**Multipliers versus Modulators versus Mixers**

Inputs:

- **Carrier** $A_c \cos(\omega_c t)$
- **Message** $A_m \cos(\omega_m t)$

**Multiplier**

In electronics, a **Multiplier**, or analog **Multiplier**, is a device which takes two analog signals and produces an output which is their product.

![Analog Multiplier Diagram]

The output of a Multiplier is an instantaneous product of its inputs. The above two inputs to a “perfect Multiplier” give

$$V_{OUT}(t) = K A_m A_c \cos(\omega_m t) \cdot \cos(\omega_c t) = \frac{K}{2} A_m A_c \left[ \cos(\omega_m + \omega_c) t + \cos(\omega_m - \omega_c) t \right]$$

by using the familiar trigonometric identity, $\cos(\theta) \cdot \cos(\phi) = 0.5[\cos(\theta - \phi) + \cos(\theta + \phi)]$.

In examining the above equation, we see that new frequencies have been generated, namely, $(\omega_m + \omega_c)$ and $(\omega_m - \omega_c)$. The reason for this is the analog Multiplier is not actually a linear, time-invariant component. Multipliers can be operated with both input signals, $V_X$ and $V_Y$, over a wide range of amplitudes.

**Modulator**
The output of a Modulator is the instantaneous product of one of its inputs (usually the message signal) and the sign of the other signal (known as the carrier signal). That is, the carrier signal is large signal and serves to operate switching behavior within the modulator circuitry. A very simple way to view the Modulator is with the following figure.

![Modulator Simple Model](https://www.analog.com/en/analog-dialogue/articles/multipliers-vs-modulators.html)

The Modulator can be understood as either a nonlinear component or a time-varying component. Either interpretation can generate new frequencies such as created by the expression,

\[
V_{\text{OUT}}(t) = KA_m A_c \cos(\omega_m t) \cdot \cos(\omega_c t) = \frac{K}{2} A_m A_c \left[ \cos(\omega_m + \omega_c) t + \cos(\omega_m - \omega_c) t \right]
\]

However, because of the large-signal nature of the Modulator many additional frequencies are generated beyond the two frequencies of \((\omega_m + \omega_c)\) and \((\omega_m \pm \omega_c)\) as required for generating DSB-SC signals. These other frequencies must be removed by filtering.

**Whys use Modulators instead of Multipliers?**

Both input ports of Multipliers are linear so noise on both port signals multiply together adding the product of the noise signals to the output. However, in a Modulator one of the input signals (usually the carrier) drives switching devices within the Modulator and the noise on the carrier signal does not affect the operation of the switches. So, the noise on the carrier
signal does not contribute to the output signal. Thus, Modulators have less noise than Multipliers.

**Mixer**

In electronics, a **Mixer**, or **frequency Mixer**, is a nonlinear electrical circuit that creates new frequencies from two signals applied to it. In its most common application, two signals are applied to a mixer, and it produces new signals at the sum and difference of the original frequencies. Other frequency components may also be produced in a practical frequency mixer. Almost any nonlinearity will work as a Mixer.

Mixers are widely used to shift signals from one frequency range to another, a process known as heterodyning, for convenience in transmission or further signal processing. For example, a key component of a superheterodyne receiver is a Mixer used to move received signals to a common intermediate frequency. Frequency Mixers are also used to modulate a carrier signal in radio transmitters.

![Ideal Mixer (Multiplier)](image)


A Modulator is also called a Mixer when used for “frequency translation” or “frequency shifting.” Mixing can be performed by both Modulators and Multipliers. All three components demand good design to minimize unwanted signals from harmonics and signal feedthrough (both RF and LO feedthrough).