SENSOR

(MATA KULIAH MKBKM)

Ahmad Zarkasi, S.Si., M.Si

Referensi

- Wilson, Jhon S. (2005). Sensor Technology Handbook. Published by Newnes, an imprint of Elsevier. ISBN: 0-7506-7729-5.
- Rangaan, C. S. (1990). Instrumentation : Devices and Systems/ McGraw-Hill Publishing Company Ltd.
- Sinclair, Ian R. (2001), Sensors and Transducers – Third Edition. Published by Newnes, an imprint of Butterworth-Heinemann. ISBN: 0-7506-4932-1.

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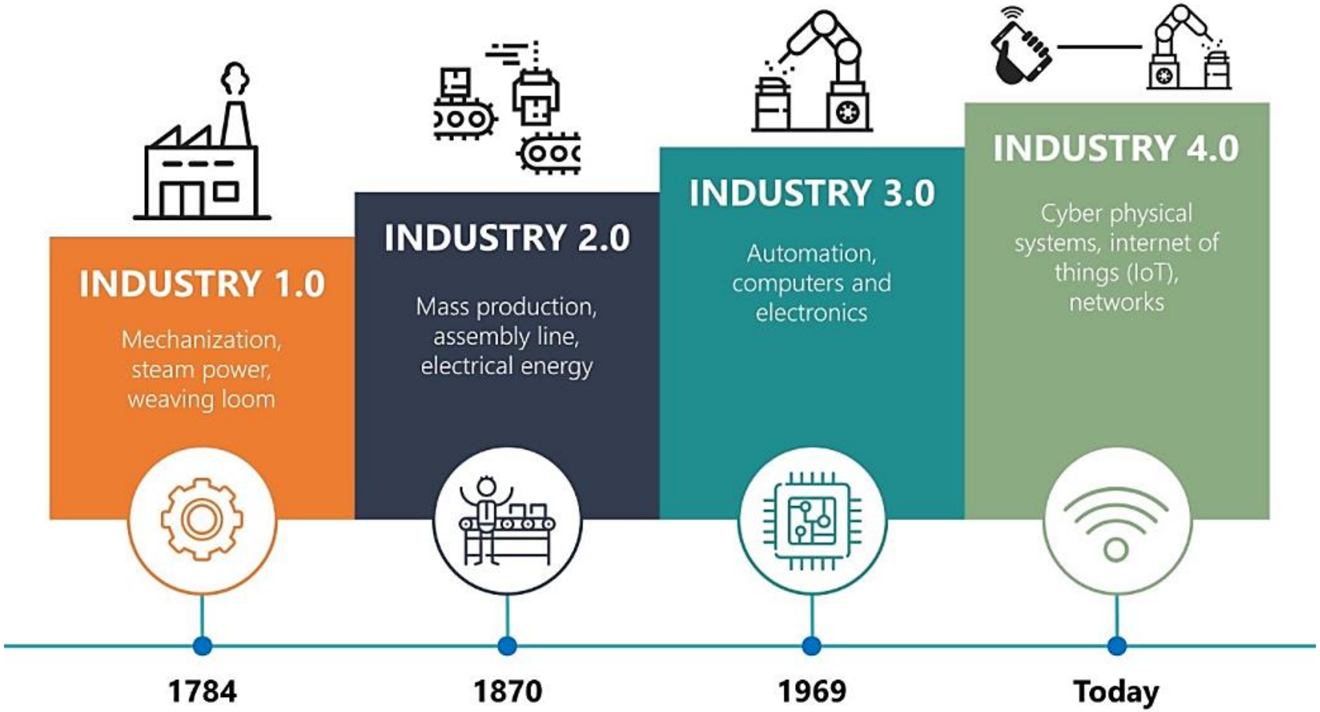
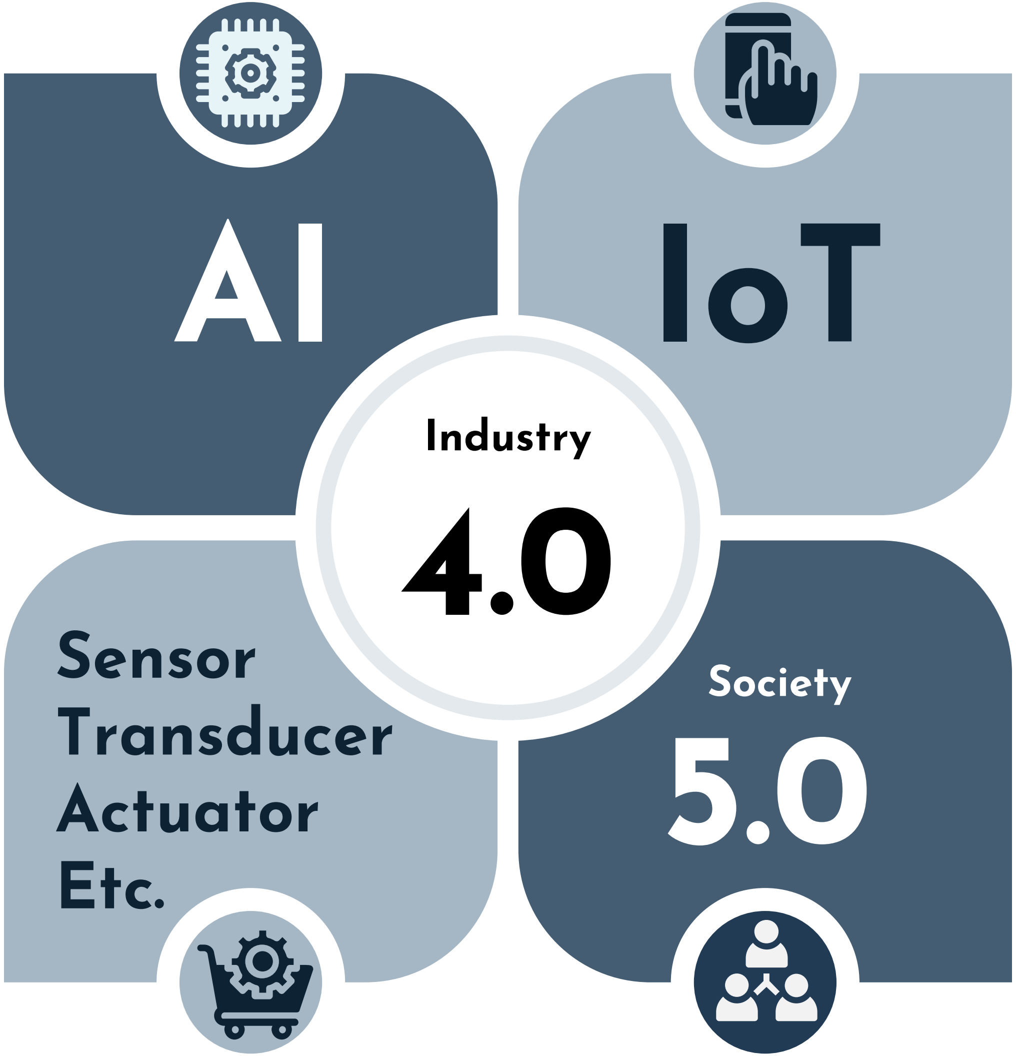
Pendahuluan

Oleh: Ahmad Zarkasi, S.Si., M.Si

Industries



Sumber: impactdakota.com


AI
IoT
Industry
4.0
Sensor
Transducer
Actuator
Etc.
Society
5.0

1

Sensor, Transduser, dan Aktuator

Oleh: Ahmad Zarkasi, S.Si., M.Si

TRANSDUCER

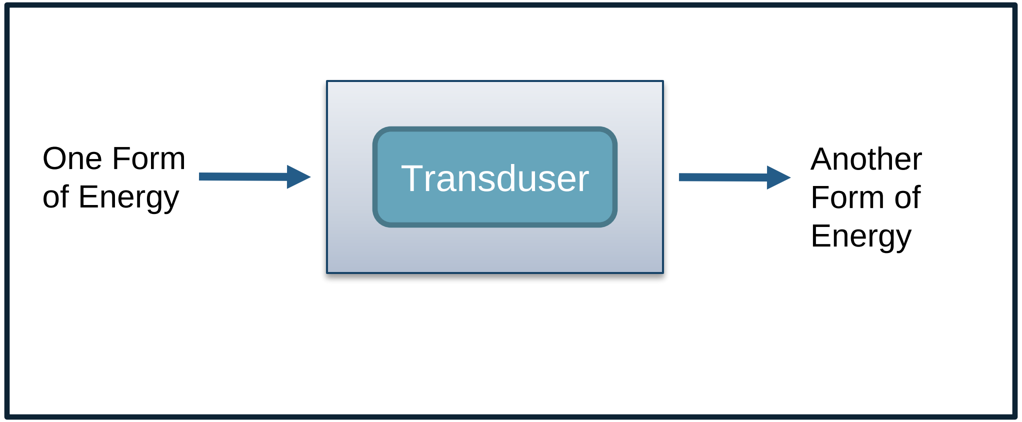
Menurut Kamus:

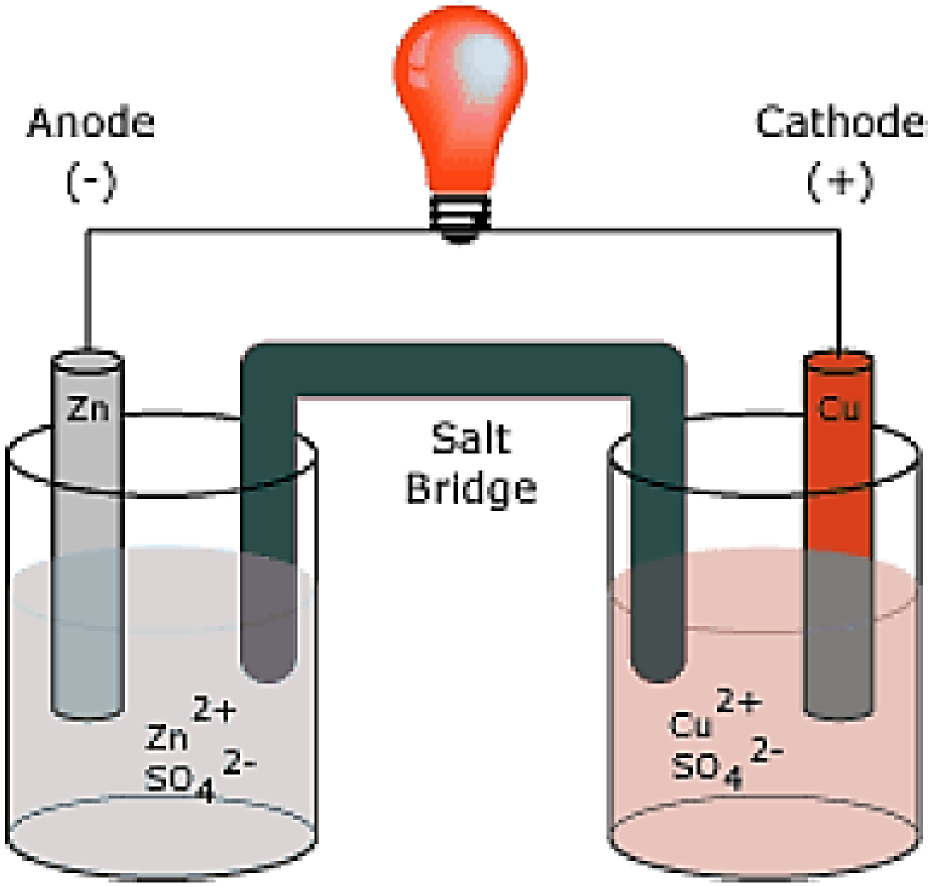
- A substance or device, such as a piezoelectric crystal, that converts input energy of one form into output energy of another. (https://www.ahdictionary.com)
- A device that is actuated by power from one system and supplies power usually in another form to a second system (a loudspeaker is a transducer that transforms electrical signals to sound energy). (http://www.merriam-webster.com)
- A device that converts a signal in one form of energy to another form of energy.[1] Energy types include (but are not limited to) electrical, mechanical, electromagnetic (including light), chemical, acoustic and thermal energy. While the term transducer commonly implies the use of a sensor/detector, any device which converts energy can be considered a transducer. Transducers are widely used in measuring instruments. (http://en.wikipedia.org/wiki/Transducer)

TRANSDUCER

A transducer is a **device** designed to take advantage of physical **transduction** mechanisms that can transform energy from one form to another.

Transducers can be classified as **sensors** or **actuators.**





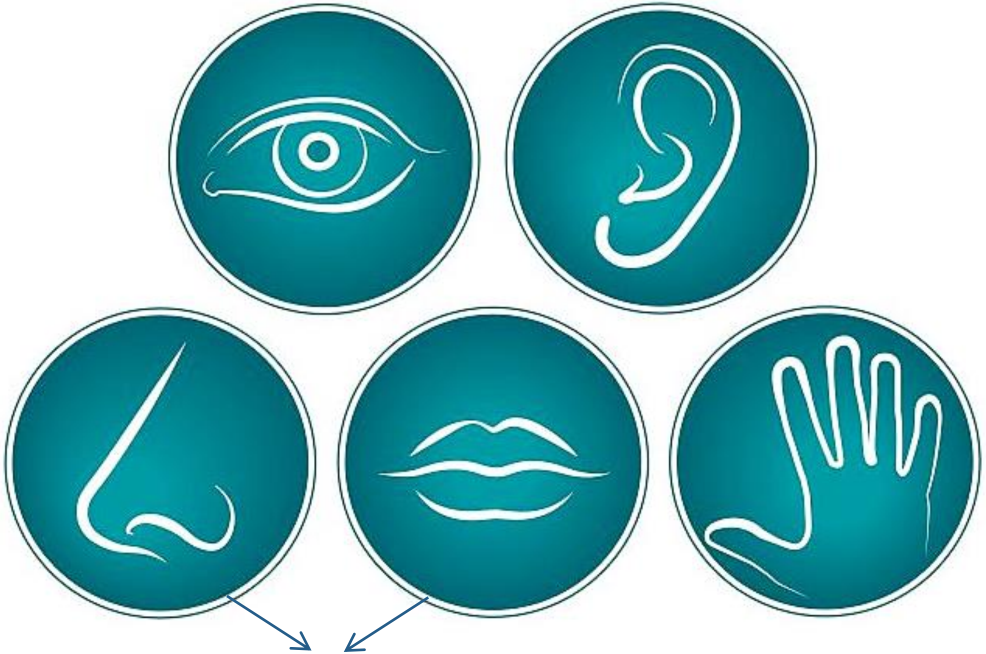
Electrochemical
Transducer

Transduser Classifications

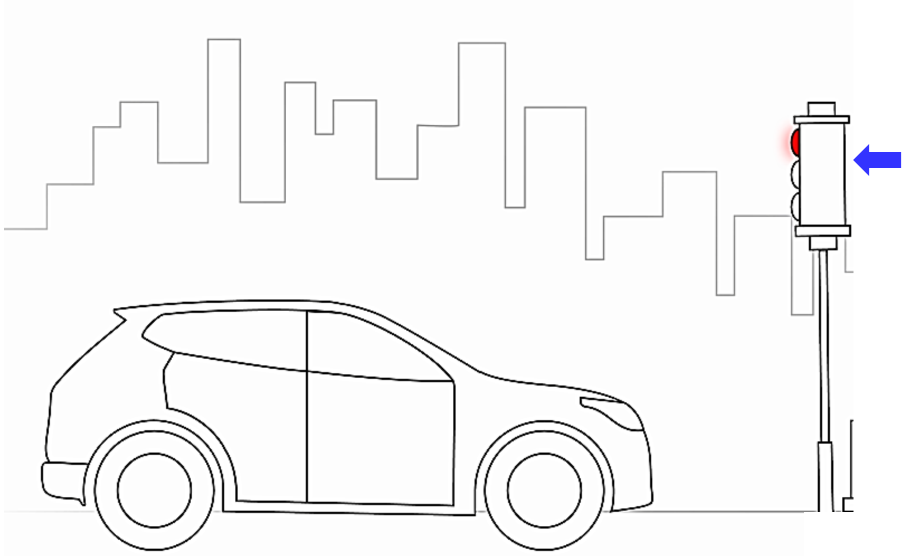
Transducer Classifications	Characteristic	Examples
Self Generating Transducer (Active)	This transducer generates electrical energy directly from the transducer itself In this case the transducer acts as a voltage source.	Piezoelectric, Thermocouple, Photovoltaic
External Power Transducer (Passive)	A transducer that requires a amount of external energy to produce an output.	Thermistor, Resistance Temperatur Detector, LVDT, Potensiometer

SENSOR

A sensor is a device that "sense" something.



SENSOR

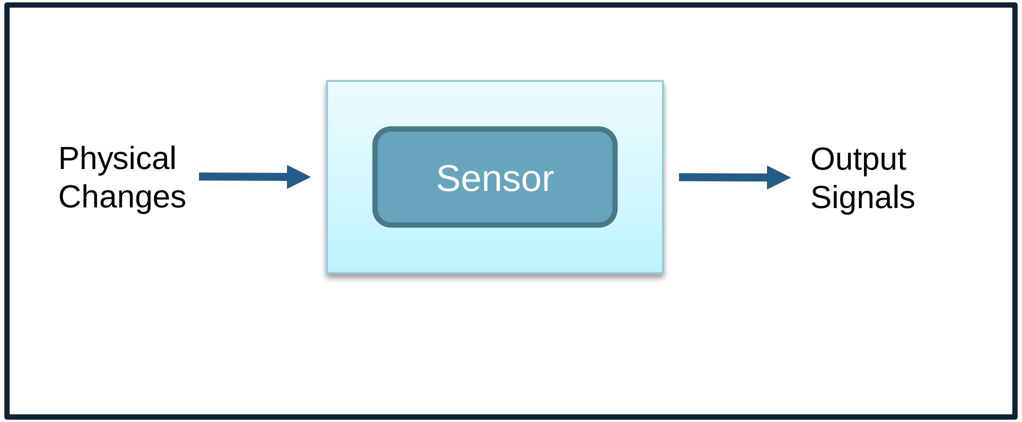


SENSOR

- A device, such as a photoelectric cell, that receives and responds to a signal or stimulus. (https://www.ahdictionary.com)
- A device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control). (http://www.merriam-webster.com)
- A device that detects events or changes in quantities and provides a corresponding output, generally as an electrical or optical signal (http://en.wikipedia.org)
- A device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing. (http://whatis.techtarget.com)

SENSOR

Sensor is a device that can detect a physical quantity and convert the data into an electrical signal.



Sensor Classifications

Sensor Classifications	Functions	Examples
Thermal	Detects temperature changes in a certain object / place	Thermistor, Resistance Temperature Detector
Mechanical	Detect changes in mechanical motion such as displacement, position shift, linear motion, circular motion, flow, pressure and level	Potensiometer, Ultrasonic, Accelerometer
Optical/Light	detect changes in light from the light source	Photodiode, Photo voltaic, Light Dependent Resistor

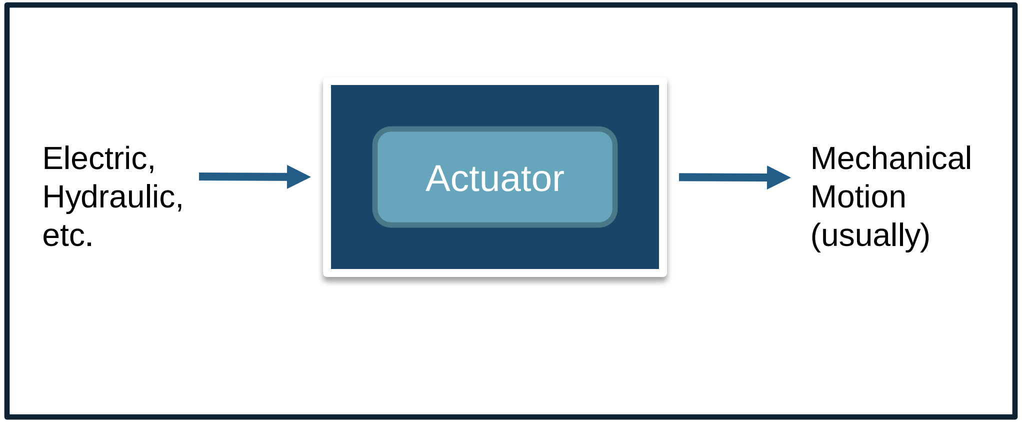
ACTUATOR

Actuators: are hardware devices that convert a controller command signal into a change in a physical parameter.

The change is usually mechanical (e.g., position or velocity).

An actuator is also a transducer because it changes one type of physical quantity into some alternative form (e.g. electric current to rotational speed of electric motor).

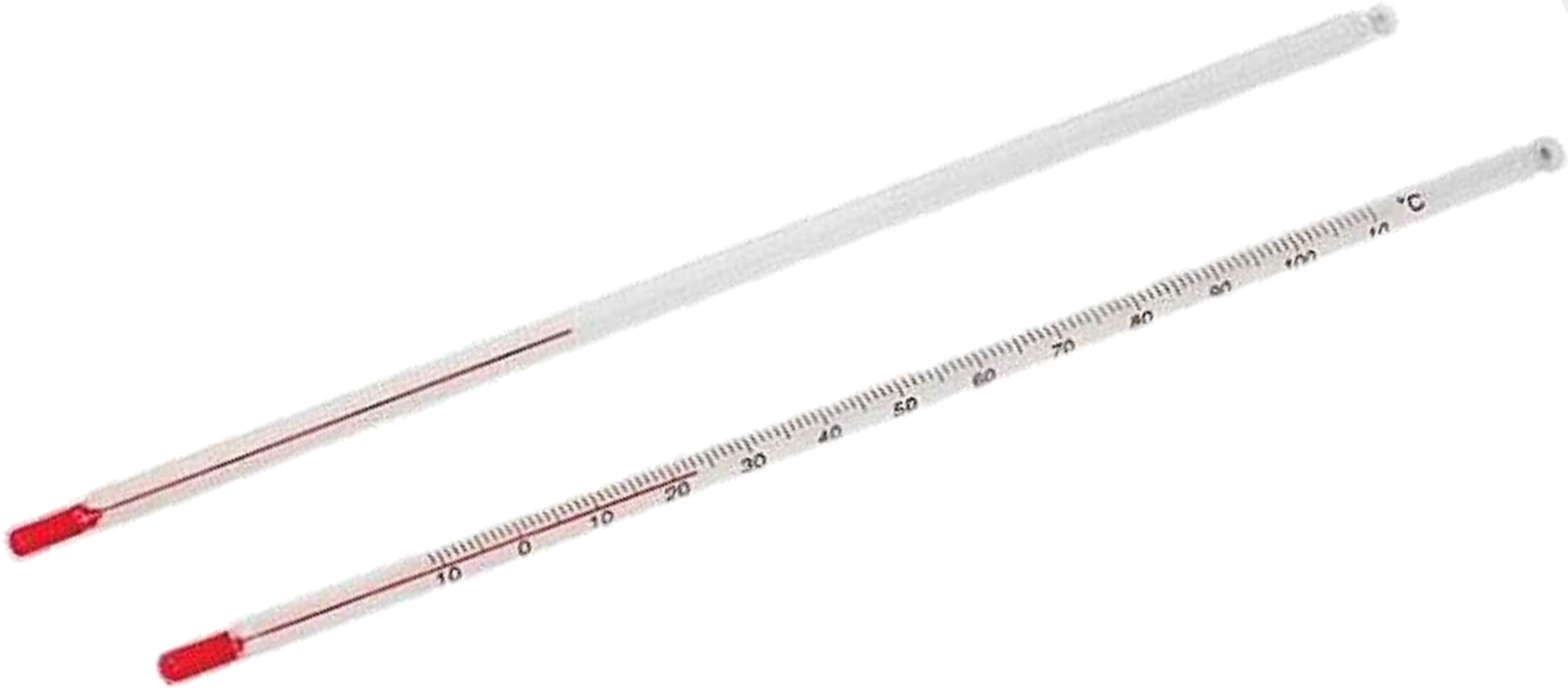
ACTUATOR

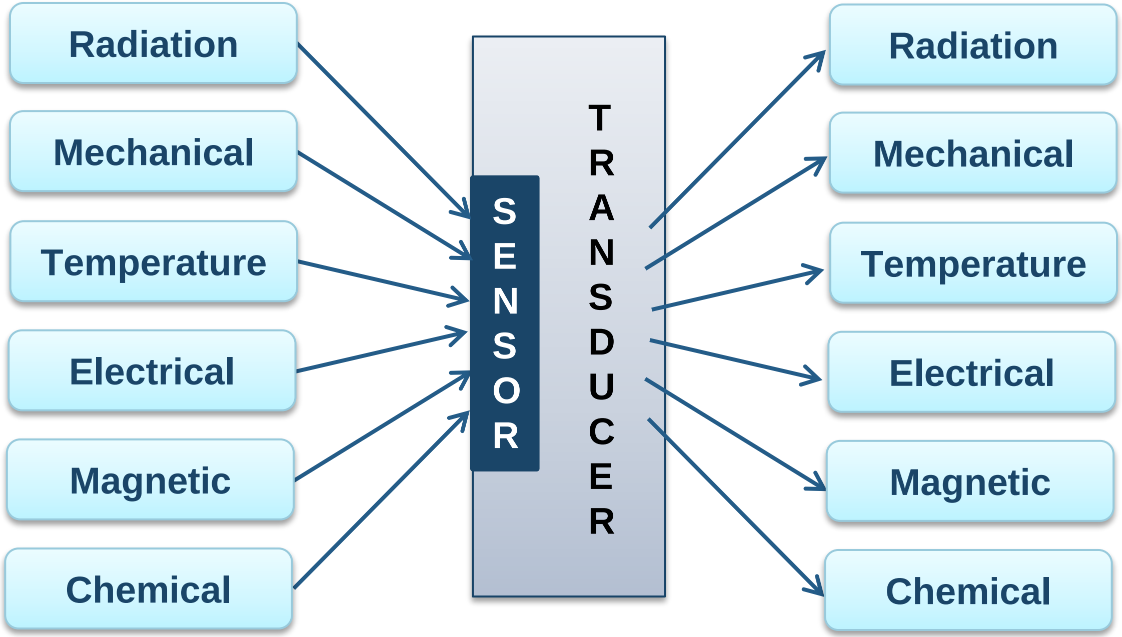

Electric,
Hydraulic,
etc.
Actuator
Mechanical
Motion
(usually)

Sensor Vs Transducer

Basis For Comparison	Sensor	Transducer
Definition	Senses the physical changes occurs in the surrounding and converting it into a readable quantity.	The transducer is a device which, when actuates transforms the energy from one form to another.
Components	Sensor itself	Sensor and signal conditioning
Function	Detects the changes and induces the corresponding electrical signals.	Conversion of one form of energy into another.
Examples	Proximity sensor, Magnetic sensor, Accelerometer sensor, Light sensor etc.	Thermistor, Potentiometer, Thermocouple, etc.

What's the difference?

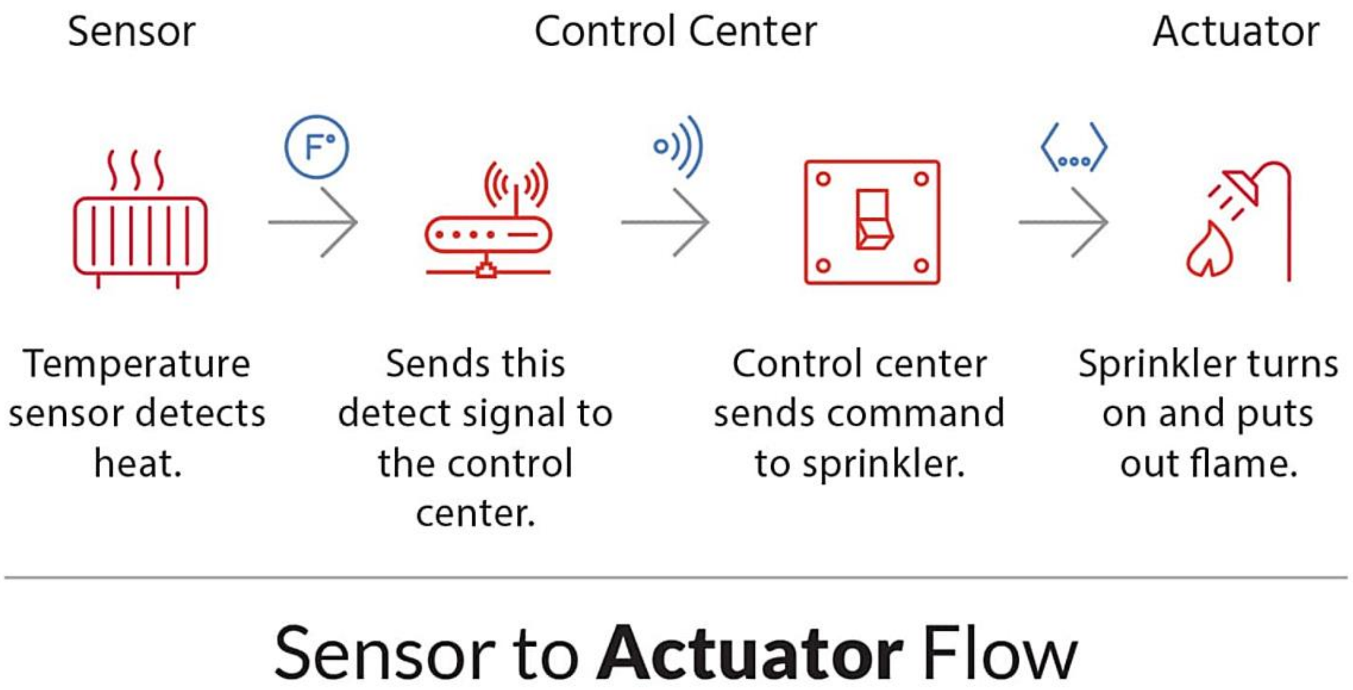



Radiation
Mechanical
Temperature
Electrical
Magnetic
Chemical
SENSOR
TRANSDUCER
Radiation
Mechanical
Temperature
Electrical
Magnetic
Chemical

Sensor Vs Actuator

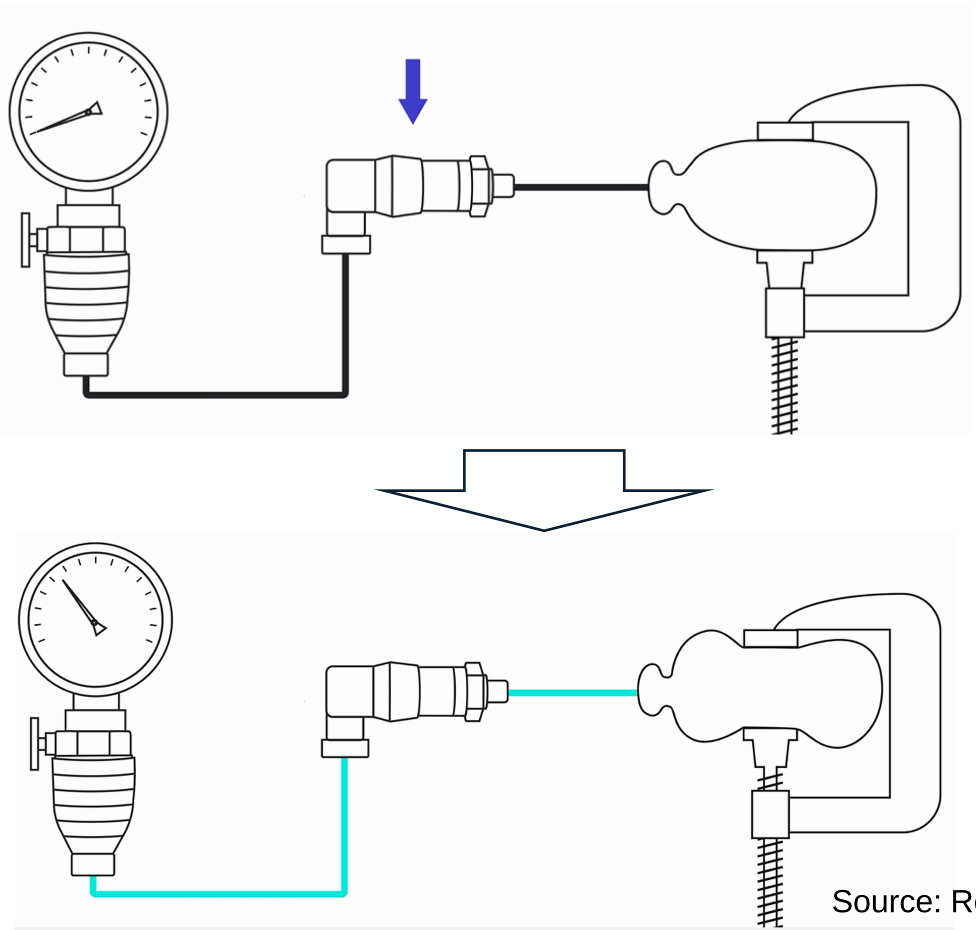
Sensor	Actuator
It converts physical characteristics into electrical signals	It converts electrical signals into physical characteristics
It takes input from environment	It takes input from output conditioning unit of system
It gives output to input conditioning unit of system	It gives output to environment
Sensor generated electrical signals	Actuator generates heat or motion
It is placed at input port of the system	It is placed at output port of the system
It is used to measure the physical quantity	It is used to measure the continuous and discrete process parameters
It gives information to the system about environment	It accepts command to perform a function
Example: Photo-voltaic cell which converts light energy into electrical energy	Example: Stepper motor where electrical energy drives the motor

Sensor & Actuator



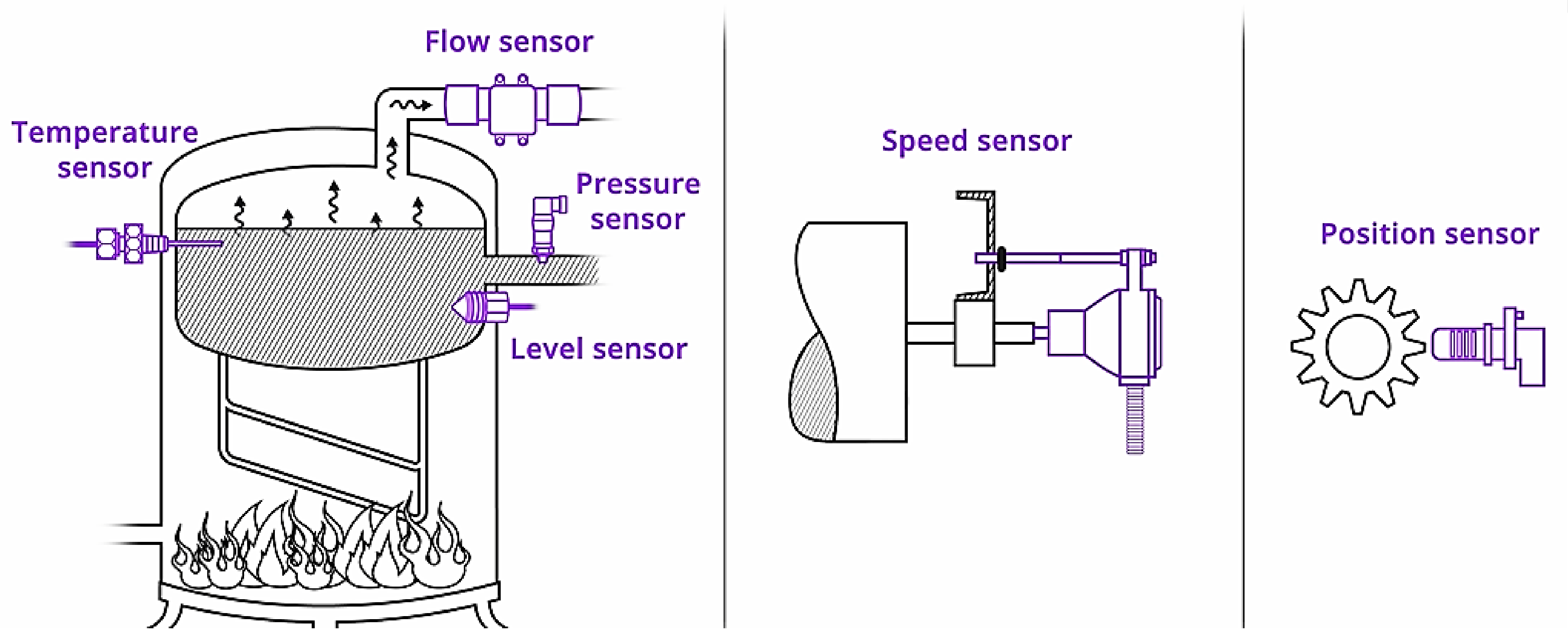
MORE ABOUT SENSOR

In the world of instrumentation and process control, we define a Sensor as a device that detects changes in **physical**, **electrical**, or **chemical** properties and produces an electrical output in response to that change.



Source: Realpars

A few of physical properties:

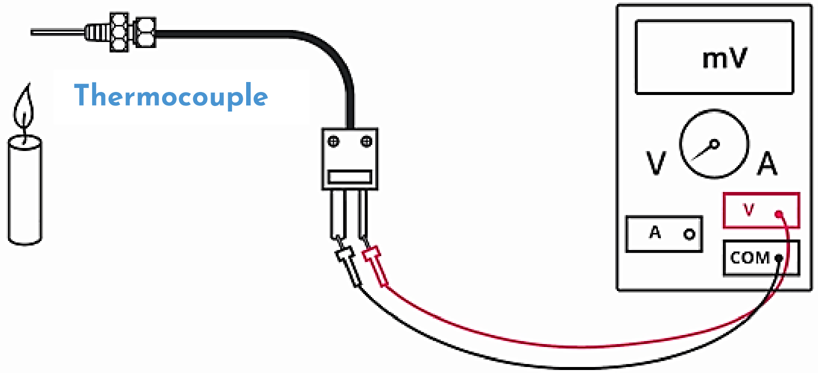


Source: Realpars

Process Control Perspective

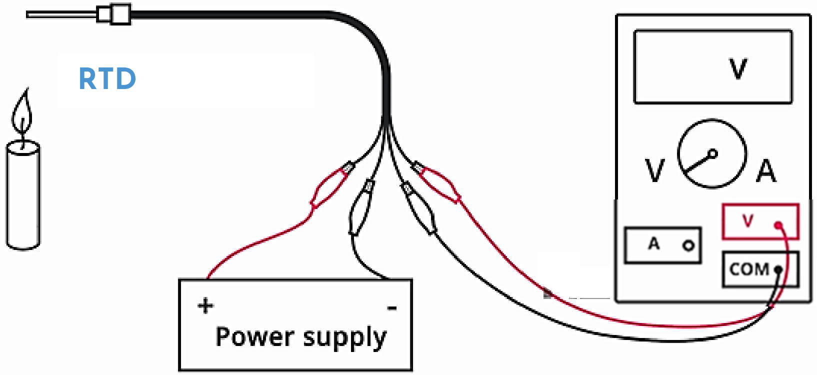
Sensor

Active: Does not require an external source



Another example: Piezoelectric

Passive: Requires an external source



Another example: Strain gauge

Sensor/Transducer/Actuator?

Microphone :
Speaker :
Bulb :

Thank You

2
Basic Sensor Vs Smart Sensor

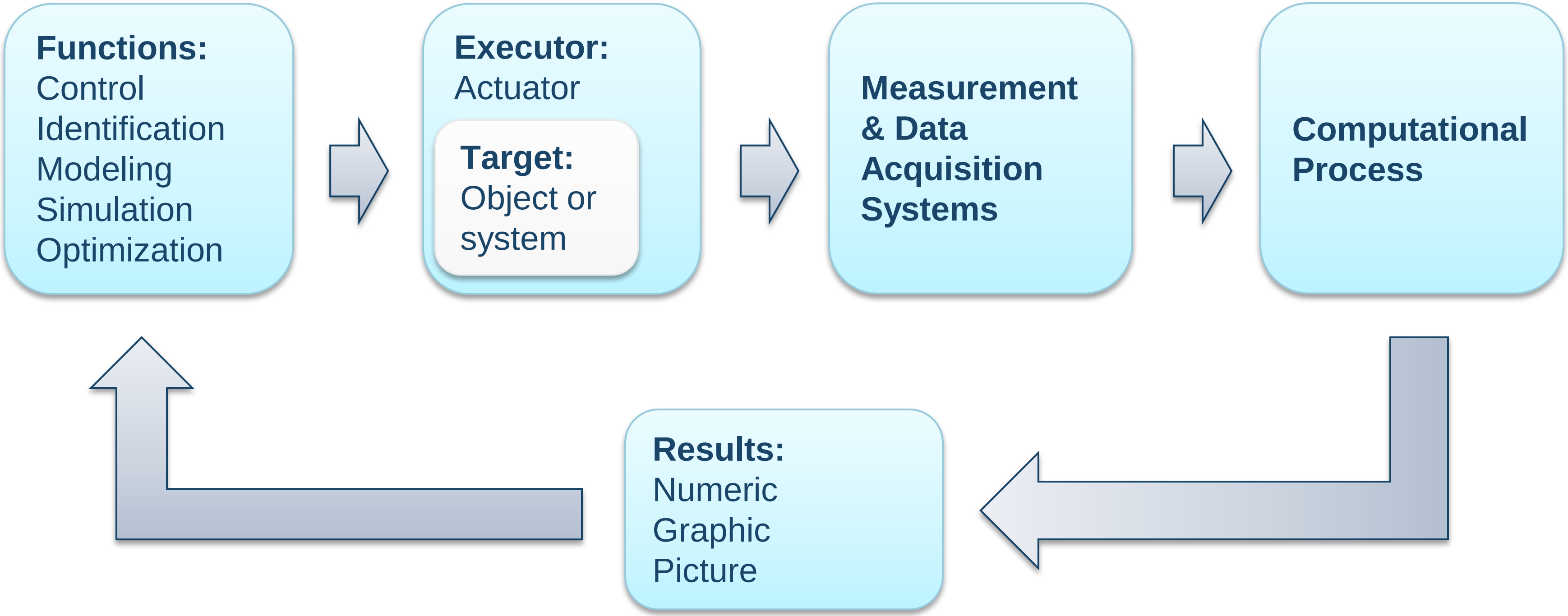
Oleh: Ahmad Zarkasi, S.Si., M.Si

Instrumentation

Instrumentation – is a collection of **Instruments** and their application for the purpose of **Observation**, **Measurement** and **Control**.
(Instrument Society of America).

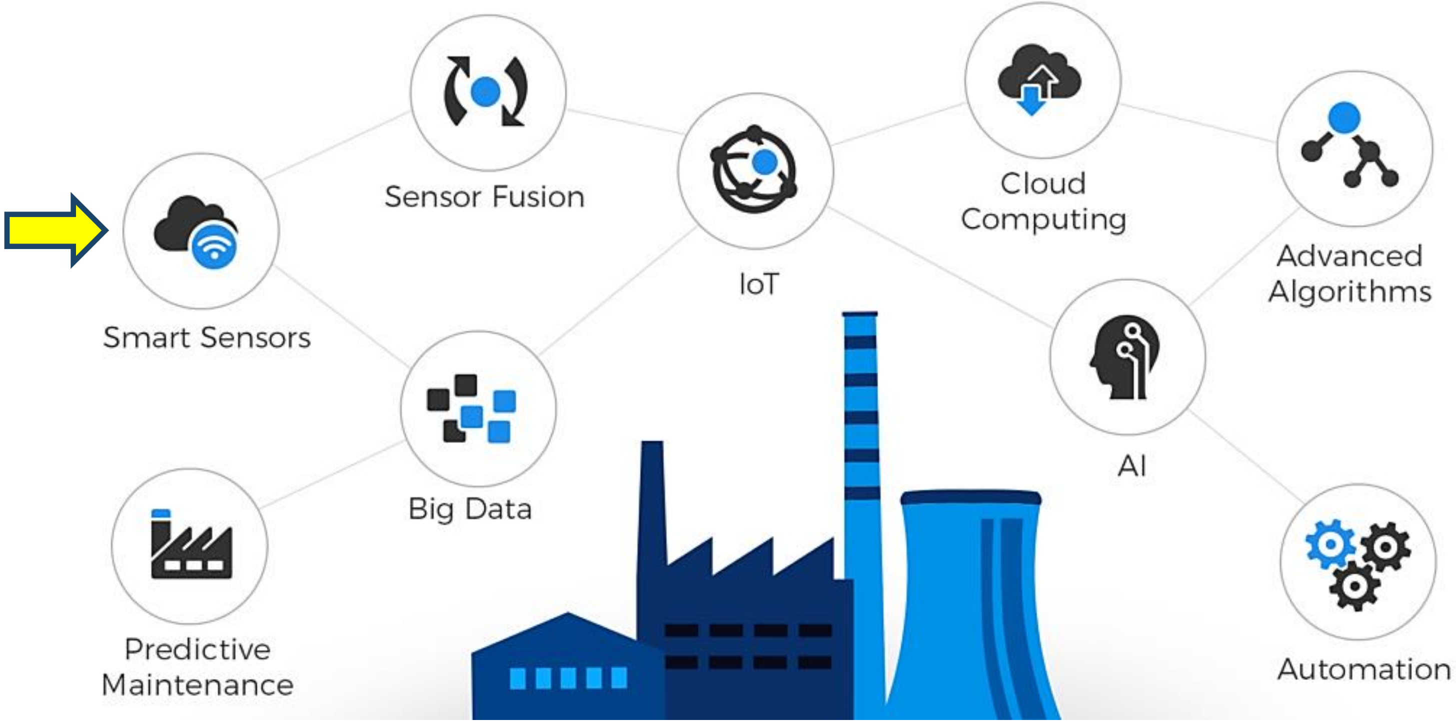
Instrumentation - is a device or system that has functions to **detect**, **quantify**, **measure**, **monitor**, and **control** physical quantities or parameters including **identification**, **modeling**, **simulation**, and **optimization**. In general, instrumentation is a measurement system as an interface between humans and physical quantities on **natural phenomena**, **machines**, **the environment**, and others.

Instrumentation Process



Perkembangan Teknologi Instrumentasi

Sensor



Sensor

Material

- Conductor
- Semiconductor
- Quartz
- Ferromagnetic
- Etc.

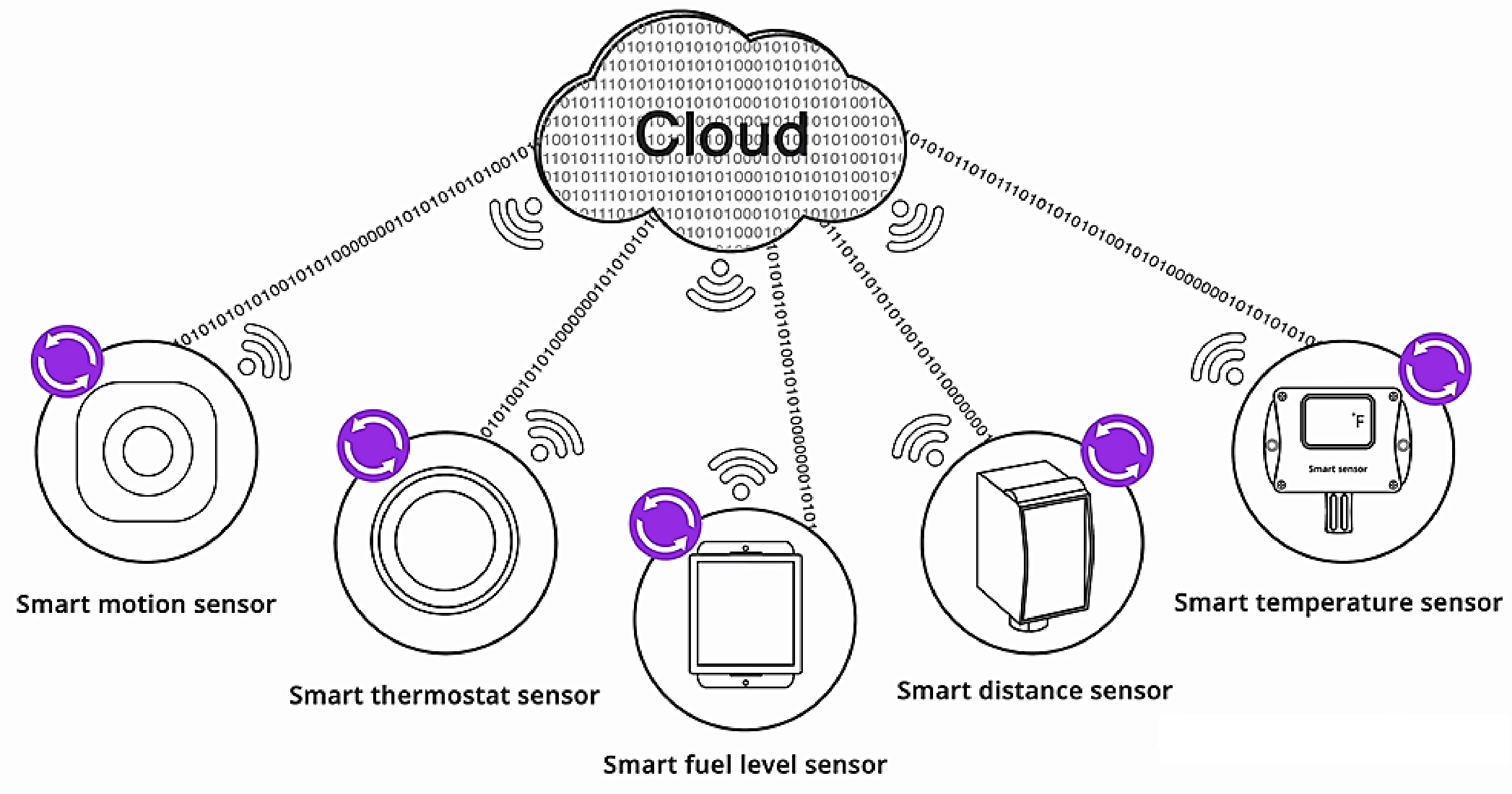
Characteristic

- Size <<
- Sensitivity >>
- Range detection >>
- Robust >>
- Less invasive
- Non invasive
- Smart & intelligent
- Etc.

<u>Quantities:</u>

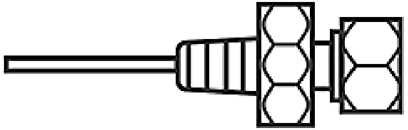
- Mechanical
- Optical
- Electrical
- Etc.

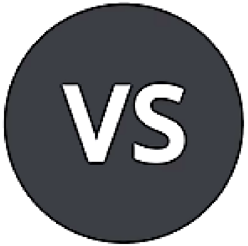
Smart Sensor

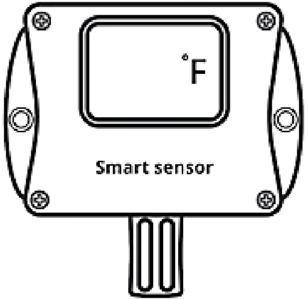


Source: Realpars

What makes a "Base Sensor" different than a "Smart Sensor"?





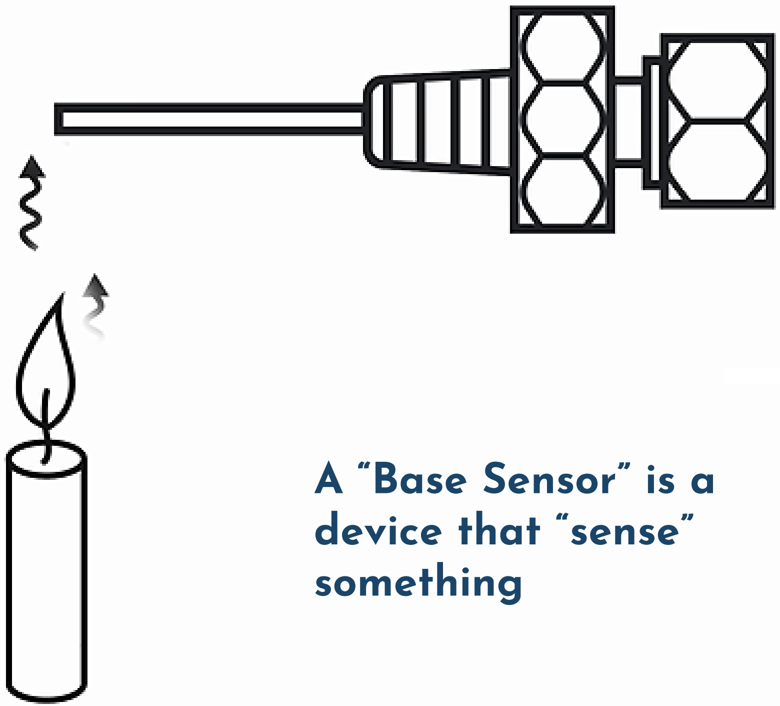


Base temperature sensor

Smart temperature sensor

Source: Realpars

A "Base Sensor"



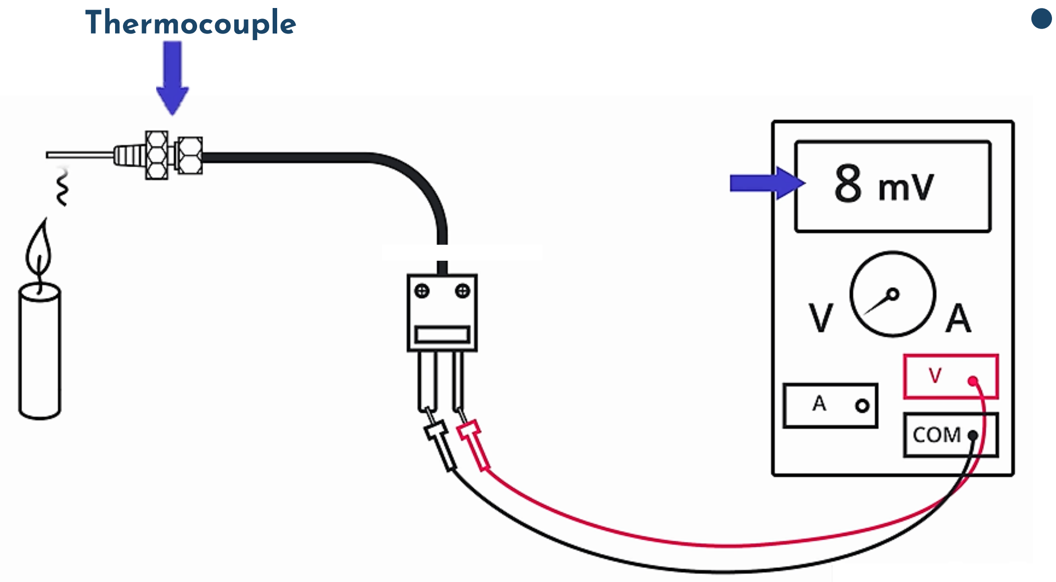
A "Base Sensor" is a device that "sense" something

Source: Realpars

A “Base Sensor”

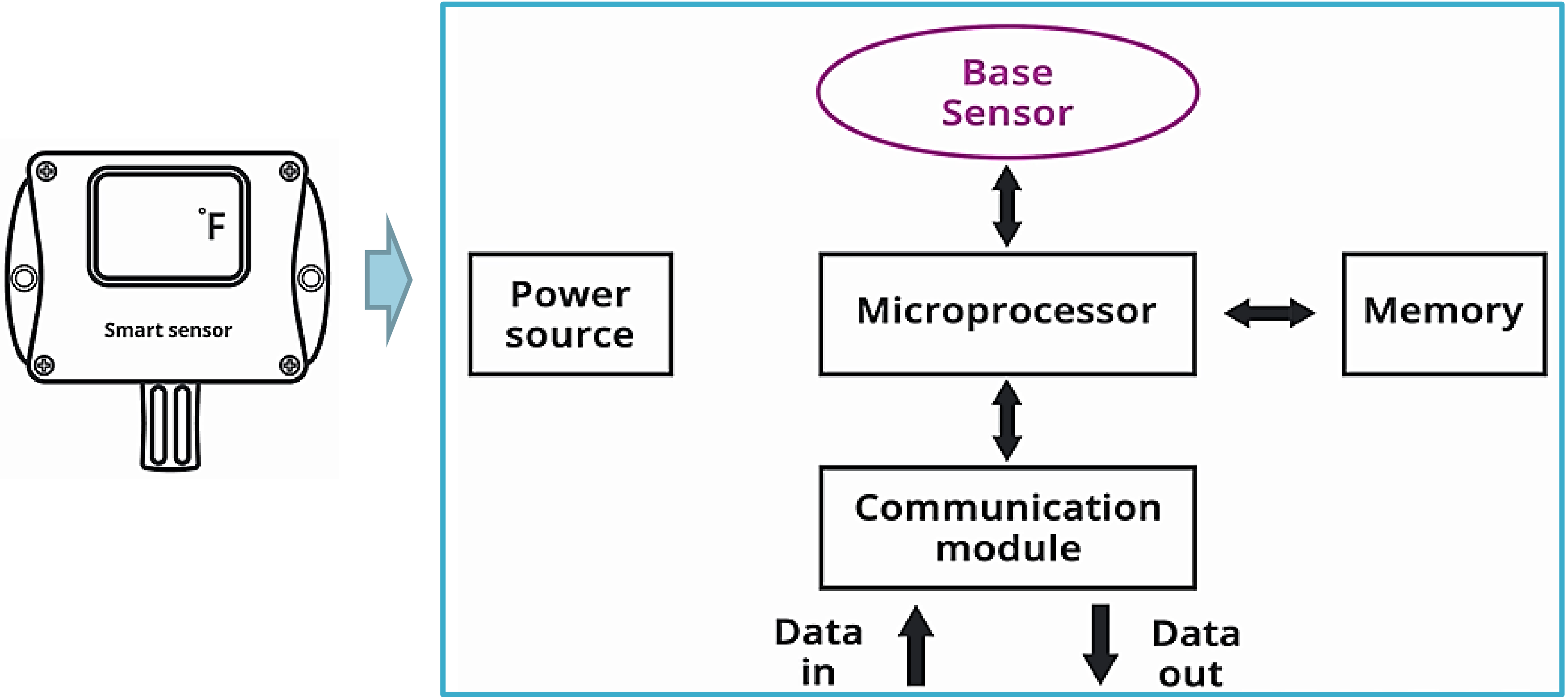
In the world of instrumentation and process control, we define a sensor as a device that detects changes in physical properties an produces an electrical output in response that change.

A “Thermocouple” is a temperature sensor that will produce an increasing voltage across it when exposed to an increasing temperature



Source: Realpars

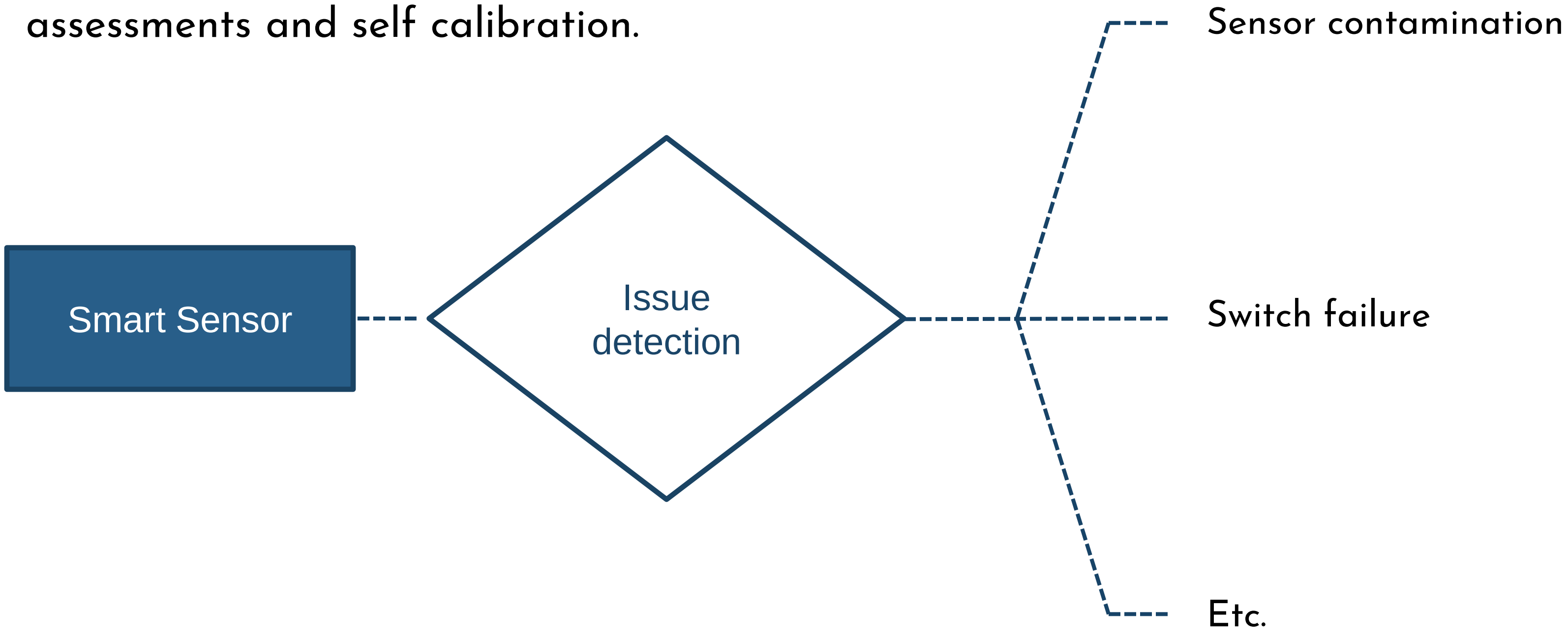
A “Smart Sensor”



Source: Realpars

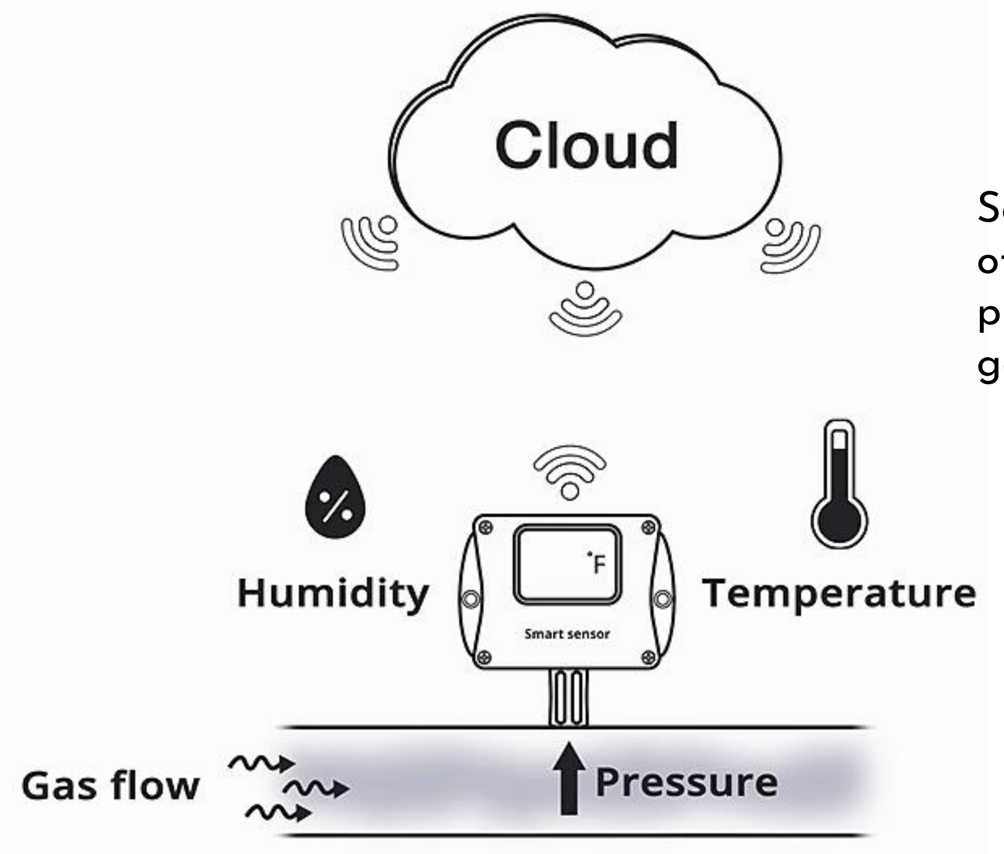
A "Smart Sensor"

Smart sensors are capable of a variety of functions and options. Smart sensors can perform self assessments and self calibration.



Source: Realpars

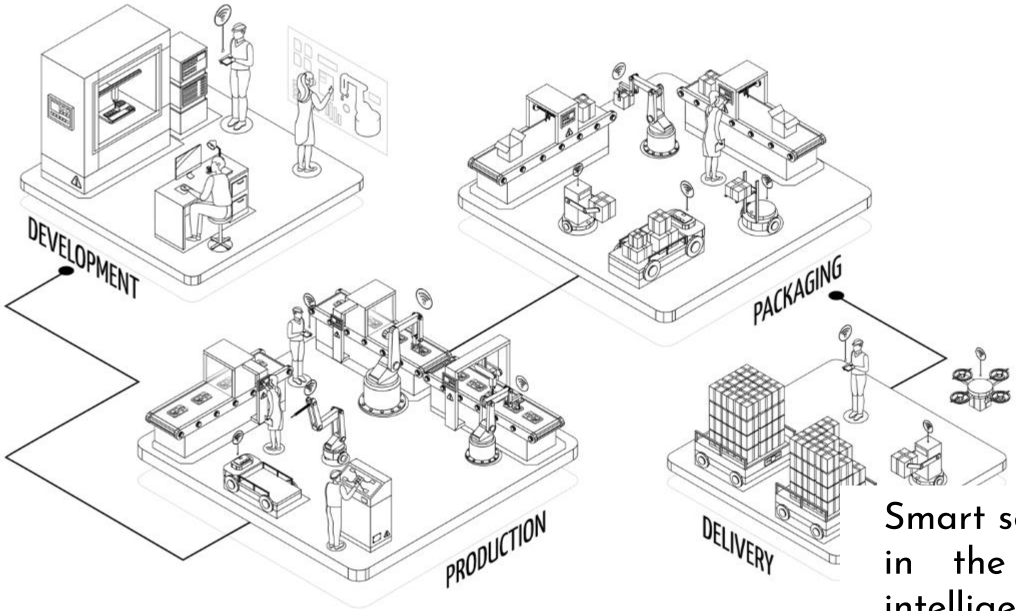
A “Smart Sensor”



Some smart sensors are capable of multi-sensing and can measure pressure, temperature, humidity, gas flow and more.

Source: Realpars

Manufacturing Intelligence



Smart sensors play a very important role in the new era of "manufacturing intelligence". They will be come more and more important as industry develops increasingly sophisticated and complex processes.

Source: Realpars

3

Sensor Characteristics

Oleh: Ahmad Zarkasi, S.Si., M.Si

Static Characteristics

Static Characteristics

If we have a thermometer in a room and its reading shows a temperature of 20°C, then it does not really matter whether the true temperature of the room is 19.5°C or 20.5°C.

The static characteristics of instruments are related with steady state response, it means the relationship between the output and the input when the input does not change, or the input is changing with a slow rate.

Static Characteristics

Static or Steady-State Characteristics (of elements) of measurement system: these are the relationships which may occur between output (O) and input (I) of element when I is either at a constant value or changing slowly.

General static characteristics of MS:

- Accuracy (measurement uncertainty)
- Precision/repeatability/reproducibility
- Sensitivity
- Resolution
- Linearity
- Hysteresis
- Threshold
- Range or Span

Repeatability & Reproducibility

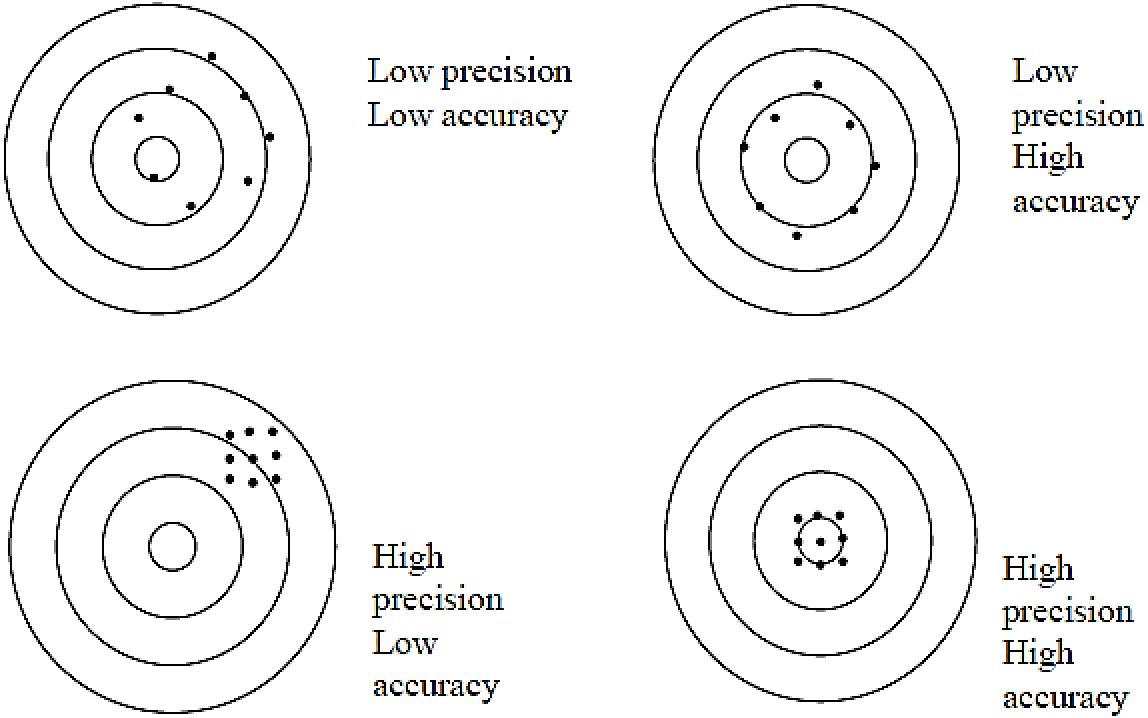
Repeatability → the closeness of output readings when the same input is applied repetitively over short period of time, with the **same** measurement conditions, same instrument and observer and same location.

Reproducibility → the closeness of output readings when the same input where there are **changes** in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement.

Precision Vs Accuracy

Precision is often, though incorrectly, confused with accuracy

→ Here it is.

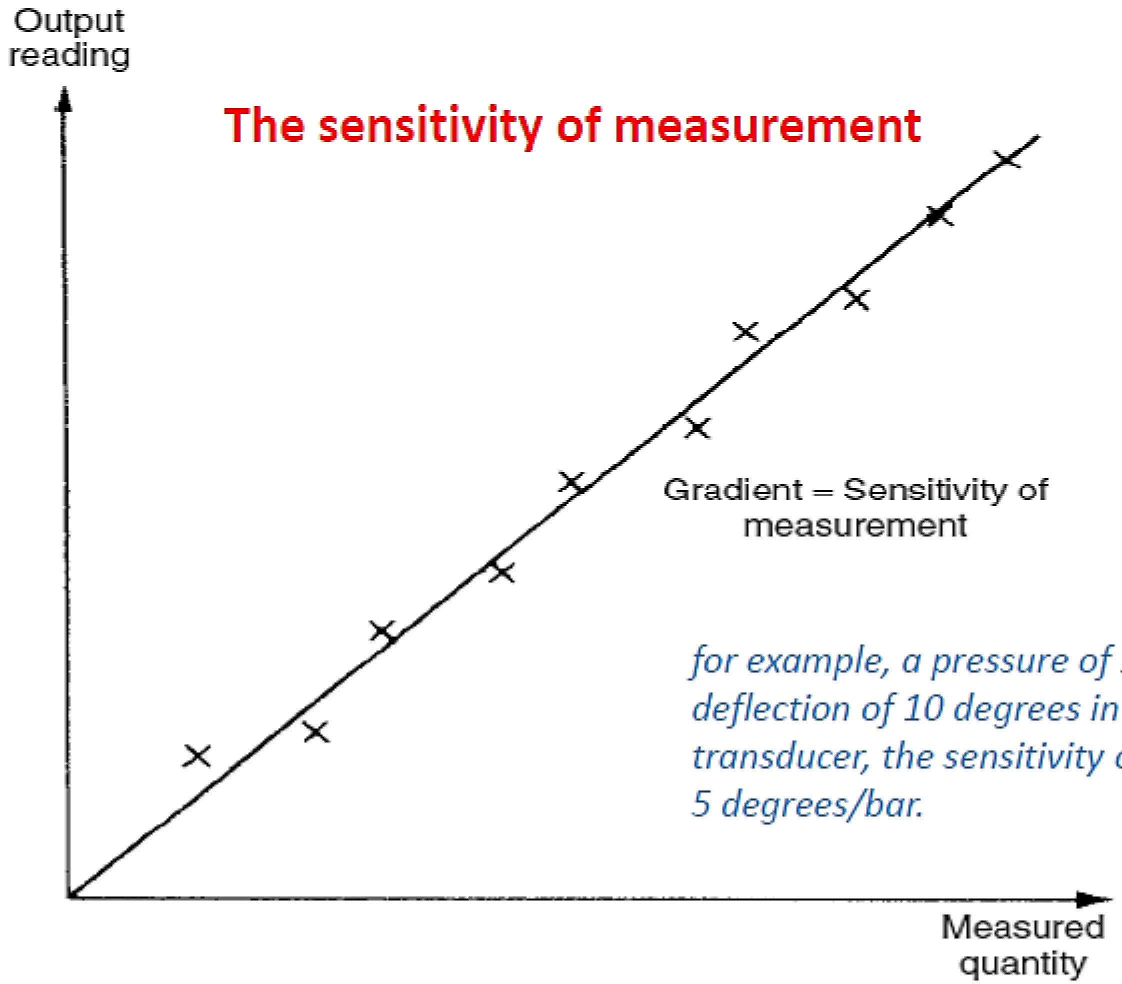


Sensitivity

Is a measure of the change in instrument output that occurs when the quantity being measured changes by given amount. Thus, sensitivity is the ratio of scale deflection / value of measurand producing deflection.

$$\textbf{Sensitivity} = \frac{Scale\ deflection}{Value\ of\ measruand\ producing\ deflection}$$

The sensitivity of measurement

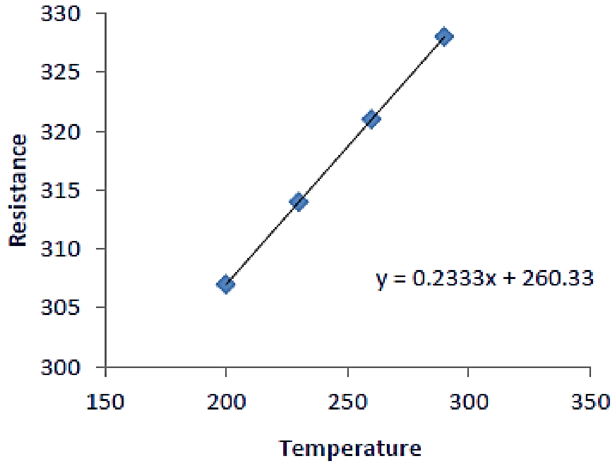


for example, a pressure of 2 bar produces a deflection of 10 degrees in a pressure transducer, the sensitivity of the instrument is 5 degrees/bar.

Example

The following resistance values of a platinum resistance thermometer were measured at a range of temperatures. Determine the measurement sensitivity of the instrument in ohms/°C.

Resistance (Ω)	*Temperature* (°C)
307	200
314	230
321	260
328	290



Threshold

If the input to an instrument is gradually increased from zero, the input will have to reach a certain minimum level before the change in the instrument output reading is of a large enough magnitude to be detectable. This minimum level of input is known as the *threshold* of the instrument.

As an illustration, a car speedometer typically has a threshold of about 5 km/h. This means that, if the vehicle starts from rest and accelerates, no output reading is observed on the speedometer until the speed reaches 5 km/h.

Resolution

Resolution is how finely its output scale is divided into subdivisions. *Sometimes specified as an* absolute value and sometimes as a percentage of f.s. deflection.

Using a car speedometer as an example again, this has subdivisions of typically 5 km/h. This means that when the needle is between the scale markings, we cannot estimate speed more accurately than to the nearest 5 km/h.

Range/Span

Range → the input of MS is specified by the minimum and maximum values of I, i.e. IMIN to IMAX. The output range is specified by the minimum and maximum values of O, i.e. OMIN to OMAX.

Span → maximum variation in input and output, i.e. input span is to IMAX – IMIN, and output span is OMAX – OMIN.

Examples ???

Range/Span

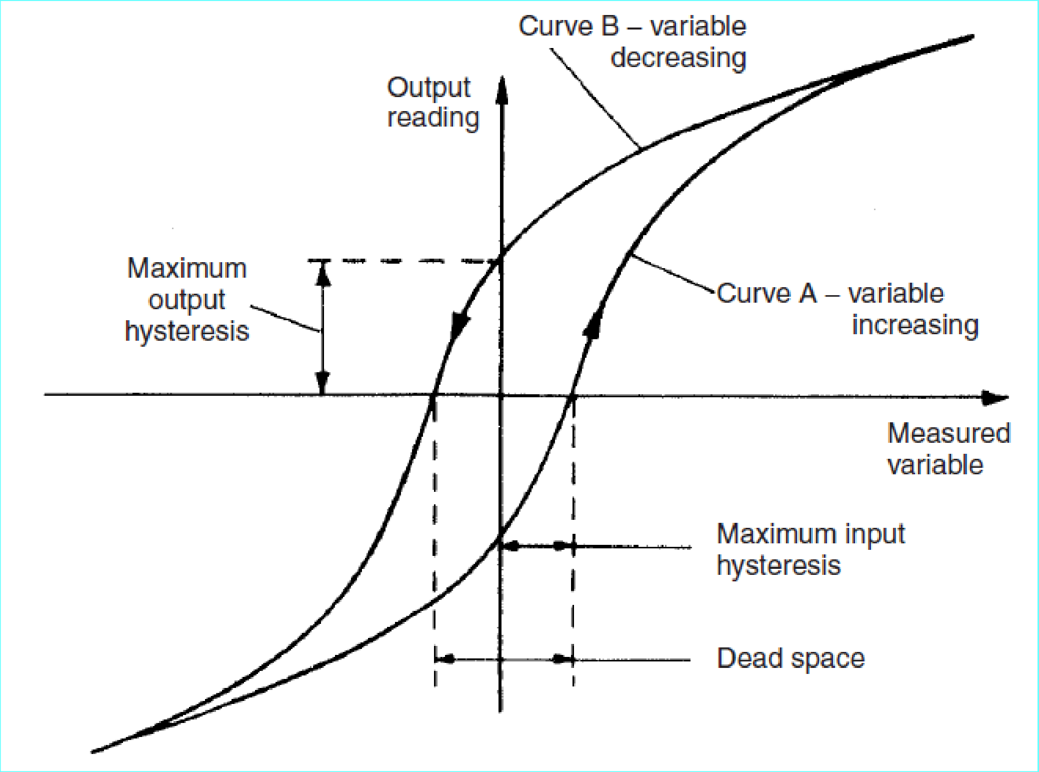
An MS is said to be linear if corresponding of I and O lie on a straight line.

The ideal straight line connect the minimum point $A(I_{Min},O_{Min})$ to maximum point $B(I_{Max},O_{Max})$ and therefore has linear equation.

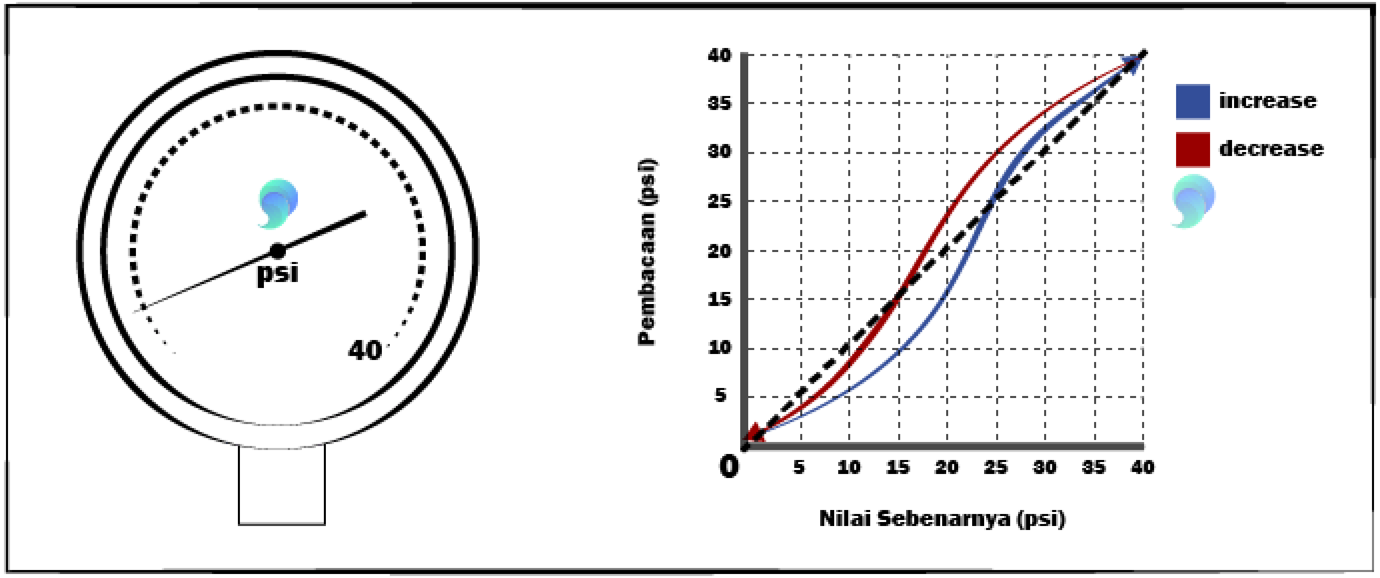
Graphics ???
Equations ???

Hysteresis Effects

If the input measured quantity to the instrument is steadily increased from a negative value, the output reading varies in the manner shown in curve (a). If the input variable is then steadily decreased, the output varies in the manner shown in curve (b). The non-coincidence between these loading and unloading curves is known as **hysteresis.**



Measurement and Control System



Dynamic Characteristics

Selengkapnya akan dipelajari di **Fisika Instrumentasi**

Penugasan

Carilah sebuah Paper Internasional (Terindeks Scopus) yang lalu:

- **Buat ringkasan**
- **Presentasikan**

Catatan: Tonjolkan mengenai pemanfaatan / desain / investigasi / perbandingan hasil / dan lain-lain berkenaan dengan sensor yang digunakan

Thank You

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Karakteristik Sistem

Oleh: Ahmad Zarkasi, S.Si., M.Si

Prodi Fisika FMIPA UNMUL

Characteristics of Instrumentation System

- Static Characteristics
- Dynamics Characteristics

Static Characteristics

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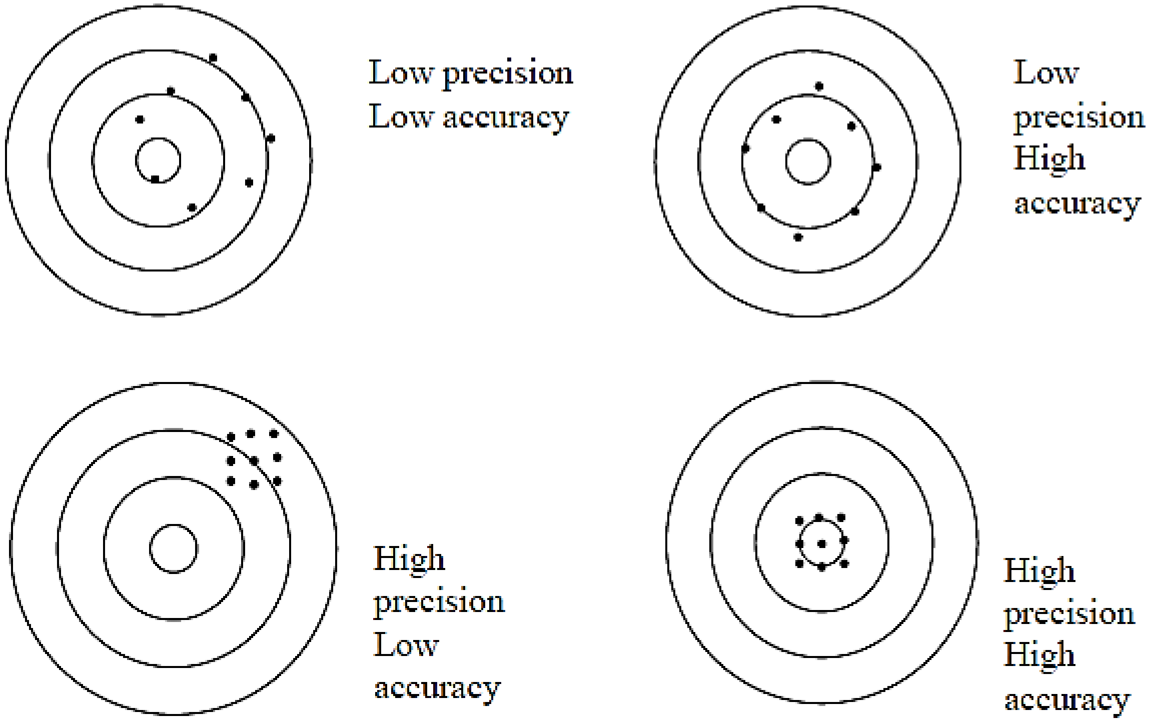

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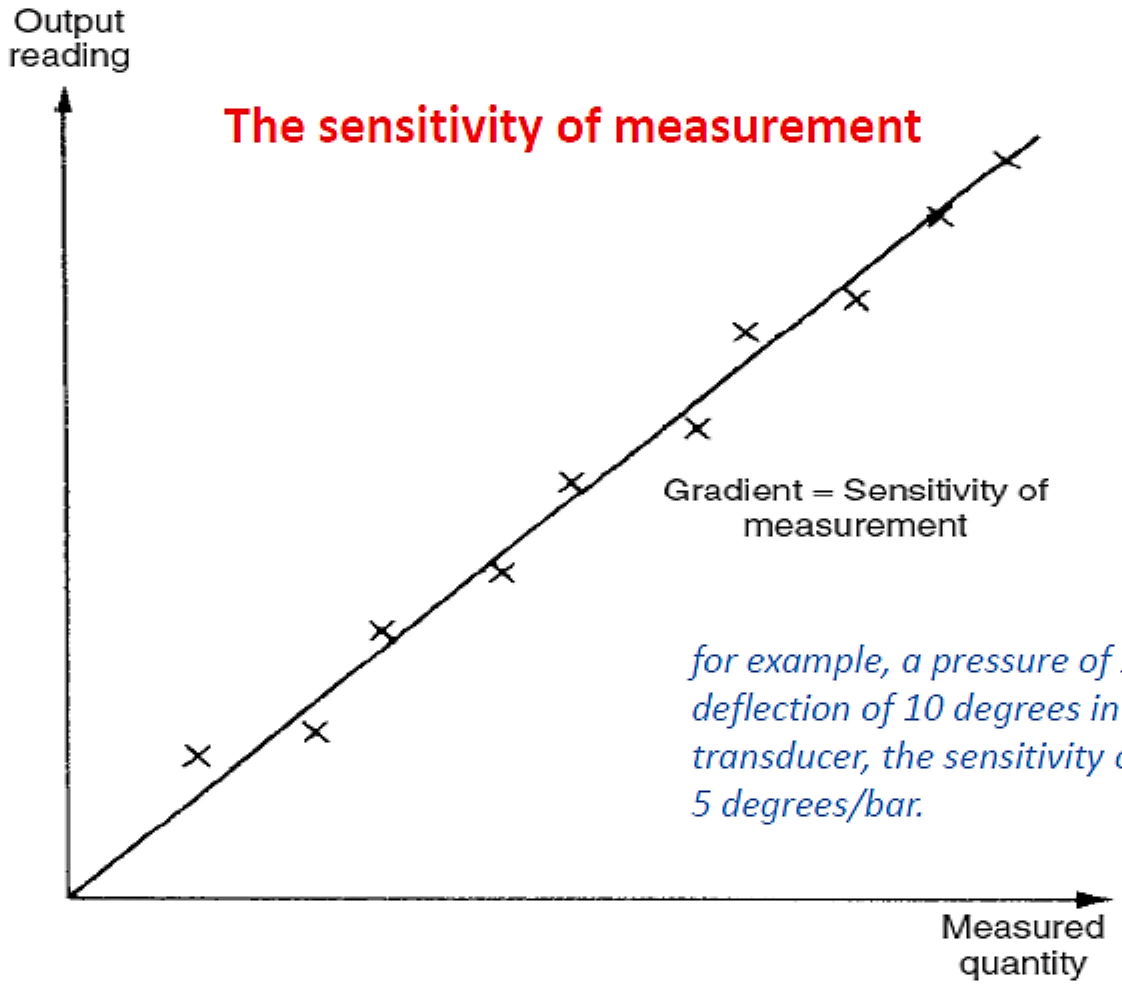

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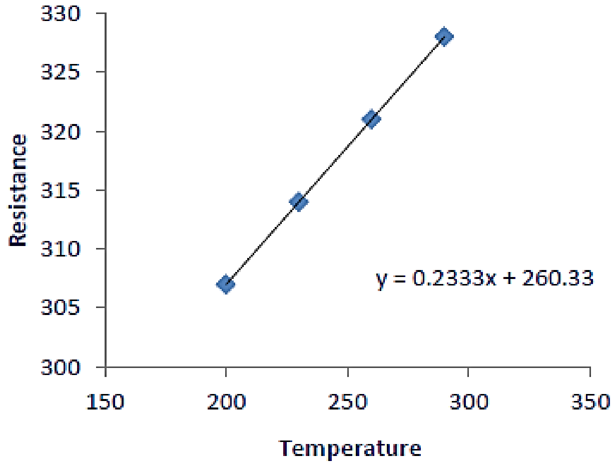

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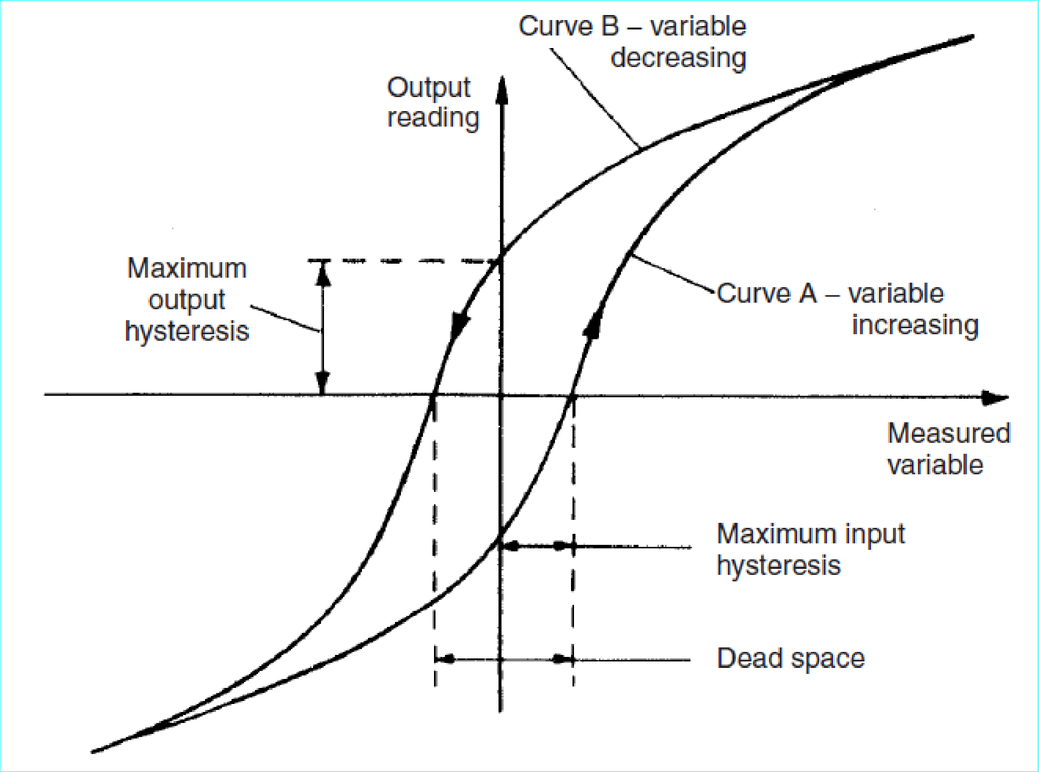
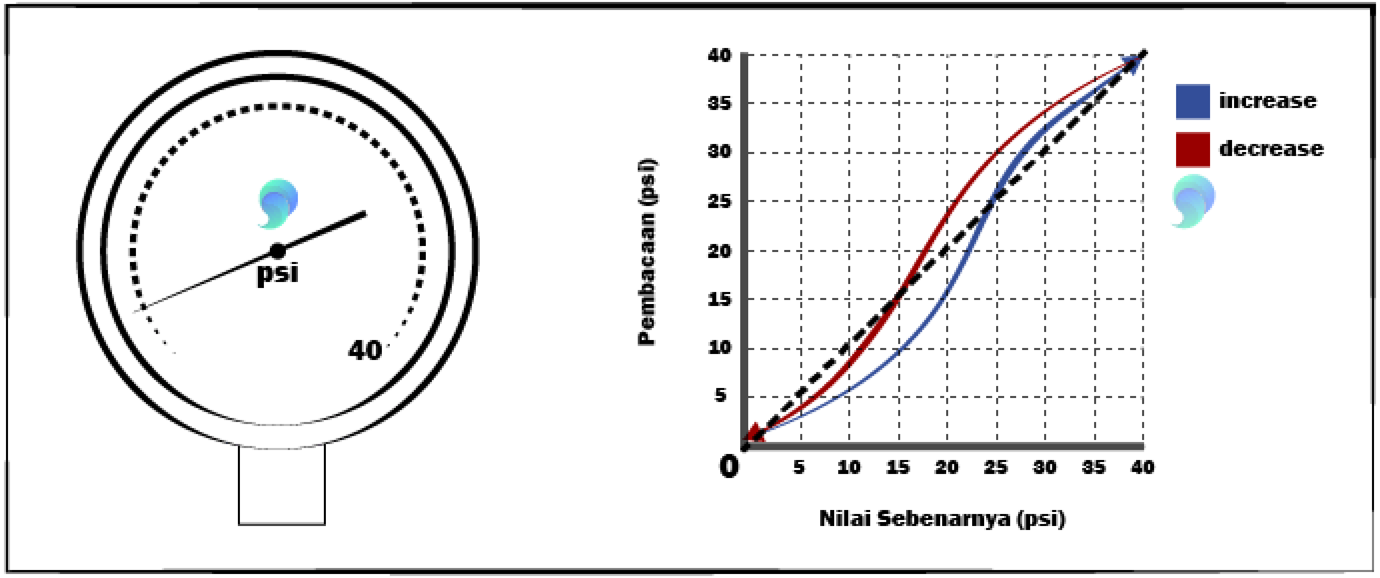
Hysteresis Effects

If the input measured quantity to the instrument is steadily increased from a negative value, the output reading varies in the manner shown in curve (a). If the input variable is then steadily decreased, the output varies in the manner shown in curve (b). The non-coincidence between these loading and unloading curves is known as **hysteresis.**



Measurement and Control System



Dynamic Characteristics

Dynamic Characteristics

The dynamic characteristics of a measuring instrument describe its behavior between the time a measured quantity changes value and the time when the instrument output attains a steady value in response.

1. Zero order measurement system
2. First order measurement system
3. Second order measurement system

Mathematical Model

In any linear time-invariant measuring system, the following general relation can be written between input and output for time (t)>0:

$$a_n \frac{d^n q_o}{dt^n} + a_{n-1} \frac{d^{n-1} q_o}{dt^{n-1}} + \cdots + a_1 \frac{dq_o}{dt} + a_0 q_o$$
$$= b_m \frac{d^m q_i}{dt^m} + b_{m-1} \frac{d^{m-1} q_i}{dt^{m-1}} + \cdots + b_1 \frac{dq_i}{dt} + b_0 q_i$$

q_i : Measured quantity

q_o : Output reading

$a_0 \ldots a_n;\ b_0 \ldots b_m$: Constants

If we limit consideration to that of step changes in the measured quantity only, then the equation reduces to:

$$a_n \frac{d^n q_o}{dt^n} + a_{n-1} \frac{d^{n-1} q_o}{dt^{n-1}} + \cdots + a_1 \frac{dq_o}{dt} + a_0 q_o = b_0 q_i$$

Further simplification can be made by taking certain special cases of that equation, which collectively apply to nearly all measurement systems.

- Zero order instrument
- First order instrument
- Second order instrument

Zero order instrument

Is all coefficient a_1 … a_n other than a_0 are assumed zero, then

$$a_0 q_o = b_0 q_i$$ or $$q_o = \frac{b_0}{a_0} q_i = K q_i$$

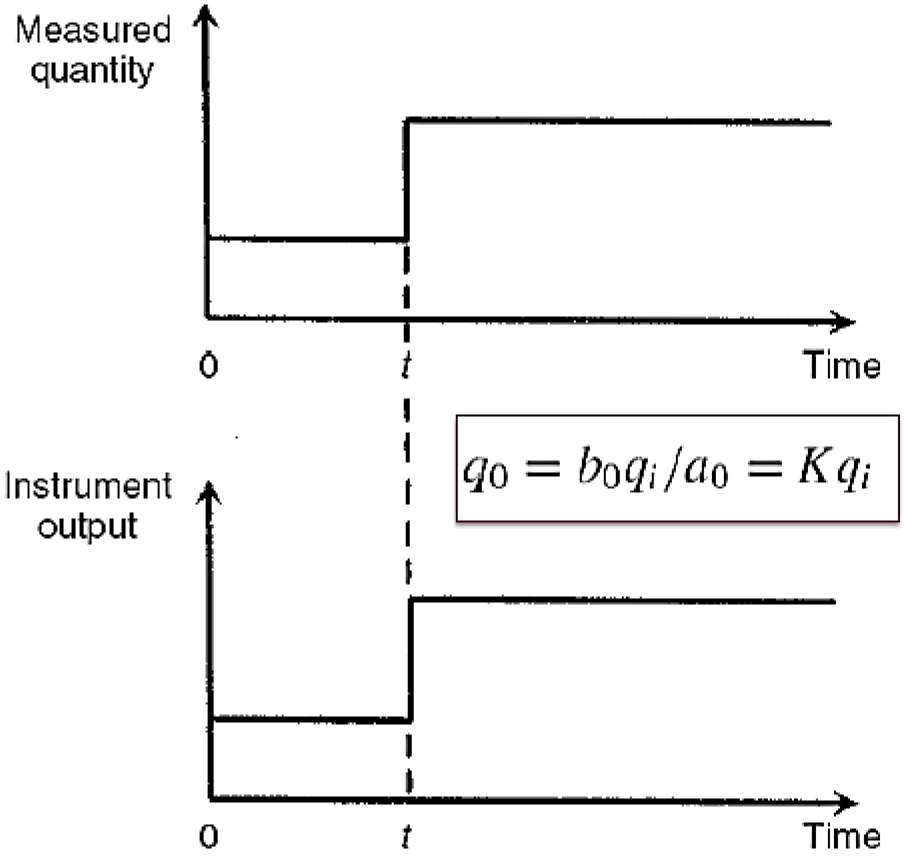
$K = b_0/a_0$

K is a constant known as the instrument sensitivity

Where ***K*** is a constant known as the instrument sensitivity. Any instrument that behaves according to the equation is known as a zero order instrument.

Following a step change in the measured quantity at time t, the instrument output moves immediately to a new value at the same time instant *t*

Zero order instrument characteristic



$$q_0 = b_0 q_i / a_0 = K q_i$$

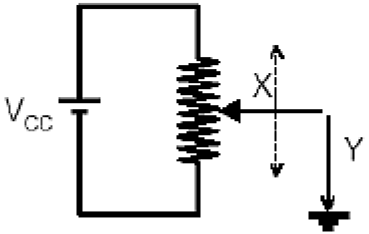
A potentiometer, which measures motion, is a good example of such an instrument, where the output voltage changes instantaneously as the slider is displaced along the potentiometer track.

Zero-order sensors

- **Input and output are related by an equation of the type**

$$y(t) = k \cdot x(t) \Rightarrow \frac{Y(s)}{X(s)} = k$$

- Zero-order is the desirable response of a sensor
  - No delays
  - Infinite bandwidth
  - The sensor only changes the amplitude of the input signal
- Zero-order systems do not include energy-storing elements
- Example of a zero-order sensor
  - A potentiometer used to measure linear and rotary displacements
    - This model would not work for fast-varying displacements



First order instrument

Is all coefficient a_2 … a_n other than a_0 and a_1 are assumed zero, then

$$a_1 \frac{dq_o}{dt} + a_0 q_o = b_0 q_i$$

If

$$\frac{d}{dt} = D$$

then

$$a_1 D q_o + a_0 q_o = b_0 q_i$$

$$q_o = \frac{(b_0 / a_0) q_i}{[1 + (a_1 / a_0) D]} = \frac{K q_i}{[1 + \tau D]}$$

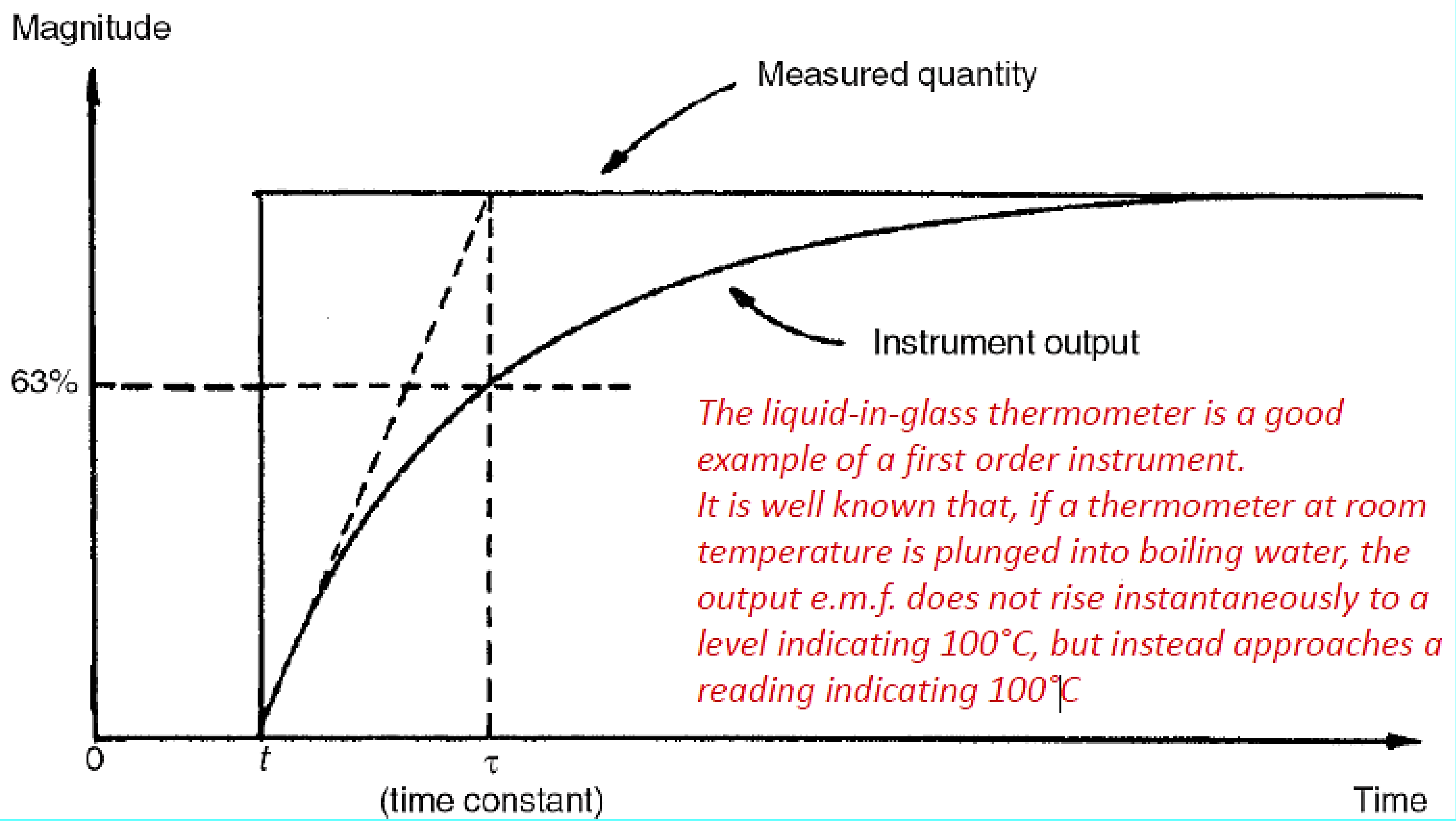
Where time constant of the system

$$\tau = a_1 / a_0$$

Any instrument that behaves according to the equation is known as **a first order instrument.**

If equation is solved analytically, the output quantity q_0 in response to a step change in q_i at time t varies with time. The time constant of the step response is the time taken for the output quantity q_0 to reach **63% of its final value**.

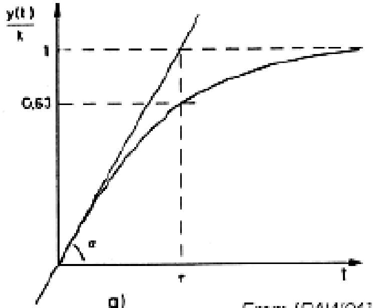
First order instrument characteristic



The liquid-in-glass thermometer is a good example of a first order instrument.
It is well known that, if a thermometer at room temperature is plunged into boiling water, the output e.m.f. does not rise instantaneously to a level indicating 100°C, but instead approaches a reading indicating 100°C

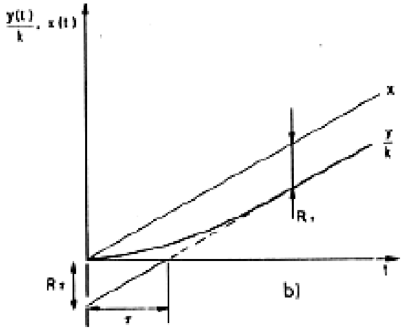
First order sensor response

- Step response

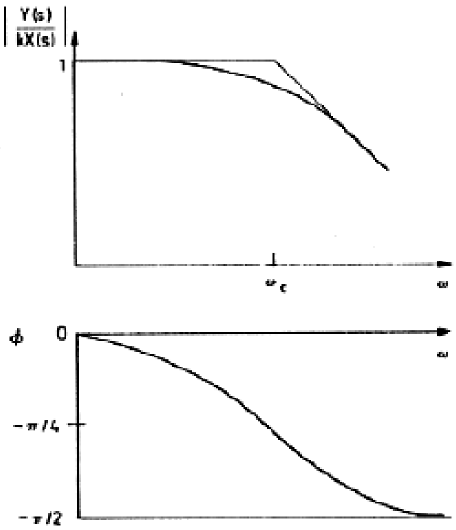


From [PAW91]

- Ramp response

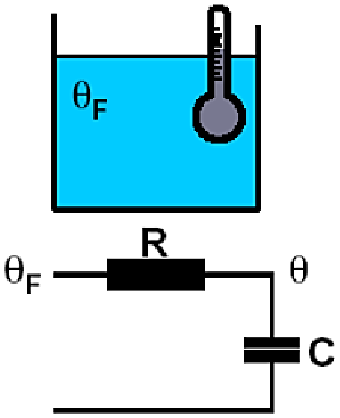


- Frequency response
  - Corner frequency $\omega_c=1/\tau$
  - Bandwidth



Example

- **A mercury thermometer immersed into a fluid**
  - What type of input was applied to the sensor?
  - Parameters
    - C: thermal capacitance of the mercury
    - R: thermal resistance of the glass to heat transfer
    - θ_F: temperature of the fluid
    - $\theta(t)$: temperature of the thermometer
  - The equivalent circuit is an RC network



- **Derivation**
  - Heat flow through the glass $\left(\theta_F - \theta(t)\right)/R$
  - Temperature of the thermometer rises as $\dfrac{d\theta(t)}{dt} = \dfrac{\theta_F - \theta(t)}{RC}$
  - Taking the Laplace transform

$$s\,\theta(s) = \frac{\theta_F(s) - \theta(s)}{RC} \Rightarrow (RCs+1)\,\theta(s) = \theta_F(s) \Rightarrow$$

$$\Rightarrow \theta(s) = \frac{\theta_F(s)}{(RCs+1)} \Rightarrow \theta(t) = \theta_F\left(1 - e^{-t/RC}\right)$$

Second order instrument

Is all coefficient a_3 … a_n other than a_0, a_1 and a_2 are assumed zero, then

$$a_2 \frac{d^2 q_o}{dt^2} + a_1 \frac{dq_o}{dt} + a_0 q_o = b_0 q_i$$

Then applying D operator again:

$$a_2 D^2 q_o + a_1 D q_o + a_0 q_o = b_0 q_i$$

$$q_o = \frac{b_0 q_i}{[a_0 + a_1 D + a_2 D^2]}$$

It is convenient to re-express the variables a_0, a_1, a_2 and b_0 in terms of tree parameters:

- K : static sensitivity
- ω : un-damped natural frequency
- ξ : damping ratio

where

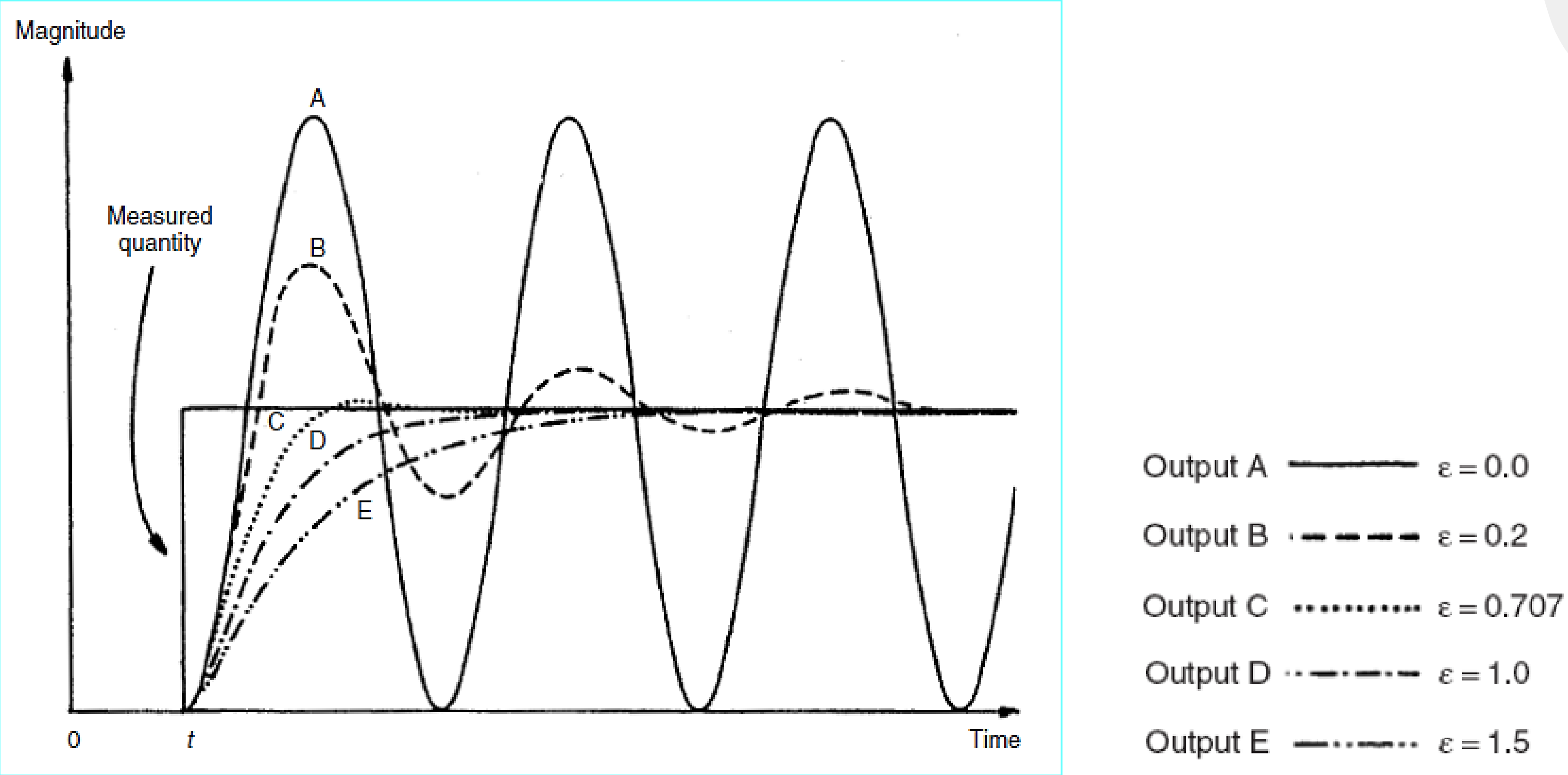
$$K = b_0 / a_0 \qquad \omega = a_0 / a_2 \qquad \xi = a_1 / 2a_0a_2$$

We get:

$$q_o = \frac{K}{\frac{D^2}{\omega^2} + 2\xi\frac{D}{\omega} + 1} q_i$$

This is the standard equation for second order system and any instrument whose response can be described by it is known as second order instrument.

Response characteristics of second order instruments



Penugasan

- Pertemuan 4 → Masih melanjutkan materi tentang salah satu contoh/jenis/tipe sensor.
- Masing-masing mahasiswa memilih salah satu jenis/tip sensor berdasarkan materi di buku.
- Dapat menambah referensi dari luar
- Tiap pertemuan 2 mahasiswa presentasi.

Thank You

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Signal Conditioning Element

Oleh: Ahmad Zarkasi, S.Si., M.Si

Signal Conditioning Element

Takes the output of the sensing element and converts it into a form more suitable for further processing.

Examples:

- Deflection bridge which converts an impedance change into voltage change.
- Amplifier which amplifies millivolts to volts.
- Oscillator which converts an impedance change into a variable frequency voltage.

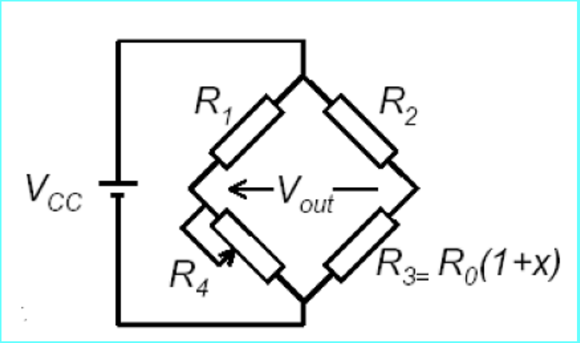
Signal Conditioning Element

- **Impedance** transformation
- **Amplification** or **Attenuation**
- **Level** shifting
- **Span** and **Base** adjustment
- **Filtering** to reduce noise or interference

Impedance Transformation

Wheatstone Bridge

- A circuit that consist of two dividers
  - **A reference voltage divider (left)**
  - **A sensor voltage divider**



- Wheatstone bridge operating modes
  - **Null mode**
    - R_4 adjusted until the balance condition is met:

$$V_{out} = 0 \rightarrow R_3 = R_4 \frac{R_2}{R_1}$$

    - Advantage : measurement is **independent** of fluctuation in Vcc

  - **Deflection mode**
    - The unbalanced voltage Vout is used as the output of the circuit

$$V_{out} = V_{CC}\left(\frac{R_3}{R_2 + R_3} - \frac{R_4}{R_1 + R_4}\right)$$

    - Advantage : **speed**

AC Bridges

- The structure of the Wheatstone bridge can be used to measure capacitive and inductive sensors
  - Resistance replaced by generalized impedance
  - DC bridge excitation replaced by an AC source

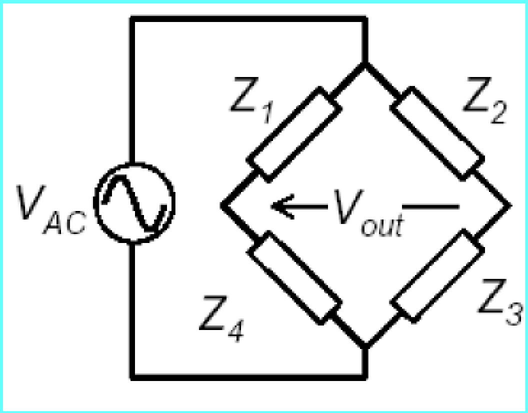
- The balance condition becomes

$$\frac{Z_1}{Z_4} = \frac{Z_2}{Z_3}$$

  - which yields two equalities, for real and imaginary component

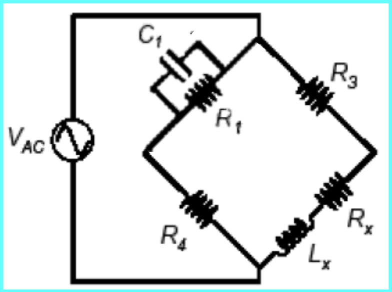
$$R_1R_3 - X_1X_3 = R_2R_4 - X_2X_4$$
$$R_1R_3 + X_1X_3 = R_2R_4 + X_2X_4$$

- There is a large number of AC bridge arrangements
  - These are named after their respective developer

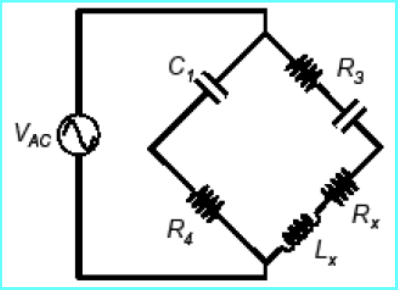


More AC Bridges...

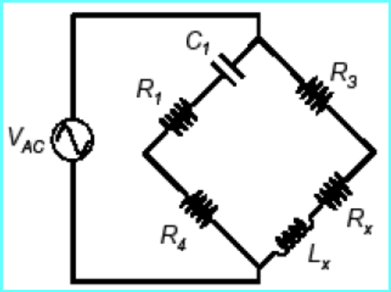
- Inductance measurement
  - Maxwell bridge



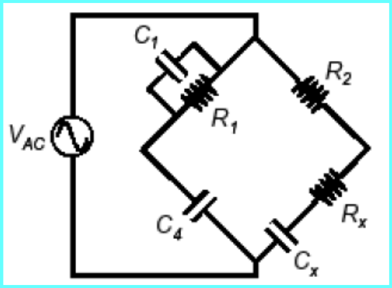
  - Owen bridge



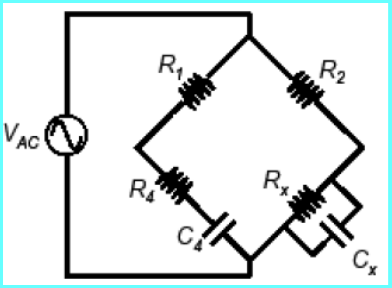
  - Hay bridge



- Capacitance measurement
  - Schering bridge

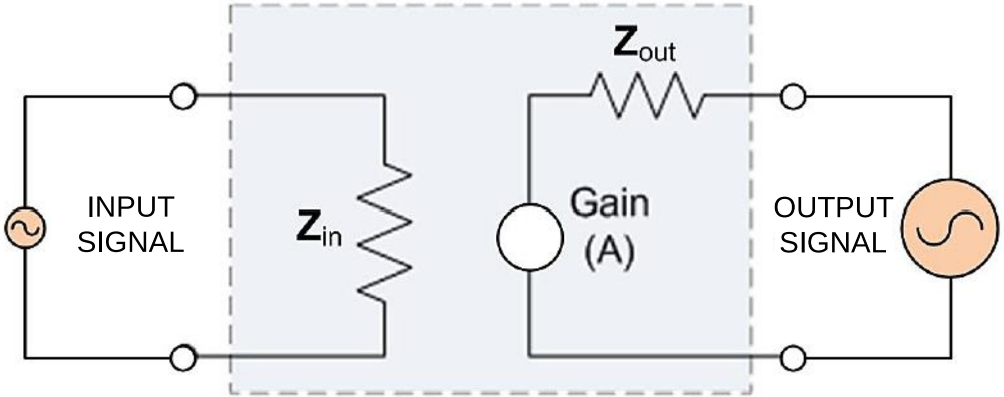


  - Wien bridge



Amplification

- **Generally, the sensor output signal is very small, so it's need to be strengthened. Amplifier works for amplify the signal (current, voltage, or power).**
- **The working model of an amplifier:**



- **Amplifiers:**
  - Transistor Based Circuits
  - OpAmp Based Circuits

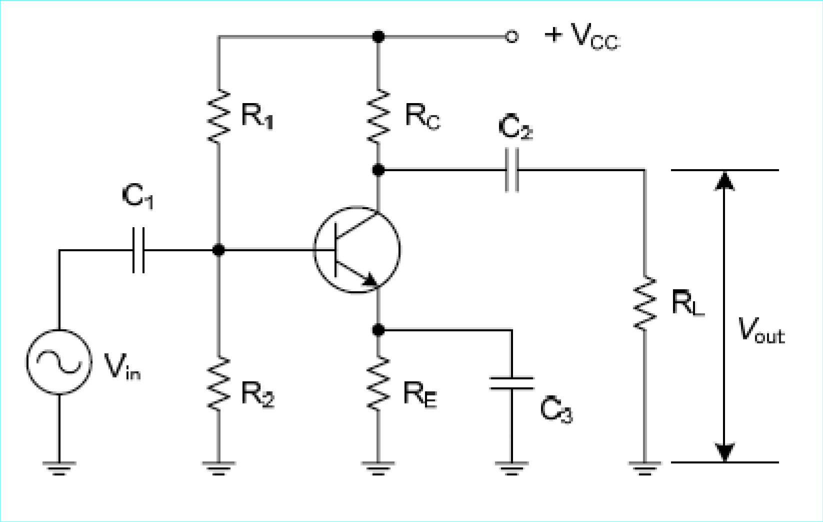
Meliputi:

- Sinyal hasil keluaran sensor umumnya sangat kecil, sehingga perlu dikuatkan.
- Amplifier atau penguat, berfungsi menguatkan sinyal (arus, tegangan, atau daya).
- Amplifiers

– Transistor Based Circuits

– OpAmp Based Circuits

Penguat Transistor: BJT-CE



Misal: R1=47kΩ, R2=15kΩ, RC=10kΩ, RE=8,2kΩ, RL=3,3kΩ, β=200, Vcc=30V, dan Vin=5mV, maka dapat dicari Vout, impedansi masukan dan impedansi keluarannya.

$$Z_{in} = R_1 // R_2 // \beta r_e'$$

$$Z_{out} = r_L = R_C // R_L$$

$$V_B = \frac{R_2}{R_2 + R_1} V_{cc}$$

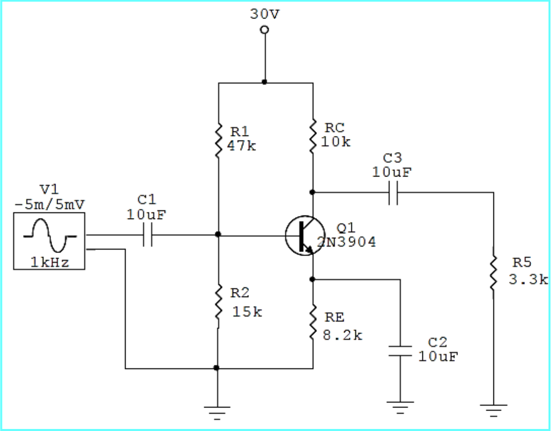
$$I_E = \frac{V_E}{R_E} = \frac{V_B - V_{BE}}{R_E}$$

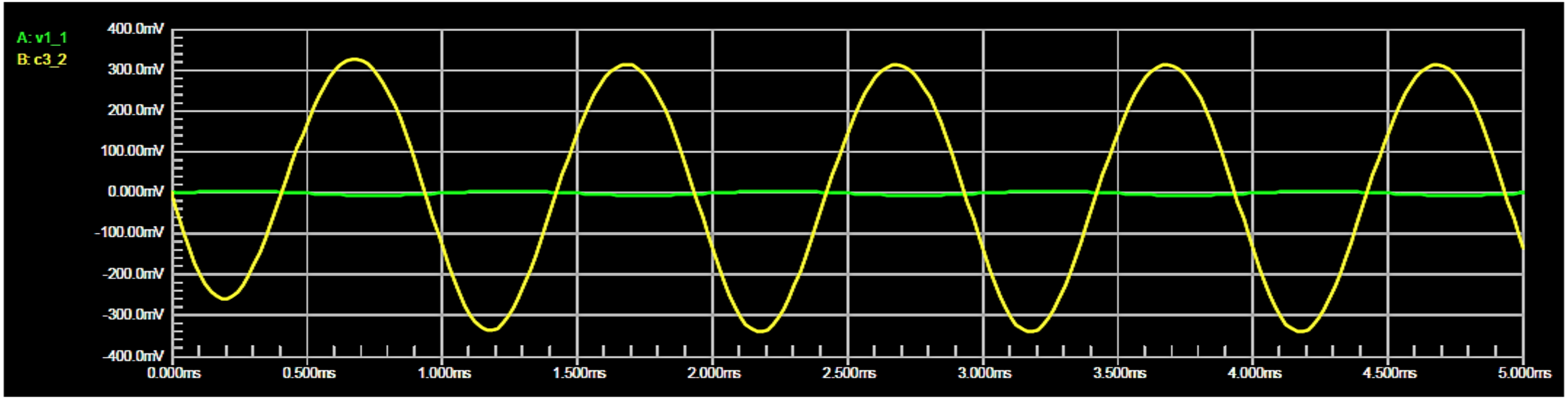
$$r_e' = \frac{25\ mV}{I_E}$$

$$A_v = \frac{r_L}{r_e'}$$

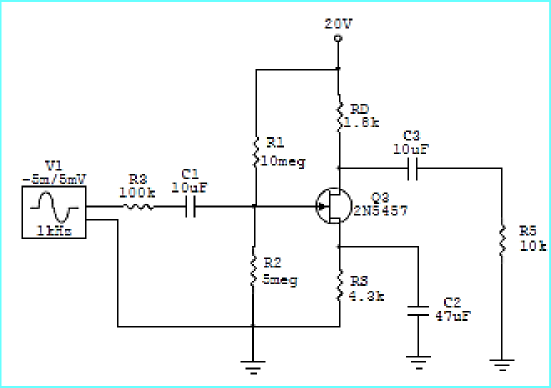
$$V_{out} = A_v x V_{in}$$

Transistor Based Circuits: - Bipolar Junction Transistor - CE

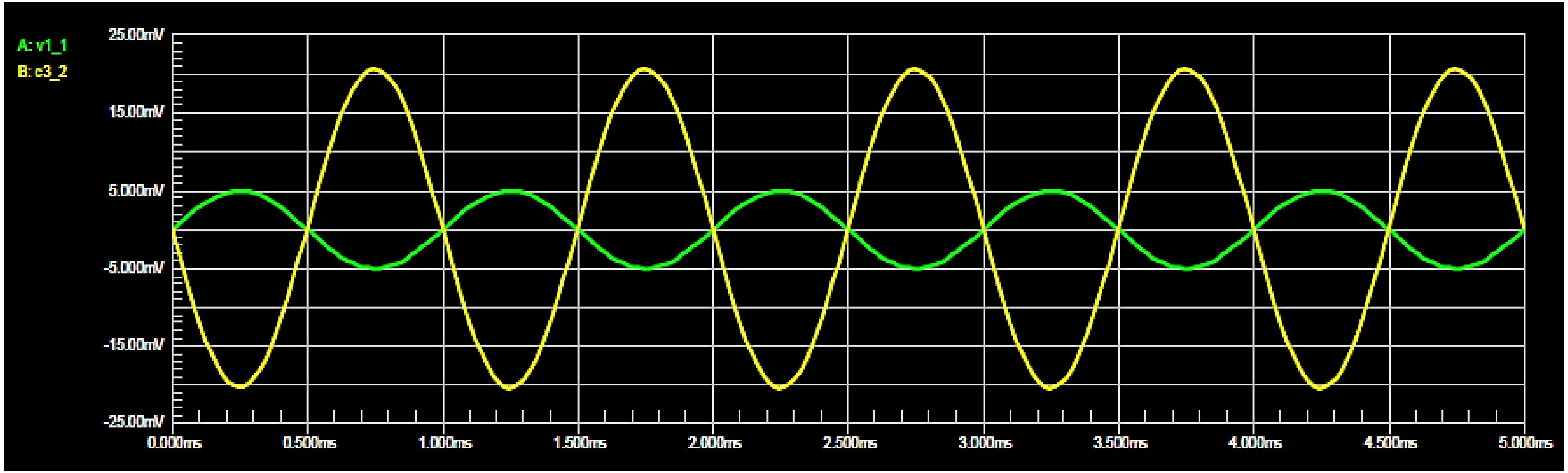




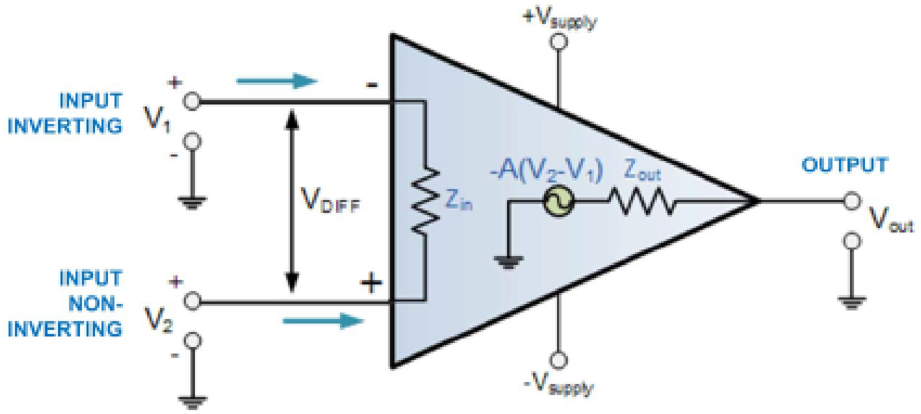
Transistor Based Circuits: - FET



$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

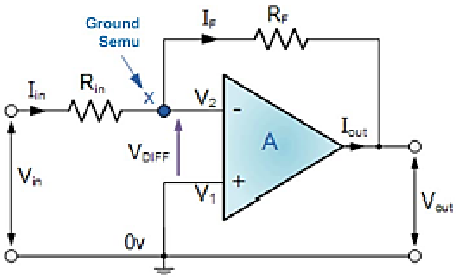


OpAmp Based Circuits:



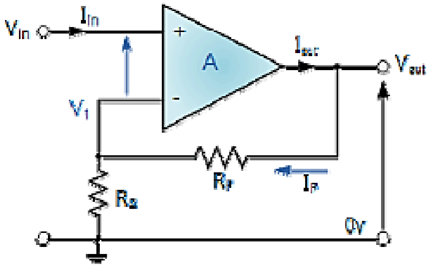
Nama Parameter	Simbol	Nilai Ideal	Nilai Riel
Arus Masukan	I_{IN}	0	rendah (<0,5 µ A)
Tegangan Offset Masukan	V_{OS}	0	rendah (<10 mV,0,2 µ A)
Impedansi Masukan	Z_{IN}	∞	tinggi (>10 M Ω)
Impedansi Keluaran	Z_{OUT}	0	rendah (<500 Ω)
Gain (Penguatan)	a	∞	sangat tinggi (>10^4)
Bandwidth (lebar pita frekuensi)	f_{BW}	∞	
CMRR	CMRR	∞	Tinggi (>70 dB)

Inverting Amplifier



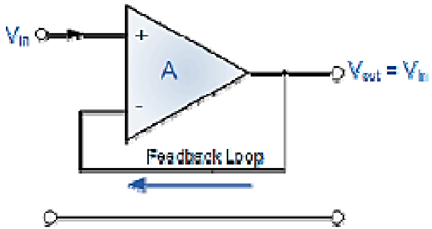
$$V_{out} = -\frac{R_F}{R_{in}} V_{in}$$

The Non-inverting Amplifier

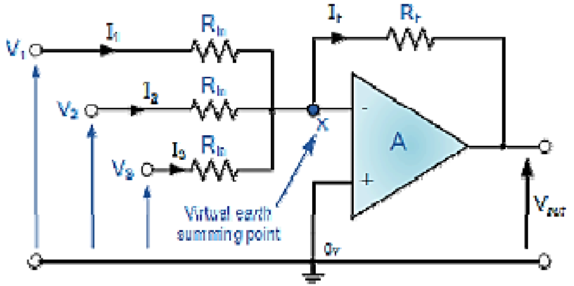


$$V_{out} = \left(\frac{R_F}{R_{in}} + 1 \right) V_{in}$$

Buffer Amplifier (Unity Gain Buffer, Voltage Follower)



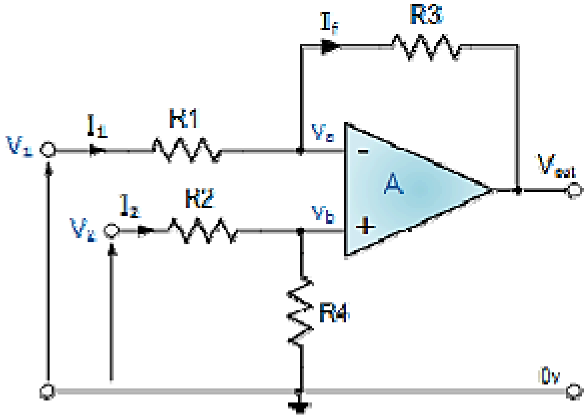
Summing Amplifier



$$V_{out} = -\left(\frac{R_F}{R_1} + \frac{R_F}{R_2} + \frac{R_F}{R_3} \right) V_{in} = -\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right) R_F V_{in}$$

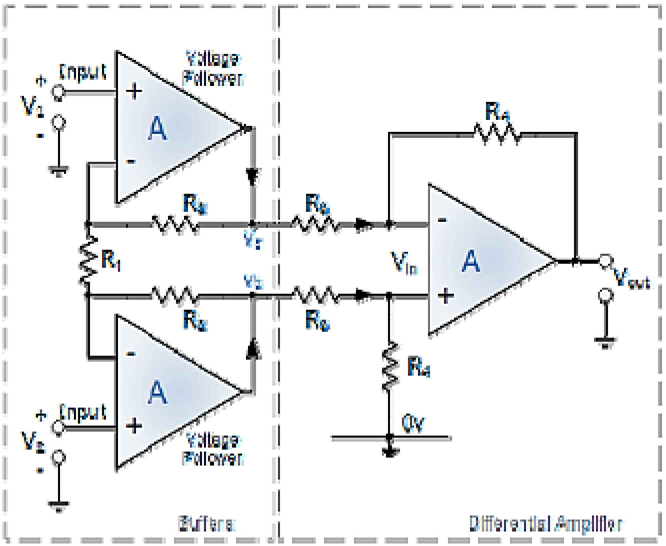
And more…

Differential Amplifier



$$V_{out} = \left(\frac{R_1 + R_3}{R_2 + R_4}\right)\left(\frac{R_4}{R_1}\right)V_2 - \frac{R_3}{R_1}V_1$$

Instrumentation Amplifier



$$V_{out} = \left(\frac{R_4}{R_3}\right)\left(\frac{2R_2}{R_1} + 1\right)(V_2 - V_1)$$

Rangkaian Filter

Rangkaian Filter adalah rangkaian yang berfungsi meloloskan sinyal yang mempunyai frekuensi tertentu yang dikehendaki dan memblok sinyal pada frekuensi yang tidak dikehendaki.

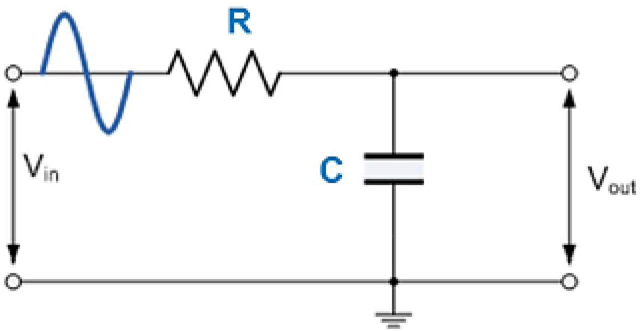
Rangkaian Filter dapat dibedakan atas filter pasif dan filter aktif, dan masing-masing mempunyai sifat:

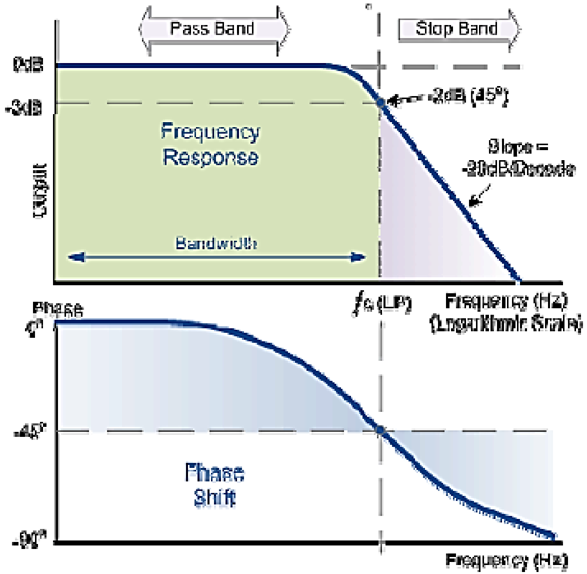
- Lowpass (Filter yang meloloskan sinyal frekuensi rendah)
- Highpass (Filter yang meloloskan sinyal frekuensi tinggi)
- Bandpass (Filter yang meloloskan frekuensi pita)
- Band Reject (Filter yang menolak frekuensi pita)

Ditinjau dari kemiringanya atau ketajamannya, sebuah filter dapat berupa:

- Filter orde-1, kemiringan=-20 dB/dekade
- Filter orde-2, kemiringan=-40 dB/dekade
- Filter orde-3, kemiringan=-60 dB/dekade.
- Dsb…

Low Pass Filter





$$V_{out} = \frac{X_C}{X_C + R} V_{in} = \frac{j\omega C}{\dfrac{1}{j\omega C} + R} V_{in}$$

$$V_{out} = \frac{1}{\left(1 + j\dfrac{\omega}{\omega_0}\right)} V_{in}$$

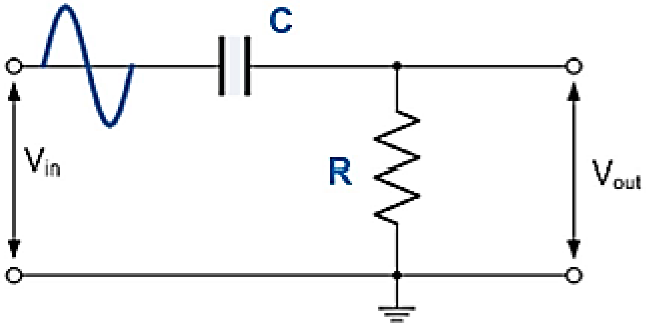
$$\omega_0 = \frac{1}{\tau_0} = \frac{1}{RC}$$

Untuk $\omega \ll \omega_0$, maka $\theta = \tan^{-1}\left(-\dfrac{\omega}{\omega_0}\right) = \tan^{-1}(0) = 0°$

Untuk $\omega = \omega_0$, maka $\theta = \tan^{-1}\left(-\dfrac{\omega}{\omega_0}\right) = \tan^{-1}(-1) = -45°$

Untuk $\omega \gg \omega_0$, maka $\theta = \tan^{-1}\left(-\dfrac{\omega}{\omega_0}\right) = \tan^{-1}(-\infty) = -90°$

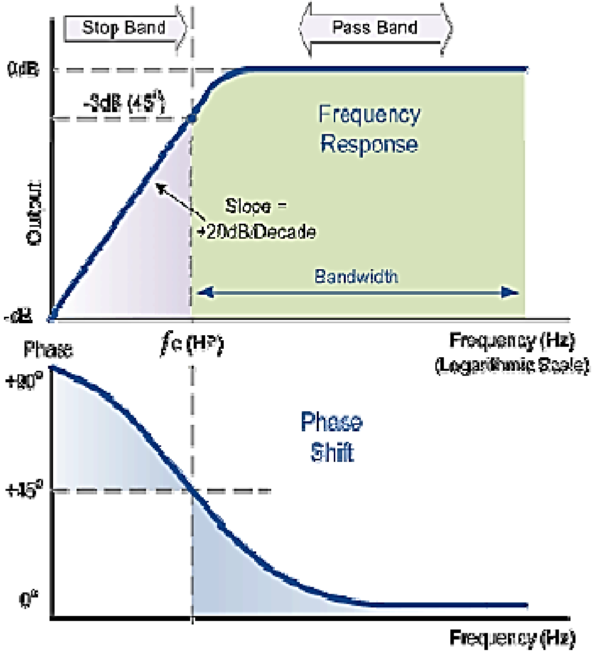
High Pass Filter



$$V_{out} = \frac{R}{X_C + R} V_{in} = \frac{R}{\frac{1}{j\omega C} + R} V_{in}$$

$$V_{out} = \frac{1}{\left(\frac{\omega_0}{j\omega} + 1\right)} V_{in}$$

$$\omega_0 = \frac{1}{\tau_0} = \frac{1}{RC}$$

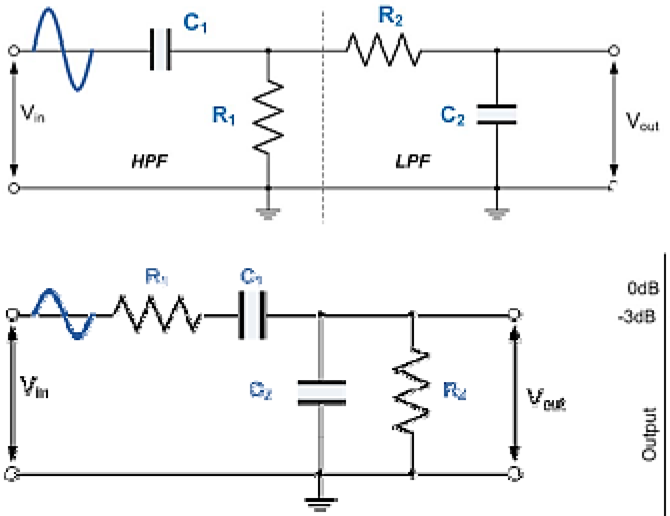


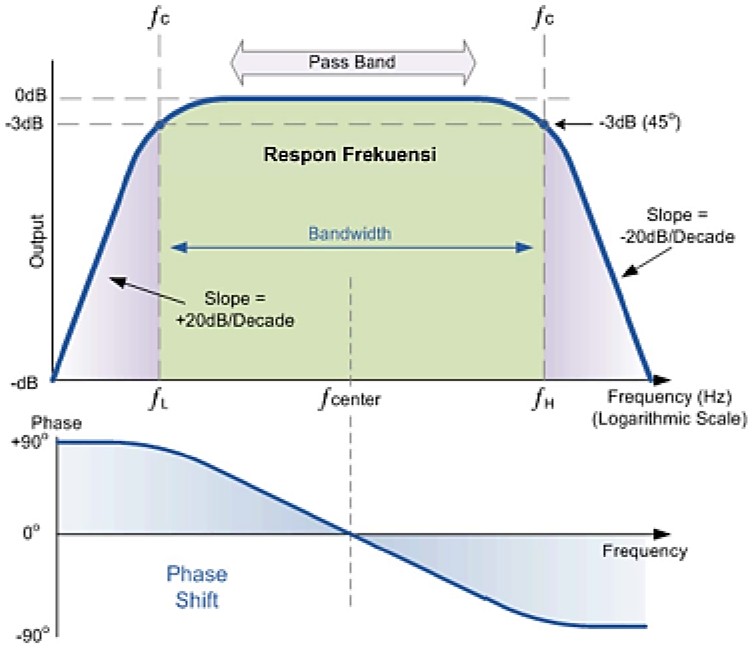
Untuk $\omega << \omega_0$, maka $\theta = \tan^{-1}\left(\frac{\omega_0}{\omega}\right) = \tan^{-1}(\infty) = 90°$

Untuk $\omega = \omega_0$, maka $\theta = \tan^{-1}\left(\frac{\omega_0}{\omega}\right) = \tan^{-1}(1) = 45°$

Untuk $\omega >> \omega_0$, maka $\theta = \tan^{-1}\left(\frac{\omega_0}{\omega}\right) = \tan^{-1}(0) = 0°$

Band Pass Filter





Batas frekuensi bawah: $f_L = \dfrac{1}{2\pi R_1 C_1}$

Batas frekuensi bawah: $f_H = \dfrac{1}{2\pi R_2 C_2}$

Signal Processing Element?

...→ Next meeting

Signal Processing Element

Oleh: Ahmad Zarkasi, S.Si., M.Si

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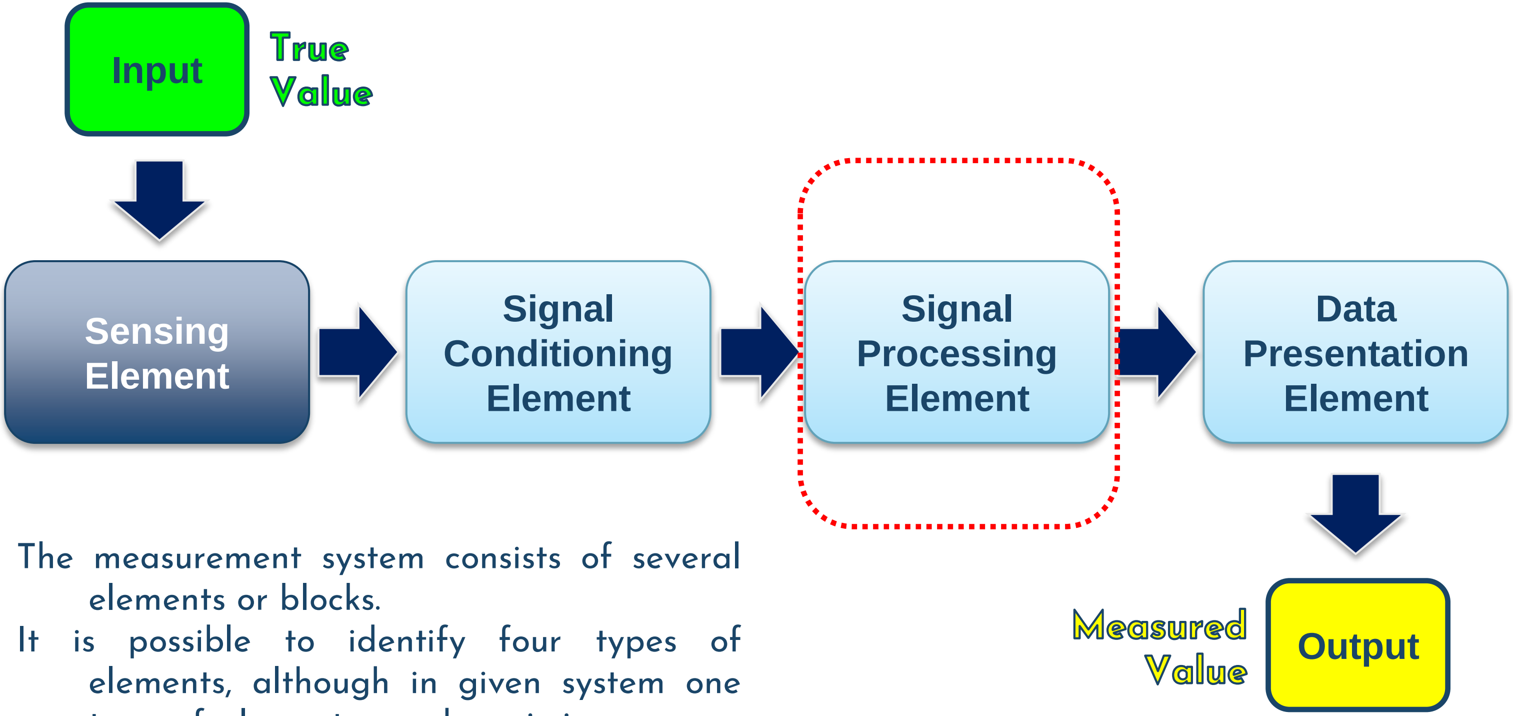
Measurement and Control System



The measurement system consists of several elements or blocks.

It is possible to identify four types of elements, although in given system one type of element may be missing or may occur more than once.

Signal Processing Element

This takes the output of the signal conditioning element and converts it into a form more suitable for presentation.

Examples:

1. ADC which converts a voltage into a digital form for input to a computer.
2. A microcomputer which calculates the measured value of the variable from incoming digital data.

Sinyal dan Bentuk Sinyal

Definisi Sinyal:

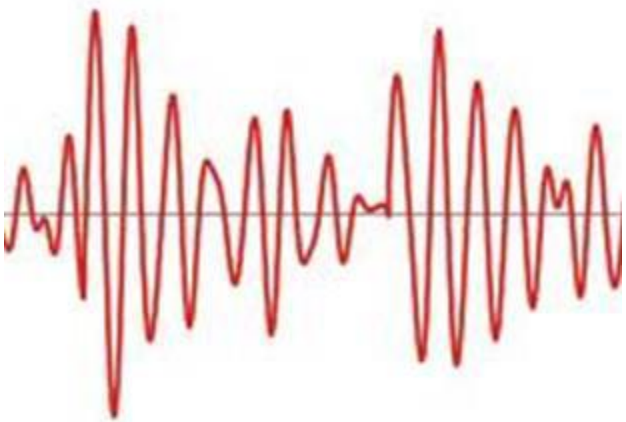
→*Isyarat yang mengandung informasi*

→*Kuantitas fisis yang bervariasi terhadap waktu dan atau ruang, serta mengandung informasi*

Bentuk Sinyal:

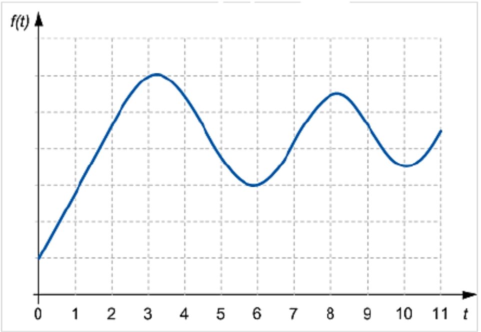
→ *kontinyu, diskrit*

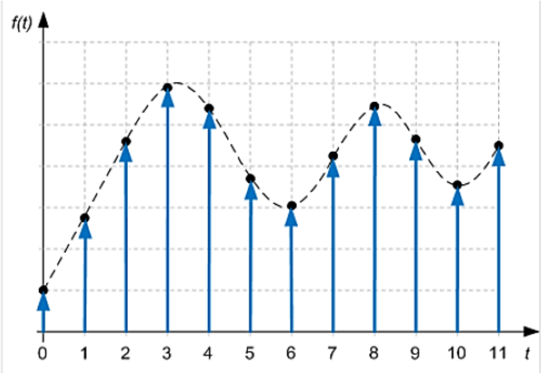
→ *analog, digital*



Kontinyu vs Diskrit

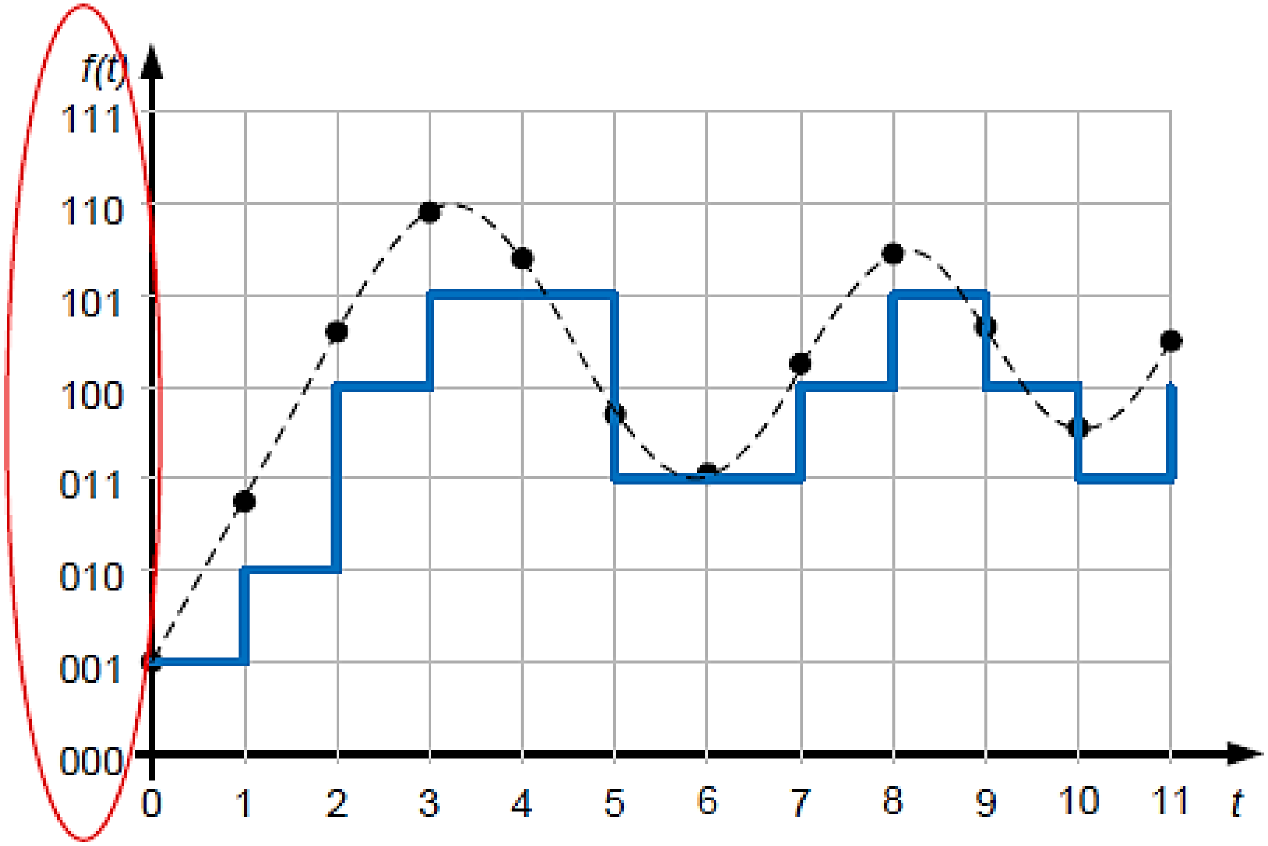
- Kriteria kontinyu-diskrit bergantung pada argumen (biasanya waktu).
- Jika keberadaan sinyal hanya pada waktu-waktu tertentu, maka dikategorikan sebagai sinyal diskrit.
- Jika keberadaannya selalu ada di setiap saat , maka adalah sinyal kontinyu.





Analog vs Digital

- Kriteria analog-digital didasarkan pada bentuk dan cara mereprentasikan nilainya.
- Sinyal digital selalu dinyatakan dalam kumpulan digit biner (*binary digit*, bit), yaitu: 0 dan 1.
- Nilai digital sebuah sinyal ditentukan oleh jumlah dari bobot masing-masing bitnya, dan ini bersifat diskrit.
- Sinyal analog dapat mempunyai harga yang kontinyu, sehingga sinyal analog adalah sinyal kontinyu.

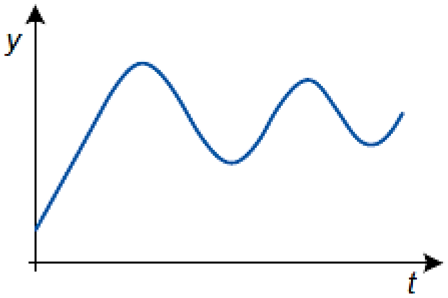


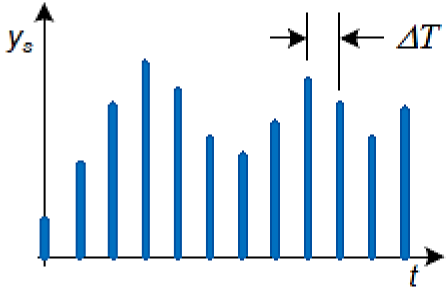
f(t)
111
110
101
100
011
010
001
000
0
1
2
3
4
5
6
7
8
9
10
11
t

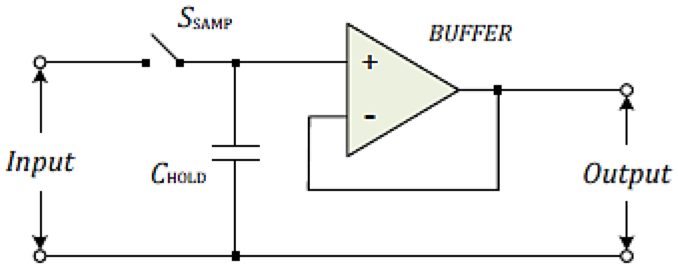
Mengubah sinyal kontinyu menjadi diskrit

→ *Disampling : Proses Sampling*

- Sampling periodik (lebih disukai)
- Sampling non periodik







- Suatu sinyal kontinyu $y(t)$, dapat direpresentasikan sebagai himpunan dari sampel sinyal tersebut y_i, (i = 1, 2, ...N).

- y_i ini diambil atau dicuplik pada interval waktu ΔT. Dalam proses sampling, periode sampling T_S biasanya dibuat konstan.

- Kebalikan dari periode sampling adalah frekuensi sampling, yang dinyatakan dalam $f_S = 1/T_S$.

- Semakin banyak data sampling, sinyal rekonstruksi akan semakin mirip dengan bentuk aslinya, dan berlaku sebaliknya.

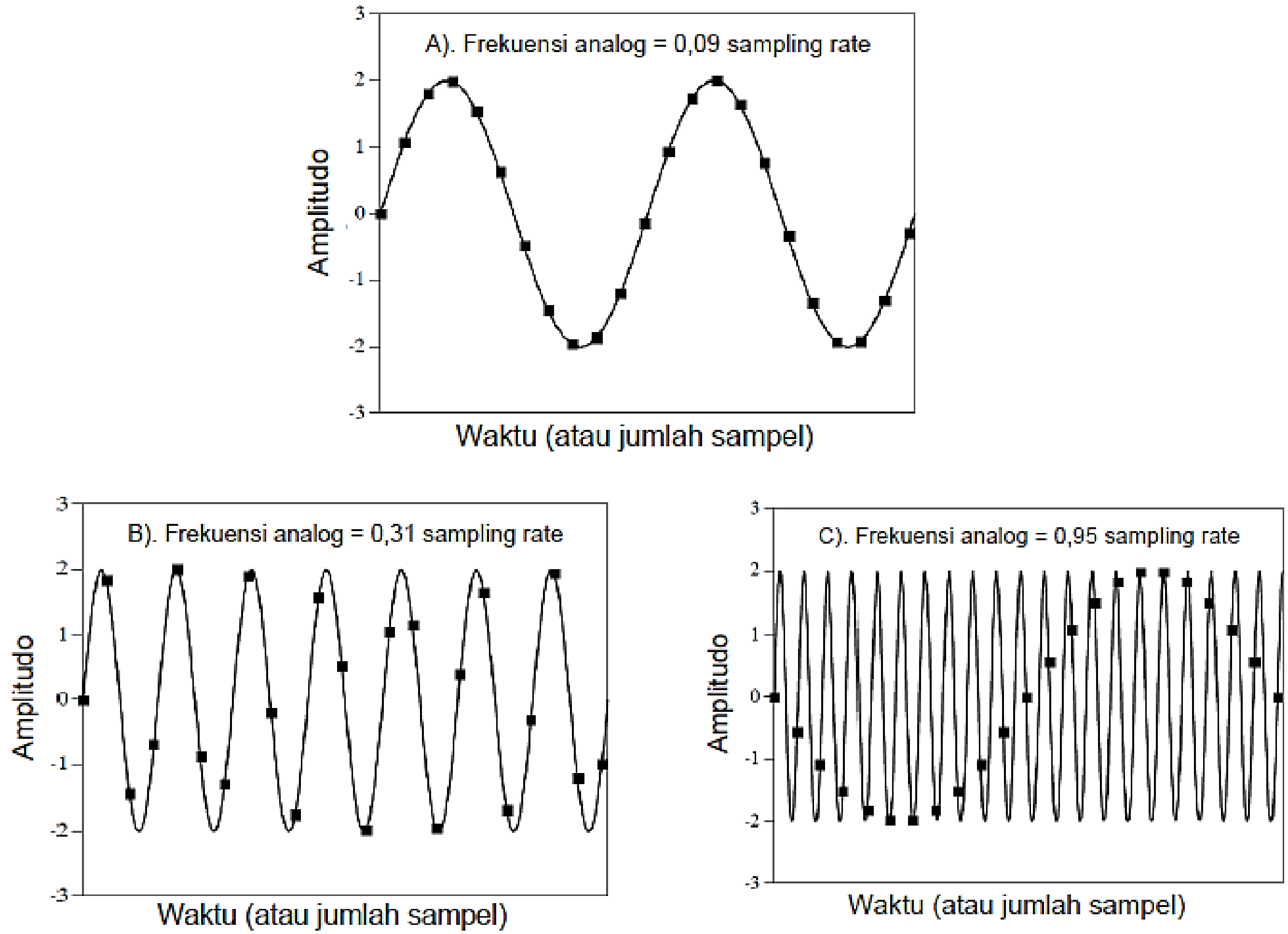
- Teorema **Shannon-Nyquist** menyatakan:

  "agar tidak ada informasi yang hilang ketika pencuplikan sinyal, maka kecepatan pencuplikan (*sampling rate*) harus minimal dua kali dari lebar pita sinyal tertingginya f_U".

  Frekuensi sampling f_S yang didefinisikan oleh teorema diatas disebut **frekuensi Nyquist**, dimana:

$$f_S > 2 f_U$$

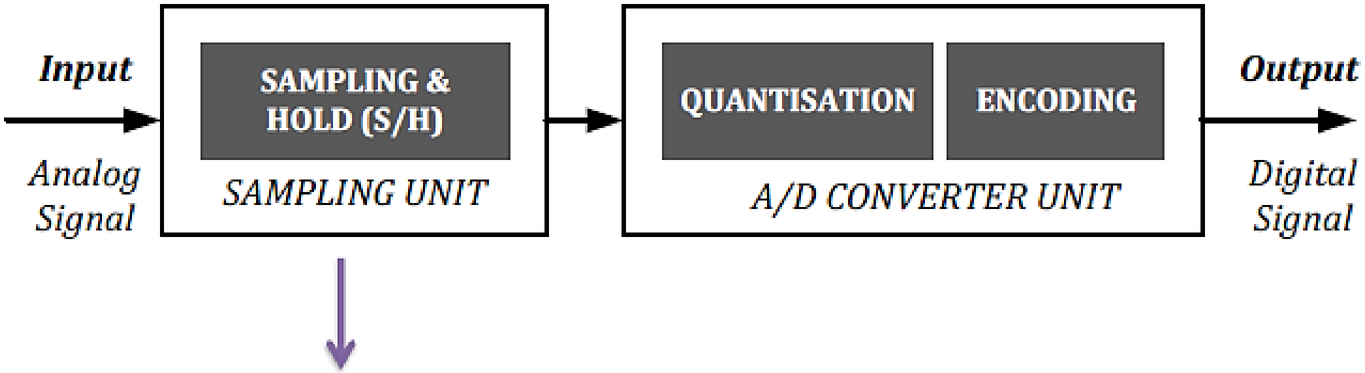
- Apabila frekuensi sampling tidak memenuhi persamaan ini, maka reproduksi sinyal diskrit akan menghasilkan sinyal yang **terdistorsi** atau cacat.
- Dan apabila frekuensi sampling terlalu rendah maka akan timbol efek **aliasing**.


A). Frekuensi analog = 0,09 sampling rate
Amplitudo
Waktu (atau jumlah sampel)
B). Frekuensi analog = 0,31 sampling rate
Amplitudo
Waktu (atau jumlah sampel)
C). Frekuensi analog = 0,95 sampling rate
Amplitudo
Waktu (atau jumlah sampel)

Mengubah sinyal analog menjadi digital

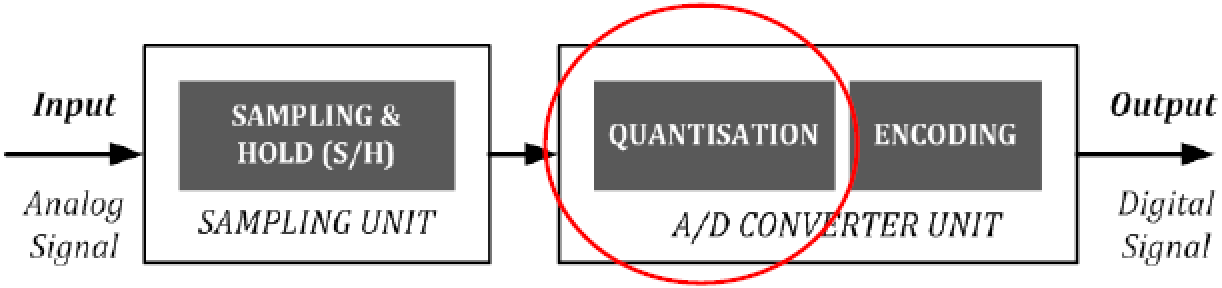
→ *Menggunakan rangkaian Analog to Digital Converter (ADC)*

Prinsip Kerja



Diskritisasi (1)

Kuantisasi (*Quantisation*)



- *Output dari unit sampling adalah kumpulan sinyal diskrit y_i dengan interval waktu tertentu (ΔT).*
- *Sedangkan nilai dari sinyal analog adalah sembarang bilangan real dalam rentang y_{min} sampai dengan y_{mak}.*
- *Pada proses kuantisasi, sampel tegangan hasil pencuplikan sinyal "y_i" akan dibulatkan ke nilai kuantisasi Q atau level V_q, dimana q = 0,1,2,...(Q-1).*

- *Terdapat dua macam kuantisasi yang sering digunakan (walaupun sebenarnya prosesnya sama saja), yaitu cara atau metode interval penuh, dan metode setengah interval.*
- *Pada metode interval penuh, nilai sinyal sampling y_i akan dibulatkan ke nilai diskrit V_q yang ada di bawahnya.*
- *Pada metode setengah interval, nilai sinyal sampling y_i dibulatkan ke nilai diskrit V_q yang paling dekat.*

Jika $V_0 = y_{min}$ dan $V_Q = y_{mak}$

- *formula kuantisasi interval penuh*

$$\Delta V = \frac{y_{mak} - y_{min}}{Q}$$

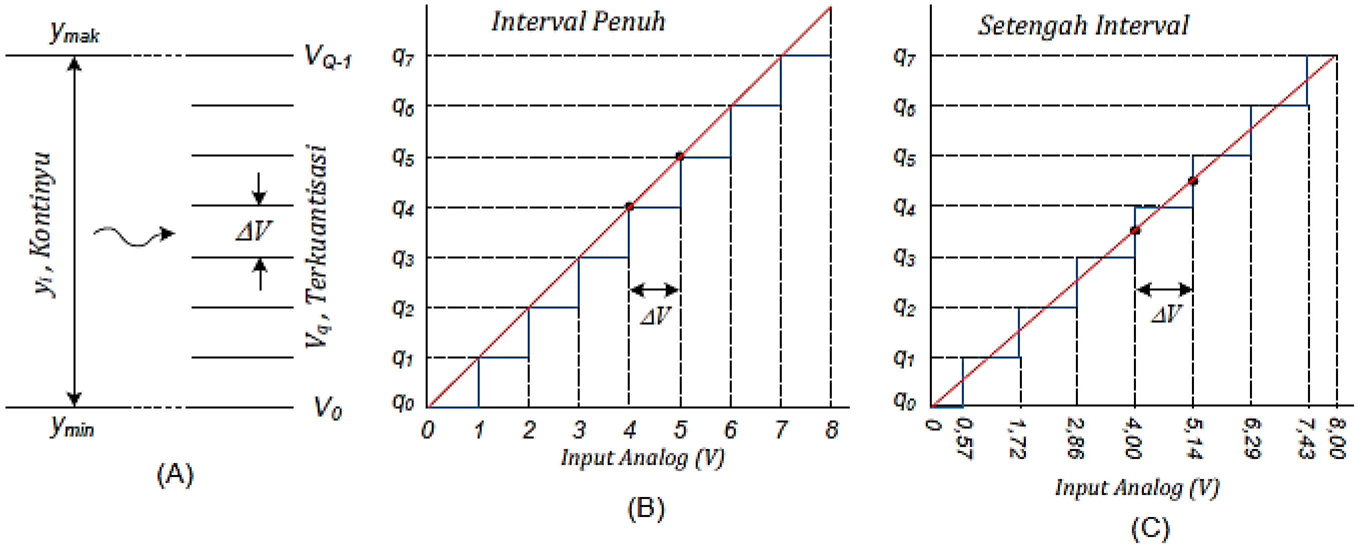
- *formula kuantisasi setengah interval*

$$\Delta V = \frac{y_{mak} - y_{min}}{Q - 1}$$

- *Contoh. Suatu ADC akan digunakan untuk mengkonversi tegangan analog yang mempunyai nilai tegangan minimum V_{min}=0V dan tegangan maksimum V_{mak}=8V. Jumlah level kuantisasi (Q) ADC tersebut adalah 8 (merupakan ADC 3 bit). Maka beda tegangan antar level dapat dihitung sebagai berikut:*

Untuk interval penuh: $\Delta V = \frac{(8-0)\ volt}{8} = 1\ volt$

Untuk setengah interval: $\Delta V = \frac{(8-0)\ volt}{7} = 1{,}143\ volt$



- *Nilai kuantisasi merupakan nilai minimum agar tegangan sampel dapat diubah ke dalam kode digital tertentu.*
- *Dalam proses kuantisasi, terdapat selisih nilai tegangan analog dengan hasil kuantisasi.*
- *Kesalahan ini disebut **kesalahan kuantisasi** (quantisation error).*

Thank You

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Acceleration, Shock, and Vibration Sensor

Oleh: Ahmad Zarkasi, S.Si., M.Si

Prodi Fisika FMIPA UNMUL

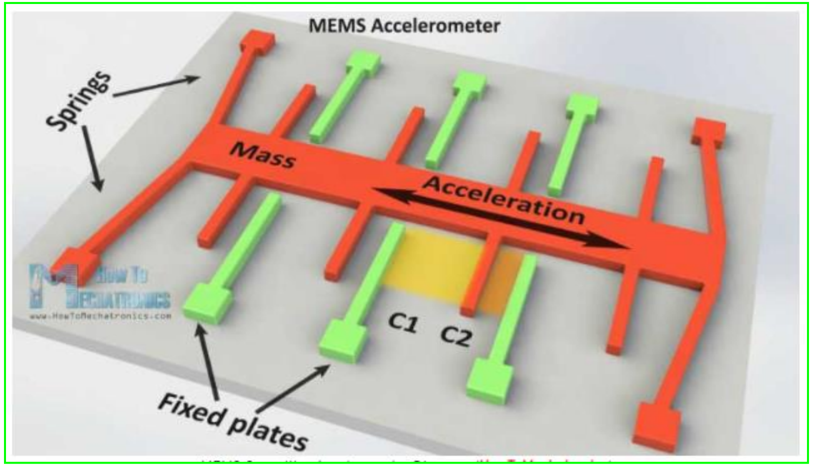
Accelerometers are sensing transducers that provide an output proportional to acceleration, vibration and shock

- Acceleration
- Vibration
- Shock

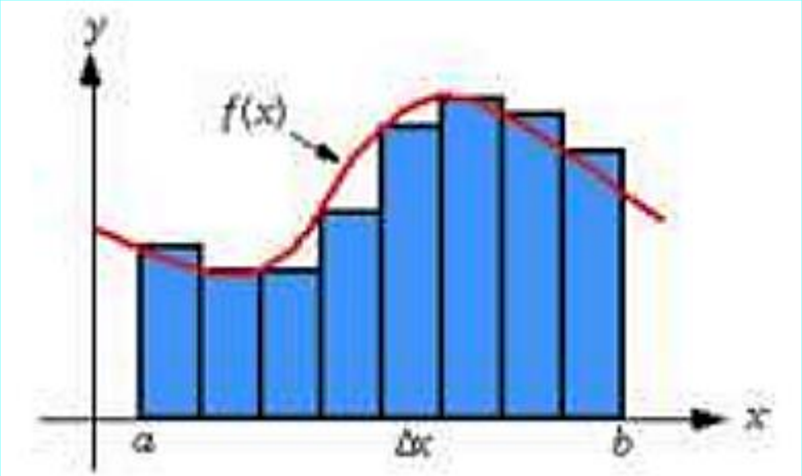
- Static
- Dynamic

An accelerometer is an electronic **sensor** that measures the acceleration forces acting on an object, in order to determine the object's **position** in space and monitor the object's movement. Acceleration, which is a **vector quantity**, is the rate of change of an object's velocity (velocity being the **displacement of the object divided by the change in time**).

When a car is acted on by a powerful dynamic force, the accelerometer (sensing a rapid deceleration) sends an electronic signal to an embedded computer, which in turn deploys the airbags.

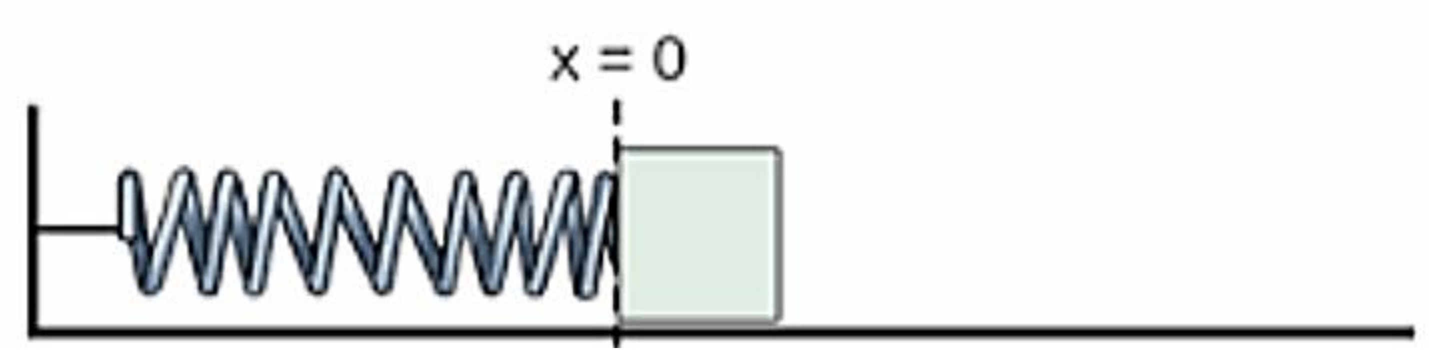


$$\vec{s} = \int \left(\int (\vec{a})\, dt \right) dt$$



$$\int_a^b f(x)\, dx = \lim_{n \to \infty} \sum_{i=1}^{n} f(x_i)\, \Delta x$$

Principle

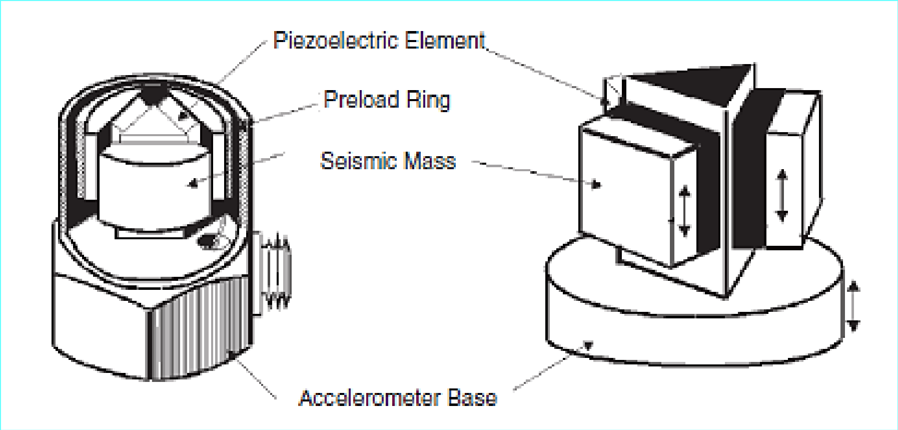


Technology Fundamentals

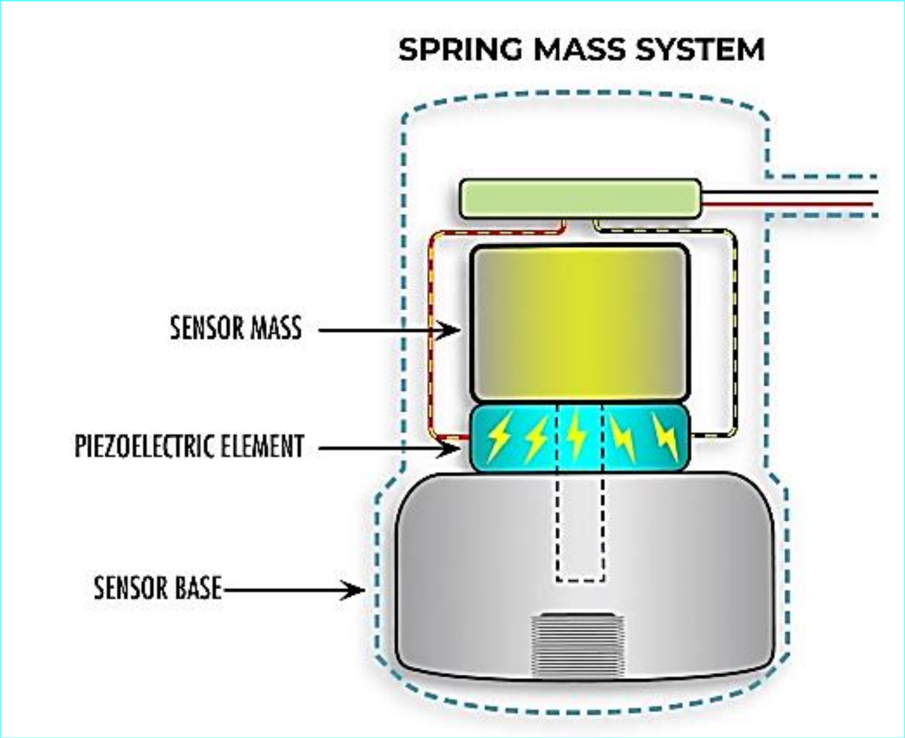
Piezoelectric Accelerometer

- Piezoelectric accelerometers are **self-generating** devices characterized by an extended region of flat frequency response range, a large linear amplitude range and excellent durability. These inherent properties are due to the use of a **piezoelectric material** as the sensing element for the sensor.

- Piezoelectric materials are characterized by their **ability** to output a **proportional** electrical signal to the stress applied to the material.

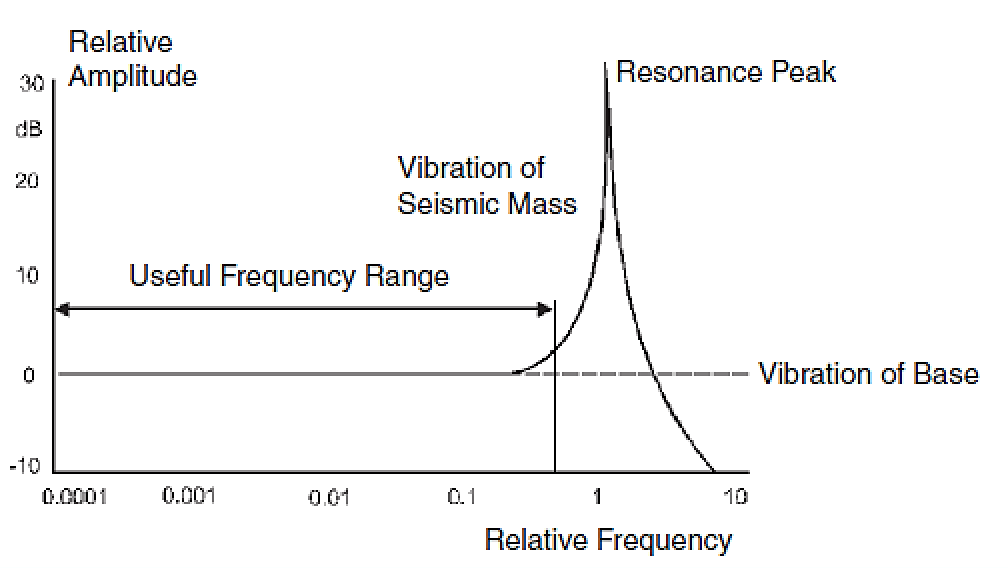


- When an input is present at the base of the accelerometer, a **force** (*F*) is created on piezoelectric material **proportional** to the applied **acceleration** (*a*) and size of the seismic **mass** (*m*)
- The sensor is governed by Newton's law of motion ***F = ma***
- The frequency response of the sensor is determined by the resonant frequency of the sensor, which can generally be modeled as a simple single degree of freedom system. Using this system, the resonant frequency (ω) of the sensor can be estimated by: $\omega = \sqrt{k/m}$



- Frequency response
- Sensitivity rating
- Easy installation

Typical frequency response
of piezoelectric accelerometer.



Based on Operation Mode

- ❑ Internally amplified accelerometers or IEPE (Internal Electronic PiEzoelectric)

  → *contain built-in microelectronic signal conditioning*

- ❑ Charge mode accelerometers

  → *Contain only the self-generating piezoelectric sensing element and have a high impedance charge output signal*

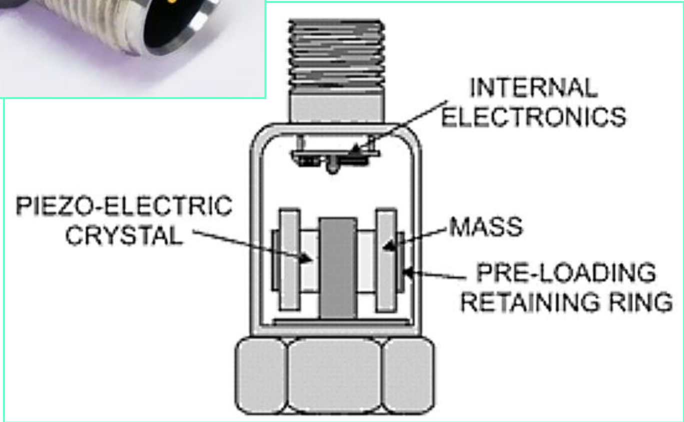
IEPE Accelerometers

- Signal-conditioning (**built in**)

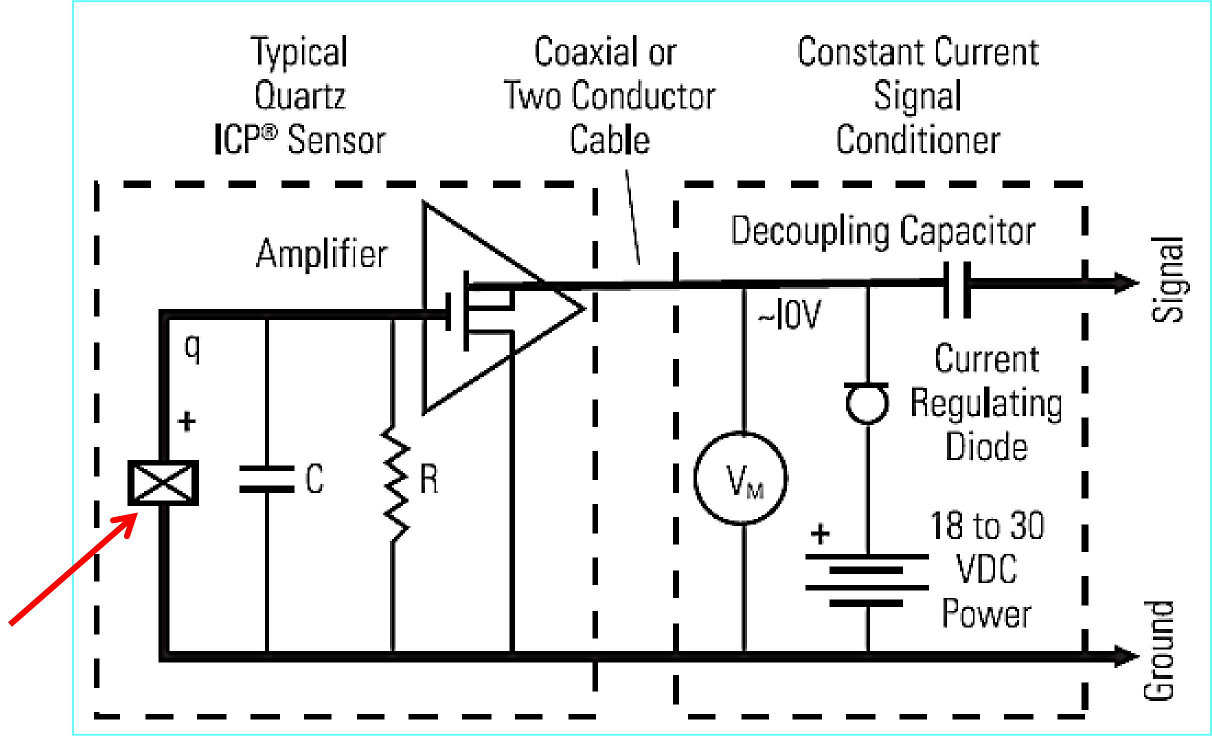
- Function of signal conditioning: convert the **high-impedance** **charge** signal generated by the piezoelectric sensing element into a usable **low-impedance** **voltage** signal

- The low-impedance signal can be transmitted over **long cable distances** and used in **dirty field** or **factory environments**

- SC Including: gain, filtering and self-test features



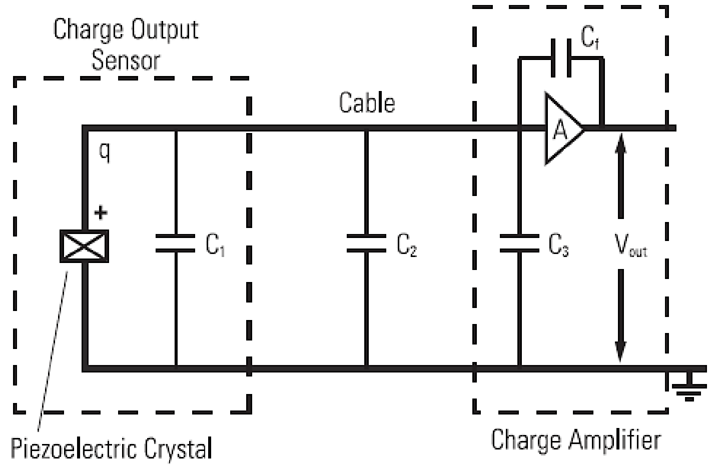
IEPE System



Typical Quartz ICP® Sensor
Coaxial or Two Conductor Cable
Constant Current Signal Conditioner
Amplifier
Decoupling Capacitor
Signal
q
+
C
R
~I0V
Current Regulating Diode
V_M
+
18 to 30 VDC Power
Ground

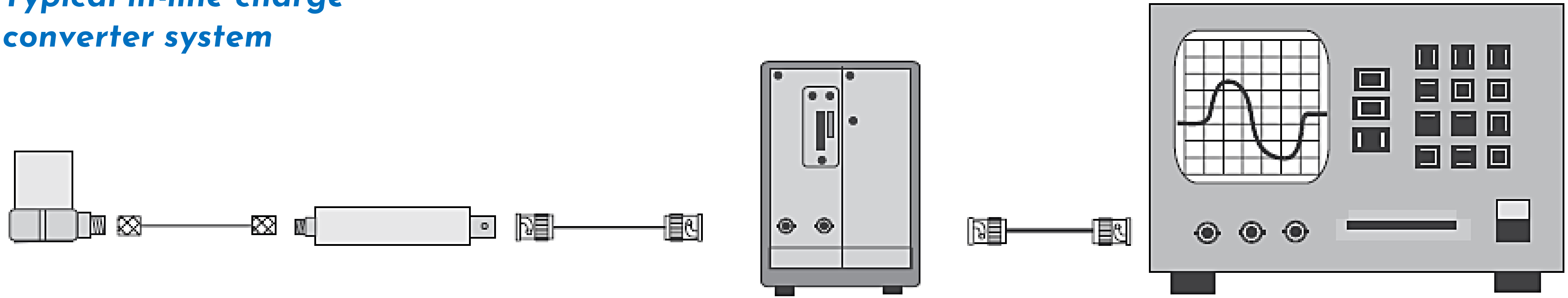
Charge Mode Accelerometers

- Electrical charge signal that is generated directly by the piezoelectric sensing element
- This signal is sensitive to corruption from environmental influences and cable-generated noise
- It is necessary to condition this signal to a low-impedance voltage before it can be input to a readout or recording device
- It used when high temperature survivability is required



Laboratory charge amplifier system

Typical in-line charge converter system



Based on Materials

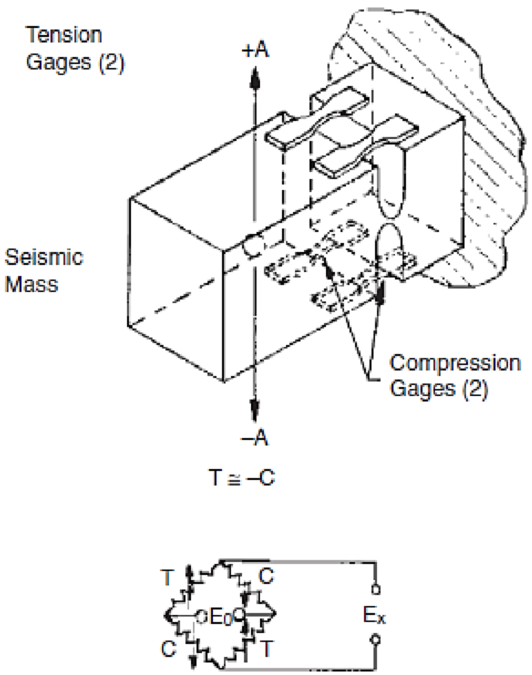
- ❑ Quartz (natural)
  - → *Advantages: accurate, high stability, good repeatability, low noise, and does not exhibit the pyroelectric effect*

- ❑ Polycrystalline ceramics
  - → *Advantages: easily manufactured, easily fit into specific applications*

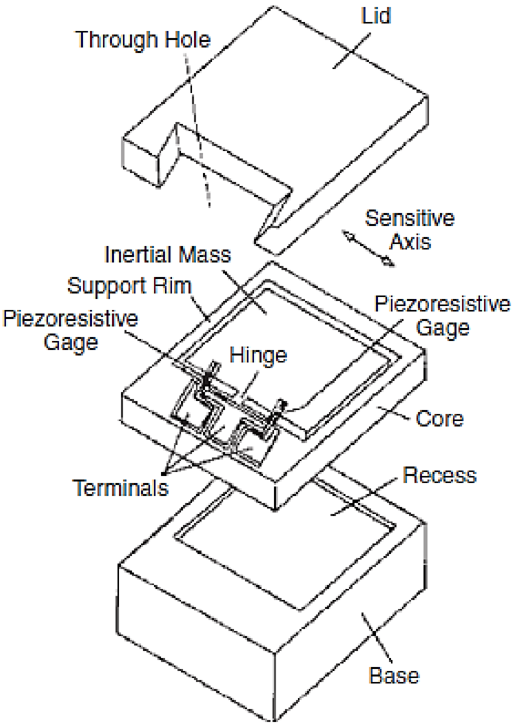
Types of Piezoelectric Sensors

Piezoresistive Accelerometers

High resonant frequency (ω), high stiffness



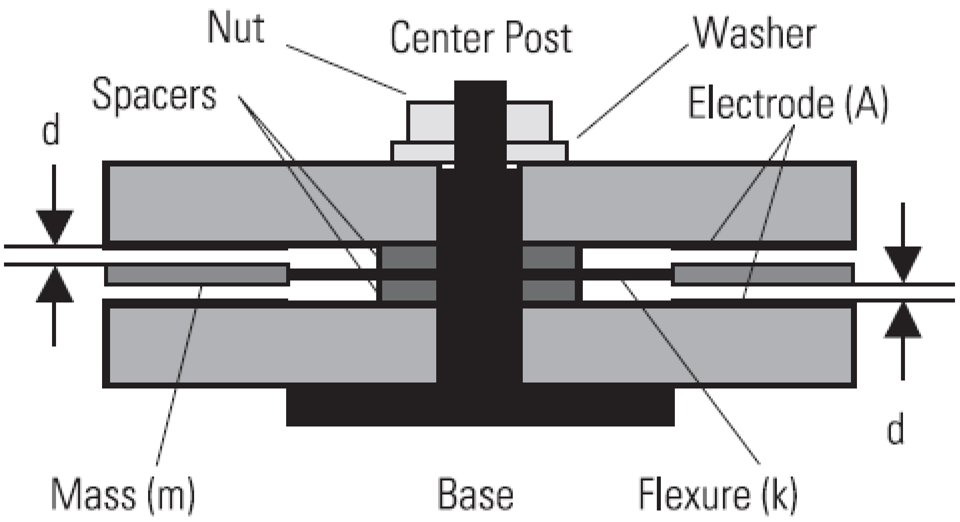
Bulk silicon resistors bonded to metal beam accelerometer flexure



MEMS piezoresistive accelerometer flexure

Capacitive Accelerometers

The sensing element consists of two parallel plate capacitors acting in a differential mode



Capacitive sensor element construction

$$F = ma$$

$$x = \frac{F}{k}$$

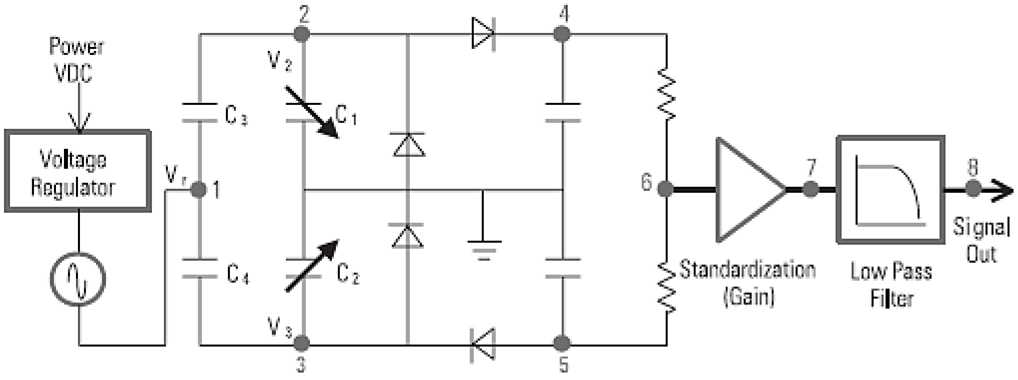
$$C = \left(\frac{\varepsilon}{d \pm x}\right) A_E$$

F = inertial force acting on spring-mass
m = distributed mass of spring-mass
a = acceleration experienced by sensing element

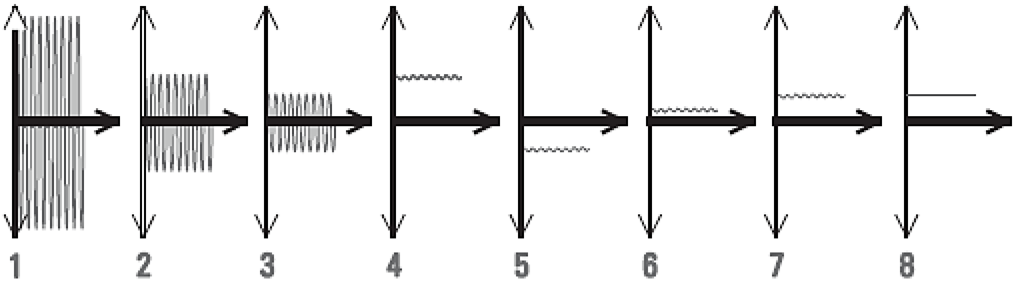
x = deflection of spring-mass
k = stiffness of spring-mass

C = element capacitance
A_E = surface area of electrode
ε = permittivity of air
d = distance between spring-mass and electrode

Operation of builtin circuit for capacitive accelerometer



Circuit Schematic



Response from Circuit due to applied +1g Static Acceleration
(x-axis = time and y-axis = voltage)

Comparison of accelerometer types

Accelerometer Type	Advantages	Limitations	Typical Applications
IEPE Piezoelectric Accelerometer	Wide Dynamic Range Wide Frequency Range Durable (High Shock Protection) Powered by Low Cost Constant Current Source Fixed Output Less Susceptible to EMI and RF Interference Can be Made Very Small Less Operator Attention, Training and Installation Expertise Required High Impedance Circuitry Sealed in Sensor Long Cable Driving without Noise Increase Operates into Many Data Acquisition Devices with Built-in Constant Current Input Operates across Slip Rings Lower System Cost per Channel	Limited Temperature Range Max Temperature of 175°C (350°F) Low Frequency Response is Fixed within the Sensor Built in amplifier is exposed to same test environment as the element of the sensor	Modal Analysis NVH Engine NVH Flight testing Body In White Testing Cryogenic Drop Testing Ground Vibration Testing HALT/HASS Seismic Testing Squeak and Rattle Helmet and Sport Equipment Testing Vibration Isolation and Control

Comparison of accelerometer types

Accelerometer Type	Advantages	Limitations	Typical Applications
Charge Piezoelectric Accelerometer	High operating temperatures to 700°C Wide dynamic Range Wide Frequency Range (Durable) High Shock Protection Flexible Output Simpler Design fewer parts Charge Converter electronics is usually at ambient condition, away from test environment	More Care/attention is required to install and maintain High impedance circuitry must be kept clean and dry Capacitive loading from long cable run results in noise floor increase Powered By Charge Amp which can be complicated and expensive Need to use Special Low Noise Cable	Jet Engine High Temperature Steam Pipes Turbo Machinery Steam Turbine Exhaust Brake

Pembagian Tugas Presentasi

CHAPTER 10:
Flow and Level Sensors

CHAPTER 11:
Force, Load and Weight Sensors

CHAPTER 12:
Humidity Sensors

CHAPTER 20:
Temperature Sensors

CHAPTER 14:
Optical and Radiation Sensors

CHAPTER 15:
Position and Motion Sensors

CHAPTER 16:
Pressure Sensors

CHAPTER 19:
Strain Gages

CHAPTER 6:
Biosensors

CHAPTER 7:
Chemical Sensors

CHAPTER 8:
Capacitive and Inductive Displacement Sensors

Thank You

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RENCANA PEMBELAJARAN SEMESTER (RPS)

Perguruan Tinggi	: Universitas Mulawarman
Fakultas	: Matematika dan Ilmu Pengetahuan Alam
Mata Kuliah	: Sensor
Kode Mata Kuliah	: 1970704603P057
Semester/SKS	: V/3
Mata Kuliah Prasyarat	:
Nama Dosen	: Dr. Syahrir, M.Si dan Ahmad Zarkasi, S.Si., M.Si

A. Capaian Pembelajaran Lulusan (CPL) / *Program Learning Outcomes* (PLO) pada mata kuliah ini adalah:

1. Menunjukkan sikap profesional atas pekerjaan di bidang keahliannya secara mandiri (RS10).
2. Menguasai pengetahuan tentang teknologi yang berdasarkan fisika dan penerapannya (PP3).
3. Menguasai terapan fisika dalam bidang keahlian, meliputi elektronika-instrumentasi, geofisika, fisika medis, oseanografi, dan fisika material (PP4).
4. Menerapkan pemikiran logis, kritis, sistematis, dan inovatif dalam konteks pengembangan atau implementasi ilmu pengetahuan dan/atau teknologi sesuai dengan bidang keahliannya (KU1).
5. Mampu memprediksi potensi penerapan perilaku fisis dalam teknologi (KK4).

B. Capaian Pembelajaran Mata Kuliah (CPMK) / *Course Outcome*

Setelah menyelesaikan mata kuliah ini pada akhir semester, mahasiswa mampu 1) menjelaskan perbedaan sensor, transduser, dan actuator; 2) memahami perkembangan teknologi sensor; 3) memahami karakteristik sensor dan sistem instrumentasi; serta 4) memahami karakteristik dan prinsip kerja beragam jenis sensor.

C. PIP UNMUL yang diintegrasikan

Menghasilkan karya ilmiah sains dan teknologi dalam bidang Fisika Modern dan aplikasinya terkait pengelolaan hutan hujan tropis.

D. Deskripsi Mata Kuliah

Mata kuliah ini membahas tentang pengenalan dan perkembangan teknologi sensor, perbedaan sensor dengan transduser dan aktuator, sistem instrumentasi yang melibatkan sensor, karakteristik sistem, dan beragam jenis sensor.

E. Daftar Referensi

1. Jhon Wilson (2005). *Sensor Technology Handbook*. ISBN: 0-7506-7729-5.
2. Muhammad Yusro dan Aodah Diamah (2019). Sensor dan Transduser – Teori dan Aplikasi: FT UNEJ.
3. Sinclair, Ian R. (2001). *Sensors and Transducers.* Third Edition. Published by Butterworth-Heineman. ISBN: 0-7506-4932-1.
4. Materi Ajar Mata Kuliah Sensor.

SENSOR

Pertemuan Ke-	Kemampuan Khusus (Sub-CPMK)	Indikator	Materi Pokok	Metode/Model Pembelajaran	Pengalaman Belajar	Penilaian		Bobot (%)	Waktu	Referensi
						Jenis	Kriteria			
1	Mahasiswa memahami isi kontrak perkuliahan serta pengertian sensor, transduser, dan aktuator	• Mahasiswa mampu menjelaskan isi kontrak perkuliahan • Mahasiswa mampu menjelaskan pengertian sensor, transduser, dan actuator beserta contoh masing-masing • Mahasiswa mampu membedakan perangkat yang termasuk sensor, transduser, dan aktuator	• Kontrak perkuliahan • Sensor, Transduser, dan Aktuator	• Ceramah, diskusi, dan tanya jawab	• Mahasiswa menyimak pemaparan kontrak kuliah • Mahasiswa menyimak penjelasan dan mendiskusikan tentang sensor, transduser, dan aktuator	Tes tertulis	Ketepatan menjelaskan perbedaan antara sensor, transduser, dan actuator beserta contoh masing-masing	5	150’	1, 2, 4
2	Mahasiswa memahami perkembangan teknologi sensor berupa *smart sensor* beserta contoh aplikasinya	• Mahasiswa mampu menjelaskan perbedaan *base sensor* dan *smart sensor* • Mahasiswa mampu menjelaskan beberapa contoh aplikasi *smart sensor*	Karakteristik *base sensor* dan *smart sensor*	Ceramah, diskusi, dan tanya jawab	Mahasiswa menyimak penjelasan mengenai *base sensor* dan *smart sensor*	Tes tertulis	Ketepatan menjelaskan perbedaan *base sensor* dan *smart sensor*	5	150’	4

Pertemuan Ke-	Kemampuan Khusus (Sub-CPMK)	Indikator	Materi Pokok	Metode/Model Pembelajaran	Pengalaman Belajar	Penilaian		Bobot (%)	Waktu	Referensi
						Jenis	Kriteria			
3-4	Mahasiswa memahami peran sensor dan elemen-elemen lain pada sistem instrumentasi	• Mampu menjelaskan peran sensor pada sistem instrumentasi • Mampu menjelaskan *signal conditioning element* • Mampu menjelaskan *signal processing element*	• *Sensing element* • *Signal conditioning element* • *Signal processing elemen*	Ceramah, diskusi, dan tanya jawab	Mahasiswa menyimak penjelasan dan berdiskusi tentang karakteristik sensor dan elemen-elemen lain pada sistem instrumentasi	Tes tertulis	Ketepatan menjelaskan elemen-elemen pada suatu sistem instrumentasi	10	2x150’	1,2,3,4
5	Mahasiswa memahami karakteristik statis dan dinamis dari suatu sensor	Mahasiswa mampu menjelaskan karakteristik statis dan dinamis suatu sensor	• Karakteristik statis • Karakteristik dinamis	Ceramah, diskusi, dan tanya jawab	Mahasiswa menyimak penjelasan mengenai karakteristik statis dan dinamis suatu sensor	Tes tertulis	Ketepatan menjelaskan materi tentang karakteristik statis dan dinamis	5	150’	1,2,4
6	Mahasiswa memahami prinsip fisis dan aplikasi dari akselerometer yang merupakan sensor akselerasi, kejut, dan vibrasi	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor akselerasi, sensor kejut, dan sensor vibrasi	Sensor akselerasi, sensor kejut, dan sensor vibrasi	Ceramah, diskusi, dan tanya jawab	Mahasiswa menyimak penjelasan tentang sensor akselerasi, sensor kejut, dan sensor vibrasi	Tes tertulis	Ketepatan menjelaskan materi tentang sensor akselerasi, sensor kejut, dan sensor vibrasi	5	150’	1,2,3,4
7	Mahasiswa memahami prinsip fisis dan aplikasi dari *biosensor*	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi *biosensor*	*Biosensor*	Ceramah, diskusi, dan tanya jawab	• Mahasiswa menyimak penjelasan tentang *biosensor* • Mahasiswa melakukan undian untuk pembagian tugas presentasi	Tes tertulis	Ketepatan menjelaskan materi tentang *biosensor*	5	150’	1,2,3,4
8	**UJIAN TENGAH SEMESTER (UTS)**									

Pertemuan Ke-	Kemampuan Khusus (Sub-CPMK)	Indikator	Materi Pokok	Metode/Model Pembelajaran	Pengalaman Belajar	Penilaian		Bobot (%)	Waktu	Referensi
						Jenis	Kriteria			
9	Mahasiswa memahami prinsip fisis dan aplikasi dari sensor kimia	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor kimia	Sensor kimia	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai sensor kimia	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
10	Mahasiswa memahami prinsip fisis dan aplikasi dari sensor perpindahan	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor perpindahan baik yang bersifat induktif maupun kapasitif	Sensor perpindahan	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai sensor perpindahan	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
11	Mahasiswa memahami prinsip fisis dan aplikasi dari sensor level dan aliran	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor level dan aliran	Sensor level dan aliran	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai level dan sensor aliran	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
12	Mahasiswa memahami prinsip fisis dan aplikasi dari *quartz sensor* dan *strain gauge* yang merupakan sensor untuk gaya, beban, dan berat.	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi *quartz sensor* dan *strain gauge*	*Quartz sensor* dan *strain gauge*	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai *quartz sensor* dan *strain gauge*	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
13	Mahasiswa memahami prinsip fisis dan aplikasi dari sensor temperatur dan sensor kelembaban	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor temperatur dan sensor kelembaban	Sensor temperatur dan sensor kelembaban	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai sensor temperatur dan sensor kelembaban	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
14	Mahasiswa memahami prinsip fisis dan aplikasi dari sensor radiasi dan optik	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi sensor radiasi dan optik	Sensor radiasi dan optik	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai sensor radiasi dan optik	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
15	Mahasiswa memahami prinsip fisis dan aplikasi dari *wireless sensor*	Mahasiswa mampu menjelaskan prinsip kerja dan aplikasi *wireless sensor*	*Wireless sensor*	Presentasi dan tanya jawab	Mahasiswa mempresentasikan berdiskusi mengenai *wireless sensor*	Presentasi	Penguasaan materi dan keaktifan saat berdiskusi	9,3	150’	1,2,3
16	**UJIAN AKHIR SEMESTER (UAS)**									

F. PENILAIAN

Penilaian pada mata kuliah Sensor menggunakan Skema V

1. Kuis/Ujian Tengah Semester : 30%
2. Ujian/Proyek Akhir Semester : 40%
3. Tugas : 20%
4. Afektif : 10%

Samarinda, 21 Mei 2021

Mengetahui,
Koordinator Program Studi

Dr. Rahmawati M, M.Si
NIP. 19801201 200604 2 001

Dosen Pengampu Mata Kuliah

Ahmad Zarkasi, S.Si., M.Si
NIP. 19910423 202012 1 007

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN,
RISET DAN TEKNOLOGI
UNIVERSITAS MULAWARMAN
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
Jalan Barong Tongkok No. 4 Kampus Gunung Kelua, Samarinda – Kalimantan Timur 75123 Indonesia
Telp./Fax: 0541-77974, Email: fmipa@unmul.ac.id, https://www.fmipa.unmul.ac.id

SURAT TUGAS
Nomor : 1515 /UN17.7/PP/2022

Dekan Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Mulawarman, dengan ini menugaskan nama-nama yang tercantum dalam lampiran surat tugas ini sebagai :

Dosen Pengampu Mata Kuliah Program Merdeka Belajar Kampus Merdeka (MBKM) Semester Ganjil Tahun Akademik 2022/2023 pada Program Studi S1 Statistika, S1 Matematika, S1 Biologi, S1 Kimia, S1 Fisika dan S1 Geofisika Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Mulawarman.

Surat tugas ini dibuat untuk dilaksanakan dengan penuh tanggung jawab.

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si.
NIP 19711008 199802 1 001

Lampiran 1
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

**PENGANGKATAN DOSEN PENGAMPU MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 STATISTIKA, S1 MATEMATIKA, S1 BIOLOGI,
S1 KIMIA, S2 KIMIA, S1 FISIKA DAN S1 GEOFISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS MULAWARMAN**

PROGRAM STUDI : S1-STATISTIKA

NO	KODE MK	MATA KULIAH	SKS/ SMT/ KLS	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	210701603W002	Algoritma dan Pemrograman I	3/I	W	2021	Rito Goejantoro, S.Si., M.Si Surya Prangga, S.Si., M.Si
2	210701603W008	Pengantar Statistika Matematika I	3/III	W	2021	Dr. Suyitno, S.Pd., M.Sc Andrea Tri Rian Dani, S.Stat., M.Stat
3	210701603W009	Metode Statistika	3/III	W	2021	Dr. Sifriyani, S.Pd., M.Si Meiliyani Siringoringo, S.Si., M.Si
4	210701603W010	Komputasi Statistika	3/III	W	2021	Surya Prangga, S.Si., M.Si Meiliyani Siringoringo, S.Si., M.Si
5	210701603W011	Analisis dan Perancangan Survey I	3/III	W	2021	Memi Nor Hayati, S.Si., M.Si Dr. Sifriyani, S.Pd., M.Si
6	210701603W012	Pengantar Data Sains	3/III	W	2021	Siti Mahmuda, S.Si., M.Si Dr. M. Fathurahman, M.Si
7	210701603P013	Metode Numerik untuk Statistika	3/III	P	2021	Asmaidi, S.Pd., M.Si Dr. Suyitno, S.Pd., M.Sc
8	210701602P014	Matematika Keuangan	2/III	P	2021	Andrea Tri Rian Dani, S.Stat., M.Stat Dr. M. Fathurahman, M.Si
9	210701603P015	Pengantar Kependudukan dan Demografi	3/III	P	2021	Ika Purnamasari, S.Si., M.Si Meirinda Fauziyah, S.Si., M.Stat
10	210701603P018	Kalkulus III	3/III	P	2021	Qonita Qurrota A'yun, S.Si., M.Sc Asmaidi, S.Pd., M.Si
11	210701603P019	Statistika Non Parametrik	3/III	P	2021	Ika Purnamasari, S.Si., M.Si Dr. Darnah A. Nohe, M.Si
12	190701603W027	Analisis Multivariat	3/V	W	2019	Dr. Sri Wahyuningsih, M.Si Siti Mahmuda, S.Si., M.Si
13	190701603W028	Analisis Data Kategorik	3/V	W	2019	Dr. Darnah A. Nohe, M.Si Dr. M. Fathurahman, M.Si
14	190701603W029	Metode Penelitian	3/V	W	2019	Dr. Darnah A. Nohe, M.Si Dr. Sifriyani, S.Pd., M.Si
15	190701603W030	Analisis Runtun Waktu	3/V	W	2019	Dr. Sri Wahyuningsih, M.Si Meiliyani Siringoringo, S.Si., M.Si
16	190701603P031	Official Statistics	3/V	P	2019	Ika Purnamasari, S.Si., M.Si Meiliyani Siringoringo, S.Si., M.Si
17	190701603P032	Statistika Spasial	3/V	P	2019	Dr. Sifriyani, S.Pd., M.Si Dr. Suyitno, S.Pd., M.Sc

NO	KODE MK	MATA KULIAH	SKS/ SMT	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
18	190701602P033	Proses Stokastik	2/V	P	2019	Dr. Suyitno, S.Pd., M.Sc
						Dr. Sri Wahyuningsih, M.Si
19	190701603P034	Pemrograman Visual	3/V	P	2019	Surya Prangga, S.Si., M.Si
						Siti Mahmuda, S.Si., M.Si
20	190701603P044	Kapita Selekta Statistika	3/VII	P	2019	Dr. Darnah A. Nohe, M.Si
						Dr. M. Fathurahman, M.Si

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI
UNIVERSITAS MULAWARMAN
FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 2
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM) SEMESTER GANJIL TAHUN AKADEMIK 2022/2023 PROGRAM STUDI S1 STATISTIKA FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen : Dr. Sri Wahyuningsih, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Analisis Multivariat	W	Siti Mahmuda, S.Si., M.Si	2	1	V
2	Analisis Runtun Waktu	W	Meiliyani Siringoringo, S.Si., M.Si	2	1	V
3	Proses Stokastik	P	Dr. Suyitno, S.Pd., M.Sc	2	0	V
Total				6	2	

Nama Dosen : Rito Goejantoro, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Algoritma dan Pemrograman I	W	Surya Prangga, S.Si., M.Si	2	1	I
Total				2	1	

Nama Dosen : Dr. Darnah A. Nohe, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Statistika Nonparametrik	P	Ika Purnamasari, S.Si., M.Si	2	1	III
2	Analisis Data Kategorik	W	Dr. M. Fathurahman, M.Si	2	1	V
3	Metode Penelitian	W	Dr. Sifriyani, S.Pd., M.Si	3	0	V
4	Kapita Selekta Statistika	P	Dr. M. Fathurahman, M.Si	3	0	VII
Total				10	2	

Nama Dosen : Dr. Suyitno, S.Pd., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Statistika Matematika I	W	Andrea Tri Rian Dani, S.Stat., M.Stat	3	0	III
2	Metode Numerik untuk Statistika	P	Asmaidi, S.Pd., M.Si	2	1	III
3	Statistika Spasial	P	Dr. Sifriyani, S.Pd., M.Si	2	1	V
4	Proses Stokastik	P	Dr. Sri Wahyuningsih, M.Si	2	0	V
Total				9	2	

Nama Dosen : Dr. M. Fathurahman, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Data Sains	W	Siti Mahmuda, S.Si., M.Si	2	1	III
2	Matematika Keuangan	P	Andrea Tri Rian Dani, S.Stat., M.Stat	2	0	III
3	Analisis Data Kategorik	W	Dr. Darnah Andi Nohe, M.Si	2	1	V
4	Kapita Selekta Statistika	P	Dr. Darnah Andi Nohe, M.Si	3	0	VII
Total				9	2	

Nama Dosen : Dr. Sifriyani, S.Pd., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Metode Statistika	W	Meiliyani Siringoringo, S.Si., M.Si	2	1	III
2	Analisis dan Perancangan Survey I	W	Memi Nor Hayati, S.Si., M.Si	2	1	III
3	Metode Penelitian	W	Dr. Darnah Andi Nohe, M.Si	3	0	V
4	Statistika Spasial	P	Dr. Suyitno, S.Pd., M.Sc.	2	1	V
Total				9	3	

Nama Dosen : Ika Purnamasari, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Kependudukan dan Demografi	P	Meirinda Fauziyah, S.Si., M.Stat.	3	0	III
2	Statistika Nonparametrik	P	Dr. Darnah Andi Nohe, M.Si	2	1	III
3	Official Statistics	P	Meliyani Siringoringo, S.Si., M.Si	2	1	V
Total				7	2	

Nama Dosen : Memi Nor Hayati, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Analisis dan Perancangan Survey I	W	Dr. Sifriyani, S.Pd., M.Si	2	1	III
Total				2	1	

Nama Dosen : Meiliyani Siringoringo, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Metode Statistika		Dr. Sifriyani, S.Pd., M.Si	2	1	III
2	Komputasi Statistika		Surya Prangga, S.Si., M.Si	2	1	III
3	Analisis Runtun Waktu		Dr. Sri Wahyuningsih, M.Si	2	1	V
4	Official Statistics		Ika Purnamasari, S.Si., M.Si	2	1	V
Total				8	4	

Nama Dosen : Surya Prangga, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Algoritma dan Pemrograman I	W	Rito Goejantoro, S.Si., M. Si	2	1	I
2	Komputasi Statistika	W	Meliyani Siringoringo, S.Si., M.Si	2	1	III
3	Pemrograman Visual	P	Siti Mahmuda, S.Si., M.Si	2	1	V
Total				6	3	

Nama Dosen : Siti Mahmuda, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Data Sains	W	Dr. M. Fathurahman, M.Si	2	1	III
2	Analisis Multivariat	W	Dr. Sri Wahyuningsih, M.Si	2	1	V
3	Pemrograman Visual	P	Surya Prangga, S.Si., M.Si	2	1	V
Total				6	3	

Nama Dosen : Meirinda Fauziyah, S.Si., M.Stat

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Kependudukan dan Demografi	P	Ika Purnamasari, M.Si	3	0	III
Total				3	0	

Nama Dosen : Andrea Tri Rian Dani, S.Stat., M.Stat

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Statistika Matematika I	W	Dr. Suyitno, S.Pd., M.Sc	3	0	III
2	Matematika Keuangan	P	Dr. M. Fathurahman, M.Si	2	0	III
Total				5	0	

Nama Dosen : Asmaidi, S.Pd., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Metode Numerik untuk Statistika	P	Dr. Suyitno, S.Pd., M.Sc	2	1	III
2	Kalkulus III	P	Qonita Qurrota A'yun, S.Si., M.Sc	2	1	III
Total				4	2	

Nama Dosen : Qonita Qurrota A'yun, S.Si., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kalkulus III	P	Asmaidi, S.Pd., M.Si	2	1	III
Total				2	1	

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN RISET DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 3
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

PENGANGKATAN DOSEN PENGAMPU MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 STATISTIKA, S1 MATEMATIKA, S1 BIOLOGI,
S1 KIMIA, S2 KIMIA, S1 FISIKA DAN S1 GEOFISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS MULAWARMAN

PROGRAM STUDI : S1-MATEMATIKA

NO	KODE MK	MATA KULIAH	SKS/ SMT	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	210706603W008	Kalkulus Peubah Banyak	3/III	W	2021	Qonita Qurrota A'yun, S.Si., M.Sc
						Indriasri Raming, S.Si., M.Si
2	210706603W011	Matematika Diskrit	3/III	W	2021	Fidia Deny Tisna Amijaya, M.Si
						Hardina Sandariria, S.Si., M.Sc
3	210706603W013	Metode Numerik	3/III	W	2021	Wasono, S.Si., M.Si
						Dr. Syaripuddin, M.Si
4	190706603W027	Persamaan Differensial Parsial	3/V	W	2019	Moh. Nurul Huda, S.Si., M.Si
						Indriasri Raming, S.Si., M.Si
5	190706603W028	Riset Operasi I	3/V	W	2019	Dr. Syaripuddin, M.Si
						Wasono, S.Si., M.Si
6	190706602P034	Pengantar Matematika Keuangan	2/V	P	2019	Sri Wigantono, S.Si., M.Sc
						Dr. M. Fathurahman, M.Si
7	190706602P035	Matematika Aktuaria	2/V	P	2019	Wasono, S.Si., M.Si
						Dr. Suyitno, S.Pd., M.Sc
8	190706603P036	Data Mining	3/V	P	2019	Fidia Deny Tisna Amijaya, M.Si
9	190706602P038	Sistem Dinamik Diskrit	2/V	P	2019	Moh. Nurul Huda, S.Si., M.Si
						Sri Wigantono, S.Si., M.Sc

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 4
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 MATEMATIKA FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen : Dr. Syaripuddin, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Metode Numerik	W	Wasono, S.Si., M.Si.	2	1	III
2	Riset Operasi I	W	Wasono, S.Si., M.Si.	3	0	V
Total				5	1	

Nama Dosen : Fidia Deny Tisna Amijaya, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Matematika Diskrit	W	Hardina Sandariria, S. Si., M.Sc.	3	0	III
2	Data Mining	P	-	3	0	V
Total				6	0	

Nama Dosen : Qonita Qurrota A'yun, S.Si., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kalkulus Peubah Banyak	W	Indriasri Raming, S.Si., M.Si.	3	0	III
Total				3	0	

Nama Dosen : Moh. Nurul Huda, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Persamaan Differensial Parsial	W	Indriasri Raming, S.Si., M.Si.	4	0	III
2	Sistem Dinamik Diskrit	P	Sri Wigantono, S.Si., M.Sc.	2	0	V
Total				6	0	

Nama Dosen : Hardina Sandariria, S.Si., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Matematika Diskrit	W	Fidia Deny Tisna Amijaya, S.Si., M.Si.	3	0	III
Total				3	0	

Nama Dosen : Sri Wigantono, S.Si., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Matematika Keuangan	P	Dr. M. Fathurahman, M.Si.	2	0	V
2	Sistem Dinamik Diskrit	P	Moh. Nurul Huda, S.Si., M.Si.	2	0	V
Total				4	0	

Nama Dosen : Indriasri Raming, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kalkulus Peubah Banyak	W	Qonita Qurrota A'yun, S.Si., M.Sc.	3	0	III
2	Persamaan Differensial Parsial	W	Moh. Nurul Huda, S.Si., M.Si.	3	0	V
Total				6	0	

Nama Dosen : Wasono, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Metode Numerik	W	Dr. Syaripuddin, M.Si.	2	1	III
2	Riset Operasi I	W	Dr. Syaripuddin, M.Si.	3	0	V
3	Matematika Aktuaria	P	Dr. Suyitno, S.Pd., M.Sc.	2	0	V
Total				7	1	

Nama Dosen : Dr. Suyitno, S.Pd., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Matematika Aktuaria	P	Wasono, S.Si., M.Si	2	0	V
Total				2	0	

Nama Dosen : Dr. M. Fathurahman, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pengantar Matematika Keuangan	W	Sri Wigantono, S.Si., M.Sc.	2	0	V
Total				2	0	

Samarinda, 5 Agustus 2022
Dekan,

Dr. Eng. Idris Mandang, M.Si
NIP 19711008 199802 1 001

Lampiran 5
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

PENGANGKATAN DOSEN PENGAMPU MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 STATISTIKA, S1 MATEMATIKA, S1 BIOLOGI, S1 KIMIA, S2 KIMIA, S1 FISIKA DAN S1 GEOFISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS MULAWARMAN

PROGRAM STUDI : S1-BIOLOGI

NO	KODE MK	MATA KULIAH	SKS/ SMT/ KLS	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	190702603P040	Fisiologi Reproduksi Hewan	3/V	P	2019	Prof. Rudy Agung Nugroho, M.Si., Ph.D
						Mukhlis, S.Pd, M.Sc
2	190702603P043	Biologi Dipterokarpa	3/V	P	2019	Dr. Medi Hendra, M.Si
						Dr. Dwi Susanto, M.Si
3	190702603P044	Etnobiologi	3/V	P	2019	Dr. Medi Hendra, M.Si
						Dr. Linda Oktavianingsih, M.Si
4	190702603P047	Fitopatologi	3/V	P	2019	Imam Rosadi, S.Si., M.Si
						Dr. Linda Oktavianingsih, M.Si

Samarinda, 5 Agustus 2022
Dekan,

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 6
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 BIOLOGI FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen : Prof. Rudy Agung Nugroho, M.Si., Ph.D

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisiologi Reproduksi Hewan	P	Mukhlis, S.Pd, M.Sc	2	1	V
Total				2	1	

Nama Dosen : Dr. Dwi Susanto, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Biologi Dipterokarpa	P	Dr. Medi Hendra, M.Si	2	1	V
Total				2	1	

Nama Dosen : Dr. Medi Hendra, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Biologi Dipterokarpa	P	Dr. Dwi Susanto, M.Si	2	1	V
2	Etnobiologi	P	Dr. Linda Oktavianingsih, M.Si	2	1	V
Total				4	2	

Nama Dosen : Dr. Linda Oktavianingsih, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Etnobiologi	P	Dr. Medi Hendra, M.Si	2	1	V
2	Fitopatologi	P	Imam Rosadi, S.Si., M.Si	2	1	V
Total				4	2	

Nama Dosen : Imam Rosadi, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fitopatologi	P	Dr. Linda Oktavianingsih, M.Si	2	1	V
Total				2	1	

Nama Dosen : Mukhlis, S.Pd., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisiologi Reproduksi Hewan	P	Prof. Rudy Agung Nugroho, M.Si., Ph.D	2	1	V
Total				2	1	

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN RISET DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 7
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

PENGANGKATAN DOSEN PENGAMPU MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 STATISTIKA, S1 MATEMATIKA, S1 BIOLOGI,
S1 KIMIA, S2 KIMIA, S1 FISIKA DAN S1 GEOFISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS MULAWARMAN

PROGRAM STUDI : S1-KIMIA

NO	KODE MK	MATA KULIAH	SKS/ SMT/ KLS	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	210703602P035	Kimia Batu Bara	2/III/ A&B	P	2021	Dr. Subur P. Pasaribu, M.Si
						Dr. Saibun Sitorus, M.Si
2	190703602P041	Kimia Energi Terbarukan	2/V	P	2019	Dr. R.R. Dirgarini Julia N S, M.Sc
						Dr. Rahmat Gunawan, M.Si
3	190703602P043	Kimia Material Anorganik	2/V	P	2019	Dr. Noor Hindryawati, M.Si
						Irfan Ashari Hiyahara, S.Pd., M.Si
4	190703602P045	Analisis Lingkungan	2/V	P	2019	Dr. Soerja Koesnarpadi, M.Si
						Prof. Dr. Aman Sentosa Panggabean, M.Si
5	190703602P052	Biokimia Bahan Makanan	2/V	P	2019	Ritbey Ruga, M.P., Ph.D
						Djihan Ryn Pratiwi, M.Si

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP 19711008 199802 1 001

Lampiran 8
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 KIMIA FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen Dr. Subur P. Pasaribu, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Batu Bara	P	Dr. Saibun Sitorus, M.Si	2	0	III
Total				2	0	

Nama Dosen : Dr. Saibun Sitorus, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Batu Bara	P	Dr. Subur P. Pasaribu, M.Si	2	0	III
Total				2	0	

Nama Dosen : Dr. R.R. Dirgarini Julia N S, M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Energi Terbarukan	P	Dr. Rahmat Gunawan, M.Si	2	0	V
Total				2	0	

Nama Dosen : Dr. Rahmat Gunawan, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Energi Terbarukan	P	Dr. R.R. Dirgarini Julia N S, M.Sc	2	0	V
Total				2	0	V

Nama Dosen : Dr. Noor Hindryawati, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Material Anorganik	P	Irfan Ashari Hiyahara, S.Pd., M.Si	2	0	V
Total				2	0	V

Nama Dosen : Irfan Ashari Hiyahara, S.Pd., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Kimia Material Anorganik	P	Dr. Noor Hindryawati, M.Si	2	0	V
Total				2	0	

Nama Dosen : Dr. Soerja Koesnarpadi, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Analisis Lingkungan	P	Prof. Dr. Aman Sentosa Panggabean, M.Si	2	0	V
Total				2	0	

Nama Dosen : Prof. Dr. Aman Sentosa Panggabean, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Analisis Lingkungan	P	Dr. Soerja Koesnarpadi, M.Si	2	0	V
Total				2	0	

Nama Dosen : Ritbey Ruga, M.P., Ph.D

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Biokimia Bahan Makanan	P	Djihan Ryn Pratiwi, S.Si., M.Si	2	0	V
Total				2	0	

Nama Dosen : Djihan Ryn Pratiwi, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Biokimia Bahan Makanan	P	Ritbey Ruga, M.P., Ph.D	2	0	V
Total				2	0	

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI
UNIVERSITAS MULAWARMAN
FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 9
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

PENGANGKATAN DOSEN PENGAMPU MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 STATISTIKA, S1 MATEMATIKA, S1 BIOLOGI,
S1 KIMIA, S2 KIMIA, S1 FISIKA DAN S1 GEOFISIKA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS MULAWARMAN

PROGRAM STUDI : S1-FISIKA

NO	KODE MK	MATA KULIAH	SKS/ SMT	JENIS MK (W/P)	KURIKULUM	DOSEN PENGAMPU MK
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	190704603P043	Fisika Instrumentasi	3/III	P	2019	Dr. Syahrir, M.Si
						Ahmad Zarkasi, S.Si., M.Si
2	190704603P057	Sensor	3/V	P	2019	Dr. Syahrir, M.Si
						Ahmad Zarkasi, S.Si., M.Si
3	190704603W072	Fisika Kristal	3/VII	W	2019	Suhadi Muliyono, S.Si., M.Si
						Dr. Rahmawati M, M.Si
4	190704603W080	Fisika Semikonduktor	3/VII	P	2019	Dr. Dadan Hamdani, M.Si
						Dr. Rahmawati M, M.Si

Samarinda, 5 Agustus 2022
Dekan,

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001

Lampiran 10
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 FISIKA FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen : Dr. Syahrir, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisika Instrumentasi	P	Ahmad Zarkasi, S.Si., M.Si	3	0	III
2	Sensor	P	Ahmad Zarkasi, S.Si., M.Si	3	0	V
Total				6	0	

Nama Dosen : Ahmad Zarkasi, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisika Instrumentasi	P	Dr. Syahrir, M.Si	3	0	III
2	Sensor	P	Dr. Syahrir, M.Si	3	0	V
Total				6	0	

Nama Dosen : Suhadi Muliyono, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisika Kristal	P	Dr. Rahmawati M, M.Si	3	0	VII
Total				3	0	

Nama Dosen : Dr. Rahmawati M, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisika Kristal	P	Suhadi Muliyono, S.Si., M.Si	3	0	VII
2	Fisika Semikonduktor	P	Dr. Dadan Hamdani, M.Si	3	0	VII
Total				6	0	

Nama Dosen : Dr. Dadan Hamdani, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Fisika Semikonduktor	P	Dr. Rahmawati M, M.Si	3	0	VII
Total				3	0	

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP 19711008 199802 1 001

Lampiran 12
Surat Tugas Dekan FMIPA Universitas Mulawarman.
Nomor 1515 /UN17.7/PP/2022,
Tanggal 5 Agustus 2022.

MATRIKS MATA KULIAH
PROGRAM MERDEKA BELAJAR-KAMPUS MERDEKA (MB-KM)
SEMESTER GANJIL TAHUN AKADEMIK 2022/2023
PROGRAM STUDI S1 GEOFISIKA FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM UNIVERSITAS MULAWARMAN

Nama Dosen : Dr. Eng. Idris Mandang, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Manajemen Pesisir dan Laut	P	Dr. Sc. Mustaid Yusuf, M.Si	2	0	V
2	Dinamika Estuari	P	Dr. Dadan Hamdani, M.Si.	2	1	VII
Total						

Nama Dosen : Dr. Sc. Mustaid Yusuf, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Manajemen Pesisir dan Laut	P	Dr. Eng. Idris Mandang, M.Si	2	0	V
2	Pemodelan Lingkungan Laut	P	Muhammad Riza, S.Si., M.Si	3	0	VII
Total				5	0	

Nama Dosen : Drs. Piter Lepong, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Geofisika Teknik	W	Dr. Supriyanto, M.T	3	0	V
2	Geofisika Pertambangan	P	Dr. Djayus, M.T	2	1	VII
3	Karakteristik Reservoar	P	Andi Alamsyah, S.Si., M.Sc	2	1	VII
Total				7	2	

Nama Dosen : Dr. Supriyanto, MT

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Geofisika Teknik	P	Drs. Piter Lepong, M.Si	3	0	V
Total				3	0	

Nama Dosen : Dr. Djayus, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Geologi Minyak dan Gas Bumi	P	Andi Alamsyah, S.Si., M.Sc	3	0	V
2	Geofisika Pertambangan	P	Drs. Piter Lepong, M.Si	2	1	VII
Total				5	1	

Nama Dosen : Andi Alamsyah, S.Si., M.Sc

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Geologi Minyak dan Gas Bumi	P	Dr. Djayus, M.T	3	0	V
2	Karakterisasi Reservoar	P	Drs. Piter Lepong, M.Si	2	1	VII
Total				5	1	

Nama Dosen : Muhammad Riza, S.Si., M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Pemodelan Lingkungan Laut	P	Dr. Sc. Mustaid Yusuf, M.Si	3	0	VII
Total				3	0	

Nama Dosen : Dr. Dadan Hamdani, M.Si

NO	MATA KULIAH	W/P	DOSEN PARTNER	SKS		SMT
				TEORI	PRAKTEK	
1	Dinamika Estuari	P	Dr. Eng. Idris Mandang, M.Si	2	1	VII
Total				2	1	

Samarinda, 5 Agustus 2022
Dekan,

KEMENTERIAN PENDIDIKAN KEBUDAYAAN, RISET, DAN TEKNOLOGI UNIVERSITAS MULAWARMAN FMIPA

Dr. Eng. Idris Mandang, M.Si
NIP19711008 199802 1 001