EE 204 - Analog Circuits
Lecture 12

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September 15, 2023

Contents

1 Operational Amplifier (OpAmp)

In the previous lecture, we have seen the basic operation of an OpAmp and also delved slightly into the types of Operational Amplifier based on the configuration.

Types of Operational Amplifiers

There are basically two types of Operational Amplifier (based on configuration):

- Non-Inverting Amplifier
- Inverting Amplifier

Applications of Operational Amplifier

In this lecture we also discuss some Applications of OpAmp such as:

- Summing Amplifier
- Differential Amplifier (Subtractor)
- Differentiator
- Integrator

Basic Assumptions for an Ideal OpAmp

Some of the basic assumptions that we make for an Ideal OpAmp are -

1. Input current is zero
2. Input offset voltage is zero
3. Input impedance is infinite
4. Output impedance is zero
5. Open Loop Gain is infinite
6. Common Mode Gain is zero

So, first let's go over a quick overview of Inverting and Non-Inverting Amplifier

1.1 Inverting Amplifier

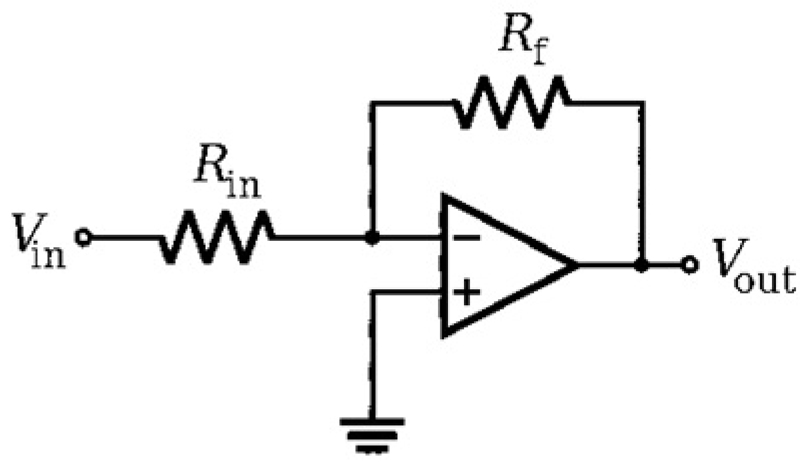

Figure 1: Inverting Amplifier

In this type of amplifier, the output (o/p) is precisely 180° out of phase to the input (i/p). When a positive voltage is applied to the circuit, then the o/p of the circuit will be negative.

If the amplifier is assumed as ideal, then we apply the **Virtual Short** concept at the i/p terminals of the op-amp. So the voltage at the two terminals is equivalent.

Then, by applying KVL/KCL at the terminals, we get open-loop gain

$$A_v = -\frac{R_f}{R_in}$$

1.2 Non-Inverting Amplifier

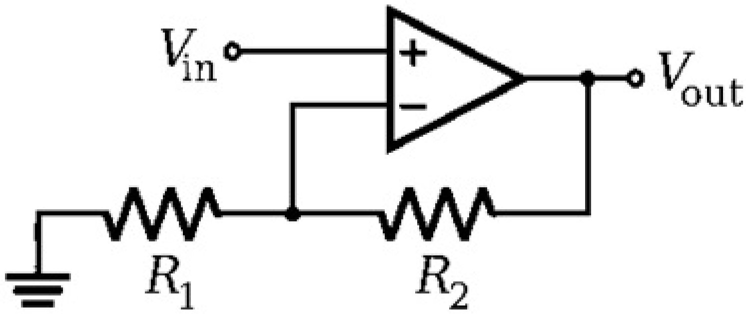

Figure 2: Non-Inverting Amplifier

In a non-inverting amplifier, we connect the voltage source to the non-inverting / positive terminal, leaving the rest of the circuit same as before.

So, in this kind of amplifier, the output is exactly in phase to input. When a positive voltage is applied to the circuit, then the o/p will be positive. The o/p is non-inverted in terms of phase.

Then, by applying KVL/KCL at the terminals, we get open-loop gain

$$A_v = 1 + \frac{R_2}{R_1}$$

2 Applications of OpAmp

Since, we have discussed the basic configurations of the Operational Amplifier, let us start with the applications of Operational Amplifier.

2.1 Summing Amplifier

In the above circuit, we give a 3-bit digital input which on going through the circuit gives a analog output. The circuit feeds the weighted sum of the individual digital inputs to the input terminal of the Operational Amplifier, which gives us the analog output v_{out} at the o/p terminal.

This circuit can be generalised for N such resistors, on which applying KVL and KCL gives the following equation:

$$v_{out} = -R_f\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + ... + \frac{v_N}{R_N}\right)$$

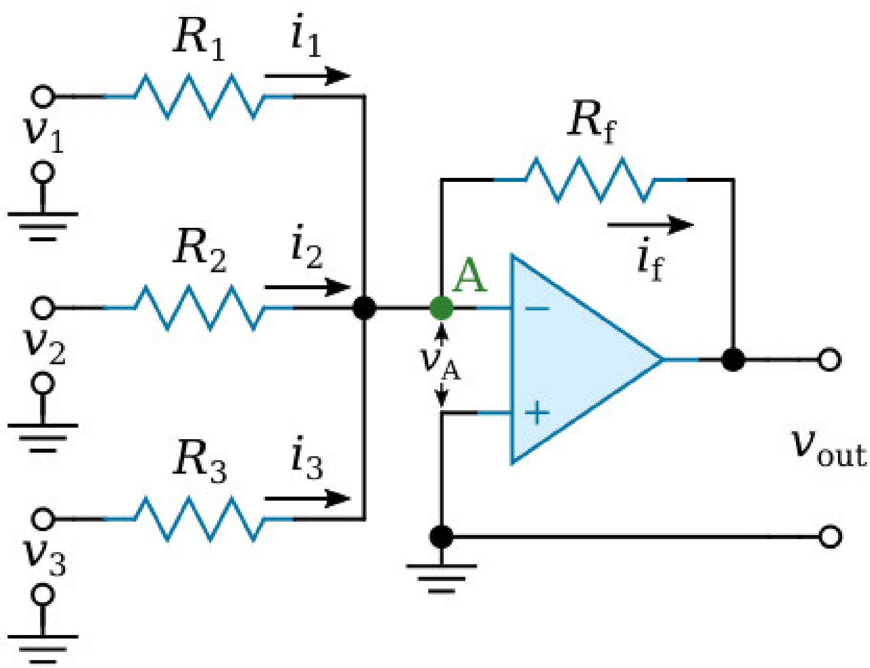

Figure 3: Summing Amplifier

2.2 Differential Amplifier (Subtractor)

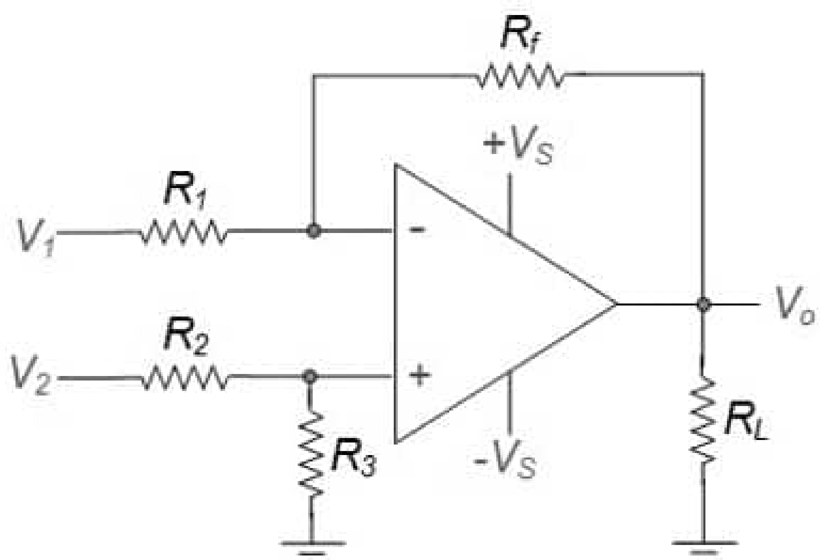

Figure 4: Differential Amplifier

The differential amplifier circuit amplifies the difference between signals applied to the inputs. Superposition is used to calculate the output voltage resulting from each input voltage, and then the two output voltages are added to arrive at the final output voltage.

For the amplifier circuit, we can write

$$V_O = A_d V_{id} + A_{cm} V_{icm}$$

where, $V_1 = V_{icm} - \frac{V_{id}}{2}$

and, $V_2 = V_{icm} + \frac{V_{id}}{2}$

In order to define the quality of an amplifier, we need some ratio or measurement of its quality in some sense. For this purpose, we define the Common Mode Rejection Ratio (CMRR) for an Amplifier.

$$CMRR = 20 \log \left(\frac{|A_d|}{|A_{cm}|} \right)$$

Ideally, we would like the CMRR to be infinite.

On solving the circuit, we get

$$V_O = \left(-\frac{R_f}{R_1}\right) V_1 + \left(1 + \frac{R_f}{R_1}\right) V_2 \left(\frac{R_3}{R_2 + R_3}\right)$$

If, we apply the condition, $\frac{R_f}{R_1} = \frac{R_3}{R_2}$, then V_O simplifies to -

$$V_O = \frac{R_f}{R_1}(V_2 - V_1)$$

This gives us our differential amplifier, or a subtractor in simpler sense.

2.3 Differentiator

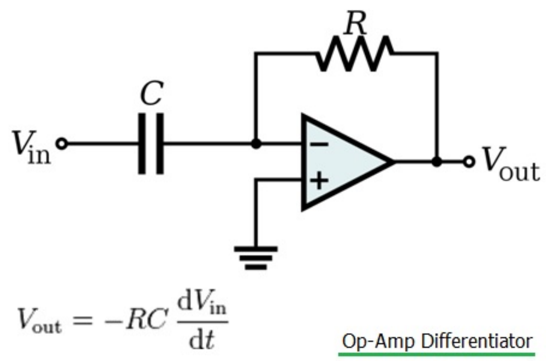

Figure 5: Differentiator

2.4 Integrator

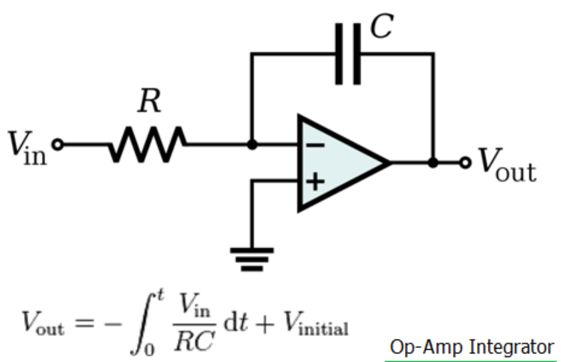

Figure 6: Integrator