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DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Cascode Amplifier

Q1. Calculate DC voltages at each mode and DC currents in the given circuit.

Given: $R_1 = 65k\Omega$, $R_2 = 33k\Omega$, $R_C = 2.7k\Omega$, $R_L = 6.2k\Omega$, $R_E = 0.5k\Omega$, $R_3 = 12k\Omega$, $V_{CC} = 12V$, $\beta 1 = \beta 2 = 100$.

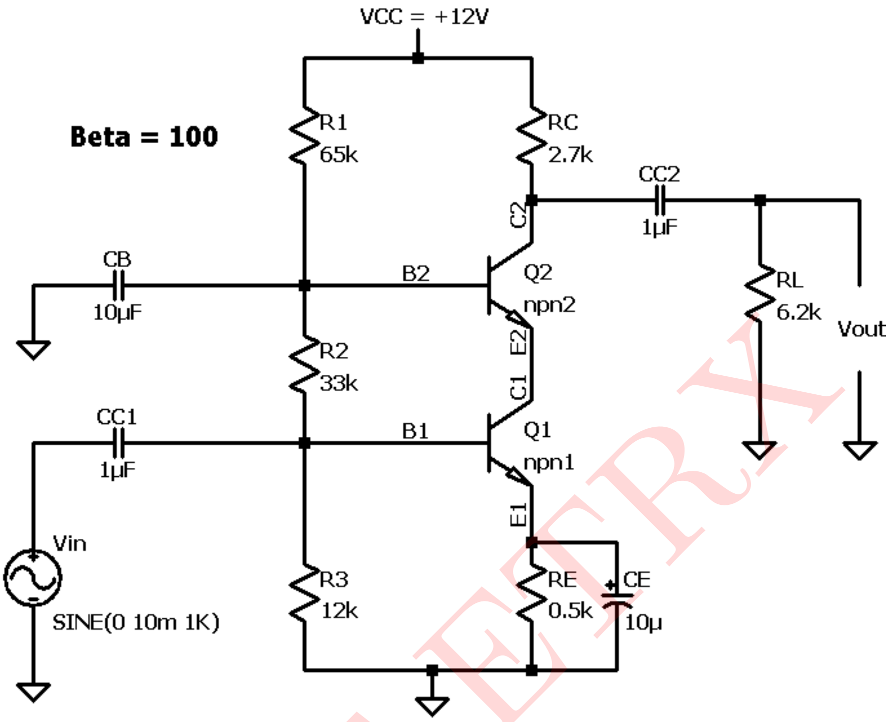

Figure 1: Circuit 1

Solution:

The above circuit is a CE-CB bjt cascode amplifier

$$V_{B1} = \left(\frac{R_3}{R_1 + R_2 + R_3}\right) \times V_{CC} = \left(\frac{12k}{65k + 33k + 12k}\right) 12 = \mathbf{1.3090V}$$

$$V_{B1} = \left(\frac{R_3 + R_2}{R_1 + R_2 + R_3}\right) \times V_{CC} = \left(\frac{12k + 33k}{65k + 33k + 12k}\right) 12 = \mathbf{4.090V}$$

Applying KVL to the B-E loop of Q1

$V_{E1} = V_{B1} - V_{BE1} = 1.309 - 0.7 = \mathbf{0.609V}$

$V_{E1} = I_{E1} R_E$

$I_{E1} = V_{E1}/R_E = 0.609/500 =$ **1.218mA**

$I_{C1} = I_{E1} = I_{E2} = I_{C2} =$ **1.218mA**

$V_{C2} = V_{CC} - I_{C2} R_C = 12 - (1.218mA)(2.7k) = \mathbf{8.7114V}$

$V_{E2} = V_{B2} - V_{BE2} = 4.909 - 0.7 = \mathbf{4.209V}$

$V_{E2} = V_{C1} = 4.209V$

$V_{CE1} - V_{C1} - V_{E1} = 4.209 - 0.609 = \mathbf{3.6V}$

$V_{CE2} - V_{C2} - V_{E2} = 8.7114 - 4.209 = \mathbf{4.5024V}$

$I_C = \beta I_B$

$I_B = I_C/\beta = 1.218mA/100 = \mathbf{12.18\mu A}$

Small signal parameters:

$r_\pi = \dfrac{\beta V_T}{I_{CQ}} = \dfrac{100 \times 26 \times 10^{-3}}{1.218 \times 10^{-3}} = \mathbf{2.134k\Omega}$

$g_m = \dfrac{I_{CQ}}{V_T} = \dfrac{1.218 \times 10^{-3}}{26 \times 10^{-3}} = \mathbf{46.846\ mA/V}$

Mid frequency equivalent circuit:

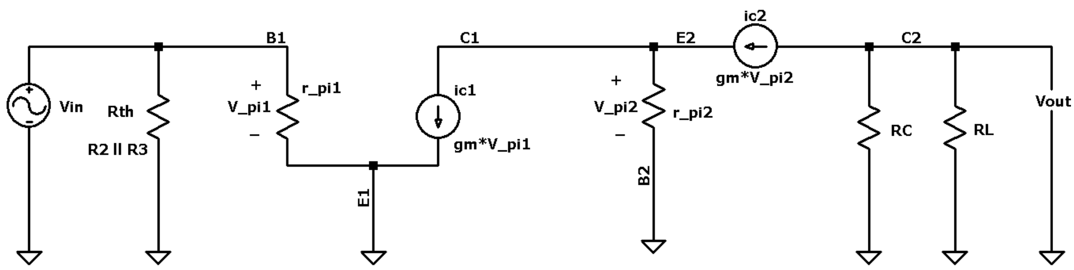

Figure 2: Mid frequency equivalent circuit

$Z_i = R_2 \mid\mid R_3 \mid\mid r_\pi = 33k \mid\mid 12k \mid\mid 2.134k = \mathbf{1.717k\Omega}$

$Z_o = R_C \mid\mid R_L = 2.7k \mid\mid 6.2k = \mathbf{1.88k\Omega}$

Gain of CB stage $= A_{V_2} = g_m(R_C||R_L) = \dfrac{46.864mA/V}{1.88k} = \mathbf{88.0714}$

Gain of CB stage $= A_{V_1} = -g_m\left(\dfrac{r_\pi}{1+\beta}\right) = -46.842\left(\dfrac{2.134k}{101}\right) = \mathbf{-0.9897}$

$A_{V_T} = A_{V_1} \times A_{V_2} = 88.0704 \times -0.9897 = \mathbf{-87.1632}$

A_{V_T} in dB $= 20\ \log(87.16321) = \mathbf{38.806dB}$

SIMULATED RESULTS:

Above circuit was simulated in LTSpice and results are presented below:

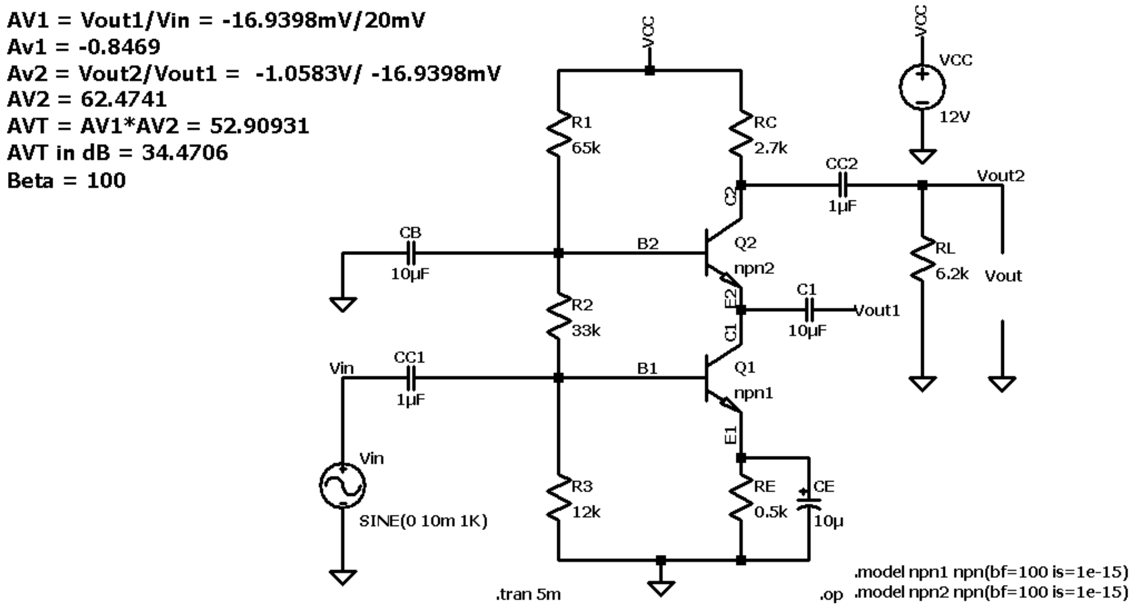

Figure 3: Circuit Schematic

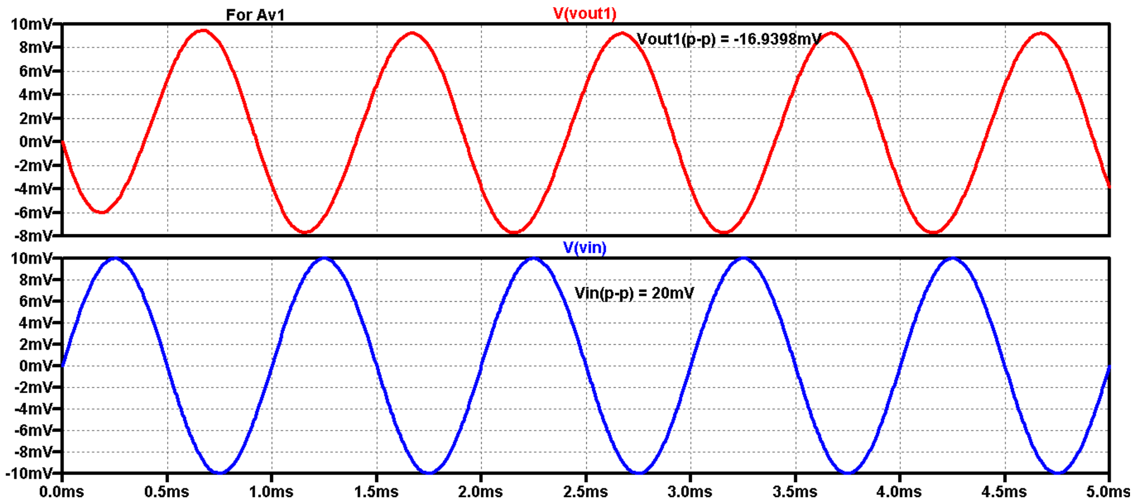

Figure 4: Input output waveform for A_{V_1}

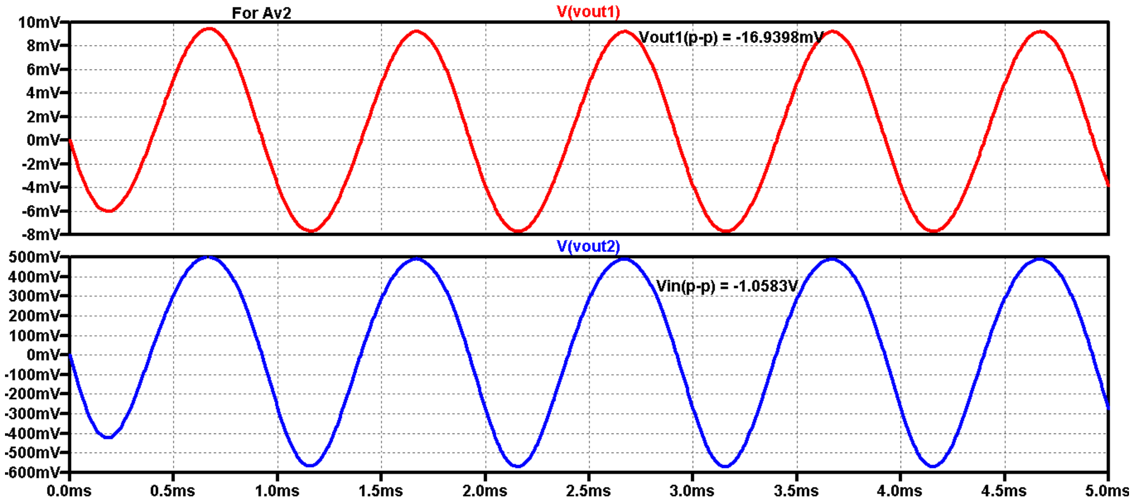

Figure 5: Input output waveform for A_{V_2}

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
Stage 1: I_{E1}	0.876mA	1.218mA
I_{B1}, I_{C1}	8.764μA, 0.8764mA	12.18μA, 1.218mA
V_{B1}, V_{C1}	1.153V, 3.905V	1.309V, 4.209V
V_{E1}, V_{CE1}	0.442V, 3.463V	0.609V, 3.6V
Stage 2: I_{E2}	0.876mA	1.218mA
I_{B2}, I_{C2}	8.677μA, 0.876mA	12.18μA, 1.218mA
V_{B2}, V_{C2}	4.616V, 9.657V	4.909V, 8.7114V
V_{E2}, V_{CE2}	3.905V, 5.752V	4.209V, 4.5024V
A_{V_1}	-0.8469	-0.9897
A_{V_2}	62.4741	88.0704
A_{V_T} in dB	34.4706dB	38.8066dB
Z_i	–	1.717kΩ
Z_o	–	1.88kΩ

Table 1: Numerical 1

Q2. Calculate DC voltages at each mode and DC currents in the give circuit.

Given:
$R_1 = 110k\Omega$, $R_2 = 33k\Omega$, $R_S = 1k\Omega$, $R_D = 3.3k\Omega$, $R_3 = 12k\Omega$, $V_{DD} = 20V$, $k_{n1} = k_{n2} = 0.8\ mA/V^2$.

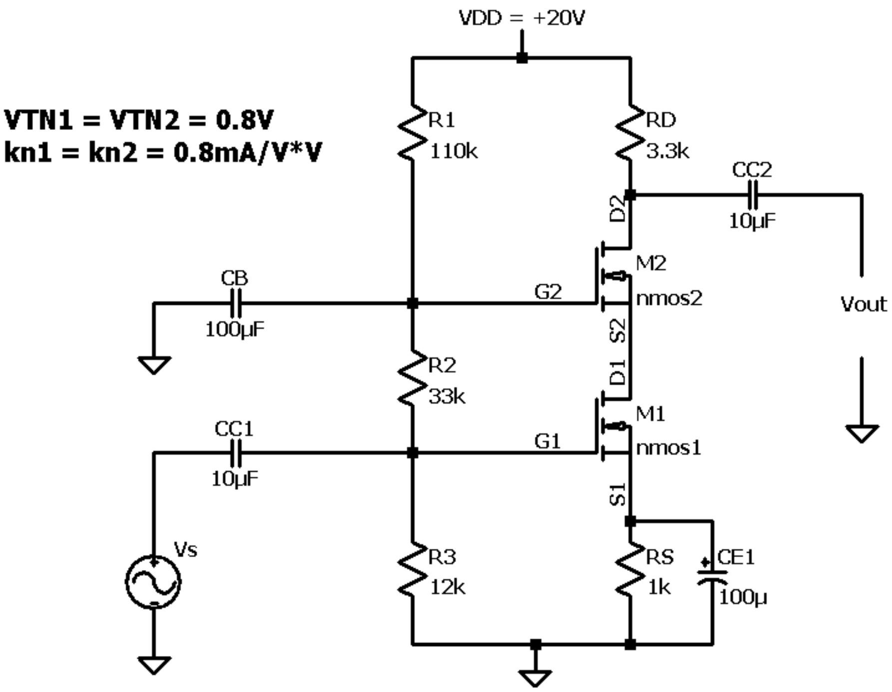

Figure 6: Circuit 1

Solution:

The above circuit is a CS-CG directly coupled MOSFET amplifier

$R_T = R_1 + R_2 + R_3 =$ 110k + 33k + 12k = 155KΩ

$$V_{G1} = \left(\frac{R_3}{R_1 + R_2 + R_3}\right) \times V_{DD} = \left(\frac{12k}{155k}\right) 20 = \mathbf{1.548V}$$

$$V_{G2} = \left(\frac{R_3 + R_2}{R_1 + R_2 + R_3}\right) \times V_{DD} = \left(\frac{12k + 33k}{155k}\right) 20 = \mathbf{5.806V}$$

Applying KVL to the B-E loop of Q1

$V_{GS1} = V_{G1} - V_{S1}$

$V_{GS1} = V_{G1} - I_{D1} R_S$

$V_{GS1} = V_{G1} - I_{D1} \times 1k$ ——- (1)

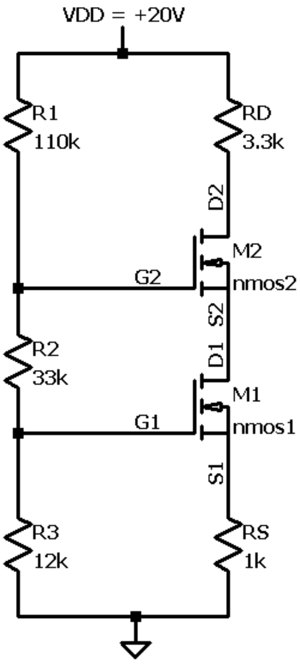

Figure 7: DC equivalent circuit

Assuming NMOS in Saturation Region

$I_{D1} = k_{n1}(V_{GS1} - V_{TN1})^2$

$I_{D1} = 0.8 \times 10^{-3}(V_{GS1} - 0.8)^2$ ——- (2)

Solving equations (1) and (2)

$V_{GS1} = 1.548 - 0.8(V_{GS1} - 0.8)^2$

$V_{GS1} = 1.548 - 0.8(V_{GS}^2 + 0.64 - 1.6V_{GS1})$

$0.8V_{GS1}^2 - 0.28V_{GS1} - 1.036 = 0$

$V_{GS1} = 1.3263V$ or -0.9763V

We choose V_{GS1}= 1.3263 $(\because V_{GS1} > V_{TN1})$

$I_{D1} = 0.8 \times 10^{-3}(V_{GS1} - 0.8)^2$

$I_{D1} = 0.8 \times 10^{-3}(1.3263 - 0.8)^2$

$I_{D1} = I_{D2} =$ **0.2215mA**

$V_{GS2} = V_{G2} - V_{S2}$

$V_{S2} = V_{GS2} - V_{G2} = 5.806 - 1.3263 =$ **4.4797V**

$V_{DS2} = V_{D2} - V_{S2} = 19.269 - 4.4797 =$ **14.7893V**

$V_{DS1} = V_{D1} - V_{S1} = 4.4797 - 0.2215 =$ **4.2582V**

Small signal parameters:

$g_{m1} = g_{m2} = 2k_n(V_{GS} - V_{TN})$ = 2 × 0.8 ×10^{-3}(1.3263 - 0.8) = **40.84208 mA/V**

Mid frequency equivalent circuit:
$Z_i = R_2 \,||\, R_3 = 33k \,||\, 12k =$ **8.8kΩ**

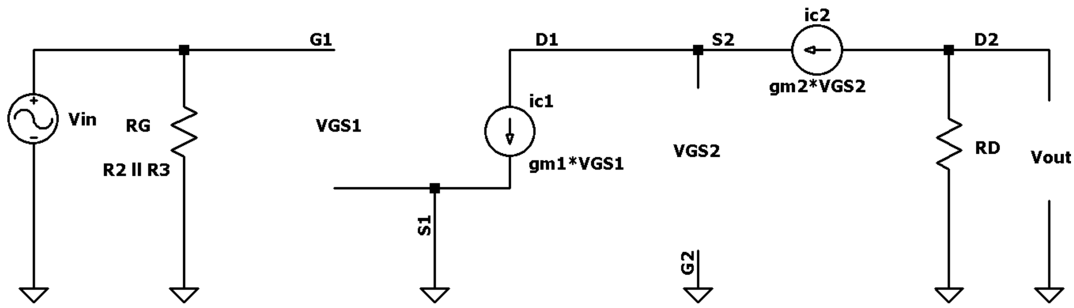

Figure 8: Mid frequency equivalent circuit

$Z_o = R_D = \ \mathbf{2.7788k\Omega}$

$A_{V_2} = -g_m(R_D) = 0.84208 \times 3.3 = \ \mathbf{2.7788}$

$A_{V_1} = \dfrac{-V_{gs2}}{V_{gs1}} = \mathbf{-1}$

$A_{V_T} = A_{V_1} \times A_{V_2} = 2.7788 \times -1 = -\mathbf{2.7788}$

A_{V_T}in dB $= 20\ \log_{10}(-2.7788) = \mathbf{8.8771dB}$

SIMULATED RESULTS:

Above circuit was simulated in LTSpice and results are presented below:

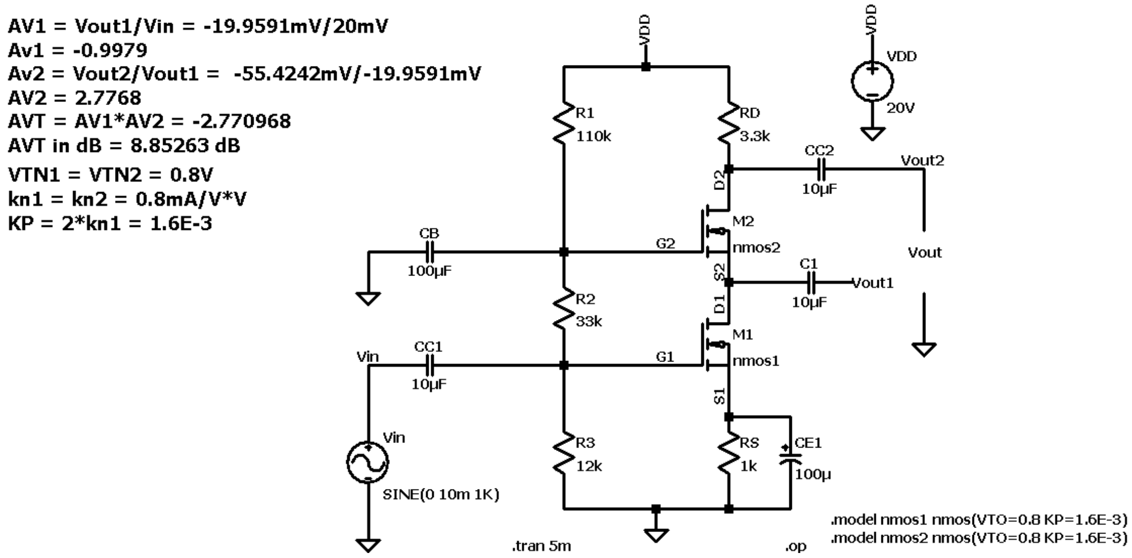

Figure 9: Circuit Schematic

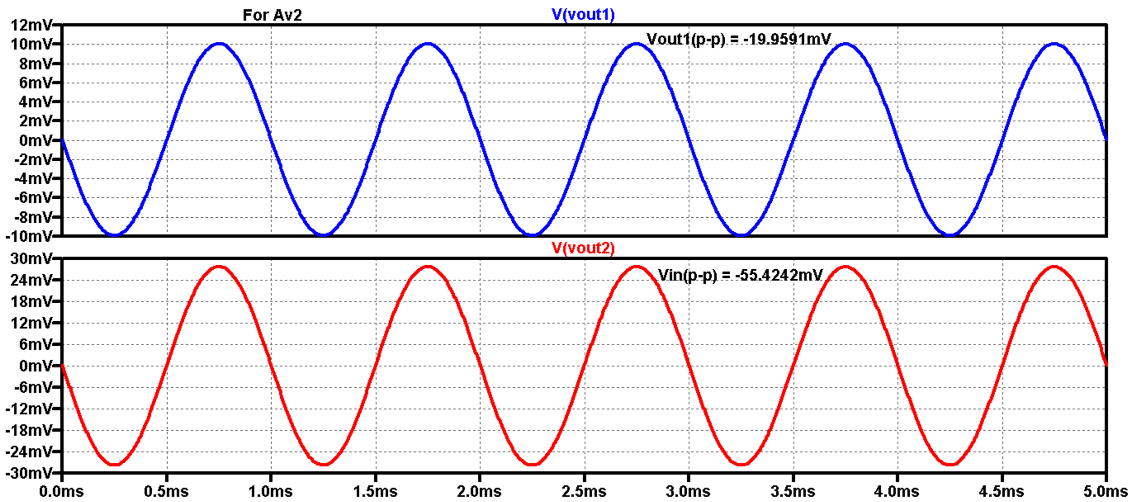

Figure 10: Input output waveform for A_{V_2}

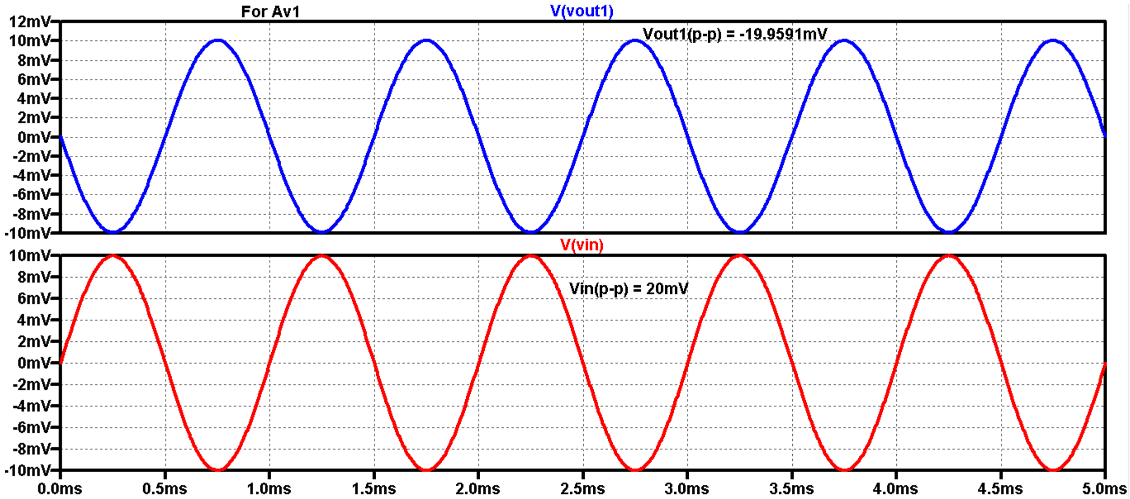

Figure 11: Input output waveform for A_{V_1}

Comparison of Theoretical and Simulated Values:

Parameters	Simulated	Theoretical
Stage 1:		
V_{G1}, I_{D1}	1.548V, 0.2218mA	1.548V, 0.2215mA
V_{S1}, V_{D1}	0.2218V, 4.4798V	0.2215V, 4.4797V
V_{GS1}, V_{DS1}	1.3265V, 4.258VV	1.3263V, 4.2582V
Stage 2:		
I_{G2}, I_{D2}	5.806V, 0.2218mA	5.806V, 0.2215mA
V_{S2}, V_{D2}	4.4698V, 19.268V	4.4797V, 19.269V
V_{GS2}, V_{DS2}	1.3262V, 14.7882V	1.3263V, 14.789V
A_{V_1}	-0.9979	-1
A_{V_2}	2.7768	2.7788
A_{V_T} in dB	8.88526	8.8771
Z_i	–	8.8kΩ
Z_o	–	3.3kΩ

Table 2: Numerical 2

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