Lab 8
Revision 10/01

Name: ___________________________

Partner: ___________________________

Date: ___________

TA: ___________________________

N Channel FET Common Source Transistor Amplifier
    DC Behavior
    AC Behavior

Frequency Selective Amplifier: An Active Filter
Lab Grade:  __________ (90 maximum)

Presentation Grade:  __________ (10 maximum)
(organization, clarity, neatness)

Total:  __________ (100 maximum)

Grader’s Comments:

Hand in all lab and work sheets, either stapled securely or in a folder.
# Laboratory Exercise

## 1.1 Purpose
We will construct an n channel FET common source amplifier and explore its DC and AC behavior. We will overdrive the amplifier with signal, then over and under drive it with bias voltage to see what effect the resulting distortion has on the output waveform. Then, we will explore using AC coupling and a low-pass filter on the amplifier output to examine its behavior as an active filter.

## 1.2 Related Reading
Textbook: Ch. 6: Filters
Textbook: Ch. 9: FETs

## 1.3 Equipment
1) Knight board
2) Oscilloscope
3) Function generator
4) Digital multimeter
5) Instrument leads and jumper wires
6) Resistors: 1kΩ (Qty. 2), 100 kΩ (Qty. 2)
7) Capacitors: 0.1 uF (# 9109F), 3 nF
8) Transistor: 2N3819 or MPF102 n Channel FET (see below)

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### N Channel FET Data Sheets

**2N3819**

- **Absolute Maximum Ratings**
  - BV: 25V
  - IDN: 360mW
  - VGS (OFF): -3.5V
  - Noise Figure: 2.5dB
- **Typicals at VDS: 15V**
  - G: 5.0mmhos
  - IDN: 10mA
- **Applications**
  - Designed as a high frequency, low-noise RF amplifier, mixer and switch.

**MPF102**

- **Pin Designations**
  - 1: Drain
  - 2: Source
  - 3: Gate
- **Absolute Maximum Ratings (at 25°C)**
  - Power Dissipation: 310mW
  - Drain-Source Voltage: 25V
  - Gate-Source Voltage: 25V
  - Gate Current: 10mA
- **Electrical Characteristics**
  - Forward transfer admittance:
    - (at 1kHz) 2000-5000µmhos
    - (at 100MHz) 1600µmhos (min.)
  - Input capacitance (1MHz): 7.0pF (max.)
  - Input conductance (100MHz): 800µmhos (max.)
  - Output conductance (100MHz): 200µmhos (max.)

**BEWARE:** They look the same but have differing pinouts!!!
1.4 Experimental Data and Results

1.4.1 N Channel FET Common Source Amplifier: DC Behavior

Now we will build the simple common emitter NPN amplifier in Fig. 8-1. The 12V supply used in the output side is your fixed 12 V supply. The –12 to 12 V supply is either the positive or negative 0 – 18V supply on the Knight board, depending on the polarity you need.

Be careful that you connect your transistor correctly. Use the pinout from the previous page that matches your particular part number.

First, we need to determine how your transistor behaves. Since this is an n channel device, we expect that the transistor will conduct from drain to source better for higher values of Vgs. When the transistor is completely on, Vout should be approximately 0.6V; this means that the transistor is conducting as efficiently as it possibly can. Adjust Vgs slowly up from 0 zero until the transistor is completely “on.” Record this value.

\[
V_{gs\ SAT} = ___________
\]

Now, try to shut the transistor completely “off.” This would correspond to Vout being the full 12 volts. You will find that Vgs needs to be less than zero to completely turn the transistor off. This is because the transistors we are using are actually depletion mode devices, which means that with no gate voltage they are already a bit on.

\[
V_{gs\ CUTOFF} = ___________
\]

Knowing these voltages is important since any input voltage outside this range will have no further effect on transistor operation.

Now, set Vgs so that Vout is 6V, and measure the following values accurate to three decimal places using the DMM and enter in the table below.
Develop calculated values for each of the four quantities above, and complete the table below:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Measured</th>
<th>Calculated</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_G$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_D$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_S$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.4.2 N Channel FET Common Source Amplifier: AC Behavior

Now, let's drive his amplifier with some AC! Add on to your existing circuit to build the circuit in Figure 8-2 below.

Set the FG to 250 Hz, and adjust the amplitude for a 1V P-P sinusoid.

Display the FG output on Ch. A1 and Vout on Ch. A2 of your scope. Use 10X probe settings.

Adjust your bias voltage to see what happens to the output. Too low a bias voltage will cause clipping on the high end of your output. Why? Setup this condition, and then save your display and hand in a plot comparing these two waveforms labeled **Plot 8-1**. Make sure the amplitudes are apparent. Record the bias voltage used to establish this condition.

\[ V_{bias} = \]
Too high a bias voltage will cause clipping on the low end of your output. Why? Setup this condition, and then save your display and hand in a plot comparing these two waveforms labeled Plot 8-2. Make sure the amplitudes are apparent. Record the bias voltage used to establish this condition.

\[ V_{bias} = \quad \] 

A good bias somewhere between these two extremes will give a reasonably shaped output waveform. Setup this condition, and then save your display and hand in a plot comparing these two waveforms labeled Plot 8-3. Make sure the amplitudes are apparent. Record the bias voltage used to establish this condition.

\[ V_{bias} = \quad \] 

What voltage gain for the amplifier do these plots represent?

What do you think the current gain for this amplifier is? Why?
1.4.3 Frequency Selective Amplifier

Setup the circuit of Figure 8-3. You just need to add the two capacitors and a 1K resistor to your existing circuit. Leave your bias voltage set at the “reasonable” level determined in the last section. The 0.1 uF capacitor is marked # 9109F.

![Fig. 8-3](image)

Set the FG for about 1 V p-p, 1 kHz sine waves.

View Vin on Ch. A1 and Vout on Ch. A2 of your scope, and adjust for about three waves on the scope screen.

Increase the FG amplitude until you see the onset of output clipping. Then, adjust the bias voltage and the FG amplitude so that clipping is symmetric.

Reduce FG amplitude so that no clipping occurs. Your output waveform may be a little asymmetric.

1.4.3.1 Phase Difference

We’re looking mainly at amplitude variation with frequency, but every amplifier introduces phase distortion, too. That is, the phase of the output will not be exactly the same as the phase of the input.

What is the phase distortion of your amplifier at 1 kHz? Adjust the FG amplitude (and the bias voltage if necessary) so that Vout is 6 V p-p and make sure the centerlines of both of your waves are aligned. Then measure the distance between their zero crossings. You may want to change your sample rate to expand the zero crossing region.

\[
\text{Phase Difference} = \text{___________ mS}
\]
1.4.3.2 Frequency Response

Now, let’s focus on the output amplitude as we vary the input frequency. For this section, keep Vin p-p constant.

Fill in Vout as you increase the frequency according to the table below. Make sure Vin p-p stays constant, and just keep increasing your oscilloscope sample rate to keep a few waves on the screen, so you can easily see Vout p-p.

Fill in the voltage gain column, which is simply the ratio of the output voltage to the input voltage. Also, normalize these gains so that the gain at 1 KHz is 1.0. Show these numbers in the last column.

How do you normalize the gains?

<table>
<thead>
<tr>
<th>Freq. (Hz)</th>
<th>Vin (p-p)</th>
<th>Vout (p-p)</th>
<th>Voltage Gain</th>
<th>Normalized Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1K</td>
<td>Constant</td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>5K</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10K</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15K</td>
<td>Constant</td>
<td></td>
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</tr>
<tr>
<td>20K</td>
<td>Constant</td>
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<tr>
<td>50K</td>
<td>Constant</td>
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<td></td>
</tr>
<tr>
<td>100K</td>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200K</td>
<td>Constant</td>
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</tr>
</tbody>
</table>

Plot your Voltage Gain data on graph paper or using a spreadsheet. Plot the frequencies on a log scale across the horizontal axis. Attach this as Plot 8-4 to your write-up.
While here in lab, try to explain why the voltage gain is not constant for all frequencies. It must have to do with the capacitors, right?

1.4.4 Flat Response Amplifier

OK, let's find out! Remove the capacitors from your circuit and re-establish the circuit of Figure 8-2.

Recheck your voltage gains by filling in the following table, to make sure they are constant across the entire range of frequencies.

<table>
<thead>
<tr>
<th>Freq. (Hz)</th>
<th>Vin (p-p)</th>
<th>Vout (p-p)</th>
<th>Voltage Gain</th>
<th>Normalized Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Constant</td>
<td></td>
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<tr>
<td>200</td>
<td>Constant</td>
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<td>500</td>
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<tr>
<td>1K</td>
<td>Constant</td>
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<td></td>
<td>1.0</td>
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<tr>
<td>5K</td>
<td>Constant</td>
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<tr>
<td>10K</td>
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<tr>
<td>15K</td>
<td>Constant</td>
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<td>20K</td>
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<td>100K</td>
<td>Constant</td>
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<tr>
<td>200K</td>
<td>Constant</td>
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</tbody>
</table>

Make another nice log plot of this “Frequency Response” data after lab and include it with your writeup as **Plot 8-5**.

Explain the differences between your two plots in your write-up.