Electronic Instrumentation
Instrumentação Eléctrónica

solution

7/II/2011

<u>Question 1)</u> See lecture notes

<u>Question 2)</u> When a signal arrives at V_i, the transistor Q is conducting, shorting THR and TRI (x) to ground. The capacitor instantaneously discharges. This stays like this as long as V_i is high. The moment V_i is 'released', the transistor stops conducting and the capacitor starts charging

$V_x(t=0) = 0$ because C begins discharged

$V_x(t=\infty) = V_{cc}$ because then $I = 0$

$\tau = RC$

$$V_x(t) = V_{cc}\left(1 - \exp(-t/RC)\right)$$

When this overtakes $1/3\, V_{cc}$ nothing happens (second opamp goes from $+V_{cc}$ to 0, without effect)

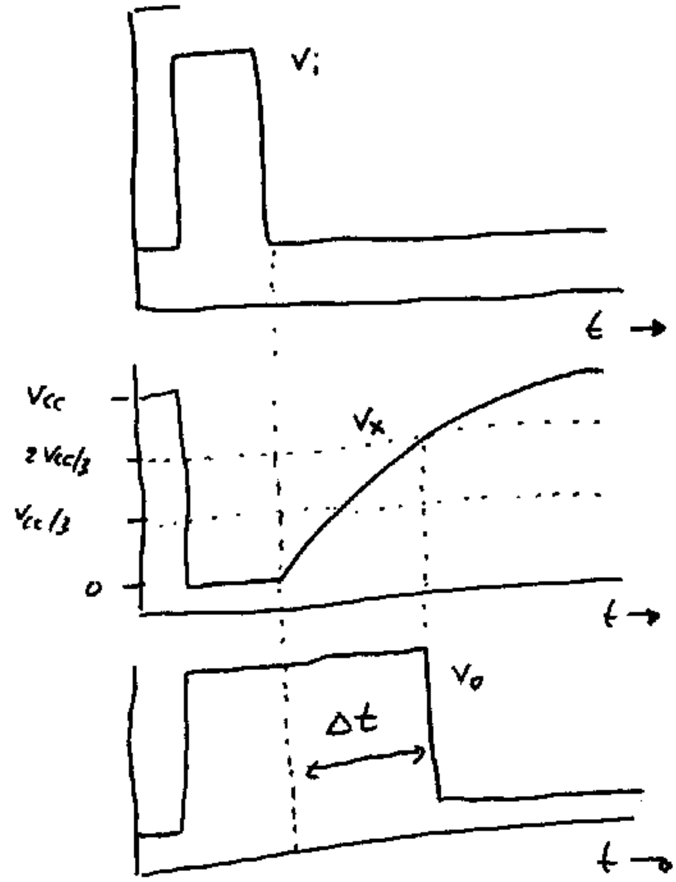
When it overtakes $2/3\, V_{cc}$ the first opamp commutates. This happens at

$$V_{cc}\left(1 - \exp\left(-\frac{t}{RC}\right)\right) = 2/3\, V_{cc}$$

thus $t = RC \ln(3)$.

The output of the flip flop is reset.

Conclusion: after a time $\Delta t = RC \ln(3)$ after the input went low again, the output goes low.



b) $RC \ln(3) = 10^{-3}$ s

ex. $C = 1\,\mu F \Rightarrow R = 910\,\Omega$

Question 3)

a) $f = \dfrac{\sqrt{\gamma \rho}}{2M}$

$f = 5 \times 10^{6}$ Hz

$\gamma = 2.947 \times 10^{10}$ kg / m s^2

$\rho = 2.648 \times 10^{3}$ kg / m^3

$$\Rightarrow M = \frac{\sqrt{\gamma\rho}}{2f} = 0.883 \text{ kg/m}^2$$

$$M = \frac{m}{A} \Rightarrow m = MA$$

$$A = \pi\left(\frac{2.5 \times 10^{-2}}{2}\right)^2 = 4.9 \times 10^{-4}\text{ m}^2$$

$m = 4.33 \times 10^{-4}$ kg

$\Delta f = 1$ Hz . repeat calculations for $f = 4.99999$ MHz

or

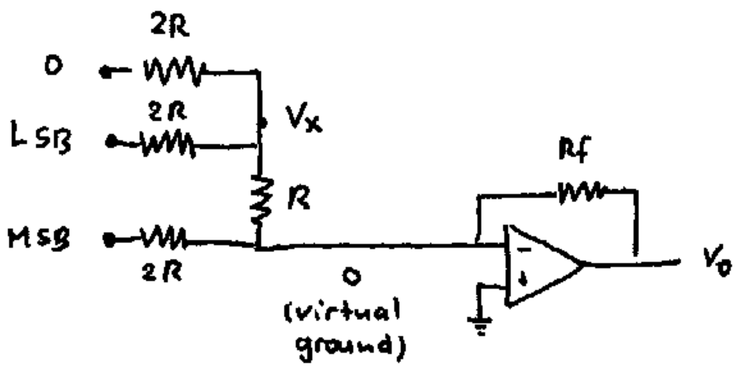
$$\Delta m = \frac{\Delta f}{df/dm}, \quad \frac{df}{dm} = \frac{df}{dM}\frac{dM}{dm} = -\frac{\sqrt{\gamma\rho}}{2M^2}\cdot\frac{1}{A} = -\frac{f}{m}$$

$$\Delta m = \frac{1\ \text{Hz}}{5\ \text{MHz} / 4.33 \times 10^{-4}\ \text{kg}} = 8.7 \times 10^{-11}\ \text{kg}$$

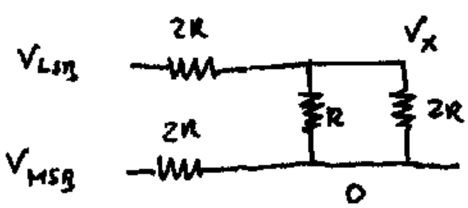
b) see lecture notes

Question 4)

Two-bit DAC



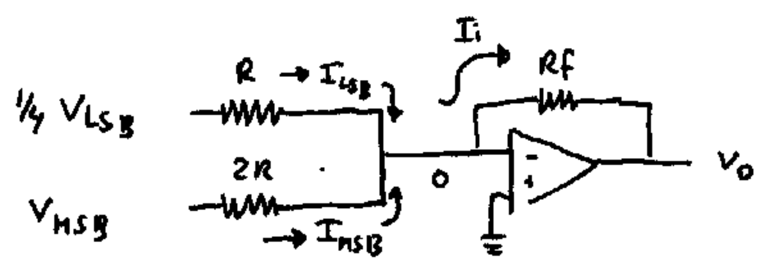
To find V_x we can make equivalent circuit:



$$V_x = V_{LSB} \times \frac{R /\!/ 2R}{R /\!/ 2R + 2R} = \frac{1}{4} V_{LSB}$$

$$(R /\!/ 2R = 2/3\, R)$$

So we have the following circuit (effectively):



This is a normal standard 'adder'

$$I_{LSB} = (1/4\ V_{LSB} - 0) / R = \frac{V_{LSB}}{4R}$$

$$I_{MSB} = (V_{MSB} - 0) / 2R = \frac{V_{MSB}}{2R} \quad +$$

$$I_i = I_{LSB} + I_{MSB} = \frac{1}{2R}\left(V_{MSB} + \frac{1}{2} V_{LSB}\right)$$

$V_o = 0 - I_i R_f$

$= -\frac{R_f}{2R}\left(V_{MSB} + \frac{1}{2}V_{LSB}\right)$. For example $R = 1\,k\Omega$, $R_f = 2\,k\Omega$)

#n	MSB	LSB	V_{MSB}	V_{LSB}	V_o
0	0	0	0	0	0
1	0	1	0	-1 V	-0.5 V
2	1	0	-1 V	0	-1.0 V
3	1	1	-1 V	-1 V	-1.5 V

$V_o = (-0.5\text{ V}) \times \#n$ DAC !

b) see lecture notes

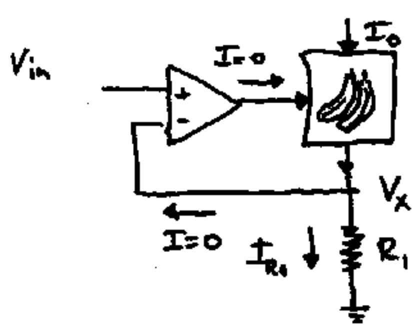
Question 5)

a) Saturation? no, then $V_p = V_n$

$r_{in} = \infty$ (no current goes into entrances)

$r_{out} = 0$ (can supply any current necessary to maintain)

b) Because the MOS-FET draws no current, I_o must be equal to I_{R_1}. There is nowhere any point where current can be coming from or going to. We might even have connected a bunch of bananas; it would make no difference !!!



I_o must be I_{R_1} !!

But ($V_p = V_n$) : $V_x = V_{in}$

thus $I_{R_1} = \frac{V_{in}}{R_1} \Longrightarrow$

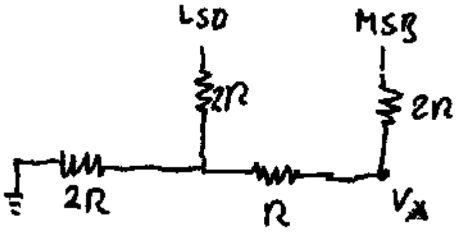
$I_o = \frac{V_{in}}{R_1}$

Question 6) see lecture notes.

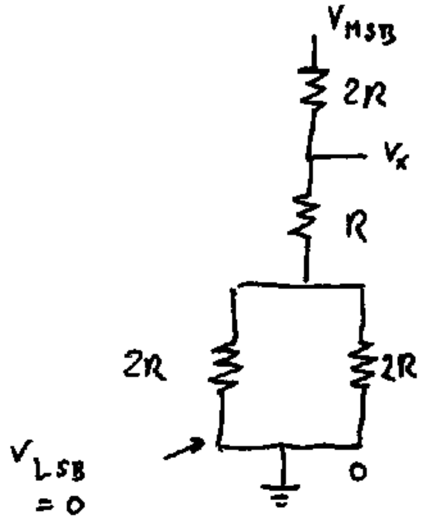
Question 4) alternative

5 /5

2-bit DAC (right version with voltage follower)



$\Rightarrow$ superposition principle



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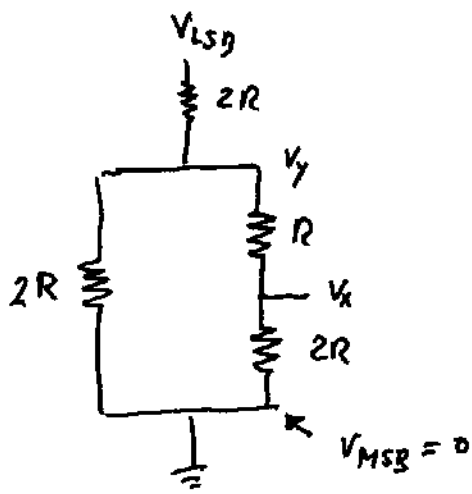

$(2R /\!/ 2R = R)$

$2R /\!/ 3R = \frac{6}{5} R$

$$V_x = V_{MSB} \times \frac{2R}{2R + 2R} = \frac{1}{2} V_{MSB}$$

$$V_y = \frac{\frac{6}{5}R}{\frac{6}{5}R + \frac{10}{5}R} V_{LSB} = \frac{6}{16} V_{LSB}$$

$$V_x = \frac{2R}{2R + R} V_y = \frac{2}{3} V_y = \frac{1}{4} V_{LSB}$$

$$V_x = \frac{1}{2} V_{MSB} + \frac{1}{4} V_{LSB}$$

$$V_0 = \frac{1}{2} V_{MSB} + \frac{1}{4} V_{LSB} \quad \text{(voltage follower)}$$

#n	MSB	LSB	V_{MSB}	V_{LSB}	V_0
0	0	0	0	0	0
1	0	1	0	1 V	0.25 V
2	1	0	1 V	0	0.5 V
3	1	1	1 V	1V	0.75 V

$$V_0 = (0.25\ V) \times \#n$$