Electronic Instrumentation

recurso (second call) 17-II-2010

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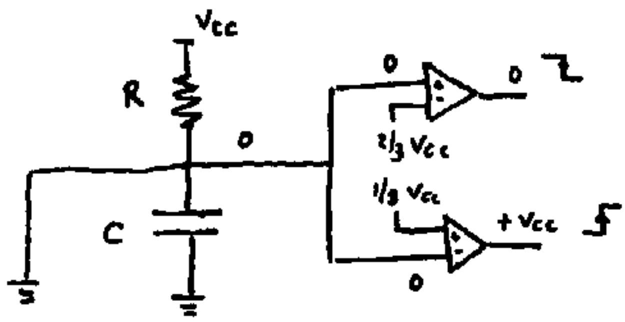
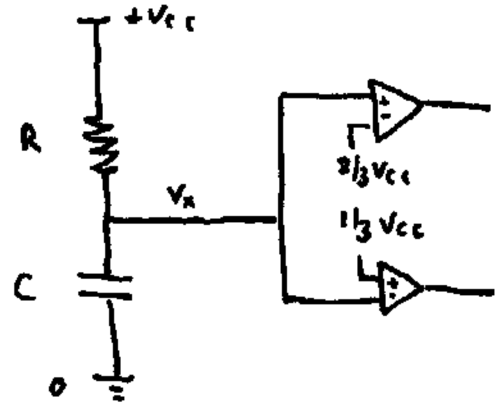
1)) When V_{in} is high (> 0.7 V), the transistor at V_{in} opens and the capacitor is instantaneously discharged, because we have effectively the following circuit



The lower comparator goes from low to high (the upper comparator goes from high to low, but this is irrelevant, because the flip-flop only responds to changes low → high). The lower comparator thus sets the output to high OUT → $+V_{cc}$.

The moment the input signal goes to low (< 0.7 V) the transistor closes and the capacitor starts charging through R. This is a simple RC circuit that (thus) behaves exponential. Effectively we have the circuit below:



$$V_x(t=0) = 0$$

$$V_x(t=\infty) = +V_{cc}$$

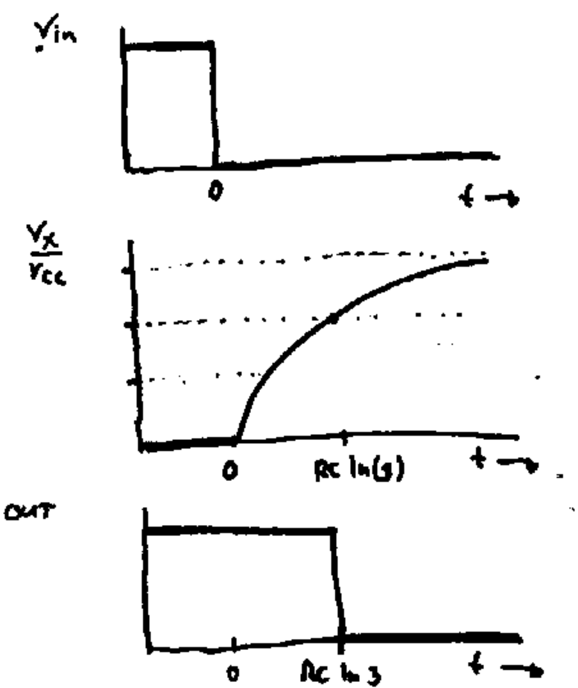
$$\tau = RC$$

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

At a certain point in time, V_x becomes larger than $\frac{1}{3} V_{cc}$. The lower comparator will go from high to low, but this does not do anything to the flip-flop. When V_x becomes larger than $\frac{2}{3} V_{cc}$, the top comparator changes state (low → high) and this triggers a reset of the flip-flop. This occurs at a time

$$v(t) = V_{cc}\left[1 - \exp(-t/RC)\right] = \tfrac{2}{3} V_{cc} \Rightarrow$$

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



Conclusion:

OUT goes to low at a time $\Delta t = RC \ln(3)$ after V_{in} went to low! see figure.

b) $RC \ln(3) = 1\ \text{ms}$

ex. $C = 1\ \mu F$

$R = 910\ \Omega$

2)) a)

$V_o = A(V_p - V_n)$

ideal:

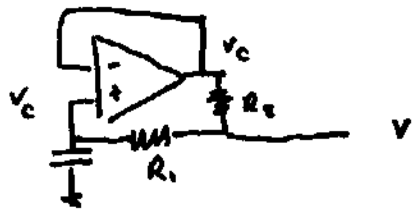
$A = \infty \Rightarrow V_p = V_n$ (unless saturation)

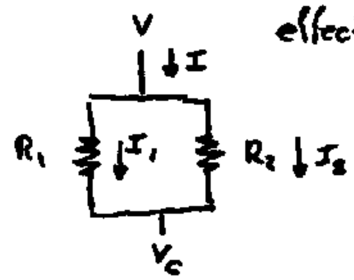
$r_{in} = \infty$ (draws no current)

$r_{out} = 0$ (ideal voltage source)

b+c) $C = Q/V$, Q is charge is integral of current

The op-amp is configured as a tension-follower (100% negative feedback). $V_o = V_p = V_c$



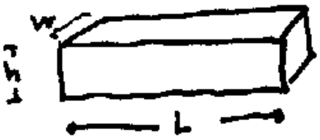


effectively

when V is changed, for instance raised, a current is drawn from V source to charge the capacitor C. This current is I_1. But a parallel current I_2 is also drawn that is 'wasted'. If $I_1 = \frac{V - V_c}{R_1}$, then $I_2 = \frac{V - V_c}{R_2} = I_1 \times \frac{R_1}{R_2}$. In total $I = I_1 + I_2$ $= I_1 \left(1 + \frac{R_1}{R_2}\right)$. The external 'observer' does not see /know that the current I_2 is wasted, thus it feels like a larger current is needed $C_{eff} = C \times \left(1 + \frac{R_1}{R_2}\right)$

c) $R_1 = 0 \ldots 99\ k\Omega$, $R_2 = 1\ k\Omega$, $C = 1\ nF$

3))



$$R = \rho \cdot \frac{L}{wh} = \rho \frac{L(T)}{w(T)\,h(T)}$$

$$\frac{dR}{dT} = \frac{dR}{dL}\cdot\frac{dL}{dT} + \frac{dR}{dw}\cdot\frac{dw}{dT} + \frac{dR}{dh}\cdot\frac{dh}{dT}$$

$$= \frac{\rho}{wh}\cdot\frac{dL}{dT} - \frac{\rho}{w^2h}\cdot\frac{dw}{dT} - \frac{\rho}{wh^2}\cdot\frac{dh}{dT}$$

$$\frac{dR}{dT}\cdot\frac{1}{R} = \frac{dR}{dT}\cdot\frac{wh}{\rho L} = \frac{dL/L}{dT} - \frac{dw/w}{dT} - \frac{dh/h}{dT}$$

$$= \alpha - \alpha - \alpha$$

$$= -\alpha$$

$$\frac{dR/R}{dT} = -\alpha = -5\times 10^{-6}\ /\ K$$

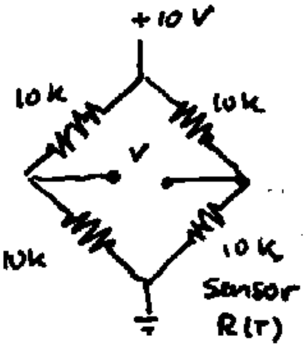
$$\frac{dR}{dT} = -\alpha R = -5\times 10^{-6}\cdot\frac{1}{K}\times 10^{4}\,\Omega$$

$$= -5\times 10^{-2}\ \Omega/K$$

a) $R \approx 10\,k\Omega \rightarrow$ Scale: $20\,k\Omega \Rightarrow \Delta R = 10\,\Omega$

$$\Delta T = \frac{\Delta R}{dR/dT} = \frac{10\,\Omega}{5\times 10^{-2}\,\Omega/K} = 200\ K$$

b)



Wheatstone
bridge

c) $$V = 10\,V \times \frac{R(T)}{R(T) + 10\,k\Omega}$$

$$\frac{dV}{dR} = 10\,V \times \frac{10\,k\Omega}{(20\,k\Omega)^2} = 0.25\ mV/\Omega$$

$$\Delta T = \frac{\Delta V}{dV/dT}$$

$$\frac{dV}{dT} = \frac{dV}{dR} \times \frac{dR}{dT} = 0.25 \ \frac{mV}{\Omega} \times 5 \times 10^{-2} \ \frac{\Omega}{K}$$

$$= 12,5 \ \mu V/K$$

$$\Delta V = 1 \ \mu V$$

$$\Rightarrow \Delta T = \frac{1 \mu V}{12.5 \mu V/K} = 80 \ mK$$

4)) see lecture notes

5)) see lecture notes