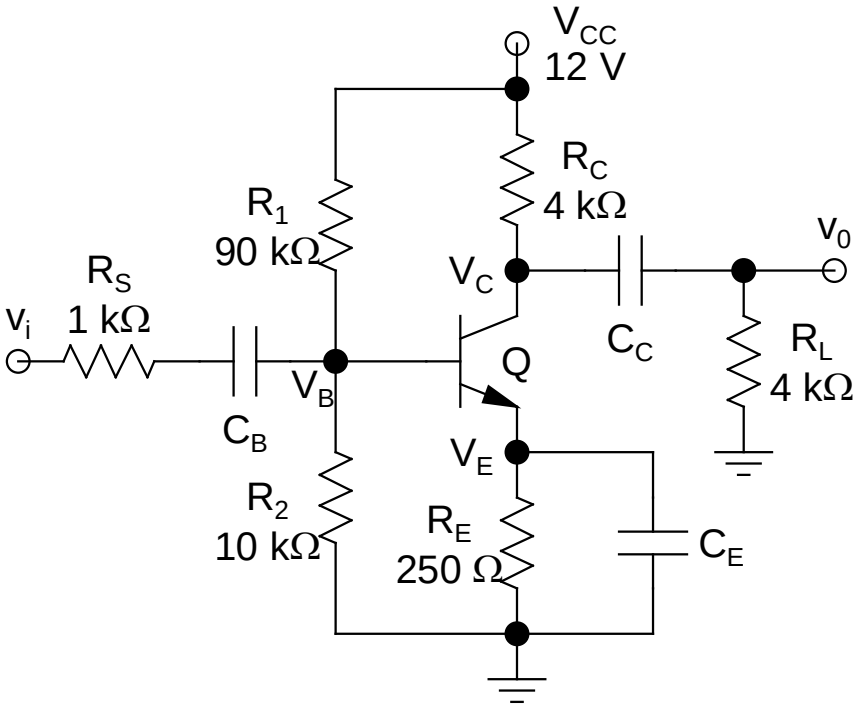
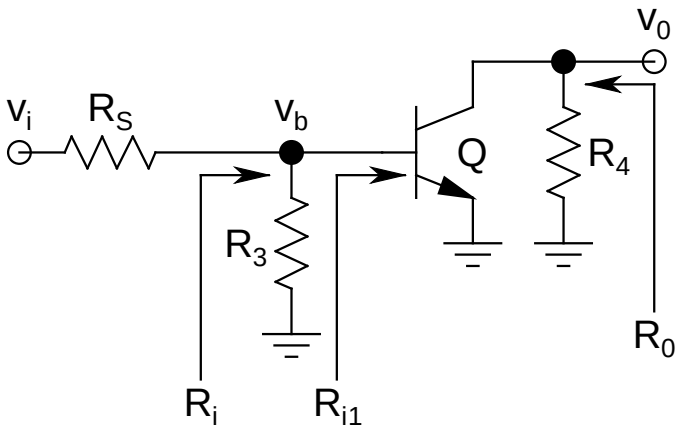


Complete Circuit



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***:

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

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

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

$V_C = V_{CC} - I_C R_C = 4$ 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***)

- $r_E = V_T/I_C = 13\ \Omega$, and $r_\pi = \beta r_E = 1.3\ k\Omega$
- $R_{i1} = r_\pi = 1.3\ k\Omega$
- $R_i = R_{i1} \| R_3 = 1.14\ k\Omega$
- Total resistance ***seen*** by $v_i = R_S + R_i = 2.14\ k\Omega$
- For calculation of ***voltage gain*** A_v, apply ***chain rule***:

$A_v = v_0/v_i = (v_0/v_b) \times (v_b/v_i)$

$v_0/v_b = -R_4/r_E = -153.85$ (***CE stage***)

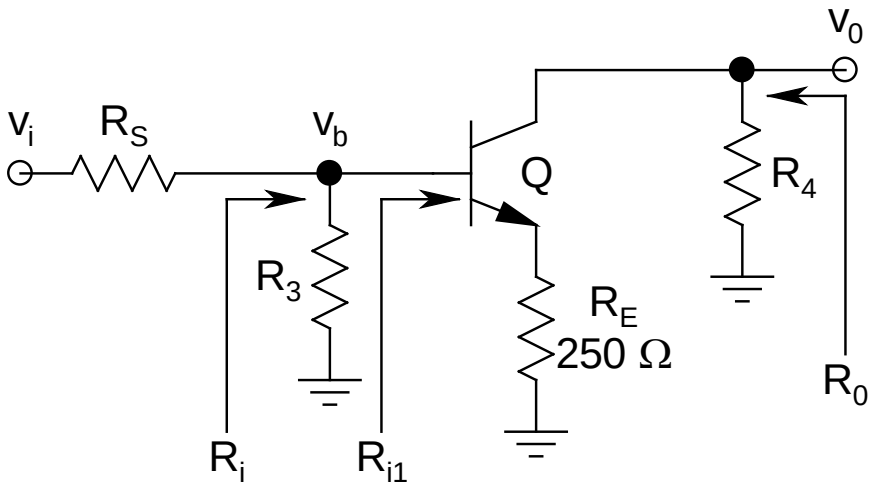
$v_b/v_i = R_i/(R_i + R_S) = 0.533$

$\Rightarrow A_v = -82$ (***Very Good Gain***!)

- Note that v_i and v_0 are ***exactly out of phase***, which is expected from a ***CE stage***
- $R_0 = r_0 \| R_4 \approx R_4 = 2\ k\Omega$

  (since for ***discrete circuits***, r_0 is generally ***neglected***)
- ***This completes the analysis of the stage***
- ***Summary***:
  - $A_v = -82$
  - $R_i = 1.14\ k\Omega$
  - Resistance ***seen*** by $v_i = 2.14\ k\Omega$
  - $R_0 = 2\ k\Omega$

- Now let's explore what happens if ***C_E were absent***, i.e., ***R_E unbypassed***
- Redraw the ***ac schematic***:

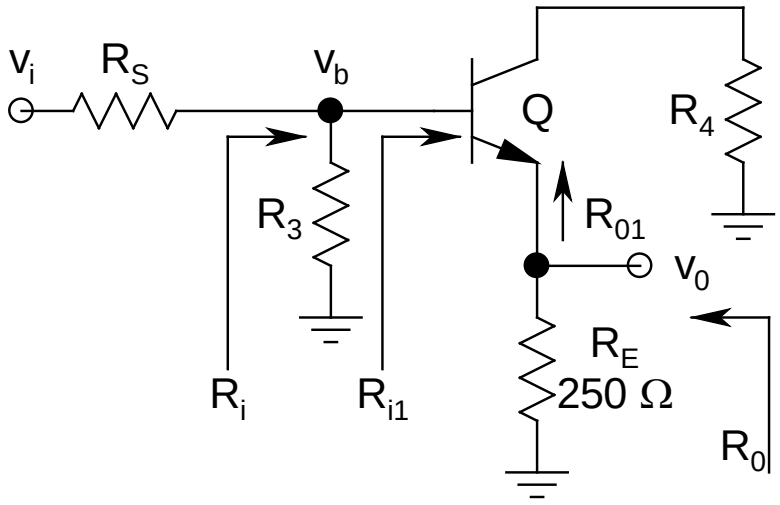


ac Schematic for R_E unbypassed

- ***Note***: ***Degeneration Factor*** = $(1 + g_m R_E) \approx (1 + R_E/r_E) = 20.23$
- $R_{i1} = r_\pi + (\beta + 1)R_E = 26.55\ k\Omega$
  - ***Exactly 20.23 times of the previous case*** (1.3 kΩ)
- $R_i = R_{i1} \| R_3 = 6.72\ k\Omega$
- Total resistance ***seen*** by $v_i = R_S + R_i = 7.72\ k\Omega$
- $v_0/v_b = -R_4/(r_E + R_E) = -7.6$ [***CE(D) Stage***]
  - ***Reduced by exactly 20.23 times of the previous case*** (– 153.85)
- $v_b/v_i = R_i/(R_i + R_S) = 0.87$
  - ***Improvement as compared to previous case*** (0.533)

- $A_v = -6.6$
  - ***Compare with −82 obtained in previous case*** (***significant reduction***)
- $R_0 \approx R_4 = 2\ k\Omega$ (***if r_0 is neglected***)
- ***If r_0 is considered, analysis becomes significantly complicated, since the Golden Rule can't be applied due to the presence of resistance (apart from r_π) in the base of Q***
- ***Summary***:
  - $A_v = -6.6$
  - $R_i = 6.72\ k\Omega$
  - Resistance ***seen*** by $v_i = 7.72\ k\Omega$
  - $R_0 = 2\ k\Omega$

- ***What if the output is taken from emitter***?
- Redraw the ***ac schematic***:



ac Schematic for Output Taken from Emitter

- ***R_4 actually redundant for this case*** (***collector of Q could have been connected to V_{CC} directly***)
- R_{i1} = 26.55 kΩ, R_i = 6.72 kΩ, and resistance ***seen*** by v_i = 7.72 kΩ (***same as before***)
- $v_0/v_b = R_E/(r_E + R_E) = 0.95$ (***CC Stage***)
- $v_b/v_i = R_i/(R_i + R_S) = 0.87$ (***same as before***)
- A_v = 0.827 (<1, as expected, but ***could have been made closer to unity by better design***!)
- $R_0 = R_E \| R_{01}$
- ***Computation of R_{01} is slightly more involved, but quite easy if the trick is understood***!

- ***First, short v_i to ground***

  $\Rightarrow$ ***R_3 comes in parallel with R_S (call this combination R_5)***

  $\Rightarrow R_5 = R_3 \| R_S = 900\ \Omega$

- ***R_5 comes in series with r_π (call this combination R_6)***

  $\Rightarrow R_6 = R_5 + r_\pi = 2.2\ k\Omega$

- ***Transform R_6 to emitter by dividing it by (β +1)***

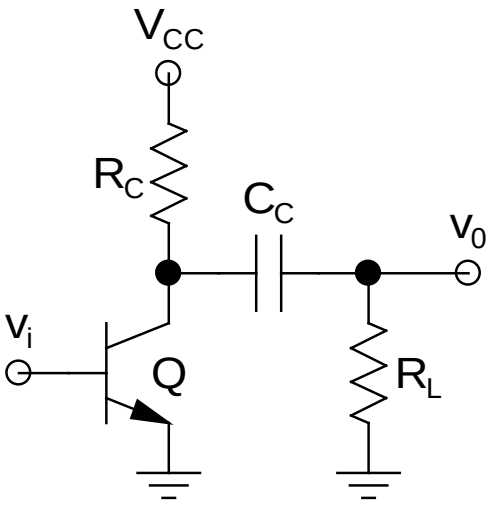
  $\Rightarrow R_{01} = R_6/(\beta + 1) = 21.8\ \Omega$

- Thus, $R_0 = 20\ \Omega$ (***Easy***?)
- ***Summary***:
  - $A_v = 0.827$
  - $R_i = 6.72\ k\Omega$
  - Resistance ***seen*** by $v_i = 7.72\ k\Omega$
  - $R_0 = 20\ \Omega$
- Thus, this circuit has ***voltage gain close to unity***, ***ok input resistance***, and ***very small output resistance***
  - ***Ideal characteristics*** needed for a ***Buffer***/***Isolator***/ ***Impedance Matcher***

- ***Loading Effect***:
  - ***Neglecting r_0***:

    $A_v = -g_m(R_C \| R_L)$

  - ***R_L has no role in DC biasing, but comes into picture in ac calculations***



  - As $R_L \downarrow \Rightarrow |A_v| \downarrow$
    - Known as ***Loading Effect***
  - Similar situation happens when a ***high output resistance driver*** drives a ***low input resistance load*** (e.g., ***CE stage driving a CB stage***)

- The ***gain of the CE stage*** will be ***severely compromised*** due to ***low input resistance*** of the ***CB stage***
  - Known as ***Impedance Mismatch*** between ***Driver and Load***
- Under such a situation, need an ***Isolator***/***Buffer***/ ***Impedance Matcher*** between the two stages
- A ***CC stage perfectly fits the bill*** due to its ***high input resistance*** and ***low output resistance***, and ***can be used to couple the CE stage to CB stage***
- ***MOS circuits generally don't have this problem***