Nisshinbo Micro Devices Inc.

PRELIMINARY SPECIFICATIONS SUBJECT TO CHANGE

NL6000/NL6002/NL6004

Precision, Low Power, Rail-to-Rail Input/Output, High EMC performance Operational Amplifier

FEATURES

(V^+ = 3.3V, V^- = 0V, Typical value)

- Low Input Offset Voltage 150µV max.
- Low Input Offset Voltage Drift 0.9µV/°C max.
- Operating Voltage 1.6V to 5.5V
- Rail-to-Rail Input / Output
- Internal EMI filter EMIRR = 96 dB at f = 1.8GHz
- Low Supply Current 15µA/ch
- Low Input Bias Current 1pA
- CMOS Architecture
- Operating Temperature Range -40°C to 125°C
- Package SOT-23-5-DC, EMP-8-AN, VSP-8-AF, DFN3030-8-GF, SSOP-14-BC

APPLICATIONS

- Battery-Powered Equipment
- Various Sensor Amplifiers
  Strain Gage, Thermopile, Flow, etc.
- Photodiode Amplifier

GENERAL DESCRIPTION

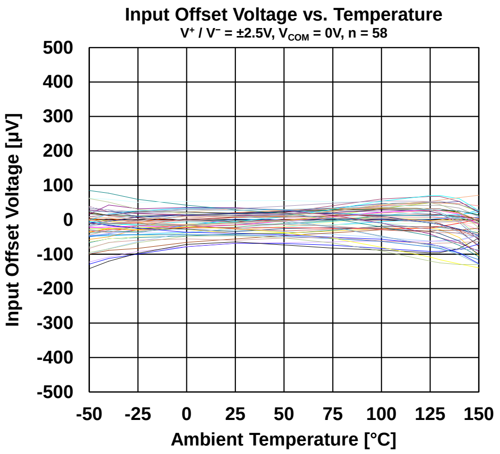
NL6000/NL6002/NL6004 is a high precision Rail-to-Rail Input/Output Single/Dual/Quad CMOS operational amplifier featuring a low supply current of 15µA typ., low input offset voltage of 150µV max., low temperature drift of 0.9µV/°C max. and low bias current of 1pAtyp..

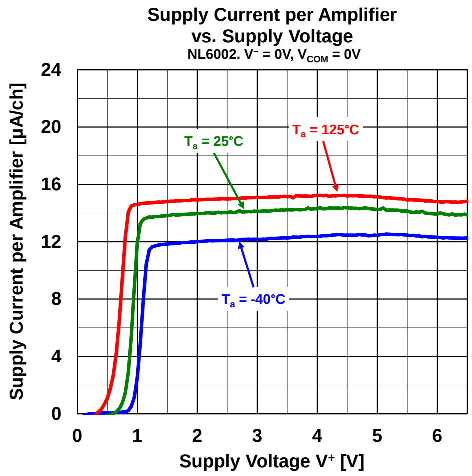
The NL600x series also has a high EMI noise immunity which can reduce malfunctions caused by RF noises from mobile phones and others.

The combination of these specifications makes the NL600x series well-suited for sensor applications such as a temperature sensor, weight sensor and others, high precision current sensing amplifiers and current voltage converters.

Precison Opamp Lineup

Description	Single	Dual	Quad
10µV, 0.05µV/°C, Zero-Drift	NL6010, NL6011	NL6012	
150µV, 5µV/°C, 10nV/√Hz	NJU7076	NJU7077	NJU7078
15µV, 0.05µV/°C, 10V, Zero-Drift	NJU7098AF1C		





NISSHINBO

■ PRODUCT NAME INFORMATION

NL600x aa A bb D

Description of configuration

Composition	Item	Description
x	Number of circuits	Indicates number of circuits. 0: 1ch 2: 2ch 4: 4ch
aa	Package code	Indicates the package. DC: SOT-23-5-DC AN: EMP-8-AN GF: DFN3030-8-GF BC: SSOP-14-BC
A	Version	Product Version. Default is A.
bb	Packing	Refer to the packing specifications.
D	Grade	Indicates the quality grade.

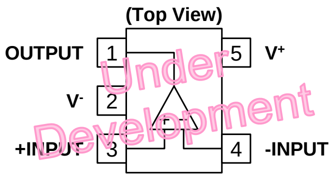
Grade

	Applications	Operating Temperature Range	Test Temperature
D	Industrial equipment and Social infrastructures	-40°C to 125°C	-40°C, 25°C, 125°C

■ ORDER INFORMATION

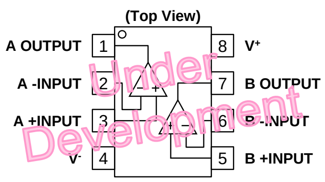
Product Name	Package	RoHS	Halogen-Free	Terminal Finish	Weight (mg)	MOQ (pcs)
NL6000DCAE1D	SOT-23-5-DC	✓	✓	Sn2Bi	15	3000
NL6002ANAE2D	EMP-8-AN	✓	✓	Sn2Bi	76	2000
NL6002AFAE2D	VSP-8-AF	✓	✓	Sn2Bi	21	2000
NL6002GFAE3D	DFN3030-8-GF	✓	✓	Sn2Bi	18	1500
NL6004BCAE2D	SSOP-14-BC	✓	✓	Sn2Bi	65	2000

■ PIN DESCRIPTION (SOT-23-5)

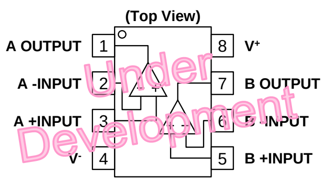


Pin No.	Symbol	I/O	Description
1	OUTPUT	O	Output channel
4	−INPUT	I	Inverting input channel
3	+INPUT	I	Non-inverting input channel
5	V^+	-	Positive supply
2	V^-	-	Negative supply or GND (single supply)

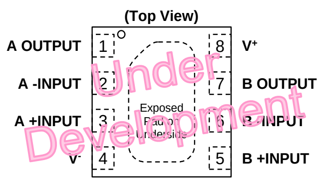
■ PIN DESCRIPTIONS (8 Pin)



EMP-8-AN



VSP-8-AF

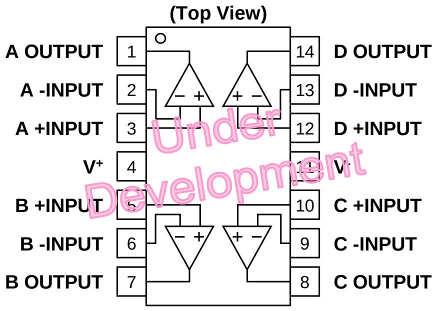


DFN3030-8-GF

Pin No.			Symbol	I/O	Description
EMP-8-AN	VSP-8-AF	DFN3030-8-GF			
1	1	1	A OUTPUT	O	Output channel A
2	2	2	A −INPUT	I	Inverting input channel A
3	3	3	A +INPUT	I	Non-inverting input channel A
7	7	7	B OUTPUT	O	Output channel B
6	6	6	B −INPUT	I	Inverting input channel B
5	5	5	B +INPUT	I	Non-inverting input channel B
8	8	8	V^+	-	Positive supply
4	4	4	V^-	-	Negative supply or GND (single supply)

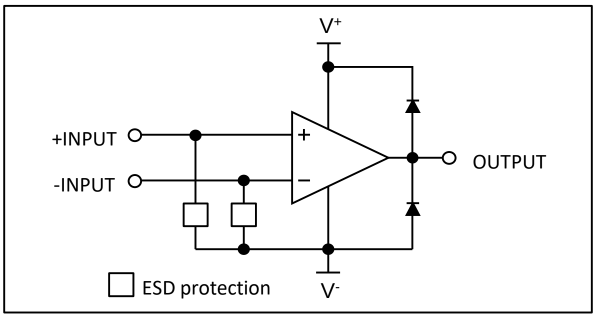
*Connect to exposed pad to V−

■ PIN DESCRIPTION (SSOP14)



Pin No.	Symbol	I/O	Description
1	A OUTPUT	O	Output channel A
2	A −INPUT	I	Inverting input channel A
3	A +INPUT	I	Non-inverting input channel A
7	B OUTPUT	O	Output channel B
6	B −INPUT	I	Inverting input channel B
5	B +INPUT	I	Non-inverting input channel B
8	C OUTPUT	O	Output channel C
9	C −INPUT	I	Inverting input channel C
10	C +INPUT	I	Non-inverting input channel C
14	D OUTPUT	O	Output channel D
13	D −INPUT	I	Inverting input channel D
12	D +INPUT	I	Non-inverting input channel D
4	V^+	-	Positive supply
11	V^-	-	Negative supply or GND (single supply)

■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATINGS

	Symbol	Rating	Unit
Supply Voltage $V_S = V^+ - V^-$	$V^+ - V^-$	6.5	V
Input Voltage*1	V_{IN}	V^- - 0.3 to V^+ + 0.3	V
Input Current*1	I_{IN}	-10	mA
Output Terminal Input Voltage*2	V_O	V^- - 0.3 to V^+ + 0.3	V
Differential Input Voltage*3	V_{ID}	±6.5	V
Output Short-Circuit Duration*4		Continuous	
Storage Temperature	T_{stg}	-55 to 150	°C
Junction Temperature *5	T_j	150	°C

*1 Input voltages below the negative supply voltage will be clamped by ESD protection diodes. If the input voltage lower than V^- - 0.3V, the input current must be limited 10 mA or less by using a restriction resistance. Input current outflow is negative.

*2 The output terminal input voltage is limited at 6.5V.

*3 Differential voltage is the voltage difference between +INPUT and −INPUT.

*4 Power loss increases when output is short-circuited; do not exceed T_j.

*5 Calculate the power consumption of the IC from the operating conditions, and calculate the junction temperature with the thermal resistance. Please refer to "Thermal characteristics" for the thermal resistance under our measurement board conditions.

ABSOLUTE MAXIMUM RATINGS
Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause permanent damage and may degrade the lifetime and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

■ THERMAL CHARACTERISTICS

Package	Measurement Result		Unit
	Thermal Resistance (θja)	Thermal Characterization Parameter (ψjt)	
SOT-23-5-DC	192	58	°C/W
EMP-8-AN	125	27	°C/W
VSP-8-AF	189	53	°C/W
DFN3030-8-GF	69	18	°C/W
SSOP-14-BC	202	52	°C/W

θja:Junction-to-Ambient Thermal Resistance
ψjt:Junction-to-Top Thermal Characterization Parameter
Mounted on glass epoxy board (76.2 mm × 114.3 mm × 1.6 mm: based on EIA/JEDEC standard, 4-layer FR-4), internal Cu area: 74.2 mm × 74.2 mm.

■ ELECTROSTATIC DISCHARGE (ESD) PROTECTION VOLTAGE

	Conditions	Protection Voltage
HBM	C = 100 pF, R = 1.5 kΩ	±2000 V
CDM		±1000 V

ELECTROSTATIC DISCHARGE RATINGS
The electrostatic discharge test is done based on JEDEC JS001, JS002. In the HBM method, ESD is applied using the power supply pin and GND pin as reference pins.

■ RECOMMENDED OPERATING CONDITIONS

	Symbol	Conditions	Rating	Unit
Supply Voltage	$V^+ - V^-$		1.6 to 5.5	V
Operating Temperature	T_a		-40 to 125	°C

RECOMMENDED OPERATING CONDITIONS
All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

■ ELECTRICAL CHARACTERISTICS (5V Supply, NL6000)

$V^+ = 5V$, $V^- = 0V$, $V_{COM} = V^+/2$, $R_L = 100k\Omega$ to $V^+/2$, $T_a = 25°C$, unless otherwise specified.

Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}		-	10	200	µV
		$T_a = -40°C$ to 125°C	-	-	450	µV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	$T_a = -40°C$ to 125°C	-	0.3	0.9	µV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	$V_{COM} = 0V$, $V_O = 0.1V$ to 4.9V	100	113	-	dB
Common-Mode Rejection Ratio	CMR	$V_{COM} = V^- - 0.2V$ to $V^+ - 1.1V$	70	100	-	dB
		$V_{COM} = V^- - 0.2V$ to $V^+ + 0.2V$	70	100	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	$V^- - 0.2$	-	$V^+ + 0.2$	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	$R_L = 100k\Omega$ to $V^+ / 2$	$V^+ - 0.025$	$V^+ - 0.01$	-	V
		$R_L = 10k\Omega$ to $V^+ / 2$	$V^+ - 0.100$	$V^+ - 0.05$	-	V
Low-level Output Voltage	V_{OL}	$R_L = 100k\Omega$ to $V^+ / 2$	-	6	25	mV
		$R_L = 10k\Omega$ to $V^+ / 2$	-	50	100	mV
		$R_L = 100k\Omega$ to V^-	-	0.5	5	mV
		$R_L = 10k\Omega$ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	20 / 20	-	mA
POWER SUPPLY						
Supply Current	I_{SUPPLY}	No Signal, $V_{COM} = 0V$	-	15	21	µA
Supply Voltage Rejection Ratio	SVR	$V^+ = 1.6V$ to 5.5V, $V_{COM} = 0V$	70	100	-	dB
AC CHARACTERISTICS						
Slew Rate	SR	$C_L = 50pF$, $V_{IN} = 1V_{PP}$, $G_V = 1$	-	0.04	-	V/µs
Gain Bandwidth Product	GBW	$C_L = 50pF$	-	120	-	kHz
Settling Time 0.1%	t_s	$C_L = 50pF$, $V_{IN} = 4V_{PP}$	-	100	-	µs
Phase Margin	Φ_M	$C_L = 50pF$	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, $V_O = 1.5Vrms$	-	0.05	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.4	-	$µV_{PP}$
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz

[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

■ ELECTRICAL CHARACTERISTICS (3.3V Supply, NL6000)

$V^+ = 3.3V$, $V^- = 0V$, $V_{COM} = V^+/2$, $R_L = 100k\Omega$ to $V^+/2$, $T_a = 25°C$, unless otherwise specified.

Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}		-	10	150	μV
		$T_a = -40°C$ to 125°C	-	-	400	μV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	$T_a = -40°C$ to 125°C	-	0.3	0.9	μV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	$V_{COM} = 0V$, $V_O = 0.1V$ to 3.2V	100	112	-	dB
Common-Mode Rejection Ratio	CMR	$V_{COM} = V^- - 0.2V$ to $V^+ - 1.1V$	70	100	-	dB
		$V_{COM} = V^- - 0.2V$ to $V^+ + 0.2V$	70	100	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	$V^- - 0.2$	-	$V^+ + 0.2$	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	$R_L = 100k\Omega$ to $V^+ / 2$	$V^+ - 0.025$	$V^+ - 0.01$	-	V
		$R_L = 10k\Omega$ to $V^+ / 2$	$V^+ - 0.100$	$V^+ - 0.05$	-	V
Low-level Output Voltage	V_{OL}	$R_L = 100k\Omega$ to $V^+ / 2$	-	6	25	mV
		$R_L = 10k\Omega$ to $V^+ / 2$	-	50	100	mV
		$R_L = 100k\Omega$ to V^-	-	0.5	5	mV
		$R_L = 10k\Omega$ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	10 / 10	-	mA
POWER SUPPLY						
Supply Current	I_{SUPPLY}	No Signal, $V_{COM} = 0V$	-	15	21	μA
AC CHARACTERISTICS						
Slew Rate	SR	$C_L = 50pF$, $V_{IN} = 1V_{PP}$, $G_V = 1$	-	0.04	-	V/μs
Gain Bandwidth Product	GBW	$C_L = 50pF$	-	120	-	kHz
Settling Time 0.1%	t_S	$C_L = 50pF$, $V_{IN} = 2.3V_{PP}$	-	80	-	μs
Phase Margin	Φ_M	$C_L = 50pF$	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, $V_O = 0.9Vrms$	-	0.05	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.3	-	μV_{PP}
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz

[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

■ ELECTRICAL CHARACTERISTICS (1.8V Supply, NL6000)

$V^+ = 1.8V$, $V^- = 0V$, $V_{COM} = 0V$, $R_L = 100k\Omega$ to $V^+/2$, $T_a = 25°C$, unless otherwise specified.

Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}	$V_{COM} = 0V$	-	10	250	μV
		$T_a = -40°C$ to 125°C	-	-	500	μV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	$V_{COM} = 0V$, $T_a = -40°C$ to 125°C	-	0.3	0.9	μV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	$V_{COM} = 0V$, $V_O = 0.1V$ to 1.7V	98	110	-	dB
Common-Mode Rejection Ratio	CMR	$V_{COM} = V^- - 0.2V$ to $V^+ - 1.1V$	70	96	-	dB
		$V_{COM} = V^- - 0.2V$ to $V^+ + 0.2V$	70	96	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	$V^- - 0.2$	-	$V^+ + 0.2$	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	$R_L = 100k\Omega$ to $V^+ / 2$	$V^+ - 0.025$	$V^+ - 0.01$	-	V
		$R_L = 10k\Omega$ to $V^+ / 2$	$V^+ - 0.100$	$V^+ - 0.05$	-	V
Low-level Output Voltage	V_{OL}	$R_L = 100k\Omega$ to $V^+ / 2$	-	6	25	mV
		$R_L = 10k\Omega$ to $V^+ / 2$	-	50	100	mV
		$R_L = 100k\Omega$ to V^-	-	0.5	5	mV
		$R_L = 10k\Omega$ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	1 / 1	-	mA
POWER SUPPLY						
Supply Current	I_{SUPPLY}	No Signal, $V_{COM} = 0V$	-	15	21	μA
AC CHARACTERISTICS						
Slew Rate	SR	$C_L = 50pF$, $V_{IN} = 1V_{PP}$, $G_V = 1$	-	0.04	-	V/μs
Gain Bandwidth Product	GBW	$C_L = 50pF$	-	120	-	kHz
Settling Time 0.1%	t_S	$C_L = 50pF$, $V_{IN} = 0.8V_{PP}$	-	50	-	μs
Phase Margin	Φ_M	$C_L = 50pF$	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, $V_O = 0.4Vrms$	-	0.5	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.4	-	$μV_{PP}$
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz

[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

■ ELECTRICAL CHARACTERISTICS (5V Supply, NL6002 / NL6004)

$V^+ = 5V$, $V^- = 0V$, $V_{COM} = V^+/2$, $R_L = 100k\Omega$ to $V^+/2$, $T_a = 25°C$, unless otherwise specified.

Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}		-	10	200	µV
		$T_a = -40°C$ to 125°C	-	-	450	µV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	$T_a = -40°C$ to 125°C	-	0.3	0.9	µV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	$V_{COM} = 0V$, $V_O = 0.1V$ to 4.9V	100	113	-	dB
Common-Mode Rejection Ratio	CMR	$V_{COM} = V^- - 0.2V$ to $V^+ - 1.1V$	70	100	-	dB
		$V_{COM} = V^- - 0.2V$ to $V^+ + 0.2V$	70	100	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	$V^- - 0.2$	-	$V^+ + 0.2$	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	$R_L = 100k\Omega$ to $V^+ / 2$	$V^+ - 0.025$	$V^+ - 0.01$	-	V
		$R_L = 10k\Omega$ to $V^+ / 2$	$V^+ - 0.100$	$V^+ - 0.05$	-	V
Low-level Output Voltage	V_{OL}	$R_L = 100k\Omega$ to $V^+ / 2$	-	6	25	mV
		$R_L = 10k\Omega$ to $V^+ / 2$	-	50	100	mV
		$R_L = 100k\Omega$ to V^-	-	0.5	5	mV
		$R_L = 10k\Omega$ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	20 / 20	-	mA
POWER SUPPLY						
Supply Current per Amplifier	I_{SUPPLY}	No Signal, $V_{COM} = 0V$	-	15	21	µA
Supply Voltage Rejection Ratio	SVR	$V^+ = 1.6V$ to 5.5V, $V_{COM} = 0V$	70	100	-	dB
AC CHARACTERISTICS						
Slew Rate	SR	$C_L = 50pF$, $V_{IN} = 1V_{PP}$, $G_V = 1$	-	0.04	-	V/µs
Gain Bandwidth Product	GBW	$C_L = 50pF$	-	120	-	kHz
Settling Time 0.1%	t_S	$C_L = 50pF$, $V_{IN} = 4V_{PP}$	-	100	-	µs
Phase Margin	Φ_M	$C_L = 50pF$	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, $V_O = 1.5Vrms$	-	0.05	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.4	-	$µV_{PP}$
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz
Channel Separation	CS	f = 1kHz	-	120	-	dB

[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

■ ELECTRICAL CHARACTERISTICS (3.3V Supply, NL6002 / NL6004)

$V^+ = 3.3V$, $V^- = 0V$, $V_{COM} = V^+/2$, $R_L = 100k\Omega$ to $V^+/2$, $T_a = 25°C$, unless otherwise specified.

Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}		-	10	150	µV
		$T_a = -40°C$ to 125°C	-	-	400	µV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	$T_a = -40°C$ to 125°C	-	0.3	0.9	µV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	$V_{COM} = 0V$, $V_O = 0.1V$ to 3.2V	100	112	-	dB
Common-Mode Rejection Ratio	CMR	$V_{COM} = V^- - 0.2V$ to $V^+ - 1.1V$	70	100	-	dB
		$V_{COM} = V^- - 0.2V$ to $V^+ + 0.2V$	70	100	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	$V^- - 0.2$	-	$V^+ + 0.2$	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	$R_L = 100k\Omega$ to $V^+/2$	$V^+ - 0.025$	$V^+ - 0.01$	-	V
		$R_L = 10k\Omega$ to $V^+/2$	$V^+ - 0.100$	$V^+ - 0.05$	-	V
Low-level Output Voltage	V_{OL}	$R_L = 100k\Omega$ to $V^+/2$	-	6	25	mV
		$R_L = 10k\Omega$ to $V^+/2$	-	50	100	mV
		$R_L = 100k\Omega$ to V^-	-	0.5	5	mV
		$R_L = 10k\Omega$ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	10 / 10	-	mA
POWER SUPPLY						
Supply Current per Amplifier	I_{SUPPLY}	No Signal, $V_{COM} = 0V$	-	15	21	µA
AC CHARACTERISTICS						
Slew Rate	SR	$C_L = 50pF$, $V_{IN} = 1V_{PP}$, $G_V = 1$	-	0.04	-	V/µs
Gain Bandwidth Product	GBW	$C_L = 50pF$	-	120	-	kHz
Settling Time 0.1%	t_S	$C_L = 50pF$, $V_{IN} = 2.3V_{PP}$	-	80	-	µs
Phase Margin	Φ_M	$C_L = 50pF$	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, $V_O = 0.9Vrms$	-	0.05	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.3	-	$µV_{PP}$
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz
Channel Separation	CS	f = 1kHz	-	120	-	dB

[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

■ ELECTRICAL CHARACTERISTICS (1.8V Supply, NL6002 / NL6004)

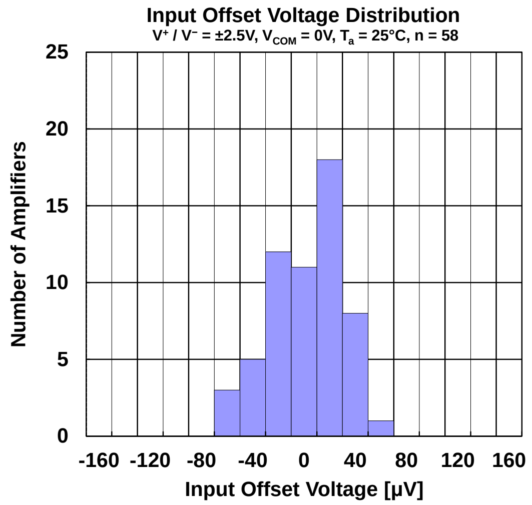
V^+ = 1.8V, V^- = 0V, V_{COM} = 0V, R_L = 100kΩ to V^+/2, T_a = 25°C, unless otherwise specified.

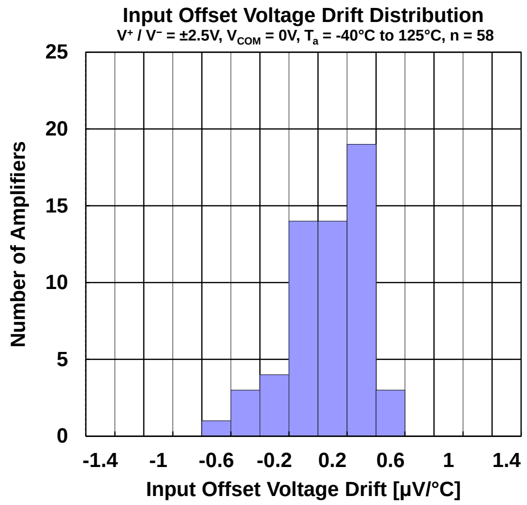
Parameter	Symbol	Conditions	MIN	Typ	MAX	Unit
INPUT CHARACTERISTICS [*1]						
Input Offset Voltage	V_{IO}	V_{COM} = 0V	-	10	250	µV
		T_a = −40°C to 125°C	-	-	500	µV
Input Bias Current	I_B		-	1	-	pA
Input Offset Current	I_{IO}		-	1	-	pA
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	V_{COM} = 0V, T_a = −40°C to 125°C	-	0.3	0.9	µV/°C
Input Resistance	R_{IC}		-	1000	-	GΩ
Input Capacitance	C_{IN}		-	10	-	pF
Open-Loop Voltage Gain	A_V	V_{COM} = 0V, V_O = 0.1V to 1.7V	98	110	-	dB
Common-Mode Rejection Ratio	CMR	V_{COM} = V^- - 0.2V to V^+ - 1.1V	70	96	-	dB
		V_{COM} = V^- - 0.2V to V^+ + 0.2V	70	96	-	dB
Common-Mode Input Voltage Range	V_{ICM}	CMR ≥ CMR min	V^- - 0.2	-	V^+ + 0.2	V
OUTPUT CHARACTERISTICS						
High-level Output Voltage	V_{OH}	R_L = 100kΩ to V^+ / 2	V^+ - 0.025	V^+ - 0.01	-	V
		R_L = 10kΩ to V^+ / 2	V^+ - 0.100	V^+ - 0.05	-	V
Low-level Output Voltage	V_{OL}	R_L = 100kΩ to V^+ / 2	-	6	25	mV
		R_L = 10kΩ to V^+ / 2	-	50	100	mV
		R_L = 100kΩ to V^-	-	0.5	5	mV
		R_L = 10kΩ to V^-	-	0.5	5	mV
Capacitive Load Drive	C_L		-	100	-	pF
Output Short-Circuit Current	I_{SC}	Source / Sink	-	1 / 1	-	mA
POWER SUPPLY						
Supply Current per Amplifier	I_{SUPPLY}	No Signal, V_{COM} = 0V	-	15	21	µA
AC CHARACTERISTICS						
Slew Rate	SR	C_L = 50pF, V_{IN} = 1V_{PP}, G_V = 1	-	0.04	-	V/µs
Gain Bandwidth Product	GBW	C_L = 50pF	-	120	-	kHz
Settling Time 0.1%	t_S	C_L = 50pF, V_{IN} = 0.8V_{PP}	-	50	-	µs
Phase Margin	Φ_M	C_L = 50pF	-	50	-	Deg
Total Harmonic Distortion + Noise	THD+N	Gain = 2, f = 1kHz, V_O = 0.4Vrms	-	0.5	-	%
Equivalent Input Noise Voltage	V_{NI}	f = 0.1Hz to 10Hz	-	1.4	-	µV_{PP}
Equivalent Input Noise Voltage	e_n	f = 100Hz	-	80	-	nV/√Hz
		f = 1kHz	-	65	-	nV/√Hz
Channel Separation	CS	f = 1kHz	-	120	-	dB

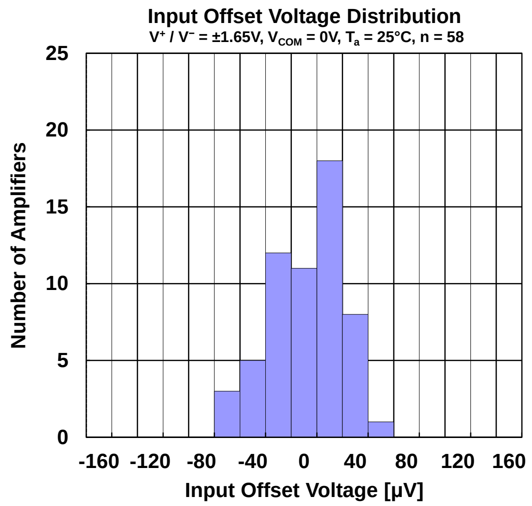
[*1] Input offset voltage and drift, Input bias and offset current are positive or negative, its absolute values are listed in electrical characteristics.

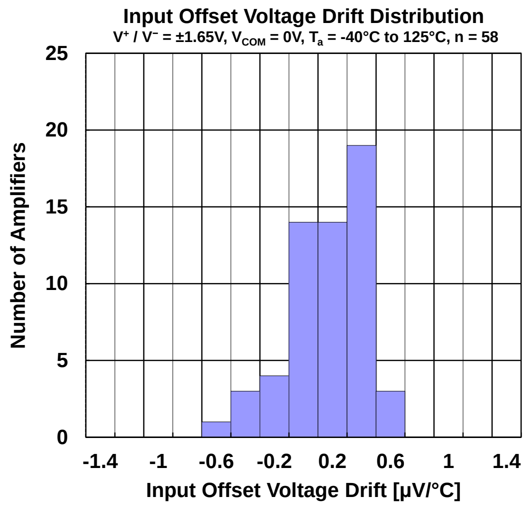
■ TYPICAL CHARACTERISTICS

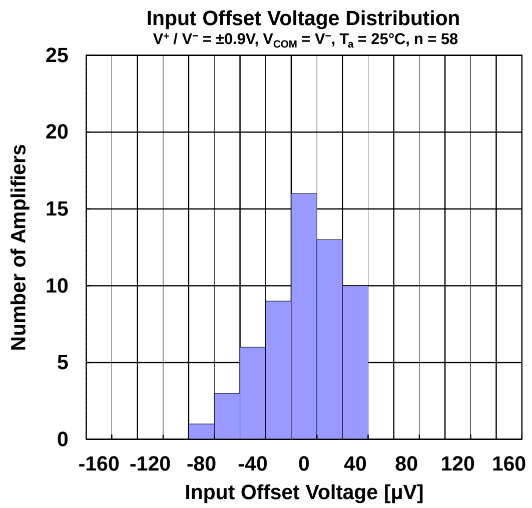
Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

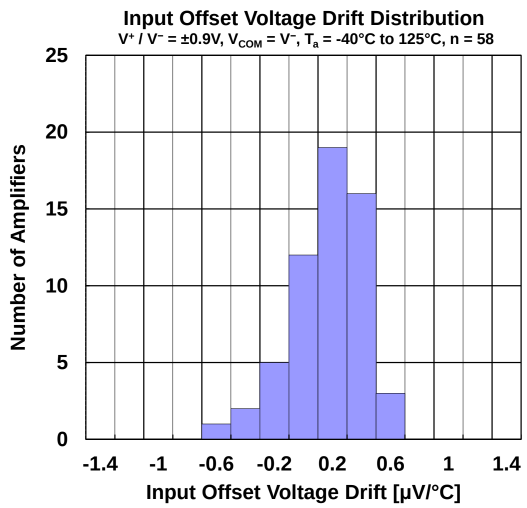












■ TYPICAL CHARACTERISTICS

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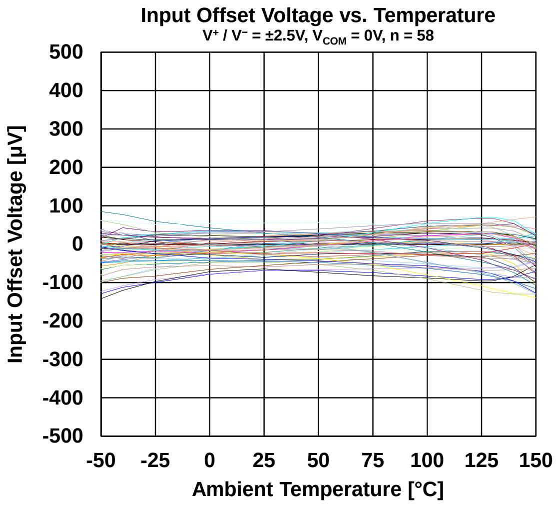
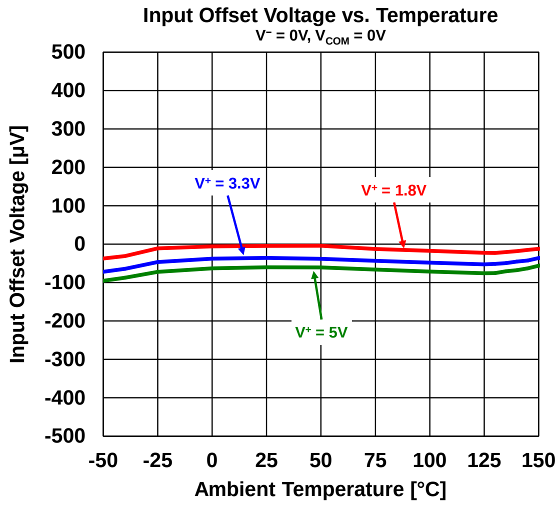
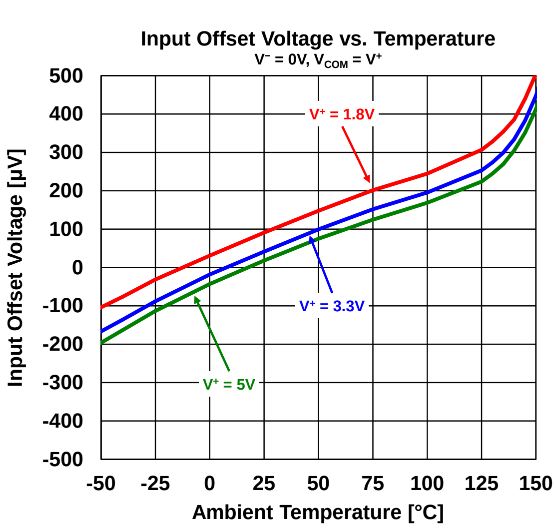
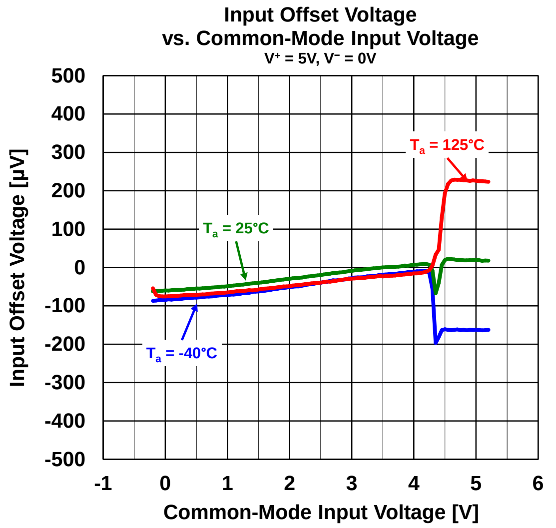
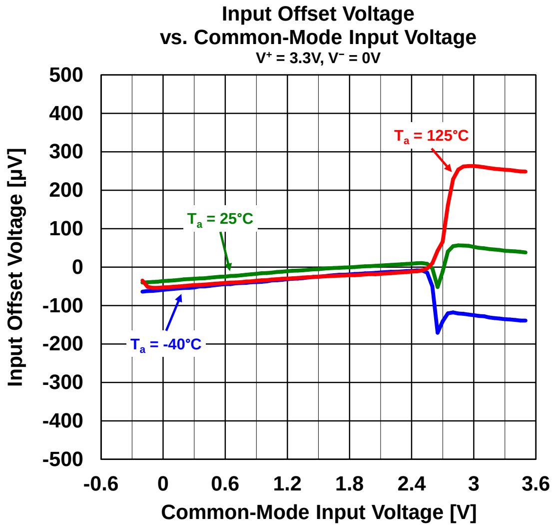
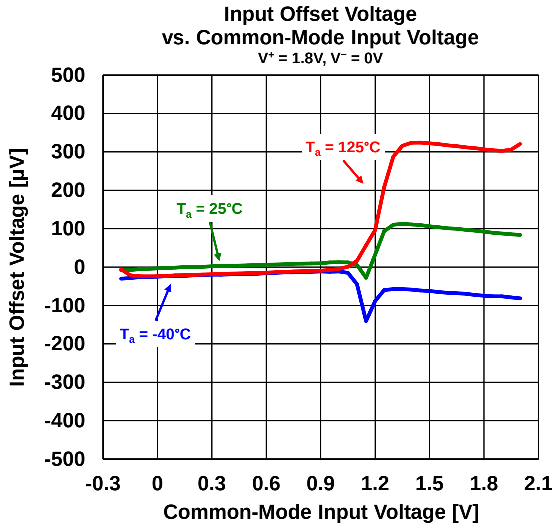








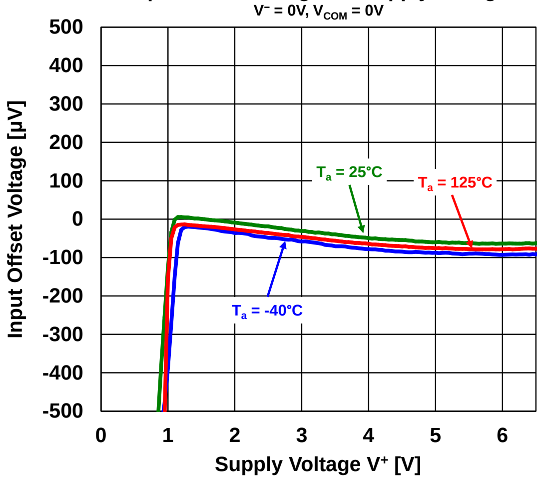




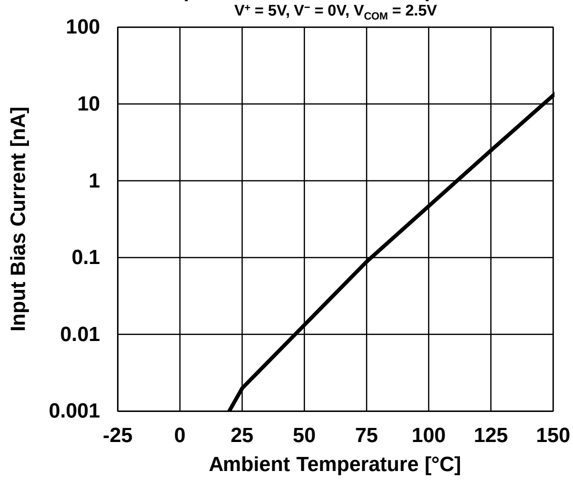
■ TYPICAL CHARACTERISTICS

Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

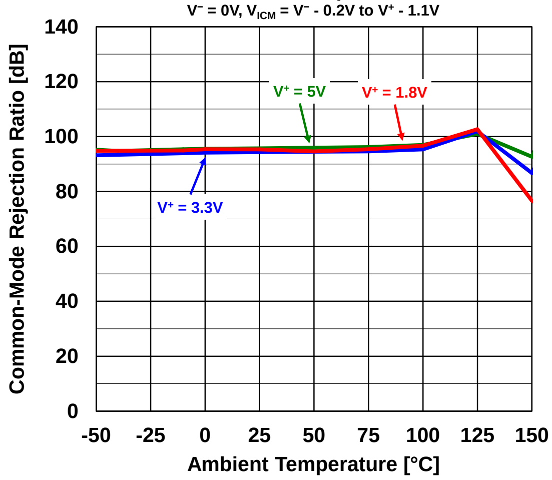
Input Offset Voltage vs. Supply Voltage
$V^- = 0V, V_{COM} = 0V$



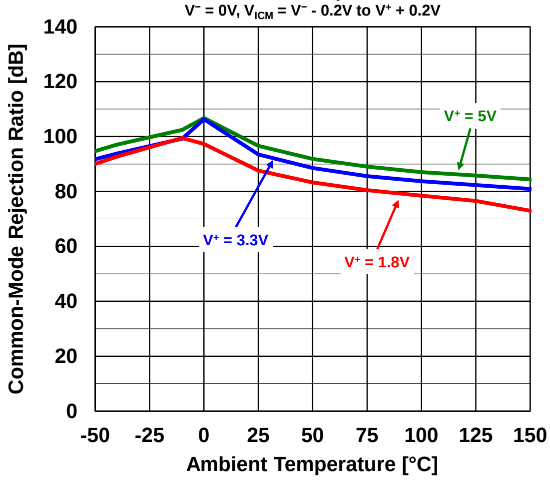
Input Bias Current vs. Temperature
$V^+ = 5V, V^- = 0V, V_{COM} = 2.5V$



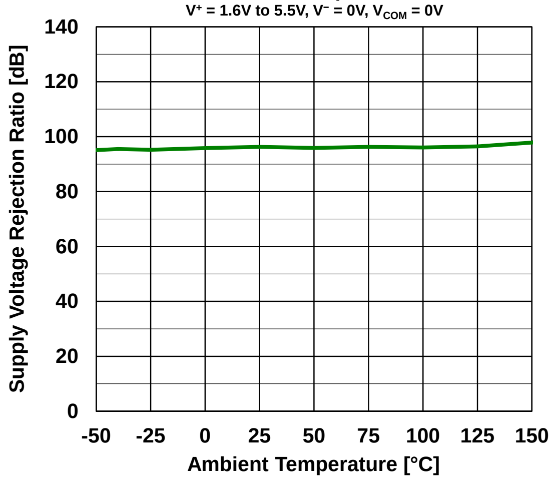
CMR vs. Temperature
$V^- = 0V, V_{ICM} = V^- - 0.2V$ to $V^+ - 1.1V$



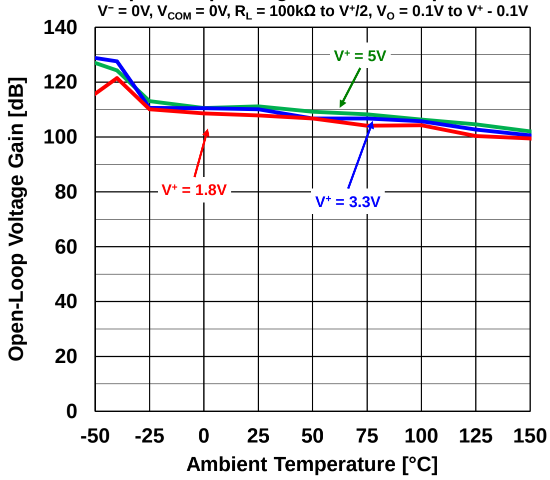
CMR vs. Temperature
$V^- = 0V, V_{ICM} = V^- - 0.2V$ to $V^+ + 0.2V$



SVR vs. Temperature
$V^+ = 1.6V$ to $5.5V, V^- = 0V, V_{COM} = 0V$



Open-Loop Voltage Gain vs. Temperature
$V^- = 0V, V_{COM} = 0V, R_L = 100k\Omega$ to $V^+/2, V_O = 0.1V$ to $V^+ - 0.1V$



■ TYPICAL CHARACTERISTICS

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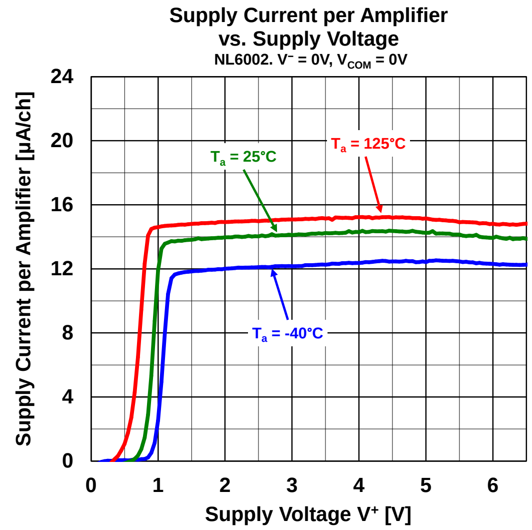
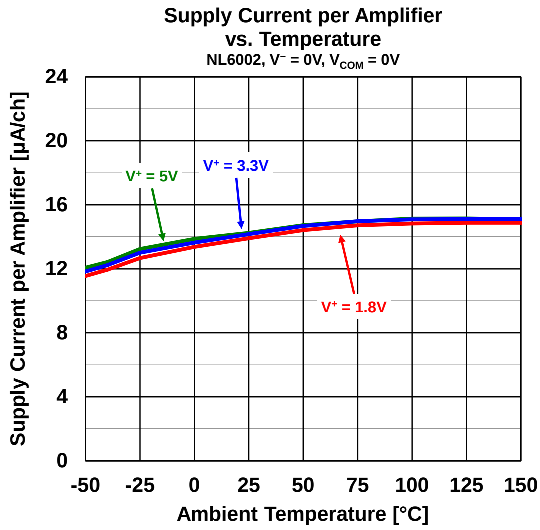
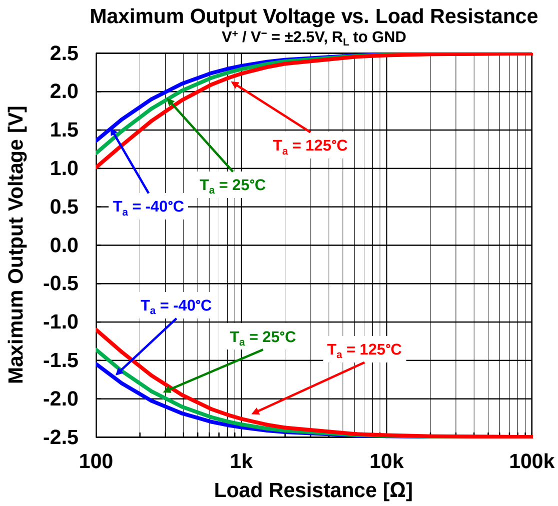
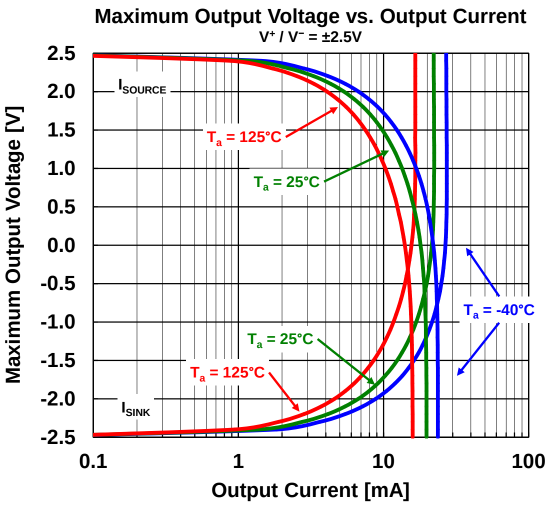
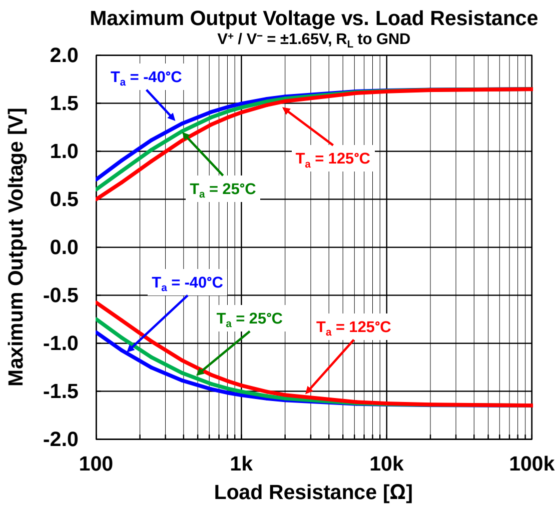
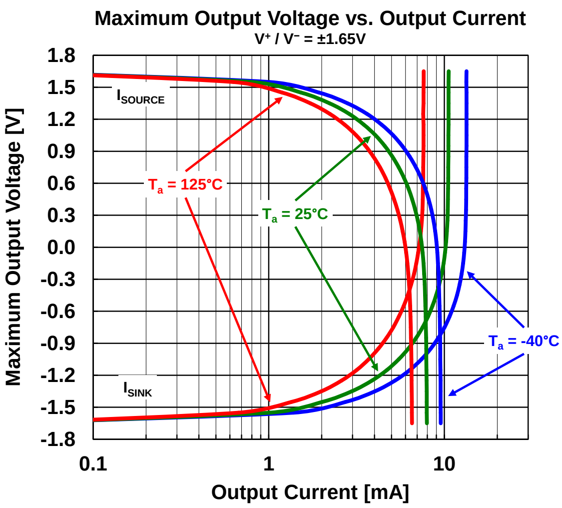








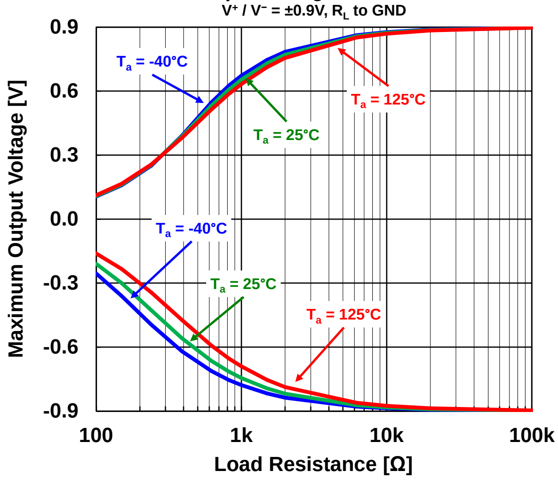




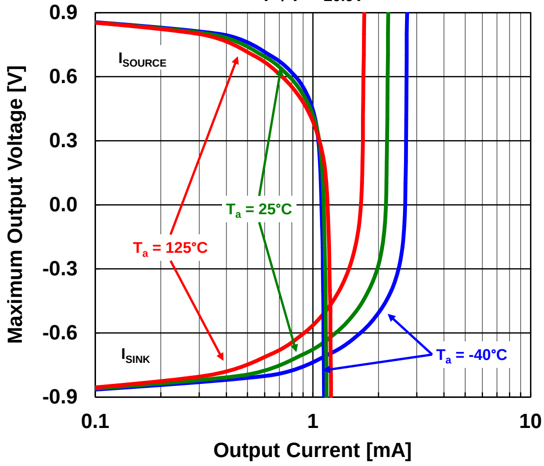
■ TYPICAL CHARACTERISTICS

Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

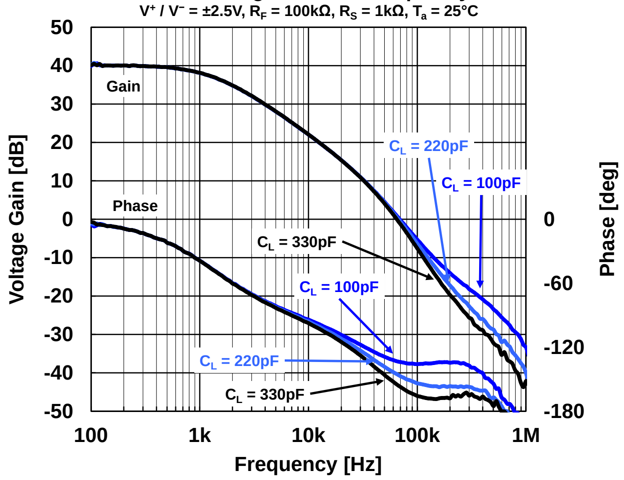
Maximum Output Voltage vs. Load Resistance
$V^+ / V^- = \pm 0.9V$, R_L to GND



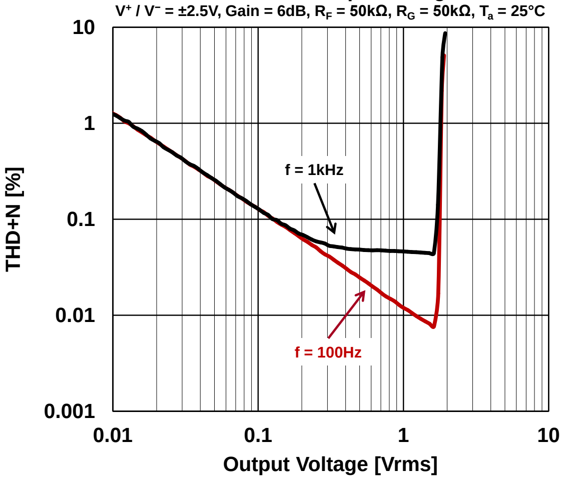
Maximum Output Voltage vs. Output Current
$V^+ / V^- = \pm 0.9V$



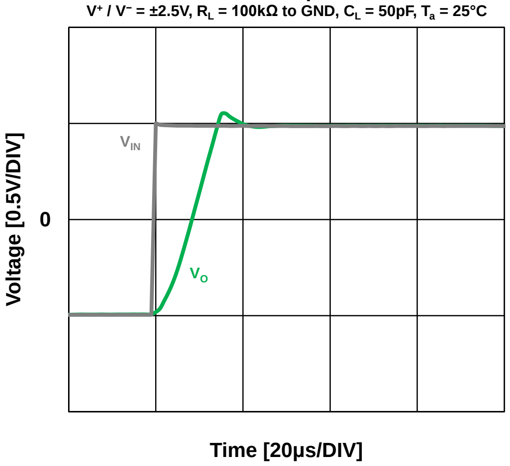
40dB Voltage Gain vs. Frequency
$V^+ / V^- = \pm 2.5V$, $R_F = 100k\Omega$, $R_S = 1k\Omega$, $T_a = 25°C$



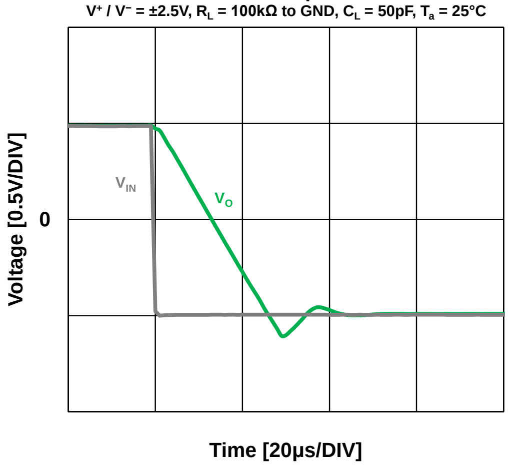
THD+N vs. Output Voltage
$V^+ / V^- = \pm 2.5V$, Gain = 6dB, $R_F = 50k\Omega$, $R_G = 50k\Omega$, $T_a = 25°C$



Pulse Response
$V^+ / V^- = \pm 2.5V$, $R_L = 100k\Omega$ to GND, $C_L = 50pF$, $T_a = 25°C$



Pulse Response
$V^+ / V^- = \pm 2.5V$, $R_L = 100k\Omega$ to GND, $C_L = 50pF$, $T_a = 25°C$



■ TYPICAL CHARACTERISTICS

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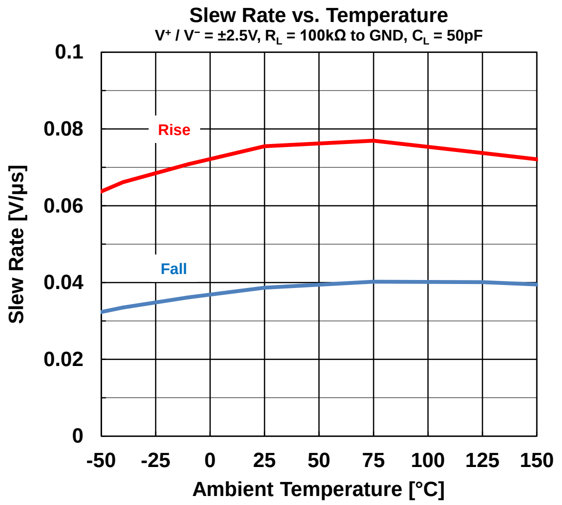
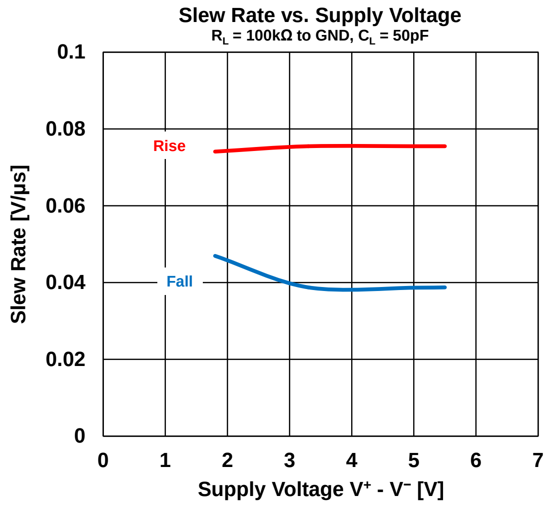
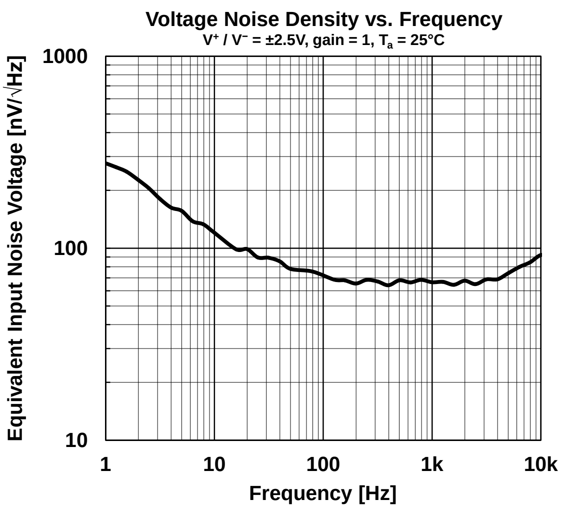
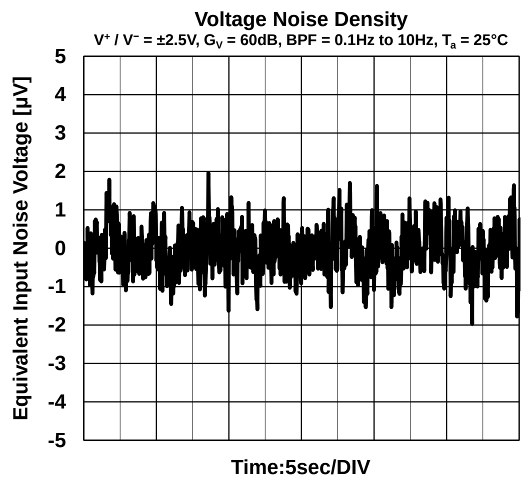
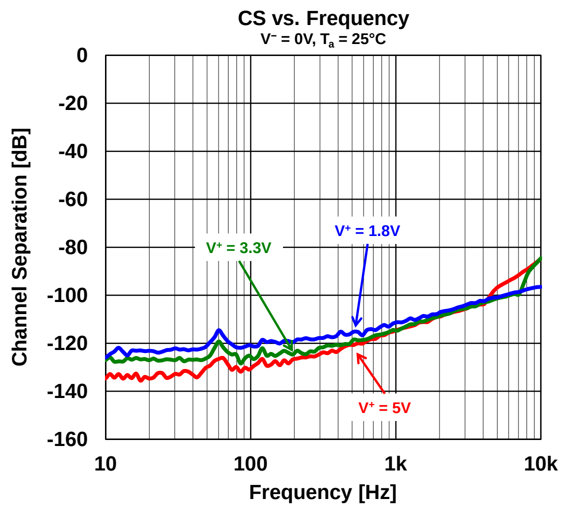
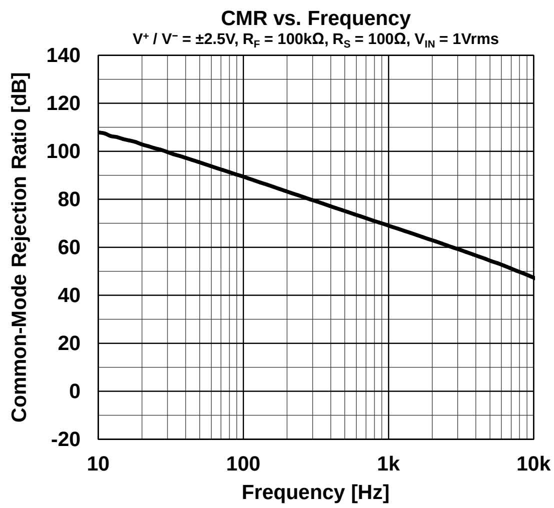






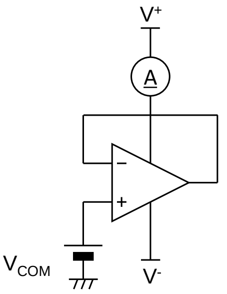






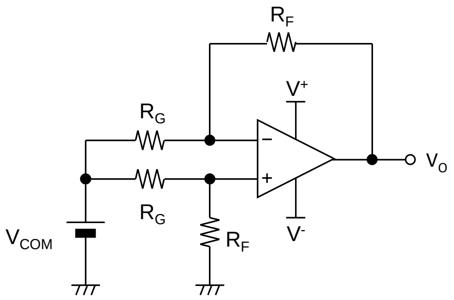
■ TEST CIRCUITS

● I_{SUPPLY}



● V_{IO}, CMR, SVR

R_G = 50Ω, R_F = 50kΩ



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

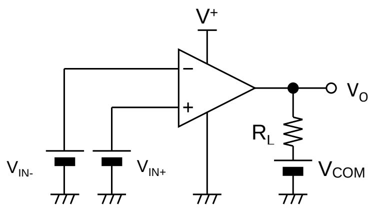
$$CMR=20\log\frac{\Delta V_{COM}\left(1+\frac{R_F}{R_G}\right)}{\Delta V_O}$$

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

$V_S=V^+-V^-$

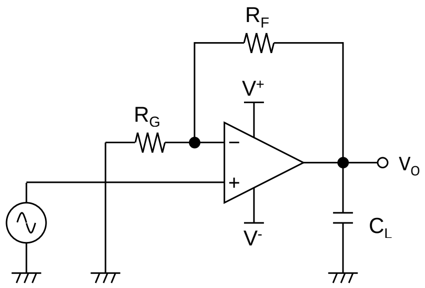
● V_{OH}, V_{OL}

V_{OH}; $V_{IN+} = V_{COM} + 1V$, $V_{IN-} = V_{COM}$, $V_{COM} = V^+ / 2$
V_{OL}; $V_{IN+} = V_{COM}$, $V_{IN-} = V_{COM} + 1V$, $V_{COM} = V^+ / 2$



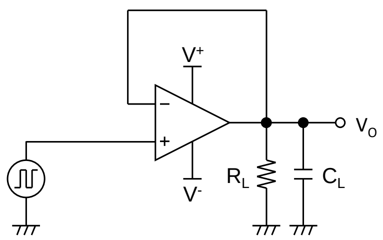
● GBW

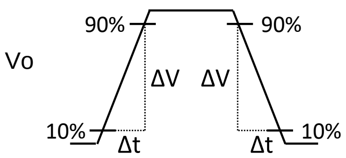
R_G = 1kΩ, R_F = 100kΩ



● SR

R_L = 10kΩ





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

■ APPLICATION NOTE

Single and Dual Supply Voltage Operation

The NL600x series works with both single supply and dual supply when the voltage supplied is between V^+ and V^-. These amplifiers operate from single 1.6V to 5.5V supply and dual ±0.8V to ±2.75V supply.

Bypassing power supply

To provide a stable supply voltage with low noise to the operational amplifier, connect the bias capacitor as close to the power supply pin as possible.

Input Offset Voltage Drift

The NL601x is a precision low power rail-to-rail input/output CMOS operational amplifier featuring low input offset voltage (150µV max.), low input offset voltage drift (0.9µV/°C max.) and low current consumption (15µA/ch).

The Xtended trimming™ high-precision trimming technology reduces the spread of offset voltage due to temperature drift compared to conventional trimming, achieving 0.9uV/°C max. in the -40°C to 125°C range. The offset change over this range is 149uV, which corresponds to 1LSB (200uV) of 3.3V, 14bit.

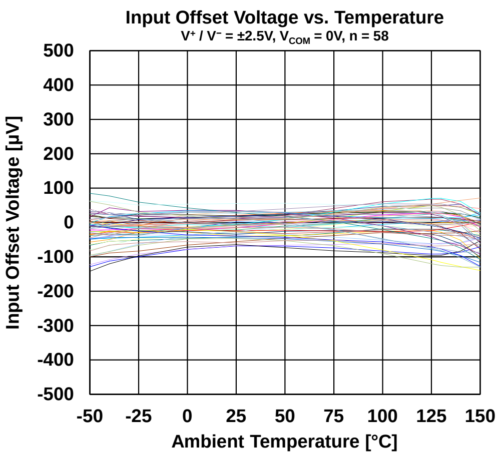
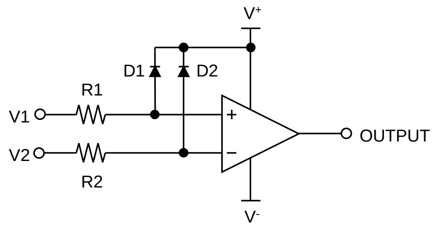


Figure1. Input Offset Voltage Drift

Input Voltage Exceeding the Supply Voltage

For the input voltage 300mV below the negative supply voltage, the ESD protection operates to protect the input terminal. At this moment, the current flowing in protection element is allowed up to 10 mA. Momentary voltages above V^+ + 0.3V, the ESD protection also activate, and clamp inputs, but cannot protect against overvoltage excepting ESD.

In some applications, it may be necessary to prevent excessive overvoltage. Figure 2 is example to protect input transistors. The external resistors R1, R2 limit the current through external diodes D1, D2.



$$(R1, R2) > \frac{V^- - (V1, V2)}{10mA}$$

$$(R1, R2) > \frac{(V1,\ V2) - V^+}{I_F}$$

I_F:Forward current of external diode.

Figure 2. Example of input protection

■ APPLICATION NOTE

Capacitive Load

The NL600x series can use at unity gain follower, but 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 cause overshoot and ringing in the step response.
The NL600x series is unity gain stable for capacitive loads of 220pF. To drive heavier capacitive loads, an isolation resistor, R_{ISO} as shown Figure 3, 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.

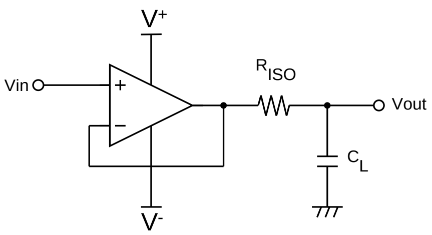


Figure 3. Isolating capacitive load

Terminating unused OpAmps

Examples of common methods of terminating an uncommitted OpAmp are shown in Figure 4. Improper termination can be result increase supply current, heating and noise in OpAmps.

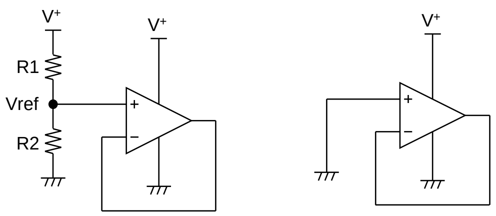
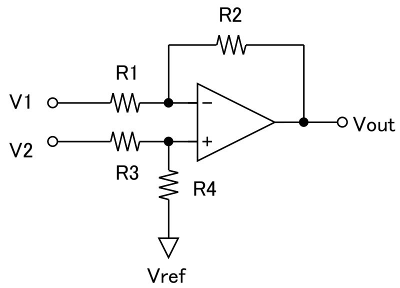


Figure 4. Terminating unused OpAmps

Differential Amplifier

Figure 5 shows a one OpAmp differential amplifier that consists of the single OpAmp and four external resistors. Differential amplifier amplifies the difference between its two input pins, and rejects the common- mode input voltage at both input pins. This is used in variety of applications including current sensing, differential to single-end converter, isolation amplifier to remove common-mode noise.



$$Vout=\left(\frac{R1+R2}{R3+R4}\right)\frac{R4}{R1}V2-\frac{R2}{R1}V1+\left(\frac{R1+R2}{R3+R4}\right)\frac{R3}{R1}Vref$$

R1=R3, R2=R4

$$Vout=\frac{R2}{R1}(V2-V1)+Vref$$

Figure 5. Differential Amplifier

The differential amplifier's common-mode rejection ratio (CMR) is primarily determined by resistor mismatches, not by the OpAmp's CMR. Ideally, the resistors are chosen such that R2/R1 = R4/R3. The CMR due to the resistors in differential amplifier can be calculated using the below formula:

$$CMR_{R\_error} \approx 20\log\left(\frac{1+\frac{R2}{R1}}{4R_{error}}\right)$$

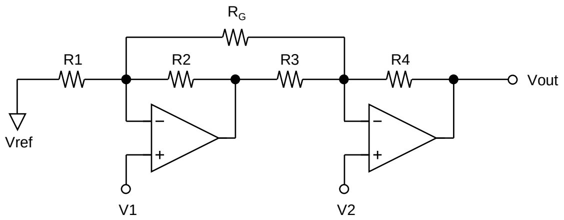
CMR_{R_error} = CMR due only to the resistors
R_{error} = Resistor's tolerance

Example:
R2 / R1 = 1 and R_{error} = 0.1%, then CMR = 54dB
R2 / R1 = 1 and R_{error} = 1%, then CMR = 34dB
If using resistors with 1% tolerance and gain = 1, the CMR will only be 34dB.

■ APPLICATION NOTE

Instrumentation Amplifier

The instrumentation amplifier is suitable for requiring high input impedance and high CMR. Figure 6 and Figure 7 is instrumentation amplifier using two or three OpAmp. Supply the reference voltage (Vref) with a low impedance source to keep accuracy.

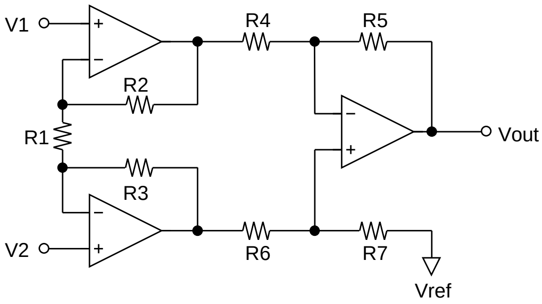


$$Vout = \left(1+\frac{R4}{R3}+\frac{2R4}{R_G}\right)(V2\text{-}V1)+Vref$$

$R1=R4, R2=R3$

$$CMR_{R\_error} \approx 20\log\left(\frac{1+\frac{R4}{R3}+\frac{2R4}{R_G}}{4R_{error}}\right)$$

Figure 6. Instrumentation Amplifier with two OpAmp



$$Vout = \left(1+\frac{2R2}{R1}\right)\left(\frac{R5}{R4}\right)(V_2\text{-}V_1)+Vref$$

$R2=R3, R4=R6, R5=R7$

$$CMR_{R\_error} \approx 20\log\left(\frac{R1+2R2}{R1}\times\frac{1+\frac{R5}{R4}}{4R_{error}}\right)$$

Figure 7. Instrumentation Amplifier with three OpAmp

Current Sensing

Current sensing applications are one such application in a wide range of electronic applications and mostly used for feedback control systems, including power metering battery life indicators and chargers, over- current protection and supervising circuit, automotive, and medical equipment. In such applications, it is desirable to use a shunt with very low resistance to minimize the series voltage drop and minimizes wasted power, and allows the measurement of high current. The NL600x series is ideal for these current sensing applications.
Figure 8 shows a high-side current sensing circuit, and Figure 9 shows a low-side current sensing circuit. The NL600x series has rail-to-rail input and output characteristics, thus allows the both of high-side and low-side current sensing circuit.
The current detection circuit uses a differential amplifier consisting of an OpAmp and resistors R1/R2/R3/R4. The differential amplifier's common-mode rejection ratio (CMR) is primarily determined by resistor mismatches. For details, refer to "Differential Amplifier" in the application note.

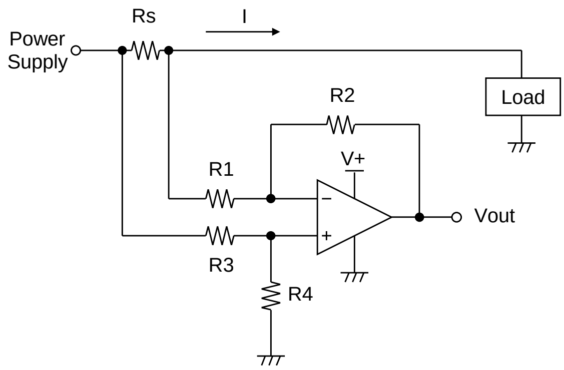


Figure 8. High-Side Current Sensing

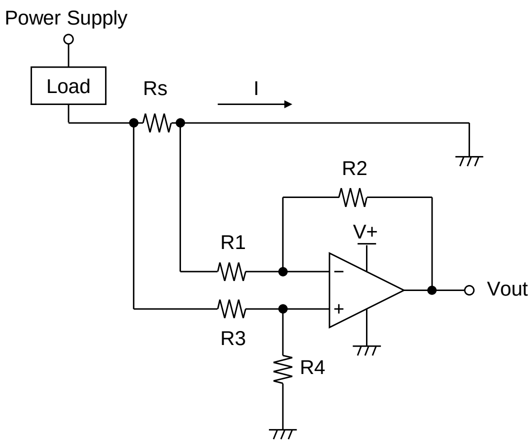
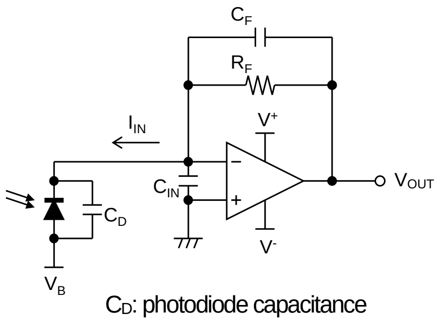


Figure 9. Low-Side Current Sensing

■ APPLICATION NOTE

Transimpedance Amplifier

The features high input impedance with CMOS input and low power can be used for transimpedance amplifier applications shown in Figure 10. The output voltage of amplifier is given by the equation $V_{OUT} = I_{IN} \cdot R_F$. Since the output voltage swing of amplifier is limited, R_F should be selected such that all possible values of I_{IN} can be detected.



C_D: photodiode capacitance
C_{IN}: OpAmp input capacitance

Figure 10. Transimpedance amplifier

The C_D, C_{IN} and R_F generate a phase lag which causes gain-peaking and can destabilized circuit. The essential component for obtaining a maximally flat response is a feedback capacitor C_F. C_F is usually added in parallel with R_F to maintain circuit stability and to control the frequency response. To maximally flat, 2nd order response, R_F and C_F should be chosen by using below equation.

$$C_F = \sqrt{\frac{C_{IN}+C_D}{GBW \times 2\pi \times R_F}}$$

Bridge Amplifier

Bridge sensors for measuring strain, pressure, and temperature are often used in the Wheatstone bridge circuit shown in Figure 11.
Since bridge output signals are typically small, amplifiers may need to operate with high gain, low offset voltage, drift, and low noise.

In addition, the bridge output signal is differential, so amplifier circuits are typically used with differential amplifiers or Instrumentation Amplifiers.

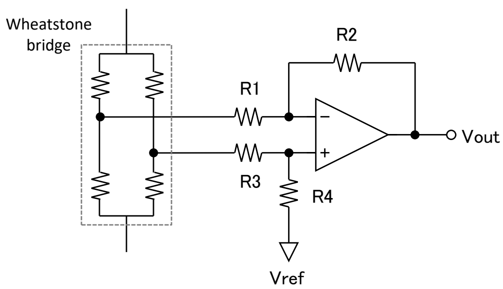


Figure 11. Bridge Amplifier

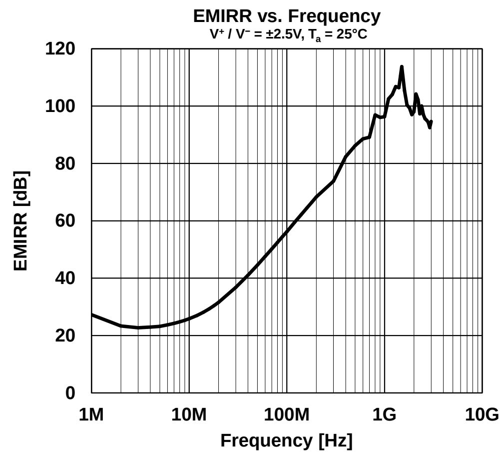
EMIRR (EMI Rejection Ratio) Definition

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

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

V_{RF_PEAK}: RF Signal Amplitude [V_P]
ΔV_{IO}: Input offset voltage shift quantity [V]

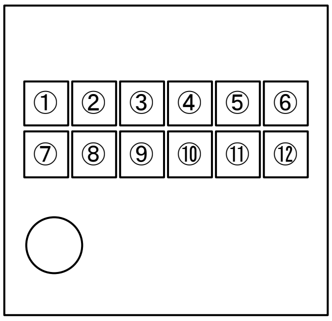
The tolerance of the RF signal can be grasped by measuring an RF signal and offset voltage shift quantity. Offset voltage shift is small so that a value of EMIRR is big. And it understands that the tolerance for the RF signal is high. In addition, about the input offset voltage shift with the RF signal, 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.



*For details, refer to "Application Note for EMI Immunity" in our HP.

■ MARKING SPECIFICATION (VSP-8-AF)

① to ⑦	Product Code	Refer to *Part Marking List*
⑧ to ⑫	Lot Number	Alphanumeric Serial Number



1Pin

NOTICE
There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact our sales or distributor before attempting to use AOI.

Part Marking List

Product Name	①	②	③	④	⑤	⑥	⑦
NL6002AFAE2D	L	6	0	0	2	A	D

■ REVISION HISTORY

Date	Revision	Changes
August 1, 2022	Ver.0.0	Initial Release
January 19, 2023	Ver.0.1	Changed Input offset voltage drift value in typical characteristics. Updated TBD values in typical characteristics.
March 6, 2023	Ver.0.2	Changed Product grade.
October 19, 2023	Ver.0.3	Added Application Note.

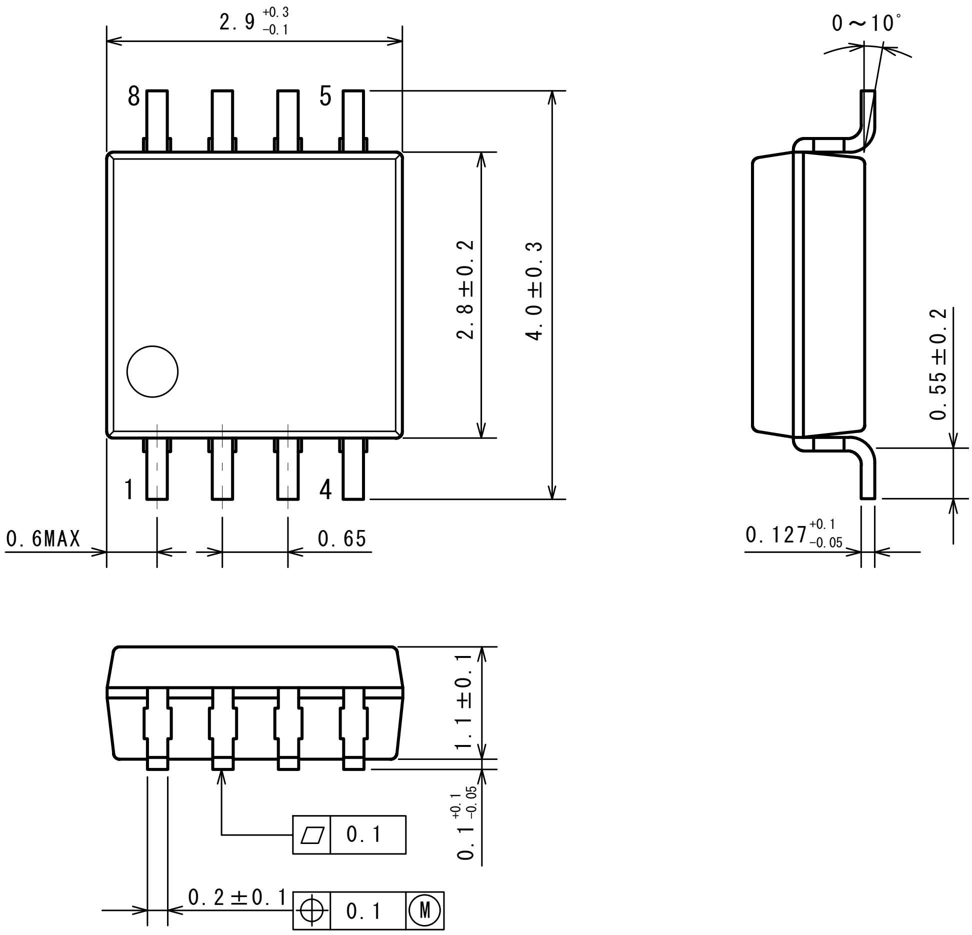
Nisshinbo Micro Devices Inc.

VSP-8-AF

PI-VSP-8-AF-E-A

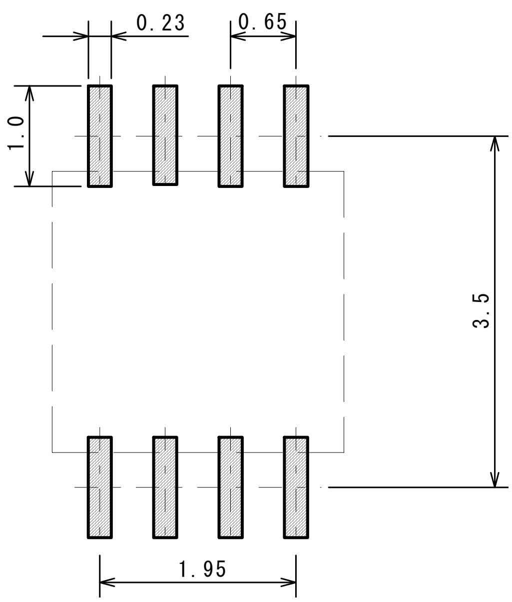
■ PACKAGE DIMENSIONS

UNIT: mm



■ EXAMPLE OF SOLDER PADS DIMENSIONS

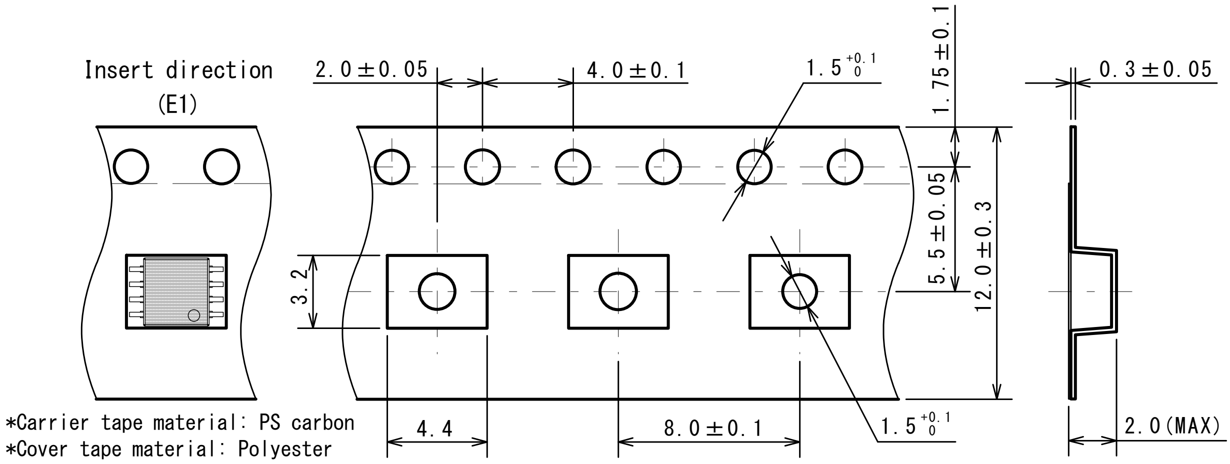
UNIT: mm

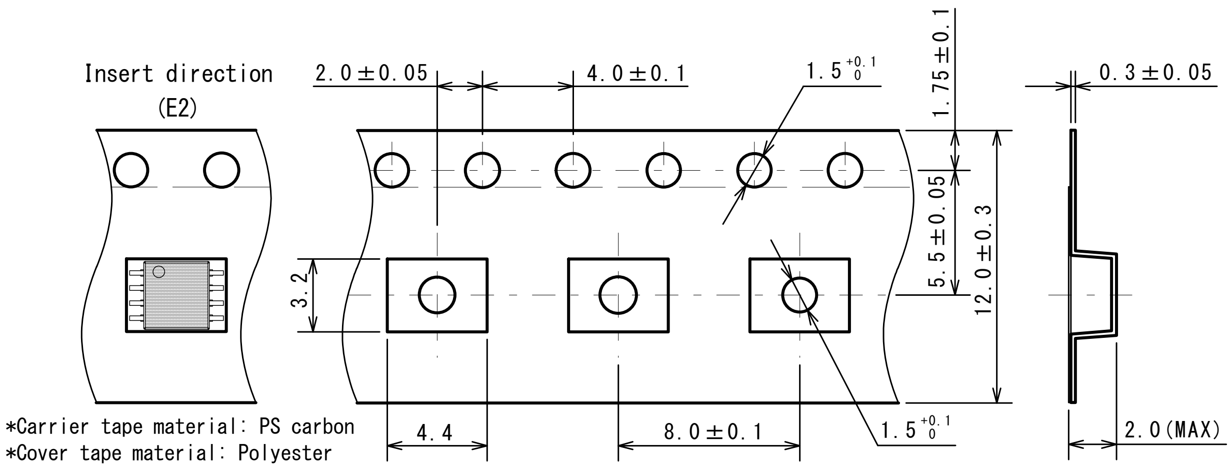


■ **PACKING SPEC**

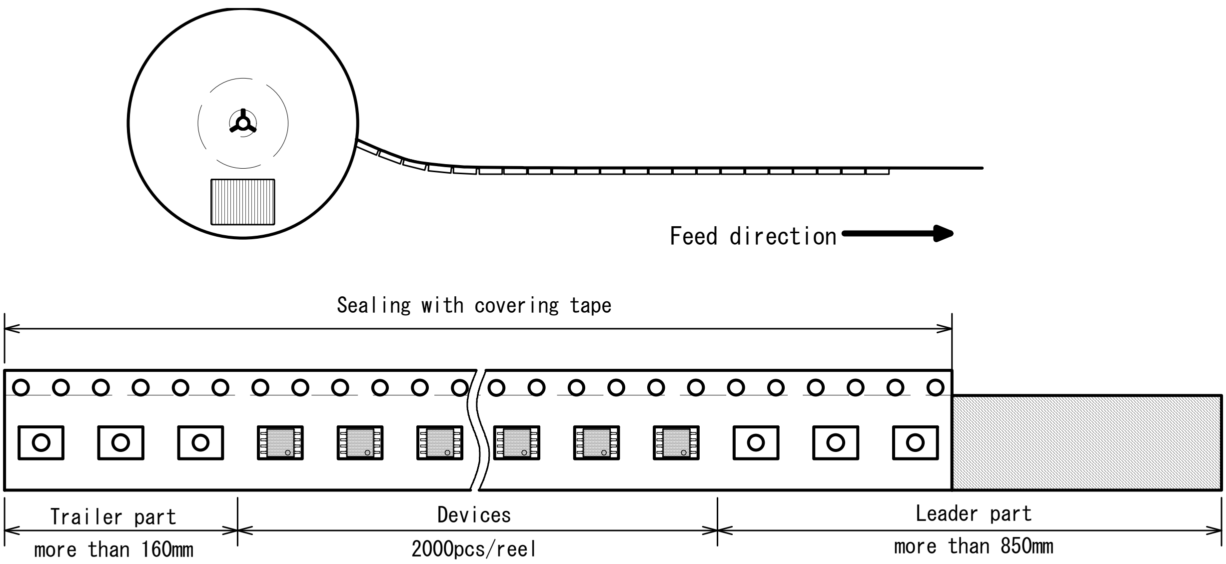
UNIT: mm

(1) Taping dimensions / Insert direction

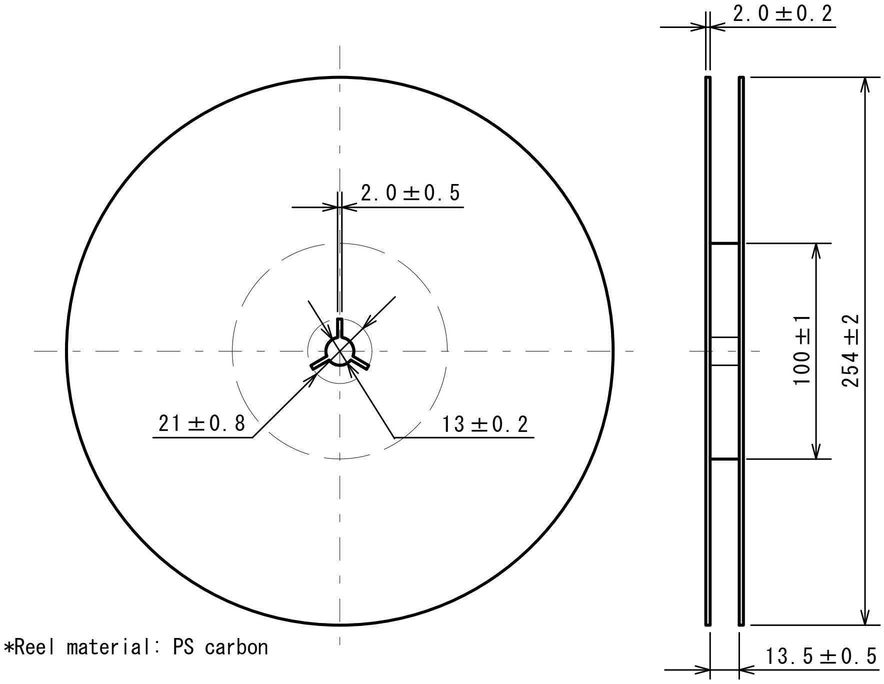




(2) Taping state



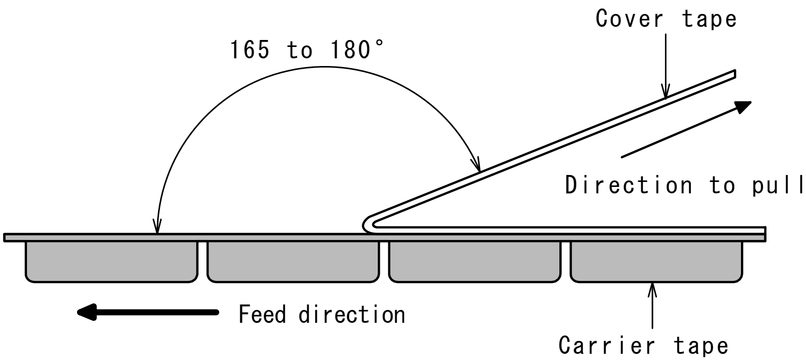
(3) Reel dimensions



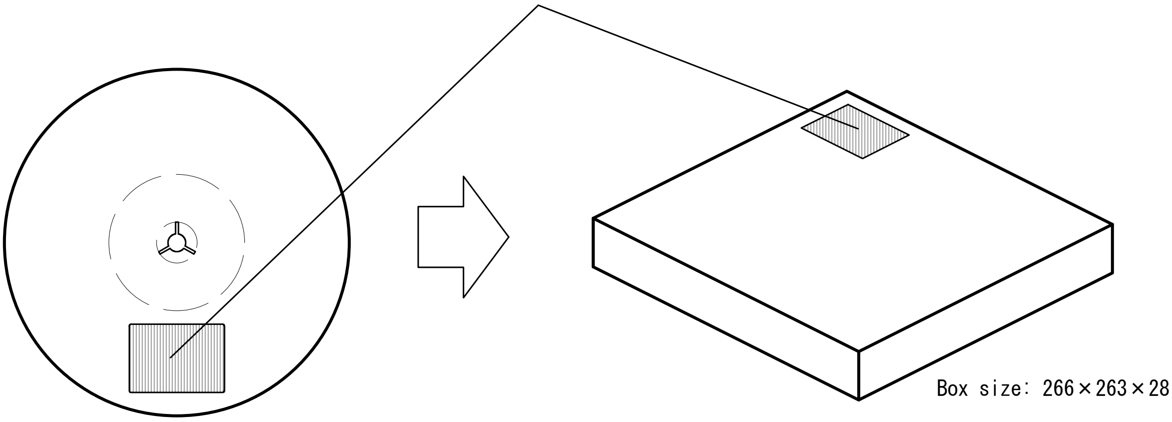
(4) Peeling strength

Peeling strength of cover tape

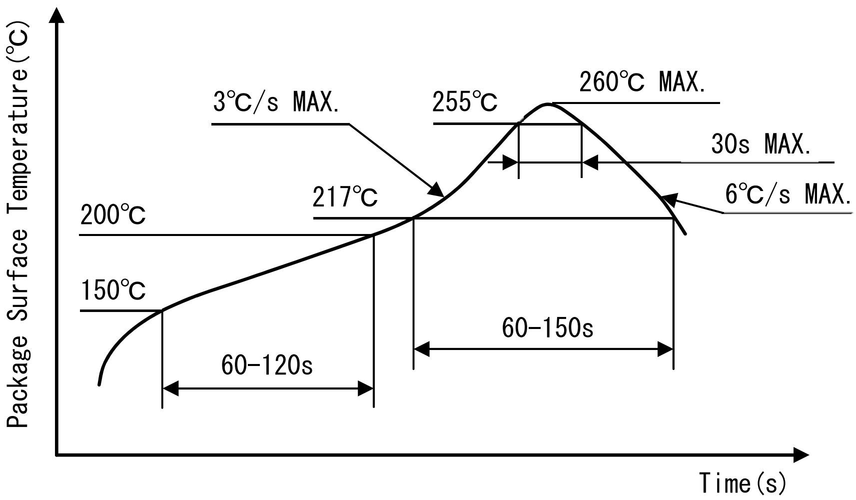
・Peeling angle	165 to 180° degrees to the taped surface.
・Peeling speed	300mm/min
・Peeling strength	0.1 to 1.3N



(5) Packing state



■ **HEAT-RESISTANCE PROFILES**



Reflow profile

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    When it has been proved defective due to manufacturing factors as a result of defect analysis by us, we will either deliver a substitute for the defective product or refund the purchase price of the defective product.
    Note that such delivery or refund is sole and exclusive remedies to your company for the defective product.

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