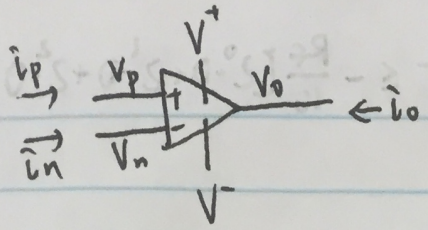
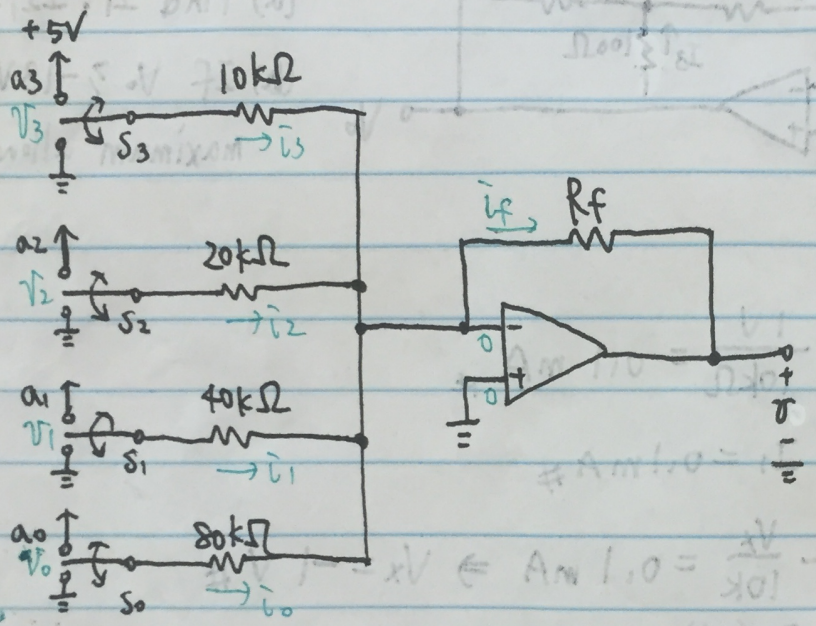
*Operational Amplifier



- virtual short: $v_p = v_n$
- high input resistance: $i_p = i_n = 0$



a_0, a_1, a_2, a_3 are the inputs of the circuit. $a_i = 0$ when S_i switches to 0V and $a_i = 1$ when S_i switches to 5V.

Show

$$v = -\frac{R_f}{16}\left[2^0 a_0 + 2^1 a_1 + 2^2 a_2 + 2^3 a_3\right]$$

$$i_f = i_0 + i_1 + i_2 + i_3 = \frac{v_0}{80k} + \frac{v_1}{40k} + \frac{v_2}{20k} + \frac{v_3}{10k}$$

$$= \frac{0 - v}{R_f} = -\frac{v}{R_f}$$

$$-\frac{v}{R_f} = \frac{v_0}{80} + \frac{v_1}{40} + \frac{v_2}{20} + \frac{v_3}{10}$$

$$= \frac{5a_0}{80} + \frac{5a_1}{40} + \frac{5a_2}{20} + \frac{5a_3}{10}$$

$$\Rightarrow v = -\frac{R_f}{16}\left[2^0 a_0 + 2^1 a_1 + 2^2 a_2 + 2^3 a_3\right] \#$$

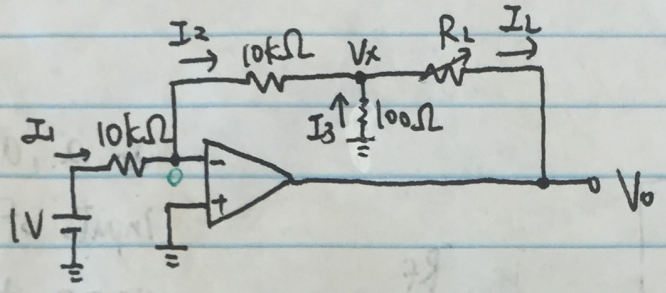
(continue)

Find the value of R_f so that $-12 \le V \le 0$

$$-\frac{R_f}{16}[2^0\cdot 1+2^1\cdot 1+2^2\cdot 1+2^3\cdot 1] \le V \le -\frac{R_f}{16}[2^0\cdot 0+2^1\cdot 0+2^2\cdot 0+2^3\cdot 0]$$

$$-\frac{15}{16}R_f \le V \le 0$$

$$-\frac{15}{16}R_f = -12 \Rightarrow R_f = \frac{64}{5} = 12.8\ (k\Omega)\ \#$$



(a) Find I_1, I_2, I_3, and V_x

(b) If $V_o \ge -13V$, find the maximum allowed value of R_L

(a) $I_1 = \frac{1V}{10k\Omega} = 0.1\ mA\ \#$

$I_2 = I_1 = 0.1\ mA\ \#$

$I_2 = -\frac{V_x}{10k} = 0.1\ mA \Rightarrow V_x = -1\ V\ \#$

$I_3 = \frac{0-(-1)}{100\Omega} = 10\ mA\ \#$

(b) $I_L = I_2 + I_3 = 10.1\ mA = \frac{V_x - V_o}{R_L} = \frac{-1-V_o}{R_L}$

$R_{L,max} = [-1-(-13)]/10.1\ mA = 1.19\ k\Omega\ \#$