Sensors with nonlinearity:

In many cases, when nonlinearity cannot be ignored, the transfer function can be approximated by a multitude of linear mathematical functions;

1. Logarithmic function:

$$S = A + B \ln s$$

$$s = e^{\frac{S-A}{B}}$$

2. Exponential function:

$$S = Ae^{ks}$$

$$s = \frac{1}{k} \ln \frac{S}{A}$$

3. Power function:

$$S = A + Bs^k$$

$$s = \sqrt[k]{\frac{S-A}{B}}$$

where A, B are parameters and k is the power factor.

Polynomial Approximations:

A sensor may have such a transfer function that none of the above functional approximations would fit sufficiently well. In this case, a polynomial approximation, that is a power series, can be applied.

Example:

$$S = Ae^{ks}$$

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The above exponential function can be approximately calculated by a third order polynomial by dropping all the higher terms of its series expansion:

$$S = Ae^{ks} \approx A\left(1 + ks + \frac{k^2}{2!}s^2 + \frac{k^3}{3!}s^3\right)$$

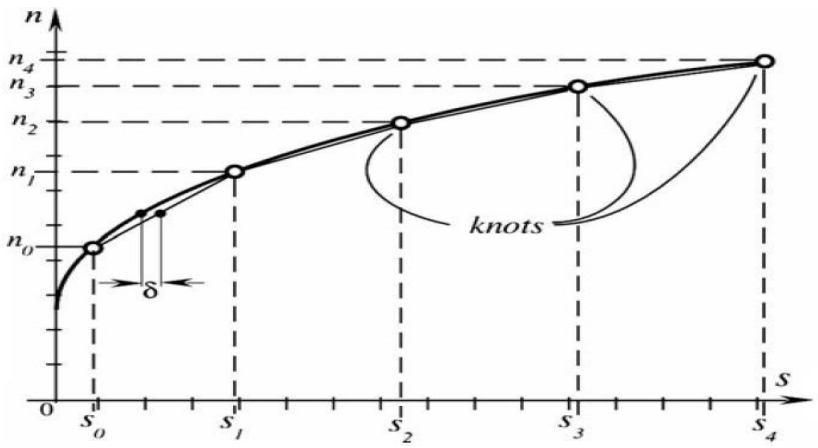
In many cases it is sufficient to investigate approximation of a sensor's response by the 2nd and 3rd degree polynomials that can be expressed as;

$$S = a_2 s^2 + b_2 s + c_2$$

$$S = a_3 s^3 + b_3 s^2 + c_3 s + d_3$$

Linear Piecewise Approximation:

➢ The idea is to break up a nonlinear transfer function of any shape into sections and consider each such section being linear. Curved segments between the sample points (knots) are replaced with straight line segments.

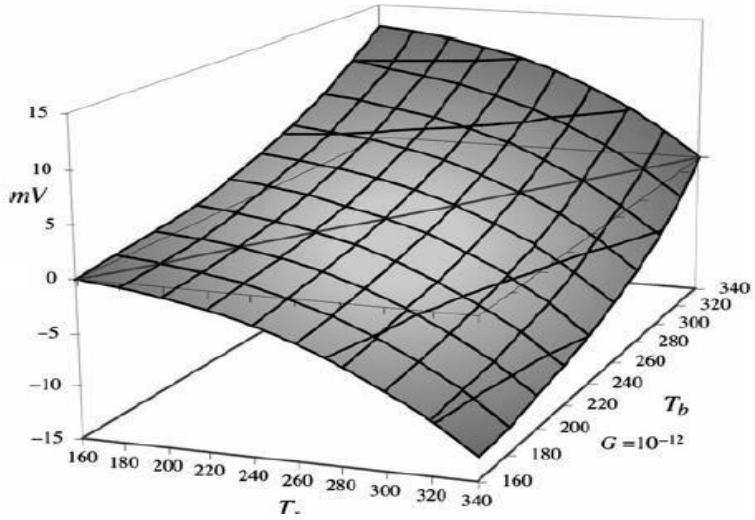


- An error of a piecewise approximation can be characterized by a maximum deviation (δ) of the approximation lines from the real curve.
- The knots do not need to be equally spaced. They should be closer to each other where a nonlinearity is high and farther apart where a nonlinearity is small.
- The spline interpolation method is using a different 3rd order polynomial interpolation between the selected experimental points called knots.

Multidimensional Transfer Functions:

A transfer function may be a function of more than one variable when the sensor's output is dependent on more than one input stimulus.

Example: Humidity sensor output depends on two input variables; relative humidity and temperature.



Example: The transfer function of a thermal radiation (infrared) sensor has two parts; the absolute Temperature (Tb), and the absolute temperature (Ts) of the sensor's surface (measured by a separate temperature sensor. The output voltage (V) is nonlinear and proportional to the difference;

$$V = G\left(T_b^4 - T_s^4\right)$$