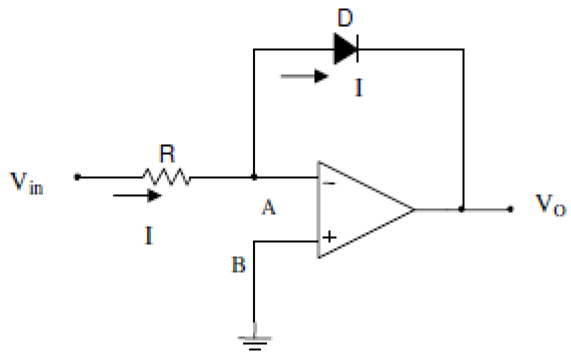
Log Amplifier

The circuit diagram of a basic log amplifier using diode is shown in figure. The diode is used in the feedback path.



By virtual ground $V_A = V_B = 0$.

As the op-amp draws zero input current, from the input side, we write

$$I = \frac{V_{in} - V_A}{R} = \frac{V_{in}}{R}$$

The current I also flows through the feedback path. Hence we write,

Voltage across the diode is $V_B - V_O = -V_O$. Hence using the diode current equation we write,

$$-V_O = \eta V_T \ln\left(\frac{I}{I_O}\right)$$

Substituting for I, we get,

$$V_O = -\eta V_T \ln\left(\frac{V_{in}}{R I_O}\right)$$

As $I_O R$ is constant dc voltage, it is referred as V_{ref}.

$$V_O = -\eta V_T \ln\left(\frac{V_{in}}{V_{ref}}\right)$$

It is seen that the output voltage is a function of logarithm of the input voltage. The basic log amplifier can also be constructed by replacing diode by a transistor. The output is proportional to the logarithm of the input given by

$$V_O = -V_T \ln\left(\frac{V_{in}}{V_{ref}}\right)$$

However these circuits face demerits. They are

1. The reverse saturation current of the diode changes with change in temperature.

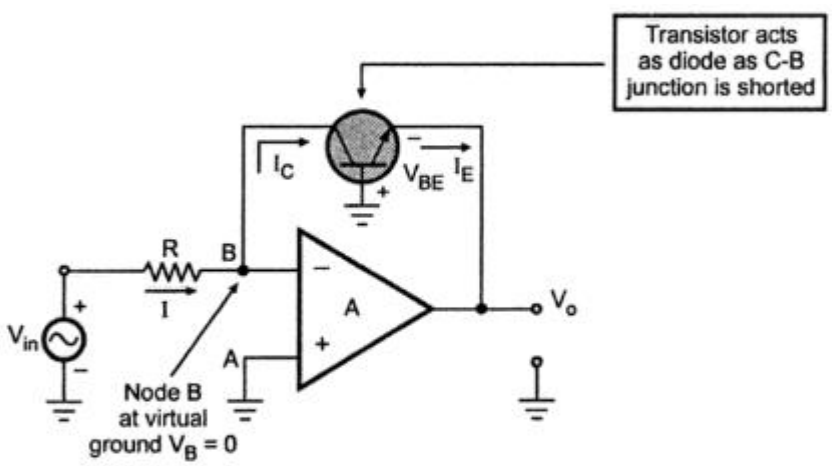
2. The Emitter saturation current also varies from one transistor to other and also with temperature. Hence setting Vref becomes difficult.

3. V_T is also a function of temperature.

Hence some sort of temperature compensation is required. Due to the presence of active elements like transistor, diodes in the feedback the circuit tends to oscillate. The circuit is compensated by an emitter resistance and a capacitor across the negative feedback. This lowers the gain as the frequency increases and avoids oscillations. The resistance range as 1 KΩ and 100pF respectively.

Basic Log amplifier using transistor

It is obtained by using a transistor as a diode in the feedback loop of an op-amp as shown in the figure.



$$I = \frac{V_{in} - V_B}{R} = \frac{V_{in}}{R}$$

As the op-amp current is zero, I = I_C = Collector current. VCB = 0 as the collector is at virtual ground and base is grounded. Hence we can write,

$$V_{BE} = V_T \ ln\left(\frac{I_C}{I_s}\right)$$

Applying to the output side we get,

$$V_o + V_{BE} = 0$$

$$\therefore \quad V_{BE} = -V_o$$

and $$I_C = I = \frac{V_{in}}{R}$$

Substituting in the equation (9),

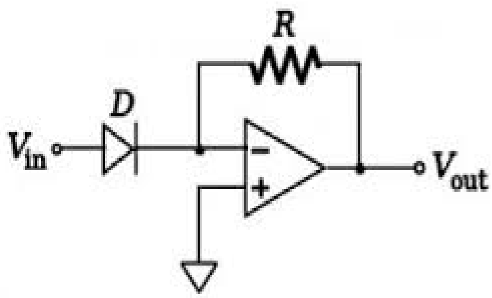
$$-V_o = V_T \, ln\left(\frac{V_{in}}{R\,I_s}\right)$$

Let $$V_{ref} = R\,I_s,$$

$$\boxed{V_o = -V_T \, ln\left[\frac{V_{in}}{V_{ref}}\right]}$$

Antilog Amplifier

The basic antilog amplifier is shown in the figure. The positions of diode and resistor are interchanged w.r.t log amplifier.



By virtual ground V_A=V_B=0. Let V_{in} be the drop across the diode. From the diode equation,

$$I_f = I_O e^{V_{in}/\eta V_T}$$

As the op-amp draws zero input current I_f = I. Hence we write,

$$I = I_f = \frac{V_B - V_O}{R_f} = -\frac{V_O}{R_f}$$

Equating 3.1 & 3.2 we get,

$$-\frac{V_O}{R_f} = I_O e^{V_{in}/\eta V_T}$$

$$\therefore V_O = -I_O R_f e^{V_{in}/\eta V_T}$$

As $I_O R$ is constant dc voltage, it is referred as V_{ref}

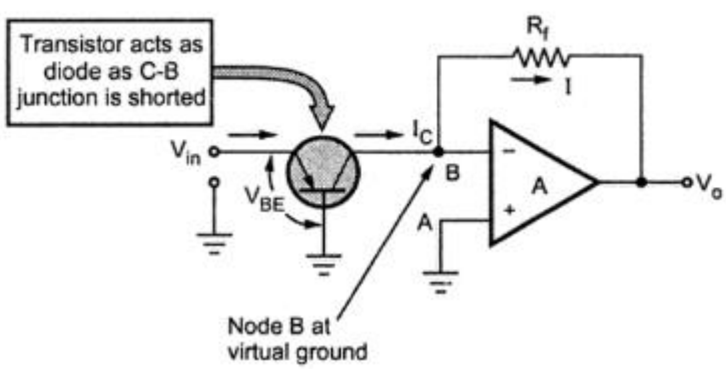
$$\therefore V_O = -V_{ref} e^{V_{in}/\eta V_T}$$

it is seen that the output voltage is exponential function of the input. The basic antilog amplifier can also be constructed by replacing diode by a transistor. The output is proportional to the antilogarithm of the input given by the above equation. This equation holds good for both the cases. This equation is temperature dependant and hence as temperature changes the equation varies. So the antilog amplifier also suffers from the same problem as that of log amplifier. Hence some sort of temperature compensation is required. The antilog amplifier is subjected to noise, bias currents, offset voltages, drifts and frequency stability problems. Transistorized circuits give accuracy, reduced bulk resistance and high operating ranges.

Basic Anti Log amplifier using transistor

It is obtained by using a transistor as a diode in the input path of an op-amp as shown in the figure. The node B is at virtual ground, hence $V_B = 0$. Thus the collector and base are both at ground potential and $V_{CB} = 0$. Hence the voltage across the transistor is V_{BE} and we can write,

$$I_C = I_s e^{V_{BE}/V_T}$$



From the figure, $V_{BE} = V_{in}$. Then

$$I_C = I_s e^{V_{in}/V_T}$$

Now the current I_C and current I are same as op-amp input current is zero.

$$\therefore \quad I = I_C = \frac{V_B - V_o}{R_f} = \frac{-V_o}{R_f}$$

$$\therefore \quad \frac{-V_o}{R_f} = I_s\, e^{V_{in}/V_T}$$

$$\therefore \quad V_o = -I_s\, R_f\, e^{V_{in}/V_T}$$

Let $V_{ref} = I_s R_f$, we get

$$V_o = -V_{ref}\, e^{V_{in}/\eta V_T}$$

Thus the output voltage is proportional to the exponential of V_{in} i.e. antilog of V_{in}. Thus circuit works as basic antilog amplifier.

In both the above circuits, it can be seen that the terms I_o, I_s and V_T are present in the output equation. All these are the function of temperature. Hence as temperature changes, these parameters also change and cause serious errors at the output. So the basic antilog circuits also face the same limitations as that of basic log amplifier circuits. And hence temperature compensation is must for the antilog amplifier circuits as well.