2EC402-ANALOG CIRCUITS

SPECIAL ASSIGNMENT

TOPIC : **NON LINEAR APPLICATIONS OF OP-AMP**

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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
    Oh ’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)

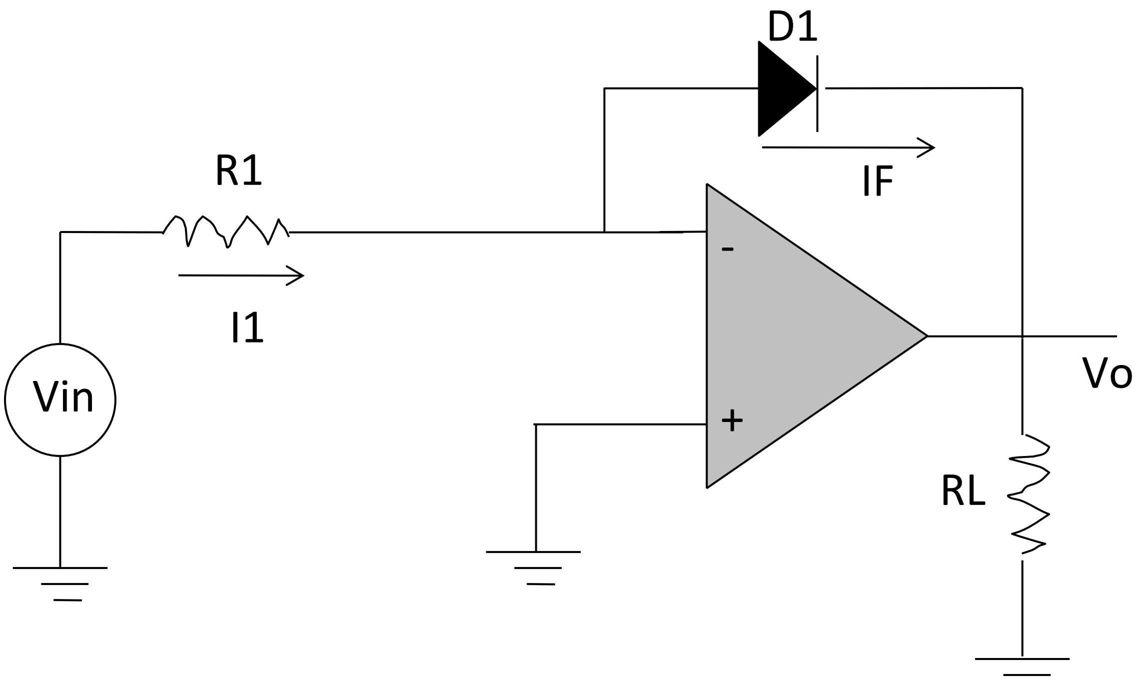
<u>Logarithmic Amplifier</u>

- 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 des i ed y Sho kley's e uatio

  $I_F = I_s e^{(V_F/\eta V_T)}$

  - 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



- $I1 = Vin/R1$
- $IF = - I1$
- $IF = - Vin/R1$
- $V0 = -VF = -\eta VT \ln(IF/IS)$
- $V0 = -\eta VT \ln[Vin/(R1IS)]$
- $rD = 26 \text{ mV} / IF$

- $IF < 1$ mA (log amps)

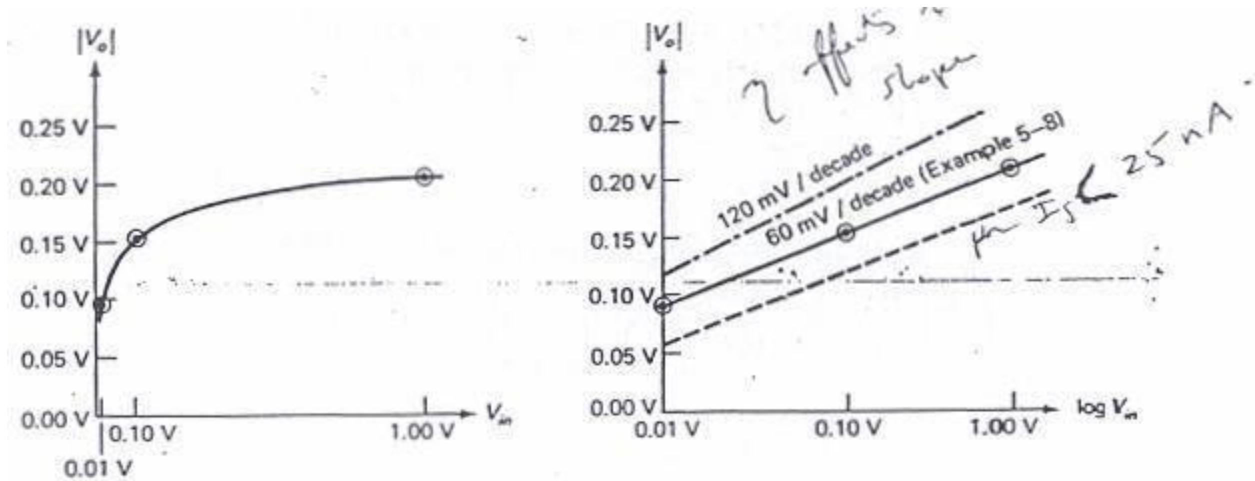
- At higher current levels (IF > 1 mA) diodes begin to behave somewhat linearly

Logarithmic Amplifier

- Linear graph: voltage gain is very high for low input voltages and very low for high input voltages

- Transfer characteristics of log amps are usually expressed in terms of slope of V_0 versus V_{in} plot in millivolts per decade

- η affects slope of transfer curve; I_S determines the y intercept



INPUT/OUTPUT CHARACTERISTICS OF OP AMP

The voltage/current characteristic of a transistor is logarithmic, thus the circuit produces a log response. In order to find an output equation, we start with the basic Shockley Equation for PN junctions:

Ic=Is(ϵqVBEKT−1)(7.6.1)

Where Is

is the reverse saturation current, ε

is log base, q

is the charge on one electron 1.6·10−19

Coulombs, K

is Boltzmann's constant 1.38·10-23 Joules/Kelvin, and T

is the absolute temperature in Kelvin.

Using 300K (approximately room temperature) and substituting these constants into Equation 7.6.1

produces

$I_c=I_s(\epsilon^{38.6 V_{BE}}-1) \quad (7.6.2)$

Normally, the exponent term is much larger than one, so this may be approximated as

$I_c=I_s\epsilon^{38.6 V_{BE}} \quad (7.6.3)$

Using the inverse log relationship and solving for VBE

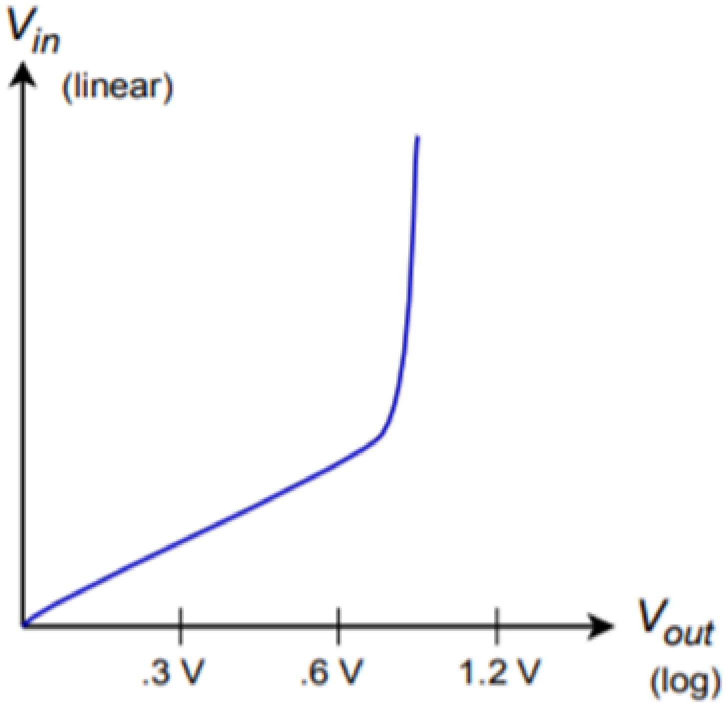
, this is reduced to

$$V_{BE} = 0.0259 \ln \frac{I_c}{I_s} \tag{7.6.4}$$

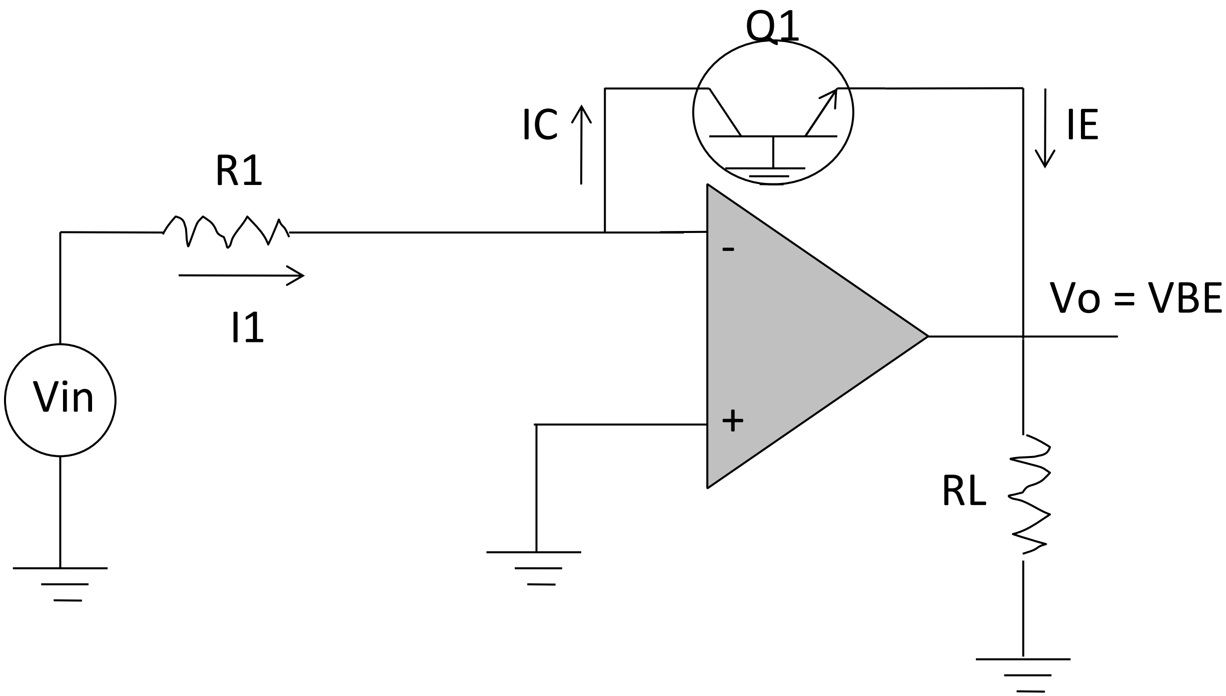
Earlier it was noted that the current I_c is a function of the input voltage and R_i. Also, note that $V_{out} = -V_{BE}$. Substituting these elements into Equation 7.6.4 yields

$$V_{out} = -0.0259 \ln \frac{V_{in}}{R_i I_s} \tag{7.6.5}$$

We now have an amplifier that takes the log of the input voltage and also multiplies the result by a constant. It is very important that the anti-log circuit multiply by the reciprocal of this constant, or errors will be introduced. If the input voltage (or current) is plotted against the output voltage, the result will be a straight line if plotted on a semi-log graph, as shown in Figure 7.57. The rapid transition at approximately 0.6 V is due to the fast turn-on of the transistor's base-emitter junction. If output voltages greater than 0.6 V are required, amplifying stages will have to be added.



Additional Log Amp Variations



$$IC = IESe^{(V_{BE}/V_{T})}$$

- 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

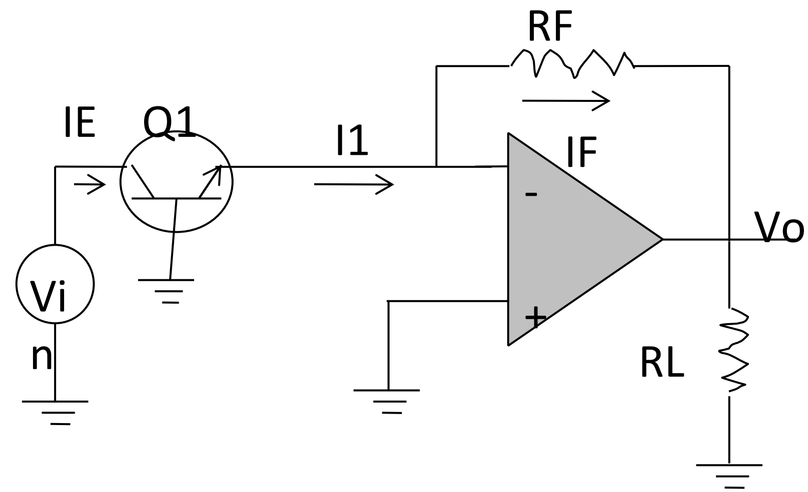
- Output of an antilog amp is proportional to the antilog of the input voltage

- with diode logging element
  - $V_0 = -R_F I_S e^{(V_{in}/V_T)}$

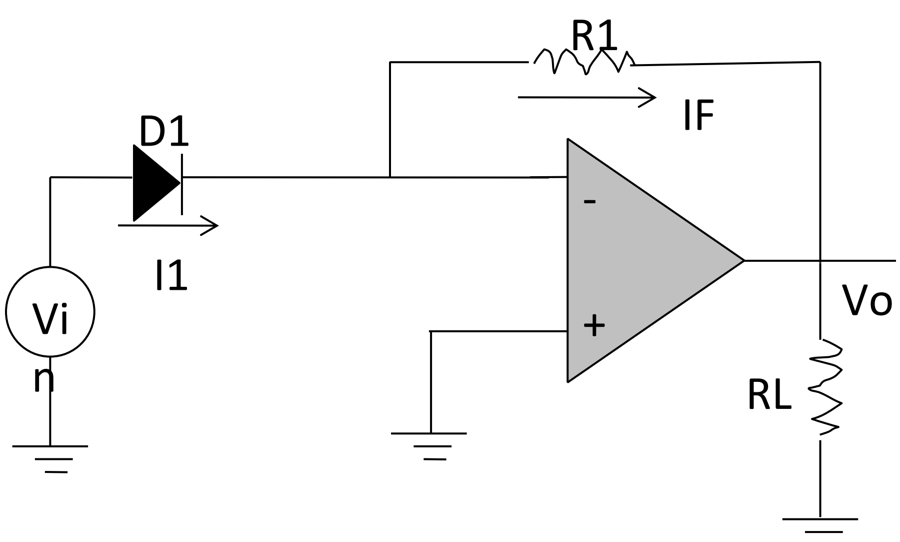
- With transdiode logging element
  - $V_0 = -R_F I_{ES} e^{(V_{in}/V_T)}$

- As with log amp, it is necessary to know saturation currents and to tightly control junction temperature

Antilogarithmic Amplifier

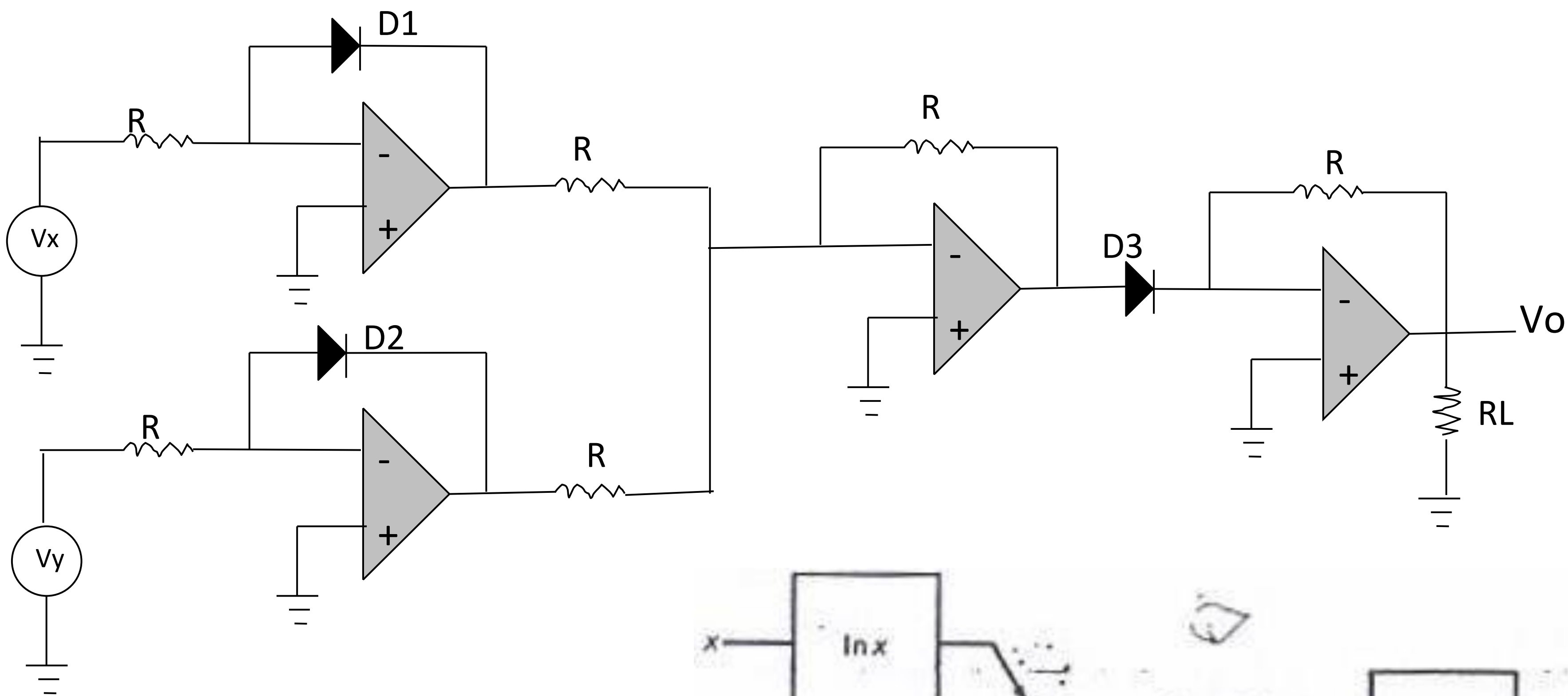


$(\alpha = 1)\ I1 = IC = IE$

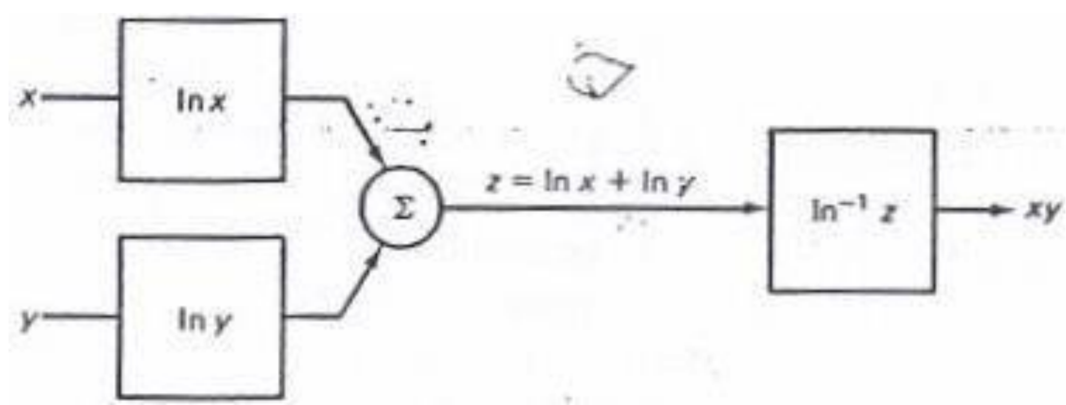


Logarithmic Amplifier Applications

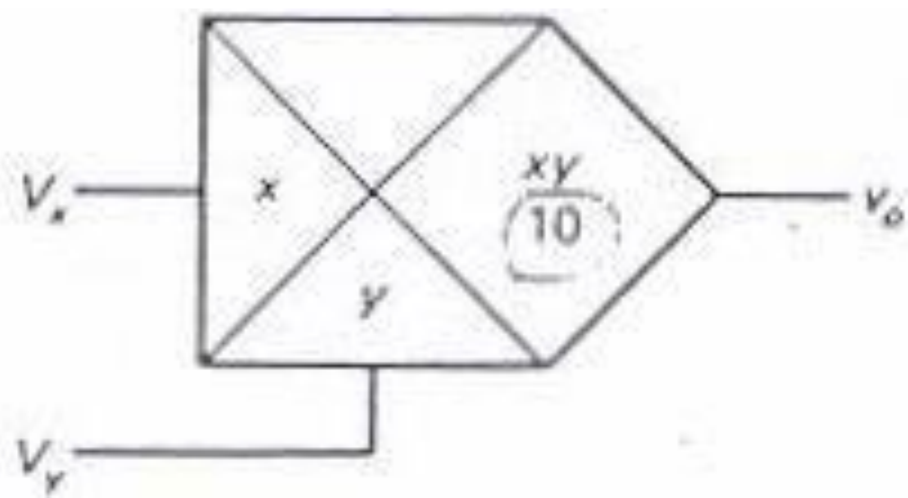
- Logarithmic amplifiers are used in several areas
  - Log and antilog amps to form analog multipliers
  - Analog signal processing
- Analog Multipliers
  - $\ln xy = \ln x + \ln y$
  - $\ln (x/y) = \ln x - \ln y$



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

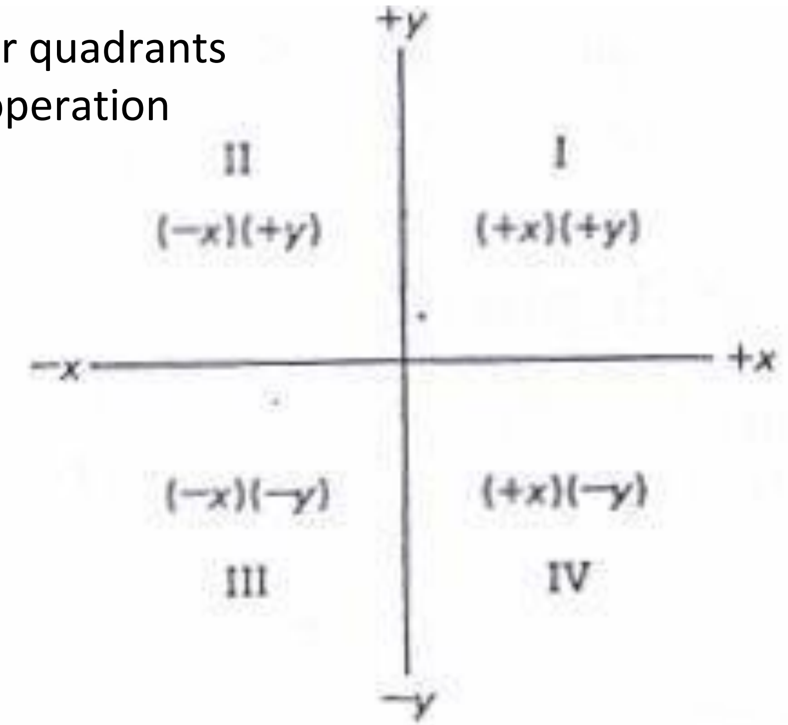


Analog Multipliers



General symbol

Four quadrants of operation



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

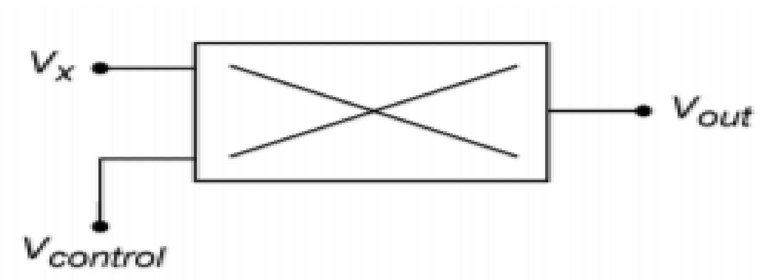
Analog Multipliers

Four-quadrant multiplier: any combinations of polarities on their input operations; A four-quadrant multiplier is a device with two inputs and a single output. The output potential is the product of the two inputs along with a scaling factor, K.

$V_{out} = K V_x V_y$

Typically, K is 0.1 in order to minimize the possibility of output overload. The schematic symbol for the multiplier is shown in Figure .

Analog Multipliers



It is called a fourquadrant device, as both inputs and the output may be positive or negative. An example device is the Analog Devices AD834. The AD834 operates from DC through 500 MHz and can be powered by supplies from ±

4 V through ±

Analog Multipliers

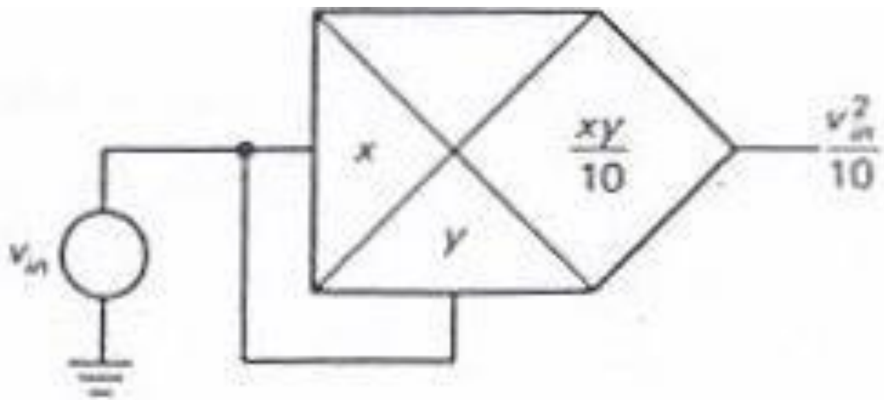
15 V. Although multipliers are not really “non-linear” in and of themselves, they can be used in a variety of out-of-the-ordinary applications and in areas where log amps might be used.

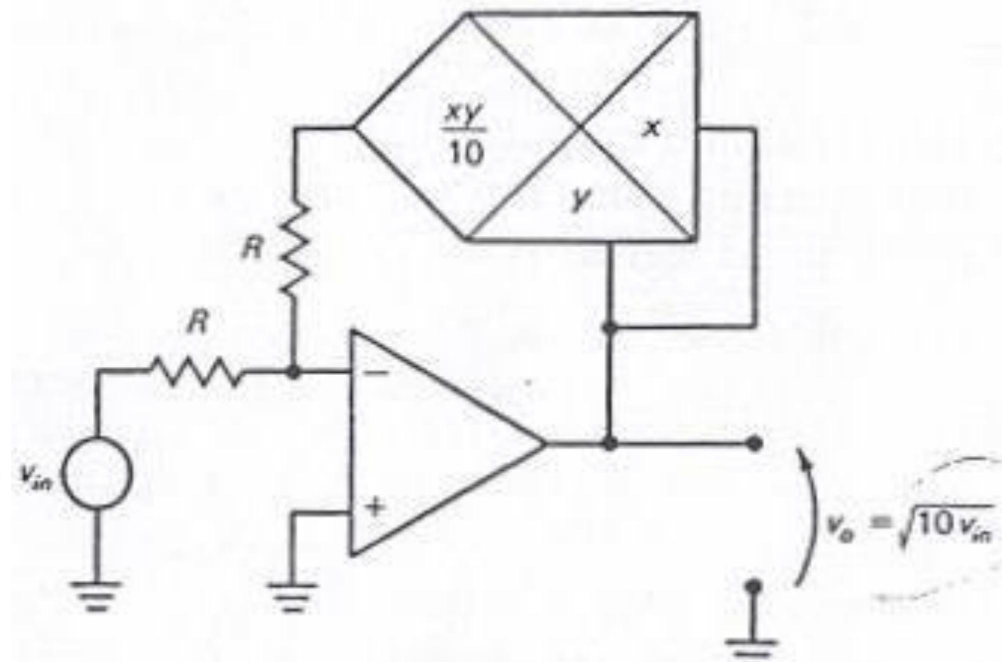
Multipliers have many uses including squaring, dividing, balanced modulation/demodulation, frequency modulation, amplitude modulation, and automatic gain control. The most basic operation, multiplication, involves using one input as the signal input and the other input as the gain control potential. Unlike the simple VCA circuit discussed earlier, this gain control potential is allowed to swing both positive and negative. A negative polarity will produce an inverted output.

Analog Multipliers

This same circuit can be used as a balanced modulator. This is very useful for creating dual sideband signals for communications work. Multiplier ICs may have external connections for scale factor and offset adjust potentiometers. Also, they may be modeled as current sources, so an external op amp connected as a current-to-voltage converter may be required.

Analog Multipliers





Implementation of mathematical Square root Circuit

Squaring Circuit . Squaring circuits can be very useful for RMS calculations and for frequency doubling.


THANK YOU