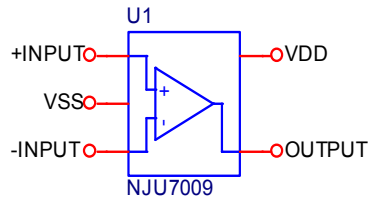


# Device Modeling Report

COMPONENTS: CMOS OPERATIONAL AMPLIFIER  
PART NUMBER: NJU7009  
MANUFACTURER: NEW JAPAN RADIO



## Pin Configuration



## Spice Model (1/2)

```

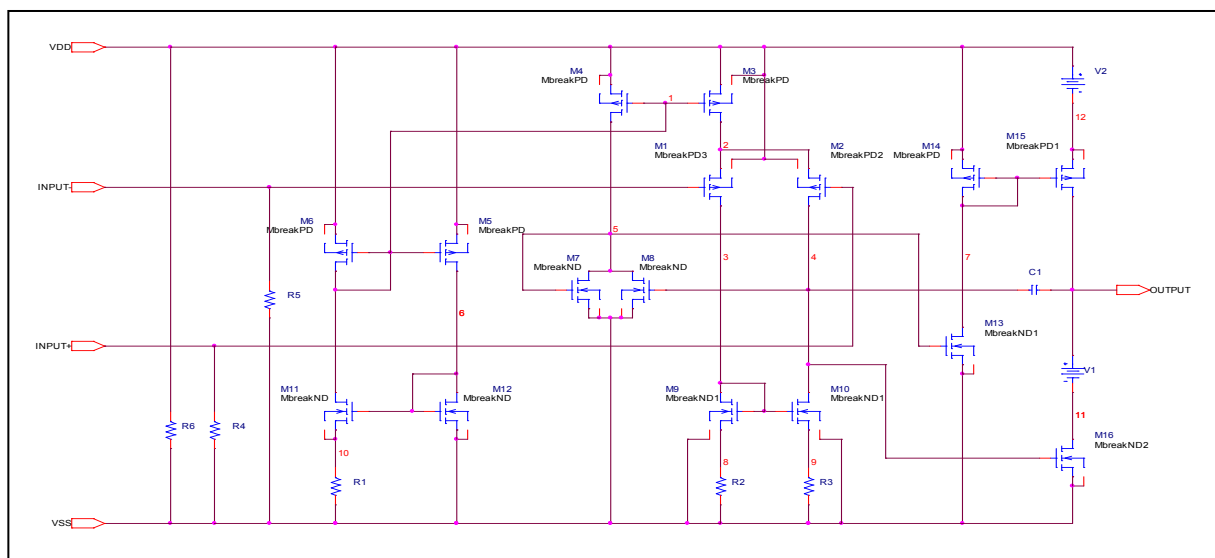
*$
*PART NUMBER: NJU7009
*MANUFACTURER: NEW JAPAN RADIO
*CMOS OPAMP
*All Rights Reserved Copyright (C) Bee Technologies Corporation 2009
.SUBCKT NJU7009 INPUT+ VSS INPUT- OUTPUT VDD
M_M1 3 INPUT- 2 VDD MbreakPD3 L=6u W=2.5m
M_M2 4 INPUT+ 2 VDD MbreakPD2 L=6u W=2.5m
M_M3 2 1 VDD VDD MbreakPD
M_M4 5 1 VDD VDD MbreakPD
M_M5 6 1 VDD VDD MbreakPD
M_M6 1 1 VDD VDD MbreakPD
M_M7 5 5 VSS VSS MbreakND
M_M8 5 4 VSS VSS MbreakND
M_M9 3 3 8 VSS MbreakND1 L=6u W=65m
M_M10 4 3 9 VSS MbreakND1 L=6u W=85m
M_M11 1 6 10 10 MbreakND
M_M12 6 6 VSS VSS MbreakND
M_M13 7 5 VSS VSS MbreakND1
M_M14 7 7 VDD VDD MbreakPD
M_M15 OUTPUT 7 12 12 MbreakPD1 L=2u W=50m
M_M16 11 4 VSS VSS MbreakND2 L=2u W=15m
V_V1 OUTPUT 11 0.089
V_V2 VDD 12 0.099
R_R1 10 VSS 200k
R_R2 8 VSS 200
R_R3 9 VSS 200
R_R4 INPUT+ VSS 1.0E+12
R_R5 INPUT- VSS 3.0E+12
R_R6 VDD VSS 10.123E+3
C_C1 OUTPUT 4 0.415p

```

## Spice Model (2/2)

```
.model MbreakND NMOS ( LEVEL=3 L=6u W=128u VTO=0 RS=10.000E-3
+ RD=10.000E-3 RDS=10E6 TOX=2.0E-6 RG=5 RB=1.0000E-3
+ KP=10E-6)
.model MbreakND1 NMOS (LEVEL=3 L=6u W=200u VTO=0 RS=10.000E-3
+ RD=10.000E-3 RDS=2.4E6 TOX=2.0000E-6 RG=5 RB=1.0000E-3
+ KP=10E-6)
.model MbreakND2 NMOS ( LEVEL=3 VTO=0 RS=10.000E-3 RD=10.000E-3
+ RDS=1.0000E6 TOX=2.0000E-6 RG=5 RB=1.0000E-3
+ KP=10E-6)
.model MbreakPD PMOS ( LEVEL=3 L=6u W=27u VTO=0 RS=10.000E-3
+ RD=10.00E-3 RDS=1.00E9 TOX=2.0000E-6 RG=5 RB=1.0000E-3
+ KP=10E-6 )
.MODEL MbreakPD1 PMOS (LEVEL=3 VTO=-0.1 RS=10.000E-3 RD=10.000E-3
+ RDS=1.00E6 TOX=2.0000E-6 RG=5 RB=1.0000E-3 KP=50E-6 )
.MODEL MbreakPD2 PMOS (LEVEL=3 VTO=0 RS=10.000E-3 RD=10.00E-3
+ RDS=5E9 TOX=2.0000E-6 RG=5 RB=1.000E-3 KP=1E-6)
.MODEL MbreakPD3 PMOS (LEVEL=3 VTO=-5.25m RS=10.000E-3
RD=10.00E-3
+ RDS=5E9 TOX=2.000E-6 RG=5 RB=1.000E-3 KP=1E-6 )
.ENDS NJU7009
*$
```

## Equivalent Circuit

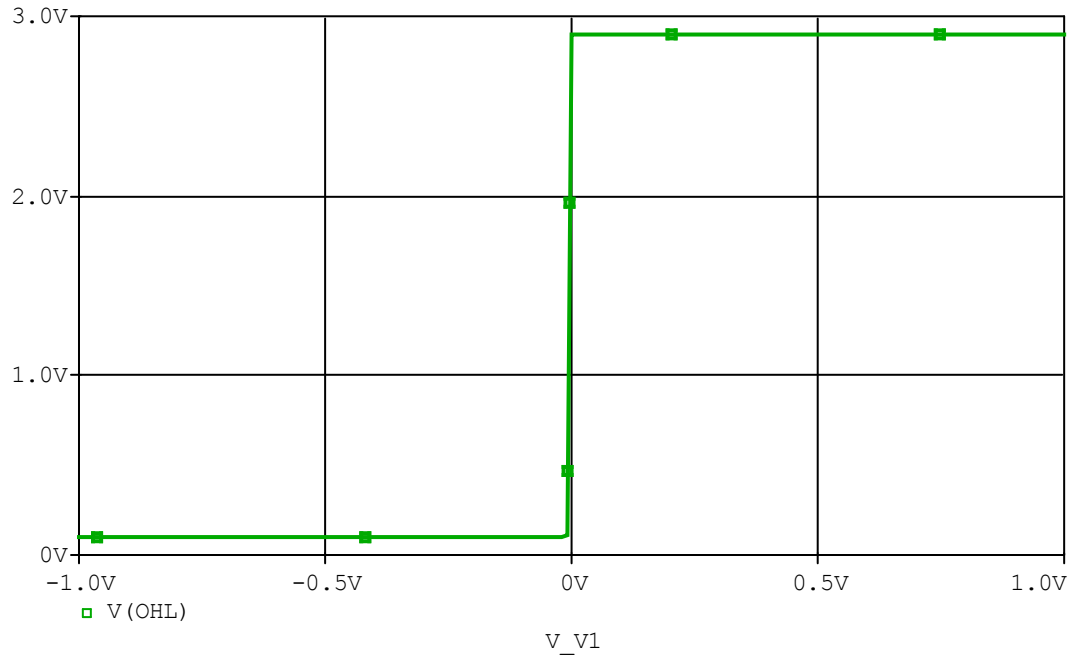


## MOSFET MODEL

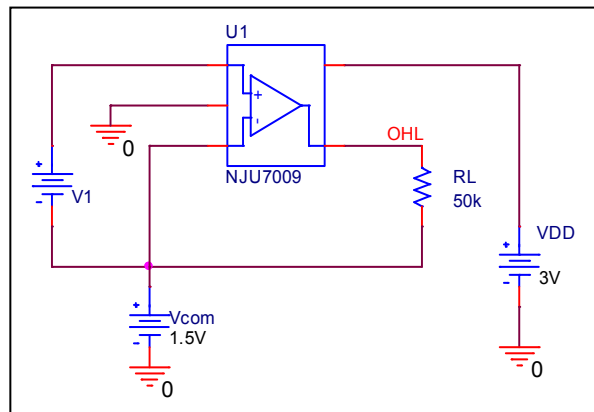
PSpice model parameter	Model description
LEVEL	
L	Channel Length
W	Channel Width
KP	Transconductance
RS	Source Ohmic Resistance
RD	Ohmic Drain Resistance
VTO	Zero-bias Threshold Voltage
RDS	Drain-Source Shunt Resistance
TOX	Gate Oxide Thickness
CGSO	Zero-bias Gate-Source Capacitance
CGDO	Zero-bias Gate-Drain Capacitance
CBD	Zero-bias Bulk-Drain Junction Capacitance
MJ	Bulk Junction Grading Coefficient
PB	Bulk Junction Potential
FC	Bulk Junction Forward-bias Capacitance Coefficient
RG	Gate Ohmic Resistance
IS	Bulk Junction Saturation Current
N	Bulk Junction Emission Coefficient
RB	Bulk Series Resistance
PHI	Surface Inversion Potential
GAMMA	Body-effect Parameter
DELTA	Width effect on Threshold Voltage
ETA	Static Feedback on Threshold Voltage
THETA	Mobility Modulation
KAPPA	Saturation Field Factor
VMAX	Maximum Drift Velocity of Carriers
XJ	Metallurgical Junction Depth
UO	Surface Mobility

## Output Voltage Swing - $V_{OH}$ , $V_{OL}$

### Simulation result



### Evaluation circuit



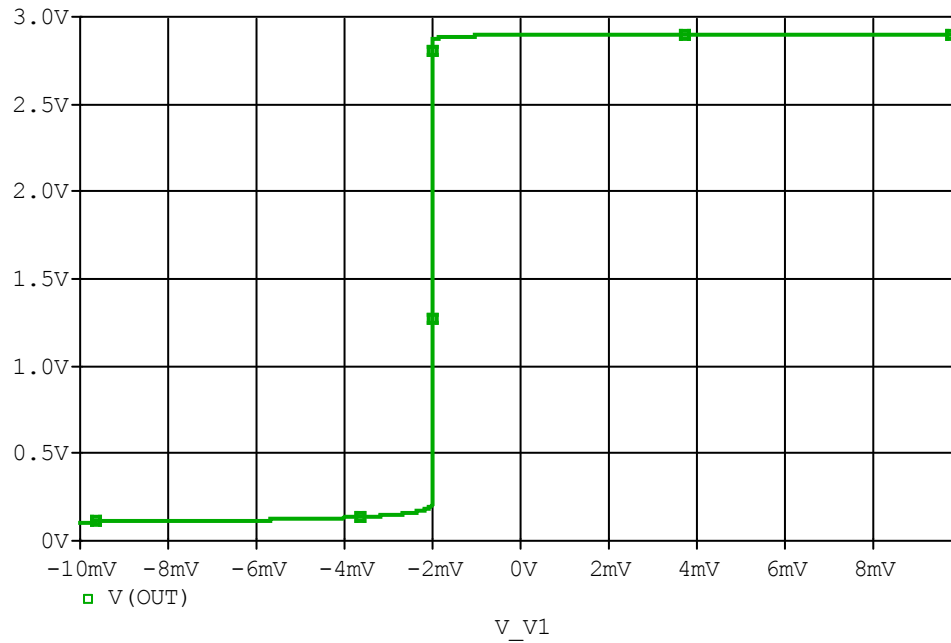
### Comparison table

(Condition:  $R_L=50k\Omega$  to 1.5V)

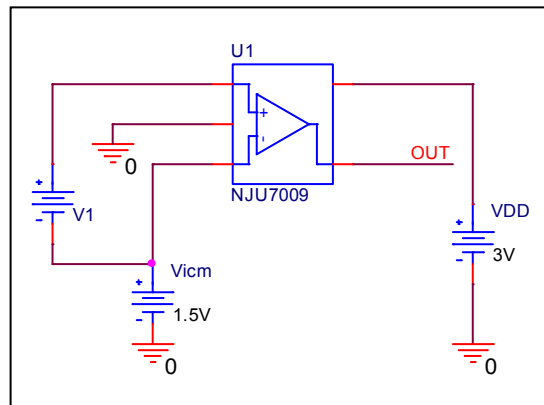
Parameter	Measurement	Simulation	%Error
$V_{OH}[V]$	2.900	2.901	0.03
$V_{OL}[V]$	0.100	0.099	1.00

## Input Offset Voltage - $V_{IO}$

### Simulation result



### Evaluation circuit

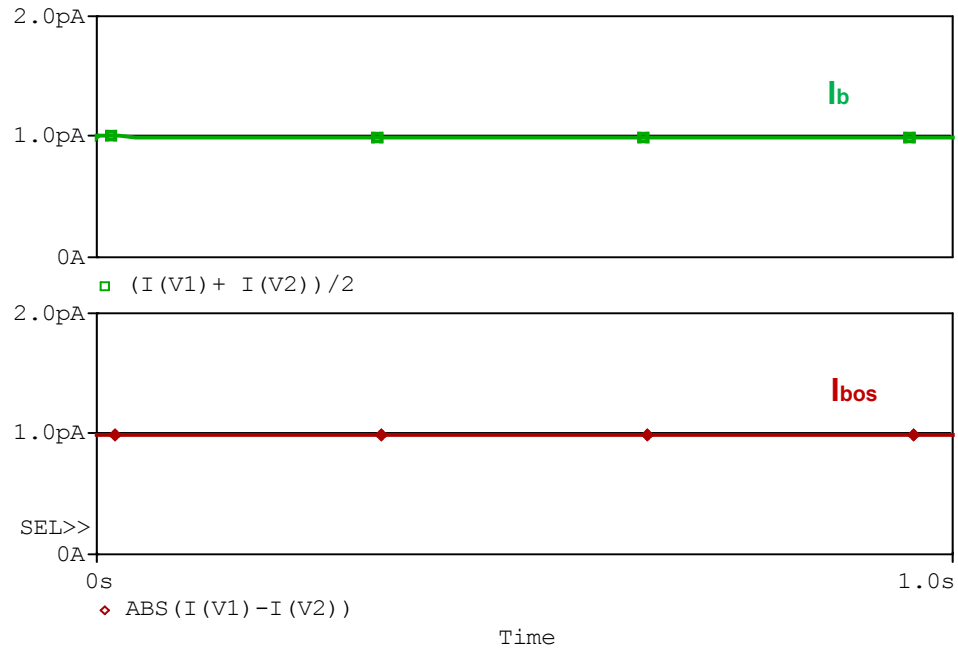


### Comparison table

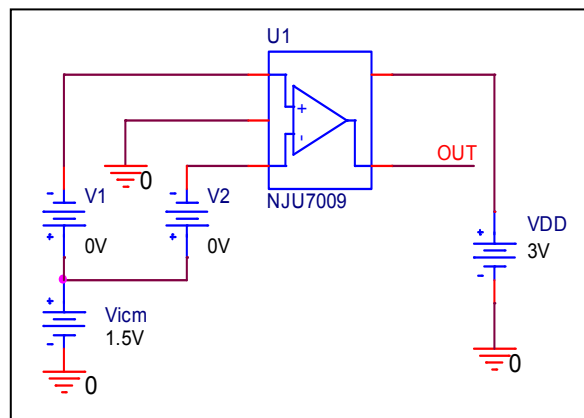
Parameter	Measurement	Simulation	%Error
$ V_{IO} $ [mV]	2.000	2.0074	0.37

## Input Current - $I_b$ , $I_{bos}$

### Simulation result



### Evaluation circuit

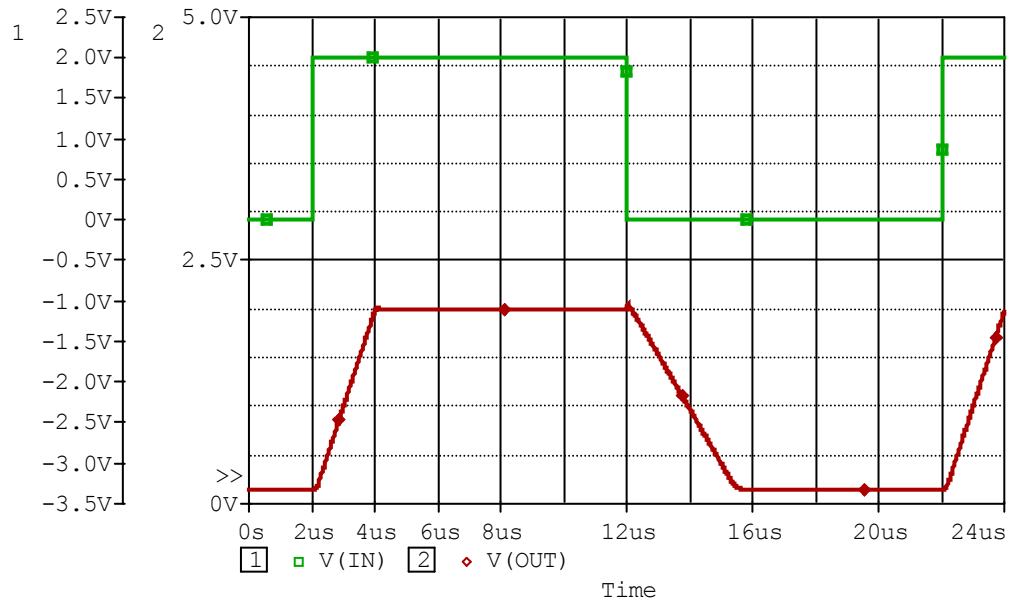


### Comparison table

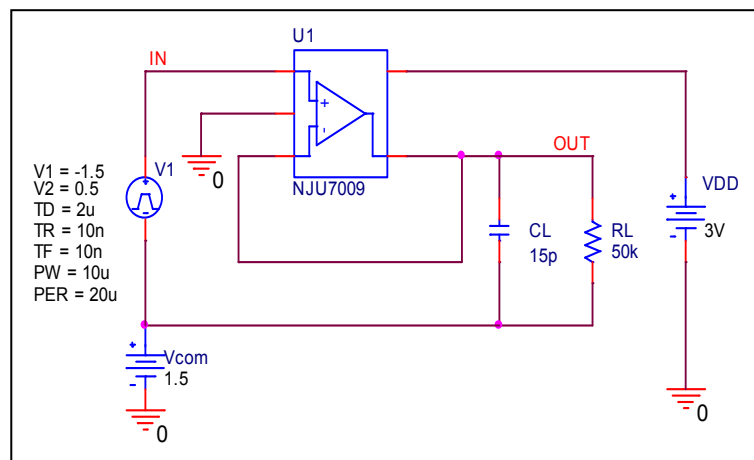
Parameter	Measurement	Simulation	%Error
$I_b$ [pA]	1.000	1.000	0
$I_{bos}$ [pA]	1.000	1.000	0

## Slew Rate - SR

### Simulation result



### Evaluation circuit



### Comparison table

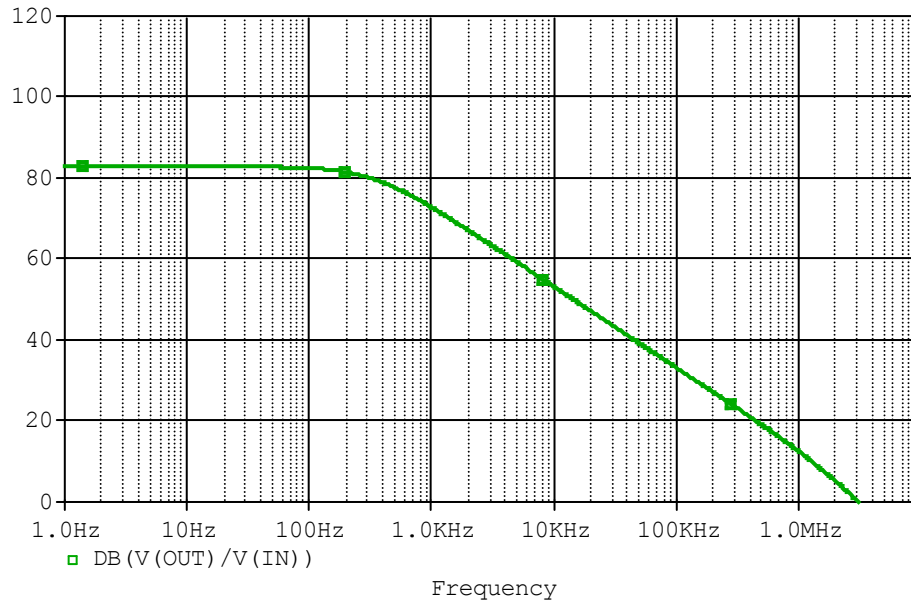
(Condition: GV=0dB, CL=15pF, RL=50kΩ to 1.5V)

Parameter	Measurement	Simulation	%Error
SR[V/us]	1.000	0.992	0.8

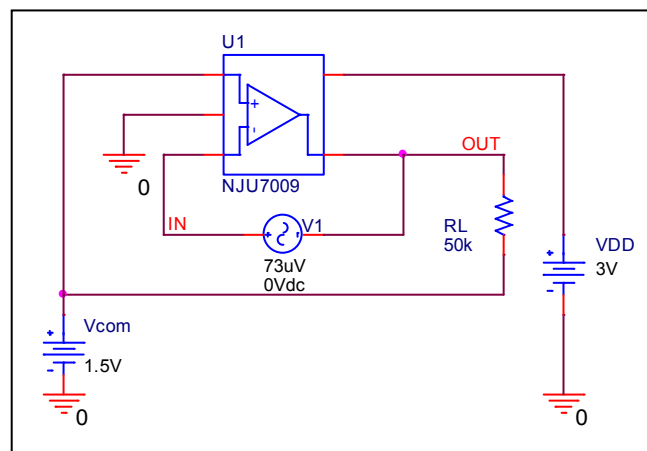


## Large Signal Voltage Gain - $A_v$

### Simulation result



### Evaluation Circuit



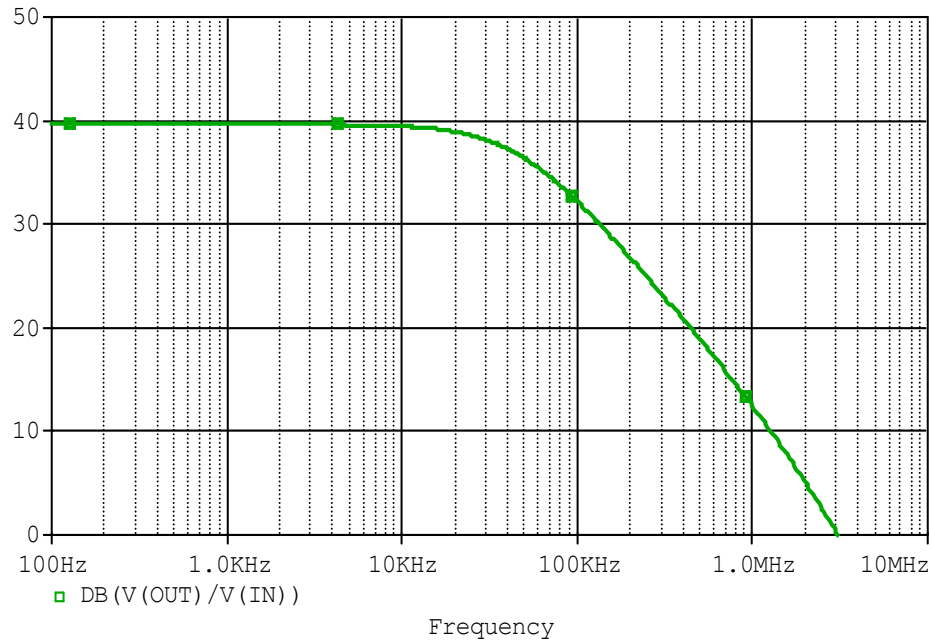
### Comparison Table

(Condition:  $R_L=50k\Omega$  to 1.5V,  $V_o=1.5V$ )

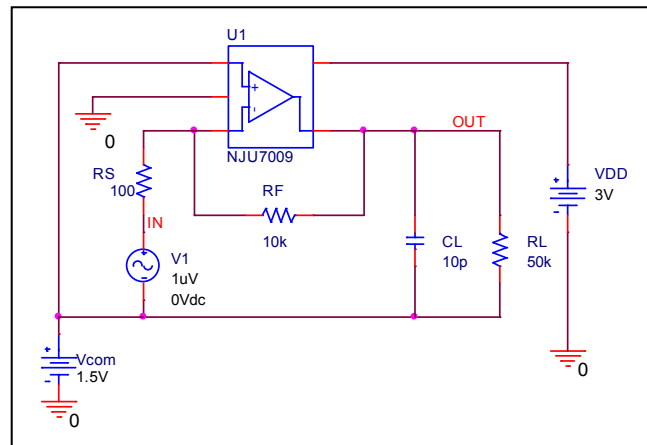
Parameter	Measurement	Simulation	%Error
$A_v$ [dB]	80.000	82.846	3.56

## Unity Gain Frequency - $f_T$

### Simulation result



### Evaluation Circuit



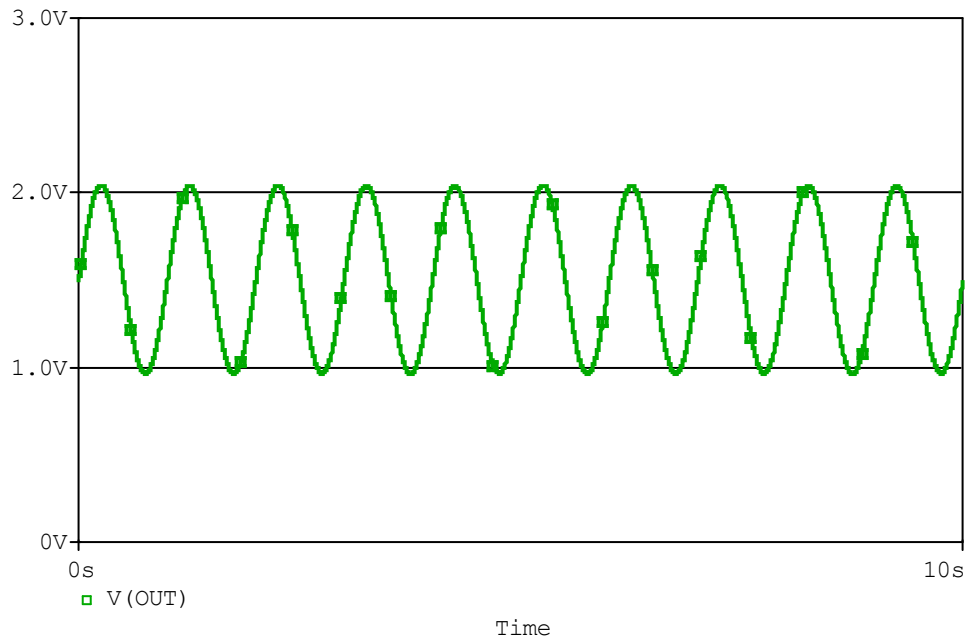
### Comparison Table

( $R_L=50k\Omega$  to 1.5V,  $C_L=10pF$ )

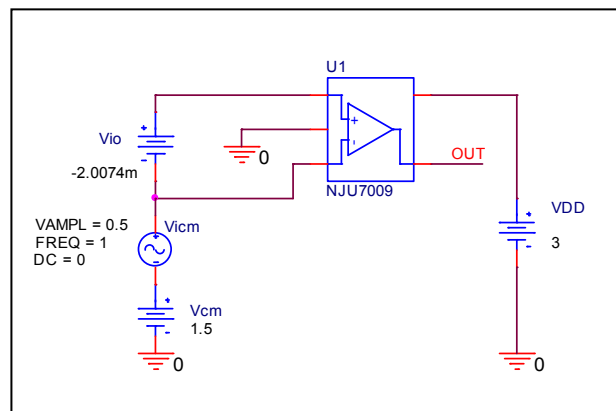
$G_v=40[dB]$	Measurement	Simulation	%Error
$f_T$ [MHz]	3.000	3.084	2.80

## Common Mode Rejection Ratio – CMR

### Simulation result



### Evaluation circuit



### Comparison Table

(Condition:  $V_{cm}=0V\sim 2.1V$ )

Parameter	Measurement	Simulation	%Error
CMR[dB]	80.000	82.214	-3.54

※ Common Mode Rejection Ratio =  $20 \cdot \log(A_v/A_{vcm}) = 20 \cdot \log(13877/1.0755) = 82.214\text{dB}$