04/12/03 Major Corrections on 8.1

EECS 42 – Introduction to Electronics for Computer Science

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Solution to Problem Set # 8 (by Farinaz Koushanfar)

8.1 (a) Let's call the current of R_0, i_0. Since at the output node, $\beta i_B = i_0$, then at the node v_E, the currents between v_E and v_{out} cancel out each other, so the current i_B goes into the resistance R_E. If we write the KVL of the input loop, we get:

$v_{in} - i_B(R_s+R_{in}+R_E) = 0 \;\Rightarrow\; v_{in}/(R_s+R_{in}+R_E) = i_B$

At the output node, $i_0=\beta i_B$, $v_{out} = v_E + i_0R_0 = i_BR_E - R_0\beta i_B = (R_E - R_0\beta)\, v_{in}/(R_s+R_{in}+R_E)$

$v_{out}/v_{in} = (R_E - R_0\beta)/(R_s+R_{in}+R_E) = (100\ \Omega - 100\ K\Omega.100)/(1\ K\Omega+10\ K\Omega+100\ \Omega) = -$ **9999.9**/11.1 = -**900.8**

(b) The input resistance at AA' while output is short circuit, is v_{IN}/i_B. Now, the resistances R_E and R_0 are in parallel with each other and parallel with the dependent source $\beta.i_B$. The voltage at the node v_E is $v_{IN}- i_B.R_{in}$. The KCL at node v_E now becomes:

$i_B = (v_{IN}-i_B.R_{IN})/(R_E||R_0) - \beta.i_B$ ➔ $i_B\,(1+\beta+ R_{IN}/(R_E||R_0)) = v_{IN}/(R_E||R_0)$

➔ $R(AA') = v_{IN}/ i_B = (R_E||R_0)\,(1+\beta+ R_{IN}/(R_E||R_0)) =$ **$R_{IN} + (\beta+1)(R_E||R_0)$**

The physical significance is that the extra dependent source current through $R_E||R_0$ maginifies the value.

c) Short circuit A and A' and look at the output resistance.

Putting a bag around the dependent source and R_0 shows that the currnet i_{out} flows through Rin and Re in parallel and $v_E= i_{out}\,(R_E||R_{IN})$ and $i_b = - i_{out}\,(R_E/(R_{IN} + R_E))$.

The current donward through $R_0 = i_{Ro} = - \beta.i_B + i_{out}$

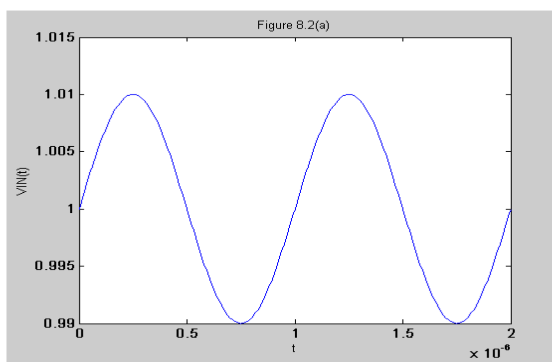
$v_{OUT} = i_{Ro}\,R_0 + v_E = R_0(- \beta.i_b + i_{out}) + i_{out}\,(R_E||R_{IN})$

$v_{OUT} = R_0(\beta.\, i_{out}\,(R_E/(R_{IN} + R_E)) + i_{out}) + i_{out}\,(R_E||R_{IN})$

Solving $v_{OUT} / i_{out} =(\beta\, R_E/(R_{IN} + R_E) +1)R_0 + (R_E||R_{IN})$

The physical significance is that the extra dependent source current adjusted for the fraction that makes it through through R_{IN}, maginifies the value of R_0 by raising the top to bottom voltage drop on R_0. The dependent source in some sense 'burps' and current flows upward through it when ever current flows into the output. The resistance is nonetheless still positive.

8.2 (a) the sketch is shown :



(b) The voltage at the Op-AMP input is:

$V\_ = (V_{REF}+V_{IN})/2$.

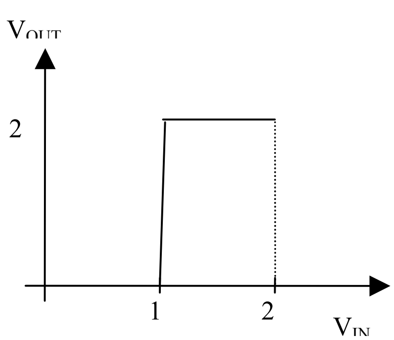
Voltage V_{OUT} is an amplified version of V_{IN}. for this condition to hold, we should have $V_{REF}+V_{IN}\leq 0$. In other words, $V_{REF}= -1$ V.

(c) $V_{RAIL-}=0$, $V_{RAIL+} = 2$

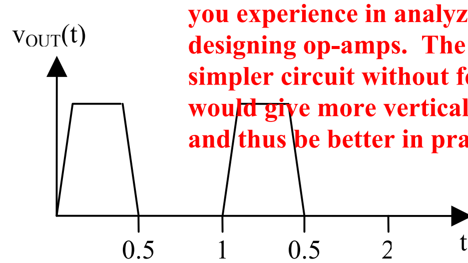
(d) $v\_ = v_{IN}/2$, $v_{OUT} = v\_ + v\_.R_2/R_1 = v\_(1+R_2/R_1) = v_{IN}(1+R_2/R_1)/2$

$v_{OUT}/v_{IN} = (1+R_2/R_1)/2 = 1000$, $R_1=1\ K\Omega \Rightarrow R_2 = 1999\ K\Omega$

(e)



(f)



Please note that this problem gave you experience in analyzing and designing op-amps. The much simpler circuit without feedback would give more vertical transitions and thus be better in practice.