Protecting Delta-Sigma ADC from EOS – Component Selection for RTD Protection

TI Precision Labs – ADCs

Presented by Scott Cummins

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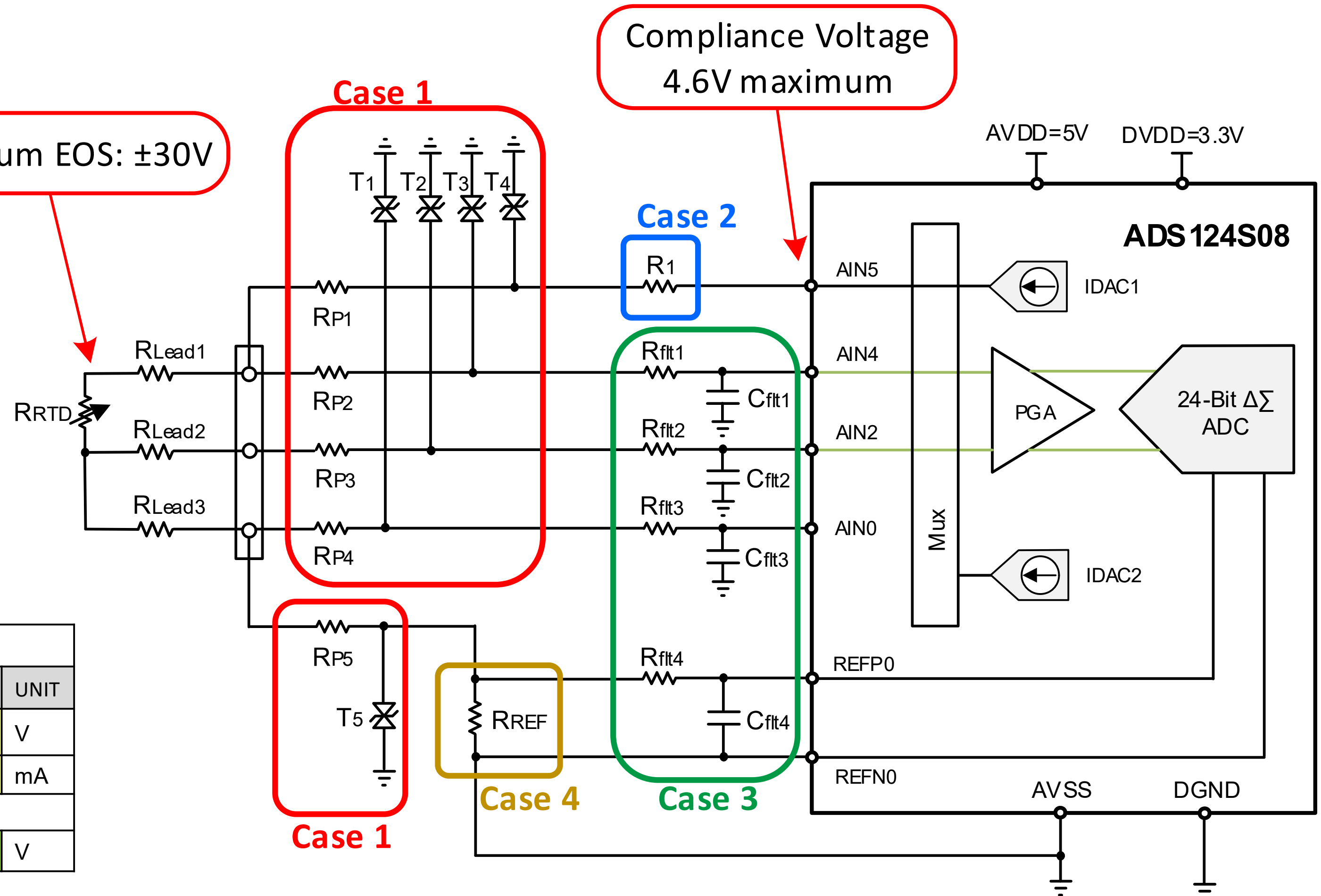
Protection: 3-Wire RTD, Low-side Reference Measurement



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

Choose Rp1 and R1 with conventional TVS diode

Part Number	MFG	Reverse Standoff Voltage(V_R)	Breakdown Voltage (V_{BR})		Clamping Voltage Max (V_C@I_{PP})	Reverse Leakage Max (I_R@V_R) 25°C	Breakdown Current (I_{BR}@V_{BR})	Peak pulse Current (I_{PP})	Peak Power Dissipation (P_{PP})	Steady State Power Dissipation(P_{PP})
			Min	Max						
SMBJ14CA	Bourns	14V	15.6	17.9	23.2V	1uA	1mA	25.9A	600W	5W

Positive EOS: (+30V)

1	$R_{P1} \geq \frac{V_{EOS\_max} - V_{BR\_min}}{I_{fault}} = \frac{30V - 15.6V}{25mA} = 576\Omega$ $(\textbf{\textit{choose 590}}\boldsymbol{\Omega})$
2	$R_1 \geq \frac{V_{BR\_min} - V_{in\_max}}{I_{ADC}} = \frac{15.6V - 5.3V}{5mA} = 2.06k\Omega$ $(\textbf{\textit{choose 2.2k}}\boldsymbol{\Omega}, 5mA < I_{Ain\_Abs})$

Negative EOS: (-30V)

3	$R_{P1} \geq \frac{V_{EOS\_max} - V_{BR\_min}}{I_{fault}} = \frac{-30V - (-15.6V)}{-25mA} = 576\Omega$ $(\textbf{\textit{choose 590}}\boldsymbol{\Omega})$
4	$R_1 \geq \frac{V_{BR\_min} - V_{in\_min}}{I_{ADC}} = \frac{-15.6V - (-0.3V)}{-5mA} = 3.06k\Omega$ $(\textbf{\textit{choose 3.4k}}\boldsymbol{\Omega}, 5mA < I_{Ain\_Abs})$
5 Power	$P_{RP1} = \frac{(V_{EOS\_max} - V_{BR\_min})^2}{R_{P1}} = \frac{(-30V - (-15.6V))^2}{590\Omega} = 351mW$ $(\textbf{\textit{choose}} \geq 702mW\ for\ P_{RP1})$
6 Power	$P_{R1} = \frac{(V_{BR\_min} - V_{in\_min})^2}{R_1} = \frac{(-15.6V - (-0.3V))^2}{3.4k\Omega} = 68.85mW$
7 Power	$P_{TVSmax} = (\frac{V_{EOS\_max} - V_{BR\_min}}{R_{P1}} - \frac{V_{BR\_min} - V_{in\_max}}{R_1}) \cdot V_C = (\frac{-30V - (-15.6V)}{590\Omega} - \frac{-15.6V - (-0.3V)}{3.4k\Omega}) \cdot 23.2V = 461mW$

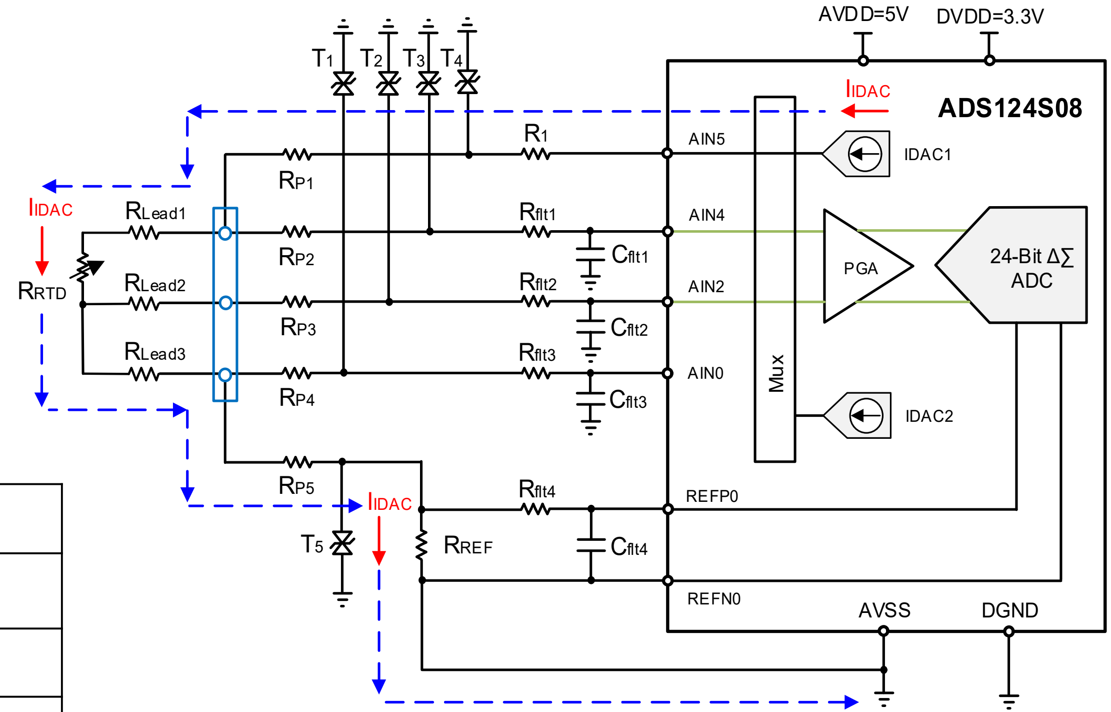
Select Worst Case! (→ rows 3 and 4)

Select Reference Resistor - R_{REF}

Parameters Known:		
PT100	Min (-200°C)	Max (+850°C)
	20Ω	400Ω *
Lead Resistance	Min	Max
	0Ω	10Ω
Components Selected: $R_P = 590\Omega, R_1 = 3.4k\Omega$		

* Approximate value.

Select R_{REF} regarding maximum voltage across R_{RTD}:	
1	Use $I_{DAC} = 0.5mA$ (lower sensor self-heating: 0.093mW<0.1mW)
2	$V_{RTD\_max} = I_{IDAC} \cdot R_{RTD\_max} = 0.5mA \cdot 400\Omega = 0.2V$
3	Use $Gain = 4$, $V_{REF\_min} = V_{RTD\_max} \cdot Gain = 0.2V \cdot 4 = 0.8V$ => $V_{REF} = 1V$
4	$R_{REF} = V_{REF}/I_{IDAC} = 1V/0.5mA = 2k\Omega$

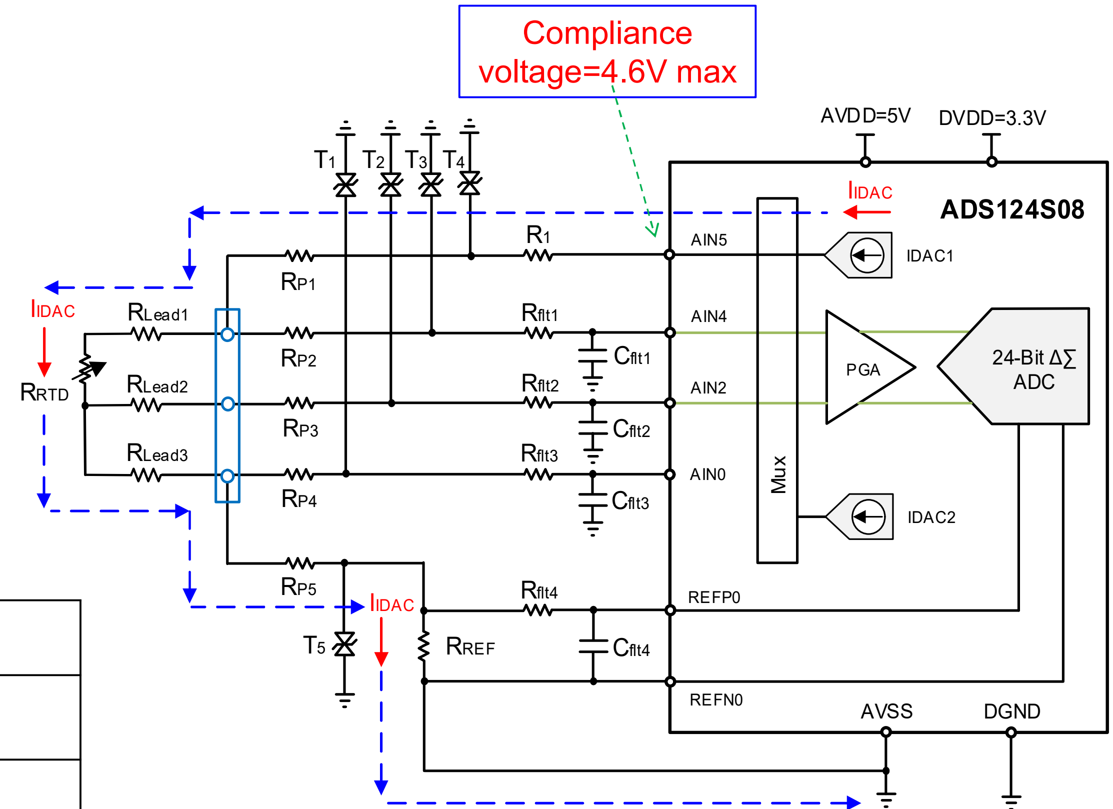


A guide to RTD measurements:
http://www.ti.com/lit/pdf/sbaa275

Verify IDAC Compliance Voltage, and Input Range

Parameters Known:	
PT100 (max)	400Ω
Lead Resistance (max)	10Ω
Excitation Current (I_{DAC})	0.5mA
Compliance voltage (V_C)	0.4V< V_C< 4.6V *
$V_{(AINx)}$ (Gain=4)	0.45V< $V_{(AINx)}$<4.55V *
Components Selected: $R_P = 590\Omega,\ R_1 = 3.4k\Omega,\ R_{REF} = 2k\Omega$	

* Limit calculated under specified conditions: (IDAC=0.5mA, Gain=4, AVDD=5V).



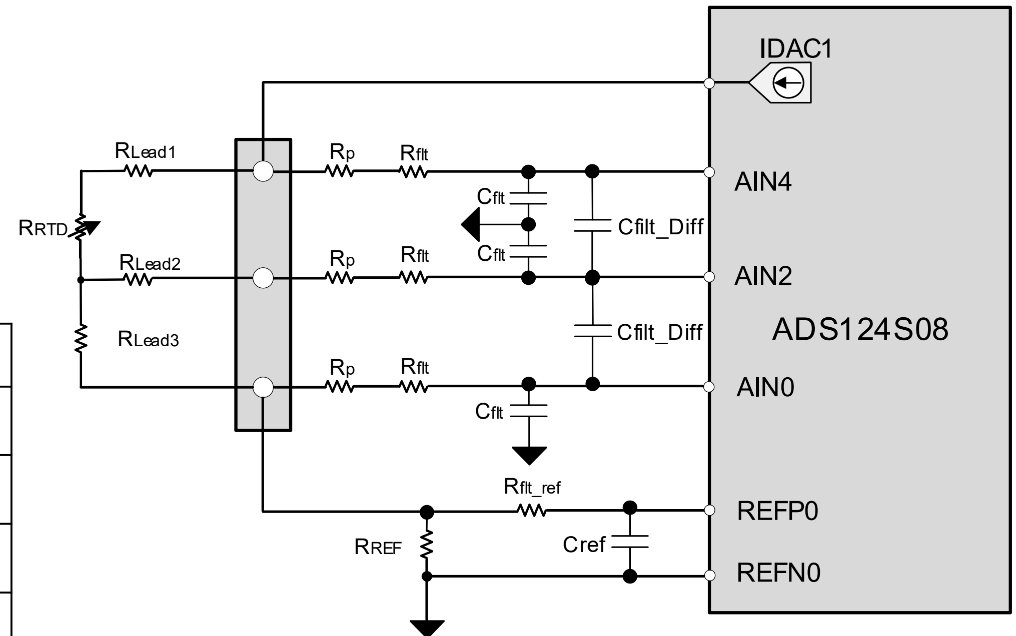
(*Common-mode capacitor not shown)

	Verify Node Voltage under Normal Operation:
1	$V_{AIN4} = I_{IDAC}\cdot(R_{RTD} + R_{REF} + R_{P5} + R_{Lead3} + R_{Lead1})$ $= 0.5mA\cdot(400\Omega + 2k\Omega + 590\Omega + 10 + 10) = 1.505V$
2	$V_{AIN2} = I_{IDAC}\cdot(R_{REF} + R_{P5} + R_{Lead3}) = 0.5mA\cdot(2k\Omega + 590\Omega + 10)$ $= 1.3V$
3	$V_{AIN0} = I_{IDAC}\cdot(R_{REF} + R_{P5}) = 0.5mA\cdot(2k\Omega + 590\Omega) = 1.295V$
4	$V_{AIN5} = I_{IDAC}\cdot(R_1 + R_{P1} + R_{lead1} + R_{RTD} + R_{lead3} + R_{P5} + R_{REF}) = 0.5mA\cdot(3.4k\Omega + 590\Omega + 10\Omega + 400\Omega + 10\Omega + 590\Omega + 2k\Omega) = 3.35V < 4.6V$ *

Select Rflt and Cflt for Differential and Common-mode Filter

- Keep bandwidth of differential filter ≥ 10×data rate.
- Keep differential capacitor ≥ 10× Common-mode capacitor.
- Keep input resistance < 10kΩ for proper input sampling.
- Higher resistance helps to limit current to ADC input.
- Keep resistance low on REFN0 since for single power supply.

For ADC Input Filtering:	
1	Choose Rfilt > R1=3.4k, and Rfilt < 10k: Rfilt =4.99kΩ
2	Choose f_{inDif} > 10xData_Rate: Data_Rate = 200Hz, f_{inDif} = 3kHz
3	$C_{in_{Diff}} = 1/[2 \cdot \pi \cdot f_{in_{Diff}} \cdot (R_{RTD} + 2 \cdot R_{flt} + 2 \cdot R_p)] = 4.6nF$ **(choose 4.7nF)**
4	$C_{in_{CM}} = C_{in_{Diff}}/10 = 470pF$
5	$C_{ref} = C_{in_{CM}} = 470pF$
6	$f_{in_{Diff}} = 1/[2 \cdot \pi \cdot C_{in_{Diff}} \cdot (R_{RTD} + 2 \cdot R_{flt} + 2 \cdot R_p)] = 2.92kHz$
7	$f_{in_{CM}} = 1/[2 \cdot \pi \cdot C_{in_{CM}}(R_{flt} + R_p)] = 60.6kHz$

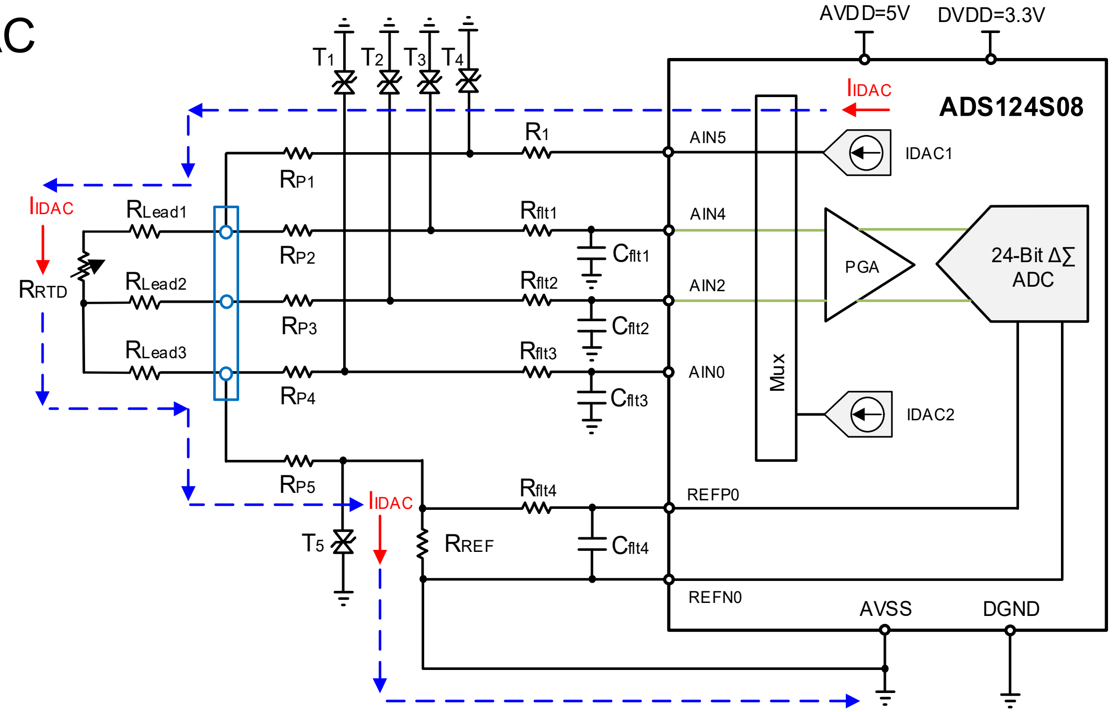


(*TVS diodes not shown)

Thanks for your time!
Please try the quiz.

Questions: Protecting RTD input Delta-Sigma

1. For the circuit below, what limits the maximum value of Rp1 and R1?
   a. Power dissipation
   b. Compliance voltage of the IDAC
   c. Leakage current error



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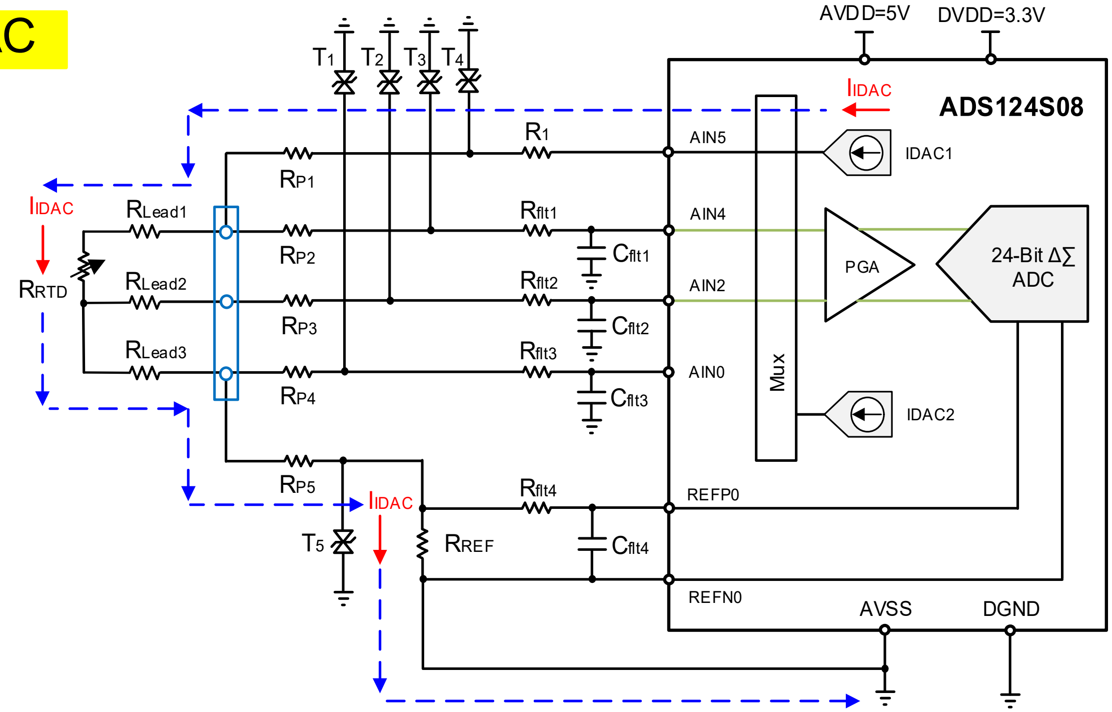
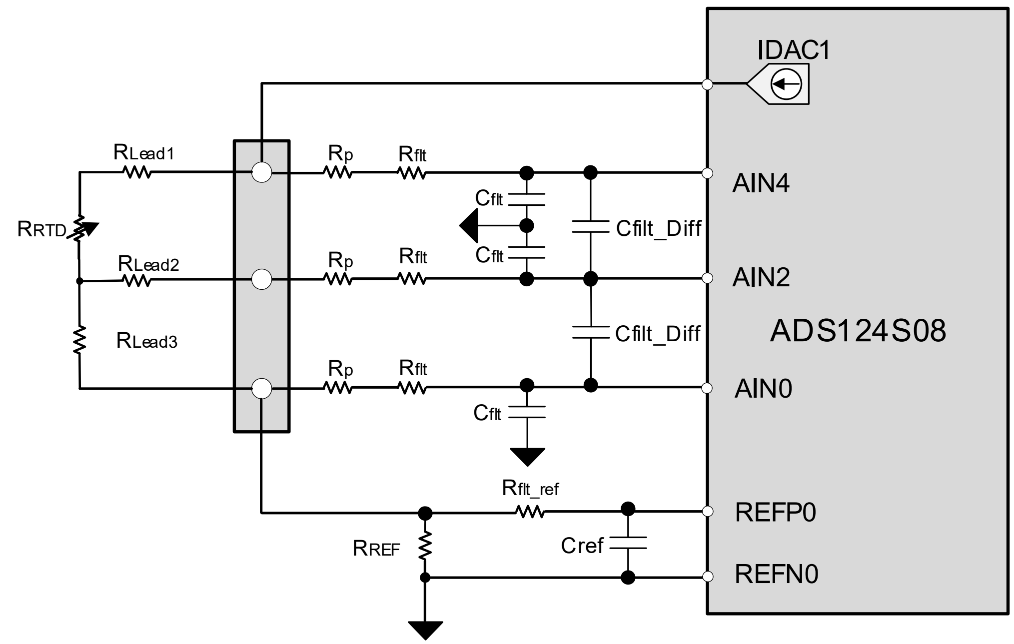


Questions: Protecting RTD input Delta-Sigma

2. For the circuit below, what is the purpose of Rfilt?
   a. Rfilt limits the input current to the ESD diodes and sets the filter cutoff frequency
   b. Rfilt protects the TVS diode
   c. Rfilt minimizes system noise



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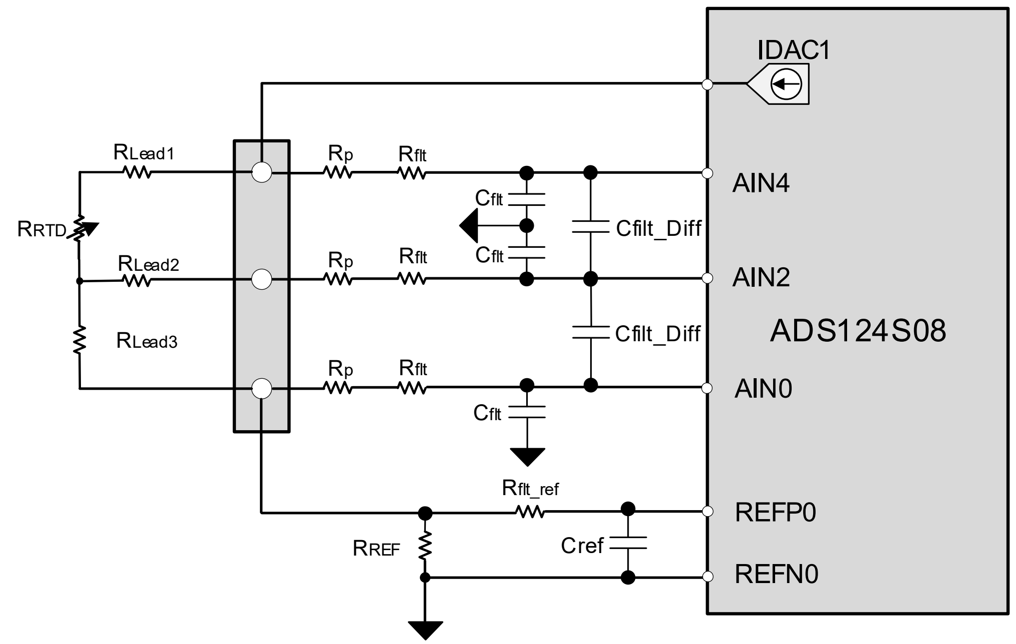

Thanks for your time!