Electronics Homework

Series + Parallel R + C.

1. a) For $V_1 = 1.0V$ + $V_2 = 4.0V$, V_3 must be: $10-(1+4) = \underline{5.0V}$
So, we need to mimic this 1:4:5 ratio with our resistors with the largest resistor producing the Largest V. Therefore one option is $R_1 = 50\Omega$, $R_2 = 200\Omega$ + $R_3 = 250\Omega$ $(\frac{200+}{50})$

b) $V_3 = 5.0V$

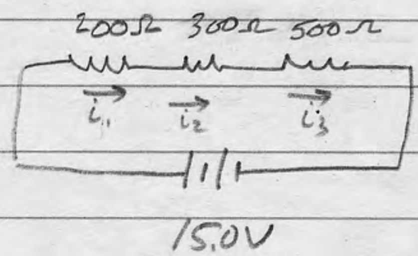
c) $V_s = IR_{net}$

$$R_{net} = 50\Omega + 200\Omega + 250\Omega = 500\Omega$$

$$\therefore I = \frac{V_s}{R_{net}} = \frac{10.0V}{500\Omega} = \boxed{0.020\ A}$$

d) $P = I^2 R_{net} = (0.020A)^2 \cdot 500\Omega = \boxed{0.20W}$

2.



a) $V_2 = 12.0V\left(\frac{R_2}{R_{net}}\right) = 12.0V\left(\frac{300\Omega}{1000\Omega}\right)$

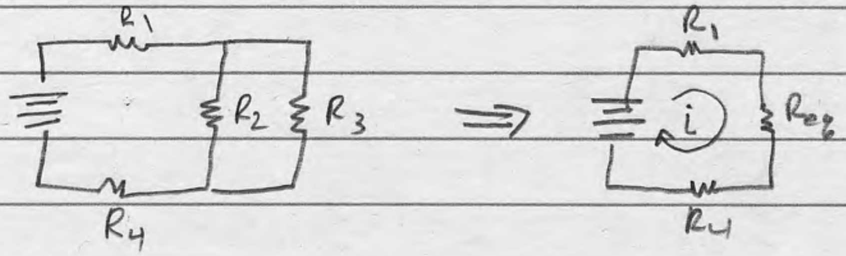
$$\boxed{V_2 = 3.60V}$$

$$i_1 = i_2 = i_3 = i_{net} = \frac{V_s}{R_{net}} = \frac{12.0V}{1000\Omega} = \boxed{0.012A}$$

b) $P_2 = i_2^2 R_2 = (0.012A)^2(300\Omega) = \boxed{0.043W}$

c) $\frac{P_2}{P_T} = \frac{\cancel{i_2^2} R_2}{\cancel{i_{net}^2} R_{net}} = \frac{R_2}{R_{net}} = \frac{300\Omega}{1000\Omega} = 0.30$ or $\boxed{30\%}$

(3)



$R_{eq} = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$

$R_{eq} = \left(\frac{1}{500\Omega} + \frac{1}{200\Omega}\right)^{-1}$

$R_{eq} = 143\,\Omega$

a) $i = \frac{V_s}{R_{eq}} = \frac{10.0\,V}{(100 + 143 + 1000)\,\Omega} = \underline{0.00805\,A}$

$V_1 = iR_1 = 0.00805\,A \cdot 100\,\Omega = \underline{0.805\,V}$

$V_2 = V_3 = iR_{eq} = \underline{1.15\,V}$

$V_4 = iR_4 = \underline{8.05\,V}$

b) $i_1 = i_5 = i_2 + i_3 = \boxed{0.00805\,A}$

$i_3 = i_4$

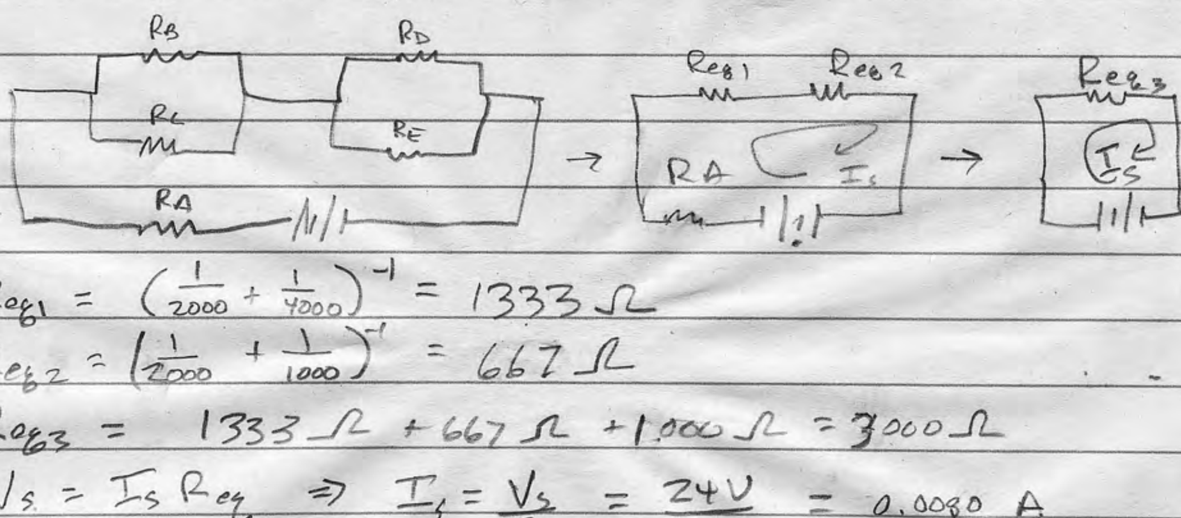
$i_2 = \frac{V_2}{R_2} = \frac{1.15V}{500\Omega} = \boxed{0.0023\,A}$

$i_3 = i_4 = \frac{V_3}{R_3} = \frac{1.15V}{200\Omega} = \boxed{0.00575\,A}$

c) $P = I^2R = (0.0023\,A)^2 \cdot 500\,\Omega = \boxed{0.0026\,W}$

d) $V_{3\text{-}4} = 10.0V - V_1 = 10.0V - 0.805\,V = \boxed{9.20\,V}$

(4)



$R_{eq1} = \left(\frac{1}{2000} + \frac{1}{4000}\right)^{-1} = 1333\,\Omega$

$R_{eq2} = \left(\frac{1}{2000} + \frac{1}{1000}\right)^{-1} = 667\,\Omega$

$R_{eq3} = 1333\,\Omega + 667\,\Omega + 1000\,\Omega = 3000\,\Omega$

$V_s = I_s R_{eq} \Rightarrow \underline{I_s} = \frac{V_s}{R_{eq}} = \frac{24V}{3000\Omega} = 0.0080\,A$

4, cont. a) $P = I^2 R_{eq_1} = (0.0080\,A)^2 \cdot 1333\,\Omega = \boxed{0.085\,W}$

b) $I = \boxed{0.0080\,A}$

c) $V_A = I R_A = 0.0080\,A \cdot 1000\,\Omega = \boxed{8.0\,V}$

d) $V_D = I R_{eq_2} = 0.0080\,A \cdot 667\,\Omega = \boxed{5.34\,V}$

e) $V_{5\text{-}4} = 24 - V_A = 24 - 8 = \boxed{16.0\,V}$

5 a) $V = iR \Rightarrow R = \dfrac{V}{i} = \dfrac{1.00\,V}{50\times10^{-6}\,A} = 20{,}000\,\Omega = \boxed{20\,k\Omega}$

b) 1% error $= 0.01 \cdot 50\,\mu A = 0.50\,\mu A$

$R = \dfrac{V}{i} = \dfrac{1.0\,V}{0.50\times10^{-6}} = 2{,}000{,}000\,\Omega = \boxed{2\,M\Omega}$

6 $i = I_{init}\,e^{-t/RC} \Rightarrow \dfrac{i}{I_{init}} = e^{-t/RC} \Rightarrow t = -RC \ln \dfrac{i}{I_{init}}$

when 1% charged $i/I_{init} = 1/100 = 0.01$

$\therefore\ -R\cdot(0.035\times10^{-6}\,F)\ln(0.01) = t$

a) $R = 10\times10^6\,\Omega$; $t = \boxed{1.61\,s}$

b) $R = 1\times10^6\,\Omega$; $t = \boxed{0.161\,s}$ (161 ms)

c) $R = 10^3\,\Omega$; $t = \boxed{1.61\times10^{-4}\,s}$ (161 μs)

7 a) $R\cdot C = (50\times10^3\,\Omega)\cdot(0.015\times10^{-6}\,F) = \boxed{7.50\times10^{-4}\,s = 0.75\,ms}$

b) $I_{init} = \dfrac{V}{R} = \dfrac{25\,V}{50{,}000\,\Omega} = 0.00050\ A$

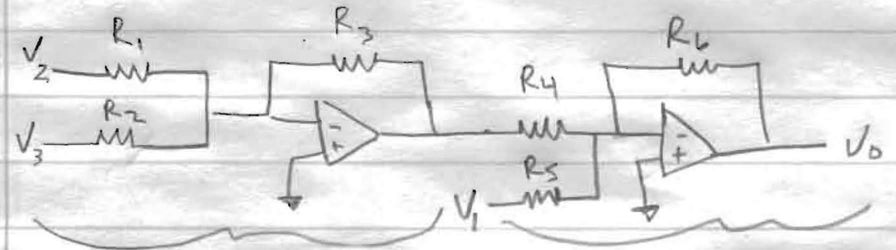
for charging $\begin{cases} i = I_{init}\,e^{-t/RC} \\ V_R = V_{init}\,e^{-t/RC} \\ V_C = V_{init} - V_c \end{cases}$

discharge $\begin{cases} V_c = V_0\,e^{-t/RC} \\ V_r = -V_c \\ i = V_r/R \end{cases}$

	A	B	C	D
1	**Charging**			
2	t	i	Vc	Vr
3	ms	uA	V	V
4	0	500.00	25.00	0.00
5	1	131.80	6.59	18.41
6	2	34.74	1.74	23.26
7	3	9.16	0.46	24.54
8	4	2.41	0.12	24.88
9	5	0.64	0.03	24.97
10	10	0.00	0.00	25.00
11				
12				
13	**Discharge**			
14	t	Vc	Vr	i
15	ms	V	V	uA
16	0	25.00	-25.00	-500.00
17	1	6.59	-6.59	-131.80
18	2	1.74	-1.74	-34.74
19	3	0.46	-0.46	-9.16
20	4	0.12	-0.12	-2.41
21	5	0.03	-0.03	-0.64
22	10	0.00	0.00	0.00
23				
24	B4=500*EXP((-A4/1000)/0.00075)			
25	C4=25*EXP(-(A4/1000)/0.00075)			
26	D4=25-C4			
27				
28	B16=D10*EXP((-A16/1000)/0.00075)			
29	C16=-B16			
30	D16=1000000*(C16/50000)			

Op-Amps

1. There are several options. Here's one:

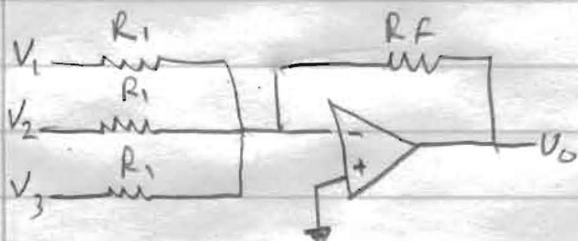


$\frac{R_3}{R_1} = 3, \quad \frac{R_3}{R_2} = 6$

$\frac{R_6}{R_4} = 1, \quad \frac{R_6}{R_5} = 2$

$V_{O_1} = -3V_2 - 6V_3 \qquad -V_{O_2} = 2V_1 + V_{O_1}$

2. Here is one option, we need to accomplish this math: $V_o = \frac{1}{1000}\left(\frac{V_1 + V_2 + V_3}{3}\right) = \frac{V_1 + V_2 + V_3}{3000}$



we need $\frac{R_F}{R_1} = \frac{1}{3000}$

perhaps $R_F = 1K\Omega$ & $R_1 = 3M\Omega$

* in this case $-V_o = \frac{V_1 + V_2 + V_3}{3000}$, we could add a second op amp to change the sign of V_o

3. We have 2 addition operations in series.

for the first op amp:

$$V_{O_1} = -\left(\frac{R_{f1}}{R_1} V_1 + \frac{R_{f1}}{R_2} V_2\right)$$

for the second op amp:

$$-V_{O_2} = \frac{R_{f2}}{R_4} \cdot V_{O_1} + \frac{R_{f2}}{R_3} V_3$$

$$-V_{O2} = R_{f2}/R_4 \left(-\frac{R_{f1}}{R_1} V_1 - \frac{R_{f1}}{R_2} V_2\right) + \frac{R_{f2}}{R_3} V_3$$

$$-V_{O2} = -V_1\left(R_{f1}R_{f2}/R_1R_4\right) - V_2\left(R_{f1}R_{f2}/R_2R_4\right) + V_3\left(R_{f2}/R_3\right)$$

So

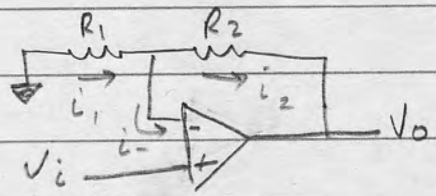
$$V_o = V_1\left(R_{f1}R_{f2}/R_1R_4\right) + V_2\left(R_{f1}R_{f2}/R_2R_4\right) - V_3\left(R_{f2}/R_3\right)$$

3 b) Inserting Values:

$$V_o = V_1\left(\frac{200K\,400K}{200K\quad 400K}\right) + V_2\left(\frac{200K\cdot 400K}{50K\quad 400K}\right) - V_3\left(\frac{400K}{10K}\right)$$

$$\therefore \boxed{V_o = V_1 + 4V_2 - 40V_3}$$

4



$$V_i = V_+$$

$$V_+ = V_- = V_i$$

$$i_1 = i_2 + i_- \quad \text{but } i_- = 0$$

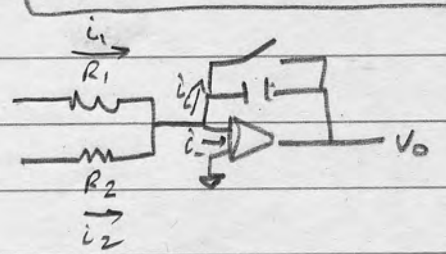
$$i_1 = i_2$$

$$\therefore \frac{0 - V_-}{R_1} = \frac{V_- - V_o}{R_2} \Rightarrow \frac{-V_i}{R_1} = \frac{V_i - V_o}{R_2}$$

$$-\left(\frac{R_2}{R_1}\right)V_i = V_i - V_o$$

$$\boxed{V_o = V_i + \frac{R_2}{R_1}V_i = \left(\frac{R_1 + R_2}{R_1}\right)V_i}$$

5



$$i_1 + i_2 = i_c + \cancel{i_-}^{\,0}$$

$$i_1 + i_2 = i_c \qquad i_c = -C\frac{dV_o}{dt}$$

$$\frac{V_1 - V_-}{R_1} + \frac{V_2 - V_-}{R_2} = -C\frac{dV_o}{dt}$$

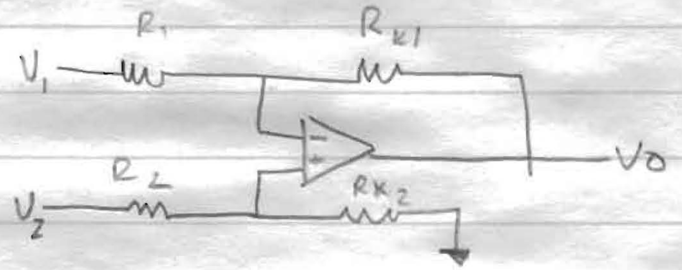
$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = -C\frac{dV_o}{dt}$$

$$dV_o = -\frac{1}{C}\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right)dt = -\frac{1}{0.01\mu F}\left(\frac{V_1}{20M\Omega} + \frac{V_2}{5M\Omega}\right)dt$$

$$dV_o = -\left(\frac{V_1}{0.2s} + \frac{V_2}{0.05s}\right)dt$$

$$V_o = -\int_0^t\left(\frac{V_1}{0.2\,sec} + \frac{V_2}{0.05\,sec}\right)dt \quad \text{or} \quad V_o = -\int_0^t\left(5s^{-1}V_1 + 20s^{-1}V_2\right)dt$$

6



$R_1 = R_2 = R_{x1} = R_{x2}$

$$\frac{V_1 - V_-}{\cancel{R_1}} = \frac{V_- - V_o}{\cancel{R_{x1}}} \quad \text{but } R_1 = R_{x1}$$

* so $V_1 - V_- = V_- - V_o$

$$\frac{V_2 - V_+}{\cancel{R_2}} = \frac{V_+ - 0}{\cancel{R_{x2}}} \quad \text{but } R_2 = R_{x2}$$

* so $V_2 - V_+ = V_+$

$V_+ = \frac{V_2}{2}$ and $V_- = \frac{V_1 - V_o}{2}$ and $V_+ = V_-$

so $\frac{V_2}{2} = \frac{V_1 - V_o}{2}$

and $V_2 = V_1 - V_o$

or $\boxed{V_o = V_1 - V_2}$

A/D

① absolute | Relative

a) $\frac{10V}{2^8} = 0.039V$ $\qquad \frac{0.039V}{5V} \cdot 100\% = 0.78\%$

b) $\frac{10V}{2^{12}} = 0.00244V$ $\qquad 0.0488\%$

c) $\frac{10V}{2^{16}} = 0.000153$ $\qquad 0.00305\%$

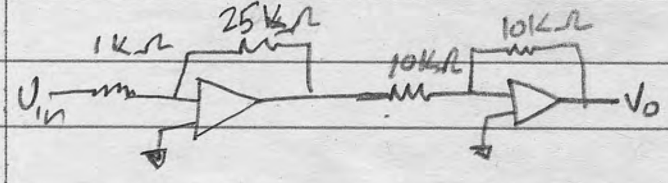
abs | Rel

② a) $\frac{10V}{2^8} = 0.039V$ $\qquad \frac{0.039V}{0.2V} \cdot 100\% = 19.5\%$

b) $\frac{10V}{2^{12}} = 0.00244V$ $\qquad 1.22\%$

c) $\frac{10V}{2^{16}} = 0.000153V$ $\qquad 0.0763\%$

if we amplify the signal by 25x, our % uncertainty will be as in pt. a, This circuit will do it.



(3) ∴ AD can't respond faster than 15 μs, or in terms of frequency: $\frac{1}{8 \mu s} = 66{,}600$ Hz

To accomplish Nyquist, maximum rate is $\frac{1}{2}(66{,}600 \text{ Hz}) = \underline{33{,}300 \text{ Hz}}$ or sample once every 30 μS