4. Technical Review – Sensors

:: EAM 5715 Electronic Devices for Human Interface Systems (EDHIS)

Background

❑ Sensor?

- A device that receives and responds to a signal or stimulus

- A device that receives a signal or stimulus (measurand) and responds with an electrical signal

❑ Natural sensor – electrochemical signal

❑ Man-made sensor – electrical signal (in most cases)

❑ Passive sensor – directly generate an electrical signal in response to an external stimulus without any additional power source; thermocoulple, piezoelectric etc

❑ Active sensor – changes its own properties in response to an external effect and these properties are subsequently converted into electrical signal; thermister etc

# Sensors in a system
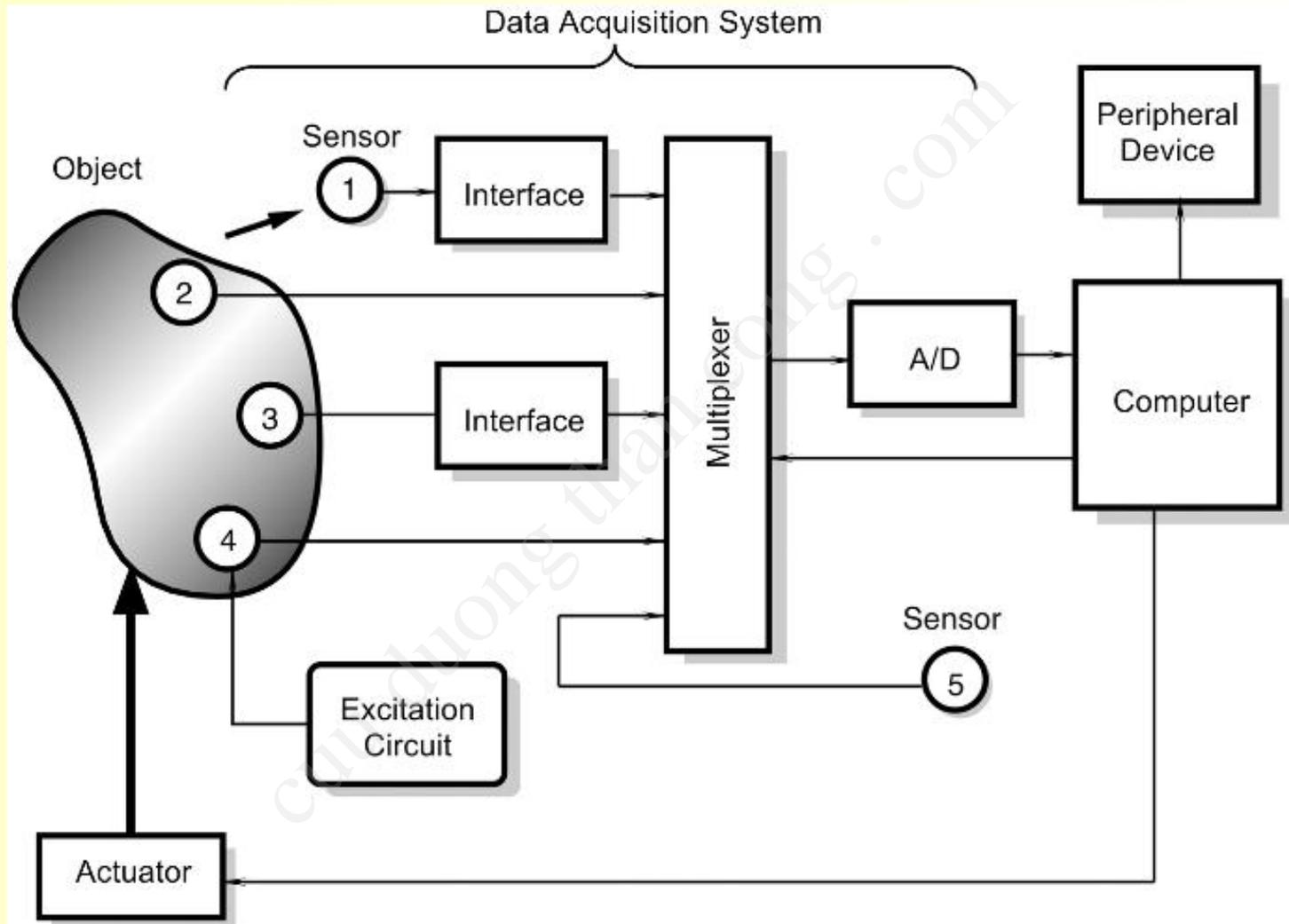
From Fraden

Transfer function

❑ Sensor output – stimulus (measurand) relationship: $S = f(s)$
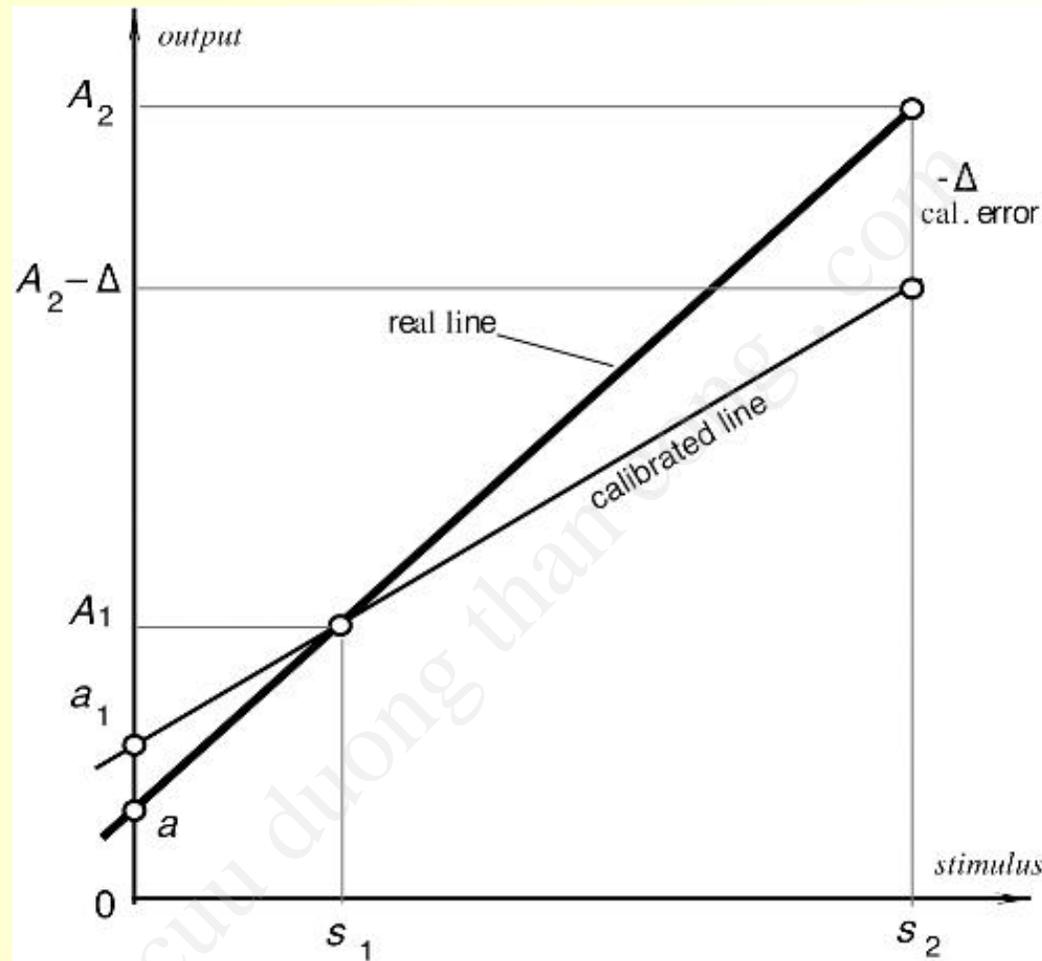
❑ Linear or non-linear

Sensor characteristics

❑ Span; input full scale (FS) – a dynamic range of stimuli that may be converted by a sensor. The highest possible input value that can be applied without causing unacceptable large inaccuracy.

❑ Full scale output (FSO)- algebraic difference between the electrical output signals measured with maximum input stimulus and the lowest input stimulus applied

❑ Accuracy – inaccuracy in true meaning. A highest deviation of a value represented by the sensor from the ideal or true value at its input.

Can be represented:

- in terms of measured deviation (Δ)

- in percent of input span

- in terms of output signal

❑ Precision (standard deviation) - the closeness of repeated measurements to each other. vs. Accuracy is the closeness of a measured or derived data value to its true value
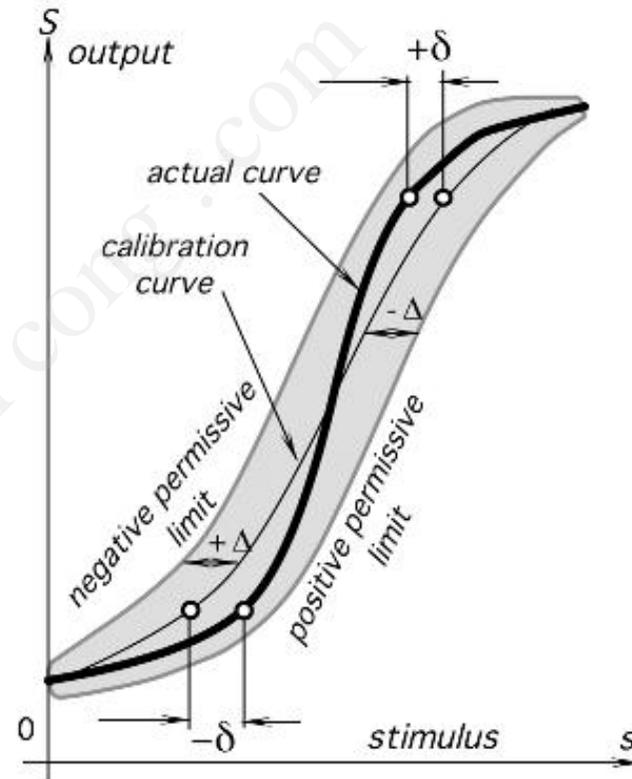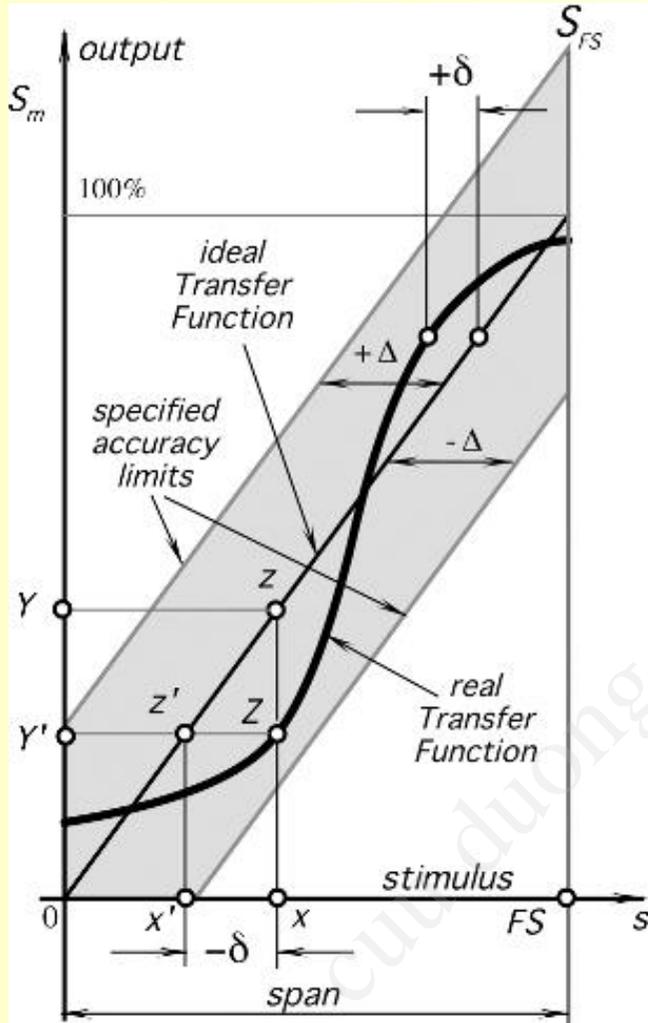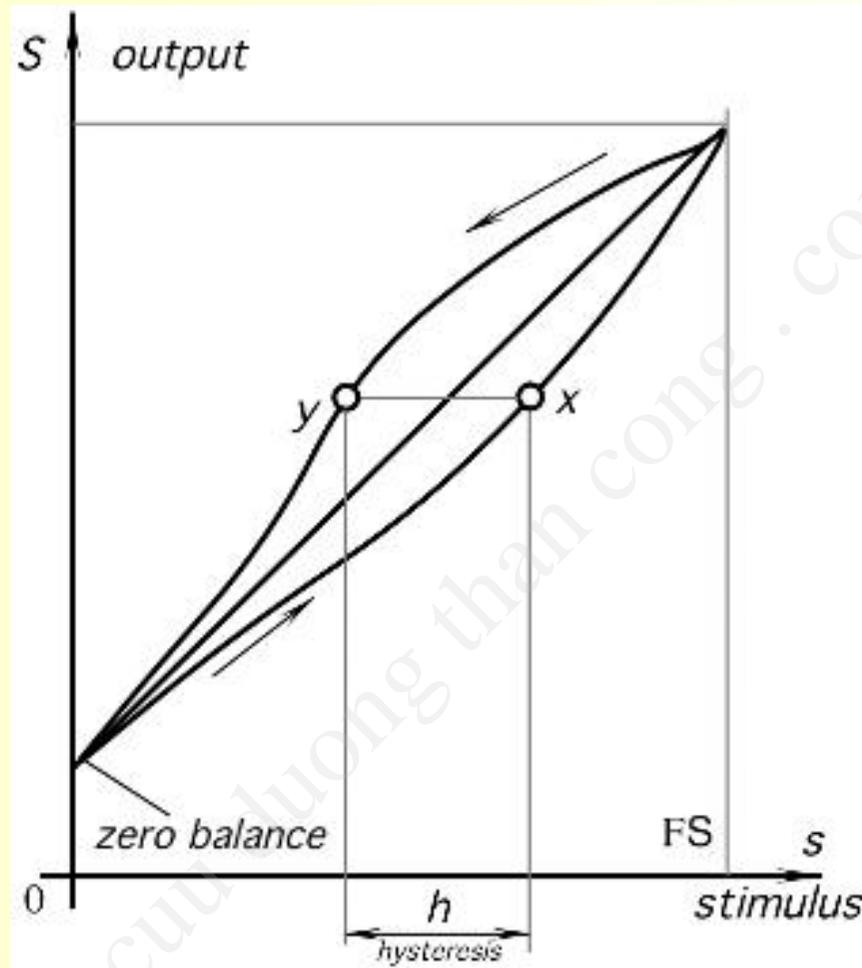
From Fraden

❑ Calibration error - inaccuracy permitted by a manufacturer when a sensor is calibrated in the factory. Systematic error.

❑ Hysteresis error – deviation if the sensor's output at a specified point of the input signal when it is approached from the opposite direction (mainly due to friction and structural changes in materials)

❑ Nonlinearity error – maximum deviation of a real transfer function from the approximation straight line in % span or in terms of measured value
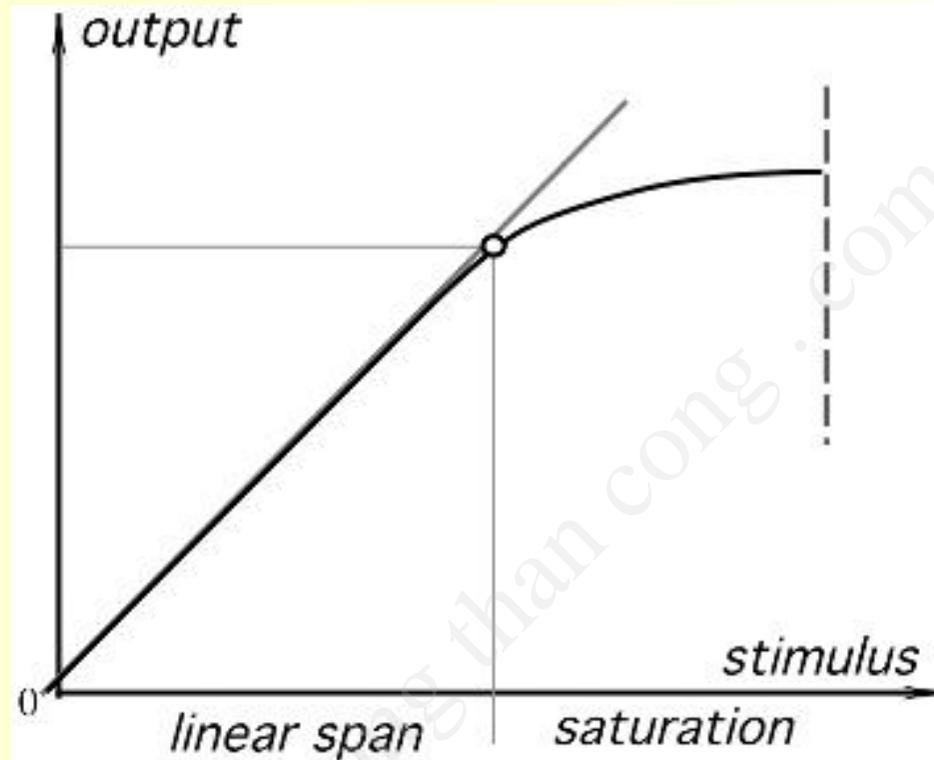
From Fraden

Transfer Function with Hysteresis (From Fraden)
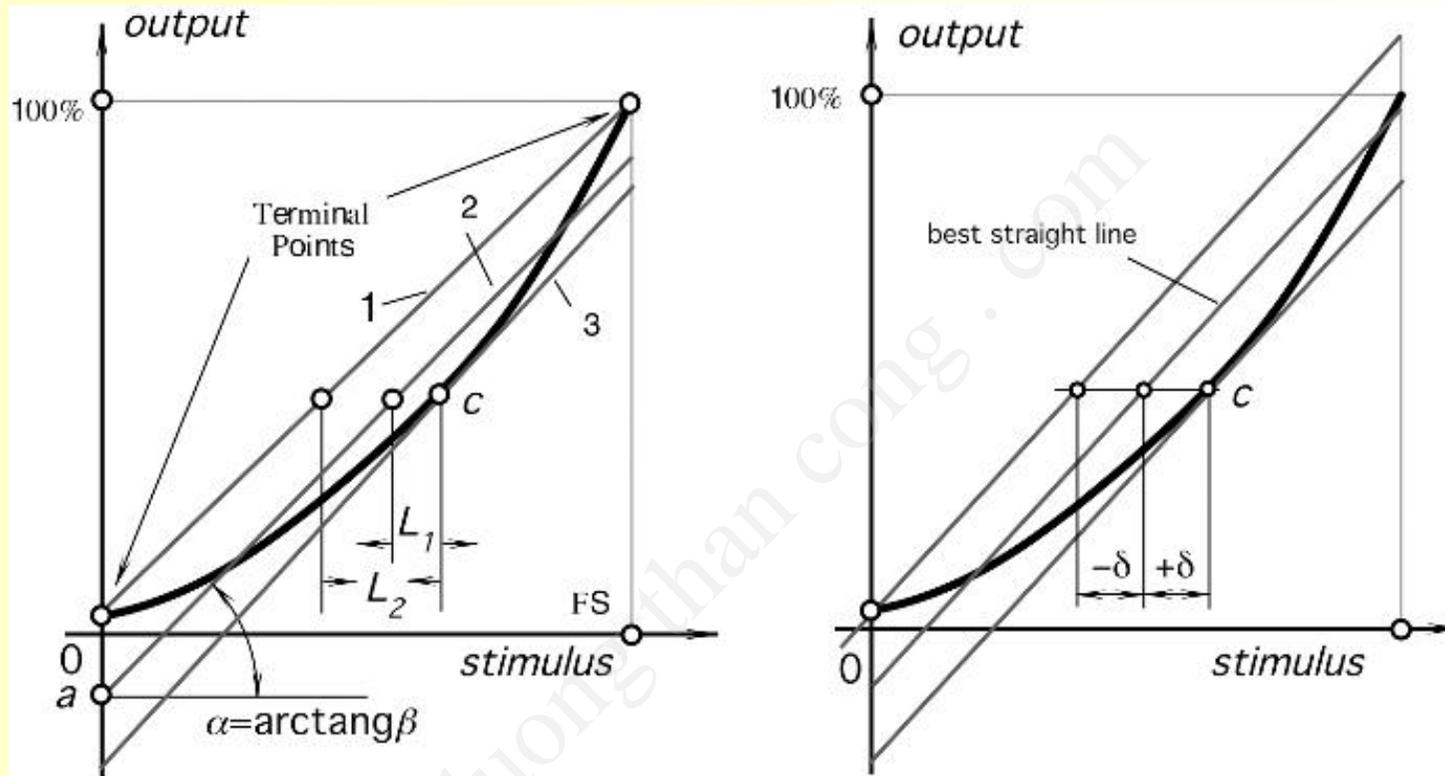
Linear approximations of a nonlinear function and independent linearity

❑ Saturation, span-end nonlinearity – transfer function in which sensor output signal is no longer responsive

❑ Repeatability error – a measure of inability of a sensor to represent the same value under identical conditions. Maximum difference between output reading as determined by two calibrating cycles. Represented often in terms of % ; (Δ/FS) x 100

❑ Dead band- insensitivity of a sensor in a specific range of input signals. The output may remain near a certain value (often zero) over an entire dead band zone

❑ Resolution – smallest increments of stimulus which can be sensed.

From Fraden

From Fraden
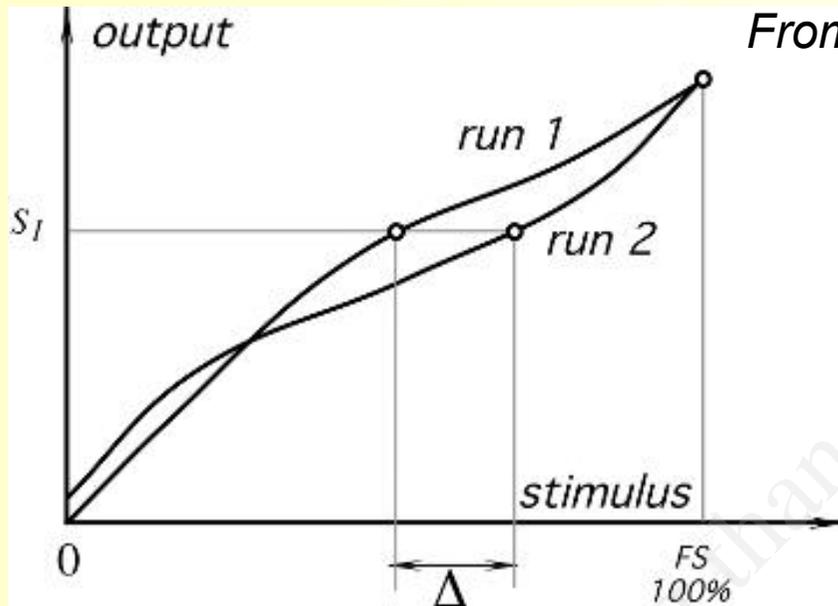
Repeatability error
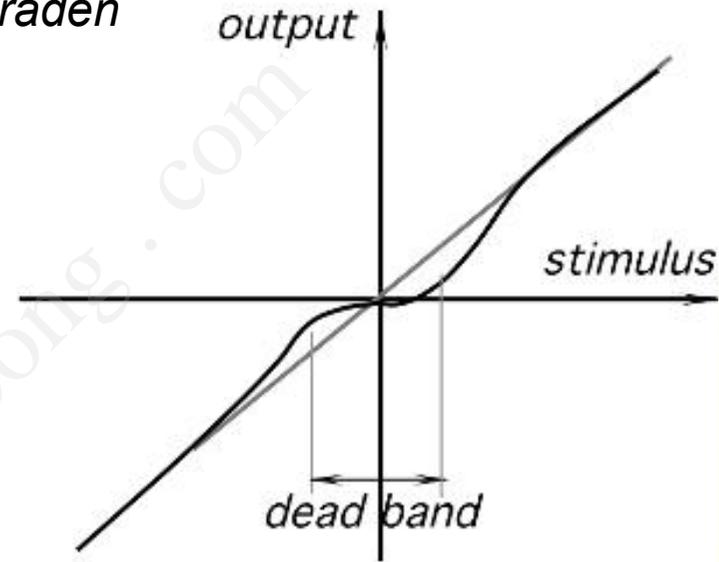
Dead band zone

Sensor dynamic characteristics

❑ Warm-up time – the time between applying to the sensor power or excitation signal and the moment when the sensor can operate within its specified accuracy.

❑ Frequency response – how fast the sensor can react to a change in the input stimulus

❑ Time constant – a measure of sensor's inertia. A product of capacitance and resistance (electrical or thermal). System response is, $S = S_{max} [1 - \exp(-t/\tau)]$

❑ Phase shift – how the output signal lags behind in representing the stimulus change.

❑ Resonant frequency – a frequency where the sensor's output signal increases considerably.

Physical sensor examples

❑ Capacitive sensor

❑ Temperature sensor

Chemical sensors

- ❑ Chemical sensor - a device that transforms chemical or biochemical information of a quantitative or qualitative type into an analytically useful signal

- ❑ Biosensor - a device incorporating a biological sensing element either intimately connected to or integrated within a transducer. One family member of chemical sensors.

http://www.electrochem.org/ecs/centennial/support/S11_1.pdf
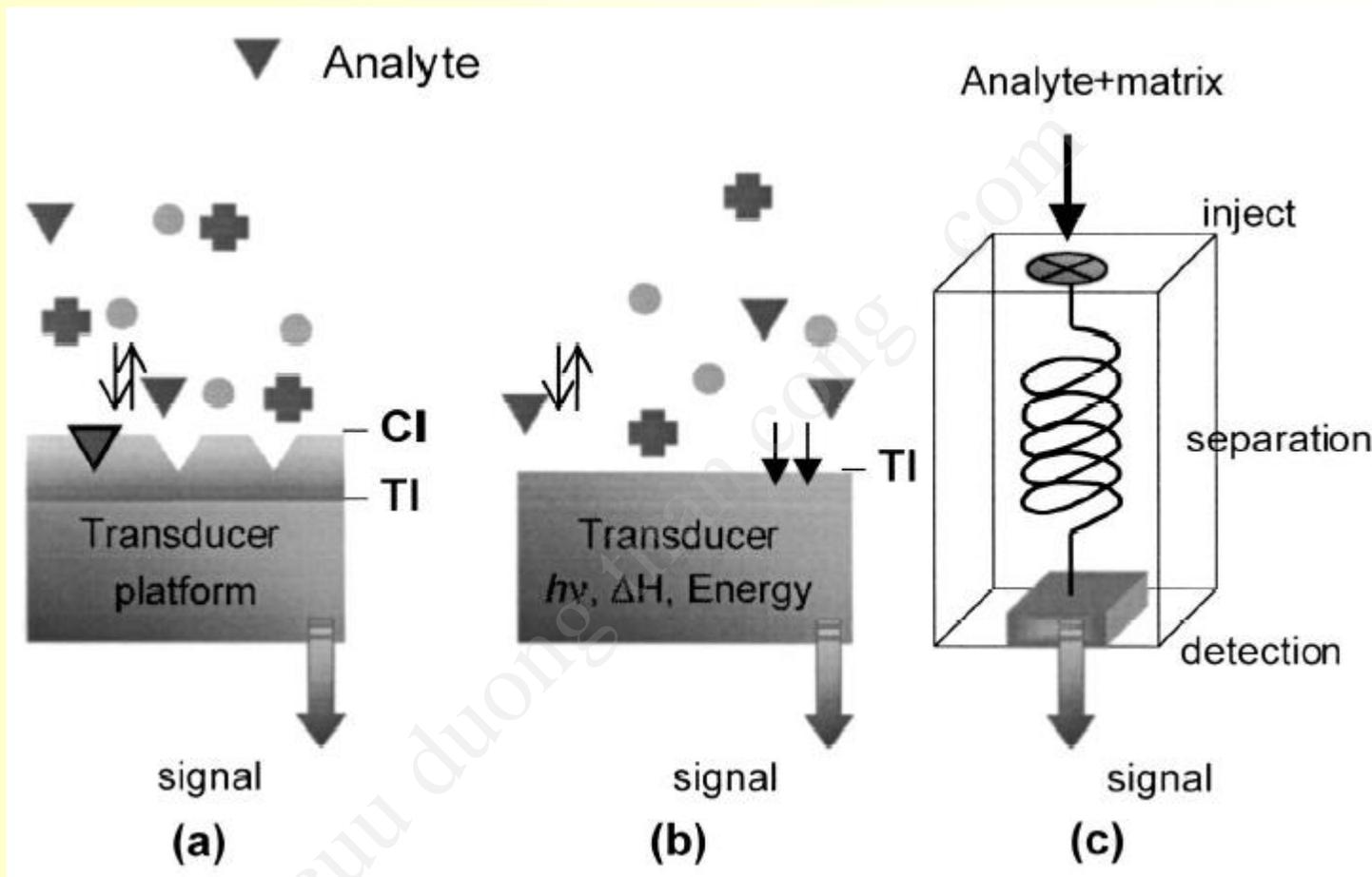
(a) Chemical sensor (b) Physical sensor for chemical sensing (c) µTAS concept, CI: Chemical interface TI: Transducer interface

http://www.electrochem.org/ecs/centennial/support/S11_1.pdf

❑ Signal – current, voltage or impedance/conductance change caused by concentration of quality change

❑ Chemical sensor = physical transducer + chemically sensitive layer or recognition layer

❑ Physical sensor for chemical sensing = physical transducer ($\rightarrow$ interpretation)

Biosensor
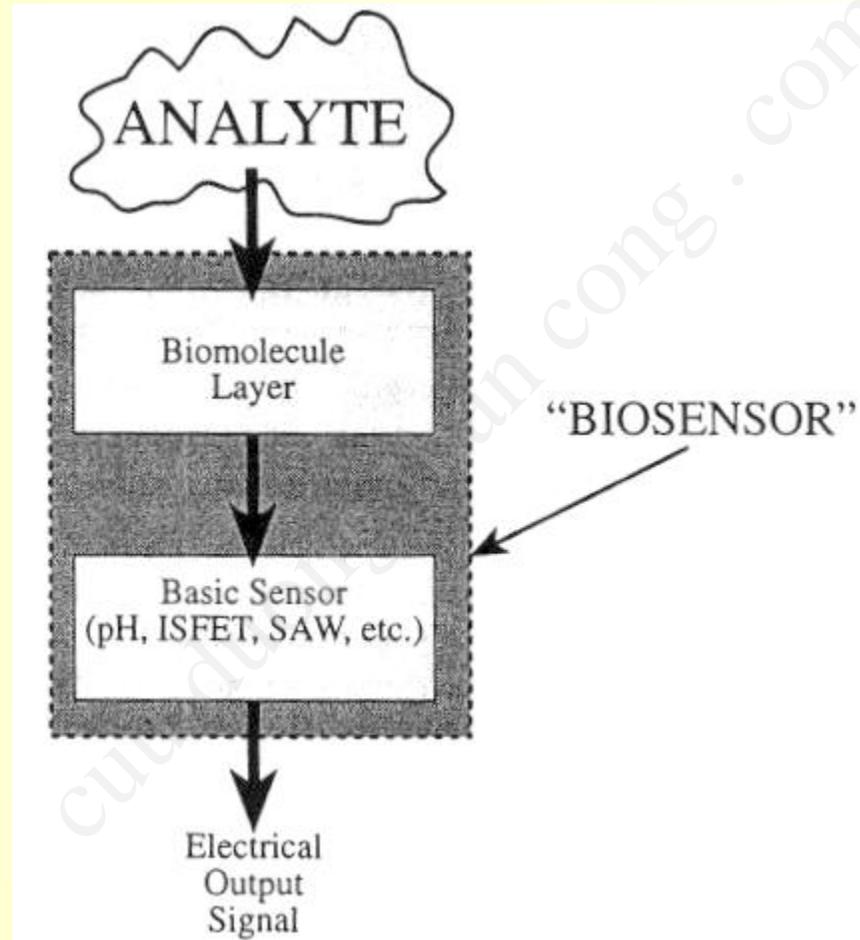
From G. T. A. Kovacs, Micromachined Transducers Sourcebook, McGraw-Hill

Biosensor surface immobilization
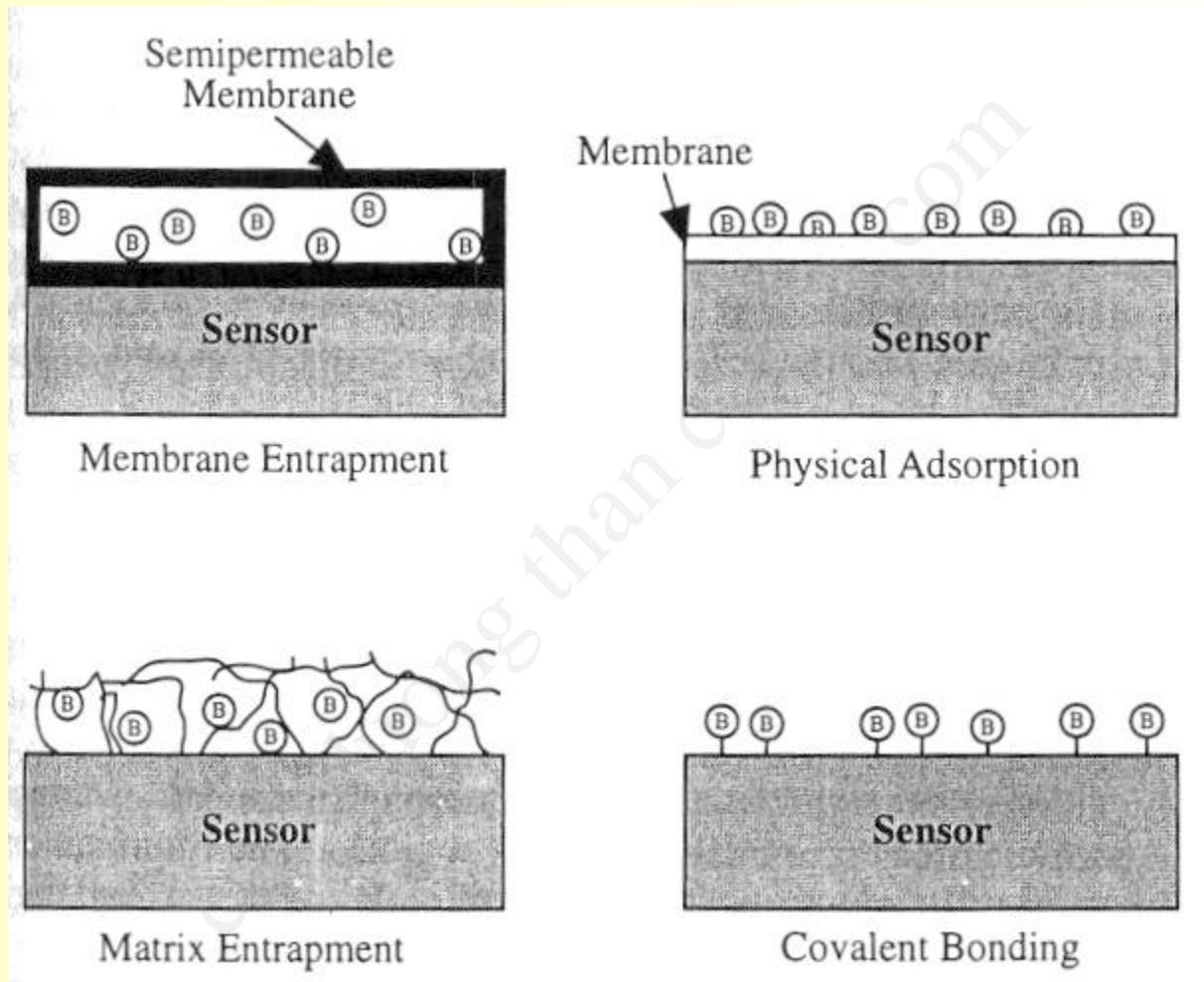
From Kovacs

Selectivity and others

❑ The ability of a sensor to respond primarily to only one chemical element or compound (species) in the presence of other species.

❑ In most biological systems, this is achieved by shape recognition, which involves a comparison with some kind of a stereotype.

❑ An absolutely selective sensor really does not exist.

❑ Stability and reproducibility

Chemical sensor examples

❑ Passive chemical sensors – chemiresistors, chemicapacitors, chemomechanical sensors, calorimetric sensors, metal-oxide gas sensors

❑ Workfunction based sensors – CHEMFET

❑ Electrochemistry based sensors

❑ Optics based sensors

❑ Acoustics based sensors

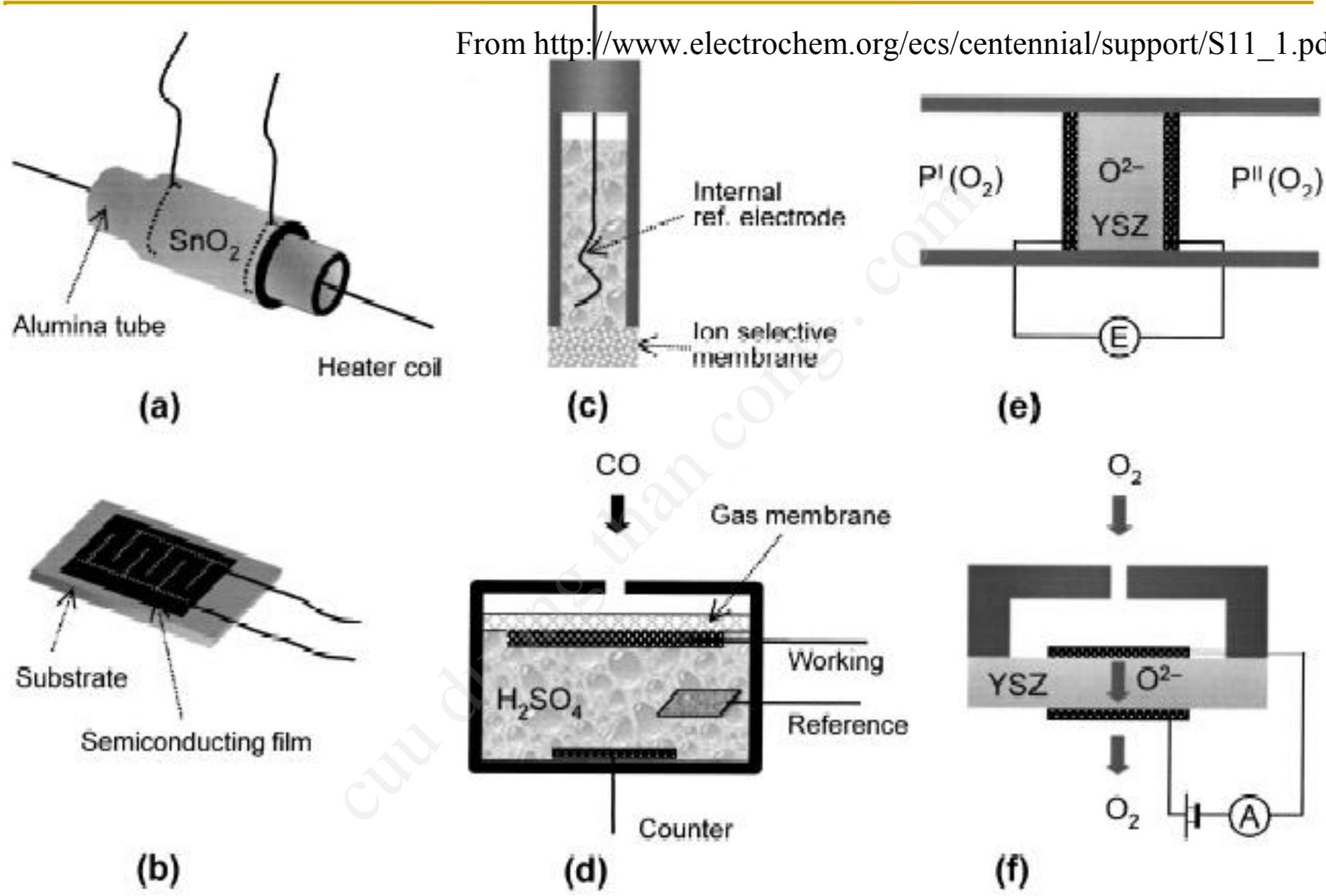From http://www.electrochem.org/ecs/centennial/support/S11_1.pdf

Figure 2. Typical chemical sensors: (a) tubular type SnO_2 gas sensor; (b) planar semiconductor sensor; (c) ion selective electrode (potentiometric); (d) amperometric gas sensor with liquid electrolyte; (e) potentiometric solid electrolyte O_2 sensor (concentration cell); (f) amperometric solid electrolyte O_2 sensor (current-limit type).

References

J. Fraden, Handbook of modern sensors, AIP Press, 1997

G. T. A. Kovacs, Micromachined Transducers Sourcebook, McGraw-Hill, 1998

W. Göpel, T. A. Jones, M. Kleitz, I. Lundström and T. Seiyama, Chemical and Biosensors Part II, Sensors A Comprehensive Survey, Vol. 3, VCH, 1992