## Features

- Operating Voltage: 2.0V to 5.5V
- Supply Current: 220μA/amplifier typical
- Rail-to-Rail Output
- Gain Bandwidth: 2.3MHz typical
- Unity Gain Stable
- Available in Single, Dual and Quad Op's package types
- Package type:
  - ♦ HT9231: SOT23-5
  - ♦ HT9232: 8-pin DIP/SOP
  - ♦ HT9234: 14-pin DIP/SOP

## Applications

- Automotive
- Portable Equipment
- Photo diode Amplifier
- Analog Filters
- Notebooks and PDAs
- Battery Powered Systems

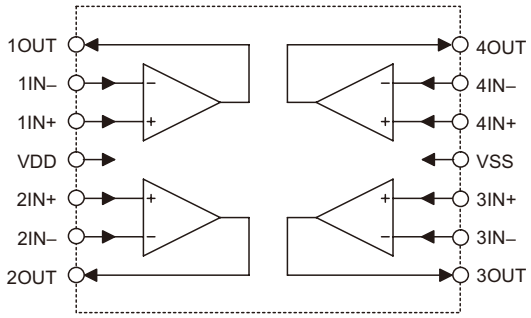
## General Description

The Holtek HT9231/HT9232/HT9234 range of Operational Amplifiers operate with a single supply voltage as low as 2.0V and offer a low supply current of only 220μA/amplifier. In offering rail-to-rail output voltage the devices can operate with a maximum voltage range. The devices also provide a gain bandwidth product of 2.3MHz and are also unity gain stable. These products are suitable for a wide range of analog signal processing applications but especially suitable for the portable device and battery powered equipment application areas.

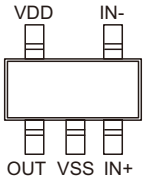
## Selection Table

| Part No. | Amplifiers | Package |
|---|---|---|
| HT9231 | 1 | SOT23-5 |
| HT9232 | 2 | 8DIP/SOP |
| HT9234 | 4 | 14DIP/SOP |

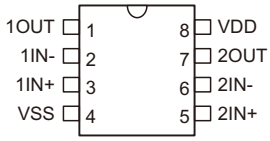
## Block Diagram



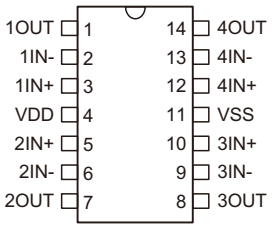

## Pin Assignment




HT9231
SOT23-5




HT9232
8 DIP-A/SOP-A




HT9234
14 DIP-A/SOP-A

## Pin Descriptions

**HT9231**

| Pin No. | Pin Name | Description |
|---|---|---|
| 1 | OUT | Analog output |
| 2 | VSS | Negative power supply |
| 3 | IN+ | Non-inverting input |
| 4 | IN- | Inverting input |
| 5 | VDD | Positive power supply |

**HT9232**

| Pin No. | Pin Name | Description |
|---|---|---|
| 1 | 1OUT | Analog output (operation amplifier 1) |
| 2 | 1IN- | Inverting input (operation amplifier 1) |
| 3 | 1IN+ | Non-inverting input (operation amplifier 1) |
| 4 | VSS | Negative power supply |
| 5 | 2IN+ | Non-inverting input (operation amplifier 2) |
| 6 | 2IN- | Inverting input (operation amplifier 2) |
| 7 | 2OUT | Analog output (operation amplifier 2) |
| 8 | VDD | Positive power supply |

**HT9234**

| Pin No. | Pin Name | Description |
|---|---|---|
| 1 | 1OUT | Analog output (operation amplifier 1) |
| 2 | 1IN- | Inverting input (operation amplifier 1) |
| 3 | 1IN+ | Non-inverting input (operation amplifier 1) |
| 4 | VDD | Positive power supply |
| 5 | 2IN+ | Non-inverting input (operation amplifier 2) |
| 6 | 2IN- | Inverting input (operation amplifier 2) |
| 7 | 2OUT | Analog output (operation amplifier 2) |
| 8 | 3OUT | Analog output (operation amplifier 3) |
| 9 | 3IN- | Inverting input (operation amplifier 3) |
| 10 | 3IN+ | Non-inverting input (operation amplifier 3) |
| 11 | VSS | Negative power supply |
| 12 | 4IN+ | Non-inverting input (operation amplifier 4) |
| 13 | 4IN- | Inverting input (operation amplifier 4) |
| 14 | 4OUT | Analog output (operation amplifier 4) |

## Absolute Maximum Ratings

Supply Voltage ..... 6.0V
Difference Input Voltage ..... $\pm(V_{DD}-V_{SS})$
Storage Temperature ..... −65°C to +150°C
Junction Temperature ..... 150°C
Input Voltage ..... $V_{SS}$-0.3V~$V_{DD}$+0.3V
ESD protection on all pins (HBM;MM) ...≥4kV; 400V
Operating Temperature ..... −40°C to 85°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

## Electrical Characteristics

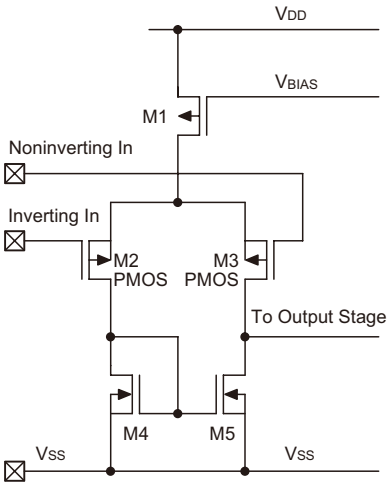
Unless otherwise indicated, $V_{SS}$=GND, Ta=25°C, $V_{CM}=V_{DD}/2$, $V_L=V_{DD}/2$, and $R_L$=10kΩ to $V_L$, $C_L$=60pF

| Symbol | Parameter | Test Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| | | $V_{DD}$ | Conditions | | | | |
| $V_{DD}$ | Supply Voltage | — | — | 2.0 | — | 5.5 | V |
| $V_{OS}$ | Input Offset Voltage | 5V | $V_{IN}=V_{CM}/2$ | −5.0 | — | 5.0 | mV |
| $\Delta V_{OS}/\Delta T$ | Drift with Temperature | 5V | $V_{IN}=V_{CM}/2$ | — | ±2 | — | μV/°C |
| $I_{OS}$ | Input Offset Current | 5V | Ta=25°C | — | ±5 | — | pA |
| $I_B$ | Input Bias Current | 5V | Ta=25°C | — | ±50 | — | pA |
| $V_{CM}$ | Input Common Mode Range | 5V | — | 0 | — | $V_{DD}$−1.4 | V |
| $V_{OH}$ | Maximum Output Voltage Swing | 5V | 0.5V input overdrive $R_L$=10kΩ to $V_L$ | $V_{SS}$+50 | — | $V_{DD}$−100 | mV |
| $V_{OL}$ | Maximum Output Voltage Swing | 5V | 0.5V input overdrive $R_L$=2kΩ to $V_L$ | $V_{SS}$+150 | — | $V_{DD}$−250 | mV |
| $A_{OL}$ | DC Open-Loop Gain (large signal) | 5V | $V_{OUT}$=0.2V to $V_{DD}$− 0.2V, $V_{IN}=V_{CM}/2$ | 70 | 100 | — | dB |
| GBW | Gain BandWidth Product | 5V | $R_L$=10kΩ, $C_L$=60pF, $V_{IN}=V_{CM}/2$ | — | 2.3 | — | MHz |
| Φm | Phase Margin | 5V | $R_L$=10kΩ, $C_L$=60pF G=+1V/V, $V_{IN+}=V_{DD}/2$ | — | 63 | — | ° |
| CMRR | Common Mode Rejection Ratio | 5V | $V_{CM}$=0V to $V_{DD}$− 1.4V | 60 | 90 | — | dB |
| PSRR | Power Supply Rejection Ratio | 5V | $V_{CM}$ = 0.2V | 65 | 95 | — | dB |
| $I_{CC}$ | Supply Current Per Single Amplifier | 5V | Io=0A | 100 | 220 | 340 | μA |
| SR | Slew Rate at Unity Gain | 5V | $R_L$=10kΩ, $C_L$=60pF | — | 2 | — | V/μs |
| $I_{O\_SOURCE}$ | Output Short Circuit Source Current | 5V | $V_{IN+}-V_{IN-}\geq$ 10mV | −5.0 | −9.0 | — | mA |
| $I_{O\_SINK}$ | Output Short Circuit Sink Current | 5V | $V_{IN-}-V_{IN+}\geq$ 10mV | 5.5 | 9.5 | — | mA |

## Functional Description

### Input Stage

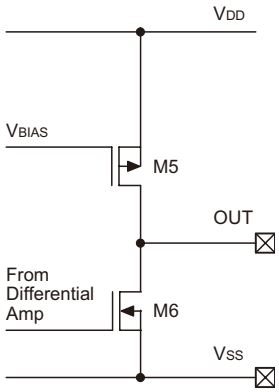
As the input stage of these op-amps is a PMOS differential amplifiers, the amplifiers can offer an extended common mode low input voltage down to $V_{SS}$-0.6V. At the other end of the voltage spectrum, the common mode input voltage has to be maintained at a level below $V_{DD}$-1.4 to keep the input devices, M2 and M3, in their active region. This implies that when using HT9231/HT9232/HT9234 in voltage follower applications, the inputs as well as the output active range will be limited between $V_{SS}$~$V_{DD}$-1V (approx.). It is necessary to avoid applying any voltage greater than $V_{DD}$+0.6V or less than $V_{SS}$-0.6V to the input pins, otherwise the internal input protection devices may be damaged




Since the input impedance of a PMOS transistor is inherently very high, they can be directly coupled to high impedance elements without loading effects. Examples could be coupling to ceramic transducers, integrating capacitors and resistor networks. It is this high input impedance characteristic that is its major advantage over its bipolar counterpart in certain application fields such as integrators where op-amp input currents can cause significant errors.

### Output Stage

The devices use a push-pull CMOS configuration for the op-amp output stage to minimise power consumption and to provide adequate output drive currents. Note that the output is an unbuffered structure, therefore the open loop gain will be affected by the load resistor since the voltage gain of this stage is expressed as (gm5+ gm6)×$R_L$.

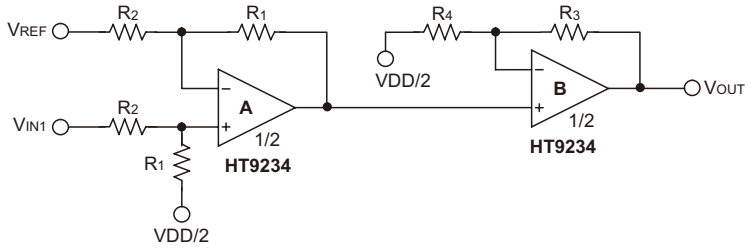



To keep power consumption to a minimum, the output short circuit current is limited to about -9mA for the source drive and 9.5mA for the sink drive. This is considered to be enough for most low power systems, however it is recommended only to used load resistors of >10kΩ for most applications. For heavy load driving applications, an external buffer stage using bipolar transistors is recommended.

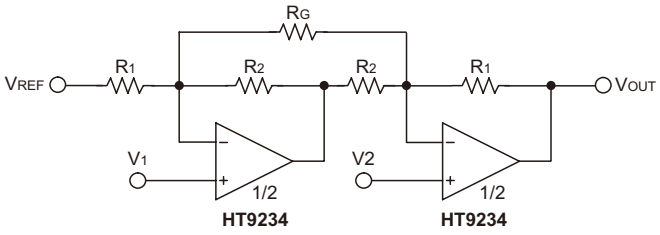
The HT9231/HT9232/HT9234 is internally compensated for AC stability and can drive capacitive loads of up to 60pF.

## Application Circuits

**Difference Amplifier Circuit**




**Two Op Amp Instrumentation Amplifier**




$$V_{OUT} = (V_2 - V_1) \times \left(1 + \frac{R_1}{R_2} + \frac{2R_1}{R_G}\right) + V_{REF}$$

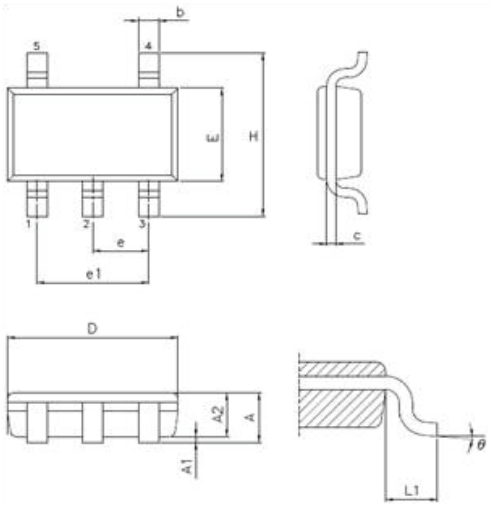
## Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the Holtek website for the latest version of the package information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Further Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- Packing Meterials Information
- Carton information
- PB FREE Products
- Green Packages Products

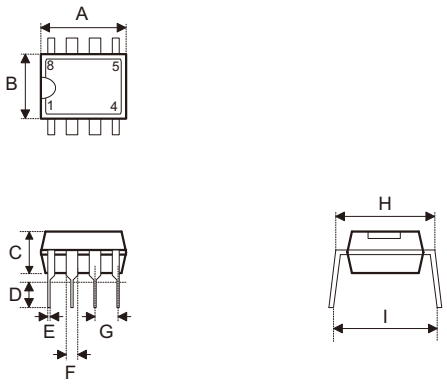
## 5-pin SOT23-5 Outline Dimensions




| Symbol | Dimensions in inch | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 0.030 | — | 0.031 |
| A1 | 0.000 | — | 0.002 |
| A2 | 0.028 | 0.030 | 0.031 |
| b | 0.014 | — | 0.020 |
| C | 0.004 | — | 0.008 |
| D | — | 0.114 BSC | — |
| E | — | 0.110 BSC | — |
| E1 | — | 0.063 BSC | — |
| e | — | 0.037 BSC | — |
| e1 | — | 0.075 BSC | — |
| L | 0.015 | 0.018 | 0.024 |
| L1 | — | 0.024 BSC | — |
| θ | 0° | — | 8° |

| Symbol | Dimensions in mm | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 0.75 | — | 0.80 |
| A1 | 0.00 | — | 0.05 |
| A2 | 0.70 | 0.75 | 0.78 |
| b | 0.35 | — | 0.50 |
| C | 0.10 | — | 0.20 |
| D | — | 2.90 BSC | — |
| E | — | 2.80 BSC | — |
| E1 | — | 1.60 BSC | — |
| e | — | 0.95 BSC | — |
| e1 | — | 1.90 BSC | — |
| L | 0.37 | 0.45 | 0.60 |
| L1 | — | 0.60 BSC | — |
| θ | 0° | — | 8° |

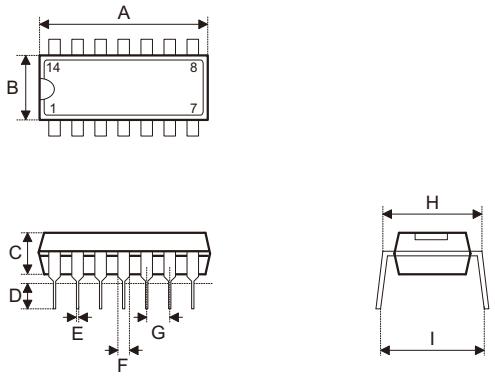
## 8-pin DIP (300mil) Outline Dimensions




| Symbol | Dimensions in inch | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 0.355 | 0.365 | 0.400 |
| B | 0.240 | 0.250 | 0.280 |
| C | 0.115 | 0.130 | 0.195 |
| D | 0.115 | 0.130 | 0.150 |
| E | 0.014 | 0.018 | 0.022 |
| F | 0.045 | 0.060 | 0.070 |
| G | — | 0.100 BSC | — |
| H | 0.300 | 0.310 | 0.325 |
| I | — | — | 0.430 |

| Symbol | Dimensions in mm | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 9.02 | 9.27 | 10.16 |
| B | 6.10 | 6.35 | 7.11 |
| C | 2.92 | 3.30 | 4.95 |
| D | 2.92 | 3.30 | 3.81 |
| E | 0.36 | 0.46 | 0.56 |
| F | 1.14 | 1.52 | 1.78 |
| G | — | 2.54 BSC | — |
| H | 7.26 | 7.87 | 8.26 |
| I | — | — | 10.92 |

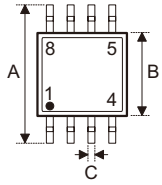
## 14-pin DIP (300mil) Outline Dimensions

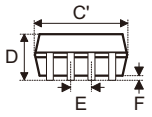


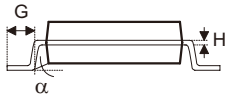

| Symbol | Dimensions in inch | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 0.735 | 0.750 | 0.775 |
| B | 0.240 | 0.250 | 0.280 |
| C | 0.115 | 0.130 | 0.195 |
| D | 0.115 | 0.130 | 0.150 |
| E | 0.014 | 0.018 | 0.022 |
| F | 0.045 | 0.060 | 0.070 |
| G | — | 0.10 BSC | — |
| H | 0.300 | 0.310 | 0.325 |
| I | — | — | 0.430 |

| Symbol | Dimensions in mm | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | 18.67 | 19.05 | 19.69 |
| B | 6.10 | 6.35 | 7.11 |
| C | 2.92 | 3.30 | 4.95 |
| D | 2.92 | 3.30 | 3.81 |
| E | 0.36 | 0.46 | 0.56 |
| F | 1.14 | 1.52 | 1.78 |
| G | — | 2.54 BSC | — |
| H | 7.62 | 7.87 | 8.26 |
| I | — | — | 10.92 |

## 8-pin SOP (150mil) Outline Dimensions



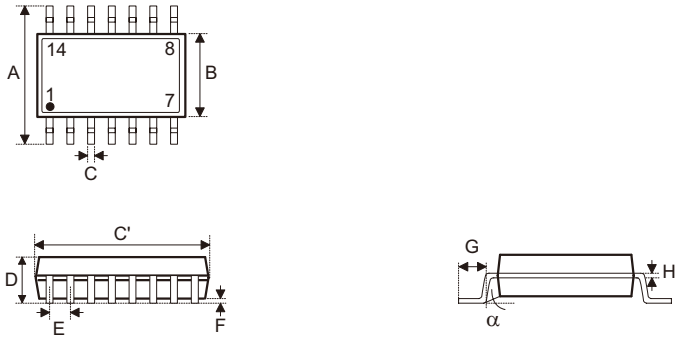




| Symbol | Dimensions in inch | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | — | 0.236 BSC | — |
| B | — | 0.154 BSC | — |
| C | 0.012 | — | 0.020 |
| C′ | — | 0.193 BSC | — |
| D | — | — | 0.069 |
| E | — | 0.050 BSC | — |
| F | 0.004 | — | 0.010 |
| G | 0.016 | — | 0.050 |
| H | 0.004 | — | 0.010 |
| α | 0° | — | 8° |

| Symbol | Dimensions in mm | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | —F | 6.00 BSC | — |
| B | — | 3.90 BSC | — |
| C | 0.31 | — | 0.51 |
| C′ | — | 4.90 BSC | — |
| D | — | — | 1.75 |
| E | — | 1.27 BSC | — |
| F | 0.10 | — | 0.25 |
| G | 0.40 | — | 1.27 |
| H | 0.10 | — | 0.25 |
| α | 0° | — | 8° |

## 14-pin SOP (150mil) Outline Dimensions




| Symbol | Dimensions in inch | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | — | 0.236 BSC | — |
| B | — | 0.154 BSC | — |
| C | 0.012 | — | 0.020 |
| C′ | — | 0.341 BSC | — |
| D | — | — | 0.069 |
| E | — | 0.050 BSC | — |
| F | 0.004 | — | 0.010 |
| G | 0.016 | — | 0.050 |
| H | 0.004 | — | 0.010 |
| α | 0° | — | 8° |

| Symbol | Dimensions in mm | | |
|---|---|---|---|
| | Min. | Nom. | Max. |
| A | — | 6.00 BSC | — |
| B | — | 3.90 BSC | — |
| C | 0.31 | — | 0.51 |
| C′ | — | 8.65 BSC | — |
| D | — | — | 1.75 |
| E | — | 1.27 BSC | — |
| F | 0.10 | — | 0.25 |
| G | 0.40 | — | 1.27 |
| H | 0.10 | — | 0.25 |
| α | 0° | — | 8° |

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