Transistors applications: AC amplifiers

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Lecture 07

Summary of simple emitter follower

\[ V_{cc} \]
\[ V_{in} \]
\[ V_{out} \]
\[ R_e \]

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.
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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
Push-Pull emitter follower improved

[Diagram of a Push-Pull emitter follower circuit]

AC-coupled emitter follower

[Diagram of an AC-coupled emitter follower circuit]

Design rules
- maximum output swing
  - $V_o = V_{cc}/2$
- disregarding $V_{be} = 0.6$ V
  - $V_o = V_{be} = V_{cc}/2$
  - thus $R_i = R_0$
- quiescent current $I_q = V_o/R_e$
- we want $I_{R_1+R_2} \gg I_b$
  - factor of 10 for a safe margin
  - $I_{R_1+R_2} = 10I_b = 10I_e/\beta$
  - thus $R_1 = R_2 = R_{be}/10$

Notes
AC-coupled emitter follower: capacitors choice

From AC point of view

- Input is RC high-pass
  - $C = C_1$
  - $R = R_1 | \beta R_e | R_c$
  - $f_{3dB} = \frac{1}{2 \pi (R_1 | \beta R_e | R_c)}$
  - with above rules $R \approx R_c / 2$

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- Output is also RC high-pass
  - $C = C_2$
  - $R = R_L$
  - $f_{3dB} = \frac{1}{2 \pi R_L}$
  - for unloaded filter $R_L > R_e$
  - factor of 10 for a safe margin
  - $R_L = 10 R_e$

Notes

Common emitter (inverting) amplifier

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Common emitter (inverting) amplifier

- \( I_C = I_B = (V_T - 0.6\ V) / R_E \)
- \( V_{out} = V_C - R_C I_C \)
- \( V_{out} = V_C - R_C (V_T - 0.6\ V) / R_E \)
- \( V_{out} = (V_C + (0.6\ V) R_C / R_E) - V_B R_C / R_E \)
- gain \( G = -R_C / R_E \)
- attractive to put \( R_E = 0 \)
  - transistor model fails
  - transistor emitter resistance \( r_e = 25mV / I_e \)
  - gain \( G = -R_C / R_E \)

Notes

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AC-coupled common emitter (inverting) amplifier

Design rules
- chose gain \( G = R_C / R_E \)
- maximum output swing
  - \( V_C = V_{cc} / 2 \)
- quiescent current
  - \( I_C = (V_{cc} - V_C) / R_C = V_{cc} / 2 R_C \)
  - \( R_E = V_{cc} / (2 I_C) \)
  - \( R_E = R_C / G \)
- we want \( I_E + I_B \gg I_C \)
  - factor of 10 for a safe margin
- \( I_E + I_B = 10 I_C = 10 I_e / 3 \)
- \( R_E + R_B = V_{cc} / (10 I_e) \)
- \( V_B = V_C + 0.6 \)
- \( R_E / (R_1 + R_2) = V_B / V_{cc} \)

Notes

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AC-coupled (inverting) amplifier signal output impedance

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AC-coupled (inverting) amplifier signal output impedance

In the pass band we can neglect capacitors

\[ V_{\text{out}} = V_{\text{cc}} - I_c R_c = V_{\text{cc}} - (I_{\text{ce}} + I_e) R_c \]
\[ = (V_{\text{cc}} - I_{\text{ce}} R_c) - I_e R_c \]
\[ = V_{\text{in}} - I_e R_c \]

Thévenin's equivalent

\[ V_{\text{th}} = V_{\text{cc}} - I_{\text{ce}} R_c \]
\[ R_{\text{th}} = R_c \]

Rule of 10 must be satisfied

\[ R_L \geq 10 R_c \]

Notes
AC-coupled (inverting) amplifier capacitors choice

Input equivalent

![Input Equivalent Diagram]

Output equivalent

![Output Equivalent Diagram]

See notes about AC-coupled emitter follower

AC-coupled (inverting) amplifier with HF gain boost

From  
To

![HF Gain Boost Diagram]

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

Notes