DIODE MIXER

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Abstract: **In electronic circuits we use converters at different junctions to get the desired frequency. Mixer or frequency mixer is a non-linear electrical circuit that creates new frequencies from two signals applied to it. In its most common application, two signals at frequencies f1 & f2 are applied to a mixer and it produces new signals at the sum f1+f2 & difference f1-f2 of the original frequencies. Other frequency components may also be produced in a practical frequency mixer. In this paper diodes are used which can create a simple unbalanced mixer. The significant property of the diode is its non- linearity which means that its response is not proportional to the input(voltage). A mixer circuit is also used as a product detector, modulator, phase detector or frequency multiplier.**

I. Introduction

The purpose of the mixer is to convert a signal from one frequency to another. In a receiver, this conversion is from radio frequency to an intermediate frequency, or to baseband for a direct conversion receiver. In a transmitter, this conversion is from baseband or some intermediate frequency up to the radio frequency. Mixing requires a circuit with a nonlinear transfer function, since nonlinearity is fundamentally necessary to generate new frequencies. If an input RF signal and a local oscillator signal are passed through a system with a second-order nonlinearity, the output signals will have components at the sum and difference frequencies. A circuit realizing such nonlinearity could be as simple as a diode followed by some filtering to remove unwanted components. On the other hand, it could be more complex; such as the double-balanced cross-coupled circuit, commonly called the Gilbert cell. In an integrated circuit, the more complex structures are often preferred, since extra transistors can be used with little extra cost but with improved performance. In this chapter, the focus will be on the cross-coupled double-balanced mixer. Consideration will also be given as to how to design a mixer in a low voltage process.

Mixer Basics

Mixers are inherently nonlinear devices Mixers use the nonlinearity of their devices to convert input frequencies to new output frequencies. Most mixers are either down converting mixers that produce, at their output, a difference frequency between two input frequencies, or they are up converting mixers, which produce at their output a sum (or difference frequency) of their two inputs, raising the frequency of the output, which is regarded as the signal. In general, the output frequency of a mixer is

Fout = Fr +/– Fl

where Fr is the RF input frequency, and Fl is the LO input frequency.

A basic mixer is shown symbolically in Figure 1. By virtue of their inherent nonlinearity, mixers internally produce harmonics of their Fr and Fl input frequencies. These internally generated harmonic frequencies mix with each other to produce unwanted output frequencies called N × M spurs . A general expression of the N *M spur frequencies is

Fout (N * M) = NFR

Fout (N *M) = NFR +/– MFL

Since a mixer is a frequency-conversion device, its primary electrical specification is called conversion gain (or loss). Since the input Fr and Fl frequencies are unwanted at the output port (and at each other’s input ports), isolation specifications are important for understanding the degree to which unconverted signals are suppressed at the mixer’s various inputs and outputs. The three most important isolations are L-to-R isolation, L-to-I (where I is the output port),

and R-to-I isolation. It is important that these isolations be high enough to assure that the frequency-converted output signal is much stronger than non-frequency-converted signals from the mixer's inputs. Noise figure is also an important specification for a mixer. In the case of passive mixers (mixers that use diodes rather than transistors and inherently exhibit conversion loss), the mixer's noise figure is always equal to its conversion loss. In the case of active mixers (mixers using transistor devices),their noise figure may assume a value similar to, or higher than, that of an amplifier using the same transistor and operating at the Fr frequency (down
converted noise from the image frequency may increase overall NF.) As with amplifiers, mixers generate two-tone intermodulation spurs. Like amplifiers, two tone intermodulation.
spurs represent an important performance parameter. In the case of mixers, two-tone intermodulation performance is specified in terms of an input inter modulation intercept point called IIP3. IIP3 is closely related to the concept of OIP3 in an amplifier. The relationship between IIP3 and OIP3 is simply
IIP3 = OIP3 – Gconv

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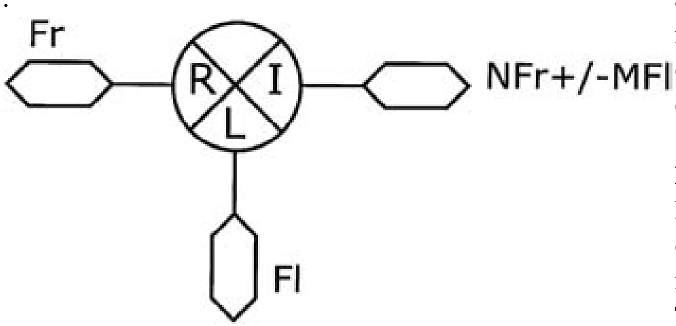

Fig 1:The basic schematic symbol for a mixer function.

LO power level for proper operation is also an important mixer specification. As mentioned above, it is necessary to specify the N × M spurs of a mixer. Any mixer can be understood by performing a mathematical power-series analysis on its nonlinear device in the presence of two input signals of different frequencies. The power-series expression of the nonlinear behavior of a generalized active device may be written as $I(t) = I0 + K1V + K2V2 + K3V3 + \dots$

Assuming that

$V = V1\cos 1t + V2\cos 2t$ where$V1\cos 1t$ is the R port signal.$V2\cos 2t$ is the L port signal. we obtain an expanded expression for the second-order term as

$I(t) = K2[(V1\cos 1t)2 + (V1\cos 1t)(V2\cos 2t) + (V1\cos 1t)2]$

where the first and the third term are responsible for generating the second harmonic of the R and the L signals respectively. It is the center term that is responsible for mixer action. By using a well-known trigonometric identity, it can be shown that the center term can be expanded as

$I(t) = K2[(V1V2)/2]([\cos(1 – 2)t] + [\cos(1 + 2)t])$

Where The first term is associated with the difference mixing frequency. The second term is associated with the sum mixing frequency. Both sum and difference frequencies are always present at a mixer's output port. To eliminate one or the other, it will be necessary to filter out the undesirable
output. . This filtering process is most often accomplished by connecting a low-pass filter to the mixer's output to suppress the sum frequency output or by connecting a high-pass filter to the mixer's output to suppress the difference frequency output.

Diode Mixers

Diode mixers having conversion loss rather than conversion gain are known as passive mixers. Passive mixers use diodes as their nonlinear mixing devices. There are several kinds of diode mixers, depending on configuration and complexity. The simplest is called the single-ended diode mixer. The basic circuit schematic for a single-ended diode mixer is shown in Figure 4.The diode is shunted to ground across a transmission line that delivers both the R and L signal to the diode. An RF choke connecting the ungrounded terminal of the diode to dc ground provides a conduction path so that dc current may flow within the diode in response to R and L

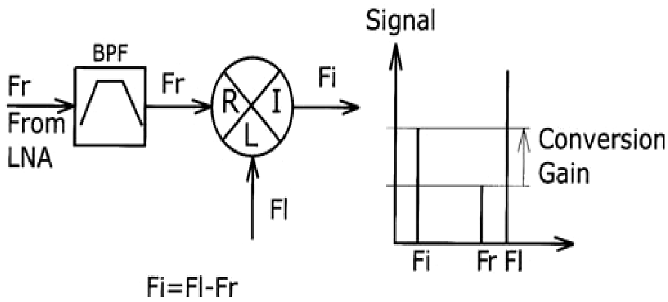

Fig 2: The block diagram and spectrum of a down converting mixer

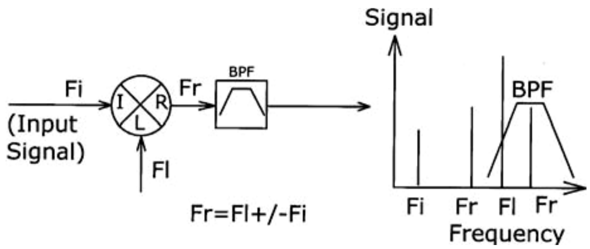

Fig 3: The block diagram and spectrum of an up converting mixer.

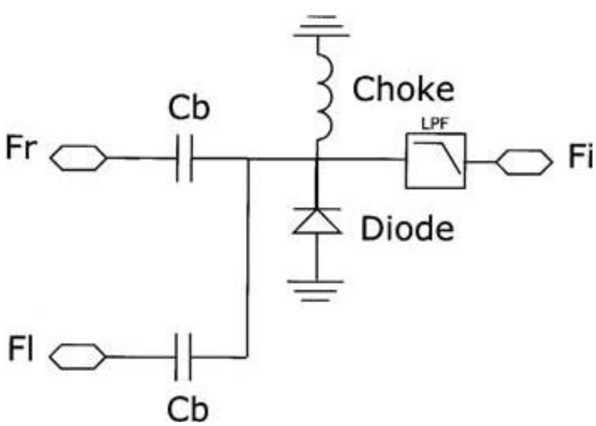

Fig 4: The schematic diagram of a simple single-diode mixer

input signal powers. By controlling the flow of dc current (using L power) to just the right current (where the diode's operating point provides the maximum nonlinearity) it is possible to keep the mixer's conversion loss to a minimum. In well-performing mixers of this class, conversion loss is expected to be in the 5–10 dB range. High isolation is difficult to achieve with this type of mixer. Since the R and L ports are essentially hardwired, the L-to-R isolation is nearly zero, unless a diplexer device is provided at one or both ports. In practice, such a diplexer will be effective only if the frequency separation between Fr and Fl is fairly large, which is not always the case. The L-to-I and the R-to-I isolations can be quite good, depending on the quality of the output port's low pass filter. Since this mixer always experiences conversion loss, its noise figure is equal to the conversion loss. The L power requirement is approximately 3mW per diode. IIP3 for this class of mixer is approximately equal to the L power. To increase its IIP3, the mixer's L power can be increased accompanied by adding two or more diodes in series, increasing the total forward voltage, Vf , which appears across the diode when it is stimulated into forward conduction, by the L power. An important variation on the single-ended diode mixer is the single-balanced mixer, whose schematic diagram is shown in figure This type of mixer achieves a naturally high amount of L-to-I and L-to-R isolation by making use of a technique called a virtual ground. When using a virtual ground, the L signal is split into two paths with a 180° phase difference, using a transformer (or a balun). The out-of-phase secondary ports of the transformer are connected to the top and bottom of a series combination of two identical diodes. If the transformer has a grounded center tap, the center point of the diode pair is fixed at ground potential.

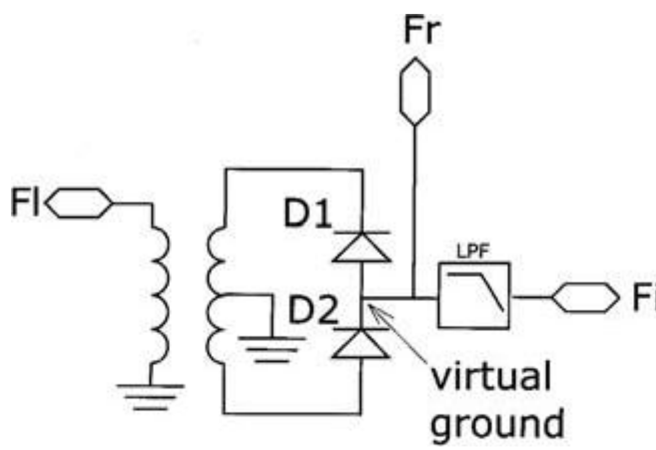

Fig 5: The schematic diagram of a single-balanced two-diode mixer.

for the L signal by the virtual ground process. By connecting the R and I ports to this point in the circuit, the mixer achieves a naturally high amount of L-to-R and L-to-I isolation as a direct result of the transformer's virtual ground. The mixer's R-to-I isolation may be increased with the proper use of a low-pass (or a high-pass in the case of up conversion) filter connected between the mixer's R and I ports. Because there are two diodes in this mixer, the LO power and IIP3 are raised by 3 dB relative to those in the single-diode mixer previously discussed. The final type of passive diode mixer we shall discuss is the double-balanced diode mixer, whose schematic diagram is shown in Figure 11.6. In this mixer, as in the single-balanced mixer, virtual ground techniques are used to achieve high isolation by canceling the R and I signals at output ports from which we don't wish them to escape. In the double-balanced case, two transformers (baluns) are used to achieve this goal. One transformer is connected to the R port, and the second one is connected to the L port. By arranging four diodes in a ring configuration and connecting two transformers to the diode ring, we create a situation where the L port energy is cancelled by virtual ground effects before it can reach either the R or I

ports. Likewise, the R power is cancelled by its transformer before it can reach either the L or I port. The double-balanced mixer naturally achieves high L-to-Rand L-to-I isolations without the need for filters. Another benefit of this kind of mixer is that by using a four-diode architecture, L power and IIP3 are increased by a factor of four relative to the single-diode case. The double-balanced diode mixer is about as good as a passive mixer can get. For RFICs transistors can be easily configured to operate as diodes. By connecting the base and collector terminals together, the transistor's base-to-emitter junction acts as a diode, which may be used in a wide range of mixer applications.

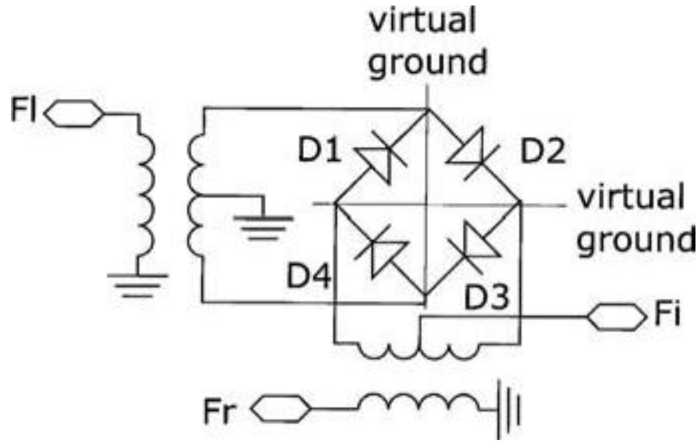

Fig 6: The schematic diagram of a double-balanced four-diode mixer.

References

[1] Maas, S., Microwave Mixers, Boston: Artech House, 1986.

[2] Henderson, B., "Reliably Predict Mixer IM Suppression," Microwaves and RF, Vol. 22, No. 11, 1983, p. 63.

[3] Mattauch, R., "Frequency and Noise Limits of Schottky-Barrier Mixer Diodes," Microwave J., Vol. 28, No. 3, 1985, p. 101.

[4] Burington, R., Handbook of Mathematical Tables and Formulas, Sandusky, OH: Handbook Publishers, 1955.

[5] Lee, T., The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge: Cambridge University Press, 1998.

[6] Razavi, B., RF Microelectronics, Upper Saddle River, NJ: Prentice Hall, 1998.

[7] Gray, P., et al., Analysis and Design of Analog Integrated Circuits, New York: John Wileyand Sons, 2001.