SBOS393C – MARCH 2007 – REVISED OCTOBER 2007

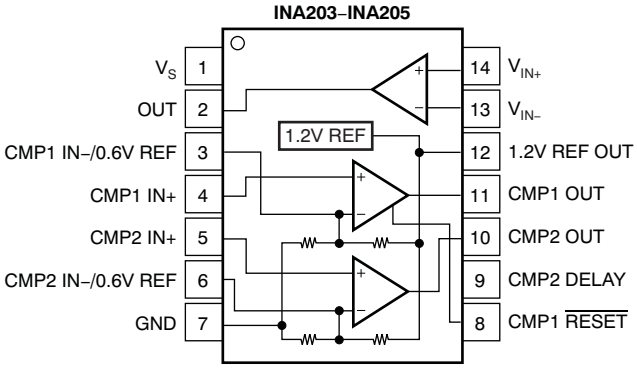
Unidirectional Measurement Current-Shunt Monitor with Dual Comparators

FEATURES

- **COMPLETE CURRENT SENSE SOLUTION**
- **DUAL COMPARATORS:**
  - **Comparator 1 with Latch**
  - **Comparator 2 with Optional Delay**
- **COMMON-MODE RANGE: –16V to +80V**
- **HIGH ACCURACY: 3.5% (max) Over Temperature**
- **BANDWIDTH: 500kHz**
- **QUIESCENT CURRENT: 1.8mA**
- **PACKAGES: SO-14, TSSOP-14, MSOP-10**

APPLICATIONS

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



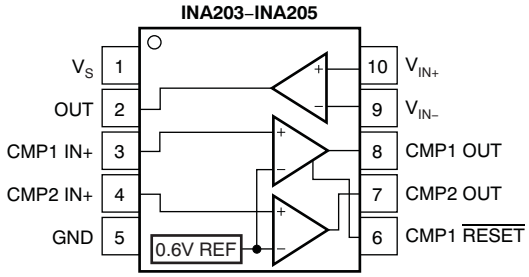
SO-14, TSSOP-14

DESCRIPTION

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

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

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



MSOP-10

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

RELATED PRODUCTS

FEATURES	PRODUCT
Variant of INA203–INA205 Comparator 2 polarity	INA206–INA208
Current-shunt monitor with single Comparator and V_{REF}	INA200–INA202
Current-shunt monitor only	INA193–INA198
Current-shunt monitor with split stages for filter options	INA270–INA271

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

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

ORDERING INFORMATION(1)

PRODUCT	GAIN	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING	1.2V REF OUT	EXTERNAL COMP1 AND COMP2 REF INPUTS	INTERNAL COMP1 AND COMP2 0.6V REF	COMP2 DELAY PIN
INA203	20V/V	SO-14	D	INA203A	X	X	X	X
		MSOP-10	DGS	BQN			X	
		TSSOP-14	PW	INA203A	X	X	X	X
INA204	50V/V	SO-14	D	INA204A	X	X	X	X
		MSOP-10	DGS	BQO			X	
		TSSOP-14	PW	INA204A	X	X	X	X
INA205	100V/V	SO-14	D	INA205A	X	X	X	X
		MSOP-10	DGS	BQP			X	
		TSSOP-14	PW	INA205A	X	X	X	X

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

		INA203, INA204, INA205	UNIT
Supply Voltage, V+		18	V
Current-Shunt Monitor Analog Inputs, V_{IN+} and V_{IN-}	Differential (V_{IN+}) – (V_{IN-})	–18 to +18	V
	Common-Mode	–16 to +80	V
Comparator Analog Input and Reset Pins		GND – 0.3 to (V+) + 0.3	V
Analog Output, Out Pin		GND – 0.3 to (V+) + 0.3	V
Comparator Output, Out Pin		GND – 0.3 to 18	V
V_{REF} and CMP2 Delay Pin		GND – 0.3 to 10	V
Input Current Into Any Pin		5	mA
Operating Temperature		–55 to +150	°C
Storage Temperature		–65 to +150	°C
Junction Temperature		+150	°C
ESD Ratings	Human Body Model (HBM)	4000	V
	Charged Device Model (CDM)	500	V

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

ELECTRICAL CHARACTERISTICS: CURRENT-SHUNT MONITOR

Boldface limits apply over the specified temperature range: **T_A = –40°C to +125°C.**
At T_A = +25°C, V_S = +12V, V_{CM} = +12V, V_{SENSE} = 100mV, R_L = 10kΩ to GND, $R_{PULL-UP}$ = 5.1kΩ each connected from CMP1 OUT and CMP2 OUT to V_S, and CMP1 IN+ = 1V and CMP2 IN– = GND, unless otherwise noted.

CURRENT-SHUNT MONITOR PARAMETERS		CONDITIONS	INA203, INA204, INA205			UNIT
			MIN	TYP	MAX	
INPUT						
Full-Scale Sense Input Voltage	V_{SENSE}	$V_{SENSE} = V_{IN+} - V_{IN-}$		0.15	$(V_S - 0.25)$/Gain	V
Common-Mode Input Range	**V_{CM}**		**–16**		**80**	**V**
Common-Mode Rejection Ratio	CMRR	V_{CM} = –16V to +80V	80	100		dB
Over Temperature		**V_{CM} = +12V to +80V**	**100**	**123**		**dB**
Offset Voltage, RTI(1)	V_{OS}			±0.5	±2.5	mV
+25°C to +125°C					±3	mV
–40°C to +25°C					±3.5	mV
vs Temperature	**dV_{OS}/dT**	**T_{MIN} to T_{MAX}**		**5**		**µV/°C**
vs Power Supply	**PSR**	**V_{OUT} = 2V, V_{CM} = +18V, 2.7V**		**2.5**	**100**	**µV/V**
Input Bias Current, V_{IN-} Pin	**I_B**			**±9**	**±16**	**µA**
OUTPUT (V_{SENSE} ≥ 20mV)						
Gain:	G					
INA203				20		V/V
INA204				50		V/V
INA205				100		V/V
Gain Error		V_{SENSE} = 20mV to 100mV		±0.2	±1	%
Over Temperature		**V_{SENSE} = 20mV to 100mV**			**±2**	**%**
Total Output Error(2)		V_{SENSE} = 120mV, V_S = +16V		±0.75	±2.2	%
Over Temperature		**V_{SENSE} = 120mV, V_S = +16V**			**±3.5**	**%**
Nonlinearity Error(3)		V_{SENSE} = 20mV to 100mV		±0.002		%
Output Impedance, Pin 2	R_O			1.5		Ω
Maximum Capacitive Load		No Sustained Oscillation		10		nF
OUTPUT (V_{SENSE} < 20mV)(4)						
INA203, INA204, INA205		–16V ≤ V_{CM} < 0V		300		mV
INA203		0V ≤ V_{CM} ≤ V_S, V_S = 5V			0.4	V
INA204		0V ≤ V_{CM} ≤ V_S, V_S = 5V			1	V
INA205		0V ≤ V_{CM} ≤ V_S, V_S = 5V			2	V
INA203, INA204, INA205		V_S < V_{CM} ≤ 80V		300		mV
VOLTAGE OUTPUT(5)						
Output Swing to the Positive Rail		**V_{IN-} = 11V, V_{IN+} = 12V**		**(V+) – 0.15**	**(V+) – 0.25**	**V**
Output Swing to GND(6)		**V_{IN-} = 0V, V_{IN+} = –0.5V**		**(V_{GND}) + 0.004**	**(V_{GND}) + 0.05**	**V**
FREQUENCY RESPONSE						
Bandwidth:	BW					
INA203		C_{LOAD} = 5pF		500		kHz
INA204		C_{LOAD} = 5pF		300		kHz
INA205		C_{LOAD} = 5pF		200		kHz
Phase Margin		C_{LOAD} < 10nF		40		Degrees
Slew Rate	SR			1		V/µs
Settling Time (1%)		V_{SENSE} = 10mV_{PP} to 100mV_{PP}, C_{LOAD} = 5pF		2		µs
NOISE, RTI						
Output Voltage Noise Density				40		nV/√Hz

(1) Offset is extrapolated from measurements of the output at 20mV and 100mV V_{SENSE}.
(2) Total output error includes effects of gain error and V_{OS}.
(3) Linearity is best fit to a straight line.
(4) For details on this region of operation, see the Accuracy Variations section in the Applications Information.
(5) See Typical Characteristic curve *Positive Output Voltage Swing vs Output Current* (Figure 8).
(6) Specified by design; not production tested.

ELECTRICAL CHARACTERISTICS: COMPARATOR

Boldface limits apply over the specified temperature range: **T_A = –40°C to +125°C.**
At T_A = +25°C, V_S = +12V, V_{CM} = +12V, V_{SENSE} = 100mV, R_L = 10kΩ to GND, and $R_{PULL-UP}$ = 5.1kΩ each connected from CMP1 OUT and CMP2 OUT to V_S, unless otherwise noted.

COMPARATOR PARAMETERS	CONDITIONS	INA203, INA204, INA205			UNIT
		MIN	TYP	MAX	
OFFSET VOLTAGE					
Offset Voltage	Comparator Common-Mode Voltage = Threshold Voltage		2		mV
Offset Voltage Drift, Comparator 1			**±2**		**µV/°C**
Offset Voltage Drift, Comparator 2			**+5.4**		**µV/°C**
Threshold	T_A = +25°C	590	608	620	mV
Over Temperature		**586**		**625**	**mV**
Hysteresis(1), CMP1	T_A = –40°C to +85°C		–8		mV
Hysteresis(1), CMP2	T_A = –40°C to +85°C		8		mV
INPUT BIAS CURRENT(2)					
CMP1 IN+, CMP2 IN+			0.005	10	nA
vs Temperature				**15**	**nA**
INPUT IMPEDANCE					
Pins 3 and 6 (14-pin packages only)			10		kΩ
INPUT RANGE					
CMP1 IN+ and CMP2 IN+			0V to V_S – 1.5V		V
Pins 3 and 6 (14-pin packages only)(3)			0V to V_S – 1.5V		V
OUTPUT					
Large-Signal Differential Voltage Gain	CMP V_{OUT} 1V to 4V, R_L ≥ 15kΩ Connected to 5V		200		V/mV
High-Level Output Current	V_{ID} = 0.4V, V_{OH} = V_S		0.0001	1	µA
Low-Level Output Voltage	V_{ID} = –0.6V, I_{OL} = 2.35mA		220	300	mV
RESPONSE TIME(4)					
Comparator 1	R_L to 5V, C_L = 15pF, 100mV Input Step with 5mV Overdrive		1.3		µs
Comparator 2	R_L to 5V, C_L = 15pF, 100mV Input Step with 5mV Overdrive, C_{DELAY} Pin Open		1.3		µs
RESET					
RESET Threshold(5)			1.1		V
Logic Input Impedance			2		MΩ
Minimum RESET Pulse Width			1.5		µs
RESET Propagation Delay			3		µs
Comparator 2 Delay Equation(6)			C_{DELAY} = t_D/5		µF
Comparator 2 Delay t_D	C_{DELAY} = 0.1µF		0.5		s

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

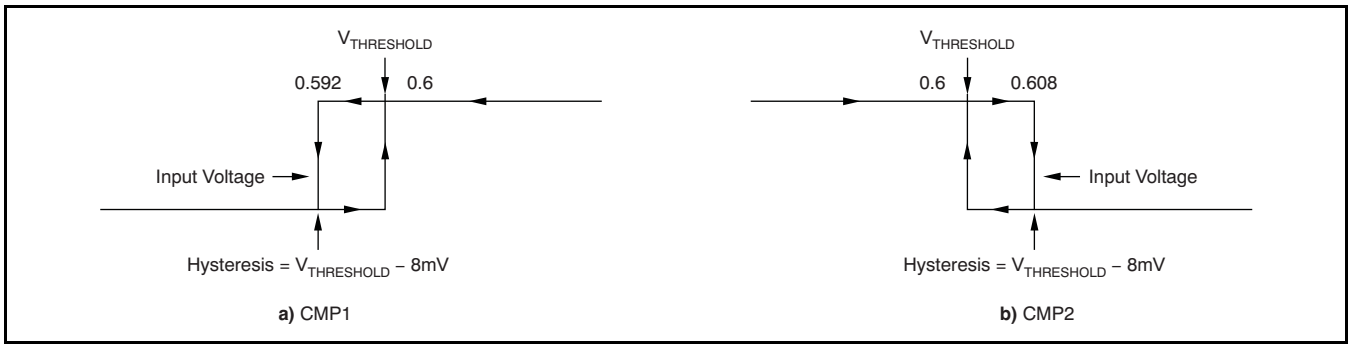


Figure 1. Comparator Hysteresis

ELECTRICAL CHARACTERISTICS: REFERENCE

Boldface limits apply over the specified temperature range: **T_A = –40°C to +125°C.**
At T_A = +25°C, V_S = +12V, V_{CM} = +12V, V_{SENSE} = 100mV, R_L = 10kΩ to GND, and $R_{PULL-UP}$ = 5.1kΩ each connected from CMP1 OUT and CMP2 OUT to V_S, unless otherwise noted.

REFERENCE PARAMETERS		CONDITIONS	INA203, INA204, INA205 MIN	TYP	MAX	UNIT
REFERENCE VOLTAGE						
1.2V_{REFOUT} Output Voltage			1.188	1.2	1.212	V
Reference Drift	dV_{OUT}/dT	T_A = –40°C to +85°C		40	100	ppm/°C
0.6V_{REF} Output Voltage (Pins 3 and 6 of 14-pin packages only)				0.6		V
Reference Drift	dV_{OUT}/dT	T_A = –40°C to +85°C		40	100	ppm/°C
LOAD REGULATION	**dV_{OUT}/dI_{LOAD}**					
Sourcing		0mA < I_{SOURCE} < 0.5mA		0.4	2	mV/mA
Sinking		0mA < I_{SINK} < 0.5mA		0.4		mV/mA
LOAD CURRENT	**I_{LOAD}**			1		mA
LINE REGULATION	**dV_{OUT}/dV_S**	2.7V < V_S < 18V		30		µV/V
CAPACITIVE LOAD						
Reference Output Maximum Capacitive Load		No Sustained Oscillations		10		nF
OUTPUT IMPEDANCE						
Pins 3 and 6 of 14-Pin Packages Only				10		kΩ

ELECTRICAL CHARACTERISTICS: GENERAL

Boldface limits apply over the specified temperature range: **T_A = –40°C to +125°C.**
All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, V_{SENSE} = 100mV, R_L = 10kΩ to GND, $R_{PULL-UP}$ = 5.1kΩ each connected from CMP1 OUT and CMP2 OUT to V_S, and CMP1 IN+ = 1V and CMP2 IN– = GND, unless otherwise noted.

GENERAL PARAMETERS		CONDITIONS	INA203, INA204, INA205 MIN	TYP	MAX	UNIT
POWER SUPPLY						
Operating Power Supply	**V_S**		**+2.7**		**+18**	**V**
Quiescent Current	I_Q	V_{OUT} = 2V		1.8	2.2	mA
Over Temperature		**V_{SENSE} = 0mV**			**2.8**	**mA**
Comparator Power-On Reset Threshold[1]				1.5		V
TEMPERATURE						
Specified Temperature Range			–40		+125	°C
Operating Temperature Range			–55		+150	°C
Storage Temperature Range			–65		+150	°C
Thermal Resistance	θ_{JA}					
MSOP-10 Surface-Mount				200		°C/W
SO-14, TSSOP-14 Surface-Mount				150		°C/W

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

TYPICAL CHARACTERISTICS

All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, and V_{SENSE} = 100mV, unless otherwise noted.

GAIN vs FREQUENCY

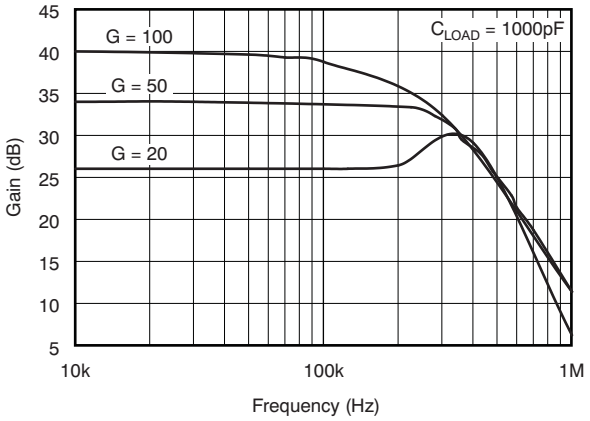


Figure 2.

GAIN vs FREQUENCY

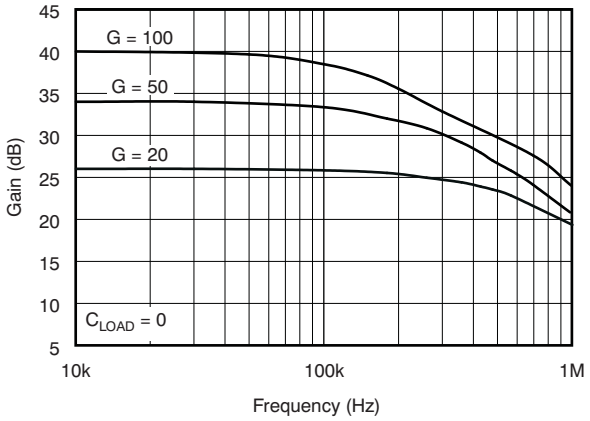


Figure 3.

GAIN PLOT

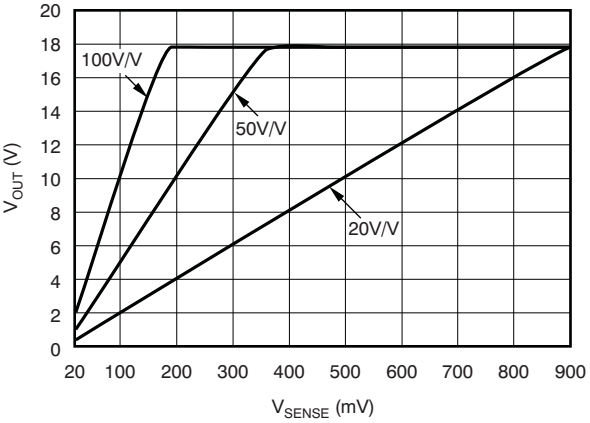


Figure 4.

COMMON-MODE AND POWER-SUPPLY REJECTION vs FREQUENCY

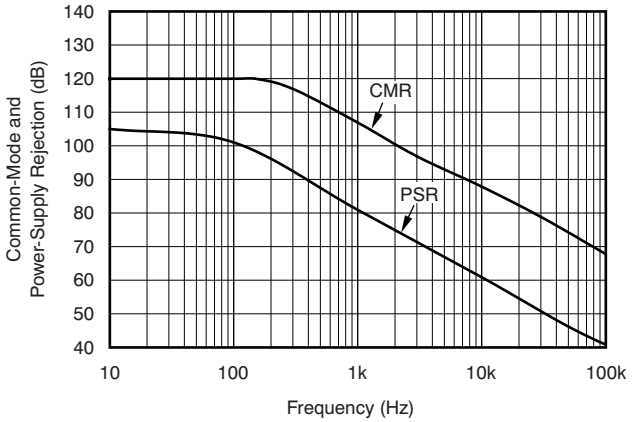


Figure 5.

TOTAL OUTPUT ERROR vs V_{SENSE}

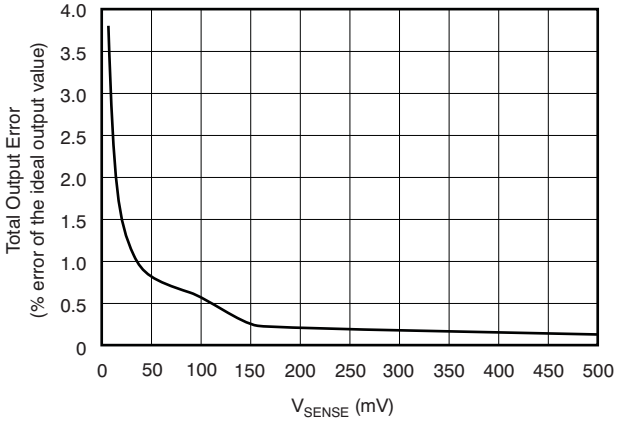


Figure 6.

TOTAL OUTPUT ERROR vs COMMON-MODE VOLTAGE

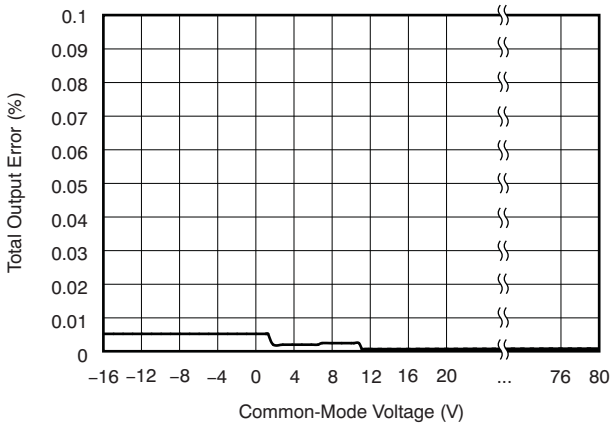


Figure 7.

TYPICAL CHARACTERISTICS (continued)

All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, and V_{SENSE} = 100mV, unless otherwise noted.

POSITIVE OUTPUT VOLTAGE SWING vs OUTPUT CURRENT

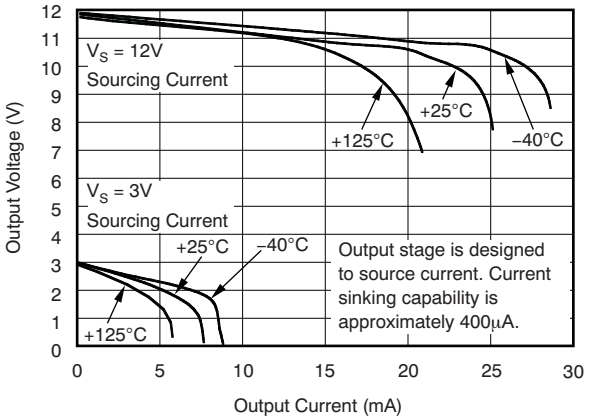


Figure 8.

QUIESCENT CURRENT vs OUTPUT VOLTAGE

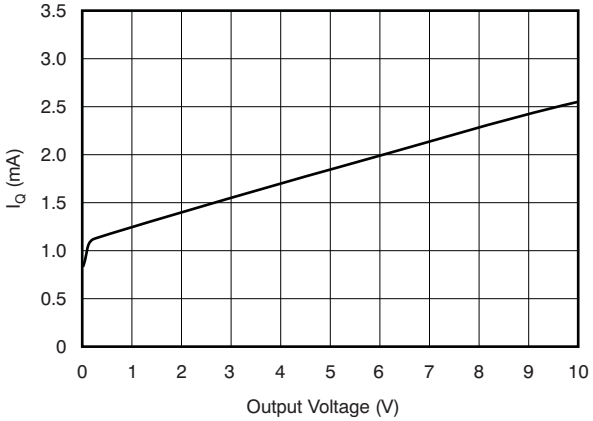


Figure 9.

QUIESCENT CURRENT vs COMMON-MODE VOLTAGE

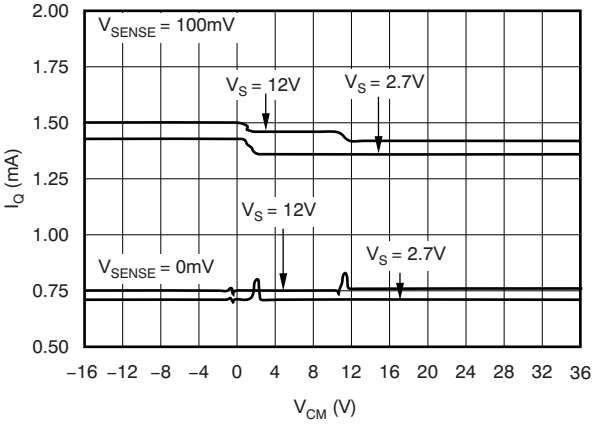


Figure 10.

OUTPUT SHORT-CIRCUIT CURRENT vs SUPPLY VOLTAGE

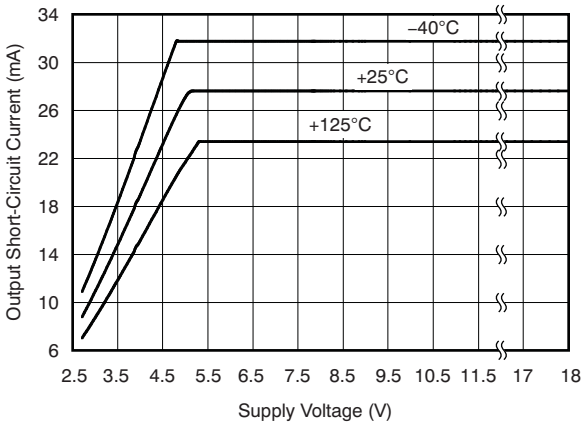


Figure 11.

STEP RESPONSE

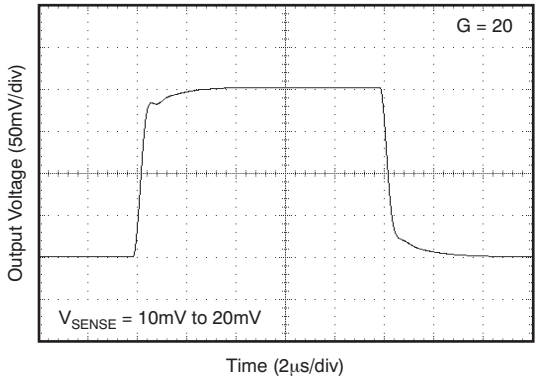


Figure 12.

STEP RESPONSE

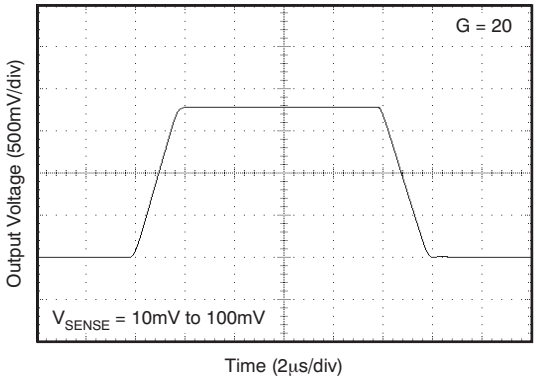


Figure 13.

TYPICAL CHARACTERISTICS (continued)

All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, and V_{SENSE} = 100mV, unless otherwise noted.

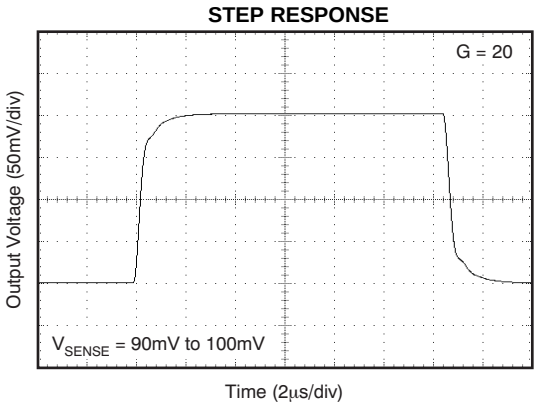


Figure 14.

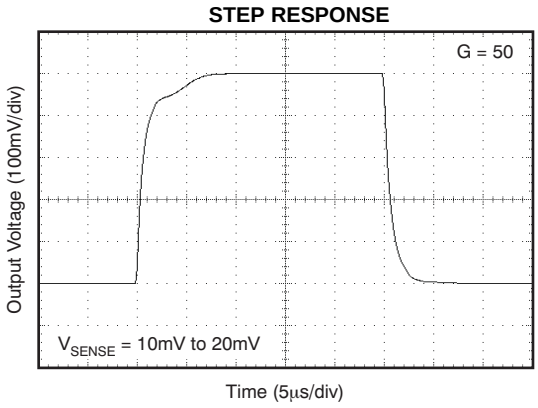


Figure 15.

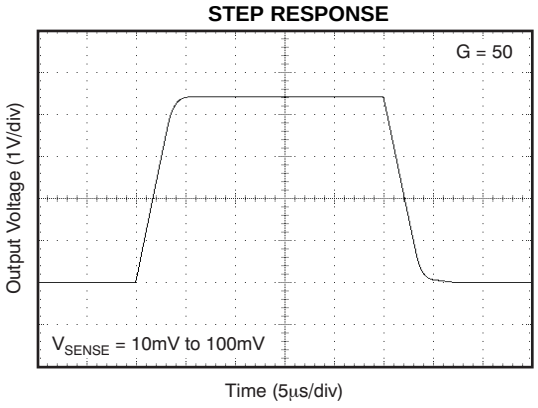


Figure 16.

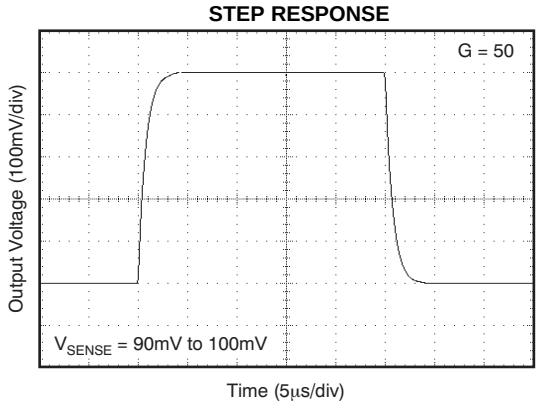


Figure 17.

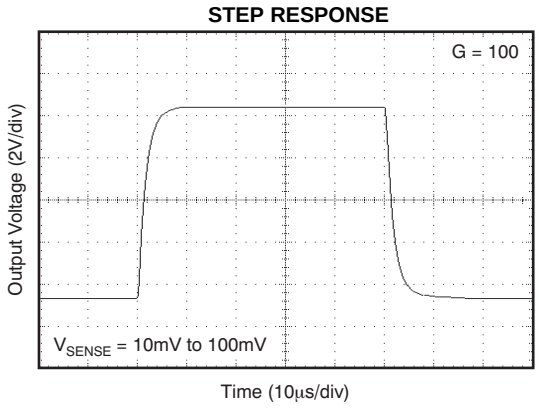


Figure 18.

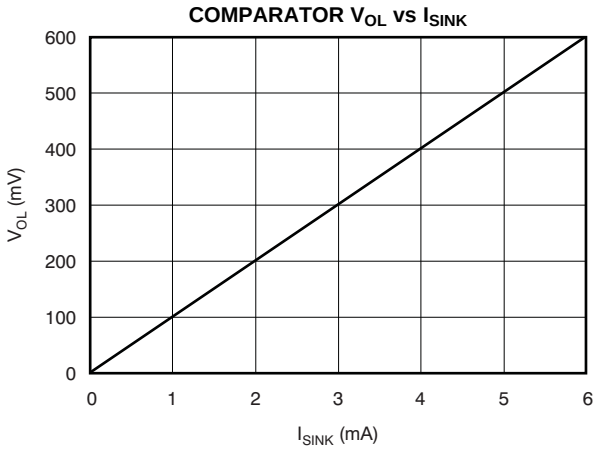


Figure 19.

TYPICAL CHARACTERISTICS (continued)

All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, and V_{SENSE} = 100mV, unless otherwise noted.

COMPARATOR TRIP POINT vs SUPPLY VOLTAGE

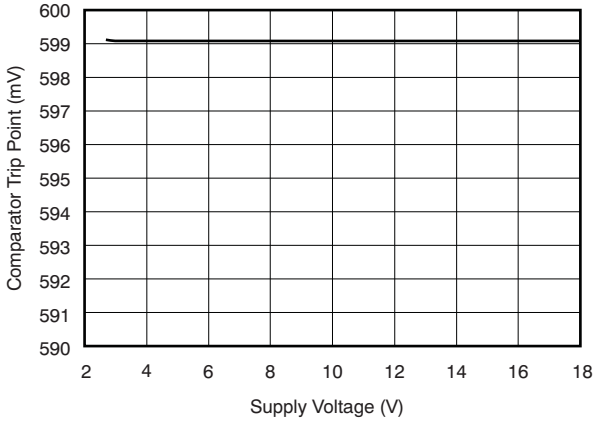


Figure 20.

COMPARATOR TRIP POINT vs TEMPERATURE

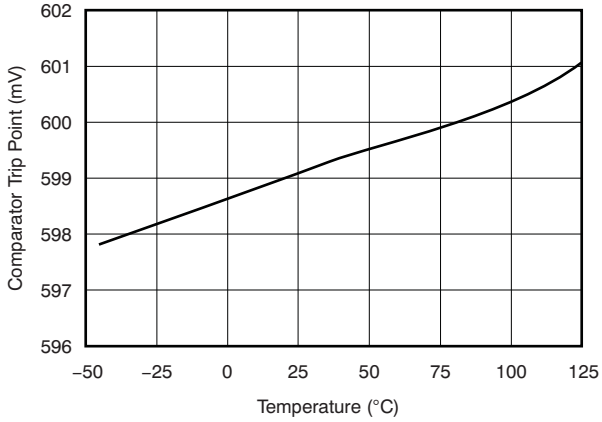


Figure 21.

COMPARATOR 1 PROPAGATION DELAY vs OVERDRIVE VOLTAGE

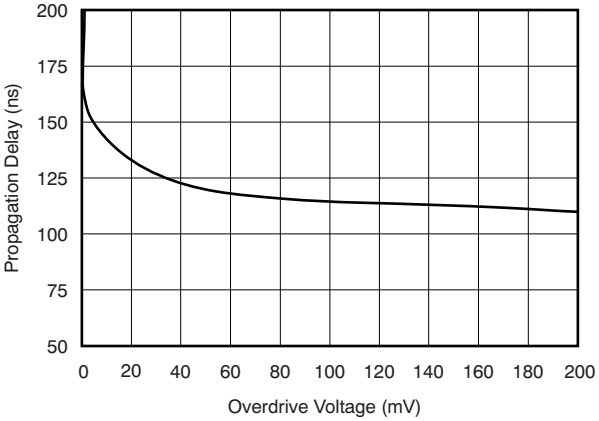


Figure 22.

COMPARATOR 2 PROPAGATION DELAY vs OVERDRIVE VOLTAGE

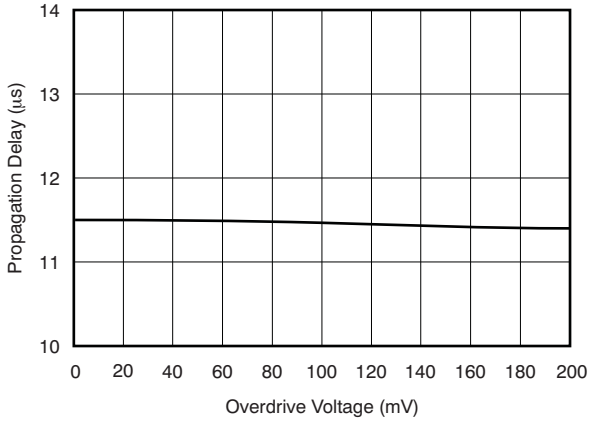


Figure 23.

COMPARATOR RESET VOLTAGE vs SUPPLY VOLTAGE

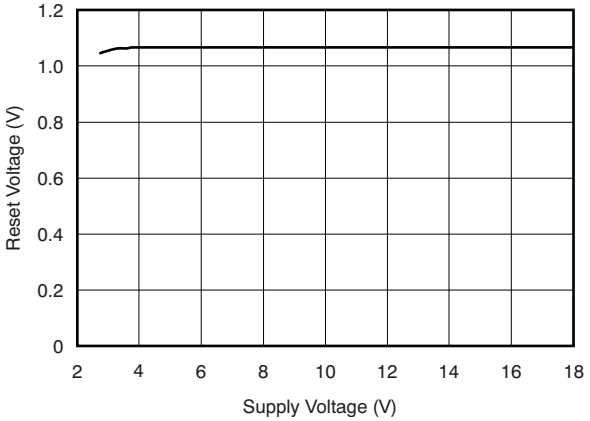


Figure 24.

COMPARATOR 1 PROPAGATION DELAY vs TEMPERATURE

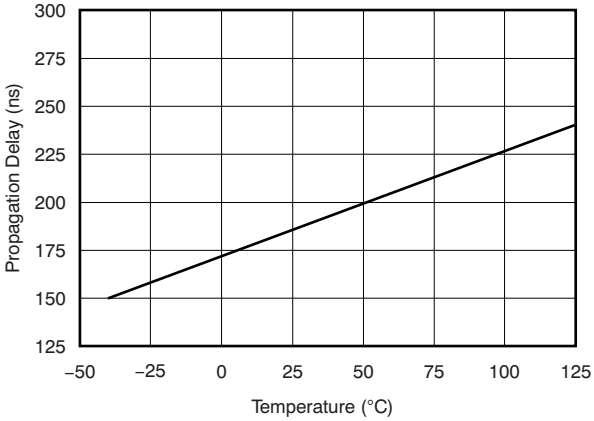


Figure 25.

TYPICAL CHARACTERISTICS (continued)

All specifications at T_A = +25°C, V_S = +12V, V_{CM} = +12V, and V_{SENSE} = 100mV, unless otherwise noted.

COMPARATOR 2 PROPAGATION DELAY vs CAPACITANCE

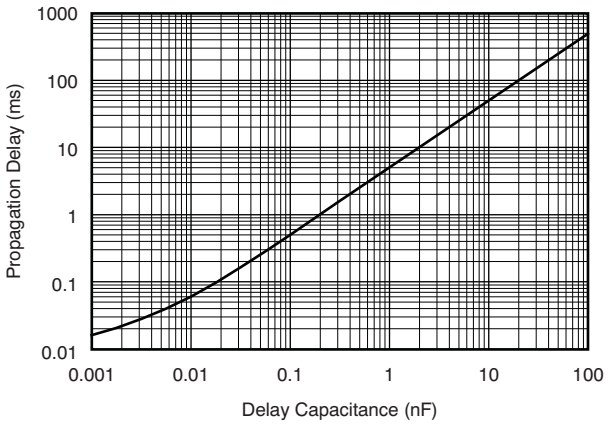


Figure 26.

COMPARATOR 1 PROPAGATION DELAY

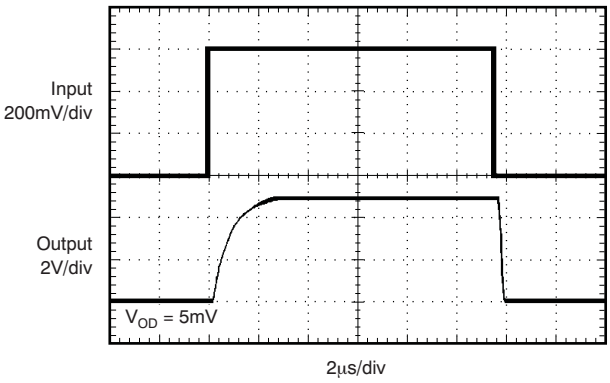


Figure 27.

COMPARATOR 2 PROPAGATION DELAY

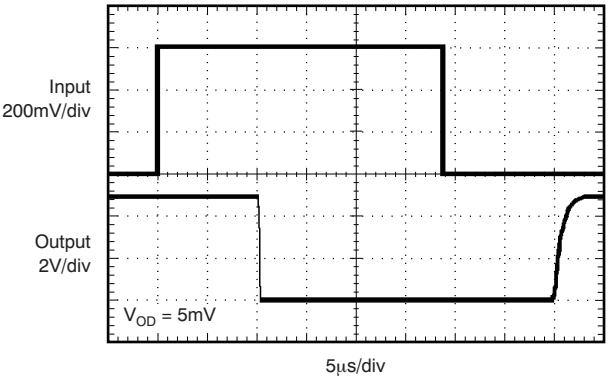


Figure 28.

REFERENCE VOLTAGE vs TEMPERATURE

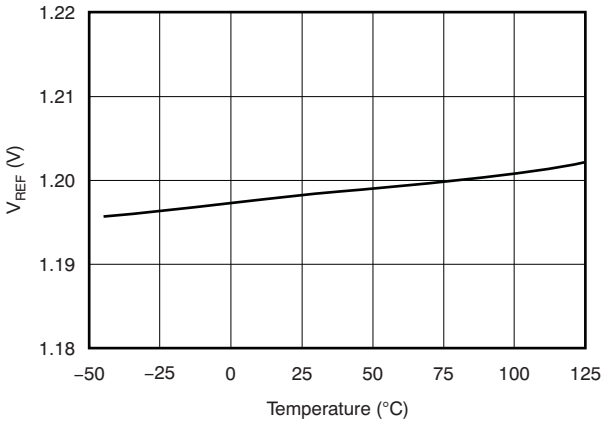


Figure 29.

APPLICATIONS INFORMATION

BASIC CONNECTIONS

Figure 30 shows the basic connections of the INA203, INA204, and INA205. The input pins, V_{IN+} and V_{IN-}, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

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

POWER SUPPLY

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

ACCURACY VARIATIONS AS A RESULT OF V_{SENSE} AND COMMON-MODE VOLTAGE

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

This section addresses the accuracy of these specific operating regions:

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

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

This region of operation provides the highest accuracy. Here, the input offset voltage is characterized and measured using a two-step method. First, the gain is determined by Equation 1.

$$G = \frac{V_{OUT1} - V_{OUT2}}{100mV - 20mV} \quad (1)$$

where:

V_{OUT1} = Output Voltage with V_{SENSE} = 100mV

V_{OUT2} = Output Voltage with V_{SENSE} = 20mV

Then the offset voltage is measured at V_{SENSE} = 100mV and referred to the input (RTI) of the current shunt monitor, as shown in Equation 2.

$$V_{OS}\text{RTI (Referred-To-Input)} = \left[\frac{V_{OUT1}}{G}\right] - 100mV \quad (2)$$

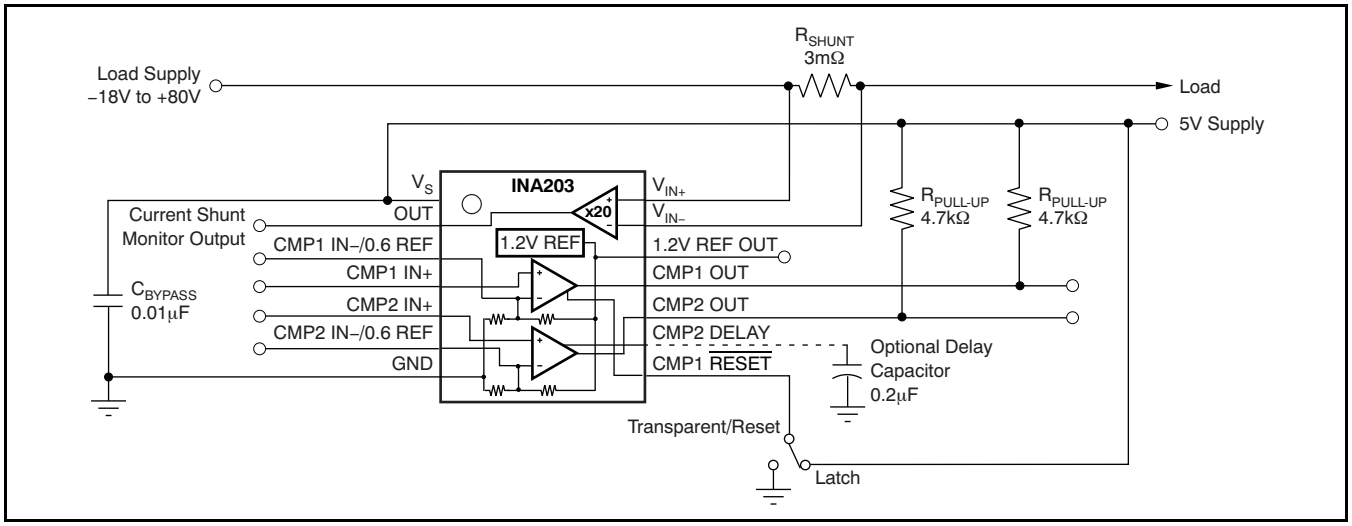


Figure 30. INA20x Basic Connection

In the Typical Characteristics, the *Output Error vs Common-Mode Voltage* curve (Figure 7) shows the highest accuracy for this region of operation. In this plot, V_S = 12V; for V_{CM} ≥ 12V, the output error is at its minimum. This case is also used to create the V_{SENSE} ≥ 20mV output specifications in the Electrical Characteristics table.

Normal Case 2: V_{SENSE} ≥ 20mV, V_{CM} < V_S

This region of operation has slightly less accuracy than Normal Case 1 as a result of the common-mode operating area in which the part functions, as seen in the *Output Error vs Common-Mode Voltage* curve (Figure 7). As noted, for this graph V_S = 12V; for V_{CM} < 12V, the Output Error increases as V_{CM} becomes less than 12V, with a typical maximum error of 0.005% at the most negative V_{CM} = –16V.

Low V_{SENSE} Case 1:

V_{SENSE} < 20mV, –16V ≤ V_{CM} < 0; and Low V_{SENSE} Case 3: V_{SENSE} < 20mV, V_S < V_{CM} ≤ 80V

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

As V_{SENSE} approaches 0mV, in these V_{CM} regions, the device output accuracy degrades. A larger-than-normal offset can appear at the current shunt monitor output with a typical maximum value of V_{OUT} = 300mV for V_{SENSE} = 0mV. As V_{SENSE} approaches 20mV, V_{OUT} returns to the expected output value with accuracy as specified in the Electrical Characteristics. Figure 31 illustrates this effect using the INA205 (Gain = 100).

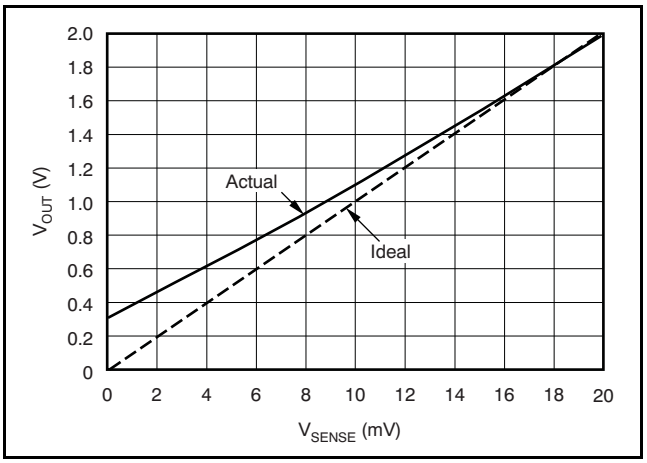
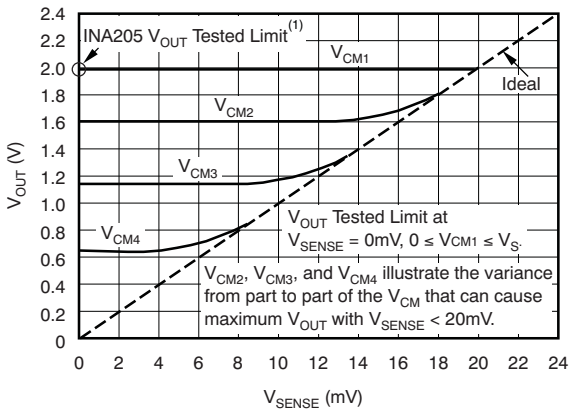


Figure 31. Example for Low V_{SENSE} Cases 1 and 3 (INA205, Gain = 100)

Low V_{SENSE} Case 2: V_{SENSE} < 20mV, 0V ≤ V_{CM} ≤ V_S

This region of operation is the least accurate for the INA203 family. To achieve the wide input common-mode voltage range, these devices use two op amp front ends in parallel. One op amp front end operates in the positive input common-mode voltage range, and the other in the negative input region. For this case, neither of these two internal amplifiers dominates and overall loop gain is very low. Within this region, V_{OUT} approaches voltages close to linear operation levels for Normal Case 2. This deviation from linear operation becomes greatest the closer V_{SENSE} approaches 0V. Within this region, as V_{SENSE} approaches 20mV, device operation is closer to that described by Normal Case 2. Figure 32 illustrates this behavior for the INA205. The V_{OUT} maximum peak for this case is tested by maintaining a constant V_S, setting V_{SENSE} = 0mV, and sweeping V_{CM} from 0V to V_S. The exact V_{CM} at which V_{OUT} peaks during this test varies from part to part, but the V_{OUT} maximum peak is tested to be less than the specified V_{OUT} Tested Limit.



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

Figure 32. Example for Low V_{SENSE} Case 2 (INA205, Gain = 100)

SELECTING R_{SHUNT}

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

TRANSIENT PROTECTION

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

OUTPUT VOLTAGE RANGE

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

INPUT FILTERING

An obvious and straightforward location for filtering is at the output of the INA203, INA204, and INA205 series; however, this location negates the advantage of the low output impedance of the internal buffer. The only other option for filtering is at the input pins of the INA203, INA204, and INA205, which is complicated by the internal 5kΩ + 30% input impedance; this configuration is illustrated in Figure 33. Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. The effect on initial gain is given by Equation 3:

$$\text{Gain Error \%} = 100 - \left(100 \times \frac{5k\Omega}{5k\Omega + R_{FILT}}\right) \quad (3)$$

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

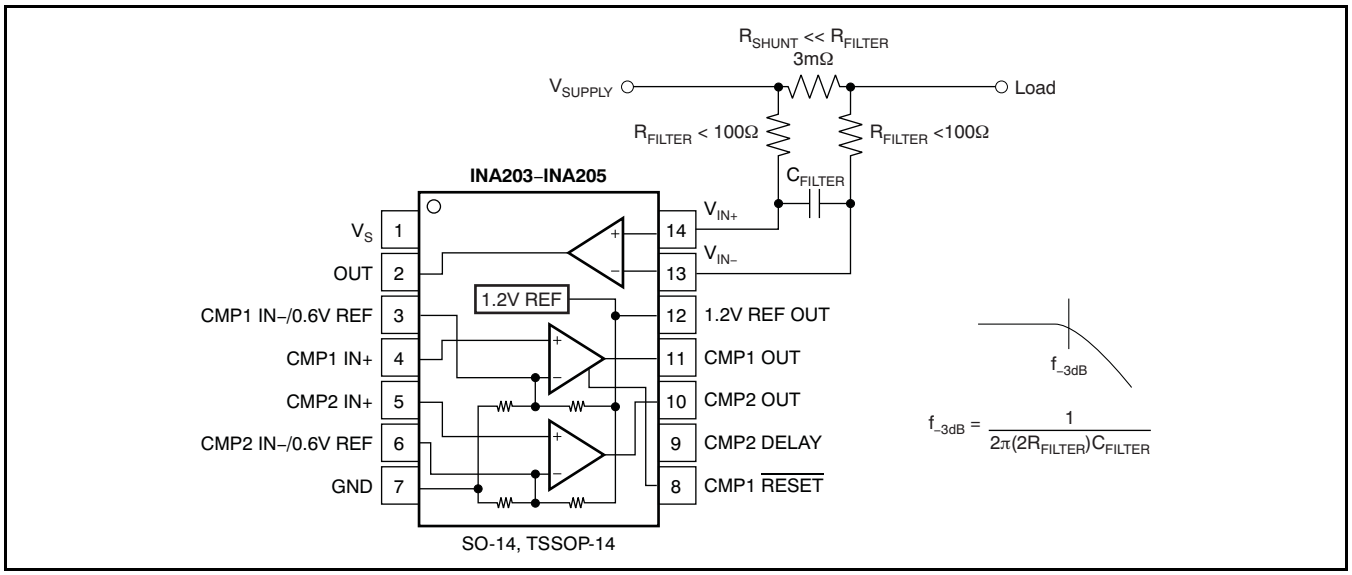


Figure 33. Input Filter (Gain Error: 1.5% to –2.2%)

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

REFERENCE

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

COMPARATOR

The INA203, INA204, and INA205 devices incorporate two open-drain comparators. These comparators typically have 2mV of offset and a 1.3µs (typical) response time. The output of Comparator 1 latches and is reset through the CMP1 $\overline{\text{RESET}}$ pin, as shown in Figure 35. This configuration applies to both the 10- and 14-pin versions. Figure 34 illustrates the comparator delay.

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

COMPARATOR DELAY (14-Pin Version Only)

The Comparator 2 programmable delay is controlled by a capacitor connected to the CMP2 Delay Pin; see Figure 30. The capacitor value (in µF) is selected by using Equation 4:

$$C_{DELAY} \text{ (in } \mu\text{F)} = \frac{t_D}{5} \quad (4)$$

A simplified version of the delay circuit for Comparator 2 is shown in Figure 34. The delay comparator consists of two comparator stages with the delay between them. Note that I1 and I2 cannot be turned on simultaneously; I1 corresponds to a U1 low output and I2 corresponds to a U1 high output. Using an initial assumption that the U1 output is low, I1 is on, then U2 +IN is zero. If U1 goes high, I2 supplies 120nA to C_{DELAY}. The voltage at U2 +IN begins to ramp toward a 0.6V threshold. When the voltage crosses this threshold, the U2 output goes high while the voltage at U2 +IN continues to ramp up to a maximum of 1.2V when given sufficient time (twice the value of the delay specified for C_{DELAY}). This entire sequence is reversed when the comparator outputs go low, so that returning to low exhibits the same delay.

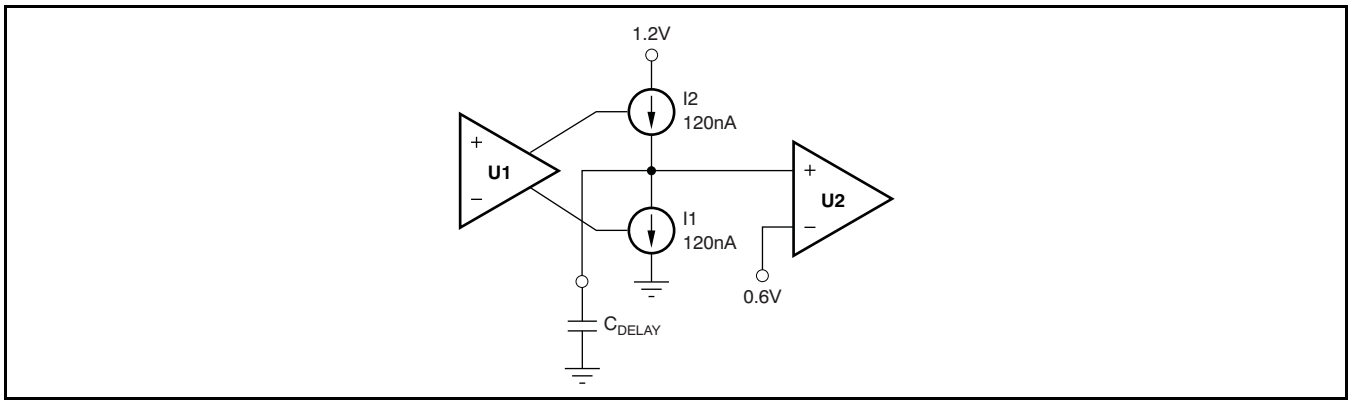


Figure 34. Simplified Model of the Comparator 2 Delay Circuit

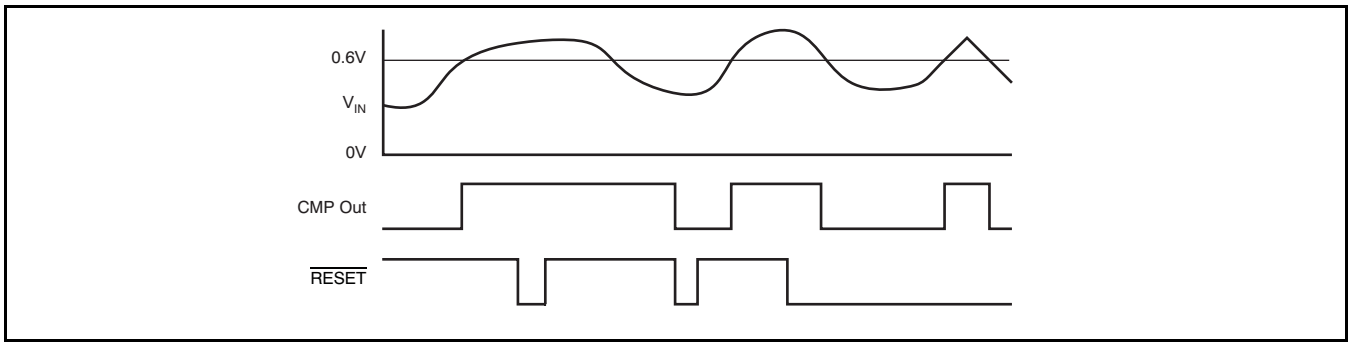


Figure 35. Comparator Latching Capability

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

In essence, when analyzing Comparator 2 for behavior with events more rapid than its delay setting, use the model shown in Figure 34.

COMPARATOR MAXIMUM INPUT VOLTAGE RANGE

The maximum voltage at the comparator input for normal operation is up to (V+) – 1.5V. There are special considerations when overdriving the reference inputs (pins 3 and 6). Driving either or both inputs high enough to drive 1mA back into the reference introduces errors into the reference. Figure 36 shows the basic input structure. A general guideline is to limit the voltage on both inputs to a total of 20V. The exact limit depends on the available voltage and whether either or both inputs are subject to the large voltage. When making this determination, consider the 20kΩ from each input back to the comparator. Figure 37 shows the maximum input voltage that avoids creating a reference error when driving both inputs (an equivalent resistance back into the reference of 10kΩ).

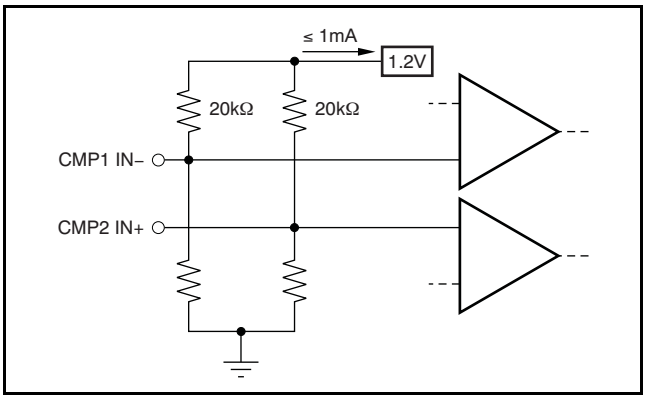


Figure 36. Limit Current Into Reference ≤ 1mA

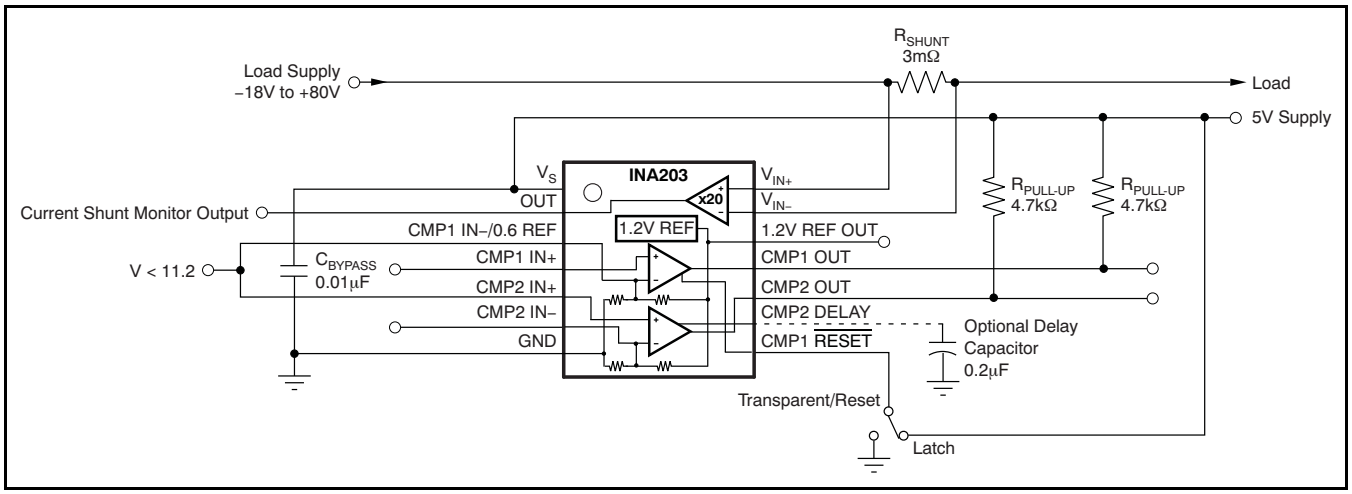
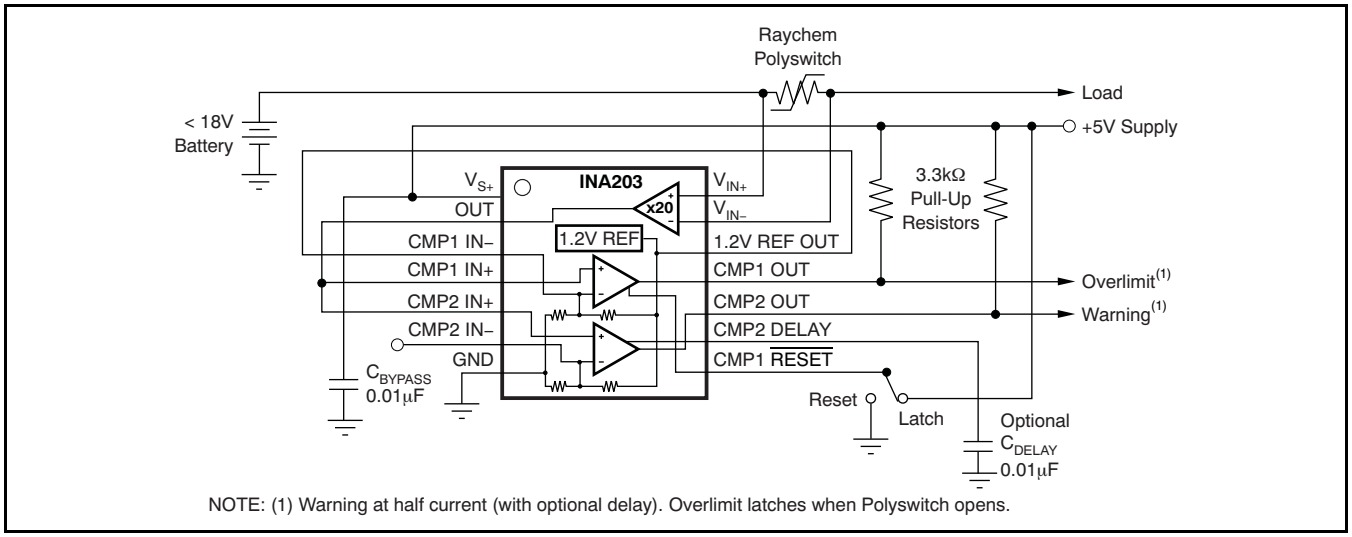


Figure 37. Overdriving Comparator Inputs Without Generating a Reference Error



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

Figure 38. Polyswitch Warning and Fault Detection Circuit

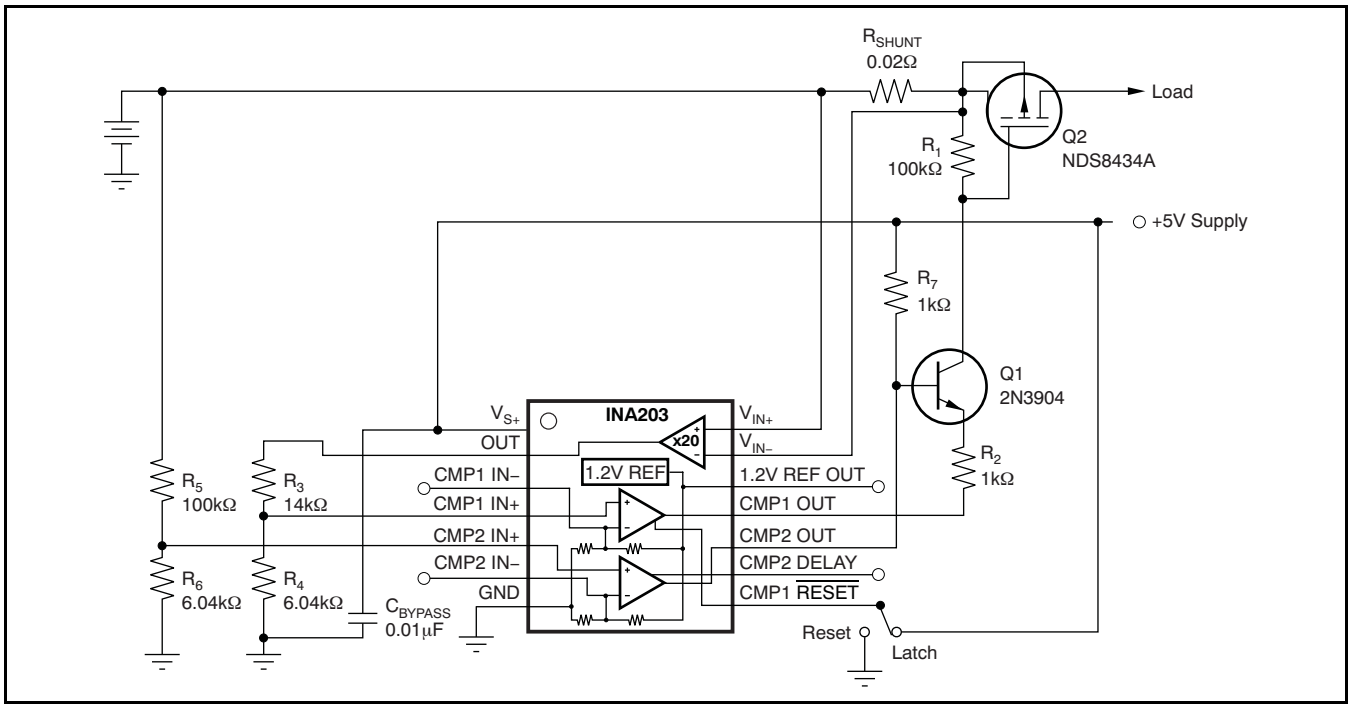


Figure 39. Lead-Acid Battery Protection Circuit

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
INA203AID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDGSR	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDGSRG4	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDGST	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDGSTG4	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA203AIPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDGSR	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDGSRG4	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDGST	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDGSTG4	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA204AIPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
INA205AIDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDGSR	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDGSRG4	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDGST	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDGSTG4	ACTIVE	MSOP	DGS	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA205AIPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

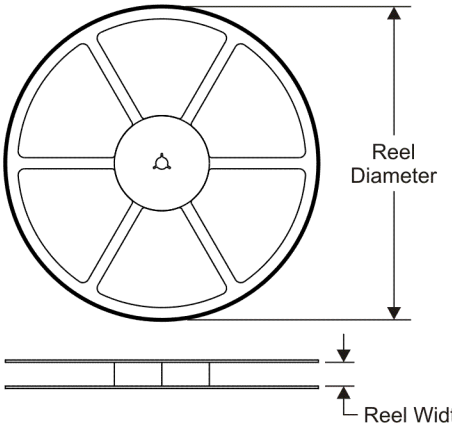
[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

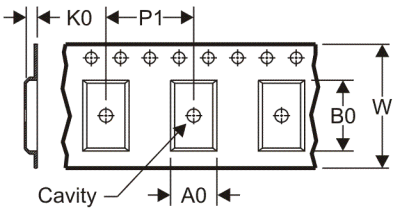
[3] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

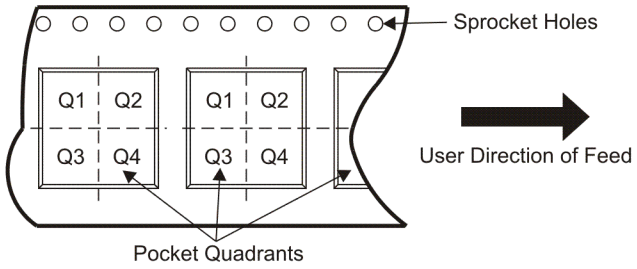


TAPE DIMENSIONS



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

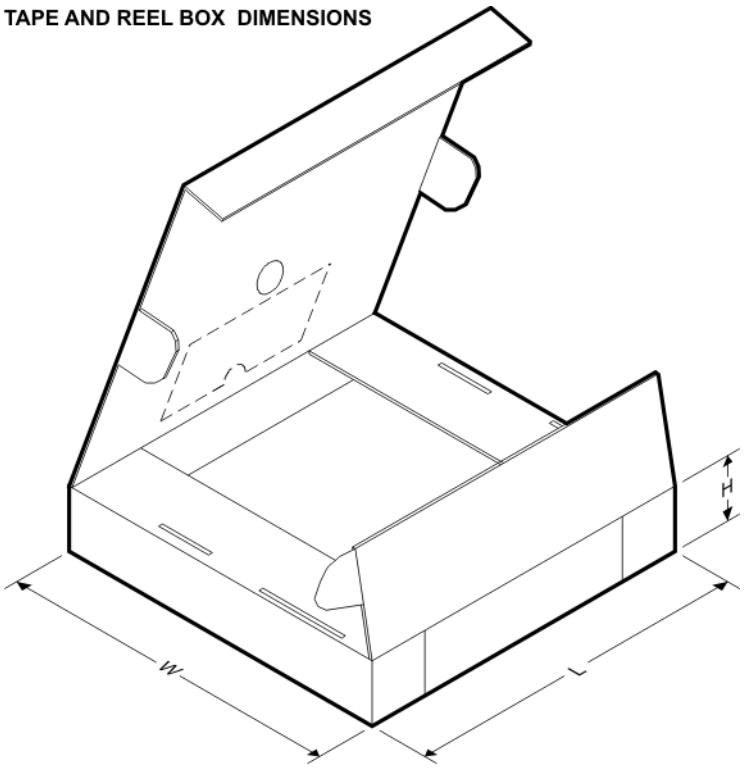
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
INA203AIDGSR	MSOP	DGS	10	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA203AIDGST	MSOP	DGS	10	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA203AIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
INA203AIPWR	TSSOP	PW	14	2000	330.0	12.4	7.0	5.6	1.6	8.0	12.0	Q1
INA204AIDGSR	MSOP	DGS	10	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA204AIDGST	MSOP	DGS	10	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA204AIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
INA204AIPWR	TSSOP	PW	14	2000	330.0	12.4	7.0	5.6	1.6	8.0	12.0	Q1
INA205AIDGSR	MSOP	DGS	10	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA205AIDGST	MSOP	DGS	10	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA205AIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
INA205AIPWR	TSSOP	PW	14	2000	330.0	12.4	7.0	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

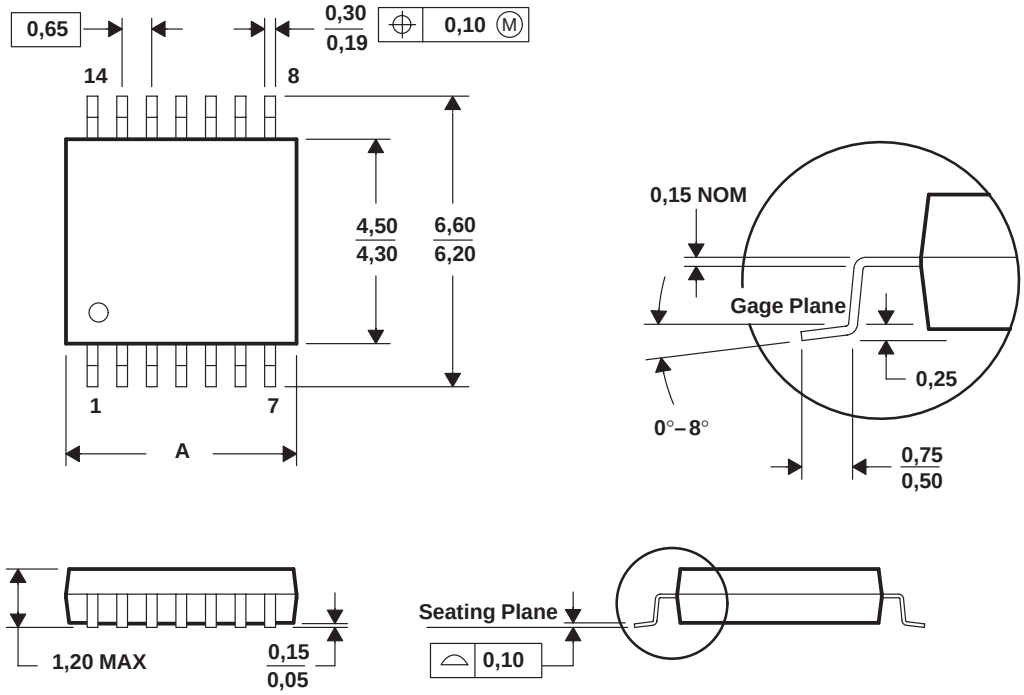


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA203AIDGSR	MSOP	DGS	10	2500	346.0	346.0	29.0
INA203AIDGST	MSOP	DGS	10	250	184.0	184.0	50.0
INA203AIDR	SOIC	D	14	2500	346.0	346.0	33.0
INA203AIPWR	TSSOP	PW	14	2000	346.0	346.0	29.0
INA204AIDGSR	MSOP	DGS	10	2500	346.0	346.0	29.0
INA204AIDGST	MSOP	DGS	10	250	184.0	184.0	50.0
INA204AIDR	SOIC	D	14	2500	346.0	346.0	33.0
INA204AIPWR	TSSOP	PW	14	2000	346.0	346.0	29.0
INA205AIDGSR	MSOP	DGS	10	2500	346.0	346.0	29.0
INA205AIDGST	MSOP	DGS	10	250	184.0	184.0	50.0
INA205AIDR	SOIC	D	14	2500	346.0	346.0	33.0
INA205AIPWR	TSSOP	PW	14	2000	346.0	346.0	29.0

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN

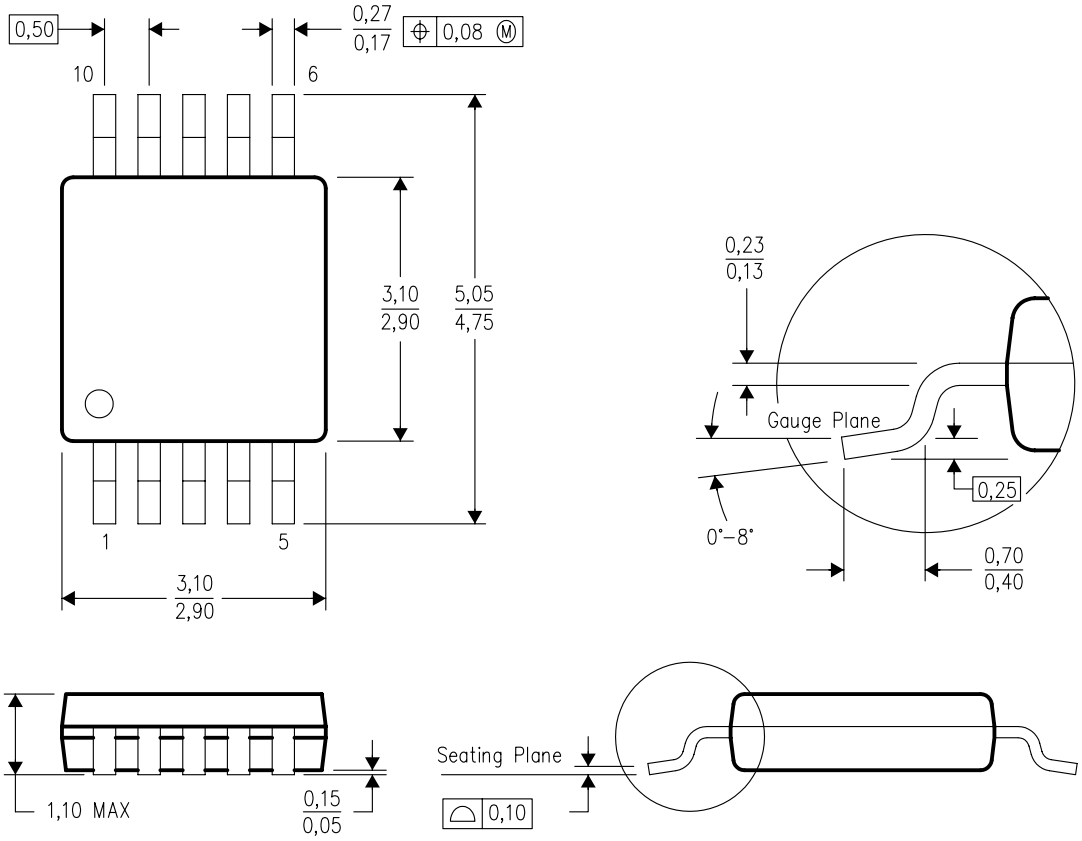


DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

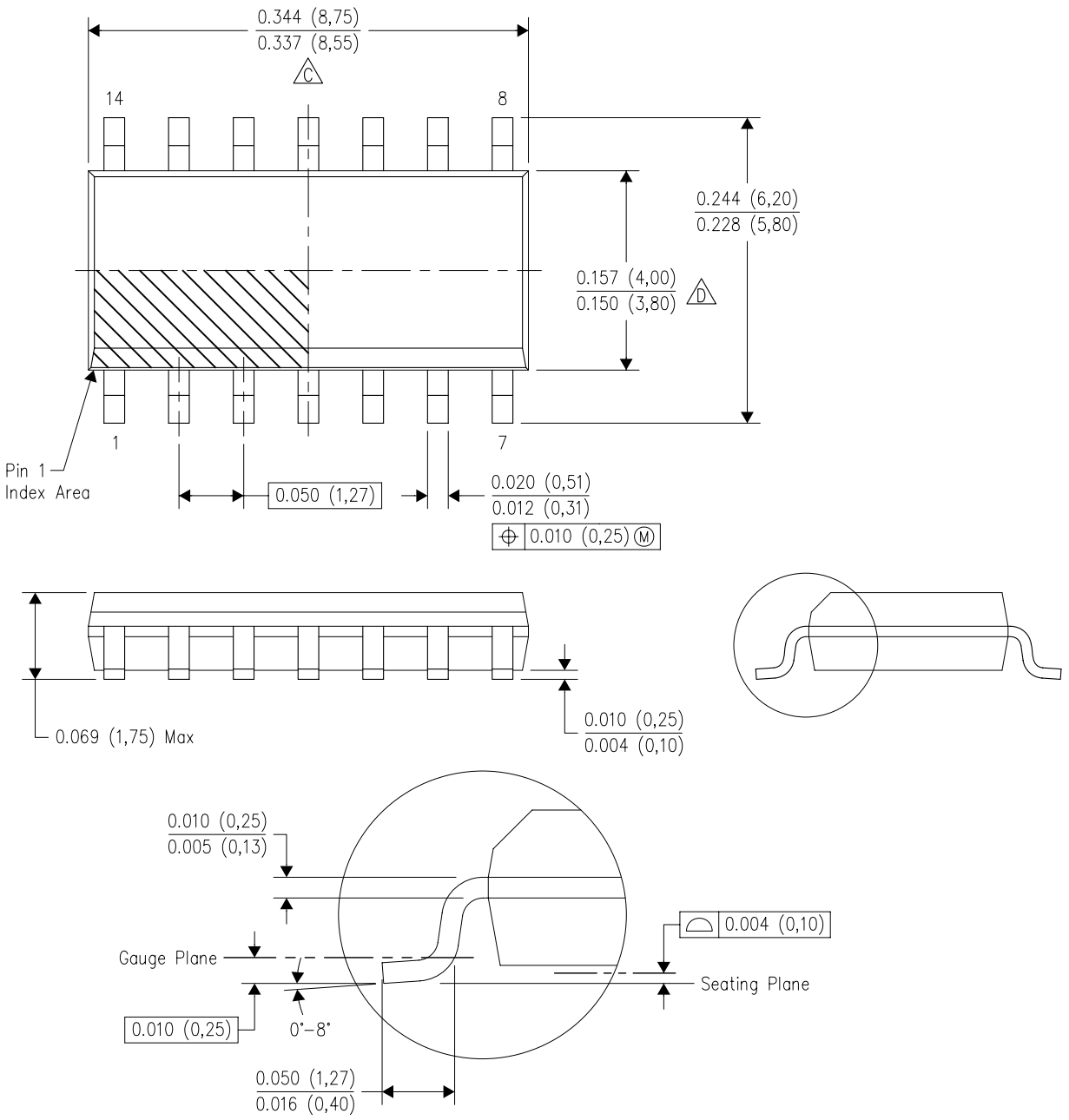
DGS (S–PDSO–G10) PLASTIC SMALL–OUTLINE PACKAGE



4073272/C 02/04

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–187 variation BA.

D (R–PDSO–G14) PLASTIC SMALL–OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in inches (millimeters).
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 .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS–012 variation AB.