1) $S_r(s) = \frac{200}{(s)(s+2)(s+50)}$ $\quad \lim_{t\to\infty} s_r(t) = \lim_{s\to 0} sS_r(s) = 2$

DOMINANT POLE AT -2, $T_s \approx \frac{4}{2} = 2$ sec ; POLE AT -50 FAR AWAY!

2) $T = \frac{G}{1+G} = \frac{\frac{5}{s+4}}{1+\frac{5}{s+4}} = \frac{5}{s+9}$

$S_r(s) = \frac{5}{(s)(s+9)}$ $\quad \lim_{t\to\infty} s_r(t) = \lim_{s\to 0} sS_r(s) = \frac{5}{9}$

DOMINANT POLE AT -9, $T_s \approx \frac{4}{9}$

3) $\omega_n = \sqrt{35} = 5.916$ $\quad 2\zeta\omega_n = 4$, $\zeta = 0.3381$

$c_{step}(\infty) = \lim_{s\to 0} s\left(\frac{T}{s}\right) = \frac{25}{35} = 0.7143$ $\quad T_s = \frac{4}{\zeta\omega_n} = \frac{8}{2\zeta\omega_n} = \frac{8}{4} = 2$ $\quad \%OS = \exp(-\zeta\pi/\sqrt{1-\zeta^2}) \times 100\% = 32.35\%$

$\omega_n = 5.916$ rad/s $\quad \zeta = 0.3381$ $\quad \omega_d = \omega_n\sqrt{1-\zeta^2} = 5.568$ rad/s

4) $T = \frac{G}{1+G} = \frac{35}{s^2+s+40}$ $\quad \omega_n = \sqrt{40} = 6.325$ $\quad 2\zeta\omega_n = 1$ $\quad \zeta = \frac{1}{2\omega_n} = 0.07906$

$c_{step}(\infty) = \lim_{s\to 0} s\left(\frac{T}{s}\right) = \frac{35}{40} = 0.875$ $\quad T_s = \frac{8}{2\zeta\omega_n} = 8$ sec $\quad \%OS = \exp(-\zeta\pi/\sqrt{1-\zeta^2}) \times 100\% = 77.95\%$

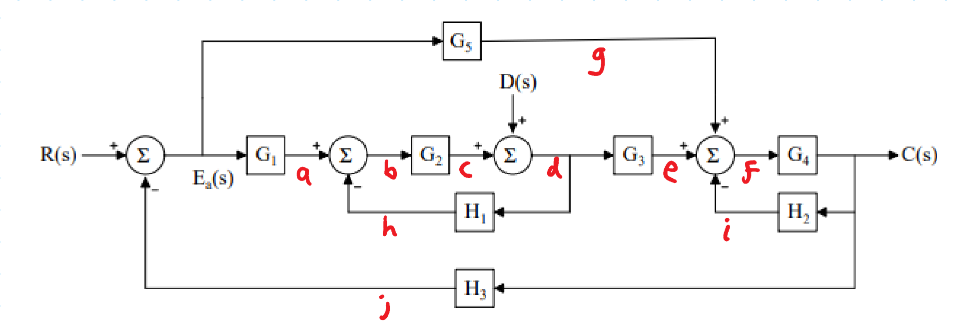
$\omega_n = 6.325$ rad/s $\quad \zeta = 0.07906$ $\quad \omega_d = \omega_n\sqrt{1-\zeta^2} = 6.305$ rad/s

5) $c_{step}(\infty) = 0.8$ $\quad T_s = 5$ sec $\quad \%OS = 10\%$

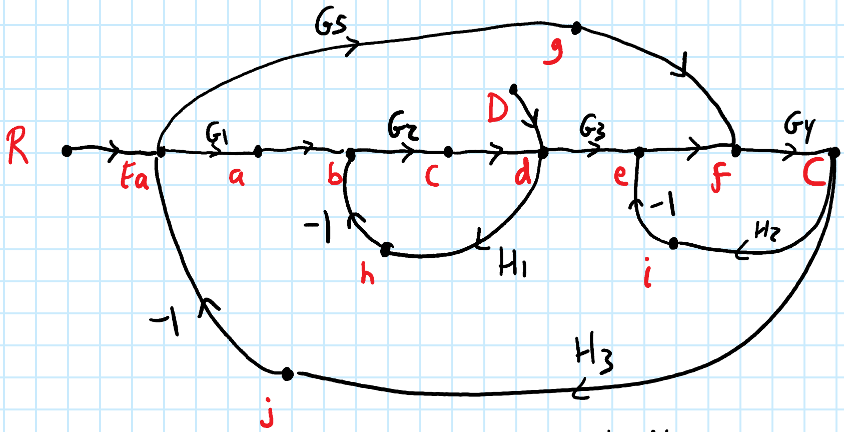
$\zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}} = 0.5912$ $\quad T_s = \frac{4}{\zeta\omega_n}$ $\quad \omega_n = \frac{4}{(5)(.5912)} = 1.353$ $\quad \omega_d = \omega_n\sqrt{1-\zeta^2} = 1.0914$

$s = -\zeta\omega_n \pm j\omega_d = -0.8 \pm j1.0914$

2



(1)



(2) $R \to C$ $\quad T_1: 1\, E_a\, a\, b\, c\, d\, e\, f\, C = G_1G_2G_3G_4 \quad L_1: bcdhb = -G_2H_1 \quad L_3 = E_a abcdefCjE_a = -G_1G_2G_3G_4H_3$

$T_2: RE_a gfC = G_4G_5 \quad L_2: efCie = -G_4H_2 \quad L_4: E_a gfCjE_a = -G_4G_5H_3$

$\Delta = 1 - L_1 - L_2 - L_3 - L_4 + L_1L_2 + L_1L_4 \qquad \Delta_1 = 1 \qquad \Delta_2 = 1 - L_1$

$$\frac{C}{R} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

(3) $D \to E_a$: $\quad T_1 = DefCjE_a = -G_3G_4H_3 \qquad L_i$ & Δ SAME AS ABOVE

$\Delta_1 = 1 \qquad \frac{E_a}{D} = \frac{T_1\Delta_1}{\Delta}$

(1)

s^3	b	d	$b>0$
s^2	c	e	$c>0$
s^1	$\frac{be-cd}{-c}$		if $c>0$, $cd>be$
s^0	e		$e>0$

MARGINAL: i) $e=0$ & $b,c,d>0$: POLE AT 0

ii) $b,c,e>0$ & $be=cd$: POLES AT $\pm j\sqrt{e/c}$

iii) $b,d>0$ $c=e=0$: POLES AT $0, \pm j\sqrt{d/b}$

(2) POLE-ZERO CANCELLATIONS OR THINGS LIKE $d=0$...

(3)

$$T = \frac{G}{1+G(1)} = \frac{K(s+4)}{s^4+14s^3+56s^2+(34+K)s+4K-105} \quad \text{USING } \frac{N}{D+N}$$

	s^4	1	56	$4K-105$
	s^3	14	$34+K$	
$K<750$	s^2	$\frac{750-K}{14}$	$4K-105$	
	s^1			
$K>26.25$	s^0	$4K-105$		

$$\frac{(1)(34+K)-(14)(56)}{-14} = \frac{750-K}{14}$$

$$\frac{(14)(4K-105) - \frac{(750-K)(34+K)}{14}}{-\left(\frac{750-K}{14}\right)} \times 14$$

$$(14)(14)(4K-105) - (750-K)(34+K) < 0$$

$$784K - 20580 - 25500 - 750K + 34K + K^2 < 0$$

$$K^2 + 68K - 46080 < 0$$

ROOTS: $\frac{-68 \pm \sqrt{68^2 - 4\cdot(-46080)}}{2}$

$$\frac{-68 \pm \sqrt{4624 + 184320}}{2} = -34 \pm 217.34$$

$K = 183.34, -251.34$

$$(K+251.34)(K-183.34) < 0$$

$$-251.34 < K < 183.34$$

MOST RESTRICTIVE

$\boxed{26.25 < K < 183.34}$

(b) $K = 26.25$ POLE AT 0

$K = 183.34 \rightarrow 40.48s^2 + 628.36 = 0$, $s = \pm j3.94$ rad/s

(c) TYPE 0 $\quad K_p = \lim_{s\to 0} G = \frac{-4K}{105} \quad e_{step} = \frac{1}{1+K_p} = \boxed{\frac{105}{105-4K}}$

$$G = \frac{s^2 - 2s + 5}{s^3 + 6s^2 + 8s} \qquad T = \frac{KG}{1 + KG} = \frac{K(s^2 - 2s + 5)}{s^3 + (6+K)s^2 + (8-2K)s + 5K}$$

(1) MARGINAL GIVEN s IN DENOMINATOR ;
NOTE: STEP RESPONSE IS UNBOUNDED!

(2)

	s^3	1	$8-2K$
$K > -6$	s^2	$6+K$	$5K$
	s^1	$\longrightarrow$	
$K > 0$	s^0	$5K$	

$$\frac{(1)(5K) - (6+K)(8-2K)}{-(6+K)}$$ ← K>-6 FROM s^2 LINE; SO:

$$5K - 48 + 12K - 8K + 2K^2 < 0$$

$$2K^2 + 9K - 48 < 0$$

$$K = \frac{-9 \pm \sqrt{81 - (4)(2)(-48)}}{(2)(2)}$$

$$= \frac{-9 \pm 21.56}{4} = -7.64 \ , 3.14$$

$$(K + 7.64)(K - 3.14) < 0$$

$$-7.64 < K < 3.14$$

$$\boxed{0 < K < 3.14}$$

(3) TYPE 1

(4) K_v , ramp

(5) $K_v = \lim_{s \to 0} sG(K) = \frac{5K}{8}$

(6) $K = 3.14 \rightarrow K_v = 1.9625 \quad e_{ramp} = \frac{1}{K_v} = \underline{0.5096}$

(7) (a) $-0.421 \pm j0.797$

(b) UNDERDAMPED → COMPLEX POLES W/ NEGATIVE REAL PARTS

$$T = \frac{K(s+5)}{s^3 + 8s^2 + (K-15)s + 5K - 54} \qquad G_{eq} = \frac{T}{1-T} = \frac{K(s+5)}{s^3 + 8s^2 - 15s - 54}$$

(1)

	s^3	1	$K-15$
	s^2	8	$5K-54$
$K > 22$	s^1		
$K > 10.8$	s^0	$5K-54$	

$$\frac{(5K-54)-(8)(K-15)}{-8} > 0$$

FLIP > TO < FOR X -8

$$5K - 54 - 8K + 120 < 0$$

$$-3K + 66 < 0$$

$$K > 22$$

(2) TYPE 0

(3) K_p , STEP

(4) $K_p = \lim_{s \to 0} G = \frac{-5K}{54}$ $\qquad e_{step} = \frac{1}{1+K_p} = \frac{54}{54 - 5K}$

(5) $K = 22$; (6) $8s^2 + 56 = 0$ $\quad s = \pm j\sqrt{7} = \pm j\,2.646$ rad/sec