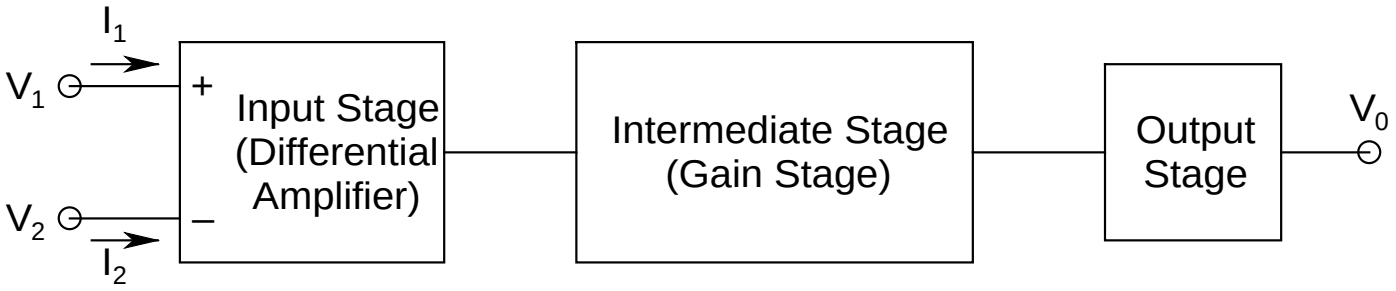
THE OPERATIONAL AMPLIFIER (OP-AMP)

- ***The Ultimate***: A ***phenomenal application*** of everything that we have learnt so far in this course
- ***Op-Amp***: ***Operational Amplifier***
- ***Hugely powerful block***
- ***Capable of performing various circuit functions***
- ***Original inventor***: ***George Philbrick*** of ***Bell Labs*** in ***1952*** using ***vacuum tube technology***

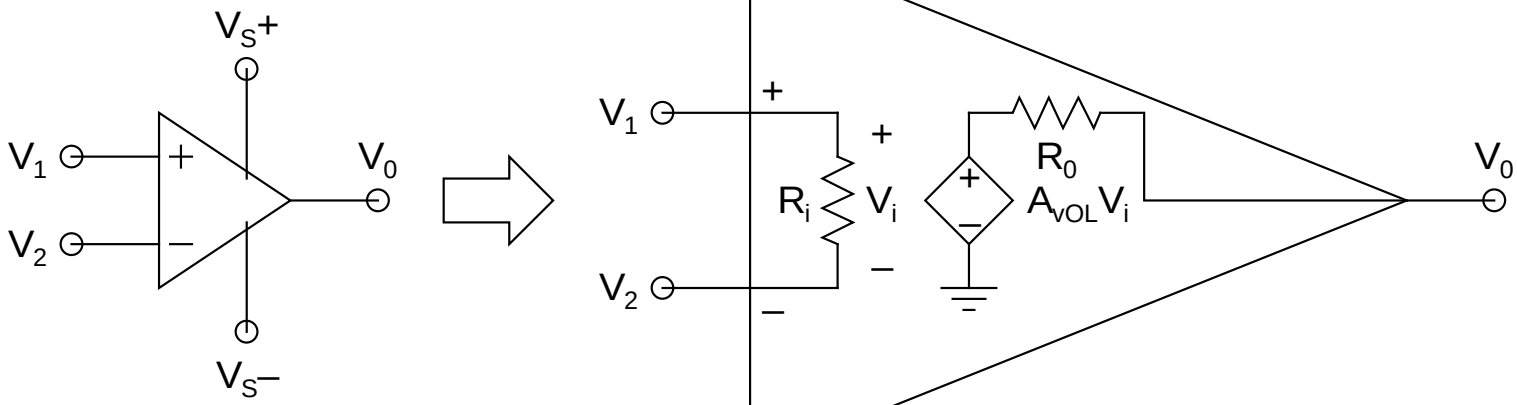
- ***Remarkable innovations*** in ***design*** in the form of an ***IC*** by ***Bob Widlar*** of ***Fairchild Semiconductors*** in ***1963***
- After that, ***several improvements*** took place, and the ***most versatile design***, widely came to be known as the ***741 op-amp***, originated
- Basically a ***three-stage architecture***:
  - ***The Input Stage***
  - ***The Gain Stage***
  - ***The Output Stage***

- ***The Input Stage*:**
  - ***Should be capable of double-ended to single-ended conversion***
  - ***Should have moderate to high gain***
  - ***Must definitely have extremely large CMRR (this is the main requirement)***
  - ***Almost invariably a Differential Amplifier (DA)***

- ***The Gain Stage***:
  - ***Can be any one of the many that we have studied in the chapter on Amplifiers***
  - ***CC-CE Darlington configuration preferred***
  - ***Should have moderate to large gain***
- ***The Output Stage***:
  - ***Needed when the op-amp is expected to either source or sink large amount of current to or from the load***



Basic Three-Stage Architecture of an Op-Amp



Symbol

MacroModel

- ***2 Input Terminals***:
  - V_1 (***non-inverting*** [+])
  - V_2 (***inverting*** [–])
- ***1 Output Terminal***: V_0
- V_1, V_2, and V_0 can be ***simply DC***, or ***simply ac,*** or a ***combination of both***
- I_1, I_2: ***Input currents flowing into the + and – terminals respectively***
- ***Dual symmetric power supplies*** (***V_S+ and V_S–***)

- Refer to the ***MacroModel***:
  - R_i: ***Input Resistance***
    - ***Very high*** (***ideally infinite***)
  - R_0: ***Output Resistance***
    - ***Very small*** (***ideally zero***)
  - A_{vOL}: ***Open-Loop Gain***
    - ***Very large*** (***ideally infinite***)
- ***Input-Output Relation***:

$$V_0 = A_{vOL}(V_1 - V_2)$$

- V_1, V_2, and V_0 are measured ***w.r.t. ground***, but V_i is a ***floating signal*** (***difference*** between V_1 and V_2)
- The ***controlled source*** in the ***MacroModel*** is ***VCVS***
- For $V_1 > (<) V_2$, V_0 is ***positive*** (***negative***)
- ***Typical values for 741 op-amp***:
  - $A_{vOL} \sim 10^5$ (***100 dB***), $R_i >$ ***1 MΩ***, $R_0 <$ ***100 Ω***, CMRR ~ ***80-100 dB***, V_S+ and V_S–: ***±3 V to ±15 V***