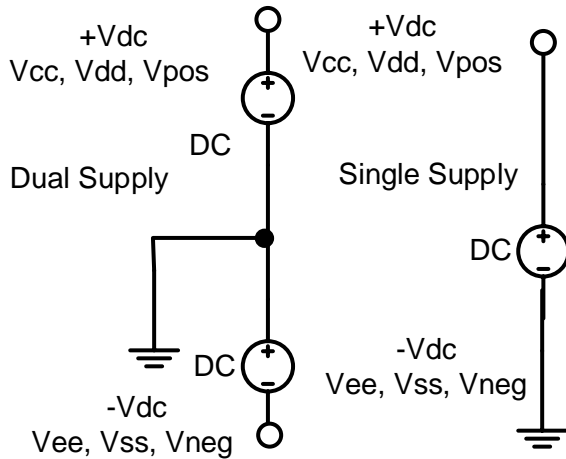


ECE 3274
MOSFET CS Amplifier Project
 Richard Cooper

1. Objective

This project will show the biasing, gain, frequency response, and impedance properties of the MOSFET common source (CS) amplifiers. We will use a single supply in the lab classroom in person.



2. Components

Qty	Device
1	2N7000 N-MOS Transistor

3. Introduction

The circuit in Figures 1. The common source CS amplifiers, like all MOSFET amplifiers, have the characteristic of high input impedance. The value of the input impedance for the amplifier is limited only by the biasing resistors R_{g1} and R_{g2} for $R_{in} < 1M\Omega$. Values of R_{g1} and R_{g2} are usually chosen as high as possible to keep the input impedance high. High input impedance is desirable to keep the amplifier from loading the signal source. One popular biasing scheme for the CS configurations consists of the voltage divider R_{g1} and R_{g2} . This voltage divider supplies the MOSFET gate with a constant dc voltage. This is very similar to the BJT biasing arrangement described in common emitter amplifier. The main difference with the BJT biasing scheme and MOSFET is that ideally no current flows from the voltage divider into the MOSFET.

The CS MOSFET amplifiers can be compared to the CE BJT amplifiers respectively. Like the CE amplifier, the CS amplifier has negative voltage gain and output impedance approximately equal to the drain resistor in parallel with MOSFET drain to source resistance ($R_d \parallel r_o$). The corner frequencies of the CS frequency response can also be approximated using the short circuit and open circuit time constant methods.

The 2N7000 MOSFET used in this project are an n-channel enhancement-type MOSFET. For the enhancement-type MOSFET, the gate to source voltage must be positive and no drain current will flow until V_{GS} exceeds the positive threshold voltage V_{TN} . V_{TN} is a parameter of each particular MOSFET and is temperature sensitive. This parameter sensitivity to temperature is one reason

for establishing a stable dc bias. The 2N7000 MOSFET data sheet lists the minimum and maximum values of V_{TN} as 0.8 V and 3.0 V respectively.

The MOSFET can be easily damaged by static electricity, so careful handling is important.

You should refer to your lab lecture notes, your Electronics II Lecture notes, your textbook, the course website, and other reference material to determine how best to design your amplifier. This lab is intended as a design project and not as a step-by-step guide.

4. Requirements

Your **common-source** amplifier design must meet the following requirements.
VRs = the bias voltage sum across the series resistors R_{sf} and R_{sb}.

Requirement	Specification
Choose a Voltage Gain A_v	Between 6.0 to 9.0 V/V
Low Frequency Cutoff	Between 100 Hz and 300 Hz
High Frequency Cutoff	Between 75 kHz and 200 kHz
Choose an Input Impedance	Between 8k Ω and 10 k Ω
Output Voltage	5.0V _{pp}
Choose VRs	Between 2.0 and 3.0V _{dc}
Load Resistance	5.6 k Ω
Power Supply Voltage	Single V _{dd} = +12V _{dc} V _{ss} = 0V _{dc}

Table 1. Common-source amplifier requirements.

5. Prelab Design Project: Include your CRN on your prelab.

For this project, you will design the common source amplifier. These circuits are shown in Figure 1. You should refer to your class notes, textbook, instructor, and other reference material to help you design the circuits. Start with the output requirement calculate the $V_{out_{peak}}$. DC design and then move onto the AC design.

Component	Value
R_i	150 Ω
C_{byp}	0.1 μ F, 0.047 μ F, or 0.01 μ F

Table 2. Fixed component values.

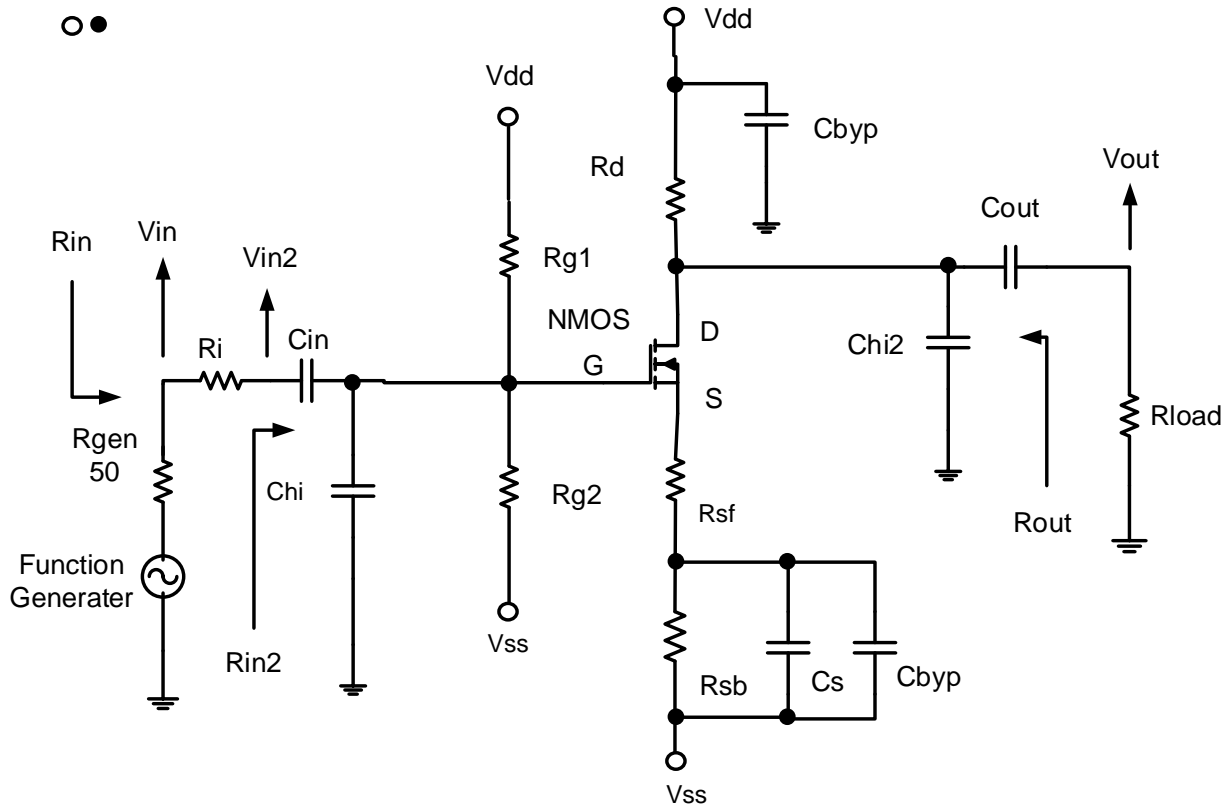


Figure 1. Common-source amplifier circuit.

5.1 DC Bias

Begin by designing the DC bias networks for the amplifiers. You will start by examining the output requirements to select the Q-point, Choose the sum of the voltage drop across $V_{Rsf} + V_{Rsb}$ to 2V to 3V for the CS amplifier. Once you have designed the DC bias network, use the transistor characteristics for the 2N7000 transistor to determine the transistor parameters from the curves for where you are operating. If the Q-point falls close to a curve, use the curves above and below that curve to find the g_m . Note that there is no single correct answer and that your design may differ significantly from your colleagues'. You should show all work and walk through all calculations. You must calculate and show all of the following values for the amplifier.

Component Values	Device Parameters	Voltages and Currents
R_{G1}	V_{TN}	V_{DS}
R_{G2}	r_o	V_{GS}
R_{Sf}	g_m	V_S
R_{Sb}		
R_D		I_D

Table 3. DC Bias and Amplifier Parameters

5.2 AC Design

Design the ac characteristics of the amplifier. You must calculate and show all of the following values. You will need to calculate a value for R_{sf} other than zero if you are to design for a voltage gain (A_v). The high frequency cutoff is controlled by **Chi and Chi2** = $1/(2 \pi FH' Req)$. Because we will set the all poles for the high frequency break point at the same frequency.

We will use the bandwidth shrinkage formula to adjust the frequency of each pole

$$BW_{shrinkage} = \sqrt{2^{1/n} - 1} \text{ where (n) number of high frequency poles at the same frequency.}$$

$$FH' = (FH) / (BW_{shrinkage}) \text{ where } n = 2.$$

$$F_{chi} = F_{chi2} = FH' \text{ Each break point}$$

$$C_{hi} = 1/(2\pi F_{chi} R_{chi}) \quad C_{hi2} = 1/(2\pi F_{chi2} R_{chi2})$$

The low frequency cutoff is controlled by **C_{in}, C_{out}, and C_s** = 1/(2 π FL' Req). Because we will set the all zeros for the low frequency break point at the same frequency.

We will use the bandwidth shrinkage formula to adjust the frequency of each zero

$$BW_{shrinkage} = \sqrt{2^{1/n} - 1} \text{ Where (n) number of low frequency zeros at the same frequency.}$$

For the CS there are 3 low frequency capacitors C_{in}, C_{out}, and C_s so use

$$FL' = (FL) * (BW_{shrinkage}) \text{ where } n = 3.$$

$$F_{cin} = F_{cout} = F_{cs} = FL' \text{ Each break point.}$$

$$C_{in} = 1/(2\pi F_{cin} R_{ci}) \quad C_{out} = 1/(2\pi F_{cout} R_{cout}) \quad C_s = 1/(2\pi F_{cs} R_{cs})$$

Component Values	Amplifier Parameters	Voltages, Currents, and Power
C _{in}	Voltage Gain	V _{in}
C _{out}	Current Gain	V _{out}
C _s	Power Gain (in dB)	i _{in}
C _{hi}	Low Frequency Cutoff	i _{out}
C _{hi2}	High Frequency Cutoff	p _{in}
	Input Resistance	p _{out}
	Output Resistance	

Table 4. Small Signal (ac) Amplifier Parameters

5.5 Computer-aided Analysis (25 points)

Once you have completed your two amplifier designs, use LTspice to analyze their performance.

You will need to **install 2N7000 model** for LTspice it is available from the class web site. Note:

Must include LTspice schematics. Generate the following plots:

- A time-domain plot of the input and output, with the output voltage at the specified voltage of the CSamp at 5 kHz. The output should not have any distortion or clipping. Calculate the midband gain remember the gain is **V_{out}/V_{in}** not V_{out}/V_{gen}, and indicate it on the plot. Compare this to your calculated values.
- An FFT of your time-domain waveform. Circle and indicate the height of any strong harmonics, in dB relative to your fundamental frequency at 5 kHz.
- A frequency sweep of the amplifier from 10 Hz to 1 MHz. Indicate the high and low break point frequencies on the plot (these should correspond to the half-power, or 3dB below midband points). Compare these to your calculated values.

6. Lab Procedure

You must test your 2N7000 MOSFET with the curve tracer before build your experiment.

Set curve trace to N-FET, I_s Max = 10ma, V_{ds} max = 10V, V_g/step = 0.1V, Offset = 1.8V, R_{load} = 0.25Ω, N Steps = 10. Use any socket they are wired in parallel, S = E, G = B, and D = C of the sockets.

6.1. Construct the CS amplifier shown in Figure 1. Remember that $R_{gen} = 50\Omega$ is internal to the function generator $F_{gen} = 5\text{kHz}$. Record the values of the bias network resistors and the capacitors you used in the circuit. $R_L =$ given resistor value.

6.2. Measure the following values:

Turn off the function generator output when measuring the DC bias point.

(a) Q-point: V_{GS} , V_{DS} , V_S , V_G , V_D , and I_D (measure voltage across a known resistor).

Turn on the function generator output, measure at 5kHz.

(b) Voltage, current, and power gains.

(c) Maximum undistorted peak-to-peak output voltage.

(d) **In the on campus Lab only** THD% of output waveform (add distortion step) from basic scope capture.

Add step – Analysis – Frequency Domain Measurement - Distortion

(e) Input and output resistance at 5kHz.

AC sweep

(f) Low and high cutoff frequencies and BW (half power point) AC sweep.

Recall that input impedance is given by $R_{in} = v_{in}/i_{in}$ where $i_{in} = V_{Ri} / R_i$, output impedance is given by $R_{out} = (V_{oc}-V_{load})/i_{load}$, voltage gain is given by $A_v = v_{out}/v_{in}$, and current gain is given by $A_i = i_{load}/i_{in}$.

Additionally, plot the following:

(a) Input and output waveform at the maximum undistorted value. At 5kHz

(b) **In the on campus lab only.** Power spectrum (add step) showing the fundamental and first few harmonics. At 5kHz

Add step – Analysis – Frequency Domain Measurement – Power Spectrum

(b.1) **At home** use FFT plot function of the scope of the V_{out} .

(c) Frequency response (ACsweep) from 10 Hz to 1 MHz set the input voltage (generator output) to a value that does not cause distortion across the entire passband of the amplifier.

6.3. Replace the load resistor, R_L , with a 560Ω and a $27\text{k}\Omega$ resistor, and measure the maximum V_{pp} output and voltage gain **without clipping**. Comment on the loading effect, and remember to change back to a given load resistor after this step.

ECE 3274 MOSFET Amplifier Procedure Report Data Sheet

Name: _____ **CRN:** _____ **Bench:** _____
Group: _____ **Lab Date:** _____

Remember to include units for all answers and to label all printouts. There are a total of four printouts in this lab. Use the 2N7000 V-I curves on the web site
 Submit the reports online, include plots, data sheets, and photo of as built circuit.

This is only for in class: You must **test** your 2N7000 MOSFET with the curve tracer before build your experiment.

Set curve trace to N-FET, Is Max = 10ma, Vds max =10V, Vg/step = 0.1V, Offset = 1.8V, Rload=0.25Ω, N Steps = 10. Use any socket they are wired in parallel note: S = E, G = B, and D = C.

6.1. Common source amplifier component values

R_{G1}:		R_{G2}:		R_D:		R_{S1}:		R_{Sb}:	
C_{in}:		C_{out}:		C_S:		C_{hi}:		C_{hi2}:	
R_L:		R_i:		C_{BYP}:		V_{pos}:		V_{neg}:	

6.2. Common-source amplifier. There are 4 printouts (Vin, Vout, Power spectrum, and ACsweep). Fgen = 5kHz.

DC Q-Point:	V_{GS}:		V_{DS}:		I_D:	
	V_S:		V_G:		V_D:	
Gain:	Voltage:		Current:		Power:	
Voltage Output:	Max:		THD%			
	V_{in}:		V_{Ri}		I_{in}:	
	V_{load}:		I_{Load}		V_{oc}:	
Resistance:	Input		Output			
Frequency Response:	Low:		High:		BW	

6.3. Common-source amplifier with a variable load resistor. There are no printouts here. 560Ω Load Resistor:

Gain:	Voltage:		Current:		Power:	
Voltage Output:	Max:					

27kΩ Load Resistor:

Gain:	Voltage:		Current:		Power:	
Voltage Output:	Max:					