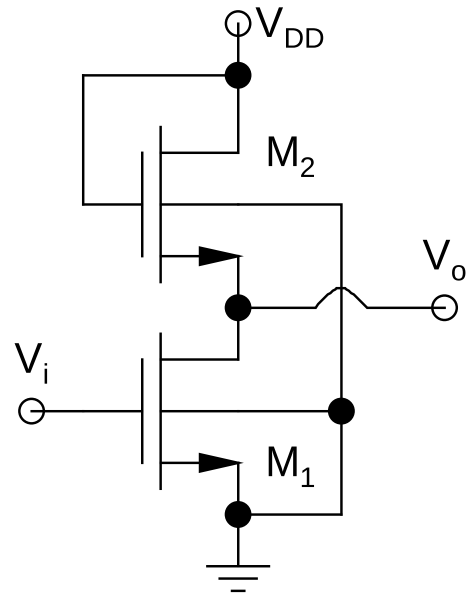
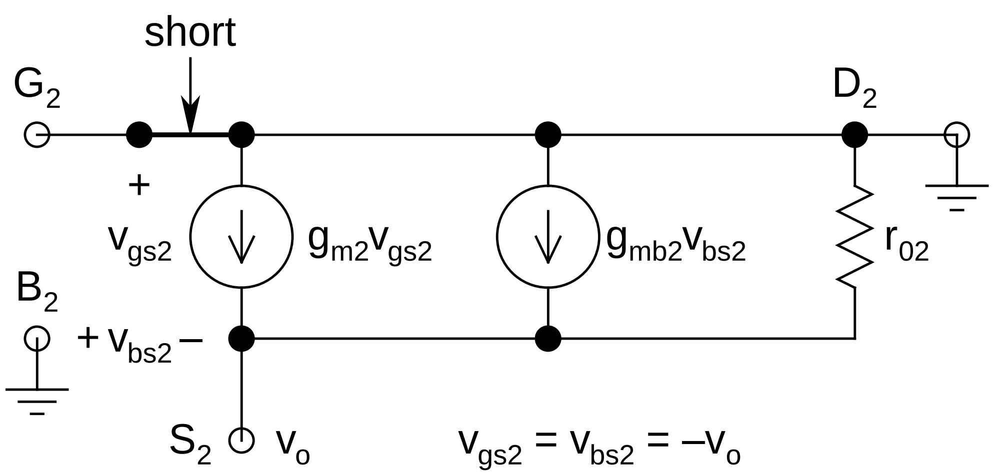
- ***Saturated Enhancement Load***:
  - ***Both bodies tied to ground***
    - ***For M_1***: ***$V_{SB1} = 0$***
    - ***For M_2***: ***$V_{SB2} = V_o$***
  - ***M_2 is enhancement mode***
    - ***V_{TN02} positive***
  - ***M_2 is also diode-connected***
    - ***Always operates in saturation***
  - ***M_2 has a floating body effect problem***: ***V_o is a variable*** and ***V_{TN2} will continuously change with a change in V_o***

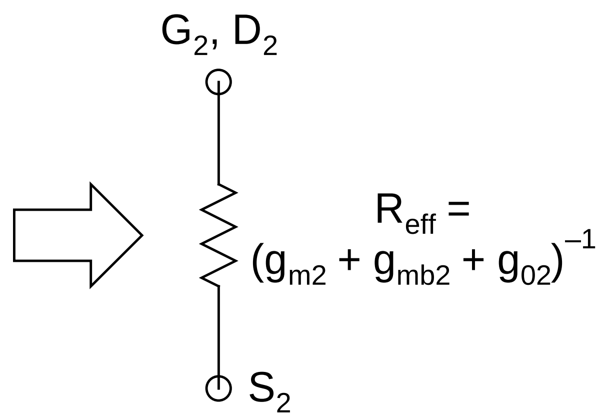


Circuit Schematic

- ***Solution of this equation would give $V_{o,max}$***
- ***Once $V_{o,max}$ is obtained***, the ***best bias point would be at $V_0 = V_{o,max}/2$***
- Before doing ***ac analysis***, ***let's investigate M_2***:



ac Midband Equivalent of M_2

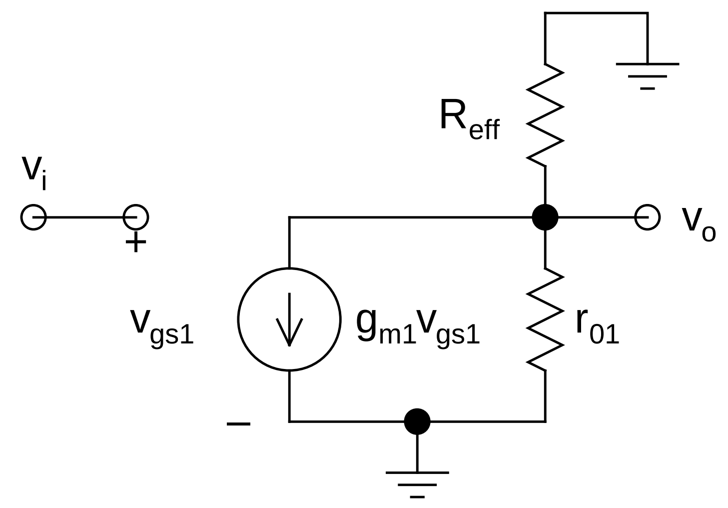


Simplified Equivalent

- Thus, the ***complete equivalent***:
- ***By inspection***:

$$A_v = \frac{v_o}{v_i} = -g_{m1}\left(r_{01} \parallel R_{eff}\right)$$

$$= -\frac{g_{m1}}{g_{m2} + g_{mb2} + g_{01} + g_{02}}$$



Complete Equivalent

- Now, in general,

$(g_{m2} + g_{mb2}) >> (g_{01} + g_{02})$

$$\Rightarrow A_v \approx -\frac{g_{m1}}{g_{m2} + g_{mb2}} = -\frac{g_{m1}}{g_{m2}\left(1 + \chi_2\right)}$$

$$\chi_2 = \frac{\gamma}{2\sqrt{2\phi_F + V_{0Q}}}$$

V_{0Q} = ***Quiescent DC output voltage***

- Now, if M_2 can be put in its ***separate island***, then S_2 and B_2 can be ***connected together***

$$\Rightarrow \boldsymbol{v_{sb2} = 0} \Rightarrow \boldsymbol{g_{mb2}v_{sb2} = 0}$$

$$\Rightarrow A_v \approx -\frac{g_{m1}}{g_{m2}} = -\sqrt{\frac{(W/L)_1}{(W/L)_2}}$$

- $R_0 = (g_{m2} + g_{mb2} + g_{01} + g_{02})^{-1}$

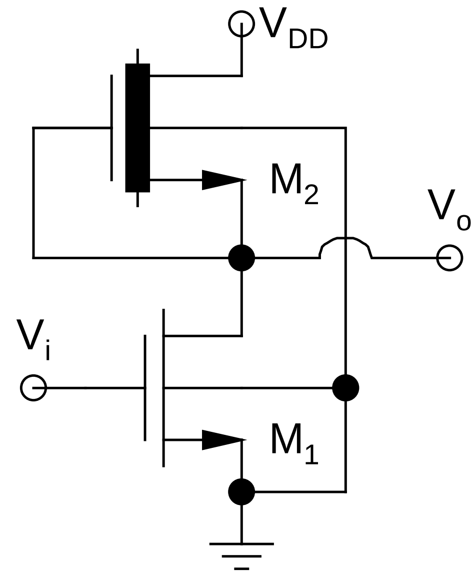
- ***Insights***:
  - ***V_o doesn't go all the way to V_{DD}***

    $\Rightarrow$ ***Full rail-to-rail swing can't be achieved***
  - ***When V_o falls below ΔV of M_1***, ***it leaves the saturation region***, and ***enters non-saturation region***

    $\Rightarrow$ ***Distortion will set in at the output***
  - Even for a ***moderate voltage gain of 10***, the ***ratio of the aspect ratios of M_1 and M_2 has to be 100***!
  - ***All these problems coupled together make this circuit highly unattractive for practical use***

- ***Depletion Load***:
  - M_2 is ***depletion mode***, having ***negative*** V_{TN0} (***denoted by*** V_{TD0})
  - ***Back bias of*** M_2:

    $V_{SB2} = V_o$
  - ***With*** V_o, V_{TD2} ***changes***
  - ***Maximum*** V_o ***desired*** $= V_{DD}$
  - ***This is also the maximum back bias of*** M_2



Circuit Schematic

- ***M_2 has GS short*** $\Rightarrow$ ***$V_{GS2} = 0$***
- ***Even with $V_o = V_{SB2}(max) = V_{DD}$, V_{TD2} should remain negative with a cushion of at least 100 mV***

  $\Rightarrow$ ***V_{TD2} with $V_{SB2} = V_{DD}$ should be –100 mV***

  $\Rightarrow$ ***V_{TD0} should be chosen based on this***
- Now, ***$V_{DS2}(min) = V_{DD} - V_o(max) = 0$***
- Under this condition, ***$V_{GS2} - V_{TD2} = \Delta V_2 = 100$ mV***

  $\Rightarrow$ ***M_2 is in the linear region*** (***since $V_{DS2} < \Delta V_2$***)