UNIT IV – ANALOG MULTIPLIER AND PLL

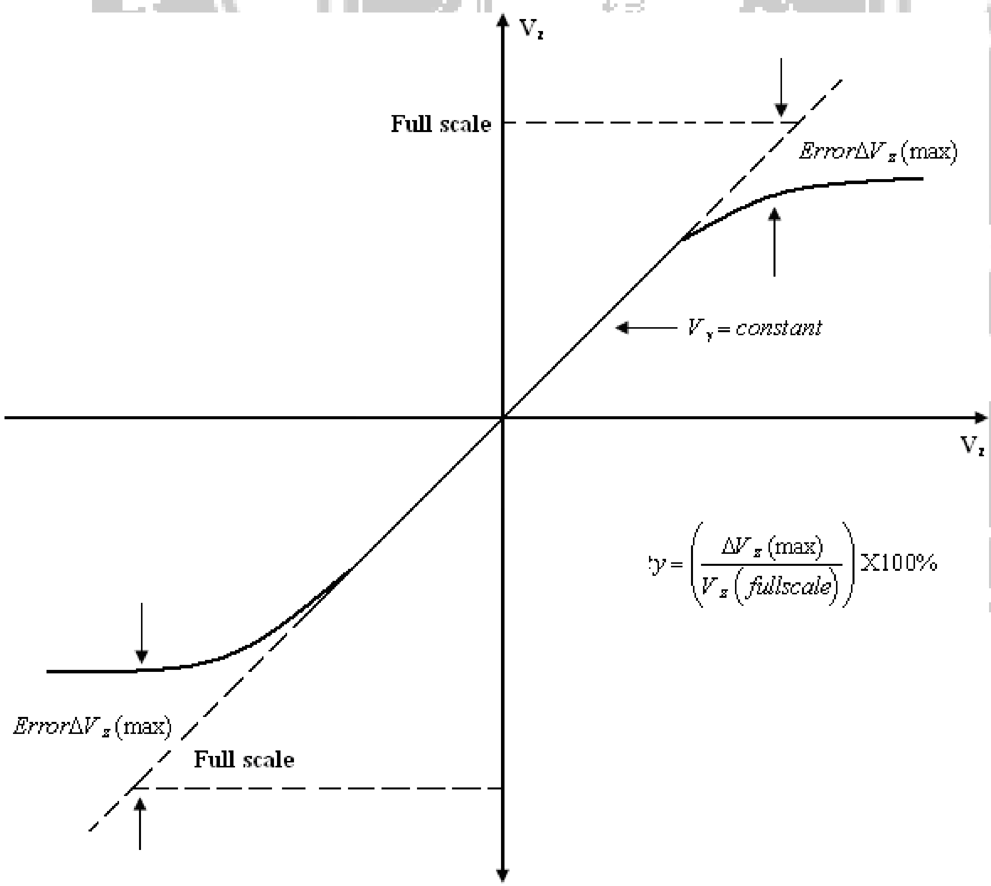
Analog Multipliers:

A multiple produces an output V_0 , which is proportional to the product of two inputs V_x and V_y.

That is, $V_0 = KV_xV_y$ where K is the scaling factor that is usually maintained as (1/10) V^{-1} . There are various methods available for performing analog multiplication. Four of such techniques, namely,

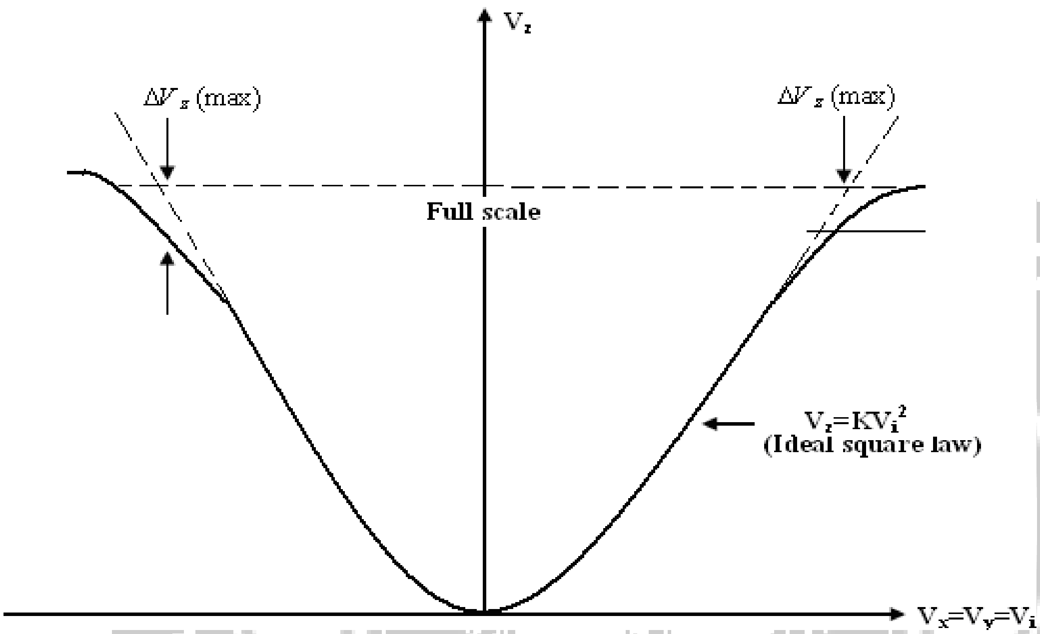
1. Logarithmic summing technique
2. Pulse height/width modulation Technique
3. Variable trans conductance Technique
4. Multiplication using Gilbert cell and
5. Multiplication using variable trans conductance technique.

An actual multiplier has its output voltage V_0 defined by



Squaring Mode Accuracy:

The Square – law curve is obtained with both the X and Y inputs connected together and applied with the same input signal. The maximum derivation of the output voltage from an ideal square – law curve expresses the squaring mode accuracy.



Bandwidth:

The Bandwidth indicates the operating capability of an analog multiplier at higher frequency values. Small signal 3 dB bandwidth defines the frequency f_0 at which the output reduces by 3dB from its low frequency value for a constant input voltage. This is identified ind ividually for the X and Y input channels normally.

The transconductance bandwidth represents the frequency at which the transconductance of the multiplier drops by 3dB of its low frequency value. This characteristics defines the application frequency ranges when used for phase detection or AM detection.

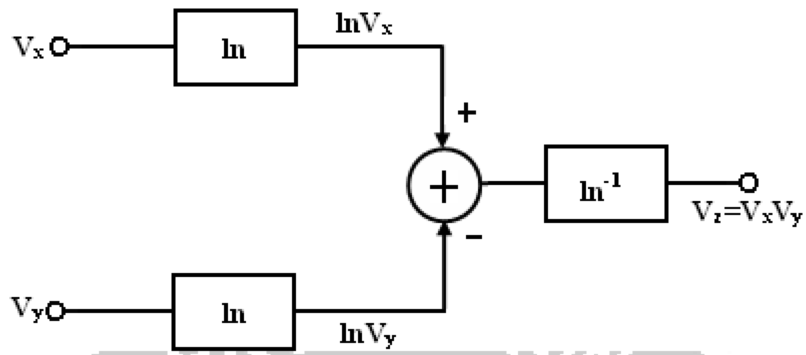
Quadrant:

The quadrant defines the applicability of the circuit for bipolar signals at its inputs. First – quadrant device accepts only positive input signals, the two quadrant device accepts one bipolar signal and one unipolar signal and the four quadrant device accepts two bipolar signals.

Logarithmic summing Technique:

This technique uses the relationship

$\ln V_x + \ln V_y = \ln(V_x V_y)$



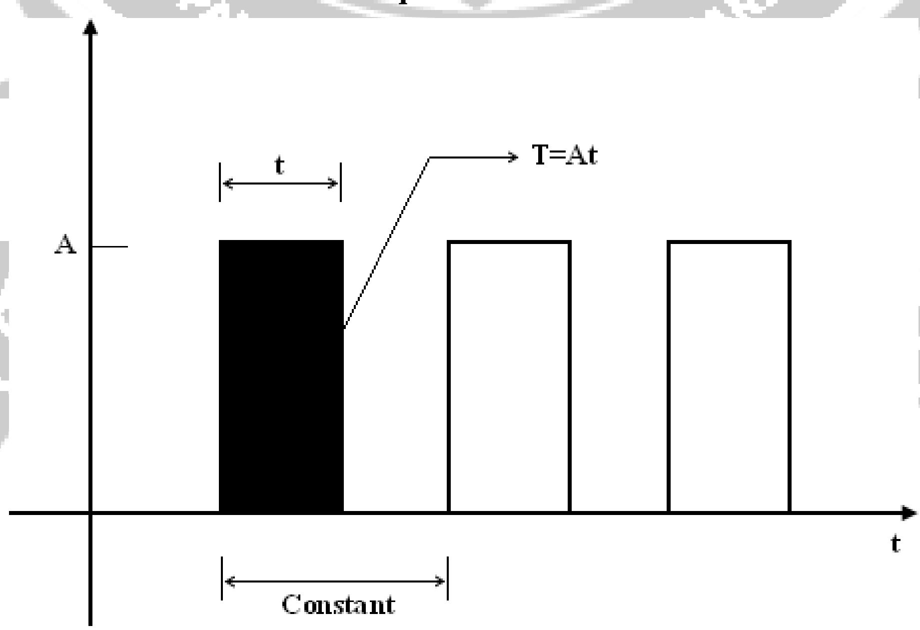
As shown in figure the input voltages V_x and V_y are converted to their logarithmic equivalent, which are then added together by a summer. An antilogarithmic converter produces the output voltage of the summer. The output is given by,

$V_z = ln^{-1} (ln(V_x V_y)) = V_x V_y$ The exponential relationship between the collector current and base

to emitter voltage of bipolar transistor during its active mode of operation could be explained for the logarithmic and anti- logarithmic conversions. The relationship between I_0 and V_{BE} of the transistor is given by

$I_C = I_0e^{(VBE /VT)}$ It is found that the transistor follows the relationship very accurately in the range of 10nA to 100mA. Logarithmic multiplier has low accuracy and high temperature instability. This method is applicable only to positive values of V_x and V_y. Therefore, this type of multiplier is restricted to one quadrant operation only.

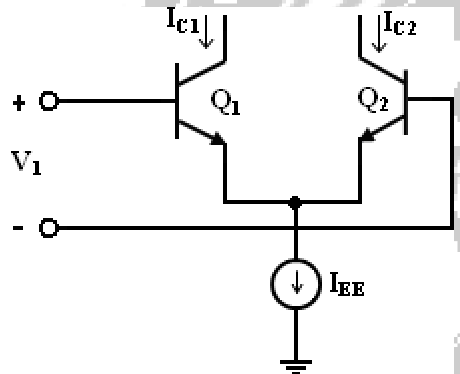
Pulse Height/ Width Modulation Technique:



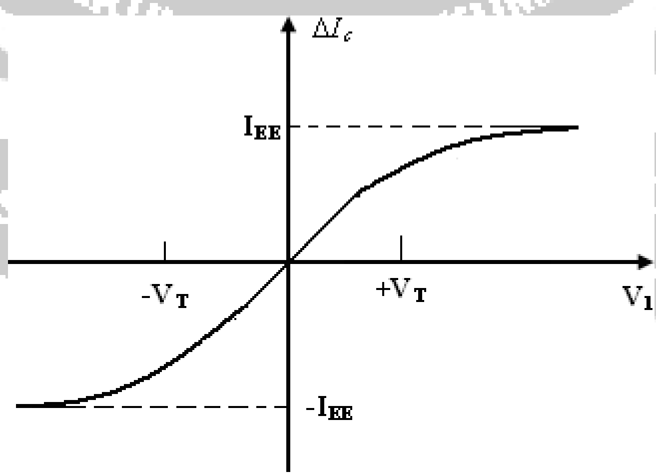
In this method, the pulse width of a pulse train is made proportional to one input voltage and the pulse amplitude is made proportional to the second input voltage. Therefore, $V_x = K_x A$, $V_y = K_y t$, and $V_z = K_z T$ where K_x , K_y , K_z are scaling factors. In figure A is the amplitude of the pulse, t is the pulse width and T is the area of the pulse. Therefore,

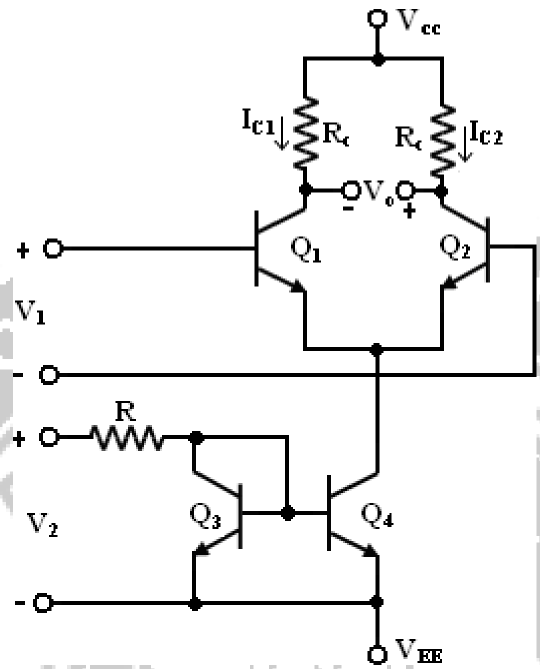
The modulated pulse train is passed through an integrated circuit. Therefore, the input of the integrator is proportional K to the area of pulse, which in turn is proportional to the product of two input voltages.

A simple multiplier using an Emitter coupled Transistor pair:



A circuit using an emitter coupled pair is shown in figure. The output currents I_{C1} and I_{C2} arrelatedto the differential input voltage The dc transfer characteristics of the emitter – coupled pair is shown in figure. It shows that the emitter coupled pair can be used as a simple multiplier using this configuration. When the differential input voltage $V_1 << V_T$, we can appropriate as given by





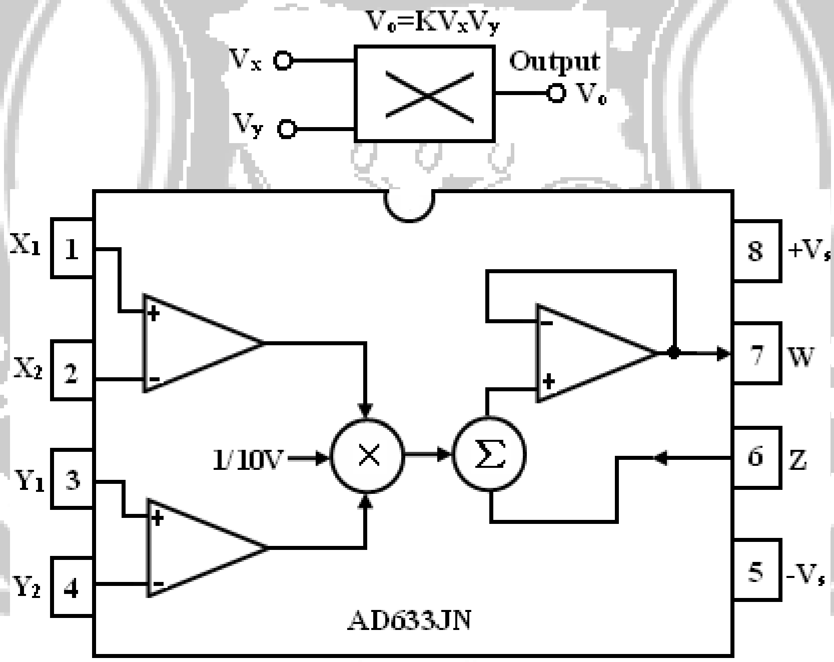
This arrangement is shown in figure. It is a simple modulator circuit constructed using a differential amplifier. It can be used as a multiplier, provided V_1 is small and much less than 50mV, and V_2 is greater than $V_{BE(on)}$. But, the multiplier circuit shown in figure has several limitations. The first limitation is that V_2 is offset by $V_{BE(on)}$. The second is that V_2 must always be positive which results in only a two-quadrant multiplier operation. The third limitation is that, the tanh (X) is approximately as X, where $X = V_1 / 2V_T$. The first two limitations are overcome in the Gilbert cell.

Gilbert Multiplier cell:

The Gilbert multiplier cell is a modification of the emitter coupled cell and this allows four – quadrant multiplication. Therefore, it forms the basis of most of the integrated circuit balanced multipliers. Two cross- coupled emitter- coupled pairs in series connection with an emitter coupled pair form the structure of the Gilbert multiplier cell.

Analog Multiplier ICs

Analog multiplier is a circuit whose output voltage at any instant is proportional to the product of instantaneous value of two individual input voltages. The important applications of these multipliers are multiplication, division, squaring and square – rooting of signals, modulation and demodulation. These analog multipliers are available as integrated circuits consisting of op-amps and other circuit elements. The Schematic of a typical analog multiplier, namely, AD633 is shown in figure.



The AD633 multiplier is a four – quadrant analog multiplier. It possesses high input impedance, and this characteristic makes the loading effect on the signal source negligible. It can operate with supply voltages ranging from ±18V. The IC does not require external components. The calibration by user is not necessary. The typical range of the two input signals is ±10V.

Schematic representation of a multiplier:

The schematic representation of an analog multiplier is shown in figure. The output V_0 is the product of the two inputs V_x and V_y is divided by a reference voltage Vref. Normally, the reference voltage Vref is internally set to 10V. Therefore, V_0 =VxVy/10. In other words, the basic input – output relationship can be defined by $KV_x V_y$ when K = 1/10, a constant. Thus for peak input voltages of 10V, the peak magnitude of output voltage is 1/10 *10 *10 =10V. Thus, it can be noted that, as long as V_x < 10V and V_y < 10V, the multiplier output will not saturate.

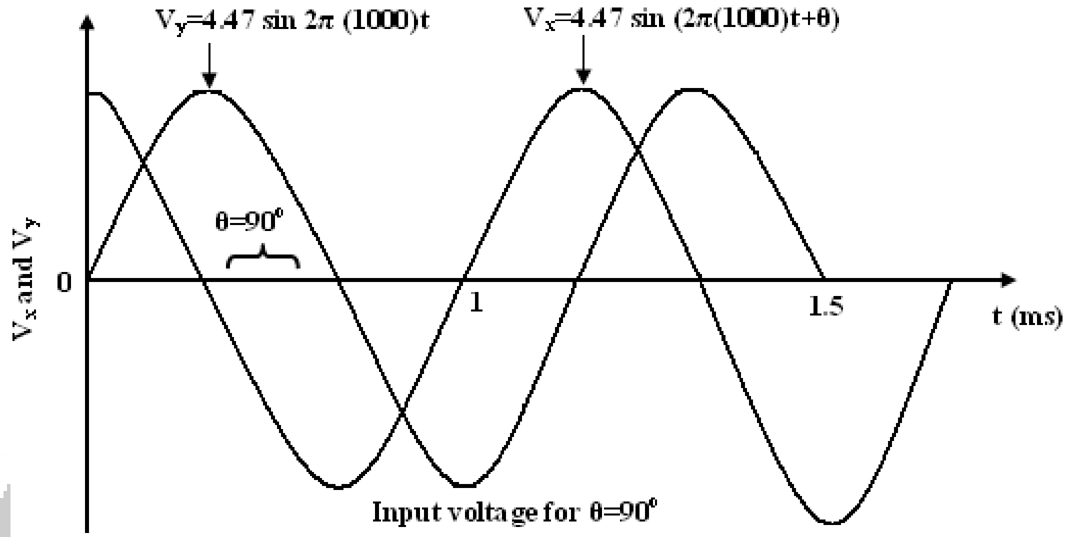
Multiplier quadrants:

The transfer characteristics of a typical four-quadrant multiplier is shown in figure. Both the inputs can be positive or negative to obtain the corresponding output as shown in the transfer characteristics.

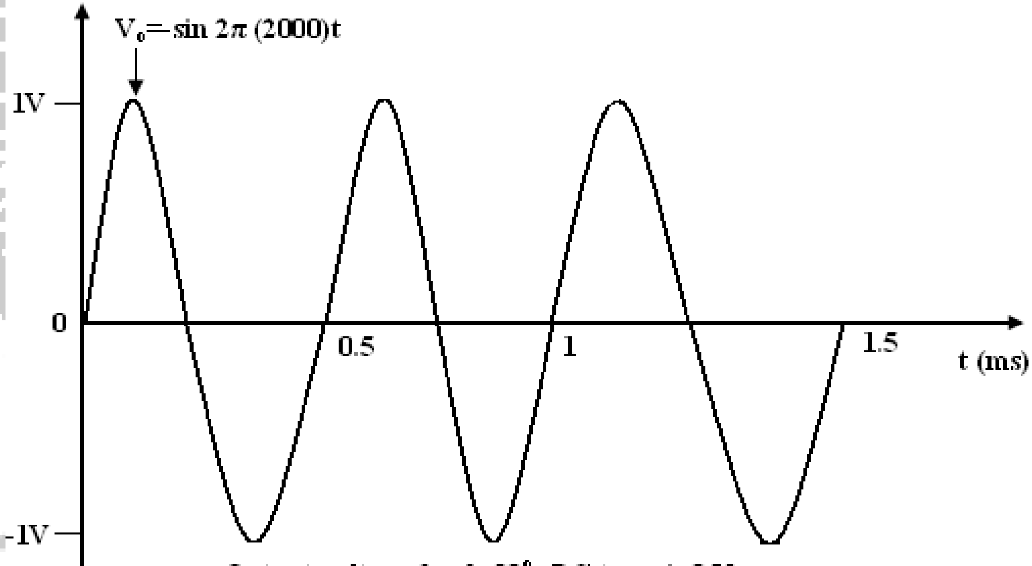
Applications of Multiplier ICs:

The multiplier ICs are used for the following purposes:

1. Voltage Squarer
2. Frequency doubler



Input voltage for θ=90°



Output voltage for θ=90°; DC term is 0 V