13.39 In the circuit in Fig. P13.39, switch 1 closes at $t = 0$, and the make-before-break switch moves instantaneously from position a to position b.

P

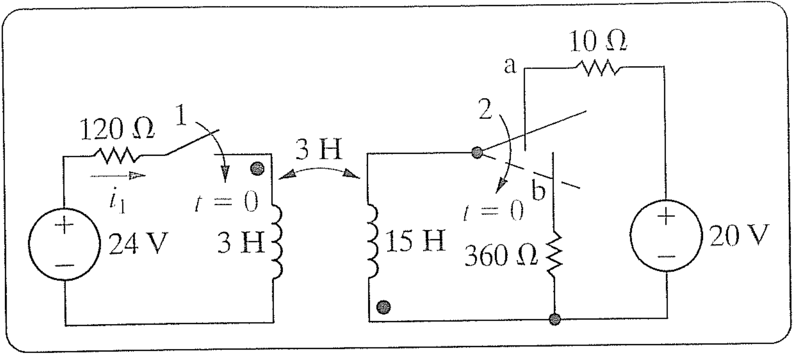
a) Construct the s-domain equivalent circuit for $t > 0$.

b) Find I_1.

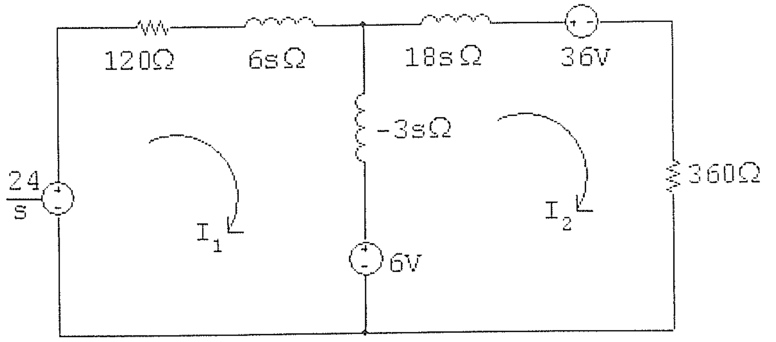
c) Use the initial- and final-value theorems to check the initial and final values of i_1.

d) Find i_1 for $t \geq 0^+$.

Figure P13.39



P 13.39 [a] s-domain equivalent circuit is



Note: $i_2(0^+) = -\frac{20}{10} = -2\text{ A}$

[b] $\frac{24}{s} = (120 + 3s)I_1 + 3sI_2 + 6$

$0 = -6 + 3sI_1 + (360 + 15s)I_2 + 36$

In standard form,

$(s + 40)I_1 + sI_2 = (8/s) - 2$

$sI_1 + (5s + 120)I_2 = -10$

$$\Delta = \begin{vmatrix} s+40 & s \\ s & 5s+120 \end{vmatrix} = 4(s + 20)(s + 60)$$

$$N_1 = \begin{vmatrix} (8/s)-2 & s \\ -10 & 5s+120 \end{vmatrix} = \frac{-200(s - 4.8)}{s}$$

$$I_1 = \frac{N_1}{\Delta} = \frac{-50(s - 4.8)}{s(s + 20)(s + 60)}$$

[c] $sI_1 = \frac{-50(s - 4.8)}{(s + 20)(s + 60)}$

$$\lim_{s\to\infty} sI_1 = i_1(0^+) = 0\text{ A}$$

$$\lim_{s\to 0} sI_1 = i_1(\infty) = \frac{(-50)(-4.8)}{(20)(60)} = 0.2\text{ A}$$

[d] $I_1 = \frac{K_1}{s} + \frac{K_2}{s + 20} + \frac{K_3}{s + 60}$

$$K_1 = \frac{240}{1200} = 0.2; \qquad K_2 = \frac{-50(-20) + 240}{(-20)(40)} = -1.55$$

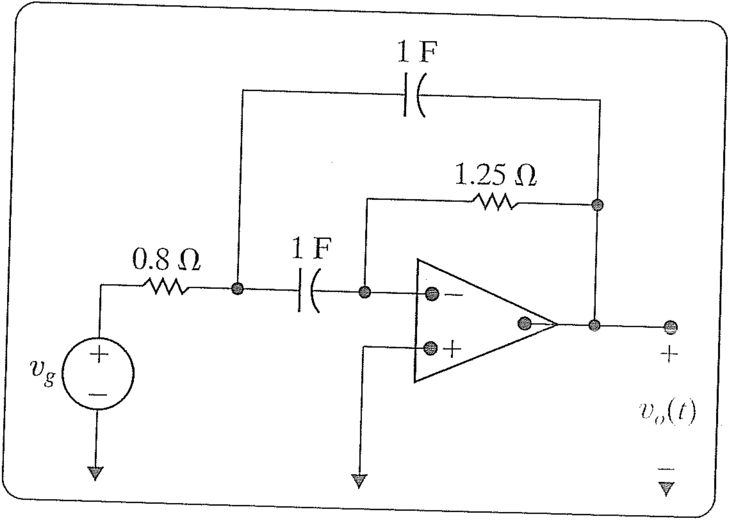
$$K_3 = \frac{-50(-60) + 240}{(-60)(-40)} = 1.35$$

$$i_1(t) = [0.2 - 1.55e^{-20t} + 1.35e^{-60t}]u(t)\ \text{A}$$

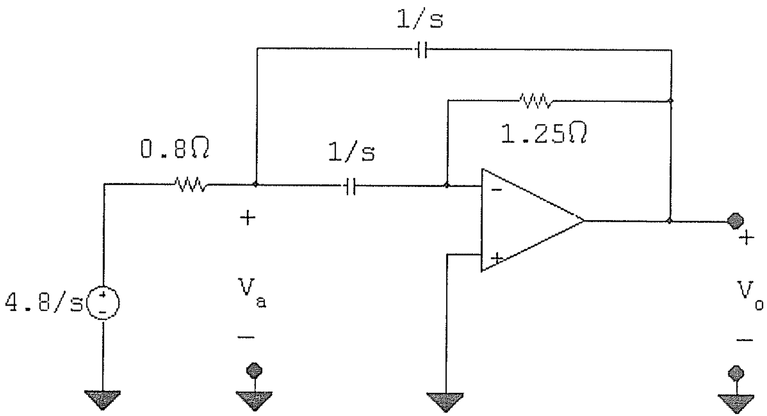
13.44 Find $v_o(t)$ in the circuit shown in Fig. P13.44 if the ideal op amp operates within its linear range and $v_g = 4.8u(t)$ V.

P

Figure P13.44



P 13.44



$$\frac{V_{\rm a} - 4.8/s}{0.8} + \frac{V_{\rm a}}{1/s} + \frac{V_{\rm a} - V_o}{1/s} = 0$$

$$\frac{0 - V_{\rm a}}{1/s} + \frac{0 - V_o}{1.25} = 0$$

$$V_{\rm a} = \frac{-V_o}{1.25s}$$

$$V_{\rm a}(2s + 1.25) - sV_o = 6/s$$

$$-V_o\left[\frac{(2s+1.25)}{1.25s}+s\right]=6/s$$

$$-V_o\left[\frac{125s^2+2s+1.25}{1.25s}\right]=6/s$$

$$V_o=\frac{-7.5}{1.25s^2+2s+1.25}=\frac{-6}{s^2+1.6s+1}$$

$$=\frac{K_1}{s+0.8-j0.6}+\frac{K_1^*}{s+0.8+j0.6}$$

$$K_1=\frac{-6}{s+0.8+j0.6}\bigg|_{s=-0.8+j0.6}=5\underline{/90^\circ}$$

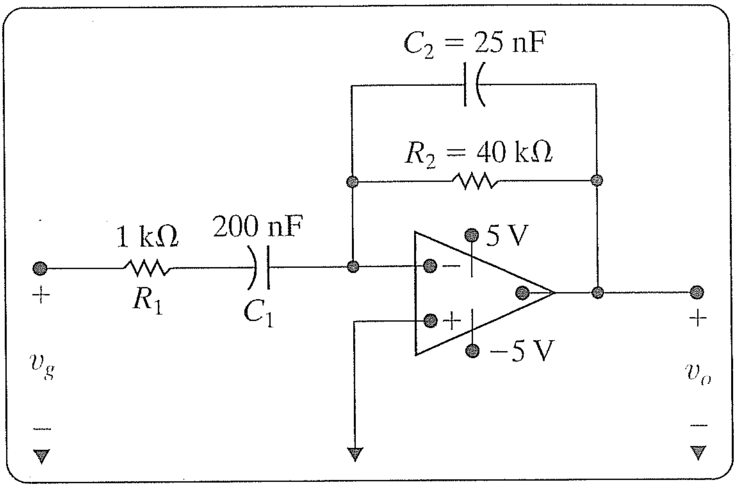
$$v_o(t)=10e^{-0.8t}\cos(0.6t+90^\circ)u(t)\text{ V}=-10e^{-0.8t}\sin(0.6t)u(t)\text{ V}$$

13.52 The operational amplifier in the circuit in Fig. P13.52 is ideal.

a) Find the numerical expression for the transfer function $H(s) = V_o/V_g$.

b) Give the numerical value of each zero and pole of $H(s)$.

Figure P13.52



P 13.52 **[a]** $Z_i = 1000 + \frac{5 \times 10^6}{s} = \frac{1000(s + 5000)}{s}$

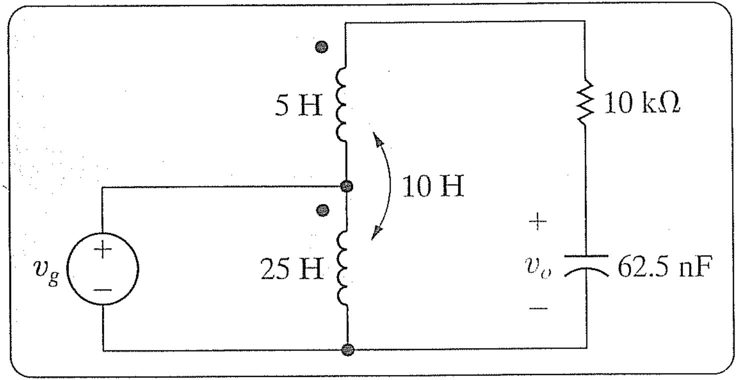
$$Z_f = \frac{40 \times 10^6}{s} \| 40{,}000 = \frac{40 \times 10^6}{s + 1000}$$

$$H(s) = -\frac{Z_f}{Z_i} = \frac{-40 \times 10^6/(s + 1000)}{1000(s + 5000)/s} = \frac{-40{,}000s}{(s + 1000)(s + 5000)}$$

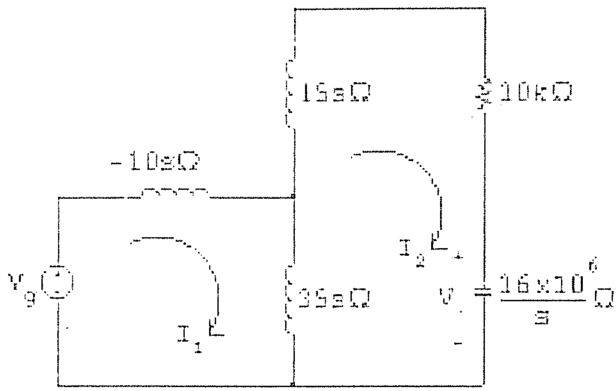
[b] Zero at $s = 0$; Poles at $-p_1 = -1000$ rad/s and $-p_2 = -5000$ rad/s

13.54 In the circuit of Fig. P13.54 v_o is the output signal and v_g is the input signal. Find the poles and zeros of the transfer function.

Figure P13.54



P 13.54



$$V_g = 25sI_1 - 35sI_2$$

$$0 = -35sI_1 + \left(50s + 10.000 + \frac{16\times10^6}{s}\right)I_2$$

$$\Delta = \begin{vmatrix} 25s & -35s \\ -35s & 50s + 10{,}000 + 16\times10^6/s \end{vmatrix} = 25(s+2000)(s+8000)$$

$$N_2 = \begin{vmatrix} 25s & V_g \\ -35s & 0 \end{vmatrix} = 35sV_g$$

$$I_2 = \frac{N_2}{\Delta} = \frac{35sV_g}{25(s+2000)(s+8000)}$$

$$V_o = \frac{16\times10^6}{s}I_2 = \frac{22.4\times10^6 V_g}{(s+2000)(s+8000)}$$

$$H(s) = \frac{V_o}{V_g} = \frac{22.4\times10^6}{(s+2000)(s+8000)}$$

$\therefore \quad -p_1 = -2000$ rad/s; $\quad -p_2 = -8000$ rad/s

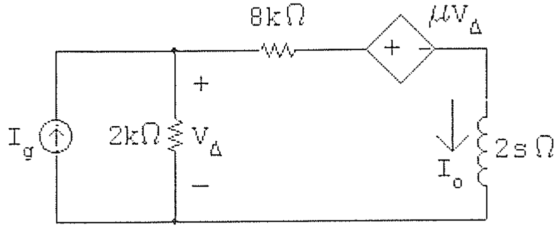
13.56 a) Find the transfer function I_o/I_g as a function of μ for the circuit seen in Fig. P13.56.

P

b) Find the largest value of μ that will produce a bounded output signal for a bounded input signal.

c) Find i_o for $\mu = -3$, 0, 4, 5, and 6 if $i_g = 5u(t)$ A.

P 13.56 **[a]**



$$2000(I_o - I_g) + 8000I_o + \mu(I_g - I_o)(2000) + 2sI_o = 0$$

$$\therefore\ I_o = \frac{1000(1-\mu)}{s + 1000(5-\mu)} I_g$$

$$\therefore\quad H(s) = \frac{1000(1-\mu)}{s + 1000(5-\mu)}$$

[b] $\mu < 5$

[c]

μ	$H(s)$	I_o
-3	$4000/(s+8000)$	$20{,}000/s(s+8000)$
0	$1000/(s+5000)$	$5000/s(s+5000)$
4	$-3000/(s+1000)$	$-15{,}000/s(s+1000)$
5	$-4000/s$	$-20{,}000/s^2$
6	$-5000/(s-1000)$	$-25{,}000/s(s-1000)$

$\mu = -3$:

$$I_o = \frac{2.5}{s} - \frac{2.5}{(s+8000)}; \qquad i_o = [2.5 - 2.5e^{-8000t}]u(t)\text{ A}$$

$\mu = 0$:

$$I_o = \frac{1}{s} - \frac{1}{s+5000}; \qquad i_o = [1 - e^{-5000t}]u(t)\text{ A}$$

$\mu = 4$:

$$I_o = \frac{-15}{s} + \frac{15}{s+1000}; \qquad i_o = [-15 + 15e^{-1000t}]u(t)\text{ A}$$

$\mu = 5$:

$$I_o = \frac{-20{,}000}{s^2}; \qquad i_o = -20{,}000t\,u(t)\text{ A}$$

$\mu = 6$:

$$I_o = \frac{25}{s} - \frac{25}{s - 1000}; \qquad i_o = 25[1 - e^{1000t}]u(t)\ \mathrm{A}$$