ELEC-313
Lab 7: MOSFET Amplifier Circuits

November 13, 2013

Date Performed:	November 06, 2013
Partners:	Charles Pittman
	Stephen Wilson

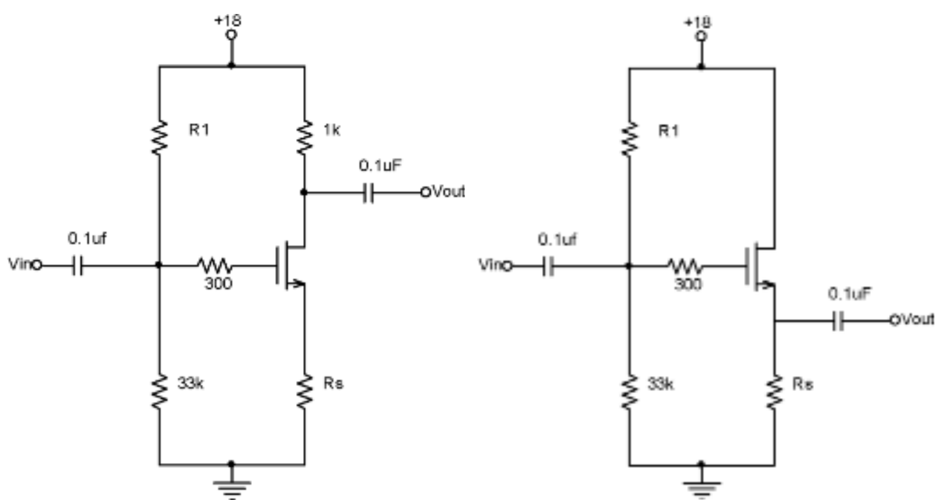
1 Objective

The objective is to observe the basic operation of two MOSFET amplifier circuits: a common-source amplifier, and a source-follower amplifier.

2 Equipment

Transistor: 2N7000	Power supply: HP E3631A
Function generator: HP 33120	Multimeter: HP 34401A
Oscilloscope: Agilent 54622D	Capacitors: 0.1 µF
Resistors: 100 Ω, 300 Ω, 470 Ω, 1 kΩ (x2) 33 kΩ, 100 kΩ (x2)	

3 Schematics



(a) Common-source amplifier (b) Source-follower amplifier

Figure 1: Circuits used in this lab. $R_1 = 100\,\text{k}\Omega$, $R_s = 470\,\Omega$

4 Procedure

The following procedures were identified to observe the basic operation of MOSFET amplifier circuits.

4.1 Common-Source Amplifier

1. Build the circuit shown in Figure 1a. Use the closest resistor values available for R_1 and R_S.

2. Measure and record the drain current and DC voltages at all terminals of the MOSFET.
3. Set the function generator for a $200\,\mathrm{V_{pp}}$, $20\,\mathrm{kHz}$ sine wave with $0\,\mathrm{VDC}$ offset. Connect it to V_{in}.
4. Connect a $100\,\mathrm{k\Omega}$ load resistor from V_{out} to ground. This will be considered a no-load scenario.
5. Connect channel 1 of the oscilloscope to V_{in} and channel 2 to V_{out}. Set the scope to trigger off of channel 1.
6. Adjust the function generator to an amplitude of $200\,\mathrm{V_{pp}}$ as measured on channel 1 of the oscilloscope.
7. Measure the peak-to-peak output voltage on channel 2 of the oscilloscope.
8. Repeat step 6 for input voltages of 300, 400, 500, 600, 700, 800, 900, and $1000\,\mathrm{mV_{pp}}$.
9. Replace the $100\,\mathrm{k\Omega}$ from V_{out} to ground with a $1\,\mathrm{k\Omega}$ load resistor.
10. Reset the function generator to an amplitude of $200\,\mathrm{V_{pp}}$ as measured on channel 1 of the oscilloscope.
11. Measure the peak-to-peak output voltage on channel 2 of the oscilloscope.

4.2 Source-Follower Amplifier

1. Construct the circuit shown in Figure 1b by removing the $1\,\mathrm{k\Omega}$ drain resistor and moving the output capacitor to the source of the MOSFET.
2. Measure and record the drain current and DC voltages at all terminals of the MOSFET.
3. Connect a $100\,\mathrm{k\Omega}$ load resistor from V_{out} to ground. This will be considered a no-load scenario.
4. Adjust the function generator to an amplitude of $200\,\mathrm{V_{pp}}$ as measured on channel 1 of the oscilloscope.
5. Measure the peak-to-peak output voltage on channel 2 of the oscilloscope.
6. Repeat step 4 for input voltages of 300, 400, 500, 600, 700, 800, 900, and $1000\,\mathrm{mV_{pp}}$.
7. Reset the function generator to an amplitude of $200\,\mathrm{V_{pp}}$ as measured on channel 1 of the oscilloscope.
8. Replace the $100\,\mathrm{k\Omega}$ resistor from V_{out} to ground with a $1\,\mathrm{k\Omega}$ resistor and measure the peak-to-peak output voltage on channel 2 of the oscilloscope.
9. Replace the $1\,\mathrm{k\Omega}$ load resistor with a 100 ohm load resistor and measure the peak-to-peak output voltage on channel 2 of the oscilloscope.

5 Results

	V_G (V)	V_D (V)	V_S (V)	I_D (mA)
Measured	4.391	13.498	2.11	4.52
Theoretical	4.466	14.000	2.4214	4.00
% Difference	1.712%	3.719%	14.800%	11.500%

Table 1: Transistor characteristics

V_{in} (mV)	V_{out} (V)	A_V
200	0.382	1.91
300	0.566	1.89
400	0.760	1.90
500	0.939	1.88
600	1.140	1.90
700	1.340	1.91
800	1.530	1.91
900	1.721	1.91
1000	1.90	1.90

Table 2: Voltage gain of common-source amplifier

$V_{out,load}$ (mV)	$V_{out,noload}$ (mV)	R_L (Ω)	R_o (Ω)
382	192	1000	990

Table 3: Output resistance of common-source amplifier

V_{in} (mV)	V_{out} (mV)	A_V
200	182	0.910
300	268	0.893
400	360	0.900
500	451	0.902
600	541	0.902
700	634	0.906
800	725	0.906
900	813	0.903
1000	906	0.906

Table 4: Voltage gain of source-follower amplifier

$V_{out,load}$ (mV)	$V_{out,noload}$ (mV)	R_L (Ω)	R_o (Ω)
182	174	1000	43.6

Table 5: Output resistance of source-follower amplifier

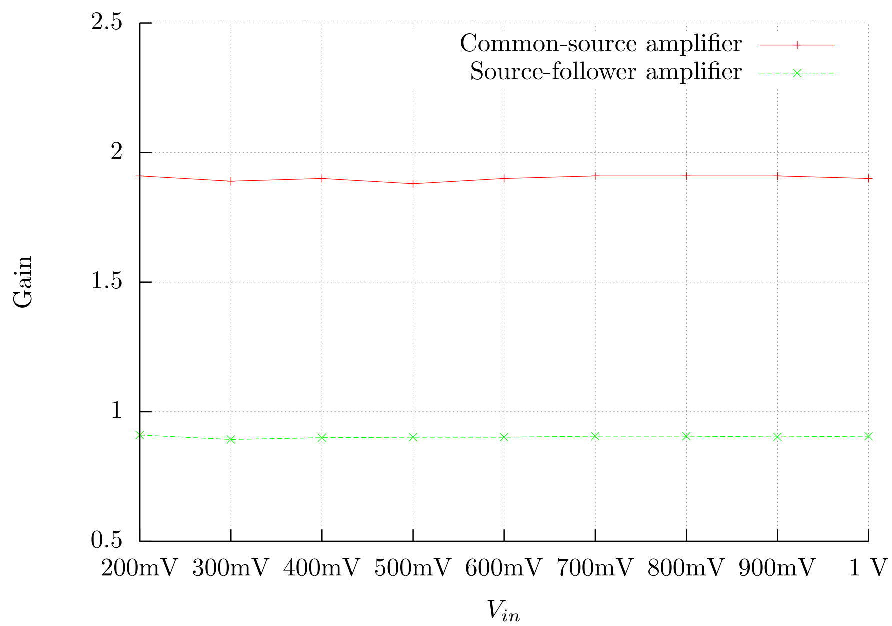


Figure 2: Gain vs. V_{in}

6 Conclusion

The % difference is relatively close for V_G and the V_D. Using Equation 5 to calculate a current of 4.49 mA instead of the assumed 4 mA from the prelab would have generated even closer calculated values for V_G and V_D. The relatively large % difference for the V_S values is probably due to the V_{TN} not being 2 V but instead more like 2.3 V.

The mean voltage gain (A_V) for the common-source amplifier is 1.90 (Table 2) and the output resistance (R_o) is 9.9 kΩ or roughly the same as the 1 kΩ drain resistor (R_D). The output voltage is 180° out of phase from the input voltage. The gain for the source-follower amplifier is 0.903 (Table 4) and the output resistance is relatively low at 43.6 Ω. The input and the output voltages are also in phase. The input resistance is much higher than the output resistance therefore the output current is much higher. A common-source amplifier is useful when a voltage gain is desired and when an output voltage is needed to be 180° out of phase. A source-follower amplifier is useful when no voltage gain is desired, a large current gain is desired, and the output voltage is needed to be in phase with the input voltage.

7 Equations

$$V_{out,load} = \frac{R_L}{R_o + R_L} \cdot V_{out,noload} \tag{1}$$

$$V_G = \frac{V_{DD} \cdot 33\,\mathrm{k\Omega}}{100\,\mathrm{k\Omega} + 33\,\mathrm{k\Omega}} \tag{2}$$

$$V_S = V_G \cdot \sqrt{\frac{I_D}{K_N}} - V_{TN} \tag{3}$$

$$V_D = V_{DD} - I_D \cdot 1\,\mathrm{k\Omega} \tag{4}$$

$$I_D = \frac{V_S}{R_S} \tag{5}$$

$$A_V = \frac{V_{out}}{V_{in}} = \frac{-g_m \cdot R_D}{1 + g_m \cdot R_S} \tag{6}$$

$$\%_{diff} = \frac{|measured - theoretical|}{theoretical} \times 100\% \tag{7}$$