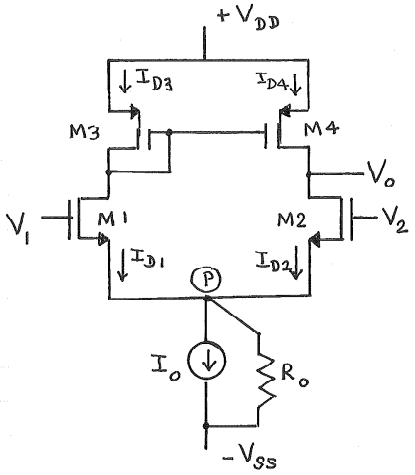
**EE 381 ELECTRONICS I**
**(Madhu)**
**SUMMARY SHEET – CMOS DIFFERENTIAL AMPLIFIER**

## ACTIVELY LOADED MOS DIFFERENTIAL PAIR (Also known as: CMOS DIFF AMP)

In the CMOS diff amp shown, M1 and M2 are the drive transistors (since they receive the input signals) while M3 and M4 serve as the active load. It is assumed that M1 and M2 are identical to each other; similarly, M3 and M4 are identical to each other. [In some circuits, all four of them may be identical.]

The current source output resistance is usually denoted by $R_{SS}$ as shown in this diagram.



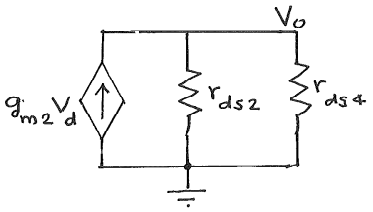

**Q POINT**: $V_1 = V_2 = 0$.
$I_{D1} = I_{D2} = I_{D3} = I_{D4} = 0.5I_o$.
$V_{GS1} = V_{GS2}$ and $V_{GS3} = V_{GS4}$

We will need $g_{m2}$, $r_{ds2}$ and $r_{ds4}$ in small signal analysis.

**DIFFERENTIAL MODE OPERATION:**

$V_1 = 0.5V_d$ and $V_2 = -0.5\ V_d$

As was proved in class, the equivalent circuit reduces to that shown here.




$$\therefore A_d = g_{m2}\left(r_{ds2} \| r_{ds4}\right)$$

You will frequntly see the symbol $G_m$ in such diagrams and equations. Gm is called the transconductance of the diff amp. In the present case, we have $G_m = g_{m1}$.

**COMMON MODE OPERATION:**

$$A_{CM} = -\frac{1}{2R_{SS}}\frac{r_{ds4}}{\left(1 + g_{m3}r_{ds3}\right)}$$

where $R_{SS}$ is the resistance of the biasing current source. (The resistor labeled $R_o$ in the top diagram is the same as $R_{SS}$.) Making use of the fact that $r_{ds3} = r_{ds4}$ and $g_{m3} = g_{m4}$, the last equation reduced to:

$$A_{CM} = -\frac{1}{2R_{SS}}\frac{r_{ds4}}{\left(1 + g_{m4}r_{ds4}\right)} \approx -\frac{1}{2g_{m4}R_{SS}}$$

Remember that the subscripts of the transistors may vary from one diagram to the next. To avoid any errors, be sure to identify the drive transistors and load transistors correctly before you use any of the above formulas.