

LAB 5.12

PMOS Source Follower

[See Section 5.8.5, p. 321 of Sedra/Smith]

OBJECTIVES:

To study a PMOS-based source follower by:

- Completing the DC and small-signal analysis based on its theoretical behavior.
- Simulating it to compare the results with the paper analysis.
- Implementing it in an experimental setting, taking measurements, and comparing its performance with theoretical and simulated results.
- Qualitatively seeing the impact of transistor-to-transistor variations.

MATERIALS:

- Laboratory setup, including breadboard
- 1 enhancement-type PMOS transistor (e.g., MC14007)
- 3 large (e.g., 47- μF) capacitors
- Several resistors of varying sizes
- Wires

PART 1: DESIGN AND SIMULATION

Consider the circuit shown in Figure L5.12:

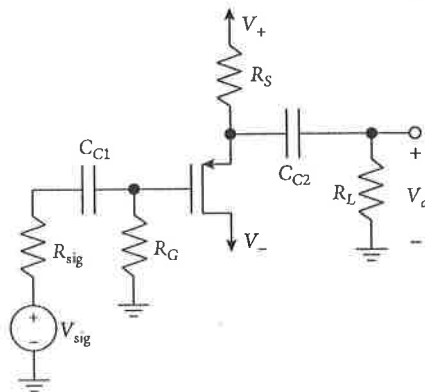


FIGURE L5.12: Source follower circuit, with coupling capacitors, and resistor R_G for DC-biasing purposes. Based on Fig. 5.60 p. 321 S&S.

Design the amplifier such that $I_D = 2$ mA. Use supplies of $V_+ = -V_- = 15$ V, $R_{\text{sig}} = 50 \Omega$, and $R_G = 10 \text{ k}\Omega$. What is the minimum value of R_L that satisfies the requirements? Obtain the datasheet for the PMOS transistor that will be used. In your lab book, perform the following.

DC Operating Point Analysis

- Sketch a DC model of the circuit in your lab book, replacing the large-valued coupling capacitors C_{C1} and C_{C2} by open circuits (for simplicity you may also omit v_{sig} , R_{sig} , and R_L). What is the DC current through R_G ?
- Based on the required value of I_D , what is $V_{OV} = V_{SG} - |V_{tp}|$? What value of R_S must you use?

AC Analysis

- Sketch a small-signal model of the circuit in your lab book, replacing the transistor with its small-signal model (try a T model, ignoring r_o), replacing the capacitors with short circuits, and replacing V_+ and V_- with an AC ground. Label the gate of the transistor as v_i , i.e., the small-signal voltage at the input.
- What is the ratio of v_o/v_{sig} ? How would you approximate it in further calculations?
- Derive an expression for $A_v = v_o/v_i$.
- What is the value of g_m ? What is A_v ?
- What is the minimum value of R_L that satisfies the design requirements?
- Calculate the output resistance of your amplifier.

Simulation

- Simulate the performance of your circuit. Use capacitor values $C_{C1} = C_{C2} = 47 \mu\text{F}$ and the value of R_S based on your preceding calculations. Use a $10\text{-mV}_{\text{pk-pk}}$, 1-kHz sinusoid with no DC component applied at v_{sig} .
- From your simulation, report the DC values of V_{SG} , V_{SD} , and I_D . How closely do they match your calculations? (Remember: The simulator has its own, more complex model of the real transistor, so there should be some small variations.)
- From your simulation, report A_v . How closely does it match your calculations?

PART 2: PROTOTYPING

- Assemble the circuit onto your breadboard using the specified component values and those just calculated. Note that R_{sig} represents the output resistance of the function generator, and therefore you should *not* include it in your circuit.

PART 3: MEASUREMENTS

- *DC bias point measurement:* Using a digital multimeter, measure the DC voltages of your circuit at the gate (V_G) and source (V_S) of your transistor.

- *AC measurement:* Using a function generator, apply a $10\text{-mV}_{\text{pk-pk}}$, 1-kHz sinusoid with no DC component to your circuit. (*Note:* Some function generators only allow inputs as small as $50\text{ mV}_{\text{pk-pk}}$. If this is the case, use that value instead.)
- Using an oscilloscope, generate plots of v_o and v_i vs. t .
- Using a digital multimeter, measure all resistors to three significant digits.

PART 4: POST-MEASUREMENT EXERCISE

- Calculate the values of V_{SG} and V_{SD} that you obtained in the lab. How do they compare to your pre-lab calculations? Explain any discrepancies.
- Based on the measured values of V_D and V_S , and your measured resistor values, what is the real value of I_D based on your lab measurements?
- What is the measured value of A_v ? How does it compare to your pre-lab calculations? Explain any discrepancies.
- What would happen if you used the function generator with $50\text{-}\Omega$ output resistance to directly drive your load resistor? What gain would you get? What would happen if the output resistance of the function generation was changed from $50\ \Omega$ to $5\text{ k}\Omega$? What do you conclude? Recall the value of output resistance you calculated earlier.
- *Hint:* The single biggest source of variations from your pre-lab simulation results will be due to variations in the transistor's threshold voltage V_{tp} . Remember: Its value will be somewhere within the range indicated on the transistor's datasheet.

PART 5 [OPTIONAL]: EXTRA EXPLORATION

- Add a $500\text{-}\Omega$ resistor between the function generator output and capacitor C_{C1} . How does the gain of your circuit change? Can you explain this?