Name: _____

Hands-on Introduction to Electrical Engineering
Assignment 3: Small-signal analysis

1 Topics

In this assignment, you will review the following topics:

- MOSFET operation: cutoff, triode, saturation,
- Small-signal analysis of the MOSFET amplifier,
- Superposition.

Please make sure that you are familiar with these topics prior to the lab session.

2 Background

Fig. 1 shows the circuit that we will construct in this assignment. The purpose of this circuit is to amplify the input signal, and to drive a speaker. We take the following parameters:

- Supply voltage $V_S = 5$ V,
- Load resistor $R_L = 100\ \Omega$,
- An 8 Ω speaker (*i.e.* the speaker can be thought of as an 8 Ω resistor).

While the circuit in Fig. 1 is the most complicated circuit you have encountered so far, it is in fact a cascade of two circuit fragments that you have already examined. Namely, they are:

- the "MOSFET amplifier" (a.k.a. the "MOSFET inverter" or the "common-source amplifier"), and
- the "source follower" that you analyzed in 6.002x Homework 5.

This assignment will demonstrate why both circuit fragments are necessary to build a speaker amplifier.

Finally, note that we will use the large- and small-signal notation throughout this assignment. So, the "total" input signal v_{IN} can be thought of as

$$v_{IN} = V_{IN} + v_{in},$$

where V_{IN} is the large-signal DC bias, and v_{in} is the small-signal AC signal.

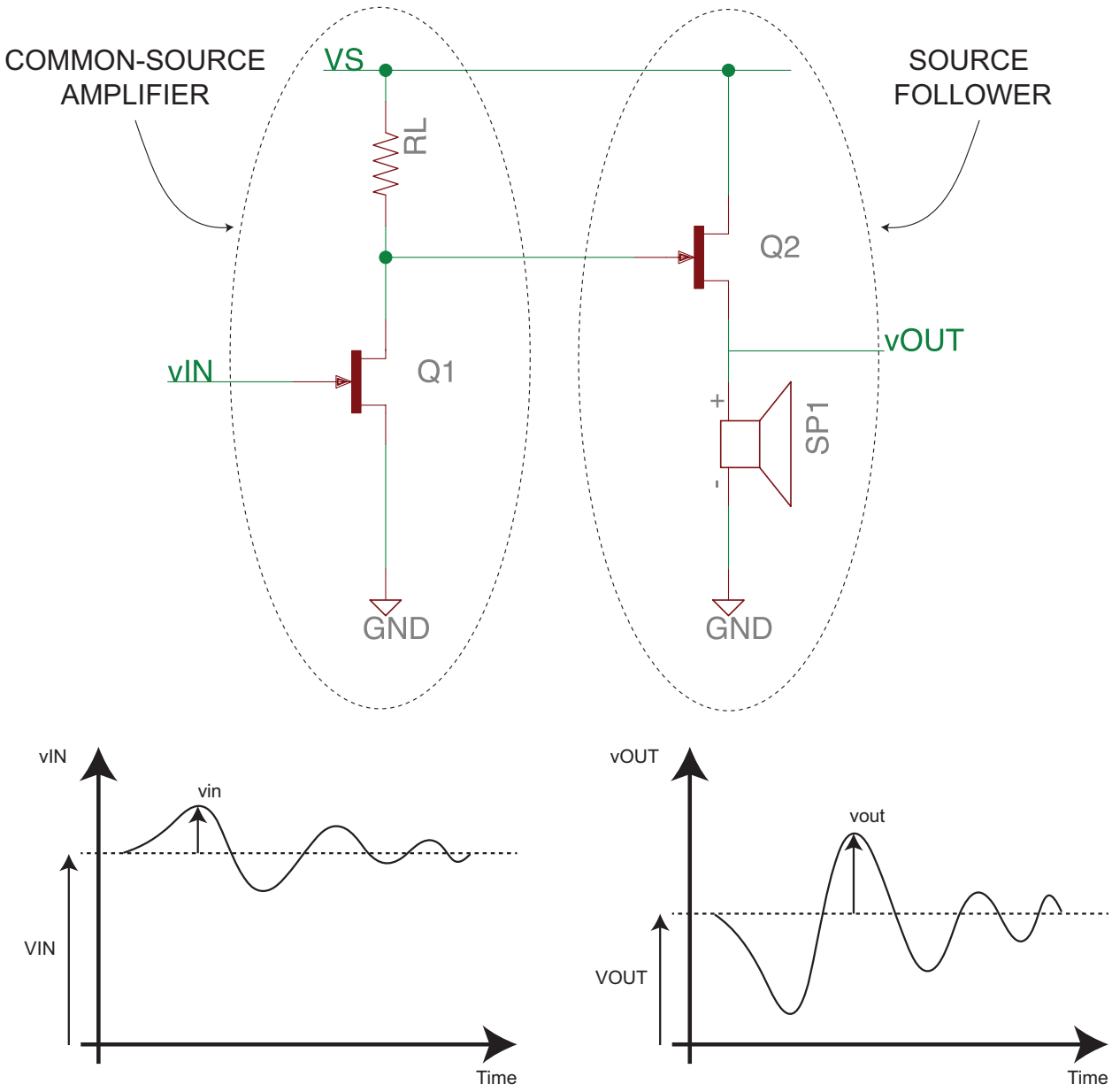


Figure 1: Amplifier circuit that we will construct in the assignment. Note that the circuit is a cascade of two familiar circuit fragments: the MOSFET amplifier (a.k.a. MOSFET inverter) and the source follower seen in 6.002x Homework 5. (The speaker can be modeled as an 8 Ω resistor. The graphs below show the input-output relationship of the overall circuit, using the usual convention $v_{IN} = V_{IN} + v_{in}$.

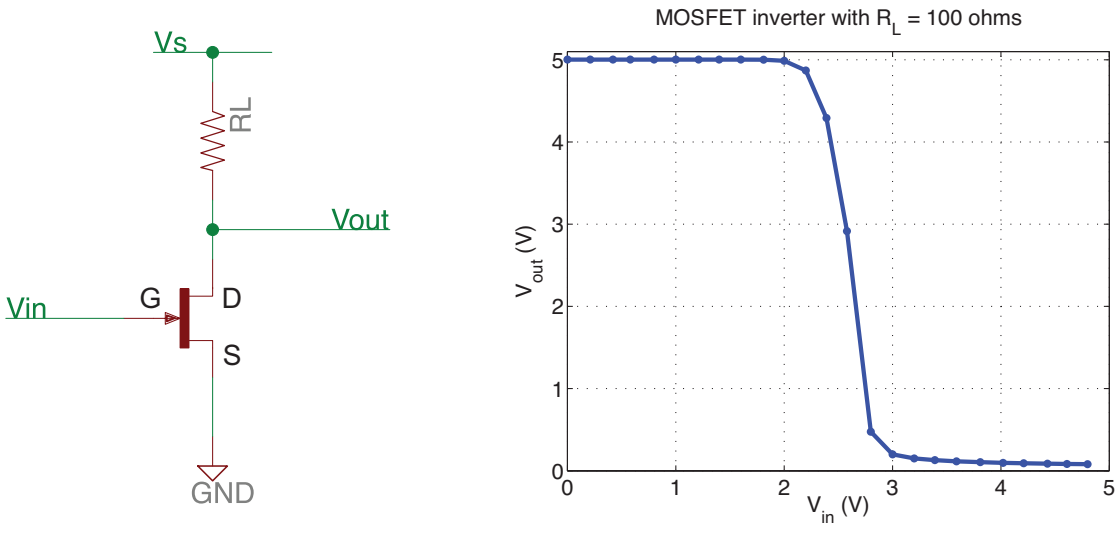


Figure 2: The input-output characteristic of the MOSFET amplifer with $R_L = 100\ \Omega$, as measured previously in Assignment 2.

3 MOSFET amplifier ("Common-source amplifier")

Fig. 2 shows the input-output relationship of the MOSFET amplifier that you built in Assignment 2. What is the approximate threshold voltage?

$V_T =$

In what mode of operation is the MOSFET in, for $V_{\text{in}} = 0 - 2$ V? (Circle one)

Cutoff	Triode	Saturation

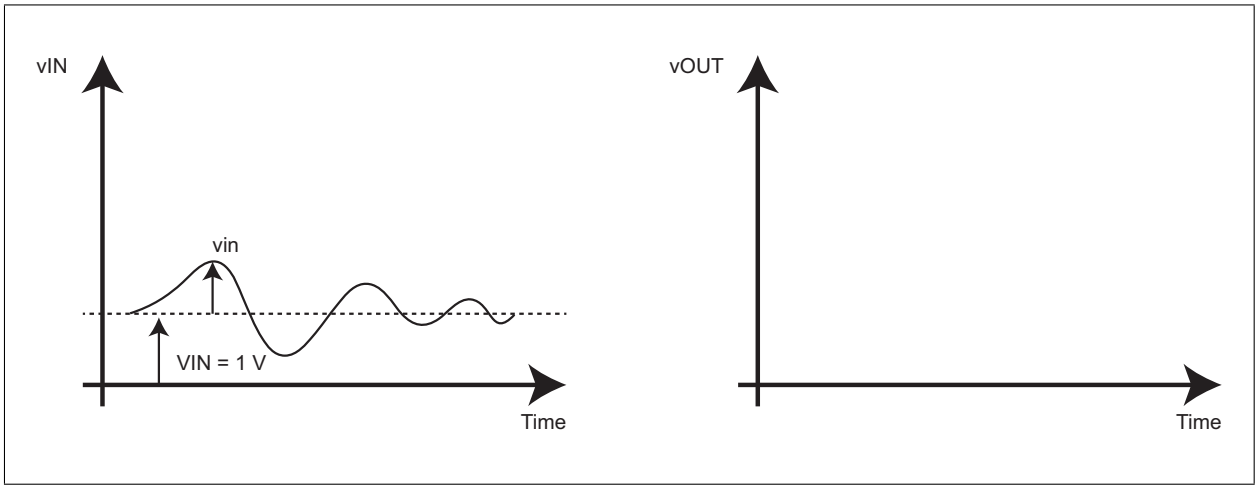
In what mode of operation is the MOSFET in, for $V_{\text{in}} = 2 - 2.8$ V?

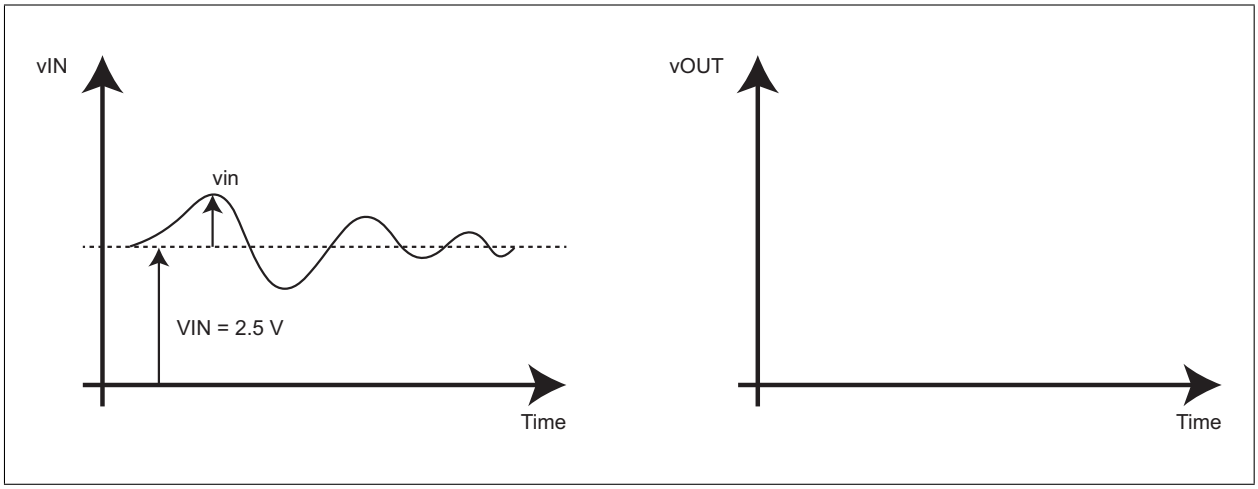
Cutoff	Triode	Saturation

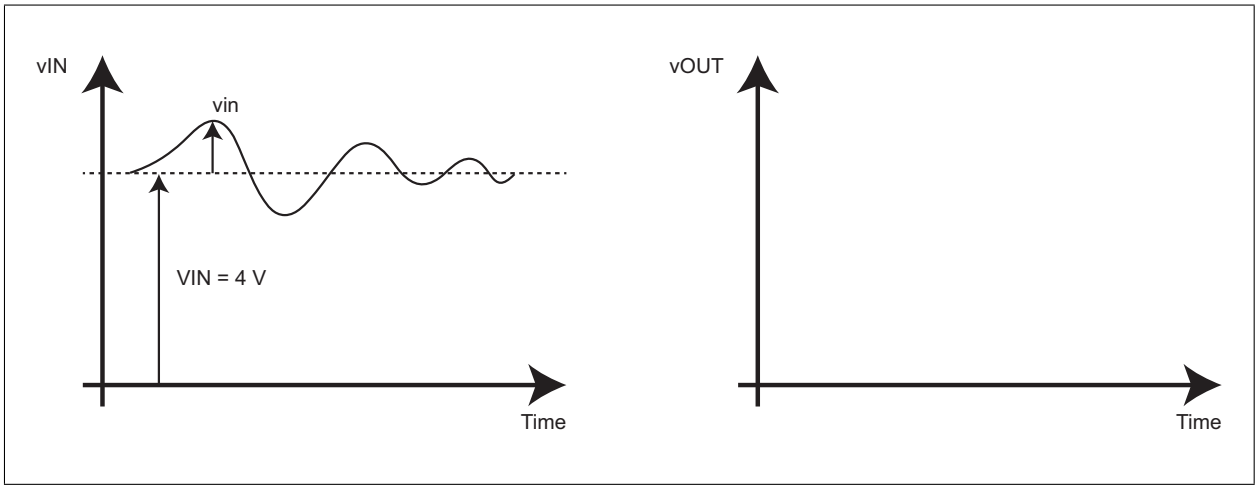
In what mode of operation is the MOSFET in, for $V_{\text{in}} = 2.8 - 5$ V?

Cutoff	Triode	Saturation

For each of the following inputs to the MOSFET amplifier, please sketch the expected output.







4 Set-up the input $v_{IN} = V_{IN} + v_{in}$

As in Lab 1, we will use

- A potentiometer to produce a DC signal $V_1 = 0 - 5$ Volts.
- The function generator to produce an AC sinusoidal signal V_2.

We wish to build a circuit that achieves

$$V_{\text{sum}} \approx \frac{9}{10}V_1 + \frac{1}{10}V_2.$$

Draw your circuit in the space below, and then construct it.

5 Build the common-source amplifier

Next, build the common-source amplifier, with V_{sum} from Section 4 as the input. The following figure (from Assignment 2) should be helpful.

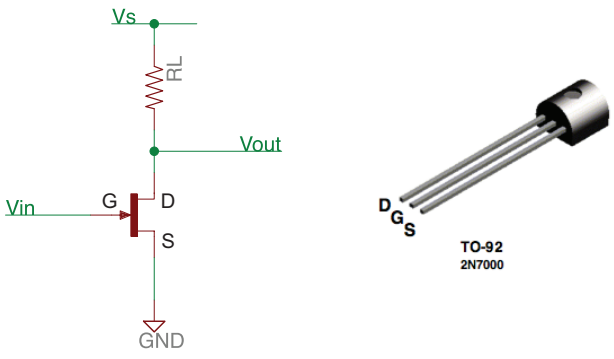


Figure 3: The common-source amplifier and MOSFET pinout.

Now, attempt to drive the speaker from the common-source amplifier output directly. What happens? Describe in words:

6 Build the source-follower

You should have found that the common-source amplifier is not able to drive the speaker directly. Intuitively speaking, the common-source amplifier is not "powerful" enough to drive the speaker.

Instead, we can insert the source-follower circuit – as shown in Fig. 4 – as a buffer between the common-source amplifier and the speaker. In other words, the source-follower circuit is powerful enough to electrically drive the speaker.

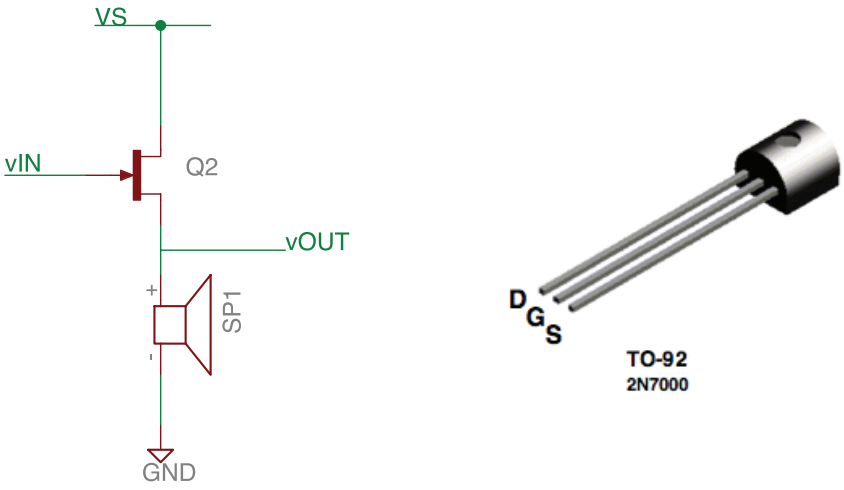


Figure 4: The source-follower circuit and MOSFET pinout.

Build the source-follower circuit. Is it able to drive the speaker?

Yes	No

Figure 5: A hidden microphone in a cell wall in the former Stasi prison Bautzen II in Bautzen, Germany. Microphones in the jail cells listened to prisoners' conversations from behind the plaster, a few layers of paint. [Source: NY Post, Day in Photos: Dec. 14, 2011]

7 A (bad) application

One disturbing application of our circuit is to spy on unsuspecting conversations. Such practices were common in the former East Germany for example, where the state police (the "Stasi") implanted microphones such as the one shown in Fig. 5 in order to spy on the citizenry.

Can you use the microphone sensor (from Lab 1), along with the speaker circuit, to listen in on the conversations in a different room?