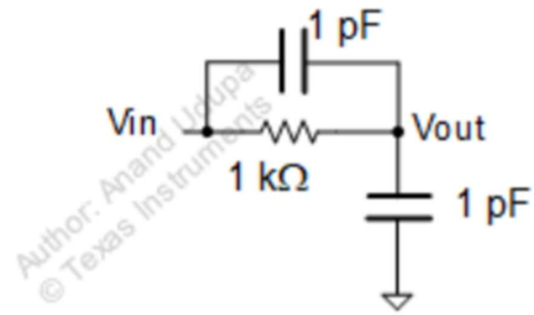
TI BYTE Simulation Exercise

Week 5 : Buffers

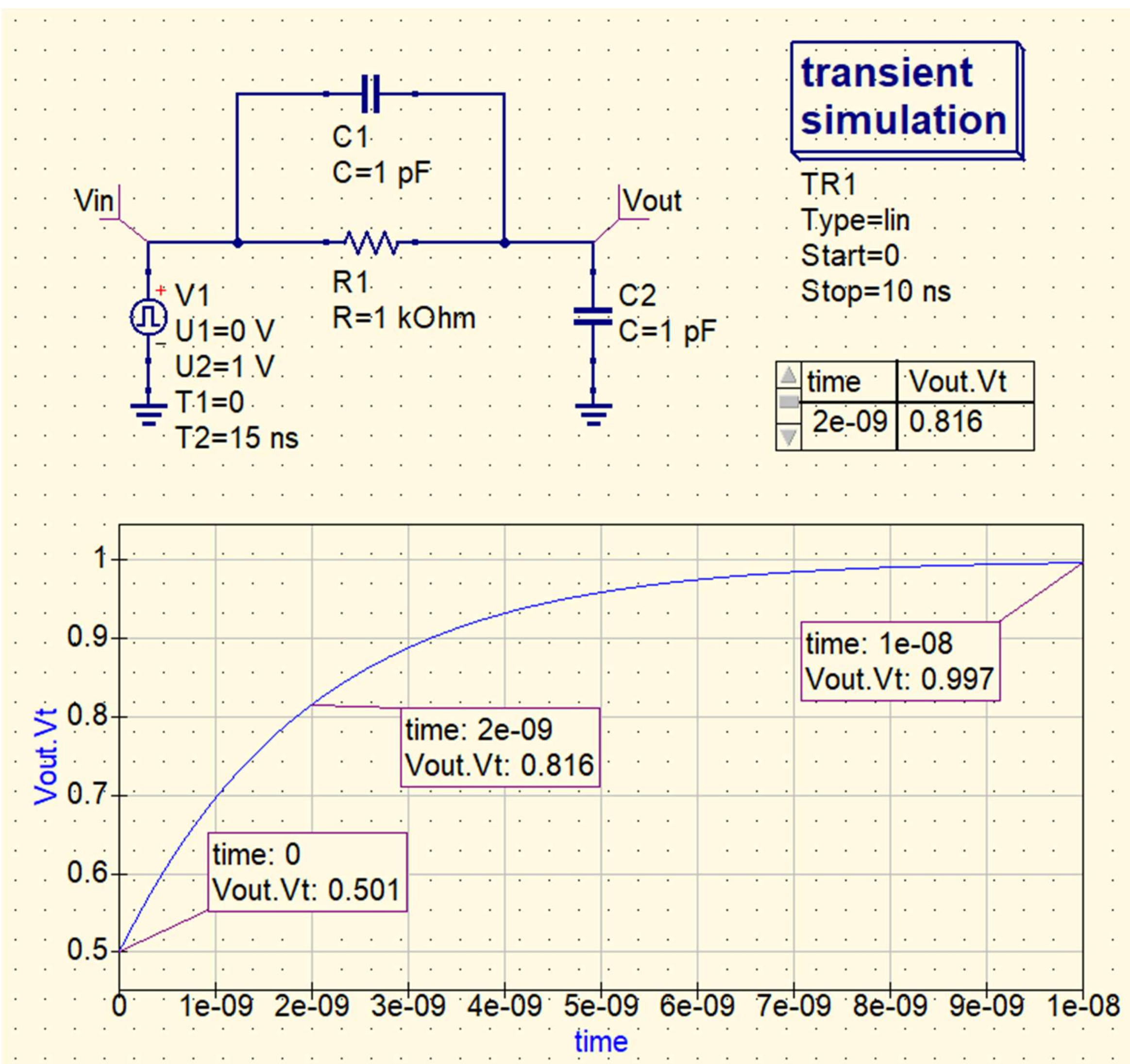
- **Question 1:**

710. In the circuit shown below, the input is driven with a waveform VIN=1.u(t). At a time of 2ns, the voltage at VOUT is roughly equal to:

(a) 1 V
(b) 0.315 V
(c) 0.93 V
(d) 0 V
(e) 0.81 V
(f) 0.5 V
(g) 0.63 V
(h) 0.99 V



➢ **QUCS Circuit:**



- **V_{in} is the input given with waveform V_{in} = 1.u(t)**
- **V_{out} is used to label the output node and find the voltage at that node.**
- **Both the capacitors are uncharged and have zero initial voltage in them.**

➢ QUCS Result:

Therefore, from the simulation, we get our answer as:

V_{out} | at t = 2 ns = 0.816 V ≈ 0.81 V

Answer: (e)

➢ Conclusion:

- **Initially, since the capacitors are uncharged, they provide minimal impedances. So, at t = 0⁺,**

$$V_{out} = \frac{C_1}{C_1 + C_2} \times V_{in} = \frac{1\,pF}{1\,pF + 1\,pF} \times 1\,V = 0.5\,V$$

- **At t = ∞, the capacitors are charged and behave as o.c., therefore,**

$$V_{out} = V_{in} = 1\,V$$

- **The R_{eq} of the circuit between V_{out} and V_{in} is = 1 kΩ**
- **The C_{eq} of the circuit between V_{out} and V_{in} is = 1 pF + 1 pF = 2 pF**
- **Time constant of the circuit = $R_{eq} \times C_{eq} = 1\,k\Omega \times 2\,pF = 2\,ns$**
- **Therefore, using the F.I.F. formula, we get the charging curve of V_{out} across the capacitor C2,**

$$V_{out} = V_f + (V_i - V_f)e^{-t/\tau}$$

where, $V_i = V_{out}(t = 0^+)$ and $V_f = V_{out}(t = \infty)$.

$$V_{out} = 1 + (0.5 - 1)e^{-t/2\,ns}$$

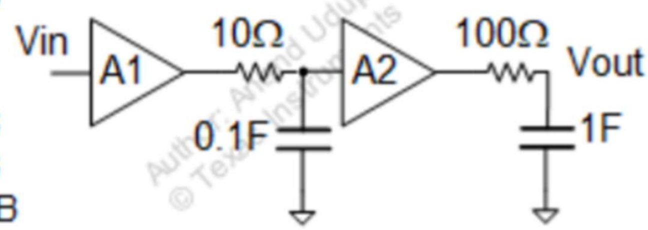
- **Thus, at t = 2 ns, $V_{out} = 1 - 0.5 \times e^{-2\,ns/2\,ns} = 1 - 0.5 \times e^{-1}$**

= 0.816 V

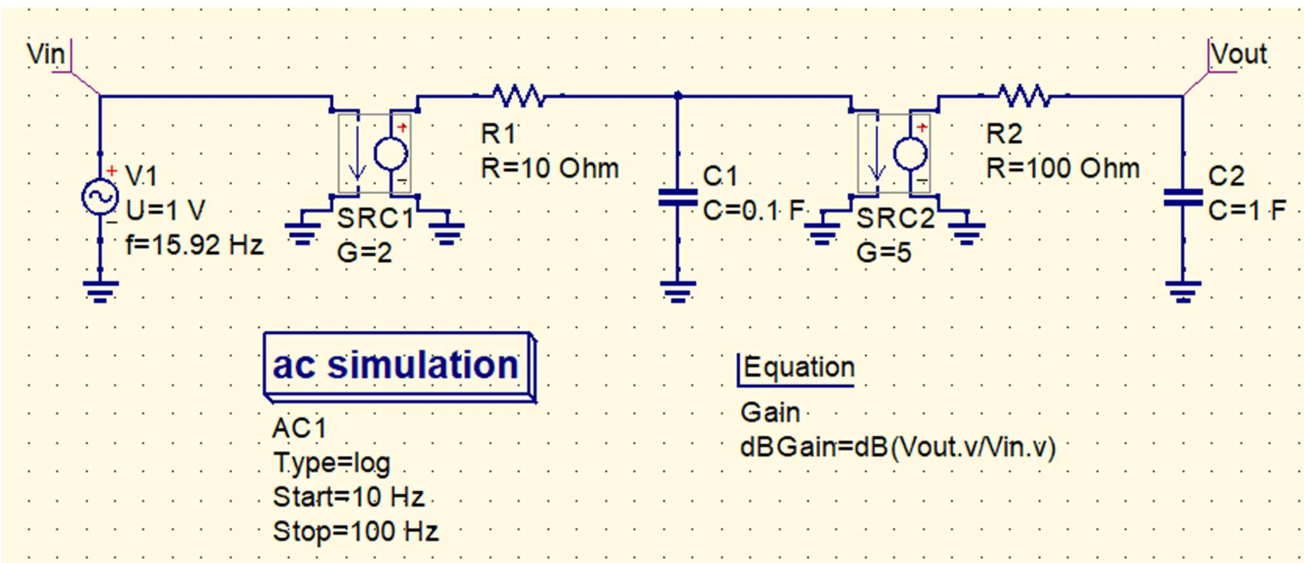
- **Thus, our answer is verified with the simulated result.**

- **<u>Question 2:</u>**

706. A1 and A2 are ideal buffers with gain of 2 and 5 respectively. Magnitude of Vout with respect to Vin at a frequency of 100 rad/s is:
(a) -40 dB
(b) -50 dB
(c) 0 dB
(d) 20 dB
(e) -80 dB
(f) -60 dB
(g) -120 dB
(h) -100 dB

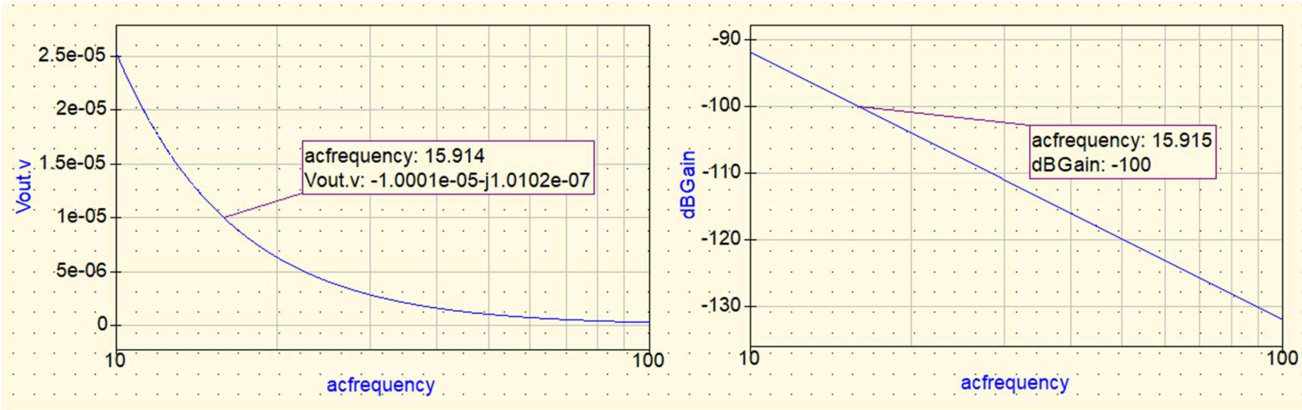


> **<u>QUCS Circuit:</u>**



- **V_{in} is a sinusoidal input given with an amplitude of 1V and frequency of 100 rad/s = 15.915 Hz**
- **V_{out} is used to label the output node and find the voltage at that node.**
- **Both the capacitors are uncharged and have zero initial voltage in them.**
- **The Buffer Amplifiers are implemented using Voltage Controlled Voltage Sources (VCVS), since they are ideal buffers with infinite input resistance and zero output resistance.**

➢ QUCS Result:



Therefore, from the simulation, we get our answer as:

A_v = -1.0001e-05 – j1.0102e-07 = -100 dB

Answer: (h)

➢ Conclusion:

- **The Transfer function can be given by.**

$$H(s) = \frac{V_{out}}{V_{in}} = \frac{A_1 A_2}{(1 + sR_1C_1)(1 + sR_2C_2)}$$

- **Thus H(s) has two poles and no zeroes.**
- **The total DC gain between V_{in} and V_{out} (A_{V_0}) = A1 × A2**

  = 2 × 5 = 10

  A_{V_0} = 20 dB

- **Now, due to the presence of the buffers, the two RC circuits R1C1 and R2C2 are electrically isolated. Thus, the effect due to the poles are also independent of each other.**
- **Therefore, the pole due to R1C1 is,**

$$\omega_1 = -\frac{1}{10\,\Omega \times 0.1\,F} = -1 \text{ rad/s}$$

and, the pole due to R2C2 is,

$$\omega_2 = -\frac{1}{100\,\Omega \times 1\,F} = -0.01 \text{ rad/s}$$

- **Since both the pole lie on the -ve s-axis of the s-jω plane, the system is stable.**
- **For a single pole at any frequency, the roll-off rate is -20dB/decade.**
- **Now, at $\omega = 100\ rad/s$, Gain due to the individual poles,**

$$A_{V_1} = -20 \times log\left(\frac{\omega}{|\omega_1|}\right) = -20 \times log\left(\frac{100}{1}\right) = -40\ dB$$

$$A_{V_2} = -20 \times log\left(\frac{\omega}{|\omega_2|}\right) = -20 \times log\left(\frac{100}{0.01}\right) = -80\ dB$$

- **Thus, total gain at $\omega = 100\ rad/s$,**

$$A_V = A_{V_0} + A_{V_1} + A_{V_2} = 20\ dB - 40\ dB - 80\ dB = -100\ dB$$

- **From the simulation, we got the same result, thus our answer is correct and verified.**