

# INA203-Q1 Automotive Grade, -16 V to +80 V, Low- or High-Side, High-Speed, Voltage Output Current Shunt Monitor With Dual Comparators and Reference

## 1 Features

- Qualified for Automotive Applications
- Current Sense Amplifier
  - Common-Mode Range: -16 V to +80 V
  - Accuracy: 3.5% (Maximum) Over Temperature
  - Bandwidth: 500 kHz
  - Gain: 20 V/V
- Integrated Dual Comparators:
  - Comparator 1 With Latch
  - Comparator 2 With Optional Delay
- Quiescent Current: 1.8 mA
- Latch-Up Performance Meets 100 mA Per AEC-Q100, Level I
- Packages: TSSOP-14

## 2 Applications

- Electric Power Steering (EPS) Systems
- Body Control Modules
- Brake Systems
- Electronic Stability Control (ESC) Systems

## 3 Description

The INA203-Q1 is a unidirectional current-shunt monitor (also called a current sense amplifier) with voltage output, dual comparators, and voltage reference. The INA203-Q1 can sense drops across shunts at common-mode voltages from -16 V to +80 V. The INA203-Q1 is available with 20-V/V gain with up to 500-kHz bandwidth.

The INA203-Q1 incorporates two open-drain comparators with internal 0.6-V references and also provides a 1.2-V reference output. The comparator references can be overridden by external inputs. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay.

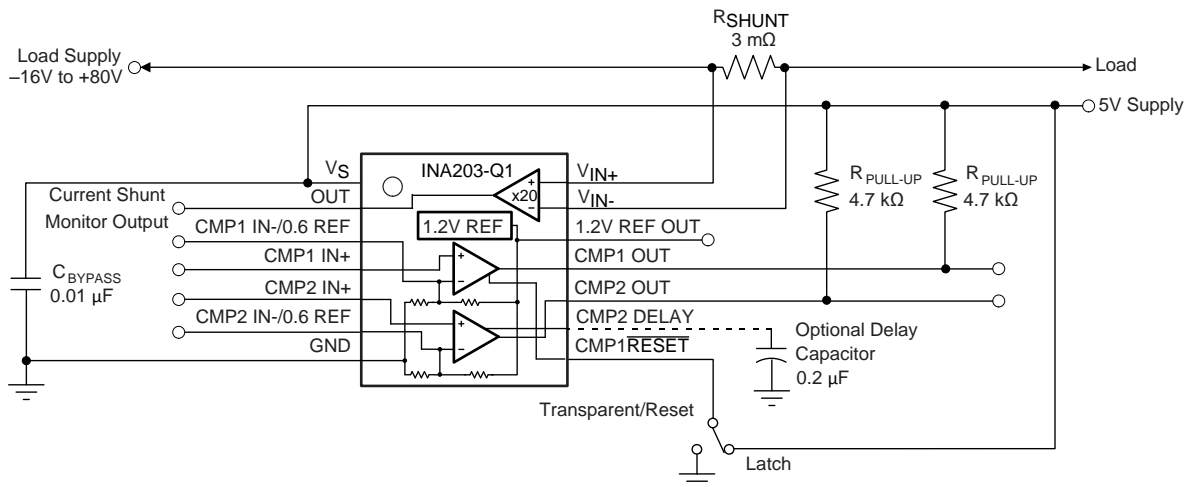
The INA203-Q1 operates from a single 2.7 V to 18 V supply. It is specified over the extended operating temperature range of -40°C to +125°C.

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA203-Q1	TSSOP (14)	5.00 mm x 4.40 mm

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

### Basic Connections Schematic



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## 4 Revision History

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

### Changes from Original (December 2010) to Revision A

Page

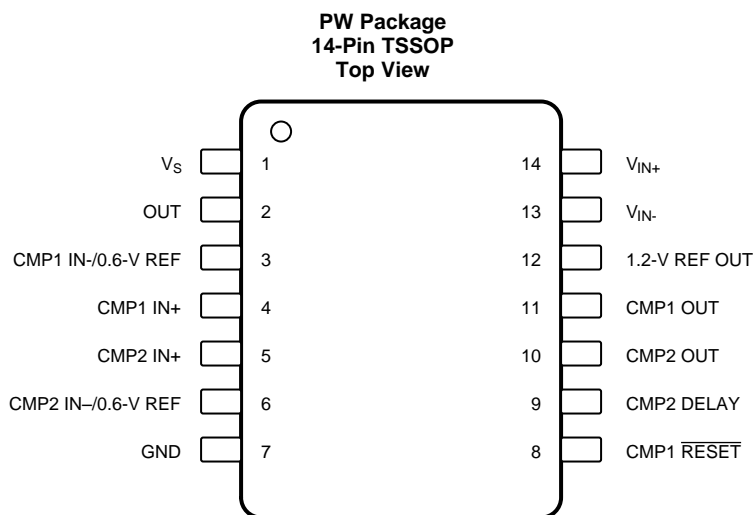
• Updated data sheet title, <i>Features</i> , <i>Applications</i> , and <i>Description</i> .....	<b>1</b>
• Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, <i>Mechanical, Packaging, and Orderable Information</i> section, <i>Pin Configuration and Functions</i> section, <i>Recommended Operating Conditions Table</i> , and <i>Thermal Information Table</i> .....	<b>1</b>
• Added <i>Device Comparison Table</i> .....	<b>3</b>
• Changed V+ to V <sub>S</sub> throughout .....	<b>4</b>
• Changed MAX value 18 to (V <sub>S</sub> ) + 0.3 for Comparator output pins .....	<b>4</b>
• Changed MAX value 10 to (V <sub>S</sub> ) up to 10 for 1.2-V REF and CMP2 DELAY pins .....	<b>4</b>
• Changed pin names in <i>Absolute Maximum Ratings</i> to show correct names .....	<b>4</b>
• Added Operating Temperature to <i>Absolute Maximum Ratings</i> table .....	<b>4</b>
• Changed CMP2 IN– to CMP2 IN+ in <i>Electrical Characteristics: Current-Shunt Monitor</i> condition statement .....	<b>5</b>
• Changed CMP2 IN– to CMP2 IN+ in <i>Electrical Characteristics: General</i> condition statement .....	<b>7</b>
• Updated <i>Overview</i> section .....	<b>12</b>
• Deleted 10-pin device image .....	<b>12</b>
• Changed text from "RFILT – 3%" to "RFILT + 3%" in 2nd paragraph of <i>Input Filtering</i> section .....	<b>16</b>
• Changed Figure 35 caption .....	<b>16</b>

## 5 Device Comparison Table

**Table 1. Related Products**

PRODUCT	DESCRIPTION
<a href="#">INA200-Q1</a>	Single comparator alternative to the INA203's dual comparators
<a href="#">INA193A-Q1</a>	Same amplifier performance without the comparators integrated
<a href="#">INA282-Q1</a>	High-accuracy, high common-mode capable current sense amplifier
<a href="#">INA300-Q1</a>	36-V overcurrent protection comparator
<a href="#">INA301</a>	High-accuracy, high slew-rate current sense amplifier with integrated high-speed comparator optimized for overcurrent protection.

## 6 Pin Configuration and Functions


**Pin Functions**

PIN		I/O	DESCRIPTION
NO.	NAME		
1	$V_S$	I	Power supply
2	OUT	O	Output voltage
3	CMP1 IN-/0.6-V REF	I	Comparator 1 negative input, can be used to override the internal 0.6-V reference
4	CMP1 IN+	I	Comparator 1 positive input
5	CMP2 IN+	I	Comparator 2 positive input
6	CMP2 IN-/0.6-V REF	I	Comparator 2 negative input, can be used to override the internal 0.6-V reference
7	GND	I	Ground
8	CMP1 $\overline{\text{RESET}}$	I	Comparator 1 output reset, active low
9	CMP2 DELAY	I	Connect an optional capacitor to adjust comparator 2 delay
10	CMP2 OUT	O	Comparator 2 output
11	CMP1 OUT	O	Comparator 1 output
12	1.2-V REF OUT	O	1.2-V reference output
13	$V_{IN-}$	I	Amplifier Negative Input. Connect to shunt low side
14	$V_{IN+}$	I	Amplifier Positive Input. Connect to shunt high side

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
Supply voltage	$V_S$		18	V
Current-shunt monitor analog inputs, $V_{IN+}$ and $V_{IN-}$	Differential ( $V_{IN+}$ ) – ( $V_{IN-}$ )	–18	18	V
	Common-mode	–16	80	V
Comparator analog input	CMP1 IN+, CMP1 IN-/0.6-V REF, CMP2 IN+, CMP2 IN-/0.6-V REF	GND – 0.3	$(V_S) + 0.3$	V
Comparator reset	CMP1 $\overline{\text{RESET}}$	GND – 0.3	$(V_S) + 0.3$	
Analog output	OUT	GND – 0.3	$(V_S) + 0.3$	V
Comparator output	CMP1 OUT, CMP2 OUT	GND – 0.3	$(V_S) + 0.3$	V
1.2-V REF and CMP2 DELAY pins		GND – 0.3	$(V_S)$ up to 10	V
Input current into any pin			5	mA
Operating temperature		–55	150	°C
Junction temperature			150	°C
Storage temperature, $T_{stg}$		–65	150	°C

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

### 7.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup>	±2000	V
	Charged-device model (CDM), per AEC Q100-011	±500	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 7.3 Recommended Operating Conditions

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

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

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		INA203-Q1	UNIT
		PW (TSSOP)	
		14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	112.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	37.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	55.4	°C/W
$\psi_{JT}$	Junction-to-top characterization parameter	2.7	°C/W
$\psi_{JB}$	Junction-to-board characterization parameter	54.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	150	°C/W

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

## 7.5 Electrical Characteristics: Current-Shunt Monitor

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>INPUT</b>							
$V_{SENSE}$	Full-scale sense input voltage	$V_{SENSE} = V_{IN+} - V_{IN-}$			0.15	$(V_S - 0.25)/\text{Gain}$	V
$V_{CM}$	Common-mode input range	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		-16		80	V
CMRR	Common-mode rejection ratio	$V_{CM} = -16\text{ V}$ to $+80\text{ V}$		80	100		dB
		$V_{CM} = 12\text{ V}$ to $80\text{ V}$	$T_A = 25^\circ\text{C}$ to $125^\circ\text{C}$	100	123		dB
	Over temperature	$T_A = -40^\circ\text{C}$ to $+25^\circ\text{C}$		90	100		dB
$V_{OS}$	Offset voltage, RTI <sup>(1)</sup>				$\pm 0.5$	$\pm 2.5$	mV
		$T_A = 25^\circ\text{C}$ to $125^\circ\text{C}$				$\pm 3$	mV
		$T_A = -40^\circ\text{C}$ to $+25^\circ\text{C}$				$\pm 3.5$	mV
$dV_{OS}/dT$	Versus temperature	$T_{MIN}$ to $T_{MAX}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		5		$\mu\text{V}/^\circ\text{C}$
PSR	Versus power supply	$V_{OUT} = 2\text{ V}$ , $V_{CM} = +18\text{ V}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		2.5	100	$\mu\text{V}/\text{V}$
$I_B$	Input bias current, $V_{IN-}$ Pin	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			$\pm 9$	$\pm 16$	$\mu\text{A}$
<b>OUTPUT (<math>V_{SENSE} \geq 20\text{ mV}</math>)</b>							
G	Gain				20		V/V
	Gain error	$V_{SENSE} = 20\text{ mV}$ to $100\text{ mV}$			$\pm 0.2\%$	$\pm 1\%$	
	Over temperature	$V_{SENSE} = 20\text{ mV}$ to $100\text{ mV}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			$\pm 2\%$	
	Total output error <sup>(2)</sup>	$V_{SENSE} = 120\text{ mV}$ , $V_S = +16\text{ V}$			$\pm 0.75\%$	$\pm 2.2\%$	
	Over temperature	$V_{SENSE} = 120\text{ mV}$ , $V_S = +16\text{ V}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			$\pm 3.5\%$	
	Nonlinearity error <sup>(3)</sup>	$V_{SENSE} = 20\text{ mV}$ to $100\text{ mV}$			$\pm 0.002\%$		
$R_O$	Output impedance, Pin 2				1.5		$\Omega$
	Maximum capacitive load	No sustained oscillation			10		nF
<b>OUTPUT (<math>V_{SENSE} &lt; 20\text{ mV}</math>)<sup>(4)</sup></b>							
$V_{OUT}$	Output voltage	$-16\text{ V} \leq V_{CM} < 0\text{ V}$			300		mV
		$0\text{ V} \leq V_{CM} \leq V_S$ , $V_S = 5\text{ V}$				0.4	V
		$V_S < V_{CM} \leq 80\text{ V}$			300		mV
<b>VOLTAGE OUTPUT<sup>(5)</sup></b>							
	Output swing to the positive rail	$V_{IN-} = 11\text{ V}$ , $V_{IN+} = 12\text{ V}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		$(V_S) - 0.15$	$(V_S) - 0.25$	V
	Output Swing to GND <sup>(6)</sup>	$V_{IN-} = 0\text{ V}$ , $V_{IN+} = -0.5\text{ V}$	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		$(V_{GND}) + 0.004$	$(V_{GND}) + 0.05$	V
<b>FREQUENCY RESPONSE</b>							
BW	Bandwidth	$C_{LOAD} = 5\text{ pF}$			500		kHz
	Phase margin	$C_{LOAD} < 10\text{ nF}$			40		Degrees
SR	Slew rate				1		V/ $\mu\text{s}$
	Settling time (1%)	$V_{SENSE} = 10\text{ mV}_{PP}$ to $100\text{ mV}_{PP}$ , $C_{LOAD} = 5\text{ pF}$			2		$\mu\text{s}$
<b>NOISE, RTI</b>							
	Output Voltage Noise Density				40		nV/ $\sqrt{\text{Hz}}$

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

## 7.6 Electrical Characteristics: Comparator

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>					
Offset voltage	Comparator common-mode voltage = threshold voltage		2		mV
Offset voltage drift, comparator 1	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		$\pm 2$		$\mu\text{V}/^\circ\text{C}$
Offset voltage drift, comparator 2	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		5.4		$\mu\text{V}/^\circ\text{C}$
Threshold	Rising Edge on Non-Inverting input, $T_A = +25^\circ\text{C}$	590	608	620	mV
Over temperature	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	586		625	mV
Hysteresis <sup>(1)</sup> , CMP1	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		-8		mV
Hysteresis <sup>(1)</sup> , CMP2	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		8		mV
<b>INPUT BIAS CURRENT<sup>(2)</sup></b>					
CMP1 IN+, CMP2 IN+			0.005	10	nA
Over temperature	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			15	nA
<b>INPUT IMPEDANCE</b>					
Pins 3 and 6			10		k $\Omega$
<b>INPUT RANGE</b>					
CMP1 IN+ and CMP2 IN+		0 V to $V_S - 1.5\text{ V}$			V
Pins 3 and 6 <sup>(3)</sup>		0 V to $V_S - 1.5\text{ V}$			V
<b>OUTPUT</b>					
Large-signal differential voltage gain	CMP $V_{\text{OUT}} 1\text{ V}$ to $4\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ connected to $5\text{ V}$		200		V/mV
High-level output current	$V_{\text{ID}} = 0.4\text{ V}$ , $V_{\text{OH}} = V_S$		0.0001	1	$\mu\text{A}$
Low-level output voltage	$V_{\text{ID}} = -0.6\text{ V}$ , $I_{\text{OL}} = 2.35\text{ mA}$		220	300	mV
<b>RESPONSE TIME<sup>(4)</sup></b>					
Comparator 1	$R_L$ to $5\text{ V}$ , $C_L = 15\text{ pF}$ , $100\text{ mV}$ input step with $5\text{ mV}$ overdrive		1.3		$\mu\text{s}$
Comparator 2	$R_L$ to $5\text{ V}$ , $C_L = 15\text{ pF}$ , $100\text{ mV}$ input step with $5\text{ mV}$ overdrive, $C_{\text{DELAY}}$ pin open		1.3		$\mu\text{s}$
<b>RESET</b>					
RESET threshold <sup>(5)</sup>			1.1		V
Logic input impedance			2		M $\Omega$
Minimum RESET pulse width			1.5		$\mu\text{s}$
RESET propagation delay			3		$\mu\text{s}$
Comparator 2 delay equation <sup>(6)</sup>			$C_{\text{DELAY}} = t_d/5$		$\mu\text{F}$
$t_d$ Comparator 2 delay	$C_{\text{DELAY}} = 0.1\text{ }\mu\text{F}$		0.5		s

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

### 7.7 Electrical Characteristics: Reference

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>REFERENCE VOLTAGE</b>							
1.2 $V_{REFOUT}$ output voltage			1.188	1.2	1.212	V	
$dV_{OUT}/dT$	Reference drift <sup>(1)</sup>	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		40	100	ppm/ $^\circ\text{C}$	
0.6 $V_{REF}$ Output voltage (Pins 3 and 6)				0.6		V	
$dV_{OUT}/dT$	Reference drift <sup>(1)</sup>	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		40	100	ppm/ $^\circ\text{C}$	
<b>LOAD REGULATION</b>							
$dV_{OUT}/dI_{LOAD}$	Sourcing	$0\text{ mA} < I_{SINK} < 0.5\text{ mA}$	$V_{REFOUT} - 1.2\text{ V}$		0.4	2	mV/mA
	Sinking		$0\text{ mA} < I_{SOURCE} < 0.5\text{ mA}$		0.4		mV/mA
<b>LOAD CURRENT</b>							
$I_{LOAD}$				1		mA	
<b>LINE REGULATION</b>							
$dV_{OUT}/dV_S$		$2.7\text{ V} < V_S < 18\text{ V}$		30		$\mu\text{V}/\text{V}$	
<b>CAPACITIVE LOAD</b>							
Reference output maximum capacitive load		No sustained oscillations		10		nF	
<b>OUTPUT IMPEDANCE</b>							
Pins 3 and 6				10		k $\Omega$	

(1) Specified by design; not production tested.

### 7.8 Electrical Characteristics: General

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

GENERAL PARAMETERS		CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SUPPLY</b>						
$V_S$	Operating Power Supply	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	2.7		18	V
$I_Q$	Quiescent current	$V_{OUT} = 2\text{ V}$		1.8	2.2	mA
	Over temperature	$V_{SENSE} = 0\text{ mV}$ $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			2.8	mA
	Comparator power-on reset threshold <sup>(1)</sup>			1.5		V

(1) The INA203-Q1 is 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.



Figure 1. Comparator Hysteresis

### 7.9 Typical Characteristics

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

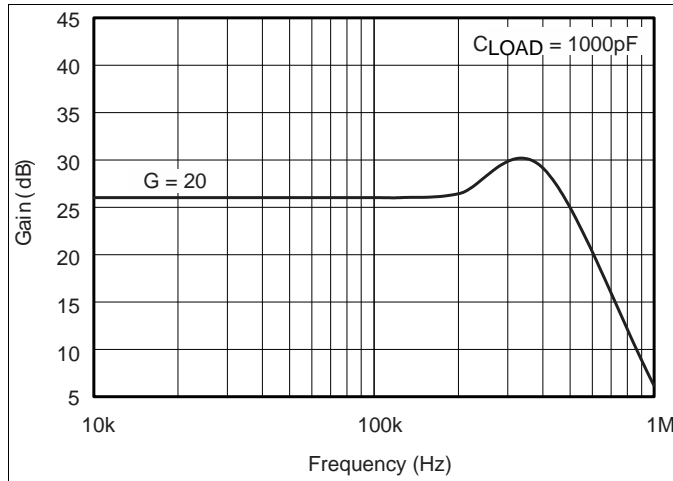


Figure 2. Gain vs Frequency

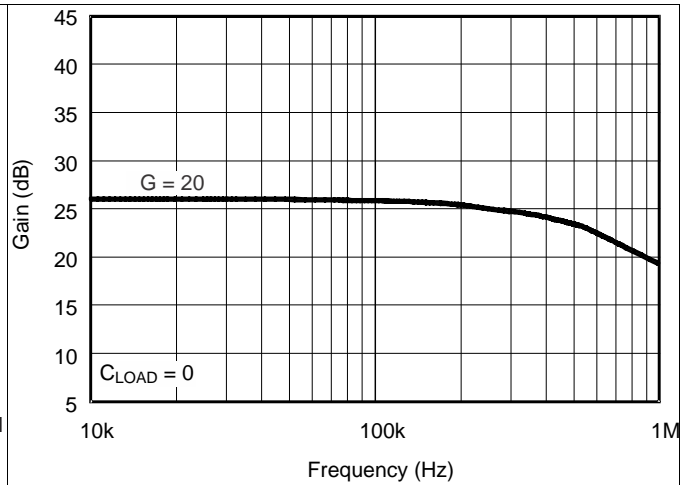


Figure 3. Gain vs Frequency

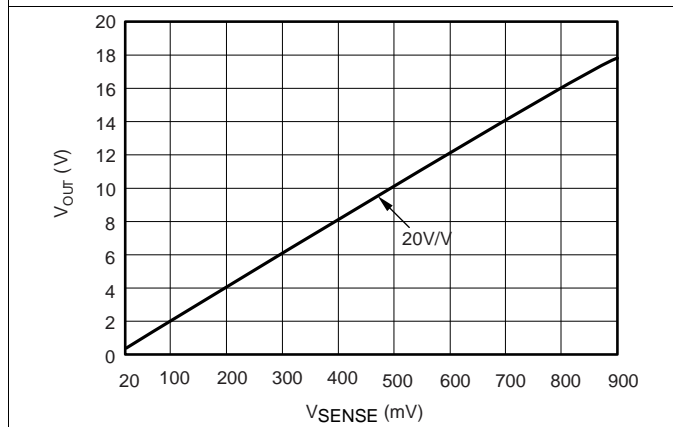


Figure 4. Gain Plot

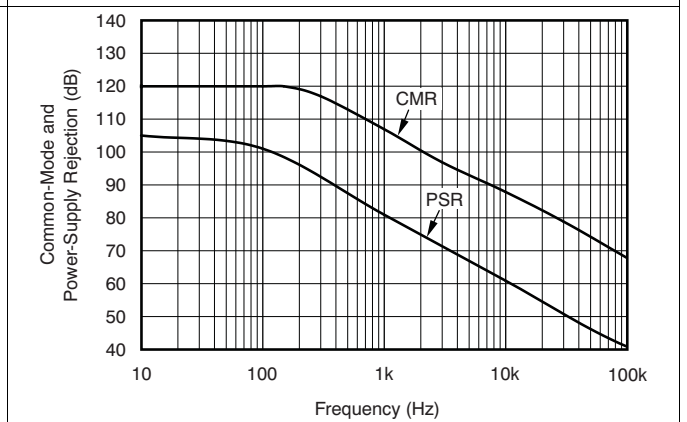


Figure 5. Common-Mode and Power-Supply Rejection vs Frequency

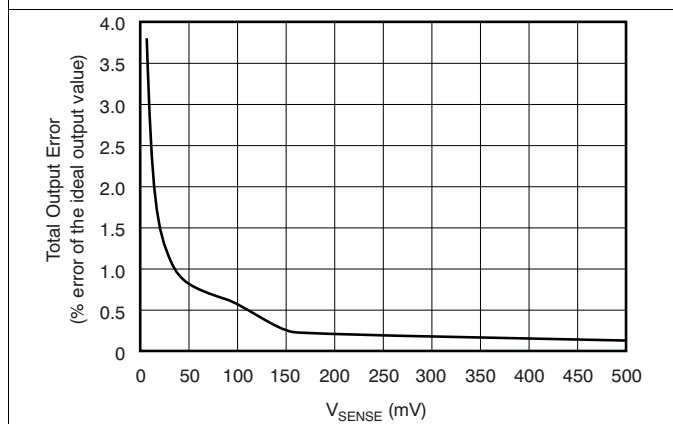


Figure 6. Total Output Error vs  $V_{SENSE}$

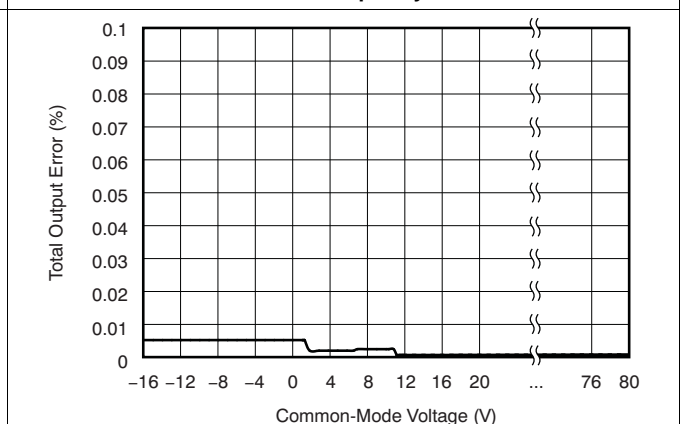


Figure 7. Total Output Error vs Common-Mode Voltage



Typical Characteristics (continued)

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

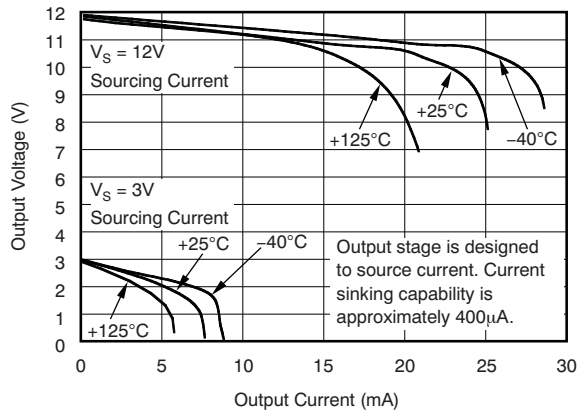


Figure 8. Positive Output Voltage Swing vs Output Current

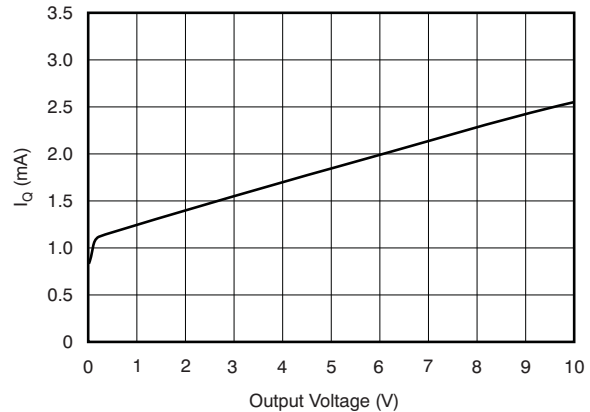


Figure 9. Quiescent Current vs Output Voltage

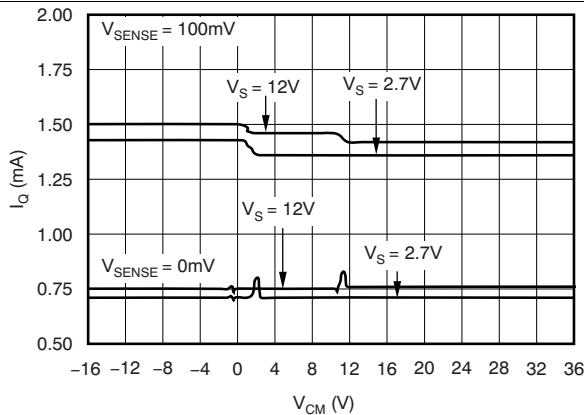


Figure 10. Quiescent Current vs Common-Mode Voltage

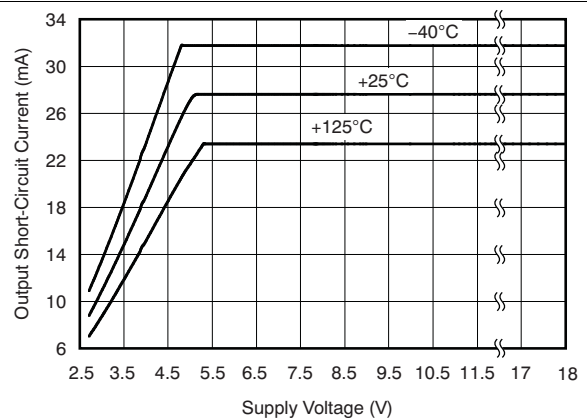


Figure 11. Output Short-Circuit Current vs Supply Voltage

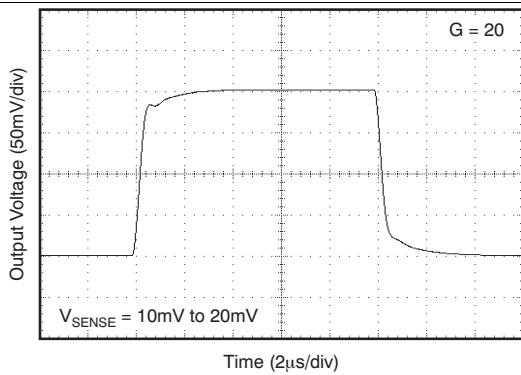


Figure 12. Step Response

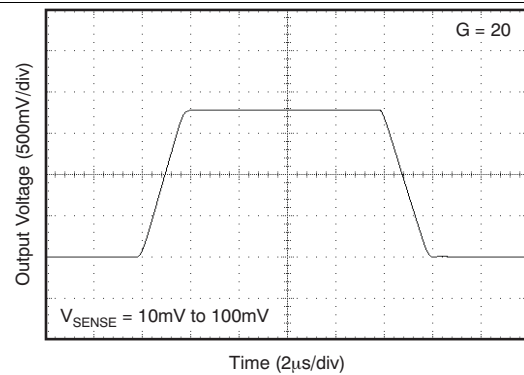


Figure 13. Step Response

### Typical Characteristics (continued)

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

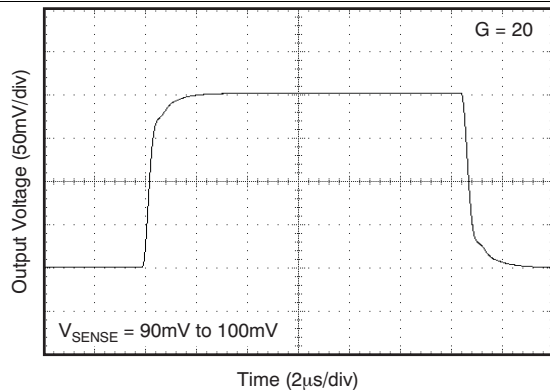


Figure 14. Step Response

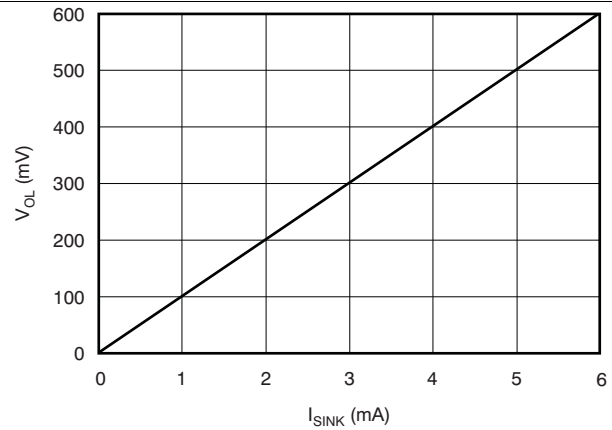


Figure 15. Comparator  $V_{OL}$  vs  $I_{SINK}$

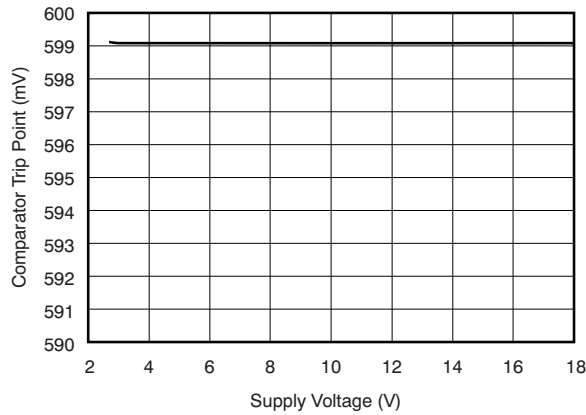


Figure 16. Comparator Trip Point vs Supply Voltage

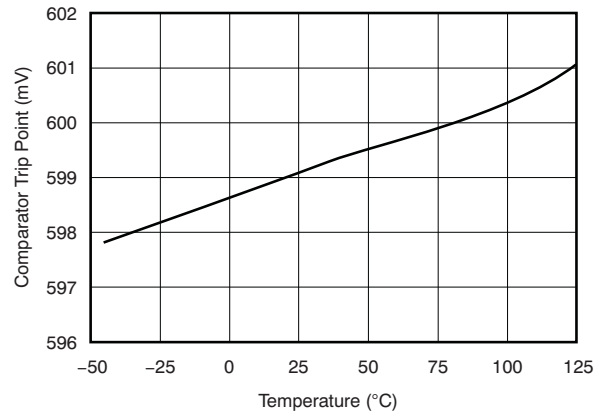


Figure 17. Comparator Trip Point vs Temperature

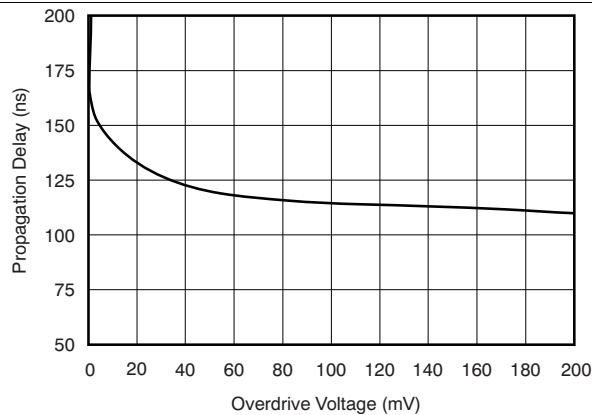


Figure 18. Comparator 1 Propagation Delay vs Overdrive Voltage

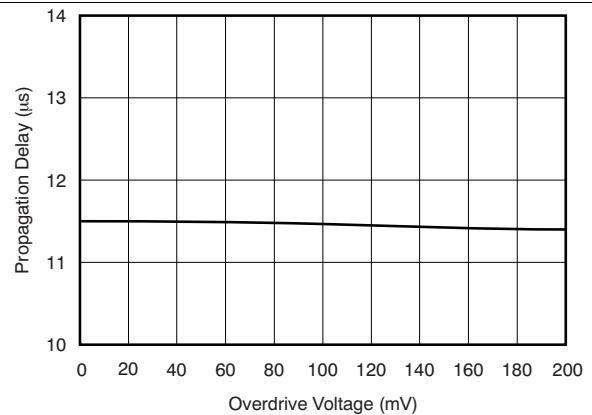


Figure 19. Comparator 2 Propagation Delay vs Overdrive Voltage

Typical Characteristics (continued)

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

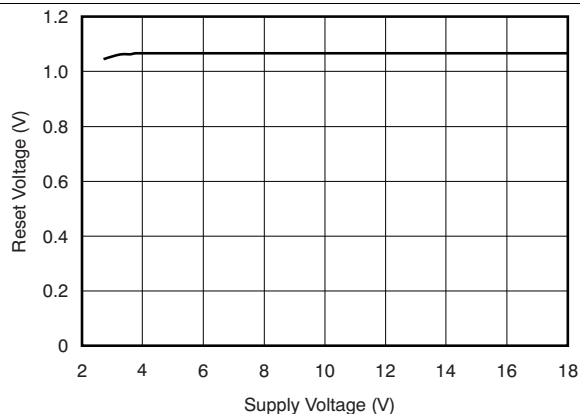


Figure 20. Comparator Reset Voltage vs supply Voltage

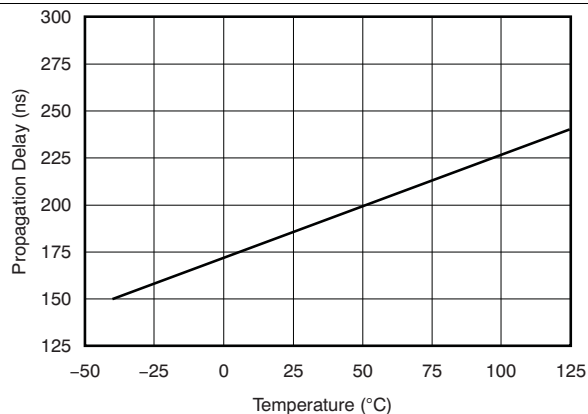


Figure 21. Comparator 1 Propagation Delay vs Temperature

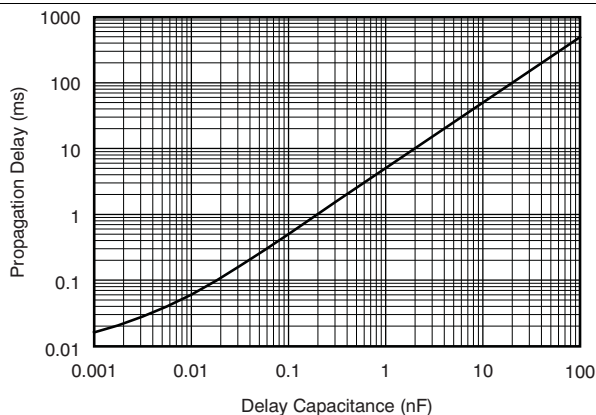


Figure 22. Comparator 2 Propagation Delay vs Capacitance

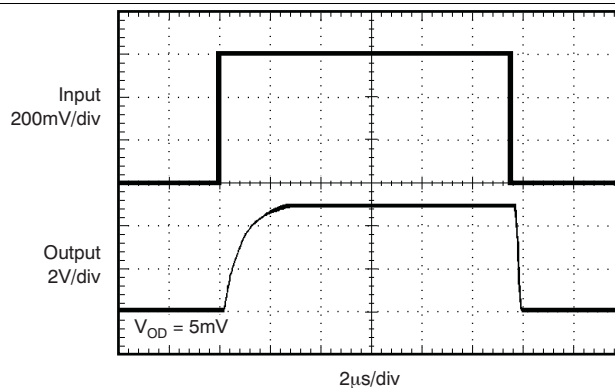


Figure 23. Comparator 1 Propagation Delay

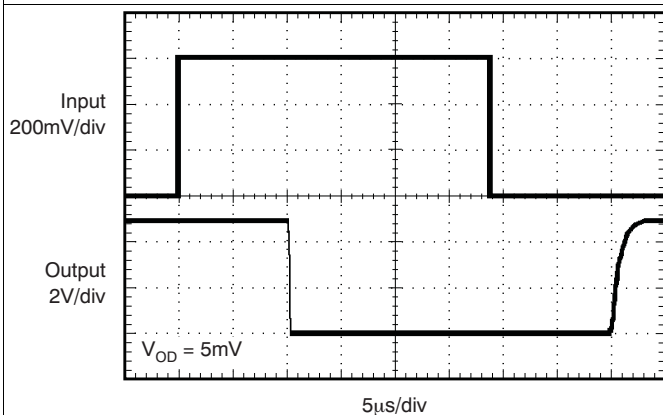


Figure 24. Comparator 2 Propagation Delay

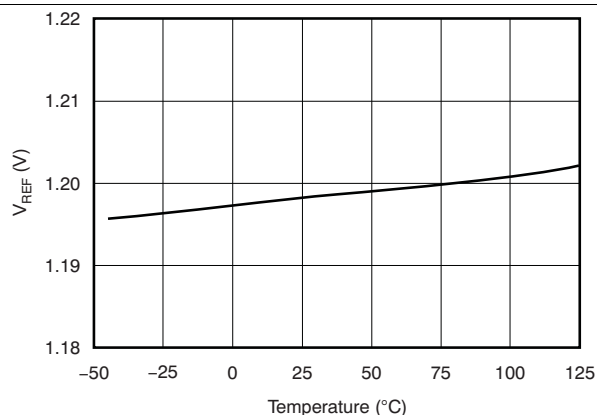


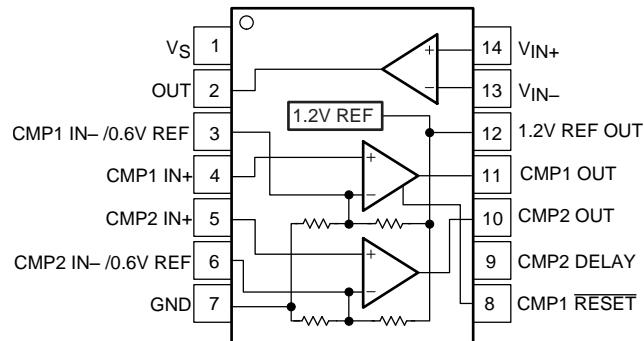
Figure 25. Reference Voltage vs Temperature

## 8 Detailed Description

### 8.1 Overview

The INA203-Q1 device is a unidirectional voltage output current-sense amplifier with dual comparators and voltage reference. The INA203-Q1 operates over a wide range of common-mode voltage (–16 V to +80 V) and incorporates two open-drain comparators with internal 0.6-V references. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay. The device also incorporates a 1.2-V reference output.

### 8.2 Functional Block Diagram



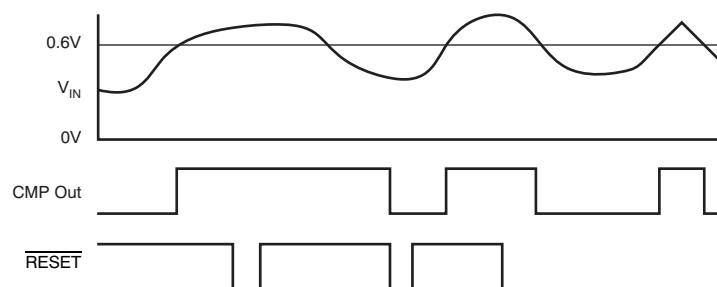
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### 8.3 Feature Description

#### 8.3.1 Comparator

The INA203-Q1 incorporates two open-drain comparators. These comparators typically have 2 mV of offset and a 1.3- $\mu$ s (typical) response time. The output of Comparator 1 latches and is reset through the CMP1 RESET pin, as shown in [Figure 26](#).

The INA203-Q1 device includes 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.



**Figure 26. Comparator Latching Capability**

#### 8.3.2 Comparator Delay

The Comparator 2 programmable delay is controlled by a capacitor connected to the CMP2 Delay Pin; see [Figure 30](#). The capacitor value (in  $\mu$ F) is selected by using [Equation 1](#):

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

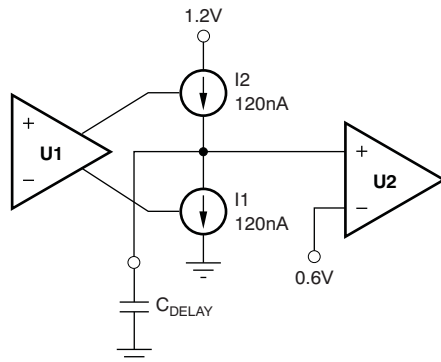
A simplified version of the delay circuit for Comparator 2 is shown in [Figure 27](#). The delay comparator consists of two comparator stages with the delay between them.

## Feature Description (continued)

### NOTE

I1 and I2 cannot be turned on simultaneously; I1 corresponds to a U1 low output and I2 corresponds to a U1 high output.

Using an initial assumption that the U1 output is low, I1 is on, then U2 +IN is zero. If U1 goes high, I2 supplies 120 nA to C<sub>DELAY</sub>. The voltage at U2 +IN begins to ramp toward a 0.6-V threshold. When the voltage crosses this threshold, the U2 output goes high while the voltage at U2 +IN continues to ramp up to a maximum of 1.2 V when given sufficient time (twice the value of the delay specified for C<sub>DELAY</sub>). This entire sequence is reversed when the comparator outputs go low, so that returning to low exhibits the same delay.



**Figure 27. Simplified Model of The Comparator 2 Delay Circuit**

It is important to note the behavior of the Comparator 2 when the events at the inputs occur more rapidly than the set delay timeout. For example, when the U1 output goes high (turning on I2), but returns low (turning I1 back on) prior to reaching the 0.6 V transition for U2. The voltage at U2 +IN ramps back down at a rate determined by the value of C<sub>DELAY</sub>, 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 27](#).

### 8.3.3 Comparator Maximum Input Voltage Range

The maximum voltage at the comparator input for normal operation is up to  $(V_S) - 1.5$  V. There are special considerations when overdriving the reference inputs (pins 3 and 6). Driving either or both inputs high enough to drive 1 mA back into the reference introduces errors into the reference. [Figure 28](#) shows the basic input structure. A general guideline is to limit the voltage on both inputs to a total of 20 V. The exact limit depends on the available voltage and whether either or both inputs are subject to the large voltage. When making this determination, consider the 20 k $\Omega$  from each input back to the comparator. [Figure 29](#) shows the maximum input voltage that avoids creating a reference error when driving both inputs (an equivalent resistance back into the reference of 10 k $\Omega$ ).



## 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.

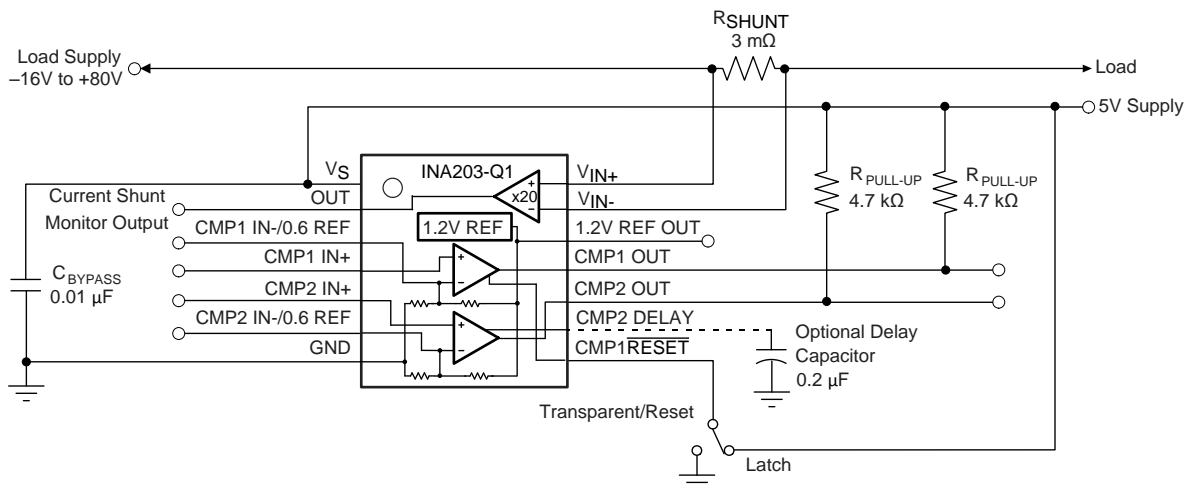
### 9.1 Application Information

The INA203-Q1 device is designed to enable easy configuration for detecting overcurrent conditions and current monitoring in an application. This device is also incorporate two open-drain comparators with internal 0.6-V references. The comparator references can be overridden by external inputs. Comparator 1 includes a latching capability, and Comparator 2 has a user-programmable delay. The INA203-Q1 also provides a 1.2-V reference output. This device can also be paired with minimum additional devices to create more sophisticated monitoring functional blocks.

#### 9.1.1 Basic Connections

Figure 30 shows the basic connections of the INA203-Q1. Connect the input pins,  $V_{IN+}$  and  $V_{IN-}$ , 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.



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Figure 30. INA203-Q1 Basic Connection

#### 9.1.2 Selecting $R_{SHUNT}$

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

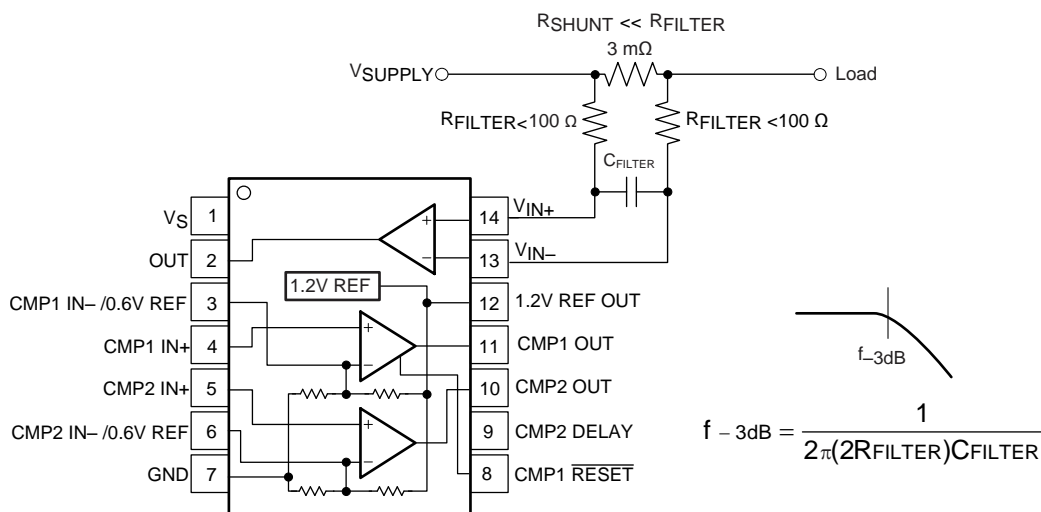
## Application Information (continued)

### 9.1.3 Input Filtering

An obvious and straightforward location for filtering is at the output of the INA203-Q1 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-Q1, which is complicated by the internal 5 kΩ + 30% input impedance; this configuration is illustrated in [Figure 31](#). Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. [Equation 2](#) gives the effect on initial gain:

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

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



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**Figure 31. Input Filter**

#### NOTE

The specified accuracy of the INA203-Q1 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.

### 9.1.4 Accuracy Variations as a Result of $V_{\text{SENSE}}$ and Common-Mode Voltage

The accuracy of the INA203-Q1 current-shunt monitors is a function of two main variables:  $V_{\text{SENSE}}$  ( $V_{\text{IN}+} - V_{\text{IN}-}$ ) and common-mode voltage,  $V_{\text{CM}}$ , relative to the supply voltage,  $V_{\text{S}}$ .  $V_{\text{CM}}$  is expressed as  $(V_{\text{IN}+} + V_{\text{IN}-})/2$ ; however, in practice,  $V_{\text{CM}}$  is seen as the voltage at  $V_{\text{IN}+}$  because the voltage drop across  $V_{\text{SENSE}}$  is usually small.

This section addresses the accuracy of these specific operating regions:

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



## Application Information (continued)

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

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

$$G = \frac{V_{OUT1} - V_{OUT2}}{100\text{mV} - 20\text{mV}}$$

where

- $V_{OUT1}$  = output voltage with  $V_{SENSE} = 100 \text{ mV}$
  - $V_{OUT2}$  = output voltage with  $V_{SENSE} = 20 \text{ mV}$
- (3)

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

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

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

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

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

### 9.1.4.3 Low $V_{SENSE}$ Case 1:

$V_{SENSE} < 20 \text{ mV}$ ,  $-16 \text{ V} \leq V_{CM} < 0$ ; and

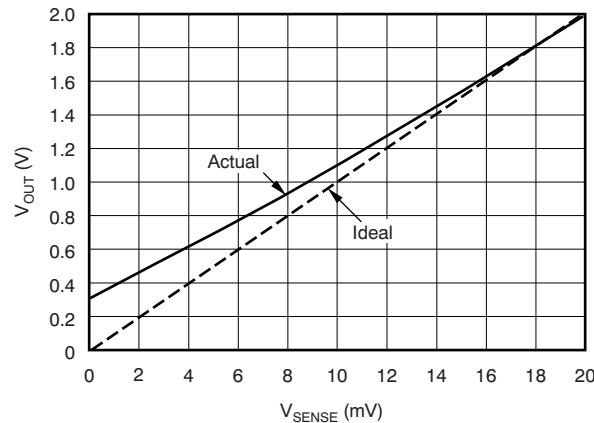
Low  $V_{SENSE}$  Case 3:

$V_{SENSE} < 20 \text{ mV}$ ,  $V_S < V_{CM} \leq 80 \text{ V}$

Although the INA203-Q1 is 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-Q1. It is important to know what the behavior of the devices will be in these regions.

As  $V_{SENSE}$  approaches  $0 \text{ mV}$ , in these  $V_{CM}$  regions, the device output accuracy degrades. A larger-than-normal offset can appear at the current shunt monitor output with a typical maximum value of  $V_{OUT} = 300 \text{ mV}$  for  $V_{SENSE} = 0 \text{ mV}$ . As  $V_{SENSE}$  approaches  $20 \text{ mV}$ ,  $V_{OUT}$  returns to the expected output value with accuracy as specified in the [Electrical Characteristics](#). [Figure 32](#) illustrates this effect (Gain = 100).

Application Information (continued)

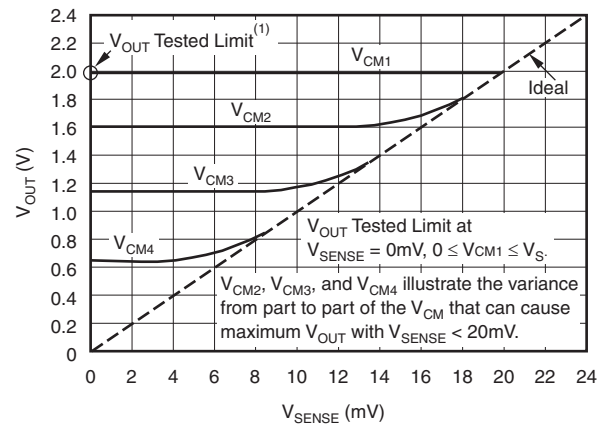


Data taken from INA205, a device of INA20x family with Gain = 100

Figure 32. Example for Low  $V_{SENSE}$  Cases 1 and 3 (Gain = 100)

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

This region of operation is the least accurate for the INA203-Q1. To achieve the wide input common-mode voltage range, this device uses two operational amplifiers (Opamp) front ends in parallel. One Opamp 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 dominate and overall loop gain is very low. Within this region,  $V_{OUT}$  approaches voltages close to linear operation levels for Normal Case 2. This deviation from linear operation becomes greatest the closer  $V_{SENSE}$  approaches 0 V. Within this region, as  $V_{SENSE}$  approaches 20 mV, device operation is closer to that described by Normal Case 2. Figure 33 illustrates this behavior. The  $V_{OUT}$  maximum peak for this case is tested by maintaining a constant  $V_S$ , setting  $V_{SENSE} = 0\text{ mV}$ , and sweeping  $V_{CM}$  from 0 V to  $V_S$ . The exact  $V_{CM}$  at which  $V_{OUT}$  peaks during this test varies from part to part, but the  $V_{OUT}$  maximum peak is tested to be less than the specified  $V_{OUT}$  Tested Limit.



NOTE: (1) INA203-Q1  $V_{OUT}$  Tested Limit = 0.4V.

Data taken from INA205, a device of INA20x family with Gain = 100

Figure 33. Example for Low  $V_{SENSE}$  Case 2 (Gain = 100)

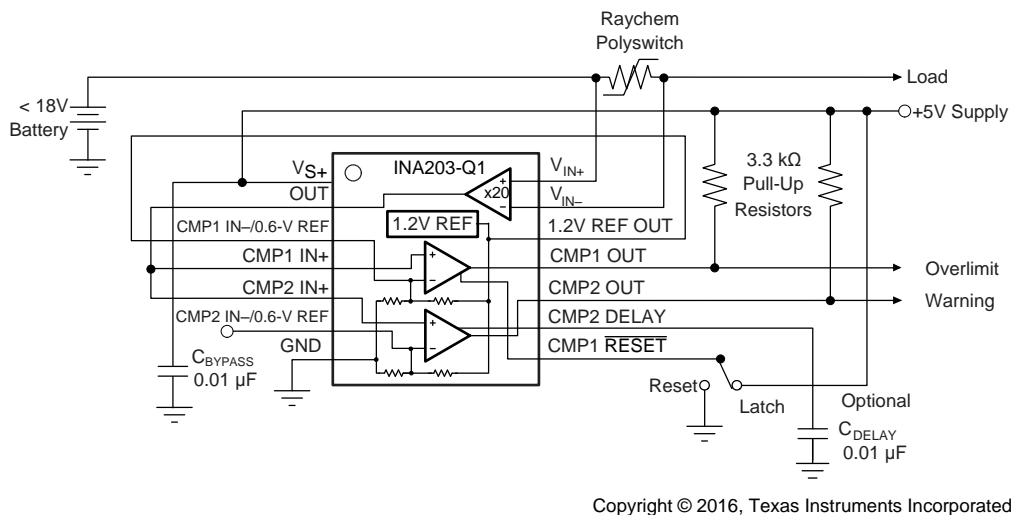
## Application Information (continued)

### 9.1.5 Transient Protection

The  $-16\text{ V}$  to  $+80\text{ V}$  common-mode range of the INA203-Q1 is ideal for withstanding automotive fault conditions ranging from 12-V battery reversal up to 80-V transients, since no additional protective components are needed up to those levels. In the event that the INA203-Q1 is 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-Q1 to be exposed to transients greater than 80 V (that is, allow for transient absorber tolerance, as well as additional voltage because of transient absorber dynamic impedance). Despite the use of internal zener-type ESD protection, the INA203-Q1 does not lend itself to using external resistors in series with the inputs because the internal gain resistors can vary up to  $\pm 30\%$  but are closely matched. (If gain accuracy is not important, then resistors can be added in series with the INA203-Q1 inputs with two equal resistors on each input.)

## 9.2 Typical Applications

### 9.2.1 Polyswitch Warning and Fault Detection Circuit



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Figure 34. Polyswitch Warning and Fault Detection Circuit Schematic

#### 9.2.1.1 Design Requirements

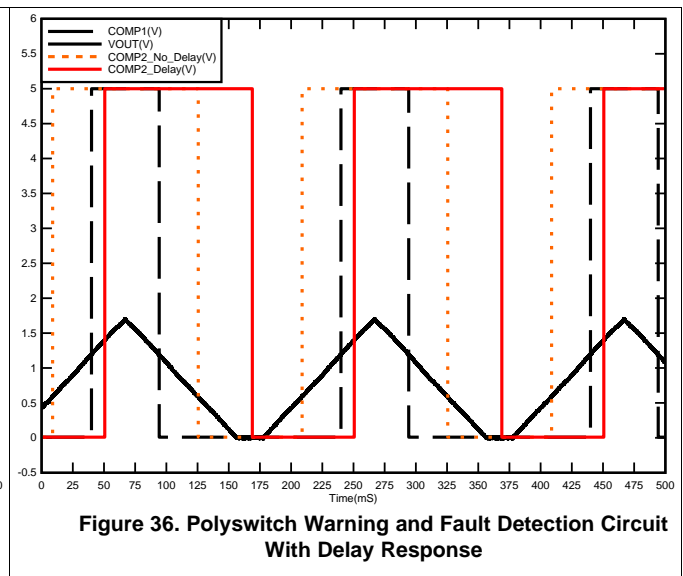
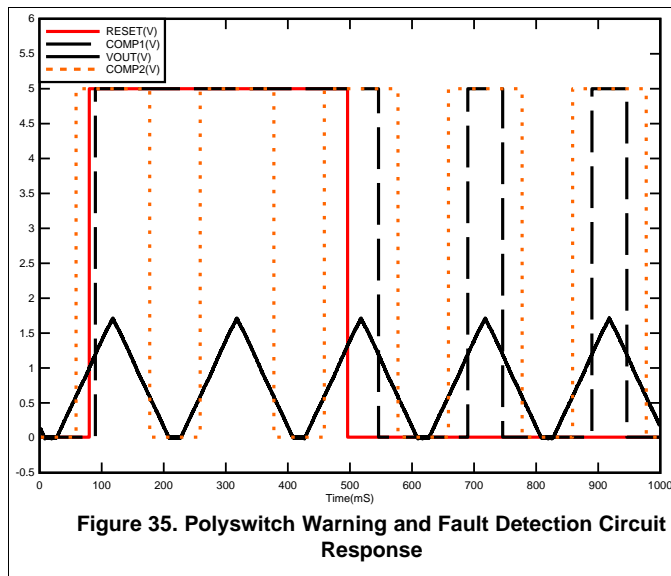
The device measures current through a resistive shunt with current flowing in one direction, thus enabling detection of an overlimit or warning event only when the differential input voltage exceeds the corresponding threshold limits. When the current reaches the warning limit of 0.6 V, the output of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

#### 9.2.1.2 Detailed Design Procedure

Figure 34 shows the basic connections of the device. The input terminals,  $V_{IN+}$  and  $V_{IN-}$ , should be connected as close as possible to the current-sensing resistor or polymeric switch to minimize any resistance in series with the shunt resistance. Additional resistance between the current-sensing resistor and input terminals can result in errors in the measurement. When input current flows through this external input resistance, the voltage developed across the shunt resistor can differ from the voltage reaching the input terminals.

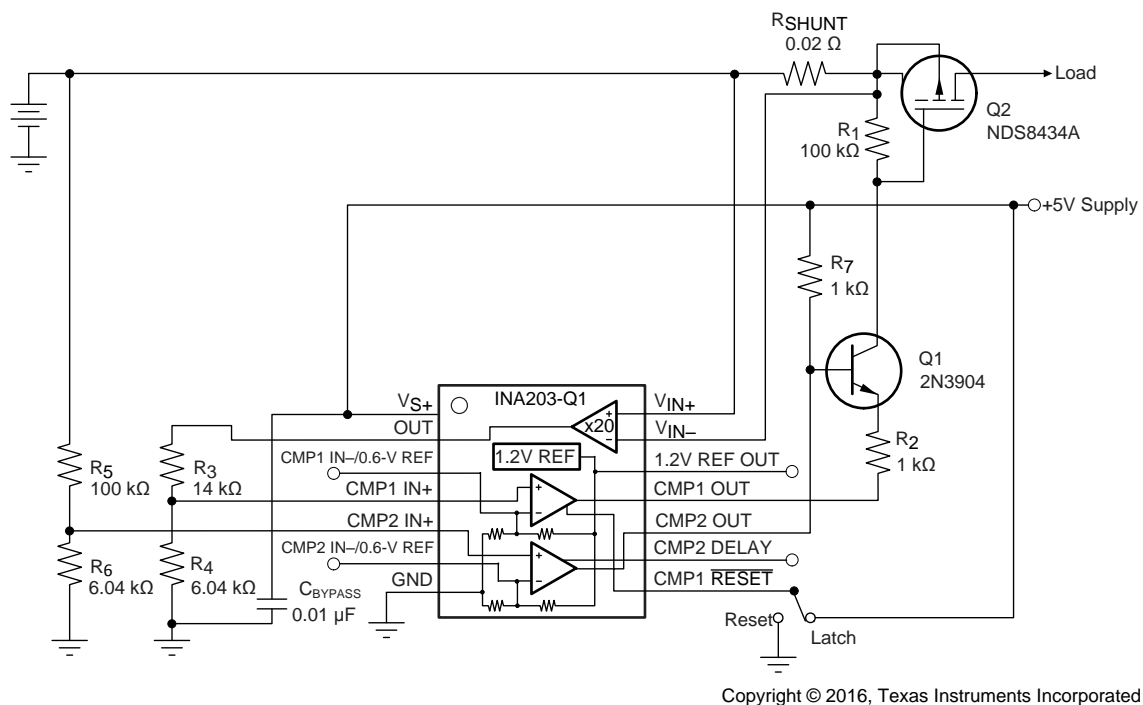
## Typical Applications (continued)

### 9.2.1.3 Application Curves



### 9.2.2 Lead-Acid Battery Protection Circuit

See [Figure 37](#) for a protection scheme using INA203-Q1 for a lead-acid battery application.



**Figure 37. Lead-Acid Battery Protection Circuit Schematic**

## 10 Power Supply Recommendations

The input circuitry of the INA203-Q1 can accurately measure beyond the power-supply voltage,  $V_S$ . For example, the  $V_S$  power supply can be 5 V, whereas the load power-supply voltage is up to 80 V. The output voltage range of the OUT terminal, however, is limited by the voltages on the power-supply pin.

## 11 Layout

### 11.1 Layout Guidelines

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

### 11.2 Layout Example

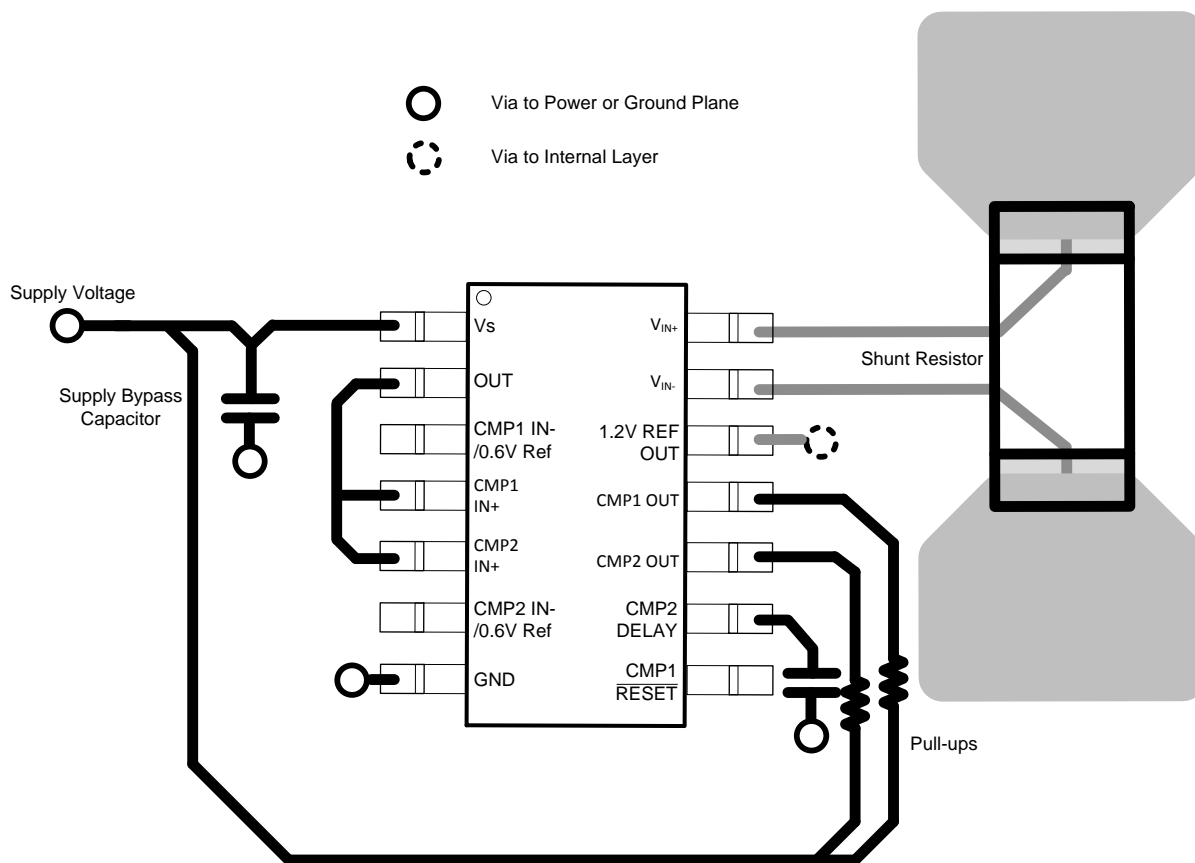


Figure 38. Layout Recommendation

## 12 Device and Documentation Support

### 12.1 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](#).

**TI E2E™ Online Community** *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](http://e2e.ti.com), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

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

### 12.2 Trademarks

E2E is a trademark of Texas Instruments.  
All other trademarks are the property of their respective owners.

### 12.3 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.

### 12.4 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 finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
INA203AQPWRQ1	ACTIVE	TSSOP	PW	14	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	I203AQ	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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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF INA203-Q1 :**

- Catalog: [INA203](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product



**TAPE AND REEL INFORMATION**

**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
INA203AQPWRQ1	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA203AQPWRQ1	TSSOP	PW	14	2000	367.0	367.0	35.0



PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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