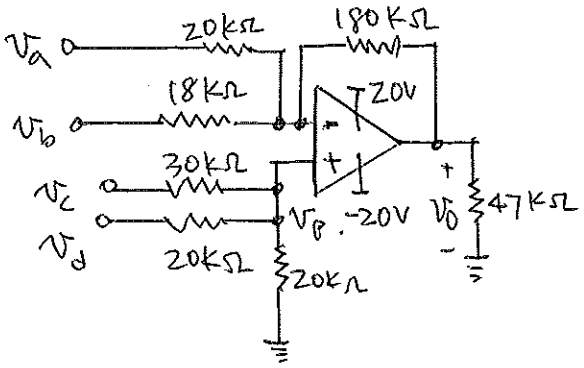
Example 5.28



(a) Find v_o when $v_a = 1$ V. $v_b = 2$V. $v_c = 3$V and $v_d = 4$V.

(b) If v_a, v_b and v_d are held constant, what values of v_c will not saturate the op amp.

(a) Find v_p as function of v_c, v_d, and then from $v_p = v_N$, solve the relation between v_o and v_N. (v_a, v_b, v_c, v_d) ...

Applying KCL at v_p: $\frac{v_p}{20000} + \frac{v_p - v_c}{30000} + \frac{v_p - v_d}{20000} = 0$

$\Rightarrow 8v_p = 2v_c + 3v_d = 8v_N$

Applying KCL at v_N: $\frac{v_N - v_a}{20000} + \frac{v_N - v_b}{18000} + \frac{v_N - v_o}{180000} = 0$.

$\therefore v_o = 20v_N - 9v_a - 10v_b$

$= 20\left[\frac{1}{4}v_c + \frac{3}{8}v_d\right] - 9v_a - 10v_b$

$= 16$V.

(b). From previous:

$$v_o = 5v_c + \frac{60}{8}v_d - 9v_a - 10v_b$$

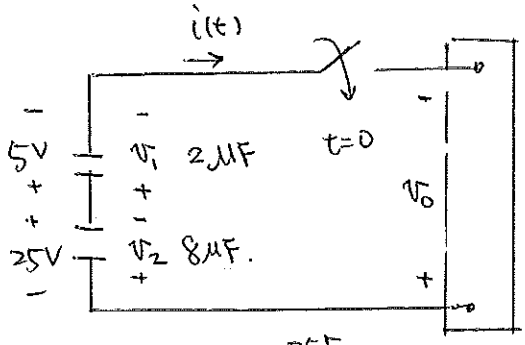
and

-20V $= 5v_c + 1$. (edge of saturation).

$\therefore v_c = -4.2$V. and $v_c = 3.8$V.

$\Rightarrow \quad -4.2\text{V} \le v_c \le 3.8\text{V}$.

Example: 6.31.



$i(t) = 800\,e^{-25t}\ \mu A \quad t>0.$

(a) C_{eq} = ?

(b) Find $v_1(t)$ } $t \geq 0$.

(c) Find $v_2(t)$.

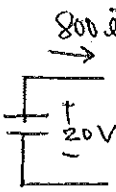
(d) Energy delivered to black box

(e) Initial E stored by Cs

(f) E. trapped.

(a). C_{eq}: Capacitor in series..

$$C_{eq} = \frac{2\times 8}{2+8} = 1.6\,\mu F \Rightarrow$$



$t > 0.$

$$v_o = \frac{10^6}{1.6}\int_0^t 800\mu\, e^{-25x}\,dx - 20 \quad \left[v = \frac{1}{C}\int_0^t i\,dx\right]$$

$$= \frac{10^6}{1.6}\times 800\times 10^{-6}\int_0^t e^{-25x}\,dx - 20.$$

$$= 500\times\frac{1}{-25}\left(e^{-25t}-1\right) - 20 = -20\,e^{-25t}\ V. \quad t\geq 0$$

(b) $$v_1 = \frac{10^6}{2}\int_0^t 800\mu\, e^{-25x}\,dx + 5 = -16\,e^{-25t} + 21\ V. \quad t\geq 0.$$

(c) $$v_2(t) = \frac{10^6}{8}\int_0^t 800\mu\, e^{-25x}\,dx - 25 = -4\,e^{-25t} - 21\ V \quad t\geq 0.$$

(d) Total Energy:

$$p = -iv = -(-20\,e^{-25t})(800\times 10^{-6})\,e^{-25t}$$

$$= 16\times 10^{-3}\,e^{-50t} \quad (\text{power})$$

$$E = \int_0^\infty p\,dt = \int_0^\infty 16\times 10^{-3}\,e^{-50t}\,dt = 16\times 10^{-3}\times\frac{1}{-50}\left(e^{-50t}\right)\Big|_0^\infty$$

$$= 320\,\mu J.$$

(e) Intial Energy: from $\frac{1}{2}CV^2$.

$$E = \frac{1}{2}(2\times 10^{-6})\times 5^2 + \frac{1}{2}(8\times 10^{-6})\times 25^2 = 2525\,\mu J.$$

(f) E. trapped:

$$\frac{1}{2}(2\times 10^{-6})(21)^2 + \frac{1}{2}(8\times 10^{-6})(21)^2 = 2205\,\mu J$$