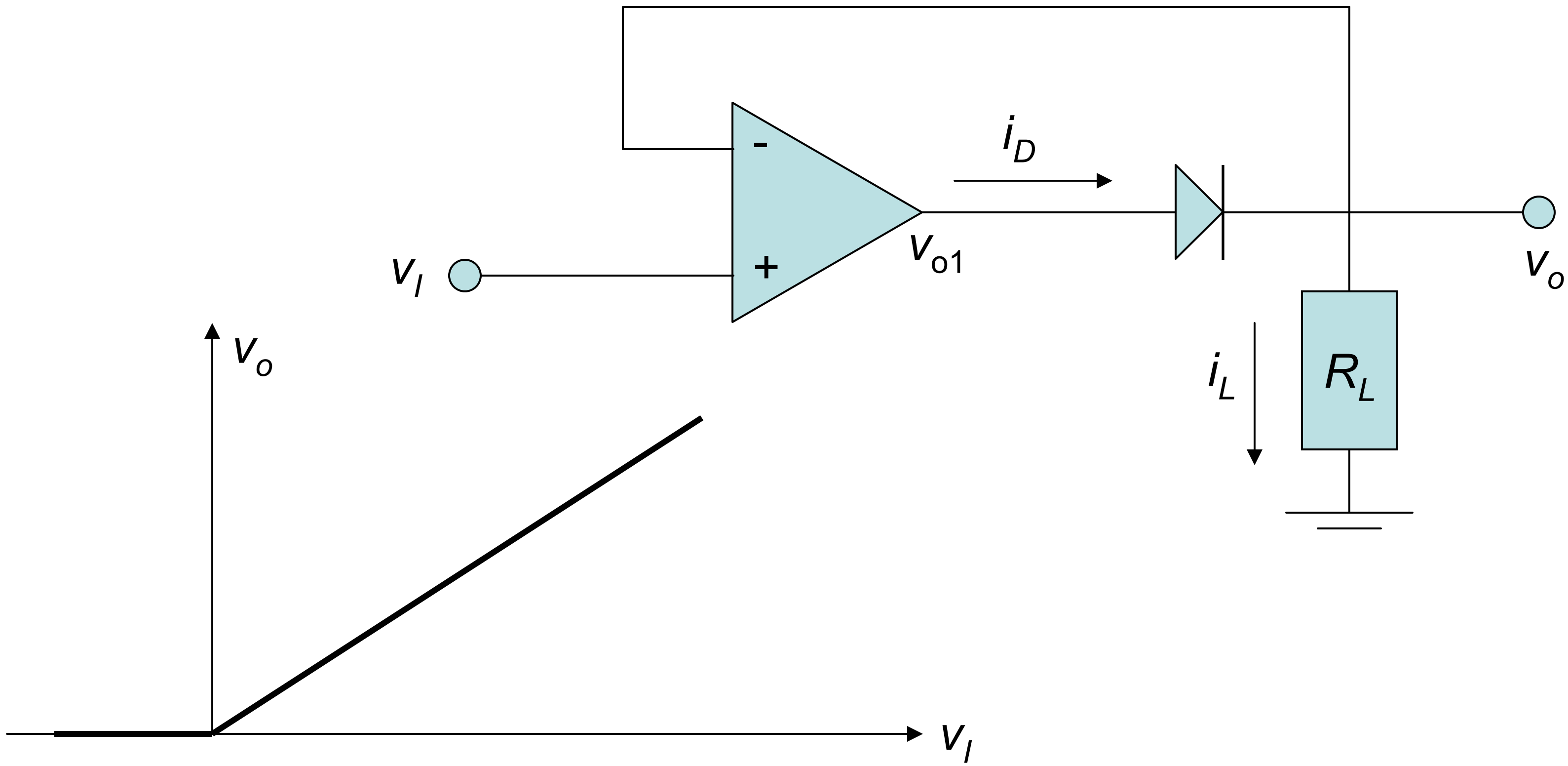
OP-Amp Circuit Design
Nonlinear Circuit Applications

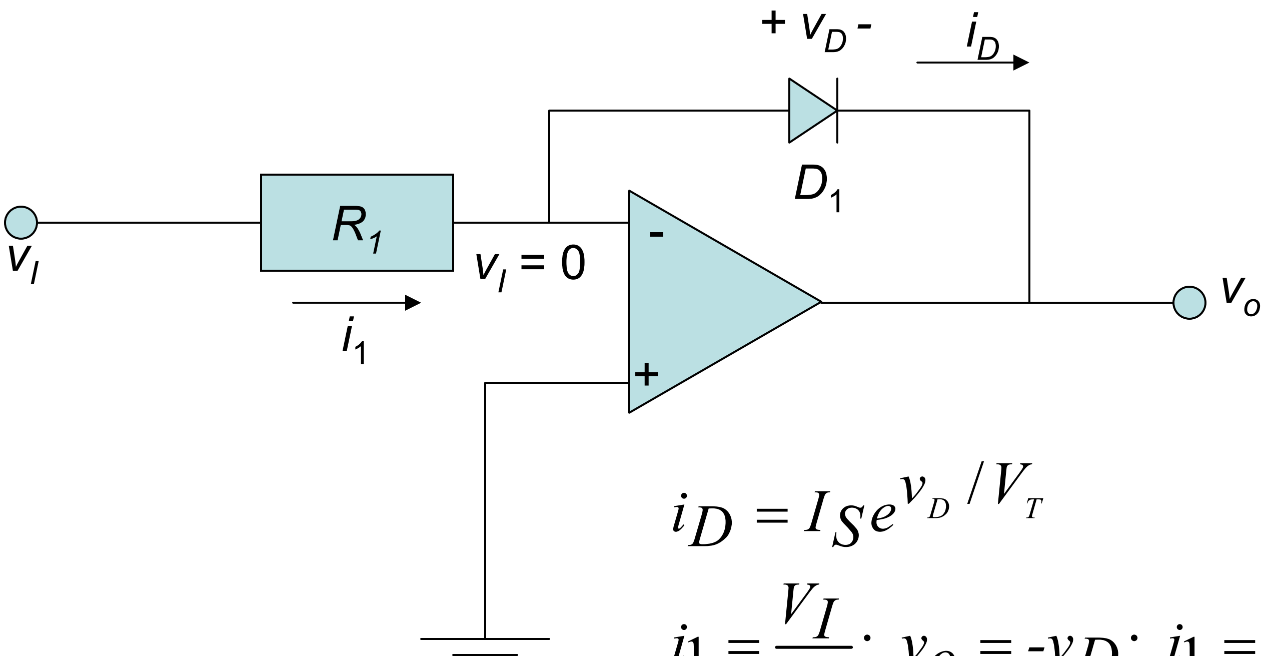
- So far we have used linear passive elements in conjunction with the op-amp. Many useful circuits can be fabricated if nonlinear elements, such as diodes or transistors are used in the op-amp circuits. We will consider the following circuits:
  - Precision Half-Wave Rectifier
  - Log Amplifier
  - Antilog or Exponential Amplifier

Precision Half Wave Rectifier

For $v_I \rangle 0$, the circuit behaves as voltage follower ($v_o = v_I$) and the load current i_L is positive. For $v_I \langle 0$, v_o tends to be negative which tends to produce negative diode current which cannot exists.



Log Amplifier



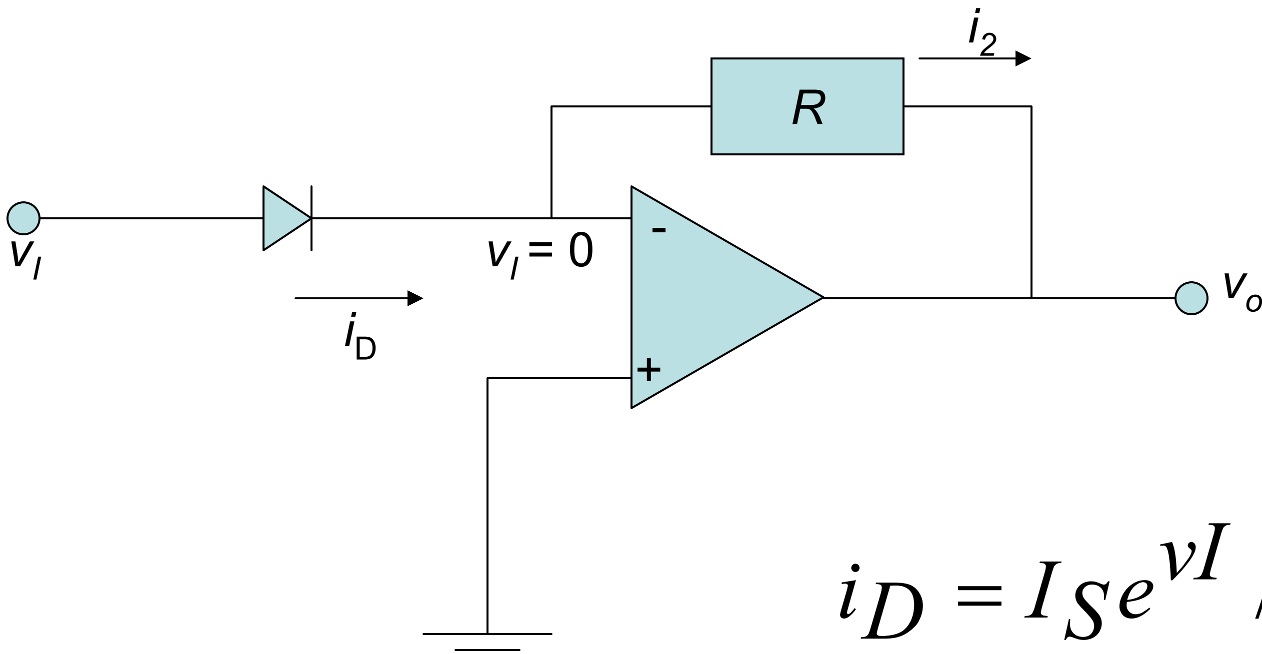
$$i_D = I_S e^{v_D / V_T}$$

$$i_1 = \frac{V_I}{R_1};\; v_O = -v_D;\; i_1 = i_D$$

$$i_1 = \frac{v_I}{R_1} = i_D = I_S e^{-v_o / V_T}$$

$$\ln\left(\frac{v_I}{I_S R_1}\right) = -\frac{v_O}{V_T};\; vo = -V_T \ln\left(\frac{V_I}{I_S R_1}\right)$$

Antilog or Exponential Amplifier

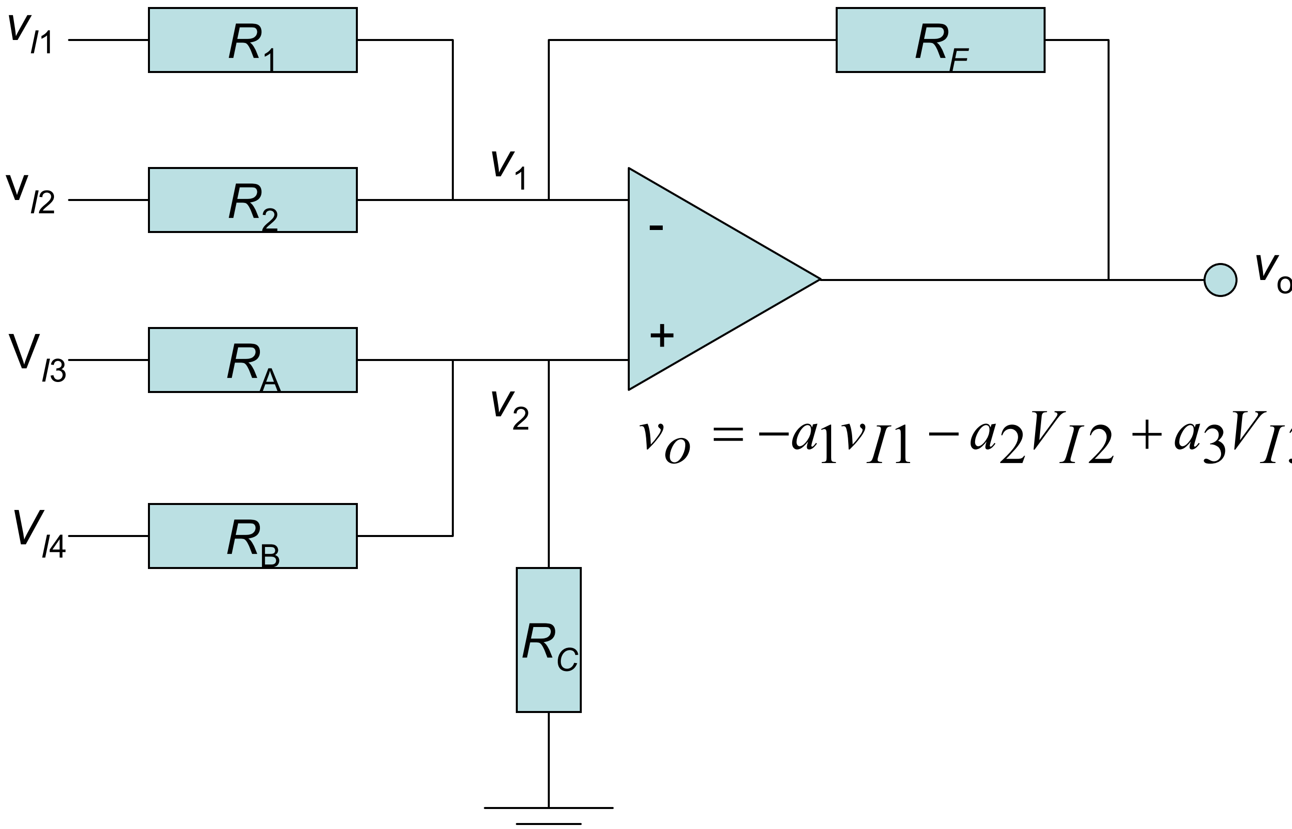


$$i_D = I_S e^{v_I / V_T}$$

$$v_O = -i_2 R = -i_D R$$

$$v_O = -I_S R\, e^{v_I / V_T}$$

Summing OP-Amp Circuit Design



$$v_O = -a_1 v_{I1} - a_2 V_{I2} + a_3 V_{I3} + a_4 v_{I4}$$

$$v_o(v_{I1}) = -\frac{R_F}{R_1} v_{I1};\ v_o(v_2) = -\frac{R_F}{R_2} v_{I2}$$

$$v_2(V_{I3}) = \frac{R_B // R_C}{R_A + R_B // R_C} v_{I3} = v_1(V_{I3})$$

$$v_o(V_{I3}) = \left(1 + \frac{R_F}{R_1 // R_2)}\right) v_1(V_{I3}) = (1 + \frac{R_F}{R_1 // R_2})(\frac{R_B // R_C}{R_A + R_B // R_C}) v_{I3}$$

$$v_o(V_{I3}) = (1 + \frac{R_F}{R_N})(\frac{R_P}{R_A}) v_{I3}; R_N = R_1 // R_2; R_P = R_A // R_B // R_C$$

$$v_o(V_{I4}) = (1 + \frac{R_F}{R_N})(\frac{R_P}{R_A}) v_{I4}$$

$$v_o = -\frac{R_F}{R_1} v_{I1} - \frac{R_F}{R_2} v_{I2} + \left(1 + \frac{R_F}{R_N}\right)\left[\frac{R_P}{R_A} v_{I3} + \frac{R_P}{R_B} v_{I4}\right]$$

Design Example: Design a summing op-amp that produces the following equation. The smallest resistor should be 20 kΩ

$$v_O = -10v_{I1} - 4v_{I2} + 5v_{I3} + 2v_{I4}$$

$$\frac{R_F}{R_1} = 10; \ \frac{R_F}{R_2} = 4; \ \text{Choose } R_1 = 20\ \text{k}\Omega$$

$$R_F = 200\ \text{k}\Omega; \ R_2 = 50\ \text{k}\Omega$$

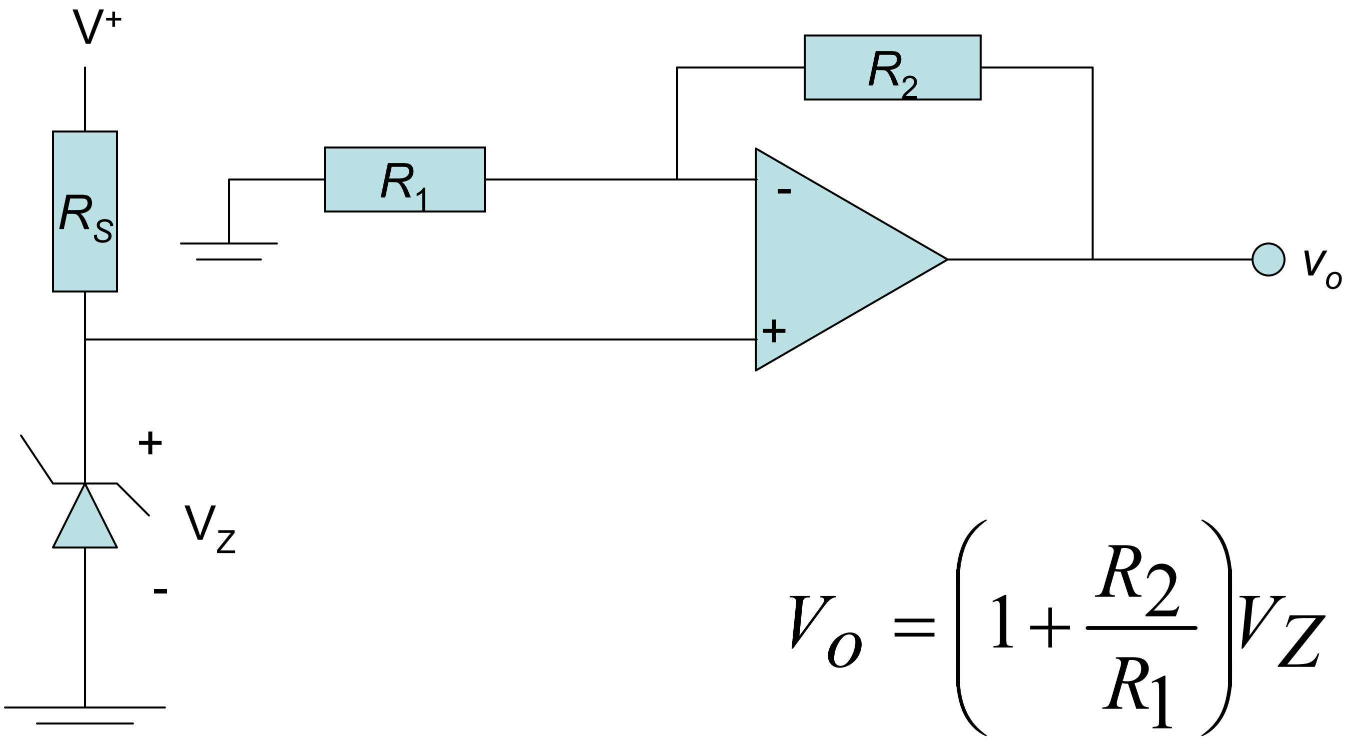
$$(1 + \frac{R_F}{R_1 // R_2}) = (1 + \frac{200}{20 // 50}) = 15$$

$$(15)(\frac{R_P}{R_A}) = 5; \ 15(\frac{R_P}{R_B}) = 2; \ \frac{R_B}{R_A} = \frac{5}{2}$$

$$\text{If we choose } R_A = 80\ \text{k}\Omega, \text{ then } R_B = 200\ \text{k}\Omega,$$

$$R_P = 26.67\ \text{k}\Omega, R_C = 50\ \text{k}\Omega$$

Reference Voltage Source Gain



$$V_O = \left(1 + \frac{R_2}{R_1}\right) V_Z$$