

PS9551AL4

R08DS0121EJ0100

Rev.1.00

Mar 20, 2014

Optically Isolated Delta-Sigma Modulator

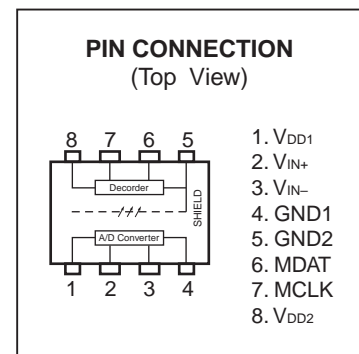
DESCRIPTION

The PS9551AL4 is an optically isolated Delta – Sigma Modulator that includes high-Accuracy A/D convertor and converts an analog voltage input into one-bit data stream. PS9551AL4 provides Effective Number of Bit (ENOB) is 12 bits (typ) with a Sinc³ digital filter.

The PS9551AL4 is designed specifically for high common mode transient immunity (CMR) and high linearity (nonlinearity). The PS9551AL4 is suitable for current sensing and voltage sensing in motor drives.

FEATURES

- Internal Reference Voltage Tolerance ($GE = \pm 1\% \text{ MAX.}$)
- Effective Number of Bit (ENOB = 12 bits TYP.)
- Operating Ambient Temperature ($T_A = -40 \text{ to } 105^\circ\text{C}$)
- Non-linearity (INL = 0.14% MAX.)
- Input Offset Voltage ($V_{OS} = 3 \text{ mV MAX.}$)
- Input Offset Voltage Drift vs. Temperature ($|dV_{OS}/dT_A| = 2 \mu\text{V}/^\circ\text{C TYP.}$)
- Output Clock Frequency ($f_{CLK} = 10 \text{ MHz TYP.}$)
- High common mode transient immunity (CMR= 15 kV/ μs MIN.)
- Package: 8-pin DIP lead bending type (Gull-wing) for long creepage distance for surface mount (L4)
- Embossed tape product: PS9551AL4-E3: 1 000 pcs/reel
- Pb-Free product
- <R> • Safety standards
 - UL approved: No. E72422
 - CSA approved: No. CA 101391 (CA5A, CAN/CSA-C22.2 60065, 60950)
 - SEMKO approved (EN 60065, EN60950)
 - DIN EN 60747-5-5 (VDE 0884-5) approved (Option)



APPLICATIONS

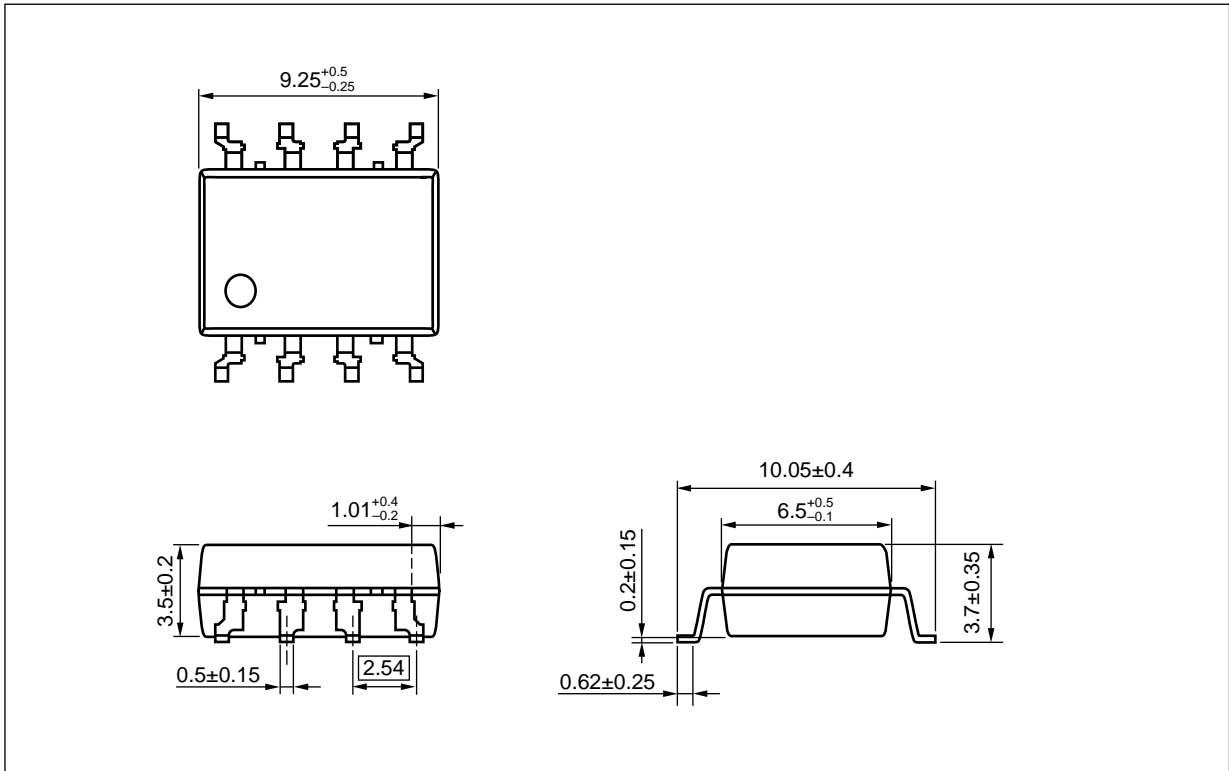
- AC Servo, inverter
- Solar inverter
- Measurement equipment

The mark <R> shows major revised points.

The revised points can be easily searched by copying an "<R>" in the PDF file and specifying it in the "Find what:" field.

PACKAGE DIMENSIONS (UNIT: mm)

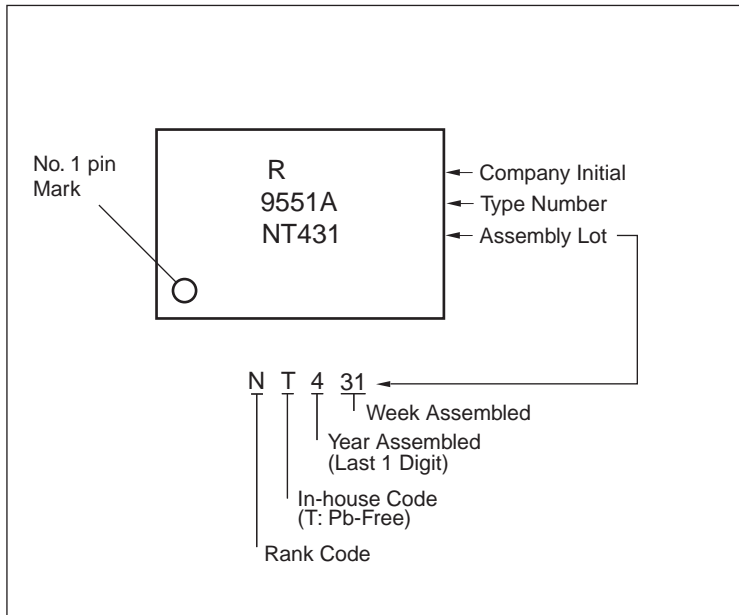
Lead Bending Type (Gull-wing) For Long Creepage Distance For Surface Mount (L4)



PHOTOCOUPLER CONSTRUCTION

| Parameter | MIN. |
|-------------------------|--------|
| Air Distance | 8 mm |
| Outer Creepage Distance | 8 mm |
| Isolation Distance | 0.4 mm |

<R> MARKING EXAMPLE



<R> ORDERING INFORMATION

| Part Number | Order Number | Solder Plating Specification | Packing Style | Safety Standard Approval | Application Part Number* ¹ |
|----------------|-------------------|------------------------------|------------------------------|---|---------------------------------------|
| PS9551AL4 | PS9551AL4-AX | Pb-Free (Ni/Pd/Au) | Magazine case 50 pcs | Standard products (UL, CSA, SEMKO approved) | PS9551AL4 |
| PS9551AL4-E3 | PS9551AL4-E3-AX | | Embossed Tape 1 000 pcs/reel | | |
| PS9551AL4-V | PS9551AL4-V-AX | | Magazine case 50 pcs | UL, CSA, SEMKO, DIN EN 60747-5-5 (VDE 0884-5) | |
| PS9551AL4-V-E3 | PS9551AL4-V-E3-AX | | Embossed Tape 1 000 pcs/reel | | |

*1 For the application of the Safety Standard, following part number should be used.

<R> **ABSOLUTE MAXIMUM RATINGS (T_A = 25°C, unless otherwise specified)**

| Parameter | Symbol | Ratings | Unit |
|-----------------------------------|---------------------------------------|-------------------------------|---------|
| Operating Ambient Temperature | T _A | -40 to +105 | °C |
| Storage Temperature | T _{stg} | -55 to +125 | °C |
| Supply Voltage | V _{DD1} , V _{DD2} | 0 to 5.5 | V |
| Input Voltage | V _{IN+} , V _{IN-} | -2 to V _{DD1} +0.5 | V |
| 2 Seconds Transient Input Voltage | V _{IN+} , V _{IN-} | -6 to V _{DD1} +0.5 | V |
| Output Voltage | V _{OUT+} , V _{OUT-} | -0.5 to V _{DD2} +0.5 | V |
| Isolation Voltage*1 | BV | 5 000 | Vr.m.s. |

*1 AC voltage for 1 minute at T_A = 25°C, RH = 60% between input and output.
Pins 1-4 shorted together, 5-8 shorted together.

<R> **RECOMMENDED OPERATING CONDITIONS**

| Parameter | Symbol | MIN. | TYP. | MAX. | Unit |
|---------------------------------------|-------------------------------------|------|------|------|------|
| Operating Ambient Temperature | T _A | -40 | | 105 | °C |
| Supply Voltage | V _{DD1} , V _{DD2} | 4.5 | 5 | 5.5 | V |
| Input Voltage (Accurate and Linear)*1 | V _{IN+} , V _{IN-} | -200 | | 200 | mV |

*1 Using V_{IN-} = 0 V (to be connected to GND1) is recommended. Avoid using V_{IN-} of 2.5 V or more, because the internal test mode is activated when the voltage V_{IN-} reaches more than 2.5 V.

<R> ELECTRICAL CHARACTERISTICS

(TYP.: $T_A = 25^\circ\text{C}$, $V_{IN+} = V_{IN-} = 0\text{ V}$, $V_{DD1} = V_{DD2} = 5\text{ V}$,

MIN., MAX.: refer to RECOMMENDED OPERATING CONDITIONS, unless otherwise specified)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|-------------|--|-----------|------|------|-------------------------|
| Input Supply Current | I_{DD1} | $V_{IN+} = 350\text{ mV}$ | | 12 | 15 | mA |
| Output Supply Current | I_{DD2} | $V_{IN+} = -350\text{ mV}$ | | 6 | 15 | mA |
| Input Bias Current | I_{IN} | | -5 | -0.6 | 5 | μA |
| Low Level Saturated Output Voltage | V_{OL} | $I_{OUT} = 1.6\text{ mA}$ | | 0.1 | 0.6 | V |
| High Level Saturated Output Voltage | V_{OH} | $I_{OUT} = -100\ \mu\text{A}$ | 3.9 | 4.9 | | V |
| Output Short-circuit Current | $ I_{OSC} $ | $V_{OUT} = V_{DD2}$ or $V_{OUT} = \text{GND2}$ | | 17 | 40 | mA |
| Equivalent Input Resistance | R_{IN} | | | 450 | | $\text{k}\Omega$ |
| Output Clock Frequency | f_{CLK} | | 8.2 | 10 | 13.2 | MHz |
| Isolation Resistance | R_{I-O} | $V_{I-O} = 1\text{ kVDC}$, $T_A = 25^\circ\text{C}$ | 10^{11} | | | Ω |
| Isolation Capacitance | C_{I-O} | $f = 1\text{ MHz}$ | | 0.7 | | pF |
| Data Hold Time ^{*1} | t_{HDDAT} | | 4 | 10 | 16 | ns |
| Common Mode Transient Immunity ^{*2} | CMR | $V_{CM} = 1\text{ kV}$, $T_A = 25^\circ\text{C}$ | 15 | | | $\text{kV}/\mu\text{s}$ |

*1 The data hold time (t_{HDDAT}) is that the data (MDAT) will stay stable following the rising edge of the clock (MCLK). t_{HDDAT} is shown in the below timing chart.

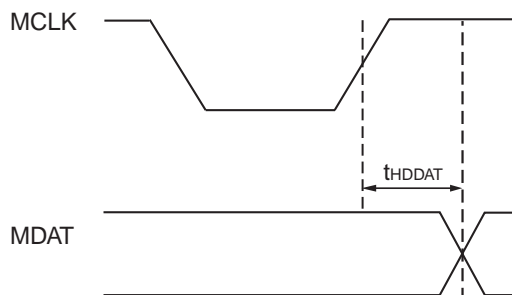


Fig. Timing Chart

*2 Common Mode Transient Immunity (CMR) is specified by the rate of rise / fall of a pulse applied between GND1 on the input side and GND2 on the output side (pins 4 and 5) by using the circuit shown in Fig. 6 CMR Test Circuit. CMR is defined at the point that clock signals are corrupted.

<R> **ELECTRICAL CHARACTERISTICS (Tested with Sinc³ filter, 256 decimation ratio.)**
(TYP.: T_A = 25°C, V_{IN+} = V_{IN-} = 0 V, V_{DD1} = V_{DD2} = 5 V,
MIN., MAX.: refer to RECOMMENDED OPERATING CONDITIONS, unless otherwise
specified)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|--------------------------------------|-------------------------------------|------|------|------|--------|
| Integral Non-linearity *3 | INL | -200 mV ≤ V _{IN+} ≤ 200 mV | | 3 | 30 | LSB |
| | | | | 0.01 | 0.14 | % |
| Differential Non-linearity *4 | DNL | -200 mV ≤ V _{IN+} ≤ 200 mV | | | 1 | LSB |
| Input Offset Voltage *5 | V _{OS} | | -3 | 0 | 3 | mV |
| Input Offset Voltage Drift vs. Temperature | dV _{OS} /dT _A | | | 2 | 10 | μV/°C |
| Input Offset Voltage Drift vs. Supply Voltage | dV _{OS} /dV _{DD1} | | | 0.1 | | mV/V |
| Internal Reference Voltage *6 | V _{REF} | | | 320 | | mV |
| Absolute Internal Reference Voltage Tolerance | GE | T _A = 25°C | -1 | | 1 | % |
| | | T _A = -40 to 105°C | -4 | | 4 | % |
| Internal Reference Voltage Drift vs. Temperature | dV _{REF} /dT _A | | | 60 | | ppm/°C |
| Internal Reference Voltage Drift vs. Supply Voltage | dV _{REF} /dV _{DD1} | | | 0.2 | | mV/V |
| Input DC Common-Mode Rejection Ratio *7 | CMRR _{IN} | | | 70 | | dB |

*3 Integral non-linearity (INL) is the maximum deviation between the ideal conversion line (best-fit line) and measured points. The best-fit line is obtained by using the least-squares method from the differential input voltage (V_{IN+} – V_{IN-}: V_{IN+} = –200 mV to 200 mV, V_{IN-} = 0 V) and the output data that is measured under the circuit shown in **Fig. 7 INL Test Circuit**. INL is defined as the ratio (%) obtained by dividing [Half of the peak to peak value of the deviation] by [full-scale differential input voltage 400 mV].

For example, if the differential input voltage is V_{IN+} = –200 mV to 200 mV, and the peak to peak value of the deviation is 1.12 mV, Integral non-linearity is obtained as follows:

$$\text{INL} = 1.12 \text{ mV} / (2 \times 400 \text{ mV}) = 0.14\%$$

And Input Full-Scale 640 mV (–320 to 320 mV) of PS9551A is assigned 15 bits (2¹⁵ = 32768).

Therefore, Least Significant Bit (LSB) is 19.5 μV.

By LSB indication, above-mentioned INL is 1.12 mV / (2 × 0.0195 mV) = 29 LSBs.

*4 Differential non-linearity (DNL) is the difference between a measured code width and ideal 1 LSB in the ADC transfer curve.

*5 Input offset voltage (V_{OS}) is a measured value after Sinc³ digital filter when the input voltage is 0 V (V_{IN+} = V_{IN-} = 0 V).

*6 Absolute Internal Reference Voltage Tolerance (GE) is the gap rate between the ideal conversion line slope (Slope = 1) and a best-fit line slope that provided by the least-squares method from a real conversion level output for the differential input voltage (V_{IN+} – V_{IN-}: V_{IN+} = –200 mV to 200 mV, V_{IN-} = 0 V).

*7 Input DC Common-Mode Rejection Ratio (CMRR_{IN}) is the ratio of the differential signal (V_{IN+} = –200 mV to 200 mV, V_{IN-} = 0 V) to the common-mode signal (V_{IN+} = V_{IN-} = –200 mV to 200 mV: Both input pins are connected). CMRR_{IN} is defined as follows,

$$\text{CMRR}_{\text{IN}} (\text{dB}) = 20 \log (V_{\text{do}}/V_{\text{co}})$$

V_{do} : Output voltage when the differential signal voltage input

V_{co} : Output voltage when the common-mode signal voltage input

<R> **ELECTRICAL CHARACTERISTICS (Tested with Sinc³ filter, 256 decimation ratio.)**
(TYP.: T_A = 25°C, V_{IN+} = V_{IN-} = 0 V, V_{DD1} = V_{DD2} = 5 V,
MIN., MAX.: refer to RECOMMENDED OPERATING CONDITIONS, unless otherwise
specified)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|--------|---|------|------|------|------|
| Signal to Noise Ratio *8 | SNR | V _{IN+} = 35 Hz, 400 mVpk-pk (141 mVr.m.s.) sine wave | 62 | 74 | | dB |
| Total Harmonic Distortion *9 | THD | | | -80 | | dB |
| Signal to Noise and Distortion Ratio *10 | SNDR | | | 72 | | dB |
| Effective Number of Bit *11 | ENOB | | 10 | 12 | | bits |

*8 Signal to Noise Ratio (SNR) is the ratio of the AC signal power to the noise power that excludes harmonic signals and DC. SNR is defined as follows,

$$\text{SNR (dB)} = 10\log(P_s/P_N)$$

P_s: Signal power (fundamental)

P_N: Noise power (excluding harmonic signals and DC)

*9 Total Harmonic Distortion (THD) is the ratio of the AC signal power (fundamental) to the sum of harmonic signals that are occurred by the non-linearity. THD is defined as follows,

$$\text{THD (dB)} = 10\log((P_{H2} + P_{H3} + \dots + P_{H5})/P_s)$$

P_s: Signal power (fundamental)

P_{H2}, P_{H3} ... P_{H5}: Second through fifth harmonics power

*10 Signal to Noise and Distortion ratio (SNDR) is the ratio of the AC signal power (fundamental) to the noise power plus distortion power. SNDR is defined as follows,

$$\text{SNDR (dB)} = 10\log(P_s/(P_N + P_{H2} + P_{H3} + \dots + P_{H5}))$$

P_s: Signal power (fundamental)

P_N: Noise power (excluding harmonic signals and DC)

P_{H2}, P_{H3} ... P_{H5}: Second through fifth harmonics power

*11 Effective Number of Bit (ENOB) is the effective resolution of ADC that is considered the noise.

ENOB is defined as follows,

$$\text{ENOB (bits)} = (\text{SNR} - 1.76)/6.02$$

<R> TEST CIRCUIT

Fig.1 IDD1 Test Circuit

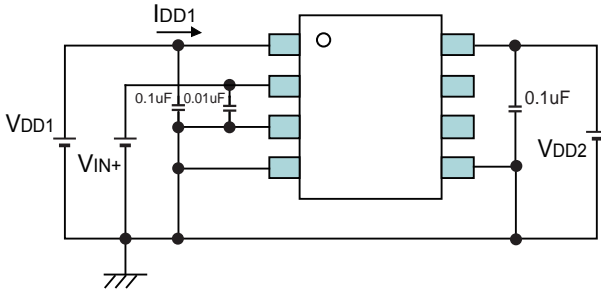


Fig.2 IDD2 Test Circuit

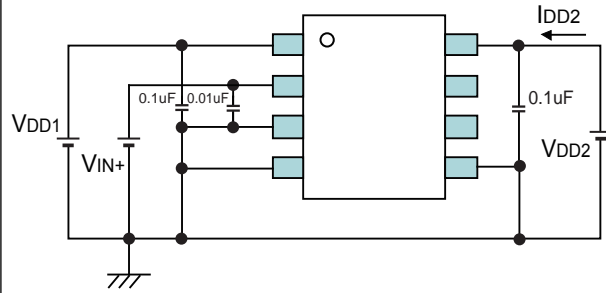


Fig.3 IIN Test Circuit

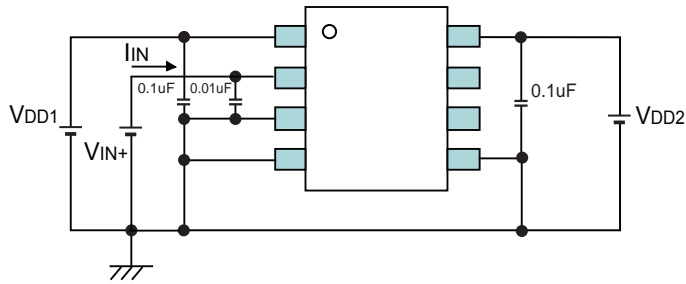
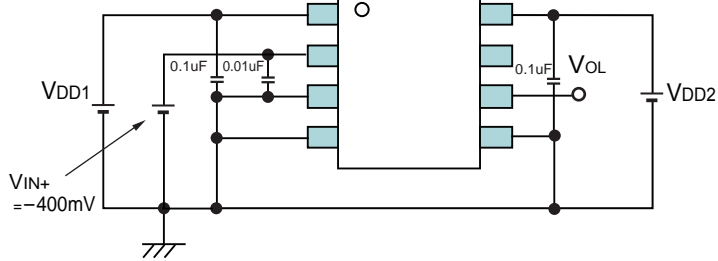


Fig.4 Vout Test Circuit

(VOL)



(VOH)

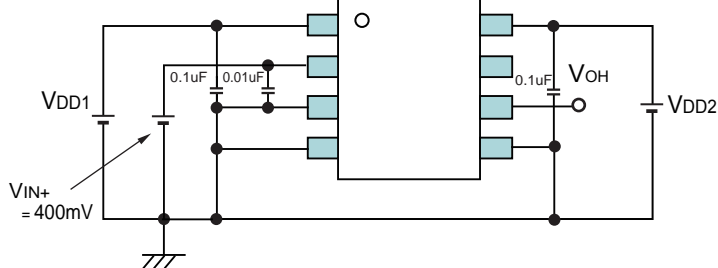


Fig.5 Iosc Test Circuit

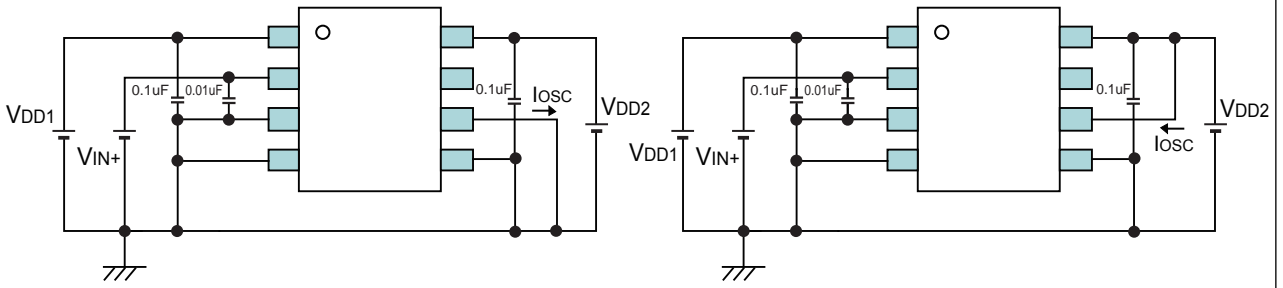


Fig.6 CMR Test Circuit

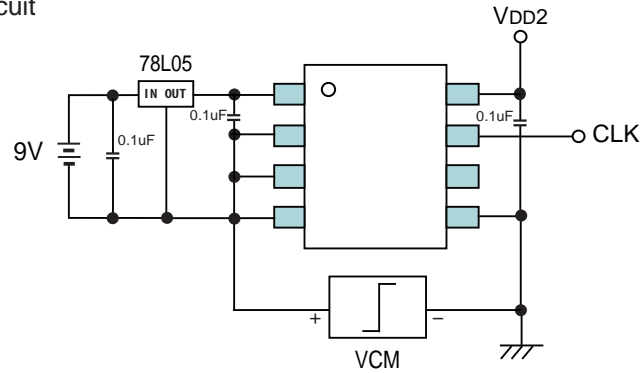
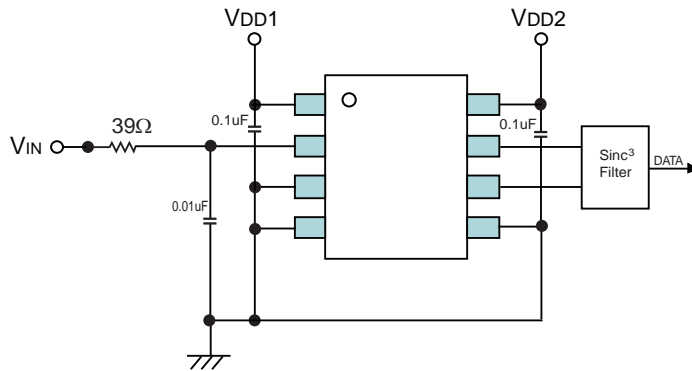
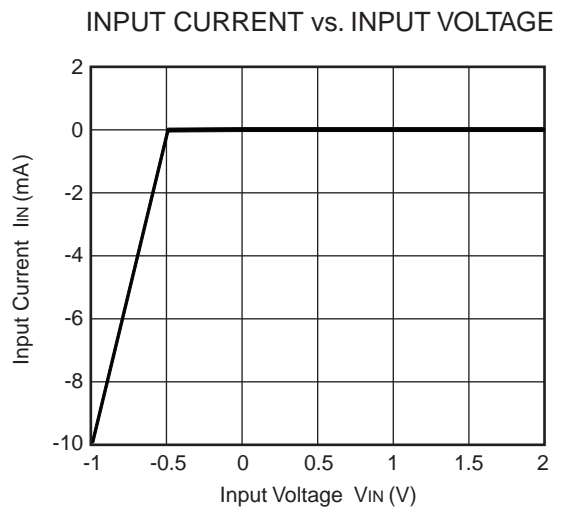
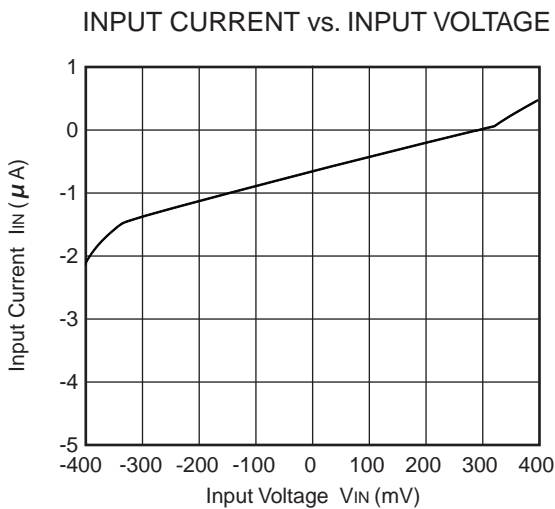
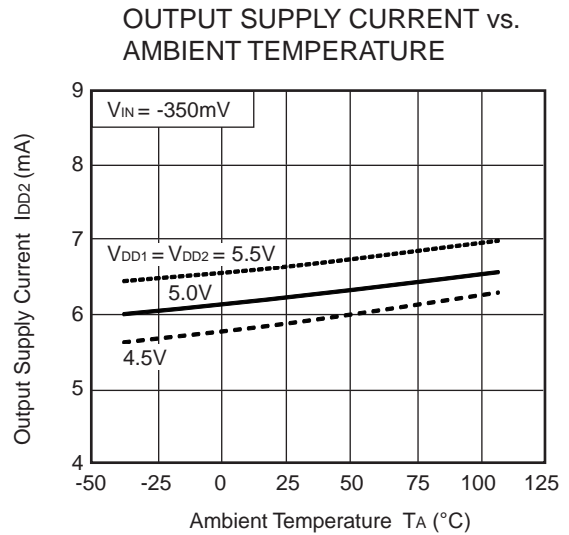
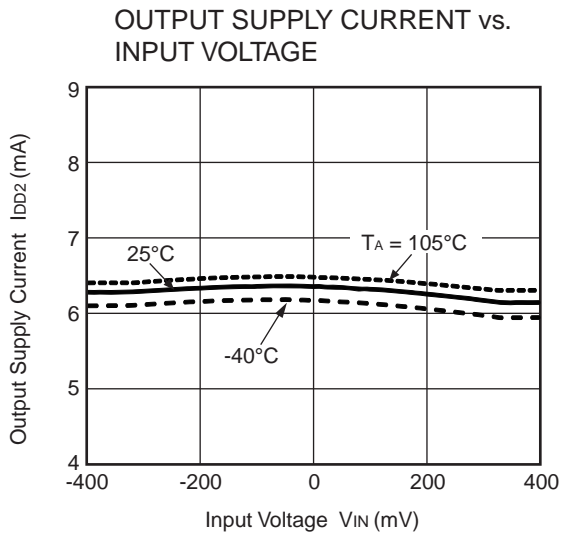
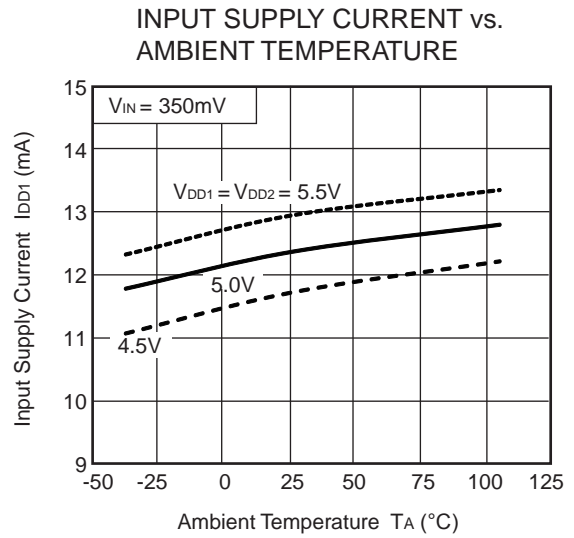
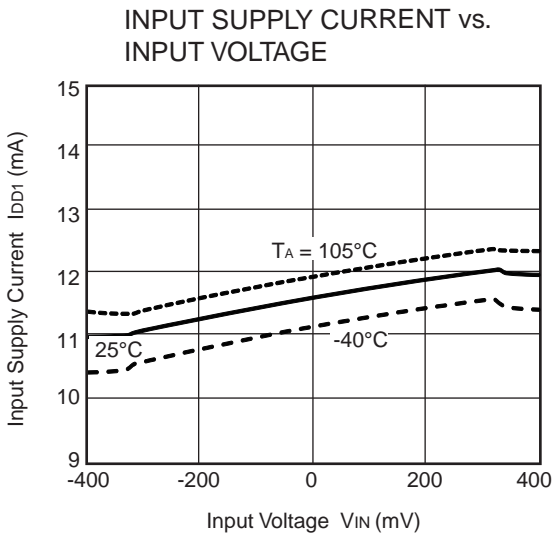


Fig.7 Vos, INL, DNL, Ge, SNR, THD, SNDR, ENOB Test Circuit

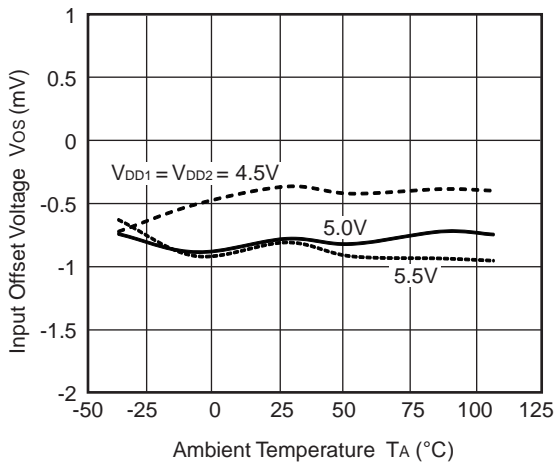


<R> **TYPICAL CHARACTERISTICS** ($T_A = 25^\circ\text{C}$, $V_{IN+} = V_{IN-} = 0\text{ V}$, $V_{DD1} = V_{DD2} = 5\text{ V}$, tested with Sinc³ filter, 256 decimation ratio, unless otherwise specified)

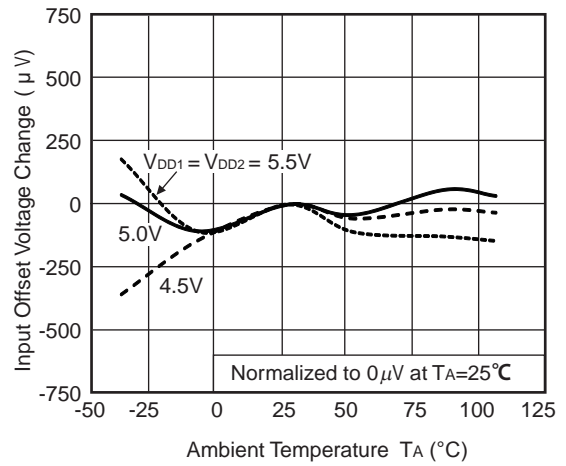


Remark The graphs indicate nominal characteristics.

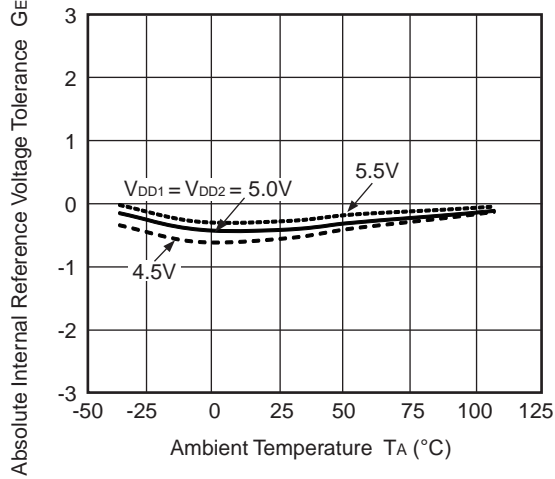
INPUT OFFSET VOLTAGE vs. AMBIENT TEMPERATURE



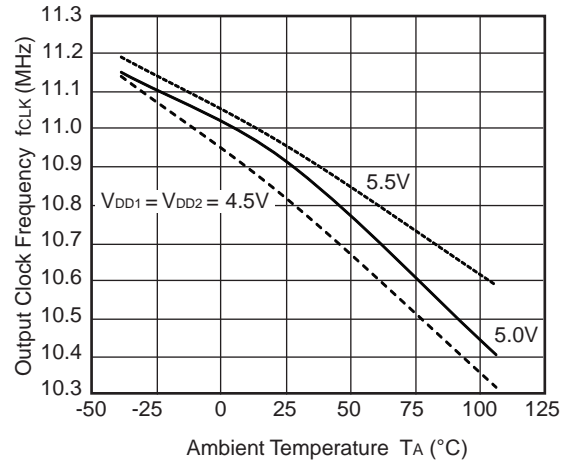
INPUT OFFSET VOLTAGE CHANGE vs. AMBIENT TEMPERATURE



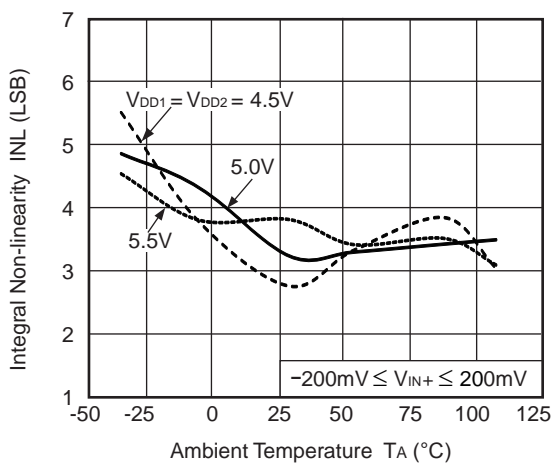
ABSOLUTE INTERNAL REFERENCE VOLTAGE TOLERANCE vs. AMBIENT TEMPERATURE



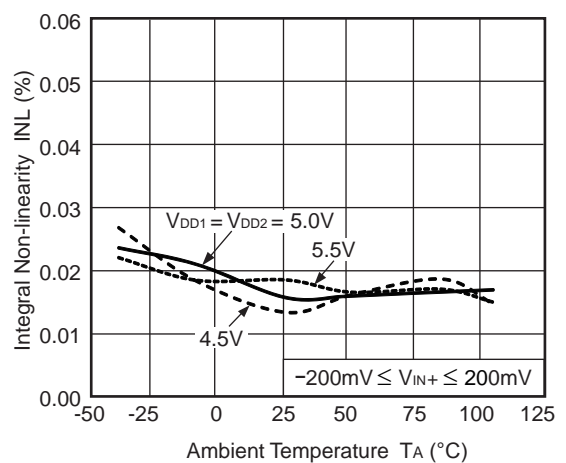
OUTPUT CLOCK FREQUENCY vs. AMBIENT TEMPERATURE



INTEGRAL NON-LINEARITY(LSB) vs. AMBIENT TEMPERATURE

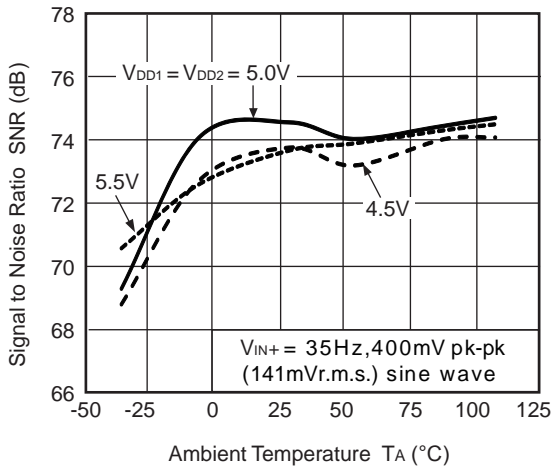


INTEGRAL NON-LINEARITY(%) vs. AMBIENT TEMPERATURE

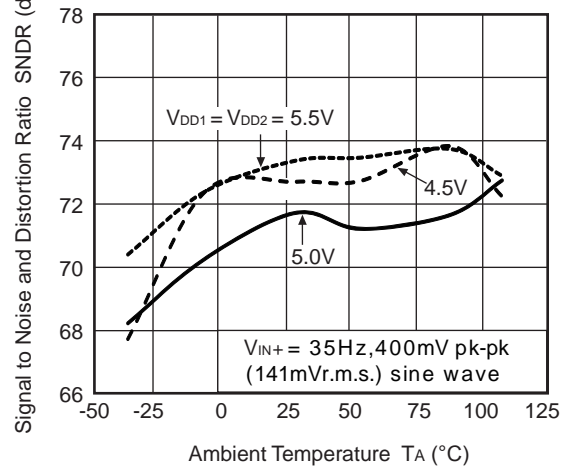


Remark The graphs indicate nominal characteristics.

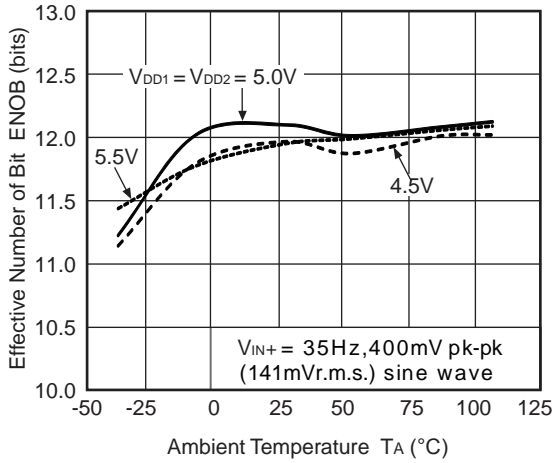
SIGNAL TO NOISE RATIO vs. AMBIENT TEMPERATURE



SIGNAL TO NOISE AND DISTORTION RATIO vs. AMBIENT TEMPERATURE



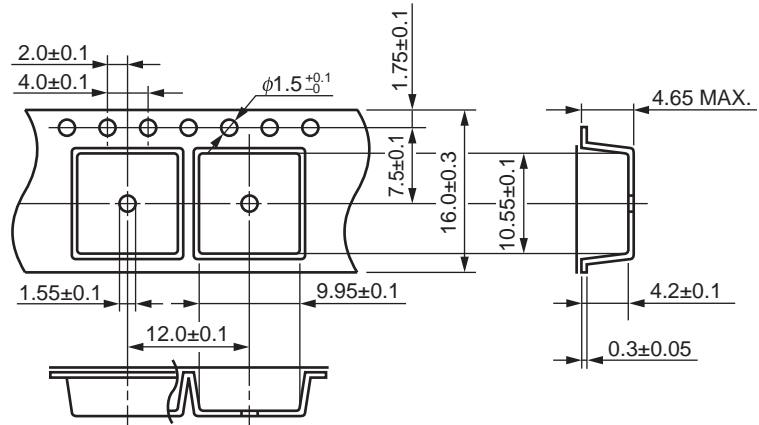
EFFECTIVE NUMBER OF BIT vs. AMBIENT TEMPERATURE



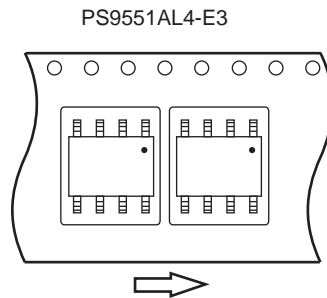
Remark The graphs indicate nominal characteristics.

TAPING SPECIFICATIONS (UNIT: mm)

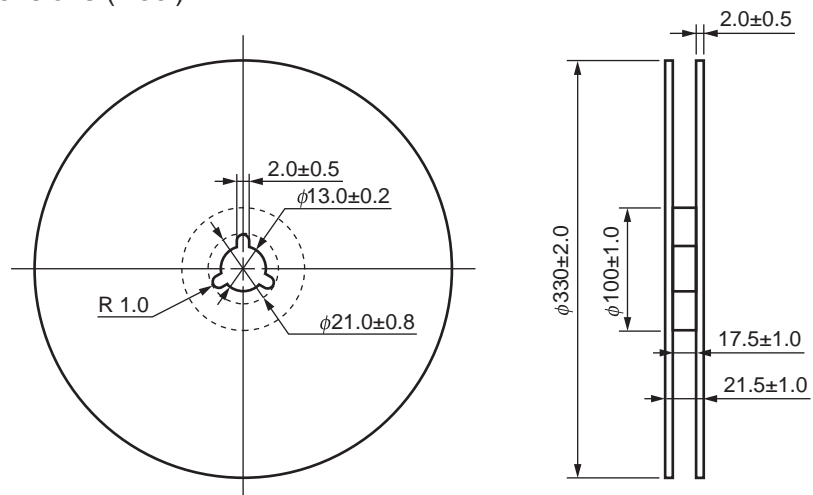
Outline and Dimensions (Tape)



Tape Direction

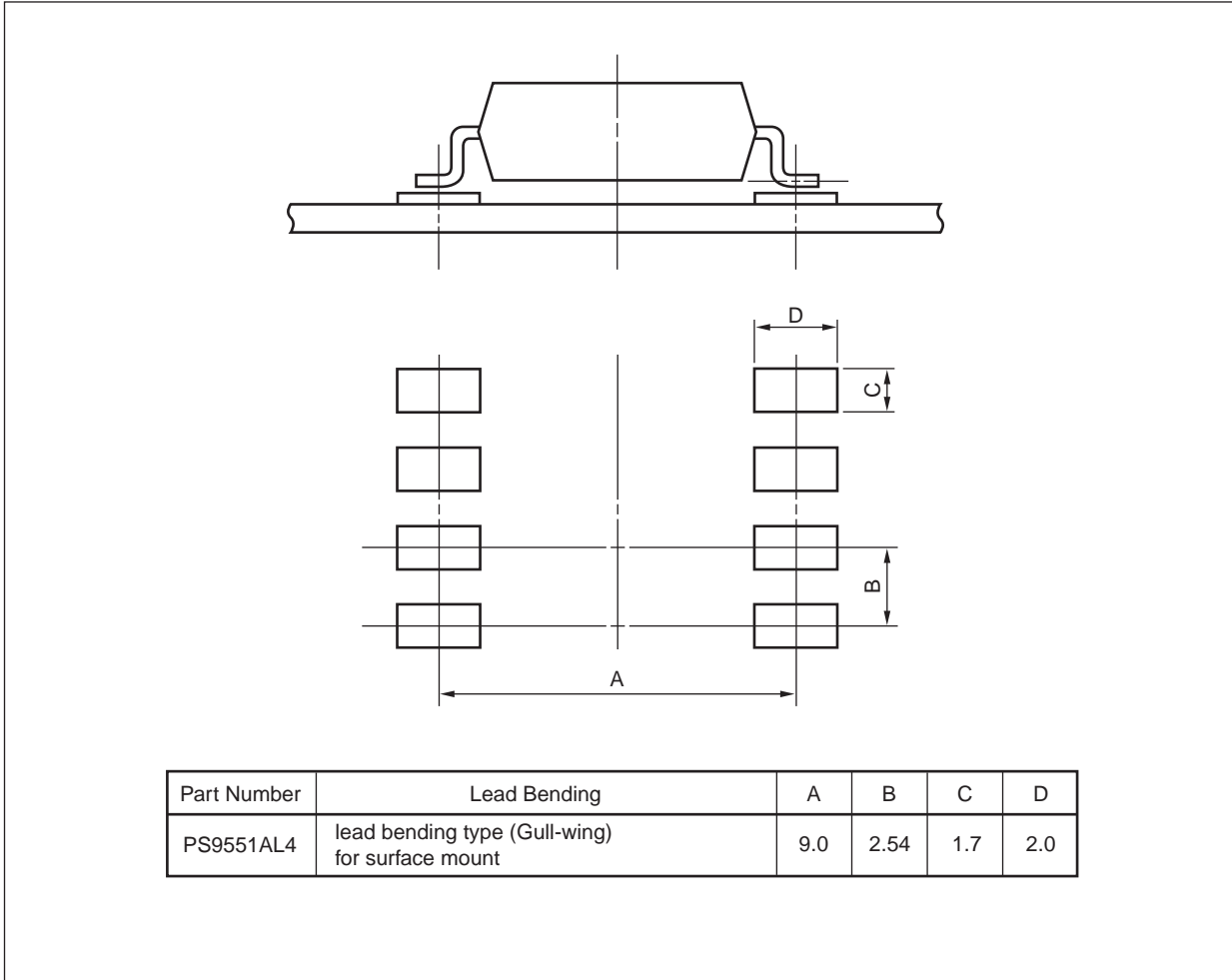


Outline and Dimensions (Reel)



Packing: 1 000 pcs/reel

<R> RECOMMENDED MOUNT PAD DIMENSIONS (UNIT: mm)



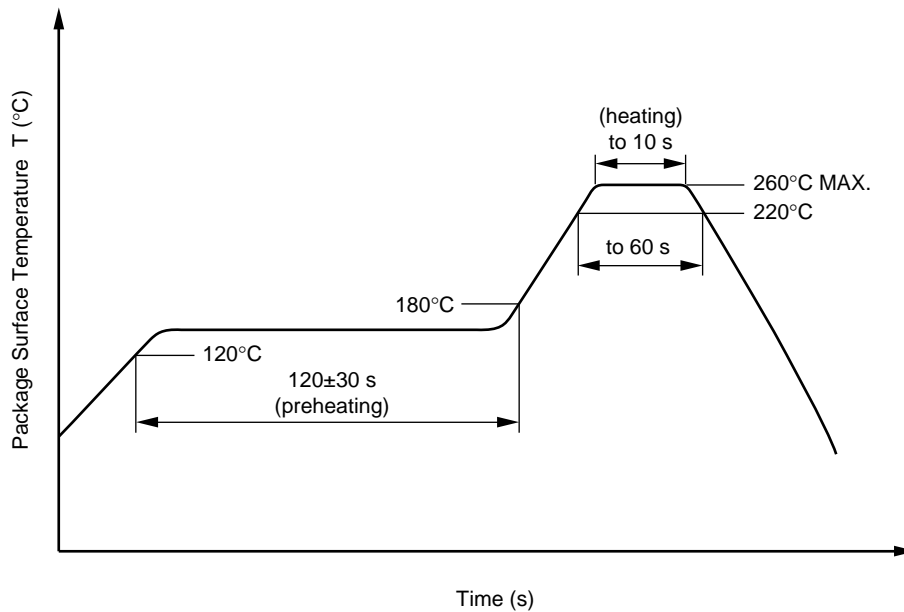
NOTES ON HANDLING

1. Recommended soldering conditions

(1) Infrared reflow soldering

- Peak reflow temperature 260°C or below (package surface temperature)
- Time of peak reflow temperature 10 seconds or less
- Time of temperature higher than 220°C 60 seconds or less
- Time to preheat temperature from 120 to 180°C 120±30 s
- Number of reflows Three
- Flux Rosin flux containing small amount of chlorine (The flux with a maximum chlorine content of 0.2 Wt% is recommended.)

Recommended Temperature Profile of Infrared Reflow



(2) Wave soldering

- Temperature 260°C or below (molten solder temperature)
- Time 10 seconds or less
- Preheating conditions 120°C or below (package surface temperature)
- Number of times One (Allowed to be dipped in solder including plastic mold portion.)
- Flux Rosin flux containing small amount of chlorine (The flux with a maximum chlorine content of 0.2 Wt% is recommended.)

(3) Soldering by Soldering Iron

- Peak Temperature (lead part temperature) 350°C or below
- Time (each pins) 3 seconds or less
- Flux Rosin flux containing small amount of chlorine (The flux with a maximum chlorine content of 0.2 Wt% is recommended.)

(a) Soldering of leads should be made at the point 1.5 to 2.0 mm from the root of the lead

(4) Cautions

• Fluxes

Avoid removing the residual flux with freon-based and chlorine-based cleaning solvent.

2. Cautions regarding noise

Be aware that when voltage is applied suddenly between the photocoupler's input and output at startup, the output transistor may enter the on state, even if the voltage is within the absolute maximum ratings.

<R> USAGE CAUTIONS

1. This product is weak for static electricity by designed with high-speed integrated circuit so protect against static electricity when handling.

2. Board designing

(1) Below figure shows a typical application circuit where the PS9551A is used. A digital filter (Sinc³ filter) reduces high frequency quantization noise from the PS9551A and converts from one-bit data stream to 3-wire serial data.

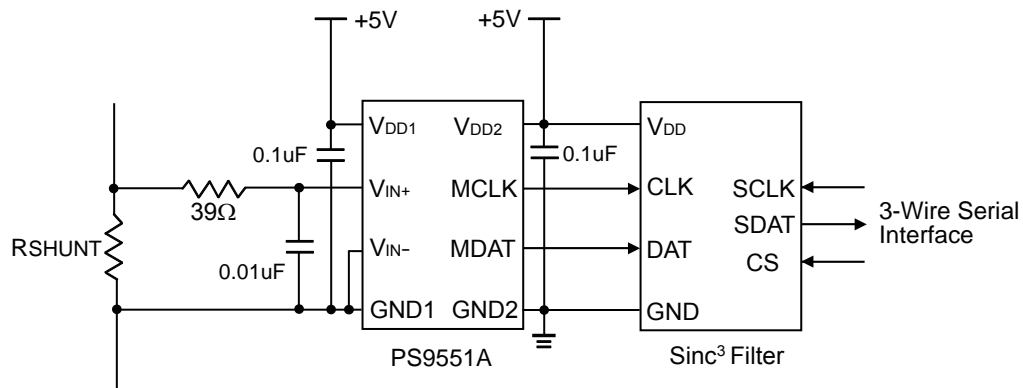


Fig. PS9551A Typical application circuit

(2) By-pass capacitor of more than 0.1 μF is used between V_{DD} and GND near device. Also, ensure that the distance between the leads of the photocoupler and capacitor is no more than 10 mm.

(3) Keep the pattern connected the input ($V_{\text{IN+}}$, $V_{\text{IN-}}$) and the output (MCLK, MDAT), respectively, as short as possible. MCLK and MDAT are digital signal, but when the lines between the photocoupler and a digital filter are long, the digital filter might not read the data.

When using long lines, use a line driver between the photocoupler and the digital filter, and keep the pattern between the output (MCLK, MDAT) and the line driver as short as possible.

(4) Do not connect any routing to the portion of the frame exposed between the pins on the package of the photocoupler. If connected, it will affect the photocoupler's internal voltage and the photocoupler will not operate normally.

(5) Because the maximum frequency of the signal input to the photocoupler must be lower than the allowable frequency band, be sure to connect an anti-aliasing filter (an RC filter with $R = 39 \Omega$ and $C = 0.01 \mu\text{F}$, for example).

(6) When V_{DD} is lower than 4.5 V that is the outside of recommended operating condition, the output (MCLK, MDAT) of this product is unstable, and this might produce undesirable operation. Be sure to check the operation of an IC that is connected to this product during Power-up and Power-down process. And we recommend to use a disable function (shutdown function) of the connected IC or a reset IC to avoid this undesirable operation.

3. Avoid storage at a high temperature and high humidity.

<R> SPECIFICATION OF VDE MARKS LICENSE DOCUMENT

| Parameter | Symbol | Spec. | Unit |
|---|----------------------|------------------------|----------------------|
| Climatic test class (IEC 60068-1/DIN EN 60068-1) | | 40/105/21 | |
| Dielectric strength | | | |
| maximum operating isolation voltage | U_{IORM} | 1 130 | V_{peak} |
| Test voltage (partial discharge test, procedure a for type test and random test) $U_{pr} = 1.6 \times U_{IORM}, Pd < 5 \text{ pC}$ | U_{pr} | 1 808 | V_{peak} |
| Test voltage (partial discharge test, procedure b for all devices) $U_{pr} = 1.875 \times U_{IORM}, Pd < 5 \text{ pC}$ | U_{pr} | 2 119 | V_{peak} |
| Highest permissible overvoltage | U_{TR} | 8 000 | V_{peak} |
| Degree of pollution (DIN EN 60664-1 VDE 0110 Part 1) | | 2 | |
| Comparative tracking index (IEC 60112/DIN EN 60112 (VDE 0303 Part 11)) | CTI | 175 | |
| Material group (DIN EN 60664-1 VDE 0110 Part 1) | | III a | |
| Storage temperature range | T_{stg} | -55 to +125 | $^{\circ}\text{C}$ |
| Operating temperature range | T_A | -40 to +105 | $^{\circ}\text{C}$ |
| Isolation resistance, minimum value $V_{IO} = 500 \text{ V dc at } T_A = 25^{\circ}\text{C}$ $V_{IO} = 500 \text{ V dc at } T_A \text{ MAX. at least } 100^{\circ}\text{C}$ | Ris MIN. Ris MIN. | 10^{12} 10^{11} | Ω Ω |
| Safety maximum ratings (maximum permissible in case of fault, see thermal derating curve) | | | |
| Package temperature | T_{si} | 175 | $^{\circ}\text{C}$ |
| Current (input current I_F , $P_{si} = 0$) | I_{si} | 400 | mA |
| Power (output or total power dissipation) | P_{si} | 700 | mW |
| Isolation resistance $V_{IO} = 500 \text{ V dc at } T_A = T_{si}$ | Ris MIN. | 10^9 | Ω |

| | |
|------------------------------|--|
| Caution GaAs Products | <p>This product uses gallium arsenide (GaAs). GaAs vapor and powder are hazardous to human health if inhaled or ingested, so please observe the following points.</p> <ul style="list-style-type: none">• Follow related laws and ordinances when disposing of the product. If there are no applicable laws and/or ordinances, dispose of the product as recommended below.<ol style="list-style-type: none">1. Commission a disposal company able to (with a license to) collect, transport and dispose of materials that contain arsenic and other such industrial waste materials.2. Exclude the product from general industrial waste and household garbage, and ensure that the product is controlled (as industrial waste subject to special control) up until final disposal.• Do not burn, destroy, cut, crush, or chemically dissolve the product.• Do not lick the product or in any way allow it to enter the mouth. |
|------------------------------|--|

Revision History**PS9551AL4 Data Sheet**

| Rev. | Date | Description | |
|-------------|--------------|--------------------|--|
| | | Page | Summary |
| 1.00 | Mar 20, 2014 | Throughout | Preliminary Data Sheet -> Data Sheet |
| | | Throughout | Safety standards approved |
| | | p.3 | Modification of MARKING EXAMPLE Addition of ORDERING INFORMATION |
| | | p.4 | Modification of ABSOLUTE MAXIMUM RATINGS Modification of RECOMMENDED OPERATING CONDITIONS |
| | | p.5 to 7 | Modification of ELECTRICAL CHARACTERISTICS |
| | | p.8 to 9 | Addition of TEST CIRCUIT |
| | | p.10 to 12 | Addition of TYPICAL CHARACTERISTICS |
| | | p.14 | Addition of RECOMMENDED MOUNT PAD DIMENSIONS |
| | | p.16 | Modification of USAGE CAUTIONS |
| | | p.17 | Addition of SPECIFICATION OF VDE MARKS LICENSE DOCUMENT |

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California Eastern Laboratories, Inc.

4590 Patrick Henry Drive, Santa Clara, California 95054, U.S.A.
Tel: +1-408-919-2500, Fax: +1-408-988-0279

Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.

Room 1709, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.

Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited

Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.

13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.

80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.

Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.

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Тел: +7 (812) 336 43 04 (многоканальный)

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