Faculty of Engineering
Department of Electrical & Computer Engineering (ECE)

Control Systems (ECE 331)

Experiment No: 07

"Time Domain Analysis for Control System"

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Control Systems ECE 331

Experiment 07
Time Domain Analysis for Control System

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1 Transient Response for Second Order System

Because systems that stores energy cannot respond instantaneously, they exhibit a transient response when they are subjected to inputs or disturbances. Consequently, the transient response characteristics constitute one of the most important factors in system design.

In many practical cases, the desired performance characteristics of control systems can be given in terms of transient-response specifications. Frequently, such performance characteristics are specified in terms of the transient response to unit-step input, since such an input is easy to generate and is sufficiently drastic. (If the response of a linear system to a step input is known, it is mathematically possible to compute the systems response to any input).

The transient response of a system to a unit step-input depends on initial conditions. For convenience in comparing the transient responses of various systems, it is common practice to use standard initial conditions: The system is at rest initially, with its output and all time derivatives thereof zero. Then the response characteristics can be easily compared.

1.1 Transient Response Specification

The transient response of a practical control system often exhibits damped oscillations before reaching a steady state.In specifying the transient-response characteristics of a control system to a unit-step input, it is common to name the following:

1. **Delay Time T_d:** The delay time T_d is the time needed for the response to reach half of its final value the very first time.
2. **Rise Time T_r:** The rise time T_r is the time required for the response to rise from 10% to 90%, 5% to 95%, or 0% to 100% of its final value. For underdamped second order systems, the 0% to 100% rise time normally used. For overdamped systems, the 10% to 90% rise time is common.
3. **Peak Time T_p:** The peak time T_p is the time required for the response to reach the first peak of the overshoot.
4. **Maximum (Percentage Overshoot) M_p or % Overshoot:** The maximum percentage overshoot M_p is the maximum peak value of the response curve [the curve of $c(t)$ vs. t], measured from $c(\infty)$. If $c(\infty) = 1$, the maximum percentage overshoot is $M_p \times 100\%$. If the final steady state value $c(\infty)$ of the response differs from unity, then it is common practice to use the following definition of the maximum percentage

1. Delay time, T_d
2. Rise time, T_r
3. Peak time, T_p
4. Maximum overshoot, M_p
5. Settling time, T_s

These specifications are defined next and are shown in graphically in Figure

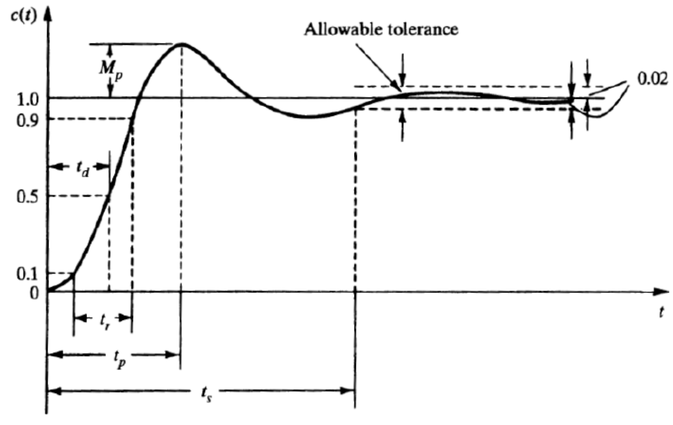

Figure Transient-response specifications.

Figure 1: Transient Response Specification

overshoot.

Maximum Percentage Overshoot $= \frac{C(t_p)-C(\infty)}{C(\infty)} \times 100\%$

5. Settling Time T_s : The settling time T_s is the time required for the response curve to reach and stay within 2% of the final value. In some cases, 5% instead of 2%, is used as the percentage of the final value. The settling time is the largest time constant of the system.

1.1.1 Comments on Transient Response Specifications:

In addition of requiring a dynamic system to be stable. i.e. its response does not increase unbounded with time (a condition that is satisfied for a second order system provided that $\xi \geq 0$), we also require the response:

- to be fast.
- does not excessively overshoot the desired value (i.e. relatively stable), and
- to reach and remain close to the desired reference value in the minimum time possible.

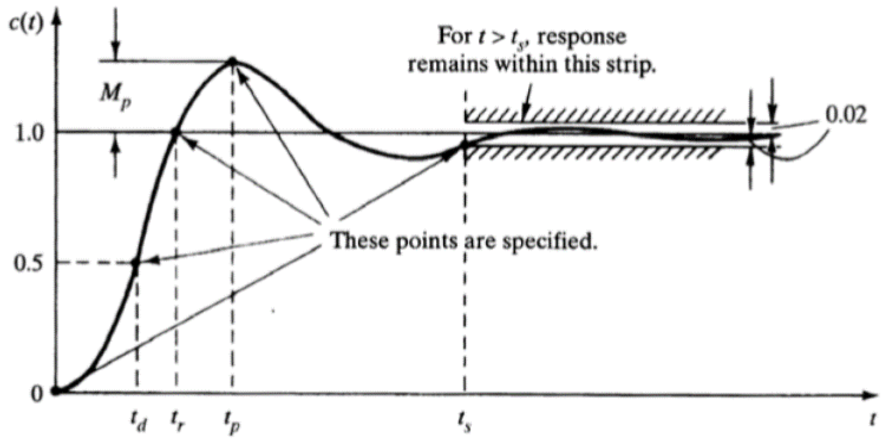

Figure 2: Standard Transient Response Specification Curve

2 Analysis using Step Response

Consider the systems having following MATLAB script file,

```
clc
clear all

sys = tf([1 5],[1 2]);
S = stepinfo(sys,'RiseTimeLimits',[0.05,0.95])
t = 0:0.01:2;
step(sys,t)
```

The answer is:

```
S =

RiseTime: 1.4722
SettlingTime: 1.9560
SettlingMin: 2.4282
SettlingMax: 2.5000
Overshoot: 0
Undershoot: 0
Peak: 2.5000
PeakTime: 5.2729
```

The graph for the same is:

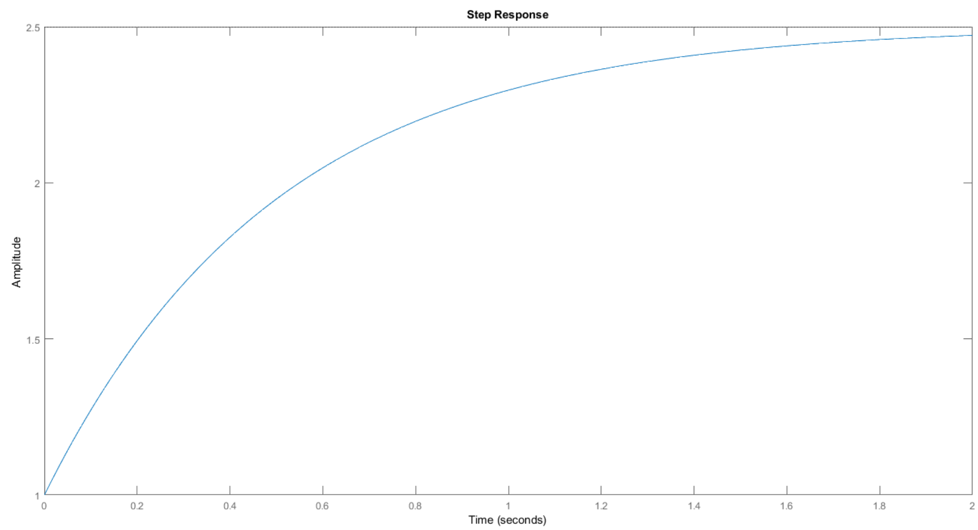

Figure 3: Step Transient Response