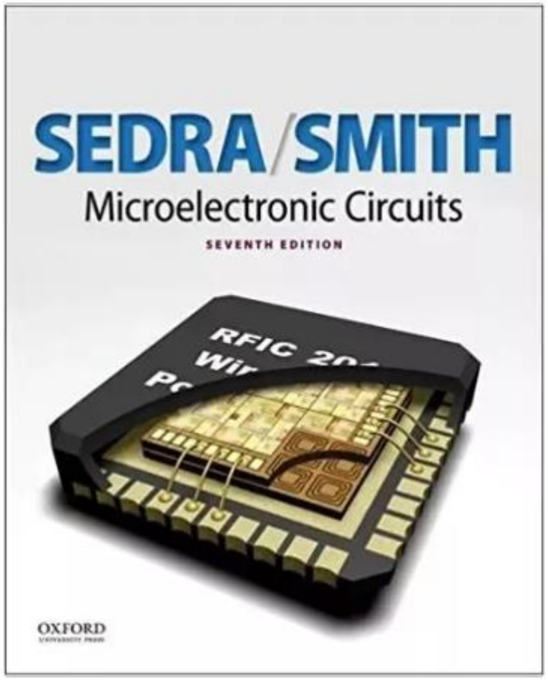
Amplificadores Operacionais

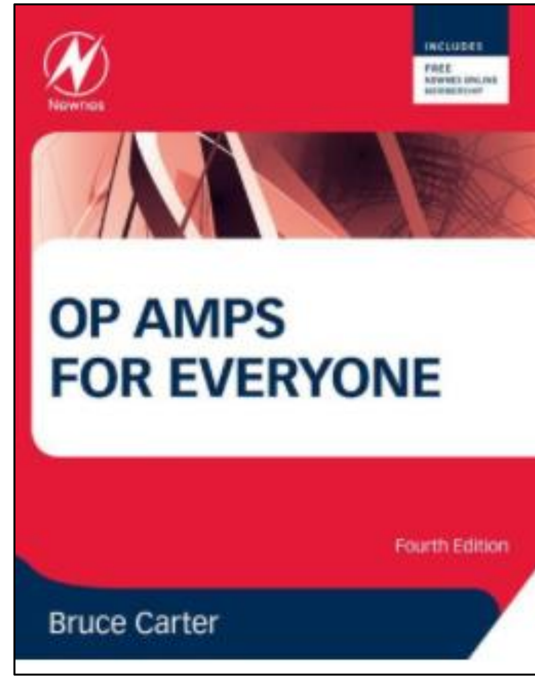
Referências Bibliográficas



Oxford University Press
2015, 7th Edition

(Chapter 2 e 13)

Bookman,
2014, 8ª edição



Newnes
4ª edição, 2012

1 **In the mid-1960s the first integrated-circuit (IC) op amp was produced**. This unit (the µA 709) was made up of a relatively large number of transistors and resistors all on the same silicon chip. Although its characteristics were poor (by today's standards) and its price was still quite high, its appearance signaled a new era in electronic circuit design.

2 **Electronics engineers started using op amps in large quantities, which caused their price to drop dramatically.** They also demanded better-quality op amps. Semiconductor manufacturers responded quickly, and within the span of a few years, high-quality op amps became available at extremely low prices (tens of cents) from a large number of suppliers.

3 One of the reasons for the popularity of the op amp is its **versatility**.

One can do almost anything with op amps !

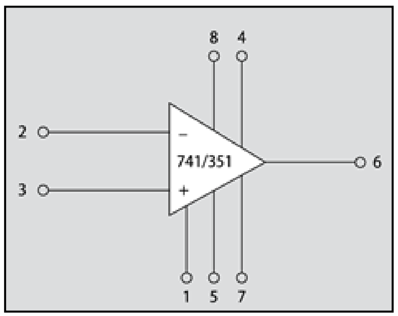
Equally important is the fact that the **IC op amp has characteristics that closely approach the assumed ideal**. This implies that it is quite easy to design circuits using the IC op amp.

Also, **op-amp circuits work at performance levels that are quite close to those predicted theoretically**. It is for this reason that we are studying op amps at this early stage.

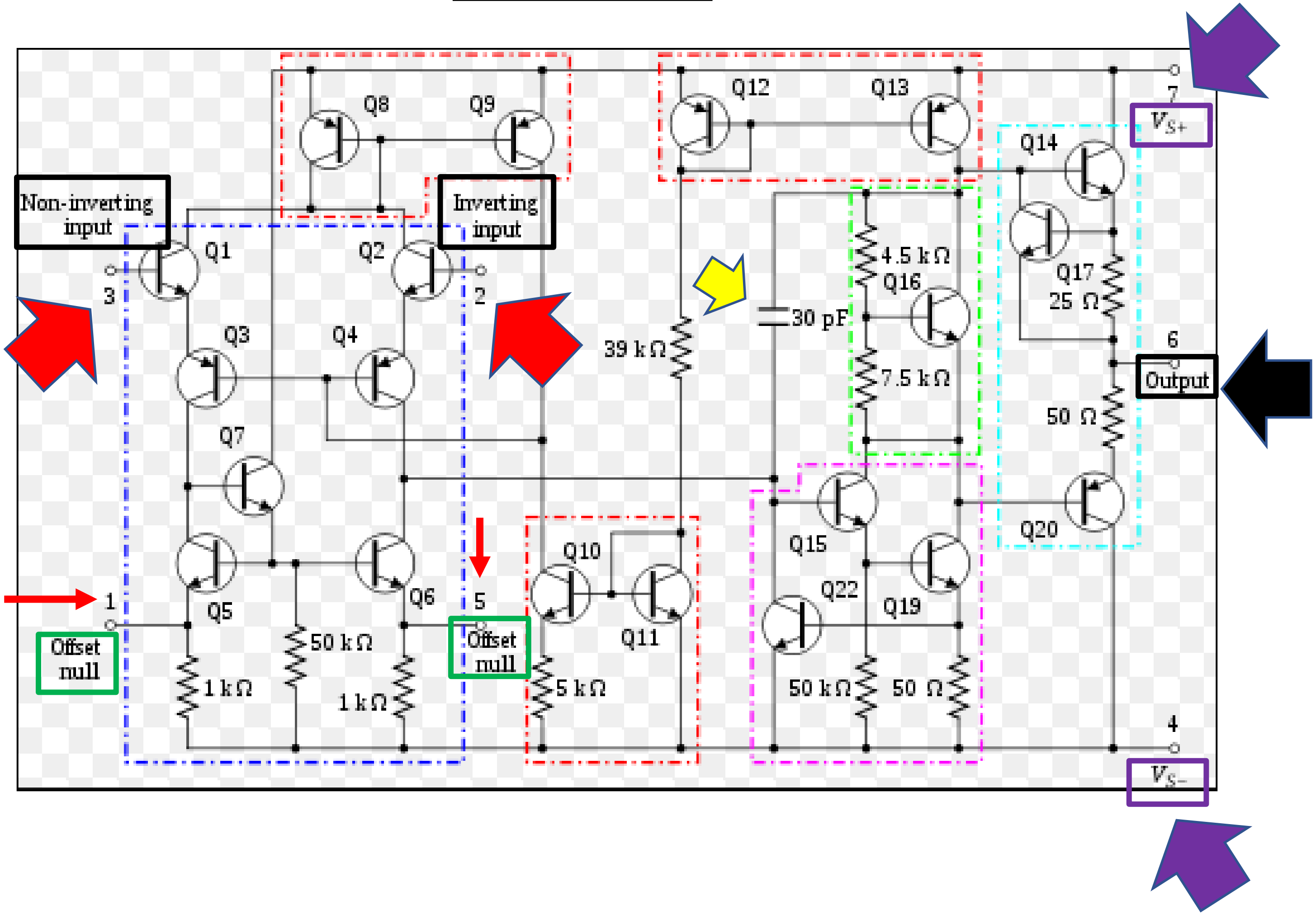
4 **The circuit inside the op amp will not be discussed at this moment**. Rather, **we will treat the op amp as a circuit building block and study its terminal characteristics and its applications. This approach is quite satisfactory in many op-amp applications**.

Nevertheless, for the more difficult and demanding applications **it is quite useful to know what is inside the op-amp package. This topic is studied in Chapter 13 – Operational Amplifiers Circuit of the book Microelectronics Circuits (Sedra – Smith, 7th edition)**. More advanced applications of op amps appears in the later chapters of this book.

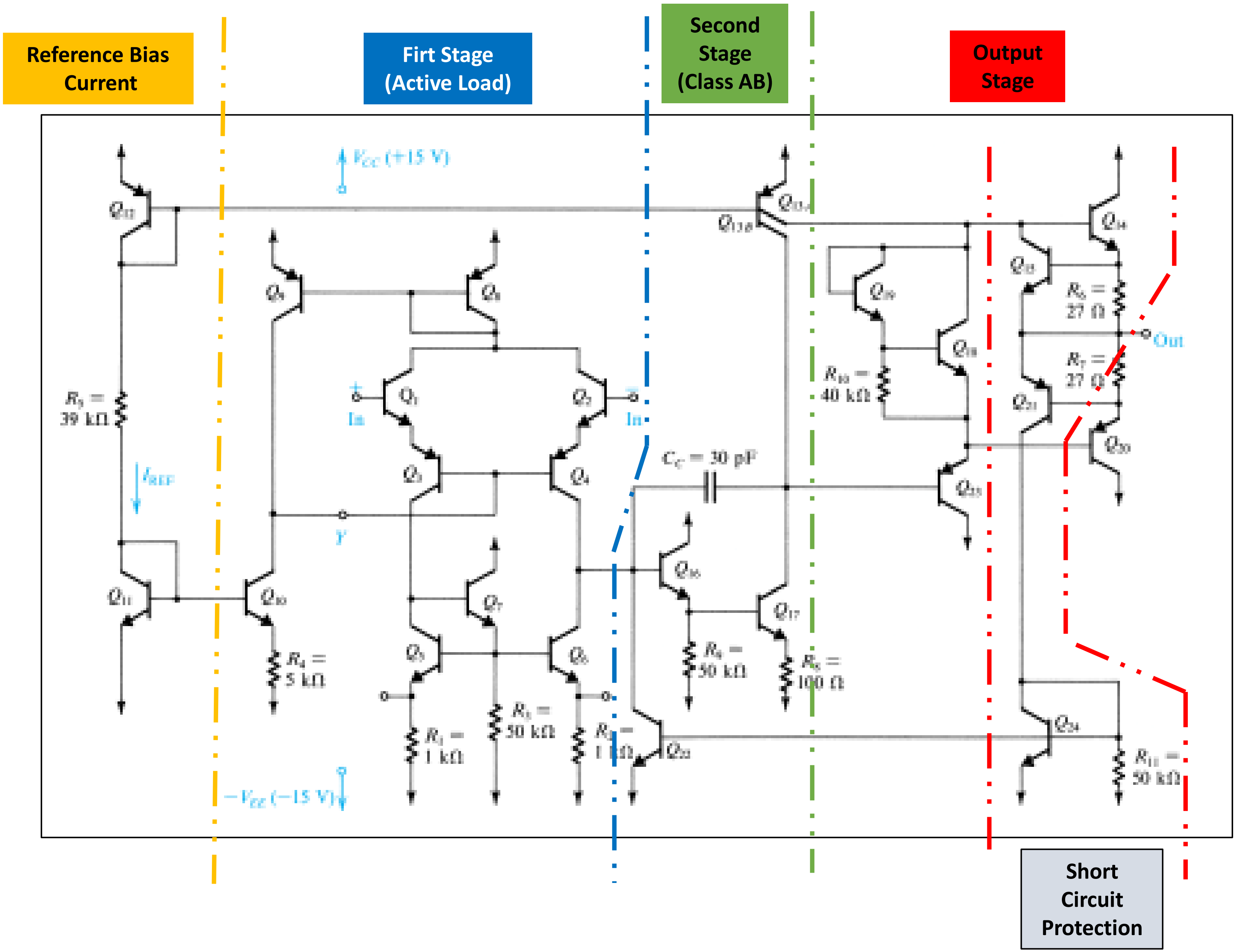
5 O Op Amp é um circuito integrado composto de **resistores, transistores e capacitores** e **blocos de circuitos**.



Op Amp 741

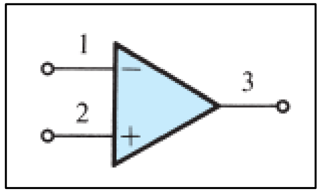


Op Amp 741

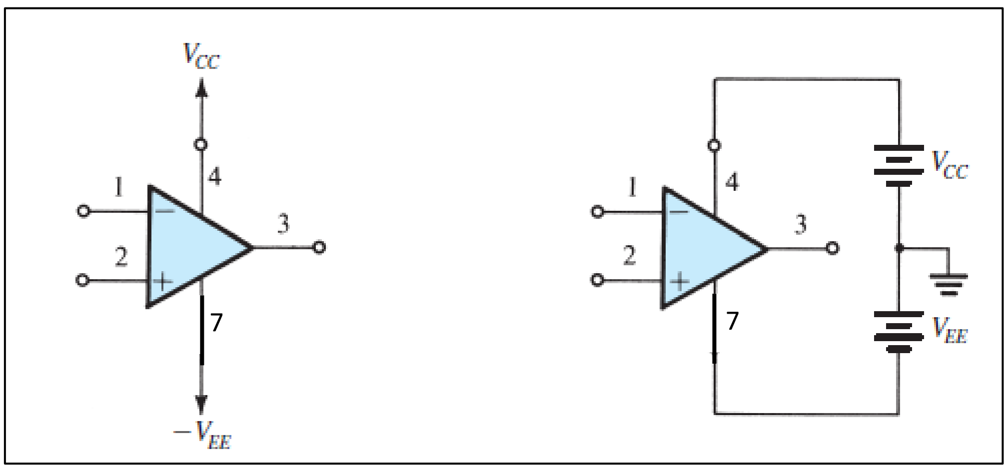


Reference Bias Current
Firt Stage (Active Load)
Second Stage (Class AB)
Output Stage
Short Circuit Protection
V_{CC} (+15 V)
$-V_{EE}$ (−15 V)
Q_{12}
Q_{13A}
Q_{13B}
Q_{14}
Q_{15}
Q_{19}
Q_{18}
Q_{21}
Q_{20}
Q_{23}
Q_{8}
Q_{9}
Q_{1}
Q_{2}
Q_{3}
Q_{4}
Q_{7}
Q_{5}
Q_{6}
Q_{16}
Q_{17}
Q_{22}
Q_{24}
Q_{11}
Q_{10}
+ In
− In
R_5 = 39 kΩ
I_{REF}
y
R_4 = 5 kΩ
R_1 = 1 kΩ
R_3 = 50 kΩ
R_2 = 1 kΩ
C_C = 30 pF
R_9 = 50 kΩ
R_8 = 100 Ω
R_{10} = 40 kΩ
R_6 = 27 Ω
R_7 = 27 Ω
Out
R_{11} = 50 kΩ

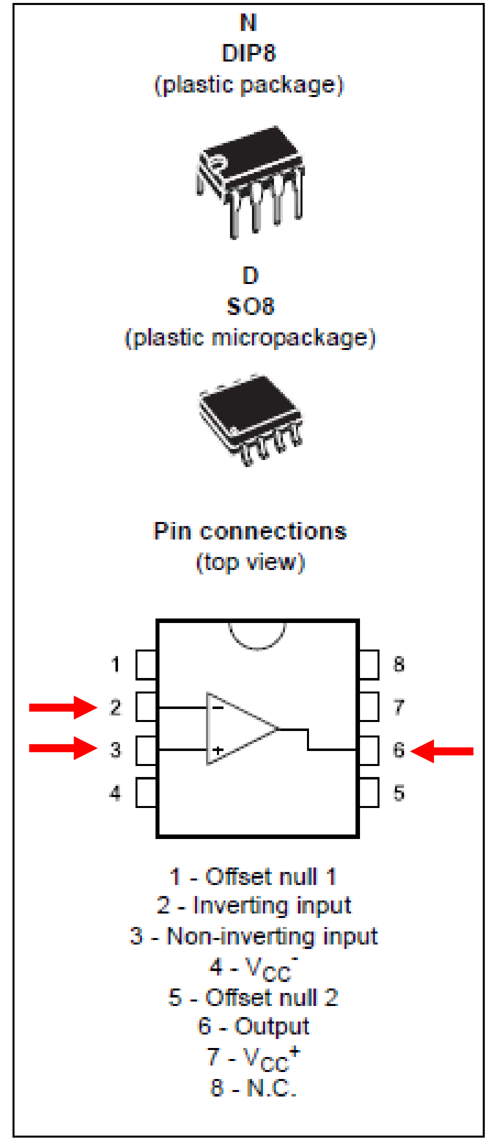
The Op-Amp Terminals



circuit symbol

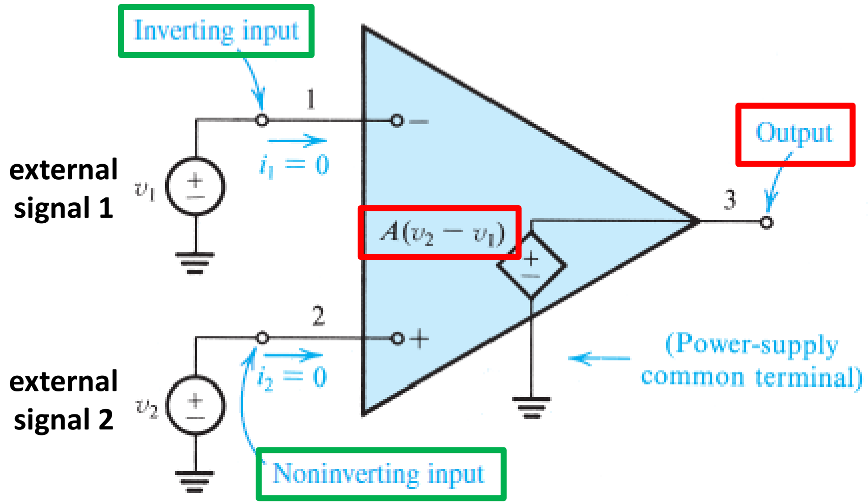


The op amp shown is connected to dc power supplies !



Ideal Op Amp

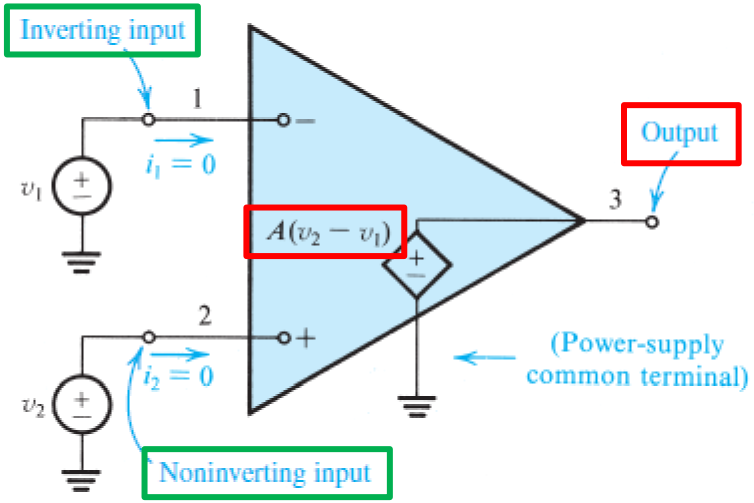
Function and Characteristics of the Ideal Op Amp



1 **The op amp is designed to sense the difference between the voltage signals applied at its two input terminals (v_1 and v_2), multiply this by a number A, and cause the resulting voltage the resulting voltage $A(v_2 - v_1)$ to appear at output terminal 3**. The voltage at a terminal we mean the voltage between that terminal and ground. Thus:

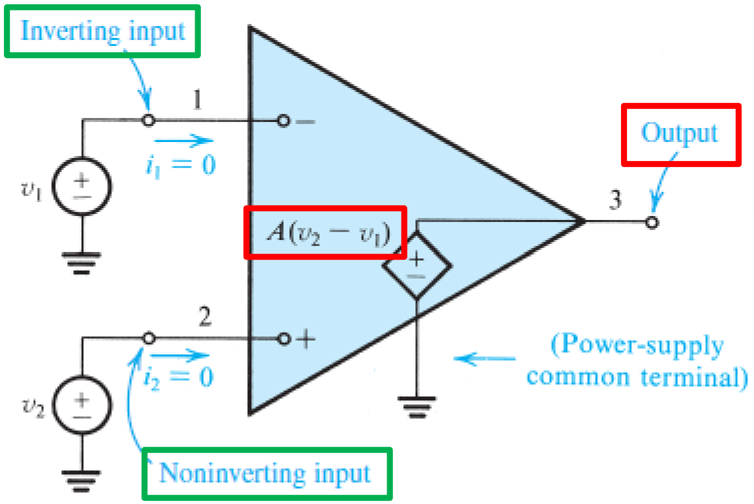
$$v_3 = A(v_2 - v_1)$$

2 **The ideal op amp is not supposed to draw any input current**. That is, the signal current into terminal 1 and the signal current into terminal 2 are both zero. In other words, **the input impedance of an ideal op amp is supposed to be infinite**.



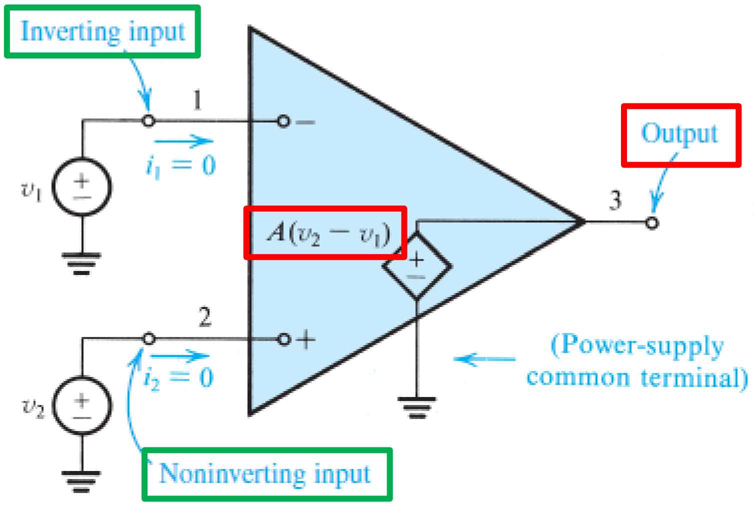
3 This terminal 3 is supposed to act as the output terminal of an ideal voltage source. That is, the voltage between terminal 3 and ground will always be equal to $A(v_2 - v_1)$, independent of the current that may be drawn from terminal 3 into a load impedance. In other words, **the output impedance of an ideal op amp is supposed to be zero.**

4 **The output is out of phase with v_1 (has the opposite sign of) and in phase with v_2 (has the same sign as).** For this reason, input terminal 1 is called the **inverting input terminal** and is distinguished by a "–" sign, while input terminal 2 is called the **noninverting input terminal** and is distinguished by a "+" sign.



5 **The op amp** responds only to the *difference* signal $v_2 - v_1$ and hence **ignores any signal common to both inputs**. That is, if *v*1 = *v*2 = 1 V, then the output will (ideally) be zero. We call this property **common-mode rejection**, and we conclude that an ideal op amp has zero common-mode gain or, equivalently, **infinite common- mode rejection.**

6 The **gain *A*** is called the **differential gain**, for obvious reasons. Perhaps not so obvious is another name that we will attach to *A*: the **open-loop gain**. The reason for this name will become obvious later on when we "close the loop" around the op amp and define another gain, the closed-loop gain.



7 **The ideal op amp has a gain *A* that remains constant down to zero frequency and up to infinite frequency**. That is, ideal op amps will amplify signals of any frequency with equal gain, and are thus said to have **infinite bandwidth**.

8 **The ideal op amp should have a gain A whose value is very large and ideally infinite**. One may justifiably ask: If the gain *A* is infinite, how are we going to use the op amp? The answer is very simple: **In almost all applications the op amp will *not* be used alone in a so-called open-loop configuration. Rather, we will use other components to apply feedback to close the loop around the op amp.**

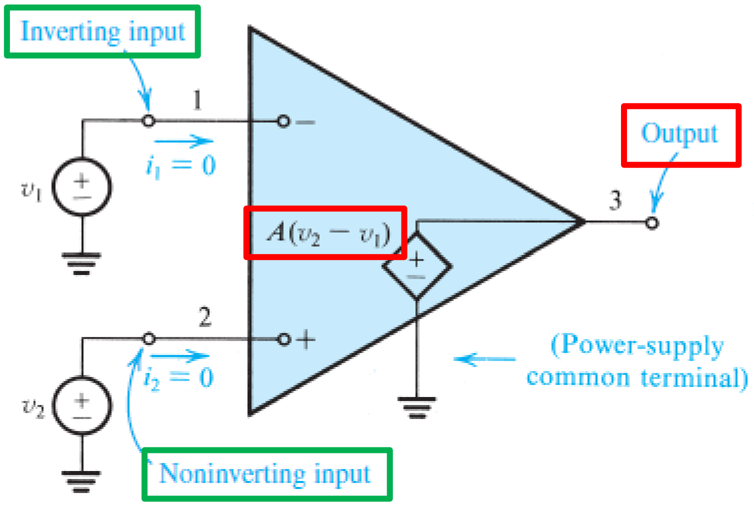


Table 2.1 Characteristics of the Ideal Op Amp

1. Infinite input impedance
2. Zero output impedance
3. Zero common-mode gain or, equivalently, infinite common-mode rejection
4. Infinite open-loop gain A
5. Infinite bandwidth

Differential and Common-Mode Signals

1 The **differential input signal** v_{Id} is simply the difference between the two input signals v_1 and v_2; that is,

$$v_{Id} = v_2 - v_1$$

2 The **common-mode input signal** v_{Icm} is the average of the two input signals v_1 and v_2:

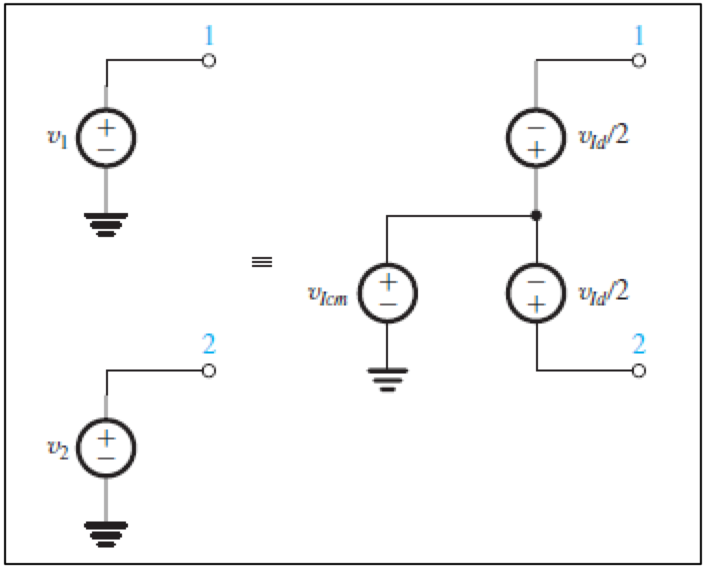
$$v_{Icm} = \frac{1}{2}(v_2 + v_1)$$

$$v_{Id} = v_2 - v_1$$

$$v_{Icm} = \frac{1}{2}(v_2 + v_1)$$

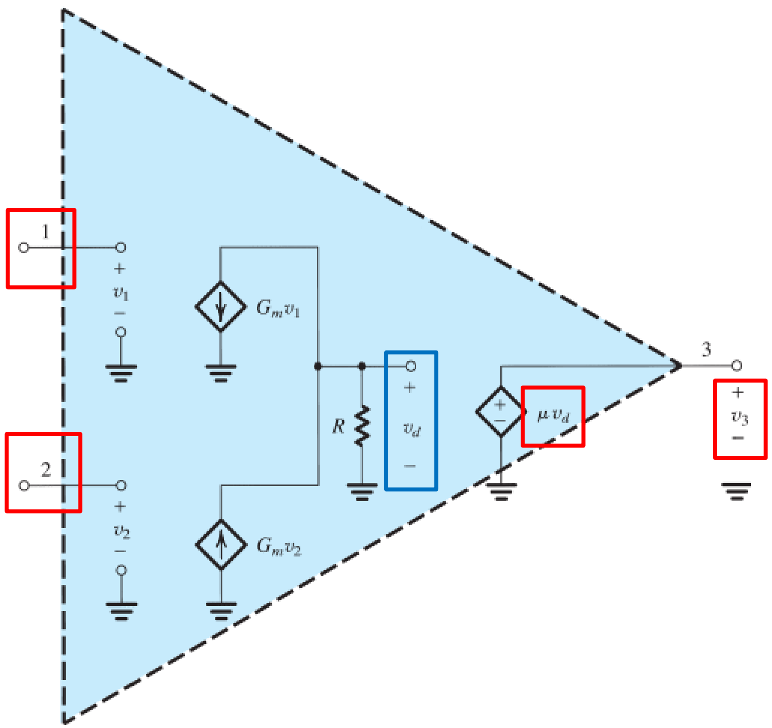
$$v_1 = v_{Icm} - \frac{v_{Id}}{2}$$

$$v_2 = v_{Icm} + \frac{v_{Id}}{2}$$



EXERCISES

The internal circuit of a particular op amp can be modeled by the circuit shown in the figure below. Express v_3 as a function of v_1 and v_2. For the case G_m = 10 mA/V, R = 10 kΩ, and μ = 100, find the value of the open-loop gain A.



$$v_3 = \mu v_d$$

$$v_d = (G_m v_2 - G_m v_1)\mathrm{R} = G_m\, \mathrm{R}\,(v_2 - v_1)$$

$$\rightarrow \quad v_3 = \mu G_m \mathrm{R}\,(v_2 - v_1)$$

$$v_3 = \mathrm{A}(v_2 - v_1) \quad \rightarrow \quad A = \mu G_m R$$

$$A = \mu G_m R = 100x10x10 = 10^4 \mathrm{V/V}$$

$$A_{dB} = 20logA = 20log10^4 = 80\ dB$$

O ganho A tem valor muito elevado !