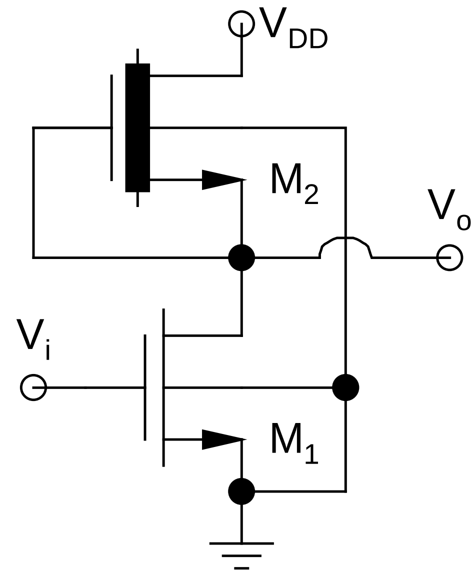
- ***Depletion Load***:
  - M_2 is ***depletion mode***, having ***negative*** V_{TN0} (***denoted by*** V_{TD0})
  - ***Back bias of*** M_2: $V_{SB2} = V_o$
  - ***With*** V_o, V_{TD2} ***changes***
  - ***Maximum*** V_o ***desired*** = V_{DD}
  - ***This is also the maximum back bias of*** M_2



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*

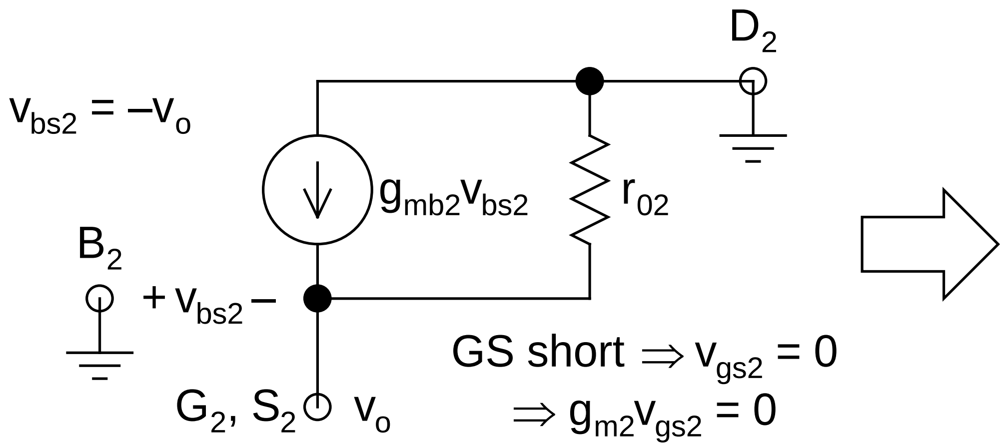
  $\Rightarrow V_{TD2}$ *with* $V_{SB2} = V_{DD}$ *should be –100 mV*

  $\Rightarrow V_{TD0}$ *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*

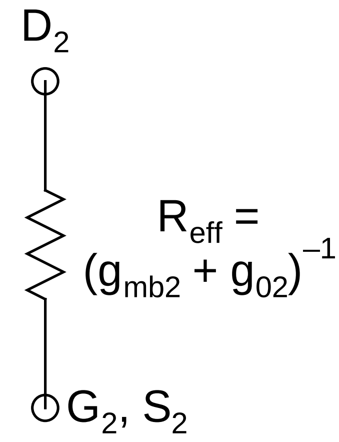
  $\Rightarrow M_2$ *is in the linear region* (*since* $V_{DS2} < \Delta V_2$)

- ***This has to be lived with***, and ***slight distortion would appear at the output as $V_o \to V_{DD}$***
- For ***best biasing***, $V_{0Q} = V_{DD}/2$

  $\Rightarrow$ ***Fixes the DC operating point***
- Before doing ***ac analysis***, ***let's investigate M_2***:



ac Midband Equivalent of M_2

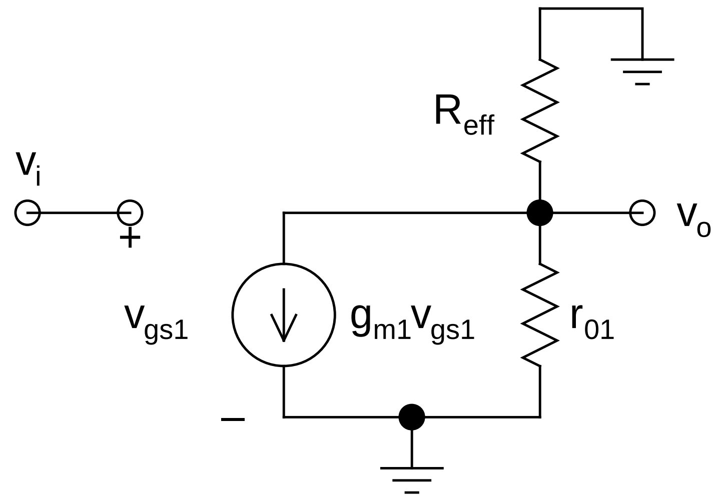


Simplified Equivalent

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

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

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



Complete Equivalent

- Now, in general,

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

$$\Rightarrow A_v \approx -\frac{g_{m1}}{g_{mb2}} = -\frac{g_{m1}}{\chi_2 g_{m2}} = -\frac{1}{\chi_2}\sqrt{\frac{(W/L)_1}{(W/L)_2}}$$

$$\chi_2 = \frac{\gamma}{2\sqrt{2\phi_F + V_{DD}/2}} < 1$$

$\Rightarrow$ ***Improvement*** as compared to previous stage

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

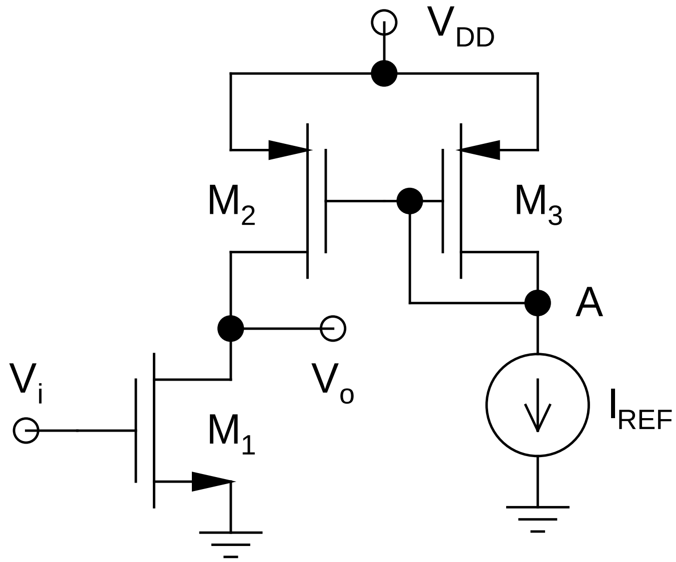
$\Rightarrow$ $\boldsymbol{v_{sb2} = 0}$ $\Rightarrow$ $\boldsymbol{g_{mb2} v_{sb2} = 0}$

$$\Rightarrow A_v = -\frac{g_{m1}}{g_{01} + g_{02}}$$

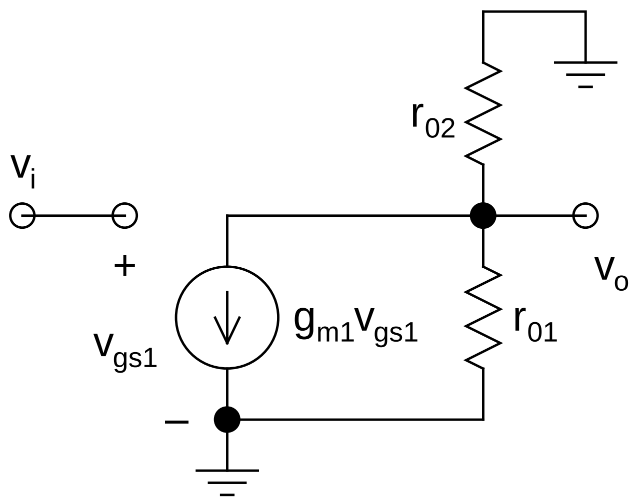
  - Can be ***very large*** (***a magnitude greater than 100 is possible***)

- $R_0 = (g_{mb2} + g_{01} + g_{02})^{-1}$ (***with body effect***)
- $R_0 = (g_{01} + g_{02})^{-1}$ (***without body effect***)
- The latter case produces ***very high R_0***
- Thus, this circuit produces ***much superior performance*** as compared to the ***saturated enhancement load***, in terms of:
  - ***Rail-to-rail swing***
  - ***With island technology***:
    - ***Very large A_v and R_0***
  - ***Without island technogy***:
    - ***Moderate A_v and R_0***

- ***Complementary PMOS Load***:
  - Also known as ***CMOS Gain Stage***
    - ***CMOS*** (***Complementary MOS***: ***Having both NMOS and PMOS*** in the circuit)
  - ***The Ultimate***: ***Much superior performance*** and ***outclasses all other gain stages***
  - ***Widely used***
  - ***High A_v and R_0***
  - ***Easy to bias and easy to operate***
  - ***Design also extremely simple***
  - ***Doesn't produce any anomalies***



Circuit Schematic



ac Midband Equivalent

- ***M_1 body connected to ground*, *M_2-M_3 bodies connected to V_{DD}***
  - *No body effect problem for any of the devices* (***biggest advantage of this circuit***)