EE112 - Fall 2016
Analog Integrated Circuits I

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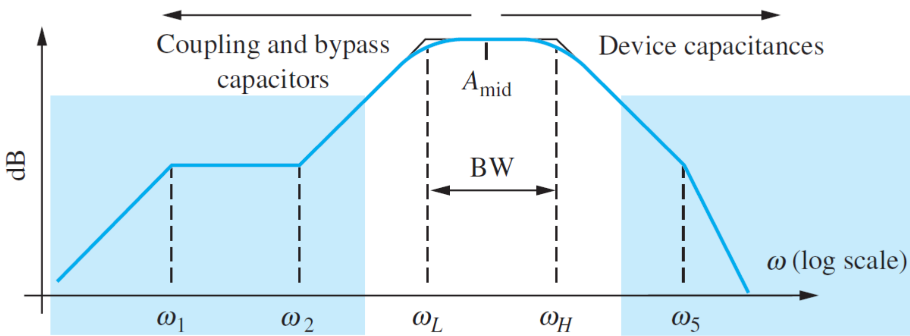
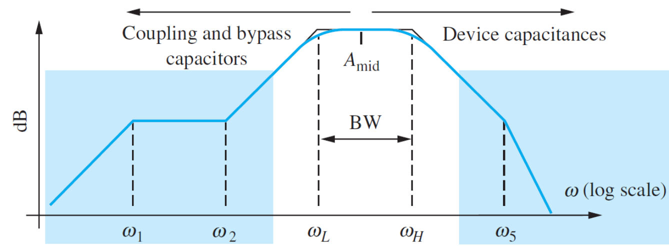
Amplifier Frequency Response Transfer Function Analysis



- Midband gain A_{mid} and upper and lower cutoff frequencies ω_H and ω_L that define bandwidth of an amplifier are often of more interest than the complete transfer function.
- Coupling and bypass capacitors determine ω_L, whereas transistor (and stray) capacitances determine ω_H.

Lower Cutoff Frequency (ω_L): The Short-Circuit Time Constant Estimate

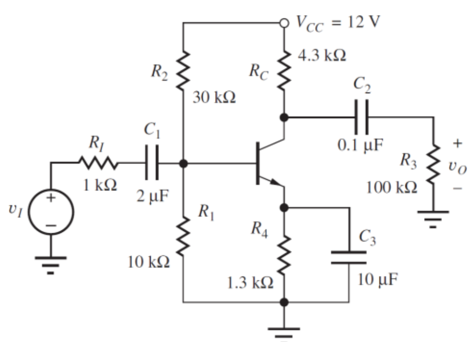


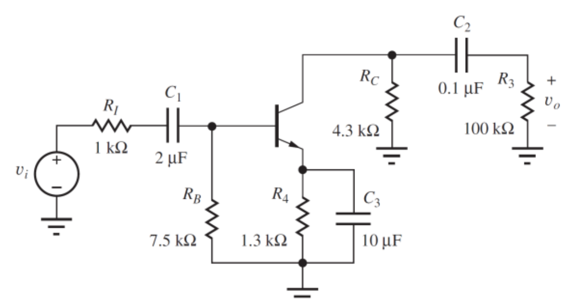
- Transistor capacitances are relatively small in value and their large impedances at low frequencies and can be neglected.
- Thus, coupling and bypass capacitors determine an amplifier's low frequency response.
- Lower cutoff frequency for a network with *n* coupling and bypass capacitors is given by:

$$\omega_L \cong \sum_{i=1}^{n} \frac{1}{R_{iS}C_i}$$

  - Where R_{iS} is resistance at the terminals of the *i*-th capacitor C_i with all other capacitors replaced by short circuits.
  - The product $R_{iS}C_i$ is termed the short-circuit time constant associated with C_i.

Lower Cutoff Frequency (ω_L) The SCTC Estimate: C-E Amplifier





- The general method of Short-Circuit Time Constants is:

$$\omega_L \cong \sum_{i=1}^{n} \frac{1}{R_{iS}C_i}$$

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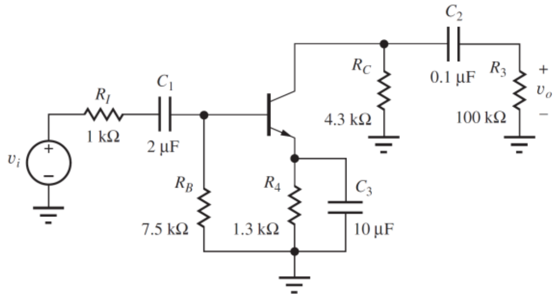

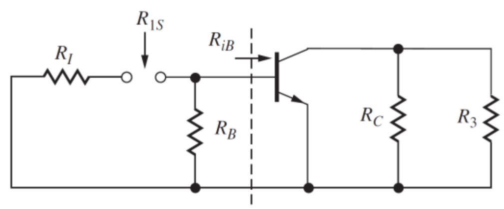

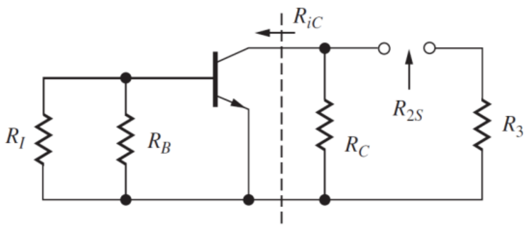

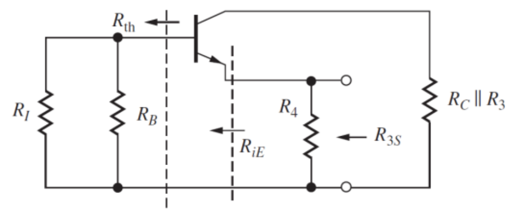

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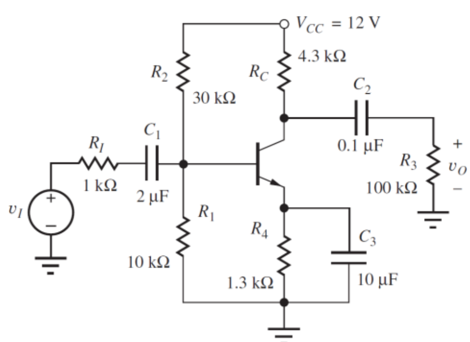

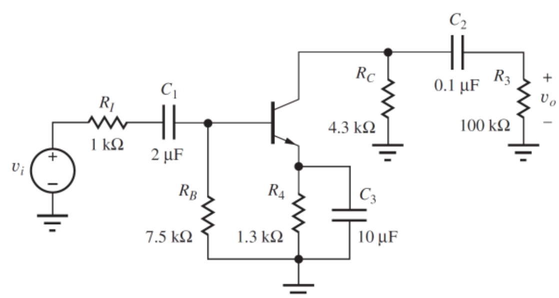

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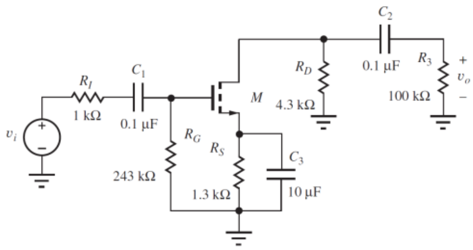
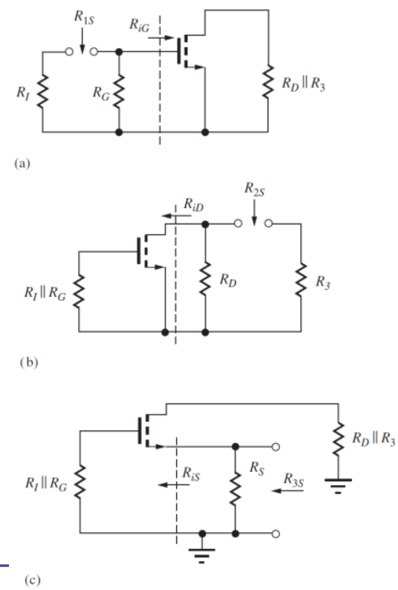
Lower Cutoff Frequency (ω_L)
The SCTC Estimate: C-S Amplifier





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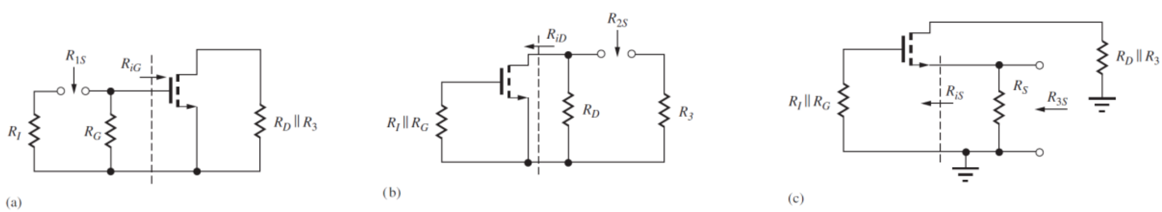
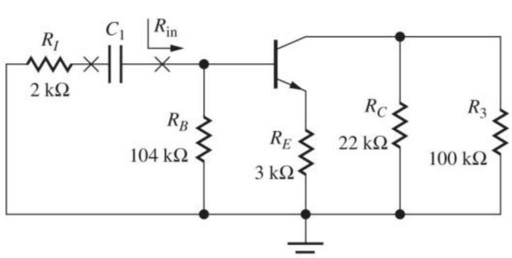
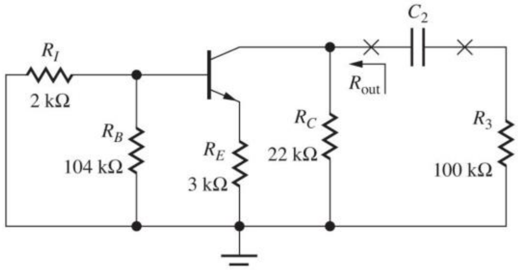


Coupling and Bypass Capacitor Design

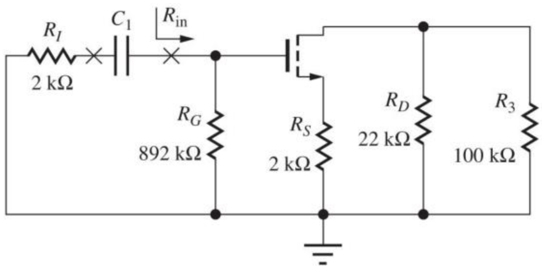
- Since the impedance of a capacitor increases with decreasing frequency, coupling and bypass capacitors reduce amplifier gain at low frequencies.
- To choose capacitor values, the short-circuit time constant (SCTC) method is used: each capacitor is considered separately with all other capacitors replaced by short circuits.
- To be able to neglect a capacitor at a given frequency*, the magnitude of the capacitor's impedance must be much smaller than the equivalent resistance appearing at its terminals at that frequency.
  - » *(i. e. to replace it with a short in the ac equivalent circuit)

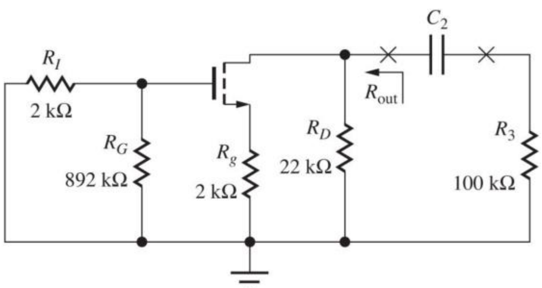
Coupling and Bypass Capacitor Design
Common-Emitter Amplifiers





Coupling and Bypass Capacitor Design Common-Source Amplifiers





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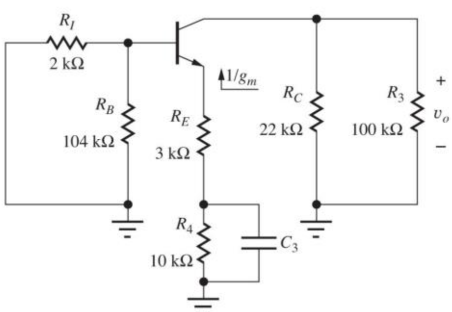
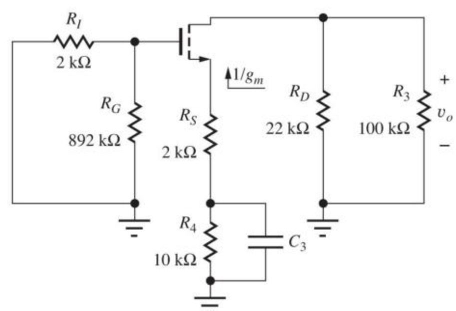


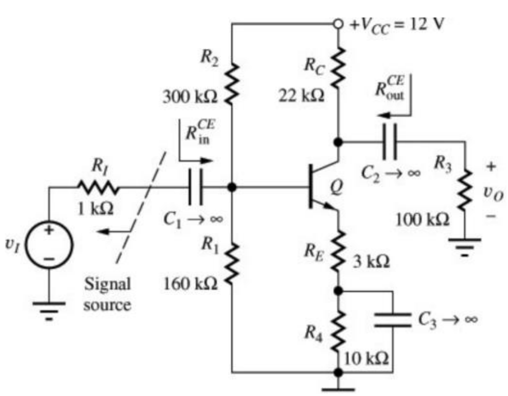


- In this case, neglect the impedances of capacitors C_1 and C_2 (assume they are shorts), and find the equivalent resistance looking up into the emitter or source of the amplifier.

Lower Cutoff Frequency f_L
Dominant Pole Design

- Instead of having the lower cutoff frequency set by the interaction of several poles, it can be set by the pole associated with just one of the capacitors. The other capacitors are then chosen to have their pole frequencies much below f_L.
- The capacitor associated with the emitter or source part of the circuit tends to be the largest due to low resistance presented by emitter or source terminal of transistor and is commonly used to set f_L.
- Values of other capacitors are increased by a factor of 10 to push their corresponding poles to much lower frequencies.

Coupling and Bypass Capacitors
Dominant Pole Design (Example)



- Goal: design coupling/bypass capacitances to achieve dominant pole frequency of 1kHz: