Interpreting manufacturers' IP3 specifications

I have been searching for broadband MMIC amplifiers for my current work assignment. One of the key specs I am looking for is third order intercept point, since this amplifier will be handling a fairly high signal level. It seems that different manufacturers use different techniques for measuring IP3. Is there a standard method for this measurement, or do I need to find out each company's methods?

No standards, but some common practices

Unfortunately, you will need to examine each company's test procedures. Fortunately, the conditions for testing are almost always noted on the data sheet. Several companies have an extensive collection of application notes and product test practices available on their web sites.

A brief review of IMD testing may be useful—The objective of this type of test is to identify the magnitude of non-linearity in terms of the creation of unwanted signals that are mathematically related to the original signals. The minimum number of input signals that can combine into intermodulation products is two, hence the simplest IMD test is the "two-tone" test. (Some specific products for CATV and multi-channel cellular applications may also have multi-tone tests to show compliance with industry standards, but we'll stick to the basics here.)

Each tone (let's call them f_1 and f_2) is an "original" signal, and thus a *first order* product. *Second order* intermodulation products are the sums and differences in groups of two. These include the second harmonics, $f_1 + f_1$ and $f_2 + f_2$, plus the sum and difference of the two tones, $f_1 + f_2$ and $|f_1 - f_2|$. Using these relationships, we see that two tones at 1000 and 1001 MHz will have second-order products at 2000, 2002, 2001 and 1 MHz, respectively.

Third order intermodulation products are too many to list conveniently, but they follow the same pattern. Typically, the most troublesome third order products are $(f_1 + f_1 - f_2)$ and $(f_2 + f_2 - f_1)$, because they fall close to the frequencies of the original tones. A circuit with poor third order IMD performance will have unwanted spurious signals in the passband, along with the desired signal(s). These products are also convenient for measurement, since a spectrum analyzer display can include the two test tones and the third order products in a fairly narrow span.

The term "intercept point" refers to the fictional amplitude where IMD products would be equal to the input signal level. First, a plot of gain (input versus output at f_1 or f_2) is extended linearly beyond the point where would otherwise flatten out due to amplifier saturation. IMD products, by definition, are not linear. For MMIC amplifiers, we can assume square-law behavior, which means that third order IMD products increase at a slope of three (dB scale), once the input level is sufficient to generate them at an observable level. The intersection of the IMD plot with the linear plot defines the intercept point. IMD levels are almost always referenced to the level of one of the two test tones, not their combined power.

Now, let's move on to industry practices. In our own search, we found that the most common setup for measuring IP3 is with two tones spaced 1 MHz. However, some companies use 10 MHz spacing, and a few products have additional tests at specific frequencies and spacing, usually to measure IMD performance in adjacent or alternate channels. Published specs are universally *output intercept points* (OIP3), not *input intercept points* (IIP3). Subtracting the gain of the device will give you the approximate IIP3.

The difference in measured performance with 1 MHz versus 10 MHz spacing can be small, as long as high quality signal sources and measuring equipment are used. The bandwidth of the measuring equipment (spectrum analyzer or receiver) must be narrow enough to separate each test tone and IMD product. Also, any variation in performance of the device under test must be small over the measurement span.

The good news is that current complex modulation systems have encouraged component companies to refine design and manufacturing processes, creating products with ever-higher intercepts points.

Send your questions by e-mail to:
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A correction

An error was discovered in an equation in the article, "The Twisted-Pair Telephone Transmission Line," by Richard LAO, published in our November 2002 issue. Equation (3) on page 22 should read:

$$u = Z_0^2 = \frac{R' + i\omega L'}{G' + i\omega C'} = \frac{(R' + i\omega L')(G' - i\omega C')}{G'^2 + \omega^2 C'^2}$$

$$= \frac{\left(R'G' + \omega^2 L'C'\right) + i\omega\left(L'G' - R'C'\right)}{G'^2 + \omega^2 C'^2}$$

The $(G' - i\omega C')$ term incorrectly had a "+" sign in the original article.

Comments were also received from readers who suggested that some lines in the TrueBASIC program listing in Table 1 had incorrect syntax. We suggest that you contact the author directly by e-mail at: richard_lao@us.sumida.com for more information on the program.