JACK BROWNE | Technical Contributor

Make the Most of MICROWAVE MIXERS

Frequency mixers provide a reliable means of translating signal frequencies higher or lower as needed, and across the wide bandwidths required in many RF/microwave systems.

Frequency conversion or translation serves a wide range of electronic systems, and the frequency mixer has long been the component of choice to accomplish this function. Frequency mixers can be specified for many different frequency ranges and bandwidths, to shift signals upward (upconversion) or downward (downconversion) in frequency. They come in a number of different package configurations, including with coaxial connectors and in surface-mount-technology (SMT) type miniature packages.

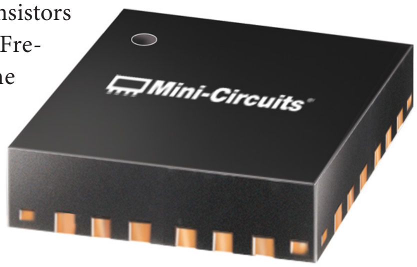
Frequency-mixer circuits feature three ports: radio frequency (RF), local oscillator (LO), and intermediate frequency (IF). Two function as input ports, with the remaining port serving as the output port. The LO port always involves an input signal. The RF and IF ports, on the other hand, can switch functions—it depends on whether a mixer is being used for upconversion, with the IF port as an input port and the RF port as an output port, or for downconversion, where the roles reverse.

For upconversion, lower-frequency IF signals are mixed with higher-frequency LO signals to produce higher-frequency signals at the RF port (the output port). For downconversion, higher-frequency RF signals mix with high-frequency LO signals to produce lower-frequency signals at outputs at the IF port. Downconversion is typically performed in high-frequency receivers while upconversion normally takes place in high-frequency transmitters.

Mixers are fabricated as either passive devices, with signal mixing taking place in Schottky diodes, or as active devices, typically based on GaAs field-effect transistors (FETs) for the signal mixing. Frequency translation follows the simple addition and subtraction of signal frequencies at the mixer RF port (f_{RF}) and the mixer LO port (f_{LO}) to produce sum and difference IF signals (f_{IF}):

$$n(f_{RF} \pm f_{LO}) = f_{IF}$$

The "n" in this relationship refers to the harmonic number of the signals being mixed. By means of different types of filtering, different mixing products can be selected and/or suppressed to accomplish a designed frequency translation.



1. This surface-mount housing packs a mixer IC, LO amplifier, and IF amplifier. *[Photo courtesy of Mini-Circuits (www.minicircuits.com).]*

A BROAD MIX OF MIXERS

Various types of frequency mixers are commercially available in different chip and package formats, including single-balanced mixers, double-balanced mixers, image-reject mixers, single-sideband mixers, double-sideband mixers, and in-phase/quadrature (I/Q) mixers. Single-balanced mixers can be realized with simple circuits implementing a single diode, while double-balanced mixers are typically formed with four Schottky diodes in a quad ring configuration. Two balanced transformers are used as transformers to achieve high isolation for the LO and RF ports. A triple-balanced mixer incorporates two well-matched quad diode rings to typically operate with wider LO and RF bandwidths than double-balanced mixers, with higher dynamic range and lower distortion.

"Mixers continue to evolve from simple frequency-conversion components to multiple-function components with additional pre-selection and IF filters, and even active circuitry like amplifiers."

Frequency mixers are characterized by a number of parameters that describe their frequency-translation performance, including conversion loss or gain, port-to-port isolation, VSWR, noise figure, 1-dB compression point, and third-order intercept point. An excellent introduction to the basic mixer parameters can be found in "Mixer Basics Primer: A Tutorial for RF & Microwave Mixers," a 12-page application note available for free download from Marki Microwave (www.markimicrowave.com).

The firm also provides an advanced mixer search tool on its website for performing a search by means of LO, RF, and IF frequency ranges. In addition, the text *Microwave Mixers* by Stephen A. Maas and available from Artech House (www.artechhouse.com) is an industry-standard information source on RF/microwave mixers.

Most searches for mixers begin by finding a unit with suitable RF, LO, and IF frequency ranges, usually with the lowest conversion loss. In a passive mixer, such as a diode mixer, conversion loss results from impedance mismatches and circuit junctions (e.g., diode connection points) that can cause signal reflections and losses in the circuit. For an upconversion mixer, conversion loss is evidenced by the difference in signal amplitude between the IF input signal and the RF output signal. For a downconversion mixer, conversion loss is the difference in signal level between the RF input signal and the IF output signal.

Ideally, with no conversion loss, and the appropriate LO signal level, the amplitude of the RF and the IF signals in both of the above cases would be the same. But any variation in impedance in a mixer circuit will contribute to conversion loss and result in some loss of signal from input to output ports. With active circuitry, such as the biasing of transistors in a GaAs FET mixer, it's possible to achieve conversion gain in a mixer, although additional bias energy must be consumed in the mixer in order to account for the signal gain through the component.

Isolation is a measure of the power leakage from one port to another. The isolation from the LO to the RF port indicates the leakage of LO power into the RF port. High LO-to-RF isolation minimizes the contamination of RF signals by LO power and/or noise. Isolation from the LO to the IF port provides insight into the amount of leakage of LO signal power into the IF port. When this form of isolation is low, it can contribute to saturation of an IF amplifier and cause deviations in a mixer's conversion-loss response.

Isolation from the RF to the IF port represents the amount of leakage that occurs from one port to the other. While it may not have the impact of maintaining high isolation between the LO and other two ports, high isolation from the RF to the IF port is usually a sign that the mixer will exhibit low conversion loss with good conversion loss flatness.

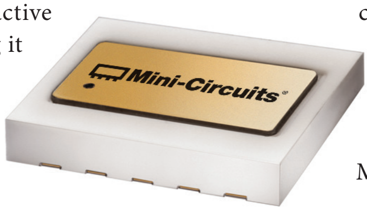
Dynamic range is the difference between the maximum amplitude of signals, usually denoted by the 1-dB compression point or where compression begins, and the lowest practical signal level (typically the mixer noise figure). The 1-dB compression point represents a difference in a linear relationship between input and output signal levels for a mixer, where the output power level drops by 1 dB relative to the power level applied at the input port. Since the 1-dB compression point is related to the available LO power level, mixers with higher dynamic range will also typically be specified for higher LO drive levels while exhibiting low conversion loss.

Mixers come in many different package formats, with and without coaxial connectors, and even in die form for mounting on printed-circuit boards (PCBs). The model HMC1106, a GaAs MMIC double-balanced mixer from Hittite Microwave Corp. (www.hittite.com), is supplied in die form. It can be used as an upconverter or a downconverter, with 10-dB typical conversion loss in either direction. The broadband chip mixer is designed for an RF range of 15 to 36 GHz, an LO range of 20 to 50 GHz, and an IF range of dc to 24 GHz.

A HIGHER FREQUENCY OF HIGH-FREQUENCY MIXERS

With increasing use of millimeter-wave frequencies for such applications as high-data-rate communications links, medical electronic systems, and vehicular radar safety systems, more mixers are being designed for higher-frequency purposes. Marki Microwave, for example, has stressed the importance of maintaining linearity in these higher-frequency mixers, working with commercial simulation software suppliers to develop physics-based nonlinear mixer models that can accurately predict the performance of its different high-frequency mixers in various applications. On that front, model MM1-2567LS from Marki Microwave is a double-balanced passive mixer with a specified RF and LO frequency range of 25 to 67 GHz and an IF range of dc to 30 GHz. It has typical conversion loss of 9 dB across that wide frequency range, with a 1-dB compression point of +1 dBm.

At millimeter-wave frequencies, mixers generally incorporate waveguide ports. Such is the case with many of the higher-frequency mixers from Spacek Labs (www.spaceklabs.com). The company's model MW-1B-6X broadband mixer features RF and LO ports spanning 75 to 110 GHz in WR-10 waveguide. The mixer simplifies LO connections by in- cluding a 6× LO W-band active multiplier on the LO port, thereby making it possible use LO signals from 12.5 to 18.33 GHz to reach the required 75- to 110-GHz LO frequency range for mixing. It accepts those LO signals at levels ranging from +13 to +18 dBm, and reduces IF signals to a range of 10 MHz to 3 GHz, available at a port with a female coaxial SMA connector. Typical conversion loss is 7 dB and no greater than 12 dB across the wide frequency range. In addition, broadband mixers with lower conversion loss are available for reduced bandwidths.



2. The MAC series of surface-mount mixers makes use of LTCC technology and monolithic active devices to achieve high-performance mixers in tiny hermetic packages. *[Photo courtesy of Mini-Circuits (www.minicircuits.com).]*

Spacek Labs also recently introduced its model MV-1B with V-band coverage of 50 to 75 GHz for the RF and LO ports in WR-15 waveguide. By using dc bias (10 mA at +12 V dc), the required LO power is only 0 to +5 dBm, with IF signals from 10 MHz to 3 GHz made available at a female SMA connector. Typical conversion loss is 6 dB and no more than 9 dB across the frequency range.

BUILT-IN MULTIFUNCTIONALITY

Mixers continue to evolve from simple frequency-conversion components to multiple-function components with additional preselection and IF filters, and even active circuitry like amplifiers. This ultimately provides more of a receiver's or transmitter's circuitry within a rather compact mixer housing.

For example, model MDA4-752H+ from Mini-Circuits (www.minicircuits.com) is a multichip module (MCM) supplied in a 4- × 4-mm MCLP package, which is essentially a quad-flatpack-no-lead (QFN) type package. The small package *(Fig. 1)* includes a mixer integrated circuit (IC), an LO amplifier, and an IF amplifier. It has LO and RF frequency ranges of 2.2 to 7.5 GHz and an IF range of 0.03 to 1.6 GHz. By integrating the amplifiers, it achieves conversion gain and enables operation with an LO power level of 0 dBm. The packaged mixer/amplifier combination suits commercial communications, defense radar systems, and satellite-communications (satcom) systems.

The firm, which supplies frequency mixers with coaxial connectors and in different types of drop-in and surface-mount packages (fitting applications through millimeter-wave frequencies), aids visitors to its website with a versatile "Yoni2" search-engine program. The search engine locates a mixer product based on key mixer search parameters, such as RF/LO frequency range, conversion loss, LO power level, and package style.

The company has extensive lines of surface-mount mixers employing a number of different mixer circuit technologies. For example, its "MAC" lines of mixers combine semiconductor devices with low-temperature-cofired-ceramic (LTCC) circuit materials to achieve high-performance levels in miniature hermetic surface-mount packages *(Fig. 2)*. One model in this line, the MAC-113H+, features an RF/LO frequency range of 3.8 to 11.0 GHz and IF range of dc to 2 GHz. It has a relatively high LO level requirement of +17 dBm and provides 6.5-dB typical conversion loss. The LO-to-RF isolation is typically 28 dB, and the rugged LTCC mixer is designed to handle operating temperatures from –55 to +125°C.

Synergy Microwave Corp.'s (www.synergymwave.com) Galaxy series of wideband surface-mount mixers includes the SGS-5-10 double-balanced mixer, which builds on the firm's SYNSTRIP multilayer circuit technology and REL-PRO patented technology to achieve low conversion loss over broad bandwidths. This mixer has an RF/LO frequency range of 3 to 19 GHz and an IF range of dc to 4 GHz, with typical conversion loss of 7.5 dB.

The SGS-5-10 operates with +10-dBm LO power for a –2-dBm 1-dB compression point, and features 25-dB typical LO-to-RF isolation, 12-dB typical LO-to-IF isolation, and 25-dB typical RF-to-IF isolation. The surface-mount device measures only 0.275 × 0.200 in. and maintains its performance over an operating temperature range of –40 to +85°C.

As evidenced by this small sampling of technologies and products, frequency mixers are very much a significant part of the electronic systems in the RF/microwave industry, and will be even more so as technology and design advances further boost their performance. Currently, mixers are making millimeter-wave links and applications possible and affordable whether in chip or packaged forms. Eventually, the continued trend of integration with other components should foster even more affordable RF/microwave mixers in the not-too-distant future. mw