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EEEE1002
Applied Engineering Design

Session 3 Episode 1

A Brief Introduction on Optical Sensors

Sensors

Introduction

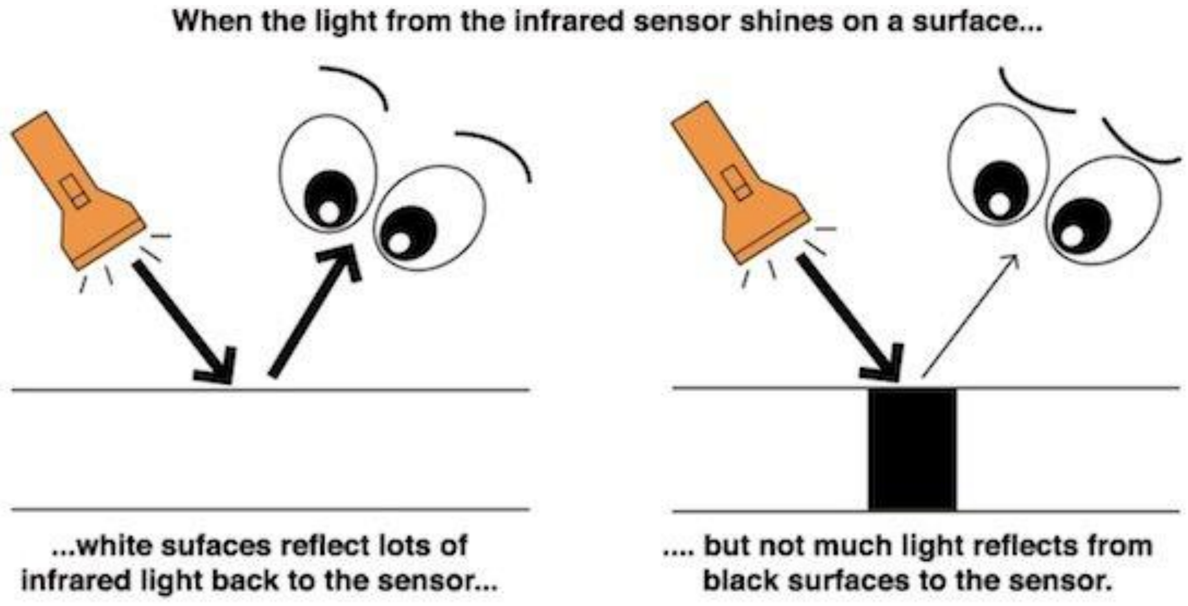
- A sensor is a device that **detects** and **responds** to some type of **input** from the physical environment.

- Will use **sensors** to “interact” with the world to recognise certain patterns and make decisions…

Sensors

Optical Sensors

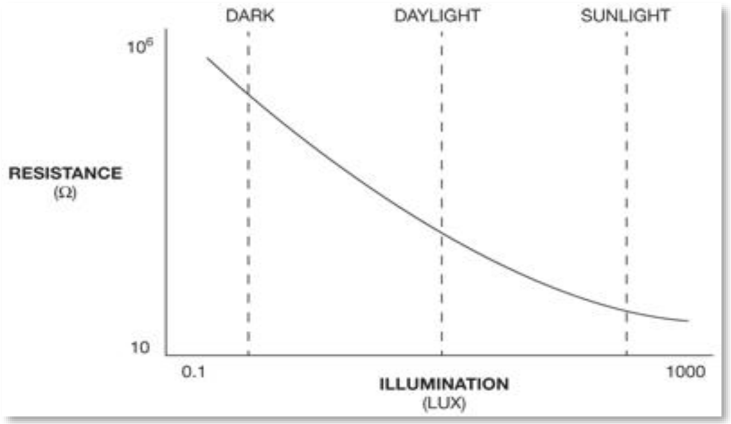
- Optical sensors respond to a change in light energy to vary the flow of current through them

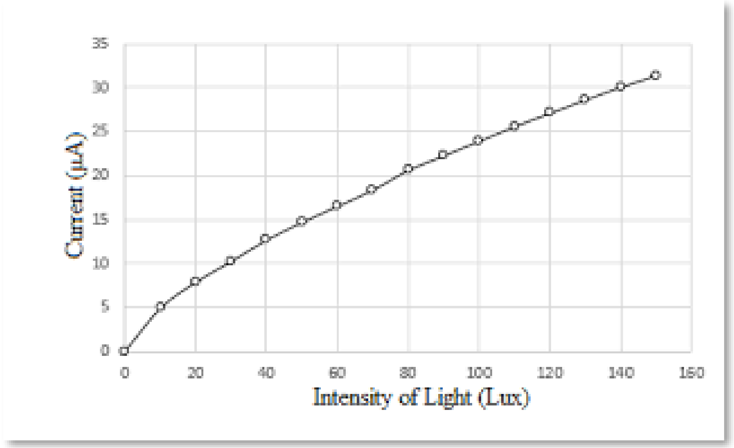


Sensors

Optical Sensors

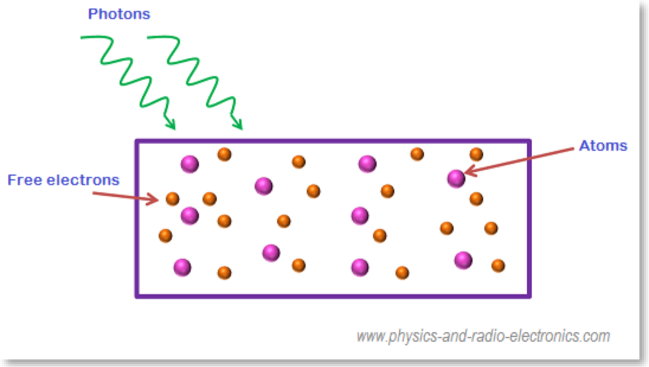
- There are several devices (photo detectors) that are used for detecting light, we will discuss two that may be used in our applications: **photo resistors** and **photodiodes**.
- Photoresitor – device resistance is a function of illumination
- Photodiode generates photocurrent proportional to the level of illumination

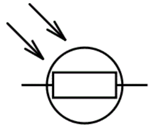




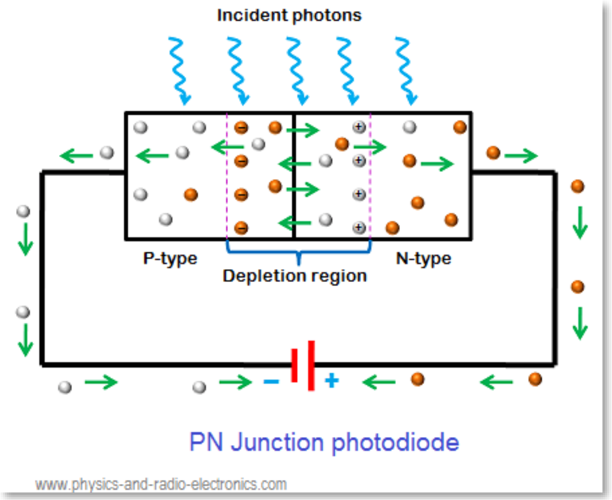
Optical Sensors

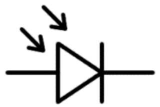
- Photoresistor – resistance decreases as light increases
  - Cheap
  - Bidirectional
  - However, slow response time





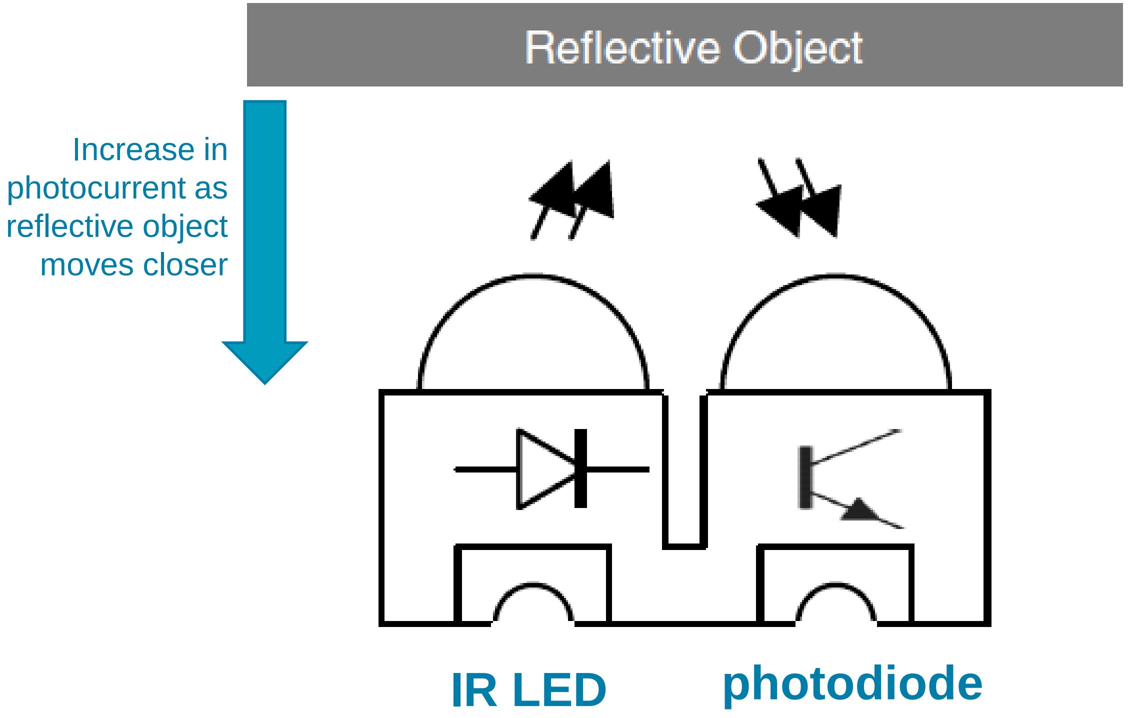
- Photodiode – converts light into current
  - Highly sensitive
  - Quick response time
  - Requires amplification





Photodiode

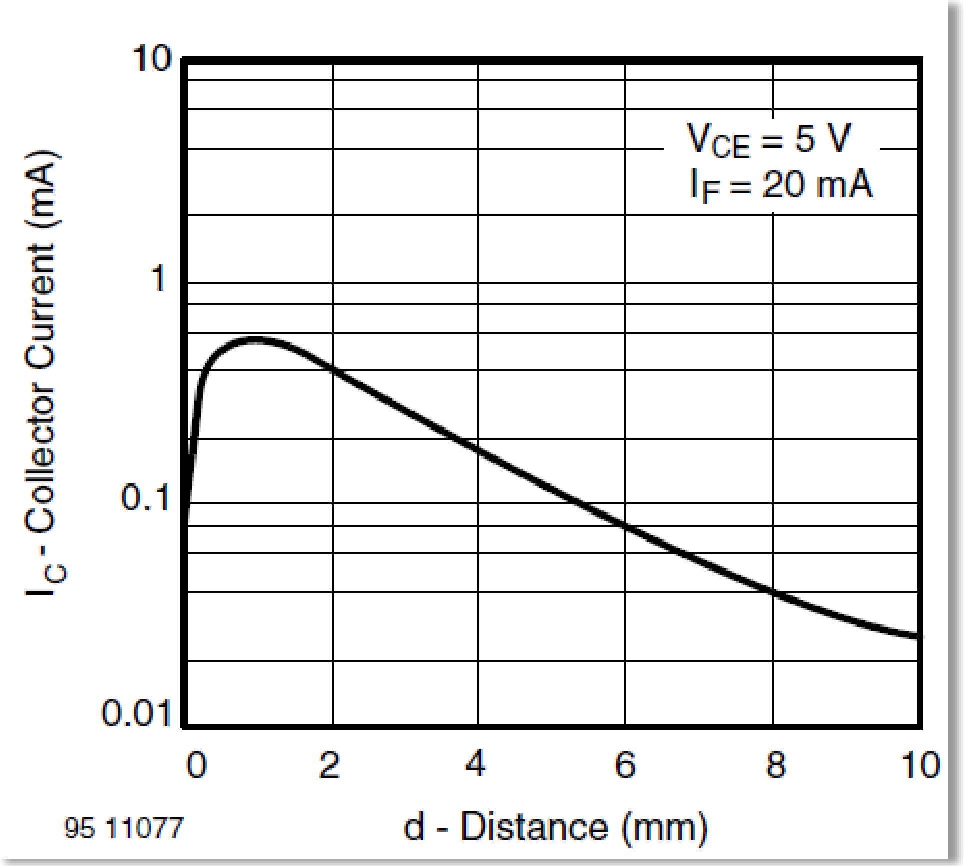
- Here, a reflective sensor houses an infrared (IR) emitter and IR sensitive photo detector adjacent to each other, in a single package. When an object is brought into the sensing area, the emitted light is reflected back towards the photodiode and, the amount of light energy reaching the detector increases causing an increase in current flow. This change in 'photo current' is then used as the input signal to a circuit or system.



Sensors

Photodiode

- Typical current versus distance of a sensor from a reflective material
- Ideally you would chose a sensor whose peak ‘collector current’ occurs at the chosen operating distance
  - e.g. an optical mouse may have a peak collector current around 0.5 to 1mm

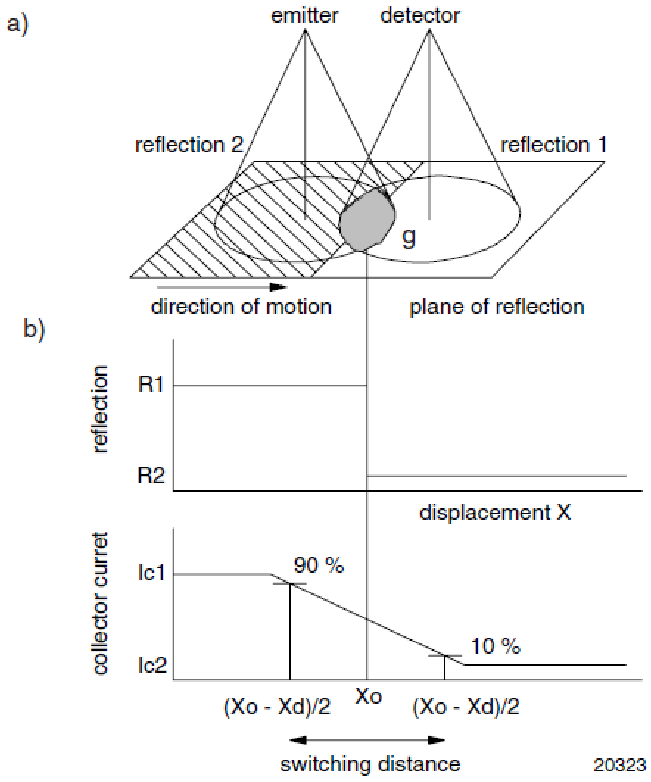


Sensors

Photodiode

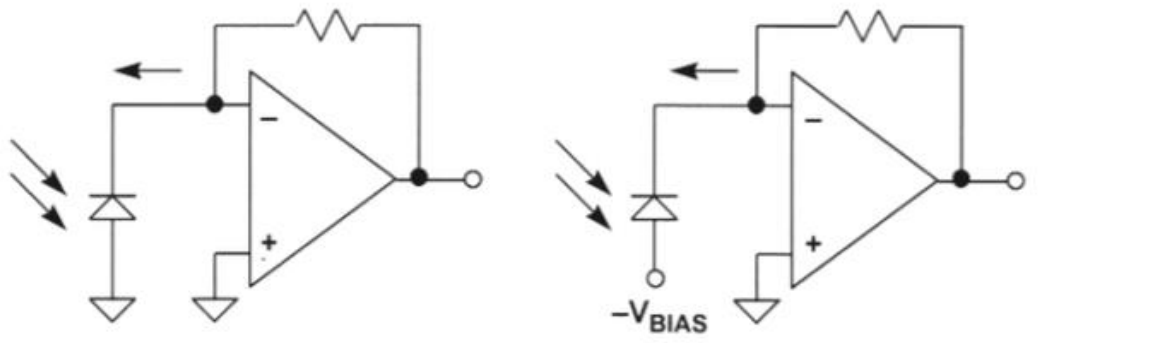
- Transition between **high-reflectivity** and **low-reflectivity** area does not result in a simple off-on
- Photo detector will ‘see’ varying contribution from both high and low-reflectivity areas
- There is a gradual fall and rise in photocurrent
- If changes in reflectivity occur at intervals of <switching distance then the change may not be recognised

Sensor pair scans across a surface with areas of differing reflectivity



Photodiode

- Can be connected in the **photovoltaic** or **photoconductive** mode



PHOTOVOLTAIC

- Zero Bias
- No "Dark" Current
- Linear
- Low Noise (Johnson)
- Precision Applications

PHOTOCONDUCTIVE

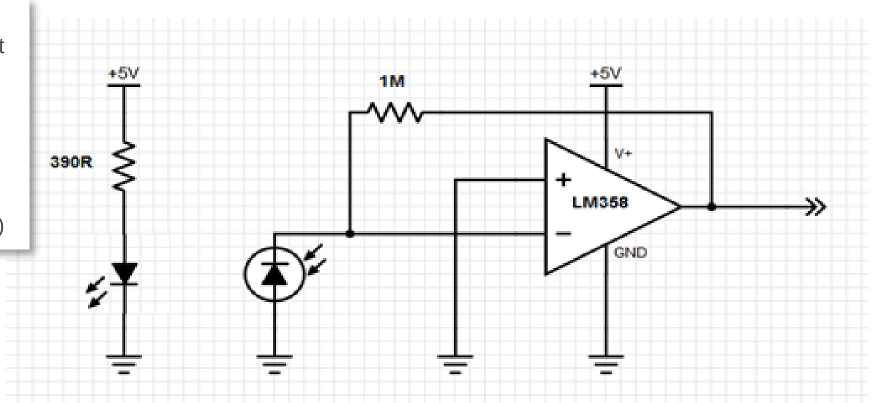
- Reverse Bias
- Has "Dark" Current
- Nonlinear
- Higher Noise (Johnson + Shot)
- High Speed Applications

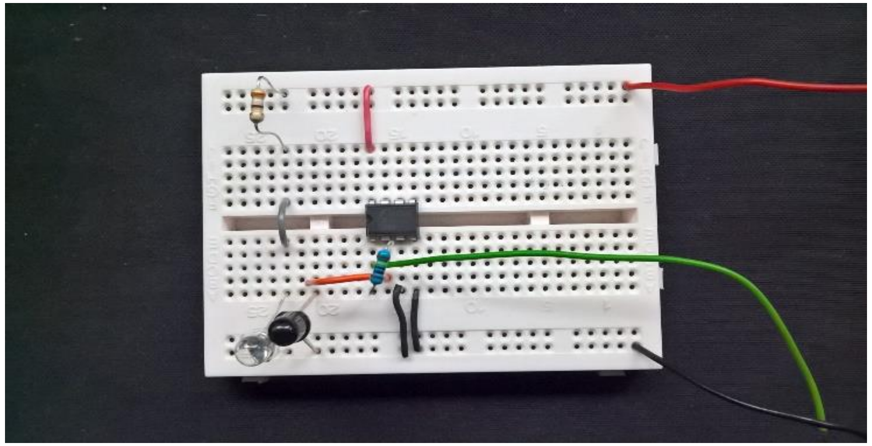
Sensors

Optical Sensors

- Photocurrent is small and practical applications will require some amplification
- **Build the circuit**
- **Use the oscilloscope to test your circuit**
- Use your Lab book to note and describe your observations
- **Can the circuit be used to measure distance?**

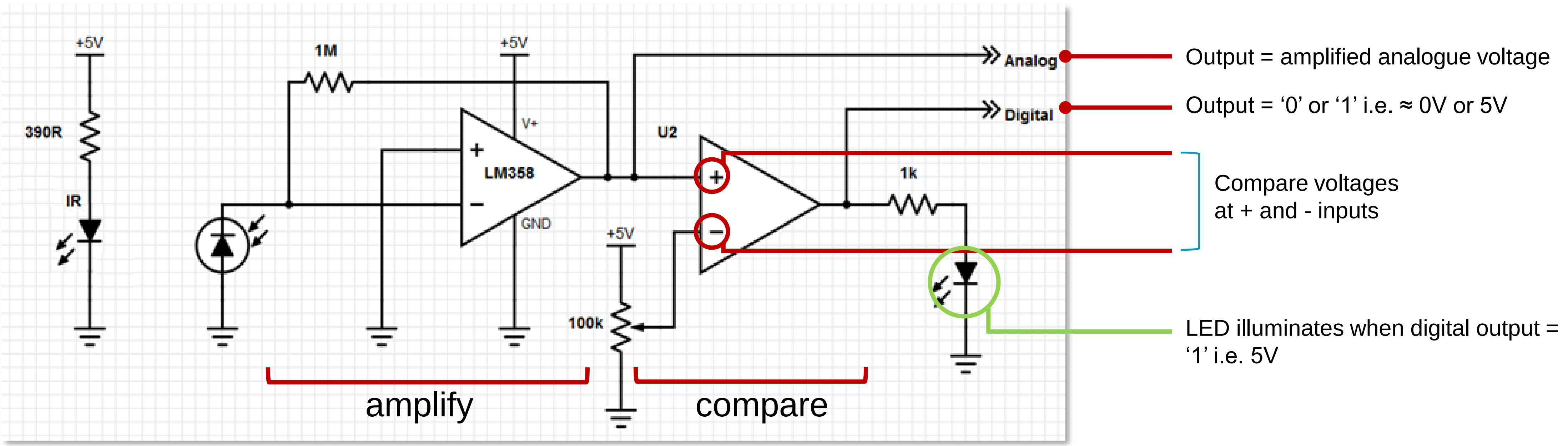
Whilst the schematic shows 390R as the current limiting resistor these may not be in your kit of parts. What value do you have that can be used?
(hint: rewind to SE1 E02 slide 25 & 26 and the IR LED datasheet on Moodle)





Photodiode

- In this circuit a second Op Amp is used as voltage comparator, i.e. it compares the voltage levels between its inverting input and non-inverting input and gives an appropriate high / low output.



Photodiode

- Implement the circuit on the previous slide
- Use your Lab book to note and describe your observations

A Note on Sensor Calibration

Sensor Calibration Basics

Measurement Error

- **Error:** Result of a measurement minus a true value of the measurand (departure from the true value)
- Measurement errors:
  - **Systematic error** (E_s)

    = mean {many measurements} – true value
  - **Random error** (E_r)

    = a measurement - mean {many measurements}

Sensor Calibration Basics

Measurement Error

A

E_s: close to zero

E_r : very small

C

E_s: large

E_r : very small

B

E_s: close to zero

E_r : large

D

E_s: large

E_r : large

Note: C take away the systematic error = A

Sensor Calibration Basics

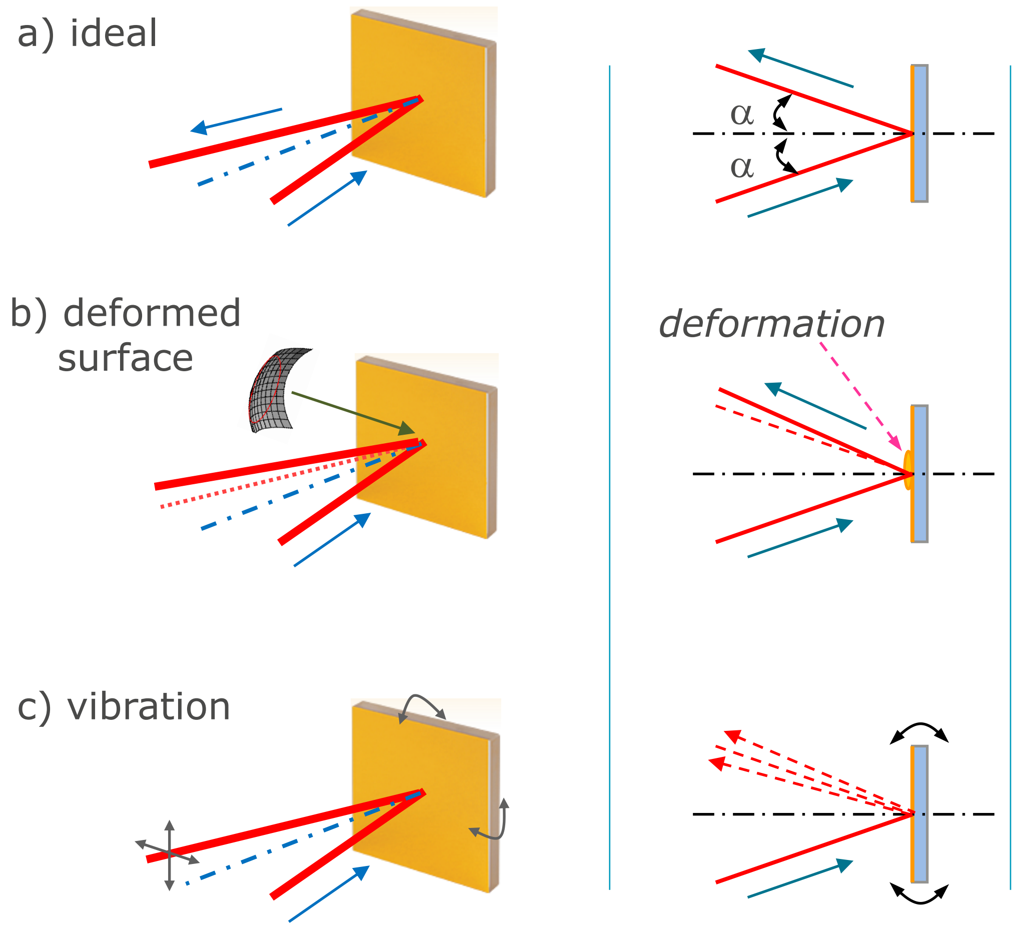
Measurement Error: Sources of Error

- Systematic error:
    - Faulty components and/or equipment
    - Incorrect calibration
    - Inappropriate operating conditions
- Random error:
    - Fundamental noise: shot noise, Johnson noise, flicker noise
    - Changes in the environment: vibration, temperature, pressure, humidity

Sensor Calibration Basics

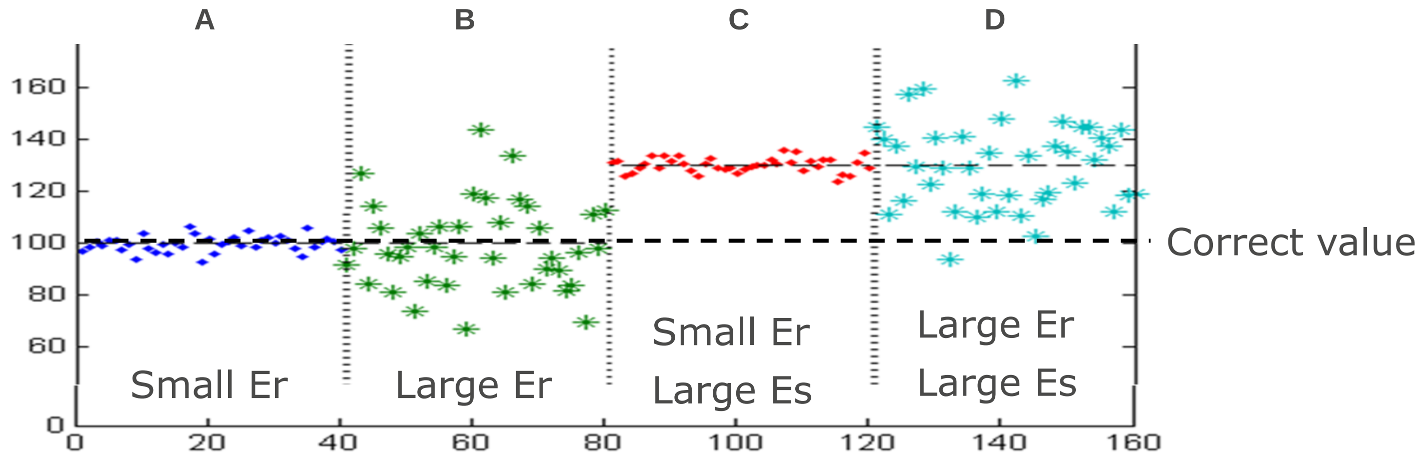
Measurement Error: Example

- Ideal: α in = α out, easy to predict result of tilting mirror
- Deformation: α in ≠ α, difficult to predict result of tilting mirror
- Vibration: reflected beam will change direction in a random manner (temporally and in magnitude)



Sensor Calibration Basics

Error Minimisation



- **Systematic error:** use traceable reference samples to **calibrate** system regularly.
  - Stick to the designed operating environment.
- **Random error:** modify system, for example, ac rather than dc operation.
  - Control operating environment, such as temperature, vibration and electrical interference.
- **Need to understand the system before the appropriate method can be selected.**

Sensor Calibration Basics

Presenting Results

- If X = [x_1, x_2, x_3,…,x_n] is the outcome of a repeated set of measurements
- Arithmetic mean: $\bar{x} = \frac{1}{N}\sum_{j=1}^{N} x_j$
- Variance: $\sigma^2(x_j) = \frac{1}{N}\sum_{j=1}^{N}\left(x_j - \bar{x}\right)^2$
- Standard deviation: σ
- Measurements then presented as a value $\pm\,\sigma$

The smaller the variance the closer the measurements are to each other i.e. the smaller the spread. A variance of zero implies all measurements are identical

Square root of variance, the standard deviation is a more intuitive indicator of measurement precision

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End of Episode 1