

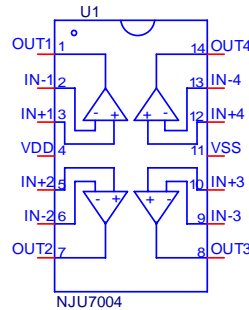
# Device Modeling Report

COMPONENTS : OPERATIONAL AMPLIFIER (CMOS)  
PART NUMBER : NJU7004  
MANUFACTURER : NEW JAPAN RADIO



**Bee Technologies Inc.**

## SPICE MODEL



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*PART NUMBER: NJU7004
*MANUFACTURER: NEW JAPAN RADIO
*CMOS OPAMP
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.SUBCKT nju7004 IN-1 IN+1 IN-2 IN+2 VDD VSS OUT1 OUT2
+ IN-3 IN+3 IN-4 IN+4 OUT3 OUT4
X_U1 IN-1 IN+1 VDD VSS OUT1 nju7004_s
X_U2 IN-2 IN+2 VDD VSS OUT2 nju7004_s
X_U3 IN-3 IN+3 VDD VSS OUT3 nju7004_s
X_U4 IN-4 IN+4 VDD VSS OUT4 nju7004_s
.ENDS nju7004

*$
.SUBCKT nju7004_S  IN- IN+ VDD VSS OUT
M1      2 IN- 3 VDD MbreakPD3
M2      2 IN+ 4 VDD MbreakPD2
M3      VDD 1 2 VDD MbreakPD
M4      VDD 1 5 VDD MbreakPD
M5      VDD 1 6 VDD MbreakPD
M6      VDD 1 1 VDD MbreakPD
M7      5 5 VSS VSS MbreakND  W=3.2m  L=6u
M8      5 4 VSS VSS MbreakND3
M9      3 3 IN1 VSS MbreakND1
M10     4 3 IN2 VSS MbreakND1
M11     1 6 11 11 MbreakND  W=9m  L=6u
M12     6 6 VSS VSS MbreakND3
M13     7 5 VSS VSS MbreakND1
M14     VDD 7 7 VDD MbreakPD
M15     VDD 7 OUT VDD MbreakPD1
M16     OUT 4 VSS VSS MbreakND2
C1      OUT 7 15p
C2      OUT 1 10p
Cout    OUT IN- 70p

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R1      11 VSS  1.522k
R2      IN1 VSS 2.0k
R3      IN2 VSS  3.93k
I1      0 IN-  0.505p
I2      0 IN+  1.5p
X_U1    VSS 3 DbreakZ
X_U2    VSS 4 DbreakZ
.model MbreakND NMOS (LEVEL=3 VTO=0.9 RS=10.000E-3 RD=10.000E-3
+ RDS=1.0000E6 TOX=2.0000E-6 CGSO=4.000E-12 CGDO=1.000E-12
+ CBD=1.000E-12 RG=5 RB=1.0000E-3 KP=10E-6)
.model MbreakND1 NMOS (LEVEL=3 L=6u W=0.5 VTO=1 RS=10.000E-3
+ RD=10.000E-3 RDS=1.0000E6 TOX=2.0000E-6
+ CGSO=3.00E-12 CGDO=1.000E-12 CBD=1.000E-12
+ RG=5 RB=1.0000E-3 KP=10E-6)
.model MbreakND2 NMOS (LEVEL=3 L=6u W=0.483m VTO=0.9
+ RS=10.000E-3 RD=10.000E-3 RDS=1.0000E6 TOX=2.0000E-6
+ CGSO=4.000E-12 CGDO=1.00E-12 CBD=1.000E-12
+ RG=5 RB=1.0000E-3 KP=10E-6)
.model MbreakND3 NMOS (LEVEL=3 L=6u W=3.2m VTO=0.9
+ RS=10.000E-3 RD=10.000E-3 RDS=1.0000E6 TOX=2.0000E-6
+ CGSO=5.000E-7 CGDO=1.000E-13 CBD=10.000E-6
+ RG=5 RB=1.0000E-3 KP=10E-6)
.model MbreakPD PMOS (LEVEL=3 L=6u W=0.023 VTO=-1 RS=10.000E-3
+ RD=10.000E-3 RDS=1.0000E6 TOX=2.0000E-6 CGSO=4.000E-12
+ CGDO=1.000E-12 CBD=1.000E-12 RG=5 RB=1.0000E-3 KP=1E-6)
.MODEL MbreakPD1 PMOS (LEVEL=3 L=6u W=0.0056 VTO=-0.9
+ RS=10.000E-3 RD=10.000E-3 RDS=1.00E6 TOX=2.0000E-6
+ CGSO=4.000E-12 CGDO=1.000E-12 CBD=1.000E-12
+ RG=5 RB=1.0000E-3 KP=1E-6)
.MODEL MbreakPD2 PMOS (LEVEL=3 L=6u W=0.13 VTO=-1.5
+ RS=10.000E-3 RD=10.00E-3 RDS=1.00E6 TOX=2.0000E-6
+ CGSO=4.000E-12 CGDO=1.000E-12 CBD=1.00E-12
+ RG=5 RB=1.0000E-3 KP=1E-6)
.MODEL MbreakPD3 PMOS (LEVEL=3 L=6u W=0.14 VTO=-1.5
+ RS=10.000E-3 RD=10.00E-3 RDS=1.E6 TOX=2.0000E-6
+ CGSO=4.000E-12 CGDO=1.000E-12 CBD=1.00E-12
+ RG=5 RB=1.0000E-3 KP=1E-6)
.ENDS nju7004_s

```

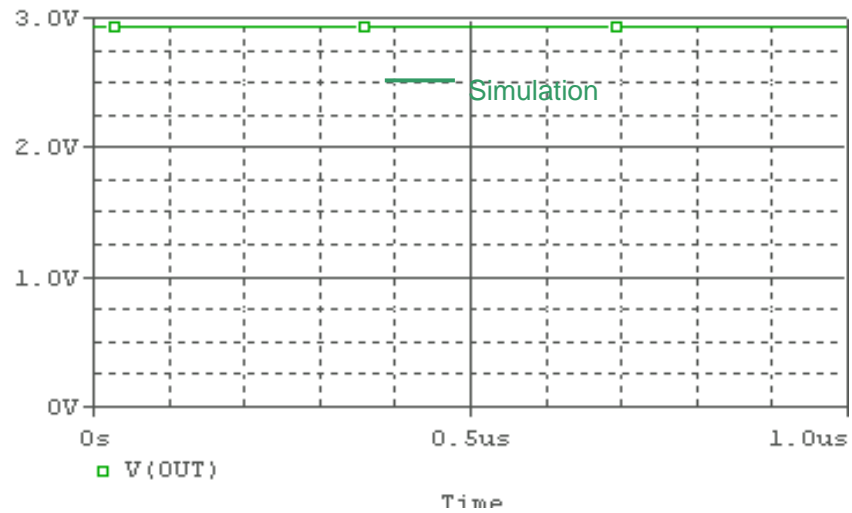
```
.SUBCKT DbreakZ  A K  
D1 A K DF  
DZ A2 A DR  
VZ K A2 1  
.MODEL DF D  
.MODEL DR D  
.ENDS DbreakZ  
*$
```

## MOSFET MODEL

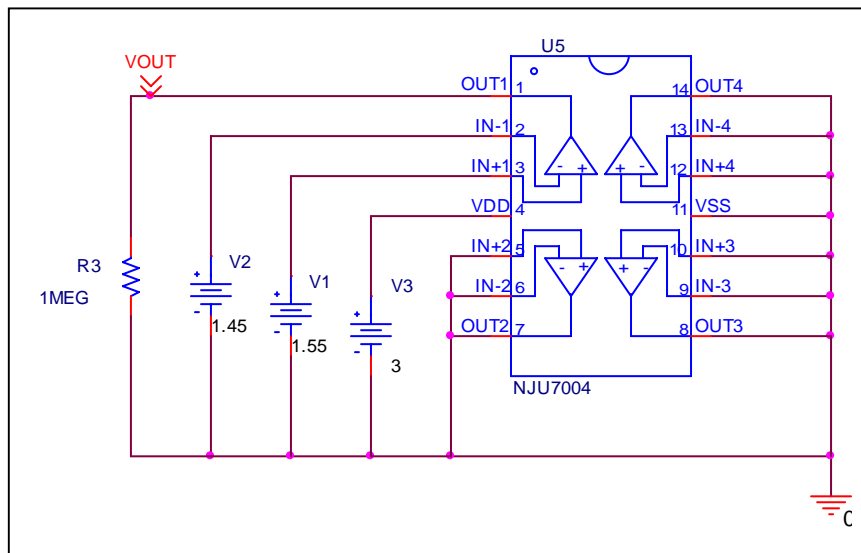
Pspice model parameter	Model description
LEVEL	
L	Channel Length
W	Channel Width
KP	Transconductance
RS	Source Ohmic Resistance
RD	Ohmic Drain Resistance
VTO	Zero-bias Threshold Voltage
RDS	Drain-Source Shunt Resistance
TOX	Gate Oxide Thickness
CGSO	Zero-bias Gate-Source Capacitance
CGDO	Zero-bias Gate-Drain 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	Modility Modulation
KAPPA	Saturation Field Factor
VMAX	Maximum Drift Velocity of Carriers
XJ	Metallurgical Junction Depth
UO	Surface Mobility

## Output Voltage Swing

### Simulation result



### Evaluation Circuit

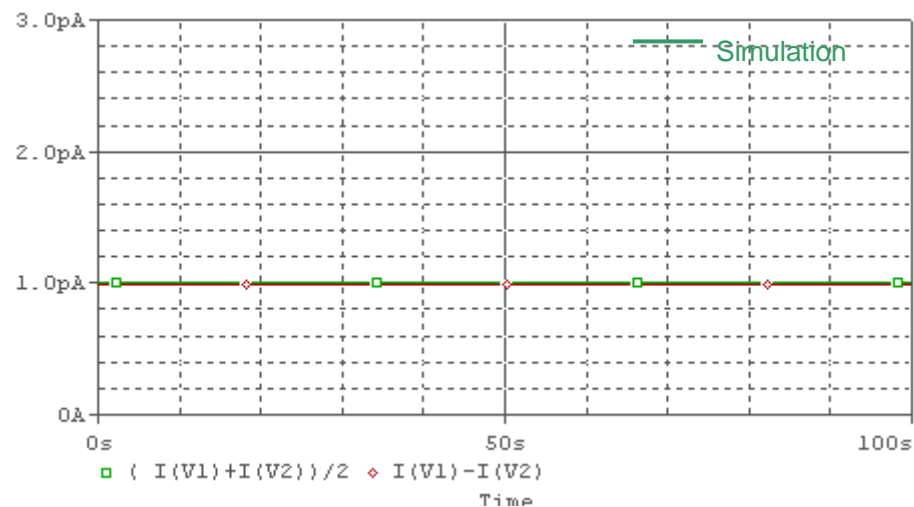


### Compasion Table

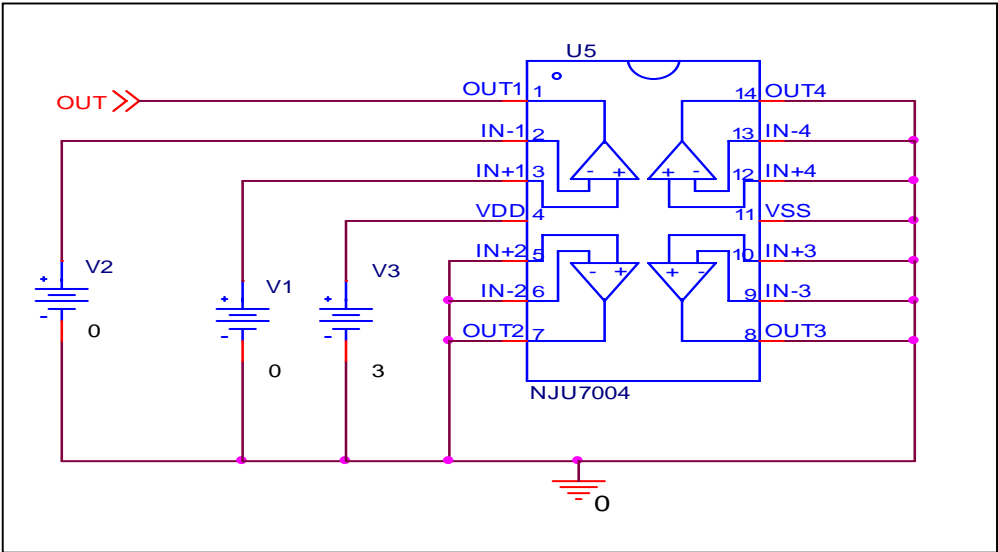
	Measurement	Simulation	%Error
<b>V<sub>OM</sub> (V)</b>	2.940	2.939	-0.034

# Input Current

## Simulation result



## Evaluation Circuit

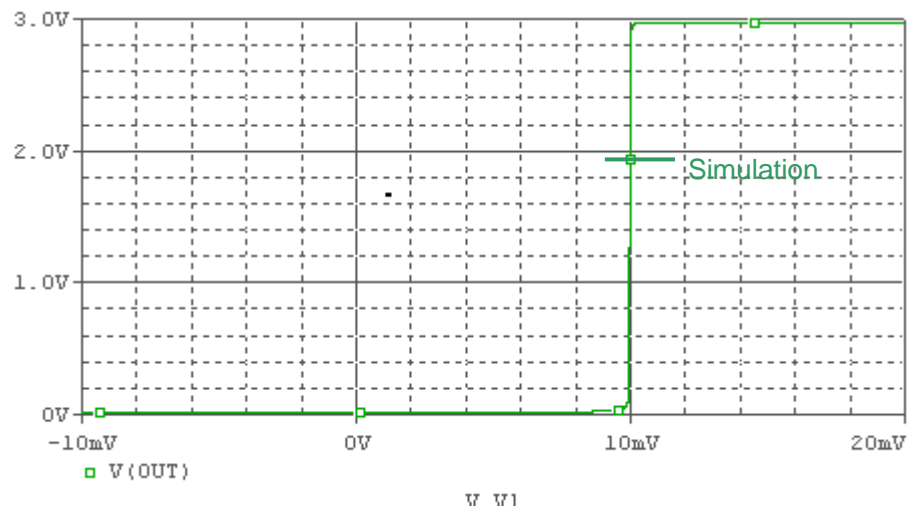


## Comparison Table

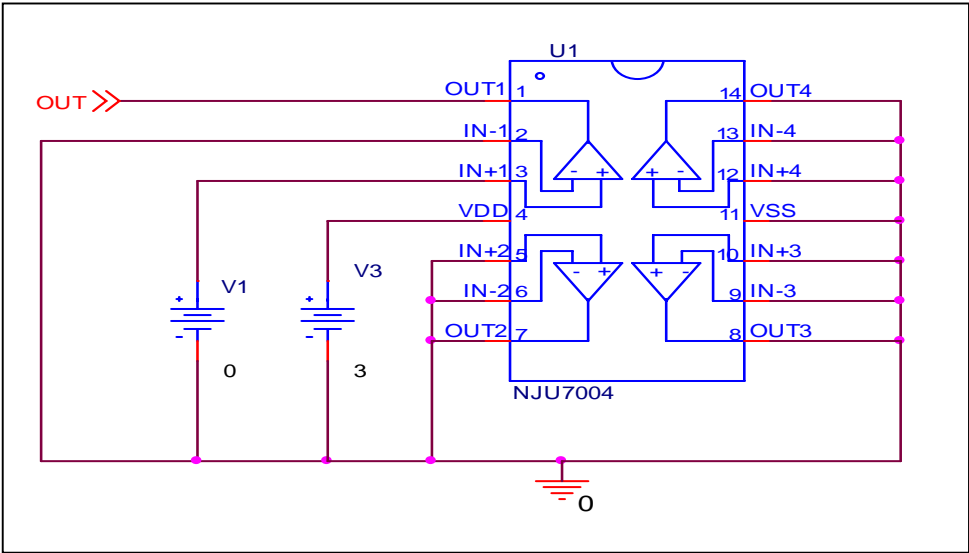
	Measurement	Simulation	% Error
$I_b$ (pA)	1.000	1.002	0.200
$I_{os}$ (pA)	1.000	0.995	-0.500

# Input Offset Voltage

## Simulation result



## Evaluation Circuit



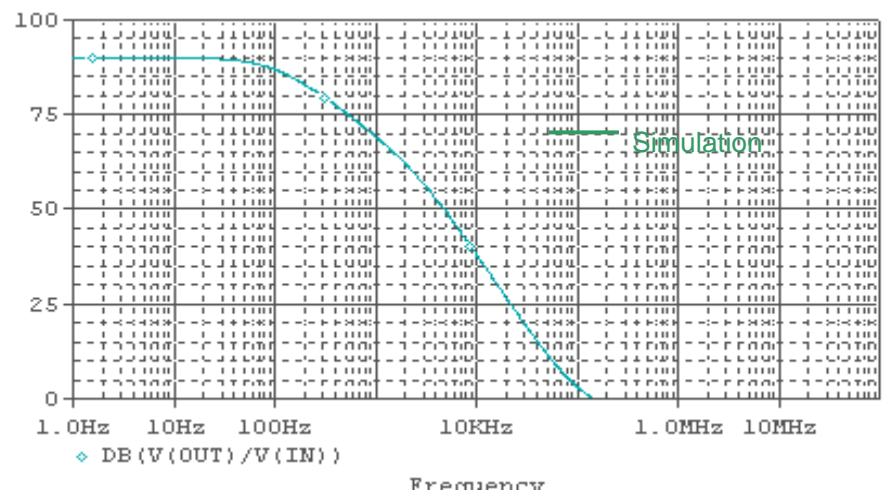
## Compasion Table

	Measurement	Simulation	%Error
$V_{os}$ (mV)	10.000	9.972	-0.280

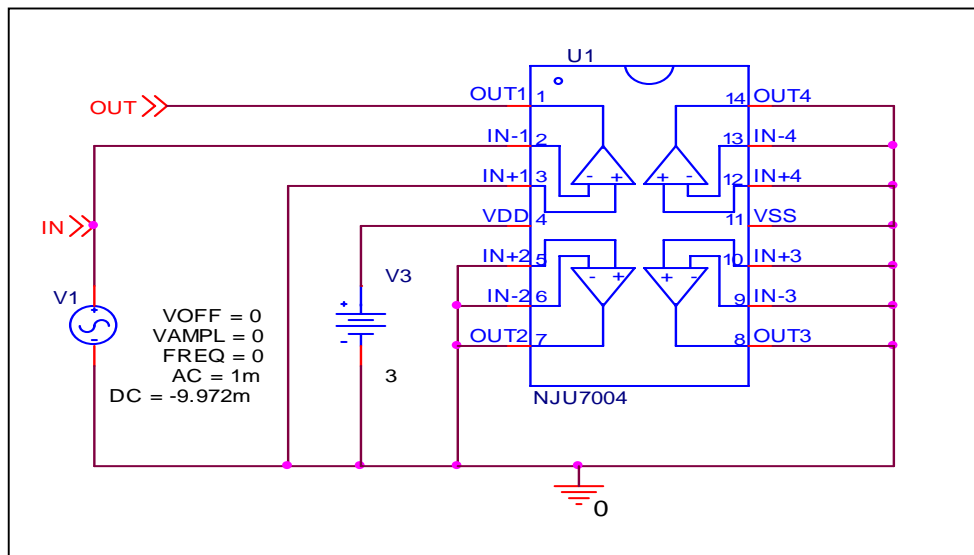


# Open loop Voltage Gain

## Simulation result



## Evaluation Circuit

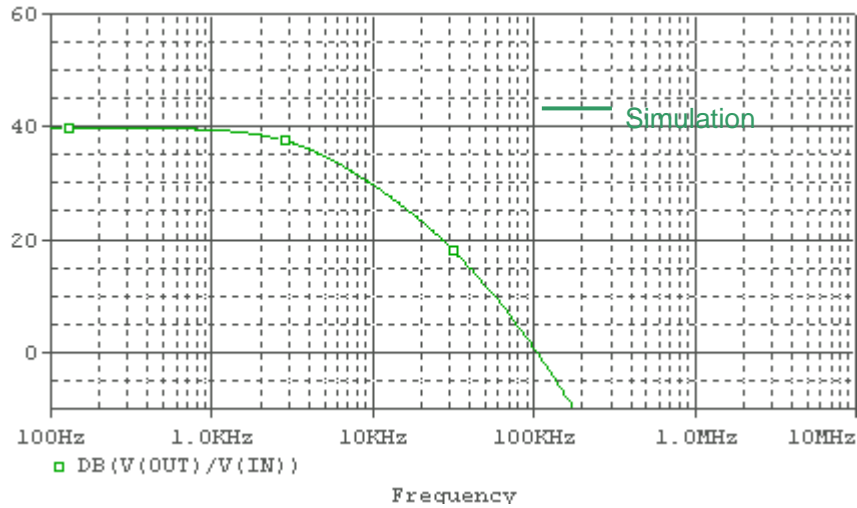


## Compasion Table

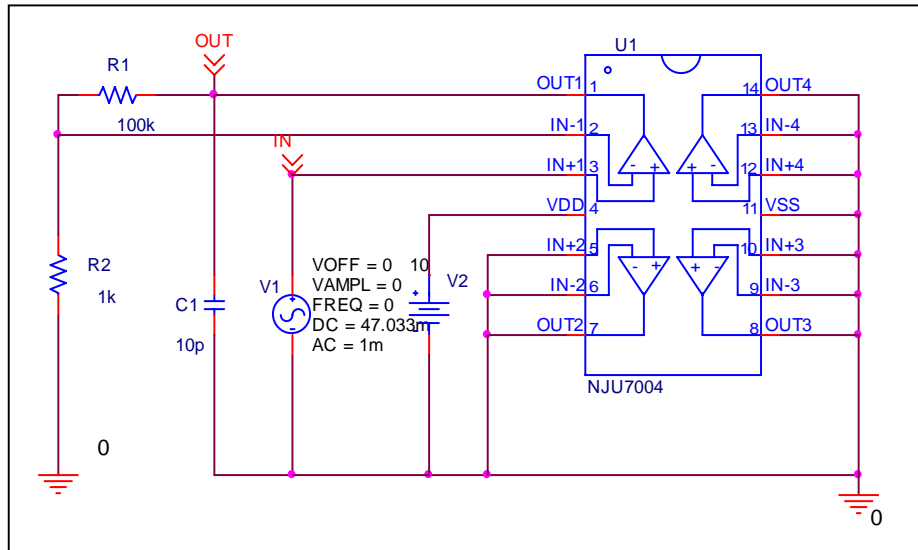
	Measurement	Simulation	%Error
Av (dB)	90.000	90.000	0

# Unity Gain Frequency

## Simulation result



## Evaluation Circuit

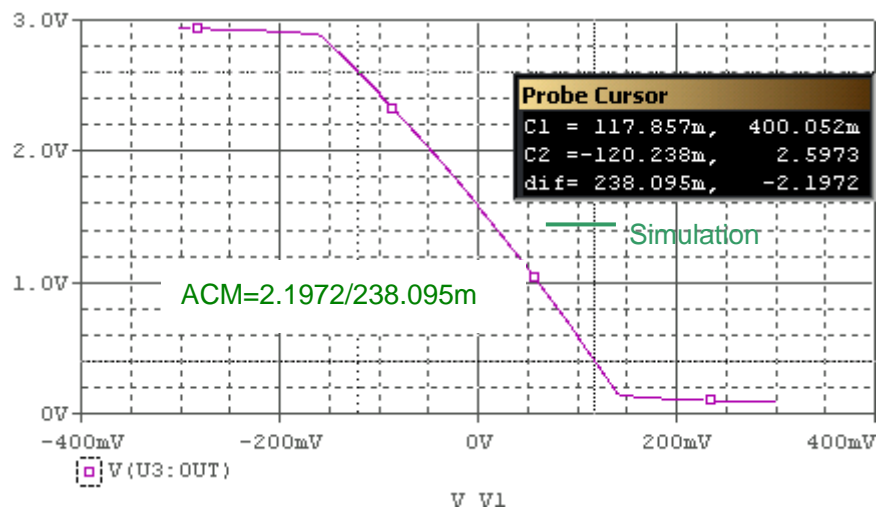


## Compasion Table

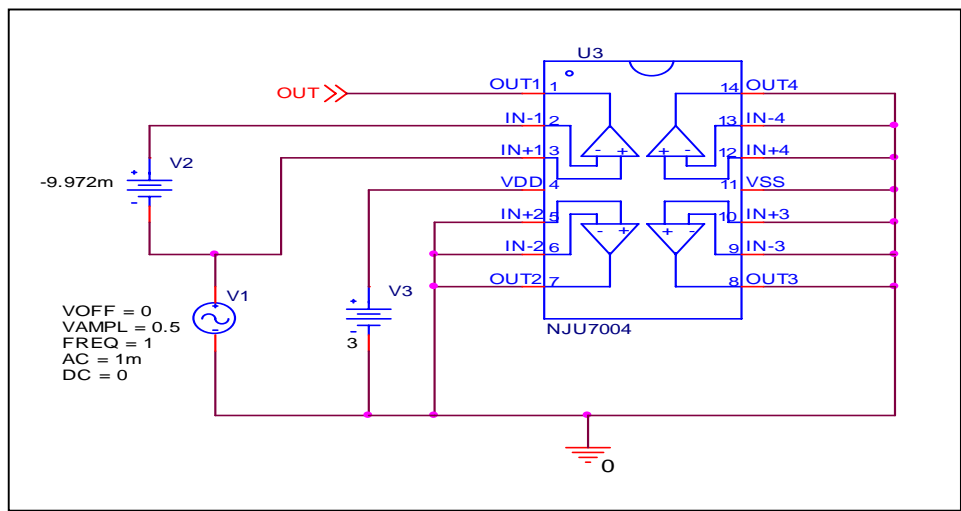
$A_v=40\text{dB}, C_L=10\text{pF}$	Measurement	Simulation	%Error
<b>Ft(MHz)</b>	0.100	0.099	-1.000

# Common-Mode Rejection Ratio

## Simulation result



## Evaluation Circuit



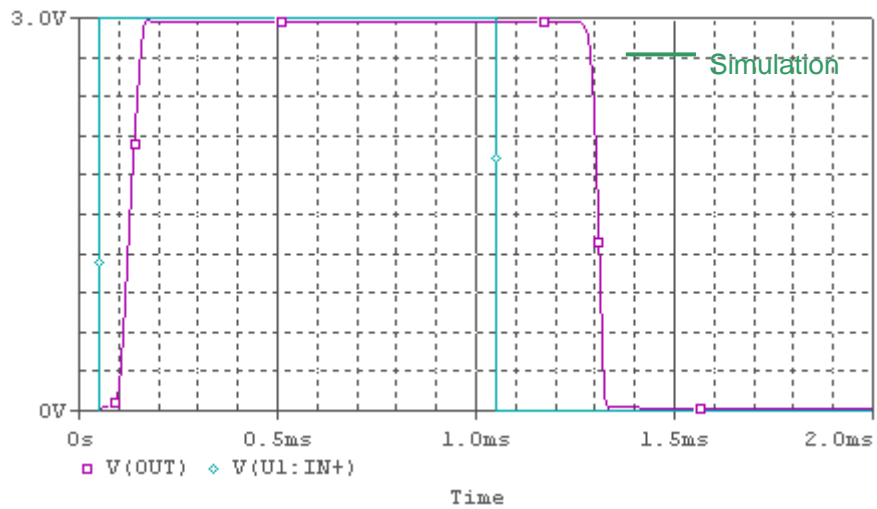
$$CMRR = AV/ACM$$

## Comparison Table

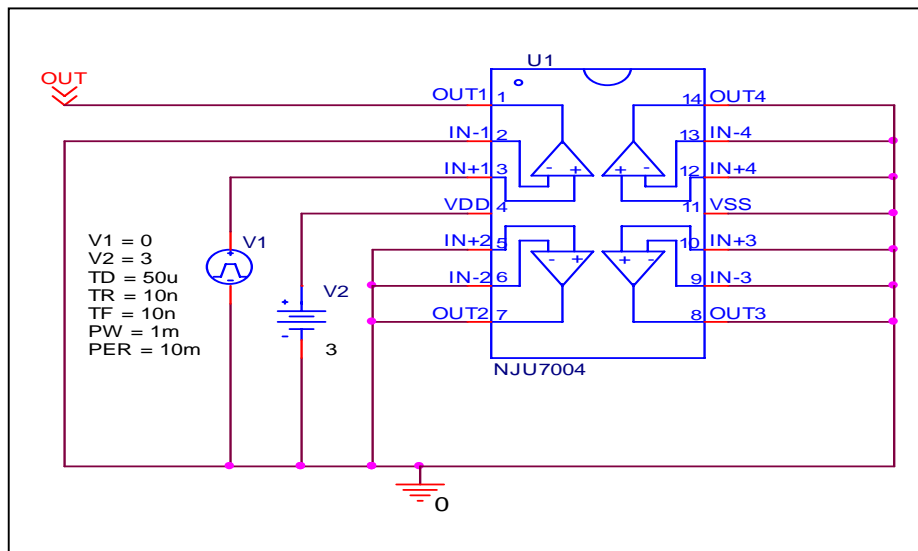
	Measurement	Simulation	%Error
CMRR (dB)	70.000	70.680	0.975

## Slew Rate

### Simulation result



## Evaluation Circuit



	Measurement	Simulation	% Error
SR (V/us)	0.050	0.051	2.000