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Current-Mode Active-Only Universal Filter Employing CCIIs and OTAs

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Outline

- Introduction
- Active-only Current-mode Integrators Using CCIIs
- Proposed Active-only Filter Circuit
- Simulation Results
- Conclusions
- References

Introduction

- Several continuous-time filter designs without using external passive elements are reported in the literature [1-11].
- These circuits are referred to as active-only filters and use voltage operational amplifiers (VOAs) together with operational transconductance amplifiers (OTAs) and current conveyors (CCIIs).
- However, parasitic capacitances of another building blocks can also be utilized for designing active-only circuits. For example, the terminal impedances of CCIIs can be also taken into consideration.
- In this study, a new active-only filter that employs the parasitic capacitances of CCIIs is presented which provides lowpass, bandpass, highpass and bandstop responses simultaneously.

Active-only Current-mode Integrator Using only CCIIs

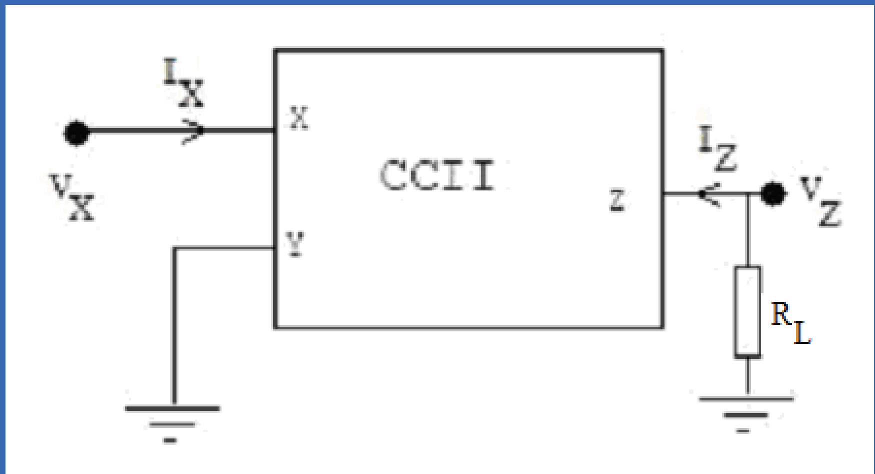

Fig. 1a.Current-mode Active-only Integrator-1

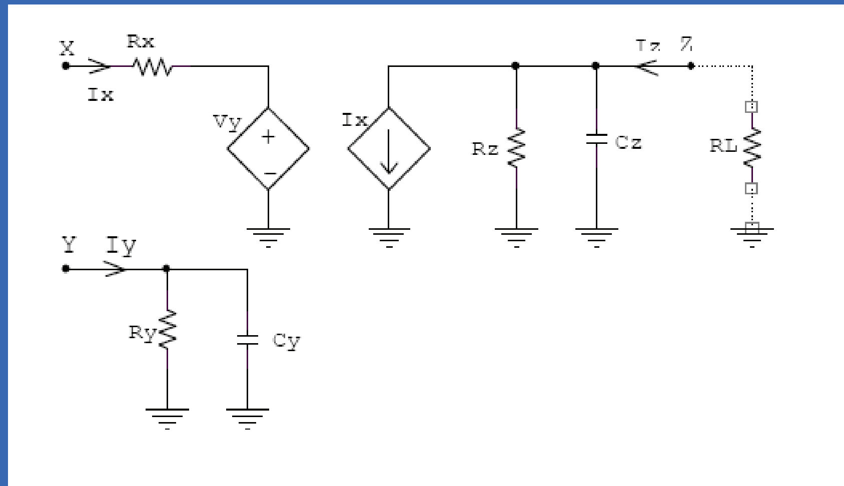

Fig. 1b.Equivalent of the circuit of Fig. 1a

$$\frac{I_Z}{I_X} = \frac{1}{R_L C_Z}\left[\frac{1}{s+\omega_Z}\right] \quad (1)$$

$\omega >> \omega_Z$

$$\frac{I_Z}{I_X} = \frac{1}{R_L C_Z}\left[\frac{1}{s}\right] = \frac{K}{s} \quad (2)$$

$$K = \frac{1}{R_L C_Z} \quad (3)$$

Active-only Current-mode Integrator Using only CCIIs *(Cont'd)*

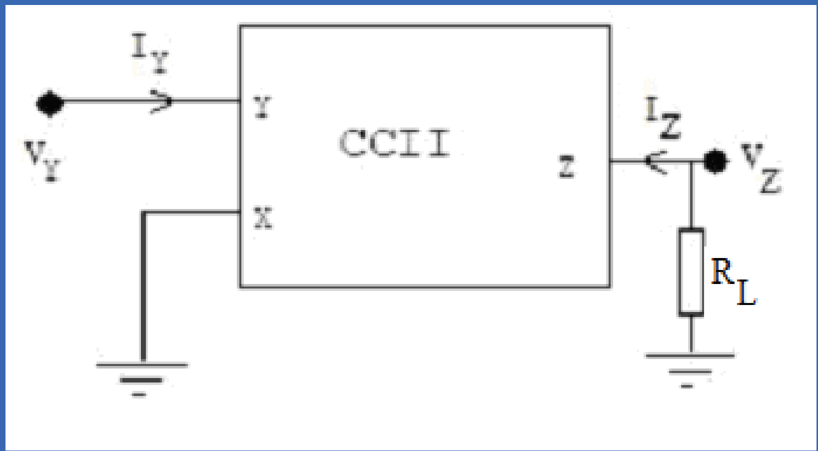

Fig. 2a.Current-mode Active-only Integrator-2

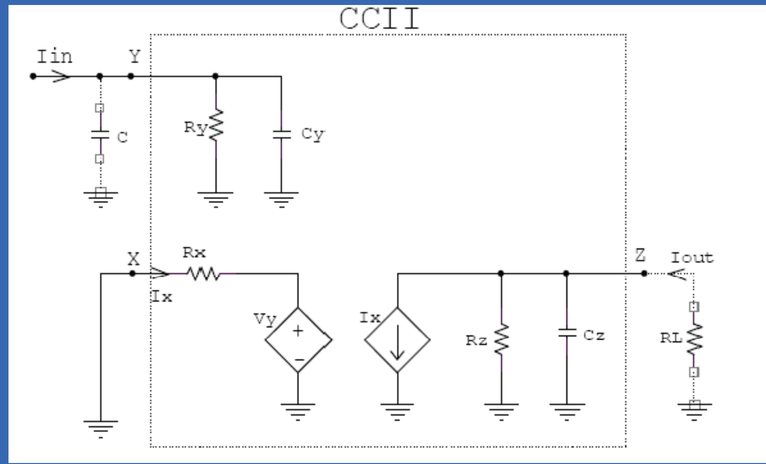

Fig. 2b.Equivalent of the circuit of Fig. 2a

$$\frac{I_Y}{I_Z} = \frac{1}{R_X C_Z}\left[\frac{1}{s+\omega_Z}\right] \quad (4)$$

$\omega >> \omega_Z$ →

$$\frac{I_Y}{I_Z} = \frac{K}{s} \quad (5)$$

$$K = \frac{1}{R_X C_Z} \quad (6)$$

Proposed Active-only Filter Circuit *(Cont'd)*

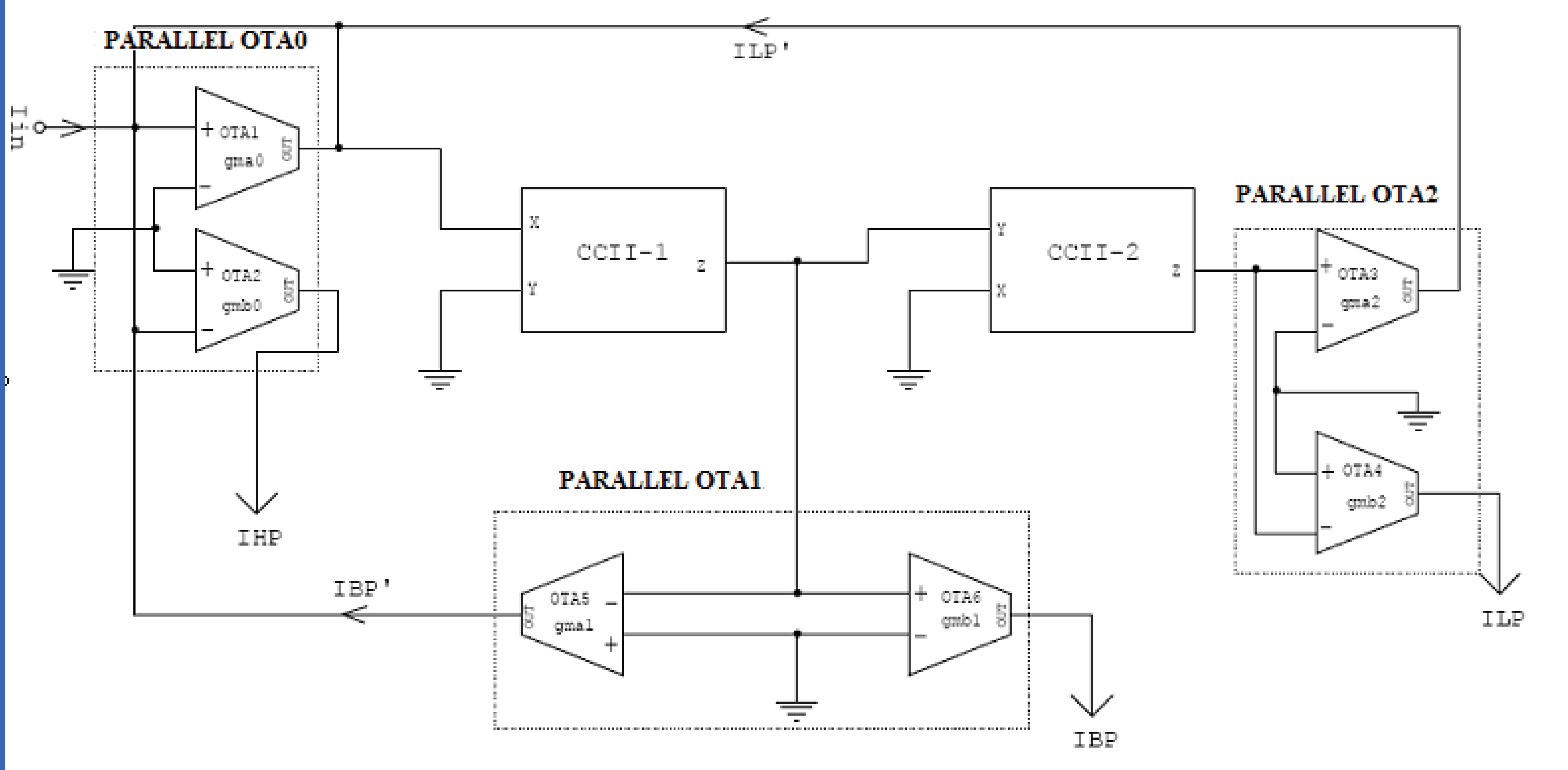

Fig. 3. Proposed active-only filter circuit

Proposed Active-only Filter Circuit *(Cont'd)*

- In the proposed filter circuit, OTAs are used for adjusting the filter parameters and outputting the currents from high-impedance nodes.
- If the integration constant of $CCII_1$ is K_1, and $CCII_2$ is K_2:

$$T_{LP}(s) = \frac{I_{LP}(s)}{I_{in}(s)} = \frac{g_{mb2}K_1K_2}{g_{ma0}s^2 + g_{ma1}K_1 s + g_{ma2}K_1K_2} \quad (7a)$$

$$T_{HP}(s) = \frac{I_{HP}(s)}{I_{in}(s)} = \frac{g_{ma0}s^2}{g_{ma0}s^2 + g_{ma1}K_1 s + g_{ma2}K_1K_2} \quad (7c)$$

$$T_{BP}(s) = \frac{I_{BP}(s)}{I_{in}(s)} = \frac{g_{ma1}K_1 s}{g_{ma0}s^2 + g_{ma1}K_1 s + g_{ma2}K_1K_2} \quad (7b)$$

$$T_{BS}(s) = \frac{I_{BS}(s)}{I_{in}(s)} = \frac{g_{ma0}s^2 + g_{ma2}K_1K_2}{g_{ma0}s^2 + g_{ma1}K_1 s + g_{ma2}K_1K_2} \quad (7d)$$

$$\omega_0 = \sqrt{\frac{g_{ma2}K_1K_1}{g_{ma0}}} \quad (8)$$

$$Q = \frac{1}{g_{ma1}}\sqrt{\frac{g_{ma0}g_{ma2}K_2}{K_1}} \quad (9)$$

Simulation Results

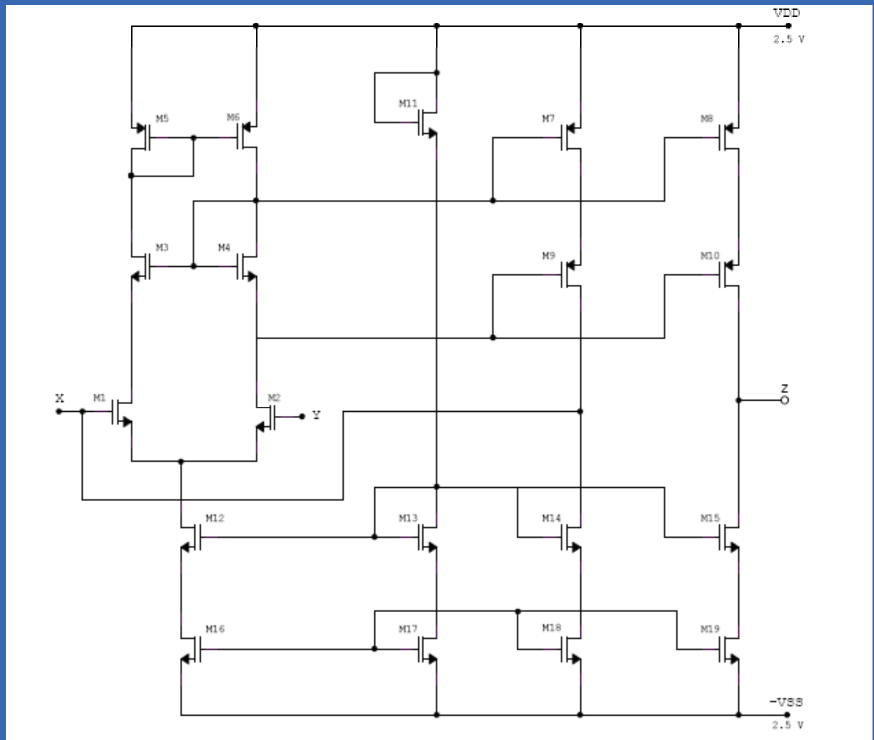

Fig. 4 CMOS CCII circuit used in simulations

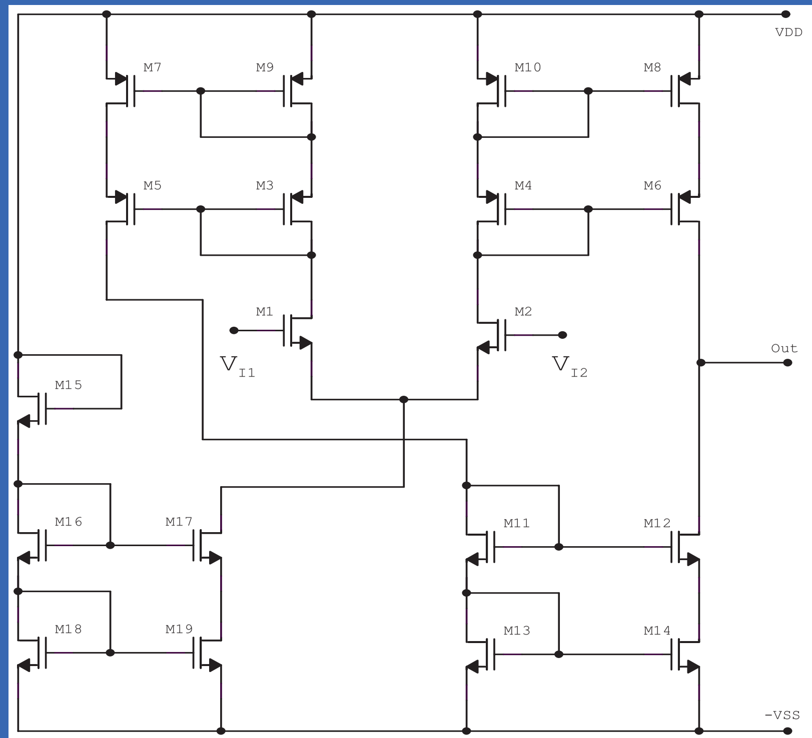

Fig. 5 CMOS OTA circuit used in simulations

Simulation Results *(Cont'd)*

Transistor	W(µm)	L(µm)
M1-M4	10	4
M5-M6	25	2
M7-M10	25	1
M11	85	1
M12-M19	55	1

Table 1. CCII circuit MOS dimensions

Transistor	W(µm)	L(µm)
M1-M2	5	1
M3-M10	15	1
M11-M14	10	1

Table 2 OTA circuit MOS dimensions

Simulation Results *(Cont'd)*

- MIETEC 0.5μm CMOS process parameters are used in simulations.
- Supply voltages of all elements are selected as ±2.5V.
- The obtained filter characteristics for different control currents (I_1 is the control current of OTAs with g_{m1}, I_2 is the control current of OTAs with g_{m2}) are shown in Figs. 6a, 6b and 6c.

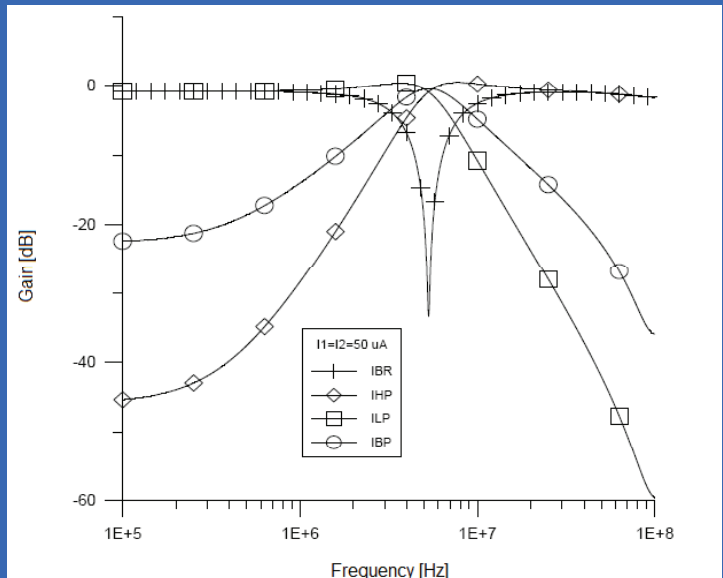

Fig. 6a. Filter characteristics for $I_1=I_2=50\mu A$ (5.3MHz pole frequency is obtained from simulations)

Simulation Results *(Cont'd)*

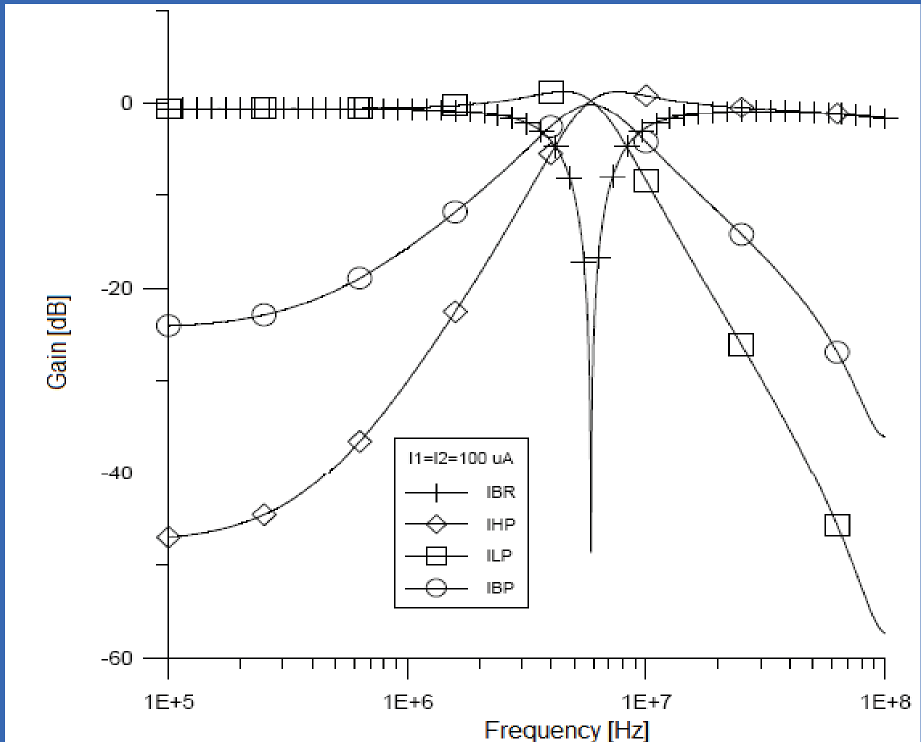

Fig. 6b.Filter characteristics for $I_1=I_2=100\ \mu A$ (5.87MHz pole frequency is obtained from simulations)

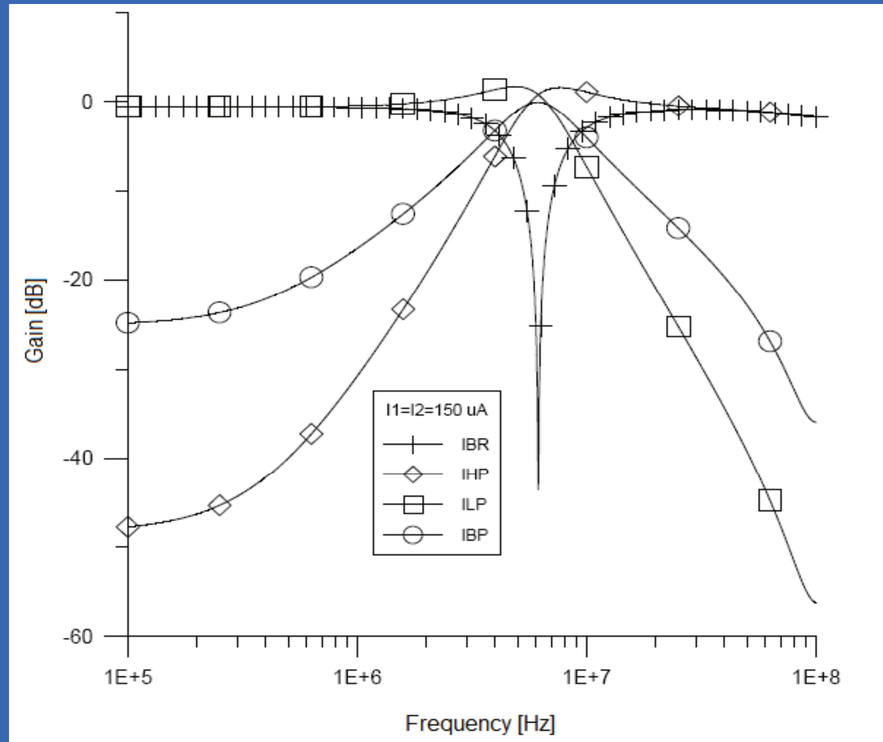

Fig. 6c.Filter characteristics for $I_1=I_2=150\mu A$ (6.2MHz pole frequency is obtained from simulations)

Simulation Results *(Cont'd)*

• The variation of the pole frequency by adjusting the biasing currents of OTAs is obtained, given in Table 3 and plotted in Fig.7, respectively.

$I_0[\mu A]$	$I_1\ [\mu A]$	$I_2\ [\mu A]$	f_0 (MHz)
50	50	50	5.3
100	100	100	5.87
150	150	150	6.2
200	200	200	6.35
250	250	250	6.47
300	300	300	6.58
350	350	350	6.74

Table 3. Pole frequencies of the filter for various control currents

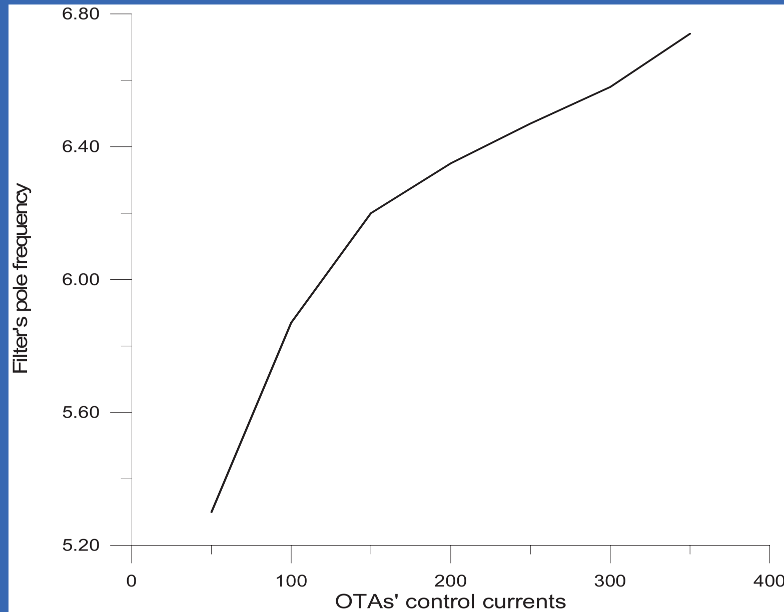

Fig. 7 Variation of pole frequency versus control current

Simulation Results *(Cont'd)*

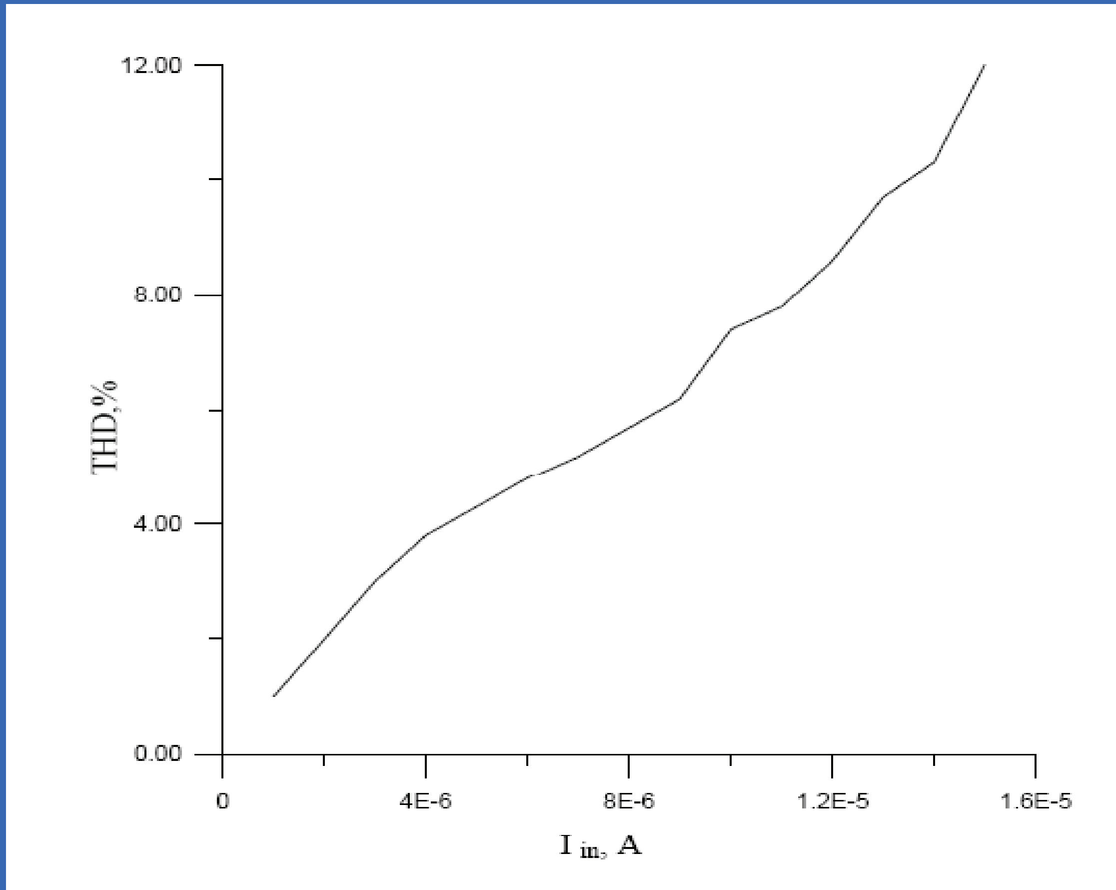

Fig. 8.THD introduced by the presented circuit versus input current amplitude at 5.3MHz

Conclusions

Novel active-only current-mode filter circuit is presented with the following properties:

- It employs CCIIs as integrating active elements instead of op-amps,
- It uses low number of integrator elements (Two CCIIs in open-loop),
- It gives simultaneous output currents for lowpass, bandpass, highpass and bandstop responses, thus being a universal filter,
- Output currents are taken from high-impedance nodes (OTAs' outputs),
- Input current is given to input of low-impedance node,
- Pole frequency and quality factor of the filter can be tuned electronically and independently,
- SPICE simulation results of the proposed filter verify the proper operation of the circuit and also the advantage of electronically tuneability.
- From the SPICE simulations, it is found that the circuit provides electronically tuneability from 5.3MHz to 6.74MHz. Moreover, the bandstop response provides more than 45dB attenuation.

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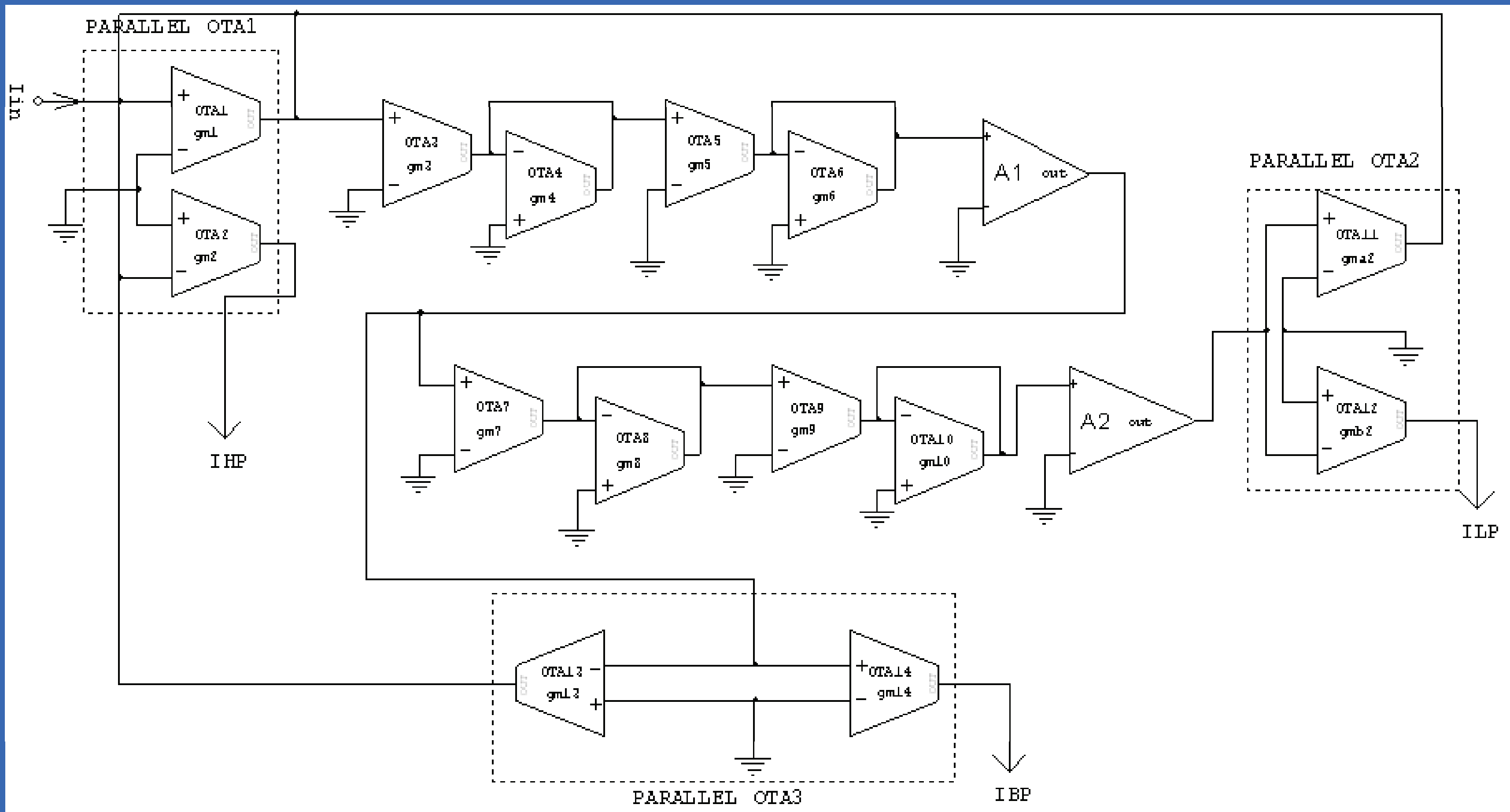
- Thank you for your attending
- and listening!

- Any questions?

- **Proposed Filter Topology (AE’ 2008)**



- Proposed active-only universal current-mode filter (OTAs –OP-AMPs)

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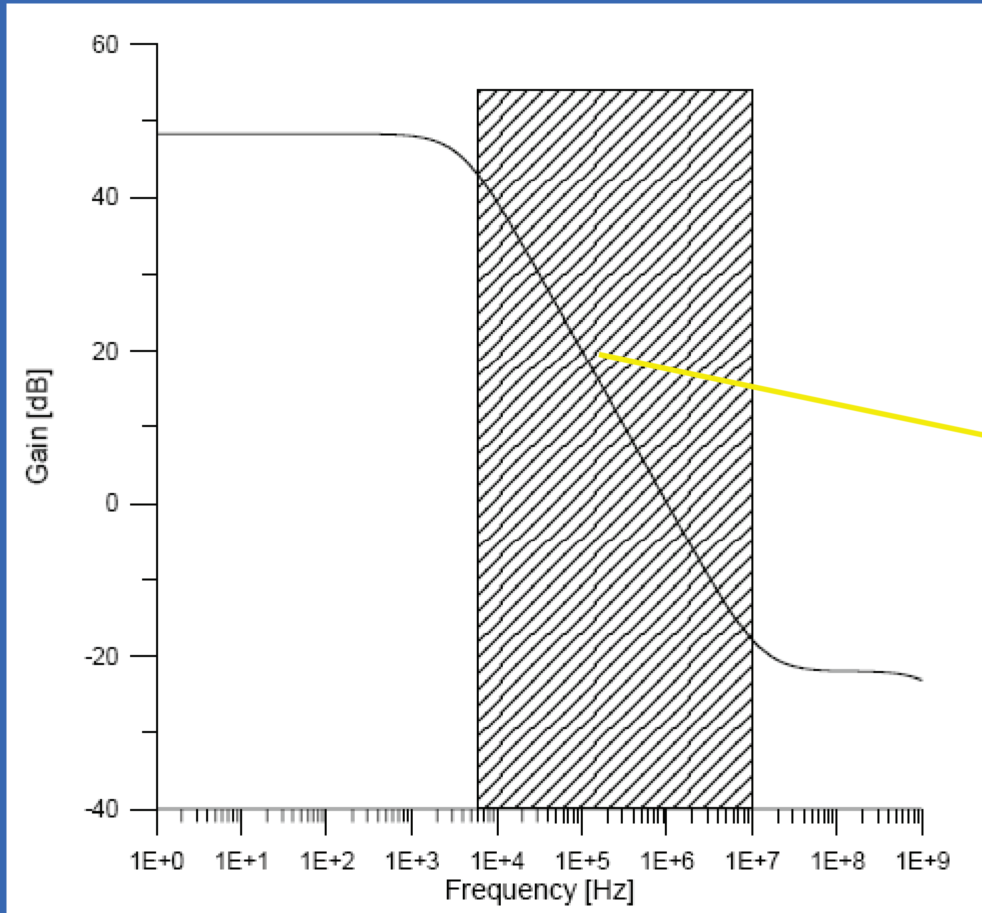
- The filter utilizes opamps with internal compensation capacitors which
- have a frequency characteristics (AE'2008)



$$A_i(s) = B/s$$

- Open-loop gain-frequency characteristics of a CMOS
- operational amplifier

```
.MODEL N NMOS LEVEL=3
+UO=460.5 TOX=1.0E-8 TPG=1 VTO=.62 JS=1.8E-6
+XJ=.15E-6 RS=417 RSH=2.73 LD=0.04E-6  VMAX=130E3
+NSUB=1.71E17 PB=.761 ETA=0 THETA=0.129 PHI=0.905
+GAMMA=0.69 KAPPA=0.1 CJ=76.4E-5  MJ=0.357  CJSW=5.68E-10
+MJSW=.302 CGSO=1.38E-10 CGDO=1.38E-10 CGBO=3.45E-10
+KF=3.07E-28 AF=1 WD=.11E-6 DELTA=0.42  NFS=1.2E11

.MODEL P PMOS LEVEL=3
+UO=100 TOX=1E-8 TPG=1 VTO=-.58 JS=.38E-6
+XJ=0.1E-6 RS=886 RSH=1.81 LD=0.03E-6  VMAX=113E3
+NSUB=2.08E17 PB=.911 ETA=0 THETA=0.120 PHI=0.905
+GAMMA=0.76 KAPPA=2 CJ=85E-5  MJ=0.429  CJSW=4.67E-10
+MJSW=.631 CGSO=1.38E-10 CGDO=1.38E-10 CGBO=3.45E-10
+KF=1.08E-29 AF=1 WD=.14E-6 DELTA=0.81  NFS=0.52E11
```

- MIETEC 0.5µm SPICE parameters