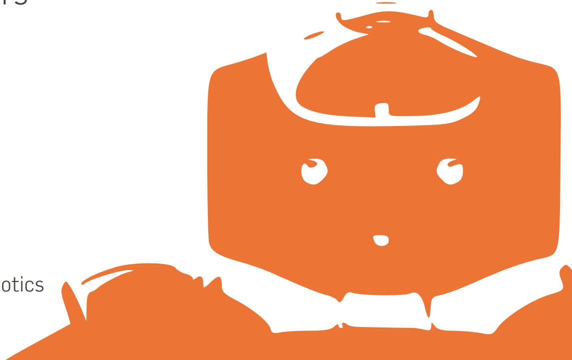
You can download the sources of this presentation here:
github.com/severin-lemaignan/module-introduction-sensors-actuators

ROBOTICS WITH PLYMOUTH UNIVERSITY

ROCO222
Intro to Sensors and Actuators
Force and Torque Sensors



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Plymouth University

LABS ASSESSMENT

- Coursework: 60% of final mark
- Complete lab journal submitted **Thursday 16:00, 11th January 2018**

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Marking scheme for the lab journal:

- DC motor + encoder project: 30%
- Robotic arm project: 30%
- Other (GIT, command-line, stepper motors): 20%
- Presentation (Markdown syntax, photos, videos), use of GIT: 20%

Following and reporting on each of the steps in the lab instruction sheets should give you a 75% mark. Good analysis of your motor/arm supported by drawings and pictures, and design explorations/programming beyond what was requested bring you above that mark.

LABS ASSESSMENT

I will pay particular attention to:

- Demonstration of actual understanding of the principles (with drawings/equations where needed)
- Reporting on the performance of your motor/arm, reflections on how to improve it
- Reflection on encountered pitfalls

Less important:

- The design of your robot arm (the design of the DC motor armature is important, though!)

Individual reports, but I accept a level of similarity within groups (e.g. photos). Please put the name of your teammate in your report.

LAST LECTURE NEXT WEEK

Go to www.menti.com and use the code 57 51 24

TODAY'S OBJECTIVES

- Know how to measure force and torque
- (lots more on sensors during ROCO318 next year)

MEASURING FORCE

DEFINITION OF FORCE

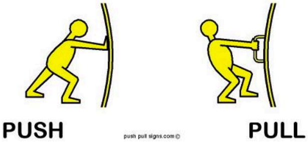
- A push or a pull
- The ability to do work

- Is is a vector quantity
- Has magnitude and direction

- Measured in Newtons (N)

- **Newton's Second Law**
- A force acting on a mass will accelerate or decelerate it
- F = ma

where F is Force (N), m is mass (Kg), a is acceleration (ms^{-2})

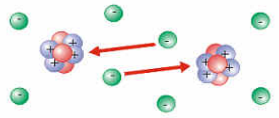


FOUR FUNDAMENTAL FORCES IN NATURE

1. Gravity
Dominates at large distances

2. Electromagnetic forces

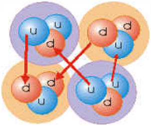
Observed in the interactions between atoms



3 . & 4. Nuclear forces

Strong & weak

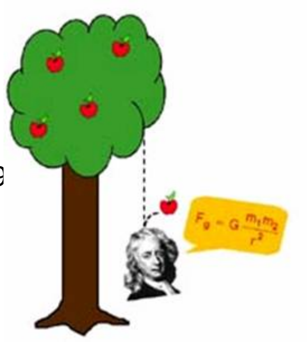
Both very short range



FORCE ARISES FROM GRAVITY ACTING ON A MASS

- Force arises from gravity acting on a mass

- F = mg
  - where F is Force (N),
  - m is mass (Kg),
  - g is acceleration due to gravity ≈ 9



MEASURING FORCE BY BALANCING KNOWN FORCE

- Use gravity acting on a known mass as source of known force

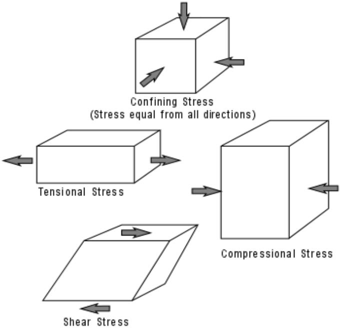
- Search for equilibrium position to find gravitational mass of test object

MEASURING FORCE BY MEASURING STRAIN

- Stress defined as "force per area"
- Strain is defined as: "deformation of a solid due to stress”
- When we apply force
- Induced s**tress** results in a **strain**

$E = stress\ /\ strain = (F\ /\ A_0)\ /\ (\Delta L\ /\ L_0)$

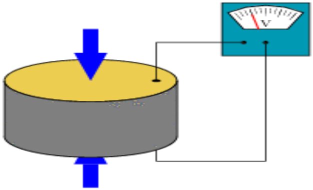
Where
E is the Young's modulus (modulus of elasticity)
F is the force exerted on an object under tension
A_0 is the cross-sectional area
ΔL is the amount by which object length changes
L_0 is the original length of the object

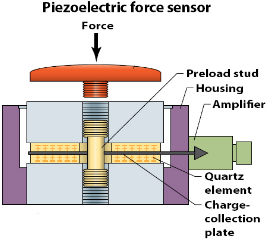


- By measuring strain of a material of known properties can estimate force

PIEZO-ELECTRIC EFFECT

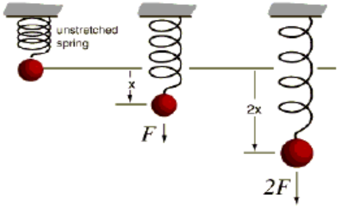
- Some materials generate electric charge under mechanical stress



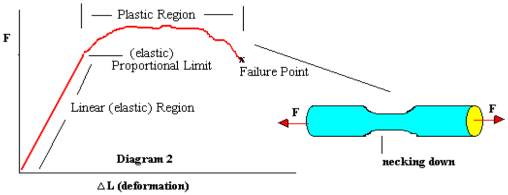


- Force results in a separation of charges with in structure
- Capacitive effect generates output voltage.
- Leakage causes charge dissipation and voltage decay over time
- Suitable for dynamic measurements

MEASUREMENT OF ELASTIC DEFORMATION



Hooke's law: $F = -kx$



Hooke's law only holds over the elastic region

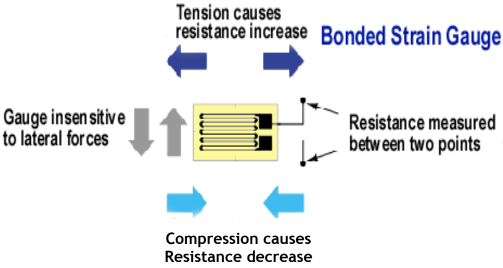
DIRECT MEASUREMENT OF ELASTIC DEFORMATION

+

Can simply observe extension to estimate force

Other mechanical methods
Proving ring - Displacement measured directly using micrometer or dial gauge

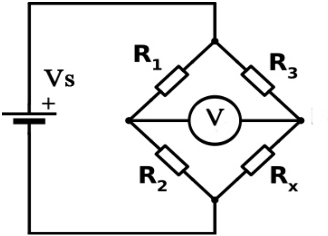
STRAIN GAUGE



- This is an electrical method of force measurement
- The gauge measures strain of substrate to which it is attached
- Provided substrate load operated in elastic region of the material, this is linearly relates to the applied force by Young's modulus

- Strain gauge measures strain because when film stretches it becomes narrower and longer and this increases its resistance
- Gauge is much more sensitive to strain is direction along the longer thin regions
- Overall during use such a sensor delivers only a fraction of percent change in resistance
- Resistance change is usually measured using a Wheatstone bridge

WHEATSTONE BRIDGE CIRCUIT



$$I_{LeftBranch} = \frac{V_s}{R_1 + R_2}$$

$$V_{R2} = \frac{V_s R_2}{R_1 + R_2}$$

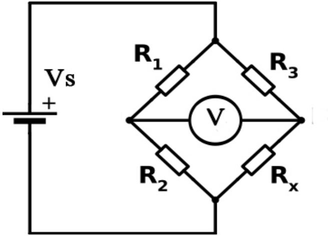
$$I_{RightBranch} = \frac{V_s}{R_3 + R_x}$$

$$V_{Rx} = \frac{V_s R_x}{R_3 + R_x}$$

- Wheatstone bridge converts change in resistance to change in voltage

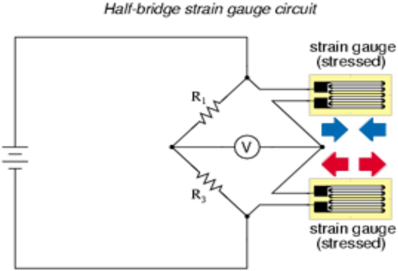
$$V = \left(\frac{R_x}{R_3 + R_x} - \frac{R_2}{R_1 + R_2} \right) V_s$$

WHEATSTONE BRIDGE CIRCUIT



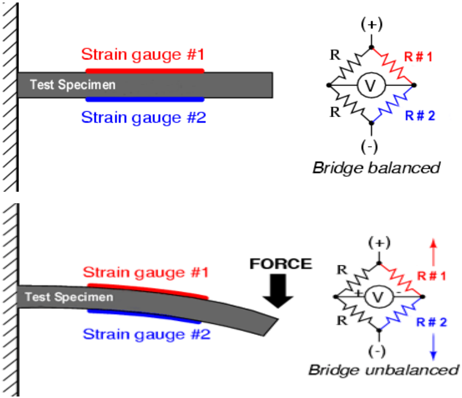
$$V = \left(\frac{R_x}{R_3 + R_x} - \frac{R_2}{R_1 + R_2} \right) V_s$$

- By placing strain gauges into the bridge, changes in their resistance resulting from the strain in the substrate gives rise to changes in voltage that can be measured



- Bridge arrangement cancels out changes that occur in all the resistive elements
- This compensates for resistance changes due to changes on temperature and also for strains in unwanted directions

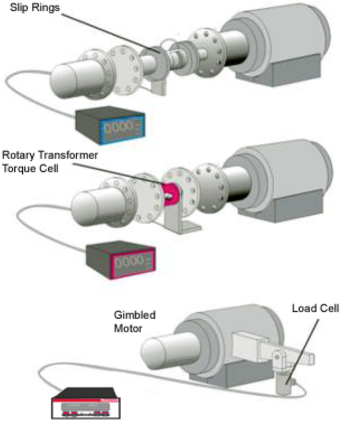
SIMPLE CANTILEVER LOAD CELL



- If gauges are centrally mounted then
- no change in output voltage due to a side load

MEASURING TORQUE

MEASURING TORQUE



- Two common ways to obtain torque measurements are by strain-gauging the shaft and by using in-line torque cells.

- Both have two technical obstacles: getting power to the gauges over the stationary/rotating gap and getting the signal back.

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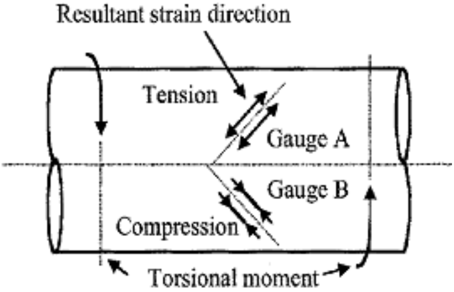
MEASURING TORQUE USING A GAUGE ON SHAFT



- The gauges lie perpendicular to one another at 45 deg to the plane about which the tensional moment is applied.

6 DOF LOAD CELLS

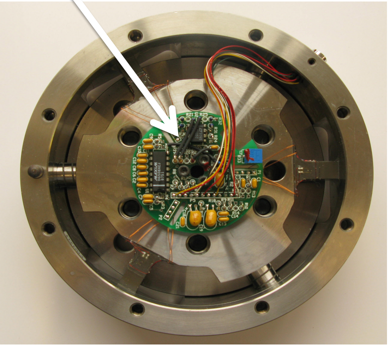
1 translational DOF

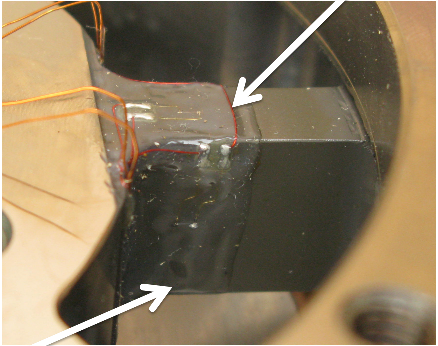
3 translational & 3 rotational DOFs

INSIDE A LARGE 6 DOF FT

Signal conditioning circuitry

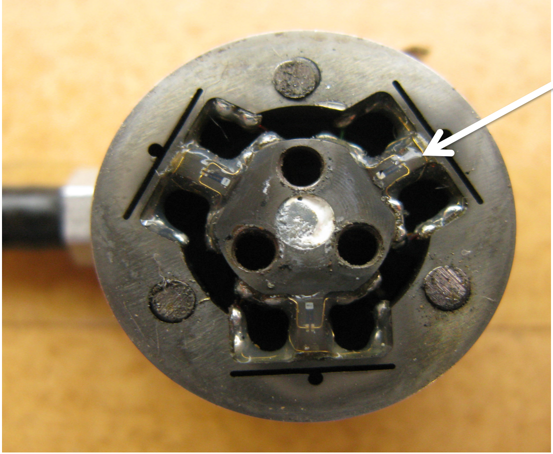
Silicon strain gauges





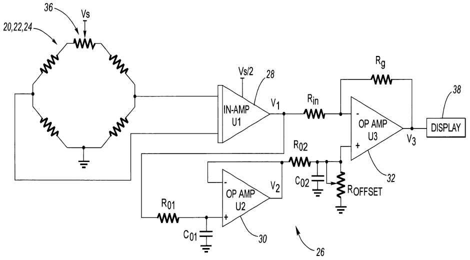
Massive structure which deforms under stress

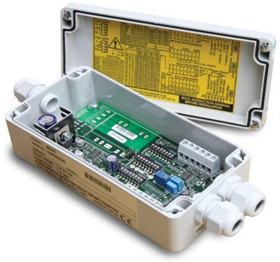
INSIDE A SMALL 6 DOF FT



Silicon strain gauges

A SIGNAL CONDITIONING AMPLIFIER IS NEEDED





- The amplifier needed because voltage changes generates by Wheatstone bridge are small
- Need differential input to cancel interference
- Also it can filter unwanted signal outside the bandwidth of interest

That's all, folks!

Questions:
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Slides:
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