# *Time Domain Specifications*

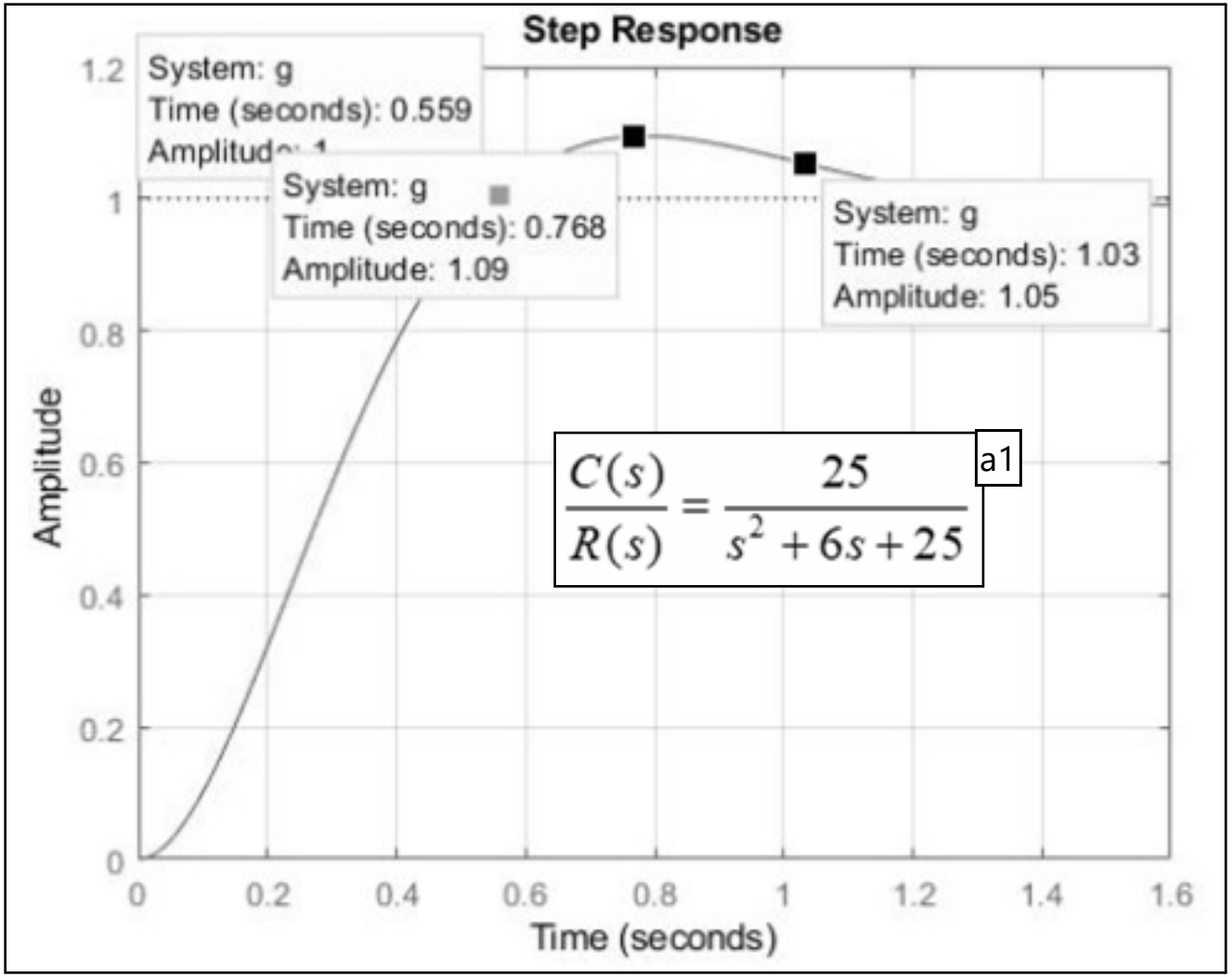
For a closed loop **2nd order** transfer function having a peak overshoot of **9.5%** and settling time (5%) of **1 sec**, determine the **rise** time and **peak** time and **verify** these.

$$M_p = 0.095 = e^{-\pi\zeta/\sqrt{1-\zeta^2}} \rightarrow \frac{\zeta}{\sqrt{1-\zeta^2}} = 0.749$$

$$\zeta = 0.6; \quad T_s(5\%) = 1 = \frac{3}{\sigma} \rightarrow \sigma = 3; \quad \omega_n = 5.0$$

$$\omega_d = 4.0; \quad T_p = \frac{\pi}{\omega_d} = 0.78s; \quad T_r = \frac{1}{\omega_d}\tan^{-1}\left(\frac{\omega_d}{-\sigma}\right) = 0.55s$$

# *Verification with MATLAB*



## Slide 2

**a1** admin, 07-10-2019

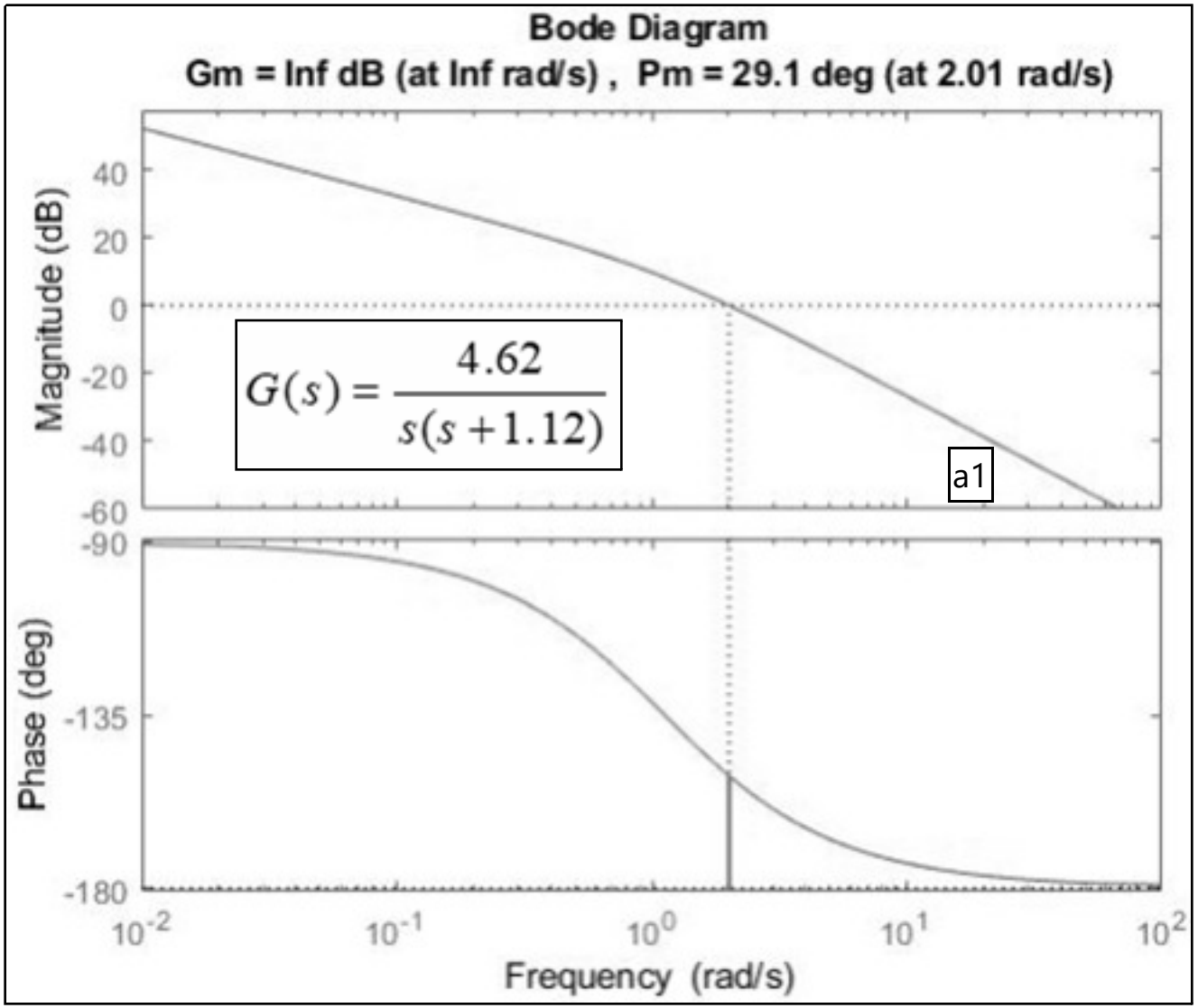
# *PM & GCO Specifications*

A **closed loop** system needs to have a **PM of 30$^o$** at a GCO of **2 rad/s**. Determine corresponding closed loop **transfer function** and time domain **response** features.

$$PM^\circ = 30 \rightarrow \zeta \approx 0.3(0.26); \quad \omega_{GCO} = 2 = \omega_n \sqrt{\sqrt{1+4\zeta^4} - 2\zeta^2}$$

$$\omega_n = 2.15; \quad \sigma = 0.56; \quad \frac{C(s)}{R(s)} = \frac{4.62}{s^2 + 1.12s + 4.62}$$

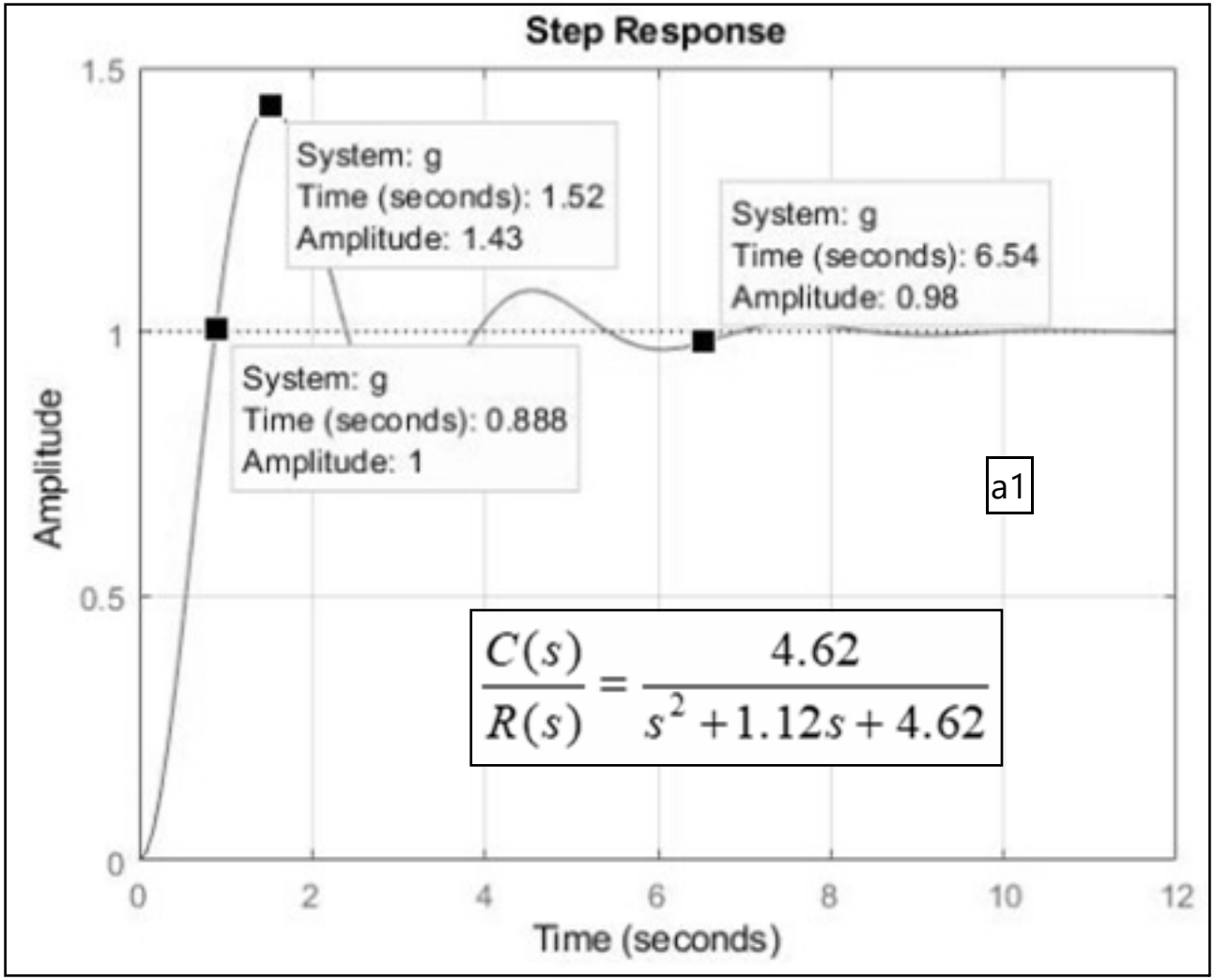
# *Verification with MATLAB*



## Slide 4

**a1** admin, 07-10-2019

# *Verification with MATLAB*



## Slide 5

**a1** admin, 07-10-2019

# *Resonant Peak & Bandwidth*

Consider a closed loop system with $\mathbf{M_r}$ of 2 dB and **bandwidth** of 3 rad/s. **Determine** the peak overshoot, settling time (2%), **including** GCO and PM.

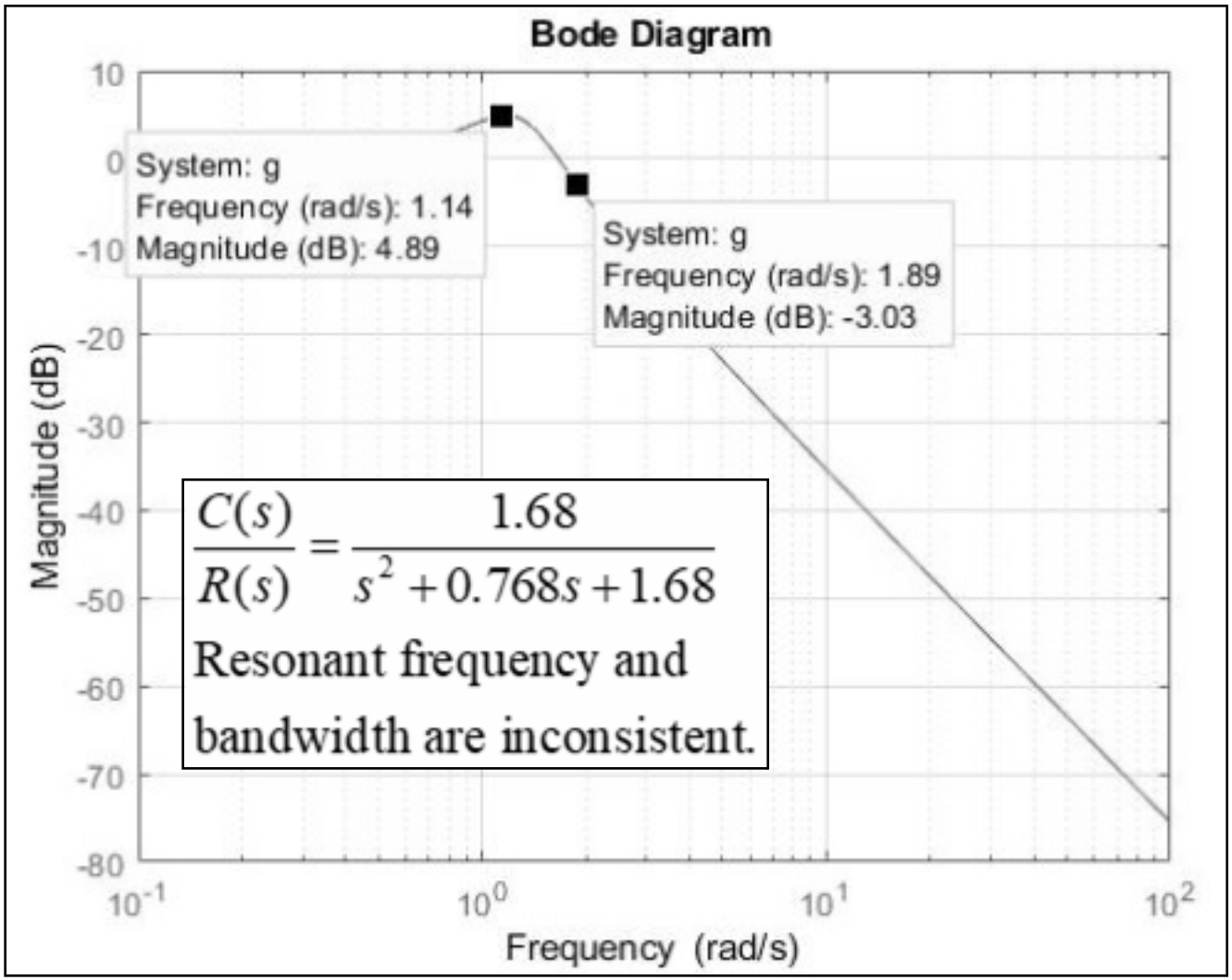
$$M_r = 2dB = 1.26 = \frac{1}{2\zeta\sqrt{1-\zeta^2}} \rightarrow \zeta = 0.196; \quad \omega_r = 1.88$$

$$\omega_b = 3 = \omega_n\sqrt{\sqrt{\left(1-2\zeta^2\right)^2+1}+\left(1-2\zeta^2\right)} \rightarrow \omega_n = 1.96$$

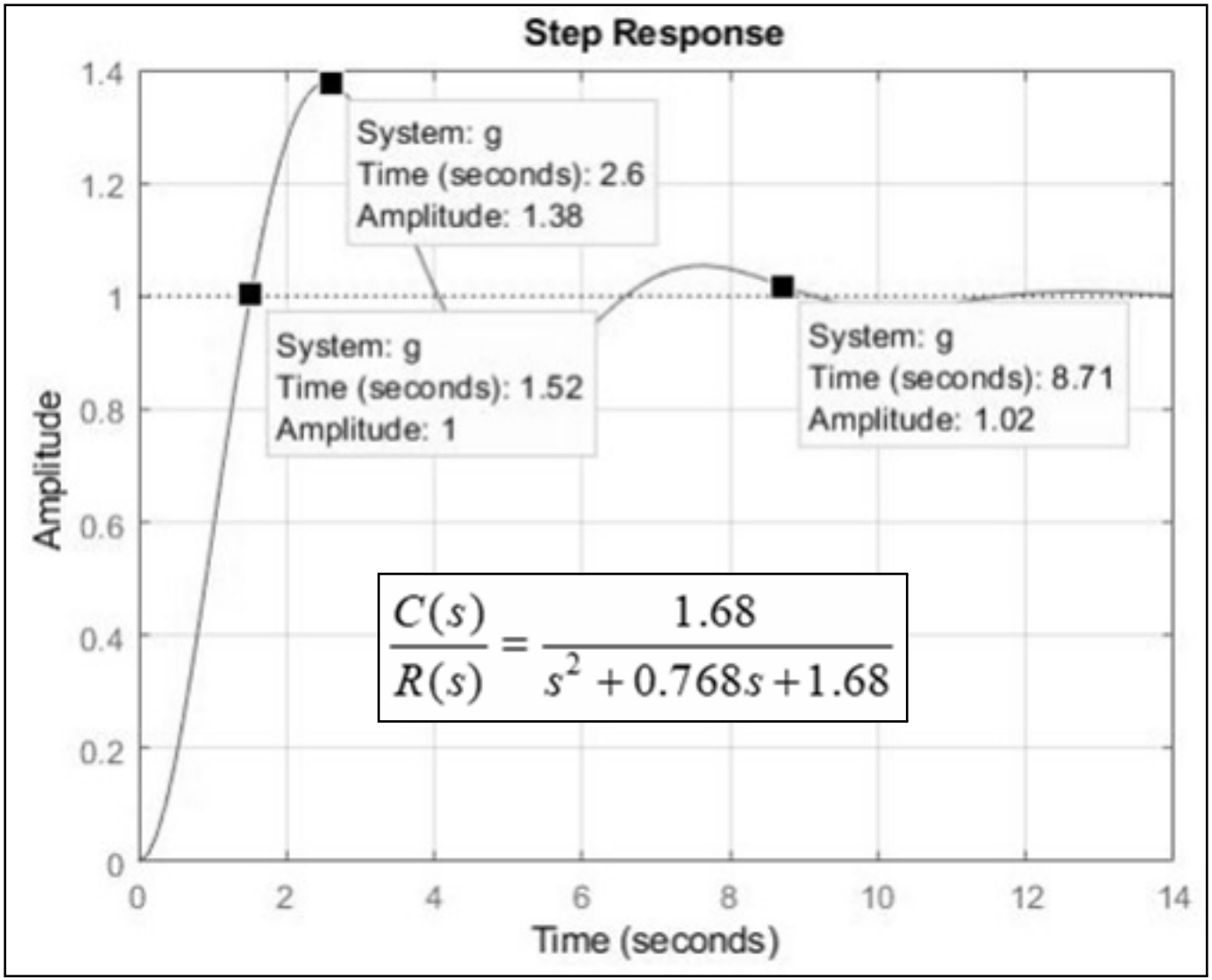
$$\sigma = 0.384; \quad \omega_d = 1.92; \quad M_p = 0.53(53\%); \quad T_s = \frac{4}{\sigma} = 10.4s$$

$$PM \approx 19.6^o; \quad \omega_{GCO} = \omega_n\sqrt{\sqrt{1+4\zeta^4}-2\zeta^2} = 1.29$$

# *Verification with MATLAB*



# *Verification with MATLAB*



# *Verification with MATLAB*