

INA101

High Accuracy INSTRUMENTATION AMPLIFIER

FEATURES

- **LOW DRIFT:** 0.25 μ V/ $^{\circ}$ C max
- **LOW OFFSET VOLTAGE:** 25 μ V max
- **LOW NONLINEARITY:** 0.002%
- **LOW NOISE:** 13nV/ $\sqrt{\text{Hz}}$
- **HIGH CMR:** 106dB AT 60Hz
- **HIGH INPUT IMPEDANCE:** 10¹⁰ Ω
- **14-PIN PLASTIC, CERAMIC DIP, SOL-16, AND TO-100 PACKAGES**

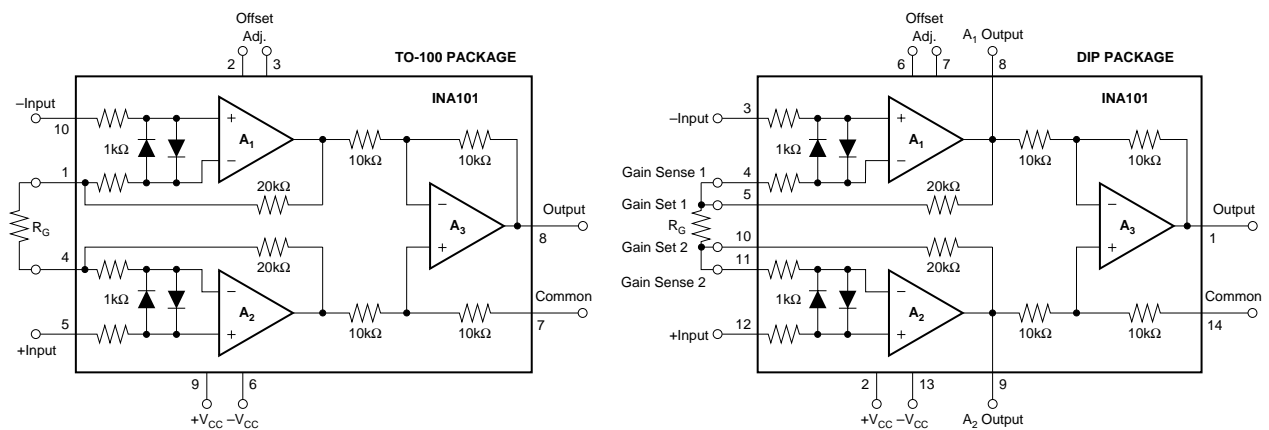
APPLICATIONS

- **STRAIN GAGES**
- **THERMOCOUPLES**
- **RTDs**
- **REMOTE TRANSDUCERS**
- **LOW-LEVEL SIGNALS**
- **MEDICAL INSTRUMENTATION**

DESCRIPTION

The INA101 is a high accuracy instrumentation amplifier designed for low-level signal amplification and general purpose data acquisition. Three precision op amps and laser-trimmed metal film resistors are integrated on a single monolithic integrated circuit.

The INA101 is packaged in TO-100 metal, 14-pin plastic and ceramic DIP, and SOL-16 surface-mount packages. Commercial, industrial and military temperature range models are available.



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SPECIFICATIONS

ELECTRICAL

At +25°C with ±15VDC power supply and in circuit of Figure 1, unless otherwise noted.

| PARAMETER | INA101AM, AG | | | INA101SM, SG | | | INA101CM, CG | | | INA101HP, KU | | | UNITS |
|----------------------------------------|--------------|---------------------------------|-----------------------------------|--------------|--------------------------|--------------------------|--------------|--------------------------|--------------------------|--------------------------------|-------------------------------|----------------|-------------|
| | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| GAIN | 1 | | | * | | | * | | | * | | | V/V |
| Range of Gain | | | 1000 | * | * | * | * | * | * | * | * | * | V/V |
| Gain Equation | | $G = 1 + (40k/R_G)$ | | | * | * | * | * | * | * | * | * | % |
| Error from Equation, DC ⁽¹⁾ | | $\pm(0.04 + 0.00016G - 0.02/G)$ | $\pm(0.1 + 0.0003G - 0.05/G)$ | | * | * | * | * | * | $\pm(0.1 + 0.00015G - 0.05/G)$ | $\pm(0.3 + 0.0002G - 0.10/G)$ | * | |
| Gain Temp. Coefficient ⁽³⁾ | | | | | * | * | * | * | * | * | * | * | ppm/°C |
| G = 1 | | 2 | 5 | | * | * | * | * | * | * | * | * | ppm/°C |
| G = 10 | | 20 | 100 | | * | * | * | * | * | * | * | * | ppm/°C |
| G = 100 | | 22 | 110 | | * | * | * | * | * | * | * | * | ppm/°C |
| G = 1000 | | 22 | 110 | | * | * | * | * | * | * | * | * | ppm/°C |
| Nonlinearity, DC ⁽²⁾ | | $\pm(0.002 + 10^{-5} G)$ | $\pm(0.005 + 2 \times 10^{-5} G)$ | | $\pm(0.001 + 10^{-5} G)$ | $\pm(0.002 + 10^{-5} G)$ | | $\pm(0.001 + 10^{-5} G)$ | $\pm(0.002 + 10^{-5} G)$ | | * | * | % of p-p FS |
| RATED OUTPUT | | | | | | | | | | | | | V |
| Voltage | ±10 | ±12.5 | | * | * | * | * | * | * | * | * | * | V |
| Current | ±5 | ±10 | | * | * | * | * | * | * | * | * | * | mA |
| Output Impedance | | 0.2 | | | * | * | | * | * | | * | * | Ω |
| Capacitive Load | | 1000 | | | * | * | | * | * | | * | * | pF |
| INPUT OFFSET VOLTAGE | | | | | | | | | | | | | μV |
| Initial Offset at +25°C | | ±(25 + 200/G) | ±(50 + 400/G) | | ±10+100/G | ±(25 + 200/G) | | ±(10+100/G) | ±(25 + 200/G) | | ±(125 + 450/G) | ±(250 + 900/G) | μV |
| vs Temperature | | | ±(2 + 20/G) | | | ±(0.75 + 10/G) | | | ±(0.25 + 10/G) | | ±(2 + 20/G) | | μV/°C |
| vs Supply | | ±(1 + 20/G) | | | * | * | | * | * | | * | * | μV/V |
| vs Time | | ±(1 + 20/G) | | | * | * | | * | * | | * | * | μV/mo |
| INPUT BIAS CURRENT | | | | | | | | | | | | | nA |
| Initial Bias Current (each input) | | ±15 | ±30 | | ±10 | * | | ±5 | ±20 | | * | * | nA |
| vs Temperature | | ±0.2 | | | * | * | | * | * | | * | * | nA/°C |
| vs Supply | | ±0.1 | | | * | * | | * | * | | * | * | nA/V |
| Initial Offset Current | | ±15 | ±30 | | ±10 | * | | ±5 | ±20 | | * | * | nA |
| vs Temperature | | ±0.5 | | | * | * | | * | * | | * | * | nA/°C |
| INPUT IMPEDANCE | | | | | | | | | | | | | Ω pF |
| Differential | | 10 ¹⁰ 3 | | | * | * | | * | * | | * | * | Ω pF |
| Common-mode | | 10 ¹⁰ 3 | | | * | * | | * | * | | * | * | Ω pF |
| INPUT VOLTAGE RANGE | | | | | | | | | | | | | V |
| Range, Linear Response | ±10 | ±12 | | * | * | * | * | * | * | * | * | * | V |
| CMR with 1kΩ Source Imbalance | | | | | * | * | | * | * | | * | * | dB |
| DC to 60Hz, G = 1 | 80 | 90 | | | * | * | | * | * | 65 | 85 | | dB |
| DC to 60Hz, G = 10 | 96 | 106 | | | * | * | | * | * | 90 | 95 | | dB |
| DC to 60Hz, G = 100 to 1000 | 106 | 110 | | | * | * | | * | * | 100 | 105 | | dB |
| INPUT NOISE | | | | | | | | | | | | | μV, p-p |
| Input Voltage Noise | | | | | * | * | | * | * | | * | * | μV, p-p |
| f _B = 0.01Hz to 10Hz | | 0.8 | | | * | * | | * | * | | * | * | μV, p-p |
| Density, G = 1000 | | | | | * | * | | * | * | | * | * | nV/√Hz |
| f ₀ = 10Hz | | 18 | | | * | * | | * | * | | * | * | nV/√Hz |
| f ₀ = 100Hz | | 15 | | | * | * | | * | * | | * | * | nV/√Hz |
| f ₀ = 1kHz | | 13 | | | * | * | | * | * | | * | * | nV/√Hz |
| Input Current Noise | | | | | * | * | | * | * | | * | * | pA, p-p |
| f _B = 0.01Hz to 10Hz | | 50 | | | * | * | | * | * | | * | * | pA, p-p |
| Density | | | | | * | * | | * | * | | * | * | pA/√Hz |
| f ₀ = 10Hz | | 0.8 | | | * | * | | * | * | | * | * | pA/√Hz |
| f ₀ = 100Hz | | 0.46 | | | * | * | | * | * | | * | * | pA/√Hz |
| f ₀ = 1kHz | | 0.35 | | | * | * | | * | * | | * | * | pA/√Hz |
| DYNAMIC RESPONSE | | | | | | | | | | | | | kHz |
| Small Signal, ±3dB Flatness | | | | | * | * | | * | * | | * | * | kHz |
| G = 1 | | 300 | | | * | * | | * | * | | * | * | kHz |
| G = 10 | | 140 | | | * | * | | * | * | | * | * | kHz |
| G = 100 | | 25 | | | * | * | | * | * | | * | * | kHz |
| G = 1000 | | 2.5 | | | * | * | | * | * | | * | * | kHz |
| Small Signal, ±1% Flatness | | | | | * | * | | * | * | | * | * | kHz |
| G = 1 | | 20 | | | * | * | | * | * | | * | * | kHz |
| G = 10 | | 10 | | | * | * | | * | * | | * | * | kHz |
| G = 100 | | 1 | | | * | * | | * | * | | * | * | Hz |
| G = 1000 | | 200 | | | * | * | | * | * | | * | * | Hz |
| Full Power, G = 1 to 100 | | 6.4 | | | * | * | | * | * | | * | * | kHz |
| Slew Rate, G = 1 to 100 | 0.2 | 0.4 | | * | * | * | * | * | * | * | * | * | V/μs |
| Settling Time (0.1%) | | | | | * | * | | * | * | | * | * | μs |
| G = 1 | | 30 | 40 | | * | * | | * | * | | * | * | μs |
| G = 100 | | 40 | 55 | | * | * | | * | * | | * | * | μs |
| G = 1000 | | 350 | 470 | | * | * | | * | * | | * | * | μs |
| Settling Time (0.01%) | | | | | * | * | | * | * | | * | * | μs |
| G = 1 | | 30 | 45 | | * | * | | * | * | | * | * | μs |
| G = 100 | | 50 | 70 | | * | * | | * | * | | * | * | μs |
| G = 1000 | | 500 | 650 | | * | * | | * | * | | * | * | μs |
| POWER SUPPLY | | | | | | | | | | | | | V |
| Rated Voltage | | ±15 | | * | * | * | * | * | * | * | * | * | V |
| Voltage Range | ±5 | | ±20 | * | * | * | * | * | * | * | * | * | V |
| Current, Quiescent ⁽²⁾ | | ±6.7 | ±8.5 | | * | * | | * | * | | * | * | mA |
| TEMPERATURE RANGE⁽⁶⁾ | | | | | | | | | | | | | °C |
| Specification | -25 | | +85 | -55 | | +125 | * | * | * | 0 | | +70 | °C |
| Operation | -55 | | +125 | * | | * | * | * | * | -25 | | +85 | °C |
| Storage | -65 | | +150 | * | | * | * | * | * | -40 | | +85 | °C |

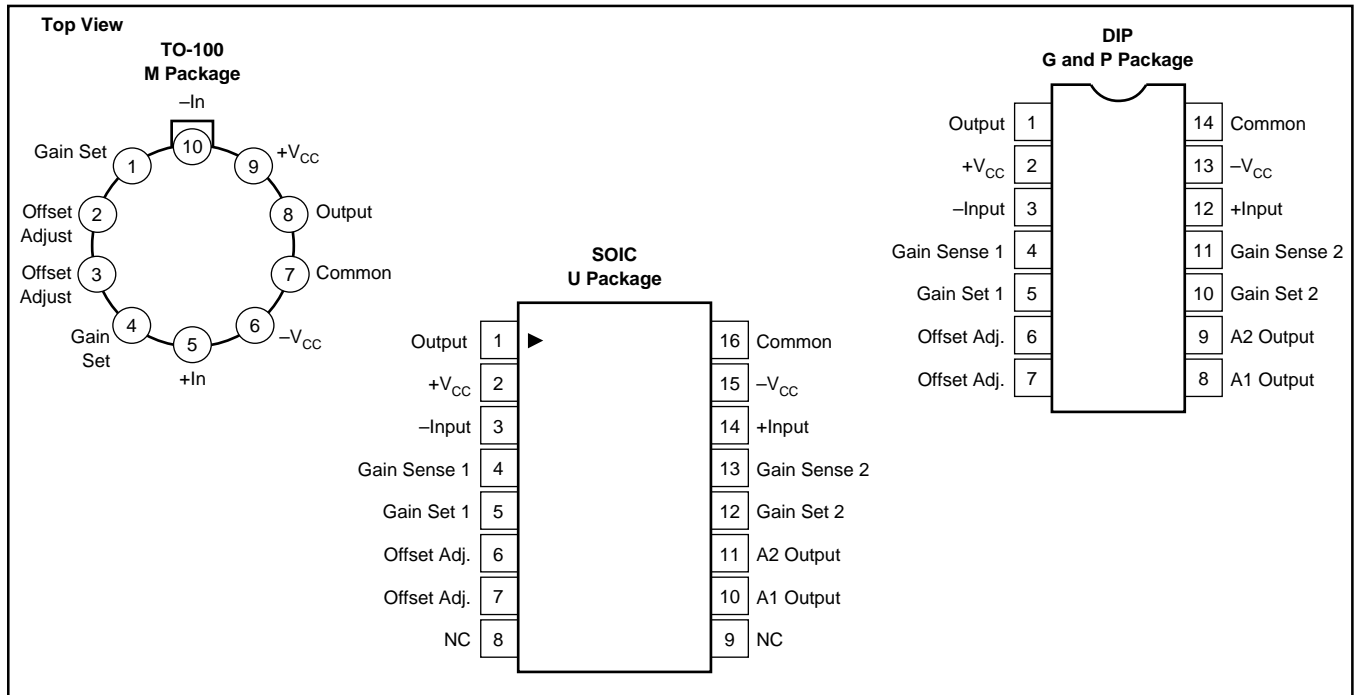
* Specifications same as for INA101AM, AG.

NOTES: (1) Typically the tolerance of R_G will be the major source of gain error. (2) Nonlinearity is the maximum peak deviation from the best straight-line as a percentage of peak-to-peak full scale output. (3) Not including the TCR of R_G. (4) Adjustable to zero at any one gain. (5) θ_{IC} output stage = 113°C/W, θ_{IC} quiescent circuitry = 19°C/W, θ_{CA} = 83°C/W.



INA101

PIN CONFIGURATIONS



ORDERING INFORMATION

| PRODUCT | PACKAGE | TEMPERATURE RANGE |
|----------|----------------------|-------------------|
| INA101AM | 10-Pin Metal TO-100 | -25°C to +85°C |
| INA101CM | 10-Pin Metal TO-100 | -25°C to +85°C |
| INA101AG | 14-Pin Ceramic DIP | -25°C to +85°C |
| INA101CG | 14-Pin Ceramic DIP | -25°C to +85°C |
| INA101HP | 14-Pin Plastic DIP | 0°C to +70°C |
| INA101KU | SOL-16 Surface-Mount | 0°C to +70°C |
| INA101SG | 14-Pin Ceramic DIP | -55°C to +125°C |
| INA101SM | 10-Pin Metal TO-100 | -55°C to +125°C |

ABSOLUTE MAXIMUM RATINGS

| | |
|---------------------------------------------------|------------------|
| Supply Voltage | ±20V |
| Power Dissipation | 600mW |
| Input Voltage Range | ±V _{CC} |
| Output Short Circuit (to ground) | Continuous |
| Operating Temperature M, G Package | -55°C to +125°C |
| P, U Package | -25°C to +85°C |
| Storage Temperature M, G Package | -65°C to +150°C |
| P, U Package | -40°C to +85°C |
| Lead Temperature (soldering, 10s) M, G, P Package | +300°C |
| Lead Temperature (wave soldering, 3s) U Package | +260°C |

PACKAGE INFORMATION

| PRODUCT | PACKAGE | PACKAGE DRAWING NUMBER ⁽¹⁾ |
|----------|----------------------|---------------------------------------|
| INA101AM | 10-Pin Metal TO-100 | 007 |
| INA101CM | 10-Pin Metal TO-100 | 007 |
| INA101AG | 14-Pin Ceramic DIP | 169 |
| INA101CG | 14-Pin Ceramic DIP | 169 |
| INA101HP | 14-Pin Plastic DIP | 010 |
| INA101KU | SOL-16 Surface-Mount | 211 |
| INA101SG | 14-Pin Ceramic DIP | 169 |
| INA101SM | 10-Pin Metal TO-100 | 007 |

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.



ELECTROSTATIC DISCHARGE SENSITIVITY

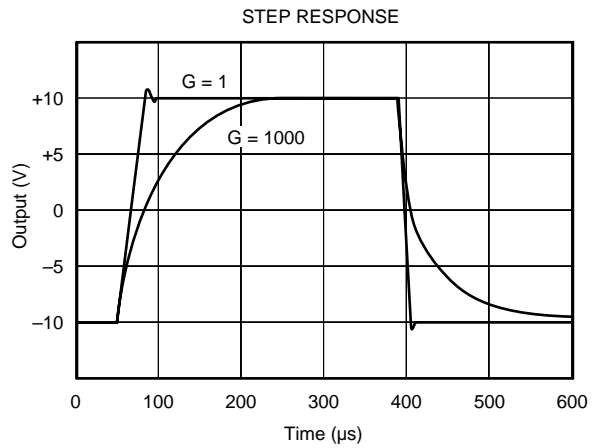
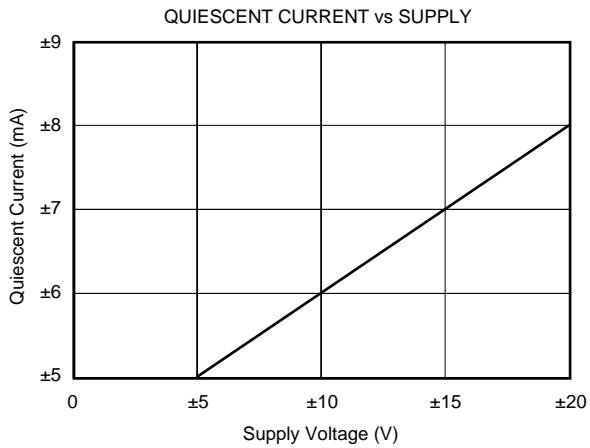
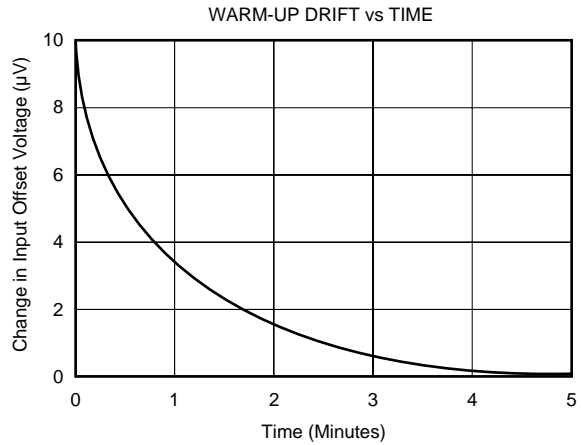
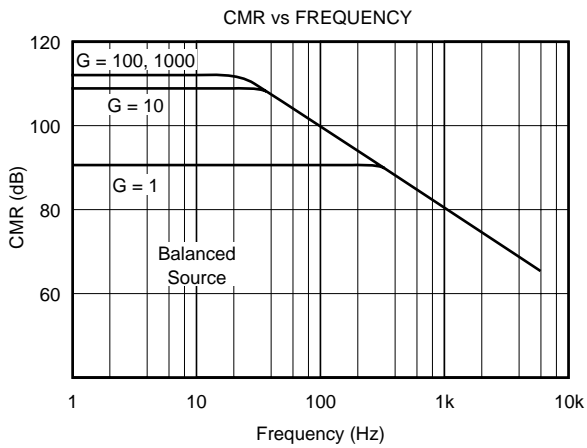
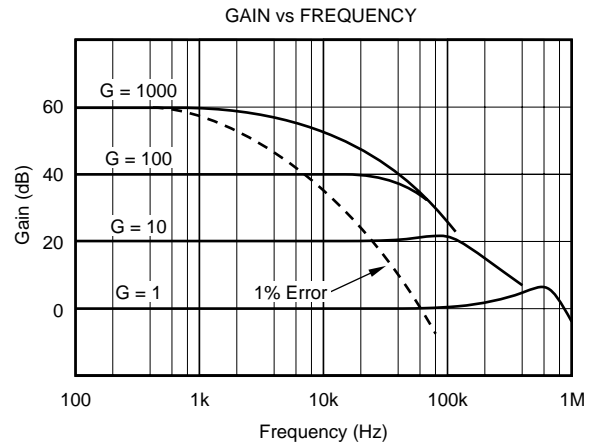
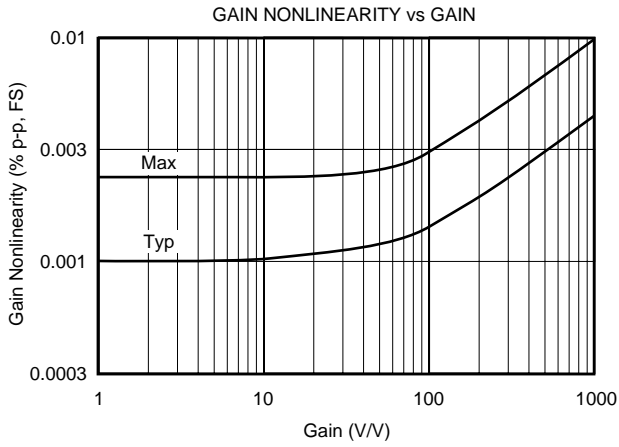
This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

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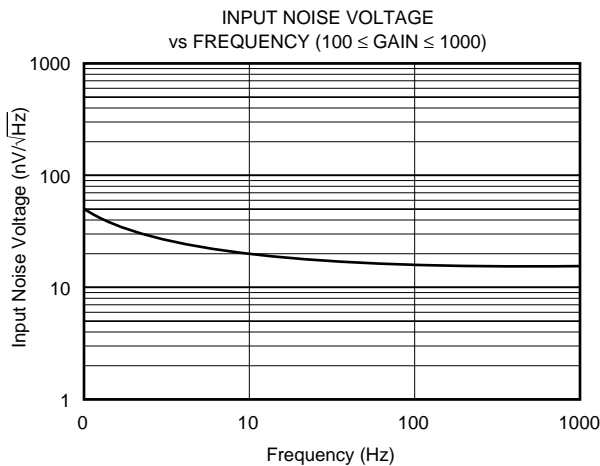
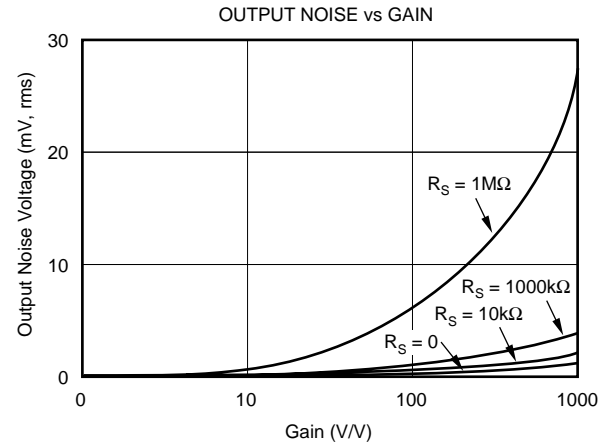
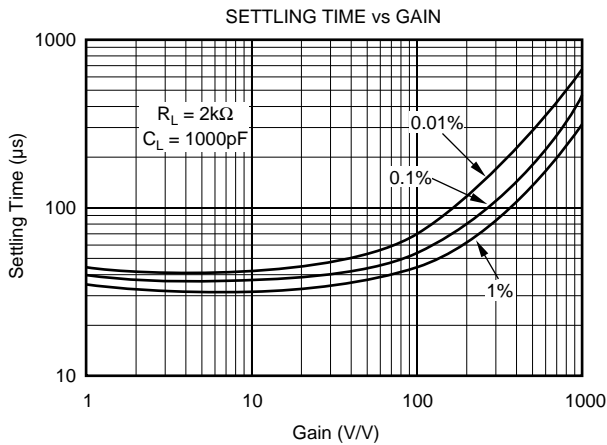
TYPICAL PERFORMANCE CURVES

At +25°C, $V_{CC} = \pm 15V$ unless otherwise noted.



TYPICAL PERFORMANCE CURVES (CONT)

At +25°C, $V_{CC} = \pm 15V$ unless otherwise noted.



APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA101. (Pin numbers shown are for the TO-100 metal package.) Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins as shown.

The output is referred to the output Common terminal which is normally grounded. This must be a low-impedance connection to assure good common-mode rejection. A resistance greater than 0.1Ω in series with the Common pin will cause common-mode rejection to fall below 106dB.

SETTING THE GAIN

Gain of the INA101 is set by connecting a single external resistor, R_G :

$$G = 1 + \frac{40k\Omega}{R_G} \quad (1)$$

The $40k\Omega$ term in equation (1) comes from the sum of the two internal feedback resistors. These are on-chip metal film resistors which are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA101.

The stability and temperature drift of the external gain setting resistor, R_G , also affects gain. R_G 's contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance which will contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater. The gain sense connections on the DIP and SOL-16 packages (see Figure 2) reduce the gain error produced by wiring or socket resistance.

OFFSET TRIMMING

The INA101 is laser trimmed for low offset voltage and drift. Most applications require no external offset adjustment. Figure 2 shows connection of an optional potentiometer connected to the Offset Adjust pins for trimming the input offset voltage. (Pin numbers shown are for the DIP package.) Use this adjustment to null the offset voltage in high gain ($G \geq 100$) with both inputs connected to ground. Do not use this adjustment to null offset produced by the source or other system offset since this will increase the offset voltage drift by $0.3\mu\text{V}/^\circ\text{C}$ per $100\mu\text{V}$ of adjusted offset.

Offset of the output amplifier usually dominates when the INA101 is used in unity gain ($G = 1$). The output offset

voltage can be adjusted with the optional trim circuit connected to the Common pin as shown in Figure 2. The voltage applied to Common terminal is summed with the output. Low impedance must be maintained at this node to assure good common-mode rejection. The op amp connected as a buffer provides low impedance.

THERMAL EFFECTS ON OFFSET VOLTAGE

To achieve lowest offset voltage and drift, prevent air currents from circulating near the INA101. Rapid changes in temperature will produce a thermocouple effect on the package leads that will degrade offset voltage and drift. A shield or cover that prevents air currents from flowing near the INA101 will assure best performance.

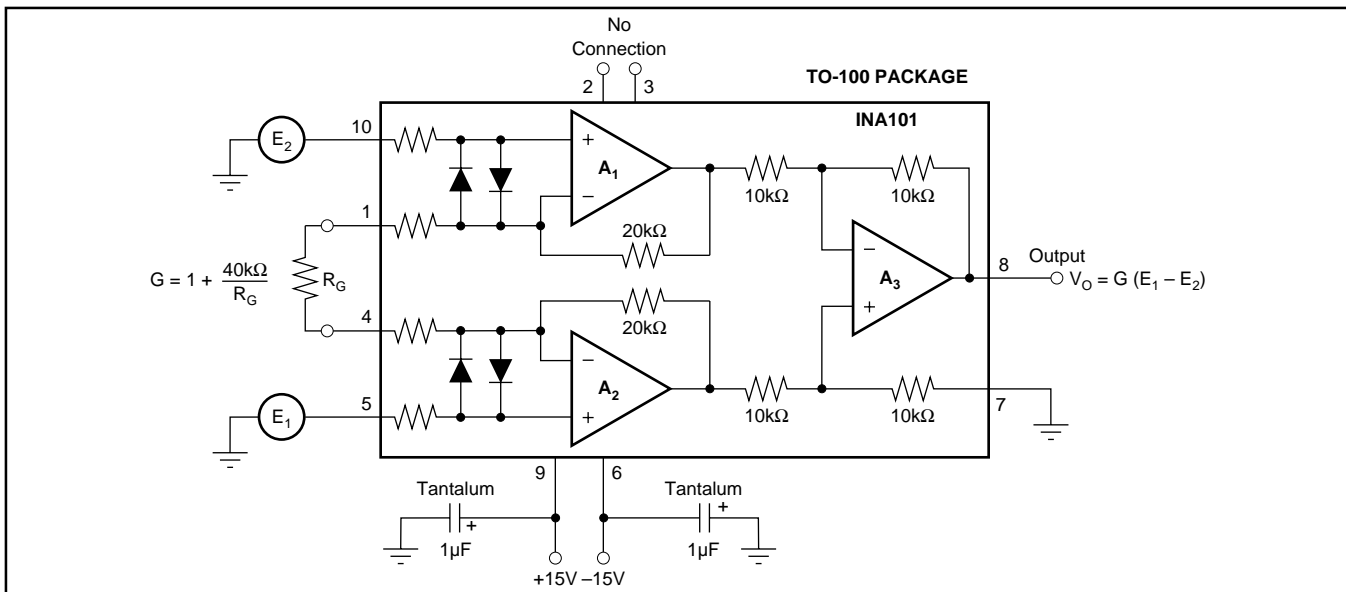


FIGURE 1. Basic Connections.

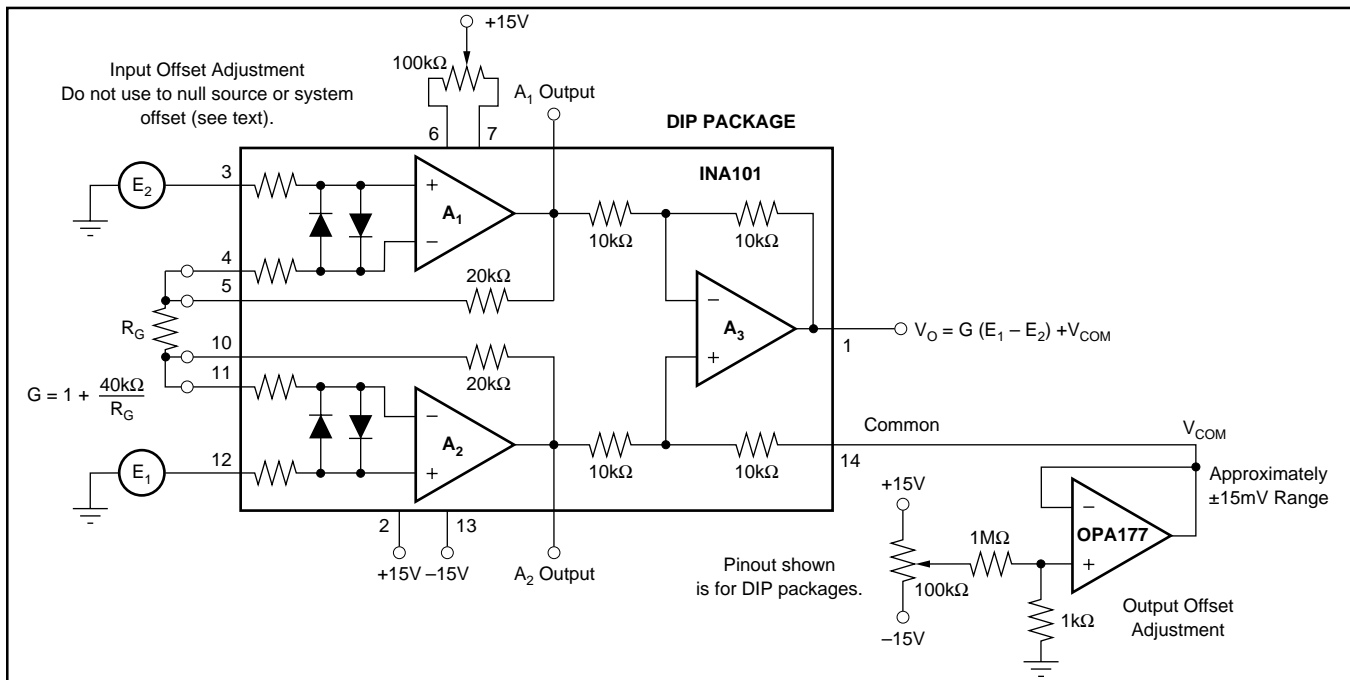


FIGURE 2. Optional Trimming of Input and Output Offset Voltage.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|---------|
| INA101AG | NRND | CDIP SB | JD | 14 | 1 | RoHS & Green | AU | N / A for Pkg Type | | INA101AG | |
| INA101AM | NRND | TO-100 | LME | 10 | 20 | RoHS & Green | Call TI | N / A for Pkg Type | | INA101AM | |
| INA101CM | NRND | TO-100 | LME | 10 | 20 | RoHS & Green | Call TI | N / A for Pkg Type | | INA101CM | |
| INA101HP | ACTIVE | PDIP | N | 14 | 25 | RoHS & Green | NIPDAU | N / A for Pkg Type | -55 to 125 | INA101HP | Samples |
| INA101HPG4 | ACTIVE | PDIP | N | 14 | 25 | RoHS & Green | NIPDAU | N / A for Pkg Type | -55 to 125 | INA101HP | Samples |
| INA101KU | ACTIVE | SOIC | DW | 16 | 40 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | | INA101KU | Samples |
| INA101KU/1K | ACTIVE | SOIC | DW | 16 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | | INA101KU | Samples |
| INA101KUE4 | ACTIVE | SOIC | DW | 16 | 40 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | | INA101KU | Samples |
| INA101SM | NRND | TO-100 | LME | 10 | 20 | RoHS & Green | AU | N / A for Pkg Type | | INA101SM | |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSELETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

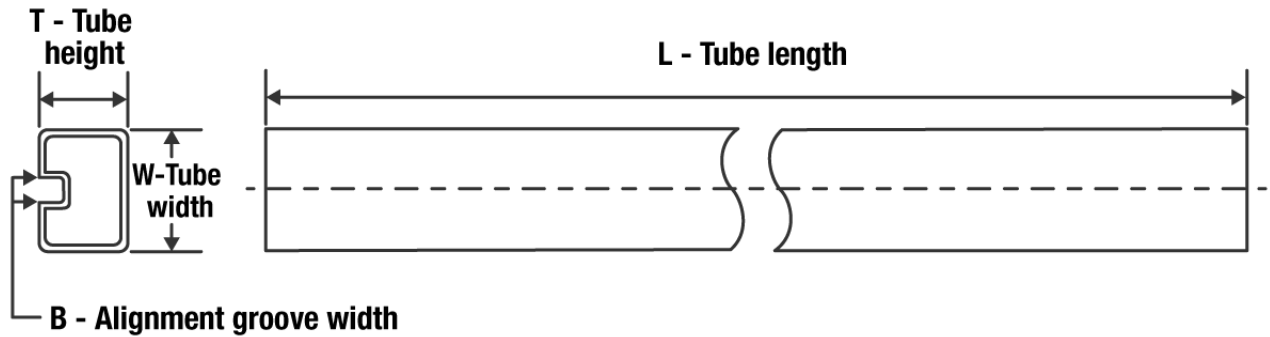

*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| INA101KU/1K | SOIC | DW | 16 | 1000 | 330.0 | 16.4 | 10.75 | 10.7 | 2.7 | 12.0 | 16.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| INA101KU/1K | SOIC | DW | 16 | 1000 | 853.0 | 449.0 | 35.0 |

TUBE


*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| INA101AG | JD | CDIP SB | 14 | 1 | 506.98 | 15.24 | 12290 | NA |
| INA101AM | LME | TO-CAN | 10 | 20 | 532.13 | 21.59 | 889 | NA |
| INA101CM | LME | TO-CAN | 10 | 20 | 532.13 | 21.59 | 889 | NA |
| INA101HP | N | PDIP | 14 | 25 | 506 | 13.97 | 11230 | 4.32 |
| INA101HPG4 | N | PDIP | 14 | 25 | 506 | 13.97 | 11230 | 4.32 |
| INA101KU | DW | SOIC | 16 | 40 | 507 | 12.83 | 5080 | 6.6 |
| INA101KUE4 | DW | SOIC | 16 | 40 | 507 | 12.83 | 5080 | 6.6 |
| INA101SM | LME | TO-CAN | 10 | 20 | 532.13 | 21.59 | 889 | NA |

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