16

ENSC 220 Mid Term (Oct. 13, 2005)

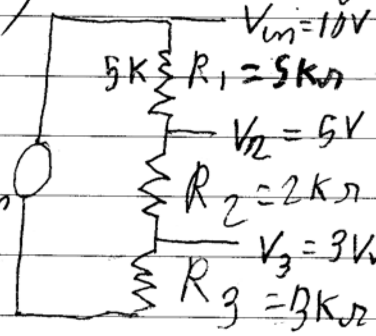
NOTE: **Do 2 questions in part I 25 marks each for a total of 50 marks**
Do 1 question in part II for 50 marks.
Test Total is 100 marks.

Section 1: Do 2 of these 3 questions: 25 marks each

1. (a) Given a 10 volt ideal source, design a circuit that will deliver both 3 volts and 5 volts to another circuit. Assume the other circuit does not load down these output voltages, and that the maximum current supplied by the voltage source is 1 mA. Show the point where the output circuit must be placed. (13 marks)

(b) Given a 12 mA ideal source, design a circuit that will deliver 4 mA to another circuit. Assume the other circuit does not load down this output current, and that the maximum voltage supplied by the source is 8 V. Show the point where the output circuit must be placed. (12 marks)

To obtain multiple voltages use a voltage divider of 3 resistors (because no load)



Outputs 10 V (full) = V_{in}
5 V (2nd resistor)
3 V 3rd resistor

Max current $I = 1mA$

$\therefore I_0 = \frac{V_{in}}{R_T}$ $\quad \therefore R_T = \frac{V_{in}}{I_0} = \frac{10}{10^{-3}} = 10K\Omega$

no name -1

$\therefore V_2 = 5V = \frac{(R_2+R_3)V_{in}}{R_T}$

no common -1
ground -1

$V_3 = 3V = \frac{R_3}{R_T} V_{in}$

no formulas -6

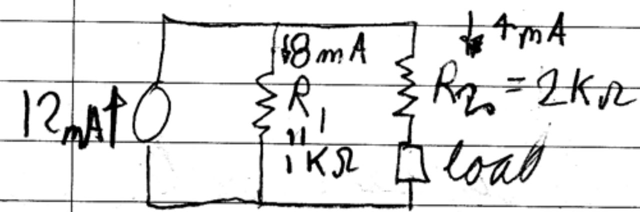
$R_3 = \frac{V_3}{V_{in}} R_T = \frac{3}{10} 10^4 = 3K\Omega$

$R_2 + R_3 = \frac{V_2}{V_{in}} R_T$ thus $R_2 = \frac{V_2}{V_{in}} R_T - R_3 = \frac{5}{10}(10^4) - 3\times10^3$

$R_2 = 2\times10^3 = 2K\Omega$

(13) $R_1 = R_T - R_2 - R_3 = 10k - 2k - 3k = 5K\Omega$

(b) This is a current divider



Since this a current divider

$\therefore I_0 = I_{R_1} + I_{R_2}$

$I_{R_1} = I_0 - I_{R_2} = 12\cancel{A} - 4mA = 8mA$

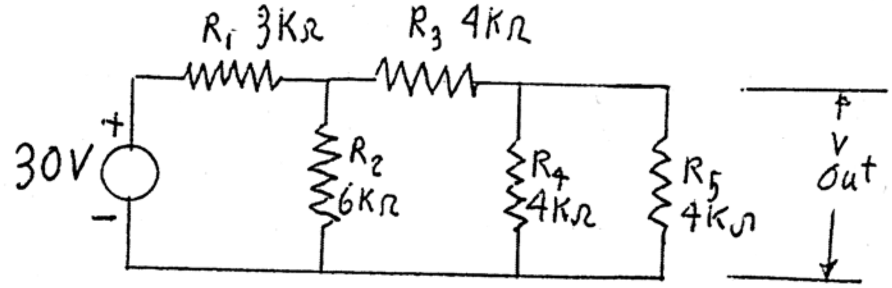
$I_1 R_1 = I_2 R_2 = 8V$

$\therefore R_2 = \frac{8V}{I_2} = \frac{8V}{4\times10^{-3}} = 2\times10^3\,\Omega = 2K\Omega$

(12) $R_1 = \frac{8V}{I_1} = \frac{8V}{8\times10^{-3}} = 1K\Omega$

2. (a) Find the Thevenin equivalent of the circuit as seen at the V_{out} output. (20 marks)
(b) Find the Norton equivalent of the circuit. (5 marks)

2(a)



First need open circuit voltag

$$R_{4\|5} = \frac{R_4 R_5}{R_4+R_5} = \frac{4k\,4k}{4k+4k} = 2K\Omega$$

$$R_{3\|} = R_3 + R_{4\|5} = 4K\Omega + 2K = 6K\Omega$$

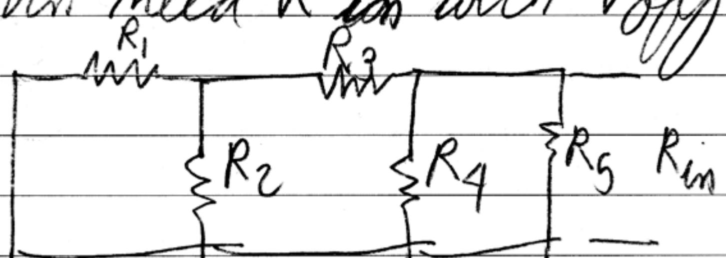
$$R_{2\|} = R_{2\|}(R_3+R_{4\|5}) = \frac{R_2 R_{3\|}}{R_2+R_{3\|}} = \frac{6k\,6k}{6k+6k} = 3K\Omega$$

$$\therefore V_{R_2} = \frac{R_{2\|}}{R_1+R_{2\|}} V_{in} = \frac{3k(30)}{3k+3k} = 15V$$

$$V_{out} = V_{R4} = \frac{R_{4\|} V_{R_2}}{R_3+R_{4\|}} = \frac{R_{4\|} V_{R_2}}{R_{3\|}} = \frac{2k}{6k}(15) = 5V$$

$$\therefore V_{th} = V_{out} = 5V$$

For thevin need R in with V off (ie shorted)



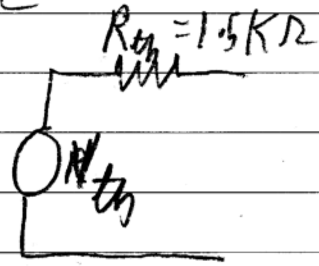
$$R_{11} = \frac{R_1 R_2}{R_1 + R_2} = \frac{3k\,6k}{3k+6k} = \frac{18k^2}{9k} = 2k\Omega$$

$$R_{3T} = R_3 + R_{11} = 4k + 2k = 6k\Omega$$

$$\frac{1}{R_{in}} = \frac{1}{R_{3T}} + \frac{1}{R_4} + \frac{1}{R_5}$$

$$= \frac{1}{6k} + \frac{1}{4k} + \frac{1}{4k} = \frac{0.6606}{k}$$

$$R_{in} = \frac{k}{0.606} = 1.5k\Omega$$

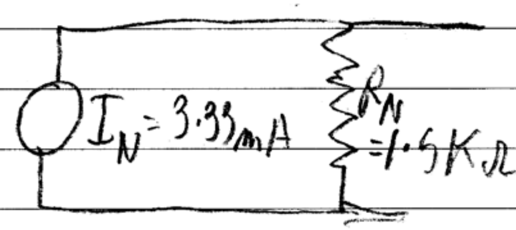


$\therefore R_{th} = 1.5k\Omega$
$V_{th} = 5\ V$

(b) Norton equivalent

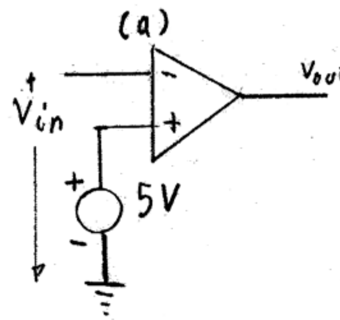
$$I_N = \frac{V_{th}}{R_{th}} = \frac{5}{1.5k} = 3.33\ mA$$

$\therefore R_N = R_{th} = 1.5\ k\Omega$

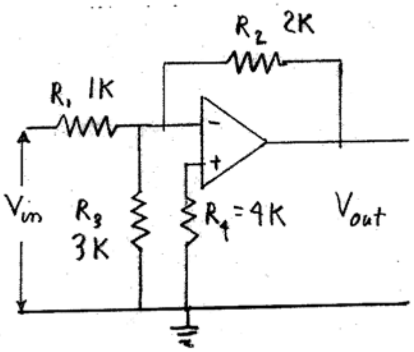


3

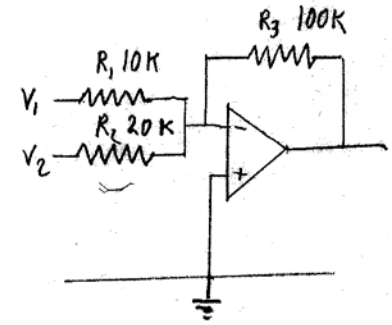
3. (a-c) In the following operational amplifier circuits assume V_{CC} = +15 V and V_{EE} = -15 V. In all cases give a formula that relates the input voltage(s) to the output voltage and draw the output voltage vs the input voltage. For (c) plot the output voltage vs an appropriate formula for the 2 input voltages. (7 marks each part)
(d) Draw an op-amp circuit that will give you a gain of +3. What is the name of this type of op-amp circuit. Plot the output voltage vs input voltage of this circuit. (4 marks)



(a)

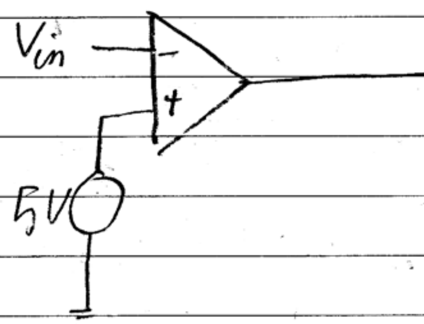


(b)



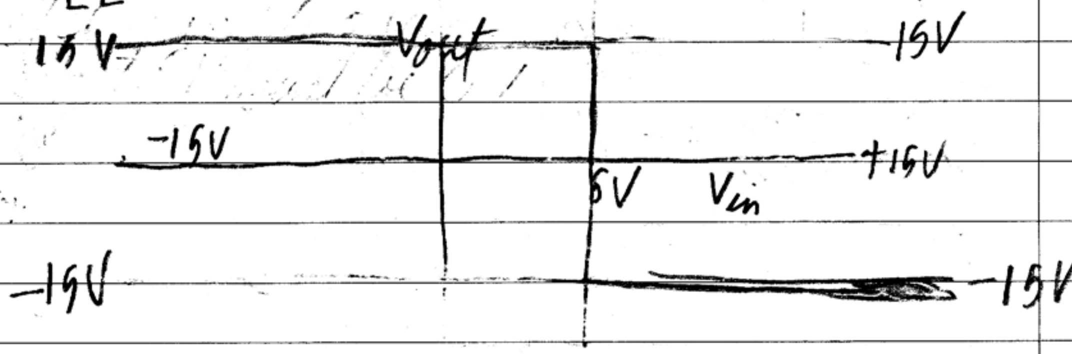
(c)

(a) This is a voltage comparitor since no voltage across input allowed ideally



$V_{out} = V_{CC}$ for $V_{in} < 5V$
$= +15V$

$V_{out} = V_{EE} = -15V$ for $V_{in} \geq 5V$



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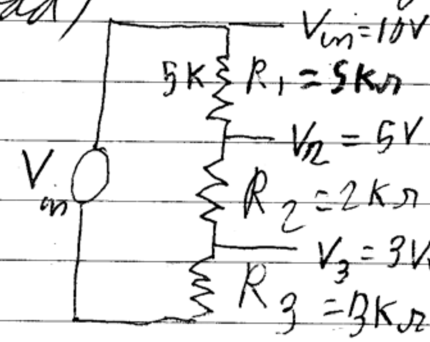

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$\therefore V_2 = 5V = \frac{(R_2+R_3)V_{in}}{R_T}$

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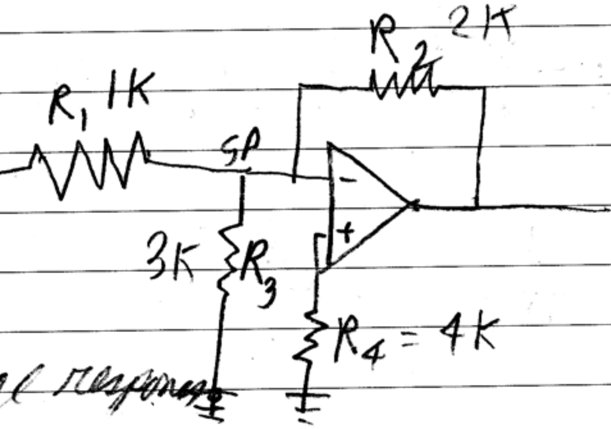
(b) This is inverting OP with added R's
since $I_{SP} = 0$
SP = ground

& R_4 has no effect



Since SP ground
R_3 does not change response

∴ just inverting formula

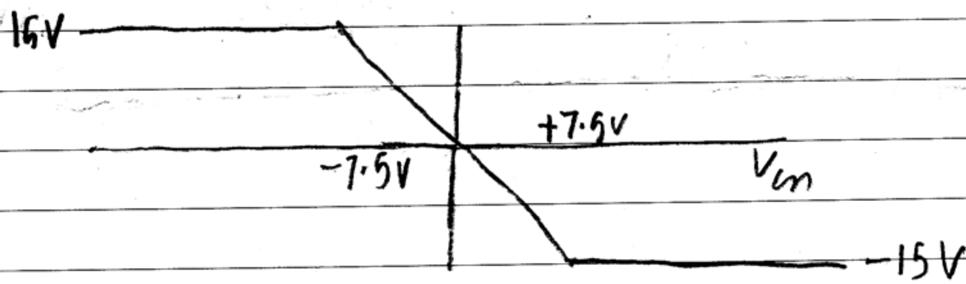
Gain $= A_V = -\frac{R_2}{R_1} = -\frac{2k}{1k} = 2$

∴ $V_{out} = -2V_{in}$

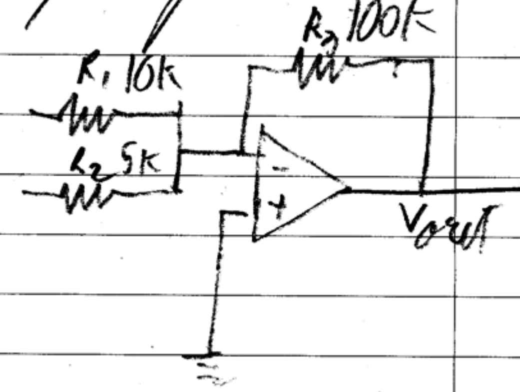
$V_{in}\ max = \frac{-V_{EE}}{-2} = \frac{-15}{-2} = 7.5V$

$V_{in}\ min = \frac{V_{CC}}{-2} = \frac{15}{-2} = -7.5V$

$V_{in} > V_{max} = 7.5V$ $\quad V_{out} = V_{EE} = -15V$
$V_{in} < V_{min} = -7.5V$ $\quad V_{out} = V_{CC} = +15V$



(c) This is a summing inverting op amp

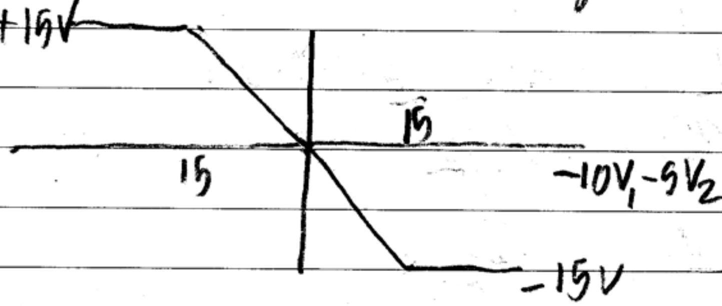


$A_{v_1} = -\frac{R_3}{R_1} = -\frac{100K}{10K} = -10$

$A_{v_2} = -\frac{R_3}{R_2} = -\frac{100K}{20K} = -5$

∴ $V_{out} = -10V_1 - 5V_2$

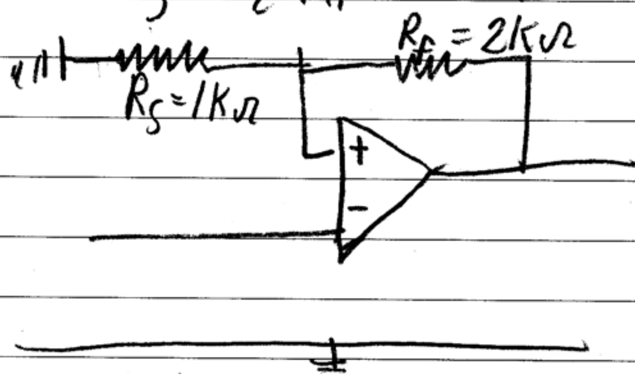
$V_{max} = -10V_1 - 5V_2 > 15V$ if $V_2 = 0$ $V_{1max} = 1.5V$
$V_{min} = -10V_1 - 5V_2 < -15V$ if $V_1 = 0$ $V_{2max} = 3V$



(d) Gain +3 Thus non inverting op amp

∴ $A_v = \frac{R_s + R_f}{R_s}$ ∴ $R_s(A_v+1) = R_f$ ∴ $R_s = \frac{1}{(3-1)}R_f = \frac{1}{2}R_f$

∴ let $R_f = 2K$ ∴ $R_s = \frac{1}{2}R_f = 1K$



I & V,

$V_{R_1} = I_1 R_1 = 10^3 \times 0.01 = 10V \quad I_{R_1} = I_1 = 10mA$

$V_{R2} = V_1 = 20V \quad I_{R4} = \frac{V_2}{R_4} = \frac{20}{4K} = 5mA$

$V_{R3} = V_1 - V_2 = 20 - 10 = 10V \quad I_{R_3} = \frac{V_1 - V_2}{R_3} = \frac{10}{2K} = 5mA$

$V_{R4} = V_2 = 10V \quad I_{R4} = \frac{V_2}{R_4} = \frac{10}{10K} = 1mA$

at node 1 $\quad I_1 = I_{R_2} + I_{R_3} = 5 + 5mA = 10mA$

at node 2 $\quad I_2 = I_{R_3} - I_{R4} = 5 - 1 = 4mA$

$I_1 = 10mA$

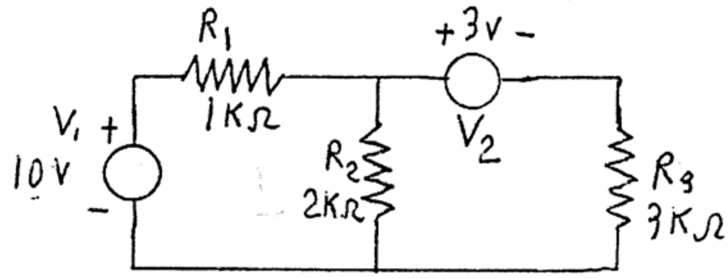
$V_{I_1} = V_1 + I_1 R_1 = 20 + 10V = 30V$

$I_2 = 4mA$

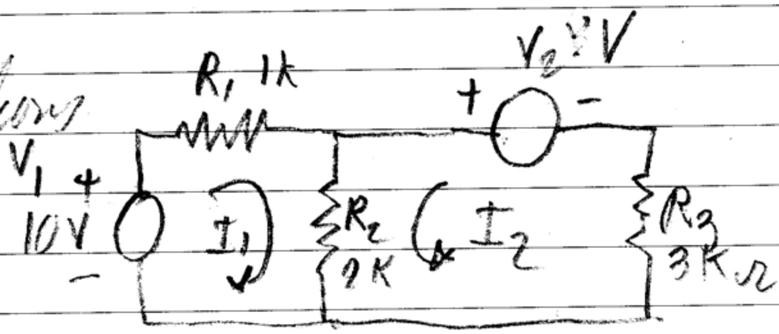
$V_{I_2} = V_2 = 10V$

(c) R_1 does not affect the node V's only I_1's voltage

(5) For the following circuit
(a) Write the mesh equations. (16 marks)
(b) Analysis the circuit for current and voltage for each element. As part of this state a formula for one mesh current in terms of the other. (34 marks)



a) loop equations



loop1

$$I_1 R_1 + R_2(I_1+I_2) = V_1$$

$$I_1(1000+2000) + I_2(2000) = 10V$$

loop 2

$$+R_2(I_1+I_2) + R_3 I_2 = V_2$$

$$I_1(2000) + I_2(2000+3000) = 3V$$

E220 midterm 2005 q5

i index	R matrix		V matrix
1	3000	2000	10
2	2000	5000	3

	R inverse		V matrix	I solution
1	0.000455	-0.000182	10	0.004
2	-0.000182	0.000273	3	-0.001

I & V's

$I_{R_1} = I_1 = 4mA$ $\quad V_{R_1} = I_1 R_1 = 1K(4m) = 4V$

$I_{R2} = I_1 + I_2 = 4_m - 1_m = 3mA$ $\quad V_{R_2} = I_{R_2} R_2 = 3_m(9K) = 6V$

$I_{R3} = I_2 = -1mA$ $\quad V_{R3} = -I_2 R_3 = 1m\,3K = -3V$ tagm

$I_{V1} = I_1 = 4mA$ $\quad V_1 = 10V$

$I_{V2} = I_2 = -1mA$ $\quad V_2 = 3V$

$\therefore V_2$ charging

Check loop 1

$V_1 = V_{R_1} + V_{R2} = 4 + 6 = 10V$

loop 2

$V_2 = -V_{R2} + V_{R3} = 6 - 3 = 3V$