The Strain Gauge

James K Beard, Ph.D.

Rowan Hall Auditorium

beard@rowan.edu

http://rowan.jkbeard.com

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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

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

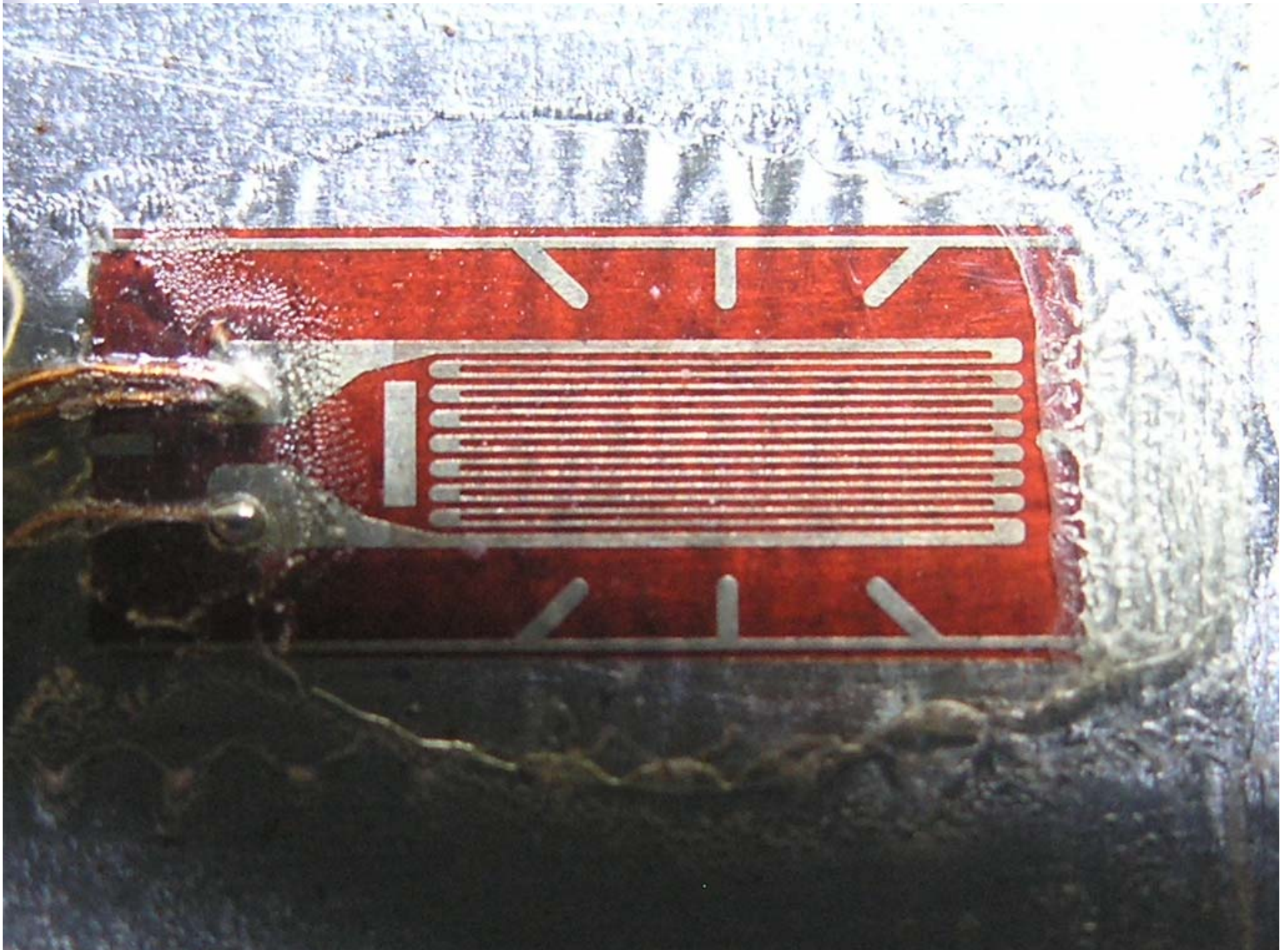
- The factor *K* is the *gauge factor*
  - Theoretical value is 2
  - Actual value can vary due to
    - Physics of stretching
    - Temperature
    - Backing, adhesive
    - Small differences during manufacturing
- Calibration of the gauge factor is necessary for best accuracy

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



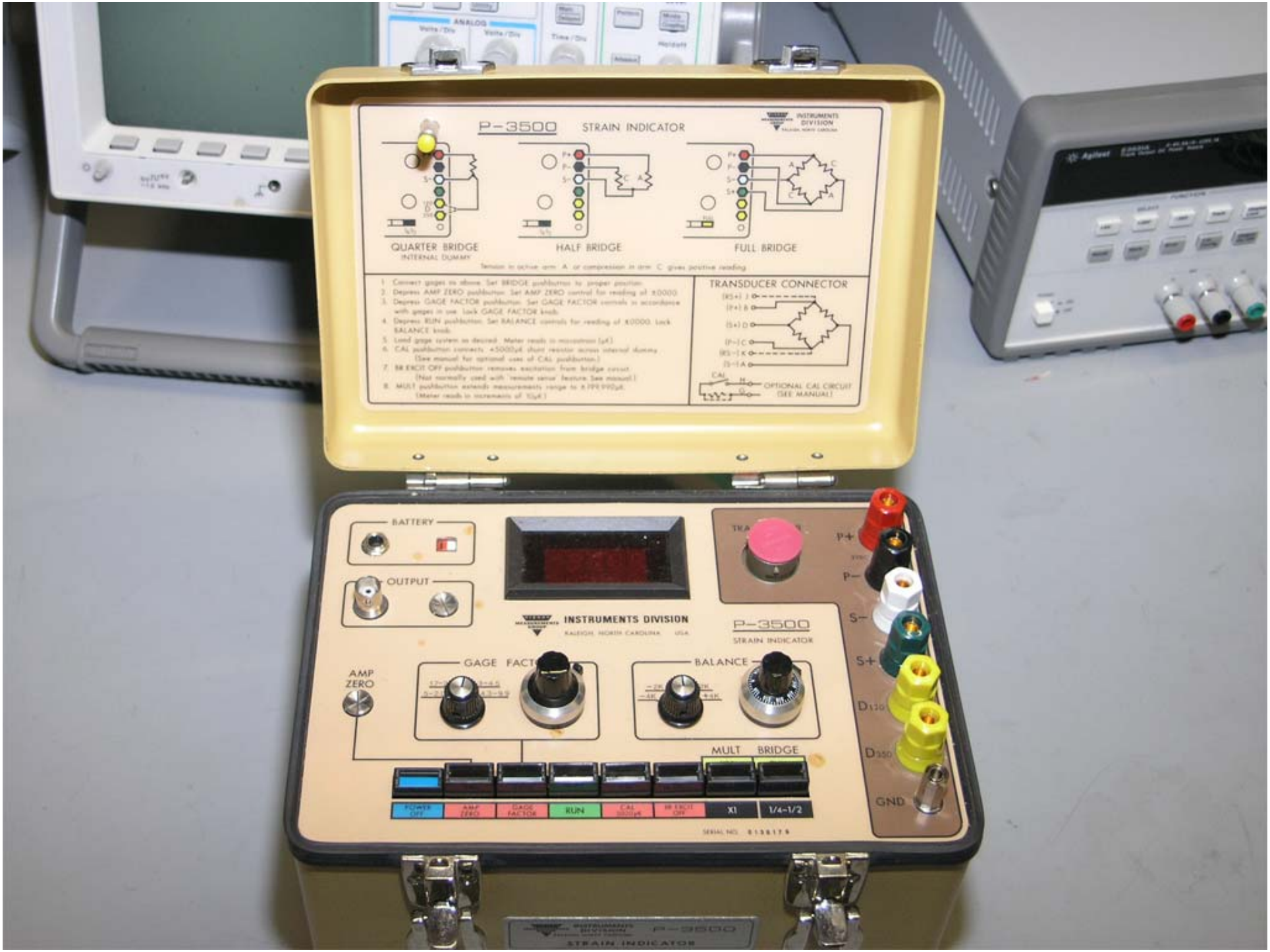
The P-3500 Strain Indicator

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

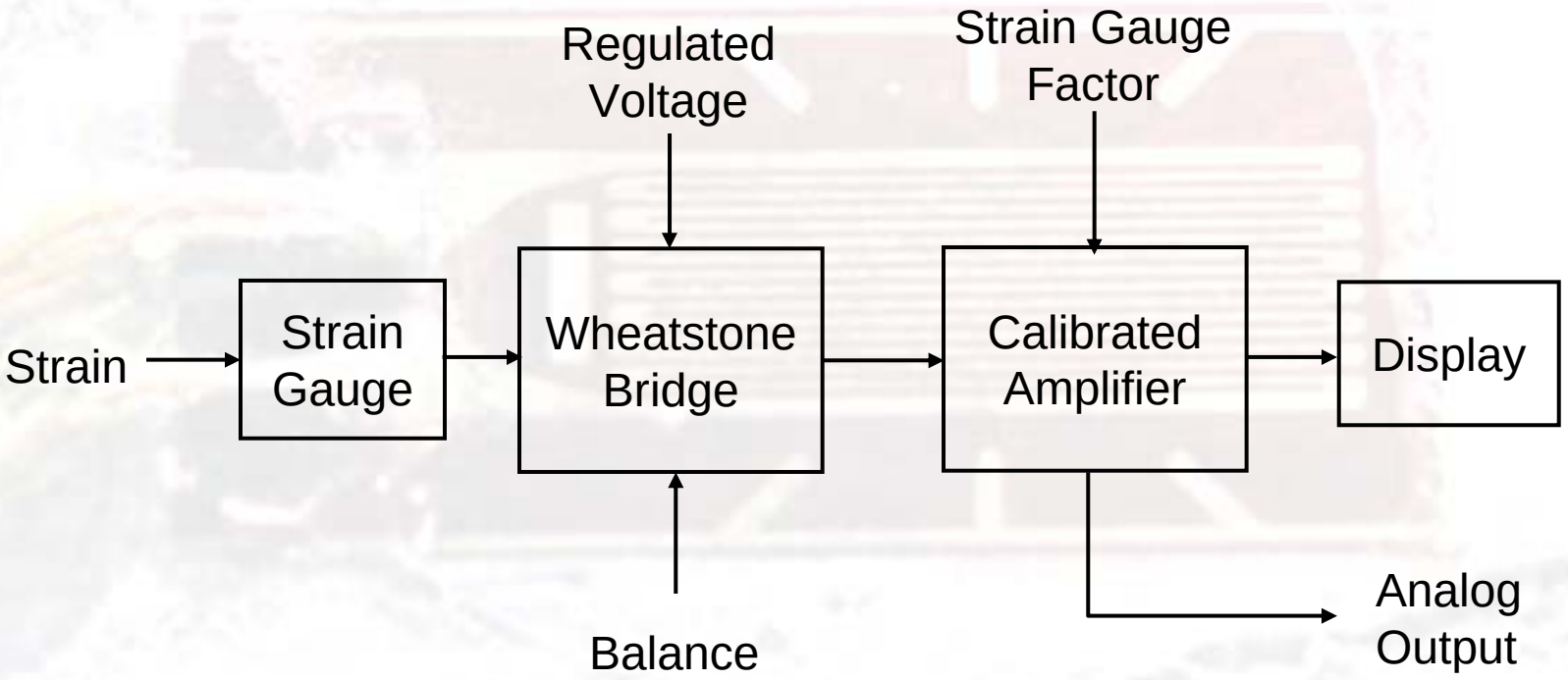
- Battery-powered
- Electronics to
  - Put the strain gauge in a Wheatstone bridge
  - Balance the bridge for zero strain
  - Measure the output of the Wheatstone bridge
  - Calibrate a four-digit display to read strain in microstrains
  - Provide a ground-referenced analog output


P-3500 STRAIN INDICATOR
INSTRUMENTS DIVISION
QUARTER BRIDGE
INTERNAL DUMMY
HALF BRIDGE
FULL BRIDGE
TRANSDUCER CONNECTOR
OPTIONAL CAL CIRCUIT (SEE MANUAL)
BATTERY
OUTPUT
INSTRUMENTS DIVISION
P-3500
STRAIN INDICATOR
AMP ZERO
GAGE FACTOR
BALANCE
MULT
BRIDGE
POWER OFF
AMP ZERO
GAGE FACTOR
RUN
CAL 5000μ
BR EXCIT OFF
X1
1/4-1/2
P+
P-
S-
S+
D130
D350
GND
P-3500
STRAIN INDICATOR

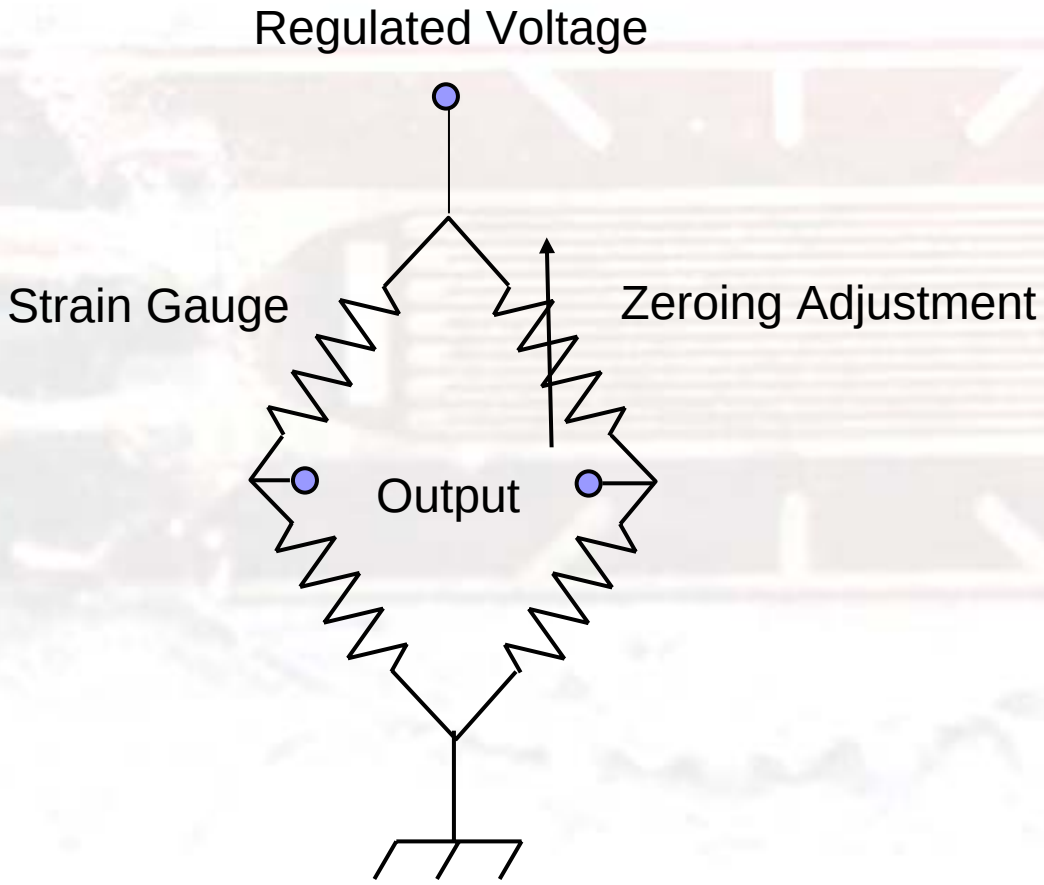
How a Strain Gauge Indicator Works

- 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

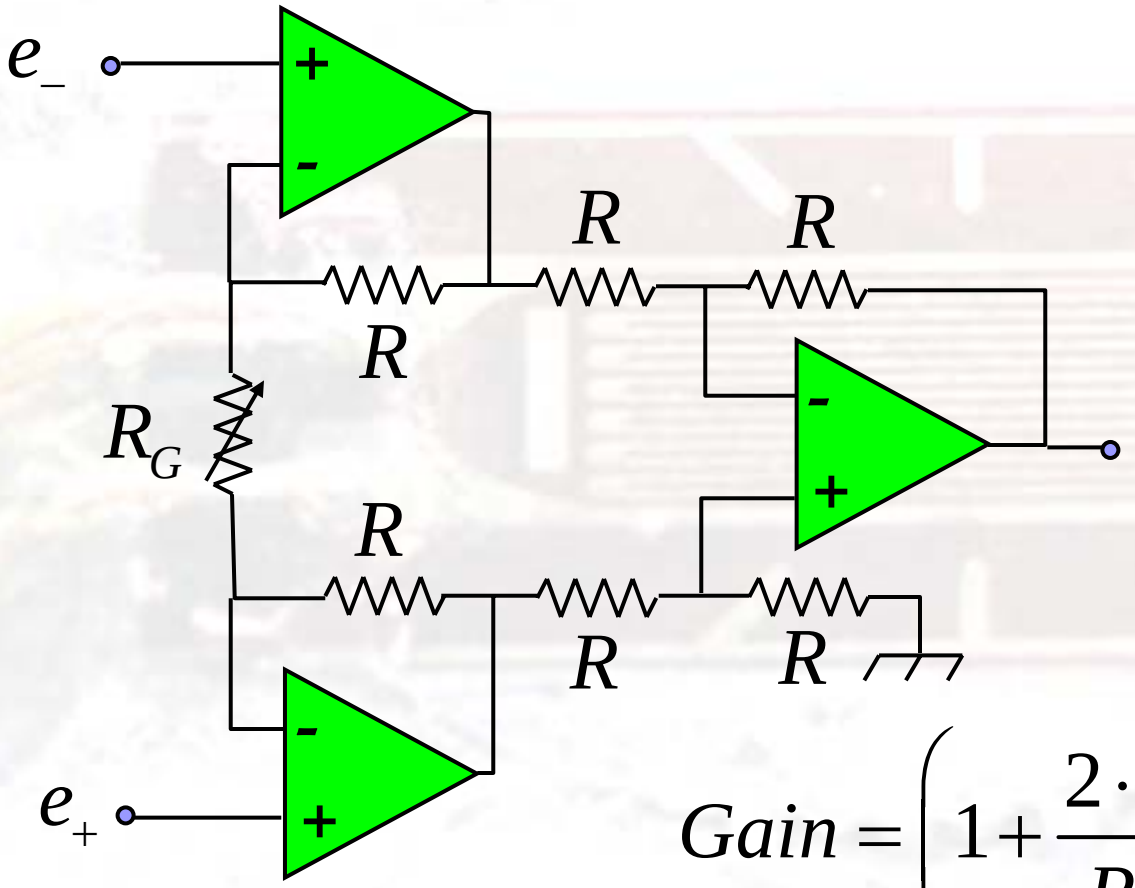
Strain Indicator



Wheatstone Bridge



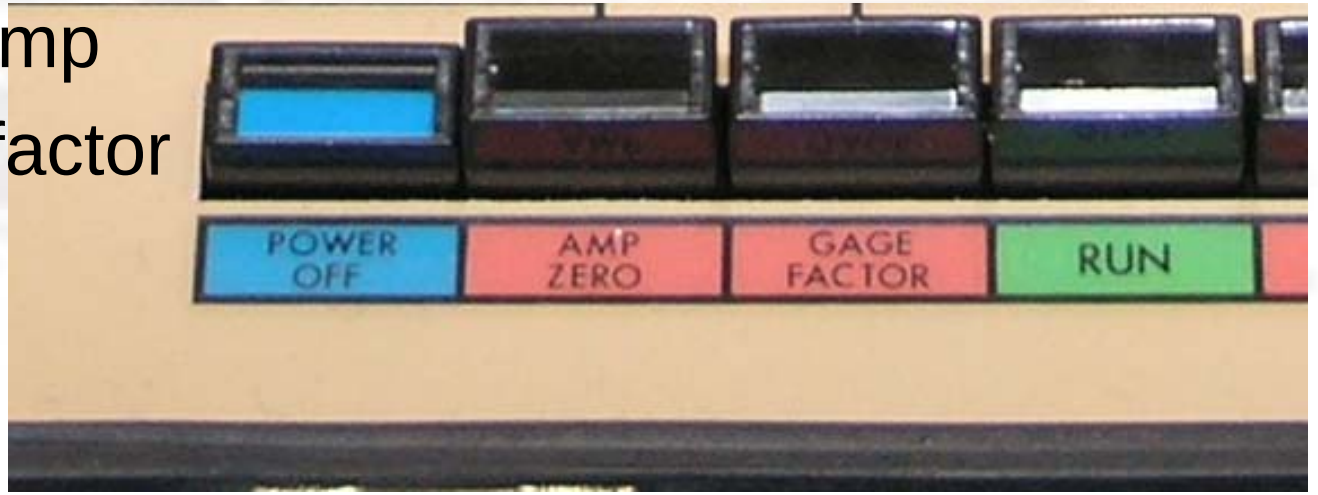
Differential Amplifier



$$Gain = \left(1 + \frac{2 \cdot R}{R_G}\right) \cdot \left(e_+ - e_-\right)$$

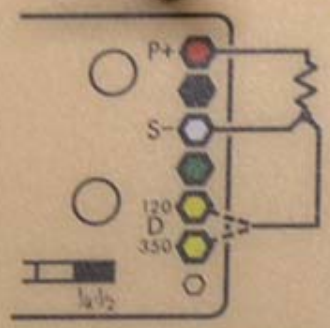
How to Operate

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

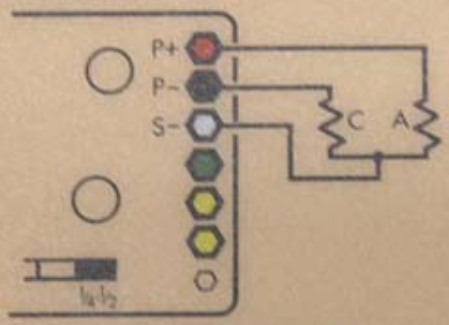


P-3500 STRAIN INDICATOR

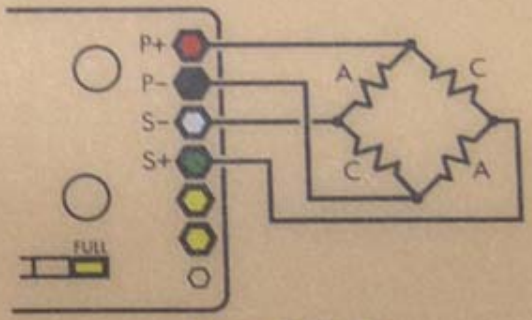
INSTRUMENTS DIVISION
RALEIGH, NORTH CAROLINA



QUARTER BRIDGE
INTERNAL DUMMY



HALF BRIDGE

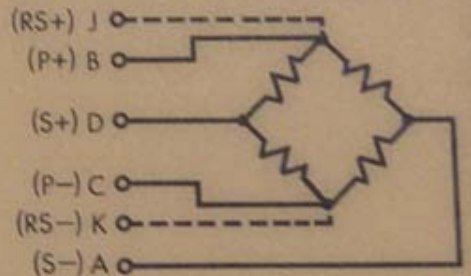


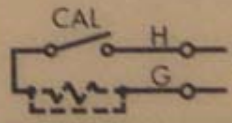
FULL BRIDGE

Tension in active arm A or compression in arm C gives positive reading.

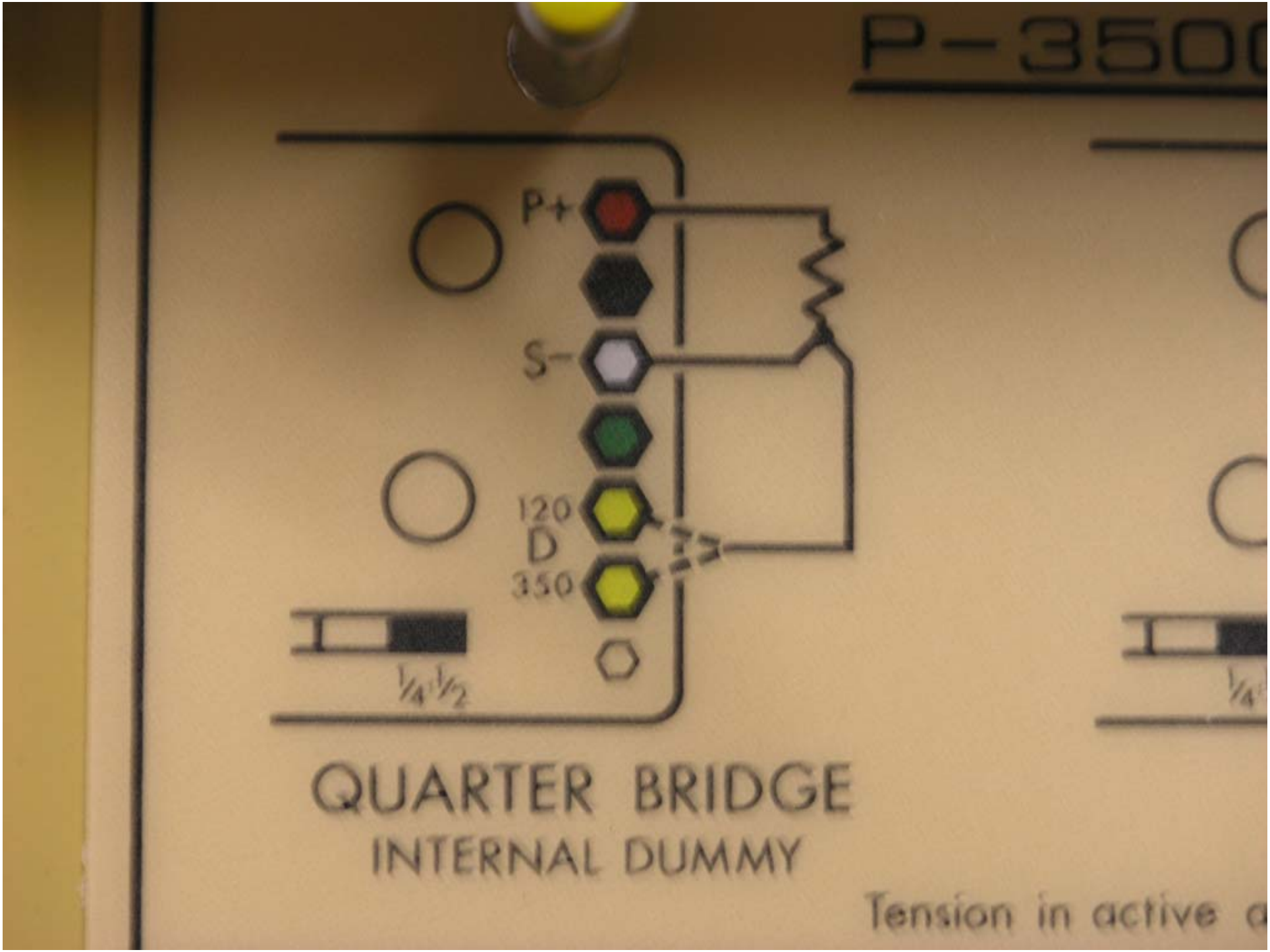
1. Connect gages as above. Set BRIDGE pushbutton to proper position.
2. Depress AMP ZERO pushbutton. Set AMP ZERO control for reading of ±0000.
3. Depress GAGE FACTOR pushbutton. Set GAGE FACTOR controls in accordance with gages in use. Lock GAGE FACTOR knob.
4. Depress RUN pushbutton. Set BALANCE controls for reading of ±0000. Lock BALANCE knob.
5. Load gage system as desired. Meter reads in microstrain (με).
6. CAL pushbutton connects +5000με shunt resistor across internal dummy. (See manual for optional uses of CAL pushbutton.)
7. BR EXCIT OFF pushbutton removes excitation from bridge circuit. (Not normally used with "remote sense" feature. See manual.)
8. MULT pushbutton extends measurements range to ±199,990με. (Meter reads in increments of 10με.)

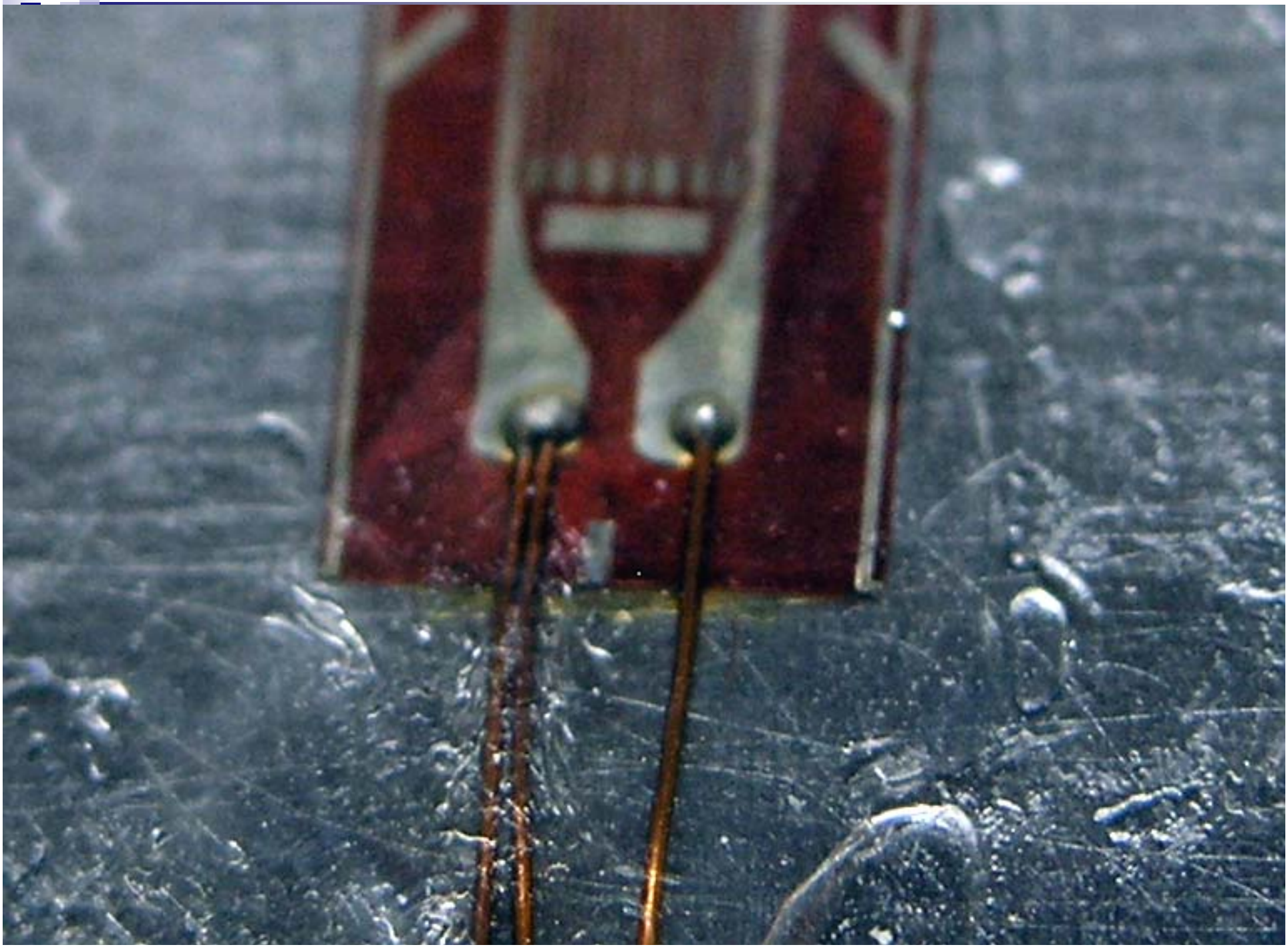
TRANSDUCER CONNECTOR

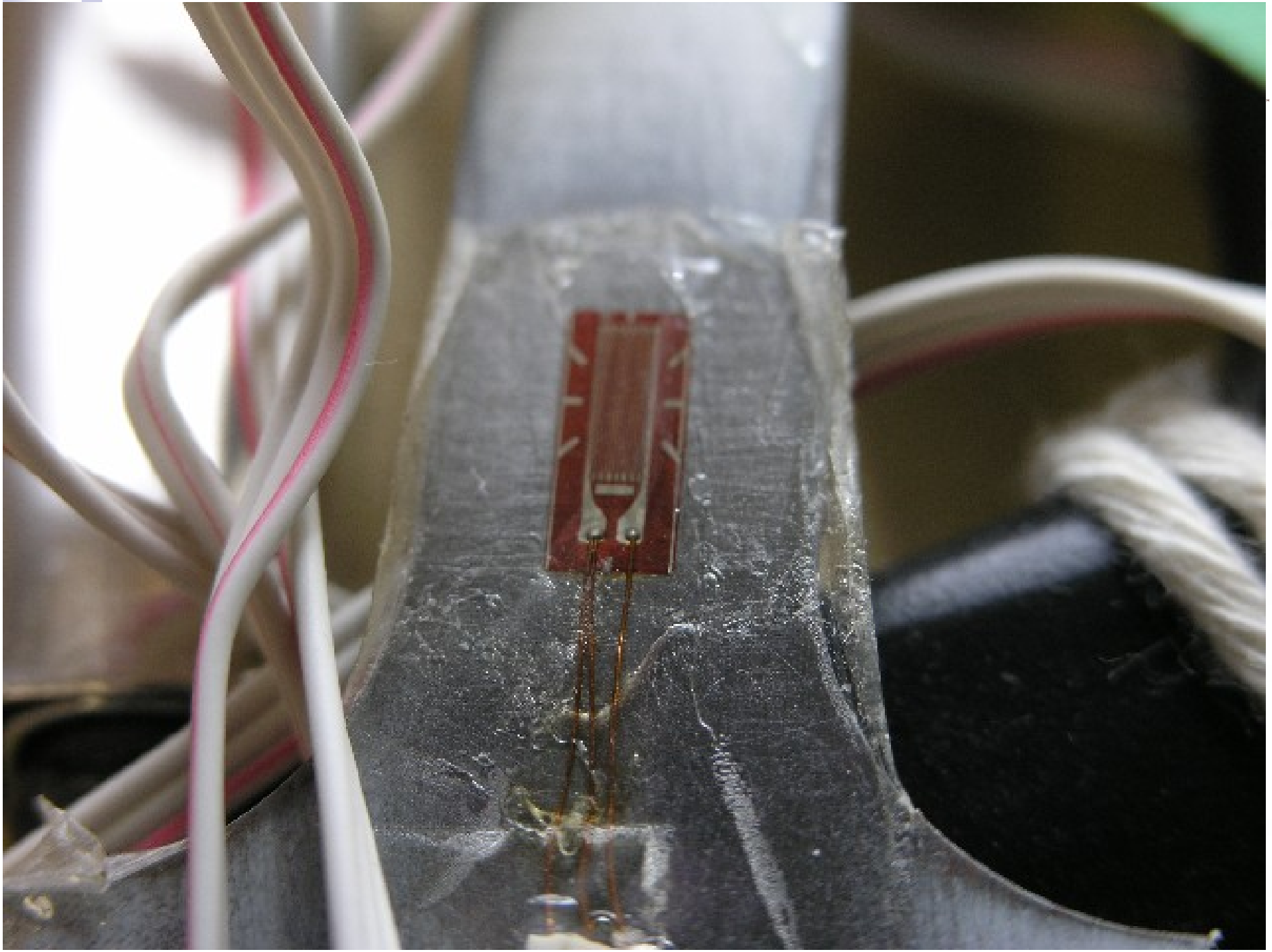




OPTIONAL CAL CIRCUIT
(SEE MANUAL)


P-3500
P+
S-
120
D
350
1/4
1/2
QUARTER BRIDGE
INTERNAL DUMMY
Tension in active





In Use


BATTERY
OUTPUT
0127
INSTRUMENTS DIVISION
RALEIGH, NORTH CAROLINA USA
P-3500
STRAIN INDICATOR
GAGE FACTOR
BALANCE
AMP ZERO
MULT
BRIDGE
X10
FULL
RUN
X1
1/4=1/2

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