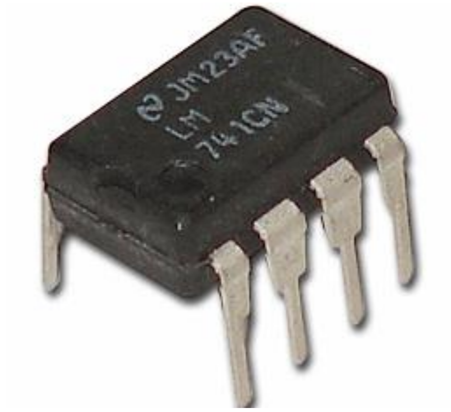
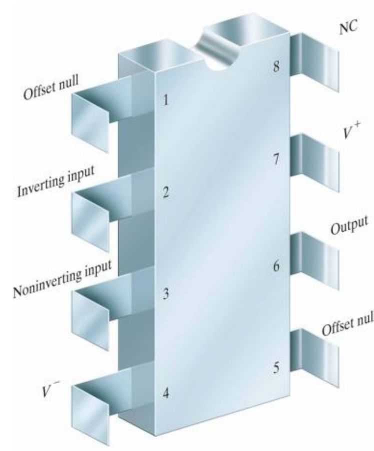
The Operation Amplifier (Op-Amp)

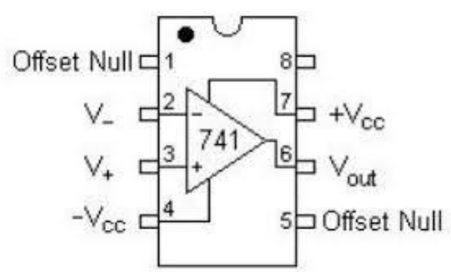
An op-amp is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.



*The **ideal op amp** is an amplifier with infinite input impedance, infinite open-loop gain, zero output impedance, infinite bandwidth, and zero noise. It has positive and negative inputs which allow circuits that use feedback to achieve a wide range of functions.*

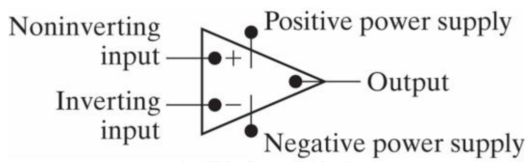


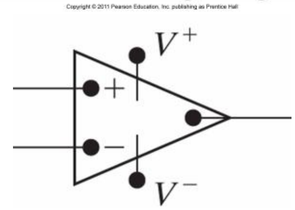
- Using op amps, it's easy to make amplifiers, comparators, log amps, filters, oscillators, data converters, level translators, references, and more.
- Mathematical functions like addition, subtraction, multiplication, and integration can be easily accomplished.
- One key to op amp design is nodal analysis. Since the input impedance is infinite, the current in and out of the + and - input nodes defines the circuit's behavior.



μA741 (The *μA* prefix is used by Fairchild to indicate a microcircuit fabrication of the amplifier.)

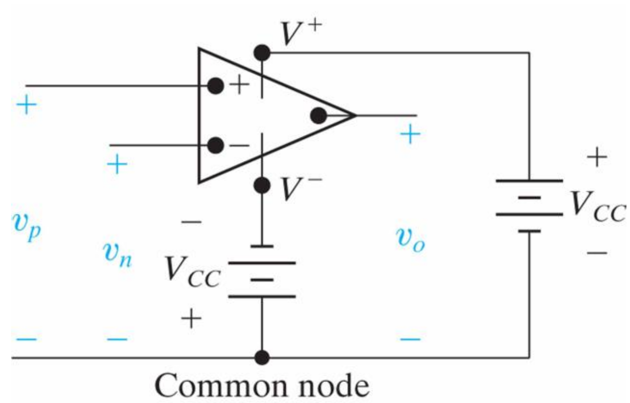
Our focus on the terminal behavior of the operational amplifier implies taking a black box approach to its operation; that is, we are neither interested in the internal structure of the amplifier nor in the currents and voltages that exist in this structure. The important thing to remember is that the internal behavior of the amplifier accounts for the voltage and current constraints imposed at the terminals.





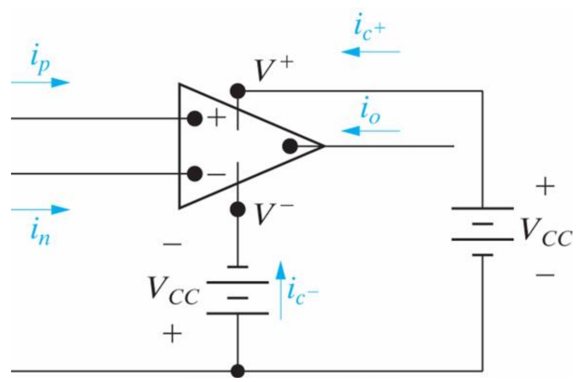
Terminal Voltages and Currents:

Voltages:



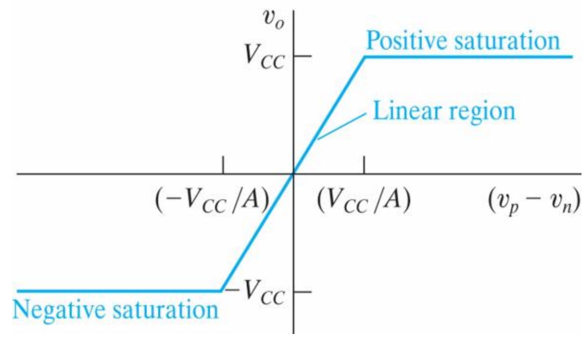
- Figure shows the voltage variables with their reference polarities.The voltage variables are measured from a common reference node.
- All voltages are considered as voltage rises from the common node.
- This convention is the same as that used in the node-voltage method of analysis.
  - A positive supply voltage (V_{cc}) is connected between $V^+$and the common node.
  - A negative supply voltage ($-V_{cc}$) is connected between$V^-$and the common node.
  - The voltage between the inverting input terminal and the common node is denotedv_n.
  - The voltage between the non-inverting input terminal and the common node is designated asv_p.
  - The voltage between the output terminal and the common node is denotedv_o.

Currents:



- Figure shows the current variables with their reference directions. Note that all the current reference directions are into the terminals of the operational amplifier
  - i_n is the current into the inverting input terminal.
  - i_p is the current into the non-inverting input terminal.
  - i_0 is the current into the output terminal
  - $i_{c^+}$is the current into the positive power supply terminal.
  - i_{c^-} is the current into the negative power supply terminal.

Terminal Behavior:



The terminal behavior of the op amp as a linear circuit element is characterized by constraints on the input voltages and the input currents.

The voltage constraint is derived from the voltage transfer characteristic of the op amp integrated circuit and is pictured in Figure.

The voltage transfer characteristic describes how the output voltage varies as a function of the input voltages; that is, how voltage is transferred from the input to the output.

Note that for the op amp, the output voltage is a function of the difference between the input voltages: $v_p - v_n$.

The equation for the voltage transfer characteristic is:

$$v_o = \begin{cases} -V_{CC} & A(v_p - v_n) < -V_{CC}, \\ A(v_p - v_n) & -V_{CC} \le A(v_p - v_n) \le +V_{CC}, \\ +V_{CC} & A(v_p - v_n) > +V_{CC}. \end{cases}$$