INA253 High Voltage, Bidirectional, Zero-Drift, Current-Shunt Monitor with Integrated 2-mΩ Precision Low Inductive Shunt Resistor

1 Features

- Precision Integrated Shunt Resistor
  - Shunt Resistor: 2 mΩ
  - Shunt Inductance: 3 nH
  - Shunt Resistor Tolerance: 0.1% (Max)
  - ±15 A Continuous from – 40°C to 85°C
  - 0°C to 125°C Temperature Coefficient: 10 ppm/°C
- Higher –3 dB Bandwidth of 380 Khz
- Enhanced PWM rejection
- Excellent CMRR
  - >120-dB DC CMRR
  - 90-dB AC CMRR at 50 kHz
- Accuracy:
  - Gain:
    - Gain Error: 0.75% (Max)
    - Gain Drift: 45 ppm/°C (Max)
  - Offset:
    - Offset Current: ±12.5 mA (Max)
    - Offset Drift: 125 µA/°C (Max)
- Wide Common-Mode Range: –4 V to 80 V
- Available Gains: 100 mV/A, 200 mV/A, and 400 mV/A
- Quiescent Current: 3 mA (Max)

2 Applications

- Solenoid and Valve Controls
- Transmission control
- Motor Controls
- Actuator Controls
- DC-DC Converters
- Factory Automation

3 Description

The INA253 is a voltage-output, current sense amplifier with an integrated shunt resistor of 2 mΩ. The INA253 is designed to monitor bi-directional currents over a wide command mode range from –4 V to 80 V, independent of the supply voltage. Three fixed gains are available: 100 mV/A, 200 mV/A, and 400 mV/A. The integration of the precision resistor with a zero-drift chopped amplifier provides calibration equivalent measurement accuracy, ultra-low temperature drift performance of 15 ppm/°C, and an optimized Kelvin layout for the sensing resistor.

The INA253 is designed with enhanced PWM rejection circuitry to suppress large (dv/dt) signals to enable real time continuous current measurements. The measurements are critical for in-line current measurements in a motor drive application and for Solenoid valve control applications.

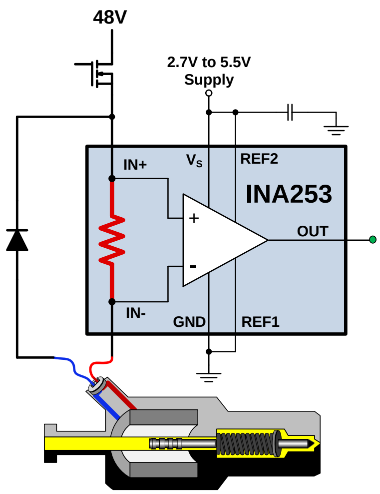
This device operates from a single 2.7-V to 5.5-V power supply, drawing a maximum of 3 mA of supply current. All gain versions are specified over the extended operating temperature range (–40°C to 125°C) and are available in an 20-pin TSSOP package.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA253	TSSOP (20)	6.50 mm × 4.40 mm

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

Simple Schematic



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4 Revision History

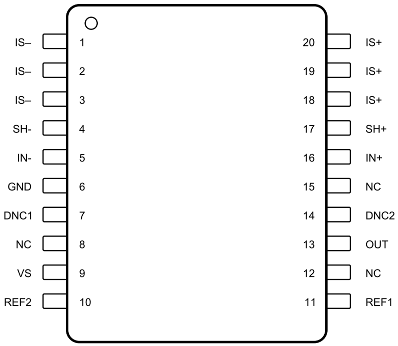
DATE	REVISION	NOTES
May 2018	*	Initial release.

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 it 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 it floating.
15	NC	Analog	Reserved, Recommended to connect it 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

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 (VIN+, VIN-)	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	UNIT
		PW (TSSOP)	
		20 PINS	
$R_{\theta JA}$	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
ψ_{JT}	Junction-to-top characterization parameter	114.1	°C/W
ψ_{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.

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		±11		mA/V
I_{OS}	Offset current, input-referred	I_{SENSE} = 0 A		±2.5	±12.5	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		±0.25%	±0.75%	
		T_A = –40°C to +125°C		±0.5	±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}=0V, 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

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
	Settling time - output settles to 0.5% of final value	INA253A1, INA253A2, INA253A3		10		µs
SR	Slew rate			2		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	
TEMPERATURE RANGE						
	Specified range		–40		125	°C
	Operating range		–55		150	°C

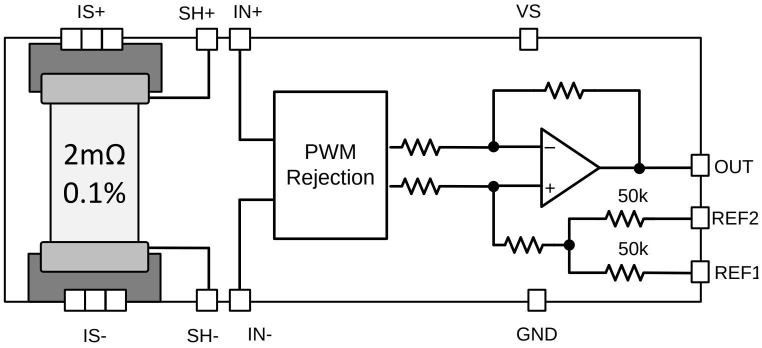
(4) See *Bandwidth* section for more details

8 Detailed Description

8.1 Overview

The INA253 features a 2-mΩ, precision, current-sensing resistor and a 80-V common-mode, zero-drift topology, precision, excellent common-mode rejection ratio (CMRR). It features enhanced pulse width modulation (PWM) rejection current-sensing amplifier integrated into a single package. High precision measurements are enabled through the matching of the shunt resistor value and the current-sensing amplifier gain providing a highly-accurate, system-calibrated solution. 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. 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 to allow for precision measurements over the entire specified temperature range of –40°C to 125°C. The integrated current-sensing resistor ensures measurement stability over temperature as well as improving 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 via the SH+ and SH– pins, this resistor is not intended to be used as a stand-alone component. The INA253 is system-calibrated to ensure 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. 2 mΩ of this total package resistance 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 IN+ and IN– 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 carrying 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 ensure that the heat dissipated across the package is limited so that no damage to the resistor or the package itself occurs or that the internal junction temperature of the silicon does not exceed a 150°C limit.

Feature Description (continued)

External factors (such as ambient temperature, external air flow, and PCB layout) can contribute to how effectively the heat developed as a result of the current flowing through the total package resistance can be removed from within the device. Under the conditions of no air flow, a maximum ambient temperature of 85°C, and 1-oz. copper input power planes, the INA253 can accommodate continuous current levels up to 15 A. As shown in Figure 1, the current handling capability is derated at temperatures above 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 can safely accommodate continuous current levels up to 15 A over the entire –40°C to 125°C temperature range.

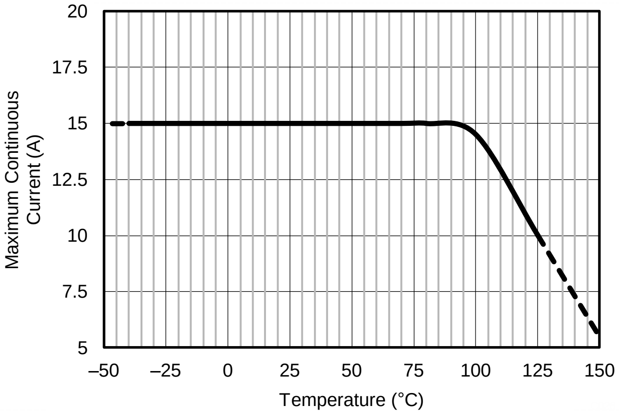


Figure 1. Maximum Continuous Current vs Temperature

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. Figure 2 shows the short-circuit duration curve for the INA253.

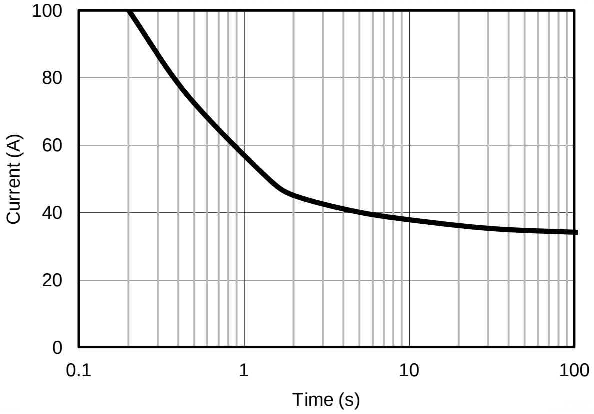


Figure 2. Short-Circuit Duration

8.3.3 Temperature Stability

System calibration is common for many industrial applications to eliminate initial component and system-level errors that can be present. A system-level calibration can reduce the initial accuracy requirement for many of the individual components because the errors associated with these components are effectively eliminated through the calibration procedure. Performing this calibration enables precision measurements at the temperature in which the system is calibrated. As the system temperature changes as a result of external ambient changes or due to self heating, measurement errors are reintroduced. Without accurate temperature compensation used in

Feature Description (continued)

addition to the initial adjustment, the calibration procedure is not effective. The user must account for the temperature-induced changes. One of the primary benefits of the low temperature coefficient of the INA250 (including both the integrated current-sensing resistor and current-sensing amplifier) is ensuring that the device measurement remains accurate, even when the temperature changes throughout the specified temperature range of the device.

For the integrated current-sensing resistor, the drift performance is shown in Figure 3. Although several temperature ranges are specified in the table, applications operating in ranges other than those described can use Figure 3 to determine how much variance in the shunt resistor value can be expected. 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 INA250, 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.

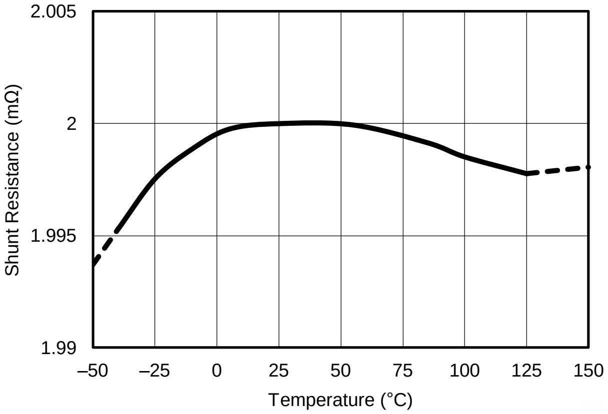


Figure 3. Sensing Resistor vs Temperature

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 ΔV/Δt transients. Large ΔV/Δt common-mode transients associated with PWM signals are employed in applications such as motor or solenoid drive and switching power supplies. Traditionally, large ΔV/Δt 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 ΔV/Δt 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.

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 Specifications. 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.

ADVANCE INFORMATION

Feature Description (continued)

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.

For applications requiring distortion sensitive signals, Figure 4 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 is required to determine the acceptance criteria and to validate the performance levels meet the system specifications.

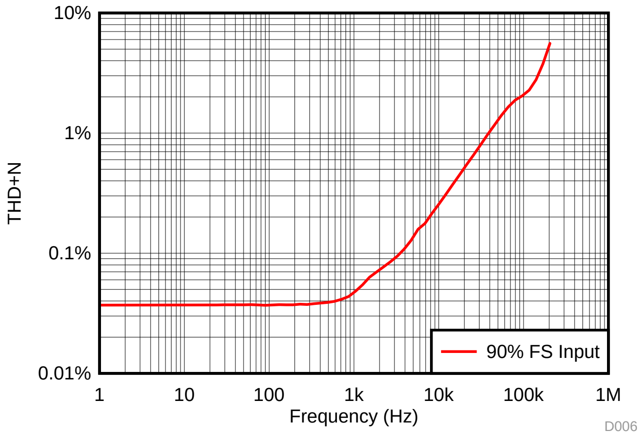


Figure 4. Performance Over Frequency

8.4 Device Functional Modes

8.4.1 Adjusting the Output Midpoint With the Reference Pins

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

NOTE

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.

Device Functional Modes (continued)

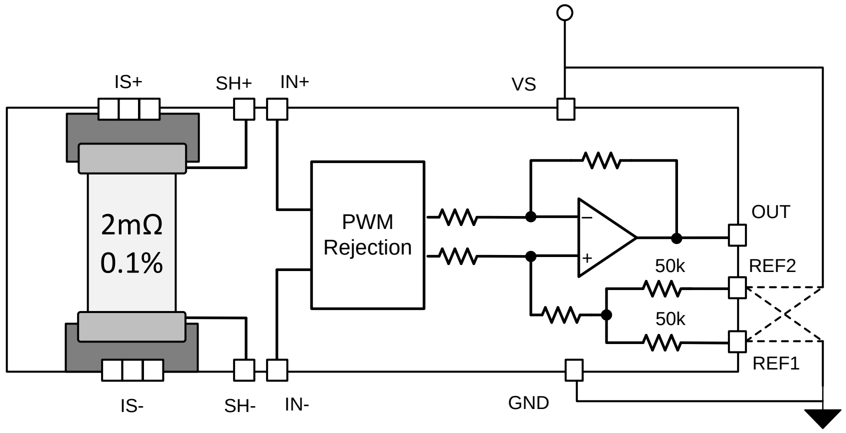


Figure 5. Adjusting the Output Midpoint

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 a unidirectional mode with a ground referenced output, both reference inputs are connected to ground; this configuration takes the output to ground when there is a 0-A flowing across the internal shunt (as Figure 6 shows).

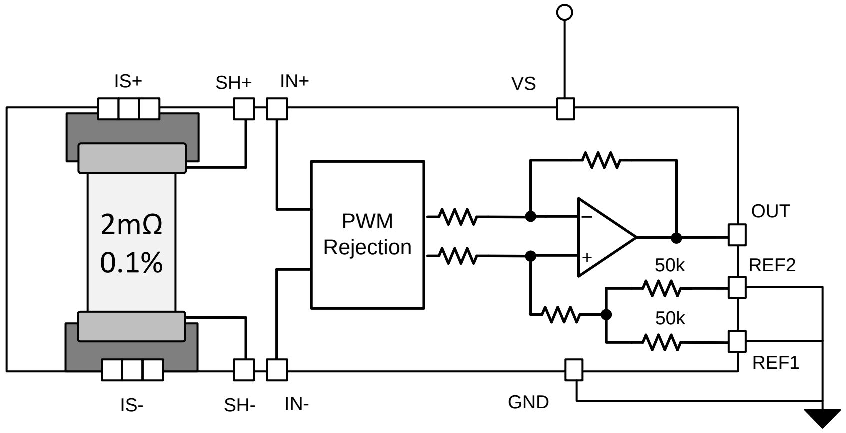


Figure 6. Ground Referenced Output

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 operation case, the output voltage can be set 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 non-symmetrical.

Device Functional Modes (continued)

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. This configuration is shown in Figure 7. 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.

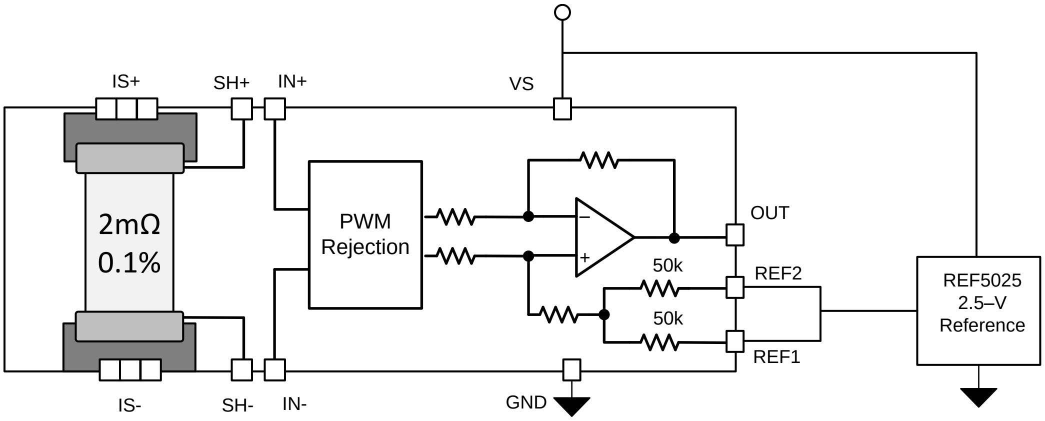


Figure 7. External Reference Output

8.4.5 Output Set to Mid-Supply Voltage

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, as shown in Figure 8. This method creates a ratiometric offset to the supply voltage, where the output voltage remains at VS / 2 for 0 V applied to the inputs.

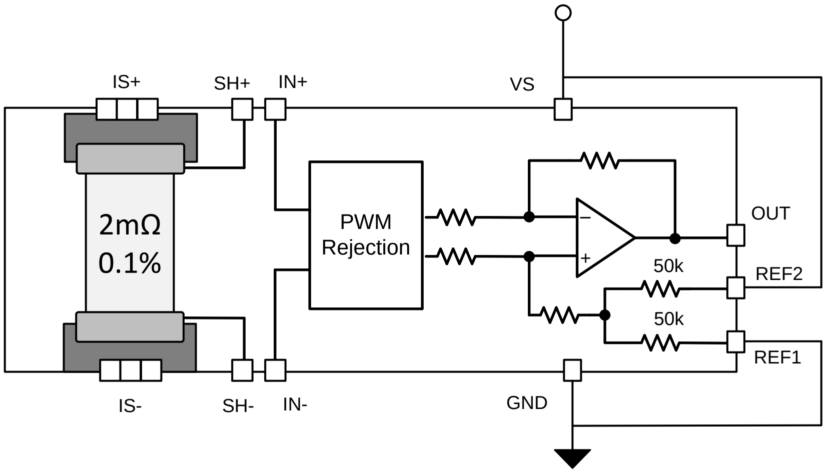


Figure 8. Mid-Supply Voltage Output

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 Figure 9.

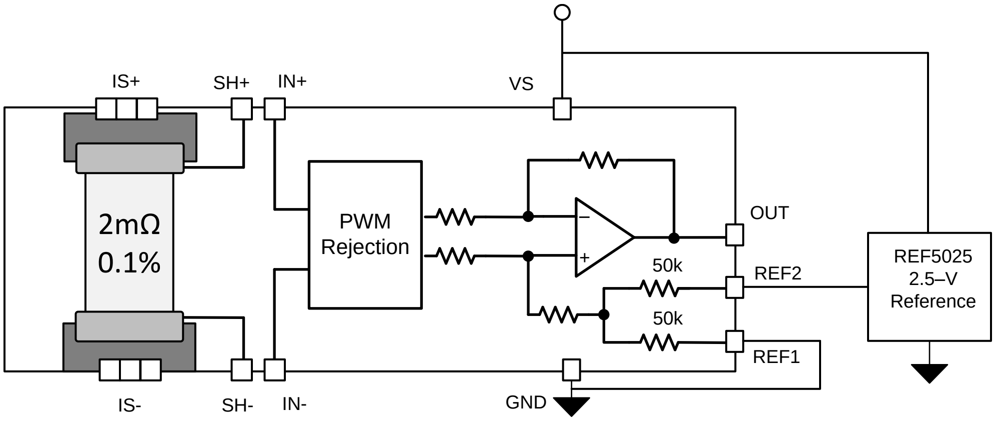


Figure 9. Mid-External Reference Output

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 Figure 10, use the output as a differential signal with respect to the resistor divider voltage. Use of the amplifier output as a single-ended signal in this configuration is not recommended because the internal impedance shifts can adversely affect device performance specifications.

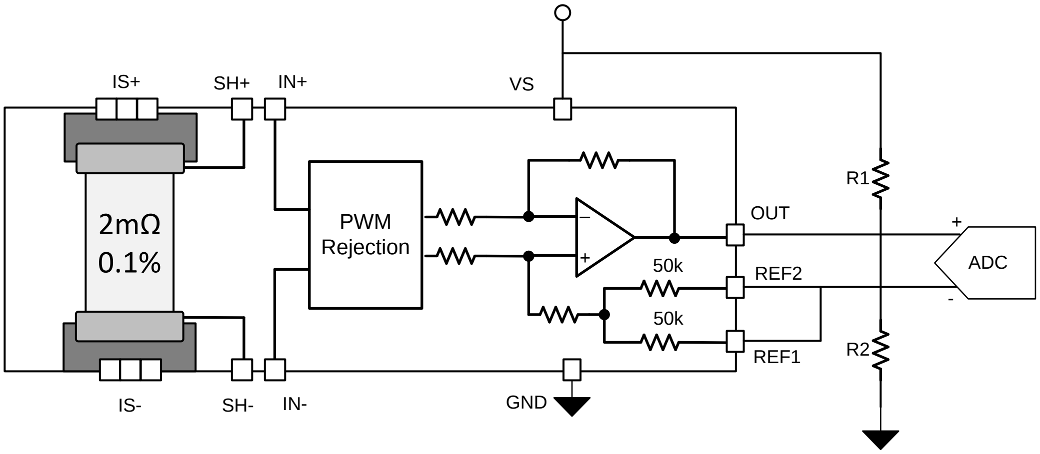


Figure 10. Setting the Reference Using a Resistor Divider

9 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. 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

NOTE

Input filters are not required for accurate measurements using the INA253. Use of filters in this location is not recommended. If filter components are used on the input of the amplifier, follow the guidelines in this section to minimize the 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 satisfies the filtering requirement also, but the components should be carefully selected to minimally impact device performance. Figure 11 shows a filter placed at the inputs pins.

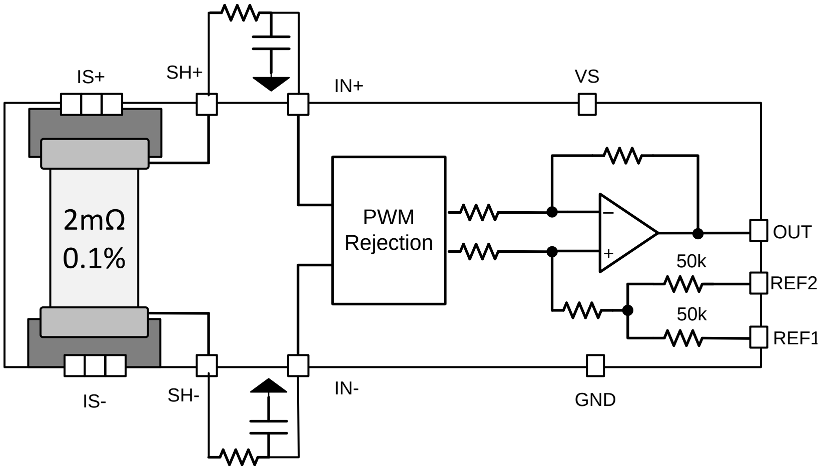


Figure 11. Filter at Input Pins

External series resistance provide a source of additional measurement error, so keep the value of these series resistors to 10-Ω or less to reduce loss of accuracy. The internal bias network shown in Figure 11 creates a mismatch in input bias currents (see Figure 12) when a differential voltage is applied between the input pins. 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.

Application Information (continued)

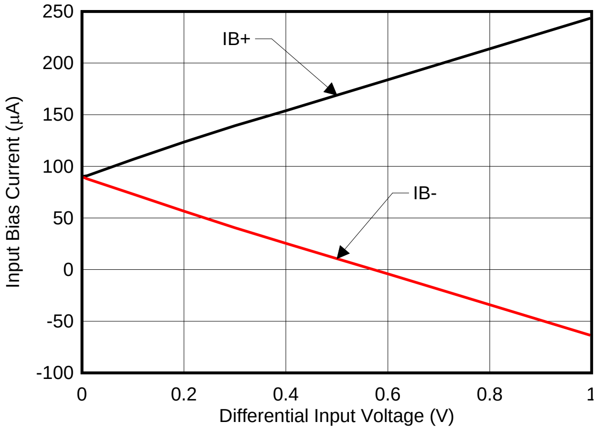


Figure 12. Input Bias Current vs Differential Input Voltage

The measurement error expected from the additional external filter resistors can be calculated using Equation 1, where the gain error factor is calculated using Equation 2.

$$\text{Gain Error (\%)} = 100 - (100 \times \text{Gain Error Factor}) \tag{1}$$

The gain error factor, shown in Equation 1, can be calculated to determine the gain error introduced by the additional external series resistance. Equation 1 calculates the deviation of the shunt voltage resulting from the attenuation and imbalance created by the added external filter resistance. Table 1 provides the gain error factor and gain error for several resistor values.

$$\text{Gain Error Factor} = \frac{3000}{R_S + 3000}$$

Where:

- R_S is the external filter resistance value (2)

Table 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

ADVANCE INFORMATION

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 over temperature 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 well suited 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.

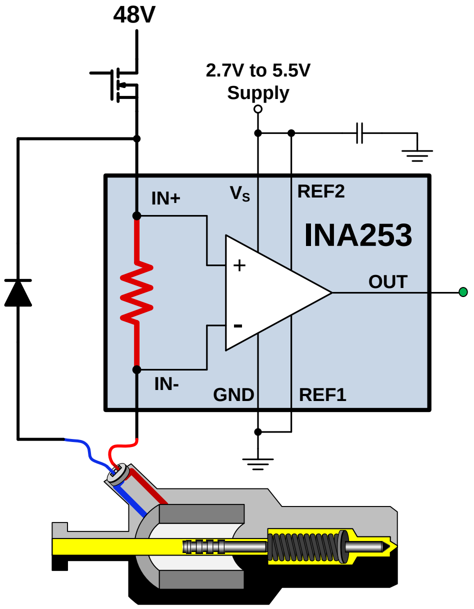


Figure 13. Solenoid Drive Application Circuit

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.

Table 2. Design Parameters

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

9.2.1.2 Detailed Design Procedure

To demonstrate the performance of the device, the INA253 with a gain of 400mV/A was 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

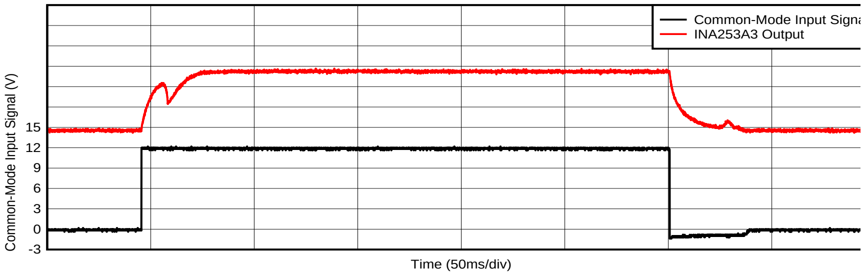


Figure 14. Solenoid Drive Current Sense Input and Output Signals

9.2.2 Speaker Enhancements and Diagnostics using Current Sense Amplifier

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

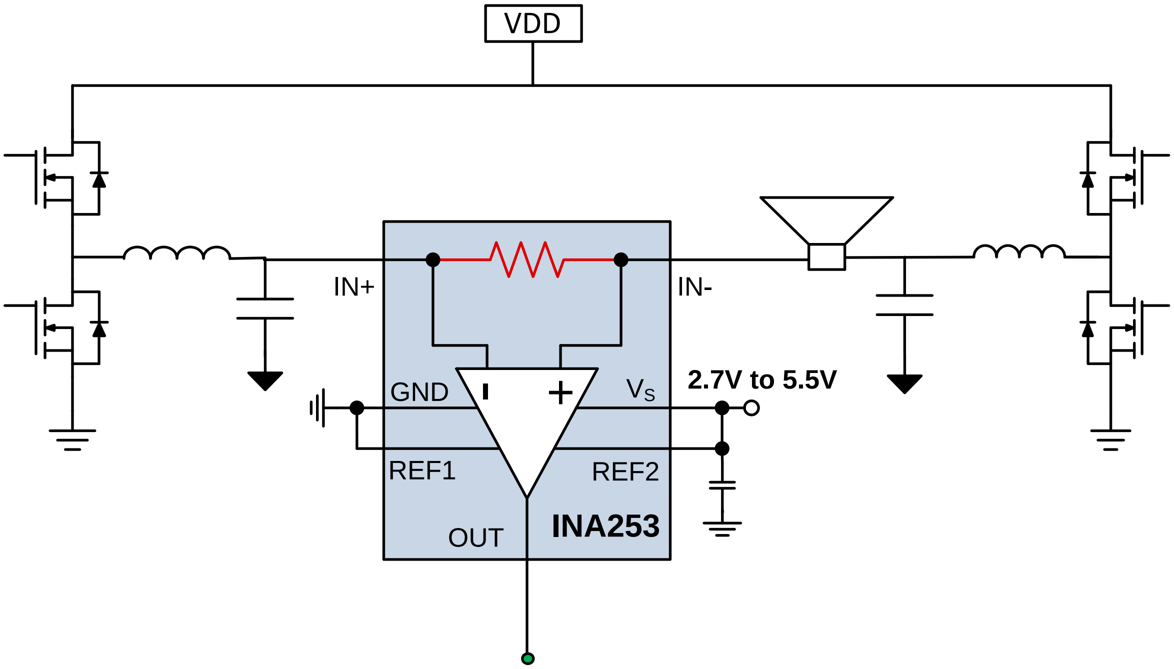


Figure 15. Current Sensing in a CLASS-D subsystem

9.2.2.1 Design Requirements

Table 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 - 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 a low inductance of 3 nH is ideal for current sensing in speaker application. The low inductive shunt enables accurate current sensing across frequencies over the range of audio 20 hz to 20 kHz.

The INA253 is setup in a bi-directional with the reference set to mid-supply. 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.

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 Figure 16.

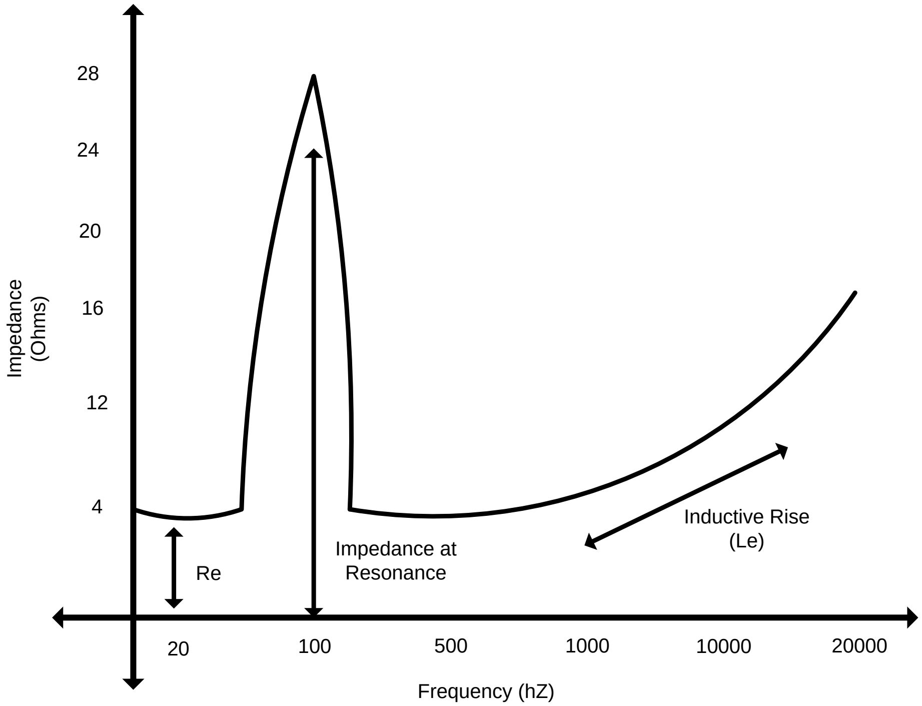


Figure 16. Speaker Impedance Measurement

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 series 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 extreme care must be taken to minimize noise on the power supply.

11 Layout

11.1 Layout Guidelines

- The INA253 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 the INA253 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 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

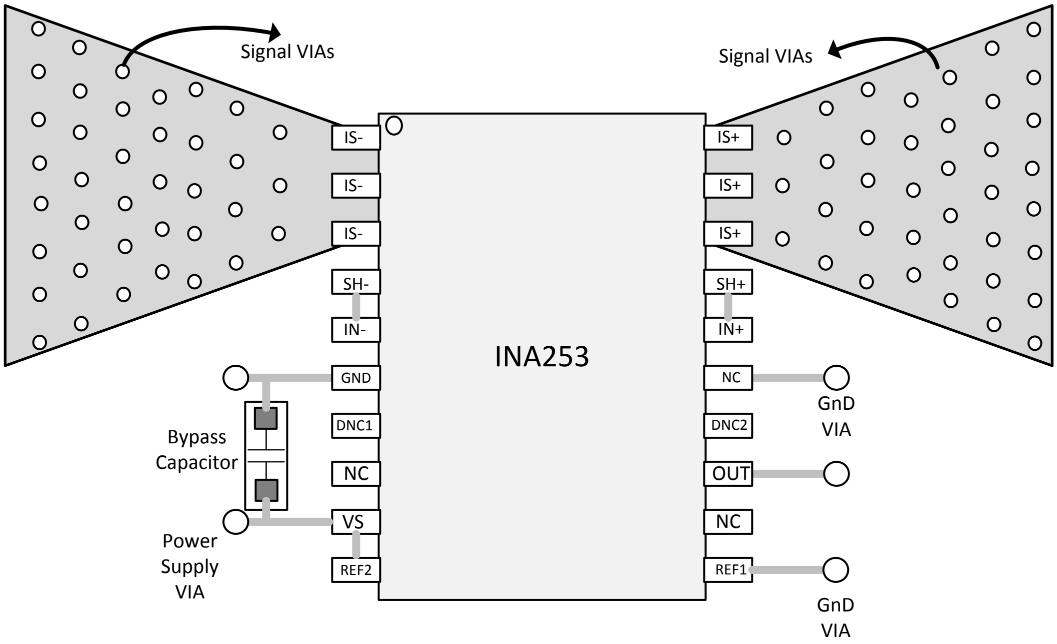


Figure 17. INA253 Layout Example

ADVANCE INFORMATION

12 Device and Documentation Support

12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* 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.

12.2 Community Resources

The following links connect to TI community resources. Linked contents are 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.

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Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.3 Trademarks

E2E is a trademark of Texas Instruments.

12.4 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.5 Glossary

SLYZ022 — *TI Glossary*.

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

13 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 Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PINA253A1IPW	ACTIVE	TSSOP	PW	20	70	TBD	Call TI	Call TI	-40 to 125		Samples
PINA253A2IPW	ACTIVE	TSSOP	PW	20	1	TBD	Call TI	Call TI	-40 to 125		Samples
PINA253A3IPW	ACTIVE	TSSOP	PW	20	70	TBD	Call TI	Call TI	-40 to 125		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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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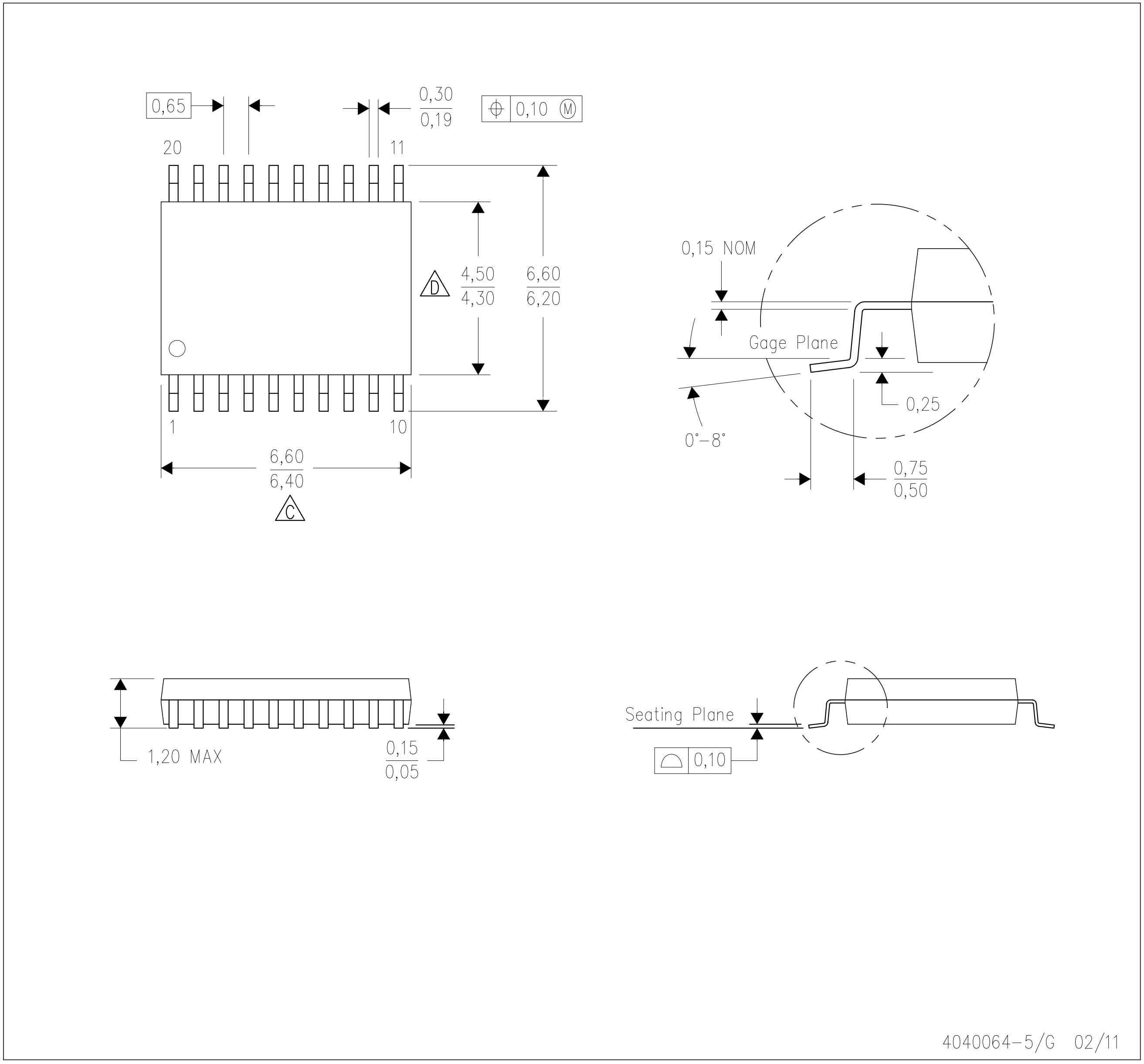
PW (R–PDSO–G20) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
- B. This drawing is subject to change without notice.
- C Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
- D Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
- E. Falls within JEDEC MO–153

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