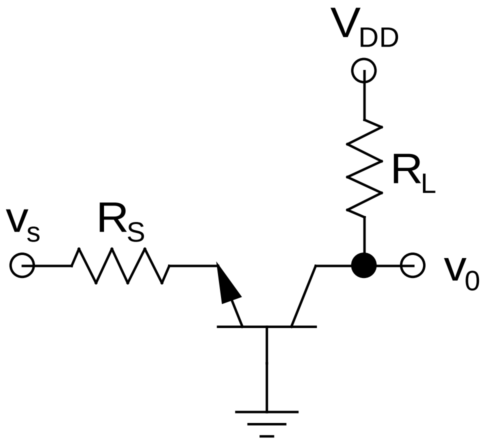
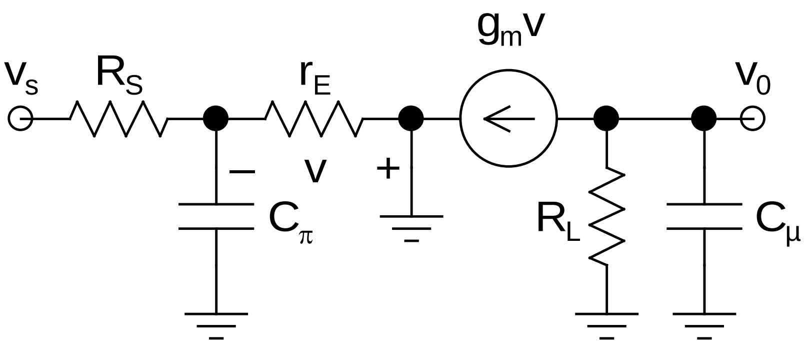
- ***CB*** :





ac Schematic **High-Frequency Equivalent**

➢ ***Note that there is no input-output coupling capacitor present in this circuit***

$\Rightarrow$ ***Miller effect will be absent***, and the ***circuit will have very high f_H***

- ***C_π***:

  $$R_\pi^0 = R_S \parallel r_E \quad \text{and} \quad \tau_1 = R_\pi^0 C_\pi$$

- ***C_μ***:

  $$R_\mu^0 = R_L \quad \text{and} \quad \tau_2 = R_\mu^0 C_\mu$$

- Taking the ***values*** of our previous ***example***:

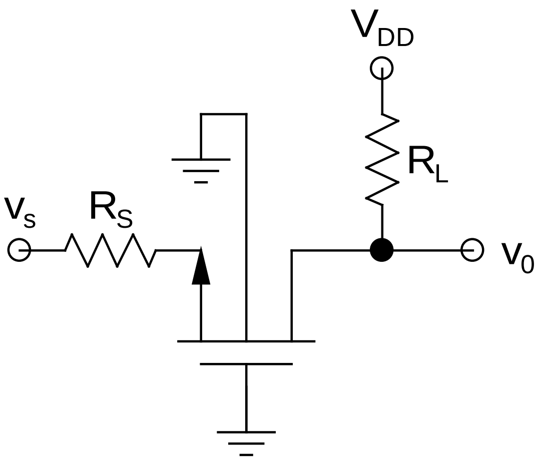
  $$R_\pi^0 = 25.34\ \Omega,\ \ \tau_1 = 0.253\ \text{ns}$$

  $$R_\mu^0 = 2\ \text{k}\Omega,\ \ \tau_2 = 1\ \text{ns}$$

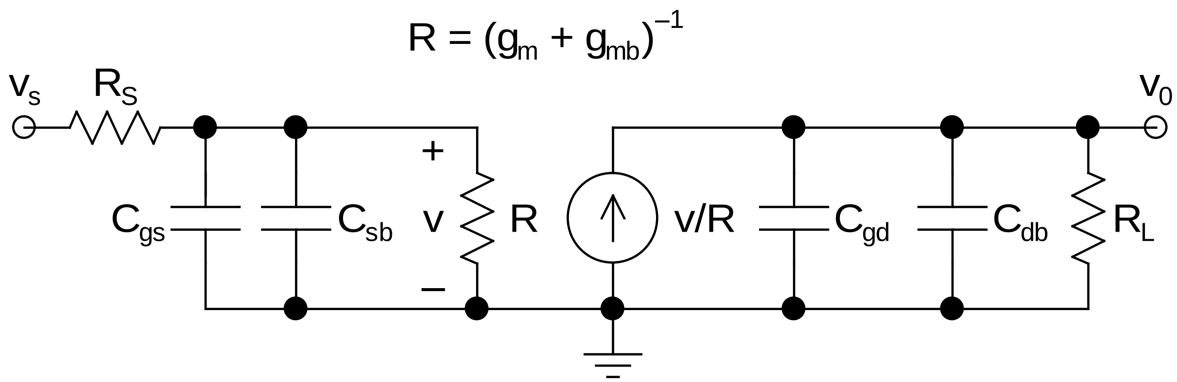
  $$\Rightarrow \tau_{net} = 1.25\ \text{ns} \quad \text{and} \quad f_H = 127.3\ \text{MHz}$$

- ***Note the enormous increase of f_H from about 4 MHz for a CE amplifier***

- ***CG*** :



ac Schematic



High-Frequency Equivalent

- ***Note that all 4 capacitors would be present*** and ***none could be eliminated***

- ***C_{gs} and C_{sb} are in parallel***

  $\Rightarrow$ ***Can be clubbed to a single capacitor*** $C_1 = C_{gs} + C_{sb}$, with time constant τ_1

- Also, ***C_{gd} and C_{db} can be clubbed to another single capacitor*** $C_2 = C_{gd} + C_{db}$, with time constant τ_2

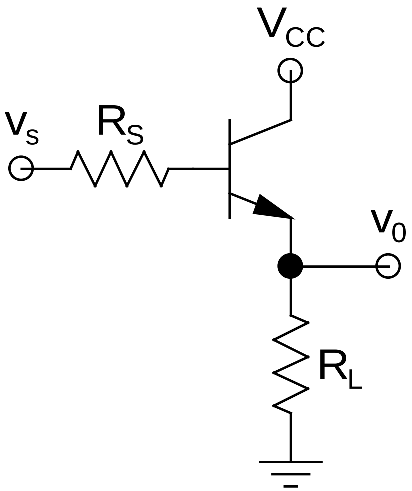
- ***Again note the absence of any input-output coupling capacitor***

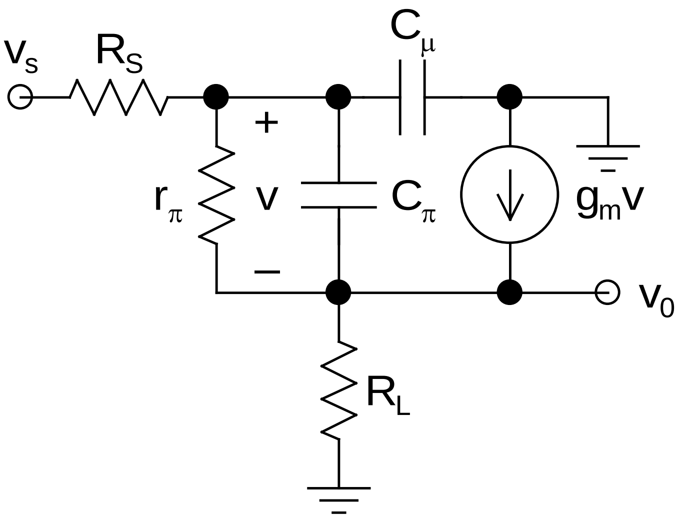
  $\Rightarrow$ ***This circuit should also have very high f_H***

- ***C_1***: $R_1^0 = R_S \| R$ and $\tau_1 = R_1^0 C_1$

- ***C_2***: $R_2^0 = R_L$ and $\tau_2 = R_2^0 C_2$

- ***CC*** :





ac Schematic **High-Frequency Equivalent**

- ➢ ***This circuit is slightly more involved* - *can't be done by inspection***
- ➢ ***But we will have some other Standard Forms***

- This circuit has a ***peculiar frequency response***
  - ***At midband***:

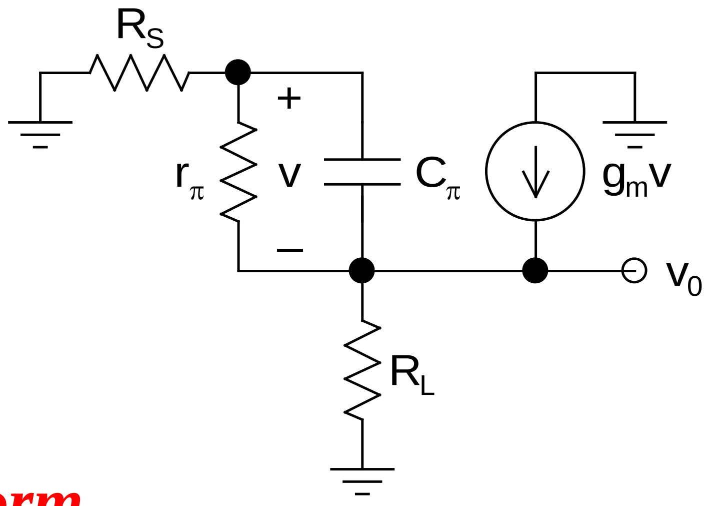
    $A_v = v_0/v_s = [R_L/(R_L + r_E)] \times [R_i/(R_i + R_S)]$

    $R_i = r_\pi + (\beta + 1)R_L$
  - ***Beyond f_H, as $f\uparrow$, reactance of $C_\pi\downarrow$ earlier than that of C_μ*** (***since, in general, $C_\pi >> C_\mu$***)
  - Eventually, ***reactance of C_π would approach zero***, thus ***shorting out r_π***
  - Under this condition, circuit behaves like a ***simple voltage divider*** with a ***gain*** of $R_L/(R_L + R_S)$
  - ***If $f\uparrow$ further***, then ***eventually C_μ also will short out***, and ***v_0 would go to zero***

- Thus, the ***frequency response*** of this circuit looks like a ***staircase***, having ***two steps***

➢ C_π:

- R_π^0 ***can't be obtained by inspection***
- ***Analyze the circuit and show that***:



$$R_\pi^0 = r_\pi \,||\, \left(\frac{R_S + R_L}{1 + g_m R_L} \right)$$

$$\Rightarrow \tau_1 = R_\pi^0 C_\pi$$

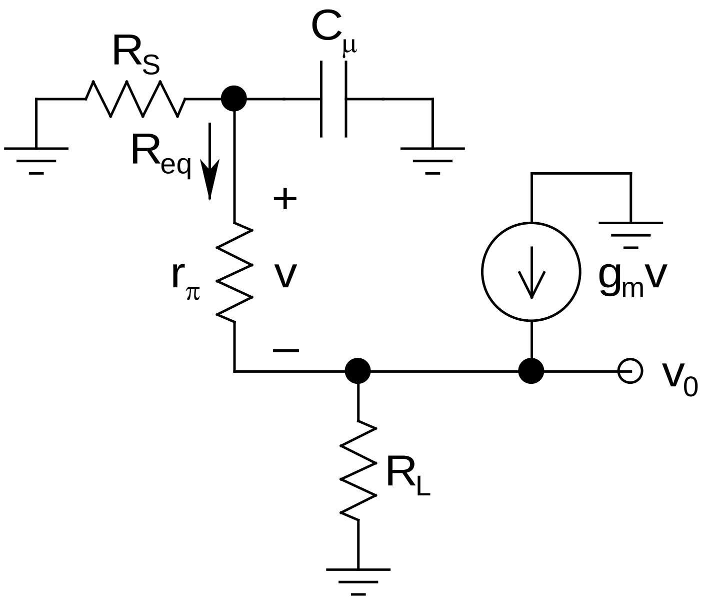
- This is another ***Standard Form*** and the ***topology should be carefully noted***

- C_μ:
  - This is ***relatively straightforward***
  - ***By inspection***:

$$R_{eq} = r_\pi + (\beta + 1) R_L$$

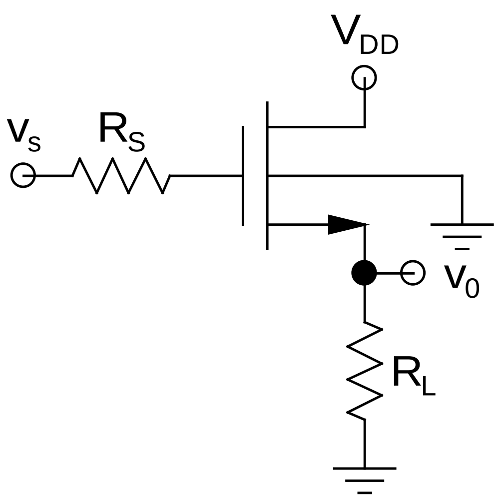
$$R_\mu^0 = R_S \,||\, R_{eq}$$

$$\Rightarrow \tau_2 = R_\mu^0 C_\mu$$

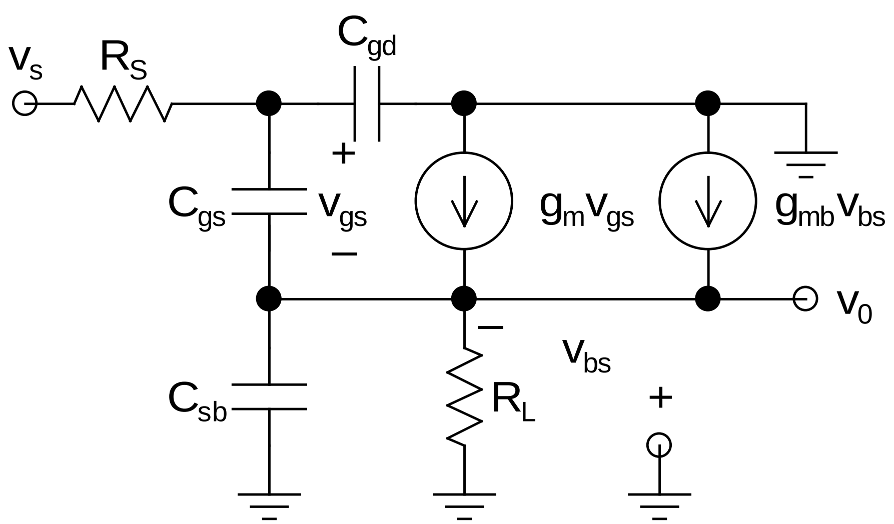


- ***This circuit also has reasonably good frequency response***

- ***CD*** :



ac Schematic



High-Frequency Equivalent

- ***C_{db} absent due to obvious reason***

- $v_{bs} = -v_0$

  $\Rightarrow$ ***$g_{mb}v_{bs}$ is simple a conductance g_{mb}, in parallel with R_L***

  $\Rightarrow$ ***Club them to R*** $[= R_L \| (1/g_{mb})]$

- ***C_{gs}*** :
  - ***Standard Form sans r_π*** (***CC***)

    $$\Rightarrow R_{gs}^0 = \frac{R_S + R}{1 + g_m R}$$

    $$\Rightarrow \tau_1 = R_{gs}^0 C_{gs}$$

- ***C_{gd}*** :
  - ***By inspection***:

    $$R^0_{gd} = R_S$$

    $$\Rightarrow \tau_2 = R^0_{gd} C_{gd}$$

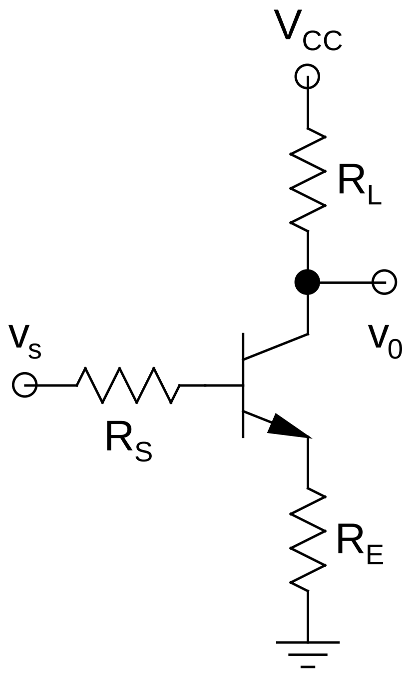
- ***C_{sb}*** :
  - ***By inspection***:

    $$R^0_{sb} = R \,||\, \left(1/g_m\right)$$

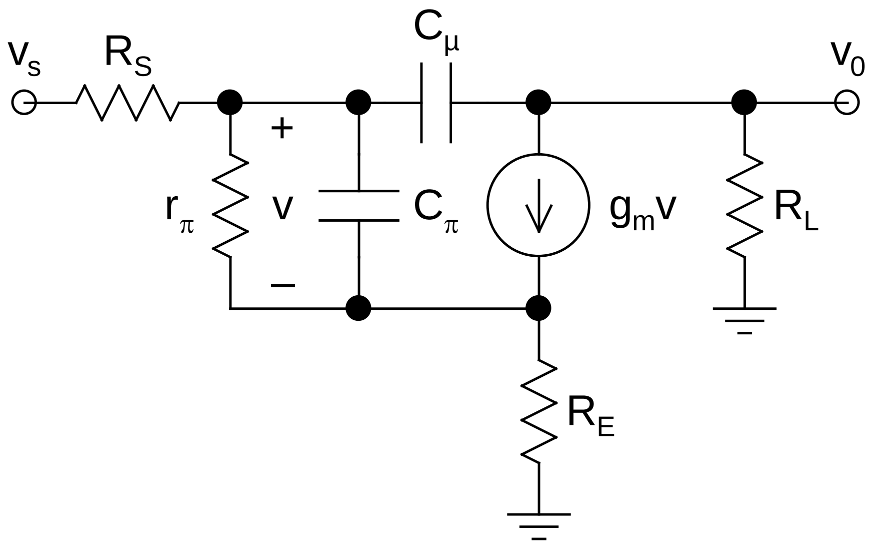
    $$\Rightarrow \tau_3 = R^0_{sb} C_{sb}$$

- ***Loving it*** ? :)

- ***CE(D)*** :



ac Schematic



High-Frequency Equivalent

- ***C_π***:
  - ***Standard Form*** (***similar to CC***, with ***R_L replaced by R_E***)

$$\Rightarrow R_\pi^0 = r_\pi \,||\, \left(\frac{R_S + R_E}{1 + g_m R_E}\right)$$

$$\Rightarrow \tau_1 = R_\pi^0 C_\pi$$

- ***C_μ***:
  - ***Slightly more complicated***
  - ***Remove C_π*** and ***look across 2 terminals of C_μ***
  - ***Can be represented by a 2-port network***

- ***Show that***:

  $R_{eq} = R_S||R_\pi$

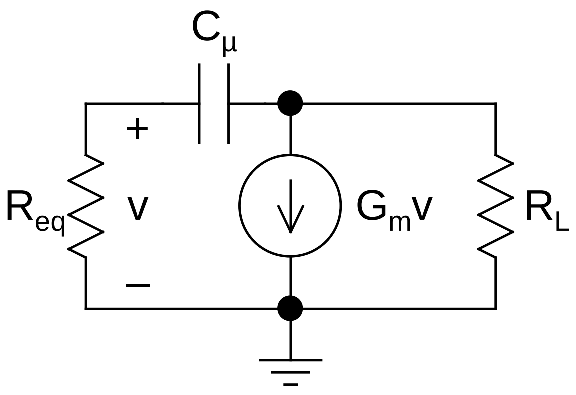
  with $R_\pi = r_\pi(1 + g_m R_E)$

  $G_m = g_m/(1 + g_m R_E)$

- This can be ***easily identified*** as a ***Three-Legged Creature***

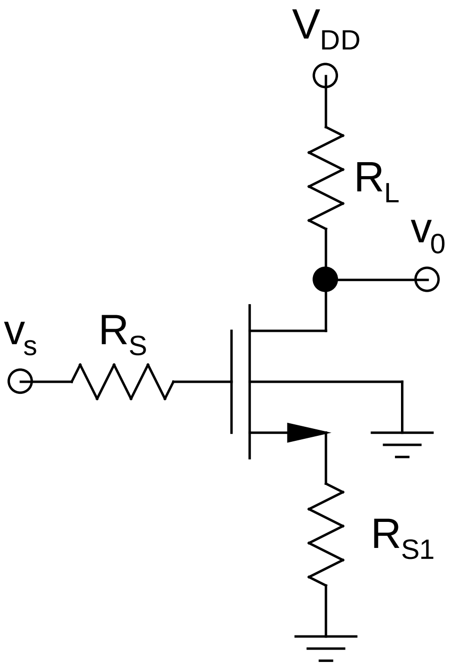
  $$\Rightarrow R_\mu^0 = R_{eq} + R_L + G_m R_{eq} R_L$$

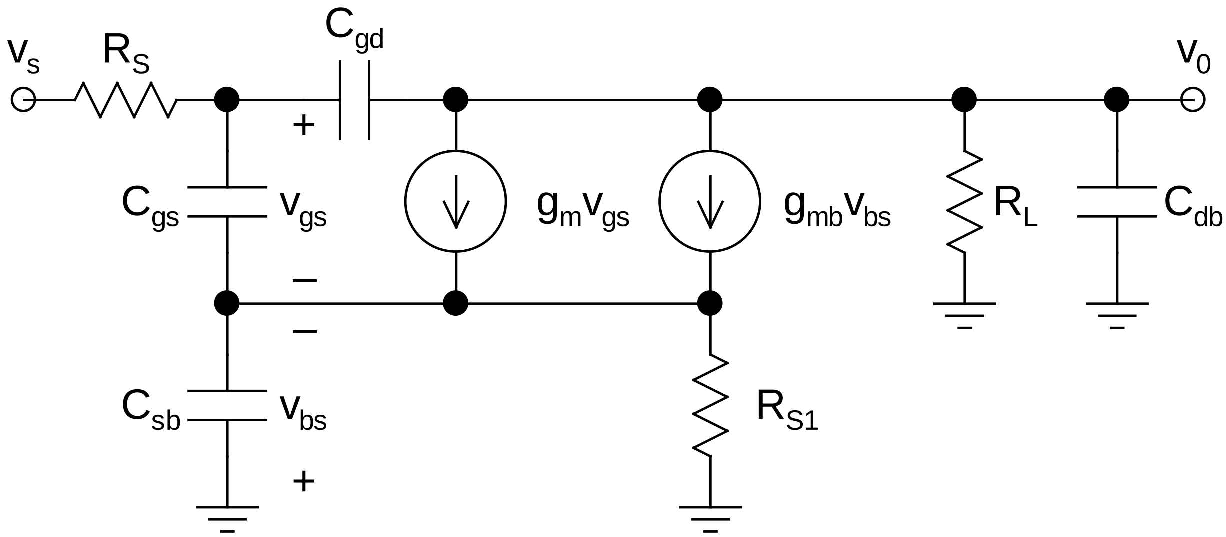
  $$\Rightarrow \tau_2 = R_\mu^0 C_\mu$$



2-Port Representation of a CE(D) Stage

- ***CS(D)*:**

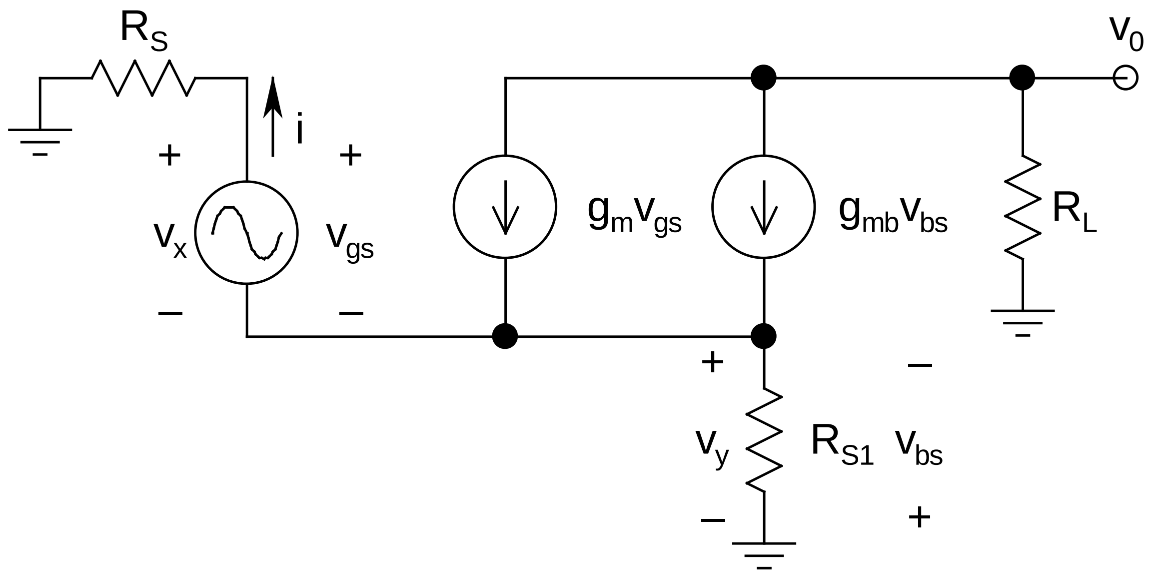




ac Schematic

High-Frequency Equivalent

- ***Inarguably, the most complex module***
  - ***All the capacitors will be present***
  - ***Except C_{db}, none else will have Standard Form***
  - ***Detailed analysis needed for each of them***
- ***C_{gs}:***



- ***Open all other capacitors***
- ***Replace C_{gs} by a voltage source v_x***
- $v_{gs} = v_x$ and $v_{bs} = -v_y$
- $i = (v_x + v_y)/R_S$

  $= g_m v_{gs} + g_{mb} v_{bs} - v_y/R_{S1}$

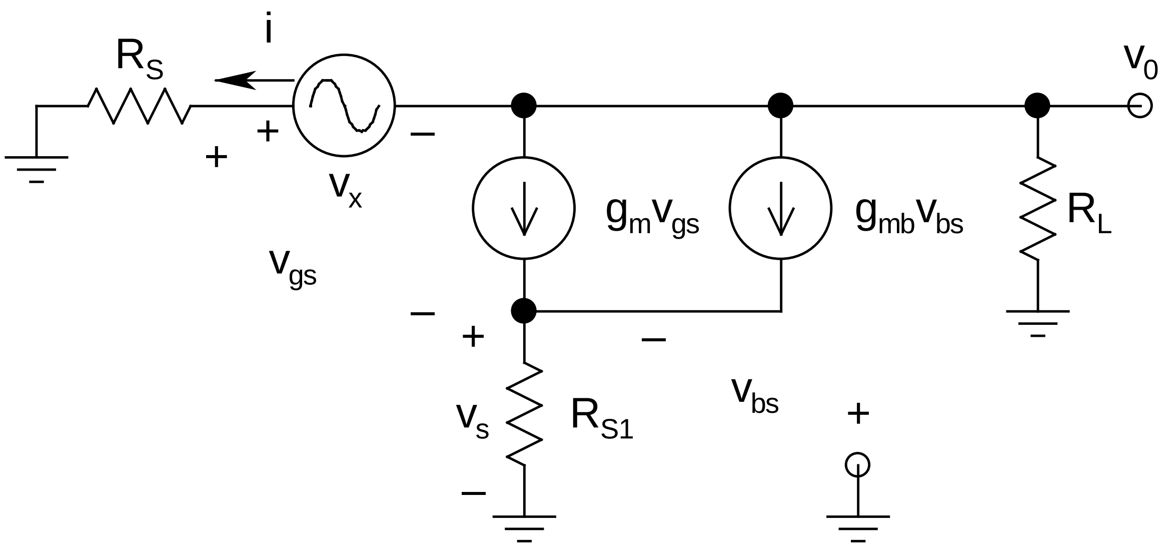
  $= g_m v_x - g_{mb} v_y - v_y/R_{S1}$

  $\Rightarrow v_y = [R_{S1}(g_m R_S - 1)]v_x/(R_{S1} + R_S + g_{mb} R_S R_{S1})$

  $$\Rightarrow R_{gs}^0 = \frac{v_x}{i} = \frac{R_S + R_{S1} + g_{mb} R_S R_{S1}}{1 + \left(g_m + g_{mb}\right) R_{S1}}$$

  $$\Rightarrow \tau_1 = R_{gs}^0 C_{gs}$$
- Note that ***if body effect is neglected*** (***g_{mb} ignored***), then it becomes ***identical to that of a CD stage***

➢ *C_{gd}*:



- ***Open all other capacitors***
- ***Replace C_{gd} by v_x***
- $v_{gs} = (v_0 + v_x - v_s)$ and $v_{bs} = -v_s$

- $i = (v_0 + v_x)/R_S$
- $v_s = (g_m v_{gs} + g_{mb} v_{bs})R_{S1}$

  $\Rightarrow v_s = g_m R_{S1}(v_0 + v_x)/[1 + (g_m + g_{mb})R_{S1}]$
- ***KCL at output node***:

  $i + g_m v_{gs} + g_{mb} v_{bs} + v_0/R_L = 0$
- ***The rest of the process involves huge amount of algebra***!
- ***Finally, if done right*** (***check***!)

$$R_{gd}^0 = \frac{v_x}{i} = R_L \left[1 + g_m R_S + \frac{R_S}{R_L} - \frac{(g_m + g_{mb}) g_m R_S R_{S1}}{1 + (g_m + g_{mb}) R_{S1}} \right]$$

$$\Rightarrow \tau_2 = R_{gd}^0 C_{gd}$$

- ***This is by far the most complicated calculation/expression***
- However, an ***exact analysis*** would have yielded a ***4^{th}-order transfer function*** in ω, which had to be ***solved*** to get the ***individual poles***
- ***This is still simpler than that*** :)

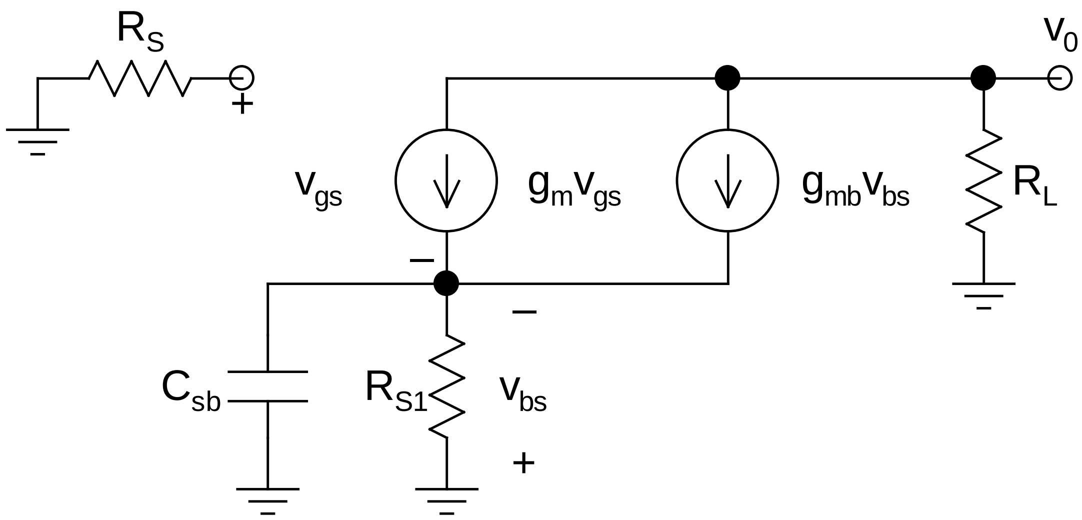
➢ ***C_{db}***:

- ***The easiest of the lot***
- ***By inspection***:

$$R_{db}^{0} = R_L$$

$$\Rightarrow \tau_3 = R_{db}^{0} C_{db}$$

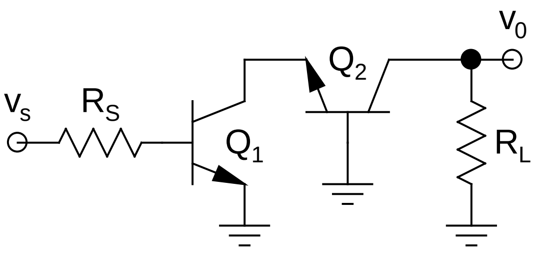
➢ C_{sb}:



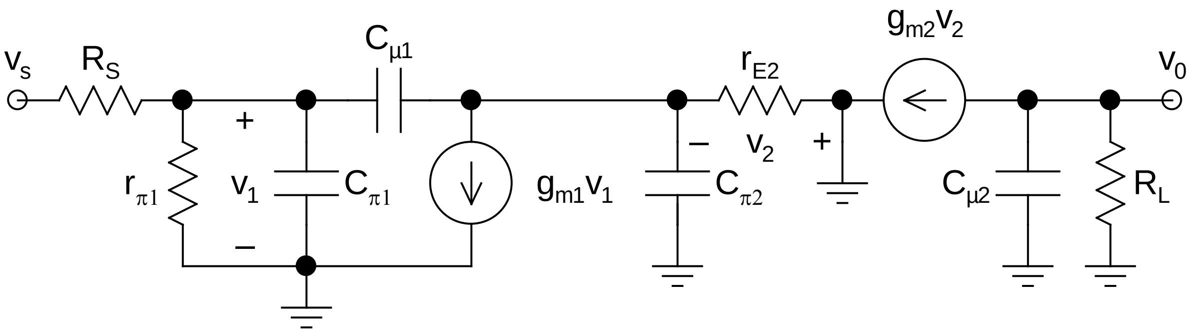
- ***Analysis of this circuit is pretty straightforward***

$$R_{sb}^{0} = \frac{R_{S1}}{1+\left(g_m + g_{mb}\right)R_{S1}} \quad \Rightarrow \quad \tau_4 = R_{sb}^{0} C_{sb}$$

- ***npn Cascode***:



ac Schematic



High-Frequency Equivalent

- ***Looks intimidating***, but ***extremely easy to solve*** (***just by inspection***)
- Also known as ***Wideband*** (or ***Broadband***) ***Amplifier*** due to its ***superb frequency response***