Stage with *Common Emitter*

- High Voltage gain $A_V$
- High Current gain $A_I$
- Inverting: $\Delta \phi = 180^\circ$
- Low $R_{\text{in}} \approx r_\pi$
- High $R_{\text{out}} \approx (r_o \parallel R_C)$
Stage with *Common Collector*

- Suitable as a *current buffer*

\[ V_{in} = V_{BE} + V_E = i_B r_\pi + (i_B + i_C) R_E = i_B [r_\pi + (1+\beta)R_E] \approx i_B \beta R_E \]

- High input resistance \( R_{in} = V_{in}/i_B \approx \beta R_E \)

- Low output resistance \( R_{out} \)

- No Voltage gain \( A_V \approx 1 \)
Stage with *Common Base*

- **High bandwidth** of voltage gain
- Low input resistance $R_{in} \approx r_\pi$
- High output resistance $R_{out} \approx (r_o \parallel R_C)$
- Inverting: $\Delta \varphi = 180^\circ$
- No Current Gain: $\alpha = \Delta i_C / \Delta i_E \leq 1$

\[
\alpha = \frac{\beta}{\beta + 1} \approx 1
\]
Load line and Q-point of the gain stage

\[ V_{CE} = V_{CC} - i_C R_C \]

- The load line can be determined using two points:
  1) \( V_{CE} = V_{CC} \) at \( i_C = 0 \)
  2) \( i_C = V_{CC}/R_C \) at \( V_{CE} = 0 \)

- Quiescent (or Q) point is the intersection of the load line with the corresponding output characteristic
- The slope of the load line equals \( 1/R_C \)
- Setting the Q-point in the middle of the load line allows to obtain the maximum swing of output signal
The load line defines the relationship between the variation of $i_B$ and the variation of $V_{BE}$. 

- $i_C$ (mA)
- $V_{CE}$ (V)
- $\Delta i_B$
- $\Delta V_{CE}$

- $30 \mu A$
- $20 \mu A$
- $10 \mu A$
Optimization of the $Q$-point

- The maximum undistorted swing of the output voltage depends on the position of $Q$-point

1) Optimum $Q$

2) $Q_1$ or $Q_2$
The desirable operating point is $V_{CE} \approx V_{CC}/2$
Load line and $Q$-point for AC signal

- If capacitor $C_E$ is in parallel to $R_E$, the AC load line is

$$V_{CE} = V^* - i_C R_C$$

- $Q$-point is the same for DC and AC load lines

- $V^* = V_{CC} - i_{CQ} R_E$, $i_{CQ}$ - the current corresponding to Q-point
Properties of BJT at High Frequencies

- At high frequencies the gain is mainly limited by the diffusion time $\tau_D$ of minor carriers through the base.

\[ f_T \approx \frac{1}{2\pi\tau_D} \]

- Cut-off frequency $f_T$ corresponds to unity gain $\beta = 1$.

- Gain-bandwidth product $\beta \cdot \Delta f = f_T$ allows to estimate the number of stages to obtain the required gain in the specified bandwidth.