1.5V, 0.23µA/ch, Ultralow Power, Rail-to-Rail Input/Output Single/Dual/Quad CMOS Operational Amplifier

FEATURES (V^+=5V)

- Supply Current
  - NJU77000/NJU77001 0.29µA typ.
  - NJU77002/NJU77004 0.23µA/ch typ.
- Operating Voltage 1.5V to 5.5V
- Input Offset Voltage
  - NJU77000/NJU77001 1.0mV max.
  - NJU77002 1.3mV max.
  - NJU77004 1.5mV max.
- Input Offset Voltage Drift 0.65µV/°C typ.
- Input Bias Current 10pA max.
- Unity Gain Frequency 1.0kHz
- Slew Rate 0.7V/ms
- Rail-to-Rail Input/Output
- RF Noise Immunity
- CMOS Technology
- Package
  - NJU77000 SOT-23-5
  - NJU77001 SC-88A, SOT-23-5
  - NJU77002 SOP8 JEDEC 150mil
    MSOP8 (TVSP)*
    *JEDEC MO-187-DA / thin type
    DFN8-U1(ESON8-U1)
  - NJU77004 SSOP14

APPLICATIONS

- Battery powered Instruments
- Micro power oxygen sensor and gas sensor
- Power line monitoring
- Micropower current sensing
- Healthcare instruments

DESCRIPTION

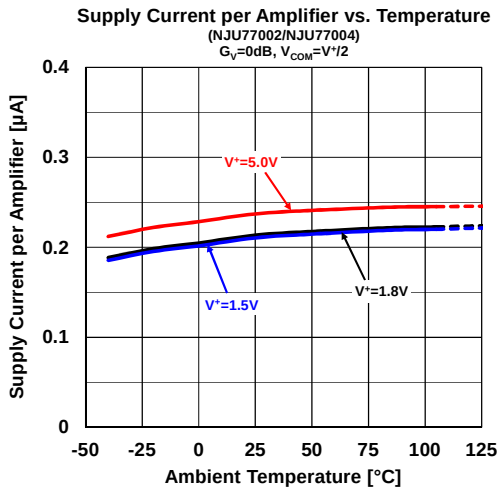
The NJU77000/NJU77001/NJU77002/NJU77004 is single/dual/quad ultralow power 345nW/ch operational amplifiers designed to extend battery life and performance for portable applications. The operating voltage range of 1.5V to 5.5V and supply current of 0.29uA(single), 0.23uA/ch(dual/quad) typical, with stable over temperature and input voltage change make them ideal for micropower oxygen sensors, gas sensors and remote sensor applications.

In addition to the ultralow power and low operating voltage, rail-to-rail input and output, input offset voltage of 1.0mV(single), 1.3mV(dual), 1.5mV(quad) maximum with 0.65uV/°C drift, input bias current of 10pA maximum and ability to drive 470pF loads, make the NJU77000 series ideal when requiring excellent performance in battery powered applications.

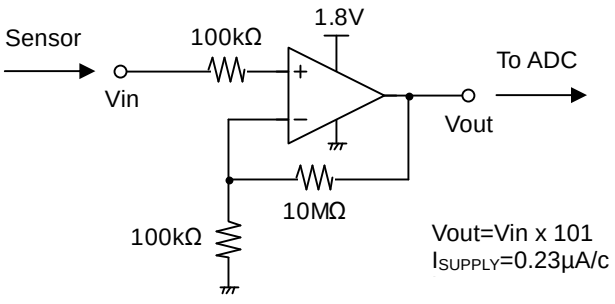
NJU77000 series are specified normal grade (NJU7700x) and A-Grade (NJU7700xA). A-Grade is guaranteed lower offset voltage and supply voltage from -40 to +105 °C than the normal grade.

The NJU77000 is available in the 5-pin SOT-23 package. NJU77001 is available in the 5-pin SOT-23 and SC-88A package. NJU77000 and NJU77001 have difference pin function (see pin configuration). The NJU77002 is available in the 8-pin SOP8: JEDEC 150mil, MSOP8 (TVSP8): JEDEC MO-187-DA / thin type and DFN(ESON) that is thin and 2mm square small packages. The NJU77004 is available in 14-pin SSOP14 package.

TYPICAL CHARACTERISTIC



TYPICAL APPLICATION



V^+=3V to 2V @ end of life

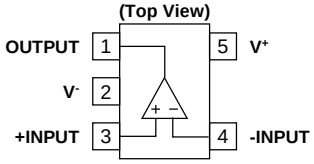
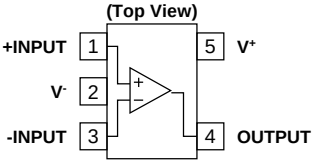
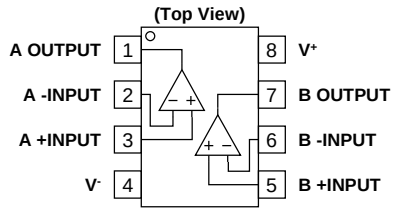
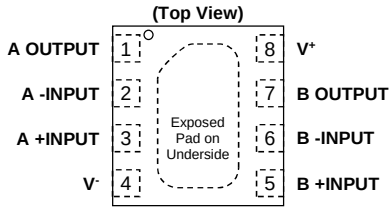
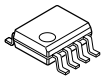
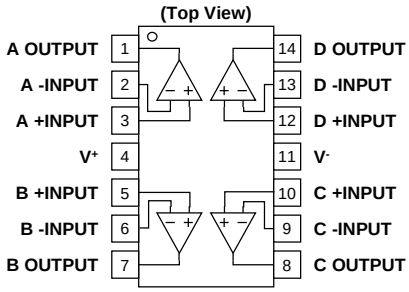
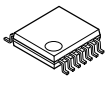
CR2032: coin type battery
220mAh = 13years @4circuit

40dB micropower sensor amplifier

■ PRODUCT INFORMATION

V_{IO} max. at 25°C	I_{SUPPLY} max. at 25°C	I_B max. at 25°C	Package / Product Name					
			SC-88A	SOT-23-5	SOP8 JEDEC 150 mil.	MSOP8 (TVSP8)	DFN8-U1 (ESON8-U1)	SSOP14
1.8mV	0.49µA	-	NJU77001F3	NJU77000F NJU77001F	-	-	-	-
1.0mV	0.39µA	10pA	NJU77001AF3	NJU77000AF NJU77001AF	-	-	-	-
2.0mV	0.66µA	-	-	-	NJU77002E	NJU77002RB1	NJU77002KU1	-
1.3mV	0.76µA	10pA	-	-	NJU77002AE	NJU77002ARB1	NJU77002AKU1	-
2.2mV	1.32µA	-	-	-	-	-	-	NJU77004V
1.5mV	1.22µA	10pA	-	-	-	-	-	NJU77004AV

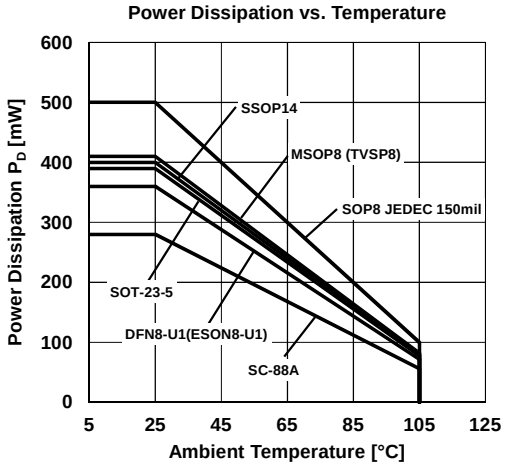
■ PIN CONFIGURATION

Pin Function			
Package	 SOT-23-5	 SOT-23-5	 SC-88A
Product Name	**NJU77000F NJU7700AF**	**NJU77001F NJU77001AF**	**NJU77001F3 NJU77001AF3**
Pin Function			 Connect to exposed pad to V-
Package	 SOP8 JEDEC 150 mil.	 MSOP8(TVSP8)	 DFN8-U1(ESON8-U1)
Product Name	**NJU77002E NJU77002AE**	**NJU77002RB1 NJU77002ARB1**	**NJU77002KU1 NJU77002AKU1**
Pin Function			
Package	 SSOP14		
Product Name	**NJU77004V NJU77004AV**		

■ ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	RATING	UNIT
Supply Voltage	$V^+ - V^-$	7	V
Differential Input Voltage (1)	V_{ID}	±7 (2)	V
Input Voltage	V_{IN}	V^- - 0.3 to V^+ + 0.3	V
Power Dissipation (3)		(2-layer)	
SOT23-5		390	
SC-88A		280	
SOP8 JEDEC 150 mil.	P_D	500	mW
MSOP8 (TVSP8)		410	
DFN8-U1(ESON8-U1)		360	
SSOP14		400	
Operating Temperature Range	T_{opr}	-40 to +105	°C
Storage Temperature Range	T_{stg}	-55 to +125	°C

(1) Differential voltage is the voltage difference between +INPUT and -INPUT.
(2) For supply voltage less than +7V, the absolute maximum rating is equal to the supply voltage.
(3) Power dissipation is the power that can be consumed by the IC at Ta=25°C, and is the typical measured value based on JEDEC condition. When using the IC over Ta=25°C subtract the value [mW/°C]=$P_D/(T_{stg}(MAX)-25)$ per temperature.
2-layer: EIA/JEDEC STANDARD Test board (76.2x114.3x1.6mm, 2layers, FR-4) mounting



■ RECOMMENDED OPERATING CONDITION (Ta=25°C)

PARAMETER	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Voltage	$V^+ - V^-$		1.5	-	5.5	V

■ELECTRICAL CHARACTERISTICS

(V^+=5V, V^-=0V, V_{COM}=2.5V, R_L=100kΩ to 2.5V, Ta=25°C, unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	NJU7700xA			NJU7700x			UNIT
			MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
DC CHARACTERISTICS									
Supply Current (all channel)		No Signal							
NJU77000/NJU77001			-	0.29	0.39	-	0.29	0.49	
		Ta=-40°C to 105°C	-	-	0.39	-	-	-	
NJU77002	I_{SUPPLY}		-	0.46	0.66	-	0.46	0.76	µA
		Ta=-40°C to 105°C	-	-	0.66	-	-	-	
NJU77004			-	0.92	1.22	-	0.92	1.32	
		Ta=-40°C to 105°C	-	-	1.22	-	-	-	
Input Offset Voltage		V_{COM}=0V							
NJU77000/NJU77001			-	0.35	1	-	0.35	1.8	
		Ta=-40°C to 105°C	-	-	1.2	-	-	-	
NJU77002	V_{IO}		-	0.35	1.3	-	0.35	2.0	mV
		Ta=-40°C to 105°C	-	-	1.5	-	-	-	
NJU77004			-	0.35	1.5	-	0.35	2.2	
		Ta=-40°C to 105°C	-	-	1.7	-	-	-	
Input Offset Voltage Drift		V_{COM}=0V, Ta=-40°C to 105°C							
NJU77000/NJU77001	$\Delta V_{IO}/\Delta T$		-	0.65	17	-	0.65	-	µV/deg
NJU77002			-	0.65	21	-	0.65	-	
NJU77004			-	0.65	24	-	0.65	-	
Input Bias Current	I_B		-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Input Offset Current	I_{IO}		-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Open-Loop Voltage Gain	A_V	Vout=0.5V to 4.5V	70	100	-	70	100	-	dB
		Ta=-40°C to 105°C	70	-	-	-	-	-	
Common-Mode Rejection Ratio	CMR	V_{COM}=0V to 5V	60	80	-	60	80	-	dB
		Ta=-40°C to 105°C	60	-	-	-	-	-	
Supply Voltage Rejection Ratio	SVR	V^+=1.5V to 5.5V, V_{COM}=0V	70	90	-	70	90	-	dB
		Ta=-40°C to 105°C	70	-	-	-	-	-	
Maximum Output Voltage	V_{OH}	R_L=100kΩ to 2.5V	4.9	4.95	-	4.9	4.95	-	V
		Ta=-40°C to 105°C	4.9	-	-	-	-	-	
	V_{OL}	R_L=100kΩ to 2.5V	-	0.05	0.1	-	0.05	0.1	V
		Ta=-40°C to 105°C	-	-	0.1	-	-	-	
Common-Mode Input Voltage Range	V_{ICM}	CMR≥60dB	0	-	5	0	-	5	V
		Ta=-40°C to 105°C	0	-	5	-	-	-	
AC CHARACTERISTICS									
Slew Rate		Gv=0dB, C_L=20pF, V_{IN}=1Vpp							
NJU77000/NJU77001	SR		-	0.8	-	-	0.8	-	V/ms
NJU77002/NJU77004			-	0.7	-	-	0.7	-	
unity-Gain Frequency		Gv=20dB, C_L=20pF							
NJU77000/NJU77001	f_T		-	1.1	-	-	1.1	-	kHz
NJU77002/NJU77004			-	1.0	-	-	1.0	-	
Phase Margin	Φ_M	C_L=20pF	-	60	-	-	60	-	deg
Gain Margin	G_M	C_L=20pF	-	30	-	-	30	-	dB
Equivalent Input Noise Voltage		f=100Hz							
NJU77000/NJU77001	V_{NI}		-	600	-	-	600	-	nV/√Hz
NJU77002/NJU77004			-	700	-	-	700	-	

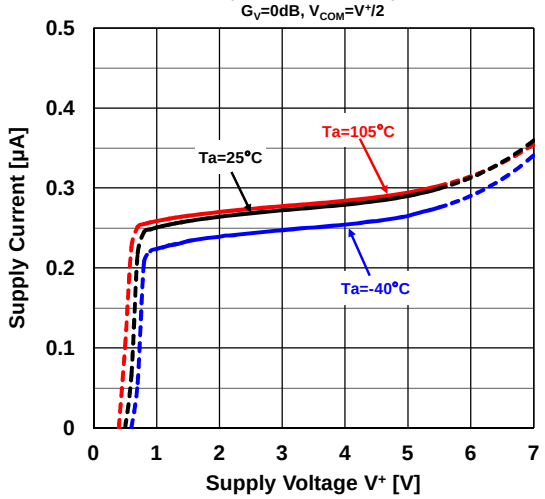
■ELECTRICAL CHARACTERISTICS

(V^+=1.8V, V^-=0V, V_{COM}=0.9V, R_L=100kΩ to 0.9V, Ta=25°C, unless otherwise noted.)

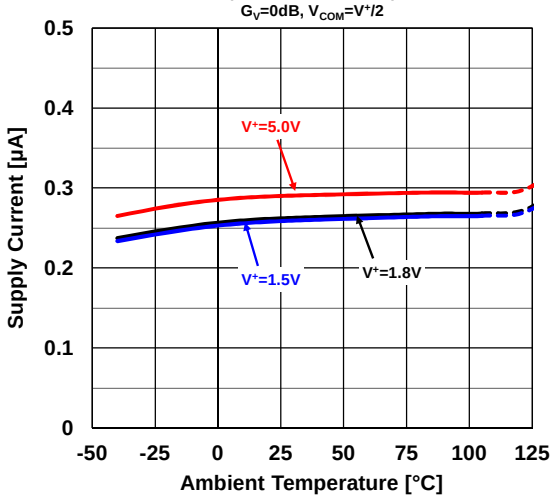
PARAMETER	SYMBOL	TEST CONDITION	NJU7700xA			NJU7700x			UNIT
			MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
DC CHARACTERISTICS									
Supply Current (all channel)		No Signal							
NJU77000/NJU77001			-	0.26	0.36	-	0.26	0.46	
		Ta=-40°C to 105°C	-	-	0.36	-	-	-	
NJU77002	I_{SUPPLY}		-	0.42	0.62	-	0.42	0.72	µA
		Ta=-40°C to 105°C	-	-	0.62	-	-	-	
NJU77004			-	0.84	1.17	-	0.84	1.27	
		Ta=-40°C to 105°C	-	-	1.17	-	-	-	
Input Offset Voltage		V_{COM}=0V							
NJU77000/NJU77001			-	0.35	1	-	0.35	1.8	
		Ta=-40°C to 105°C	-	-	1.2	-	-	-	
NJU77002	V_{IO}		-	0.35	1.3	-	0.35	2.0	mV
		Ta=-40°C to 105°C	-	-	1.5	-	-	-	
NJU77004			-	0.35	1.5	-	0.35	2.2	
		Ta=-40°C to 105°C	-	-	1.7	-	-	-	
Input Offset Voltage Drift		V_{COM}=0V, Ta=-40°C to 105°C							
NJU77000/NJU77001	$\Delta V_{IO}/\Delta T$		-	0.65	17	-	0.65	-	µV/deg
NJU77002			-	0.65	21	-	0.65	-	
NJU77004			-	0.65	24	-	0.65	-	
Input Bias Current	I_B		-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Input Offset Current	I_{IO}		-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Open-Loop Voltage Gain	A_V	Vout=0.5V to 1.3V	70	100	-	70	100	-	dB
		Ta=-40°C to 105°C	70	-	-	-	-	-	
Common-Mode Rejection Ratio	CMR	V_{COM}=0V to 1.8V	55	80	-	55	80	-	dB
		Ta=-40°C to 105°C	55	-	-	-	-	-	
Supply Voltage Rejection Ratio	SVR	V^+=1.5V to 5.5V, V_{COM}=0V	70	90	-	70	90	-	dB
		Ta=-40°C to 105°C	70	-	-	-	-	-	
Maximum Output Voltage	V_{OH}	R_L=100kΩ to 0.9V	1.7	1.75	-	1.7	1.75	-	V
		Ta=-40°C to 105°C	1.7	-	-	-	-	-	
	V_{OL}	R_L=100kΩ to 0.9V	-	0.05	0.1	-	0.05	0.1	V
		Ta=-40°C to 105°C	-	-	0.1	-	-	-	
Common-Mode Input Voltage Range	V_{ICM}	CMR≥55dB	0	-	1.8	0	-	1.8	V
		Ta=-40°C to 105°C	0	-	1.8	-	-	-	
AC CHARACTERISTICS									
Slew Rate		Gv=0dB, C_L=20pF, V_{IN}=1Vpp							
NJU77000/NJU77001	SR		-	0.7	-	-	0.7	-	V/ms
NJU77002/NJU77004			-	0.6	-	-	0.6	-	
Unity-Gain Frequency		Gv=20dB, C_L=20pF							
NJU77000/NJU77001	f_T		-	1.0	-	-	1.0	-	kHz
NJU77002/NJU77004			-	0.9	-	-	0.9	-	
Phase Margin	Φ_M	C_L=20pF	-	60	-	-	60	-	deg
Gain Margin	G_M	C_L=20pF	-	30	-	-	30	-	dB
Equivalent Input Noise Voltage		f=100Hz							
NJU77000/NJU77001	V_{NI}		-	700	-	-	700	-	nV/√Hz
NJU77002/NJU77004			-	800	-	-	800	-	

■ TYPICAL CHARACTERISTICS

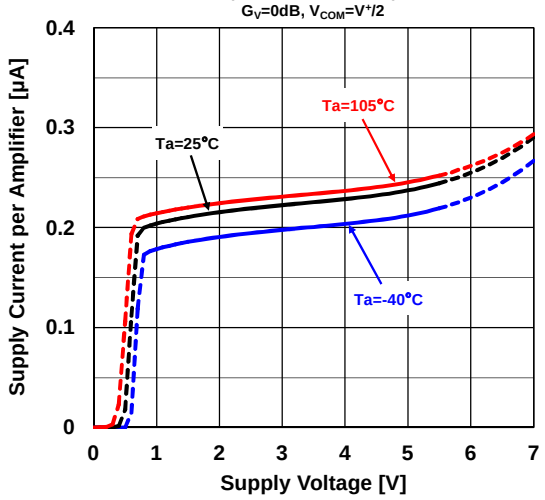
Supply Current vs. Supply Voltage
(NJU77000/NJU77001)
G_V=0dB, V_{COM}=V^+/2



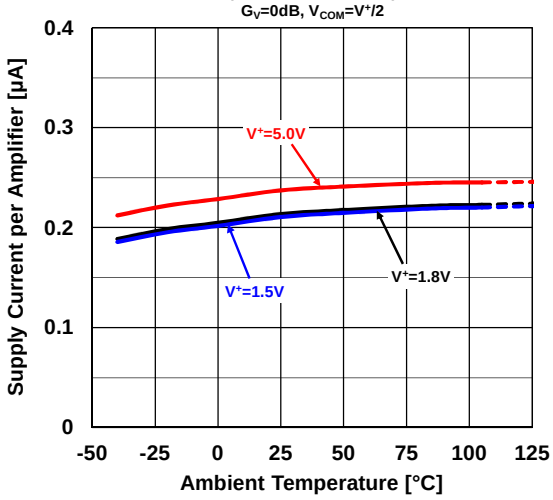
Supply Current vs. Temperature
(NJU77000/NJU77001)
G_V=0dB, V_{COM}=V^+/2



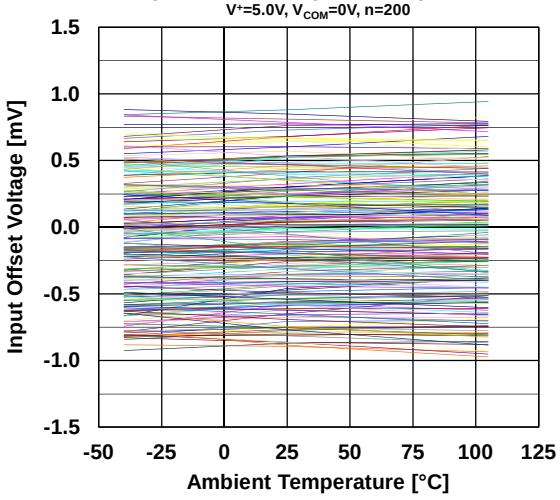
Supply Current per Amplifier vs. Supply Voltage
(NJU77002/NJU77004)
G_V=0dB, V_{COM}=V^+/2



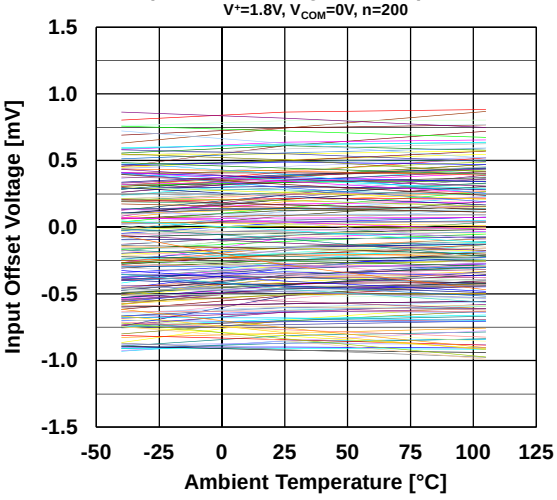
Supply Current per Amplifier vs. Temperature
(NJU77002/NJU77004)
G_V=0dB, V_{COM}=V^+/2



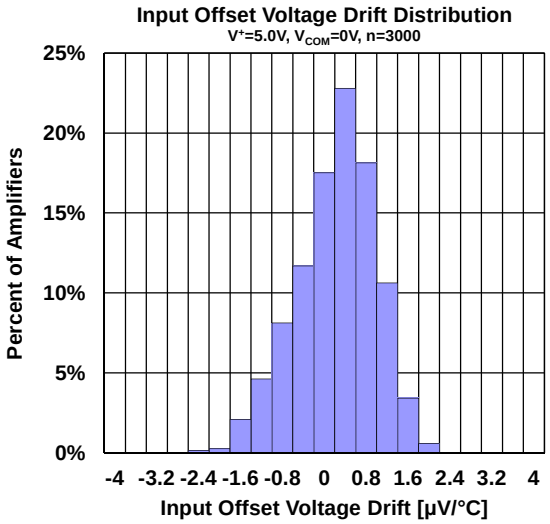
Input Offset Voltage vs. Temperature
V^+=5.0V, V_{COM}=0V, n=200

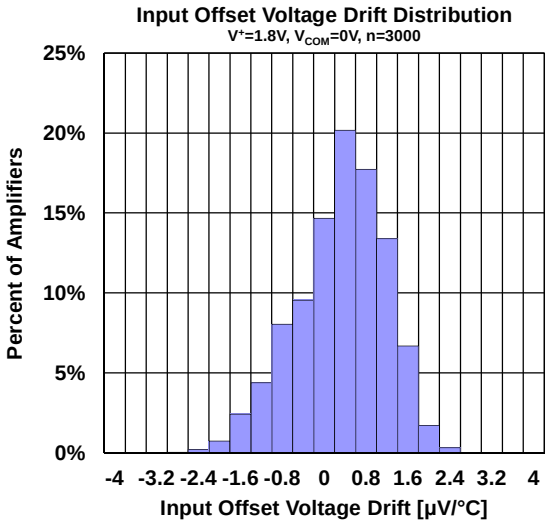


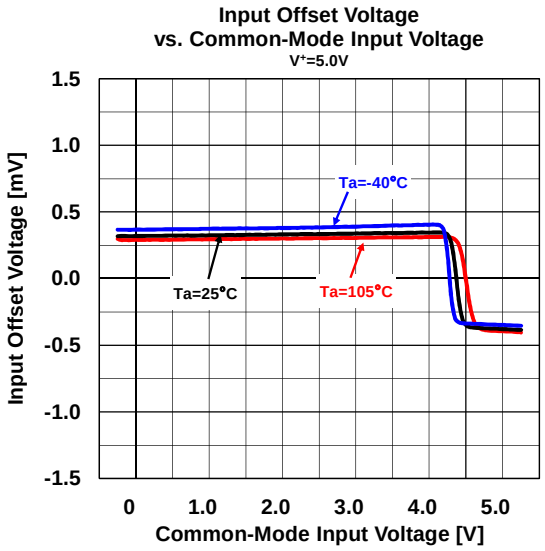
Input Offset Voltage vs. Temperature
V^+=1.8V, V_{COM}=0V, n=200

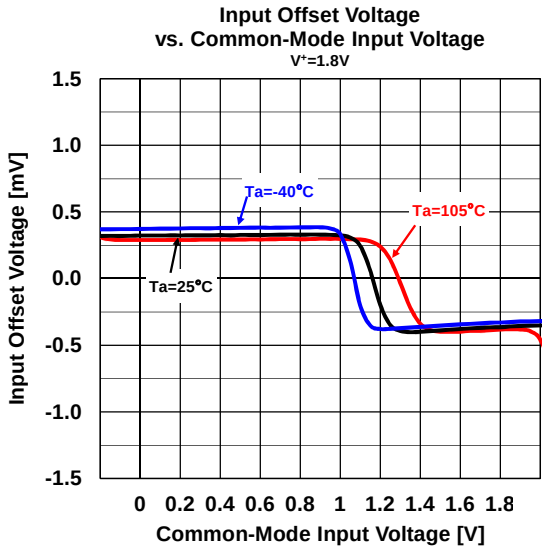


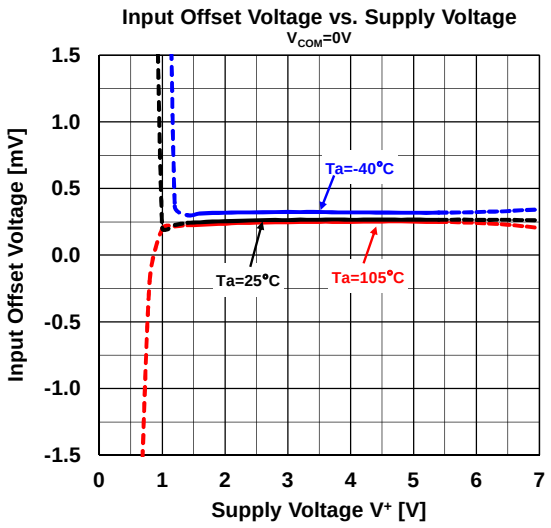
■ TYPICAL CHARACTERISTICS

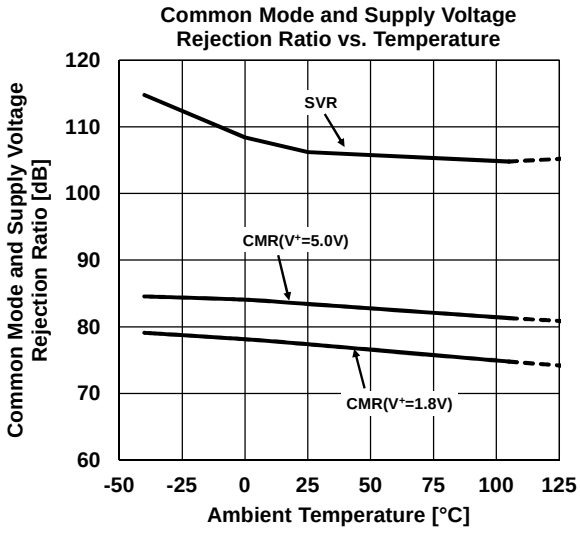






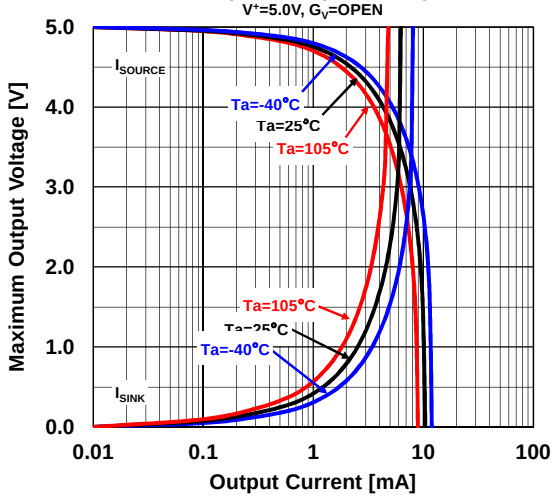




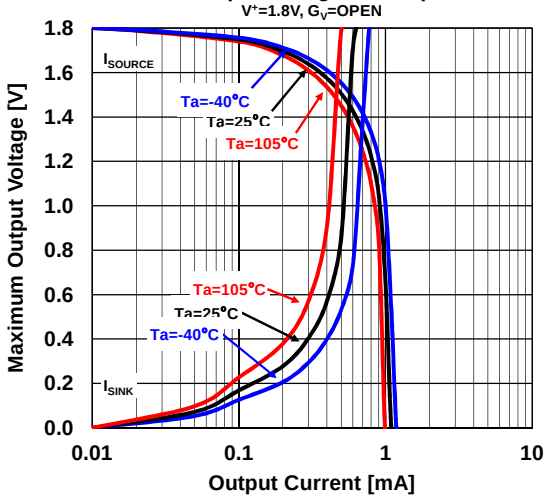


■ TYPICAL CHARACTERISTICS

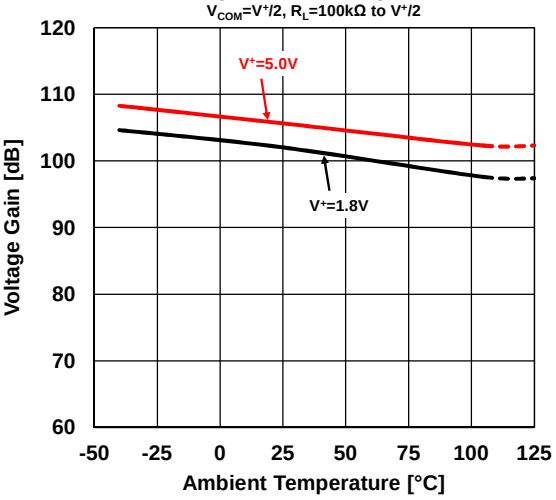
Maximum Output Voltage vs. Output Current
V⁺=5.0V, G_V=OPEN



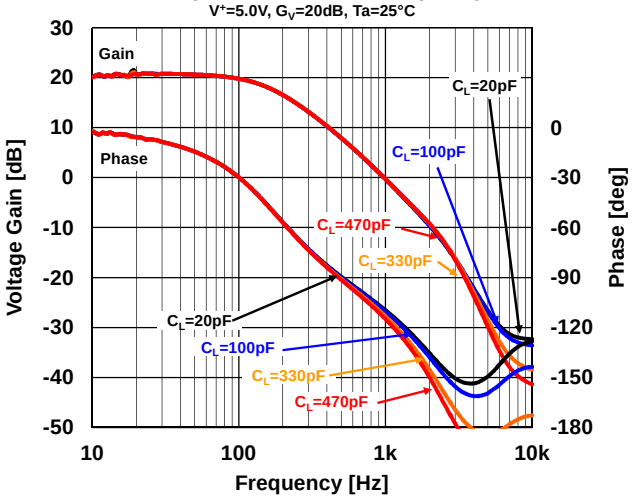
Maximum Output Voltage vs. Output Current
V⁺=1.8V, G_V=OPEN



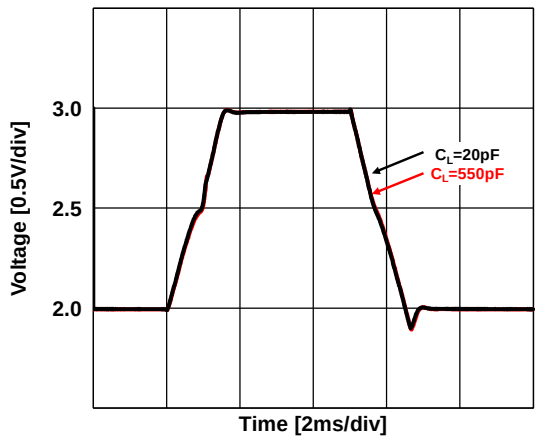
Voltage Gain vs. Temperature
V_{COM}=V⁺/2, R_L=100kΩ to V⁺/2



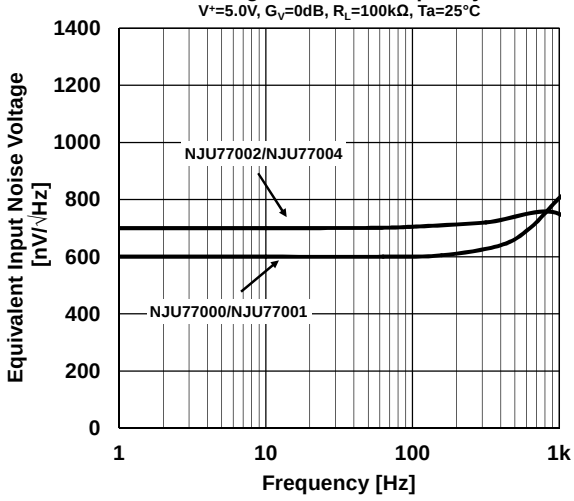
Voltage Gain/Phase vs. Frequency
V⁺=5.0V, G_V=20dB, Ta=25°C



Pulse Response
V⁺=5.0V, G_V=0dB, R_L=100kΩ to 2.5V, Ta=25°C



Voltage Noise vs. Frequency
V⁺=5.0V, G_V=0dB, R_L=100kΩ, Ta=25°C



■ APPLICATION NOTE

■ Capacitive load

The unity gain follower is the most sensitive configuration to capacitive loading. The combination of capacitive load placed directly on the output of an amplifier along with the output impedance of the amplifier creates a phase lag which in turn reduces the phase margin of the amplifier. If phase margin is significantly reduced, the response will be either underdamped or the amplifier will oscillate.

The NJU77000/NJU77001/NJU77002/NJU77004 can directly drive capacitive loads of up to 470pF without oscillating. To drive heavier capacitive loads, an isolation resistor, R_{ISO} as shown Figure1, should be used. R_{ISO} improves the feedback loop's phase margin by making the output load resistive at higher frequencies. The larger the value of R_{ISO}, the more stable the output voltage will be. However, larger values of R_{ISO} result in reduced output swing, reduced output current drive and reduced frequency bandwidth.

Figure2 shows R_{ISO} values at unity gain follower without oscillating. After selecting R_{ISO} for your circuit, double-check the resulting frequency response peaking and step response overshoot. Modify R_{ISO}'s value until the response is reasonable.

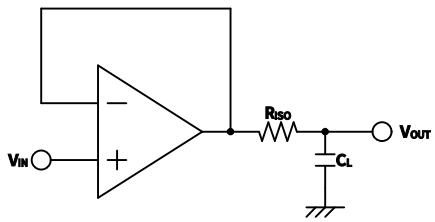


Figure1. Isolating capacitive load

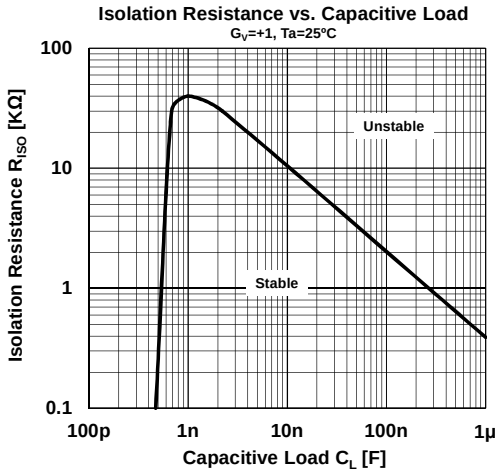
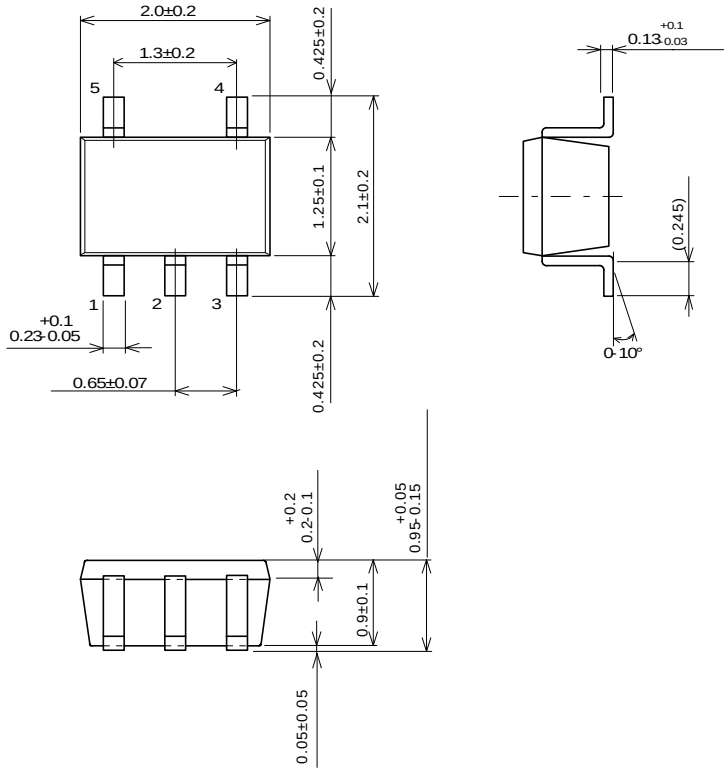


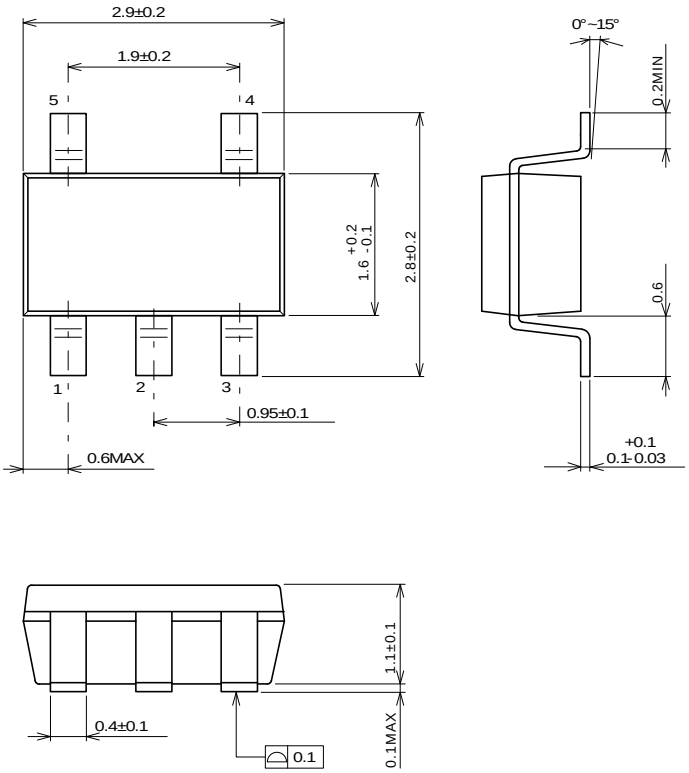
Figure2. Isolation resistance to improve stability

■ PACKAGE DIMENSIONS



Unit: mm

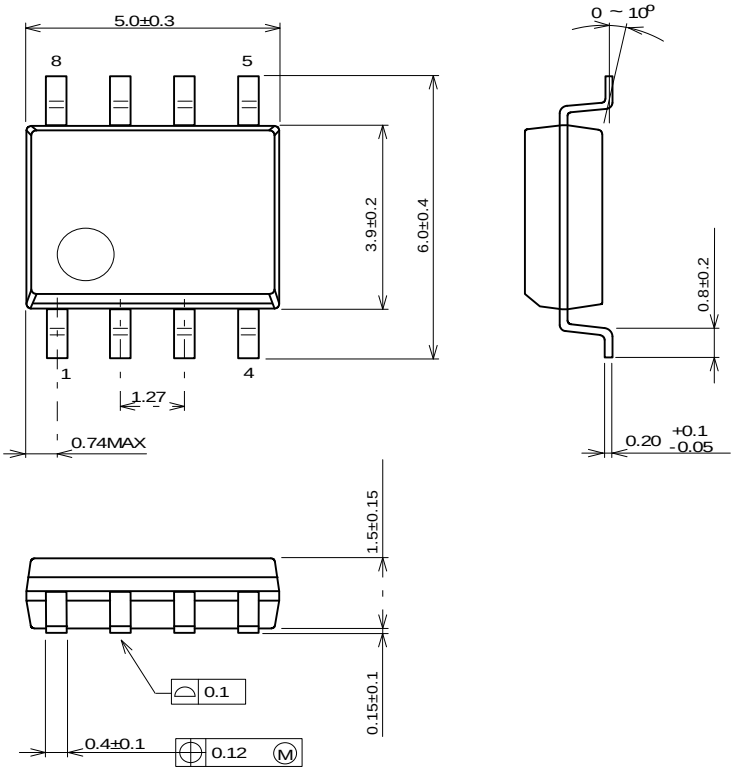
SC-88A Package



Unit: mm

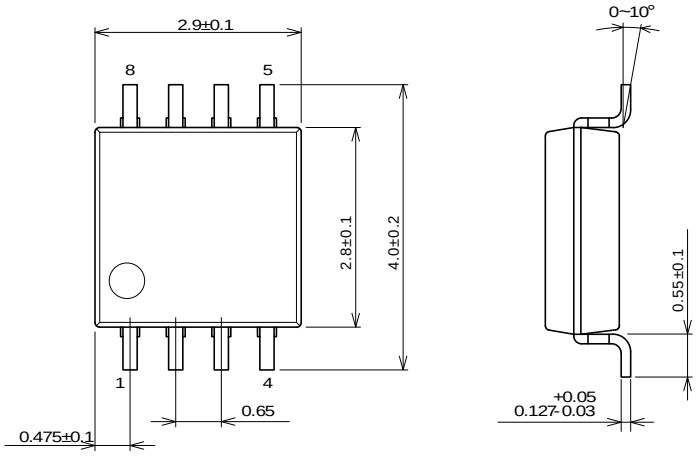
SOT-23-5 Package

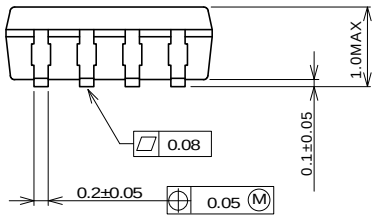
■ PACKAGE DIMENSIONS



Unit: mm

SOP8 JEDEC 150mil Package

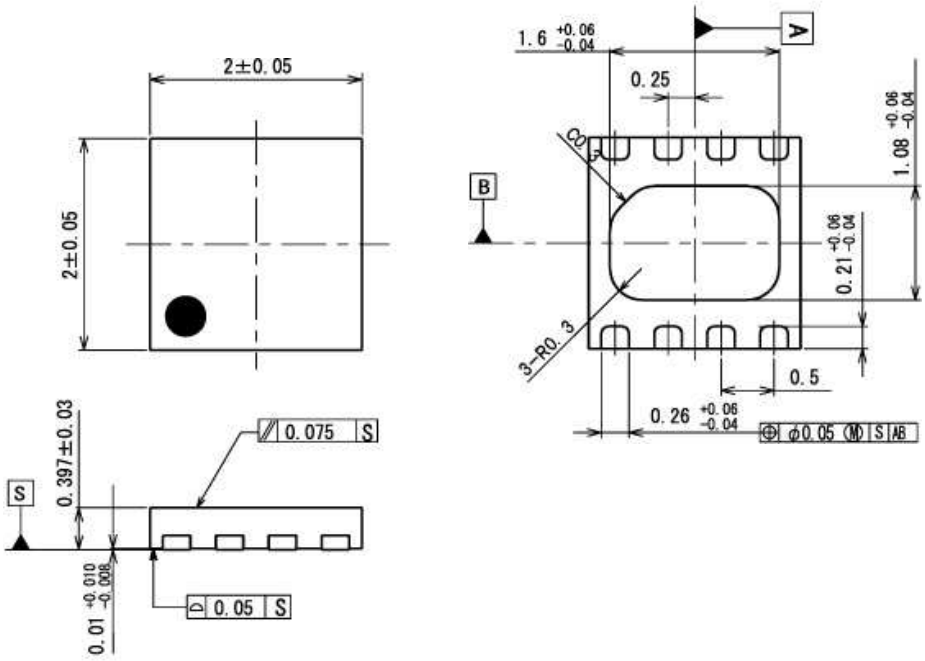




Unit: mm

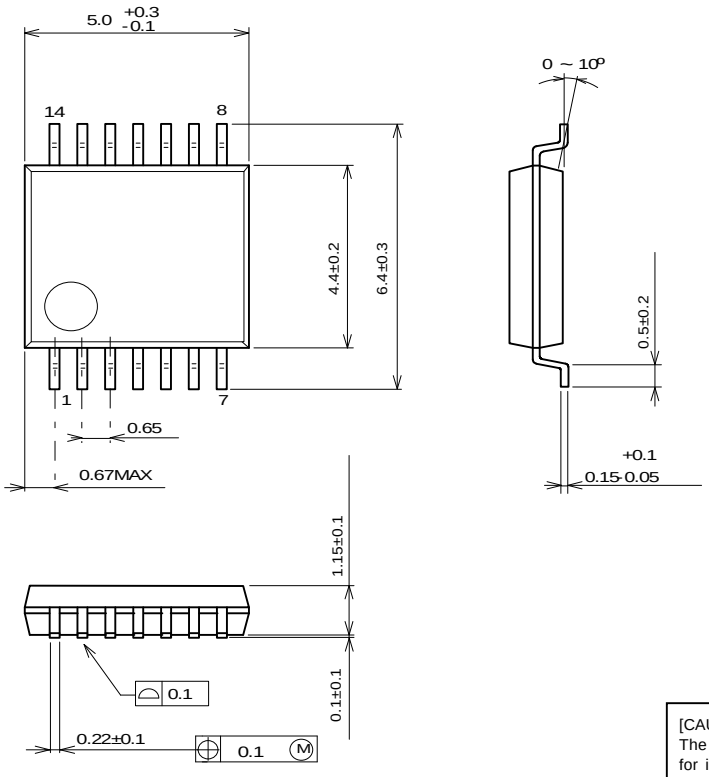
MSOP8 (TVSP8) JEDEC MO-187-DA / thin type Package

■ PACKAGE DIMENSIONS



Unit: mm

DFN8-U1(ESON8-U1) Package



Unit: mm

SSOP14 Package

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