ELE509E
Current-Mode Analog Circuit Design
Homework 4 (07.12.2009)

Starting from the voltage mode filter topology shown in Fig.1, design a current-mode 6th order elliptic filter using adjoint network theorem, employing current amplifiers. The related transfer function is given by

$$H(s)=\frac{H_1(s^2+\omega_{Z1}^2)}{s^2+\frac{\omega_{P1}}{Q_{P1}}s+\omega_{P1}^2}\,\frac{H_2(s^2+\omega_{Z2}^2)}{s^2+\frac{\omega_{P2}}{Q_{P2}}s+\omega_{P2}^2}\,\frac{H_3\omega_{P3}^2}{s^2+\frac{\omega_{P3}}{Q_{P3}}s+\omega_{P3}^2}$$

To obtain a 3.5 MHz cut-off frequency, the related pole, zero and quality factor values are specified as

f_{P1} = 3.6 MHz, f_{Z1} = 4.5 MHz, Q_{P1} = 5.7, f_{P2} = 3.3MHz, f_{Z2} = 5.78MHz, Q_{P2} = 1.53, f_{P3} = 2.74MHz, Q_{P3} = 0.58.

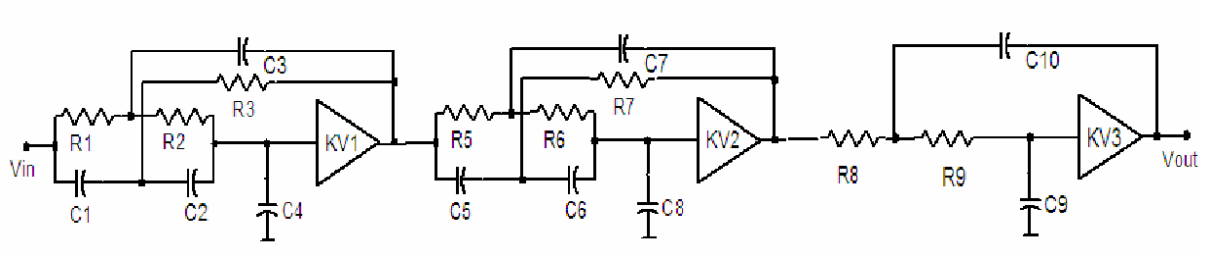

Fig.1. Voltage-mode 6th order elliptic filter for video frequency range.

The complete filter in Fig.1 consists of two LP notch sections and one LP section. The filter circuit is realized employing voltage amplifiers K_{V1} = 1.07, K_{V2} = 1.23 and K_{V3} = 1, respectively. The component values are specified as

C1 = C2 = 6.8pF, C3 = 13.6pF, C4 = 1.8pF, C5 = C6 = 5.6pF, C7 = 11.2pf, C8 = 5.6pF, C9= 10pF, C10 = 13pF, R1 = R2 = R5 = R6 = R8 = R9 = 5kOhm, R3 = R7 = 2.5kOhm

a- Using adjoint network theorem, derive the current-mode equivalent of the circuit given in Fig.1.
b- Design CMOS current amplifiers for the current-mode video filter realization. Use a current buffer at the output. Choose an adequate CMOS current amplifier structure for each stage, determine the transistor aspect ratios to obtain the required gains.
c- Choose adequate supply voltages.

Using SPICE simulation program:

d- Draw the input-output characteristic of each current amplifier, specify the operating limits.
e- Draw the frequency response of the current amplifiers.

f- Draw the frequency responses of the second-order sections i_{out1}/i_{in}, i_{out2}/i_{out1}, i_{out}/i_{out2} and the frequency response of the total filter circuit i_{out}/i_{in} (ideal and actual responses together).

Investigate the large signal response of the designed filter:

g- Apply a sinusoidal input current in the passband to the input and observe the total harmonic distortion THD at the output for different input levels; draw the plot of THD against i_{out}. (Connect an adequate load resistance to the output terminal).

h- investigate the dependence of the output voltage upon the load resistance R_L keeping the input level constant at a low distortion level, observe the harmonic distortion THD at the output for each load resistance value; draw the plot of V_O against R_L.

i- Give a detailed evaluation of your results. Specify the advantages and disadvantages of the designed circuit.

References:

- *A. Uygur and H. Kuntman, A High Performance CMOS Opamp and An LP Filter Design Example for Video Applications, WSEAS Transactions on Circuits and Systems, Issue 2, Vol. 2, pp.404-408, 2003.*
- *A. Uygur, H. Kuntman, Yüksek başarımlı bir CMOS işlemsel kuvvetlendirici gerçekleştirilmesi ve aktif süzgeç tasarımına uygulanması, Elektrik-Elektronik-Bilgisayar Müh. 10. Ulusal Kongresi Bildiri Kitabı, Cilt II, 259-262, İstanbul Teknik Üniversitesi-EMO İstanbul Şubesi, 18-21 Eylül, İstanbul, 2003.*
- *C. Toumazou, F.J. Lidgey, D.G. Haigh (ed.), Analog IC design: the current-mode approach, Peter Peregrinus Ltd., 1998.*