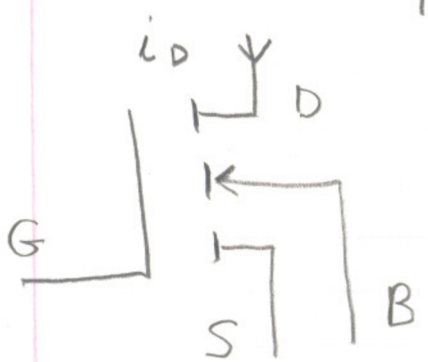
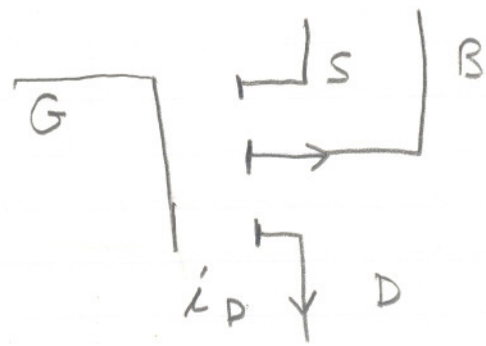
Circuit Symbols for MOSFETs

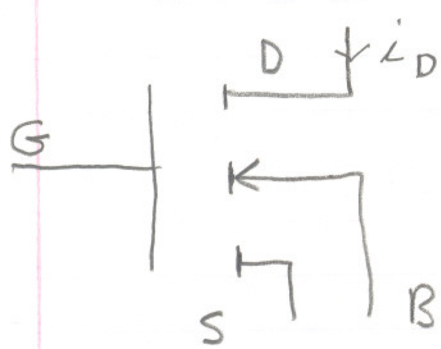
Four Terminal [Enhancement]

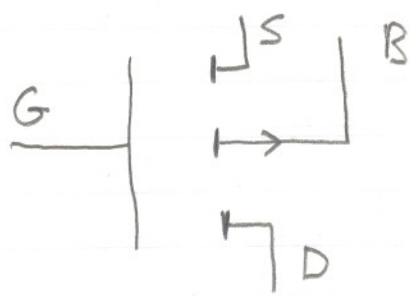


N Channel



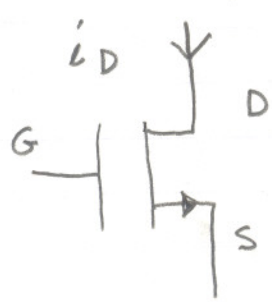
P Channel



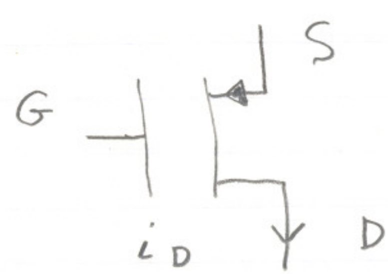


Three Terminal [Enhancement]

Body Connected to Source



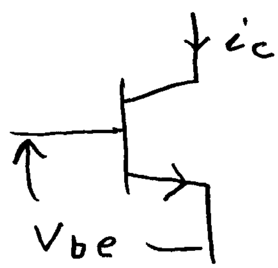
N Channel



P Channel

MOSFETs versus BJTs as analog amplifiers

NPN BJT



$$i_c = g_m V_{be}$$

$$g_m = \left.\frac{\partial i_c}{\partial V_{be}}\right|_{V_{CE} = \text{constant}}$$

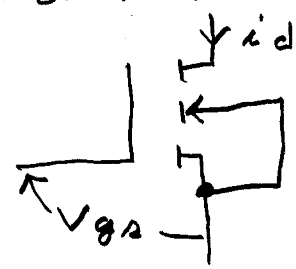
$$g_m = \frac{I_C}{V_T}$$

$$I_C = 1\ mA$$

$$V_T = 25.9\ mV$$

$$g_m = 38.6\ m\mho$$

N Channel Enhancement Mode MOSFET



$$i_d = g_m V_{gs}$$

$$g_m = \left.\frac{\partial i_d}{\partial V_{gs}}\right|_{V_{DS} = \text{constant}}$$

$$g_m = 2\sqrt{K I_D}$$

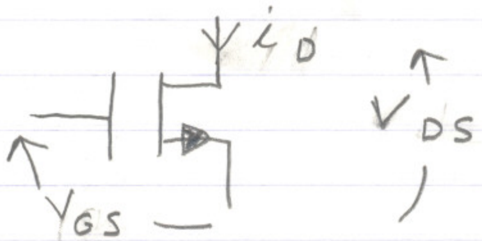
$$I_D = 1\ mA$$

$$K = 0.2\ mA/V^2$$

$$g_m = 0.894\ m\mho$$

Thus, g_m is 43.2 larger for the BJT.

Terminal Equations for 3 terminal N Channel Enhancement Mode MOSFET



$$i_D = \begin{cases} 0 & \text{if } V_{GS} \le V_{TO} \\ 2K\left[(V_{GS} - V_{TO})V_{DS} - \dfrac{V_{DS}^2}{2}\right] & \text{if } V_{GS} - V_{TO} > V_{DS} \\ K(V_{GS} - V_{TO})^2 & \text{if } V_{GS} - V_{TO} < V_{DS} \end{cases}$$

$$K = \frac{k'}{2}(1 + \lambda V_{DS})\frac{W}{L}$$

k' = SPICE parameter KP

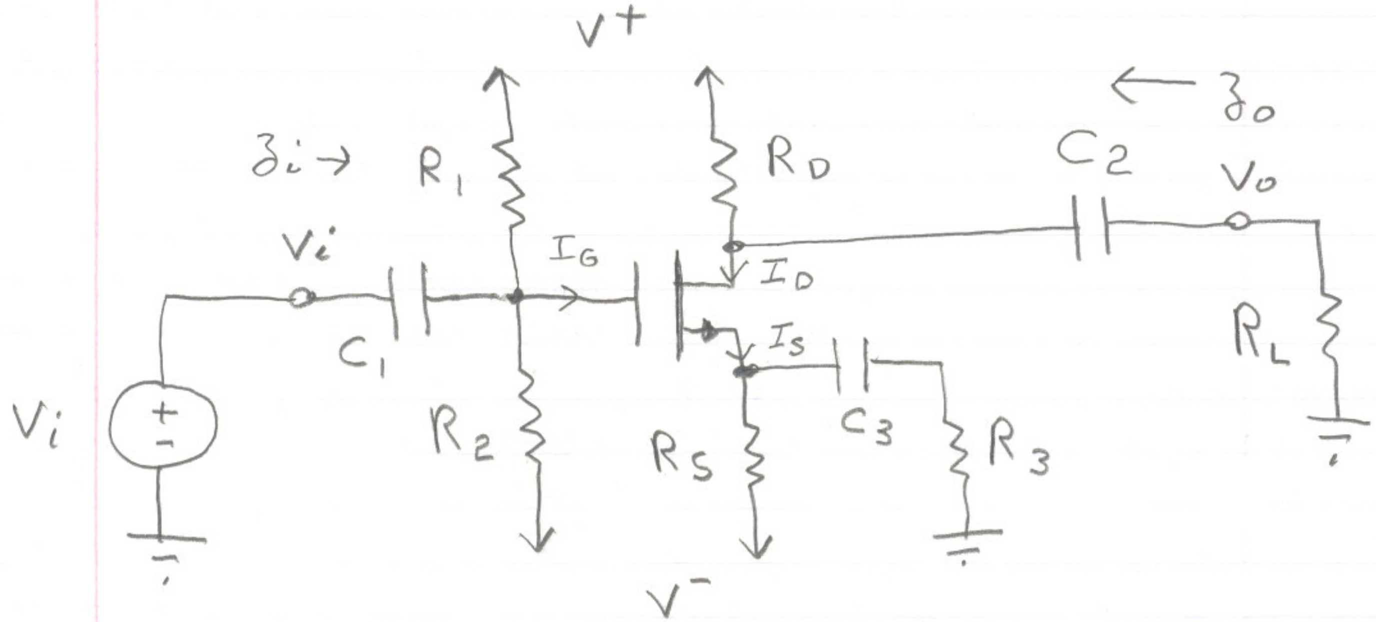
V_{TO} = SPICE parameter VTO

λ = SPICE parameter LAMBDA

If in saturation region

$$g_m = \left.\frac{\partial i_D}{\partial V_{GS}}\right|_{V_{DS}\ \text{constant}} = 2K(V_{GS} - V_{TO}) = 2\sqrt{K I_D}$$

COMMON SOURCE AMPLIFIER



$$I_D = K\left[V_{GS} - V_{TO}\right]^2 = I_S \,, \quad I_G = 0$$

$K \equiv$ transconductance parameter
$V_{TO} \equiv$ threshold voltage

dc gate voltage $V_G = \dfrac{R_2 V^+ + R_1 V^-}{R_1 + R_2}$

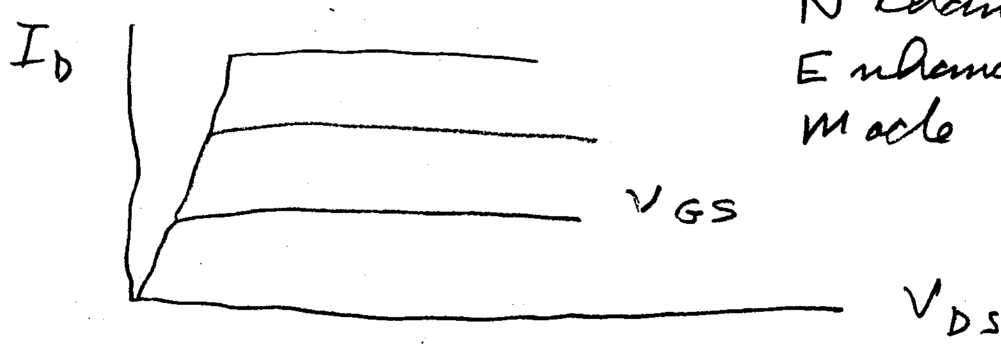
dc source voltage $V_S = V^- + I_S R_S$

Given I_D & the parameters of the transistor, determine $V_{GS} = V_G - V_S$

Pick V_G & then select R_S to obtain desired V_{GS}

Small Signal Analysis

N Channel Enhancement Mode MOSFET

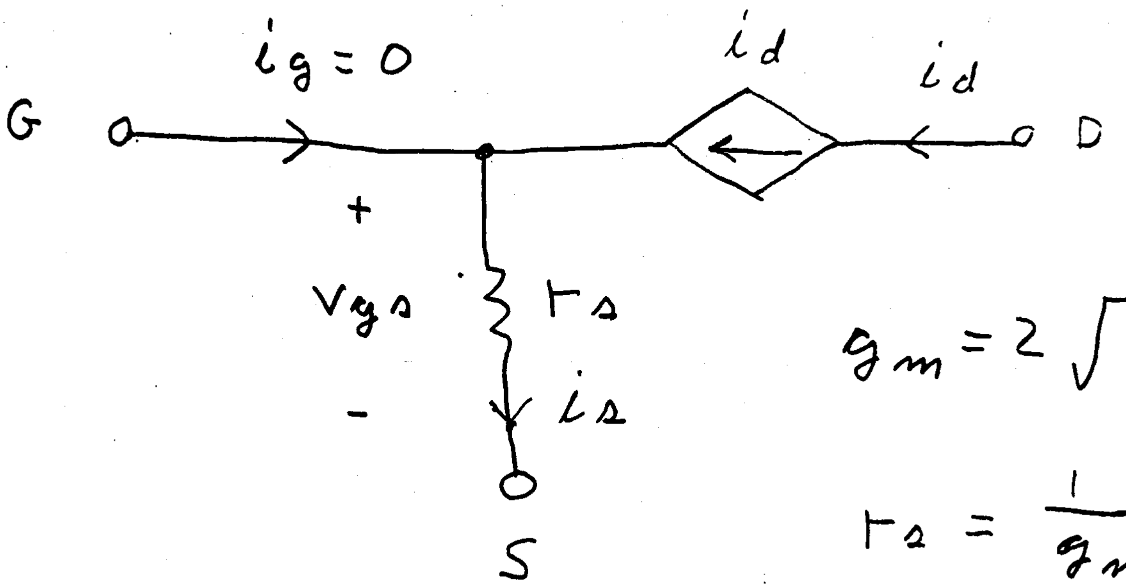


If $\lambda = 0$ lines are horizontal for V_{DS}

$$r_o = \frac{1 + \lambda V_{DS}}{\lambda I_D} = \infty$$

Small Signal Model for the N Channel Enhancement Mode MOSFET

T Model



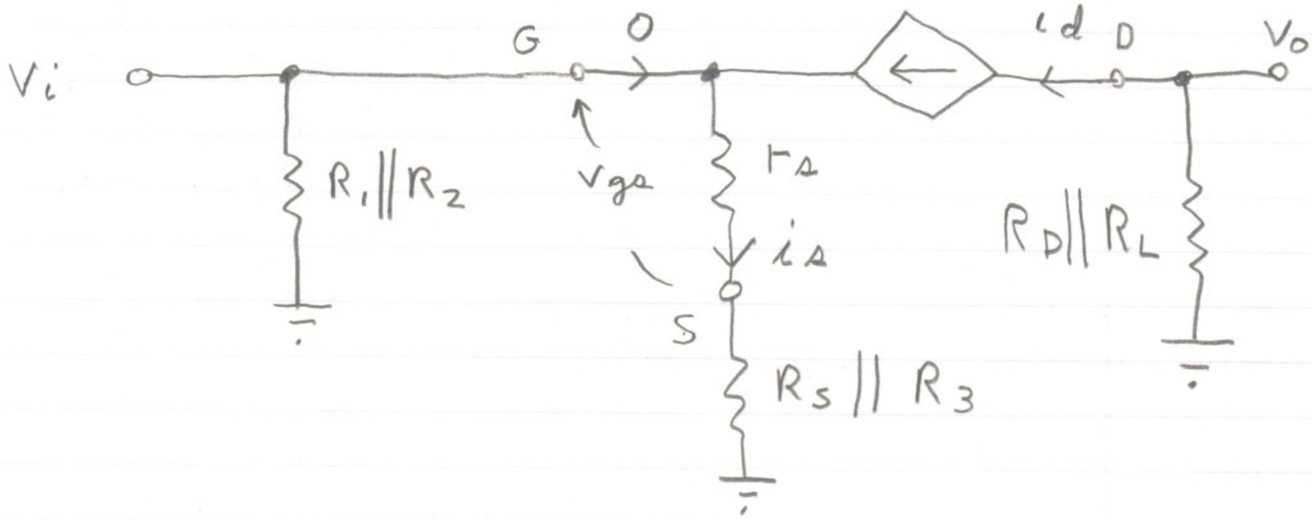
$$g_m = 2\sqrt{K I_D}$$

$$r_s = \frac{1}{g_m}$$

$r_s \equiv$ the intrinsic source resistance

$$i_s = i_d = g_m v_{gs} = \frac{v_{gs}}{r_s}$$

In the midband frequency range



$$v_{gs} = v_i \frac{r_s}{r_s + R_s || R_3}$$

$$i_s = i_d = \frac{v_{gs}}{r_s} = v_i \frac{1}{r_s + R_s || R_3}$$

$$v_o = -i_d \left(R_D || R_L \right)$$

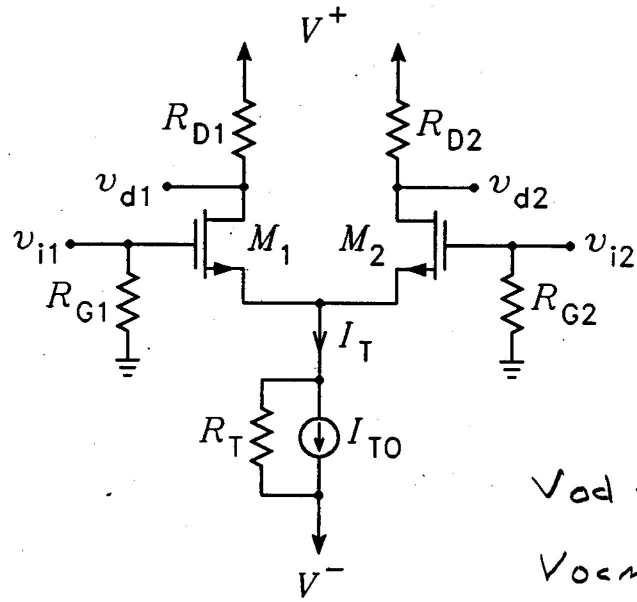
$$\bar{T} = \frac{v_o}{v_i} = -\frac{R_D || R_L}{r_s + R_s || R_3}$$

$$z_i = R_1 || R_2 \quad , \quad z_o = R_D$$

$$G_{cm} = \frac{1}{\frac{1}{g_m} + 2R_T}$$

$$G_d = \frac{g_m}{2}$$

$$g_m = 2\sqrt{K I_D}$$



Assume matched transistors

$R_{D1} = R_{D2}$

$R_{G1} = R_{G2}$

$$V_{id} = V_{i1} - V_{i2}$$

$$V_{icm} = \frac{V_{i1} + V_{i2}}{2}$$

$$V_{od} = V_{d1} - V_{d2}$$

$$V_{ocm} = \frac{V_{d1} + V_{d2}}{2}$$

$$V_{d1} = \left[-G_d V_{id} + G_{cm} V_{icm}\right] R_D$$

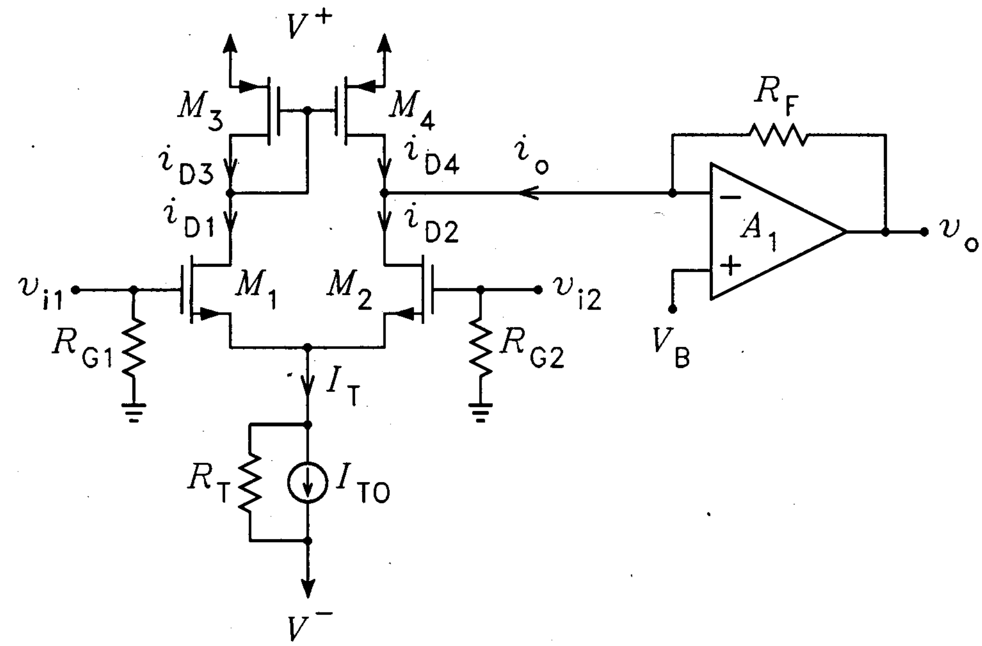
$$V_{d2} = \left[G_d V_{id} + G_{cm} V_{icm}\right] R_D$$

$A_d \equiv$ differential gain $= \dfrac{V_{od}}{V_{id}} = -2 G_d R_D$

$A_{cm} \equiv$ common mode gain $= \dfrac{V_{ocm}}{V_{icm}} = -G_{cm} R_D$

$$CMRR = \frac{A_d}{A_{cm}} = 1 + 2 g_m R_T$$

Current Mirror Active Load $\quad i_{D3} = i_{D4}$



$i_{D1} = i_{D3} = i_{D4}$

Ignoring Common Mode

$i_{d1} = G_d V_{id}$, $\quad i_{d2} = -G_d V_{id}$

$i_{d4} = G_d V_{id}$

$i_o = i_{d2} - i_{d4} = -2 G_d V_{id}$

$V_o = -2 G_d R_F V_{id}$

Georgia Institute of Technology

School of Electrical and Computer Engineering

ECE 3042 Microelectronic Circuits Laboratory Verification Sheet

NAME:____ SECTION:____________________________

GT NUMBER:__________________________________ GTID:______________________________

Experiment 16: MOSFET Amplifiers

Procedure	Time Completed	Date Completed	Verification (Must demonstrate circuit)	Points Possible	Points Received
3. Common Source Amplifier				25	
4. JFET Current Source				25	
4. Diff Amp with Resistive Load				25	
5. Diff Amp with Active Load				25	

To be permitted to complete the experiment during the open lab hours, you must complete at least **three** procedures during your scheduled lab period or spend your entire scheduled lab session attempting to do so. A signature below by your lab instructor, Dr. Brewer, or Dr. Robinson permits you to attend the open lab hours to complete the experiment and receive full credit on the report. Without this signature, you may use the open lab to perform the experiment at a 50% penalty.

SIGNATURE:_____________________________________ DATE:______________________________________

ECE 3042 Check-off Requirements for Experiment 16

Make sure you have made all required measurements before requesting a check-off. For all check-offs, you must demonstrate the circuit or measurement to a lab instructor. All screen captures must have a time/date stamp.

3. Common Source Amplifier
   - ✓ Measurement of drain current with dc ammeter.
   - ✓ Screen capture displaying 1kHz 1Vpp input sine wave and output. Display the Vpp measurements for both channels.
   - ✓ Calculation of the midband gain.
   - ✓ Plot of gain versus frequency with Labview or VEE. Use the cursors to determine the upper and lower -3dB frequencies. Set the input voltage to 0.1 Vrms to prevent clipping.
   - ✓ Screen capture displaying 1kHz 1Vpp input SQUARE wave and output. Display the Vpp measurements for both channels.

4. Design of JFET Current Source
   - Build the circuit shown in Fig. 15.5 (a) using the 2N5457 JFET. Adjust the potentiometer until the specified bias current for the diff amp is obtained. The tail current through the JFET is twice that through each MOSFET in the diff amp.
   - Disconnect the grounded end of the dc ammeter and connect it to the sources of the diff amp transistors and verify that the current is still correct.
   - ✓ Measurement of JFET current.

4. MOSFET Diff Amp with Resistive Load
   - ✓ Screen capture displaying drain voltages for a 1kHz 1Vpp input sine wave and v_{i2} grounded. Display the Vpp measurements for both channels.
   - ✓ Calculation of the single ended gain $(v_{d2} - v_{d1})/v_{\text{in}}$
   - ✓ Screen capture displaying the input and output showing the output hard clipped. Display the max and min measurements.
   - ✓ Screen capture displaying drain voltages for a differential input. Use the circuit of Fig. 15.4(b) to apply 1kHz 1Vpp sine wave to v_{i1} and this signal inverted to v_{i2}. Display the Vpp measurements for both channels.
   - ✓ Calculation of the differential gain $(v_{d2} - v_{d1})/(v_{i2} - v_{i1})$
   - ✓ Screen capture showing common mode output and input.
   - ✓ Measurement of the common mode gain.
   - ✓ Calculation of the CMRR.

5. MOSFET Diff Amp with Active Load
   - For V_B use 7.5V. Generate this voltage at the output of a two resistor voltage divider having equal resistor values of 10k connected between +15V and ground.
   - ✓ Screen capture displaying output voltage and one input for a differential input. Apply 1kHz 1Vpp sine wave to v_{i1} and this signal inverted to v_{i2} again using the circuit of Fig. 15.4(b). Display the Vpp measurements for both channels.
   - ✓ Calculation of $G_{m(d)}$.
   - ✓ Screen capture displaying one input and output showing the output hard clipped. Display the max and min measurements.
   - ✓ Screen capture showing common mode output and input.
   - ✓ Measurement of the common mode gain.
   - ✓ Calculation of the CMRR.