The Current Conveyors,Current Followers and Current-mode Feedback Amplifiers

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CCI

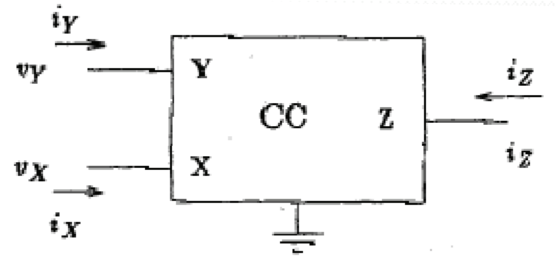


Figure 1:Black Box of CC

$$\begin{bmatrix} i_Y \\ v_X \\ i_Z \end{bmatrix} = \begin{bmatrix} 0 & a & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} v_Y \\ i_X \\ v_Z \end{bmatrix}$$

Figure 2: Hybrid equations the CCI

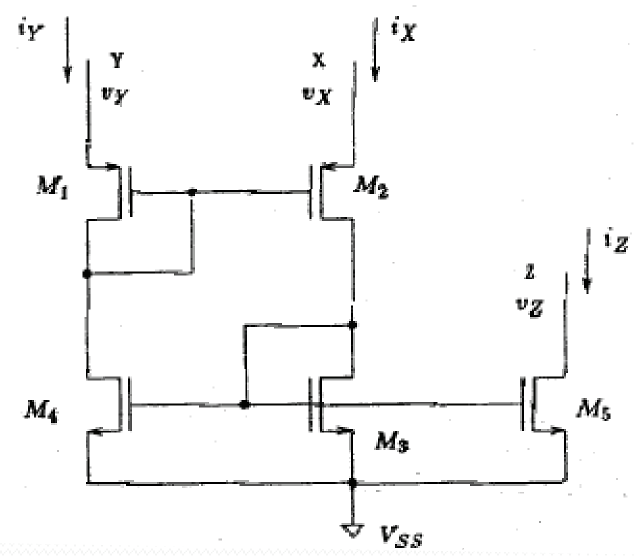


Figure 3: First order CMOS implementation CCI

CCI

- Operation of the device can be described as if a voltage is applied to input terminal Y, an equal potential will appear on the input terminal X.
- As well, an input current I being forced into terminal X will result in an equal amount of current flowing into terminal Y.
- As a result the current I will be conveyed to output terminal Z which has the characteristics of a current source of value I with high output impedance that we can figure out all from figure 1,2 and 3

CCII

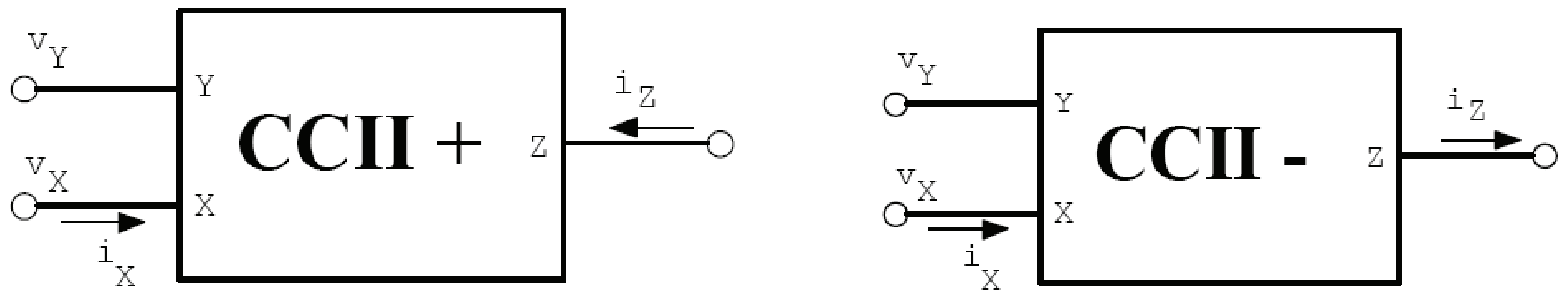


Figure 4: CCII+ and CCII-

$$\begin{bmatrix} i_Y \\ v_X \\ i_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} v_Y \\ i_X \\ v_Z \end{bmatrix}$$

Figure 5: Hybrid equations the CCII

$$\begin{aligned} v_X &= v_Y \\ i_Y &= 0 \\ i_Z &= \mp i_X \end{aligned}$$

CCII

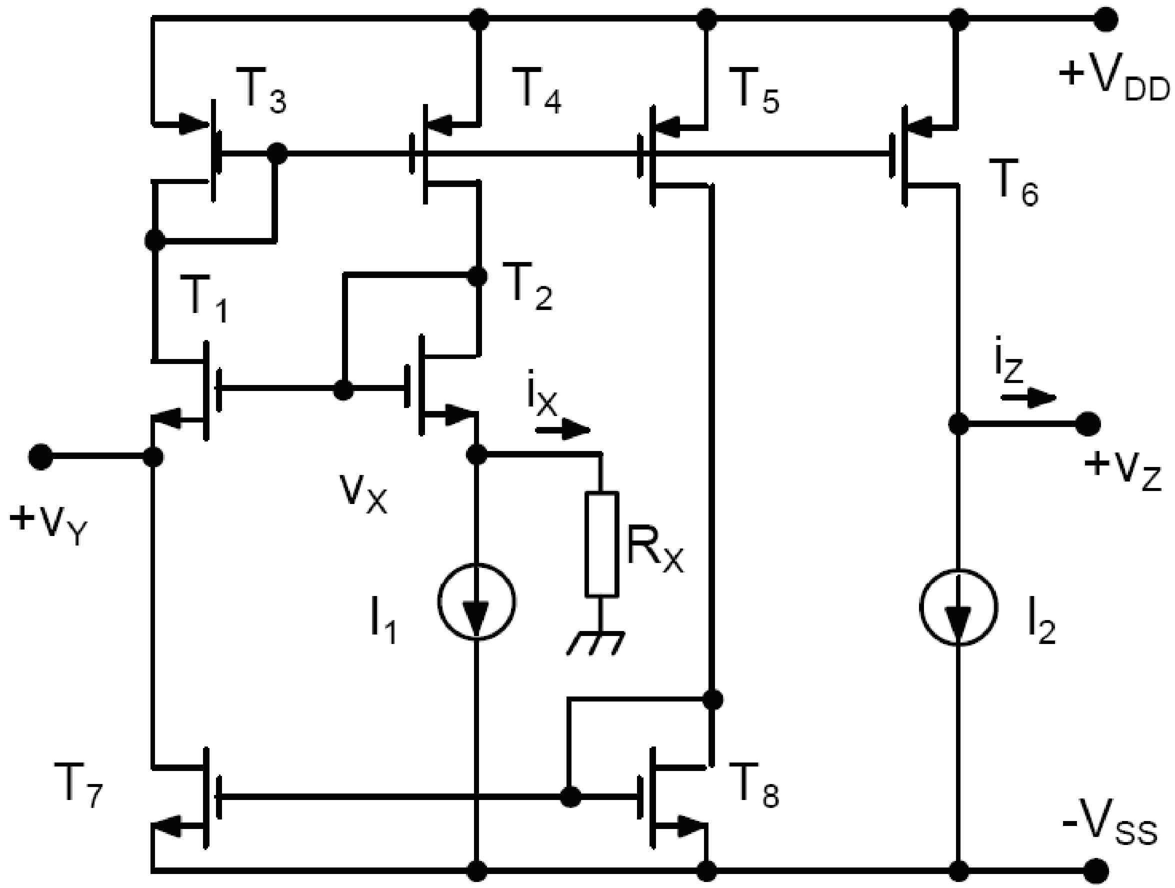


Figure 6: CMOS implementation CCII+

CCII

- T_3-T_6 PMOS transistors and T_7-T_8 NMOS transistors are used as current mirrors.
- I_1 current source creates the biasing current for the circuit.
- Assuming that transistors are equal, current mirros have unity gain and all of the transistors are working in active region

CCII

- We can describe the circuit as the T_3 - T_4 transistors accomplishes driving equal currents from T_1 and T_2 so $V_{gs1}=V_{gs2}$ which is meaning V_Y will be equal to V_X .
- I_X current which is flowing from R_X also flows from T_2 transistor and T_3-T_4 current mirror.
- In case of $V_X > 0$ current $I_X=V_X/R_X$ will flow out from T_2's source and so T_3-T_4 current sources value will be I_1+i_X .

CCII

- This current will be reflected to the T_1's source through T5 transistor and T7-T8 current mirror to compensate source current changes of T_1 so I_Y will be zero all the time .
- At the same time T6 transistor will reflect I_1+i_X current to the Z node in case of I_1 being equal to the I_2, $i_Z=i_X$ current flows out from node Z

CCII

- As noticeable i_Z currents direction is same as the i_X current so we call this type of circuits positive current conveyors (CCII+).
- If i_Z currents direction is opposite of the i_X current then we call it negative current conveyors (CCII-).
- An CCII- can be described similarly and it is shown figure 7.

CCII

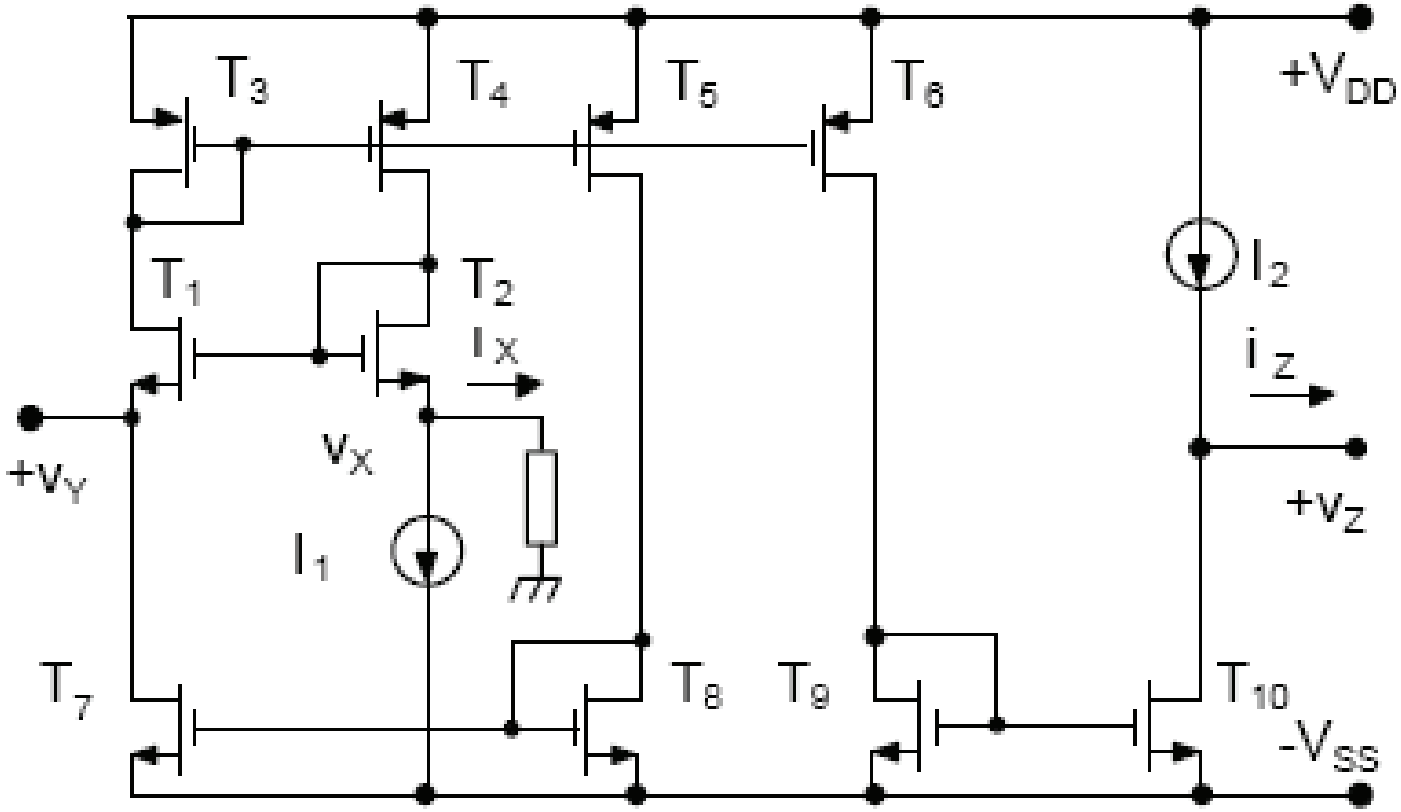


Figure 7: CMOS implementation CCII-

CCII

- Also there are other topologies which we can create CCII's these are shown in figures 8,9 and 10.

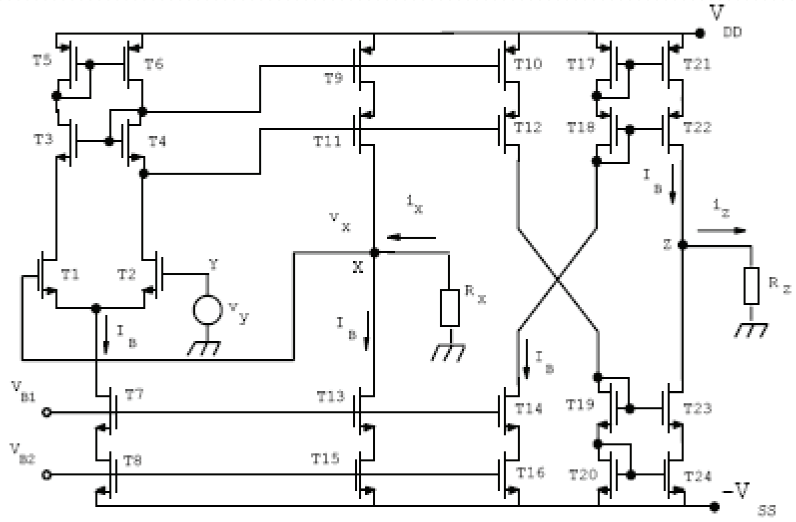


Figure 8: CMOS implementation CCII-

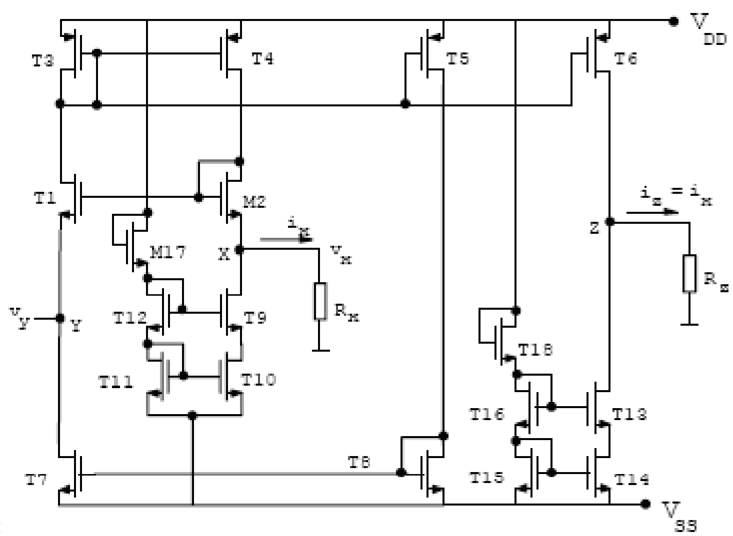


Figure 9: CMOS implementation CCII+

CCII

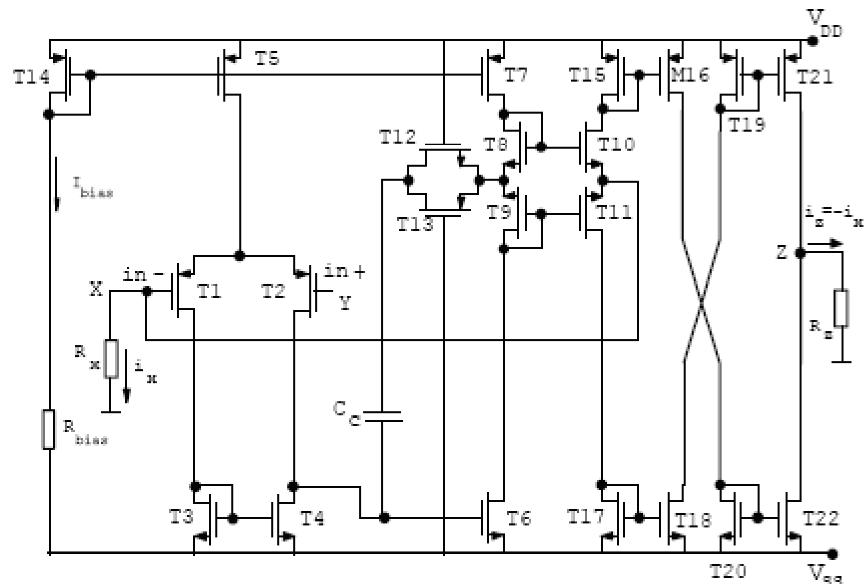


Figure 10: CMOS implementation CCII-

CCII

- Last but not the least there are current conveyor realisations using VOA's

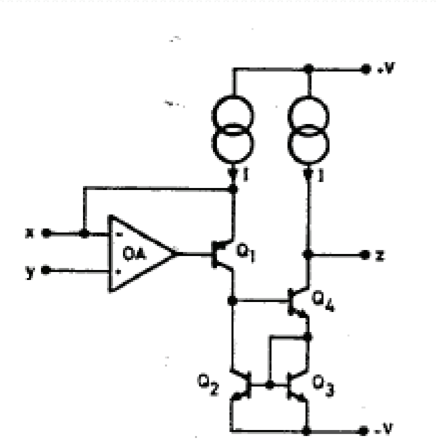


Figure 11: Bakhitiar and Aronhimes's CC

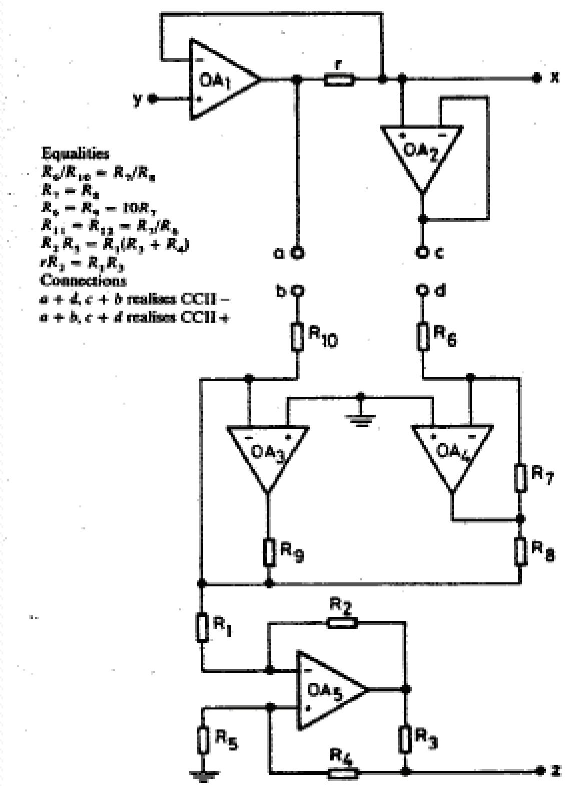


Figure 12:Pookaiyaudom and Srisarakham's single ended CCII+

CCII Applications

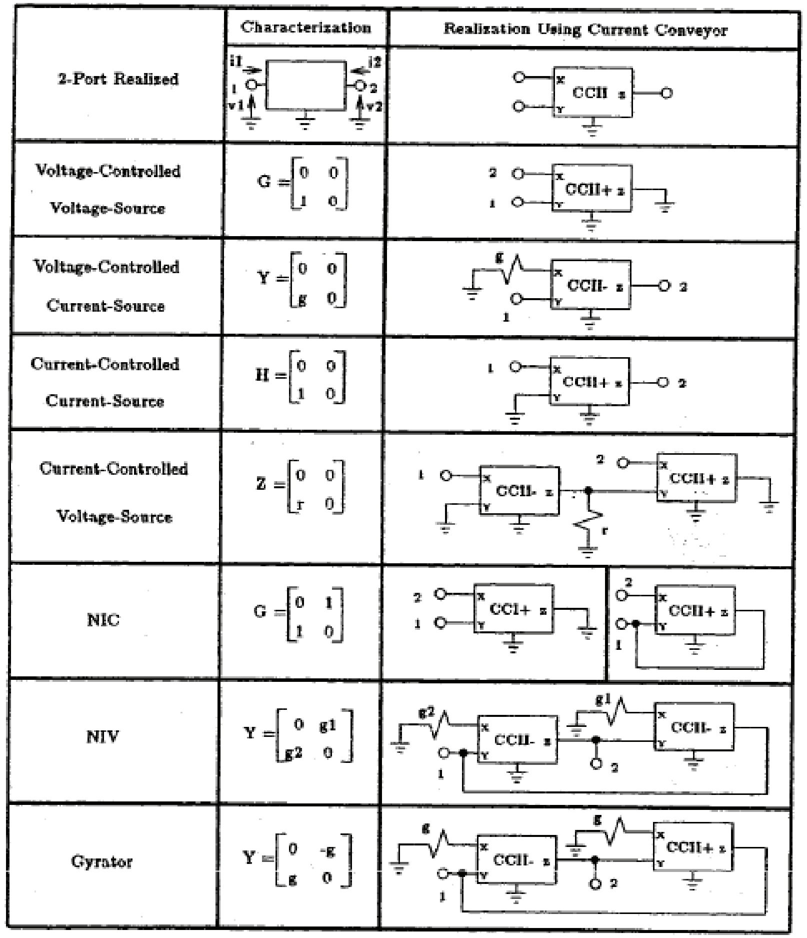


Figure 13: Applications of CCII to active network synthesis

CCII Applications

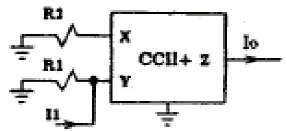
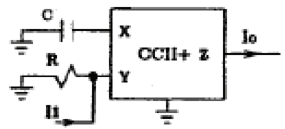
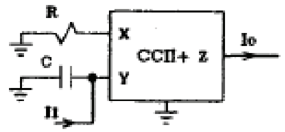
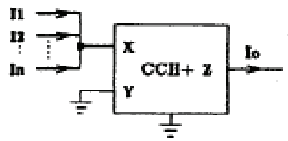
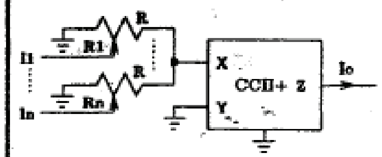
Functional Element	Function	Realization Using Current Conveyor
Current Amplifier	$Io = (R1/R2)I1$	
Currrent Differentiator	$Io = CR\, dI1/dt$	
Current Integrator	$Io = 1/CR \int I1dt$	
Current Summer	$Io = -\sum_{j}^{n} Ij$	
Weighted Current Summer	$Io = -\sum_{j}^{n} Ij\, Rj/R$	

Figure 14: Applications of CCII to analog computaion

CCII Applications

- Also with the adjoint network concept Active-RC circuits can be converted to equivalent current conveyor circuits
- Adjoint network concept simply means we can change the voltage mode circuits to current mode circuits by reciprocal or interreciprocal networks

CCII Applications(Adjoint network concept)

Reciprocal network

- Same network can be used as in figure 15

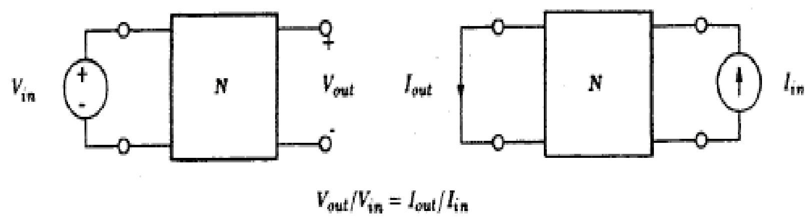


Figure 15: Reciprocal N network

Interreciprocal network

- A adjoint network N_A can be used as in figure 16

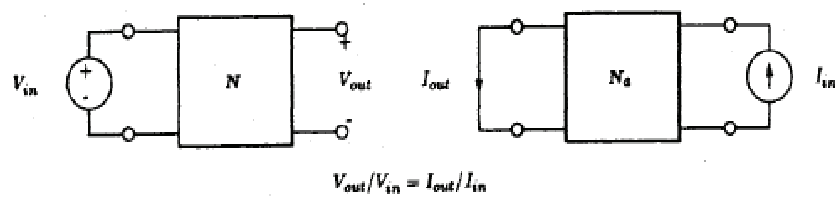


Figure 16: Interreciprocal N and N_A network

CCII Applications(Adjoint network concept)

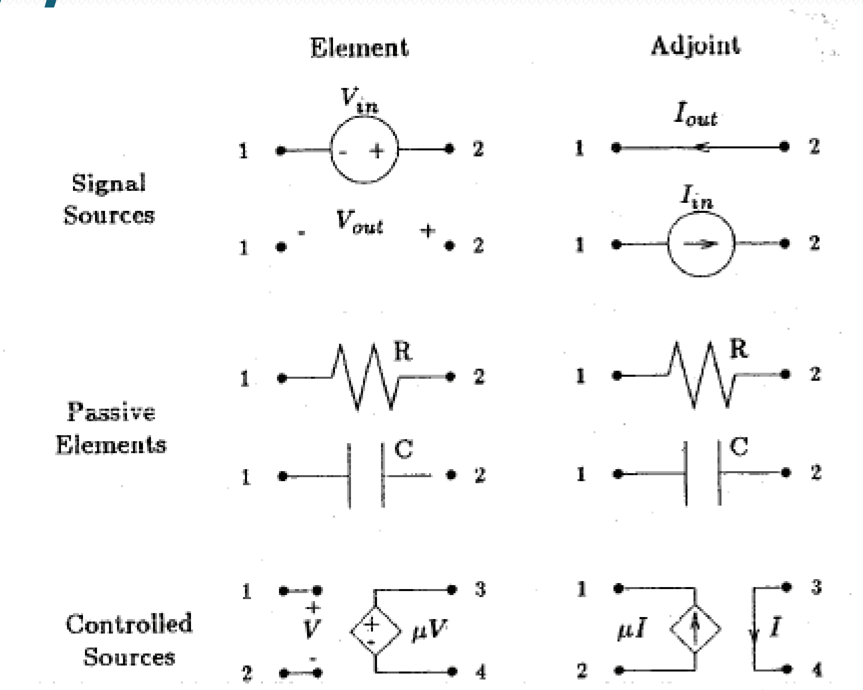


Figure 17: Some electrical elements and their corresponding adjoint elements

CCII Applications(Adjoint network concept)

- In figure 18 we see a voltage mode circuit with adjoint network concept we can change this circuit into the circuit in figure 19

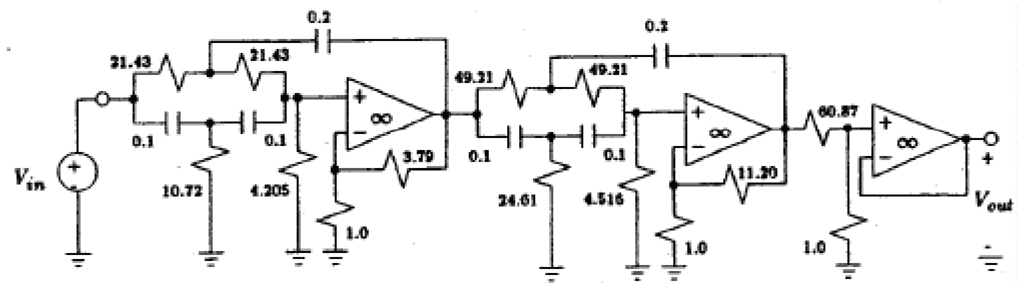


Figure 18: 4-th order HP elliptic filter as a cascade op-amp

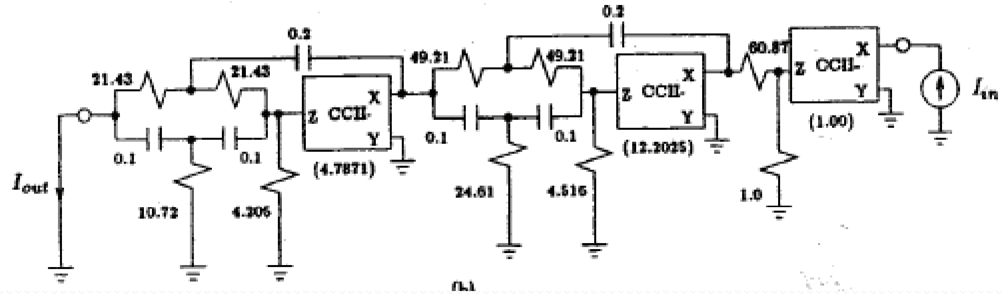


Figure 19: 4-th order HP elliptic filter as a corresponding CCII equivalent

Current Followers

- Current followers are structures that are configured into unity gain current controlled current sources.
- They are circuits with extremely low input impedance, extremely high output impedance.
- It is expected to produce a current drive to load equal in value to the short circuit current obtainable from the input signal source.
- Generaly they can be catogorised into two groups.

Current Followers

- One group considers techniques that make two equal in-phase output currents available by current mirroring the VOA's supply currents with respect to the positive and negative supply voltages, and summing them to a single ended output.
- Figure 20 is an example of this group, an supply current sensing current follower, its performance can be given as $i_O/i_S = 1/(1 + jf(K_1 + 1)/GB)$ where K_1 is $(R_O+R_L)/R_O$.

Current Followers

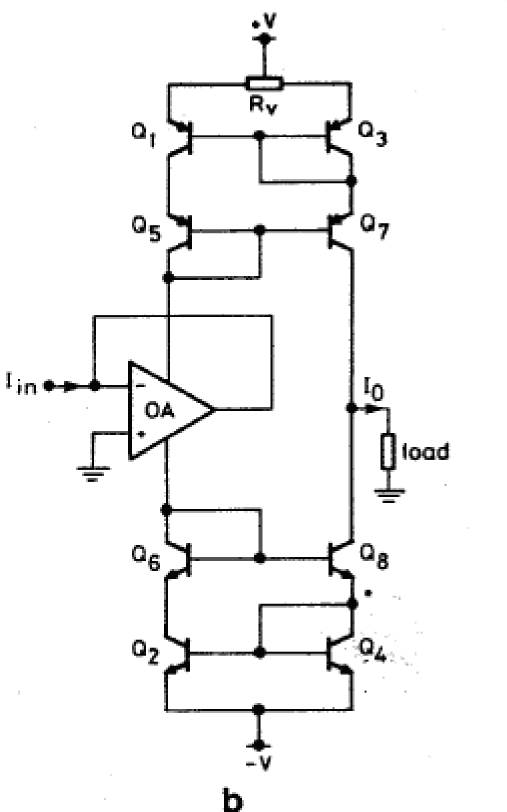


Figure 20: Supply current sensing current follower

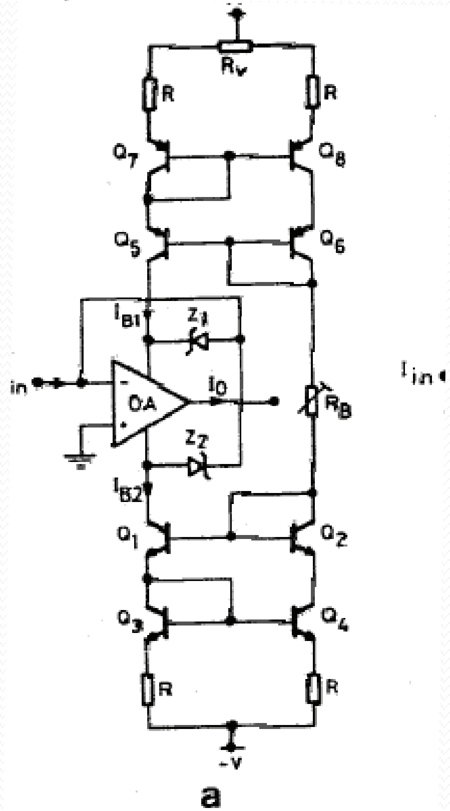


Figure 21: Floating VOA current follower

Current Followers

- The other group provides the VOA with two equal but opposite output currents, with characteristics similar to that of a floating VOA (Nullor).
- An example of this group circuit, floating VOA current follower shown in figure 21.
- Current transfer performance of the circuit in figure 21 can be given $i_o/i_s = \lambda(j\varpi)[(1+jf/GB)/(1+jf.K2/GB)]$ where $\lambda(j\varpi)$ is the frequency dependent current transfer of the current mirror and K2 is $(1+R_O/R_S)$ assuming bandwith is determined by the VOA.

Current-Mode Feedback Amplifiers(Translinear class AB current amplifier)

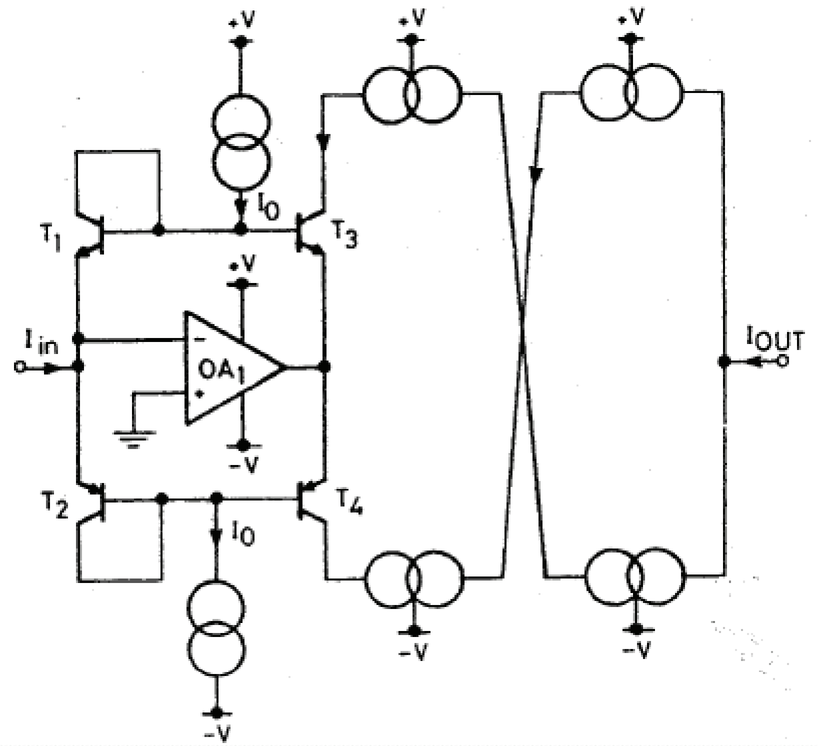


Figure 22: Translinear class AB current amplifier

Current-Mode Feedback Amplifiers(Translinear class AB current amplifier)

- In figure 22 an operational amplifier OA1 is embeded within the translinear cell from T1 to T4 .
- The d.c. Current source and sink ensures that all four BJTs are actively biassed with current I_O ,providing the desirable class AB input/output performance.
- The voltage following action of the translinear cell provides negative feedback around OA1 ensuring that the output of OA1 is a virtual ground and the input empedance of the amplifier is low.

Current-Mode Feedback Amplifiers(Translinear class AB current amplifier)

- Current gain of this circuit $A=\beta_3= \beta_4= \beta$ isprovided by the transistors T_3 and T_4 .
- Four current mirrors are needed to translate the phase-split output currents from T_3 and T_4 to the output node and create the correct phase rewlationship.
- Total current gain of this circuit can be given $\lambda^2\beta$ and the output impedance is determined by the R_O of the current mirrors.

Current-Mode Feedback Amplifiers

- In figure 23 we are seeing an alternative feedback structure to achive voltage gain

$$V_o/V_{in} = -(\lambda/(\lambda + 1)).R2/R1$$

and

output resistance

$$R_{out} = R2//(R_o/(\lambda + 1))$$

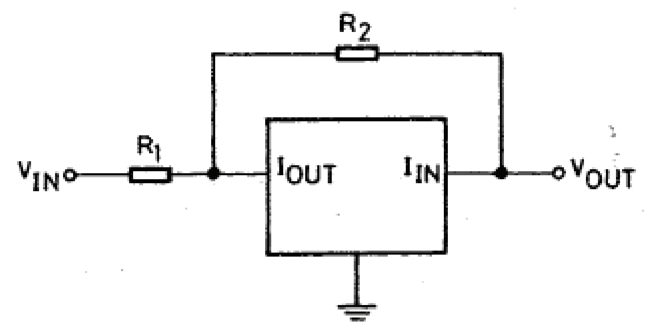


Figure 23: Alternative closed-loop voltage amplifier

Current-Mode Feedback Amplifiers(Transimpedance Operational Amplifier)

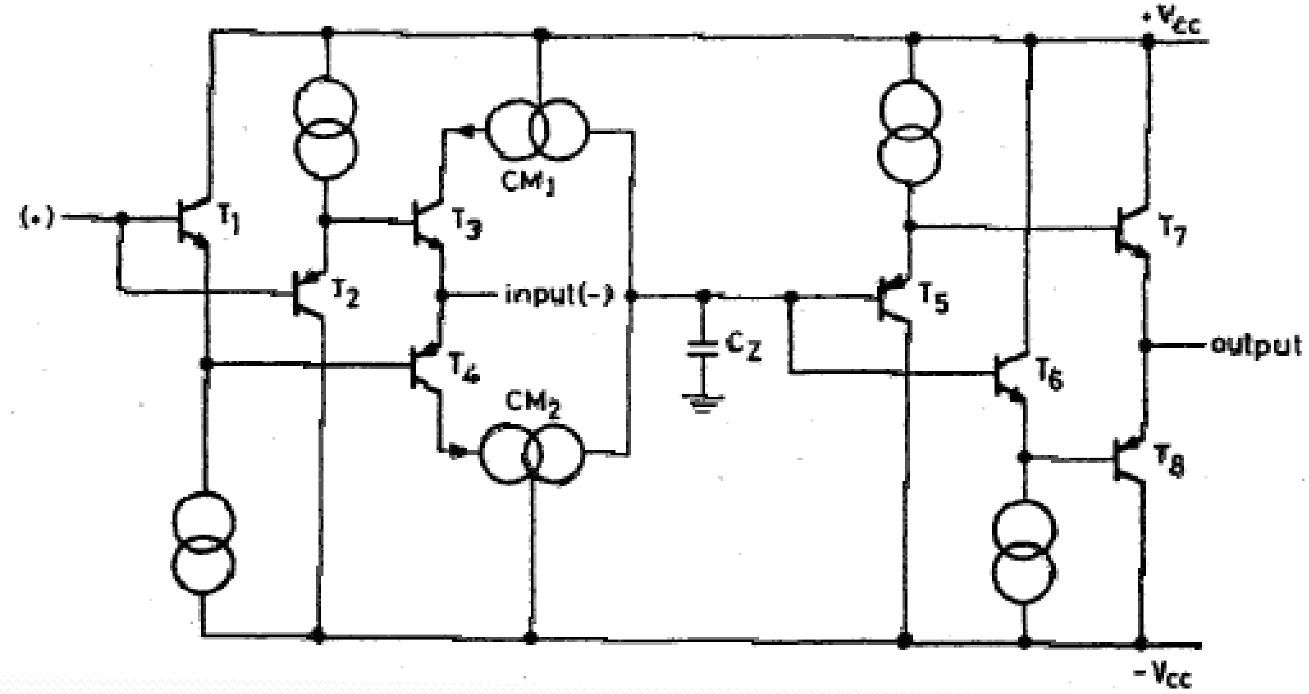


Figure 24: “Current feedback” transimpedance operational amplifier

Current-Mode Feedback Amplifiers (Transimpedance Operational Amplifier)

- Examining the circuit in figure 24, noninverting input corresponds to the Y terminal of the current conveyor and inverting input corresponds to the X input of current conveyor and the Z node, although not accessible in the device, is the output mode of the current conveyor.

Current-Mode Feedback Amplifiers(OFC)

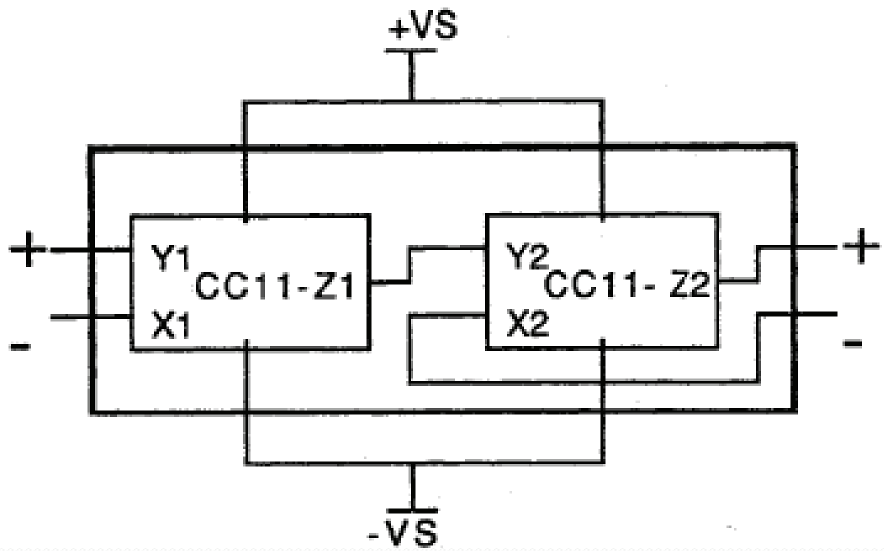


Figure 25: Operational Floating Conveyor

Current-Mode Feedback Amplifiers(OFC)

- Operational floating conveyor is a four port general purpose analogue building block, it has similar transmission properties to the current-feedback op-amp and current conveyor but with an additional output which allows accurate output sampling.
- Figure 25 consist of two series connected CCII-.
- X_1 and Y_1 of the first CCII as inverting and non-inverting input terminals respectively and X_2 and Z_2 of the second conveyor as inverting and non-inverting output terminals respectively

Current-Mode Feedback Amplifiers(OFC)

- This result in a very elegant hybrid of amplifier stages between different input and output ports.
- As an example there is high open-loop transimpedance gain between X2 and X1,current gain between Z2 and X1, voltage gain between X2 and Y1 and transadmittance gain between Z2 and Y1 assuming a load termination at X2 and Z2 in all of the cases.
- This transmission of multiple transfer functions allows four main amplifier types to be accurately configured in closed loop.

Current-Mode Feedback Amplifiers(OFC)

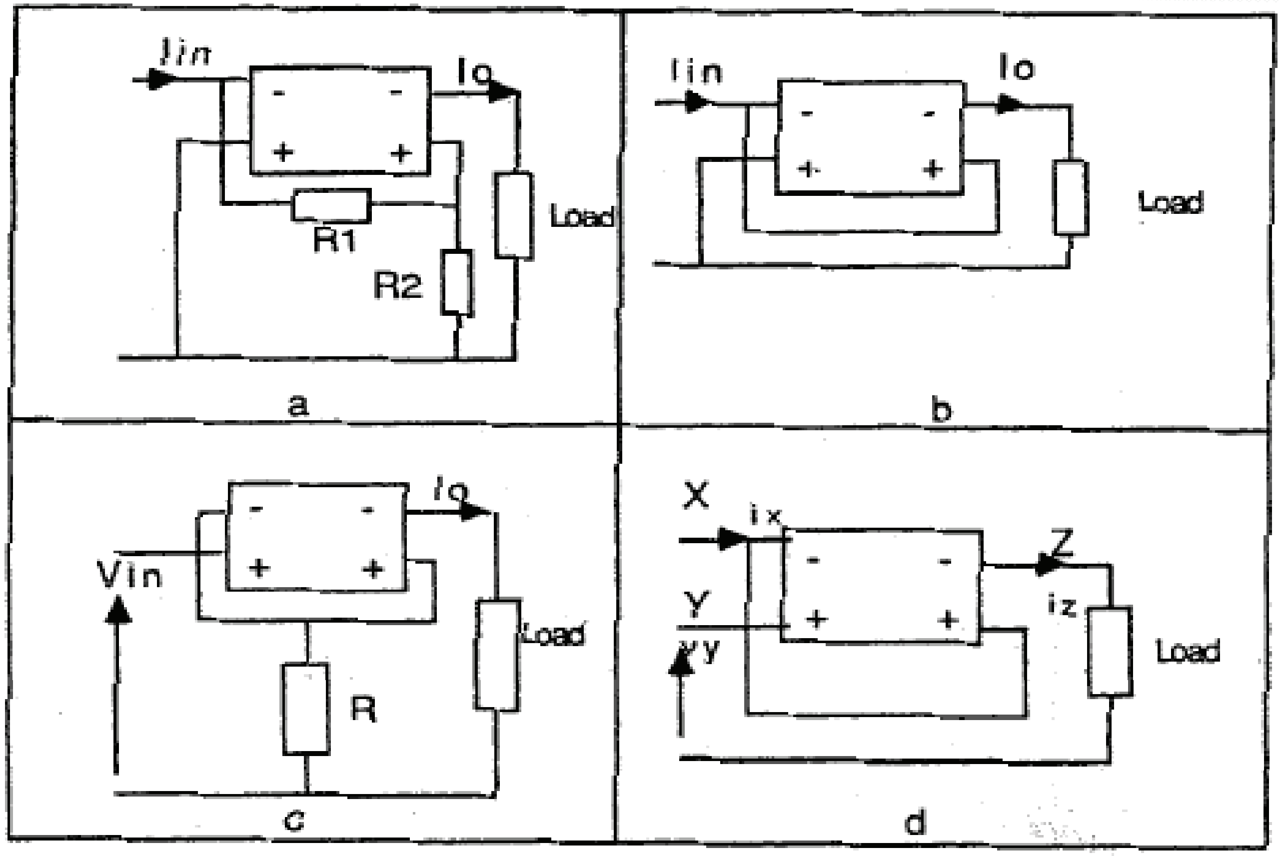


Figure 26:Closed loop controlled current output circiuts aplications

Current-Mode Feedback Amplifiers(OFC)

- In figure 26 this types of applications are given, in figure 26.a it is a current amplifier ($I_O/I_{IN}=1+R1/R2$), in figure 26.b it is a current follower ($I_O/I_{IN}=1$), in figure 26.c we see a transconductance amplifier ($I_O/V_{IN}=-1/R$) and in 26.d there is a current conveyor.

References

- C. Toumazou,F.J.Lidges & D.G.Haigh, Analogue IC Design: The Current Mode Approach, Peter Peregrinus LTD., 1998.
- H. Hakan Kuntman, Analog MOS Tümdevre Tekniği (Ders Kitabı), ITÜ Kütüphanesi, Sayı 1587, 1997.