2.9 TIME RESPONSE ANALYSIS

- Two types of inputs can be applied to a control system
- Command Input or Reference Input $y_r(t)$
- Disturbance Input w(t)

(External disturbances w(t) are typically uncontrolled variations in the load on a control system). In systems controlling mechanical motions, load disturbances may represent forces. In voltage regulating systems, variations in electrical load area major source of disturbances.

In general, the closed loop transfer function of a system is denoted as M(s).

$$M(s)=\frac{b_0s^M+b_1s^{M-1}+b_2s^{M-2}+\ldots\ldots+b_{M-1}s+b_M}{a_0s^N+a_1s^{N-1}+a_2s^{N-2}+\ldots\ldots+a_{N-1}s+a_N}$$

EFFECT OF ADDING POLES AND ZEROS

Adding poles generally slows down a system, reduces stability (shifts root locus right), and increases oscillations, while adding zeros speeds up the response, improves stability (shifts root locus left), decreases overshoot, and increases bandwidth, effectively acting like a derivative control to anticipate errors and damp oscillations. Poles near the origin (left half-plane) slow transient response, while zeros closer to the origin dominate, making the system faster, with the magnitude and proximity to the imaginary axis being key factors.

- Slows Response: Introduces more inertia, increasing rise/settling time.
- Reduces Stability: Pulls the root locus to the right, potentially destabilizing the system.
- Increases Oscillation: Complex poles near the imaginary axis cause more ringing.
- Improves Steady-State (sometimes): Can improve steady-state error, especially if a pole is added at the origin (like in Integral Control).