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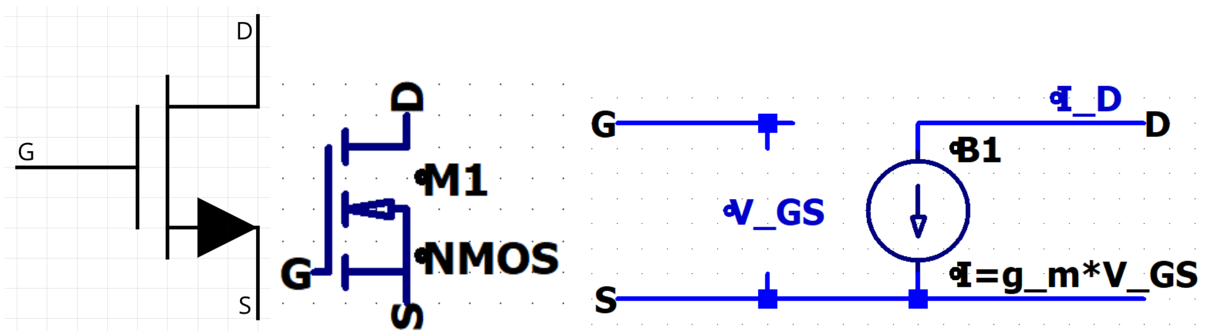
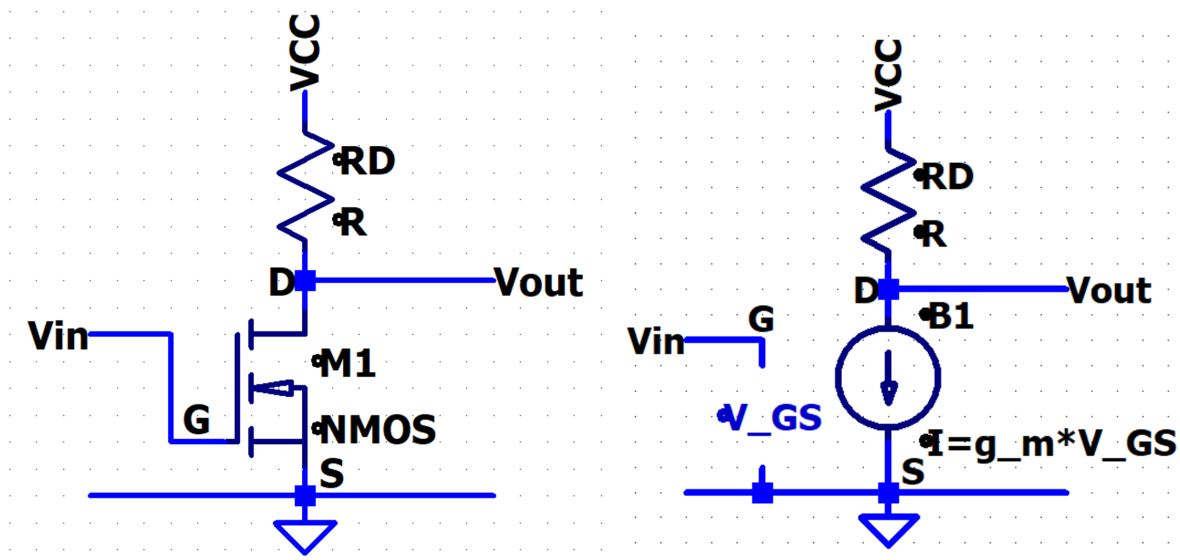
Intro to Electronics HW10

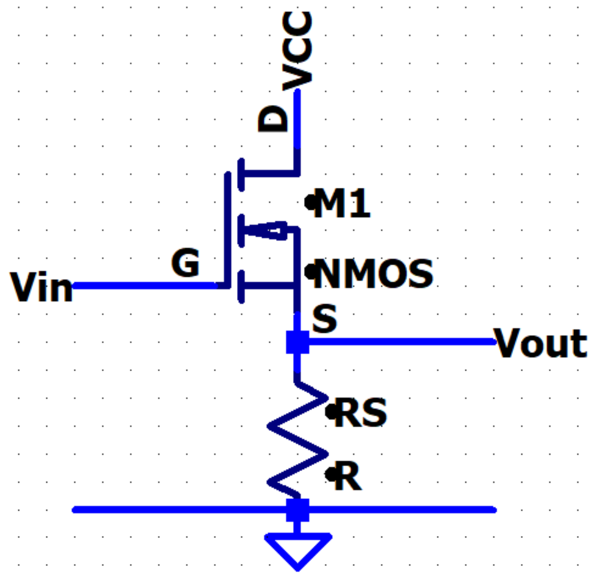
1. FET amplifier circuits:
   The present problem concerns common-source, common-drain, and common-gate amplifier circuits. Assume that the amplifiers do not have a gate-biasing-resistor network.
   a. (a) Draw the FET circuit symbol of an n-channel FET and the corresponding AC small-signal equivalent circuit.

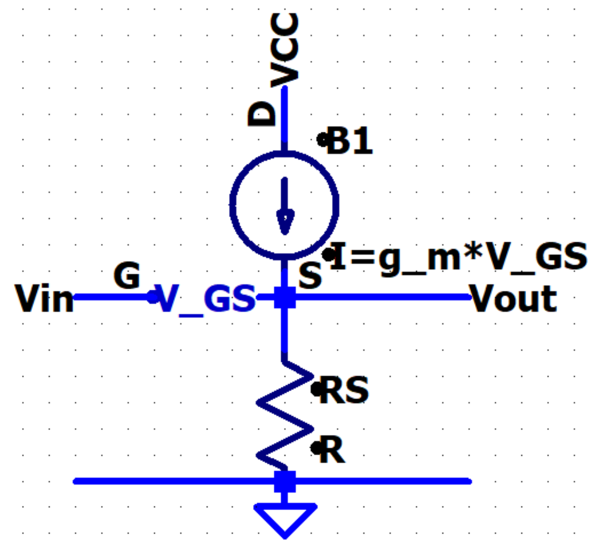


   b. (b) Draw a basic common-source (common-S) amplifier circuit and include a drain resistance RD (but no other resistance). Draw the AC small-signal equivalent circuit of the amplifier (mark the G, S, and D terminals). Derive a symbolic expression for zin (input impedance), zout (output impedance), AVOC (open-circuit voltage amplification), and AISC (short-circuit current amplification).

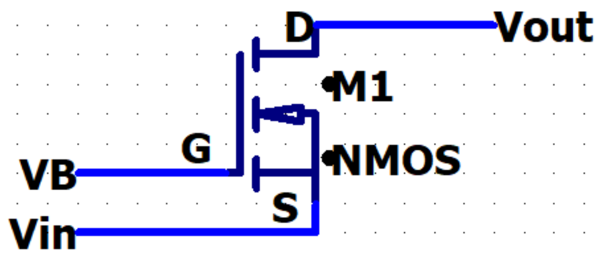


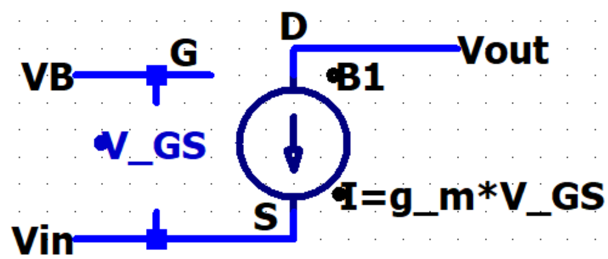
   c. (c) Draw a basic common-drain (common-D) amplifier circuit and include a source resistance RS (but no other resistance). Follow the same instructions as for the previous question.





d. (d) Draw a basic common-gate (common-G) amplifier circuit and do not include any resistor. Follow the same instructions as for the previous question.





e. (e) Make a table having three columns listing the three basic transistor configurations (common-source, common-drain, and common-gate configuration) and four rows listing the amplifier parameters (zin , zout , AVOC , and AISC).

Amp [with additions]]	Common S	Common D	Common G
Zin	Infinite [R1||R2]	Infinite [R1||R2]	1/gm
Zout	RD	RS [RS/(gmRS+1)]	0 [gmRSr0]
AVOC	-gmRD [-gmRD(1+gmRS)]	gmRS/(1+gmRS)	Infinite [gmRL]
AISC	Infinite [gm(R1||R2)]	Infinite [gm(R1||R2)]	1
notes	High AISC	AVOC~=1, S=G, source follower	Less common, low noise, easy z match

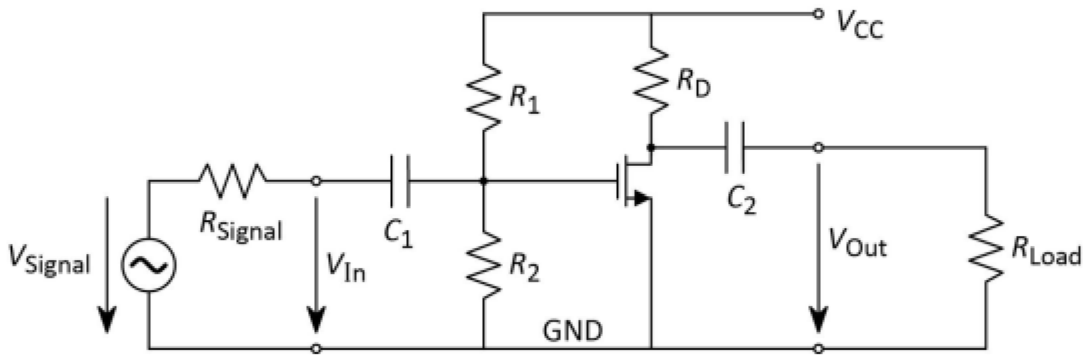
f. (f) Which of the three circuits has the lowest output impedance? Is this desirable?
Common D, this is desirable for a voltage source, making a good voltage follower.

g. (g) Which of the three circuits has the lowest input impedance? Is this desirable?
Common G, this is desirable for a current source, making a good current follower.

h. (h) Which of the three circuits has a voltage amplification (AVOC) of about 1.0?
Common D,

i. (i) Which of the three circuits are the most useful ones?
They all have their uses, but common S is probably the most commonly used one

2. FET amplifier circuit and Miller capacitance:
   The present problem concerns an FET amplifier circuit and its frequency response. The circuit diagram is shown in the figure below. The FET has a k-value of k = 20 mA/V2 and a threshold voltage of Vth = 1 V. The FET gate-bias network consists of two resistors with R1 = 80 kΩ and R2 = 20 kΩ. The AC signal source has an AC voltage amplitude of VSignal and an internal resistance of RSignal = 5 kΩ. The load resistance is RLoad = 1 kΩ. The DC power supply voltage is VCC = 10 V. Assume that the capacitors C1 and C2 are sufficiently large to let pass all AC signals (yet block DC signals).



   a. (a) Which one of the three basic amplifier configurations does the present amplifier have? Determine the Q-point of the amplifier circuit by calculating the drain current ID .

Common S,
VGS=VCC R2/(R1+R2)=10V*20kOhm(80kOhm+20kOhm)=2V
ID=1/2 k (VGS-VTH)^2=1/2 20mA*V^2 (2V-1V)^2=10mA

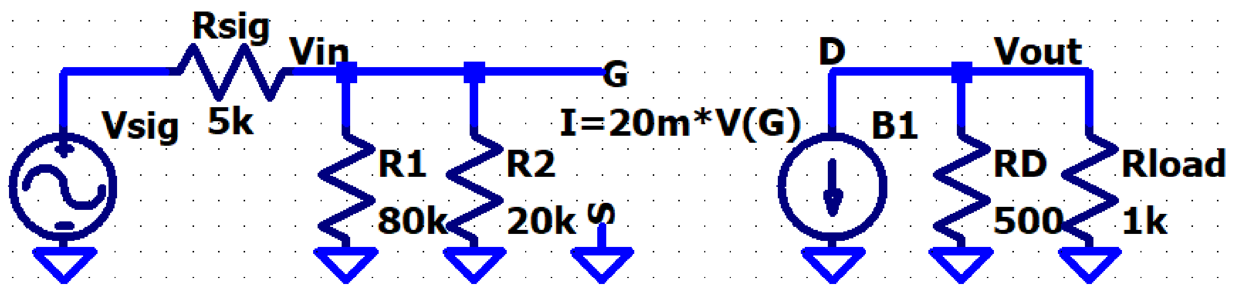
   b. (b) Choose RD so that the Q-point is in the middle of the load line, that is, at VDS = 5 V.

VDS=VCC-VRD
5V=10V-VRD
VRD=5V
VRD=RD*ID
5V=RD*10mA
RD=500Ohm

   c. (c) Determine the transconductance of the amplifier circuit (gm) at the Q-point.

gm=k(VGS-VTH)=20mA/V^2 (2V-1V)=20mA/V

   d. (d) Draw the AC small-signal equivalent circuit of the amplifier; include the signal source and load.



e. (e) Calculate the open-circuit voltage amplification AVOC (symbolic expression and numerical value). Also calculate the voltage amplification AV (symbolic expression and numerical value).

AVOC=Vout/Vin |_RL=\infty
AVOC=-gmRD=-10mA*500ohm /V=-5
AV=Vout/Vin
AV=-gmRD/(gmRS+1)=-20m*500/(20m*5k+1)=10/101=0.099

f. (f) Explain the following quantities:
   i. (i) Drain-gate capacitance CDG and

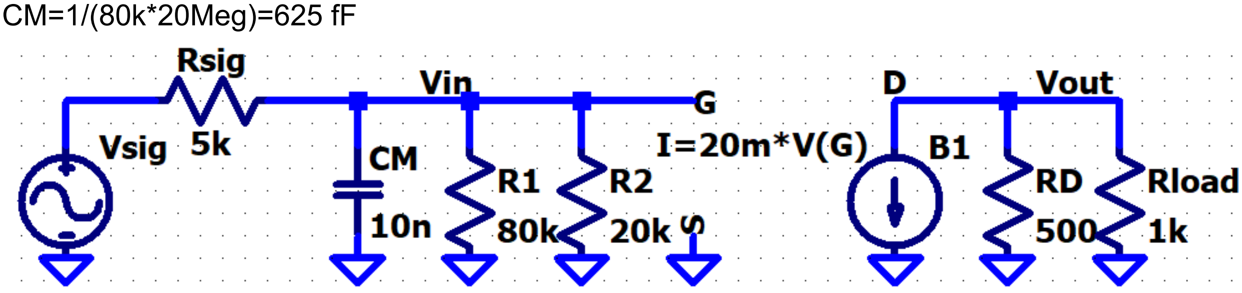
The capacitance between the drain and gate of the MOSFET

   ii. (ii) the Miller capacitance CMiller .

The capacitance in an inverting amp between the input and output terminals, the equivalent input capacitance

g. (g) The experimental analysis of AV as a function of frequency reveals that the amplifier has a high-frequency cutoff at frequency fCutoff = 20 MHz. It is determined that the high-frequency cutoff is due to the Miller capacitance. Redraw the AC small signal equivalent circuit and now include the Miller capacitance. Determine the RC time constant (τ = RC) of the input side of the circuit (symbolic expression and numerical value).

fCutoff=1/T=1/RC
CM=1/(R*fCutoff)
CM=1/(80k*20Meg)=625 fF



T=RC=1/fCutoff=50 ns

h. (h) Calculate the Miller capacitance (numerical value). Calculate the drain-gate capacitance CDG (numerical value).

fCutoff=1/T=1/RC
CM=1/(R*fCutoff)
CM=1/(80k*20Meg)=625 fF

CM=(AV+1)CDG
CDG=CM/(AV+1)
CDG=625fF/(1.099)=568 fF

i. (i) Is there a basic amplifier configuration that suffers less (or not at all) from the limitations of the Miller capacitance?

Common D works well as a pre amp because of it’s low output impedance, creating a smaller resistance, shorter time constant, and higher fCutoff