# Lab 11:
# MOSFET Amplifier Configurations

Name: Wan-Yu Liao

ECEN 325 Section 514

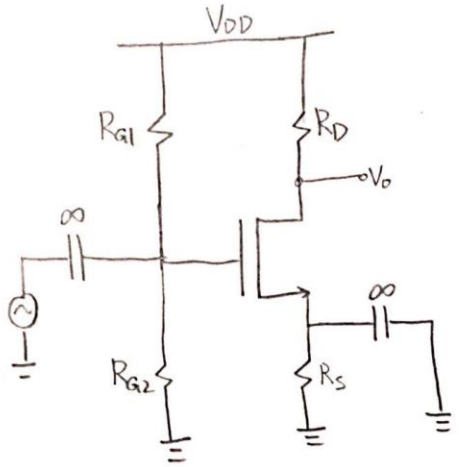
TA: Mandela

Lab Date: November 15, 2019

Lab Report Due Date: November 19, 2019

## Calculation

Common - Source




$V_{DD} = 5V$

$|A_v| = 25$

from last lab:

$V_T = 2.23V$

$K'\frac{W}{L} = 0.0895\ A/V^2$

$V_{RS} = 1V$ Choose $\hat{V}_o = 1.3V$, $R_i = 11k\Omega$

$$V_{RD} = \frac{V_{DD} - \hat{V}_o - V_{RS}}{1 + \frac{2}{|A_v|}} = \frac{5 - 1.3 - 1}{1 + \frac{2}{25}} = 2.5V$$

$$V_{ov} = \frac{2 \cdot V_{RD}}{|A_v|} = \frac{2 \cdot 2.5}{25} = 0.2V$$

$$I_D = \frac{K'}{2}\frac{W}{L}V_{ov}^2 = \frac{0.0895}{2} \cdot (0.2)^2 = 1.79\,mA$$

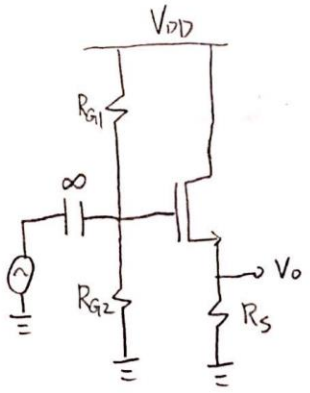
$$R_D = \frac{V_{RD}}{I_D} = \frac{2.5}{1.79m} = 1.4k\Omega \qquad R_S = \frac{V_{RS}}{I_D} = \frac{1}{1.72m} = 559\Omega$$

$$V_{RG2} = V_{RS} + |V_T| + V_{ov} = 1 + 2.23 + 0.2 = 3.43V$$

$$R_{G1} = \frac{R_i V_{DD}}{V_{RS} + |V_T| + V_{ov}} = \frac{11k \cdot 5}{3.43} = 16035\Omega$$

$$R_{G2} = \frac{16035 \cdot 11000}{16035 + 11000} = 35032\Omega$$

# Common-Drain




$V_{DD} = 5V$

$R_{G1} = 16035\Omega$

$R_{G2} = 35032\Omega$

$R_S = 559\Omega$

$V_{ov} = 0.2V$

$$g_m = K'\frac{W}{L}V_{ov} = 0.0895 \cdot 0.2 = 0.0179\ A/V$$

$$A_v = \frac{R_S}{\frac{1}{g_m} + R_S} = \frac{559}{\frac{1}{0.0179} + 559} = 0.909$$

$$R_i = R_{G1} \| R_{G2} = 11\ K\Omega$$

$$R_o = R_S \| \frac{1}{g_m} = \frac{559 \cdot \frac{1}{0.0179}}{559 + \frac{1}{0.0179}} = 50.79\Omega$$

## Simulation

Common-Source Amplifier

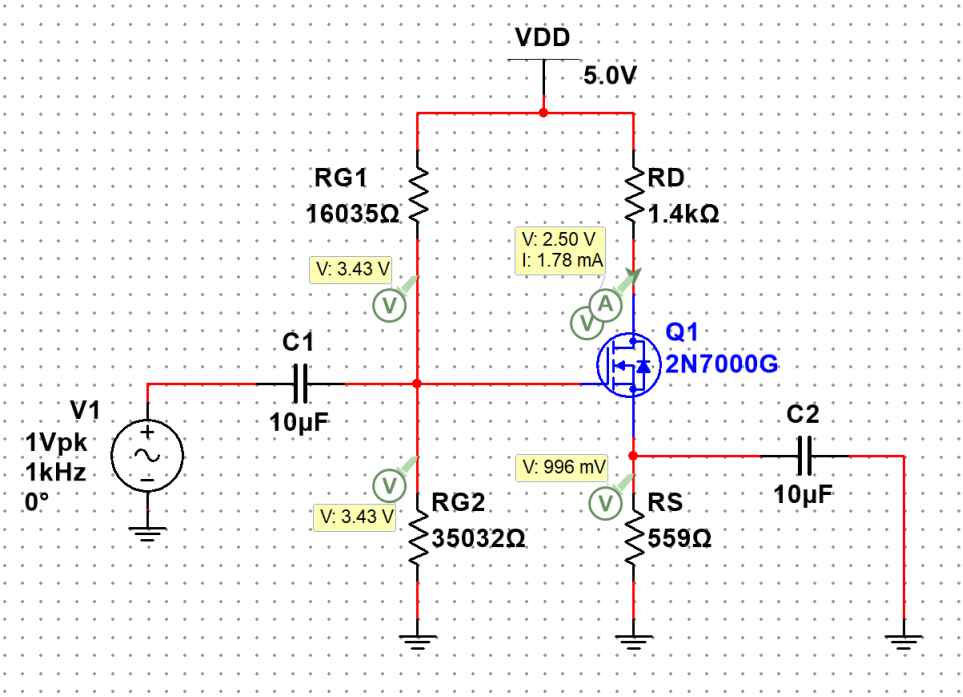



**Figure 1:** DC Solution for common-source amplifier ▲

$V_{RG2} = 3.43V$

$V_{RS} = 0.996V$

$V_{RD} = 5\text{-}2.5 = 2.5V$

$V_{o,dc} = 2.5V$

$I_D = 1.78mA$

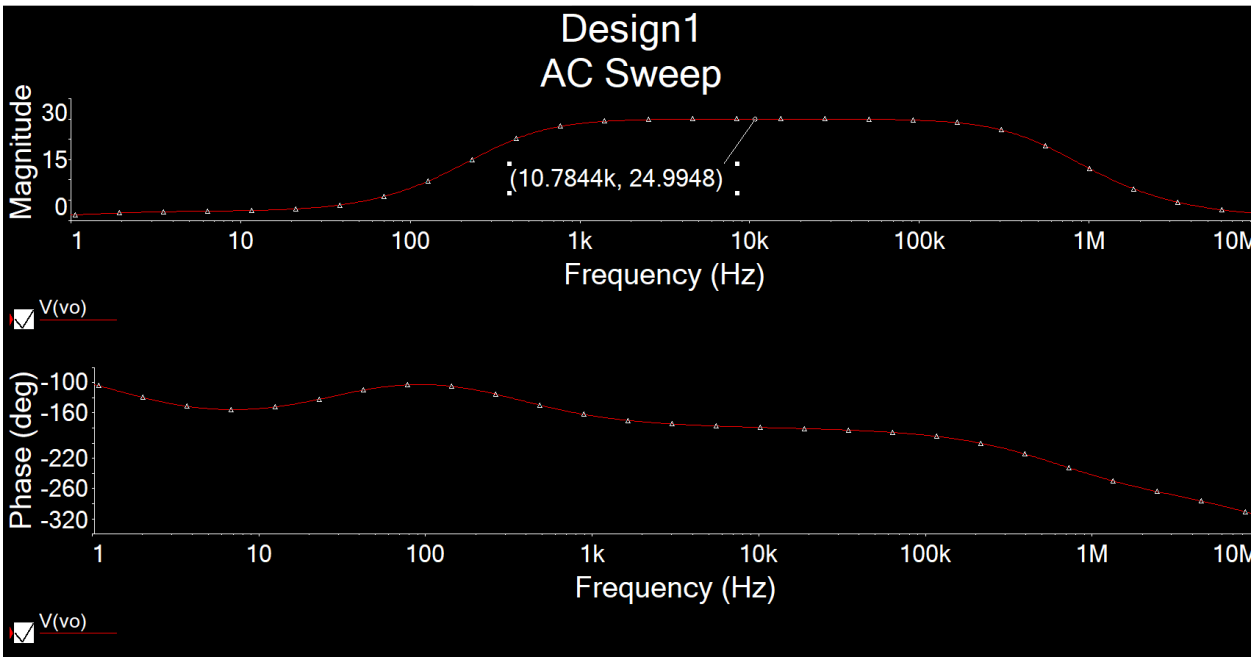



**Figure 2.1:** AC Simulation of $A_V$ for common-source amplifier ▲

$A_V = 24.9948$

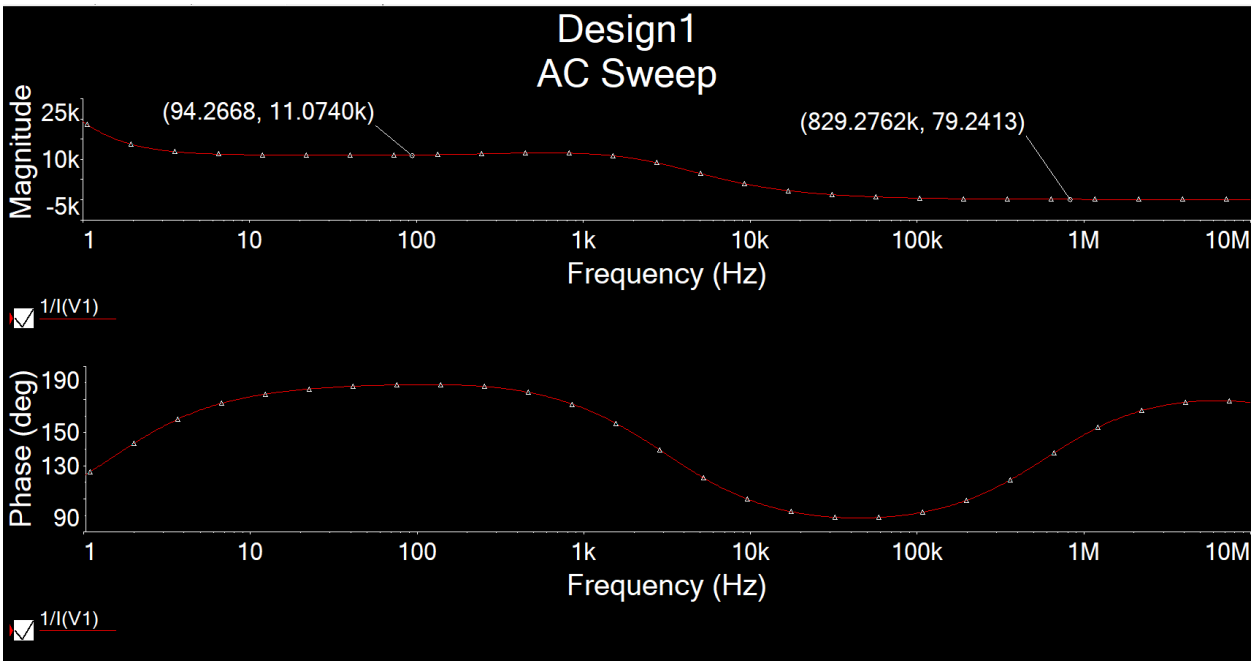



**Figure 2.2:** AC Simulation of $R_i$ for common-source amplifier ▲

$R_i = 11.0740k\Omega$

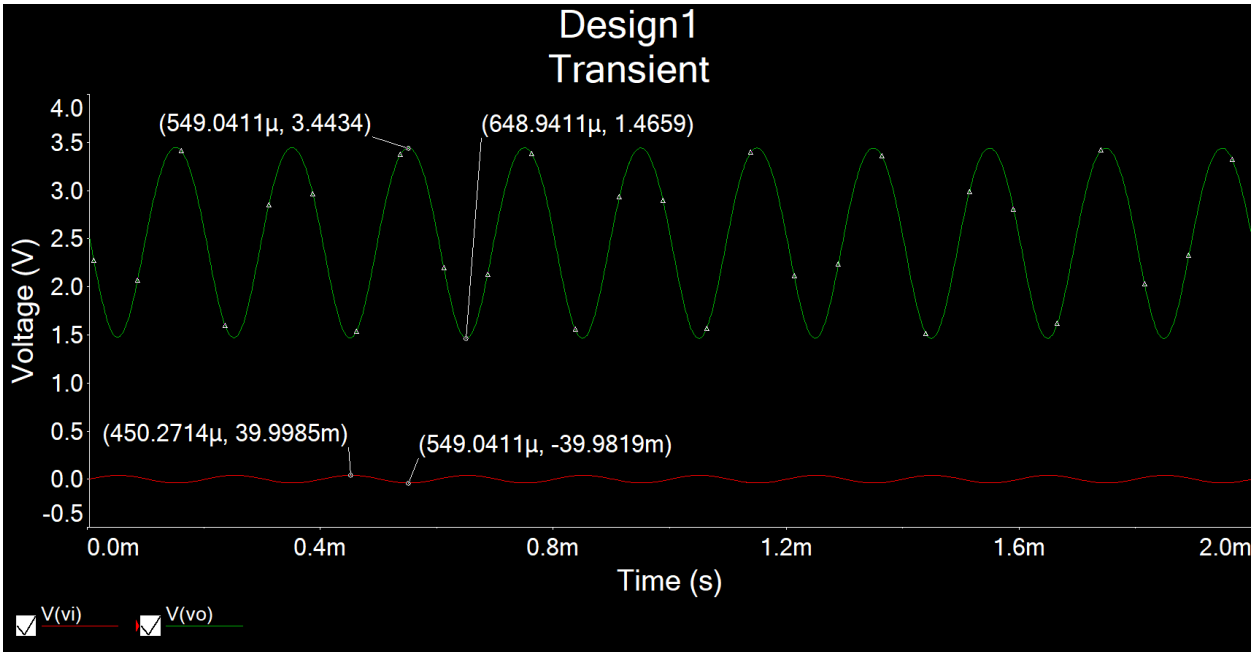



**Figure 3:** Time-domain waveform of $V_i$ = 40mV for common-source amplifier ▲

$$A_V = \frac{3.4434-1.4659}{0.039-(-0.039)} = 25.35 \approx 25$$

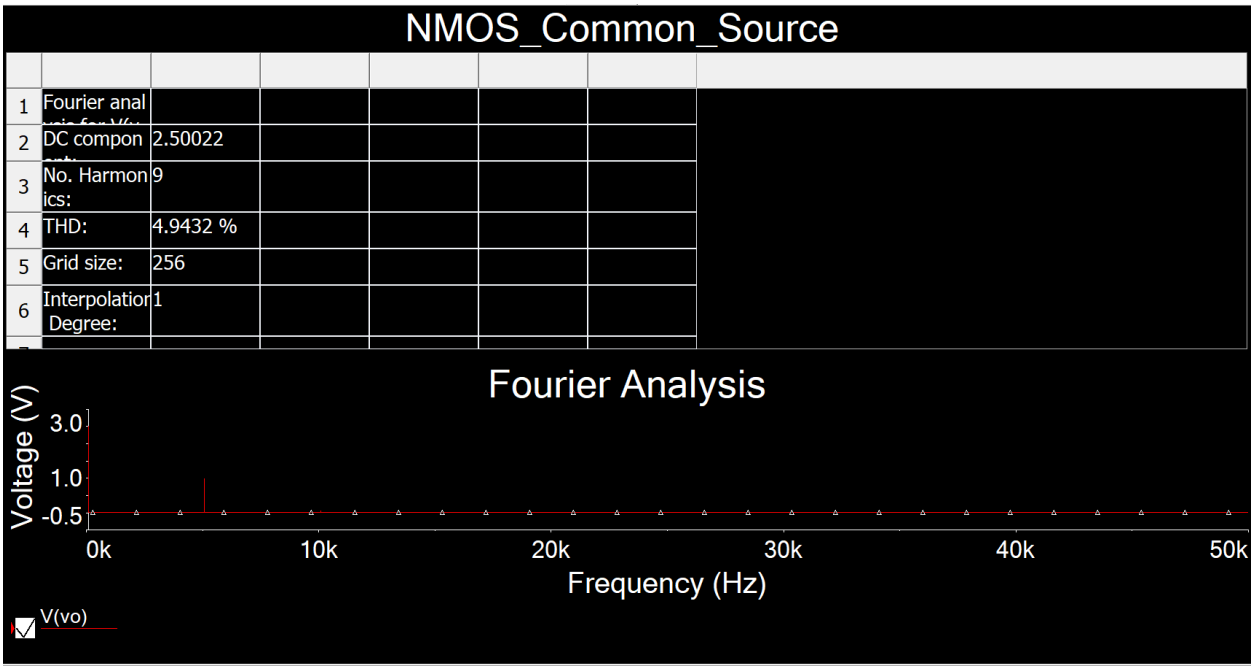



**Figure 4:** Total harmonic distortion (THD) for common-source amplifier ▲

THD = 4.9432% ≤ 5%

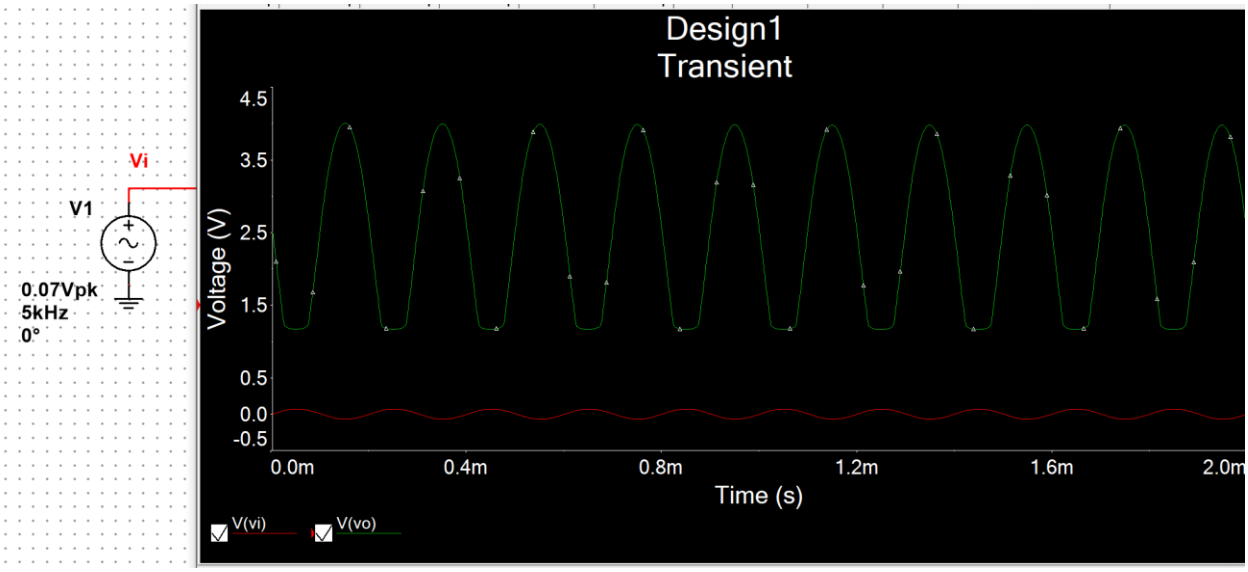



**Figure 5:** Clipping voltage for common-source amplifier ▲

Clipping voltage = 70mV

Common-Drain Amplifier

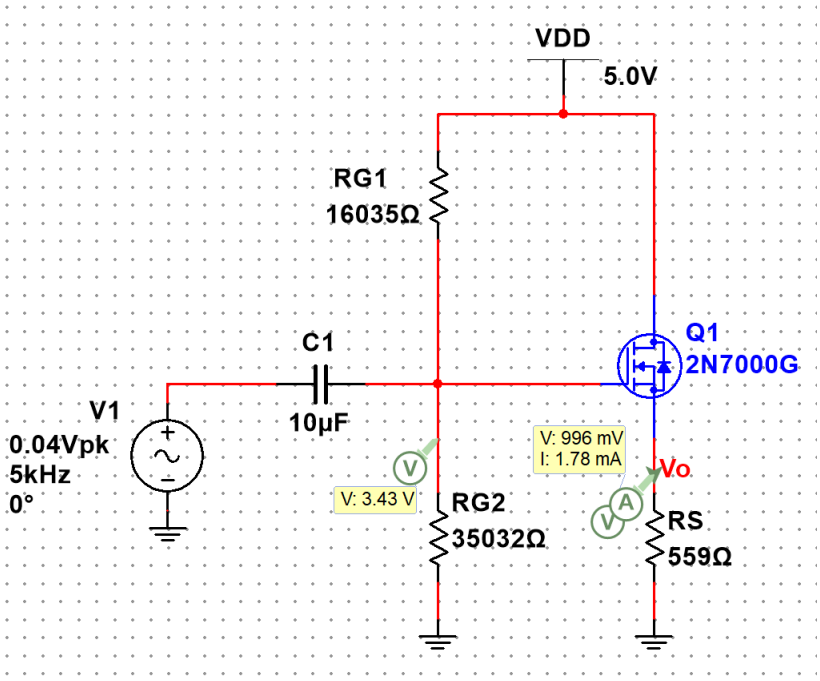



**Figure 6:** DC Solution for common-drain amplifier ▲

$V_{RG2}$ = 3.43V

$V_{RS}$ = 0.996V

$I_D$ = 1.78mA

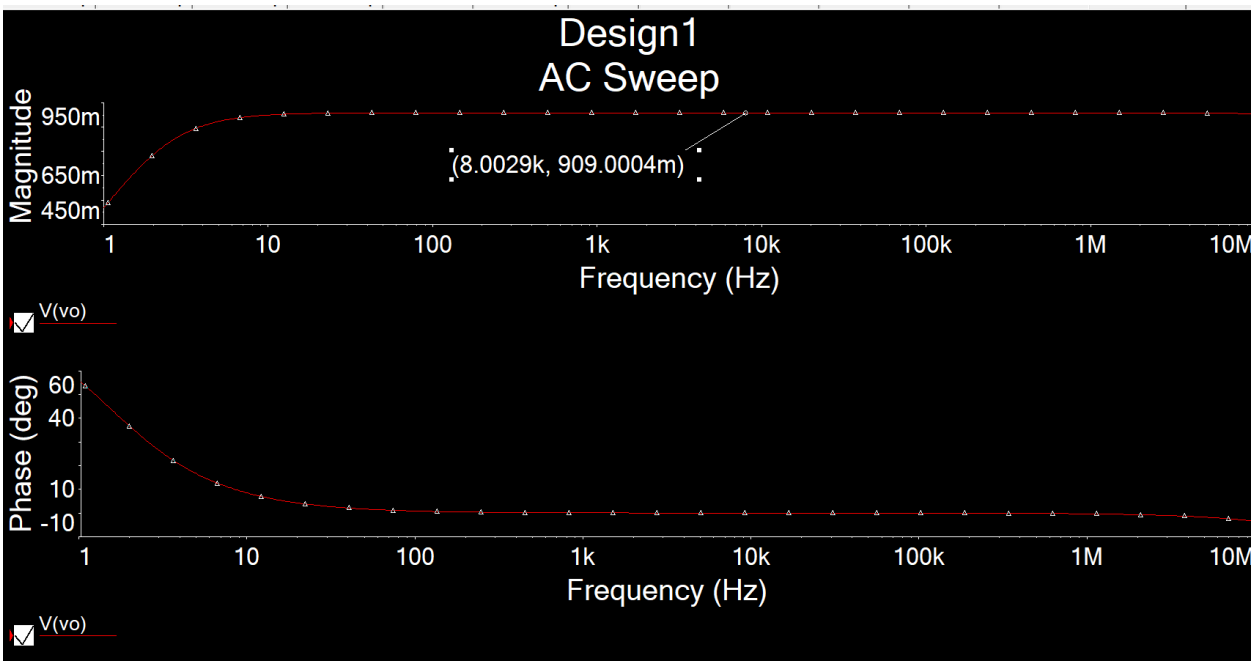



**Figure 7.1:** AC Simulation of $A_V$ for common-drain amplifier ▲

$A_V = 0.909$

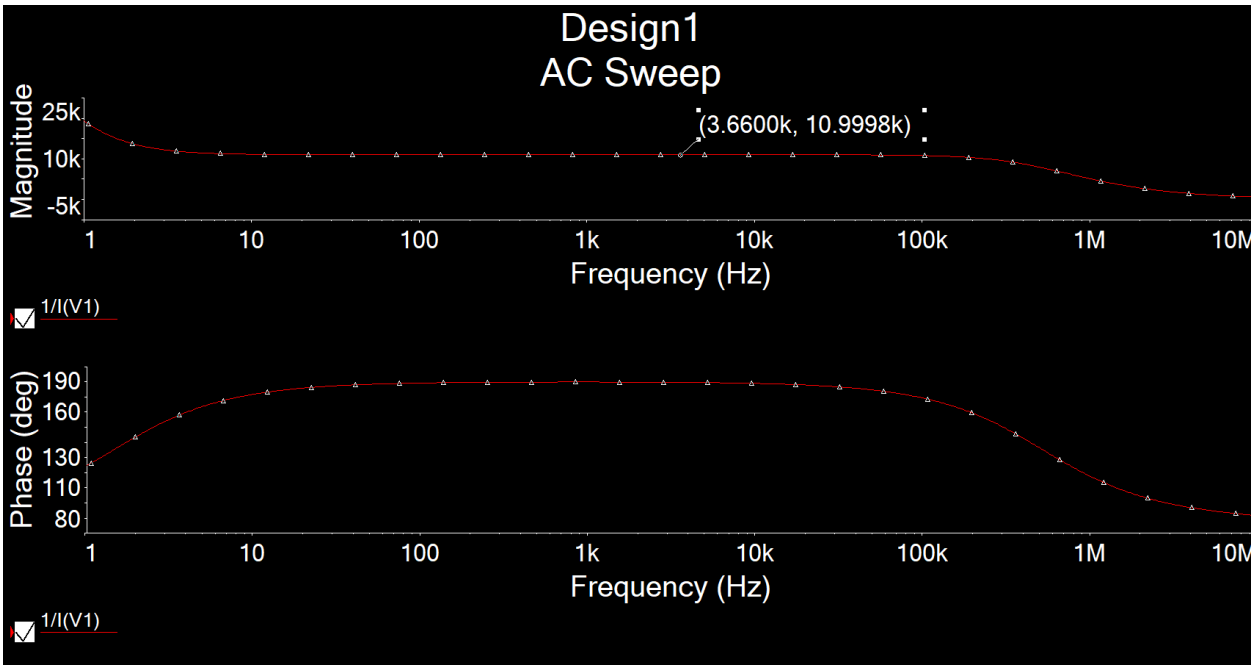



**Figure 7.2:** AC Simulation of $R_i$ for common-drain amplifier ▲

$R_i = 10.9998k\Omega$

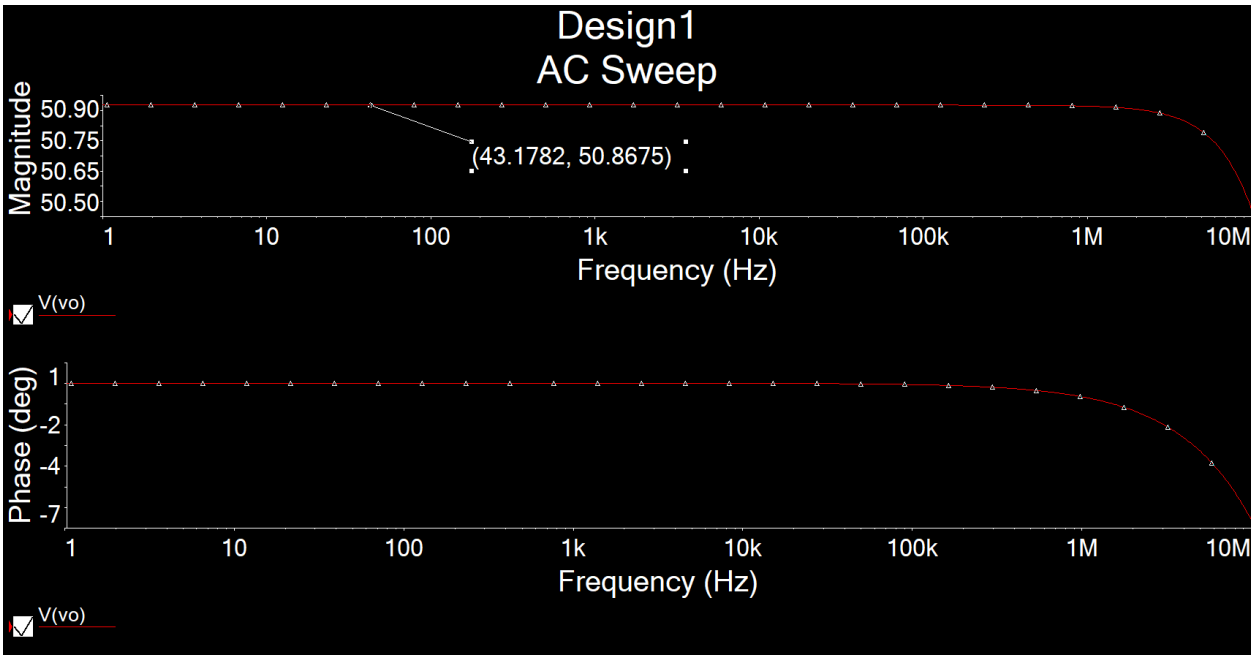



**Figure 7.3:** AC Simulation of $R_o$ for common-drain amplifier ▲

$R_o = 50.8675\Omega$

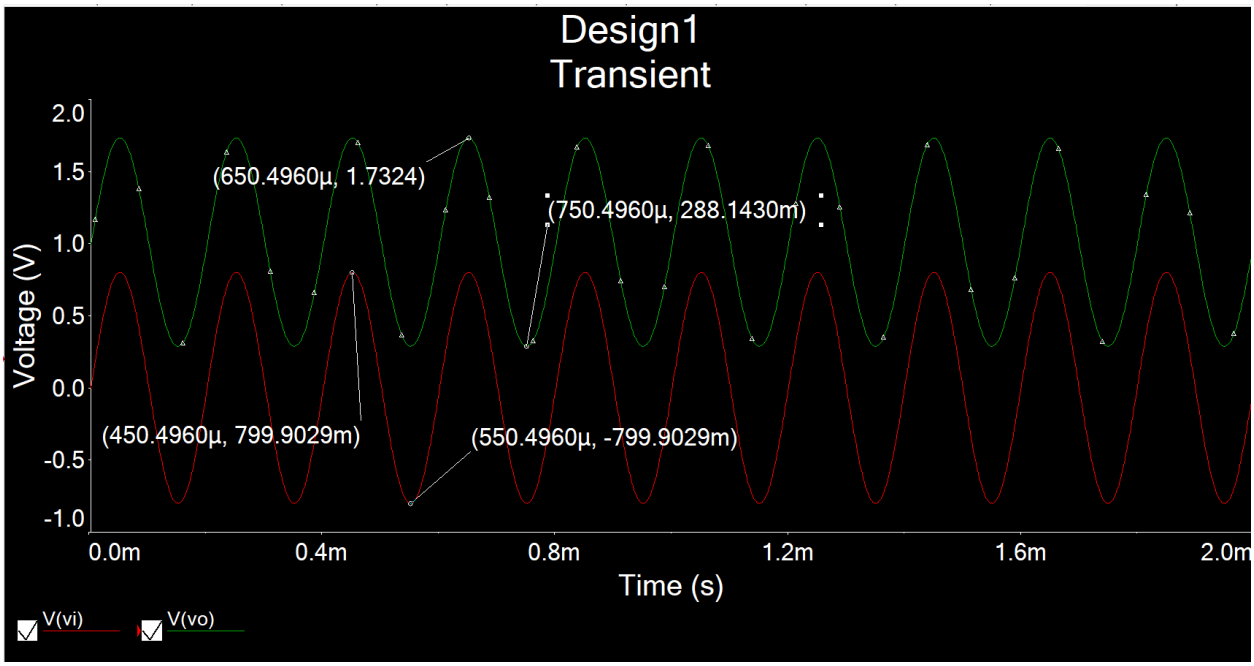



**Figure 8:** Time-domain waveform of $V_i = 0.8V$ for common-drain amplifier ▲

$$A_V = \frac{1.7324-0.2881}{0.7999-(-0.7999)} = 0.903$$

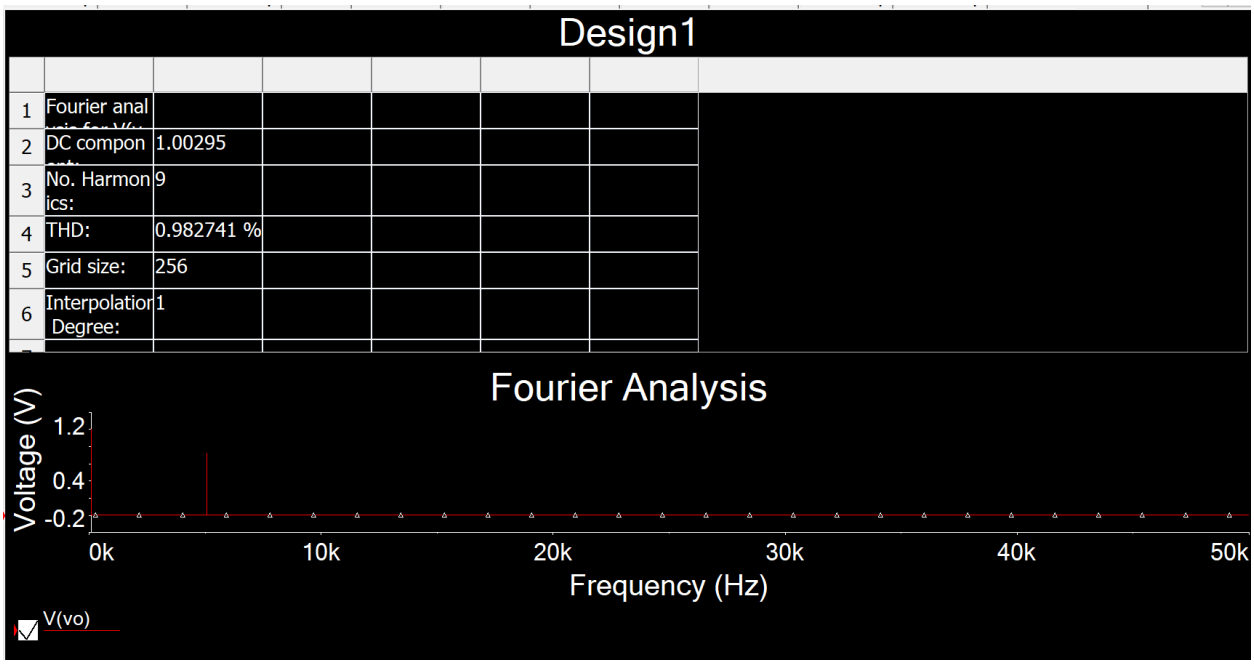



**Figure 9:** Total harmonic distortion (THD) for common-drain amplifier ▲

THD = 0.983%

## Measurement

Common-Source Amplifier:

DC Solutions:

$V_{RG2}$ = 3.276V, $V_{RS}$ = 1.082V, $V_{RD}$ = 5-2.31 = 2.69V, $V_{o,dc}$ = 2.31V, $I_D$ = 2.69/1.4k = 1.92mA

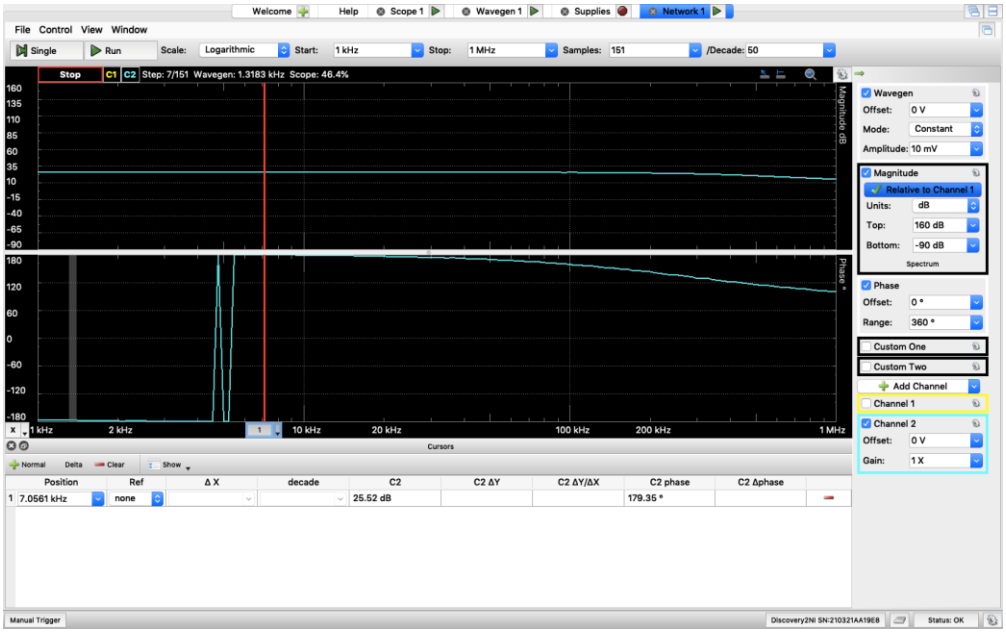



**Figure 10.1:** AC Simulation of $A_V$ for common-source amplifier ▲

$A_V$ = 25.52dB = 18.88

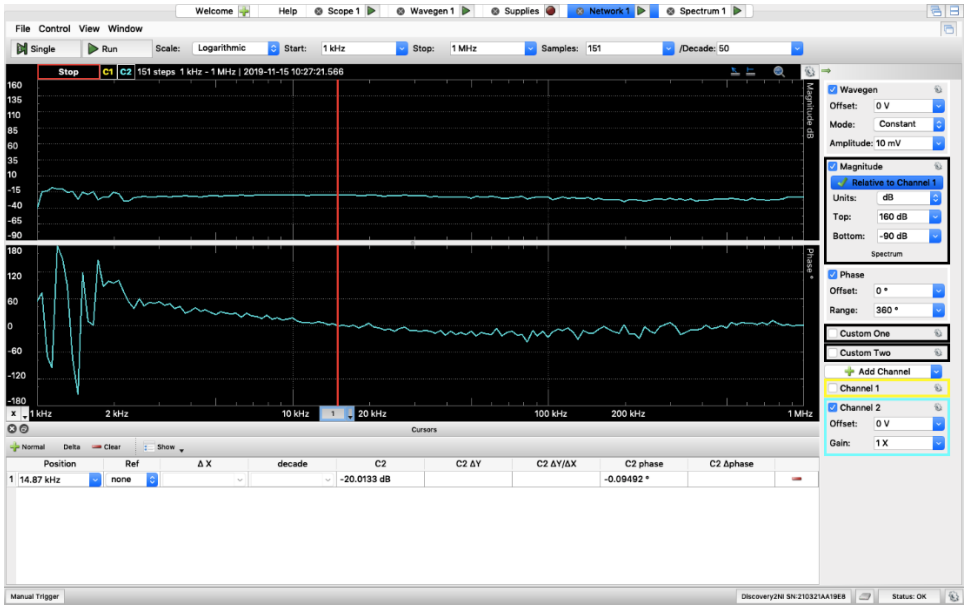



**Figure 10.2:** AC Simulation of $R_i$ for common-source amplifier ▲

$R_i / ( R_i + R_{test}) = -20.0133dB = 0.0998 \Rightarrow R_{test} = 10k\Omega$, $R_i = 1108\Omega$

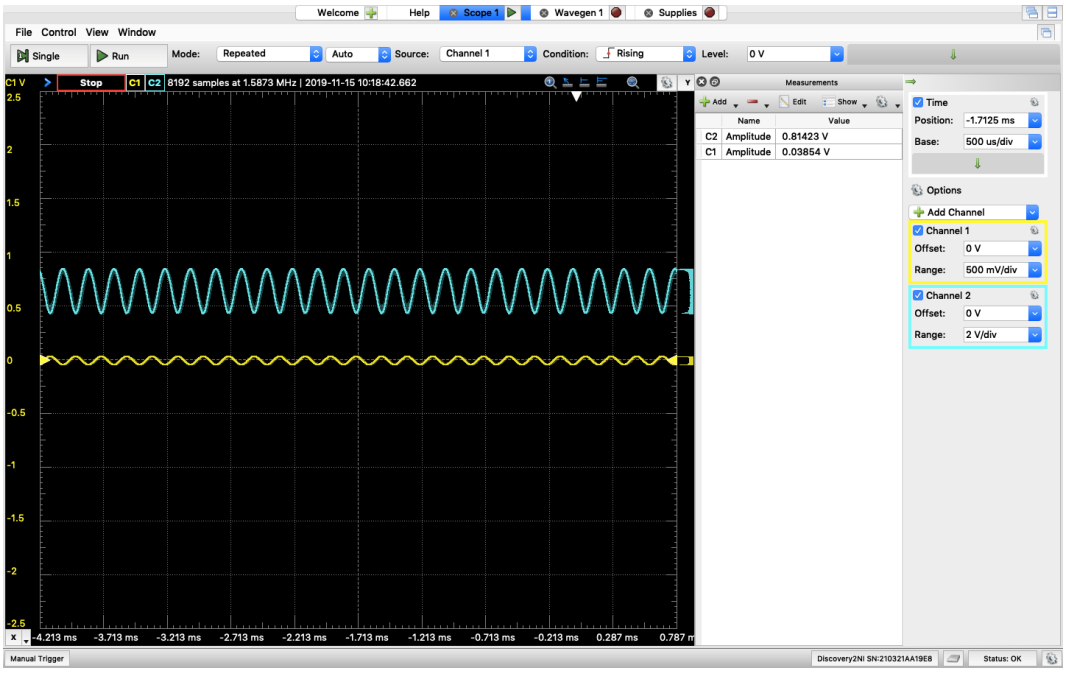



**Figure 11:** Waveform simulation for common-source amplifier ▲

$A_V = 0.81/0.038 = 21.32$

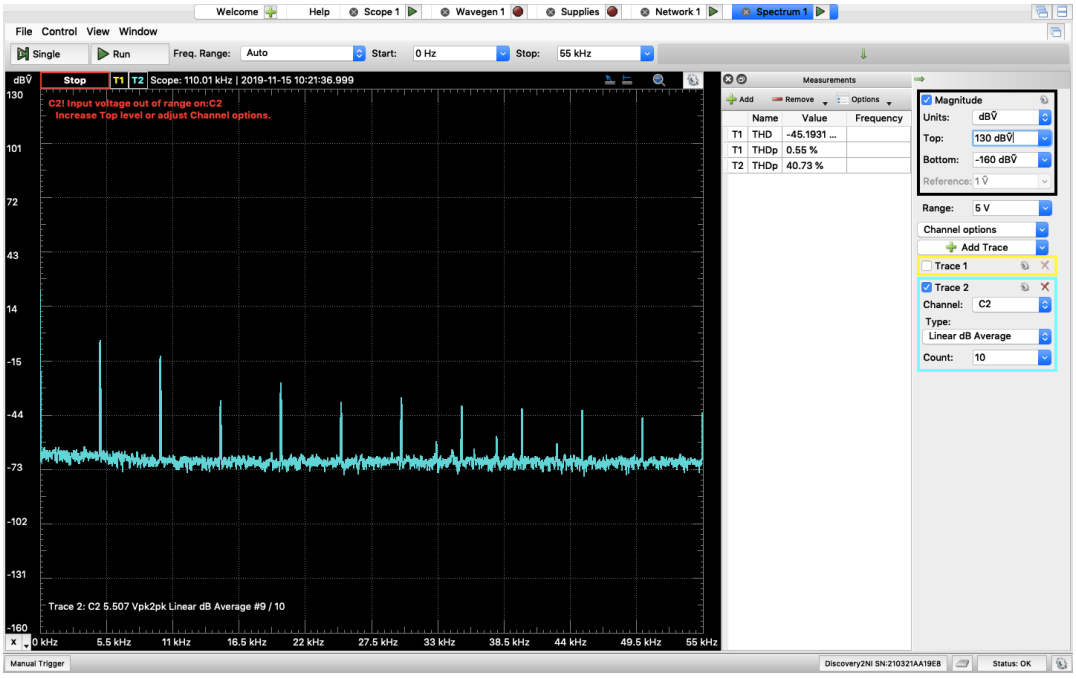



**Figure 12:** THD for common-source amplifier ▲

THD = 40.73%

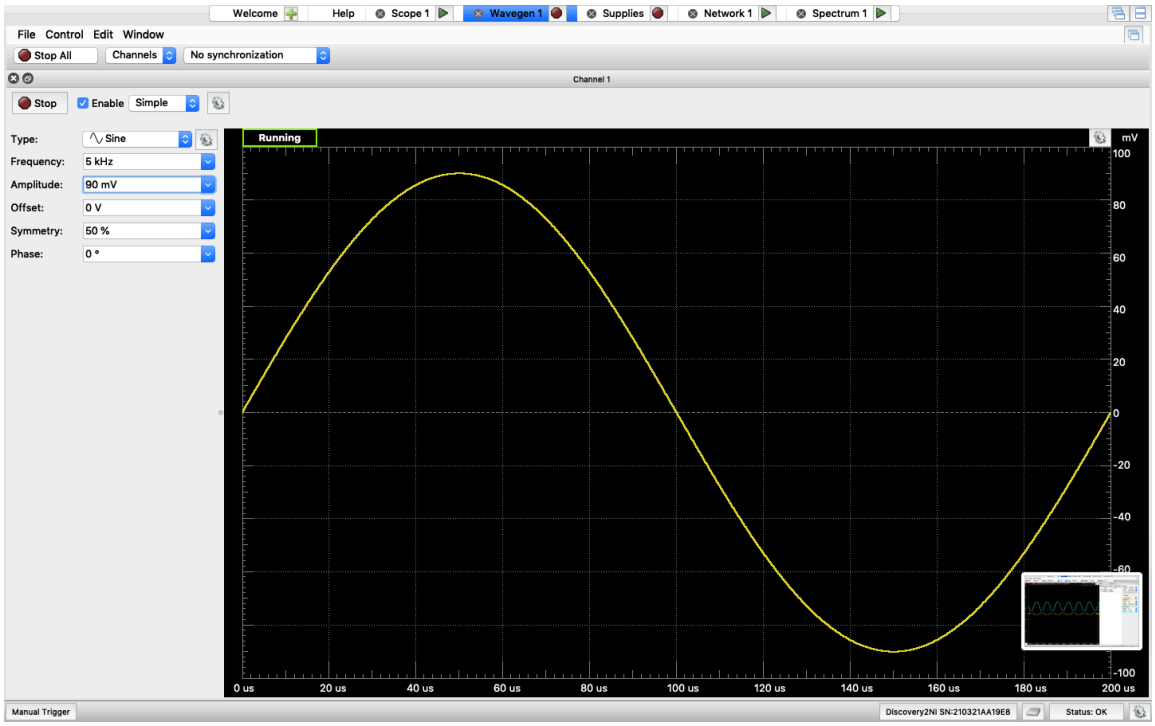



**Figure 13.1:** $V_i$ of clipping voltage for common-source amplifier ▲

$V_i$ clipping = 90mV

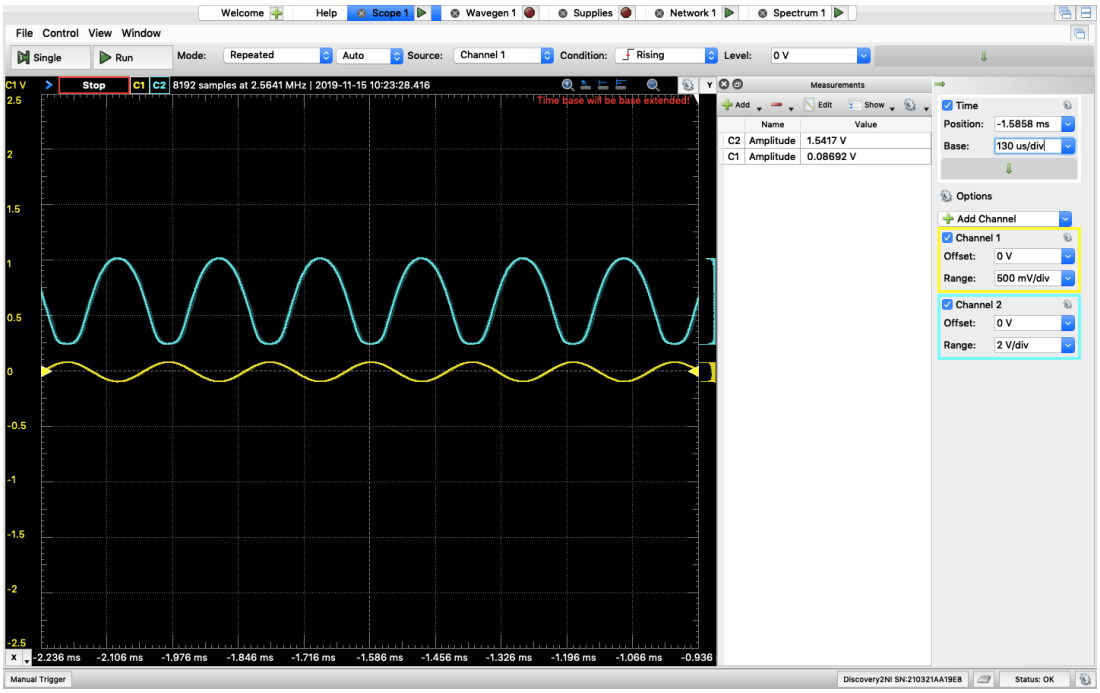



**Figure 13.2:** Waveform of clipping voltage for common-source amplifier ▲

Common-Drain Amplifier:

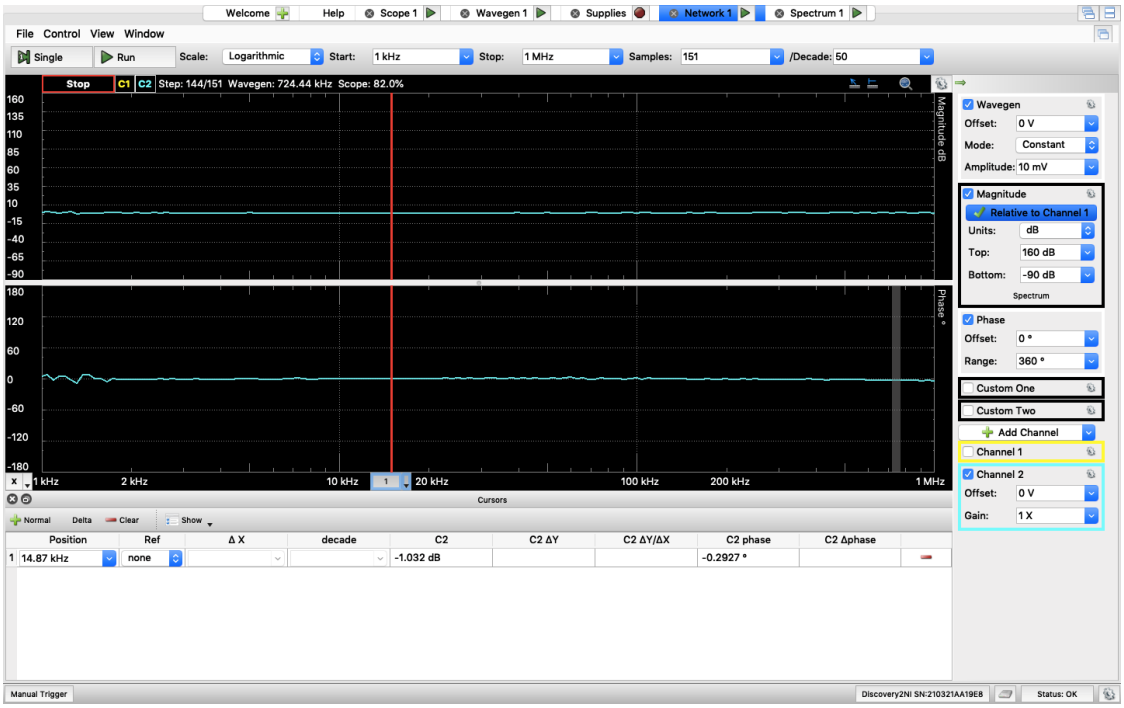



**Figure 14.1:** AC Simulation of $A_V$ for common-drain amplifier ▲

$$A_V = -1.032dB = 0.888$$

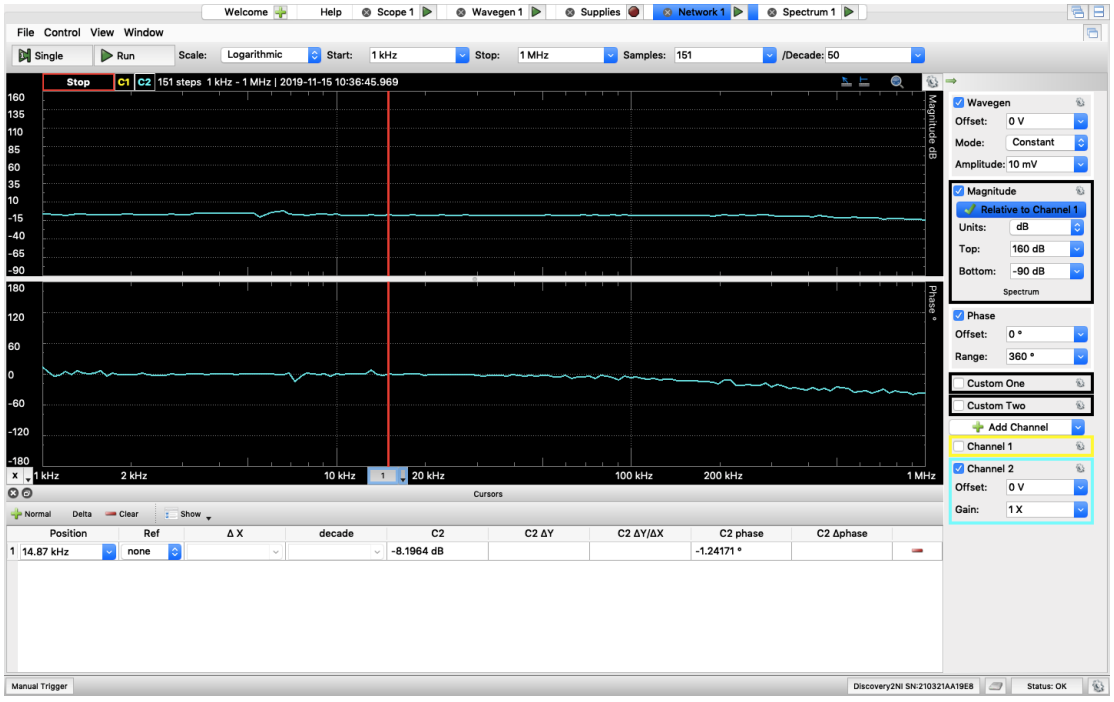


**Figure 14.2:** AC Simulation of $R_i$ for common-drain amplifier ▲

$R_i / ( R_i + R_{test}) = -8.2dB = 0.389 \Rightarrow R_{test} = 10k\Omega, R_i = 6366\Omega$

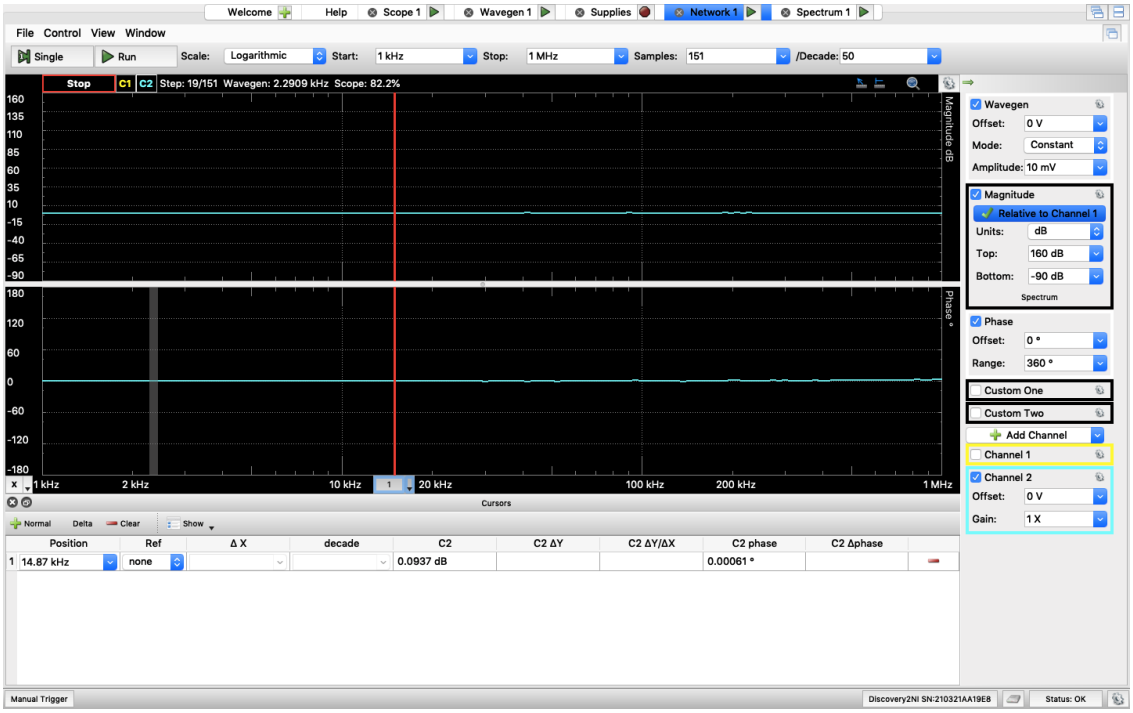



**Figure 14.3:** AC Simulation of $R_o$ for common-drain amplifier ▲

$R_o / ( R_o + R_{test}) = 0.0937dB = 1.01 \Rightarrow R_{test} = 1k\Omega, R_o = -10.1k\Omega$ (Impossible)

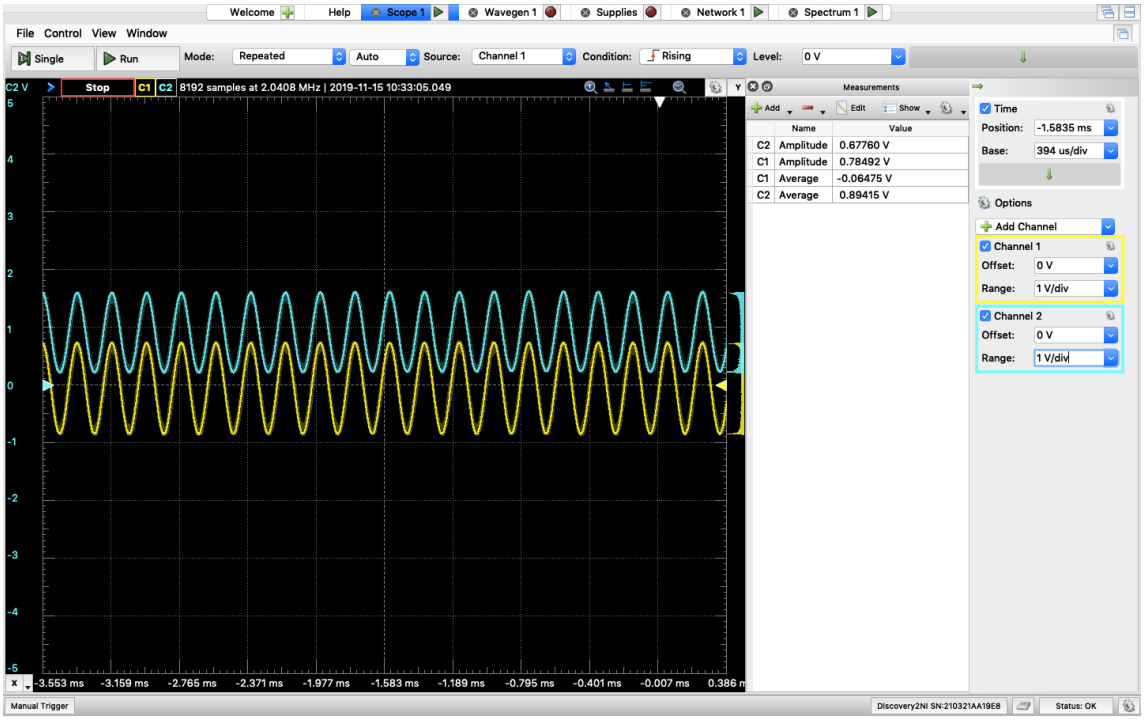


**Figure 15:** Waveform for common-drain amplifier ▲

$A_V = 0.67760/0.78492 = 0.863$

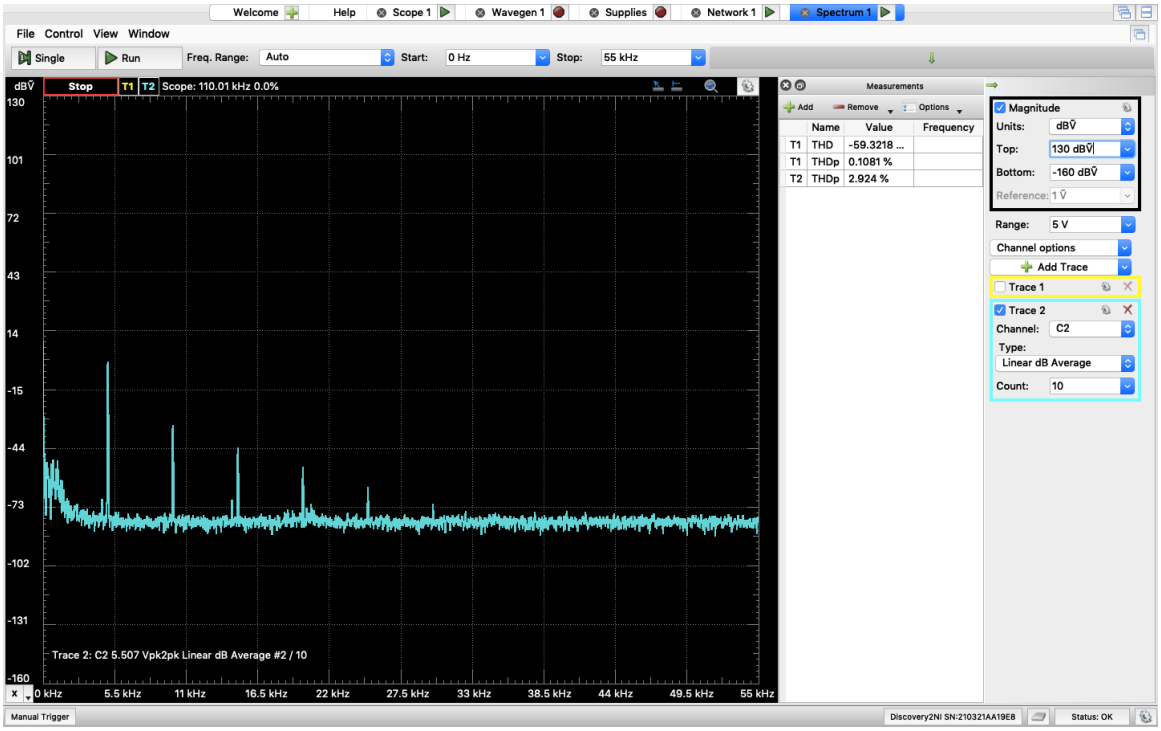



**Figure 16:** THD for common-drain amplifier ▲

THD = 2.924%

# Table

**Common-Source Amplifier**

| | Calculation | Simulation | Measurement |
|---|---|---|---|
| $V_{RG2}$ | 3.43V | 3.43V | 3.27V |
| $V_{RS}$ | 1V | 0.996V | 1.082V |
| $V_{RD}$ | 2.5V | 2.5V | 2.69V |
| $V_{o,dc}$ | 2.5V | 2.5V | 2.31V |
| $I_D$ | 1.79mA | 1.78mA | 1.92mA |
| $A_V$ | 25 | 24.9948 | 21.32 |
| $R_i$ | 11kΩ | 11.0740kΩ | 1108Ω |
| **THD** | | 4.9432% | 40.73% |

**Common-Drain Amplifier**

| | Calculation | Simulation | Measurement |
|---|---|---|---|
| $V_{RG2}$ | 3.43V | 3.43V | 3.19V |
| $V_{RS}$ | 1V | 0.996V | 1.07V |
| $I_D$ | 1.79mA | 1.78mA | 1.91mA |
| $A_V$ | 0.909 | 0.909 | 0.863 |
| $R_i$ | 11kΩ | 10.9998kΩ | 6366Ω |
| $R_o$ | 50.97Ω | 50.8675Ω | -10.1kΩ (impossible) |
| **THD** | | 0.983% | 2.924% |

# Comment

Overall, calculation values and simulation values are very similar. For measurement, I used different β and $V_T$ values for 2N7000 transistor to calculate resistor values since I got different β and $V_T$ values for measurement part from Lab 10. However, for common-source amplifier, it only gave me a gain of 21.32 which is not close to 25. This might because the real-world components do not act as ideal cases and the power consumption limit of Analog Discovery 2. Also, the output resistor for common-drain amplifier is negative which is impossible.