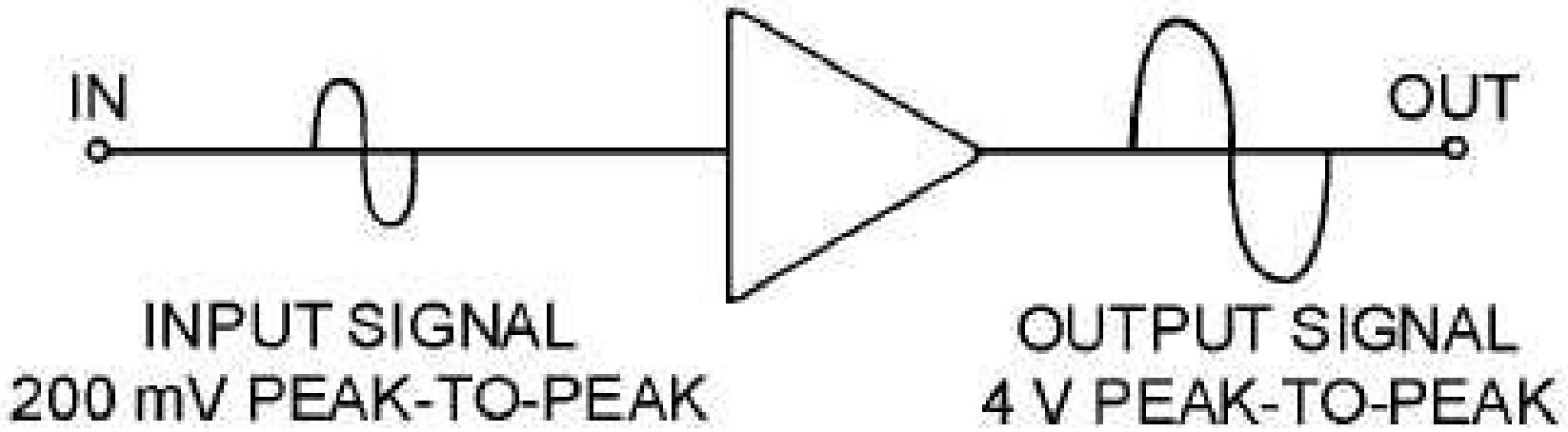
Analog Circuit Design

AVI SINGH

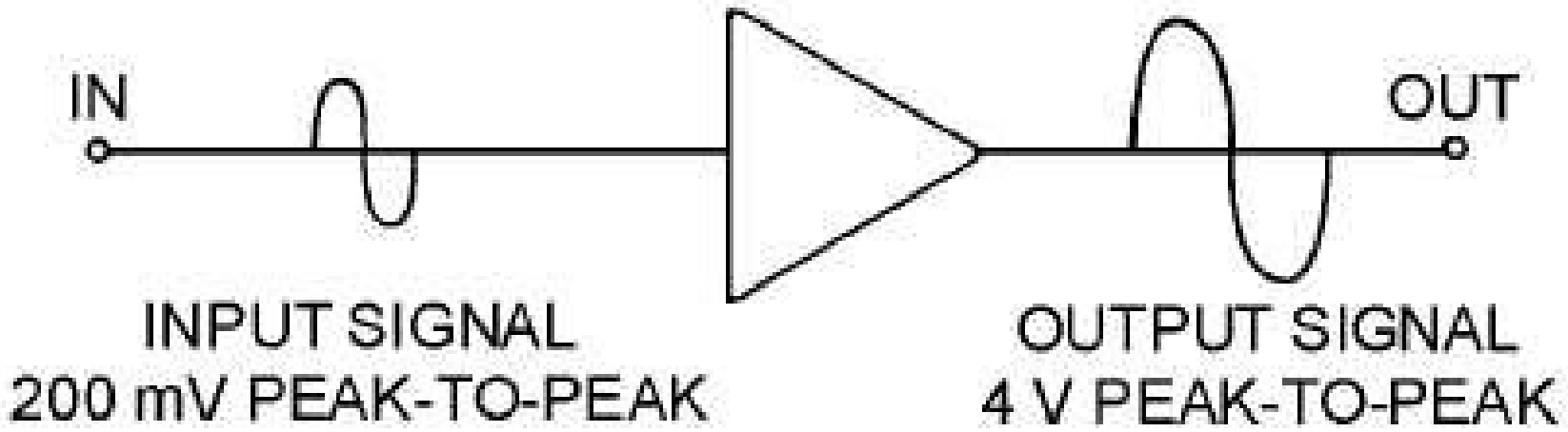
Amplifier

What is an amplifier?



Necessary Conditions

There is a “power gain”.



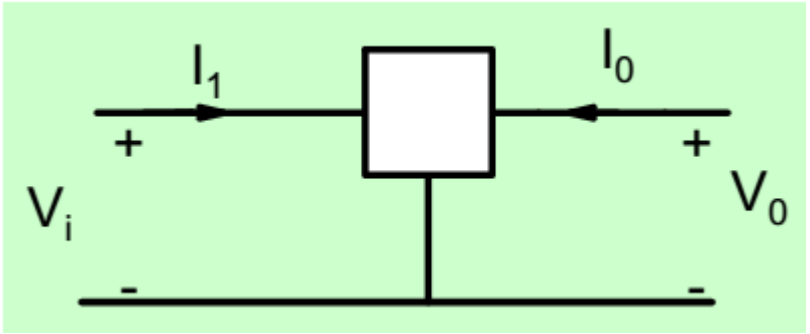
Voltage Amplifier

Input and output: both are voltages

LHS: Input Terminal

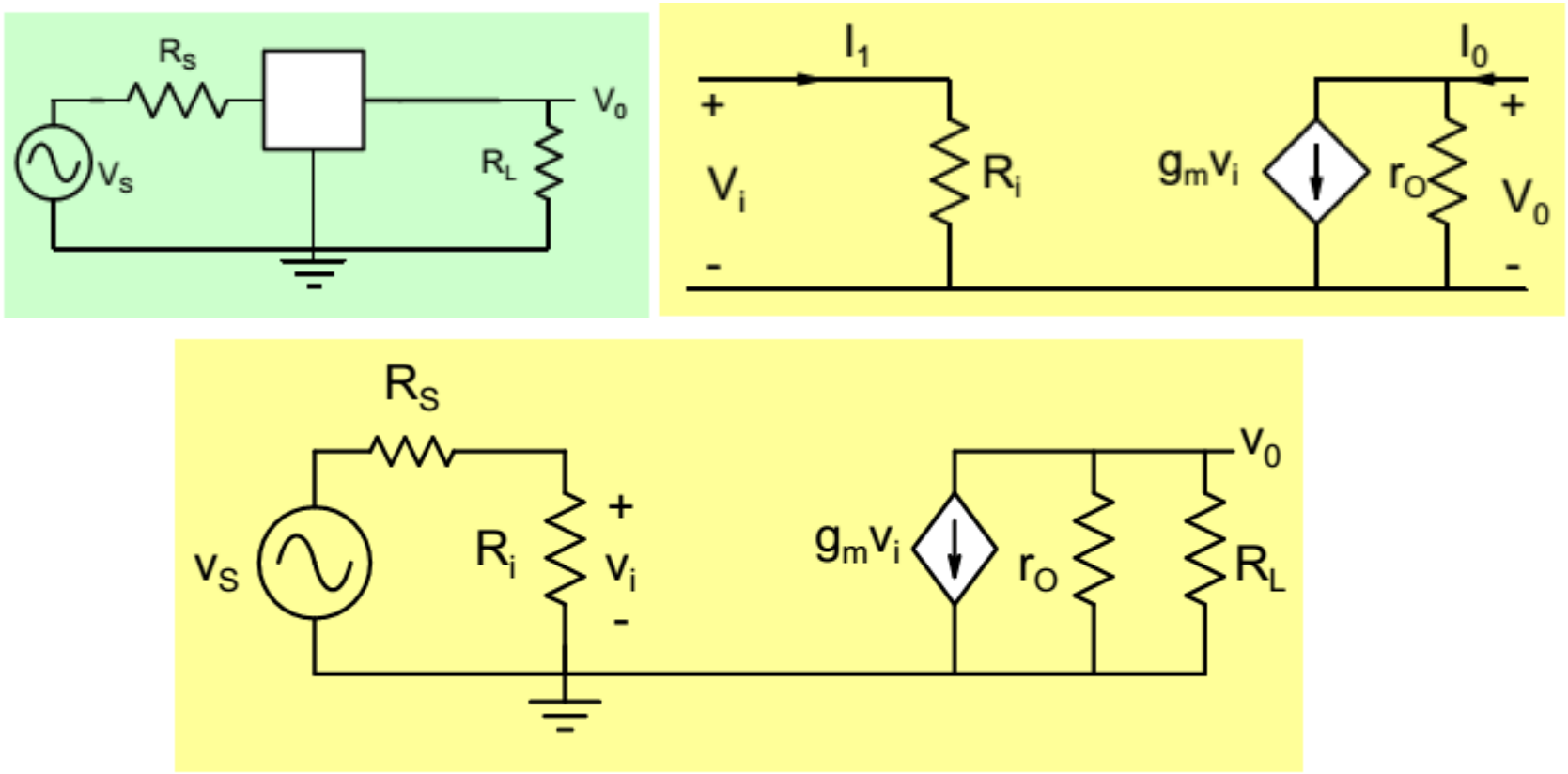
RHS: Output Terminal

The bottom wire is similar to a ‘common ground’



An equivalent Circuit

Note: There is a voltage-dependent current source in the circuit.



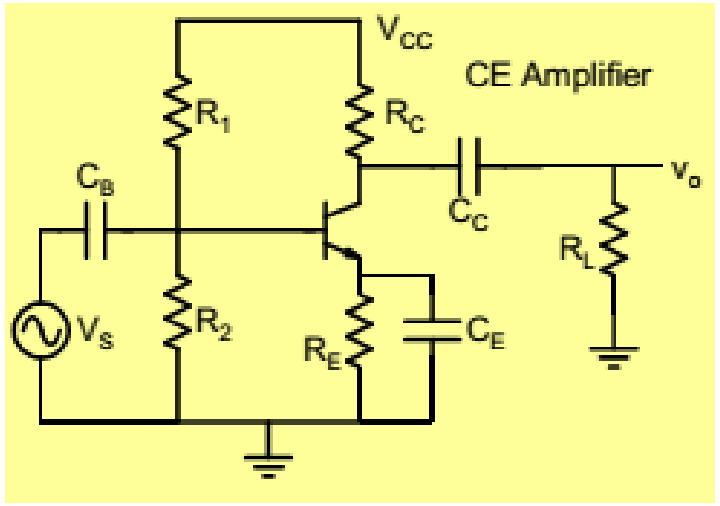
How do we build an amplifier?

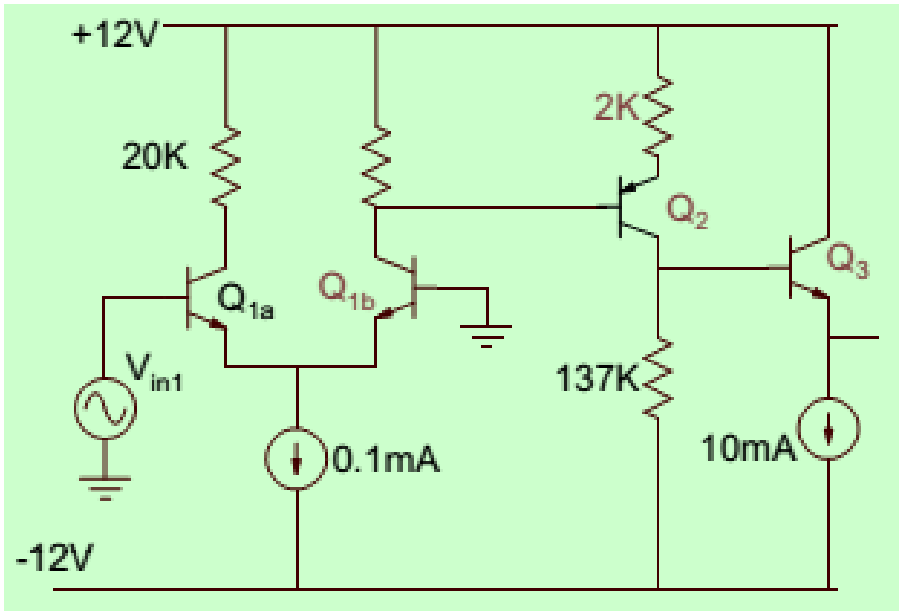
Amplifiers cannot be built simply using resistors, capacitors or inductors alone.

You need external power source also (for the power gain).

Some ‘simple’ amplifier designs

It is not possible for everyone to design their own amplifiers without





So, how do we proceed?

Our dilemma: Amplifiers already might not satisfy all our specific requirements, while it is very difficult to design a good amplifier from scratch.

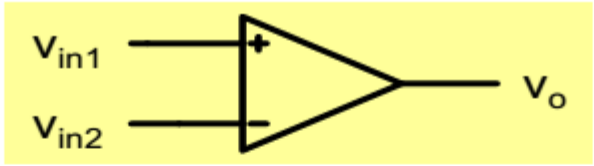
The answer: A Semi-Custom Approach

We use some amplifiers that have been already built, and customize them according to our own requirements.

An Example of such an amplifier that we can customize according to our needs: An Operational Amplifier

Difference Amplifiers

They are insensitive to what is common between two signals, and sensitive to what is differen



$$v_{id} = v_{in1} - v_{in2}$$

$$v_{ic} = \frac{v_{in1} + v_{in2}}{2}$$

$$v_o = A_d v_{id} + A_{cm} v_{ic}$$

A_d : Differential mode gain

A_{cm} : Common mode gain

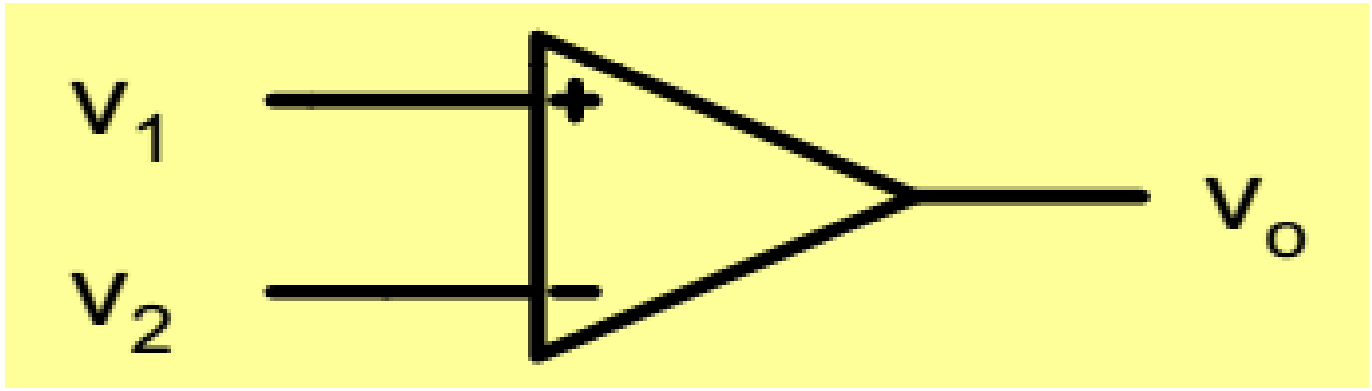
$$A_d >> A_{cm}$$

$$\text{Common Mode Rejection Ratio: } CMRR = \frac{A_d}{A_{cm}}$$

An Operational Amplifier(Op-Amp)

A special type of difference amplifier

Very high common mode rejection ratio.



Data sheet of a 741 op-amp

LM741
Operational Amplifier

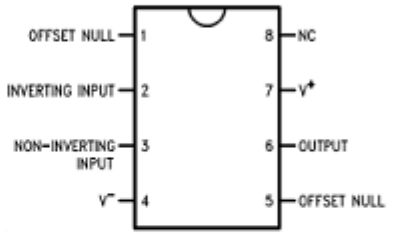
General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

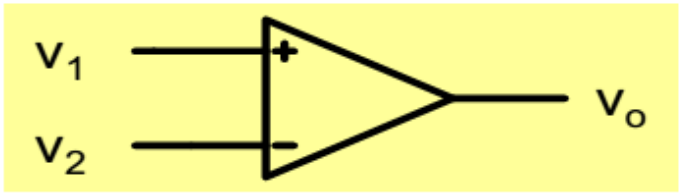
The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

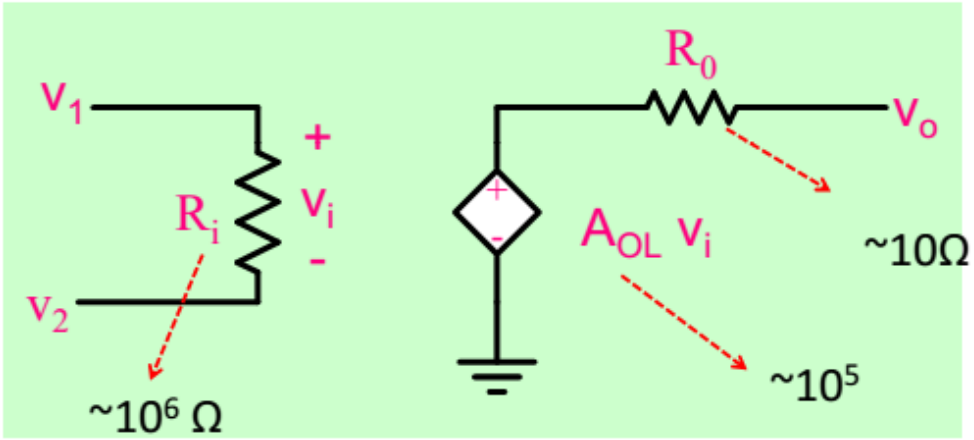
Dual-In-Line or S.O. Package



Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Resistance	T_A = 25°C, V_S = ±20V	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} < T_A < T_{AMAX}$, V_S = ±20V	0.5									MΩ
Large Signal Voltage Gain	T_A = 25°C, $R_L \geq 2$ kΩ										
	V_S = ±20V, V_O = ±15V	50									V/mV
	V_S = ±15V, V_O = ±10V				50	200		20	200		V/mV
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 10$ kΩ, V_{CM} = ±12V				70	90		70	90		dB
	$R_S \leq 50$Ω, V_{CM} = ±12V	80	95								dB

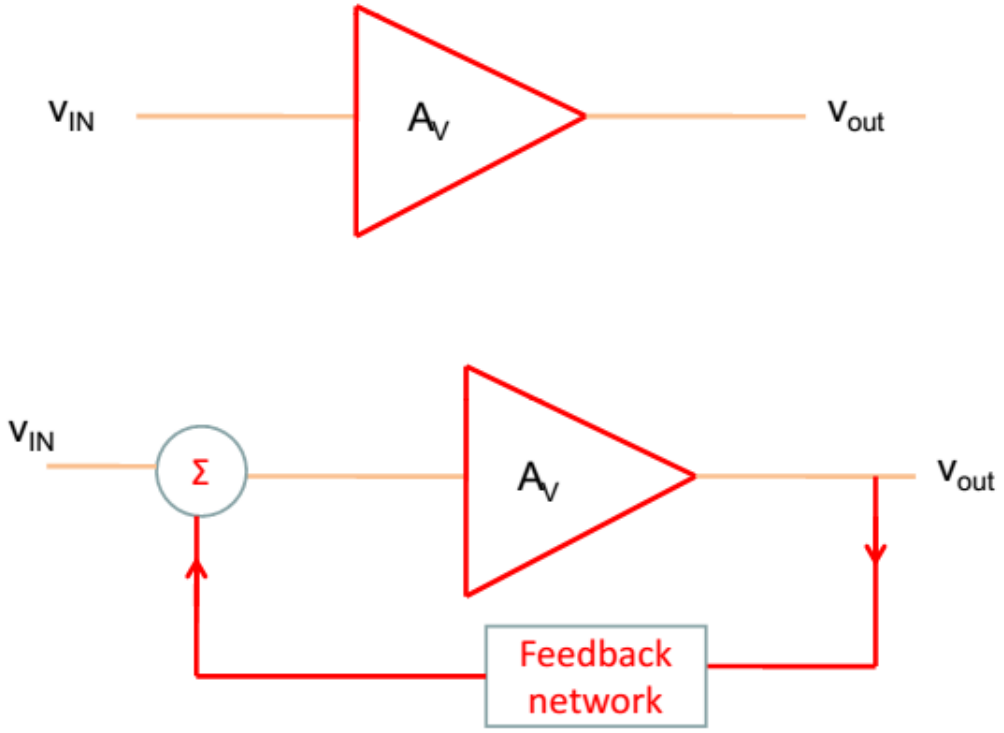
Equivalent Circuit of an Op-Amp



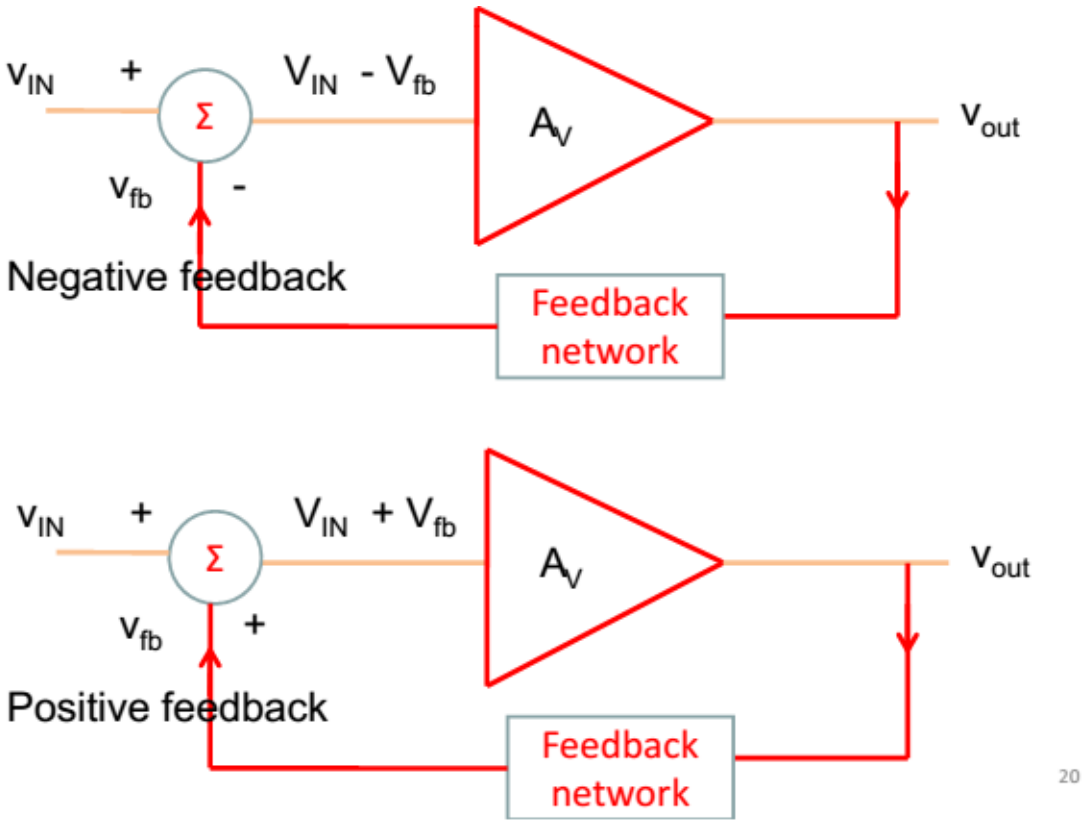


This assumes very high CMRR

Feedback

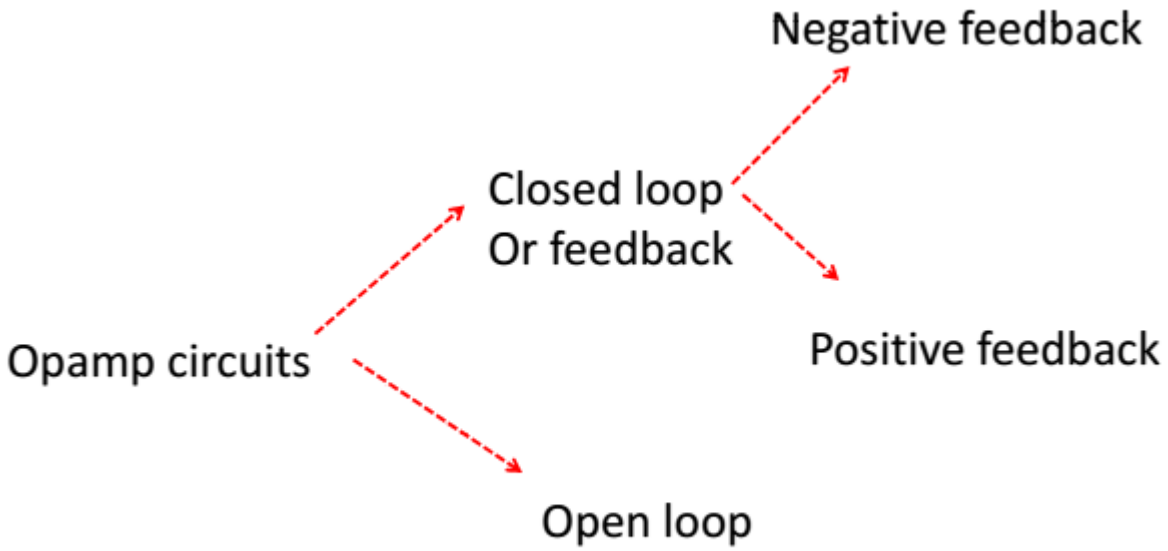


Negative and Positive Feedback

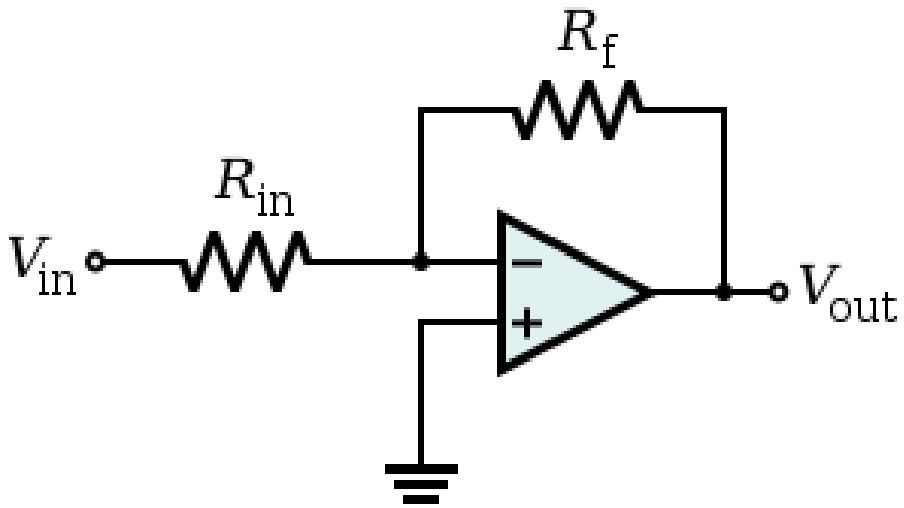


Different Op-Amp Circuits

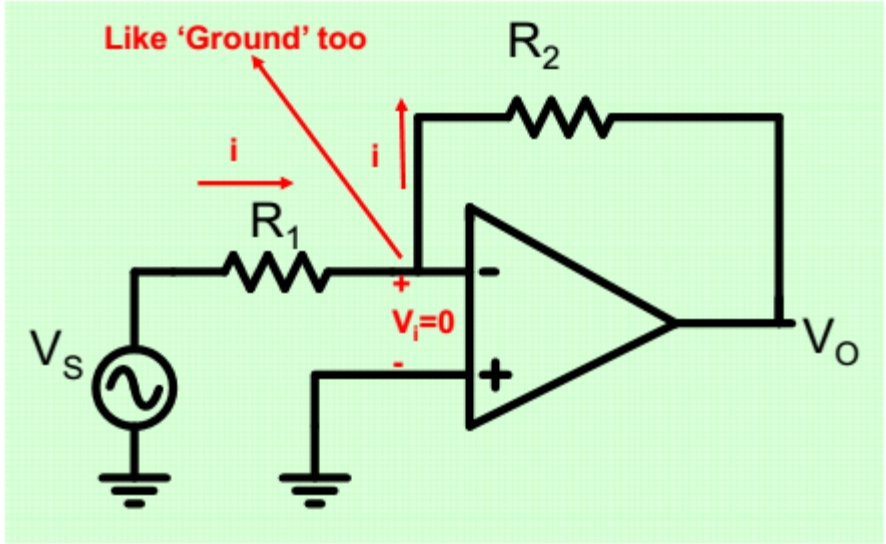
We mostly use op-amp circuits that employ negative feedback.

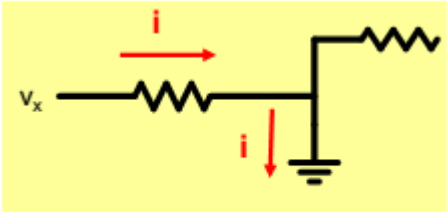


Op Amp with Negative Feedback



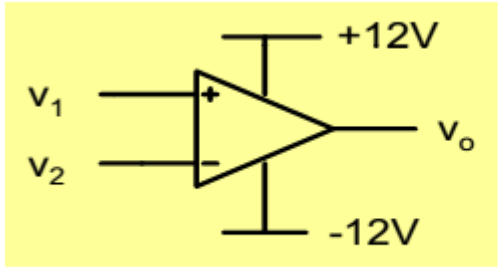
Virtual Ground Property





For actual ground

Virtual Ground Prope



$$v_1 \cong v_2$$

In op-amp circuits employing negative feedback, the voltage at the positive input terminal is almost equal to the voltage at the negative input terminal, given that the gain of the op-amp is very high.

It does not hold under:

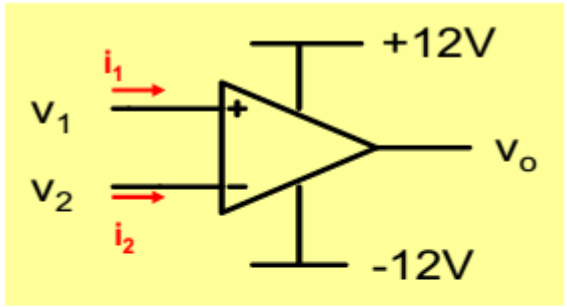
1. Open Loop System

2. Positive Feedback

3. If the op-amp is saturated (that is, it is driving the maximum current that it can)

Golden Rules for Analysing Op-Amp Circuits

Note: These hold true only and only under negative feedback.

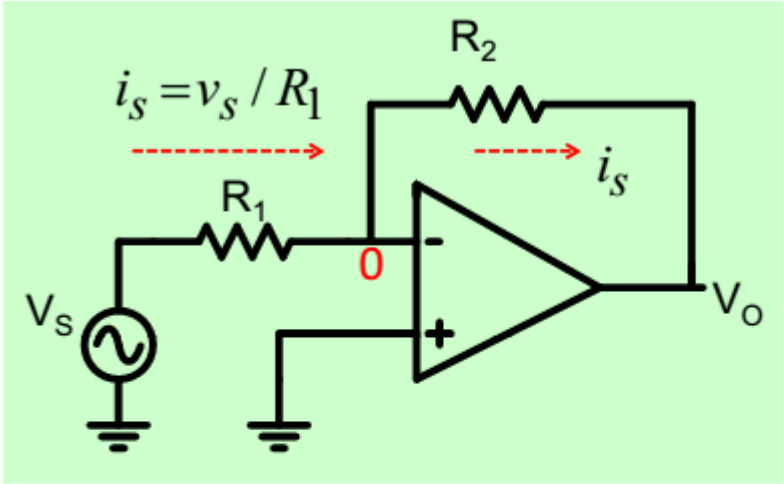


1. $v_1 = v_2$

2. $i_1 = i_2 = 0$

Some simple amplifiers made using Op-Amps

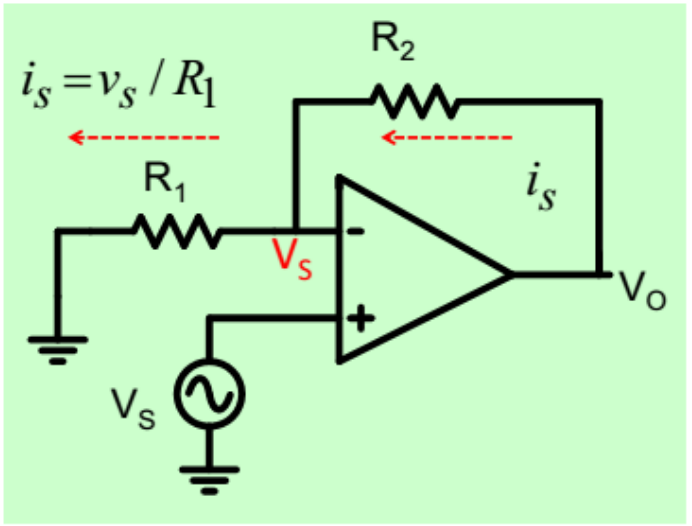
Inverting Amplifiers



$$\frac{0 - v_o}{R_2} = i_s = \frac{v_s}{R_1}$$

$$\frac{v_o}{v_s} = -\frac{R_2}{R_1}$$

Non-Inverting Amplifiers



1. $v_1 = v_2$

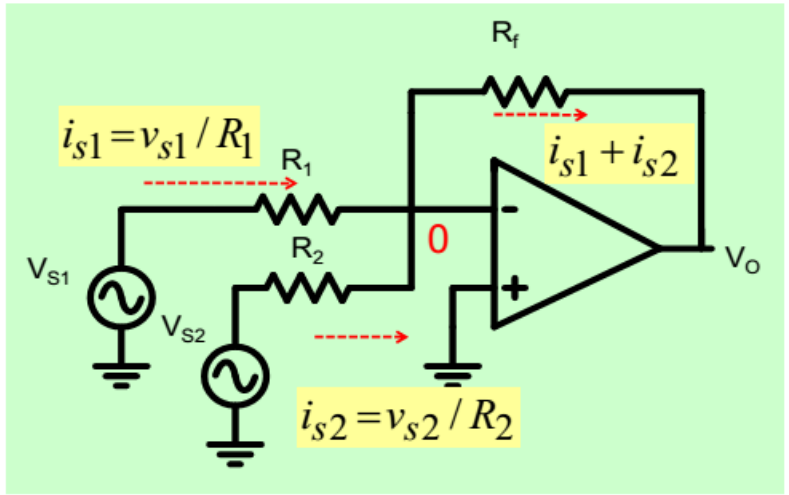
2. $i_1 = i_2 = 0$

$$\frac{v_o - v_s}{R_2} = i_s = \frac{v_s}{R_1}$$

$$\frac{v_o}{v_s} = 1 + \frac{R_2}{R_1}$$

An Adder

Adder

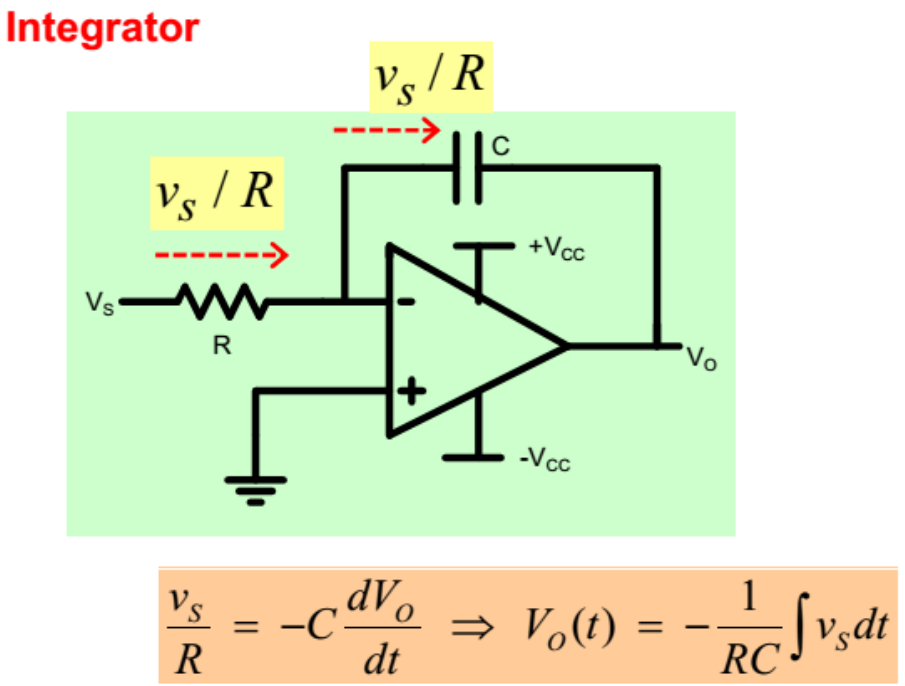


$$\frac{0-v_o}{R_f}=i_{s1}+i_{s2}=\frac{v_{s1}}{R_1}+\frac{v_{s2}}{R_2}$$

$$v_o=-\left(\frac{R_f}{R_1}v_{s1}+\frac{R_f}{R_2}v_{s2}\right)$$

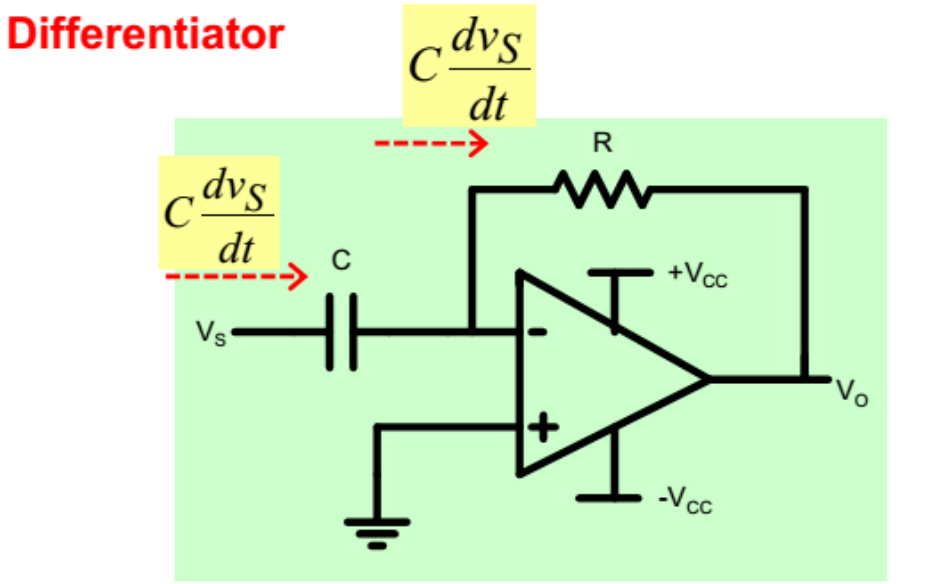
For $R_1=R_2=R$ $\quad v_o=-\frac{R_f}{R}(v_{s1}+v_{s2})$

Integrator



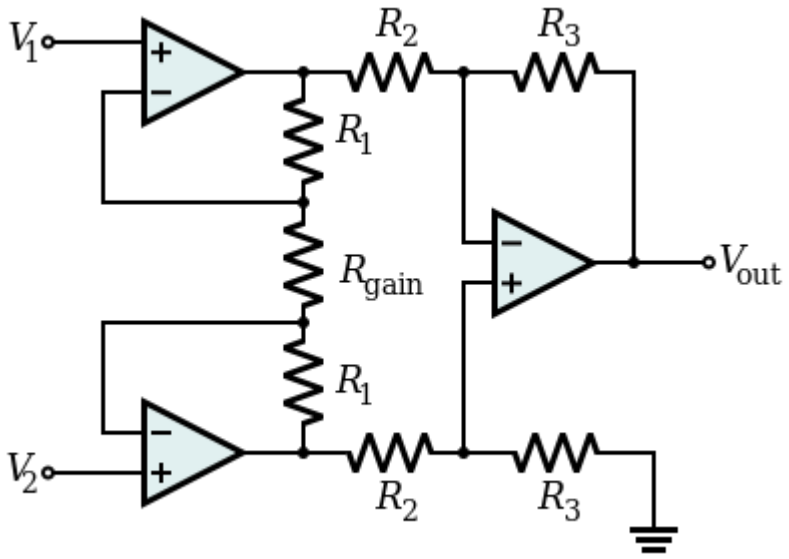
$$\frac{v_S}{R} = -C\frac{dV_o}{dt} \Rightarrow V_O(t) = -\frac{1}{RC}\int v_S dt$$

Differentiator



$$-\frac{V_O}{R} = C\frac{dv_S}{dt} \Rightarrow V_O(t) = -RC\frac{dv_S}{dt}$$

Instrumentation Amplifier



Instrumentation Amplifier

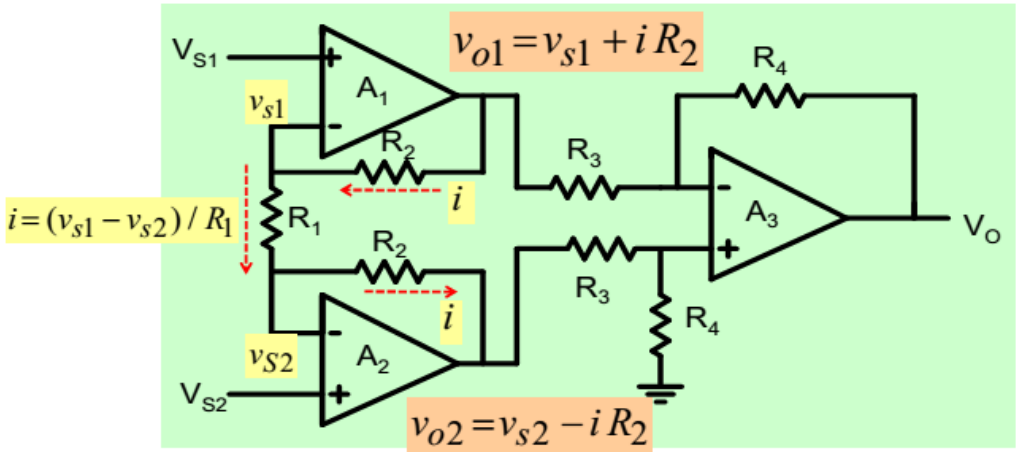
Has limited use: not as flexible as the operational amplifier
Made up for four op-amps

Feedback resistor is internal

Mainly used for high-precision gain

Only one of the resistors is determined externally that is Rg.

Analysis



$$v_o = \frac{R_4}{R_3} \times (1 + \frac{2R_2}{R_1}) \times (v_{s2} - v_{S1})$$

Very high input Resistance

Can change one resistor R_1 and change gain

Thank You