Analog Electronic Devices
(ESI038 / SE047)

Lab Experiment 3
FETs: Designing a Single-Stage FET Amplifier

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January-May 2007

Objectives

The objectives of this lab experiment are:

a) to design a single-stage voltage amplifier using a field-effect transistor
b) to measure the most important DC parameters of a FET
c) to simulate some of the most important parameters of a voltage amplifier using SPICE
d) to measure some of the most important parameters of a voltage amplifier using lab equipment
e) to contrast hand calculations, SPICE simulations and lab measurements for a FET amplifier.

Components and Instrumentation

A general purpose n-channel field-effect transistor (JFET or MOSFET) (2N5457, 2N5458, CD4007, etc.)

Several resistors, and capacitors

An adjustable DC power supply

A low frequency function generator

A digital multi-meter (DMM) with 2½ or more digits

An oscilloscope with x10 or x1 probes

A circuit simulation software: OrCad, WinSpice, Electronic Work Bench, or something similar.

Measuring the FET Internal Parameters

1. Design a procedure to measure the most important static parameters of either a discrete general purpose MOSFET (K and V_{TH}) or a discrete general purpose JFET (I_{DSS} and V_P). Show the circuit that you propose, and indicate the measurement instruments that you will need, as well as the way they will be connected.
2. Implement in the lab the procedure you designed to measure the FET parameters. Since accuracy is especially important in this step, measure with a DMM the resistors you are using (i.e., do not assume that a nominal 1KΩ resistor will have 1000 ohms), and the DC voltage you are applying (make sure it is equal to 12V).

Designing the Amplifier

3. Taking into account the parameters you just measured, design a single-stage voltage amplifier to satisfy the following specifications:
    a. Magnitude of the voltage gain at middle frequencies of at least 40 V/V
    b. Magnitude of the input impedance at middle frequencies of at least 1MΩ
    c. Magnitude of the output impedance at middle frequencies of at least 1KΩ
    d. With a minimum output voltage swing of $4V_{p\text{-}p}$ (distortion limits greater than 2V)
    e. Loaded with a 10KΩ resistor
    f. Biased with a DC power supply of 12V
4. Once you have calculated all the component values of your amplifier, re-analyze it and fill in the second column of Table I.

Simulation and Lab Characterization of the Amplifier

5. Simulate your complete single-stage voltage amplifier using SPICE:
    a. Perform a DC simulation to observe its DC drain to source current, I_{DS}.
    b. Perform a transient simulation from 0 to 5 ms using an input sinusoidal signal v_s of 1mV of amplitude and 10KHz of frequency. Plot the output voltage v_o at the load resistor of 10KΩ, and calculate the magnitude of the voltage gain $|A_v| = |v_o/v_s|$. Increase the amplitude of v_s from 1mV to 500mV and plot again the output voltage v_o to measure the distortion limits.
    c. Perform an AC sweep simulation from 10Hz to 500MHz to observe the steady-state frequency domain response of the amplifier. Use an AC input signal of 1V. Plot the magnitude of the voltage gain $|A_v| = |v_o/v_s|$ versus frequency, and plot also the magnitude of the input impedance $|Z_{in}| = |v_s/i_s|$ versus frequency.
    d. Modify the circuit topology so that you can measure the output impedance with SPICE (delete the original AC input signal and apply a new AC input signal at the amplifier's output, then plot the output impedance $|Z_o| = |v_o/\text{-}i_o|$ versus frequency).
    e. Using the results obtained in the previous four steps, fill in the third column of Table I.
6. Implement in the lab your amplifier:
    f. Using a DMM, measure the DC drain to source current I_{DS}.
    g. Using a function generator, apply a sinusoidal input of 10mV of amplitude and 10KHz of frequency to your amplifier. Using an oscilloscope, measure the input and output voltages and calculate the voltage gain. Using a potentiometer and the oscilloscope, measure the input resistance.
    h. Increase the amplitude of the function generator from 10mV to 500mV and measure the output voltage with an oscilloscope to calculate the distortion limits.
    i. Connect the amplifier's input to ground, remove the load resistor, and apply an input sinusoidal

signal (10mV-10KHz) to the amplifier's output so that you can measure its output resistance.

j. Using the results obtained in the previous four steps, fill in the fourth column of Table I.

TABLE I

Parameter	Hand calculation	SPICE simulation	Lab measurement
I_{DS} (DC)			
$\|A_v\|$ (at 10KHz)			
$\|Z_{in}\|$ (at 10KHz)			
$\|Z_o\|$ (at 10KHz)			
Positive distortion limit, DL^+			
Negative distortion limit, DL^-			

Report

Write a report including all the theoretical, simulation and lab procedures as well as your conclusions. Since it is a design problem, it is very important to justify all the critical decisions during the design process (related to calculations as well as to the selection of components). The report must include the schematic of the complete final circuit, indicating the tolerances for the passive components (and their exact values when they were measured).

Deadline and Assessment

The deadline for submitting the report is on Tuesday April 10, 2007. The report can be written either in English or in Spanish.

This lab experiment can be realized in teams of up to 3 students. The evaluation of the report will be as follows:

Quality of the report	30%
Accuracy of the theoretical analysis	30%
Lab measurements and procedures	40%

If the report is written in acceptable English, an extra 10% can be granted.