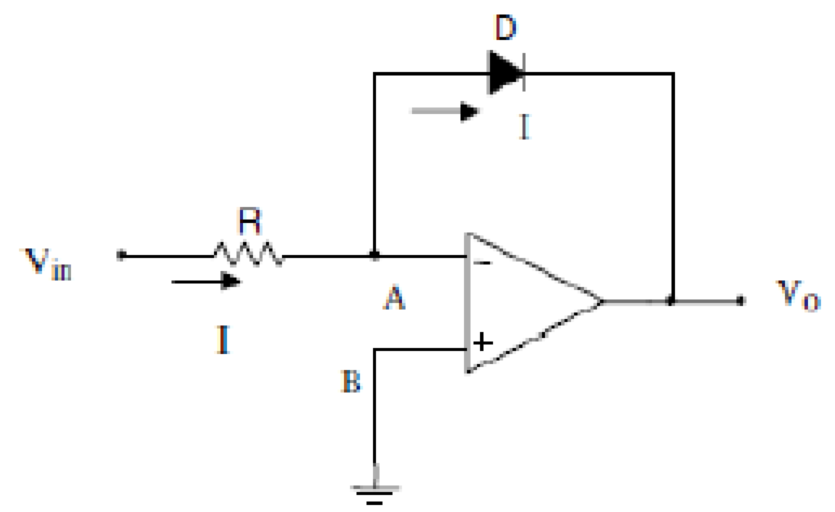
OP-AMP BASED SIGNAL CONDITIONING CIRCUITS

Log amplifier, Antilog Amplifier, Instrumentation Amplifier, & AD620

Log amplifier



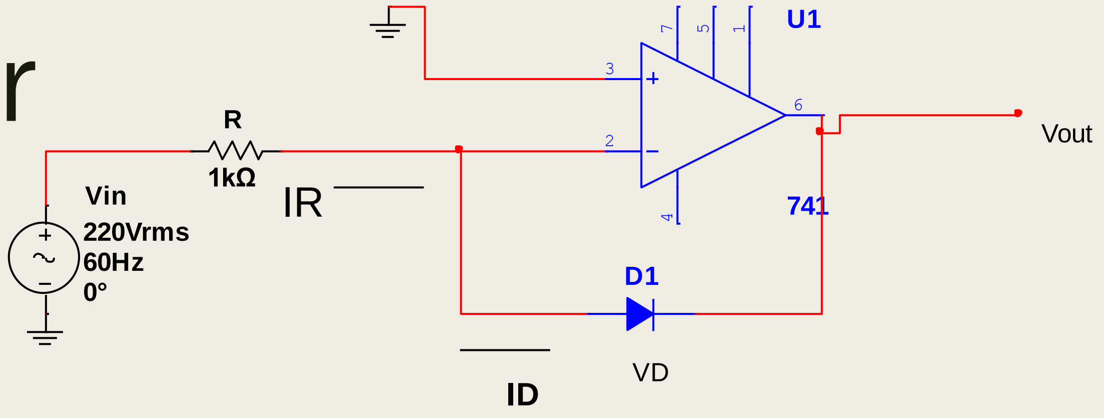
- Log amplifier is a linear circuit in which the output voltage will be a constant times the natural logarithm of the input.
- Log amplifier finds a lot of application in electronic fields like multiplication or division.
- These are used in signal processing, computerized process control, compression, decompression, RMS value detection etc.
- The basic output equation of a log amplifier is

  $V_{out} = K \ln (V_{in}/V_{ref})$;

  where V_{ref} is the constant of normalisation,

  and K is the scale factor.

Analysis of Log Amplifier



- The pin 2 is at virtual zero.

$$V_{out} = -V_D$$

$$I_R = I_D \qquad V_{in} = I_R R; \quad I_D = \frac{V_{in}}{R}$$

- I_D is Forward diode current is given by $I_D = I_s \left\{ e^{\left(\frac{V_D}{\eta V_T}\right)} - 1 \right\}$ (1)
- Where V_T=thermal voltage of diode
- V_D=forward voltage of diode,
- η=ideality factor (between 1 or 2)
- Rearranging equation (1) by putting various values and taking log both sides
- So $\frac{I_D}{I_s} = e^{\left(\frac{V_D}{\eta V_T}\right)}$

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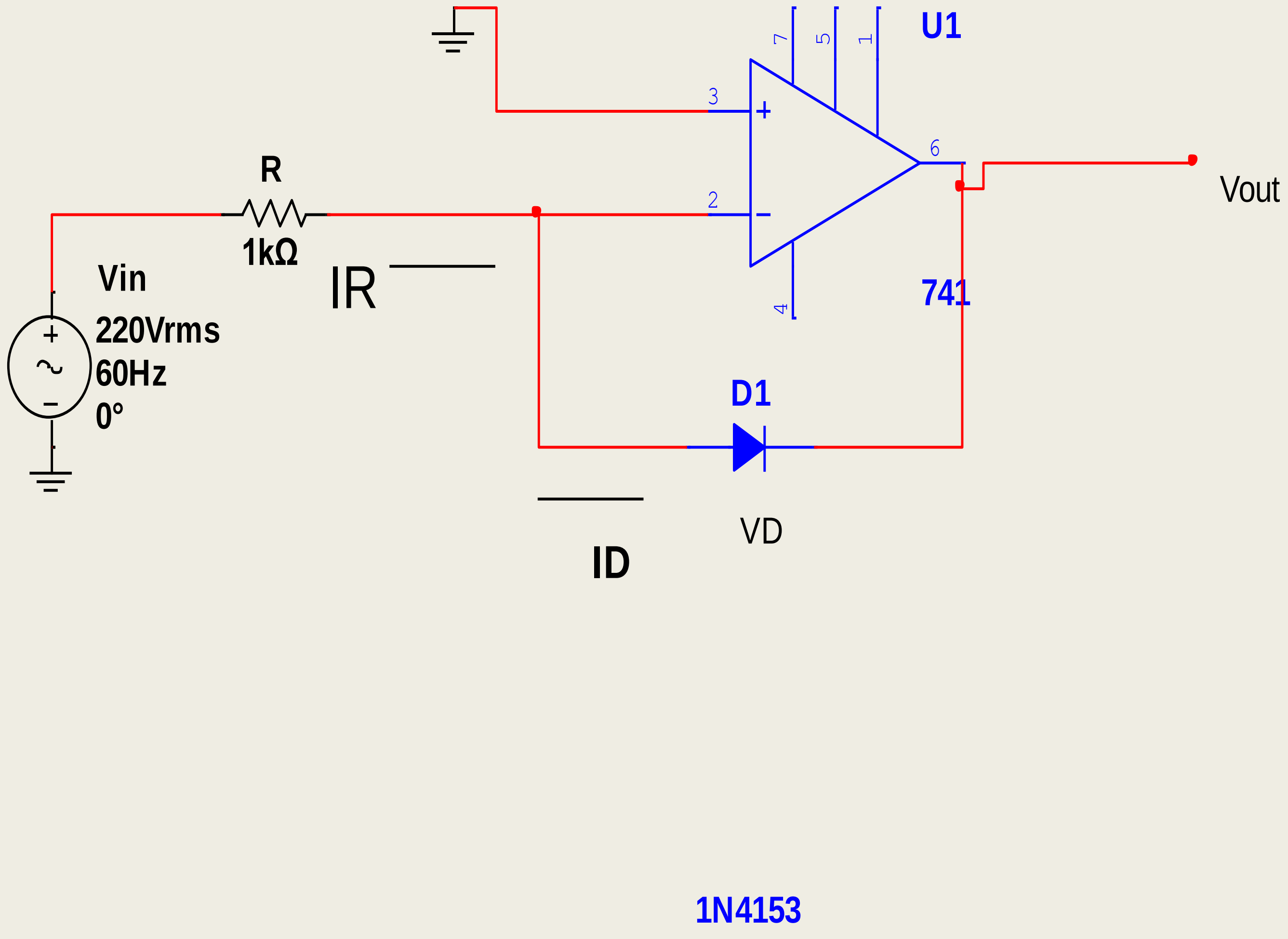


- Now $\log\left(\frac{I_D}{I_s}\right) = \left(\frac{V_D}{\eta V_T}\right)$
- As $V_{out} = -V_D$

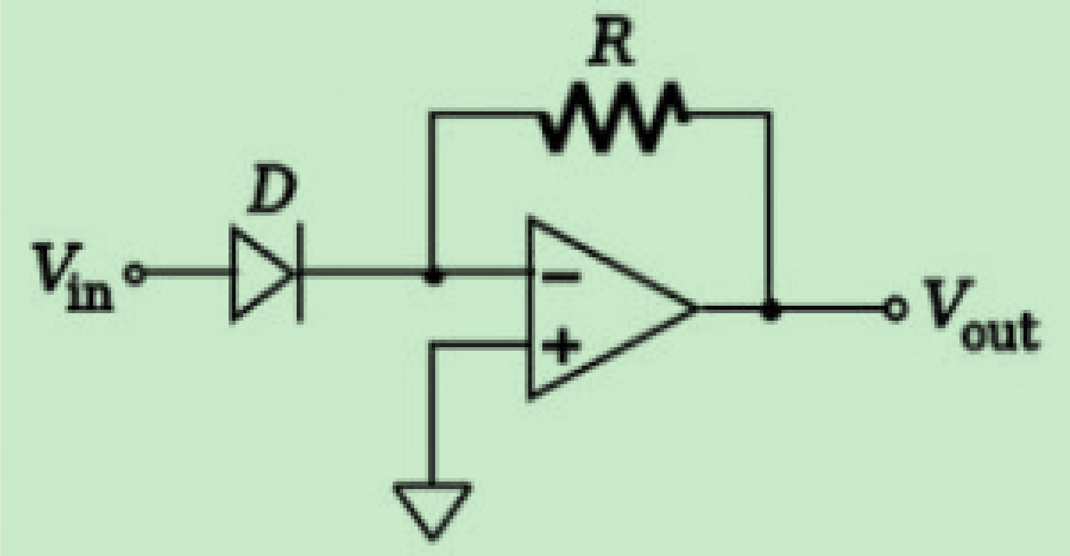
$$V_D = \eta V_T \log\left(\frac{I_D}{I_s}\right)$$

$$V_{out} = -\eta V_T \log\left(\frac{I_D}{I_s}\right)$$

$$but \quad I_D = \frac{V_{in}}{R}$$

$$V_{out} = -\eta V_T \log\left(\frac{V_{in}}{RI_s}\right)$$

Antilog Amplifier



- Anti log amplifier is one which provides output proportional to the anti log i.e. exponential to the input voltage.
- If V_i is the input signal applied to a Anti log amplifier then the output is

  V_o=K*exp(a*V_i)

  where K is proportionality constant, a is constant.
- The negative feedback is provided from output to inverting terminal.
- Antilog amplifier does the exact opposite of a log amplifier.
- Antilog amplifiers along with log amplifiers are used to perform analogue computations on the input signals.

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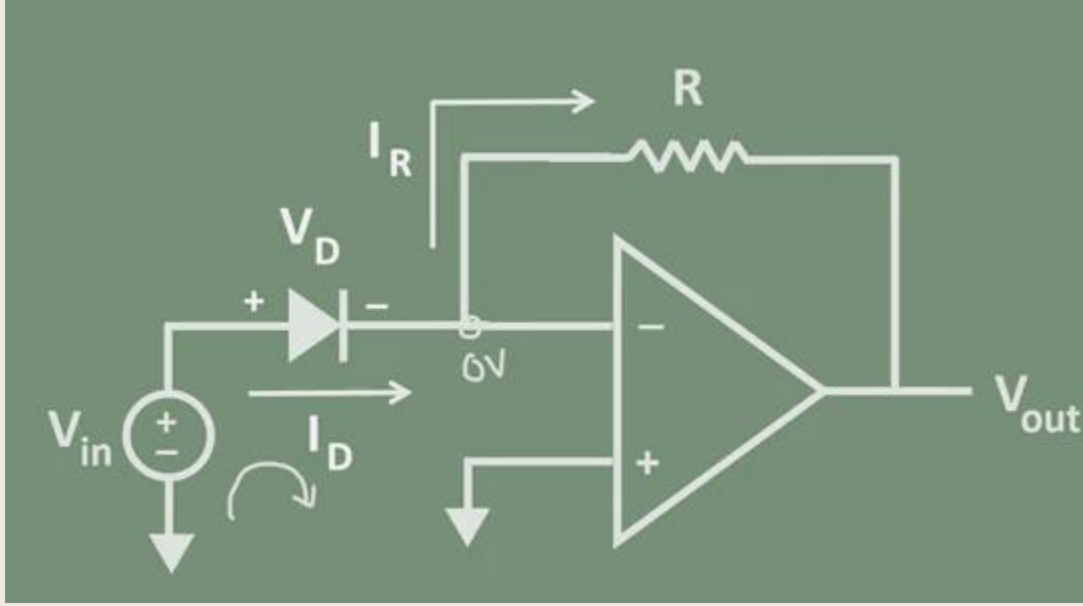

- Apply Node equation $V_{in} - V_D = 0, \quad V_{in} = V_D$
- Diode current

$$I_D = \mathrm{I_R}, \quad I_R = -\frac{Vout}{R}, I_D = -\frac{Vout}{R}$$

$$I_D R = -V_{out} \qquad I_D = I_s e^{\left(\frac{V_D}{\eta V_T}\right)}$$

$$V_{out} = -I_s R\, e^{\left(\frac{V_D}{\eta V_T}\right)} \qquad V_{out} = -I_s R\, e^{\left(\frac{V_{in}}{\eta V_T}\right)}$$

Note: Due to ideality factor the range of operation of diode based Log/antilog amplifier is limited one.

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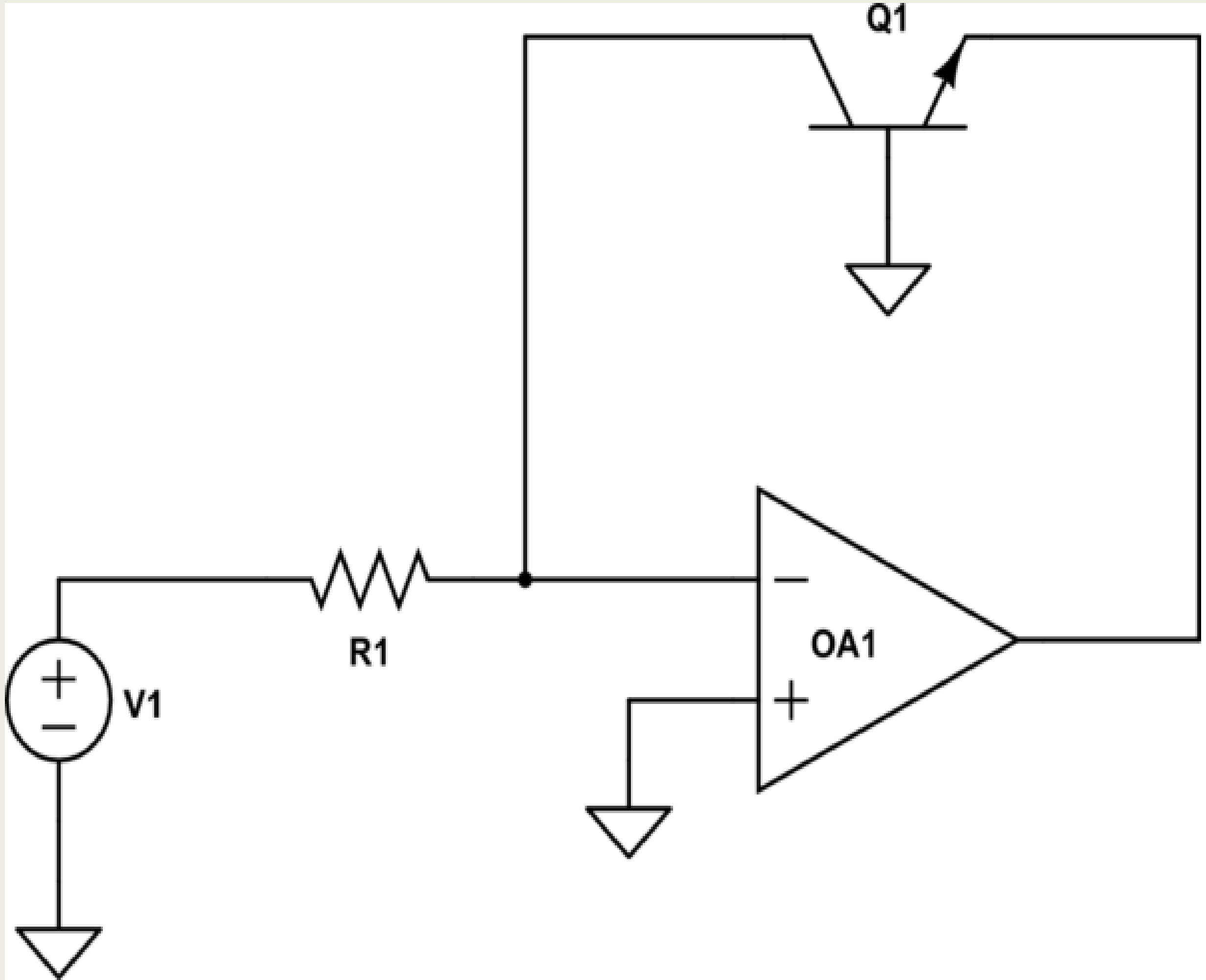

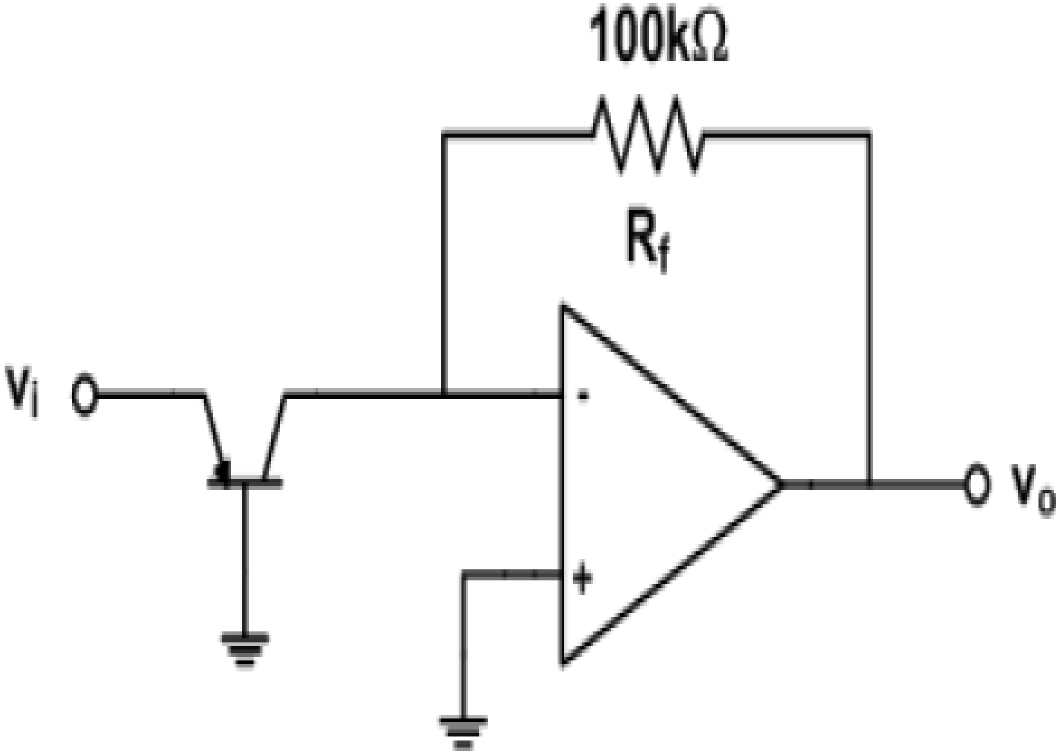

Instrumentation Amplifier

- An instrumentation amplifier is a differential amplifier which meets certain industry standard requirements.

Features

- Precise low level signal amplification
- Low noise
- Low thermal drift
- High input resistance
- Accurate closed loop gain and easier gain adjustment
- Low power dissipation
- High CMRR
- High slew rate

Need of Instrumentation amplifier

- There are numerous applications where a differential signal needs to be amplified.
- These include low-level resistance measurements, microphone signals, communications equipment, thermocouple amplifiers etc.
- So these applications can be implemented with the differential op amp.
- But there are few limitations to this configurations.
- It is practically impossible to achieve matched high impedance inputs while maintaining high gain and satisfactory offset and noise performance.
- Also the input impedances are not isolated.
- The impedance of one input may very well be a function of the signal present on the other input.
- Simply this is an unacceptable situation when a precision amplifier is needed, particularly if the source impedance is not very low.

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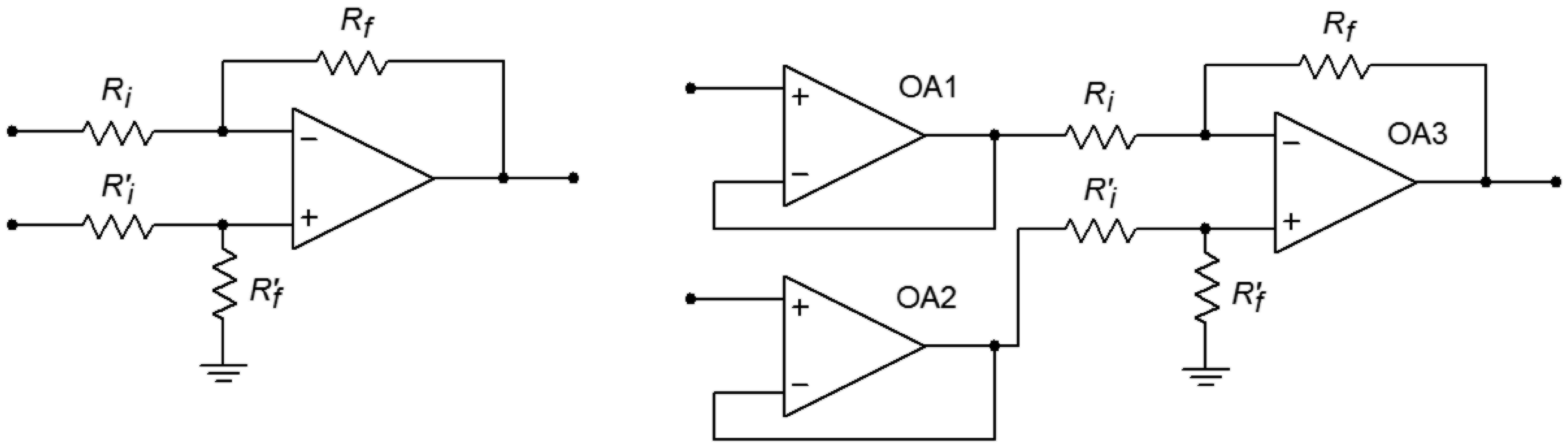
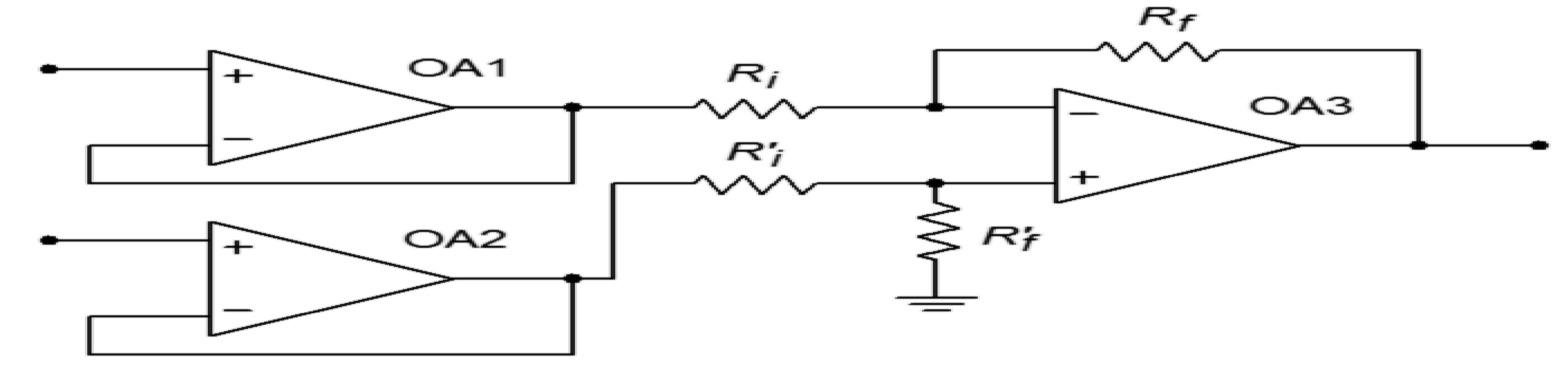
An *instrumentation amplifier* overcomes these problems.

- Instrumentation amplifiers offer very high impedance, isolated inputs along with high gain, and excellent CMRR performance.
- Instrumentation amplifiers can be build from separate op amps.
- They are also available on a single IC for highest performance.
- In differential amplifier, the Vout is also include the common mode signal along with Vd.



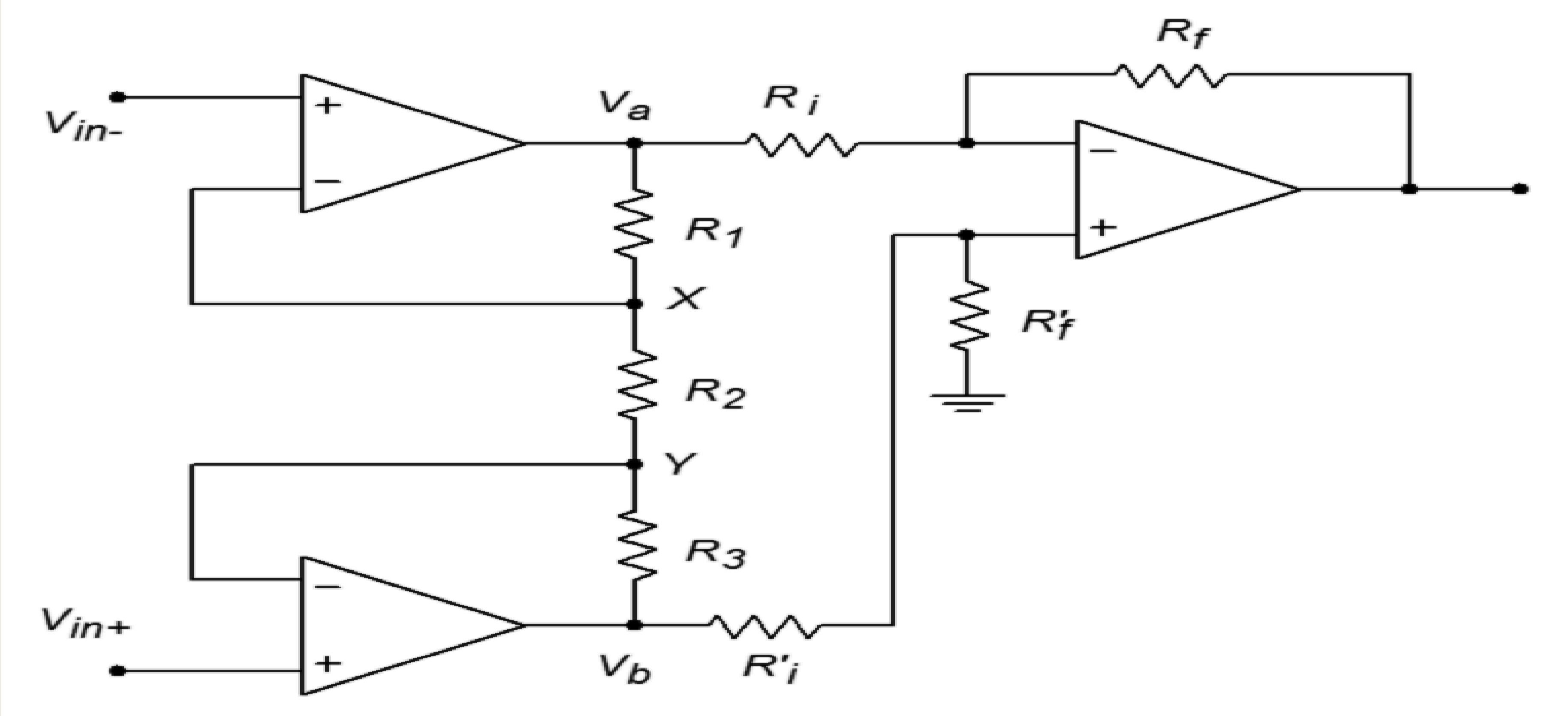
Working of Instrumentation OP AMP

- Instrumentation amplifiers are, in essence, a three-amplifier design.
- One way to increase the input impedances and also maintain input isolation, is to place a voltage follower in front of each input.
- The source now drives the very high input impedance followers. The followers exhibit very low output impedance and have no trouble driving the differential stage.
- op amp 3 is used for common-mode rejection as well as for voltage gain.
- The gain-bandwidth requirement for op amp 3 is considerably higher than for the input followers
- The major problem with this configuration is that it requires very close matching of resistors in order to keep the gains the same.
- Any mismatch in gain between the two inputs will result in a degradation of CMRR.



Improved Instrumentation amplifier

- There is a slight modification that will remove the problem of mismatched gains.
- This modification involves joining the R_i values of op amps 1 and 2 into a single resistor.
- In order to prevent possible confusion with op amp 3, the three resistors used for the input section have been labelled as R_1, R_2, and R_3.

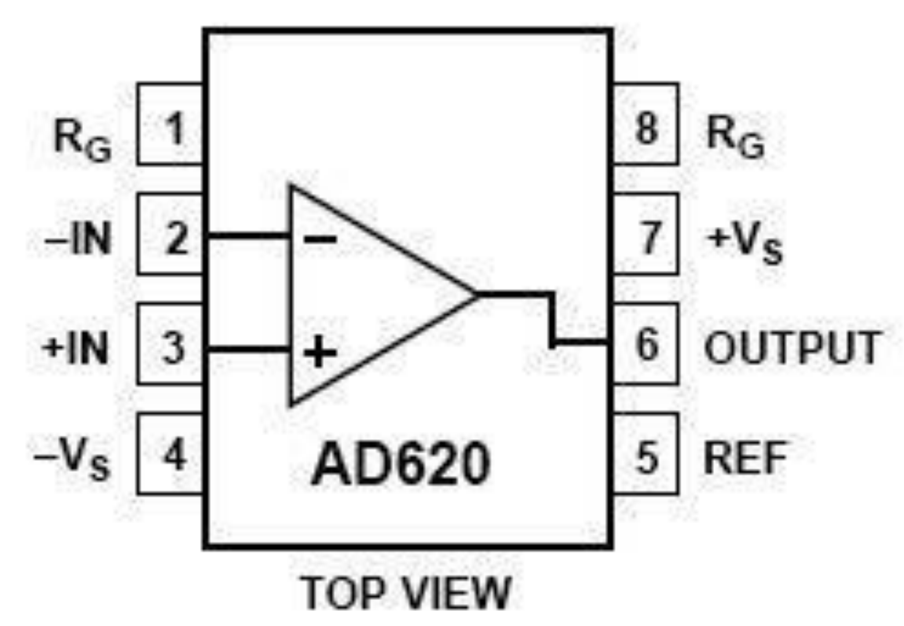


$$V_{out} = (V_{in+} - V_{in-})\left(\frac{R_f}{R_i}\right)\left(1 + 2\frac{R_1}{R_2}\right)$$

AD620

- This has been the industry standard, high performance, low cost amplifier.
- It is completely monolithic available in both 8-lead DIP and SOIC (small outline integrated circuit) packages.
- The user can obtain any desired gain from 1 to 1000 using a single external resistor.
- By design, the fixed resistor values for gains of 10 and 100 are standard 1% metal film resistor values.
- Manufactured by Analog Devices company
- Industry standard Low cost and high accuracy Instrumentation amplifier

Pin Diagram of AD620



- RG – External Gain setting Resistor

Applications

- They are used extensively in Bio-medical applications like ECG's and EEG's.
- Instrumentation Amplifiers are used where long-term stability is essential like Industrial applications that includes automation.
- Instrumentation amplifiers are incorporated with pressure transducers in Weighing Systems to monitor various physical quantities such as weight, force, pressure, displacement and torque.
- They are used in Gaming industry.
- Instrumentation Amplifiers are also used in hand held batteries.
- The biggest disadvantage of Instrumentation Amplifier is the occurrence of noise when used for long range transmission purpose

References

- *Coughlin, R.F., Operational Amplifiers and Linear Integrated Circuits, Pearson Education (2006).*
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- Franco, S., Design with Operational Amplifier and Analog Integrated circuit, McGraw Hill (2016).
- *Terrell, D., Op Amps Design Application and Troubleshooting, Newness (1996).*