# Small Size, Low-Power, Unidirectional, CURRENT SHUNT MONITOR Zerø-Drift Series

**Check for Samples: INA216**

## FEATURES

- **CHIP-SCALE PACKAGE**
- **COMMON-MODE RANGE: +1.8V to +5.5V**
- **OFFSET VOLTAGE: ±30μV**
- **GAIN ERROR: ±0.2% MAX**
- **CHOICE OF GAINS:**
  - **INA216A1: 25V/V**
  - **INA216A2: 50V/V**
  - **INA216A3: 100V/V**
  - **INA216A4: 200V/V**
- **QUIESCENT CURRENT: 13μA**
- **BUFFERED VOLTAGE OUTPUT: No Additional Op Amp Needed**

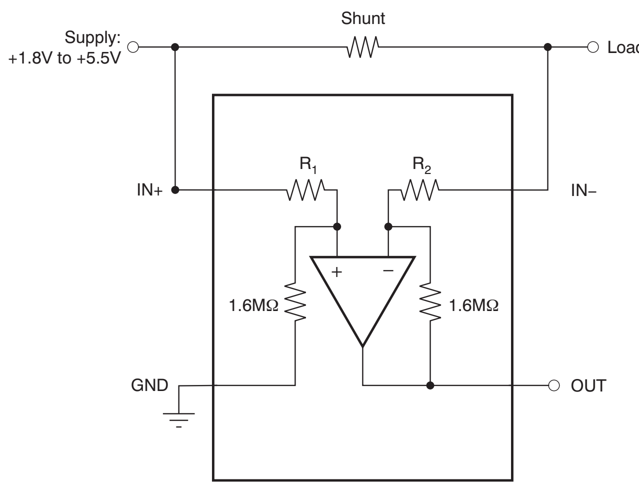
## APPLICATIONS

- **NOTEBOOK COMPUTERS**
- **CELL PHONES**
- **TELECOM EQUIPMENT**
- **POWER MANAGEMENT**
- **BATTERY CHARGERS**

## DESCRIPTION

The INA216 is a high-side voltage output current shunt monitor that can sense drops across shunts at common-mode voltages from +1.8V to +5.5V. Four fixed gains are available: 25V/V, 50V/V, 100V/V, and 200V/V. The low offset of the Zerø-Drift architecture enables current sensing with maximum drops across the shunt as low as 10mV full-scale, or with wide dynamic ranges of over 1000:1.

These devices operate from a single +1.8V to +5.5V power supply, drawing a maximum of 25μA of supply current. The INA216 series are specified over the temperature range of –40°C to +125°C, and offered in a chip-scale package.




| PRODUCT | GAIN | $R_1 = R_2$ |
|---|---|---|
| INA216A1 | 25 | 64kΩ |
| INA216A2 | 50 | 32kΩ |
| INA216A3 | 100 | 16kΩ |
| INA216A4 | 200 | 8kΩ |

This integrated circuit can be damaged by ESD. Texas Instruments 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.

## PACKAGE INFORMATION(1)

| PRODUCT | GAIN | PACKAGE-LEAD | PACKAGE DESIGNATOR | PACKAGE MARKING |
|---|---|---|---|---|
| INA216A1 | 25V/V | WCSP-4 | YFF | OW |
| | | ThinQFN-10 | RSW | SNJ |
| INA216A2 | 50V/V | WCSP-4 | YFF | OX |
| | | ThinQFN-10 | RSW | SOJ |
| INA216A3 | 100V/V | WCSP-4 | YFF | OY |
| | | ThinQFN-10 | RSW | SPJ |
| INA216A4 | 200V/V | WCSP-4 | YFF | OZ |
| | | ThinQFN-10 | RSW | SQJ |

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or visit the device product folder at www.ti.com.

## ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range, unless otherwise noted.

| | | INA216 | UNIT |
|---|---|---|---|
| Supply Voltage | | +7 | V |
| Analog Inputs, $V_{IN+}$, $V_{IN-}$(2) | Differential ($V_{IN+}$)–($V_{IN-}$) | –5.5 to +5.5 | V |
| | Common-Mode(3) | GND–0.3V to +5.5 | V |
| Output(3) | | GND–0.3V to (V+)+0.3 | V |
| Input Current into Any Pin(3) | | 5 | mA |
| Operating Temperature | | –55 to +150 | °C |
| Storage Temperature | | –65 to +150 | °C |
| Junction Temperature | | +150 | °C |
| ESD Ratings: | Human Body Model | 2.5 | kV |
| | Charged Device Model | 1 | kV |
| | Machine Model | 200 | V |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) $V_{IN+}$ and $V_{IN-}$ are the voltages at the IN+ and IN– pins, respectively.
(3) Input voltage at any pin may exceed the voltage shown if the current at that pin is limited to 5mA.

## THERMAL INFORMATION

| THERMAL METRIC(1) | | INA216A1YFF, INA216A2YFF INA216A3YFF, INA216A4YFF | UNITS |
|---|---|---|---|
| | | YFF | |
| | | 4 PINS | |
| $\theta_{JA}$ | Junction-to-ambient thermal resistance | 160 | °C/W |
| $\theta_{JC(top)}$ | Junction-to-case(top) thermal resistance | 75 | |
| $\theta_{JB}$ | Junction-to-board thermal resistance | 76 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 3 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 74 | |
| $\theta_{JC(bottom)}$ | Junction-to-case(bottom) thermal resistance | n/a | |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

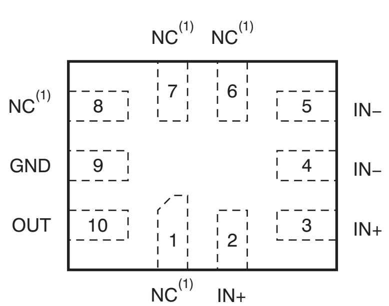
## THERMAL INFORMATION

| THERMAL METRIC(1) | | INA216A1RSW, INA216A2RSW INA216A3RSW, INA216A4RSW | UNITS |
|---|---|---|---|
| | | RSW | |
| | | 10 PINS | |
| $\theta_{JA}$ | Junction-to-ambient thermal resistance | 114.9 | °C/W |
| $\theta_{JC(top)}$ | Junction-to-case(top) thermal resistance | 66.3 | |
| $\theta_{JB}$ | Junction-to-board thermal resistance | 21.4 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 1.9 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 21.4 | |
| $\theta_{JC(bottom)}$ | Junction-to-case(bottom) thermal resistance | N/A | |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

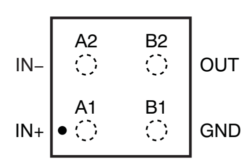
## PIN CONFIGURATIONS

**RSW PACKAGE**
**ThinQFN-10**
**(TOP VIEW)**




(1) No internal connection.

**YFF PACKAGE**
**WCSP-4**
**(TOP VIEW)**




(2) Bump side down. Drawing not to scale.

(3) Power supply is derived from shunt (minimum common-mode range = 1.8V)

## ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range, **$T_A$ = –40°C to +125°C.**
At $T_A$ = +25°C and $V_{CM}$ = $V_{IN+}$= 4.2V, unless otherwise noted.

| PARAMETER | | CONDITIONS | INA216 | | | UNIT |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| **INPUT** | | | | | | |
| Offset Voltage, RTI (1) | $V_{OS}$ | | | | | |
| INA216A1 | | | | ±30 | ±100 | μV |
| **vs Temperature** | **$dV_{OS}/dT$** | | | **0.06** | **0.2** | **μV/°C** |
| INA216A2 | | | | ±20 | ±75 | μV |
| **vs Temperature** | **$dV_{OS}/dT$** | | | **0.05** | **0.25** | **μV/°C** |
| INA216A3 | | | | ±20 | ±75 | μV |
| **vs Temperature** | **$dV_{OS}/dT$** | | | **0.03** | **0.25** | **μV/°C** |
| INA216A4 | | | | ±20 | ±75 | μV |
| **vs Temperature** | **$dV_{OS}/dT$** | | | **0.1** | **0.3** | **μV/°C** |
| Common-Mode Input Range | $V_{CM}$ | | 1.8 | | 5.5 | V |
| **Common-Mode Rejection (2)** | **CMRR** | **$V_{IN+}$ = +1.8V to +5.5V** | **90** | **108** | | **dB** |
| Power-Supply Rejection | **PSRR** | | **90** | **108** | | **dB** |
| Input Bias Current | $I_{IN–}$ | | | 3 | | μA |
| **OUTPUT** | | | | | | |
| Gain | G | | | | | |
| INA216A1 | | | | 25 | | V/V |
| INA216A2 | | | | 50 | | V/V |
| INA216A3 | | | | 100 | | V/V |
| INA216A4 | | | | 200 | | V/V |
| Gain Error | | | | | | |
| INA216A1 | | $V_{OUT}$ = 0.2V to $V_{OUT}$ = 2.5V | | ±0.01 | ±0.2 | % |
| **vs Temperature** | | **$V_{OUT}$ = 0.2V to $V_{OUT}$ = 2.5V** | | **0.01** | **0.025** | **m%/°C** |
| INA216A2 | | | | 0.05 | ±0.2 | % |
| **vs Temperature** | | | | **0.017** | **0.1** | **m%/°C** |
| INA216A3 | | | | 0.06 | ±0.2 | % |
| **vs Temperature** | | | | **0.023** | **0.1** | **m%/°C** |
| INA216A4 | | | | 0.03 | ±0.2 | % |
| **vs Temperature** | | | | **0.076** | **0.3** | **m%/°C** |
| Nonlinearity Error | | | | ±0.01 | | % |
| Maximum Capacitive Load | | No sustained oscillation | | 750 | | pF |
| **VOLTAGE OUTPUT (3)** | | **$R_L$ = 10kΩ to GND** | | | | |
| **Swing to V+ Power-Supply Rail** | | | | **(V+) –0.1** | **(V+) –0.3** | **V** |
| **Swing to GND (3)** | | | | **($V_{GND}$) +0.001** | **($V_{GND}$) +0.002** | **V** |
| Output Impedance | | | | 42 | | Ω |
| **FREQUENCY RESPONSE** | | | | | | |
| Bandwidth | BW | $C_{LOAD}$ = 10pF | | | | |
| INA216A1 | | | | 20 | | kHz |
| INA216A2 | | | | 10 | | kHz |
| INA216A3 | | | | 5 | | kHz |
| INA216A4 | | | | 2.5 | | kHz |

(1) RTI: Referred-to-input.
(2) CMRR and PSRR are the same because $V_{CM}$ is the supply voltage.
(3) See Typical Characteristics graph, *Output Swing to Rail* (Figure 9).

## ELECTRICAL CHARACTERISTICS (continued)

**Boldface** limits apply over the specified temperature range, **$T_A$ = –40°C to +125°C.**
At $T_A$ = +25°C and $V_{CM}$ = $V_{IN+}$= 4.2V, unless otherwise noted.

| PARAMETER | | CONDITIONS | INA216 | | | UNIT |
|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | |
| **FREQUENCY RESPONSE,** *continued* | | | | | | |
| Slew Rate | SR | | | 0.03 | | V/μs |
| **NOISE, RTI** (4) | | | | | | |
| Voltage Noise Density | | | | 60 | | nV/√Hz |
| **POWER SUPPLY** | | | | | | |
| **Specified Range** | **$V_{IN+}$** | | **+1.8** | | **+5.5** | **V** |
| Quiescent Current | $I_Q$ | | | 13 | 25 | μA |
| **Over Temperature** | | | | | **30** | **μA** |
| **TURN-ON TIME** | | $V_{IN+}$ = 0 to +2.5V; $V_{SENSE}$ = 10mV; $V_{OUT}$ ±0.5% | | 200 | | μs |
| **TEMPERATURE RANGE** | | | | | | |
| Specified Temperature Range | | | –40 | | +125 | °C |

(4) RTI: Referred-to-input.

## TYPICAL CHARACTERISTICS

The INA216A1 is used for typical characteristic measurements at $T_A$ = +25°C, $V_S$ = +4.2V, unless otherwise noted.

**INPUT OFFSET VOLTAGE PRODUCTION DISTRIBUTION**

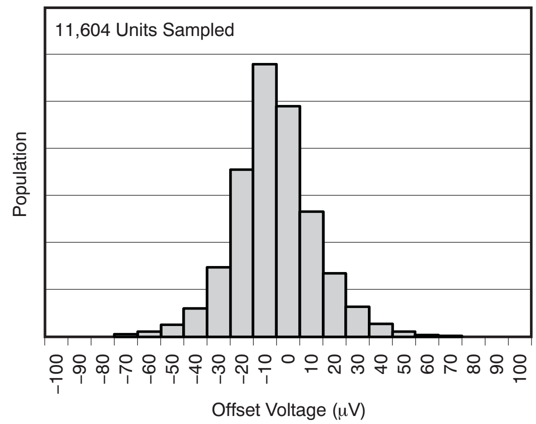



**Figure 1.**

**OFFSET VOLTAGE vs TEMPERATURE**

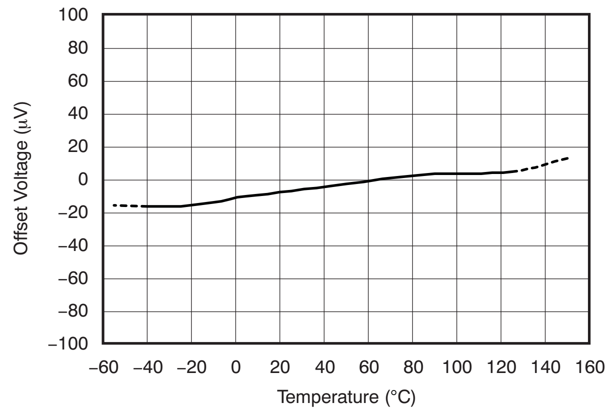



**Figure 2.**

**COMMON-MODE REJECTION RATIO vs TEMPERATURE**

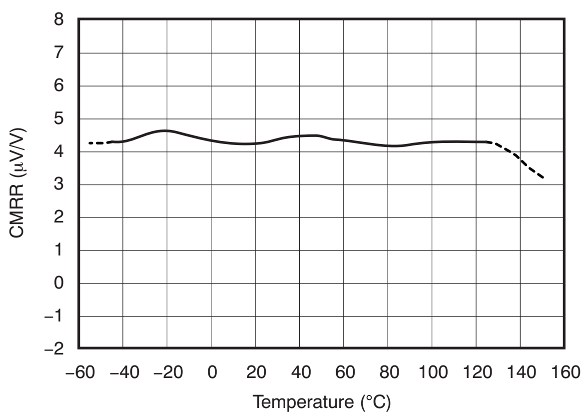



**Figure 3.**

**GAIN ERROR vs TEMPERATURE**

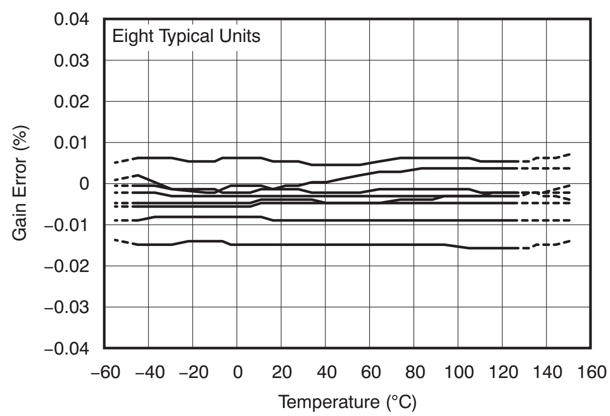



**Figure 4.**

**QUIESCENT CURRENT AND NEGATIVE INPUT BIAS CURRENT vs TEMPERATURE**

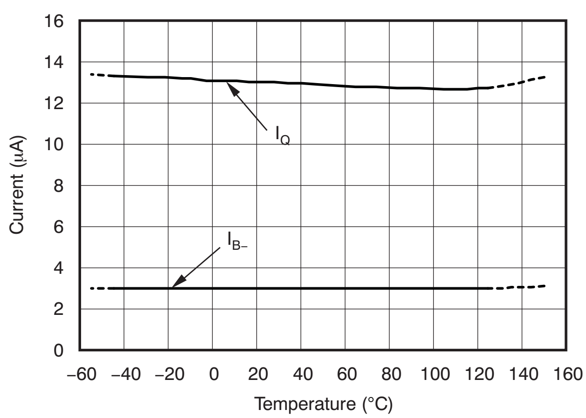



**Figure 5.**

**GAIN vs FREQUENCY**

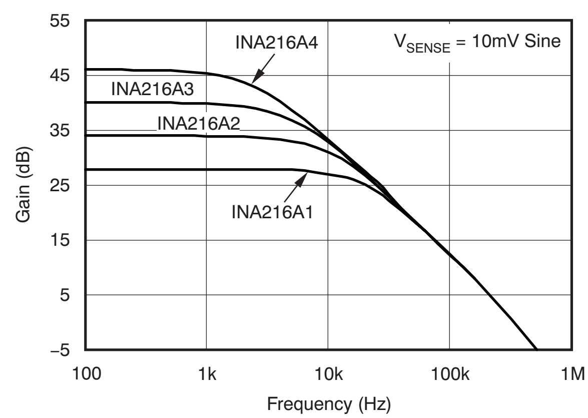



**Figure 6.**

## TYPICAL CHARACTERISTICS (continued)

The INA216A1 is used for typical characteristic measurements at $T_A$ = +25°C, $V_S$ = +4.2V, unless otherwise noted.

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

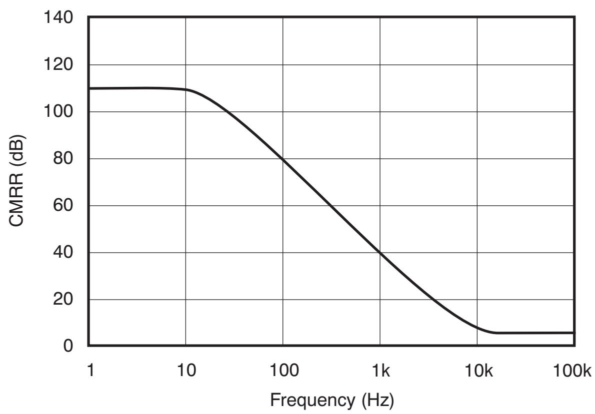



Figure 7.

**QUIESCENT CURRENT AND NEGATIVE INPUT BIAS CURRENT vs $V_{SENSE}$**

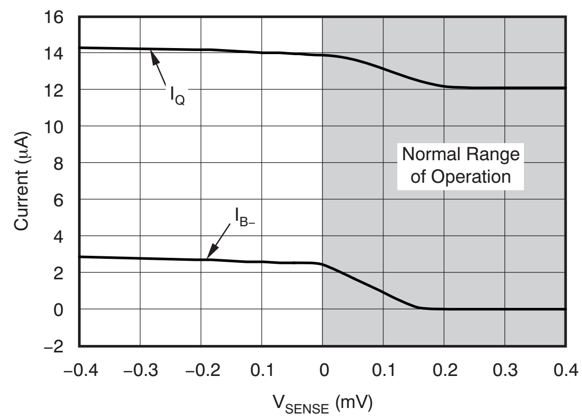



Figure 8.

**OUTPUT VOLTAGE SWING vs OUTPUT CURRENT**

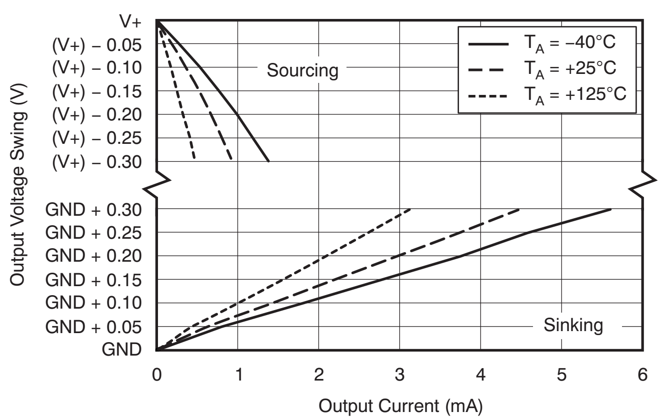



Figure 9.

**INPUT-REFERRED VOLTAGE NOISE vs FREQUENCY**

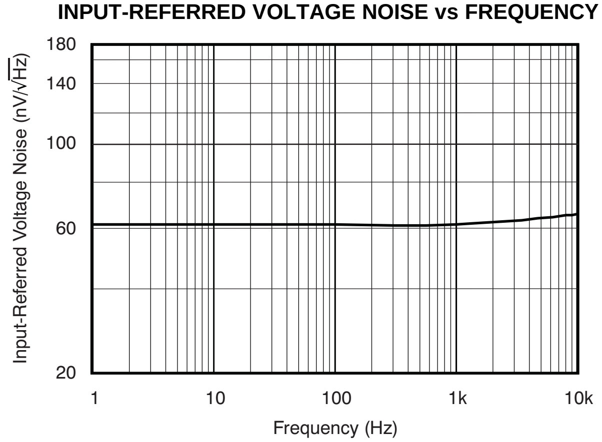



Figure 10.

**0.1Hz to 10Hz VOLTAGE NOISE, RTI**

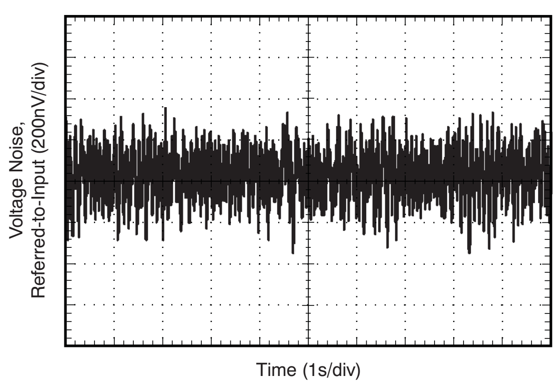



Figure 11.

**STEP RESPONSE ($80mV_{PP}$ Input Step)**

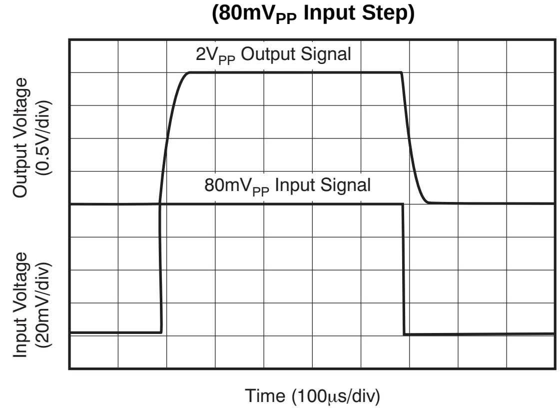



Figure 12.

## TYPICAL CHARACTERISTICS (continued)

The INA216A1 is used for typical characteristic measurements at $T_A$ = +25°C, $V_S$ = +4.2V, unless otherwise noted.

**COMMON-MODE VOLTAGE TRANSIENT RESPONSE**

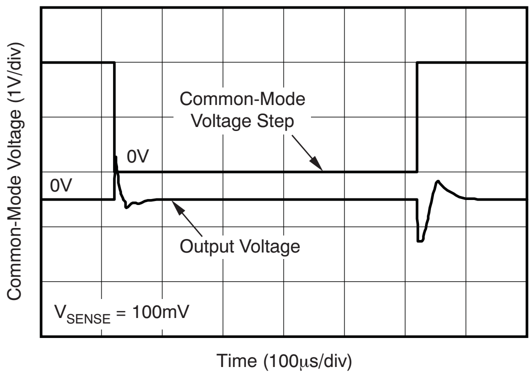



**Figure 13.**

**INVERTING DIFFERENTIAL INPUT OVERLOAD**

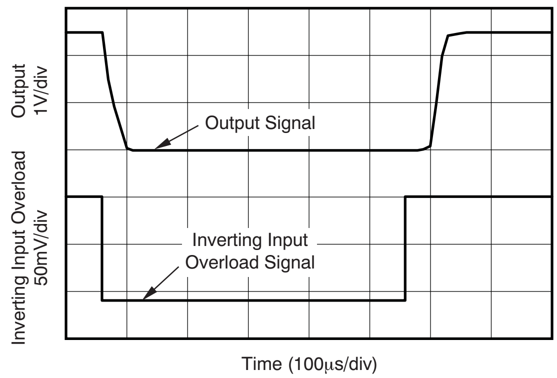



**Figure 14.**

**NONINVERTING DIFFERENTIAL INPUT OVERLOAD**

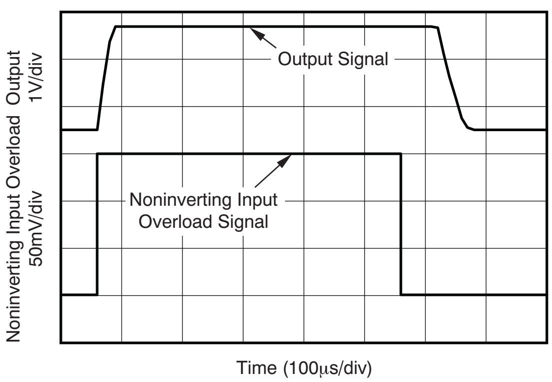



**Figure 15.**

**STARTUP RESPONSE**

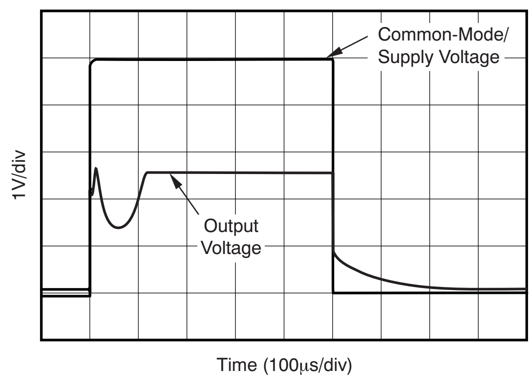



**Figure 16.**

**BROWNOUT RECOVERY**

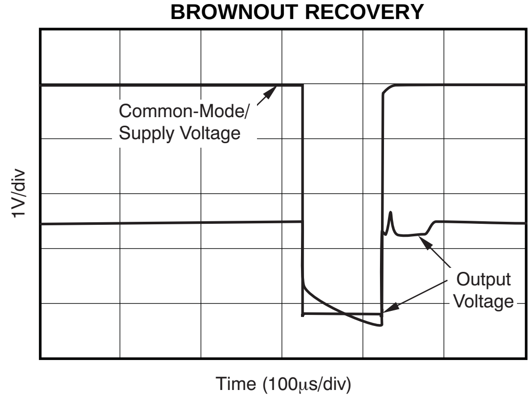



**Figure 17.**

# APPLICATION INFORMATION

## Basic Connections

Figure 18 shows the basic connections of the INA216. The input pins, IN+ and IN–, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

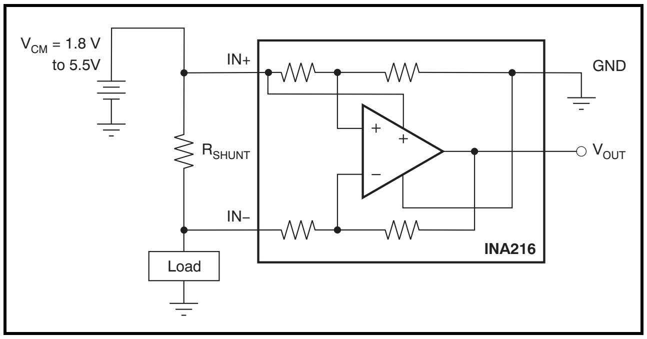



**Figure 18. Typical Application**

Figure 19 illustrates the INA216 connected to a shunt resistor with additional trace resistance in series with the shunt placed between where the current shunt monitors the input pins. With the typically low shunt resistor values commonly used in these applications, even small amounts of additional impedance in series with the shunt resistor can significantly affect the differential voltage present at the INA216 input pins.

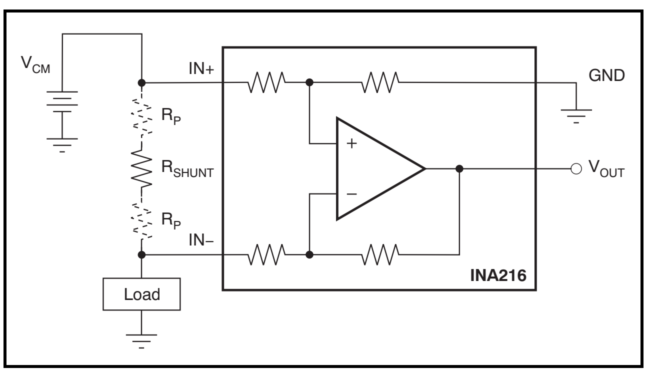



**Figure 19. Shunt Resistance Measurement Including Trace Resistance, $R_P$**

Figure 20 shows a proper Kelvin, or four-wire, connection of the shunt resistor to the INA216 input pins. This connection helps ensure that the only impedance between the current monitor input pins is the shunt resistor.

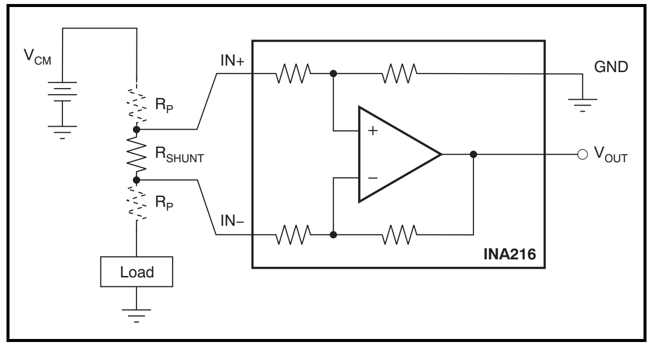



**Figure 20. Shunt Resistance Measurement Using a Kelvin Connection**

## Power Supply

The INA216 does not have a dedicated power-supply pin. Instead, an internal connection to the IN+ pin serves as the power supply for this device. Because the INA216 is powered from the IN+ pin, the common-mode input range is limited on the low end to 1.8V. Therefore, the INA216 cannot be used as a low-side current shunt monitor.

## Selecting $R_S$

The selection of the value of the shunt resistor ($R_S$) to use with the INA216 is based on the specific operating conditions and requirements of the application. The starting point for selecting the resistor is to first determine the desired full-scale output from the INA216. The INA216 is available in four gain options: 25, 50, 100, and 200. By dividing the desired full-scale output by each of the gain options, there are then four available differential input voltages that can achieve the desired full-scale output voltage, given that the appropriate gain device is used. With four values for the total voltage that is to be dropped across the shunt, the decision on how much of a drop is allowed in the application must be made. Most applications have a maximum drop allowed to ensure that the load receives the required voltage necessary to operate. Assuming that there are now multiple shunt voltages that are acceptable (based on the design criteria), the choice of what value shunt resistor to use can be made based on accuracy. As a result of the INA216 auto-zero architecture, the input offset voltage is extremely low. However, even the 100μV maximum input offset voltage specification plays a role in the decision of which shunt resistor value to choose. With a larger shunt voltage present at the current shunt monitor input, less error is introduced by the input offset voltage.

These comments have framed the decision on what the shunt resistor value should be, based on the full-scale value; but many applications require accurate measurements at levels as low as 10% of the full-scale value. At this level, the input offset voltage of the current shunt monitor becomes a larger percentage of the shunt voltage, and thus contributes a larger error to the output. The percentage of error created by the input offset voltage relative to the shunt voltage is shown in Equation 1.

$$Error\_V_{OS} = \frac{V_{OS}}{V_{SENSE}} \bullet 100 \quad (1)$$

Ideally, the differential input voltage at 10% would be increased to minimize the effects of the input offset voltage; however, we are bound by the full-scale value. The full-scale output voltage on the INA216 is limited to 200mV below the supply voltage (IN+). Selecting a shunt resistor to increase the shunt voltage at the low operating range of the load current could easily saturate the output of the current shunt monitor at the full-scale load current. For applications where accuracy over a larger range is needed, a lower gain option (and therefore, a larger differential input voltage) is selected. For applications where a minimal voltage drop on the line that powers the load is required, a higher gain option (and so, a smaller differential input voltage) is selected.

For example, consider a design that requires a full-scale output voltage of 4V, a maximum load current of 10A, and a maximum voltage drop on the common-mode line of 25mV. The 25mV maximum voltage drop requirement and a 4V full-scale output limits the gain option to the 200V/V device. A 100V/V setting would require a maximum voltage drop of 40mV with the other two lower gain versions creating larger voltage drops. Based on the gain of 200 on a 4V full-scale output, the maximum differential input voltage would be 20mV. The shunt resistor needed to create a 20mV drop with a 10A load current is 2mΩ.

When choosing the proper shunt resistor, it is also important to consider that at higher currents, the power dissipation in the shunt resistor becomes greater. Therefore, it is important to evaluate the drift of the sense resistor as a result of power dissipation, and choose an appropriate resistor based on its power wattage rating.

## Calculating Total Error

The electrical specifications for the INA216 include the typical individual errors terms such as gain error, offset error, and nonlinearity error. Total error including all of these individual error components is not specified in the *Electrical Characteristics* table. To accurately calculate the error that can be expected from the device, we must first know the operating conditions to which the device is subjected. Some current shunt monitors specify a total error in the product data sheet. However, this total error term is accurate under only one particular set of operating conditions. Specifying the total error at this one point has little practical value, though, because any deviation from these specific operating conditions no longer yields the same total error value. This section discusses the individual error sources, with information on how to apply them in order to calculate the total error value for the device under normal operating conditions.

The typical error sources that have the largest impact on the total error of the device are input offset voltage, common-mode voltage rejection, gain error, and nonlinearity error.

The nonlinearity error of the INA216 is relatively low compared to the gain error specification, which results in a gain error that can be expected to be relatively constant throughout the linear input range of the device. While the gain error remains constant across the linear input range of the device, the error associated with the input offset voltage does not. As the differential input voltage developed across a shunt resistor at the input of the INA216 decreases, the inherent input offset voltage of the device becomes a larger percentage of the measured input signal, resulting in an increase in measurement error. This varying error is present among all current shunt monitors, given the input offset voltage ratio to the voltage being sensed by the device. The low input offset voltages present in the INA216 devices, however, limit the amount of contribution the offset voltage has on the total error term.

Two examples are provided that detail how different operating conditions can affect the total error calculations. Typical and maximum calculations are shown as well to provide the user more information on how much error variance could be present from device to device.

### Example 1

### Conditions: INA216A3; $V_{CM} = V_S = 3.3V$; $V_{SENSE} = 20mV$

**Table 1. Example 1**

| TERM | LABEL | EQUATION | TYPICAL | MAXIMUM |
|---|---|---|---|---|
| Maximum initial input offset voltage | VIO | — | 20µV | 75µV |
| Added input offset voltage as result of common-mode voltage | VIO_CM | $\frac{1}{10^{\left(\frac{CMRR\_dB}{20}\right)}} \cdot \lvert 4.2V - V_{CM} \rvert$ | 3.6µV | 28µV |
| Total input offset voltage | VIO_Total | $\sqrt{(VIO)^2 + (VIO\_CM)^2}$ | 20µV | 80µV |
| Error because of input offset voltage | Error_VIO | $\frac{VIO\_Total}{V_{SENSE}} \cdot 100$ | 0.1% | 0.4% |
| Gain error | Error_Gain | — | 0.06% | 0.2% |
| Nonlinearity error | Error_Lin | — | 0.01% | 0.01% |
| Total error | | $\sqrt{(Error\_VIO)^2 + (Error\_Gain)^2 + (Error\_Lin)^2}$ | 0.12% | 0.45% |

### Example 2

### Conditions: INA216A1; $V_{CM} = V_S = 5V$; $V_{SENSE} = 160mV$

**Table 2. Example 2**

| TERM | LABEL | EQUATION | TYPICAL | MAXIMUM |
|---|---|---|---|---|
| Maximum initial input offset voltage | VIO | — | 30µV | 100µV |
| Added input offset voltage as result of common-mode voltage | VIO_CM | $\frac{1}{10^{\left(\frac{CMRR\_dB}{20}\right)}} \cdot \lvert 4.2V - V_{CM} \rvert$ | 3.1µV | 25.2µV |
| Total input offset voltage | VIO_Total | $\sqrt{(VIO)^2 + (VIO\_CM)^2}$ | 30µV | 100µV |
| Error because of input offset voltage | Error_VIO | $\frac{VIO\_Total}{V_{SENSE}} \cdot 100$ | 0.02% | 0.06% |
| Gain error | Error_Gain | — | 0.01% | 0.2% |
| Nonlinearity error | Error_Lin | — | 0.01% | 0.01% |
| Total error | | $\sqrt{(Error\_VIO)^2 + (Error\_Gain)^2 + (Error\_Lin)^2}$ | 0.025% | 0.21% |

## Input Filtering

An ideal location where filtering is implemented is at the inputs for a device. Placing an input filter in front of the INA216, though, is not recommended but can be implemented if it is determined to be necessary. This location is not recommended for filtering because adding input filters induces an additional gain error to the device that can easily exceed the device maximum gain error specification of 0.2%. In the INA216, the nominal current into the IN+ pin is in the range of 13μA while the bias current into the IN– pin is in the range of approximately 3μA. The current flowing into the IN+ pin includes both the input bias current as well as the quiescent current. Where the issue of input filtering begins to become more of an issue is that as the quiescent current of the INA216 also flows through the IN+ pin, when the output begins to drive current, this additional current also flows through the IN+ pin, creating an even larger error.

Placing a typical common-mode filter of 10Ω in series with each input and a 0.1μF capacitor across the input pins, as shown in Figure 21, introduces an additional gain error into the system. For example, consider an application using the INA216A3 with a full-scale output of 4V, assuming that the device is not driving any output current. The shunt voltage needed to create the 4V output with a gain of 100 is 40mV. With 10Ω filter resistors on each input, there is a difference voltage created that subtracts from the 40mV full-scale differential current. The error can be calculated using Equation 2.

$$\text{Error\_R}_{\text{FILTER}} = \frac{(I_{IN+} - I_{IN-}) \bullet R_{FILTER}}{V_{SHUNT}} \bullet 100 \quad (2)$$

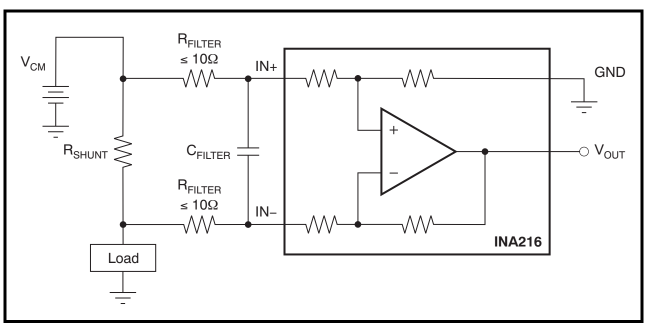



**Figure 21. Input Filter**

As mentioned previously, the current flowing into the IN+ pin increases once the output begins to drive current because of the quiescent current also flowing into the IN+ pin. The previous example resulted in an additional gain error of 0.3% as a result of the 10Ω filter resistors (assuming the output stage was not driving any current). Connecting a 100kΩ load to the 4V output now increases the current by an additional 40μA. This increase in current flowing through the IN+ pin would change the additional gain error from 0.3% to 1.3%.

If filtering is required for the application and the gain error introduced by the input filter resistors exceeds the available error budget for this circuit, a filter can be implemented following the INA216. Placing a filter at the output of the current shunt monitor is not typically the ideal location because the benefit of the low impedance output of the amplifier is lost. Applications that require the low impedance output require an additional buffer amplifier that follows the post current shunt monitor filter.

## Using the INA216 With Transients Above 5.5V

With a small amount of additional circuitry, INA216 can be used in circuits subject to transients higher than 5.5V. Use only zener diode or zener-type transient absorbers, which are sometimes referred to as *Transzorbs*. Any other type of transient absorber has an unacceptable time delay. To use these protection devices, resistors are required in series with the INA216 inputs, as shown in Figure 22. These resistors serve as a working impedance for the zener. It is desirable to keep these resistors as small as possible because of the error described in the *Input Filtering* section. These protection resistors are most often around 10Ω. Larger values can be used with a greater impact to the total gain error. Because this circuit limits only short-term transients, many applications are satisfied with a 10Ω resistor along with conventional zener diodes of the lowest power rating that can be found. This combination uses the least amount of board space. These diodes can be found in packages as small as SOT-523 or SOD-523. The use of these protection components may allow the INA216 to survive from being damaged in environments where large transients are common.

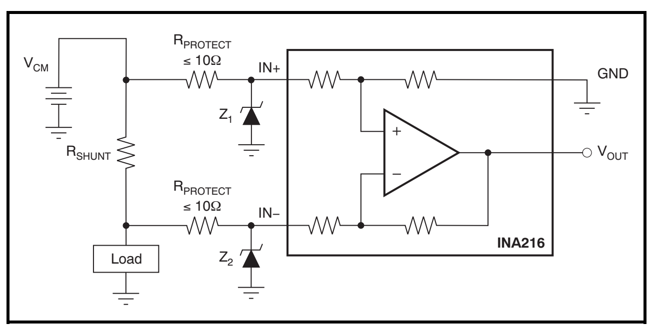



**Figure 22. Transient Protection Using Dual Zener Diodes**

## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision B (June 2010) to Revision C | Page |
|---|---|
| • Changed product status from Mixed Status to Production Data | 1 |
| • Updated *Package Information* table to include RSW package information | 2 |
| • Added *Thermal Information* table for RSW package | 3 |
| • Added RSW package pinout drawing | 3 |

| Changes from Revision A (June, 2010) to Revision B | Page |
|---|---|
| • Removed product preview status of INA216A2, INA216A3, and INA216A4 devices | 2 |
| • Added offset voltage specifications for INA216A2, INA216A3, and INA216A4 | 4 |
| • Added gain and gain error specifications for INA216A2, INA216A3, and INA216A4 | 4 |
| • Added bandwidth specifications for INA216A2, INA216A3, and INA216A4 | 4 |
| • Updated graph grid for Figure 2 through Figure 5 | 6 |
| • Revised Table 1 and Table 2 | 11 |
| • Changed description of nominal current into IN+ pin to 13μA and bias current into IN– pin to 3μA | 12 |

## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| INA216A1RSWR | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SNJ |
| INA216A1RSWR.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SNJ |
| INA216A1RSWT | Obsolete | Production | UQFN (RSW) \| 10 | - | - | Call TI | Call TI | -40 to 125 | SNJ |
| INA216A1YFFR | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OW |
| INA216A1YFFR.A | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OW |
| INA216A2RSWR | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SOJ |
| INA216A2RSWR.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SOJ |
| INA216A2RSWRG4.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SOJ |
| INA216A2RSWT | Active | Production | UQFN (RSW) \| 10 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SOJ |
| INA216A2RSWT.A | Active | Production | UQFN (RSW) \| 10 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SOJ |
| INA216A2YFFR | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OX |
| INA216A2YFFR.A | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OX |
| INA216A2YFFT | Last Time Buy | Production | DSBGA (YFF) \| 4 | 250 \| SMALL T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OX |
| INA216A3RSWR | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SPJ |
| INA216A3RSWR.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SPJ |
| INA216A3RSWRG4.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SPJ |
| INA216A3RSWT | Obsolete | Production | UQFN (RSW) \| 10 | - | - | Call TI | Call TI | -40 to 125 | SPJ |
| INA216A3YFFR | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OY |
| INA216A3YFFR.A | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OY |
| INA216A3YFFT | Obsolete | Production | DSBGA (YFF) \| 4 | - | - | Call TI | Call TI | -40 to 125 | OY |
| INA216A4RSWR | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SQJ |
| INA216A4RSWR.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SQJ |
| INA216A4RSWRG4.A | Active | Production | UQFN (RSW) \| 10 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | SQJ |
| INA216A4YFFR | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OZ |
| INA216A4YFFR.A | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OZ |
| INA216A4YFFR.B | Active | Production | DSBGA (YFF) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OZ |
| INA216A4YFFT | Last Time Buy | Production | DSBGA (YFF) \| 4 | 250 \| SMALL T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | OZ |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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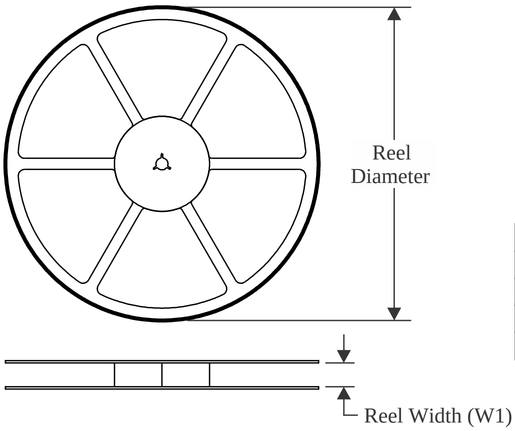
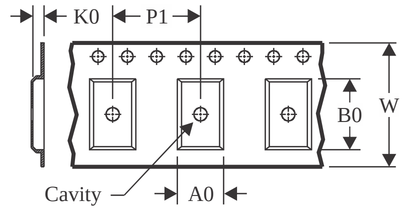
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

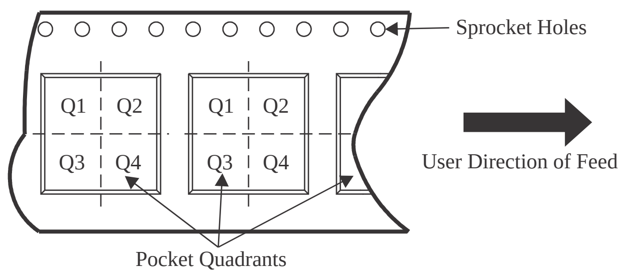



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

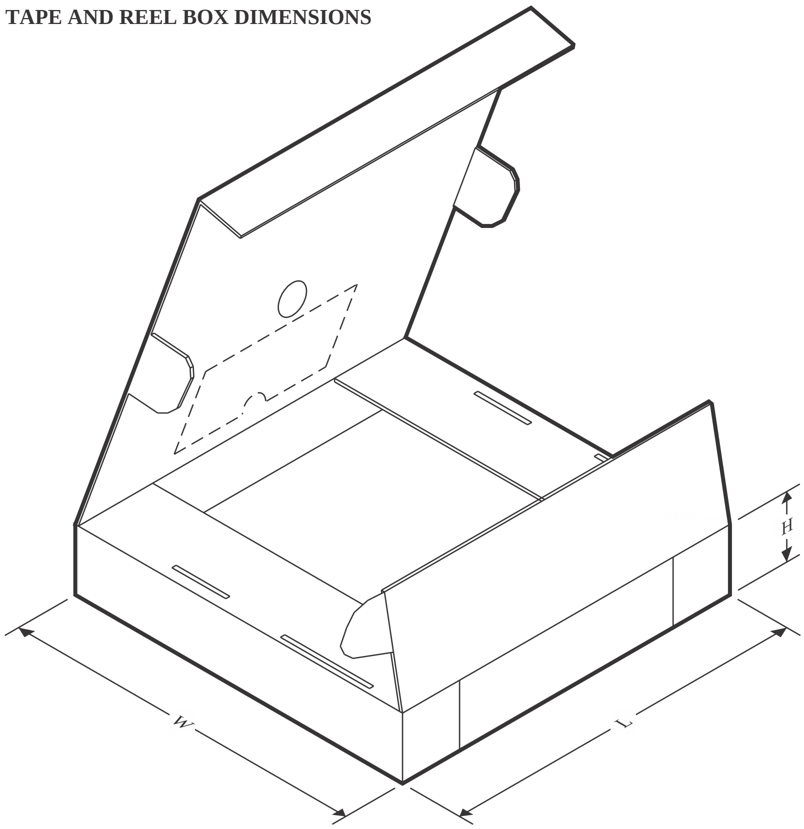
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

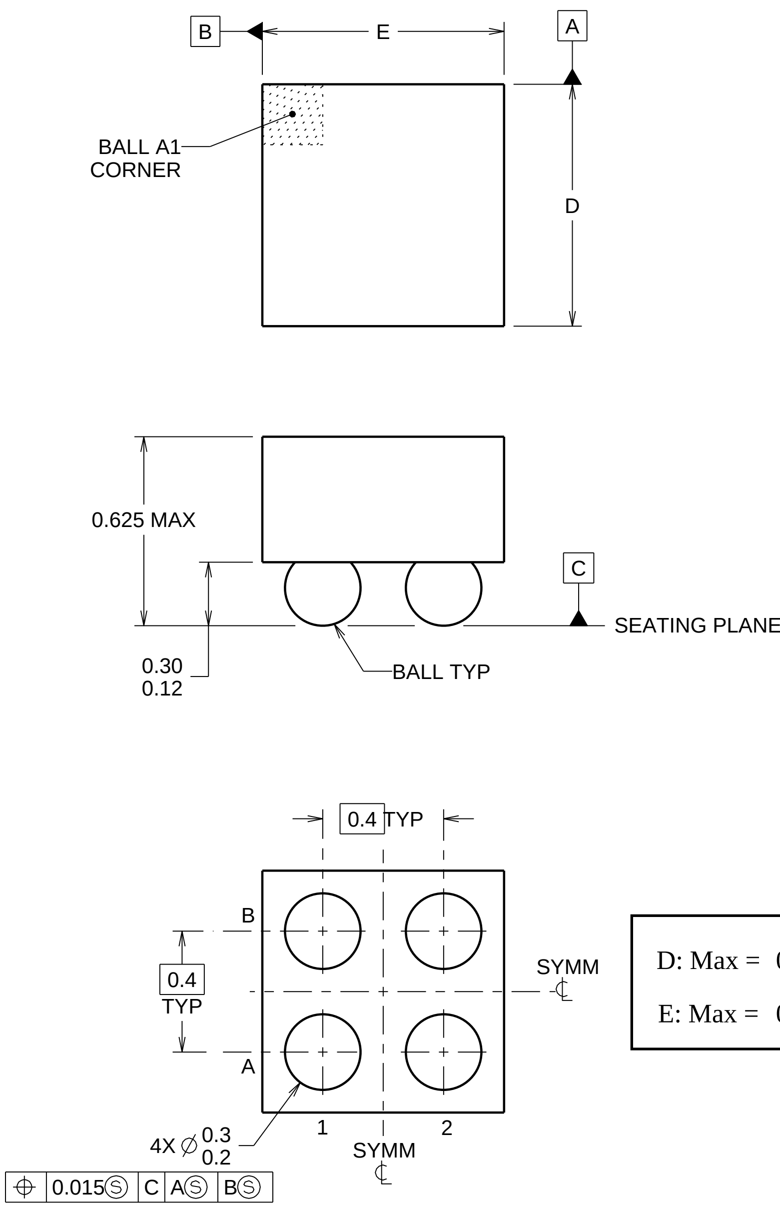
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA216A1YFFR | DSBGA | YFF | 4 | 3000 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |
| INA216A2YFFR | DSBGA | YFF | 4 | 3000 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |
| INA216A2YFFT | DSBGA | YFF | 4 | 250 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |
| INA216A3YFFR | DSBGA | YFF | 4 | 3000 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |
| INA216A4RSWR | UQFN | RSW | 10 | 3000 | 179.0 | 8.4 | 1.7 | 2.1 | 0.7 | 4.0 | 8.0 | Q1 |
| INA216A4YFFR | DSBGA | YFF | 4 | 3000 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |
| INA216A4YFFT | DSBGA | YFF | 4 | 250 | 180.0 | 8.4 | 0.85 | 0.85 | 0.64 | 4.0 | 8.0 | Q1 |

## TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA216A1YFFR | DSBGA | YFF | 4 | 3000 | 182.0 | 182.0 | 20.0 |
| INA216A2YFFR | DSBGA | YFF | 4 | 3000 | 182.0 | 182.0 | 20.0 |
| INA216A2YFFT | DSBGA | YFF | 4 | 250 | 182.0 | 182.0 | 20.0 |
| INA216A3YFFR | DSBGA | YFF | 4 | 3000 | 182.0 | 182.0 | 20.0 |
| INA216A4RSWR | UQFN | RSW | 10 | 3000 | 200.0 | 183.0 | 25.0 |
| INA216A4YFFR | DSBGA | YFF | 4 | 3000 | 182.0 | 182.0 | 20.0 |
| INA216A4YFFT | DSBGA | YFF | 4 | 250 | 182.0 | 182.0 | 20.0 |




D: Max = 0.79 mm, Min = 0.73 mm

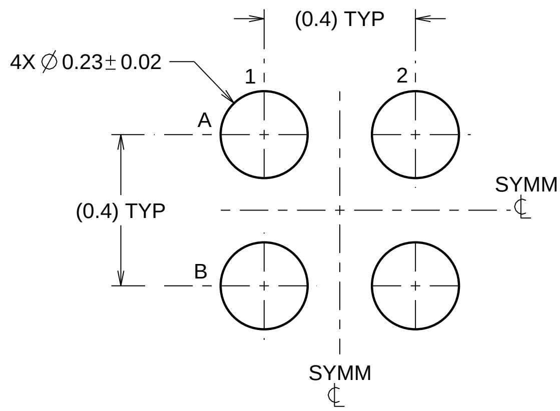
E: Max = 0.79 mm, Min = 0.73 mm

4219460/A 02/2014

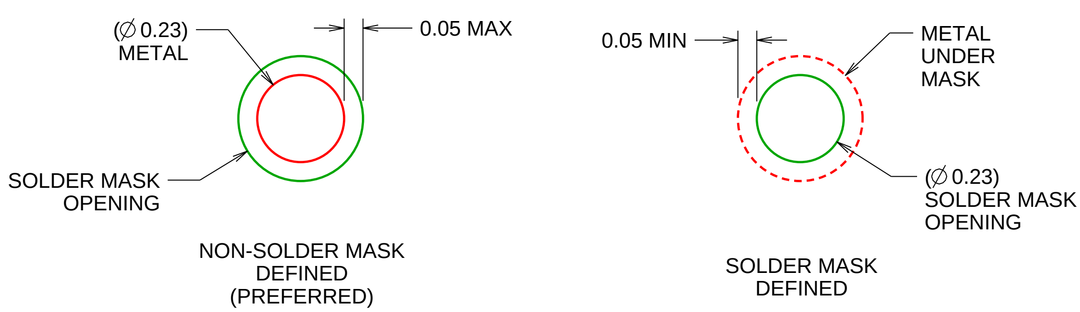
NOTES:

NanoFree Is a trademark of Texas Instruments.

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. NanoFree™ package configuration.




LAND PATTERN EXAMPLE
SCALE:50X

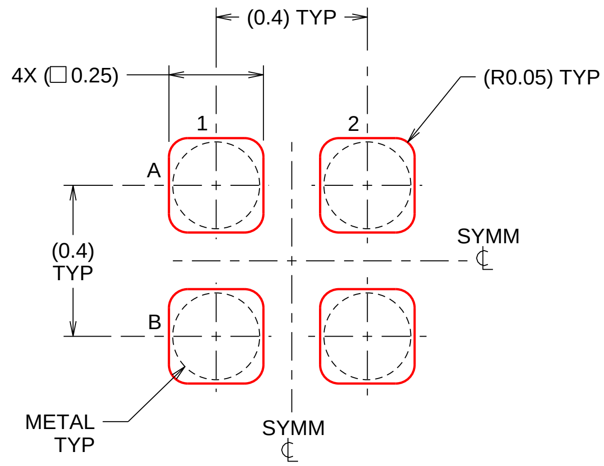



SOLDER MASK DETAILS
NOT TO SCALE

4219460/A 02/2014

NOTES: (continued)

4. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SBVA017 (www.ti.com/lit/sbva017).

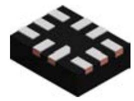



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:50X

4219460/A 02/2014

NOTES: (continued)

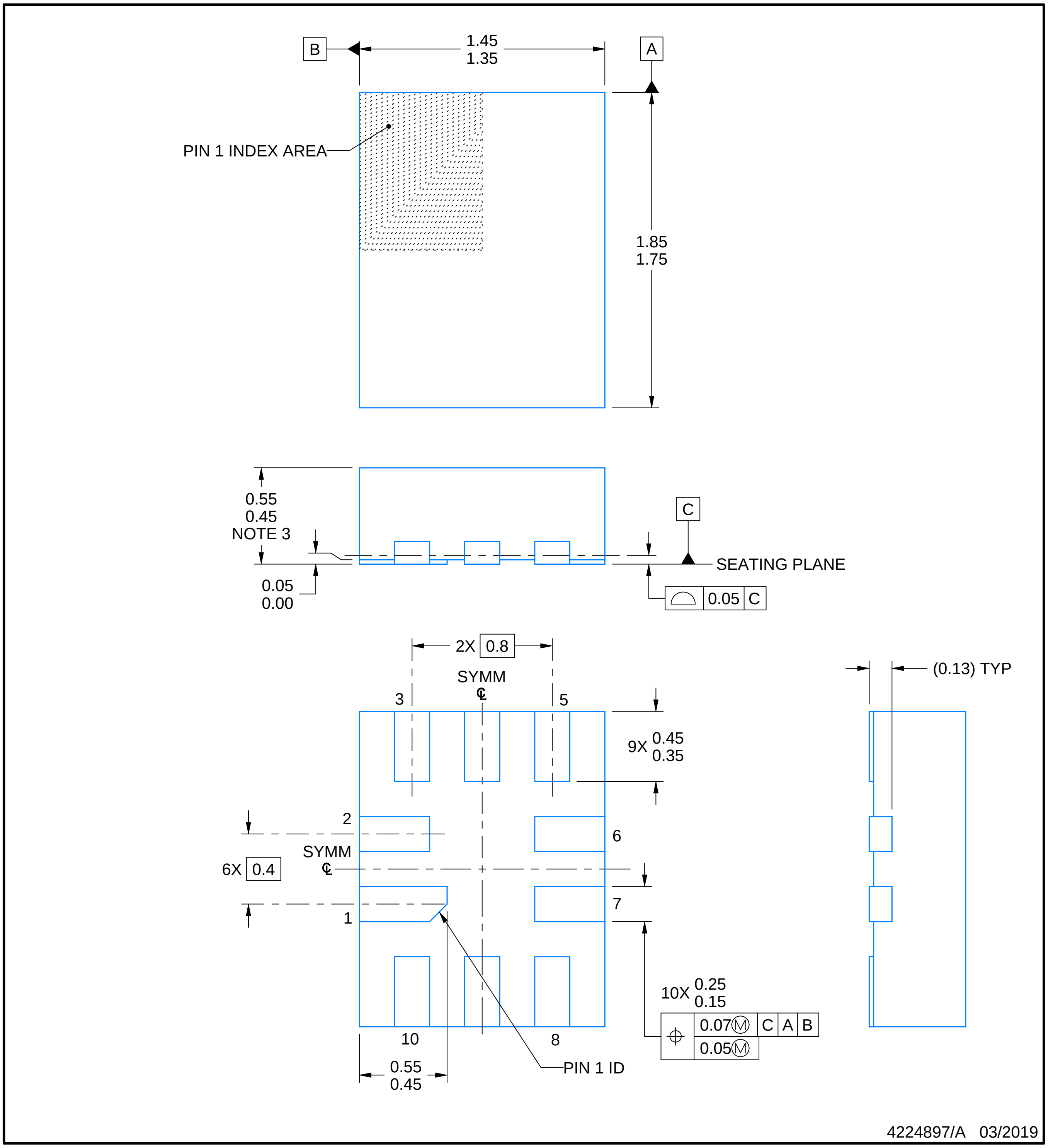
5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.



# PACKAGE OUTLINE

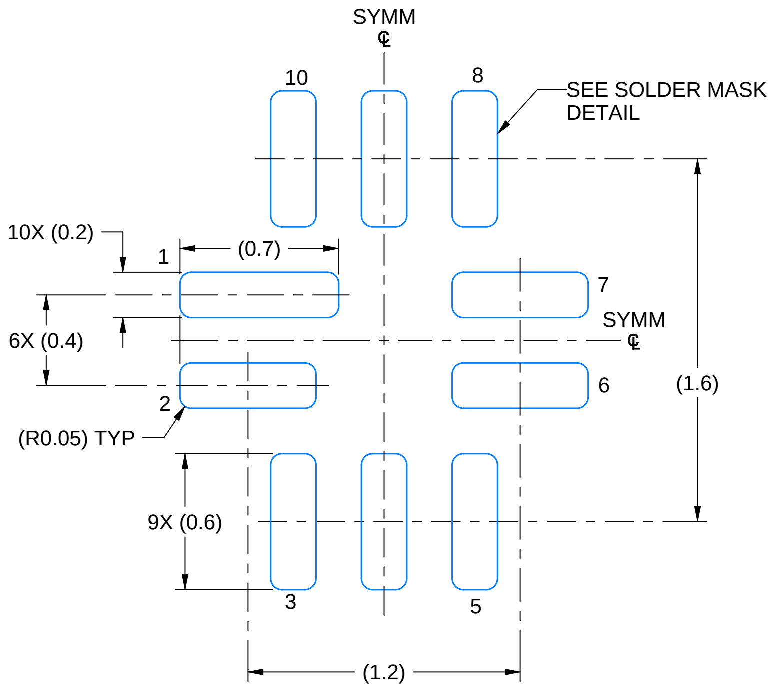
## UQFN - 0.55 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

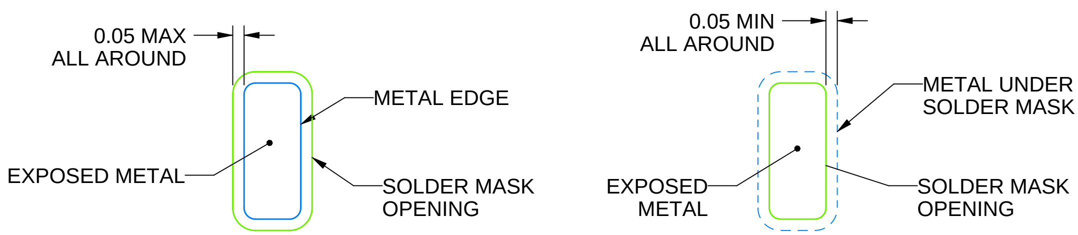



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package complies to JEDEC MO-288 variation UDEE, except minimum package height.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 30X




NON SOLDER MASK
DEFINED
(PREFERRED)

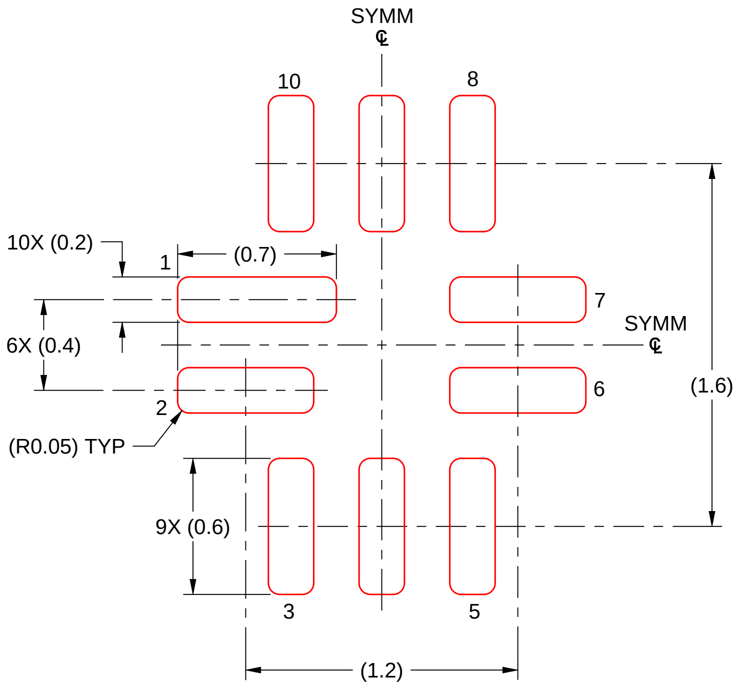
SOLDER MASK DEFINED

SOLDER MASK DETAILS

4224897/A 03/2019

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.




SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 30X

4224897/A 03/2019

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.