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A current-mode circuit without external passive elements

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Abstract: *This paper presents a current-mode circuit with no external passive elements. The proposed circuit is solely constructed with operational amplifiers (OAs) and operational trans-conductance amplifiers (OTAs). This circuit can realize high-pass response, and the circuit response can be tuned electronically through adjusting the trans-conductance gains of the OTAs. A design example is given together with simulation result by PSPICE.*

Key words: *current-mode circuit, high-pass characteristic, OAs, OTAs, CMOS technology*

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I. Introduction

The design of active circuits with high performances has received much attention. In the designs, current-mode circuits are becoming popular, since they have many advantages compared with their voltage-mode counterparts. The designs of the current-mode circuits employing active devices such as the OAs, OTAs and second generation current conveyors (CCIIs) have been reported in the literature [1]-[6].

It is well known that the circuits utilizing the finite and complex nature of the OA gain are suitable for high frequency operation. However, as the OA is a voltage controlled voltage source, the dynamic range of the OA-based circuits depends upon the loading conditions. On the other hand, since both OTAs and CCIIs have current output sources, they present no such problems as the OAs. Furthermore, the OTA provides highly linear electronic tunability and wide tunable range of its trans-conductance gain.

Usually, the circuit circuits are synthesized by active-R, active-C and active-RC techniques. The circuit configurations [7],[8] with no external passive elements are very attractive, and are more suitable for monolithic integration than the ones based on above syntheses. However, such circuit design has not sufficiently been studied as yet.

This paper focuses on a synthesis of such current-mode circuit mentioned above. The proposed circuit is constructed solely with the OAs and OTAs. The circuit enables the high-pass response, and that the circuit characteristic can be tuned electronically through adjusting the trans-conductance gains of the OTAs.

As an example, third-order Butterworth circuit is given with the simulation result by PSPICE. The workability was confirmed.

II. Circuit configuration and analysis

Figure 1 shows the proposed circuit configuration. The circuit has been solely constructed with the OAs and OTAs.

Assuming the open-loop gain $A_i(s)$ of the OA to be of the following form, where B_i is the gain-bandwidth product,

$$A_i(s) = \frac{B_i}{s} \qquad (i = 1,2,\cdots,N) \qquad (1)$$

the circuit transfer function $T(s)(=I_{out}(s)/I_{in}(s))$ is given by

$$T(s) = \frac{Hs^N}{s^N + \sum_{i=1}^{N} a_i s^{N-i}} \qquad (2)$$

where

$$\left.\begin{aligned} a_{N-i} &= \sum_{j=i}^{N} \frac{g_{mj}}{g_{m0}} \prod_{k=j-(i-1)}^{j} B_k \\ H &= 1.0 \end{aligned}\right\} \quad (3)$$

In (3), g_{mx} denotes the trans-conductance gain of the OTA. Equations (2) and (3) show that the high-pass transfer function. And it is found that the circuit characteristic can be tuned electronically by adjusting the trans-conductance gains.

The way to implement a dual current output OTA have been discussed in the past [3],[4].

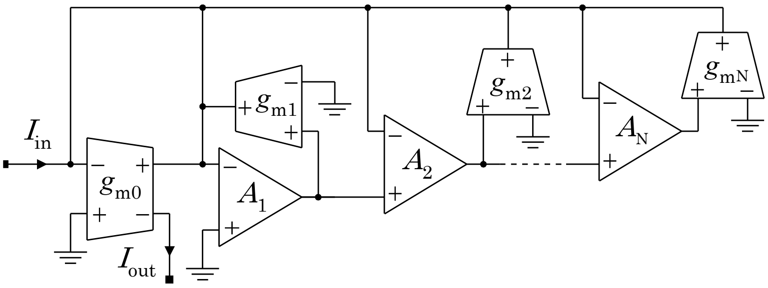

Figure 1: Current-mode circuit configuration.

III. Design example and simulation result

As an example, let us design third-order Butterworth high-pass circuit. From (2), the circuit transfer function is given by

$$T(s) = \frac{Hs^3}{s^3 + a_2 s^2 + a_1 s + a_0} \quad (4)$$

In PSPICE simulation, we use a macro model [3] for a CA3080 OTA shown in Fig.2. Here, it is assumed that the parameters of the OTA are g_{ni}=10.0μS, C_{ni}=2.6pF, g_{no}=14.3nS and C_{no}=3.6pF, respectively. Under a LF356 OA, the gain-bandwidth product B_i takes the value of $2\pi\times(6.392)\times10^6$rad/sec. When the trans-conductance listed in Table 1 are used, the circuit has Butterworth characteristic with the cut-off frequency f_c=100kHz and the gain constant H=1.0. For proper circuit operation, the proportional blocks using the OTAs shown in Fig.3 are added at the output terminals of the OAs.

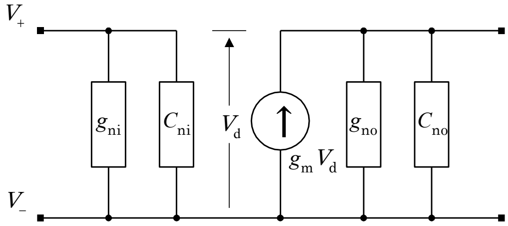

Figure 2: Macro model of CA3080 OTA.

Table 1 Trans-conductance gains.

g_{mx}	Value (mS)	g_{mx}	Value (mS)
g_{m0}	2.00	g_{m12}	2.00
g_{m1}	0.860	g_{m21}	0.10
g_{m2}	0.330	g_{m22}	2.00
g_{m3}	6.126×10^{-2}	g_{m31}	0.10
g_{m11}	0.10	g_{m32}	2.00

Figure 4 shows the simulation responses with PSPICE. The simulated result is quite good over a wide frequency range. In this simulation, the dual current output OTA has been constructed with single-ended OTAs in parallel connections.

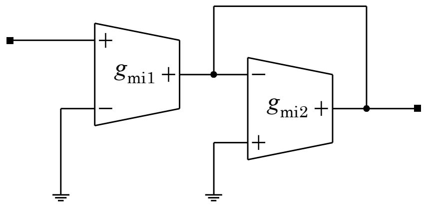

Figure 3: Proportional block with OTAs.

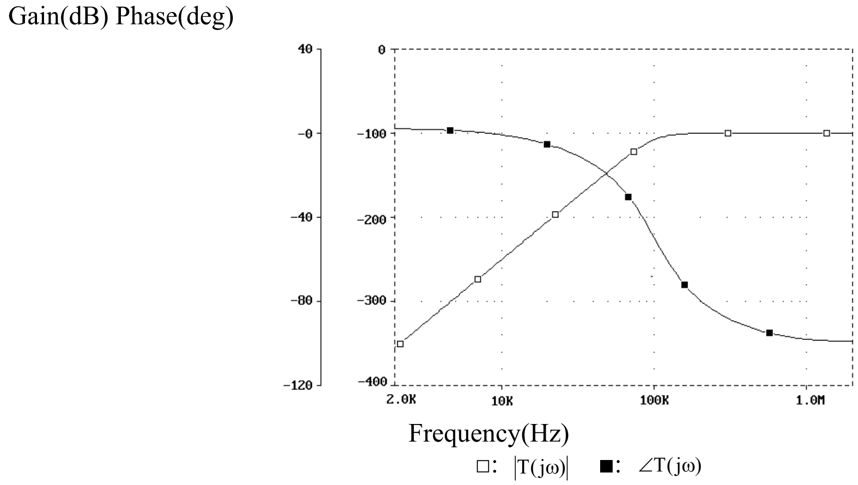

Figure 4: Simulation responses.

IV. Conclusions

A current-mode high-pass circuit using OAs and OTAs has been proposed. It has been shown that the proposed circuit provides electronically tuning capability of the circuit characteristic through adjusting the trans-conductance gains of the OTAs. In PSPICE simulation, the simulation responses have been quite good over a wide frequency range.

The effects of the non-idealities of the OA and OTA on the circuit characteristic must be discussed further. The work on this will be presented in the near future.

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