UNIT-4
Lecture-1

Log, Anti Log Amplifiers, Analog Multipliers and their applications

Nonlinear Op-Amp Circuits

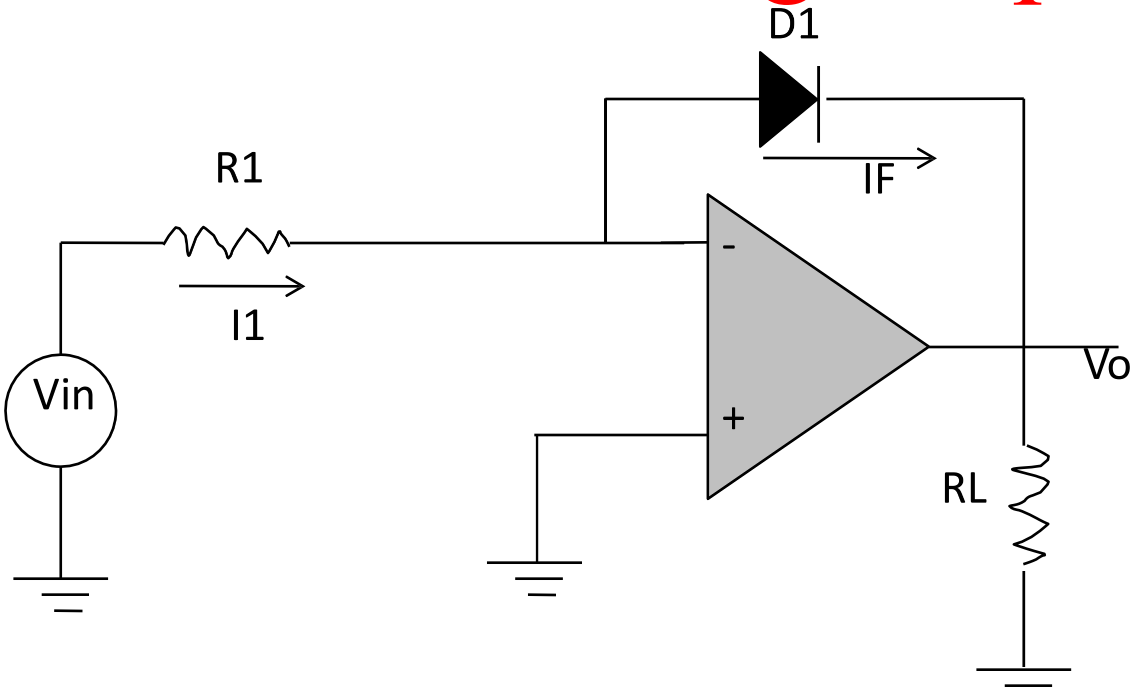
- Most typical applications require op amp and its components to act linearly
  - I-V characteristics of passive devices such as resistors, capacitors should be described by linear equation (Ohm's Law)
  - For op amp, linear operation means input and output voltages are related by a constant proportionality (A_v should be constant)
- Some application require op amps to behave in nonlinear manner (logarithmic and antilogarithmic amplifiers)

Logarithmic Amplifier

- Output voltage is proportional to the logarithm of input voltage
- A device that behaves nonlinearly (logarithmically) should be used to control gain of op amp
  - Semiconductor diode
- Forward transfer characteristics of silicon diodes are closely described by Shockley's equation

  $I_F = I_s e^{(VF/\eta VT)}$
  - I_s is diode saturation (leakage) current
  - e is base of natural logarithms (e = 2.71828)
  - V_F is forward voltage drop across diode
  - V_T is thermal equivalent voltage for diode (26 mV at 20°C)
  - η is emission coefficient or ideality factor (2 for currents of same magnitude as I_S to 1 for higher values of I_F)

Basic Log Amp operation

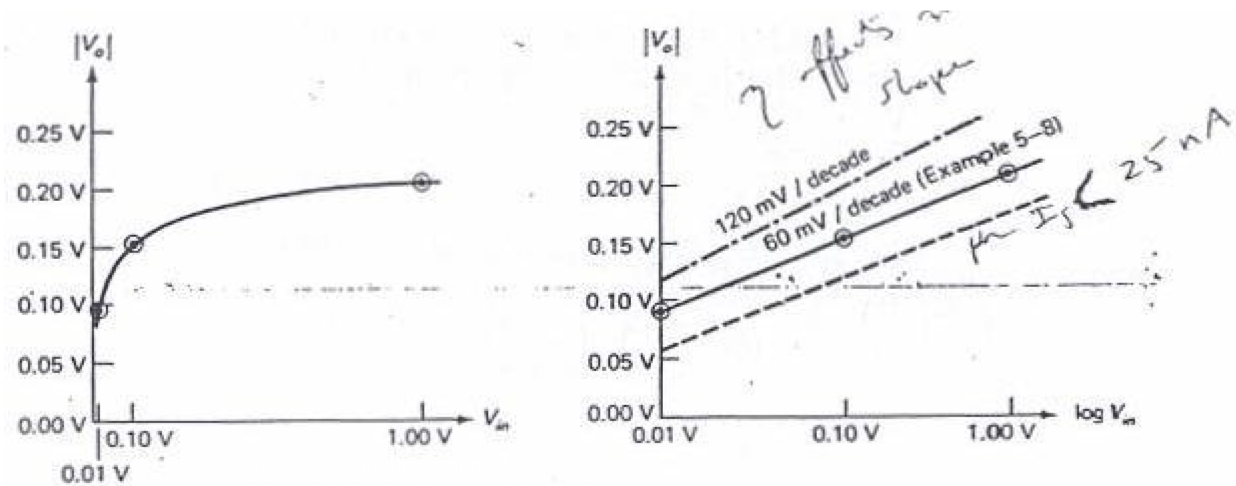


- $I1 = Vin/R1$
- $IF = - I1$
- $IF = - Vin/R1$
- $V0 = -VF = -\eta VT \ln(IF/IS)$
- $V0 = -\eta VT \ln[Vin/(R1IS)]$
- $rD = 26\ mV / IF$
- $IF < 1\ mA$ (log amps)

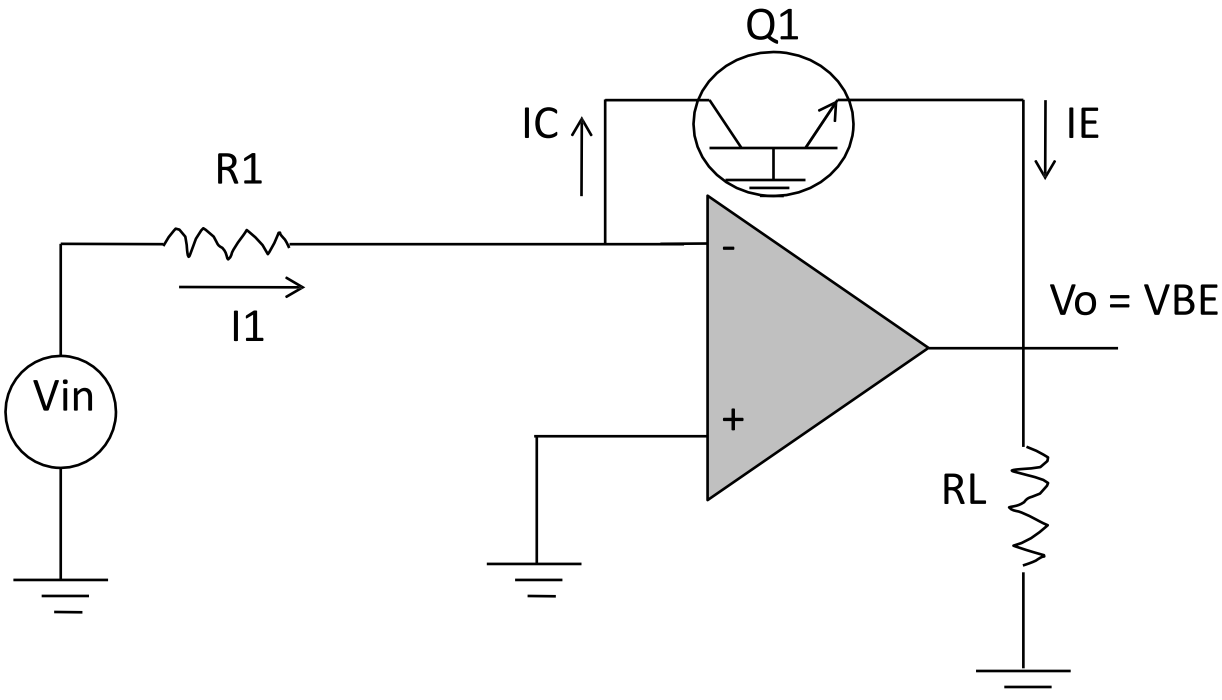
- At higher current levels ($IF > 1\ mA$) diodes begin to behave somewhat linearly

Logarithmic Amplifier

- Linear graph: voltage gain is very high for low input voltages and very low for high input voltages
- Semilogarithmic graph: straight line proves logarithmic nature of amplifier's transfer characteristic
- Transfer characteristics of log amps are usually expressed in terms of slope of V_0 versus V_{in} plot in milivolts per decode
- η affects slope of transfer curve; I_S determines the y intercept



Additional Log Amp Variations



$IC = IESe^{(VBE/VT)}$

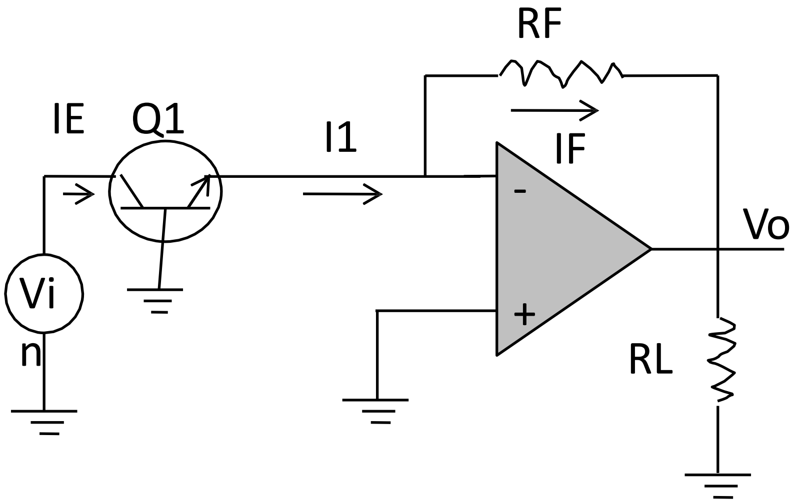
- IES is emitter saturation current
- VBE is drop across base-emitter junction

- Often a transistor is used as logging element in log amp (transdiode configuration)
- Transistor logging elements allow operation of log amp over wider current ranges (greater dynamic range)

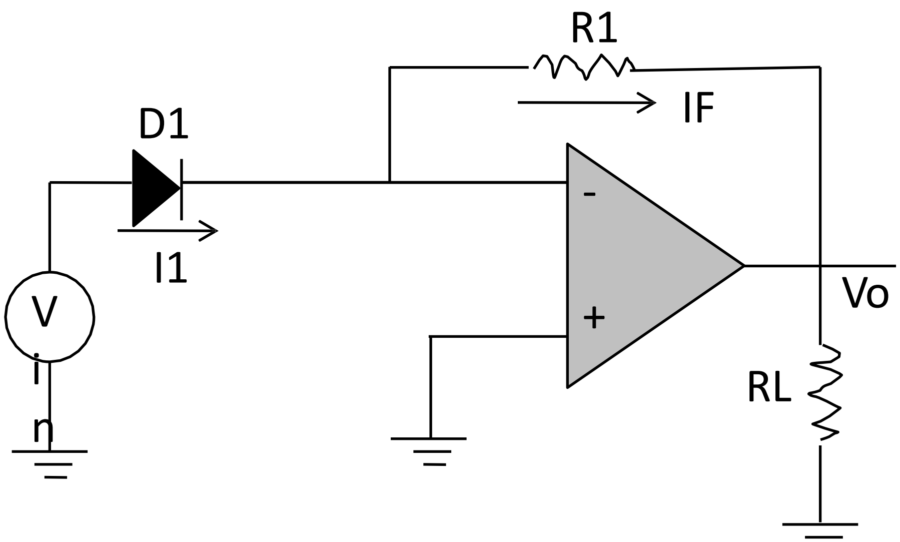
Antilogarithmic Amplifier

- Output of an antilog amp is proportional to the antilog of the input voltage
- with diode logging element
  - $V_0 = -R_F I_S e^{(Vin/VT)}$
- With transdiode logging element
  - $V_0 = -R_F I_{ES} e^{(Vin/VT)}$
- As with log amp, it is necessary to know saturation currents and to tightly control junction temperature

Antilogarithmic Amplifier



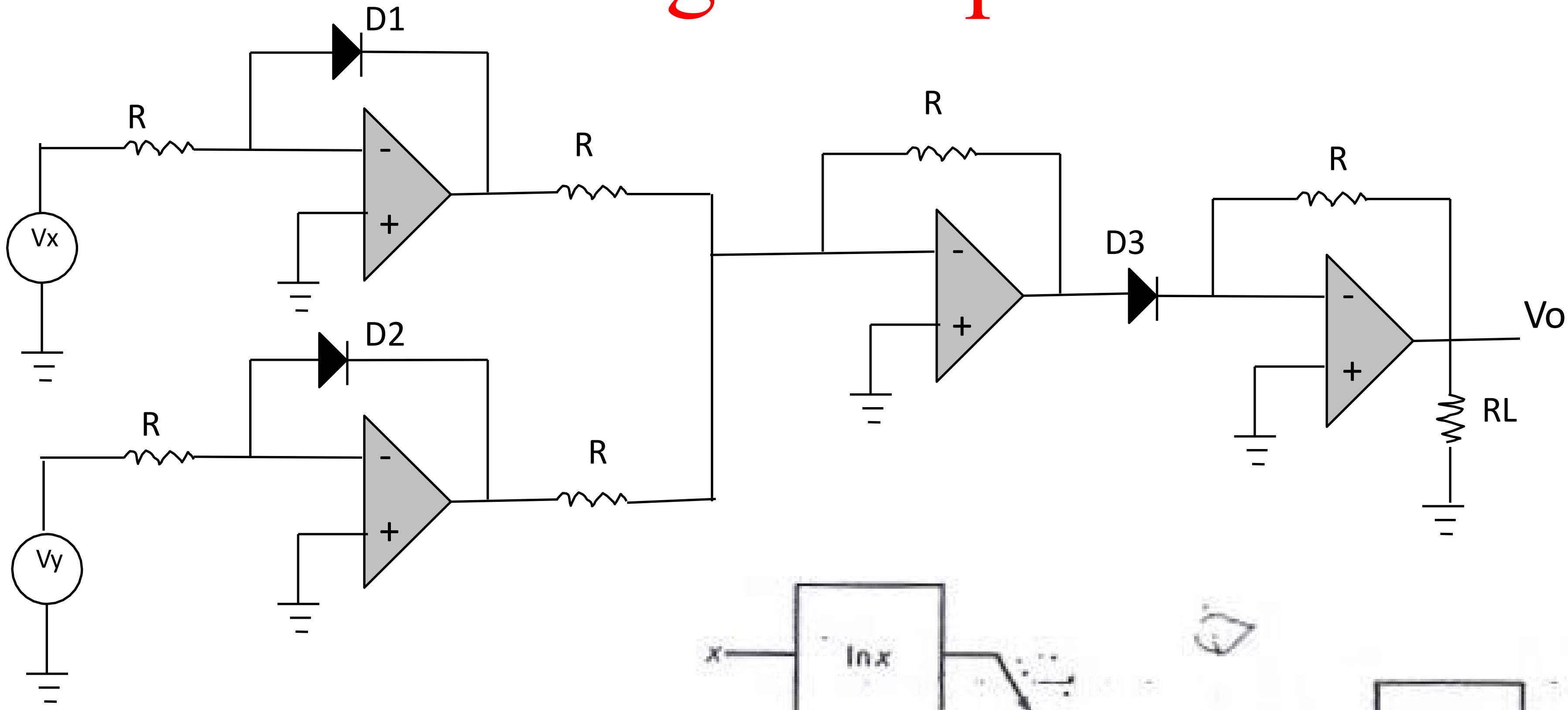
(α = 1) I1 = IC = IE



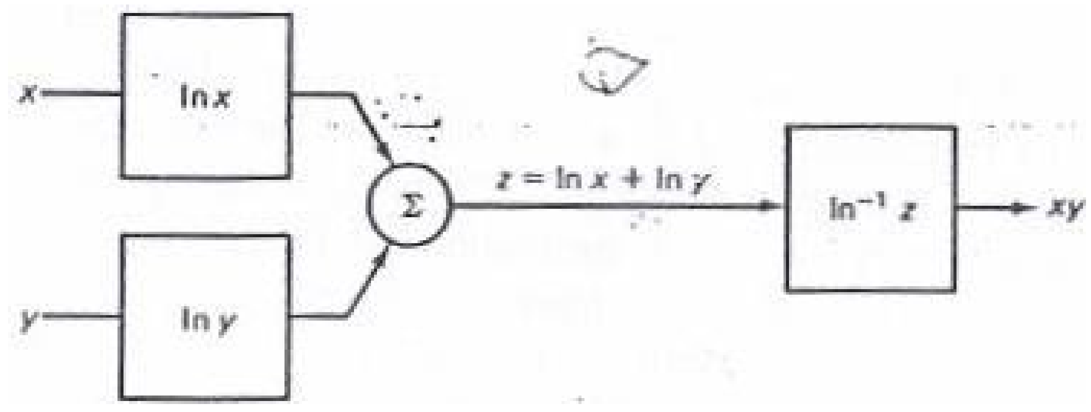
Logarithmic Amplifier Applications

- Logarithmic amplifiers are used in several areas
  - Log and antilog amps to form analog multipliers
  - Analog signal processing
- Analog Multipliers
  - $\ln xy = \ln x + \ln y$
  - $\ln (x/y) = \ln x - \ln y$

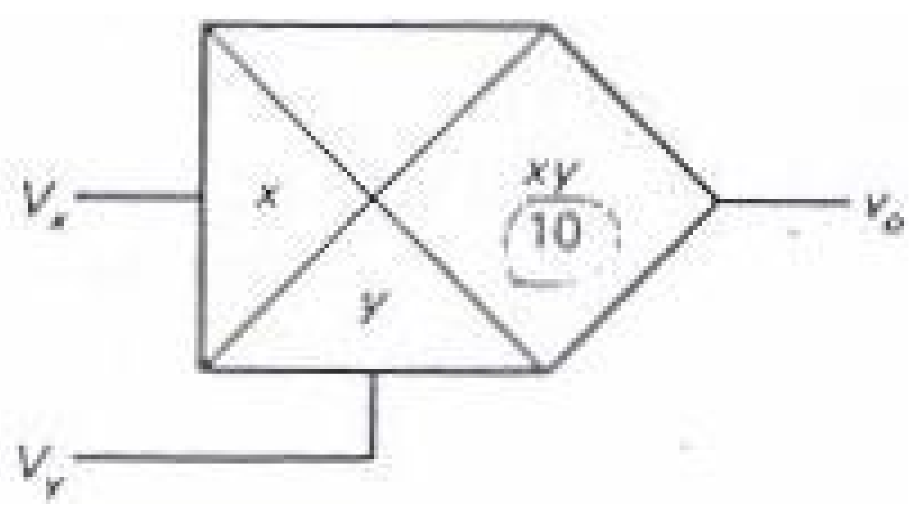
Analog Multipliers



One-quadrant multiplier: inputs must both be of same polarity

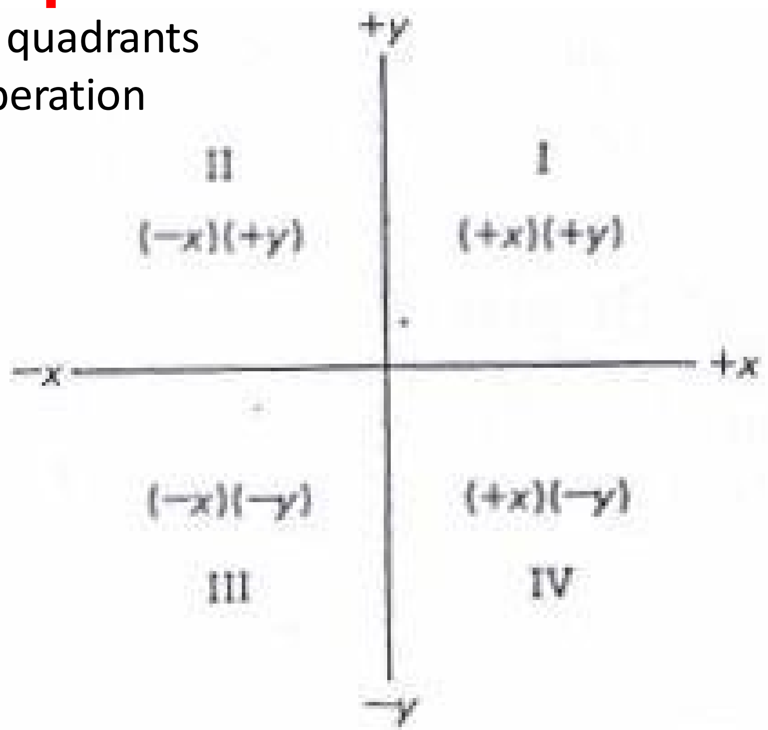


Analog Multipliers



General symbol

Four quadrants of operation

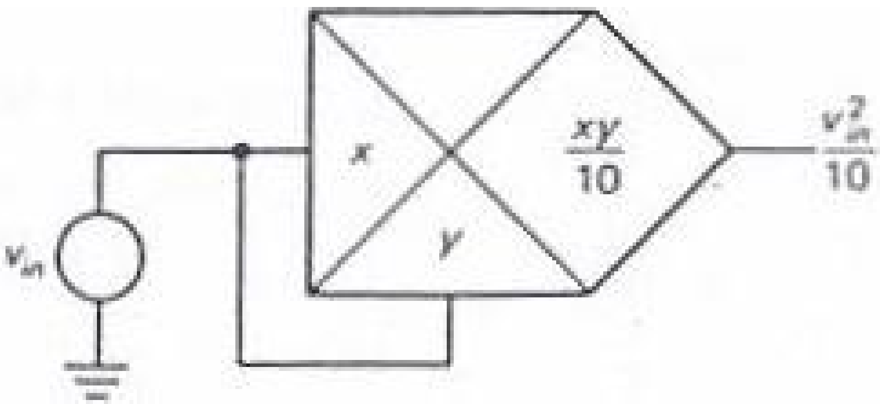


Two-quadrant multiplier: one input should have positive voltages, other input could have positive or negative voltages

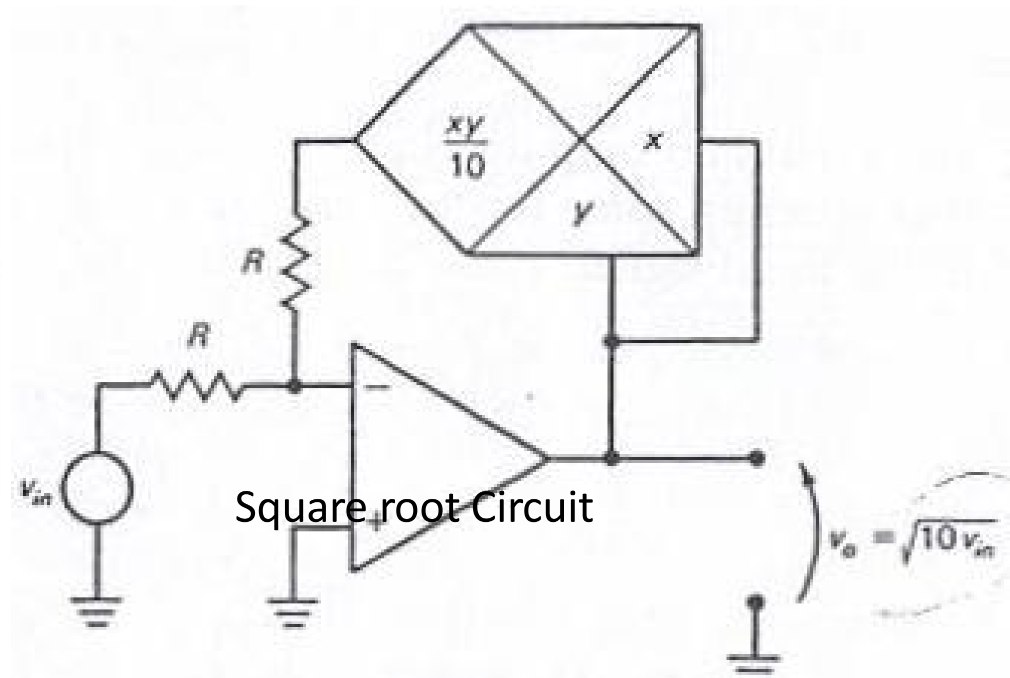
Four-quadrant multiplier: any combinations of polarities on their inputs

Analog Multipliers

Implementation of mathematical operations



Squaring Circuit



Square root Circuit

Signal Processing

- Many transducers produce output voltages that vary nonlinearly with physical quantity being measured (thermistor)
- Often It is desirable to linearize outputs of such devices; logarithmic amps and analog multipliers can be used for such purposes
- Linearization of a signal using circuit with complementary transfer characteristics