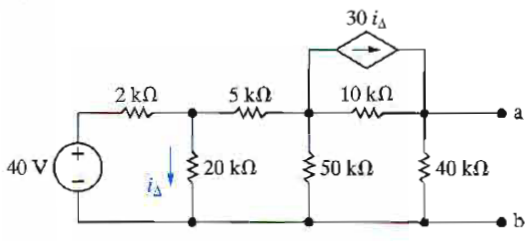
4.72 Find the Thévenin equivalent with respect to the terminals a,b for the circuit seen in Fig. P4.72.
PSPICE

Figure P4.72

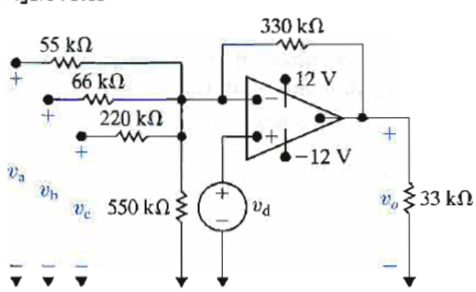


5.14 The 330 kΩ feedback resistor in the circuit in Fig. P5.13 is replaced by a variable resistor R_f. The voltages $v_a - v_d$ have the same values as given in Problem 5.13(a).
PSPICE

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

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 P5.13



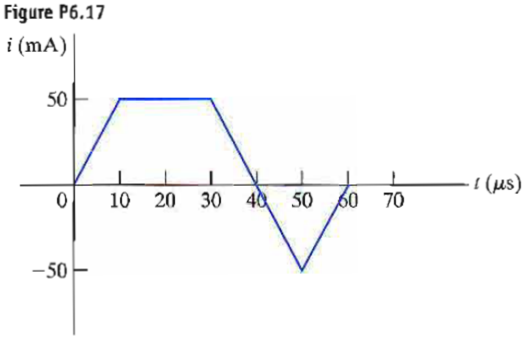
6.17 The current shown in Fig. P6.17 is applied to a 0.25 μF capacitor. The initial voltage on the capacitor is zero.
PSPICE

a) Find the charge on the capacitor at $t = 30$ μs.

b) Find the voltage on the capacitor at $t = 50$ μs.

c) How much energy is stored in the capacitor by this current?

Figure P6.17



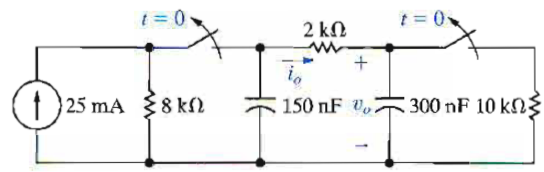
7.25 Both switches in the circuit in Fig. P7.25 have been closed for a long time. At $t = 0$, both switches open simultaneously.
PSPICE

a) Find $i_o(t)$ for $t \geq 0^+$.

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

c) Calculate the energy (in microjoules) trapped in the circuit.

Figure P7.25



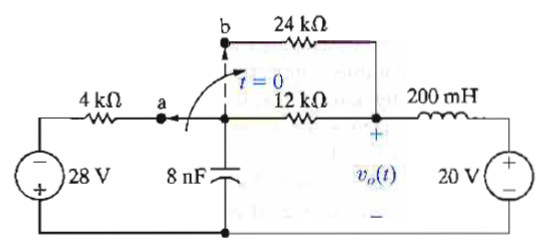
8.51 The switch in the circuit of Fig. P8.51 has been in position a for a long time. At $t = 0$ the switch moves instantaneously to position b. Find
PSPICE

a) $v_o(0^+)$

b) $dv_o(0^+)/dt$

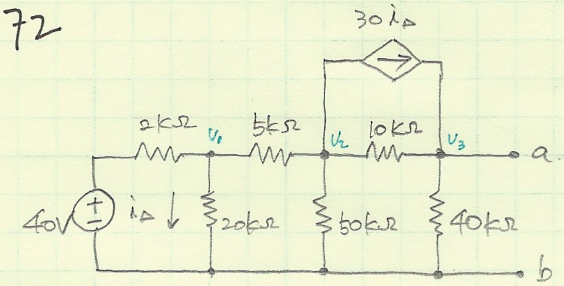
c) $v_o(t)$ for $t \geq 0$.

Figure P8.51



Calculate the following complex number: (1+3j)+(2-2j)/(2+j). Give answer in both Cartesian and angular (magnitude and phase) form.

P.4.72



$\leftarrow V_{ab} = V_{Th} = V_3.$

$i_\Delta = \dfrac{V_1}{20000}$

at V_1 node. $\dfrac{V_1 - 40}{2000} + \dfrac{V_1}{20000} + \dfrac{V_1 - V_2}{5000} = 0.$

at V_2 node. $\dfrac{V_2 - V_1}{5000} + \dfrac{V_2}{50000} + \dfrac{V_2 - V_3}{10000} + 30 \cdot \dfrac{V_1}{20000} = 0$

at V_3 node. $\dfrac{V_3 - V_2}{10000} + \dfrac{V_3}{40000} - 30 \dfrac{V_1}{20000} = 0$

$$\begin{cases} V_1\left(\dfrac{1}{2000} + \dfrac{1}{20000} + \dfrac{1}{5000}\right) + V_2\left(-\dfrac{1}{5000}\right) + V_3(0) = \dfrac{40}{2000} \\ V_1\left(-\dfrac{1}{5000} + \dfrac{30}{20000}\right) + V_2\left(\dfrac{1}{5000} + \dfrac{1}{50000} + \dfrac{1}{10000}\right) + V_3\left(-\dfrac{1}{10000}\right) = 0 \\ V_1\left(-\dfrac{30}{20000}\right) + V_2\left(-\dfrac{1}{10000}\right) + V_3\left(\dfrac{1}{10000} + \dfrac{1}{40000}\right) = 0 \end{cases}$$

$$\begin{cases} V_1(10+1+4) + V_2(-4) + V_3(0) = 400 \\ V_1(-10+75) + V_2(10+1+5) + V_3(-5) = 0. \\ V_1(-60) + V_2(-4) + V_3(4+1) = 0. \end{cases}$$

$V_1(15) + V_2(-4) + V_3(0) = 400$ — ①
$V_1(65) + V_2(16) + V_3(-5) = 0$ — ②
$V_1(-60) + V_2(-4) + V_3(5) = 0$ — ③

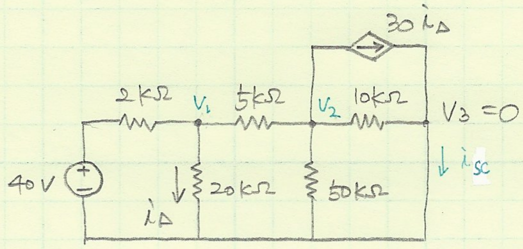
① − ③ ; $V_1(75) + V_3(-5) = 400$ — ④
①×4 + ② ; $V_1(125) + V_3(-5) = 1600$ — ⑤

④ − ⑤ ; $V_1(-50) = -1200 \rightarrow V_1 = 24\ V.$

from ①, $V_2 = (400 - 15 \times 24)/(-4) = -10\ V.$

from ④. $V_3 = (400 - 75 \times 24)/(-5) = 280\ V.$

$\therefore\ V_{Th} = V_3 = 280\ V.$ (*)



if $V_3 = 0$

$$\begin{cases} V_1\left(\frac{1}{2000} + \frac{1}{20000} + \frac{1}{5000}\right) + V_2\left(-\frac{1}{5000}\right) = \frac{40}{2000} \\ V_1\left(-\frac{1}{5000} + \frac{30}{20000}\right) + V_2\left(\frac{1}{5000} + \frac{1}{50000} + \frac{1}{10000}\right) = 0 \end{cases}$$

$V_1(15) + V_2(-4) = 400$ — ①′
$V_1(65) + V_2(16) = 0$ — ②′

①′×4 + ② : $V_1(125) = 1600$ ∴ $V_1 = 1600/125 = 12.8\,V$
from ②′ : $V_2 = -V_1 \times 65/16 = -52\,V$

$\therefore i_\Delta = V_1/20000 = 0.64\ mA$

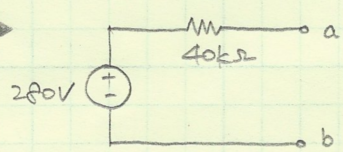
$\therefore i_{sc} = 30\, i_\Delta + \frac{V_2}{10000} = 30 \times 0.64 \times 10^{-3} + \frac{-52}{10000}$

$= \underline{14\ mA}$ (**)

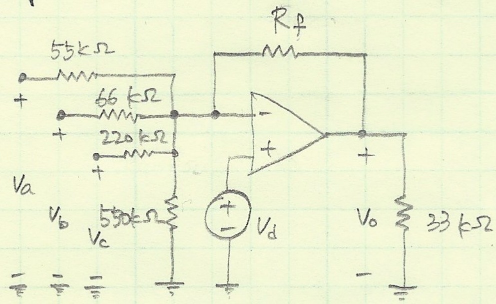
From (*) and (**)

$$R_{Th} = \frac{280\,V}{14\,mA} = \underline{20\,k\Omega}$$

$\Longrightarrow$



5.14



$V_a = 16V$
$V_b = 12V$
$V_c = -6V$
$V_d = 10V$

a) Assuming ① $V(+) = V(-) = V_d$
② No current into Op-Amp.

$$\rightarrow \frac{V_a - V_d}{55000} + \frac{V_b - V_d}{66000} + \frac{V_c - V_d}{220000} - \frac{V_d}{550000} = \frac{V_d - V_o}{R_f}$$

$$12(V_a - V_d) + 10(V_b - V_d) + 3(V_c - V_d) - 1.2V_d = 660000(V_d - V_o)/R_f$$

$$12(16-10) + 10(12-10) + 3(-6-10) - 1.2(10) = 660000(10-V_o)/R_f$$

$$72 + 20 - 48 - 12 = 660000(10-V_o)/R_f$$

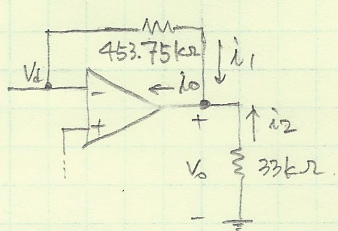
$$32 R_f = 660000(10 - V_o)$$

When saturated, $V_o = \pm 12V$.

i) $V_o = 12 \rightarrow R_f < 0$

ii) $V_o = -12 \rightarrow R_f = 660000(10+12)/32 = 453.75\ k\Omega$.

b) $V_o = -12V$.



$$i_o = i_1 + i_2$$

$$\therefore i_o = \frac{V_d - V_o}{453750} + \frac{-V_o}{33000}$$

$$= \frac{10-(-12)}{453750} + \frac{12}{33000}$$

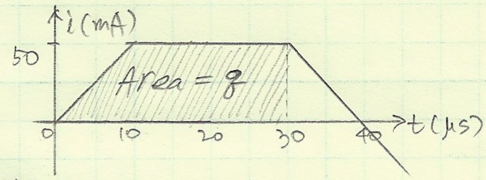
$$= 412.121\ \mu A.$$

6.17

$C = 0.25\ \mu F$

a) the charge on the capacitor at $t = 30\,\mu s$?

$$\begin{cases} 0 \le t \le 10\mu s & i = \dfrac{50\times10^{-3}}{10\times10^{-6}}\, t = 5\times10^{3} t \ \text{A} \\ 10\mu s < t < 30\mu s. & i = 50\times10^{-3}\ \text{A} \end{cases}$$



from $i = dq/dt$

$$q = \int i\,dt = \int_0^{10\mu} 5\times10^3 t\, dt + \int_{10\mu}^{30\mu} 50\times10^{-3}\, dt$$

$$= 5\times10^3 \cdot \frac{t^2}{2}\Big|_0^{10\mu} + 50\times10^{-3}\, t\Big|_{10\mu}^{30\mu}$$

$$= 5\times10^3 \cdot (10^{-10}/2) + 50\times10^{-3}(20\times10^{-6})$$

$= 1.25\,\mu C$ ← the same as the area above.

b) the voltage on the capacitor at $t = 50\mu s$?

$30\,\mu s \le t \le 50\,\mu s \qquad i = 200\times10^{-3} - 5\times10^3 t$ A

$\therefore\ q = \int i\,dt + q_0 \qquad (q_0 = 1.25\,\mu C$ from (a))

$$= \int_{30\mu}^{50\mu} 200\times10^{-3}\, dt - \int_{30\mu}^{50\mu} 5\times10^3 t\, dt + q_0$$

$$= 200\times10^{-3}(20\times10^{-6}) - 5\times10^3\times\frac{1}{2}(2500-900)\times10^{-12} + q_0$$

$$= 4\mu C - 4\mu C + 1.25\,\mu C$$

$= \underline{1.25\,\mu C}$

from $q = CV \longrightarrow V = q/C = 1.25/0.25 = \underline{5\ V}$

c) Stored energy ?

the charge at $t = 60\mu s$

; $50\mu s \le t \le 60\mu s. \rightarrow i = -300\times10^{-3} + 5\times10^3 t$

$$\therefore\ q = \int_{50\mu}^{60\mu} -300\times10^{-3}\, dt + \int_{50\mu}^{60\mu} 5\times10^3 t\, dt + q_0$$

$$= -300\times10^{-3}(10\times10^{-6}) + 5\times10^3\times\frac{1}{2}(3600-2500)\times10^{-12} + q_0$$

$$= -3\mu C + 2.75\mu C + 1.25\mu C$$

$= 1\,\mu C$

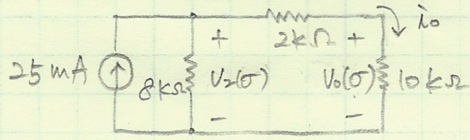
We need to use the equation: $W = \frac{1}{2} CV^2$

from $q = CV \rightarrow V = q/C = 1/0.25 = 4\,V$

$\therefore W = \frac{1}{2}(0.25 \times 10^{-6})(4^2) = 2\,\mu J$

7.25

a) when $t<0$; No current through capacitors as system is in steady state.
(So $C \cdot \frac{dV}{dt} = 0$)



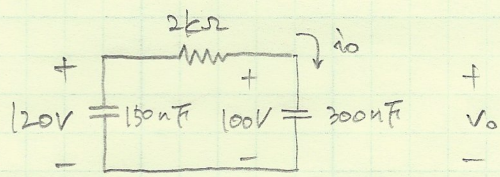
$$i_o(0^-) = \frac{(25\times10^{-3})\,8}{8+12} = 10\times10^{-3} = \underline{10\,mA}$$

$$V_o(0^-) = i_o(0^-)\times 10000 = \underline{100\,V}$$

$$V_2(0^-) = \{25\times10^{-3} - i_o(0^-)\}\times 8000$$

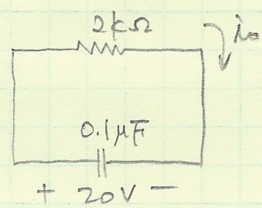
$$= 15\times10^{-3}\times 8\times10^{3} = \underline{120V}$$

when $t>0$



$$C_{Tot} = \left(\frac{1}{150\times10^{-9}} + \frac{1}{300\times10^{-9}}\right)^{-1} = \frac{300\times150\times10^{-18}}{(300+150)\times10^{-9}}$$

$$= 0.1\,\mu F.$$



$$\tau = RC = 0.2\ ms$$

$$\therefore i_o(t) = \frac{20}{2000}e^{-t/\tau}$$

$$= 10\,e^{-t/0.2\times10^{-3}}\ mA$$

$$= \underline{10\,e^{-5000t}\ mA.}$$

b) $q = CV$

$$\therefore v = \frac{1}{C}q = \frac{1}{C}\int i\,dt$$

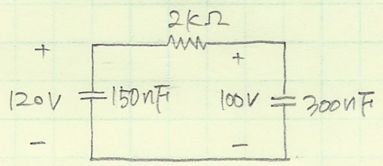
$$V_o = \frac{1}{300\times10^{-9}}\int_0^t 10\times10^{-3}\cdot e^{-5000t}\,dt + V_0$$

$$= \frac{10^9}{300}\times10^{-2}\times\left(\frac{1}{-5000}\right)e^{-5000t}\Big|_0^t + 100$$

$$= -\frac{20}{3}\cdot\left(e^{-5000t}-1\right) + 100 \qquad \left(\frac{20}{3}+100 = \frac{320}{3}\right)$$

$$= \underline{-\frac{20}{3}e^{-5000t} + \frac{320}{3}\ V} \quad (t\geq 0)$$

c) The energy (in μJ) trapped in the circuit.



from $W = \frac{1}{2} C V_0^2$

&

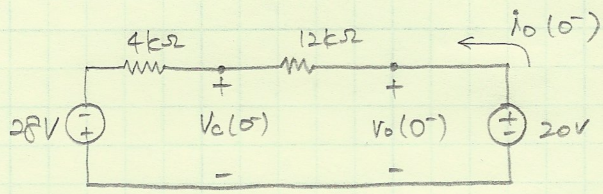
$V_0(t) = -\frac{20}{3} e^{-5000t} + \frac{320}{3}$ → The final voltage $V_0(\infty) = 320/3$

$\therefore \; W_{trapped} = \frac{1}{2}(150 \times 10^{-9})\left(\frac{320}{3}\right)^2 + \frac{1}{2}(300 \times 10^{-9})\left(\frac{320}{3}\right)^2$

$= 2560 \; \mu J$

8.51

a) when $t<0$

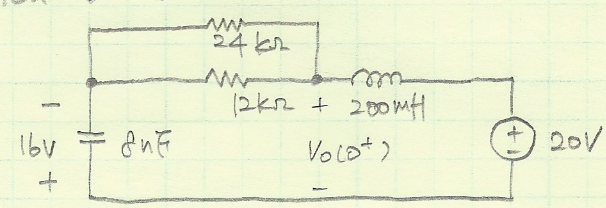


$$i_o(0^-) = [20-(-28)]/16000 = 3\,mA$$

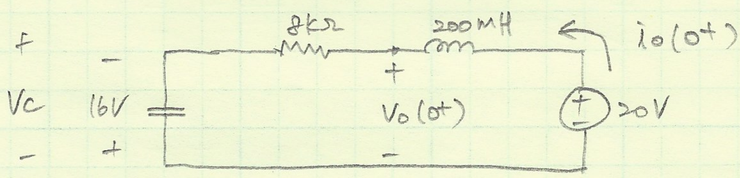
$$V_o(0^-) - V_c(0^-) = 12000 \times 3\times10^{-3} = 36V$$

$$\therefore V_c(0^-) = V_o(0^-) - 36V = 20-36 = -16V$$

when $t = 0^+$



$$24k\Omega \,/\!/\, 12k\Omega = \left(\frac{1}{24}+\frac{1}{12}\right)^{-1} = 8k\Omega$$



$$i_o(0^+) = \frac{V_o(0^+)-(-16)}{8000} = 3\times10^{-3}$$

$$\therefore V_o(0^+) = 24-16 = \underline{8V}$$

b) $V_o(0^+) = 8000\, i_o(0^+) + V_c(0^+)$

$$\frac{dV_o(0^+)}{dt} = 8000\frac{di_o(0^+)}{dt} + \frac{dV_c(0^+)}{dt}$$

① from $V_L(0^+) = L\cdot\frac{di_o(0^+)}{dt} \rightarrow \frac{di_o(0^+)}{dt} = V_L(0^+)/L$

$$= (20-8)/0.2 = 60\ A/s$$

② from $i_o(0^+) = C\cdot\frac{dV_c(0^+)}{dt} \rightarrow \frac{dV_c(0^+)}{dt} = \frac{3\times10^{-3}}{8\times10^{-9}} = 375000$

$Cv = \int i\,dt$

$$\therefore \frac{dV_o(0^+)}{dt} = 8000(60) + 375000 = \underline{855000\ V/s}$$

c) $V_o(t)$ for $t \geq 0$.

For a series RLC circuit with voltage source, V

$$\frac{d^2V_c}{dt^2} + \frac{R}{L}\frac{dV_c}{dt} + \frac{V_c}{RL} = \frac{V}{LC}$$

$$\omega_o^2 = 1/LC = 625 \times 10^6 \rightarrow \omega_o = 25000 \text{ rad/s}$$

$$\alpha = R/2L = 20000 \text{ rad/s} \rightarrow \alpha^2 = 400 \times 10^6$$

$$\alpha^2 - \omega_o^2 = -225 \times 10^6 < 0 \quad \therefore \text{Underdamped.}$$

$$s_1, s_2 = -20000 \pm j\sqrt{225 \times 10^6}$$

$$= -20000 \pm j15000 \quad \text{rad/s}$$

For underdamped RLC circuits,

$$V_o(t) = V_f + B_1' e^{-\alpha t}\cos\omega_d t + B_2' e^{-\alpha t}\sin\omega_d t$$

$$V_f = V_o(\infty) = 20V$$

At $t = 0^+$,

$$V_o(0^+) = 8V \text{ ---------------- ①}$$

$$\frac{dV_o(0^+)}{dt} = 855000 \quad V/s \text{ ------ ②}$$

from ①, $8 = 20 + B_1' \rightarrow B_1' = -12$

from ②, $855000 = B_1'(-\alpha) + B_2'\omega_d$

$$\therefore B_2 = \frac{855000 + 20000(-12)}{15000} = 41$$

$$\because \frac{dV_o(t)}{dt} = 0 + B_1'(-\alpha)e^{-\alpha t}\cos\omega_d t + B_1'(\omega_d)e^{-\alpha t}(\cancel{-\sin\omega_d t})$$
$$+ B_2'(-\alpha)e^{-\alpha t}\cancel{\sin\omega_d t} + B_2'(\omega_d)e^{-\alpha t}\cos\omega_d t$$

$$\therefore \underline{V_o(t) = 20 - 12e^{-20000t}\cos 25000t + 41e^{-20000t}\sin 25000t}$$

6.

$$(1+3j) + \frac{2-2j}{2+j} = \frac{(1+3j)(2+j)+(2-2j)}{2+j}$$

$$= \frac{2+7j-3+2-2j}{2+j}$$

$$= \frac{1+5j}{2+j} = \frac{(1+5j)(2-j)}{(2+j)(2-j)}$$

$$= \frac{2+10j-j+5}{5}$$

$$= \frac{7+9j}{5} = 1.4+1.8j \quad \text{(Cartesian form)}$$

$$= \sqrt{1.4^2+1.8^2} \angle \tan^{-1}(1.8/1.4)$$

$$= 2.28 \angle 52.125^\circ \quad \text{(polar form)}$$

OR,

$$\frac{1+5j}{2+j} = \frac{\sqrt{1^2+5^2} \angle \tan^{-1}(5/1)}{\sqrt{2^2+1^2} \angle \tan^{-1}(1/2)}$$

$$= \frac{\sqrt{26} \angle 78.690^\circ}{\sqrt{5} \angle 26.565^\circ}$$

$$= 2.28 \angle (78.690^\circ - 26.565^\circ)$$

$$= 2.28 \angle 52.125^\circ$$