13.13 The switch in the circuit in Fig. P13.13 has been closed for a long time before opening at $t = 0$.
PSPICE

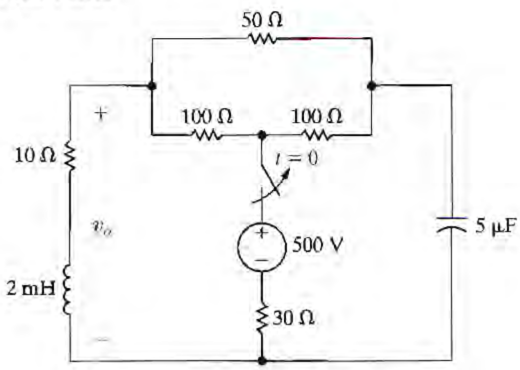
a) Construct the s-domain equivalent circuit for $t > 0$.

b) Find V_o.

c) Find v_o for $t \geq 0$.

d) Check your answer to (c) with PSpice.

Figure P13.13

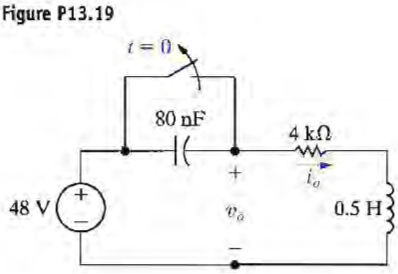


13.19 The switch in the circuit in Fig. P13.19 has been closed for a long time. At $t = 0$, the switch is opened.
PSPICE

a) Find $v_o(t)$ for $t \geq 0$.

b) Find $i_o(t)$ for $t \geq 0$.

Figure P13.19



13.32 There is no energy stored in the circuit in Fig. P13.32 at the time the current source turns on. Given that $i_g = 100u(t)$ A:
PSPICE

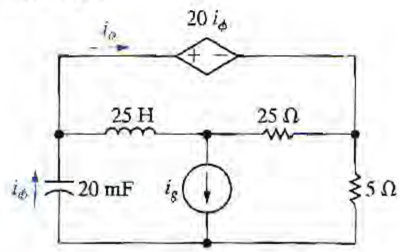
a) Find $I_o(s)$.

b) Use the initial- and final-value theorems to find $i_o(0^+)$ and $i_o(\infty)$.

c) Determine if the results obtained in (b) agree with known circuit behavior.

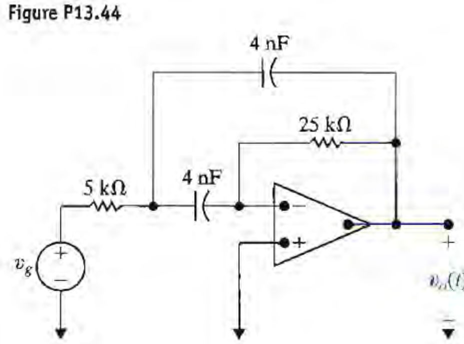
d) Find $i_o(t)$.

Figure P13.32



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 $v_g = 400u(t)$ mV.
PSPICE

Figure P13.44

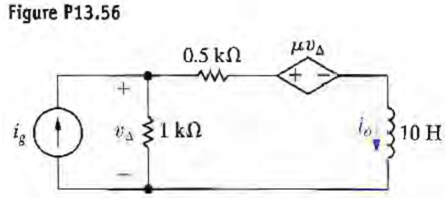


13.56 a) Find the transfer function I_o/I_g as a function of μ for the circuit seen in Fig. P13.56.
PSPICE

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

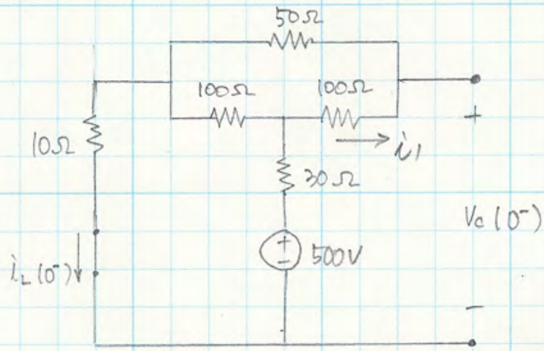
c) Find i_o for $\mu = -0.5$, 0, 1, 1.5, and 2 if $i_g = 10u(t)$ A.

Figure P13.56



13.13

(a) For $t < 0$,



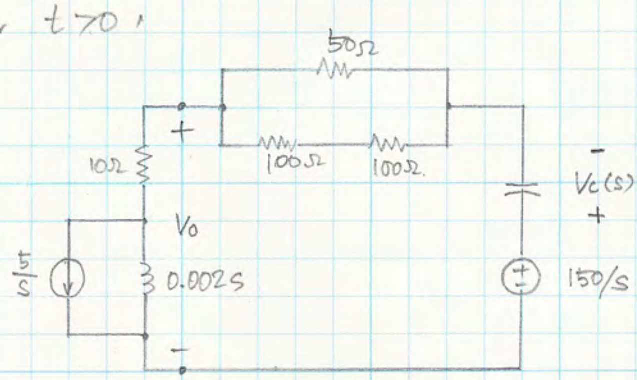
$$100 \parallel (100+50) = \frac{100 \times 150}{100+150} = 60\Omega$$

$$\therefore i_L(0^-) = \frac{500}{30+60+10} = 5\,A.$$

$$i_1 = 5 \times \frac{100}{100+150} = 2A.$$

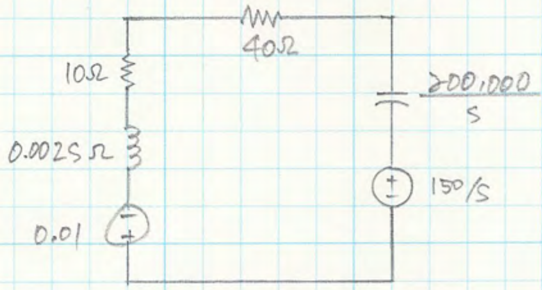
$$\rightarrow V_c(0^-) = 500 - 30 \cdot i_L(0^-) - 100\, i_1$$
$$= 500 - 150 - 200$$
$$= \underline{150\,V.}$$

For $t > 0$,



$$50 \parallel (100+100) = \frac{50 \times 200}{50+200} = 40\,\Omega$$

Via source transform.



(b) $$\frac{V_o + 0.01}{10 + 0.0025} + \frac{V_o - 150/s}{40 + \frac{200,000}{s}} = 0$$

$$V_o\left[\frac{1}{10+0.002s} + \frac{1}{40+\frac{200000}{s}}\right] = \frac{150/s}{40+\frac{200,000}{s}} - \frac{0.01}{10+0.002s}$$

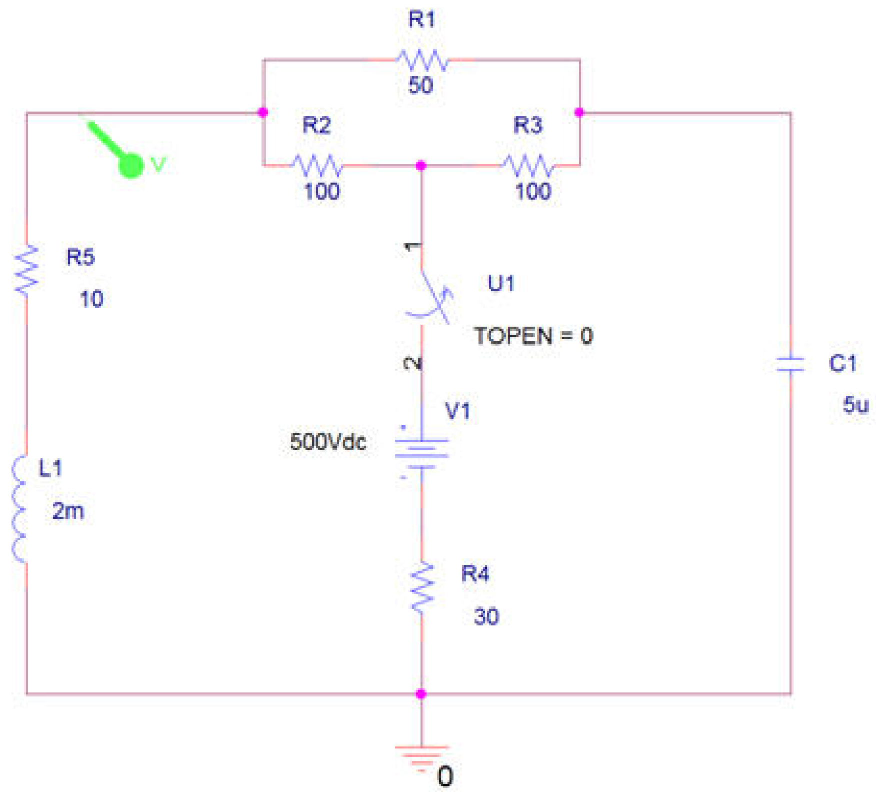
$$V_o\left[\frac{500}{s+5000} + \frac{s}{40(s+5000)}\right] = \frac{150}{40(s+5000)} - \frac{50}{s+5000}$$

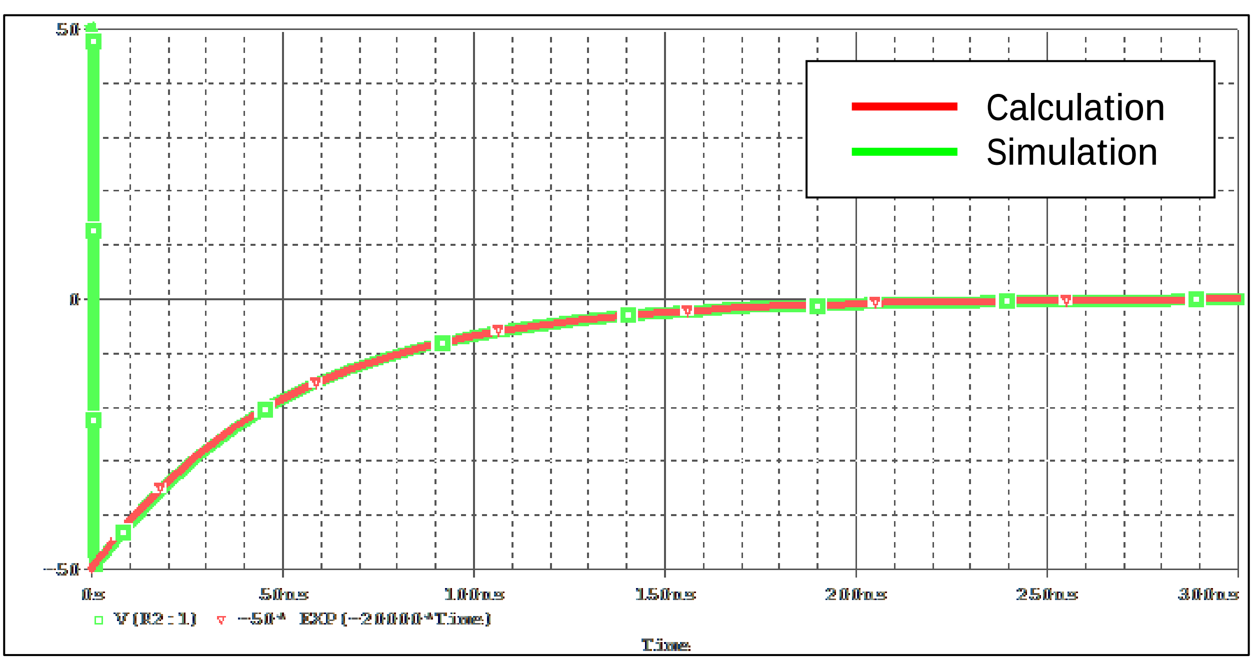
$$V_o\left[500\times 40 + s\right] = 150 - 50\times 40 = -50.$$

$$\therefore V_o = \frac{-50.}{s+20000}$$

(c) $$v_o(t) = -50 \cdot e^{-20000t} \cdot u(t) \ \text{V}$$

(d) check next page

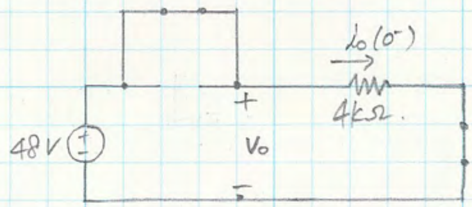

R1
50
R2
100
R3
100
V
R5
10
U1
TOPEN = 0
C1
5u
V1
500Vdc
L1
2m
R4
30
0


Calculation
Simulation
50
0
-50
0s
50ms
100ms
150ms
200ms
250ms
300ms
V(R2:1)
-50* EXP(-20000*Time)
Time

13.19

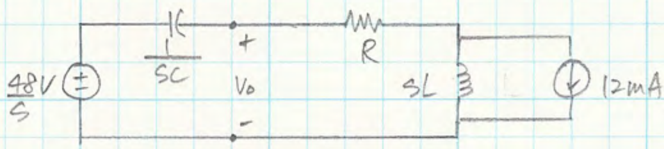
(a) Find $V_o(t)$ for $t \geq 0$.

for $t < 0$.

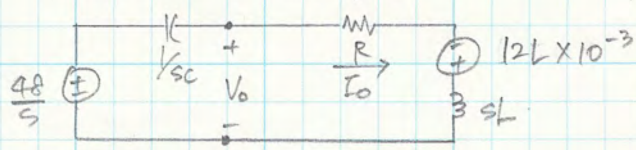


$i_o(0^-) = 48/4k = \underline{12\ mA}$

for $t > 0$



Via Source transform



$$\frac{V_o - 48/s}{1/sC} + \frac{V_o + 12L \times 10^{-3}}{R + sL} = 0$$

$$(sCV_o - 48C)(R + sL) + V_o + 12L \times 10^{-3} = 0$$

$$V_o(sRC + s^2LC + 1) = s48LC + 48RC - 12L \times 10^{-3}$$

$$\therefore V_o = \frac{s\,48LC + 48RC - 12L \times 10^{-3}}{s^2LC + sRC + 1}$$

$$= \frac{48(s + R/L) - 12 \times 10^{-3}/C}{s^2 + s(R/L) + (1/LC)}$$

$R/L = 8000$

$1/LC = 2.5 \times 10^7$

$$= \frac{48s + 48 \times 8000 - 150 \times 10^3}{s^2 + 8000s + 2.5 \times 10^7}$$

$$= \frac{48(s + 4875)}{s^2 + 8000s + 2.5 \times 10^7}$$

$s = -4000 \pm j3000$

cont.

$$\therefore V_o = \frac{k_1}{s+4000-j3000} + \frac{k_2}{s+4000+j3000}$$

$$48(s+4875) = k_1(s+4000+j3000) + k_2(s+4000-j3000)$$

$s=-4000+j3000$

$$48(-4000+j3000+4875) = k_1(j6000)$$

$$\therefore k_1 = \frac{48(875+j3000)}{j6000}$$

$\sqrt{875^2+3000^2} = 3125$

$$= \frac{48\times 3125\angle 73.74^\circ}{6000\angle 90^\circ}$$

$\text{atan}(3000/875) = 73.74$

$$= 25\angle(73.74^\circ - 90^\circ)$$

$$= 25\angle -16.26^\circ$$

$$k_2 = k_1^* = 25\angle 16.26^\circ$$

$$\rightarrow V_o = \frac{25\angle -16.26^\circ}{s+4000-j3000} + \frac{25\angle 16.26^\circ}{s+4000+j3000}$$

$$\hookrightarrow v_o(t) = 2\times 25\, e^{-4000t}\cos(3000t - 16.26^\circ)\, u(t)\ \text{V}$$

(b) Find $i_o(t)$ for $t \geq 0$

$$I_o = \frac{48/s + 12L\times 10^{-3}}{1/sC + R + sL} = \frac{48C + sC\cdot 12L\times 10^{-3}}{s^2LC + sRC + 1}$$

$$= \frac{48/L + s\cdot 12\times 10^{-3}}{s^2 + 8000s + 2.5\times 10^7}$$

$$= \frac{12\times 10^{-3}(s+8000)}{(s+4000-j3000)(s+4000+j3000)}$$

$$= \frac{k_1}{s+4000-j3000} + \frac{k_2}{s+4000+j3000}$$

$$12\times 10^{-3}(s+8000) = k_1(s+4000+j3000) + k_2(s+4000-j3000)$$

$$s = -4000+j3000 \rightarrow 12\times 10^{-3}(-4000+j3000+8000) = k_1(j6000)$$

$$\therefore k_1 = \frac{12\times 10^{-3}(4000+j3000)}{j6000}$$

$$k_1 = \frac{12\times10^{-3}\times 5000\angle 36.87^\circ}{6000\angle 90^\circ} = 10\times10^{-3}\angle -53.13^\circ$$

$$\therefore k_2 = k_1^* = 10\times10^{-3}\angle 53.13^\circ$$

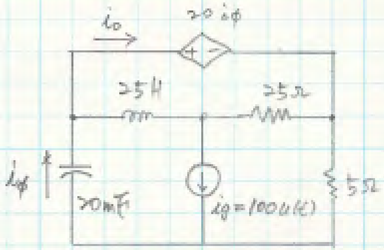
$$I_o = \frac{10\times10^{-3}\angle -53.13}{s+4000-j3000} + \frac{10\times10^{-3}\angle 53.13^\circ}{s+4000+j3000}$$

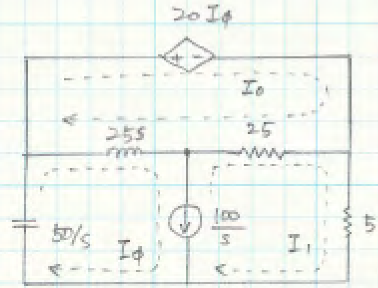
$$\hookrightarrow i_o(t) = 2\times10\times10^{-3}\cdot e^{-4000t}\cos(3000t-53.13^\circ)\ \text{A}$$

$$= 20\cdot e^{-4000t}\cos(3000t-53.13^\circ)\ \text{mA}.$$

13.32

(a)





$$20 I_\phi + 25(I_o - I_1) + 25s(I_o - I_\phi) = 0 \quad \text{------- ①}$$

$$\frac{50}{s} I_\phi + 25s(I_\phi - I_o) + 25(I_1 - I_o) + 5I_1 = 0 \quad \text{------- ②}$$

$$I_\phi - I_1 = 100/s \quad \text{------- ③}$$

from ① + ② ,

$$20 I_\phi + 5 I_1 + 50/s \; I_\phi = 0$$

using ③

$$20 I_\phi + 5\left(I_\phi - \frac{100}{s}\right) + \frac{50}{s} I_\phi = 0$$

$$I_\phi\left(20 + 5 + \frac{50}{s}\right) = \frac{500}{s}$$

$$\therefore \; I_\phi = \frac{500}{25s + 50} = \frac{20}{s+2}$$

$$\rightarrow \; I_1 = I_\phi - \frac{100}{s} = \frac{20}{s+2} - \frac{100}{s}$$

$\therefore$ equation ① becomes

$$I_o(25 + 25s) = I_\phi(25s - 20) + 25 I_1$$

$$I_o = I_\phi \frac{5s-4}{5(s+1)} + I_1 \cdot \frac{1}{s+1}$$

$$= \frac{\cancel{20}\,4}{s+2} \cdot \frac{5s-4}{\cancel{5}(s+1)} + \left(\frac{20}{s+2} - \frac{100}{s}\right)\frac{1}{s+1}$$

$$= \frac{20s - 16}{(s+1)(s+2)} + \frac{20}{(s+1)(s+2)} - \frac{100}{s(s+1)}$$

$$= \frac{20s^2 - 16s + 20s - 100s - 200}{s(s+1)(s+2)}$$

$$= \frac{20s^2 - 96s - 200}{s(s+1)(s+2)}$$

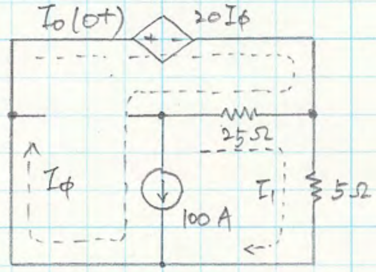
(b) $\lim_{t \to 0^+} f(t) = \lim_{s \to \infty} s F(s)$ (if $f(t)$ contains no impulse function)

$$= \lim_{s \to \infty} \frac{20s^2 - 96s - 200}{(s+1)(s+2)} = 20 \text{ A}$$

$\lim_{t \to \infty} f(t) = \lim_{s \to 0} s F(s)$ (if the poles of $F(s)$, except for a first-order pole at the origin lie in the left half of the s plane)

$$= \lim_{s \to 0} \frac{20s^2 - 96s - 200}{(s+1)(s+2)} = \frac{-200}{2} = -100 \text{ A}$$

(c) at $t = 0^+$ (inductor → open)



$$20 I_\phi + 5 I_1 = 0.$$

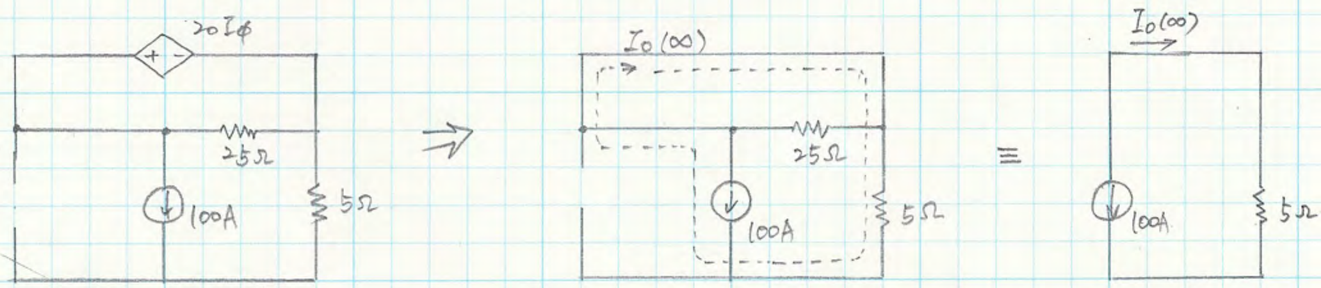
$$I_\phi - I_1 = 100.$$

$$\therefore\ 20 I_\phi + 5(I_\phi - 100) = 0$$

$$25 I_\phi = 500.$$

$$\therefore\ I_\phi = 20\ A. = I_o(0^+)$$

at $t \to +\infty$ (capacitor open, $I_\phi = 0$)



$$I_o(\infty) = -100\ A$$

(d) $$I_o = \frac{20s^2 - 96s - 200}{s(s+1)(s+2)} = \frac{k_1}{s} + \frac{k_2}{s+1} + \frac{k_3}{s+2}$$

$$20s^2 - 96s - 200 = k_1(s+1)(s+2) + k_2\, s(s+2) + k_3 \cdot s(s+1)$$

$s=0.$ $\quad -200 = 2k_1 \to k_1 = -100$

$s=-1.$ $\quad 20 + 96 - 200 = k_2(-1) \to k_2 = 84$

$s=-2.$ $\quad 80 + 192 - 200 = k_3(2) \to k_3 = 36$

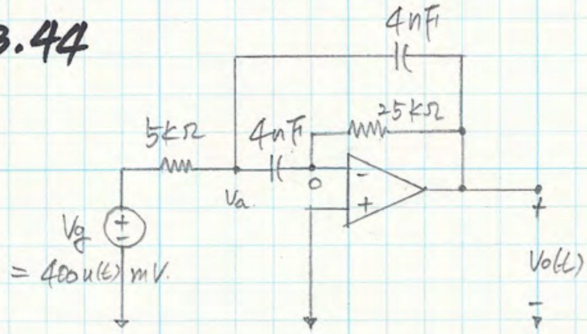
$$\therefore\ I_o(s) = \frac{-100}{s} + \frac{84}{s+1} + \frac{36}{s+2}$$

$$\hookrightarrow\ i_o(t) = [-100 + 84e^{-t} + 36e^{-2t}]\,u(t)\ A$$

check) IVT $i_o(0^+) = -100 + 84 + 36 = 20\ A$

FVT $i_o(\infty) = -100\ A$

13.44



Find Vo(t)

$$\frac{1}{sC} = 250\times10^6/s$$

KCL at Va node → $\dfrac{V_a - 0.4/s}{5000} + \dfrac{V_a - V_o}{250\times10^6/s} + \dfrac{V_a}{250\times10^6/s} = 0$ ⋯ ①

KCL at inverting input → $\dfrac{0 - V_a}{250\times10^6/s} + \dfrac{0 - V_o}{25000} = 0$ ⋯ ②

$$V_a = -\frac{V_o}{25000}\times\frac{250\times10^6}{s} = \frac{-10^4 V_o}{s}$$

equation ①.

$$50000\left(V_a - 0.4/s\right) + s(V_a - V_o) + sV_a = 0$$

$$50000\left(-\frac{10^4 V_o}{s} - \frac{0.4}{s}\right) + s\left(\frac{-10^4 V_o}{s} - V_o\right) + s\left(-\frac{10^4 V_o}{s}\right) = 0.$$

$$V_o\left(\frac{-50000\times10^4}{s} - 10^4 - s - 10^4\right) = \frac{20000}{s}$$

$$V_o\left(-5\times10^8 - 2\times10^4 s - s^2\right) = 2\times10^4$$

$$\therefore V_o = \frac{-2\times10^4}{s^2 + 2\times10^4 s + 5\times10^8} \qquad \leftarrow s = -10000 \pm j20000$$

$$= \frac{k_1}{s + 10000 - j20000} + \frac{k_2}{s + 10000 + j20000}$$

$$-2\times10^4 = k_1(s + 10000 + j20000) + k_2(s + 10000 - j20000)$$

$s = -1000 + j20000.$

$$\rightarrow -20000 = k_1(j40000) \qquad \therefore k_1 = j0.5 = 0.5\angle 90^\circ$$

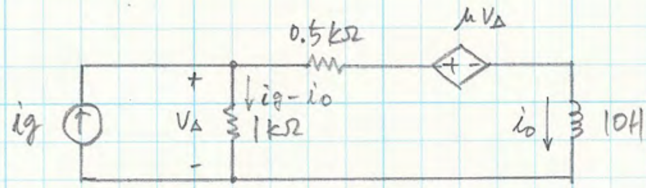
$$k_2 = k_1^* = 0.5\angle -90^\circ$$

$$V_o = \frac{0.5\angle 90^\circ}{s + 10000 - j20000} + \frac{0.5\angle -90^\circ}{s + 10000 - j20000}$$

$$\rightarrow V_o(t) = 2\times0.5\,e^{-10000t}\cos(20000t + 90^\circ)\cdot u(t)\ \text{V}$$

$$= e^{-10000t}\sin(20000t)\cdot u(t)\ \text{V}$$

13.56



(a) Find the transfer function I_o/I_g

$$1000\,(I_g - I_o) = V_\Delta \quad \text{-------------} \; ①$$

$$V_\Delta = 500\, I_o + \mu V_\Delta + 10s\, I_o \quad \text{---------} \; ②$$

from ① and ②,

$$1000\,(I_g - I_o) = 500\, I_o + \mu \cdot 1000\,(I_g - I_o) + 10s\, I_o$$

$$I_g\,(1000 - 1000\mu) = I_o\,(1000 + 500 - 1000\mu + 10s)$$

$$\therefore \frac{I_o}{I_g} = \frac{1000\,(1-\mu)}{10s + 1500 - 1000\mu} = \frac{100\,(1-\mu)}{s + 100\,(1.5-\mu)}$$

(b) Bounded output ; Pole(s) should be in the left half of the s-plane. (except for a first order pole at the origin)

$$\therefore 1.5 - \mu > 0.$$

(c) Find $i_o(t)$ for $\mu = -0.5,\ 0,\ 1,\ 1.5$ and 2.

$(\, i_g(t) = 10\,u(t)\ A\,)$

$$I_o = I_g \cdot \frac{100\,(1-\mu)}{s + 100\,(1.5-\mu)} = \frac{1000\,(1-\mu)}{s\,[s + 100\,(1.5-\mu)]}$$

1) $\mu = -0.5$

$$I_o = \frac{1500}{s\,(s+200)} = \frac{7.5}{s} - \frac{7.5}{s+200}$$

$$i_o(t) = [\,7.5 - 7.5\,e^{-200t}\,]\,u(t)\ A.$$

2) $\mu = 0$

$$I_o = \frac{1000}{s(s+150)} = \frac{6.666}{s} - \frac{6.666}{s+150}$$

$$i_o(t) = [6.666 - 6.666\,e^{-150t}]\,u(t)\ A$$

3) $\mu = 1$.

$$I_o = 0.$$

$$i_o(t) = 0.$$

4) $\mu = 1.5$

$$I_o = \frac{-500}{s^2}$$

$$i_o(t) = -500t \cdot u(t)\ A$$

5) $\mu = 2$.

$$I_o = \frac{-1000}{s(s-50)} = \frac{20}{s} - \frac{20}{s-50}$$

$$i_o(t) = [20 - 20\,e^{50t}]\,u(t)\ A.$$