1

PSS

20
−2.5
iout

−5 40
−25
9
2
±
±5
40
−2.5

−2.5

$\frac{-2.5}{1} = -2.5$

$-2.5 \cdot 9 = -22.5$

$V_{out} = -25\ V$
$i_{out} = -2.5\ mA$

i_{out}

V_{out}

1.5 (+/−) 1.5

8

20

20 ↓.075

10 ←.375
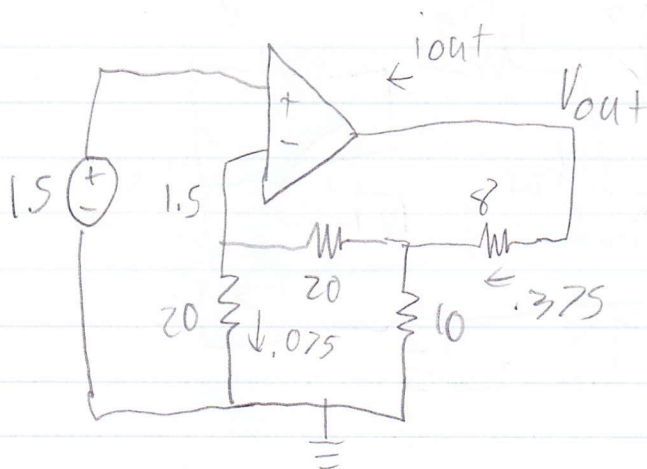
$\dfrac{1.5}{20} = .075$

$\dfrac{10}{40+10} \cdot i = .075$

$i = .375$

$i_{out} = -.375 \, mA$

$V_{out} = 6V$

$40 \cdot .075 + 8 \cdot .375 = 6$

V_a 10 V_c 20 V_E

20

20

40

$-12V$

V_b V_d 20 V_f

12 20 40 40
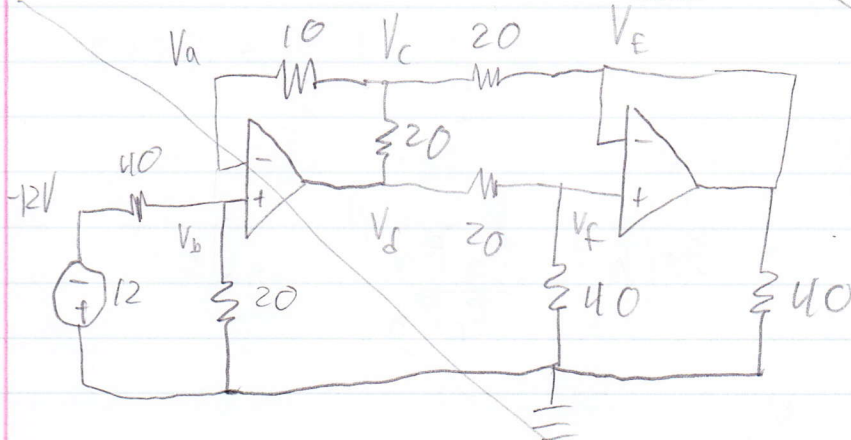
$V_a - V_b = 0$

$V_e - V_f = 0$

$\dfrac{3}{40} V_e - \dfrac{1}{20} V_d = 0$

$3V_e - 2V_d = 0$

$3V_e = 2V_d$ $V_e = \dfrac{2}{3}V_d$

V_a	V_b	V_c	V_d	V_e	V_f		C
$\frac{1}{10}$	0	$-\frac{1}{10}$	0	0	0		0
0	$\frac{1}{40}+\frac{1}{20}$	0	0	0	0		$\frac{-12}{40}$
$-\frac{1}{10}$	0	$\frac{1}{10}+\frac{1}{20}+\frac{1}{20}$	$-\frac{1}{20}$	$-\frac{1}{20}$	0		0
0	0	$-\frac{1}{20}$	$\frac{1}{20}+\frac{1}{20}$	0	$-\frac{1}{20}$		0
0	0	$-\frac{1}{20}$	0	$\frac{1}{20}+\frac{1}{40}$	0		0
0	0	0	$-\frac{1}{20}$	0	$\frac{1}{20}+\frac{1}{40}$		0

$-.4$

$.2V_c - .05V_d$

$.05V_c + \frac{1}{15}V_d = 0$

$-.05V_c + \frac{1}{15}V_d = 0$

S3

Circuit diagram with nodes V_a, V_c, V_e across top with resistors 10, 20. V_B, V_d, V_f labels, resistors 40, 20, 20, 20, 40, 40. 12V source.

$V_e = V_f$
$V_a = 4$

$V_b = -4$
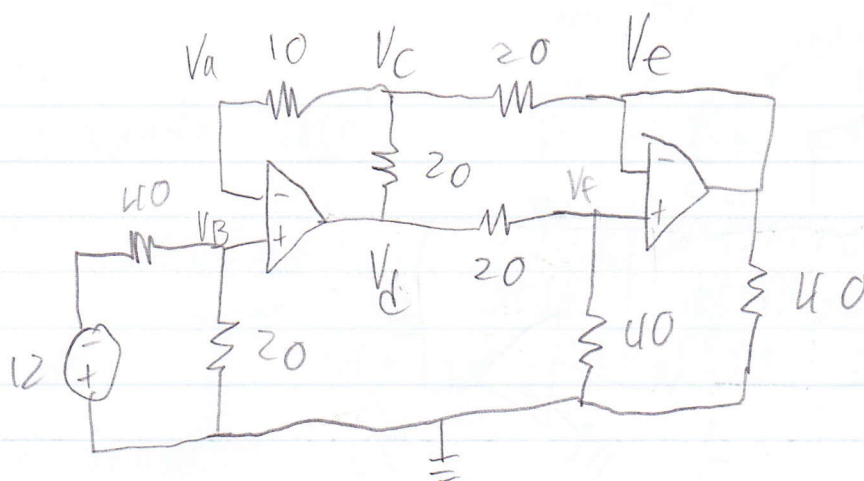
$$V_a: \quad \frac{1}{10}V_a \quad - \frac{1}{10}V_c \qquad\qquad = 0$$

$$V_c: \quad -\frac{1}{10}V_a + \left(\frac{1}{10}+\frac{1}{20}+\frac{1}{20}\right)V_c - \frac{1}{20}V_d - \frac{1}{20}V_e \qquad = 0$$

$$V_f: \qquad\qquad\qquad -\frac{1}{20}V_d + \left(\frac{1}{20}+\frac{1}{40}\right)V_f = 0$$

$$OPA \quad V_a \qquad\qquad\qquad\qquad = -4$$

$$OPB \qquad\qquad\qquad\qquad V_e - V_f = 0$$

$$
\begin{array}{ccccc}
V_a & V_c & V_d & V_e & V_f
\end{array}
$$

$$
\begin{bmatrix}
\frac{1}{10} & -\frac{1}{10} & 0 & 0 & 0 \\
-\frac{1}{10} & \frac{1}{10}+\frac{1}{20}+\frac{1}{20} & -\frac{1}{20} & -\frac{1}{20} & 0 \\
0 & 0 & -\frac{1}{20} & 0 & \frac{1}{20}+\frac{1}{40} \\
1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & -1
\end{bmatrix}^{-1}
\begin{bmatrix}
0 \\ 0 \\ 0 \\ -4 \\ 0
\end{bmatrix}
=
\begin{bmatrix}
-4 \\ -4 \\ -4.8 \\ -3.2 \\ -3.2
\end{bmatrix}
\begin{array}{l}
V_a \\ V_c \\ V_d \\ V_e \\ V_f
\end{array}
$$

$$\frac{V_d - V_f}{20} = \frac{-4.8 - -3.2}{20} = -.08 \, MA$$
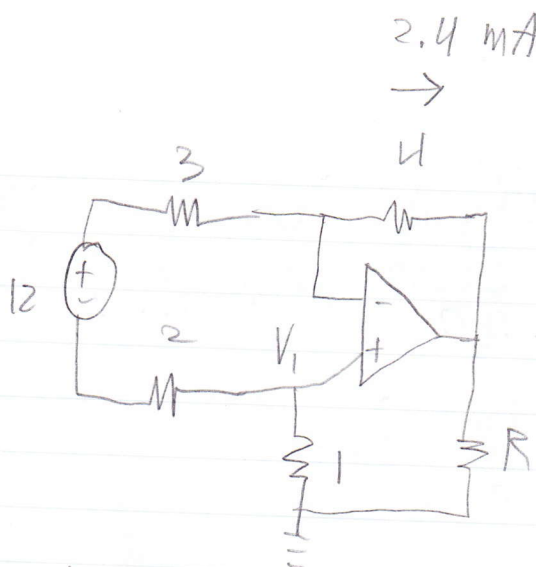
4
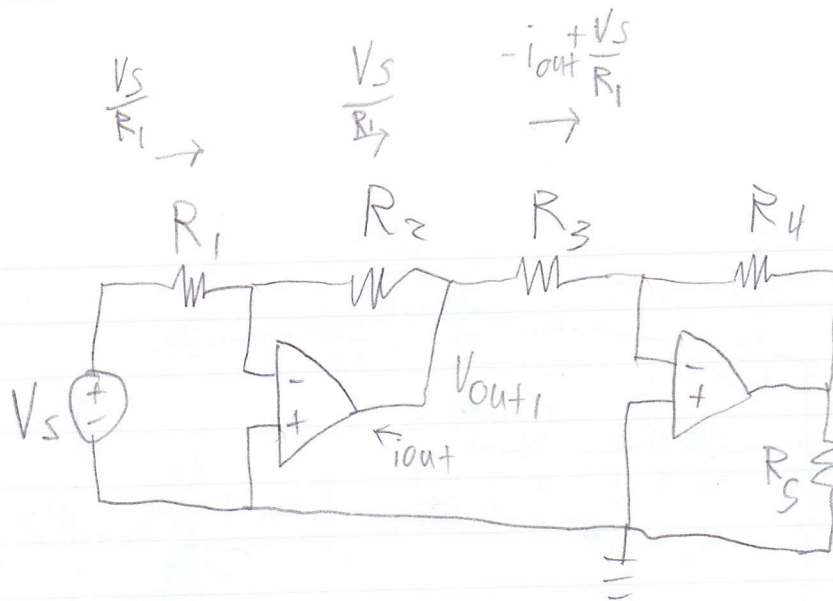
$$V_{out_1} = \frac{R_2}{R_1} V_S$$

$$\frac{\frac{R_2}{R_1} V_S}{R_3} \cdot R_4 = V_{out}$$

$$\frac{\frac{R_2 R_4 V_S}{R_1 R_3}}{V_S} = gain = \frac{R_2 R_4}{R_1 R_3}$$

$$i_{out} + \frac{R_2 V_S}{R_1 R_3} = \frac{V_S}{R_1}$$

$$i_{out} = \frac{V_S}{R_1}\left(1 - \frac{R_2}{R_3}\right)$$

2.4 mA

→

4

3

12

2

V_1

R

1

$$\frac{V_1}{1} = \frac{V_{out} - V_1}{4}$$

$$V_{out} = 5V_1$$

$$V_1 + 2V_1 + 12 + 3V_1 = V_1$$
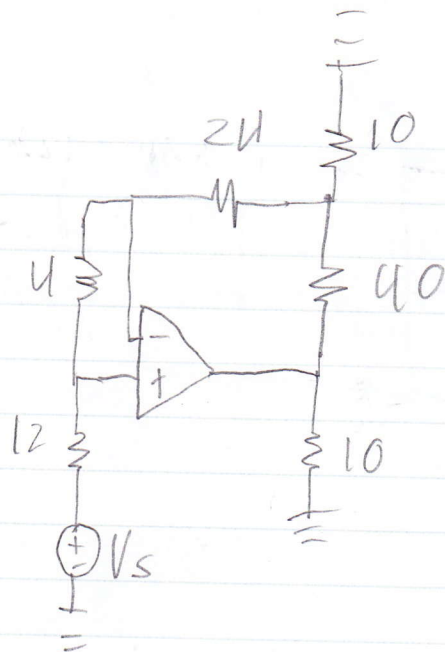
$$12 = -5V_1$$

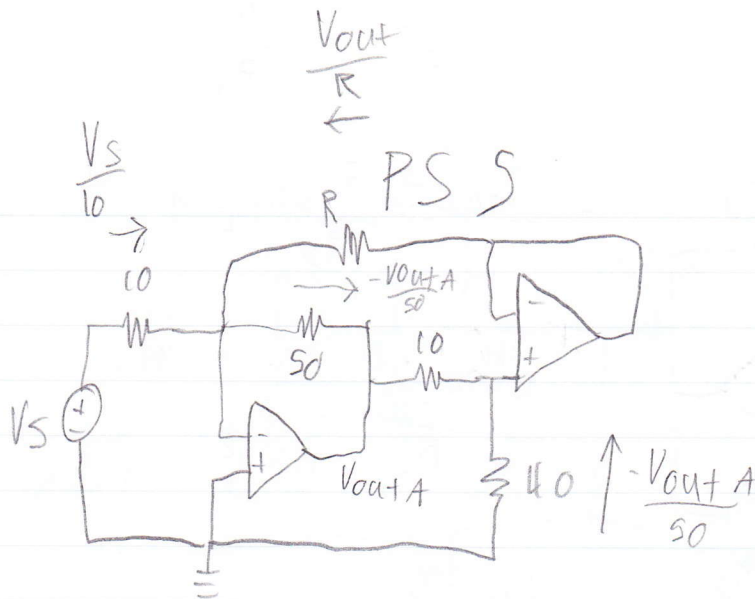$$V_1 = -2.4$$

$$V_1 \cdot 5 = V_{out} = -12$$

$$i = 2.4 \, mA$$

6

$$\frac{V_{out}}{50} \cdot 10 = V_{in} = V_s$$

$$5 V_s = V_{out}$$

5.7

$$\frac{V_S}{10}$$

$$\frac{V_{out}}{R}$$

$$\frac{V_S}{10} + \frac{V_{out}}{R} = \frac{-V_{out}}{40}$$

$$\frac{V_S}{10} = -V_{out}\left(\frac{1}{R} + \frac{1}{40}\right)$$

$$\frac{V_{out}A}{50} = \frac{V_{out}}{40}$$

$$\frac{V_{out}}{V_S} = \frac{\frac{-1}{10}}{\frac{1}{R} + \frac{1}{40}}$$

$$\frac{V_{out}A}{50} \cdot 40 = V_{out}$$

$$\frac{\frac{1}{10}}{\frac{40+R}{40R}}$$

$$V_{out}A = \frac{5}{4}V_{out}$$

$$G(R) = \frac{V_{out}}{V_S} = \frac{-4R}{40+R}$$
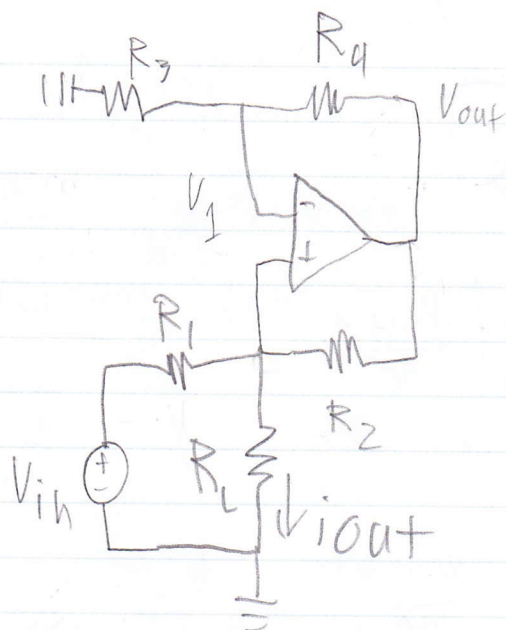
$$G(\infty) = -4 \qquad G(0) = 0$$

$$-3 = \frac{-4R}{40+R} \cdot 1$$

$$-120 - 3R = -4R$$
$$-120 = -R$$
$$R = 120 \, k\Omega$$

8

$$i_3 = i_4 = \frac{V_1}{R_3}$$

$$V_{out} - \frac{R_4 V_1}{R_3} = V_1$$

$$\frac{V_{out} - V_1}{R_2} = i_2$$

$$\frac{V_{in} - V_1}{R_1} = i_1$$

$$i_{out} = \frac{V_1}{R_L} = \frac{V_{in} - V_1}{R_1} + \frac{V_{out} - V_1}{R_2}$$

$$V_{out} = V_L \left(1 + \frac{R_4}{R_3} \right)$$

$$\frac{V_L}{R_1} = \frac{V_{in} - V_1}{R_1} + \frac{V_1 + \frac{V_1 R_3}{R_4} - V_1}{R_2}$$

$$V_L = V_{in} - V_1 + V_1 \frac{R_1 R_3}{R_2 R_4}$$

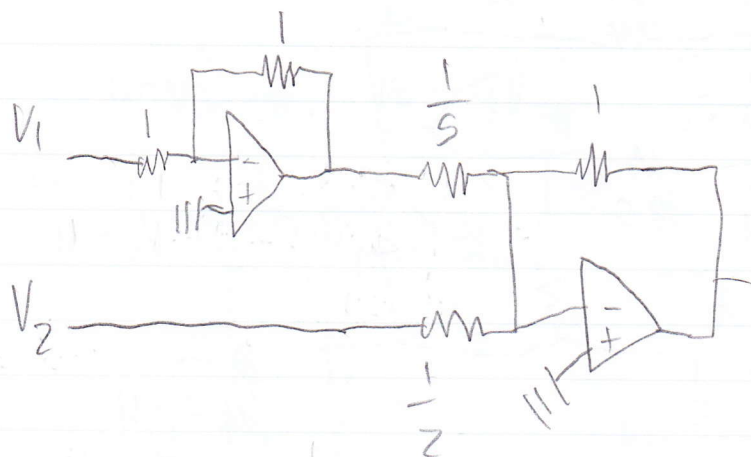$$V_L = V_{in} - V_1 \left(\frac{R_1 R_3}{R_2 R_4} - 1 \right)$$

$$R_2 R_3 = R_1 R_4$$

$$R_3 = \frac{R_1 R_4}{R_2}$$

9

V_1

V_2

$\dfrac{1}{5}$

$\dfrac{1}{2}$

10

V_{in}

V_{out}

2