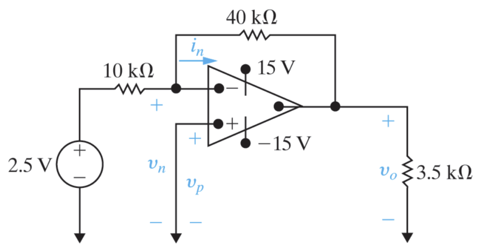
5.2

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: $-6\text{ V}$, $-3.5\text{ V}$, $-1.25\text{ V}$, 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

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

$\boxed{\text{the voltage source must be between } -3.75V \text{ and } 3.75V \text{ to avoid saturation}}$

---

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

a. Calculate $v_o$ if $v_a = 4\text{ V}$ and $v_b = 0\text{ V}$.

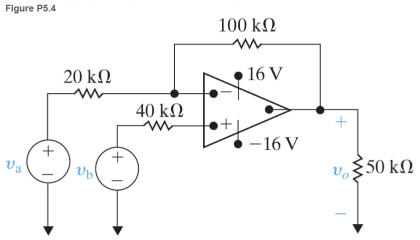
b. Calculate $v_o$ if $v_a = 2\text{ V}$ and $v_b = 0\text{ V}$.

c. Calculate $v_o$ if $v_a = 2\text{ V}$ and $v_b = 1\text{ V}$.

d. Calculate $v_o$ if $v_a = 1\text{ V}$ and $v_b = 2\text{ V}$.

e. If $v_b = 1.6\text{ V}$, 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) $V_o = -5(1) + 6(2)$

$\boxed{V_o = 7V}$

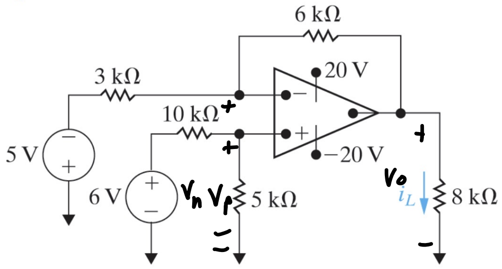
e) $16 = -5V_a + 6(1.6)$ + $-16 = -5V_a + 6(1.6)$

$V_a = -1.25$  $V_a = 5.12$

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

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

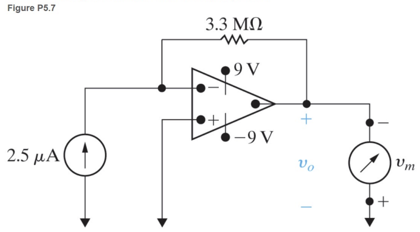
$i_L = \frac{V_o}{8K\Omega} = \frac{16}{8K}$

$\boxed{i_1 = 2mA}$

---

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 $V_o$

$\boxed{V_m = -8.25V}$

---

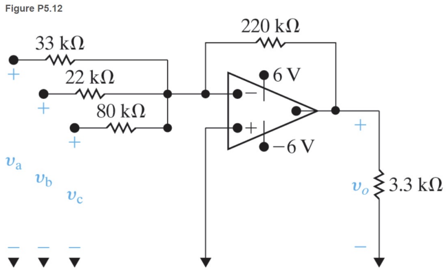
5.12 PSPICE MULTISIM The op amp in Fig. P5.12 is ideal.

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

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

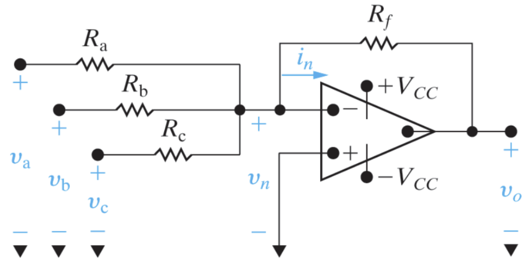
① $6 = -19 - 10V_b \Rightarrow V_b = -2.5V$

② $-6 = -19 - 10V_b \Rightarrow V_b = -1.6V$

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

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

**Figure 5.11 A summing amplifier.**




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

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

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

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

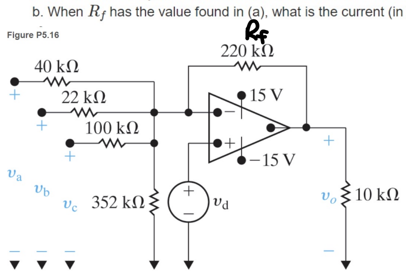
---

5.17 PSPICE MULTISIM The $220\,\text{k}\,\Omega$ 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 $R_f = \frac{-7}{-2.73\times10^{-5}} = 256.41\text{k}\Omega$

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

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

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

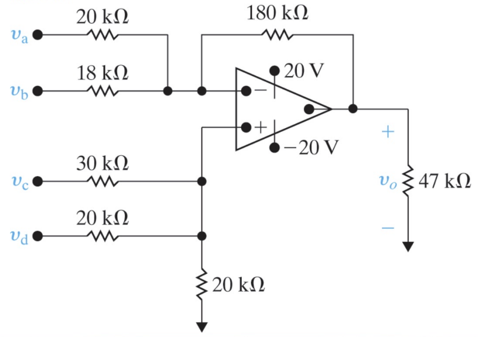
$$\boxed{i = -1.53\text{mA}}$$

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

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

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 $-20=5V_c+1$

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

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