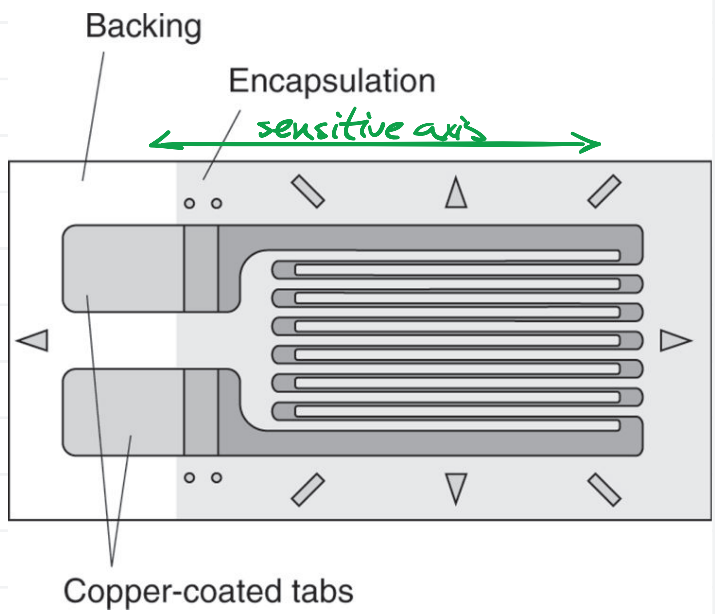
Strain gages

A strain gage is a resistive sensor used to measure strain. The resistance of a conductor varies with changes in its length and cross-sectional area. A straing gage can be thought of as a long, thin wire that changes resistance as it is stretched along its length. The figure shows a typical strain gage.



Strain gages are characterized by their engineering gage factor

$$G_e \equiv \frac{\Delta R/R}{\Delta l/l} \leftarrow \text{strain } \varepsilon$$

where R + ΔR are the nominal + change in resistance and l + Δl are the nominal + change in length of the wire.

The gage factor is typically around 2, and is usually provided by the manufacturer.

Strain gages with wheatstone bridges

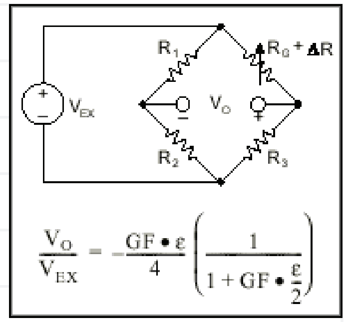
(figures from NI white paper "Measuring Strain with Strain Gages," 2014)

In practice, strain gages are nearly always used with wheatstone bridge circuits for signal transduction. We will look three possible configurations.

The quarter-bridge

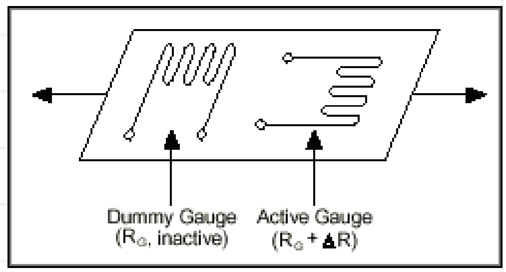
If we begin with a balanced bridge that has, as one of its arms, a strain gage, as shown in the next figure, we can relate ratios of output to input voltages to strain (using the definition of G_e and the bridge circuit analysis). In our notation,

$$\frac{V_o}{V_{EX}} = -\frac{G_e \varepsilon}{4} \cdot \frac{1}{1 + G_e\varepsilon/2}.$$



The half-bridge

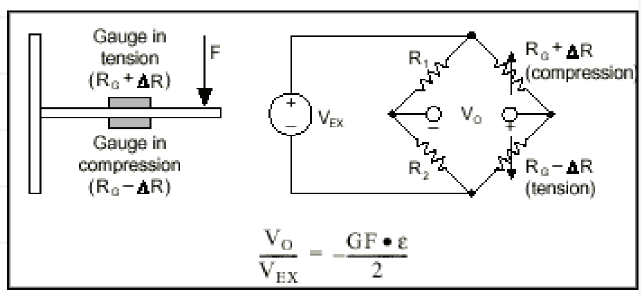
In order to mitigate measurement errors due to temperature effects on the resistance of strain gages, sometimes we use a second arm of the bridge (to complete one "side") as another — dummy — strain gage. This gage is placed in the transverse direction such that it experiences very little strain, yet is near-enough the active gage to change resistance with the same temperature change.



Since the bridge equation includes only ratios of resistance along each side, both gages changing together has no effect.

Another half-bridge application doubles the sensitivity. If the application allows, the second gage can be arranged to be in compression when the first is in tension and vice-versa. We write

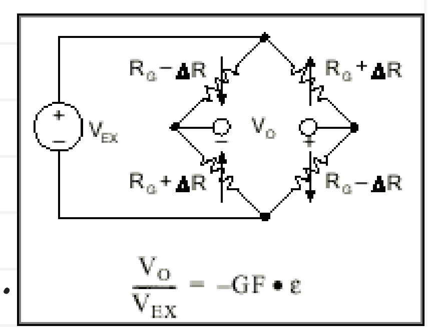
$$\frac{V_o}{V_{EX}} = -\frac{G_e \varepsilon}{2}.$$



The full-bridge

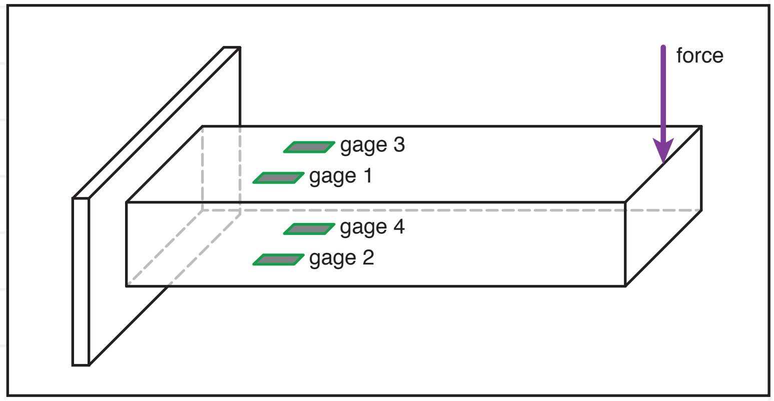
The full bridge adds additional sensitivity. It yields

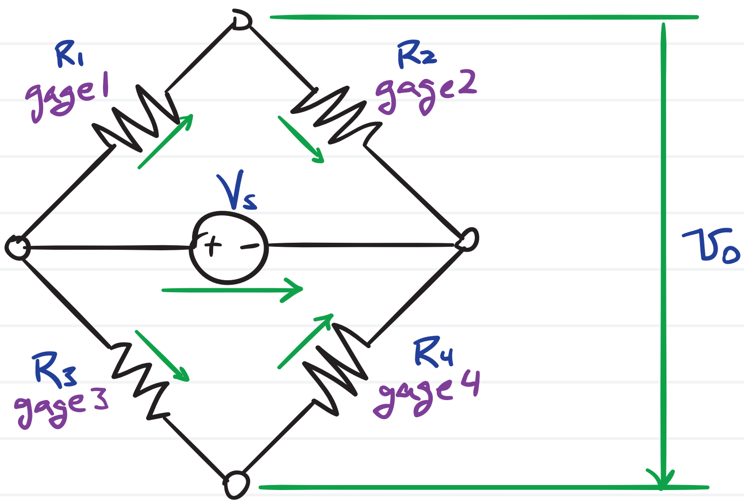
$$\frac{V_o}{V_{EX}} = -G_e \varepsilon.$$



Example

Consider the loaded beam with four strain gages in the figure. Let the gages be connected in the wheatstone bridge configuration shown.





If we measure $v_o = 1\,mV$ after balancing the bridge and then loading it, what is the strain ε? Let the strain gages have engineering gage factors of $G_e = 2$. We are using a voltage source $V_s = 12\,V$.

Solution: we are using a full-bridge, therefore:

$$\frac{v_o}{V_s} = -G_e \varepsilon$$

$$\Rightarrow \varepsilon = -\frac{v_o}{G_e V_s}$$

$$= -\frac{0.001}{2 \cdot 12}$$

$$= 4.17e{-5}.$$