Electronic Circuits

Operational Amplifier

Lecture 6

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Op-Amp Applications

- **Non linear Applications**

9- Logarithmic Amplifier

10- Anti-Logarithmic Amplifier

11- Analog Multiplier

12- Analog Divider

13- Voltage Regulator

14- Comparator

15- Schmitt Trigger

16- Digital to Analog Converter

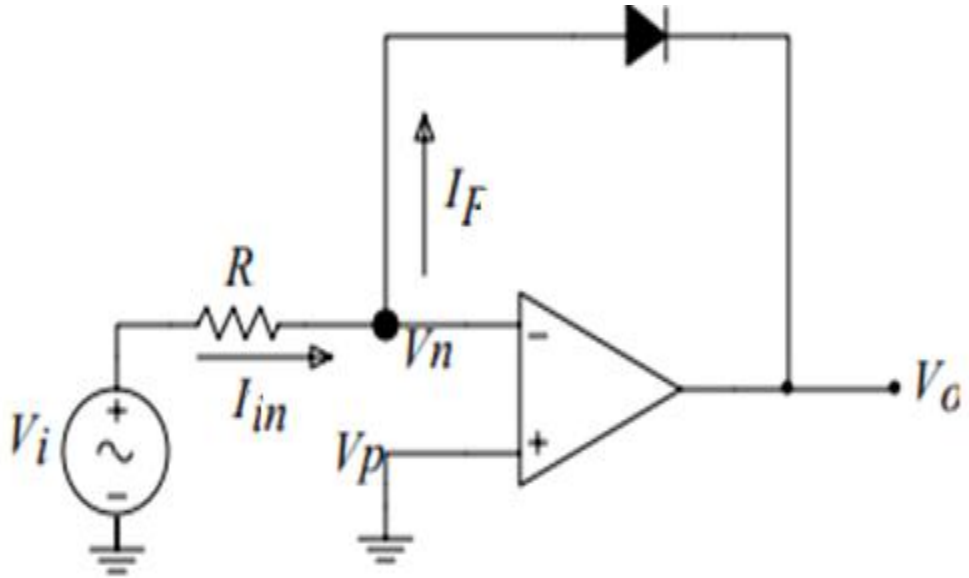
17- Rectifying using Op-Amp

18- Clipping using Op-Amp

19- Instrumentation Amplifier

9- The Logarithmic Amplifier

- If we are interested in processing a signal that has a very wide dynamic range we take advantage of the exponential i-v characteristics of the diode and design an amplifier whose output is proportional to the logarithm of the input.



9- The Logarithmic Amplifier using Diode

- If we use this signal as the input to an inverting amplifier we may linearize the signal by using a diode in the feedback path of the amplifier.

$$I_F = I_0\left(e^{\frac{V_F}{\eta V_T}} - 1\right), \quad V_F = 0 - V_0 = -V_0$$

$$I_f \simeq I_0\, e^{\frac{-V_0}{\eta V_T}}, \quad I_f = I_{in} = \frac{V_{in}}{R}$$

$$\frac{V_{in}}{R} \simeq I_0\, e^{\frac{-V_0}{\eta V_T}} \rightarrow \frac{V_{in}}{R I_0} = e^{-\frac{V_0}{\eta V_T}}$$

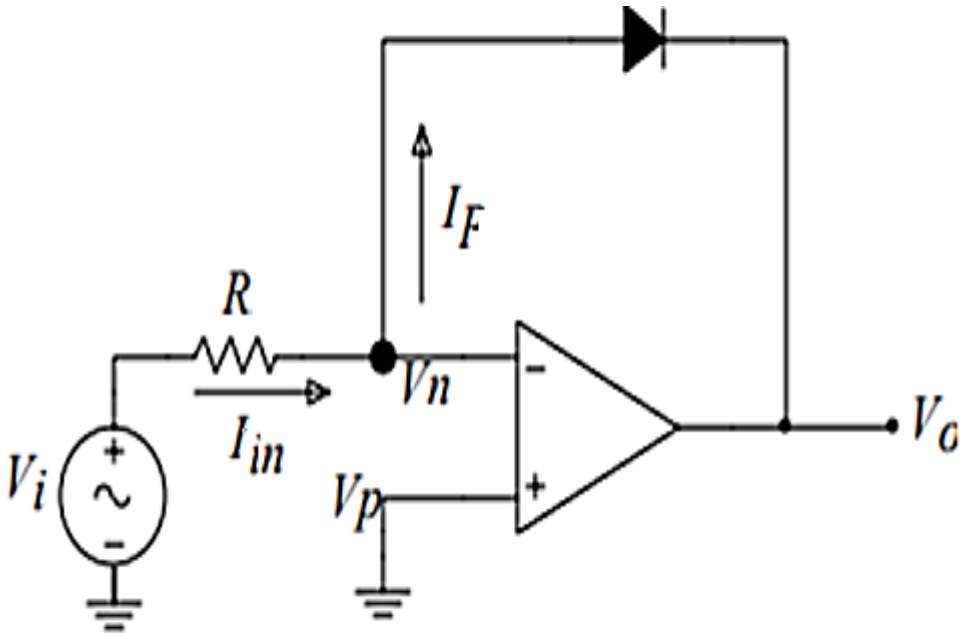
$$\ln \frac{V_{in}}{I_0 R} = \ln e^{\frac{-V_0}{\eta V_T}}$$

$$\ln \frac{V_{in}}{I_0 R} = \frac{-V_0}{\eta V_T}$$

$$V_0 = -\eta V_T \ln \frac{V_{in}}{I_0 R}$$

if $\eta V_T = 1$, $I_0 R = 1$

$$\boxed{V_0 = -\ln V_{in}}$$



9- The Logarithmic Amplifier using Transistor

$$V_{be} = 0 - V_o = -V_o$$

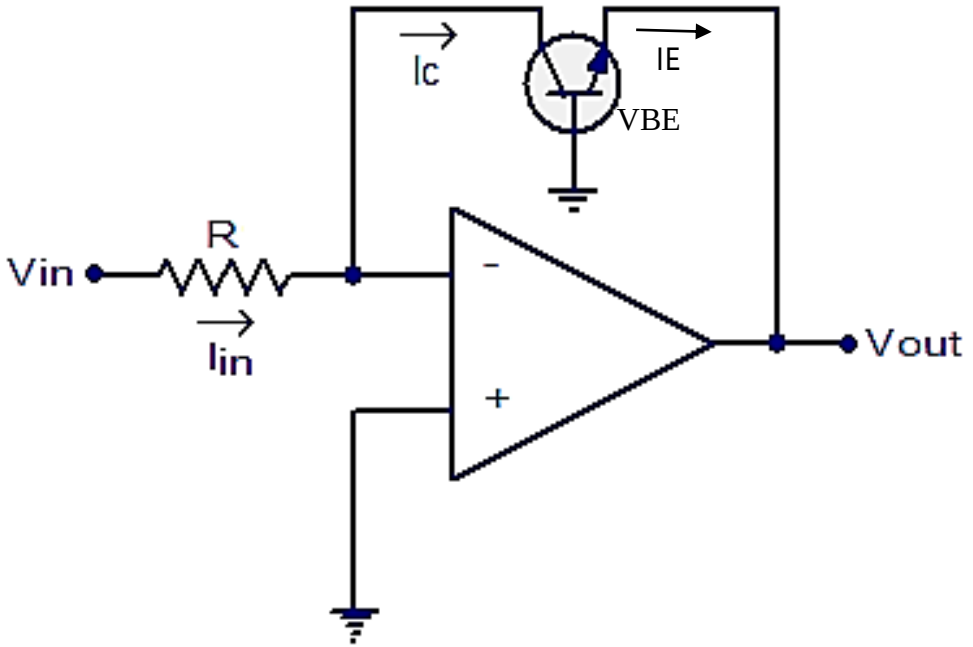
$$I_{in} = I_C \cong I_E = I_{E0}\, e^{-\frac{V_o}{\eta V_T}}$$

$$\frac{V_{in}}{R} = I_{E0}\, e^{\frac{V_{be}}{\eta V_T}}$$

$$\frac{V_{in}}{I_{E0} R} = e^{\frac{V_{be}}{\eta V_T}}$$

$$\ln \frac{V_{in}}{I_{E0} R} = \frac{V_{be}}{\eta V_T} \quad , \; V_{be} = -V_o$$

$$\therefore V_o = -\eta V_T \ln \frac{V_{in}}{I_{E0} R}$$



if $\eta V_T = 1$, $I_{E0} R = 1$

$$\Rightarrow V_o = -\ln V_{in}$$

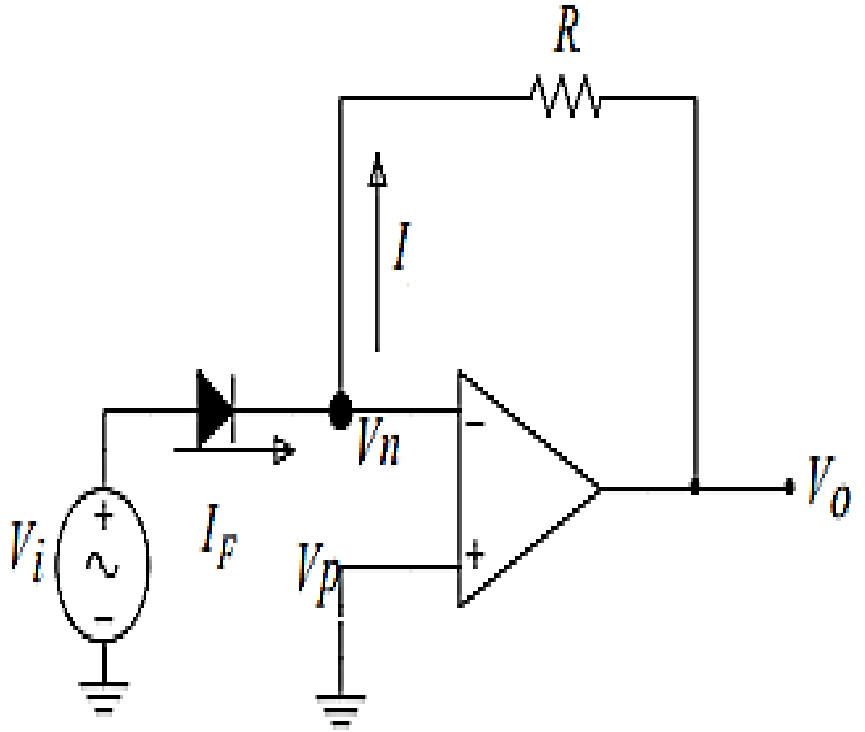
10- The Antilogarithmic Amplifier using Diode

- Similarly the antilogarithmic amplifier may be constructed by placing the diode in series with the signal source.

$$I_f \cong I_0 \, e^{\frac{V_f}{\eta V_T}}$$

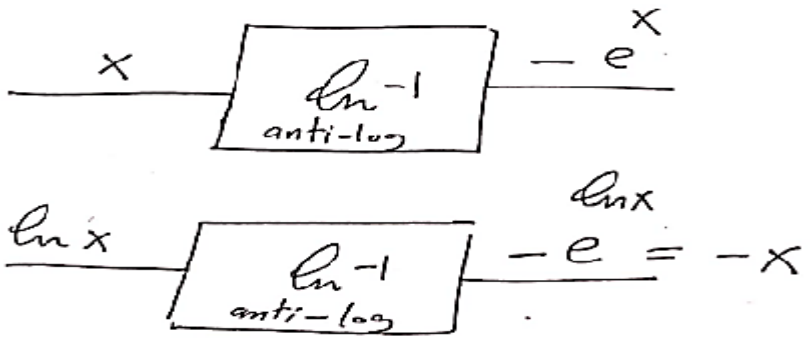
$$\frac{-V_o}{R} = I_0 \, e^{\frac{V_{in}}{\eta V_T}}, \qquad I_f = I = -\frac{V_o}{R}$$

$$\boxed{V_o = -I_0 R \, e^{\frac{V_{in}}{\eta V_T}}}$$



if $I_0 R = 1$, $\eta V_T = 1$

$$\Rightarrow \boxed{V_o = -e^{V_{in}}} \qquad \boxed{V_o = -\ln^{-1}(V_{in})}$$



10- The Antilogarithmic Amplifier using Transistor

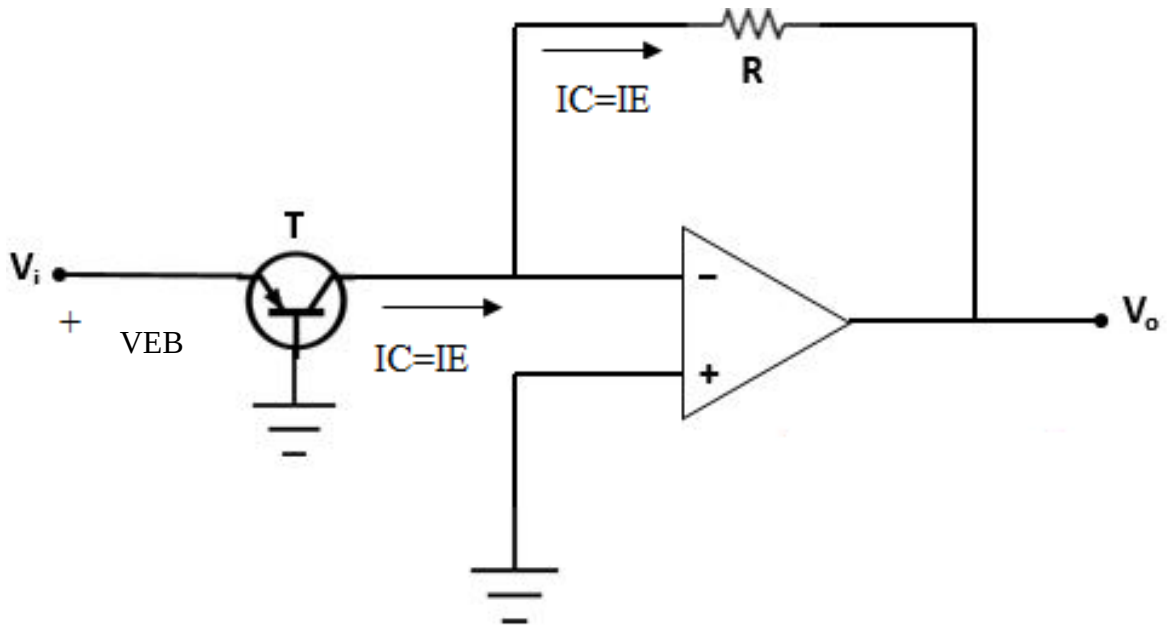
$$V_o = -I_c R \simeq -I_E R$$

$$I_E = I_{E_0} e^{\frac{V_{eb}}{\eta V_T}}$$

$$\because V_{eb} = V_{in} \Rightarrow I_E = I_{E_0} e^{\frac{V_{in}}{\eta V_T}}$$

$$\therefore V_o = -I_E R = -R \cdot I_{E_0} e^{\frac{V_{in}}{\eta V_T}}$$

$$\boxed{V_o = -I_{E_0} R \, e^{\frac{V_{in}}{\eta V_T}}}$$



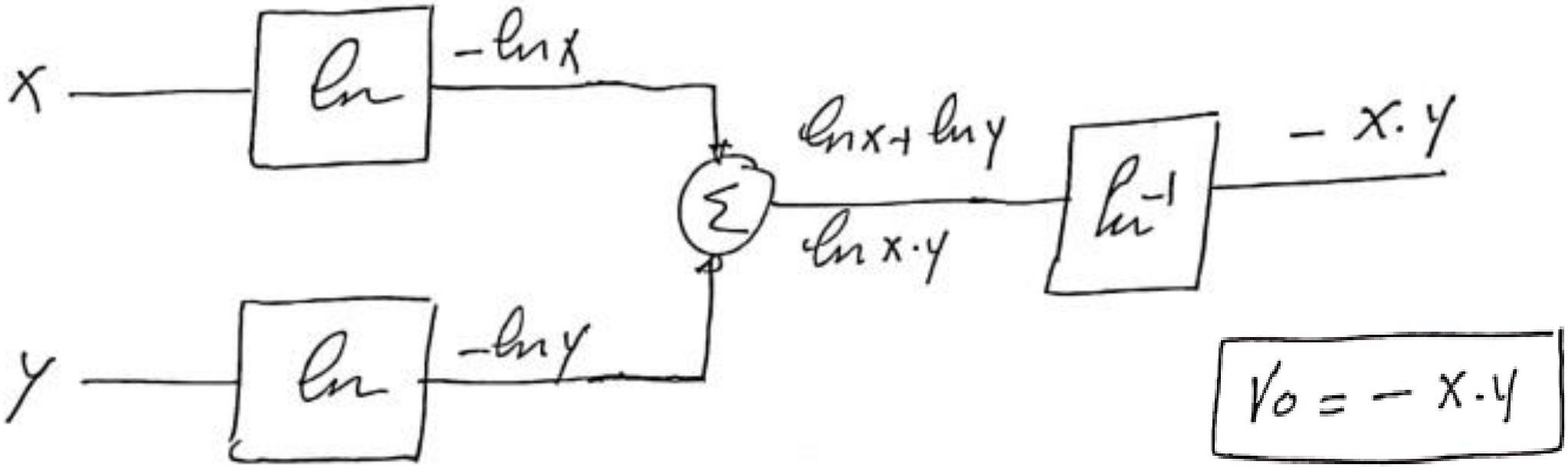
if $I_{E_0} R = 1$, $\eta V_T = 1$

$$\therefore \boxed{V_o = -e^{V_{in}}}$$

$$\boxed{V_o = -\ln^{-1}(V_{in})}$$

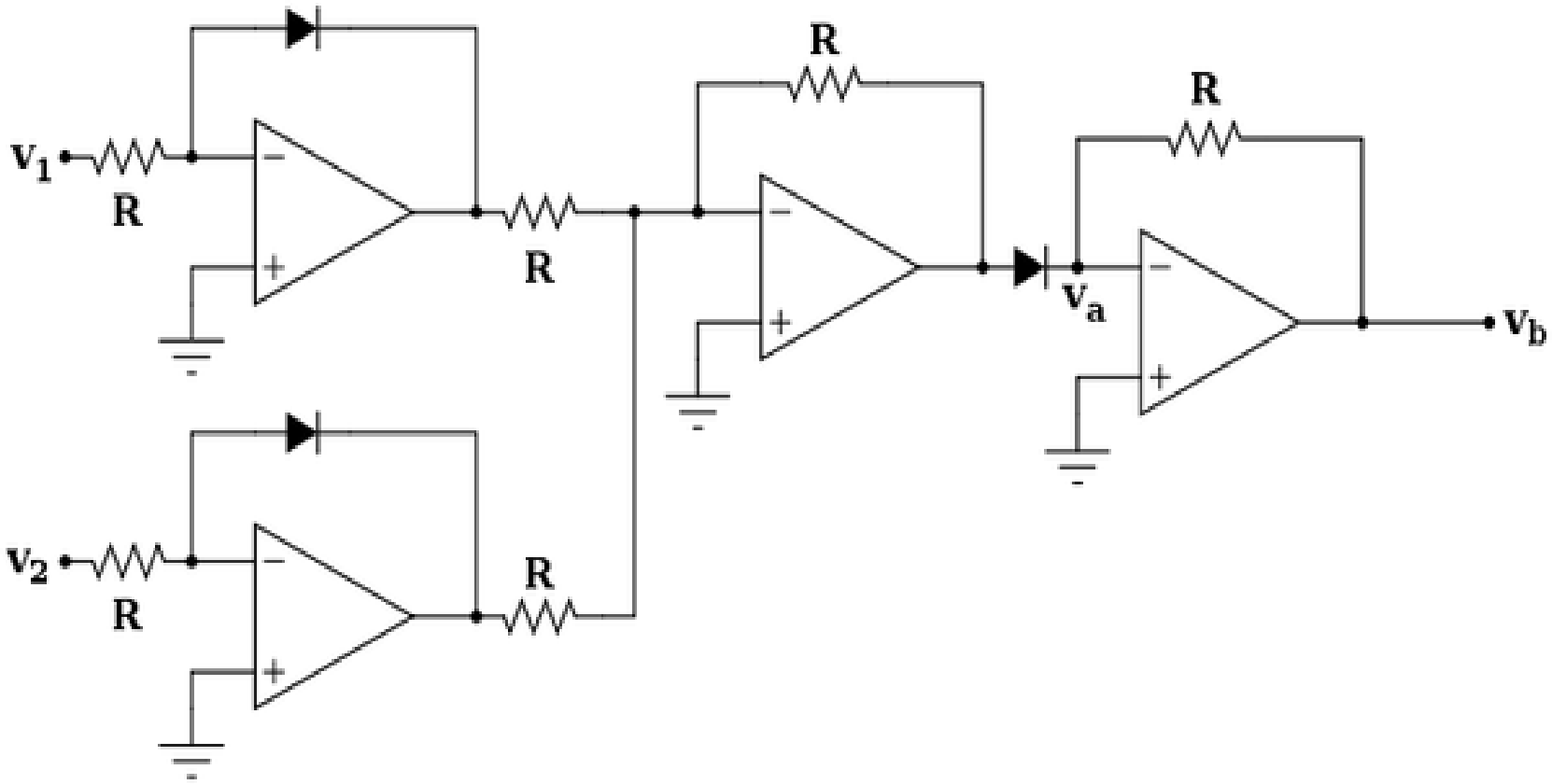
11- The Analog Multiplier

- Combing between summing, logarithmic and antilogarithmic circuits and the output will be the multiply of two inputs.



11- The Analog Multiplier

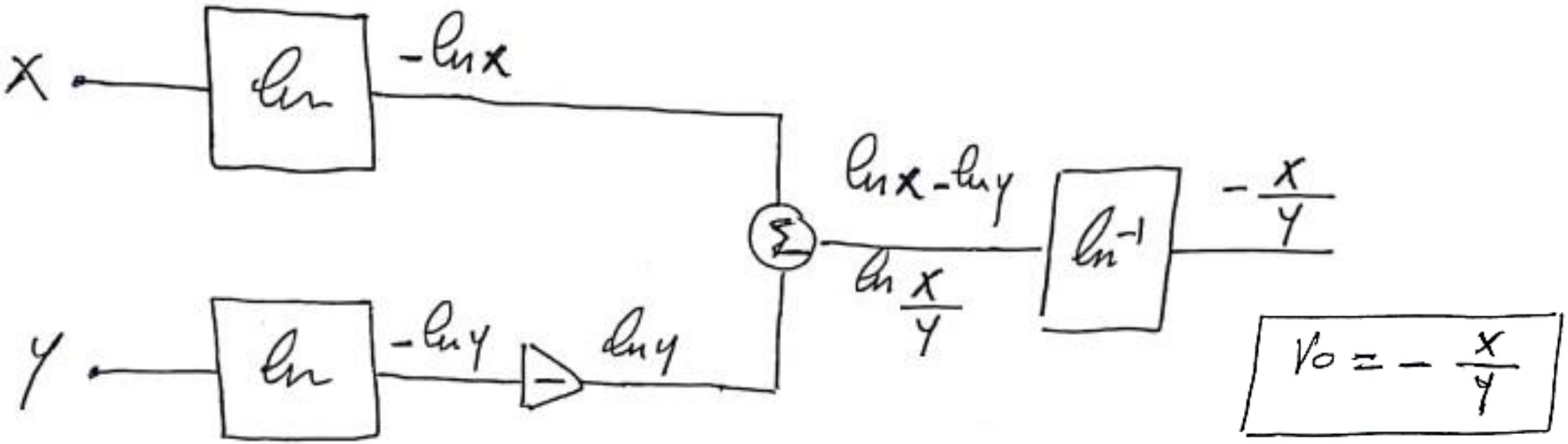
- **Vb= - V1*V2**



Vb= - V1*V2

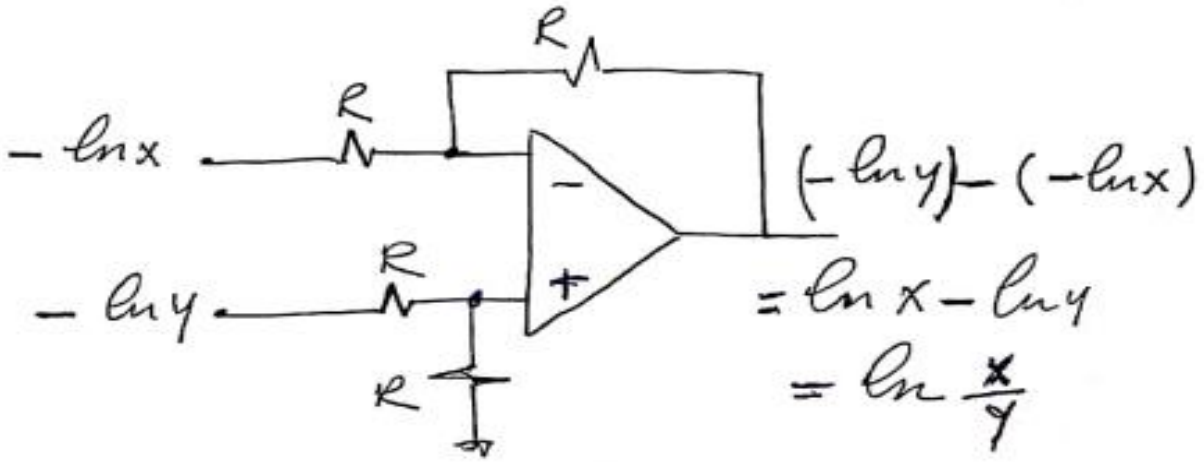
12- The Analog Divider

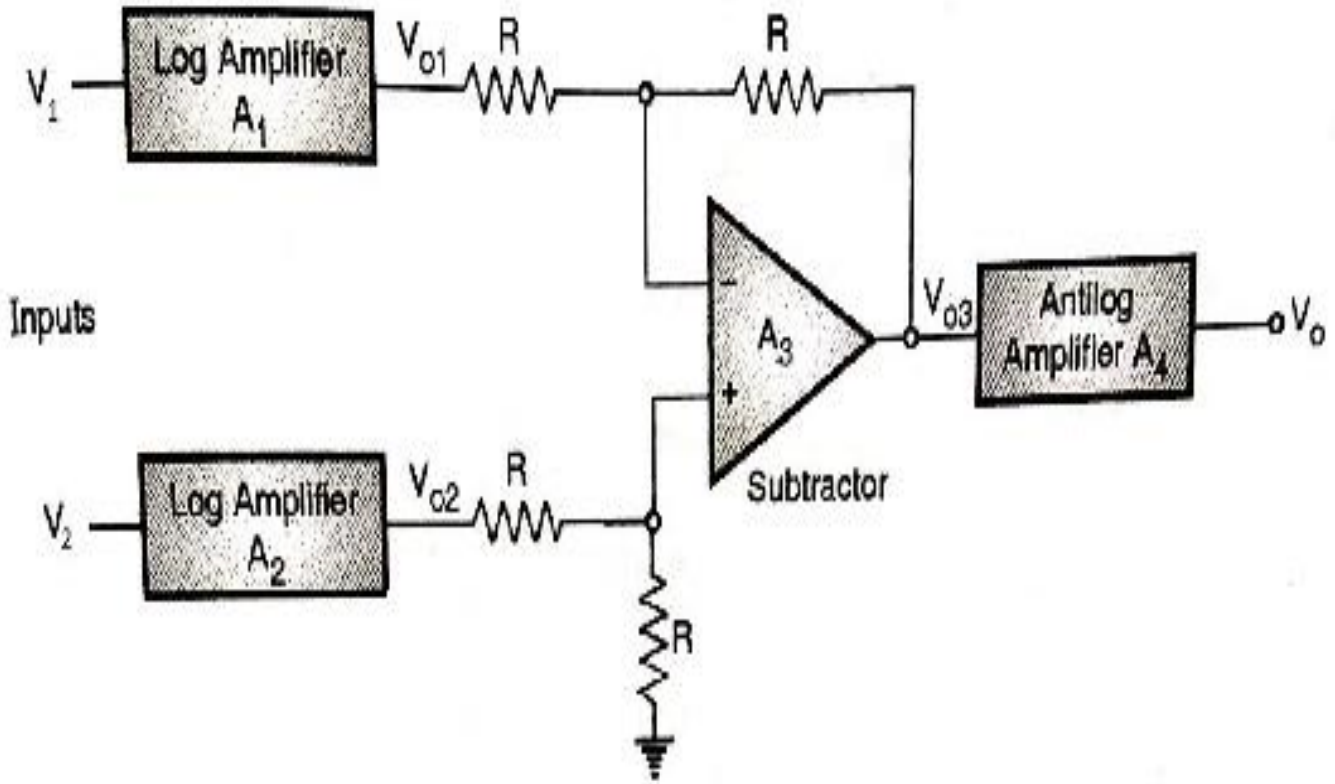
- Combing between Difference amplifier with logarithmic and antilogarithmic circuits and the output will be the dividing of two inputs.



12- The Analog Divider

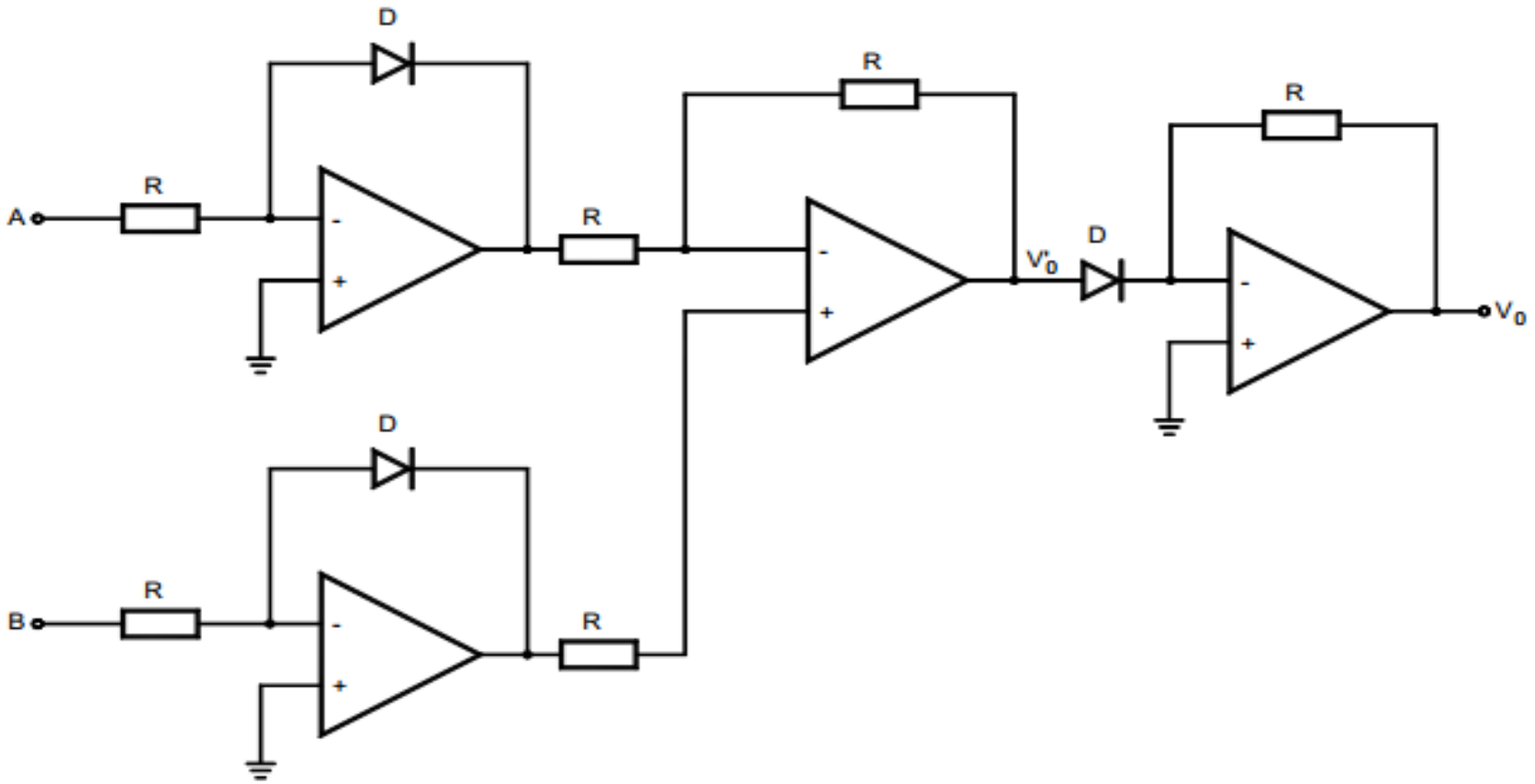
- **Vo= - V1/V2**





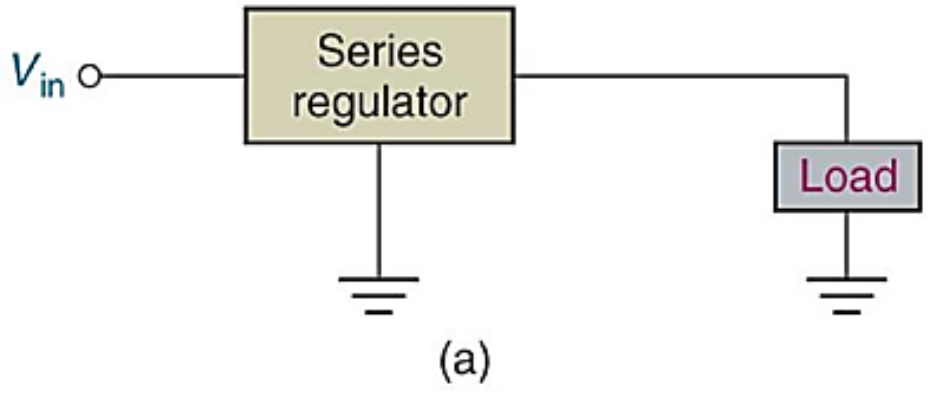
12- The Analog Divider

- **Vo= - V1/V2**

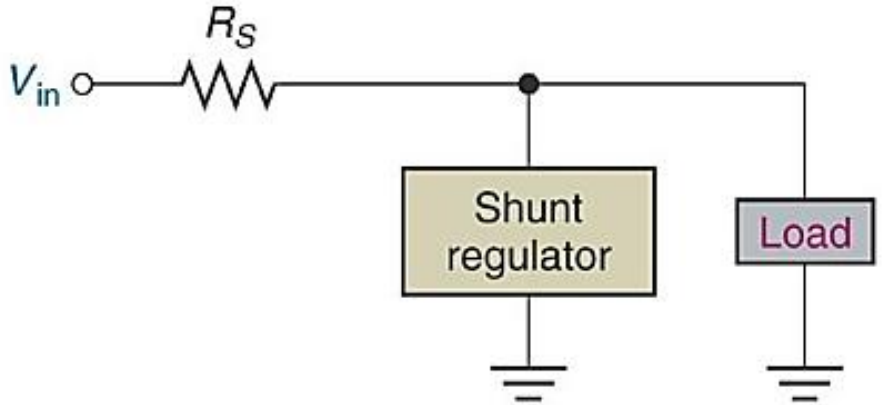


13- The Voltage Regulator

- Fundamental classes of voltage regulators are linear regulators and switching regulators.
- Two basic types of linear regulator are the series regulator and the shunt regulator.
- The series regulator is connected in series with the load and the shunt regulator is connected in parallel with the load.

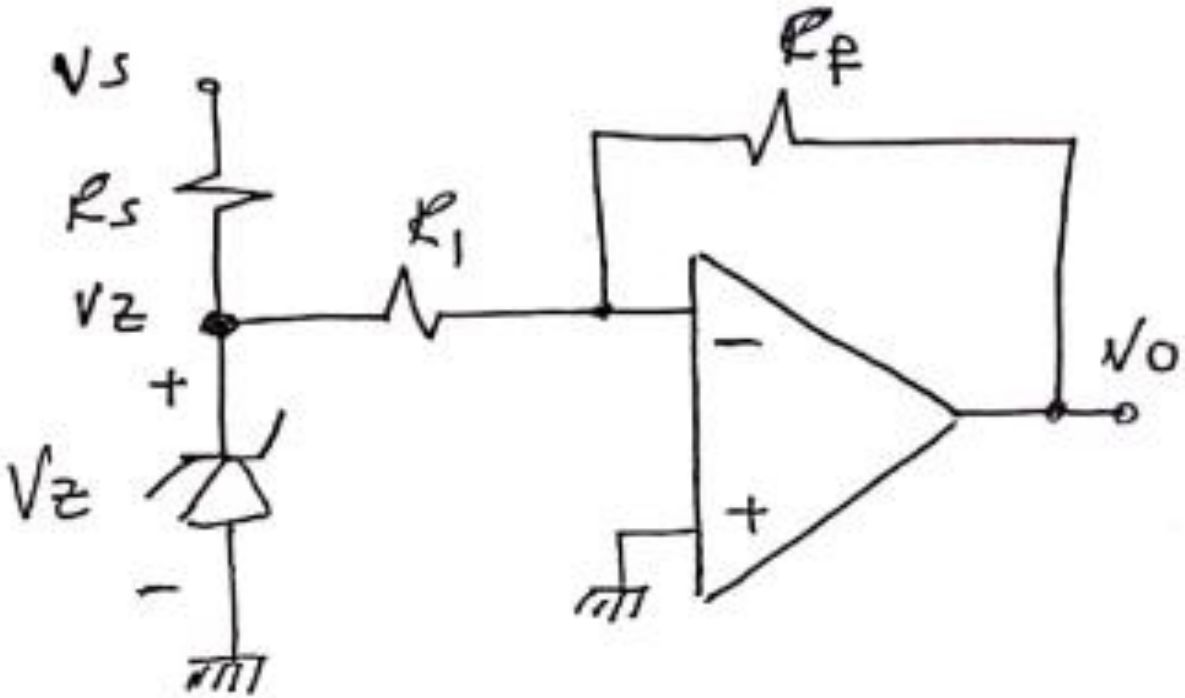


(a)



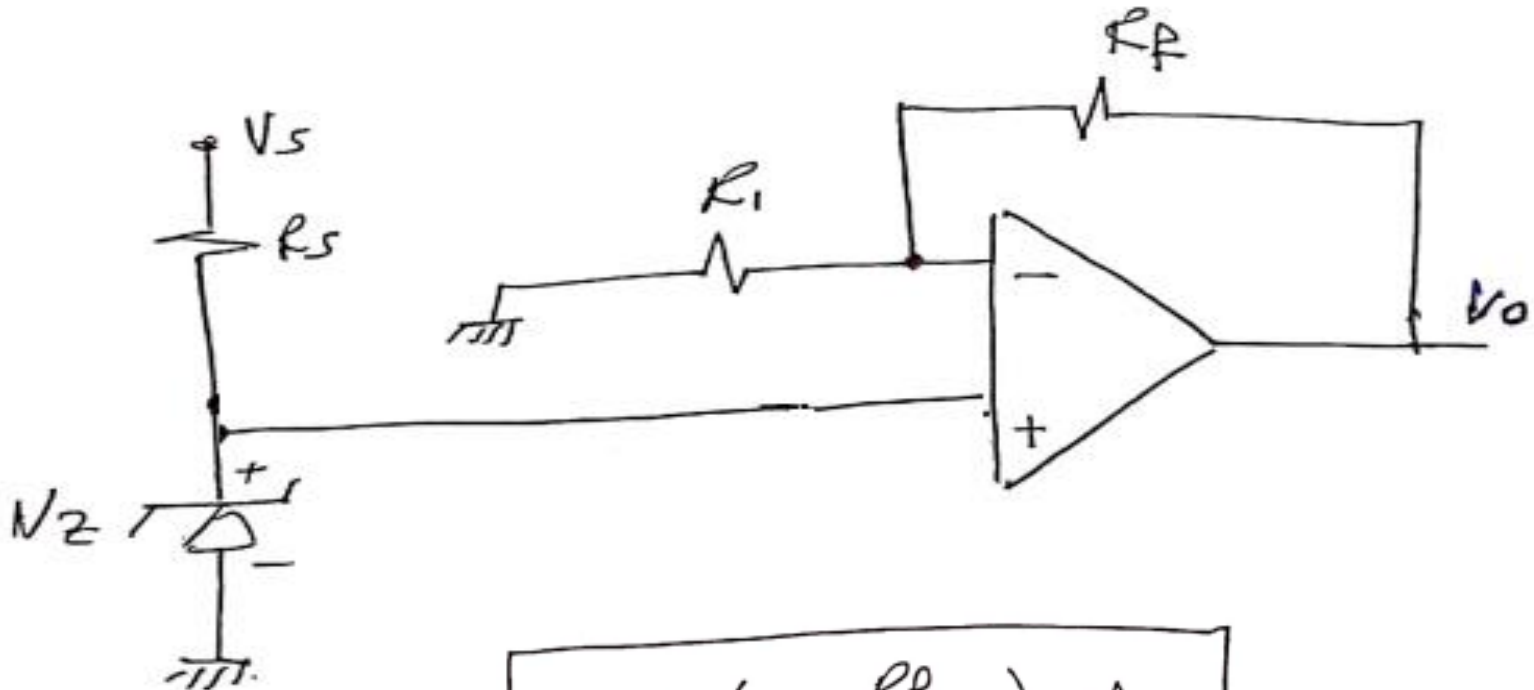
(b)

13- The Voltage Regulator



$$V_o = -\frac{R_f}{R_1} V_z$$

13- The Voltage Regulator



$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_Z$$