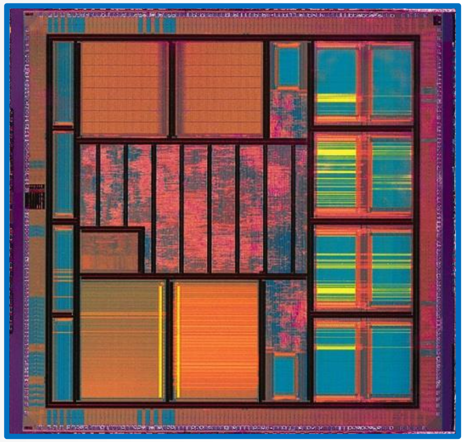
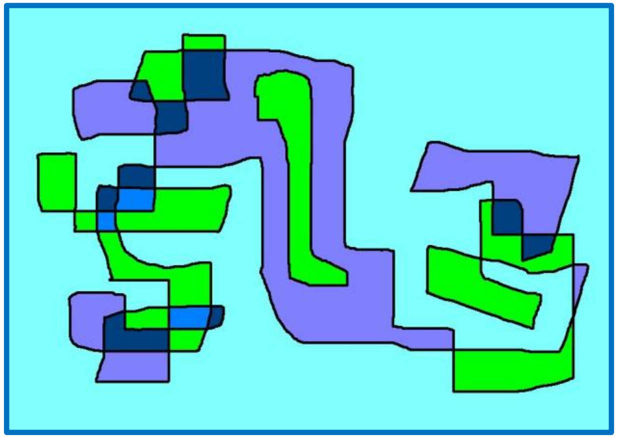
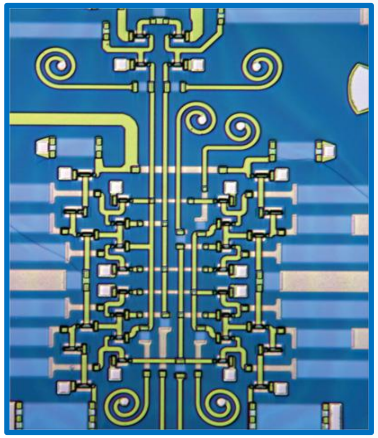






ENE/EIE 211 : Electronic Devices and Circuit Design II

Lecture 1: Introduction

Course Name: ENE/EIE 211 Electronic Devices and Circuit Design II
Credits: 3
Prerequisite: ENE/EIE 210 Electronic Devices and Circuit Design I
Class Time: Every Wednesday 1:30 PM – 16:20 PM in RM CB40904
Instructor: Asst. Prof. **THORiN T**heeradejvanichkul, Ph.D. **TA**: TBA
Office Hours: Mon 13:30 PM -16:20 PM or by appointment
Course Website:
http://webstaff.kmutt.ac.th/~thorin.the/EIE211/eie211front.html
Course Description:

Analysis and design of selected electronic circuits for communications and instrumentation by using discrete and IC devices: theory of operations, characteristics and specifications of the devices, frequency response feedback oscillator Noise reduction in electronic circuits. Printed Circuit design techniques.

Recommended Textbooks

1. Electronic Devices and Circuits by Theodore F. Bogart, Jr., Jeffrey S. Beasley and Guillermo Rico. Prentice Hall International Inc. 2003
2. Microelectronic Circuit Design by Richard C. Jaeger. The McGraw-Hill Companies, Inc. 2011
3. Microelectronic Circuits by Adel S. Sedra & Kenneth C. Smith. Saunders College Publishing, 2014

Grading Policy:

Homework, Quizzes and Class Attendance	10%
Micro Project	20%
Midterm	30%
Final	40%
Extra Credits (Formula Sheets) upto	15%

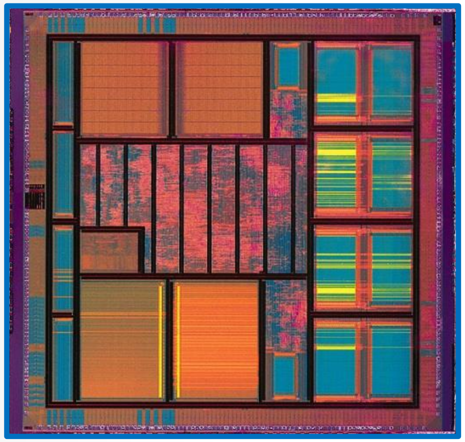
NOTE: If your attendance falls below 80%, you'll receive an F !

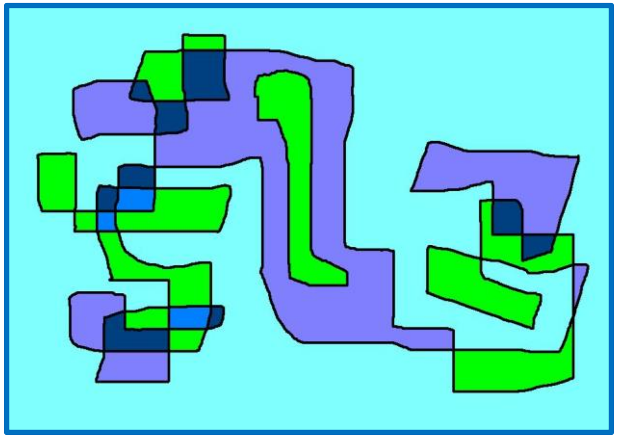
Micro Project: to build a simple electronic project **based on the knowledge learned in this class**. This is an individual project, and not a group project.

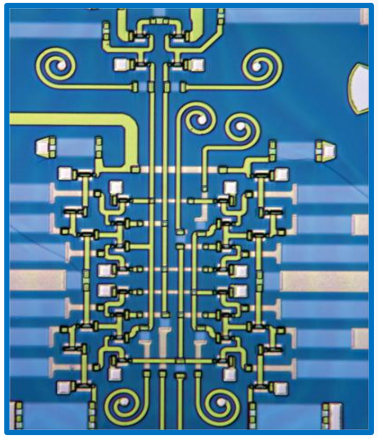
- Submit a 1-2 paged proposal that includes project title, objectives and expected results.
- Proposal submission is due 1 week before the midterm.
- After approval, complete your project and write the report.
- Your report must include project title, objectives, theory, equipment, procedure, results including percentage error, discussion, conclusion and references.

(Tentative) List of Topics:

- Op-Amp basics, differential and common mode signals, inverting amp
- Weighted-summer, finite-loop gain, noninverting amp, difference amp, instrumentation amp, non-ideal op-amp
- Slew rate, output current limit, voltage and current offsets, summer, instrumentation amps, integrators, differentiators
- Current mirrors, single-stage IC amps, cascode
- Frequency response, differential amps, 741 op amp
- Filters: 1st order, Bessel, Butterworth and Chebyshev
- Filters: 2nd and higher orders, resonators, op-amp RC active filters
- Two-port network, feedback, Nyquist plot
- Feedback amp (cont.), stability, gain and phase margins
- Oscillators: Barkhausen criteria, nonlinear amplitude control, Wien-bridge, phase-shift, Colpitts LC-tuned
- Multivibrators, Schmitt-trigger, square and triangular waveform generators
- Regulators and phase-locked loops
- Noise reduction techniques, PCB design



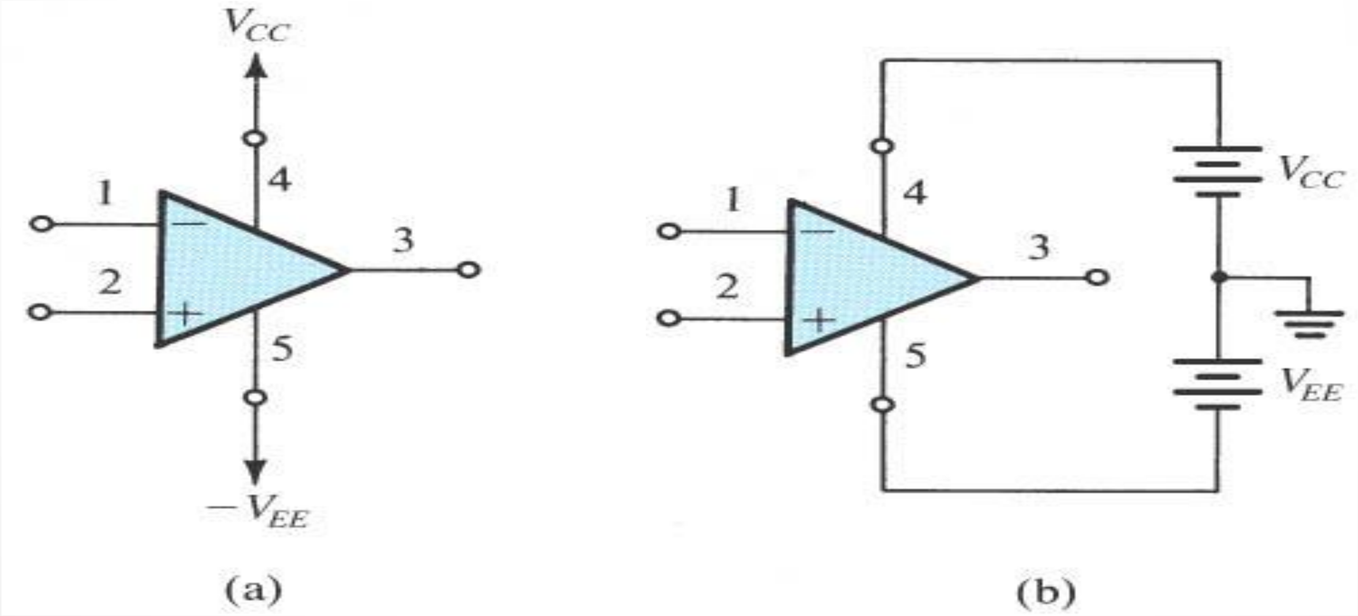




Operational Amplifiers

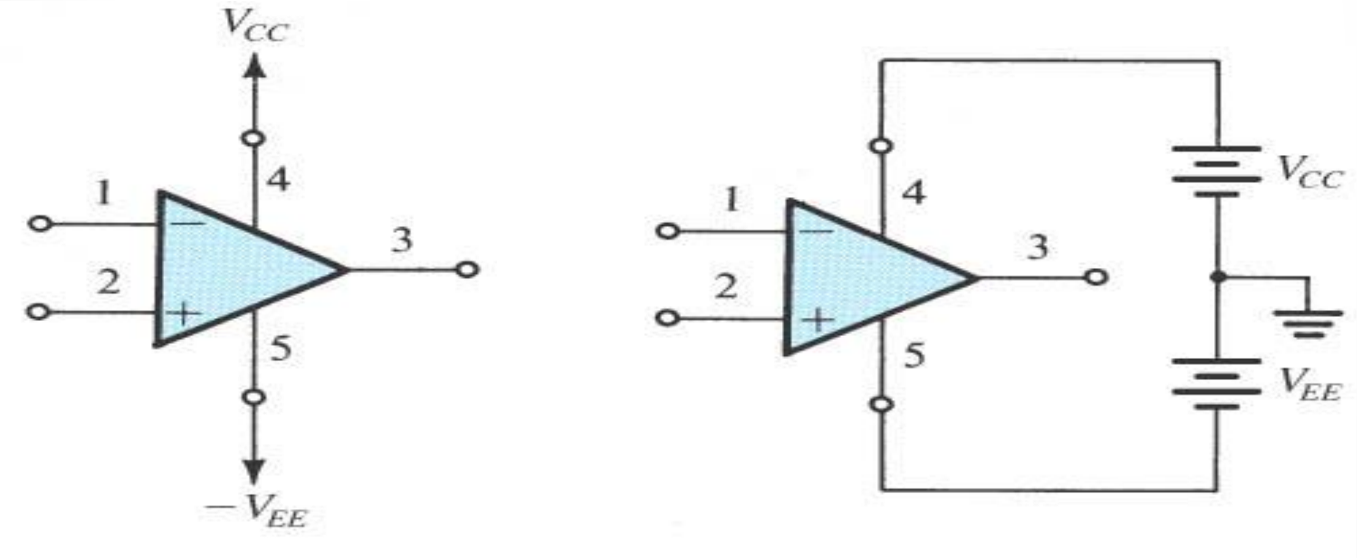
Operational Amplifier

• An op amp is a high voltage gain, DC amplifier with high input impedance, low output impedance, and differential inputs.
• Positive input at the non-inverting input produces positive output, positive input at the inverting input produces negative output.



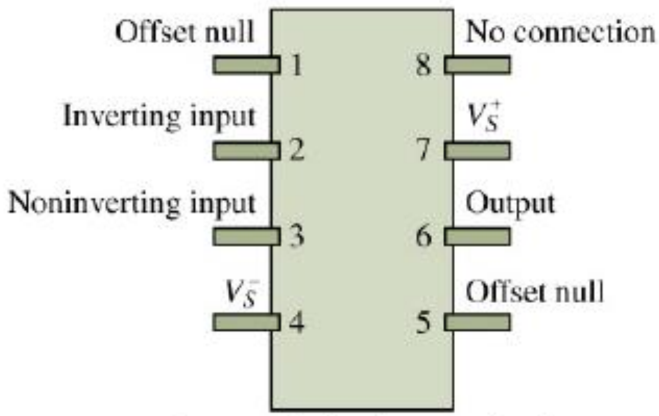
1. Inverting input
2. Non-inverting input
3. Output
4. V_{CC}
5. $-V_{EE}$

Since the power delivered to the load is greater than the power drawn from the signal source, the question arises as to the source of this additional power. The answer is found by observing that amplifiers need dc power supplies for their operation. These dc sources supply the extra power delivered to the load as well as any power that might be dissipated in the internal ckt of the amplifier.

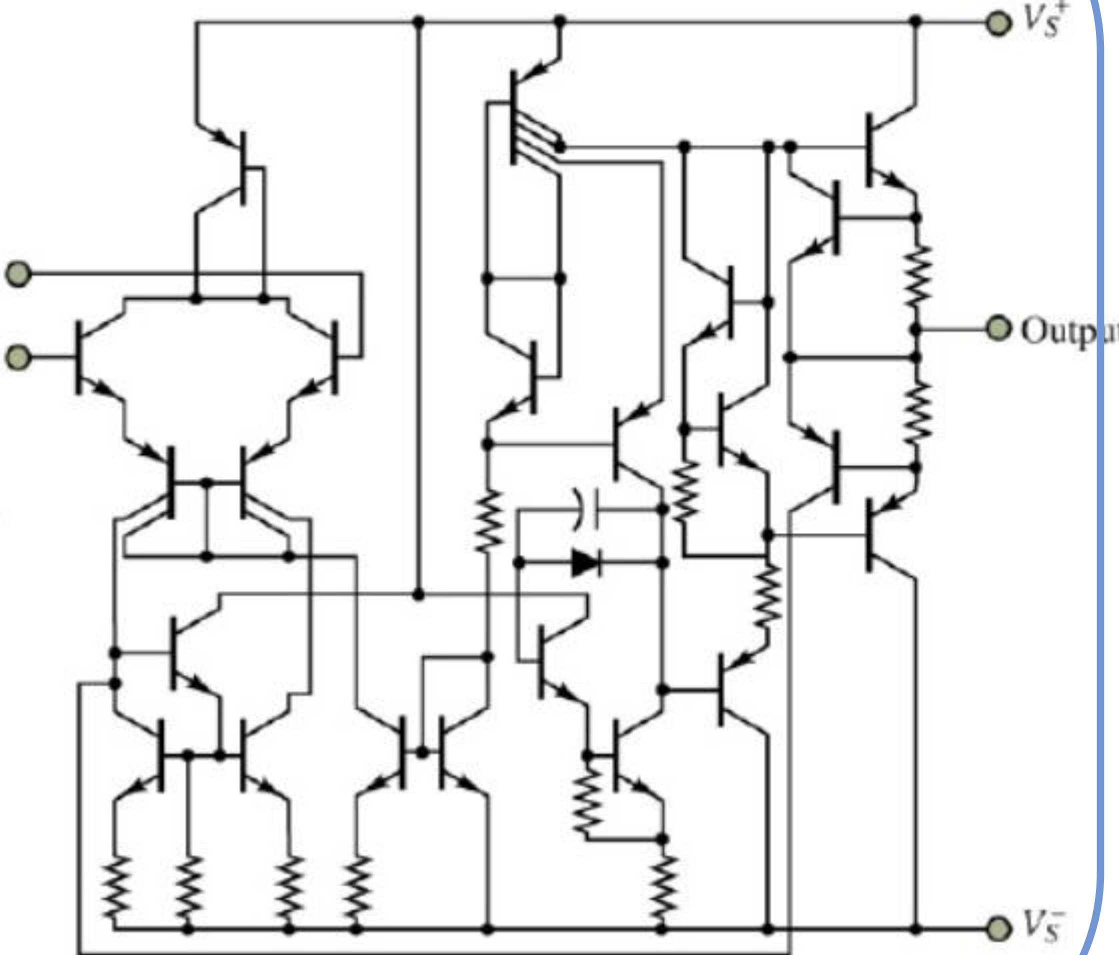


(a) (b)

- Integrated circuit containing ~20 transistors, multiple amplifier stages

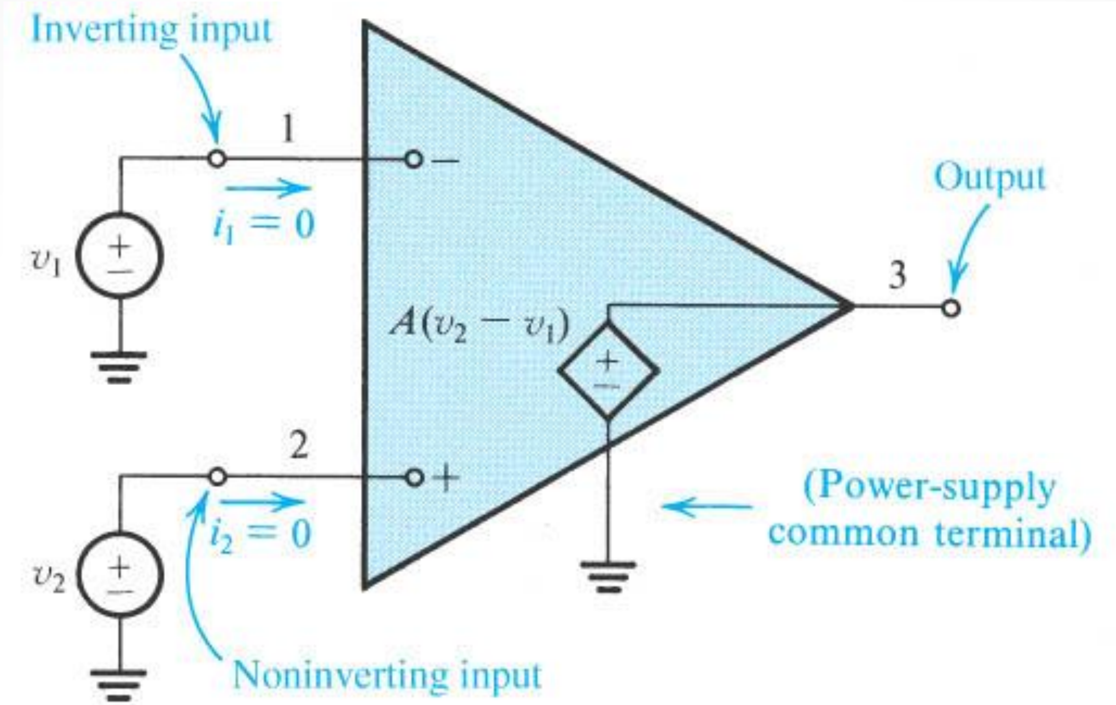


Integrated-circuit operational amplifier (IC op-amp)

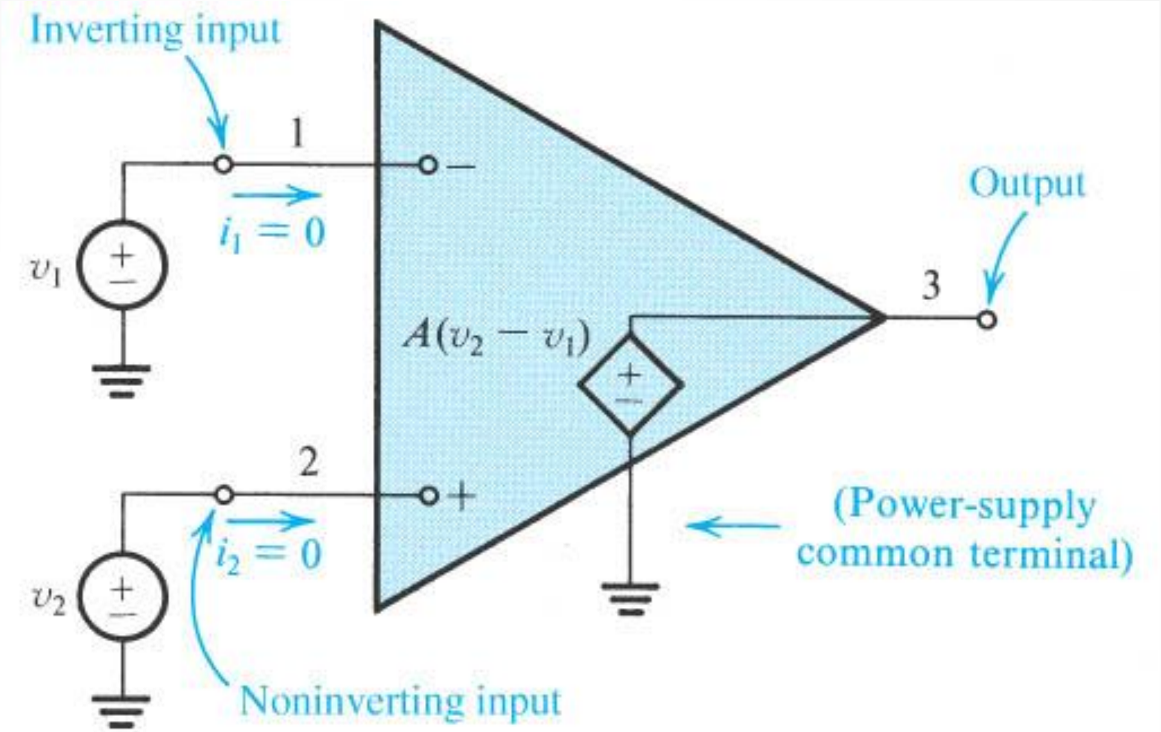


IC op-amp diagram

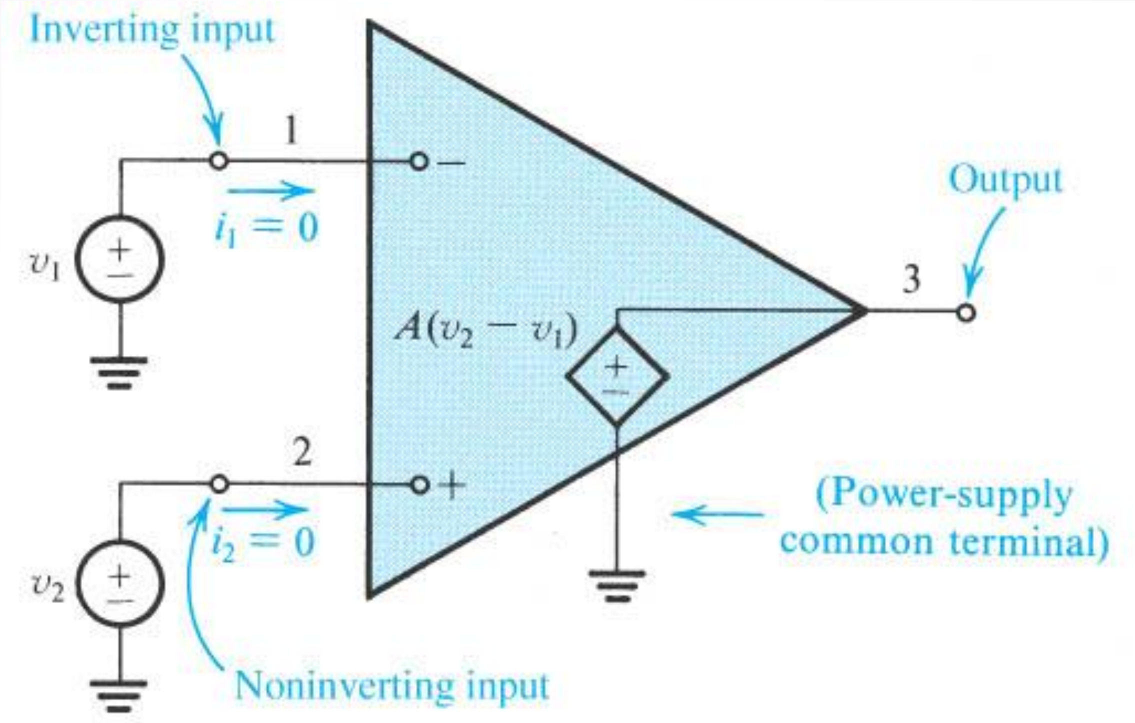
Function and Characteristics of the ideal Op Amp



The op amp is designed to sense the difference between the voltage signals applied at its two input terminals (v2 – v1), multiply this by a number A, and cause the resulting voltage A(v2-v1) to appear at the output terminal.

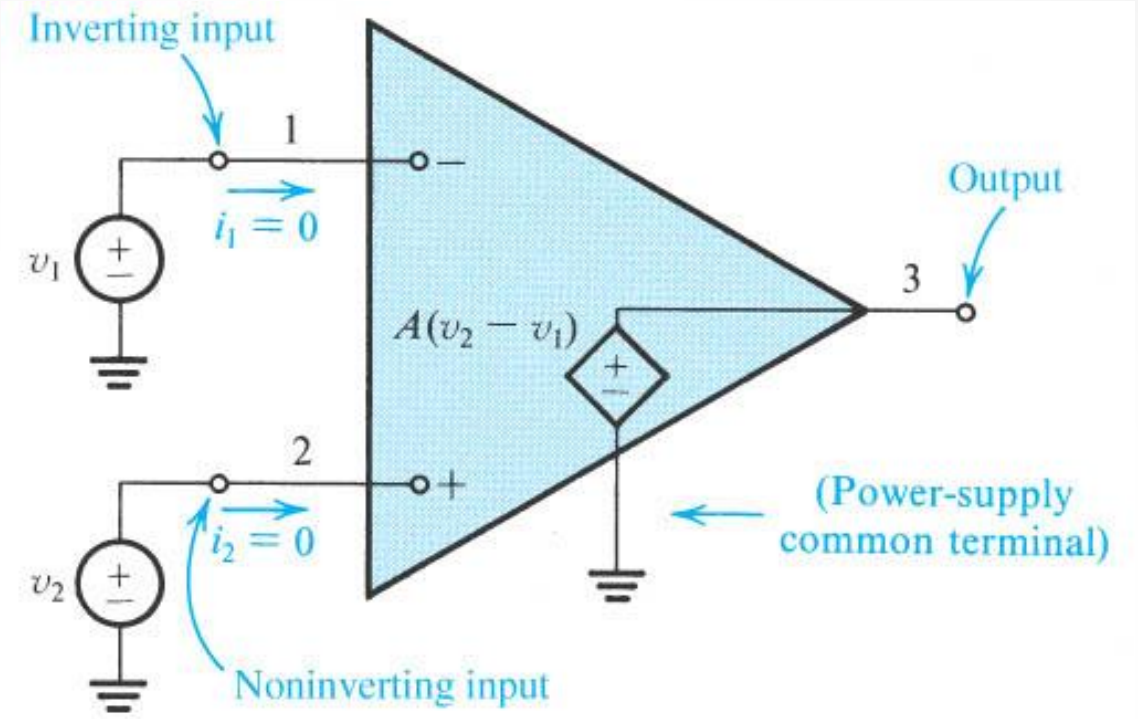


The ideal op amp is not supposed to draw any current; that is, the signal current into terminal 1 and the signal current into terminal 2 are both zero.
In other words, the input impedance of an ideal op amp is supposed to be infinite.



Terminal 3 acts as the output terminal of an ideal voltage source. That is, the voltage between terminal 3 and ground will always be equal to A(v2 –v1), 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 0.



The output is in phase with (has the same sign as) v2 and is out of phase with (has the opposite sign of) v1. 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 non-inverting input terminal and has a “+” sign.

Op amp responds only the difference signal v2-v1 and hence ignores any signal common to both inputs. We call this property common-mode rejection, and we Conclude that an ideal op amp has zero common-mode gain or infinite common Mode rejection.

Op amp is a differential-input, single-ended-output amplifier.

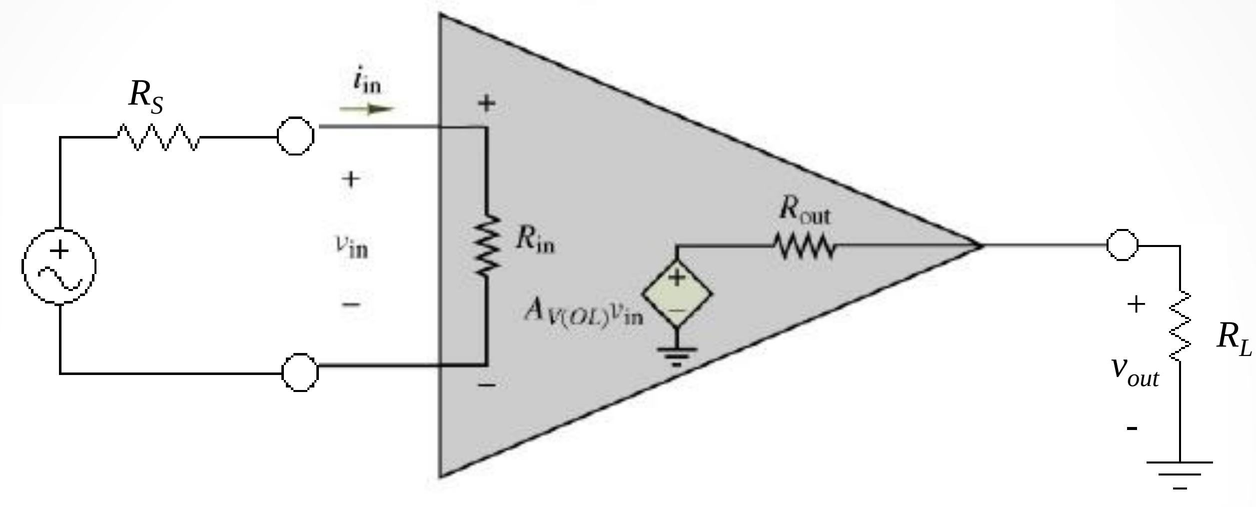
Gain, A, is called the differential gain or the open-loop gain.

Op amp is direct-coupled or dc amplifier that amplifies signal whose freq is as low as 0.

The ideal op amp has a gain A that remains constant down to zero freq and up to infinite freq. Thus, it has infinite bandwidth.

Ideal op-amp

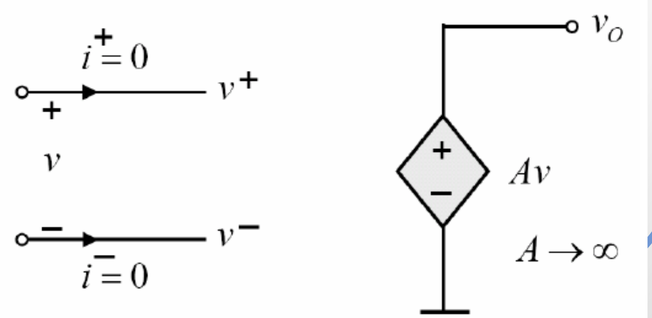
- Place a source and a load on the model



Op-amp model

So the equivalent circuit of an ideal op-amp looks like this:

- Infinite internal resistance R_{in} (so $v_{in}=v_s$).
- Zero output resistance R_{out} (so $v_{out}=A_v v_{in}$).
- "A" very large
- i_{in}=0; no current flow into op-amp



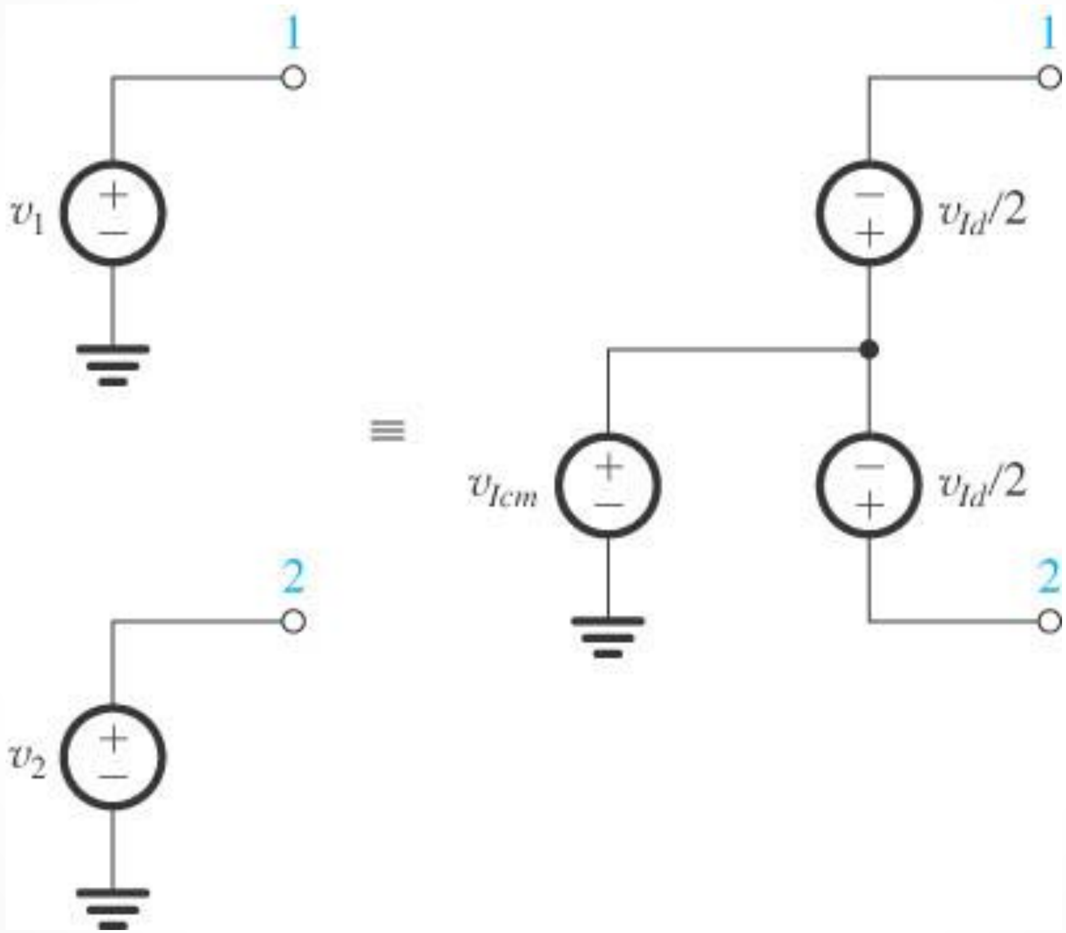
Summary: characteristics of op amps

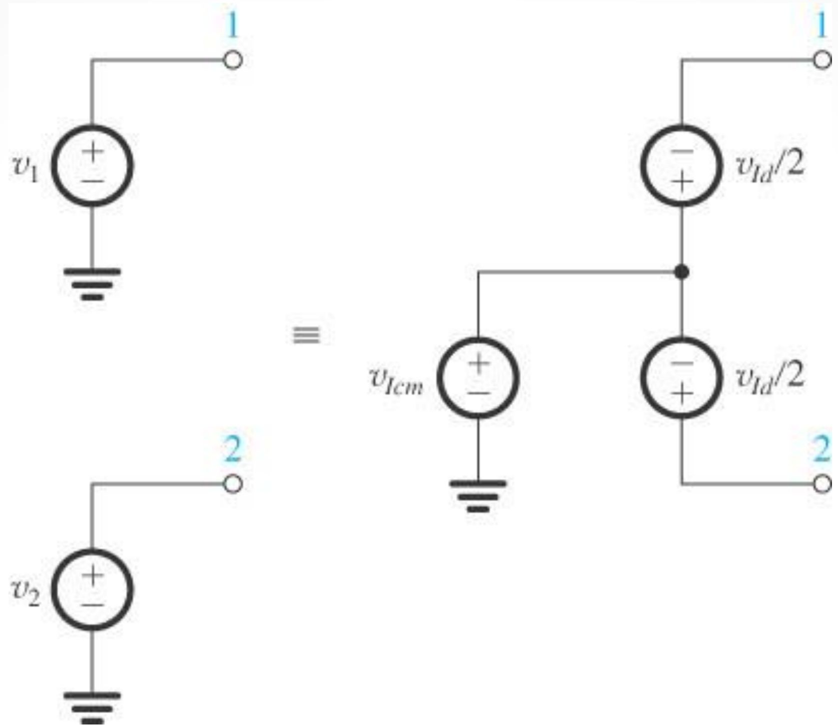
1. Infinite Input Impedance
2. Zero Output impedance
3. Zero common-mode gain, or infinite common-mode rejection
4. Infinite open loop gain A
5. Infinite bandwidth

Applications

- Amplifiers
- Adders and subtractors
- Integrators and differentiators
- Clock generators
- Active Filters
- Digital-to-analog converters

Differential and Common-Mode Signals





The differential input signal $v_{Id} = v_2 - v_1$

The common-mode input signal $v_{Icm} = (v_1 + v_2)/2$

Therefore, $v_1 = v_{Icm} - v_{Id}/2$

$v_2 = v_{Icm} + v_{Id}/2$

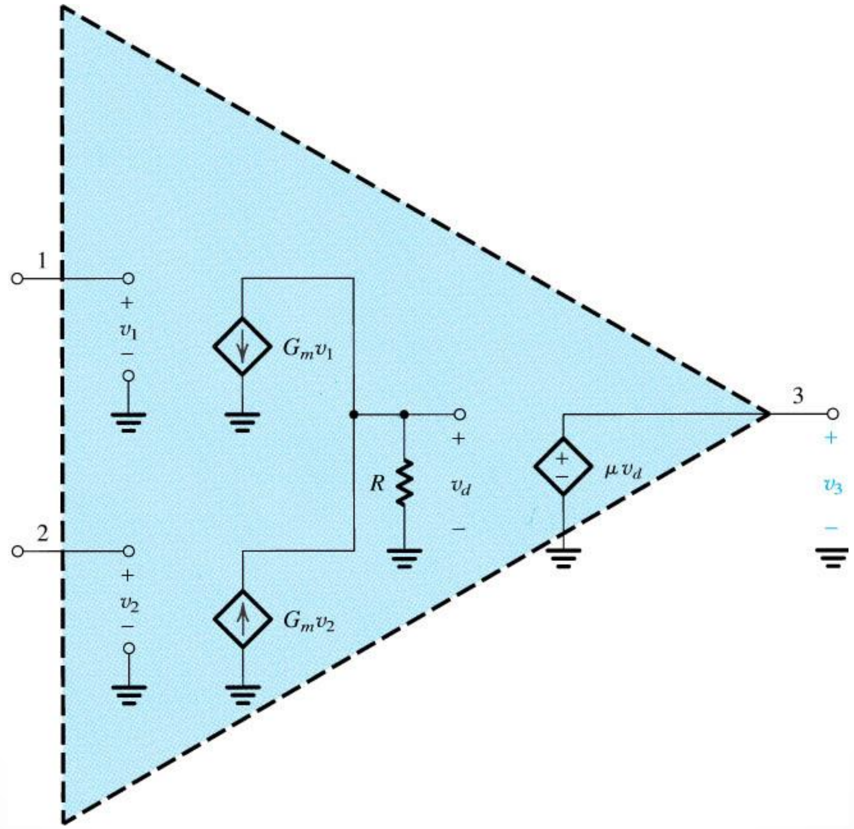
Ex 1: Consider an op amp that is ideal except that its open-loop gain $A = 10^3$. The op amp is used in a feedback ckt, and the voltages appearing at two of its three signal terminals are measured. In each of the following cases, use the measured values to find the expected value of the voltage at the third terminal. Also give the differential and common-mode input signals in each case.

(a) $v2 = 0$ V and $v3 = 2$ V

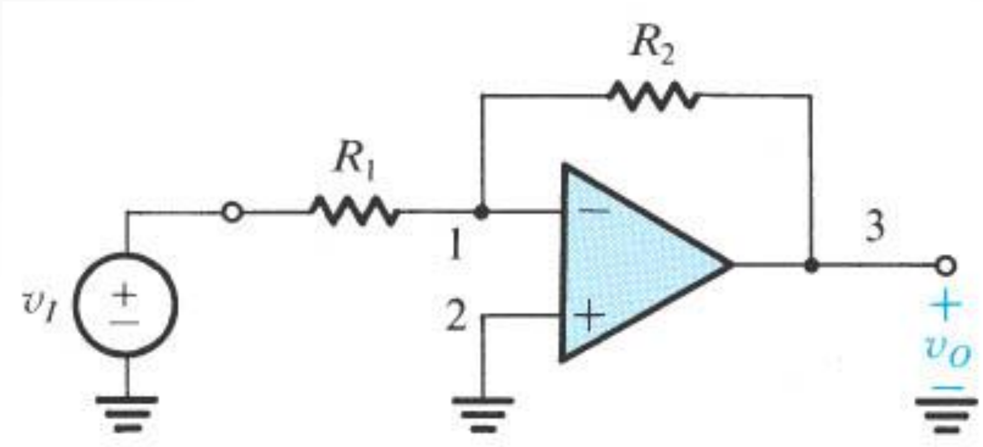
(b) $v2 = 5$ V and $v3 = -10$ V

(c) $v1 = 1.002$ V and $v2 = 0.998$ V

Ex 2: The internal ckt of a particular op amp can be modeled by the ckt shown Below. Express v3 as a function of v1 and v2. For the case Gm = 10 mA/V, R = 10 kΩ and μ = 100, find the value of the open-loop gain A.



The inverting configuration



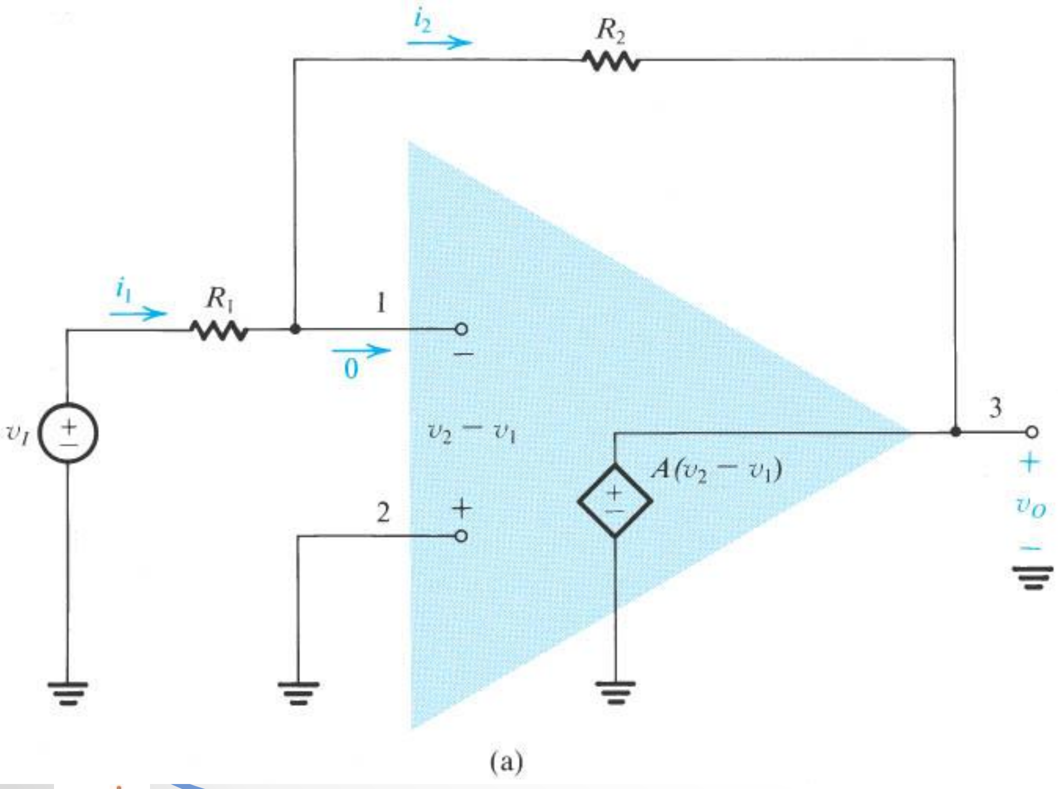
One op amp and 2 resistors. Resistor R2 connects the output back to the inverting or negative input terminal. R2 therefore provides negative feedback.

If R2 were to connect the output and the noninverting input, it would provide a positive feedback.

Now, we want to analyze the circuit to determine the closed-loop gain G, Defined as

$$G = \frac{v_O}{v_I}$$

Since op amp is ideal, A is infinite. Therefore, $v_2 - v_1 = \frac{v_O}{A} = 0$



The voltage v1 approaches and ideally equals v2. We speak of this as the two input terminals "tracking each other in potential."

Since terminal 2 is connected to Ground. We call terminal 1 a "virtual ground", that is having zero voltage but not physically connected to ground.

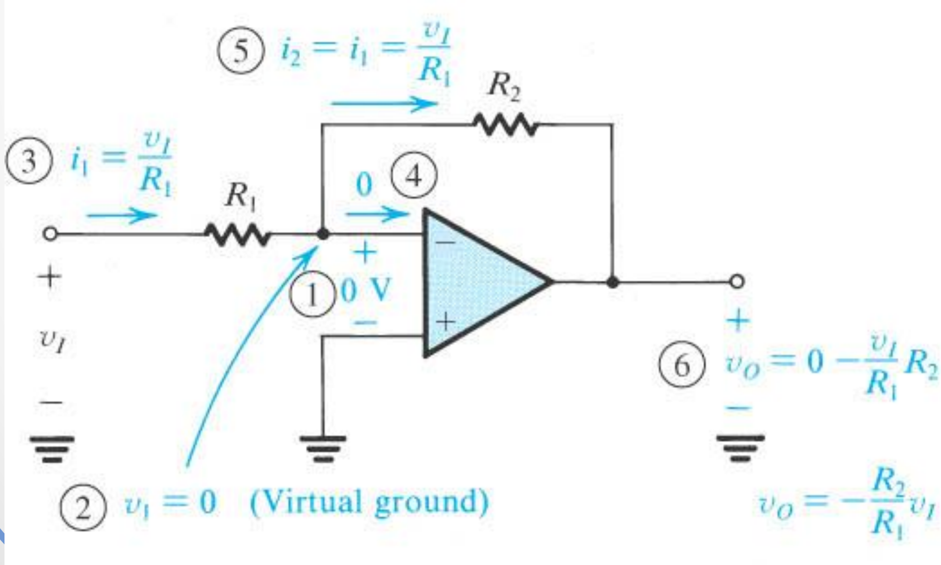
Next, apply Ohm's law to find the current i_1 flowing into terminal 1

$$i_1 = \frac{v_I - v_1}{R_1} = \frac{v_I - 0}{R_1} = \frac{v_I}{R_1}$$

Because an ideal op amp has infinite input impedance, the current i_1 cannot go into op amp. It will flow through R_2 to the low-impedance terminal 3. Next we can apply Ohm's law to find vo; that is,

$$v_O = v_1 - i_1 R_2 = 0 - \frac{v_I}{R_1} R_2$$

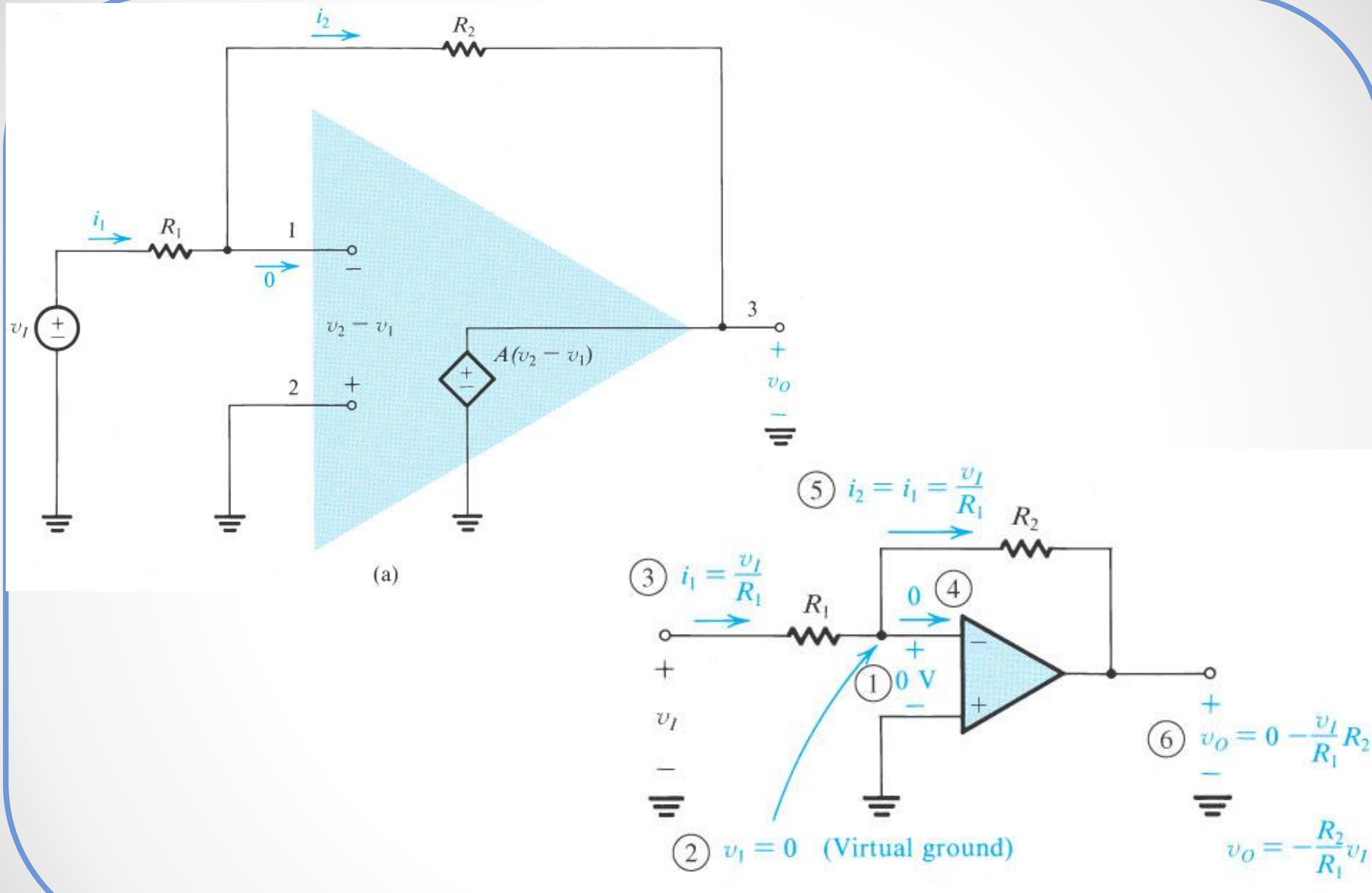
Therefore, $\frac{v_O}{v_I} = -\frac{R_2}{R_1}$ which is the required closed-loop gain.



(b)

The minus sign means that the closed-loop gain proves signal inversion (or 180° phase shift).

This closed-loop gain R_2/R_1 is much smaller than A but is stable and predictable. Hence, we are trading gain for accuracy (and stability).



i_2
R_2
i_1
R_1
1
0
−
v_I
$v_2 - v_1$
3
$A(v_2 - v_1)$
2
+
v_O
⑤ $i_2 = i_1 = \frac{v_I}{R_1}$
③ $i_1 = \frac{v_I}{R_1}$
0 ④
① 0 V
⑥ $v_O = 0 - \frac{v_I}{R_1} R_2$
② $v_1 = 0$ (Virtual ground)
$v_O = -\frac{R_2}{R_1} v_I$

(a)

(b)

Closed-loop input and output resistances

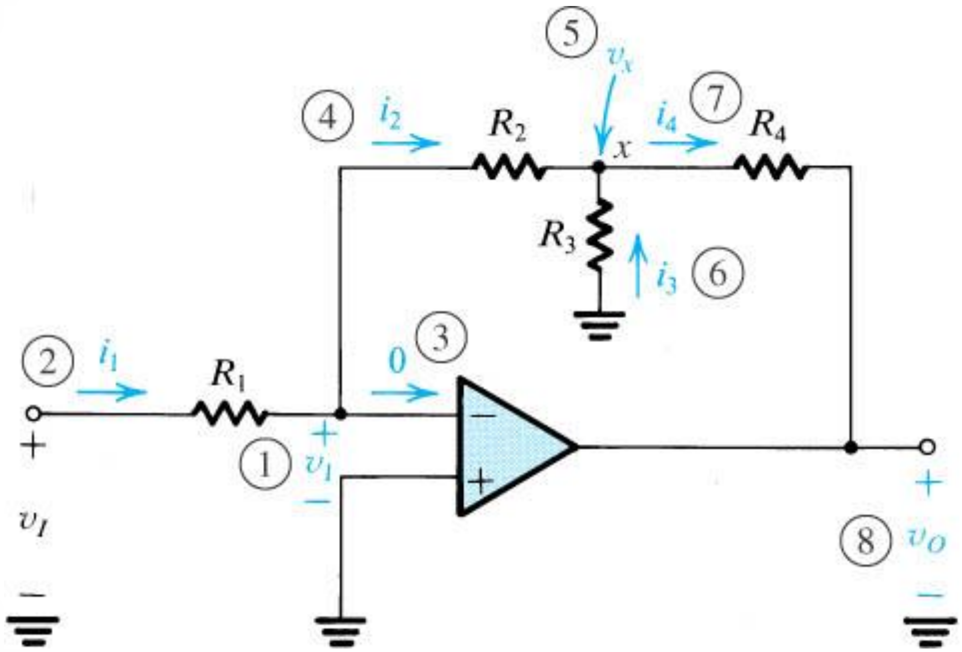
- Assume an ideal op amp with infinite open-loop gain, the input resistance of the closed-loop inverting amp is simply R_1 . This can be shown as

$$R_1 = \frac{v_I}{i_1} = \frac{v_I}{v_I / R_1} = R_1$$

Recall that the amplifier input resistance forms a voltage divider with the resistance of the source that feeds the amplifier. To avoid the loss of the signal strength, voltage amplifiers are required to have high input resistance. To make R1 high, as well as high gain. R2 will need to be large! It may be impractically large. Hence, the inverting configuration suffers from a low input resistance.

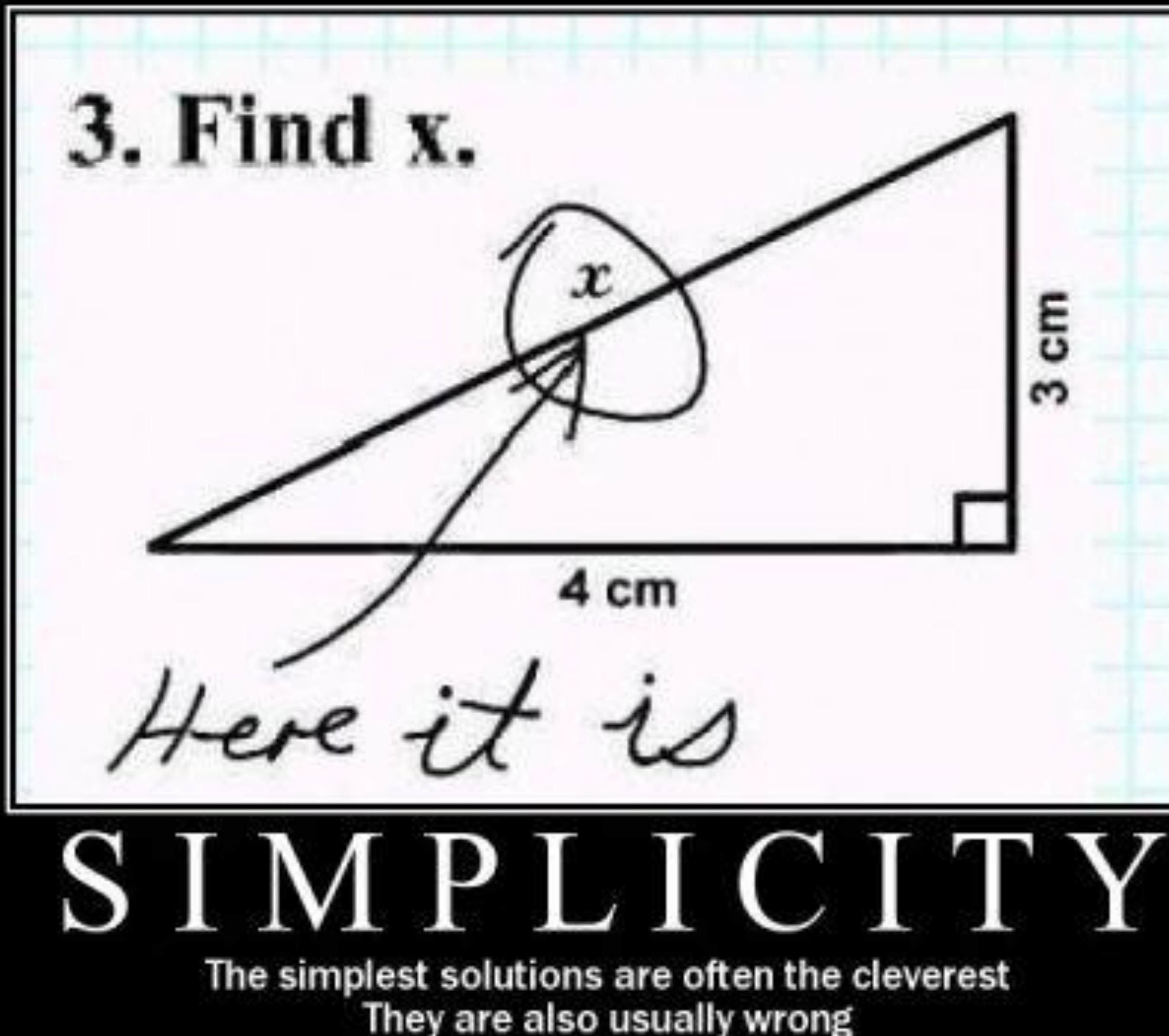
- Since the output of the inverting configuration is taken at the terminals of the ideal voltage source $A(v_2 - v_1)$, it follows that the output resistance of the closed-loop amplifier is zero.

Ex 3. Assuming the op amp to be ideal, derive an expression for the closed-loop gain v_O/v_I of the ckt shown. Use this ckt to design an inverting amp with a gain of 100and input resistance of 1 MΩ. (In your design, avoid using R's greater than 1 MΩ for practical purposes.)



Reference

Microelectronic Circuits by Adel S. Sedra & Kenneth C. Smith. Saunders College Publishing


3. Find x.
x
3 cm
4 cm
Here it is
SIMPLICITY
The simplest solutions are often the cleverest
They are also usually wrong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