Microelectronics
Circuit Analysis and Design

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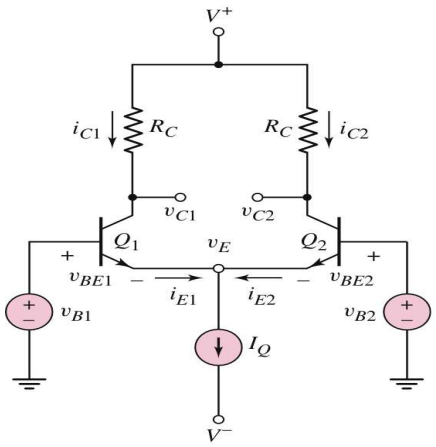
Chapter 11

Differential and Multistage Amplifiers

In this chapter, we will:

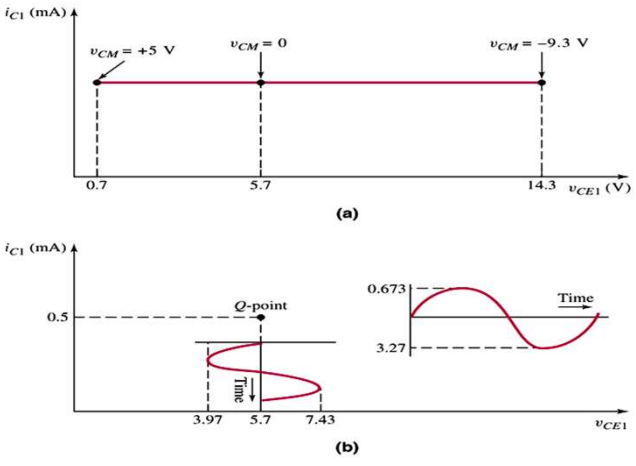
- Describe the characteristics and terminology of the ideal differential amplifier.
- Describe the characteristics of and analyze:
  - the basic bipolar differential amplifier.
  - the basic FET differential amplifier.
  - BJT and FET differential amplifiers with active loads.
  - various BiCMOS circuits.
- Analyze multistage amplifiers.
- Analyze the frequency response of the differential amplifier.

BJT Differential-Pair Amplifier

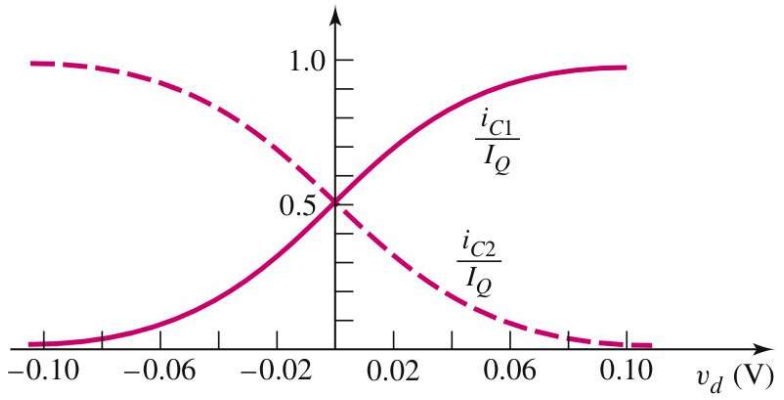


Variation of Q-Point for Diff-Amp

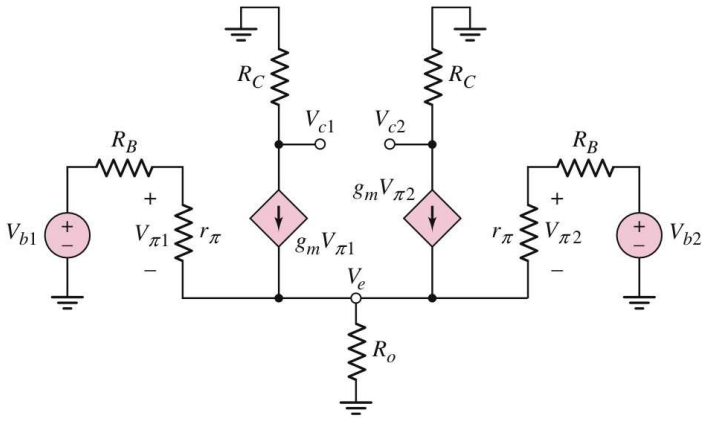
Common-mode input voltage varied between +5V to -9.3V



DC Transfer Characteristics: Bipolar Differential Amplifier

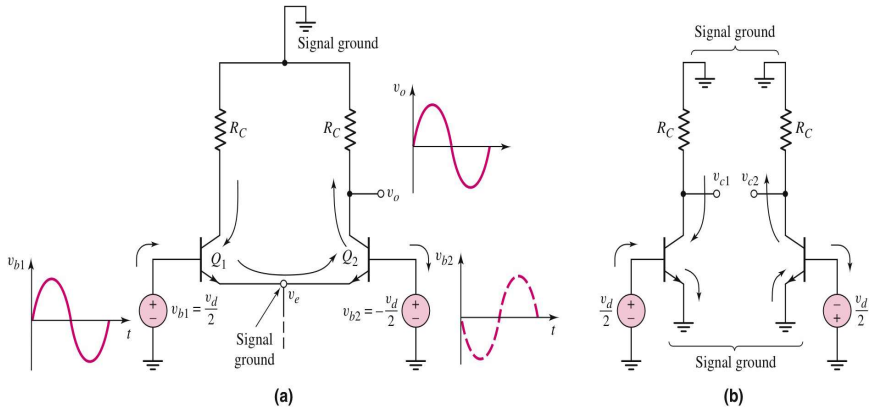


Small-Signal Equivalent Circuit: Bipolar Differential Amplifier



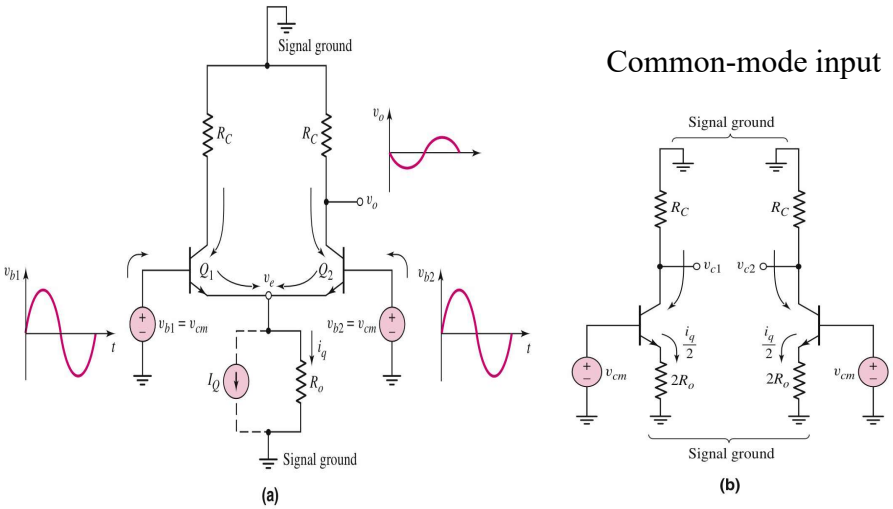
Equivalent AC Circuit: Bipolar Differential Amplifier

Differential-mode input



Equivalent AC Circuit: Bipolar Differential Amplifier

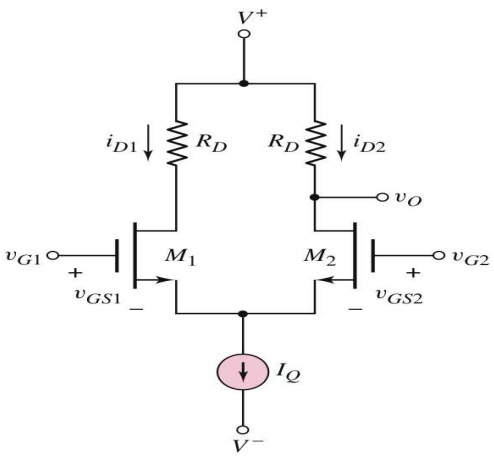
Common-mode input



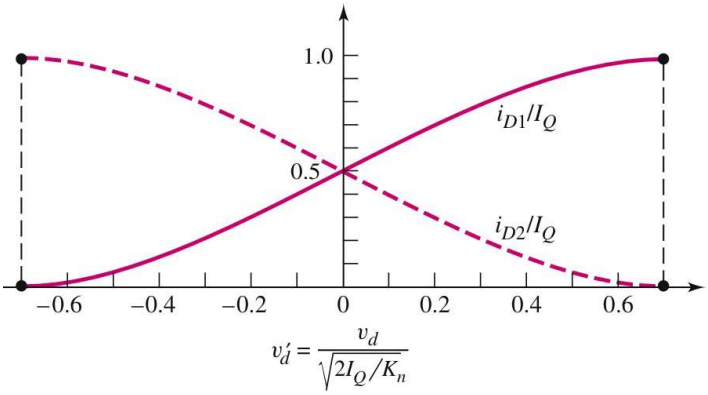
Problem-Solving Technique: Diff-Amps with Resistive Loads

1. Apply pure differential-mode input voltage and use differential-mode half-circuit to determine differential-mode gain.
2. Apply pure common-mode input voltage and use common-mode half-circuit to determine common-mode gain.

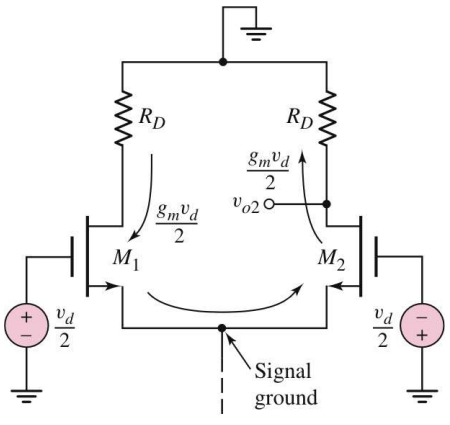
MOSFET Differential Pair



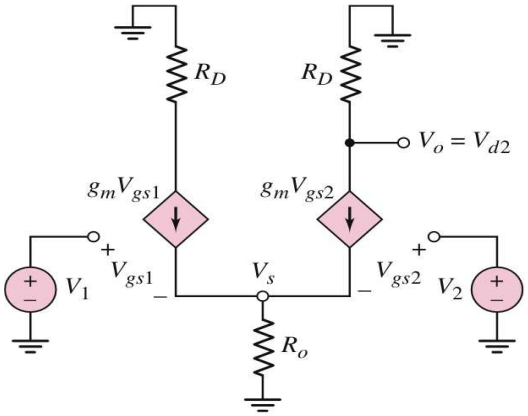
DC Transfer Characteristics: MOSFET Differential Amplifier



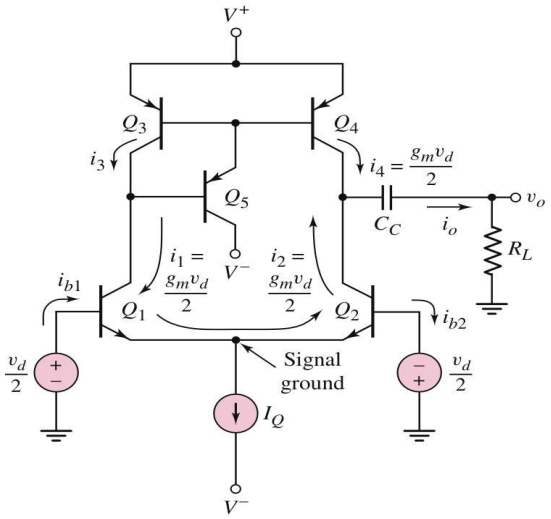
Small-Signal Equivalent Circuit: MOSFET Differential Amplifier



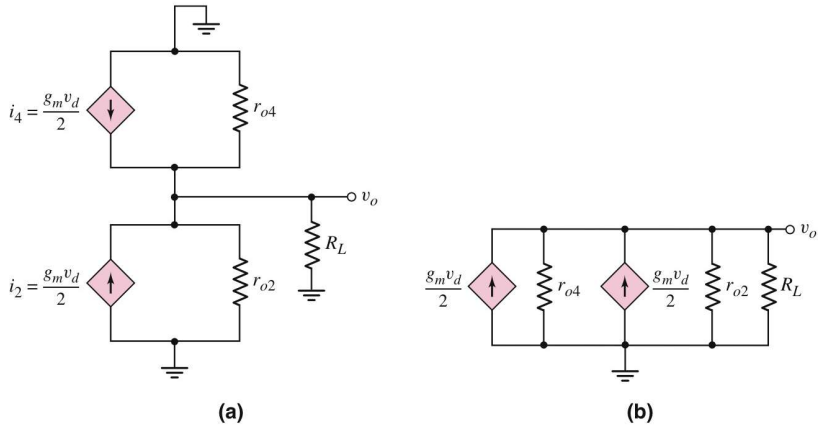
Small-Signal Equivalent Circuit: MOSFET Differential Amplifier



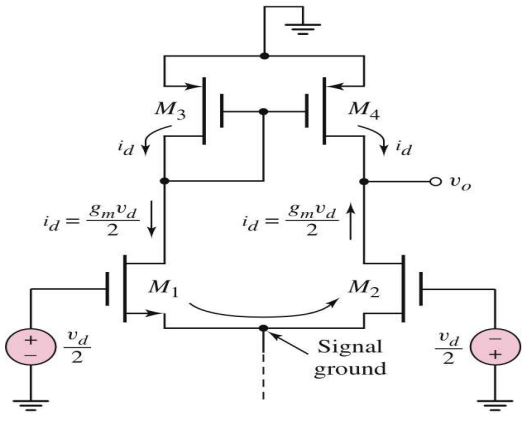
BJT Diff-Amplifier with 3-Transistor Active Load



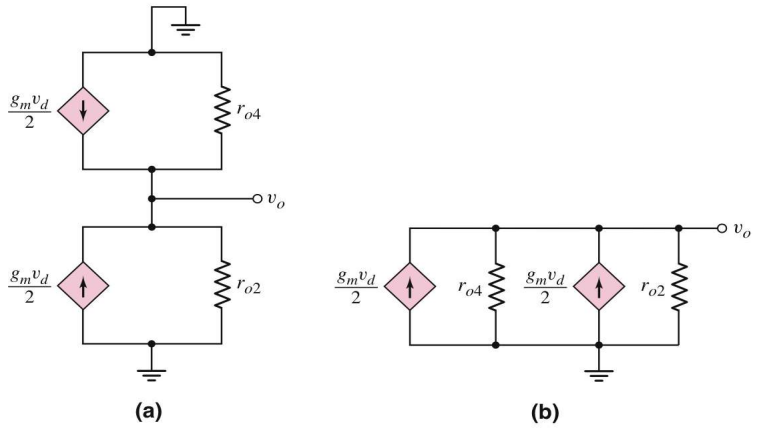
Small-Signal Equivalent Circuit: BJT Diff-Amplifier with Active Load



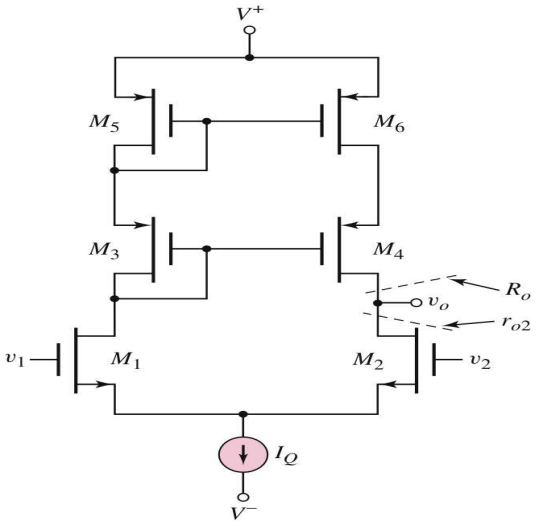
AC Equivalent Circuit: MOSFET Diff-Amp with Active Load



Small-Signal Equivalent Circuit: MOSFET Diff-Amplifier with Active Load

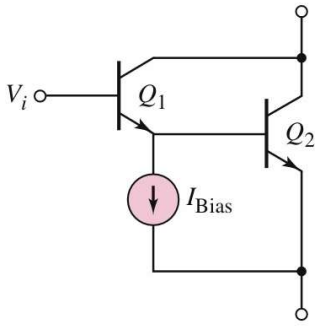


MOSFET Diff-Amp with Cascode Active Load



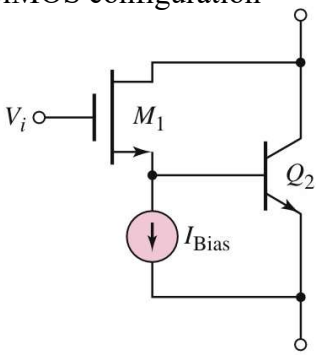
Darlington Pair

Bipolar configuration



(a)

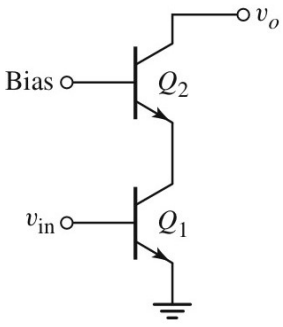
BiMOS configuration



(b)

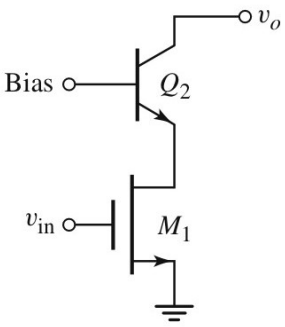
Cascode Configuration

Bipolar configuration



(a)

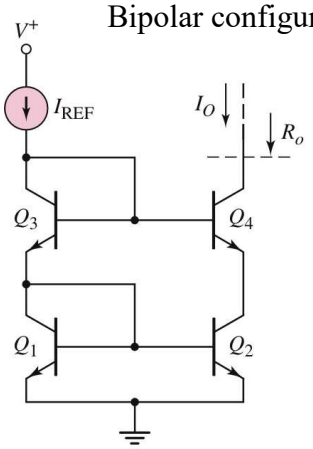
BiMOS configuration



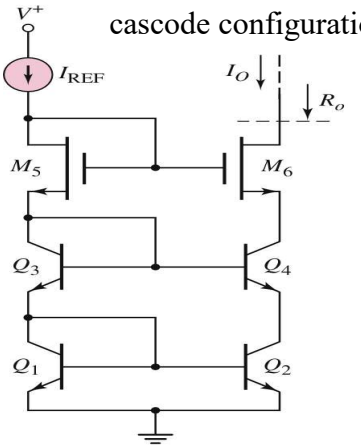
(b)

Cascode Constant-Current Source

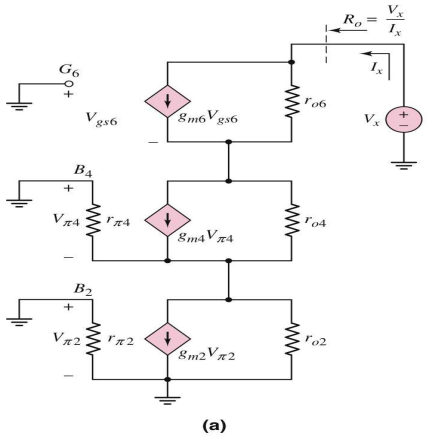
Bipolar configuration



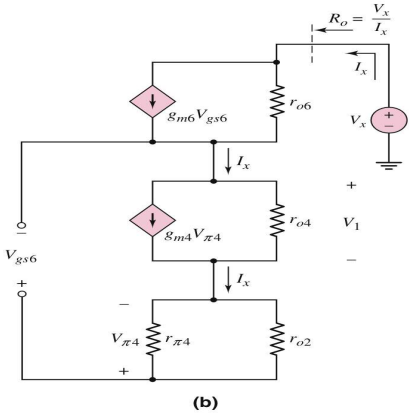
BiMOS double cascode configuration



Small-Signal Equivalent Circuit: BiMOS Double Cascode Current Source

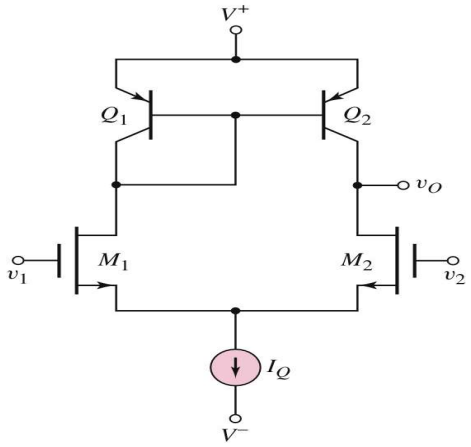


(a)



(b)

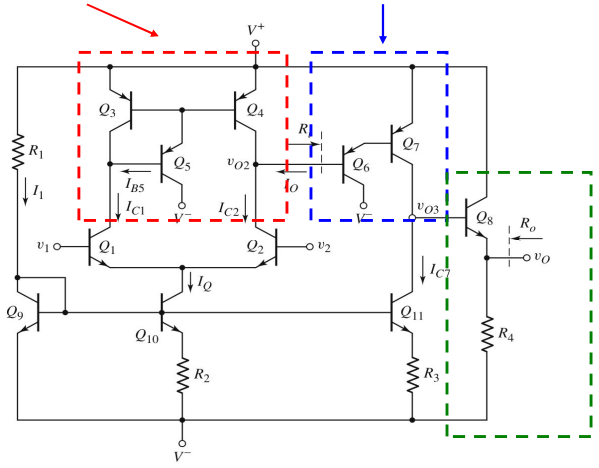
BiMOS Diff-Amp



BJT Diff-Amp

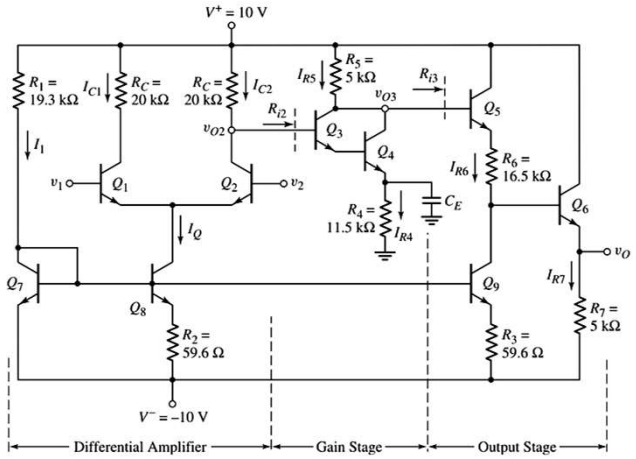
3-Transistor Active Load

Darlington Pair Gain Stage

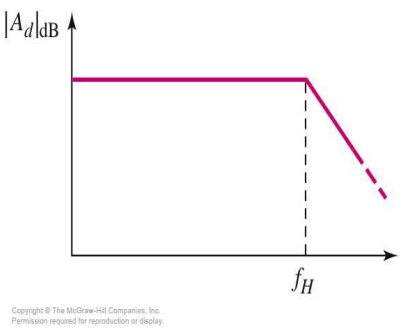


Emitter-Follower Output Stage

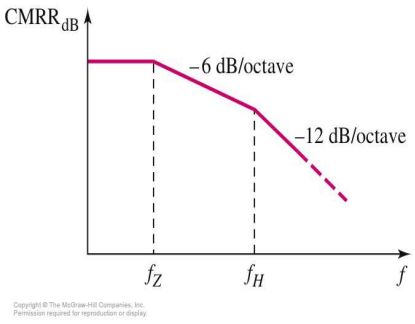
BJT Op-Amp



Frequency Response of Diff-Amp

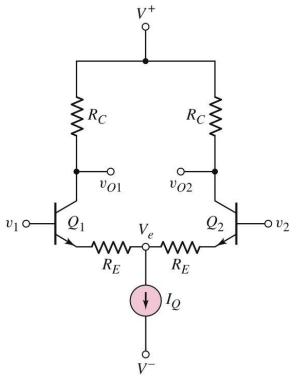


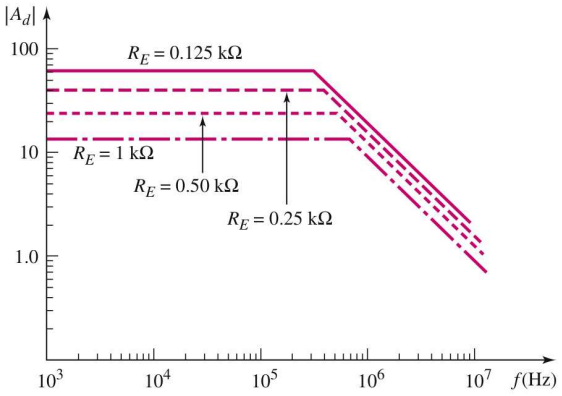
Differential-mode gain



Common-mode rejection ratio (CMRR)

BJT Diff-Amp with Emitter-Degeneration Resistors





BJT Diff-Amp with Active Load and Single-Sided Input