BJT Examples

For each of the following single-stage BJT amplifier circuits, specify or determine the following:

1) What kind of amplifier is it?
2) Derive the expression for the dc bias current, \( I_E \)
3) Draw the small-signal model
4) Determine \( \frac{\Delta A}{\Delta V} = \frac{\Delta I}{\Delta V} \), \( A_i \), \( R_{in} \), and \( R_{out} \).

Make a table of your results:

| Type (Example)          | \( \frac{\alpha R_c || R_L}{R_{\pi} + R_c} \) | \( \frac{\alpha R_c}{R_c + R_L} \) | \( \frac{R_{\pi}}{\beta + 1} \) | \( R_c \) |
|-------------------------|---------------------------------|---------------------------------|---------------------------------|----------|
| Common-Base             | \( \frac{\alpha R_c || R_L}{R_{\pi} + R_c} \) | \( \frac{\alpha R_c}{R_c + R_L} \) | \( \frac{R_{\pi}}{\beta + 1} \) | \( R_c \) |
| Common-Emitter          | \( \frac{-\beta R_c || R_L}{R_{\pi} R_c + R_{\pi} R_L} \) | \( \frac{-\beta R_c}{R_{\pi} R_c + R_{\pi} R_L} \) | \( R_{\pi} || R_c \) | \( R_{\pi} || R_c \) |
| Common-Collector or     | See soln.                        | See soln.                       | See soln.                       | See soln.|
| Common-Follower         | \( \approx 1 \)                  | \( \approx (\beta + 1) \)       | \( \approx (\beta + 1) \)       | \( \approx (\beta + 1) \) |
| Common-Emitter resistor in | \( \frac{-\beta (R_c || R_L)}{R_e + R_{in}} \) | \( \frac{-\beta R_c}{R_e + R_L} \) | \( R_{\pi} + (\beta + 1) R_e \) | \( R_c \) |

Make comparisons between the different types based on your results and typical small-signal parameter values and resistor values. Although the biasing circuits are not the same, we can gain some general insights.

5) Is the voltage gain low or high?
6) Is the current gain low or high?
7) Is the input impedance low, moderate, or high? Or what does it depend on?
8) Is the output impedance low, moderate, or high? Or what does it depend on?
9) Is the amplifier inverting or non-inverting?

Note: Sect 4.11 does a comparison of all 4 configurations using the same biasing circuit.
Example 1

1. Common Base
2. \( I_e = \tau \)
3. \( V_{CC} \)
4. \( R_{in} = \frac{\frac{\alpha}{\beta+1}}{} \)
5. \( R_{out} = R_c \)
6. \( A_v = \frac{V_o}{V_s} = \frac{V_o}{V_{be}} \cdot (-g_m R_e / R_c) \left( \frac{-\frac{\alpha}{\beta+1}}{\frac{\alpha}{\beta+1} + R_s} \right) = \frac{\alpha R_e / R_c}{\frac{\alpha}{\beta+1} + R_s} \)
7. \( A_i = \frac{I_o}{I_i} = \frac{V_o / R_L}{V_s / (R_s + R_c)} = \frac{V_o}{V_s} \cdot \frac{R_c + \frac{\alpha}{\beta+1}}{R_L} = \frac{\alpha R_e}{R_c + R_L} \)
8. Vel. gain depends on Curricula: \( R_c \)
9. If \( R_c \) is considered as part of load so that \( R_c' = R_c / R_L \) and \( I_o \) is through \( R_c' \), or if \( R_c \) is much larger than \( R_L \), then current gain \( \approx 1 \)
10. Low input impedance
11. Output impedance depends on \( R_c \)
12. Non-inverting
Example 2

1. Common Emitter
2. \[ I_E = \frac{V_{EE} - V_{BE}}{R_E + \frac{R_B}{(s+1)}} \]
3. \[ \text{Common Base} \]
4. \[ R_{in} = R_E//R_T \]
   \[ R_{out} = \beta R_C \]
   \[ A_V = \frac{V_o}{V_s} = -g_m \frac{(R_0//R_C)}{R_L} \]
   \[ A_I = \frac{i_o}{i_c} = \frac{V_o}{V_s} \frac{R_E}{R_L} = \frac{V_o}{V_s} \frac{(R_0//R_T)}{R_L} = -g_m \frac{(R_0//R_C)}{R_L} \cdot \frac{R_0//R_T}{R_L} = -\beta \frac{R_0//R_C}{R_0//R_C + R_L} \cdot \frac{R_0}{R_0 + R_T} \]
5. High voltage gain
6. High current gain
7. Intermediate input impedance
8. High output impedance (since \( R_C \) would be as large as possible for high \( A_V \))
9. Inverting
Example 3

1. Common-Collector (or Emitter-Follower)

2. \[ I_E = \frac{V_{2E} - V_{2E}}{R_E + \frac{R_E}{(B+1)}} \]

3. \[ R_{in} = \frac{R_E \| R_2 \| [R_T + (B+1)(R_E \| R_L)]}{B+1} \]

4. \[ R_{out} = \frac{g_{m} \| R_E \| [R_T + \frac{R_E \| R_L}{B+1}]}{B+1} \]

5. \[ A_v = \frac{V_o}{V_i} = \frac{V_o}{V_i} \quad A_i = \frac{I_o}{I_i} = \frac{V_o/RL}{V_i/(Rs \cdot R_i)} = \frac{R_i \| R_E \| R_L}{[R_i \| R_E \| R_L + \frac{R_L}{B+1}]} R_L \]

Note: if \( R_o \ll R_L, R_E \ll R_L, \) and \( R_i \ll R_2 \) is large, then \( R_{in} \approx R_T + 1 + R_L + U_L, \) and \( A_i \approx \beta + 1 \)
Example 4

1. Common-nothing OR
   Common-Emitter w/reaction in emitter

2. \( I_E = I \)

3. \( \frac{R_s}{V_T} \)

4. \( R_{in} = r_T + (\beta + 1)R_E \)
   \( R_{out} = R_C \)

5. \( A_V = \frac{v_o}{v_s} = \frac{I_b}{I_b} = -\beta \left( \frac{R_C || R_L}{R_s + R_{in}} \right) \left( \frac{1}{R_s + R_{in}} \right) = -\frac{\beta (R_C || R_L)}{R_s + R_T + (\beta + 1)R_E} \)

6. \( A_I = \frac{i_o}{i_i} = \frac{v_0}{v_s} \frac{R_L}{R_s + R_{in}} = -\frac{\beta (R_C || R_L)}{R_L} = -\frac{\beta R_C}{R_C + R_L} \)

5. \( R_E \) would effectively reduce the volt.gain compared to CE, but still a large gain
6. High current gain
7. Relatively high compared to CE due to \( R_E \)
8. Depends on \( R_C \) (will be large if \( R_C \) is made large to achieve high \( A_V \))
9. Inverting