How to select a mixer

Select the proper mixer for your needs. There are hundreds of models available. Underspecify and face marginal performance, overspecify and pay for more than you need. Here's the proper approach.

Mixers are abundant in electronic systems ranging from inexpensive consumer products to sophisticated military hardware. You'll find them in video games. TV sets and video cassette recorders as well as communications gear, test instruments, radar units and countermeasure systems. Mini-Circuits offers well over a hundred different off-the-shelf models with thousands of variations. Different connector configurations, tighter specs, Hi-Rel, MIL, TX options are available on request. Improper mixer selection bears a penalty - under- specify and face marginal performance; overspecify and pay extra for unnecessary performance characteristics.

making the right choice

Simply stated, there are three basic steps- (1) Selecting the mixer level required in the applications, (2) deciding on a printed-circuit [PC] or connector version, and (3) picking a model that extends over the frequency range involved. Sounds simple enough so let's examine some of the details. The most important step requires understanding your specific needs; so it is strongly recommended that you organize the requirements for your application and put it in writing. Decide what frequency range is involved, the LO drive available, the level of harrnonic and two-tone, third-order intermodulation (IM) distortion you can tolerate and other factors. Fill-out the Specifications Checklist.

l. DETERMINE THE LO LEVEL REQUIRED.

In many mixer applications there are specifications involving distortion at a particular level of the RF input signal. In most cases this specification will be the governing factor in determining the level mixer required; i.e. Level 7, Level l0, Level 17, etc. As a first order approximation, the LO power should be 10dB greater than the highest input signal level anticipated. Keep in mind that it is desirable to select the lowest level mixer that will meet the application because it would be more economical and it would result in the least amount of LO leakage within the system. This 10dB criteria is a first degree approximation.

In many cases this number may be modified. The trade-off is generally between performance versus cost. Mini-Circuits offers a wide range of different level mixers, from 7 to 27. Referring to Fig. 2, and the discussion on 1 dB compression point to follow, select the level mixer for your requirement.

II. DETERMINE THE TYPE OF CONNECTIONS: PC BOARD MOUNTING OR COAXIAL CONNECTORS

Generally, the designer has evaluated his system requirements and will know beforehand whether the mixer is to be mounted on a pc board or is to have coaxial connectors.

Mini-Circuits has both types available. All pc board mounting units have at least 4 pins to ensure a

mechanically rugged connection to the pc board. Many of these units easily comply with standard miliary requirements. The connector version mixers are available in five standard types: BNC, TNC, SMB, SMA and N. These units are available with or without a mounting bracket (please specify connector and bracket requirement)

III. DETERMINE THE FREQUENCY RANGE REQUIRED AND SELECT A MODEL.

Mini-Circuits offers extremely wideband mixers with a considerable amount of frequency overlap between models. Determine the required frequency range of operation. Then select the mixer whose frequency range specifications best "straddles" the range of frequency operation. It is good practice to try to select a mixer whose midband frequency range covers the frequency range of intended operation. Mini-Circuits has taken this design philosophy in specifying the frequency range of its models. All MCL mixers perform well at the edges of their frequency specification. In fact, many users operate outside of the band edge specified by MCL and expect and receive repeatable (unit to unit) high performing mixers.

1dB compression point key to choosing mixer level

What does the 1dB compression point signify? As RF input level is increased, IF output should follow in a linear manner. However, after a certain point, IF output increases at a lower rate until the mixer IF output becomes fairly constant.

The RF input level for which the IF output level deviates from linearity by 1 dB is termed the 1 dB compression point. Fig. 2 displays the RF input level at 1dB compression for various type mixer levels.

This 1 dB compression point is useful in comparing dynamic range, maximum output and two-tone performance of various mixers. It is a basis on which mixer level is established.

The 1dB compression point, which defines the linearity of a mixer at high RF input levels, is relatively simple to test and thus this parameter is included on data sheets supplied by all mixer manufacturers. But, in real life, mixer linearity may be specified in accordance with the intended application. For example, in a receiver application, two-tone, third-order intermod may be the critical parameter; for TV applications, percent distortion or intercept point may be specified; and in an attenuator measurement system, compression may be important for a given RF input level. With this in mind, the engineer needs a convenient means to relate the particular parameter for his application with the published spec, the 1 dB compression point.

Fig. 3 lists ways mixer linearity might be specified.

1. MAXIMUM RF INPUT LEVEL ANTICIPATED.
If you know this parameter, simply select the lowest level mixer whose maximum RF input level, at 1 dB compression, exceeds your requirement. For example, if the maximum encountered RF level is +5 dBm, select a Level 13 mixer, rated at +7 dBm maximum RF input for 1 dB compression point.

2. PERCENT DISTORTION.
The percent distortion is usually specified in voltage. Thus, a 0.1% distortion figure means 0.999 of the desired voltage appears at the mixer output. Next, convert this voltage ratio to a power ratio in dB by squaring and taking ten times the log. The resultant figure is the amount of compression for the

specified RF input level. Now this must be extrapolated to 1 dB compression for a corresponding RF input level. As a rule of thumb, extrapolation may be achieved by assuming a linear relationship in dB, between compression and RF input level. So a ten-times increase in compression corresponds to a ten-times increase in RF input level.

Let's illustrate with an example using a 0.1 percent distortion spec at 10 dBm RF input level. The 0.1 percent corresponds to a relative 0.999 voltage output; squaring this yields 0.988 power ratio or 0.009 dB. We, therefore, know that 0.1% distortion at 10 dBm input means the maximum allowable compression is 0.009 dB. Extrapolating, using the rule-of-thumb relationship, states that 0.09 dB compression corresponds to an allowable RF of 0 dBm, and 0.9 dB compression at a maximum allowable RF input level of 10 dBm. So which mixer is appropriate? A Level 17S, with +13 dBm RF input level at the 1 dB compression point, see Fig. 2

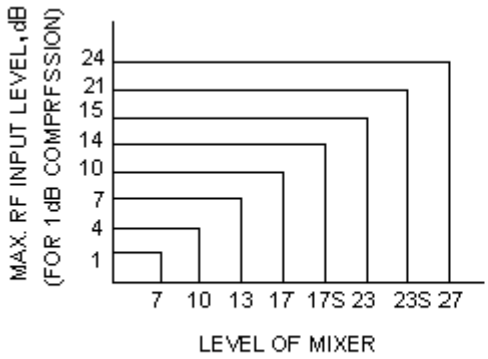


FIG.2 **The 1 dB compression point as a function of the level of mixer**

FIG. 3 **Dynamic range parameters affecting mixer selection**

1. maximum RF input level anticipated
2. percent distortion acceptable
3. Intercept point
4. Two-tone, 3rd order IM _____dB at_____dBm, RF input each tone
5. RF input at 1 dB compression level
6. LO power available
7. none of the above specified

Let's correlate every parameter in Fig. 3 with the published 1dB compression point to show how simple it is to select the proper mixer level, Fig. 2.

3. INTERCEPT POINT.

This parameter is a figure of merit corresponding to the amount of intermodulation products generated relative to the desired IF output. An intercept point can be defined for a second-order, third-order, fifth-order, product, etc. As a rule-of-thumb, two-tone third-order intercept point is approximately 15 dB above the 1 dB compression point. So, if the intercept point figure is given, merely subtract 15 dB from this figure and pick a mixer which meets the 1 dB compression point spec, see Fig. 2.

4. TWO-TONE, THIRD-ORDER INTERMODULATION (IM).

When a two-tone, third-order IM spec is given, the intercept point can be calculated. Remember that for each 10 dB increase in signal level, there is a 20 dB degradation in two-tone, third-order product. Once the intercept point is calculated, simply subtract 15 dB from the figure to find the 1 dB compression point and select the appropriate mixer.

5. 1dB RF INPUT COMPRESSION LEVEL.

This key parameter is listed on mixer spec sheets so merely choose the lowest level mixer that will meet the requirement.

6. LO DRIVE.

The LO drive is critical since the function of the LO drive is to switch the mixer diodes fully on and

off for lowest distortion. So, for optimum performance, select the mixer level to match the LO drive. Mini-Circuits conveniently identifies its mixer levels by the LO drive requirement; thus a Level 7 mixer refers to a LO drive level of +7 dBm. If there are constraints on the LO power available, select the lowest level mixer closest to the available LO power. For example, if +12 dBm LO drive is available, select a Level 10 mixer.

7. NO PARTICULAR SPEC TO MEET.
Choose a Level 7 mixer. Why? Because it is the most popular and it offers the widest choice of models at lowest cost.

frequency range last deciding factor

Once the mixer level has been decided, you may find a wide variety of models to exercise your decision making. The specification pages are arranged by mixer level. For a particular level, photos and case styles describe various configurations available for your choosing. You may notice models within a series with overlapping frequency ranges. Why? So you can choose the optimum mixer for your requirement. Each model within a series has a different low-frequency limit. Select a mixer with the highest low-frequency limit and whose mid-band range best covers your application.

Specs on the data sheets are given in three ranges. The lower frequency range, L, covers the lowest specified frequency to one decade higher; the upper frequency range; U, covers the highest frequency to one octave lower and mid-range, M, covers the frequency between L and U. Thus a mixer specified from 0.5 to 500 MHz could offer a low-frequency range of 0.5 to 5 MHz, an upper frequency range of 250 to 500 MHz, and a mid-range of 5 MHz to 250 MHz.

what about "Specials"?

When a particular model in a series has been selected the designer must determine if the model will meet the electrical performance criteria he has generated. All MCL mixers are characterized and a significant number of performance curves and tabulated data describing the models are given on the data sheets. The performance curves on the data sheets describe typical performance. Sometimes the designer requires higher isolation, lower conversion loss, temperature tracking of conversion loss, unit to unit tracking of conversion loss, selection of higher order harmonic products, less than 100 microvolts of phase detector DC offset, larger specified bandwidths, etc. Mini-Circuits offers these special performance criteria and many more. Our high volume production enables us to select units to customer specifications at extremely low cost. Mini-Circuits maintains a highly documented system to handle specialized customer requirements.

In summary, contact us about "specials" and we'll do our best to satisfy your needs without excessive cost or delivery date extensions. Sometimes, "special" means shipping a quantity of mixers within a very short time span; since Mini-Circuits is the largest manufacturer of mixers in the world, this may hardly be considered "special" and you may be pleasantly surprised. Try us.

practical questions

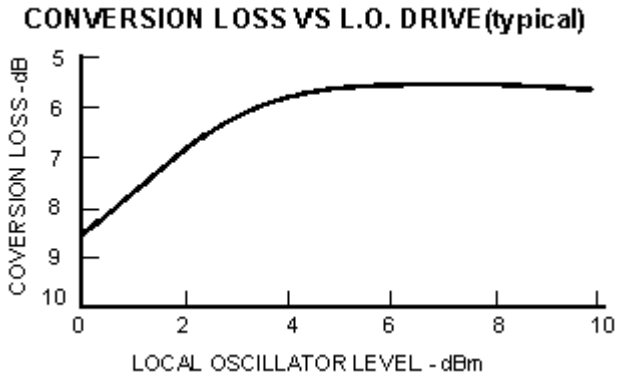
We get a lot of phone calls in which questions came up regarding mixer selection. Here are the most popular and their answers.

Q. I'm ready to select a mixer. But there are so many models to choose from, where do I start?

A. Start by defining your requirements as best you can, including electrical, mechanical, environmental, etc. Do you need printed circuit (PC) or connector version? What is the frequency range of interest? Use the MIXER SELECTION GUIDE to jot down key details. The objective of listing the requirements is to define what you *really* need, including the level of mixer required ... mixer level is the key for mixer selection. Once level has been determined, the specific mixer selection will be easy. Of course, there may be variables you may not know or that are not critical, so make the best estimate and proceed.

Q. How critical is LO level in a mixer application?

A. The purpose of the LO signal is to switch the mixer doides on and off. Manufacturers select a fixed LO level so they can test and specify at a particular level. In practice, however, LO drive can vary with minimal effect on mixer performance. For example, a Mini-Circuits' SRA-1 unit is specified at +7 dBm LO level; if the LO drive was only 3 dBm perhaps a 0.5 dB increase in conversion loss might take place. Or a high-level SRA-1H might experience a 0.3 dB increase in conversion loss if LO level was +14 dBm instead of the specified +17 dBm LO.



Q. I notice Mini-Circuits offers many series of mixers, such as the SRA, TAK, TFM, ASK, etc. including over 450 models. Why so many models?

A. Mixers are used in systems covering communications, weapons, test instruments, radar, data transmission and countless other applications. A mixer manufacturer can opt to produce a dozen models and thus, in a sense, force the design engineer to compromise his specific needs by offering a rather narrow selection. Mini-Circuits approach is to offer a wide variety so the designer can buy what he needs, and thus neither compromise his design nor pay for more than he really needs. That's why Mini-Circuits offers more off-the-shelf models than all other manufacturers combined.

But that's not enough. As needs change, new models will be available. For example, the recent demand for higher density packaging has been filled by Mini-Circuits' ASK flatpack series, more than doubling packaging density on a PC board.

Finally, although we list over 450 off-the-shelf models, we can supply hundreds of variations (such as connector configurations, tighter specs, etc.) at our customer's request.

Q. What's the difference between "Level 7", "Level 10", and "Level 27" mixers?

A. The different levels of mixers are determined by the LO drive required for a particular application. Thus each particular level mixer has been optimized for a given LO drive, and will offer low distortion even at the maximum input level specified for the mixer. The higher the level of mixer, the lower the distortion expected. It is obvious that the highest level mixer could satisfy most requirements. However, high LO drive would be necessary and the cost of a level 27 mixer is higher than a lower level mixer, such as level 10 or level 7.

Thus, rather than overspecify, select the level of mixer that will optimize your system.

Q. I don't have enough LO drive even for a level 7 mixer. What can I do?

A. Some level 7 mixers (TFM/ZFM series), although specified for +7dBm LO, will operate well with LO drive as low as 0 dBm.

However, there is some degradation; about 1 dB additional conversion loss, the upper frequency limit might be slightly reduced and there may be a slight increase in two-tone, third-order IM. Our exclusive CAPD data service can provide specific information on how LO drive variations affect mixer specs for your application.

Q. I am operating over a wide bandwidth and my LO drive level changes by about 3 dB. How should I take this into account when I select a mixer?

A. The preferred approach would be to determine the lowest LO drive level over the band and then select a mixer for this drive level. Remember that as LO level increases over the nominal (to + 10 dBm for a level 7 mixer), conversion loss is flat and thus optimum performance will be maintained and not degraded.

Don't guess; consult our CAPD data.

Q. From my requirement for intercept point, I have selected a Level 13 mixer. Can I apply a +7 dBm LO drive and expect the high performance specified in the data sheets?

A. No. Performance to the specifications take place when the mixer diodes are driven full "on" by the LO drive. Therefore, when LO drive is insufficient, the diodes operate on a different portion of their I-V characteristic curve. In addition to the LO drive, the RF input signal will influence the range in which the diodes operate on the I-V curve and thus increase nonlinearity and distortion.

That's why Mini-Circuits offers so many series of different mixer levels, (Level 7, 10, 13, 17, 17S, 23, 23S and 27).

Q. I need a mixer with a flat conversion loss over my frequency range spec. How do I go about selecting a model ?

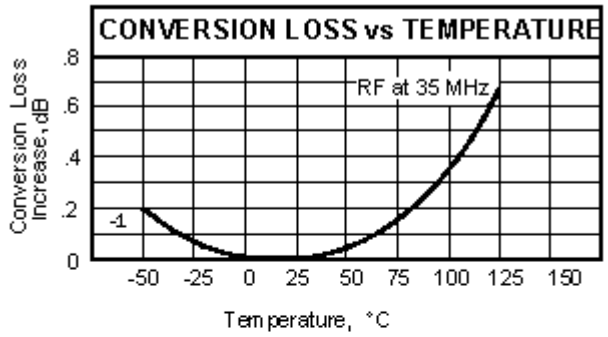
A. Conversion loss over the midrange response of a mixer is usually flat. So select a mixer that has a midrange response covering the frequency range you need.

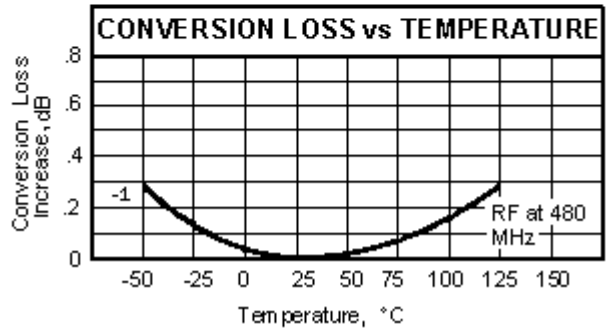
Also, the VSWR of the mixer (especially the RF and IF ports) should be checked in order to minimize mismatch errors which could compromise the conversion loss flatness.

Q. I expect wide temperature extremes for my latest RF design project and mixer conversion loss vs. *temperature concerns me. What advice can you offer?*

A. For extreme cold environments (down to -55°C), to maintain flat conversion loss, pick a mixer that operates a minimum of two octaves below your lowest frequency of operation. For example, if your application involves operation at 30 MHz, select a mixer that extends to 7.5 MHz or lower. Why? The permeability of the ferrite core in the mixer transformer will drop at reduced temperature, resulting in higher losses or frequency fall off at the low end of the band.

In extreme heat or high-temperature environments, the mixer diodes will be the predominant factor affecting conversion loss. Diode impedance will change and cause mixer mismatch to upset flat conversion loss. So select a mixer whose upper frequency is an octave higher than that of your application. For example, if you are concerned with high temperature performance at 500 MHz, select a mixer good up to 1000 MHz (such as the SRA-2CM or TFM-2).





Q. The RF-IF isolation spec is not shown on mixer data sheets. Is this spec important when I select a mixer?

A. Generally, the RF-IF isolation spec is not important since the RF level is usually considerably lower than the LO level. As a rule of thumb, for Mini-Circuits mixers, the RF-IF isolation spec is about 10 dB less than the LO-RF isolation spec. If, for your particular application, the RF-IF isolation spec is important, specify your needs when you place the order and Mini-Circuits will screen and test to this spec at no additional charge.

However, in a phase detector application, the RF-IF spec may be critical, since the RF level is comparable to the LO level.

Q. Do you supply a mixer with a specified maximum VSWR?

A. Generally, a maximum VSWR spec is not given in the mixer data sheets. As a general rule, try to select a mixer whose midrange covers your fre- quency band of interest. In addition, if you state the maximum VSWR requirement, Mini-Circuits can screen and test to meet your needs. In addition, you can examine detailed CAPD data of VSWR at all three ports as well as VSWR sensitivity to LO power level changes.

Mixer VSWR V. LO power

(LO frequency 150 MHz for R, and I port measurement)

model SBL-1

freq.	**VSWR, RF port**			**VSWR, LO port**			**VSWR, IF port**		
freq. (MHz)	**LO +5dBm**	**LO +7dBm**	**LO +9dBm**	**LO +5dBm**	**LO +7dBm**	**LO +9dBm**	**LO +5dBm**	**LO +7dBm**	**LO +9dBm**
1.000	1.68	1.70	1.71	2.84	3.54	4.64	1.18	1.13	1.08
27.263	1.09	1.14	1.19	2.18	2.84	3.62	1.21	1.15	1.10
53.526	1.10	1.14	1.18	2.06	2.66	3.35	1.20	1.15	1.11
79.789	1.11	1.15	1.18	2.22	2.88	3.74	1.21	1.17	1.13
106.053	1.16	1.22	1.25	2.05	2.57	3.18	1.32	1.27	1.22
132.316	1.18	1.23	1.27	2.11	2.72	3.38	1.36	1.31	1.27
158.579	1.19	1.23	1.28	2.13	2.71	3.44	1.38	1.33	1.29
184.842	1.21	1.25	1.29	1.99	2.46	3.03	1.46	1.42	1.36
211.105	1.22	1.27	1.29	2.04	2.56	3.14	1.52	1.49	1.42
237.368	1.29	1.35	1.38	2.00	2.50	3.04	1.75	1.71	1.62
263.632	1.31	1.35	1.40	1.95	2.38	2.86	1.80	1.72	1.67
289.895	1.27	1.31	1.34	2.02	2.50	2.99	1.71	1.69	1.61
316.158	1.32	1.39	1.39	1.91	2.32	2.71	1.99	1.98	1.83
342.421	1.35	1.41	1.43	1.98	2.39	2.85	2.14	2.13	1.96
368.684	1.38	1.45	1.46	1.97	2.39	2.80	2.39	2.38	2.15
394.947	1.39	1.44	1.48	1.87	2.22	2.60	2.40	2.35	2.25

421.210	1.34	1.42	1.40	1.90	2.26	2.68	2.17	2.29	2.02
447.474	1.40	1.50	1.49	1.87	2.23	2.60	2.86	3.13	2.60
473.737	1.44	1.51	1.53	1.94	2.29	2.64	3.08	3.13	2.85
500.00	1.43	1.49	1.51	1.98	2.31	2.66	2.92	2.95	2.71

Q. My application involves maximum RF input signal levels of -20 dBm. I notice the 1 dBm compression point specification of many mixers is at +1 dBm and higher. Should this spec be of concern to me?

A. Yes, if two-tone, third-order IM is critical or if receiver response to unwanted signals is important. The 1 dB compression point is related to the intercept point which is a "figure-of-merit" of the linearity or distortion characteristic of a mixer. It also indicates the susceptibility of the mixer to unwanted signals.

Q. I've selected an SRA-1 mixer as the best model for my application. However, I need the typical isolation spec as a guaranteed minimum. What should I do?

A. Mini-Circuit's specs are conservative and, thus, our typical specs will apply to just about every production unit. But ... that's not a good enough answer to your question. If you request a minimum isolation spec from us, we'll assign a special part number to our model. Then we'll screen and test on a 100% basis to your specification, at no extra charge. Mini-Circuit's commitment is to satisfy your requirement.

Q. I need a mixer that nominally operates at + 10 dBm LO drive but requires protection against sudden surges of RF input power as high as 250 mW. What mixer should I select?

A. To avoid damage from a 250 mW input signal, choose a Level 17 mixer. Reason ... a Level 17 mixer containing eight diodes, each rated for 100 mW dissipation, easily copes with the 250 mW input. But, there is a penalty. For minimum distortion, you'll require +17 dBm LO drive, which may be higher than your original intent. Or, you can operate at a lower LO drive but suffer an additional conversion loss of 1.0 to 1.5 dB. The decision is up to you ... but the Level 17 mixer will be safe from the 250 mW surges.

Q. l have an application requiring an RF frequency response from 100 Hz to 10 MHz. I don't see any mixers specified with an RF this low. What can I do?

A. One of the characteristics of most double-balanced mixers (DBM) is that IF response usually extends from DC to the highest frequency specified for the mixer. Since all ports of the DBM are balanced and thus isolated from each other, simply connect the RF input signal to the IF port and take the IF output from the RF port. Make sure the RF frequency response of the mixer will handle the IF frequency requirements.

Disadvantages? Yes. Generally, the linearity characteristic will not be as good as with the signal connected in the conventional manner. Also, there is a danger that transients at the RF port (previously the IF port) can damage the diodes internal to the mixer.

Q. How is DC offset voltage measured?

A. It can be measured statically or dynamically. For a static measurement, terminate the RF port with 50 ohms and apply a signal only to the LO input. Measure the DC at the IF port through a low-pass filter; this is the DC offset voltage.

A disadvantage of the static approach is that any DC offset contributed by the RF input signal is not included.

In a dynamic test, an RF input signal and an LO signal of equal amplitude are applied to their respective ports, with the RF signal slightly offset (10 kHz) from the LO. Then a low pass filter is connected to the IF port to eliminate all frequency components including the 10 kHz difference frequency. Now, the DC offset voltage reading at the low-pass filter output is more accurate since it is measured under typical operating conditions.

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