# The George Washington University
# School of Engineering and Applied Science
# Department of Electrical and Computer Engineering
# ECE 20 - LAB

## Experiment # 11
*MOSFET Amplifiers testing and designing*

**Equipment:**
You must make up a complete equipment list and have your instructor review it before you start.

**Objectives:**

- To verify the operating point for a MOSFET biasing network
- To verify the small signal performance for a given CSC amplifier: RIN, ROUT, Av, Ai , maximum input amplitude without distortion Vin max , etc.
- To verify the small signal performance for a given CDC amplifier: RIN, ROUT, Av, Ai , maximum input amplitude without distortion Vin max , etc.
- To establish the relationship between the voltage gain and the load

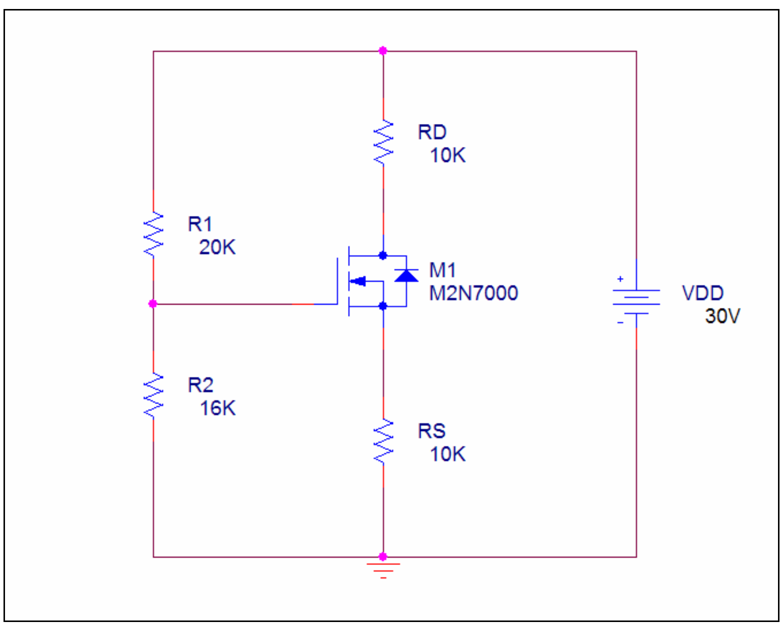


**Figure # 1** – DC Biased MOSFET

**1.- (HW) Analysis**

a. Analyze the circuit shown in Figure # 1 (use nominal values) and find VGG, VG, VS, VD, and ID

   (assume **VDD** = 30 Volts DC, **K** = 64 mAmp/Volt$^2$ , $\mathbf{V_{th}}$ = 1.73 V).

   ***note***: K= $k_n$' (W/L)

b. Assemble this circuit on SPICE

   -For M1, use Part: M2N7000 (***note***: the student edition doesn't include this part)
   -Analysis Type: Bias Type
   -Show the DC Node Voltages and Currents, to verify your calculations

**2.- Verification**

a. Build and fully test the circuit shown in Figure #1. Measure VG, VS, VD, and ID using the DMM.

## 3.- (HW) Analysis

Figure #1 can be configured as a CSC or CDC Amplifier. The DC Bias voltages and current remain the same as in Part 1 of this lab. Using the DC Bias Voltages & Currents that you have found, analyze the two different Amplifier Configurations below:

1. Refer to Figure #2 which shows the CSC configuration of the amplifier:

    a. Find ROUT, RIN, Avo, Av (set RL=ROUT) and Ai (set RL=ROUT).
    b. Also, find the maximum input voltage (Vin max) that the amplifier can accept before the output distorts (loaded and unloaded).

2. Create Figure #3, which connects Figure #1 in the CDC configuration.

    a. Use a "*shorting capacitor*" **CS,** as was done in Figure #2, to short RD.
    b. Find ROUT, RIN, Avo, Av (RL=ROUT) and Ai (RL=ROUT).
    c. Also, find the maximum input voltage (Vin max) that the amplifier can accept before the output distorts (loaded and unloaded).

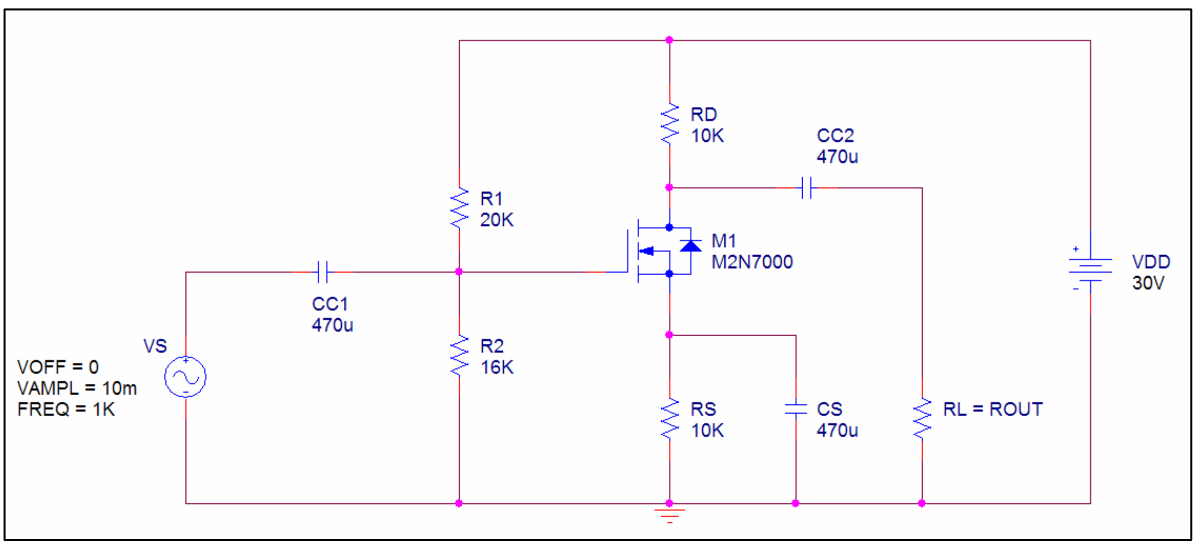


**Figure #2** – MOSFET configured as a CSC (Common Source Configuration) Amplifier

**Figure #3 – (HW)** MOSFET configured as a CDC (Common Drain Configuration) Amp

## 4.- Verification

Build and fully test the circuits shown in Figure #2 & Figure #3. Applying a sinusoidal signal, **Vs** (using the function generator), such that the small signal approximation holds (use Vs=10mV at 1KHz), measure:

1. Build the CSC Amplifier from Figure #2:

    a. Voltage gain $\mathbf{Av_0}$ the assembled circuit for the *unloaded* case (no CC2 or RL). Repeat and find Av with a load of RL=ROUT. Use the oscilloscope to compare VS to Vout
    b. Find RIN (input impedance) and ROUT (output impedance) of the assembled circuit.
    c. Find the maximum input voltage that the amplifier can accept before the output distorts (loaded case RL = ROUT). Plot the output signal and the corresponding input.
    d. Determine the phase relationship between the input and output voltages.
    e. Compare the measured results to your analysis calculations.

2. Build the CDC Amplifier from Figure #3. *(**note**: This portion may be skipped to save lab time – this is at the discretion of your GTA)*:

    a. Voltage gain $Av_0$ the assembled circuit for the *unloaded* case (no CC2 or RL). Repeat and find Av with a load of RL=ROUT. Use the oscilloscope to compare VS to Vout.
    b. Find RIN (input impedance) and ROUT (output impedance) of the assembled circuit.
    c. Find the maximum input voltage that the amplifier can accept before the output distorts (loaded case RL = ROUT). Plot the output signal and the corresponding input.
    d. Determine the phase relationship between the input and output voltages.
    e. Compare the measured results to your analysis calculations.

**Hint:** Connect a large capacitor between VCC and ground in order to remove all the noise from the source. The noise is amplified and mixes with the output. You may also apply a bandpass filter to channel 1 of the digital oscilloscope to reduce the noise.

## 5.- (HW) Design of Common Source

Design a Common Source voltage amplifier (with shorting capacitor) similar to the one shown in Figure # 1. Use SPICE to verify that all the specifications have been achieved.

**Design Specifications of the Amplifier**

- **VDD = 18 V DC**
- **RL= 5 kΩ**
- **|AV| ~ 30 (with RL). |AV| > 30 is even better!**
- **750 kΩ < RIN < 10 kΩ — R1 and R2 should be in the kΩ range**
- **Vin max(before distortion) ≥ 60 mVpeak (when loaded with RL=5 k Ω)**
- **Maximum Power must occur when loaded with RL= 5 k Ω ± 5%**

 (Recall maximum power transfer theorem related to thevenin's theorem)

 *Assumptions*:

- **K** = 64 mAmp/Volt$^2$ ***note***: K= $k_n$' (W/L)
- **Vth =** 1.73 V
- **Vs = Vds** = 1/3(**VDD**) ("Rule of Thumb" from textbook)
- **RD = RS**, and that $r_0$ >> RD and $r_0$ >> RS

- Find R1, R2, RD & RS, as well as all voltages/currents. Show all design calculations.
- Compare the SPICE results to your design calculations and specifications and explain any and all differences.

## 6.- Assembly, Test and Verification of Specifications

Build and test your design. Measure and verify that your design meets all the given specifications.

a. Measure VG, VS, VD, and ID with no input.

b. Measure Avo, Av(RL= at max power transfer), Rin (input impedance) and Rout (output impedance) of the assembled circuit.

c. Find the maximum input voltage that the amplifier can accept before the output distorts.

d. Measure the phase relationship between the input and output voltages.

## 5.- Conclusion

a. Considering that these amplifiers are quite typical, what can you say about Rin, Rout, and the Av for the CSC and CDC amplifiers.

b. Based on your observation, what are the primary differences between BJT and MOSFET Amplifiers?

c. Compare the measured results to your design calculations and specifications. Explain any and all differences!