1.5V, 0.23µA/ch, Ultra-Low Power, Excellent EMI Immunity, Rail-to-Rail Input/Output, CMOS Operational Amplifiers

FEATURES (V^+=5V)

●Supply Voltage	1.5V to 5.5V
●Input Offset Voltage	
NJU77000 / NJU77001	1.0mV max.
NJU77002	1.3mV max.
●Input Offset Voltage Drift	0.65µV/°C typ.
●Input Bias Current	10pA max.
●Integrated EMI Filter	EMIRR=89dB typ. @f=900MHz
●Rail-to-Rail Input / Output	
●CMOS Technology	
●Slew Rate	0.7V/ms
●Unity Gain Frequency	1.0kHz
●Ultra-Low Power Supply Current	
NJU77000 / NJU77001	0.29µA typ.
NJU77002	0.23µA/ch typ.
●Package	
NJU77000	SOT-23-5(1)
NJU77001	SC-88A, SOT-23-5(1)
NJU77002	SOP8 JEDEC 150mil(1)
	MSOP8 (TVSP8)*
	*JEDEC MO-187-DA / thin type
	DFN8-U1 (ESON8-U1)(1)

APPLICATIONS

●Battery-Powered Instruments
●Micro-Power Oxygen Sensors and Gas Sensors
●Power Line Monitoring
●Micro Power Current Sensing
●Healthcare Instruments

DESCRIPTION

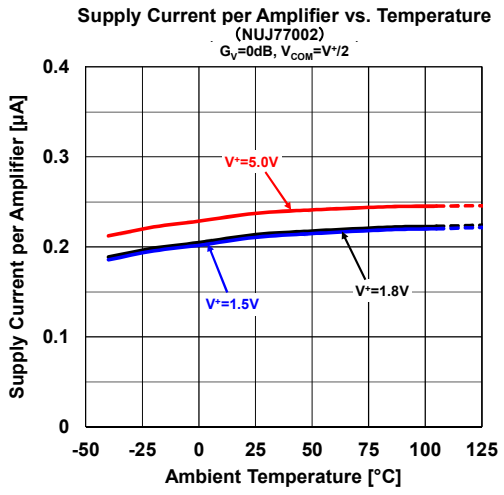
The NJU77000/NJU77001/NJU77002 are single/dual ultra-low power CMOS operational amplifiers designed specifically to extend battery life and performance for portable applications. The supply voltage range is 1.5V to 5.5V and supply current is 0.29µA typ. (single), 0.23µA/ch typ. (dual). The supply current is stable against ambient temperature and voltage change, making them suitable for micro power oxygen sensors, gas sensors, and remote sensor applications.

These devices also feature rail-to-rail I/O and input offset voltage of 1.0mV max. (single), 1.3mV max. (dual). Moreover, this series has excellent characteristics ideal for battery-powered applications, such as 0.65uV/°C typ. input offset voltage drift, input bias current of 10pA max. and ability of capacity load drive of 470pF.

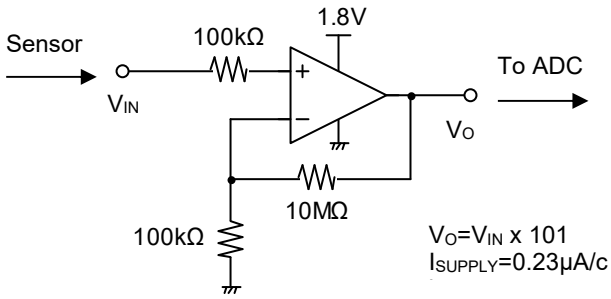
NJU77000 series has normal grade (NJU7700x) and A-Grade (NJU7700xA). A-Grade has improved offset voltage and supply voltage than normal grade, and other characteristics are also guaranteed from -40 to 105 °C.

The NJU77000 is available in a 5-pin SOT-23 package. NJU77001 is offered in 5-pin SOT-23 and SC-88A packages. NJU77000 and NJU77001 have different pin functions (see pin configurations). The NJU77002 is offered in 8-pin SOP JEDEC 150mil, MSOP (TVSP JEDEC MO-187-DA / thin type) and DFN (ESON) that is thin and 2mm square small package.

■ TYPICAL CHARACTERISTIC



■ TYPICAL APPLICATION



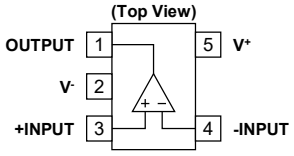
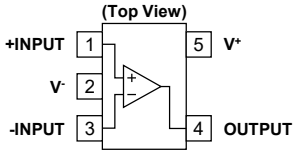
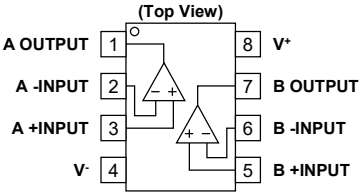
40dB micro power sensor amplifier

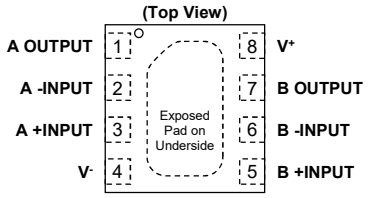
(1) Some packages are under development. Refer to ■PRODUCT INFORMATION for details.

■ PRODUCT INFORMATION (Ta=25°C)

V_O max.	I_{SUPPLY} max.	I_B max.	PACKAGE / PRODUCT NAME				
			SC-88A	SOT-23-5	SOP8 JEDEC 150 mil	MSOP8 (TVSP8)	DFN8-U1 (ESON8-U1)
1.8mV	0.49µA	-	NJU77001F3	NJU77000F(1) NJU77001AF(1)	-	-	-
1.0mV	0.39µA	10pA	NJU77001AF3	NJU77000AF(1) NJU77001AF(1)	-	-	-
2.0mV	0.66µA	-	-	-	NJU77002E(1)	NJU77002RB1	NJU77002KU1
1.3mV	0.76µA	10pA	-	-	NJU77002AE(1)	NJU77002ARB1	NJU77002AKU1(1)

■ PIN CONFIGURATIONS

PRODUCT NAME	NJU77000F(1) NJU77000AF(1)	NJU77001F(1) NJU77001AF(1)	NJU77001F3 NJU77001AF3	NJU77002E(1) NJU77002AE(1)	NJU77002RB1 NJU77002ARB1
Package	SOT-23-5	SOT-23-5	SC-88A	SOP8 JEDEC 150 mil	MSOP8 (TVSP8)
Pin Functions					

PRODUCT NAME	NJU77002KU1 NJU77002AKU1(1)
Package	DFN8-U1 (ESON8-U1)
Pin Functions	

■ PRODUCT NAME INFORMATION

NJU77000 F - TE1 / NJU77000 F (TE1)

Part Number — Package — Taping Form

(1) Under development.

■ ORDER INFORMATION

PRODUCT NAME	PACKAGE	RoHS	HALOGEN-FREE	TERMINAL FINISH	MARKING	WEIGHT (mg)	MOQ (pcs)
NJU77000F(1)	SOT-23-5	Yes	Yes	Sn2Bi	17	15	3000
NJU77000AF(1)	SOT-23-5	Yes	Yes	Sn2Bi	1A	15	3000
NJU77001F(1)	SOT-23-5	Yes	Yes	Sn2Bi	16	15	3000
NJU77001AF(1)	SOT-23-5	Yes	Yes	Sn2Bi	18	15	3000
NJU77001F3	SC-88A	Yes	Yes	Sn2Bi	AH	7.5	3000
NJU77001AF3	SC-88A	Yes	Yes	Sn2Bi	AK	7.5	3000
NJU77002E(1)	SOP8 JEDEC 150 mil	Yes	Yes	Sn2Bi	77002	76	2000
NJU77002AE(1)	SOP8 JEDEC 150 mil	Yes	Yes	Sn2Bi	77002A	76	2000
NJU77002RB1	MSOP8 (TVSP8)	Yes	Yes	Sn2Bi	77002	18	2000
NJU77002ARB1	MSOP8 (TVSP8)	Yes	Yes	Sn2Bi	77002A	18	2000
NJU77002KU1	DFN8-U1(ESON8-U1)	Yes	Yes	Sn2Bi	77002	5.3	3000
NJU77002AKU1(1)	DFN8-U1(ESON8-U1)	Yes	Yes	Sn2Bi	77002A	5.3	3000

■ ABSOLUTE MAXIMUM RATINGS

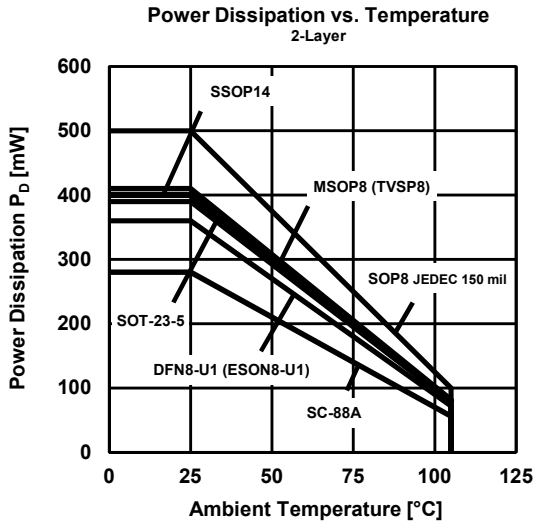
PARAMETER	SYMBOL	RATING	UNIT
Supply Voltage	$V^+ - V^-$	7	V
Differential Input Voltage(2)	V_{ID}	±7(3)	V
Input Voltage	V_{IN}	V^--0.3 to V^++0.3(4)	V
Power Dissipation (Ta=25°C) SOT-23-5 SC-88A SOP8 JEDEC 150 mil MSOP8 (TVSP8) DFN8-U1 (ESON8-U1)	P_D	2-Layer / 4-Layer(5) 390 / 520 280 / 390 500 / 700 410 / 540 360 / 940	mW
Storage Temperature Range	T_{stg}	-55 to 125	°C
Maximum Junction Temperature	T_{jmax}	125	°C

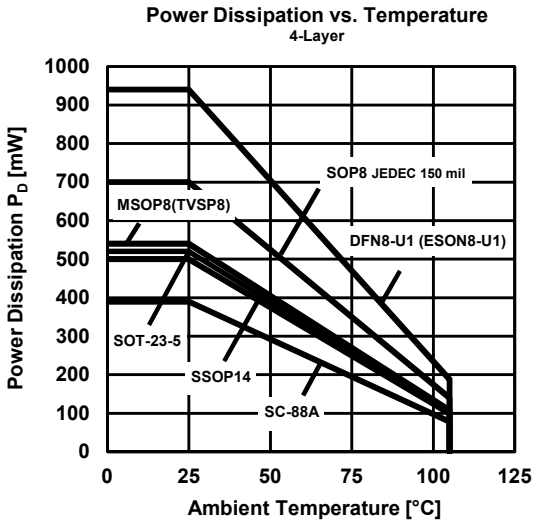
■ THERMAL CHARACTERISTICS

PACKAGE	SYMBOL	VALUE	UNIT
Junction-to-Ambient Thermal Resistance SOT-23-5 SC-88A SOP8 JEDEC 150 mil MSOP8 (TVSP8) DFN8-U1 (ESON8-U1)	Θja	2-Layer / 4-Layer(5) 256 / 192 357 / 256 182 / 122 244 / 185 278 / 106	°C/W
Junction-to-Top of Package Characterization Parameter SOT-23-5 SC-88A SOP8 JEDEC 150 mil MSOP8 (TVSP8) DFN8-U1 (ESON8-U1)	Ψjt	2-Layer / 4-Layer(5) 67 / 58 91 / 73 32 / 27 51 / 45 42 / 25	°C/W

(1) Under development.
(2) Differential voltage is the voltage difference between +INPUT and -INPUT.
(3) For supply voltage less than 15V, the absolute maximum rating is equal to the supply voltage.
(4) The absolute maximum input voltage is limited at 7V.
(5) 2-Layer: Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIA/JDEC standard, 2-layer FR-4)
4-Layer: Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIA/JDEC standard, 4-layer FR-4), internal Cu area: 74.2×74.2mm

■ POWER DISSIPATION vs. AMBIENT TEMPERATURE





■ RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	CONDITIONS	VALUE	UNIT
Supply Voltage	$V^+ - V^-$	Ta=25°C	1.5 to 5.5	V
Operating Temperature Range	T_{opr}		-40 to 105	°C

■ 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 CONDITIONS	NJU7700xA			NJU7700x			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
INPUT CHARACTERISTICS									
Input Offset Voltage		V_{COM}=0V							
NJU77000 / NJU77001	V_{IO}	Ta=25°C	-	0.35	1	-	0.35	1.8	mV
		Ta=-40°C to 105°C	-	-	1.2	-	-	-	
NJU77002		Ta=25°C	-	0.35	1.3	-	0.35	2.0	
		Ta=-40°C to 105°C	-	-	1.5	-	-	-	
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	V_{COM}=0V, Ta=-40°C to 105°C							μV/deg
NJU77000 / NJU77001			-	0.65	17	-	0.65	-	
NJU77002			-	0.65	21	-	0.65	-	
Input Bias Current	I_B	Ta=25°C	-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Input Offset Current	I_{IO}	Ta=25°C	-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Open-Loop Voltage Gain	A_V	V_O=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	-	-	-	-	-	
Common-Mode Input Voltage Range	V_{ICM}	CMR≥60dB	0	-	5	0	-	5	V
		Ta=-40°C to 105°C	0	-	5	-	-	-	
OUTPUT CHARACTERISTICS									
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	-	-	-	
POWER SUPPLY									
Supply Current (All Amplifiers)	I_{SUPPLY}	No Signal							μA
NJU77000 / NJU77001		Ta=25°C	-	0.29	0.39	-	0.29	0.49	
		Ta=-40°C to 105°C	-	-	0.39	-	-	-	
NJU77002		Ta=25°C	-	0.46	0.66	-	0.46	0.76	
		Ta=-40°C to 105°C	-	-	0.66	-	-	-	
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	-	-	-	-	-	
AC CHARACTERISTICS									
Slew Rate	SR	G_V=0dB, C_L=20pF, V_{IN}=1V_{PP}							V/ms
NJU77000 / NJU77001			-	0.8	-	-	0.8	-	
NJU77002			-	0.7	-	-	0.7	-	
Unity-Gain Frequency	f_T	G_V=20dB, C_L=20pF							kHz
NJU77000 / NJU77001			-	1.1	-	-	1.1	-	
NJU77002			-	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 Current	V_{NI}	f=100Hz			-				nV/√Hz
NJU77000 / NJU77001			-	600	-	-	600	-	
NJU77002			-	700	-	-	700	-	

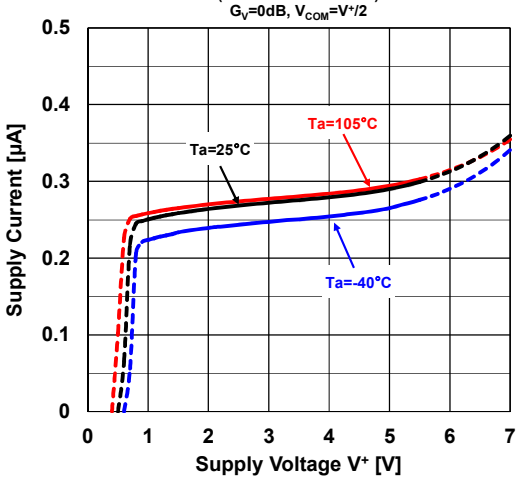
■ ELECTRICAL CHARACTERISTICS

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

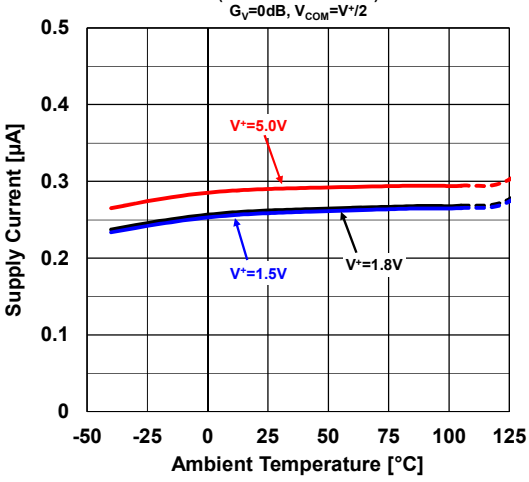
PARAMETER	SYMBOL	TEST CONDITIONS	NJU7700xA			NJU7700x			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
INPUT CHARACTERISTICS									
Input Offset Voltage		V_{COM}=0V							
NJU77000 / NJU77001	V_{IO}	Ta=25°C	-	0.35	1	-	0.35	1.8	mV
		Ta=-40°C to 105°C	-	-	1.2	-	-	-	
NJU77002		Ta=25°C	-	0.35	1.3	-	0.35	2.0	
		Ta=-40°C to 105°C	-	-	1.5	-	-	-	
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	V_{COM}=0V, Ta=-40°C to 105°C							μV/deg
NJU77000 / NJU77001			-	0.65	17	-	0.65	-	
NJU77002			-	0.65	21	-	0.65	-	
Input Bias Current	I_B	Ta=25°C	-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Input Offset Current	I_{IO}	Ta=25°C	-10	1	10	-	1	-	pA
		Ta=-40°C to 105°C	-100	-	100	-	-	-	
Open-Loop Voltage Gain	A_V	V_O=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	-	-	-	-	-	
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	-	-	-	
OUTPUT CHARACTERISTICS									
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	-	-	-	
POWER SUPPLY									
Supply Current (All Amplifiers)	I_{SUPPLY}	No Signal							μA
NJU77000 / NJU77001		Ta=25°C	-	0.26	0.36	-	0.26	0.49	
		Ta=-40°C to 105°C	-	-	0.36	-	-	-	
NJU77002		Ta=25°C	-	0.42	0.62	-	0.42	0.76	
		Ta=-40°C to 105°C	-	-	0.62	-	-	-	
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	-	-	-	-	-	
AC CHARACTERISTICS									
Slew Rate	SR	G_V=0dB, C_L=20pF, V_{IN}=1V_{PP}							V/ms
NJU77000 / NJU77001			-	0.7	-	-	0.7	-	
NJU77002			-	0.6	-	-	0.6	-	
Unity-Gain Frequency	f_T	G_V=20dB, C_L=20pF							kHz
NJU77000 / NJU77001			-	1.0	-	-	1.0	-	
NJU77002			-	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 Current	V_{NI}	f=100Hz			-				nV/√Hz
NJU77000 / NJU77001			-	700	-	-	700	-	
NJU77002			-	800	-	-	800	-	

■ TYPICAL CHARACTERISTICS

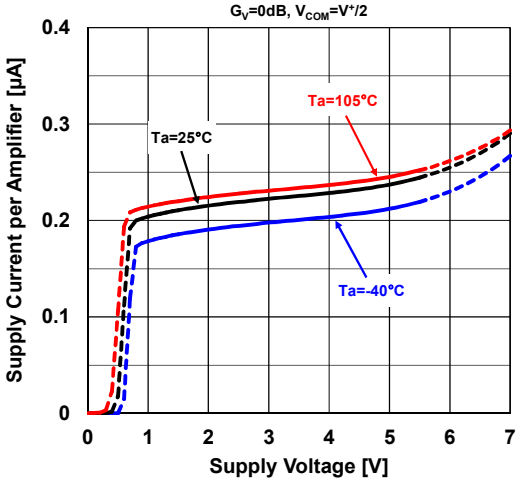
Supply Current vs. Supply Voltage
(NJU77000/NJU77001)
G_V=0dB, V_{COM}=V⁺/2



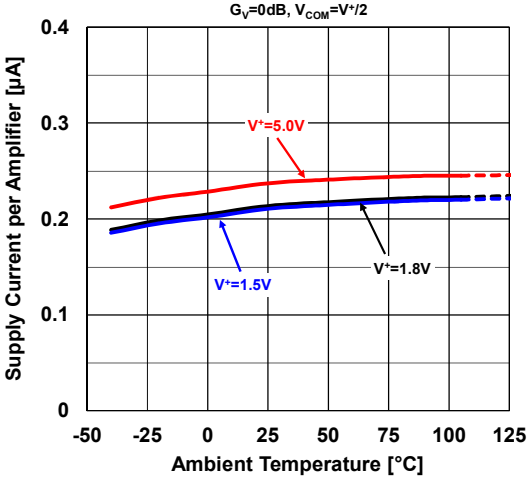
Supply Current vs. Temperature
(NJU77000/NJU77001)
G_V=0dB, V_{COM}=V⁺/2



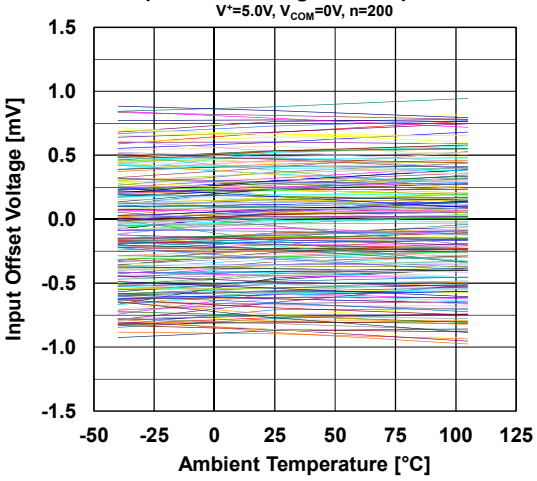
Supply Current per Amplifier vs. Supply Voltage
(NJU77002)
G_V=0dB, V_{COM}=V⁺/2



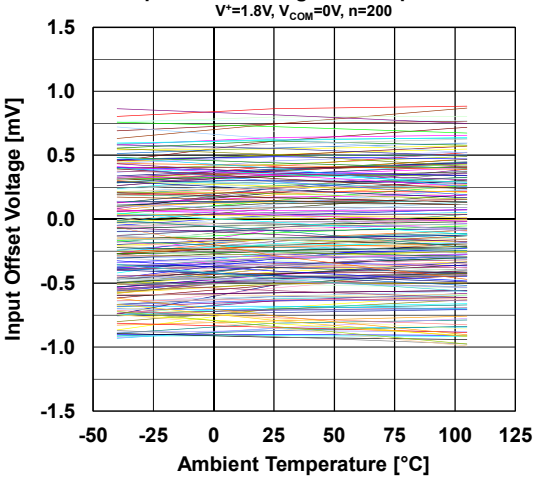
Supply Current per Amplifier vs. Temperature
(NJU77002)
G_V=0dB, V_{COM}=V⁺/2



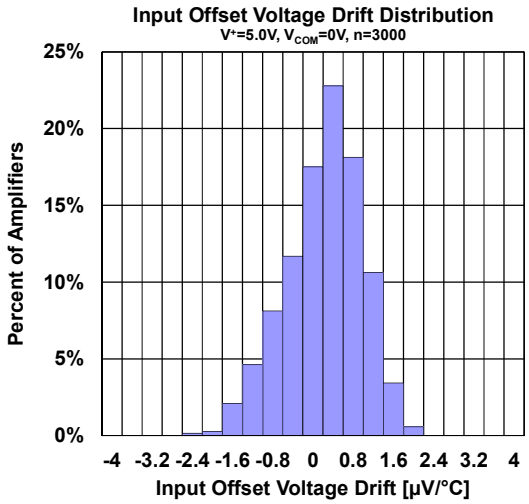
Input Offset Voltage vs. Temperature
V⁺=5.0V, V_{COM}=0V, n=200

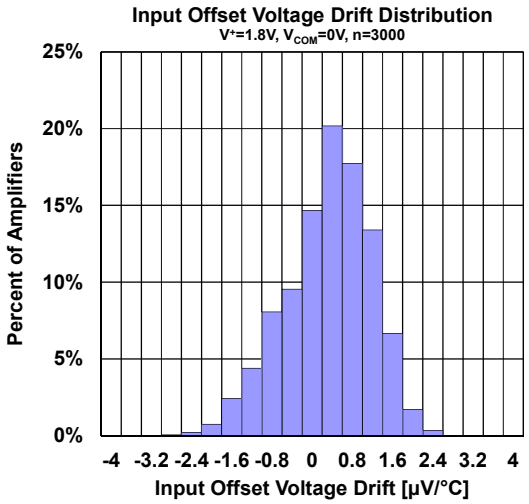


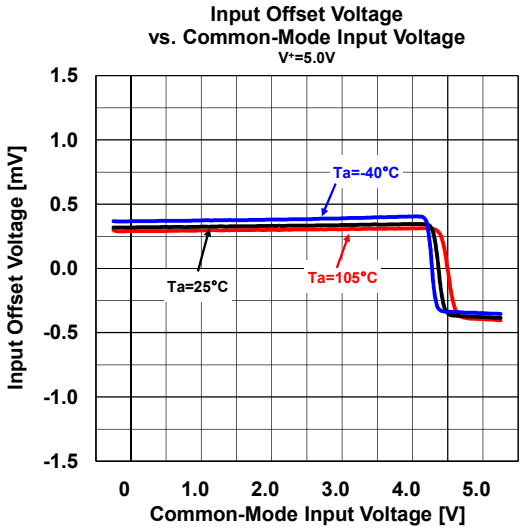
Input Offset Voltage vs. Temperature
V⁺=1.8V, V_{COM}=0V, n=200

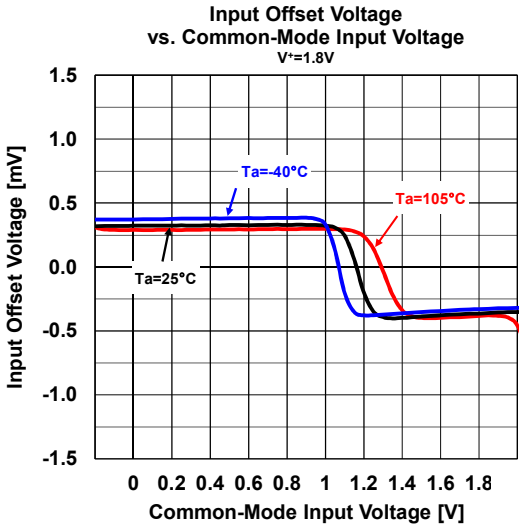


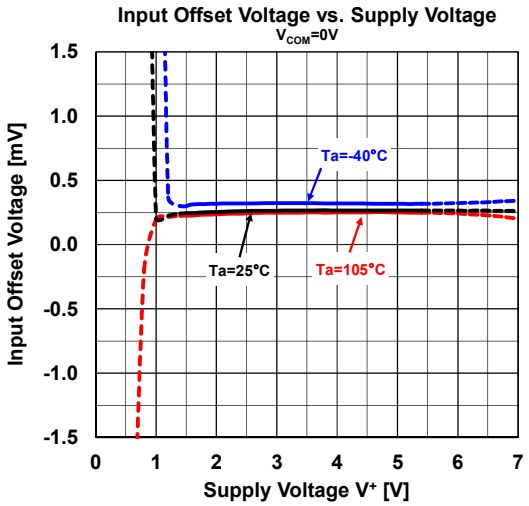
■ TYPICAL CHARACTERISTICS

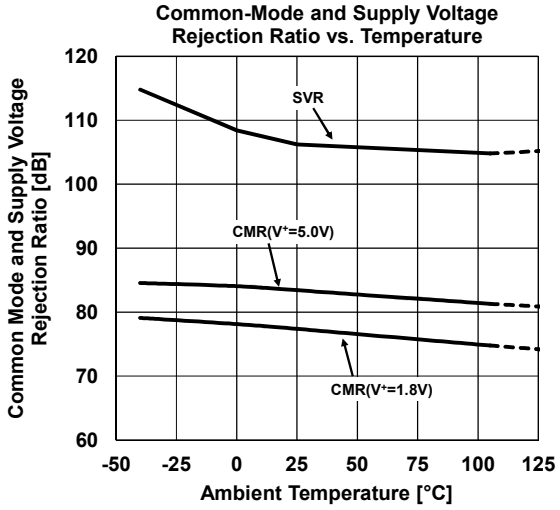






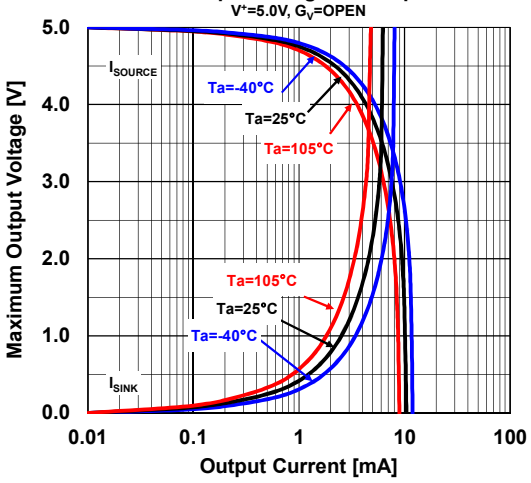




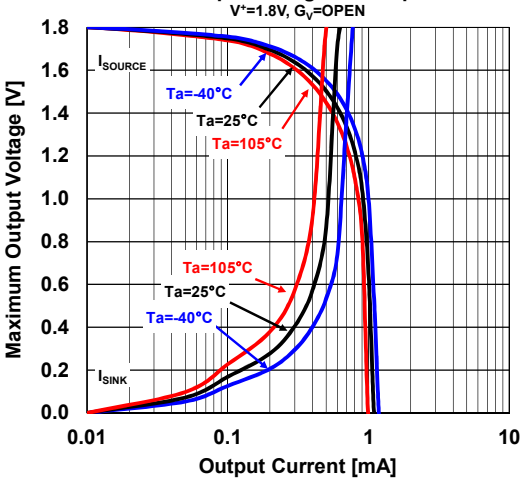


■ TYPICAL CHARACTERISTICS

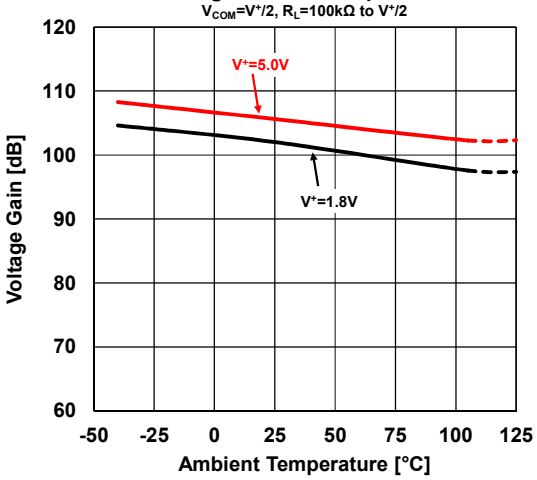
Maximum Output Voltage vs. Output Current
V⁺=5.0V, G_V=OPEN



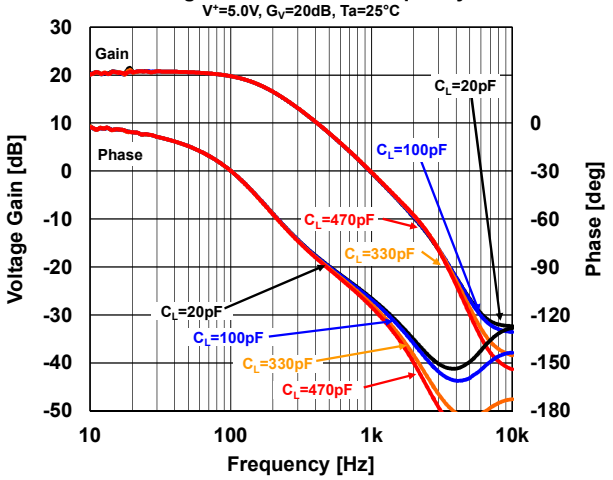
Maximum Output Voltage vs. Output Current
V⁺=1.8V, G_V=OPEN



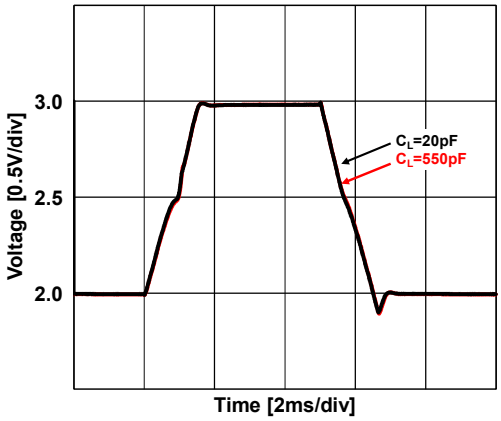
Voltage Gain vs. Temperature
V_{COM}=V⁺/2, R_L=100kΩ to V⁺/2



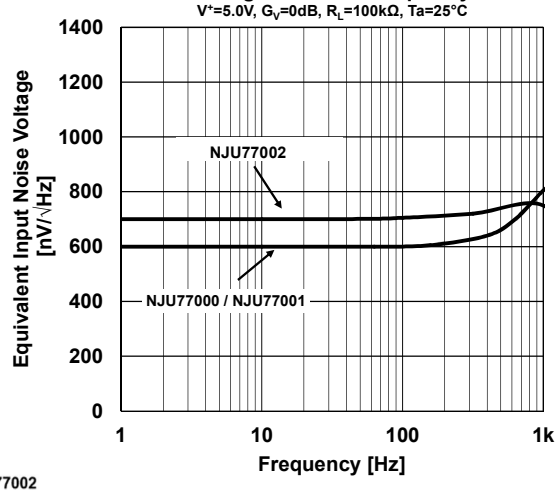
Voltage Gain/Phase vs. Frequency
V⁺=5.0V, G_V=20dB, Ta=25°C



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



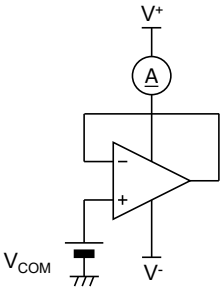
Voltage Noise vs. Frequency
V⁺=5.0V, G_V=0dB, R_L=100kΩ, Ta=25°C



RR77002

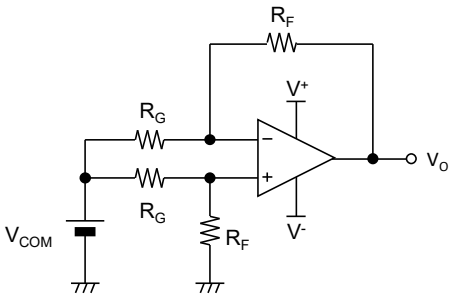
■ TEST CIRCUIT

● I_{SUPPLY}



● V_{IO}, CMR, SVR

R_G=50Ω, R_F=50kΩ



$$V_{IO}=\frac{R_G}{(R_G+R_F)}\times(V_O\text{-}Vcom)$$

$$CMR=20\log\frac{\Delta V_{com}\left(1+\frac{R_F}{R_G}\right)}{\Delta V_O}$$

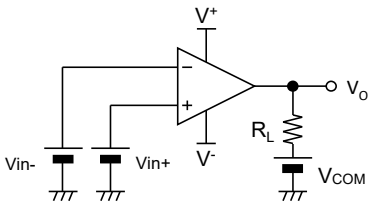
$$SVR=20\log\frac{\Delta V_S\left(1+\frac{R_F}{R_G}\right)}{\Delta V_O}$$

$V_S=V^+\text{-}V^-$

● V_{OH}, V_{OL}

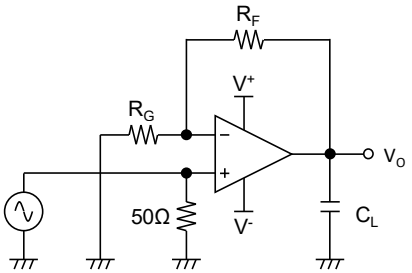
V_{OH}; Vin+ = V^+/2 + 0.1V, Vin- = V^+/2, V_{COM}=V^+/2

V_{OL}; Vin+ = V^+/2, Vin- = V^+/2 + 0.1V, V_{COM}=V^+/2

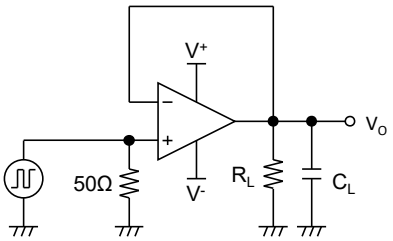


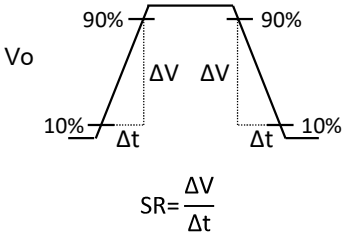
● GBW

R_G=1kΩ, R_F=100kΩ



● SR





$$SR=\frac{\Delta V}{\Delta t}$$

■ 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 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.

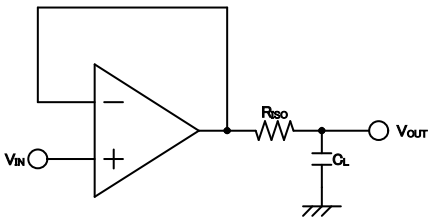


Figure1. Isolating capacitive load

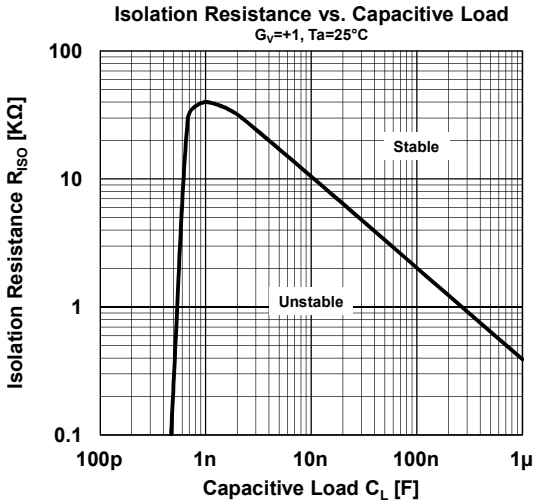


Figure2. Isolation resistance to improve stability

EMIRR (EMI Rejection Ratio) Definition

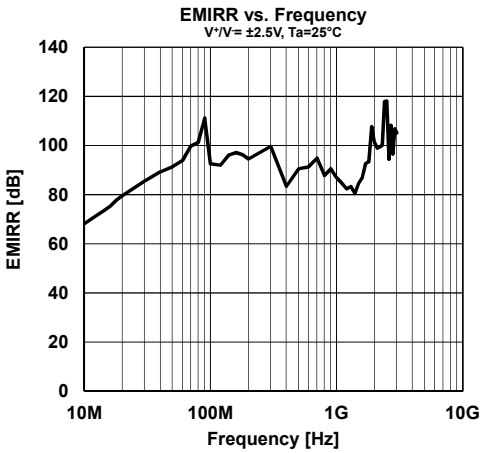
EMIRR is a parameter indicating the EMI robustness of an Op-Amp. The definition of EMIRR is given by the following equation1.

$$\mathrm{EMIRR} = 20 \cdot \log\left(\frac{V_{RF\_PEAK}}{|\Delta V_{IO}|}\right) \quad --- \text{ eq.1}$$

V_{RF_PEAK}: RF Signal Amplitude [VP]

ΔV_{IO}: Input offset voltage shift quantity [V]

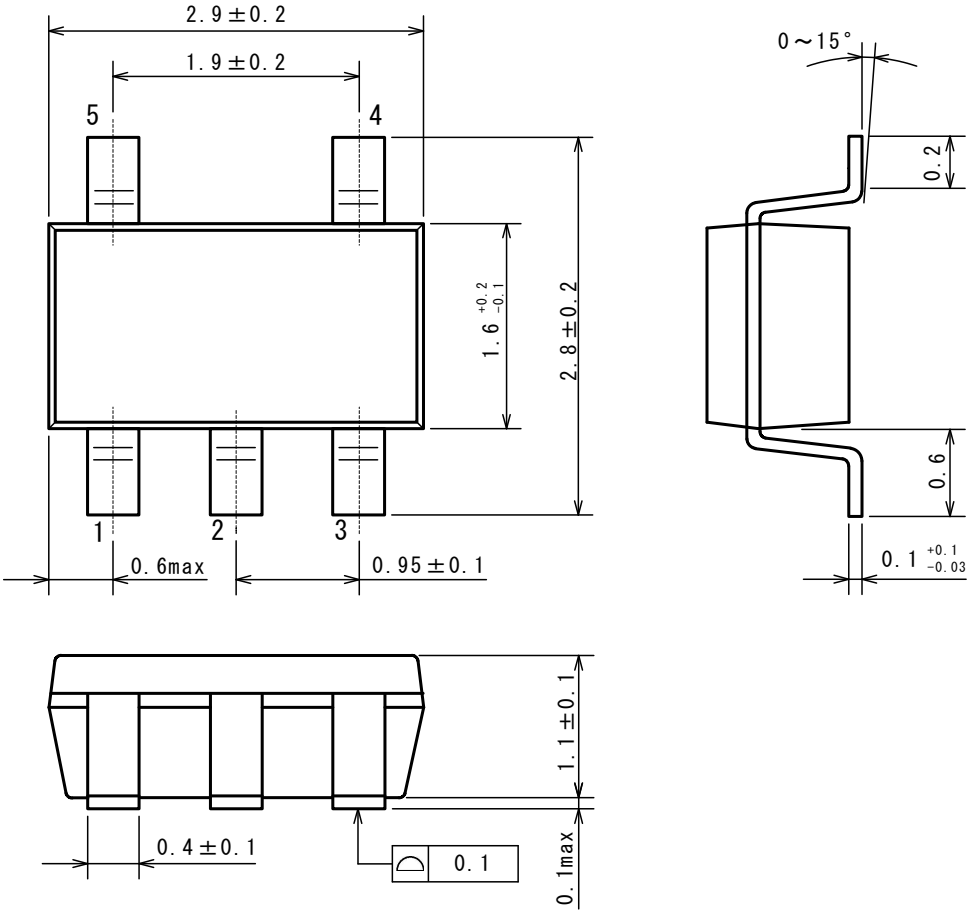
The tolerance of the RF signal can be grasped by measuring an RF signal and offset voltage shift quantity. Offset voltage shift is small so that a value of EMIRR is big. And it understands that the tolerance for the RF signal is high. In addition, about the input offset voltage shift with the RF signal, there is the thinking that influence applied to the input terminal is dominant. Therefore, generally the EMIRR becomes value that applied an RF signal to +INPUT terminal.



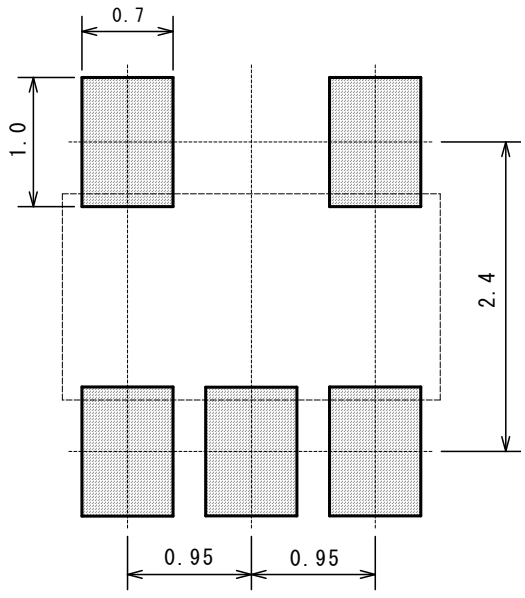
SOT-23-5

Unit: mm

■ **PACKAGE DIMENSIONS**



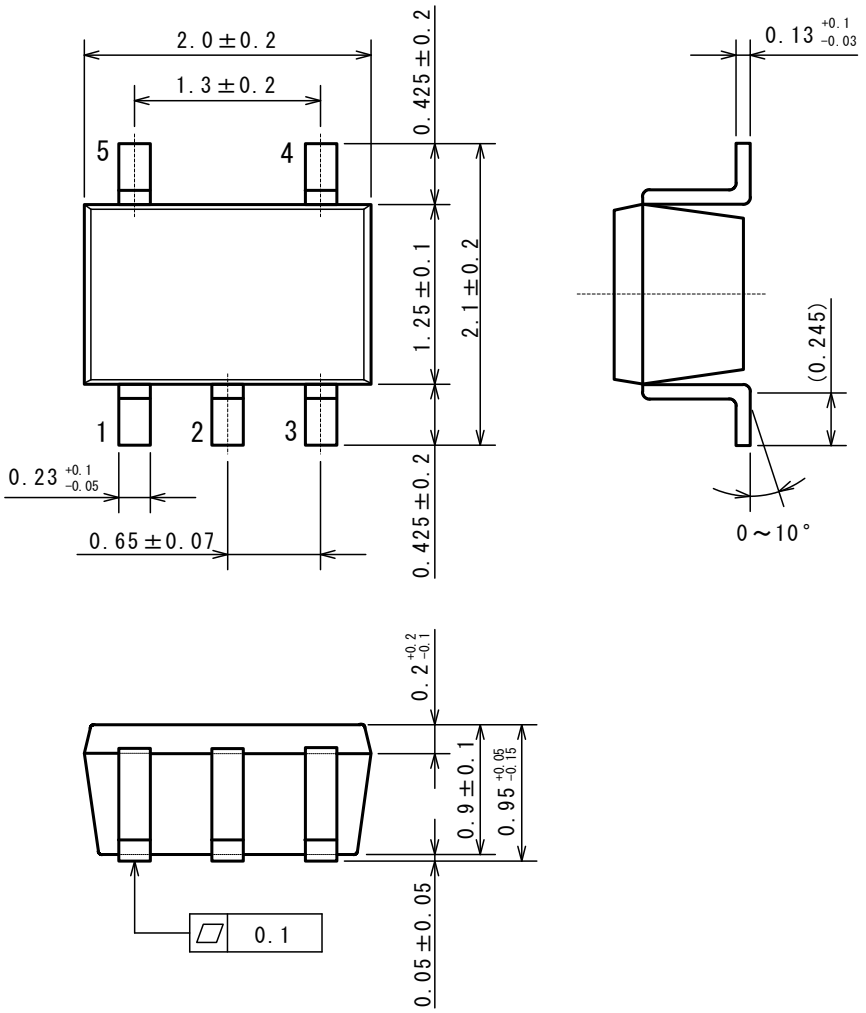
■ **EXAMPLE OF SOLDER PADS DIMENSIONS**



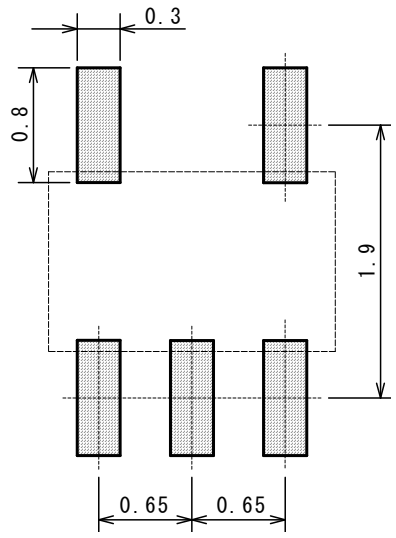
SC-88A

Unit: mm

■ **PACKAGE DIMENSIONS**



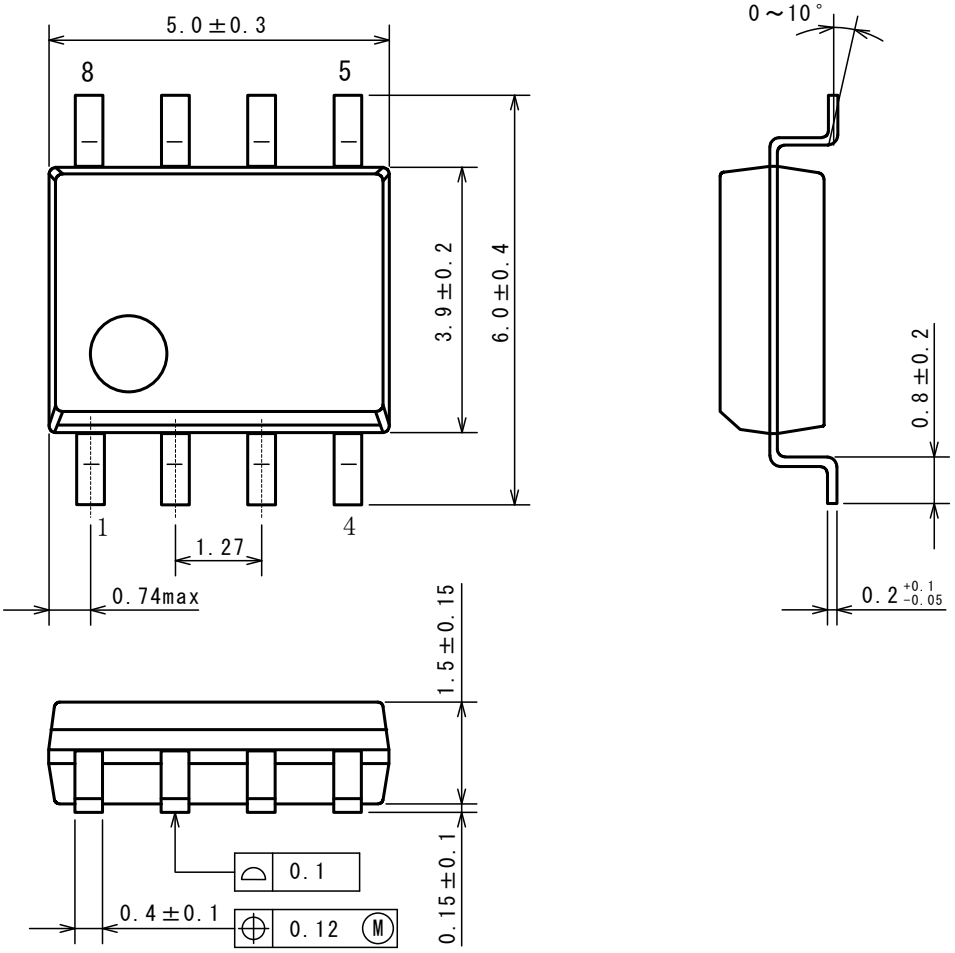
■ **EXAMPLE OF SOLDER PADS DIMENSIONS**



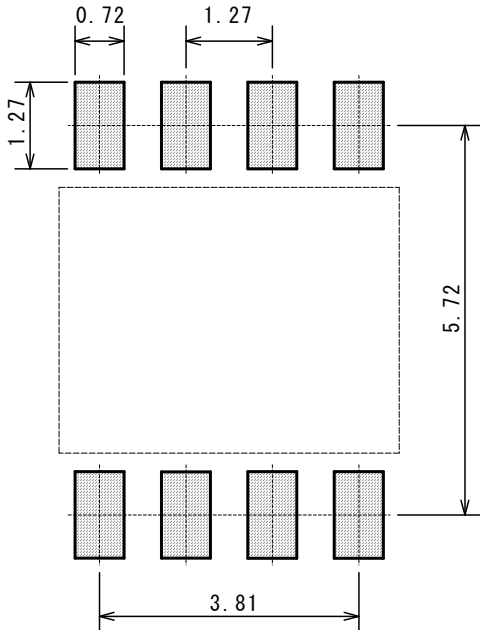
SOP8 JEDEC 150mil (EMP8)

Unit: mm

■ **PACKAGE DIMENSIONS**



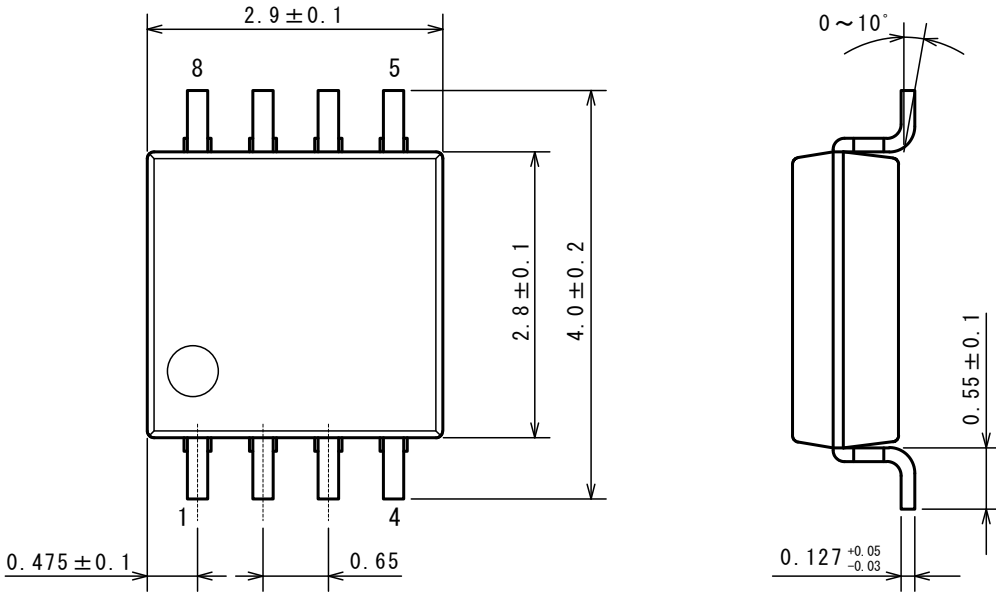
■ **EXAMPLE OF SOLDER PADS DIMENSIONS**



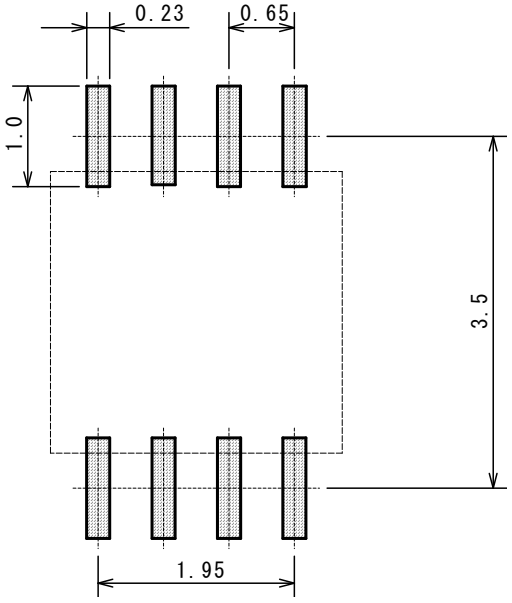
MSOP8 (TVSP8) MEETS JEDEC MO-187-DA/THIN TYPE

Unit: mm

■ PACKAGE DIMENSIONS



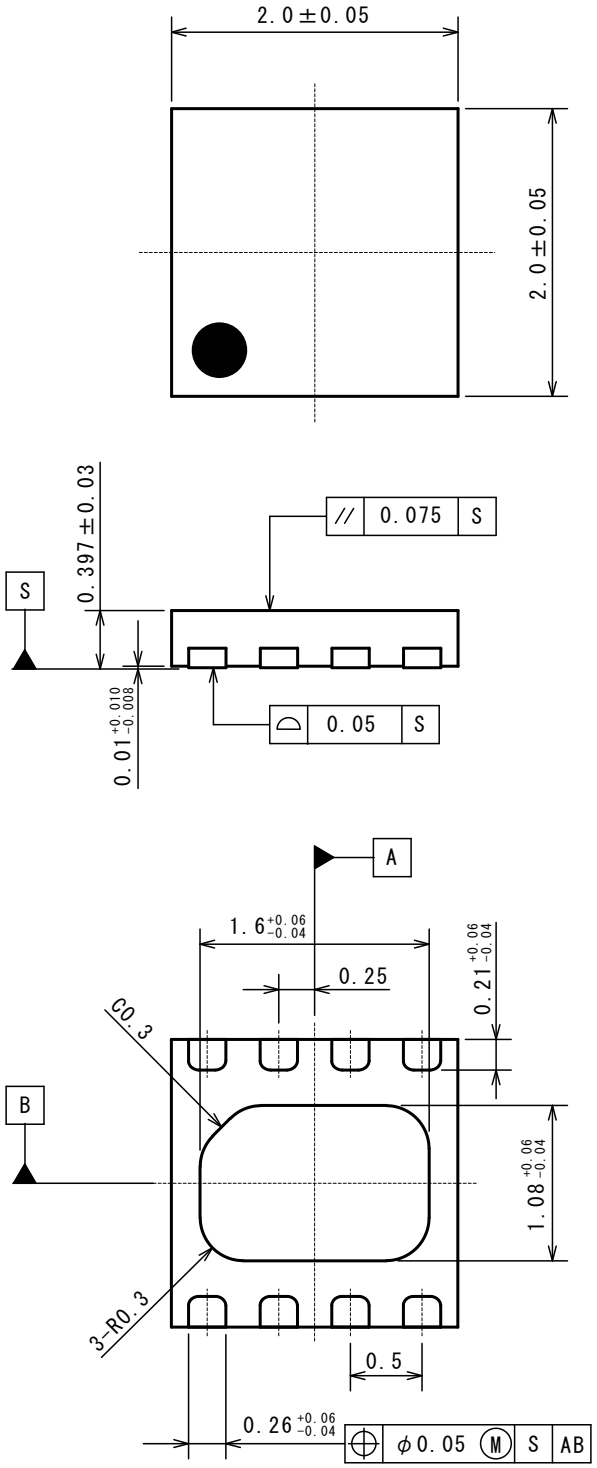
■ EXAMPLE OF SOLDER PADS DIMENSIONS



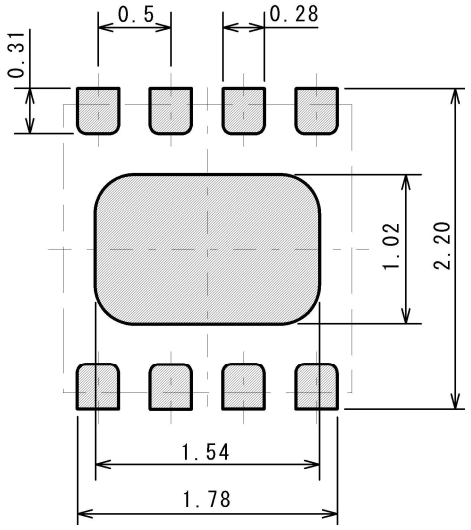
DFN8-U1 (ESON8-U1)

Unit: mm

■ PACKAGE DIMENSIONS

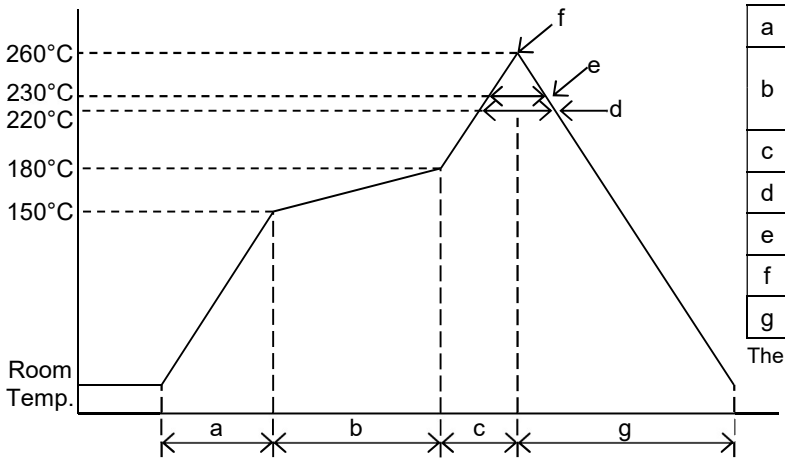


■EXAMPLE OF SOLDER PADS DIMENSIONS



■ RECOMMENDED MOUNTING METHOD

INFRARED REFLOW SOLDERING PROFILE



a	Temperature ramping rate	1 to 4°C/s
b	Pre-heating temperature	150 to 180°C
	Pre-heating time	60 to 120s
c	Temperature ramp rate	1 to 4°C/s
d	220°C or higher time	shorter than 60s
e	230°C or higher time	shorter than 40s
f	Peak temperature	lower than 260°C
g	Temperature ramping rate	1 to 6°C/s

The temperature indicates at the surface of mold package.

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