Transistors applications: AC amplifiers

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Lecture 07

Summary of simple emitter follower

Advantages
- input impedance increase $Z_{in} = \beta R_e$
- power/current gain
- output does not depend on $\beta$
- simple

Disadvantages
- input signal must be positive
- even more it should be above 0.6 V
- no voltage gain

Real life signal

In real life signals usually swing around zero.
Real life signal

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We need to do something with our simple emitter follower.

Solution 1: Push-Pull follower
Solution 2: AC-coupled biased-amplifier

NPN and PNP emitter follower

Notes
NPN and PNP emitter follower

NPN emitter follower

\[ V_{cc} \]

[\text{R}]

\[ V_{in} \]

\[ V_{out} \]

\[ V_0 - 0.6 \]

\[ t \]

\[ V_{in}(t) \]

\[ V_{out}(t) \]

PNP emitter follower

\[ -V_{ee} \]

[\text{R}]

\[ V_{in} \]

\[ V_{out} \]

\[ -V_0 + 0.6 \]

\[ t \]

\[ V_{in}(t) \]

\[ V_{out}(t) \]

Push-Pull emitter follower

\[ V_{cc} \]

[\text{R}]

\[ V_{in} \]

\[ V_{out} \]

\[ V_0 - 0.6 \]

\[ t \]

\[ V_{in}(t) \]

\[ V_{out}(t) \]
Push-Pull emitter follower

![Push-Pull emitter follower circuit diagram]

Notes

Push-Pull follower crossovers

![Push-Pull follower crossovers diagram]

Notes

Notes
Push-Pull emitter follower improved

Design rules
- Maximum output swing
  - \( V_e = \frac{V_{cc}}{2} \)
- Disregarding \( V_{be} = 0.6 \text{ V} \)
  - \( V_b = \frac{V_c}{2} \)
  - Thus \( R_1 = R_2 \)
- Quiescent current \( I_q = \frac{V_c}{R_e} \)
- We want \( I_{R1+R2} \gg I_b \)
  - Factor of 10 for a safe margin
  - \( I_{R1+R2} \geq 10I_b = 10I_e/\beta \)
  - Thus \( R_1 = R_2 \leq R_e \beta/10 \)

AC-coupled emitter follower

Notes
From AC point of view
- Input is RC high-pass
  - \(C = C_1\)
  - \(R = R_1 (|R_2| + |R_6|)\)
  - \(f_{ab} = \frac{1}{2 \pi R C}\)
    - with above rules \(R \approx R_1 / 2\)

- Output is also RC high-pass
  - \(C = C_2\)
  - \(R = R_6\)
  - \(f_{ab} = \frac{1}{2 \pi R C}\)
    - for unloaded filter \(R_L \gg R_6\)
      - factor of 10 for a safe margin
      - \(R_L = 10 R_6\)

Common emitter (inverting) amplifier

Notes

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Common emitter (inverting) amplifier

- $I_C = I_B = (V_{IN} - 0.6V) / R_E$
- $V_{OUT} = V_{CC} - I_C R_C$
- $V_{OUT} = V_{CC} - R_E (V_{IN} - 0.6V) / R_E$
- $V_{OUT} = (V_{CC} + (0.6V) R_C / R_E) - V_B R_C / R_E$
- gain $G = -R_C / R_E$
- attractive to put $R_E = 0$
- transistor model fails
- transistor emitter resistance $r_e = 25mV / I_C$
- gain $G = -R_C / r_e$

Notes

Common emitter amplifier signal output impedance

In the pass band we can neglect capacitors

$V_{OUT} = V_{CC} - I_C R_C = V_{CC} - (I_B + I_L) R_C$

$= (V_{CC} - I_B R_C) - I_L R_C$

$= V_{TH} - I_L R_{TH}$

Notes

Thévenin's equivalent

$V_{TH} = V_{CC} - I_B R_C$

$R_{TH} = R_C$

Notes
In the pass band we can neglect capacitors

\[ V_{\text{out}} = V_{cc} - I_c R_c = V_{cc} - (I_{ce} + I_b) R_c \]
\[ = (V_{cc} - I_{ce} R_e) - I_b R_c \]
\[ = V_{th} - I_b R_c \]

\( R_L \geq 10 R_c \)

Design rules

- Chose gain \( G = R_c / R_e \)
- Maximum output swing
  - \( V_c = V_{cc} / 2 \)
- Quiescent current
  - \( I_c = (V_{cc} - V_c) / R_c = V_{cc} / 2 R_c \)
  - \( R_e = V_{cc} / (2 I_c) \)
- \( R_b = R_c / G \)
- We want \( I_{b1} + R_b \gg I_b \)
  - Factor of 10 for a safe margin
    - \( I_{b1} + R_b \geq 10 I_b = 10 I_c / 3 \)
    - \( R_b + R_c \leq V_{cc} / (10 I_c) \)
- \( V_b = 0.6 V \)
- \( R_2 / (R_1 + R_2) = V_b / V_{cc} \)
AC-coupled (inverting) amplifier capacitors choice

Input equivalent

Output equivalent

See notes about AC-coupled emitter follower

AC-coupled (inverting) amplifier with HF gain boost

Think what happens with equivalent impedance of $R_e$ at high frequencies