Mixers Application Information

The information contained below is applicable to all mixers in general and should be useful to anyone using, specifying, or designing mixers.

DEFINITIONS

Conversion Loss is the ratio of the output signal level to the low-level input signal level expressed in dB. In a single sideband system, only one sideband is used; therefore, 3 dB of the loss is theoretical. The additional loss is diode and transformer loss. These losses can be minimized by driving the diodes with sufficient current and operating in the best portion of the frequency band.

Conversion loss is specified in a 50-ohm system with an fL drive level of +7 dBm for low-level mixers. High-level mixers require more drive level power. A short circuit at the output port for the unwanted sideband will usually improve the conversion loss and noise figure by 0.5 dB if operation at the I-port is below 500 MHz.

Noise Figure is the signal-to-noise ratio at the input divided by the signal-to-noise ratio at the output expressed in dB. It does not include the noise figure of an IF amplifier or 1/f flicker noise.

The IF frequency range is normally specified from 400 kHz to the upper frequency range of the device. Appreciable noise contribution from 1/f noise is not noticeable above 10 kHz. Use of specially selected Schottky-Barrier diodes ensures extremely low 1/f noise for phase detection applications. With the recommended drive level the noise figure and conversion loss are essentially identical.

Isolation is the amount of "leakage" or "feedthru" between the mixer ports. The f_L at R isolation is the amount of f_L drive level signal is attenuated when measured at the R-port. The f_L at I isolation is the amount the f_L drive level signal is attenuated when measured at the I-port. Normally, only the f_L isolation is specified since the f_R signal level is much lower than the f_L signal level and is not a problem. The fI at L and f_R at L isolations are normally the same as the f_L at I and f_L at R isolations. At low frequencies, where diode parameters are matched and circuit parasitics are negligible, isolation greater than 60 dB is possible.

Conversion Compression is the f_R input level above which the f_R input vs. fI output curve deviates from linearity. Above this level additional increases in input level do not result in equal increases in output level. Conversion compression is not specified for all low-level mixers. However, low-level units normally have the same compression level, i.e., typically 0.3 dB deviation from linearity with an f_R signal level of +2 dBm and a +7 dBm f_L drive level. This f_R level can be raised to +4 dBm if the drive level is increased to +13 dBm. Conversion compression for high-level mixers is specified since it sometimes provides an indication of the mixer's two-tone performance and it is likely to be important in high-level operation.

Dynamic Range is the amplitude range over which a mixer can operate without degradation of performance. It is dictated by the conversion compression point and the noise figure of the mixer.

Since the thermal noise of each mixer is about the same, the conversion compression point normally determines the mixer's dynamic range.

Intercept Point is the point at which the fundamental response and the 3rd-order spurious response curves intercept. It is often used to predict the 2-tone, 3rd-order suppression of a mixer. The higher the intercept point, the better the 3rd-order suppression. Relative to the input, the intercept point is typically 9 to 11 dB higher than the conversion compression point.

Two-Tone, Third-Order Intermodulation Distortion is the amount of 3rd-order distortion caused from a second received signal being present at the R-port. Mathematically, 3rd-order distortion is defined as $(2 f_{R2} - f_{R1}) \pm f_L$ where f_{R2} is the second signal. Usually the higher the conversion compression or intercept point of a mixer, the greater the suppression of this product. Normally this parameter is not specified as it is dependent on the input frequencies and terminating impedances.

Desensitization is the compression of the desired signal caused by a strong second interfacing signal. For a low-level mixer, this compression is typically less than 1.0 dB for an f_{R2} signal level of +1 dBm and less than 10.0 dB for an f_{R2} signal level of +10 dBm. The desensitization level is normally 3 dB below the conversion compression level.

APPLICATIONS

Harmonic Intermodulation Distortion results from the mixing of mixer generated harmonics of the input signals. Mathematically, it is expressed as $mf_L \pm n f_R$ where m and n represent the harmonic numbers of the input signals. Typical performance is not normally specified since the relative level depends on input frequencies, input levels and terminating impedances.

Cross Modulation Distortion is the amount of modulation transferred from a modulated carrier to an unmodulated carrier when both signals are applied to the R-port of the mixer. The higher the conversion compression or intercept point of a mixer, the greater the attenuation of the cross modulation.

GENERAL APPLICATIONS

Mixing: When two signals are fed to the mixer, sum and difference frequencies are produced at the third port. Best isolation is usually achieved by feeding the LO signal to the L port. In downconverters the RF input signal is fed to the R port and the output is taken from the I port. For up-converting applications, feed the low frequency input signal to the I port and take the output from the R port.

Drive Level: A minimum drive level is recommended when it is necessary to reduce the level of intermodulation products in the lower two rows of the intermodulation chart or minimize the 1/f output noise. A drive level below the minimum recommended level degrades the conversion loss and noise figure of the mixer over the full temperature and frequency range.

Operation at a high drive level is recommended to achieve best two-tone performance, best suppression of the intermodulation products in the rows above the second row in the intermodulation chart, and the best flatness of conversion loss as a function of frequency. A drive level above the recommended level will result in an increase in noise figure and an increase in mf_L feedthrough.

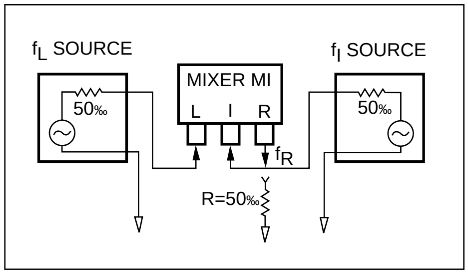
RF Input Level: With the recommended f_L level, and to avoid deviations from linearity by more than 1 dB, the f_R level should not exceed the following levels:

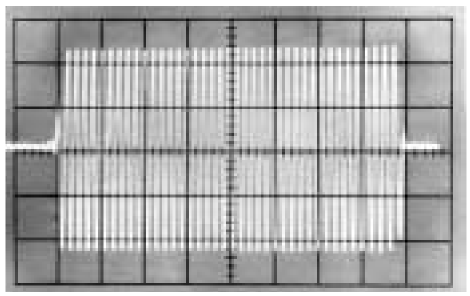
Mixer Type	f_R Level dBm
Low Level	+1 to +4
High Level	+10 to +14
Ultra High Level	+21

The f_R signal level should be as low as possible when there is a problem with higher order fR intermodulation products.

PULSE, AMPLITUDE, AND BI-PHASE MODULATION

For amplitude modulation, apply a dc current along with the modulating signal at the I-port. The carrier signal is applied at the L-port and the modulated signal appears at the R-port. The dc current at the I-port controls the amount of carrier present in the output.

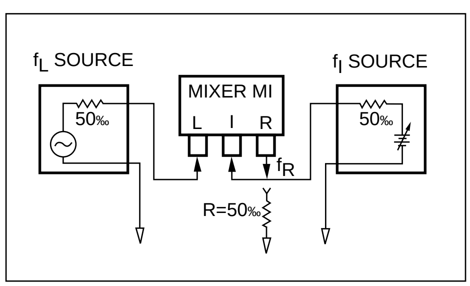




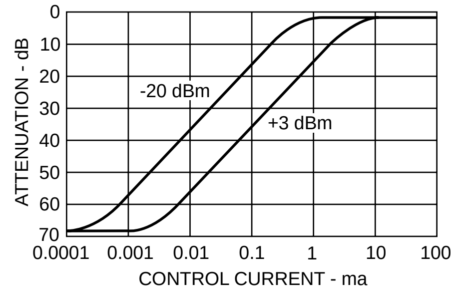
For pulse modulation, feed the unmodulated signal to the L-port and the modulating pulse to the I-port. No dc offset current should be used. Pulse lengths can be of unlimited length since the I-port is direct coupled. A 20 mA level is sufficient to fully turn on the diodes. Rise and fall times less than 1 nsec can be achieved. Zero current turns the diodes off. Either a positive or a negative pulse may be used.

For bi-phase modulation, reverse the polarity of the switching signal. Upon reversal, the output phase will shift by 180 degrees.

CURRENT-CONTROLLED ATTENUATION



The amount of signal passing through the mixer from the L-port to the R-port is determined by the dc control current present at the I-port. Maximum attenuation is

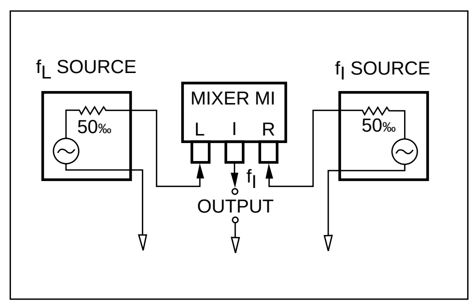


Typical Attenuation vs. Control Current

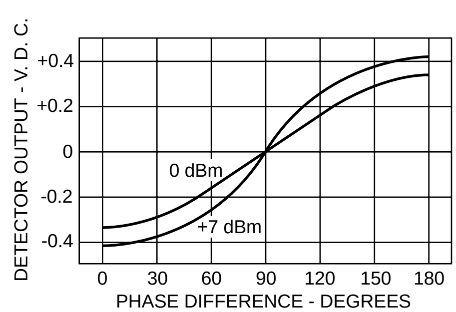
achieved with no dc current and corresponds to the isolation of the mixer. Minimum attenuation is achieved with a dc current of 20 mA or greater.

A plot showing the attenuation characteristics of a typical diode mixer is shown for a 10 MHz signal with signal levels of -20 dBm and +3 dBm. For input signal levels of -20 dBm or less, the attenuation is relatively independent of the signal level.

PHASE DETECTION



A balanced mixer may be used for phase detection. With identical frequencies connected to the R- and L-ports, a dc output related to the phase difference between the



Typical Phase Detector Output vs. Phase Difference two signals will appear at the I-port. The two inputs to the phase detector are normally the same level. The output is usually loaded with 1000 ohms or greater.

The sinusoidal output voltage shown below is from a phase detector in which the inputs are two sinusoidal signals of the same level and the output is loaded with 1000 ohms. The output voltage waveform as a function of phase difference is sinusoidal. With two square wave inputs the output voltage would be linear. Input levels of +7 dB in are recommended for best phase detection. A higher level introduces unbalance and a lower level results in a loss of output level.

TYPICAL TWO-TONE PERFORMANCE AT 25°C

Definition: In a mixer application where the input must be wideband, two signals (f_{R1} and f_{R2}) may mix with the local oscillator signal (f_L) to produce in-band, two-tone third-order intermodulation products ($2 f_{R2}$ - f_{R1}) ± f_L.

Two-Tone Supression vs. Input Level: With each dB decrease in fR input level, the third-order product is decreased an additional 2 dB.

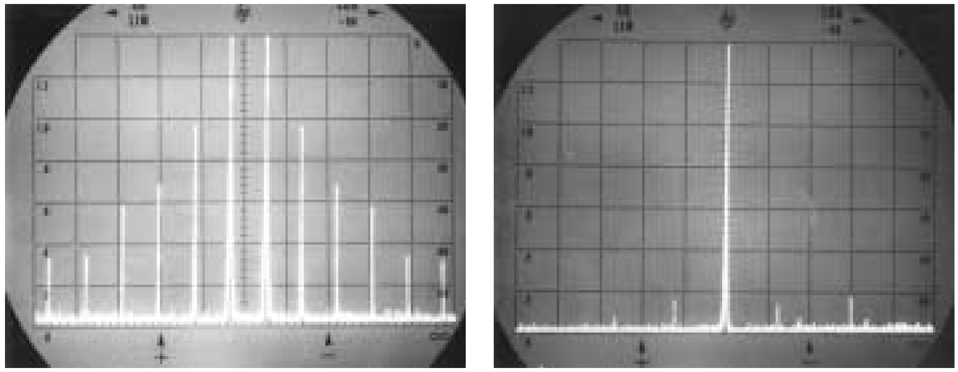
Two-Tone Performance of High- Level, Double-Balanced Mixers: In the spectrum analyzer photos, mixers using various LO drive levels are compared. The input conditions were as follows:

f_L = 352 MHz, f_{R1} = 322 MHz at 0 dBm, f_{R2} = 320 MHz at 0 dBm.

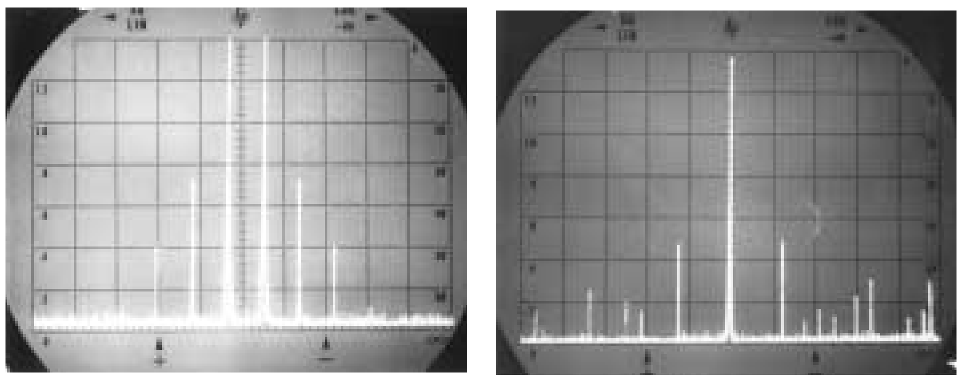
Horizontal Scale: 2.5 MHz/cm, centered at ≈ 31 MHz.

Vertical Scale: 10 db/cm.

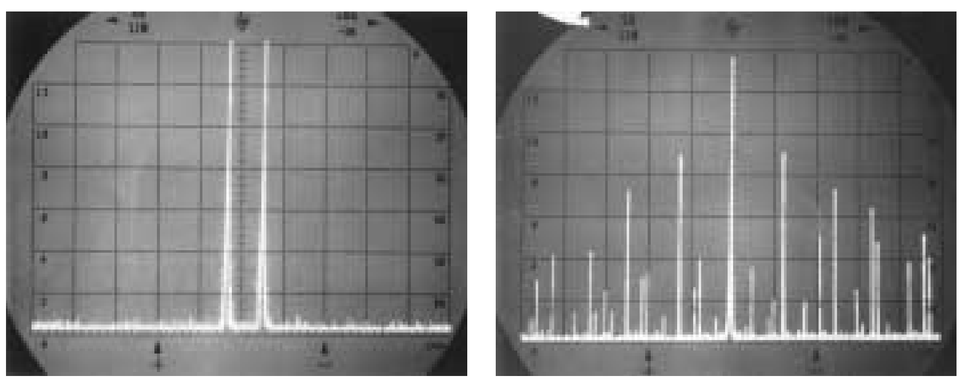
These represent the performance of class I, class II, and class III mixers, as described in “Mixers Part II”.



Low drive: With a +7 dBm fL drive level, a balanced mixer can suppresses many of the two-tone spurs. However, a number of relatively unsuppressed products remain



Medium drive: With a +17 dBm fL drive level, a higher-power mixer provides an additional 12 dB of suppression of the third-order product.



High drive: With a +27 dBm fL drive level, a high power mixer virtually eliminates all two-lone products from the 60 dB spectrum.

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TYPICAL DISPLAY OF HARMONIC PRODUCTS AS AN INTERMODULATION TABLE

Harmonics of f_R									
7	79>99>99	>90>90>90	69 79>99	>90>90>90	80>99>99	>90>90>90	74 78>99	>90>90>90	83>99>99
	>90>90>90	83 78>99	01>90>90	78>99>99	>90>90>90	60 81>99	>90>90>90	71 99>99	>90>90>90
6	90>99>99	>90>90>90	86>99>99	>90>90>90	91>99>99	>90>90>90	91>99 97	>90>90>90	90>99>99
	>90>90>90	84>99>99	>90>90>90	93>99>99	>90>90>90	84>99>99	>90>90>90	88>99 98	>90>90>90
5	72 93>99	>90>90>90	70 73 96	80>90>90	71 87>99	>90>90>90	52 72 95	71>90>90	77 88>99
	>90>90>90	46 66>99	00>90>90	75 85>99	>90>90>90	45 64 90	65>90>90	73 62>99	88 -90>90
4	80 96 88	86>90>90	79 80 91	>90>90>90	82 96>99	86>90>90	77 80 92	88>90>90	82 95 90
	88>90>90	76 82 95	85>90>90	77 98 87	88>90>90	72 78 94	65>90>90	77 90 87	>90>90>90
3	51 63 81	67 87>90	49 58 73	64 77>90	53 65 85	69 87>90	51 60 69	50 78>90	55 65 85
	77>90>90	48 55 68	47 75>90	54 64 85	74 85>90	53 54 64	44 77 89	58 66 87	74 88>90
2	69 68 64	73 86 73	72 67 71	73 75 83	79 76 62	74 84 75	67 67 70	70 75 79	75 80 63
	71 86 80	66 66 70	64 74 80	77 82 61	69 87 77	68 66 62	64 74 62	75 83 64	69 84 79
1	25 25 24	24 23 24	0 0 0	0 0 0	39 39 35	35 39 34	13 11 11	13 11 11	45 50 42
	40 46 42	22 16 19	24 14 18	54 59 50	45 62 49	37 19 39	28 19 37	59 59 49	49 53 49
0		36 39 29	26 27 18	45 42 20	35 31 10	52 46 32	39 36 23	63 58 24	50 47 14
		45 37 29	41 36 19	60 55 27	53 51 17	71 49 30	49 37 21	64 75 29	
	0	1	2	3	4	5	6	7	8

Harmonics Of f_L

f_R at -10 dBm; f_L at +7/+17/+27 dBm respectively for class I, II, and II mixers.

Intermodulation signals which result from the mixing of mixer-generated harmonics of the input signals are shown above for various mixer classes. Mixing product suppression is indicated by the number of dB below the f_L ± f output level. The performance was measured with fR at 49 MHz, fL at 50 MHz, and using the following input levels:

fR at 0 dBm; f_L at +7/+17/+27 dBm respectively for class I, II, III.

Improved performance can be obtained at lower frequencies, and for harmonics of f_R >2, with f_R at a lower level.

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