

# INA203-Q1 采用两个比较器和基准的汽车级、-16 V 至 +80 V、低侧或高侧、高速电压输出分流监测计

## 1 特性

- 汽车电子 应用认证
- 电流感测放大器
  - 共模范围: -16V 至 +80V
  - 精度: 整个温度范围内的精度为 3.5% (最大值)
  - 带宽: 500 kHz
  - 增益: 20V/V
- 集成双比较器:
  - 具有锁存功能的比较器 1
  - 延迟可选的比较器 2
- 静态电流: 1.8mA
- 锁存性能可达 100mA, 符合 AEC-Q100 I 级标准
- 封装: 薄型小外形尺寸 (TSSOP)-14

## 2 应用

- 电动助力转向 (EPS) 系统
- 车身控制模块
- 刹车系统
- 电子稳定性控制 (ESC) 系统

## 3 说明

INA203-Q1 是一款单向分流监测计 (也称电流感测放大器), 具备电压输出、两个比较器和电压基准。INA203-Q1 能够在 -16V 至 +80V 范围内的共模电压下感测分流器两端的压降。INA203-Q1 的增益为 20V/V, 带宽高达 500kHz。

INA203-Q1 采用两个开漏比较器及 0.6V 内部基准, 还可提供 1.2V 基准输出。比较器基准可由外部输入替代。比较器 1 具备锁存功能, 而比较器 2 的延迟可由用户通过编程设定。

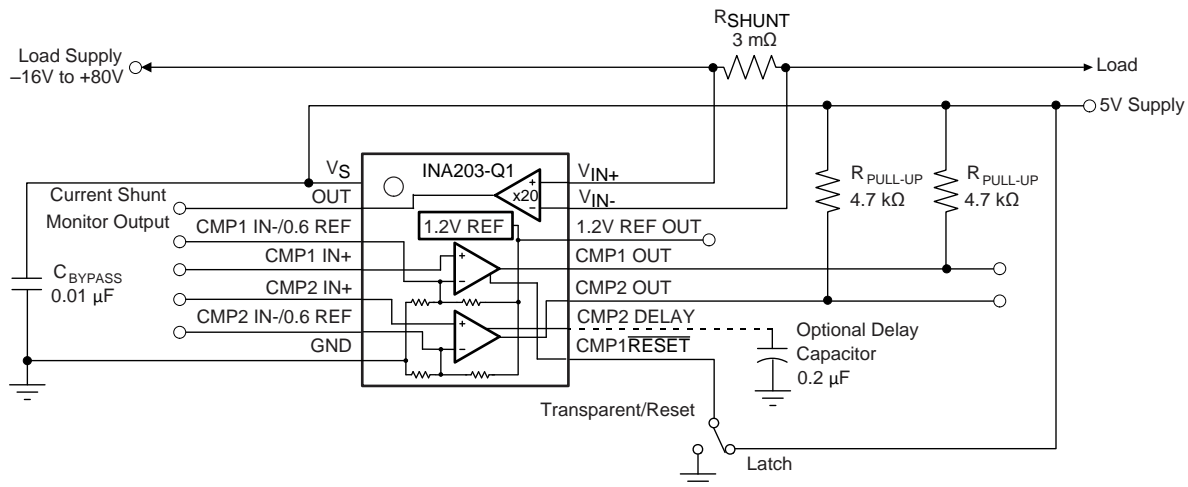
INA203-Q1 由 2.7V 至 18V 单电源供电。该器件可在 -40°C 至 +125°C 扩展工作温度范围内额定运行。

器件信息(1)

器件型号	封装	封装尺寸 (标称值)
INA203-Q1	TSSOP (14)	5.00mm x 4.40mm

(1) 要了解所有可用封装, 请见数据表末尾的可订购产品附录。

基础连接电路原理图



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## 4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

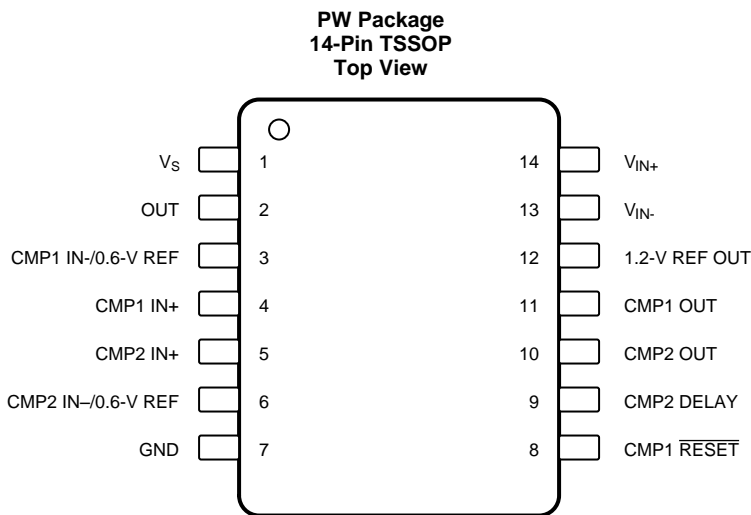
Changes from Original (December 2010) to Revision A	Page
• 已更新数据表标题，特性, 应用, 和 说明 .....	1
• 已添加 <b>ESD</b> 额定值表，特性 描述部分，器件功能模式，应用和 实施部分，电源相关建议部分，布局部分，器件和文档支持部分，机械、封装和可订购信息部分，引脚配置和功能部分，建议运行条件表以及热性能信息表 .....	1
• Added <i>Device Comparison Table</i> .....	3
• Changed V+ to V <sub>S</sub> throughout .....	4
• Changed MAX value 18 to (V <sub>S</sub> ) + 0.3 for Comparator output pins .....	4
• Changed MAX value 10 to (V <sub>S</sub> ) up to 10 for 1.2-V REF and CMP2 DELAY pins .....	4
• Changed pin names in <i>Absolute Maximum Ratings</i> to show correct names .....	4
• Added Operating Temperature to <i>Absolute Maximum Ratings</i> table .....	4
• Changed CMP2 IN– to CMP2 IN+ in <i>Electrical Characteristics: Current-Shunt Monitor</i> condition statement .....	5
• Changed CMP2 IN– to CMP2 IN+ in <i>Electrical Characteristics: General</i> condition statement .....	7
• Updated <i>Overview</i> section .....	12
• Deleted 10-pin device image .....	12
• Changed text from "RFILT – 3%" to "RFILT + 3%" in 2nd paragraph of <i>Input Filtering</i> section .....	16
• Changed Figure 35 caption .....	16

## 5 Device Comparison Table

**Table 1. Related Products**

PRODUCT	DESCRIPTION
INA200-Q1	Single comparator alternative to the INA203's dual comparators
INA193A-Q1	Same amplifier performance without the comparators integrated
INA282-Q1	High-accuracy, high common-mode capable current sense amplifier
INA300-Q1	36-V overcurrent protection comparator
INA301	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, $T_{\text{stg}}$		–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
$V_{\text{(ESD)}}$ 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
$V_{\text{CM}}$	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	
$R_{\theta\text{JA}}$	Junction-to-ambient thermal resistance	112.6	°C/W
$R_{\theta\text{JC(top)}}$	Junction-to-case (top) thermal resistance	37.2	°C/W
$R_{\theta\text{JB}}$	Junction-to-board thermal resistance	55.4	°C/W
$\psi_{\text{JT}}$	Junction-to-top characterization parameter	2.7	°C/W
$\psi_{\text{JB}}$	Junction-to-board characterization parameter	54.7	°C/W
$R_{\theta\text{JC(bot)}}$	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
INPUT							
V <sub>SENSE</sub>	Full-scale sense input voltage	V <sub>SENSE</sub> = V <sub>IN+</sub> – V <sub>IN–</sub>		0.15		(V <sub>S</sub> – 0.25)/Gain	V
V <sub>CM</sub>	Common-mode input range	T <sub>A</sub> = –40°C to +125°C		–16		80	V
CMRR	Common-mode rejection ratio	V <sub>CM</sub> = –16 V to +80 V		80	100		dB
	Over temperature	V <sub>CM</sub> = 12 V to 80 V	T <sub>A</sub> = 25°C to 125°C	100	123		dB
		T <sub>A</sub> = –40°C to +25°C		90	100		dB
V <sub>OS</sub>	Offset voltage, RTI <sup>(1)</sup>				±0.5	±2.5	mV
		T <sub>A</sub> = 25°C to 125°C				±3	mV
		T <sub>A</sub> = –40°C to +25°C				±3.5	mV
dV <sub>OS</sub> /dT	Versus temperature	T <sub>MIN</sub> to T <sub>MAX</sub>	T <sub>A</sub> = –40°C to +125°C	5			μV/°C
PSR	Versus power supply	V <sub>OUT</sub> = 2 V, V <sub>CM</sub> = +18 V	T <sub>A</sub> = –40°C to +125°C	2.5		100	μV/V
I <sub>B</sub>	Input bias current, V <sub>IN–</sub> Pin	T <sub>A</sub> = –40°C to +125°C		±9		±16	μA
OUTPUT (V <sub>SENSE</sub> ≥ 20 mV)							
G	Gain			20			V/V
	Gain error	V <sub>SENSE</sub> = 20 mV to 100 mV		±0.2%		±1%	
	Over temperature	V <sub>SENSE</sub> = 20 mV to 100 mV	T <sub>A</sub> = –40°C to +125°C			±2%	
	Total output error <sup>(2)</sup>	V <sub>SENSE</sub> = 120 mV, V <sub>S</sub> = +16 V		±0.75%		±2.2%	
	Over temperature	V <sub>SENSE</sub> = 120 mV, V <sub>S</sub> = +16 V	T <sub>A</sub> = –40°C to +125°C			±3.5%	
	Nonlinearity error <sup>(3)</sup>	V <sub>SENSE</sub> = 20 mV to 100 mV		±0.002%			
R <sub>O</sub>	Output impedance, Pin 2			1.5			Ω
	Maximum capacitive load	No sustained oscillation		10			nF
OUTPUT (V <sub>SENSE</sub> < 20 mV) <sup>(4)</sup>							
V <sub>OUT</sub>	Output voltage	–16 V ≤ V <sub>CM</sub> < 0 V		300			mV
		0 V ≤ V <sub>CM</sub> ≤ V <sub>S</sub> , V <sub>S</sub> = 5 V				0.4	V
		V <sub>S</sub> < V <sub>CM</sub> ≤ 80 V		300			mV
VOLTAGE OUTPUT <sup>(5)</sup>							
	Output swing to the positive rail	V <sub>IN–</sub> = 11 V, V <sub>IN+</sub> = 12 V	T <sub>A</sub> = –40°C to +125°C	(V <sub>S</sub> ) – 0.15		(V <sub>S</sub> ) – 0.25	V
	Output Swing to GND <sup>(6)</sup>	V <sub>IN–</sub> = 0 V, V <sub>IN+</sub> = –0.5 V	T <sub>A</sub> = –40°C to +125°C	(V <sub>GND</sub> ) + 0.004		(V <sub>GND</sub> ) + 0.05	V
FREQUENCY RESPONSE							
BW	Bandwidth	C <sub>LOAD</sub> = 5 pF		500			kHz
	Phase margin	C <sub>LOAD</sub> < 10 nF		40			Degrees
SR	Slew rate			1			V/μs
	Settling time (1%)	V <sub>SENSE</sub> = 10 mV <sub>PP</sub> to 100 mV <sub>PP</sub> , C <sub>LOAD</sub> = 5 pF		2			μs
NOISE, RTI							
	Output Voltage Noise Density			40			nV/√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  $T_A = +25^\circ\text{C}$ ,  $V_S = +12\text{ V}$ ,  $V_{CM} = +12\text{ V}$ ,  $V_{SENSE} = 100\text{ mV}$ ,  $R_L = 10\text{ k}\Omega$  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>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 $V_{OUT}$ 1 V to 4 V, $R_L \geq 15\text{ k}\Omega$ connected to 5 V		200		V/mV
High-level output current	$V_{ID} = 0.4\text{ V}$ , $V_{OH} = V_S$		0.0001	1	$\mu\text{A}$
Low-level output voltage	$V_{ID} = -0.6\text{ V}$ , $I_{OL} = 2.35\text{ mA}$		220	300	mV
<b>RESPONSE TIME<sup>(4)</sup></b>					
Comparator 1	$R_L$ to 5 V, $C_L = 15\text{ pF}$ , 100 mV input step with 5 mV overdrive		1.3		$\mu\text{s}$
Comparator 2	$R_L$ to 5 V, $C_L = 15\text{ pF}$ , 100 mV input step with 5 mV overdrive, $C_{DELAY}$ pin open		1.3		$\mu\text{s}$
<b>RESET</b>					
RESET threshold <sup>(5)</sup>			1.1		V
Logic input impedance			2		M $\Omega$
Minimum RESET pulse width			1.5		$\mu\text{s}$
RESET propagation delay			3		$\mu\text{s}$
Comparator 2 delay equation <sup>(6)</sup>			$C_{DELAY} = t_D/5$		$\mu\text{F}$
$t_D$ Comparator 2 delay	$C_{DELAY} = 0.1\text{ }\mu\text{F}$		0.5		s

- (1) Hysteresis refers to the threshold (the threshold specification applies to a rising edge of a noninverting input) of a falling edge on the noninverting input of the comparator; refer to [Figure 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 V.
- (5) The CMP1 RESET input has an internal 2 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	
REFERENCE VOLTAGE							
1.2 V <sub>REFOUT</sub> output voltage			1.188	1.2	1.212	V	
dV <sub>OUT</sub> /dT	Reference drift <sup>(1)</sup>	T <sub>A</sub> = −40°C to +85°C		40	100	ppm/°C	
0.6 V <sub>REF</sub> Output voltage (Pins 3 and 6)				0.6		V	
dV <sub>OUT</sub> /dT	Reference drift <sup>(1)</sup>	T <sub>A</sub> = −40°C to +85°C		40	100	ppm/°C	
LOAD REGULATION							
dV <sub>OUT</sub> /dI <sub>LOAD</sub>	Sourcing	0 mA < I <sub>SINK</sub> < 0.5 mA	V <sub>REFOUT</sub> − 1.2 V		0.4	2	mV/mA
	Sinking		0 mA < I <sub>SOURCE</sub> < 0.5 mA		0.4		mV/mA
LOAD CURRENT							
I <sub>LOAD</sub>				1		mA	
LINE REGULATION							
dV <sub>OUT</sub> /dV <sub>S</sub>		2.7 V < V <sub>S</sub> < 18 V		30		μV/V	
CAPACITIVE LOAD							
Reference output maximum capacitive load		No sustained oscillations		10		nF	
OUTPUT IMPEDANCE							
Pins 3 and 6				10		kΩ	

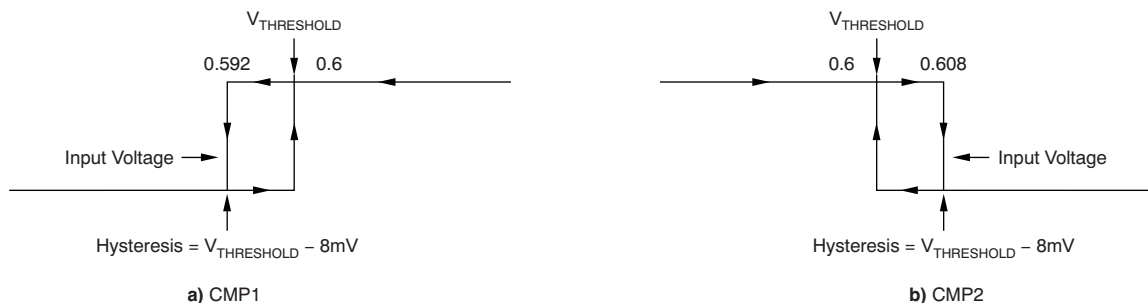
(1) Specified by design; not production tested.

## 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

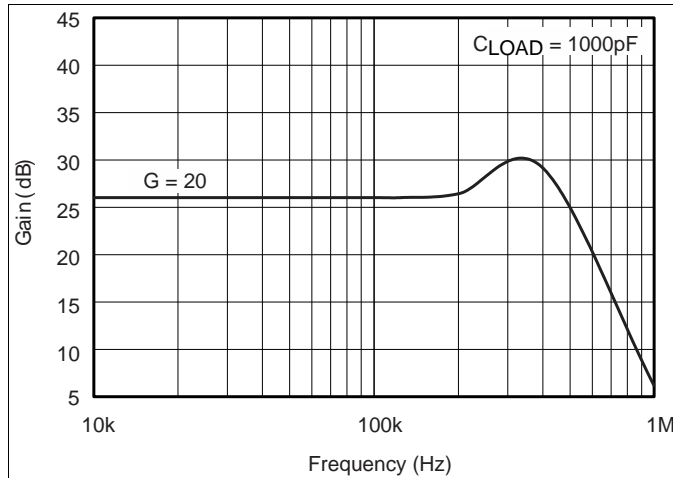
(1) The INA203-Q1 is designed to power-up with the comparator in a defined reset state as long as CMP1  $\overline{\text{RESET}}$  is open or grounded. The comparator will be in reset as long as the power supply is below the voltage shown here. The comparator assumes a state based on the comparator input 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.



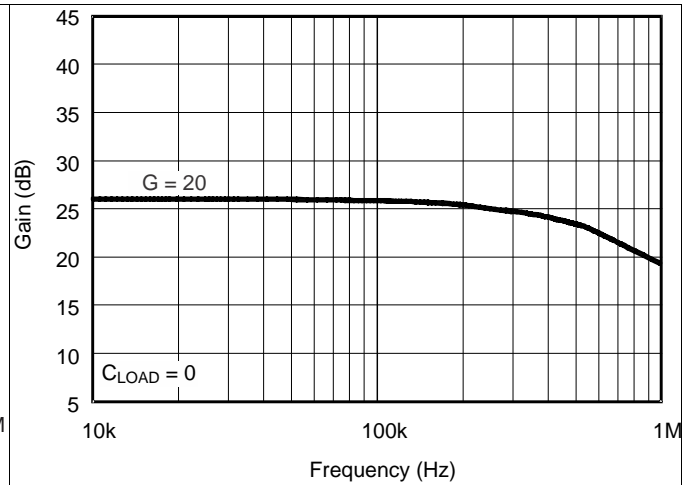
**Figure 1. Comparator Hysteresis**

## 7.9 Typical Characteristics

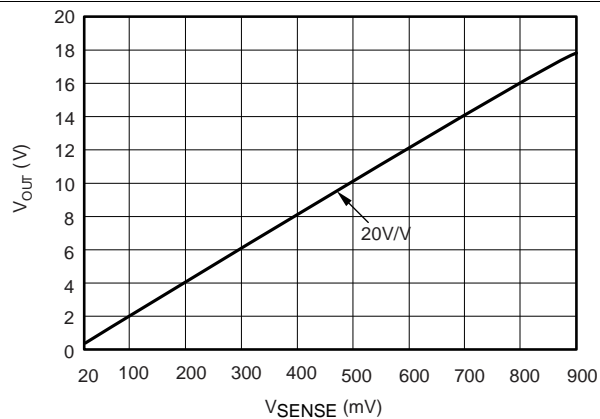
All specifications at  $T_A = +25^\circ\text{C}$ ,  $V_S = +12\text{ V}$ ,  $V_{CM} = +12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



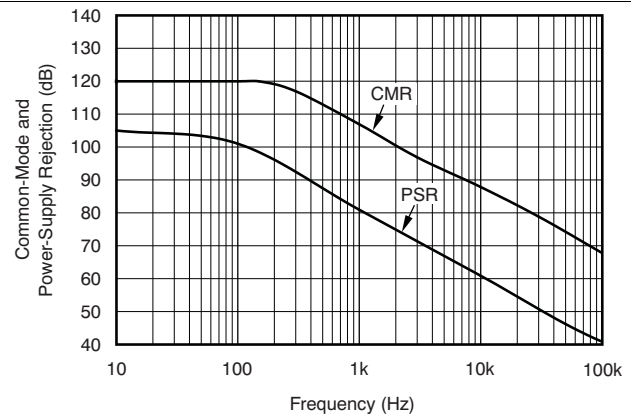
**Figure 2. Gain vs Frequency**



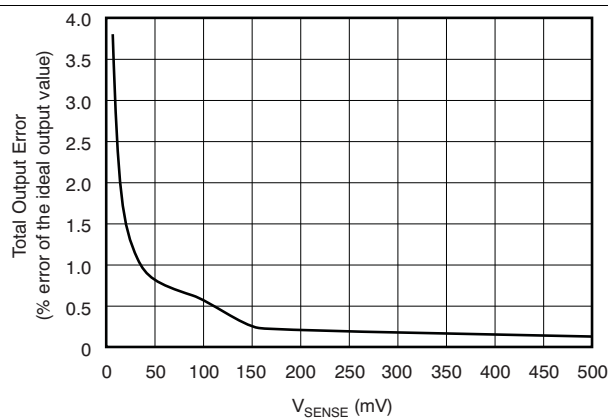
**Figure 3. Gain vs Frequency**



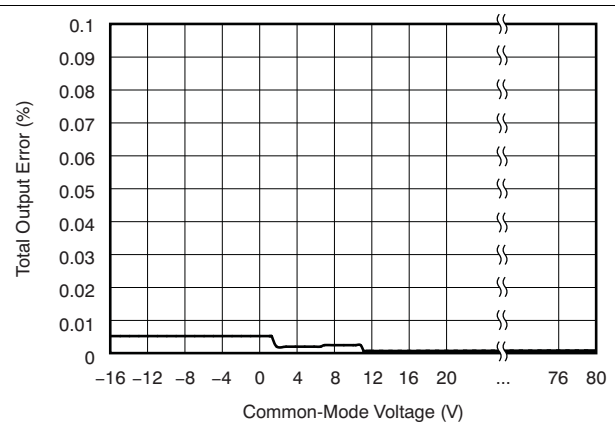
**Figure 4. Gain Plot**



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



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

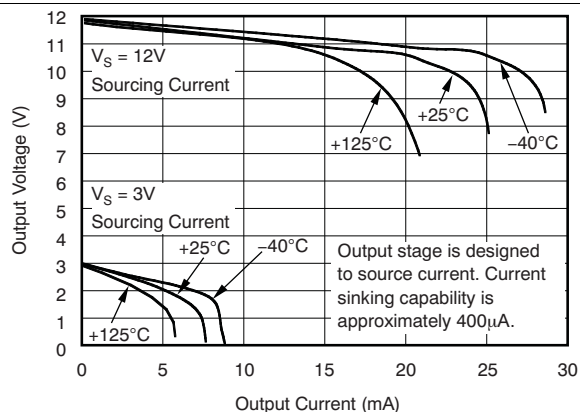


**Figure 7. Total Output Error vs Common-Mode Voltage**

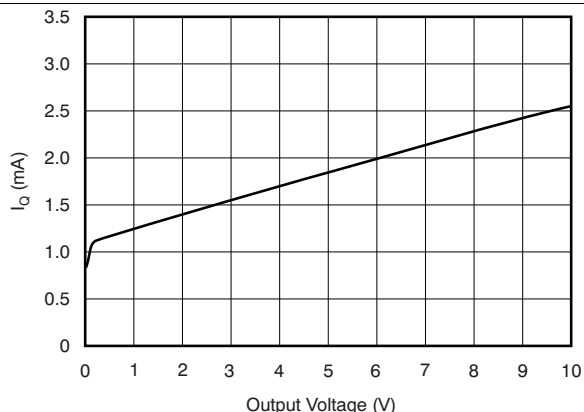


## Typical Characteristics (continued)

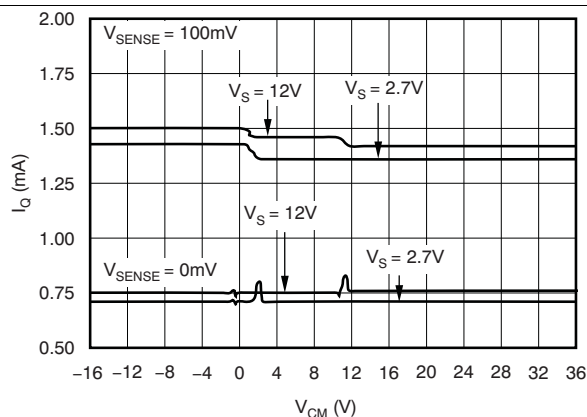
All specifications at  $T_A = +25^\circ\text{C}$ ,  $V_S = +12\text{ V}$ ,  $V_{CM} = +12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



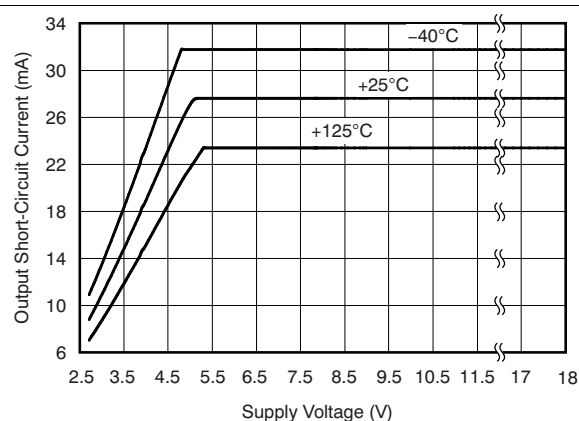
**Figure 8. Positive Output Voltage Swing vs Output Current**



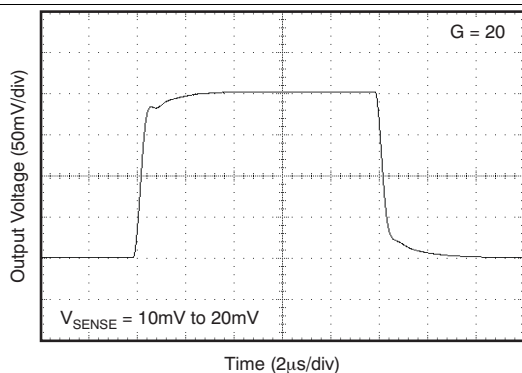
**Figure 9. Quiescent Current vs Output Voltage**



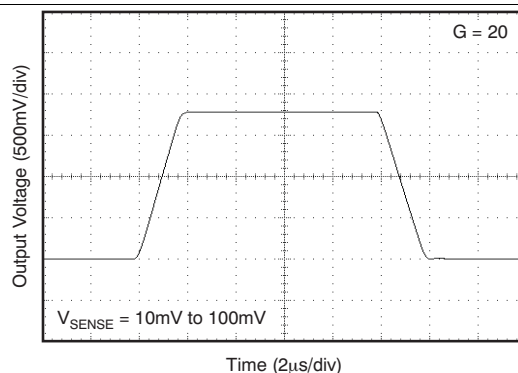
**Figure 10. Quiescent Current vs Common-Mode Voltage**



**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.

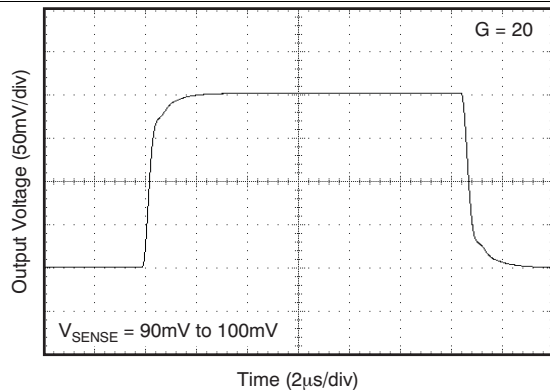


Figure 14. Step Response

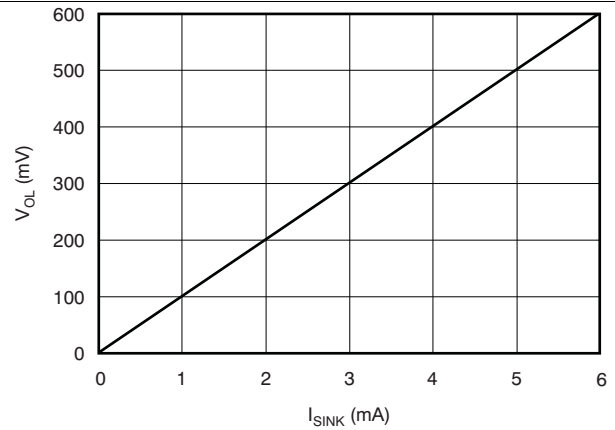


Figure 15. Comparator  $V_{OL}$  vs  $I_{SINK}$

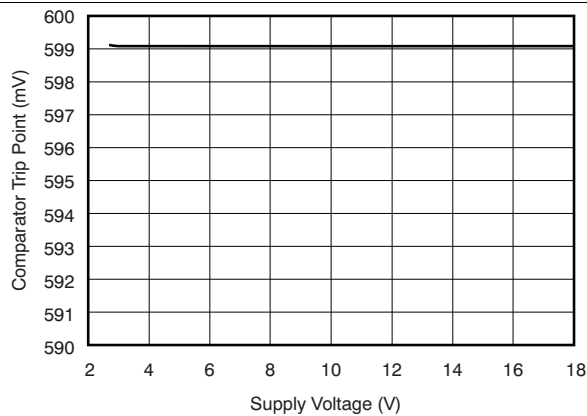


Figure 16. Comparator Trip Point vs Supply Voltage

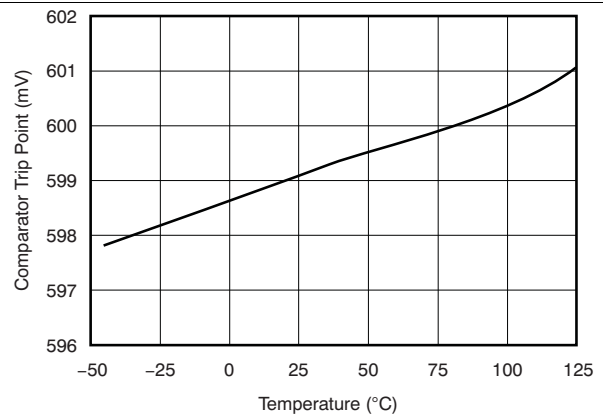


Figure 17. Comparator Trip Point vs Temperature

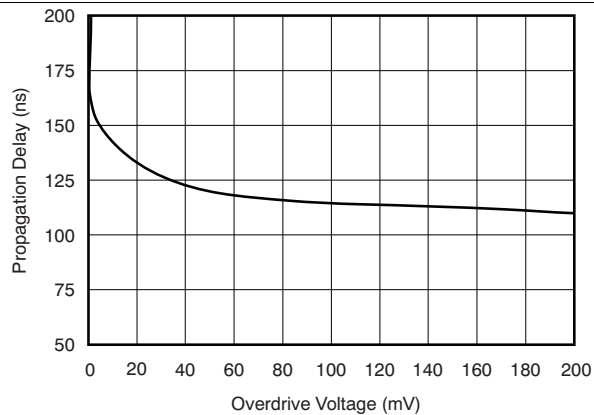


Figure 18. Comparator 1 Propagation Delay vs Overdrive Voltage

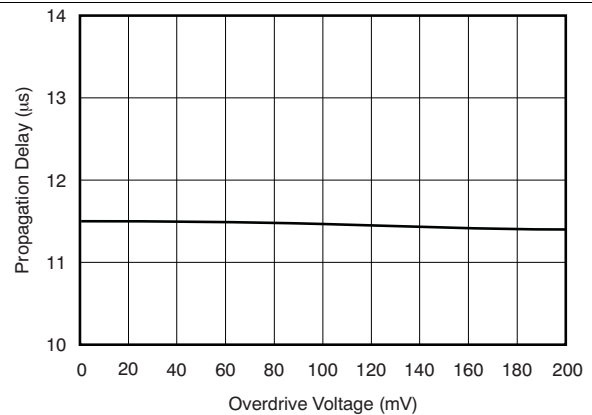
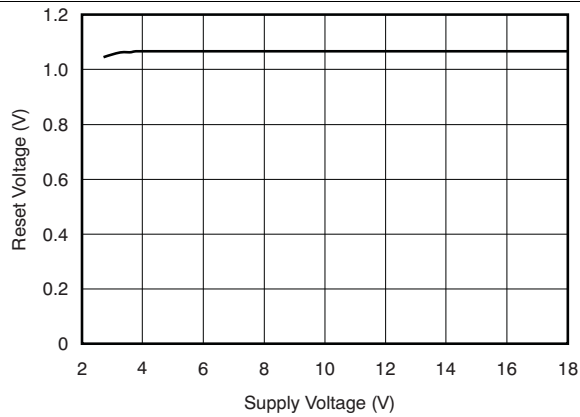


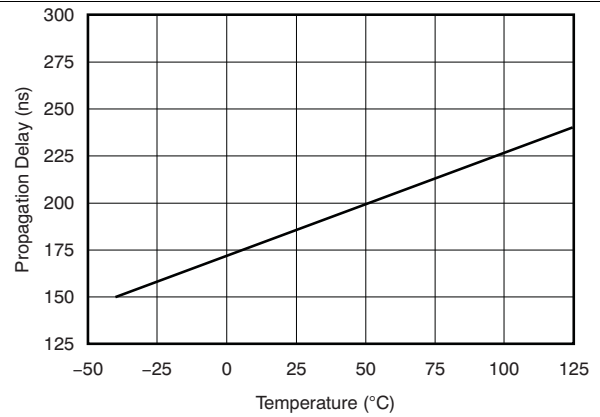
Figure 19. Comparator 2 Propagation Delay vs Overdrive Voltage

## Typical Characteristics (continued)

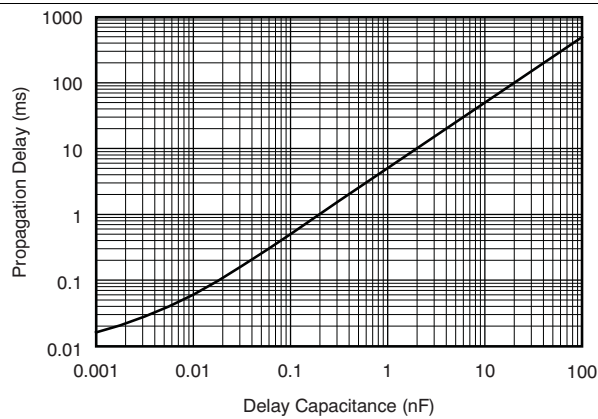
All specifications at  $T_A = +25^\circ\text{C}$ ,  $V_S = +12\text{ V}$ ,  $V_{CM} = +12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



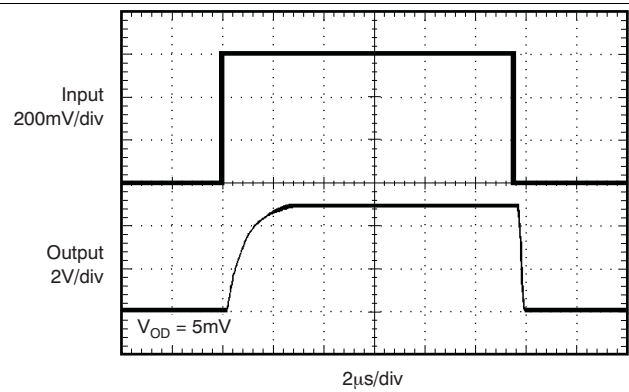
**Figure 20. Comparator Reset Voltage vs supply Voltage**



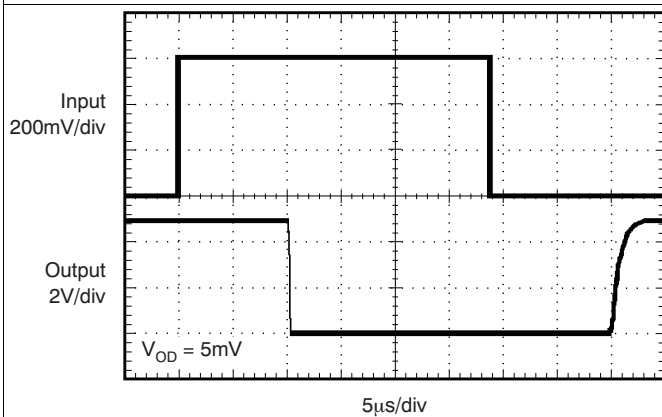
**Figure 21. Comparator 1 Propagation Delay vs Temperature**



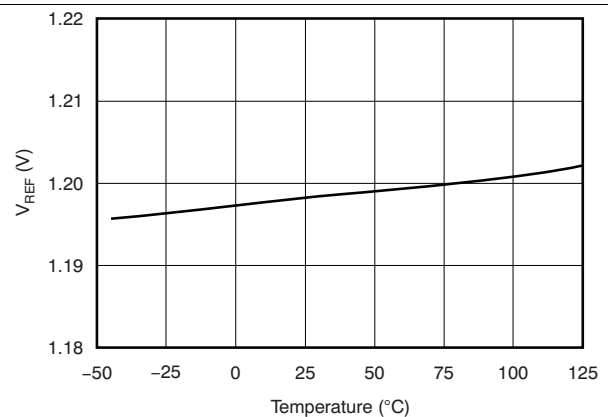
**Figure 22. Comparator 2 Propagation Delay vs Capacitance**



**Figure 23. Comparator 1 Propagation Delay**



**Figure 24. Comparator 2 Propagation Delay**



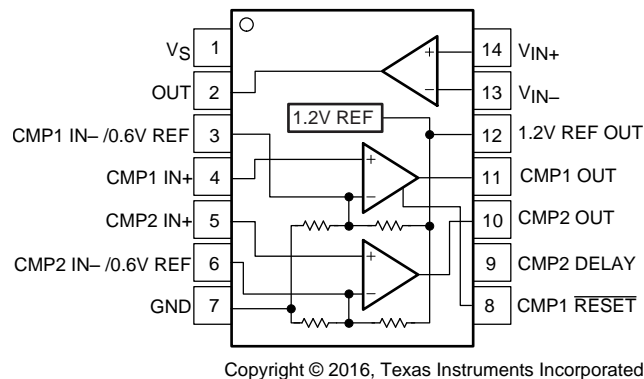
**Figure 25. Reference Voltage vs Temperature**

## 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

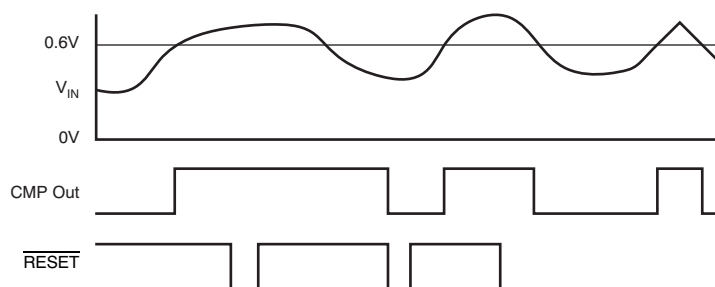


### 8.3 Feature Description

#### 8.3.1 Comparator

The INA203-Q1 incorporates two open-drain comparators. These comparators typically have 2 mV of offset and a 1.3-μs (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 μF) is selected by using [Equation 1](#):

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

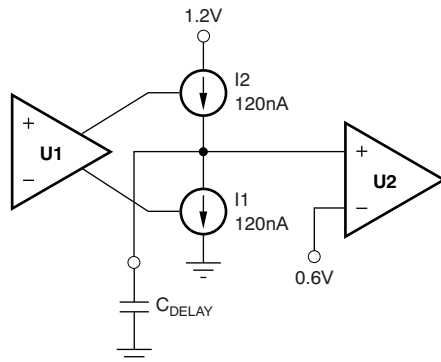
A simplified version of the delay circuit for Comparator 2 is shown in [Figure 27](#). The delay comparator consists of two comparator stages with the delay between them.

## 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**

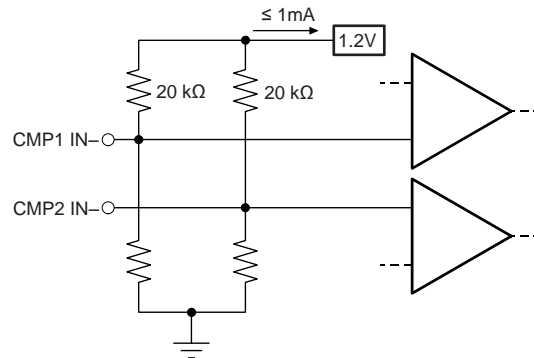
It is important to note the behavior of the Comparator 2 when the events at the inputs occur more rapidly than the set delay timeout. For example, when the U1 output goes high (turning on I2), but returns low (turning I1 back on) prior to reaching the 0.6 V transition for U2. The voltage at U2 +IN ramps 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

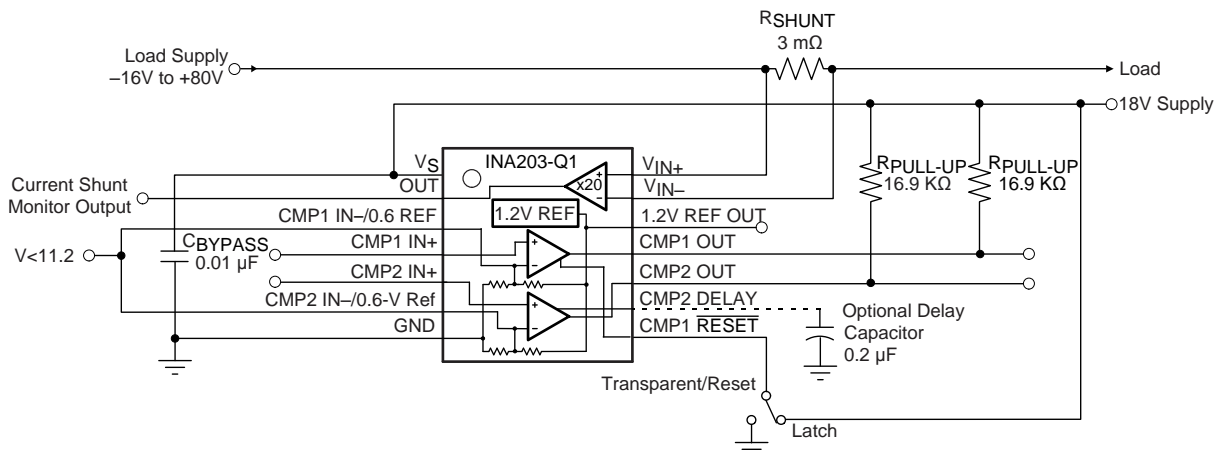
The maximum voltage at the comparator input for normal operation is up to (V<sub>S</sub>) – 1.5 V. There are special considerations when overdriving the reference inputs (pins 3 and 6). Driving either or both inputs high enough to drive 1 mA back into the reference introduces errors into the reference. [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 kΩ 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 kΩ).

### Feature Description (continued)



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**Figure 28. Limit Current Into Reference  $\leq 1$  mA**



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**Figure 29. Overdriving Comparator Inputs Without Generating a Reference Error**

### 8.3.4 Reference

The INA203-Q1 include an internal voltage reference that has a load regulation of 0.4 mV/mA (typical), and not more than 100 ppm/°C of drift. The device allows external access to reference voltages, where voltages of 1.2 V and 0.6 V are both available. Output current versus output voltage is illustrated in the [Typical Characteristics](#) section.

### 8.3.5 Output Voltage Range

The output of the INA203-Q1 is accurate within the output voltage swing range set by the power-supply pin,  $V_S$ . Given the device gain of 20, where a 250 mV full-scale input from the shunt resistor requires an output voltage swing of +5 V, and a power-supply voltage sufficient to achieve +5 V on the output.

## 8.4 Device Functional Modes

The INA203-Q1 has a single functional mode and is operational when the power-supply voltage is greater than 2.7 V. The common-mode voltage must be between -16 V and +80 V. The maximum power supply voltage for the INA203-Q1 is 18 V.

## 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.

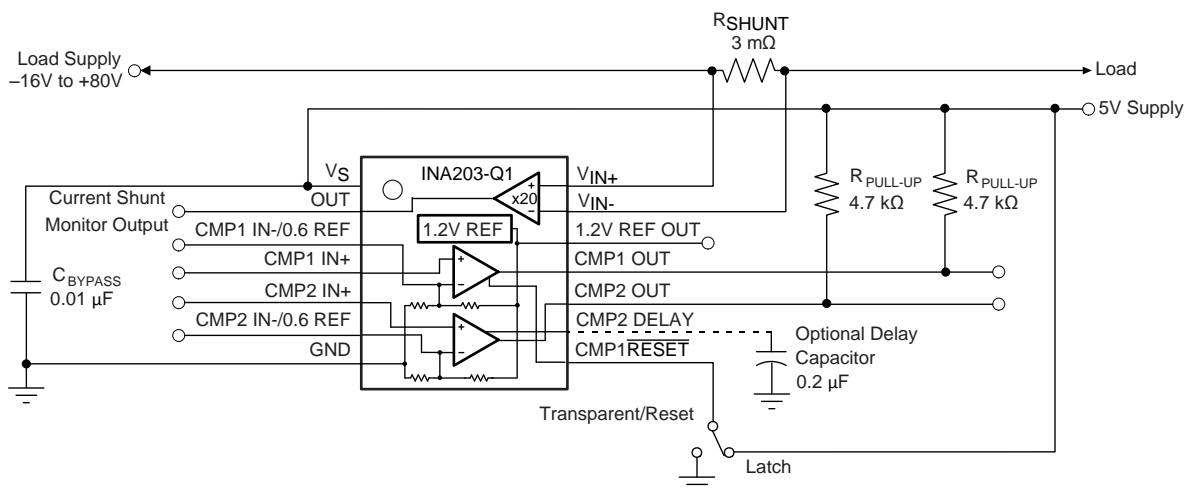
### 9.1 Application Information

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  $(V_{SHUNT} - 0.25)/\text{Gain}$ .

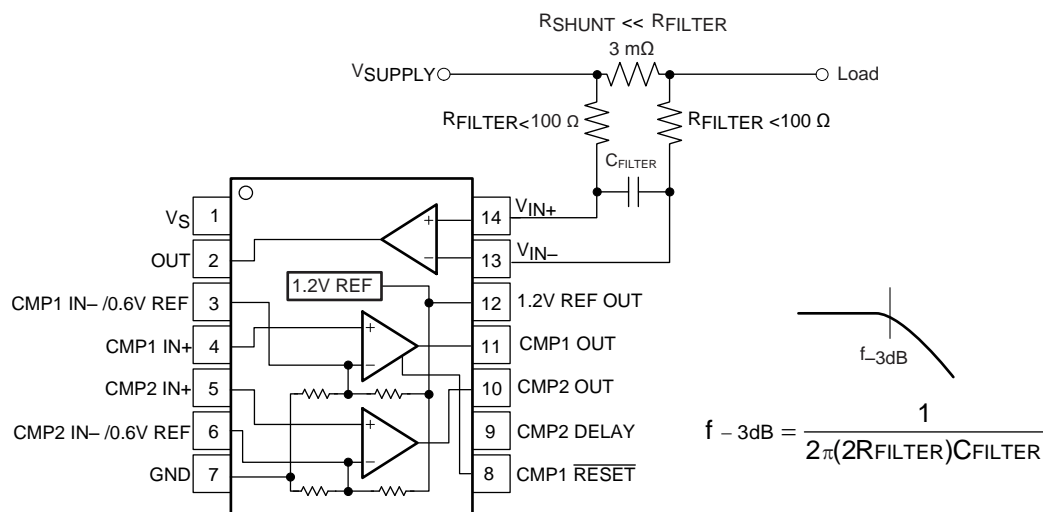
## Application Information (continued)

### 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

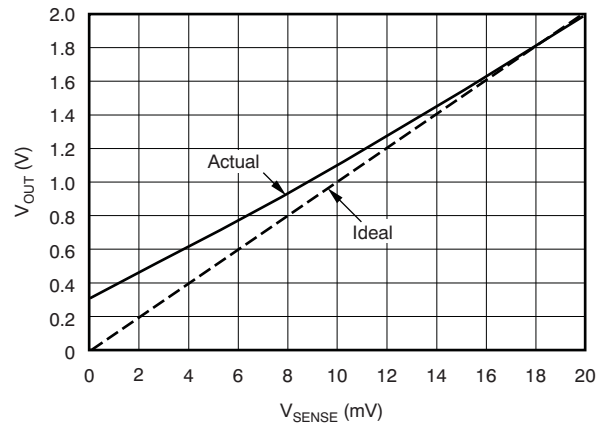
Low  $V_{SENSE}$  Case 3:

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

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)

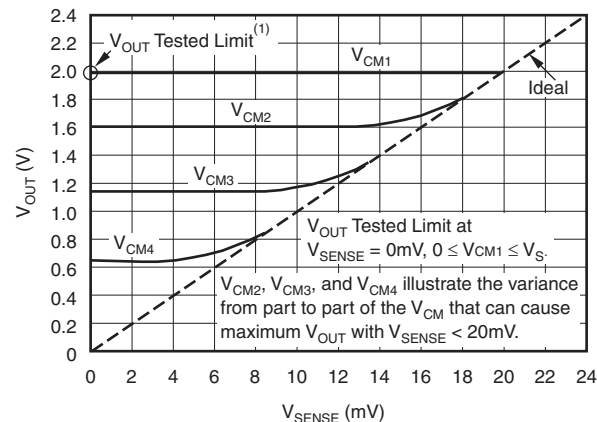


Data taken from INA205, a device of INA20x family with Gain = 100

**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.

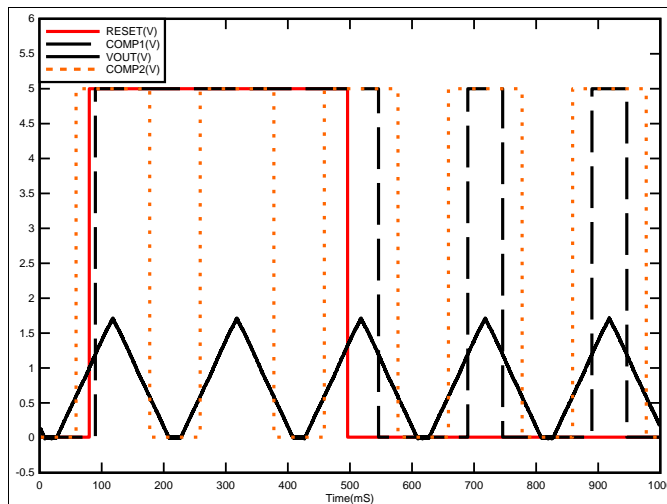
Data taken from INA205, a device of INA20x family with Gain = 100

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

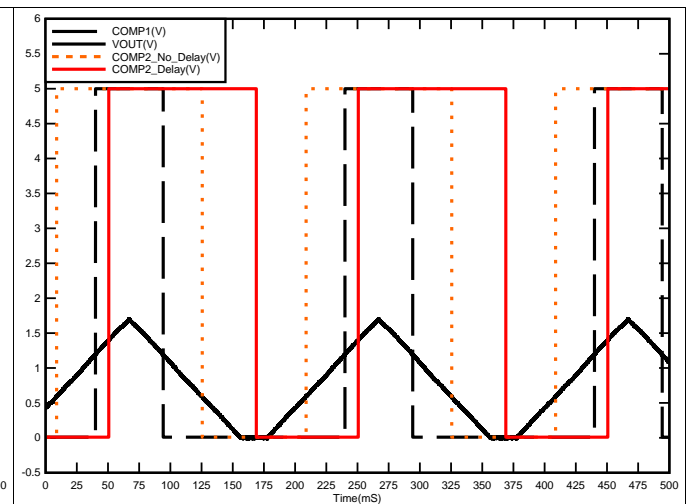


## Typical Applications (continued)

### 9.2.1.3 Application Curves



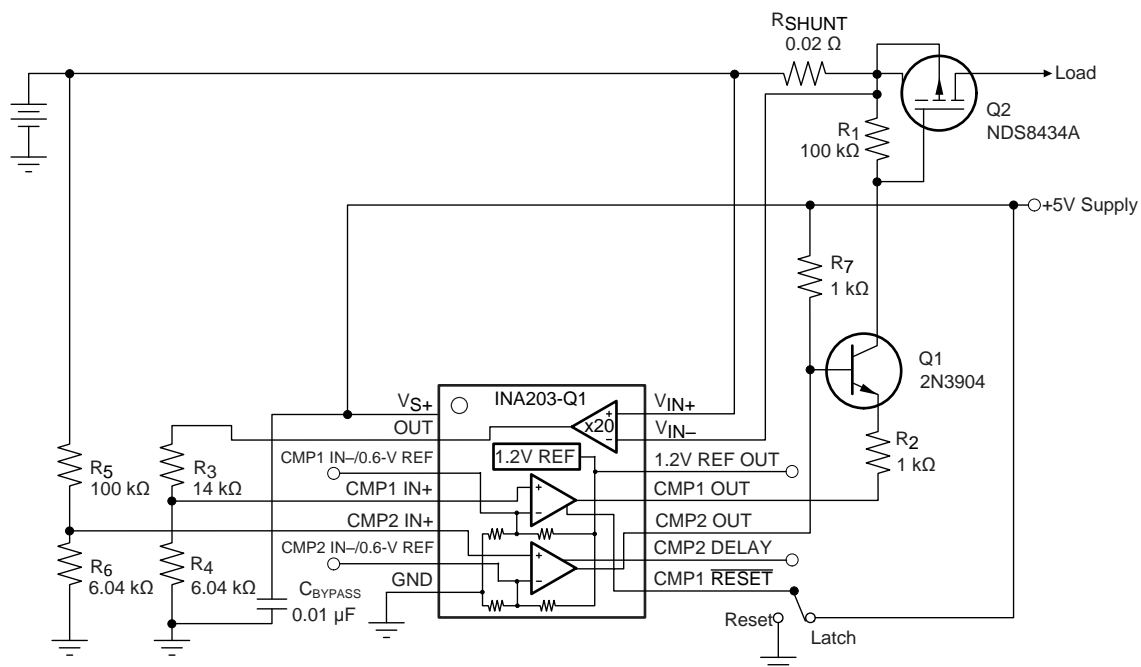
**Figure 35. Polyswitch Warning and Fault Detection Circuit Response**



**Figure 36. Polyswitch Warning and Fault Detection Circuit With Delay Response**

### 9.2.2 Lead-Acid Battery Protection Circuit

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



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

## 10 Power Supply Recommendations

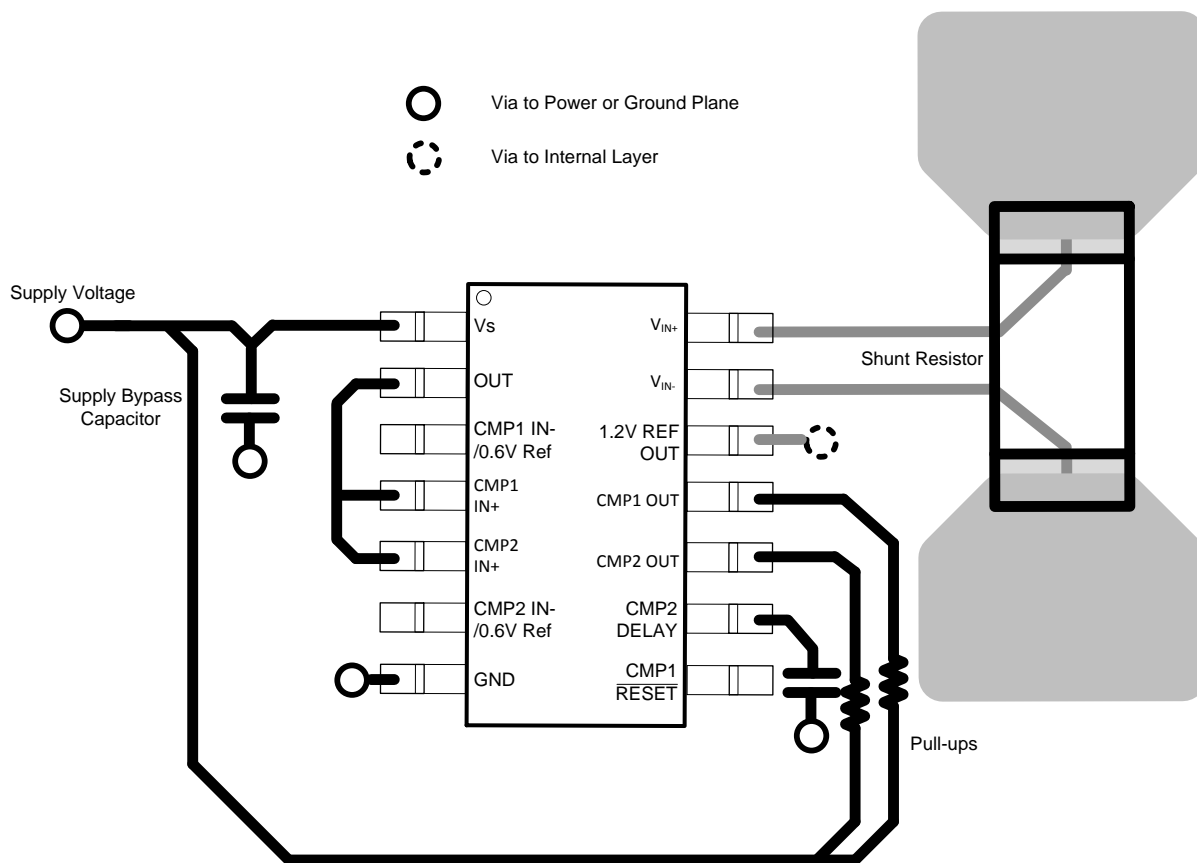
The input circuitry of the INA203-Q1 can accurately measure beyond the power-supply voltage,  $V_S$ . For example, the  $V_S$  power supply can be 5 V, whereas the load power-supply voltage is up to 80 V. The output voltage range of the OUT terminal, however, is limited by the voltages on the power-supply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

### 12.1 社区资源

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.

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### 12.3 静电放电警告



这些装置包含有限的内置 ESD 保护。存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

### 12.4 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。要获得这份数据表的浏览器版本，请查阅左侧的导航栏。

## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
INA203AQPWRQ1	Active	Production	TSSOP (PW)   14	2000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	I203AQ
INA203AQPWRQ1.A	Active	Production	TSSOP (PW)   14	2000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	I203AQ

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

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

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

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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### OTHER QUALIFIED VERSIONS OF INA203-Q1 :

- Catalog : [INA203](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product



## TAPE AND REEL INFORMATION



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
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	353.0	353.0	32.0



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## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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

# EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

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NOTES: (continued)

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

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