1) Review

Sensor → Input Transducer

C, R, T, MAG, MEC —to→ E energy domain

Actuator → Output Transducer

E —to→ C, R, T, MAG, MEC energy domains

2. Sensor Considerations

(1) Sensitivity → ratio of magnitude of output signal to input stimulus

(2) Linearity → how linearly proportional is the output signal to the input stimulus

(3) Accuracy

(4) Responsivity (Resolution) → the minimal detectable input stimulus level

(5) Noise

(6) Dynamic Range → ratio of highest to lowest detectable stimulus level

(7) Bandwidth → the detectable frequency range for a time varying stimulus

(8) Precision → the ability of a sensor to give the same reading for the same stimulus

(9) Drift → loss of precision over time

(10) Reliability → how does the sensor's performance degrade over use, time or in harsh conditions

(11) Crosstalk (Interference) → how sensitive is the sensor to different stimuli → also called specificity

(12) Development cost and time

a. Noise Considerations

Noise is present in all real systems.

Various noise sources:

(1) Thermal Noise

→ due to thermal fluctuation of electrons and particles

→ has a Gaussian distribution

→ in circuits, represented by a noise voltage:

$$V_{noise} = \sqrt{4KTRB}$$

K = Boltmann's constant = $1,3806 \times 10^{-23}$ J/K

T = absolute temperature in K

R = resistance

B = bandwidth in Hz

Also called Johnson noise

→ in mechanical systems too:

$$F_{noise} = \sqrt{4KTcB} = \text{noise force}$$

c = mechanical damping coefficient

c is equivalent to R → both dissipate energy and represent losses

(2) Shot Noise

→ Gaussian distribution

→ noise due to quantum fluctuation of electric current due to discrete passage of charges across an energy barrier

$$I_{noise} = \sqrt{2 q I_{dc} B}$$

q = electron charge

I_{dc} = dc current

B = bandwidth

(3) 1/f Noise (flicker noise)

→ noise due to conductance fluctuation when a current passes through an interface

$$P_{noise} \propto \frac{1}{f}$$

b. Noise is an issue that must be considered in all sensitive electronic systems

3. Actuator Considerations

(1) Torque or Force Output Capacity

(2) Range of Motion

(3) Dynamic Response Speed (Bandwidth)

(4) Fabrication Ease, Materials and Cost

(5) Power Consumption and Energy Efficiency

(6) Linearity of Displacement Vs. Input

(7) Cross-Sensitivity / Environmental Stability

(8) Footprint → size and/or weight