Transistors applications: AC amplifiers

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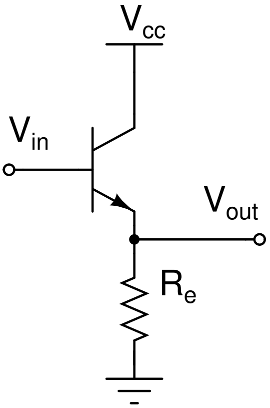
Lecture 07

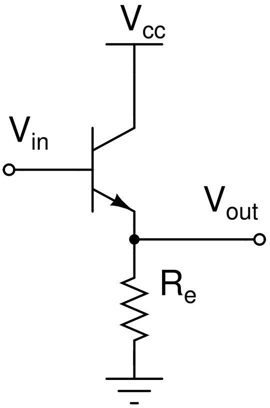
Summary of simple emitter follower



Advantages

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

Summary of simple emitter follower



Advantages

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

Disadvantages

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

Real life signal

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Solution 1: Push-Pull follower

Real life signal

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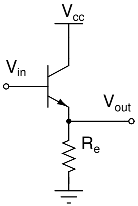
We need to do something with our simple emitter follower.

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

NPN and PNP emitter follower

NPN emitter follower



NPN and PNP emitter follower

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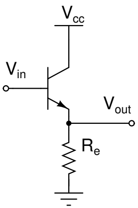

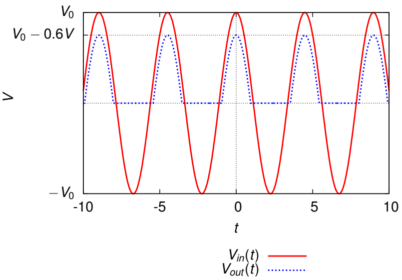

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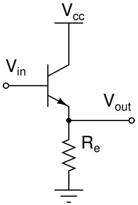
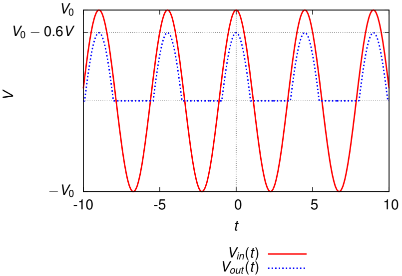
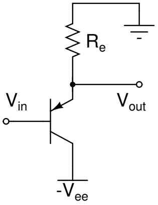




PNP emitter follower



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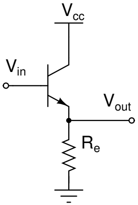

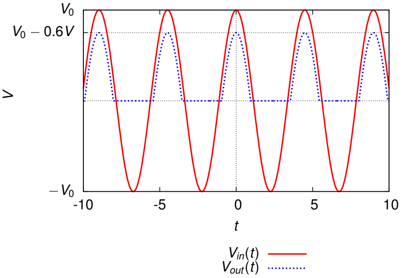

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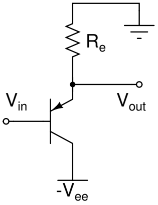
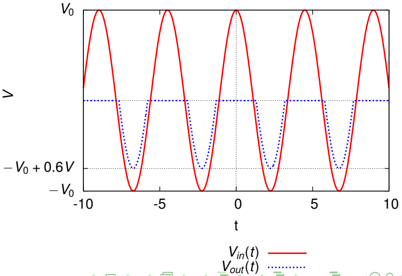
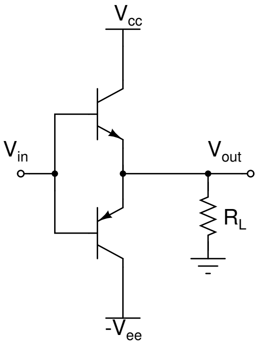




Push-Pull emitter follower



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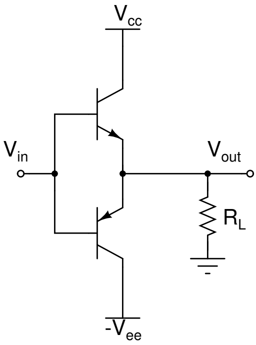
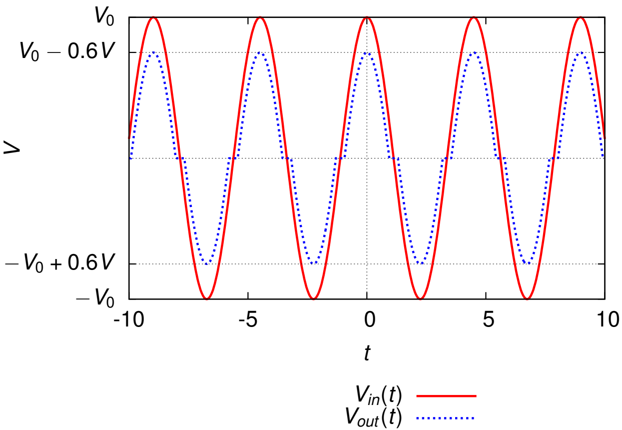
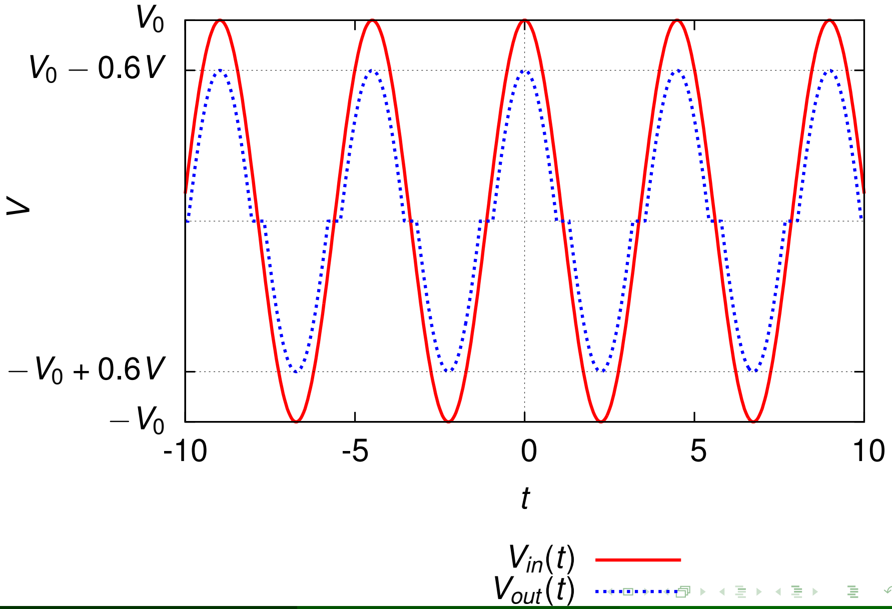




Push-Pull follower crossovers



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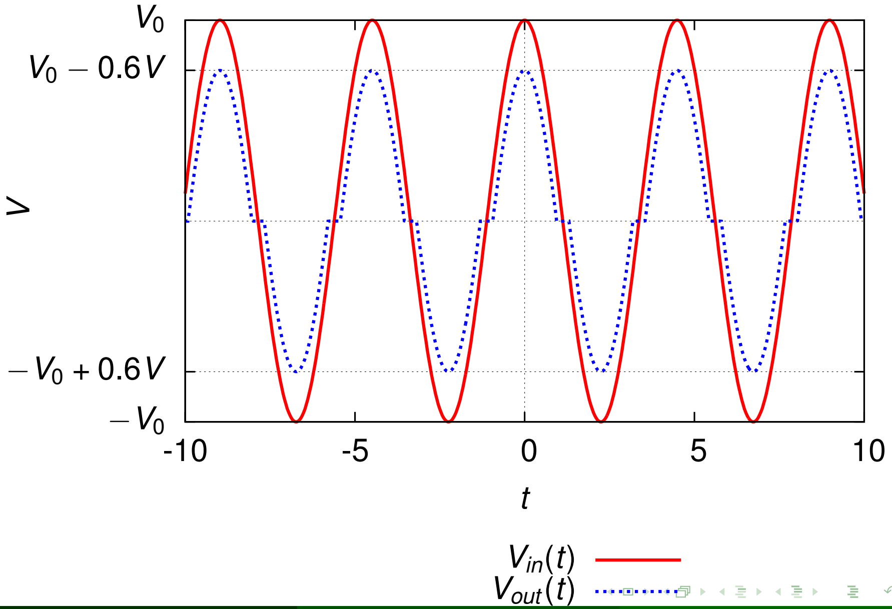

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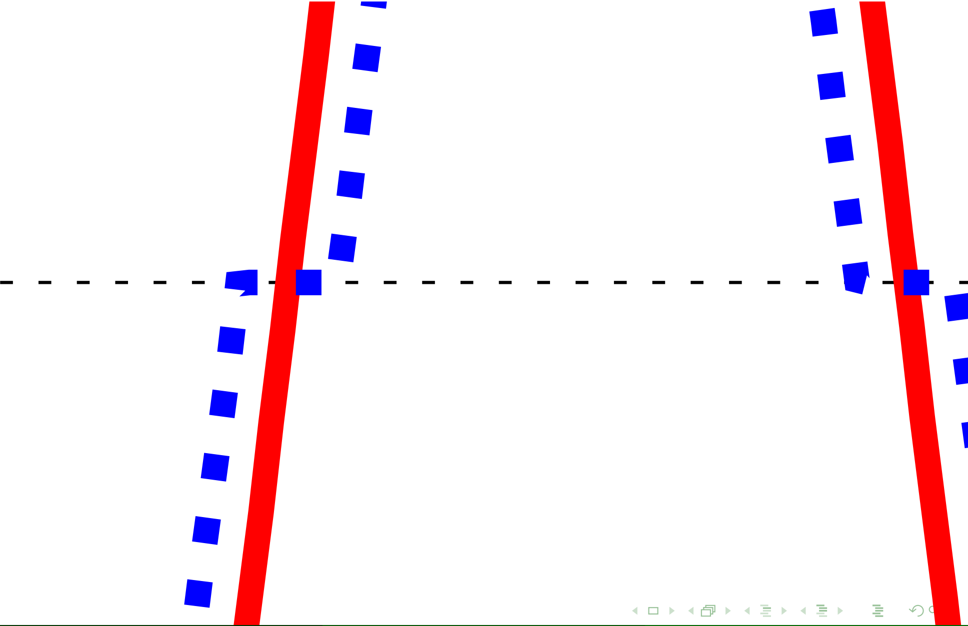
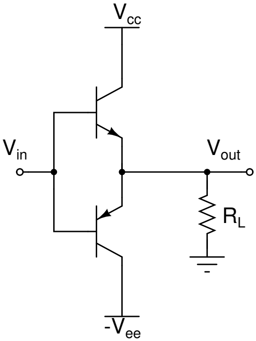


Push-Pull emitter follower improved



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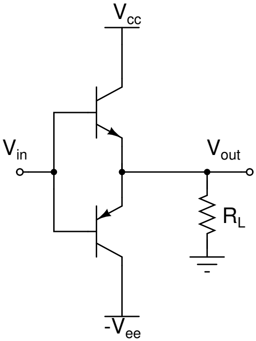
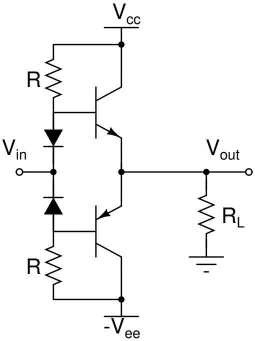
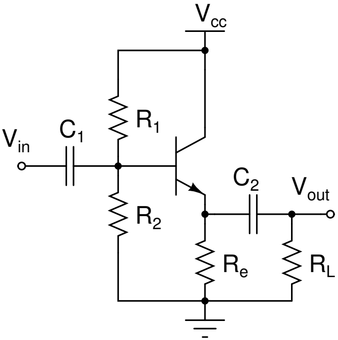




AC-coupled emitter follower



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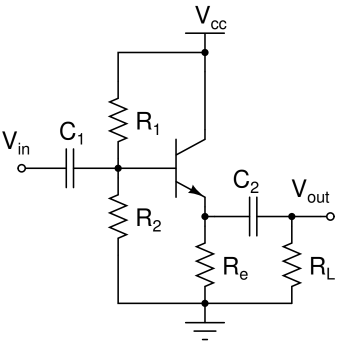
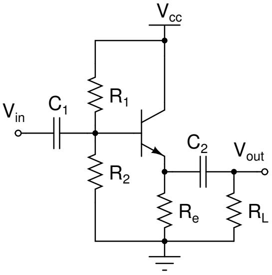


Design rules

- maximum output swing
  - $V_e = V_{cc}/2$
- disregarding $V_{be} = 0.6$ V
  - $V_b \approx V_e = V_{cc}/2$
  - thus $R_1 = R_2$
- quiescent current $I_e = V_e/R_e$
- we want $I_{R_1+R_2} \gg I_b$
  - factor of 10 for a safe margin $I_{R_1+R_2} \geq 10 I_b = 10 I_e/\beta$
  - thus $R_1 = R_2 \leq R_e\beta/10$

AC-coupled emitter follower: capacitors choice



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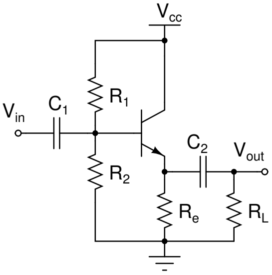
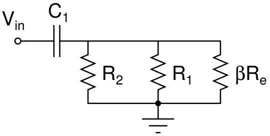
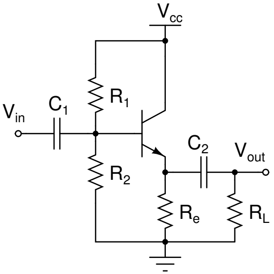


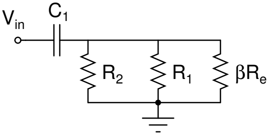


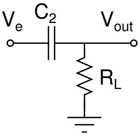
From AC point of view

- Input is RC high-pass
  - $C = C_1$
  - $R = R_1 || R_2 || \beta R_e$
  - $f_{3db} = \frac{1}{2\pi} \frac{1}{C_1 (R_1 || R_2 || \beta R_e)}$
    - with above rules $R \approx R_1/2$

AC-coupled emitter follower: capacitors choice







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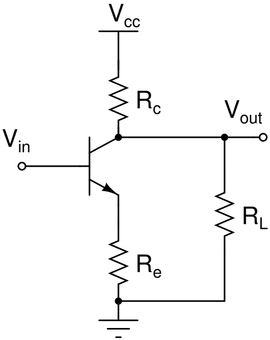
  - $f_{3db} = \frac{1}{2\pi}\frac{1}{C_1(R_1||R_2||\beta R_e)}$
    - with above rules $R \approx R_1/2$
- Output is also RC high-pass
  - $C = C_2$
  - $R = R_L$
  - $f_{3db} = \frac{1}{2\pi}\frac{1}{C_2 R_L}$
  - for unloaded filter $R_L \gg R_e$
    - factor of 10 for a safe margin $R_L = 10R_e$

Common emitter (inverting) amplifier



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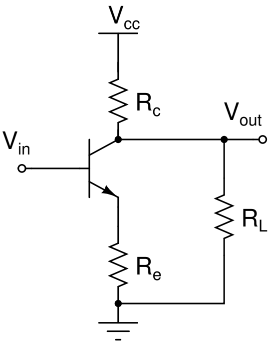
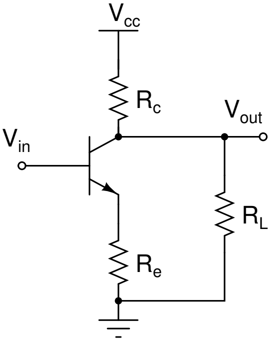


- $I_c = I_e = (V_{in} - 0.6V)/R_e$
- $V_{out} = V_{cc} - R_c I_c$
- $V_{out} = V_{cc} - R_c(V_{in} - 0.6V)/R_e$
- $V_{out} = (V_{cc} + (0.6V)R_c/R_e) - V_{in}R_c/R_e$
- gain $G = -R_c/R_e$
- attractive to put $R_e = 0$
  - transistor model fails
  - transistor emitter resistance $r_e = 25mV/I_c$
  - gain $G = -R_c/r_e$

Common emitter amplifier signal output impedance



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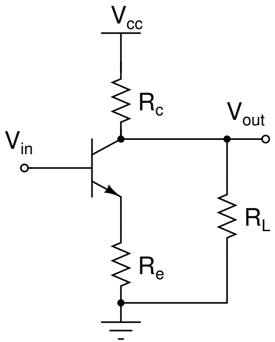

In the pass band we can neglect capacitors

$$\begin{aligned} V_{out} &= V_{cc} - I_c R_c = V_{cc} - (I_{ce} + I_L) R_c \\ &= (V_{cc} - I_{ce} R_c) - I_L R_c \\ &= V_{th} - I_L R_{th} \end{aligned}$$

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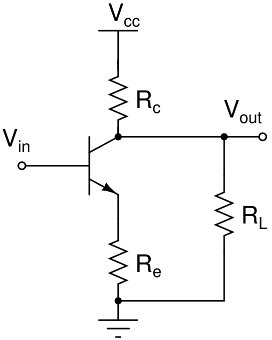

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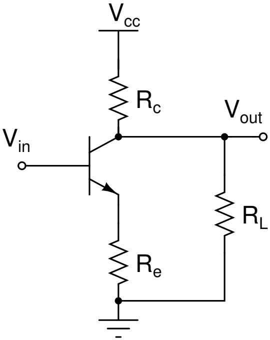
Thévenin's equivalent

$$\begin{aligned} V_{th} &= V_{cc} - I_{ce} R_c \\ R_{th} &= R_c \end{aligned}$$

Common emitter amplifier signal output impedance



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Thévenin's equivalent

$$
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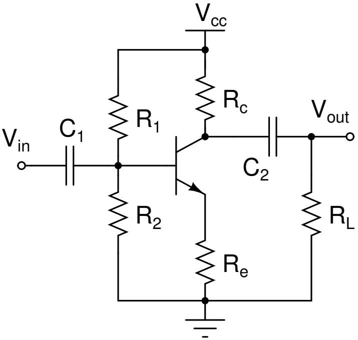
V_{th} &= V_{cc} - I_{ce} R_c \\
R_{th} &= R_c
\end{aligned}
$$

Rule of 10 must be satisfied

$$R_L \geq 10 R_c$$

AC-coupled common emitter (inverting) amplifier



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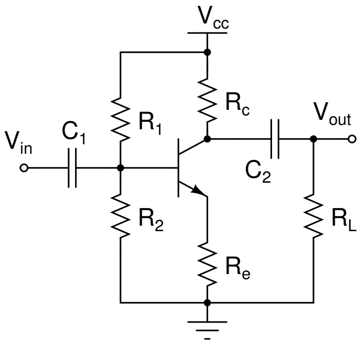
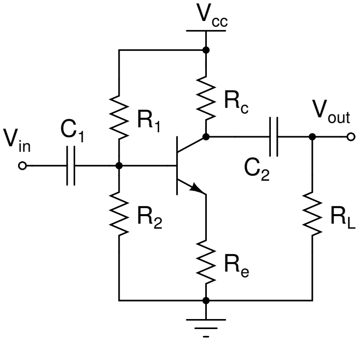


Design rules

- chose gain $G = R_c/R_e$
- maximum output swing
  - $V_c = V_{cc}/2$
- quiescent current
  $I_c = (V_{cc} - V_c)/R_c = V_{cc}/2R_c$
- $R_c = V_{cc}/(2I_c)$
- $R_e = R_c/G$
- we want $I_{R_1+R_2} \gg I_b$
  - factor of 10 for a safe margin
    $I_{R_1+R_2} \geq 10I_b = 10I_c/\beta$
  - $R_1 + R_2 \leq V_{cc}\beta/(10I_c)$
- $V_b = V_e + 0.6V$
- $R_2/(R1 + R2) = V_b/V_{cc}$

AC-coupled (inverting) amplifier capacitors choice



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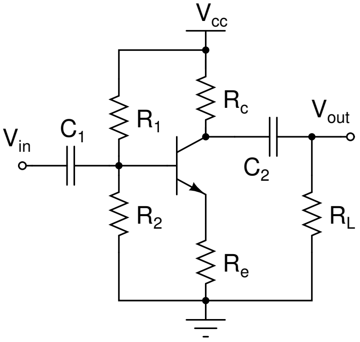
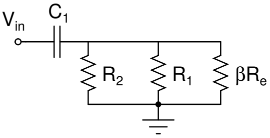


Input equivalent



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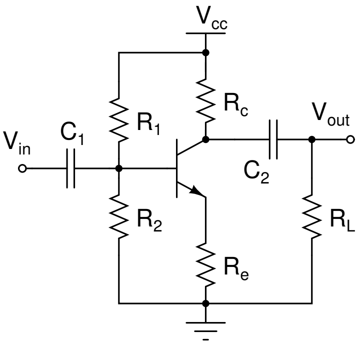

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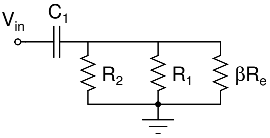

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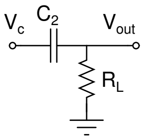

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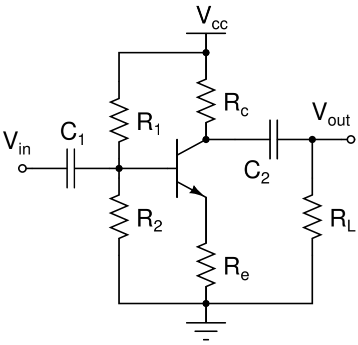

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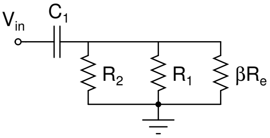

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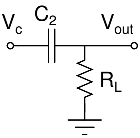
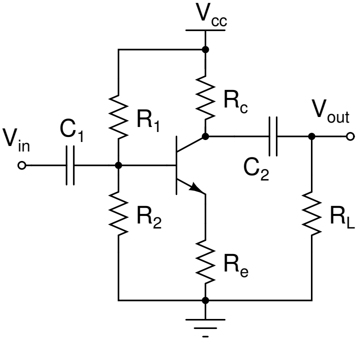


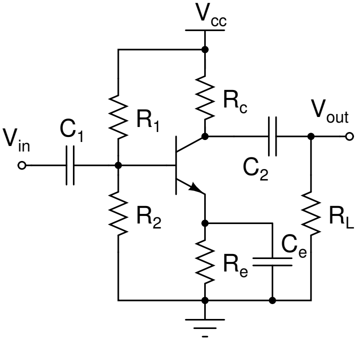
See notes about AC-coupled emitter follower

AC-coupled (inverting) amplifier with HF gain boost

From



To



Think what happens with equivalent impedance of R_e at high frequencies