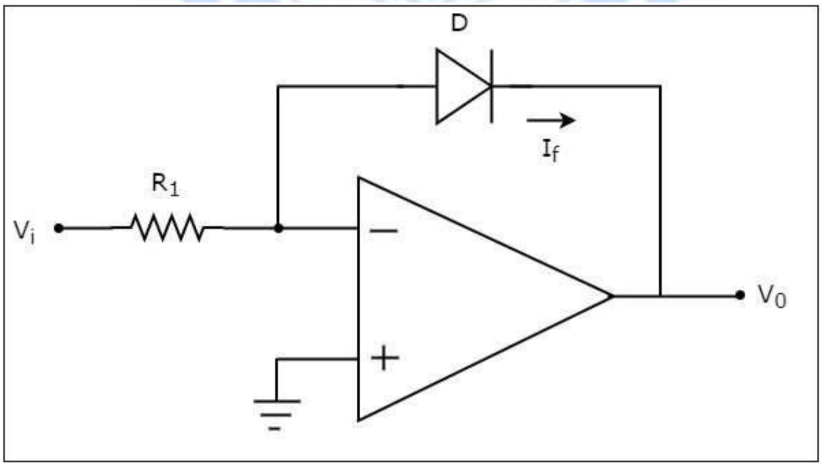
ROHINI COLLEGE OF ENGINEERING & TECHNOLOGY

Approved by AICTE and Affiliated to Anna University (An ISO Certified Institution) | Accredited with A+ Grade by NAAC
Recognized under Section 2(f) of University Grants Commission, UGC ACT 1956
(AUTONOMOUS)

LOGARITHMIC AMPLIFIER

A **logarithmic amplifier**, or a **log amplifier**, is an electronic circuit that produces an output that is proportional to the logarithm of the applied input. This section discusses about the op-amp based logarithmic amplifier in detail.

An op-amp based logarithmic amplifier produces a voltage at the output, which is proportional to the logarithm of the voltage applied to the resistor connected to its inverting terminal. The **circuit diagram** of an op-amp based logarithmic amplifier is shown in the following figure −



In the above circuit, the non-inverting input terminal of the op-amp is connected to ground. That means zero volts is applied at the non-inverting input terminal of the op-amp.

According to the **virtual short concept**, the voltage at the inverting input terminal of an op-amp will be equal to the voltage at its non-inverting input terminal. So, the voltage at the inverting input terminal will be zero volts.

1. Nodal equation at the inverting input terminal's node:

$$0 - \frac{V_i}{R_1} + I_f = 0$$

$$\Rightarrow I_f = \frac{V_i}{R_1} \qquad \text{......Equation 1}$$

2. The following is the equation for current flowing through a diode, when it is in forward bias:

$$I_f = I_s\, e^{\left(\frac{V_f}{V_T}\right)} \qquad \text{......Equation 2}$$

where,

I_s is the saturation current of the diode,

V_f is the voltage drop across diode, when it is in forward bias

V_T is the diodes thermal equivalent voltage.

3. The KVL equation around the feedback loop of the op amp will be:

$$0 - V_f - V_0 = 0$$

$$\Rightarrow V_f = -V_0$$

4. Substituting the value of V_f in Equation 2, we get:

$$I_f = I_s\, e^{\left(\frac{-V_0}{V_T}\right)} \qquad \text{......Equation 3}$$

Observe that the left hand side terms of both equation 1 and equation 3 are same. Hence, equate the right hand side term of those two equations as shown below −

5. From Equation 1 and Equation 4:

$$\frac{V_i}{R_1} = I_s\, e^{\left(\frac{-V_0}{nV_T}\right)}$$

$$\Rightarrow \frac{V_i R_1}{I_s} = e^{\left(\frac{-V_0}{nV_T}\right)} \quad \text{......Equation 5}$$

6. Applying natural logarithm on both sides, we get:

$$\ln\left(\frac{V_i R_1}{I_s}\right) = \frac{-V_0}{nV_T}$$

$$\Rightarrow -nV_T \ln\left(\frac{V_i R_1}{I_s}\right) = V_0$$

$$\boxed{V_0 = -nV_T \ln\left(\frac{V_i R_1}{I_s}\right)} \quad \text{......Equation 6}$$

Note that in the above equation, the parameters n, VT and Is are constants. So, the output voltage V0 will be proportional to the **natural logarithm** of the input voltage Vi for a fixed value of resistance R1.

Therefore, the op-amp based logarithmic amplifier circuit discussed above will produce an output, which is proportional to the natural logarithm of the input voltage VT, when R1Is=1V.

Observe that the output voltage V0 has a **negative sign**, which indicates that there exists a 180^0 phase difference between the input and the output.