

Test 1 (10/28/08)

Total # Pages 6

Total # Problems 5

Attach your one page of notes to this test

Name SOLUTION

1. (20 points) _____
2. (25 points) _____
3. (30 points) _____
4. (10 points) _____
5. (15 points) _____

Total (100 points) _____

GOOD LUCK

Note: All bulk connections that are not shown are tied to the appropriate supply voltage.

$$I_d = \begin{cases} k' \frac{W}{L} \left[(V_{gs} - V_T) V_{ds} - \frac{V_{ds}^2}{2} \right] (1 + \lambda V_{ds}) & V_{gs} \geq V_T, V_{ds} \leq V_{gs} - V_T, \text{ linear} \\ \frac{k' W}{2L} (V_{gs} - V_T)^2 (1 + \lambda V_{ds}) & V_{gs} \geq V_T, V_{ds} \geq V_{gs} - V_T, \text{ saturation} \\ 0 & V_{gs} < V_T, \text{ cutoff} \end{cases}$$

$$V_T = V_{To} + \gamma (\sqrt{|V_{sb} + \phi|} - \sqrt{|\phi|})$$

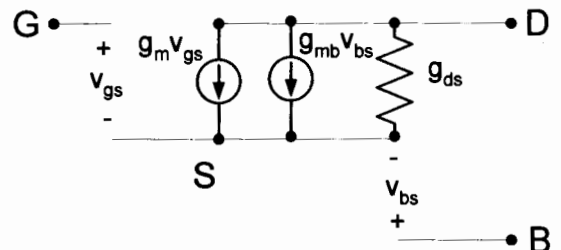
$$\text{In saturation, } V_{gs} = V_T + \sqrt{\frac{2I_d}{k' \frac{W}{L}}}$$

Small-signal parameters in saturation:

$$g_{ds} = g_o = \lambda I_d$$

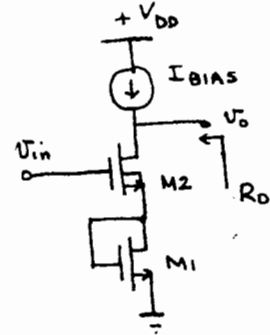
$$g_m = \sqrt{2I_d k' \frac{W}{L}} = \frac{2I_d}{V_{gs} - V_T}$$

$$g_{mb} = \eta g_m \quad \text{where } \eta = \frac{\gamma}{2\sqrt{|V_{sb} + \phi|}}$$

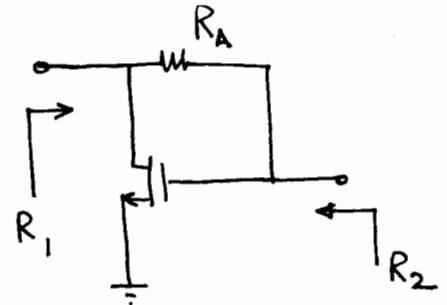
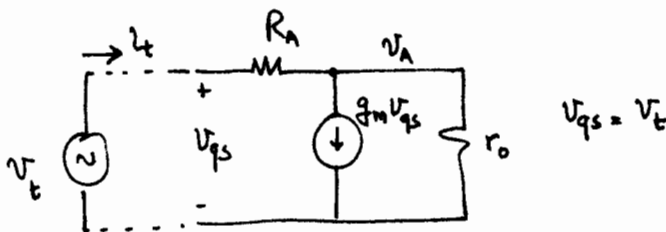


2. Write the expressions for the small-signal low-frequency quantities as shown. Assume all transistors are biased in saturation and have identical small-signal parameters. Ignore the body effect and assume that $g_m r_o \gg 1$ (25 points).

G_m (effective g_m) = $g_m/2$



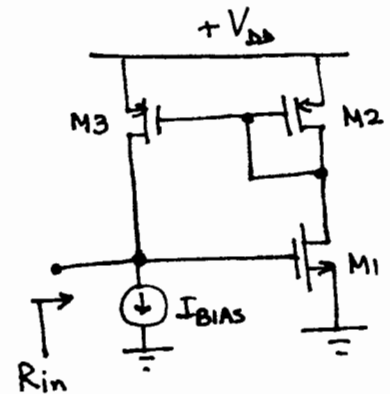
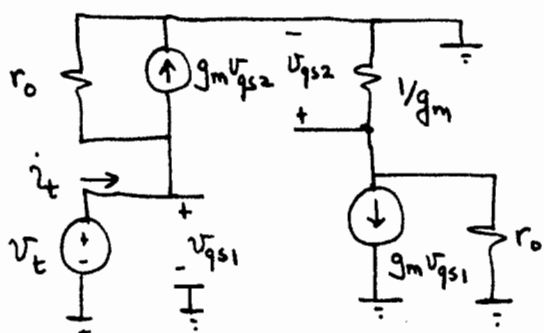
$R_1 = \frac{1}{g_m}$ $R_2 = \frac{1 + R_A/r_o}{g_m}$



$$i_t = g_m v_{gs} + v_A/r_o = g_m v_t + \frac{(v_t - i_t R_A)}{r_o}$$

$$i_t (1 + R_A/r_o) = (g_m + 1/r_o) v_t \Rightarrow R_2 \approx \frac{1 + R_A/r_o}{g_m}$$

$R_{in} = \frac{1}{g_m}$



$$i_t = g_m v_{gs2} + \frac{v_t}{r_o} = (-g_m + 1/r_o) v_t \approx -g_m v_t$$

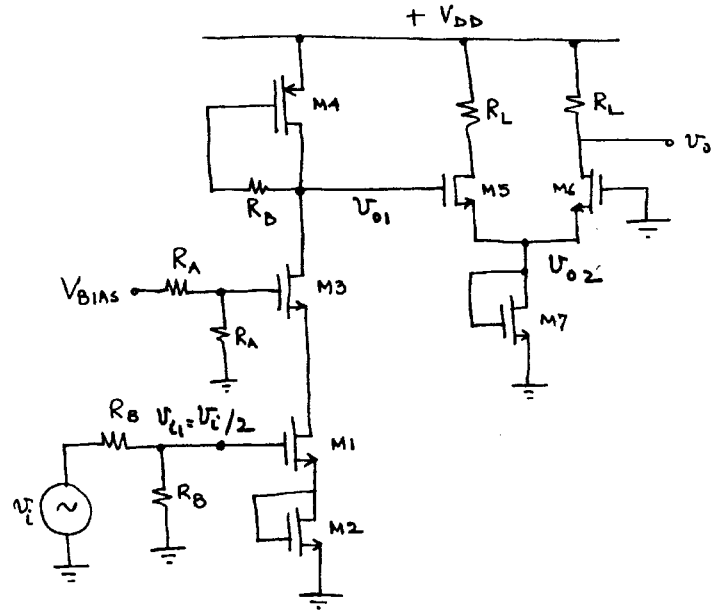
$$v_{gs2} = -\frac{1}{g_m} \left(g_m v_t + \frac{v_{gs2}}{r_o} \right) = -v_t - \frac{v_{gs2}}{g_m r_o} \Rightarrow v_{gs2} \approx -v_t$$

$\Rightarrow R_{in} = \frac{1}{g_m}$

4. Derive an expression for the low frequency small-signal voltage gain of this circuit. Assume $g_{m1} = g_{m2} = g_{m3} = g_{m4} = g_{m5} = g_{m6} = g_{m7} = g_m$ (i.e., all transistors have identical g_m 's), r_o is infinity, and the body effect can be ignored (10 points).

$$A_v = v_o/v_i = \underline{\underline{-g_m R_L/12}}$$

$$v_{i1} = v_i/2$$



$$\frac{v_{o1}}{v_{i1}} \approx -\frac{g_m}{2} \cdot \frac{1}{g_m} = -\frac{1}{2}$$

$$\frac{v_{o2}}{v_{o1}} = \frac{g_m}{g_m + 2g_m} = \frac{1}{3}$$

$$\frac{v_o}{v_{o2}} = g_m R_L$$

$$\therefore A_v = \frac{v_o}{v_i} = -\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{3} \cdot g_m R_L = -\frac{1}{12} g_m R_L$$