ELEC 207
Instrumentation and Control

5 – Deflection Bridge and Amplifier

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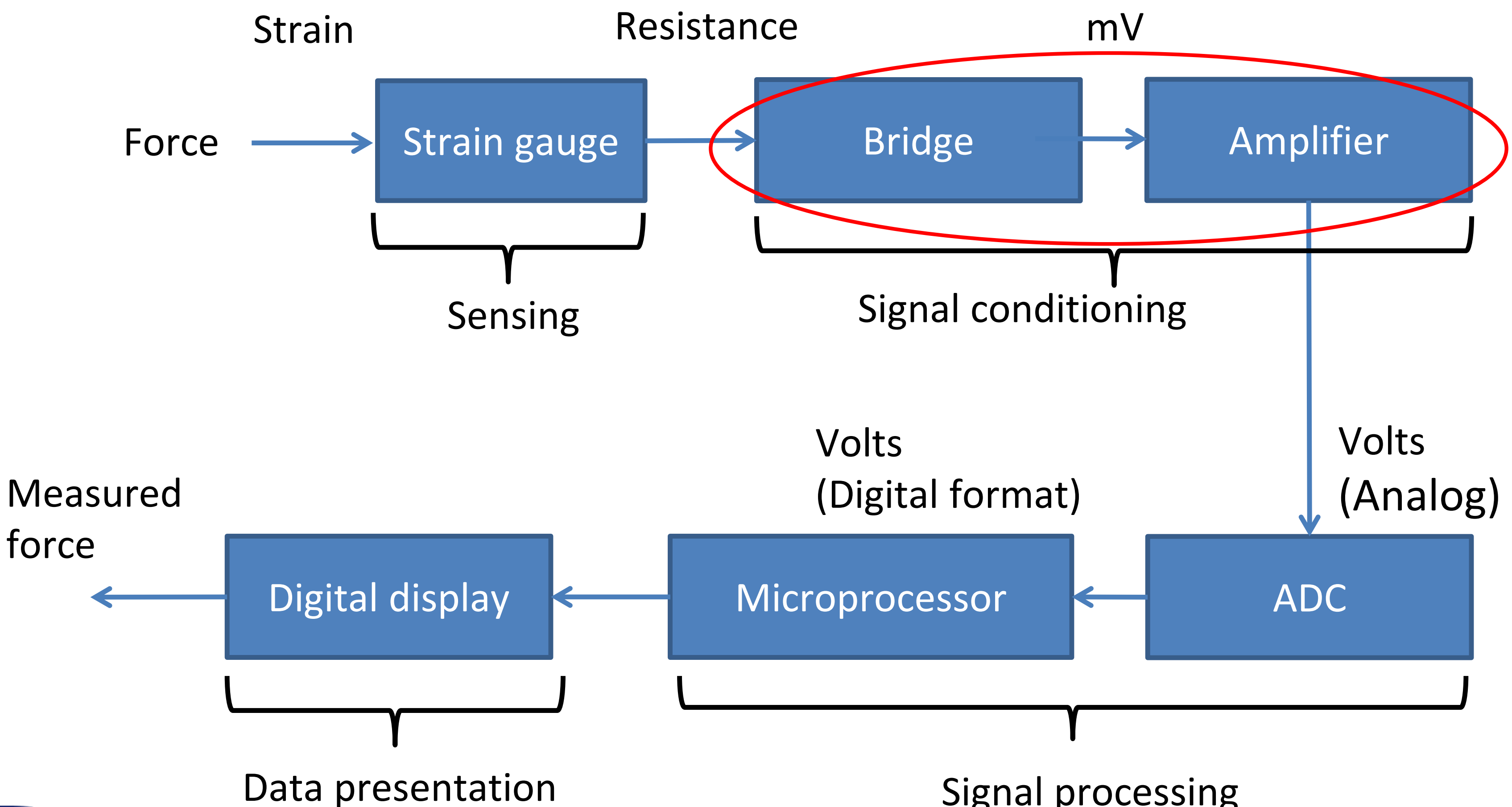
Strain measurement

Signal conditioning for strain gauge

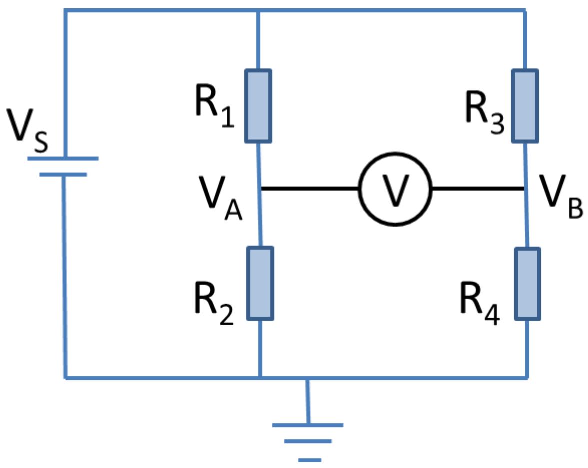


Deflection bridge

Signal conditioning

A **deflection bridge** is used to convert the output **impedance** of a transducer into a voltage:

- In case of a strain gauge, the output impedance is a resistance, so a **DC bridge** can be used;
- If the bridge output voltage is too low, it can be amplified by an **amplifier**.



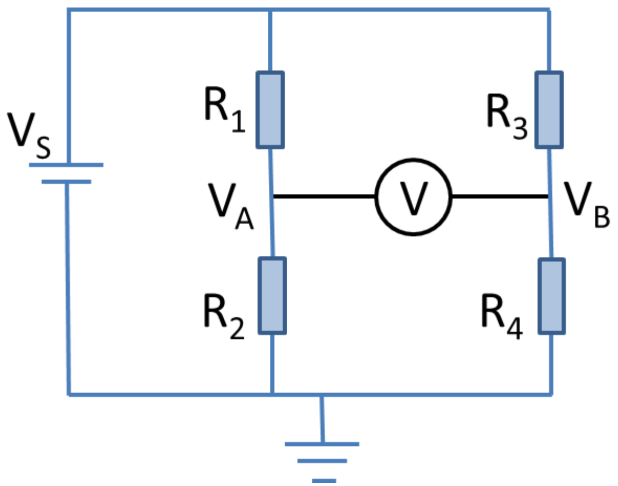
Deflection bridge

Principle of operation

- The bridge is **balanced** if $V_A = V_B$, so $V_{AB} = 0$:

$$V_s \frac{R_2}{R_1 + R_2} = V_s \frac{R_4}{R_3 + R_4}$$

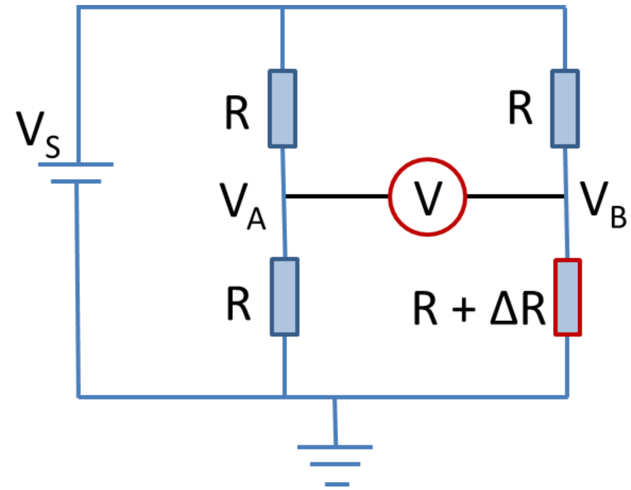
$$\Longrightarrow \quad \frac{R_2}{R_1} = \frac{R_4}{R_3}$$



- One of these resistances could be the strain gauge resistance:
  - If the resistance changes, the bridge is no longer balanced and a voltage between A and B appears: $V_{AB} \neq 0$.

Deflection bridge
Quarter bridge

In a quarter bridge only a single arm of the bridge is connected to the output of the transducer (e.g. strain gauge):



- The highest sensitivity is achieved when all resistances have the same nominal value (R);
- A change in resistance (ΔR) corresponds to a change in the **output voltage**:

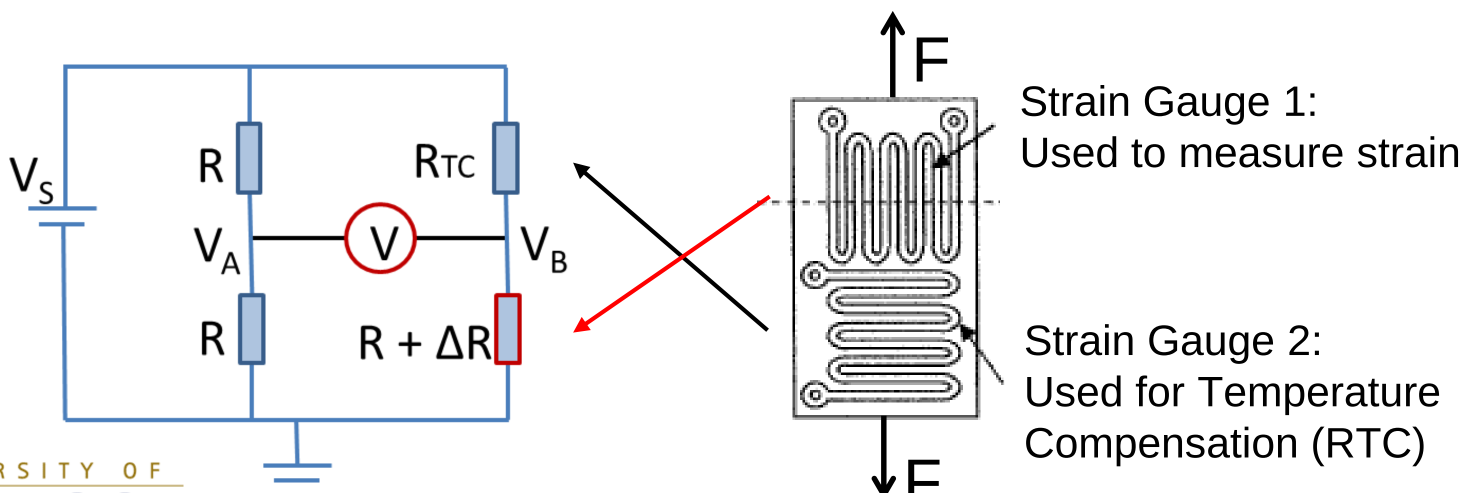
$$V_{out} = V_B - V_A = V_s \frac{R + \Delta R}{R + R + \Delta R} - V_s \frac{R}{R + R} =$$

$$= V_s \left(\frac{R + \Delta R}{2R + \Delta R} - \frac{1}{2} \right) = V_s \frac{2(R + \Delta R) - (2R + \Delta R)}{2(2R + \Delta R)} \approx V_s \frac{\Delta R}{4R} = \frac{1}{4} V_s G e$$

Deflection bridge
Temperature compensation

The resistance of the strain gauge can change also because of **temperature variations**, not only because of the strain:

- In order to accurately measure the strain, a **compensation** of the change due to temperature variation is required:
  - One option is to use a **dummy strain gauge**, which is not strained.



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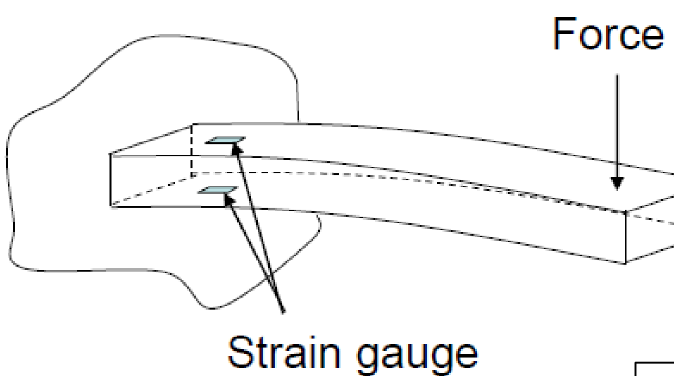
Deflection bridge

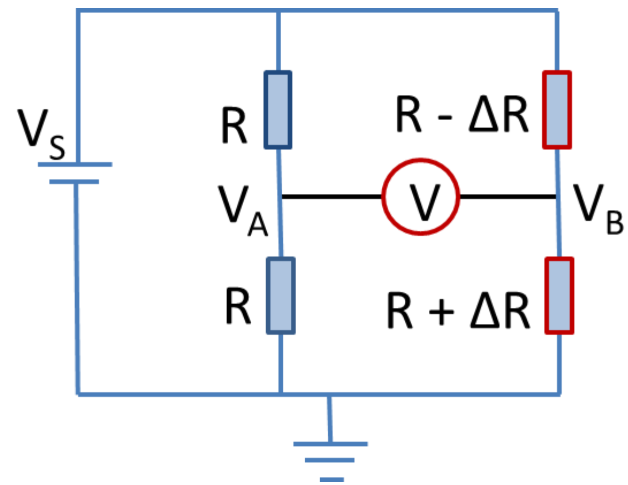
Half bridge

In a half bridge **2 equal strain gauges** are used to double the output voltage:

- One strain gauge is expanded (+ΔR), the other one is compressed (-ΔR);



$$V_{out} = \frac{1}{2} V_s G e$$

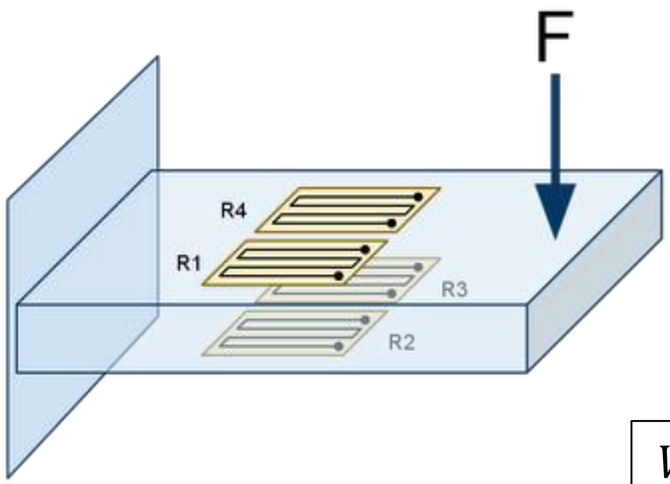


- The two strain gauges automatically achieve temperature compensation.

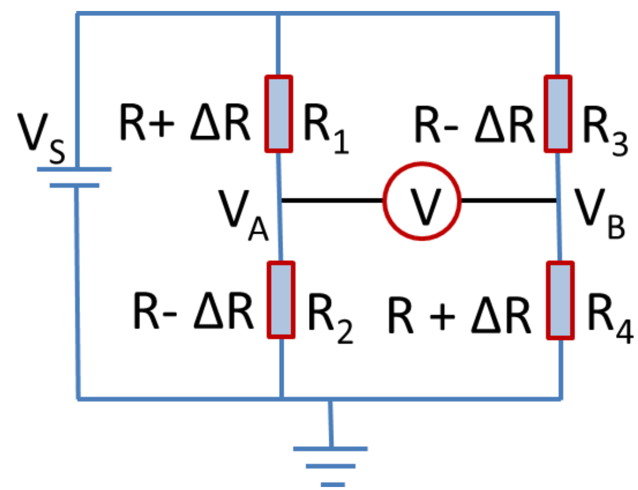
Deflection bridge
Full bridge

In a full bridge **4 strain gauges** are used to further increase the output voltage:

- Two strain gauges are expanded (+ΔR), two are compressed (-ΔR);



$$V_{out} = V_s G e$$

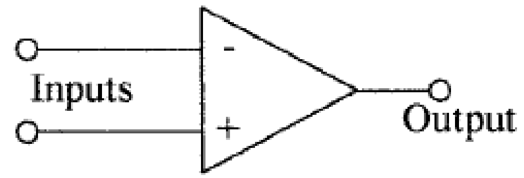


- The temperature compensation is again automatically achieved.

Signal amplification

Differential amplifier

Signal amplifiers are based on **operational amplifiers**:

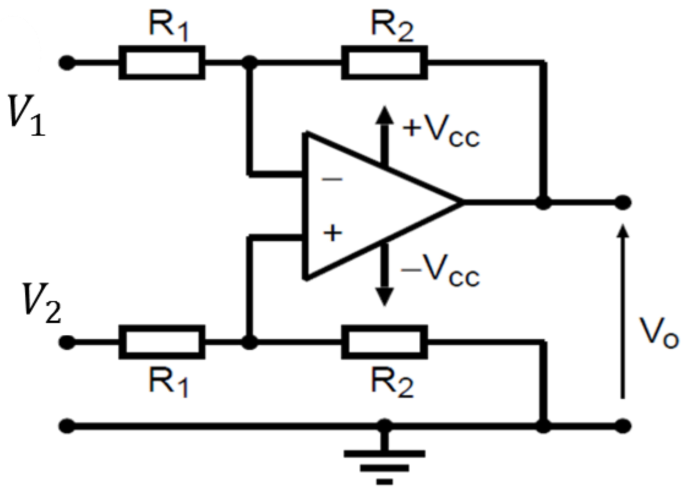


- An amplifier that amplifies the difference between two signals is called **differential amplifier**:

$$V_- = V_+ = \frac{R_2}{R_1 + R_2} V_2$$

$$V_o = V_- - R_2 \frac{V_1 - V_-}{R_1}$$

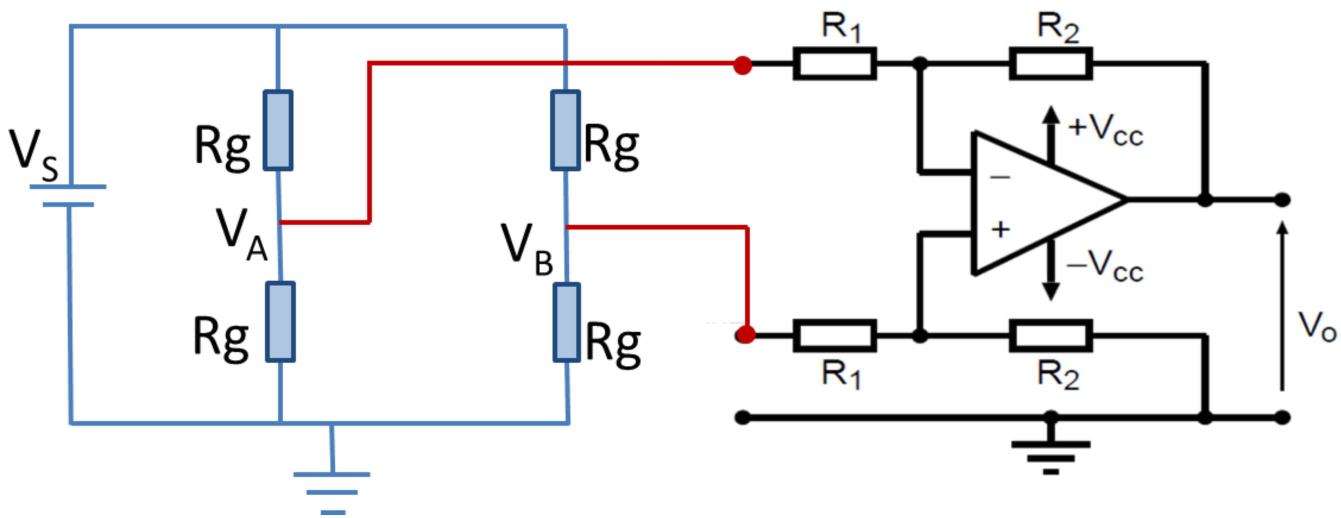
$$\Longrightarrow \quad V_o = \underbrace{\frac{R_2}{R_1}}_{\text{gain}} (V_2 - V_1)$$



Signal amplification

Differential amplifier connected to a bridge

Example of a complete signal conditioning element (**full bridge + amplifier**):



- The overall output voltage is:

$$V_o = \frac{R_2}{R_1}(V_B - V_A) = \frac{R_2}{R_1} V_s G e$$

References

Textbook: Principles of Measurement Systems, 4th ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Bentley** textbook:

- Chapter 9, Sec. 9.1.1: **Thévenin equivalent circuit for a deflection bridge**;

- Chapter 9, Sec. 9.1.2: **Design of resistive deflection bridges**;

- Chapter 9, Sec. 9.2.1: **The ideal operational amplifier and its applications**.

NOTE: Topics not covered in the lecture are not required for the exam.

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References

Textbook: Measurement and Instrumentation, 2^{nd} ed.

For further explanation about the points covered in this lecture, please refer to the following chapters and sections in the **Morris-Langari** textbook:

- Chapter 7, Sec. 7.2.2: **Deflection-type DC bridge**;
- Chapter 6, Sec. 6.9: **Signal amplification**.

NOTE: Topics not covered in the lecture are not required for the exam.