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System

input → Sensor → Actuator → output

But the system must be Intelligence → priority knowledge (المعرفة السابقة) ↔ Comb. ; adaptive learning (comes from experience) → the system يتعلم من التجارب السابقة التي افرزها

data set محتاج لـ

كل ما زاد الارتباط بين الاثنين زاد الذكاء وصار الذكاء الاصطناعي .

الانظمة الذكية

يقدر يغير الـ behavior تبعه ، يكيف ان الاداتين لطبيعة شيء معين يتصرف كذا ومبني على الامور

Intelligent Sensor Systems

- System
  - A combination of two or more elements, subsystems and parts necessary to carry out one or more functions
  - To interact with the real world, a system requires
    - Sensors: inputs devices
    - Actuators: output devices
    - Processing: signals, information and knowledge
- Sensor
  - A device that receives and responds to a stimulus
    - Stimulus: mechanical, thermal, magnetic, electric, optical, chemical, ..
    - Response: an electrical signal (in most cases)
- Intelligence
  - The ability to combine
    - A priori knowledge (available before experience) and
    - Adaptive learning (from experience)

element1 → element2, element3 → produce a function

The interaction must give a certain function.

In order to them we need sensor

مؤثرات

أمثلة على المحفزات

زي ما حطينا electrical signal

Intelligent Sensor System

- Several definitions are available
  - A sensor that is capable of modifying its internal behavior to optimize the collection of data from the external world
    - The concepts of adaptation and compensation are central to the Intelligent Sensor philosophy
  - A device that combines a sensing element and a signal processor on a single integrated circuit
    - The minimum requirements of the signal processor are not clear
      - Basic integrated electronics (signal conditioning, ADC)
      - A micro-processor
      - Logic functions and decision making
  - A smart sensor is a sensor that provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity (IEEE 1451.2)
    - This function typically simplifies the integration of the transducer into applications in a networked environment
  - "Intelligent" or "Smart" Sensors?

الاستاذ وصف الـ AI عند في "القدرة على التكيف والتغيير"

physical signals → sensor → electrical signal → يعني ال put داخل عبر electrical signal

device response for a stimulus ; input device (like sensors)

environment ياخذ من الـ

electrical signal → Actuator → physical signal → mechanical, thermal, magnetic, electrical, optical & chemical signal.

device that outputted the electrical to physical signal.

output device (like motors, Leds) حركات

environment التفاعل مع الـ

في هاظ السابقة 2/ نحكي عن نوعين من الـ microcontroller

→ Arduino
→ MBED

+ بعضها → Algorithms معينة

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MC
- Arduino → in interface teching
- MBED → in Lab.

MP → we can use our Laptops.
- X86
- ARM

Rapsery PI (in Lab) ↓ غالية
- micro computer

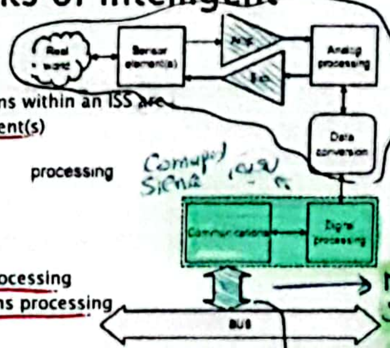
كثير انتشاره

Microcontroller will use → Data conversion, Digital processing, communications protocols.

this is cool sub

Computer Engineer شغلة ال

Building blocks of Intelligent Sensors



- The principal sub-systems within an ISS are:
  - Primary sensing element(s)
  - Excitation control
  - Amplification
  - Analogue filtering
  - Data conversion
  - Compensation
  - Digital information processing
  - Digital communications processing

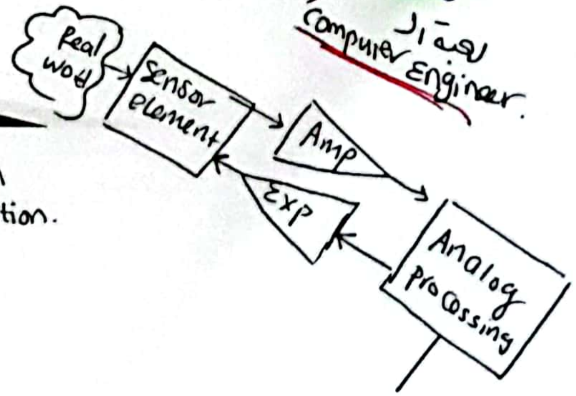
processing

interface / عملية ال step by step بالتفصيل

هاظ اللي بياخذ ال Analog ويحوله Digital

mixed signal Engineer.

Computer Engineer شغلة ال



Smart system → give a function Beyond its basic sensing

يعني ال temperature sensor بصير Smart ، اذا كان عنده امكانية يتصل على الانترنت.

"يعني اضافة انه يستشعر الحرارة كمان بيتصل على الشبكة"

the kerneal of the Linux can handel real time - application.

صار ال sensor الذكي ممكن ان التعامل معه عن طريق protocol معين (انترنت ، شبكة).

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input device (I'm intersetedto analysis this device), that's why we will study it's characteristics.

sensor + actuators ⇒ Energy convertors.

يحول الطاقه من شكل الي اخر

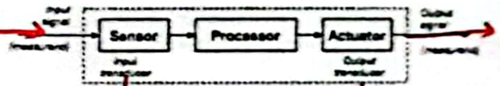
Sensor characteristics

- Transducers, sensors and measurements
- Calibration, interfering and modifying inputs ← معايرة
- Static sensor characteristics
- Dynamic sensor characteristics

Transducers: sensors and actuators

- Transducer
  - A device that converts a signal from one physical form to a corresponding signal having a different physical form
    - Physical form: mechanical, thermal, magnetic, electric, optical, chemical…
  - Transducers are ENERGY CONVERTERS or MODIFIERS
- Sensor
  - A device that receives and responds to a signal or stimulus
    - This is a broader concept that includes the extension of our perception capabilities to acquire information about physical quantities
- Transducers: sensors and actuators
  - Sensor: an input transducer (i.e., a microphone)
  - Actuator: an output transducer (i.e., a loudspeaker)

(measurement) physical signals ← input signal



output signal → physical signal. لازم تطلع

input Transducer

output Transducer.

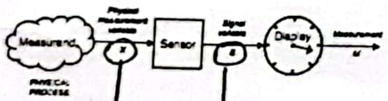
كg يعني مثلاً لما بدي أقيس الكتلة لازم احدد وحدة Pound و بار — مثل الحلي، و هكذا ← عليها القياس

Measurements

- A simple instrument model
  - A observable variable X is obtained from the measurand
    - X is related to the measurand in some KNOWN way (i.e., measuring mass)
- The sensor generates a signal variable that can be manipulated:
  - Processed, transmitted or displayed
- In the example above the signal is passed to a display, where a measurement can be taken
- Measurement
  - The process of comparing an unknown quantity with a standard of the same quantity (measuring length) or standards of two or more related quantities (measuring velocity)

ASI systems

compare unknown quantity with standards.



X: physical measurement variable

S: output of the sensor after the inputs (X)

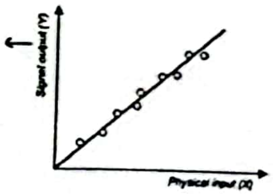
بالعادة بطلع علاقة S و X، فمنها بقدر احسب measure او اعطي (X)

Calibration

هاي منختار Amplifier بالعريقة يكون linear ←

- The relationship between the physical measurement variable (X) and the signal variable (S)
  - A sensor or instrument is calibrated by applying a number of KNOWN physical inputs and recording the response of the system

signal output ←



calibration curve, if not linear we should do linearization, by numerical methods (LMS)

① بالعادة عالدخل دايماً ال signal system
مابتدخل لحالها، بدل يدخل معها
كثير منها الأنواع other signals

Additional inputs

② ويعرفيها كمان

③ حصر ال input اللي يقدر الطبق عليه نظرية ال superpostion

clibration curve يعني ال is the same (dosnt chang)

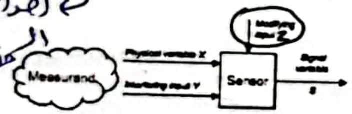
- Interfering inputs (Y):
  - Those that the sensor to respond as the linear superposition with the measurand variable X
  - Linear superposition assumption: $S(aX+bY)=aS(X)+bS(Y)$

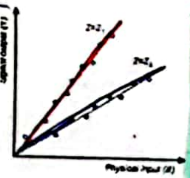
بعدها نطرح اللي ما بدنا ياه وصلك

- Modifying inputs (Z):
  - Those that change the behavior of the sensor and, hence, the calibration curve
  - Temperature is a typical modifying input

المصيبة فيه بغير ال clibration carve بيعطل ال sensor بعطل ال out put الصح

أحلاهم المقصود modifying sensor



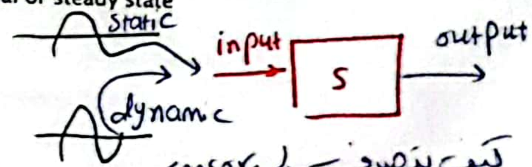


Like Slicon sensors. بتاثر في حرارة عشان هيك ما بستخدم في المواقع
ولما نلاقي ال modifying input نحاول نتجنبه
للانه حلوله بالعادة صعبة

Sensor characteristics

ادرس خصائص ال sensor
the main concept is to know the proparites of that sensor.

- Static characteristics — لما ال system مش مهزوز أو shocked
  - The properties of the system after all transient effects have settled to their final or steady state
    - Accuracy
    - Discrimination
    - Precision
    - Errors
    - Drift
    - Sensitivity
    - Linearity
    - Hystheresis (backslash)
- Dynamic characteristics — عاشتهز ال system
  - The properties of the system transient response to an input — when we apply unit step
    - Zero order systems
    - First order systems
    - Second order systems



كيف بتصرف ال sensor وقت ال static وال dynamic

يعني ال system يكون dead وانت بتحطه في shock، عشان تشوف كيف رح يتصرف

بطلع على ال Storge تبعه

* Always thing try to think, How to linearalize any system.

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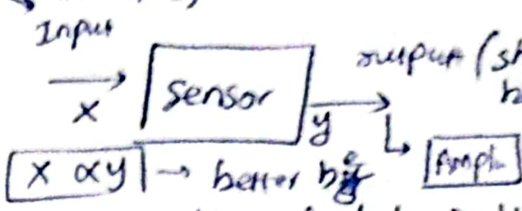


x ∝ y → better be « Linear Realtionship » → we will use "LMS" least mean square error.

→ Static Characteristic جدول نهدرس قوانين

Accuracy, discrimination and precision

أعلم إمكان أكون دقيقة ←

values the results are close to the true value

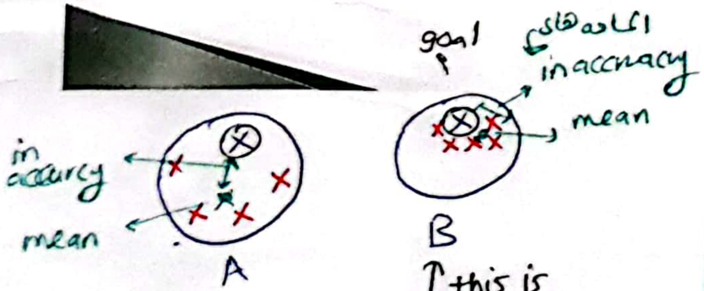
- Accuracy is the capacity of a measuring instrument to give RESULTS close to the TRUE VALUE of the measured quantity
  - Accuracy is related to the bias of a set of measurements
  - (IN)Accuracy is measured by the absolute and relative errors

كل ما كانت أقرب لل True value للـ قريب يكون Accurate measurement

- Discrimination is the minimal change of the input necessary to produce a detectable change at the output
  - Discrimination is also known as RESOLUTION
  - When the increment is from zero, it is called THRESHOLD

input أقل تغير في الـ input ← تغير في الـ output

Resolution



∴ mean A > mean B
So B is more accurate

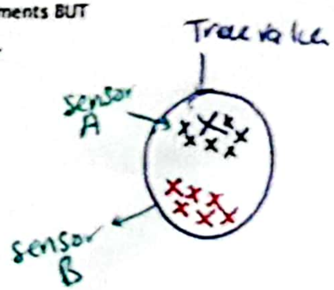
↑ this is more accurate
since take the mean "Average"

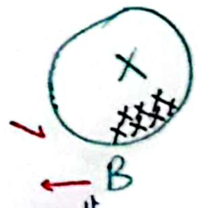
* in mathmatical we use ⇒ σ^2
Standard deviastion
"variance"

Precision

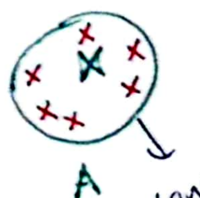
لما تكون القراءات قريبة من بعض بغض النظر عن قربها من الـ True value

- The capacity of a measuring instrument to give the same reading when repetitively measuring the same quantity under the same prescribed conditions
  - Precision implies agreement between successive readings, NOT closeness to the true value
    - Precision is related to the variance of a set of measurements
  - Precision is a necessary but not sufficient condition for accuracy
- Two terms closely related to precision
  - Repeatability
    - The precision of a set of measurements taken over a short time interval
  - Reproducibility
    - The precision of a set of measurements BUT
      - taken over a long time interval or
      - Performed by different operators or
      - with different instruments or
      - in different laboratories





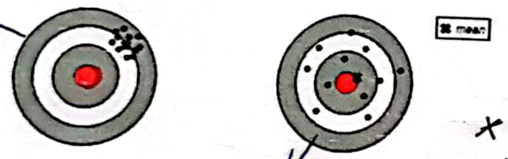
this sensor is more precisids
variace is small → Better



variance is large → not good

- Shooting darts
  - Discrimination
    - The size of the hole produced by a dart
  - Which shooter is more accurate?
  - Which shooter is more precise?

Precised



Accuracy

Accuracy and errors

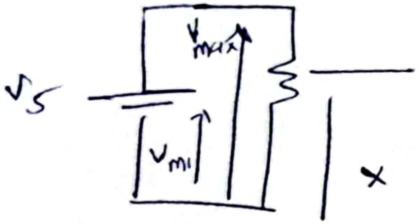
- Systematic errors ← can be solved
  - Result from a variety of factors
    - Interfering or modifying variables (i.e., temperature)
    - Drift (i.e., changes in chemical structure or mechanical stresses)
    - The measurement process changes the measurand (i.e., loading errors)
    - The transmission process changes the signal (i.e., attenuation)
    - Human observers (i.e., parallax errors)
  - Systematic errors can be corrected with COMPENSATION methods (i.e.,
    - feedback, filtering) → الواع الحل
- Random errors ← can't be solved
  - Also called NOISE: a signal that carries no information
  - True random errors (white noise) follow a Gaussian distribution
  - Sources of randomness:
    - Repeatability of the measurand itself (i.e., height of a rough surface)
    - Environmental noise (i.e., background noise picked by a microphone)
    - Transmission noise (i.e., 60Hz hum)
  - Signal to noise ratio (SNR) should be >>1
    - With knowledge of the signal characteristics it may be possible to interpret a signal with a low SNR (i.e., understanding speech in a loud environment)

* We are talking about noice

(AWGN)
- Additive
- White → موجودة على كل الـ Spectrum
- Gaussian → pdf الـ
- Modulating → احسن اشي للـ

(AWGN) عليها الـ
شو رح استخدم عشان اعرف
اذا الـ noice اذا كبيرة او اقل
→ Signal to noice Rastion
noise كل ما تكبر بتقل الـ
noise كل ما تقل بزيد الـ

* Random signal → Pdf can describe it.
we can't prevent it but we can minimize it by increasing the SN>>1 OR if the signal is digital we talk about bit error rate.



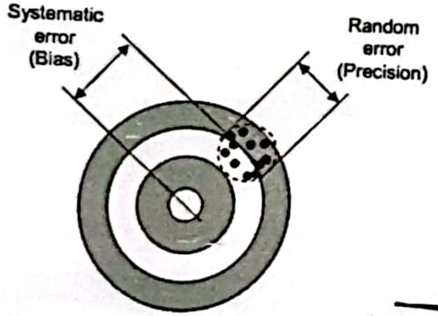
$\Rightarrow V_{on} = \frac{X - X_{min}}{X_{max} - X_{min}} (V_S)$

Pot

Plat $C = \frac{\varepsilon_0 \varepsilon_R A}{d}$

Cylen $\Rightarrow C = \frac{2\pi \varepsilon_0 \varepsilon_R h}{\ln(R_2/r_1)}$

Example: systematic and random errors



More static characteristics

to know the minimum OR maximum input to give a response

- **Input range**
  - The maximum and minimum value of the physical variable that can be measured (i.e., -40F/100F in a thermometer)
  - Output range can be defined similarly

we should draw the calibrastin carve

- **Sensitivity** → if we want to know the sensitivity of a graph
  - The slope of the calibration curve y=f(x)
    - An ideal sensor will have a large and constant sensitivity
  - Sensitivity-related errors: saturation and "dead-bands"

The slope of the calibrastin gavph

- **Linearity**
  - The closeness of the calibration curve to a specified straight line (i.e., theoretical behavior, least-squares fit)

calibration carve, must be linear

- **Monotonicity** The benifit, mapping for the value.. [It's not required to be Linear]
  - A monotonic curve is one in which the dependent variable always increases or decreases as the independent variable increases

↳ X-axsis

- **Hystheresis**
  - The difference between two output values that correspond to the same input depending on the trajectory followed by the sensor (i.e., magnetization in ferromagnetic materials)
  - Backslash: hystheresis caused by looseness in a mechanical joint

Time / بعد

system ال ز just increasing OR decreasing not both

monotonic

كل قيمة ل x الها قيمة في الy

not monotonic

هاي ال x الها اكثر من قيمة و non monotonic

مثال ال Thermometer هاي الظاهرة بتبين لما ارفع درجة الحرارة و لما اخفض درجة الحرارة

الفرق بين ال input يكون increas و descres *
هو نسبة الخطأ ← هاي الظاهرة "اي هي لا تبنت
ما بتمشي على نفس الخط" ، بصير عنا Hystheresis *
↳ diffenence between tow output values for the same input, called Hysthenesis error.

4/7/2022

* to study the dynamic characterstic ?
* أعرف كيف بتصرف لما ادخل قيم مختلفة على ال input .
* واقهم ال system → كيف اعمل model لل system

control + communication

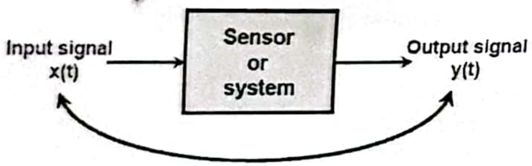
Laplace + Time domain

differential courx

ال output يجد ال input اللي ادخل

Dynamic Characteristics

Dynamic characteristics tell us about how well a sensor responds to changes in its input. For dynamic signals, the sensor or the measurement system must be able to respond fast enough to keep up with the input signals.

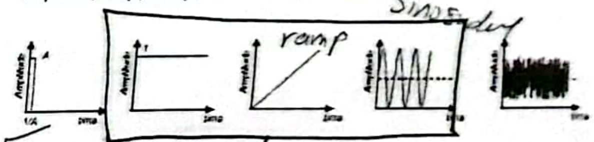


In many situations, we must use y(t) to infer x(t), therefore a qualitative understanding of the operation that the sensor or measurement system performs is imperative to understanding the input signal correctly.

* 1. should study the (Unit - Signal) : يحل ال shocked ال system.
2. (ramp input): to know ال error ممكن اي system يعطيني اياها
3. input with sertien frequency : to know the frequency response + Band width (range of signal that i can aggpply for the sensor)
(Sinosouidal / cos or sin)

*Dynamic characteristics

- The sensor response to a variable input is different from that exhibited when the input signals are constant (the latter is described by the static characteristics)
- The reason for dynamic characteristics is the presence of energy-storing elements
  - Inertial: masses, inductances
  - Capacitances: electrical, thermal
- Dynamic characteristics are determined by analyzing the response of the sensor to a family of variable input waveforms:
  - Impulse, step, ramp, sinusoidal, white noise...



→ the three signals.

The Laplace Transform (review)

no oscillistim.

- Applying the Laplace transform to the sensor model yields

$$L\left[a_k\frac{d^k y}{dt^k}+\cdots a_2\frac{d^2 y}{dt^2}+a_1\frac{dy}{dt}+a_0 y(t)=x(t)\right]$$

$$\Downarrow$$

$$\left(a_k s^k+\cdots a_2 s^2+a_1 s-a_0\right)Y(s)=X(s)$$

$$\Downarrow$$

$$G(s)=\frac{Y(s)}{X(s)}=\frac{1}{a_k s^k+\cdots a_2 s^2+a_1 s+a_0}$$

Transfer Function

system ~~sensor~~ لما نحول لـ s-domain , الاقي علاقة بين x(t) و y(t)

- G(s) is called the transfer function of the sensor

➢The position of the poles of G(s) –zeros of the denominator– in the s-plane determines the dynamic behavior of the sensor such as

- Oscillating components
- Exponential decays
- Instability → system goes crazy, Like when the gain is not true in the motors or Robots.

from poles ican know

$a_k s^k + \dots + a_2 s^2 \dots \rightarrow$ poles

when the poles are equal to zero then the system is unstable.

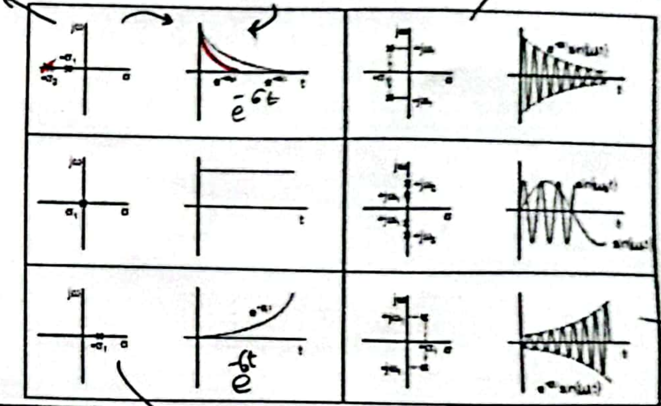
اذا بدي اوصل ال steady state بسرعة وشكل واضح
بدي اشيل ال 6 بعيدة عن ال "pole"

gives info. "How fast can i reach the stedy state" → from poles Location.

Pole location and dynamic behavior

$\sigma_2 > \sigma_1$

the system oscillatimg.



→ very bad case ✓

impossible "not allowed"

negative side لازم في poles

positive side ممنوع يكون الها

no storge element

like Potentiometer ←

Zero-order sensors

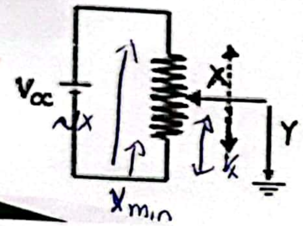
– no delay
– infinite BW

- Input and output are related by an equation of the type
  - Zero-order is the desirable response of a sensor

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

- 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

sensisor



$$V_{out} = \frac{X - X_{min}}{V_{max} - V_{m}} V_{cc}$$

one storge element

عليه اشتقاق من تحليل (1) .م

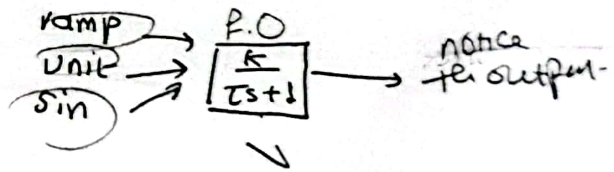
First-order sensors

→ moduling For motors + Amplifier.

- Inputs and outputs related by a first-order differential equation

$$a_1 \frac{dy}{dt} + a_0 y(t) = x(t) \Rightarrow \frac{Y(s)}{X(s)} = \frac{1}{a_1 s + a_0} = \frac{k}{\tau s + 1}$$

- First-order sensors have one element that stores energy and one that dissipates it
- Step response
  - $y(t) = Ak(1-\exp(-t/\tau))$
    - A is the amplitude of the step
    - k (=1/a0) is the static gain, which determines the static response
    - τ (=a1/a0) is the time constant, which determines the dynamic response
- Ramp response
  - $y(t) = Akt - Ak\tau u(t) + Ak\tau \exp(-t/\tau)$
- Frequency response
  - Better described by the amplitude and phase shift plots



First-Order Systems: Frequency Response

From the response of first-order system to sinusoidal inputs $x(t) = A\sin\omega t$ we have

$$\tau\frac{dy}{dt} + y = KA\sin\omega t \iff (\tau D+1)y(t) = KA\sin\omega t$$

The complete solution:

$$y(t) = \underbrace{Ce^{-t/\tau}}_{\text{Transient response}} + \underbrace{\frac{KA}{\sqrt{1+(\omega\tau)^2}}\sin(\omega t - \tan^{-1}\omega\tau)}_{\text{Steady state response = Frequency response}}$$

If we do interest in only steady state response of the system, we can write the equation in general form

$$y(t) = Ce^{-t/\tau} + B(\omega)\sin[\omega t + \phi(\omega)]$$

$$B(\omega) = \frac{KA}{\left[1+(\omega\tau)^2\right]^{1/2}}$$

$$\phi(\omega) = -\tan^{-1}\omega\tau$$

Where $B(\omega)$ = amplitude of the steady state response and $\phi(\omega)$ = phase shift

$x(t) = A\sin\omega t$

characterstic equation: $(\tau D+1)y(t) = KA\sin\omega t$

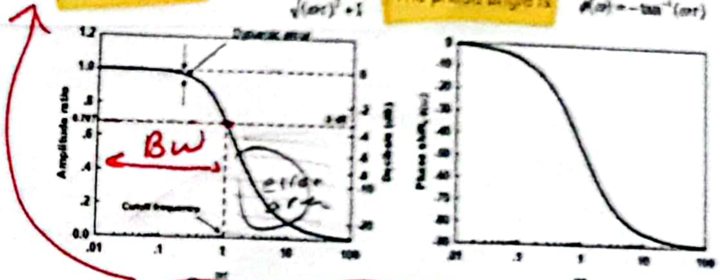
$$y(t) = \frac{KA}{\sqrt{1+(\omega\tau)^2}}\sin(\omega t - \tan^{-1}\omega\tau) + Ce^{-t/\tau}$$

Stedy Stae or frequcy resp. — Transient response

First-Order Systems: Frequency Response

$$M(\omega) = \frac{B}{KA} = \frac{1}{\left[1+(\omega\tau)^2\right]^{1/2}}$$

The amplitude ratio $M(\omega) = \frac{1}{\sqrt{(\omega\tau)^2+1}}$ The phase angle is $\phi(\omega) = -\tan^{-1}(\omega\tau)$



Frequency response of the first order system

- Dynamic error, $\delta(\omega) = M(\omega) - 1$: a measure of an inability of a system to adequately reconstruct the amplitude of the input for a particular frequency

$\tau = 38$ sec

Period $\Rightarrow \frac{3}{60}$ times per minit

Find delay

$$\text{dealy } t_d = \frac{\tan^{-1}(\omega\tau)}{\omega} = \frac{\tan^{-1}(2\pi f \tau)}{2\pi f}$$

$$= \frac{\tan^{-1}\left[2\pi\left(\frac{1}{20}\right)(38)\right]}{2\pi \frac{1}{20}}$$

$$= \frac{\tan^{-1}\left(2\pi\left(\frac{1}{20}\right)(38) \cdot \frac{360}{2\pi}\right)}{\frac{2\pi}{20} \cdot \frac{360}{2\pi}}$$

$$= \frac{\tan^{-1}(684)}{18} \Rightarrow$$