# INA253 2mΩの高精度低誘導性シャント抵抗を搭載した 高電圧、双方向、ゼロ・ドリフトの電流シャント・モニタ

## 1 特長

- **高精度のシャント抵抗を内蔵**
  - シャント抵抗: 2mΩ
  - シャント・インダクタンス: 3nH
  - シャント抵抗の公差: 0.1% (最大値)
  - -40°C～+85°Cで±15Aの連続電流
  - 0°C～125°Cの温度ドリフト係数: 10ppm/°C
- **高帯域幅**: 350kHz
- **強化されたPWM除去**
- **非常に優れたCMRR**
  - 120dBを超えるDC CMRR
  - 50kHzにおいて90dBのAC CMRR
- **精度**
  - ゲイン
    - ゲイン誤差:0.4%(最大値)
    - ゲイン・ドリフト係数: 45ppm/℃ (最大値)
  - オフセット
    - オフセット電流:±15mA(最大値)
    - オフセット・ドリフト係数:125µA/°C(最大値)
- **広い同相電圧範囲**: -4V～+80V
- **利用可能なゲイン**: 100mV/A、200mV/A、400mV/A
- **静止電流**：2.4mA（最大値）

## 2 アプリケーション

- ソレノイドおよびバルブの制御
- トランスミッション制御
- モータ制御
- アクチュエータ制御
- DC/DCコンバータ
- リモートI/Oリンク制御

## 3 概要

INA253は電圧出力、電流検出アンプで、2mΩのシャント抵抗が内蔵されています。INA253は、電源電圧にかかわらず、-4V～+80Vの広い同相電圧範囲で双方向の電流を監視するよう設計されています。

100mV/A、200mV/A、400mV/Aの3つの固定ゲインを選択可能です。高精度の抵抗とゼロ・ドリフトのチョップ・アンプが内蔵されているため、較正と等価の測定精度、15ppm/°Cという非常に低い温度ドリフト係数、センシング抵抗について最適化されたケルビン・レイアウトが実現されています。

INA253の設計には強化されたPWM除去回路が組み込まれており、大きな(dv/dt)信号を抑制し、リアルタイムで連続的な電流測定が可能です。この測定機能は、モータ・ドライブ・アプリケーションにおけるインラインの電流測定や、ソレノイドのバルブ制御アプリケーションなどに不可欠なものです。

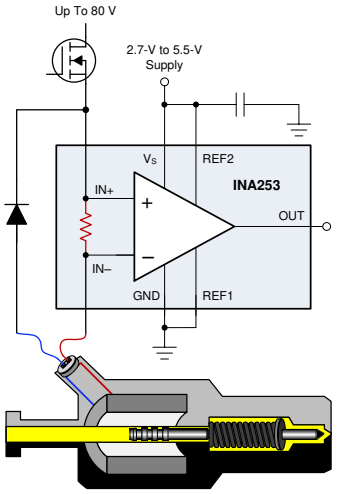
このデバイスは2.7V～5.5Vの単電源で動作し、消費電流は最大3mAです。どのゲインのバージョンも、拡張動作温度範囲(-40°C～+125°C)で動作が規定され、20ピンのTSSOPパッケージで供給されます。

**製品情報(1)**

| 型番 | パッケージ | 本体サイズ(公称) |
|---|---|---|
| INA253 | TSSOP (20) | 6.50mm×4.40mm |

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にあるパッケージ・オプションについての付録を参照してください。

**代表的なアプリケーション**

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## 4 改訂履歴

**2018年7月** 発行のものから更新 **Page**

- デバイスのステータスを「事前情報」から「量産データ」(アクティブ)に 変更 ... 1


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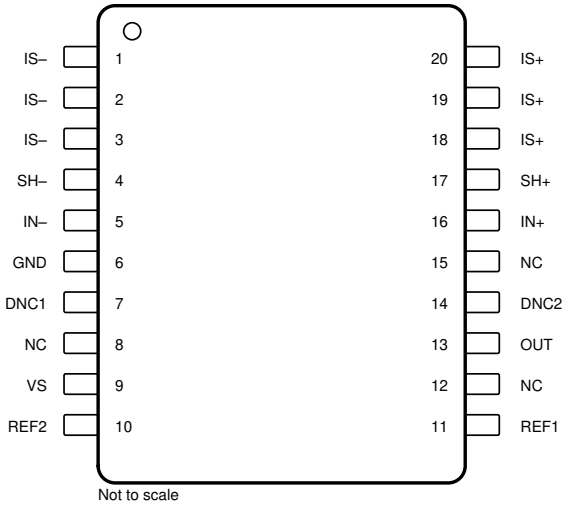
# 5 Device Comparison Table

| PRODUCT | GAIN (mV/A) |
|---|---|
| INA253A1 | 100 |
| INA253A2 | 200 |
| INA253A3 | 400 |

# 6 Pin Configuration and Functions

**PW Package**
**20-Pin TSSOP**
**Top View**




Not to scale

**Pin Functions**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NO. | NAME | | |
| 1 | IS– | Analog input | Connect to load |
| 2 | IS– | Analog input | Connect to load |
| 3 | IS– | Analog input | Connect to load |
| 4 | SH– | Analog output | Kelvin connection to internal shunt. Connect to IN– if no filtering is needed |
| 5 | IN– | Analog input | Voltage input from load side of shunt resistor |
| 6 | GND | — | Ground |
| 7 | DNC1 | — | Do not connect this pin to any potential; leave this pin floating. |
| 8 | NC | — | No connect |
| 9 | VS | Analog | Power supply, 2.7 V to 5.5 V |
| 10 | REF2 | Analog input | Reference voltage 2, 0 V to VS |
| 11 | REF1 | Analog input | Reference voltage 1, 0 V to VS |
| 12 | NC | — | No connect |
| 13 | OUT | Analog | Output voltage |
| 14 | DNC2 | — | Do not connect this pin to any potential; leave this pin floating. |
| 15 | NC | Analog | Reserved; connect this pin to ground |
| 16 | IN+ | Analog input | Voltage input from supply side of shunt resistor |
| 17 | SH+ | Analog output | Kelvin connection to internal shunt. Connect to IN+ if no filtering is needed |
| 18 | IS+ | Analog input | Connect to supply |
| 19 | IS+ | Analog input | Connect to supply |
| 20 | IS+ | Analog input | Connect to supply |

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# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Supply voltage | | | 6 | V |
| Shunt input current ($I_{SENSE}$) | Continuous | | ±15 | A |
| Analog inputs (IS+, IS–) | Common-mode | GND – 6 | 90 | V |
| Analog inputs ($V_{IN+}$,$V_{IN–}$) | Differential ($V_{IN+}$) – ($V_{IN–}$) | –80 | 80 | V |
| | Common-mode | GND – 6 | 90 | |
| Analog inputs (REF1, REF2, NC) | | GND – 0.3 | $V_S$ + 0.3 | V |
| Analog outputs (SH+, SH–) | Common-mode | GND – 6 | 90 | V |
| Analog output (OUT) | | GND – 0.3 | $V_S$ + 0.3 | V |
| Temperature | Operating, $T_A$ | –55 | 150 | °C |
| | Junction, $T_J$ | | 150 | |
| | Storage, $T_{stg}$ | –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.

## 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±2000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | ±1000 | |

(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.

## 7.3 Recommended Operating Conditions

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

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CM}$ | Common-mode input voltage | –4 | | 80 | V |
| $V_S$ | Operating supply voltage | 2.7 | | 5.5 | V |
| $T_A$ | Operating free-air temperature | –40 | | 125 | ℃ |

## 7.4 Thermal Information

| THERMAL METRIC(1) | | INA253 PW (TSSOP) 20 PINS | UNIT |
|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 110.6 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 54.1 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 87.5 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 114.1 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 87.5 | °C/W |

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


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## 7.5 Electrical Characteristics

at $T_A$ = 25 °C, $V_S$ = 5 V, $I_{SENSE}$ = IS+ = 0 A, $V_{CM}$ = 12 V, and $V_{REF1}$ = $V_{REF2}$ = $V_S$ / 2 (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **INPUT** | | | | | | |
| $V_{CM}$ | Common-mode input range | $V_{IN+}$ = –4 V to +80 V, $I_{SENSE}$ = 0 A, $T_A$ = –40°C to +125°C | –4 | | 80 | V |
| CMR | Common-mode rejection | $V_{IN+}$ = –4 V to +80 V, $I_{SENSE}$ = 0 A, $T_A$ = –40°C to +125°C | | ±125 | ±500 | µA/V |
| | | f = 50 kHz | | ±13 | | mA/V |
| $I_{OS}$ | Offset current, input-referred | $I_{SENSE}$ = 0 A | | ±2.5 | ±15 | mA |
| $dI_{OS}/dT$ | Offset current drift | $I_{SENSE}$ = 0 A, $T_A$ = –40°C to +125°C | | 25 | 125 | µA/°C |
| PSRR | Power-supply rejection ratio | $V_S$ = 2.7 V to 5.5 V, $I_{SENSE}$ = 0 A | | ±0.5 | ±5 | mA/V |
| $I_B$ | Input bias current | $I_{B+}$, $I_{B–}$, $I_{SENSE}$ = 0 A | | 90 | | µA |
| | Reference input range | | 0 | | $V_S$ | V |
| **SHUNT RESISTOR** | | | | | | |
| $R_{SHUNT}$ | Shunt resistance (SH+ to SH–) | Equivalent resistance when used with onboard amplifier | 1.998 | 2 | 2.002 | mΩ |
| | | Used as stand-alone resistor(1) | 1.9 | 2 | 2.1 | |
| | Package resistance | IS+ to IS– | | 4.5 | | mΩ |
| | Package inductance | IS+ to IS– | | 3 | | nH |
| | Resistor temperature coefficient | $T_A$ = –40°C to +125°C | | 15 | | ppm/°C |
| | | $T_A$ = –40°C to 0°C | | 50 | | |
| | | $T_A$ = 0°C to 125°C | | 10 | | ppm/°C |
| $I_{SENSE}$ | Maximum continuous current(2) | $T_A$ = –40°C to +85°C | | | ±15 | A |
| | Shunt short time overload | $I_{SENSE}$ = 30 A for 5 seconds | | ±0.05% | | |
| | Shunt thermal shock | –65°C to +150°C, 500 cycles | | ±0.1% | | |
| | Shunt resistance to solder heat | 260°C solder, 10 seconds | | ±0.1% | | |
| | Shunt high temperature exposure | 1000 hours, $T_A$ = 150°C | | ±0.15% | | |
| | Shunt cold temperature storage | 24 hours, $T_A$ = –65°C | | ±0.025% | | |
| **OUTPUT** | | | | | | |
| G | Gain | INA253A1 | | 100 | | mV/A |
| | | INA253A2 | | 200 | | |
| | | INA253A3 | | 400 | | mV/A |
| | System gain error(3) | GND + 50 mV ≤ $V_{OUT}$ ≤ $V_S$ – 200 mV, $T_A$ = 25°C | | ±0.05% | ±0.4% | |
| | | $T_A$ = –40°C to +125°C | | | ±45 | ppm/°C |
| | Nonlinearity error | GND + 10 mV ≤ $V_{OUT}$ ≤ $V_S$ – 200 mV | | ±0.01% | | |
| | Reference divider accuracy | $V_{OUT}$ = \|($V_{REF1}$ – $V_{REF2}$)\| / 2 at $I_{SENSE}$ = 0 A, $T_A$ = –40°C to +125°C | | 0.02% | 0.1% | |
| RVRR | Reference voltage rejection ratio (input-referred) | INA253A2 | | 2.5 | | mA/V |
| | | INA253A1, INA253A3 | | 1 | | |
| | Maximum capacitive load | No sustained oscillation | | 1 | | nF |
| **VOLTAGE OUTPUT** | | | | | | |
| | Swing to $V_S$ power-supply rail | $R_L$ = 10 kΩ to GND, $T_A$ = –40°C to +125°C | | $V_S$ – 0.05 | $V_S$ – 0.2 | V |
| | Swing to GND | $R_L$ = 10 kΩ to GND, $I_{SENSE}$ = 0 A, $V_{REF1}$ = $V_{REF2}$ = 0 V, $T_A$ = –40°C to +125°C | | $V_{GND}$ + 1 | $V_{GND}$ + 10 | mV |

(1) The internal shunt resistor is intended to be used with the internal amplifier and is not intended to be used as a stand-alone resistor. See the *Integrated Shunt Resistor* section for more information.
(2) See *Maximum Continuous Current* for additional information on the current derating and review *layout* recommendations to improve the current handling capability of the device at higher temperatures.
(3) System gain error includes amplifier gain error and the integrated sense resistor tolerance. System gain error does not include the stress related characteristics of the integrated sense resistor. These characteristics are described in the *Shunt Resistor* section of the *Electrical Characteristics* table.

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## Electrical Characteristics (continued)

at $T_A$ = 25 °C, $V_S$ = 5 V, $I_{SENSE}$ = IS+ = 0 A, $V_{CM}$ = 12 V, and $V_{REF1}$ = $V_{REF2}$ = $V_S$ / 2 (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **FREQUENCY RESPONSE** | | | | | | |
| BW | Bandwidth(4) | All gains, –3-dB bandwidth | | 350 | | kHz |
| | | All gains, 2% THD+N(4) | | 100 | | kHz |
| | Output settling time | Settles to 0.5% of final value | | 10 | | µs |
| SR | Slew rate | | | 2.4 | | V/µs |
| **NOISE (Input Referred)** | | | | | | |
| | Voltage noise density | | | 40 | | nV/√Hz |
| **POWER SUPPLY** | | | | | | |
| **$V_S$** | Operating voltage range | $T_A$ = –40°C to +125°C | 2.7 | | 5.5 | V |
| $I_Q$ | Quiescent current | $I_{SENSE}$ = 0 A | | 1.8 | 2.4 | mA |
| | | $I_Q$ vs temperature, $T_A$ = –40°C to +125°C | | | 2.6 | |

(4) See *Bandwidth* section for more details.


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## 7.6 Typical Characteristics

at $T_A$ = 25°C, $V_S$ = 5 V, $V_{IN+}$ = 12 V, and $V_{REF}$ = $V_S$ / 2 (unless otherwise noted)

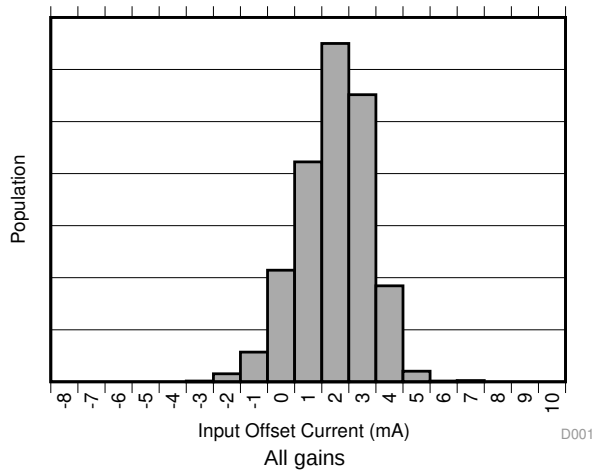


**図 1. Input Offset Voltage Production Distribution**

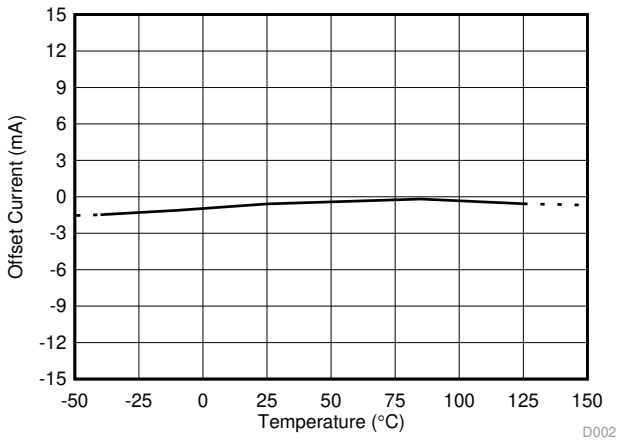


**図 2. Input Offset Current vs Temperature**

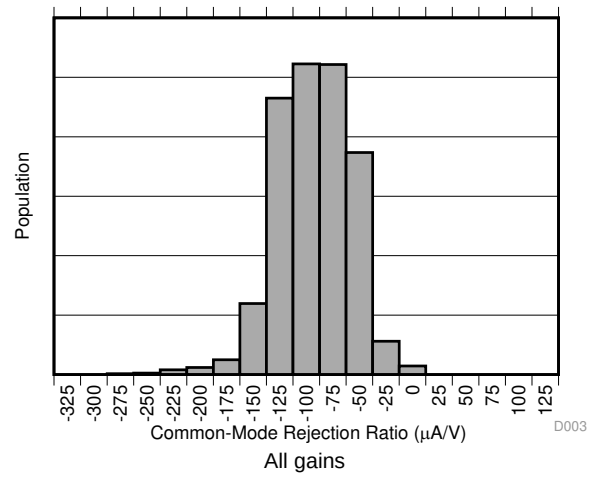


**図 3. Common-Mode Rejection Production Distribution**

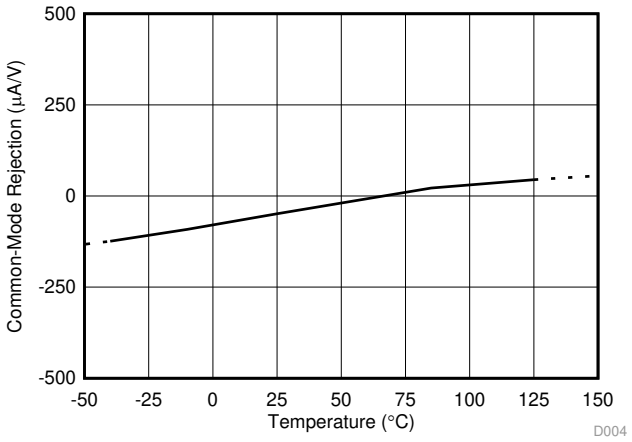


**図 4. Common-Mode Rejection Ratio vs Temperature**

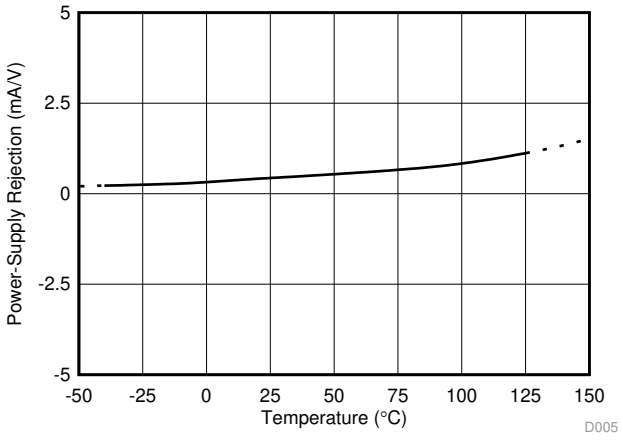


**図 5. Power-Supply Rejection Ratio vs Temperature**

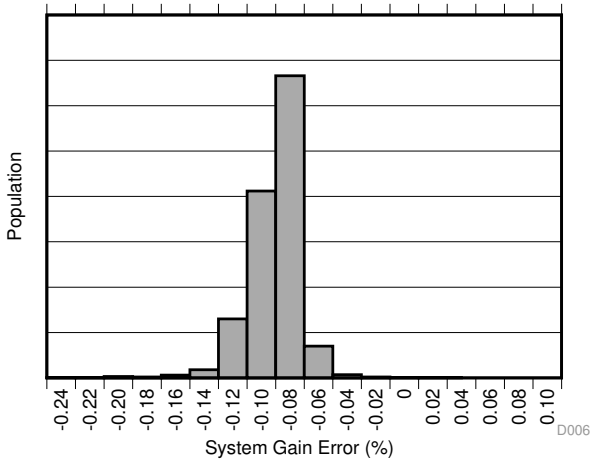


**図 6. Gain Error Production Distribution (INA253A1)**

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## Typical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = 5 V, $V_{IN+}$ = 12 V, and $V_{REF}$ = $V_S$ / 2 (unless otherwise noted)

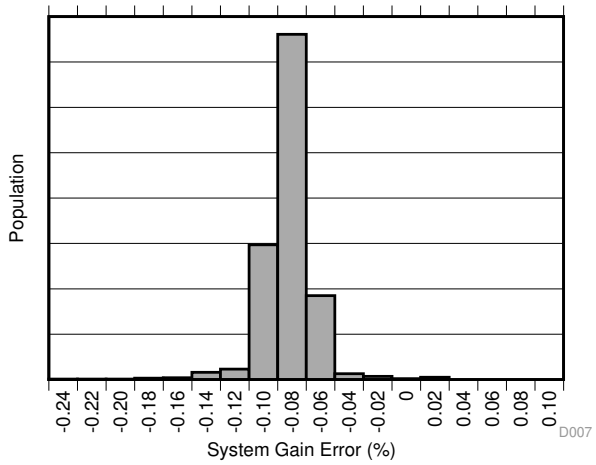



図 7. Gain Error Production Distribution (INA253A2)

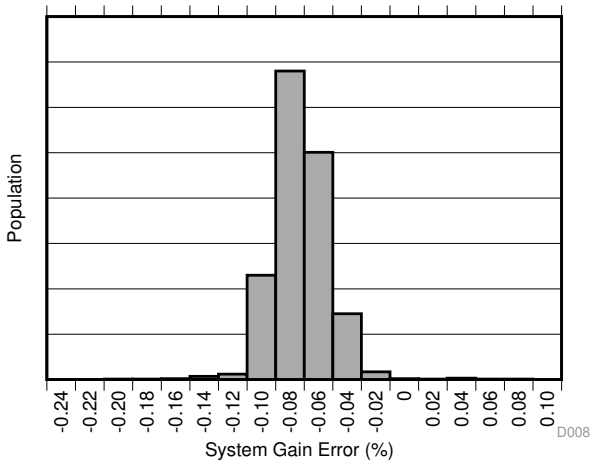



図 8. Gain Error Production Distribution (INA253A3)

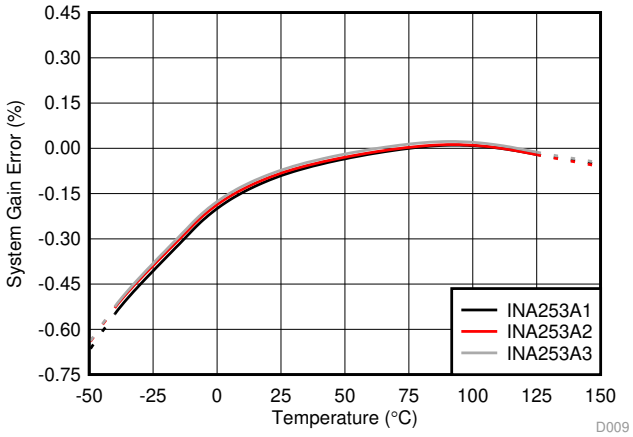



図 9. System Gain Error vs Temperature

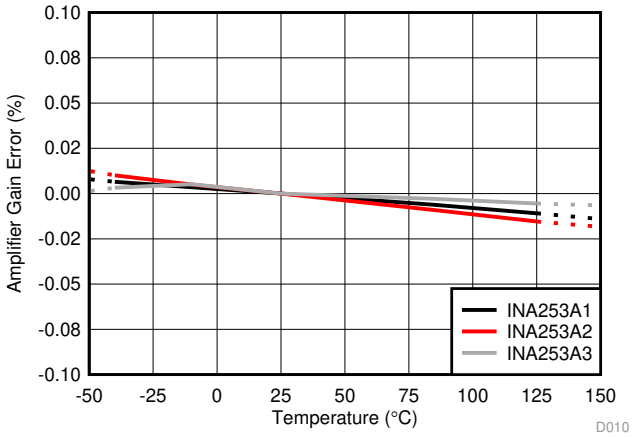
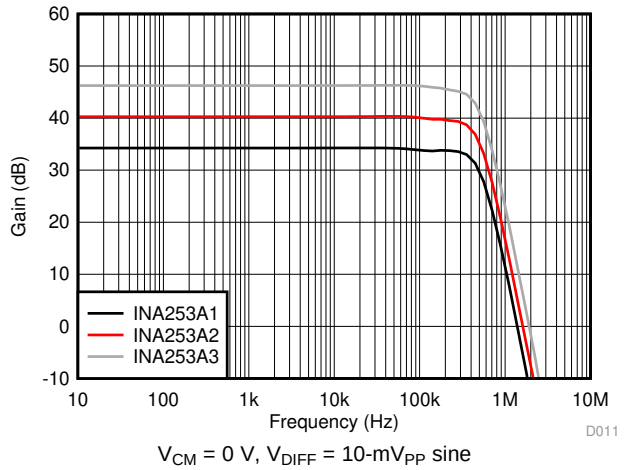



図 10. Amplifier Gain Error vs Temperature




$V_{CM}$ = 0 V, $V_{DIFF}$ = 10-$mV_{PP}$ sine

図 11. Amplifier Gain Error vs Frequency

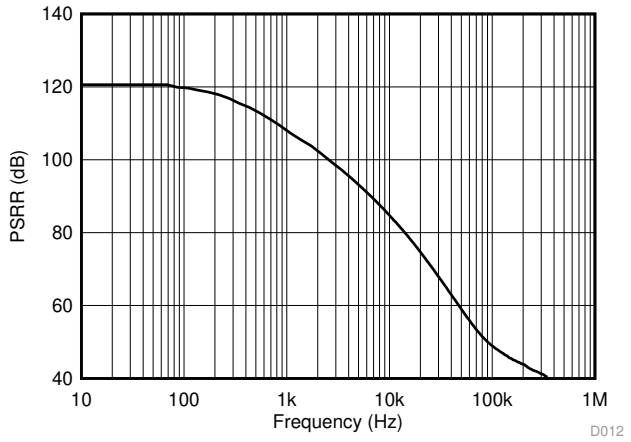



図 12. Power-Supply Rejection Ratio vs Frequency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## Typical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = 5 V, $V_{IN+}$ = 12 V, and $V_{REF}$ = $V_S$ / 2 (unless otherwise noted)

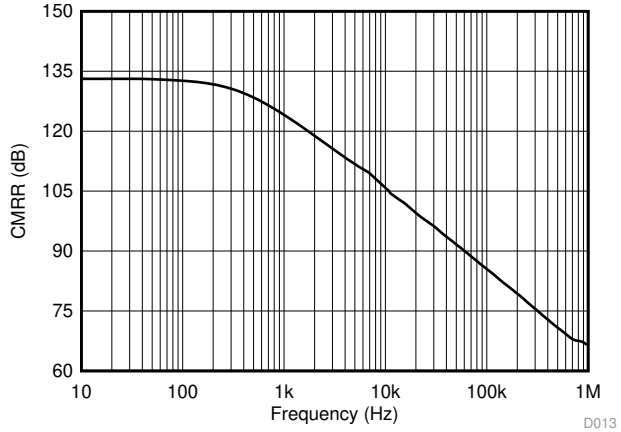
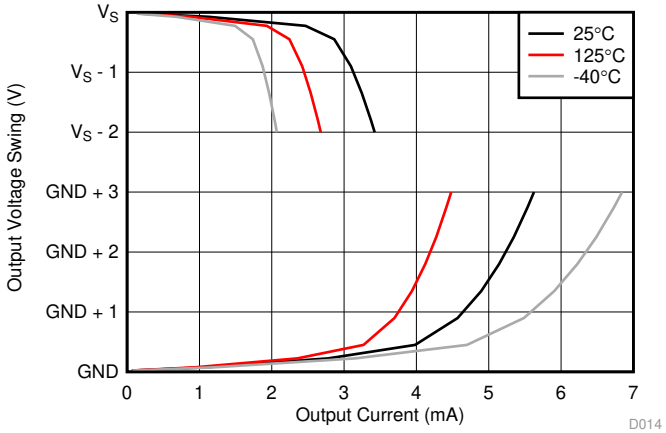
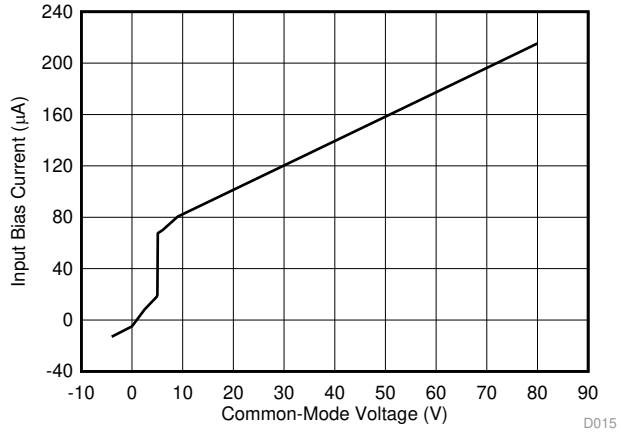



図 13. Common-Mode Rejection Ratio vs Frequency



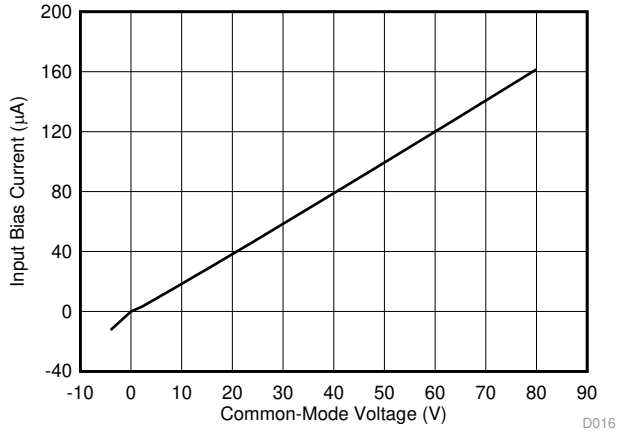

$V_S$ = 5 V

図 14. Output Voltage Swing vs Output Current




$V_S$ = 5 V

図 15. Input Bias Current vs Common-Mode Voltage




$V_S$ = 0 V

図 16. Input Bias Current vs Common-Mode Voltage

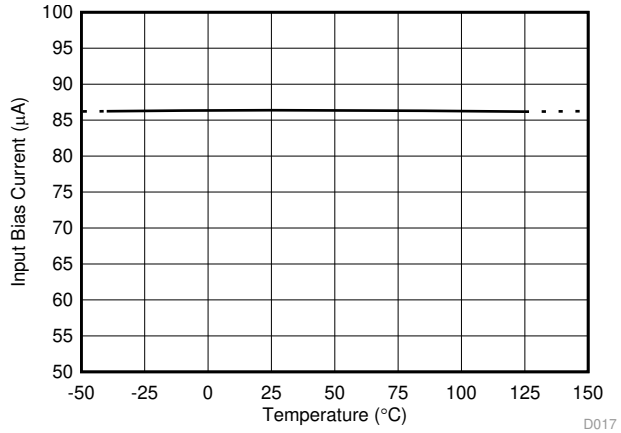



図 17. Input Bias Current vs Temperature

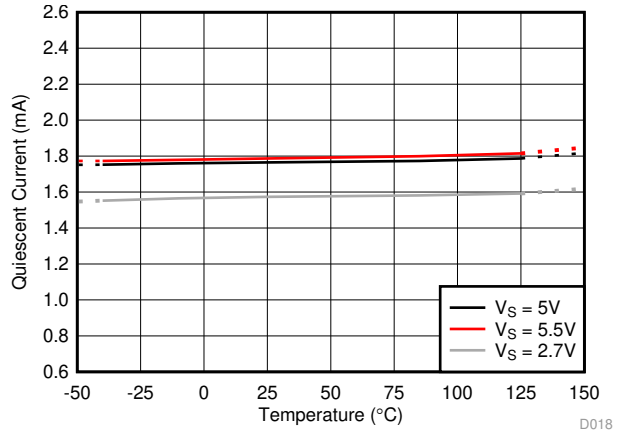



図 18. Quiescent Current vs Temperature

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## Typical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = 5 V, $V_{IN+}$ = 12 V, and $V_{REF}$ = $V_S$ / 2 (unless otherwise noted)

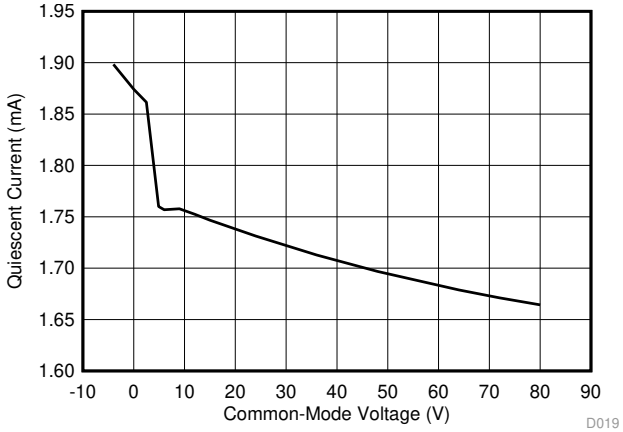



図 19. Quiescent Current vs Common-mode Voltage

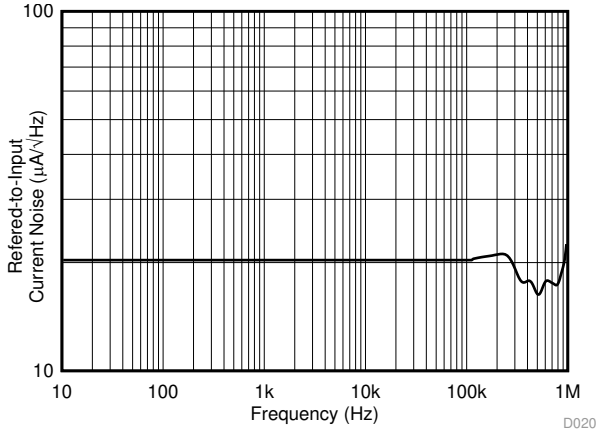



図 20. INA253A1 Input-Referred Voltage Noise vs Frequency

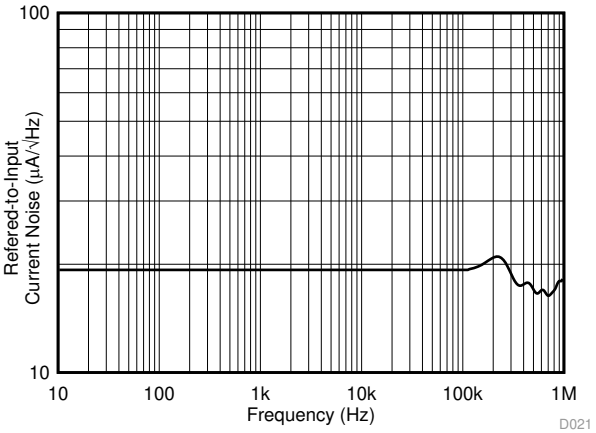



図 21. INA253A2 Input-Referred Voltage Noise vs Frequency

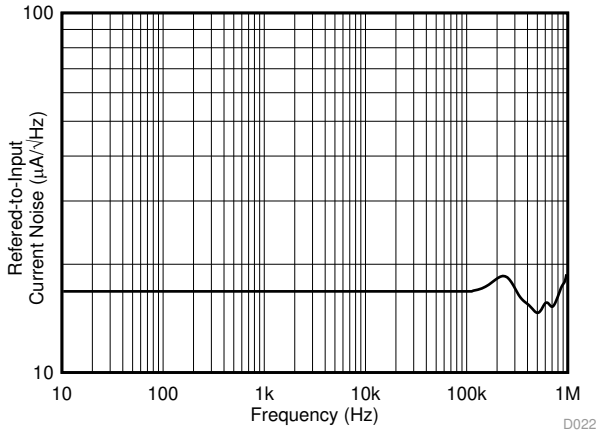



図 22. INA253A3 Input-Referred Voltage Noise vs Frequency

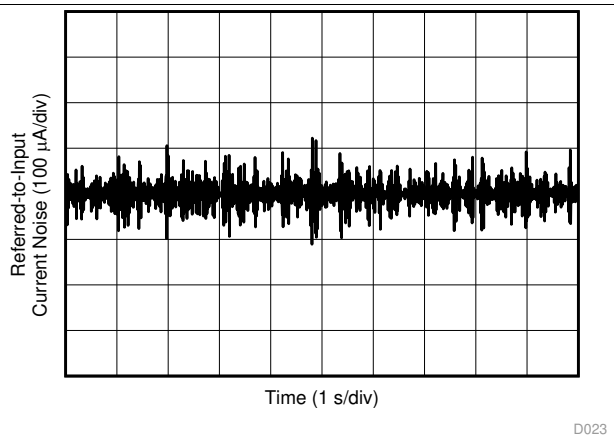
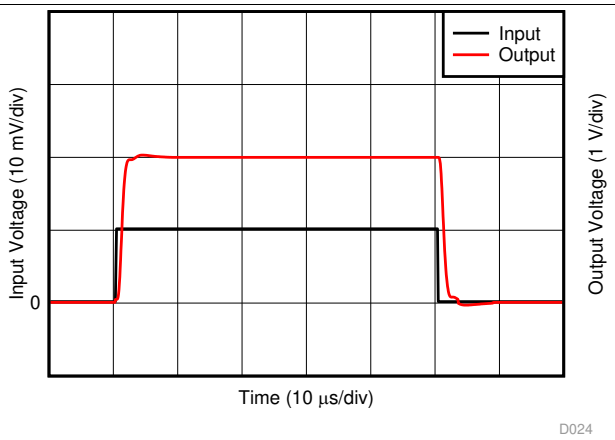



図 23. 0.1-Hz to 10-Hz Voltage Noise (Referred-to-Input)




$V_{REF1}$ = $V_{REF2}$ = 0 V, 10-$mV_{PP}$ input step

図 24. Amplifier Step Response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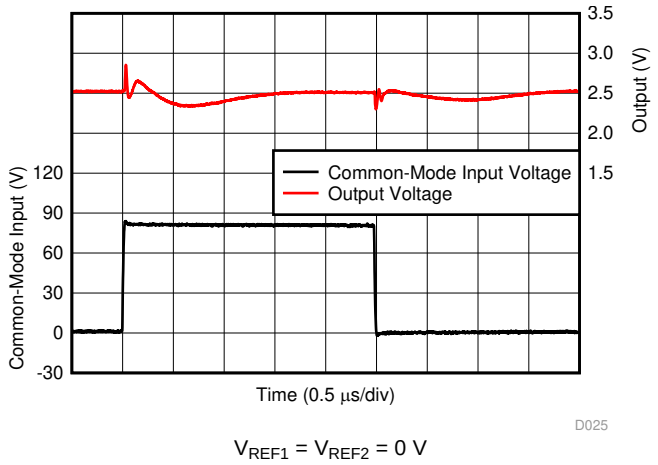
## Typical Characteristics (continued)

at $T_A$ = 25°C, $V_S$ = 5 V, $V_{IN+}$ = 12 V, and $V_{REF}$ = $V_S$ / 2 (unless otherwise noted)




$V_{REF1}$ = $V_{REF2}$ = 0 V

**図 25. Common-Mode Transient Response**

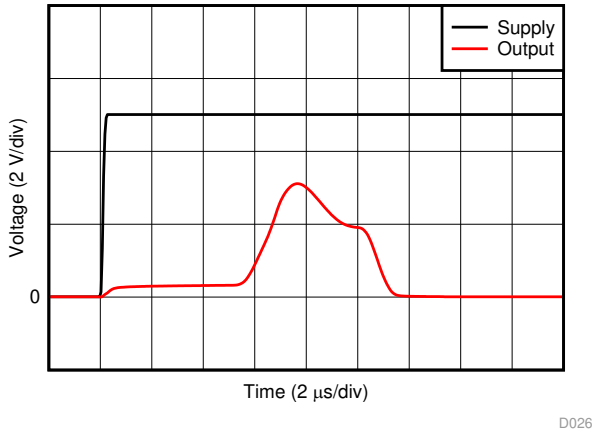
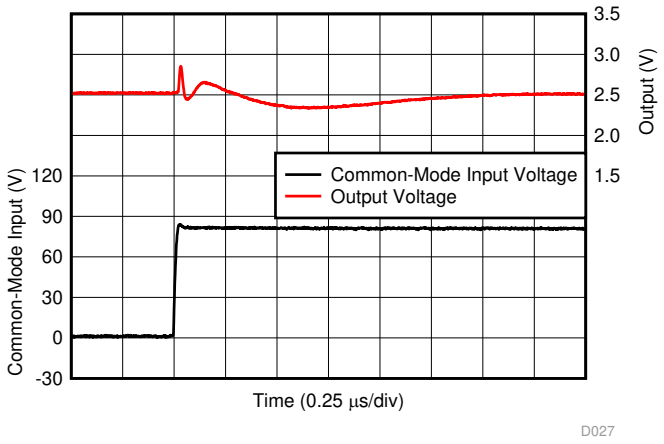
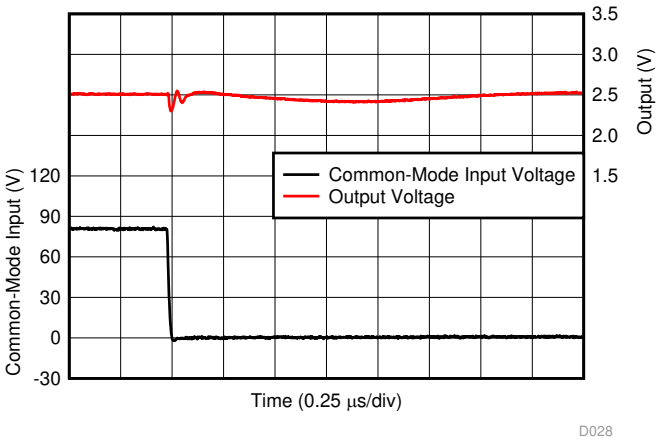



**図 26. Start-Up Response**




Rising Edge

**図 27. Common-Mode Voltage Transient Response**




Falling Edge

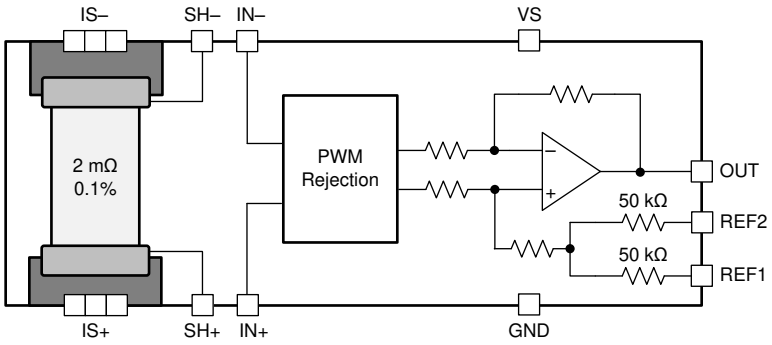
**図 28. Common-Mode Voltage Transient Response**

# 8 Detailed Description

## 8.1 Overview

The INA253 features a precision, 2-mΩ current-sensing resistor and supports common mode voltages up to 80 V. The internal amplifier features a precision zero-drift topology with excellent common-mode rejection ratio (CMRR). The internal amplifier also features an enhanced pulse-width modulation (PWM) rejection current-sensing amplifier integrated into a single package. High-precision measurements are enabled by matching the shunt resistor value and the current-sensing amplifier gain, thus providing a highly-accurate, system-calibrated method for measuring current. Enhanced PWM rejection reduces the effect of common-mode transients on the output signal that are associated with PWM signals. Multiple gain versions are available to allow for the optimization of the desired full-scale output voltage based on the target current range expected in the application.

## 8.2 Functional Block Diagram




## 8.3 Feature Description

### 8.3.1 Integrated Shunt Resistor

The INA253 features a precise, low-drift, current-sensing resistor that provides accurate measurements over the entire specified temperature range of –40°C to +125°C. The integrated current-sensing resistor provides measurement stability over temperature, and simplifies printed circuit board (PCB) layout and board constraint difficulties common in high-precision measurements.

The onboard current-sensing resistor is designed as a 4-wire (or Kelvin) connected resistor that enables accurate measurements through a force-sense connection. Connecting the amplifier inputs pins (VIN– and VIN+) to the sense pins of the shunt resistor (SH– and SH+) eliminates many of the parasitic impedances commonly found in typical very-low sensing-resistor level measurements. Although the sense connection of the current-sensing resistor can be accessed through the SH+ and SH– pins, this resistor is not intended to be used as a stand-alone component. The INA253 is system-calibrated to makes sure that the current-sensing resistor and current-sensing amplifier are both precisely matched to one another. Use of the shunt resistor without the onboard amplifier results in a current-sensing resistor tolerance of approximately 5%. To achieve the optimized system gain specification, the onboard sensing resistor must be used with the internal current-sensing amplifier.

The INA253 has approximately 4.5 mΩ of package resistance. Of this total package resistance, 2 mΩ is a precisely-controlled resistance from the Kelvin-connected current-sensing resistor used by the amplifier. The power dissipation requirements of the system and package are based on the total 4.5-mΩ package resistance between the IS+ and IS– pins. The heat dissipated across the package when current flows through the device ultimately determines the maximum current that can be safely handled by the package. The current consumption of the silicon is relatively low, leaving the total package resistance to carry the high load current as the primary contributor to the total power dissipation of the package. The maximum safe-operating current level is set to make sure that the heat dissipated across the package is limited so that no damage occurs to the resistor or the package, or that the internal junction temperature of the silicon does not exceed a 150°C limit.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## Feature Description (continued)

External factors, such as ambient temperature, external air flow, and PCB layout, contribute to how effectively the device dissipates heat. The internal heat is developed as a result of the current flowing through the total package resistance of 4.5 mΩ. Under the conditions of no air flow, a maximum ambient temperature of 85°C, and 1-oz. copper input power planes, the INA253 accommodates continuous current levels up to 15 A. 図 29 shows that the current-handling capability is derated at temperatures greater than the 85°C level, with safe operation up to 10 A at a 125°C ambient temperature. With air flow and larger 2-oz. copper input power planes, the INA253 safely accommodates continuous current levels up to 15 A across the entire –40°C to +125°C temperature range.

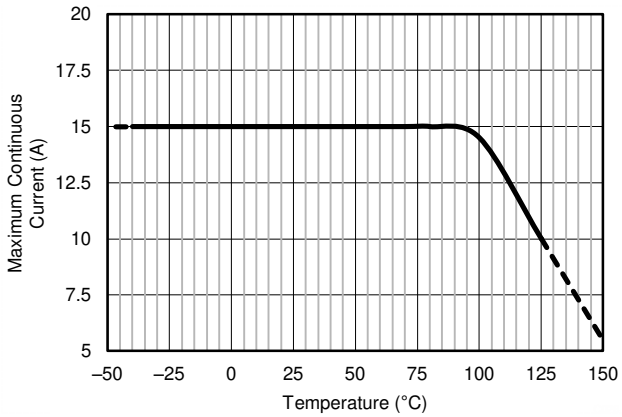


**図 29. Maximum Continuous Current vs Temperature**

### 8.3.2 Short-Circuit Duration

The INA253 features a physical shunt resistance that is able to withstand current levels higher than the continuous handling limit of 15 A without sustaining damage to the current-sensing resistor or the current-sensing amplifier, if the excursions are brief. 図 30 shows the short-circuit duration curve for the INA253.

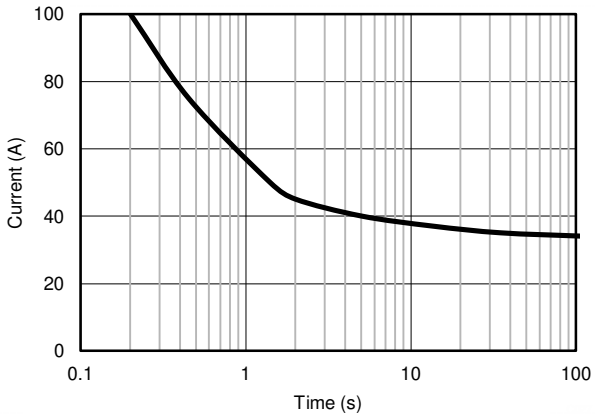


**図 30. Short-Circuit Duration**

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## Feature Description (continued)

### 8.3.3 Temperature Stability

System calibration is common for many industrial applications in order to eliminate initial component and system-level errors that can be present. A system-level calibration reduces the initial accuracy requirement for many of the individual components because the errors associated with these components are effectively eliminated through the calibration procedure. This calibration enables precise measurements at the temperature in which the system is calibrated. As the system temperature changes because of external ambient changes or self heating, measurement errors are reintroduced. Without accurate temperature compensation used in addition to the initial adjustment, the calibration procedure is not effective. The user must account for temperature-induced changes. One of the primary benefits of the low temperature coefficient of the INA253 (including both the integrated current-sensing resistor and current-sensing amplifier) is that the device measurement remains accurate, even when the temperature changes throughout the specified temperature range of the device.

図 31 shows the drift performance for the integrated current-sensing resistor. Use 図 31 to determine the typical variance in the shunt resistor value at various temperatures. As with any resistive element, the tolerance of the component varies when exposed to different temperature conditions. For the current-sensing resistor integrated in the INA253, the resistor does vary slightly more when operated in temperatures ranging from –40°C to 0°C than when operated from 0°C to 125°C. Even in the –40°C to 0°C temperature range, the drift is still low at 25 ppm/°C.

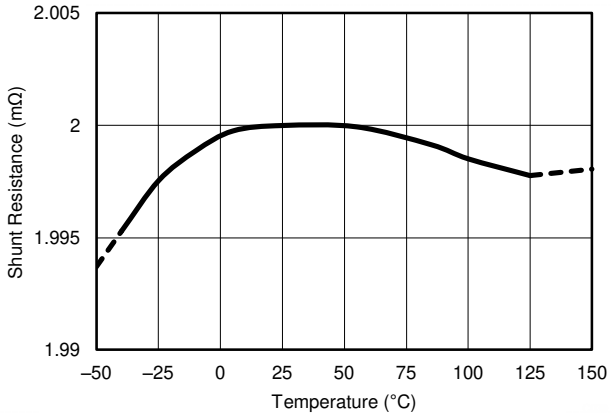


**図 31. Sensing Resistor vs Temperature**

An additional aspect to consider is that when current flows through the current-sensing resistor, power is dissipated across this component. This dissipated power results in an increase in the internal temperature of the package, including the integrated sensing resistor. This resistor self-heating effect results in an increase of the resistor temperature helping to move the component out of the colder, wider drift temperature region.

### 8.3.4 Enhanced PWM Rejection Operation

The enhanced PWM rejection feature of the INA253 provides increased attenuation of large common-mode $\Delta V/\Delta t$ transients. Large $\Delta V/\Delta t$ common-mode transients associated with PWM signals are employed in applications such as motor or solenoid drive and switching power supplies. Traditionally, large $\Delta V/\Delta t$ common-mode transitions are handled strictly by increasing the amplifier signal bandwidth, which can increase chip size, complexity and ultimately cost. The INA253 is designed with high common-mode rejection techniques to reduce large $\Delta V/\Delta t$ transients before the system is disturbed as a result of these large signals. The high ac CMRR, in conjunction with signal bandwidth, allows the INA253 to provide minimal output transients and ringing compared with standard circuit approaches.


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## Feature Description (continued)

### 8.3.5 Input Signal Bandwidth

The INA253 input signal, which represents the current being measured, is accurately measured with minimal disturbance from large ΔV/Δt common-mode transients as previously described. For PWM signals typically associated with motors, solenoids, and other switching applications, the current being monitored varies at a significantly slower rate than the faster PWM frequency.

The INA253 bandwidth is defined by the –3-dB bandwidth of the current-sense amplifier inside the device; see the *Electrical Characteristics* for more information. The device bandwidth provides fast throughput and fast response required for the rapid detection and processing of overcurrent events. Without the higher bandwidth, protection circuitry may not have adequate response time, and damage may occur to the monitored application or circuit.

図 32 shows the performance profile of the device over frequency. Harmonic distortion increases at the upper end of the amplifier bandwidth with no adverse change in detection of overcurrent events. However, increased distortion at the highest frequencies must be considered when the measured current bandwidth begins to approach the INA253 bandwidth.

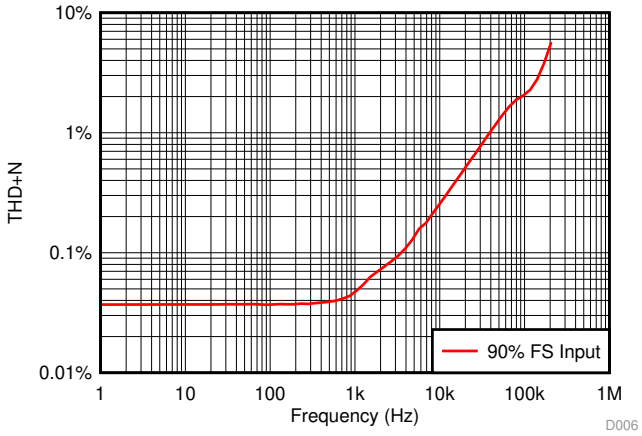


**図 32. Amplifier Performance Over Frequency**

For applications requiring distortion sensitive signals, 図 32 provides information to show that there is an optimal frequency performance range for the amplifier. The full amplifier bandwidth is always available for fast overcurrent events at the same time that the lower-frequency signals are amplified at a low distortion level. The output signal accuracy is reduced for frequencies closer to the maximum bandwidth. Individual requirements determine the acceptable limits of distortion for high-frequency, current-sensing applications. Testing and evaluation in the end application or circuit are required to determine the acceptance criteria, and to validate the performance levels meet the system specifications.

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## 8.4 Device Functional Modes

### 8.4.1 Adjusting the Output Midpoint With the Reference Pins

図 33 shows a test circuit for reference-divider accuracy. The INA253 output is configurable to allow for unidirectional or bidirectional operation.w

> **注意**
>
> Do not connect the REF1 pin or the REF2 pin to any voltage source lower than GND or higher than $V_S$.

The output voltage is set by applying a voltage or voltages to the reference voltage inputs, REF1 and REF2. The reference inputs are connected to an internal gain network. There is no operational difference between the two reference pins.

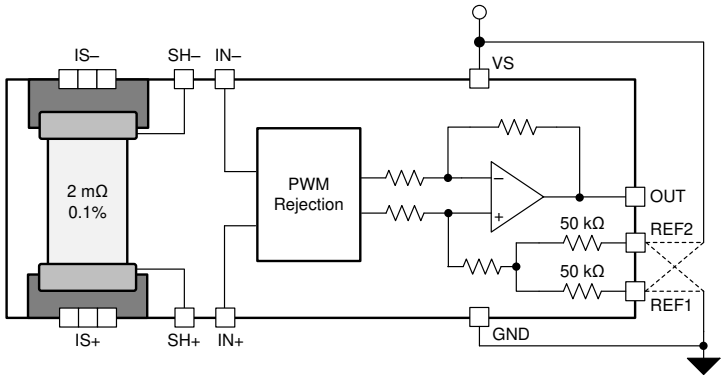


**図 33. Adjusting the Output Midpoint**

### 8.4.2 Reference Pin Connections for Unidirectional Current Measurements

Unidirectional operation allows current measurements through a resistive shunt in one direction. For unidirectional operation, connect the device reference pins together and then to the negative rail (see the *Ground Referenced Output* section). The required differential input polarity depends on the output voltage setting. The amplifier output moves away from the referenced rail proportional to the current passing through the internal shunt resistor.

### 8.4.3 Ground Referenced Output

When using the INA253 in unidirectional mode with a ground-referenced output, both reference inputs are connected to ground. 図 34 shows how this configuration takes the output to ground when there is 0-A flowing across the internal shunt.

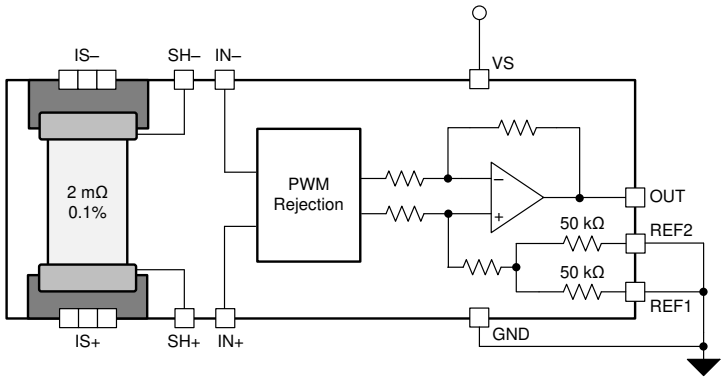


**図 34. Ground-Referenced Output**


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## Device Functional Modes (continued)

### 8.4.4 Reference Pin Connections for Bidirectional Current Measurements

Bidirectional operation allows the INA253 to measure currents through a resistive shunt in two directions. For this case, set the output voltage anywhere within the reference input limits. A common configuration is to set the reference inputs at half-scale for equal range in both directions. However, the reference inputs can be set to a voltage other than half-scale when the bidirectional current is nonsymmetrical.

#### *8.4.4.1 Output Set to External Reference Voltage*

Connecting both pins together and then to a reference voltage results in an output voltage equal to the reference voltage for the condition of shorted input pins or a 0-V differential input. 図 35 shows this configuration. The output voltage decreases below the reference voltage when the IN+ pin is negative relative to the IN– pin, and increases when the IN+ pin is positive relative to the IN– pin. This technique is the most accurate way to bias the output to a precise voltage.

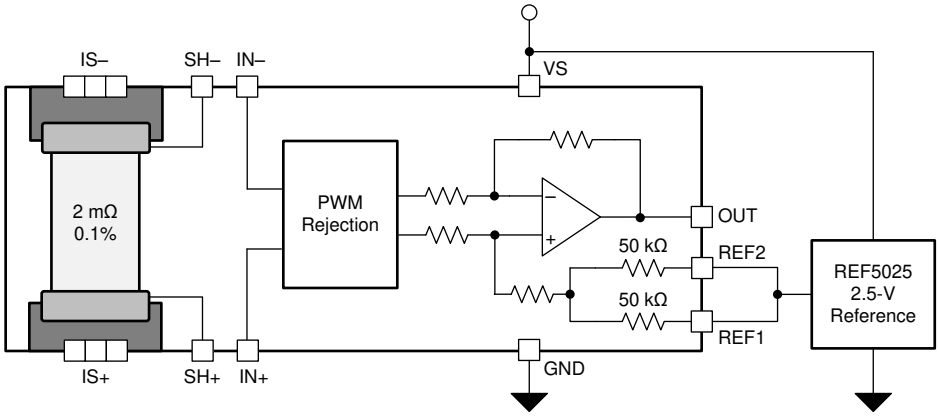


**図 35. External Reference Output**

### 8.4.5 Output Set to Mid-Supply Voltage

図 36 shows that by connecting one reference pin to VS and the other to the GND pin, the output is set at half of the supply when there is no differential input. This method creates a ratiometric offset to the supply voltage, where the output voltage remains at VS / 2 when 0 V is applied between the IN+ and IN– inputs.

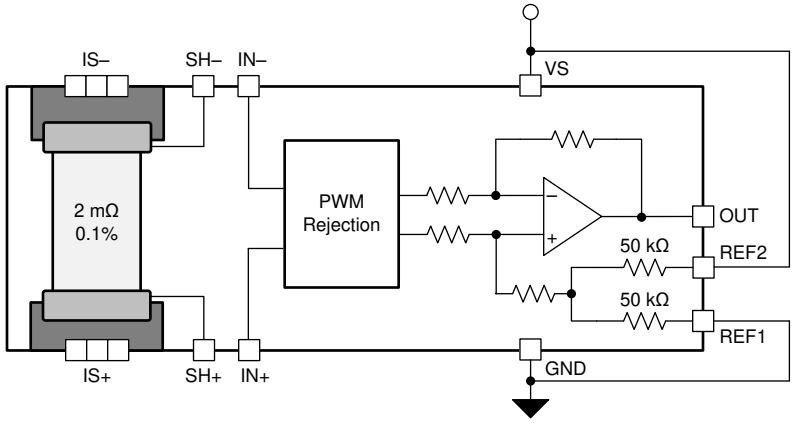


**図 36. Mid-Supply Voltage Output**

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## Device Functional Modes (continued)

### 8.4.6 Output Set to Mid-External Reference

In this example, an external reference is divided by two by connecting one REF pin to ground and the other REF pin to the reference, as shown in 図 37.

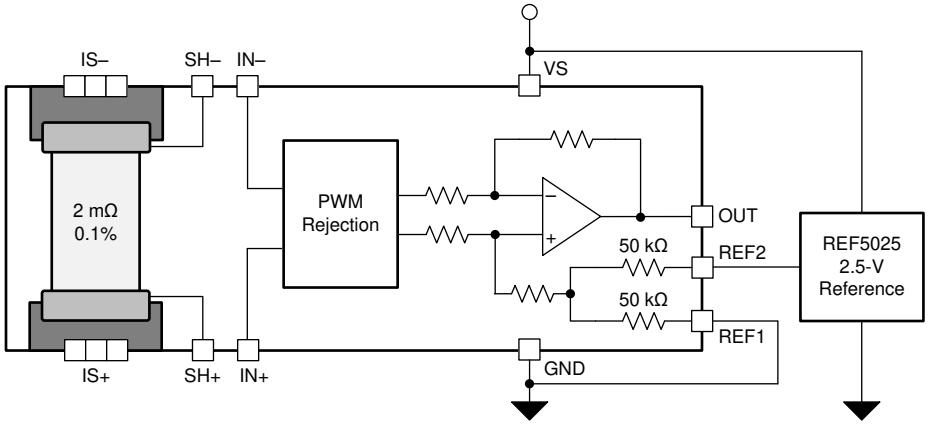


**図 37. Mid-External Reference Output**

### 8.4.7 Output Set Using Resistor Divide

The INA253 REF1 and REF2 pins allow for the midpoint of the output voltage to be adjusted for system circuitry connections to analog to digital converters (ADCs) or other amplifiers. The REF pins are designed to be connected directly to supply, ground, or a low-impedance reference voltage. The REF pins can be connected together and biased using a resistor divider to achieve a custom output voltage. If the amplifier is used in this configuration, as shown in 図 38, use the output as a differential signal with respect to the resistor divider voltage. For most accurate results, do not use single-ended measurements at the amplifier output because the internal impedance shifts can adversely affect device performance specifications.

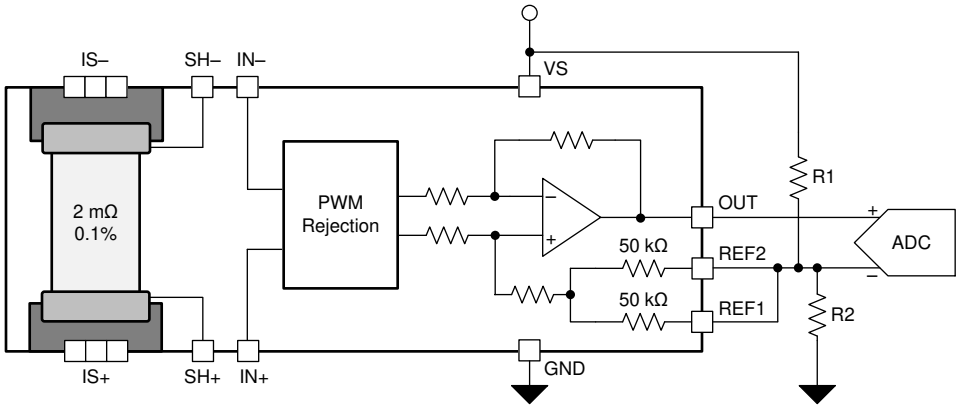


**図 38. Setting the Reference Using a Resistor Divider**


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# 9 Application and Implementation

注

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. Customers should validate and test their design implementation to confirm system functionality.

## 9.1 Application Information

The INA253 measures the voltage developed as current flows across the integrated low inductive current-sensing resistor. The device provides reference pins to configure operation as either unidirectional or bidirectional output swing. When using the INA253 for inline motor current sense or measuring current in an h-bridge, the device is commonly configured for bidirectional operation.

### 9.1.1 Input Filtering

注

Input filters are not required for accurate measurements using the INA253. For most accurate results, do not use filters at the IN+ and IN– inputs. However, If filter components are used on the input of the amplifier, follow the guidelines in this section to minimize effects on performance.

Based strictly on user design requirements, external filtering of the current signal may be desired. The initial location that can be considered for the filter is at the output of the current amplifier. Although placing the filter at the output satisfies the filtering requirements, this location changes the low output impedance measured by any circuitry connected to the output voltage pin. The other location for filter placement is at the current amplifier input pins. This location also satisfies the filtering requirement, but carefully select the components to minimize the impact on device performance. 図 39 shows a filter placed at the inputs pins.

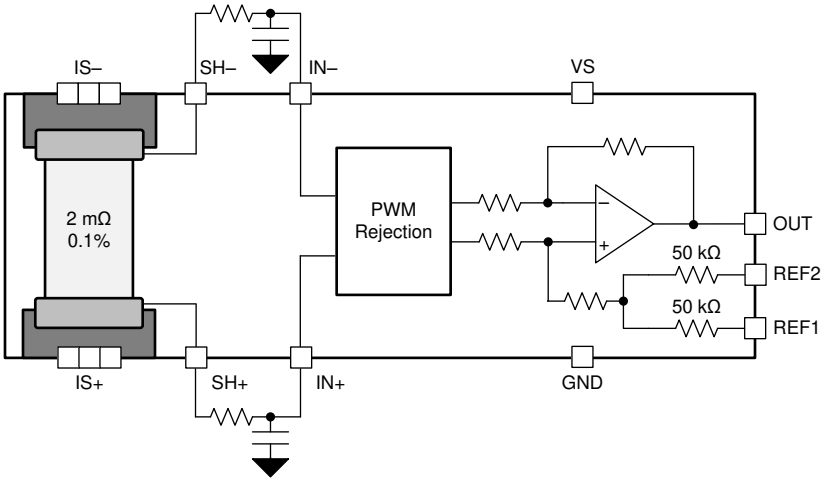


**図 39. Filter at Input Pins**

External series resistance provides a source of additional measurement error. Therefore, keep the value of these series resistors to 10-Ω or less in order to reduce loss of accuracy. The internal bias network shown in 図 39 creates a mismatch in input bias currents when a differential voltage is applied between the input pins (see 図 40). If additional external series filter resistors are added to the circuit, a mismatch is created in the voltage drop across the filter resistors. This voltage is a differential error voltage in the shunt resistor voltage. In addition to the absolute resistor value, mismatch resulting from resistor tolerance can significantly impact the error because this value is calculated based on the actual measured resistance.

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## Application Information (continued)

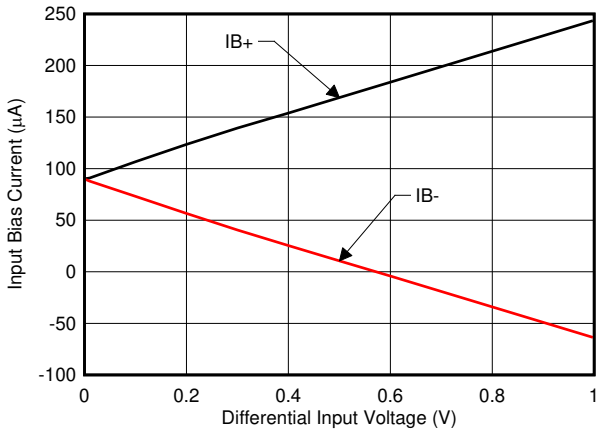


**図 40. Input Bias Current vs Differential Input Voltage**

Calculate the measurement error expected from the additional external filter resistors using 式 1.

Gain Error (%) = 100 – (100 × Gain Error Factor) (1)

where

- Gain Error Factor is calculated using 式 2.

$$\text{Gain Error Factor} = \frac{3000}{R_S + 3000} \quad (2)$$

Where:

- $R_S$ is the external filter resistance value

Calculate the gain error factor, shown in 式 2, in order to determine the gain error introduced by the additional external series resistance. 式 1 calculates the deviation of the shunt voltage resulting from the attenuation and imbalance created by the added external filter resistance. 表 1 provides the gain error factor and gain error for several resistor values.

**表 1. Gain Error Factor and Gain Error for External Input Resistors**

| EXTERNAL RESISTANCE (Ω) | GAIN ERROR FACTOR | GAIN ERROR (%) |
|---|---|---|
| 5 | 0.998 | 0.17 |
| 10 | 0.997 | 0.33 |
| 100 | 0.968 | 3.23 |


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## 9.2 Typical Applications

The INA253 offers advantages for multiple applications including the following:

- High common-mode range and excellent CMRR enables direct inline sensing
- Precision low-inductive, low-drift shunt eliminates the need for overtemperature system calibration
- Ultra-low offset and drift eliminates the necessity of calibration
- Wide supply range enables a direct interface with most microprocessors

### 9.2.1 High-Side, High-Drive, Solenoid Current-Sense Application

Challenges exist in solenoid drive current sensing that are similar to those in motor inline current sensing. In certain topologies, the current-sensing amplifier is exposed to the full-scale PWM voltage between ground and supply. The INA253 is an excellent choice for this type of application. The 2-mΩ integrated shunt with a total system accuracy of 0.2% with a total system drift of 25 ppm/°C provides system accuracy across temperature eliminating the need for tri temperature system calibration.

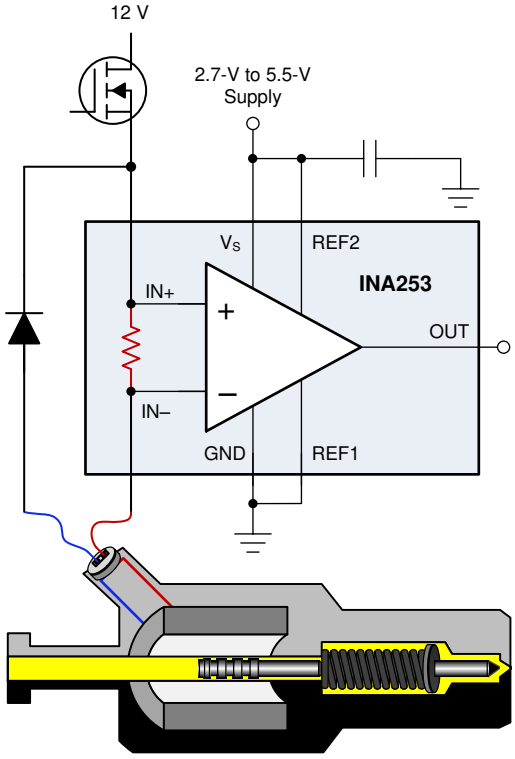


**図 41. Solenoid Drive Application Circuit**

#### *9.2.1.1 Design Requirements*

For this application, the INA253 measures current in the driver circuit of a 12-V, 500-mA hydraulic valve.

**表 2. Design Parameters**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| Common-mode voltage | 12 V |
| Maximum sense current | 500 mA |
| Power-supply voltage | 3.3 V |

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#### 9.2.1.2 Detailed Design Procedure

To demonstrate the performance of the device, the INA253, with a gain of 400mV/A, is selected for this design and powered from a 5-V supply.

Using the information in the *Output Set to Mid-Supply Voltage* section, the reference point is set to midscale by splitting the supply with REF1 connected to ground and REF2 connected to supply. Alternatively, the reference pins can be tied together and driven with an external precision reference.

#### 9.2.1.3 Application Curve

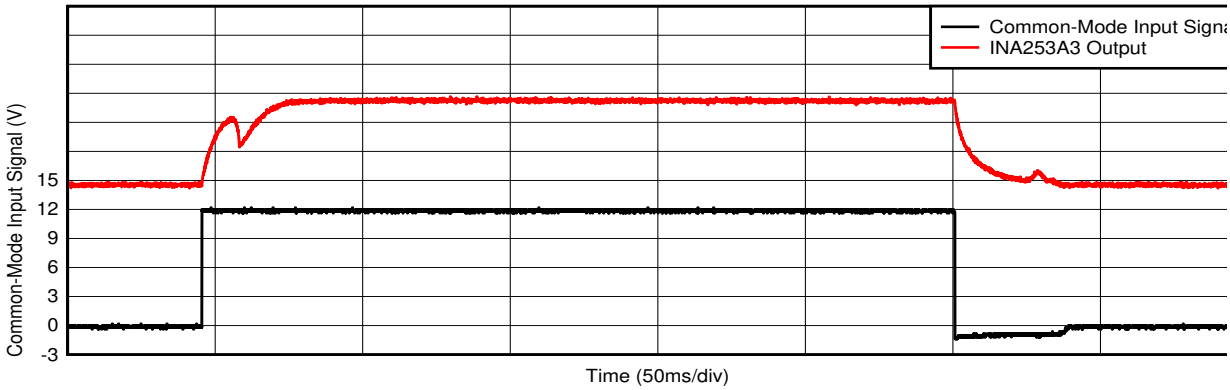


**図 42. Solenoid Drive Current Sense Input and Output Signals**


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### 9.2.2 Speaker Enhancements and Diagnostics Using Current Sense Amplifier

CLASS-D audio amplifiers in conjunction with the INA253 provide accurate speaker load current. Speaker load current is used to determine speaker diagnostics, and can further be expanded to measure key speaker parameters, such as speaker coil resistance and speaker real-time ambient temperature.

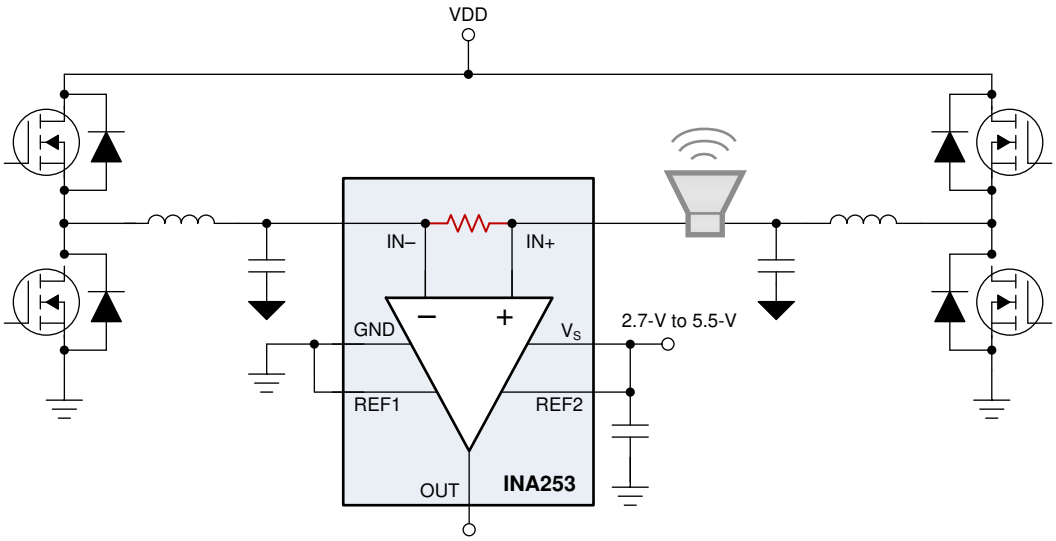


**図 43. Current Sensing in a CLASS-D Subsystem**

#### *9.2.2.1 Design Requirements*

**表 3. Design Parameters**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| Common-mode voltage | 24 V |
| Power-supply voltage | 5 V |
| Maximum rms current | 5 A |
| Frequency sweep | 20 Hz to 20 Khz |

#### *9.2.2.2 Detailed Design Procedure*

For this application, the INA253 measures current flowing through the speaker from the CLASS-D amplifier. The integrated shunt of 2 mΩ with an inductance of only 3 nH is an excellent choice for current sensing in speaker applications where low inductance is required. The low-inductive shunt enables accurate current sensing across frequencies over the audio range of 20 hz to 20 kHz.

The INA253 is setup in a bidirectional with the reference set to mid-supply as shown in 図 37. The power supply to INA253 is setup at 5 V. The output of INA253 is set at 2.5 V. The INA253 with a gain of 100 mV/A, the INA253 output for a peak to peak of 10-A current the output of the INA253 will swing from 3.5 V to 1.5 V. The output can be directly connected to ADC input that has a full scale range of 5 V. The INA253 has a low THD+N of 0.1% at 1 kHz that enables distortion measurement of speaker. The INA253 can measure the impedance of the speaker and accurately measure the resonance frequency and peak impedance at resonance frequency. The INA253 can accurately track changes in impedance real time.

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#### 9.2.2.3 Application Curve

A typical example output response of speaker of 4-Ω impedance measurement from 20 Hz to 20 kHz is as shown in 図 44.

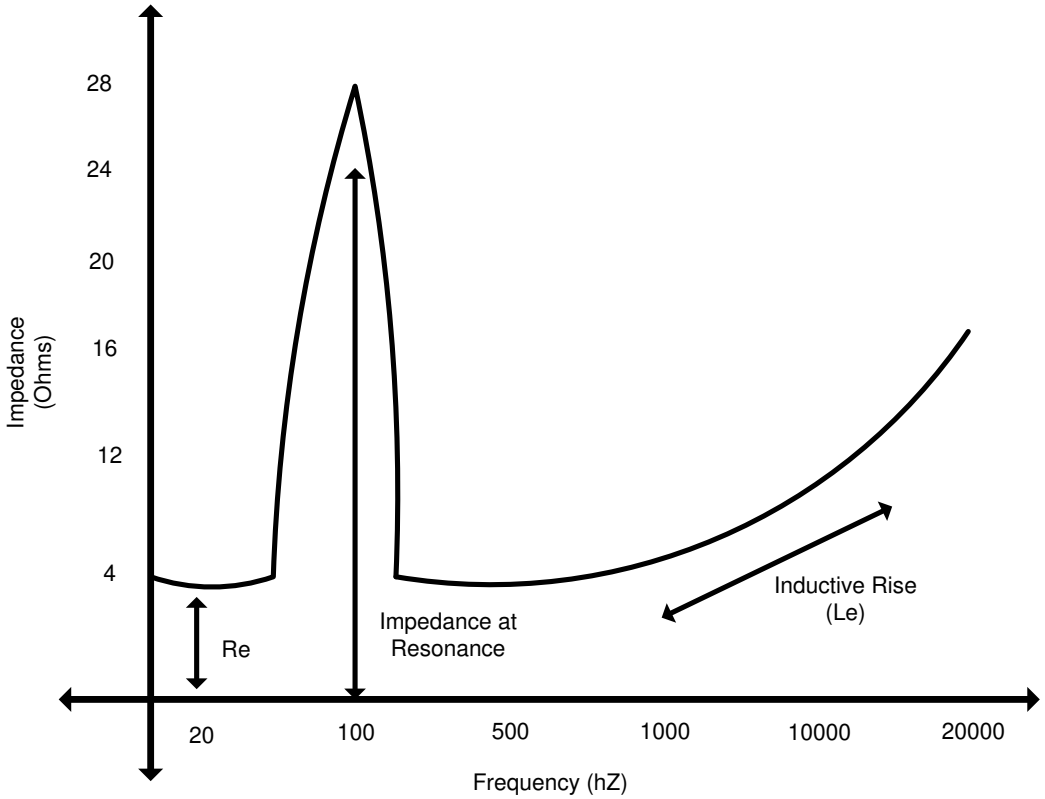


**図 44. Speaker Impedance Measurement**


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### 9.2.3 Current Sensing for Remote I/Os in PLC

In industrial remote IOs, there is often one power supply for several ports, as shown in 図 45. For example, an IO-Link master has one power supply of 24 V 5 A, but eight IO-Link ports, where each port can deliver up to 1 A. The IO-Link master must measure the total current to make sure in order to not overload the power supply. To prevent from overloading the system, each port is only turned on if sufficient headroom in the total system current is available. 図 45 shows the block diagram of such a system. This is example is implemented on TI reference design TIDA-010016. The INA253 is an excellent choice for this design because this device is simple to use, and delivers high accuracy over a wide temperature range. The integrated 2-mΩ shunt has a low voltage drop .and therefore low power dissipation.

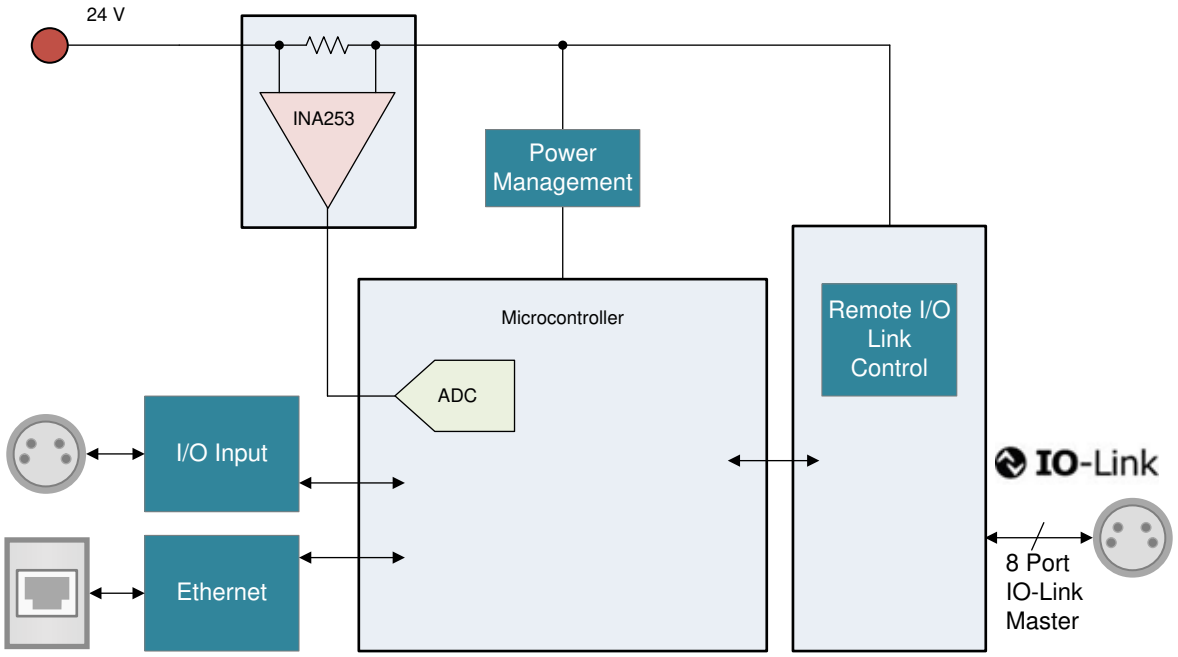


図 45. Current Sensing in Remote I/O

#### 9.2.3.1 Design Requirements

表 4. Design Parameters

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| Common-mode voltage | 24 V |
| Maximum current | 9 A |
| ADC input voltage | 1.8 V |
| Supply voltage | 3.3 V |

In this design, the current flow is unidirectional; therfore, the REF inputs must be tied to GND. Because of the given ADC input range and current, the 200-mV/A version is chosen.

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### 9.2.3.2 Application Curve

A typical response of INA253 in a remote I/O application is shown in 図 46. The common-mode voltage steps from 0 V to 24 V, and the current output across the 24 V power supply is measured using the INA253.

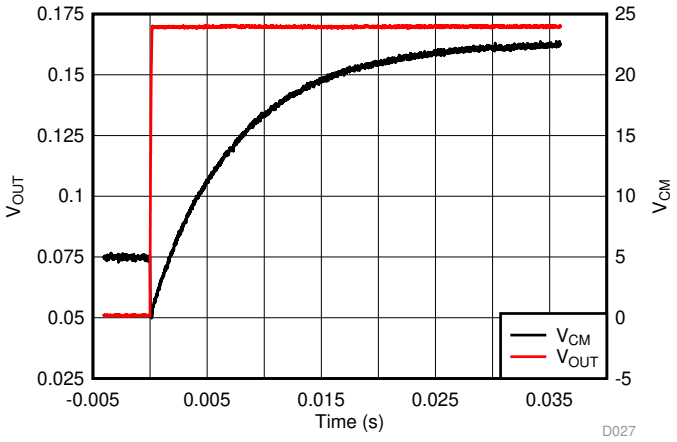


**図 46. INA253 Current Sense Output Response in Remote I/O**


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# 10 Power Supply Recommendations

The INA253 makes accurate measurements beyond the connected power-supply voltage (VS) because the inputs (IN+ and IN–) operate anywhere between –4 V and +80 V, independent of VS. For example, the VS power supply equals 5 V and the common-mode voltage of the measured shunt can be as high as 80 V. Although the common-mode voltage of the input can be beyond the supply voltage, the output voltage range of the INA253 is constrained to the supply voltage.

Place the power-supply bypass capacitor as close as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1 μF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies. If the INA253 output is set to mid-supply, then take extreme care to minimize noise on the power supply.

# 11 Layout

## 11.1 Layout Guidelines

- This device is specified for current handling of up to 10 A over the entire –40°C to +125°C temperature range using a 1-oz copper pour for the input power plane, as well as no external airflow passing over the device.
- The primary current-handling limitation for this device is how much heat is dissipated inside the package. Efforts to improve heat transfer out of the package and into the surrounding environment improve the ability of the device to handle currents of up to 15 A over the entire –40°C to +125°C temperature range.
- Heat transfer improvements primarily involve larger copper power traces and planes with increased copper thickness (2 oz), as well as providing airflow to pass over the device. The INA253 evaluation module (EVM) features a 2-oz copper pour for the planes, and is capable of supporting 15 A at temperatures up to 125°C.
- Place the power-supply bypass capacitor as close as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1 μF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

## 11.2 Layout Example

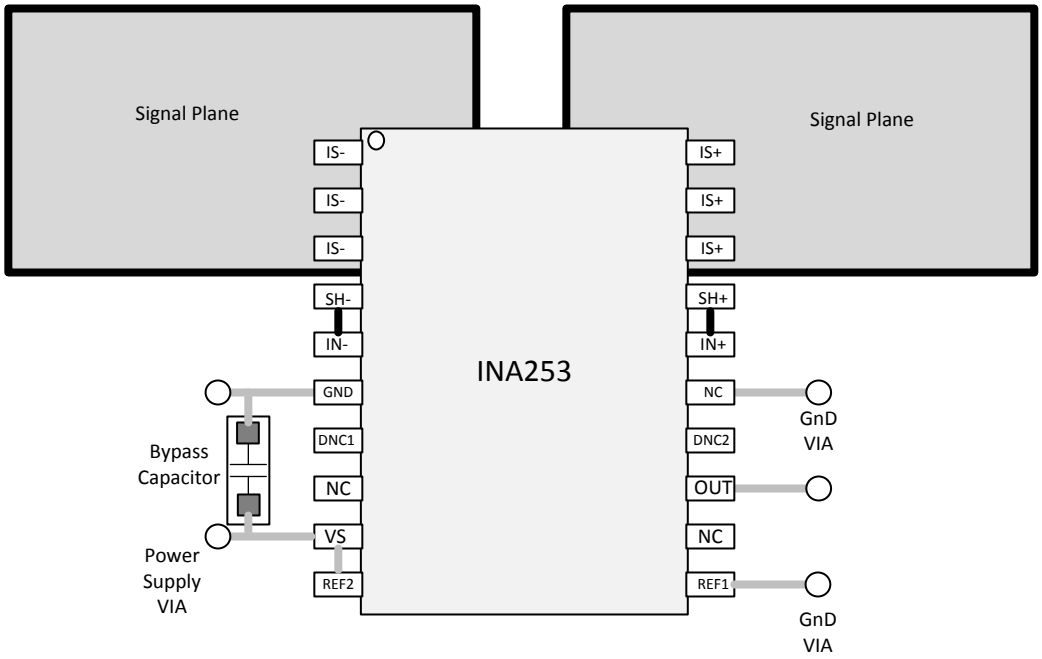


**図 47. INA253 Layout Example**

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# 12 デバイスおよびドキュメントのサポート

## 12.1 デバイス・サポート

### 12.1.1 開発サポート

*INA253評価モジュール(EVM)*

## 12.2 関連資料

関連資料については、以下を参照してください。*『INA253EVMユーザー・ガイド』*

## 12.3 ドキュメントの更新通知を受け取る方法

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## 12.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

# 13 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。


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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INA253A1IPW | NRND | TSSOP | PW | 20 | 70 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A1 | |
| INA253A1IPWR | ACTIVE | TSSOP | PW | 20 | 2000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A1 | Samples |
| INA253A2IPW | NRND | TSSOP | PW | 20 | 70 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A2 | |
| INA253A2IPWR | ACTIVE | TSSOP | PW | 20 | 2000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A2 | Samples |
| INA253A3IPW | NRND | TSSOP | PW | 20 | 70 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A3 | |
| INA253A3IPWR | ACTIVE | TSSOP | PW | 20 | 2000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | I253A3 | Samples |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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**OTHER QUALIFIED VERSIONS OF INA253 :**

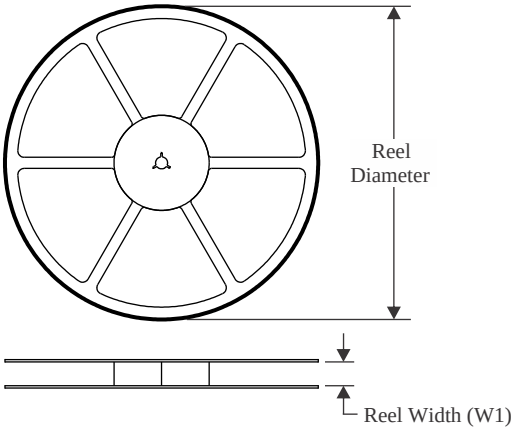
- Automotive : INA253-Q1

NOTE: Qualified Version Definitions:

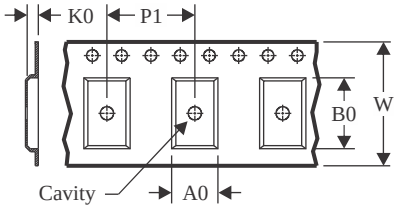
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

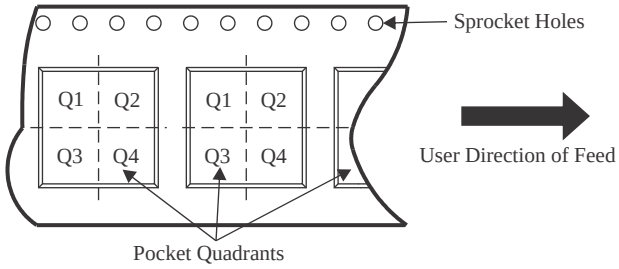



**TAPE DIMENSIONS**




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

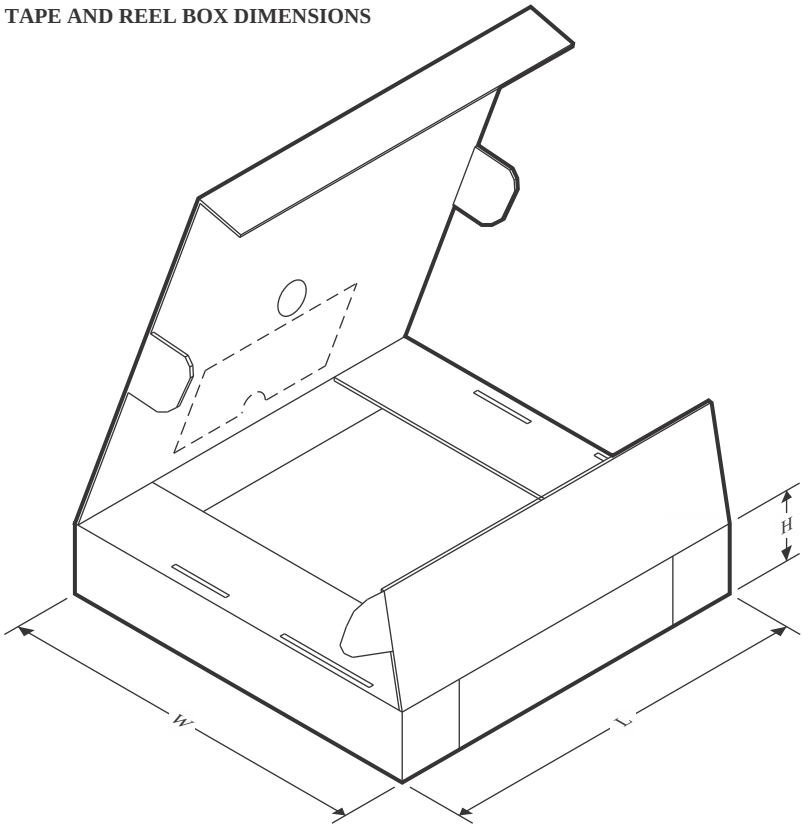
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA253A1IPWR | TSSOP | PW | 20 | 2000 | 330.0 | 16.4 | 6.95 | 7.0 | 1.4 | 8.0 | 16.0 | Q1 |
| INA253A2IPWR | TSSOP | PW | 20 | 2000 | 330.0 | 16.4 | 6.95 | 7.0 | 1.4 | 8.0 | 16.0 | Q1 |
| INA253A3IPWR | TSSOP | PW | 20 | 2000 | 330.0 | 16.4 | 6.95 | 7.0 | 1.4 | 8.0 | 16.0 | Q1 |

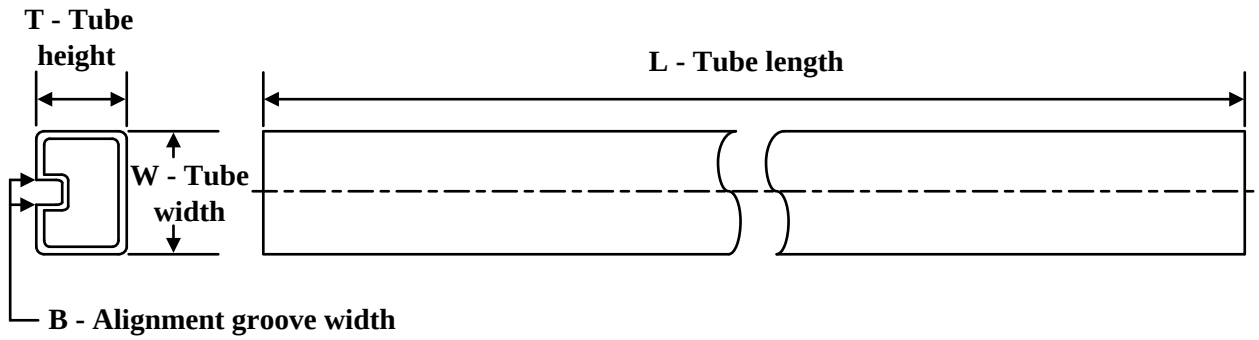
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA253A1IPWR | TSSOP | PW | 20 | 2000 | 356.0 | 356.0 | 35.0 |
| INA253A2IPWR | TSSOP | PW | 20 | 2000 | 356.0 | 356.0 | 35.0 |
| INA253A3IPWR | TSSOP | PW | 20 | 2000 | 356.0 | 356.0 | 35.0 |

## TUBE




*All dimensions are nominal

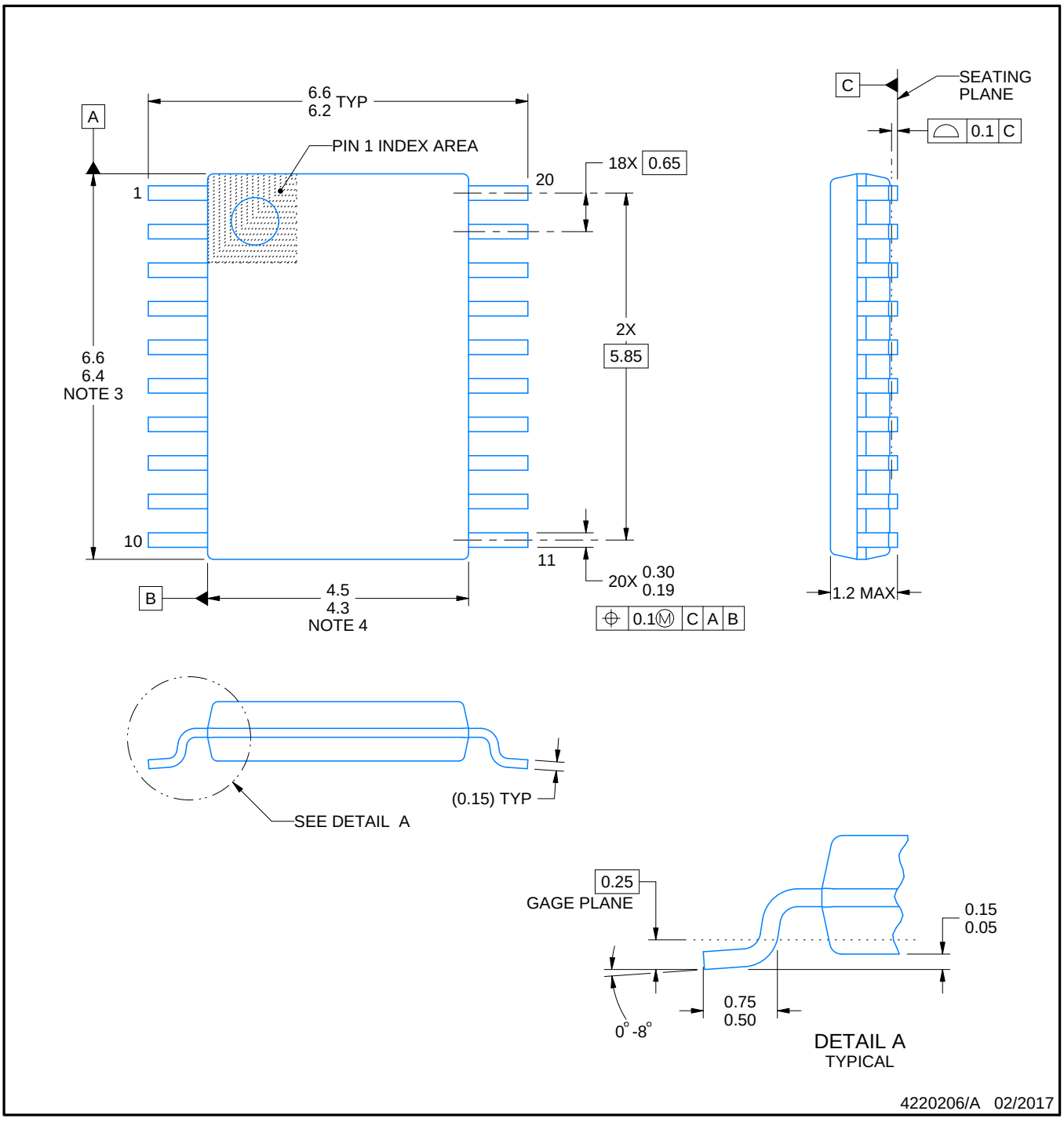
| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (µm) | B (mm) |
|---|---|---|---|---|---|---|---|---|
| INA253A1IPW | PW | TSSOP | 20 | 70 | 530 | 10.2 | 3600 | 3.5 |
| INA253A2IPW | PW | TSSOP | 20 | 70 | 530 | 10.2 | 3600 | 3.5 |
| INA253A3IPW | PW | TSSOP | 20 | 70 | 530 | 10.2 | 3600 | 3.5 |

# PACKAGE OUTLINE

## PW0020A

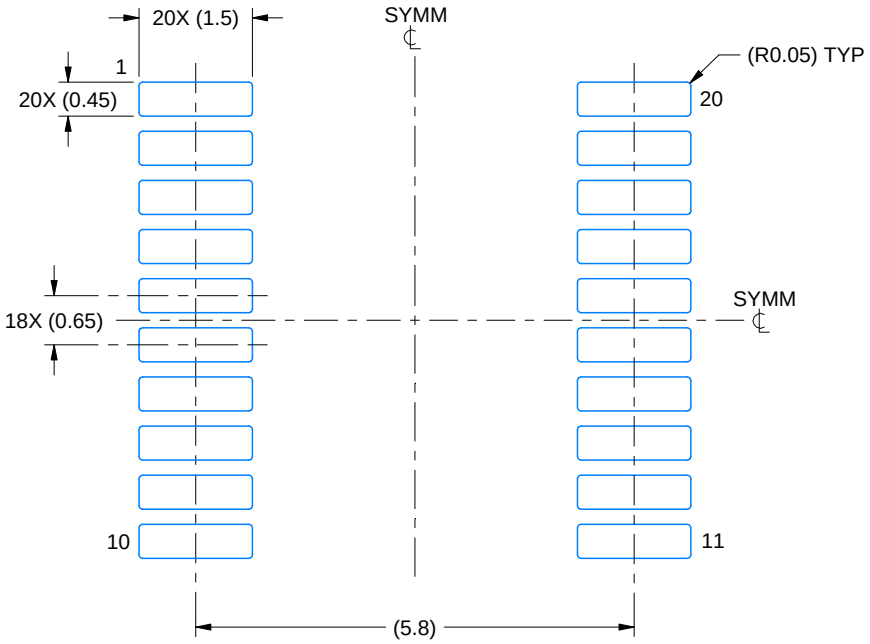
## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE




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-153.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

NON-SOLDER MASK DEFINED (PREFERRED)

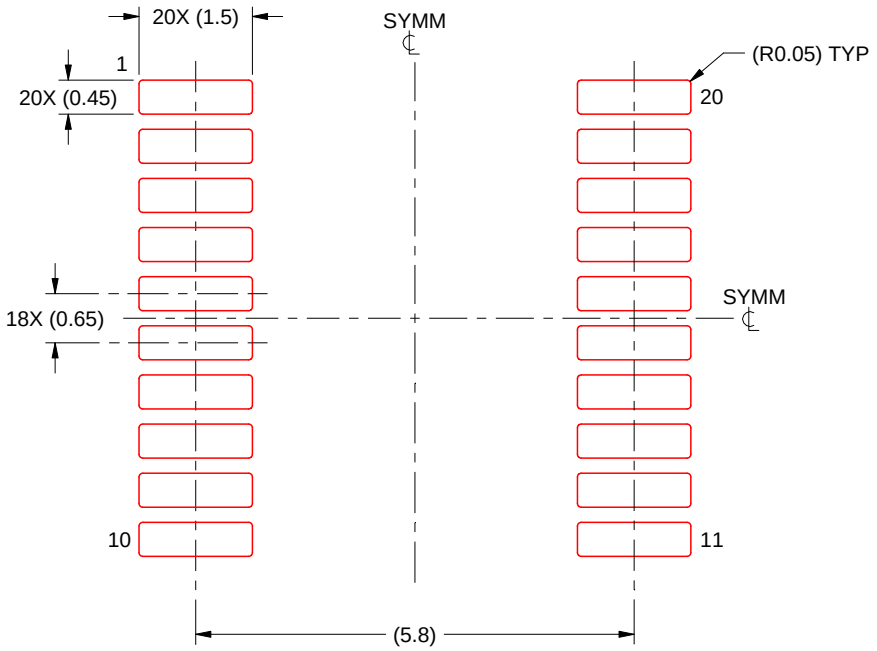
SOLDER MASK DEFINED

SOLDER MASK DETAILS

4220206/A 02/2017

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.




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

4220206/A 02/2017

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.

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