A MOS VLSI Comparator

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ABSTRACT

A comparator is designed that can coexist with digital circuits on a MOS VLSI die. Besides designing the circuit, modeling and layout techniques for the comparator or other analog devices are described that can be used to design analog circuits despite the strictly digital nature of most VLSI CAD systems. The performance of the fabricated comparator is compared to the modeled version.

1. INTRODUCTION

In order for any digital system to interface with its human operators, it must interact in a manner that humans are accustomed to. Since humans are analog beings, it is ultimately necessary for the machine to accept analog inputs and deliver analog outputs in order to make the interaction easiest on the human. The catalog of analog building blocks is relatively concise, consisting principally of digital to analog converters and their counterparts which in turn are comprised of sample-and-holds, filters, amplifiers, and comparators. More sophisticated components such as phase locked loops, voltage controlled oscillators and filters, and sensors for temperature, magnetism and light are also possible.

The comparator designed here was an exercise in modeling and layout of analog devices for CMOS VLSI technologies. A comparator was chosen because it is the simplest of analog to digital converters and has much usefulness as a building block. Construction of this circuit required no adaptation of the fabrication process.

2. DESIGN LIMITATIONS

In order for a need for MOS VLSI analog circuitry to exist, it must be assumed that the devices will be coexisting on a substrate shared with digital circuitry. Almost any other semiconductor technology is superior to the task of implementing analog circuitry (for reasons to be outlined below) so it follows that MOS VLSI analog blocks must be operated on the same supply voltages, use the same process parameters and also be small enough to not crowd the die.

There are several difficulties trying to implement a comparator on a MOS VLSI substrate. Among them are:

2.1 Passive components

Substrate connected diodes can be formed by connecting to an empty P or N well. Since light doping is used in MOS fabrication. It is possible that the diodes will encourage latch up in nearby circuits.

Resistors and capacitors are virtually unavailable. Capacitors require area, which becomes less available as new fabrication technologies allow for even higher transistor densities. The cost of losing valuable transistor area becomes greater as the level of integration increases. Resistors can be made with metal or polysilicon but their resistivity is low. Unless the value needed is on the order of 10 KΩ or less a resistor will take up inordinate amounts of area.

2.2 Bipolar Devices

Using the natural diode junctions formed when wells are doped, bipolar transistors can be fabricated. Lower output impedances and higher power outputs can be achieved using such devices on output stages, but the tendencies of these lightly doped areas to cause latch up in nearby wells requires the use of spacing rules that are not well defined.

2.3 Supply voltages

Process parameters dictate that each circuit element operate over a 5 volt potential, with the substrate being the most negative potential and connected to ground. In order to use voltages less than logic ground, the logic circuitry must itself be formed in a well, which requires extra process steps. This 5 volt maximum will limit the dynamic range of the analog circuit by restricting the headroom available. Also for best noise margin when connecting with digital elements we would like the analog inputs and outputs to handle the full 5 volt range. These factors effectively prevent the use of voltage source biasing elements because they will ultimately limit the linear voltage swing of the circuits. It is therefore convenient that these biasing elements are not readily available to begin with.

2.4 Output power

MOS transistors, unlike bipolar devices, are limited in output power capability. They are horizontal devices, meaning their current is carried on the surface of the substrate. Bipolar devices have depth and therefore allow more bulk material to sink the heat.

Typical bias currents are on the order of 10 μA. An output device such as a LED requires 10 mA and a small loudspeaker requires around an ampere. While output stages could be accommodated to drive current gain stages off the chip, it makes more to move sense the entire circuit off-chip because the other technology would most likely be superior. The design of this paper presupposes that it would be used as an input device whose output will drive a logic gate or another MOS analog stage on the same substrate. Output circuits are possible and may best be formed as current sources which can best be transformed to a voltage by an external current to voltage converter. R/2R ladders used in digital to analog converters are good examples of this.

2.5 Quantum noise

Designing with a level of integration as high as VLSI requires that the circuit be small. At feature sizes approaching one micron, the Johnson thermal noise model begins to break down. Here, individual electrons moving due to thermal activity are discretely identifiable. We can no longer assume there is a steady flow of current. This noise has a spectrum that increases as 1/f which further degrades the low frequency and DC dynamic range. This makes interface with humans more difficult because humans are low frequency creatures. Preamplification of transducers with low efficiencies will need to be handled off chip. This design presupposes that the input signals will be large in amplitude.

2.6 Bandwidth

MOS devices are capable of high speeds and, therefore, so are the analog elements formed from them. This is further enhanced as the device sizes become smaller, because the parasitic capacitances are reduced. However, this is not necessarily a virtue. The small capacitances that exist between neighboring logic circuits and connecting traces will cause significant signal currents to be cross coupled to the analog stages due to the high frequency spectral components represented by digital switching and the high input impedances inherent in MOS transistors. Faraday shielding may be an important element of the design itself. If the capacitance it subsequently adds also slows the circuit, so much the better.

2.7 Power density

An interesting parameter that needs consideration is called power density. As devices are scaled smaller, their power dissipations must also decrease. Also, the density/speed product desired with such a high level of integration dictates that the power levels be low for the device to be reliable.

Digital CMOS circuits draw virtually no power at idle. Since their inputs load capacitively, the power consumed is proportional to the clocking frequency. Analog circuits, on the other hand are biased for linear operation and therefore all devices are centered in their active regions. The result is that the circuit consumes current at all times and all power that is not delivered to the load must be dissipated in the chip. When combined with other circuits, the resultant heat may cause chip failure.

Some examples of relative power densities are shown in the table below. For example, a 100 watt light bulb emits its thermal power over an area that is defined by its glass bulb. That power density makes the bulb too hot to touch.

POWER DENSITY	SOURCE
10^3 watts/meter^2	Sunlight
10^4 watts/meter^2	100w light bulb
10^5 watts/meter^2	VLSI with grooved substrate
10^6 watts/meter^2	Space shuttle tiles

Table 1
Power Densities

Ideally we would like to keep our power density at or below 10KW/m^2 which is the range used commonly in VLSI. Since it is our objective to make this device as small as the technology will allow, the power density requirement will define the bias currents used.

2.8 Design system limitations

Most CAD systems for VLSI design presuppose that digital circuits are the objective. Test signals such as sine waves and test procedures that obtain transfer curves, model noise, or plot bandwidth are not available.

2.9 External contacts

The contacts formed on the edge of the chip usually contain logic circuitry for protection and buffering. This will cause difficulty when trying to pass an analog signal. Designers that integrate analog circuits on a chip need to use specially designed input and output pads when passing analog signals between the chip and the outside world.

3. DESIGN DEVELOPMENT

Our design begins with establishing a circuit topology shown in figure 1. The inputs are through a differential pair of transistors, M_1 and M_2, which have active loads M_3 and M_4 respectively. The input pair is fed current from M_7 which is mirrored from M_6. The output of the first stage is delivered to the second stage which consists of M_5 and its active load M_8. The current reference comes from the M_6 current source which uses M_9 as a high impedance active load.

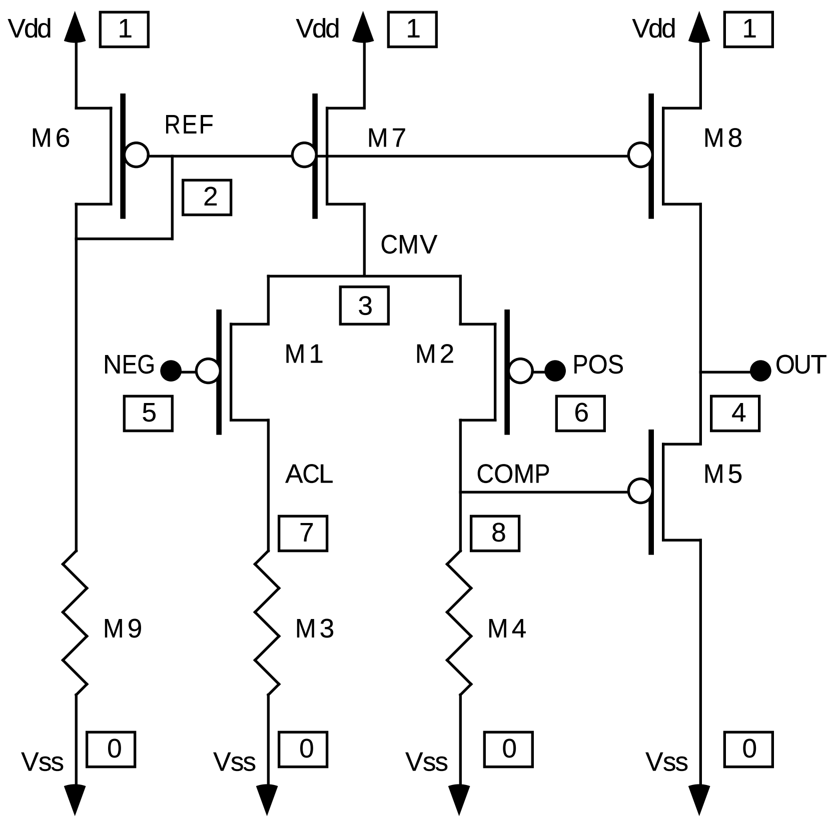

FIGURE 1
Topology of the Circuit

The input stage uses P channel FET's. While P channel devices are inferior to N channel ones, we opted to use PFET's to allow the circuit to compare signals near ground and remain in their linear region. At the other end of their common mode range, the transistors begin to turn off and the current source M_7 also starts to leave its linear area.

The next step is to select bias voltages. Node 1 is defined by the 5 volt supply. Node 4, the output, would be best centered between power and ground potentials. The current mirror reference voltage must be as high as practical to allow for the maximum common mode swing, but must allow the enhancement devices to remain in the saturation region. Since V_T is around 0.7 to 0.8 volts, V_{GS} is selected to be 1 volt. This puts the value at node 2 to be 4 volts. Node 3 is selected to be below node 2 so that the saturation condition is maintained while permitting high common mode swings. Nodes 7 and 8 are picked to be 1.5 volts so that the active loads are fully saturated while allowing maximum voltage swings for the input transistors. Hand calculations show that adequate power densities can be achieved if the bias currents are kept around 1.5 microamp for each of the three loops. Lower currents are of course permissible, but increased noise and smaller bandwidth will result. Also, as we will soon see from the geometry calculations, the devices will become longer and therefore require more area.

Once the currents and voltages have been declared, the device geometries can be calculated. The relationship used is given as:

$$S = W/L = 2I/\{K_P(V_{GS} - V_T)^2\}$$

where:

- S - Aspect ratio
- W -Channel width (microns)
- L -Channel length (microns)
- I - Channel current (A)
- V_{GS} - Gate to Source voltage
- K_P - Transconductance factor (A/V^2)
- V_T - Threshold voltage

The latter two parameters are given seperately for N and P transistors.

The parameters that are process dependent were obtained in a printout from a recent fabrication run of IC's using the same 2 micron N-well technology that the amplifier is being designed for. For the purpose of our calculations we used:

$K_{Pn} = 5.0\ A/V^2$
$K_{Pp} = 2.5\ A/V^2$
$V_{Tn} = 0.75\ V$
$V_{Tp} = 0.79\ V$

If K_P is not given, it can be calculated using the relation:

$K_{Pn} = \mu_n C_{ox}$
$K_{Pp} = \mu_p C_{ox}$

where:

- μ - Channel mobility (cm^2/V_s)
- C_{ox} - Gate oxide capacitance factor (F/cm^2)

One of the design objectives was to utilize the minimum feature limit of the process technology, which is 2 microns. As it turns out, the aspect ratios of the devices were less than 1 meaning the channels are to be longer than they are wide. The widths were fixed at the 3 micron limit in the MAGIC scmos6 technology specifications for scalable CMOS which put the lengths at:

DEVICE	LENGTH
M_1,M_2	2
M_3,M_4	26
M_5	13
M_6,M_7,M_8	37
M_9	255

The length of M_9 was considered unreasonable so a new transistor wired as an active resistor and placed in series was included as M_{10}. The new M_9 and M_{10} combination is shorter. The only penalty paid is the reduced voltage range over which the active resistors can remain linear. This is no detriment at this point because their purpose is to establish a fixed reference voltage anyway. Their lengths are:

DEVICE	LENGTH
M_9	37
M_{10}	13

The complete circuit is shown in figure 2.

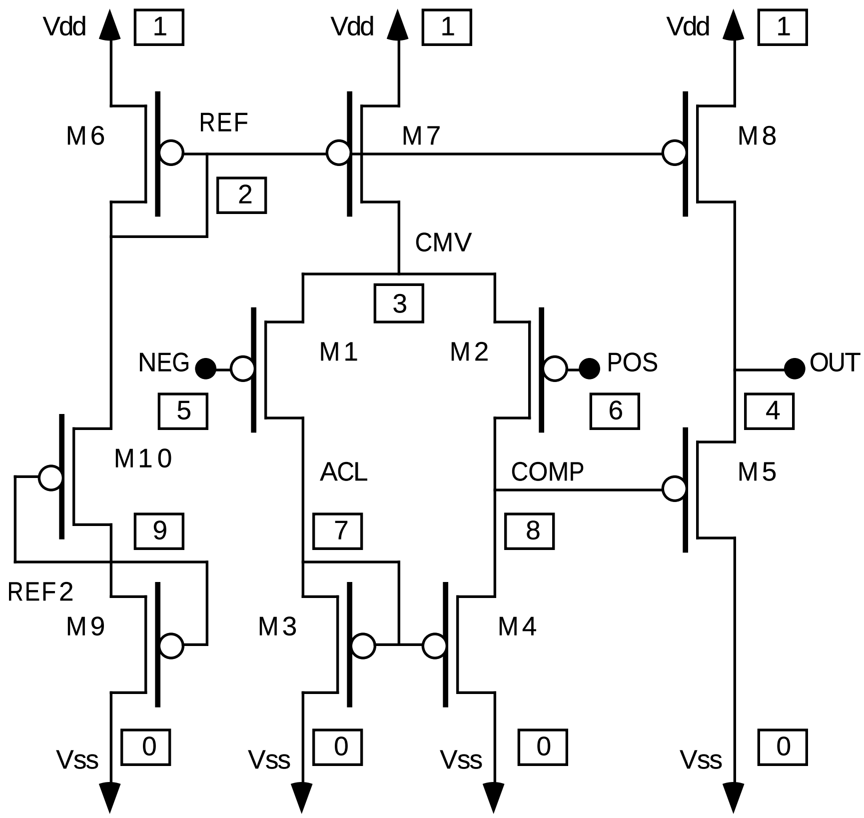

Figure 2
Comparator Circuit

After hand calculation, the circuit was modeled in SPICE. The MOSIS device parameters of figure 2 are given for SPICE simulation. The results of the SPICE simulation are summarized in Appendix 1. Common mode performance was simulated separately and the results are given in Appendix 2.

4. LAYOUT

The final step in the process was to lay the elements out in "virtual silicon" using MAGIC. The sensitive input stage was symmetrically placed in the center of the cell. The output stage and current reference were placed on either side. Since they both consume the same current, they raise the temperature of the substrate area above ambient temperature by an equal amount. The input transistors will experience identical temperatures and have less thermal drift, so that both the absolute offset voltage and the offset voltage drift can be minimized. Power nodes line the cell on top and bottom and similar low impedance nodes cover the cell in a metal1 layer. The intent is to provide the cell with a bit of Faraday shielding to protect it from electrostatically coupled signals that may come from nearby logic elements. The stray parasitic capacitances formed between the circuit elements and the shielding will appear as a capacitance to AC ground. The finished cell takes up an area 61 by 66 microns or 4026 micron^2.

A test version of the cell was fabricated. Measurement of the performance of such a device is problematic. The source follower output stage has an output impedance of 4 MΩ which is hardly an ideal voltage source. The large gain makes it almost impossible to keep the device out of saturation while measuring.

As the output signal drifts, the current in the transistors changes, causing thermal changes which in turn causes more drifting. In order to see if the fabricated unit matches the design goals, we checked the bias voltages and connected the unit as a unity gain follower to measure the frequency of oscillation which can be compared to the SPICE model. A photograph of this appears as figure 3. The device appears to meet all design expectations.

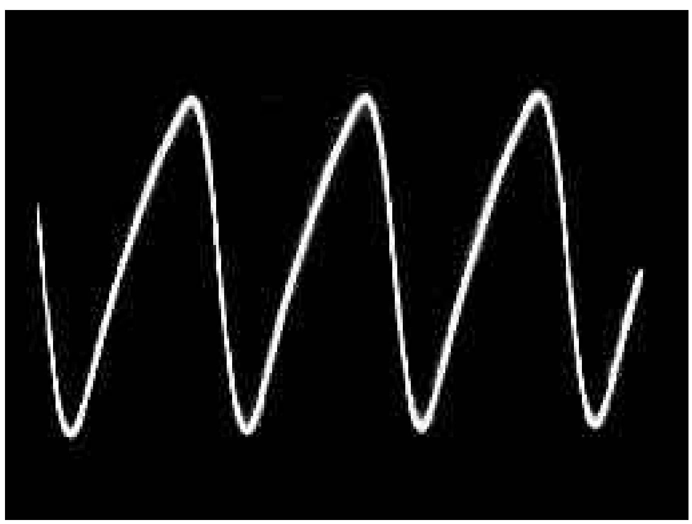

Figure 3
Photo of output in oscillation

Full specifications of the finished comparator are listed in figure 4.

Input Voltage Range	V_{max}	-0.5 to 5.5V
Supply Current	I_{dd}	$7.5x10^{-6}$A
Power Dissipation	P_d	$3.73x10^{-5}$W
Forward Gain	AV	61dB
Common Mode rejection	CMRR	67dB
Differential Input Resistance	R_i	$1x10^{20}\Omega$
Output Resistance	R_o	$3.8x10^{6}\Omega$
Gain-Bandwidth Product	GBW	$1.8x10^{10}$Hz
Unity Gain Frequency	f_T	$3x10^{8}$Hz

Figure 4
Comparator Specifications

5. SUMMARY

The purpose of this project was twofold. First, we were able to design a cell for use as a comparator. Second, and more importantly, we were able to find a means to design analog components using existing digital VLSI design tools. An N-type device can be made using the same design rules. New circuits can be made that have greater gain, less offset or other features. From there, more analog cells can be developed such as digital to analog ladders, single ended amplifiers and more. These cells can be applied to form functional blocks such as filters, oscillators, opto-isolators, and other analog circuits. Integration of analog functions on an otherwise digital chip can prove to be a useful asset in VLSI designs.

6. ACKNOWLEDGMENTS

This work was done with support of a grant for MOSIS sponsored by the National Science Foundation (USA).

7. REFERENCES

Glasser L. and Dobberpuhl D.,1985,
"The Design and Analysis of VLSI Circuits"
(Addison Wesley)

Mavretic, A
"MAGIC scmos6 specifications"

Appendix 1 SPICE Performance parameters, differential drive
Appendix 2 SPICE Performance parameters, common mode drive

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*******28-APR-89 *******  SPICE 2G.5 (10AUG81)  *******00:22:46*****
P Channel Opamp/Comparator
****     INPUT LISTING                    TEMPERATURE =   27.000 DEG C
***********************************************************************


* Node 0 Vss
* Node 1 Vdd
* Node 2 REF
* Node 3 CMV
* Node 4 OUT
* Node 5 NEG
* Node 6 POS
* Node 7 ACL
* Node 8 COMP
* Node 9 REF2
*
* Circuit Description
*
Vdd   1    0    5V
M1    7    5    3    1    CMOSP    W=3U L=2U
M2    8    6    3    1    CMOSP    W=3U L=2U
M3    7    7    0    0    CMOSN    W=3U L=26U
M4    8    7    0    0    CMOSN    W=3U L=26U
M5    4    8    0    0    CMOSN    W=3U L=13U
M6    2    2    1    1    CMOSP    W=3U L=37U
M7    3    2    1    1    CMOSP    W=3U L=37U
M8    4    2    1    1    CMOSP    W=3U L=37U
M9    9    9    0    0    CMOSN    W=3U L=26U
M10   9    9    2    1    CMOSP    W=3U L=37U
* Device effective widths have been ignored
*
* Device Parameters
*
.MODEL CMOSN NMOS LEVEL=2 LD=0.133752U TOX=399.000026E-10
+ NSUB=9.999614E+15 VTO=0.75 KP=5.044000E-05 GAMMA =0.6681
+ PHI=0.6 UO=582.823 UEXP=0.194168 UCRIT=98993.2
+ DELTA=1.740560 VMAX=56837.5 XJ=0.250000U LAMBDA=3.433891E-02
+ NFS=1.000000E+11 NEFF=1 NSS=1.000000E+12 TPG=1.000000
+ RSH=24.010001 CGDO=1.15708E-10 CGSO=1.157508E-10
+ CGBO=3.46E-11 CJ=1.461000E-04 MJ=0.644600 CJSW=5.084000E-10
+ MJSW=0.245500 PB=0.500000
* Weff= Wdrawn - DeltaW   DeltaW = -0.38U
*
```

```
.MODEL CMOSP PMOS LEVEL=2 LD=0.060915U TOX=399.000026E-10
+ NSUB=8.148127E+15 VTO=0.7922 KP=2.475000E-5 GAMMA=0.6031
+ PHI=0.6 UO=286 UEXP=0.264533 UCRIT=20482.8
+ DELTA=0.540869 VMAX=50671.1 XJ=0.250000U LAMBDA=5.107142E-02
+ NFS=4.188926E+11 NEFF=1.001 NSS=1.000000E+12 TPG=-1.000000
+ RSH=120.100001 CGDO=5.271667E-11 CGSO=5.271667E-11
+ CGBO=2.11E-10 CJ=2.479000E-04 MJ=0.572500 CJSW=2.292000E-10
+ MJSW=0.309200 PB=0.800000
* Weff= Wdrawn - DeltaW   DeltaW = -0.27U        ÜjÜŒ*
* Simulation Parameters
*
* Set initial voltages to speed convergence
.NODESET V(2)=3.0 V(3)=3.0 V(4)=2.5 V(7)=1.5 V(8)=1.5  V(9)=1.5
*
VIN   6    5    0.0    AC    0.0001 SIN(0.0 0.0001 1G)
VCM   6    0    2.5V
.DC VIN -1.0 1.0 0.05
.OP
.TF  V(4,0) VIN
.AC DEC 4 1 1G
.NOISE V(4,0) VIN
*
.PRINT DC V(4,0) V(3,0) V(7,0) V(8,0) V(2,0)
.PLOT DC  V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) (0,5)
.PRINT AC V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) VP(4,0)
.PLOT AC  V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) VP(4,0)
.PRINT NOISE ONOISE INOISE
.END
```

```
***************28-APR-89 ************************  SPICE 2G.5 (10AUG81)  **********************00:22:46***************
P Channel Opamp/Comparator
****                 MOSFET MODEL PARAMETERS                              TEMPERATURE =   27.000 DEG C
**************************************************************************************************************************
```

	CMOSN	CMOSP
TYPE	NMOS	PMOS
LEVEL	2.000	2.000
VTO	0.750	0.792
KP	5.04D-05	2.47D-05
GAMMA	0.668	0.603
PHI	0.600	0.600
LAMBDA	3.43D-02	5.11D-02
PB	0.500	0.800
CGSO	1.16D-10	5.27D-11
CGDO	1.16D-10	5.27D-11
CGBO	3.46D-11	2.11D-10
RSH	24.010	120.100
CJ	1.46D-04	2.48D-04
MJ	0.645	0.573
CJSW	5.08D-10	2.29D-10
MJSW	0.246	0.309
TOX	3.99D-08	3.99D-08
NSUB	1.00D+16	8.15D+15
NSS	1.00D+12	1.00D+12
NFS	1.00D+11	4.19D+11
TPG	1.000	-1.000
XJ	2.50D-07	2.50D-07
LD	1.34D-07	6.09D-08
UO	582.823	286.000
UCRIT	9.90D+04	2.05D+04
UEXP	0.194	0.265
VMAX	5.68D+04	5.07D+04
NEFF	1.000	1.001
DELTA	1.741	0.541

***************28-APR-89 *********************** SPICE 2G.5 (10AUG81) **********************00:22:46***************
P Channel Opamp/Comparator
**** DC TRANSFER CURVES TEMPERATURE = 27.000 DEG C
****

VIN	V(4)	V(3)	V(7)	V(8)	V(2)
-1.000E+00	1.194E-01	3.260E+00	1.511E+00	3.220E+00	3.531E+00
-9.500E-01	1.212E-01	3.217E+00	1.513E+00	3.177E+00	3.531E+00
-9.000E-01	1.232E-01	3.175E+00	1.514E+00	3.132E+00	3.531E+00
-8.500E-01	1.252E-01	3.132E+00	1.515E+00	3.088E+00	3.531E+00
-8.000E-01	1.273E-01	3.089E+00	1.516E+00	3.044E+00	3.531E+00
-7.500E-01	1.296E-01	3.046E+00	1.517E+00	2.999E+00	3.531E+00
-7.000E-01	1.319E-01	3.004E+00	1.519E+00	2.954E+00	3.531E+00
-6.500E-01	1.343E-01	2.961E+00	1.520E+00	2.909E+00	3.531E+00
-6.000E-01	1.369E-01	2.918E+00	1.521E+00	2.864E+00	3.531E+00
-5.500E-01	1.396E-01	2.875E+00	1.522E+00	2.818E+00	3.531E+00
-5.000E-01	1.425E-01	2.832E+00	1.524E+00	2.772E+00	3.531E+00
-4.500E-01	1.455E-01	2.789E+00	1.525E+00	2.726E+00	3.531E+00
-4.000E-01	1.487E-01	2.745E+00	1.526E+00	2.679E+00	3.531E+00
-3.500E-01	1.522E-01	2.702E+00	1.527E+00	2.631E+00	3.531E+00
-3.000E-01	1.559E-01	2.659E+00	1.529E+00	2.582E+00	3.531E+00
-2.500E-01	1.600E-01	2.616E+00	1.530E+00	2.532E+00	3.531E+00
-2.000E-01	1.645E-01	2.573E+00	1.531E+00	2.480E+00	3.531E+00
-1.500E-01	1.695E-01	2.529E+00	1.533E+00	2.426E+00	3.531E+00
-1.000E-01	1.755E-01	2.486E+00	1.534E+00	2.366E+00	3.531E+00
-5.000E-02	1.835E-01	2.443E+00	1.535E+00	2.294E+00	3.531E+00
2.776E-17	1.791E+00	2.401E+00	1.542E+00	1.542E+00	3.531E+00
5.000E-02	5.000E+00	2.371E+00	1.582E+00	3.394E-01	3.531E+00
1.000E-01	5.000E+00	2.347E+00	1.641E+00	2.188E-01	3.531E+00
1.500E-01	5.000E+00	2.324E+00	1.692E+00	1.491E-01	3.531E+00
2.000E-01	5.000E+00	2.299E+00	1.738E+00	9.876E-02	3.531E+00
2.500E-01	5.000E+00	2.272E+00	1.779E+00	6.066E-02	3.531E+00
3.000E-01	5.000E+00	2.242E+00	1.812E+00	3.198E-02	3.531E+00
3.500E-01	5.000E+00	2.208E+00	1.838E+00	1.188E-02	3.531E+00
4.000E-01	5.000E+00	2.170E+00	1.849E+00	3.989E-03	3.531E+00
4.500E-01	5.000E+00	2.136E+00	1.853E+00	1.820E-03	3.531E+00
5.000E-01	5.000E+00	2.108E+00	1.855E+00	9.424E-04	3.531E+00
5.500E-01	5.000E+00	2.084E+00	1.856E+00	5.447E-04	3.531E+00
6.000E-01	5.000E+00	2.064E+00	1.857E+00	3.450E-04	3.531E+00
6.500E-01	5.000E+00	2.048E+00	1.857E+00	2.353E-04	3.531E+00
7.000E-01	5.000E+00	2.034E+00	1.858E+00	1.706E-04	3.531E+00
7.500E-01	5.000E+00	2.022E+00	1.858E+00	1.298E-04	3.531E+00
8.000E-01	5.000E+00	2.012E+00	1.859E+00	1.026E-04	3.531E+00
8.500E-01	5.000E+00	2.003E+00	1.859E+00	8.374E-05	3.531E+00
9.000E-01	5.000E+00	1.995E+00	1.859E+00	7.010E-05	3.531E+00
9.500E-01	5.000E+00	1.988E+00	1.859E+00	5.995E-05	3.531E+00
1.000E+00	5.000E+00	1.982E+00	1.860E+00	5.218E-05	3.531E+00

```
***************28-APR-89 ************************  SPICE 2G.5 (10AUG81)  **********************00:22:46***************
P Channel Opamp/Comparator
****                 DC TRANSFER CURVES                                     TEMPERATURE =   27.000 DEG C
******************************************************************************************************************************

LEGEND:    *: V(4)     +: V(3)     =: V(7)     $: V(8)     0: V(2)

(*+=$0)-------------   0.000D+00                1.250D+00                2.500D+00                3.750D+00                5.000D+00
VIN         V(4)        - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
-1.000D+00    1.194D-01   . *                      .    =                   .             $+     0   .                        .
-9.500D-01    1.212D-01   . *                      .    =                   .             X      0   .                        .
-9.000D-01    1.232D-01   . *                      .    =                   .            X       0   .                        .
-8.500D-01    1.252D-01   .  *                     .    =                   .           $+       0   .                        .
-8.000D-01    1.273D-01   .  *                     .    =                   .          $+        0   .                        .
-7.500D-01    1.296D-01   .  *                     .    =                   .         $+         0   .                        .
-7.000D-01    1.319D-01   .  *                     .    =                   .        $+          0   .                        .
-6.500D-01    1.343D-01   .  *                     .    =                   .       $+           0   .                        .
-6.000D-01    1.369D-01   .  *                     .    =                   .      $+            0   .                        .
-5.500D-01    1.396D-01   .  *                     .    =                   .     $+             0   .                        .
-5.000D-01    1.425D-01   .  *                     .    =                   .    $ +             0   .                        .
-4.500D-01    1.455D-01   .  *                     .    =                   .    $+              0   .                        .
-4.000D-01    1.487D-01   .  *                     .     =                  .   $+               0   .                        .
-3.500D-01    1.522D-01   .  *                     .     =                  .  $+                0   .                        .
-3.000D-01    1.559D-01   .  *                     .     =                  . $+                 0   .                        .
-2.500D-01    1.600D-01   .  *                     .     =                  .$+                  0   .                        .
-2.000D-01    1.645D-01   .  *                     .     =                  $+                   0   .                        .
-1.500D-01    1.695D-01   .  *                     .     =                 $.+                   0   .                        .
-1.000D-01    1.755D-01   .   *                    .     =               $  +                    0   .                        .
-5.000D-02    1.835D-01   .   *                    .     =              $  +.                    0   .                        .
 2.776D-17    1.791D+00   .                        .     X    *           + .                    0   .                        .
 5.000D-02    5.000D+00   .      $                 .      =              +  .                    0   .                        *
 1.000D-01    5.000D+00   .   $                    .       =             +  .                    0   .                        *
 1.500D-01    5.000D+00   .  $                     .        =           +   .                    0   .                        *
 2.000D-01    5.000D+00   . $                      .         =          +   .                    0   .                        *
 2.500D-01    5.000D+00   .$                       .          =        +    .                    0   .                        *
 3.000D-01    5.000D+00   .$                       .          =        +    .                    0   .                        *
 3.500D-01    5.000D+00   $                        .           =      +     .                    0   .                        *
 4.000D-01    5.000D+00   $                        .           =     +      .                    0   .                        *
 4.500D-01    5.000D+00   $                        .           =     +      .                    0   .                        *
 5.000D-01    5.000D+00   $                        .           =    +       .                    0   .                        *
 5.500D-01    5.000D+00   $                        .           =    +       .                    0   .                        *
 6.000D-01    5.000D+00   $                        .           =   +        .                    0   .                        *
 6.500D-01    5.000D+00   $                        .           =   +        .                    0   .                        *
 7.000D-01    5.000D+00   $                        .           =   +        .                    0   .                        *
 7.500D-01    5.000D+00   $                        .           =  +         .                    0   .                        *
 8.000D-01    5.000D+00   $                        .           =  +         .                    0   .                        *
 8.500D-01    5.000D+00   $                        .           =  +         .                    0   .                        *
 9.000D-01    5.000D+00   $                        .           =  +         .                    0   .                        *
 9.500D-01    5.000D+00   $                        .           =  +         .                    0   .                        *
 1.000D+00    5.000D+00   $                        .           =  +         .                    0   .                        *
```

P Channel Opamp/Comparator
**** SMALL SIGNAL BIAS SOLUTION TEMPERATURE = 27.000 DEG C
****

NODE	VOLTAGE	NODE	VOLTAGE	NODE	VOLTAGE	NODE	VOLTAGE	NODE	VOLTAGE	NODE	VOLTAGE	NODE	VOLTAGE
(1)	5.0000	(2)	3.5315	(3)	2.4010	(4)	1.7907	(5)	2.5000	(6)	2.5000	(7)	1.5417
(8)	1.5417	(9)	1.7997										

VOLTAGE SOURCE CURRENTS

NAME	CURRENT
Vdd	-7.461D-06
VIN	0.000D+00
VCM	0.000D+00

TOTAL POWER DISSIPATION 3.73D-05 WATTS

```
**************28-APR-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:22:46***************
P Channel Opamp/Comparator
****                 OPERATING POINT INFORMATION                          TEMPERATURE =   27.000 DEG C
*******************************************************************************************************************************
```

**** MOSFETS

À„nÀ

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
MODEL	CMOSP	CMOSP	CMOSN	CMOSN	CMOSN	CMOSP	CMOSP	CMOSP	CMOSN	CMOSP
ID	-1.27E-06	-1.27E-06	1.27E-06	1.27E-06	2.63E-06	-2.30E-06	-2.53E-06	-2.63E-06	2.31E-06	-2.31E-06
VGS	0.099	0.099	1.542	1.542	1.542	-1.469	-1.469	-1.469	1.800	-1.732
VDS	-0.859	-0.859	1.542	1.542	1.791	-1.469	-2.599	-3.209	1.800	-1.732
VBS	2.599	2.599	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.469
VTH	0.315	0.315	0.821	0.821	0.815	0.729	0.729	0.730	0.820	0.314
VDSAT	-0.223	-0.223	0.535	0.535	0.534	-1.766	-1.767	-1.767	0.721	-1.758
GM	9.54E-06	9.54E-06	3.36E-06	3.36E-06	6.91E-06	1.51E-06	1.99E-06	2.07E-06	4.58E-06	1.88E-06
GDS	1.65E-07	1.65E-07	4.80E-08	4.80E-08	1.04E-07	5.72E-07	1.50E-07	1.61E-07	8.73E-08	1.70E-07
GMB	1.18E-06	1.18E-06	1.38E-06	1.38E-06	2.80E-06	3.97E-07	5.04E-07	5.22E-07	1.81E-06	3.51E-07
CBD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGSOVL	1.58E-16	1.58E-16	3.47E-16	3.47E-16	3.47E-16	1.58E-16	1.58E-16	1.58E-16	3.47E-16	1.58E-16
CGDOVL	1.58E-16	1.58E-16	3.47E-16	3.47E-16	3.47E-16	1.58E-16	1.58E-16	1.58E-16	3.47E-16	1.58E-16
CGBOVL	3.96E-16	3.96E-16	8.90E-16	8.90E-16	4.41E-16	7.78E-15	7.78E-15	7.78E-15	8.90E-16	7.78E-15
CGS	3.25E-15	3.25E-15	4.45E-14	4.45E-14	2.20E-14	6.25E-14	6.38E-14	6.38E-14	4.45E-14	6.38E-14
CGD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-14	0.00E+00	0.00E+00	0.00E+00	1.06E-15
CGB	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

**** SMALL-SIGNAL CHARACTERISTICS

```
V(4)/VIN                                  =  1.154D+03

INPUT RESISTANCE AT VIN                   =  1.000D+20

OUTPUT RESISTANCE AT V(4)                 =  3.767D+06
```

P Channel Opamp/Comparator

**** AC ANALYSIS TEMPERATURE = 27.000 DEG C

****

FREQ	V(4)	V(3)	V(7)	V(8)	V(2)	VP(4)
1.000E+00	1.154E-01	7.674E-05	3.321E-05	4.434E-03	3.057E-11	-5.894E-05
1.778E+00	1.154E-01	7.674E-05	3.321E-05	4.434E-03	5.436E-11	-1.048E-04
3.162E+00	1.154E-01	7.674E-05	3.321E-05	4.434E-03	9.667E-11	-1.864E-04
5.623E+00	1.154E-01	7.674E-05	3.321E-05	4.434E-03	1.719E-10	-3.315E-04
1.000E+01	1.154E-01	7.674E-05	3.321E-05	4.434E-03	3.057E-10	-5.894E-04
1.778E+01	1.154E-01	7.674E-05	3.321E-05	4.434E-03	5.436E-10	-1.048E-03
3.162E+01	1.154E-01	7.674E-05	3.321E-05	4.434E-03	9.667E-10	-1.864E-03
5.623E+01	1.154E-01	7.674E-05	3.321E-05	4.434E-03	1.719E-09	-3.315E-03
1.000E+02	1.154E-01	7.674E-05	3.321E-05	4.434E-03	3.057E-09	-5.894E-03
1.778E+02	1.154E-01	7.674E-05	3.321E-05	4.434E-03	5.436E-09	-1.048E-02
3.162E+02	1.154E-01	7.674E-05	3.321E-05	4.434E-03	9.667E-09	-1.864E-02
5.623E+02	1.154E-01	7.674E-05	3.321E-05	4.434E-03	1.719E-08	-3.315E-02
1.000E+03	1.154E-01	7.674E-05	3.321E-05	4.434E-03	3.057E-08	-5.894E-02
1.778E+03	1.154E-01	7.674E-05	3.321E-05	4.434E-03	5.436E-08	-1.048E-01
3.162E+03	1.154E-01	7.674E-05	3.321E-05	4.434E-03	9.667E-08	-1.864E-01
5.623E+03	1.154E-01	7.674E-05	3.322E-05	4.434E-03	1.719E-07	-3.314E-01
1.000E+04	1.154E-01	7.673E-05	3.323E-05	4.434E-03	3.057E-07	-5.894E-01
1.778E+04	1.154E-01	7.673E-05	3.328E-05	4.434E-03	5.435E-07	-1.048E+00
3.162E+04	1.153E-01	7.671E-05	3.343E-05	4.432E-03	9.661E-07	-1.863E+00
5.623E+04	1.152E-01	7.667E-05	3.390E-05	4.428E-03	1.716E-06	-3.312E+00
1.000E+05	1.149E-01	7.652E-05	3.532E-05	4.415E-03	3.040E-06	-5.879E+00
1.778E+05	1.138E-01	7.605E-05	3.938E-05	4.373E-03	5.344E-06	-1.039E+01
3.162E+05	1.106E-01	7.466E-05	4.941E-05	4.249E-03	9.173E-06	-1.817E+01
5.623E+05	1.019E-01	7.097E-05	6.868E-05	3.915E-03	1.473E-05	-3.075E+01
1.000E+06	8.357E-02	6.346E-05	9.436E-05	3.214E-03	2.025E-05	-4.842E+01
1.778E+06	5.784E-02	5.354E-05	1.148E-04	2.227E-03	2.142E-05	-6.837E+01
3.162E+06	3.383E-02	4.570E-05	1.185E-04	1.305E-03	1.645E-05	-8.698E+01
5.623E+06	1.711E-02	4.264E-05	1.011E-04	6.616E-04	9.438E-06	-1.016E+02
1.000E+07	7.935E-03	4.266E-05	7.115E-05	3.084E-04	4.558E-06	-1.095E+02
1.778E+07	3.760E-03	4.315E-05	4.392E-05	1.484E-04	2.181E-06	-1.115E+02
3.162E+07	1.896E-03	4.341E-05	2.552E-05	7.820E-05	1.106E-06	-1.138E+02
5.623E+07	9.644E-04	4.354E-05	1.449E-05	4.479E-05	5.707E-07	-1.210E+02
1.000E+08	4.544E-04	4.371E-05	8.150E-06	2.725E-05	2.809E-07	-1.338E+02
1.778E+08	1.863E-04	4.413E-05	4.551E-06	1.681E-05	1.306E-07	-1.492E+02
3.162E+08	6.785E-05	4.509E-05	2.515E-06	1.015E-05	6.479E-08	-1.631E+02
5.623E+08	2.341E-05	4.656E-05	1.379E-06	6.018E-06	4.043E-08	-1.755E+02
1.000E+09	7.984E-06	4.784E-05	7.667E-07	3.504E-06	3.219E-08	1.713E+02

P Channel Opamp/Comparator

**** AC ANALYSIS TEMPERATURE = 27.000 DEG C

****

FREQ	ONOISE	INOISE
1.000E+00	6.468E-05	5.605E-04
1.778E+00	6.468E-05	5.605E-04
3.162E+00	6.468E-05	5.605E-04
5.623E+00	6.468E-05	5.605E-04
1.000E+01	6.468E-05	5.605E-04
1.778E+01	6.468E-05	5.605E-04
3.162E+01	6.468E-05	5.605E-04
5.623E+01	6.468E-05	5.605E-04
1.000E+02	6.468E-05	5.605E-04
1.778E+02	6.468E-05	5.605E-04
3.162E+02	6.468E-05	5.605E-04
5.623E+02	6.468E-05	5.605E-04
1.000E+03	6.468E-05	5.605E-04
1.778E+03	6.468E-05	5.605E-04
3.162E+03	6.468E-05	5.605E-04
5.623E+03	6.468E-05	5.605E-04
1.000E+04	6.467E-05	5.605E-04
1.778E+04	6.467E-05	5.605E-04
3.162E+04	6.465E-05	5.605E-04
5.623E+04	6.459E-05	5.605E-04
1.000E+05	6.439E-05	5.605E-04
1.778E+05	6.379E-05	5.605E-04
3.162E+05	6.198E-05	5.606E-04
5.623E+05	5.712E-05	5.608E-04
1.000E+06	4.691E-05	5.613E-04
1.778E+06	3.257E-05	5.630E-04
3.162E+06	1.921E-05	5.680E-04
5.623E+06	9.948E-06	5.815E-04
1.000E+07	4.853E-06	6.116E-04
1.778E+07	2.509E-06	6.672E-04
3.162E+07	1.475E-06	7.781E-04
5.623E+07	9.947E-07	1.031E-03
1.000E+08	7.153E-07	1.574E-03
1.778E+08	4.864E-07	2.611E-03
3.162E+08	3.007E-07	4.432E-03
5.623E+08	1.753E-07	7.486E-03
1.000E+09	9.973E-08	1.249E-02

```
***************28-APR-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:22:46***************
P Channel Opamp/Comparator
****                 AC ANALYSIS                                  TEMPERATURE =   27.000 DEG C
*************************************************************************************************************************
LEGEND:    *: V(4)     +: V(3)     =: V(7)     $: V(8)     0: V(2)     <: VP(4)
(*)-----------------   1.000D-06               1.000D-04               1.000D-02               1.000D+00               1.000D+02(+)-
----------------   3.981D-05               5.012D-05               6.310D-05               7.943D-05               1.000D-04 (=)----
-------------   1.000D-07               1.000D-06               1.000D-05               1.000D-04               1.000D-03($)--------
---------   1.000D-06               1.000D-05               1.000D-04               1.000D-03               1.000D-02(0)------------
-----   1.000D-12               1.000D-10               1.000D-08               1.000D-06               1.000D-04(<)----------------
-  -2.000D+02               -1.000D+02               0.000D+00               1.000D+02               2.000D+02
    FREQ      V(4)       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 1.000D+00    1.154D-01   .                  0     .                        <            X       +   .               $        .
 1.778D+00    1.154D-01   .                     0  .                        <            X       +   .               $        .
 3.162D+00    1.154D-01   .                        0                        <            X       +   .               $        .
 5.623D+00    1.154D-01   .                        .  0                     <            X       +   .               $        .
 1.000D+01    1.154D-01   .                        .     0                  <            X       +   .               $        .
 1.778D+01    1.154D-01   .                        .        0               <            X       +   .               $        .
 3.162D+01    1.154D-01   .                        .           0            <            X       +   .               $        .
 5.623D+01    1.154D-01   .                        .              0         <            X       +   .               $        .
 1.000D+02    1.154D-01   .                        .                  0     <            X       +   .               $        .
 1.778D+02    1.154D-01   .                        .                     0  <            X       +   .               $        .
 3.162D+02    1.154D-01   .                        .                        X            X       +   .               $        .
 5.623D+02    1.154D-01   .                        .                        <  0         X       +   .               $        .
 1.000D+03    1.154D-01   .                        .                        <     0      X       +   .               $        .
 1.778D+03    1.154D-01   .                        .                        <        0   X       +   .               $        .
 3.162D+03    1.154D-01   .                        .                        <           0X       +   .               $        .
 5.623D+03    1.154D-01   .                        .                        <            X 0     +   .               $        .
 1.000D+04    1.154D-01   .                        .                        <            X     0 +   .               $        .
 1.778D+04    1.154D-01   .                        .                        <            X       +0  .               $        .
 3.162D+04    1.153D-01   .                        .                        <            X       +   0               $        .
 5.623D+04    1.152D-01   .                        .                       <.            X       +   .  0            $        .
 1.000D+05    1.149D-01   .                        .                       <.            *=      +   .     0         $        .
 1.778D+05    1.138D-01   .                        .                     <  .            * =    +    .        0      $        .
 3.162D+05    1.106D-01   .                        .                   <    .            *   =+      .           0   $        .
 5.623D+05    1.019D-01   .                        .                <       .            X       =   .              X         .
 1.000D+06    8.357D-02   .                        .            <           .+          *           =.            $  0        .
 1.778D+06    5.784D-02   .                        .      +<                .         *              .=       $       0       .
 3.162D+06    3.383D-02   .              +         .  <                     .      *                 . =$           0         .
 5.623D+06    1.711D-02   .      +                 <                        .  *                 $   =           0            .
 1.000D+07    7.935D-03   .       +              < .                       *.           $        =   .       0                .
 1.778D+07    3.760D-03   .        +            <  .                   *    .   $           =        .   0                    .
 3.162D+07    1.896D-03   .        +            <  .               *     $  .         =              .0                       .
 5.623D+07    9.644D-04   .         +         <    .           *   $        .   =                 0  .                        .
 1.000D+08    4.544D-04   .         +      <       .       *  $           = .                 0      .                        .
 1.778D+08    1.863D-04   .          + <           .  *  $         =        .             0          .                        .
 3.162D+08    6.785D-05   .        <    +        * $         =              .         0              .                        .
 5.623D+08    2.341D-05   .     <          X $     .  =                     .       0                .                        .
 1.000D+09    7.984D-06   .          *  $     + =  .                        .     0                  .                 <      .
                          - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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******* 2-MAY-89 *******  SPICE 2G.5 (10AUG81)  *******00:47:58*****
P-Channel Opamp/Comparator Common Mode Test
****     INPUT LISTING                    TEMPERATURE =   27.000 DEG C
***********************************************************************


* Node 0 Vss
* Node 1 Vdd
* Node 2 REF
* Node 3 CMV
* Node 4 OUT
* Node 6 POS connected to NEG
* Node 7 ACL
* Node 8 COMP
* Node 9 REF2
*
* Circuit Description
*
Vdd   1    0    5V
M1    7    6    3    1    CMOSP    W=3U L=2U
M2    8    6    3    1    CMOSP    W=3U L=2U
M3    7    7    0    0    CMOSN    W=3U L=26U
M4    8    7    0    0    CMOSN    W=3U L=26U
M5    4    8    0    0    CMOSN    W=3U L=13U
M6    2    2    1    1    CMOSP    W=3U L=37U
M7    3    2    1    1    CMOSP    W=3U L=37U
M8    4    2    1    1    CMOSP    W=3U L=37U
M9    9    9    0    0    CMOSN    W=3U L=26U
M10   9    9    2    1    CMOSP    W=3U L=37U
* Device effective widths have been ignored
*
* Device Parameters
*
.MODEL CMOSN NMOS LEVEL=2 LD=0.133752U TOX=399.000026E-10
+ NSUB=9.999614E+15 VTO=0.75 KP=5.044000E-05 GAMMA =0.6681
+ PHI=0.6 UO=582.823 UEXP=0.194168 UCRIT=98993.2
+ DELTA=1.740560 VMAX=56837.5 XJ=0.250000U LAMBDA=3.433891E-02
+ NFS=1.000000E+11 NEFF=1 NSS=1.000000E+12 TPG=1.000000
+ RSH=24.010001 CGDO=1.15708E-10 CGSO=1.157508E-10
+ CGBO=3.46E-11 CJ=1.461000E-04 MJ=0.644600 CJSW=5.084000E-10
+ MJSW=0.245500 PB=0.500000
* Weff= Wdrawn - DeltaW   DeltaW = -0.38U
*
```

```
.MODEL CMOSP PMOS LEVEL=2 LD=0.060915U TOX=399.000026E-10
+ NSUB=8.148127E+15 VTO=0.7922 KP=2.475000E-5 GAMMA=0.6031
+ PHI=0.6 UO=286 UEXP=0.264533 UCRIT=20482.8
+ DELTA=0.540869 VMAX=50671.1 XJ=0.250000U LAMBDA=5.107142E-02
+ NFS=4.188926E+11 NEFF=1.001 NSS=1.000000E+12 TPG=-1.000000
+ RSH=120.100001 CGDO=5.271667E-11 CGSO=5.271667E-11
+ CGBO=2.11E-10 CJ=2.479000E-04 MJ=0.572500 CJSW=2.292000E-10
+ MJSW=0.309200 PB=0.800000
* Weff= Wdrawn - DeltaW   DeltaW = -0.27U

* Simulation Parameters
*
* Set initial voltages to speed convergence
.NODESET V(2)=3.0 V(3)=3.0 V(4)=2.5 V(7)=1.5 V(8)=1.5  V(9)=1.5
*
VCM   6    0  2.5    AC  0.1  SIN(2.5  0.1  1G)
.DC VCM  0.0  5.0  0.05
.OP
.TF  V(4,0) VCM
.AC DEC 4 1 1G
*
.PRINT DC V(4,0) V(3,0) V(7,0) V(8,0) V(2,0)
.PLOT DC  V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) (0,5)
.PRINT AC V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) VP(4,0)
.PLOT AC  V(4,0) V(3,0) V(7,0) V(8,0) V(2,0) VP(4,0)
.END
```

P-Channel Opamp/Comparator Common Mode Test
**** MOSFET MODEL PARAMETERS TEMPERATURE = 27.000 DEG C
****

	CMOSN	CMOSP
TYPE	NMOS	PMOS
LEVEL	2.000	2.000
VTO	0.750	0.792
KP	5.04D-05	2.47D-05
GAMMA	0.668	0.603
PHI	0.600	0.600
LAMBDA	3.43D-02	5.11D-02
PB	0.500	0.800
CGSO	1.16D-10	5.27D-11
CGDO	1.16D-10	5.27D-11
CGBO	3.46D-11	2.11D-10
RSH	24.010	120.100
CJ	1.46D-04	2.48D-04
MJ	0.645	0.573
CJSW	5.08D-10	2.29D-10
MJSW	0.246	0.309
TOX	3.99D-08	3.99D-08
NSUB	1.00D+16	8.15D+15
NSS	1.00D+12	1.00D+12
NFS	1.00D+11	4.19D+11
TPG	1.000	-1.000
XJ	2.50D-07	2.50D-07
LD	1.34D-07	6.09D-08
UO	582.823	286.000
UCRIT	9.90D+04	2.05D+04
UEXP	0.194	0.265
VMAX	5.68D+04	5.07D+04
NEFF	1.000	1.001
DELTA	1.741	0.541

*************** 2-MAY-89 *********************** SPICE 2G.5 (10AUG81) **********************00:47:58***************
P-Channel Opamp/Comparator Common Mode Test
**** DC TRANSFER CURVES TEMPERATURE = 27.000 DEG C
****

VCM	V(4)	V(3)	V(7)	V(8)	V(2)
0.000E+00	1.320E+00	1.592E+00	1.560E+00	1.560E+00	3.531E+00
5.000E-02	1.320E+00	1.592E+00	1.560E+00	1.560E+00	3.531E+00
1.000E-01	1.320E+00	1.593E+00	1.560E+00	1.560E+00	3.531E+00
1.500E-01	1.321E+00	1.593E+00	1.560E+00	1.560E+00	3.531E+00
2.000E-01	1.321E+00	1.594E+00	1.560E+00	1.560E+00	3.531E+00
2.500E-01	1.322E+00	1.595E+00	1.560E+00	1.560E+00	3.531E+00
3.000E-01	1.322E+00	1.596E+00	1.560E+00	1.560E+00	3.531E+00
3.500E-01	1.322E+00	1.597E+00	1.560E+00	1.560E+00	3.531E+00
4.000E-01	1.323E+00	1.597E+00	1.560E+00	1.560E+00	3.531E+00
4.500E-01	1.324E+00	1.598E+00	1.560E+00	1.560E+00	3.531E+00
5.000E-01	1.324E+00	1.599E+00	1.560E+00	1.560E+00	3.531E+00
5.500E-01	1.325E+00	1.600E+00	1.560E+00	1.560E+00	3.531E+00
6.000E-01	1.325E+00	1.602E+00	1.560E+00	1.560E+00	3.531E+00
6.500E-01	1.326E+00	1.603E+00	1.560E+00	1.560E+00	3.531E+00
7.000E-01	1.327E+00	1.604E+00	1.560E+00	1.560E+00	3.531E+00
7.500E-01	1.328E+00	1.605E+00	1.560E+00	1.560E+00	3.531E+00
8.000E-01	1.329E+00	1.607E+00	1.560E+00	1.560E+00	3.531E+00
8.500E-01	1.330E+00	1.609E+00	1.560E+00	1.560E+00	3.531E+00
9.000E-01	1.331E+00	1.610E+00	1.560E+00	1.560E+00	3.531E+00
9.500E-01	1.332E+00	1.612E+00	1.560E+00	1.560E+00	3.531E+00
1.000E+00	1.333E+00	1.615E+00	1.560E+00	1.560E+00	3.531E+00
1.050E+00	1.335E+00	1.617E+00	1.560E+00	1.560E+00	3.531E+00
1.100E+00	1.336E+00	1.620E+00	1.560E+00	1.560E+00	3.531E+00
1.150E+00	1.338E+00	1.622E+00	1.559E+00	1.559E+00	3.531E+00
1.200E+00	1.340E+00	1.626E+00	1.559E+00	1.559E+00	3.531E+00
1.250E+00	1.342E+00	1.630E+00	1.559E+00	1.559E+00	3.531E+00
1.300E+00	1.344E+00	1.634E+00	1.559E+00	1.559E+00	3.531E+00
1.350E+00	1.347E+00	1.639E+00	1.559E+00	1.559E+00	3.531E+00
1.400E+00	1.351E+00	1.645E+00	1.559E+00	1.559E+00	3.531E+00
1.450E+00	1.355E+00	1.651E+00	1.559E+00	1.559E+00	3.531E+00
1.500E+00	1.360E+00	1.660E+00	1.559E+00	1.559E+00	3.531E+00
1.550E+00	1.366E+00	1.670E+00	1.558E+00	1.558E+00	3.531E+00
1.600E+00	1.373E+00	1.683E+00	1.558E+00	1.558E+00	3.531E+00
1.650E+00	1.383E+00	1.699E+00	1.558E+00	1.558E+00	3.531E+00
1.700E+00	1.395E+00	1.720E+00	1.557E+00	1.557E+00	3.531E+00
1.750E+00	1.413E+00	1.750E+00	1.556E+00	1.556E+00	3.531E+00
1.800E+00	1.436E+00	1.789E+00	1.556E+00	1.556E+00	3.531E+00
1.850E+00	1.462E+00	1.833E+00	1.555E+00	1.555E+00	3.531E+00

1.900E+00	1.487E+00	1.877E+00	1.554E+00	1.554E+00	3.531E+00
1.950E+00	1.513E+00	1.920E+00	1.553E+00	1.553E+00	3.531E+00
2.000E+00	1.538E+00	1.964E+00	1.552E+00	1.552E+00	3.531E+00
2.050E+00	1.564E+00	2.008E+00	1.551E+00	1.551E+00	3.531E+00
2.100E+00	1.589E+00	2.052E+00	1.550E+00	1.550E+00	3.531E+00
2.150E+00	1.615E+00	2.096E+00	1.549E+00	1.549E+00	3.531E+00
2.200E+00	1.640E+00	2.139E+00	1.548E+00	1.548E+00	3.531E+00
2.250E+00	1.665E+00	2.183E+00	1.547E+00	1.547E+00	3.531E+00
2.300E+00	1.690E+00	2.227E+00	1.546E+00	1.546E+00	3.531E+00
2.350E+00	1.716E+00	2.270E+00	1.545E+00	1.545E+00	3.531E+00
2.400E+00	1.741E+00	2.314E+00	1.544E+00	1.544E+00	3.531E+00
2.450E+00	1.766E+00	2.357E+00	1.543E+00	1.543E+00	3.531E+00
2.500E+00	1.791E+00	2.401E+00	1.542E+00	1.542E+00	3.531E+00
2.550E+00	1.816E+00	2.445E+00	1.541E+00	1.541E+00	3.531E+00
2.600E+00	1.840E+00	2.488E+00	1.540E+00	1.540E+00	3.531E+00
2.650E+00	1.865E+00	2.531E+00	1.539E+00	1.539E+00	3.531E+00
2.700E+00	1.890E+00	2.575E+00	1.538E+00	1.538E+00	3.531E+00
2.750E+00	1.915E+00	2.618E+00	1.537E+00	1.537E+00	3.531E+00
2.800E+00	1.939E+00	2.662E+00	1.536E+00	1.536E+00	3.531E+00
2.850E+00	1.964E+00	2.705E+00	1.535E+00	1.535E+00	3.531E+00
2.900E+00	1.988E+00	2.748E+00	1.534E+00	1.534E+00	3.531E+00
2.950E+00	2.012E+00	2.791E+00	1.533E+00	1.533E+00	3.531E+00
3.000E+00	2.037E+00	2.834E+00	1.532E+00	1.532E+00	3.531E+00
3.050E+00	2.061E+00	2.878E+00	1.531E+00	1.531E+00	3.531E+00
3.100E+00	2.085E+00	2.921E+00	1.531E+00	1.531E+00	3.531E+00
3.150E+00	2.109E+00	2.964E+00	1.530E+00	1.530E+00	3.531E+00
3.200E+00	2.133E+00	3.007E+00	1.529E+00	1.529E+00	3.531E+00
3.250E+00	2.157E+00	3.050E+00	1.528E+00	1.528E+00	3.531E+00
3.300E+00	2.181E+00	3.093E+00	1.527E+00	1.527E+00	3.531E+00
3.350E+00	2.205E+00	3.136E+00	1.526E+00	1.526E+00	3.531E+00
3.400E+00	2.229E+00	3.178E+00	1.525E+00	1.525E+00	3.531E+00
3.450E+00	2.253E+00	3.221E+00	1.524E+00	1.524E+00	3.531E+00
3.500E+00	2.279E+00	3.264E+00	1.523E+00	1.523E+00	3.531E+00
3.550E+00	2.317E+00	3.306E+00	1.522E+00	1.522E+00	3.531E+00
3.600E+00	2.365E+00	3.349E+00	1.520E+00	1.520E+00	3.531E+00
3.650E+00	2.424E+00	3.391E+00	1.518E+00	1.518E+00	3.531E+00
3.700E+00	2.494E+00	3.433E+00	1.515E+00	1.515E+00	3.531E+00
3.750E+00	2.574E+00	3.475E+00	1.512E+00	1.512E+00	3.531E+00
3.800E+00	2.666E+00	3.516E+00	1.509E+00	1.509E+00	3.531E+00
3.850E+00	2.770E+00	3.558E+00	1.505E+00	1.505E+00	3.531E+00
3.900E+00	2.885E+00	3.599E+00	1.501E+00	1.501E+00	3.531E+00
3.950E+00	3.012E+00	3.640E+00	1.497E+00	1.497E+00	3.531E+00
4.000E+00	3.151E+00	3.681E+00	1.492E+00	1.492E+00	3.531E+00
4.050E+00	3.291E+00	3.722E+00	1.487E+00	1.487E+00	3.531E+00
4.100E+00	3.391E+00	3.763E+00	1.481E+00	1.481E+00	3.531E+00
4.150E+00	3.467E+00	3.803E+00	1.475E+00	1.475E+00	3.531E+00

4.200E+00	3.536E+00	3.843E+00	1.469E+00	1.469E+00	3.531E+00
4.250E+00	3.599E+00	3.883E+00	1.462E+00	1.462E+00	3.531E+00
4.300E+00	3.658E+00	3.923E+00	1.455E+00	1.455E+00	3.531E+00
4.350E+00	3.715E+00	3.963E+00	1.447E+00	1.447E+00	3.531E+00
4.400E+00	3.769E+00	4.002E+00	1.439E+00	1.439E+00	3.531E+00
4.450E+00	3.822E+00	4.041E+00	1.430E+00	1.430E+00	3.531E+00
4.500E+00	3.874E+00	4.081E+00	1.422E+00	1.422E+00	3.531E+00
4.550E+00	3.924E+00	4.119E+00	1.412E+00	1.412E+00	3.531E+00
4.600E+00	3.973E+00	4.158E+00	1.402E+00	1.402E+00	3.531E+00
4.650E+00	4.021E+00	4.196E+00	1.392E+00	1.392E+00	3.531E+00
4.700E+00	4.069E+00	4.235E+00	1.381E+00	1.381E+00	3.531E+00
4.750E+00	4.116E+00	4.273E+00	1.370E+00	1.370E+00	3.531E+00
4.800E+00	4.162E+00	4.310E+00	1.358E+00	1.358E+00	3.531E+00
4.850E+00	4.208E+00	4.348E+00	1.346E+00	1.346E+00	3.531E+00
4.900E+00	4.253E+00	4.385E+00	1.333E+00	1.333E+00	3.531E+00
4.950E+00	4.298E+00	4.422E+00	1.319E+00	1.319E+00	3.531E+00
5.000E+00	4.342E+00	4.458E+00	1.305E+00	1.305E+00	3.531E+00

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*************** 2-MAY-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:47:58***************
P-Channel Opamp/Comparator Common Mode Test
****                 DC TRANSFER CURVES                                                    TEMPERATURE =   27.000 DEG C
*************************************************************************************************************************

LEGEND:

*: V(4)     +: V(3)     =: V(7)     $: V(8)     0: V(2)

(*+=$0)-------------   0.000D+00                1.250D+00                2.500D+00                3.750D+00                5.000D+00
  VCM        V(4)         - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 0.000D+00    1.320D+00   .                        .*    X+                 .                    0   .                        .
 5.000D-02    1.320D+00   .                        .*    X+                 .                    0   .                        .
 1.000D-01    1.320D+00   .                        .*    X+                 .                    0   .                        .
 1.500D-01    1.321D+00   .                        .*    X+                 .                    0   .                        .
 2.000D-01    1.321D+00   .                        .*    X+                 .                    0   .                        .
 2.500D-01    1.322D+00   .                        .*    X+                 .                    0   .                        .
 3.000D-01    1.322D+00   .                        .*    X+                 .                    0   .                        .
 3.500D-01    1.322D+00   .                        .*    X+                 .                    0   .                        .
 4.000D-01    1.323D+00   .                        .*    X+                 .                    0   .                        .
 4.500D-01    1.324D+00   .                        .*    X+                 .                    0   .                        .
 5.000D-01    1.324D+00   .                        .*    X+                 .                    0   .                        .
 5.500D-01    1.325D+00   .                        .*    X+                 .                    0   .                        .
 6.000D-01    1.325D+00   .                        . *   X+                 .                    0   .                        .
 6.500D-01    1.326D+00   .                        . *   X+                 .                    0   .                        .
 7.000D-01    1.327D+00   .                        . *   X+                 .                    0   .                        .
 7.500D-01    1.328D+00   .                        . *   X+                 .                    0   .                        .
 8.000D-01    1.329D+00   .                        . *   X+                 .                    0   .                        .
 8.500D-01    1.330D+00   .                        . *   X+                 .                    0   .                        .
 9.000D-01    1.331D+00   .                        . *   X+                 .                    0   .                        .
 9.500D-01    1.332D+00   .                        . *   X+                 .                    0   .                        .
 1.000D+00    1.333D+00   .                        . *   X+                 .                    0   .                        .
 1.050D+00    1.335D+00   .                        . *   X+                 .                    0   .                        .
 1.100D+00    1.336D+00   .                        . *   X+                 .                    0   .                        .
 1.150D+00    1.338D+00   .                        . *   X+                 .                    0   .                        .
 1.200D+00    1.340D+00   .                        . *   X +                .                    0   .                        .
 1.250D+00    1.342D+00   .                        . *   X +                .                    0   .                        .
 1.300D+00    1.344D+00   .                        . *   X +                .                    0   .                        .
 1.350D+00    1.347D+00   .                        . *   X +                .                    0   .                        .
 1.400D+00    1.351D+00   .                        . *   X +                .                    0   .                        .
 1.450D+00    1.355D+00   .                        . *   X +                .                    0   .                        .
 1.500D+00    1.360D+00   .                        . *   X +                .                    0   .                        .
 1.550D+00    1.366D+00   .                        . *   X +                .                    0   .                        .
 1.600D+00    1.373D+00   .                        . *   X  +               .                    0   .                        .
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1.650D+00    1.383D+00   .                        .  *  X  +               .                    0   .                        .
1.700D+00    1.395D+00   .                        .  *  X  +               .                    0   .                        .
1.750D+00    1.413D+00   .                        .  *  X   +              .                    0   .                        .
1.800D+00    1.436D+00   .                        .   * X    +             .                    0   .                        .
1.850D+00    1.462D+00   .                        .   * X     +            .                    0   .                        .
1.900D+00    1.487D+00   .                        .    *X      +           .                    0   .                        .
1.950D+00    1.513D+00   .                        .    *X      +           .                    0   .                        .
2.000D+00    1.538D+00   .                        .     X       +          .                    0   .                        .
2.050D+00    1.564D+00   .                        .     X        +         .                    0   .                        .
2.100D+00    1.589D+00   .                        .     X*        +        .                    0   .                        .
2.150D+00    1.615D+00   .                        .     X*         +       .                    0   .                        .
2.200D+00    1.640D+00   .                        .     X *         +      .                    0   .                        .
2.250D+00    1.665D+00   .                        .     X *          +     .                    0   .                        .
2.300D+00    1.690D+00   .                        .     X  *          +    .                    0   .                        .
2.350D+00    1.716D+00   .                        .     X  *          +    .                    0   .                        .
2.400D+00    1.741D+00   .                        .     X   *          +   .                    0   .                        .
2.450D+00    1.766D+00   .                        .     X   *           +  .                    0   .                        .
2.500D+00    1.791D+00   .                        .     X    *           + .                    0   .                        .
2.550D+00    1.816D+00   .                        .     X    *            +.                    0   .                        .
2.600D+00    1.840D+00   .                        .     X     *            +                    0   .                        .
2.650D+00    1.865D+00   .                        .     X     *            .+                   0   .                        .
2.700D+00    1.890D+00   .                        .     X      *           .+                   0   .                        .
2.750D+00    1.915D+00   .                        .     X      *           . +                  0   .                        .
2.800D+00    1.939D+00   .                        .     X       *          .  +                 0   .                        .
2.850D+00    1.964D+00   .                        .     X       *          .   +                0   .                        .
2.900D+00    1.988D+00   .                        .     X        *         .    +               0   .                        .
2.950D+00    2.012D+00   .                        .     X        *         .     +              0   .                        .
3.000D+00    2.037D+00   .                        .     X         *        .      +             0   .                        .
3.050D+00    2.061D+00   .                        .     X         *        .       +            0   .                        .
3.100D+00    2.085D+00   .                        .     X          *       .       +            0   .                        .
3.150D+00    2.109D+00   .                        .     X          *       .        +           0   .                        .
3.200D+00    2.133D+00   .                        .     X           *      .         +          0   .                        .
3.250D+00    2.157D+00   .                        .     X           *      .          +         0   .                        .
3.300D+00    2.181D+00   .                        .     X            *     .           +        0   .                        .
3.350D+00    2.205D+00   .                        .     X            *     .            +       0   .                        .
3.400D+00    2.229D+00   .                        .     X             *    .             +      0   .                        .
3.450D+00    2.253D+00   .                        .    X              *    .             +      0   .                        .
3.500D+00    2.279D+00   .                        .    X               *   .              +     0   .                        .
3.550D+00    2.317D+00   .                        .    X               *   .               +    0   .                        .
3.600D+00    2.365D+00   .                        .    X                *  .                +   0   .                        .
3.650D+00    2.424D+00   .                        .    X                 * .                 +  0   .                        .
3.700D+00    2.494D+00   .                        .    X                   *                  + 0   .                        .
3.750D+00    2.574D+00   .                        .    X                   .*                 + 0   .                        .
3.800D+00    2.666D+00   .                        .    X                   .  *                +0   .                        .
3.850D+00    2.770D+00   .                        .    X                   .    *               X   .                        .
3.900D+00    2.885D+00   .                        .    X                   .       *            0+  .                        .
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 3.950D+00    3.012D+00   .                        .    X                   .         *          0 + .                        .
 4.000D+00    3.151D+00   .                        .    X                   .            *       0  +.                        .
 4.050D+00    3.291D+00   .                        .    X                   .               *    0  +.                        .
 4.100D+00    3.391D+00   .                        .    X                   .                 *  0   +                        .
 4.150D+00    3.467D+00   .                        .    X                   .                  * 0   .+                       .
 4.200D+00    3.536D+00   .                        .   X                    .                    X   . +                      .
 4.250D+00    3.599D+00   .                        .   X                    .                    0*  .  +                     .
 4.300D+00    3.658D+00   .                        .   X                    .                    0 * .  +                     .
 4.350D+00    3.715D+00   .                        .   X                    .                    0  *.   +                    .
 4.400D+00    3.769D+00   .                        .   X                    .                    0   *    +                   .
 4.450D+00    3.822D+00   .                        .   X                    .                    0   .*    +                  .
 4.500D+00    3.874D+00   .                        .  X                     .                    0   . *    +                 .
 4.550D+00    3.924D+00   .                        .  X                     .                    0   .  *   +                 .
 4.600D+00    3.973D+00   .                        .  X                     .                    0   .   *   +                .
 4.650D+00    4.021D+00   .                        .  X                     .                    0   .    *   +               .
 4.700D+00    4.069D+00   .                        .  X                     .                    0   .     *   +              .
 4.750D+00    4.116D+00   .                        . X                      .                    0   .      *  +              .
 4.800D+00    4.162D+00   .                        . X                      .                    0   .       *  +             .
 4.850D+00    4.208D+00   .                        . X                      .                    0   .        *  +            .
 4.900D+00    4.253D+00   .                        . X                      .                    0   .         *  +           .
 4.950D+00    4.298D+00   .                        .X                       .                    0   .          * +           .
 5.000D+00    4.342D+00   .                        .X                       .                    0   .           * +          .
                          - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

*************** 2-MAY-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:47:58***************
P-Channel Opamp/Comparator Common Mode Test
****                 SMALL SIGNAL BIAS SOLUTION                              TEMPERATURE =   27.000 DEG C
*************************************************************************************************************************

 NODE   VOLTAGE      NODE   VOLTAGE      NODE   VOLTAGE      NODE   VOLTAGE      NODE   VOLTAGE      NODE   VOLTAGE      NODE   VOLTAGE

(  1)    5.0000     (  2)    3.5315     (  3)    2.4010     (  4)    1.7907     (  6)    2.5000     (  7)    1.5417     (  8)    1.5417

(  9)    1.7997


    VOLTAGE SOURCE CURRENTS

    NAME        CURRENT

    Vdd      -7.461D-06
    VCM       0.000D+00


    TOTAL POWER DISSIPATION   3.73D-05  WATTS
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P-Channel Opamp/Comparator Common Mode Test
****   OPERATING POINT INFORMATION   TEMPERATURE =   27.000 DEG C
****

**** MOSFETS

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
MODEL	CMOSP	CMOSP	CMOSN	CMOSN	CMOSN	CMOSP	CMOSP	CMOSP	CMOSN	CMOSP
ID	-1.27E-06	-1.27E-06	1.27E-06	1.27E-06	2.63E-06	-2.30E-06	-2.53E-06	-2.63E-06	2.31E-06	-2.31E-06
VGS	0.099	0.099	1.542	1.542	1.542	-1.469	-1.469	-1.469	1.800	-1.732
VDS	-0.859	-0.859	1.542	1.542	1.791	-1.469	-2.599	-3.209	1.800	-1.732
VBS	2.599	2.599	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.469
VTH	0.315	0.315	0.821	0.821	0.815	0.729	0.729	0.730	0.820	0.314
VDSAT	-0.223	-0.223	0.535	0.535	0.534	-1.766	-1.767	-1.767	0.721	-1.758
GM	9.54E-06	9.54E-06	3.36E-06	3.36E-06	6.91E-06	1.51E-06	1.99E-06	2.07E-06	4.58E-06	1.88E-06
GDS	1.65E-07	1.65E-07	4.80E-08	4.80E-08	1.04E-07	5.72E-07	1.50E-07	1.61E-07	8.73E-08	1.70E-07
GMB	1.18E-06	1.18E-06	1.38E-06	1.38E-06	2.80E-06	3.97E-07	5.04E-07	5.22E-07	1.81E-06	3.51E-07
CBD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGSOVL	1.58E-16	1.58E-16	3.47E-16	3.47E-16	3.47E-16	1.58E-16	1.58E-16	1.58E-16	3.47E-16	1.58E-16
CGDOVL	1.58E-16	1.58E-16	3.47E-16	3.47E-16	3.47E-16	1.58E-16	1.58E-16	1.58E-16	3.47E-16	1.58E-16
CGBOVL	3.96E-16	3.96E-16	8.90E-16	8.90E-16	4.41E-16	7.78E-15	7.78E-15	7.78E-15	8.90E-16	7.78E-15
CGS	3.25E-15	3.25E-15	4.45E-14	4.45E-14	2.20E-14	6.25E-14	6.38E-14	6.38E-14	4.45E-14	6.38E-14
CGD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E-14	0.00E+00	0.00E+00	0.00E+00	1.06E-15
CGB	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

****   SMALL-SIGNAL CHARACTERISTICS

V(4)/VCM = 4.987D-01

INPUT RESISTANCE AT VCM = 1.000D+20

OUTPUT RESISTANCE AT V(4) = 3.767D+06

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*************** 2-MAY-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:47:58***************
P-Channel Opamp/Comparator Common Mode Test
****                AC ANALYSIS                                          TEMPERATURE =   27.000 DEG C
*******************************************************************************************************¬************
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FREQ	V(4)	V(3)	V(7)	V(8)	V(2)	VP(4)
1.000E+00	4.987E-02	8.701E-02	1.916E-03	1.916E-03	3.628E-11	8.925E-05
1.778E+00	4.987E-02	8.701E-02	1.916E-03	1.916E-03	6.452E-11	1.587E-04
3.162E+00	4.987E-02	8.701E-02	1.916E-03	1.916E-03	1.147E-10	2.822E-04
5.623E+00	4.987E-02	8.701E-02	1.916E-03	1.916E-03	2.040E-10	5.019E-04
1.000E+01	4.987E-02	8.701E-02	1.916E-03	1.916E-03	3.628E-10	8.925E-04
1.778E+01	4.987E-02	8.701E-02	1.916E-03	1.916E-03	6.452E-10	1.587E-03
3.162E+01	4.987E-02	8.701E-02	1.916E-03	1.916E-03	1.147E-09	2.822E-03
5.623E+01	4.987E-02	8.701E-02	1.916E-03	1.916E-03	2.040E-09	5.019E-03
1.000E+02	4.987E-02	8.701E-02	1.916E-03	1.916E-03	3.628E-09	8.925E-03
1.778E+02	4.987E-02	8.701E-02	1.916E-03	1.916E-03	6.452E-09	1.587E-02
3.162E+02	4.987E-02	8.701E-02	1.916E-03	1.916E-03	1.147E-08	2.822E-02
5.623E+02	4.987E-02	8.701E-02	1.916E-03	1.916E-03	2.040E-08	5.019E-02
1.000E+03	4.987E-02	8.701E-02	1.916E-03	1.916E-03	3.628E-08	8.925E-02
1.778E+03	4.987E-02	8.701E-02	1.916E-03	1.916E-03	6.452E-08	1.587E-01
3.162E+03	4.987E-02	8.701E-02	1.916E-03	1.916E-03	1.147E-07	2.822E-01
5.623E+03	4.987E-02	8.701E-02	1.916E-03	1.917E-03	2.040E-07	5.018E-01
1.000E+04	4.988E-02	8.701E-02	1.916E-03	1.917E-03	3.629E-07	8.921E-01
1.778E+04	4.992E-02	8.701E-02	1.916E-03	1.918E-03	6.454E-07	1.585E+00
3.162E+04	5.003E-02	8.701E-02	1.916E-03	1.923E-03	1.148E-06	2.811E+00
5.623E+04	5.037E-02	8.701E-02	1.917E-03	1.936E-03	2.046E-06	4.954E+00
1.000E+05	5.145E-02	8.701E-02	1.917E-03	1.977E-03	3.657E-06	8.573E+00
1.778E+05	5.462E-02	8.701E-02	1.918E-03	2.100E-03	6.608E-06	1.406E+01
3.162E+05	6.300E-02	8.701E-02	1.922E-03	2.422E-03	1.227E-05	2.012E+01
5.623E+05	8.039E-02	8.700E-02	1.930E-03	3.093E-03	2.378E-05	2.179E+01
1.000E+06	1.045E-01	8.699E-02	1.940E-03	4.023E-03	4.610E-05	1.378E+01
1.778E+06	1.229E-01	8.698E-02	1.921E-03	4.737E-03	7.770E-05	-3.608E+00
3.162E+06	1.243E-01	8.699E-02	1.798E-03	4.802E-03	9.993E-05	-2.758E+01
5.623E+06	1.069E-01	8.701E-02	1.503E-03	4.137E-03	9.418E-05	-5.675E+01
1.000E+07	8.010E-02	8.703E-02	1.117E-03	3.113E-03	6.836E-05	-8.897E+01
1.778E+07	5.846E-02	8.706E-02	8.177E-04	2.300E-03	4.306E-05	-1.221E+02
3.162E+07	4.620E-02	8.709E-02	6.597E-04	1.895E-03	2.854E-05	-1.543E+02
5.623E+07	3.893E-02	8.719E-02	5.941E-04	1.795E-03	2.808E-05	1.751E+02
1.000E+08	3.130E-02	8.749E-02	5.657E-04	1.863E-03	3.753E-05	1.450E+02
1.778E+08	2.162E-02	8.831E-02	5.394E-04	1.935E-03	4.749E-05	1.155E+02
3.162E+08	1.241E-02	9.023E-02	4.885E-04	1.841E-03	5.320E-05	8.827E+01
5.623E+08	6.023E-03	9.316E-02	3.987E-04	1.533E-03	5.554E-05	6.530E+01
1.000E+09	2.664E-03	9.569E-02	2.977E-04	1.153E-03	5.638E-05	4.898E+01

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*************** 2-MAY-89 ***********************  SPICE 2G.5 (10AUG81)  **********************00:47:58***************
P-Channel Opamp/Comparator Common Mode Test
****                 AC ANALYSIS                                    TEMPERATURE =   27.000 DEG C
*********************************************************************************************************************

LEGEND:    *: V(4)     +: V(3)     =: V(7)     $: V(8)     0: V(2)     <: VP(4)


(*)-----------------   1.000D-03                1.000D-02                1.000D-01                1.000D+00                1.000D+01(+)-
----------------   8.318D-02                8.710D-02                9.120D-02                9.550D-02                1.000D-01(=)-----
------------   1.000D-04                3.162D-04                1.000D-03                3.162D-03                1.000D-02($)---------
--------   1.000D-03                1.585D-03                2.512D-03                3.981D-03                6.310D-03(0)-------------
----   1.000D-12                1.000D-10                1.000D-08                1.000D-06                1.000D-04(<)-----------------
-2.000D+02               -1.000D+02                0.000D+00                1.000D+02                2.000D+02
    FREQ      V(4)      - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 1.000D+00    4.987D-02   .                  0    +.         $      *       <             =          .                        .
 1.778D+00    4.987D-02   .                      0+.         $      *       <             =          .                        .
 3.162D+00    4.987D-02   .                       +.0        $      *       <             =          .                        .
 5.623D+00    4.987D-02   .                       +.   0     $      *       <             =          .                        .
 1.000D+01    4.987D-02   .                       +.      0  $      *       <             =          .                        .
 1.778D+01    4.987D-02   .                       +.         X      *       <             =          .                        .
 3.162D+01    4.987D-02   .                       +.         $  0   *       <             =          .                        .
 5.623D+01    4.987D-02   .                       +.         $     0*       <             =          .                        .
 1.000D+02    4.987D-02   .                       +.         $      * 0     <             =          .                        .
 1.778D+02    4.987D-02   .                       +.         $      *     0 <             =          .                        .
 3.162D+02    4.987D-02   .                       +.         $      *       <0            =          .                        .
 5.623D+02    4.987D-02   .                       +.         $      *       <   0         =          .                        .
 1.000D+03    4.987D-02   .                       +.         $      *       <      0      =          .                        .
 1.778D+03    4.987D-02   .                       +.         $      *       <         0   =          .                        .
 3.162D+03    4.987D-02   .                       +.         $      *       <            0=          .                        .
 5.623D+03    4.987D-02   .                       +.         $      *       <             = 0        .                        .
 1.000D+04    4.988D-02   .                       +.         $      *       <             =    0     .                        .
 1.778D+04    4.992D-02   .                       +.         $      *       <             =        0 .                        .
 3.162D+04    5.003D-02   .                       +.         $      *       .<            =          .0                       .
 5.623D+04    5.037D-02   .                       +.          $      *      .<            =          .   0                    .
 1.000D+05    5.145D-02   .                       +.           $     *      . <           =          .      0                 .
 1.778D+05    5.462D-02   .                       +.              $  *      .   <         =          .         0              .
 3.162D+05    6.300D-02   .                       +.                   *  $ .    <        =          .             0          .
 5.623D+05    8.039D-02   .                       +.                      * .    <     $  =          .                0       .
 1.000D+06    1.045D-01   .                       +.                        *  <          =          .$                   0   .
 1.778D+06    1.229D-01   .                       +.                       <. *           =          .        $              0.
 3.162D+06    1.243D-01   .                       +.                 <      . *          =           .         $              0
 5.623D+06    1.069D-01   .                       +.          <             .*       =               . $                      0
 1.000D+07    8.010D-02   .                        +  <                   * . =         $            .                      0 .
 1.778D+07    5.846D-02   .                  <     +                  *$=   .                        .                   0    .
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3.162D+07    4.620D-02   .          <             +         $     =*       .                        .                 0      .
5.623D+07    3.893D-02   .                        .+     $      =*         .                        .                 0<     .
1.000D+08    3.130D-02   .                        . +      $  *=           .                        .          <        0    .
1.778D+08    2.162D-02   .                        .       X  $=            .                        .   <                0   .
3.162D+08    1.241D-02   .                        . *     $=         +     .                     <  .                     0  .
5.623D+08    6.023D-03   .                  *   $ .    =                   .           +   <        .                     0  .
1.000D+09    2.664D-03   .       $  *            =.                        .           <            .+                    0  .
                         - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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