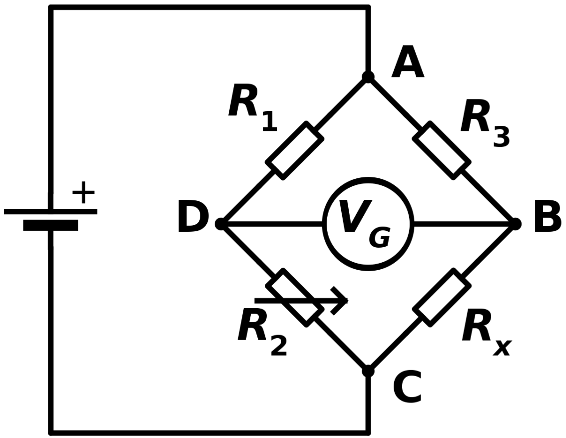

Wheatstone Bridges and Load Cells

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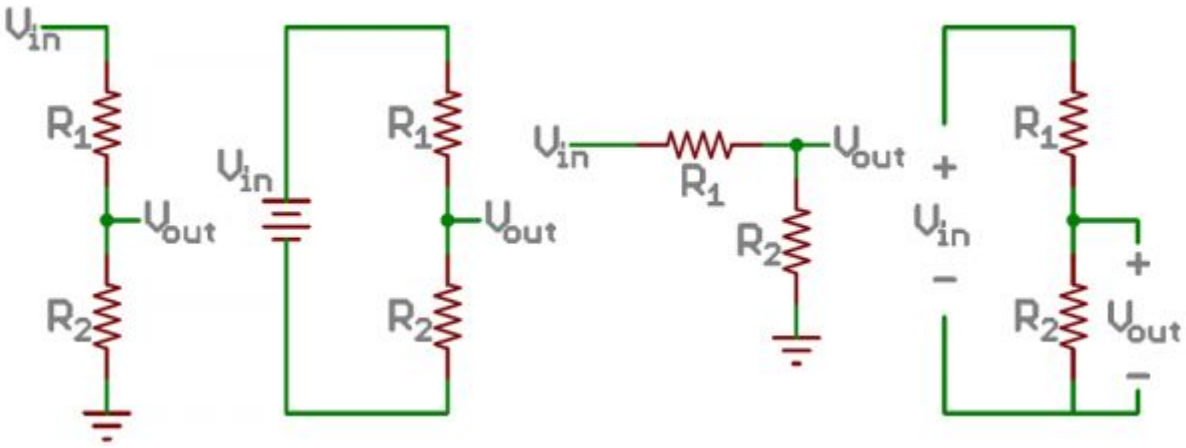
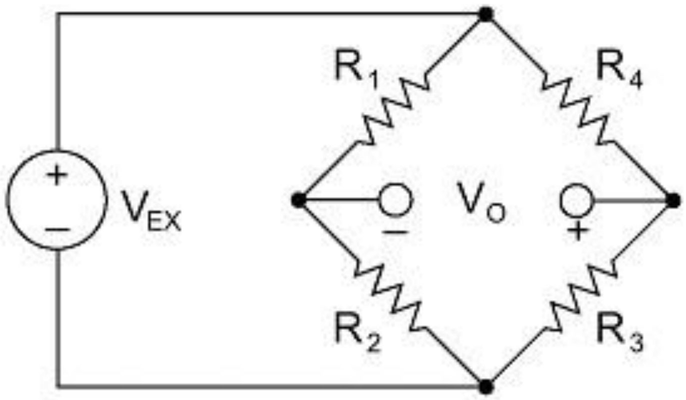
Image: WikiPedia, Omega

Remember the voltage divider? It's back!



$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

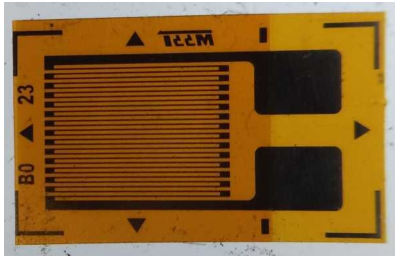
Wheatstone bridges are a great way to precisely measure changes in resistance at the expense of differential output



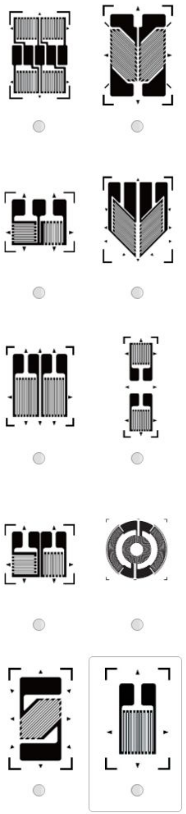
$$V_o = V_i \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right]$$

Images: National Instruments

Strain is measured with strain gauges and forms the basis for many other sensing technologies



$$GF = \frac{\frac{\Delta R}{R}}{\epsilon}$$



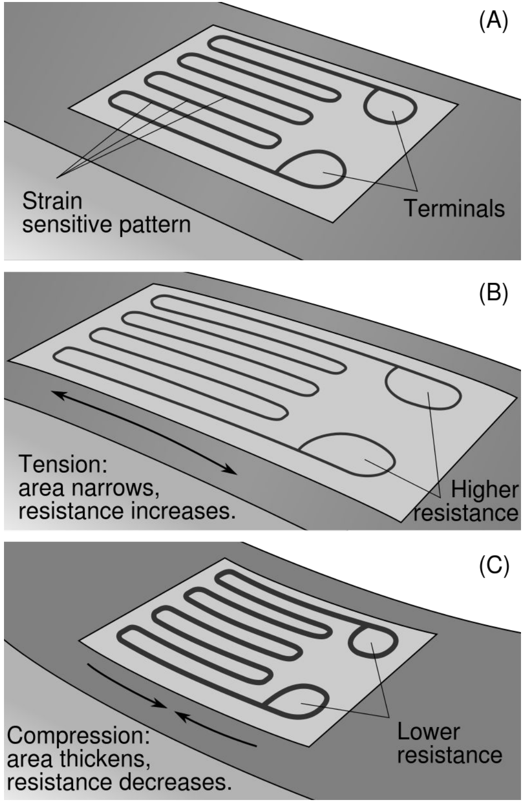


Image: dsfs

Strain gauges can be arranged in a variety of ways to measure different components of strain

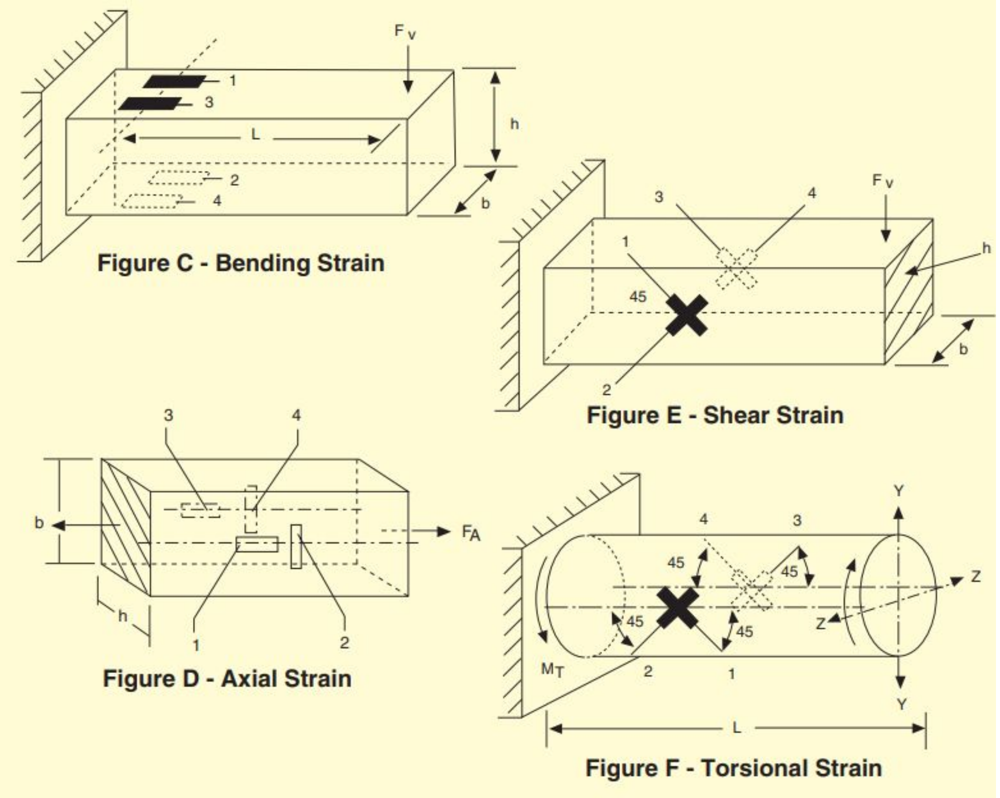


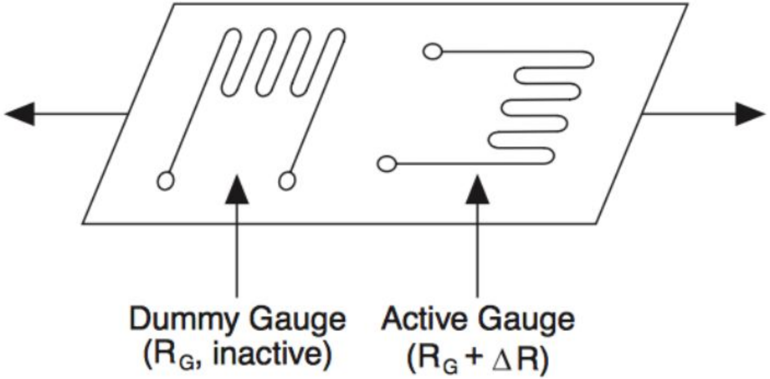
Image: Omega

Measurement Type	Quarter Bridge		Half-Bridge		Full-Bridge		
	Type I	Type II	Type I	Type II	Type I	Type II	Type III
Axial Strain	Yes	Yes	Yes	No	No	No	Yes
Bending Strain	Yes	Yes	Yes	Yes	Yes	Yes	No
Compensation							
Transverse Sensitivity	No	No	Yes	No	No	Yes	Yes
Temperature	No	Yes	Yes	Yes	Yes	Yes	Yes
Sensitivity							
Sensitivity at 1000 με	~0.5 mV/V	~0.5 mV/V	~0.65 mV/V	~1.0 mV/V	~2.0 mV/V	~1.3 mV/V	~1.3 mV/V
Installation							
Number of Bonded Gages	1	1*	2	2	4	4	4
Mounting Location	Single Side	Single Side	Single Side	Opposite Sides	Opposite Sides	Opposite Sides	Opposite Sides
Number of Wires	2 or 3	3	3	3	4	4	4
Bridge Completion Resistors	3	2	2	2	0	0	0

*A second strain gage is placed in close thermal contact with structure but is not bonded.

Image: National Instruments

We often use dummy gauges (not bonded or bonded in an unstrained direction) to compensate for temperature



$$\frac{\Delta R}{R} = \mathrm{GF}\epsilon + \alpha\Delta T$$

Image: National Instruments

Bonding, placement, wiring, resistance testing, and more are required and each with a lot of odd sensitivities

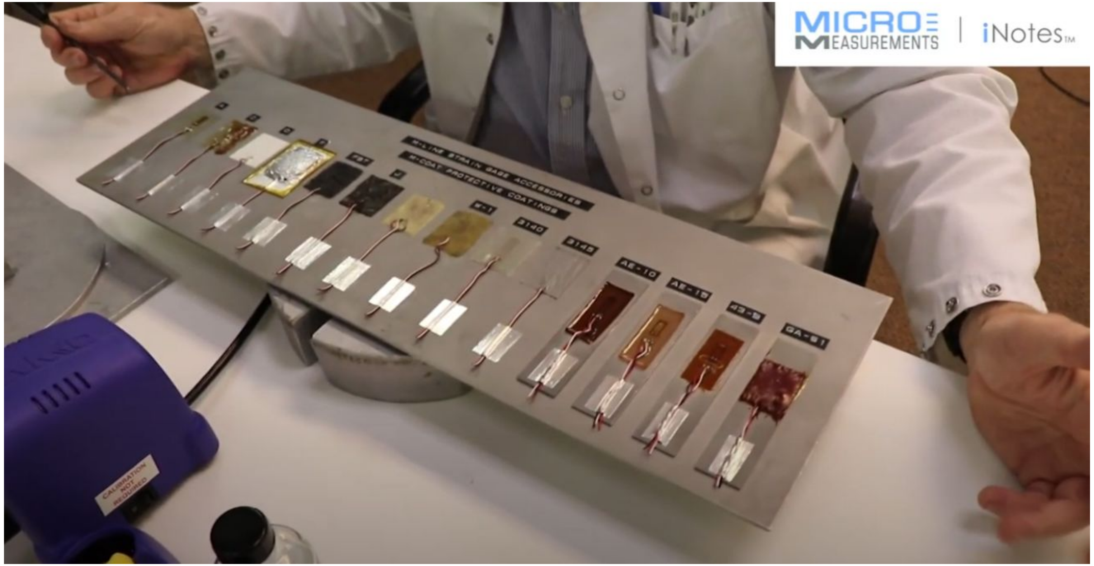
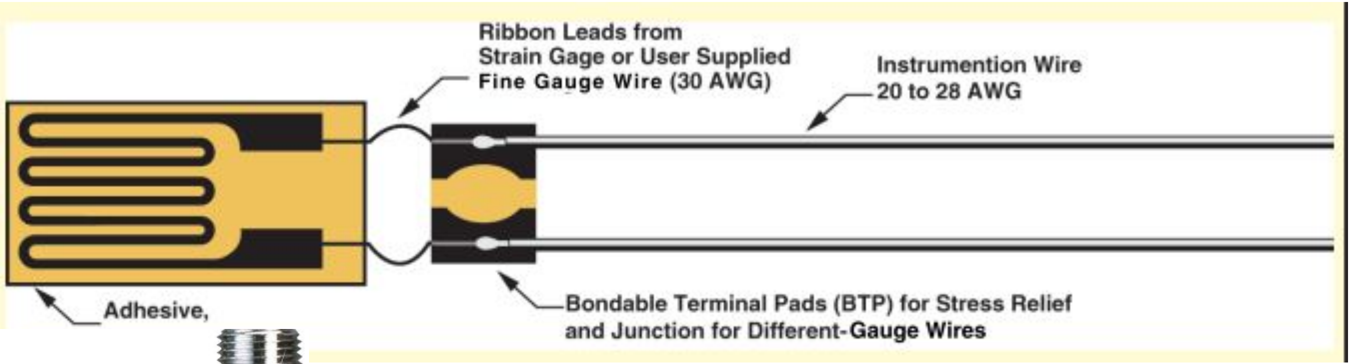
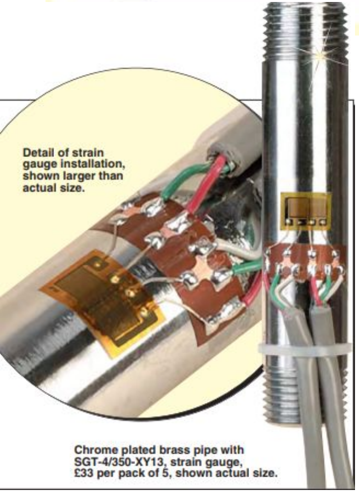
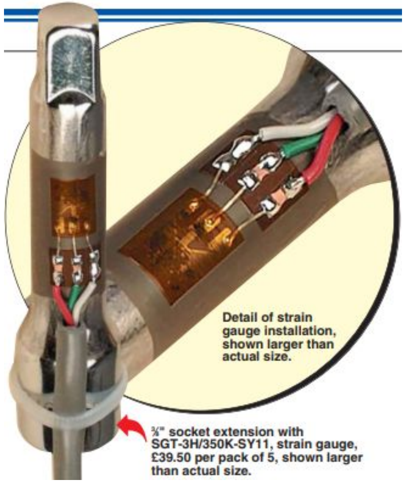


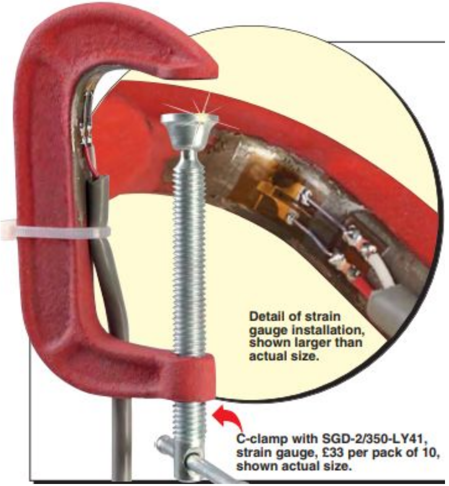
Image: Micromeasurements

Managing heat is the trickiest part of installing strain gauges









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Images: Omega

Installation is done in a few simple steps

1. Clean everything to a smooth wettable surface (including tools!)
2. Mark orientation of gage
3. Bond gauge without touching it
4. Clean
5. Solder connections
6. Clean again
7. Apply protective coating

If you're designing a load cell, there is math to predict the response!

$$\lambda = \frac{G(E-2G)}{3G-E}$$

$$\epsilon_1 = \sigma_1 \frac{(\lambda + G)}{G(3\lambda + 2G)} - \sigma_2 \frac{\lambda}{2G(3\lambda + 2G)} - \sigma_3 \frac{\lambda}{2G(3\lambda + 2G)}$$

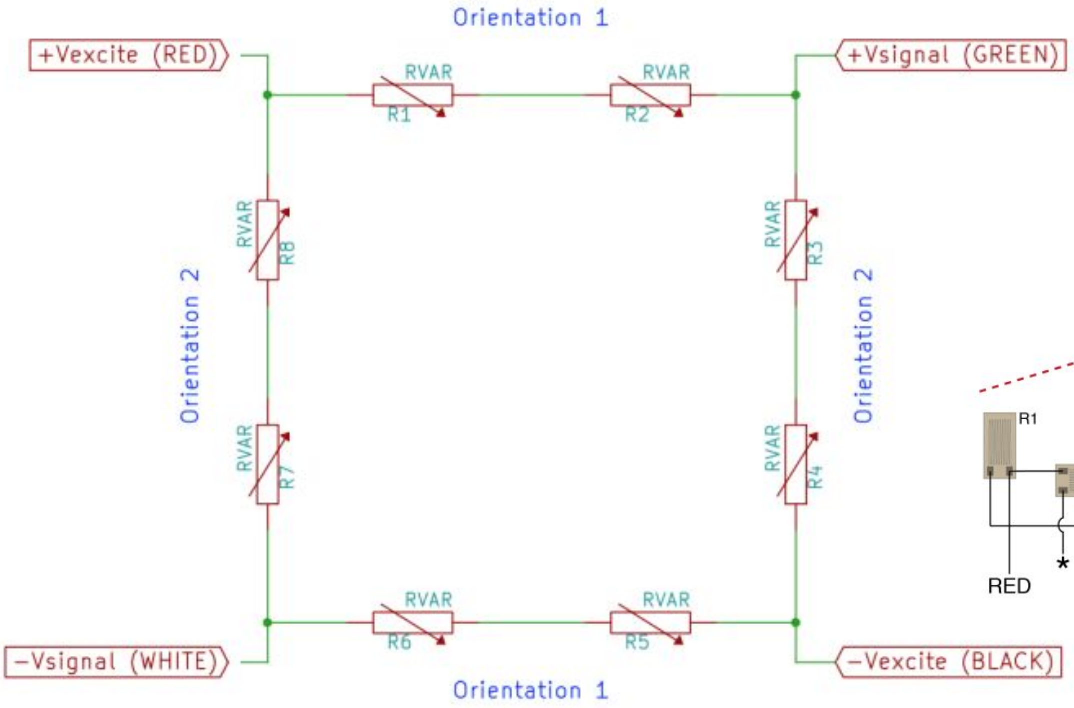
$$\epsilon_2 = -\sigma_1 \frac{\lambda}{2G(3\lambda + 2G)} + \sigma_2 \frac{(\lambda + G)}{G(3\lambda + 2G)} - \sigma_3 \frac{\lambda}{2G(3\lambda + 2G)}$$

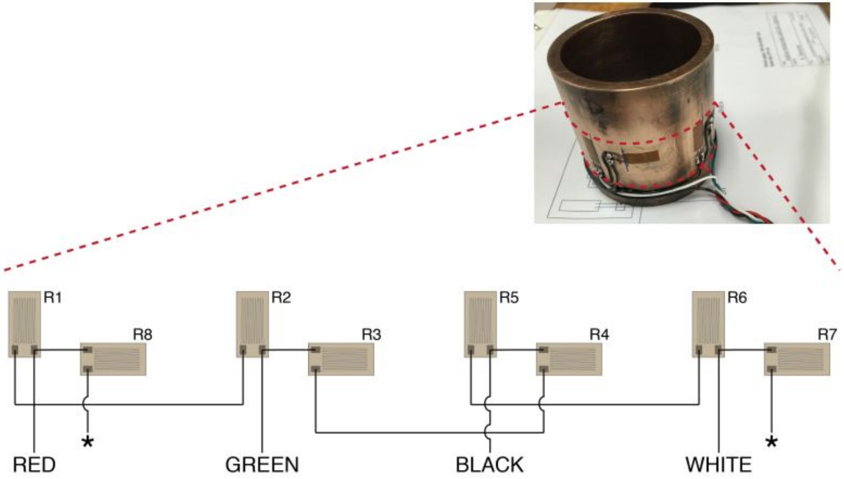
$$\epsilon_3 = -\sigma_1 \frac{\lambda}{2G(3\lambda + 2G)} - \sigma_2 \frac{\lambda}{2G(3\lambda + 2G)} + \sigma_3 \frac{(\lambda + G)}{G(3\lambda + 2G)}$$

$$\epsilon_c = \frac{\Delta c}{c_i} = \frac{\pi(d_f - d_i)}{\pi d_i}$$

Let’s calculate the response of our load cell that we’ll build

We do often use 8 gauge cells to enhance the response





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