

# INA20x –16-V to 80-V, 500-kHz Current Sense Amplifier With Dual Comparators

## 1 Features

- Complete current sense solution
- Three gain options available:
  - INA203 = 20 V/V
  - INA204 = 50 V/V
  - INA205 = 100 V/V
- Dual comparators:
  - Comparator 1 with latch
  - Comparator 2 with optional delay
- Common-mode range: –16 V to 80 V
- High accuracy: 3.5% (maximum) over temperature
- Bandwidth: 500 kHz
- Quiescent current: 1.8 mA
- Packages: SO-14, TSSOP-14, VSSOP-10

## 2 Applications

- Notebook computers
- Cell phones
- Telecom equipment
- Automotive
- Power management
- Battery chargers
- Welding equipment

## 3 Description

The INA203, INA204, and INA205 are a family of unidirectional current-shunt monitors with voltage output, dual comparators, and voltage reference. The INA203, INA204, and INA205 can sense drops across shunts at common-mode voltages from –16 V to 80 V. The INA203, INA204, and INA205 are available with three output voltage scales: 20 V/V, 50 V/V, and 100 V/V, with up to 500-kHz bandwidth.

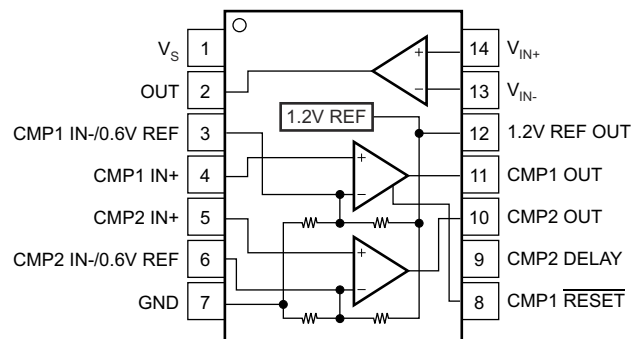
The INA203, INA204, and INA205 also incorporate two open-drain comparators with internal 0.6-V references. On 14-pin versions, the comparator references can be overridden by external inputs. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay. 14-pin versions also provide a 1.2-V reference output.

The INA203, INA204, and INA205 operate from a single 2.7-V to 18-V supply. They are specified over the extended operating temperature range of –40°C to 125°C.

### Device Information (1)

| PART NUMBER                  | PACKAGE    | BODY SIZE (NOM)   |
|------------------------------|------------|-------------------|
| INA203,<br>INA204,<br>INA205 | SOIC (14)  | 8.65 mm × 3.91 mm |
|                              | VSSOP (10) | 3.00 mm × 3.00 mm |
|                              | TSSOP (14) | 5.00 mm × 4.40 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.



**Simplified Schematic**



## Table of Contents

|                                                            |           |                                                                  |           |
|------------------------------------------------------------|-----------|------------------------------------------------------------------|-----------|
| <b>1 Features</b> .....                                    | <b>1</b>  | 7.3 Feature Description.....                                     | <b>14</b> |
| <b>2 Applications</b> .....                                | <b>1</b>  | 7.4 Device Functional Modes.....                                 | <b>18</b> |
| <b>3 Description</b> .....                                 | <b>1</b>  | <b>8 Application and Implementation</b> .....                    | <b>22</b> |
| <b>4 Revision History</b> .....                            | <b>2</b>  | 8.1 Application Information.....                                 | <b>22</b> |
| <b>5 Pin Configuration and Functions</b> .....             | <b>4</b>  | 8.2 Typical Application.....                                     | <b>22</b> |
| <b>6 Specifications</b> .....                              | <b>5</b>  | <b>9 Power Supply Recommendations</b> .....                      | <b>23</b> |
| 6.1 Absolute Maximum Ratings.....                          | <b>5</b>  | <b>10 Layout</b> .....                                           | <b>24</b> |
| 6.2 ESD Ratings.....                                       | <b>5</b>  | 10.1 Layout Guidelines.....                                      | <b>24</b> |
| 6.3 Recommended Operating Conditions.....                  | <b>5</b>  | 10.2 Layout Example.....                                         | <b>24</b> |
| 6.4 Thermal Information.....                               | <b>5</b>  | <b>11 Device and Documentation Support</b> .....                 | <b>25</b> |
| 6.5 Electrical Characteristics: Current-Shunt Monitor..... | <b>6</b>  | 11.1 Related Links.....                                          | <b>25</b> |
| 6.6 Electrical Characteristics: Comparator.....            | <b>7</b>  | 11.2 Receiving Notification of Documentation Updates.....        | <b>25</b> |
| 6.7 Electrical Characteristics: Reference.....             | <b>9</b>  | 11.3 Support Resources.....                                      | <b>25</b> |
| 6.8 Electrical Characteristics: General.....               | <b>9</b>  | 11.4 Trademarks.....                                             | <b>25</b> |
| 6.9 Typical Characteristics.....                           | <b>10</b> | 11.5 Electrostatic Discharge Caution.....                        | <b>25</b> |
| <b>7 Detailed Description</b> .....                        | <b>14</b> | 11.6 Glossary.....                                               | <b>25</b> |
| 7.1 Overview.....                                          | <b>14</b> | <b>12 Mechanical, Packaging, and Orderable Information</b> ..... | <b>25</b> |
| 7.2 Functional Block Diagrams.....                         | <b>14</b> |                                                                  |           |

## 4 Revision History

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

|                                                                                                                                                                                                                                                                                                                                                      |             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <b>Changes from Revision E (November 2015) to Revision F (June 2021)</b>                                                                                                                                                                                                                                                                             | <b>Page</b> |
| • Updated the numbering format for tables, figures, and cross-references throughout the document.....                                                                                                                                                                                                                                                | <b>1</b>    |
| • Changed maximum input voltage for accurate measurements from: $(V_{SHUNT} - 0.25) / \text{Gain}$ to: $(V_{OUT} - 0.25) / \text{Gain}$ .....                                                                                                                                                                                                        | <b>15</b>   |
| <b>Changes from Revision D (May 2009) to Revision E (November 2015)</b>                                                                                                                                                                                                                                                                              | <b>Page</b> |
| • Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section ..... | <b>1</b>    |
| • Moved thermal values from <i>Electrical Characteristics: General</i> to <i>Thermal Information</i> table. Removed duplicate storage temperature parameter.....                                                                                                                                                                                     | <b>9</b>    |
| <b>Changes from Revision C (October 2007) to Revision D (May 2009)</b>                                                                                                                                                                                                                                                                               | <b>Page</b> |
| • Changed <a href="#">Figure 6-1</a> .....                                                                                                                                                                                                                                                                                                           | <b>7</b>    |

## Device Comparison

**Table 5-1. Device Gain**

| DEVICE | GAIN    |
|--------|---------|
| INA203 | 20 V/V  |
| INA204 | 50 V/V  |
| INA205 | 100 V/V |

**Table 5-2. Related Products**

| FEATURES                                                   | PRODUCT                       |
|------------------------------------------------------------|-------------------------------|
| Variant of INA203–INA205 Comparator 2 polarity             | <a href="#">INA206–INA208</a> |
| Current-shunt monitor with single Comparator and $V_{REF}$ | <a href="#">INA200–INA202</a> |
| Current-shunt monitor only                                 | <a href="#">INA193–INA198</a> |
| Current-shunt monitor with split stages for filter options | <a href="#">INA270–INA271</a> |

## 5 Pin Configuration and Functions

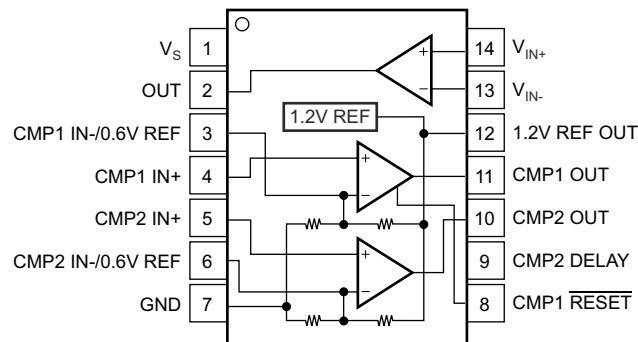


Figure 5-1. D and PW Packages 14-Pin SOIC and TSSOP Top View

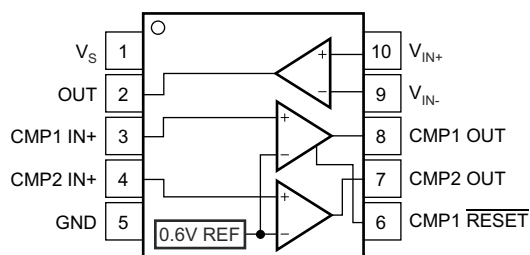


Figure 5-2. DGS Package 10-Pin VSSOP Top View

Table 5-1. Pin Functions

| NAME               | PIN         |       | I/O | DESCRIPTION                                                                       |
|--------------------|-------------|-------|-----|-----------------------------------------------------------------------------------|
|                    | SOIC, TSSOP | VSSOP |     |                                                                                   |
| V <sub>S</sub>     | 1           | 1     | I   | Power Supply                                                                      |
| OUT                | 2           | 2     | O   | Output voltage                                                                    |
| CMP1 IN-/0.6-V Ref | 3           | —     | I   | Comparator 1 negative input, can be used to override the internal 0.6-V reference |
| CMP1 IN+           | 4           | 3     | I   | Comparator 1 positive input                                                       |
| CMP2 IN+           | 5           | —     | I   | Comparator 2 positive input                                                       |
| CMP2 IN-           | —           | 4     | I   | Comparator 2 negative input                                                       |
| CMP2 IN-/0.6-V Ref | 6           | —     | I   | Comparator 2 negative input, can be used to override the internal 0.6-V reference |
| GND                | 7           | 5     | I   | Ground                                                                            |
| CMP1 RESET         | 8           | 6     | I   | Comparator 1 output reset, active low                                             |
| CMP2 DELAY         | 9           | —     | I   | Connect an optional capacitor to adjust comparator 2 delay                        |
| CMP2 OUT           | 10          | 7     | O   | Comparator 2 output                                                               |
| CMP1 OUT           | 11          | 8     | O   | Comparator 1 output                                                               |
| 1.2-V REF OUT      | 12          | —     | O   | 1.2-V reference output                                                            |
| V <sub>IN-</sub>   | 13          | 9     | I   | Connect to shunt low side                                                         |
| V <sub>IN+</sub>   | 14          | 10    | I   | Connect to shunt high side                                                        |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

See (1)

|                                                              |                                            | MIN       | MAX             | UNIT |
|--------------------------------------------------------------|--------------------------------------------|-----------|-----------------|------|
| Supply Voltage, $V_S$                                        |                                            |           | 18              | V    |
| Current-Shunt Monitor Analog Inputs, $V_{IN+}$ and $V_{IN-}$ | Differential ( $V_{IN+}$ ) – ( $V_{IN-}$ ) | –18       | 18              | V    |
|                                                              | Common-Mode                                | –16       | 80              | V    |
| Comparator Analog Input and Reset Pins                       |                                            | GND – 0.3 | ( $V_S$ ) + 0.3 | V    |
| Analog Output, Out Pin                                       |                                            | GND – 0.3 | ( $V_S$ ) + 0.3 | V    |
| Comparator Output, Out Pin                                   |                                            | GND – 0.3 | 18              | V    |
| $V_{REF}$ and CMP2 Delay Pin                                 |                                            | GND – 0.3 | 10              | V    |
| Input Current Into Any Pin                                   |                                            |           | 5               | mA   |
| Operating Temperature                                        |                                            | –55       | 150             | °C   |
| Junction Temperature                                         |                                            | –65       | 150             | °C   |
| Storage temperature, $T_{stg}$                               |                                            | –65       | 150             | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

|                                     |                                                                               | VALUE | UNIT |
|-------------------------------------|-------------------------------------------------------------------------------|-------|------|
| $V_{(ESD)}$ Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins (1)              | ±4000 | V    |
|                                     | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins (2) | ±500  |      |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.  
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

|          |                                | MIN | NOM | MAX | UNIT |
|----------|--------------------------------|-----|-----|-----|------|
| $V_{CM}$ | Common-mode input voltage      | –16 | 12  | 80  | V    |
| $V_S$    | Operating supply voltage       | 2.7 | 12  | 18  | V    |
| $T_A$    | Operating free-air temperature | –40 | 25  | 125 | °C   |

### 6.4 Thermal Information

| THERMAL METRIC (1)   |                                              | INA20x   |             |            | UNIT |
|----------------------|----------------------------------------------|----------|-------------|------------|------|
|                      |                                              | D (SOIC) | DGS (VSSOP) | PW (TSSOP) |      |
|                      |                                              | 14 PINS  | 10 PINS     | 14 PINS    |      |
| $R_{\theta JA}$      | Junction-to-ambient thermal resistance       | 84.9     | 161.3       | 112.6      | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance    | 44       | 36.8        | 37.2       | °C/W |
| $R_{\theta JB}$      | Junction-to-board thermal resistance         | 39.4     | 82.3        | 55.4       | °C/W |
| $\Psi_{JT}$          | Junction-to-top characterization parameter   | 10.3     | 1.3         | 2.7        | °C/W |
| $\Psi_{JB}$          | Junction-to-board characterization parameter | 39.1     | 80.8        | 54.7       | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | 150      | 200         | 150        | °C/W |

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

## 6.5 Electrical Characteristics: Current-Shunt Monitor

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND,  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , and CMP1 IN+ = 1 V and CMP2 IN- = GND, unless otherwise noted.

| PARAMETER                                          |                                                     | TEST CONDITIONS                                               |                                 | MIN | TYP                         | MAX                          | UNIT  |
|----------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------|---------------------------------|-----|-----------------------------|------------------------------|-------|
| INPUT                                              |                                                     |                                                               |                                 |     |                             |                              |       |
| V <sub>SENSE</sub>                                 | Full-Scale Sense Input Voltage                      | V <sub>SENSE</sub> = V <sub>IN+</sub> – V <sub>IN–</sub>      |                                 |     | 0.15                        | (V <sub>S</sub> – 0.25)/Gain | V     |
| V <sub>CM</sub>                                    | Common-Mode Input Range                             | T <sub>A</sub> = –40°C to 125°C                               |                                 | –16 |                             | 80                           | V     |
| CMRR                                               | Common-Mode Rejection Ratio                         | V <sub>CM</sub> = –16 V to 80 V                               |                                 | 80  | 100                         |                              | dB    |
|                                                    | CMRR over Temperature                               | V <sub>CM</sub> = 12 V to 80 V                                | T <sub>A</sub> = –40°C to 125°C | 100 | 123                         |                              | dB    |
| V <sub>OS</sub>                                    | Offset Voltage, RTI <sup>(1)</sup>                  |                                                               |                                 |     | ±0.5                        | ±2.5                         | mV    |
|                                                    |                                                     | 25°C to 125°C                                                 |                                 |     |                             | ±3                           | mV    |
|                                                    |                                                     | –40°C to 25°C                                                 |                                 |     |                             | ±3.5                         | mV    |
| dV <sub>OS</sub> /dT                               | Offset Voltage, RTI <sup>(1)</sup> vs. Temperature  | T <sub>MIN</sub> to T <sub>MAX</sub>                          | T <sub>A</sub> = –40°C to 125°C |     | 5                           |                              | μV/°C |
| PSR                                                | Offset Voltage, RTI <sup>(1)</sup> vs. Power Supply | V <sub>OUT</sub> = 2 V, V <sub>CM</sub> = 18 V, 2.7 V         | T <sub>A</sub> = –40°C to 125°C |     | 2.5                         | 100                          | μV/V  |
| I <sub>B</sub>                                     | Input Bias Current, V <sub>IN–</sub> Pin            | T <sub>A</sub> = –40°C to 125°C                               |                                 |     | ±9                          | ±16                          | μA    |
| OUTPUT (V <sub>SENSE</sub> ≥ 20 mV)                |                                                     |                                                               |                                 |     |                             |                              |       |
| G                                                  | Gain                                                | INA203                                                        |                                 |     | 20                          |                              | V/V   |
|                                                    |                                                     | INA204                                                        |                                 |     | 50                          |                              | V/V   |
|                                                    |                                                     | INA205                                                        |                                 |     | 100                         |                              | V/V   |
|                                                    | Gain Error                                          | V <sub>SENSE</sub> = 20 mV to 100 mV                          |                                 |     | ±0.2%                       | ±1%                          |       |
|                                                    | Gain Error over Temperature                         | V <sub>SENSE</sub> = 20 mV to 100 mV                          | T <sub>A</sub> = –40°C to 125°C |     |                             | ±2%                          |       |
|                                                    | Total Output Error <sup>(2)</sup>                   | V <sub>SENSE</sub> = 120 mV, V <sub>S</sub> = 16 V            |                                 |     | ±0.75%                      | ±2.2%                        |       |
|                                                    | Total Output Error <sup>(2)</sup> over Temperature  | V <sub>SENSE</sub> = 120 mV, V <sub>S</sub> = 16 V            | T <sub>A</sub> = –40°C to 125°C |     |                             | ±3.5%                        |       |
|                                                    | Nonlinearity Error <sup>(3)</sup>                   | V <sub>SENSE</sub> = 20 mV to 100 mV                          |                                 |     | ±0.002%                     |                              |       |
| R <sub>O</sub>                                     | Output Impedance, Pin 2                             |                                                               |                                 |     | 1.5                         |                              | Ω     |
|                                                    | Maximum Capacitive Load                             | No Sustained Oscillation                                      |                                 |     | 10                          |                              | nF    |
| OUTPUT (V <sub>SENSE</sub> < 20 mV) <sup>(4)</sup> |                                                     |                                                               |                                 |     |                             |                              |       |
|                                                    | INA203, INA204, INA205 output                       | –16 V ≤ V <sub>CM</sub> < 0 V                                 |                                 |     | 300                         |                              | mV    |
|                                                    | INA203 output                                       | 0 V ≤ V <sub>CM</sub> ≤ V <sub>S</sub> , V <sub>S</sub> = 5 V |                                 |     |                             | 0.4                          | V     |
|                                                    | INA204 output                                       | 0 V ≤ V <sub>CM</sub> ≤ V <sub>S</sub> , V <sub>S</sub> = 5 V |                                 |     |                             | 1                            | V     |
|                                                    | INA205 output                                       | 0 V ≤ V <sub>CM</sub> ≤ V <sub>S</sub> , V <sub>S</sub> = 5 V |                                 |     |                             | 2                            | V     |
|                                                    | INA203, INA204, INA205 output                       | V <sub>S</sub> < V <sub>CM</sub> ≤ 80 V                       |                                 |     | 300                         |                              | mV    |
| VOLTAGE OUTPUT <sup>(5)</sup>                      |                                                     |                                                               |                                 |     |                             |                              |       |
|                                                    | Output Swing to the Positive Rail                   | V <sub>IN–</sub> = 11 V, V <sub>IN+</sub> = 12 V              | T <sub>A</sub> = –40°C to 125°C |     | (V <sub>S</sub> ) – 0.15    | (V <sub>S</sub> ) – 0.25     | V     |
|                                                    | Output Swing to GND <sup>(6)</sup>                  | V <sub>IN–</sub> = 0 V, V <sub>IN+</sub> = –0.5 V             | T <sub>A</sub> = –40°C to 125°C |     | (V <sub>GND</sub> ) + 0.004 | (V <sub>GND</sub> ) + 0.05   | V     |

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND,  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , and CMP1 IN+ = 1 V and CMP2 IN- = GND, unless otherwise noted.

| PARAMETER                    | TEST CONDITIONS                                                                       | MIN | TYP | MAX | UNIT                   |
|------------------------------|---------------------------------------------------------------------------------------|-----|-----|-----|------------------------|
| <b>FREQUENCY RESPONSE</b>    |                                                                                       |     |     |     |                        |
| BW      Bandwidth            | INA203; $C_{LOAD} = 5\text{ pF}$                                                      |     | 500 |     | kHz                    |
|                              | INA204; $C_{LOAD} = 5\text{ pF}$                                                      |     | 300 |     | kHz                    |
|                              | INA205; $C_{LOAD} = 5\text{ pF}$                                                      |     | 200 |     | kHz                    |
| Phase Margin                 | $C_{LOAD} < 10\text{ nF}$                                                             |     | 40  |     |                        |
| SR      Slew Rate            |                                                                                       |     | 1   |     | V/ $\mu\text{s}$       |
| Settling Time (1%)           | $V_{SENSE} = 10\text{ mV}_{PP}$ to $100\text{ mV}_{PP}$ ,<br>$C_{LOAD} = 5\text{ pF}$ |     | 2   |     | $\mu\text{s}$          |
| <b>NOISE, RTI</b>            |                                                                                       |     |     |     |                        |
| Output Voltage Noise Density |                                                                                       |     | 40  |     | nV/ $\sqrt{\text{Hz}}$ |

- (1) Offset is extrapolated from measurements of the output at 20 mV and 100 mV  $V_{SENSE}$ .
- (2) Total output error includes effects of gain error and  $V_{OS}$ .
- (3) Linearity is best fit to a straight line.
- (4) For details on this region of operation, see the [Accuracy Variations as a Result Of  \$V\_{SENSE}\$  and Common-Mode Voltage](#) section in the [Application and Implementation](#).
- (5) See Typical Characteristic curve [Positive Output Voltage Swing vs. Output Current \(Positive Output Voltage Swing vs. Output Current\)](#).
- (6) Specified by design; not production tested.

## 6.6 Electrical Characteristics: Comparator

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND, and  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , unless otherwise noted.

| PARAMETER                                          | TEST CONDITIONS                                                            | MIN | TYP                         | MAX | UNIT                         |
|----------------------------------------------------|----------------------------------------------------------------------------|-----|-----------------------------|-----|------------------------------|
| <b>OFFSET VOLTAGE</b>                              |                                                                            |     |                             |     |                              |
| Offset Voltage                                     | Comparator Common-Mode Voltage = Threshold Voltage                         |     | 2                           |     | mV                           |
| Offset Voltage Drift, Comparator 1                 | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$                           |     | $\pm 2$                     |     | $\mu\text{V}/^\circ\text{C}$ |
| Offset Voltage Drift, Comparator 2                 | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$                           |     | 5.4                         |     | $\mu\text{V}/^\circ\text{C}$ |
| Threshold                                          | $T_A = 25^\circ\text{C}$                                                   | 590 | 608                         | 620 | mV                           |
| Threshold over Temperature                         | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$                           | 586 |                             | 625 | mV                           |
| Hysteresis <sup>(1)</sup> , CMP1                   | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$                            |     | -8                          |     | mV                           |
| Hysteresis <sup>(1)</sup> , CMP2                   | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$                            |     | 8                           |     | mV                           |
| <b>INPUT BIAS CURRENT <sup>(2)</sup></b>           |                                                                            |     |                             |     |                              |
| CMP1 IN+, CMP2 IN+                                 |                                                                            |     | 0.005                       | 10  | nA                           |
| CMP1 IN+, CMP2 IN+ vs. Temperature                 | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$                           |     |                             | 15  | nA                           |
| <b>INPUT IMPEDANCE</b>                             |                                                                            |     |                             |     |                              |
| Pins 3 and 6 (14-pin packages only)                |                                                                            |     | 10                          |     | k $\Omega$                   |
| <b>INPUT RANGE</b>                                 |                                                                            |     |                             |     |                              |
| CMP1 IN+ and CMP2 IN+                              |                                                                            |     | 0 V to $V_S - 1.5\text{ V}$ |     | V                            |
| Pins 3 and 6 (14-pin packages only) <sup>(3)</sup> |                                                                            |     | 0 V to $V_S - 1.5\text{ V}$ |     | V                            |
| <b>OUTPUT</b>                                      |                                                                            |     |                             |     |                              |
| Large-Signal Differential Voltage Gain             | CMP $V_{OUT}$ 1 V to 4 V, $R_L \geq 15\text{ k}\Omega$<br>Connected to 5 V |     | 200                         |     | V/mV                         |

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND, and  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , unless otherwise noted.

| PARAMETER                                  | TEST CONDITIONS                                                                                  | MIN | TYP                 | MAX | UNIT          |
|--------------------------------------------|--------------------------------------------------------------------------------------------------|-----|---------------------|-----|---------------|
| High-Level Output Current                  | $V_{ID} = 0.4\text{ V}$ , $V_{OH} = V_S$                                                         |     | 0.0001              | 1   | $\mu\text{A}$ |
| Low-Level Output Voltage                   | $V_{ID} = -0.6\text{ V}$ , $I_{OL} = 2.35\text{ mA}$                                             |     | 220                 | 300 | mV            |
| <b>RESPONSE TIME</b> <sup>(4)</sup>        |                                                                                                  |     |                     |     |               |
| Comparator 1                               | $R_L$ to 5 V, $C_L = 15\text{ pF}$ , 100-mV Input Step with 5-mV Overdrive                       |     | 1.3                 |     | $\mu\text{s}$ |
| Comparator 2                               | $R_L$ to 5 V, $C_L = 15\text{ pF}$ , 100-mV Input Step with 5-mV Overdrive, $C_{DELAY}$ Pin Open |     | 1.3                 |     | $\mu\text{s}$ |
| <b>RESET</b>                               |                                                                                                  |     |                     |     |               |
| RESET Threshold <sup>(5)</sup>             |                                                                                                  |     | 1.1                 |     | V             |
| Logic Input Impedance                      |                                                                                                  |     | 2                   |     | M $\Omega$    |
| Minimum RESET Pulse Width                  |                                                                                                  |     | 1.5                 |     | $\mu\text{s}$ |
| RESET Propagation Delay                    |                                                                                                  |     | 3                   |     | $\mu\text{s}$ |
| Comparator 2 Delay Equation <sup>(6)</sup> |                                                                                                  |     | $C_{DELAY} = t_D/5$ |     | $\mu\text{F}$ |
| $t_D$ Comparator 2 Delay                   | $C_{DELAY} = 0.1\text{ }\mu\text{F}$                                                             |     | 0.5                 |     | s             |

- (1) Hysteresis refers to the threshold (the threshold specification applies to a rising edge of a noninverting input) of a falling edge on the noninverting input of the comparator; refer to [Figure 6-1](#).
- (2) Specified by design; not production tested.
- (3) See the [Comparator Maximum Input Voltage Range](#) section in the [Application and Implementation](#).
- (4) The comparator response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.
- (5) The CMP1 RESET input has an internal 2-M $\Omega$  (typical) pulldown. Leaving the CMP1 RESET open results in a LOW state, with transparent comparator operation.
- (6) The Comparator 2 delay applies to both rising and falling edges of the comparator output.



**Figure 6-1. Comparator Hysteresis**

## 6.7 Electrical Characteristics: Reference

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND, and  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , unless otherwise noted.

| PARAMETER                                   | TEST CONDITIONS                                 | MIN   | TYP | MAX   | UNIT                  |
|---------------------------------------------|-------------------------------------------------|-------|-----|-------|-----------------------|
| <b>REFERENCE VOLTAGE</b>                    |                                                 |       |     |       |                       |
| 1.2- $V_{REFOUT}$ Output Voltage            |                                                 | 1.188 | 1.2 | 1.212 | V                     |
| $dV_{OUT}/dT$ Reference Drift               | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |       | 40  | 100   | ppm/ $^\circ\text{C}$ |
| 0.6- $V_{REF}$ Output Voltage               | Pins 3 and 6 of 14-pin packages only            |       | 0.6 |       | V                     |
| $dV_{OUT}/dT$ Reference Drift               | $T_A = -40^\circ\text{C}$ to $85^\circ\text{C}$ |       | 40  | 100   | ppm/ $^\circ\text{C}$ |
| <b>LOAD REGULATION</b> $dV_{OUT}/dI_{LOAD}$ |                                                 |       |     |       |                       |
| Sourcing                                    | $0\text{mA} < I_{SOURCE} < 0.5\text{mA}$        |       | 0.4 | 2     | mV/mA                 |
| Sinking                                     | $0\text{mA} < I_{SINK} < 0.5\text{mA}$          |       | 0.4 |       | mV/mA                 |
| $I_{LOAD}$ Load Current                     |                                                 |       | 1   |       | mA                    |
| $dV_{OUT}/dV_S$ Line Regulation             | $2.7\text{ V} < V_S < 18\text{ V}$              |       | 30  |       | $\mu\text{V/V}$       |
| <b>CAPACITIVE LOAD</b>                      |                                                 |       |     |       |                       |
| Reference Output Maximum Capacitive Load    | No Sustained Oscillations                       |       | 10  |       | nF                    |
| <b>OUTPUT IMPEDANCE</b>                     |                                                 |       |     |       |                       |
| Output Impedance                            | Pins 3 and 6 of 14-Pin Packages Only            |       | 10  |       | k $\Omega$            |

## 6.8 Electrical Characteristics: General

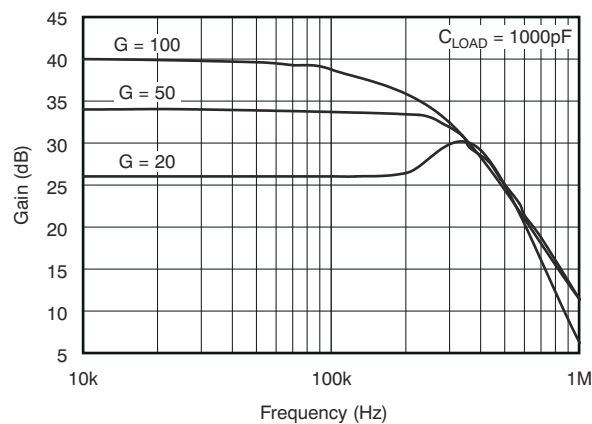
All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  to GND,  $R_{pullup} = 5.1\text{ k}\Omega$  each connected from CMP1 OUT and CMP2 OUT to  $V_S$ , and CMP1 IN+ = 1 V and CMP2 IN- = GND, unless otherwise noted.

| PARAMETER                                          | TEST CONDITIONS                                  | MIN | TYP | MAX | UNIT             |
|----------------------------------------------------|--------------------------------------------------|-----|-----|-----|------------------|
| <b>POWER SUPPLY</b>                                |                                                  |     |     |     |                  |
| $V_S$ Operating power supply                       | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$ | 2.7 |     | 18  | V                |
| $I_Q$ Quiescent current                            | $V_{OUT} = 2\text{ V}$                           |     | 1.8 | 2.2 | mA               |
| Quiescent current over temperature                 | $V_{SENSE} = 0\text{ mV}$                        |     |     | 2.8 | mA               |
| Comparator power-on reset threshold <sup>(1)</sup> |                                                  |     | 1.5 |     | V                |
| <b>TEMPERATURE</b>                                 |                                                  |     |     |     |                  |
| Specified temperature                              |                                                  | -40 |     | 125 | $^\circ\text{C}$ |
| Operating temperature                              |                                                  | -55 |     | 150 | $^\circ\text{C}$ |

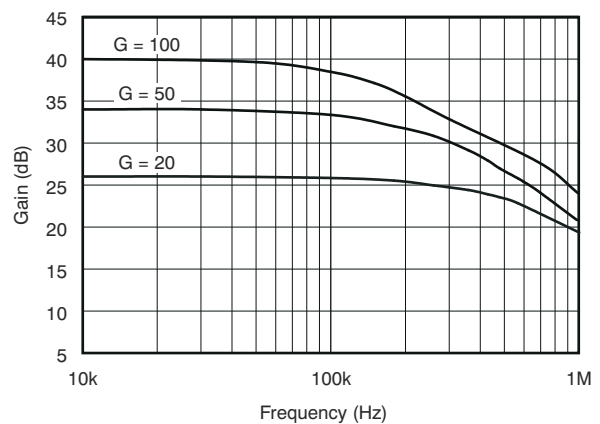
- (1) The INA203, INA204, and INA205 are designed to power-up with the comparator in a defined reset state as long as CMP1 RESET is open or grounded. The comparator will be in reset as long as the power supply is below the voltage shown here. The comparator assumes a state based on the comparator input above this supply voltage. If CMP1 RESET is high at power-up, the comparator output comes up high and requires a reset to assume a low state, if appropriate.

## 6.9 Typical Characteristics

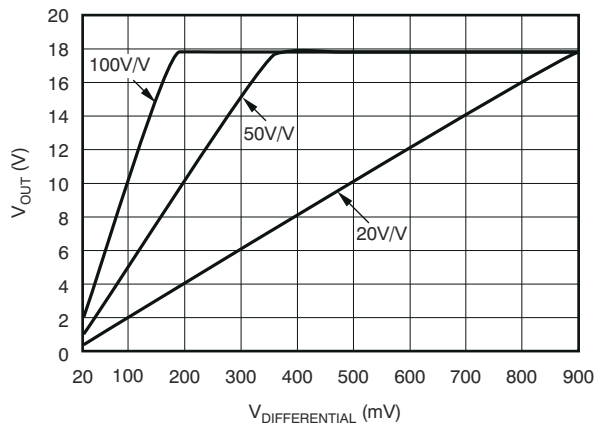
All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{CM} = 12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



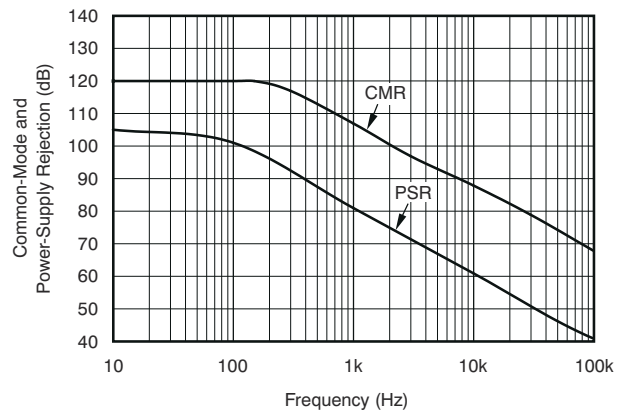
**Figure 6-2. Gain vs. Frequency**



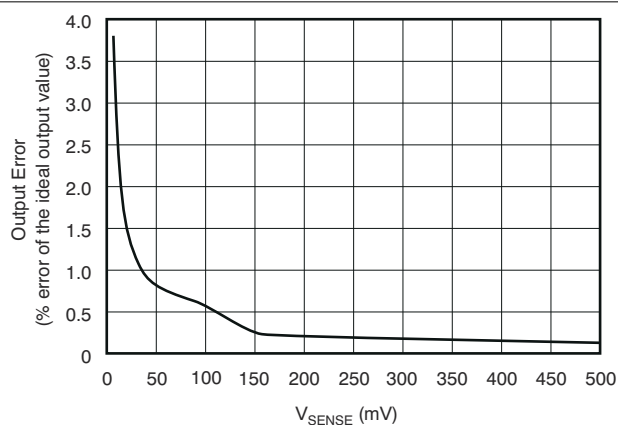
**Figure 6-3. Gain vs. Frequency**



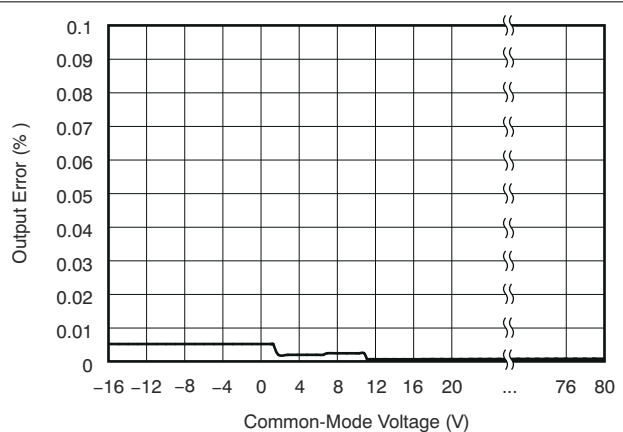
**Figure 6-4. Gain Plot**



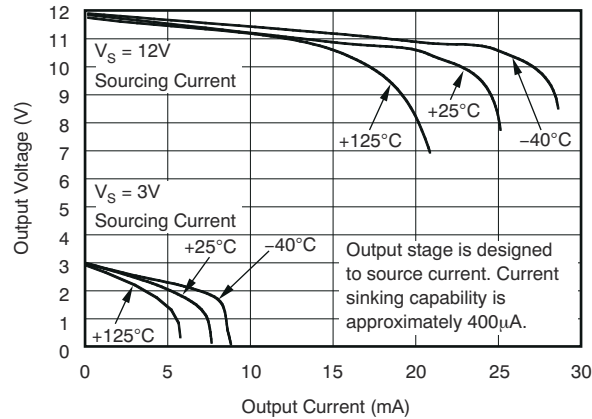
**Figure 6-5. Common-Mode and Power-Supply Rejection vs. Frequency**



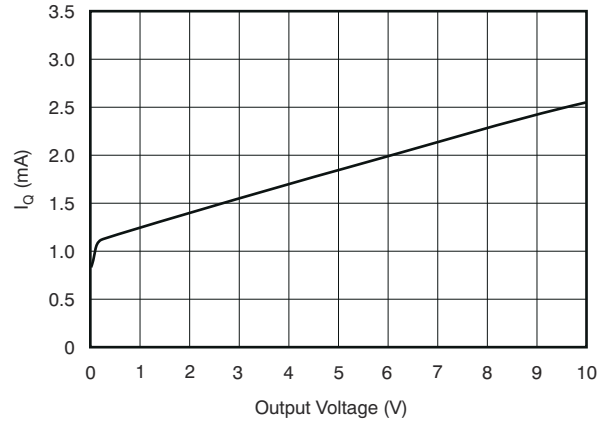
**Figure 6-6. Total Output Error vs.  $V_{SENSE}$**



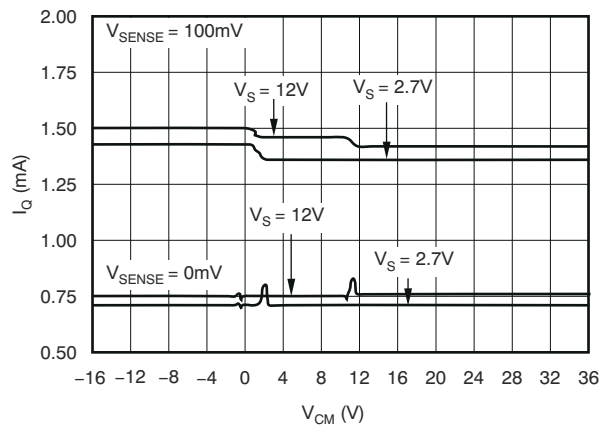
**Figure 6-7. Total Output Error vs. Common-Mode Voltage**



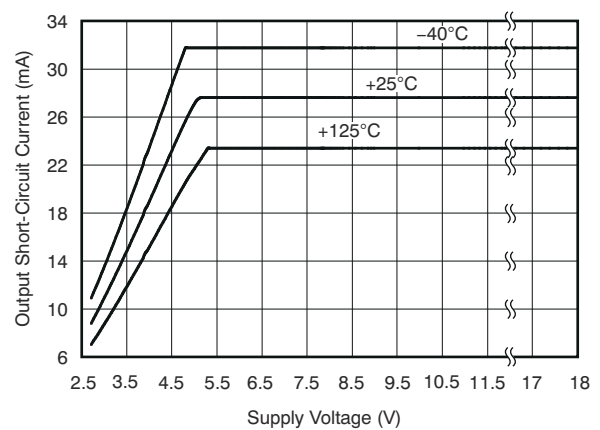
**Figure 6-8. Positive Output Voltage Swing vs. Output Current**



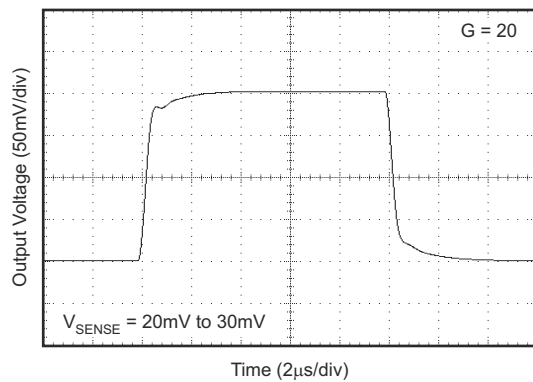
**Figure 6-9. Quiescent Current vs. Output Voltage**



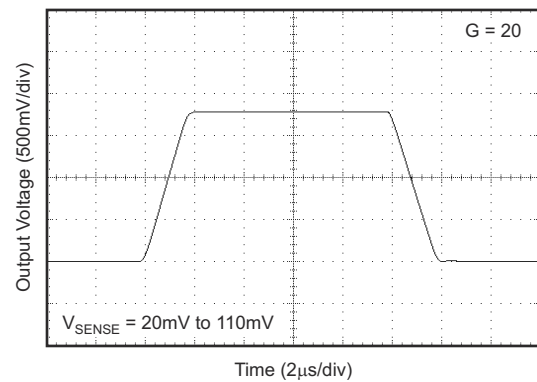
**Figure 6-10. Quiescent Current vs. Common-Mode Voltage**



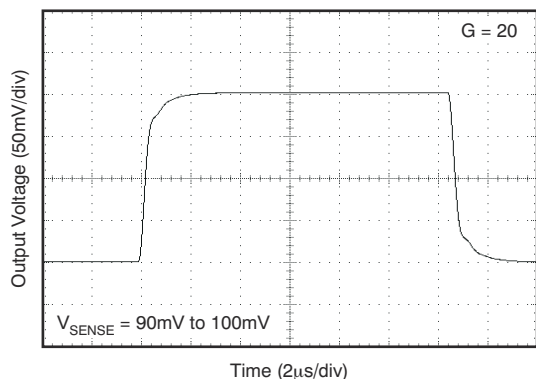
**Figure 6-11. Output Short-Circuit Current vs. Supply Voltage**



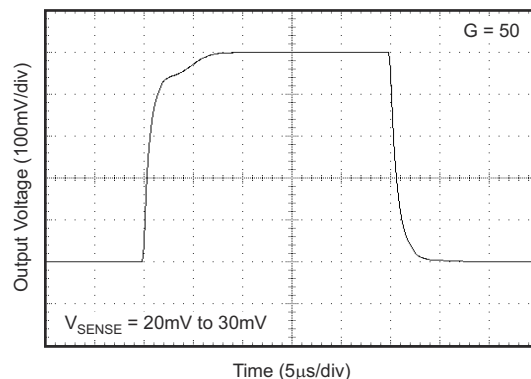
**Figure 6-12. Step Response**



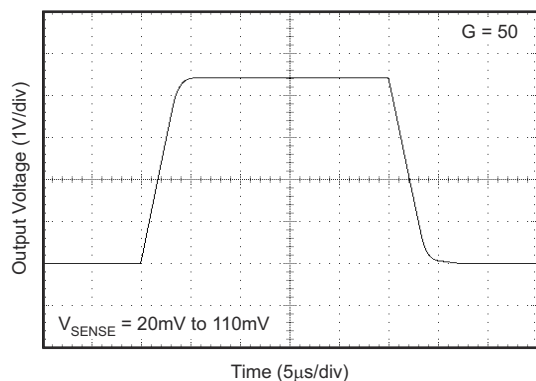
**Figure 6-13. Step Response**



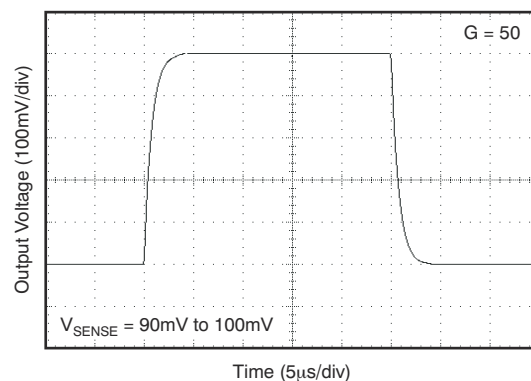
**Figure 6-14. Step Response**



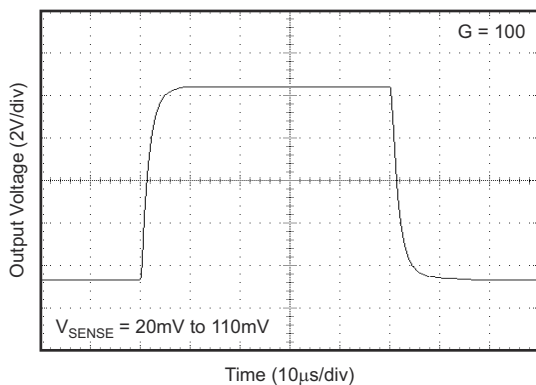
**Figure 6-15. Step Response**



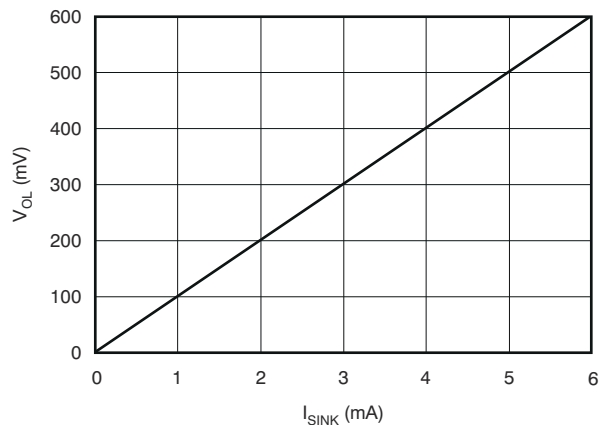
**Figure 6-16. Step Response**



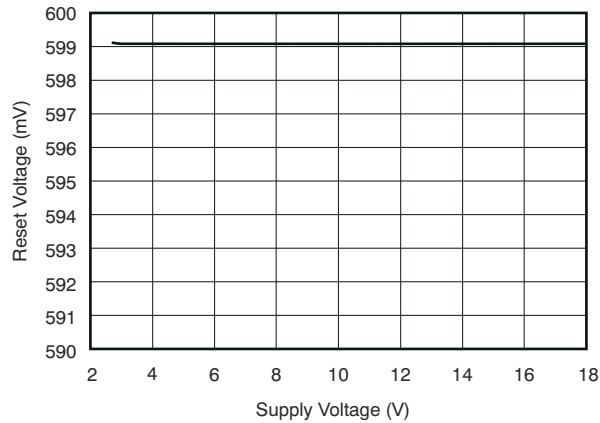
**Figure 6-17. Step Response**



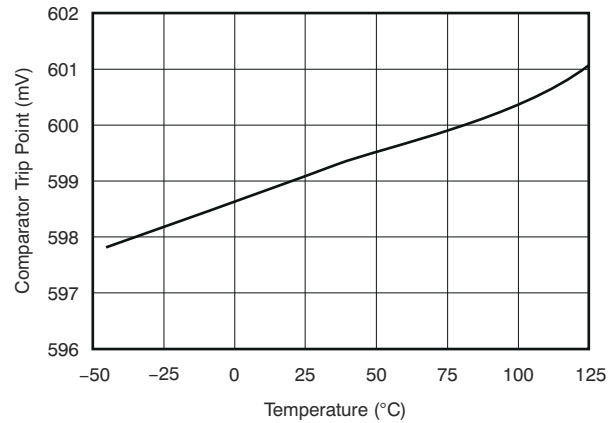
**Figure 6-18. Step Response**



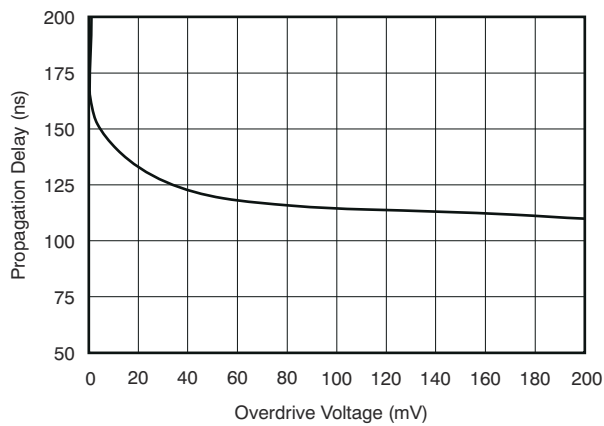
**Figure 6-19. Comparator  $V_{\text{OL}}$  vs.  $I_{\text{SINK}}$**



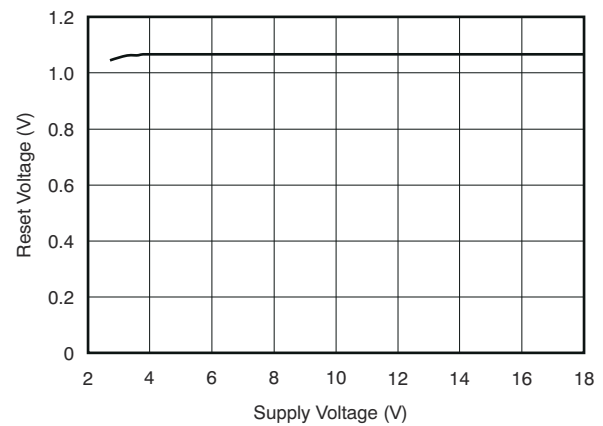
**Figure 6-20. Comparator Trip Point vs. Supply Voltage**



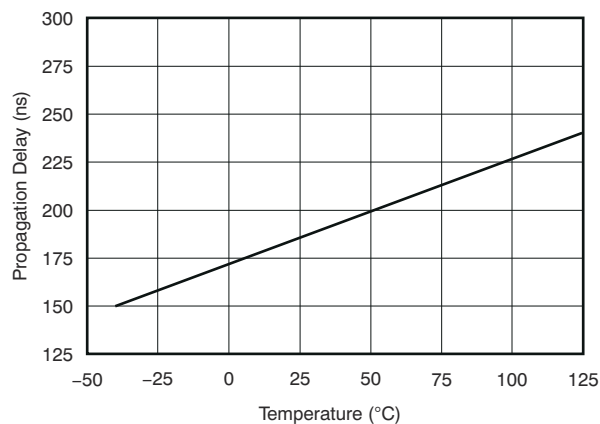
**Figure 6-21. Comparator Trip Point vs. Temperature**



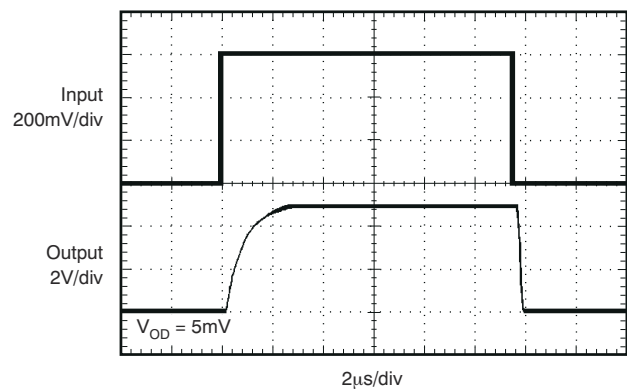
**Figure 6-22. Comparator 1 Propagation Delay vs. Overdrive Voltage**



**Figure 6-23. Comparator Reset Voltage vs. supply Voltage**



**Figure 6-24. Comparator Propagation Delay vs. Temperature**



**Figure 6-25. Comparator Propagation Delay**

## 7 Detailed Description

### 7.1 Overview

The INA203, INA204, and INA205 are a family of unidirectional current-shunt monitors with voltage output, dual comparators, and voltage reference. The INA203, INA204, and INA205 can sense drops across shunts at common-mode voltages from  $-16\text{ V}$  to  $80\text{ V}$ . The INA203, INA204, and INA205 are available with three output voltage scales:  $20\text{ V/V}$ ,  $50\text{ V/V}$ , and  $100\text{ V/V}$ , with up to  $500\text{-kHz}$  bandwidth. The INA203, INA204, and INA205 also incorporate two open-drain comparators with internal  $0.6\text{-V}$  references. On 14-pin versions, the comparator references can be overridden by external inputs. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay. 14-pin versions also provide a  $1.2\text{-V}$  reference output. The INA203, INA204, and INA205 operate from a single  $2.7\text{-V}$  to  $18\text{-V}$  supply. They are specified over the extended operating temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### 7.2 Functional Block Diagrams

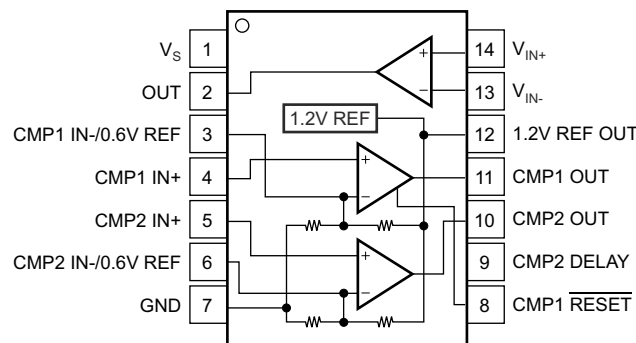


Figure 7-1. SO-14, TSSOP-14 Functional Block Diagram

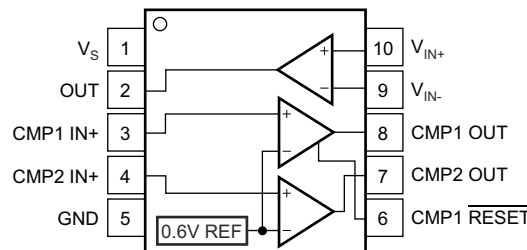


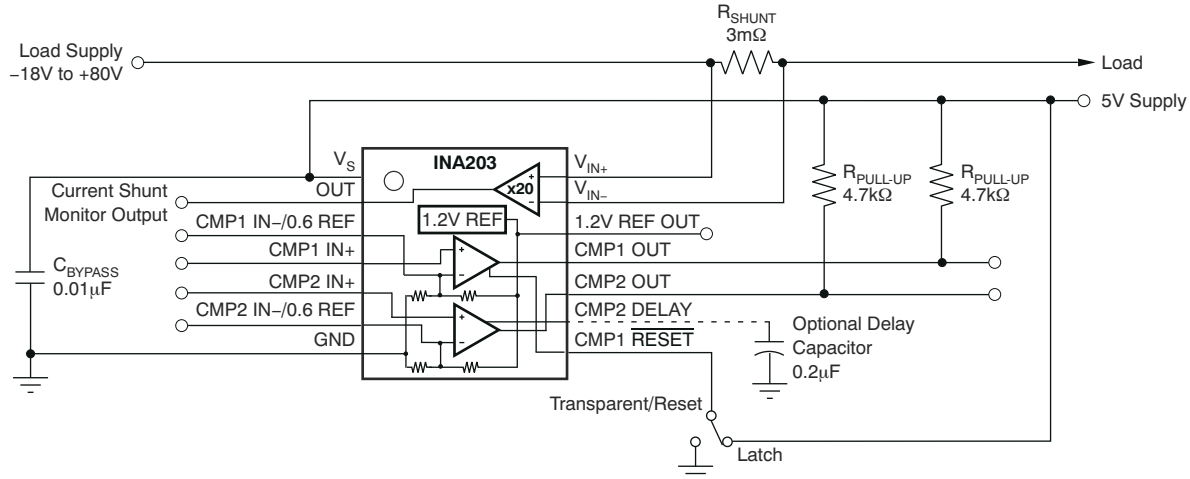
Figure 7-2. VSSOP-10 Functional Block Diagram

### 7.3 Feature Description

#### 7.3.1 Basic Connections

Figure 7-3 shows the basic connections of the INA203, INA204, and INA205. The input pins,  $V_{IN+}$  and  $V_{IN-}$ , should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

Power-supply bypass capacitors are required for stability. Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.



**Figure 7-3. INA20x Basic Connection**

### 7.3.2 Selecting $R_{SHUNT}$

The value chosen for the shunt resistor,  $R_{SHUNT}$ , depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of  $R_{SHUNT}$  provide better accuracy at lower currents by minimizing the effects of offset, while low values of  $R_{SHUNT}$  minimize voltage loss in the supply line. For most applications, best performance is attained with an  $R_{SHUNT}$  value that provides a full-scale shunt voltage range of 50 mV to 100 mV. Maximum input voltage for accurate measurements is  $(V_{OUT} - 0.25) / \text{Gain}$ .

### 7.3.3 Comparator

The INA203, INA204, and INA205 devices incorporate two open-drain comparators. These comparators typically have 2 mV of offset and a 1.3-μs (typical) response time. The output of Comparator 1 latches and is reset through the CMP1  $\overline{\text{RESET}}$  pin, as shown in Figure 7-5. This configuration applies to both the 10- and 14-pin versions. Figure 7-4 illustrates the comparator delay.

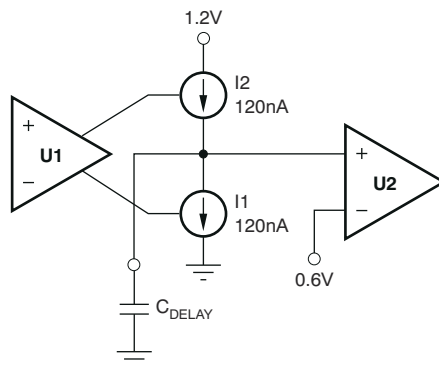
The 14-pin versions of the INA203, INA204, and INA205 devices include additional features for comparator functions. The comparator reference voltage of both Comparator 1 and Comparator 2 can be overridden by external inputs for increased design flexibility. Comparator 2 has a programmable delay.

### 7.3.4 Comparator Delay (14-Pin Version Only)

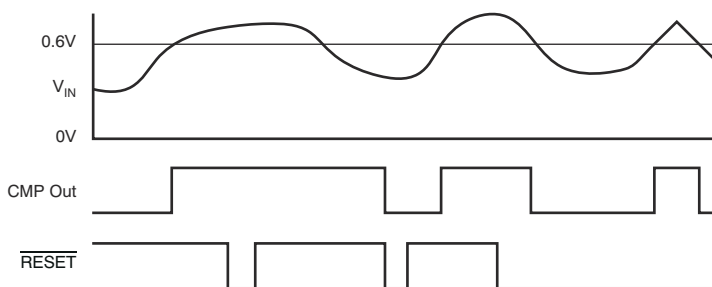
The Comparator 2 programmable delay is controlled by a capacitor connected to the CMP2 Delay Pin; see Figure 7-3. The capacitor value (in μF) is selected by using Equation 1:

$$C_{\text{DELAY}} (\text{in } \mu\text{F}) = \frac{t_D}{5} \quad (1)$$

A simplified version of the delay circuit for Comparator 2 is shown in Figure 7-4. The delay comparator consists of two comparator stages with the delay between them. I1 and I2 cannot be turned on simultaneously; I1 corresponds to a U1 low output and I2 corresponds to a U1 high output. Using an initial assumption that the U1 output is low, I1 is on, then U2 +IN is zero. If U1 goes high, I2 supplies 120 nA to  $C_{\text{DELAY}}$ . The voltage at U2 +IN begins to ramp toward a 0.6-V threshold. When the voltage crosses this threshold, the U2 output goes high while the voltage at U2 +IN continues to ramp up to a maximum of 1.2 V when given sufficient time (twice the value of the delay specified for  $C_{\text{DELAY}}$ ). This entire sequence is reversed when the comparator outputs go low, so that returning to low exhibits the same delay.



**Figure 7-4. Simplified Model of the Comparator 2 Delay Circuit**



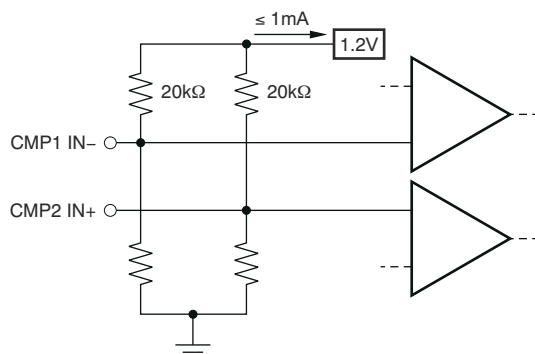
**Figure 7-5. Comparator Latching Capability**

Take care to note what will happen if events occur more rapidly than the delay timeout; for example, when the U1 output goes high (turning on I2), but returns low (turning I1 back on) prior to reaching the 0.6-V transition for U2. The voltage at U2 +IN ramps back down at a rate determined by the value of  $C_{DELAY}$ , and only returns to zero if given sufficient time.

In essence, when analyzing Comparator 2 for behavior with events more rapid than its delay setting, use the model shown in [Figure 7-4](#).

### 7.3.5 Comparator Maximum Input Voltage Range

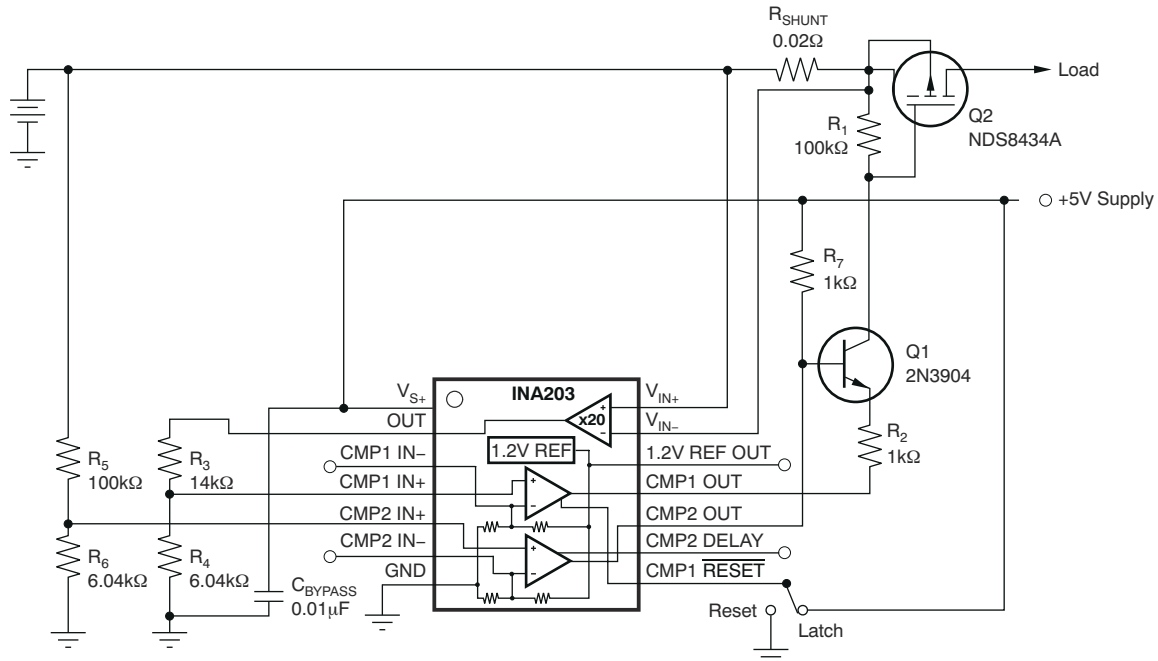
The maximum voltage at the comparator input for normal operation is up to  $(V_s) - 1.5$  V. There are special considerations when overdriving the reference inputs (pins 3 and 6). Driving either or both inputs high enough to drive 1 mA back into the reference introduces errors into the reference. [Figure 7-6](#) shows the basic input structure. A general guideline is to limit the voltage on both inputs to a total of 20 V. The exact limit depends on the available voltage and whether either or both inputs are subject to the large voltage. When making this determination, consider the 20 k $\Omega$  from each input back to the comparator. [Figure 7-7](#) shows the maximum input voltage that avoids creating a reference error when driving both inputs (an equivalent resistance back into the reference of 10 k $\Omega$ ).



**Figure 7-6. Limit Current Into Reference  $\leq 1$  mA**



### Figure 7-8. Polyswitch Warning and Fault Detection Circuit



### Figure 7-9. Lead-Acid Battery Protection Circuit

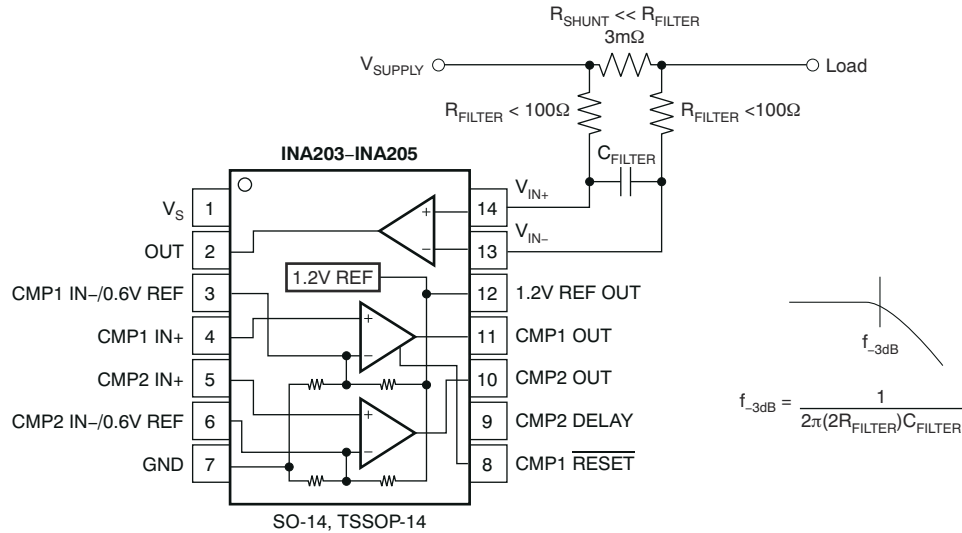
## 7.4 Device Functional Modes

### 7.4.1 Input Filtering

An obvious and straightforward location for filtering is at the output of the INA203, INA204, and INA205 series; however, this location negates the advantage of the low output impedance of the internal buffer. The only other option for filtering is at the input pins of the INA203, INA204, and INA205, which is complicated by the internal 5 k $\Omega$  + 30% input impedance; this configuration is illustrated in [Figure 7-10](#). Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. Use [Equation 2](#) to calculate the effect on initial gain.

$$\text{Gain Error \%} = 100 - \left[ 100 \times \frac{5\text{k}\Omega}{5\text{k}\Omega + R_{\text{FILT}}} \right] \quad (2)$$

Total effect on gain error can be calculated by replacing the 5-k $\Omega$  term with 5 k $\Omega$  – 30%, (or 3.5 k $\Omega$ ) or 5 k $\Omega$  + 30% (or 6.5 k $\Omega$ ). The tolerance extremes of R<sub>FILT</sub> can also be inserted into the equation. If a pair of 100  $\Omega$  1% resistors are used on the inputs, the initial gain error will be 1.96%. Worst-case tolerance conditions will always occur at the lower excursion of the internal 5-k $\Omega$  resistor (3.5 k $\Omega$ ), and the higher excursion of R<sub>FILT</sub> – 3% in this case.



**Figure 7-10. Input Filter (Gain Error: 1.5% to -2.2%)**

The specified accuracy of the INA203, INA204, and INA205 must then be combined in addition to these tolerances. While this discussion treated accuracy worst-case conditions by combining the extremes of the resistor values, it is appropriate to use geometric mean or root sum square calculations to total the effects of accuracy variations.

#### 7.4.2 Accuracy Variations as a Result Of $V_{SENSE}$ and Common-Mode Voltage

The accuracy of the INA203, INA204, and INA205 current shunt monitors is a function of two main variables:  $V_{SENSE}$  ( $V_{IN+} - V_{IN-}$ ) and common-mode voltage,  $V_{CM}$ , relative to the supply voltage,  $V_S$ .  $V_{CM}$  is expressed as  $(V_{IN+} + V_{IN-}) / 2$ ; however, in practice,  $V_{CM}$  is seen as the voltage at  $V_{IN+}$  because the voltage drop across  $V_{SENSE}$  is usually small.

This section addresses the accuracy of these specific operating regions:

- Normal Case 1:  $V_{SENSE} \geq 20$  mV,  $V_{CM} \geq V_S$
- Normal Case 2:  $V_{SENSE} \geq 20$  mV,  $V_{CM} < V_S$
- Low  $V_{SENSE}$  Case 1:  $V_{SENSE} < 20$  mV,  $-16$  V  $\leq V_{CM} < 0$
- Low  $V_{SENSE}$  Case 2:  $V_{SENSE} < 20$  mV,  $0$  V  $\leq V_{CM} \leq V_S$
- Low  $V_{SENSE}$  Case 3:  $V_{SENSE} < 20$  mV,  $V_S < V_{CM} \leq 80$  V

##### 7.4.2.1 Normal Case 1: $V_{SENSE} \geq 20$ mV, $V_{CM} \geq V_S$

This region of operation provides the highest accuracy. Here, the input offset voltage is characterized and measured using a two-step method. First, the gain is determined by Equation 3.

$$G = \frac{V_{OUT1} - V_{OUT2}}{100\text{mV} - 20\text{mV}} \quad (3)$$

where

- $V_{OUT1}$  = Output Voltage with  $V_{SENSE} = 100$  mV.
- $V_{OUT2}$  = Output Voltage with  $V_{SENSE} = 20$  mV.

Then the offset voltage is measured at  $V_{SENSE} = 100$  mV and referred to the input (RTI) of the current shunt monitor, as shown in Equation 4.

$$V_{OS\text{RTI}} (\text{Referred-To-Input}) = \left[ \frac{V_{OUT1}}{G} \right] - 100\text{mV} \quad (4)$$

In the [Typical Characteristics](#), [Total Output Error vs. Common-Mode Voltage](#) shows the highest accuracy for this region of operation. In this plot,  $V_S = 12\text{ V}$ ; for  $V_{CM} \geq 12\text{ V}$ , the output error is at its minimum. This case is also used to create the  $V_{SENSE} \geq 20\text{-mV}$  output specifications in the [Electrical Characteristics: Current-Shunt Monitor](#) table.

#### 7.4.2.2 Normal Case 2: $V_{SENSE} \geq 20\text{ mV}$ , $V_{CM} < V_S$

This region of operation has slightly less accuracy than Normal Case 1 as a result of the common-mode operating area in which the part functions, as seen in [Total Output Error vs. Common-Mode Voltage](#). As noted, for this graph  $V_S = 12\text{ V}$ ; for  $V_{CM} < 12\text{ V}$ , the Output Error increases as  $V_{CM}$  becomes less than  $12\text{ V}$ , with a typical maximum error of  $0.005\%$  at the most negative  $V_{CM} = -16\text{ V}$ .

#### 7.4.2.3 Low $V_{SENSE}$ Case 1

- $V_{SENSE} < 20\text{ mV}$ ,  $-16\text{ V} \leq V_{CM} < 0$ ;
- Low  $V_{SENSE}$  Case 3:
- $V_{SENSE} < 20\text{ mV}$ ,  $V_S < V_{CM} \leq 80\text{ V}$

Although the INA203 family of devices are not designed for accurate operation in either of these regions, some applications are exposed to these conditions; for example, when monitoring power supplies that are switched on and off while  $V_S$  is still applied to the INA203, INA204, or INA205. Take care to know what the behavior of the devices will be in these regions.

As  $V_{SENSE}$  approaches  $0\text{ mV}$ , in these  $V_{CM}$  regions, the device output accuracy degrades. A larger-than-normal offset can appear at the current shunt monitor output with a typical maximum value of  $V_{OUT} = 300\text{ mV}$  for  $V_{SENSE} = 0\text{ mV}$ . As  $V_{SENSE}$  approaches  $20\text{ mV}$ ,  $V_{OUT}$  returns to the expected output value with accuracy as specified in the [Electrical Characteristics: Current-Shunt Monitor](#). Figure 7-11 illustrates this effect using the INA205 (Gain = 100).

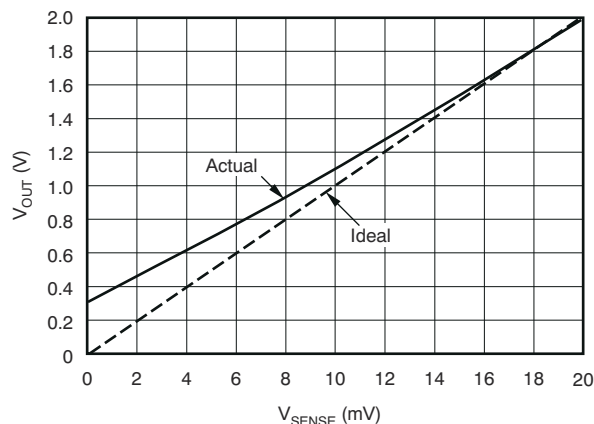
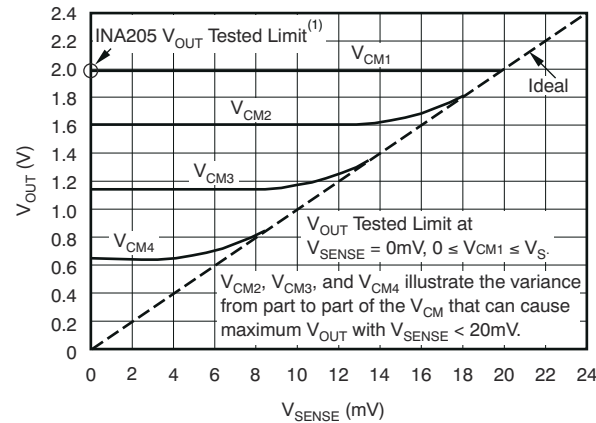


Figure 7-11. Example for Low  $V_{SENSE}$  Cases 1 and 3 (INA205, Gain = 100)

#### 7.4.2.4 Low $V_{SENSE}$ Case 2: $V_{SENSE} < 20\text{ mV}$ , $0\text{ V} \leq V_{CM} \leq V_S$

This region of operation is the least accurate for the INA203 family. To achieve the wide input common-mode voltage range, these devices use two op amp front ends in parallel. One operational amplifier front end operates in the positive input common-mode voltage range, and the other in the negative input region. For this case, neither of these two internal amplifiers dominates and overall loop gain is very low. Within this region,  $V_{OUT}$  approaches voltages close to linear operation levels for Normal Case 2. This deviation from linear operation becomes greatest the closer  $V_{SENSE}$  approaches  $0\text{ V}$ . Within this region, as  $V_{SENSE}$  approaches  $20\text{ mV}$ , device operation is closer to that described by Normal Case 2. Figure 7-12 illustrates this behavior for the INA205. The  $V_{OUT}$  maximum peak for this case is tested by maintaining a constant  $V_S$ , setting  $V_{SENSE} = 0\text{ mV}$ , and sweeping  $V_{CM}$  from  $0\text{ V}$  to  $V_S$ . The exact  $V_{CM}$  at which  $V_{OUT}$  peaks during this test varies from part to part, but the  $V_{OUT}$  maximum peak is tested to be less than the specified  $V_{OUT}$  Tested Limit.



NOTE: (1) INA203  $V_{OUT}$  Tested Limit = 0.4V. INA204  $V_{OUT}$  Tested Limit = 1V.

**Figure 7-12. Example For Low  $V_{SENSE}$  Case 2 (INA205, Gain = 100)**

### 7.4.3 Transient Protection

The  $-16\text{ V}$  to  $80\text{ V}$  common-mode range of the INA203, INA204, and INA205 is ideal for withstanding automotive fault conditions ranging from 12-V battery reversal up to 80-V transients, since no additional protective components are needed up to those levels. In the event that the INA203, INA204, and INA205 are exposed to transients on the inputs in excess of their ratings, then external transient absorption with semiconductor transient absorbers (Zeners or *Transzorbs*) are necessary. Use of metal oxide varistors (MOVs) or video disk recorders (VDRs) is not recommended except when they are used in addition to a semiconductor transient absorber. Select the transient absorber such that it will never allow the INA203, INA204, and INA205 to be exposed to transients greater than 80 V (that is, allow for transient absorber tolerance, as well as additional voltage because of transient absorber dynamic impedance). Despite the use of internal Zener-type ESD protection, the INA203, INA204, and INA205 do not lend themselves to using external resistors in series with the inputs because the internal gain resistors can vary up to  $\pm 30\%$  but are closely matched. (If gain accuracy is not important, then resistors can be added in series with the INA203, INA204, and INA205 inputs with two equal resistors on each input.)

### 7.4.4 Output Voltage Range

The output of the INA203, INA204, and INA205 is accurate within the output voltage swing range set by the power-supply pin,  $V_S$ . This performance is best illustrated when using the INA205 (a gain of 100 version), where a 100-mV full-scale input from the shunt resistor requires an output voltage swing of 10 V, and a power-supply voltage sufficient to achieve 10 V on the output.

### 7.4.5 Reference

The INA203, INA204, and INA205 include an internal voltage reference that has a load regulation of 0.4 mV/mA (typical), and not more than 100 ppm/ $^{\circ}\text{C}$  of drift. Only the 14-pin package allows external access to reference voltages, where voltages of 1.2 V and 0.6 V are both available. Output current versus output voltage is illustrated in the [Typical Characteristics](#) section.

## 8 Application and Implementation

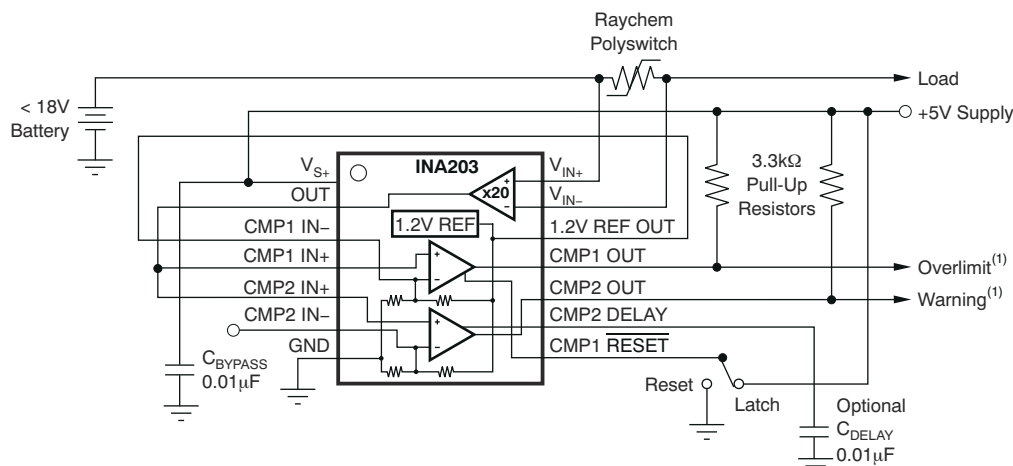
### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

The INA203, INA204, and INA205 series is designed to enable easy configuration for detecting overcurrent conditions and current monitoring in an application. This device is also incorporate two open-drain comparators with internal 0.6-V references. On 14-pin versions, the comparator references can be overridden by external inputs. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay. 14-pin versions also provide a 1.2-V reference output. This device can also be paired with minimum additional devices to create more sophisticated monitoring functional blocks.

### 8.2 Typical Application



NOTE: (1) Warning at half current (with optional delay). Overlimit latches when Polyswitch opens.

**Figure 8-1. Polyswitch Warning and Fault Detection Circuit**

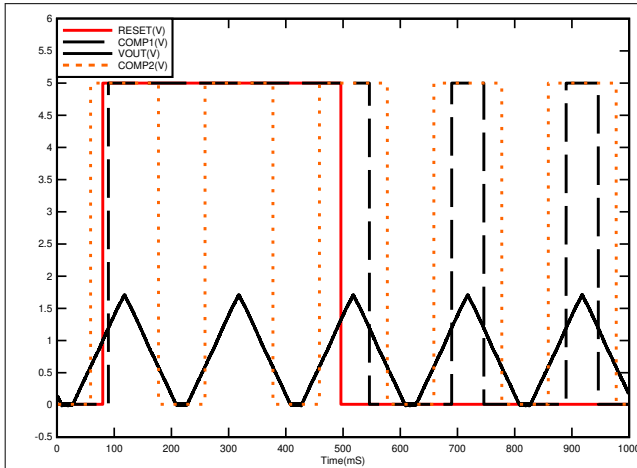
#### 8.2.1 Design Requirements

The device measures current through a resistive shunt with current flowing in one direction, thus enabling detection of an overlimit or warning event only when the differential input voltage exceeds the corresponding threshold limits. When the current reaches the warning limit of 0.6 V, the output of CMP2 will transition high indicating a warning condition. When the current further increases to or past the overlimit limit of 1.2 V, the output of CMP1 will transition high indicating an overlimit condition. Optional  $C_{DELAY}$  can be sized to add delay to CMP1.

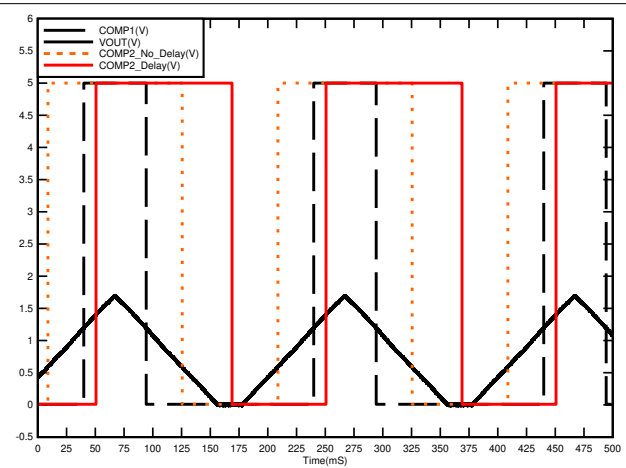
#### 8.2.2 Detailed Design Procedure

Figure 8-1 shows the basic connections of the device. The input terminals, IN+ and IN–, should be connected as closely as possible to the current-sensing resistor or polymeric switch to minimize any resistance in series with the shunt resistance. Additional resistance between the current-sensing resistor and input terminals can result in errors in the measurement. When input current flows through this external input resistance, the voltage developed across the shunt resistor can differ from the voltage reaching the input terminals.

### 8.2.3 Application Curves



**Figure 8-2. Polyswitch Warning and Fault Detection Circuit Response**



**Figure 8-3. Polyswitch Warning and Fault Detection Circuit With Delay Response**

## 9 Power Supply Recommendations

The input circuitry of the INA203, INA204, and INA205 can accurately measure beyond the power-supply voltage,  $V_S$ . For example, the  $V_S$  power supply can be 5 V, whereas the load power-supply voltage is up to 80 V. The output voltage range of the OUT terminal, however, is limited by the voltages on the power-supply pin.

## 10 Layout

### 10.1 Layout Guidelines

- Connect the input pins to the sensing resistor using a Kelvin or 4-wire connection. This connection technique ensures that only the current-sensing resistor impedance is detected between the input pins. Poor routing of the current-sensing resistor commonly results in additional resistance present between the input pins. Given the very low ohmic value of the current resistor, any additional high-current carrying impedance can cause significant measurement errors.
- The power-supply bypass capacitor should be placed as closely as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1  $\mu\text{F}$ . Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

### 10.2 Layout Example

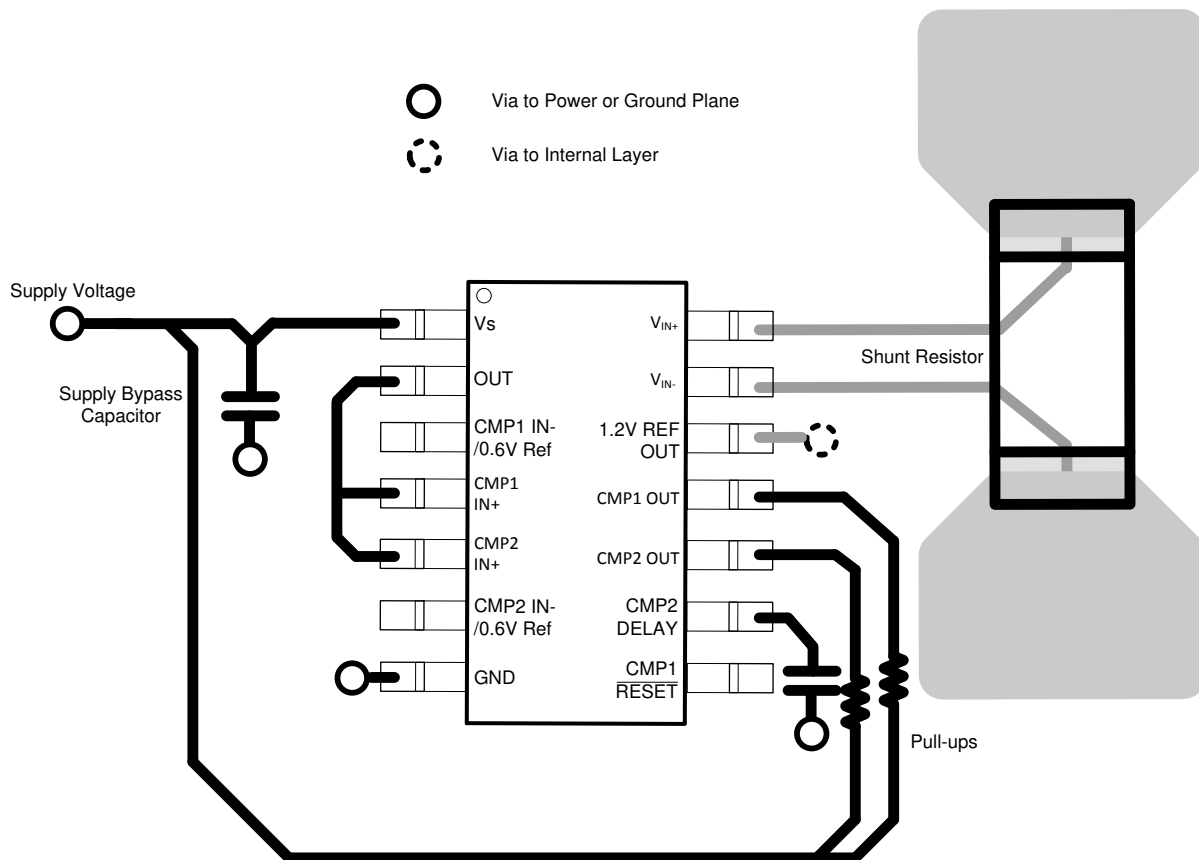


Figure 10-1. Layout Recommendation

## 11 Device and Documentation Support

### 11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 11-1. Related Links**

| PARTS  | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|--------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| INA203 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| INA204 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| INA205 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 11.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 11.5 Electrostatic Discharge Caution



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.

### 11.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">INA203AID</a>    | Obsolete      | Production           | SOIC (D)   14    | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | INA203A             |
| <a href="#">INA203AIDGSR</a> | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | NIPDAU   NIPDAUAG                    | Level-2-260C-1 YEAR               | -40 to 125   | BQN                 |
| INA203AIDGSR.A               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | BQN                 |
| INA203AIDGSR.B               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | BQN                 |
| <a href="#">INA203AIDGST</a> | Obsolete      | Production           | VSSOP (DGS)   10 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | BQN                 |
| <a href="#">INA203AIDR</a>   | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| INA203AIDR.A                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| INA203AIDR.B                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| <a href="#">INA203AIPW</a>   | Obsolete      | Production           | TSSOP (PW)   14  | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | INA203A             |
| <a href="#">INA203AIPWR</a>  | Active        | Production           | TSSOP (PW)   14  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| INA203AIPWR.A                | Active        | Production           | TSSOP (PW)   14  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| INA203AIPWR.B                | Active        | Production           | TSSOP (PW)   14  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA203A             |
| <a href="#">INA204AID</a>    | Obsolete      | Production           | SOIC (D)   14    | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | INA204A             |
| <a href="#">INA204AIDGSR</a> | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI   Nipdauag                   | Level-2-260C-1 YEAR               | -40 to 125   | BQO                 |
| INA204AIDGSR.A               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI                              | Level-2-260C-1 YEAR               | -40 to 125   | BQO                 |
| INA204AIDGSR.B               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI                              | Level-2-260C-1 YEAR               | -40 to 125   | BQO                 |
| <a href="#">INA204AIDGST</a> | Obsolete      | Production           | VSSOP (DGS)   10 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | BQO                 |
| <a href="#">INA204AIDR</a>   | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA204A             |
| INA204AIDR.A                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA204A             |
| INA204AIDR.B                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA204A             |
| <a href="#">INA205AID</a>    | Last Time Buy | Production           | SOIC (D)   14    | 50   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| <a href="#">INA205AIDGSR</a> | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI   Nipdauag                   | Level-2-260C-1 YEAR               | -40 to 125   | BQP                 |
| INA205AIDGSR.A               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI                              | Level-2-260C-1 YEAR               | -40 to 125   | BQP                 |
| INA205AIDGSR.B               | Active        | Production           | VSSOP (DGS)   10 | 2500   LARGE T&R      | Yes         | Call TI                              | Level-2-260C-1 YEAR               | -40 to 125   | BQP                 |
| <a href="#">INA205AIDR</a>   | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| INA205AIDR.A                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| INA205AIDR.B                 | Active        | Production           | SOIC (D)   14    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| <a href="#">INA205AIPW</a>   | Obsolete      | Production           | TSSOP (PW)   14  | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | INA205A             |

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">INA205AIPWR</a> | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| INA205AIPWR.A               | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |
| INA205AIPWR.B               | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | INA205A             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **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.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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.

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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.

## OTHER QUALIFIED VERSIONS OF INA203 :

- Automotive : [INA203-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION



\*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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| INA203AIDGSR | VSSOP        | DGS             | 10   | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| INA203AIDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| INA203AIPWR  | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| INA204AIDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| INA205AIDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| INA205AIPWR  | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

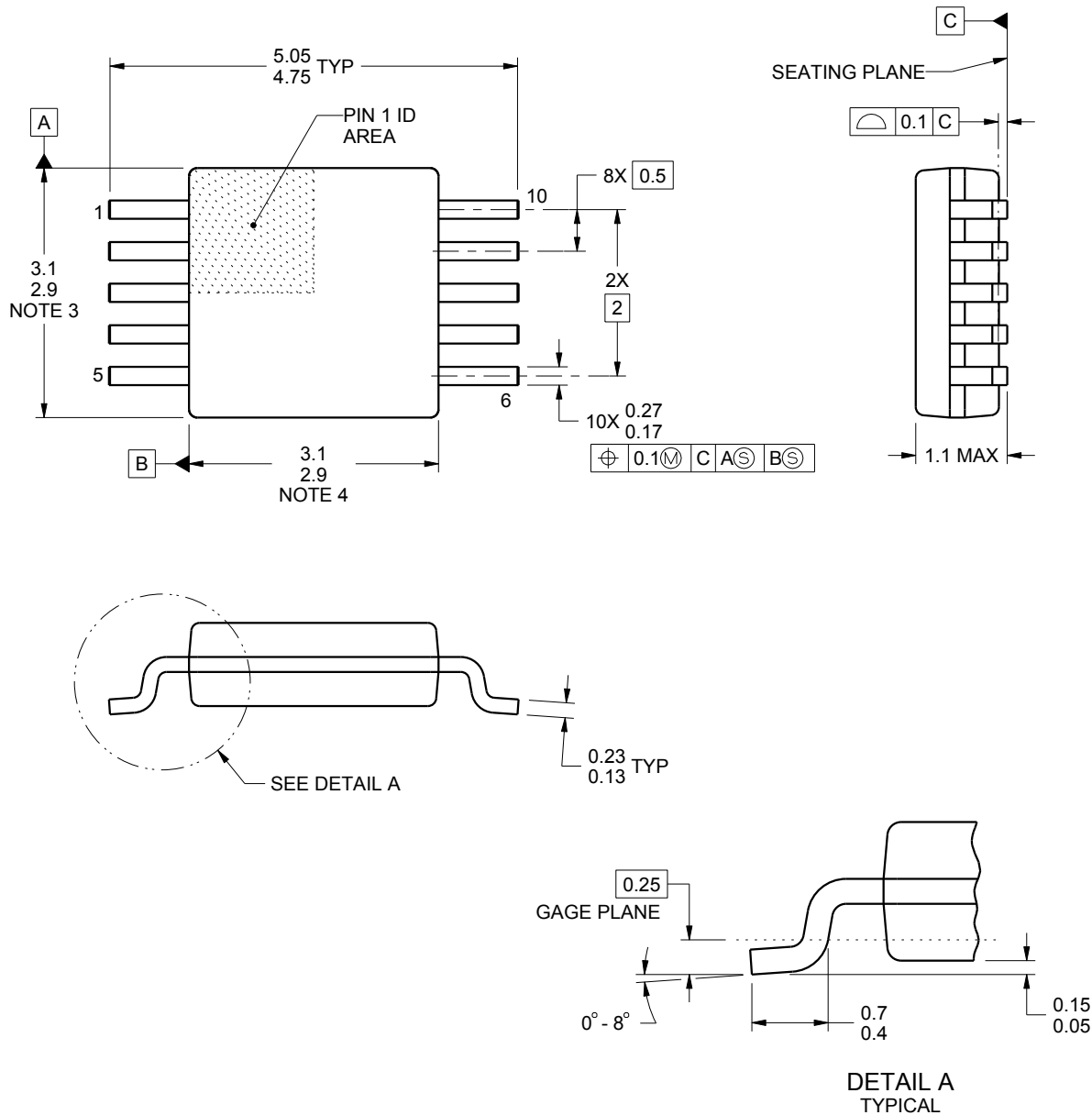
| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| INA203AIDGSR | VSSOP        | DGS             | 10   | 2500 | 353.0       | 353.0      | 32.0        |
| INA203AIDR   | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| INA203AIPWR  | TSSOP        | PW              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| INA204AIDR   | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| INA205AIDR   | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| INA205AIPWR  | TSSOP        | PW              | 14   | 2000 | 353.0       | 353.0      | 32.0        |

## TUBE



\*All dimensions are nominal

| Device    | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------|--------------|--------------|------|-----|--------|--------|--------|--------|
| INA205AID | D            | SOIC         | 14   | 50  | 506.6  | 8      | 3940   | 4.32   |



4221984/A 05/2015

## NOTES:

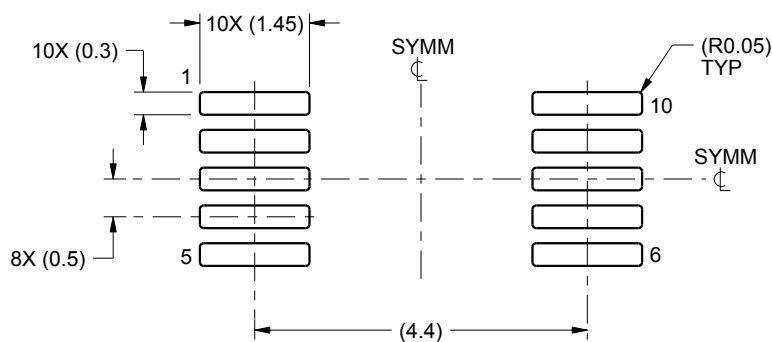
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187, variation BA.

# EXAMPLE BOARD LAYOUT

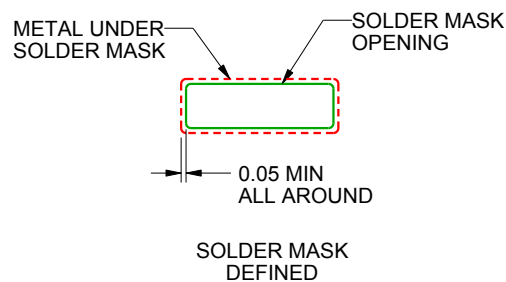
DGS0010A

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:10X



SOLDER MASK DETAILS  
NOT TO SCALE

4221984/A 05/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

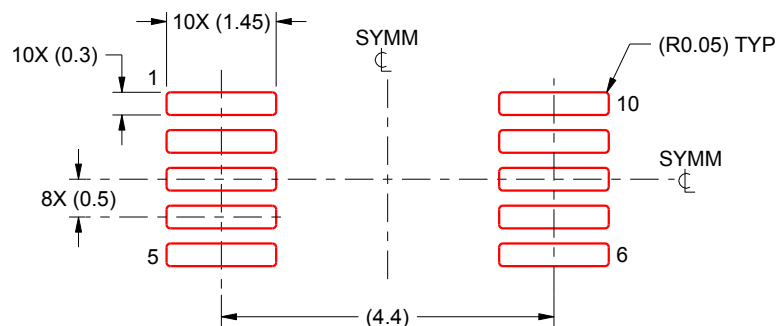
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DGS0010A

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:10X

4221984/A 05/2015

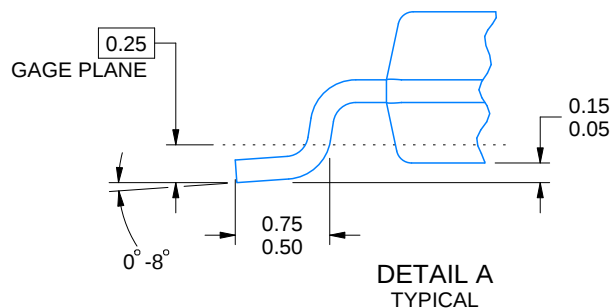
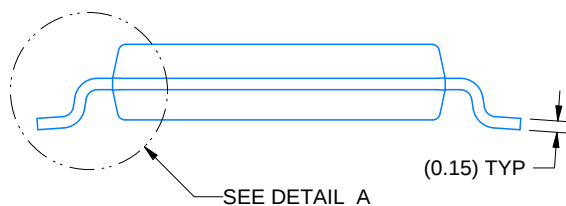
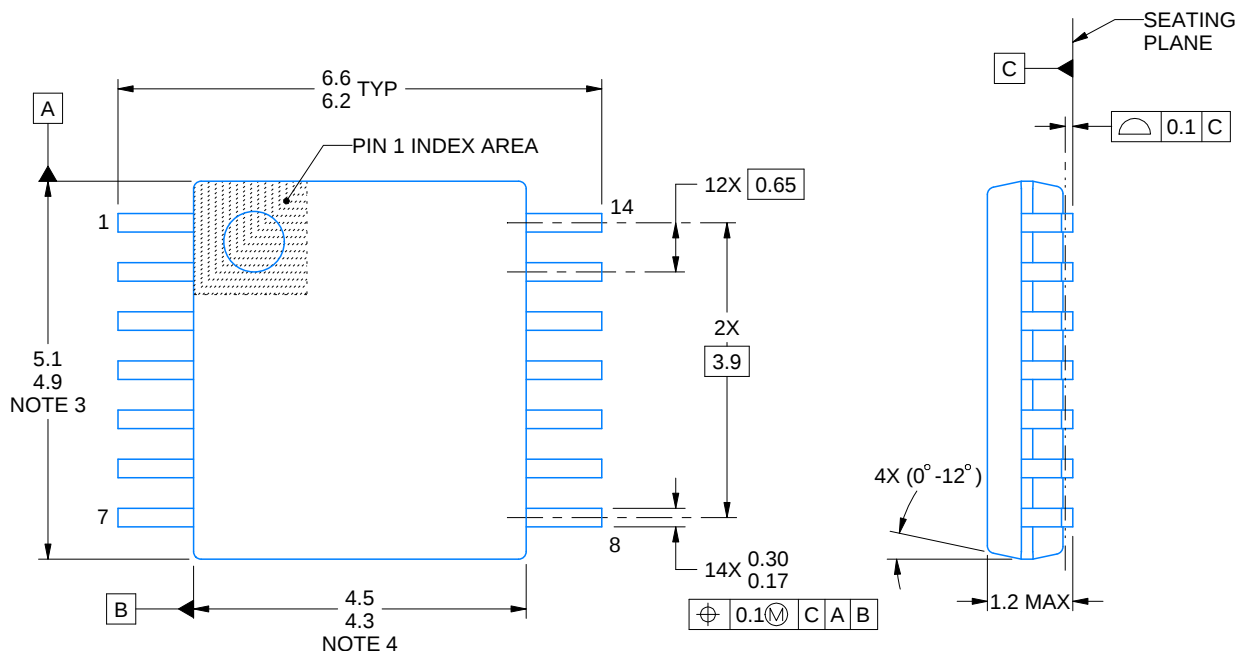
NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.



## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4220202/B 12/2023

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 dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

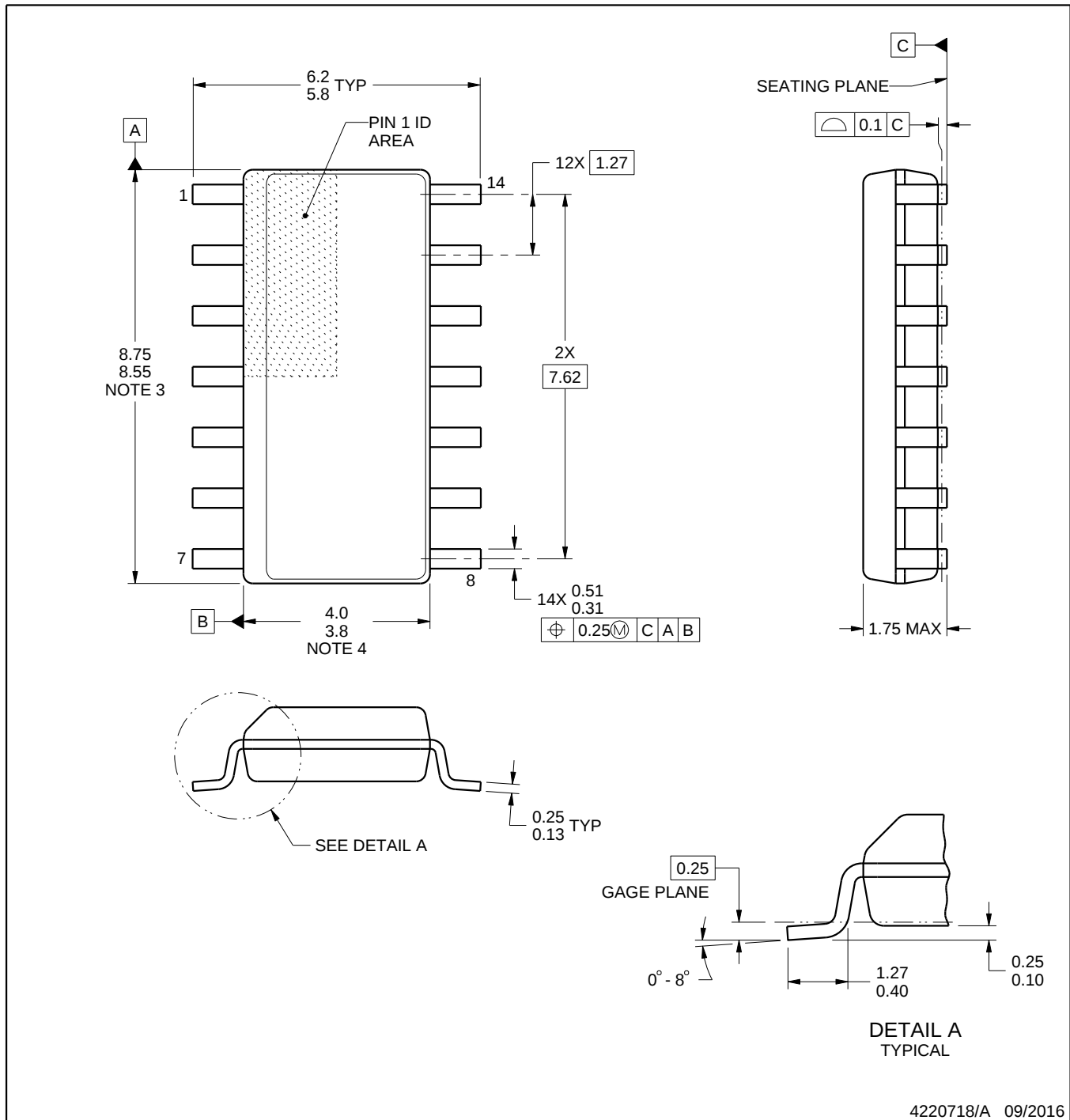
4220202/B 12/2023

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

**D0014A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



# EXAMPLE BOARD LAYOUT

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
SCALE:8X



SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:8X

4220718/A 09/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated