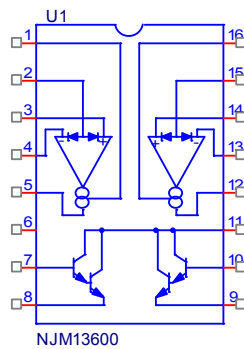# Device Modeling Report

COMPONENTS: OPERATIONAL AMPLIFIER
PART NUMBER: NJM13600
MANUFACTURER: NEW JAPAN RADIO CO., LTD.

Bee Technologies Inc.

Spice Model

U1

NJM13600

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*PART NUMBER: NJM13600
*MANUFACTURER: NEW JAPAN RADIO
*Transconductance OPAMP
*All Rights Reserved Copyright (c) Bee Technologies Inc. 2008
.SUBCKT 13600 Amp Di +IN -IN OUT VSS BUFIN BUFOUT VDD
Vop       1 -IN 0.561m
I1        -IN 0 0.0677n
I2        +IN 0 .64n
D1        DI +IN D11
D2        DI -IN D12
D3        3 VSS D14
D4        VDD 5 D13
D5        VDD 6 D15
D6        9 VSS D16
Q1        7 +IN 2 QAA2
Q2        4 1 2 QAA1
Q3        2 AMP 3 QAA3
Q4        AMP 3 VSS QAA4
Q5        4 5 VDD Q_PVAF1
Q6        8 4 5 Q_PVAF
Q7        7 6 VDD Q_pVAF2
Q8        OUT 7 6 QP_OUT
Q9        OUT 8 9 QN_OUT
Q10       8 9 VSS QAA5
QB1       10 3 VSS BUF_IN
QB2       VDD BUFIN 10 BUF1
QB3       VDD 10 BUFOUT BUF
C1        7 OUT 4.573p
.MODEL d11 D (IS=30E-14 N=1 RS=1m IKF=0 ISR=10E-15)
.MODEL d16 D (IS=10E-15 N=1 RS=1.0000E-3 IKF=0)
.MODEL d15 D (IS=10.000E-15 N=1 RS=1.0000E-3 IKF=0)
.MODEL d14 D (IS=10.000E-15 N=1 RS=1.0000E-3 IKF=0)
.MODEL d13 D (IS=10.000E-15 N=1 RS=1.0000E-3 IKF=0)
.MODEL d12 D (IS=90E-15 N=1 RS=1m IKF=0 ISR=10E-15 CJO=1p)
.model Q_PVAF PNP (IS=10.000E-15 )
.model Q_PVAF1 PNP (IS=10.000E-15)
+ NE=1.5000 BR=21 NR=1 VAR=100 NC=2 NK=.5 )
.model Q_PVAF2 PNP (IS=11.440E-15 BF=100 NF=1 VAF=100
+ NE=1.5000 BR=1 NR=1 VAR=100 NC=2 NK=.5 )
.MODEL Qaa1 NPN (IS=10.000E-15 BF=920 NF=1 VAF=100
+ NE=1.5000 BR=21 NR=1 VAR=100 NC=2 NK=.5 )
.MODEL Qaa2 NPN (IS=10.000E-15 BF=700 NF=1 VAF=100
+ NE=1.5000 BR=21 NR=1 VAR=100 NC=2 NK=.5 RE=0.249)
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.model Qaa3 NPN (IS=10.000E-15 BF=100 NF=1 VAF=100
+ NE=1.5000 BR=1 NR=1 VAR=100 NC=2 NK=.5 )
.model Qaa4 NPN (IS=10.000E-15 BF=100 NF=1 VAF=100
+ NE=1.5000 BR=1 NR=1 VAR=100 NC=2 NK=.5 )
.model Qaa5 NPN (IS=11.50E-15 BF=100 NF=1 VAF=100
+ NE=1.5000 BR=1 NR=1 VAR=100 NC=2 NK=.5 )
.MODEL QP_OUT PNP (IS=10.000E-15  BF=100  NF=1  VAF=100
+ NE=1.5 BR=.1001 VAR=100 IKR=10.010E-3 ISC=504E-12
+ NC=1.06252 NK=.56106 RB=.209 RC=0.3970 )
.MODEL QN_OUT NPN (IS=10.000E-15 BF=100 NF=1 VAF=100
+ NE=1.5 BR=52.477 VAR=100 IKR=.40837 ISC=53.671E-12
+ NC=1.8061 NK=.22646 RB=.73666 RC=25.602e-3 )
.MODEL Buf NPN (IS=10.000E-15 BF=100 NF=1 VAF=100
+ NE=1.5 BR=1 NR=1 VAR=10 NC=2 NK=.5 CJE=2p CJC=2p
.MODEL Buf1 NPN (IS=100.000E-12 BF=1590 NF=1 VAF=10
+ NE=1.5 BR=1 NR=1 VAR=100 NC=2 NK=.5 CJE=2p CJC=2p
.MODEL Buf_In NPN (IS=10.0000E-15 BF=100 NF=1 VAF=100
+ NE=1.5000 BR=1 NR=1 VAR=100 NC=2 NK=.5 CJE=2p )
.ENDS
```
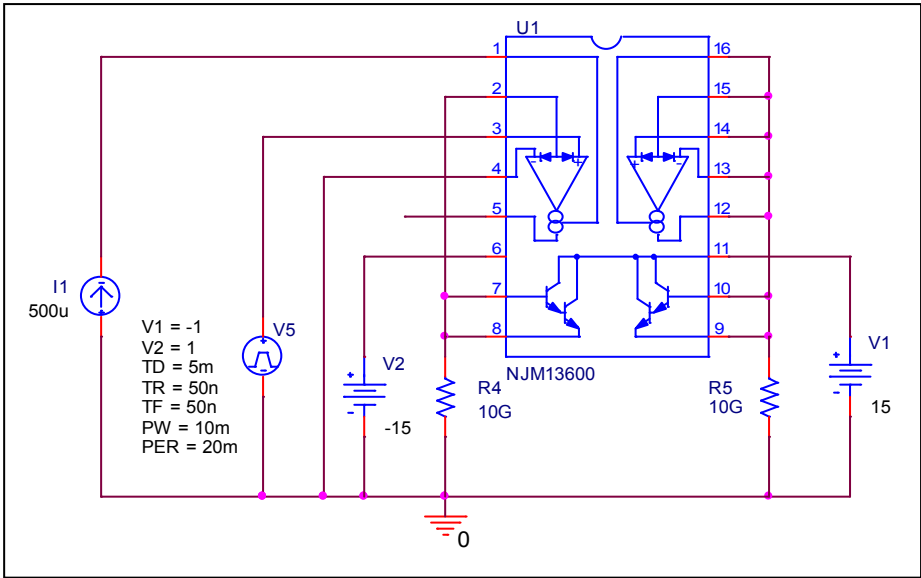
Output Voltage Positive and Negative
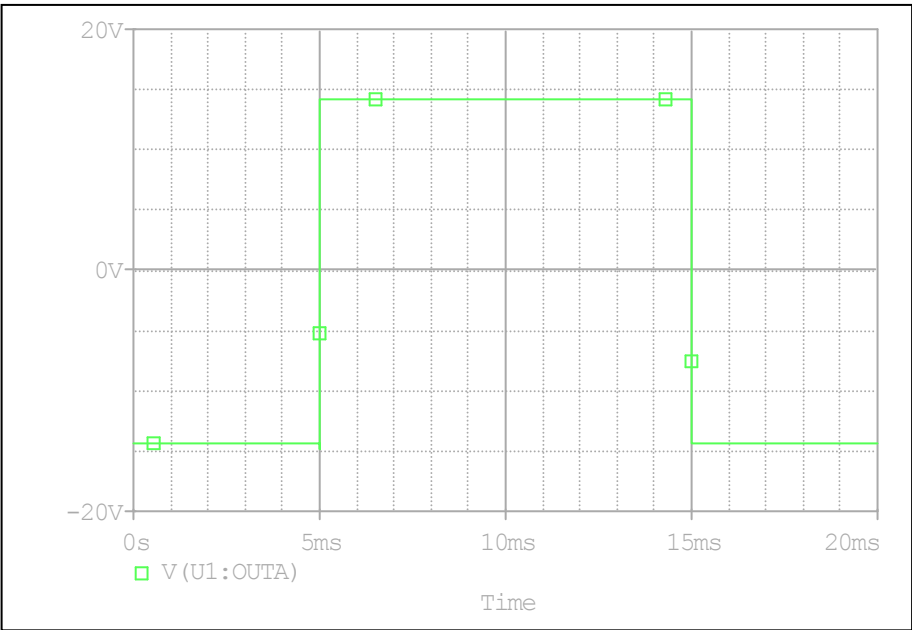
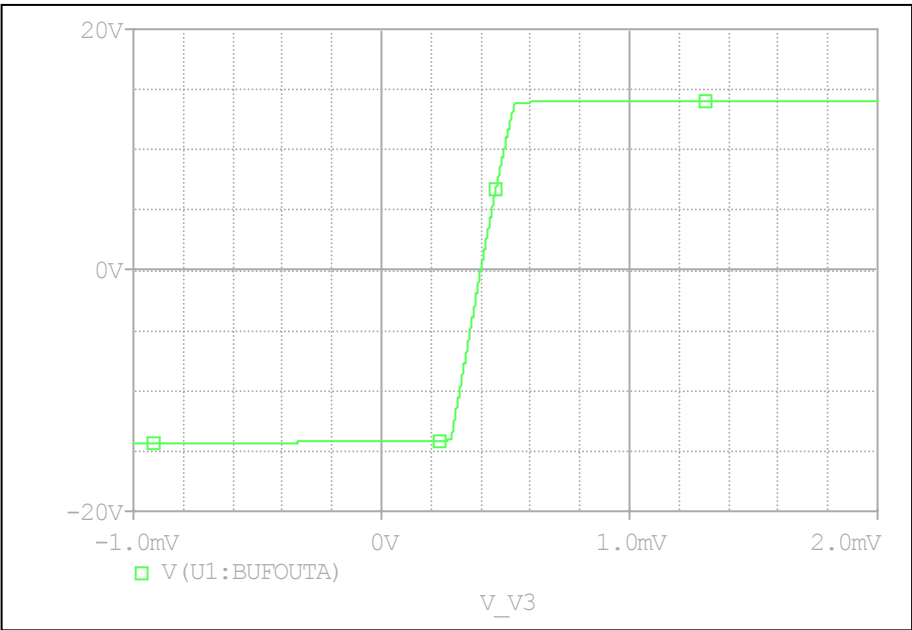| I_{ABC} = 500uA	Measurement	Simulation	%Error
V_{op} + (V)	+14.2	+14.114	-0.606
V_{op} − (V)	-14.4	-14.372	-0.194

Input Offset voltage
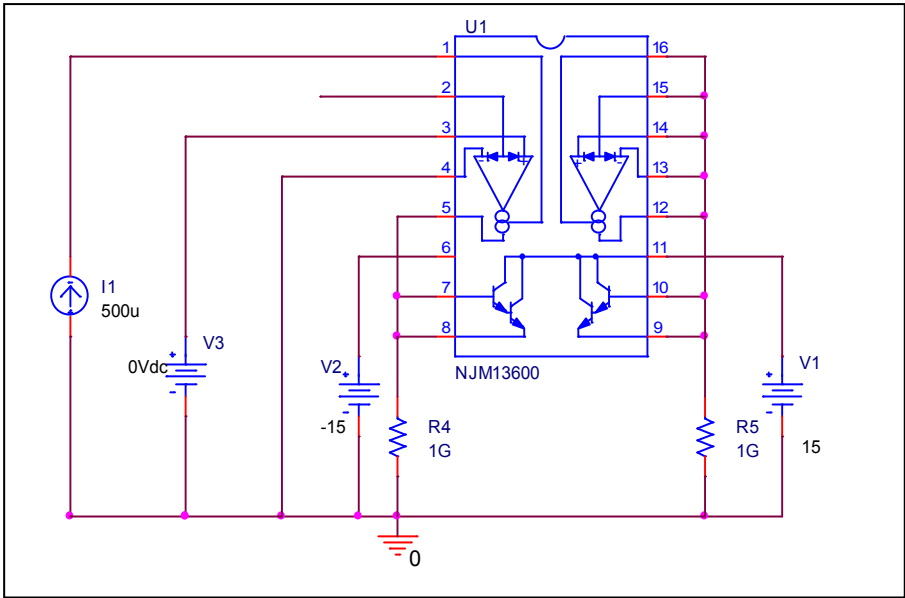
Comparison table

I_{ABC} = 500uA	Measurement	Simulation	%Error
V_{IO} (mV)	0.4	0.406	1.500

Input Bias Current and Offset Current

Simulation result
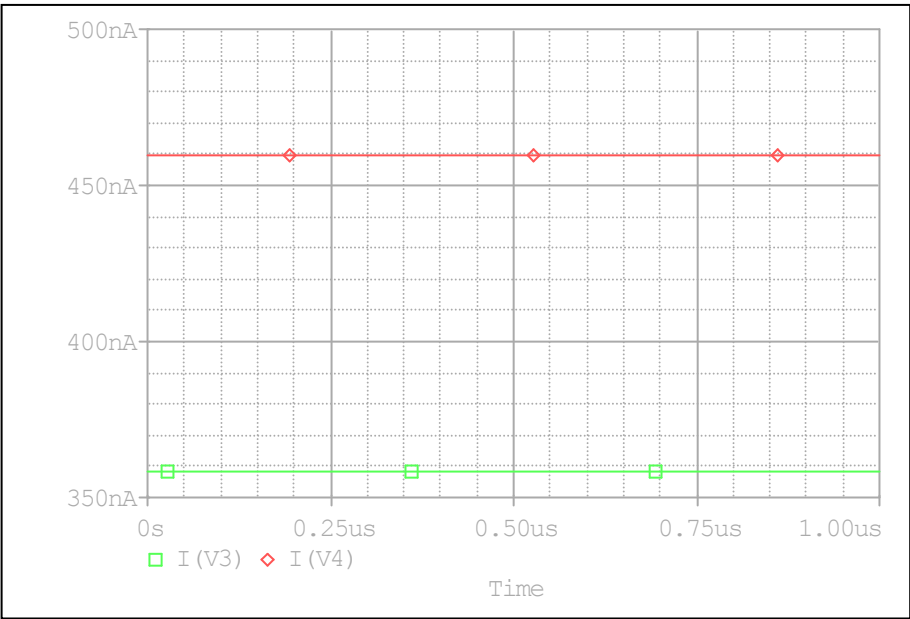
Evaluation circuit
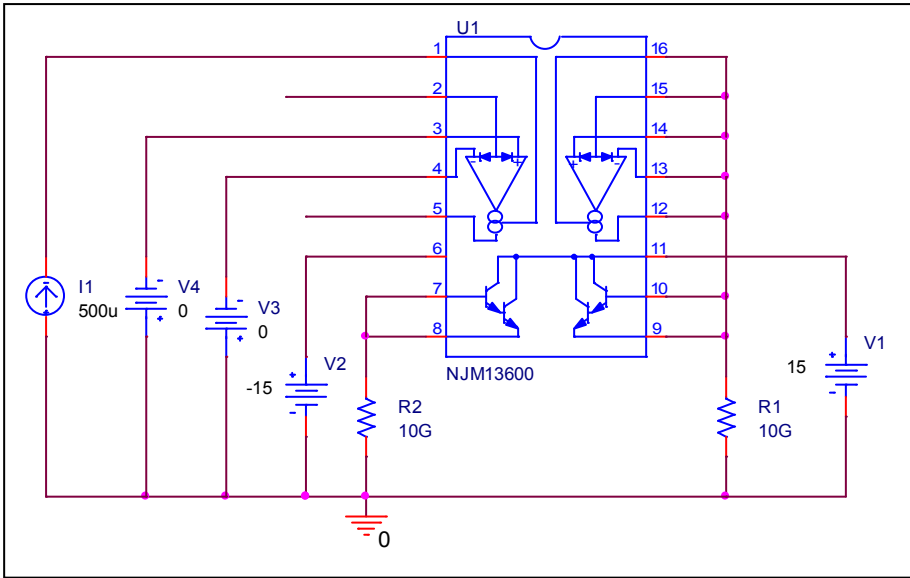
Comparison table

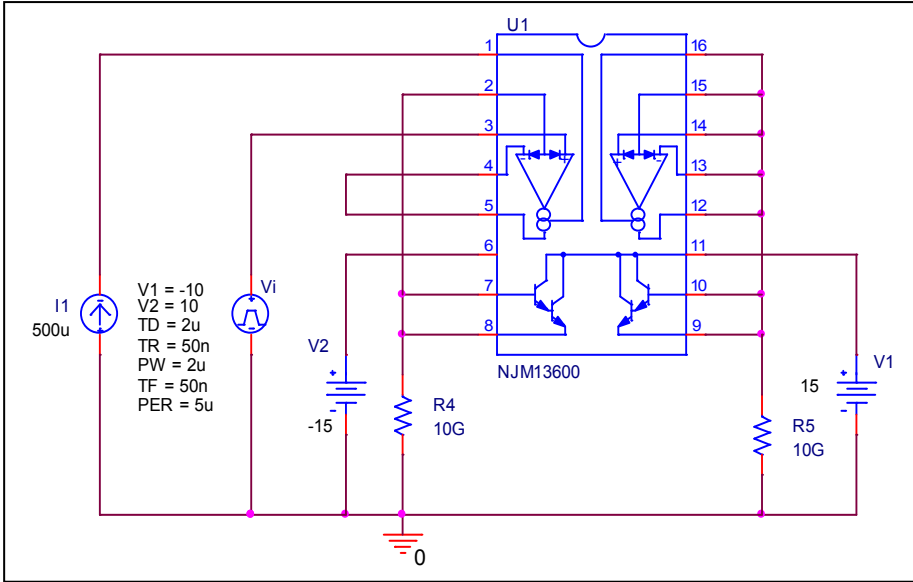| I_{ABC} = 500uA	Measurement	Simulation	%Error
I_B (uA)	0.4	0.409	2.250
I_{IO} (uA)	0.1	0.101	1.000

Slew Rate

Simulation result
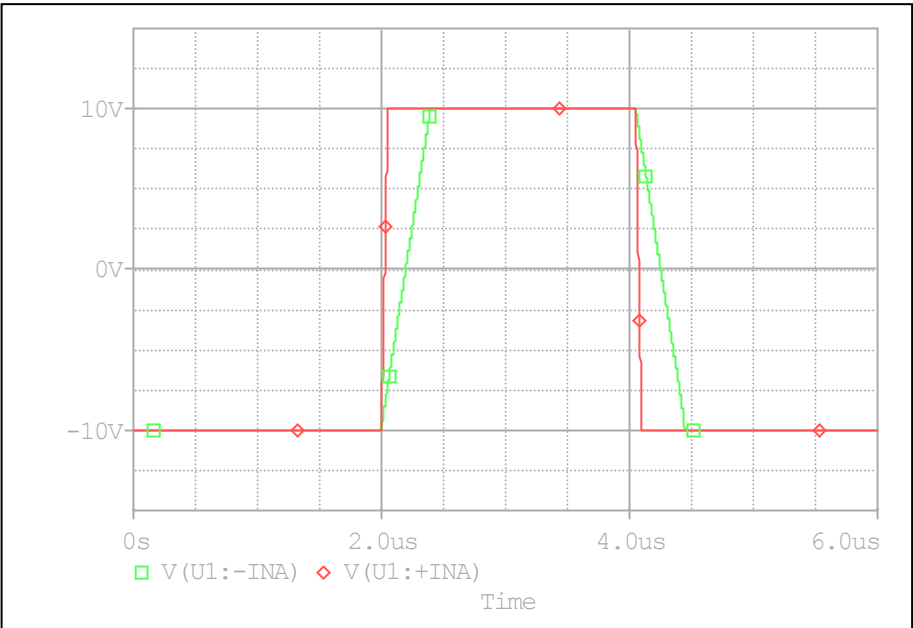
Evaluation circuit

Comparison table

I_{ABC} = 500uA	Measurement	Simulation	%Error
SR (V/us)	50	49.993	-0.014

Differential Input Current
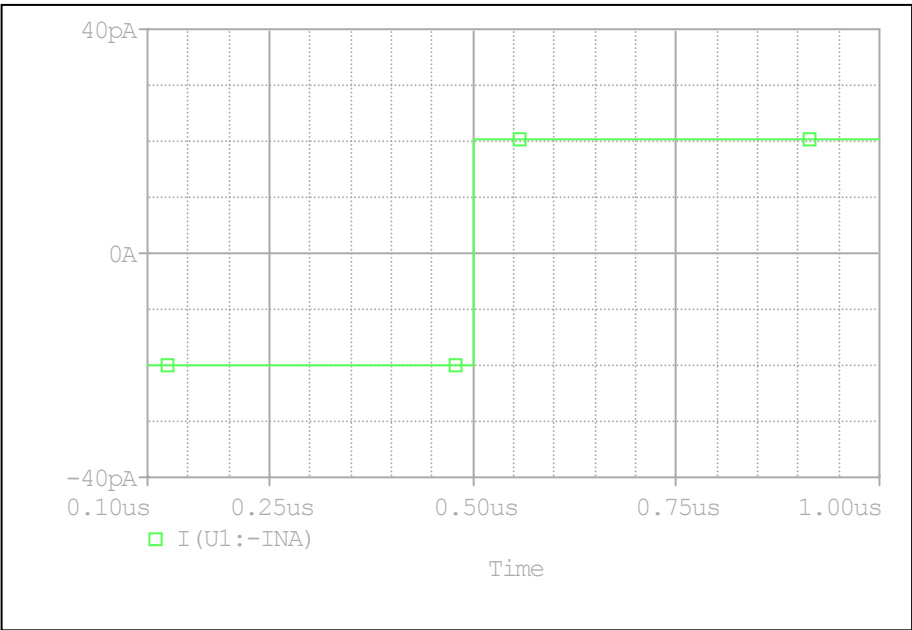
Evaluation circuit
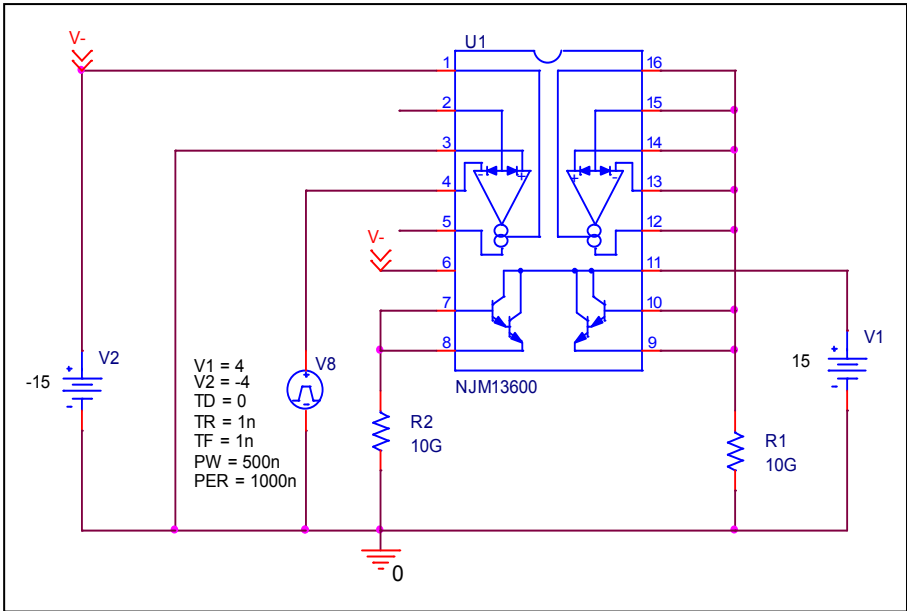
Comparison table

I_{ABC} = 0uA	Measurement	Simulation	%Error
I_{ID} (nA)	0.02	0.02	0

Buffer Input Current and Output Voltage
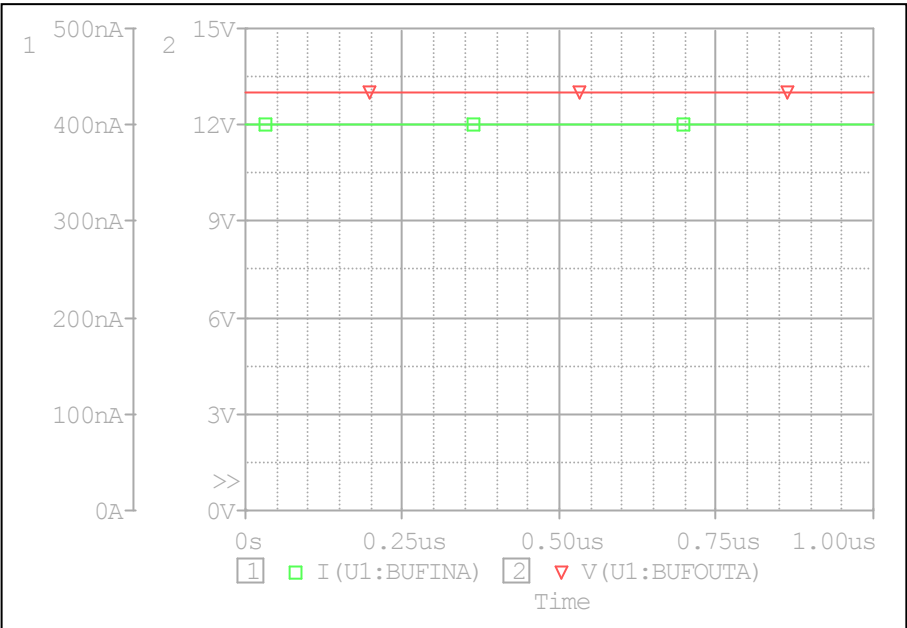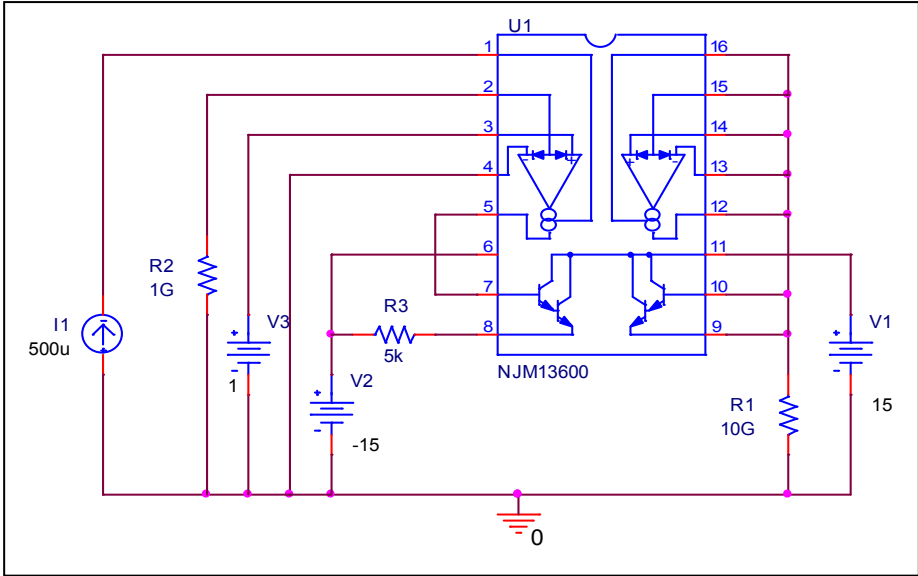
Simulation result

Evaluation circuit

Comparison table

I_{ABC} = 500uA	Measurement	Simulation	%Error
Buffer Input Current (uA)	0.4	0.4	0
Buffer Output Voltage (V)	13	13.017	0.131

Buffer Input Current and Output Voltage

Simulation result

Evaluation circuit

Comparison table

I_{ABC} = 500uA	Measurement	Simulation	%Error
Buffer Input Current (uA)	0.4	0.4	0
Buffer Output Voltage (V)	13	13.017	0.131

Forward Transconductance

Simulation result
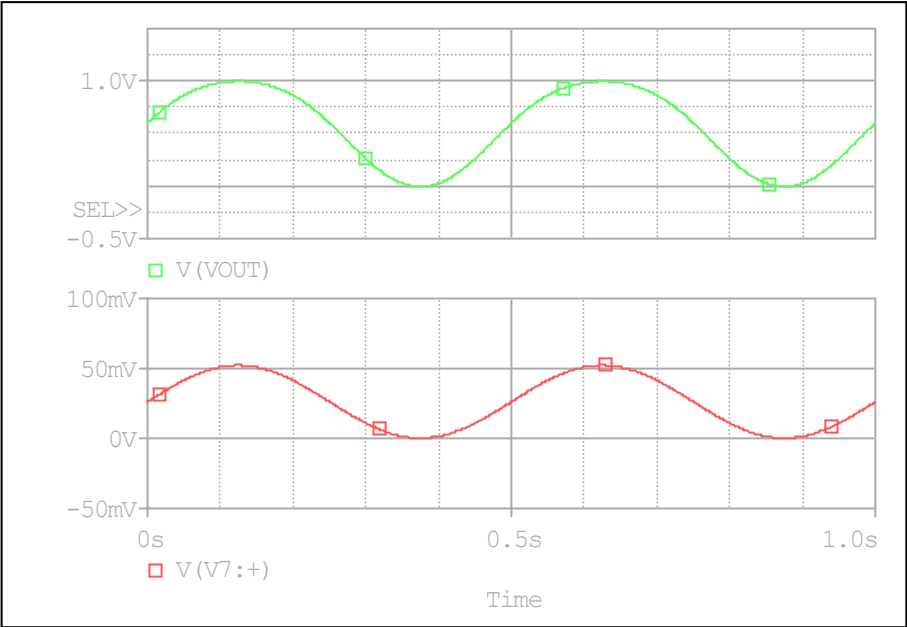
Evaluation circuit
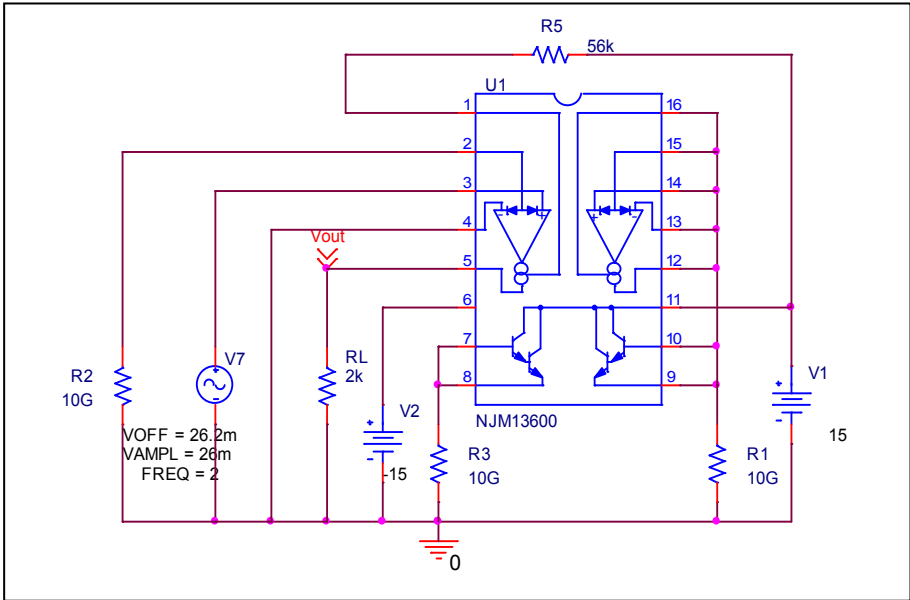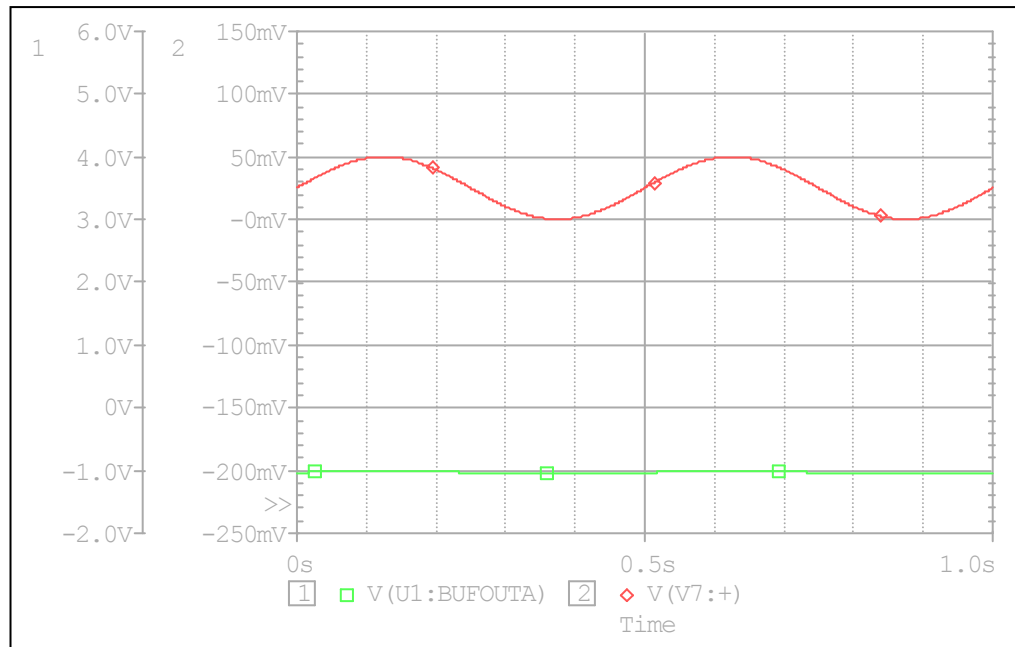

gm = (Vout/RL)/((Vin+)-(Vin-)) = (1.0035/2k)/(52m-0) = 9649 uS

Comparison table

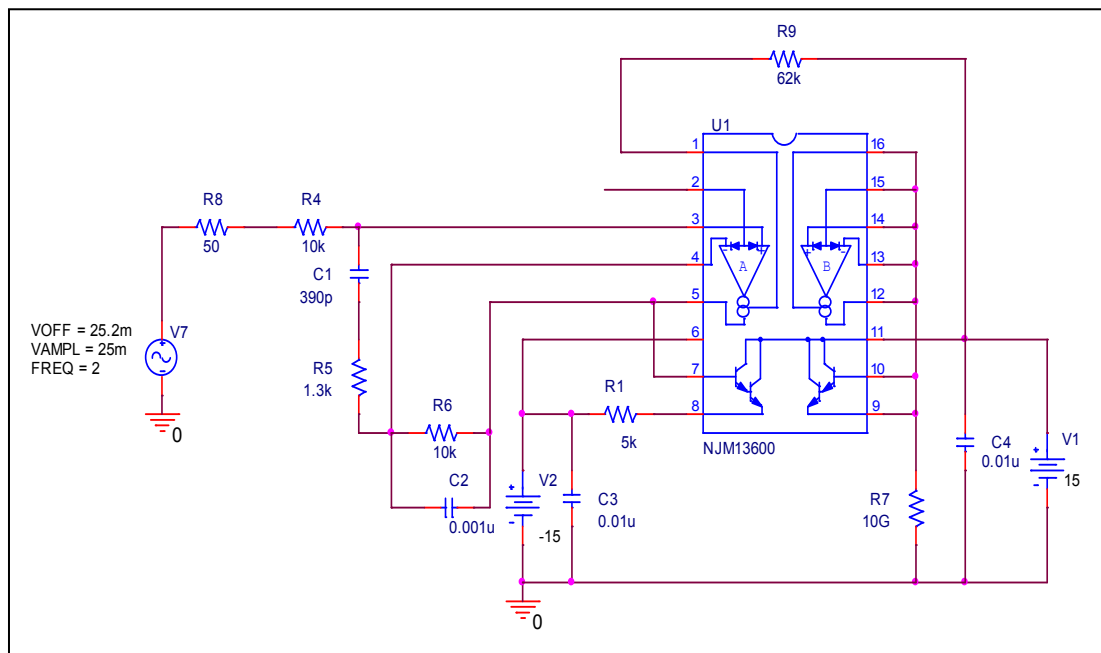| I_{ABC} = 500uA	Measurement	Simulation	%Error
gm (uS)	9600	9649	0.510

Typical Applications

Evaluation circuit

Reference

| Ch1 | 50.0mV | BW | Ch2 | 1.00 V | M | 1.00ms | A | Ch1 | ∫ | -2.00mV |