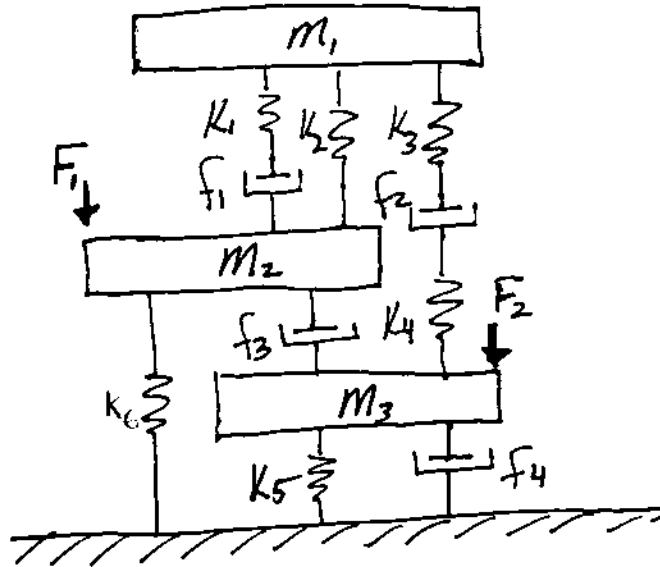
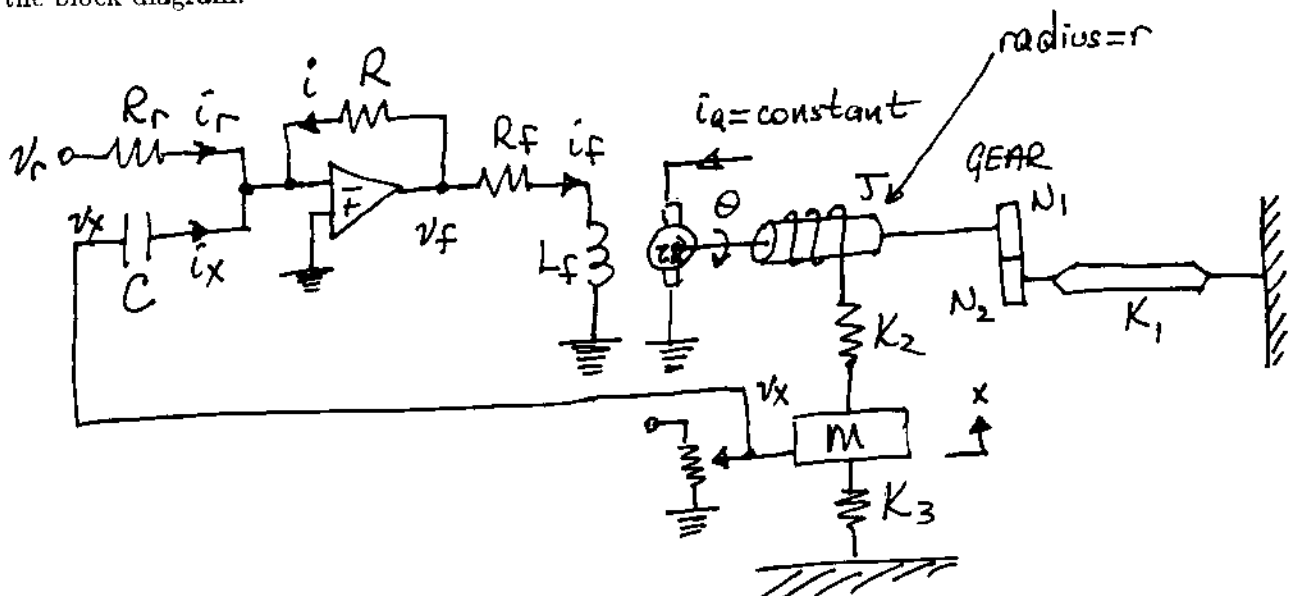


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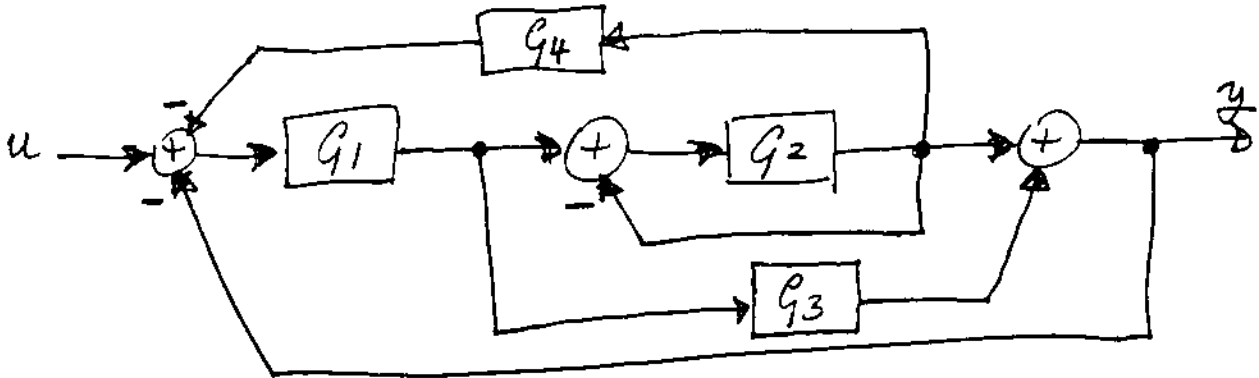
- For the mechanical system shown below, obtain *either* the force-voltage *or* the force-current analog of the system. (25pts)



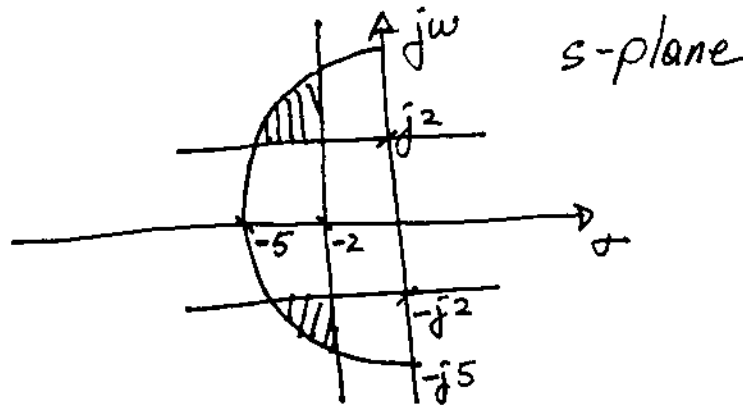
- In the following system, the location of a mass is controlled by a motor control system. Assuming that the input and the output are v_r and x , respectively, and the voltage from the variable resistor is linearly related to the location of the mass, such that $v_x = k_x x$; obtain a detailed block diagram of the system without reducing or combining the equations, and show the variables v_r , i_r , v_x , i_x , i , v_f , i_f , τ , θ , and x on the block diagram. (30pts)



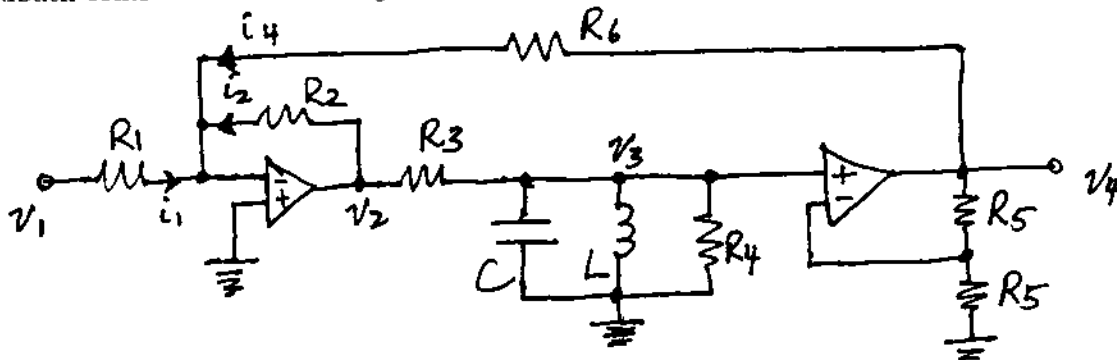
3. For the block diagram given below, determine the transfer function *either* by block diagram reduction, *or* by Mason's formula. Show your work clearly. (25pts)



4. Obtain the necessary inequalities to describe the poles in the shaded region below in terms of only ζ and ω_n of a second-order system described by $Y(s)/U(s) = \omega_n^2 / (s^2 + 2\zeta\omega_n s + \omega_n^2)$. (20pts)



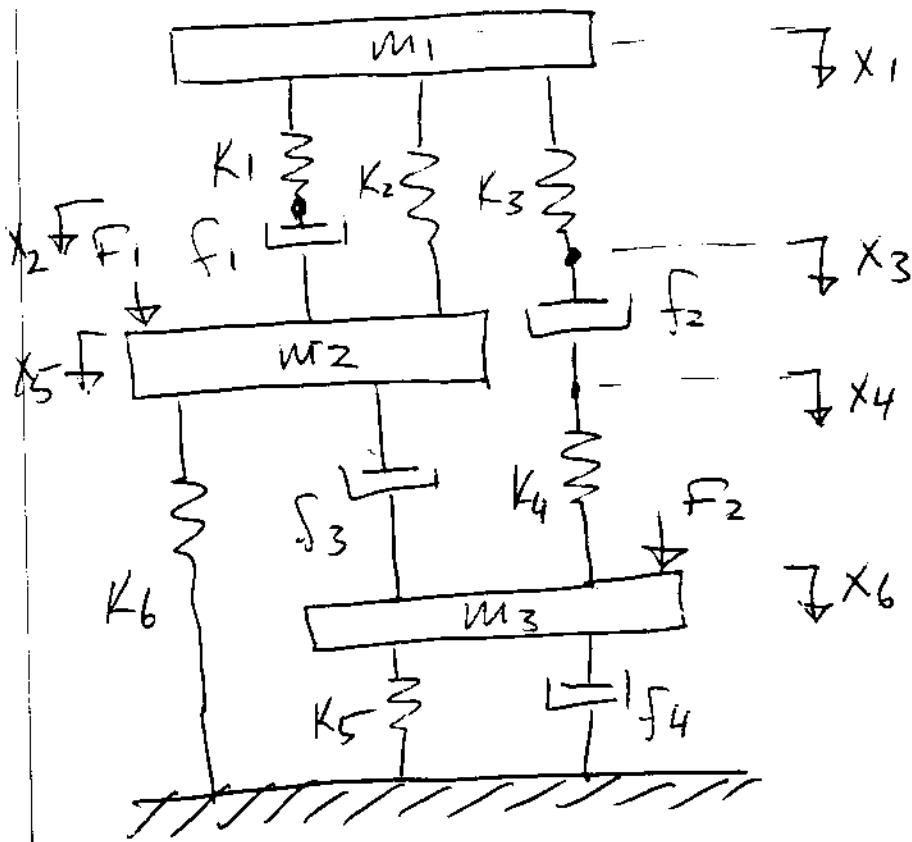
5. A feedback controller is to be designed for the following circuit.



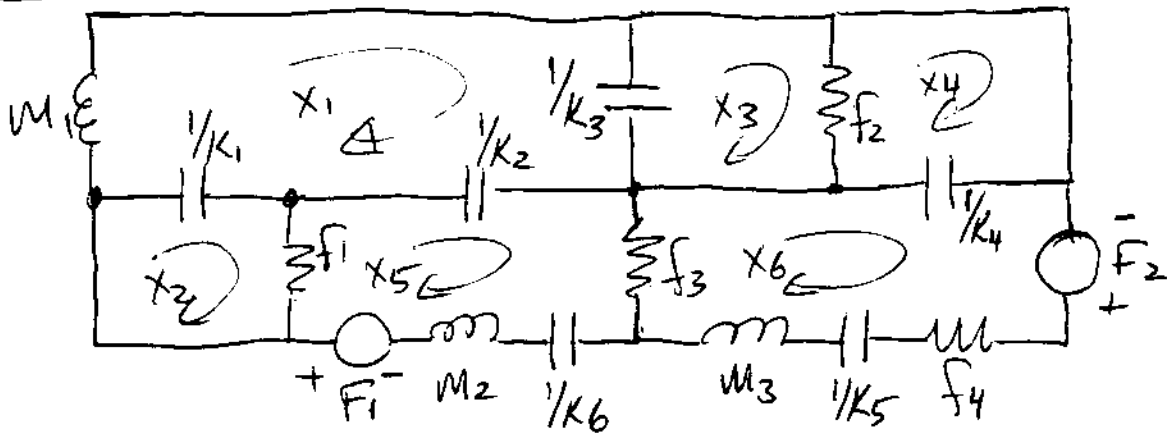
- (a) First, determine its block diagram, such that the variables v_1 , i_1 , i_2 , v_2 , v_3 , and v_4 are clearly shown. Then, obtain its transfer function from the block diagram, where v_1 is the input, and v_4 is the output. (+25pts)
- (b) Assuming that $R_1 = 5\Omega$, $R_3 = 2\Omega$, $R_4 = 4\Omega$, $R_5 = 1\Omega$, $R_6 = 5\Omega$, $L = 4\text{H}$, and $C = 1\text{F}$; design for R_2 , such that the $t_{5\%s} \approx 40/3\text{s}$. (+15pts)

#1

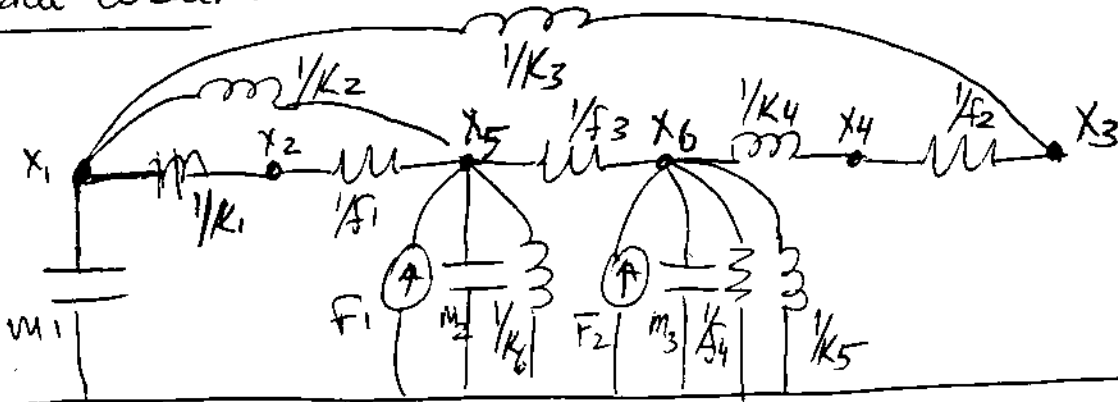
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FORCE-VOLTAGE

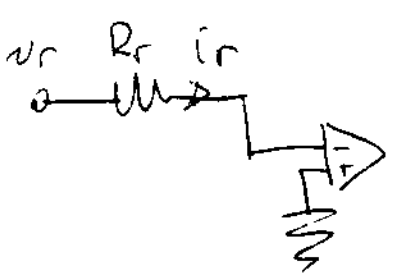
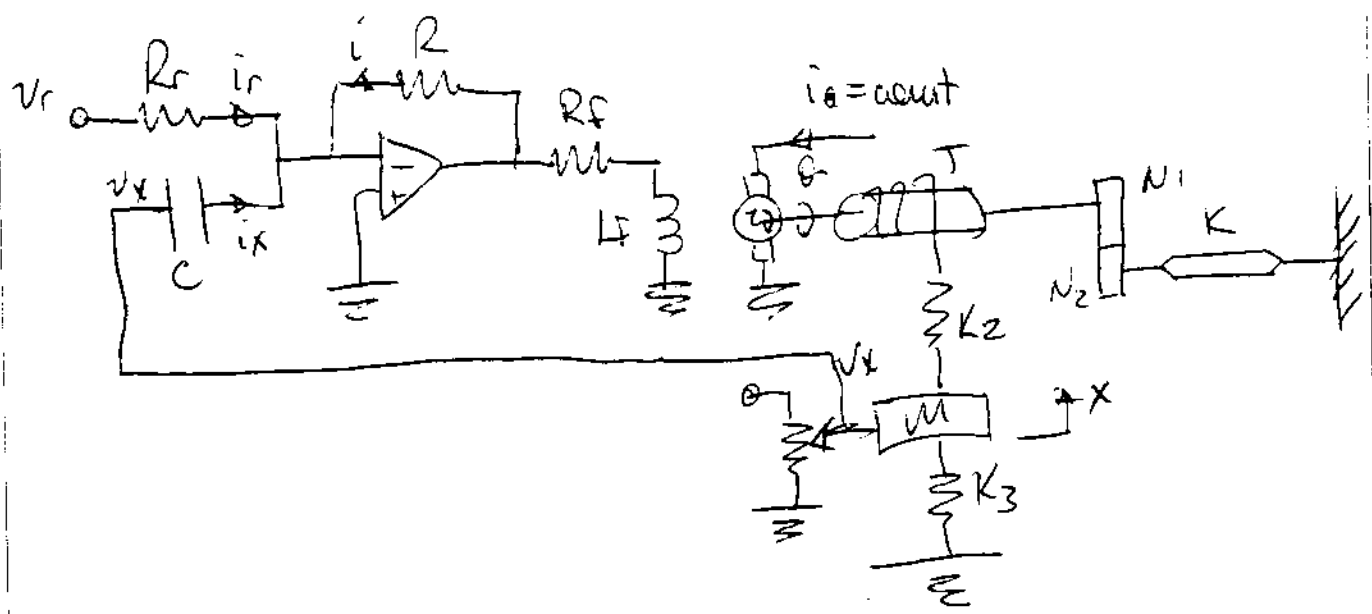


FORCE-CURRENT

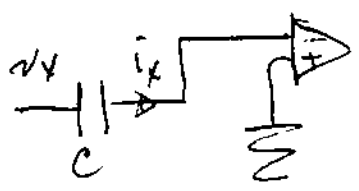
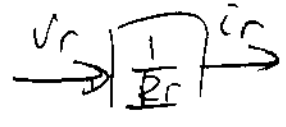


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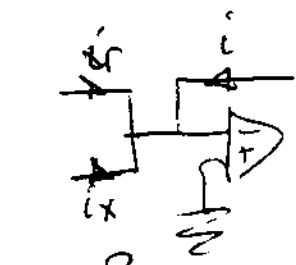
#2



$$i_r = \frac{v_r}{R_r}$$

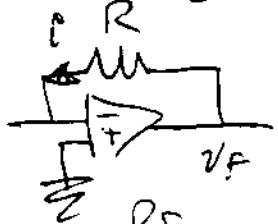
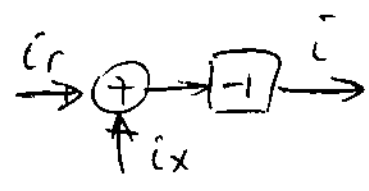


$$i_x = \frac{v_x}{1/sC} = sC v_x$$

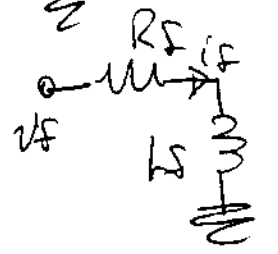
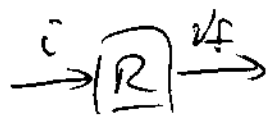


$$i + i_r + i_x = 0$$

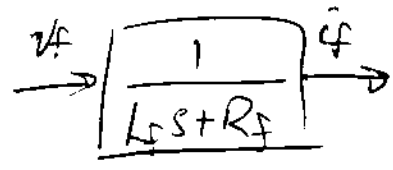
$$i = -(i_r + i_x)$$



$$v_f = R i$$

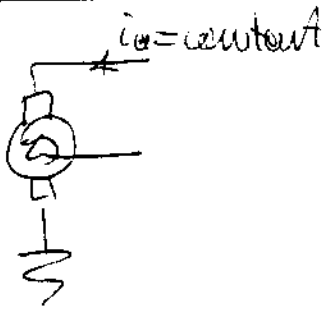


$$i_f = \frac{1}{L_f s + R_f} v_f$$

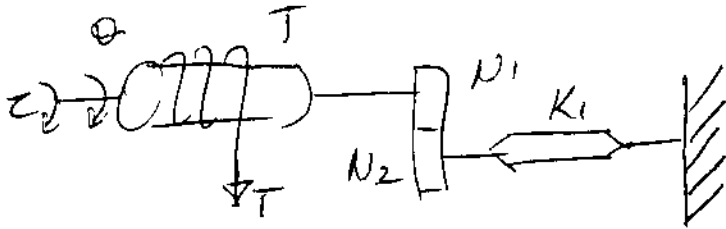


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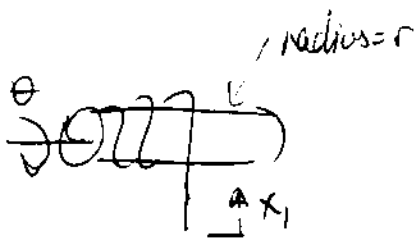
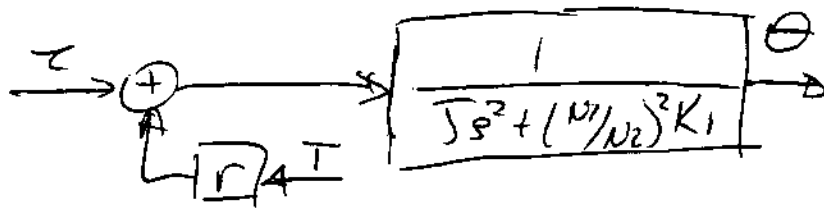


$$c = K_f i_f$$

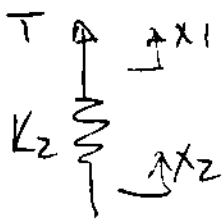


$$J \dot{s} \theta = \tau + rT - \left(\frac{N_1}{N_2}\right)^2 K_1 \theta$$

$$\theta = \frac{1}{J s^2 + \left(\frac{N_1}{N_2}\right)^2 K_1} (\tau + rT)$$



$$x_1 = -r\theta$$



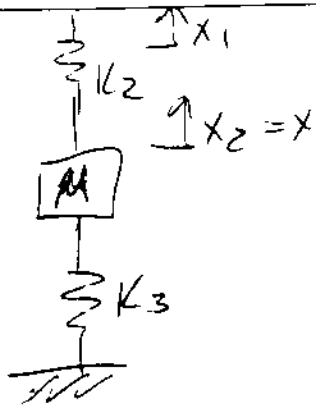
$$0 = T - K_2 (x_1 - x_2)$$

$$T = K_2 (x_1 - x_2)$$



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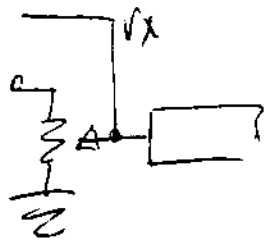
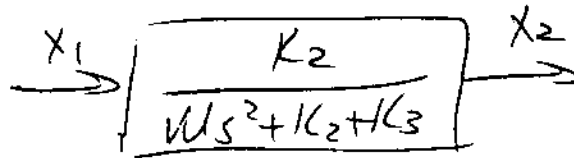




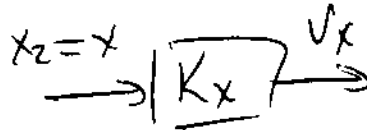
$$Ms^2 X_2 = -K_2(x_2 - x_1) - K_3 X_2$$

$$(Ms^2 + K_2 + K_3) X_2 = K_2 X_1$$

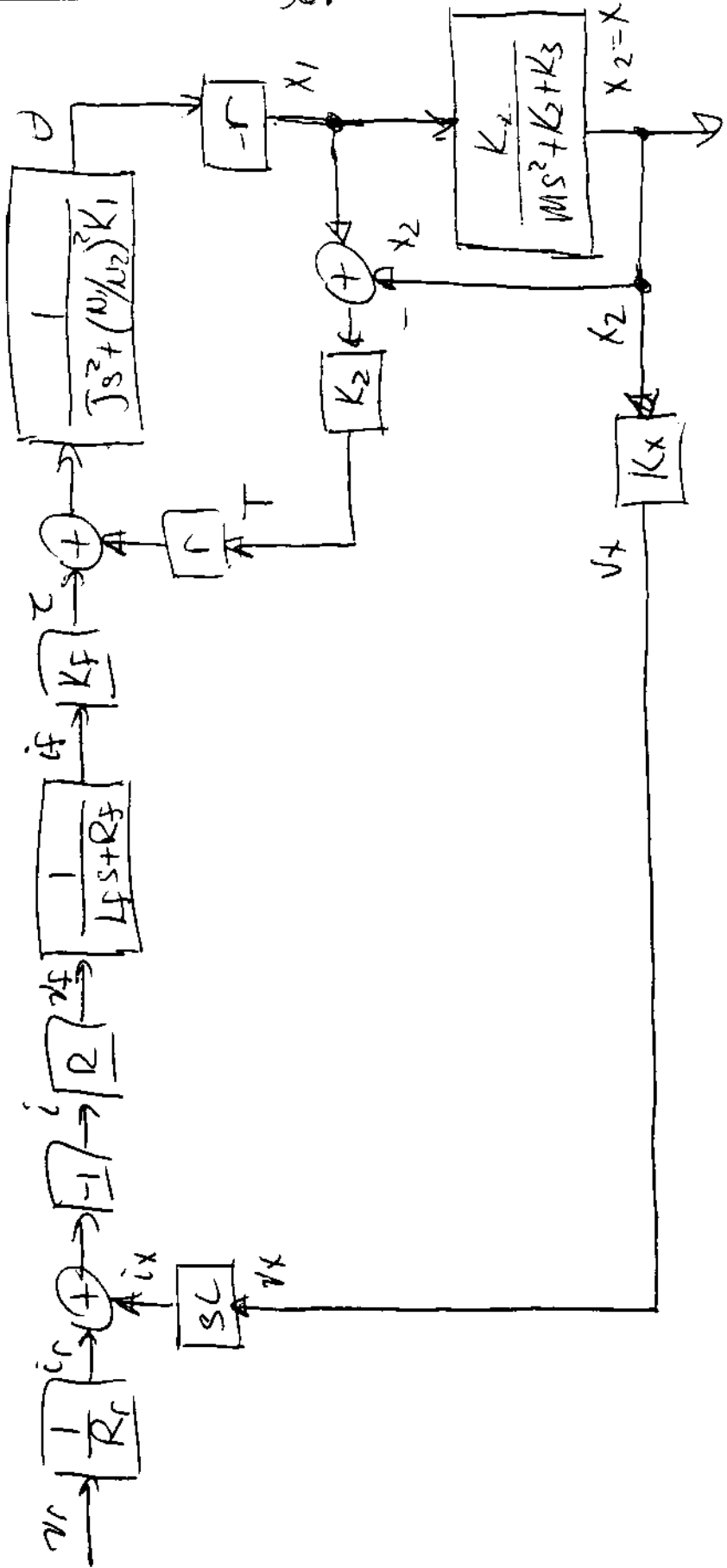
$$X_2 = \frac{K_2}{Ms^2 + K_2 + K_3} X_1$$



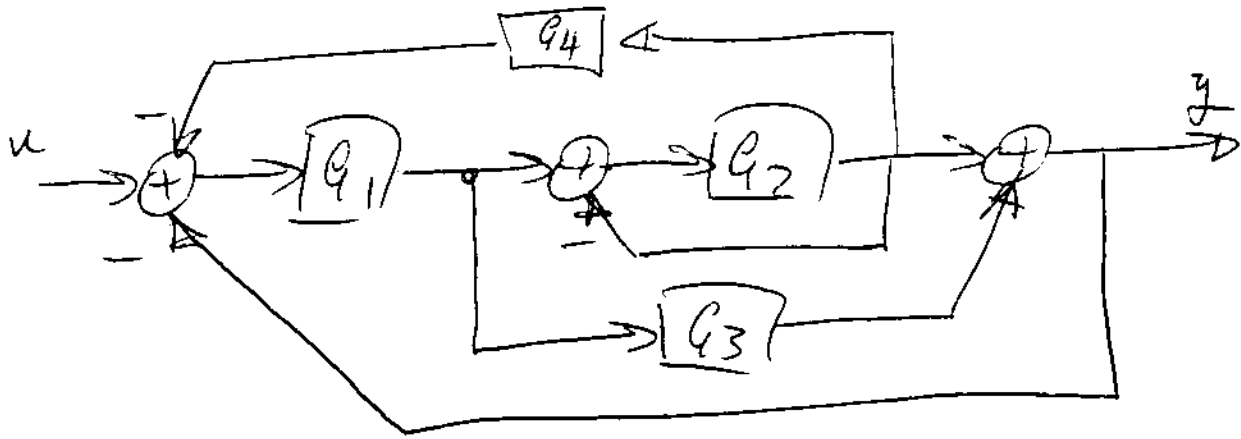
$$v_x = K_x X$$



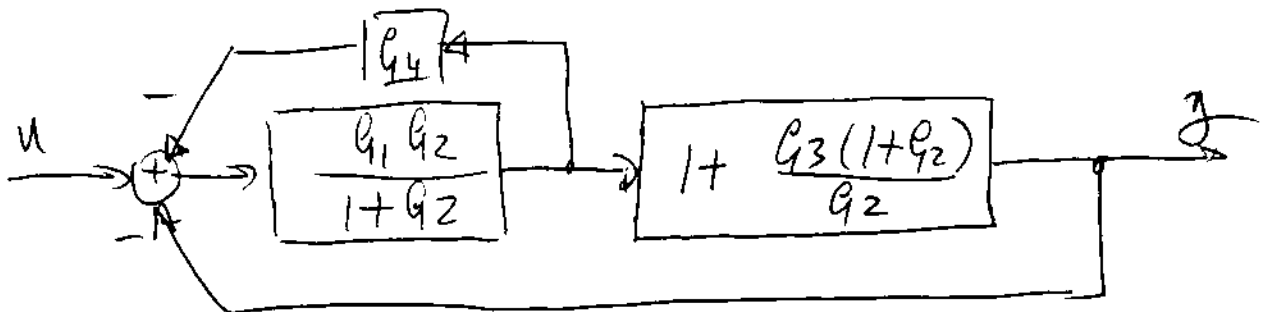
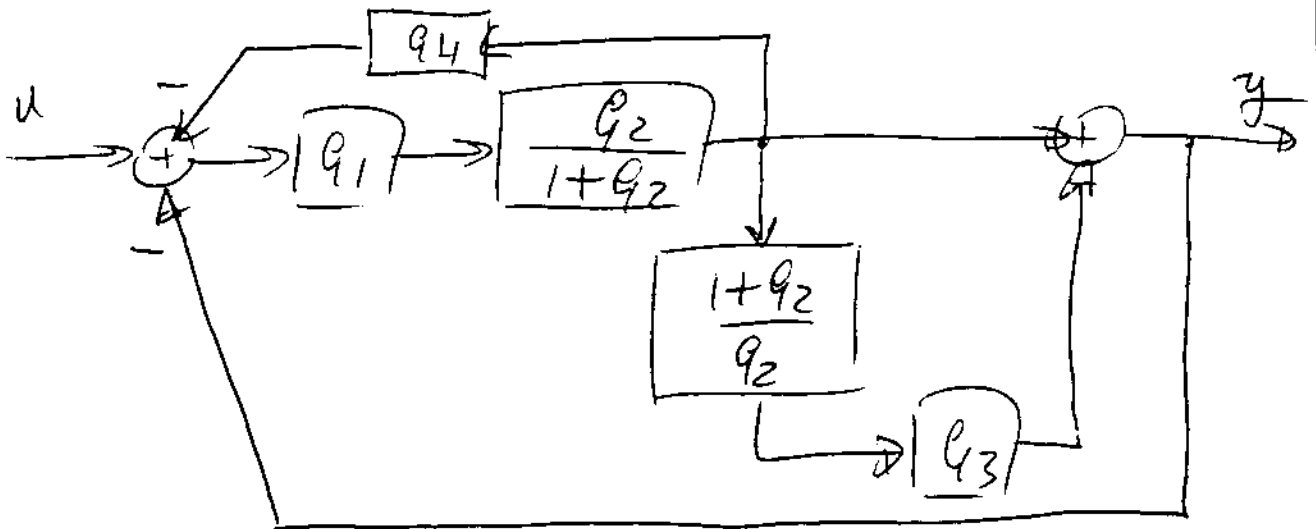
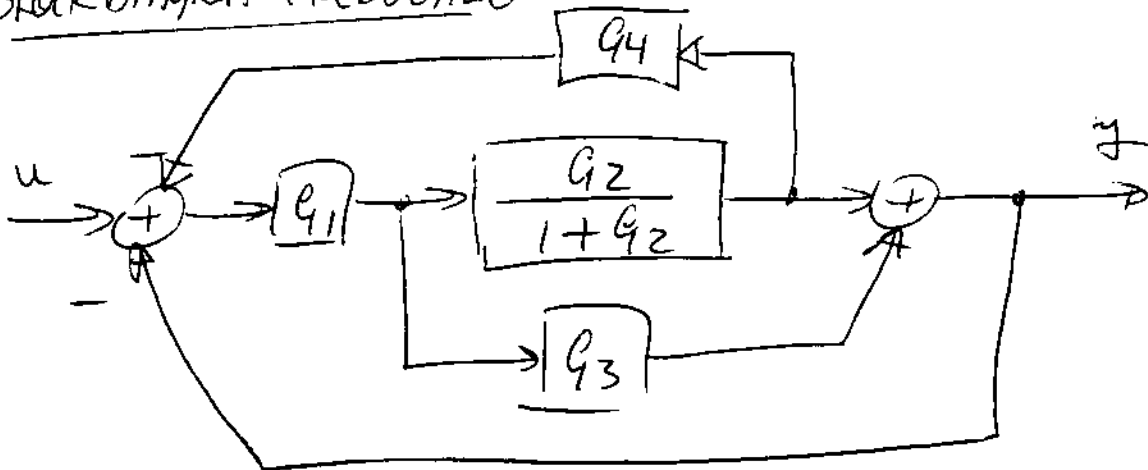
12 381 50 SHEETS (15" x 10") 5 SQUARE
 42 381 100 SHEETS (15" x 10") 5 SQUARE
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#3



BLOCK DIAGRAM REDUCTION



13 SHEETS
12 SHEETS
10 SHEETS
8 SHEETS
6 SHEETS
4 SHEETS
2 SHEETS
1 SHEET



TOUCHING
LOOPS

	l_1	l_2	l_3	l_4
l_1		T	T	N
l_2			T	T
l_3				T
l_4				

Only non-touching pair is l_1 & l_4

LOOPS OF

FORWARD PATHS

	l_1	l_2	l_3	l_4
F_1	0	0	0	0
F_2	N	0	0	0

$$\begin{aligned} \text{So } \Delta &= 1 - (l_1 + l_2 + l_3 + l_4) + l_1 l_4 \\ &= 1 + g_2 + g_1 g_2 g_4 + g_1 g_2 + g_1 g_3 \\ &\quad + g_2 g_1 g_3 \end{aligned}$$

$$\text{and } \Delta_1 = \Delta \Big|_{l_1=l_2=l_3=l_4=0} = 1$$

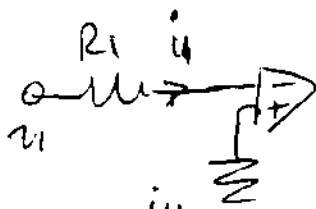
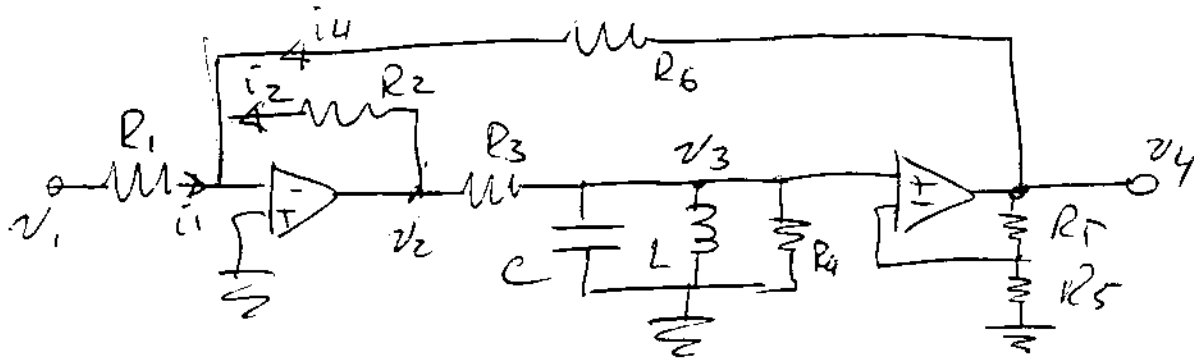
$$\Delta_2 = \Delta \Big|_{l_2=l_3=l_4=0} = 1 - l_1 = 1 + g_2$$

$$\Rightarrow \frac{y}{u} = \frac{g_1 g_2 + g_1 g_3 (1 + g_2)}{1 + g_2 + g_1 g_2 g_4 + g_1 g_2 + g_1 g_3 + g_1 g_2 g_3}$$

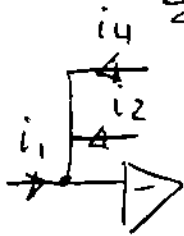
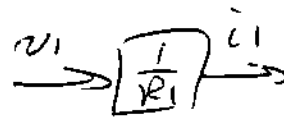
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#5

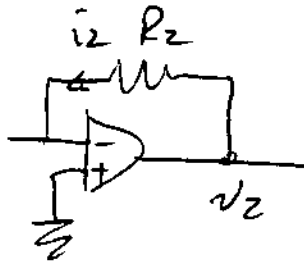


$$i_1 = \frac{1}{R_1} v_1$$

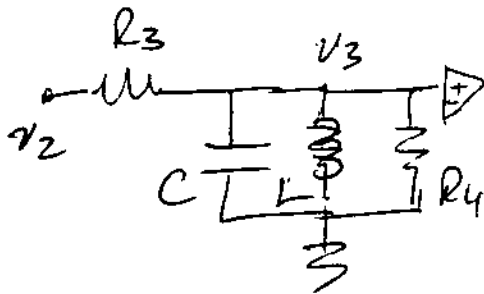
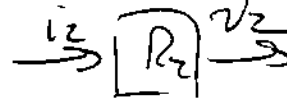


$$i_1 + i_2 + i_4 = 0$$

$$i_2 = -(i_1 + i_4)$$



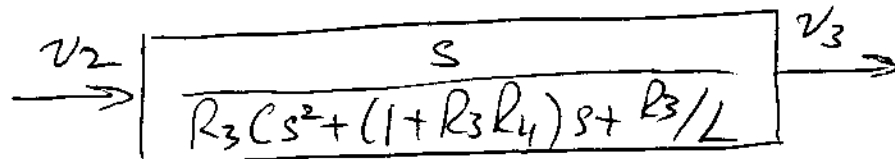
$$v_2 = R_2 i_2$$

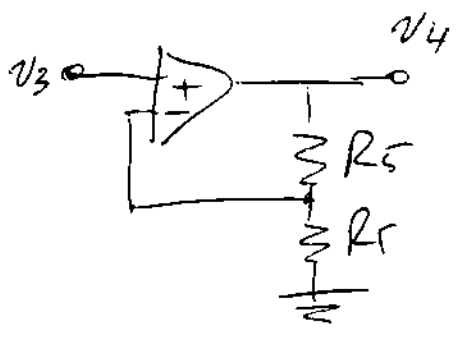


$$\frac{v_3}{1} = \frac{v_2}{R_3 + \frac{1}{sC + \frac{1}{sL} + R_4}}$$

$$v_3 = \frac{1}{R_3 C s + R_3/L s + R_3 R_4 + 1} v_2$$

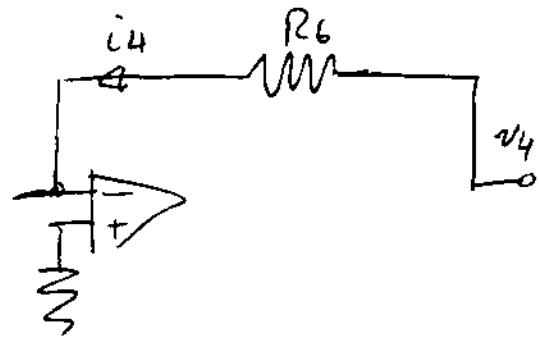
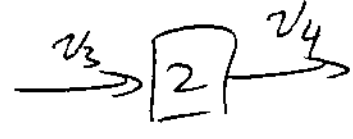
$$v_3 = \frac{s}{R_3 C s^2 + (1 + R_3 R_4) s + R_3/L} v_2$$



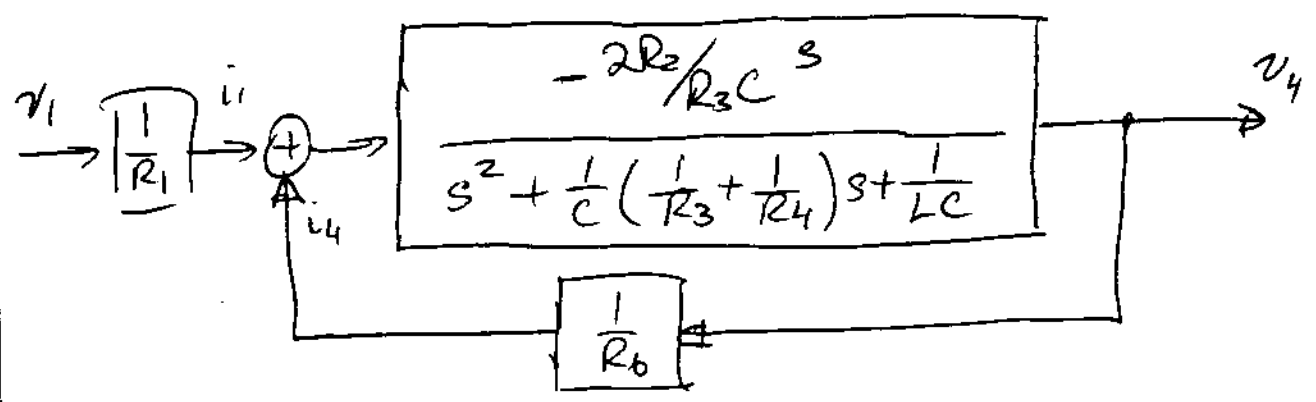
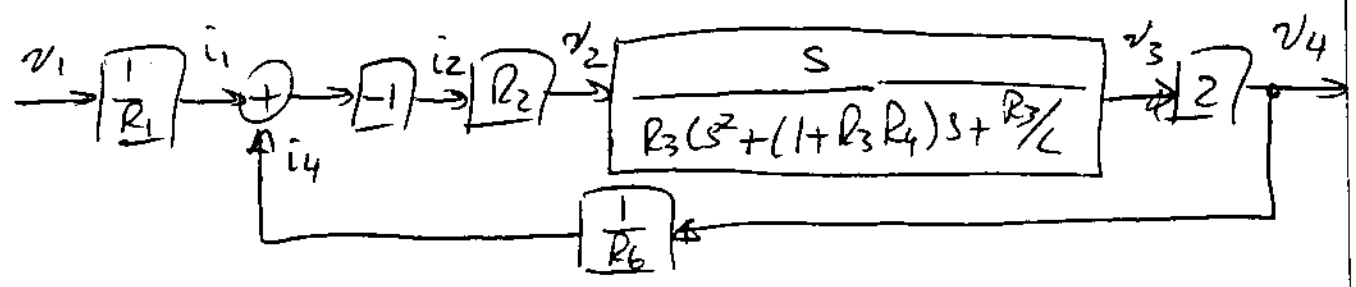
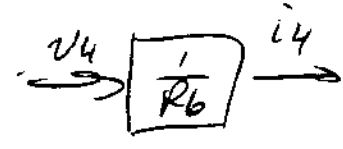


$$\frac{v_4}{2R_5} = \frac{v_3}{R_1}$$

$$v_4 = 2v_3$$



$$i_4 = \frac{1}{R_6} v_4$$



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$$\frac{v_4}{v_1} = \frac{1}{R_1} \frac{-2R_2/R_3 C s}{s^2 + \frac{1}{C} \left(\frac{1}{R_3} + \frac{1}{R_4} \right) s + \frac{1}{LC} - \left(-\frac{2R_2}{R_3 C} s \cdot \frac{1}{R_6} \right)}$$

Closed-loop poles $s^2 + \frac{1}{C} \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{2R_2}{R_3 R_6} \right) s + \frac{1}{LC} = 0$

$$t_{5\%s} \approx \frac{40}{3} \Rightarrow \frac{3}{\zeta \omega_n} = \frac{40}{3}$$

$$\zeta \omega_n = \frac{9}{40}$$

From the closed-loop pole eqn.

$$s^2 + 2\zeta \omega_n s + \omega_n^2 = 0$$

$$2\zeta \omega_n = \frac{1}{C} \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{2R_2}{R_3 R_6} \right)$$

$$\text{or } \frac{1}{C} \left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{2R_2}{R_3 R_6} \right) = 2 \cdot \frac{9}{40}$$

$$C = 1 \text{ F}, R_3 = 2 \Omega, R_4 = 4 \Omega, \text{ and } R_6 = 5 \Omega$$

$$\frac{1}{1} \left(\frac{1}{2} + \frac{1}{4} + \frac{2R_2}{2 \cdot 5} \right) = \frac{9}{20}$$

$$\frac{R_2}{5} = \frac{9}{20} - \frac{3}{4} = -\frac{6}{20}$$

$$\Rightarrow R_2 = -\frac{3}{2} \Omega \quad \text{Ops, this was supposed to be positive.}$$