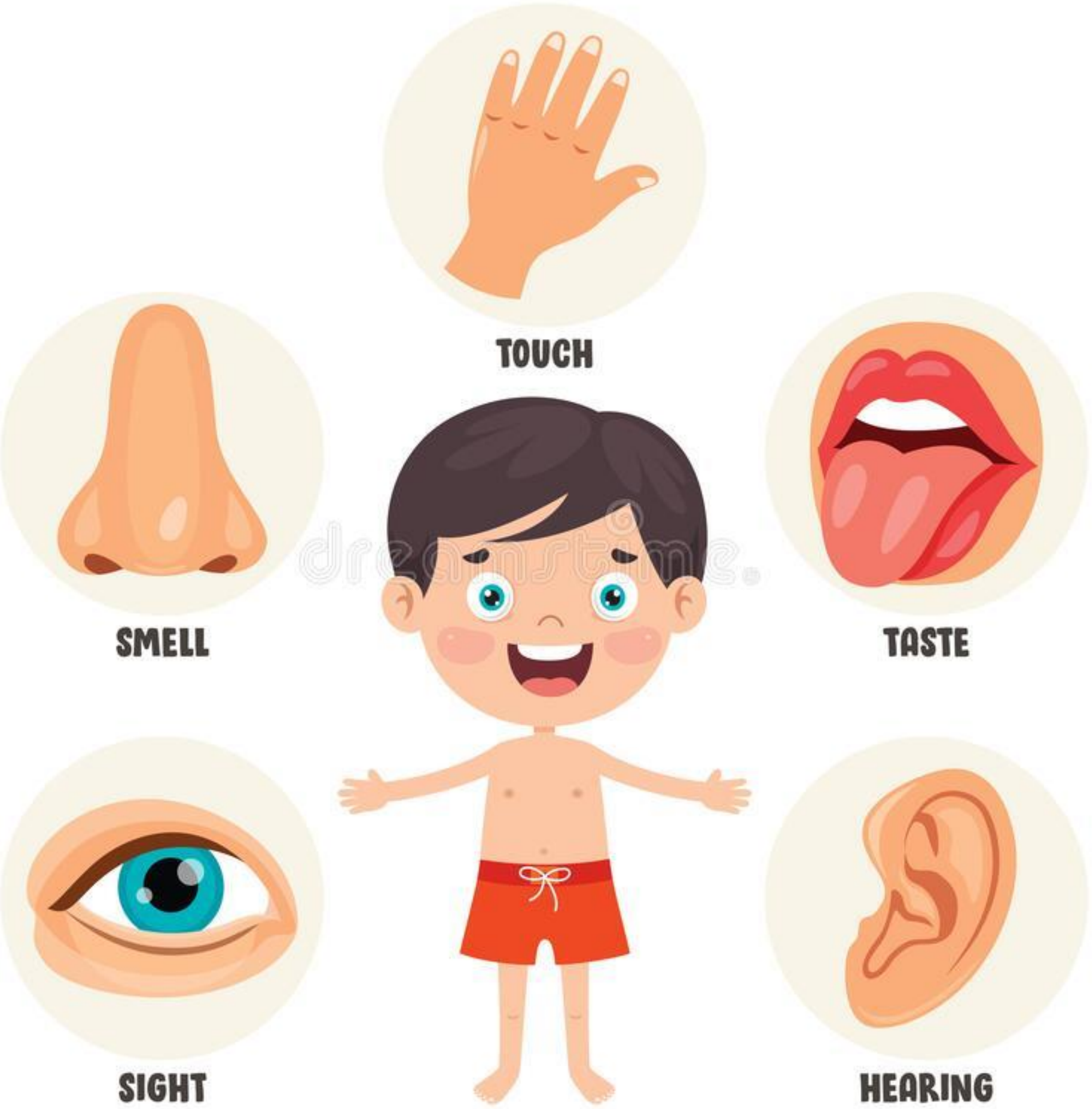
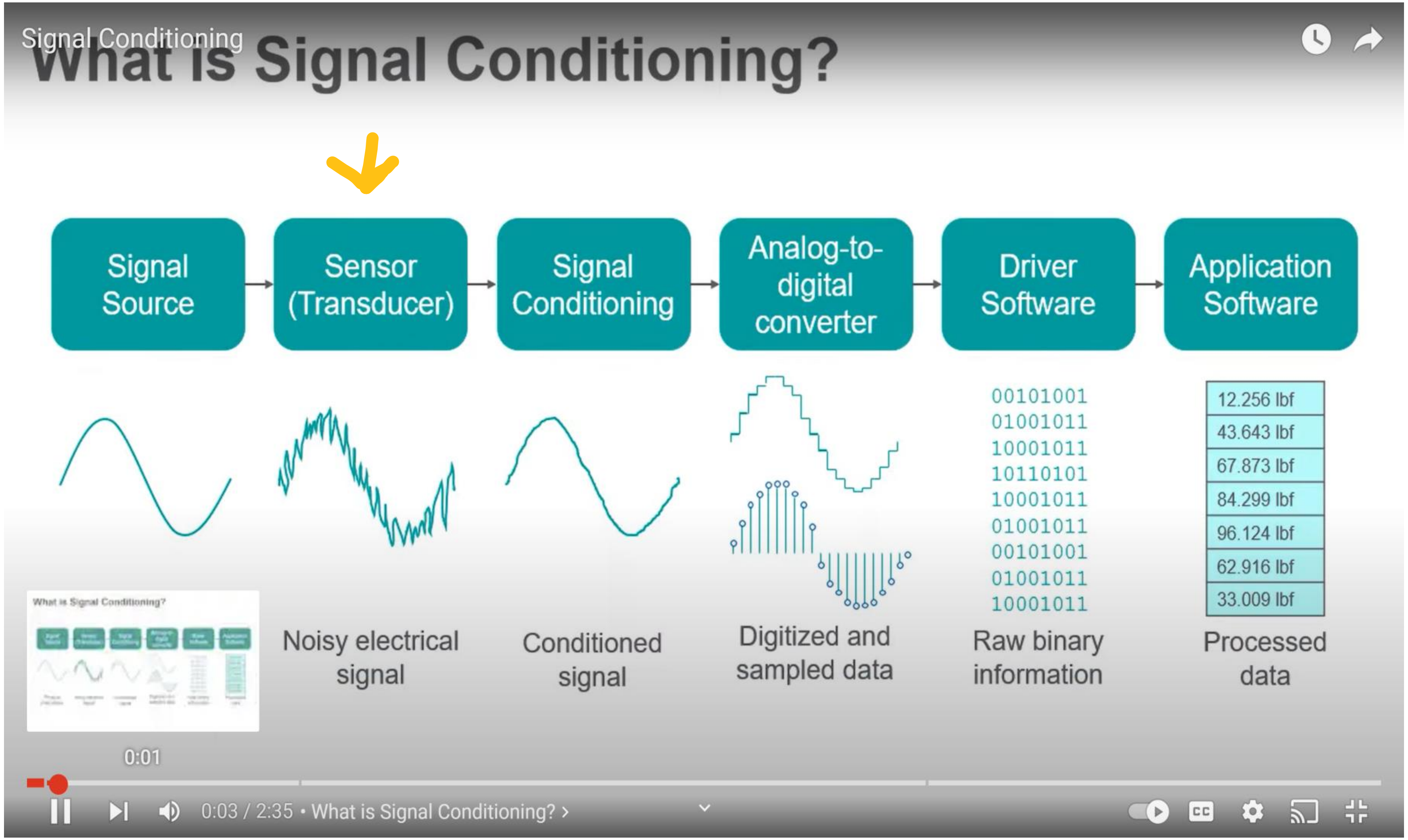

TOUCH
SMELL
TASTE
SIGHT
HEARING



https://www.youtube.com/watch?v=HSHJXXFigz8

SENSOR PROPERTIES

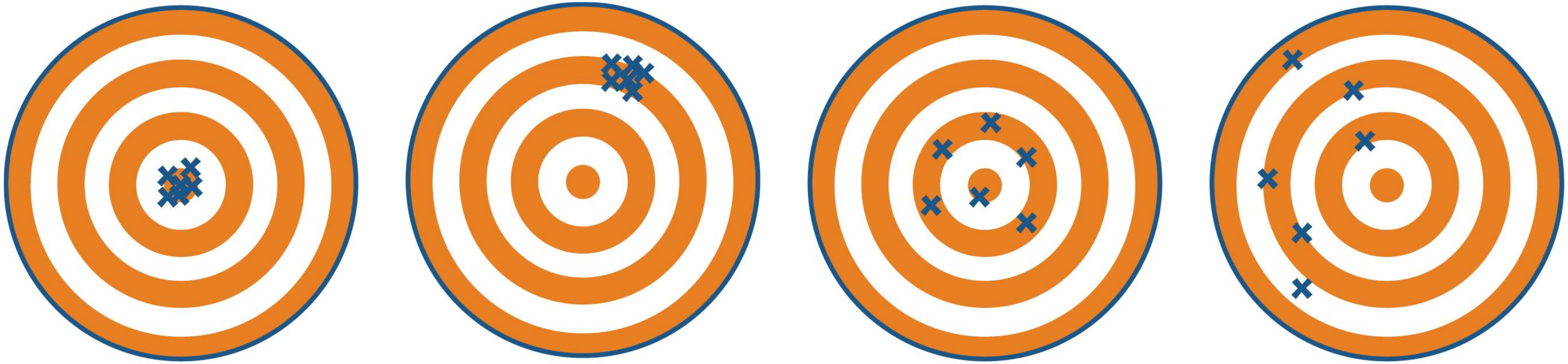
- **Cost:** The cost of a sensor is an important consideration, especially when many sensors are needed for one machine. However, the cost must be balanced with other requirements of the design, such as reliability, importance of the data they provide, accuracy, and life.
- **Size:** Depending on the application of the sensor, the size may be of primary importance. For example, the joint displacement sensors have to be adapted into the design of the joints and move with the robot's body elements. The available space around the joint may be limited. In addition, a large sensor may limit joint ranges. Thus, it is important to ensure that there is enough room for the joint sensors.
- **Weight:** Since robots are dynamic machines, the weight of the sensors is very important. A heavy sensor adds to the inertia of the arm, as well as reduces its overall payload.

NIKU

- **Type of output (digital or analog):** The output of a sensor may be digital or analog, and depending on the application, this output may be used directly, or it may have to be converted. For example, the output of a potentiometer is analog, whereas that of an encoder is digital. If an encoder is used in conjunction with a microprocessor, the output may be directly routed to the input port of the processor, while the output of a potentiometer will have to be converted to digital signal with an analog-to-digital converter (ADC). The appropriateness of the type of output must be balanced with other requirements.
- **Interfacing:** Sensors must be interfaced with other devices, such as microprocessors and controllers. The interfacing between the sensor and the device can become an important issue if they do not match or if other add-on circuits become necessary.

Front End Design to uP

- Number of digital Inputs
- Number of Analog Inputs



High Accuracy **High Precision**	**Low Accuracy** **High Precision**	**High Accuracy** **Low Precision**	**Low Accuracy** **Low Precision**

- **Accuracy:** Accuracy is defined as how close the output of the sensor is to the expected value. If for a given input, the output is expected to be a certain value, the accuracy is related to how close the sensor's output is to this value.

As an example, a temperature sensor that measures boiling water at 97.53°C has high precision but low accuracy.

- **Resolution:** Resolution is the minimum step size within the range of measurement of the sensor. In a wire-wound potentiometer, it will be equal to the resistance of one turn of the wire. In a digital device with n bits, the resolution will be

$$\text{Resolution} = \frac{\text{Full Range}}{2^n}. \tag{7.1}$$

For example, an absolute encoder with 4 bits can report positions up to $2^4 = 16$ different levels. Thus, its resolution is $360/16 = 22.5°$.

The specified resolution of an instrument has no relation to the accuracy of measurement.

However, Resolution and precision are related since in the example above the precision is limited to 16 values. Repeatability is related to precision. If different measurements of the save value are the same to the limit of resolution, the measurement is precise – BUT it may not be Accurate!

Repeatability: If the sensor's output is measured a number of times in response to the same input, the output may be different each time. Repeatability is a measure of how varied the different outputs are relative to each other.

Range: Range is the difference between the smallest and the largest outputs the sensor can produce, or the difference between the smallest and largest inputs with which it can operate properly.

In the 4-bit example, the range is 15 and the resolution is 1/16.

$Range =$ 2^n - 1 for n-bits.

Sensitivity: Sensitivity is the ratio of a change in output in response to a change in input. Highly sensitive sensors will show larger fluctuations in output as a result of fluctuations in input, including **noise.**

Linearity: Linearity represents the relationship between input variations and output variations. This means that in a sensor with linear output, the same change in input at any level within the range will produce the same change in output.

Almost all devices in nature are somewhat nonlinear, with varying degrees of nonlinearity. Certain devices can be assumed to be linear within a certain range of their operation. Others may be linearized through assumptions.

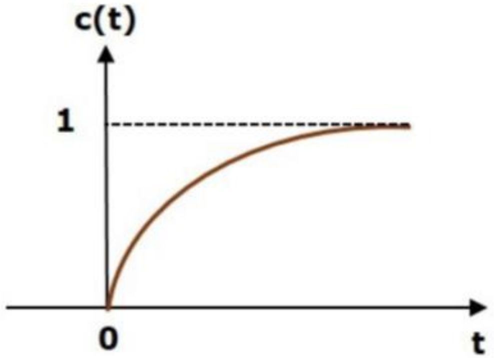
If an output is **not linear**, **but its nonlinearity is known**, the nonlinearity may be overcome by proper modeling, addition of equations, or additional electronics.

For example, suppose that a displacement sensor has an output that is varying with the sine of an angle. Then to use the sensor, the designer may divide the output by the sine of the angle, either in programming or through addition of a simple electronic circuit that divides the signal by the sine of the angle. Thus, the output will be as if the sensor were linear. (You want the angle – not the sine of the angle!)

Response time: Response time is the time that a sensor's output requires to reach a certain percentage of the total change. It is usually expressed in percentage of total change, such as 95%.

It is also defined as the time required to observe the change in output as a result of a change in input.
For example, the response time of a simple mercury thermometer is long, whereas a digital thermometer's response time, which measures temperature based on radiated heat, is short.

$$\boldsymbol{c(t) = 1 - \mathrm{A}\exp(-t/tau)}$$ **for a 1st order system**



RESPONSE TIME
About 5 time constants
To reach about 95%.

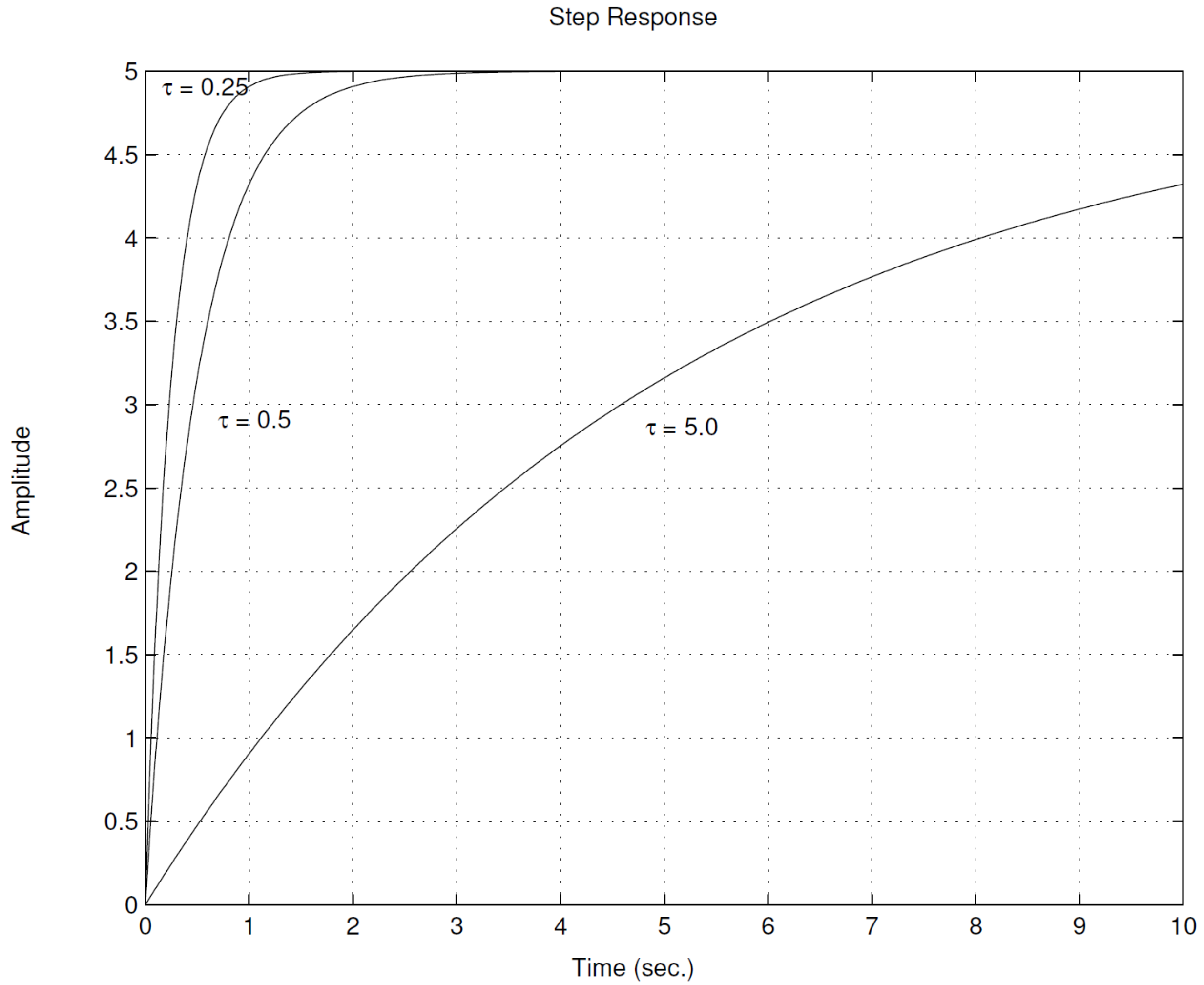


FIGURE 1.3 *Step responses*

Vary Tau - Tau = RC in an RC series circuit.

CONTROL
APPLICATIONS TLH

Frequency Response is generally inversely related to Response time.

See Resolution and Bandwidth
https://www.lionprecision.com/wp-content/uploads/2019/04/article-0010-sensor-resolution.pdf

BANDWIDTH
-3 dB

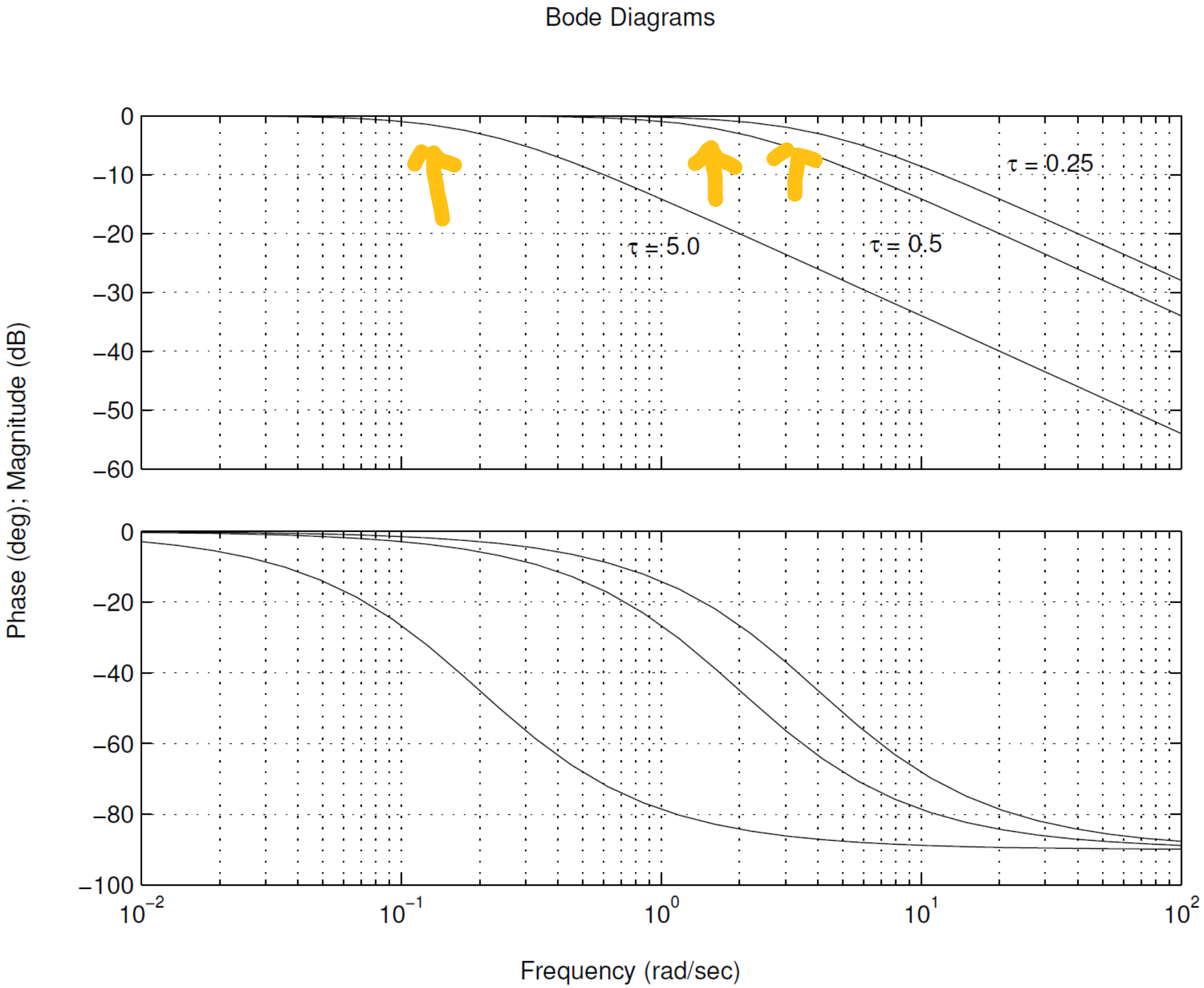


FIGURE 1.4 *Bode plots for first-order system*

Reliability: Reliability is the ratio of how many times a system operates properly divided by how many times it is tried. For continuous, satisfactory operation, it is necessary to choose reliable sensors that last a long time, while considering the cost, as well as other requirements.

MANY OTHER CHARACTERISTICS MAY BE IMPORTANT:

- Safety
- Failure Mode and Effects Analysis
- Battery Life if portable
- Environment

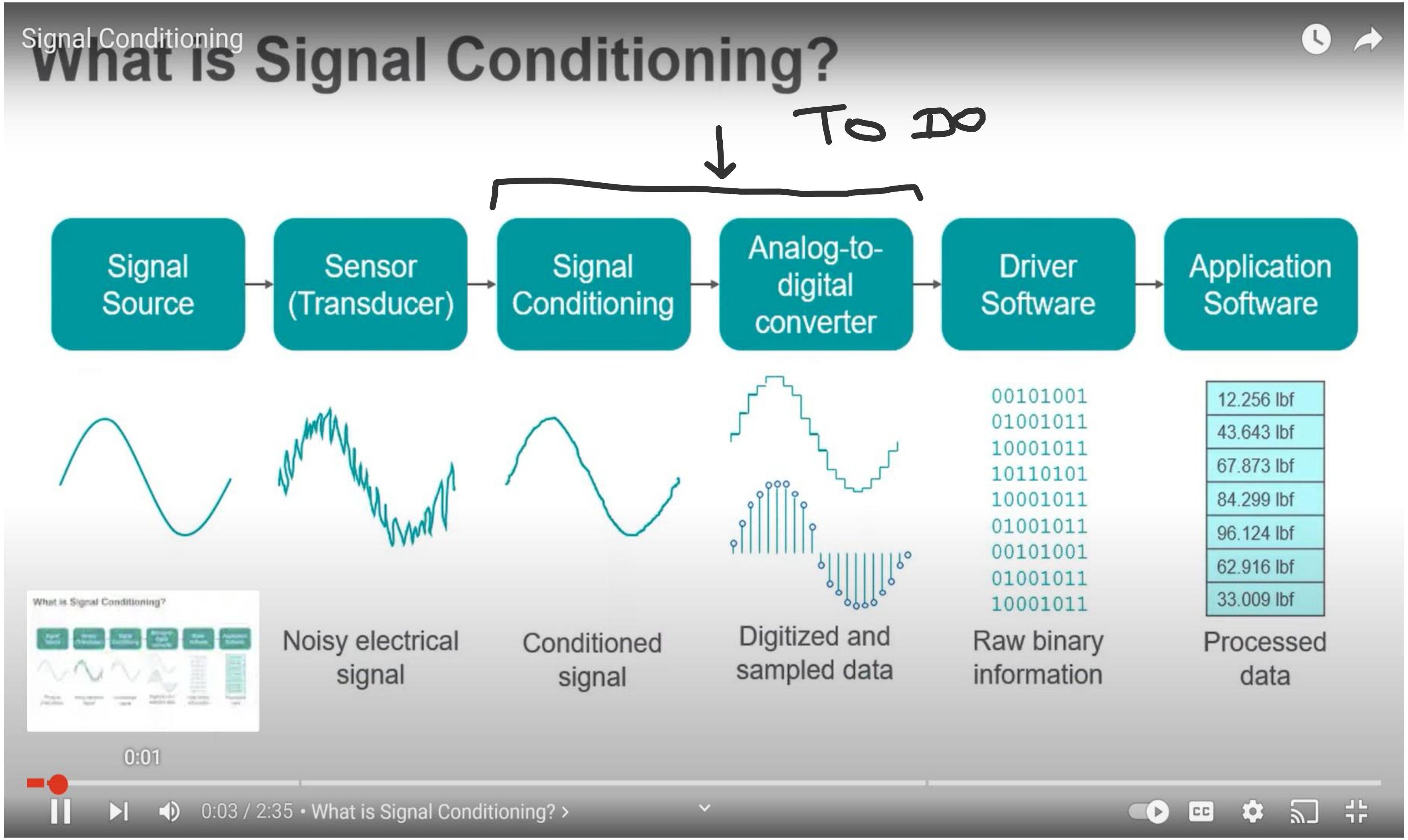
Environment – The selection of the proper sensor requires a good understanding of the environmenthttps://duotechservices.com/six-key-items-to-consider-when-selecting-a-sensor in which the instrument will be operated. Many sensors can be affected by the non-ideal conditions of a production floor (such as temperature variation, **vibration**, humidity, chemicals, etc.) It is important to take the environment into account when selecting the sensor and its packaging, mounting, and other options.

https://duotechservices.com/six-key-items-to-consider-when-selecting-a-sensor

Save Yourself a Headache

As an engineer, you WILL experienced the pain of discovering in mid-process that some component of your system doesn’t perform as you expected. By understanding **sensor resolution, its relationship to bandwidth, and the different units of measure,** you can now make confident decisions about your sensor choice.

https://www.lionprecision.com/wp-content/uploads/2019/04/article-0010-sensor-resolution.pdf



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