SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)
COIMBATORE-35
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19EET208 / DIGITAL ELECTRONICS AND INTEGRATED CIRCUITS

II YEAR / IV SEMESTER

UNIT-IV: OPERATIONAL AMPLIFIER

OP-AMP BASICS AND CHARACTERISTICS

TOPIC OUTLINE

What is an Op-Amp?

History

Pin Details IC741

Characteristics of **Ideal** Op-Amps

Characteristics of **Real** Op-Amps

Basics of Op-Amp

Inv and Non Inv Op-Amp Circuits

WHAT IS AN OP-AMP?

- An *Operational Amplifier* (known as an "Op-Amp") is a device that is used to amplify a signal using an external power source
- Op-Amps are generally composed of:
  - – Transistors, Resistors, Capacitors

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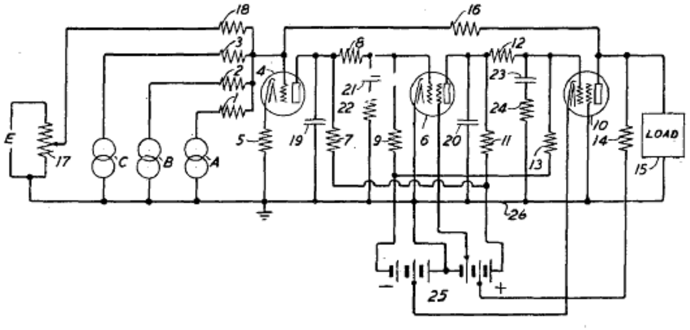
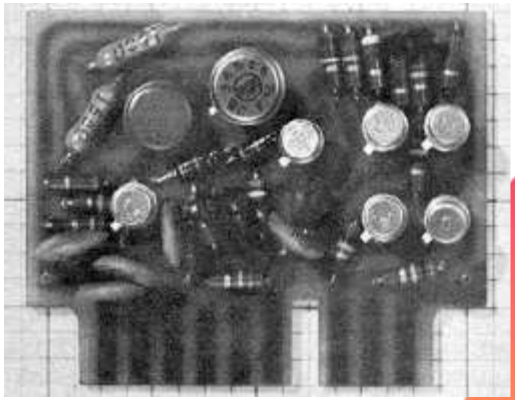
BRIEF HISTORY

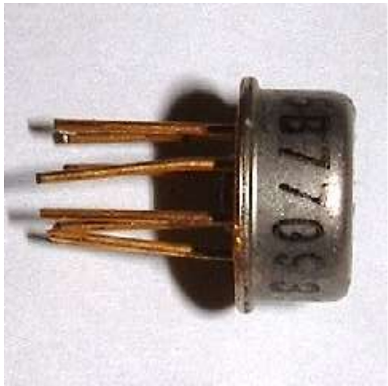
- First patent for Vacuum Tube Op-Amp (1946)



- First Commercial Op-Amp available (1953)



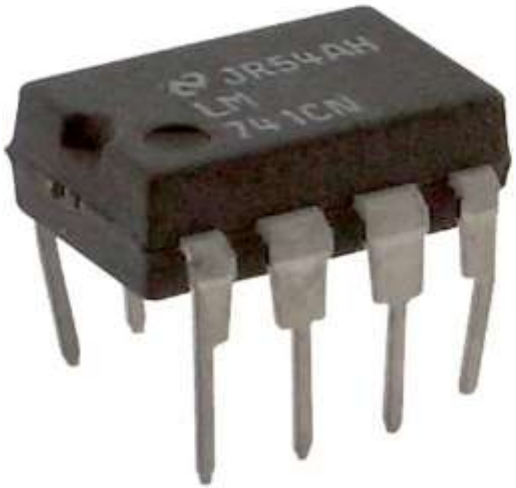
- First discrete IC Op-Amps (1961)

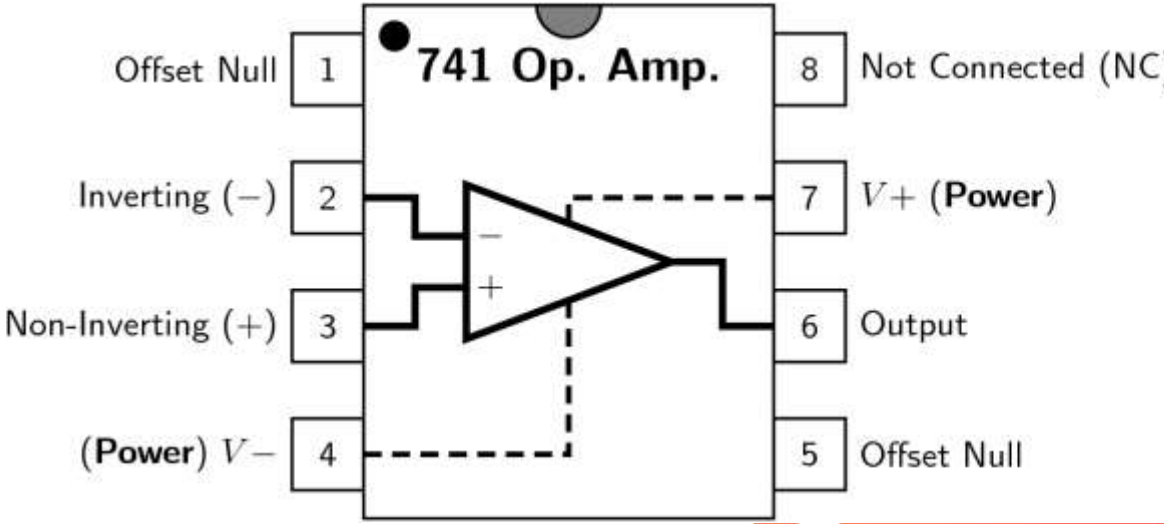


- First commercially successful Monolithic Op-Amps (1965)

IC741 – PIN DETAILS

- Leading to the advent of the modern IC which is still used even today (1967 – present)





Fairchild µA741

Electrical Schematic of µA741

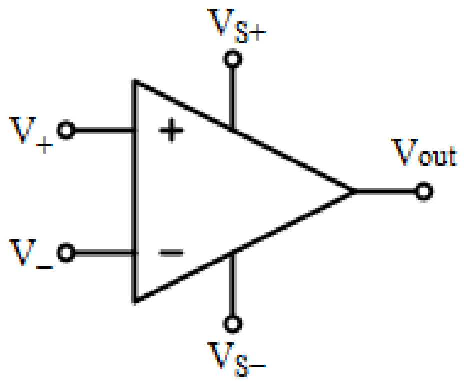
AN IDEAL OP-AMP

- Infinite voltage gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Zero input offset voltage (i.e., exactly zero out if zero in).

http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/opamp.html#c4

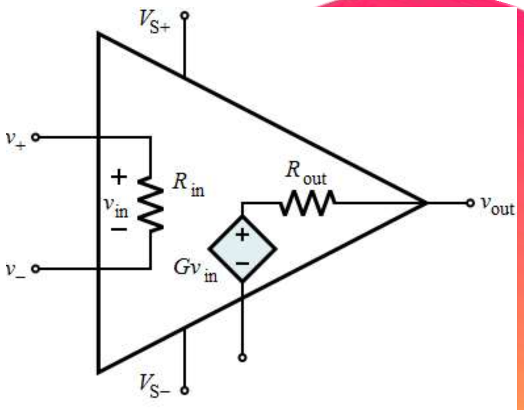
IDEAL VERSUS REAL OP-AMPS

Parameter	Ideal Op-Amp	Real Op-Amp
Voltage Gain	∞	10^5 - 10^9
Gain Bandwidth (Hz)	∞	1-20 MHz
Input Resistance (Ri)	∞	10^6 - 10^{12} Ω
Output Resistance (Ro)	0	100 - 1000 Ω



Ideal

Real



BASICS OF AN OP-AMP

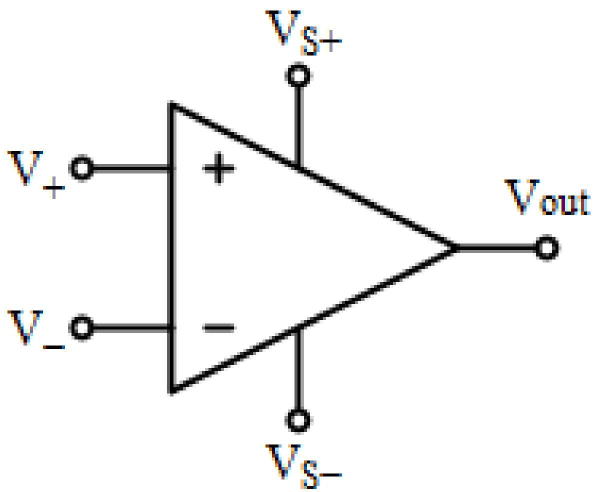
- An op-amp amplifies the difference of the inputs V_+ and V_- (known as the differential input voltage)
- This is the equation for an *open loop* gain amplifier:

$$V_{out}=K(V_+-V_-)$$

- K is typically very large – at around 10,000 or more for IC Op-Amps
- This equation is the basis for all the types of amps we will be discussing

BASICS OF AN OP-AMP

A traditional Op-Amp:



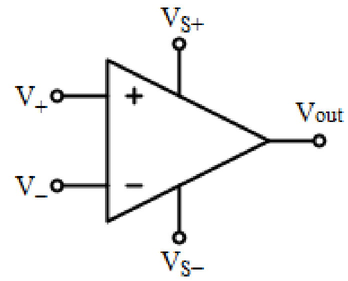
V_+ : non-inverting input
V_- : inverting input
V_{out} : output
V_{s+} : positive power supply
V_{s-} : negative power supply

$$V_{out} = K\,(V_+ - V_-)$$

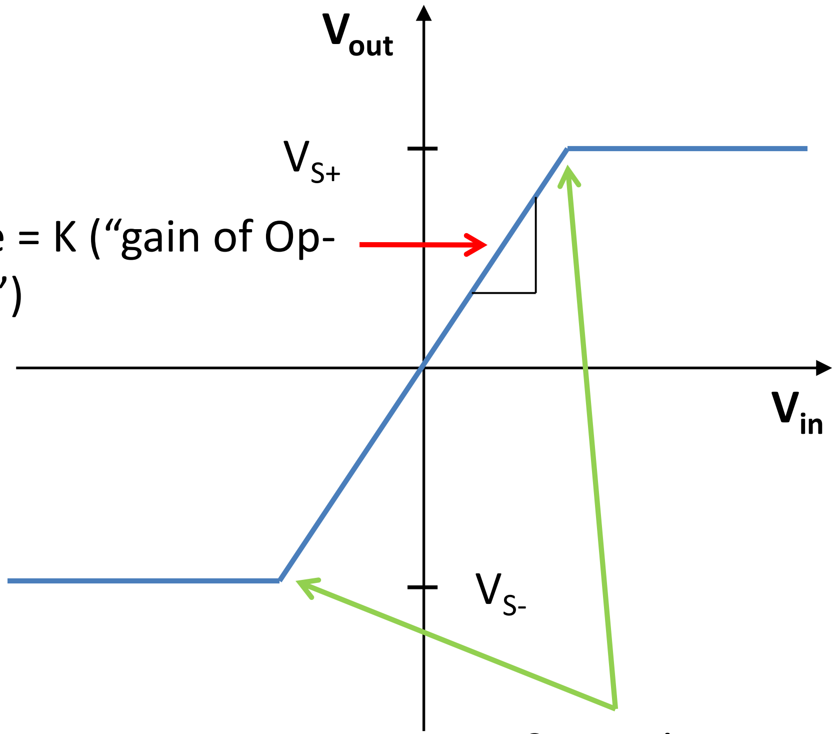
- The difference between the two inputs voltages (V_+ and V_-) multiplied by the gain (K, “amplification factor”) of the Op-Amp gives you the output voltage
- The output voltage can only be as high as the difference between the power supply (V_{s+} / V_{s-})and ground (0 Volts)

Saturation

Saturation is caused by increasing/decreasing the input voltage to cause the output voltage to equal the power supply's voltage*



Slope = K ("gain of Op-Amp")



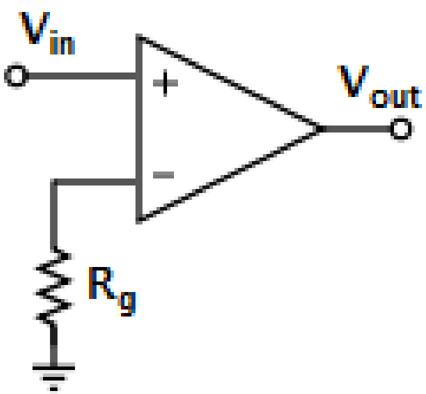
Saturation Points

The slope is normally much steeper than it is shown here. Potentially just a few milli-volts (mV) of change in the difference between V_+ and V_- could cause the op-amp to reach the saturation level

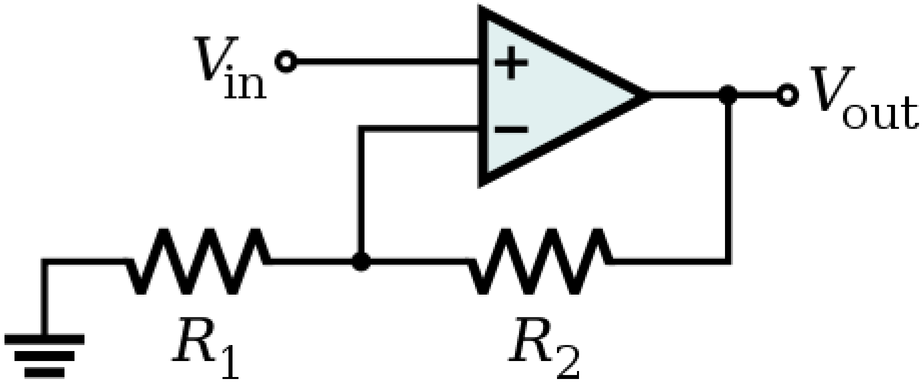
* Note that saturation level of traditional Op-Amp is 80% of supply voltage with exception of CMOS op-amp which has a saturation at the power supply's voltage

Open Loop vs Closed Loop

- A closed loop op-amp has feedback from the output to the input, an open loop op-amp does not



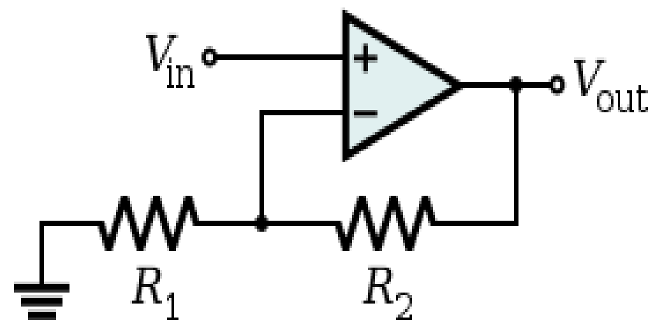
Open Loop



Closed Loop

NON-INVERTING OP-AMP

- Amplifies the input voltage by a constant
- Closed loop op-amp
- Voltage input connected to non-inverting input
- Voltage output connected to inverting input through a feedback resistor
- Inverting input is also connected to ground
- Non-inverting input is only determined by voltage output

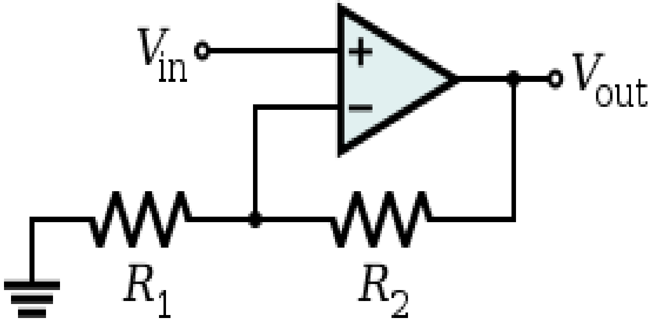


NON-INVERTING OP-AMP

$V_o = K(V_+ - V_-)$ & $R_2 = R_f$

R1/(R1+R2) ← Voltage Divider

$V_i = V_o\ (R_1/(R_1+R_2)\ )$

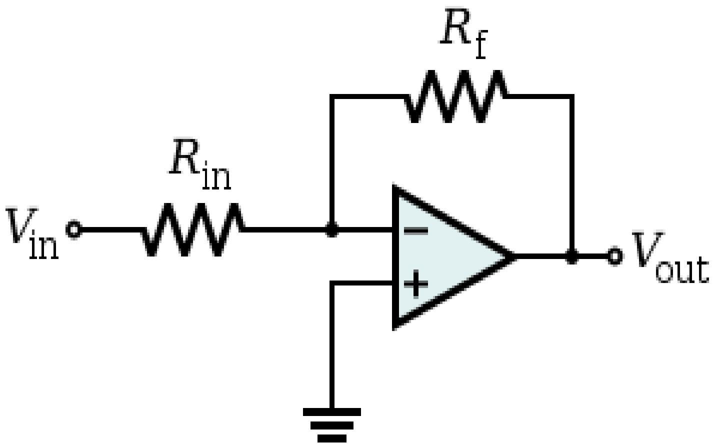


V_o/V_i = Acl $= [1+/(R_2+R_1)]$

$V_{out} = V_{in}\ (1+(R_2/R_1))$

INVERTING OP-AMP

- Amplifies and inverts the input voltage
- Closed loop op-amp
- Non-inverting input is determined by *both* voltage input and output
- The polarity of the output voltage is opposite to that of the input voltage
- Voltage input is connected to inverting input
- Voltage output is connected to inverting input through a feedback resistor
- Non-inverting input is grounded

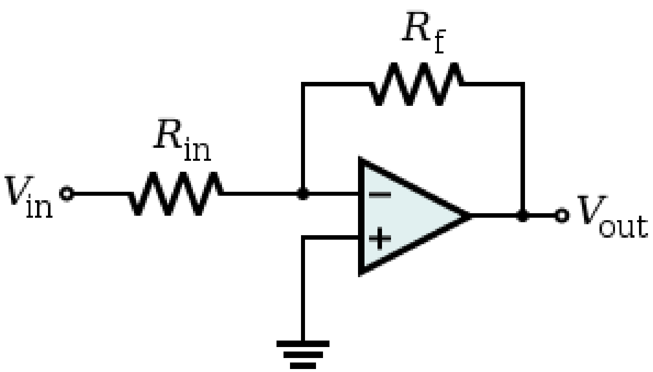


INVERTING OP-AMP

$V_{out}=K(V_+-V_-)$

Nodal equation at "a" (jn) is

$0=((V_a-V_i)/R_i)) + ((V_a-V_o)/R_f))$



Since V_a=is virtual gnd = 0

$0=((0-V_i)/R_i)) + ((0-V_o)/R_f))$

$V_o /V_i = -R_f/R_i = Acl$

$V_{out}=-V_{in}R_f/R_{in}$