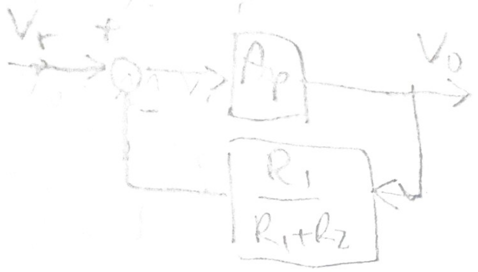
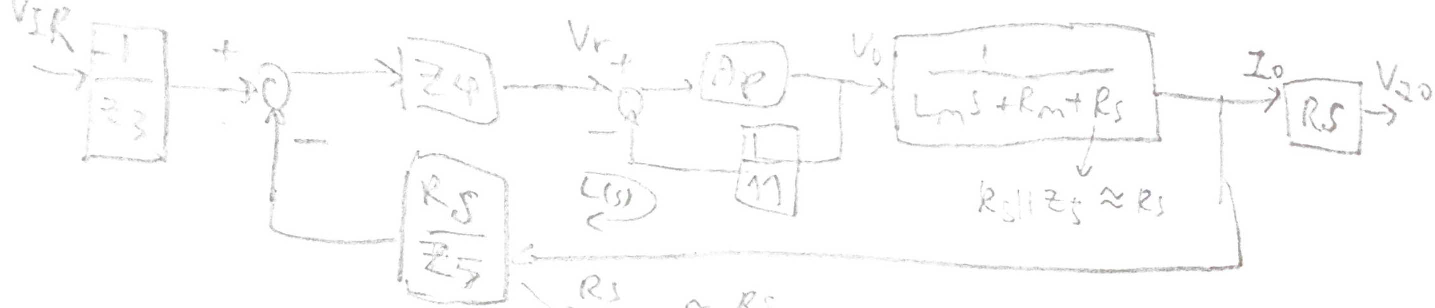
1.



$$\frac{R_1}{R_1+R_2} = \frac{1}{11}$$

2.



$$\frac{R_S}{Z_5+R_S} \approx \frac{R_S}{R_S}$$

Assume $Z_5 \gg R_S$

$R_m = 3$

$L_m = 10^{-3}$

$R_S = 0.2$

3. Conditions:

$c(\infty) = 0$

DC Gain $= 0.2$ V/V

BW > 5 KHz

$\phi_m > 60°$

→ Assume $L(j\omega)\Big|_{\omega\to 0} \to \infty$, $\dfrac{I_o}{V_{Ir}}\Big|_{\omega=0} = \dfrac{-1}{Z_3}\dfrac{Z_5}{R_S} = 0.2$

$R_S = 0.2$ → Pick Z_5 so $Z_5 >> R_S$ → $Z_5 = 1k\Omega = R_5$

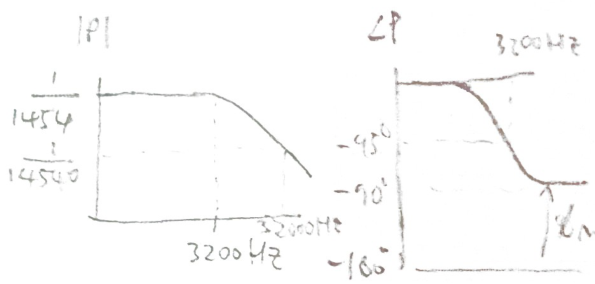
Pick Z_3 such that $\dfrac{1}{Z_3}\dfrac{Z_5}{R_S} = 1$ → $Z_3 = 5k\Omega$

$$\rightarrow L(s) = \underbrace{Z_4}_{\substack{\text{Compensator}\\ C(s)}} \underbrace{T_P (11) \frac{1}{L_m s + R_m + R_s}\left(\frac{R_S}{R_5}\right)}_{P(s)}$$

Assume $T_p = 1$ up till very high frequency

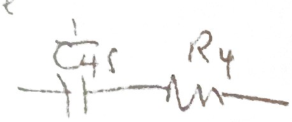
$$\rightarrow P(s) = \cancel{T_P}(11)\left(\frac{1}{10^{-3}s + 3.2}\right)\left(\frac{0.2}{1000}\right)$$

$$= \frac{6.875\times10^{-4}}{\frac{s}{3200}+1} = \frac{1/1454}{\frac{s}{3200}+1}$$



$$\rightarrow C(s) = K_p\left(1 + \frac{\omega_n}{s}\right) = R_4\left(1 + \frac{1}{R_4 C_4 s}\right) = Z_4$$

Pick this for compensator to compensate slope



→ Pick crossover frequency such that $\phi_m > 60°$

pick $\phi_m = 90°$ → $\omega_c = 3200\ Hz$

→ At $\omega = \omega_c$, $|L(j\omega)| = 1$, so we specify K_p

$$R_4\left(\frac{1}{14540}\right) = 1 \Rightarrow R_4 = 14540\,\Omega$$

→ specify ω_n of controller to introduce integral action

$$3200\ Hz = \frac{1}{R_4 C_4} \rightarrow C_4 = \frac{1}{14540(3200)} = 2.15 \times 10^{-8}\ F$$

→ since $e(\infty) = 0$ & step input → $V_{IR}(s) = \frac{1}{s}$

$$e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s\left(\frac{1}{s}\right)\frac{(-1/Z_3)}{1+G(s)}$$

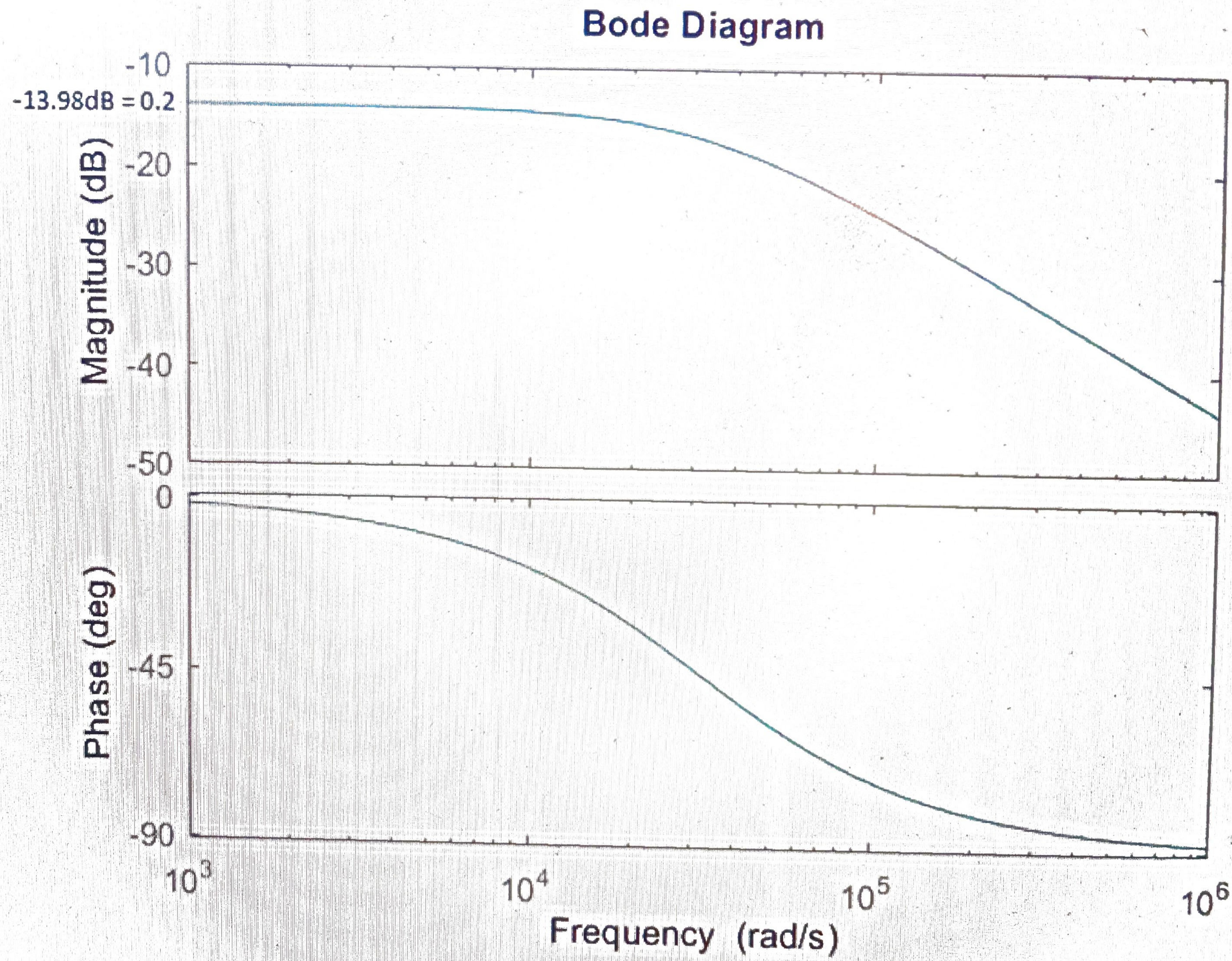
$$= \frac{-1/Z_3}{1+\lim_{s\to 0} G(s)} \quad \text{where} \quad G(s) = \frac{L(s)\left(\frac{R_5}{R_5}\right)}{1+L(s)-B(s)\left(\frac{R_5}{R_5}\right)}$$

Since we've set values such that $L(j\omega)\Big|_{\omega\to 0} = \infty$,

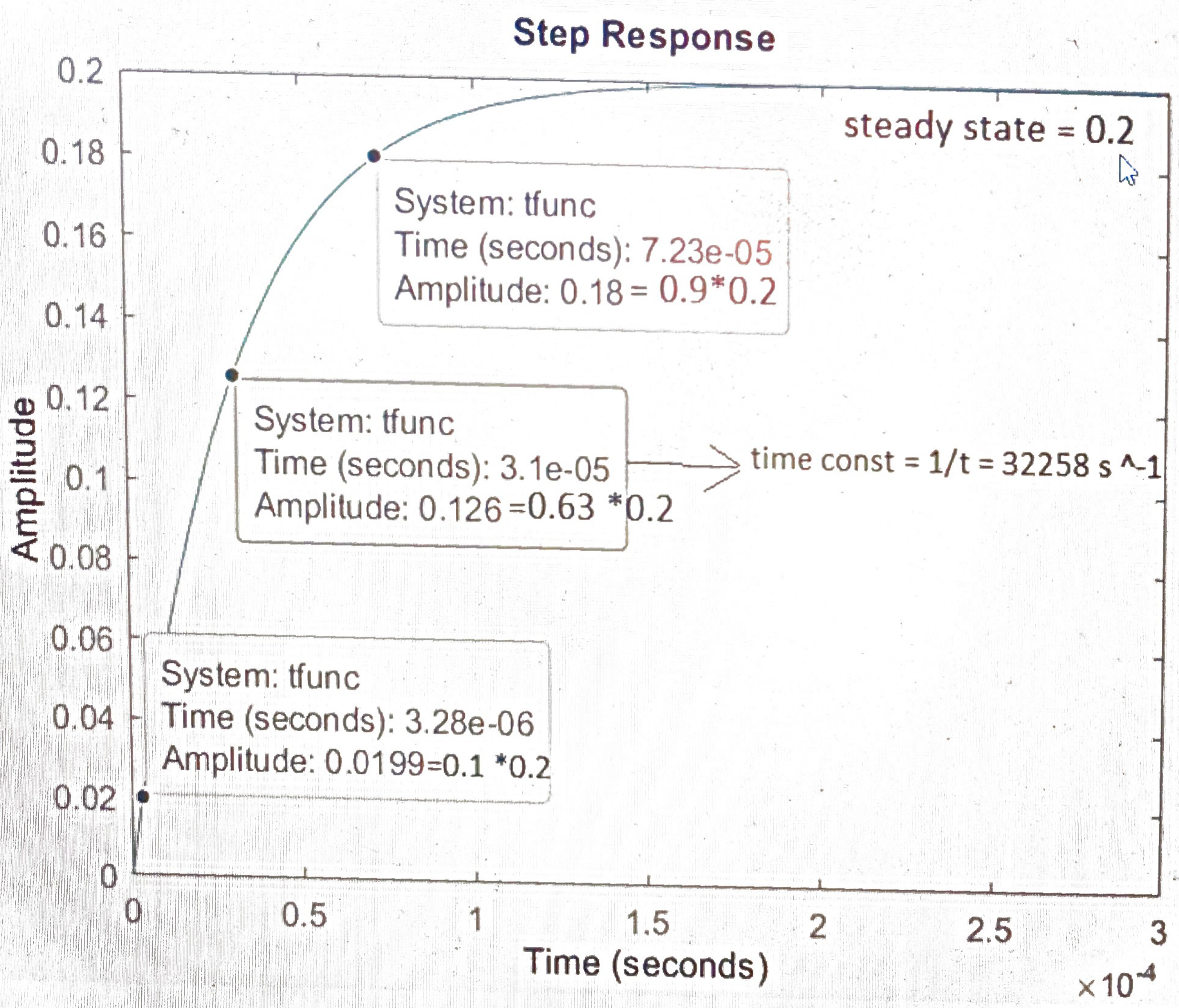
we can easily say that $\lim_{s\to 0} G(s) = \infty$

and since $e(\infty) = \dfrac{-1/Z_3}{1+\lim_{s\to 0} G(s)}$

therefore $e(\infty) = \dfrac{x}{1+\infty} = 0$



Bode Diagram
-10
-13.98dB = 0.2
-20
-30
-40
-50
Magnitude (dB)
0
-45
-90
Phase (deg)
10^3
10^4
10^5
10^6
Frequency (rad/s)



Step Response
steady state = 0.2
System: tfunc
Time (seconds): 7.23e-05
Amplitude: 0.18 = 0.9*0.2
System: tfunc
Time (seconds): 3.1e-05
Amplitude: 0.126 =0.63 *0.2
time const = 1/t = 32258 s ^-1
System: tfunc
Time (seconds): 3.28e-06
Amplitude: 0.0199=0.1 *0.2
Amplitude
Time (seconds)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
×10^-4