ELE509E
Current-Mode Analog Circuit Design
Homework 3 (21.11.2003)

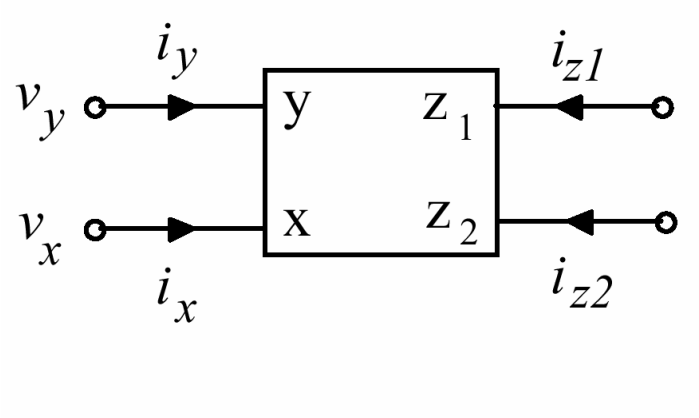

Figure 1. Circuit symbol of DOCCII.

A dual output current conveyor (DOCCII) is described by

$$\begin{bmatrix} V_X \\ I_Y \\ I_{Z1} \\ I_{Z2} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ k & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} I_X \\ V_Y \\ V_{Z1} \\ V_{Z2} \end{bmatrix}$$

k =±1. For k = 1 a DOCCII with two noninverting Z outputs is obtained. For k= -1 the Z_2 terminal yields an inverted output signal.

Design a CMOS dual output current conveyor with inverting and noninverting outputs..
1. Terminal output resistances R_{Z1}, R_{Z2}, R_Y > 25 M.Ohms, R_X < 10 Ohms.
2. Voltage tracking error ε_V < 0.1%, current tracking error ε_I < 0.1%,
3. BW of the voltage gain ($A_V = v_x/v_y$) f_{V3db} > 10 MHz,
4. BW of the current gain ($A_{I1} = i_{z1}/i_x$, $A_{I2} = i_{z2}/i_x$) f_{I3db} > 50 MHz,

The supply voltages are given as V_{DD} =2.5V, $-V_{SS}$ = -2.5V. The model parameters of the MOS transistors are given in Table 1.

a - Specify the CMOS DOCCII structure, determine transistor dimensions.

Using SPICE simulation results

a) draw the the plots of V_X against V_Y, I_{Z1} and I_{Z2} against I_X,
b) specify the limits of the operation region,

c) draw the frequency response of the voltage gain and determine the bandwidth,
d) draw the frequency response of the current gain and determine the bandwidth,
e) draw the plot of the terminal impedances against the frequency,
f) investigate the large signal behaviour of the DOCCII by applying to Y terminal a sinusoidal input voltage in the passband and observing the total harmonic distortion THD at the X, Z1 and Z2 terminals for different input levels; draw the plot of THD against i_{in} for each terminal. (Connect adequate load resistances to the X, Z1 and Z2 terminals.
g) Give a detailed evaluation of your results.

Table 1. Transistor parameters of 0.5µm CMOS process

.MODEL NT 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 ETA=0 +VMAX=130E3 NSUB=1.71E17 PB=.761 PHI=0.905

THETA=0.129 GAMMA=0.69 KAPPA=0.1 AF=1 +WD=.11E-6 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 DELTA=0.42 NFS=1.2E11

.MODEL PT 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 ETA=0 +VMAX=113E3 NSUB=2.08E17 PB=.911 PHI=0.905
THETA=0.120 GAMMA=0.76 KAPPA=2 AF=1 +WD=.14E-6 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 DELTA=0.81 NFS=0.52E11