EE 381 ELECTRONICS I
(Madhu)
SUMMARY SHEET – NMOSFET DIFFERENTIAL AMPLIFIERS WITH RESISTIVE LOADS

The symbol k is defined as: $k = \mu_n C_{ox}\left(\frac{W}{L}\right)$

Current Source:

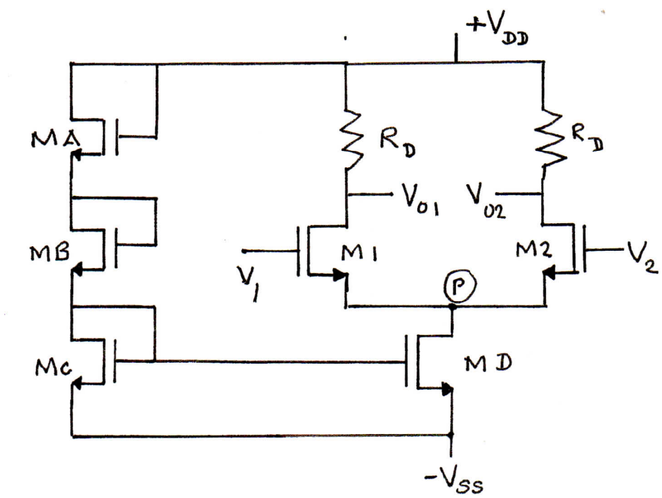
For *each* transistor in the current source portion,

$$V_{GS} = \frac{\left(V_{DD} - \left(-V_{SS}\right)\right)}{3}$$

Use this value of V_{GS} in

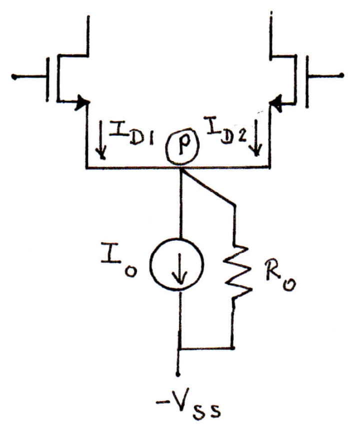
$$I_o = \frac{k}{2}\left(V_{GS} - V_T\right)^2$$

to find the current I_o.



The output resistance of the current source is given by $R_o = r_{ds}$ of transistor **MD**.

Once you have calculated I_o and R_o, simply ignore the current mirror and replace that portion of the circuit by a current source symbol with a resistor in parallel.



Q Point (DC Analysis):

Make $V_1 = V_2 = 0$.

$I_{D1} = I_{D2} = 0.5I_o$ (ignoring the small current that flows in R_o of the current source).

Find V_{GS1} by using: $I_{D1} = \frac{k_1}{2}\left(V_{GS1} - V_T\right)^2$.

The small signal model parameters of the transistors in the diff amp pair are given by:

$$g_{m1} = g_{m2} = k_1(V_{GS1} - V_T)$$

Small Signal Analysis: Remember

(1) First find the differential mode gain and the common mode gain <u>separately</u>, ignoring any actual input signal connections (if any) in a given circuit.

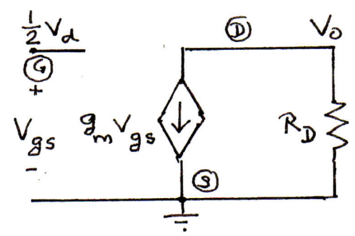
(2) You must set up the small signal equivalent circuits for *only one-half* of the diff amp pair. Which half you choose is usually not important.

(3) The voltage and current values you found in DC analysis cannot be used in small signal analysis. Only the value of g_m obtained from DC analysis can be used in small signal analysis.

Differential Mode Gain:

For this, make $V_1 = 0.5V_d$ and $V_2 = -\,0.5V_d$. Then $V_{CM} = 0$.

In the diff mode, the node P at the junction of the two source terminals is at (ac) ground!



The equations are: (Using $g_m = g_{m1} = g_{m2}$)

$$\frac{V_{o1}}{V_{gs}} = -g_m R_D\,;\quad \frac{V_{gs1}}{V_d} = 0.5$$

A product of the two values gives the differential mode gain $\frac{V_{o1}}{V_d}$.

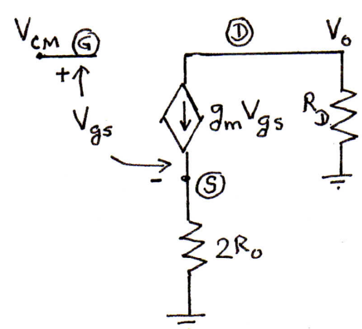
The gain calculated above is referred to as the *single-ended output* gain. If the output voltage is taken between the two drains, then $V_o = (V_{o1} - V_{o2})$ and the gain $\frac{V_{o1}}{V_d}$ can be found by using the single ended gains obtained above. The gain $\frac{V_{o1}}{V_d}$ is referred to as the *double-ended output* voltage gain (or the *differential output gain* according to our textbook).

Common Mode Gain:

For this, make $V_{i1} = V_{CM}$ and $V_{i2} = V_{CM}$. Then $V_d = 0$. In the common mode, the node at the junction of the two source terminals is <u>not</u> at (ac) ground! Split the resistor R_o into two resistors, each = $2R_o$, in parallel.

The equations are:

$$\frac{V_{o1}}{V_{gs}} = -g_m R_D\,;\quad \frac{V_{gs}}{V_{CM}} = \frac{1}{1+g_m\left(2R_o\right)}$$



A product of these values gives the common mode gain A_{CM}.

Common Mode Rejection Ratio:

$$CMRR = 20\,Log\left(\frac{A_d}{A_{CM}}\right)$$

Calculating the Output Voltage for Arbitrary Input Signals:

Once the values of the diff mode and common mode gains have been calculated, then the output voltage for any pair of arbitrary input signals can be determined. Find the diff mode component of the input signals (which is the difference between them) and the common mode component (which is the average value of the two input signals). Multiply the diff mode component by the diff mode gain and the common mode component by the common mode gain and add the two values.