MINI ANALOG SERIES
0.5 μA Rail-to-Rail CMOS OPERATIONAL AMPLIFIER

S-8943xA/B Series

The mini-analog series is a group of ICs that incorporate a general-purpose analog circuit in an ultra-small package.
The S-8943xA/B series are CMOS type operational amplifiers that feature Rail-to-Rail* I/O and an internal phase compensation circuit. These features enable driving at a lower voltage (from 0.9 V) and with lower current consumption (0.5 μA typ.) than existing general-purpose operational amplifiers, making the S-8943xA/B series ideal for use in battery-powered compact portable devices.
The S-8943xA series is a single operational amplifier, with one circuit incorporated in the ultra-small SC-88A. The S-8943xB series is a dual operational amplifier, with two circuits incorporated in the slim and small 8-pin SON(A) package and 8-pin MSOP package.

* Rail-to-Rail is a registered trademark of Motorola Inc.

■ Features

- Can be driven at lower voltage than existing general-purpose operational amplifiers: V_{DD} = 0.9 to 5.5 V
- Ultra-low current consumption: I_{DD} = 0.5 μA (typ.)
- Rail-to-rail wide I/O voltage range: V_{CMR} = V_{SS} to V_{DD}
- Low input offset voltage: 5.0 mV (max.)
- No external devices required due to an internal phase compensation
- Small package: 5-Pin SC-88A 2.0 mm × 2.1 mm
  8-Pin SON(A) 2.9 mm × 3.0 mm
  8-Pin MSOP 2.95 mm × 4.0 mm

■ Applications

- Cellular phones
- PDAs
- Notebook PCs
- Digital cameras
- Digital camcorders

■ Packages

- 5-pin SC-88A (package drawing code: NP005-B)
- 8-pin SON(A) (package drawing code: PN008-A)
- 8-pin MSOP (package drawing code: FN008-A)

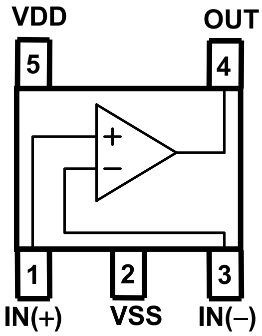
■ Selection Guide

Table 1

Package / Input Offset Voltage	SC-88A	8-Pin SON (A)	8-Pin MSOP
	Product Name (Single)	Product Name (Dual)	Product Name (Dual)
V_{IO} = 10 mV max.	S-89430ACNC-HBU-TF	S-89430BCPN-HEU-TF	S-89430BCFN-HEU-T2
V_{IO} = 5 mV max.	S-89431ACNC-HBV-TF	S-89431BCPN-HEV-TF	S-89431BCFN-HEV-T2

■ Pin Configurations

5-Pin SC-88A
Top View



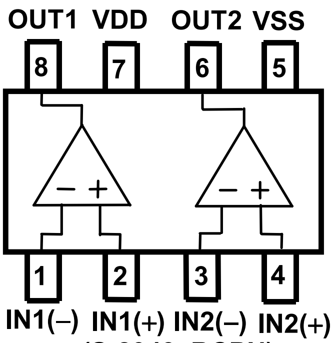
(S-8943xACNC)

Figure 1

Table 2 Pin Descriptions
(S-8943xACNC)

Pin No.	Symbol	Function	Internal Equivalent Circuit
1	IN(+)	Non-inverted input pin	Figure 5
2	VSS	GND pin	—
3	IN(−)	Inverted input pin	Figure 5
4	OUT	Output pin	Figure 4
5	VDD	Positive power pin	Figure 6

8-Pin SON(A)
Top View



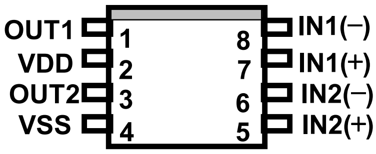
(S-8943xBCPN)

Figure 2

Table 3 Pin Descriptions
(S-8943xBCPN)

Pin No.	Symbol	Function	Internal Equivalent Circuit
1	IN1(−)	Inverted input pin 1	Figure 5
2	IN1(+)	Non-inverted input pin 1	Figure 5
3	IN2(−)	Inverted input pin 2	Figure 5
4	IN2(+)	Non-inverted input pin 2	Figure 5
5	VSS	GND pin	—
6	OUT2	Output pin 2	Figure 4
7	VDD	Positive power pin	Figure 6
8	OUT1	Output pin 1	Figure 4

8-Pin MSOP
Top View



(S-8943xBCFN)

Figure 3

Table 4 Pin Descriptions
(S-8943xBCFN)

Pin No.	Symbol	Function	Internal Equivalent Circuit
1	OUT1	Output pin 1	Figure 4
2	VDD	Positive power pin	Figure 6
3	OUT2	Output pin 2	Figure 4
4	VSS	GND pin	—
5	IN2(+)	Non-inverted input pin 2	Figure 5
6	IN2(−)	Inverted input pin 2	Figure 5
7	IN1(+)	Non-inverted input pin 1	Figure 5
8	IN1(−)	Inverted input pin 1	Figure 5

[Internal equivalent circuits]

<1> Output pin

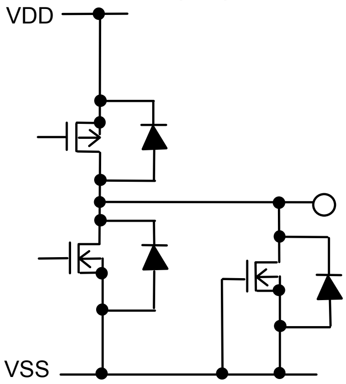


Figure 4

<2> Input pin

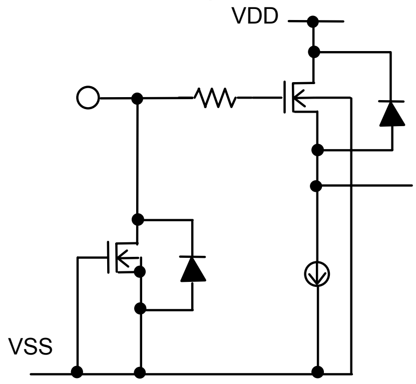


Figure 5

<3> VDD pin

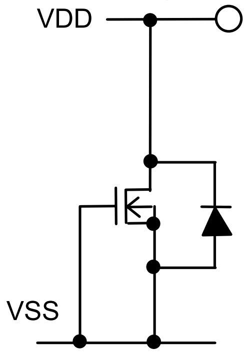


Figure 6

■ Absolute Maximum Ratings

Table 5

(Ta = 25°C unless otherwise specified)

Parameter		Symbol	Ratings	Unit
Power supply voltage		$V_{DD} - V_{SS}$	7.0	V
Input voltage		V_{IN}	V_{SS} to V_{DD}	V
Output voltage		V_{OUT}	V_{SS} to V_{DD}	V
Differential input voltage		V_{IND}	±5.5	V
Output pin current		I_{SOURCE}	7	mA
		I_{SINK}		
Power dissipation	SC-88A	P_D	200	mW
	8-pin SON (A)		300	
	8-pin MSOP		300	
Operating temperature		T_{opr}	−40 to +85	°C
Storage temperature		T_{stg}	−55 to +125	°C

Caution: Although the IC contains a static electricity protection circuit, excessive static electricity or voltage exceeding the limit of the protection circuit should not be applied.

■ Recommended Operating Power Supply Voltage Range

Table 6

Item	Symbol	Range
Operational power supply voltage range	V_{DD}	0.9 to 5.5 V

■ Electrical Characteristics

S-89430ACNC and S-89431ACNC, S-89430BCPN and S-89431BCPN, and S-89430BCFN and S-89431BCFN, differ only in the input offset voltage; all other specifications are the same.

1. V_{DD} = 3.0 V

Table 7

DC Characteristics (V_{DD} = 3.0 V) (Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Power supply current *1 (per circuit)	I_{DD}	$V_{CMR} = V_{OUT}$ = 1.5 V	—	0.5	0.9	μA	Figure 12
Input offset voltage	V_{IO}	S-89430A/B: V_{CMR} = 1.5 V	−10	±5	+10	mV	Figure 8
		S-89431A/B: V_{CMR} = 1.5 V	−5	±3	+5		
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	3.0	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V; V_{CMR} = 1.5 V, R_L = 1 MΩ	70	80	—	dB	Figure 16
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	2.95	—	—	V	Figure 10
	V_{OL}	R_L = 100 kΩ	—	—	0.05	V	Figure 11
Common mode input signal rejection ratio	CMRR	V_{SS} ≤ V_{CMR} ≤ V_{DD}	45	65	—	dB	Figure 9
Power supply voltage rejection ratio	PSRR	V_{DD} = 0.9 to 5.5 V	70	80	—	dB	Figure 7
Source current	I_{SOURCE}	$V_{OUT} = V_{DD}$ − 0.1 V	400	500	—	μA	Figure 13
		V_{OUT} = 0 V	4800	6000	—		
Sink current	I_{SINK}	V_{OUT} = 0.1 V	400	550	—	μA	Figure 14
		$V_{OUT} = V_{DD}$	4800	6000	—		

*1 When the output is saturated on the V_{DD} side, a power supply current of up to 3 to 5 μA may flow. (Refer to 4. Power supply current vs. Common-mode input voltage characteristics in the operational amplifier characteristics graphs.)

Table 8

AC Characteristics (V_{DD} = 3.0 V) (Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit
Slew rate	SR	R_L = 1.0 MΩ, C_L = 15 pF (Refer to **Figure 15**.)	—	5	—	V/ms
Gain-bandwidth product	GBP	C_L = 0 pF	—	4.8	—	kHz
Maximum load capacitance	C_L	—	—	47	—	pF

2. V_{DD} = 1.8 V

Table 9

DC Characteristics (V_{DD} = 1.8 V) (Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Power supply current *1 (per circuit)	I_{DD}	$V_{CMR} = V_{OUT}$ = 0.9 V	—	0.5	0.9	μA	Figure 12
Input offset voltage	V_{IO}	S-89430A/B: V_{CMR} = 0.9 V	−10	±5	+10	mV	Figure 8
		S-89431A/B: V_{CMR} = 0.9 V	−5	±3	+5		
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	1.8	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V; V_{CMR} = 0.9 V, R_L = 1 MΩ	66	75	—	dB	Figure 16
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	1.75	—	—	V	Figure 10
	V_{OL}	R_L = 100 kΩ	—	—	0.05	V	Figure 11
Common-mode input signal rejection ratio	CMRR	V_{SS} ≤ V_{CMR} ≤ V_{DD}	35	55	—	dB	Figure 9
		V_{SS} ≤ V_{CMR} ≤ V_{DD} − 0.3 V	45	60	—		
Power supply voltage rejection ratio	PSRR	V_{DD} = 0.9 to 5.5 V	70	80	—	dB	Figure 7
Source current	I_{SOURCE}	$V_{OUT} = V_{DD}$ − 0.1 V	220	300	—	μA	Figure 13
		V_{OUT} = 0 V	1200	1800	—		
Sink current	I_{SINK}	V_{OUT} = 0.1 V	220	300	—	μA	Figure 14
		$V_{OUT} = V_{DD}$	1200	1800	—		

*1 When the output is saturated on the V_{DD} side, a power supply current of up to 3 to 5 μA may flow. (Refer to 4. Power supply current vs. Common-mode input voltage characteristics in the operational amplifier characteristics graphs.)

Table 10

AC Characteristics (V_{DD} = 1.8 V) (Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit
Slew rate	SR	R_L = 1.0 MΩ, C_L = 15 pF (Refer to **Figure 15**.)	—	4.5	—	V/ms
Gain-bandwidth product	GBP	C_L = 0 pF	—	5	—	kHz
Maximum load capacitance	C_L	—	—	47	—	pF

3. V_{DD} = 0.9 V

Table 11

DC Characteristics (V_{DD} = 0.9 V) (Ta = 25°C unless otherwise specified)

Item	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Power supply current [*1] (per circuit)	I_{DD}	V_{CMR} = V_{OUT} = 0.45 V	—	0.5	0.9	μA	Figure 12
Input offset voltage	V_{IO}	S-89430A/B: V_{CMR} = 0.45 V	−10	±5	+10	mV	Figure 8
		S-89431A/B: V_{CMR} = 0.45 V	−5	±3	+5		
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	0.9	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V; V_{CMR} = 0.45 V, R_L = 1 MΩ	60	75	—	dB	Figure 16
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	0.85	—	—	V	Figure 10
	V_{OL}	R_L = 100 kΩ	—	—	0.05	V	Figure 11
Common-mode input signal rejection ratio	CMRR	V_{SS} ≤ V_{CMR} ≤ V_{DD}	25	55	—	dB	Figure 9
		V_{SS} ≤ V_{CMR} ≤ V_{DD} − 0.35 V	40	60	—		
Power supply voltage rejection ratio	PSRR	V_{DD} = 0.9 to 5.5 V	70	80	—	dB	Figure 7
Source current	I_{SOURCE}	V_{OUT} = V_{DD} − 0.1 V	25	65	—	μA	Figure 13
		V_{OUT} = 0 V	40	140	—		
Sink current	I_{SINK}	V_{OUT} = 0.1 V	10	65	—	μA	Figure 14
		V_{OUT} = V_{DD}	12	120	—		

*1 When the output is saturated on the V_{DD} side, a power supply current of up to 3 to 5 μA may flow. (Refer to 4. Power supply current vs. Common-mode input voltage characteristics in the operational amplifier characteristics graphs.)

Table 12

AC Characteristics (V_{DD} = 0.9 V) (Ta = 25°C unless otherwise specified)

Item	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit
Slew rate	SR	R_L = 1.0 MΩ, C_L = 15 pF (Refer to **Figure 15**.)	—	4	—	V/ms
Gain-bandwidth product	GBP	C_L = 0 pF	—	5	—	kHz
Maximum load capacitance	C_L	—	—	47	—	pF

■ Measurement Circuits

1. Power supply voltage rejection ratio

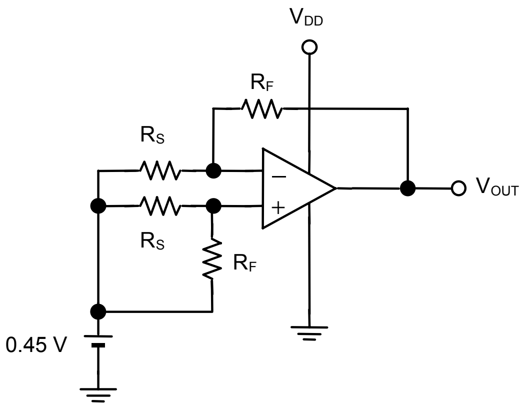


Figure 7

- Power supply voltage rejection ratio (PSRR)
  The power supply rejection ratio (PSRR) can be calculated by the following formula, with the value of V_{OUT} measured at each V_{DD}.

Measurement conditions:
When V_{DD} = 0.9 V: $V_{DD} = V_{DD1}$, $V_{OUT} = V_{OUT1}$
When V_{DD} = 5.5 V: $V_{DD} = V_{DD2}$, $V_{OUT} = V_{OUT2}$

$$PSRR = 20\log\left(\left|\frac{V_{DD1} - V_{DD2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{R_F + R_S}{R_S}\right)$$

2. Input offset voltage

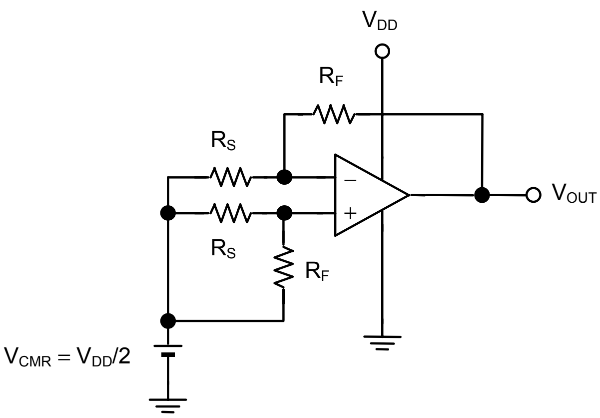


Figure 8

- Input offset voltage (V_{IO})

$$V_{IO} = \left(V_{OUT} - \frac{V_{DD}}{2}\right) \times \frac{R_S}{R_F + R_S}$$

3. Common-mode input signal rejection ratio, common-mode input voltage

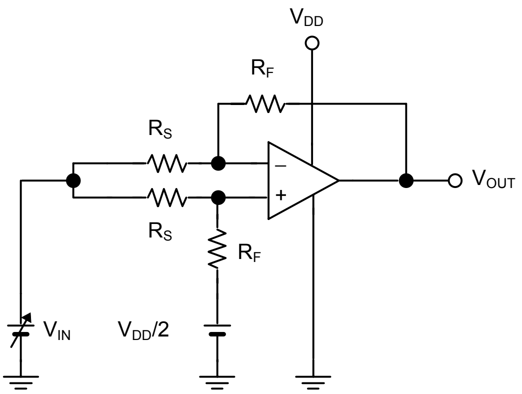


Figure 9

- Common-mode input signal rejection ratio (CMRR)

  The common-mode input signal rejection ratio (CMRR) can be calculated by the following formula, with the value of V_{OUT} measured at each V_{IN}.

  Measurement conditions:

  When $V_{IN} = V_{CMR}$ (Max.): $V_{IN} = V_{IN1}$, $V_{OUT} = V_{OUT1}$

  When $V_{IN} = V_{CMR}$ (Min.): $V_{IN} = V_{IN2}$, $V_{OUT} = V_{OUT2}$

$$CMRR = 20\log\left(\left|\frac{V_{IN1} - V_{IN2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{(R_F + R_S)}{R_S}\right)$$

- Common-mode input voltage (V_{CMR})

  The common-mode input voltage (V_{CMR}) is the range of input voltage within which V_{OUT} satisfies the common-mode rejection ratio specification when V_{IN2} is varied.

4. Maximum output swing voltage

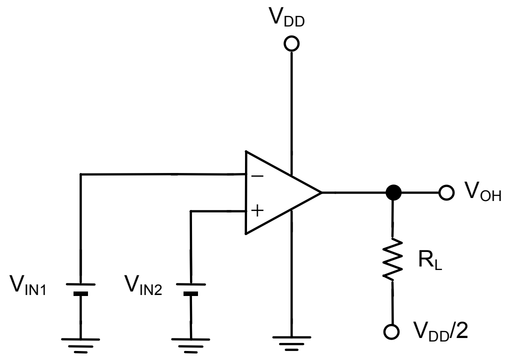


Figure 10

- Maximum output swing voltage (V_{OH})

  Measurement conditions:

$$V_{IN1} = \frac{V_{DD}}{2} - 0.1\,V$$

$$V_{IN2} = \frac{V_{DD}}{2} + 0.1\,V$$

R_L = 100 kΩ

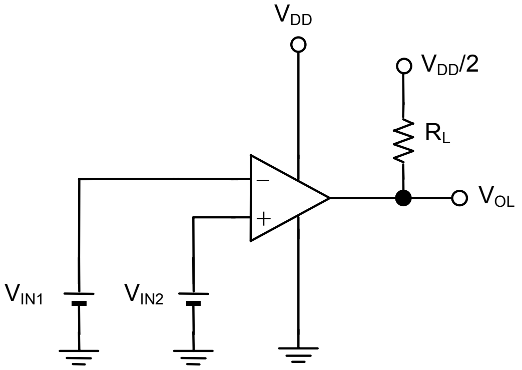


Figure 11

- Maximum output swing voltage (V_{OL})

  Measurement conditions:

$$V_{IN1} = \frac{V_{DD}}{2} + 0.1\,V$$

$$V_{IN2} = \frac{V_{DD}}{2} - 0.1\,V$$

R_L = 100 kΩ

5. Power supply current

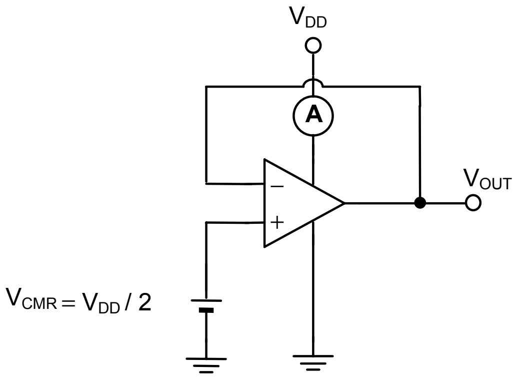


Figure 12

• Power supply current (I_{DD})

Measurement conditions:

$$V_{CMR} = \frac{V_{DD}}{2}$$

6. Source current

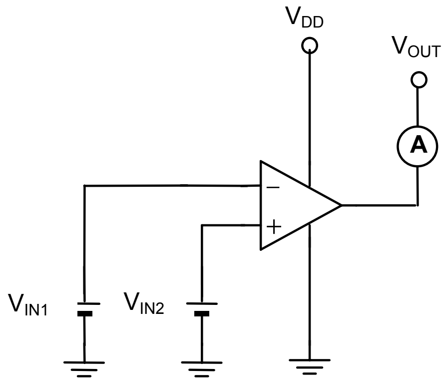


Figure 13

• Source current (I_{SOURCE})

Measurement conditions:

$V_{OUT} = V_{DD} - 0.1$ V or $V_{OUT} = 0$ V

$$V_{IN1} = \frac{V_{DD}}{2} - 0.1\ \text{V}$$

$$V_{IN2} = \frac{V_{DD}}{2} + 0.1\ \text{V}$$

7. Sink current

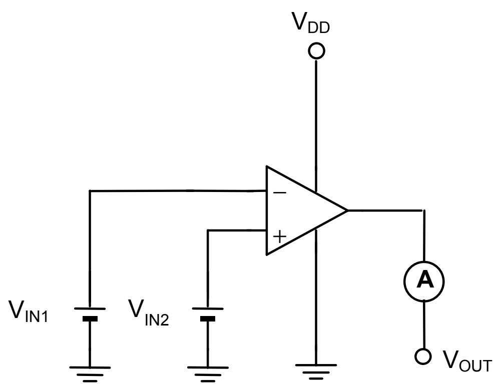


Figure 14

• Sink current (I_{SINK})

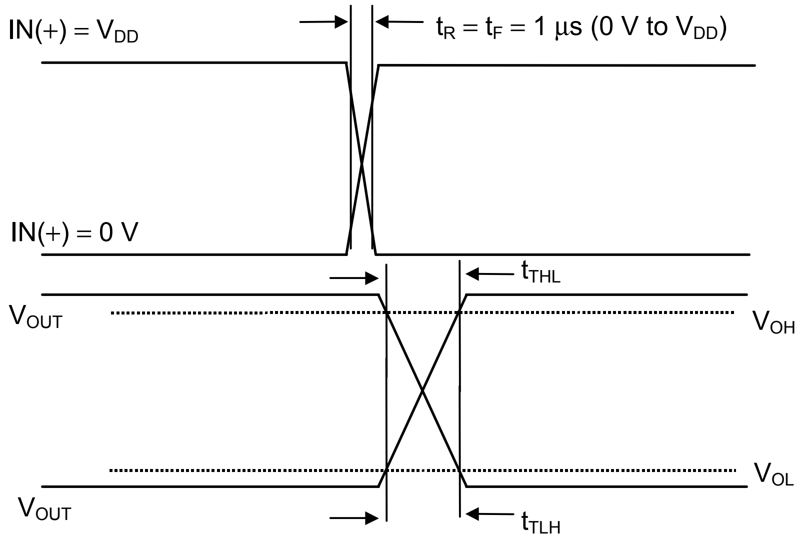
Measurement conditions:

$V_{OUT} = 0.1$ V or $V_{OUT} = V_{DD}$

$$V_{IN1} = \frac{V_{DD}}{2} + 0.1\ \text{V}$$

$$V_{IN2} = \frac{V_{DD}}{2} - 0.1\ \text{V}$$

8. Slew rate (SR)



When falling

$$SR = \frac{V_{OH} - V_{OL}}{t_{THL}}$$

When rising

$$SR = \frac{V_{OH} - V_{OL}}{t_{TLH}}$$

Figure 15

V_{OH} = 2.7 V (when V_{DD} = 3.0 V), 1.62 V (when V_{DD} = 1.8 V), 0.81 V (when V_{DD} = 0.9 V)
V_{OL} = 0.3 V (when V_{DD} = 3.0 V), 0.18 V (when V_{DD} = 1.8 V), 0.09 V (when V_{DD} = 0.9 V)

9. Voltage gain (open loop)

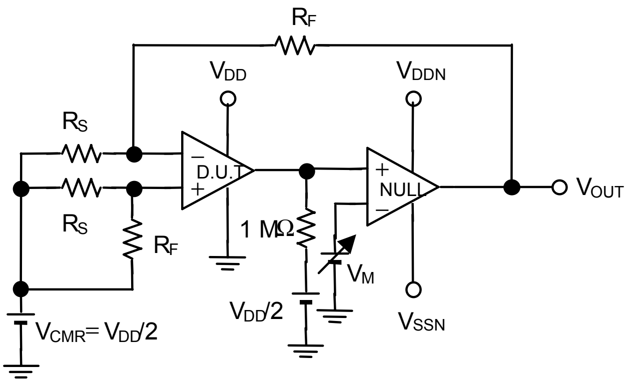


Figure 16

• Voltage gain (open loop) (A_{VOL})
The voltage gain (A_{VOL}) can be calculated by the following formula, with the value of V_{OUT} measured at each V_M.

Measurement conditions:
When $V_M = V_{DD} - 0.1$ V: $V_M = V_{M1}$, $V_{OUT} = V_{OUT1}$
When $V_M = 0.1$ V: $V_M = V_{M2}$, $V_{OUT} = V_{OUT2}$

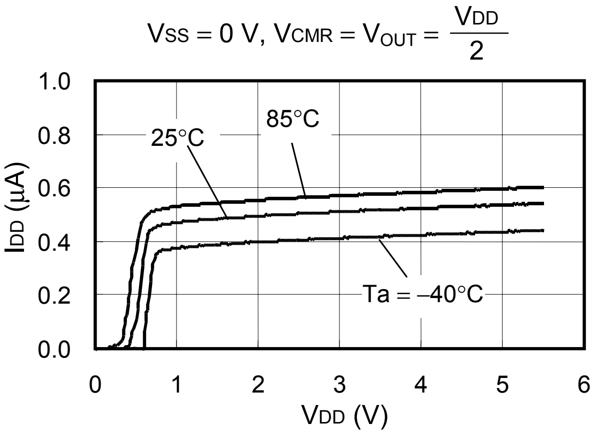
$$A_{VOL} = 20\log\left(\left|\frac{V_{M1} - V_{M2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{(R_F + R_S)}{R_S}\right)$$

■ Cautions

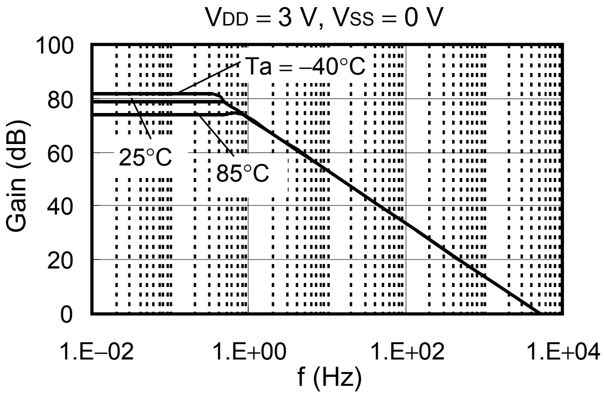
- Note that when the output is saturated on the V_{DD} side, a power supply current of up to 3 to 5 μA may flow. (Refer to 4. Power Supply Current vs. Common-mode input voltage characteristics in the operational amplifier characteristics graphs.)
- Be sure to use the product with an output current of no more than 7 mA

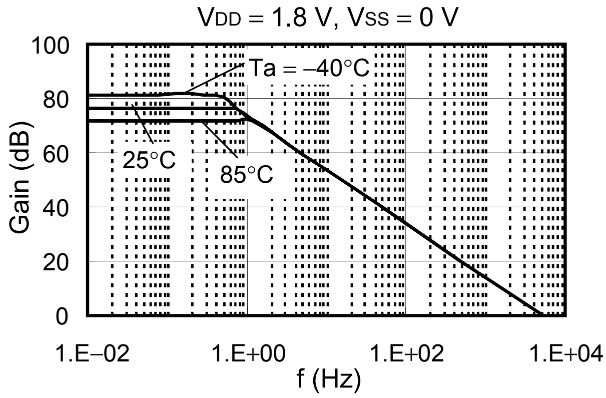
■ **Operational Amplifier Characteristics** (All Data Indicates Typical Values for One Circuit)

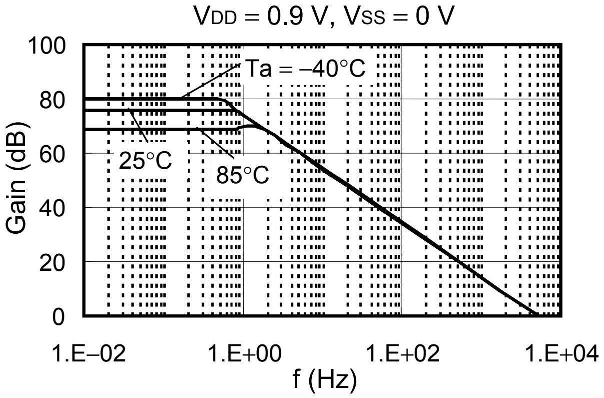
1. Power supply current vs. Power supply voltage



2. Voltage gain vs. Frequency

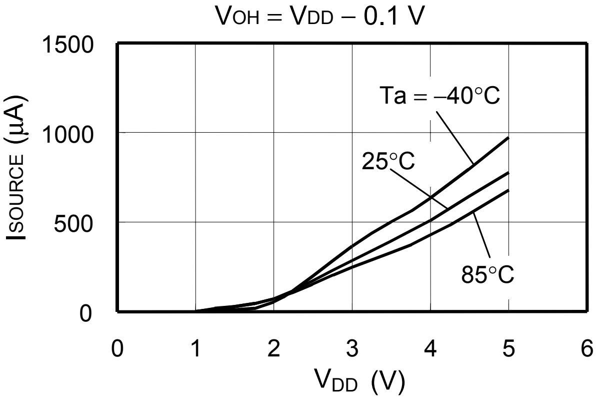




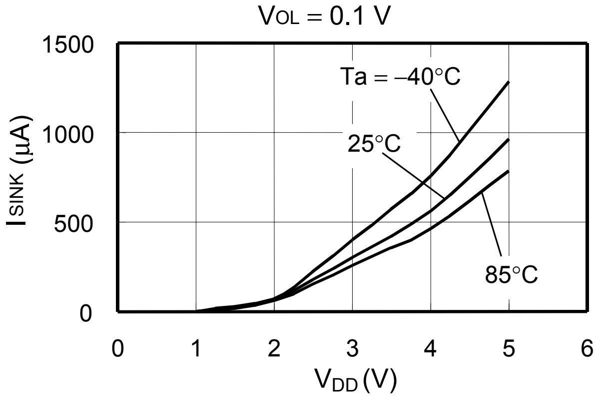


3. Output Current Characteristics

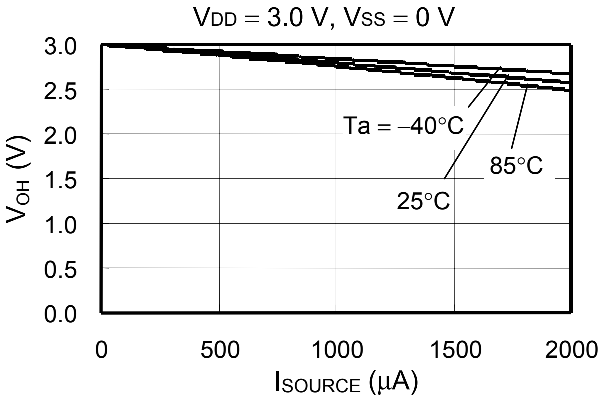
3-1. I_{SOURCE} vs. Power supply voltage

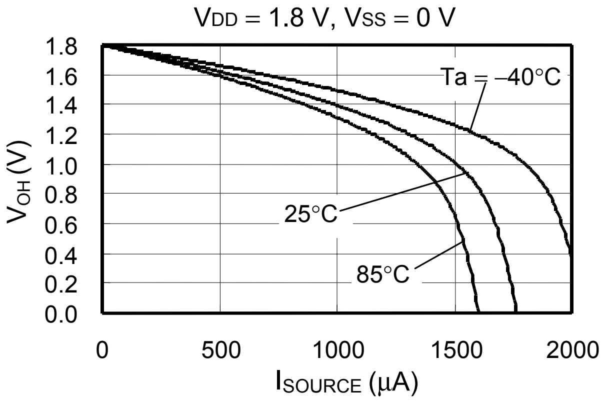


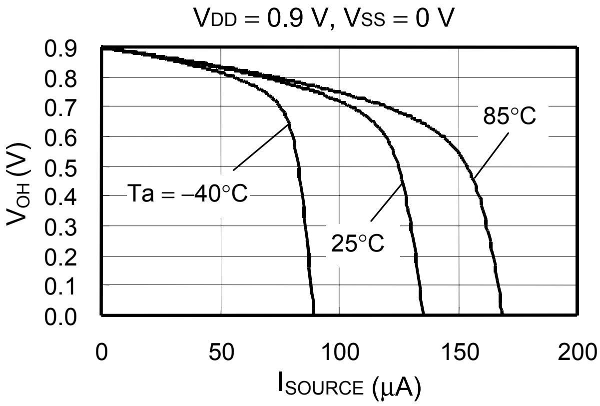
I_{SINK} vs. Power supply voltage



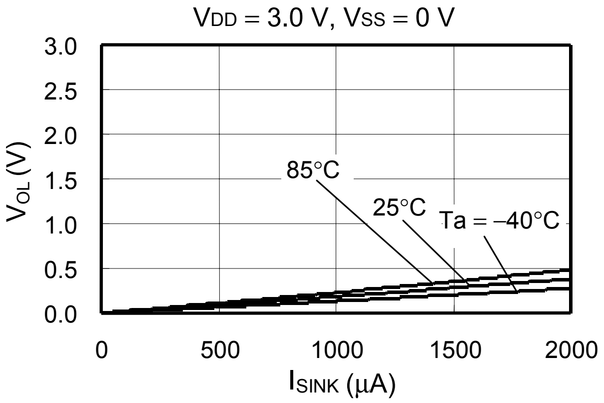
3-2. I_{SOURCE} vs. Output voltage (V_{OH})

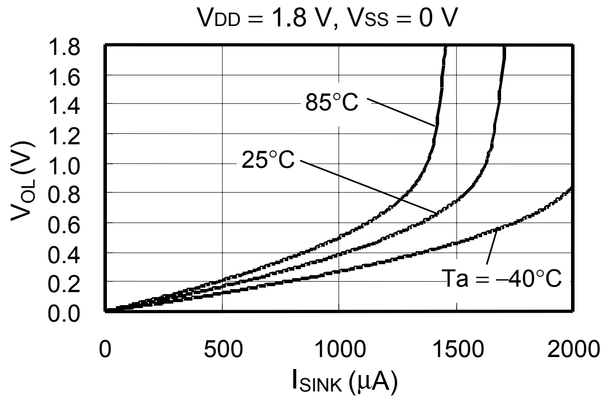


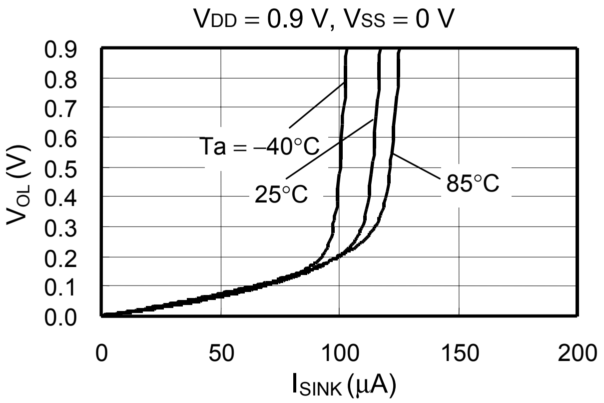




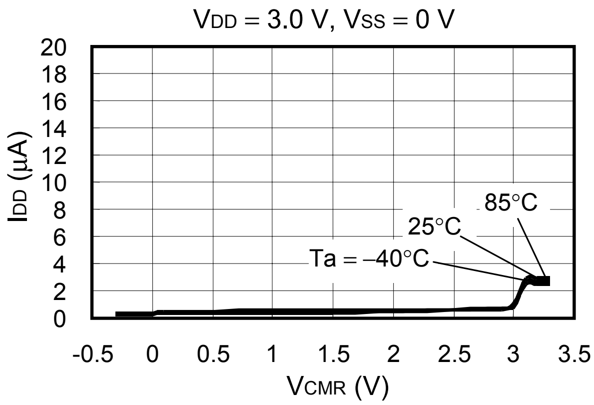
3-3. I_{SINK} vs. Output voltage (V_{OL})







4. Power supply current vs. Common-mode input voltage (voltage follower configuration)

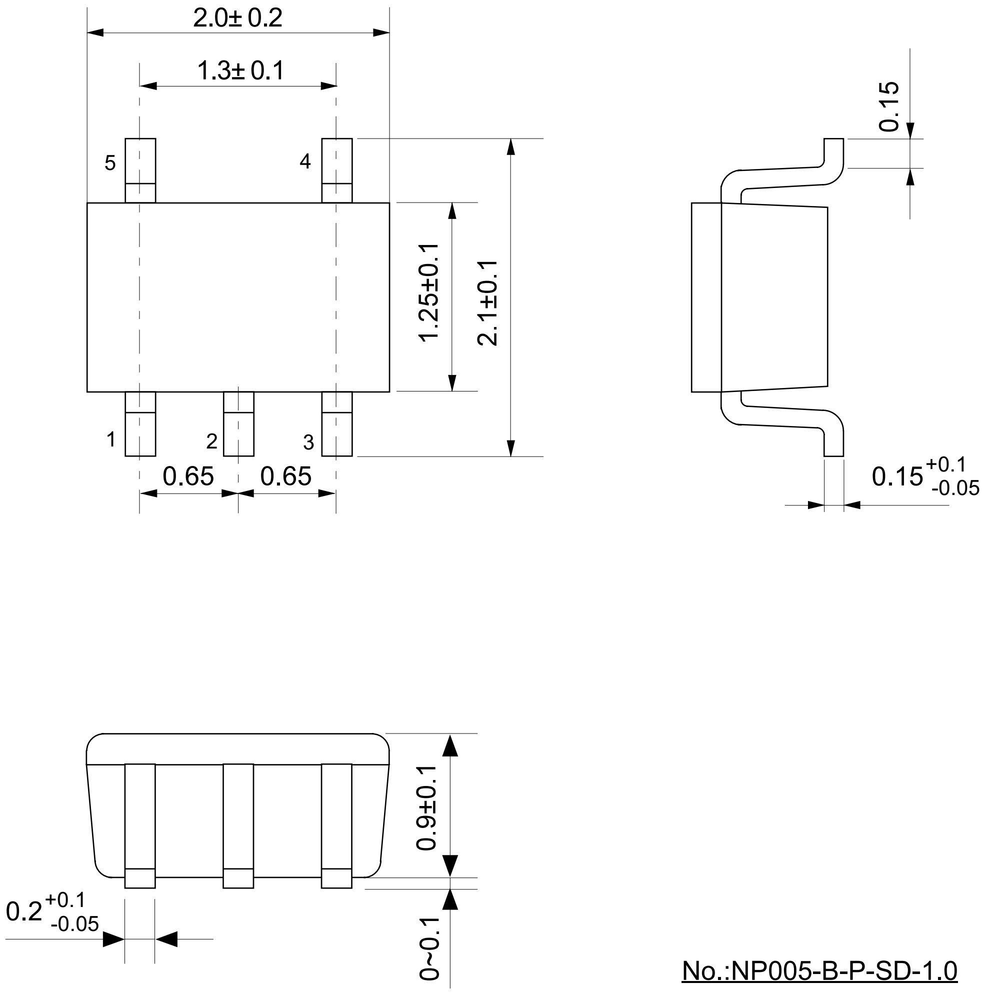


■ SC-88A

NP005-B Rev.1.1 020517

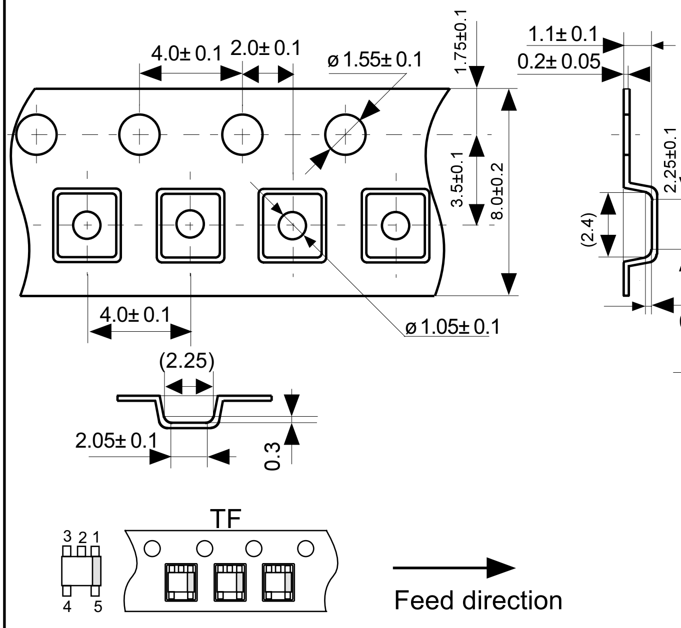
●Dimensions

Unit：mm



No.:NP005-B-P-SD-1.0

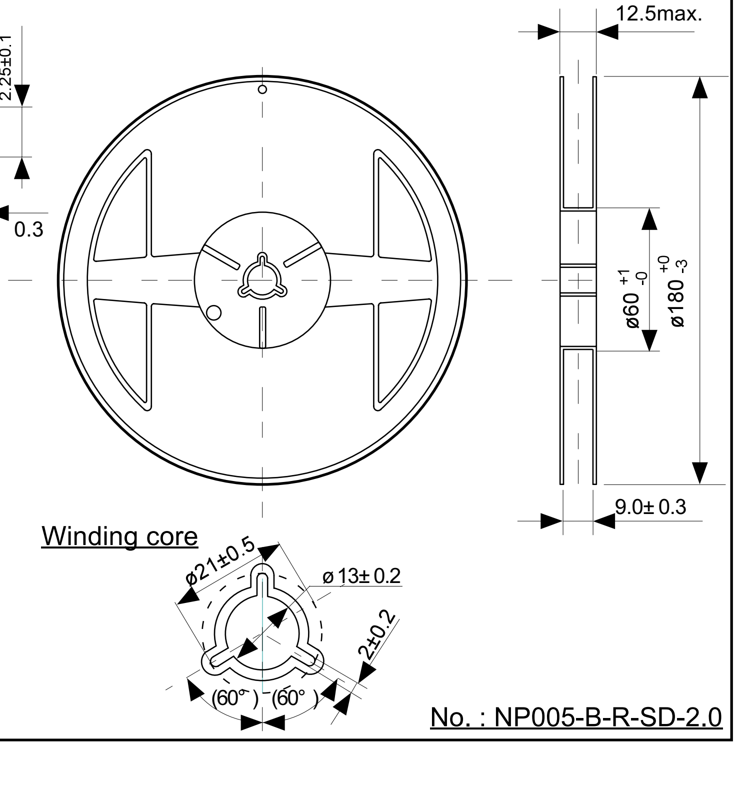
●Taping Specifications



No. : NP005-B-C-SD-1.0

●Reel Specifications

3000 pcs/reel



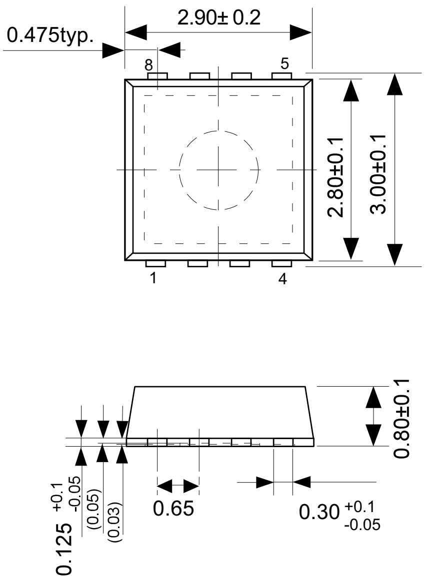
No. : NP005-B-R-SD-2.0

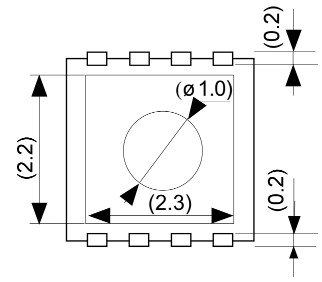
■ SON8A

PN008-A **Rev.1.0** 011218

● Dimensions

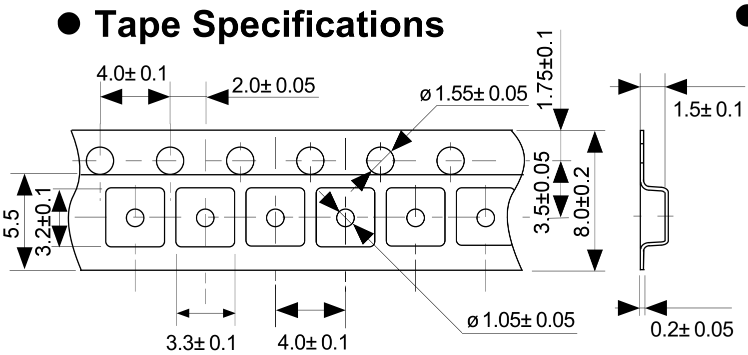
Unit : mm

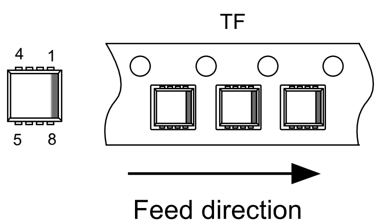




No. : PN008-A-P-SD-1.0

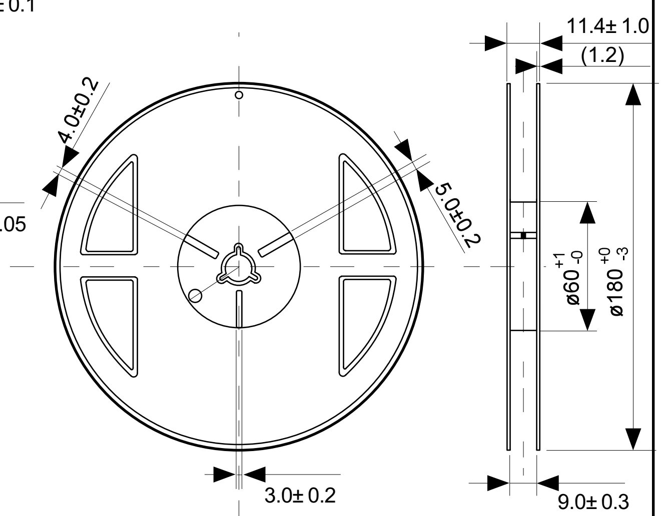
● Tape Specifications



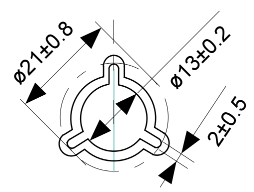


● Reel Specifications

3000 pcs/reel



Winding core



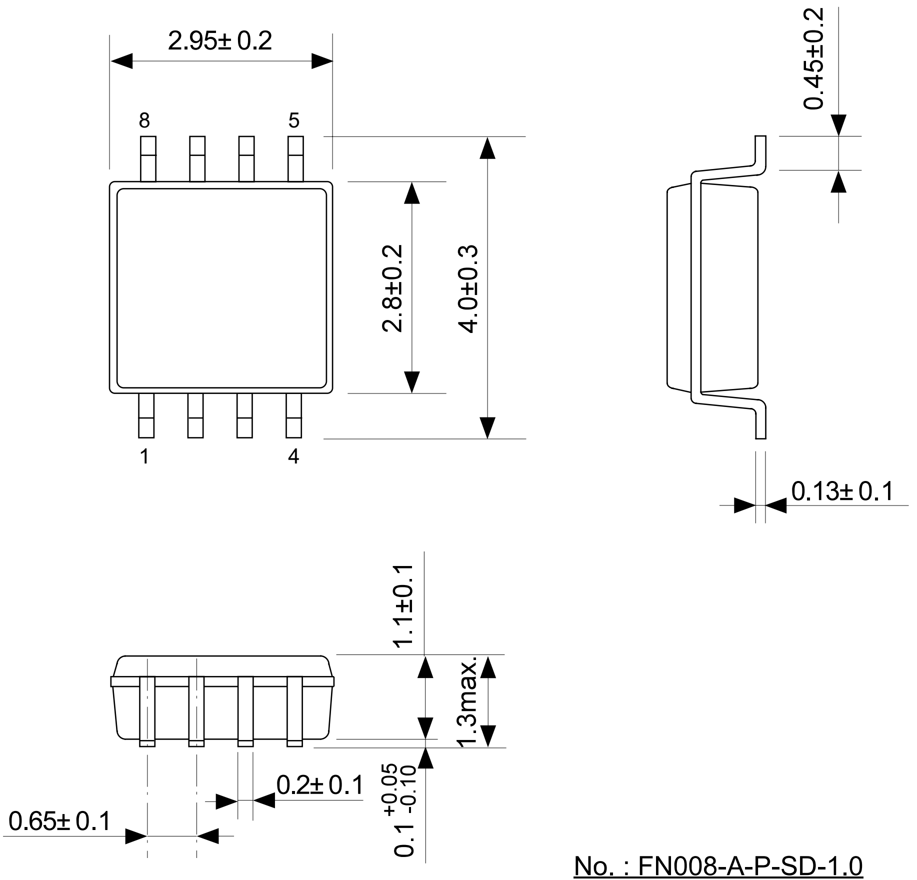
No. : PN008-A-C-SD-1.0

No. : PN008-A-R-SD-1.0

■ 8-Pin MSOP

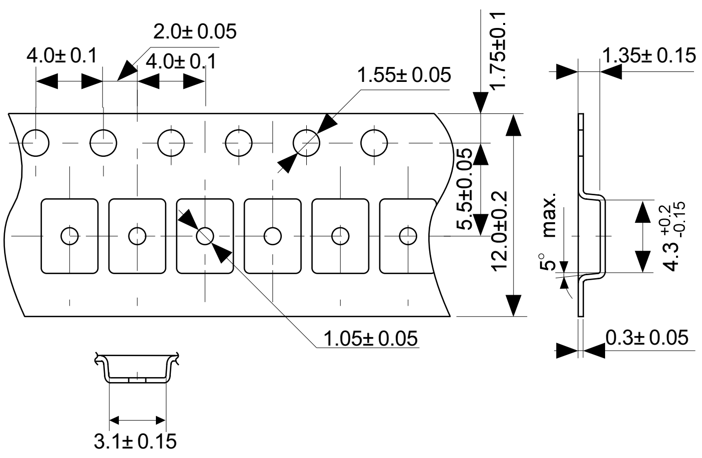
FN008-A **Rev.1.0** 020213

● Dimensions

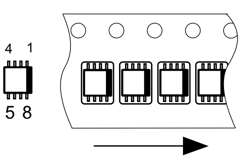


No. : FN008-A-P-SD-1.0

● Tape Specifications



T2

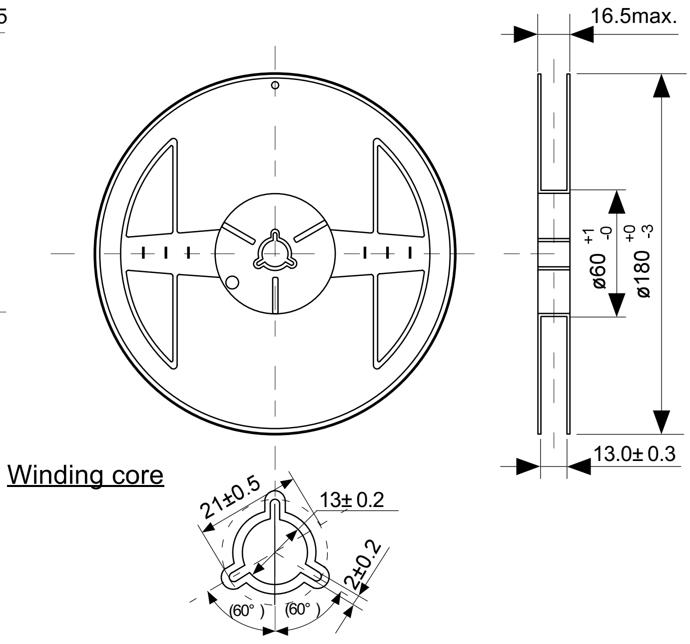


Feed direction

No. : FN008-A-C-SD-1.0

● Reel Specifications

3000 pcs/reel



No. : FN008-A-R-SD-1.0