Second-Generation Current Controlled Conveyor (CCCII)

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Second-Generation Current Controlled Conveyor (CCCII)

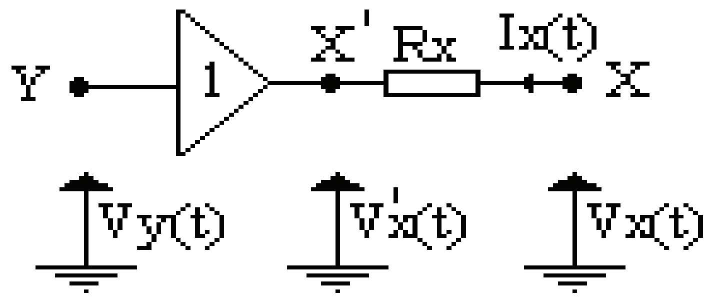
- Several current-mode filters using current conveyors have been proposed in the literature.
- *However, most of these filters suffer from the lack of electronic adjustability.*
- A current-mode filter theoretically should exhibit high output impedance to enable easy cascadability
- to enable additional filter responses by simply connecting the outputs.

Second-Generation Current Controlled Conveyor (CCCII)

- By using the second-generation current controlled conveyor (CCCII) introduced by Fabre *et al. (1995), current conveyor applications can be extended to the domain* of electronically adjustable functions.

- Electronic adjustability of the CCCII is attributed to the dependence of the parasitic resistance at port *x on the bias current of the* current conveyor.

Second-Generation Current Controlled Conveyor (CCCII)



Modeling of parasitic resistance of X terminal, ideal voltage buffer and series parasitic resistance Rx

$$R_X = \frac{V_X - V_Y}{I_X}$$

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- The input resistance R_X at terminal x is proportional to $1/I_O$ for BJT realizations
- proportional to $1/\sqrt{I_O}$ CMOS realizations
- It is possible to control its value by changing the biasing current I_O.

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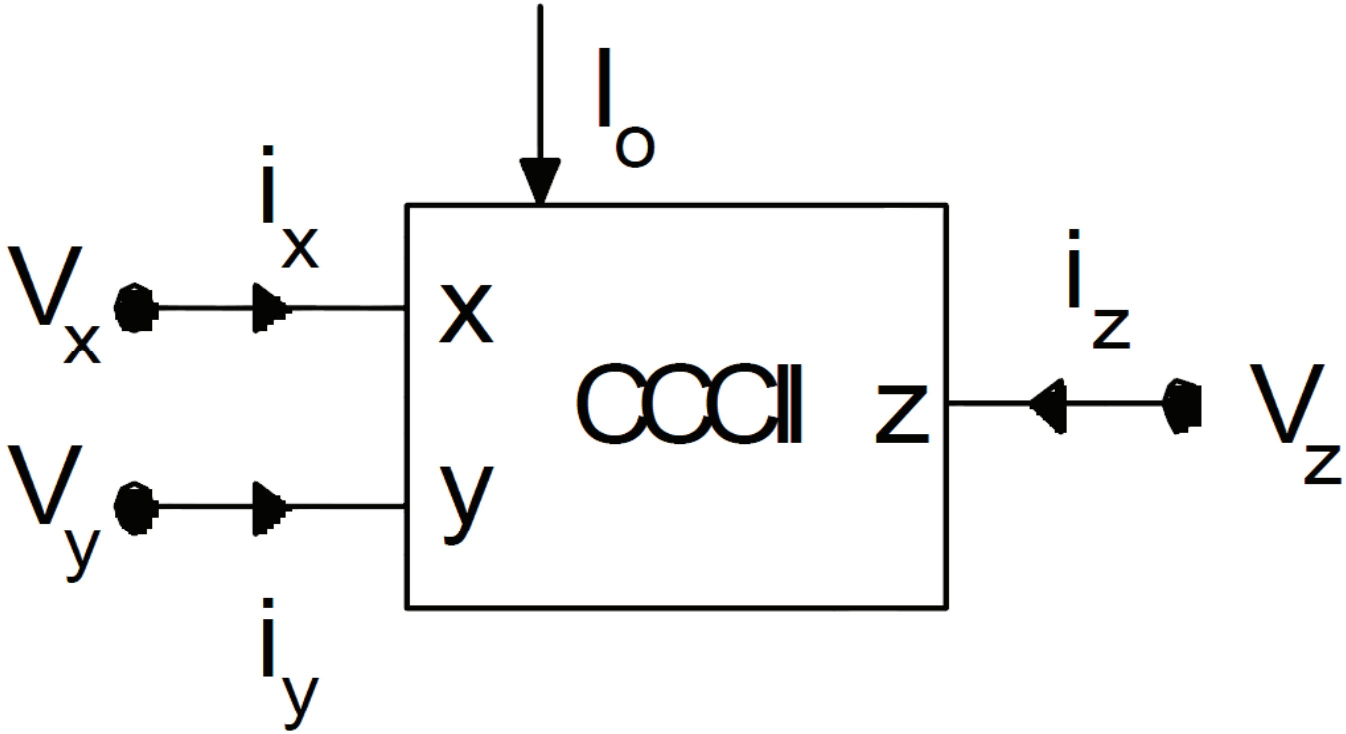

Electrical symbol of the CCCII.

Second-Generation Current Controlled Conveyor (CCCII)

- The port relations of a CCCII can be characterized by

$$\begin{bmatrix} I_y \\ V_x \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_x & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix}$$

- where the positive sign denotes a positive current controlled conveyor (CCCII+) and the negative sign denotes a negative current controlled conveyor (CCCII -).

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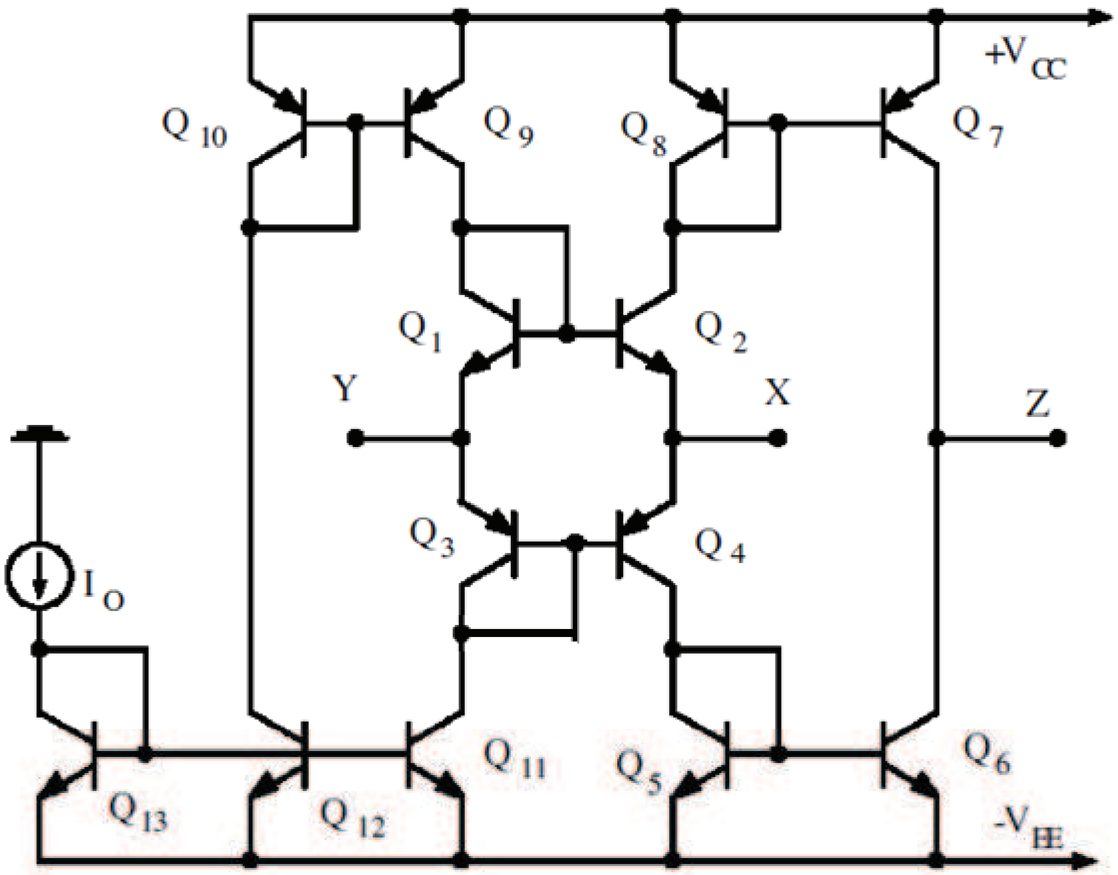
- The conveyor x-input impedance is calculated as for bipolar CCCII realization

$$R_X = \frac{V_X - V_Y}{I_X} = \frac{V_T}{2I_o}$$

- where V_T *is the thermal voltage.*
- The x-input impedance can be controlled by the bias current Io.

Second-Generation Current Controlled Conveyor (CCCII)



Bipolar Realization circuit of CCCII.

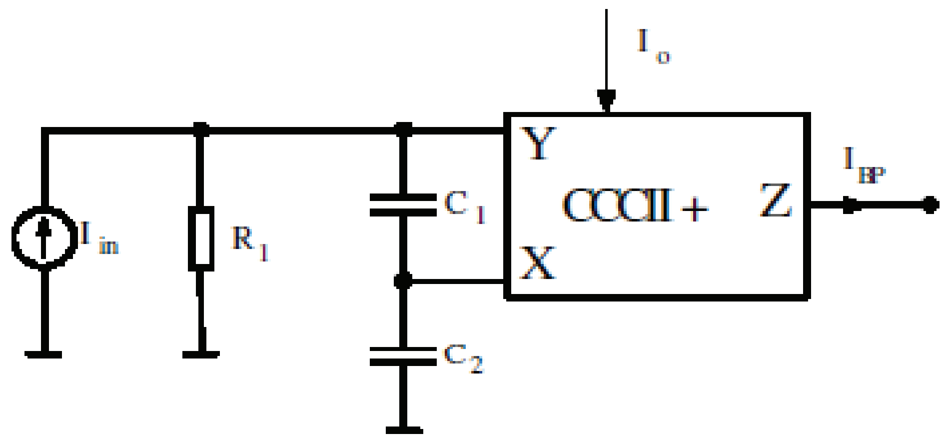
Second-Generation Current Controlled Conveyor (CCCII)

Filter Realization employing second-generation current-controlled conveyors

S.Minaei, O. Cicekoglu,H. Kuntman, S. Türköz, “High output impedance current-mode lowpass, bandpass and highpass filters using current controlled conveyors”, INT. J. ELECTRONICS, 2001, VOL. 88, NO. 8, 915-922

Second-Generation Current Controlled Conveyor (CCCII)

- The circuit of Figure (*a) comprises one CCCII+, two capacitors and one resistor*
- *realizes* bandpass Filter at high output impedance.



(a)

Second-Generation Current Controlled Conveyor (CCCII)

$$\frac{I_{BP}}{I_{in}} = \frac{\frac{1}{C_1 R_x} s}{s^2 + \frac{(C_1 + C_2)}{R_1 C_1 C_2} s + \frac{1}{R_1 R_x C_1 C_2}}$$

and the parameters ω_o and ω_o / Q can be given as

$$\omega_o = \sqrt{\frac{1}{R_1 R_x C_1 C_2}}$$

$$\frac{\omega_o}{Q} = \frac{(C_1 + C_2)}{R_1 C_1 C_2}$$

Second-Generation Current Controlled Conveyor (CCCII)

the active and passive sensitivities of the parameters ω_o and ω_o/Q are

$$S_{R_1}^{\omega_o} = S_{R_x}^{\omega_o} = S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = -\tfrac{1}{2}, \qquad S_{I_o}^{\omega_o} = \tfrac{1}{2}, \qquad S_{V_T}^{\omega_o} = -\tfrac{1}{2}$$

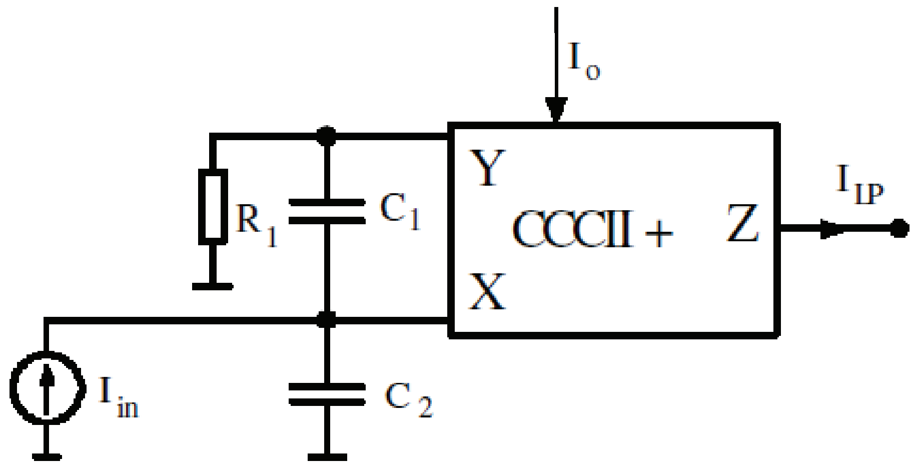
$$S_{C_1}^{\omega_o/Q} = \frac{-C_2}{C_1 + C_2}, \qquad S_{C_2}^{\omega_o/Q} = \frac{-C_1}{C_1 + C_2}, \qquad S_{R_1}^{\omega_o/Q} = -1,$$

$$S_{I_o}^{\omega_o/Q} = 0, \qquad S_{V_T}^{\omega_o/Q} = 0 \qquad S_{R_x}^{\omega_o/Q} = 0$$

which are no more than unity in magnitude.

Second-Generation Current Controlled Conveyor (CCCII)

- The Filter shown in Figure 3(*b) uses one CCCII+, two capacitors* and one resistor for realizing lowpass Filter at high output impedance.



(b)

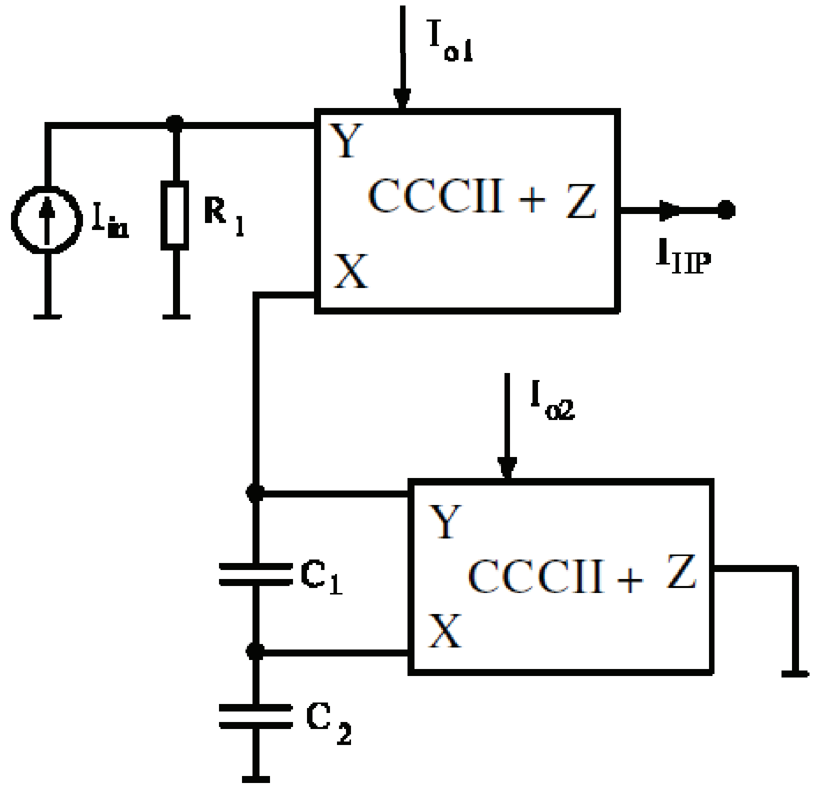
Second-Generation Current Controlled Conveyor (CCCII)

$$\frac{I_{LP}}{I_{in}} = -\frac{\frac{1}{R_1 R_x C_1 C_2}}{s^2 + \frac{(C_1 + C_2)}{R_1 C_1 C_2} s + \frac{1}{R_1 R_x C_1 C_2}}$$

The parameters ω_o and ω_o/Q are represented by the same equations as the first circuit. Also the sensitivities of this

Second-Generation Current Controlled Conveyor (CCCII)

- The third circuit shown in Figure (*c) employs two CCCII+, two capacitors and* one resistor,
- produces highpass response at high output impedance.



(c)

Second-Generation Current Controlled Conveyor (CCCII)

$$\frac{I_{HP}}{I_{in}} = \frac{\frac{R_1}{R_{x1}} s^2}{s^2 + \frac{(C_1 + C_2)}{R_{x1} C_1 C_2} s + \frac{1}{R_{x1} R_{x2} C_1 C_2}}$$

The parameters ω_o and ω_o/Q of this circuit are calculated as

$$\omega_o = \sqrt{\frac{1}{R_{x1} R_{x2} C_1 C_2}}$$

$$\frac{\omega_o}{Q} = \frac{(C_1 + C_2)}{R_{x1} C_1 C_2}$$

Second-Generation Current Controlled Conveyor (CCCII)

Sensitivity analysis shows that

$$S_{R_{x1}}^{\omega_o} = S_{R_{x2}}^{\omega_o} = S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = -\tfrac{1}{2}, \qquad S_{I_{o1}}^{\omega_o} = S_{I_{o2}}^{\omega_o} = \tfrac{1}{2}, \qquad S_{V_T}^{\omega_o} = -1$$

$$S_{C_1}^{\omega_o/Q} = \frac{-C_2}{C_1 + C_2}, \qquad S_{C_2}^{\omega_o/Q} = \frac{-C_1}{C_1 + C_2}, \qquad S_{R_{x1}}^{\omega_o/Q} = -1, \quad S_{R_{x2}}^{\omega_o/Q} = 0$$

$$S_{I_{ol}}^{\omega_o/Q} = 1, \quad S_{I_{o2}}^{\omega_o/Q} = 0, \qquad S_{V_T}^{\omega_o/Q} = -1$$

which are no more than unity in magnitude.

Second-Generation Current Controlled Conveyor (CCCII)

- The circuits in Figure (*a) and Figure (c)* can easily be converted to voltage-in current-out circuits
- Transadmittance type filter by taking the Thevenin equivalent of the signal source.
- The modified configuration can be used to interface voltage mode filters to current mode ones.
- All of the proposed filters are attractive for integrated circuit implementation for small values of the capacitors.

Second-Generation Current Controlled Conveyor (CCCII)

Simulation results

Second-Generation Current Controlled Conveyor (CCCII)

- The filters are simulated with PSPICE circuit simulation program.
- The CCCII+ is simulated using the bipolar implementation with symmetrical DC supply voltages of 2,5V.
- The PNP and the NPN transistors in CCCII+ implementation are simulated using the parameters of the NR100N and PR100N bipolar transistors given in table 1.
- The bandpass filter is designed to realize a filter response with a quality factor of $Q = 2.19$ *and natural frequency of* $f_o = 139.5$ *kHz.*
- *The* lowpass and highpass filters are designed to realize a Butterworth type filter response ($Q = 0.707$) *with a natural frequency of* $f_o = 173.1$ *kHz.*

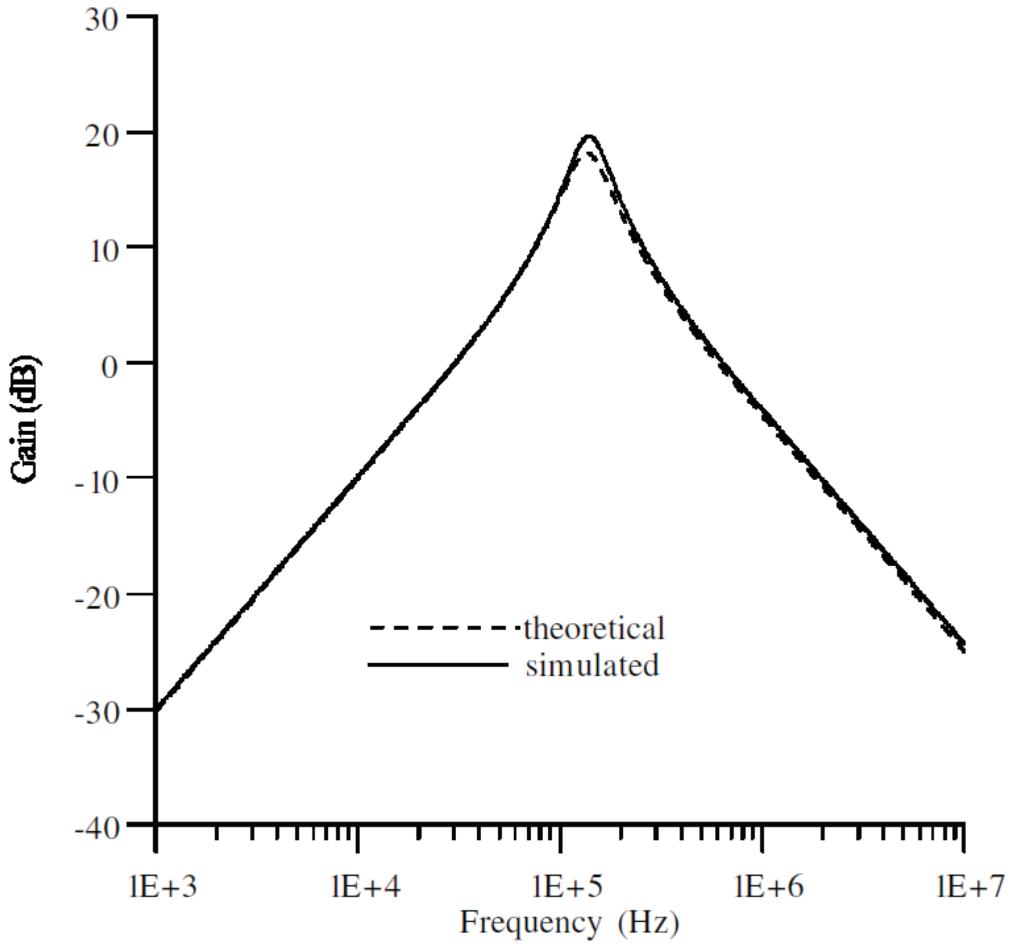
Second-Generation Current Controlled Conveyor (CCCII)

```
MODEL NR100N NPN (IS= 121E-018 BF= 137.5 VAF= 159.4 IKF= 6.974E-3 ISE= 36E-16
+ NE= 1.713 BR= 0.7258 VAR= 10.73 IKR= 2.198E-3 RE= 1 RB= 524.6 RBM= 25 RC= 50
+ CJE= 0.214E-12 VJE= 0.5 MJE= 0.28 CJC= 0.983E-13 VJC= 0.5 MJC= 0.3 XCJC= 0.034
+ CJS= 0.913E-12 VJS= 0.64 MJS= 0.4 FC= 0.5 TF= 0.425E-9 TR= 0.425E-8 EG= 1.206
+ XTB= 1.538 XTI= 2)

MODEL PR100N PNP (IS= 73.5E-018 BF= 110 VAF= 51.8 IKF= 2.359E-3 ISE= 25.1E-16
+ NE= 1.650 BR= 0.4745 VAR= 9.96 IKR= 6.478E-3 RE= 3 RB= 327 RBM= 24.55 RC= 50
+ CJE= 0.180E-12 VJE= 0.5 MJE= 0.28 CJC= 0.164E-12 VJC= 0.8 MJC= 0.4 XCJC= 0.037
+ CJS= 1.03E-12 VJS= 0.55 MJS= 0.35 FC= 0.5 TF= 0.610E-9 TR= 0.610E-8 EG= 1.206
+ XTB= 1.866 XTI= 1.7)
```

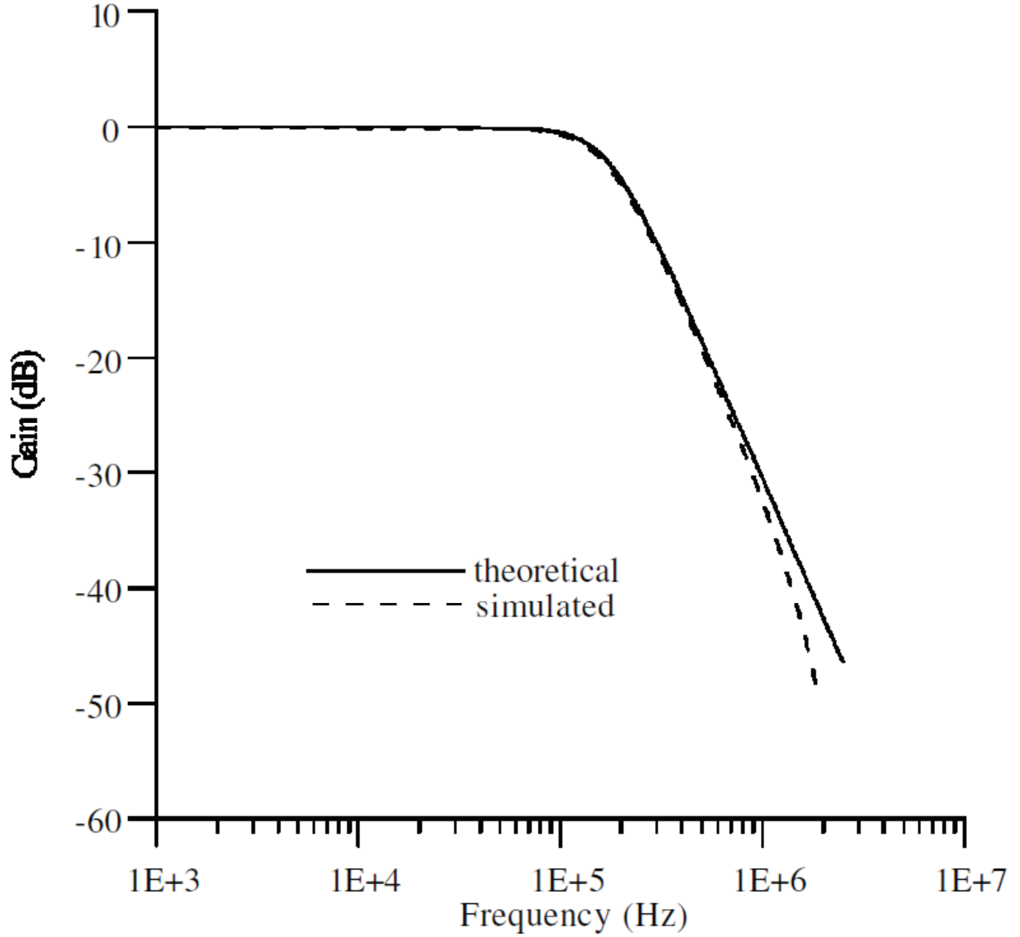
Table 1. The model parameters of the NR100N and PR100N bipolar transistors used for PSPICE simulations.

Second-Generation Current Controlled Conveyor (CCCII)



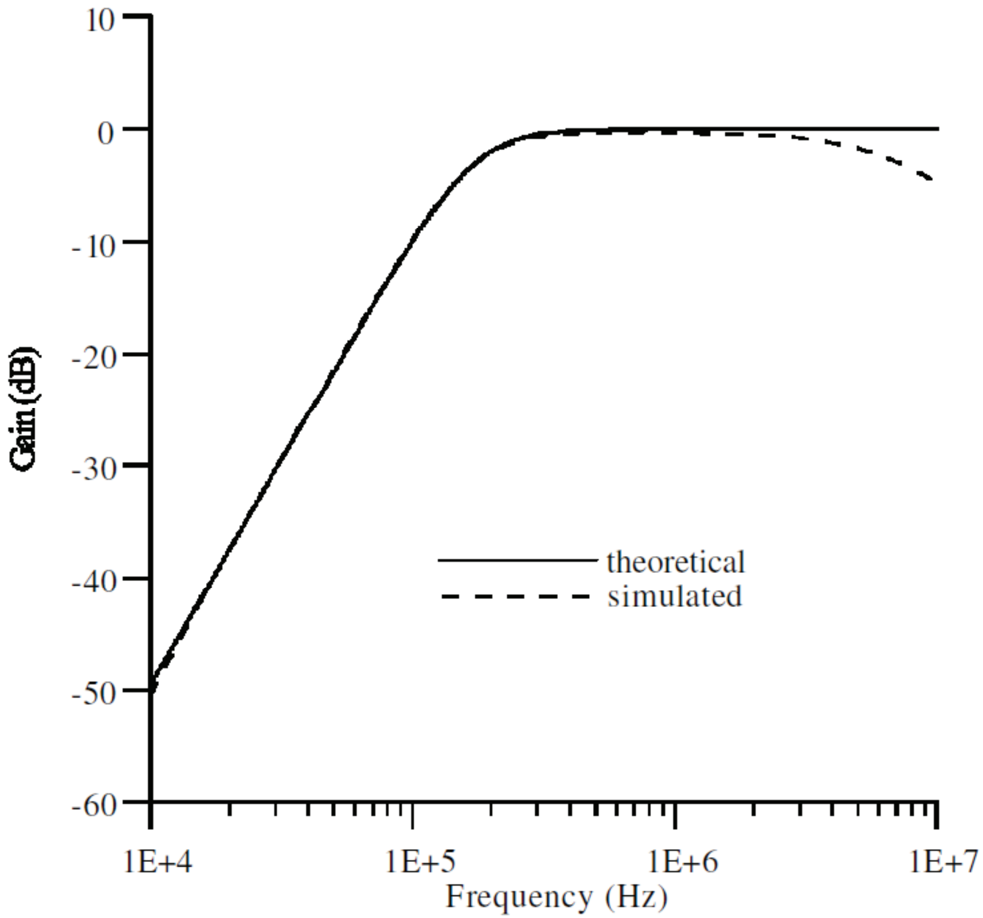
Theoretical and simulated bandpass responses.

Second-Generation Current Controlled Conveyor (CCCII)



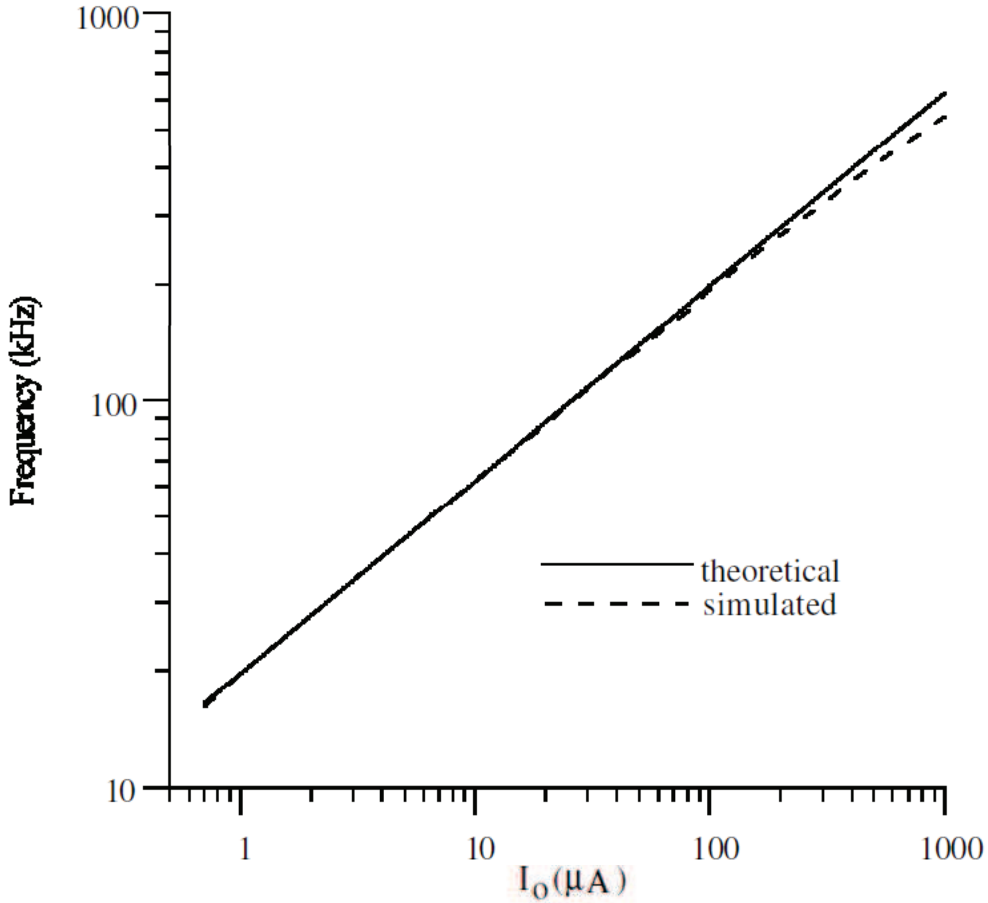
Theoretical and simulated lowpass response.

Second-Generation Current Controlled Conveyor (CCCII)



Theoretical and simulated highpass response.

Second-Generation Current Controlled Conveyor (CCCII)



Variation of the natural frequency *fo with the bias current Io for the bandpass* filter.

Second-Generation Current Controlled Conveyor (CCCII)

- The variability of the natural frequency *fo with the bias current Io for the bandpass filter.*

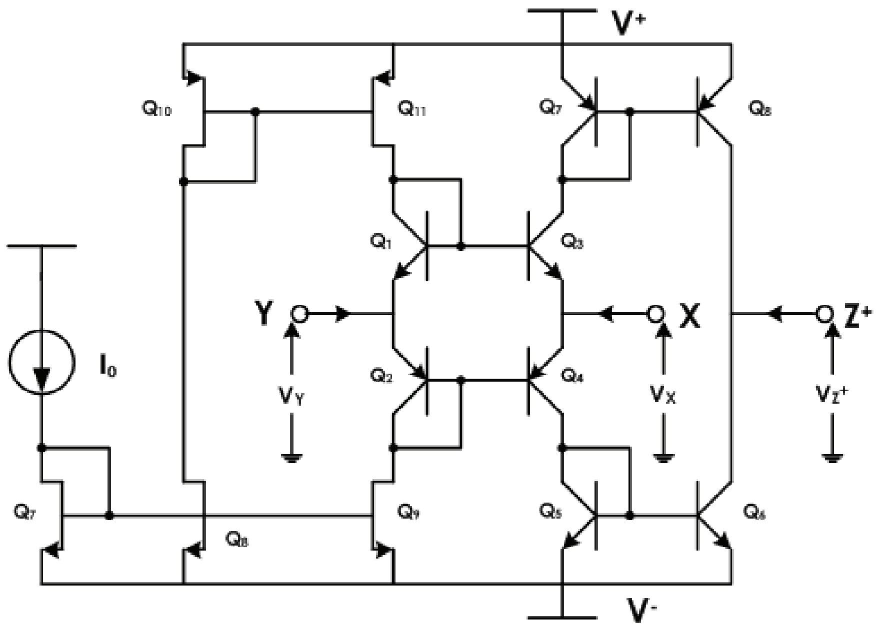
- *It can be seen* that the circuit exhibits a large tuning range.

Second-Generation Current Controlled Conveyor (CCCII)

High Frequency Applications

- Y. Lakys, B. Godara, A Fabre, “Cognitive and Encrypted Communications, Part 2 : A New Approach to ActiveFrequency-Agile Filters and Validation Results for an Agile Bandpass Topology in SiGe-BiCMOS”, Proc. of ELECO’2009: The 6th International Conference on Electrical and Electronics Engineering, Vol.2, pp.16-29, 5-8 November, Bursa, Turkey.

Second-Generation Current Controlled Conveyor (CCCII)



•The circuits were integrated in 0.25 μm SiGe BiCMOS technology from ST Micoelectronics.

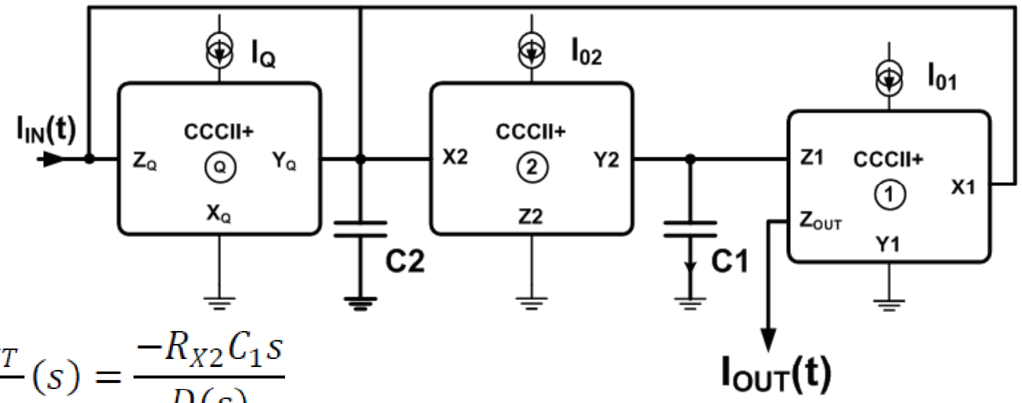
•The transition frequency of the NPN transistors in this technology is 55 GHz; the vertical PNP transistors have f_{TP} of 6 GHz.

Second-Generation Current Controlled Conveyor (CCCII)

	Voltage follower	Current follower
Gain (dB)	-0.009	0.03
-3dB Bandwidth	21.6 GHz	4.5 GHz
Input Impedance	466kΩ//0.046pF	162Ω
Output Impedance	162Ω	152kΩ//0.04pF
Output offset	486µV	3µA
Consumption	2.57 mW	2.57 mW

Characteristics of the CCCII, $V^{+}=-V^{-} = 2.5$ V; $I_0 = 100$ µA.

Second-Generation Current Controlled Conveyor (CCCII)



$$\frac{I_{OUT}}{I_{IN}}(s) = \frac{-R_{X2}C_1 s}{D(s)}$$

with:

$$D(s) = 1 + \left[R_{X1} + R_{X2} - \frac{R_{X1}R_{X2}}{R_{XQ}}\right]C_1 s + R_{X1}R_{X2}C_1C_2 s^2$$

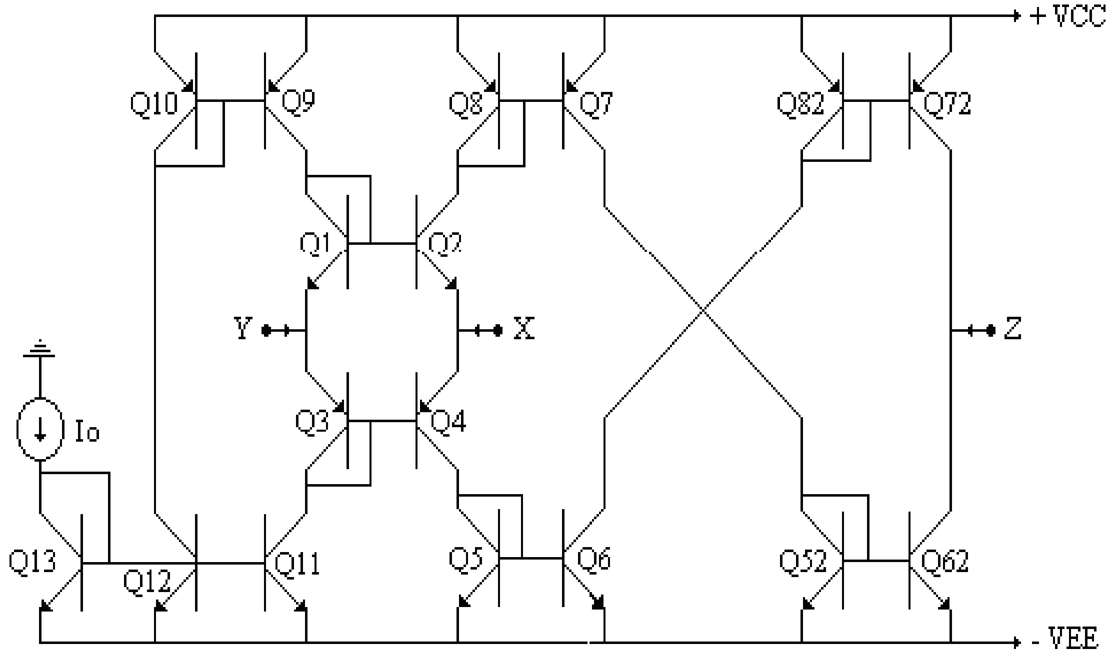
•The circuit includes three current controlled conveyors with positive current transfer from X to Z (CCCII+).

•The section conveyor (1, 2), capacitor *C1 and capacitor C2 is* equivalent to a shunt RLC circuit.

•The conveyor (Q), connected as a negative resistance; allows tuning of the quality factor of the filter through the bias current IQ.

Second-Generation Current Controlled Conveyor (CCCII)

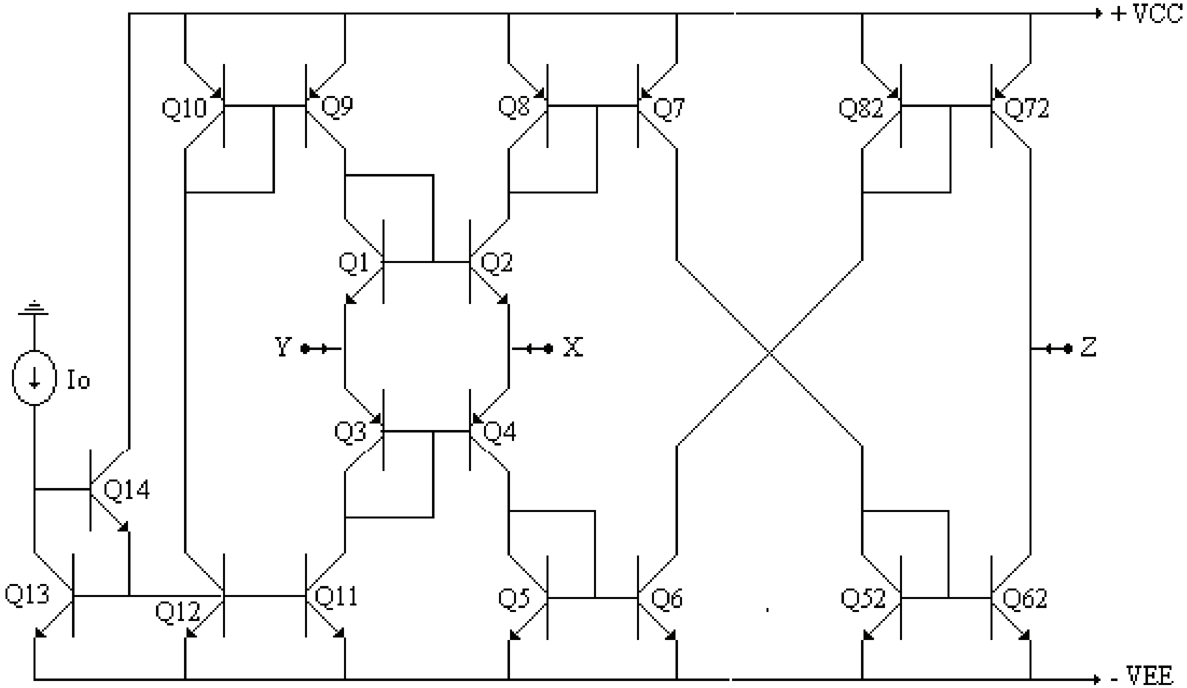
Further Bipolar Structures



Negative (inverting)current controlled current conveyor

Second-Generation Current Controlled Conveyor (CCCII)

Further Bipolar Structures

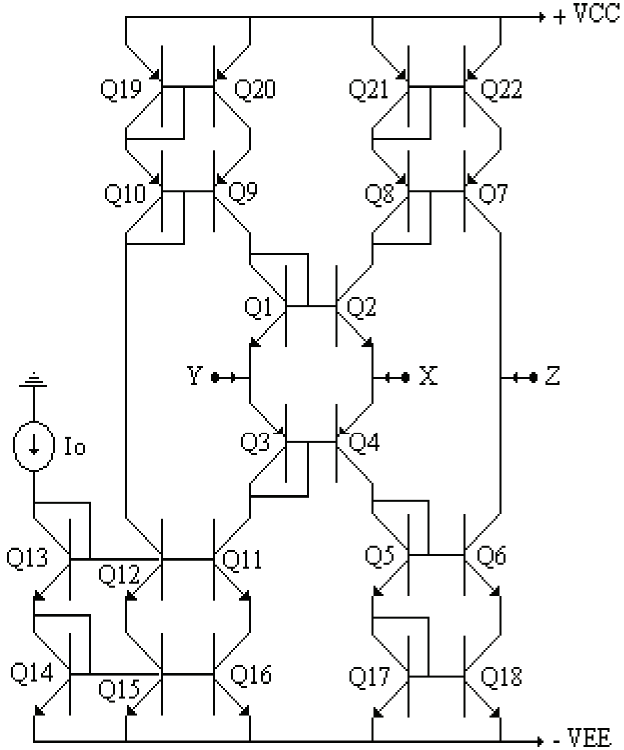


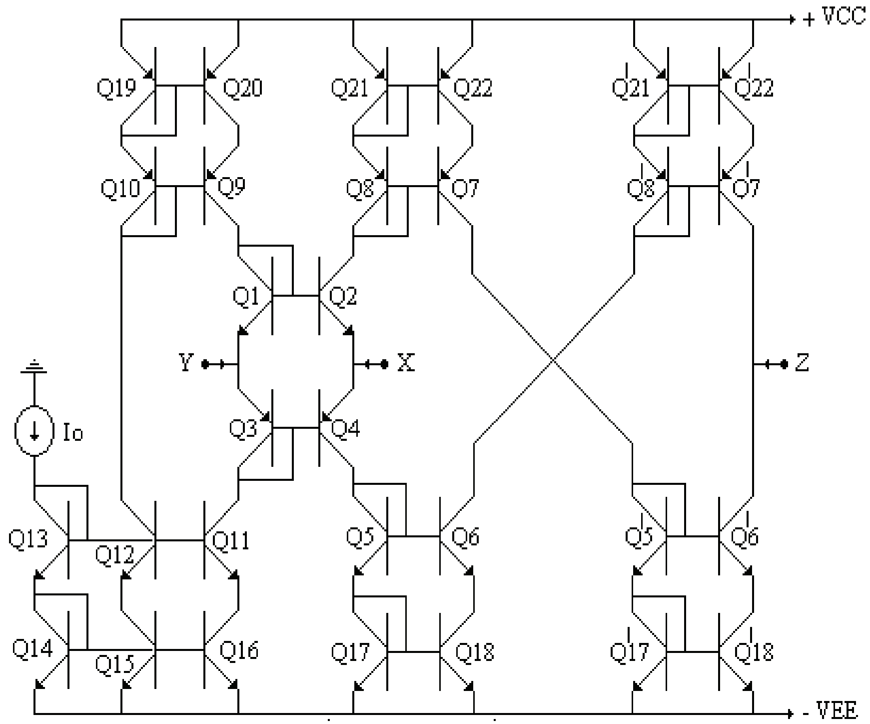
(a)

Negative (inverting)current controlled current conveyor with compensated base current

Second-Generation Current Controlled Conveyor (CCCII)

Further Bipolar Structures

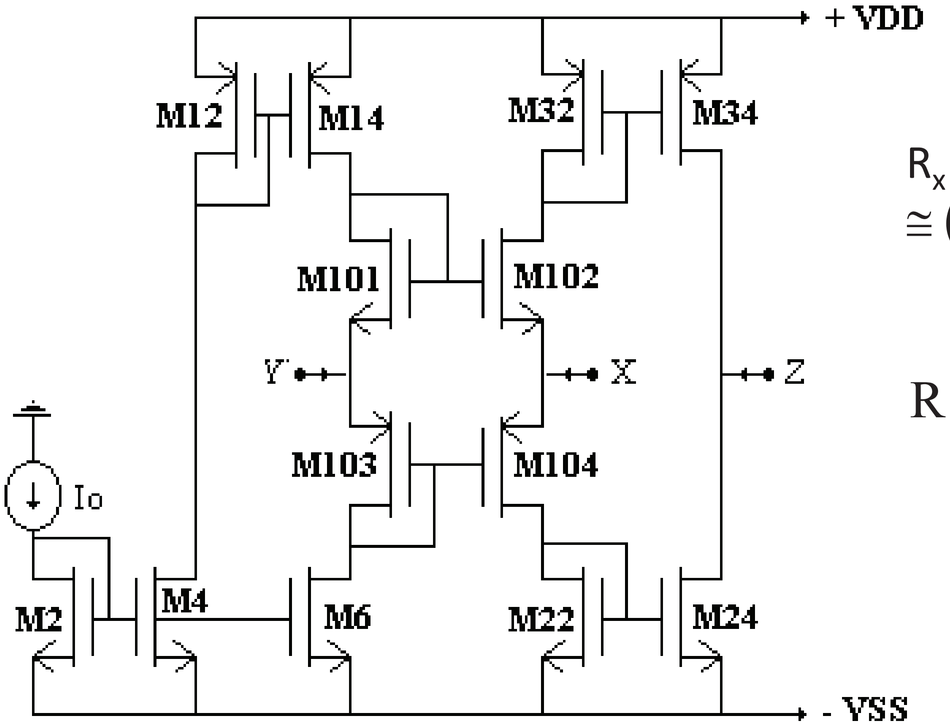




Positive and negative conveyors employing cascode current-mirrors

Second-Generation Current Controlled Conveyor (CCCII)

CMOS Structures



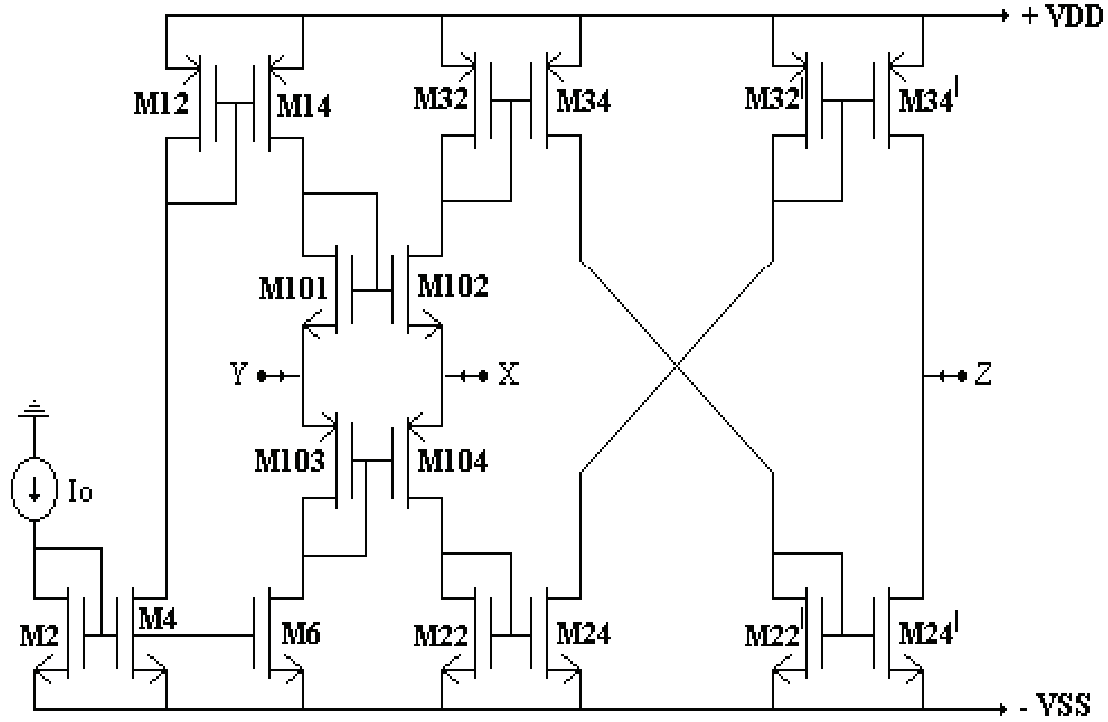
CMOS positive (noninverting) conveyor

$$R_x = (g_{m102} + g_{m104} + g_{mbs102} + g_{mbs104})^{-1}$$
$$\cong (g_{m102} + g_{m104})^{-1}$$

$$R_O = r_{d34} // r_{24} = \left(\frac{1}{\lambda_N I_O}\right) // \left(\frac{1}{\lambda_P I_O}\right)$$

Second-Generation Current Controlled Conveyor (CCCII)

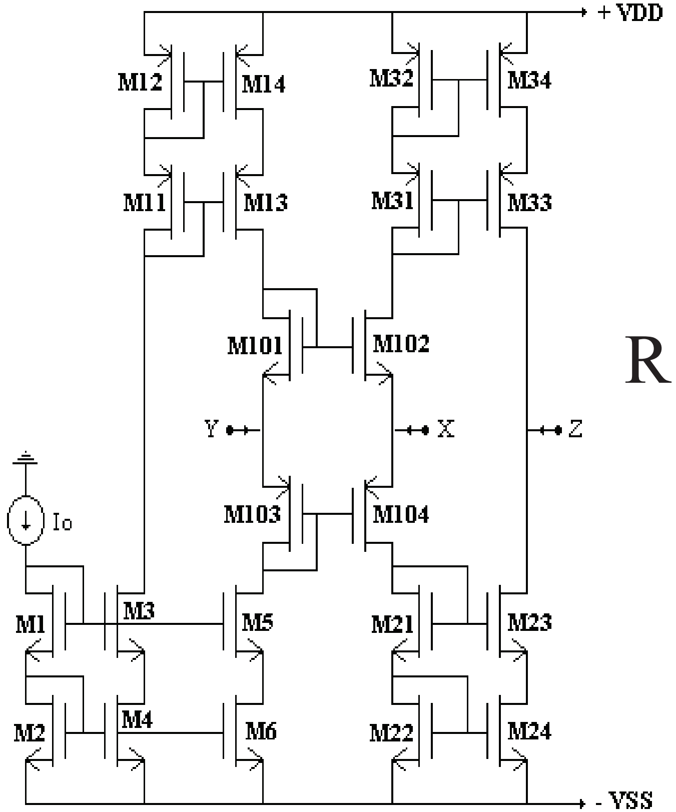
CMOS Structures



CMOS negative (inverting) conveyor

Second-Generation Current Controlled Conveyor (CCCII)

CMOS Structures



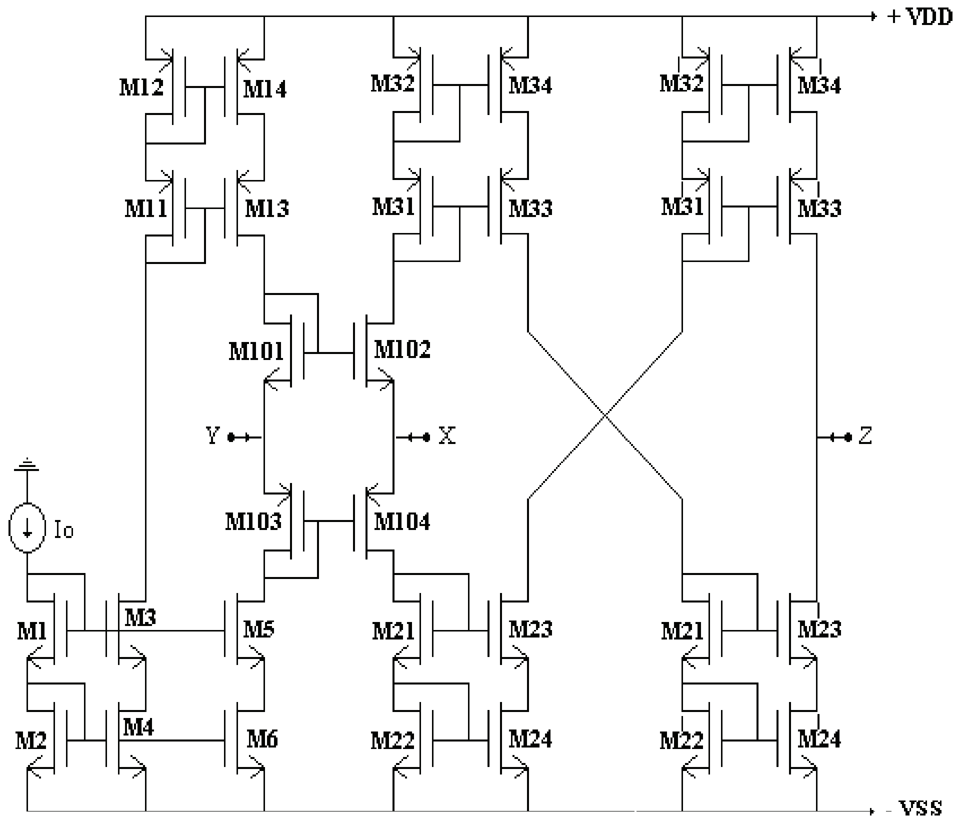
$R_x = (g_{m102} + g_{m104} + g_{mbs102} + g_{mbs104})^{-1}$
$\cong (g_{m102} + g_{m104})^{-1}$

$$R_O = (g_{m3} . r_{ds23} . r_{ds24})//(g_{m3} . r_{ds33} . r_{ds34})$$

Positive conveyor employing cascode current-mirrors

Second-Generation Current Controlled Conveyor (CCCII)

CMOS Structures



Negative conveyor employing cascode current-mirrors

Second-Generation Current Controlled Conveyor (CCCII)

References

- S.Minaei, O. Cicekoglu,H. Kuntman, S. Türköz, “High output impedance current-mode lowpass, bandpass and highpass filters using current controlled conveyors”, International Journal of Electronics, 2001, Vol. 88, No. 8, 915-922
- S. Minaei, O. Cicekoglu, H. Kuntman and S. Türköz, “Electronically Tunable Active Only Floating Inductance simulation”, International Journal of Electronics, 2003, Vol.89, No. 12, pp. 905-912.
- D.Y. Kaymak, Kontrollu akım taşıyıcılarda performans iyileştirme çalışmaları, M.Sc. Thesis, İstanbul Technical University, Institute of Science and Technology, 2001.
- Y. Lakys, B. Godara, A Fabre, “Cognitive and Encrypted Communications, Part 2 : A New Approach to ActiveFrequency-Agile Filters and Validation Results for an Agile Bandpass Topology in SiGe-BiCMOS”, Proc. of ELECO’2009: The 6th International Conference on Electrical and Electronics Engineering, Vol.2, pp.16-29, 5-8 November, Bursa, Turkey.
- Abuelma’atti, M. T., and Tasadduq, N. A., 1998, “A novel single-input multiple-output current-mode current-controlled universal filter”, *Microelectronics Journal, 29, 901-* 905.
- Abuelma’atti, M. T., and Tasadduq, N. A., 1998, “New current-mode current-controlled filters using the current-controlled conveyor”, *International Journal of Electronics, 85,* 483± 488.
- Alami, M., and Fabre, A., 1991, “Insensitive current-mode bandpass filter implemented from two current conveyors”, *Electronics Letters, 27, 897- 899*.
- Aronhime, P., Nelson, D., and Adams, C., 1990, “Applications of a first-generation current conveyor in current mode circuits”, *Electronics Letters, 26, 1456- 1457*.
- Chang, C. M., 1991, “Current mode allpass/notch and bandpass filter using single CCII”, *Electronics Letters. 27, 1812-1813*.
- Chang, C. M., 1993, “Current mode lowpass, bandpass and highpass biquads using two CCIIs”, *Electronics Letters, 29, 2020- 2021*.

Second-Generation Current Controlled Conveyor (CCCII)

- Chang, C. M., Chien, C. C., and Wang, H. Y., 1993, “Universal active current filters using single second-generation current conveyor ”, *Electronics Letters, 29, 1159-1160*.
- Fabre, A., Martin, F., and Hanafi, M., 1990, “Current mode allpass/notch and bandpass filters with reduced sensitivities ”, *Electronics Letters, 26, 1495-1496*.
- Fabre, A., Saaid, O., and Barthelemy,H., 1995, “On the frequency limitation of the circuits based on second generation current conveyors”, *Analog Integrated Circuits and Signal Processing, 7, 113- 129*.
- Fabre, A., Saaid, O., Wiest, F., and Boucheron, C., 1995, “Current controlled bandpass filter based on translinear conveyors ”, *Electronics Letters, 31, 1727-1728*.
- Frey, D. R., 1993, “Log-domain filtering: an approach to current-mode filtering ”, *IEE Proceedings -G, Circuits, Devices and Systems, 140, 406-416*.
- Higashimura, M., and Fukui,Y., 1990, “Realization of current mode allpass networks using a current conveyor ”, *IEEE Transactions on Circuits and Systems. 37, 660-661*.
- Khan, I. A., and Zaidi, M. H., 2000, “Multifunction translinear-C current-mode filter ”, *International Journal of Electronics, 87, 1047-1051*.
- Liu, S. I., Tsao, H. W., and Wu, J., 1990, “Cascadable current-mode single CCII biquads ”, *Electronics Letters, 26, 2005-2006*.
- Roberts, G. W., and Sedra, A. S., 1989, “All current-mode frequency selective circuits ”, *Electronics Letters, 25, 759-761*.