REDUCING MULTIPLIER LINEARITY ERRORS

CROSS-FEED REDUCES 2nd HARMONIC DISTORTION AND FEEDTHROUGH

by Lewis Counts*

In many transconductance-multiplier designs, the "X" feedthrough error has a pronounced quadratic component. That is, for Y = 0 and X swept over the range ±10V, a crossplot (Figure 1) shows that the output, instead of being zero, is approximately equal to $(A + BX + CX^2)$. A is removed by the conventional offset adjustment and B is removed by the linear feedthrough (Y_O) adjustment, but the remaining term appears to be part of the irreducible nonlinearity of the device. It is one of the major manifestations of linearity error.

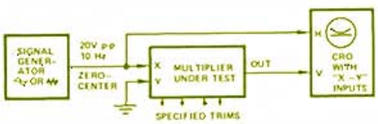

Figure 1. Multiplier "X" feedthrough crossplot test circuit. Horizontal setting: 2V/cm, dc-coupled, zero in center of screen. Vertical setting: 50mV/cm, dc-coupled zero on screen centerline.

The good news is that this feedthrough can be greatly reduced, by factors from 2 to 5, with some improvement to overall X linearity. The slightly-bad news is that it requires an additional "tweak." However, considering that low-cost multipliers, such as the 426, the AD530, and the AD532 can be helped in this manner, an overall cost saving is possible. Figure 2 is a set of "before and after" oscilloscope crossplots that show, rather dramatically, what can be achieved.

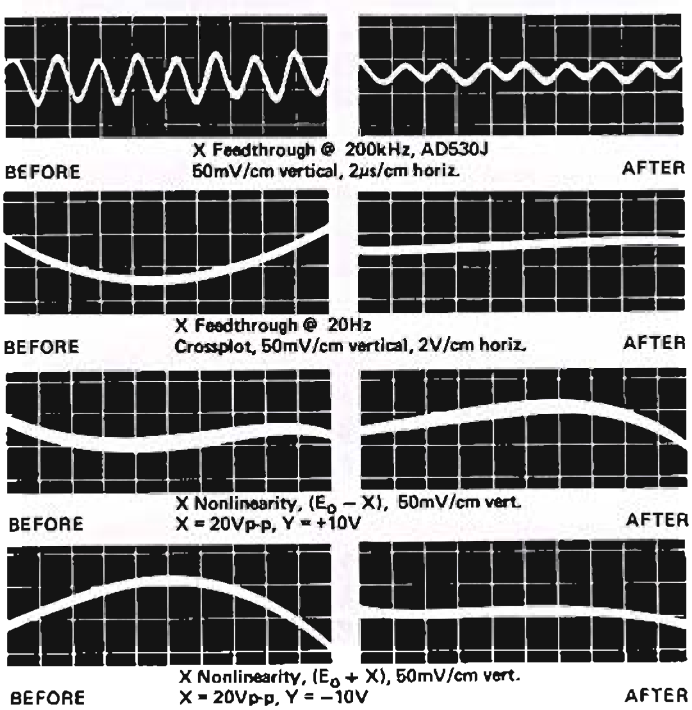

Figure 2. Effect of "X" feedthrough reduction by the cross-feed technique with a typical IC multiplier: AD530J

The "cross-coupling" compensation technique is described rather fully in the *Nonlinear Circuits Handbook* (see p. 19). It will be summarized briefly here. It is evident that the parabolic waveshape with Y = 0 indicates that a small fraction of X, (CX), is, in effect, being coupled into the Y portion of the circuit, resulting in a CX^2 term at the output. The solution, therefore, is to externally feed a small fraction of X (C'X), with opposite polarity, into the Y input, to cancel the internally-coupled increment. This is done, in practice, by first determining from the scope picture what the polarity of the error is (a "smile" is positive, a "frown" is negative). If the error is positive, a small fraction of X is fed into the negative Y input (labeled –Y) or resistively summed into the Y-offset terminal (Y_O or Y_R). If the error is negative, a small fraction of X is summed with Y passively, and the gain is retrimmed to compensate for the slight attenuation of Y. In either case, the X increment is adjusted until the parabolic shape is cancelled.

All normal trims should have been adjusted before this linearization adjustment is performed. The input signals should be at low impedance, and usually are, if they're from op amp outputs. The scheme works for parabolic, but not 3rd order nonlinearity. It can theoretically also be used for Y, but returns are diminishing. Trim circuits for several susceptible ADI multipliers† are shown in Figure 3.

▶▶▶

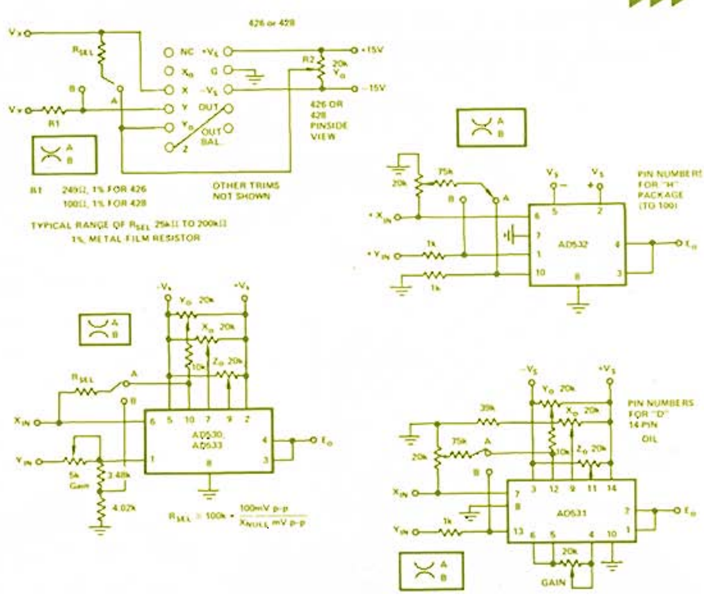

Figure 3. Linearizing circuits for Analog Devices multipliers. "A" connections are to correct for positive feedthrough error. "B" connections correct for negative error.

*Lewis Counts is Manager of Analog-Module Engineering at ADI's Modular Instrumentation Division and the author of chapters on multipliers, dividers, and rms circuits in the *Nonlinear Circuits Handbook*.

†For technical data on these multipliers, request **L14**.