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# Lecture 9

# Sensors in Mechatronics

## Mechatronics

MMME3085

Module Convenor – Abdelkhalick Mohammad

# Lecture Objectives

- Cover different sensor in Mechatronics systems such as:
  - Position sensors
  - Temperature sensors
  - Force/Pressure sensor

- Learn how to interface them to a microprocessor-based controller

# A typical Mechatronics System

Computer or micro-processor

2,3,10

1,4,10

Program e.g., in C

Buses in computer

Digital output inter-face; timer

Digital input inter-face; counters

Digital signal

DAC

Analogue signal

Digital signal

5,6

Digital signal

ADC

Analogue signal

Digital signal

7,8,9

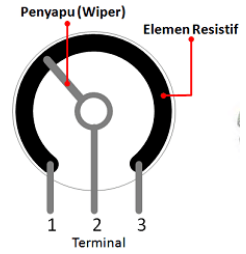
Electronic hardware

Actuators

Mechanical system

Sensors

Electronic hardware

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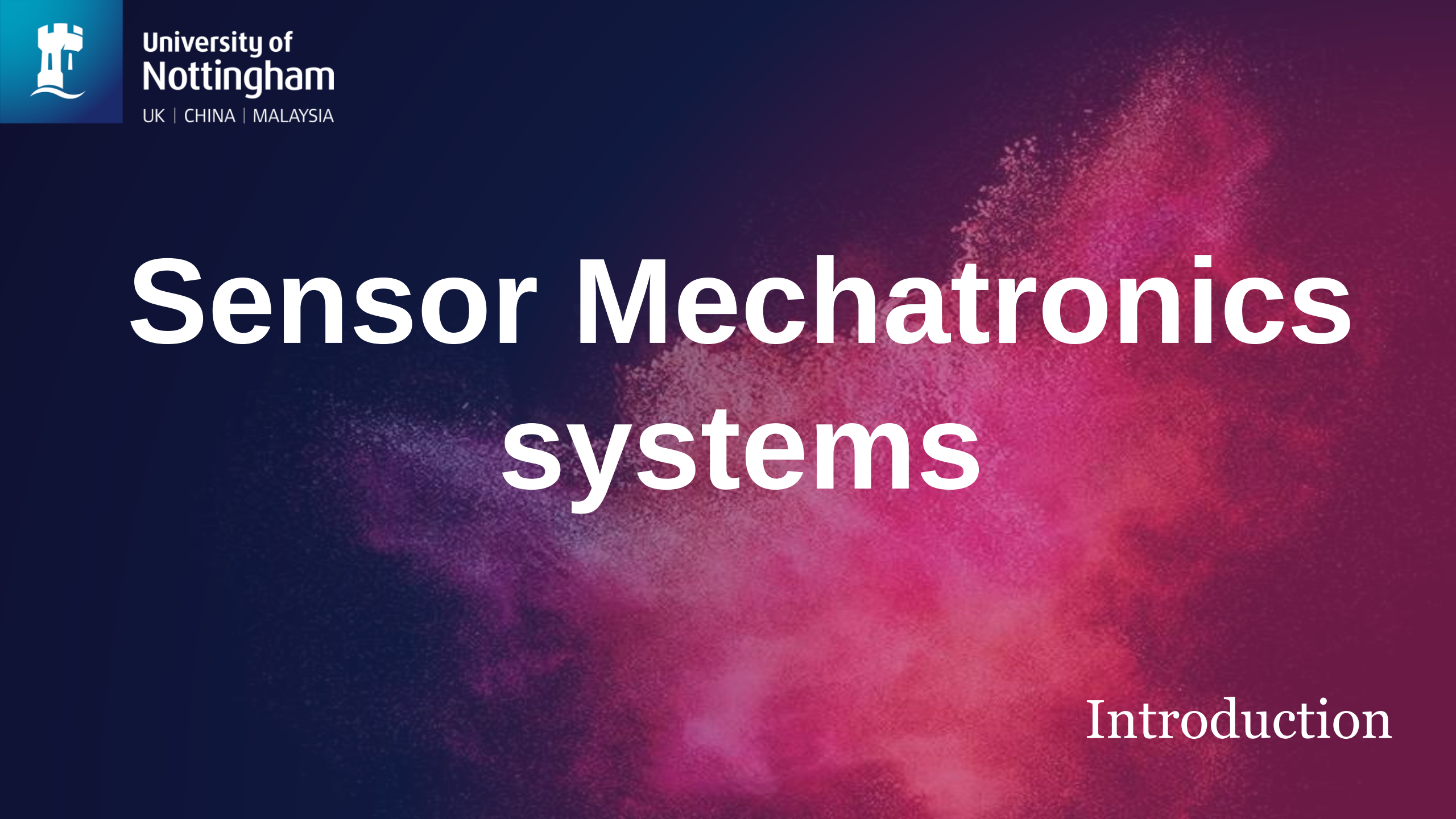
Recap

# From last lectures

So far, we learned …

- How to deal with digital signals including train of pulses
  - Generate digital signal
  - Read digital signal
- Timer/Counters as a hardware solution
- Registers in µp
- State Tables
- Finite State Machines
- Interrupt
- DAC and ADC
- DC servo Motor & Stepper Motors



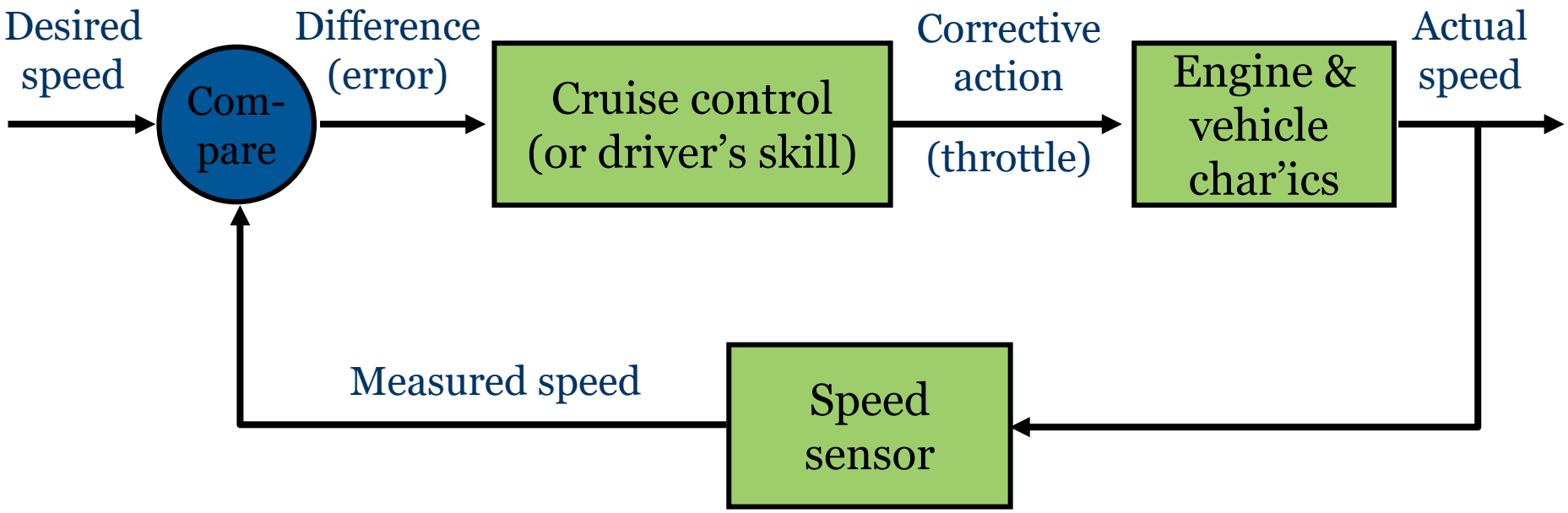

# Sensor Mechatronics systems

Introduction

# Brief Revision

- In many control and Mechatronics situations we need to:
  - measure physical quantities
  - compare with desired value
  - take corrective action
- In practice this needs
  - sensors to collect data
  - actuators to put corrective action into practice

# A typical control loop



# Brief Revision

- Most of the sensors we need were covered in MMME3053
- Will revise these only briefly, and with particular reference to interfacing them to computers (especially via Ardiuno)
- Some of these produce analogue signals, others produce digital signals
- Illustrated via labs!

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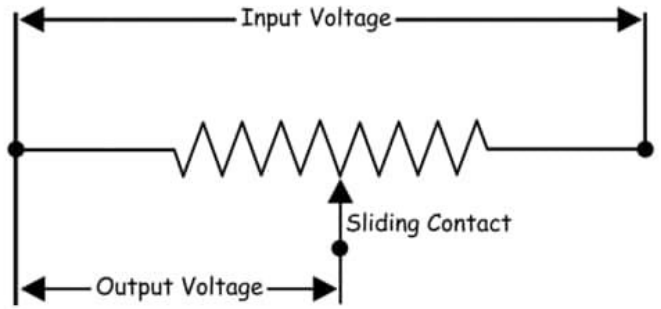
# Position sensors

# Sensor for Position: Potentiometer

- Simplest of these is the **potentiometer**
- Acts as variable voltage divider
- Analogue output, interface via ADC
- E.g. interfacing to a simple ADC card in PC

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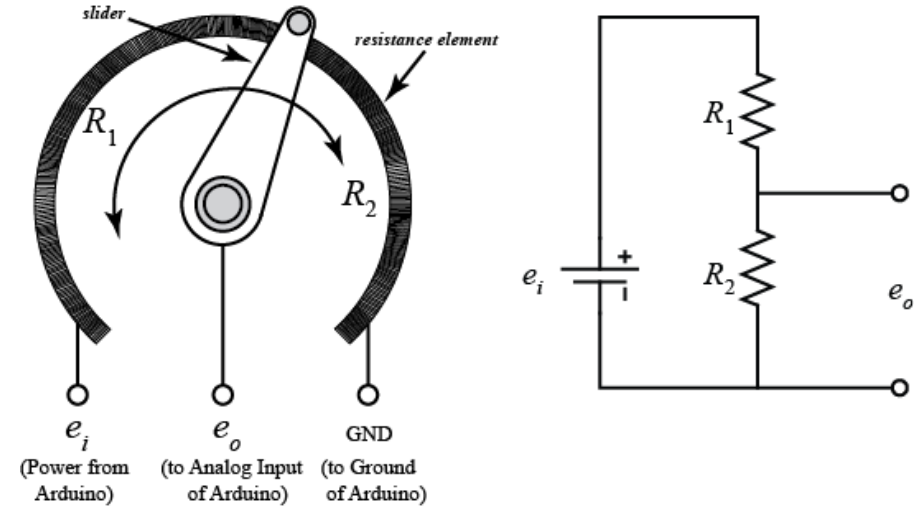

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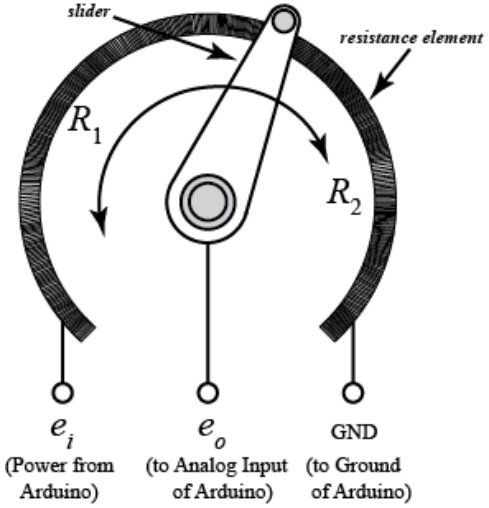


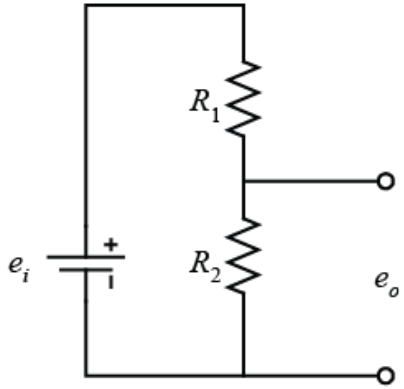

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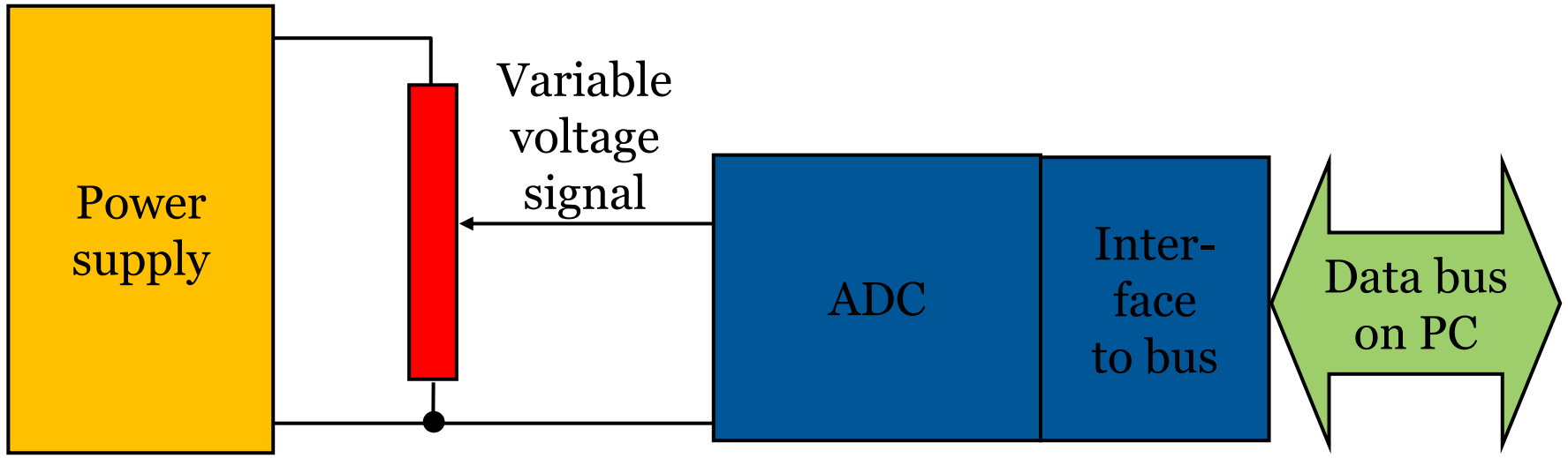
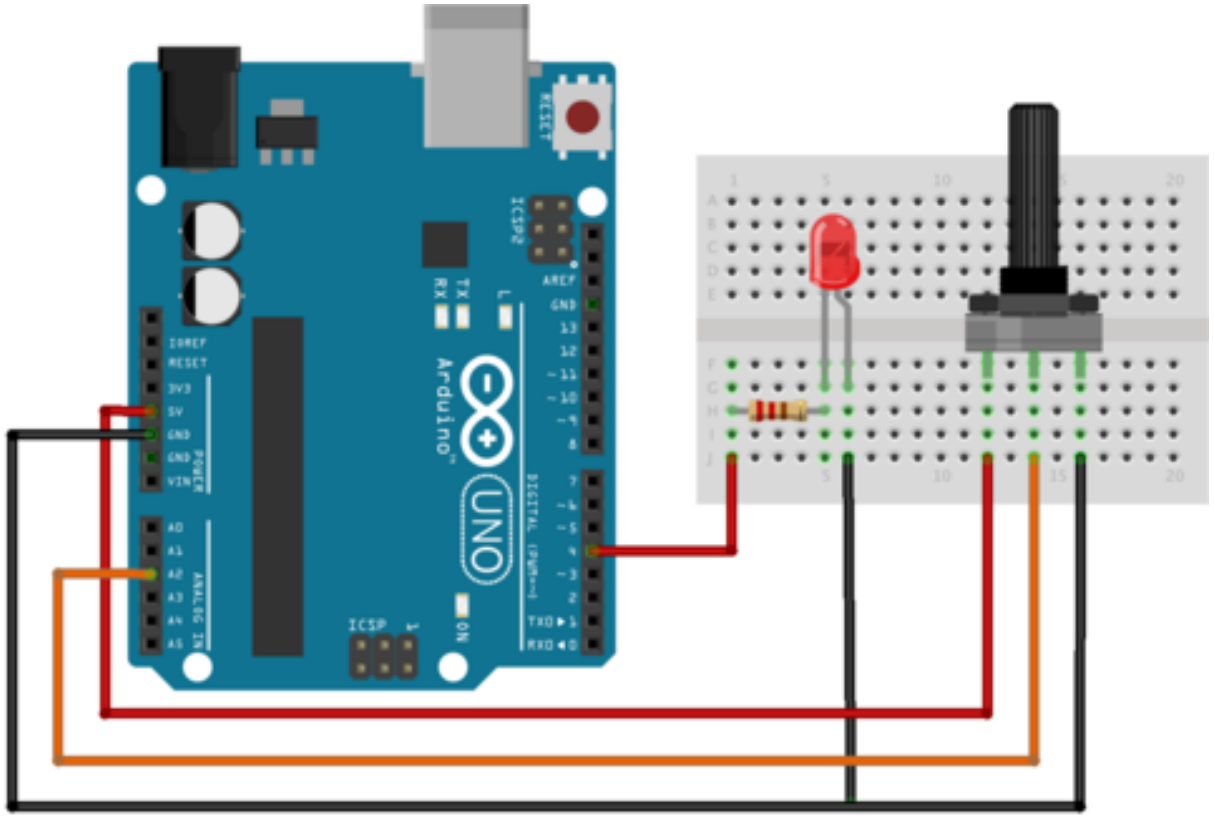


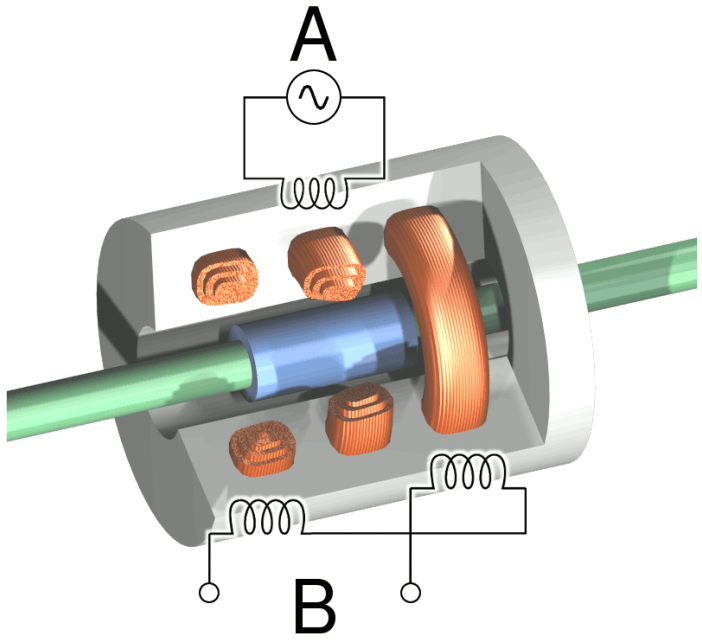
# Sensor for Position: Potentiometer

- Example to test using take-home kits



# Sensor for Position: LVDT

- **LVDT** (linear variable differential transformer) is more of a precision device
- Better resolution and less friction than “pot”
- HF AC, PSD usually included in package



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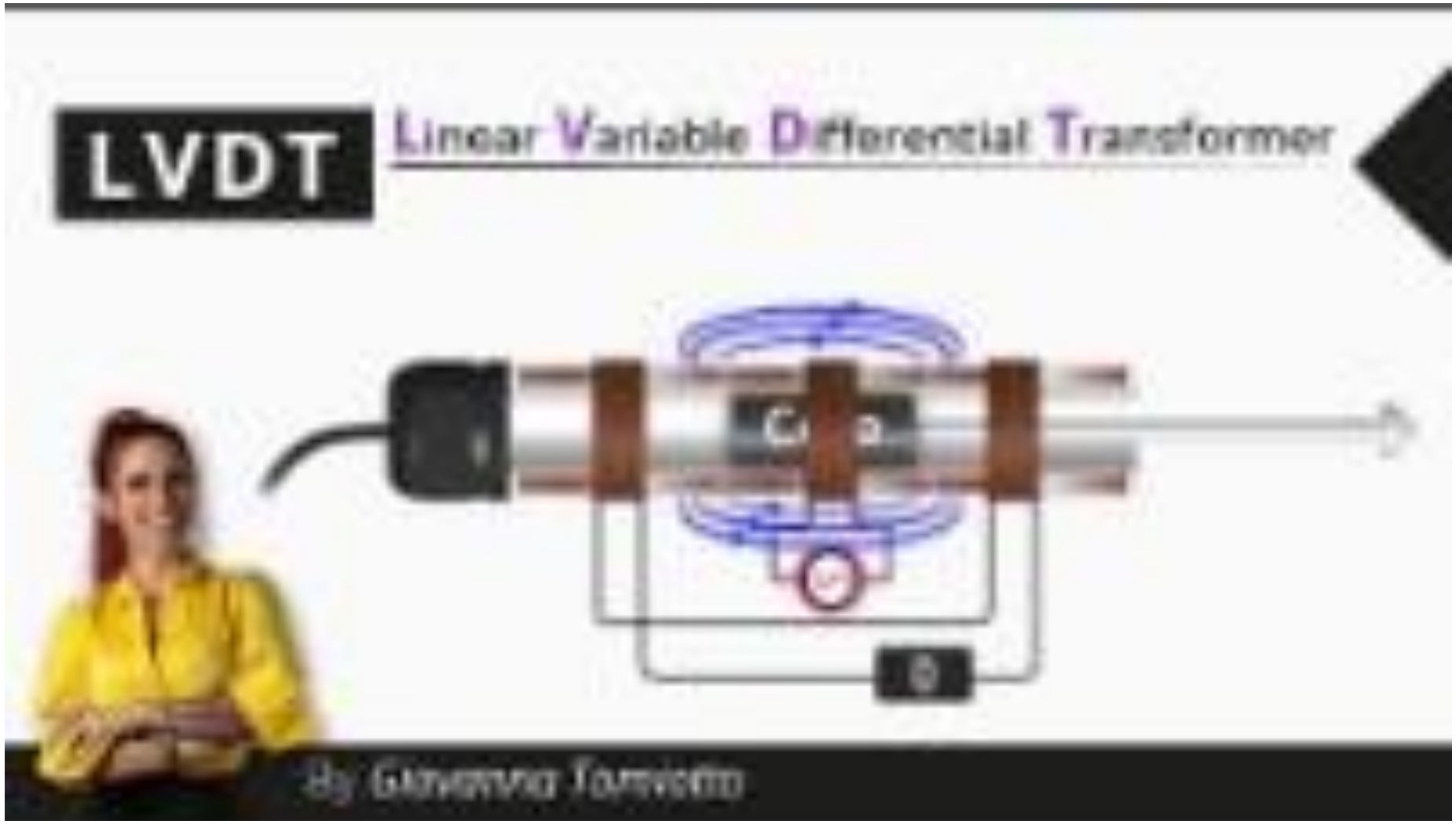


https://www.youtube.com/watch?v=o_hEmYip248&t=41s

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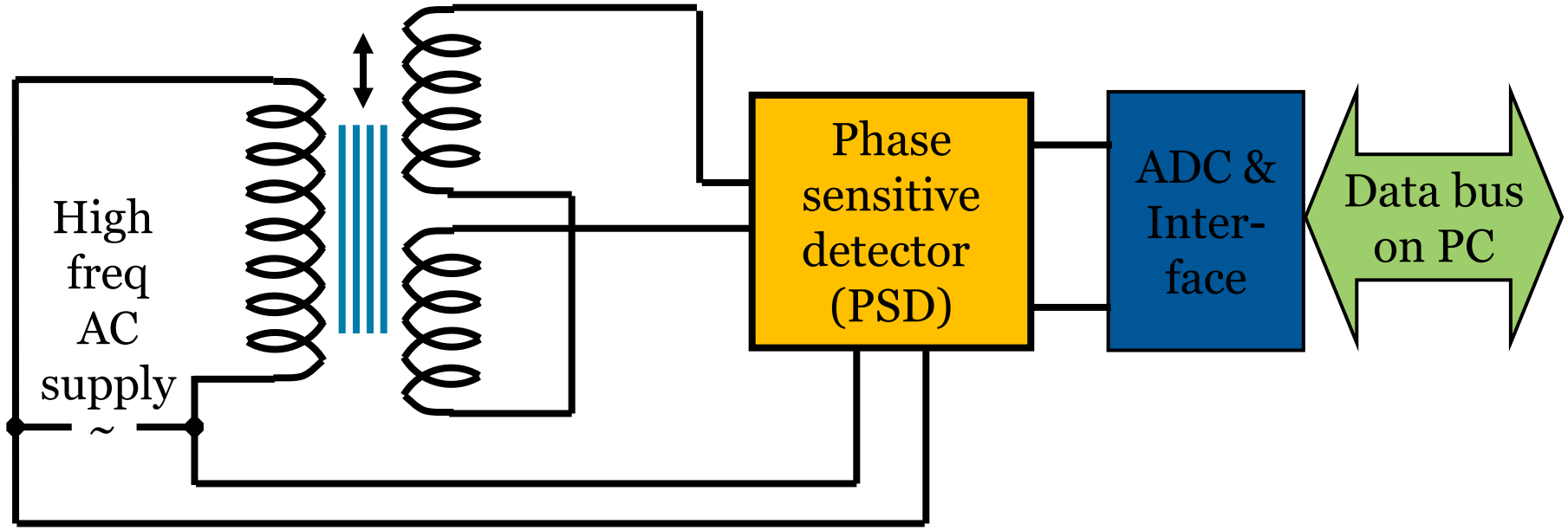

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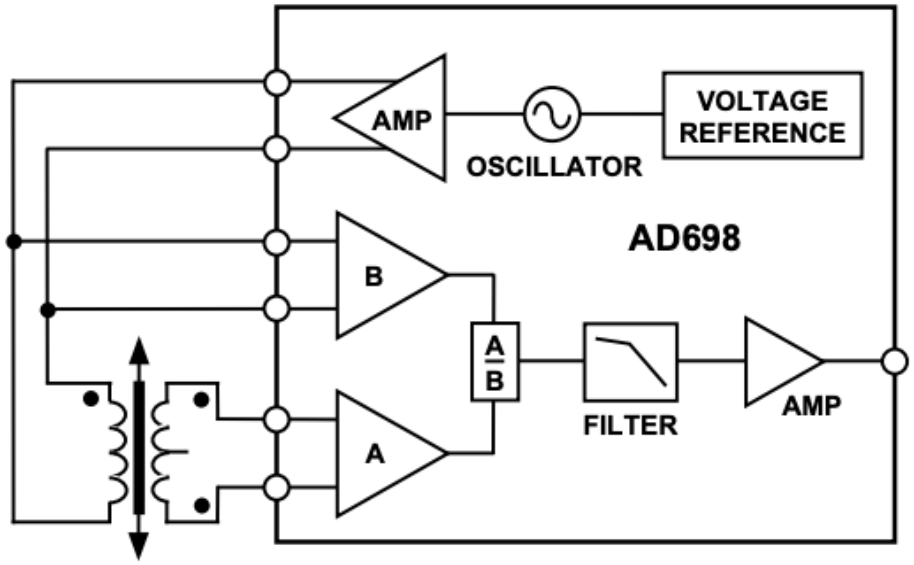
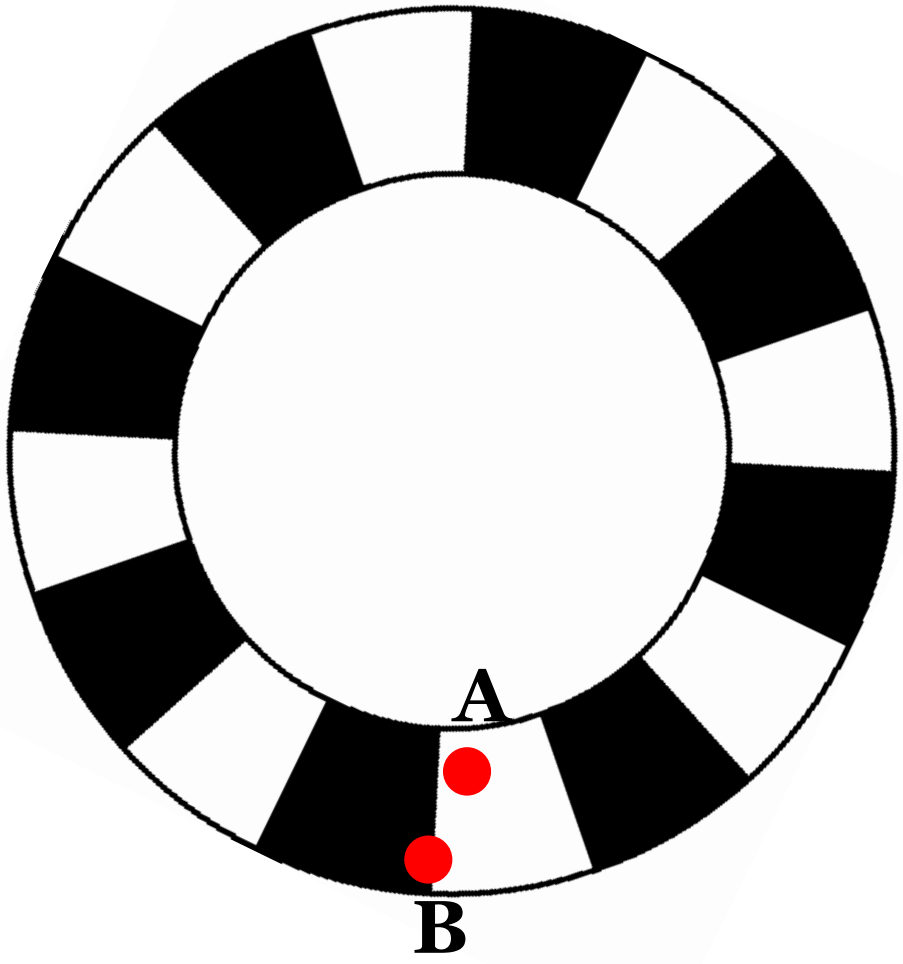
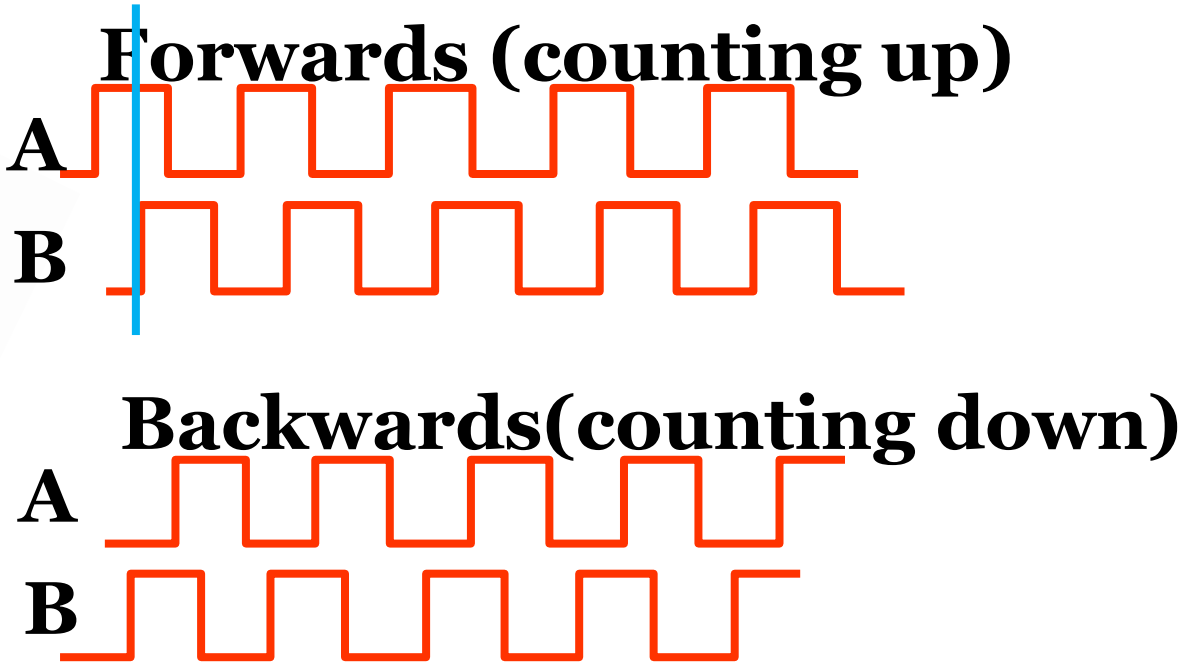


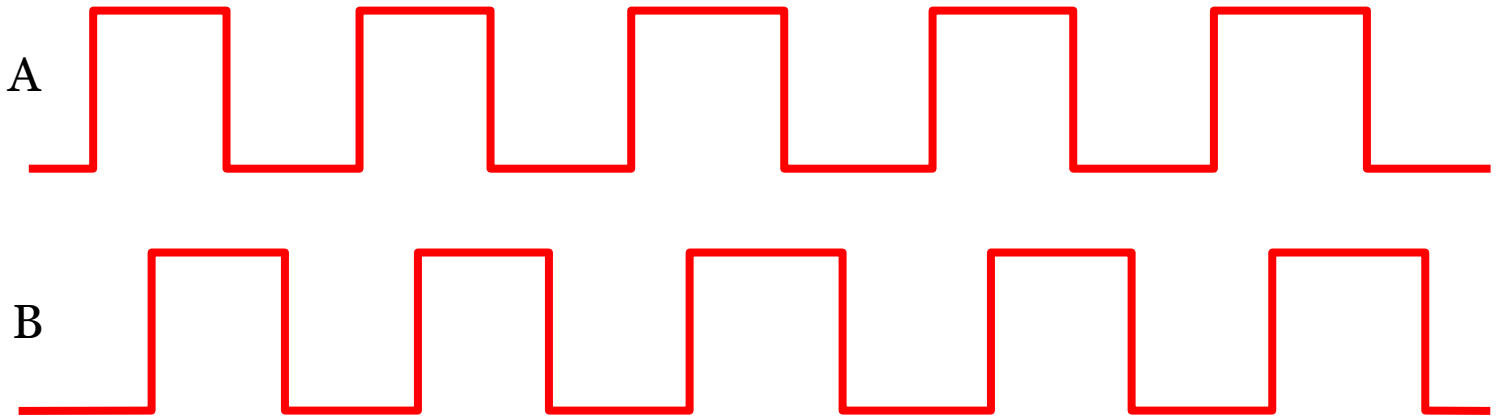
# Sensor for Position: Incremental Encoder



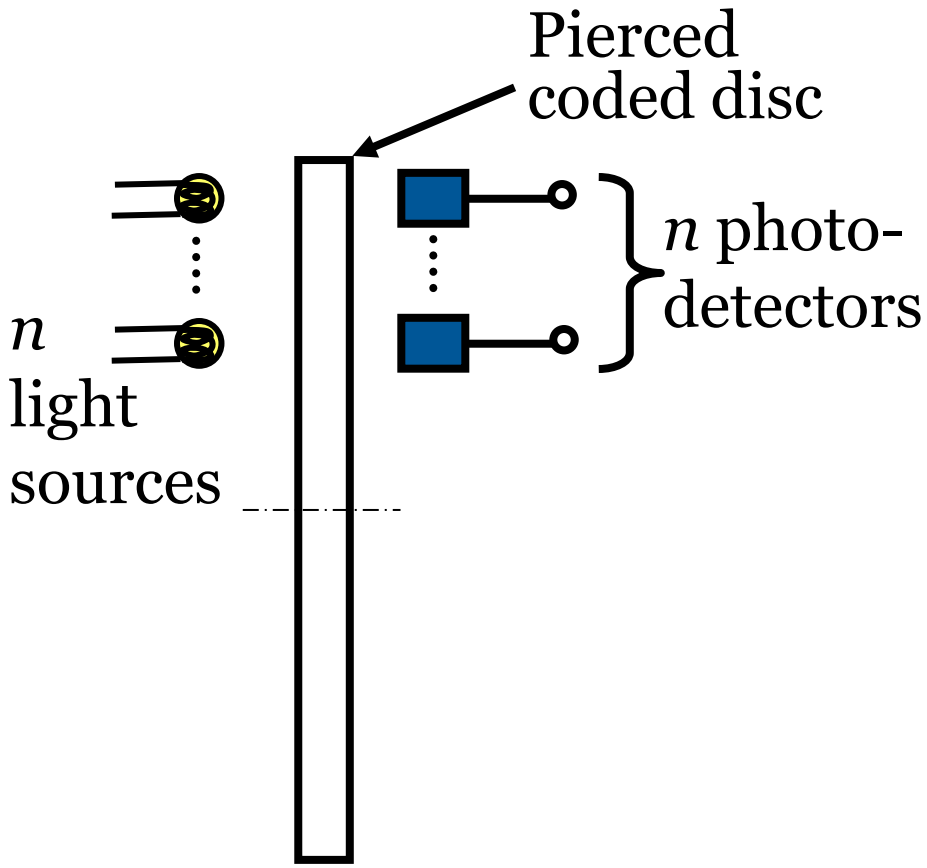



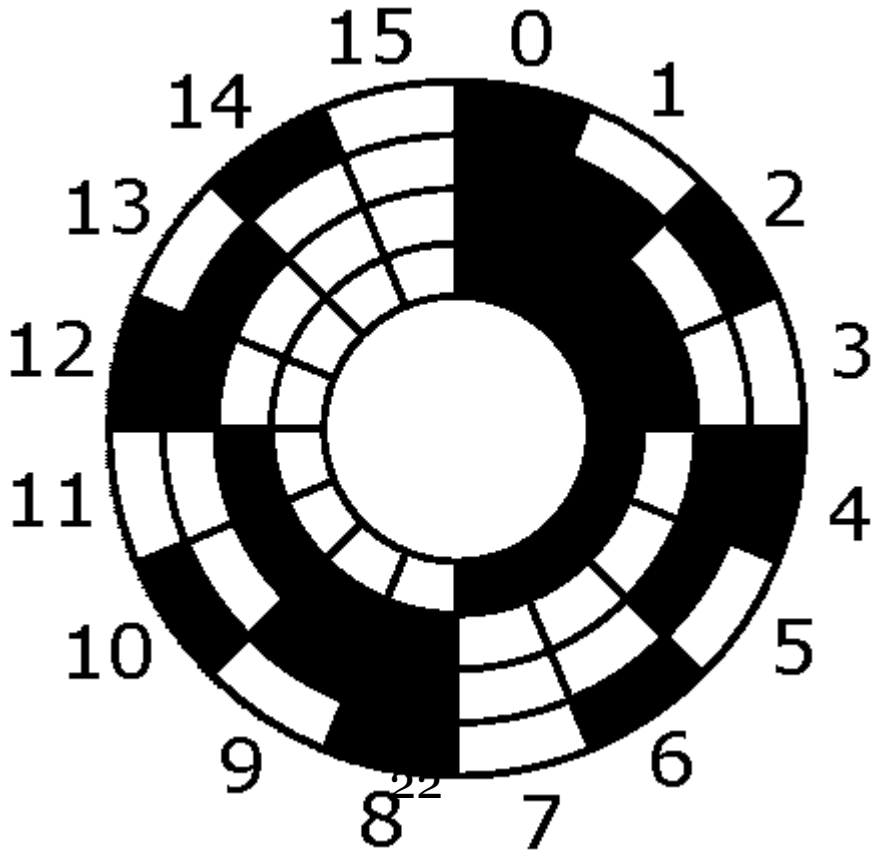
# Sensor for Position: Incremental Encoder

- Single counter no good for detecting direction of motion
- A pair of light sources/detectors phased ¼ cycle apart ("in quadrature") will detect direction, need up/down counter



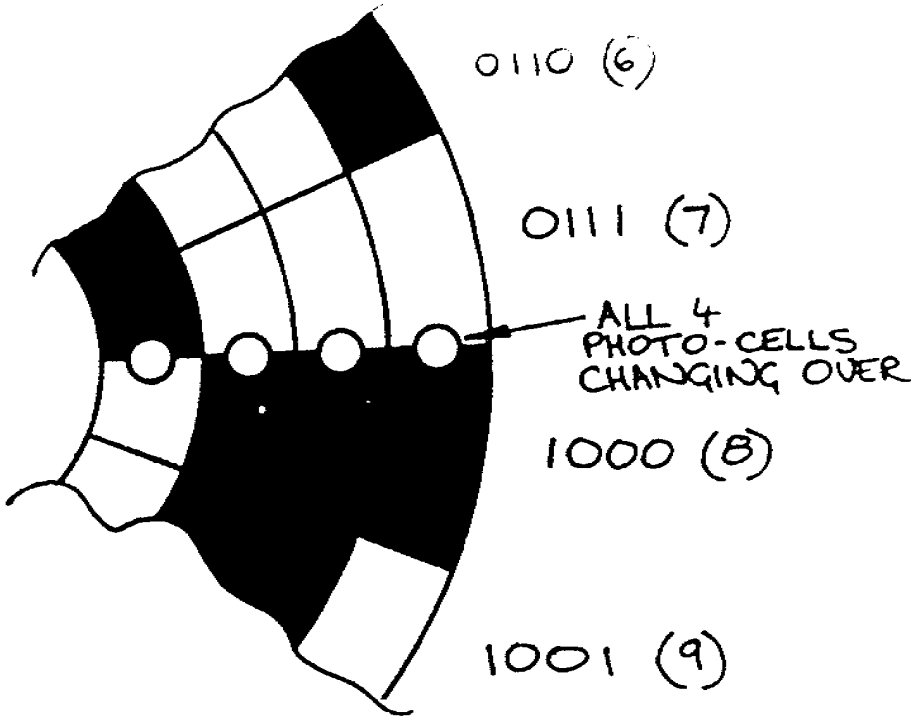
# Sensor for Position: Absolute Shaft Encoder



# Sensor for Position: Absolute Shaft Encoder

- A major problem:
- With conventional binary numbering, several digits can change at one step
- E.g. from 7 (0111) to 8 (1000).
- Problem overcome by using **Gray code**

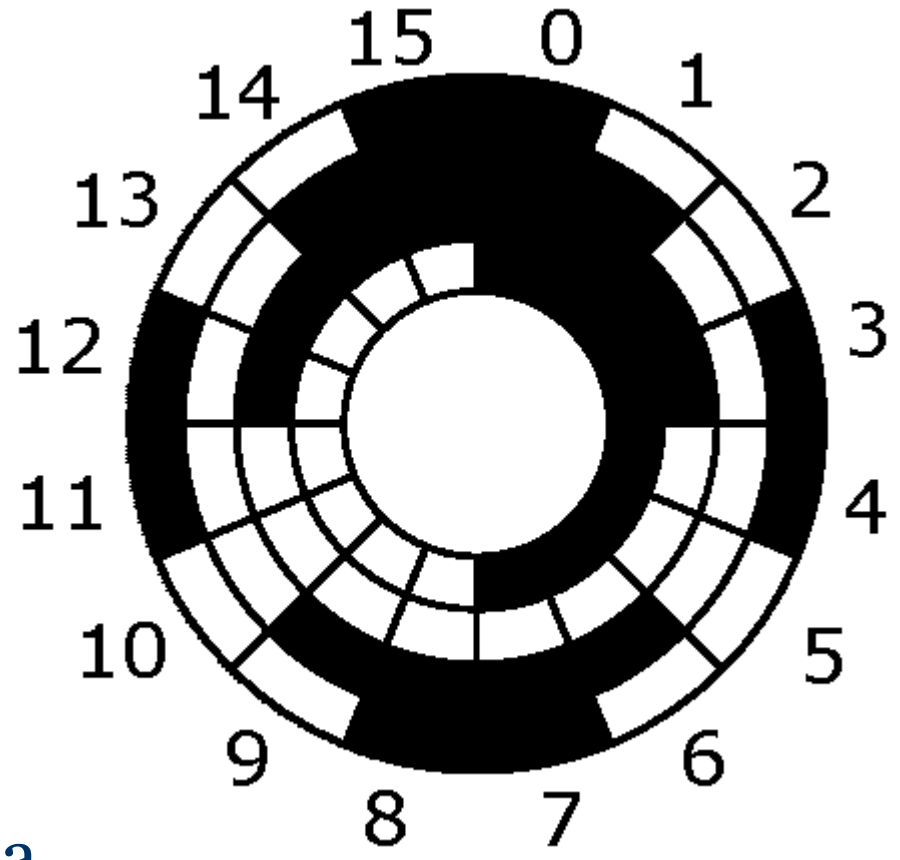


# Sensor for Position: Absolute Shaft Encoder

## Gray Code

- Only one bit changes at a time

| Decimal | 4-bit Gray | Decimal | 4-bit Gray |
|---|---|---|---|
| 0 | 0000 | 8 | 1100 |
| 1 | 0001 | 9 | 1101 |
| 2 | 0011 | 10 | 1111 |
| 3 | 0010 | 11 | 1110 |
| 4 | 0110 | 12 | 1010 |
| 5 | 0111 | 13 | 1011 |
| 6 | 0101 | 14 | 1001 |
| 7 | 0100 | 15 | 1000 |

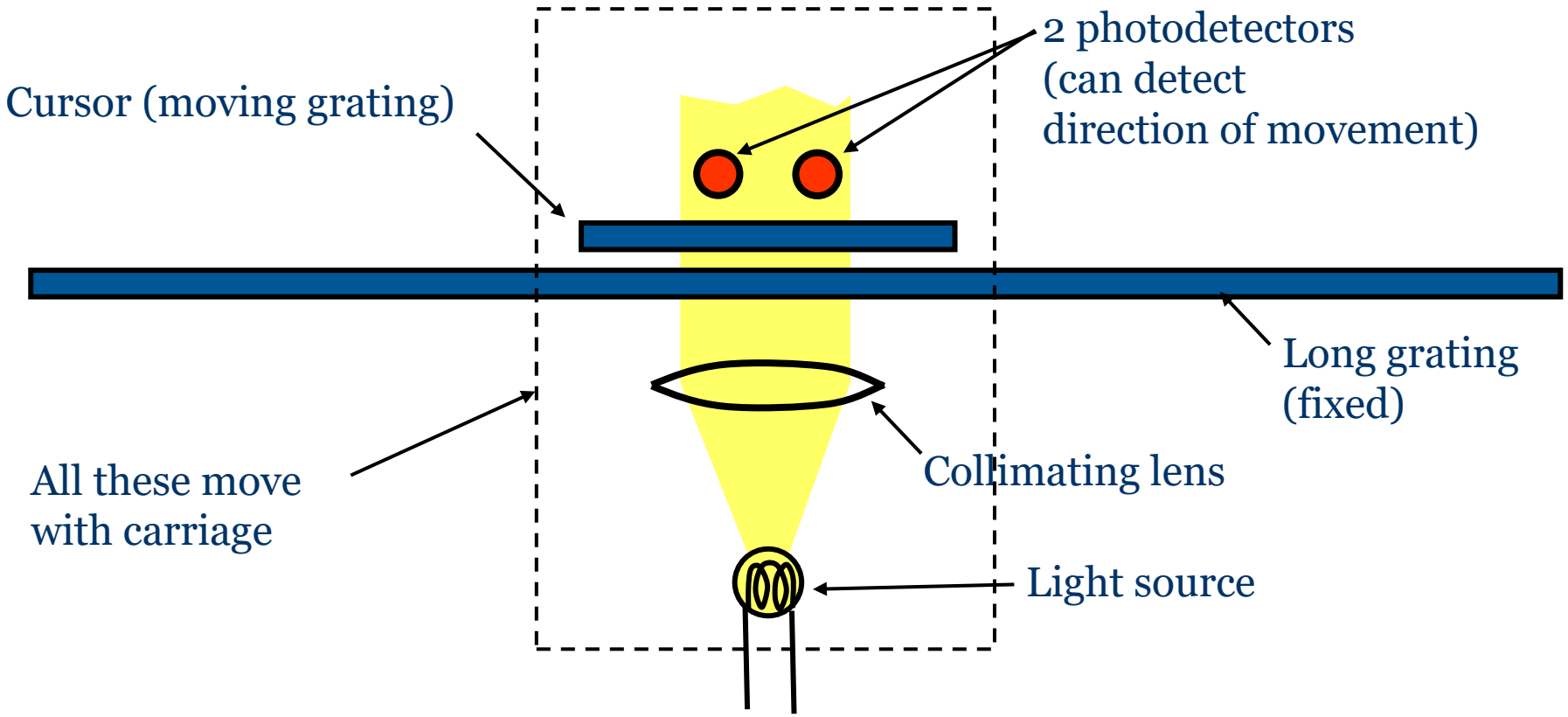



- Read into computer as parallel binary data
- Normally converted from Gray code to numeric data using software (lookup table etc.)

# Linear Grating-based (Moiré) Sensors

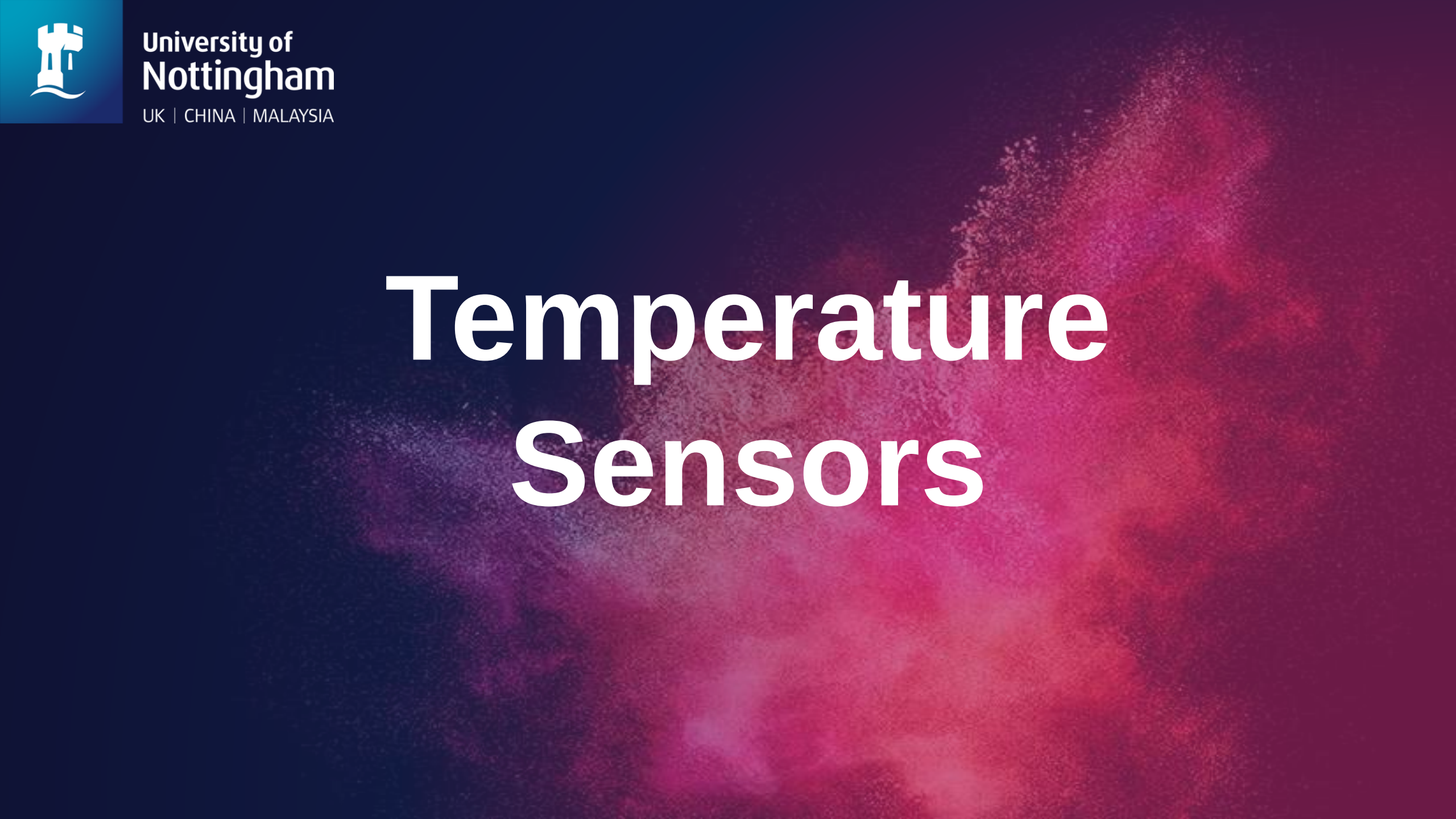
- Effectively, linear versions of the same kind of thing
- Long grating is attached to bed of  machine.
- A shorter grating (different spacing or orientated at angle) is attached to the saddle of the machine

# Linear Grating-based (Moiré) Sensors



# Linear and Rotary encoder - Incremental and Absolute encoder: Summary


https://www.youtube.com/watch?v=nnkoDV5kgMk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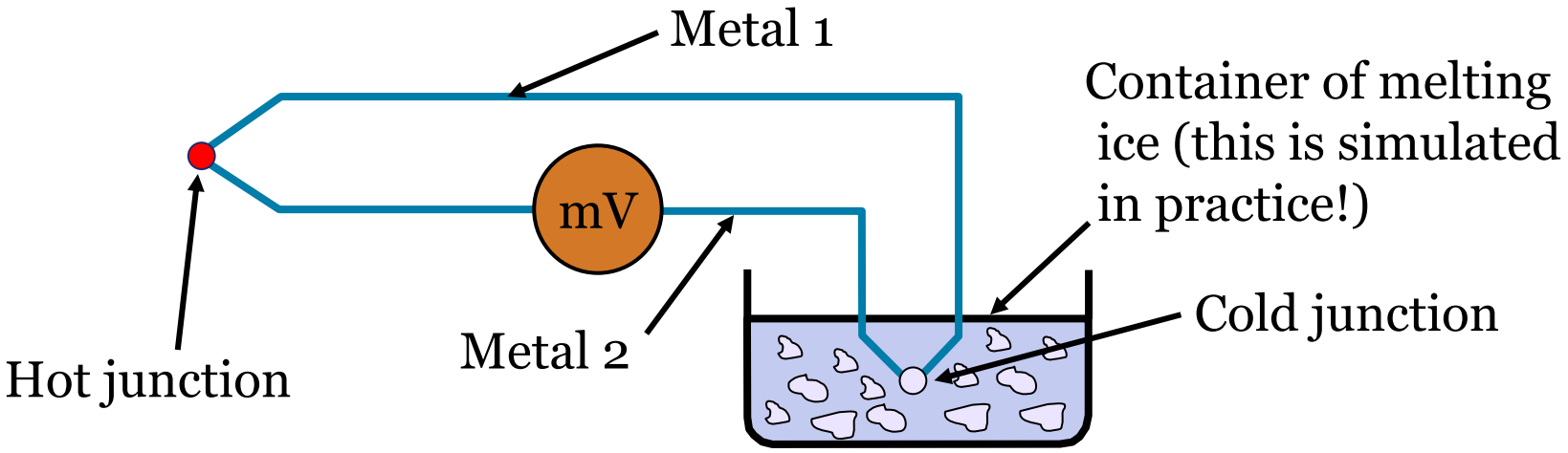
Temperature
Sensors

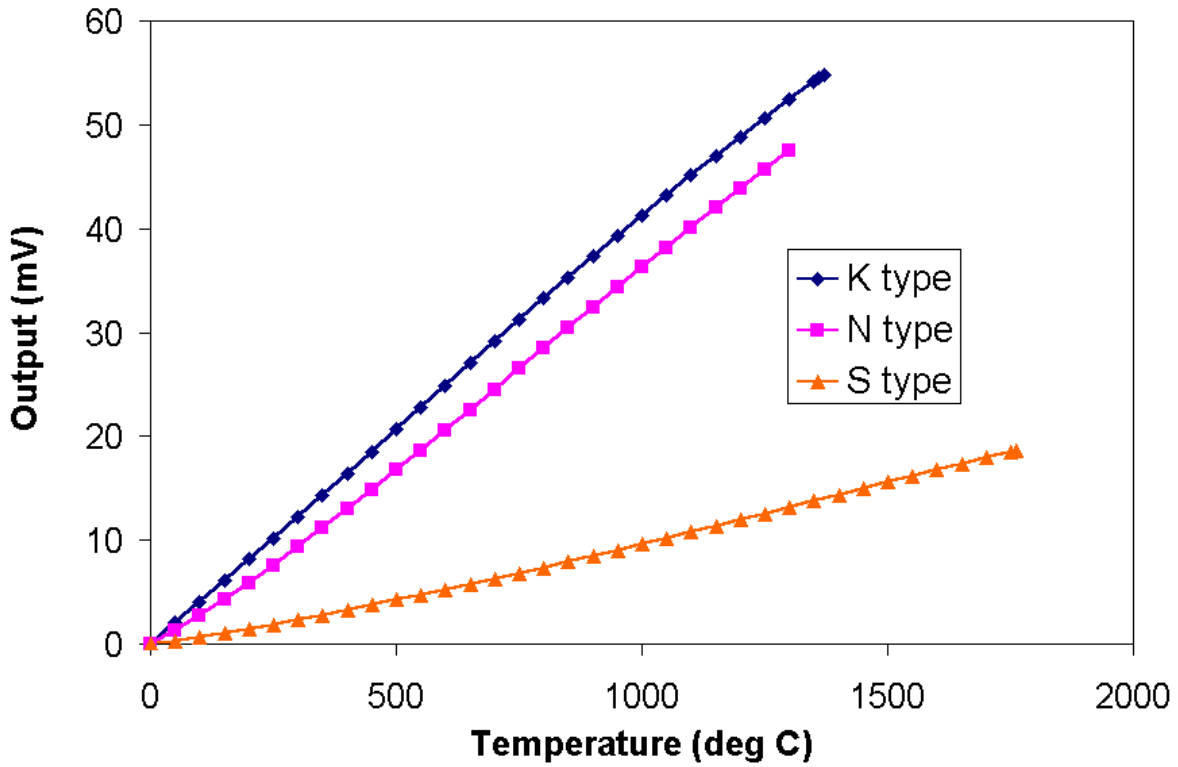
# Thermocouples

- **Thermocouples** are a simple and reliable temperature measurement technique
- Two wires, dissimilar metals, joined at each end, with millivoltmeter inserted into circuit
- EMF (a few mV) $\propto$ temperature difference



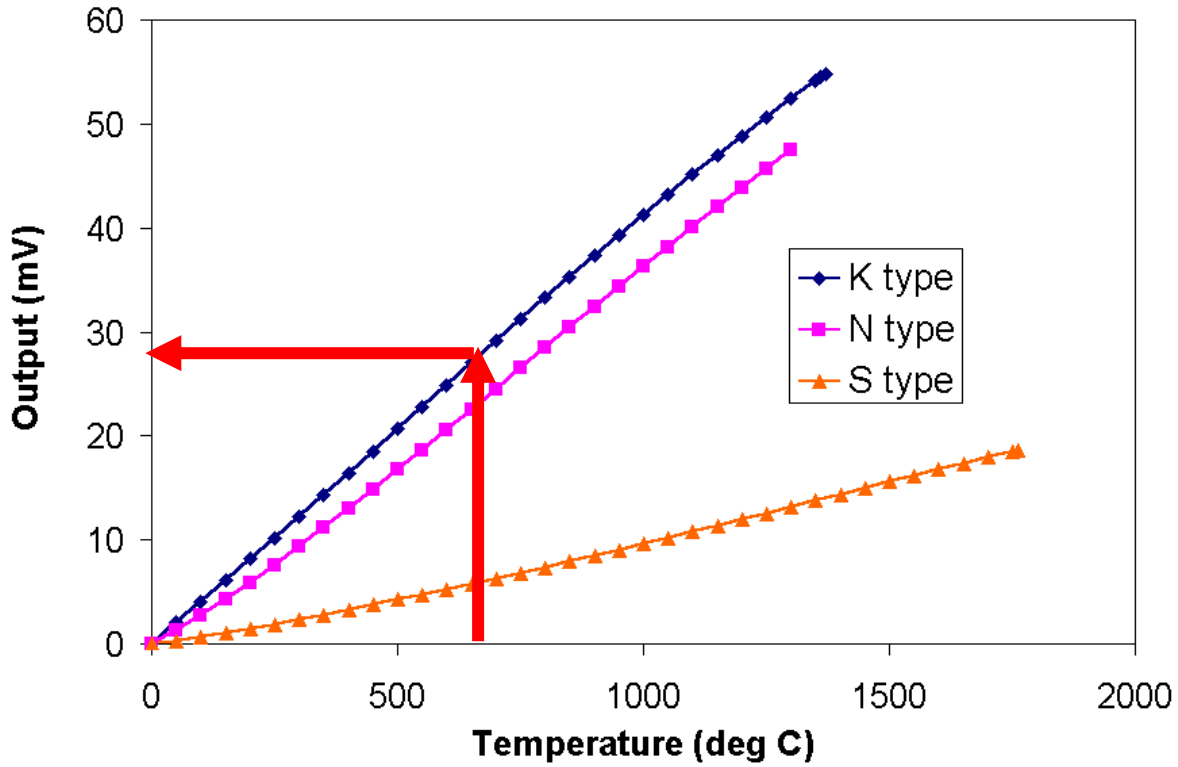
# Thermocouples

- Different combinations of alloys (K type, S type etc) give different curves



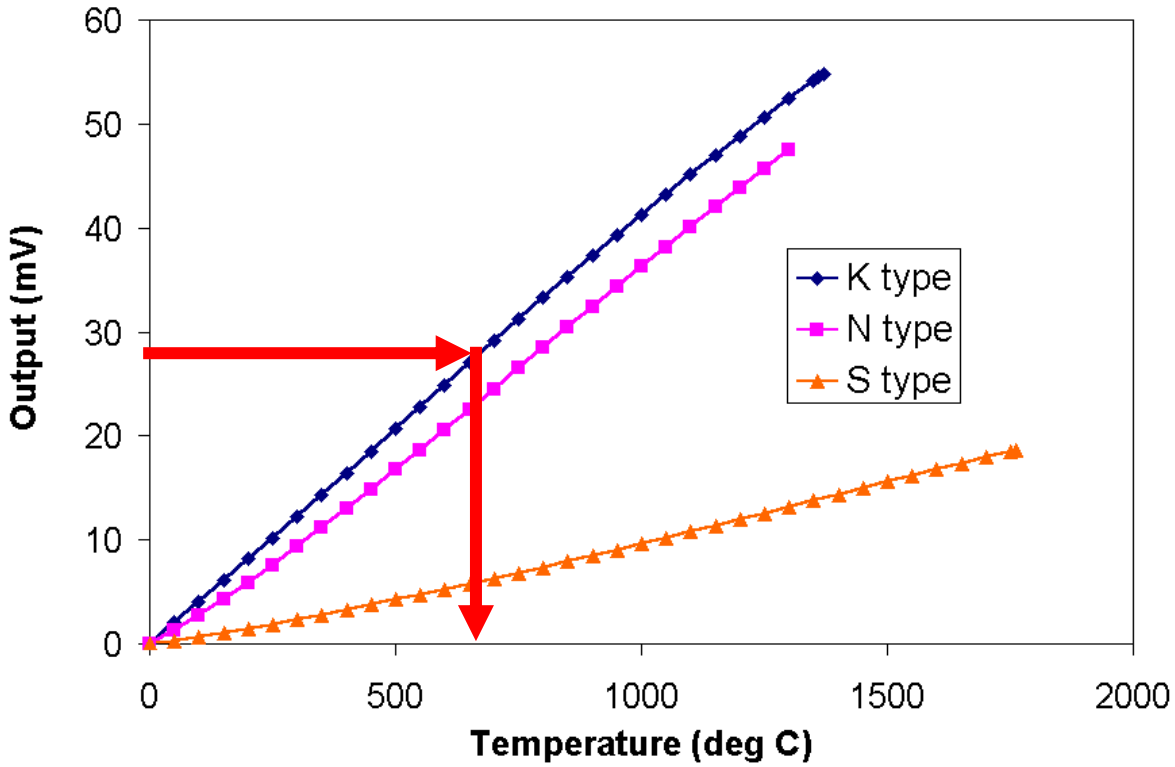
# Thermocouples

- NIST polynomials giving curves:
  - Forward (EMF in terms of temperature)



# Thermocouples

- NIST polynomials giving curves:
  - Inverse (temperature in terms of EMF)

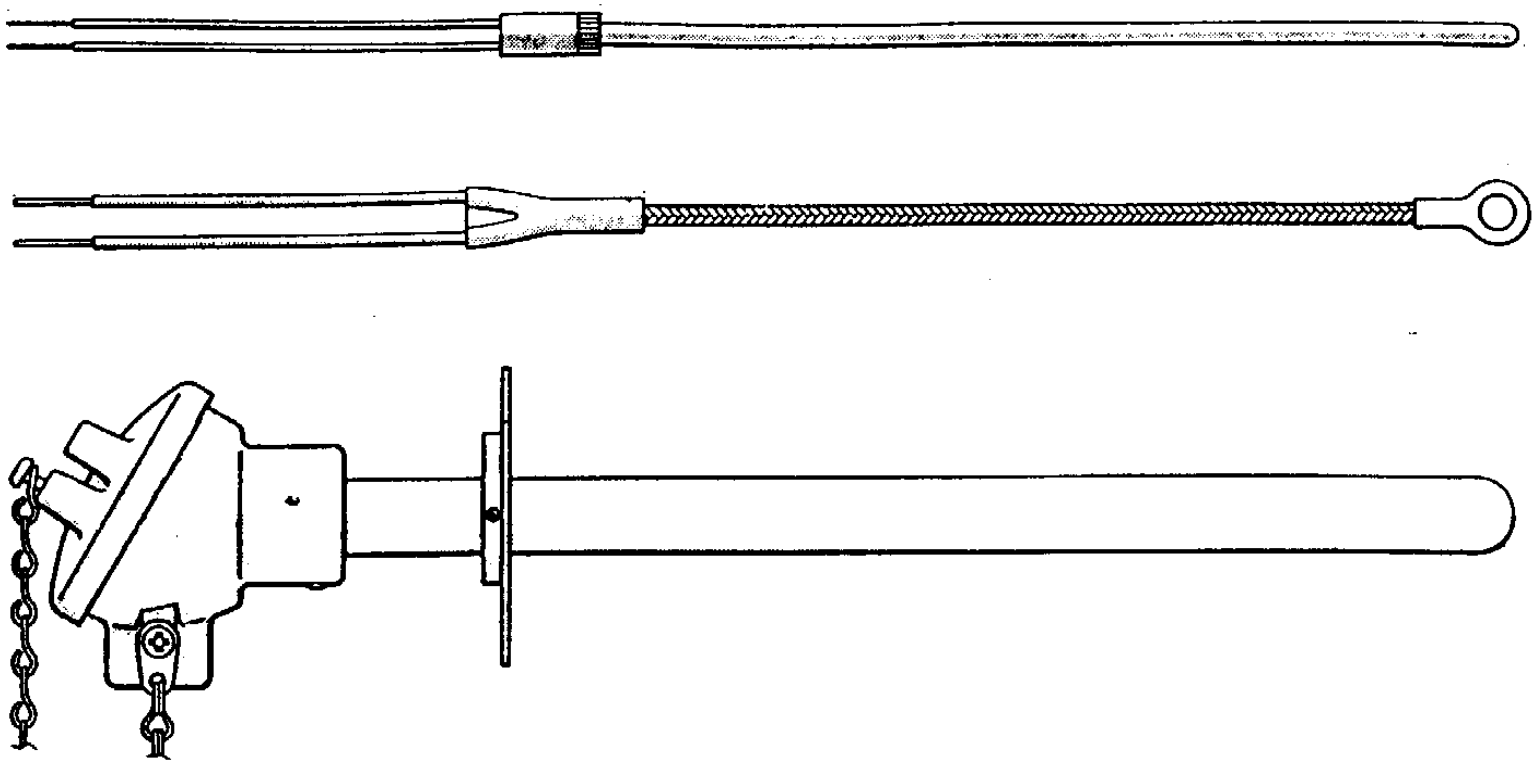


# Thermocouples

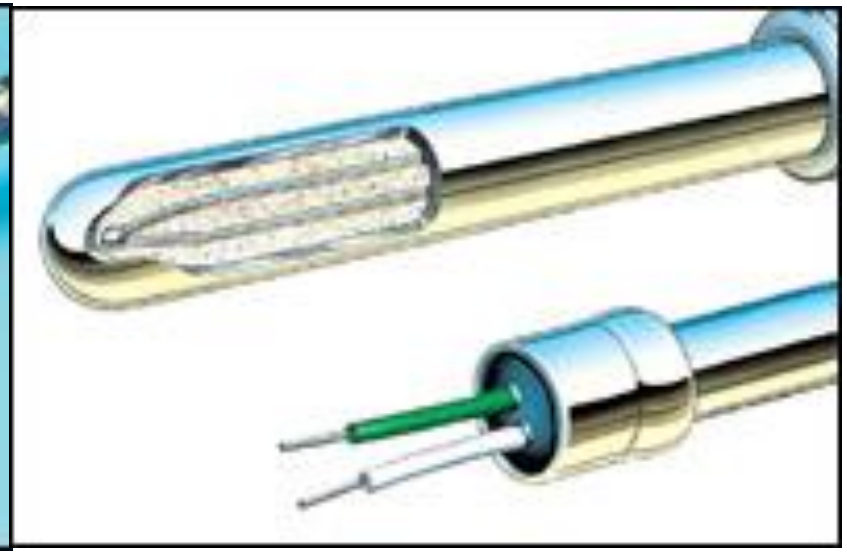
- For non-hostile environments, thermocouple is two insulated wires spot-welded together

# Thermocouples

- For industrial applications, various encapsulations and sheaths are available

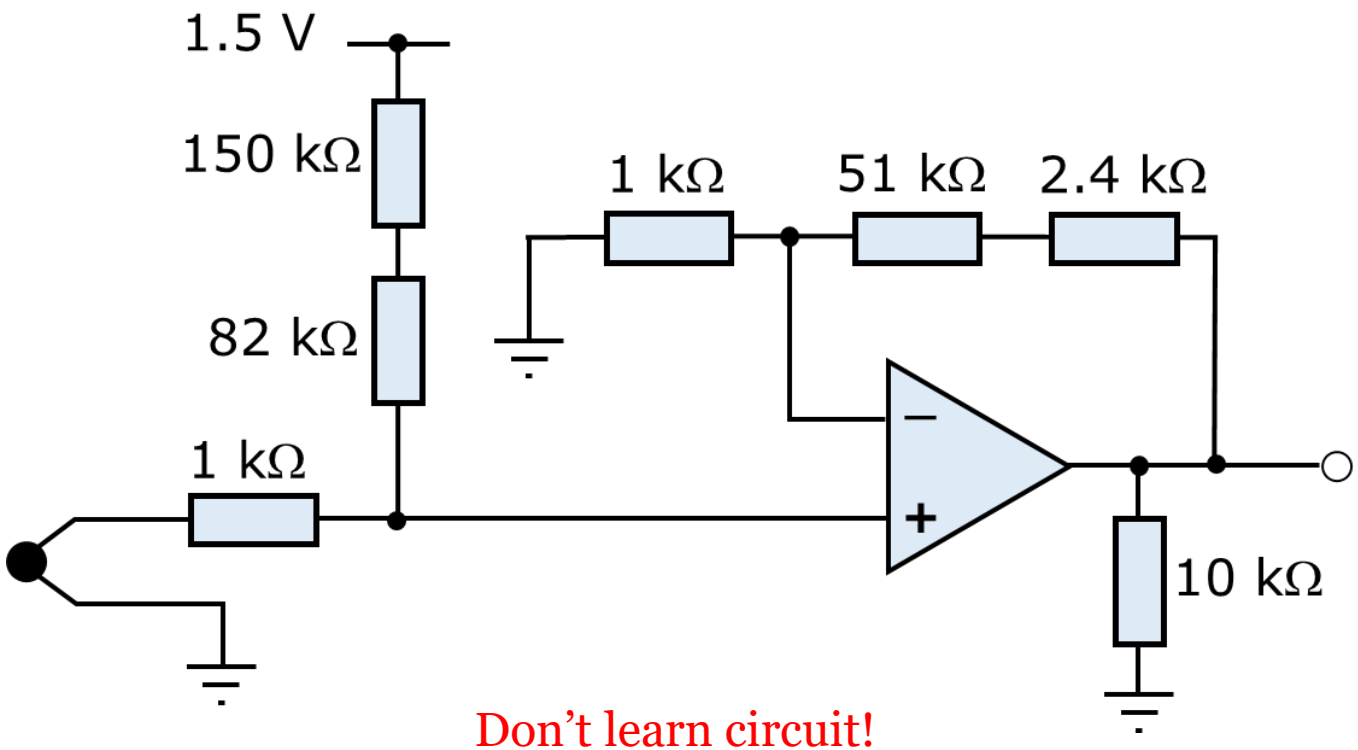


# Thermocouples



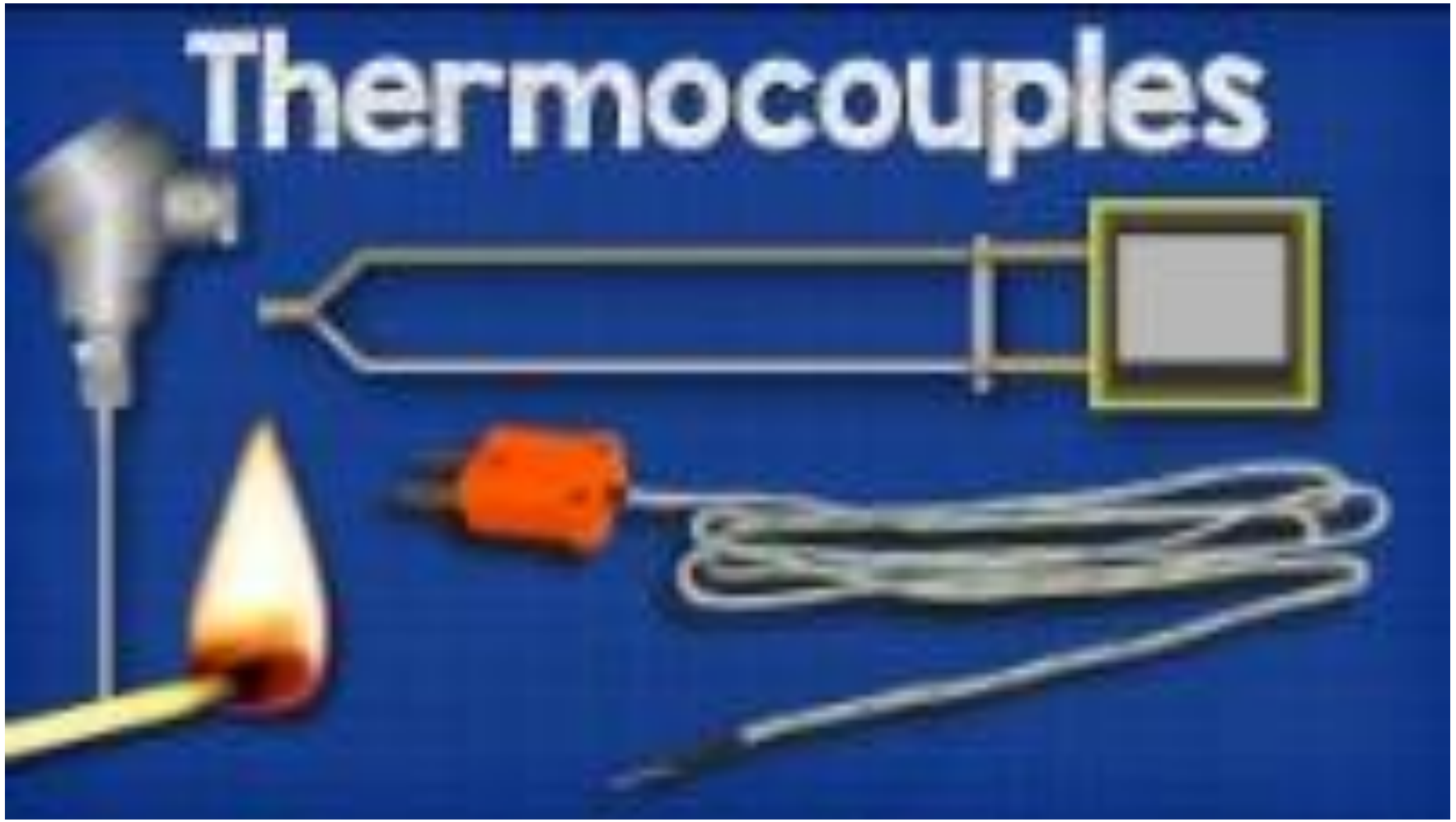
# Thermocouples

- To interface this to a computer, need:
  - A high-gain, high-stability amplifier (ideally!)




Don’t learn circuit!

# Thermocouples



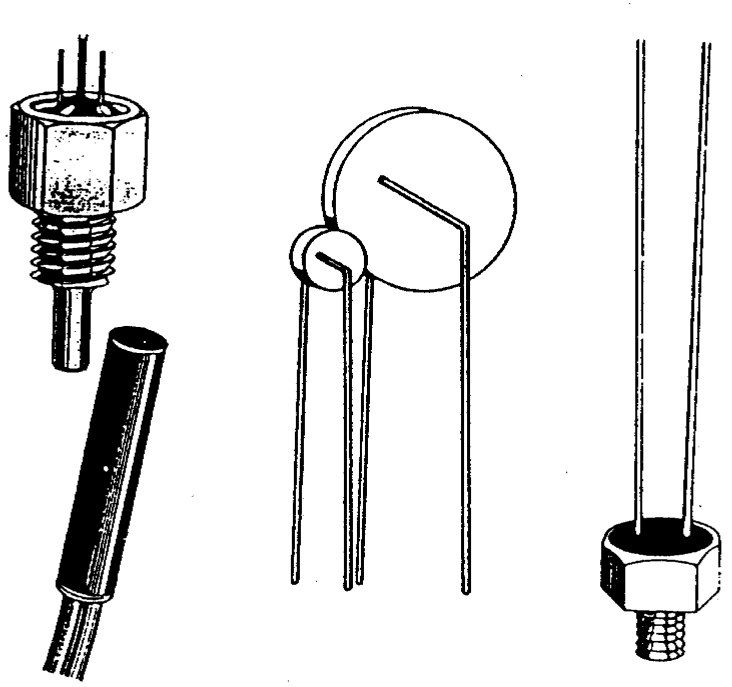

https://www.youtube.com/watch?v=v7NUi88Lxi8&t=4s

# Thermocouples

- To interface this to a computer, need:
  - A high-gain, high-stability amplifier
  - An analogue-to-digital converter
  - *Cold junction compensation* – a means of compensating for actual temperature of cold junction
  - Measure actual cold junction temperature with (e.g.) thermistor
- Readily available in data acquisition h/ware

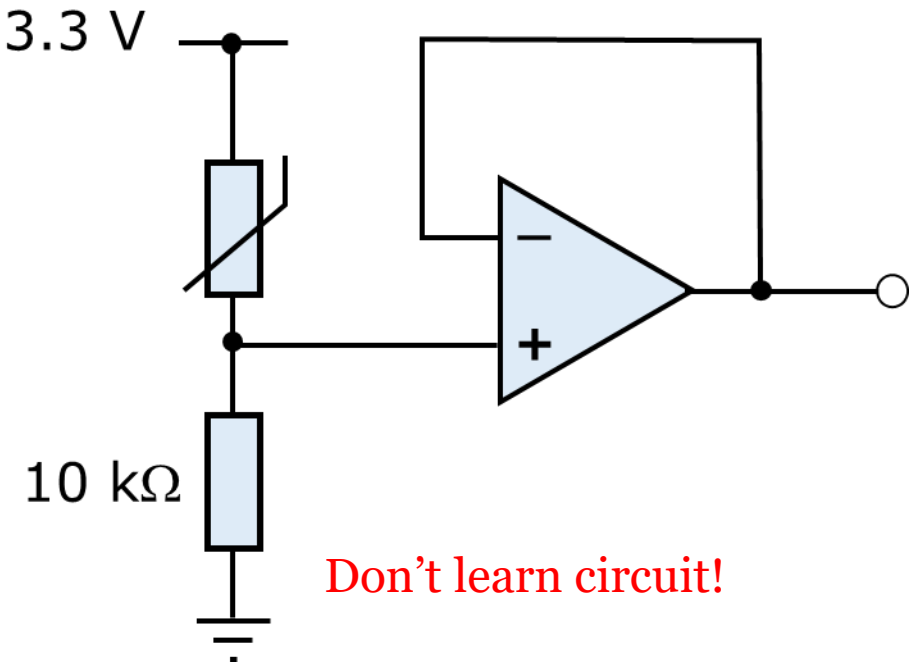
# Thermistors

- **Thermistors** involve changing resistance with temperature
- Low-cost semi-conductor devices
- Highly non-linear
- Resistance falls with temperature
- Care needed to avoid self-heating effects



# Thermistors

- Simple input circuit (learn what it does, not what it looks like or details of how it works)




Don’t learn circuit!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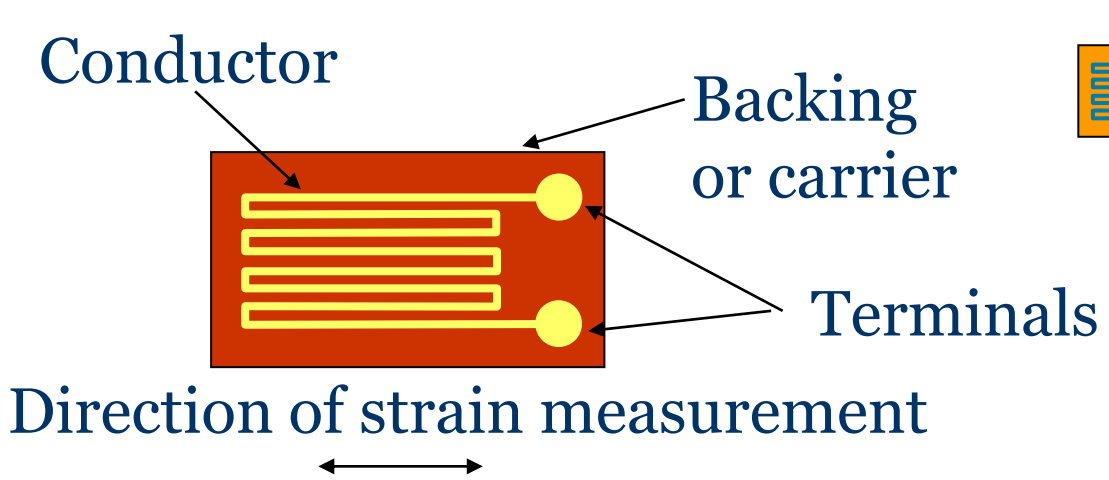
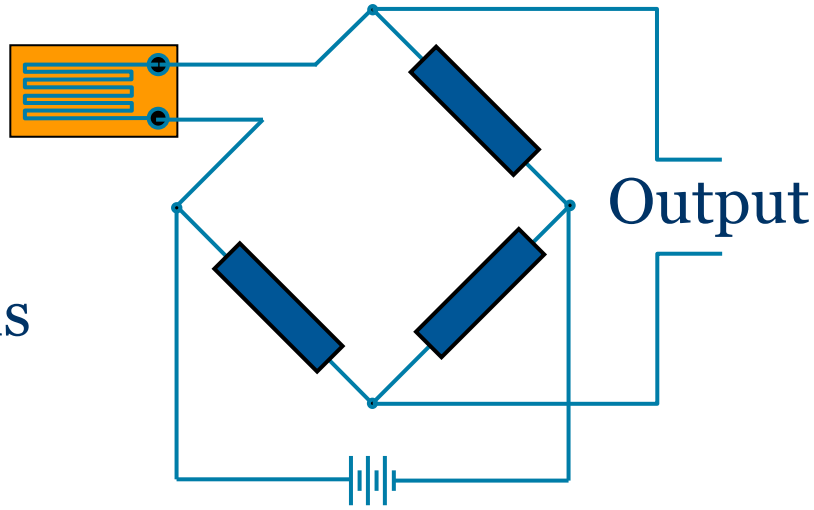
Pressure and
Force
sensors

# Strain Guage

- Grid of conductor bonded to specimen surface
- As it stretches, gauge resistance changes
- Change in resistance is usually small, detected using a Wheatstone bridge



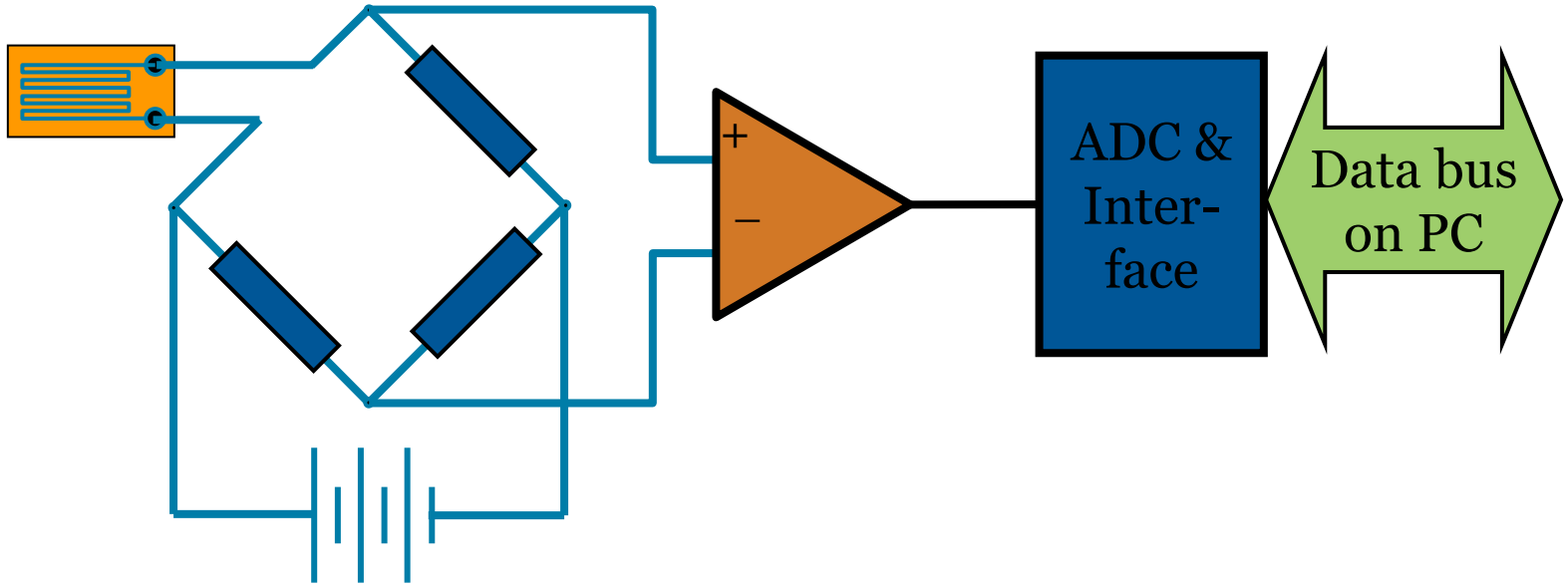



# Strain Guage

- Force and pressure sensors are usually based on strain gauges or variants of them
- Need:
  - Excitation voltage
  - Amplifier and/or signal conditioning
  - High-resolution ADC
- Various bridge configurations: quarter, half, full bridge (Wheatstone bridge)

# Strain Guage

- Either:
- Use separate power supply and signal conditioning including amplifier, with ordinary ADC



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  - Force/Pressure sensor

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