Amplifier for resolver excitation

■ FEATURES

- AEC-Q100 Grade 1 is planning
- Differential Voltage Input/ Differential Current Output
  Transconducance 13.5mA$_p$/V$_{pp}$ typ.
- Operating Voltage 2.4V to 5.5V
- Supply Current 4.5mA typ.
- Thermal shutdown
- Shutdown function
- Operating Temperature -40°C to 125°C
- Package SSOP16-B3

■ APPLICATIONS

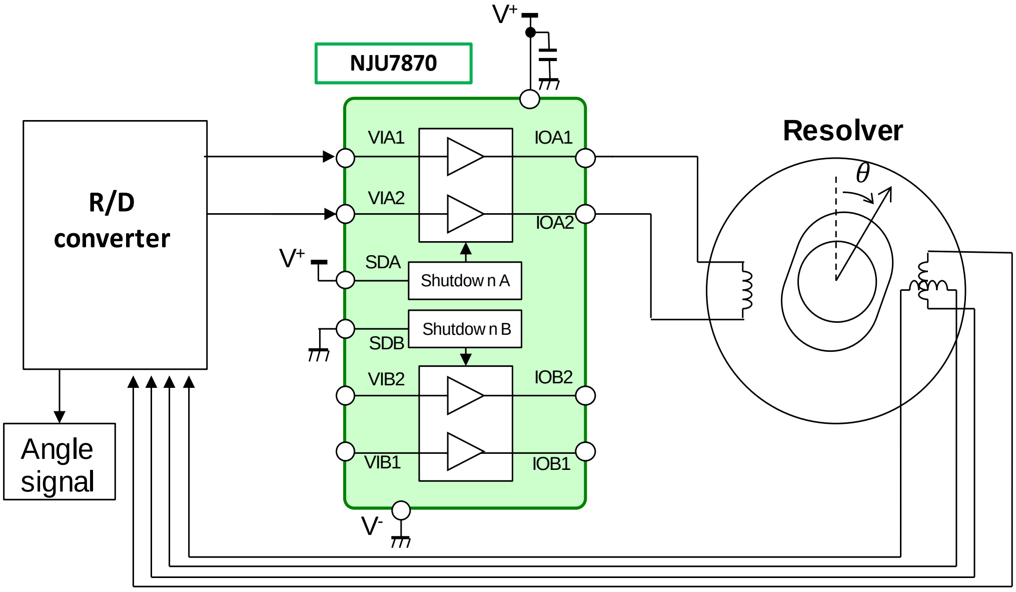
- Angle Resolver

■ DESCRIPTION

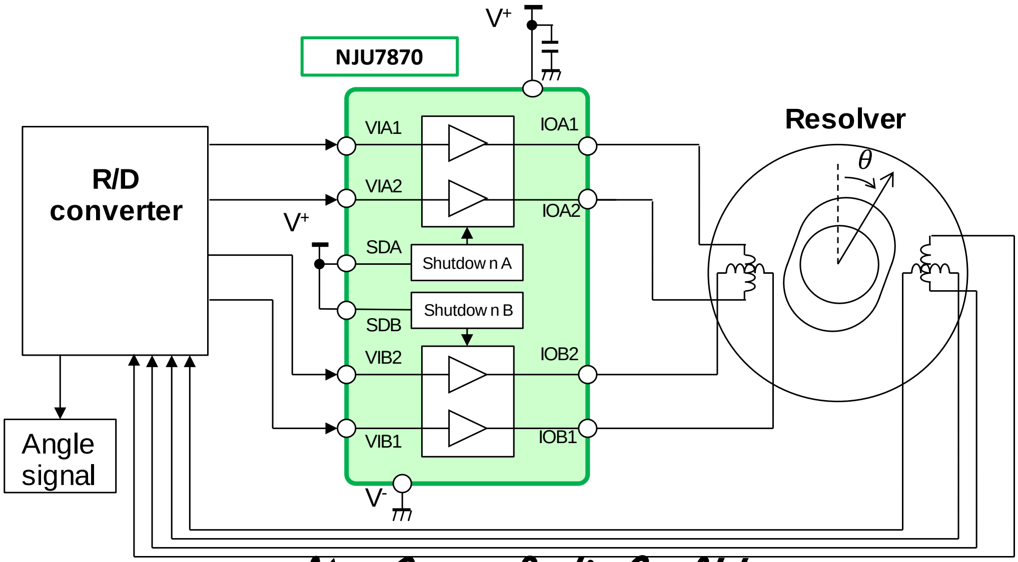
NJU7870 is an IC with integrated resolver excitation function. It has a built-in 2-channel excitation circuit for differential voltage input and differential current output. It is possible to control each circuit from the external input, and combine with various resolver systems such as 1-phase excitation or 2-phase excitation.
In addition, the NJU7870 achieves high precision performance matching for each phase that has been difficult to achieve with a discrete configuration.
The NJU7870 adopts the small package SSOP16-B3, and the external parts are only the capacitor connected to the power supply. It contributes to a significant reduction in mounting area compared with the conventional discrete circuit configuration.

■ TYPICAL APPLICATION

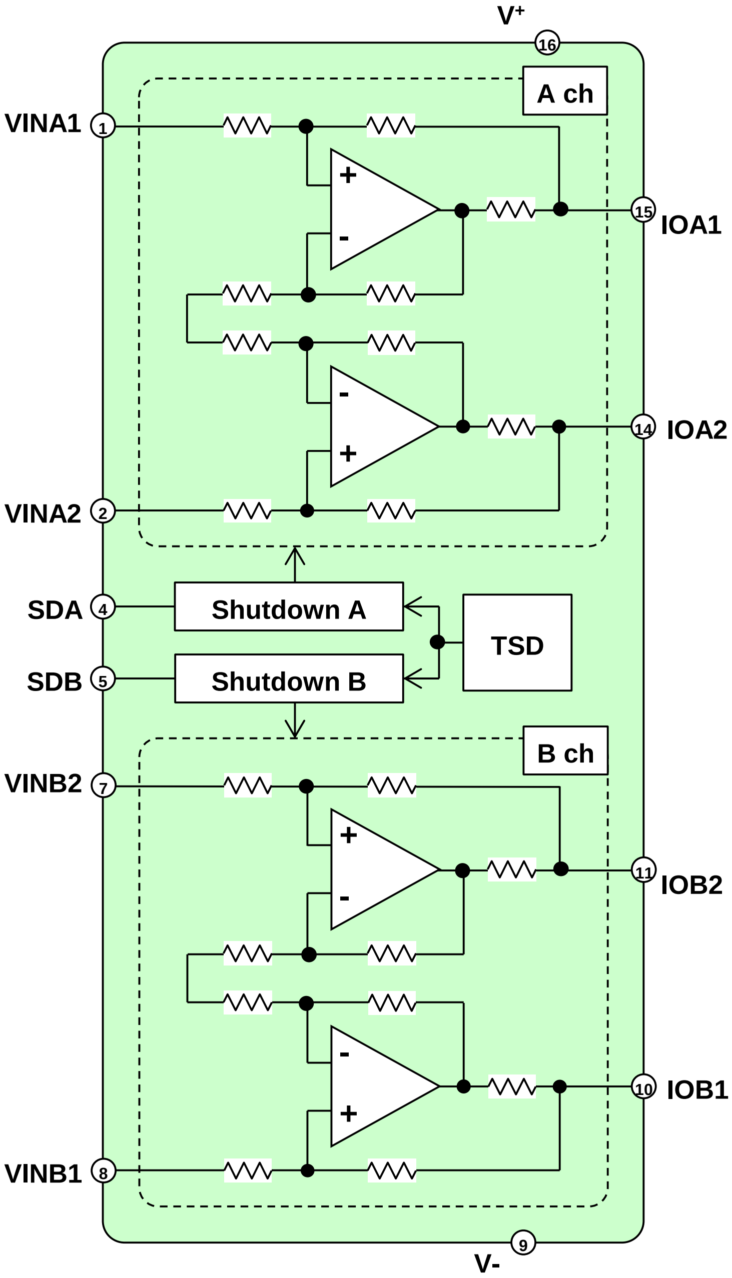
●1-phase excitation 2-phase output



●2-phase excitation 2-phase output



■ BLOCK DIAGRAM

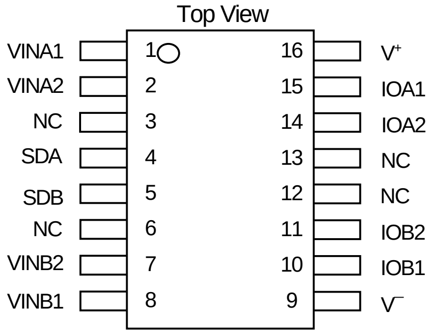


SDA SDB	State
H	Normal Function
L	Shutdown
Open	Shutdown

■ PIN CONFIGURATIONS

SSOP16-B3

Top View



PIN NO.	NAME	I/O	FUNCTION	REMARKS
1	VINA1	I	Ach Analog Input 1	
2	VINA2	I	Ach Analog Input 2	
3	NC	-	No Connect	
4	SDA	I	Ach Shutdown Input (High Active)	100k pull-down
5	SDB	I	Bch Shutdown Input (High Active)	100k pull-down
6	NC	-	No Connect	
7	VINB2	I	Bch Analog Input 2	
8	VINB1	I	Bch Analog Input 1	
9	V^-	G	GND	
10	IOB1	O	Bch Analog Output 1	
11	IOB2	O	Bch Analog Output 2	
12	NC	-	No Connect	
13	NC	-	No Connect	
14	IOA2	O	Ach Analog Output 2	
15	IOA1	O	Ach Analog Output 1	
16	V^+	-	Supply	

■ PRODUCT NAME INFORMATION

NJU7870 VB3 - Z2 (TE1)

Part Number: NJU7870
Package: VB3 (VB3: SSOP16-B3)
Grade: Z2 (Z2: Automotive)
Taping Form: (TE1)

■ ORDERING INFORMATION

PRODUCT NAME	PACKAGE	RoHS	HALOGEN FREE	TERMINAL FINISH	MARKING	WEIGHT (mg)	MOQ (pcs)
NJU7870VB3-Z2 (TE1)	SSOP16-B3	yes	yes	Sn2Bi	7870Z2	68	2000

* The detail information of automotive grades and recommended applications are described in NJR Web site.
(https://www.njr.com/electronic_device/semiconductor/application/automotive.html)

■ ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	RATING	UNIT
Supply Voltage	$V^+ - V^-$	7	V
Differential Input Voltage(1)	V_{ID}	±7	V
Input Voltage (2)	V_{IN}	V^- −0.3 to V^+ +0.3	V
Power Dissipation (T_a = 25°C) SSOP16-B3	P_D	2-Layer / 4-Layer 870 (3) / 1200 (4)	mW
Storage Temperature	T_{stg}	−55 to 150	°C
Junction Temperature	T_j	150	°C

(1) Differential voltage is the voltage difference between VINA1 and VINA2.
(2) Input voltage is the voltage should be allowed to apply to the input terminal independent of the magnitude of V^+.
(3) 2-Layer: Mounted on glass epoxy board (76.2 mm × 114.3 mm × 1.6 mm: based on EIA/JEDEC standard, 2-layer FR-4).
(4) 4-Layer: 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.

■ RECOMMENDED OPERATING CONDITIONS

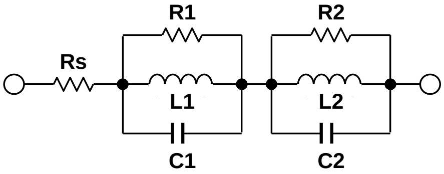
PARAMETER	SYMBOL	VALUE	UNIT
Supply Voltage	$V^+ - V^-$	2.4 to 5.5	V
Operating Temperature	T_{opr}	−40 to 125	°C

■ ELECTRICAL CHARACTERISTICS

(V^+ = 3.0V to 5.5V, V^- = 0V, V_{IC} = V^+/2, Z_L: resolver model (note1), V_{SDA}=V_{SDB}=V^+, T_a = 25°C, unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
AMP (Propagation Characteristic)						
Transconductance	G_m	ΔV_{IN} = 1V_{pp} (note2), f = 10kHz, Sin wave, T_a = −40˚C to 125˚C	9.45	13.50	17.55	mA_p/V_{pp}
Channel to Channel Matching (Transconductance)	δ_{Gm}		-1.9	-	+1.9	%
Linearity 1 (V^+ = 3V)	$L_{Gm}1$	V^+ = 3V, f = 10kHz, Sin wave, {G_m (ΔV_{IN} = 1.5V_{pp}) − G_m(ΔV_{IN} = 1V_{pp})}/G_m (ΔV_{IN} = 1V_{pp}), T_a = −40˚C to 125˚C	−3	-	+3	%
Linearity 2 (V^+ = 5.5V)	$L_{Gm}2$	V^+ = 5.5V, f = 10kHz, Sin wave, {G_m (ΔV_{IN} = 3V_{pp}) − G_m (ΔV_{IN} = 1V_{pp})}/G_m (ΔV_{IN} = 1V_{pp}), T_a = −40˚C to 125˚C	−3	-	+3	%
G_m Flatness	ΔG_m	V^+ = 3.3V, {G_m (f = 20kHz) − G_m (f = 10kHz)}/ G_m(f = 10kHz) , ΔV_{IN} = 1V_{pp}	−5	-	+5	%
Phase Difference between Input and Output	Φ	ΔV_{IN} = 1V_{pp}, f = 10kHz, Sin wave, Vin→Iout, T_a = −40˚C to 125˚C	−8	−3	+2	deg
Channel to Channel Matching (Phase Difference between Input and Output)	δ_Φ		-0.95	-	+0.95	deg
Common-mode Gain	G_{cm}	ΔV_{IN} = 0V, V_{IC} = 0.5V to (V^+) − 0.5V, T_a = −40˚C to 125˚C	0.97	1.00	1.03	V/V
Common-mode Input Voltage Range	V_{ICM}	T_a = −40˚C to 125˚C	0.5	-	(V^+)−0.5	V
AMP (Output Characteristics)						
Maximum Output Current 1	$I_{OMAX}1$	DC, V^+ = 5V, ΔV_{IN} = ±5V, T_a = −40˚C to 125˚C	30	-	-	mA
Maximum Output Current 2	$I_{OMAX}2$	DC, V^+ = 3.3V, ΔV_{IN} = ±3.3V T_a = −40˚C to 125˚C	18	-	-	mA
Maximum Output Voltage High	V_{OH}	DC, Z_L = open, V_{IN1} = V^+, V_{IN2} = 0V, T_a = −40˚C to 125˚C	(V^+)−75m	-	-	V
Maximum Output Voltage Low	V_{OL}	DC, Z_L = open, V_{IN1} = 0V,V_{IN2} = V^+, T_a = −40˚C to 125˚C	-	-	(V^-)+75m	V
Output Offset Current	I_{OS}	DC, ΔV_{IN} = 0V, T_a = −40˚C to 125˚C	-	-	0.4	mA
AMP (Input Characteristics)						
Input Sink Current	I_{IN_Sink}	DC, ΔV_{IN} = 0V, T_a = −40˚C to 125˚C	-	80	160	µA
AMP (Power Supply)						
Supply Current	I_{SUPPLY}	No Signal, T_a = −40˚C to 125˚C	-	4.5	8.5	mA
AMP (Dynamic characteristics)						
Slew Rate	SR	V^+ = 3.3V, ΔV_{IN} = 1V_{pp}	-	1.5	-	V/µs
Shutdown						
High Level Input Voltage (Normal Function)	VIH	T_a = −40˚C to 125˚C	(V^+)*0.7	-	-	V
Low Level Input Voltage (Shutdown)	VIL	T_a = −40˚C to 125˚C	-	-	(V^+)*0.3	V
Supply Current (Shutdown)	I_{SDN}	V_{SDA} = V_{SDB} = V^-, T_a = −40˚C to 125˚C	-	-	150	µA

(note 1) Resolver model



R_S = 10Ω, R1 = 2400Ω, R2 = 3600Ω
L1 = 1mH, L2 = 0.39mH.
C1 = 82pF, C2 =39pF

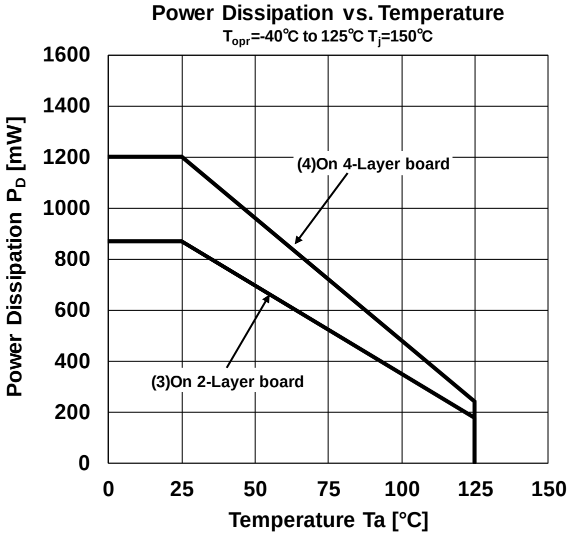
(note 2) ΔV_{IN} means differential input voltage; $\Delta V_{IN} = V_{INA1} - V_{INA2}$ or $V_{INB1} - V_{INB2}$

■ THERMAL CHARACTERISTICS

PACKAGE	SYMBOL	VALUE	UNIT
Junction-To-Ambient Thermal Resistance SSOP16-B3	θ_{ja}	2-Layer / 4-Layer 145(3) / 102 (4)	°C/W
Junction-To-Top of Package Characterization Parameter SSOP16-B3	Ψ_{jt}	2-Layer / 4-Layer 19(3) / 16(4)	°C/W

(3) 2-Layer: Mounted on glass epoxy board (76.2 mm × 114.3 mm × 1.6 mm: based on EIA/JEDEC standard, 2-layer FR-4).
(4) 4-Layer: 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.

■ POWER DISSIPATION vs. AMBIENT TEMPERATURE



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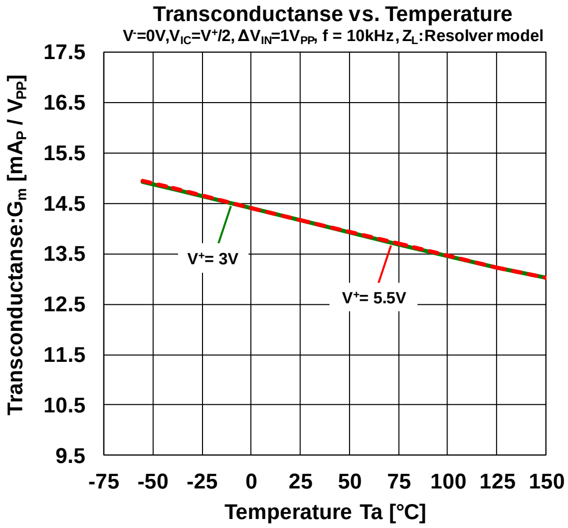
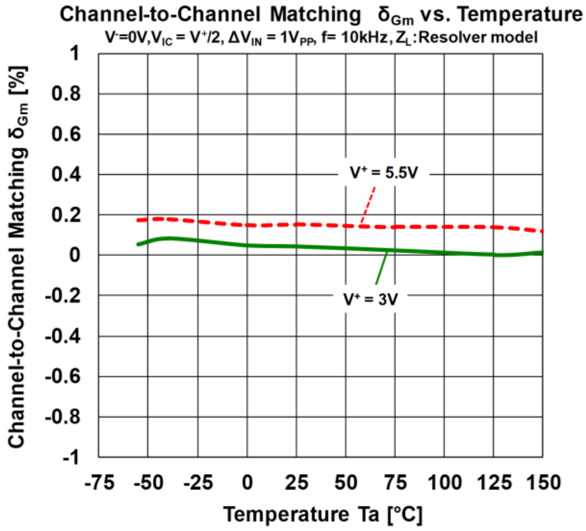
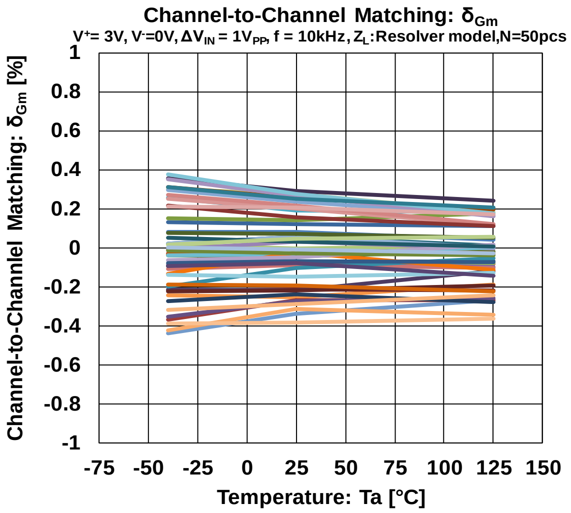
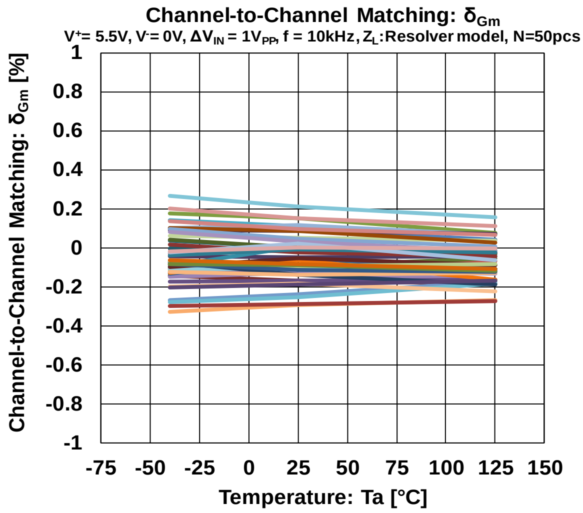
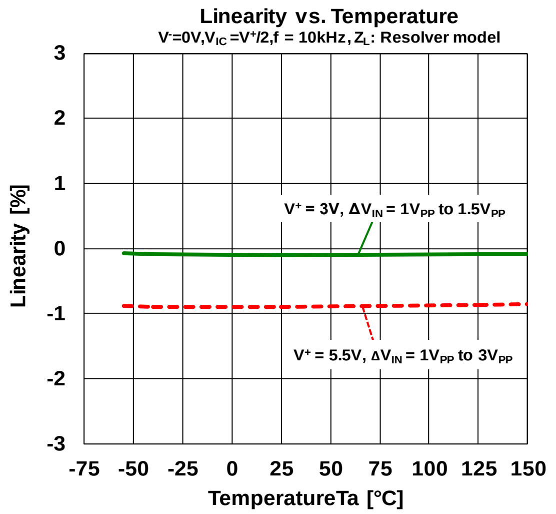
■ TYPICAL CHARACTERISTICS











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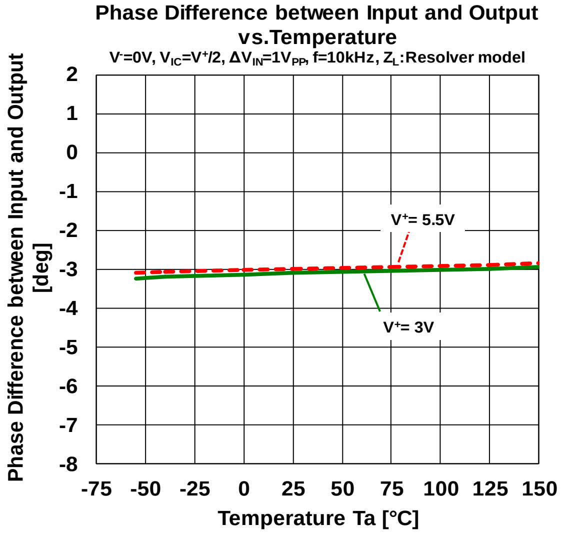

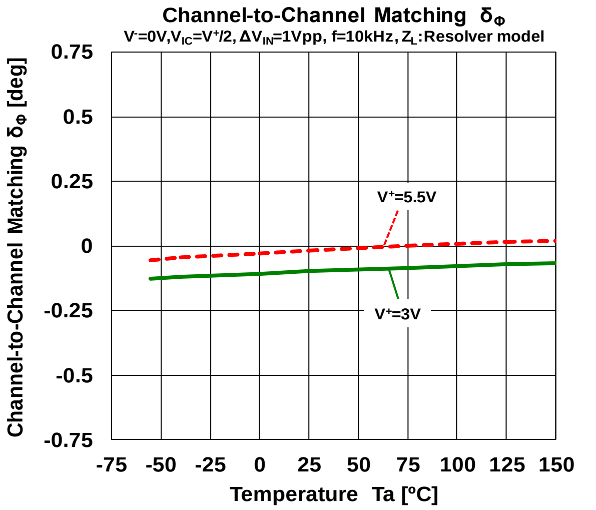

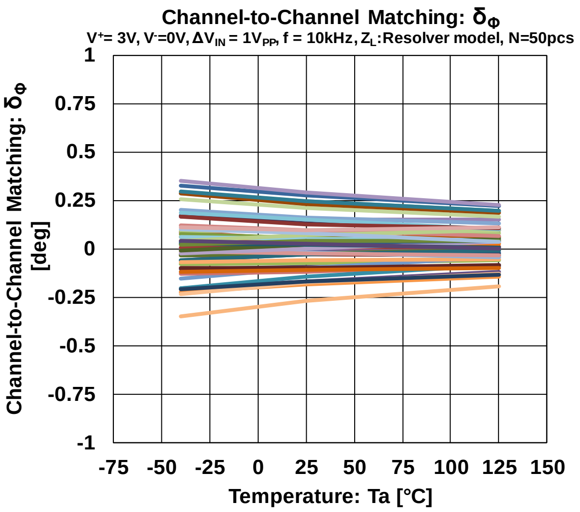

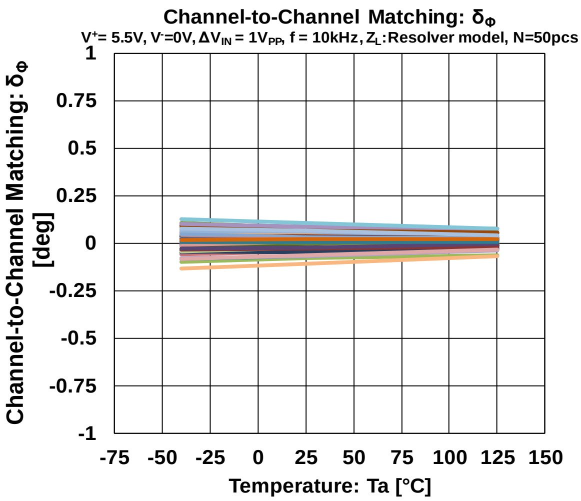

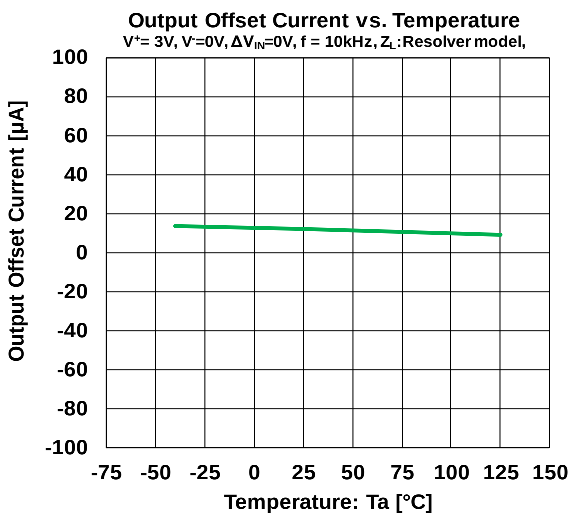

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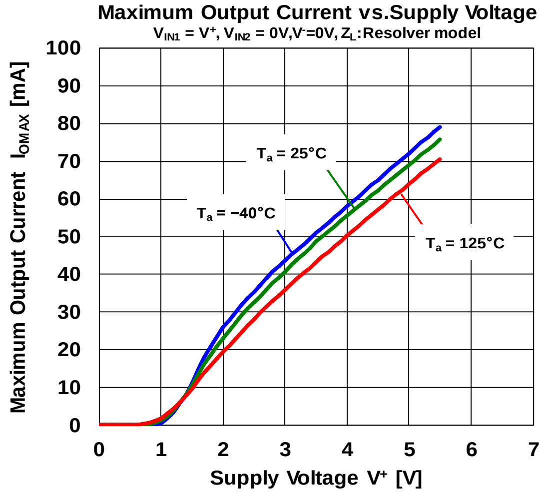

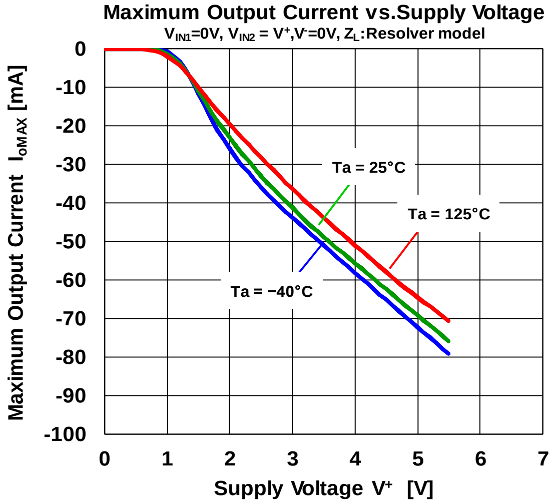

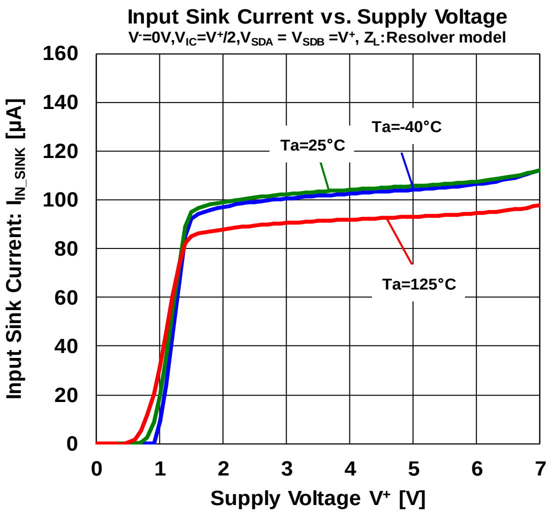

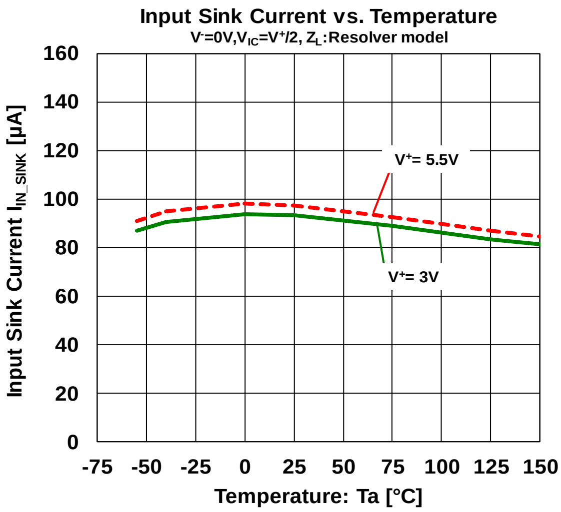

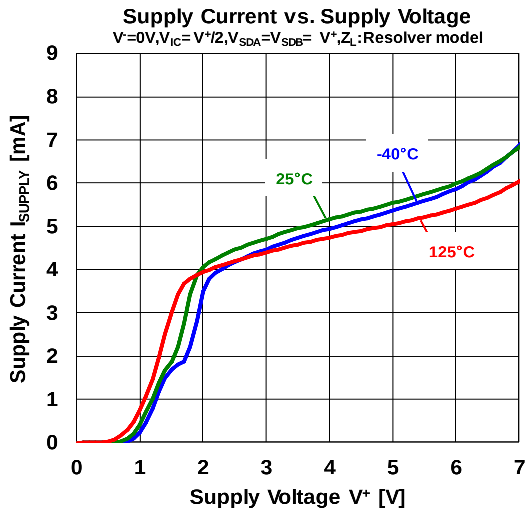

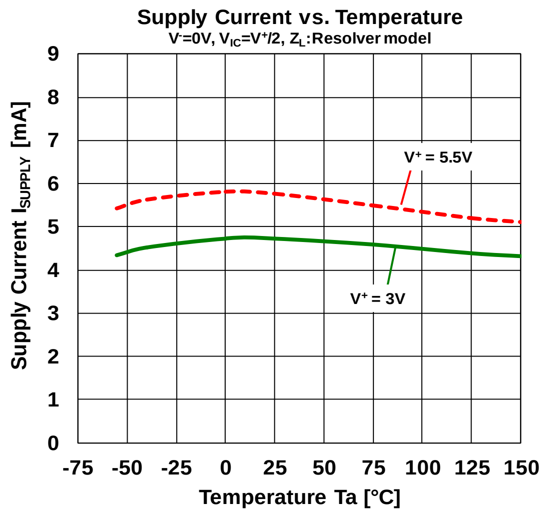

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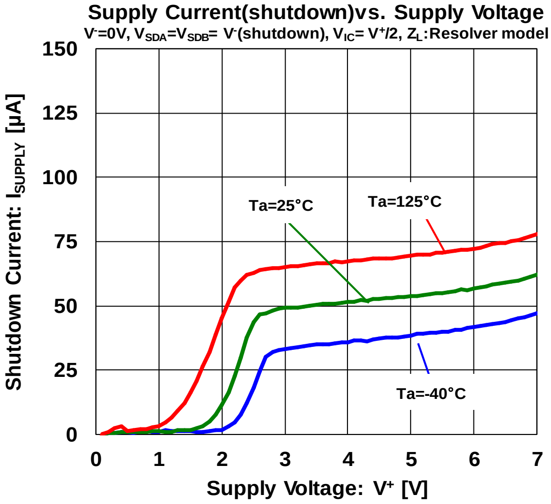
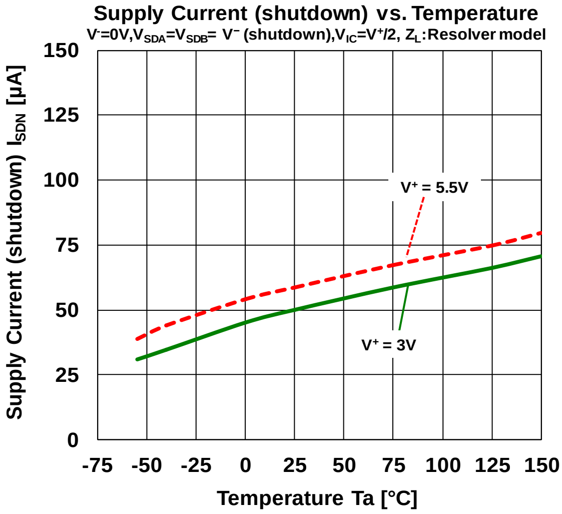
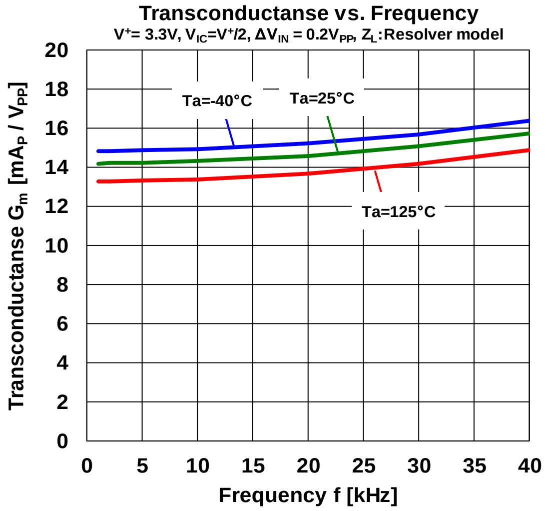
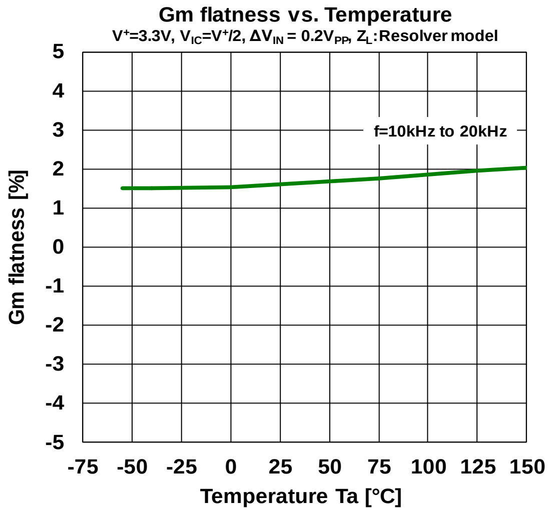
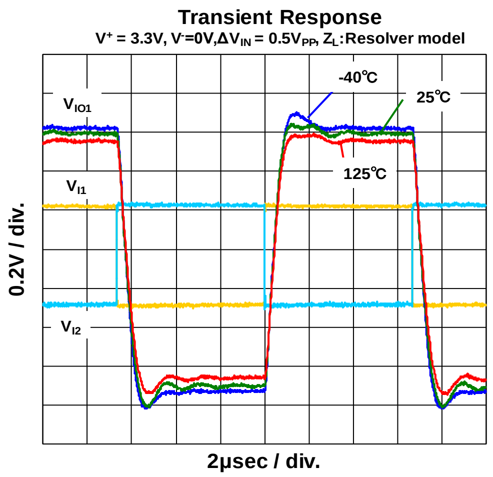










■ APPLICATION NOTE

Operating principle

NJU7870 is a transconductance amplifier with differential voltage input and differential current output. The relationship between the output current and input voltage is expressed by the following formula.

$$I_{OUT} = G_m \times \Delta V_{IN}$$

(*)G_m: Transconductance,
ΔV_{IN}: input voltage ($\Delta V_{IN} = V_{IN1} - V_{IN2}$)

example

Figure 1 shows an image of the input voltage ΔV_{IN} and output current I_{OUT} in a sinusoidal response.

$t = t_1$

$I_{OUT} = G_m \times \Delta V_{IN} = 13.5[mA_P/V_{PP}] \times (3 - 2)[V_{PP}] = 13.5[mA_P]$ (From I_{O1} to I_{O2})

$t = t_2$

$I_{OUT} = G_m \times \Delta V_{IN} = 13.5[mA_P/V_{PP}] \times (2 - 3)[V_{PP}] = -13.5[mA_P]$ (From I_{O2} to I_{O1})

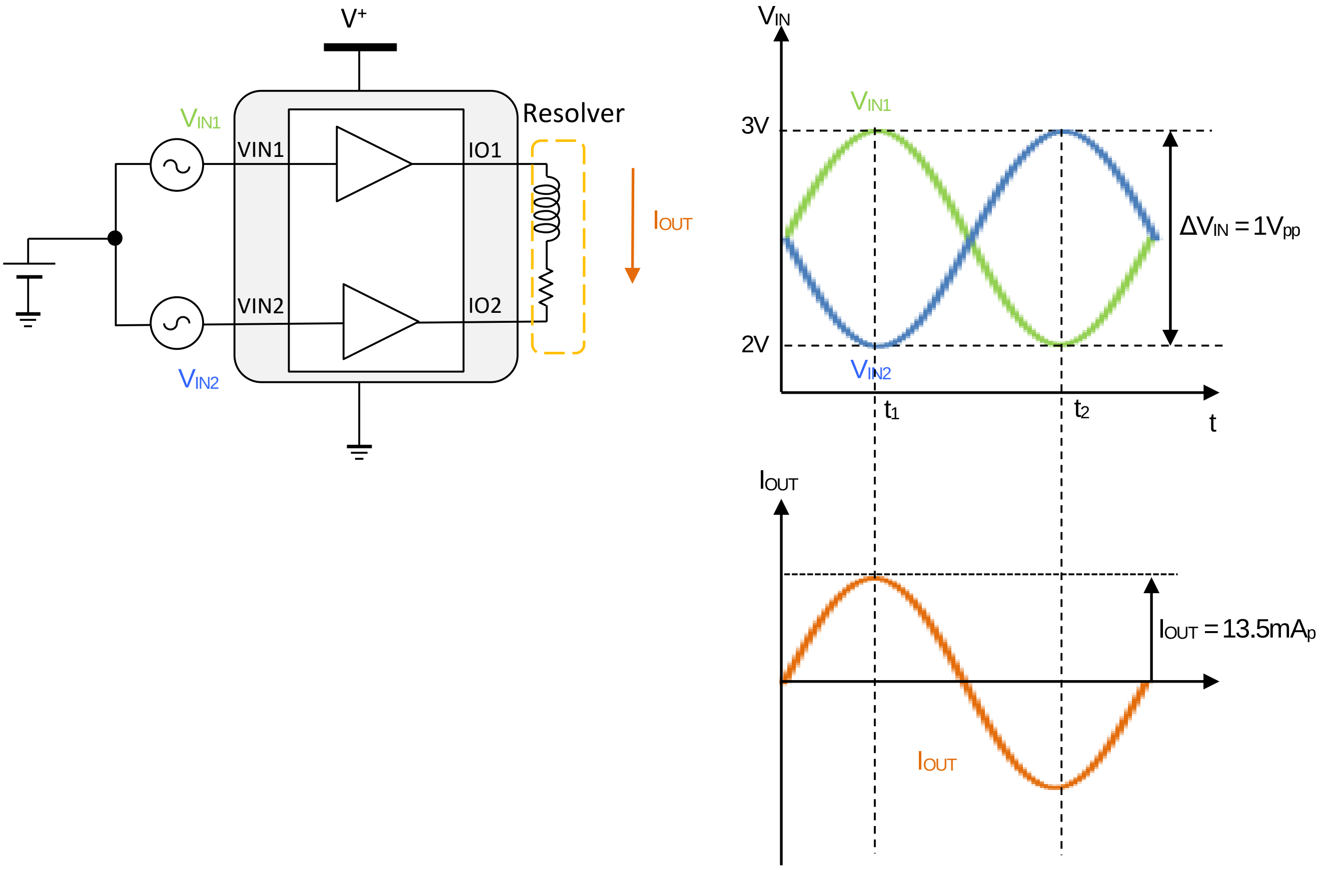


Figure 1. Operation example

Description of electrical characteristics
This section describes electrical characteristics of NJU7870. Please check the electrical characteristics on page 5 of the data sheet for detailed conditions.

AMP (Propagation Characteristic)
Transconductance (G_m)
As shown in the formula below.

$$G_m = \frac{I_{OUT}}{\Delta V_{IN}}$$

(*)I_{OUT}: Variation of output current.,ΔV_{IN} : Variation of input voltage

Channel to Channel Matching (Transconductance) (δ_{Gm})
The difference between the transconductance channels is shown as shown in the following formula.

$$\delta_{Gm} = \frac{G_{mA} - G_{mB}}{G_{mA}} \times 100[\%]$$

(*)G_{mA}: transconductance of Ach. G_{mB}: transconductance of Bch.

Linearity ($L_{Gm}1$, $L_{Gm}2$)
It shows the variation of transconductance due to the input amplitude. In NJU7870, two conditions (linearity 1 and 2) with different power supply voltage and input amplitude are specified.

Phase Difference between Input and Output (Φ)
As shown in the Figure2. below, the phase difference of the output current I_{OUT} (sine wave) is shown based on the input voltage (sine wave / f = 10kHz).

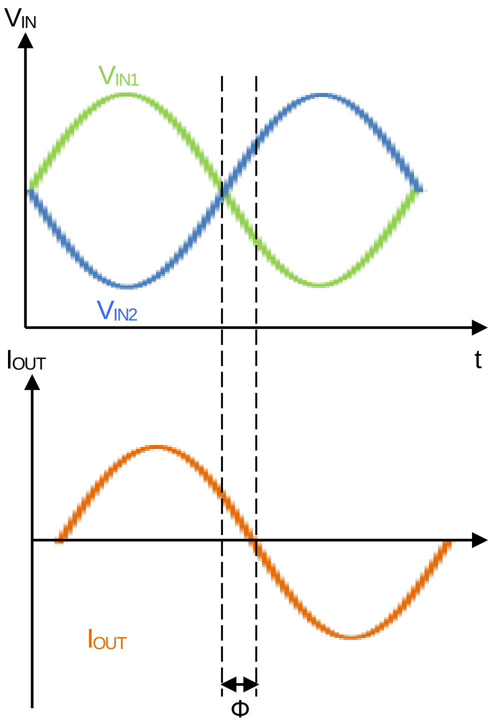


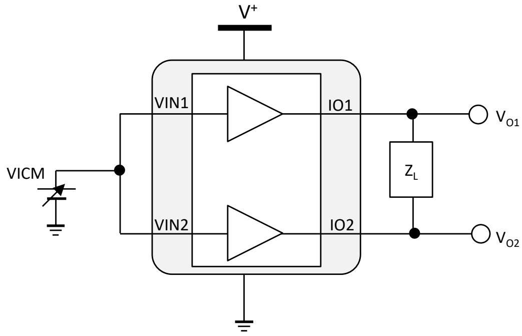
Figure2. Phase Difference between Input and Output

Channel to Channel Matching(Phase Difference between Input and Output) (δ_{Φ})
As shown in the following formula, the difference between the channels of the phase difference between input and output is shown.

$$\delta_{\Phi}=\frac{\Phi_A - \Phi_B}{\Phi_A}\times 100[\%]$$

(*)Φ_A: Phase Difference between Input and Output of Ach. Φ_B: Phase Difference between Input and Output of Bch.

Common-mode Gain (G_{cm})
As shown in the formula below.



$$V_{OCM} = \frac{V_{O1} + V_{O2}}{2}$$

$$G_{cm} = \frac{\Delta V_{OCM}}{\Delta V_{ICM}}$$

(*) ΔV_{OCM}: Variation of the common mode output voltage.,ΔV_{ICM} : Variation of the common mode input voltage

Figure3. Common-mode Gain

AMP (Output Characteristics)
Maximum output current ($I_{OMAX}1$, $I_{OMAX}2$)
This is the current value that can be output. As the lower limit (min.), it is specified as 30mA /ch. at V^+ = 5V (maximum output current 1) and 18mA/ch. at V^+ = 3.3V (maximum output current 2). However, depending on the impedance of the load, the output voltage may be distorted even if the current value is smaller than the specified lower limit. For details, refer to " Output voltage limit".

Maximum Output Voltage (V_{OH}, V_{OL})
It shows the voltage range that the amplifier can output when there is no load. V_{OH} indicates the upper limit of the outputable range, and V_{OL} indicates the lower limit of the outputable range.

Output Offset Current (I_{OS})
It shows the error current flowing from the output when the input voltage (V_{IN1}, V_{IN2}) is the same voltage.

precautions for use

Bypass Capacitor

Connect a bypass capacitor near the power supply pin (pin 16) to supply a stable power supply voltage with less noise to the IC.Install bypass capacitors as close to the package as possible, especially if the wiring from the power supply to the power supply pins is long, or if you are using a noisy signal as the power supply.

Input Current

The NJU7870 has a constant current source connected to V− from the input terminals (1pin, 2pin, 7pin, 8pin) to prevent oscillation when the input terminal is open. Therefore, it is not possible to insert a capacitor in series with the input signal as shown in figure 4. The value of the input current is specified by "Input Sink Current", and use an input signal source that can drive this current value.

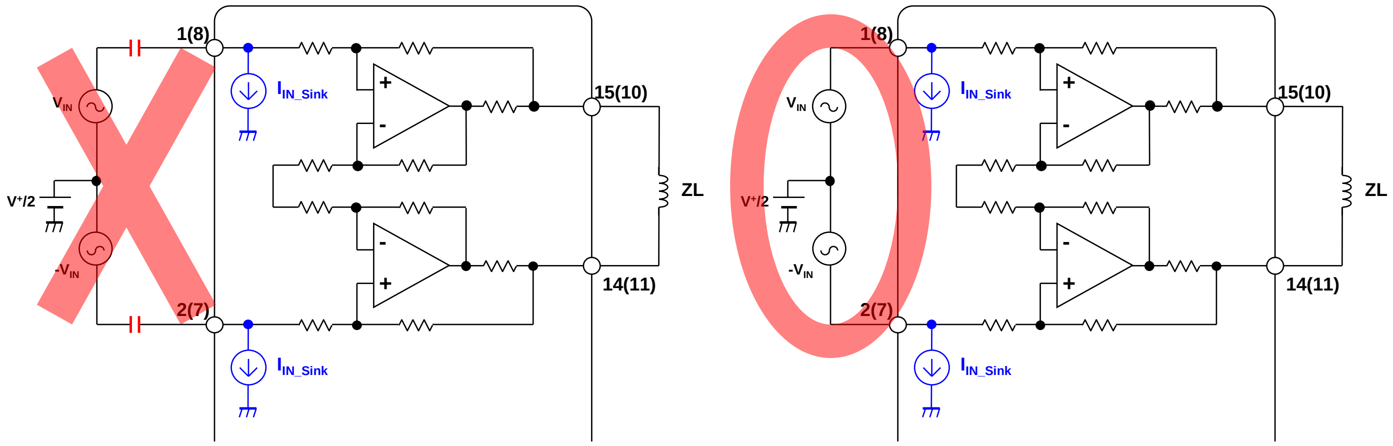


Figure 4. An AC-coupled connection example that does not function properly (left) and a DC-coupled connection example that functions correctly (right).

Output voltage limit

The amplitude of the input voltage must be set within the range where the output voltage is not distorted. Figure 5-1 is an example of the distortion waveform when an inductive load such as a resolver is driven. Figure 5-2 plots the limits of the amplitude that the NJU7870 can output without distortion for each power supply voltage. Assuming that the load impedance is Z_L, the differential input amplitude is ΔV_{IN}, and the transconductance of NJU7870 is G_m, the output voltage V_{OUT} can be calculated using the following formula.

$$V_{OUT} = \Delta V_{IN} \times G_m \times Z_L$$

Set the input voltage amplitude using Fig. 5-2 as a guide so that the output voltage amplitude does not fall into the area where it is distorted by your load. In addition, please fully evaluate the actual machine, including temperature and variations.

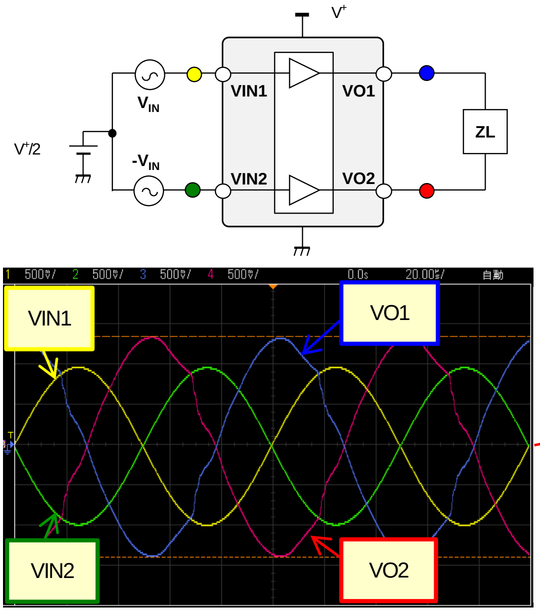


Figure5-1. Waveform at large amplitude
(Z_L: Resolver model)

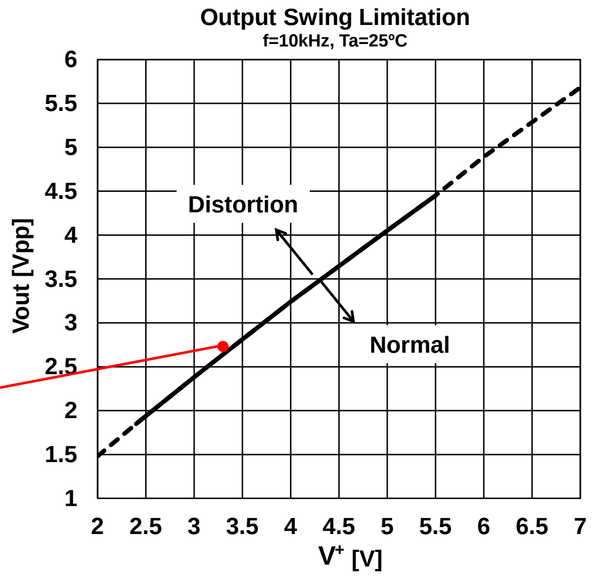


Figure5-2. Output voltage limit

e.g. Load : TS2224N1112E102 (TAMAGAWA TRADING CO., LTD. VR type Resolver), Z_L = 120Ω (f = 10kHz)

V^+ = 3.3V, V^- = 0V

If you want to set V_{OUT} <2.5V_{pp} from Fig. 5-2, then from G_m = 13.5mA_p/V_{pp},

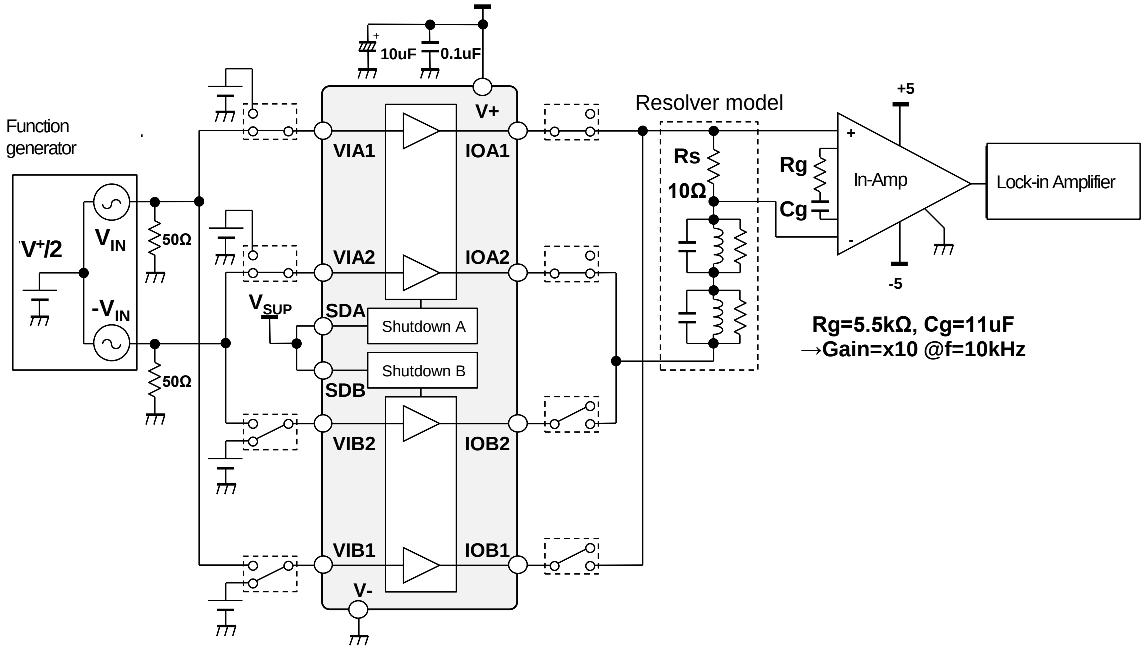
ΔV_{IN} < 2.5 / 13.5m / 120 ≒ 1.54V_{pp}

Thermal shutdown

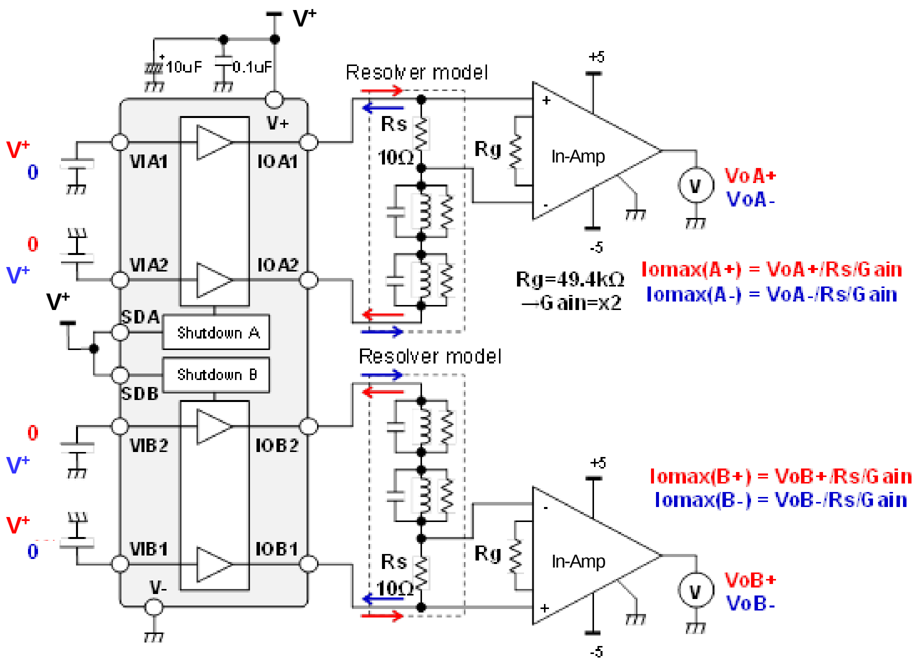
The NJU7870 is designed with Thermal Shut Down (TSD) circuit that protects itself from damage caused by overload condition. The TSD circuit operates at a junction temperature of approximately 175°C, which reduces the power consumption of the IC by blocking the output current. After that, when the junction temperature of the NJU7870 is cooled down to approximately 150℃, the NJU7870 automatically returns to normal operation and can output the current. However, the TSD circuit does not have the active cooling function of a heat sink, and continued use of the NJU7870 with the TSD circuit in operation can destroy the IC. To maintain stable operation, it is recommended to use below the specified power dissipation.

■ TYPICAL TEST CIRCUIT

Transconductance, Phase Difference between Input and Output



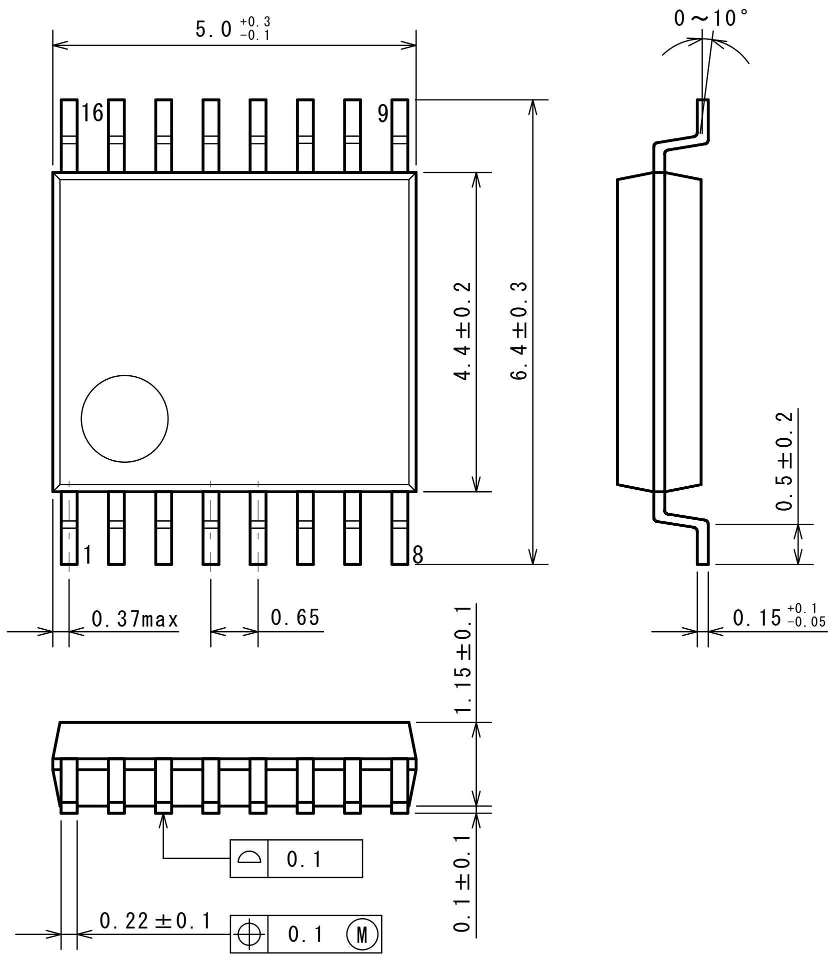
Maximum Output Current



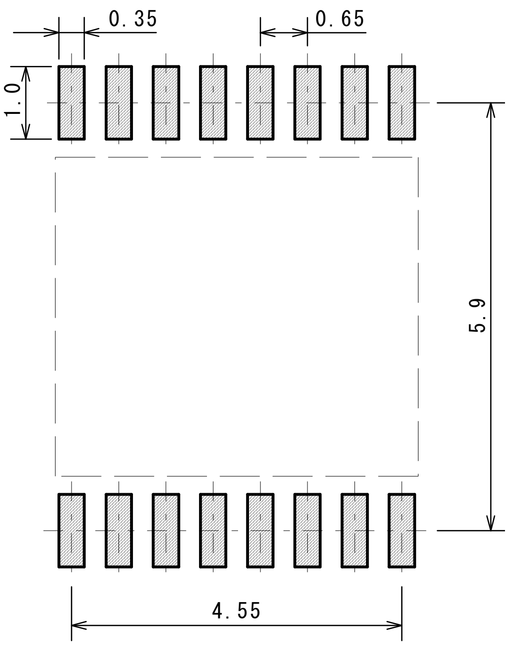
SSOP16-B3

Unit: mm

■ PACKAGE DIMENSIONS



■ EXAMPLE OF SOLDER PADS DIMENSIONS

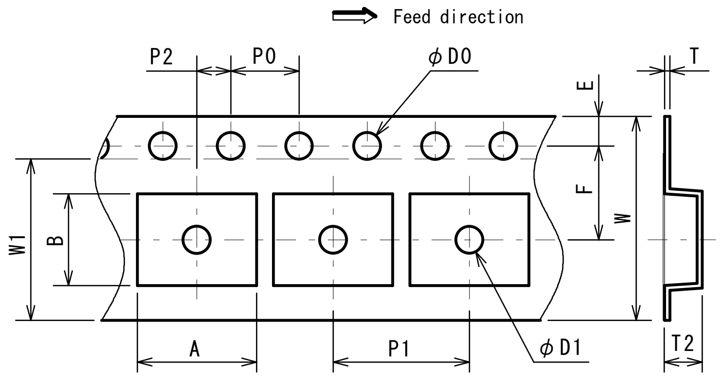


SSOP16-B3

Unit: mm

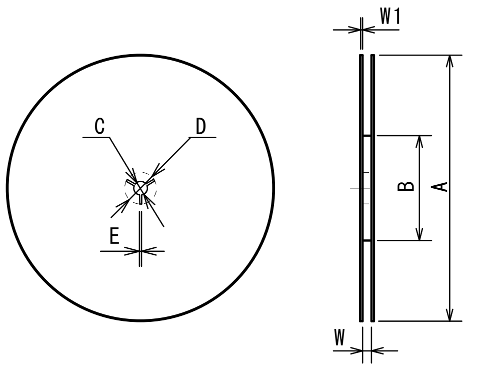
■ PACKING SPEC

TAPING DIMENSIONS



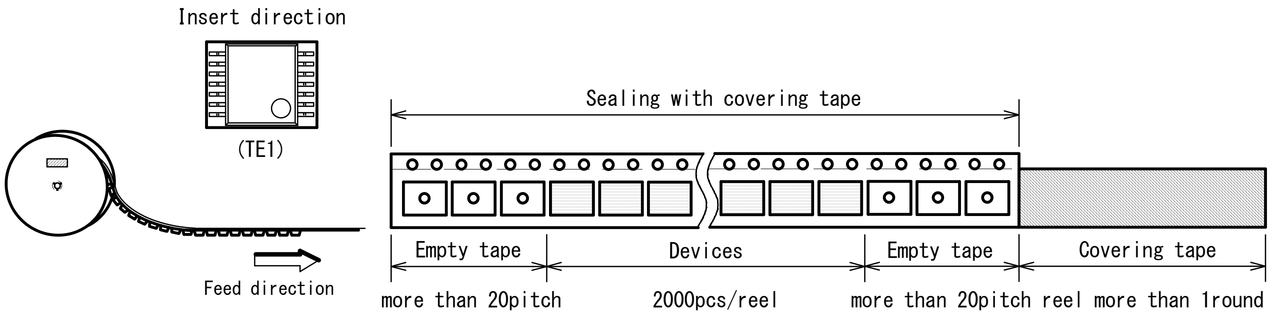
SYMBOL	DIMENSION	REMARKS
A	6.95	BOTTOM DIMENSION
B	5.4	BOTTOM DIMENSION
D0	1.55±0.05	
D1	1.55±0.1	
E	1.75±0.1	
F	5.5±0.05	
P0	4.0±0.1	
P1	8.0±0.1	
P2	2.0±0.05	
T	0.3±0.05	
T2	2.2	
W	12.0±0.3	
W1	9.5	THICKNESS 0.1max

REEL DIMENSIONS

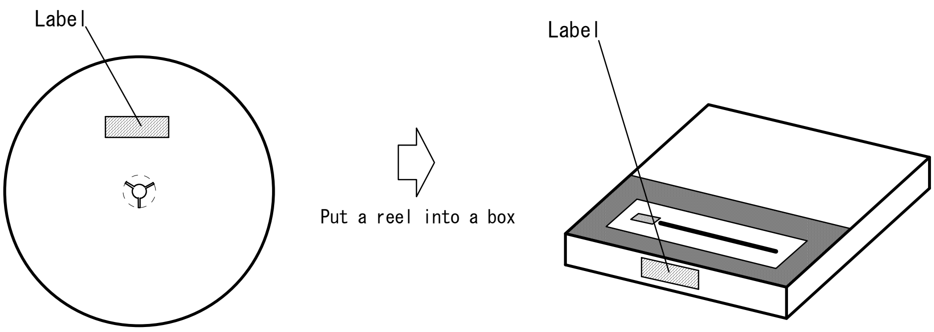


SYMBOL	DIMENSION
A	φ254±2
B	φ100±1
C	φ 13±0.2
D	φ 21±0.8
E	2±0.5
W	13.5±0.5
W1	2±0.2

TAPING STATE

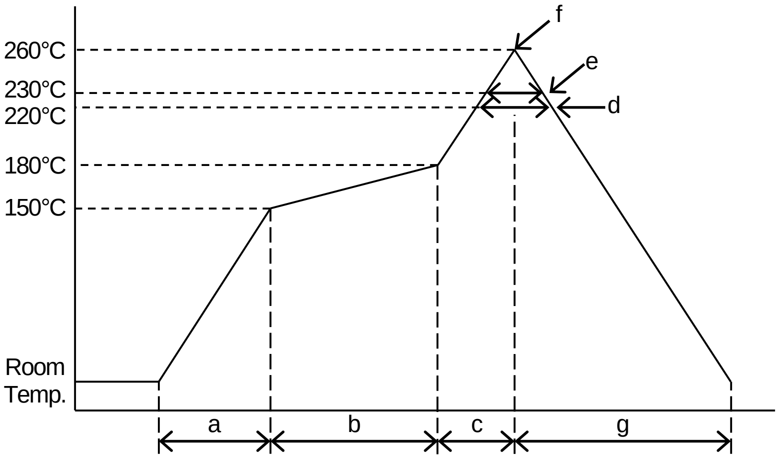


PACKING STATE



■ RECOMMENDED MOUNTING METHOD

INFRARED REFLOW SOLDERING PROFILE



a	Temperature ramping rate	1 to 4°C/s
b	Pre-heating temperature Pre-heating time	150 to 180°C 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.

■ REVISION HISTORY

DATE	REVISION	CHANGES
October 25, 2021	Ver.1.0	Initial release

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   ・Equipment Used in the Deep Sea
   ・Power Generator Control Equipment (Nuclear, steam, hydraulic, etc.)
   ・Life Maintenance Medical Equipment
   ・Fire Alarms / Intruder Detectors
   ・Vehicle Control Equipment (Airplane, railroad, ship, etc.)
   ・Various Safety Devices

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