September 10 - 12, 2003
Pilsen, Czech Republic

A NEW TICGA APPROXIMATION

DOC. ING. KAREL HÁJEK, CSC.[1]
DOC. ING. JIŘÍ SEDLÁČEK, CSC.[2]
ING. ZDENĚK ZAPLETAL[3]

Abstract: An approach is presented for solving the approximation problem as required for the filter design that simultaneously produces flat pass-band amplitude characteristics and relatively constant group delay with equiripple amplitude characteristics in stop-band. A new transitional kind of approximation (TICGA-**T**ransitional **I**nverse **C**hebyshev – **Ga**uss with zeroes) enables to design a filter with required responses in range between Inverse Chebyshev and Gauss with transfer zeroes approximation types very easily.

Keywords: filter, transitional, approximation ,amplitude , step response, group delay, equiripple, pass-band, stop-band, transfer function zeros

1 Introduction

Many types of signal transmission systems require such accurate recovery of information that distortion of any kind is a problem. One important problem area is time distortion, or varying group delay, where the different frequency components of a signal experience unequal transit times. Circuit design engineers are asked to reduce distortion in systems as performance demands escalate.

A suitable compromise, which is able to solve the above problem in a simple way can be a transitional approximation types as Thomson - Butterworth, or TICFU approximation [1], [2]. Using transitional approximation types with inserted transmission zeros many filter requirements may be solved.

However using of Thomson or TICFU approximation type, which brings improvement of the amplitude characteristic's steepness, is not already ideal

[1] Department of Electronic Engineering, Military Academy Brno, Kounicova 65, 612 00 Brno
[2] Department of Electrical Engineering, VUT FEKT Brno, Purkyňova 118, 612 00 Brno, Czech Republic
[3] Department of Electrical Engineering, VUT FEKT Brno, Purkyňova 118, 612 00 Brno, Czech Republic

solution in a very strict requirements in area of time response. The new TICGA transitional approximation type with transfer function zeros in the stop-band enables (by means of a suitable coefficient transformation) to choose a proper transfer filter responses in all the area between Gauss with inserted transmission zeroes and Inverse Chebyshev approximation types.

2 The filter design algorithm

The transfer function of a reactance low - pass filter can be written as

$$H(p)=k\frac{(a_n s_n + a_{n-1} s_{n-1} + a_{n-2} s_{n-2} + \ldots\ldots + a_0)}{(s^2+\omega_1^2)(s^2+\omega_2^2)\ldots\ldots(s^2+\omega_m^2)} = k\frac{h(s)}{f(s)} \qquad (1)$$

in terms of complex frequency s, where h(s) is the transitional polynomial, f(s) is a polynomial which presents transfer function zeros in stop-band. The transitional polynomial h(s) can be obtained from the known Gauss (p_G) and Inverse Chebyshev pole location (p_{IC}) - see Fig 1. The actual pole location depends on the transformation coefficient m and may be prescribed by

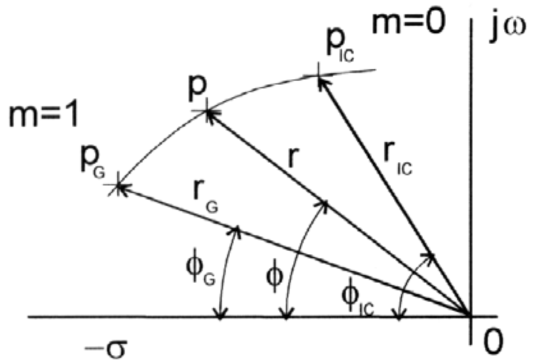


Fig.1 The filter pole location

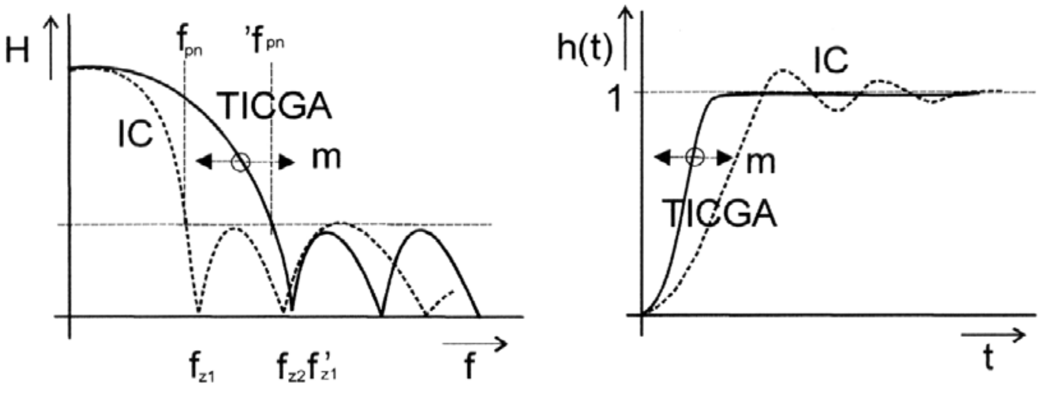
the following formulas:

$$r = r_{IC}^{1-m}\, r_T^{m}, \qquad (2)$$

$$\Phi = \Phi_{IC} - m(\Phi_{IC} - \Phi_T)\,, \qquad (3)$$

where Φ and r are co - ordinate of the given pole location. Resulting pole location (p) of the TICGA approximation determines frequency and time domain filter properties in range from the Gauss with zeroes (m = 1) to Inverse Chebyshev approximation (m = 0).The transfer zero locations of the f(s) function from eq. (1) were calculated for condition of the equiripple amplitude characteristic by means of a numeric iterative method.

As it is seen from Fig. 2, the approximation type with required parameters (consequently the required filter responses in frequency and time area) can be chosen by means of the value of the m coefficient selection during synthesis process very easily. Thus the transitional filter may be designed with optimum compromise properties simultaneously in frequency and time domain and it leads in many cases to desired optimisation of the filter prototype design. In comparison to transitional TICFU approximation [2] enable the TICGA approximation type to achieve better filter parameters in time domain (namely in a case m=1 shorter impulse rise time and step response without overshoot).



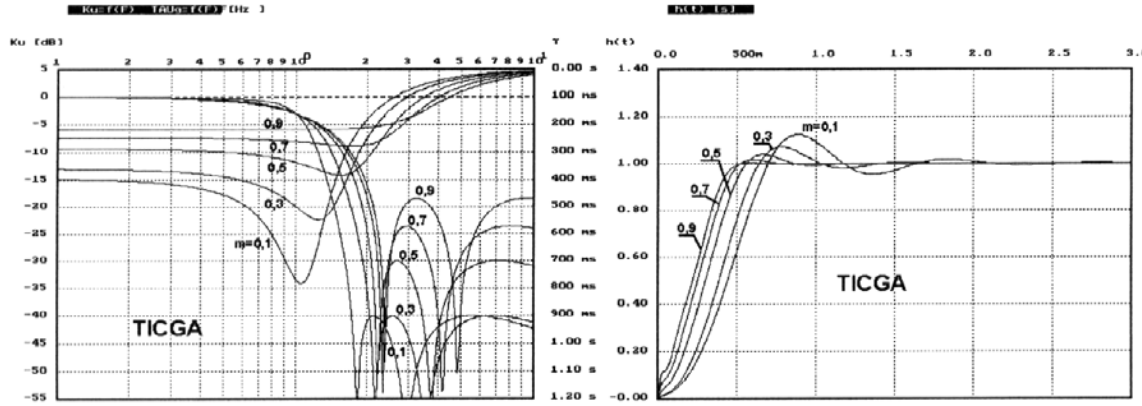
a) b)

Fig.2 The effect of filter m transformation coefficient selection

3 The TICFU approximation parameters

The algorithm of filter design presented above was implemented into a flexible PC design methodology which permits the designer to quickly and very simply to find the desired transfer function that fulfils requirements for pass-band group delay and amplitude characteristics as well as stop-band attenuation. The transformed and non-transformed approximation types can be designed for the cases of the even order LC ladder filter too.

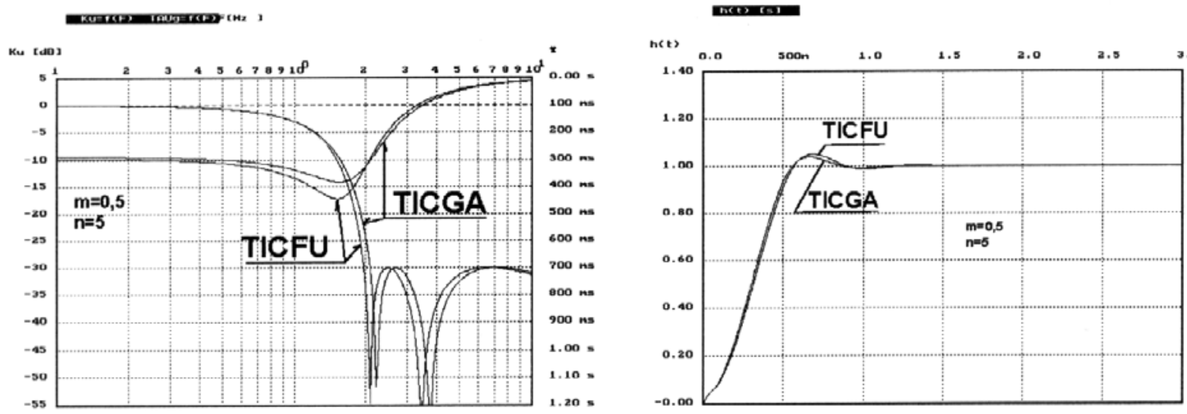
The examples of TICGA filter responses in the frequency and time domain (the filter order n=5) for the different coefficient of transformation m are shown in Fig 3a,b. A comparison was made between transitional TICFU and new transitional TICGA approximation. As it is seen in Fig. 4, the new TICGA approximation for most often used coefficient of transformation m=0.5 exhibit better properties in time domain and worse properties in frequency domain.



a) b)

Fig.3. TICGA approximation (n=5) responses in frequency and time domain

Similarly like TICFU also new transitional TICGA approximation enables by excellent filter properties in time domain to use the lower filter order and better filter steepness in transition - band in comparison to Gauss approximation type.



a) b)

Fig.4. The comparison of TICFU and TICGA approximations (n=5) types in frequency and time domain

The higher order filter design (n>5) is non-effective for a small filter attenuation (<30 dB), because steepness of the amplitude characteristics for higher orders is not higher here.

Conclusion

The paper presents the design of the new transitional approximation type when designing a filter with strictly constant group delay and step response without overshoot is wanted. Another important feature is a possibility to choose a suitable compromise between filter characteristics in frequency and time domain as it is often required. The new approximation type enriches hitherto class of the transitional types on the class of the transitional approximation types with equiripple amplitude response in stop – band.

This work has been supported by the Grant Agency of the Czech Republic under Grant 102/03/1181, 102/01/0228.

References

[1] Peles,Y.-MuRrakami,T.: Analysis and synthesis of transitional Butterworth -Thomson Filters and bandpass amplifiers. RCA Review, March 1957, pp. 60 - 94.

[2] Feistel,K.H.- Unbehauen,R.: Tiefpasse mit Tschebyscheff - Charakter der Betriebs - dampfung im Sperrbereich und maximal geebnete Laufzeit. Frequenz, 19, 1965, č.8.

[3] Feistel,K.H.- Unbehauen,R.: Tiefpasse mit Tschebyscheff - Chara- kter der Betriebs - dampfung im Sperrbereich und maximal geebnete Laufzeit. Frequenz, 19, 1965, č.8.

[4] Hájek,K.-Sedláček,J.: A New TICFU Transitional Approximation. Proceedings ECCTD 95 , Istanbul 1995, pp.913-916.