Introductory Control Systems
Dominant (or Insignificant) Poles

- The ***slowest poles*** of a system (those closest to the imaginary axis in the *s*-plane) give rise to the ***longest lasting*** terms in the transient response.
- If a pole or set of poles are ***very slow compared to others*** in the transfer function, they may ***dominate*** the transient response.
- If the transient response of the system is plotted ***without accounting for*** the transient response of the ***fastest poles***, it may be found that there is ***little difference*** from the transient response of the original system. In this case, the fastest poles are called ***insignificant***.

Example: A Third Order System

Consider a third order system that has ***one real and two complex conjugate poles***.

$$T(s) = \frac{K}{(s+p)(s^2 + 2\zeta\omega_n s + \omega_n^2)}$$

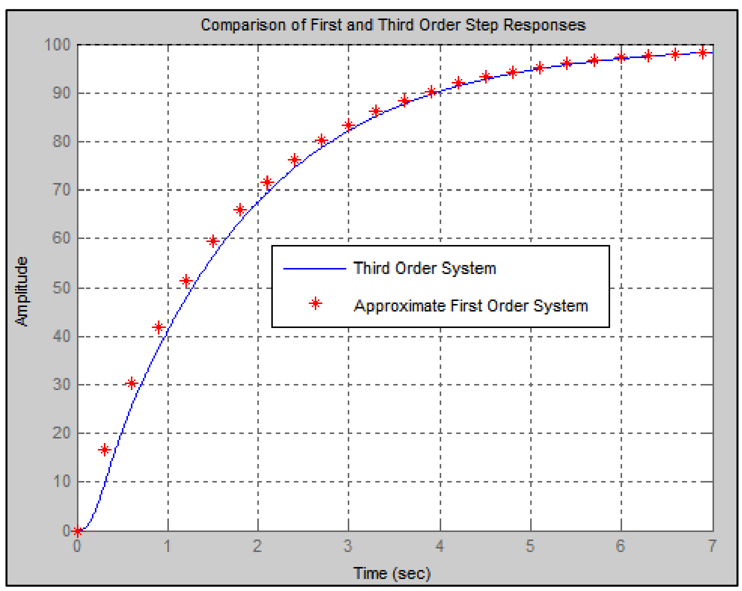
In general, all three poles contribute to the response of the system. However, some third-order systems exhibit dominant first-order or dominant second-order behavior.

Dominant First Order Behavior

If $\zeta\omega_n \geq 10p$, the system exhibits ***dominant first-order*** behavior. The ***approximate lower-order transfer function*** is

$$T(s) \approx \frac{K/\omega_n^2}{(s+p)}$$

The plot on the right shows results using $K = 6000$, $\zeta = 0.6$, $\omega_n = 10$, and $p = 0.6$.



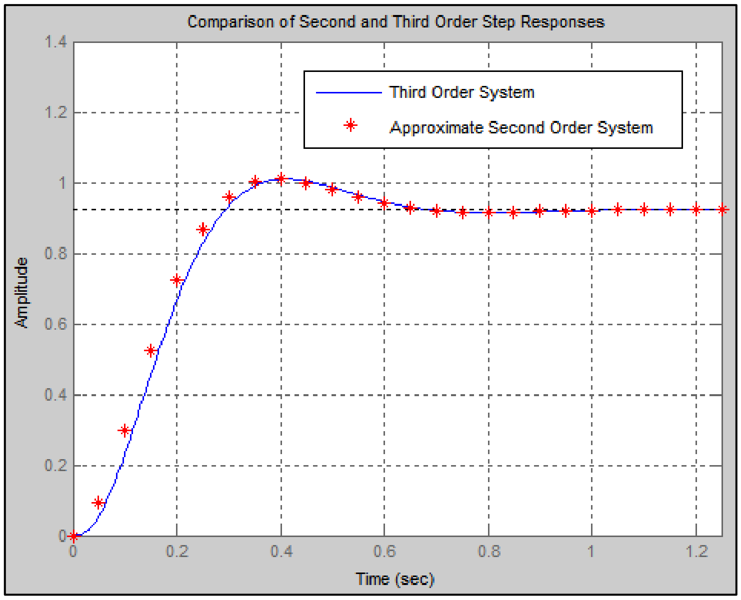
The response of the ***first-order approximation*** is ***very close*** to that of the ***third-order system***. The ***largest errors*** occur ***early*** in the response. It is important when forming the ***approximate transfer function*** to ***retain*** the ***steady-state parts*** of the insignificant poles.

Dominant Second Order Behavior

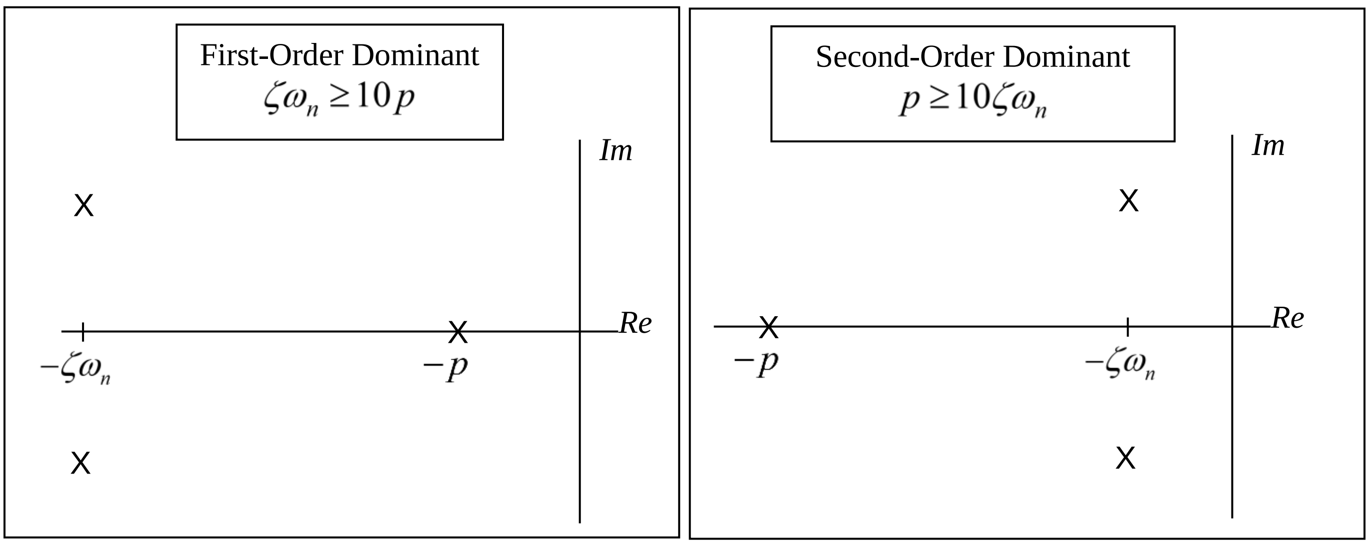
If $p \geq 10\zeta\omega_n$, the system exhibits ***dominant second-order*** behavior. The ***approximate lower order transfer function*** is

$$T(s) \approx \frac{K/p}{(s^2 + 2\zeta\omega_n s + \omega_n^2)}$$

The plot on the right shows results using $K = 6000$, $\zeta = 0.6$, $\omega_n = 10$, and $p = 65$.



In this case, the response of the ***second-order approximation*** is ***very close*** to that of the ***third-order system***. As before, the ***largest errors*** occur ***early*** in the response.



Notes:

- The concept of ***pole dominance*** can also be applied to ***higher-order*** systems. If a pole or set of poles are much closer to the imaginary axis than all other poles in the system, they may dominate the transient response. Having knowledge of the ***physical origin*** of these poles allows the analyst to focus on controlling the most important (dominant) parts of the system.
- The ***simplest approach*** for generating an approximate transfer function is to simply "drop" the ***s-dependence*** of the ***insignificant*** poles. The constant parts of these terms are kept, maintaining the correct steady-state response.