DISTORTION IN POSITIVE AND NEGATIVE FEEDBACK FILTERS

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ABSTRACT

It is known that the harmonic distortion of an active filter is greater than the distortion of the operational amplifier itself. This paper analyzes positive and negative feedback linear filters; Butterworth, Chebyshev, Bessel and bandpass filters. The distortion multiplication factor is defined (K_d) and it is plotted versus frequency. Through a computer calculation program, the maximum values of K_d found for several filters configurations, will be given in an useful way for filter designers.

INTRODUCTION

The fact that the harmonic distortion in a positive feedback active filter (PF) is much greater than the distortion in its operational amplifier is not new for any of us (1). The closest to the filter's cutoff frequency, the biggest the increase of distortion. Distortion can be increased up to two orders of magnitude. Consequently, it has been suggested that the unpleasant auditive sensation caused by some filters is due to this fact, and not to the excessive phase rotation usually associated with high slope filters.

This conclusion has been applied to negative feedback active filters (NF) in a previous publication (2), but the results of this work are not easily applicable to the improvement of filter design, since they involve the solving of complex equations.

Our investigation has a twofold goal: First, we want to find simple equations which will enable the designer to quickly estimate the increase of distortion in each filter; Second, we try to make the method as widely applicable as possible, so that it holds for filters not included in this paper, as well as for filters to be developed in the future.

DISTORTION MULTIPLICATION FACTOR

The definition of a distortion multiplication factor will help us to quickly estimate the particular behaviour of each filter. We will call it K_d and it will be expressed in dB for ease of notation and calculus.

Then,

$$K_d\,(f) = 20 \log \frac{\text{Distortion of the active filter at the frequency "F"}}{\text{Distortion of the operational amplifier with g=1}} \quad \ldots\ldots (1)$$

It is evident that K_d (f) will depend on the frequency (see Fig. 13).

In this work, as it will be explained later on, it is demonstrated that the behaviour of K_d (f) is represented by a bell shaped curve, which has its maximum value near the filter cutoff frequency, f3. This holds not only for low-pass or high-pass filters, but also for bandpass filters at the center frequency, fo.

Then we can concentrate only in the maximum value of coefficient Kd (f). Thus, we are transforming a problem of complex solution into another much simpler, which consists in determining the maximum distortion to be obtained with each filter configuration. We know beforehand that for all filters this value will be near f3 or fo.

Then,

$$Kd = \left[Kd(f) \right]_{max.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$