ELEC 207
Instrumentation and Control

Example – Strain and Temperature Measurements

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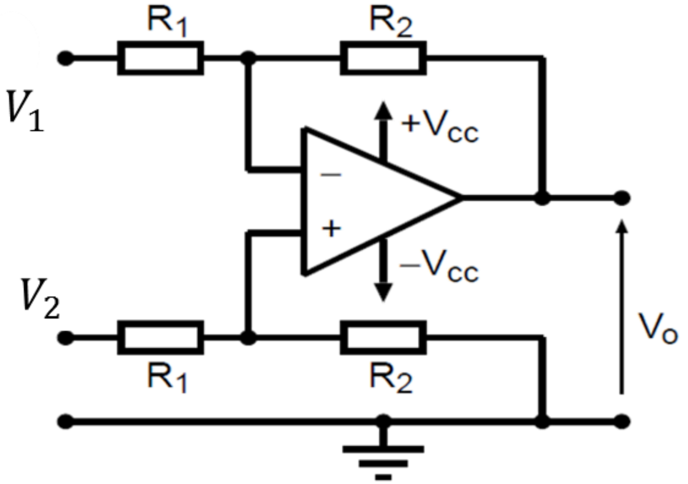
Strain measurement

Problem definition

Four identical strain gauges, with nominal resistance of 120 Ω and gauge factor equal to 2.1, are connected to a deflection bridge in **full bridge** configuration. The bridge supply voltage is 10 V:

1) Calculate the **strain** experienced by each strain gauge and the corresponding **resistance variation**, when the measured output voltage of the bridge is 31.5 mV;

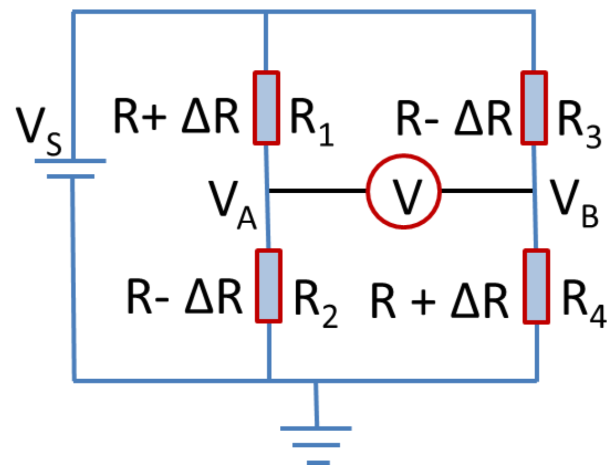
2) The **differential amplifier** shown in the figure is connected to the output of the bridge. Choose a suitable ratio between the resistances R_2 and R_1 so that a strain of 1000 microstrains produces an overall output voltage (V_o) of 1 V.



Strain measurement

Solution of Q1 – Strain calculation

In the full bridge configuration, the relationship between the strain and the bridge voltage is:



$$V_{out} = V_s \frac{\Delta R}{R} = V_s G e$$

- Therefore the **strain** corresponding to a measured output voltage of 31.5 mV is:

$$e = \frac{1}{G}\frac{V_{out}}{V_s} = 1.5 \cdot 10^{-3} = 1500 \text{ microstrains}$$

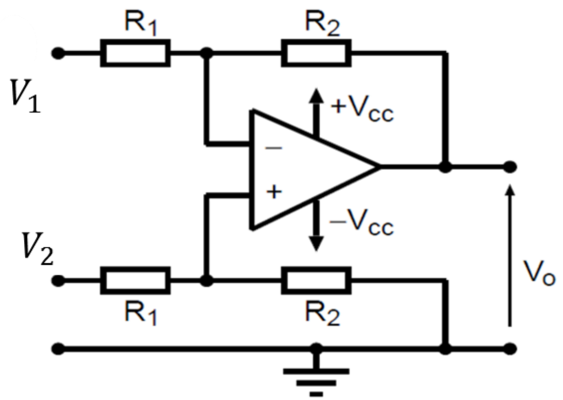
- And the corresponding **resistance variation** is:

$$\Delta R = RGe = 0.378\ \Omega$$

Strain measurement

Solution of Q2 – Amplifier design

The gain of the differential amplifier shown in the figure is R_2/R_1:



$$V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

The **output voltage of the bridge** produced by 1000 microstrains is:

$$V_{out} = V_2 - V_1 = V_s G e = 21 \text{ mV}$$

- Therefore the required **gain of the amplifier** in order to have V_o = 1 V is:

$$\frac{R_2}{R_1} = \frac{V_o}{V_2 - V_1} = 47.62$$

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Temperature measurement

Problem definition (1)

A **thermocouple** is used to measure the oil temperature in an engine.

The following table is provided by the thermocouple manufacturer, valid for a reference temperature of 0 ºC:

°C	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.059	0.118	0.176	0.235	0.294	0.354	0.413	0.472	0.532	0.591
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.010	1.071	1.131	1.192
20	1.192	1.252	1.313	1.373	1.434	1.495	1.556	1.617	1.678	1.740	1.801
30	1.801	1.862	1.924	1.986	2.047	2.109	2.171	2.233	2.295	2.357	2.420
40	2.420	2.482	2.545	2.607	2.670	2.733	2.795	2.858	2.921	2.984	3.048
50	3.048	3.111	3.174	3.238	3.301	3.365	3.429	3.492	3.556	3.620	3.685
60	3.685	3.749	3.813	3.877	3.942	4.006	4.071	4.136	4.200	4.265	4.330
70	4.330	4.395	4.460	4.526	4.591	4.656	4.722	4.788	4.853	4.919	4.985
80	4.985	5.051	5.117	5.183	5.249	5.315	5.382	5.448	5.514	5.581	5.648
90	5.648	5.714	5.781	5.848	5.915	5.982	6.049	6.117	6.184	6.251	6.319

mV

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Temperature measurement

Problem definition (2)

Answer the following questions:

1) If the **reference junction is kept at 0 ºC**, what is the oil temperature when an output voltage of 5.315 mV is measured?

2) If the **reference junction temperature is 20 ºC**, what is the oil temperature when an output voltage of 2.621 mV is measured?

3) In the same conditions as question 2) (same oil temperature), what would be the resistance of a **platinum RTD**, if its resistance at 0 ºC is 100 Ω? A linear approximation of $R(T)$ can be used, and the temperature coefficient of platinum is 0.00385 $ºC^{-1}$.

Temperature measurement

Solution of Q1 – Temperature calculation

If the reference junction is at 0 ºC, the manufacturer’s table can be directly applied:

- The **temperature** corresponding to 5.315 mV is therefore 85 ºC.

°C	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.059	0.118	0.176	0.235	0.294	0.354	0.413	0.472	0.532	0.591
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.010	1.071	1.131	1.192
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mV

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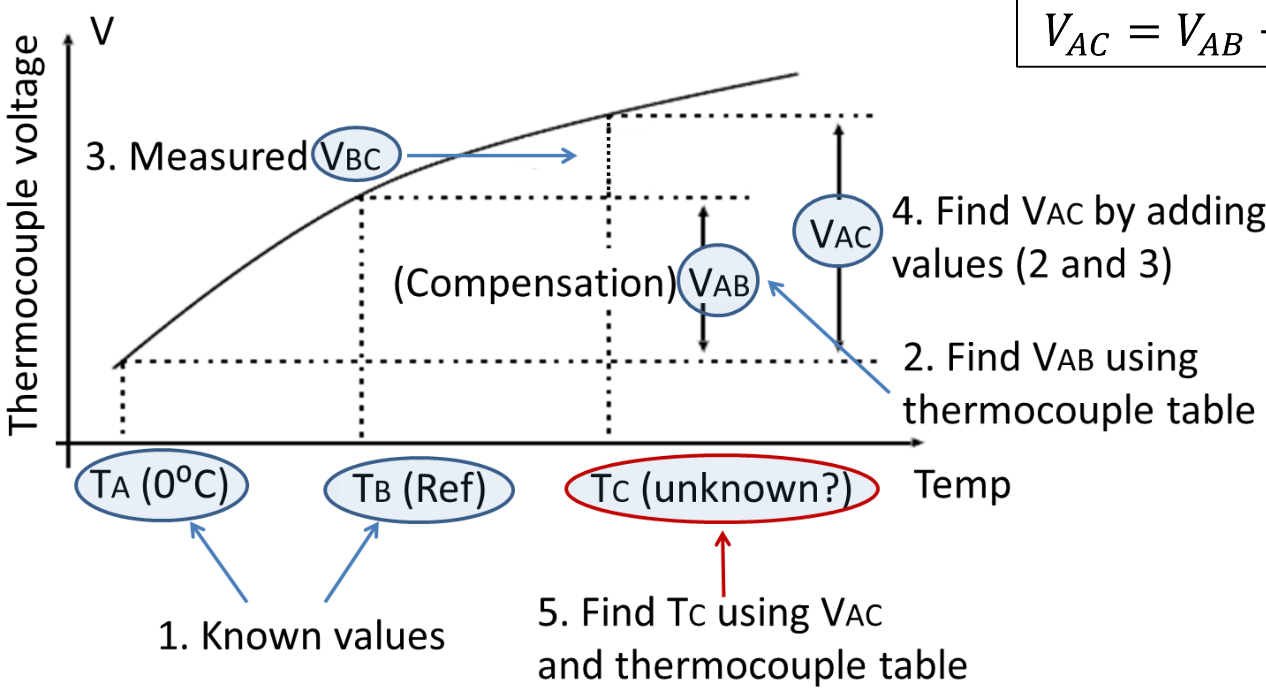
Temperature measurement

Solution of Q2 – Reference junction compensation (1)

If the reference junction is at 20 ºC, a **reference junction compensation** is necessary:

$$V_{AC} = V_{AB} + V_{BC}$$



Temperature measurement

Solution of Q2 – Reference junction compensation (2)

- The voltage corresponding to 20 ºC (cold junction) is 1.192 mV;
- The **compensated voltage** of the hot junction is 2.621 + 1.192 = 3.813 mV;
- The **hot junction temperature** is therefore 62 ºC.

°C	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.059	0.118	0.176	0.235	0.294	0.354	0.413	0.472	0.532	0.591
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.010	1.071	1.131	1.192
20	1.192	1.252	1.313	1.373	1.434	1.495	1.556	1.617	1.678	1.740	1.801
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mV

Temperature measurement

Solution of Q3 – RTD resistance calculation

The linearized relationship between resistance and temperature in a RTD is:

$$R(T) = R_0(1 + a\Delta T)$$

- In this case:

$$R_0 = 100\ \Omega$$

$$a = 0.00385\ ℃^{-1}$$

$$\Delta \mathrm{T} = 62\ ℃\ - 0\ ℃ = 62\ ℃$$

- Therefore the **resistance at 62 ºC** is:

$$R(62℃) = 123.87\ \Omega$$