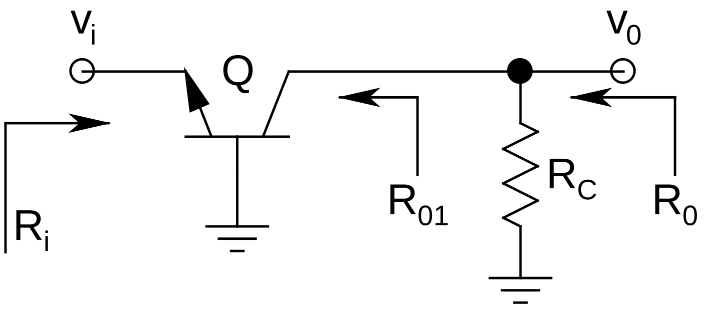
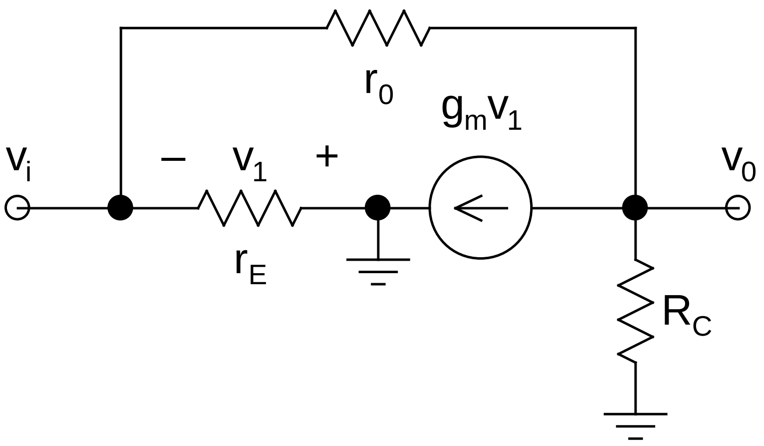
- ***Common-Base*** (CB):



ac Schematic



ac Low-Frequency Equivalent

- Note that the ***alternate hybrid-π model appropriate for CB circuit*** has been used
- ***r_0 appears between input and output***

- For now, ***neglect r_0***
- Noting that $v_1 = -v_i$:

$$A_v = \frac{v_0}{v_i} = \frac{-g_m v_1 R_C}{v_i} = +g_m R_C \simeq \frac{R_C}{r_E}$$

- Note that the ***expression*** for A_v is ***identical*** to that for the ***CE stage***, ***without the negative sign in front***
- For this circuit, ***input and output are in phase***
- $A_i = i_c/i_e = \alpha$
- $R_i = r_E$

- $R_0 = R_{01} || R_C$

  $R_{01} \rightarrow \infty$ (Why?)

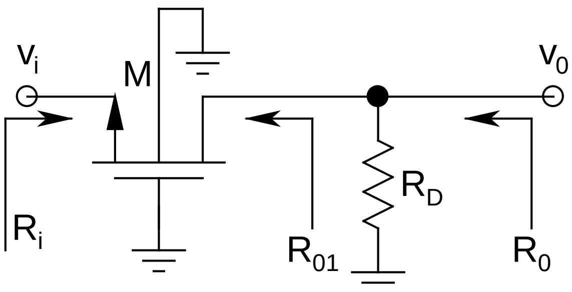
  $\Rightarrow R_0 = R_C$

- ***Ex.:*** ***Find A_v and R_i with r_0 included***

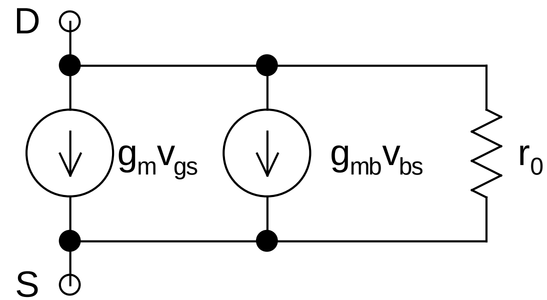
- ***With r_0 included***, the circuit shows ***two different values*** of R_{01}:
  - ***When excited by a voltage source***, $R_{01} = r_0$
  - ***When excited by a current source***, $R_{01} = \beta r_0$ (***Show***)

    [***Hint***: ***For this derivation, need to use $g_m r_E = \alpha$***]
  - ***Thus, possibility of huge R_0 under the second case, but R_C ruins it***!

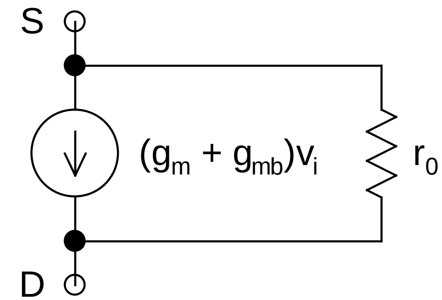
- ***Common-Gate*** (CG):



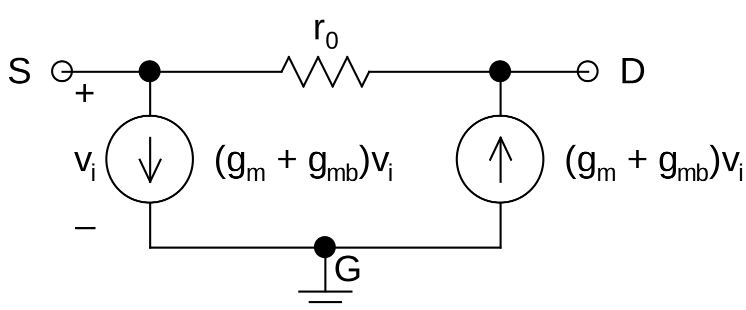
ac Schematic



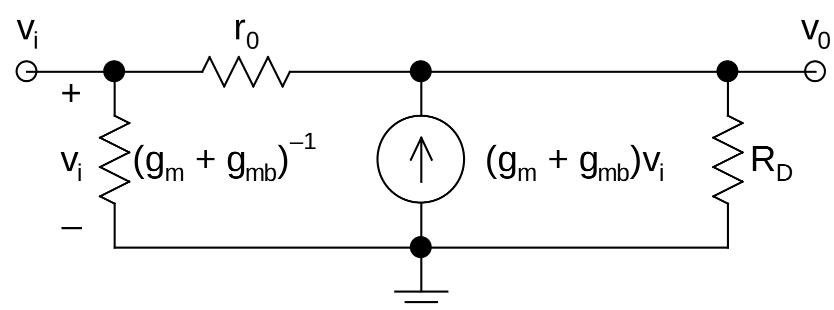
ac Low-Frequency Model for M



Simplified ac Low-Frequency Model for M



Rerouting the current source between S and D to S to G and then from G to D



Final ac Low-Frequency Equivalent for CG Stage

- ***G and B both ground***:

  $\Rightarrow v_{gs} = v_{bs} = -v_i$

  $\Rightarrow g_m v_{gs}$ and $g_{mb} v_{bs}$ can be ***combined to a single current source*** $(g_m + g_{mb})v_i$, ***flowing from S to D***

- ***Reroute this current source from S to G and then from G to D*** (***the circuit remains invariant***)

  $\Rightarrow$Leads to the ***final ac low-frequency equivalent*** of the CG stage

- ***Note again that*** r_0 ***appears between input and output*** (***similar to CB stage***)

- ***Neglect r_0 for now***
- Noting that $v_1 = v_i$:

$$A_v = \frac{v_0}{v_i} = \frac{\left(g_m + g_{mb}\right) v_1 R_D}{v_i} = +\left(g_m + g_{mb}\right) R_D$$

- ***Identical result to a CB stage***, if ***body effect is neglected***
- $R_i = (g_m + g_{mb})^{-1}$
- $R_0 = R_{01} || R_D$

  $R_{01} \rightarrow \infty$ (***Why***?)

  $\Rightarrow R_0 = R_D$

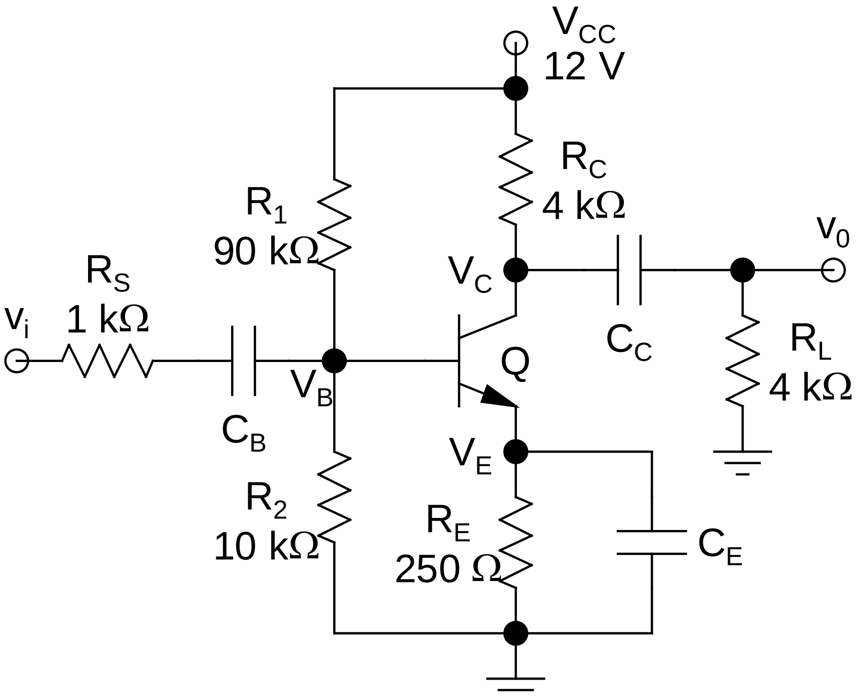
- ***Ex.:*** ***Find A_v and R_i with r_0 included***
- ***With r_0 included***, the circuit shows ***three different values*** of R_{01}:
  - ***When excited by a voltage source***, $R_{01} = r_0$
  - ***When excited by an ideal current source***, $R_{01} \to \infty$ (***Show***)
  - ***If the current source is non-ideal with shunt resistance R_S***:

    $R_{01} = r_0[1 + (g_m + g_{mb})R_S]$ (***Show***)

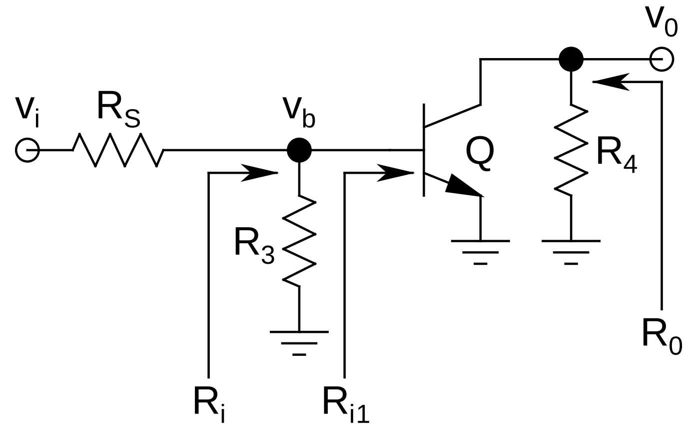
Quick Reckoner for BJT Stages

Topology	A_v	A_i	PG	R_i	R_0
CE	Moderate to Large	Large	Large	Moderate	Moderate
CC	≤ 1	Large	Moderate	Large	Small
CB	Moderate to Large	≤ 1	Moderate	Small	Moderate
CE(D)	Low to Moderate	Large	Moderate	Large	Moderate

- ***The RC-Coupled Amplifier***:
  - ***Immensely popular***, particularly for ***audio circuits***
  - Can be designed to produce ***significant power gain***
  - Several such stages can be ***cascaded*** to produce ***very large gain***
  - Can be used either with ***single-supply*** or ***dual-supply***
  - Used primarily in ***discrete designs*** (***PCB***)



Complete Circuit



ac Schematic

C_B: Base Blocking Capacitor, C_C: Collector Coupling Capacitor
C_E: Emitter Bypass Capacitor, R_S: Source Resistance, R_L: Load Resistance

- C_B,C_C: Used for ***DC isolation*** of the ***bias circuit*** from ***the source and the load***
  - ***DC biasing becomes independent of source and load***
- C_E: ***Plays no role in DC*** (***opens up***), but ***shorts out R_E in ac*** (will see its effects later)
- These 3 capacitors dictate the ***lower cutoff frequency*** (f_L) of the circuit
- Typically have values in the order of ***μF to 100s of μF*** in order to give ***f_L as close to 0*** (***DC***) as possible

- First need to do the ***DC analysis*** to find the ***operating point***
- ***All capacitors open up for DC analysis***
  - ***R_S and R_L play no role***
- ***Neglecting base current***:

$$V_B = V_{CC}R_2/(R_1 + R_2) = 1.2\ \text{V}$$

$$\Rightarrow V_E = V_B - V_{BE} = 0.5\ \text{V}$$

$$\Rightarrow I_E \approx I_C = V_E/R_E = 2\ \text{mA}$$

$$V_C = V_{CC} - I_C R_C = 4\ \text{V}$$

$V_{CE} = 3.5$ V (***quite close to $V_{CC}/3$***)

- ***DC bias point analysis done***!

- Now we can move on to the ***ac analysis***
- ***All capacitors get shorted*** due to their ***high values***, assuming ***frequency of operation*** is ***beyond f_L*** and ***less than f_H***, i.e., ***midband range***
- ***C_E bypasses R_E***

  $\Rightarrow$ ***Emitter of Q goes to ground***

  $\Rightarrow$ ***R_E plays no role in ac analysis***
- ***Refer to the ac schematic***
  - $R_3 = R_1||R_2 = 9\ k\Omega$
  - $R_4 = R_C||R_L = 2\ k\Omega$
- ***Need β for ac analysis*** (***choose 100***)