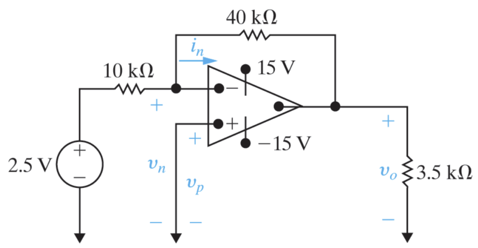
5.2

a. Replace the 2.5 V source in the circuit in **Fig. P5.1** and calculate v_o for each of the following source values: -6 V, -3.5 V, -1.25 V, 1 V, 2.4 V, 5.4 V.

b. Specify the range of voltage source values that will not cause the op amp to saturate.



a) $$\frac{V_n - V_{source}}{10K} + \frac{V_n - V_o}{40K} = 0$$

Since $V_n = 0$: $V_o = -\frac{40K\,V_{source}}{10K}$

$$\boxed{\begin{array}{l} V_{source} = -6V \Rightarrow V_o = -4(-6) = 24V \text{ Since } 24>15\ V_o = 15V \\ V_{source} = -3.5V \Rightarrow V_o = -4(-3.5) = 14V \\ V_{source} = -1.25V \Rightarrow V_o = -4(-1.25) = 5V \\ V_{source} = 1V \Rightarrow V_o = -4(1) = -4V \\ V_{source} = 2.4V \Rightarrow V_o = -4(2.4) = -9.6V \\ V_{source} = 5.4V \Rightarrow V_o = -4(5.4) = -21.6V \text{ Since } -21.6<-15\ V_o = -15V \end{array}}$$

b) 15V + −15V

$V_o = -4V_s$

for 15V

$$V_s = \frac{15}{-4} = -3.75V$$

for −15V

$$V_s = \frac{-15}{-4} = 3.75V$$

the voltage source must be between −3.75V and 3.75V to avoid saturation

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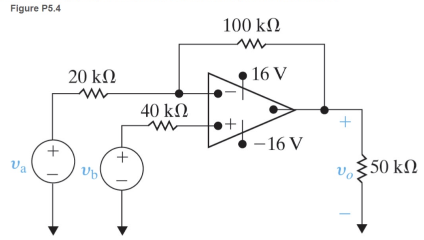
5.4 PSPICE MULTISIM The op amp in the circuit in **Fig. P5.4** is ideal.

a. Calculate v_o if $v_a = 4$ V and $v_b = 0$ V.
b. Calculate v_o if $v_a = 2$ V and $v_b = 0$ V.
c. Calculate v_o if $v_a = 2$ V and $v_b = 1$ V.
d. Calculate v_o if $v_a = 1$ V and $v_b = 2$ V.
e. If $v_b = 1.6$ V, specify the range of v_a such that the amplifier does not saturate.

Figure P5.4



$$\frac{V_b - V_a}{20} + \frac{V_b - V_o}{100} = 0$$

$V_o = -5V_a + 6V_b$

a) $V_o = -5(4) + 6(0)$

$\boxed{V_o = -16V}$

b) $V_o = -5(2) + 6(0)$

$\boxed{V_o = -10V}$

c) $V_o = -5(2) + 6(1)$

$\boxed{V_o = -4V}$

d) $V_o = -5(1) + 6(2)$

$\boxed{V_o = 7V}$

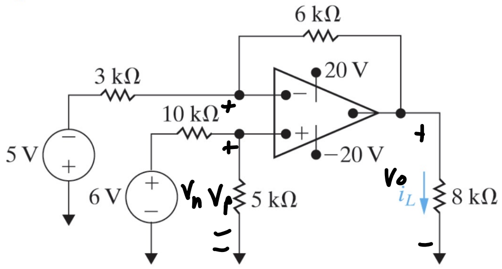
e) $16 = -5V_a + 6(1.6)$ + $-16 = -5V_a + 6(1.6)$

$V_a = -1.25$ $\qquad$ $V_a = 5.12$

$\boxed{-1.25V \le V_o \le 5.12V}$

5.6 PSPICE MULTISIM Find i_L (in milliamperes) in the circuit in **Fig. P5.6**.

Figure P5.6



$V_p = \frac{5K}{5K+10K}(6V) = 2V$

$V_n = V_p = 2V$

$\frac{V_n+5}{3K} + \frac{V_n-V_o}{6K} = 0$

$V_o = 2(2+5)+2$

$V_o = 16V$

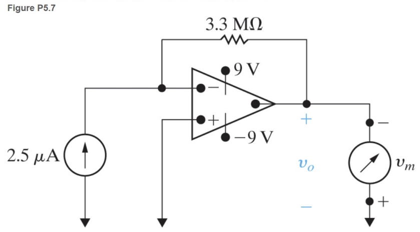
Using ohms law ($V = ir \Rightarrow i = \frac{V}{r}$)

$i_L = \frac{V_o}{8K\Omega} = \frac{16}{8K}$

$\boxed{i_1 = 2mA}$

5.7 PSPICE MULTISIM A voltmeter with a full-scale reading of 10 V is used to measure the output voltage in the circuit in **Fig. P5.7**. What is the reading of the voltmeter? Assume the op amp is ideal.

Figure P5.7



$V_o = (2.5\mu A)(3.3M\Omega) = 8.25V$

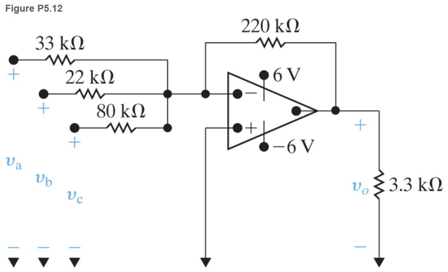
Since V_m is turned the opposite of V_o

$\boxed{V_m = -8.25V}$

5.12 PSPICE MULTISIM The op amp in **Fig. P5.12** is ideal.

a. What circuit configuration is shown in this figure?
b. Find v_o if $v_a = 1.2\,V$, $v_b = -1.5\,V$, and $v_c = 4\,V$.
c. The voltages v_a and v_c remain at 1.2 V and 4 V, respectively. What are the limits on v_b if the op amp operates within its linear region?

Figure P5.12



a) the circuit is an inverting summing amplifier

b) $V_o = -\left(\frac{R_f}{R_a}V_a + \frac{R_f}{R_b}V_b + \frac{R_f}{R_c}V_c\right)$

$V_o = -\left(\frac{220k}{33k}(1.2) + \frac{220K}{22K}(-1.5) + \frac{220k}{80k}(4)\right)$

$\boxed{V_o = -4V}$

c) $V_o = 6V + V_o = -6V$

$V_o = -(8 + 10V_b + 11) = -19 - 10V_b$

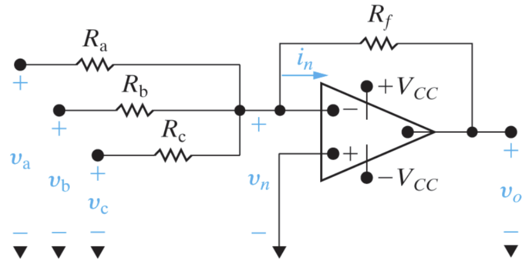
① $6 = -19 - 10V_b \Rightarrow V_b = -2.5V$

② $-6 = -19 - 10V_b \Rightarrow V_b = -1.3V$

$\boxed{-2.5V \le V_b \le -1.3V}$

5.14 PSPICE MULTISIM Refer to the circuit in **Fig. 5.11**, where the op amp is assumed to be ideal. Given that $R_a = 3\,k\Omega$, $R_b = 5\,k\Omega$, $R_c = 25\,k\Omega$, $v_a = 150\,mV$, $v_b = 100\,mV$, $v_c = 250\,mV$, and $V_{CC} = \pm 6\,V$, specify the range of R_f for which the op amp operates within its linear region.

Figure 5.11 A summing amplifier.



$$V_o = -\left(\frac{R_f}{3k}(150mV) + \frac{R_f}{5k}(100mV) + \frac{R_f}{25k}(250mV)\right)$$

$$R_f = \frac{-V_o}{8\times10^{-5}}$$

① $R_f = \frac{+6}{-8\times10^{-5}} = -75k\Omega$ ② $R_f = \frac{-6}{-8\times10^{-5}} = -75k\Omega$

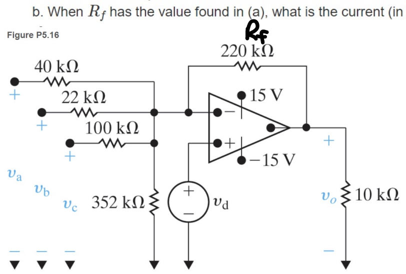
$$\boxed{0 \le R_f \le 75k\Omega}$$

5.17 PSPICE MULTISIM The $220\,k\Omega$ feedback resistor in the circuit in **Fig. P5.16** is replaced by a variable resistor R_f. The voltages $v_a - v_d$ have the same values as given in **Problem 5.16(a)**.

a. What value of R_f will cause the op amp to saturate? Note that $0 \le R_f \le \infty$.

b. When R_f has the value found in (a), what is the current (in microamperes) into the output terminal of the op amp?

Figure P5.16



$V_a = 4V$

$V_b = 9V$

$V_c = 13V$

$V_d = 8$

a) $\frac{8-4}{40K} + \frac{8-9}{22K} + \frac{8-13}{100K} + \frac{8-V_o}{R_f} + \frac{8}{352K} = 0$

$$R_f = \frac{8-V_o}{-2.73\times10^{-5}}$$

$V_o = 15$ + $V_o = -15$

① $R_f = \frac{-7}{-2.73\times10^{-5}} = 25641k\Omega$

② $R_f = \frac{23}{-2.73\times10^{-5}} = -842.5k\Omega < 0$

$$\boxed{R_f = 256.41\,k\Omega}$$

b) $i = -\left[\frac{15-8}{256.41K} + \frac{15}{10K}\right]$

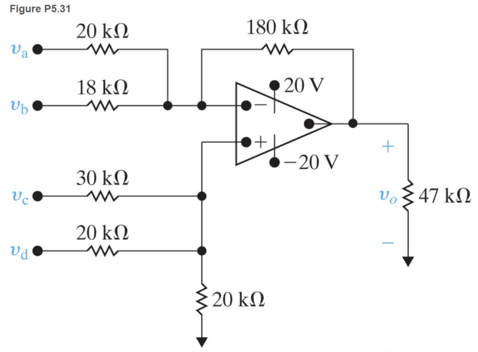
$$\boxed{i = -1.53\,mA}$$

5.31 PSPICE MULTISIM The op amp in the adder-subtracter circuit shown in Fig. P5.31 is ideal.

a. Find v_o when $v_a = 1\,\text{V}$, $v_b = 2\,\text{V}$, $v_c = 3\,\text{V}$, and $v_d = 4\,\text{V}$.

b. If v_a, v_b, and v_d are held constant, what values of v_c will not saturate the op amp?

Figure P5.31



a) Negative node

$$\frac{V_n-V_a}{20K}+\frac{V_n-V_b}{18K}+\frac{V_n-V_o}{180K}=0$$

$$9V_n-9V_a+10V_n-10V_b+V_n-V_o=0$$

$$V_o=20V_n-9V_a-10V_b=20V_n-29$$

Positive node

$$\frac{V_p}{20K}+\frac{V_p-V_c}{30K}+\frac{V_p-V_d}{20K}=0$$

$$3V_p+2V_p-2V_c+3V_p-3V_d=0$$

$$8V_p=2V_c+3V_d=18=8V_n$$

$$V_n=\frac{9}{4}=2.25$$

$$\therefore V_o=20(2.25)-29=16$$

$$\boxed{V_o=16\,V}$$

b) $V_o=5V_c+30-9-20=5V_c+1$

$V_o=\pm 20V$

① $20=5V_c+1$

$V_c=\frac{19}{5}=3.8$

② $-20=5V_c+1$

$V_c=-\frac{21}{5}=-4.2$

$$\boxed{-4.2V\le V_c\le 3.8V}$$