Application Report
SLOA228–October 2015

Current Sensing With Near-Zero Common Mode Voltage With INA19xA-Q1

Mahmoud Harmouch *MSA - Auto Signal Chain*

ABSTRACT

This report provides a summary of using the INA19xA-Q1 device when the common mode voltage is close to zero volts. In this low common-mode voltage region, the output voltage has a large error. The example for this case is low-side current sensing with a differential input below 20 mV. The INA19xA-Q1 device is not a good fit for situations where the common mode voltage is near zero. Instead TI recommends devices such as the INA282-Q1 device.

Contents

1 Block Diagram Description 2
2 Setup for Low Common-Mode Voltage Sensing 3
3 Summary 8

List of Figures

1 Block Diagram 2
2 Test Circuit 3
3 VOUT Plots Across Temperature for 30 units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from –0.7 V to 19.6 V 5
4 VOUT Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from 8 V to 16 V 6
5 Linearity Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltages at 8.4 V, 12.6 V and 16.1 V 7
6 Output Error Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from –0.7 V to 19.6 V 8

List of Tables

1 Characterization Plan 3
2 Characterization Pattern 4

1 Block Diagram Description

The INA19xA-Q1 device family uses two operational amplifier front ends, A1 and A2, to achieve a wide input common-mode voltage range. A1 amplifier is active when the common mode voltage is negative, and A2 amplifier is active when the common mode voltage is positive. When the common mode is close to zero, both amplifiers, A1 and A2, can be active resulting in high output error if the sense voltage is below 20 mV.

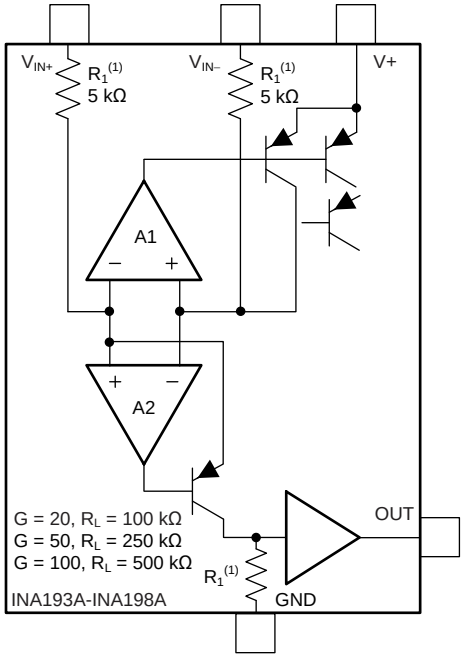
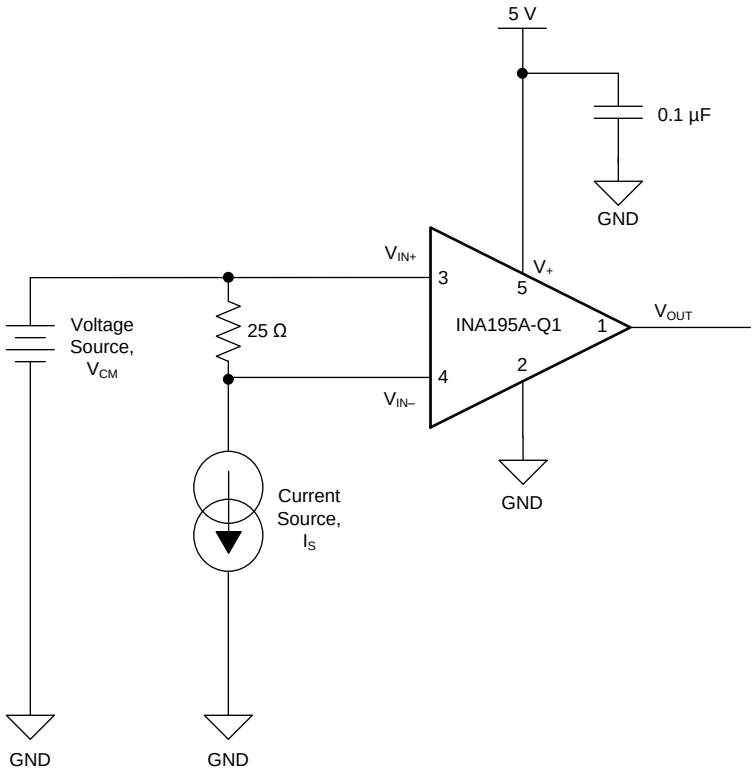


Figure 1. Block Diagram

2 Setup for Low Common-Mode Voltage Sensing

The test setup was done according to circuit in Figure 2. Table 1 lists a summary of the characterization plan.



The sense voltage, V_{SNS}, = 25 Ω × I_S

Figure 2. Test Circuit

Table 1. Characterization Plan

Parameter	Characterization Plan
Supply voltage, V+	5 V ±6%
Sense voltage, V_{SNS} [(VIN+) – (VIN–)]	0 mV to 20 mV in 2-mV steps
Common mode voltage, V_{CM}	–0.7 V to 18.9 V in 0.7-V steps
Temperatures	–40°C, 25°C, 105°C, 125°C
Number of units from 1 lot	30 pieces

2.1 Characterization

Automated test equipment (ATE) based on the values in Table 2 was used to complete the characterization.

Table 2. Characterization Pattern

Parameter	Start	Stop	Delta	Step	Runs
Supply voltage, V+	5 V	5 V	0 V	0 V	1
Sense voltage, V_{SNS} [(VIN+) – (VIN)]	0 mV	20 mV	20 mV	2 mV	11
Common mode, V_{CM}	–0.7 V	18.9 V	19.6 V	0.7 V	29

Table 2 shows the number of test runs for each unit. The sense voltages from 0 to 20 mV in 2-mV steps were tested at all common mode voltages from –0.7 to 18.9 V in 0.7-V steps. The table shows 21 runs for sense voltages and 29 runs for common mode voltages

The ambient temperature was characterized at the following temperatures:

- –40°C
- 25°C
- 105°C
- 125°C

2.2 Output Voltage Level

Figure 3 shows the output voltage (V_{OUT}) versus the common mode voltage for different temperatures and sense voltages [(VIN+) — (VIN–)] as the sense voltage varies from 0 to 20 mV and the common mode voltage varies from –0.7 V to 18.9 V. The vertical axes show the output voltage on the left and the sense voltage [(VIN+) — (VIN–)] on the right. The horizontal axis shows the temperature variations on top and the common mode voltage on the bottom. The horizontal dashed lines are set at ±20% error of ideal. As shown in the graphs in Figure 3, the output voltage moves closer to ideal by increasing V_{SNS} and V_{CM}.

Figure 4 shows the same plots as Figure 3 but varies the common mode voltage from 8 V to 16 V. In this higher range, only A2 amplifier is active and therefore the device performs as expected.

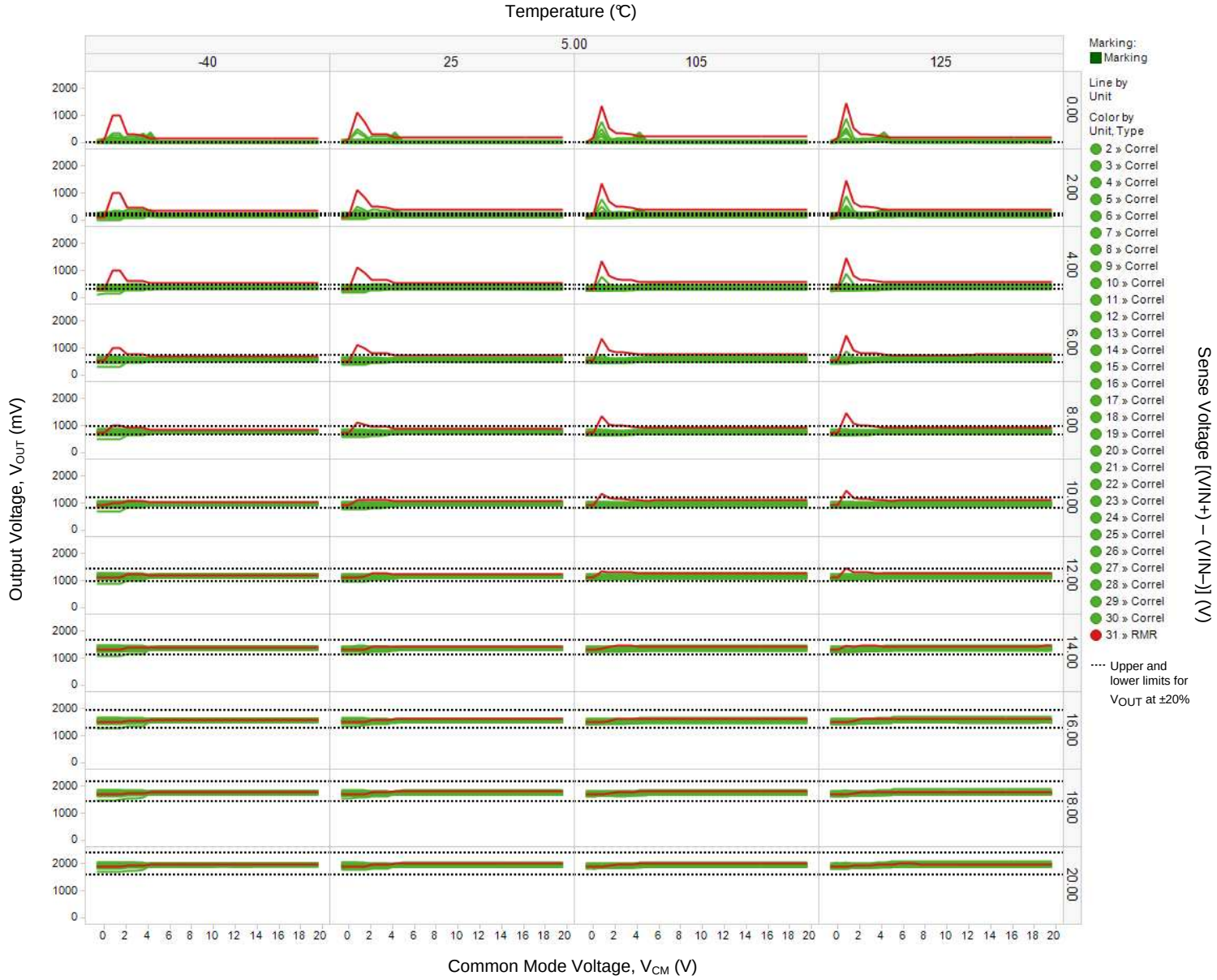
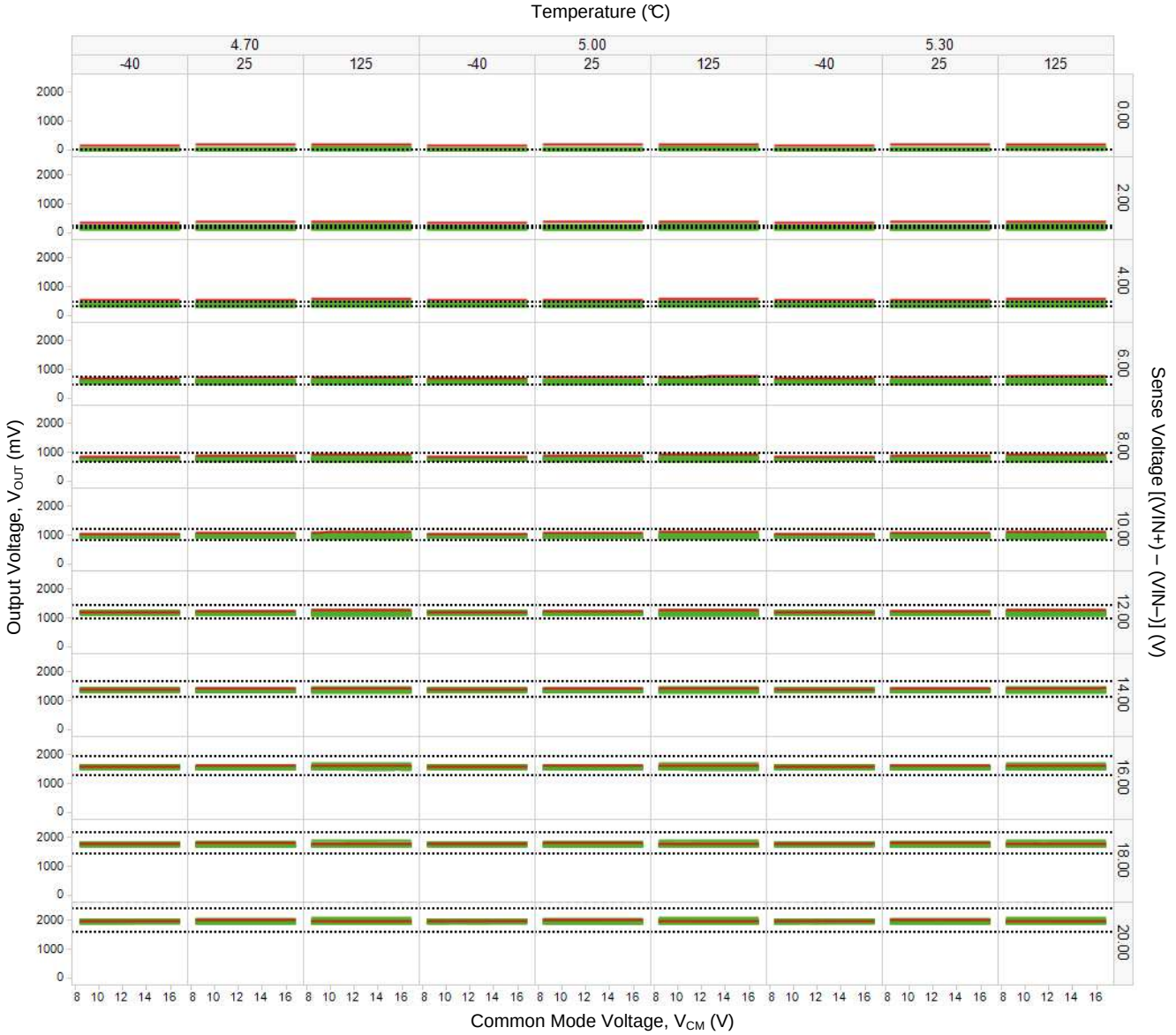


Figure 3. VOUT Plots Across Temperature for 30 units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from –0.7 V to 19.6 V



The horizontal dashed lines are the upper and lower limits for V_{OUT} at ±20%.

Figure 4. VOUT Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from 8 V to 16 V

2.3 Linearity Plots

Figure 5 shows the output voltage (V_{OUT}) versus the sense voltages [(VIN+) — (VIN–)] for different temperatures and common mode voltages as the sense voltage varies from 0 to 20 mV at 3 common mode voltages 8.4 V, 12.6 V, and 16.1 V.

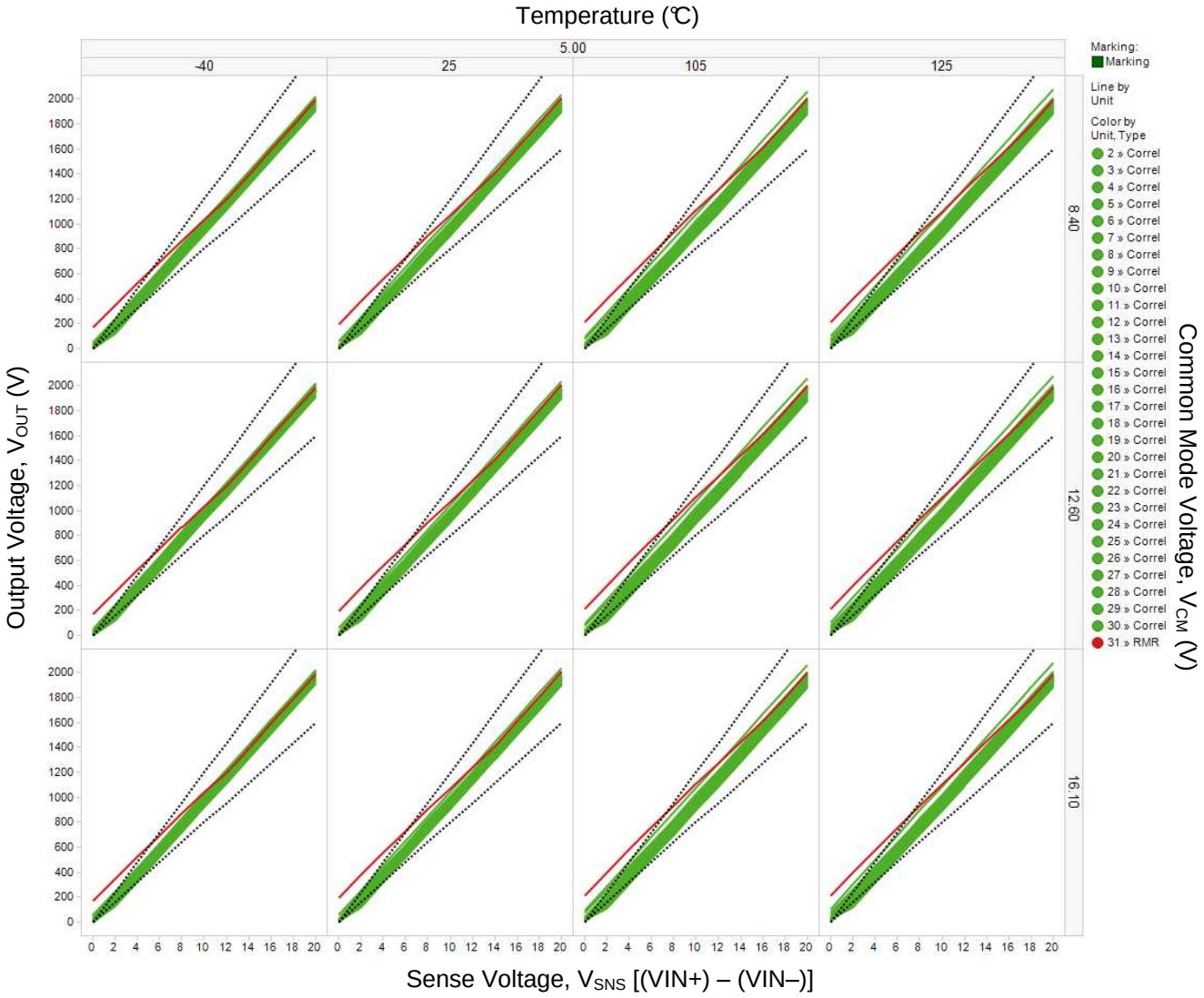


Figure 5. Linearity Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltages at 8.4 V, 12.6 V and 16.1 V

2.4 Output Error Visualization in 3 Dimension Plots

Figure 6 shows the sense voltage [(VIN+) — (VIN–)] on the horizontal X axis, the common mode on the horizontal Y axis, and the output error (%) on the vertical Z axis. As shown in this graph, the error increase dramatically when the sense voltage and common mode voltage approach zero.

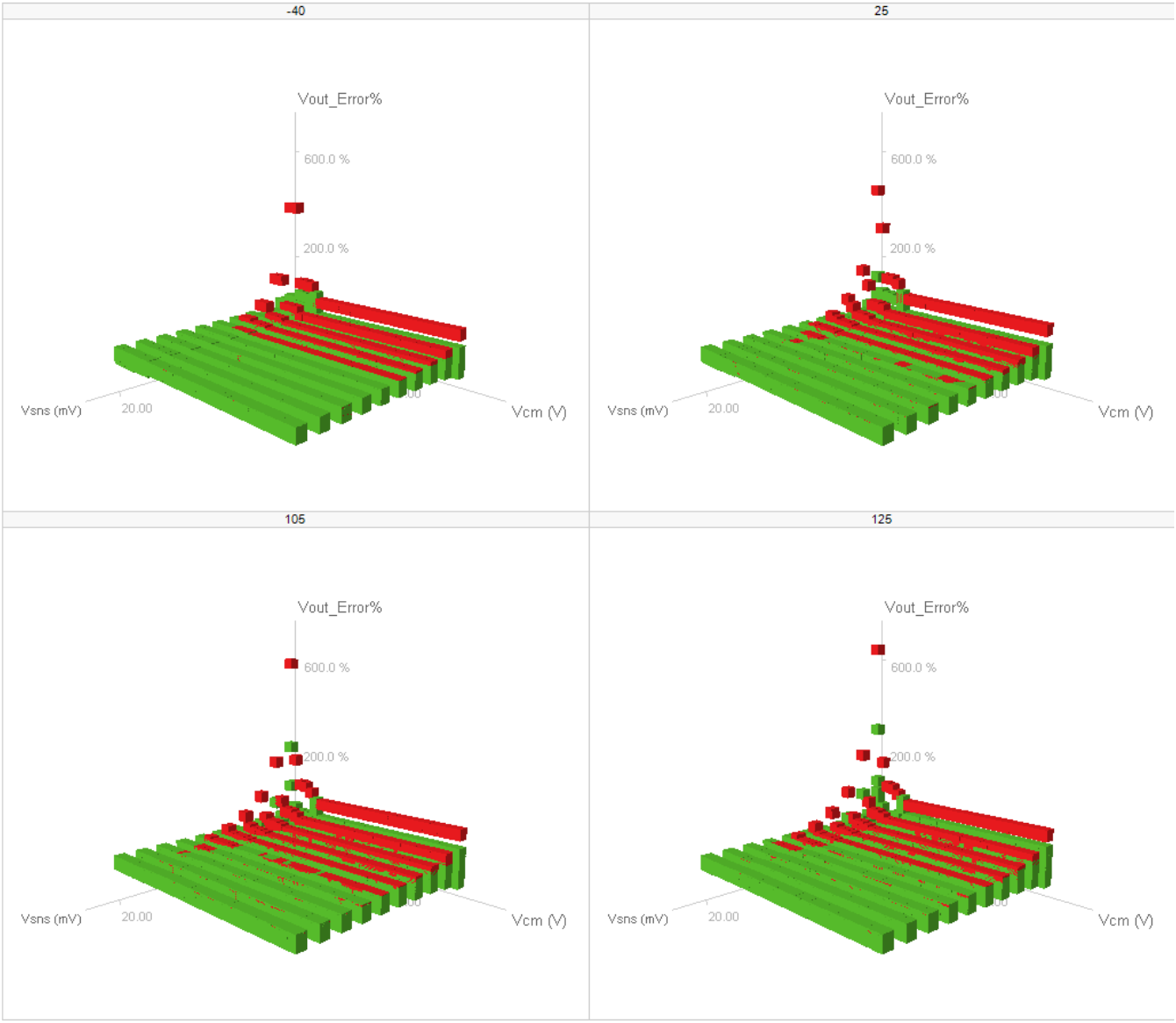


Figure 6. Output Error Plots Across Temperature for 30 Units at V+ = 5 V, [(VIN+) — (VIN–)] Varies from 0 to 20 mV and Common Mode Voltage Varies from –0.7 V to 19.6 V

3 Summary

While the INA19xA-Q1 device can be an excellent device in some applications, it should not be used in cases where the sense voltage is below 20 mV and the common mode voltage around 0 V.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265