Sensor Time Constant, Step Response and Ramp Lag

Response of a first-order sensor such as a thermocouple in a thermowell: reading after a step change, times to 63, 90, 95 and 99 %, and the lag behind a steady ramp.

Method: First-order system step and ramp response (control theory)

Input parameters

Unit system: SI

Parameter	Value	Unit
Time constant of the sensor	10.000	s
Size of the step change	100.00	K
Time after the step	30.000	s
Rate of a steady ramp	5.0000	°C/min

Calculated results

Parameter	Value	Unit
Share of the step shown at time t: 1 − e^(−t/τ)	95.021	%
Change shown by the sensor at time t	95.021	K
Error left at time t	4.9787	K
Time to 90 % of the step	23.026	s
Time to 95 %	29.957	s
Time to 99 %	46.052	s
Steady lag behind a ramp r τ	0.83333	K

Notes for this case

- First-order model: one time constant gives 63.2 % of a step. A sensor in a thermowell often behaves as two lags in series, which is slower at the start.

Formula and method

$$f = 1 - e^{-t/\tau}, \quad t_x = -\tau \ln(1 - x)$$
$$e_r = r\,\tau$$

Variables

τ	Time constant of the sensor	s
ΔT	Size of the step change	K
t	Time after the step	s
r	Rate of a steady ramp	K/s
f	Share of the step shown at time t: 1 − e^(−t/τ)	-
ΔT_r	Change shown by the sensor at time t	K
e	Error left at time t	K
t_{90}	Time to 90 % of the step	s
t_{95}	Time to 95 %	s
t_{99}	Time to 99 %	s
e_r	Steady lag behind a ramp r τ	K

Method and standards

Solution of the first-order equation τ dT_s/dt + T_s = T for a step and a ramp.

Assumptions and limits

- First-order response.

References

- First-order system step and ramp response (control theory)

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/instrumentation/temperature/sensor-time-constant-lag

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.