Protecting Delta-Sigma ADC from EOS – Protected RTD Measurement in PLC

TI Precision Labs – ADCs

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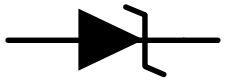
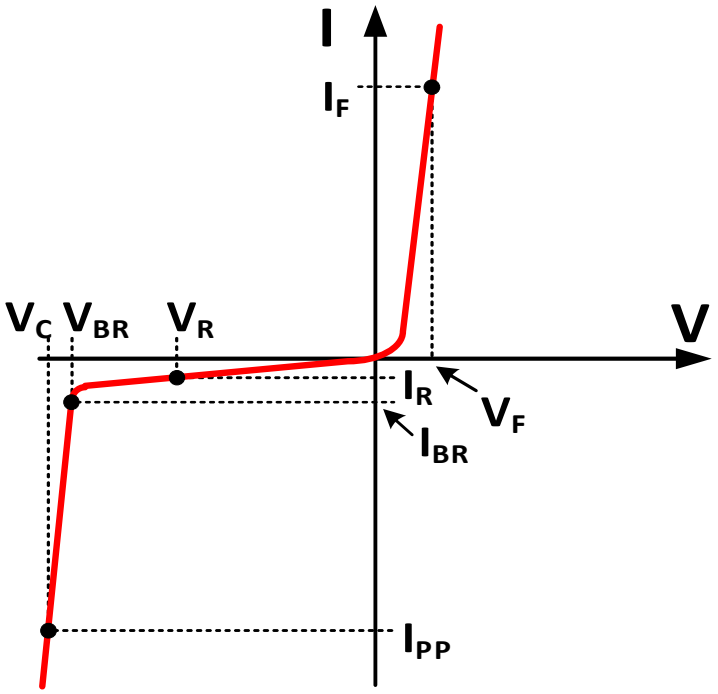
Prepared by Dale Li

Unidirectional TVS Diode
(Transient Voltage Suppressor)

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_Uni



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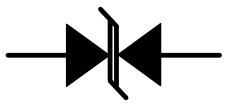
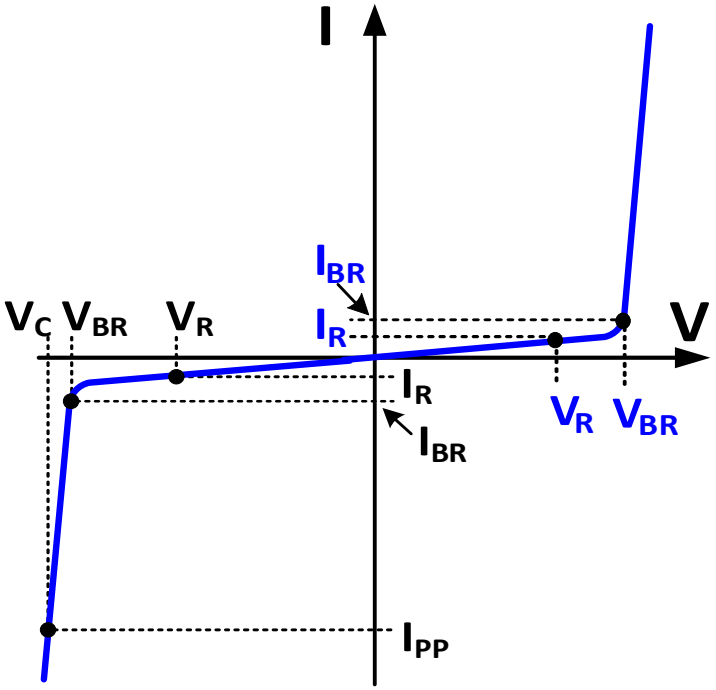
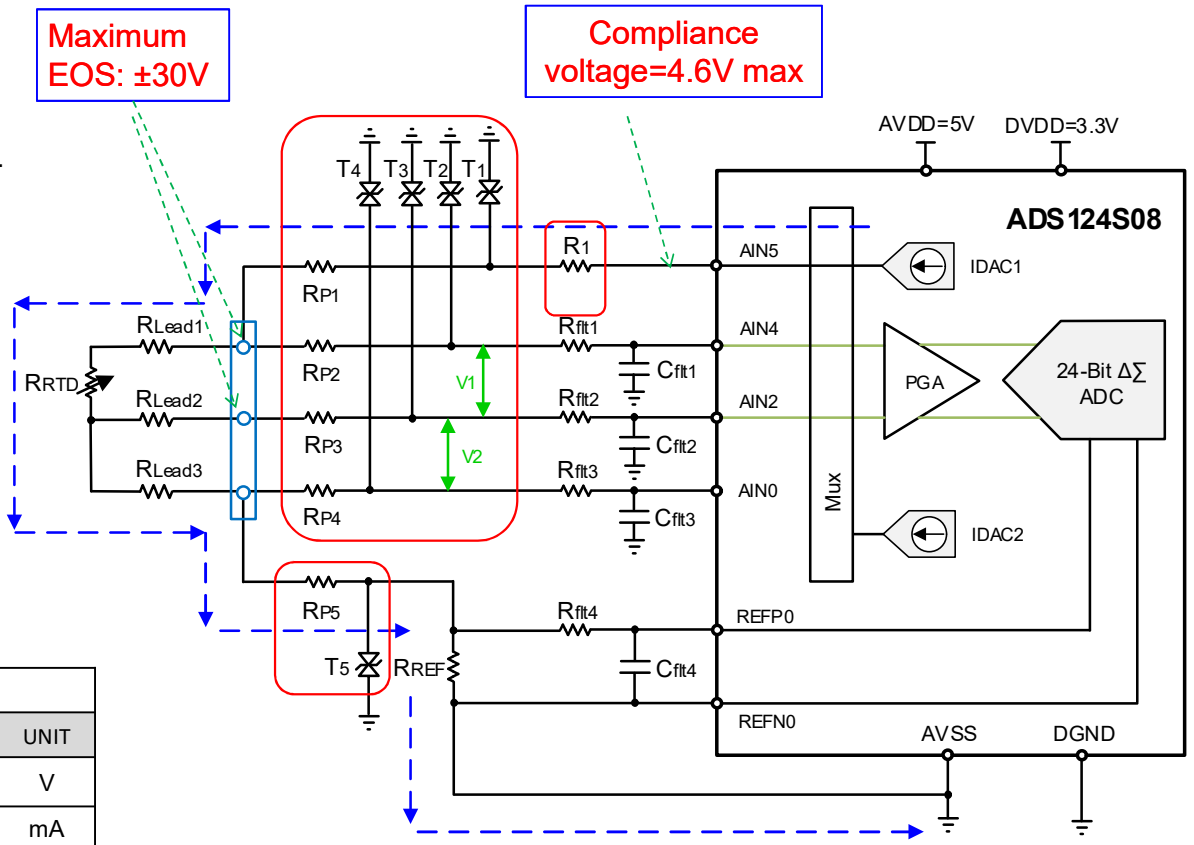


TVS_Bi



Protection: 3-Wire RTD, Low-side Reference Measurement

- **Current limiting resistors:**
  - $R_{P1}/R_{P2}/R_{P3}/R_{P4}$: limit current to TVS and ADC inputs
  - R_1 limits current to IDAC (no R_{flt} on AIN5).
  - Large value R_{P1} and R_1 limit current more: -
    Advantage: lower clamped voltage under fault condition. -
    Disadvantage: higher voltage under normal operation. (violate compliance voltage on IDAC).
  - Small value R_{P1} and R_1 limit less current, have higher power dissipation on R_{P1} and R_1.
  - Mismatching and drift affect accuracy.
- **TVS diode considerations:**
  - Proper standoff voltage(14V) -> tradeoff for R_{P1} and R_1.
  - Bidirectional TVS instead of unidirectional TVS.
  - Leakage current is a key error contribution to accuracy.
  - Temp drift of leakage current affects accuracy.



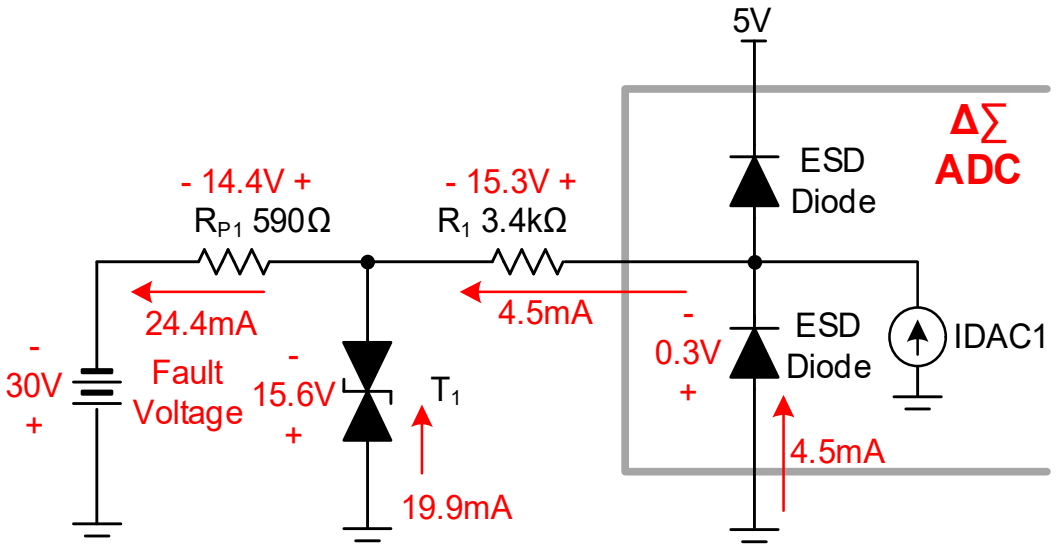
(*Common-mode capacitor not shown)

Absolute Maximum Ratings (Single 5V Power Supply)				
Parameter	MIN	TYP	MAX	UNIT
Analog Input Voltage (V_{in_Abs})	-0.3		+5.3	V
Analog Input Current (I_{in_Abs})	-10		+10	mA
Normal Input Signal				
AINx Signal (V_{in})	0		+5	V

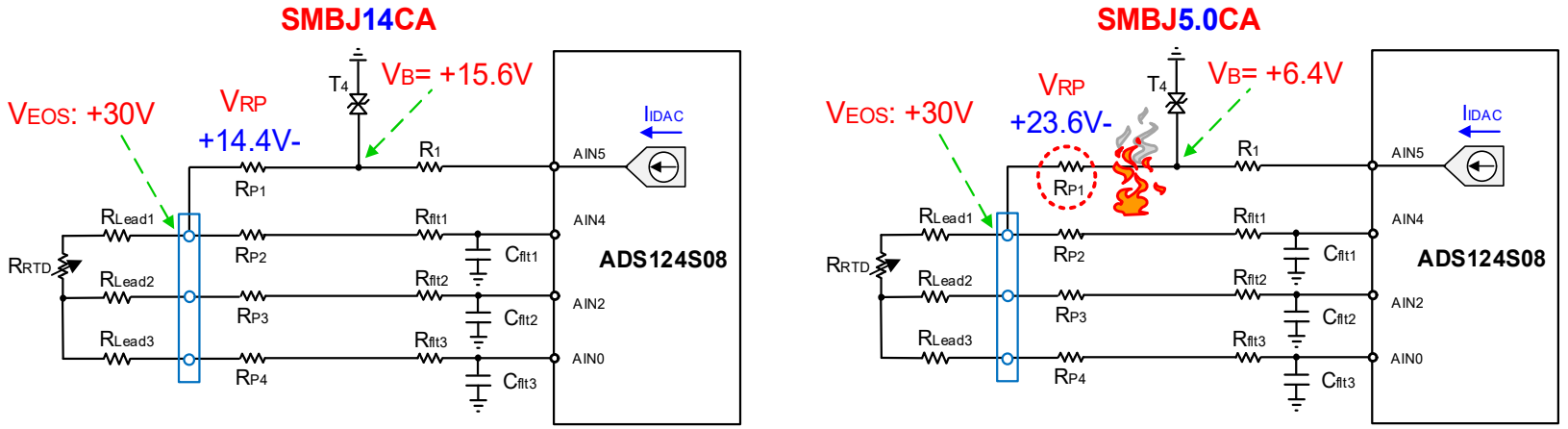
ADC internal ESD diode structure

Protection Circuit tradeoffs

- R_{P1} limits current into TVS diode
- R_1 limits current into ESD diodes
- TVS, R_1, and RP1 must have a power rating to allow continuous 30V fault
- R_{P1} + R_1 must be small enough to avoid IDAC compliance issues
- Fault current into ADC must be less than 10mA



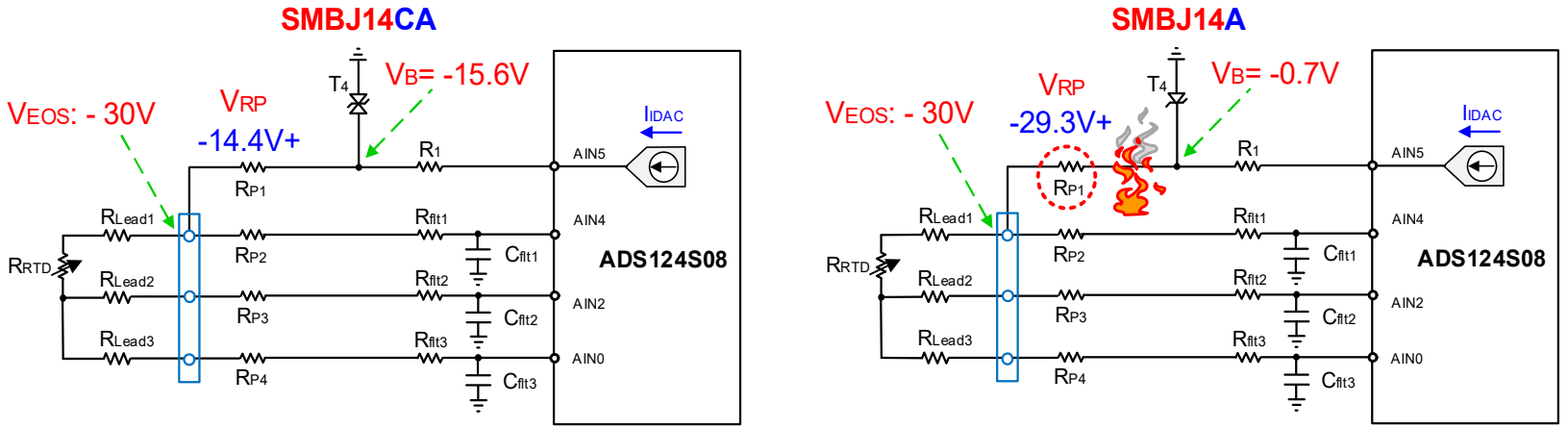
Why do we select 14V standoff voltage of TVS diode?



- Voltage drop across Rp1 may not be acceptable and Power Dissipation on Rp1 may be a challenge.
- Leakage current(maximum): 1uA - SMBJ14CA vs. 800uA - SMBJ5.0CA (Diodes from Bourns Inc.)

Diodes Inc.	**SMBJ14CA**	**SMBJ5.0CA**
V_B (Minimum Breakdown Voltage)	$15.6V$	$6.4V$
$V_{RP} = V_{EOS} - V_B$ (Volts drop on R_P)	$14.4V$	$23.6V$
$P_P = \frac{V_{RP}^2}{R_{P1}}$ (Power Dissipation on Rp)	$\frac{14.4V^2}{590\Omega} = 0.351W$	$\frac{23.6V^2}{590\Omega} = \mathbf{0.944W}$

Why do we use bidirectional TVS diode?



- Voltage drop across Rp1 can not be acceptable and Power Dissipation on Rp1 can be a challenge.

Diodes Inc.	**SMBJ14CA** (Bidirectional)	**SMBJ14A** (Unidirectional)
$\boldsymbol{V_B}$ (Breakdown Voltage)	$-15.6V$	$-0.7V$
$\boldsymbol{V_{RP}} = V_{EOS} - V_B$ (Volts on R_P)	$-14.4V$	$-29.3V$
$\boldsymbol{P_P} = \frac{V_{RP}^2}{R_{P1}}$ (Power Dissipation on Rp)	$\frac{(-14.4V)^2}{590\Omega} = 0.351W$	$\frac{(-29.3V)^2}{590\Omega} = \mathbf{1.455W}$

Thanks for your time!
Please try the quiz.

Questions: Protecting RTD input Delta-Sigma

1. For the circuits below, why is a bidirectional TVS diode used?
   a. The input signal is bidirectional so the diode needs to be bidirectional.
   b. All TVS diodes are bidirectional.
   c. Bidirectional diodes are needed in case a negative overstress signal is applied.
   d. A unidirectional diode would require a unreasonably high power rating on Rp1.
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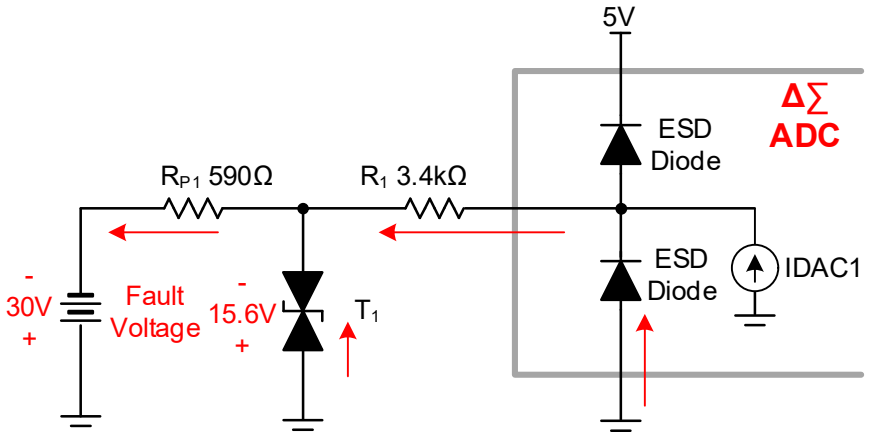

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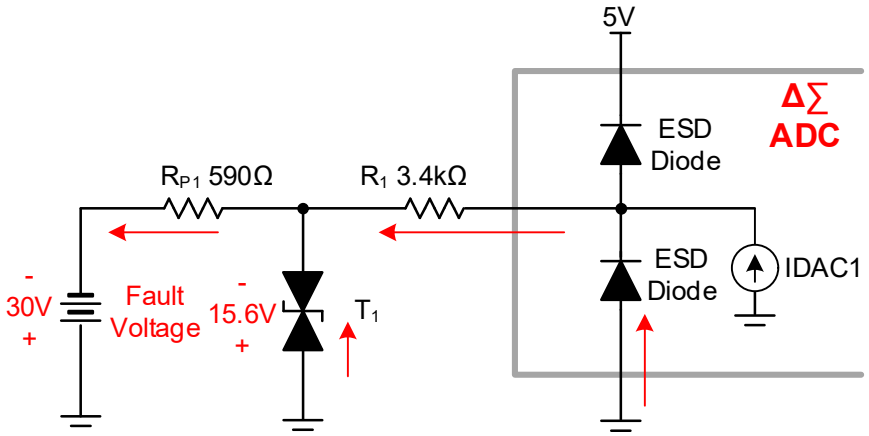

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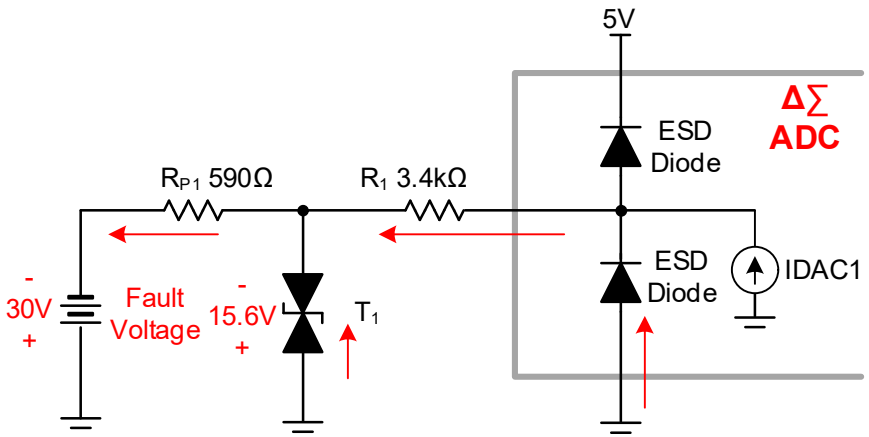

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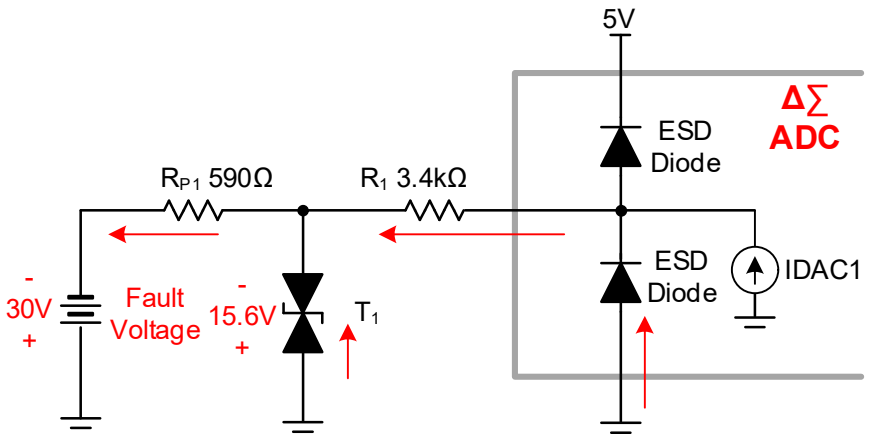

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