BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ECE-322
Electronic Circuits (B)

Lecture #1
Course Introduction and Differential Amplifiers

Instructor:
Dr. Ahmad El-Banna

SPRING 2015

Agenda

- Course Objectives
- Course Information
- Lectures List
- Differential Amplifiers

Course Objectives

- ***Understand the basics of differential and operational amplifiers.***
- ***Study the different circuits of Op-Amp.***
- ***Learn the concept and different types of Active filters.***
- ***Explore the signals generators and voltage regulators.***
- ***Study the Phase Locked Loop (PLL) circuits.***
- ***Usage of CAD packages in designing and analyzing the electronic circuits.***

Course Information

Instructor:	Dr. Ahmad El-Banna http://bu.edu.eg/staff/ahmad.elbanna Office: Room #305 Email: ahmad.elbanna@feng.bu.edu.eg ahmad.elbanna@ejust.edu.eg
Lectures:	Wednesday: 11:15 -14:00 Prerequisite: ECE-312
Office Hours:	Tuesday (12:00~15:30) & Wednesday (14:00~16:30) & Thursday(11:00~14:30)
T.A.:	Eng. Mohamed Ismail
Texts/Notes:	• Lectures slides, available by each lecture, and found online at http://bu.edu.eg/staff/ahmad.elbanna-courses/12135 • T. Floyd, **Electronic devices** - Conventional Current Version, 9th edition, Prentice Hall. • R. Boylestad, **Electronic Devices and Circuit Theory**, 11th edition, Prentice Hall.

Course Information..

Additional References:	• Sedra & Smith, **Microelectronic Circuits**, 6th edition. • Horowitz & Hill, **The Art of Electronics**, 2nd edition, Cambridge Press. • EE113 Course Notes Electronic Circuits by Prof. G. Kovacs, Stanford University, Department of Electrical Engineering.
Credit:	150 Marks

Grading:	▪ **90 Marks**
	  • Final Exam (Closed-Book)
	▪ **30 Marks**
	  • Mid Term Exam (Open-Book) (10)
	  • Quizzes and Homework (10)
	  • Tutorials Activities (10)
	▪ **30 Marks**
	  • Individual Project (10)
	  • Group Project (10)
	  • Oral Exam (10)

Lectures List

Week#1	Introduction and Differential Amplifiers
Week#2:5	Op-AMP Basics and Circuits
Week#6	Active Filters
Week#7	Mid-Term Exam
Week#8:10	Signals Generators & Voltage Regulators
Week#11	PLL Circuits
Week#12:13	Introduction to VHDL
Week#14	Oral Exam and Project Delivery

DIFFERENTIAL AMPLIFIERS

Basic Internal Arrangement of an Op-Amp.

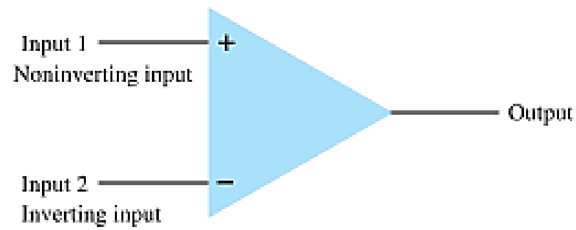
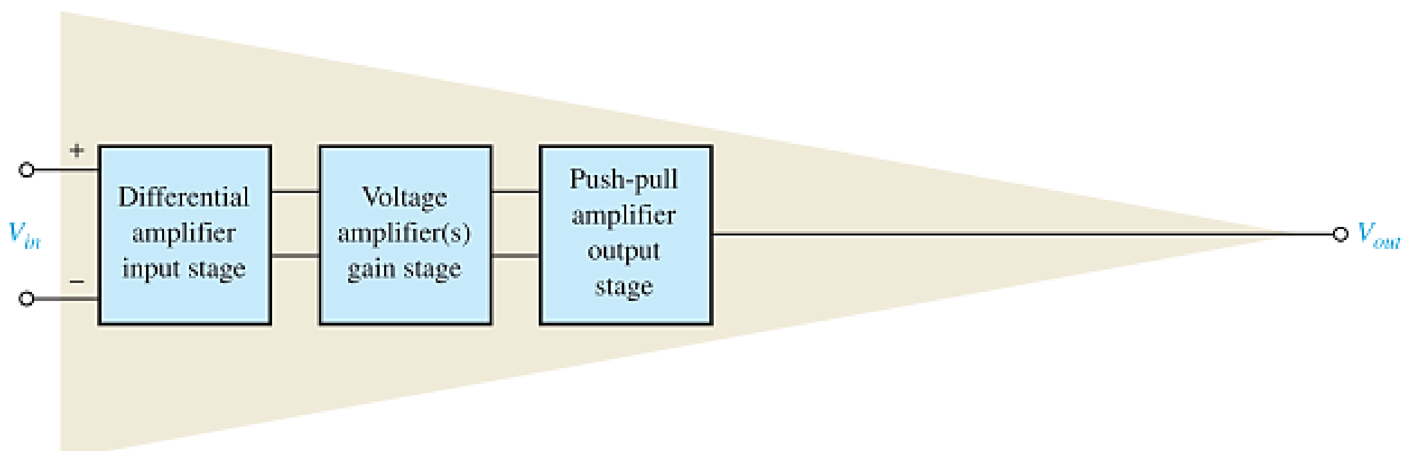


FIG. 10.1
Basic op-amp.



Stage#1 → Differential Amplifier

Single-Ended Input & Double-Ended (Differential) Input

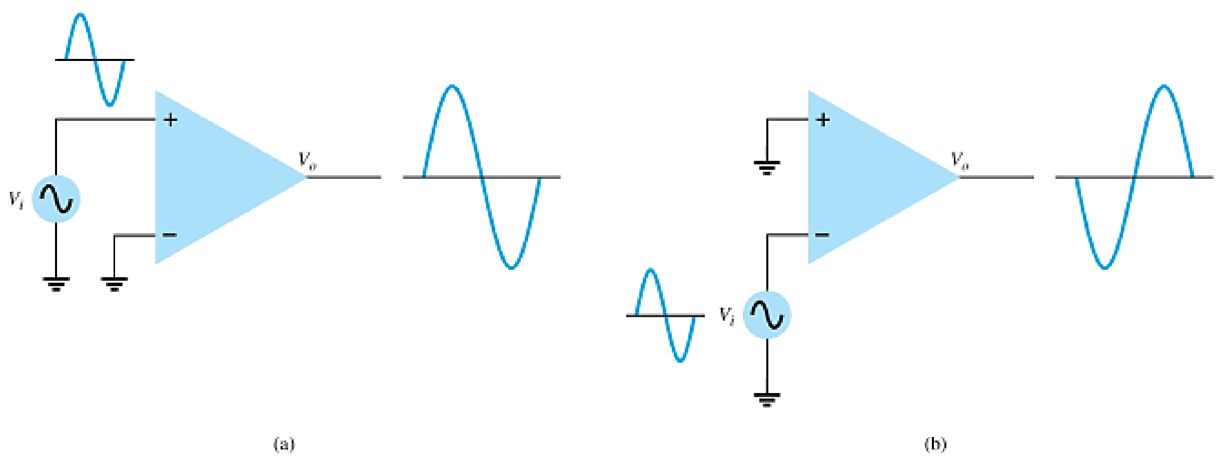


FIG. 10.2
Single-ended operation.

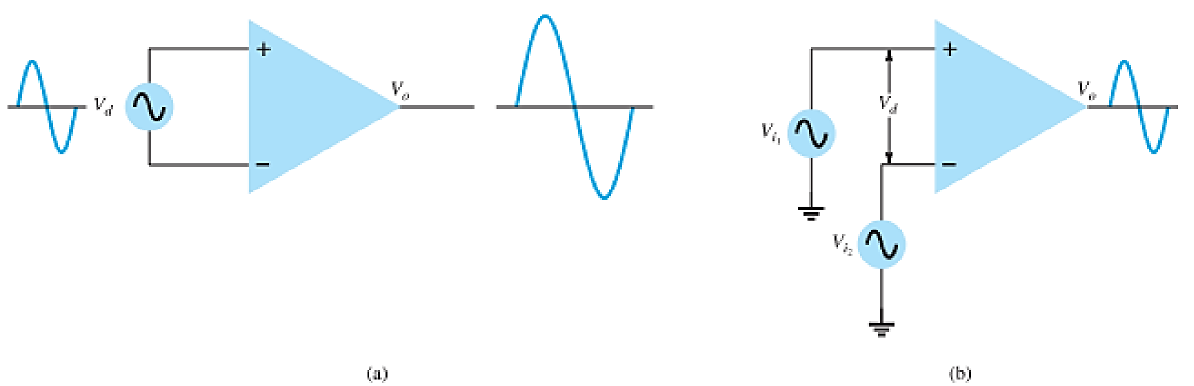


FIG. 10.3
Double-ended (differential) operation.

Double-Ended Output

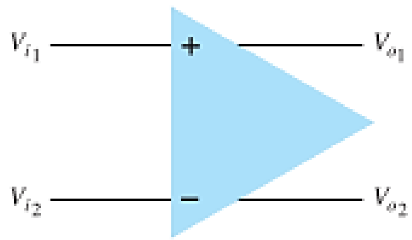


FIG. 10.4
Double-ended input with double-ended output.

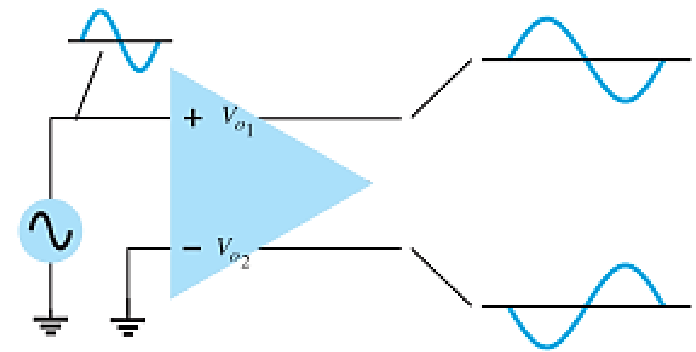


FIG. 10.5
Single-ended input with double-ended output.

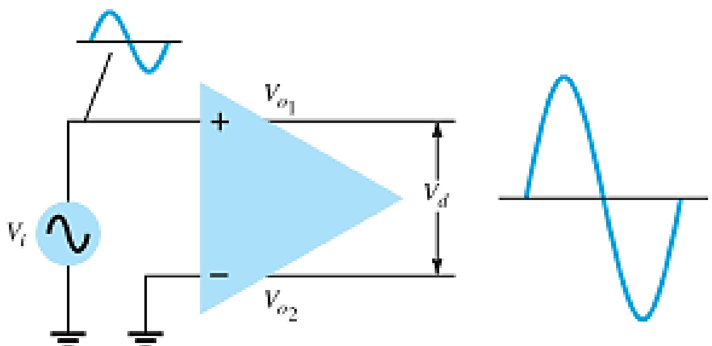


FIG. 10.6
Differential-output.

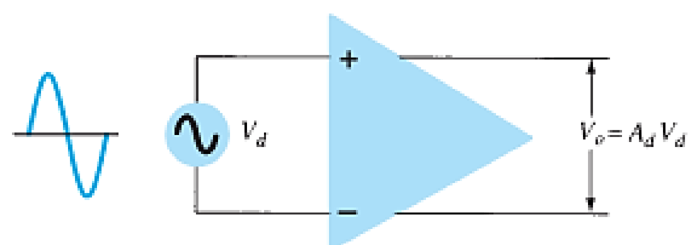


FIG. 10.7
Differential-input, differential-output operation.

Common Mode Operation

- Ideally, the two inputs are equally amplified, and since they result in opposite-polarity signals at the output, these signals cancel, resulting in 0-V output.

- Practically, a small output signal will result.

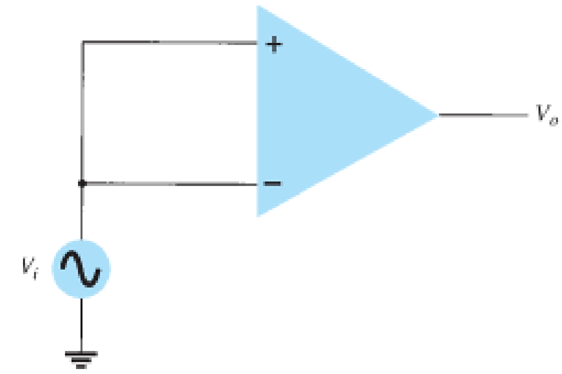


FIG. 10.8
Common-mode operation.

- **Common-Mode Rejection**

- Noise (any unwanted input signal) is generally common to both inputs, the differential connection tends to provide attenuation of this unwanted input while providing an amplified output of the difference signal applied to the inputs.
- This operating feature is referred to as *common-mode rejection* .

Differential Amplifier Circuit

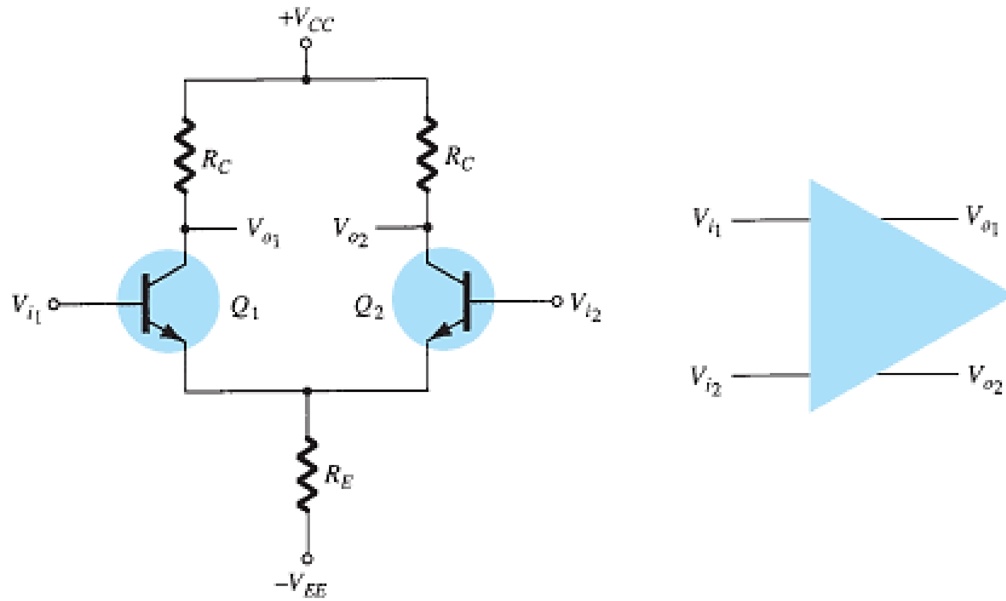


FIG. 10.9
Basic differential amplifier circuit.

Input signal combinations:

- **Single-ended** : If an input signal is applied to either input with the other input connected to ground.
- **Double-ended**: If two opposite-polarity input signals are applied.
- **Common-mode** : If the same input is applied to both inputs.

DC Biasing

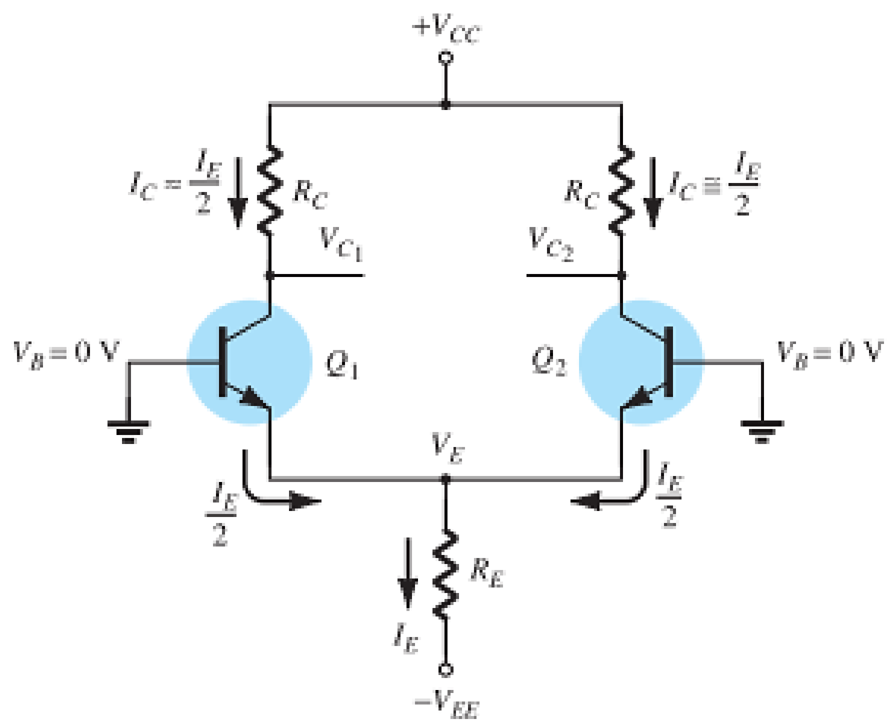
With ac inputs obtained from voltage sources, the dc voltage at each input is essentially connected to 0 V.

$$V_E = 0\text{ V} - V_{BE} = -0.7\text{ V}$$

$$I_E = \frac{V_E - (-V_{EE})}{R_E} \approx \frac{V_{EE} - 0.7\text{ V}}{R_E}$$

$$I_{C_1} = I_{C_2} = \frac{I_E}{2}$$

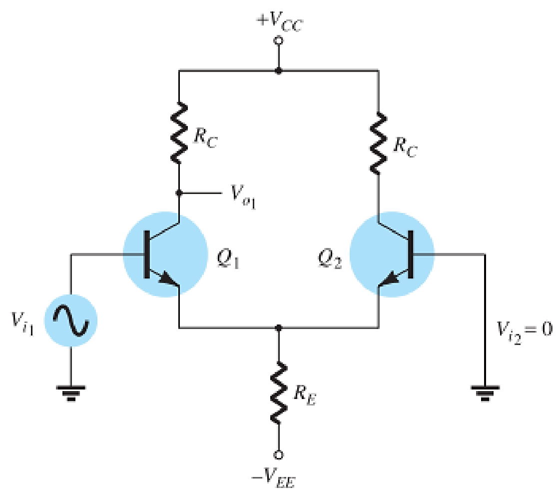
$$V_{C_1} = V_{C_2} = V_{CC} - I_C R_C = V_{CC} - \frac{I_E}{2} R_C$$

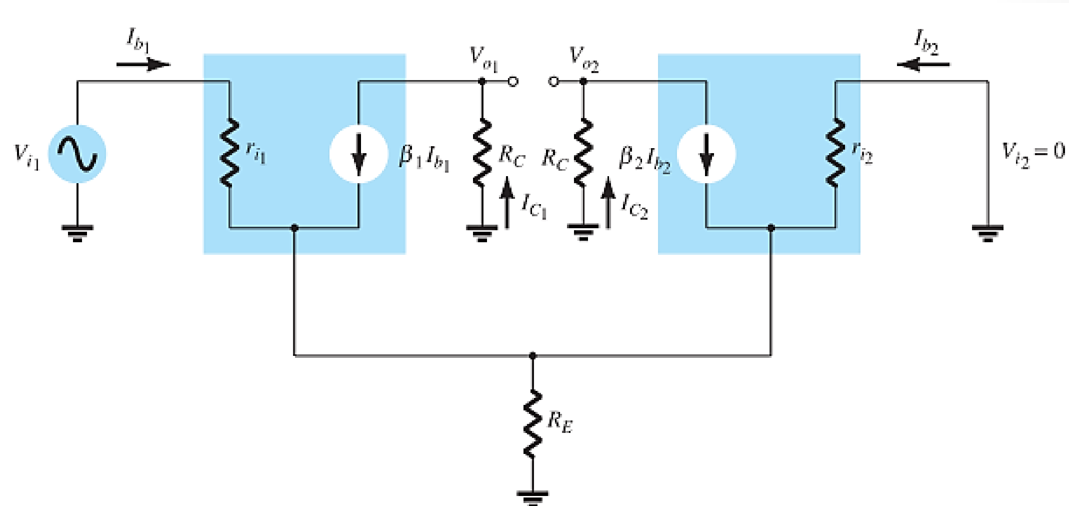


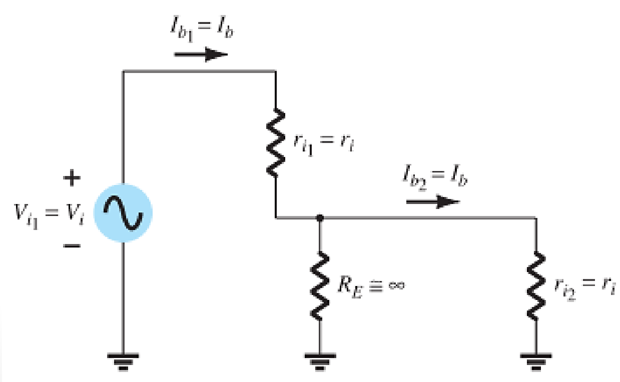
The two transistors are matched.

AC Operation

1- Single-Ended AC Voltage Gain







R_E very large (ideally infinite)

$$I_{b_1} = I_{b_2} = I_b$$
$$r_{i_1} = r_{i_2} = r_i = \beta r_e$$

$$V_{i_1} - I_b r_i - I_b r_i = 0$$

$$I_b = \frac{V_{i_1}}{2r_i} = \frac{V_i}{2\beta r_e}$$

$$\beta_1 = \beta_2 = \beta$$

$$I_C = \beta I_b = \beta\frac{V_i}{2\beta r_e} = \frac{V_i}{2r_e}$$

$$V_o = I_C R_C = \frac{V_i}{2r_e} R_C = \frac{R_C}{2r_e} V_i$$

$$A_v = \frac{V_o}{V_i} = \frac{R_C}{2r_e}$$

ac voltage gain magnitude

AC Operation..

2- Double-Ended AC Voltage Gain

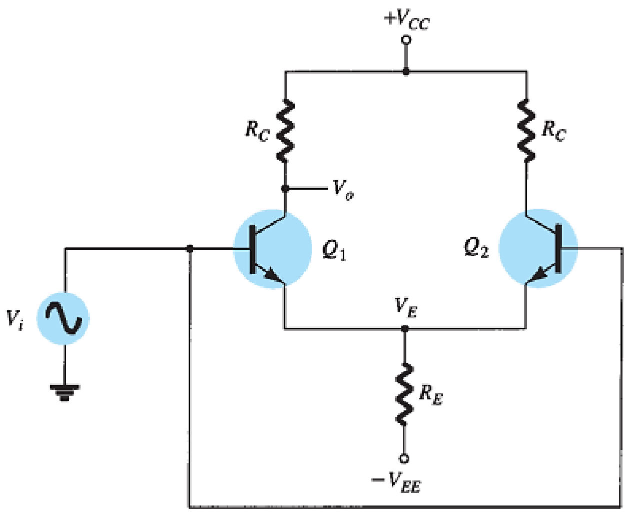
A similar analysis can be used to show that for the condition of signals applied to both inputs, the differential voltage gain magnitude is:

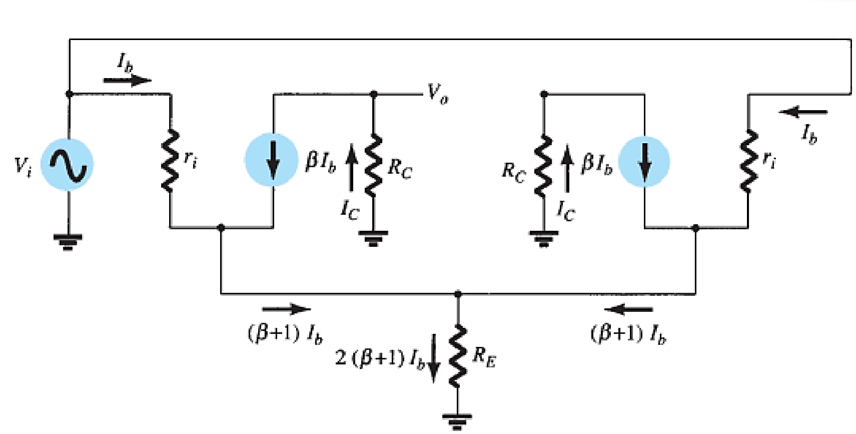
$$A_d = \frac{V_o}{V_d} = \frac{R_C}{r_e}$$

where $V_d = V_{i_1} - V_{i_2}$.

H.W. → Derive the A_d equation

Common Mode Operation





$$I_b = \frac{V_i - 2(\beta + 1)I_b R_E}{r_i}$$

which can be rewritten as

$$I_b = \frac{V_i}{r_i + 2(\beta + 1)R_E}$$

The output voltage magnitude is then

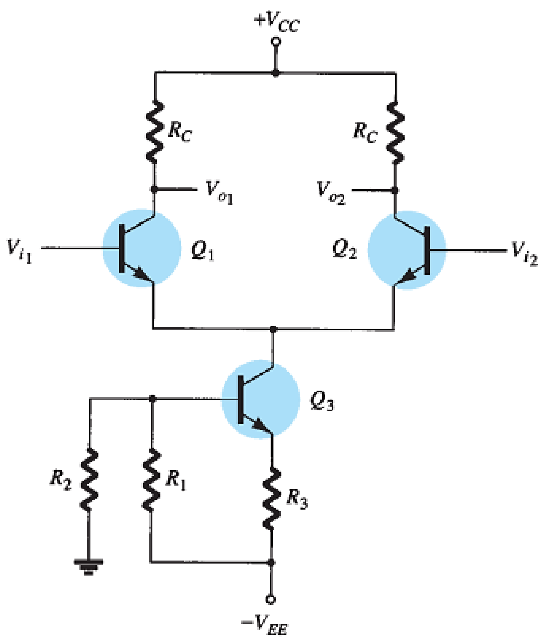
$$V_o = I_C R_C = \beta I_b R_C = \frac{\beta V_i R_C}{r_i + 2(\beta + 1)R_E}$$

providing a voltage gain magnitude of

$$A_c = \frac{V_o}{V_i} = \frac{\beta R_C}{r_i + 2(\beta + 1)R_E}$$

Use of Constant-Current Source

- A good differential amplifier has a very large difference gain A_d, which is much larger than the common-mode gain A_c.
- The common-mode rejection ability of the circuit can be considerably improved by making the common-mode gain as small as possible (ideally, 0)
- The larger R_E, the smaller is A_c.
- One popular method for increasing the ac value of R_E is using a constant-current source circuit.



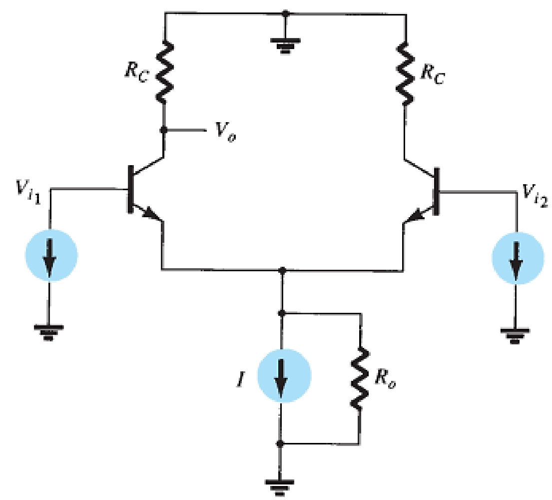


FIG. 10.21
AC equivalent of the circuit of Fig. 10.20.

- For more details, refer to:
  - Chapter 10, R. Boylestad, **Electronic Devices and Circuit Theory**, 11th edition, Prentice Hall.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12135
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg