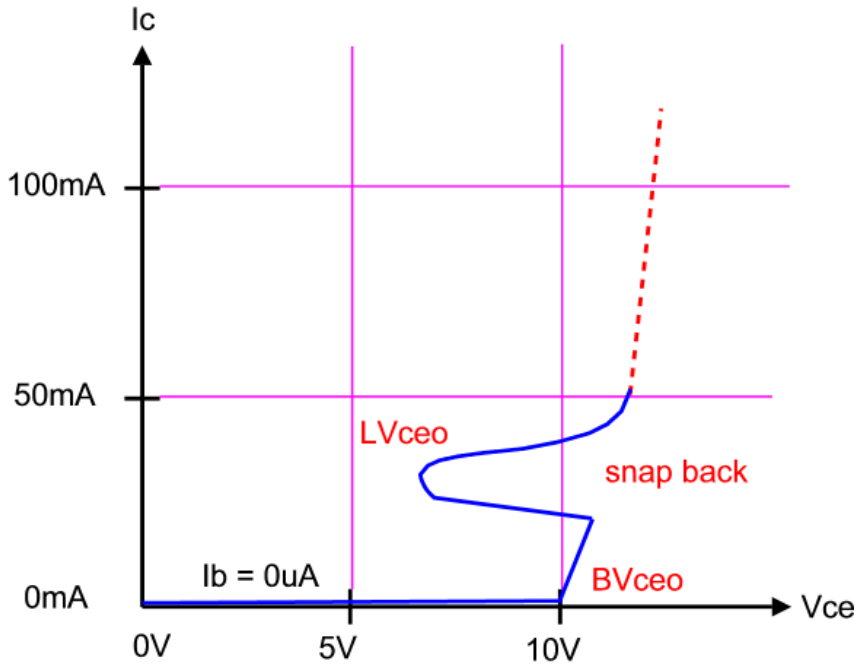


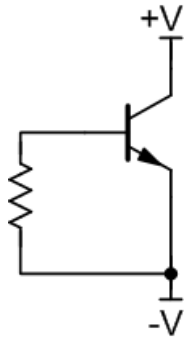
ESD Diode Curve Examples



Absorption Device







Absolute Maximum Ratings

			VALUE	UNIT
Supply voltage			±20 (+40, single supply)	V
Signal input terminals	Voltage	Common-mode	(V-) - 0.5 to (V+) + 0.5	V
		Differential	(V+) - (V-) + 0.2	V
	Current		±10	mA
Output short circuit			Continuous	mA
Operating temperature			-55 to +150	°C
Storage temperature			-55 to +150	°C
Junction temperature			+150	°C
Electrostatic discharge (ESD) ratings	Human Body Model (HBM)		4	kV
	Charged device model (CDM)		1	kV

Multiple-Choice Quiz

- ESD voltage as low as _____can cause damage to some semiconductor devices.
  a) 10V
  b) 50V
  c) 100V
  d) 1000V

- Humans can just feel ESD at_____.
  a) 3500V
  b) 2000V
  c) 1000V
  d) 100V

- (T/F) The absolute maximum input current is determined by the ESD diodes and is generally set to 10mA.
  a) True
  b) False

Multiple-Choice Quiz

- Exceeding the _____ will cause damage to the device.
  a) Specified power supply range
  b) Absolute maximum power supply range
  c) Pulsed power specification
  d) Over-current protection specification

- Internal Op Amp ESD cells are designed to_____.
  a) Protect against all EOS events once assembled in a PCB
  b) Provide latch-up-free operation under all EOS events
  c) Prevent ESD damage from out-of-circuit events
  d) Discharge any nearby lightning strikes

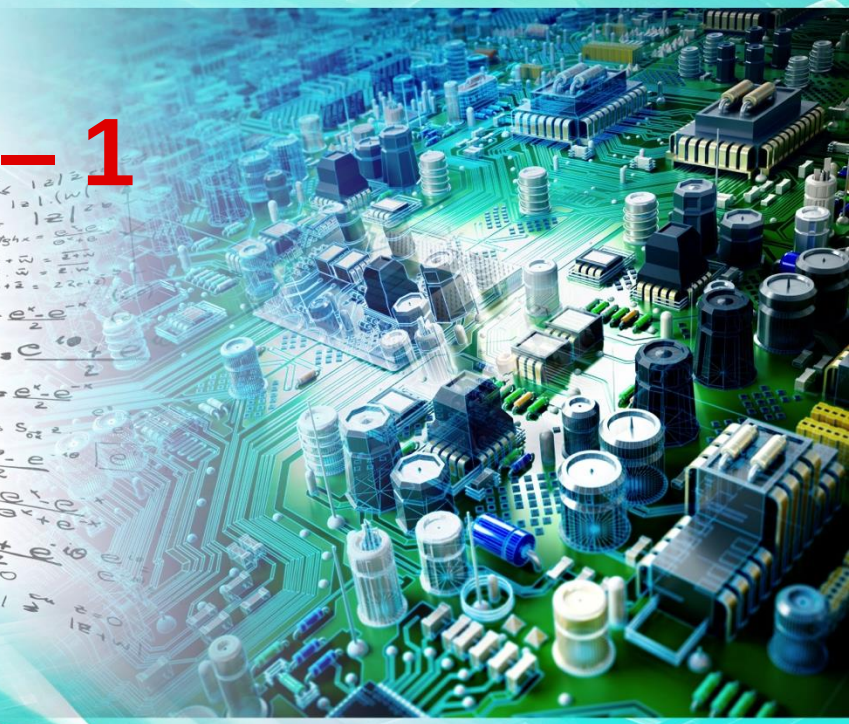
Multiple-Choice Quiz

- (T/F) ESD protective devices such as an ESD work surface or ESD wrist straps use very low resistance (0Ω) to quickly discharge ESD charge to ground.
  a) True
  b) False

- The absorption device is designed to _____.
  a) Turn on and limit the supply voltage during an electrical overstress event
  b) Turn on and limit the supply voltage during an ESD event
  c) Turn on and limit the input current during an ESD event.
  d) Turn on and limit the supply current during an ESD event.

Electrical Overstress – 1

TIPL 1411
TI Precision Labs – Op Amps



Presented by Marek Lis

ESD vs. EOS – What's the Difference?

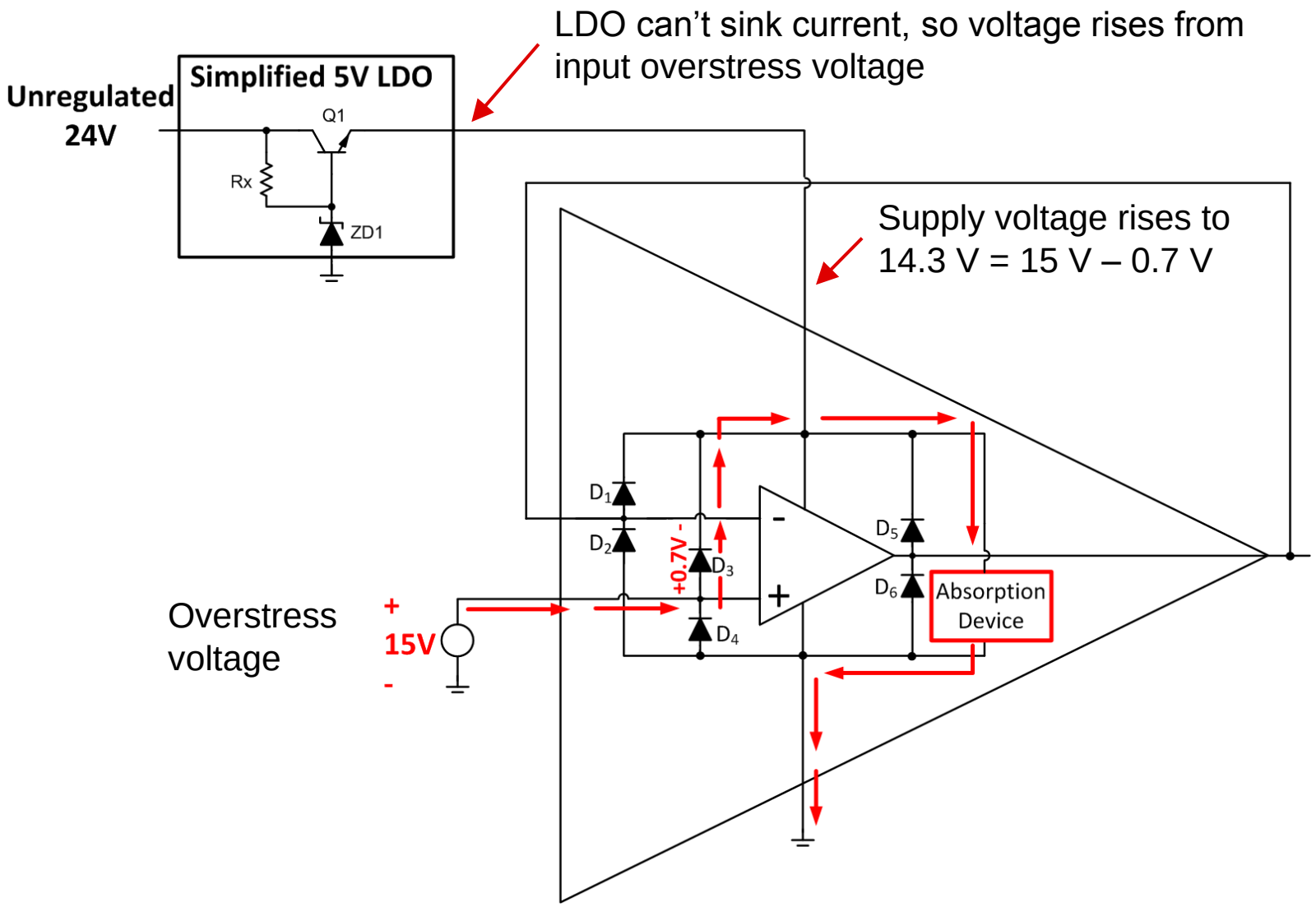
ESD

- Electrostatic discharge
- Short duration event (1-100ns)
- High voltage (kV)
- Fast edges
- Both "in-circuit" and "out-of-circuit"

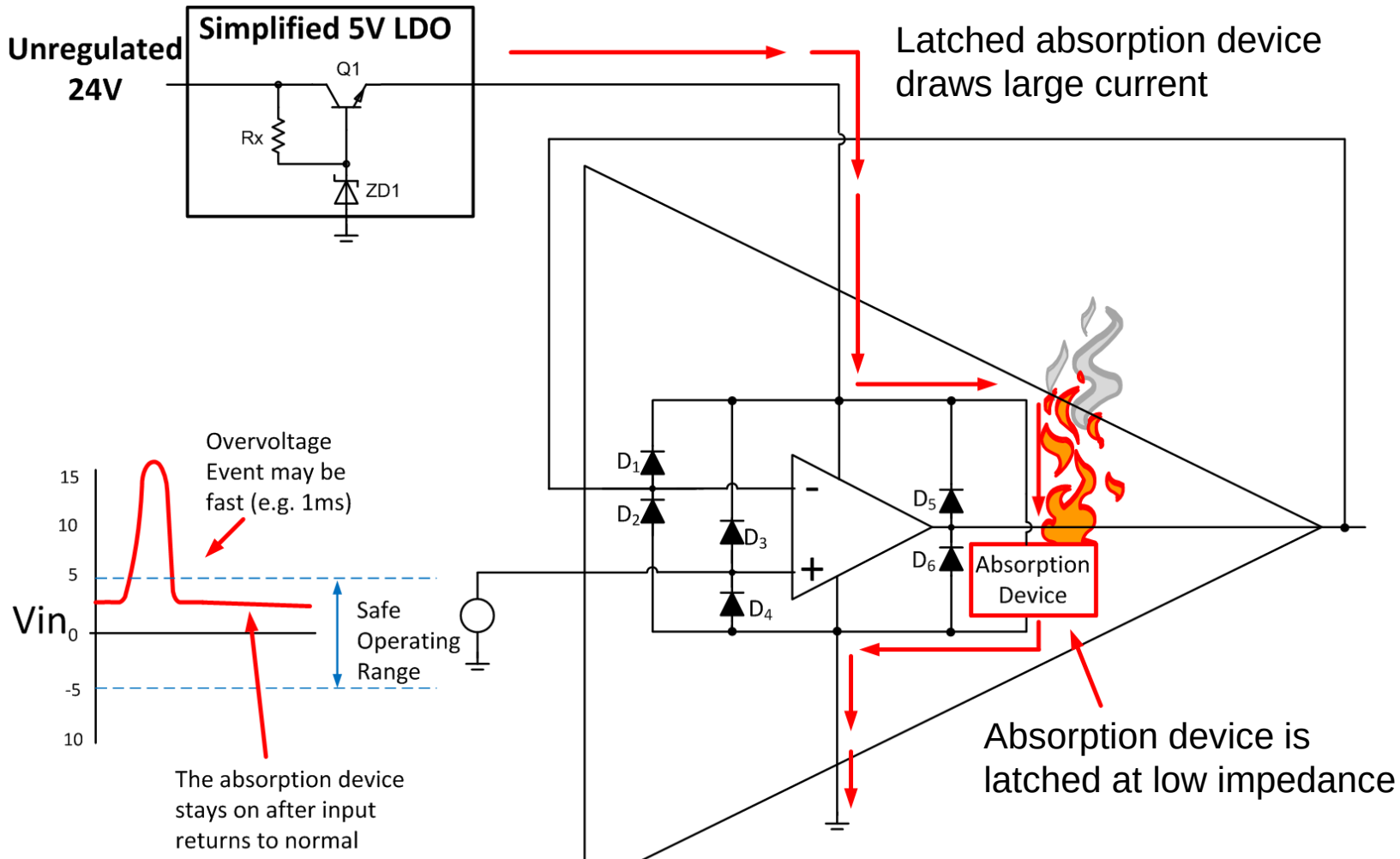
EOS

- Electrical overstress
- Longer duration event
  - Milliseconds or more
  - Can be continuous
- Lower voltage
  - May be just beyond absolute maximum ratings
- "In-circuit" event only

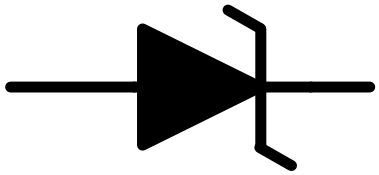
EOS Event – Overvoltage Input



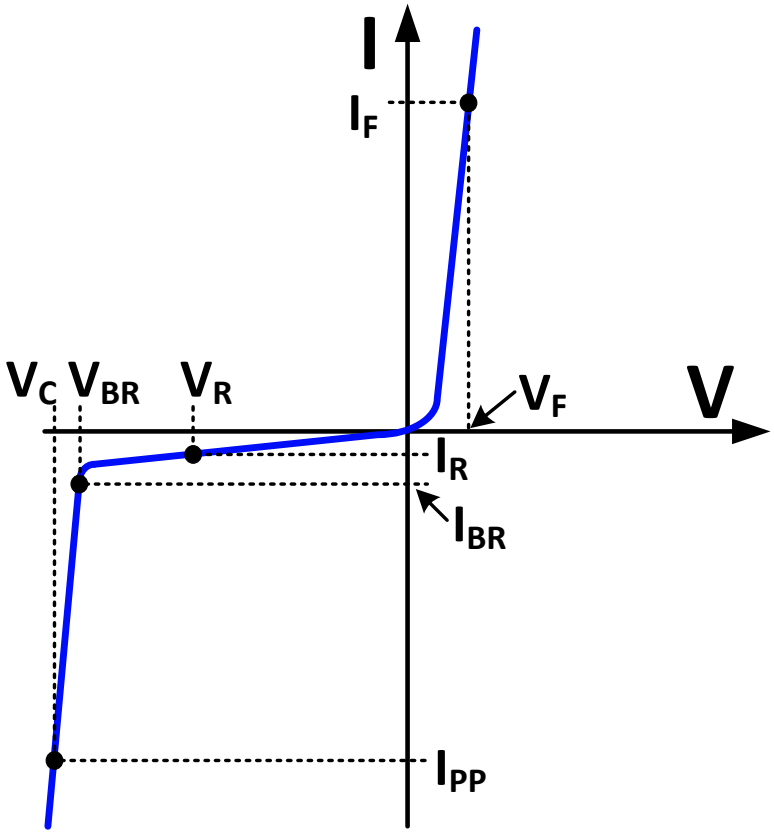
Absorption Device Latches



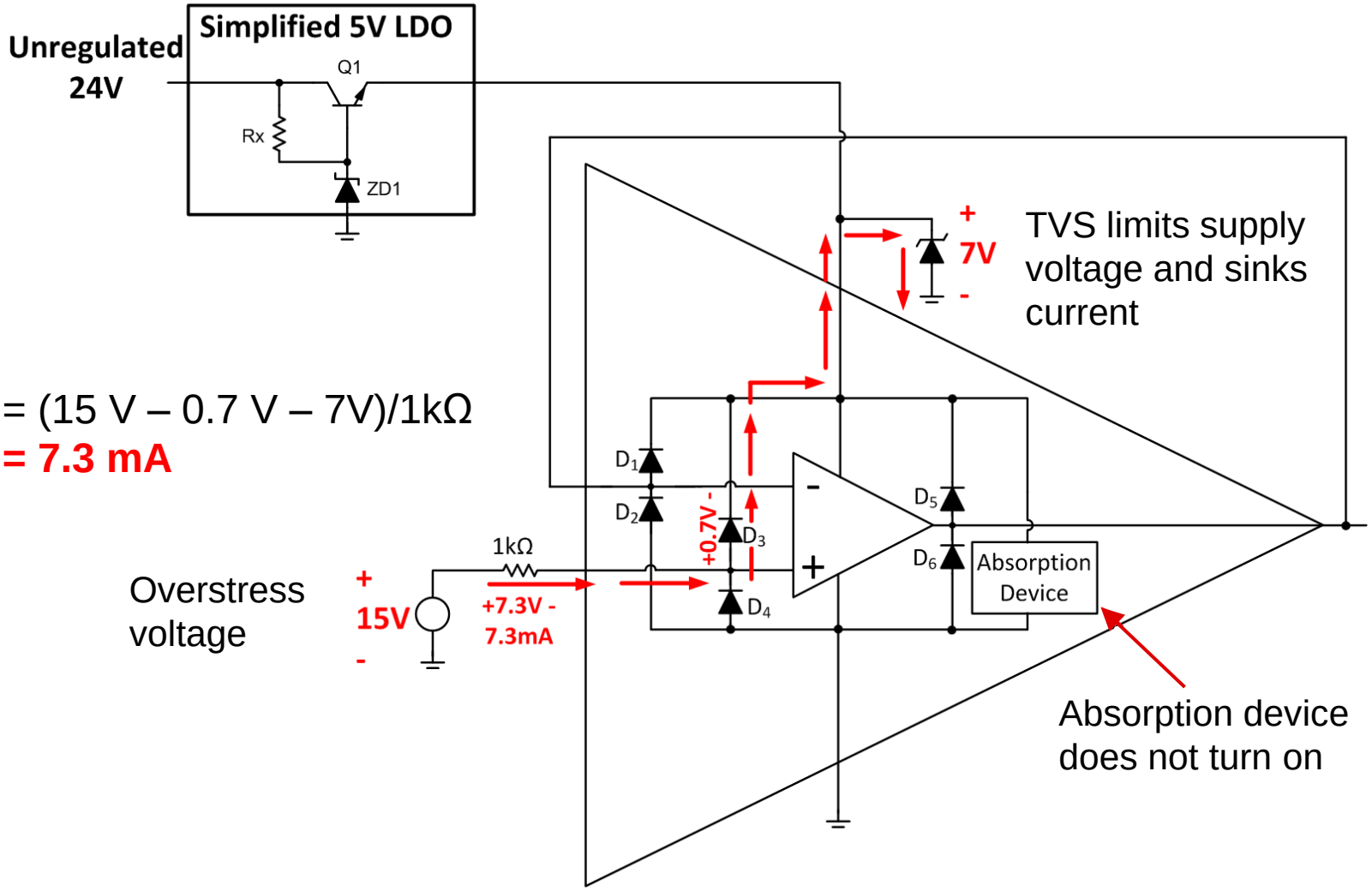
Transient Voltage Suppressor (TVS) Diode



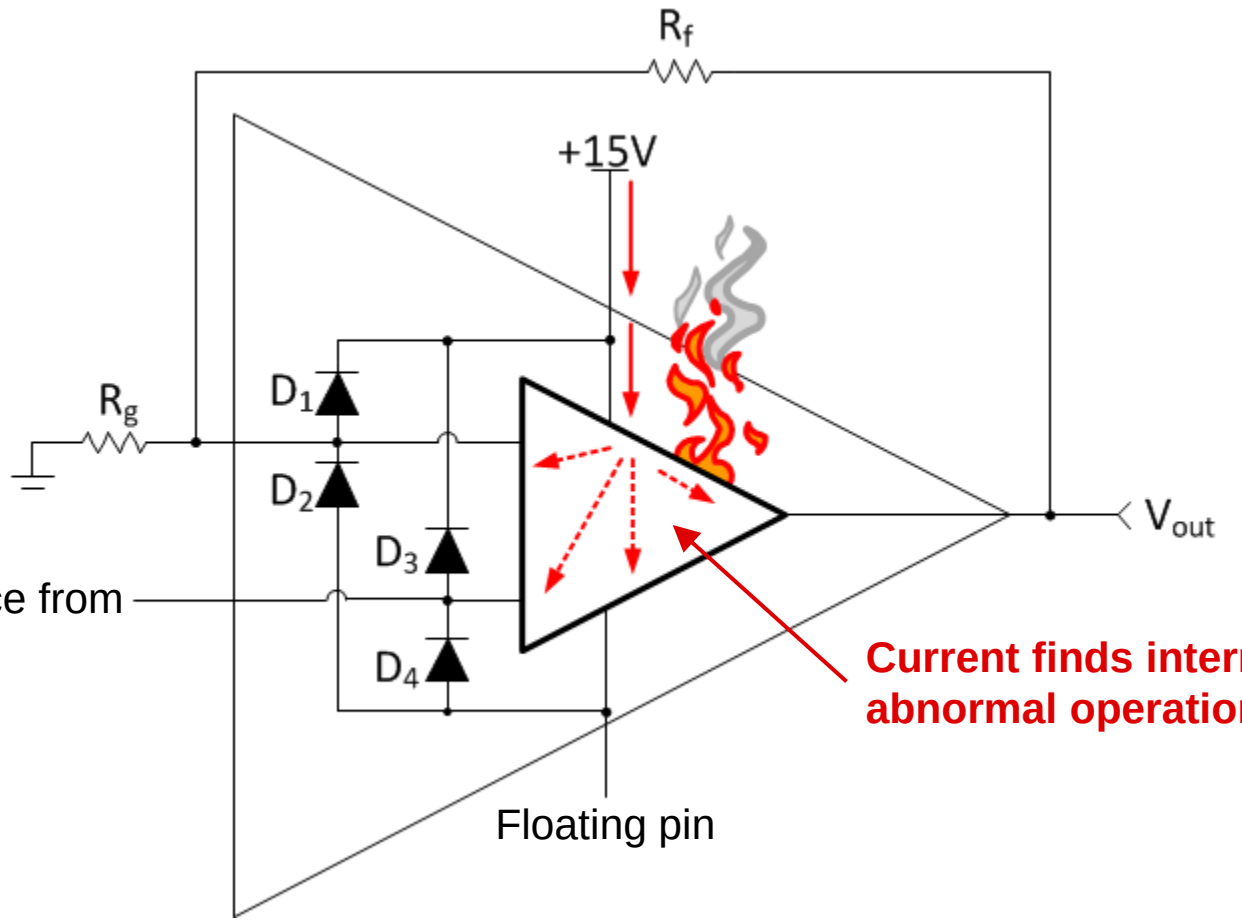
Symbol	Parameter
V_{BR}	Breakdown voltage
V_R	Stand-off voltage
V_C	Clamping voltage
V_F	Forward voltage drop
I_{BR}	Breakdown Current @ V_{BR}
I_R	Reverse Leakage @ V_R
I_F	Forward Current @ V_F
I_{PP}	Peak Pulse current @ V_C



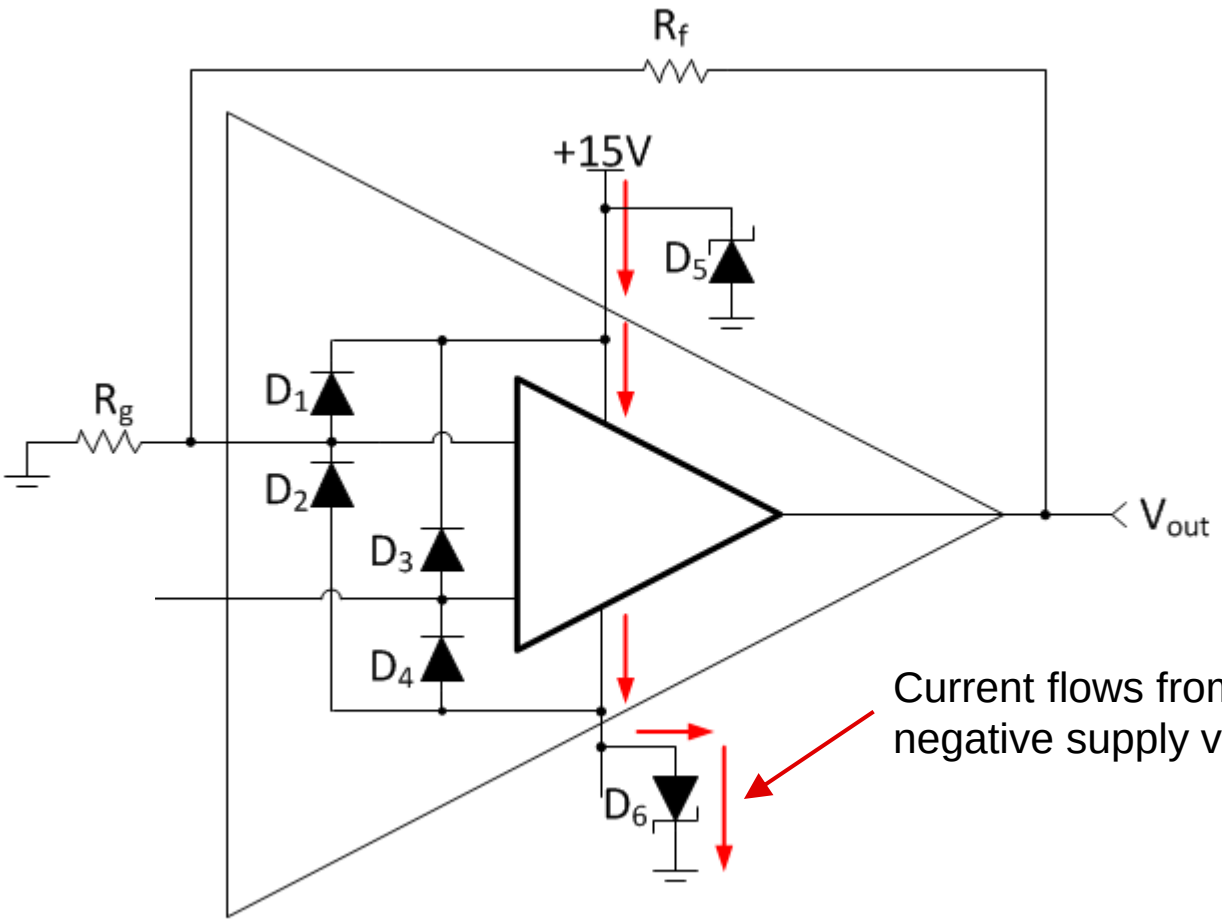
TVS Diode and Series Resistance



Power Supply Sequencing

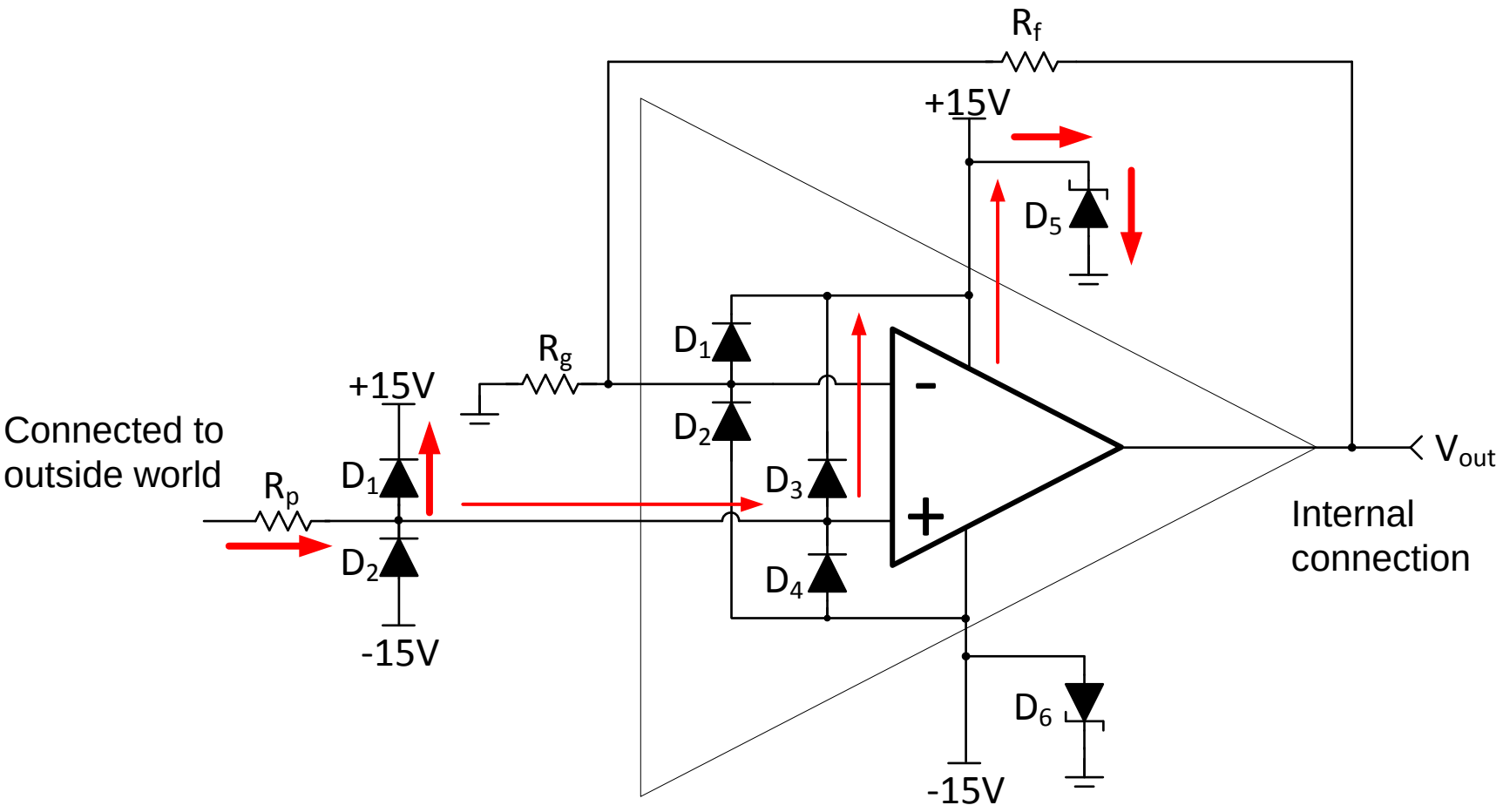


Power Supply Sequencing

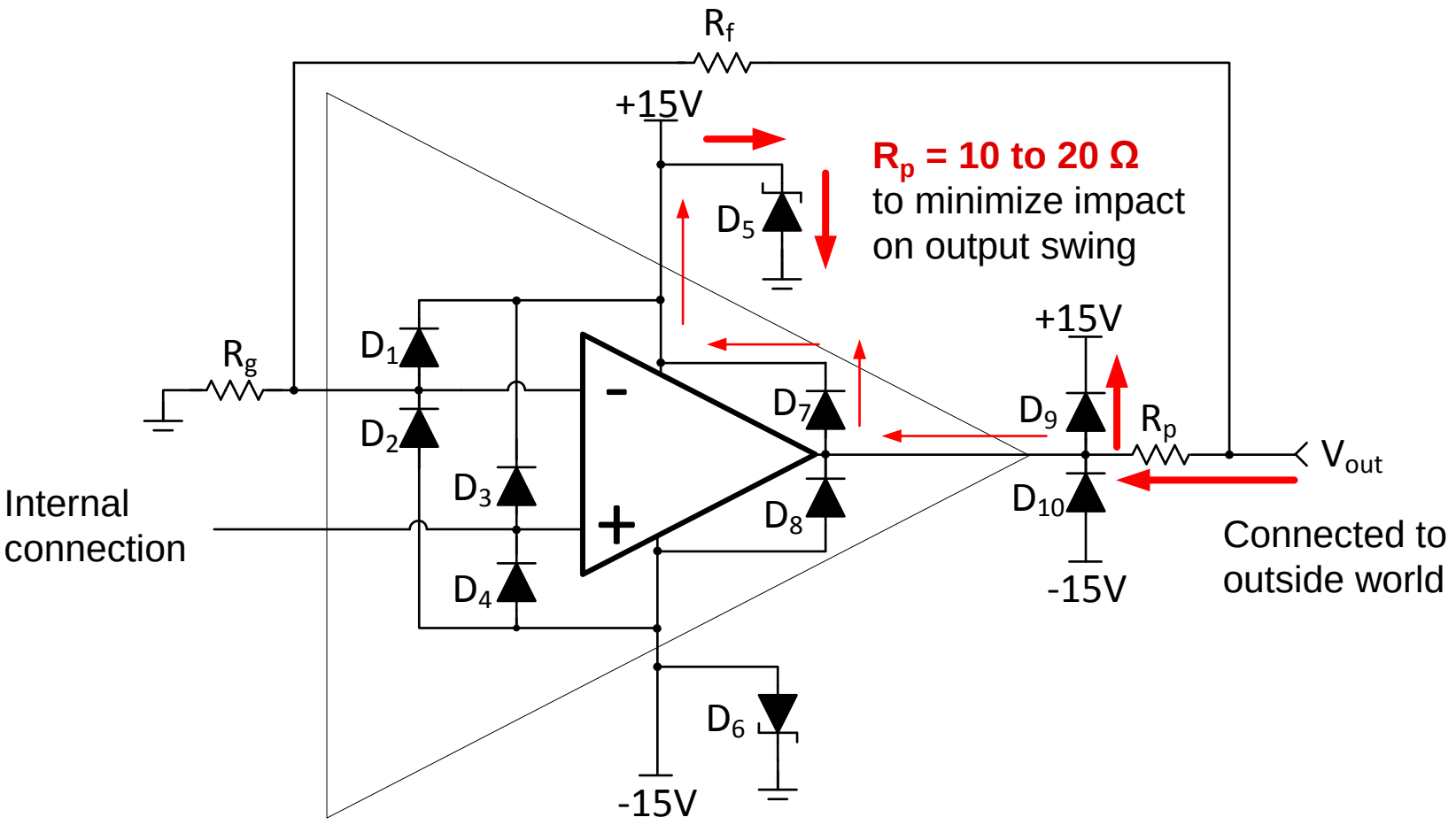


Current flows from positive to negative supply via TVS diode

Schottky Diodes – Input Protection



Schottky Diodes – Output Protection



Multiple-Choice Quiz

- EOS damage occurs when you exceed _____.
  a) The specified minimum voltage level.
  b) Two times the maximum specified voltage level.
  c) The absolute maximum voltage rating.
  d) The maximum allowable frequency for input signals.

- (T/F) EOS events are typically longer in duration than ESD events.
  a) True
  b) False

Multiple-Choice Quiz

- A TVS diode is _____.
  a) A crystal diode used to minimize RF interference.
  b) A Zener diode optimized for fast turn on time and large power dissipation.
  c) A diode with a low forward voltage that is placed in parallel with ESD diodes.
  d) A specialized diode that minimizes leakage over temperature.

- Positive LDO (low-drop-out) linear voltage regulators can _____.
  a) Sink but not source current
  b) Source and sink current equally
  c) Source but not sink current

Multiple-Choice Quiz

- The goal of the TVS diode is to _____.
  a) Limit the input current to less than 10mA during EOS events
  b) Limit the supply voltage to less than the absolute maximum during EOS
  c) Direct EOS energy to an absorption device.
  d) Maintain the temperature of the device during EOS

- What generally limits the resistance which can be connected to the output of an amplifier?
  a) The amplifier bandwidth.
  b) The amplifier output swing
  c) The amplifier slew rate
  d) The amplifier offset drift.

Multiple-Choice Quiz

- (T/F) Applying an overstress voltage to a device input can cause the absorption device to latch on and draw excessive current.
  a) True
  b) False

- Assume than an EOS event turns on the absorption device while the IC is powered on. Once the EOS event ends, the absorption device _____.
  a) Will return to normal operation
  b) Will return to normal operation with degraded performance
  c) Will continue to draw excessive current until power is cycled.

Thanks for your time!

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265