

Analog Front-End IC for Power Line Communication

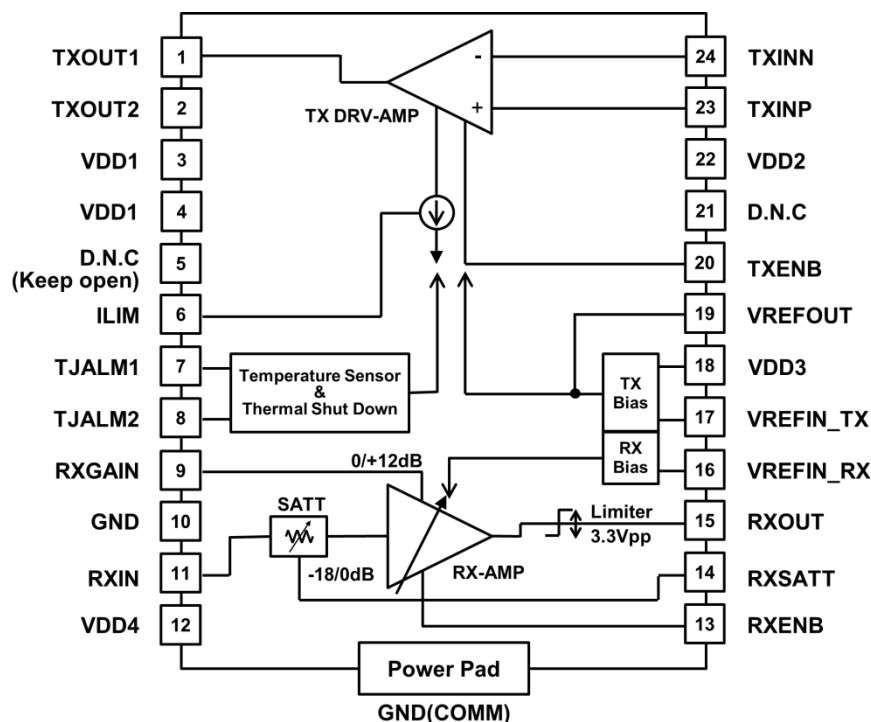
■ FEATURES

- Higher Integration
 - Power line driver with Thermal protection and current limit and low noise receiver amplifier
- Higher transmit performance
 - High output current : 3A(typical) output current provide high transmission power even under lower power line impedance circumstance
 - Low distortion (THD \leq -60dB(typical))
It gives designer easier design for circuit under all of regulations (Cenerec/ARIB/FCC)
- Flexible receive gain control
-18dB/-6dB/0dB/+12dB
- Power supply
8V to 22V (Typical usage 12V/15V)
- Small package
HTSSOP24

■ APPLICATION

- Smart Meter
- Lighting system
- HEMS system

■ BLOCK DIAGRAM



■ GENERAL DESCRIPTION

The NJM45001 is an integrated, Powerline communications (PLC) analog front-end (AFE) device that is capable of capacitive- or transformer-coupled connections to the powerline while under the control of a Renesas Electronics Corporation Modem IC (e.g. uPD809508K8).

The integrated driver is able to drive low-impedance line that require up to 3.0A (typical) into reactive road.

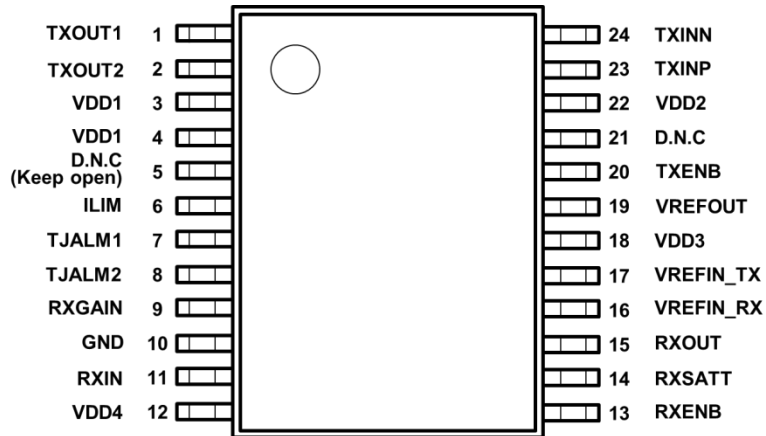
The integrated receiver is able to select gain that is -18dB, -6dB, 0dB and +12dB.

The NJM45001 operates from a single power supply in the range of 8V to 22V. At maximum output current, a wide range output swing provides an 11-Vpp capability with a nominal 15V supply.

The NJM45001 is internally protected against over-temperature conditions. It also provides an adjustable current limit. An interrupt output is provided that indicates thermal limit. There is also shutdown pin that can be used to quickly put the device into its lowest power state.

The NJM45001 is housed in a thermally-enhanced, surface-mount exposure-Pad package (HTSSOP24). Operation is specified over the junction temperature of -40°C to +150°C.

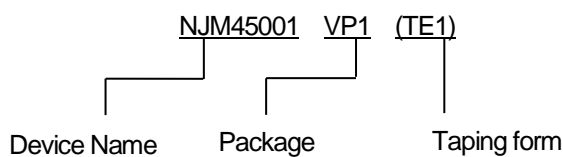
■ PIN CONFIGURATION



HSSOP24

PIN No.	SYMBOL	DESCRIPTION
1	TXOUT1	Transmitter output
2	TXOUT2	Transmitter output
3	VDD1	Power supply of Transmitter output stage
4	VDD1	Power supply of Transmitter output stage
5	D.N.C(Keep open)	Non connect. Must be open. (Do not connect)
6	ILIM	Adjust limitation of Transmitter output current with external resistor
7	TJALM1	The alarm signal of the limit of junction temperature (L: shutdown, H: normal operation)
8	TJALM2	The alarm signal of the high junction temperature (L: request low duty cycle, H: normal operation)
9	RXGAIN	Receive amplifier gain control (L: +12dB, H: 0dB)
10	GND	Ground
11	RXIN	Receiver input
12	VDD4	Power Supply of Receiver
13	RXENB	Receive enable control (L: active, H: sleep)
14	RXSATT	Receive attenuate control (L: 0dB, H: -18dB)
15	RXOUT	Receiver output
16	VREFIN_RX	Reference voltage bias input of Receiver
17	VREFIN_TX	Reference voltage bias input of Transmitter
18	VDD3	Power Supply of Bias circuit for Transmitter
19	VREFOUT	Reference voltage bias output of Transmitter
20	TXENB	Transmitter enable control (L: active, H: sleep)
21	D.N.C	Non connect. Must be open. (Do not connect)
22	VDD2	Power supply of Transmitter main part
23	TXINP	Transmit positive input
24	TXINN	Transmit negative input

■ MARK INFORMATION



■ ORDERING INFORMATION

PART NUMBER	PACKAGE OUTLINE	RoHS	HALOGEN-FREE	TERMINAL FINISH	MARKING	WEIGHT (mg)	MOQ (pcs)
NJM45001VP1	HTSSOP24	yes	yes	Sn-2Bi	45001	83	2,500

■ ABSOLUTE MAXIMUM RATINGS (Under Ta=25 °C unless otherwise noted)

PARAMETER	SYMBOL	RATINGS	UNIT
Supply Voltage (Pins 3,4,12,18,22)	V _{DD}	+24	V
Input Voltage ⁽¹⁾	V _{IN}	GND-0.3 to V _{DD2,3} +0.3 (Pins 23,24)	V
		GND-0.3 to V _{DD4} +0.3 (Pins 11)	
		GND-0.3 to 24 (Pins 9,13,14,20)	
Differential Input Voltage(Pins 23,24)	V _{ID}	±1	V
Power Dissipation	P _D	1200 ⁽²⁾ 3700 ⁽³⁾	mW
Junction Temperature Range	T _j	-40 to +150	°C
Operating Temperature Range ⁽⁴⁾	T _{opr}	-40 to +125	°C
Storage Temperature Range	T _{stg}	-55 to +150	°C

(1)Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond rails should be current limited to 10mA or less. Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.3V beyond rails should be current limited to 10mA or less.

(2)Mounted on glass epoxy board.(114.5x101.5x1.6mm:based on EIA/JEDEC standard,2Layers)

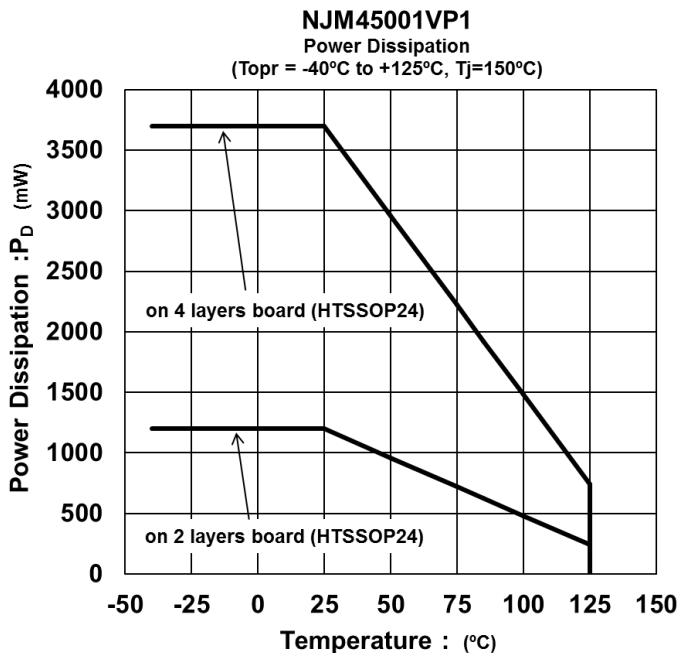
(3)Mounted on glass epoxy board.(114.5x101.5x1.6mm:based on EIA/JEDEC standard,4Layers), internal Cu area: 99.5x99.5mm
(For 4Layers : Applying 99.5x99.5mm inner Cu area and thermal via hole to board based on JEDEC standard JESD51-5)

(4)The NJM45001 automatically goes into shutdown at junction temperature that exceed +150 °C.

■ THERMAL CHARACTERISTICS

PARAMETER	SYMBOL	VALUE	UNIT
Junction-to-ambient Thermal resistance	θ _{ja}	103 ⁽²⁾	°C/W
		34 ⁽³⁾	
Junction-to-Top of package Characterization parameter	ψ _{jt}	8 ⁽²⁾	°C/W
		3 ⁽³⁾	

■ POWER DISSIPATION vs. AMBIENT TEMPERATURE



RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	RATINGS	UNIT
Operating Voltage Range	V_{DD}	+8 to +22	V
Operating Temperature Range	T_{opr}	-40 to +125	°C

ELECTRICAL CHARACTERISTICS

Power Supply Current ($V_{DD1,2,3,4}=15V$, $T_a=25^\circ C$, unless otherwise noted)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Power Supply Current1	I_{DD1}	TXEN(Pin20)=L, RXEN(Pin13)=H, No signal	-	30	50	mA
Power Supply Current2	I_{DD2}	TXEN(Pin20)=H, RXEN(Pin13)=L, No signal	-	4.7	6	mA

Transmit Amplifier ($V_{DD1,2,3,4}=15V$, $T_a=25^\circ C$, unless otherwise noted)

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Power Supply Current	I_{DDTX}	$V_{DD1,2,3}=15V$, No signal	-	30	50	mA
Shut Down Current	I_{DDSD}	$V_{DD1,2,3}=15V$, No signal	-	1.4	3	mA
Output Impedance	Z_O	$G_V=16.5dB$, $f=100kHz$	-	0.05	-	Ω
Input Offset Voltage	V_{IO}		-	1	10	mV
Input Bias Current	I_B		-	0.2	1	μA
Output Voltage	V_{om}	Isorce=1A	$V_{DD}-1.5$	$V_{DD}-1$	-	V
		Isink=1A	-	GND+1	GND+1.5	
Maximum Output Current	I_O	$V_O=5V$ drop, $3k\Omega$ connected to ILIM	2.25	3	-	A
Open Loop Gain	A_V	$R_L=50\Omega$	70	80	-	dB
Total Harmonic Distortion +N	THD1	$V_O=8V_{pp}$, $f=300kHz$, $G_V=22.5dB$, Frequency bandwidth $f_b<1.6MHz$ $R_L=50\Omega$	-	0.07	-	%
		$V_O=8V_{pp}$, $f=300kHz$, $G_V=22.5dB$, Frequency bandwidth $f_b<1.6MHz$ $R_L=1.5k\Omega$	-	0.04	-	
	THD2	$V_{DD1,2,3,4}=20V$, $V_O=16V_{pp}$, $f=300kHz$, $G_V=22.5dB$, $f_b<1.6MHz$, $R_L=50\Omega$	-	0.09	-	
		$V_{DD1,2,3,4}=20V$, $V_O=16V_{pp}$, $f=300kHz$, $G_V=22.5dB$, $f_b<1.6MHz$, $R_L=1.5k\Omega$	-	0.05	-	
Power Supply Rejection Ratio	PSRR1	$G_V=22.5dB$, $f=300kHz$	-	-29	-	dB
	PSRR2	$G_V=22.5dB$, $f=1MHz$	-	-16	-	
Gain Band Product	GBW	$G_V=40dB$, $f=10MHz$, $R_L=5\Omega$	50	70	-	MHz
Slew Rate	SR	$G_V=20dB$, $V_O=10V_{pp}$, $R_L=5\Omega$	-	40	-	V/ μs
Full Power Bandwidth	PBW	$G_V=16.5dB$, $f=1MHz$, $R_L=5\Omega$	-	10	-	V _{pp}
Input Voltage Noise Density	V_{N1}	$f=1kHz$	-	9	-	nV/ \sqrt{Hz}
	V_{N2}	$f=10kHz$	-	9	-	
	V_{N3}	$f=100kHz$	-	9	-	

Thermal Protection ($V_{DD1,2,3,4}=15V$, $T_a=25^\circ C$, unless otherwise noted)

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Thermal shutdown Temp.	T_{TSD1}	TJALM1 from H to L	-	160	-	°C
Recovery temp. from shutdown	T_{TSD2}	TJALM1 from L to H	-	140	-	
Thermal Alarm ON	T_{ARMON}	TJALM2 from H to L	-	135	-	
Thermal Alarm OFF	T_{ARMOFF}	TJALM2 from L to H	-	125	-	
TJALM1 output High	TJ1H	Load $\geq 10k\Omega$ to GND	3.0	-	3.6	V
TJALM1 output Low	TJ1L	Load $\geq 10k\Omega$ to 3.3V	0	-	0.3	V
TJALM2 output High	TJ2H	Load $\geq 10k\Omega$ to GND	3.0	-	3.6	V
TJALM2 output Low	TJ2L	Load $\geq 10k\Omega$ to 3.3V	0	-	0.3	V

Thermal Protection Output Polarity

	Normal	Detect high Temperature
TJALM1	High	Low
TJALM2	High	Low

Receive Amplifier ($V_{DD1,2,3,4}=15V$, $T_a=25^\circ C$, unless otherwise noted)

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Power Supply Current	I_{DDRX}	$V_{DD4}=15V$, No signal	-	3.3	5	mA
Shut Down Current	I_{DDSD}	RXENB=H, No signal	-	0.8	2	mA
Output Impedance	Z_O	$f=300kHz$, -6dB mode	-	0.25	-	Ω
Output Voltage difference	V_{od}	$G_V=+12dB \Rightarrow -6dB$, $G_V=0dB \Rightarrow -18dB$	-	1	20	mV
Output Voltage limit	$V_{O_{lim}}$	No Load	3.0	3.3	3.6	Vpp
Gain Bandwidth product	GBW	$G_V=12dB$, $f=5MHz$, $R_L=4k\Omega$	8.5	17	-	MHz
Power Supply Rejection Ration	PSRR1	$G_V=+12dB$, $f=300kHz$	-	-29	-	dB
	PSRR2	$G_V=+12dB$, $f=1MHz$	-	-16	-	
Noise Figure	V_{NO}	$f=10kHz$ to 500kHz SATT=0dB, $G_V=12dB$, External Resistor=440 Ω	-	26	-	dB
Total Harmonic Distortion	THD	$G_V=+12dB$, $f=1kHz$, $R_L=4k\Omega$	-	0.003	-	%
Slew Rate	SR	$V_O=2V_{pp}$, $C_L=50pF$, $R_L=4k\Omega$	-	15	-	V/ μs
Step Attenuation	SATT	$G_V=-18dB$, External BPF=550 Ω	17	18	19	dB
Input Impedance	R_{in}		-	1.3	-	k Ω

Mode Control ($V_{DD1,2,3,4}=15V$, $T_a=25^\circ C$, unless otherwise noted)

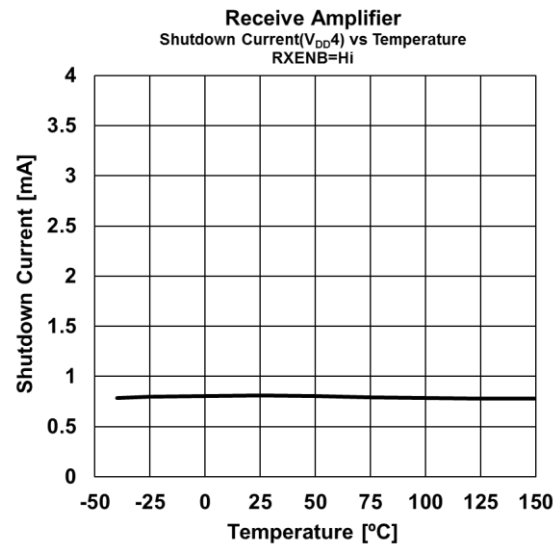
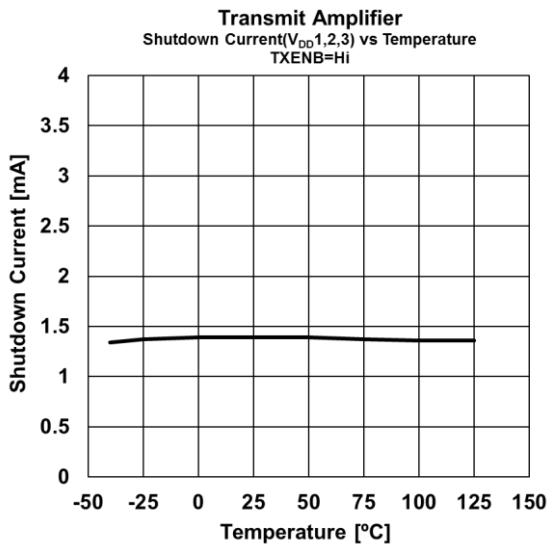
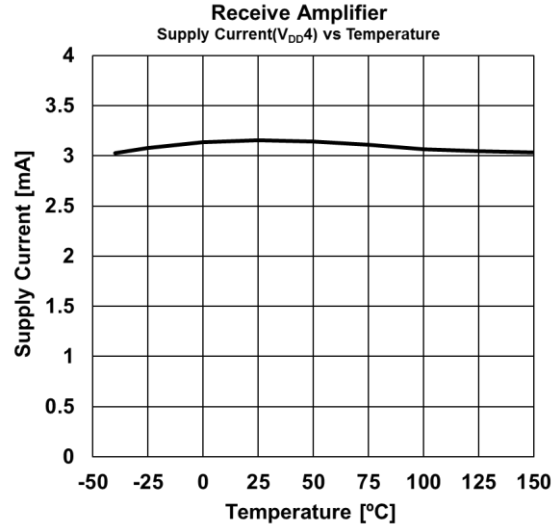
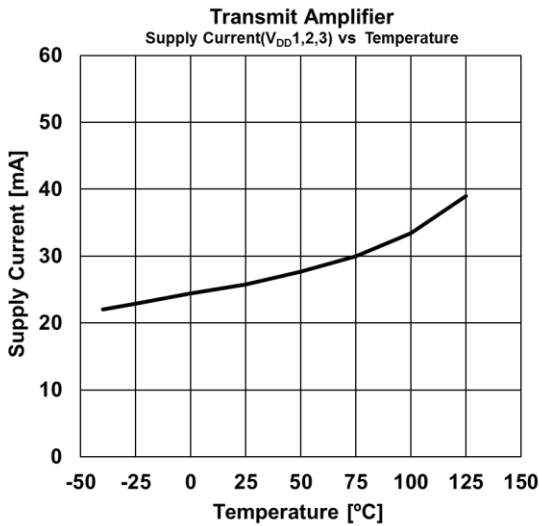
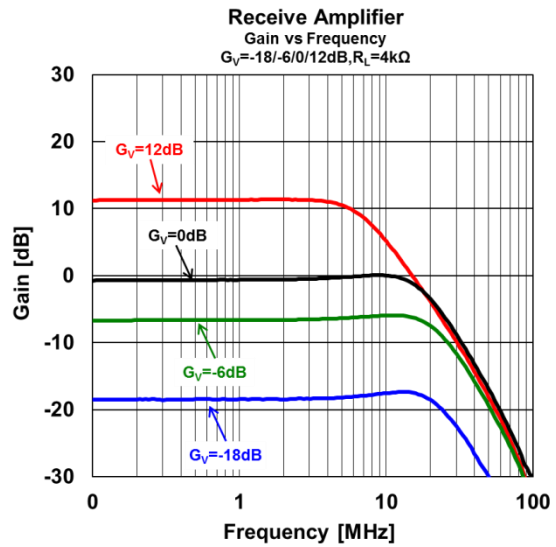
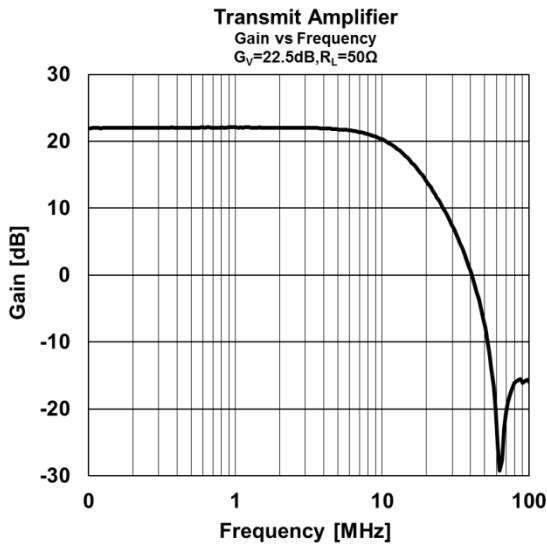
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT	
TXENB Vth	V_{thTX}	Transmit Amp. ON/OFF control	L \Rightarrow ON Vth	-	-	1	V
			H \Rightarrow OFF Vth	2.3	-	-	
RXENB Vth	V_{thRX}	Receiver Amp. ON/OFF control	L \Rightarrow ON Vth	-	-	1	V
			H \Rightarrow OFF Vth	2.3	-	-	
RXGAIN Vth	V_{thGAIN}	Receiver Amp. Gain control	L \Rightarrow +12dB	-	-	1	V
			H \Rightarrow 0dB	2.3	-	-	
RXSATT Vth	V_{thSATT}	Receiver Amp. Attenuation ON/OFF control	L \Rightarrow 0dB	-	-	1	V
			H \Rightarrow -18dB	2.3	-	-	

Receiver Amp Timing Chart

RXENB	RXGAIN	RXSATT	RXAMP GAIN
H	H/L	H/L	Hi-Z
L	L	L	12dB
L	H	L	0dB
L	L	H	-6dB
L	H	H	-18dB

■ TYPICAL CHARACTERISTICS

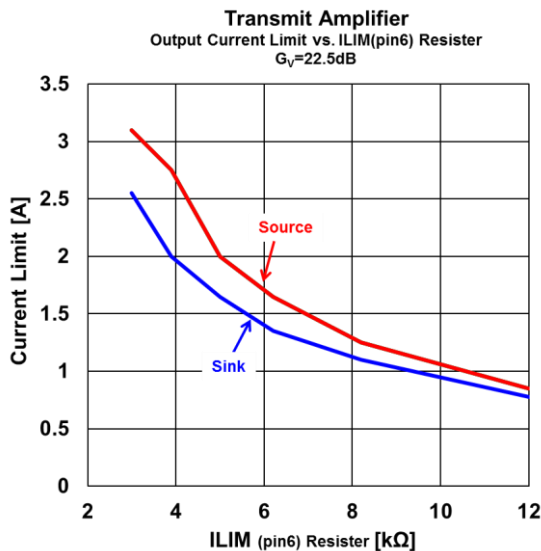
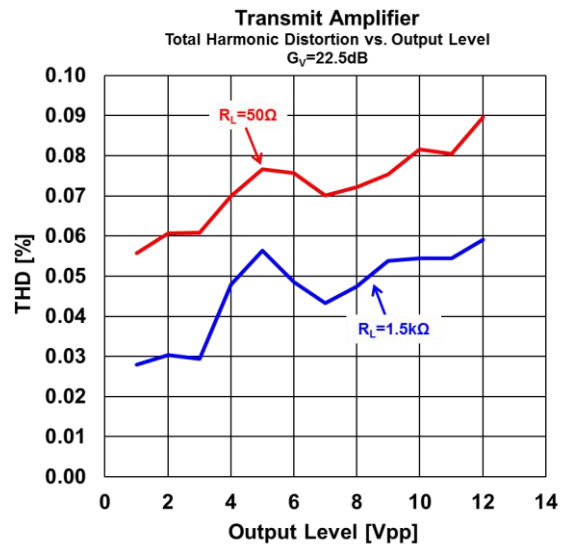
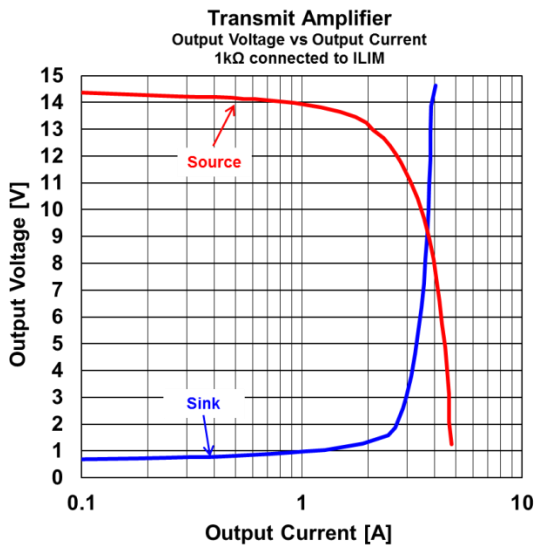
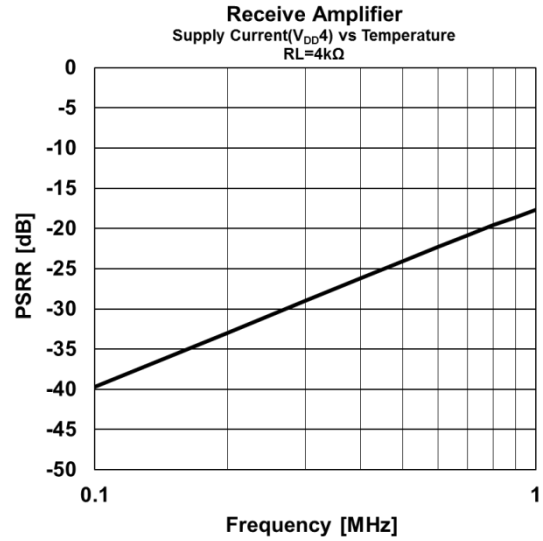
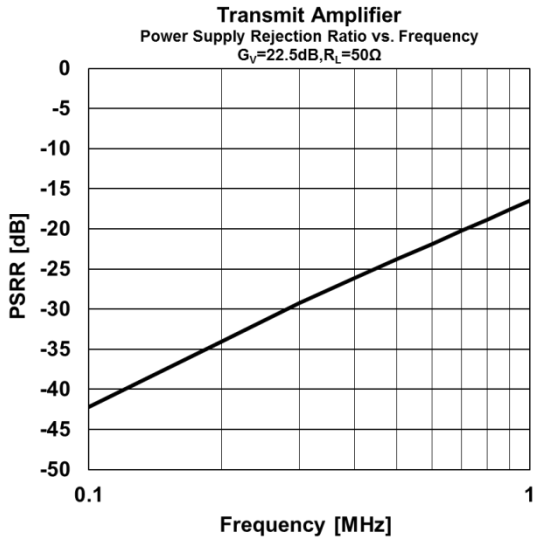
At $T_a=25^\circ\text{C}$, $V_{DD1,2,3,4}=15\text{V}$, $12\text{k}\Omega$ connected to ILIM,
 TXENB=RXENB=RXGAIN=RXSATT=Low, unless otherwise noted.



■ TYPICAL CHARACTERISTICS (continued)

At $T_a=25^\circ\text{C}$, $V_{DD1,2,3,4}=15\text{V}$, $12\text{k}\Omega$ connected to ILIM,

TXENB=RXENB=RXGAIN=RXSATT=Low, unless otherwise noted.



■ EQUIVALENT CIRCUIT

PIN No.	PIN NAME	EQUIVALENT CIRCUIT
<p>1 2</p>	<p>TXOUT1 TXOUT2</p>	
<p>5</p>	<p>D.N.C</p>	
<p>6</p>	<p>ILIM</p>	

PIN No.	PIN NAME	EQUIVALENT CIRCUIT
<p>7 8</p>	<p>TJALM1 TJALM2</p>	
<p>9 14</p>	<p>RXGAIN RXSATT</p>	
<p>11</p>	<p>RXIN</p>	

PIN No.	PIN NAME	EQUIVALENT CIRCUIT
13	RXENB	
15	RXOUT	
16	VREFIN_RX	

PIN No.	PIN NAME	EQUIVALENT CIRCUIT
<p>17 19</p>	<p>VREFIN_TX VREFOUT</p>	
<p>20</p>	<p>TXENB</p>	
<p>23 24</p>	<p>TXINP TXINN</p>	

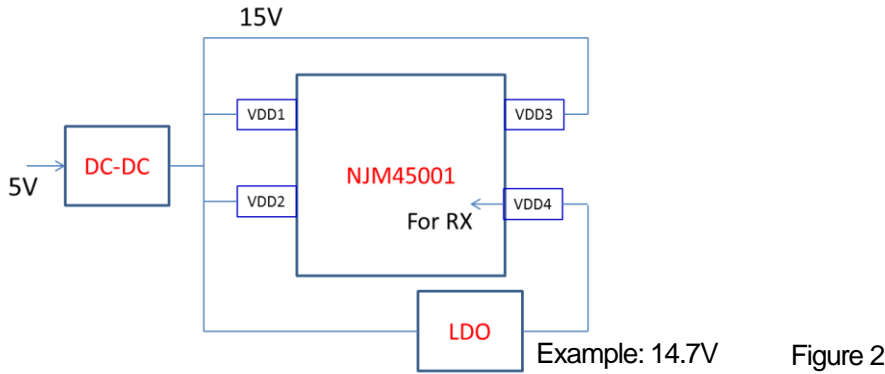


Figure 2

1.3 Power supply bypass capacitor

Figure 3 shows an example of a power supply bypass capacitor.

When the transmit parts and the receive parts operate exclusively, there is no need to separate the transmit parts power supply and the receive parts power supply.

Ultimately, it also depends on the noise etc. of the step-up switching power supply line, so check the transmit / receive output noise characteristics on the application circuit board. It is recommended to separate VDD2 and VDD3 from VDD1.

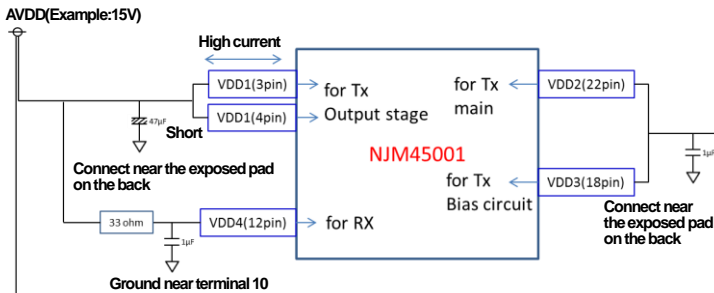


Figure 3

1.4 Each power supply terminal current for each mode (For your reference)

Typical current value

Mode	VDD2 (22pin) VDD1 (3, 4pin)	VDD4 (12pin)	VDD3 (18pin)	Total
Tx ON , Rx OFF	27.4mA	0.8mA	0.8mA	29mA
Tx OFF, Rx ON	0.6mA	3.2mA	0.7mA	4.5mA
Tx OFF, Rx OFF	0.6mA	0.8mA	0.7mA	2.1mA
Tx ON , Rx ON	27.4mA	3.2mA	0.8mA	31.4mA

Vcc=15V, Ta=25°C, No external load

Table 1

2. Thermal shutdown(TSD) function

NJM45001 has TSD function. The temperature detection sensor is placed close to the output transistor of the transmit amplifier with the highest temperature rise.

TJALM1(Terminal 7) outputs a state of TSD,

Terminal 7=Low

When NJM45001 detects a high temperature (about 160°C.), the terminal 7 becomes Low. This state indicates that the NJM45001 is forcibly stopped.

Terminal 7=High

When NJM45001 is in the normal temperature range, the terminal 7 becomes High.

TJALM2(terminal 8) outputs a state of approaching the thermal shutdown temperature as an alarm. However, control inside the NJM45001 is not performed.

Terminal 8=Low

When NJM45001 detects a high temperature (about 135°C. or higher), the terminal 8 becomes Low.

Terminal 8=High

When NJM45001 is in the normal temperature range, the terminal 8 becomes High.

Feedback the state of TJALM 8 (terminal 8) to the modem IC to reduce the transmit output amplitude or shorten the transmit time to prevent thermal shutdown.

3. Transmit amplifier of NJM45001

3.1 Transmission amplifier of NJM45001 can be used as single input or differential input.

Single input circuit example

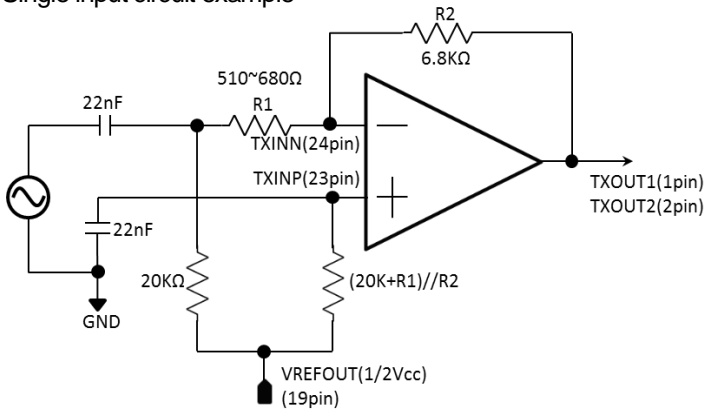


Figure 4

Differential input circuit example

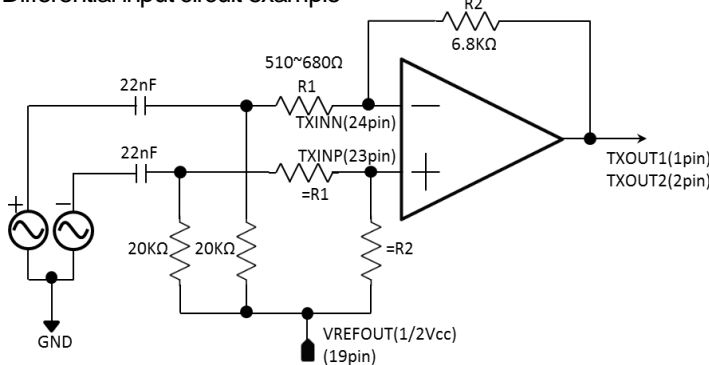


Figure 5

3.2 Regarding the timing of the transmit signal and TXENB

The transmit amplifier is in normal operation after about 10 μsec after the TXENB signal (pin 20) becomes 'Low'. If noise is included in the input signal to send, it is recommended to mask with the TXENB signal.

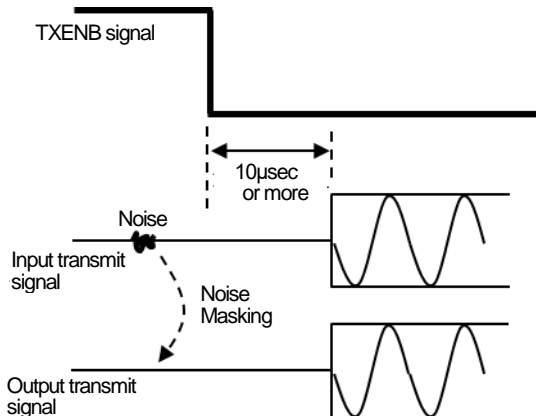


Figure 6

3.3 Relationship between spike noise of transmit output and protection diode (important matter)

It is necessary to connect a protection diode to the transmit output terminal for lightning surge protection. Please use a diode

with small leakage current. As a guide, it is 1 μA or less in the whole temperature range. When the transmit amplifier is OFF, the transmit output becomes high impedance. The leakage current of the protection diode causes a shift in the potential of the transmit amplifier output. When the transmit amplifier shifts from OFF to ON, DC potential shift occurs and output noise is generated.

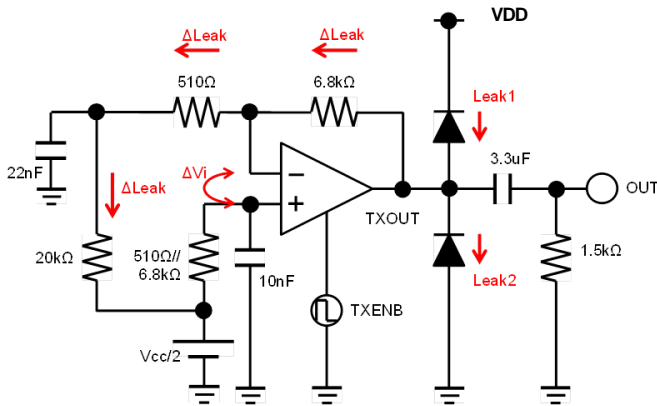


Figure 7

The difference between Leak 1 current and Leak 2 current shown in Figure 7 shifts the output DC at the time of the transmit amplifier OFF. When the transmit amplifier is turned on in this state, the transmit output DC returns to approximately 1/2 VDD, so this DC shift becomes spike noise and is output to the transmit line.

The recommended protection diode is ES3AB.

4. Regarding substrate thermal design

Maximum heat capacity (Pd) of the package adopted by NJM45001 is 3700mW when mount on EIA / JDEC standard board (114.5 × 101.5 1.6 mm, 4 layers FR - 4) of glass epoxy board. (When backside exposed pad of package is mounted on board thermal via hole of board.)

If junction temperature of IC exceeds 150°C, thermal shutdown will operate. Please thermal design according to power supply voltage to be used and assumed minimum load resistance.

4.1 Calculate the power dissipation of NJM45001. (Sine wave signal)

$$Pd(W)=P1-P2+P3+P4$$

P1: Output power dissipation of transmit amplifier part

$$P1 = \frac{VDD\sqrt{2}}{\pi RL} \times Vrms$$

P2: Power dissipation of output load part

$$P2 = \frac{Vrms^2}{RL}$$

P3: Power dissipation by supply current of transmit amplifier part

$$P3 = VDD \times IDDTX$$

P4: Power dissipation in shutdown of receive amplifier part

$$P4 = VDD \times IDSD$$

VDD: Supply voltage(V) RL: Load resistance(Ω) Vrms: Output voltage

IDDTX: Supply current of the transmit amplifier part when no-signal

IDSD: Supply current when shutdown of receive amplifier part

4.2 How to measure Tj

Junction temperature can be measured at terminal 5.
 However, since terminal 5 is a terminal (DNC) which is not normally used, please only use it experimentally.
 Figure 8 shows the equivalent circuit around terminal 5.
 The forward voltage of three diodes can be monitored at terminal 5.

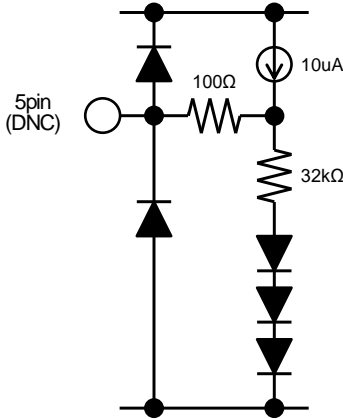
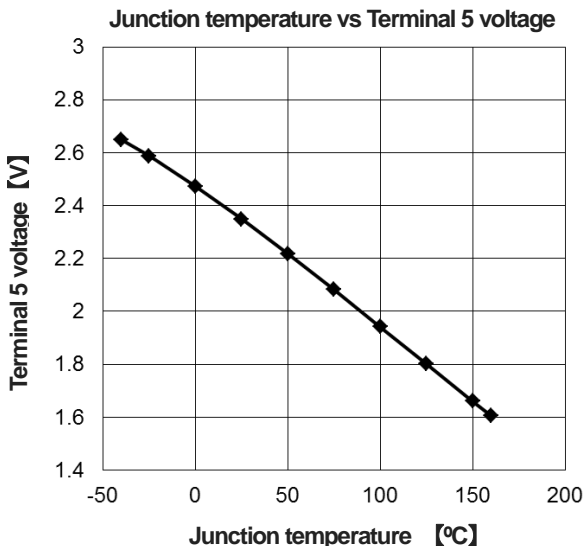


Figure 8

The temperature coefficient of three diodes is about -5.5 mV/°C as shown in graph 1. (25°C or higher)



Graph 1

At the time of signal input, measure the voltage at terminal 5 (V5_Shut) at TXENB terminal Hi and the voltage at terminal 5 (V5_signal) at TXENB terminal Lo. (RXENB terminal is Hi constant)
 When the TXENB and RXENB terminals are Hi, most functions are off, so it can be thought that junction temperature = ambient temperature.

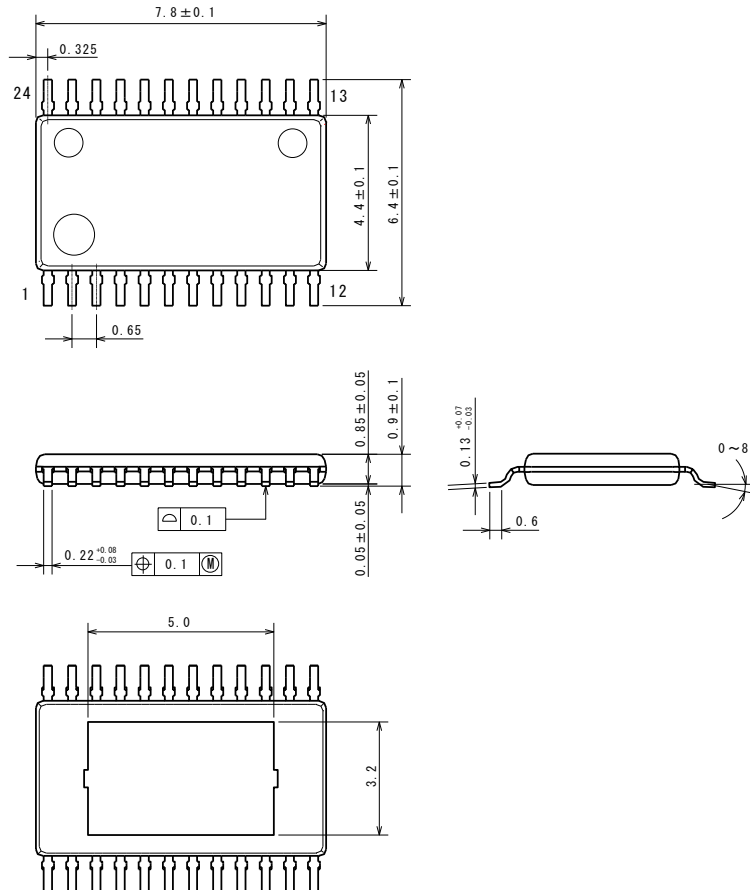
$$\frac{V5_shunt(V) - V5_signal(V)}{Ta(^{\circ}C) - Tj(^{\circ}C)} = -5.5mV/^{\circ}C$$

$$Tj(^{\circ}C) = \frac{V5_shunt(V) - V5_signal(V)}{5.5mV/^{\circ}C} + Ta(^{\circ}C)$$

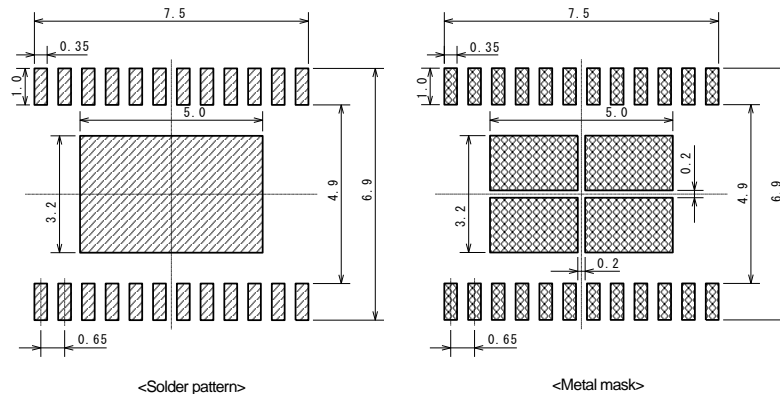
Result, thermal resistance θ is as follows.

$$\theta(^{\circ}C/W) = \frac{Tj(^{\circ}C) - Ta(^{\circ}C)}{Pd(W)}$$

■ PACKAGE DIMENSIONS



■ EXAMPLE OF SOLDER PADS DIMENSIONS



<Instructions for mounting>

Please note the following points when you mount HTSSOP24-P1 package IC because there is a backside electrode.

(1) Temperature profile of lead and backside electrode.

It is necessary that both re-flow temperature profile of lead and backside electrode are higher than preset temperature.

When solder wet temperature is lower than lead/backside electrode temperature, there is possibility of defect mounting.

(2) Design of foot pattern / metal mask

Metal mask thickness of solder pattern print is more than 0.13mm.

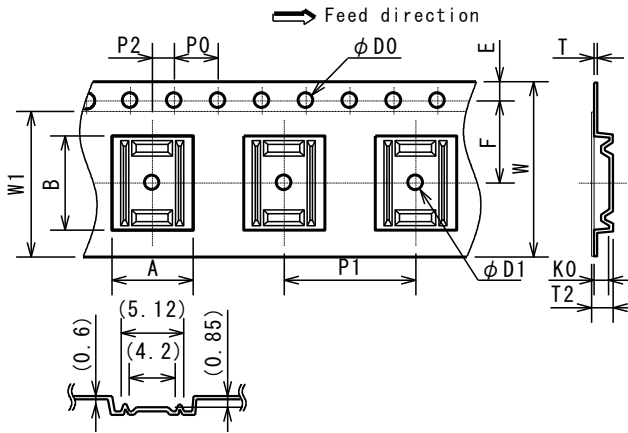
(3) Solder paste

The mounting was evaluated with following solder paste, foot pattern and metal mask. Because mounting might be greatly different according to the manufacturer and the product number even if the solder composition is the same. We will strongly recommend to evaluate mounting previously with using foot pattern, metal mask and solder paste.

Solder paste composition	Sn3Ag0.5Cu (Senju Metal Industry Co., Ltd : M705-GRN350-32-11)
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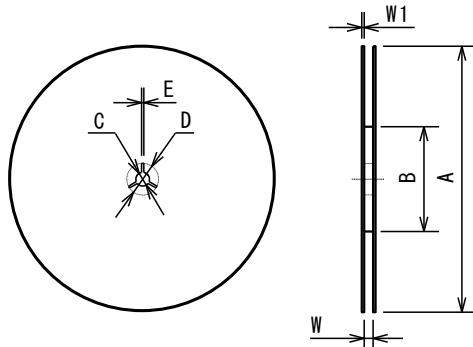
PACKING SPEC

TAPING DIMENSIONS



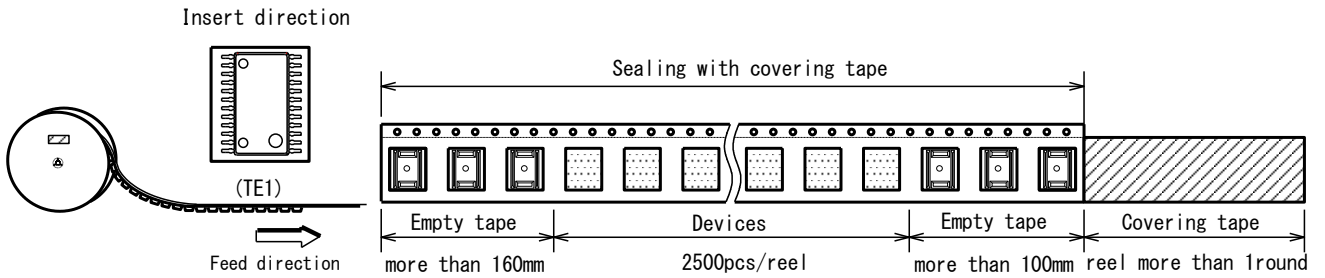
SYMBOL	DIMENSION	REMARKS
A	7.45±0.2	
B	8.60±0.1	
D0	1.5 ^{+0.1} ₀	
D1	1.5 ^{+0.1} ₀	
E	1.75±0.1	
F	7.5±0.1	
P0	4.0±0.1	
P1	12.0±0.1	
P2	2.0±0.1	
T	0.3±0.05	
T2	1.85	
K0	1.45±0.3	
W	16.0±0.3	
W1	13.3	THICKNESS 0.1max

REEL DIMENSIONS

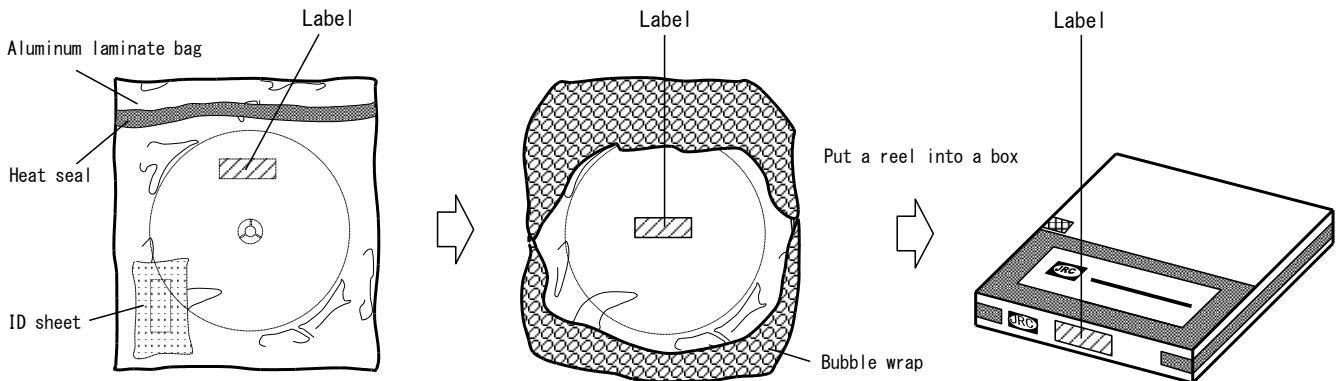


SYMBOL	DIMENSION
A	φ 330±2
B	φ 100±1
C	φ 13±0.2
D	φ 21±0.8
E	2±0.5
W	17.4±1
W1	2

TAPING STATE

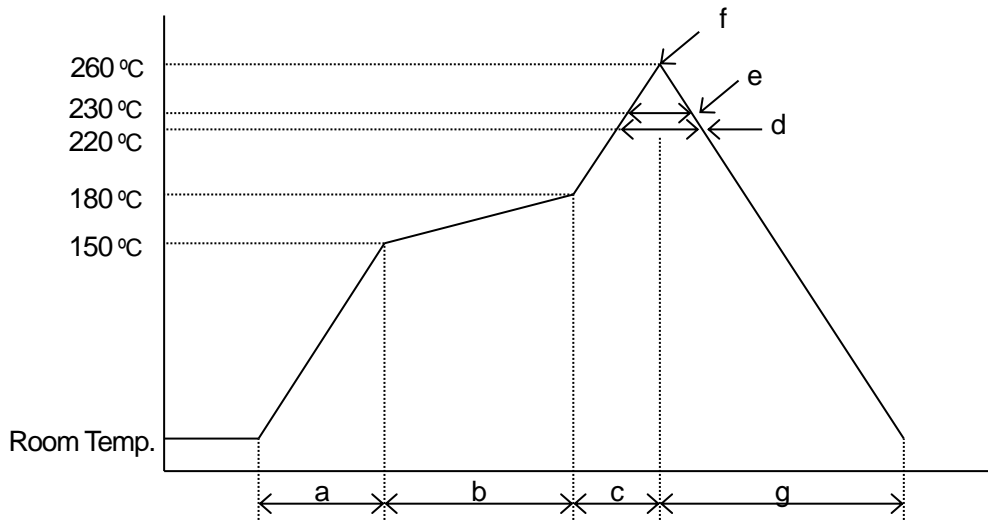


PACKING STATE



■ RECOMMENDED MOUNTING METHOD

*Recommended reflow soldering procedure



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

■ REVISION HISTORY

Date	Revision	Changes
2017/7/4	Ver.1.0	Initial Version
2017/6/1	Ver.2.0	Add application notes

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