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DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Cascode Amplifier

Numerical 1

Calculate the values of R_C, R_1, R_2 for the circuit shown in figure 1. Assume $V_{CC} = 9V$, $R_3 = 18k\Omega$, $V_{C_1} = 3V$, $V_{C_2} = 6V$, $I_C = 1mA$, $R_E = 200\Omega$

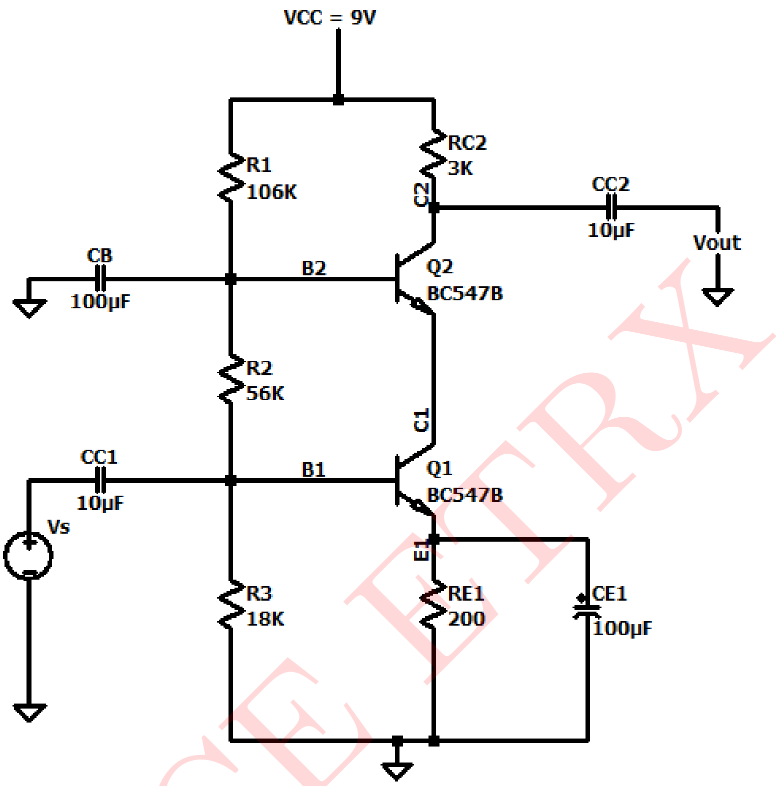

Figure 1: Circuit for Numerical 1

Solution:

DC Anaylsis:

During DC analysis, capacitors become open circuit.

The DC equivalent circuit is shown in figure 2

$\beta_1 = \beta_2 = 100$

$I_{C_1} = I_{C_2} = I_{E_1} = I_{E_2}$

Applying KVL to outer loop of figure 2 we get,

$V_{CC} - I_C R_C - V_{C_2} = 0$

$$R_C = \frac{V_{CC} - V_{C_2}}{I_C} = \frac{9V - 6V}{1mA}$$

$\mathbf{R_C = 3K\Omega}$

$V_{E_1} = I_E R_E = 1mA \times 200\Omega$

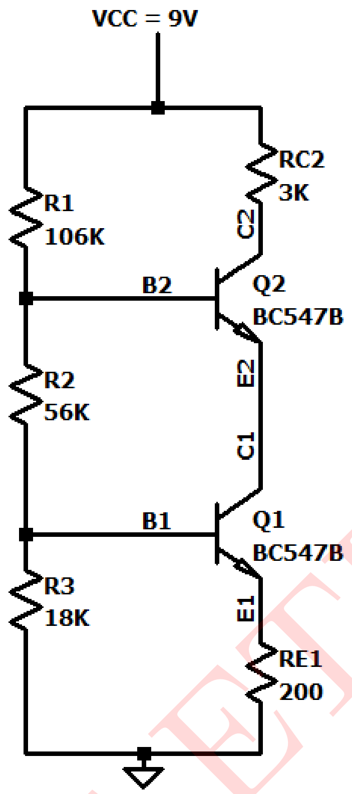

Figure 2: Thevenin's Equivalent Circuit

$$\mathbf{V_{E_1} = 0.2V}$$

$$V_{BE_1} = V_{B_1} - V_{E_1}$$

$$V_{B_1} = V_{BE_1} + V_{E_1} = 0.7V + 0.2V$$

$$\mathbf{V_{B_1} = 0.9V}$$

$$V_{B_1} = \frac{R_3}{R_1 + R_2 + R_3} \times V_{CC}$$

$$0.9V = \frac{18k}{R_1 + R_2 + 18k} \times 9V$$

$$R_1 + R_2 + 18k = \frac{18k \times 9V}{0.9V}$$

$$R_1 + R_2 + 18k = 180k$$

$$\mathbf{R_1 + R_2 = 162k} \qquad .....(1)$$

$$V_{E_2} = V_{C_1}$$

$$\mathbf{V_{E_2} = 3V}$$

$V_{BE_2} = V_{B_2} - V_{E_2}$

$V_{B_2} = V_{BE_2} + V_{E_2} = 0.7V + 3V$

$\mathbf{V_{B_2} = 3.7V}$

$$V_{B_2} = \frac{R_2 + R_3}{R_1 + R_2 + R_3} \times V_{CC}$$

$$3.7V = \frac{R_2 + 18k}{162k + 18k} \times 9V \qquad \text{(From (1))}$$

$R_2 + 18k = 74k$

$\mathbf{R_2 = 56k\Omega}$

$R_1 + R_2 = 162k$

$R_1 = 162k - R_2 = 162k - 56k$

$\mathbf{R_1 = 106k\Omega}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows:

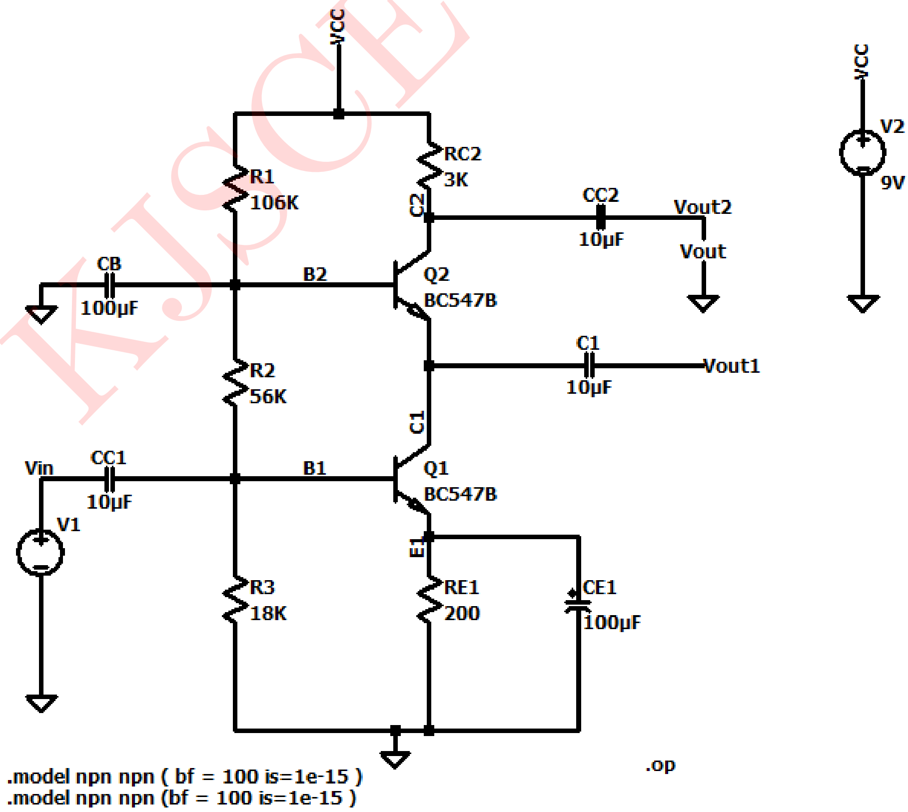

Figure 3: Circuit Schematics: Results

Comparison between theoretical and simulated values is given below:

Parameters	**Simulated Values**	**Theoretical Values**
$I_{C_1} = I_{E_1}$	$0.9mA$	$1mA$
$I_{C_2} = I_{E_2}$	$0.9mA$	$1mA$
V_{B_1}	$0.8V$	$0.9V$
V_{E_1}	$0.18V$	$0.2V$
V_{B_2}	$3.5V$	$3.7V$
V_{E_2}	$3V$	$3V$
V_{C_1}	$2.89V$	$3V$

Table 1: Numerical 1

Numerical 2

A two stage circuit is shown in figure 4, its E-MOSFET parameters are $k_{n_1} = k_{n_2} = 0.8mA/V^2$, $V_{TN_1} = V_{TN_2} = 0.8V$

a) Calculate the DC parameters of the circuits

b) Calculate the input impedance of the circuit

c) Calculate the output impedance of the circuit

d) Calculate the voltage gain of the circuit

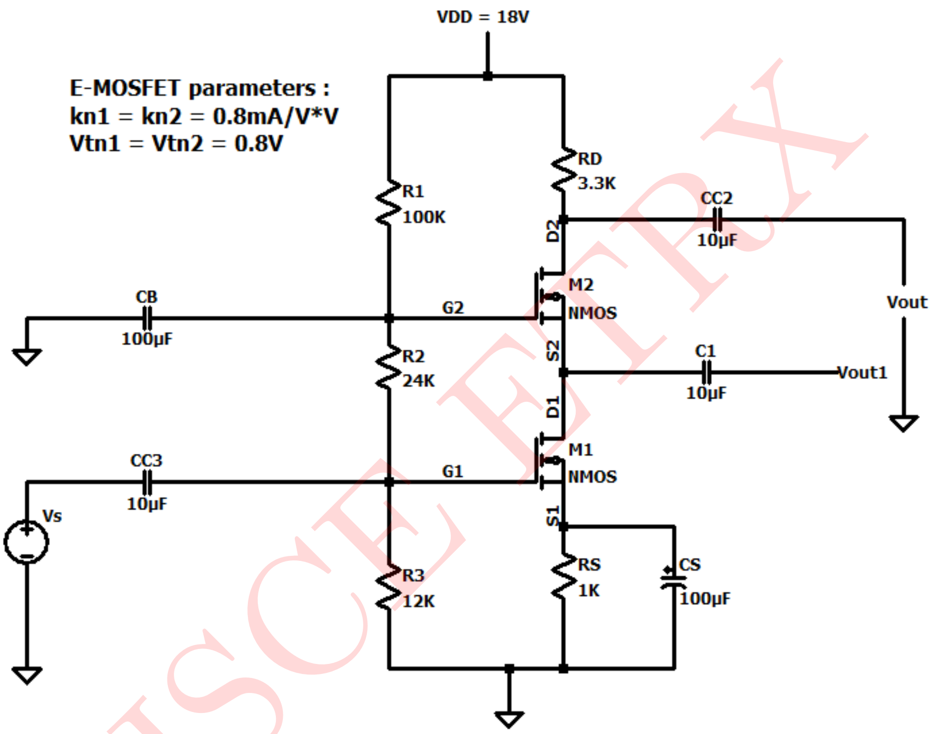

Figure 4: Circuit for Numerical 2

Solution:

DC Anaylsis: During DC analysis, capacitors become open circuit.

The DC equivalent circuit is shown in figure 5

$R_T = R_1 + R_2 + R_3 = 100k + 24k + 12k$

$\mathbf{R_T = 136k\Omega}$

$$V_{G_1} = \frac{R_3}{R_T} \times V_{DD} = \frac{12k}{136k} \times 18V$$

$\mathbf{V_{G_1} = 1.588V}$

$$V_{G_2} = \frac{R_2 + R_3}{R_T} \times V_{DD} = \frac{24k + 12k}{136k} \times 18V$$

$\mathbf{V_{G_2} = 4.764V}$

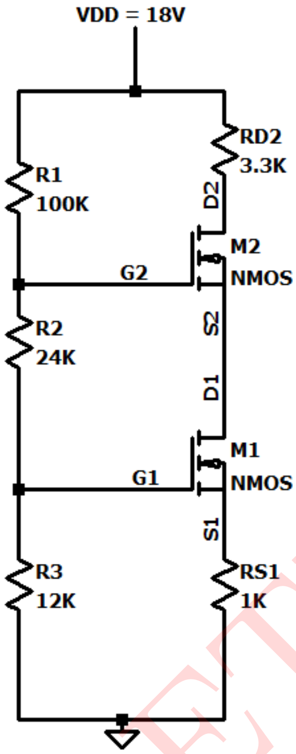

Figure 5: DC Equivalent Circuit

$V_{GS_1} = V_{G_1} - V_{S_1}$

$V_{GS_1} = 1.588V - I_{D_1} \times 1k$ .....(1)

$I_{D_1} = k_{n_1}(V_{GS_1} - V_{TN_1})^2$

$I_{D_1} = 0.8 \times 10^{-3}(V_{GS_1} - 0.8V)^2$ .....(2)

Substituting (2) in (1) we get,

$V_{GS_1} = 1.588 - 0.8 \times 10^{-3} \times 10^3(V_{GS_1} - 0.8)^2$

$V_{GS_1} = 1.588 - 0.8(V_{GS_1}^2 - 1.6V_{GS_1} + 0.64)$

$V_{GS_1} = 1.588 - 0.8V_{GS_1}^2 + 1.28V_{GS_1} - 0.512$

$0.8V_{GS_1}^2 - 0.28V_{GS_1} - 1.076 = 0$

Solving the above quadratic equation we get,

$V_{GS_1} = 1.3478V$ or $V_{GS_1} = -0.9978V$

$\mathbf{V_{GS_1} = 1.3478V}$ $(\because V_{GS_1} > V_{TN_1})$

i.e.$I_{D_1} = k_{n_1}(V_{GS_1} - V_{TN_1})^2$

$I_{D_1} = 0.8 \times 10^{-3}(1.3478 - 0.8)^2$

$\mathbf{I_{D_1} = 0.24mA}$

$\mathbf{I_{D_1} = I_{D_2} = 0.24mA}$

$V_{D_2} = V_{DD} - I_{D_2}R_D = 18 - 0.24mA \times 3.3k$

$\mathbf{V_{D_2} = 17.2V}$

$V_{S_1} = I_{D_1}R_S = 0.24mA \times 1k$

$\mathbf{V_{S_1} = 0.24V}$

$V_{S_1G} = V_{GS_2} = V_{G_2} - V_{S_2}$

$V_{S_2} = V_{G_2} - V_{GS_2} = 4.764 - 1.3478$

$\mathbf{V_{S_2} = 3.416V}$

$V_{DS_2} = V_{D_2} - V_{S_2} = 17.2 - 3.416$

$\mathbf{V_{DS_2} = 13.784V}$

$\mathbf{V_{D_1} = V_{S_2} = 3.416V}$

AC Analysis:

Calculation of small signal parameters:

$g_{m_1} = g_{m_2} = 2k_n(V_{GS} - V_{TN}) = 2 \times 0.8 \times 10^{-3}(1.3478 - 0.8)$

$\mathbf{g_{m_1} = g_{m_2} = 0.876mA/V}$

Small signal equivalent circuit is shown in figure 6

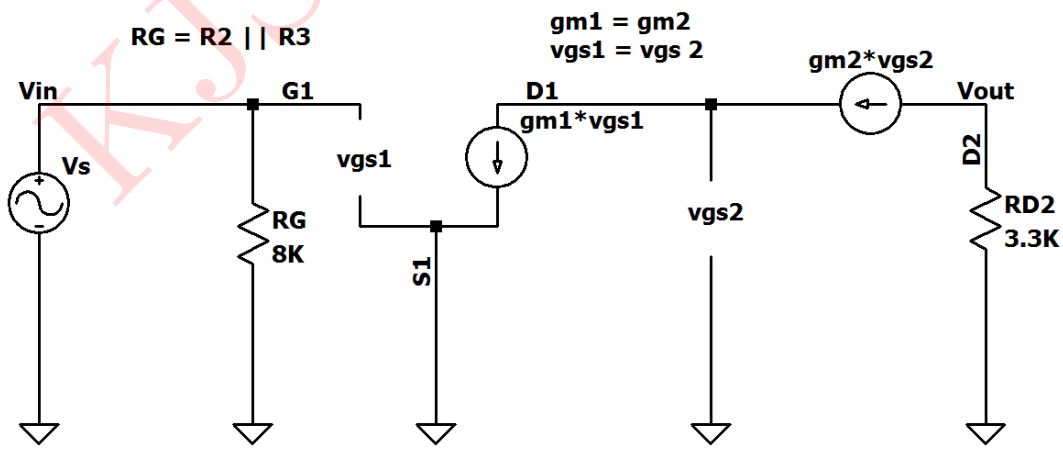

Figure 6: Small Signal Equivalent Circuit

$g_{m_1}V_{gs_1} = g_{m_2}V_{gs_2}$

$R_G = R_2 \parallel R_3 = 24k \parallel 2k$

$\mathbf{R_G = 8k\Omega}$

Calculation of voltage gain:

$$A_{V_T} = \frac{V_{out}}{V_s} = \frac{V_{out}}{V_{o_1}} \times \frac{V_{o_1}}{V_s}$$

<u>For Stage-1:</u>

$$A_{V_1} = \frac{V_{o_1}}{V_s} = \frac{-V_{gs_2}}{V_{gs_1}}$$

But $V_{gs_1} = V_{gs_2}$

$\mathbf{A_{V_1} = -1}$

<u>For Stage-2:</u>

$$A_{V_2} = \frac{V_{out}}{V_{o_1}} = \frac{-g_{m_2} V_{gs_2} R_D}{-V_{gs_2}}$$

$A_{V_2} = g_{m_2} R_D = 0.876 \times 10^{-3} \times 3.3k$

$\mathbf{A_{V_2} = 2.89}$

The overall voltage gain $\mathbf{A_{V_T}}$:

$A_{V_T} = A_{V_1} \times A_{V_2} = -1 \times 2.89$

$\mathbf{A_{V_T} = -2.89}$

Input Impedance:

$Z_i = R_G = R_2 \parallel R_3 = 24k \parallel 2k$

$\mathbf{Z_i = 8k\Omega}$

Output Impedance:

$Z_i = R_D$

$\mathbf{Z_o = 3.3k\Omega}$

Calculation of output voltage:

$V_o = A_{V_T} \times V_{in} = 2.89 \times 40mV$

$\mathbf{V_o = 115.6mV}$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows:

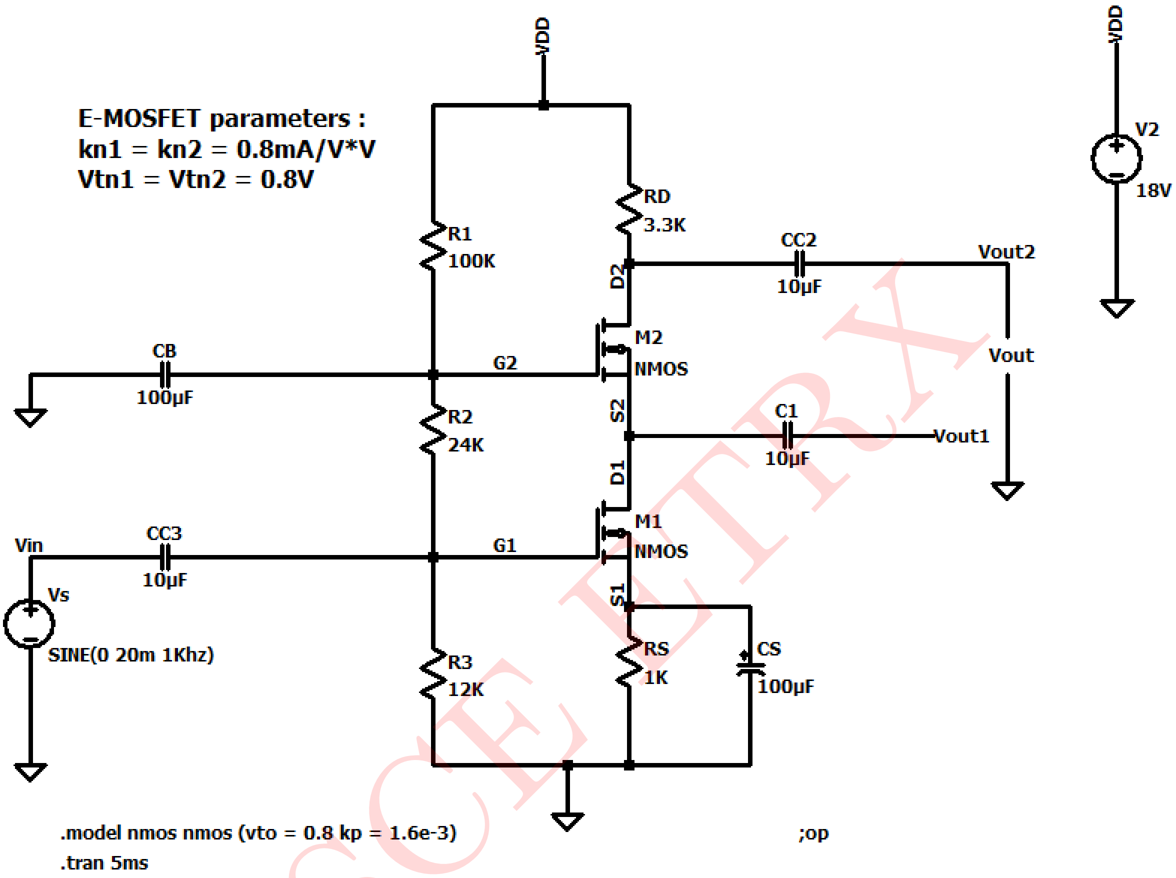

Figure 7: Circuit Schematics: Results

Output Waveforms:

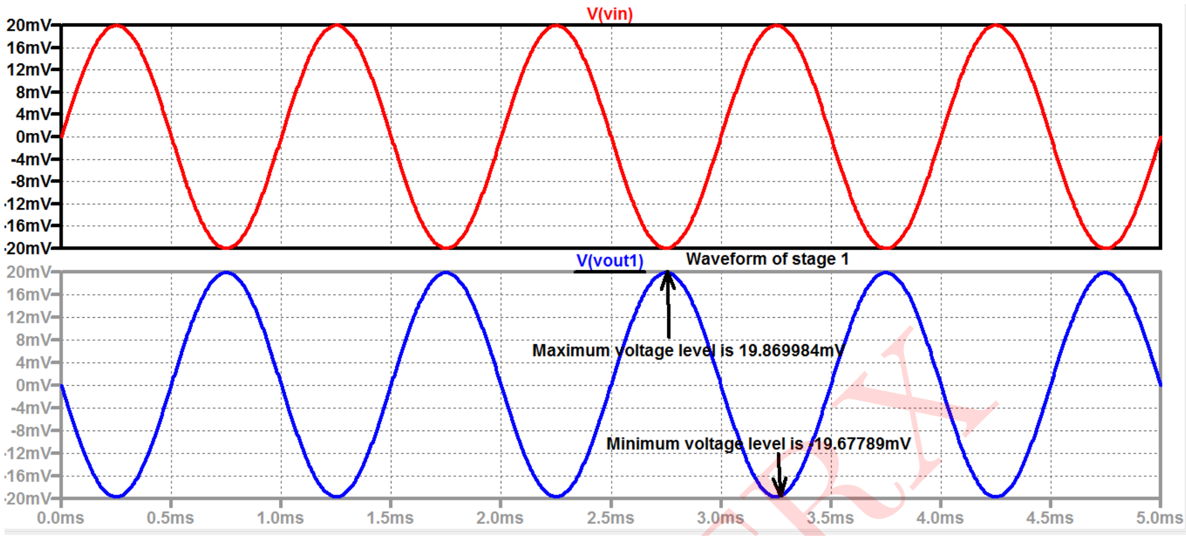

Figure 8: Input and Output Waveforms for 1^{st} Stage

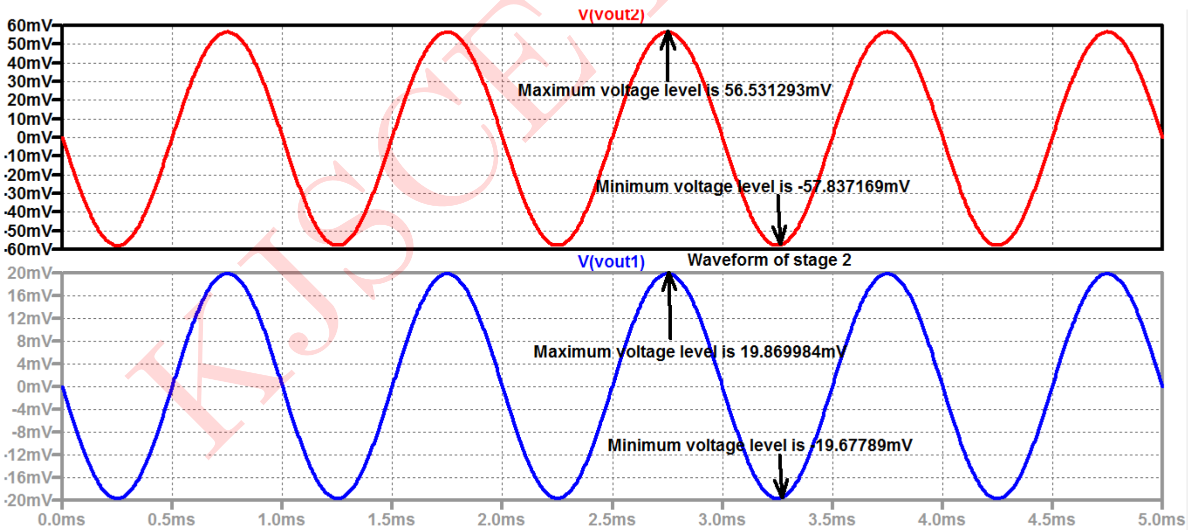

Figure 9: Input and Output Waveforms for 2^{nd} Stage

Comparison between theoretical and simulated values is given below:

Parameters	**Simulated Values**	**Theoretical Values**
V_{G_1}	$1.588V$	$1.588V$
V_{D_1}	$3.41V$	$3.416V$
V_{S_1}	$0.24V$	$0.24V$
I_{D_1}	$0.24mA$	$0.24mA$
V_{G_2}	$4.76V$	$4.764V$
V_{D_2}	$17.2V$	$17.2V$
V_{S_2}	$3.41V$	$3.416V$
I_{D_2}	$0.24mA$	$0.24mA$
Voltage gain of first stage (A_{V_1})	-0.986	-1
Voltage gain of second stage (A_{V_2})	2.89	2.89
Overall voltage gain (A_{V_T})	-2.88	-2.89
Input Impedance (Z_i)	$-$	$8k\Omega$
Output Impedance (Z_o)	$-$	$3.3k\Omega$
Output voltage (V_o)	$114.39mV$	$115.6mV$

Table 2: Numerical 2

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