Actions at the End of Axons

- Synapses; terminals of the anon, where exam interface with other axons or with other tissues, for examples the neuromuscular junctions.

    - **Chemical synapses:** information is transferred from the axon to the target cell by way of neurotransmitters, which could be used to excite or inhibit the target cells dependent on the types of neurotransmitters.

        - Slow
        - Strength of synapses: high gain with small inputs and vice versa —> high versatility

    - **Electrical synapses:** Electrical impulse transfers directly to target cell through electrical/ mechanical coupling.

        - Fast
        - No gain

Muscle Types

- Skeletal (voluntary, striated)
    - Fast, white
    - Slow, red

- Involuntary (smooth)
- Cardiac

Medical Instruments

Requirements of Medical Measurement

Range of physical variables different to many other systems

- $\mu V <$ Voltages $<$ mV
- Pressures $<$ 40kPa
- Signal bandwidths usually $<$ 20kHz (DC also important)
- Variables are rarely deterministic
- Variations between patients and in one patient over time

Equipment must:

Avoid damage/interference by the sensor (or energy put into body by measurement system e.g. x-rays).
Be reliable, safe (patient and operator).
Easy to operate withstand shocks – mechanical, chemical (e.g. corrosion), high voltage.
Operate in noisy environment – compensation by filtering and –ve feedback etc. to regulate amplitude.

Senors

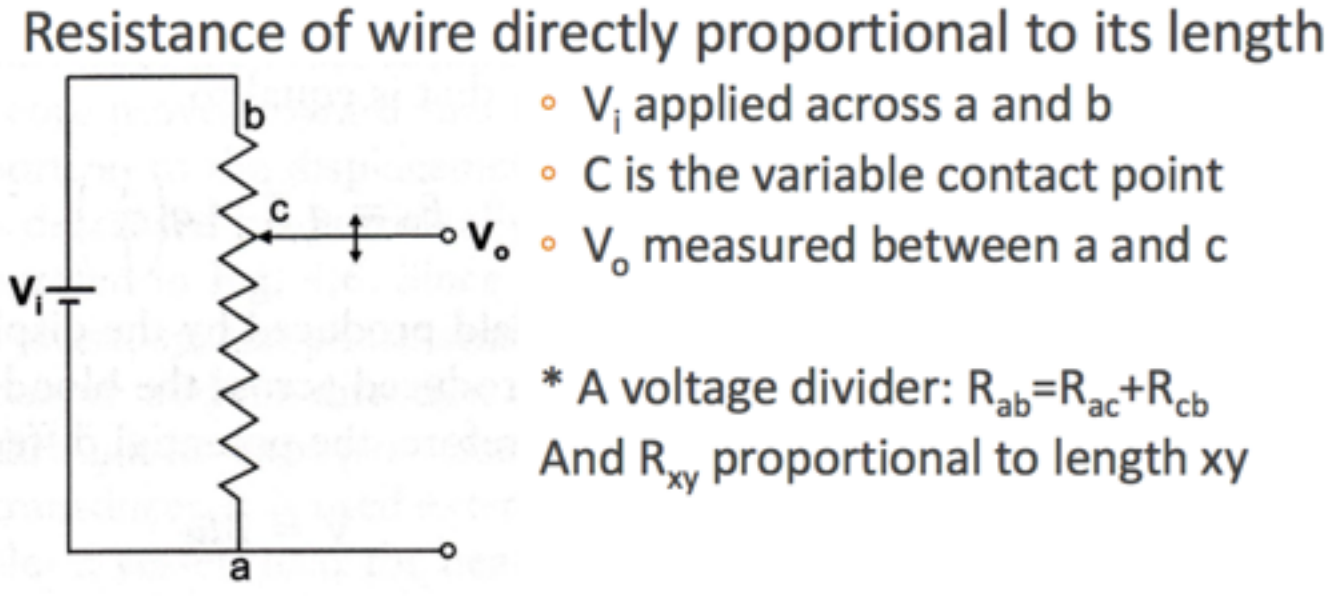
A transducer: converts energy from one form to another
A sensor: converts a physical parameter to electrical signal
An actuator: converts an electrical signal to physical output

Types of Sensors

- Displacement measurements
- Temperature measurements
- Optical sensors
- Electro-chemical sensors

Displacement Sensor
Displacement measures; size, shape, positions and changes of the aforementioned parameters
Types of displacement sensors; Resistive, Inductive, Capacitive and Piezoelectric

Potentiometer
Resistance can be changed manually by the sliding contact;

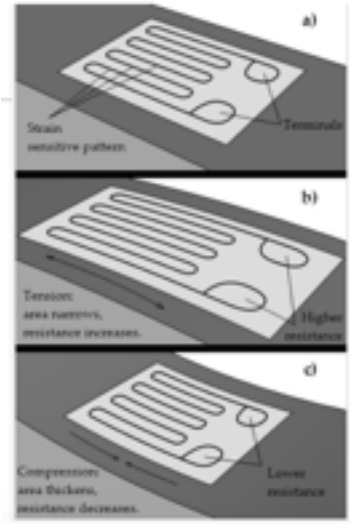


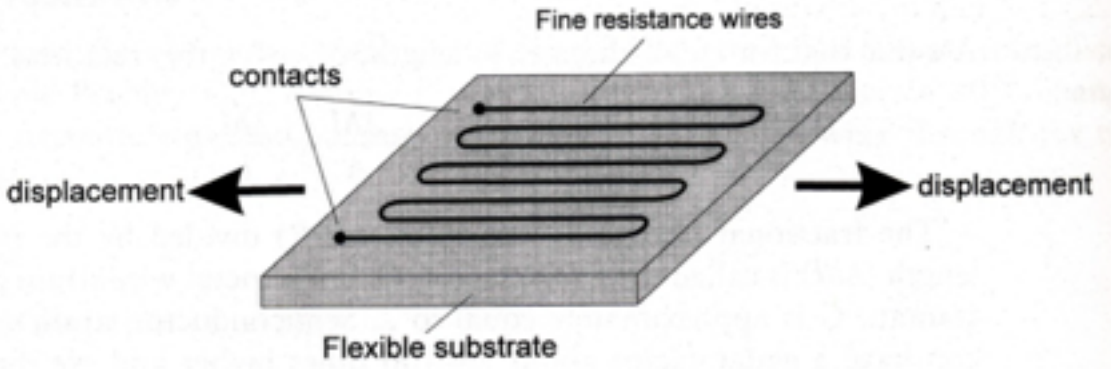
Strain Gauges

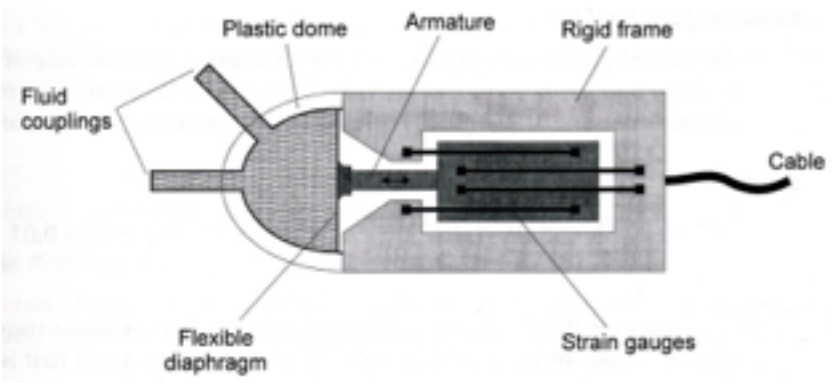
- Measure very small movements, forces and pressures
- Force applied to a structure → change in length of structure
- Strain is the ratio of the change in dimension to the original

Gauge contains conducting material;

- When electrical conductor is stretched, it becomes narrower and longer: → increase electrical resistance end to end.
- When condensed, it becomes broader and shorter: → decrease electrical resistance end to end.







Increasing pressure → armature moves to the right → outer strain gauges stretched (increase resistance), inner strain gauges contract (decrease resistance)

Summary So Far

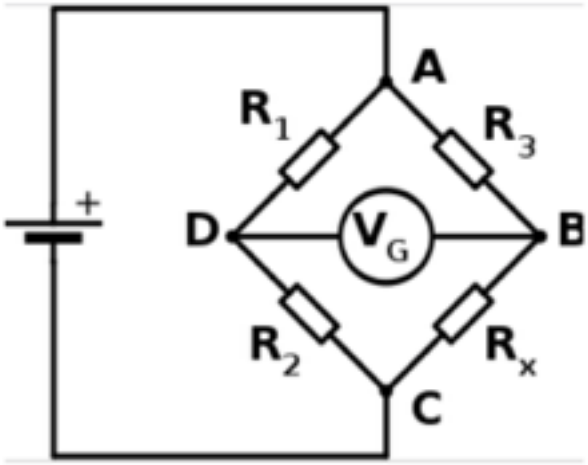
Potentiometers and Strain Gauges

- A displacement (translational or rotational) or force/pressure (causing a strain) results in a change in electrical resistance.
- Need to combine with circuitry that can measure the changes in electrical resistance

Wheatstone Bridge

In its simplest form:

- V_s is applied across nodes A and C
- R_1, R_2 and R_3 are fixed and equal R
- R_x is variable:
  - R +/- Δ
- If $R_x = R \rightarrow V_G = 0$
- If $R_x = R+\Delta \rightarrow V_G = ?$
- If $R_x = R-\Delta \rightarrow V_G = ?$



Elastic Resistance Gauges – Plethysmography

Special Strain Gauge;

Measure respiration by attaching cords (right) around chest and abdomen.

- Can measure large displacement
- Large silicone rubber cord impregnated with graphite (to make it conductive)
- Cord stretch → decrease diameter → increase resistance

Temperature Sensor

Tissue temperature – cryotherapy
Blood temperature – heart, brain operations, blood flow

Thermistors
Thermistors can be used as part of a bridge circuit to measure temperature.

- Resistor whose resistance varies with temperature: increase T → decrease R
- Very small → can be inserted through a needle to measure blood temp

Transducers

Inductive Transducer:

- Work by displacing an inductor in a coil or by displacing 2 coils with respect to each other
- Current (through primary coil) generates a magnetic field which generates a current in a secondary coil
- Presence of metal inside the inductive loop results in more current
    - Detected by the sensory circuit

Capacitive Transduce:

Similar to inductive sensors: one plate of a capacitor moves
Capacitance is directly proportional to the distance between the plates;

$$V_o(j\omega) = \frac{C_i x V_i(j\omega)}{\epsilon_i \epsilon_r A} = Kx$$

Wheatstone Bridge and Reactive Impedance

- Reactive impedance (inductor or capacitor) requires ac excitation source
- Response is amplitude modulated carrier with carrier frequency = source frequency
- Output signal must be demodulated
    - Phase sensitive demodulator (phase-locked loop)
    - Phase insensitive demodulator (square law detector, diode and low pass filter)

Piezoelectric Transducer