The Strain Gauge

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What is Strain?

- Strain is elongation or deformation of a solid body due to forces applied to it
- Physical units of strain or delta length over length
- Practical units of strain for stretching or compression stress is microstrains, or parts per million of elongation
- Compression is denoted by negative strain

What is a Strain Gauge?

- Uses resistance of magnet wire
- Resistance increases as it stretches
- Resistance of a medium:

$$R_0 = \frac{\sigma \cdot Length}{Area} = \frac{\sigma \cdot Length^2}{Volume}$$

- If the volume stays constant as the wire is stretched an incremental amount δL, the resistance increases

Resistance vs. Stretching

- Resistance increases as it stretches

$$R = \frac{\sigma \cdot \left(Length + \delta L\right)^2}{Area}$$
$$\approx \frac{\sigma \cdot \left(Length^2 + 2 \cdot Length \cdot \delta L\right)}{Area}$$
$$= \left(1 + 2 \cdot \frac{\delta L}{Length}\right) \cdot R_0$$

The Gauge Factor

- Actual strain gauge resistance is

$$R = \left(1 + K \cdot \frac{\delta L}{Length}\right) \cdot R_0$$

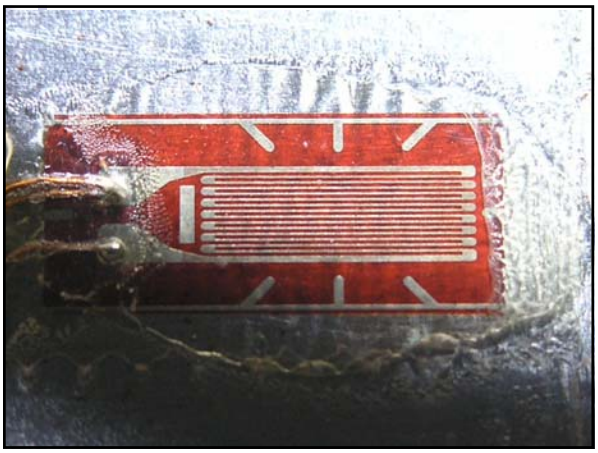
- The factor *K* is the *gauge factor*
  - Theoretical value is 2
  - Actual value can vary due to
    - Physics of stretching
    - Temperature
    - Backing, adhesive
    - Small differences during manufacturing
- Calibration of the gauge factor is necessary for best accuracy

Practical Aspects of Strain Gauge Configuration

- Requirements
  - Must easy to apply to material
  - Must be easy to use
  - Must have minimal effect on the strain being measured
- Configuration
  - Make very small
    - Physically weak compared to most materials
    - Satisfy ease of application and minimal effect on strain
  - Use folded configuration instead of straight wire
    - Keep total strain gauge size small
    - Measure the strain over a small area
    - Addresses all three requirements

How Strain Gauges are Used

- Apply so that strain-measuring wires are in the direction of the strain being measured
- Connect the strain gauge in a Wheatstone bridge circuit
- Measure the differential resistance
- Convert the differential resistance to strain for recording the measurement



The P-3500 Strain Indicator

Usage of the P-3500

- We have two for Sophomore Clinic
- Use will be under supervision of a faculty member
- Today we present strain gauges and the P-3500
  - How a strain indicator works
  - How they are hooked to the P-3500
  - How the P-3500 is used

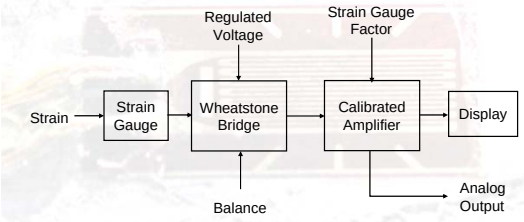
What the Strain Indicator Is

- Battery-powered
- Electronics to
  - Put the strain gauge in a Wheatstone bridge
  - Balance the bridge for zero strain
  - Measure the output of the Wheatstone bridge
  - Calibrate a four-digit display to read strain in microstrains
  - Provide a ground-referenced analog output

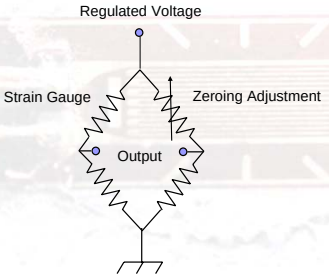
How a Strain Gauge Indicator Works

- Provides a Wheatstone bridge
  - Resistance is the nominal resistance of the strain gauge
  - One of the other resistors is varied to balance the bridge for zero strain
- A differential amplifier captures the output of the Wheatstone bridge
- A variable gain calibrates the output to microstrains
- A display provides recordable data in microstrains
- An analog output provides data for oscilloscopes, data loggers, or other purposes

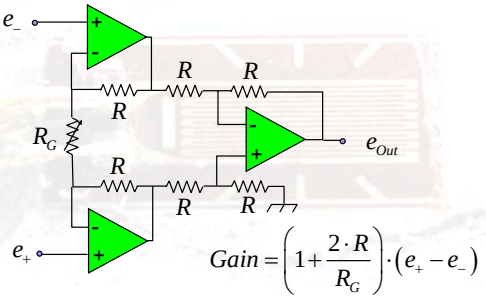
Strain Indicator



Wheatstone Bridge

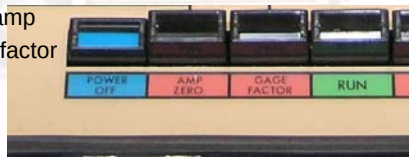


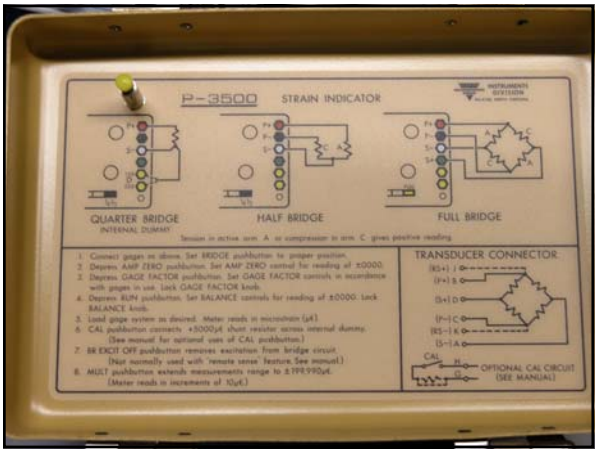
Differential Amplifier

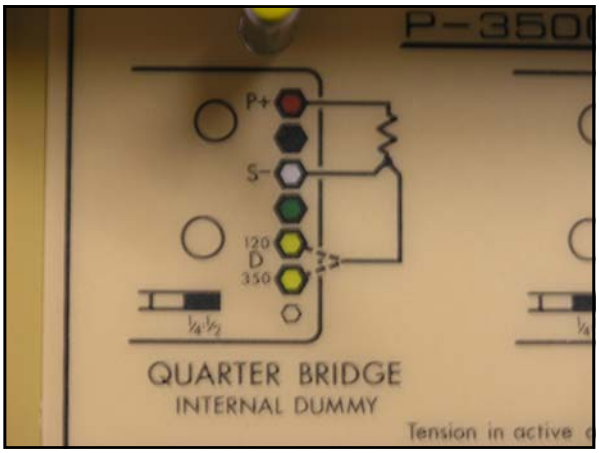


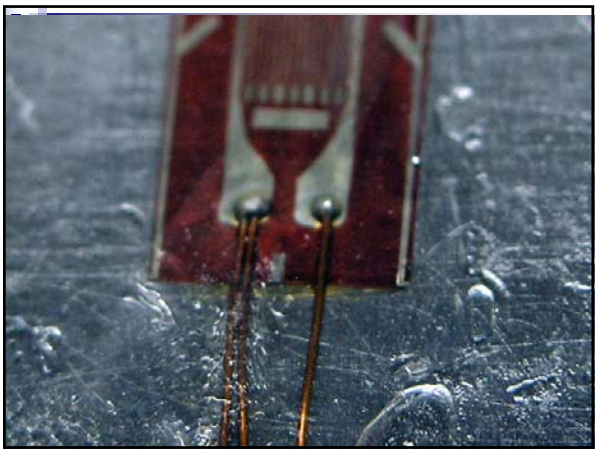
How to Operate

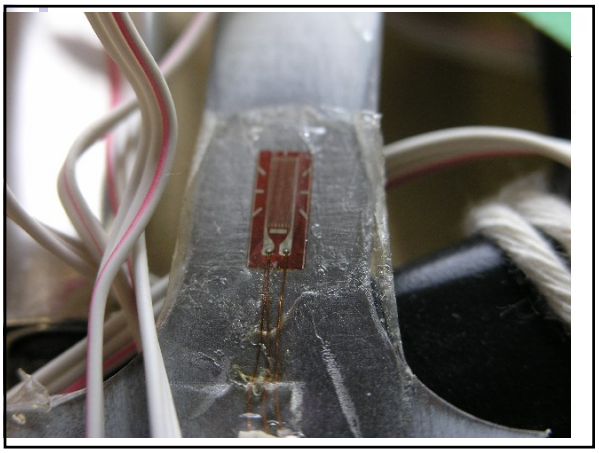
- Instructions on the inside of the lid
- We use four buttons
  - Power off
  - Zero amp
  - Gage factor
  - Run











In Use

For the Hoistinator

- Carefully select a spar for instrumentation
- Carefully select a point on the spar for a strain gauge
- Attach a strain gauge to the spar
- Relate measured strain to spar performance
  - Strain versus load
  - Failure strength
  - Failure load
- Relate measured strain to Hoistinator performance
  - Maximum safe load
  - Failure load

REMEMBER ENGINEERING SAFETY MARGINS